GOLD MINING AND MILLING

IN WESTERN AUSTRALIA WITH NOTES UPON TELLURIDE TREATMENT, COSTS, AND

MINING PRACTICE IN OTHER FIELDS:

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WITH NUMEROUS ILLUSTRATIONS, PLANS AND TABLES

London
E. & F. N. SPON, LTD., 125 STRAND
New York
SPON & CHAMBERLAIN, 123 LIBERTY STREET
1903

PREFACE.

In 1901 the Author contributed a series of five illustrated articles to *The Engineering Magazine*, entitled, 'Gold Mining and Milling in Western Australia,' which the Proprietors of *The Engineering Magazine* have kindly allowed him to incorporate in this book.

The material they contained has, however, been largely recast and revised, the statistical portion has been brought up to date, and a great deal of new matter has been added upon the geology of the gold-fields of Western Australia, oxidised and sulpho-telluride ore-treatment, mining laws, costs, economics and statistics.

The chief objects the Author has had in view are, first, to present a history of gold-mining in the Colony; secondly, to explain the peculiar difficulties that have been encountered in the treatment of the sulpho-telluride ores of Kalgoorlie and in dealing with other local problems; thirdly, to draw a comparison between the conditions that obtain in Western Australia and other mining fields; fourthly, to show by figures of production and facts that mining in Western Australia is on a sounder footing than is at present, perhaps, generally supposed; and, fifthly, to furnish data, particularly in regard to *costs*, that may serve to promote future economies by calling attention to questions that may be worth studying in this connection.

A number of expert writers have dealt with matters of which this book treats, but their observations are, to a large extent, buried in a mass of literature that can only be unearthed by a large amount of research.

The Author has, therefore, endeavoured to bring them to light, and piece together these valuable materials, which have hitherto lain in scattered fragments; so that this book embodies, not only his own views, but gives the opinions of a large number of eminent, practical and scientific professional men—geologists, mining engineers and metallurgists—who are recognised as authorities in mining matters.

But the Author has not confined his attention to technical questions only; and with a view to present the problems which beset mining in a business-like light he has endeavoured to sift and collect the views of business authorities, including chairmen of mining companies, writers in the press, and others, who have dealt with the important questions that are discussed.

It would be impossible, in the limits of a preface, for the Author to acknowledge in detail all the sources of his information, but extensive references have been given in footnotes to papers read before the leading Technical Institutions, to Government reports and statistics, to articles contributed to Journals and Magazines of recognised standing, and to the official reports of Mining Companies, as well as information that has been published in the Financial Press.

He owes special thanks to a number of professional friends for notes and material they have most kindly placed at his disposal, and to directors and secretaries of mining companies for the courtesy they have shown in answering inquiries addressed to them at different times. The Author relies on the various authorities he has named to ensure the greatest possible accuracy in figures, etc. he has quoted, and he has referred to them individually in order to present their views upon different points, and to avoid taking credit for the observations and work of others.

The Author has to acknowledge his indebtedness to the American Institute of Mining Engineers for permitting him, with the consent of Mr. T. A. Rickard, to reproduce a number of interesting cuts from his paper on 'Alluvial Mining in Western Australia'; also to the Proprietors of *The Statist*, for the use of the blocks from which the mine plans and sections in Chapter X. have been prepared; to the Proprietors of *The Financial Times* and *The Colonial Mining News* for permission to reproduce several illustrations; and to different mining companies for original photographs they kindly placed at his disposal. He will be pleased to receive any information or comments which will enable him to revise the present edition, should a later one be ever published; and he has particularly to thank his friend, Mr. C. G. Warnford Lock, for much valuable assistance.

The tendency of modern works on mining is to induce mine managers and mining engineers to turn their thoughts to further improvements and economies* than have yet been effected; and the Author ventures to hope that the money-bees in our hives of industry—men in a position to embark capital in business enterprises—may come to recognise that, although mining must always possess a speculative element, it should be directed and managed upon business lines; and when properly conducted with this object differs materially from a mere share gamble, and also pays better.

A. G. CHARLETON, A.R.S.M.

LONDON: *January* 31, 1903.

* *The Statist*, in a leading article in its issue of Jan. 10, 1903, remarks: "The value of gold—that is to say, its purchasing power—is determined in the last resort by the cos of producing the metal, and the more that cost is reduced the more also is the purchasing power lowered. But a lowering of the purchasing power is only another way of expressing the fact that a given weight of gold exchanges for less commodities than it did previously. In other words, a lowering of the cost of production of gold means a rise in the price of commodities."

As there must, however, be a limit below which the price of commodities cannot fall without danger to all kinds of industries and dislocation of international trade, the economic importance of cheap gold production is evident.—AUTHOR, Jan. 10, 1903.

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GOLD MINING AND MILLING IN WESTERN AUSTRALIA.*

CHAPTER I.

HISTORY, POPULATION, POSITION AND GENERAL FEATURES OF THE GOLD-FIELDS.

FEW people interested in mining at the present day can be unfamiliar with the name of Kalgoorlie; Kalgurli as it is sometimes written, being the name of a small hill close to the township; many, however, are at best but imperfectly informed of its remarkable history and surroundings.

A few years ago it was a small, unknown mining camp, in the "back blocks" of the Crown Colony of Western Australia, with a few canvas huts and corrugated-iron shanties dotted about; to-day it is a mining town of the first importance, the name of which will be handed down to posterity as a landmark of British colonial enterprise—a tribute that must be hereafter paid to its phenomenally rapid development, galvanised into industrial life, as it has been, by the confidence of the capitalist and the energy of the miner; of which I believe we see but the commencement.

A new gold-mining discovery always excites wide interest, because it presents a new field alike for the profitable employment of labour, and of such surplus capital as may be legitimately employed in business speculation by people possessed of the means to embark money in mining; and it offers opportunities to the capitalist for the rapid accumulation of wealth, which the ordinary investor in consols or gilt-edged securities, seldom expects

* Part of the subject matter of Chapters I., II., III., VI., VII. and VIII. was published in a series of articles under the same title contributed by the Author to the *Engineering Magazine*, that appeared in its February, March, April, May and June issues in 1901. The proprietors of the *Engineering Magazine* have kindly permitted the Author to make use of this material, which he has however considerably added to and revised, so as to bring it up to date.—A. G. C.

and is never likely to realise. But Hannan's (as Kalgoorlie is sometimes called) possesses special interest also for engineers, owing to the unique character of its surroundings and its remarkable telluride deposits, which have entailed modifications of ordinary practice in developing and working them, and brought to light various new and interesting facts, from a geological, engineering, and metallurgical point of view. The circumstance that capital has doubtless been wrecked on its "reefs" by unwise speculators is not, generally speaking, the fault of the field, the geologist, or the miner; but is quite as much due to "market causes," coupled with neglect of ordinary precautions, by which the operations of prudent business men are controlled, as distinguished from those of people who go in from time to time for a mere mining gamble.

Going back to the earliest period of the history of the Colony, it was not till long after William Dampier (the first Englishman to set foot on the Antipodes), sailing from Mindanao, landed on the west coast of Australia (New Holland as it was then called) in 1688, in company with the mutineers of the *Cygnet*, that gold mining actually sprang into existence; though Dampier is credited on his return from England, in H.M.S. *Roebuck*, several years later (1699), with the discovery of gold on the north-west seaboard, which is marked on old Dutch * or Portuguese maps *Provincia Aurifera*. Later on, in 1847, Mr. John Calvert, visiting Exmouth Gulf in the *Scout*, again drew attention to the fact that the district was gold-bearing, bringing back with him specimens, on the strength of which he is stated to have endeavoured to form a company in 1849, but failed to do so.

Proof of existence of gold in paying quantity dates back, however, only to 1886, following upon the issue in 1884 of a map by Mr. E. T. Hardman, then Government Geologist, showing places where gold was likely to be found; this was after his return from a prospecting expedition to the Kimberley district, in 1882–1883. The Kimberley field was subsequently proclaimed, May 19, 1886, when the first "rush" took place; whilst Yilgarn was next discovered by Anstey in 1887; but it was not till May or June of 1892 that Arthur Bayley and Wm. Ford, starting from Southern Cross, set out on their eventful expedition, which resulted in the discovery of the Coolgardie gold-field, † where they secured some 2000 ounces of

* 'Map of the World,' by Pieter Plancius, the Dutch geographer, 1594.

† John Ford made the first discovery of gold, near the Coolgardie water-hole, picking

gold by "dollying." This last discovery imparted an impetus to prospecting farther afield, and Kalgoorlie was located by Patrick Hannan's party in June 1893—an historical event which has proved probably as important to Western Australia as Marshall's discovery of gold in 1848, at Sutter creek, was to California.

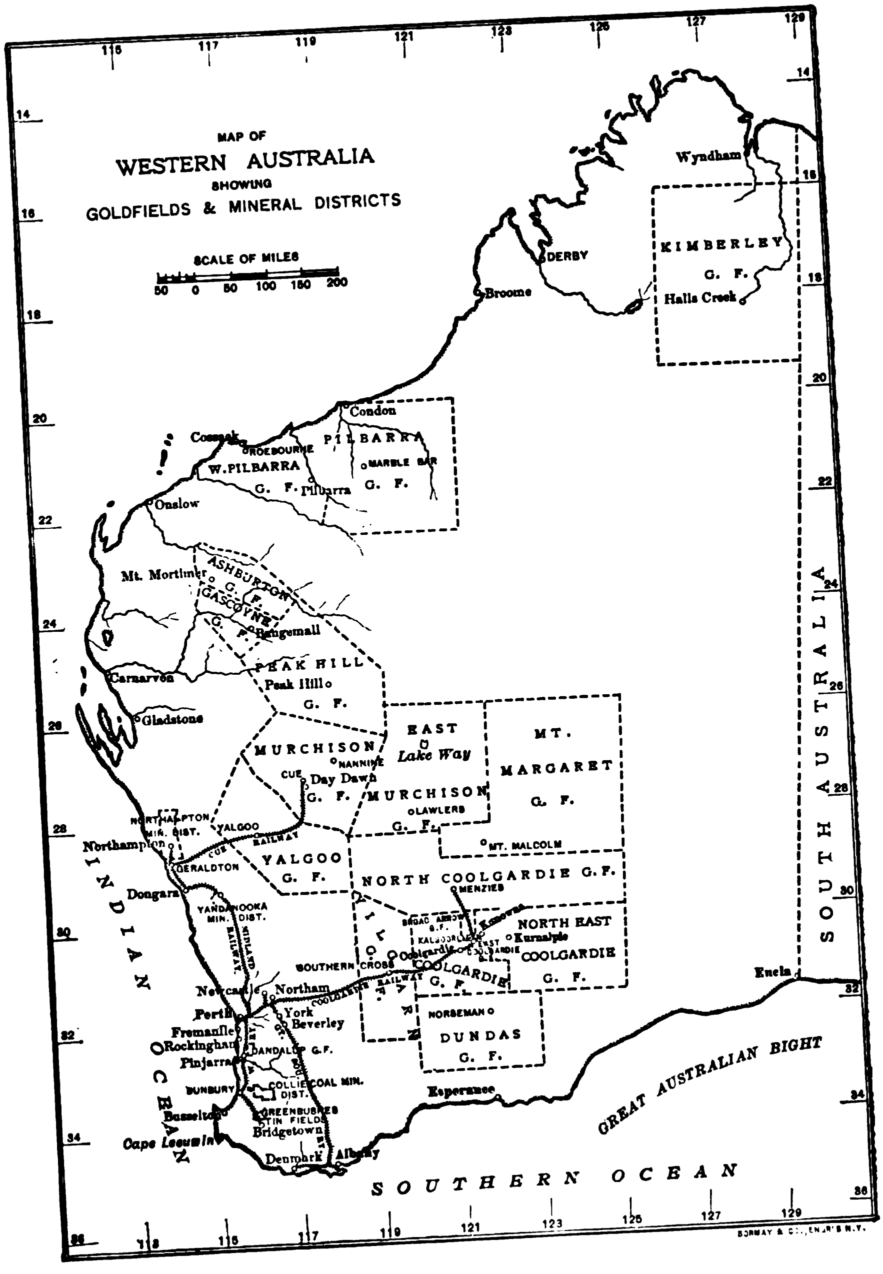
There are now nineteen recognised gold-fields in Western Australia, the two last having been recently discovered and proclaimed, viz.: (1) Kimberley; (2) Pilbarra; (3) West Pilbarra; (4) Ashburton; (5) Gascoyne; (6) Peak Hill; (7) Murchison; (8) East Murchison; (9) Mt. Margaret; (10) Yalgoo; (11) North Coolgardie; (12) Yilgarn; (13) Coolgardie; (14) Broad Arrow; (15) East Coolgardie (better known as Kalgoorlie); (16) North-East Coolgardie; (17) Dundas; (18) Donnybrook; (19) Phillips River. The general position of the seventeen older ones is shown on the map on next page, while Donnybrook is a few miles inland from the port of Bunbury, and Phillips River is some distance east of Albany. I need only add that each goldfield is divided into subdistricts, being dotted with various independent mining camps.

The discovery of these gold-fields was in some instances not altogether without romance, notwithstanding their prosaic surroundings; perhaps in no case more so than in that of the Pilbarra field, of which I may quote the story as commonly told. It appears that a discerning youth of tender years picked up a stone * to throw at a cow (some say a crow), and noticing that it contained gold, reported the fact to the "Warden." This gentleman was so excited at the news that he flashed the intelligence by wire to the then Governor of the colony, informing him that a lad had picked up a stone, to throw at a crow—but forgetting to add that he had seen gold in it! The Governor, much surprised, but moved by curiosity, wired back: "Yes; and what happened to the crow?" (or cow). This elicited explanations which led to the proclamation of the district as a goldfield, and in the rush that followed this "find" in 1888, 3493 ounces of gold are said to have been obtained, valued at 13,273*l.*, early

up a piece weighing about half-an-ounce lying on the surface at a spot afterwards known as "Fly Flat." Messrs. H. M. Lefroy, in 1863, C. C. Hunt in 1864, J. Forrest in 1871, E. Giles in 1875, and D. Lindsay in 1891, who had previously visited the district, seem to have been unaware of its auriferous character, though Hunt discovered some outcrops of quartz near Hampton Plains, in 1864. The discovery of Coolgardie was announced at Southern Cross, September 18, 1892.

* The place where this occurred was Mallina, that now forms part of the "West Pilbarra" gold-field, and the boy's name was Withnell; it is of interest as being the first discovery of gold in the North-West.

B 2


MAP OF
WESTERN AUSTRALIA
SHOWING
GOLDFIELDS & MINERAL DISTRICTS
SCALE OF MILES
50 0 50 100 150 200
KIMBERLEY G. F.
Wyndham
Derby
Broome
Halls Creek
PILBARRA G. F.
W. PILBARRA G. F.
Condon
Cossack
Roebourne
Marble Bar
Pilbarra
Onslow
Mt. Mortimer
ASHBURTON G. F.
GASCOYNE G. F.
Bangemall
PEAK HILL G. F.
Peak Hill
Carnarvon
Gladstone
MURCHISON G. F.
Nannine
Cue
Day Dawn
EAST MURCHISON
Lake Way
Lawlers
MT. MARGARET G. F.
Mt. Malcolm
NORTHAMPTON MIN. DIST.
Northampton
Geraldton
YALGOO G. F.
Yalgoo
NORTH COOLGARDIE G. F.
Menzies
NORTH EAST COOLGARDIE G. F.
Kurnalpie
COOLGARDIE G. F.
Coolgardie
Kalgoorlie
Southern Cross
Dongara
YANDANOOKA MIN. DIST.
Midland Railway
Southern Railway
Newcastle
Northam
York
Beverley
Perth
Fremantle
Rockingham
Pinjarra
DANDALUP G. F.
Bunbury
COLLIE COAL MIN. DIST.
Busselton
GREENBUSHES TIN FIELDS
Bridgetown
Cape Leeuwin
Denmark
Albany
DUNDAS G. F.
Norseman
Esperance
Eucla
INDIAN OCEAN
SOUTHERN OCEAN
GREAT AUSTRALIAN BIGHT
SOUTH AUSTRALIA

attention being drawn to the district by the discovery of several large nuggets; * one of which is stated to have weighed 140 ounces.

The East Coolgardie gold-field (to which this and subsequent articles will be chiefly devoted), covering as it does only 632 square miles, is with two exceptions the smallest of the previously named nineteen gold-fields, which at the end of 1900 possessed collectively an area of 325,513 square miles, proclaimed "open for location." Nevertheless, East Coolgardie has the enviable distinction of a larger output of the precious metals than all the other fields combined; Kalgoorlie being credited up to December 1900, with no less an output than 2,570,161 ounces of gold, produced in less than five years. The output of the whole of West Australia (Kalgoorlie of course included) from 1886 to the end of December 1900, is placed at 5,917,630 ounces 15 pennyweights 15 grains (about 181 tons avoirdupois), which calculated as having an average value of 3*l.* 16*s.* per ounce, represents 22,486,996*l.* 19*s.* 3*d.*

The colony of Western Australia, comprising all that part of the Australian Continent west of the 129th meridian, has an aggregate area of 975,920 square miles, half of which is within the tropics, and whilst the interior is dry and hot and subject to very sudden changes, the coast is warm, with a rainfall varying from 20 to as much as 47 inches at the Canning waterworks in the Darling ranges.† Commencing in 1830 with 1767, in 1895 ‡ Western Australia possessed an estimated population of 101,235, but it has since grown much larger, numbering 184,124 (exclusive of Aboriginals) at the last Census, March 31, 1901. The revenue for the year ending June 30, 1899, was 2,478,811*l.*, against which was set an expenditure of 2,539,358*l.*, or 15*l.* 0*s.* 7*d.* per head; whilst the revenue and expenditure in 1900 amounted to 2,875,396*l.* and 2,615,675*l.*; in 1901 to 3,078,034*l.* and 3,165,244*l.*; and in 1902 to 3,688,049*l.*

* A still larger one, known as the "Bobby Dazzler" (consisting of alluvial gold and quartz) was afterwards found in "Sharks Gully" (Pilbarra), and was exhibited at the Paris International Exhibition. The following particulars of it are given by E. S. Simpson, *Ann. Progress Report of the Geol. Survey*, 1899: weight, 487·13 oz.; percentage of gold, 84·85; weight of gold, 413·37 oz.; value of gold per oz., 3*l.* 5*s.* 2·9*d.*; total value, 1348*l.* 9*s.*

† The following are given as averages: Perth 33 inches a year; Bunbury 37; Guildford 34; Freemantle 30; Wyndham 29; Derby 28; Esperance 25; Geraldton 18; York 17; Cossack 10; Onslow 8; and Carnarvon 8.

‡ The great advance that has taken place since 1890 is attributable to the influx of "gold-seekers," miners, artisans and others connected with the mining industry; thus 17,008 people were added to the population in 1894, an increase of 26·14 per cent.

and 3,490,026*l.* respectively, representing a revenue of 18*l.* 13*s*, 9*d.*, and an expenditure of 17*l.* 13*s.* 8*d.* per capita in 1902.

The dividends paid or declared by Western Australian mining companies (registered in England) for four years are officially given * as: 1897, 475,150*l.*; 1898, 770,829*l.*: 1899, 2,168,556*l.*; 1900, 1,063,860*l.*; 1901, 1,191,035*l.*; total, 5,669,430*l.* In the 'Handbook of Western Australia, 1900,' Mr. E. W. Hine, in an article entitled 'The Gold-Fields of Western Australia,' draws an interesting parallel, with a view to show the growth of the mining industry in Western Australia, as compared with the Rand in its early days, the relative outputs of the two districts being shown in the subjoined table :—

Rand.	Ounces.	*Western Australia.*	Ounces.
1887	23,149	1894	207,131
1888	207,660	1895	231,513
1889	369,557	1896	281,265
1890	494,817	1897	674,994
1891	729,238	1898	1,050,184
1892	1,208,928	1899	1,643,877
Total	3,033,349	Total	4,088,964

The figures in the one case, are computed from returns compiled by the Witwatersrand Chamber of Mines, given by Messrs. Hatch and Chalmers ; † in the other from data published by the Western Australian Government ; and the periods in the history of the two countries as nearly as possible correspond ; since the discovery of "banket" in the Transvaal dates from 1885, the big rush set in during 1886, and regular work commenced in 1887 (from which year the records of the Chamber of Mines start) ; whilst in Western Australia, the "rush" to Kalgoorlie came in 1893, and work actively commenced in 1894.

From the point of view of dividends, according to Messrs. Hatch and Chalmers, ‡ during the same period 1887–92, 2,108,350*l.* was distributed amongst shareholders in Witwatersrand mines ; whilst according to the figures of the Registrar-General of the colony, the payments by Western Australian companies during the ten years § 1890–1899 aggregated 3,575,119*l.*, since when the sum of 1,392,866*l.* is stated to have been paid by West Australian companies in 1900,

* 'Statistical and other Information,' W. A. Government Office.

† *The Gold Mines of the Rand*, by F. H. Hatch and J. A. Chalmers, p. 284.

‡ *Ibid.*, p. 287.

§ During the first four years of this period, the dividends amounted to 42,801*l.*

and 1,091,856*l.* during 1901; the total amount paid to Dec. 31st, 1901, being 6,059,841*l.*

The port of Fremantle is distant only about twelve miles from Perth (the capital of the colony), but up to 1898 all mails and passengers for the gold-fields were landed at Albany, on St. George's Sound, which is connected with Perth by railroad,* the distance between the two places being 340 miles.

Kalgoorlie lies east (slightly north) of Perth, 315 miles from Spencer's Brook, a junction on the Perth-Albany line, 60 miles east of Perth; the distance by rail to Kalgoorlie from Perth thus being 375 miles, and from Albany 595 miles. The time taken by the Kalgoorlie express from Fremantle used to be reckoned at about 19 hours when the trains ran up to time.

The East Coolgardie gold-field is, however, within 200 miles of a port on the coast, at Esperance Bay, with which it must inevitably ultimately be connected by rail; and once the existing opposition to the construction of an outlet on the south coast is overcome, it must cheapen and facilitate communication with the field, benefiting Dundas and the districts in the south of the colony, to even a greater extent.

The line from Perth gradually climbs the Darling range from the coast, a rise of about 1000 feet, till it reaches the table-land of the interior—Spencer's Brook being 520 feet above sea-level—from which point the line rises gradually until it reaches an elevation of 1240 feet at Kalgoorlie.

This area forms a plateau, presenting a succession of ridges which have a gradual north-and-south direction, undulating like the surface of the ocean after a gale. Their crests, which are separated from one another by shallow valleys varying in width from a mile or less to ten miles or more, frequently consist of domes of granite, laid bare and polished by the wind-driven sand; whilst here and there an iron-stone "blow," breaks the monotony of the surroundings by its greater irregularity.

The "lake-beds," coloured blue on maps, are shallow basins (Fig. 1) with clay bottoms, dry as a rule, though perhaps containing an occasional pool of brine, or brackish water, which lingers there after the rainy season, giving rise to a so-called "soak," where

* The gauge of the Western Australian Railways is 3 feet 6 inches, and they are mostly single lines, the rails weighing 46½ lb. per lineal yard. The cost of construction has varied from 3600*l.* on the Midland to 5088*l.* on the Government lines. In Queensland, with a similar gauge, the cost on the average has been, I believe, 7068*l.* per mile.

water has accumulated in a depression and is obtained by digging through the covering of sand. The streams, which rarely run except for a brief period after heavy rains, are really sandy channels

FIG. 1.—LAKE LAPAGE.

sculptured out by the drainage system of the country, marking what may once have been the course of ancient rivers, of which a mere trace remains unobliterated by denudation.

Taking a line from Lake Darlôt to Dundas (which would average about 1400 feet above the sea) as the axis of the plateau, for 50 miles on either side there is but slight variation in altitude, and the general character of the country is everywhere very uniform. The land falls away from this central dome eastward, until the younger horizontally-bedded rocks of the Great Victoria Desert are reached ; and to the west and south, to the Indian and Southern oceans. The general impression is that of an endless plain with gentle undulations, the depressions of which are filled with the products of erosion.

In the interior the miner is dependent for all his supplies of natural drinking water on an occasional well, "clay pan," or the rock-enclosed "water-holes," which are found in hollows exclusively in the granite (Fig. 2). In the absence of well-defined watercourses, the rain water is largely absorbed by the porous sandy soil, except after heavy storms, when large tracts are covered by sheets of water which gradually soak away, or drain down to one of the aforesaid "lakes."

The rock formation of this plateau consists mostly of granite, pierced by igneous intrusions of diorite and kindred plutonic and volcanic rocks (porphyry and andesites) associated, it is said, in places with tuffs, which my friend Mr. T. A. Rickard * states have in some instances been mistaken for sedimentaries. He remarks, "There are no fossil-bearing rocks, such as would afford a datum-line from which to measure the relative geological age of the prevailing formation. The age of the rocks of the Coolgardie area can only therefore vaguely be described as Archæan."

Notwithstanding, however, some of the natural drawbacks I have referred to, Western Australia is not by any means such a bad place to live in as many other parts of the world, for it possesses several inestimable advantages—rich gold-fields, a progres-

Fig. 2.—An Australian "Water-Hole."

sive Anglo-Saxon population, handsome towns, and a climate which, if not entirely free from dust, is at any rate healthy, when proper sanitary precautions are taken.

The dust-storms, which rage for days at a time, are certainly a

* 'The Alluvial Deposits of Western Australia,' by T. A. Rickard, A.R.S.M., *Trans. Am. Inst. of Mining Engineers*, vol. xxviii.

nuisance, but a secondary source of annoyance compared with the bush flies * which give rise to the common complaint of "bungeye," a painful swelling of the eyelids. Scorpions, centipedes, snakes, and "red spiders" are more often heard of than seen, and the smaller forms of irritating insect life are those that are most to be dreaded. The rainfall varies considerably; thus, while at Kalgoorlie it only amounted to 2¾ inches in 1894 (an exceptionally dry year), in 1893 it came to 4¾ inches, but scarcely ever exceeds 8 inches. The average is probably between 4 and 7 inches. That the climate has not always been so dry, however, is evidenced (as Mr. E. S. Simpson, the Government Mineralogist, has pointed out) by the discovery near Coolgardie (which is about twenty four miles from Kalgoorlie), of a thick bed of brown coal containing numerous fossil fern-leaves.

The local meteorological conditions at two places as close even as Coolgardie and Kalgoorlie—the latter town being situated in latitude 30° 45′ south, and longitude 121° 30′ east—are by no means identical. In striking contrast to the rainfall, the rate of evaporation is estimated as equivalent to 7 feet per annum.

It must not be supposed, however, as might be expected under such climatic conditions, that the general aspect of the country is that of a South African desert. Far from it, as nearly the whole plateau is covered with "scrub" and "bush" (Fig. 3), in which the Ti-tree and Mulga (species of flowering acacias), Salmon-gum (*Eucalyptus salmonophloia*), and Gimlet-wood (*E. salubris*) predominate.† This bush remains green all the year round, individual trees attaining a height of 20 to 80 feet, and 3 inches to 3 feet in girth. Here and there, where the land is scantily forested, may be noticed a patch of "nigger-head" (*Xanthorrhœa* or *Kingia*) both varieties of the "grass-tree" (the latter being crowned with a cluster of short spiked leaves like the head-dress of a South-Sea islander), often intermixed in the coastal districts with the palm-like Macrozamia (remarkable for its deep-green fronds); whilst various curious tree-shrubs, such as the Sandalwood

* It is said that Bayard's eucalyptus oil, distilled from *Eucalyptus maculata* (var. *citrodora*) will keep off flies and mosquitoes.

† The valuable forests of Jarrah (*Eucalyptus marginata*)—which often attains a height of 100 feet with a diameter of 3 to 5 feet, and is most useful for piles, wood paving, etc., owing to its hardness and durability in water—are found in the south-west division of the colony, as also Karri (*Eucalyptus diversicolor*), which sometimes reaches a height of 250 feet.

(*Santalum cygnorum*) flourish in the sandy interior. To the pedestrian compelled to "hump his swag" * the tracks or roads, cut through the "bush" with the aggravating straightness of a Roman highway, are inexpressibly monotonous, and when an elevated point is reached, the eye sweeps over miles and miles of dull-green forest and scrub, the only evidence of human surroundings being, perhaps, a wisp of blue smoke from some distant camp fire, or a deserted "mi-mi," † lately tenanted.

Many of the eucalyptus trees shed their bark annually, when the new wood exhibits delicate tints of red, pink, salmon and green,

FIG. 3.—ON THE BULONG ROAD.

which affords a little variety, but their thin, lanceolate, greyish leaves, which at times look as if varnished, give little shade to the wayfarer. The Quandong, Kurrajong and a few other trees which grow in isolated spots, occasionally, however, afford some protection from the blazing sun. The view in these forests extends for a few hundred yards only, and grass is frequently absent, or only to be found in scattered tufts—sand, boulders, or bare rock lying all around. In spring the forest land in places is, however, abundantly

* Carrying all his worldly goods on his back, in a "pack."

† A bush hut, formed of four posts roofed with eucalyptus boughs with the leaves on.

METEOROLOGICAL CONDITIONS AT COOLGARDIE, 1897.*

Month.	Temperature.					Temperature of Dew Point. Mean.		Rainfall.	
	Mean Max.	Mean Min.	Highest Max.	Lowest Min.	Greatest Variation in one day.	9 A.M.	3 P.M.	Total Inches.	Days.
	deg.	deg.	deg.	deg.	deg.	deg.	deg.		
January	94·1	63·2	104·3	53·0	42·2	53·5	54·0	·56	4
February	89·4	58·5	104·6	47·4	47·3	51·8	53·6	·54	5
March	85·6	57·7	98·4	50·0	41·0	49·2	55·0	·10	2
April	81·2	53·9	96·1	39·1	36·5	51·3	57·4	·01	1
May	71·4	46·6	88·4	38·2	41·5	46·9	53·5	·09	3
June	62·9	43·9	71·2	31·5	29·8	44·2	49·7	1·04	9
July	65·1	42·4	74·0	36·5	33·5	43·5	47·5	·34	6
August	63·8	41·5	81·0	33·0	34·6	40·8	43·7	1·08	10
September	75·0	47·5	92·0	35·0	39·7	43·7	49·5	·29	6
October	81·0	49·8	91·0	41·0	39·7	..	..	·06	2
November	90·6	58·4	105·0	47·3	44·6	..	..	·09	1
December	91·7	59·5	109·2	51·0	44·2	..	..	1.31	4
				1898					
January	97·6	65·1	111·2	54·0	43·2	60·1	68·2	nil	..
February	89·3	62·5	107·2	48·0	37·7	57·0	60·2	·27	1

carpeted with brilliantly coloured flowers; among other unique plants of this kind may be mentioned the curious Kangaroo Paws (Anigozanthos), the varied coloured kinds of Stylideæ, and others of the "Everlasting" species, belonging to the genera Helichrysum, Helipterum, Waitzia, Podolepis and Angianthus — "magnificent splashes of colour carpeting the desert with splendor,"† but wholly devoid of perfume, and with the dry, brittle texture of immortelles.

An old-man Kangaroo, or a Wallaby, bounding off like boys in a sack-race, a mob of cattle grazing on a "station," a troop of noisy Parrakeets,‡ the flight of a leisurely circling Hawk, or a Laughing-Jackass perched on a gum-tree, occasionally breaks the pervading solitude; otherwise the bush appears a wilderness, seemingly devoid

* 'The Alluvial Deposits of Western Australia,' by T. A Rickard, A.R.S.M., *Trans. Am. Inst. of Mining Engineers*, vol. xxviii. p. 499. † T. A. Rickard, *ibid.*

‡ Thirty-two species are recorded; the Yellow-cheeked Parrakeet being one of the commonest varieties, and popularly known as the "Twenty-eight," on account of its call.

METEOROLOGICAL CONDITIONS AT KALGOORLIE, 1897.*

Month.	Temperature.					Temperature of Dew Point. Mean.		Rainfall.	
	Mean Max.	Mean Min.	Highest Max.	Lowest Min.	Greatest Variation in one day.	9 A.M.	3 P.M.	Total Inches	Days.
	deg.	deg.	deg.	deg.	deg.	deg.	deg.		
January	92·9	66·0	105·0	55·0	34·2	51·1	52·0	·38	2
February	88·2	61·6	103·0	49·0	34·7	51·2	51·5	·02	1
March	83·8	58·9	98·4	51·0	39·0	49·0	49·4	·52	6
April	80·0	55·9	95·4	38·8	32·8	48·0	46·8	·20	1
May	69·8	48·0	88·1	37·0	40·4	46·5	45·0	·10	1
June	62·9	47·4	73·2	36·2	30·2	46·4	49·1	1·26	14
July	64·4	43·3	74·0	33·2	29·8	42·8	43·7	·22	3
August	63·8	43·3	82·0	34·0	29·1	40·0	41·7	·65	9
September	74·2	48·8	90·8	37·2	40·2	41·6	43·8	·41	5
October	78·5	51·8	90·2	41·0	38·0	42·0	40·4	·11	2
November	90·2	59·0	103·0	48·0	49·0	46·8	48·7	·06	1
December	90·7	61·6	109·2	49·4	39·0	48·3	49·5	·82	4
				1898					
January	98·0	66·8	113·2	55·0	41·0	51·3	50·3	·02	1
February	90·5	63·4	109·8	48·2	38 6	51·2	49·9	·36	3

of life except when invaded by man. Lizards, amongst which the Mountain Devil (*Moloch horridus*) is one of the most conspicuous, are more often seen than anything else.

The high elevation of Kalgoorlie, and its latitude (more than 30° south), no doubt account for the coolness of the winter months (July, August and September), when, as a rule, an overcoat can be worn with comfort except at midday. Even in summer, there is a cool crispness of the air at night, though the shade temperature during December, January and February is often very high. During a visit I paid to the field, in 1898, the thermometer registered one day, January 9, as much as 113·5° F. in the Palace Hotel.

Typhoid fever and dysentery are the worst scourges in the towns, being more or less prevalent in the hot season, owing partly to the failure of sanitary arrangements to keep pace with the growth of population, to impure drinking-water, to the germs

* T. A. Rickard, *ibid.*

WIND FORCE, 1897.*

Month.	Coolgardie. 9 A.M. Max.	Coolgardie. 9 A.M. Min.	Coolgardie. 3 P.M. Max.	Coolgardie. 3 P.M. Min.	Kalgoorlie. 9 A.M. Max.	Kalgoorlie. 9 A.M. Min.	Kalgoorlie. 3 P.M. Max.	Kalgoorlie. 3 P.M. Min.
January	3	1	3	0	2	1	3	3
February	4	2	4	1	7	2	7	2
March	3	2	3	1	5	2	2	0
April	4	0	3	2	2	1	9	1
May	8	2	3	0	5	2	2	2
June	2	1	3	2	9	2	5	2
July	5	1	6	1	3	2	4	2
August	5	1	6	1	6	2	8	2
September	9	1	9	1	6	2	9	2
October	5	1	8	1	7	2	6	2
November	6	1	9	1	5	2	8	2
December	9	1	4	1	2	2	3	2

Beaufort's scale of wind force * is as follows:—

Number.	Description.	Speed of Wind in Miles per Hour.
0	Calm	3
1	Light air	8
2	Light breeze	13
3	Gentle breeze	18
4	Moderate breeze	23
5	Fresh breeze	28
6	Strong breeze	34
7	Moderate gale	40
8	Fresh gale	48
9	Strong gale	56
10	Whole gale	65
11	Storm	75
12	Hurricane	90

* T. A. Rickard, *ibid.*

VARIATIONS IN DIRECTION OF THE WIND AT KALGOORLIE DURING SEPTEMBER 1897.*

9 A.M.		3 P.M.	
Direction of Wind.	Days.	Direction of Wind.	Days.
North	4	North	4
North to East . .	5	North to East . .	4
East	3	East	1
South to East . .	5	South to East . .	3
South	1	South	4
South to West . .	6	South to West . .	7
West	1	West	5
North to West . .	2	North to West . .	2

But wind has done something more than merely disintegrate and transport the loose material lying on the surface; it has likewise "winnowed," and so *classified*, it. This is impressed on the observer travelling through the country, by acres and acres strewn with a sheet of angular fragments of white or coloured quartz, while close by patches of "black sand," glittering a steel grey in the bright sunlight, or blue-black when in the shade of a passing cloud, graduate off into beds of gravel and dust, in which one may wade up to one's ankles. The heavier magnetic or titaniferous iron-sand, the product of the decomposed diorite found close to the spot where it lies, though crumbled to powder, is scarcely affected by the wind which has collected and moved the quartz, detached from the stringers traversing the underlying rocks.

From the extent of the patches of iron-stone and quartz, collected in this manner, one might infer the probable existence of large masses of both near by, but the following extract which I may quote from Mr. Rickard's excellent paper shows that this is by no means always the case: "Owing to the extreme slowness with which denudation progresses in this arid region, and the consequent very gradual lowering of the zone of oxidation, the rocks exhibit above the drainage level a marked intensity of chemical action. The granite is kaolinised to an almost in-

* T. A. Rickard, *ibid.*

coherent clay, and the diorite is rendered abnormally heavy in iron by the surface-concentration of decomposition products. And, as the rock is eroded, the quartz, on account of its hardness, persists, so that a series of small stringers eventually yields an accumulation suggestive of its derivation from a large mass." This, no doubt, partly accounts for many mistaken statements and disappointed hopes, to be found in prospectuses, where the prospector has not satisfied himself with more than a mere examination of the surface.

The foregoing process of concentration is not, however, confined merely to the accumulation and enrichment of detrital deposits; there is ground for believing it has affected the enrichment of the upper portions of the formations regarded as lodes "in place"; since gold particles, scoured off by surface erosion, have no doubt found their way down through minute fissures and seams in the dry kaolinised rock to considerable depths, and gold in solution has doubtless enriched the deposit still further from the surface.

In sampling long cross-cuts through the country rock, in several Kalgoorlie leases, Mr. H. C. Hoover mentions,* as confirming this conclusion, that "Few assays were secured above the 100-foot level, which did not yield from a trace to 8 pennyweights of gold per ton. Yet in sampling cross-cuts at greater depths, traces of gold became smaller and smaller, until below the zone of kaolinisation, any trace of gold at all in the country rock is rare."

In the Crœsus South United, for example, a cross-cut on the 100-foot level averaged 6 pennyweights per ton, no assay yielding over 10 pennyweights; yet a cross-cut immediately beneath, on the 200-foot level, averaged but 1 pennyweight 11 grains.

The Government meteorological reports do not seem to indicate that the wind at Kalgoorlie blows steadily in any one prevalent direction, though Mr. Rickard states that his own observations would have led him to think that it followed as a rule a south-east–north-west course, which corresponds with what I myself noticed; that is to say, from the Boulder township towards Kalgoorlie.

The difference in temperature between day and night in Western Australia has also helped in moulding its physiographical outlines, through the action of dew, which, like water, changing in volume with change of temperature, however minute the change may be,

* 'The Superficial Alteration of Western Australia Ore Deposits,' by H. C. Hoover, *Trans. Am. Inst. of Mining Engineers*, vol. xxviii.

brings to bear on the rocks an enormous disintegrating effect, corresponding to the action of frost in colder climates, only on a lesser scale.

This process, assisted by the heat of the tropical sun, paves the way for the destructive effect of rain, and is the first step in the cycle of transport and classification already outlined, by which soft and hard, and light and heavy rock-constituents are separated from one another; until finally the gold released from its matrix is set free. And when the force of the transporting agency is no longer sufficient to carry its burden farther, the gold finds a quiet resting-place, until it is once more unearthed by the miner and set in commercial circulation.

In the case of water, the point where detritus settles is governed by the size of the particles, the depth of the current, the slope, size and course of the channel, as well as by the nature of the bed over which it is moved. In the case of air, movement is restricted to shorter distances, and the sorting process produces a deposit of far less regular structure; the settlement of the dust particles being influenced by the vagaries of the wind and obstructions met with in their flight, by which sand ridges are formed, and depressions which constitute natural riffles become gradually silted up. A partially classified deposit is thus gradually, however, built up, which owes its existence to wind and rain assisted by gravity.

Where an outcrop of gold-bearing quartz follows the crest of a ridge, a thin covering of sandy soil will generally be found on its lee side, which thickens perhaps lower down to several feet. A section of such a deposit frequently shows on top a few inches of dust and sand, passing into compacted fragments of stone and quartz, bound together with stiff clay, forming an "agglomerate," locally known as "cement"—"an unclassified product of erosion" (as Mr. Rickard describes it), "lying close to the place of its origin, as a mere collection of unassorted débris." Surface water has doubtless in some if not all cases aided in an intermittent way in shifting portions of such deposits from their original locus.

The underlying rock is so softened by decomposition that it may be, and often is, taken for part of the deposit superposed on it; and if a shaft is sunk it will penetrate often through feet and feet of this oxidised ground, till solid diorite or granite makes its appearance at a depth of from 50 to 200 feet, where water-level is reached.

CHAPTER II.

GEOLOGY OF WESTERN AUSTRALIA.

HAVING dealt in the last chapter with the history, position and general features of the gold-fields, with special reference to their topography, and the various agencies that have contributed to produce the results which are visible *on the surface*; I will now pass on to consider the *geological structure* of the central plateau of Western Australia, in order to afford some idea of the conditions under which its gold deposits have been formed, and the local peculiarities which characterise and distinguish them from ordinary auriferous lodes and alluvials in other districts.

Treating the subject from the broadest possible point of view, although Cambrian, Silurian, Devonian, Carboniferous, Mesozoic and more recent rocks are represented, the greater portion of Western Australia seems to consist of crystalline rocks of Archæan age (the floor upon which the lower strata have been laid down), comprising granites, gneisses and schists; these cover large areas distinct from one another, and run in parallel belts, more or less north and south, with a slight north-west trend. The coastal plain, which fringes the sea-board, is formed for the most part of shallow water-deposits (sandstones, conglomerates and shales, with occasionally incoherent sands and clays), its inner margin rising in certain localities to an altitude of 600 feet above sea level, with a more or less gentle slope seawards. Notwithstanding an outward appearance of similarity, as will be seen later on when studied in detail, each of the belts above referred to, comprising the Archæan series, presents locally considerable diversity in geological structure, which no doubt explains the existence of enormously rich gold deposits in certain areas and their poverty or absence in others, although to the superficial observer the surrounding conditions seem much the same.

Mr. H. P. Woodward, F.G.S. (late Government Geologist), considers * that the Archæan rocks may be divided into six belts, each possessing distinctive features of its own :—

1. The most westerly belt, which extends along the shores of Western Australia, from the south coast to the Murchison river—seen exposed at Northampton, the Irwin river, and between Capes Naturaliste and Leeuwin—is stated by him to comprise clay-slates (often kaolinised), quartzites and schists, penetrated by dykes of diorite and granite, and veins of quartz, which are characterised by the frequent occurrence of copper, lead, zinc, iron pyrites, and ferruginous graphite.

2. The second belt, which lies parallel with the first, forms the bold steep escarpments of the Darling range, turning north-east beyond the Murchison river; and, 200 miles further north, disappears beneath a magnesian limestone formation. These hill ranges, bounding the plateaus and plains of the interior, have an average elevation of about 1200 feet, although isolated ranges reach altitudes of 4000 feet above sea-level. In this belt the rocks are composed of hard crystalline gneiss and schist, traversed by dykes of diorite,† granite and felstone,‡ and veins of quartz, in which several minerals of commercial importance are found, viz. tin (at Greenbushes), iron, manganese, mica, asbestos, and graphite, of which last a deposit was discovered near Bridgetown in 1896.

3. The third series lies 100 miles east of the west coast, forming what Mr. Woodward calls "the great granite belt," which, so far as is yet known, seems devoid of workable deposits of mineral.

4. The fourth series, or *first auriferous belt*, possesses a width of some 20 miles, and lies east of "the great granite belt," with which it runs parallel, starting at the Phillips river, in the south of the colony, and passing through Southern Cross, Mount Magnet, and Cue; then, turning north-east at Nannine, it finally disappears beneath the Palæozoic rocks, where the Henry river valley junctions with the Ashburton.

* 'Mining Handbook to the Colony of Western Australia,' 1895, Perth. By Authority.

† A basic igneous rock of the plutonic class, belonging to the greenstone group, essentially a crystalline-granular compound of felspar and hornblende, the felspar being other than orthoclase. Colour usually dark-green when freshly broken. Occasional constituents: mica, pyrites, magnetic pyrites and iron-ore, titaniferous iron-ore, titanite, garnet and quartz.

‡ An acid igneous rock of the plutonic class, belonging to the granite group, sometimes termed petro-silex, of compact texture, with dull, smooth, conchoidal, or fissile fracture. Colour generally grey, but may have a yellow, red, green, or bluish shade; an intimate compound of quartz and felspar; sometimes massive, sometimes schistose.

The rocks of this belt are mostly hornblendic, micaceous and talcose schists, of which the hornblende schists closely resemble diorite, and are a good deal broken and faulted by granite and diorite dykes and quartz lodes, containing gold, iron and copper. There are also some large magnesian lode-masses, rich in fine gold, which Mr. Woodward thinks will probably prove to be serpentine in depth; many of these lodes, in addition to magnesia, also contain large quantities of chlorite.

5. The fifth, or second granite belt, is nearly the same width, and is in every way similar to the first mentioned, except for the absence of payable gold, and dips in the same way below the Palæozoic table-land of the Fortescue.

6. The sixth, or second auriferous belt, of which the width is yet unknown, extends from the Dundas hills, through Coolgardie, Ularring, and Lake Carey, following a parallel line with the others, and turning, like them, to the north-west, through Nullagine, Pilbarra and Mallina.

The rocks in this area are very similar in general character to those of the first gold belt, viz. hornblende, mica and talc schists, but the formation and lodes are a great deal more faulted and broken, though to make up for this they are the richest that have been discovered.

Baron Sloet van Oldruitenborgh,* believes that the table-land just described, of which the greater part of Western Australia consists, was elevated in Pre-Cambrian times, and was pierced by numerous overflows of diorite, diabase, etc. (probably submarine), which were the precursors of the uplift to which the Australian continent owes its existence.

He observes further, that "very likely towards the end of the Permo-carboniferous period, the probable sinking of the continent resulted in an intense compression in an eastward direction of the whole of this mass of rocks, generating an east-north-easterly thrust, extending along the coast of Western Australia, for a length of about 800 miles, which upheaved a doubly-folded chain, running north-north-west, perpendicular to the direction of orogenical pressure."

The roots of this chain, which has since been planed down, are in consequence now exposed at the surface, and consist of the

* 'Technical Observations in the Coolgardie Gold Field,' by Baron Sloet van Oldruitenborgh. Translated from the French for *The Mining Journal*, London.

parallel belts of granite, gneiss, etc., of which mention has been made.

Mr. C. S. Göczel* considers that in Palæozoic times this portion of the continent formed part of a volcanic archipelago, around which the greater part of Western Australia was built, and in early Mesozoic times (when the gradual upheaval of the continent was completed) volcanic action apparently died out in this part of the globe, although it continued to manifest some seismic and hydrothermal activity,—the agency to which he ascribes the formation of most of the primary gold deposits during later Palæozoic times.

With the elevation of the country above the sea, and the cessation of volcanic activity, Mr. Göczel considers a new era commenced, during which great depressions, occupied by inland lakes and estuaries, were successively filled in with rock material derived from the adjacent highlands.

The same author remarks, speaking of Coolgardie,† that "The main fissures extend for miles, and contain predominantly eruptive rock material, whereas ferruginous quartz, with a higher or lower gold yield, is only of secondary occurrence within them." The dykes, he observes, consist usually of diorites, diorite-porphyries and porphyrites.‡

Dr. Chas. Chewings, Ph.D., F.G.S.,§ like Baron van Oldruitenborgh, expresses the view that the Coolgardie gold-field is the remnant of a large mountain chain, almost obliterated by denudation, which marks a line of weakness in the earth's crust, through which the materials forming the chain were poured, whilst vast quantities remained beneath, and have been exposed at the present surface through the removal of the upper portions.

The prevailing metamorphic rocks in this area, he remarks, consist of schists and slates, which chemically range from the most

* 'The Interior Gold Region of Western Australia (Appendix IV.). Report Department of Mines for the year 1894.

† 'Report of the Department of Mines,' 1895.

‡ This rock contains in a felsitic matrix (usually of a dark colour), individual crystals of felspar, mica or hornblende, whence it is known as felspar-porphyry, mica-porphyry, or hornblende-porphyry. The matrix is sometimes vesicular, or amygdaloidal, but properly speaking the crystals should be granulitic, or micro-granular, i.e. rounded. The term has also been applied to altered andesites, typical specimens of which possess a brown, earthy matrix.

§ 'Geological Notes on the Coolgardie Gold-field,' a paper read before the Royal Colonial Institute, March 17, 1896.

acid (containing quartz) to the most basic * (free from quartz), and petrologically, from amphibole † to quartz-schist; they are probably of Pre-Cambrian age.

The absence of fossil remains, the superficial deposits covering the bed-rocks, the want of accurate geological information about many parts of the colony (much of which remains practically unexplored), and breaks in the continuity of the series, even when the position of certain "formations" can be determined here and there; all tend to render it difficult to settle the relative ages of the rocks of Western Australia, and strew the path of the wary, but untiring geologist, with difficulties.

The excellent work done by Mr. Torrington Blatchford, B.A., F.G.S., ‡ under the direction of Mr. A. Gibb Maitland, F.G.S., the present Government Geologist, throws light, however, on the structure of the Coolgardie district, which is of the greatest possible value to mining men.

THE COOLGARDIE DISTRICT.

The geology of Coolgardie is so far analogous in a general way to that of Kalgoorlie, although so dissimilar to it in many important particulars, that a survey of the one may be well prefaced by a short description of the other and older field, and the following interesting particulars may therefore be given, from Mr. Blatchford's able monograph.

Accepting Mr. Woodward's conclusion, that Western Australia may be considered as traversed by six main belts, possessing distinct geological characteristics, the principal feature that strikes one in Mr. Blatchford's description of Coolgardie (which is situated within what Mr. Woodward terms the second gold belt) is that, locally speaking, there are what I may term "belts within belts."

Topography.

Taking the township of Coolgardie as a starting point, the country presents a gradual and even slope for a considerable

* The basic rocks roughly speaking contain from 42 to 65 per cent. of silica. The acid rocks from 50 to 81 per cent. The class that overlap are sometimes grouped apart as "intermediate."

† Hornblende.

‡ *Bulletin No.* 3 of the Geological Survey of Western Australia, 'The Geology of the Coolgardie Gold-Field, 1899,' which contains an excellent geological map of the district.

distance westward, the watershed running nearly due north and south.

The eastern slope has a greater incline than the western, and is broken by ridges of diorite, which attain a height of 100 to 300 feet above the level of the surrounding country. The direction of these ridges is irregular; to the south they run more or less north and south, whilst further north their direction is more or less east and west.

The country between consists of extensive flats, covered with recent superficial deposits.

General Geological Features.

Underlying the red alluvium, the western slope of the field is traversed by an extensive mass of granite, which appears to extend approximately from the Coolgardie-Menzies and Coolgardie-Norseman telegraph lines, some three or four miles westward, its eastern boundary coinciding very closely with the watershed above described.

This granite courses north 20° west and south 20° east, and has broken through a belt of much-altered, contorted, and probably very ancient hornblende and talcose schists, dipping at angles varying from 30° to 60° east.

These schists are intersected by diorites and acid eruptive rocks, which as a rule follow the strike of the schists, and are exposed in a number of places on the eastern side of the field, east of the granite.

A marked feature of the more basic eruptives, i.e. the diorite-dykes, is that they are bordered by what would seem at surface to be narrow bands, frequently mistaken for schist, but which prove in depth to be amphibole (hornblende) rocks, which are so weathered near the surface as to have acquired a schistose structure. These amphibolites pass, by a gradual metasomatic change, into a diorite in depth, and are stated to be of an entirely different type from those adjacent to the granite, from which they vary greatly both in texture and composition.

The acid eruptives, which are found in many places as narrow dykes of porphyrite or felsite, trending towards and probably emanating from the granite, in some cases graduate imperceptibly from coarse granite into what seems to be quartzite; whilst associated with them are belts of a dark compact rock, closely resembling slate both in texture and cleavage, containing iron and arsenical pyrites, and sometimes carrying as much as 8 dwt. of gold per ton, combined with these minerals.

Mr. Blatchford adds: Since these belts of slate-rock are usually found associated with the felsitic dykes, and seeing that they often lie on each side of the latter, and possess a similar strike and dip, it appears more than probable that they are much-altered schists or hornblende rocks.

Some three miles west of the Londonderry mine, another granite intrusion occurs, which differs considerably in character and appearance from the one previously described, and whether the two are connected or not is at present undecided.

Recent Superficial Deposits.

A large portion of the Coolgardie field is covered by recent superficial deposits, which vary in depth from a few inches up to some hundreds of feet (as proved by a section at what is known as Rollo's bore-hole), the flats and slopes west of the township being buried beneath this blanket of alluvium.

On the surface it consists of loose sand and quartz fragments, resulting from the decomposition of the granite, "cement," and quartz reefs, mingled with ferruginous matter derived from the hornblendic rocks and ironstone gravels referred to later on.

The quartz particles are usually of small but various sizes, and are more or less rounded by the action of the wind, whilst at greater depth, where they lie on the eroded surface of the granite, they are larger, and are usually sub-angular, having apparently been exposed to the action of water, in what seem to have been ancient subterranean watercourses.

Quartz of this kind, it is said, rarely if ever shows any free gold. The impure oxide of iron, of which a large part of the alluvium consists, is in a fine state of division on the surface; but, lower down, large loose rounded pebbles of ironstone are met with in patches, and in many cases show free gold both on the exterior and on freshly broken surfaces. On approaching the granite on which it rests, this deposit often becomes so compact as to necessitate the use of explosives to break it, being cemented together by the iron which has been dissolved out and re-deposited. Under a lens, the finer samples show the presence of garnets and zircons, occurring in broken and partially worn fragments, together with magnetic iron commonly known as " black sand."

Ironstone Gravel Deposits.

The remnants of these deposits are found widely scattered over various parts of Western Australia, overlying the granite; they occur exposed in semi-detached patches on the Coolgardie field, following a north and south line, on the outskirts of the alluvials, to which they have doubtless contributed much of the iron which imparts to the latter their red colour. At Coolgardie and elsewhere, however, when exposed at surface, this deposit has been largely removed by denudation, except where it lies in hollows in the eroded surface of the bed-rock.

Mr. Blatchford is of opinion that these ironstone gravels have been most likely derived originally from older beds of ferruginous clay, long since altered *in situ* (through concretionary action) into ironstone nodules, that have been changed at surface into the hard ironstone pebbles which are so frequently met with.

In places these pebbles become re-cemented together into the lumps of impure ironstone which are often found outcropping on high ground, and, as judged by a sample * analysed in the Government Laboratory, the composition of this ironstone appears to be: — Fe_2O_3 35·25 per cent., FeO 0·51 per cent., equivalent to 25·07 per cent. of metallic iron; assays made of the "gravels" show from 3 up to 8 dwt. of gold per ton.

They lie at Coolgardie at a tolerably uniform level between 1380 and 1460 feet above the sea, and Mr. Blatchford thinks that the same may be said to be the case in other parts of the central table-land. Their nodular appearance seems to be due merely to surface weathering, and he regards them as ferruginous clay-stones, either resulting from volcanic dust, or a detrital deposit derived from more or less basic rock, in either case thrown down in water.

Whilst minor deposits of a somewhat similar character are found at lower levels, as at Coates' siding in the south-west portion of the colony, and elsewhere, which evidently originated from the surrounding rocks, Mr. Blatchford contends that, in view of their wide distribution, and the facts that have been already stated, there seems much likelihood that these singular ironstone gravels are of

* From the Retribution G. M. Lease.

marine origin, and he places their age between Jurassic and Miocene, or Pliocene, probably the latter, judging from their lithological character. Underneath the ironstone gravel, lying between it and the granite, patches of so-called "cement" are sometimes found, forming a substratum which attains in places an average thickness of about 3 feet, and although what little of it has been found at Coolgardie itself has not thus far proved payable, very similar "cement deposits" discovered at the "25-mile," and at other places in the surrounding districts, have turned out extremely rich.

The Underlying Rocks.

Granite.—The intrusive granite mass, on the western side of the field, appears to have burst through the older schists and slates on each side of it, contorting, altering and twisting them, and sends off-shoots (in the form of narrow dykes) that break through the diorite and schists which dip away from its eastern flank.

The granites of the western area differ, however, considerably locally, in composition and character,—in places consisting of ordinary coarse granite, whilst in others the quartz, felspar and mica are separate from one another, occurring in large patches.

The mica when thus found, is mined, averaging in places 5 to 6 inches, whilst it occasionally reaches 12 by 15; when grouped in crystals with their longer axes parallel, the mineral presents a peculiar scale-like impression, the tint varying from pale pink to pale green, although it is occasionally colourless. The felspar, which likewise occurs in large bunches, is colourless, or of a sea-green colour, and belongs to the potash variety. The quartz is almost colourless and glassy, and seems subordinate in quantity to the other two minerals.

On the Gnarlbine Road, about two miles south-west of Coolgardie, one finds a different type of granite from that previously described, viz. a holocrystalline hornblendic variety, a section of which, obtained from a bore-hole at a depth of 2370 feet, shows hornblende and quartz well developed, with a slightly-decomposed monoclinic felspar fairly evenly distributed through it.

Muscovite mica forms, in this class of granite, the most important accessory mineral, but it is in small proportion compared with the hornblende.

The acid eruptive dykes, thrown off from the main granite mass at Coolgardie eastward, seldom exceed 10 to 12 feet in width, and, although generally following the strike of the schists, they cross the country in all directions; and the dark-coloured bands that accompany them, to which previous reference has been made, having the same strike and dip as the dyke, are evidently the result of contact metamorphism, produced by their intrusion through the schists or diorite, altering it up to a distance of some 9 feet on each side.

Mr. Blatchford ascribes their banded structure to "infiltration of solutions and deposition of secondary minerals, especially magnesite and iron pyrites," which give them their schistose appearance. Their principal mineral constituents are felspars, with occasional crystals of quartz, hornblende, augite,* and numerous grains of magnesite and pyrites, arranged in wavy bands. Although often described as clay-slates, this is obviously a misnomer, inferring a sedimentary origin, with which, for reasons already explained, they can have no possible connection; besides which, they often occur in diorite and intersect the dykes at various angles.

The granite dykes show a gradual change from a holocrystalline † granitic rock, through a diminution in the size of the crystals (although the composition of the rock remains unaltered) to a felsitic ground-mass with a few larger crystals of orthoclase scattered through it, gradually becoming more and more acid, until pure quartz is reached.

In some cases the quartz would seem, however, to have segregated out on the sides of the dyke, forming what appears to be a contact vein of quartz. Such quartz reefs are almost invariably barren, although the branch-reefs or cross-leaders often yield good prospects of gold.

Schists and Amphibole Rocks.

To the east of the granites at Coolgardie a series of rocks occur, as already said, which appear at surface to be hornblende schists, and have the same strike as the intrusive diorites and granite.

It seems highly improbable, however, that they are of sedimentary origin, as in depth (below the 200-feet level) they gradually change to massive diorite or hornblende.

* A variety of pyroxene, varying in colour from deep green to black, so-called from αὐγή, lustre.

† Distinctly crystalline, oftentimes extremely coarse.

This belt is subdivided by Mr. Blatchford into two divisions: The first and most extensive, which lies adjacent to the granite, consists of hornblendic and talcose rocks, which possess, when decomposition has not been carried too far, a more or less perfect cleavage, although, when much altered, the cleavage vanishes, and the rock becomes massive and more homogeneous. Most likely, as hornblende has a tendency to decompose into either serpentine or talc, the one kind is only an altered form of the other, and it seems more than probable that they represent the weathered remains of some ancient hornblende-rock.

The second class, though resembling schists, change so quickly to massive hornblende, that there is little doubt that its apparent schistosity is due to surface weathering, and Mr. Blatchford, in fact, regards these amphibole rocks as merely altered diorite, in which hornblende preponderates.

Possibly the one may be a more altered variety of the other, and the differences that exist between the two may be accounted for by contact with the mass of granite farther west.

The strike of these rocks runs from north 20° west and south 20° east to north 20° east and south 20° west, and their dip varies from 30° to 60° to the east. In places, however, owing to the intrusion of diorite dykes, they dip westerly.

Diorites and Andesites.

These classes of rock are met with on the Coolgardie field in the form of bosses and dykes, originating from the larger masses, breaking through the schists, and in some cases through the granite; and, as they are sometimes found intersecting one another, are evidently not all of the same age, the andesites * being clearly the most recent. Microscopic examination shows that they consist of hornblende and plagioclase felspar, possessing frequently a coarse porphyritic structure in the centre of the main masses, whilst on the outside, or when followed down, they are oftentimes so fine that the individual minerals cannot be distinguished, even under a powerful lens.

* An acid igneous rock of the volcanic class, belonging to the trachyte group, containing sanidine or oligoclase felspar, combined with hornblende, augite and mica, or even quartz in subordinate amount; called trachyte when possessing a rough granular structure. Some andesites approach basalt, the crystals of oligoclase or labradorite, with augite or hornblende, being set in a lithoidal or glassy ground mass.

Gold Deposits.

The gold obtained at Coolgardie has been derived from three principal sources, alluvial deposits, lode formations, and quartz reefs; and towards the end of December 1895 there were some 6000 persons on the fields, engaged directly or indirectly in mining.

Alluvial Workings at Coolgardie.

The gold obtained from the first class of deposits above referred to has mostly been got from the loose, dry surface-alluvials, by the method peculiar to Australia, known as "dry-blowing." For its success it requires most careful manipulation, when the gold is finely divided, but in experienced hands, it gives fairly good results. That a good deal of gold is lost, however, is proved by the refuse heaps of the dry-blower, which average in many places 10 dwt. to the ton by assay.

In the absence of water, which prevents the employment of the cradle, tom or sluice-box employed by the placer miner in other countries, "dry-blowing" is designed to utilise the agency of wind in place of water, and, in the skilful hands of the "prospector," performs the function of sizing, classifying and thereby concentrating the material a step further than nature has already done.

The perfect dryness of the dirt and the heat imparted to the iron pan by a tropical sun, are factors which are indispensable for its success, giving a mobility to the material, which Mr. T. A. Rickard has aptly compared to "the behaviour of a charge in the roasting furnace, in which the hot air cushions each particle so as to give the mass an apparent fluidity."

He also points out in the paper referred to,* that much depends on the strength and uniformity of the wind. Fortunately for the dry-blower, there is generally a light breeze, except during sultry days in the height of summer and on the cloudy mornings in the wet season,—both of which times of year are unfavourable for operations of the kind.

The deposits worked in this manner are usually "patchy," and frequently lie at the head of shallow gullies, which start from ridges where a quartz vein outcrops, below which gold has been picked

* 'The Alluvial Deposits of Western Australia,' by T. A. Rickard, A.R.S.M., *Trans. Am. Inst. of Mining Engineers*, vol. xxviii.

up on surface; and, as Mr. Rickard remarks, "the distribution of gold in these deposits reminds one of its position on a vanning shovel. It may be traced up to the outcrop which yielded it, or it may be scattered in the sand for half a mile; but the rich and only workable part of the deposit will ordinarily be found at a distance of 30 or 40 feet from the reef.

Doubtless, however, as explained in the last chapter, in certain instances the gold is derived from mere stringers and auriferous deposits other than quartz veins, and therefore the existence of rich alluvials does not always lead to the discovery of what can be strictly termed "a reef," in the immediate neighbourhood of deposits of the kind.

First the alluvial is well shaken up, so as to bring the large lumps to the surface, which the "prospector" examines and skims off; then in its most primitive form, "dry-blowing" consists in dropping the "dirt" from a height, from one "dish" to another, the dust and finer particles being blown away in falling 4 or 5 feet through the air, whilst the gold and coarser gravel are caught in a second "pan" set on the ground at the miner's feet, who stands so as to face at right angles to the wind, placing the lower "pan" on a piece of coarse canvas to leeward, so as to catch any fine gold blown to one side over the edge of the "pan."

This process is sometimes repeated several times, although once may suffice, shaking up the coarse lumps in the full pan when taken up from the ground, so as to bring them to the surface again, picking them out, and pouring the residue back into the empty pan as before.

The next stage is to toss the dirt up and down in the pan, holding the pan in a slanting position, away from the operator, and jerking it back, so as to throw the dirt from the front to the back of the dish, thus winnowing it still further. Then once more shaking the pan, with a vanning movement, he brings the lumps to the top, and skims them off.

When thus reduced to a small quantity of "fines," the auriferous residue is still further shaken down, like the contents of a dish when panning it in water, and with the pan tilted forward, the miner raises it to his mouth, and completes the operation by blowing off the remaining light sand.

After this process of concentration is finished, the gold is seen fringing the edge of the iron-sand, any nuggets, or pieces coarse enough to "speck," are picked out, and the "fine gold" is either washed out with water in the usual way, or collected with the moistened point of the miner's thumb.

FIG. 5.—"DRY-BLOWING." (By courtesy of T. A. Rickard.)

This slow and laborious process is frequently superseded by a "machine" for sizing the material, operated on the same general principles, which, in its simplest form, is known as a "shaker" (Fig. 5), owing to the shaking motion imparted to it.

It consists of a couple of slanting frames (covered with screens of different sizes—generally twelve or eighteen mesh—and provided with cross riffles) fixed on legs in such a way as to allow the miner to shake the material backwards and forwards. The dirt,

Fig. 6.—Dry-Blowing Machine (Lorden's).

which is fed on to the head of the frame through a hopper fitted with a sheet-iron bottom punched with 1-inch holes, passes down the inclined screens, the finer particles falling through, the coarser ones being discharged over the end, and the gold grains and

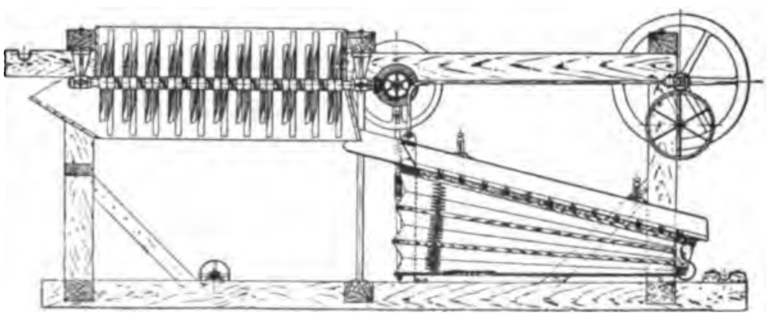


Fig. 7.—Wood's Dry Placer-Miner.

nuggets accumulating behind the riffles. The "fines" collected underneath the frame are subsequently treated by hand, by the method first described. Such a machine, measuring 4 feet by 2 feet, will put through about 5 tons of loose dirt in seven hours.

A more elaborate contrivance to fulfil the same object, illustrated in Mr. Rickard's paper, consists of a series of flat trays, with sieve bottoms, hung on a tripod ; several other machines which he describes and illustrates (Figs. 6, 8 and 9) are provided with bellows, to produce an artificial air-current, in order to blow away the finer worthless material.

One of the most effective of these contrivances I believe is "Wood's dry placer-miner,* manufactured by Messrs. Fraser and Chalmers, which is shown in side elevation and section in Fig. 7 ; whilst a smaller size prospecting-machine is illustrated in Fig. 8.

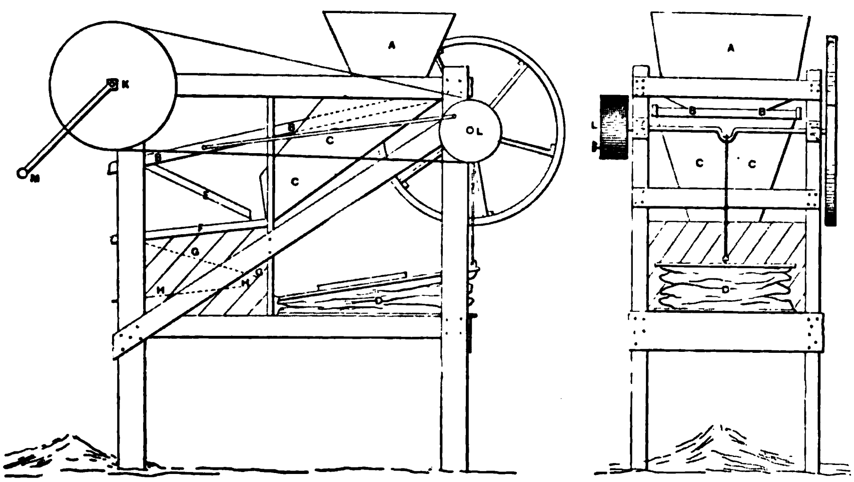


FIG. 8.—DRY-BLOWING MACHINE.

Usually in such machines the bellows and sieves are worked in synchronism, being coupled together, and driven by belting, by means of a fly-wheel turned by hand. A machine of this sort, which weighs, according to Mr. Rickard, 124 lb., and puts

* A large-size machine requires two horse-power to operate it, and is mounted on an oak frame, which covers a ground space of 5 feet by 13 feet 9 inches, weighs 2600 lb., and is stated to have a capacity of 10 cubic yards of dry screened gravel per hour. The gravel riffle board has a shaking motion of 150 strokes per minute, which helps to settle the gold to the bottom, and the blast of the bellows can be regulated so as to make it stronger or weaker. The prospecting-machine has a length of 4 feet, width of 2 feet, and height of 3 feet 10 inches ; weighs 300 lb., and its capacity is given as 1500 to 2000 lb. per hour ; the gravel is fed to the machine from a disintegrating-box, fitted with revolving steel blades.

through 10 to 14 tons a day, costs in Freemantle about 16*l.*, and can be carried on poles by a pair of men.

A small machine, known as the Pneumatic Prospector, made by P. P. Cuplin, of West Bend, Iowa, might be worth the attention of "prospectors" for testing purposes. It measures 6 by 11 by 14 inches, and only weighs 10 lb.; it seems extremely portable, and is said to give a clean prospect, equal to careful panning.

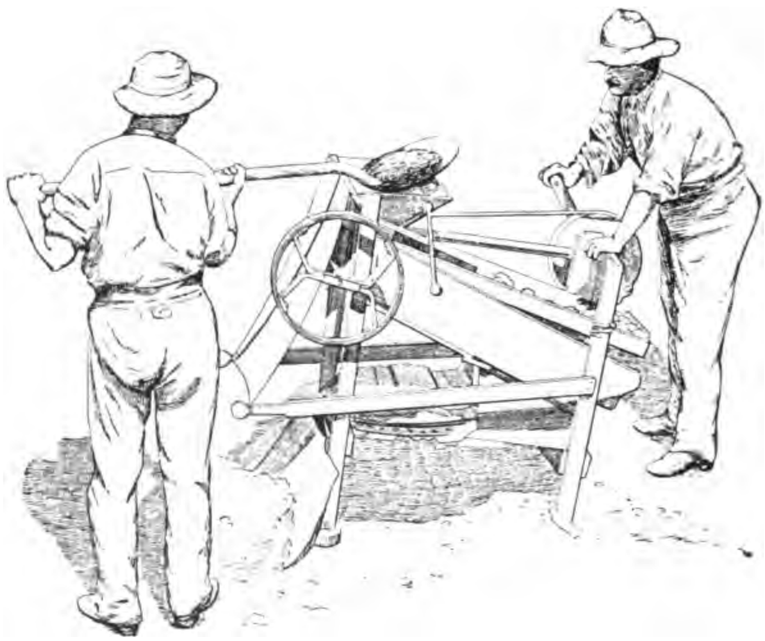


FIG. 9.—DRY-BLOWERS AT WORK.

A larger machine, which weighs 160 lb., it is claimed is able to handle 20 to 30 cubic yards of gravel per day, and to save fine and coarse gold and nuggets of any size, free from black sand.

Lode Formations.

These usually consist of lenticular patches, of much-altered schist of a ferruginous character, traversed by small quartz leaders, which form a "stockwerk" in the schistose rocks, and according to Mr. Blatchford, so far as is known at present, they invariably pinch out when they encounter hard country. Sometimes, however, the quartz leaders unite, and form a quartz reef, which, although it may continue in depth and carry pyrites below water-level, becomes as a rule low-grade.

Mr. C. S. Göczel regards reefs of this class as having been mineralised by deep-seated solfatara action, secreting the mineral in solution, along the contact zone of the granite with the diorite and diorite-schists.

The majority of these "stockwerks" seem to be closely associated with and to follow the course of the acid dykes, which were the last to force their way through to the surface.

Seldom possessing well-defined walls, such deposits are scarcely distinguishable from the country rock, except by assays showing the presence of gold, and by the quartz stringers by which they are sometimes crossed and re-crossed. When these latter are stained by iron a dark colour, Mr. Blatchford remarks that they are usually more or less auriferous; but although they have yielded considerable gold, reefs of this description are so small and irregular that the profit is eaten up in development and treatment charges, and when of workable width they are invariably low-grade.

Quartz Reefs.

The quartz reefs, which are mostly found in the schists, usually course in a general north and south direction; possess a dip of 60° to 80° to the east; and are of two distinct varieties: one closely resembles the "lode formations," forming large lenticular patches, which are often exposed at the surface as "quartz-blows"; whilst the other is represented by quartz veins of the ordinary type.

Mr. Blatchford remarks that it remains to be proved whether the former class will continue in depth; but in one notable instance, at Bayley's United mine, they certainly re-make, both in a vertical and horizontal direction. For, although they show a tendency to taper out, horizontally as well as vertically, and become apparently lost, on cross-cutting, they are often found to re-make; a new lens-shaped splice coming in as rapidly as the old one disappeared, whether on the same level or at different vertical horizons.

In depth, the quartz reefs in this district usually carry iron and arsenical pyrites, and the gold in the upper levels is thought to have been derived from the oxidation of these minerals. The gold is, however, unfortunately "patchy," although, as was the case at Bayley's, the stone is sometimes *entremely rich* in places, quite a limited area yielding it may be several thousand ounces.

Minerals Associated with the Gold.

The ore-bodies at Coolgardie in some instances are characterised by the presence of blue and green carbonates and sulphide of copper; in others, carry iron pyrites and mispickel. In Bayley's and other mines, the mispickel* (arsenical pyrites) is the richest of these minerals, showing gold both free and combined.

The iron pyrites, which mostly occurs below water-level, is found both as FeS_2 and as pyrrhotine † (magnetic pyrites) Fe_7S_8, at Sherlaw's Perseverance, and other mines.

In the Black Prince, the Lombard, the Sydenham, and other properties, copper is found above water level, both as azurite (blue carbonate) and malachite (green carbonate), and occasionally as cuprite, Cu_2O (red oxide) and native copper. The last-named is present in one case (in G. M. Lease 20) in sufficient quantity, it is said, to seriously interfere with amalgamation.

Galena, PbS (sulphide of lead), is sometimes met with, notably at the Union Jack, scattered irregularly in small cubes through the quartz; it is considered on this field, as at Charters Towers (Queensland) and elsewhere, as an indication of high-grade ore.‡ Free gold which is sometimes visible in the galena crystals, shows the intimate connection that exists between them. Vanadinite (chloro-vanadate of lead) has been detected with gold at Coolgardie, and zinc-blende (which is sometimes present in small quantities) is stated to be indicative in this locality of rich ore.§ Molybdenite, MoS_2 (sulphide of molybdenum), which may be mistaken for galena, is also occasionally found, as, for example, in the amphibole rock in the Ensign Lease.

* An orthorhombic silver-white to steel-grey mineral with a metallic lustre.

† A bronze-red mineral.

‡ Mr. T. A. Rickard, in a paper read before the Institution of Mining and Metallurgy, 'The Minerals Which Accompany Gold,' *Trans.* 1898, questions the "indicative value" of what is termed the "paragenesis of minerals," in different districts; but if the field of observation is narrowed down to any one particular locality in which the general conditions are the same, the presence of certain minerals may, I think, sometimes be looked upon by the miner as a favourable indication, just as certain varieties of quartz are considered a more "kindly" matrix than others.

§ 'The Mineral Wealth of Western Australia,' p. 28. *Bulletin No.* 4, Geological Survey, by A. Gibb Maitland, F.G.S.

Scheelite* (tungstate of calcium) is found in bunches in some of the reefs at Coolgardie and Southern Cross, but in both places is said to be characteristic of poor ore.

Cyanite (silicate of aluminium) and lepidolite (fluo-silicate of aluminium, potassium and lithium) have been found in the Londonderry mine. Of the non-metallic minerals, carbonate and sulphate of lime, and carbonate of magnesium, are said to be the most common; their secondary products, calcite and dolomite, are of frequent occurrence, filling crevices and cavities left by the removal of the former minerals.

The dolomite, which varies from pure magnesite to impure calcite, is sometimes crystalline, sometimes amorphous, and is liable in the one case to be mistaken for felspar, in the other for carbonate of lime.

The carbonates of magnesium and lime are frequently found in the amphibole rocks, taking the place of felspar in places where it is decomposed and removed; in others they seem to have been introduced by aqueous solutions penetrating the crevices in the rock.

In Sherlaw's mine an admixture of crystalline gypsum and calcite may be seen filling what was once a cross-fissure. Bayley's United, up to the end of 1898 is stated to have produced some 18,670 tons of ore, which yielded 53,249 oz. of gold, or at the rate of 2 oz. 17 dwt. per ton, the gold having an average value of 3*l.* 17*s.* 10*d.* per oz. The output since has been as follows:—1899, ore crushed 13,685 tons, yielding 19,602 oz. Tailings and slimes treated 13,030 tons, gold recovered 2905 oz.; total 22,507 oz. 1900, ore crushed 28,227 tons, yielding 16,923 oz.; tailings and slimes treated 31,733 tons, gold recovered 5976 oz.; concentrates 47 tons yielding 246 oz.; total 23,145 oz. 1901 (January to June), ore crushed 5485 tons yielding 2503 oz.; tailings and slimes treated 6772 tons, gold recovered 1073 oz.; alluvial plant 1077 tons, returned 291 oz.; total 3867 oz.

An interesting description of the various mines on the Coolgardie Field is given by Mr. Blatchford, in Bulletin No. 3 of the Geological Survey, to which I am largely indebted for these notes.

* Stibiotantalite, tantalo-niobiate of antimony, $Sb_2O_3(TaNb)_2O_5$, a yellow to brown resinous mineral, which is found associated with tin-ore at Greenbushes, is apt to be mistaken for scheelite.—*Progress Report*, Western Australia Geological Survey, 1899, p. 54.

The returns from the Coolgardie Gold-Field (Coolgardie and Kunanalling Districts) for four years are shown in the following table * :—

—	Alluvial.	Dollied and Specimens.	Ore Treated.	Gold therefrom.	Total.
	oz.	oz.	tons.	oz.	oz.
1898	52·71	1,158·96	107,622·39	98,461·17	99,672·84
1899	6,476·40	1,713·54	155,003·14	123,066·95	131,256·89
1900	1,624·76	320·06	133,087·75	100,468·19	102,413·01
1901	1,259·65	1,739·76	121,675·91	81,754·62	83,754·03

The total amounts entered for export and received at the Royal Mint (Perth Branch) are given as: 1898, 127,227·06 oz.; 1899, 141,170·08 oz.; 1900, 119,781·46 oz.; 1901, 88,600·34 oz.

The dividends paid by Coolgardie Companies (having offices in the United Kingdom) are given as follows :—

Name of Mine.	1897.	1898.	1899.	1900.
	Rate per cent.	Rate per cent.	Rate per cent.	Rate per cent.
Burbank's Birthday Gift	10	12½	20	5
Bayley's United	..	..	20	20
The Premier.	20†	..	16	20
Lady Loch Gold Mines	..	..	2½	..

* Compiled from the 'Mining Statistics,' Department of Mines, Perth.

† Paid 20 per cent in 1896.

CHAPTER III.

ALLUVIALS, CEMENT DEPOSITS, AND SURFACE GEOLOGY OF THE "25-MILE," KANOWNA,* AND KALGOORLIE DISTRICTS.

IN the last chapter I gave a brief sketch of the geographical structure of the central plateau of Western Australia, and of the local features of Coolgardie. I now propose to describe the interesting and peculiar "cement deposits" which are met with in the Kunanalling Division of the Coolgardie Gold-field and at Kanowna, and to deal with the topographical features of Kalgoorlie.

Just in the same way that California and Victoria owe their early prosperity and rapid industrial development to the discovery of *alluvial gold*, so Western Australia is indirectly indebted in a great measure for its present thriving condition to the alluvial diggers, who, acting as pioneers of the mining industry, paved the way for the quartz-miner and capitalist, who invariably follow in their wake. As Mr. T. A. Rickard † points out, however, the discovery of the rich telluride lodes at Hannan's, and the development of "this immense desert country, dotted over with the unhappy failures which were based on small pockets of specimen gold-quartz, did not happen without a sad expenditure of money and human life."

The peculiar character of the gold "rushes" is, in fact, in no small degree traceable to the nature of the gold occurrence, "since gold is found lying on the very top of the ground, and the first surface mining yields extraordinary profits" to the individual discoverer. Hundreds of ounces have thus been picked up by the

* The plans and sections (Figs. 10 to 15) are reproduced from Mr. Rickard's paper 'The Alluvial Deposits of Western Australia,' with the kind permission of the *American Institute of Mining Engineers.*

The sections, Figs. 16, 17 and 18, are reproduced from Mr. Torrington Blachford's monograph 'The Geology of the North Lead Kanowna' in the 'Annual Progress Report of the Geological Survey of Western Australia,' 1899.

† 'The Alluvial Deposits of Western Australia,' by T. A. Rickard, A.R.S.M., *Trans. Am. Inst. of Mining Engineers*, vol. xxviii.

first-comers, "specking" for gold, as it is called; the sandy patches of alluvial, where discoveries of this kind are generally made, being afterwards turned over and treated by the "dry blowers," who have trenched and pitted the surface in all directions.

On Sundays and holidays, when regular employment is at a standstill, miners otherwise engaged during the week may be often seen out "specking," employing their leisure in quartering a likely spot, with their hands in their pockets and eyes bent on the ground, like men lost in deep thought; but it is devoted to one subject, the endeavour to get on to the trail of a nuggety bit of gold. Not long since two miners in course of work unearthed a nugget weighing 123 oz., and another of 10 oz. at Kurnalpi; and a correspondent of *The Financial Times* wrote,* "There is every appearance of there being another alluvial rush a mile from Kurnalpi; since the finding of the 37 and 33 oz. 'slugs' previously reported, men have been unearthing three or four slugs each day, the slugs averaging 5 to 6 oz. each."

The fragmentary overburden of detritus, of which these "*superficial alluvials*" consist (termed by the Australian miner "made ground," to distinguish it from the underlying bed rock on which it frequently rests), covers at times accumulations of consolidated auriferous material, called "cement" (Fig. 10) which, as Mr. Rickard observes, are more extensive and, quite apart from their greater economic value, are also of superior interest, because of their better defined geological features."

The Cement Deposits.

Two of the most typical examples of deep alluvial of this class occur at Kunanalling (the 25 mile), and at Kanowna.

The "25-mile."

In this locality, a very interesting deposit of cement is found at Kintore about 6 miles north-north-west of the "25-mile" (Kunanalling), which is about 20 miles north of Coolgardie, on the road to Menzies. It was one of the earliest worked, and Mr. Rickard, describing these deposits, states that: A vertical section shows a thin layer of sand at the surface, beneath which there is a bed of kaolin 2 inches to 1 foot thick, overlying from 15 inches to 2 feet

* *The Financial Times* letter, Feb. 1, 1901.

of sand-rock, that covers the golden "cement" (the average thickness of which is about 2½ feet), whilst the bed rock below is a rotten granite with an irregular surface, decomposed to a considerable depth.

The several layers composing the deposit (which vary in coarseness) are separated by seams of "pipe-clay," resulting, like the kaolin, from the decomposition of the felspar in the granite.

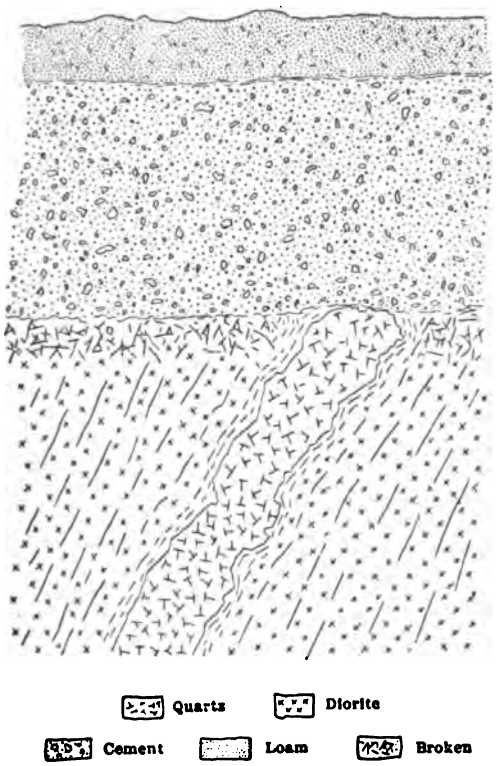


FIG. 10.—VEIN CAPPED BY ALLUVIUM.

The "sand-rock" is "a coarse incompletely-consolidated sandstone," or grit, mainly consisting of imperfectly-cemented particles of iron-stained quartz.

The "cement," which attains a maximum thickness of 5 feet, looks at a distance like a coarse sandstone, exhibits a rough joint structure, and possesses a bluish-grey tint, due to the play of light on the fragments of the quartz, but differs in various ways from

South African "banket," to which some have compared it; for example, it may be more properly called an agglomerate * than a conglomerate, and where fractures occur they do not break across the quartz pebbles, whilst these latter are bound together by comparatively soft clay.

The deposit (Figs. 11 and 12), which is traceable for about 1½ miles, though there are frequent breaks in it, starts at the east

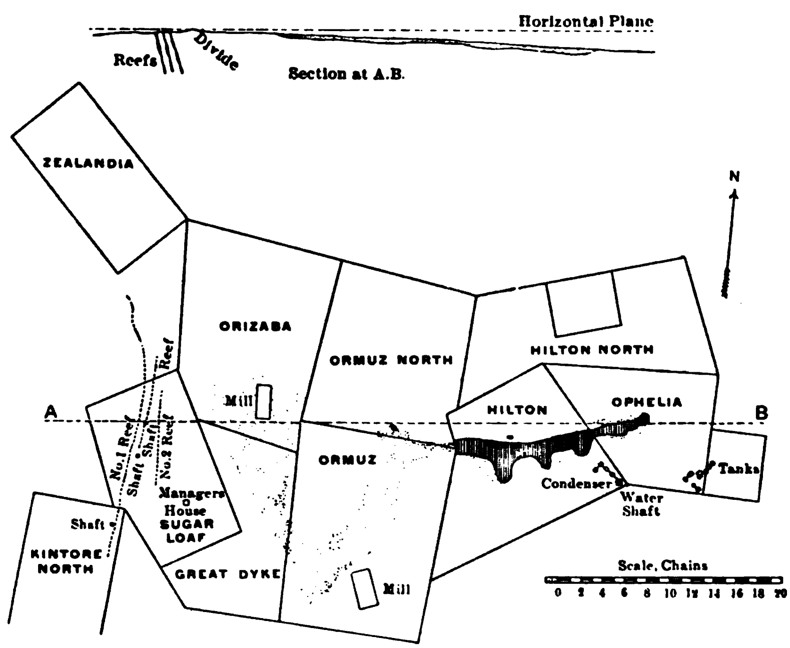


FIG. 11.—CEMENT DEPOSIT, KINTORE.

end of a shallow depression or basin, where the channel is some 15 feet wide, but it subsequently enlarges to about 100 feet in width and occasionally bulges out to 250 feet, the bed-rock rising in a westerly direction, with a grade of about 15 feet per 1000, for a distance of some 3500 feet.

Along the edges or rim, the deposit thins out and gets poorer, giving place to 2 or 3 feet of iron-stone gravel, carrying 2 to 4 dwt. of gold per ton, whilst the richest parts appear to be in the centre

* Mr. Göczel calls it "a quartz breccia," *op. cit.*

of the gutter, and in lateral embranchments from the main body of the deposit.

The kaolin has become hardened and dried, and its true character, Mr. Rickard points out, is obscured by the down-filtering of red sand through cracks reaching to the soil overhead.

The highest point along the major axis of the "lead" is a low

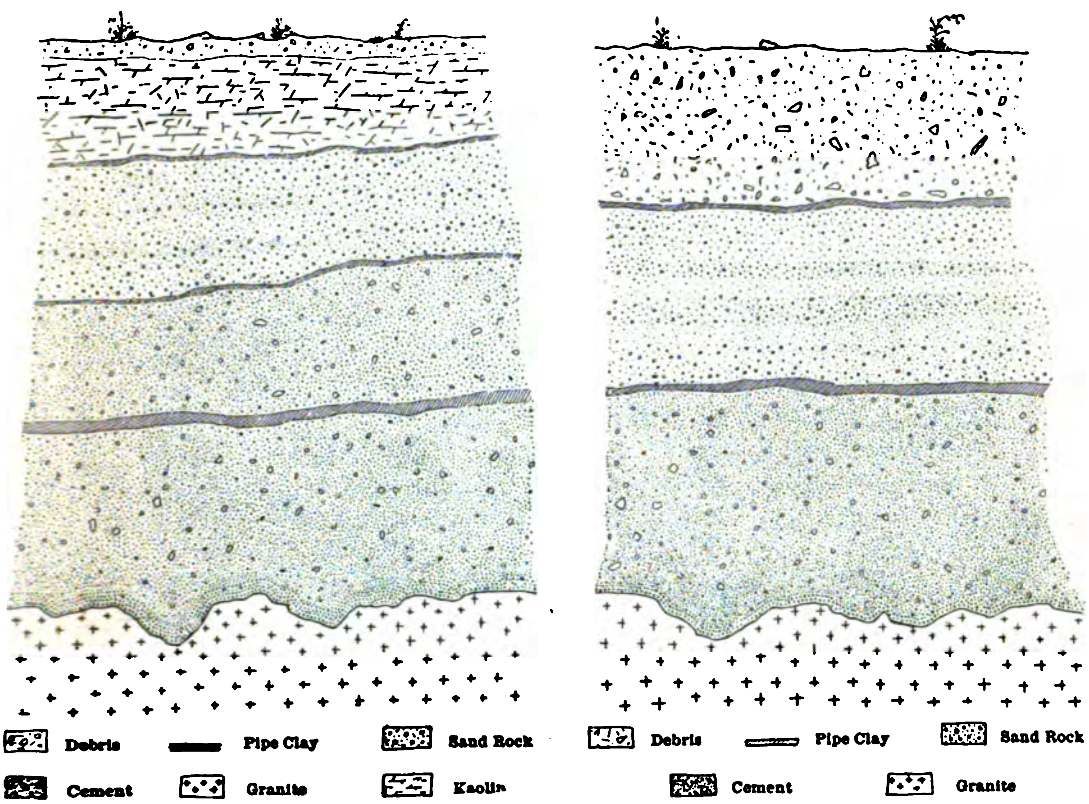


FIG. 12.—CEMENT DEPOSIT (SECTIONS IN OPEN CUT).

ridge that separates the workings of the Sugar Loaf mine from the alluvial ground, which commences on the Great Dyke Lease at a point 530 feet farther east, and 3 feet lower than the crest of this "divide"; whilst the Sugar Loaf reefs cross the country 462 feet to the west, and about 15 feet (vertical) below the dividing ridge.

If, however, as Mr. Rickard supposes, the "reefs" referred to once outcropped at a higher level than the ridge, which now separates them from the gutter containing the "cement," it is most probable that the gold was originally derived from them; and in support of this view he instances the following facts: That the veins traverse granite which has been kaolinised to 130 feet from surface. They consist of white quartz, and are narrow (4 to 12 inches), but they carry short shoots of very high grade ore (3 to 10 oz. of gold per ton). The gold occurs native in flakes penetrating the cleavage planes of the quartz like a golden mosaic, and also in coarse particles which, under closer examination, prove to be octahedral crystals with curiously rounded edges; consequently, as the gold in the cement is exactly similar to that seen in the reefs, and the quartz fragments in the alluvial are identical with the stone of the Sugar Loaf reef, the derivation of the one from the other appears to be scarcely open to doubt.

Mr. C. S. Göczel, who has also described this deposit,* mentions that it mainly consists of sharp-edged quartz grains and quartz-breccia, but occasionally contains small smooth round quartz pebbles, the whole being cemented together by crypto-crystalline silica, which being frequently more or less ferruginous, gives it a variegated colouring; the gold is often sufficiently coarse to be visible, and is embedded in the ferruginous matrix, which sometimes exhibits pseudomorphs of brown hæmatite after pyrites, part of the gold being evidently derived from the decomposition of this mineral.

Mr. Blatchford observes † that: "The cement consists of sub-angular and rounded fragments of quartz, varying in size from grains smaller than a pin's head, to pieces over an inch in diameter." "These grains are usually bound together by kaolin in varying proportions, the hardness of the rock varying with the amount of kaolin present."

"When the cementing material is more or less absent, the grains are usually of a finer or more even texture, giving the rock the appearance of sandstone, whilst it becomes so soft as to crumble easily under the pressure of the fingers.

"As a general rule, ironstone gravel overlies the cement, and fills in the pot-holes and gutters cut in the latter. In places,

* 'On the Deposits of Auriferous Cements at the 25-mile Workings.' Report of the Department of Mines for the year 1895, Perth, p. 26.

† *Bulletin No.* 3, 'The Geology ot the Coolgardie Gold Field,' Geological Survey of Western Australia, by T. Blatchford, B.A., F.G.S., Perth, 1899.

however, it is found intermixed, showing that, although the cement is of greater age, its deposition, at least in some places, was not complete when the iron-stone was in process of formation, thereby demonstrating the similarity of age of these deposits."

The cement, which has a maximum thickness of 15 feet, and a maximum width of 90 to 100 feet, occupies a serpentinous channel in the underlying eroded granite, which is about one-and-a-half miles in length, although there are frequent breaks in it, where parts of the original deposits have been denuded away.

In section, Mr. Blatchford remarks, it shows distinct horizontal stratification, leaving no doubt as to its sedimentary origin. Between the cement and the ironstone gravel there is sometimes a thin layer of nearly pure white kaolin, having a maximum thickness of 6 inches. The bed-rock is a biotite*-granite, pitted with "pot-holes" and scored with deep "gutters." The age of the deposit is considered by Mr. Blatchford to be late Tertiary or Pleistocene (judging from plant impressions found in what may be considered to be almost contemporaneous deposits in the Coolgardie district, and other evidence), whilst Mr. H. Y. L. Brown, Government Geologist of South Australia, appears to regard it as being of a similar age to the Cretaceous or Tertiary cements found in other parts of Australia, and to have been laid down along the shore of a lake or inland sea.

The ironstone gravels and kaolin contain small quantities of gold, but the only part of the deposit in which the precious metal is found in paying quantity is in the cementing material that binds the quartz pebbles together (gold being rarely though occasionally found in the pebbles themselves); and the richest portion of the deposit is stated to be usually found where the coarser material lies on the bed-rock, especially where it has gathered on the lower side, or around the rim of some of the larger pot-holes in the granite, which attain a depth of about two feet and a diameter reaching 3 feet.

When the kaolin (which gets poorer on the edge of the deposit) is of a dull grey colour, it is said to be generally barren, whilst the richer ground is indicated by the kaolin being iron-stained.

There can be little doubt, Mr. Blatchford remarks, that "the gold found throughout this deposit has been laid down by the mechanical

* Magnesia iron mica, of a black or greenish colour with a submetallic or splendent lustre.

action of water, and, judging from the nature of the associated material, this deposition took place in a small shallow lake" or trough in the granite, the gold and quartz derived from leaders and quartz reefs in the vicinity being carried down mechanically by inflowing surface waters. It seems probable, however, that æolian agencies have also played an important part in forming this deposit; a plan of which, reproduced from Mr. Rickard's paper, is given in Fig. 11.

According to official returns, the Kintore deposits yielded some 7363 oz. of gold up to the end of 1897 from 5397 tons of "cement," an average return of 1 oz. 7 dwt. 6 grains per ton, which was obtained from two leases known as the Hilton (19 acres), and Ophelia (13 acres),* that are situated at the lower end of the basin previously described. The former claim appears, however, to have been much the richer of the two, having produced 6836 oz. from 4397 tons treated, which represents an average yield of 1 oz. 11 dwt. 1 grain per ton.

The lead runs from the Hilton and Ophelia, through the Patena L 356^s, Himalaya L 357^s, Windsor L 358$_s$, Hilton North L 361$_s$, Coogee L 362s, Rock of Ages L 363s, Battler L 364^s, and Ruby L 365$_s$.

The cement is crushed in a stamp battery supplemented by cyanide works.

Kanowna.

This locality is situated some 12½ miles north-east of Kalgoorlie (with which it is connected by rail), about 60 miles east of Kintore, and is better known as White Feather. †

Since the original discovery of cement in this neighbourhood in 1893, in the old cement workings (known as the Golden Cement Leases), dry blowers fossicking about on the other side of the ridge, on the flats lying at the foot of a valley formed by the low dividing chain of hills that encircle it on the east, north and south, discovered a still more important lead, which lies in a shallow gutter, with its longer axis running east and west, on the western side of the watershed referred to.

The "cement lead" (Fig. 15) found near the head of this trough

* T. Blatchford, *op. cit.*, pp. 26, 29.

† This name arose from a fight, or rather a walk-over, enjoyed by a peaceful but pugilistic miner, whose ground was coveted by another man who found out that he had underrated his opponent's powers in attempting to "jump his claim."

on G.M.L. 637 X by Messrs. Sim and Greson in October 1897, in what is known as the Fitzroy Lead, lies half a mile or so north-west of the Kanowna Post Office, and trends westward from M.L. 637, through the Cemetery, passing between the Protestant and Catholic sections, which have been fenced in on each side. Rich prospects of gold were got where this "gutter" was first struck, at a depth of about 4 feet from the grass-roots under a thin bed of hard travertine, which had been mistaken for the true bed-rock; and it is quite distinct from the "old cement-workings" (previously referred to) which are situated on the eastern side of the divide, about 1½ miles east of these workings.

The Old Cement Workings.

Mr. T. A. Rickard, describing this deposit * (Fig. 14), says: "The discovery was made in 1893. Each digger secured a claim 50 feet square, and sank a shaft to the gold-bearing cement which the dry blowers had uncovered in the course of their prospecting. In 1895 an English Company secured the property and consolidated the claims into larger leases.

"The deposit lies in a shallow trough, the longer axis lying east and west. The body of gold-bearing cement has a length of about 700 feet and a maximum width of 105 feet.

"Vertical sections exhibit an overburden of sandy loam, from a few inches to 2½ feet thick. This was the material worked by the dry blowers. Then comes a layer of detritus, called 'wash' by the miners, composed of fragments of ironstone and quartz, imbedded in clay, and reaching to a maximum of 25 feet from the surface. This overlies the cement itself, 6 inches to 5 feet thick, and easily distinguished from its roof of detritus and floor of clay. The cement consists of particles of quartz in a greenish clay. Near the rim of the trough, the quartz occurs in larger and more angular pieces." A typical section obtained from a pillar in the old workings is given in Fig. 13 and a plan and section of the deposit in Fig. 14.

"The gold contents are irregular, the whole body of the cement probably averaging 1 oz. per ton; but only the richest parts were worked, and these carried many ounces to the ton, so that the remnants now accessible average from the surface down about

* *Op. cit.*, p. 526.

$3\frac{1}{2}$ dwt."* The clay carries 2 dwt. per ton. The material was treated in neighbouring stamp-mills.

Regarding the source from which the gold in the cement has been derived, Mr. Rickard considers that, just as in the case of the 25-mile deposits, its origin may be traced to quartz reefs to the

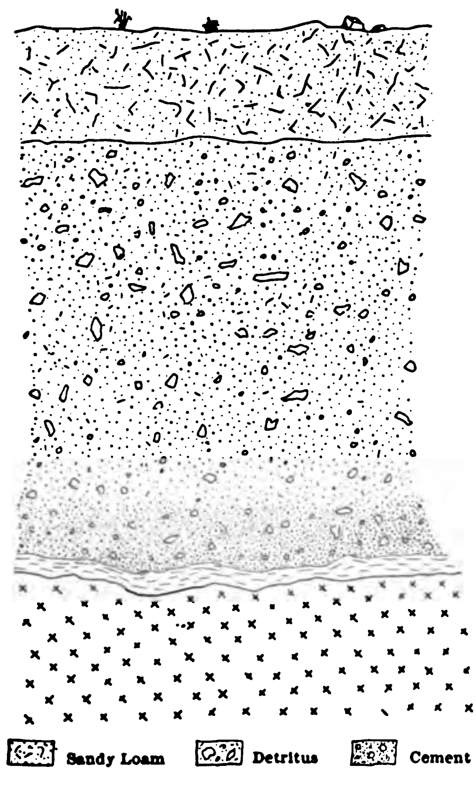


FIG. 13.—CEMENT DEPOSIT, KANOWNA (SECTION).

west of it, which cross the country close to the upper rim of the shallow depression in which it lies.

The McAuliffe vein (worked in the White Feather Reward mine) and the Main Reef (worked in the White Feather Main Reef mine), which seem to be identical, and to which the gold may most probably be traced, traverse diorite, which is penetrated in their

* From information given to Mr. Rickard by Mr. S. H. Williams.

immediate vicinity by large dykes of granite-porphyry, and the strike of the veins crosses the head of the longer axis of the trough in which this deposit lies; that forms the "low divide" separating it, as previously stated, from the "Fitzroy Lead" that trends in the opposite direction.

Mr. Rickard adds that "on comparing the veins and their encasing rock, as seen in the workings of the two mines on opposite sides of the alluvial deposit, it is not necessary to go farther to seek the origin of the latter. The cement is underlain by a clay, which

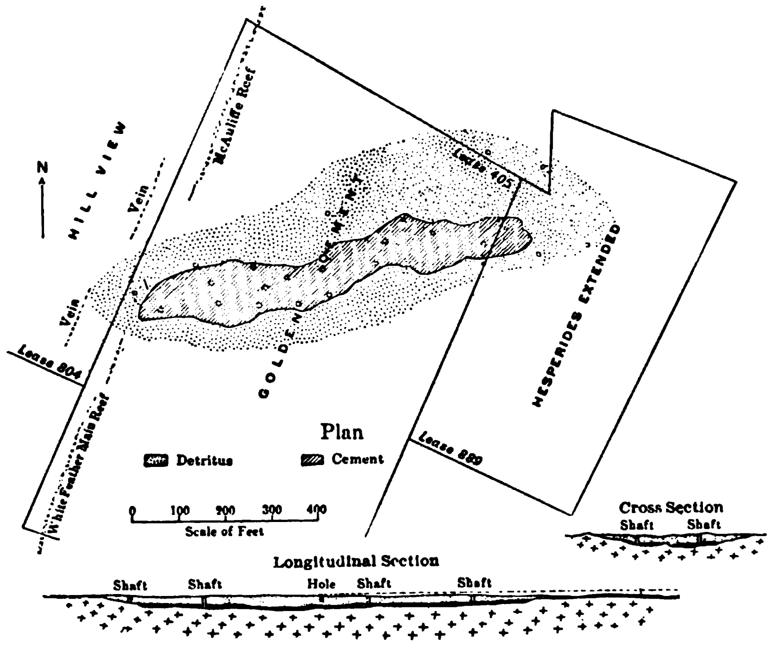


FIG. 14.—GOLDEN CEMENT DEPOSIT AT KANOWNA.

is essentially steatite, and is as readily traceable to the neighbouring diorite as the kaolin at Kintore was deducible from the granite. The green colour of the cement is imparted by chlorite, derived from the decomposition of the epidote in the diorite. The 'ironstone' of the detritus overlying the gold-bearing part of the deposit consists of fragments of altered diorite. The quartz in the cement, and the gold accompanying it, are both identical with those of the reefs close by."

Various other theories have been advanced to account for the origin of these "cement deposits," some considering them as "deep-leads," others, as already said, regarding them as similar to "banket"; both suppositions are, however, quite untenable. The former term is applied in its strict sense to old river channels in California and Victoria, of Miocene age, protected from erosion by a cap of lava (which probably overflowed the surface as a

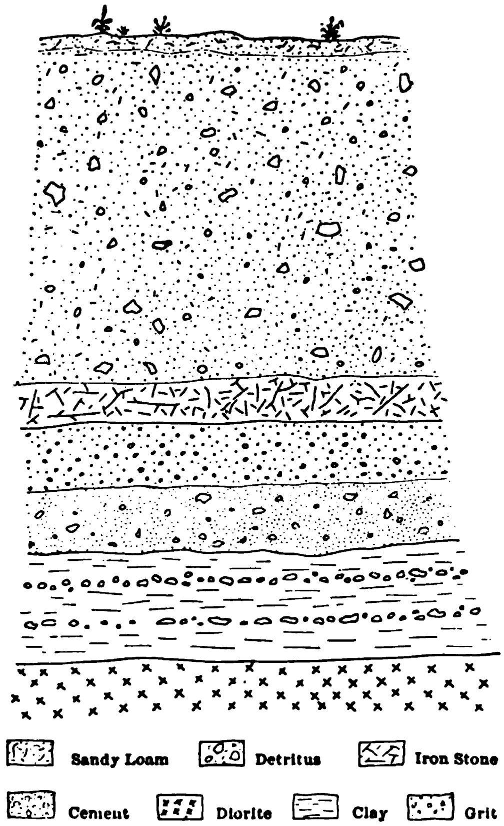


FIG. 15.—CEMENT DEPOSIT, FITZROY.

steaming volcanic mud), under which they now lie deeply buried; whilst the South African "banket" is regarded as an immense shore-deposit of gold-bearing conglomerate, covered by later sedimentary rocks. Hence these "cement deposits" may more properly be considered as the "placers" of a country destitute of running streams, and in support of this statement Mr. Rickard points out :—

1. That the quartz of the cement is subangular, and has suffered little from attrition (suggesting that it has not travelled far); on comparing it with the matrix of neighbouring veins its identity appears obvious.

2. An examination of the topography renders highly probable the derivation of the one from the other.

3. The cementing material is found to be clay resulting from the decomposition of the rock encasing the quartz veins and varying according to the decomposition of that rock, whether it be granite or diorite.

4. The gold is identical in fineness and physical character* with that of the neighbouring veins, and the scarcely-rounded edges of individual particles invite the conclusion that its place of origin is to be looked for in the immediate neighbourhood.

5. The absence of continuous running water on this desert plateau has prevented any such sifting-process as in other regions leads to the deposition of well-defined layers of clay, gravel, and gold upon a clean bed-rock as in ordinary placer-ground, and the comparatively unclassified condition of the deposit is in keeping with the evidence afforded by the material of which it is composed.

Transportation of the material would in fact seem to have been carried on by the united action of wind and intermittent flood-waters.

The Fitzroy or so-called Kanowna Deep-Lead.

The prospectors followed up their discovery of the Fitzroy Lead for the first 50 yards in an open cut, but as the overburden became thicker and thicker, it has become the practice to mine the deposit by sinking and driving on it. It consisted at first almost entirely of ironstone pebbles cemented together with oxide of iron or kaolin,† presenting in the former case much the appearance of ironstone vein-stuff. Mr. Blatchford states ‡ that "the dimensions of the 'gutter' vary considerably, ranging from 2 feet in the Prospectors, to about 8 feet in width in Messrs. Graham and party's claim, and from 2 to 4 feet in thickness."

Further to the westward the deposit alters, both in character

* Often occurring, it is said, in beautiful bright and apparently more or less crystalline forms.

† It is said that gypsum (sulphate of lime) has been found in the shallower workings *at the head of the Lead* in a crystalline form, which suggests its deposition from hot water.

‡ *Op. cit.*, p. 33.

and dimensions. Instead of the ironstone predominating as it does at the head of the " Lead," kaolin and rounded grains of quartz commence to replace it (the ironstone only occurring in patches), until at length a width of 30 feet is attained.

Lower down the Lead the deposit gradually changes to a coarse quartz gravel wash, of irregular size, and usually incoherent, and is about 5 feet thick, but only the lower 2 or 3 feet contain payable gold, which, in place of being free, is more or less associated with quartz, and is more frequently found in the form of small slugs, than at the head of the Lead.

A little farther on the Lead attains a maximum width of 80 feet, and splits into two branches, one trending north-west, called the North Lead, which has been followed for about 2 miles from the Cemetery to G.M.L. 918 X, a little beyond the point where it is joined by Wilson's Gully Lead ; the other running south-east, to a point beyond the cemetery (through which it passes, as already said), known as the Cemetery or South Lead.*

Throughout the whole of the deposit, the gold bears strong evidence of being mechanically rounded during transportation to its present position.

The north branch of the main Lead has lately been carefully studied, and its features, as disclosed by recent developments, have been described in detail by Mr. Torrington Blatchford, in the Annual Progress Report † of the Geological Survey of Western Australia, from which the following particulars are excerpt.

On the higher grounds lying to the south and west of the North Lead, the country rock consists of schists, which are intersected by acid eruptive dykes of a felsitic and quartz-porphyry type.

Schists.

These rocks belong to the chloritic group, and are the prevailing type of country rock ; in unaltered specimens they appear of a bluish-grey colour, and have a hardness of from 1 to 2 (Mohs scale). The rock possesses a fine-grained and distinctly schistose structure, and contains numerous crystals of calcite and other carbonates, and iron pyrites.

Under the microscope it is seen to consist essentially of chlorite

* Two smaller tributary "leads," known as the Q. E. D. and Moonlight, were discovered in 1898, to the north of the North Lead.

† For the year 1899, Perth, 1900.

crystals, with occasional small grains of quartz interspersed throughout.

It is most probably a much altered eruptive, considerably decomposed, the products of decomposition being usually of a much darker colour, owing to the oxidation of the ferrous to ferric oxides, though in some instances where this latter constituent has been leached out the rock becomes almost white. An interesting point to be observed is that "numerous instances of pseudomorphs of ferric oxides after pyrites occur, the cubes being sometimes covered with paint-gold, which points to the auriferous nature of the pyrites prior to decomposition."

Acid Eruptive Rocks.

These rocks occur as dykes intersecting the more basic schists; their general strike is east of north with a prevailing dip east. In hand-specimens they are found to consist of a more or less fine-grained material, in which blebs of felspar and quartz are frequently seen, sometimes in a most perfect state of crystallisation.

The weathered products are usually white, changed at times to an almost pure kaolin, in which are frequent irregular quartz crystals. In this state they offer a strong contrast to the more basic rocks. They are also characterised by the occurrence of numerous intersecting quartz leaders, which vary from mere threads to veins several inches in thickness.

These quartz veins are sometimes auriferous, and have been prospected to some extent with success.

Physical Features of the North Lead.

The natural depression which forms the North Lead for the first part of its course is bounded north and south by high ground, but bends gradually round, and at its western extremity it widens out into an extensive flat, and has been lost.

The incline of the present surface of the country, between the head of the Fitzroy Lead to a point close to (W.R. 35) near Wilson's Gully, is some 43 feet; whilst that of the underlying gutter is about 80 feet.* The fall is gradual in both cases, with but few exceptions; though the incline is slightly greater at the eastern than at the western extremity. In following the gutter, however, there are cases where a sudden fall of several feet occurs in a distance of only

* At the rate of about 40 feet to the mile.

a few yards. Its width varies from 2 to 80 feet, 15 feet being perhaps a fair average. On examining the form of the gutter (an easy matter at present, as tunnels extend for nearly its whole length), Mr. Blatchford remarks, "One is struck with the similarity of its shape to that of an ordinary river-bed. Its bottom, the steep bank near a bend, and again the gradual widening out of the trough at the junction of its tributaries, and at the western end where the incline is less, all point to the one origin, that of erosion by running water." "Since this erosion took place, beds varying from a total thickness of a few inches to 90 feet have been laid down, the deposition taking place at intervals of time, the duration of which there is little or no evidence to show." There are, however,

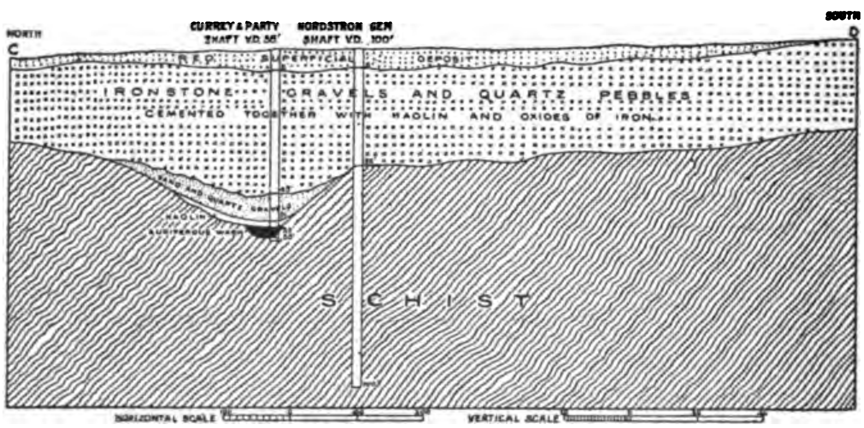


FIG. 16.—CEMENT DEPOSIT, NORTH LEAD, KANOWNA.

good grounds for stating that extensive erosion of the lower beds did take place, before the upper beds were deposited.

Mr. Blatchford goes on to observe, that the nature of the strata forming the North Lead vary considerably in character in different parts.

"Below the junction of the Fitzroy and Cemetery Leads, in the vicinity of Messrs. Currey and party's claim, a band of kaolin, some 2 feet in thickness, separates the coarse quartz gravels from the finer auriferous wash which lies in the bottom of the gutter, as can be seen in section in Fig. 16 herewith."

"The auriferous deposit varies in width from 20 to 40 feet, with an average thickness of about 2 feet. Both beds of quartz gravel were very much eroded before being covered up with the overlying beds. The dividing kaolin bed, however, does not exhibit this feature, but lies conformable to the overlying sand-bed.

"The maximum thickness of the beds in this vicinity is about 55 feet.

"From Messrs. Currey and party's claim the same beds occur in a more or less eroded state till the lead commences to turn to the west, when the auriferous wash becomes very much broken and difficult to trace, patches only being found at irregular intervals in

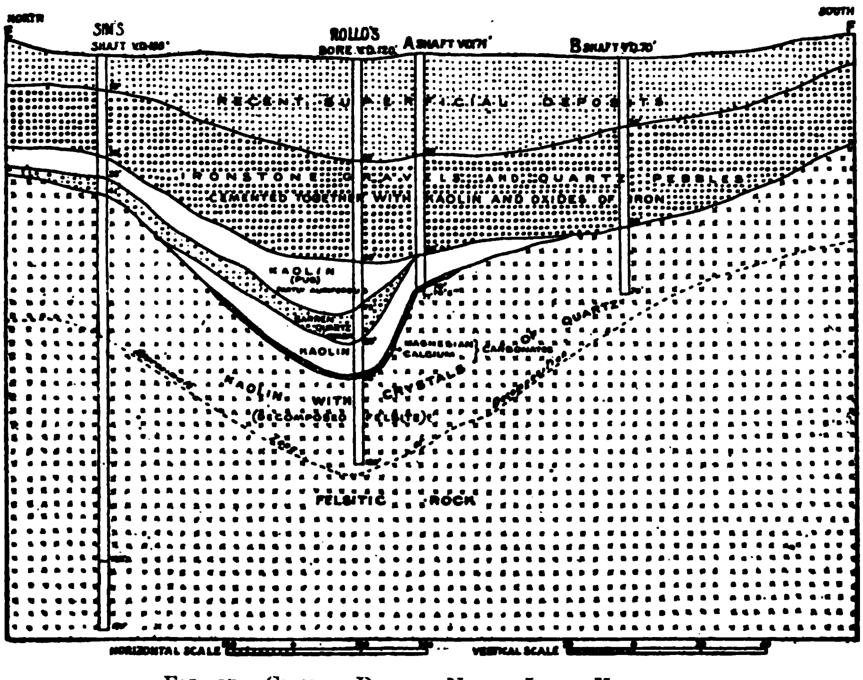


FIG. 17.—CEMENT DEPOSIT NORTH LEAD, KANOWNA.

the gutter. The top or barren quartz wash, however, is continuous though the kaolin bed is often missing."

"A new stratum of kaolin makes its appearance between the ironstone gravels and the top quartz gravels, near to where the lead turns to the west."

"In Soden's claim this kaolin bed is some 2 feet in thickness, but it gradually increases till it reaches a limit of about 20 feet."

The section (Fig. 17), as seen in Rollo's shaft, shows the relation of the various strata in this locality.

A thin bed of magnesite, usually about 6 inches in thickness, separates the lower bed of kaolin from the decomposed country rock. Owing to the sticky nature of the top kaolin bed, the name "pug" has been applied locally, more especially to that portion of the deposit which is auriferous. In the vicinity of Rollo's shaft and to the western end of the Lead, the auriferous wash is extremely patchy, and though productive in places, is too uncertain in character to be sought for. Attention is therefore being given more to the auriferous portions of the kaolin which yields good returns.

At the head of the Fitzroy Lead the payable wash varies in width from 2 feet across, gradually increasing till it reaches 80 feet, and is equally variable in thickness, ranging from a few inches to several feet.

In the North Lead lower down the wash ranges from 10 to 40 feet, with the same variable thickness as in the Fitzroy. "It was from this auriferous wash that most of the alluvial gold has up to the present been won, some of the claims, which include 150 feet of the gutter, having produced as much as 4000 oz. each."

The "pug" or kaolin bed at the western end of the North Lead is next in importance from a gold-producing point of view.

"Only portions of this deposit are payable, the maximum width being about 40 feet with a thickness of upwards of 6 feet. As a rule the lower portion of the deposit is the richest, but there is no fixed rule, the gold being frequently found in more or less isolated patches. It is noteworthy, however, that the quantity of gold in the deposit diminishes considerably at no great distance from the centre of the trough, and though the kaolin bed has been found extending for a considerable distance to the north, there is hardly sufficient gold contained to render it payable to work."

"Gold is also being won in small quantities from what are locally known as 'headings,' a term applied to the strata immediately above the rich wash."

"This includes, therefore, some of the more or less barren wash, as well as the lower portion of the ironstone gravels."

"Much picking of the ore and careful prospecting are necessary, however, before these portions of the deposits are rendered payable, though with cheaper milling appliances there would doubtless be large quantities of gold won from this source."

"One noteworthy exception to the usual sequence in the deposition of the bed occurs in Messrs. Vaughan, Davis and party's claim, where, underlying the auriferous sandstone wash, a coarse, much-broken rock is found at a depth of 96 feet carrying gold. That this may be the eastern extremity of a second auriferous wash is possible. It seems, however, on close examination to be more probably the denuded fragments of some auriferous rock *in situ*, as the component parts are not rounded to the slightest degree, in fact, perfect semi-detached crystals of orthoclase felspar and quartz are abundant, in a most perfect state of preservation. The country rock at the bottom is undoubtedly granite."

"The deposits of the Wilson's Gully Lead are identical in character with those of the North Lead. More erosion, however, has

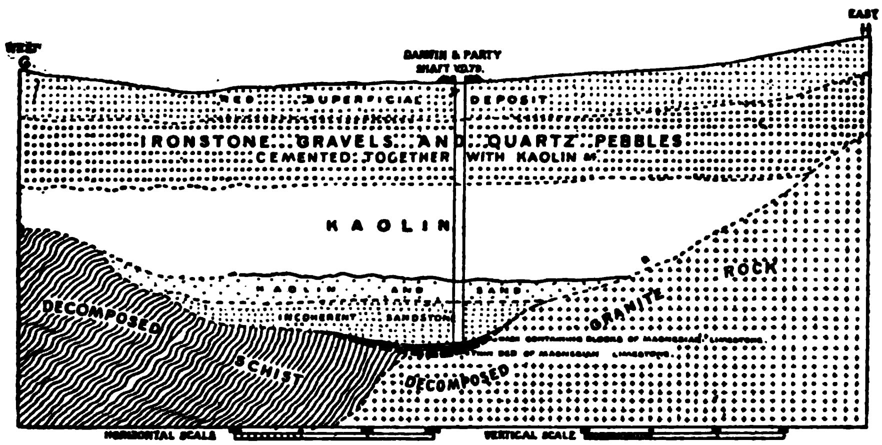


FIG. 18.—CEMENT DEPOSIT, NORTH LEAD, KANOWNA.

taken place in the lower strata, in consequence of which the auriferous wash is extremely patchy. A section (Fig. 18), as shown in Messrs. Darwin and Party's shaft, is attached."

Origin of the Deposits Forming the North Lead.

"The origin of the surface soil and ironstone gravels is probably due more to the denuding action of wind than of water, subsequent segregation having taken place in the later deposit, and formed the ironstone bands and nodules.

"The beds of incoherent quartz-gravels, etc., are, however, obviously due to the action of running water, as some of the fragments in these deposits are perfectly smoothed and rounded.

The deposits too are well classified, and laid down horizontally over the much-eroded surfaces of the beds immediately beneath them. In the Fitzroy Lead the gold in some instances was slightly water-worn, but further reference will be made to this question later on. The quartz wash is probably derived from the denudation of the quartz reefs or granite rocks of the higher grounds to the east."

"The beds of kaolin owe their origin to two sources,—(1) the decomposition and alteration of the chlorite schist, (2) the alteration of the felspars of the granite rocks. Chlorite consists essentially of a hydrous silicate of magnesia, iron, and alumina in varying proportions. The beds known as 'pug,'* on analysis in the Departmental Laboratory, prove to consist of almost pure silicate of alumina, in other words they are a kaolin or clay. This will account for the alumina of the chlorite, while the magnesia can partly if not wholly be accounted for by the beds of magnesium carbonate found in the lower portions of the lead."

"The kaolin bed of the upper portion of the lead is probably of granite origin, the texture being unlike that of the 'pug,' the difference being partly due to the presence of grains of quartz, partly to a difference of fineness of material."

Character and Origin of the Gold of the North Lead.

"In studying the occurrence of the gold of the North Lead, the nature of the associated country rocks must first be considered. The two prevailing types of rock are in the first place both auriferous,—the granite rocks containing gold in appreciable quantities, *en masse*, as well as in the intersecting quartz veins; while the chlorite schists contain auriferous pyrites disseminated throughout the rock, in addition to possible fissure lodes carrying gold."

"That much of the gold in the auriferous quartz wash was derived from the former source is evidenced by the fact that it occurs in the quartz pebbles themselves, and though the gold as a rule in this deposit is not much rounded, the edges of many pieces

* Warden P. Troy says: "In connection with the alluvial leads, a matter of much importance is the immense deposits of auriferous clay or 'pug,' which are known to exist, and which cannot be profitably treated by any known gold-saving appliances unless the ore contains more than 15 dwt. of gold to the ton."—'Report of the Department of Mines,' 1898, p. lxiv.

are sufficiently smoothed to allow of no doubt as to their mechanical transportation and deposition.

"Much controversy has arisen as to the origin of the gold in the 'pug,' the generally accepted theory being hydrotherma action. That the gold in this deposit has been chemically formed there seems little reasonable doubt, as indicated by the following phenomenon in its occurrence. No evidence in favour of hydrothermal action could be discovered."

"(1) The gold is in a finely-crystalline state, the edges of the crystals being in no way rounded by attrition.

"(2) The gold is often found following certain irregular cracks, and forming a connected chain of crystals, or covering cleavage planes, so as to give the latter the appearance of painted surfaces.

"(3) The gold is found in the vicinity of what was apparently the lowest portion of the trough in which the deposit rests, and, therefore, is where infiltrating waters would have been.

"(4) Manganese and cobalt oxides are often found in close association with the gold in scattered nodules, the three forming an auriferous wad."*

"That chemical action has taken place in the schists is seen by examining the numerous pseudomorphs of hæmatite after pyrites (locally known as "devil's dice.") which occur throughout that class of rocks. In many instances the gold may be seen coating the outside of the hæmatite crystals, though at one time it was undoubtedly included in the crystal of sulphide of iron."

Non-Sedimentary Auriferous Rocks.

Perhaps the most interesting feature of the North Lead is the occurrence of gold-bearing rocks underneath the sedimentary beds.

"Such have been looked upon as fissure lodes; lodes most of them certainly are, but only in the sense that any rock,† not of sedimentary origin, which contains gold, may be considered a lode. With two exceptions, the lode material consists of much-altered schist, impregnated in places with ironstone bands, patches

* Asbolite (cobaltiferous hydrous oxide of manganese) is said to be found principally in the "pug" and in the underlying much-weathered schists, but also occurs in nodules of magnesite. It is frequently studded with minute crystals of gold. A sample of "pug" impregnated with asbolite yielded on assay 7·56 per cent. of metallic cobalt.—'Annual Progress Report of the Geological Survey, Western Australia,' 1899, p. 55.

† This definition of a "lode" appears too broad.—AUTHOR.

of kaolin, steatite, etc., and abounding in places with pseudomorphs of hæmatite. In hand-specimens, the lode material is not distinguishable from the country rock found in the shafts sunk to the north and south of the North Lead. The acid dykes have a general trend of north-east and south-west, and underground the same strike is apparent, yet the lodes, or at least the payable portions of rock, will prove without much doubt to run north-west and south-east, for at present there is every tendency in that direction. Unfortunately, at no great depth below the sedimentary beds there is a large influx of salt water, in consequence of which, sinking below the 100-foot level has in most cases not been undertaken, so much still remains to be seen. The gold presents the same crystalline form as that found in the 'pug,' with the exception that it is usually more coarsely crystalline and at times presents a characteristically arborescent form. There seems no reasonable doubt that the origin of the gold in both is identical, and that the presence of the gold in the lodes, contrary to the accepted theory, is due to infiltration from above."

"The extent of the gold occurring in the schists is not determinable, and will depend on the depth of the zone of decomposition. At present the lode-stuff is being taken out for a width of 40 feet, and in places up to 70 feet, but not to a greater depth than 20 feet. An undoubted fissure-lode occurs in Sim's claim, where a felsitic dyke is found to be auriferous. The gold-bearing rock in this instance resembles closely the felsitic dykes worked in the Wycheproof (G.M.L. 324^{w}) and Wycheproof South (G.M.L. 1846^{x}) mines in the Bardoc district."

Mr. A. Gibb Maitland (Government Geologist), adds * :—

"The ultimate derivation of the gold in the North Lead is from the quartz veins and lodes, by which the crystalline rocks are traversed (and upon which the wash directly reposes in places), for the gold is not exclusively in the form of grains, scales, etc., but is found occurring in the quartz pebbles themselves. In addition to what may be called detrital gold, there is another massive, arborescent or coarsely-crystalline form, which occurs filling certain irregular fissures and vughs, and covering cleavage planes or shrinkage cracks, so as to present the appearance of painted surfaces. The mode of occurrence, associations and character of this gold, all point to a secondary origin. It is of importance to note

* 'Annual Progress Report of the Geological Survey, W.A.,' 1899, p. 9.

that this, what may be called secondary gold, has been deposited rom solution, not only in the alluvium and other superficial deposits, but also in the zone of decomposition of the bed-rock. These secondary forms, which result in the superficial enrichment of many auriferous deposits, are a common feature in the mineral fields of the Colony."

The yield of gold from alluvial deposits in the Kanowna field, up to the end of 1899, is shown in the accompanying table,* compiled from the 'Annual Progress Report of the Geological Survey of Western Australia, 1899.'

(*a*) Gravels.		(*b*) Cement.		
		—	Cement Crushed.	Gold Yield.
	oz. dwt. gr.		tons. cwt. qr.	oz. dwt. gr.
Previous to 1898 .	10,611 18 10	1898	45,983 4 2	68,183 10 22
In 1898 .	63,548 0 10			
„ 1899 .	17,492 15 2	1899	51,098 14 2	71,839 18 11
	91,652 13 22		97,081 19 0	140,023 5 9

Figs. 19† and 20 show some of the "open cuts" and shafts sunk on the Kanowna claims, and give a good idea of life in an alluvial "camp" in Australia. In the Bulong and Kurnalpi divisions, several large nuggets have also been unearthed; one which was discovered, if I am rightly informed, by Simmons and Hart, at Kurnalpi, weighed 109 oz. 10 dwt.; another, found in 1899, weighed 168 oz.; whilst at Hogan's Find, about 30 miles south of Bulong, quite a number were unearthed in 1899, the largest one weighing 125 oz.

"Cement" is so hard, that it has to be crushed like ore in a stamp-mill, and discoveries of a like character of secondary importance, which I need not here describe, have been made at other places. It should be pointed out, howevei, that owing to the fact

* The principal claims, and the returns they have yielded, are detailed in the Annual Reports of the Department of Mines, Perth.

† Fig. 19 is reproduced from the Supplement of *The Financial Times*, June 19, 1899, which the proprietors have kindly permitted the Author to use.

that "cement" often covers the caps of reefs, quite apart from the amount of gold such deposits have yielded, they have played an important part in leading to the discovery of valuable lodes,

FIG. 19.—AN "OPEN-CUT" AT KANOWNA. (Reproduced by courtesy of *The Financial Times*.)

notably for instance, at Kalgoorlie. An occurrence of this kind is shown in Fig. 10, which represents the outcrop of the Lady Shenton reef at Menzies.

Alluvial Deposits at Kalgoorlie.

The discovery of alluvial gold at Kalgoorlie was made on Saturday, June 17, 1893, by three prospectors, Patrick Hannan, Dan Shea and Tom Flannagan, whilst travelling from Coolgardie in the "rush" to Mount Yule. The following Sunday hundreds of men were flocking to the scene of the find, on camels, bicycles, horses and on foot, who little suspected the immense wealth that lay buried in the neighbourhood, under the arid waste of reddish loam, gritty sand, and gravel. containing ironstone, travertine,*

* Carbonate of lime, often deposited on twigs, etc.

and fragments of quartz, with which the surface of the country for miles around was covered.

The theatre of these early operations was below the hill which overlooks the township east of Kalgoorlie. Curiously enough, however, this particular discovery has not up to the present led to the finding of any reefs of importance in the immediate neighbourhood, although the surrounding area, like many others, was given up to purposeless "digging," which lent an impetus, as Mr. Rickard says,* to a great deal of reckless company-promoting. "However, just as in Colorado, the Mount Pisgah fiasco, of 1884, preceded the real development, eight years later, of Cripple Creek, so the vagaries of irresponsible schemers led to the accidental opening up, and the eventual recognition, of the magnificent series of rich lodes that have now placed Kalgoorlie amongst the few great 'mining camps' of the globe," and towards the end of 1895 there were no less than 3000 people congregated at Hannan's.

FIG. 20.—AN ALLUVIAL CLAIM AT KANOWNA.

Such veins as were found at the northern end of the field, however, were, as already said, so small, patchy, or poor, as to be practically valueless.

* *Op. cit.*

The Cement Deposits at Kalgoorlie.

The cement deposits on this particular field leading, as they have done, to the discovery of the more valuable "formations," which in consequence of the comparative softness of the lode material did not outcrop at the surface, may be regarded as of the very greatest importance, notwithstanding that the amount of gold they have returned in the aggregate is comparatively trifling. Underlying the red loam on the "flats," which covers extensive areas, a considerable thickness of blue clay is met with in places, whilst on the outskirts of the hills surrounding them it is only of slight thickness, and rests directly on the auriferous series.*

The first discovery of "cement" † was made some three or four miles south of the earlier alluvial "find," near what is now known as the "Boulder Township," where the prospectors found rich patches of surface-dirt and cement, and located several strong quartz croppings, on the strength of which the Great Boulder and other leases were "pegged out."

The quartz veins in question were larger than those previously referred to at the north end of the field, but turned out equally poor and uncertain, and it was ascertained by sinking a shaft, known as No. 3. or Gamble's North, in the eastern part of the Great Boulder Proprietary lease, that the vein that had been found there became thin and poor at a depth of 75 feet. A trench was then started to cut a big ironstone outcrop, which forms a hillock behind the present company's office. But the ironstone reef was found to carry only about 12 dwt. of gold per ton, which was too low grade in those days to pay.

This trench, when extended further west, however, penetrated another vein, which had no visible outcrop, but proved to be the cap of the eastern portion of the magnificent lode on which the company's main workings are situated, which has been mined up to the surface. The "formation" shown in the "open cut" at this point was nearly 20 feet in width; but was buried under some 2½ feet of "cement."

* 'The So-called Lode Formations of Hannan's and Telluride Deposits,' *Trans. Inst. of Mining and Metallurgy*, H. P. Woodward, 1897–1898, vol. vi.

† 'The Minerals which accompany Gold, and their Bearing upon the Richness of Ore Deposits,' *Trans. Inst. of Mining and Metallurgy*, T. A. Rickard, 1897–1898, vol. vi. p. 207.

The Great Boulder Perseverance had a somewhat similar beginning. The vein in the old No. 1 shaft turned out poor, and was abandoned, but the rich "formation" that traverses the adjoining Lake View Consols lease was found later on capped with cement, which concealed its existence, and it has since been stoped to daylight.

At the beginning of 1898 great excitement was caused by the pegging out of a number of claims on the Ivanhoe Venture lease, by Bray and party, and other alluvial men, and in the course of the year, 639 oz. 5 dwt. were obtained from some 247 tons 10 cwt. of "cement" crushed.

What was thought might prove, perhaps, an important find was also made in May 1899, in the northern part of the field, on lease 1260 E, on the property of the Kalgoorlie Mining Developments Co., Ltd., where the first alluvial prospecting shaft sunk (known as No. 1) bottomed on an ironstone "wash" (mixed with "pug" and concretionary nodules of calcite), about 10 feet thick, at a depth of 82 feet. Other shafts sunk in this lease have since proved the existence of a gutter of "cement" running apparently in a north-east and south-west direction at a depth of about 105 to 108 feet. This cement averaged about 2 feet in thickness, whilst the pay channel varied in width from 12 feet to 31 feet 6 inches, and yielded "prospects" of from 15 dwt. to an ounce and a half.

Three claims located upon this lead up to the end of December 1899 produced as follows :—

1. 444 tons of cement crushed yielded 608 oz. 14 dwt. 12 gr. of gold.
2. 429 tons yielded 427 oz. 6 dwt. 20 gr., and
3. 350 tons 10 cwt. yielded 486 oz. 11 dwt. 6 gr.

The bullion varied in value from 3*l.* 18*s.* 6*d.* to 4*l.* 1*s.* per ounce.

In course of development, several strong outcrops were also uncovered, one of which carries a dark-bluish quartz, and from the number of angular pieces of rich "float" of a similar description that have been found, it appeared not unlikely that following this "lead" up might result in the discovery of a payable reef or reefs, in this section of the field ; but so far the efforts made to do so have been unsuccessful.

Fig. 21, produced by kind permission of the Company from a photo taken underground in these workings, gives an idea of the way in which mining is carried on in deposits of this nature.

Topographical Features of the Kalgoorlie Field.

Hannan's Belt, as it is frequently called (in the centre of which Kalgoorlie is situated), is a long, narrow strip of country, some eight or ten miles in length, folded along an axial line, which runs in a north-west and south-east direction, and has a width of about two miles.

In the northern half of this district a number of leases have been taken up at various times, on quartz lodes, which have hitherto

FIG. 21.—UNDERGROUND WORKING IN AN ALLUVIAL CLAIM.

proved of little or no value, whilst the group of mines which have rendered the district famous are of a totally distinct character, and lie about four miles south-east of Kalgoorlie, in the immediate neighbourhood of the Boulder township before referred to.

This remarkably rich area, which possesses a length, measured north and south, of about a mile and a half,* extends from Hannan's Brown Hill (considered as the most northerly of the rich proven mines) to the Boulder Main Reef, at its southern extremity. Its

* Measured diagonally, that is to say, not directly along the course of the "formations"

maximum width, which is under a mile, is represented by a north-east and south-west line, extending from the Oroya (South Block) lease to the Ivanhoe.

On the east and west, the entire belt of country included in Hannan's is bounded on either side by high, rolling, more or less parallel ridges, which in places rise into hills, on the eastern rim of this basin ; whilst, looking west from the Boulder township, on the distant horizon, Mount Burgess may be seen beyond in the far distance, a conspicuous object, with its flat top, standing some 400 or 500 feet above the plateau at its base.

Patches of low scrub and a few stunted eucalyptus trees (chiefly "Salmon Gut" and "Gimlet Gum") dot the landscape here and there, but most of the "bush" between Kalgoorlie and "the Boulder" has long since been cut down, leaving large open stretches of ground quite bare.

All the richest mines at the southern end of the field are grouped around the flanks of an isolated ridge,* and several conical hills of about the same height, to the south-west of it, which break up the prevailing level of the surrounding "flats"; so that, proceeding from Kalgoorlie along the Boulder road, you gradually, though slowly, ascend, until you reach the foot of the Australia hill, the ridge referred to.

The north end of this ridge (which is occupied by the Kalgurli lease), passes southward through the Associated, Lake View, and Lake View South leases, and springs rapidly up from 150 to 200 feet above the rising ground surrounding it.

I lay stress on this feature of the topography, because it seems to me probable that these hills (the summits of which were many of them covered originally with ironstone gravels, passing in places into compact limonite) mark the principal centres where, through the pressure of the plutonic rocks, or volcanic agency, the main series of igneous eruptives (that form such an important feature of this section of the field, and to which the telluride deposits seem to owe their origin) burst their way through to the surface ; and, owing to their superior hardness, have since escaped being levelled by denudation.

The direct effect of these subterranean disturbances may well have been to crumple up, compress, fault, and elevate the rocks in

* This ridge is not of uniform height, however, being crossed by several "necks," which divide it into a series of hogs'-backs."

the neighbourhood where they were most active. It is probably, therefore, owing to this fact, that the largest and richest ore-bodies found have been discovered on or in the neighbourhood of the broken hilly ground above referred to, which dominates the surrounding central portion of the basin, running in a direction more or less parallel with, and midway between, the longer axes of the main folds that hem it in on the east and west. South of this auriferous area, the general level of the basin falls gradually towards Hannan's Lake, a large depression or "clay-pan," in which water is only seen after a heavy rainfall; and although this is of rare occurrence, a considerable quantity of salt water is conserved in the alluvial sands and clays which fill its bed.

Many of the Kalgoorlie rocks have undergone *extreme* alteration, which makes the identification and determination of their original character extremely difficult, and until the "field observations" of the Geological Survey and the Map of the Field (in preparation) are published, definite judgment must necessarily be reserved regarding the derivation and character of some of the Kalgoorlie rocks and the probable genesis of the "lode-formations"—points upon which different opinions have been expressed by different geologists.

The rocks of Kalgoorlie are very fully described in a recent Bulletin (No. 6) of the Geological Survey of Western Australia, which contains a large amount of new and interesting information.

CHAPTER IV.

THE KALGOORLIE DISTRICT.

General Geological Features.

HAVING dealt in the previous chapter with the "cement" deposits of the "25-mile," Kanowna and Kalgoorlie, and the topography of the last named district, I now propose to give a brief account of its geology.

The Underlying Rocks.

Engineers in a gold "mining camp" are usually so occupied with the business and engineering questions that beset them, that they are apt to relegate the consideration of the geological structure of a new district, to such time as it attracts sufficient attention to demand a proper Government survey. Economic geology is, however, a matter of such vital importance to mine-owners and investors in a new gold-field, that engineers cannot afford to neglect the study of the mines with which they are more immediately concerned, since a correct understanding of the geology and vein-structure of the district will often mean the difference between a judicious or wasteful expenditure of capital upon a property in the course of its development.

In this way many interesting facts have from time to time been placed on record by various mining men, to which I shall hereafter refer; and although the field as a whole, geologically speaking, is as yet* only partially surveyed, the telluride zone (surrounding the Boulder township), as will be seen later on, has been very thoroughly investigated and described.

Mr. C. S. Göczel, Government Geologist, reporting on the Coolgardie Gold-Fields (1894) said:—

"A large break in the country, consisting principally of coarse-grained diorite, extends over six miles from N.N.E. to S.S.W.† near the township of Kalgoorlie, and encloses a countless number of lodes. The line of this break is marked by low ironstone hills."

* The Geological Survey of Western Australia have, I understand, a complete map of the field in preparation.

† It appears to run, more properly speaking, N.W. to S.E.—AUTHOR.

In the early days of the Kalgoorlie field, owing to the schistose character of the rocks, seen in the shallower mine-workings, they were frequently described as "schist" and "slate," * and as such, appear at first to have been regarded as ancient sedimentary formations.

Mr. H. Y. L. Brown, who visited the district in October 1895, describes † the rock formation of the Kalgurli mine as consisting of "talcose, argillaceous and chloritic schists, clay-slate, hornblende slate, and hornblende rock, with dense and crystalline diorite dykes, and decomposed dykes of a granitic character."

Herr Schmeisser, in his report to the German Government on the Gold-Fields of Australia, ‡ seems to have regarded the Kalgoorlie deposits as occurring in a more or less schistose amphibolite. In this connection Mr. Card § points out, that although the specimens taken from the 200-feet level in the great Boulder, from the 193-feet level in the Ivanhoe, and from the 198-feet level in Hannan's Brown Hill (on which this supposition seems to have been based), may be hornblende-bearing rocks, they may have been selected as less-altered portions of "country-rock," when, in reality, they are remains of amphibolite dykes; the recent investigations in the Departmental laboratory of the Geological Survey referred to at the end of Chap. IV., appear on the other hand to support Bergrath Schmeisser's conclusion.

Mr. Frank Reed, ‖ Inspector of Mines in Western Australia, makes the following suggestive observations in this connection:— As regards "the dioritic schist-rock, which is a characteristic of the Western Australian Gold-Fields, the writer may state that this formation originally consisted of massive diorite or diabase, ¶ but by tangential dynamic pressure it has assumed a schistose form. These dioritic schists occur as breaks in the Archæan gneiss and granite, and form the country-rock of the West Australian Gold Fields."

* Parts of these formations occasionally present the appearance of a graphitic slate, which Professor Kemp (judging from specimens submitted to him by Mr. Bancroft) seems to have considered a true slate; they are, however, in all probability altered metamorphosed clay-rock; and Baron Oldruitenborgh points out that the presence of graphite may be accounted for by hydrocarbons emitted from the magma of the dykes themselves.

† 'Auriferous Deposits of Western Australia,' *South Australian Parliamentary Paper*, No. 26, 1896.

‡ *Die Goldfelder Australasiens*, Berlin, 1897.

§ *Records of the Geological Survey of N.S.W.*, vol. vi. part i.

‖ 'Hydrothermal Gold Deposits of Peak Hill, Western Australia,' *Trans. Inst of Mining Engineers*, 1897, vol. xiv.

¶ A basic igneous plutonic rock, a crystalline granular compound of oligoclase, labradorite, albite or anorthite, with pyroxene and some chlorite; specific gravity 2·7 to 2·0; silica, 43 to 56 per cent.; colour, dark green.

Baron Sloet van Oldruitenborgh * observes that it must not be supposed, however, as some geological authorities hold, that the ore-deposits occurring in these "formations" are to be regarded as shattered belts, caused by faults and fracturing, filled in at first with a compressed breccia provided by their own crushed walls, and subsequently mineralised through hydrothermal action.

Speaking generally of Western Australia, amongst other facts opposed to such a theory, he mentions that the filling of the lodes, though often of very similar nature to the enclosing rocks, is frequently entirely different, as, for instance, syenite-porphyry interbedded between hornblende-schist; vesicular trachyte between massive diabase walls; andesite between hornblende-schist; melaphyre between massive diabase walls, etc., and adds that the lode-filling, though as a rule schistose, and sometimes foliated, presents most marked flowing structure, or corrugated laminations, running strictly parallel to the capricious sinuosities of the walls of the ore-bodies.

He regards the formations as dykes, and the gold they contain as having been derived originally from igneous inclusions, rather than from fumeroles emitted from depth, though fumeroles (at first chiefly haloid and later on of a sulphide type) emitted during consolidation of the magma of the dykes may have played accessory parts in depositing the gold. He summarises the geogony, i.e. history, of these auriferous dykes as probably having been as follows:—

1. The ascent through some fracture in the earth's crust of an eruptive magma, carrying auriferous sulphides, tellurides and possibly some native gold.

2. All the primitive cracks existing within the country rocks, as well as the more porous parts of adjoining rocks, are mineralised by fumeroles.

3. Final consolidation of the magma composing the dyke; contraction cracks are generated, affecting only the dyke. First action of very hot mineral solutions silicifying and mineralising all these cracks.

4. Contraction fissures occur within the adjoining country rocks, which now and then penetrate the dykes or run along one of their walls. Hydrothermal circulations mineralising all these secondary fissures.

5. After final cooling of the whole, orogenical movements gene-

* 'Technical Observations upon the Coolgardie Gold-Fields,' *The Mining Journal*, London, 1897.

rate fractures which cross both the dykes and the country; action of very poor and rather cool mineral solutions silicifying all these fractures.

6. Surface erosion disperses the gold previously carried within the denuded belts, disseminates it over the surrounding country, producing alluvial and æolian deposits.

7. Decomposing action of oxygenated and carbonated surface water, causes alteration of the minerals in the upper levels of the dykes.

Mr. G. J. Bancroft * remarks, that "the rich area of Kalgoorlie is characterised by a bluish tinge of the rocks, while the rocks of the barren ground surrounding it have a greenish tinge. The local mineralogists have considered the two shades as different alterations of the same rock, and have given the name of diorite to both."

"It has been suggested that the blue stone † (referring probably to the grey rock mentioned later on) is a later eruptive, and that to the influence of this eruption the mineralisation of the camp was due."

"Professor Kemp has determined the blue stone to be a much-altered basic eruptive, which is now serpentine ‡ and chlorite. The green stone, as determined at Perth, is essentially the same, except that there is a little olivine present."

Mr. Bancroft also lays stress on the presence of certain "dykes" in this field, which he observes Professor Kemp, of the Columbia School of Mines, classes as a "pyroxenite" § (composed mainly of tremolite and actinolite), and he goes on to add: "Associated with the veins are lenticular bodies of graphitic slate. These have been called eruptives by some, but Professor Kemp has determined the rock to be a true slate, probably an altered and metamorphosed clay-rock."

As regards this latter point, the following description, given by Mr. Pittman, ‖ seems to indicate that the sedimentary origin of this so-called slate is open to some question, as he says: "Along the western side of the Boulder Field and parallel to

* 'Kalgoorlie, Western Australia, and its Surroundings,' by G. J. Bancroft, *Trans. Am. Inst. of Mining Engineers*, vol. xxviii.

† The author cannot say that any rock exactly answering to this description came under his own observation.

‡ Hydrated silicate of magnesia, frequently resulting from the decomposition of the olivine in igneous eruptive rocks.

§ Pyroxene (augite) is particularly characteristic of the volcanic igneous rocks, whilst hornblende is more often a constituent of the plutonic series; but hornblende very commonly arises as a partial or complete replacement of augite, being developed from it by paramorphic change, and both tremolite and actinolite are non-aluminous varieties of hornblende.

‖ *Records of the Geological Survey of N.S.W.*, vol. vi. part i.

the dykes, there extends a narrow belt of jasperoid * and chalcedonic rocks, of varying colours, and in conjunction with this is a bed of black carbonaceous slate. These rocks are seen outcropping near Hannan's Lake, where they stand up from the surface like a wall. An examination of this outcrop shows that in places the slate is in process of replacement by white chalcedony. Neither the jaspers nor the slates are visible on the surface far north of Hannan's Lake, but they have been met with in shafts in several places along the west of the principal mines, thus proving the continuity of the beds for at least 4 miles. It seems probable that these jaspers, etc. mark a contraction fissure along the western boundary of the dykes ("formations"), and that the silicification has been caused by the ascent of thermal solutions along the course of the fissure." Many of the plutonic rocks, it may be observed, develop a slaty or schistose structure. On the other hand, Mr. E. S. Simpson's more recent investigations point to the existence of a group of ancient and highly metamorphosed sedimentary rocks in this section of the field, vide footnote.†

The facts noted by other observers also appear to confirm what has already been said.

Mr. Harrison F. Bulman,‡ describing the Boulder area, says: "It consists of several highly productive gold belts or lodes with unproductive or less productive ground between, the whole being a mass of igneous eruptive rocks of great age. The productive belts have a general course of north-north-west and south-south-east," and there is evidence of a long line of fracture traversing the country for many miles.

Mr. George W. Card, A.R.S.M. (the mineralogist of the Geological Survey of New South Wales) made a careful microscopical examination of a number of specimens of country rock, and of the ore-bodies obtained from ten of the principal mines,§ which were submitted to him by Mr. William Frecheville and Mr. Edward

* Some felsitic rocks closely resemble jasper, which is a compact variety of quartz, frequently variegated in colour. In Bulletin No. 6 of the *Geological Survey of Western Australia*, p. 76, it is stated that Mr. W. D. Campbell's investigations in the field point to the possibility of some of the accompanying graphitic rocks being "foliated greenstones."

† Mr. Simpson, however, says: "Surrounded on all sides by the igneous rocks and dipping at a high angle are a series of sedimentary rocks, ranging on the one hand from a soft shale to a jasperoid slate, and on the other from a sandstone to a flinty quartzite.

‡ 'The Kalgoorlie Gold Mines, Western Australia,' *Trans. Inst. of Mining Engineers*, vol. xvii.

§ A most interesting and detailed account of these investigations is given in 'Notes on the Country Rock of the Kalgoorlie Gold Field, Western Australia,' by G. W. Card, A.R.S.M., *Records of the Geol. Survey of New South Wales*, vol. iv. Part 1, 1890.

F. Pittman (the Government Geologist of New South Wales), who visited the district in 1897.

These investigations showed that the country rock is the same throughout the field, and that the "ore-bodies" are simply more highly-altered rock of the same character. Its recognisable minerals, according to Mr. Card, are quartz (primary and secondary), felspar (orthoclase and plagioclase), titaniferous iron-ore (with leucoxene),* magnetite, pyrites, carbonates (calcite, etc.), apatite,† chlorite and sericite; ‡ of these, quartz, felspar, ilmenite, magnetite and apatite may be regarded as primary.

Mr. Edward F. Pittman, A.R.S.M. further remarks § that the rock which lies immediately beneath the ironstone gravels which cap the Boulder hills at first sight appears to be a bluish-grey micaceous or talcose schist, which in places is intersected by dykes of diorite, and also by irregular quartz reefs; but in reality, the "country rock" merely differs to a slight extent from the igneous dykes which constitute the so-called "lodes," both as regards the proportion of its component minerals and the amount of alteration it has undergone.

The Author's observations on the geology of the field, which he visited in January 1898, correspond very closely with the excellent description given of it by Mr. William Frecheville,‖ who observes, that two prominent varieties of country rock may be noticed in depth in the underground workings of the various mines. That which forms the country rock in the deeper workings of the western mines, such as the Ivanhoe, Golden Horseshoe, Great Boulder, and Lake View, and also the predominating country rock of the whole belt, is "a fine-grained, green, massive rock, of only moderate hardness, being easily scratched by a knife, with a homogeneous appearance, although on looking very closely into it, very fine specks of glassy quartz, of a black metallic-looking mineral, and an occasional speck of pyrites, can be seen here and there."

"The other rock, of a grey appearance, was noted in the more eastern mines, such as the Australia, Kalgurli, etc. This rock has generally a homogeneous appearance, and although of a distinct

* Decomposition products of ilmenite not recognisable as sphene.

† $3\ Ca_3P_2O_8 + Ca\ (Cl_2F_2)$.

‡ A green mineral of silky lustre, allied to mica, of which it is probably a secondary product.

§ 'Notes on the Geology and Mineral Deposits of Portions of Western Australia,' *Records of the Geol. Survey of New South Wales*, vol. iv. Part I.

‖ 'Notes of a Visit to the Gold Mines at Kalgoorli, Western Australia,' by Wm. Frecheville, A.R.S.M., *Trans. Inst. of Mining and Metallurgy*, vol. vi.

colour, has a good deal of resemblance to the green variety, both in its low degree of hardness, its texture, and in having fine specks of pyrites and of a black metallic-looking mineral scattered through it."

Both rocks effervesce briskly when treated with acid, owing to the presence of a considerable amount of carbonate of lime. Sometimes, as in the Australia workings, both varieties of rock are met with in the same mine.

Samples of the green rock, from the Lake View and Great Boulder mines, were submitted to Mr. Card, who describes it in a letter addressed to Mr. Frecheville as a highly-altered acid igneous rock, either granite or porphyry, probably the latter.

"The ore is the same rock, only still more altered, having had schistosity imparted to it as an effect of the intense crushing." Ilmenite was found to be present in both samples of the country rock, especially in that from Lake View. Regarding samples of the grey rock from the Australia and Kalgurli, Mr. Card remarked that it appeared to be a highly-altered granite, containing magnetite in addition to pyrites; whilst the sample from the Australia East lease, whilst evidently also a highly-altered igneous rock, is more of a felsitic than a granitic character, quartz being absent.

Detailed descriptions of a number of specimens of these rocks are given by Mr. Card in the paper previously mentioned; and summarising his observations on the particular samples submitted to him from the Australia and Ivanhoe mines, by Mr. William Frecheville, it would appear:—

1. That the unaltered country rock is generally soft, of a green colour, and has a schistose structure, which sometimes occasions a considerable amount of fissility. The divisional planes exhibit a silvery sheen, due to the development of secondary mica.

2. That it is evident, from its mineralogical constitution and structure, that this rock is of igneous origin: quartz, felspar, ilmenite and magnetite are among the original constituents, and that characteristically igneous structure, the micro-pegmatitic,* so common among the acid eruptives, is sometimes well shown. The green coloration is due to chlorite, which acts as a pigment when finely disseminated, as it generally is.

3. That there is no difference between the country-rock, which constitutes the hanging and foot-walls of the deposits, and conse-

* A minutely-crystalline graphic structure sometimes seen in granite, the cleavage surfaces of the felspar giving the effect of "lustre-mottling."

quently these "formations" cannot be classed as "contact deposits."

4. That it is of an acid character, probably a quartz-felspar-porphyry,* but may approximate to a granite in places.

5. That the rock has undergone great alteration, both chemical and mechanical, and it would appear probable that deep-seated alteration occurred prior to the lateral crushing which was one of the causes that imparted to the rock its fissility and schistose structure. Subsequently, solutions containing metallic salts, silica, carbonate of lime and magnesia, and possibly alumina, permeated the rocks, depositing their contents in the spaces resulting from the crushing and shrinkage that must have taken place, as well as by pseudomorphous replacement.

6. That the lode "formations" represent belts, along which these effects have been most severe, and the deposition of secondary material most abundant. They are, in fact, similar in character to the country rock they traverse, but are more highly altered.

7. That whilst there is no doubt that diorite dykes exist in places on the field, it is a misnomer to apply this descriptive term to the series of eruptive rocks which are associated with the principal ore-deposits at Kalgoorlie, simply because some of them happen to be of a green colour.

As Mr. Card remarks, the misuse of the term is due to the fact that *diorite* is a rock to conjure with amongst Australian miners, owing to gold-reefs being frequently found associated with diorite dykes; consequently it is especially desirable to find diorite when a property is to be placed on the market.

Two specimens that seem to me of particular interest are referred to by Mr. Card, as illustrating points to which attention has been previously called.

One, numbered 8508, country rock from the 140-feet level of the Australia East lease, described as "flesh-coloured, pyritous, and conspicuously spotted with iron-ores. It is fairly hard, and shows a general effervescence when treated with dilute acid. A calcareous vein traverses the rock. With a lens, blebs of quartz may be seen, and the whole has a felspathic appearance. Under

* The recent investigations of Mr. E. S. Simpson (*Bulletin* No. 6 of the Geological Survey of Western Australia, p. 65), who appears to have formerly shaied this opinion, lead him to believe that what were formerly thought to be acidic porphyries aie really altered amphibolites, in which the plagioclase is frequently converted into saussurite, and illman te into leucoscene. He remarks that Göczel and Schmeisser, who were the first to critically examine these rocks, looked upon them as altered plagioclase-pyroscene diabase.

the microscope, the great importance of this specimen becomes evident, as it may give the clue to the interpretation of all the others. Although highly altered, it is a quartz-orthoclase-plagioclase rock * with a granite structure, and would be termed granite by some petrologists. The readily recognisable minerals present are ***quartz, orthoclase, plagioclase, magnetite, titaniferous iron-ore, calcite and sericitic mica.***"

The other specimen, No. 8458, is from a dyke traversing the North Kalgurli, and traceable for a considerable distance. This is totally different from any of the other rocks described. "It is a dark-green and opaque-white mottled rock, with a specific gravity of 3."

"No metallic minerals are visible in it. Under the microscope it is seen to consist principally of pale actinolitic hornblende, with very dusky felspar, quartz and some apatite."

"In its present condition it is undoubtedly almost entirely reconstructed, and may be termed an amphibolite. To some extent the hornblende shows nuclei of a brown, striated, slightly pleochroic † mineral. This would appear to be diallagic in character, and from it the hornblende has probably been formed." This rock has no connection with the ore-deposits.

Broadly speaking, after carefully considering the microscopical and chemical evidence afforded by specimens of ore and country rock collected from various levels and different mines on the Kalgoorlie field, and examined by Mr. Card, the following generalisations would seem to be permissible :—

* The following table, given by Prof. John W. Judd, C.B., F.R.S., Lectures R.S.M., 1879, shows the character of the various classes of felspars :—

Acid :	Orthoclase	$K_2O\ Al_2O_3\ (SiO_2)_6$	monoclinic.
	Albite	$Na_2O\ Al_2O_3\ (SiO_2)_6$	triclinic.
Basic :	Anorthite	$(CaO)_2\ (Al_2O_3)_2\ (SiO_2)_4$	triclinic.

Orthoclastic.

Orthoclase { adularia, sanidine } potash felspar.

Plagioclastic.

Microcline . . .	potash felspar.
Loxoclase	„ soda felspar.
Albite	soda felspar.
Oligoclase . . .	„ lime felspar.
Andesine	„ „ „
Labradorite . . .	lime-soda felspar.
Anorthite	lime felspar.

† Minerals which exhibit axial colours with a dichroscope.

1. That the country rock throughout the field seems to belong practically to one type, containing invariably titaniferous iron-ore, quartz and white mica.

2. The rock is of igneous origin, as shown by its pegmatitic or graphic structure and mineralogical constitution, and the extreme alteration it has undergone in depth proves its antiquity, in evidence of which Mr. Card cites slide 8433 (a sample from the Great Boulder mine), in which, titaniferous iron-ore is seen converted into opaque yellowish-white products, the original silicates have been largely replaced by sericitic material, and the primary quartz has been split up into groups of fragments or completely absorbed.

3. The deep-seated alteration that the country rock has undergone, seems rather to have been of a chemical than a cataclastic nature (as it affords little evidence of shattering), and was probably induced under the influences of high temperature and steady pressure. Subsequently mountain-making forces exerted themselves along certain lines of weakness, shearing and crushing the rock to some extent, inducing foliation in the sericite, which has produced a certain amount of fissility in the rock, but not sufficiently pronounced to cause a general foliation and convert it into a true schist.

4. Subsequent intrusions of other and more basic eruptives, represented by the amphibolite and diorite dykes previously alluded to, probably wrought further changes in the earlier eruptives and the ore-bodies they contained, through the influence of contact metamorphism.

5. The general absence of hornblende,* and the constant presence of quartz, points to the original eruptive rocks having been of an acid character, and precludes the possibility that they could have belonged to the intermediate class of rocks, known as quartz-diorites. In some cases, their structure appears to have been granitic,† in others porphyritic ‡ or felsitic §: one specimen (8462) in particular, from the Lake View and Boulder Junction mine, resembling a felspar-porphyry ; but the presence of titaniferous iron links it with the other specimens.

Regarding the geology of this area in its broadest aspect, it

* Recent investigations show the existence of an important series of hornblende rocks (amphibolites) on the field, and it is now thought that the greenstones and chlorite schists are altered hornblendic rocks. The amphibolites are usually classed as metamorphic, and the greenstones as plutonic rocks; and the hornblende-porphyrites belong to the basic igneous plutonic rocks.

† Holocrystalline.

‡ Some of its crystalline constituents developed on a larger scale than the rest.

§ Compact, with a micro. granitic, lithoidal or glassy ground mass.

appears to be a very ancient complex of acid eruptive rocks, in some parts granitic, in others porphyritic or felsitic, in structure, which has undergone intense alteration under the influence of chemical changes combined with metamorphism, which would naturally result from the immense pressure and high temperature prevailing at great depths within the earth's crust.

This belt of acid rock was penetrated subsequently by other and more basic eruptives, represented by the amphibolites and diorite dykes previously referred to, which have undergone a parallel and similar process of deep-seated alteration.

Mountain-making forces, which later on manifested themselves along lines of weakness, afterwards resulted in shearing and crushing the rocks (of whatever description) along these lines, and produced partial foliation, aided no doubt, to some extent, by crystallisation under pressure during their primary cooling; whilst, at the same time, mineral solutions doubtless penetrated along the divisional planes of this sheared zone of country, giving rise to some of the ore-bodies. The gold they now contain may possibly, however, have been originally derived partly from inclusions in the liquid igneous magma and to a less extent from fumeroles, as suggested by Baron Oldruitenborgh.

It is probable that this district may have been very elevated in early geological time, and it has apparently never since been beneath the sea; but the disturbance of the deep-seated rocks no doubt extended to the surface, facilitating the agencies of erosion, which have reduced it to a table-land, and would have laid these deposits bare, had not the absence of running water permitted the accumulation *in situ* of the products of atmospheric weathering.

If, as has been alleged, true sedimentary slate containing fossils existed, the Archæan age of these Kalgoorlie rocks might be open to question; but in default of better evidence than has yet been produced, they may be regarded as such at present.

Mr. Card has pointed out that in some respects the broad stratigraphical features of this area would seem to bear a general kind of resemblance to those of Rhodesia, as described by Messrs. Hatch and Chalmers,* who state that the metamorphic rocks and schists which constitute the gold belts of the country occur as broad bands and patches in granite; chlorite and hornblende schists

* 'Notes on the Geology of Mashonaland and Matabeleland,' *Geol. Mag.*, 1895, ii. (4) p. 195.

occur which are regarded as having derived their foliated structure from a mechanical process analogous to "shearing," referable to crust movements along zones of weakness. Their explanation is that earth shrinkage first permitted the extrusion of igneous rocks, and then, continuing along the same line, converted them into schists, and some of the granite into gneiss, at the same time opening fissures, in which quartz was deposited. They consider that there is an intimate connection between the schists and the quartz, and that the ore will continue in depth.

General Character of the Ore Deposits.

These may be divided into two distinct classes :—

1. True quartz veins.

2. "Lode formations," * consisting, as already explained, of the remnants of ancient igneous eruptives which may have produced perhaps in some cases crushed zones of country that have become mineralised in consequence. These formations carry more or less defined ore-bodies (sometimes of a more or less quartzose character) impregnated with "mineral," which has been deposited along lines of weakness (caused both by compression and shrinkage) on joint or fault planes, and in zones or bands (due to replacement along foliation or cleavage planes) within the dykes ; but, with little ordinary characteristic gangue material distinguishing the ore from its matrix.

Quartz Veins.

As regards this first class, little need be said, as they have already been referred to, and sufficiently fully described ; but Bergrath Schmeisser remarks that in quartz veins consisting of a dark colour, particularly of a yellowish, brownish variety, the gold is generally very finely distributed through the entire mass ; while in the white or milky-white quartz, on the other hand, the gold is generally in coarse specks and angular pieces in the cleavage planes of the ore. It is only necessary to add that, speaking generally, in this district, one of the most marked features of veins of this kind is their *superficial enrichment*, sometimes in pockets † and sometimes

* Termed by Bergrath Schmeisser "composite veins."

† As examples of this, one might instance the Londonderry specimens exhibited in London, consisting of gold mixed with a little quartz ; and Professor Schmeisser mentions that a lump of gold weighing 303 oz. 10 dwt. was discovered in the outcrop of a little quartz leader at the Devon Consols claim, near the Black Flag, 6 feet below the surface.

for continuous stretches, which, as compared with quartz veins in other parts of the world, is exceptionally strongly marked.

Commenting on this peculiar fact, Mr. H. C. Hoover says* :— "There are many quartz mines of value, the exploitation of which has proved the values to continue in depth ; but the bare fact that of 161 mines 'promoted' on quartz veins in these districts, only seven or eight have proved successful, is evidence on this point ; for one must believe that the surface-indications, in the majority of these cases, gave some basis of hope." Many instances, he adds, occur to the author in which the mines above the 50-feet level did offer extraordinary prospects. Other proofs of superficial enrichment lie in the common occurrence near the surface of gold in the cleavage planes, and loose gold along the walls.

The agencies which produced this enrichment are, however, more obscure than in the case of the second class of deposits, and it yet remains to be proved whether some mines which have been rich at surface, "after passing through a barren or poor zone, may not strike it rich again in depth; the Great Fingall appears to be a case where this has happened ; and in the East Murchison United there appears to a poor zone below rich shoots in the upper workings."

Lode Formations.

The ore deposits of the second class are chiefly exemplified by a central group of eight or nine phenomenally rich mines within an area of less than a square mile, surrounded by a slightly larger number of properties of second rank, situated, as already said, in the immediate neighbourhood of the Boulder township, south-east of Kalgoorlie.

With the single exception of Hannan's Brownhill (a mine which must be included in the first rank), and perhaps in one or two other instances outside of this central area, that promise fairly well, there is so far no evidence of the extension or recurrence of similar deposits.

The "lode-formations" appear to represent, Mr. Card remarks, "belts along which the crushing effects have been most severe, and the deposition of secondary material more abundant ;" and he appears to regard them, as being, merely, more highly-altered portions of the country rock, which present evidence of considerable dynamic disturbance, exhibiting numerous "false walls," and, as

* 'The Superficial Alteration of Western Australian Ore Deposits,' by H. C. Hoover, *Trans. Am. Inst. of Mining Engineers*, vol. xxviii.

some consider, brecciated* shattered zones, that furnished channels for the percolation of the solutions, which mineralised the ore-bodies in such a way, that they present many of the features of "stockwerks."

The theory that Baron Oldruitenborgh has suggested, that the main "formations" represent the remnants of a series of ancient dykes,† of very similar composition to the original eruptive mass that they subsequently penetrated, does not, however, appear incompatible with the facts that have been mentioned.

The main system of these "lode-formations" forms a group of more or less parallel "ore-bodies," which follow a north-west and south-east course, traversing the principal leases, on the western side of the field.

Further east, however, you find what appear to be a separate series of similar ore-deposits, possessing a certain amount of parallelism, which "strike" several degrees more to the west of north and east of south (such as the Kalgurli and North Boulder formations), whilst, on the extreme eastern side of the field, the Brown Hill Extended and the Oroya may be cited as instances of "formations" approximating much more closely to a north and south course, than the first or main series.

Even in leases the side-lines of which adjoin, and in which one would expect to find the continuation of a "formation" known to exist in the one traceable into the other, it is often impossible to say positively, until the underground workings have been connected, that what appears to be the "extension" of the same "ore-body" is so in reality.

This difficulty arises from the fact that the "formations" which carry the ore-bodies (being concealed under and consequently "masked" by the detrital deposits previously described) do not out-

* In the Boulder Main Reef mine, between the ore-body and what may be termed the hanging wall, there is a thickness of about 6 inches of what appears to be a brecciated rock. Mr. Card, however, after examining a thin section of this material under a microscope, reports that "it would appear as if the breccia-like appearance were delusive, and was due to the unequal distribution of the chlorite," *Pittman, op. cit.* p. 12. So far also as the Author's observations went, the term "brecciated" scarcely seems to him to be applicable to the structure of these deposits, as they appear to show less evidence of shattering, than of crushing.

† Mr. E. F. Pittman, A.R.S.M., remarks, that a careful examination of the workings from the surface down to a little over 300 feet leads to the conclusion, "(1) That the so-called lodes are in reality intrusive dykes, and (2) That the material of the walls or country is of precisely similar origin, and differs merely in the proportion of its mineral contents, and the amount of alteration it has undergone."—*Records of the Geol. Survey of New S. Wales*, vol. vi. part i. p. 10.

crop at the surface, whilst several separate "formations" sometimes traverse the same lease, at no great distance apart, and deviate slightly, in places, from the general line of direction they follow on the whole.

No doubt, however, Mr. Willlam Frecheville was well within the mark in stating, in 1898, that some fifteen or sixteen separate veins had been already proved to exist within the area described, and others were likely to be discovered when the ground was more carefully explored.

In some cases, also "sinking" and cross-cutting have shown the existence of "blind lodes," which never reach the surface at all.

The "formations" rarely possess, anywhere in the decomposed zone near the surface, well-defined "hanging" or "foot-walls"* distinctly separating them from the country rock outside; and it is also oftentimes an extremely hard matter, in fact impossible without assaying it, to distinguish the difference between the payable "lode-stuff" and the valueless "lode-formation" by eye alone, although there is sometimes a fairly smooth plane separating the productive from the worthless stone—a feature which more particularly characterises the upper levels of the mines, where surface agencies are seen to have decomposed, oxidised and kaolinised the country rock and "formations," as well as the ore-bodies, converting the latter into "gossan"; which is locally termed "brown stone," as it is coloured brown.

The decomposed "country rock" at surface, like the lode-filling, is highly argillaceous, distinctly foliated, and of much the same general appearance as "the formation," except that it is usually less stained with iron; portions of the formation (like parts of the ore-bodies) present a mottled appearance, and are of a yellowish-white or red tint; the soft white portions consist generally either of kaolin or decomposed granular particles of quartz, the colouring matter of which has been removed; whilst the red blotches and streaks are hard, and contain a large percentage of oxide of iron.

Mr. William Frecheville, A.R.S.M., describing these deposits, says: "When the zone of schistosity is of great width, the mineralising solutions appear to have been often confined to certain parts

* Bergrath Schmeisser says: "The enclosing walls of these 'formations' are for the most part better defined on the foot wall side," a fact that the Author has been unable to confirm, from his own observation.

† 'Notes of a Visit to the Gold Mines of Kalgoorli, Western Australia,' by Wm. Frecheville, M. Inst. M.M., *Trans. Inst. of Mining and Metallurgy*, vol. vi.

of it, sometimes producing several parallel bands of ore, separated by more or less unproductive material.* The zone along which the pressure has exercised its maximum effect may have been determined by previous, or simultaneous, fissuring of the rock.

"Locally, the term 'lode' is applied to the ore formations when of a clearly defined character, differing markedly from the non-productive rock and bounded by fairly clearly-defined 'walls,' as for instance in the Great Boulder, Ivanhoe and Lake View mines; and the term 'formation,' when the zone of schistosity is of greater width, and the difference between gold-bearing and non-gold-bearing material is not evident, except by assay. The same vein may apparently exhibit both characteristics in different parts of its length. The Lake View vein, in the Lake View ground, is clearly defined, whilst in the adjoining mine to the south-east, apparently the same zone of schistosity spreads out to a width of several hundred feet, and the ore-occurrence has so far been found more patchy and uncertain."

It would therefore be better, perhaps, to apply the term "lode-formation" to the zones of ore-bearing ground, and substitute the term "ore-body" for the word "lode" as above employed.

The value of the "ore-bodies" frequently diminishes gradually from a central core, or source of impregnation, spreading out into the wall-rocks; the only practical distinction between "ore" and "formation" being the question of whether it pays to mine and treat.

The "lode-formations" as above defined are frequently extremely wide, and may be considered as being continuous; whilst the ore-bodies they contain run in places themselves up to considerable widths. But though some of these latter continue regular and payable for long distances, like the shoots in a quartz-vein, in general they present the character of a succession of lenses, or lenticular masses of ore, which, in following any particular line of "formation," make suddenly from a feathered edge, expanding up to a certain width, till they finally pinch, and cut out again after driving or sinking a certain distance † (depending on the size of the ore-body), along the axes of the lenses.

* This peculiarity might possibly give rise to a mistaken impression, by presenting the appearance of a series of parallel veins poor in the centre with the ore concentrated on the walls

† An instance of this kind is quoted by Mr. Bulman, who said: "At the Lake View Consols mine this occurred recently at the 450-feet level, but the general geological conditions point to their continuance in depth."—'The Kalgoorlie Gold Mines of Western Australia,' *Trans. Inst. of Mining Engineers*, vol. xvii.

The ore-bodies are found fortunately, however, frequently recurring, being set in echelon end to end, overlapping in splice fashion, so that when an ore-body pinches, another is frequently picked up by cross-cutting in a short distance.

This feature of the recurrence of new ore-bodies is repeated again and again, both along the course and on the dip of the principal "formations," the ordinary rule amongst the miners (in this district) being to cross-cut the "formation" east when going south, and west if proceeding north, when the "ore-body" driven upon pinches, and it is necessary to look for another. In other words, the ore-bodies have a tendency to cross the "*formations*" from the hanging to the footwall, driving south, or *vice-versâ*.

The same thing happens in sinking, an ore-body, it may be, disappearing suddenly in following it down, and others being found by cross-cutting, which do not appear at an upper level. When the pinched ends of two adjoining lenses are close together, there is often simply a turn made in the drive, which is scarcely noticeable to the casual observer, to whom it would appear that the level was driven along a continuous "pay shoot."

The arrangement of the ore-bodies in echelon, thus presented within each individual formation, may possibly have resulted from co-ordinate fracturing, which is said to characterise this "camp." In some cases, portions of the ore-bodies are undoubtedly thrown or heaved by "faults,"* and at times they are displaced by vertical "fault planes" crossing them. These various circumstances render the course to pursue, in the exploitation, development and removal of the ore-bodies, to secure the best results, a problem often of great difficulty, demanding careful consideration, local experience and technical knowledge.

The facts just stated also probably explain the tendency the ore-bodies at times exhibit to throw off spurs and branches into the walls,† either along horizontal "floors," or more or less vertical cross-fissures, which carry gold at times for a short distance outside ;

* A case of this sort was brought to the Author's notice in the Great Boulder mine.

† Baron Oldruitenborgh remarks that starting from their hanging or foot-wall, sometimes from both walls, the formations throw off numerous veins of manganiferous specular iron ore running through the country rock, varying from ½ inch to several feet in width. They are very compact, practically devoid of quartz, show no casings, and can scarcely be regarded as the result of hydrothermal action, or as derived from decomposed pyrites. He regards these as the precipitation or substitution products of haloid fumeroles, having escaped during the first phase of their consolidation from the magmas composing these complex lodes.

but they are not in any true sense "cross-veins" or "cross-courses," and their values generally fall off when they are followed for any distance.

Where a number of "lode-formations" are grouped together, there is frequently a probability of "parallel courses of rich ore" being found opposite to one another in contiguous formations ("ore against ore," as the Cornishman calls it), owing to the same influences which have enriched one having acted in much the same way on the others, within a certain belt crossing the whole series; consequently, mines that are traversed by "formations" flanking properties in the centre of the Kalgoorlie field, in which rich and extensive bodies of ore have been proved to occur, would seem better situated for making similar discoveries, perhaps, than leases on the extension of a known "line of reef" outside of the proved belt.

In the ore-bodies themselves there are "walls within walls," and consequently the pay-ore often "makes" behind what is supposed to be the true hanging or foot-wall, until this supposed wall is broken through. The need for careful and systematic cross-cutting at each level, and at levels close apart vertically, need therefore scarcely be emphasised.

Ore-bodies in the same formation, apparently similar so far as regards mineralisation, often differ considerably in their chemical composition as well as in average value, whilst individual ore-bodies exhibit at times enormous assay differences in different parts, the gold occurring in rich spots and pockets alternating with very poor ones; this, taken in conjunction with their irregularity in width, renders the task of "the sampler" who aims at placing an accurate value on a "block of ground" a matter of extreme difficulty.

The ore-bodies, or "courses of rich ore" in the principal "formations," appear to have a general tendency to "pitch" south, in the direction of the strike of the lodes; they run from a mere thread up to many feet in width, and are sometimes continuous for several hundred feet in length, carrying one- to three-ounce ore, or even richer stone in bulk; indeed, stone can often be selected in moderate quantity which would assay from 5 to 20 oz. per ton.

As a case in point, Mr. H. F. Bulman * instances the Associated gold-mine, remarking that at Tetley's shaft, at the 500-feet level, "a lode 40 feet in width, carrying 3 to 4 oz. of gold per ton," was opened up in 1898.

As further illustrating the strength of some of the richer "lode-

* *Op. cit.*

formations" at surface, Mr. Wm. Frecheville mentions that in the Lake View mine they drove " some 2400 feet on their so-called main lode, with, it is stated, payable ore practically all the way, the vein on the whole being of great width, in places going up to as much as 20 feet, and the average width being from 8 to 10 feet. The same vein is being worked immediately to the north-west in the Boulder Perseverance mine, where they drove several hundred feet on it, and in one place opened a stope 50 feet in width,* of which 30 feet " was claimed to be ore. Several of the other mines have shown ore-shoots or bodies of great length.

As a further example, Mr. E. F. Pittman, A.R.S.M., describes † an interesting section of a cross-cut in one of the principal mines :—

—	35 feet wide.	30 feet wide.	15 feet wide.	4 feet.	14 feet wide.	—
West	Average assay value about 2 oz.	Barren	Average assay value 3 to 4 oz.	Barren	Average assay value 3 to 4 oz.	East

As above shown, in a total width of 98 feet, no less than 64 consisted of high-grade ore. Mr. Pittman adds, " It has not yet been proved how far this extremely rich deposit continues in the direction of its strike, though one of the drives is at least 60 feet long." The newspapers record that one of the early shipments, consisting of 1000 tons of ore from this mine, was treated for a yield of slightly over four thousand ounces of gold.

The dip of the " ore bodies " near the surface is generally westerly, some 10° to 20° from the vertical, but at greater depths they sometimes underlie eastwardly.

Mr. Bulman describes them ‡ as being roughly vertical, the levels at increasing depths being, as a rule, nearly beneath one another, but often they incline from side to side at different depths. For instance, at the Kalgurli mine a lode proved, by their main shaft passing through it, to be dipping west, between the 200- and 300-feet levels, is seen, at the 300-feet level, it is said, to have altered its inclination to the eastward, coming into the shaft again.

Often, however, levels at different depths have been driven on separate parallel " courses of ore " close together in the same formation, where it is of considerable width, thereby giving a misleading impression of the true dip.

* The writer has seen a " stope " near the surface in the " Australia East " workings which must have been considerably wider. † *Op. cit.* ‡ *Op. cit.*

An apparent underlie is also sometimes due to horizontal slides displacing part of an ore-body. At the Ivanhoe three of these are said to occur, shifting the lode all in the same direction, between the surface and the 300-feet level.

Sometimes a horizontal floor crosses an ore-body, and below it the ground is quite barren; at other times, as Mr. Bulman remarks,* "well defined vertical walls cut across the lodes at right angles to them, without affecting the gold-bearing character of the ground on either side of the parting." Irregular quartz veins and veins of ironstone run for short distances sometimes parallel to the lodes, and sometimes at right angles to them. Flat veins, rich in gold, occur abutting against the main ore-body. Not unfrequently, the lodes divide into two arms, enclosing between them a mass of unproductive rock," or "horse" of mullock. At the Great Boulder, one of these branches passes into the Golden Horseshoe lease, and returns again 100 feet farther on.

A number of interesting analyses and microscopical determinations, made during the last three years in the Departmental Laboratory, are described by Mr. E. S. Simpson in Bulletin No. 6 of the Geological Survey (1902), and it is stated that the results of this investigation have led to the classification of the Kalgoorlie rocks under four headings: (1) Amphibolites and their derivatives, including most of the lode-stuff; the main alteration these amphibolites have undergone being a conversion of hornblende and felspar, by the action of water and carbonic acid, into chlorite, epidote and various carbonates, with the separation of free silica. (2) Newer eruptives, acid, intermediate and ultra-basic. (3) Older sediments. (4) New sediments. Whilst obsidianites have also been found on the field both chemical and mechanical. The amphibolite rocks are subdivided into four main types, viz.:—massive and foliated amphibolites; massive and foliated green-stones (chlorite-rock); chlorite schist; and massive and foliated siderite-rock. The newer eruptives are subdivided into felspar-porphyry, porphyrite and peridotite † (augitic), and the older sediments are stated to range from a soft grey shale to a jasperoid slate, and from a sandstone to a flinty quartzite. The newer sediments comprise salt, travertine, siliceous-sinter, laterite, sands and clay and ironstone gravel.

* *Op. cit.*

† On the west shore of Hannan's Lake a large dyke outcrops (in places converted into solid serpentine rock) which Mr. Simpson classes as augite-peridotite.

CHAPTER V.

THE KALGOORLIE DISTRICT (*continued*).

The Structure of the "Outcrop" Ore Bodies and their Mineralogical Character.

MR. H. P. WOODWARD * remarks: "Until quite recently the character of these lodes (i.e. 'formations') at a depth was a matter of great speculation, since, in the opinion of many undoubted authorities, they were only shrinkage cracks, filled in from above, and therefore of probably no great vertical extent. This conclusion was arrived at from the nature of the lode matter (near the surface), which generally consists of mottled clay, with quartz fragments, through which the fine gold was disseminated."

Mr. Hoover † has called attention to the similarity in chemical composition, as well as in structure, of the oxidised ore and the altered country rock, and goes on to point out that:—

All the lines of demarcation are obliterated by oxidation, and the miner has difficulty in selecting ore from "waste." "The oxidation and hydration of the accessory minerals with their subsequent leaching have produced no unusual features. The iron sulphides are the last to yield to alteration, and are usually met with above the tellurides."

"The depth of alteration is exceedingly variable, not only in neighbouring mines and districts, but also along the same lode."

At Kalgoorlie the minimum depth is represented by the Kalgurli and Associated mines, where it does not extend below 50 feet; whilst at Hannan's Brown Hill, it reaches 400 feet. It often fluctuates greatly, however, at different points along the same formation. For instance, at the Ivanhoe mine, the depression in the line of oxidation is as much as 100 feet below the highest points where

* 'The so-called "Lode Formations" of Hannan's and Telluride Deposits,' by H. P. Woodward, M. Inst. M.M., *Trans. Inst. of Mining and Metallurgy*, vol. vi.

† 'The Superficial Alteration of Western Australian Ore Deposits,' by H C. Hoover, *Trans. Am. Inst. of Mining Engineers*, vol. xxviii.

unoxidised ore is found, and in the Friday "formation" of the North Boulder mine the difference is perhaps even more marked.*

The depth of oxidation seems to bear little, if any, relation to "water level," oxidised ore being frequently found extending from the surface, or in disconnected masses, below it, whilst the unoxidised ores occasionally reach above water-level, or occur in patches within the oxidised zone.

Neither does the topography seem to influence this feature of the ore occurrence in any marked degree, as the Hannan's Brown Hill, and Associated mines, might be cited as extreme cases of an opposite kind, although both are situated on hills; in the former however, oxidation extends 150 feet below water-level; whilst in the latter it does not reach that level by 100 feet or more.

The width of "outcrop," the depth of "cap" covering it, and the extent to which the ore-bodies have been mineralised seem to be the chief factors in determining the level to which the line of oxidation extends, as explained by Mr. Woodward, who says: "The oxidising action followed gradually down the same channels, up which the mineral matter found its way, and therefore has proceeded to a considerable depth; whilst in those portions which were poor, and not so highly mineralised, little or no change has taken place, even in the same lode, and at the same levels."

Oxidation, as a rule, extended to a greater depth in the ore-bodies than in the country rock, as they naturally afforded better channels for percolation, and the *widest lenses outcropping close to the surface* (as in the Brown Hill and Lake View) would naturally present the best facilities for the penetration of oxidising agents.

Changes in water-level from time to time, leaving the ground but partially saturated, and thereby favouring the decomposition of the "lode matter," would be sufficient to explain its oxidation for short depths or in irregular isolated patches below the normal water-level; and it must be recollected that Western Australia being peculiarly subject to long droughts, "water-level" in many mines is merely indicated by dampness. Such occurrences may, however, also be explained by the agency of alkaline waters affecting some portions of the "formation" more than others.

On the other hand, the occurrence of unoxidised ore above the line of oxidation is probably explained by the lenticular shape of the ore-bodies.

* 120 to 130 feet.

Where, as Mr. Hoover points out, only the edges of the lenses reach to the surface, as in the Kalgurli, a comparatively small channel was open for the entrance of oxidising agents from above, and consequently but little opportunity was presented for alteration, or as Mr. Woodward puts it: where the country-rock has undergone but little change, and the lode is only found by sinking for it to some depth, the "50 feet or so of solid rock above it may be said to have hermetically sealed it."

Irregular masses of unoxidised ore occurring in places above water-level may be accounted for by the impermeability of individual ore-bodies, owing partly, perhaps, to their lenticular shape. Above the line of oxidation the ore-bodies consist of "brown stone" which has a banded or schistose appearance and is soft and greasy to the touch, consisting largely of hydrated silicates of alumina and magnesia, frequently carrying threads of quartz and gypsum.

The term "brown stone" is given to it owing to its prevailing colour, which is due to the predominance of limonite amongst its constituents, although it is often coloured red and yellow by iron in different stages of oxidation and hydration, and sometimes carries a good deal of black, specular iron.

The gold in the brown stone, which is mostly "free," is at times bright and coarse when found in the decomposed iron-stained quartz stringers, which are frequently encountered in it. Bergrath Schmeisser* says, they strike generally in an east and west direction, and are composed of a white, grey, yellowish, green or dark coloured quartz often of a cellular crystallised character and sometimes resembling siliceous "sinter," and the more numerous these branch leaders are, and the more the quartz appears to be of a broken or cellular character, the richer the vein as a rule.

Generally, however, the gold is scattered through the lode-stuff, in an extremely fine metallic condition, invisible to the naked eye, though it is sometimes seen on a flat surface as a dust-like efflorescence known as "paint gold," whilst occasionally it is visible in the shape of fine metallic threads or spongy filaments, and in thin flakes, with brilliant faces (flake gold), the coarser varieties presenting the appearance of grains and star-like aggregations, scales, and spiky projections.

Mr. Woodward states that when quartz stringers are entirely

* 'The Present Position of the Gold Mining Industry of Western Australia,' by Bergrath Schmeisser, 1896.

absent, little or no gold is met with, and when found in close proximity to them, it mostly presents the appearance of "parted gold," being of a brownish-yellow colour and pasty or spongy character, which has caused it to be locally termed "mustard-gold." Mr. T. A. Rickard remarks *: "It occurs in splashes like yellowish clay, and can be detected by scratching, which burnishes it so as to exhibit the unmistakable glint of the precious metal. At Cripple Creek very perfect pseudomorphs after sylvanite and krennerite are obtainable. In the Gold King vein, patches of these can be seen in a series of quartz "geodes," the gold looking, as the miners express it, "like splinters of rotten wood."

Its condition in this powdery, lustreless, amorphous form, resembling "precipitated" gold, suggests that it is a product of the decomposition of other minerals, with which it was originally chemically combined—no doubt some of the various tellurides found at deeper levels; and Mr. Hoover † observes that "no better idea can be conveyed of the exceeding minuteness of the particles (when in the form of either paint or mustard-gold), than the fact, that the slimes, which constitute an average of over 50 per cent. of the Kalgoorlie ores, are almost universally richer than the sands." Mr. Sulman has stated ‡ that "mustard-gold" was gold intimately associated and covered with tellurite of iron; and the description of the discovery of a mass of calaverite in 1877 in the Melvina mine, given by Mr. T. A. Rickard § throws further interesting light on this subject. He says that, according to his informant, Mr. Richard Pearce, "Henry Neirkirk, a Dutchman, while prospecting, drove his pick into a mass of soft, clay-like, unctuous material, and found on withdrawing it that it was gilded. The mass consisted of lemon-coloured oxide of tellurium, containing fine particles of amorphous gold, the two substances being the product of alteration from the bronze calaverite which Neirkirk found deeper down, associated with magnesite and fluorite. This dioxide of tellurium or tellurium-ochre has been found in Transylvania. It is very rare, because of its marked affinity for ferric salts, with which it forms a definite compound, the tellurite of iron. The tellurite of iron, which F. C. Knight was the first to determine, has a light-brown colour and a bright yellow streak. "Knight's

* 'The Telluride ores of Cripple Creek and Kalgoorlie,' by T. A. Rickard, State Geologist of Colorado, *Trans. Am. Inst. of Mining Engineers*, vol. xxx. † *Op. cit.*

‡ *Trans. Inst. of Mining and Metallurgy*, vol. viii. p. 496. § *Op. cit.*

analysis (*Colorado Scientific Soc.*, Oct. 1, 1894) gave a percentage of Fe_2O_3 32·72, TeO_2 65·45 and H_2O 1·83. The lustre is dull, the fracture is brittle and uneven, and the hardness is between 3 and 4. In nature a kindred action to that produced artificially by roasting probably occurs in the presence of oxidising pyrite, liberating the gold with the formation of the tellurite of iron.

Some of the gold in its present form found near the surface can in all likelihood be traced to secondary deposition of a chemical nature, that is to say, to the action of organic and carbonic acids, or other agents, which have reprecipitated gold in solution, and thus caused a marked enrichment of many of the ore-bodies, at or near their outcrops ; and sometimes in places, as already said, to a considerable depth—a circumstance which, no doubt, partly * accounts for the high average yield obtained from surface-crushings, in the early days of the field.

As Mr. Hoover explains, however,† this tendency towards surface enrichment has been, perhaps to a still greater extent, induced mechanically, owing to the soft, dry, permeable nature of the kaolinised lode-stuff and country rock ; the minute state of division of the gold naturally offered every opportunity for its re-deposition in this latter manner, the gold originally derived from the surface erosion of the lodes, during the lapse of long ages, having doubtless been carried lower down into their interstices, through minute fissures and seams, as erosion proceeded.

These influences tending towards surface enrichment have, however, probably been to some extent, counteracted by the lateral impregnation of the "country rock" outside of the lode-formations," during their partial decomposition, and hence these agencies in some cases have acted (both chemically and mechanically) in opposite ways.

Inasmuch, however, as the "formations" doubtless offered easier channels for solutions to follow (as evidenced by their decomposition to a greater depth than the country rock), it seems probable that they contained, when first discovered, much the largest proportion of gold produced by "secondary action" ; and as Mr. Hoover ‡ observes : "The general tendency of the ores towards enrichment at the surface is broadly proved by the universal decrease of from

* It is probable, however, that in the early days of this field, the reputed tonnage crushed may have been in excess of the actual amount.

† *Op. cit.* ‡ *Op. cit.*

50 to 75 per cent. in the value per ton of the output from all the leading mines."

He goes on to add: "Within the oxidised zone, at least ten mines at Kalgoorlie could be named which have decreased so much in value as to become practically worthless."

It must not be inferred from these observations, however, that he believes the mines will diminish in value with increasing depth until they become barren, as he specifically states, "these remarks *apply to the oxidised ores only*,* and those mines which have proved valuable below this zone have nothing to fear."

The enrichment of the decomposed lode-formations by lateral impregnation is more or less evidenced by the fact that the stopes are commonly wider in the oxidised than in the unoxidised ore.

Others have asserted that an enrichment of the ore takes place at water-level, and have cited the Kalgurli and Associated mines in proof of this contention; but Mr. Hoover ascribes this circumstance to the fact that the unoxidised ores, being more easily distinguished from the country rock than the oxidised ores, admit of closer selection in mining, hence whilst their value per ton remains perhaps the same as that of the oxidised ore, they do not get so many tons per fathom of stope.

As regards the possible chemical solution of the gold during or after oxidation, and its re-deposition from such solutions, Mr. Hoover points out that "The alkalinity of most of the subterranean waters of the gold-field, their contained chlorides, the organic acids of surface waters, the presence of decomposing manganese and iron sulphides, and tellurides, all, under varying conditions and combinations, could dissolve and reprecipitate gold." "All these chemical reactions are called upon to prove enrichment of the ores in depth *by leaching and re-deposition at water-level*,* but aside from the non-existence of such a general fact, the constant erosion of the surface, and rising of the horizon of re-deposition, would, in the end, produce an enrichment of the whole oxidised zone." Such a process in fact has no doubt assisted in the superficial and lateral enrichment of the "formations," as already explained.

The composition of the "brown stone" is indicated by the following determinations of free silica in average samples of oxidised ore given by the same author †:—

* The italics are the Author's. † *Op. cit.*

Mine	Silica. per cent.
Hannan's Brown Hill	18·21
Lake View Consols	28·31
Boulder Main Reef	31·06

There are no other gangue materials of consequence, the remainder being almost all kaolin. The iron which stains the "brown stone" is present in the form of stringers and bunches of hæmatite and limonite, whilst amongst the rare accessory minerals found in the oxidised ores it has been asserted that natural amalgam is sometimes met with, and that chloride of silver has been found near the surface, in one mine in considerable quantity.

The Structure of the "Deep-Level" Ore-Bodies and their Mineralogical Character.

Mr. Wm. Frecheville has given a most excellent description * of the "ore-bodies" below the line of oxidation.

He points out that in the deeper workings it is usually pretty easy to distinguish between ore and country rock, particularly in the richer mines, the veins (ore-bodies) having, as a rule, pretty clearly-defined boundaries, forming, so to speak, the "hanging" and "foot-walls." The vein-filling also, though often composed mainly of the same material as the country rock, differs from it in certain respects.

"The country rock is massive (although as might be expected near the veins, even when most clearly defined, it frequently exhibits a more or less schistose structure, which disappears on going a few yards away), and contains only a little iron pyrites as minute specks here and there; whilst the ore is schistose, and has fine iron pyrites plentifully disseminated through it, and the schistose surfaces are covered with lustrous material suggesting mica or talc, and chlorite. Sometimes the vein filling consists principally of quartz, as is often seen in the Ivanhoe and Great Boulder veins, and is quite like ore from a well-mineralised quartz lode of the ordinary type; but as a rule it is of the schistose country rock type described above, and varies in general appearance with the containing country rock, that is to say, when occurring in the green variety of rock, the vein filling will have a similar green colour, and when occurring in the grey variety, it will be grey." Samples of ore like the country rock effervesce briskly with acid.

* 'Notes of a Visit to the Gold Mines at Kalgoorli, Western Australia,' by Wm. Frecheville, A.R.S.M., *Trans. Inst. of Mining and Metallurgy*, vol. vi.

Mr. Hoover* makes the general statement that "in the unoxidised ores, more quartz is present, and it becomes evident that some replacement of the country rock by quartz and the metalliferous minerals has taken place."

The first point is one upon which Mr. Woodward has laid stress,† remarking: "The ore is a bluish-green siliceous rock, often thickly studded with minute crystals of pyrites, and intersected by quartz veins which are the richest portion of the lode; but here, as in the decomposed zone, the gold is found to extend often for a considerable distance into the mineralised rock upon either side.

"Portions of this rock taken from near the quartz veins often contain large quantities of small crystals of telluride of gold, pyrites, calcite (which also occurs in veins and vughs) and probably serpentine, thus presenting an entirely different composition from the hornblende and felspar rocks which constitute the country rock, but into which it merges so gradually that it is impossible to say where one ends or the other begins."

Mr. Pittman says‡ the formations are frequently intersected by irregular quartz reefs. "These reefs, in which the quartz is white and crystalline, sometimes follow the strike of the dykes, at other times cut across them, and enter the walls. They are not continuous for any distance, and their width varies very considerably. They sometimes, but not always, contain free gold."

The quartz, in many instances, however, is replaced by calcite, traversing the ore-bodies in the form of a network of small veins which are sometimes mistaken for quartz, and in some of the "formations" this mineral is found associated with very rich ore.

The "calcite," as Mr. Card observes,§ is therefore an important gangue material in the lode-stuff, sometimes occurring in large masses with calaverite (Block 14), whilst, as Mr. Pittman remarks: "The joints of the lode-stuff in the lower levels are frequently coated with carbonates of lime and magnesia,"‖ a large percentage of magnesia being a peculiarly marked feature.

In some cases an invasion and absorption of the quartz by calcite or sericite seems to have taken place along cracks in the rock.

Mr. Card concludes, as before said, that the ore-bodies are more

* *Op. cit.* † *Op. cit.*

‡ 'Notes on the Geology and Mineral Deposits of Portions of Western Australia, by E. F. Pittman, A.R.S.M., *Records of the Geol. Survey of New South Wales*, vol. vi. part i.

§ 'Notes on the Country Rocks of the Kalgoorlie Gold-Field, Western Australia,' by Geo. W. Card, A.R.S.M., *Records of the Geol. Survey of New South Wales*, vol. vi. part i.

‖ In the oxidised zone their place is taken by gypsum.

highly altered portions of the country rock, in which the ore was probably deposited by pseudomorphous replacement, remarking: "It will be noted that the titaniferous iron and primary quartz occur in the ore, as in the country, with a tendency, however, to granulation.

"The tellurides of gold, together with the associated carbonates of lime and magnesia and the secondary quartz, have been introduced into the ore-body by solutions, which found ready access along the planes of parting produced by the incipient foliation.

"That much of the chlorite has been introduced in the same way seems probable from its frequent occurrence in wavy bands; alumina is also present in the mine waters."

The following are descriptions of some typical specimens of ore examined under the microscope, given by Mr. Card.

Slide No. 8513.—Ore from a "winze" in the Great Boulder mine, below the 200-feet level.

This was similar in appearance to the country rock (which in the case referred to was of the dark green variety), but a much larger quantity of pyrites, in the form of very minute cubes, was present. Under the microscope it was seen to consist principally of calcite, chlorite and pyrites. Quartz was conspicuous in it, and would appear to have been abundant once, as the grains were much shrunken, and lay in a granular aggregate of clear anisotropic particles, with calcite. In other cases such aggregates existed by themselves, the quartz being entirely gone.

Slide No. 8509.—Typical ore from the Kalgurli mine, occurring in stringers traversing the country.

This was grey in colour, with a somewhat trachytic appeareanc, and a slight tendency to fissility. The divisional planes were conspicuously sericitic. It was abundantly speckled with titaniferous iron-ore and magnetite, and a slight effervescence was noticeable on a cut surface when treated with acid. Close inspection revealed the presence of limpid grains of quartz in abundance. The rock showed a little pyrites, and weathers to a deep red-brown colour. Under the microscope it was seen that the difference in appearance was mainly one of colour, consequent upon the entire absence of chlorite.

There were the same archipelagoes of optically-continuous quartz traversed by transparent rods. Vividly-polarising sericite was abundant. It was found generally arranged in one direction, but sometimes lay criss-cross. Much of the quartz was seen to be almost entirely replaced by such sericite. Carbonates were abundant.

Slide 8461.—Ore (assaying 10 oz. of gold per ton) from the 300-feet level of the Lake View Consols mine, described as a greenish rock of felsitic appearance, with pronounced schistosity and development of sericite; specific gravity, 2·86. The rock was pyritous, and effervesced slightly in acid. Under the microscope it was seen to be highly silicified, being traversed by a network of interlacing areas of secondary quartz. Primary quartz could be recognised by the presence of the included transparent rods referred to before.

Slide 8467.—Telluride ore from the Boulder Perseverance. A slide from this showed large individuals of titaniferous iron-ore, with characteristic leucoxene, magnetite and pyrites. Quartz was seen in various stages of obliteration. The opacity of the slice was against much detail being made out in the grand mass, but it was found to be largely composed of calcareous material, and colourless scales, rods, etc. variously aggregated.

Mr. William Frecheville quotes* the following comparative analysis made by Dr. Helms of Sydney, of a characteristic specimen of Great Boulder ore (a non-quartzose variety) and the country rock from its vicinity (a winze below the 200-feet level):—

		Ore.	Rock.
	Sulphur	5·49	0·22
	Carbonic acid	8·38	11·73
	Titanic acid (TiO_2)	2·57	0·71
	Soda (Na_2O)	2·93	2·46
	Potash (K_2O)	2·25	2·94
Soluble in acid.	Oxide of iron	17·84	9·69
	Iron as pyrites (calculated from the sulphur as FeS_2)	4·80	0·19
	Alumina	6·62	4·62
	Lime	4·77	8·20
	Magnesia	4·87	5·35
	Copper	0·14	0·05
	Manganous oxide	traces	traces
	Silica	0·21	0·28
Insoluble.	Silica	34·83	42·48
	Ferric oxide	1·14	1·26
	Alumina	3·05	9·29
	Magnesia	0·10	0·24
		99·99	99·71
	Gold	traces	traces
	Silver	4 dwt. 21 gr.	3 dwt. 6 gr. per ton.

As there is not enough carbonic acid shown to satisfy the lime and magnesia, Mr. Card remarks that a certain proportion must probably be to some extent present as silicates, in all likelihood in combination

* *Op. cit.*, p. 144.

with other compounds, forming the constituent minerals of the rock; whilst the presence of soda may be regarded as pointing to the existence of soda felspars. Neglecting the carbonic acid and soluble portion, the percentage composition of the remainder agrees very closely with the typical composition of an acid eruptive.

The following analyses of bulk samples, representing 100 and 150 tons of Great Boulder Main reef telluride ore, are given by Mr. Ed. Skewes *:—

		Per Cent.
Silica		48·43
Iron		10·24
Alumina		1·98
Lime		9·86
Magnesia		2·03
Sulphur		3·66
Copper		0·33
Carbonic dioxide		7·75
Oxygen		3·05
Alkalies, etc.		12·65
		99·98
Insoluble		64·00
Soluble	Metallic iron	6·64
	Sulphur	5·94
	Carbonate of lime	14·01
	Carbonate of magnesia	9·66
		100·25

Assay value	Gold	6·50 oz. per ton
	Silver	2·50 ,,

Mr. Arthur C. Claudet, A.R.S.M., gives † an analysis of Kalgoorlie ore as follows:—

	Per Cent.	
Peroxide of iron	15·48	= 10·82 % iron.
Oxide of manganese	0·15	
Copper	0·05	
Sulphur	0·12	
Lime	0·20	
Alumina	1·66	
Silicious rock	77·93	
Combined water and loss	4·41	
	100·00	

Gold (per ton of 2240 lb.) . . 3 oz. 5 dwt. 12 gr.

Silica	56·60
Alumina	16·92
Lime	0·30
Magnesia	0·25
Alkalies (chiefly potash)	3·66
Loss	0·20
	77·93

* The *Mining Journal*, London, March 12, 1898, lxviii. p. 312.

† 'Notes on the Experimental Treatment of Gold Ore from the Hannan's District, Coolgardie, Western Australia,' *Trans. Inst. of Mining and Metallurgy*, vol. v.

The silicious rock is no doubt, as Mr. Claudet surmises, a decomposed felspathic rock.

Mr. Ed. S. Simpson * gave the following analysis of typical lode-stuff from the 300-feet level of the Lake View Consols:—

		Per Cent.
Water (H_2O)	Hygroscopic	·402
	Combined	1·809
Soluble in hydrochloric acid.	Calcium carbonate ($CaCO_3$)	10·882
	Magnesium carbonate ($MgCO_3$)	6·315
	Ferrous carbonate ($FeCO_3$)	1·553
	Ferrous oxide (FeO)	1·360
	Ferric oxide (Fe_2O_3)	1·541
	Alumina (Al_2O_3)	1·326
	Manganese oxide (MnO)	trace
	Phosphoric oxide (P_2O_5)	trace
Soluble in nitric acid.	Iron (Fe)	3·990
	Sulphur (S)	4·417
	Tellurium (Te)	trace
Insoluble.	Silica (SiO_2)	51·271
	Titanic oxide (TiO_2)	·226
	Alumina (Al_2O_3)	12·519
	Ferrous oxide (FeO)	·311
	Lime (CaO)	·313
	Magnesia (MgO)	1·159
	Undetermined and loss	·606
		100·000

Gold	9 oz. 12 dwt. 18 gr. per ton.
Silver	6 oz. 7 dwt. 8 gr. per ton.

He regarded the lodes as *dykes of highly-foliated felstone*† impregnated with carbonate of lime, etc., and with auriferous pyrites and tellurides of the precious metals.

Below the zone of oxidation, the deep-level ore-bodies at Kalgoorlie contain a wide range of accessory minerals, of which perhaps the commonest are magnetite (in fairly large crystals), siderite,‡ iron, pyrites and arsenical pyrites. Mr. Hoover mentions sulphides of iron lead,§ zinc, mercury, arsenic and antimony; tellurides of gold and silver; native mercury, and bismuth, specimens of which latter mineral, from Burbanks, Yalgoo and Lawlers, have been found to carry gold. Bournonite has also been found, at Kalgoorlie with several rare minerals; among them, natural amalgam, löllingite

* 'Kalgoorlie, Western Australia, and its Surroundings,' *Trans. Am. Inst. of Mining Engineers*, vol. xxviii., Discussion, p. 809. † The italics are the Author's.

‡ H. Knutsen observes: "I am disposed to pronounce iron spar as the most characteristic mineral of these ores."—'The "Diehl" Process,' *A 'paper' read before the Institution of Mining and Metallurgy*, June 1902.

§ Vanadate of lead occurs, it is said, in the Associated mine; and crocoisite (chromate of lead) is found at Menzies; it is reported to be associated with gold in the quartz of zhni Tagilsk in the Urals.

(arsenide of iron) $FeAs_2$* and auriferous enargite Cu_3AsS_4 (sulphide of arsenic and copper). Mr. Simpson also mentions† pyrargyrite, proustite, asbolite, malachite, native tellurium, fuchsite (chromium mica) and others. Mr. Hoover adds, "The gold occurs in minor proportion as free gold, but in major values in the tellurides and sulphides, which are, as a rule, very finely disseminated through the ore, although the tellurides do occur occasionally in large patches or stringers."

Mr. Woodward observes: "The tellurides are met with as veins,‡ splashes, and disseminated minute crystals throughout the entire mass. In the first of these forms, they appear to have been deposited subsequently to the quartz, for the veins intersect the latter, often filling right-angle cracks in them; these when encountered make a great show, since they may be seen in places all the way down the side of a shaft for 40 or 50 feet as veins several inches in width, but which, when broken into, only prove to be of slight thickness, with quartz behind them. Fortunately this is not invariably the case, for in many instances, small solid veins of the tellurides, quite independent of the quartz, have been traced for a distance of 60 or 70 feet."

As a rule, however, the tellurides are so finely divided as to be indistinguishable by the eye, although, as Mr. William Frecheville remarks, "spots and splashes of some size are not at all uncommon in the stopes, and sometimes the showing of large splashes across a considerable width is quite wonderful. The tellurides go right through, and permeate the mass of the ore, like the pyrites, and are not confined to cracks, faces or cavities"; in fact, "they appear to have formed an element or feature of the mineralisation of the veins themselves, and not to be due to subsequent or secondary action, which might prove to be more local or patchy in character." Native tellurium, though a non-metallic element, is a tin-white brittle substance with a bright metallic lustre, which forms metallic combinations (tellurides) in much the same way as sulphur and selenium, at times apparently replacing the former element. It is rarely found at Cripple Creek or Kalgoorlie, but is not uncommon in Boulder County, Colorado. A mass weighing 25 lb. was found in

* 'Census of Minerals of Western Australia,' by E. S. Simpson, B.E., F.C.S., Government Mineralogist,' chap. xii., *Handbook of Western Australia*, 1901.

† 'Secondary Minerals associated with Gold,' *Bull. No.* 6 *Geol. Survey of W.A.*, p. 26

‡ These sometimes run up to nearly an inch in thickness (E. F. Pittman), and small "pockets" of telluride are sometimes found. The Author saw a stope in the Lake View, that glittered under the light of the candles, in places, like a "jeweller's shop"; and extremely rich stopes were to be seen in the Associated and other mines.

1877 at the John Jay mine near Jimtown,* and it has lately been found at the Vulcan mine in Gunnison County, Colorado, in mica-schist associated with a lode of gold-bearing pyrite, which in the oxidised zone carries native sulphur.

Of the various telluride minerals present in the Kalgoorlie ore, Mr. William Frecheville mentions a brilliant silver-white mineral as being common, probably sylvanite† or graphic tellurium (a telluride of gold and silver represented by the chemical symbol $(AgAu)Te_2$, possessing a specific gravity of 7·99 to 8·33). The latter name is derived from the fact that faces of rock are frequently found covered with twinned crystals that look like Arabic writing; it is generally steel-grey to silver-white, but as it is sometimes nearly brass-yellow in colour,‡ it has perhaps been mistaken by some observers for calaverite (another common form of telluride in this locality), which is a lustrous bronze-yellow. Those portions of the ore-bodies which carry this latter mineral, Mr. T. A. Rickard observes,§ are, it may be remarked, frequently characterised by the presence of calcite, and he inclines to the belief that it is more characteristic of the Kalgoorlie ores than sylvanite, which is the telluride most frequently met with at Cripple Creek. The fineness of the Kalgoorlie bullion up till recently would rather favour this supposition, but it is a somewhat difficult point to settle, as different mines may contain different tellurides in varying amounts.

* 'The Telluride Ores of Cripple Creek and Kalgoorlie,' by T. A. Rickard, *Trans. Am. Inst. of Mining Engineers*, vol. xxx.

† Analysis No. 1 was made by Mr. Richard Pearce, in 1894, from a Cripple Creek specimen, and No. 2 is from the sylvanite of the Red Cloud mine, made by Genth in 1874. Analysis No. 3 is its composition as given by E. S. Dana, 'A Text-Book of Mineralogy.' Mr. E. S. Simpson states that goldschmidtite, which is sometimes described as sylvanite, occurs at Kalgoorlie; its composition corresponds to the formula $(AuAg)Te_2$ and he gives the following analyses of it, *Bull. No.* 6 *Geol. Surv. of W.A.*

	No. 1. per cent.	No. 2. per cent.	No 3. per cent.
Tellurium	60·61	59·78	55·8
Gold	25·45	26·36	28·5
Silver	13·94	13·86	15·7
	100·00	100·00	100·0

	Krusch. per cent	Carnot. per cent.
Gold	28·55	29·85
Silver	9·76	9·18
Copper	·32	·15
Iron	·06	—
Nickel	·10	·10
Tellurium	60·83	60·45
Selenium	·20	..
Sulphur	09	..
	99·91	99·73

‡ Mr. T. A. Rickard says: August Frenzel (*Tsch. Min. Mitth.* 1897, xvii. 288, 289) gives the following analysis of a specimen from Kalgoorlie, which he labels sylvanite: tellurium 58·63, gold 36·60, silver 3·82 per cent., but the composition is much nearer that of krennerite, the prismatic brilliant vertically-striated crystals of which occur in the ores of the Moon-Anchor and other mines on Gold Hill, Cripple Creek. The colour of krennerite is like that of sylvanite, but it has a greater tendency to a slight brassy-yellow tinge.

§ *Trans. Inst. of Mining and Metallurgy*, vol. vi. p. 197.

Mr. E. S. Simpson considers calaverite to be the most common telluride at Kalgoorlie.

The following analyses of calaverite* $AuTe_2$ which possesses a specific gravity of 9 to 9·377, indicate its composition; No. 2 being that of a specimen submitted by Mr. F. W. Grace, A.R.S.M., to Mr. Pittman, and it will be noticed that the West Australian specimens seem to show about 42 per cent. of gold and less than 1 per cent. of silver, whilst those from Cripple Creek seem to have an average composition ranging from 38 to 40 per cent. in gold with about 3 per cent. of silver.

—	CALAVERITE (Kalgoorlie).			CALAVERITE (Cripple Creek).		
	No. 1. Analysis by Ed. Simpson.	No. 2. Analysis by J. C. H. Mingaye.	No. 3. Analysis by P. Krusch.	No. 4. Analysis by W. F. Hildebrand. (Given by T. A. Rickard.)	No. 5. Analysis by F. C. Knight. (Given by T. A. Rickard.)	No. 6. Genth's Original Determination.
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Tellurium	57·27	56·64	37·54	57·27	56·22	55·89
Gold .	41·37	41·76	58·63	38·95	40·14	40·70
Silver .	·58	·80	2·06	3·21	3·63	3·52
	99·22	99·20	†99·91	99·43	99·99	100·11
Sp. gr. .	9·311	9·377	..	..	..	9·043

In addition to these minerals, a dark variety of telluride is fairly abundant at Kalgoorlie. It is very similar in composition to coloradoite,‡ is "iron black" in colour, and has a sub-conchoidal fracture and unctuous lustre. It is a telluride of mercury HgTe,.

* Calaverite takes its name from Calaveras County, Cal., where it was first discovered in the Stanislaus mine. As elsewhere mentioned, a splendid mass was found by Henry Neirkirk in the Melvina mine, Boulder County, in 1877, associated with magnesite and fluorite.—*T. A. Rickard.*

E. S. Dana gives the following analysis of calaverite, by Genth—

	Per cent.
Tellurium	55·5
Gold	44·5
	100·0

† This analysis showed in addition to the above constituents ·29 per cent. of copper; ·09 per cent. of iron; ·07 per cent. of nickel; 1·13 per cent. of selenium; and ·10 per cent. of sulphur. *Bull. No.* 6 *Geol. Survey of W.A.*, p. 15.

‡ E. S. Dana gives the following analysis of coloradoite, by Genth—

	Per cent.	Dana quoted by Rickard. Per cent.
Tellurium	39	38·5
Mercury	61	61·5
	100	100·0

vide the following analysis of a specimen from the Australia mine given by Mr. Simpson * :—

COLORADOITE (from Kalgoorlie).

	Per cent.
Tellurium	49·48
Gold	trace
Silver	·12
Mercury	50·40
	100·00

Sp. gr. . . . . . 8·068

Coloradoite was first discovered by Genth in specimens from the Mountain Lion mine at Magnolia, Colorado.

A black opaque waxy telluride,somewhat resembling coloradoite, has also been discovered at Hannan's, which Mr. Pittman has named *kalgoorlite,* regarding it as being a new mineral,† composed of tellurium in combination with gold, silver and mercury with a trace of copper. Its composition, as given by Mr. Mingaye (Analyst to the N.S.W. Geological Survey) is as given below. It is massive and brittle, with a brilliant metallic lustre, and answers in composition to the formula $Au_2Ag_6HgTe_6$, requiring gold 19·6 per cent., silver 32·3 per cent., mercury 10 per cent., tellurium 38·1 per cent. An analysis made by Mr. A. C. Claudet of another specimen is very similar to the original one. Coolgardite, another telluride peculiar to Kalgoorlie, is steel-grey to yellow-grey in colour, devoid of cleavage, and its formula is given by E. S. Simpson as $(AuAgHg_2)Te_3$ and he gives the three following analyses of it :—

	KALGOORLITE.		COOLGARDITE.		
	Analysis by J. C. H. Mingaye, Analyst to the New South Wales Geological Survey.	Analysis by A. C. Claudet.	Analyses by A Carnot.		
	per cent.	per cent.	per cent.	per cent.	per cent.
Mercury	10·86	11	3·10	3·70	3·70
Gold	20·72	21	23·15	27·75	37·06
Silver	30·98	31	13·65	13·60	4·71
Copper	0·05	—	·10	·25	·88
Sulphur	0·13	—	—	—	—
Tellurium	37·26	(by diff.) 37	56·55	53·70	51·13
Iron	—	—	trace	trace	·90
Antimony	—	—	·20	·15	1·20
	100·00	100	99·75	99·15	99·58
Sp. gr. . .	8·791	—	—	—	—

* *Op. cit.*

† Mr. T. A. Rickard considers that "as the crystallographic features (of this mineral) do not differ materially from coloradoite it can hardly be considered as more than an im-

A specimen of telluride obtained from the 200-feet level of Tetley's shaft at the Associated gold-mine, analysed by Mr. F. W. Grace, proved to be petzite,* and in a letter to Mr. T. A. Rickard he gives its specific gravity as 9, and hardness 2·5 to 3. Mr. Grace's two analyses were as follows: analysis No. 3 is by Carnot.

	No. 1.	No. 2.	No. 3.
Silver	40·47	40·55	41·37
Gold	24·64	24·62	23·42
Tellurium	34·60	34·83	33·00
Mercury	·29	·00	2·26
Copper	—	—	·16
	100·00	100·00	100·21

Petzite $(AuAg)_2Te$, which is black or steel-grey in colour, is stated to be rare both in Kalgoorlie and at Cripple Creek, though in the former district it has been found in the Boulder Main Reef,as well as in the Associated mine. Mr. Rickard adds that he has found it in specimens from the Geneva mine, on Gold Hill, and in the ore of the Porter Gold King, above Anaconda, at Cripple Creek.

It is characteristic, he says, of the Golden Fleece mine, an isolated occurrence of tellurides in Lake County, Colorado, which between 1894 and 1896 produced 1,400,000 dollars from a comparatively small tonnage of ore.

My friend Mr. Arthur C. Claudet, A.R.S.M., has kindly given me the following interesting analysis of a specimen of telluride from the Australia mine.

MINERAL ANALYSED BY A. C. CLAUDET.

	Per cent.
Gold	19
Silver	8
Mercury	13
Tellurium	60
	100

This telluride, it would seem, may be described by the same general formula as sylvanite (RTe_2),† but with the addition of so large a proportion of mercury to its constituents it would almost appear to be entitled to rank as another new mineral, if kalgoorlite and coolgardite can be so regarded; but further investigation seems to be necessary to settle this point.

pure variety of the latter, and may be looked upon as a mixture of petzite and coloradoite." *Op. cit.* (Petzite has a composition of gold 25·5 per cent., silver 42·0 per cent., and tellurium 32·5 per cent.) Recent investigations by Mr. L. J. Spencer, *Proc. Mineralogical Soc.* (an abstract of which is given in *Nature*, June 26, 1902), seem to confirm this view.

* An analysis of Kalgoorlie petzite by Krusch showed ·10 per cent. of copper, ·07 of iron, ·08 per cent. of nickel, 1·45 per cent. of selenium, and 26 per cent of antimony, with 24·33 per cent. gold; 40·70 per cent. silver, and 32·60 per cent. of tellurium.—*Bull. No.* 6 *Geol. Survey of W.A.*, p. 17.

† From an examination that was made of it by Prof. H. Bauerman, A.R.S.M., F.G.S.

Mr. H. F. Bulman's view * corresponds with that of Mr. Card, viz. that "the tellurides of gold, together with the associated carbonates of lime and magnesia and the secondary quartz, have been introduced into the ore-bodies by solutions which found ready access along the planes of parting produced by incipient foliation."

Free gold is found in the common "rough" form and in "flakes" creating cleavage and foliation planes.

Although specks of "free gold" are occasionally seen in the *pyrites*, the gold is generally present combined with the sulphides and tellurides. In evidence of this, Mr. Frecheville states that he ground up and "panned" a small piece of ore with every care, which doubtless assayed very many ounces to the ton, showing a considerable amount of pyrites and visible telluride, but not a "colour" of gold could be seen.

Once in a while, however, small particles of crystalline gold are met with, surrounded by crystals of telluride low in gold, and Mr. Pittman notes an instance † in which large masses of beautiful "sponge gold" occurred in a "vugh" in the stone. Mr. A. G. Holroyd mentions that a specimen exhibited at the Coolgardie Exhibition, of what is locally called "sponge gold," was found at the 200-feet level of the Great Boulder, consisting of a mass of brilliant gold crystals and nodules discovered in a "vugh" in the ore, where about 70 lb. weight was taken out in a few hours on March 19, 1897.

Speaking of a recent "strike" in the Great Boulder Perseverance, 125 feet east of No. 4 Shaft at the 300-feet level, the Kalgoorlie correspondent of *The Australian Mail*, in its issue of March 15, 1900, thus described what may be regarded as a still more rare and peculiar occurrence.

"Big veins and splashes of telluride occur in the rock, while the whole of it is, in addition, full of small particles mixed with iron pyrites. The cross-cleavage of the rock also carries coarse gold, some of it occurring in the form of *small bars*, similar to those met with at the 500-feet level of the Great Boulder.‡ This

* 'The Kalgoorlie Gold Mines,' by H. F. Bulman, *Trans. Inst. of Mining Engineers*, vol. xvii.

† The Author found true "sponge gold" of a deep-red colour in cavities in the ore of the North Boulder mine.

‡ Apparently a different discovery from the "sponge gold" found in the same vein (at the 200-feet level), described by Mr. Holroyd; as it seems to have been some form of "crystalline" or "plate gold," such as a cubical crystal found at Norseman which had three faces about 1 inch long fully developed; and some gold from Bulong showed triangular groups of crystal faces developed on the surface of flat sheets of metal. The italics are the Author's.

is the second time in the history of the field that these flat *bands of gold* running up to nearly one-sixteenth of an inch in thickness have been met with."

Both at Cripple Creek and Boulder County, Colorado, fluorite, of an amethyst or purple colour, is frequently associated with telluride ores; and in the latter district, roscoelite * (a brownish-grey or olive-green vanadium mica) is closely associated with calaverite and sylvanite, and Mr. T. A. Rickard † mentions that he found the same rare mineral in the telluride ores of Kalgoorlie. He also observed tourmaline in the form of acicular crystals, in contact with coarse gold, in these deposits, and also in a condition of minute diffusion forming dark blotches in the white quartz. A similar occurrence of tourmaline, he states, may be seen at Niagara, Pinyalling, and elsewhere in Western Australia, and the gold ores of Mysore, in India, carry the same mineral. Chlorite seems to be characteristic of Cripple Creek and the protogene of Boulder, in Colorado, as well as of the schistose Kalgoorlie "formations"; whilst quartz, it may be noted, occurs in all these localities, in remarkably small amount.

Telluride ores, when weathered, are said to be characterised by a chocolate tint, and when roasted, the gold sweats out in round metallic buttons, which present a scoriaceous appearance; they were first discovered, I believe, at Kalgoorlie, on Block 45, by Mr. J. C. Moulden, A.R.S.M., in May 1896. Mr. J. W. Broomhead in *The Financial Times* of November 4, 1897, gave the following list of mines in which tellurides have been found, with the approximate date of the discoveries.

* In Mr. Rickard's paper, 'The Telluride Ores of Cripple Creek and Kalgoorlie,' he gives several analyses of this mineral by Genth, Roscoe and Hildebrand, and one of special interest by F. C. Knight, from a paper by Mr. Richard Pearce, entitled 'Notes on a Peculiar Occurrence of Tellurium in a Gold-ore from the Great Boulder Main Reef, W.A.,' *Bul. Colo Sci. Soc.*, No. 8, 1897, showing SiO_2 43·65, V_2O_3 27·11, Al_2O_3 9·95, CaO 1·43, MgO 1·51. This uncommon mineral is stated to have been found in handfuls in the form of greenish-brown micaceous spangles by the miners who worked the placer ground in the ravine below Sutter's mill, California, where gold was first discovered. Waldemar Lindgren states in the *Min. and Sci. Press*, June 1, 1901, that it was first discovered in small quartz veins near Caloma, El Dorado County, California. He says it occurs abundantly in the recently discovered rich shoot of the Belle of Baker, in the rich shipping ore found some time ago in the Golconda mine, and finally in a similar rich shipping ore lately discovered in the Columbia mine in Eastern Oregon. The mineral, which is very conspicuous and looks much like finely-divided chlorite, has a dull-greenish colour with a slight tinge of yellow. It occurs intimately intergrown with quartz in micro-crystalline aggregates of tufted fibres, generally so fine that its separation from the quartz is almost impossible. The mineral has a high double refraction, but the fibres do not seem to be strongly pleochroic. The gold with which it is generally closely associated in gold quartz veins is frequently intergrown with it, or surrounded by it.

† 'The Minerals which accompany Gold, and their Bearing upon the Richness of Ore Deposits,' *Trans. Inst. of Mining and Metallurgy*, vol. vi.

Company.	Date of Discovery.
Associated Gold Mines	November 1896
Brown Hill Central	October 1897
,, Excelsior	May 1897
,, Junction	June 1897
Brookman Bros. Boulder	—
Central Boulder	—
Chaffers	August 1897
Crœsus	November 1896
Golden Horse Shoe	February 1897
Great Boulder Main Reef	November 1896
,, Perseverance	January 1897
,, Proprietary	November 1896
Hannan's Block 45	March 1896
,, Golden Group	April 1897
,, Oroya	January 1897
,, Paringa	February 1897
,, Reward	January 1897
,, Star	February 1897
Ivanhoe	November 1896
,, S. Extended	September 1897
Kalgoorlie Gold Mines	January 1897
Lake View	November 1896
,, Central	September 1897
,, South	,, 1897
Mount Charlotte	February 1897
North Boulder	April 1897
,, Kalgurli	April-May 1897
Sherlaw's Perseverance	June 1897
South Kalgurli	April 1897
True Blue	January 1897

In Europe, Klaproth is stated to have discovered * tellurium in the ores of Zalathna in Transylvania, in 1802, and tellurides have been found associated with rich gold ores at Nagyág and Offenbánya. In America they were discovered about 1857 and have been known as important ores of gold and silver since 1865.† Tellurides were subsequently found in the La Plata mountains, in Colorado and several mining camps (notably at the Smugglers mine) in Boulder County (where they are stated to have been discovered between 1872 and 1874, in commercial quantities), and more recently at Cripple Creek. Other American localities might, however, be named where they occur, such as California, Virginia, North Carolina, Canada (Lake of the Woods) and South Dakota; and in South America, in Brazil.

Some of the early discoveries of tellurides in Colorado were very rich, the ore, which was of a dark-brown or black colour, selling to the smelters, it is said, at 10*s*. to 50*s*. a lb.‡ "The mines were not,

* Tellurium was discovered by F. J. Müller von Reichenstein in 1782, and first investigated by Klaproth in 1798.

† Their discovery in the Stanislaus mine in California was described in a "paper" by C. A. Stetefeld on the 'Reduction of Telluric Gold and Silver Ores.'

‡ *Mining Journal*, London, Oct. 5, 1901.

however, a success, being of the same class as the Cornishman describes as a feast and a fast, " bal," where the fasts were too long for the feasts. In the Marysville district, Pinte County, Utah, few small rich pockets of telluride were found; the ore was soft and black, not unlike copper-ore. The miners used to carry the specimens in their pockets, and would occasionally rub them on their clothes, when specks of gold would occasionally appear. Friction in that camp was the miner's ready method of detecting telluride, just as a few years later the heat of a cooking-stove was the mode adopted at Cripple Creek by the early prospectors for the same purpose. The sulphur and tellurium were easily volatilised, leaving small shells or bubbles—not shot—of gold.

Cripple Creek is stated to have produced $18,073,539 from its telluride ores in 1900; and $17,261,579 in 1901.

Tellurides are said to have been found in Upper Burmah, and in South Africa. They are met with again in the North Island of New Zealand, and were discovered by Mr. E. S. Simpson in the sulphide ore of Mount Morgan, in Queensland; whilst in Western Australia they accompany the ores of Red Hill and Bardoc, as well as Kalgoorlie.

It will thus be seen that the occurrence of tellurides is much more common than is generally supposed, and its mere presence in no way guarantees the commercial value of the deposit,* as outside of Transylvania, Cripple Creek and Kalgoorlie, tellurides can only be regarded as interesting minerals accompanying various gold ores, and in themselves of little economic importance, being usually present in too insignificant quantity.

The presence of tellurium (an element which has a specific gravity of about 6·33 and an atomic weight of 129) does not even always denote high-grade ores, since some tellurides (as may be seen by referring to the analysis of coloradoite) only contain a trace, if any, gold; still, as a rule, I believe the precious metal has hitherto invariably been found associated, in greater or less amount, with tellurides.

The idea that the presence of tellurides *necessarily* assures persistence in depth, is also popular, because it happens to be an

* In proof of this I may cite an instance given by Mr. Rickard (*ibid.*), who says, " An experience of nearly twenty-five years in the mining districts of Magnolia, Salina and Sunshine, in Boulder County, Colorado, has proved to the miners that these ores occur in comparatively small bodies, of remarkable richness, but of very irregular and uncertain behaviour."

agreeable fallacy; and in proof of this, Mr. Rickard instances Transylvania as an example of *impoverishment* in depth.

This brings me to the question of the alleged *marked* enrichment of the Kalgoorlie ores with depth; a proposition which has supporters (amongst stock-operators), and dissentients amongst many mining engineers.

Such an enrichment might take place in two ways, either at the period when the deposits were originally formed, which may be called for the sake of distinction, "primary enrichment," or it might have occurred subsequently, as in the case of the oxidised ores, through secondary deposition of the gold, by what is termed "secondary enrichment."

Mining men who support the idea of "secondary enrichment" in, depth do so on the grounds :—

(*a*) That the solvent power of the surface waters has carried gold down from the surface, and so enriched the deeper levels.

But against this view, there are three very strong arguments :—

1. The absence of surface water in any quantity, as evidenced by the fact, mentioned by Mr. Rickard, that in the Great Boulder Main Reef mine, at Kalgoorlie, the roots of trees have been found penetrating to a depth of 85 feet below the surface, as he suggests, in search of moisture.

2. That the solvent power of the surface-water *to any large extent*, is open to question.

3. That any gold so dissolved would be precipitated, as already shown, in the brown-stone zone, by the action of organic acids and other precipitating agents it would meet with near the surface in its downward course.

(*b*) "Secondary enrichment" might, however, take place by the action of circulating underground waters; and the advocates of this idea claim that the mine waters at Kalgoorlie contain a certain proportion of free sulphuric acid, derived from the decomposition of the pyrites; whilst it is an indisputable fact, that they are in many instances exceedingly brackish,* and if, as Mr. Grayson believes, gold is soluble in sulphuric acid, when tellurium oxide is present in water charged with these salts (owing doubtless to the

* An analysis made at the Great Boulder mine, furnished Mr. Rickard by Mr. Richard Hamilton, showed an average in solids of 8·9 per cent., of which 6·2 was chloride of sodium, 0·45 chloride of magnesia and 0·73 sulphate of lime. The water from the Lane Shaft gave the maximum of 11·9 per cent. solids; containing 8·8 $NaCl$; 0·51 $MgCl_2$; and 1·1 $CaSO_4$.

fact that the telluric oxide, like manganese di-oxide, in presence of salt and sulphuric acid, generates chlorine), as Mr. Rickard points out, a theory is established, which, if it has no very strong evidence to confirm it, is tenable from a chemical standpoint.

Still, after all, admitting such a possibility, it would probably merely mean the "robbing of Peter to pay Paul," the enrichment of one part of the formation below water level, at the expense of another.

As regards the evidence of "primary enrichment" below water-level, or, in other words, the question whether the sulpho-telluride ores will be found generally richer in depth than the oxidised ores, what has been already said, in considering the circumstances that have tended to enrich the brown-stone above water-level, shows that the evidence on the whole rather points the other way, if the relative quantity of gold which a fathom of "formation" yields is taken as a basis of comparison; and in this connection, there is certainly no ground for the belief, as some persons endeavour to claim, that there is a "progressive enrichment" of the "formations" with increasing depth.

On the other hand, considering that some of the tellurides carry as much as 41 per cent. of gold, it is to be expected that *certain parts* of the unoxidised ore-bodies in which telluride minerals are found occurring in considerable quantities, if compared with the "brown-stone" formation *considered as a whole* (in which the gold has probably been redistributed to a greater extent), may be considerably richer,* ton for ton mined and treated,† whilst other portions, which happen to be less mineralised, are doubtless poorer than the richer class of "brown-stone." In fact, there is no "golden rule," and parts of the "formation" below water-levels, like portions above it, must necessarily vary in value from

* As a case in point, it is stated that samples taken from the first 100 tons of the 1000 ton shipment of telluride ore sent from the Lake View Consols to Illawarra in April 1899, assayed 67 oz. of gold and ·7 oz. of silver per ton; whilst 2620 tons treated are stated in the Company's Annual Report (1899) to have actually yielded an average of 38·97 oz. per ton.

† Mr. Pittman says: "So far as I could ascertain there has not been any notable decrease in the richness of the ore-bodies as they descend. On the contrary, in some mines the value of the ore appears to have increased in the lower levels. However, as the greatest depth hitherto attained is only a little over 300 feet, it would be risky to predict that no impoverishment will take place as the excavations are carried downwards. Indeed it will be more reasonable to expect that the auriferous ores will be found to occur in 'shoots,' as is the case in so many true lodes."—*Ibid.*, p. 13.

point to point; whilst it may be added that the ore-bodies generally seem to be narrower in the unoxidised zone,* but more clearly defined.

As an instance of what has been said, I might cite a strike at the Boulder Perseverance, at the 300-feet level, of which mention has been made, which was described in a report of the discovery in the following terms:—

"It is 3½ feet thick, and is by far the richest make of stone yet opened in this property. The reef has been driven on for a length of about 15 feet north and south from the cross-cut, and samples tried indicate that the value varies from 20 oz. to 30 oz. per ton all through."

It is impossible in fact to say, in any general sense, that the "formations" get richer on the whole in depth, considering, as Mr. William Frecheville has pointed out, that bulk crushings in the early days of the field frequently yielded as high a return as 2 to 4 oz. to the ton, in 20- to 30-stamp mills; in spite of the fact that 6 to 8 feet was quite a moderate width of stope, and they often reached 15 or 20 feet in width in the brown-stone "formations." A falling off in the average mill yields, which appears to have led some people to jump to the opposite conclusion, does not, however, necessarily indicate a deterioration in the value of the "ore-bodies"; since it is invariably the case that when increased capacity is demanded in the reduction works, to keep up the output, large quantities of low-grade ore come to be treated (because it pays to do so on a large scale) which would have to be left on one side by small mills; and it has lately been observed (1901) that in the deeper workings of some of the mines the ore has become of a more acid and pyritic character, carrying tellurides in more or less quantity, and silver is present in larger proportion.

The apparent falling off in value in depth in some of the mines (judged simply by crushing returns) need not, therefore, I think cause anxiety, as in most cases where telluride deposits have proved unreliable they seem to have been "quartz reefing districts." The "lode formations" of Kalgoorlie, like the pegmatite dykes of Boulder County and the "phonolite dykes" of Cripple Creek—a field discovered in 1891, the output of which has been remarkable—

* I do not mean by this to suggest that I think the ore-bearing "*formations*" are likely to pinch out in depth, as I hold personally quite the contrary view, on grounds elsewhere stated.

are, however, of a totally different character, the ore-bodies in both cases being closely associated with rocks of distinctly igneous origin; and whilst the deposits in Transylvania are stated to have become more or less impoverished, they are of a different type, viz. quartz-veins in younger volcanic rocks (andesites), Tertiary limestones, sandstones, and conglomerates.

To sum up the position, it seems probable that the Kalgoorlie formations owe their origin to a complex series of igneous eruptive intrusions (some of which no doubt were more acid in character than others) which burst through the older mass of eruptives, at different periods; a series of dyke fissures thus came into existence, without any marked yawning or gaping, except such as might be produced by longitudinal faulting* and compression, and more particularly by the contraction of the dykes in cooling.

Spaces would thus have been formed, along which heated solutions and possibly vapours may have been forced,† which perhaps penetrated the country rock on each side of such cracks along the foliation planes and other crevices in the rock, dissolving out certain of its constituents and replacing them by others, thus altering the nature of the rock to a large extent in the neighbourhood of the dyke, but gradually less and less further away, until, where the country rock retains its original form no alteration at all took place, and any open spaces were healed and filled up by silica and lime deposited from solution as the rock cooled.‡

Mr. Pittman remarks§:—"When the mode of occurrence of the tellurides is studied, when they are seen to be disseminated

* Evidence of such "faulting" is shown by "slickensides" (of which an example might be mentioned in the North Boulder mine), to which reference is made by Professor Schmeisser. *Op cit.*

† Mr. Pittman says, p. 14, *ibid.*: "The question as to whether the deposition of the minerals has resulted from "lateral secretion" or from "ascension" of such solutions, is one that will require more investigation than is possible at present, but in view of the dense character of the unproductive rocks adjoining the productive belts, I venture to think that if the ore deposits be due to lateral secretion, the leaching of the precious metals from the enclosing rocks must have taken place from a lower level than has, as yet, been reached in the mine workings," an opinion the Author is inclined to hold.—A. C.

‡ In an ancient volcanic area such as this is proved to be, considering the presence of the various telluride minerals containing mercury, which is perhaps more commonly present than is generally supposed, it does not seem unlikely that sublimation may have also originally played a part, although perhaps a subordinate one, in the formation of these interesting deposits.

§ *Annual Report of the Department of Mines and Agriculture, New South Wales*, 1897, p. 141, quoted by H. F. Bulman. *Op. cit.*

through dykes of igneous origin, there are, I think, reasonable grounds for expecting that the enrichment of the deposit by these minerals will continue probably with intermissions, to very considerable depths." Anyhow, even if the ore-bodies do not *increase* in value, there is no reason to suppose that in sinking others will not be met with comparable in size and value with those at present being opened up in the deeper levels of the different mines, as they gradually work down to greater depths.

Indeed, so far as one can venture an opinion, judging from its past production, as Mr. William Frecheville has aptly said, it appears as if the centre of the Boulder area "forms the richest square mile of gold-mining ground known anywhere."

In the *Mineral Industry*, vol. vi., Professor J. Kemp gives a very full description of "The Geological Occurrence and Associates of Telluride Gold Ores." In the same volume, Mr. S. M. Dennis (p. 636) describes a simple method of detecting tellurium in association with other minerals, given by Professor Rich. Pearce in the *Engineering and Mining Journal*, April 17, 1897.

In conclusion, it may be remarked, that the eruptive rocks are thought by von Richthofen to have been poured out in the following succession: (1) propylite, equivalent in part to the older named greenstone-trachyte; (2) andesite; (3) trachyte; (4) rholite; (5) basalt; and Professor Kemp observes that the same succession has been noticed in America; the significant point being that the earliest eruptives are rocks of medium percentages in silica, the next following are successively more and more siliceous through rhyolite, after which there is an abrupt change and, the most basic of all, basalt closes the eruptive activity.

Whilst Professor Kemp regards the telluride deposits, in Colorado, as having a close connection with the dykes (the dykes having, in some cases, filled a fissure), he considers them as being true veins mostly formed along lines of displacement, that have as a rule been slight.

A new and interesting telluride—a telluride of copper—that has been named Rickardite, after Mr. T. A. Rickard, who first called attention to it, occurs at Vulcan, Colorado, in the Good Hope mine, and has recently been described by Mr. W. E. Ford (*Am. Jl. of Science*, vol. xv.); an abstract of this paper is given in the *Eng. and Min. Journal*, Jan. 17, 1903.

CHAPTER VI.

WATER PROBLEMS.

In the early days of the Western Australian fields, the question of obtaining an adequate supply of water for mining purposes presented no little difficulty, but various expedients soon suggested themselves, by which the apparent want of this essential element for the development of the industry on a fairly extensive scale might be overcome.

The ordinary and natural means of obtaining the requisite supply were :—

(1) By conserving the rain-water in dams.

(2) By drawing it from natural reservoirs, such as the salt-lakes and creek-beds, in the sandy bottoms of which fairly large quantities of water are often found stored; more particularly in the northern part of the colony, owing to the comparatively heavy rainfall in that region.

(3) By pumping up the "ground-water," drawn from shafts, bores, etc., which is usually found at the ordinary drainage level of the country, viz. at the horizon where surface-oxidation ceases, and the relatively less permeable underlying rocks offer a certain barrier to the further descent of the water which has penetrated the overlying ground. Below this line, the water often decreases, and the mine workings are in consequence frequently almost dry.

Conservation in Dams.

A rainfall of 4 to 8 inches per annum, such as obtains around Coolgardie and Kalgoorlie, will yield a very large water-supply, provided any considerable portion of it can be retained, always assuming, as records show, that over 50 per cent. falls in heavy showers (which is necessary to make a flow of water on the surface, except on rock-areas), a fall of 1 inch of rain * representing no less than 3630 cubic feet = 22,607 gallons per acre, or nearly 14½ million gallons per square mile.

* Three-fifths of the rainfall is usually reckoned available for storage.

The nature of the surface in the catchment area of the dam is, however, a matter of great importance, and where, as in many parts of the colony, large bare bosses of granite are met with, running from 10 up to 200 acres in extent, they offer a splendid catchment for even the slightest showers. The rain thus collected (as may be seen at the Government dams on the road from Southern Cross to Coolgardie) is caught by cutting a drain around the toe of the rock, and leading the water thence to a tank excavated on the lower side.

Some of the valleys, which would otherwise form good catchment areas, are rendered useless, owing to the pervious character of the surface soil, as all but very heavy rain is at once absorbed in the ground, and does not find its way to the tank.

There are, however, certain valleys (generally flanked by low ridges, strewn with black-ironstone pebbles), the surface of which is covered with a thin coating of clay which is impervious to even a heavy downpour of rain, preventing the absorption of the water by the dry earth beneath.

These clay-pans, formed in natural depressions in various localities, have yielded a large portion of the water-supply that outside prospectors have had to depend upon, and answer the purpose excellently, so long as the surface of the ground in the catchment area remains undisturbed. As showing the importance of this latter condition, Mr. J. Wilson Archibald states * that about a mile south-east of Coolgardie, there are two Government tanks of about half-a-million gallons capacity each, and every shower of rain adds to their supply; whilst in two other tanks in the neighbourhood, where the surface of the basin has been disturbed by "dry-blowers," only heavy rains will cause any water to flow into the dams at all.

The configuration of the country in the interior being generally flat, there are but few sites available where water can be impounded in any large quantity by means of "weirs," and therefore, as a rule, tanks for storage have to be excavated.

Mr. Archibald remarks that the sites for these excavations have to be carefully selected, and proved by test-holes, as in some cases, the "greenstone" bottom contains small pipes or bores ½ inch to 1 inch in diameter, found to be filled with soluble salts, and in cases where their existence has been overlooked, on the inflow of water into the dam an active ebullition has taken place, the

* *Financial Times*, May 1, 1896.

soluble minerals being dissolved out of the bore-holes, which then present the appearance of small round holes, with a clean hard casing, and convey the water away to where it is lost in the rocks. In a dam near Coolgardie, of 500,000 gallons capacity, filled by a storm in the early part of 1895, Mr. Archibald states that within 16 hours all the water had run out, and the bottom of the tank showed 83 such holes.

This difficulty has been overcome by puddling the bottom and sides of the tanks; in many cases, however, the alluvium in the valley is deep enough to afford tight ground.

Most of the dams of the Public Water Supply Department are stated to have had originally a capacity of about 500,000 gallons,* and Mr. Archibald says that, "Taking for example the dam known as the 42-mile dam, on the northern road from Coolgardie, a storm rainfall of between 3 and 4 inches in one day was registered there, in the Government gauge, shortly after the construction of the dam. This dam has a good ironstone-pebble and clay soil catchment area, of about 9 square miles, and, judging by the erosion of the water-course of the overflow, there can be no doubt that a dam of even greater capacity than ten times this size would have been filled."

The chief objections to this method of conservation are the delay in making a tank, and the uncertainty in regard to the time which may elapse before a storm will fill it; and this means of storage met at first with some discouragement, owing to the failure of many tanks to hold water, before the nature of the ground was understood, and the proper remedies were applied. The Government has wisely, however, voted and laid out very large sums of money for works of this kind.

Natural Reservoirs.

The chain of salt lakes, which run in a north by east direction from the head of the waters that flow into the Great Australian Bight on the south, through Lakes Cowan, Lefroy, I.O.U., Carey, and Darlot northward, are flanked as a general rule by diorite ridges, intersected by well-defined east and west valleys, which, through long periods of time, have emptied their storm-waters into

* Eighteen tanks on the Eastern gold-fields possessed capacities varying from 1,008,500 gallons up to 38,750,000 gallons at the end of 1899; and at the end of 1899 seventeen completed tanks possessed a gross storage capacity of 87,872,200 gallons, with a watershed area of 41,917 acres and an approximate capital value of 228,893*l*.

these depressions. They probably owe their origin to a general subsidence of the country, somewhat parallel with the ranges, which were elevated during a period of volcanic activity that doubtless occasioned an extensive series of "faults" along this line of country; and the deep beds of alluvium (the product of the disintegration of the underlying rocks) collected in the lake-bottoms (known as "soaks") which have levelled up large areas, are now the storing-places of large accumulations of water, which they protect from too rapid evaporation. In other places the rock-bottom lies evenly within a few inches of the surface of the lake, and in such cases the loss from evaporation is very great.

Mr. Archibald observes :—"Occasionally, during the winter months or in time of heavy storms, the surface of these lakes are covered with sheets of water. The surface waters draining into these lakes, for long periods of time, have in their course picked up quantities of soluble minerals, derived from the decomposition of the volcanic rocks. The evaporation which is excessive on such large shallow areas, has caused the precipitation and consequent concentration of the salts in these lakes to such an extent that the water met with in their alluvium is almost saturated, carrying as a rule 20 to 28 per cent. of solid matter. The minerals taken into solution are mostly soluble salts of sodium, lime and magnesia. Of these, the sulphate of lime being less soluble, was first precipitated out of the saturated fluid on the surface of the lake, the more soluble sodium chlorides being carried deeper into the silt-beds. The crystals, mostly of gypsum, being exposed on the surface of the lake, have, by the action of the wind, been accumulated in the sand-ridges occurring in the low passes between the lakes. In localities where the rock bottom of the lake is comparatively deep, very large quantities of salt water are stored in the silt-deposits, and they are in places being utilised for milling purposes by opening long trenches through the lakes." The water soaks into these trenches, and is thence conducted to a central pumping station, and although supplies of this nature are dependent on the character of the salt lakes from which they are drawn, under the most favourable conditions large quantities of brackish water may be obtained from such sources.

The neighbourhood of these lakes appears also to offer good natural sites for catchment areas of great extent, which hereafter may be utilised for the construction of large impounding-dams for public water-supply purposes.

Ground-water, Wells, Bores, etc.

At different depths, down to 200 or 300 feet, supplies of water are met with, varying in quantity and quality with the surrounding local conditions. Such water is due to absorption into the rocks of the rainfall during long periods in places where the surface consists of loose soil, as in the "sand-plains," or where the out-cropping rocks are of a more or less porous nature, and a slow accumulation takes place through the fissures and joints. Consequently, by a careful examination of the surface features and character of the rocks, the points where such wells can be advantageously located may be decided with reasonable certainty.

In the granite rocks and gneiss-granites near Coolgardie, Mr. Archibald states there are many such wells with a daily output ranging from 1000 to 6000 gallons per day, principally situated near the contact of the granite and greenstones. The water is found in shafts at a depth ranging from 170 to 180 feet, being in some cases fresh, in others carrying as much as 2 per cent. of solid matter.

As a rule these rocks have yielded by their disintegration the loose sandy soil forming the "sand-plains," and the water has percolated through the soil into the more pervious part of the rock, until water-tight ground is met with below, when, by putting in drives across the general run of the fissures that carry the water, it can be conveyed to a main water-shaft.

Mr. Archibald ascribes the comparative freshness of the water in some cases to the fact that the felspars of the granite rocks are more insoluble than those of the greenstones.

In the diorite and schists variable supplies are met with from the same source, but the water generally carries a higher percentage of soluble salts.

In places where soft dykes, reefs, etc. intersect these rocks, or where the soft decomposed diorite-schists extend downwards to a considerable depth, supplies of water are, however, often struck, which, when considered in regard to the small amount of work done in developing them, are of considerable extent. Thus, in the vicinity of Coolgardie such mines as Cosgroves and Bayley's Consols were stated to produce, from limited developments, from 10,000 to 20,000 gallons, and the Hit or Miss mine near Kanowna is said to have yielded 18,000 gallons daily from above the 120-feet level.

Many shafts, however, are dry, which are much below levels where water is usually obtained.

When, as frequently is the case, a stratum of harder and impervious rock is met with, underlying the softer rocks where water is found, by sinking a well into the impervious rock and running out drives across the strike of the country at this level, just as in the case of a shaft, a water-supply of this kind stands the best chance of being developed to its fullest capacity, and in some such wells at any rate the production appears fairly constant. Thus the Government well at Coolgardie, Mr. Archibald mentions, yielded for a couple of years 6000 gallons per day, and the flow of water did not seem to increase at the time of rainfalls; indicating that the percolation into the shaft, although slow, extends for some distance.

The sinking of other wells in the gneiss-granite within a chain or two of one another, moreover, does not appear to have affected the supply, and the same may also be said of the water-shafts at some of the mines. In certain cases, however, where the rock is of a more permeable nature, a diminution of water takes place when the reservoir is heavily drained, the water gravitating towards the deepest shaft, when the only remedy is to enlarge the area of drainage by sinking new shafts.

Bores.

On the Hampton Plains, in Block 49, a diamond-drill bore, located in one of the long valleys before referred to (running east and west), which was put down to 280 feet, passed through deep beds of alluvium, sand, cement and decomposed rock, to a depth of 150 feet, and at 170 feet met with hard rock, where a supply of water was struck, stated to amount to over 41,000 gallons per diem. Mr. Archibald adds:—"It is worthy of remark that the decomposed rocks have several cracks and fissures through them, which do not extend into the hard rocks below. Apparently the hard rocks below this (170 feet) level do not add to the supply, and it does not appear likely that further boring would do so." Other bore-holes have been put down with success near Coolgardie and elsewhere.

General Character of the Water-supply.

Considering what has been said, it is scarcely surprising that the water of the country generally is excessively salt, almost in fact to the point of saturation, and had it not been for the energetic action of the Government, supplemented by private enterprise, in establishing "condensing-plants" along the main roads, to convert the brine of the wells into potable water for man and beast, travel from place to place in the early days would have been greatly restricted, and conditions of existence in some of the older mining-camps would have been rendered intolerable, postponing their development in all probability indefinitely.

Comparing it with ordinary sea-water, which contains some 3½ per cent. of salts (three-quarters of which is sodium chloride) Mr. T. A. Rickard,* to illustrate the excessive salinity of the water in Western Australia,† states that at the Queensland Menzies mine he found them using water in September 1897, which contained 17 per cent. of salts; and he was informed by the manager that evaporation in the hot weather in December increased the amount to 30 per cent.‡ For this liquid, which came from a neighbouring "soak," twenty-five shillings § was paid per thousand gallons, and the item of water alone for milling, in a ten-stamp mill, amounted to thirteen shillings per ton, whilst the condensed water, bought for use in the boilers, cost twenty shillings per 100 gallons.

An analysis of the water of the Great Boulder Proprietary mine (also given by Mr. Rickard) showed the results appended. The sample was turbid, and it was found that the matter in suspension amounted to 5·25 grains per gallon, or ·075 grammes per liter.

The clear water on analysis yielded:—

	Grammes per liter.
Silica (SiO_2)	0·038
Alumina and ferric oxide (Al_2O_3 and Fe_2O_3)	0·024
Lime (CaO)	1·878
Magnesia (MgO)	8·106
Soda (Na_2O)	48·470
Carbonic acid (CO_2)	0·064
Sulphuric anhydride (SO_3)	6·026
Chlorine (Cl)	67·230
	131·836
Deduct oxygen equivalent to chlorine	15·150
	116·686
Combined water, organic matter and loss	8·534
Total solids	125·220

* 'The Alluvial Deposits of Western Australia,' by T. A. Rickard, *Trans. Am. Inst. of Mining Engs.*, vol. xxviii.

† The water of the Dead Sea only carries 20 to 26 per cent., of which 10 per cent. is common salt.

‡ The Author is informed that it occasionally runs up to 32 per cent.

§ The Author is informed that 10*s.* per 1000 was paid for water in Kalgoorlie in November 1897, and Mr. Hoover states that as much as 30*s.* ($7·50) per thousand has been given for salt water in Western Australia, *Eng. and Min. Journal*, Dec. 17, 1898.

The chief salts probably present, Mr. Rickard considers, were therefore :—

	Grammes per liter.
Calcium carbonate ($CaCO_3$)	0·145
Calcium sulphate ($CaSO_4$)	4·365
Magnesium sulphate ($MgSO_4$)	5·189
Magnesium chloride ($MgCl_2$)	15·144
Sodium chloride (NaCl)	91·467

Expressed in grains per gallon, Mr. Rickard adds, "the results appear more striking, the proportion of common salt amounting to no less than 6402·7 grains per gallon," ordinary drinking water containing about 3 grains.

Mr. Bulman * gives another analysis of Kalgoorlie water made by Mr. Bowen Jenkins :—

	per cent.
Chloride of magnesium and sodium	6·95
Carbonate of lime	0·86
Alumina and oxide of iron	0·49
Sulphur	0·12
Total solid matter	8·42

Investigations in regard to the general character of the natural waters of the colony, instituted during 1898 as a result of the difficulty experienced at the public batteries in using these waters for crushing, are detailed in the Annual Progress Report of the Geological Survey of Western Australia for the year 1899; and Mr. Edward S. Simpson, B.E., F.C.S., gives complete analyses of sixteen samples of water analysed in the Government Laboratory.

These were collected from Nullagine, Marble Bar, Cue, Menzies, Mulgarrie, Vosperton, Lindsay's, Coolgardie, Kalgoorlie, Southern Cross and Norseman, which may be looked upon as typical of a very large area of the colony occupied by metamorphic rocks or the closely adjacent masses of granite.

Of the many marked points of similarity presented by these waters, the more noticeable are :—

1. They all have an alkaline reaction from the presence of bicarbonate of lime.

2. With three exceptions (all of which are comparatively very low in solid contents), from 60 to 80 per cent. of the total solid matter is sodium chloride.

* 'The Kalgoorlie Gold Mines, Western Australia,' by H. F Bulman, *Trans. Inst. of Mining Engineers*, vol. xvii.

3. All contain a remarkably high percentage of magnesium, principally as chloride and sulphate.

4. As a consequence of the alkali dissolved in the water, the percentage of alumina is consistently low.

It is worthy of note that the specific gravity is almost a definite function of the total percentage of solids, the ratio being

$$S = \frac{400}{3}(G_4 - 1);$$

where S = percentage of solids and G_4 the specific gravity of the water at 4° C. To render the analyses comparable with those given in Thorpe's 'Dictionary of Applied Chemistry,' these waters are classified into:—

1. Muriated saline. Samples from Cue, Coolgardie, Lindsay's, Vosperton, Mulgarrie, Hannan's Lake, Boulder, Norseman (Lake Cowan) and Woolgar (Menzies).
2. Alkaline saline. Sample from Southern Cross.
3. Alkaline earthy. Sample from Marble Bar.
4. Earthy saline. Sample from Mount Robinson (near Hannan's Lake).
5. Sulphated. Sample from Nullagine.

Some of these waters contain from traces up to a fraction of 1 per cent. of sodium iodide, NaI; sodium bromide, NaBr; potassium sulphate, K_2SO_4; sodium bicarbonate, $NaHCO_3$; magnesium bicarbonate, $MgH_2(CO_3)_2$; calcium bicarbonate, $CaH_2(CO_3)_2$; ferrous bicarbonate, $FeH_2(CO_3)_2$; sodium nitrate, $NaNO_3$; and sodium silicate, Na_2SiO_3; in addition to the more ordinary constituents given in the accompanying table of analyses of Western Australian mineral-waters analysed by Dr. Earp,* which, with one exception (Coolgardie), are of waters from the Kalgoorlie district.

Dr. Earp's analyses, as published in the Transactions in which they appeared, were in terms of grains per gallon, but in the table below (reproduced from the Annual Report of the Geological Survey already quoted) they have been recalculated to percentages. In making these calculations it has been assumed that the specific gravity of the water at 4 degrees is equal to $1 + \frac{3}{28000} \times$ (total solids in grains per gallon), an assumption based upon figures obtained with similar waters.

* 'Transactions of the Australian Association for the Advancement of Science,' vol. vii.

MINERAL WATERS ANALYSED BY DR. EARP.

(Results expressed in parts per cent.)

—	Hannan's Brown Hill G. M., Kalgoorlie.	Hannan's Brown Hill G. M., Kalgoorlie.	Hannan's Brown Hill Water-Shaft, Kalgoorlie.	Hannan's Brown Hill Extended G. M., Kalgoorlie.	Hannan's Lake.	Government Bore-hole, Kalgoorlie.	Ivanhoe G. M., Boulder.	Kalgoorlie Mint G. M., Boulder.	Golden Bar G. M., Coolgardie.	Crœsus South United G. M., Boulder.	Lake View, and Boulder Junction G. M., Boulder.*
	1895	1897	1896	1897	1895	1895	1896	1896	1895	1897	1899
Potassium chloride, KCl	trace	..	trace	..	·133	..	..	..	trace	..	·0700
Sodium chloride, NaCl	4·123	3·887	3·477	4·487	5·090	7·904	3·453	3·056	1·939	3·819	3·2142
Magnesium chloride, $MgCl_2$	..	..	·255	..	·771	·790	..	·648	·098	..	·5229
Sodium sulphate, Na_2SO_4	..	..	..	..	..	..	..	·271	..	..	..
Magnesium sulphate, $MgSO_4$	·766	·518	·290	·460	·285	·496	·580	..	·499	·463	·3908
Calcium sulphate, $CaSO_4$	..	..	.	·130	..	..	·213	·329	..	·116	·1878
Magnesium carbonate, $MgCO_3$	..	·222	..	..	..	·993	..	..	..	..	..
Calcium carbonate, $CaCO_3$	·633	·240	058	·124	·105	·533	..	..	·059	·232	·0641 †
Alumina, Al_2O_3 (plus iron oxide).	..	·021	·058	·036	·105	..	·048	·029	·059	·025	·0047
Silica, SiO_2	..	·031	·019	·022	·038	·092	..	..	trace	·020	·0009
Organic matter and loss	·038	·264	·387	·181	·048	trace	..	..	·147	·060	..
Total per cent.	5·560	5·183	4·515	5·440	6·575	10·808	4·294	4·333	2·800	4·735	4·4554

* Analysed in the Government Laboratory.

† Calcium bicarbonate, $CaH_2(CO_3)_2$.

Aërial Condensers.

To render water of the above description fit for consumption, or use in steam boilers, it must needs be distilled, and the apparatus employed for this purpose, termed a "condenser," Fig. 22, in Western Australia, is a prominent feature of every district where a settlement exists, or mining is carried on.

It might more properly be called a "still," to distinguish it from a vacuum-condenser, but Mr. Rickard traces the use of the

FIG. 22.—BUYING WATER AT A CONDENSER IN WESTERN AUSTRALIA.
(By courtesy of T. A. Rickard.)

term "condenser" to the sailors who took part in the early exploring expeditions.

Any suitable type of boiler can be used for converting the salt water into steam, which is then condensed in vessels presenting a maximum of cooling surface.

In the older "condenser plants," the general type of boiler used consisted of ships' tanks having a capacity of 400 gallons, which were usually set on edge in pairs, as shown in Figs. 23 and 24. The average product of each such tank is reckoned at about 300 gallons of distilled water daily, and the steam is drawn off from the tanks through short vertical iron pipes, which pass into the condensing chambers or "coolers."

Mr. Rickard states that a first class "condenser plant" of this description would require at least eight boilers, furnishing with an output of 300 gallons of distilled water each a daily yield of 2400 gallons; but the capacity of the plant at some of the mines at a later date, according to Mr. H. F. Bulman,* amounted to 5000 gallons or more per diem, and the condenser plants at some of the big mines now far exceed this quantity.

The "coolers" at first employed to condense the steam were plain circular towers, about 30 feet in height and 3 feet in diameter, built of sheets of corrugated iron, riveted and soldered

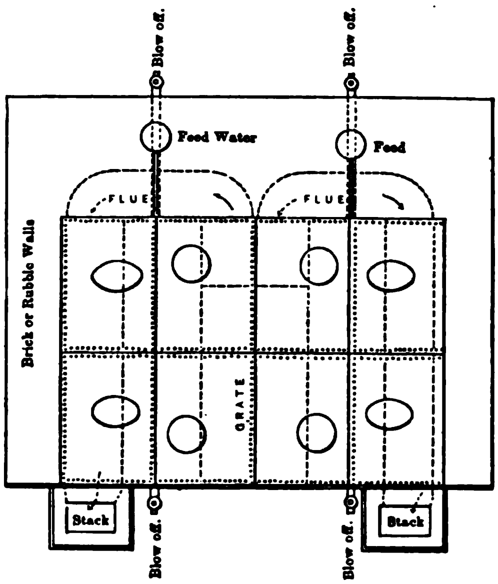


FIG. 23.—PLAN OF ORDINARY CONDENSER.

together, and closed at the top and bottom with flat sheets of galvanised iron. Several such towers were connected by 6-inch pipe, so that the steam travelled up one and down the next.

"Annular coolers" were next substituted, consisting of an outer cylinder of corrugated iron, 2·5 feet in diameter, surrounding an inner 1·5 foot cylinder, so as to leave a circular space 6 inches wide between them, containing the steam; and the inner tube

* 'The Kalgoorlie Gold Mines, Western Australia,' by Harrison F. Bulman, *Trans. Inst. of Mining Engineers*, vol. xvii.

being open at both ends, by tilting the "cooler" at a slight angle, a current of air is made to pass through the centre of the surrounding steam-jacket. A plant of this kind, which cost about 100*l*., is shown in Mr. Rickard's paper; it was erected some years back at the Lake View and Boulder Junction mine, and possessed a capacity of 1500 gallons of condensed water a day. The water which came from this mine has a specific gravity of 1·03385, the total solids amounting, according to an analysis by Mr. E. S. Simpson,* to 4·9308 per cent., and the chlorine present to 2·3933 per cent.

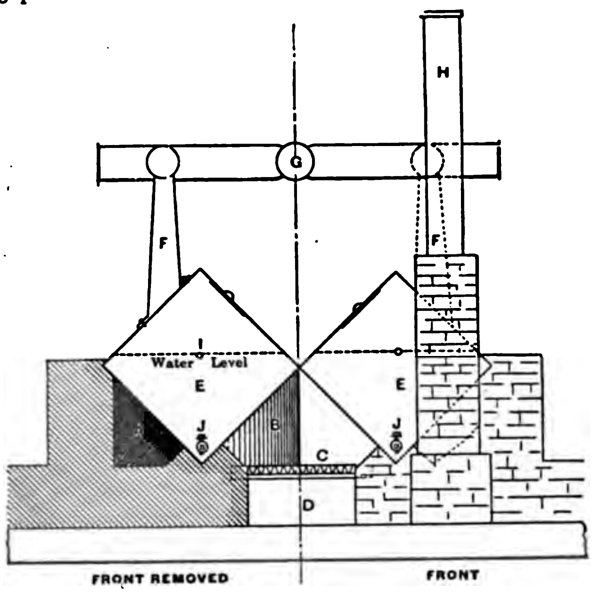


FIG. 24.—SECTION AND ELEVATION OF ORDINARY CONDENSER.

In plants which have been more recently built, the boilers—termed "evaporators" or "stills"—are now frequently constructed either of the cylindrical under-fired class, Fig. 25, about 18 feet long and 4 feet in diameter, like those at the Great Boulder; or of V-shape in cross-section. They are provided with necessary fittings, and built in like a steam boiler; whilst the fronts are made removable, so as to clean them out quickly and easily, which is a matter of great importance. Two "evaporators" of this type, I

* A more recent analysis, giving the constituents of this water, will be found in the Table on page 126.

am informed, supply enough steam to produce 1200 to 2000 gallons of fresh water daily.

The coolers have also been greatly improved upon, consisting in some cases of a battery of long galvanised pipes of comparatively small diameter (4 inches to 6 inches) cooled by the surrounding air,* connected with steam chests at each end; but more commonly they are formed of galvanised iron drums (like water-tanks) closed at top and bottom, except where the pipe for the entry and exit of the steam joins them together; these contain sets of

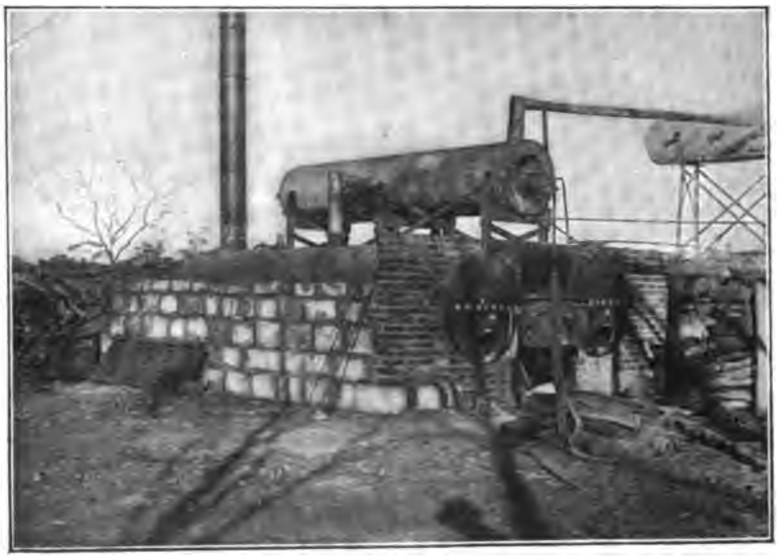


FIG. 25.—CONDENSER AT THE IRON KING MINE, KALGOOLIE.
(By courtesy of T. A. Rickard.)

about five 4-inch pipes open at the ends, running through them longitudinally, which allows air to pass through the tubes, when the drum is slightly tilted out of the horizontal. This type is also frequently used in combination with vertical water-coolers, similar to the "annular air-coolers" previously described, but with one end of the central space closed by a plate, so that, when set upright, the centre can be filled with water. Pipes are, of course, provided

* There seems no reason why a nest of pipes of this sort should not be "jacketed" and water-cooled, using the cold salt water coming from the mine, heating it on its way to the evaporator, by which, benefit ought to be derived both ways, and the cost of condensation be correspondingly reduced.

in the bottom of the coolers for drawing off the condensed water into tanks, where it is stored and cooled.

The Statist * mentions that in the year 1895 the cost of the necessary water to treat one ton of ore at the Lake View Consols came to 4*l.*; and the high price of salt water in the early days of the fields has already been referred to.

In 1898, Mr. Rickard observes that salt water cost 2*s.* to 4*s.* per 1000 gallons; but this did not evidently include delivery (which varies with the distance and quantity pumped); and even at the time in question these figures appear rather low, as in a paper written about the same time (the beginning of 1898) Mr. Wm. Frecheville stated † it was selling at 5*s.*, and this was, I believe, about the general price at the larger number of water-shafts in 1897. The price, however, fell shortly afterwards, when water could be purchased for 3*s.* 6*d.*; whilst later still (in 1900) it could be bought for 2*s.* 6*d.* at the shaft's mouth.

Without allowing anything for first cost of laying down pipes and pumps, but paying pumping charges, salt water was, however, costing some of the largest of the Kalgoorlie mines 4*s.* 6*d.* per 1000 gallons *delivered* in 1899, ‡ and it cannot certainly even now be got for less than 4*s.* when, as in some cases, the water has to be pumped by the consumer, with a small engine and boiler, half-a-mile or more; the wages paid and wood actually consumed may easily add as much as 2*s.* per 1000 for delivery to the cost price of the water at the shaft. In a case of the kind which came under the writer's notice, a 3 feet by 7 feet 6 inch vertical type boiler burnt about five-eighths of a cord of hard wood on two shifts, i.e. 16 hours, supplying steam to a No. 4 Tangye pump, having 3-inch water and 4½-inch steam cylinders, with a 7-inch stroke, and required a man on each shift to look after the firing of the boiler. The water is measured by meter.

Mr. Richard Hamilton informed the Author, in January 1900, that about 70,000 gallons of salt water were supplied to the Great Boulder from various sources per day; this water, which was drawn principally from various shafts on the property and the adjoining leases, contained from 4·84 to 11·02 per cent. of soluble salts, and

* September 15, 1900, p. 418.

† 'Notes on a Visit to the Gold Mines at Kalgoorlie, Western Australia,' by Wm. Frecheville, M. Inst. M.M., *Trans. Inst. of Mining and Metallurgy*, vol. vi.

‡ This was the contract price at Lake View in 1900. *Annual Report*, p. 17.

exclusive of purchase of water, he reckoned it costs ½*d.* per gallon to condense.

At the Ivanhoe mine the Author was informed by Mr. Thos. Hewitson, about the same time, that the water supply was drawn from a low-lying alluvial flat situated to the west of the gold-belt, where the company own 76 acres of leased water-rights, on which a shaft has been sunk to a depth of 135 feet, and equipped for baling and pumping water up to the mine, a distance of 6000 feet; the vertical lift from the surface of the water area, up to that of the mining lease, is about 90 feet.

This water-lease furnished a supply of 40,000 to 50,000 gallons per day, containing about 7 per cent. of solid salts, and it was proposed to supplement it, I believe, by bringing in water from the Hampton Plains Estate.

Mr. Hewitson reckoned the actual cost of condensing in ordinary galvanised "coolers" at 2*l.* 5*s.* per 1000 gallons, but the price varies, no doubt, somewhat with the quality of the water and the season, as it would appear from figures given by Mr. T. A. Rickard that in 1898 the cost of labour and fuel for condensing might be reckoned at about 5*s.* per 100 gallons during the cool season, and 6*s.* 6*d.* during the summer.

The cost of condensing water, it would thus appear, has been reduced, as it used to be reckoned to cost from 1*d.* to. 3*d.* per gallon. In November 1897, condensed water purchased sold for 100*s.* to 150*s.* per 1000 gallons, or, on the average, about 12*s.* per 100;* whilst in 1899 the price in the hot season had fallen to about 7*s.* per 100, and it only stood at 9*s.* in the cold season, or an average of 8*s.*†

As a basis for calculation, Mr. T. A. Rickard figures that on a production of 2400 gallons of fresh water per day,‡ the expenditure would include the labour of two men (one on each shift), 2½ cords of wood (one cord of wood per 1000 gallons of condensed water), and 3200 gallons of salt water.

Water for drinking and household purposes is partly obtained

* In some cases, however, it cost over 14*s.*

† Mr. H. F. Bulman quotes the price at 7*s.* 6*d.* to 8*s.* 6*d.* per 100 gallons. Quite recently Mr. F. A. Govett stated (at the Fifth Ordinary General Meeting of the Ivanhoe Company, May 2, 1902), that condensed water cost about 7*s.* per 100 gallons, and the Ivanhoe required nearly 20,000 gallons per diem.

‡ The Lake View mine is stated to be equipped with a condensing plant capable of supplying 10,000 gallons of fresh water daily.

from tanks, which catch the rainfall from the roofs, but it is apt to become contaminated with salts of zinc, and impurities due to dust, dead frogs, etc.

The density of the salt water is no doubt an obstacle to amalgamation, in consequence of the fact that the ore being particularly liable to "slime," the fine particles can less easily settle on the "copper-plates," and run the risk of being carried away in the tailings. To prevent the decomposition of the stock-solution in the cyanide works, the magnesia is precipitated with lime. The chloride of magnesium present in the mill-water, according to Mr. H. P. Woodward, tends, however, to sicken the mercury in the mills.

Estimates of the loss of water from various causes are exceedingly variable; thus, whilst it is claimed that milling and cyaniding can be done with a loss of 0·25 ton of water to the ton of ore (using the water, of course, over and over again), Mr. Geo. Bancroft estimates that in most of the mills 0·5 ton of water is lost per ton of ore, whilst Mr. H. C. Hoover * put the average mill, steam, and domestic loss considerably higher, viz. at about 400 gallons † per ton of ore milled.

When the tailings and slimes are treated, however, he states that some portion of this can be saved, reducing the loss to about 250 gallons per ton of ore. At the North Boulder Mine, in October 1898, the loss amounted to 367 gallons per ton, and in December to 496 gallons.

The actual ordinary loss is probably, therefore, as Mr. Wm. Frecheville says, between 200 ‡ and 400 gallons per ton, although in the warm weather I am informed by Mr. Ed. Skews that (owing to evaporation in shallow dams) the loss sometimes rises from 311 to nearly 1000 gallons per ton. Cyaniding alone, according to Mr. Bancroft, entails a loss of 15 per cent. Mr. H. C. Callahan considered, I am told, that there was an average difference in consumption in summer and winter of some 300 gallons per ton. It would, however, be interesting, and of value, to have more complete data on these points, showing under what heads losses occur, and what they amount to under different conditions.

* 'Mining and Milling Gold Ores in Western Australia,' *The Eng. and Min. Journal*, December 17, 1898.

† A gallon of distilled water weighs 10 lb.

‡ In an article on 'Westralian Mines' in the *Financial Times* of November 5, 1902, it is remarked: "Most of the mines use only about 200 gallons per ton of ore treated, as against the common use of from 1500 to 2000 gallons in localities where water is abundant."

Patent Vacuum Condensers for Economising Steam.

At Hannan's Star mine, Ledward condensers are used, which have a large cooling surface; and they are submerged in an excavated bricked or cemented tank 40 feet by 15 feet by 8 feet deep.

A double 7-inch single-acting ram pump conveys cool water through a line of 6-inch piping 450 feet long from the dam to the bottom of the condenser-tank, and a wooden launder carries the top heated water from the tank back to the dam. In this connection it is most important that a rapid circulation should be kept up, otherwise the cooling water gets heated, and incrustations are liable to form; these impair the efficiency of a condenser, even when thus cooled, if salt water is used.

In connection with this system of condensers, a double 15-inch single-acting air-pump is employed, to create a vacuum on the main mill-engine.

At the Lake View Consols, a Forwood-Down condensing-plant was erected at the main shaft in 1901,* with driving engine, vacuum and circulating pumps and accessories and cooling towers.

At the Norseman Gold Mines, a Fouché's aëro-condenser is connected with a 40 horse-power expansion engine and several engines of minor importance; and the consumption of condensed water, based on one year's average, is stated † to have amounted to 50 gallons per diem, showing, it is said, a great economy over the "surface-condensers," which are ordinarily used in connection with steam plants on the gold fields.

In proof of this, Dr. Simon states that at one well-known mine at Kalgoorlie, where a "surface-condenser" of the ordinary type is used, in connection with a 150 horse-power engine, the quantity of water lost for cooling purposes amounts to 18,000 gallons daily.

In the Fouché form of "condenser," the steam passes through pipes which are cooled by a strong current of air produced by a "fan," condensation being aided by an air-pump; and an oil separator is connected with the steam supply-pipe.

Further particulars of this system can be found in the paper

* The mill-engines are fitted with a similar plant; this gives a vacuum of 4 lb., and is stated to effect a saving of 13 per cent., the engine having formerly worked under a back pressure of 10 to 25 lb. *Report*, Bewick Moreing & Co., Kalgoorlie, April 3, 1902.

† 'Notes on Fouché's Aëro-Condenser,' by Dr. A. L. Simon, *Trans. Inst. of Mining and Metallurgy*, vol. vii.

by Dr. Simon referred to, and an interesting series of tests, made at Kalgoorlie, are recorded in the *Report* of the Chamber of Mines of Western Australia, Sept. 1902.

Mining companies generally allow their workmen, if single, 2 to 3 gallons of condensed water a day gratis, and married men 4 gallons, which is regularly served out to them; the tanks in which the condensed water is stored are arranged so that the taps are padlocked, to prevent theft.

It will be clear from what has been already said, that dry as the country appears to be on the surface, there is an abundance of water for carrying on *ordinary small mining undertakings*, but, on the other hand, it is evident that a large and important "camp," like Kalgoorlie, could not be expected to expand on a scale commensurate with its possibilities, and the value at which mining properties in the district have been capitalised, as long as it has to depend on the sources of supply of which mention has been made; for the simple reason that *large quantities of low-grade ore* that exist, can never be worked at a profit under such conditions.

As it is a well recognised fact that the success of a mining field largely depends on the ability to work its *low-grade ores cheaply*, as it is always far more profitable to do so than to treat high-grade ores in small quantity; the question of how to solve the water difficulty (which is perhaps quite as important, if not more so, than the "sulphide problem") has long exercised the minds of everyone interested in the West Australian mining industry.

Optimists, whose wishes have been the parents of their thoughts, at one time hoped that by putting down deep bore-holes in the gold-fields, an artesian supply might be struck in large volume, the same as in parts of Queensland and elsewhere in Australia; but the geological conditions do not seem to favour the probability of this expectation being realised so far as regards the "Central Plateau" of West Australia;* although it may be, that sufficiently large quantities of water will be obtained, on the Hampton Plains, or elsewhere, comparatively close to the gold-fields, which will supplement the supply that the completion of the Government scheme will furnish. The Hampton Plains are some

* The question of obtaining supplies of artesian water in other parts of Western Australia is discussed in *Bulletin No.* 4 of the Geol. Survey of Western Australia, and it would appear that in all probability artesian water areas exist in the Recent and Tertiary strata of the Coastal Plains, in the southern portion of the colony, and in the vicinity of the Swan River.

twenty miles from Kalgoorlie, and the Cane Grass Valley Works * were, I believe, expected to furnish a very considerable quantity. Cheap water is, in fact, one of the things the country most requires, as it would not only enable mines that cannot be worked at a profit under present conditions to enter the producing list, but would give encouragement to agriculture as well, if a surplus supply was available.

The Coolgardie Water Scheme.

When the Government undertaking is in full working order there is no doubt that it will give a new impetus to mining on the fields.

In California, millions of gallons of water are "flumed" hundreds of miles to various mining camps, entailing enormous engineering difficulties, but this particular project is unique in the history of mining, as it is intended to provide for the delivery of 5,000,000 gallons of fresh water daily; in order to keep the thickness of the pipe within practical limits, this is to be pumped from eight stations to be established along the line a distance of 325 miles, through 30-inch pipe, with an aggregate lift of 1245 feet, the lifts generally being through short sections of the line, with long sections of falling grade from station to station between them.

The source of supply is the Helena River, which is in the Mount Darling Range near the coast; a concrete weir, which will dam the river back some 7½ miles (forming a reservoir capable of containing over 4,600,000,000 gallons) is under construction at Mundaring, about twenty-three miles from Perth, at an elevation of some 320 feet above sea-level. The weir is being built in a gorge, and will be 720 feet long on top, and 110 feet high near the middle,† made of cement concrete, faced with ashlar work of very hard micaceous granite. The excavation for the foundations of the dam (amounting to 50,000 or 60,000 cubic yards) have been some time since completed. The width of the weir at the bottom of the river-bed will be 85 feet, and about fifteen feet at the crest.

* The Kalgoorlie correspondent of *The Financial Times*, in a letter dated May 24, 1902, says: "The 'Gorge,' the company's chief reservoir, is a natural basin about two miles from town [Coolgardie], and at the present time contains close on 20,000,000 gallons of fresh water; a very efficient pumping plant is in constant work, and, in addition to the Coolgardie consumption, about 60,000 gallons of water are pumped every day to the Kalgoorlie mines, a distance of about 20 miles."

† As the foundation is in one place for a length of 15 feet nearly 100 feet below the river bed, the total height of the weir from the bottom of the foundation to the top of the crest is about 200 feet.

The crest and lip of the weir are designed for a "curve of contact" to avert any leaping by the overflow during exceptional floods. The waste-weir is to be formed on the main wall, and will provide for a free overflow 5 feet deep and 400 feet wide. The lowest level from which water will be pumped is 20 feet above the river bed, and the capacity of the reservoir (viz. 4600 million gallons) is reckoned above that level. The weir is provided with the usual valve-tower, scour-pipes, outlet-pipes, gangway, etc. Cement, slacking and storage-sheds, stone-crushing plant, concrete-mixing machinery, and general repairing shops, were erected for its construction; and an electric lighting-plant was set up, to enable the work to proceed night and day.

Pumping Installations.

The first pumping-station is located close to the main Greenmount storage reservoir, and the machinery at this and the next three stations will consist of three sets of boilers, engines and pumps—two sets to work and one to spare, each set being capable of pumping 2,800,000 imperial gallons per diem, against a head, including friction, of 450 feet. The second station is situated on the pipe-line, at a distance of about 1½ miles from the first station, and will raise the water to a high point on the Darling Ranges, from which it will gravitate through pipes (laid generally alongside the railway line) for a distance of about 75 miles to pumping-station No. 3 (77 miles from station No. 2). From station No. 3 the water will be pumped to station No. 4, 61½ miles, at a distance of 140 miles from the head works. The other four stations are located close to the railway, and at the following mileages on the pipe-line: No. 5, 171 miles; No. 6, 217 miles; No. 7, 248 miles; No. 8, 293 miles.

The pipe-line at each pumping-station (No. 2 to No. 8 inclusive) is to be broken by a receiving tank, 20 feet or more in depth, holding not less than 2,400,000 gallons (possessing sufficient capacity to provide for irregularities in the pumping, and for other contingencies), into which the water will flow, and from which it will be pumped to the station beyond. The greatest distance between any adjoining stations is a little under 80 miles.

Between the second and third stations, an extra reservoir 25 feet deep, with a capacity of 6,000,000 gallons,* is to be located to reduce

* It appears that the capacity of this dam has been increased to 12,000,000 gallon *The Mining Journal, London*, July 12, 1902.

the head at this point by some 200 feet, otherwise the closing of the stop-valve at the third station would place about thirty-six miles of main under a head of 450 to 650 feet; and at various high points along the line, "regulating reservoirs" will be constructed, with a capacity of one million to twelve million gallons each (for which surveys, trial-bores, and shafts were made), from which the water will flow by gravity to the next station, so that a great portion of the pipe-line will ordinarily be simply under the pressure due to the elevation to which the water is raised at these regulating reservoirs, and the hydraulic gradient.

The location of the pump-stations is such that the head against which the water will be pumped will be practically the same at each of the first four and second four stations, the object being to secure uniformity in the pumping machinery, of which there will be only two sizes proportioned to the two different lifts. At stations 5 to 8 (inclusive) there will be only two sets of boilers, engines and pumps, one to work and one to spare at each station, and the total nominal lift provided for at each, is 225 feet; but with the further provision that while each set of pumping-engines will be capable of raising the full supply to that height, it will also be capable of pumping past any station or reservoir on to the next station or reservoir a reduced supply, corresponding to the increased head.

The pipe main will be adjacent to the railway throughout, and the pumping arrangements will be such that a reduced quantity of water can be pumped from station No. 5 past No. 6 to No. 7; also from No. 6 past No. 7 to No. 8; and from No. 7 past No. 8 to the main service reservoir.

With the pumping machinery arranged as above, and the requisite storage capacity provided along the route and near the terminus, the contingency of cessation of pumping at any one station for a period of seven days is provided for.

Triple-expansion engines, with surface-condensers, are to be used, but it is stated that economy of coal-consumption will, to some extent, be sacrificed to simplicity of design.

The water, by this means, will be raised to the main distributing-reservoir at the top of Mount Burgess, at an elevation of 1585 feet above sea-level, from whence it will be distributed by gravity to Kalgoorlie, Coolgardie, Menzies, and other camps. As the lowest supply level from which water will be pumped is 340 feet above sea-level, the total net lift to the Mount Burgess reservoir may be reckoned at a maximum of 1245 feet, and adding to this the head due to frictional resistance in the pipe main (with a liberal margin for incrustation and allowance for maximum possible loss of head due to variations of level at pumping-stations and other contingencies) the total gross lift, including friction, is reckoned at 2632 feet.

At Coolgardie there is to be a "service reservoir" having a capacity of at least 24,000,000 gallons, and other "service reservoirs" will be built on hills in the vicinity of Kalgoorlie and elsewhere. A steel main, about 21 inches in diameter, 25 miles in length, will connect Coolgardie with Kalgoorlie, and the project includes about 100 miles of 12-inch distributing mains.

Two contracts for the supply of half the total quantity of pipes and joint-rings required were let, one to Mr. Mephan Ferguson, of Falkirk, near Perth, W.A., the other to Messrs. G. & C. Hoskins, of Midland Junction, near Guildford, at a combined cost of 1,025,124*l.* The weight of steel, without jointing-rings, is about 74,442 * long tons, and the coating adds 3867 long tons. The contract price for the pipe coated is stated to have been about 13*l.* per ton, f.o.b., Falkirk or Midland Junction, and the contractors were called upon to supply as many welded steel joint-rings as might be required, up to 61,856 of such rings, at the rate of 1*l.* 2*s.* 6*d.* Orders for the valves required, and all special joints, were to be placed in England.

The pipe forming the main conduit has an internal diameter throughout of 30 inches, with a minimum thickness of $\frac{1}{4}$ inch and maximum of $\frac{5}{16}$ inch, and is of Mephan-Ferguson's Patent (rivetless) or locking-bar pattern, supplied in lengths of 28 feet. A section of it can be seen at the office of the Agent General for Western Australia.

The contract, it is stated, required 1000 lengths to be $\frac{5}{16}$ inch thick and 30 inches internal diameter, and 60,856 lengths to be $\frac{1}{4}$ inch thick, of similar size. The total number of lengths required was 62,229.

The peculiarity of this pipe is that it is made of steel plates fastened together with two longitudinal locking-bars, made by swelling the longitudinal edges of the plates, and bringing them together in grooves, made in the opposite sides of the bars. The bars are then closed on to the swollen edges of the plates by pressure.

* 68,452 tons without strips or rings.

The *Iron and Coal Trades Review* of January 13th, 1899, gives sections of the locking-bar and joint-rings, and details of the specification, which need not be entered into here.*

I may mention, however, that the plates and bars are required to be of open-hearth acid steel, the plates to be capable of withstanding a tensile strain of not less than 25 or more than 29 tons per square inch, with an elongation in 10 inches of not less than 20 per cent, and a contraction area of not less than 45 per cent.

The steel must also resist the following drift test: A hole ⅝ inch in diameter to be punched within 1¼ inches of any edge of a plate, and to be drifted out cold, to a diameter of 1⅛ inches, without showing signs of fracture. The test pieces must bend cold around a bar of a diameter three times the thickness of the plate, without signs of fracture. Not less than two tensile tests to be made from each cast, and bending and drifting tests from each plate. No chemical requirements were specified.

Before the longitudinal joints are made, the locking-bars and edges of the plates are required to be completely freed from black oxide, by dipping in a bath of dilute sulphuric acid, and then in a bath of lime-water, followed if necessary by scrubbing. This was to be done under cover. and the plates and bars were not to be exposed to the weather after dipping, but to be at once formed into pipes. They were then to be submitted to hydraulic pressure of 400 lb. per square inch, tapping them smartly with a hammer, and after being tested and approved, thoroughly cleaned in baths of dilute sulphuric acid and lime water; finally they were to be heated uniformly to 300° Fahr., and coated by dipping in Trinidad asphaltum and creasote.

The result of the working of the line will be watched by engineers with much interest, as, if this form of pipe proves a success a great improvement will have been effected; the locking-bar and ring-joint have, however, yet to be tried; whilst the riveted joint is an old and trusty friend.

The selection of this new form of pipe was decided upon, however, on what appear sound reasons, viz. whilst the engineer's estimate for 330 miles of 30-inch spiral riveted steel-pipe was 1,068,000*l.*, the contractors' tenders for lock-bar pipe came to only 998,000*l.*, against which the actual tenders for spiral riveted and

* Further particulars are given in an article upon 'The Coolgardie Gold Fields Water Scheme,' in *Fielden's Magazine*, May 1900.

welded pipe of 26, 27½, and 29 inch diameter (which it was at first intended to employ) came, it is stated, to 1,220,000*l.* Consequently the saving in cost thus effected admitted of employing a larger size pipe, without exceeding the engineer's estimate,* and all rivets being done away with, as also changes in the diameter of the pipe every 28 feet (which would have been caused by placing the sections alternately inside and outside each other), the adoption of these pipes ought to considerably decrease friction, and effect a saving in pumping charges, which it was calculated would amount to 10,000*l.* per annum.

The transverse joint steel rings or double-socketed sleeves are to be caulked with lead, but no caulking of the locking-bar joint is to be permitted.

It was proposed originally to lay this pipe on timber bolsters or sleepers (hollowed to a depth of not less than 6 inches to fit the under side of the pipe), placed on the ground; and although with a range of temperature of 75° F. the amount of expansion to be provided for is about ⅝ inch for every 100 feet length of pipe, as this would not be likely to occur except if the pipes are emptied during extremes of heat and cold, it was expected that expansion joints placed every 120 feet would meet the difficulty.

So placed, however, the pipes would offer but little resistance to motion, and "creeping" might occur, unless prevented; whilst in all curves, the joints would have a tendency to move radially from the centre of the curve. With a 30-inch pipe, under a head of 400 feet, laid on a curve having a radius of 660 feet, the radial thrust on each length between the expansion joints has been calculated, I believe, at about 9 tons, whilst in the event of the sudden closing of a valve, this pressure might be much increased.

The tendency to creep and to move at the curves would therefore have to be prevented. To obviate such movements, 3 feet from the end of every fourth 28-feet length of pipe, it was proposed to double rivet to the under side of the pipe three 12-inch pieces of angle iron, 6 by 4 by ¾ inches, to bear against "piles" or a mass of concrete; piles or concrete blocks, to be placed on the outer side of the pipe, on curves.

The plan of laying the pipes on the surface is not, as seems generally supposed, new in Australia, as water was pumped from the Burdekin River to Charters Towers in Queensland, through a line

* The combined cost of the pipes and joint-rings appears to have been 1,025,124*l.*

of this description; laid, if I recollect rightly, in 1888. The reasons urged in its favour at Kalgoorlie were:—(1) That in a line like the one described, of such extreme length, the question of leakage is important, and as small leaks from the joints and rivets of steel pipes, when subjected to strains caused by expansion and contraction, are certain to occur, they can be easily detected early and thus be at once repaired; (2) decreased cost of laying; (3) the fact that the soil along most of the line contains salt, which would induce rust; and (4) there is no prolonged frost to guard against, and no difficulty to be apprehended from wilful damage. I understand, however, that it has finally been decided to lay the pipes in trenches.

Stop-valves are to be used in the Kalgoorlie pipe line at the inlet to each reservoir, at the outlets of the pumps, at every important depression, and at points not exceeding five miles apart. Scour-valves having openings 6 to 9 inches in diameter are to be placed on the under side of the main at every depression. Back-pressure valves are to be provided at the inlet to each reservoir, and immediately above each pumping station. There are to be air-valves at all summits on the line, to liberate air when charging the main, and to keep it free from air disengaged from the water flowing into it.

These air-valves are to work automatically, and will be placed in groups of three or four in one casing, and have a considerable discharging capacity. They are to be protected from the possibility of interference or injury by strong covers. They will also admit air to the main, in case the pressure in it falls below that of the atmosphere. To prevent the air being carried past these valves by the flow of the water, the provision of air-domes, consisting of 12-inch cast-iron pipes 18 inches in depth, with flanges fitted to the crown of the main, has been recommended. Immediately above each dome, it was proposed to fix a 3-inch stop-valve, and above that the air-valve proper. Instead of cutting a 12-inch hole in the main, it was to be perforated with numerous smaller holes. In addition to this, at the most important summits, about sixteen in number, the enlargement of the main to about twice the normal diameter was contemplated, thus forming chambers in which the velocity of the water will be reduced, and where air or gas can freely disengage itself from the water and escape through the air-valves.

The estimated cost of the undertaking, which is being carried out by the Public Works Department of Western Australia, would, it was said, amount to about 2,400,000*l.* The charge to be made for the water was at first variously stated at from 2*s.* 6*d.* to 3*s.* 6*d.* per thousand gallons; but from a later paragraph in the newspapers it appears that the price was expected to be fixed at 4*s.* per thousand, and that several of the leading mines had arranged to take 5000 gallons per diem, when the pipe line to Kalgoorlie was completed.

The actual saving to the existing population has been reckoned as follows. Assuming the number served to be 42,000, and their average consumption per head (including some provision for condensed water for machinery and live stock) to be 5 gallons per diem, by carefully reckoning the people within the area this water supply would command, it was ascertained some time ago that the consumption was 210,000 gallons, and this costs the community 800*l.* a day, which is equivalent to 292,000*l.* per annum.

To supply an equal amount of water at the rate estimated in the water scheme would cost the population only about 36*l.* per day, or say 14,000*l.* per annum, an annual saving of considerably over a quarter of a million sterling.

Or to put the matter in another way, the community could readily use four times the quantity of water they at present use, and if they got the water for 3*s.* 6*d.* per thousand gallons,* they could consume four times the present quantity at less than a fifth of what they now pay for a totally inadequate supply.

It is also evident that an enormous gain must result to the various mining companies, who are at present obliged to condense large quantities of salt water, if they were able to buy fresh water for 3*s.* 6*d.*, where it now costs them 3*s.* to 4*s.* 6*d.* to obtain a supply of brackish water: not to mention the saving of fuel, which is at present being unavoidably wasted on the gold-fields.

The following summary of the principal particulars of the undertaking is given † by Mr. C. Y. O'Connor, C.M.G., Engineer-in-chief.

The first section was tested, when, on March 26, 1902, 620,000,000 gallons of water were pumped into the main reservoir. For the

* This price only allowed for delivery at Bulla Bulling, and it appears from the May Report of the Chamber of Mines of Western Australia (1902), that a higher price is likely to be charged by the Government for water delivered on the gold-fields as the scheme has cost considerably more than the original estimate. *The Mining Journal, London*, July 12, 1902.

† *Handbook of Western Australia*, 1901, p. 160.

principal details of this project the Author is indebted to the description given of it by Mr. C. Y. O'Connor, in the *Handbook of Western Australia*, 1900; the article in *The Iron and Coal Trades Review*, to which reference has already been made; and two interesting articles in *The Engineer*, of Jan. 21 and 28, 1898. The foregoing description affords a general idea of the principal features of the scheme, subject of course to such modifications in detail as circumstances may have necessitated in carrying it into execution.

The line was officially opened on April 30, 1902, as far as Cunderdin, where No. 3 pumping station is situated.

Item.	Description.	Unit of Measure.	Amount.
1	Quantity of water required to be pumped per day of 24 hours	gallons	5,600,000
2	Length of pipe main from storage reservoir to Coolgardie	miles	325
3	Diameter (internal) of pipes to be laid (steel locking-bar type)	inches	30
4	Velocity of water per second	feet	2·124
5	Net lift from storage reservoir to main distributing reservoir . . . 1245 Plus allowance for intermediate reservoirs 165	,,	1,410
6	Head per mile allowed for friction	,,	3·76
7	Total head allowed for friction	,,	1,222
8	Estimated gross head	,,	2,632
9	Weight of water to be raised per diem	tons	25,000
10	Work per diem	1000 ft.-tons	65,800
11	Net effective power required	No. of H.P.	3,102
12	Power to be supplied— H.P. of engines in work . . . 3712 Plus H.P. ,, reserve . . 2475	No. of H.P.	6,187

The works were officially opened at Kalgoorlie by Sir John Forrest on Jan. 24, 1903.

Although the works are stated to be able to deliver 6,000,000 gallons per diem, it is not expected, I believe, that more than 2,500,000 gallons will be delivered at present, and it is reported that the price to be charged at the reservoir will be 6*s*. to 7*s*. per 1000. Some further time will be also required for completing the reticulation scheme to the mines at Boulder. The capital raised to complete the works has amounted to 2,750,000*l*.

CHAPTER VII.

MINING PRACTICE AT KALGOORLIE.

The Town.

THE town of Kalgoorlie cannot but impress the visitor with its air of prosperity, with its public buildings, banks, and hotels, built of brick and stone, rapidly replacing the corrugated iron and wooden "shanties" of a few years back,—although some of these latter still linger in the main streets, to remind one of the "canvas town" and "bush shelters" from which Kalgoorlie has sprung. The contrast between present and past, as you gaze on the town at night from the balcony of, say, the Palace Hotel, is rendered all the more striking when lighted up by electricity.*

The streets or avenues are exceptionally broad, like a town in Queensland, or an American "city," skirted by the familiar wooden side-walks, sheltered from the fierce glare of the tropical sun by verandahs supported on wooden posts, generally provided with a hook to "hitch-up" a horse to, and turned at Christmas-time into veritable groves of evergreen, with eucalyptus-boughs, cut and brought in fresh from the "bush."

Outside the town the side-walks are of extra width, the outer portion forming a well-beaten bicycle-track or camel-path, along which a caravan of camels, in charge of their native Afghan attendants, could formerly frequently be seen starting "up-country"; whilst bicycles are now largely used for going about, when speed is an object, in place of horses and buggies, owing to the flatness of the roads.

Land and Mining Booms.

1895–1897 witnessed a land boom, the Government, it is said, realising, in November 1896 alone, 41,235*l.* from the sale of land

* The Electric Power and Lighting Corporation has, it is said, entered into a contract with the Kalgoorlie-Boulder Tram-line for the supply of electric power, and several of the leading mines propose to utilise electric power. The first section of the tram-line from Kalgoorlie to Boulder, including the principal streets in Kalgoorlie, was expected to be opened for traffic by the beginning of June, and the official opening by the Mayor took place on May 20, 1902. The line to Boulder is now completed.

in Kalgoorlie (town lots with 66 feet frontage on the main street commanding as much as 5000*l.*). This was, however, followed by the inevitable reaction, and the mad speculation which took place was succeeded by a period which gave pause for more sober reflection, affording a parallel to the still earlier mining boom which is associated with Coolgardie.

To quote Mr. T. A. Rickard * :—

"Looking back over the history of the four years, 1892–1896, as told by prospectuses, reports, and abandoned mines, one stands aghast at the monumental foolishness written on every page of it. The original cause of it all was the finding of small pockets of specimen-ore. At the Londonderry, for example, 8000 oz. of gold, valued at over 30,000*l.*, were taken out of a hole not more than 2½ feet deep, 6 feet long, and 5 feet wide. The diggers who owned the claim sold it for 180,000*l.*, and it was then floated in London for 700,000*l.* The pocket on whose richness the value of the mine was based did not continue even one foot deeper than the prospector's 'golden hole.'"

"There is no doubt that many men, comparatively experienced, were carried away by the sight of gold in such unusual quantities, and failed to realise the essentially restricted character of these phenomenal discoveries.

"There were many cases, also, where small cross-veins so enriched a large lode at the place of intersection as to deceive the unwary. In the general bewilderment, due to chicanery and ignorance, it was easy to impute the reputation of a gold vein to a barren 'buck reef,' on the most slender evidence. The general result is expressed by the fact that over 15,000,000*l.* is estimated to have been 'invested' in West Australian 'mines' during these three years.

"There were very few capable and honest men on the spot at the time, and they were compelled by the force of events to keep in the background. The promoters paid those who piped their tune."

As a consequence, the profession was "rendered ridiculous by ship-stewards, plasterers, hotel-keepers, newspaper reporters, and many others," whose failure in their own walk of life led them to pose in the more lucrative guise of 'mining experts' (!) borne along on the wave of mining excitement when the reports of any charlatan will obtain credence, and mining engineers, as a body, paid a heavy penalty for this.

* *Eng. and Mining Journal*, April 16, 1898.

Shoals of globe-trotting "salesmen" spent their time hunting for "wild-cats" with presentable skins for the London market, and "of the few men who really possessed experience, and knew better, some proved too weak to resist the temptation of becoming suddenly rich. Their names are now by-words among the very people whose schemes they furthered." The early annals of other fields can scarcely show an equal to the bogus financiering and engineering which were the motive forces behind the boom of 1895; and when the awakening came, worthless mines were shut down, machinery was left to rust on the ground, and abandoned shafts were turned from profitless gold-mines into useful, if less profitable, water-wells.

The confidence of those who believed in Western Australia was rudely shaken, and a severe financial panic set in, which seemed destined to check the progress of the Colony, and jeopardise its future for years to come, when, in April 1895, the Great Boulder mine at Kalgoorlie made a 10-oz. crushing, and heralded the beginning of the growth of the Kalgoorlie Gold-fields.

In 1898, Mr. H. C. Hoover * stated, that out of 580 mining companies promoted in Western Australia during the "boom," not more than 18, or about three per cent., could be termed large mines; still, they leavened the loaf, and were mines of which any gold-field might be proud, eight or nine being situated at Kalgoorlie, and the others scattered over a wide area. It must be recollected, however, that the country, even now, possesses vast tracts still unprospected, and comparatively recently a very promising gold-field was stated † to have been discovered at Phillips River, 170 miles east of Albany. The Edjudina find, about seven miles west of Kookynie, near Menzies, is a yet more recent discovery; and, writing from Kalgoorlie on August 10th, 1901, the special correspondent of the *Financial Times* said:—"What promises to be a valuable discovery has been made about 15 miles out of Kalgoorlie, and at a spot about four miles due south of the old Golden Ridge mine. A good deal of dollying has been done, and as a rule the prospects run between two and three ounces. If the reef, which is apparently three or four feet wide, carries 2-oz. values at a depth of 50 feet, then the owners will have a valuable property, for the stuff can be easily mined and milled. The place rejoices in the name of The Waterfall." This shows how little is yet known, even of the neighbourhood of the big camps.

* *Eng. and Mining Journal*, Dec. 17, 1898.

† *Financial Times*, Aug. 31, 1900.

The 18 mines referred to by Mr. Hoover (p. 147) are credited with having produced, up to June 1898, a total of 642,284 oz. of gold, from 295,096 tons of ore. The average value of the ore may therefore be taken at 2·15 oz. per ton, whilst it can safely be reckoned that 1 oz. more was left in the tailings. Their aggregate market value was at this time (1898) estimated at over 12,500,000*l.* sterling, and there were 1787 "stamps" at work, distributed in 186 mills, or less than an average of 10 stamps to each plant.

As might consequently be expected, when the large quantities of low-grade ore, which many of these mines possessed, came to be worked on a more extensive scale, upon the erection of larger mills, "two-ounce returns," for which these early days were remarkable, became rarer; and it was found, in fact, that it was more profitable to crush lower-grade ore in larger quantity, in proportion as expenses decreased and more economical methods of handling and treatment were introduced. The high cost with which Australian mines were at first saddled, were due amongst other causes to inefficient management, unskilled labour, defective equipment scarcity of timber and bad water, expensive freight-rates, and the severe conditions of labour, which necessitated high wages.

The Boulder Group of Mines.

The situation of the leading Kalgoorlie mines near the Boulder township, has already been described in a previous chapter, and the general position of the principal leases is shown on the convenient little pocket-map (Fig. 26) published by Mr. H. T. de la Crouée, which the Author has been permitted to reproduce. Its scale precludes the possibility of showing the topographical features, area, and official numbers of leases, the position of the main shafts * or the underground-workings, but these can be ascertained from larger plans of the field, such as Messrs. Clarke and Co.'s,† Messrs. Bewick, Moreing and Co.'s ‡ map, or that of the Cie. Belge des Mines d'Or Australiennes † (June 1902). It is difficult to epitomise one's impressions of a mining camp like Kalgoorlie, but its principal features may be summarised under the following heads.

Nature of the Ore Deposits.—This subject has been already dealt

* It may be mentioned that the collar-set of Judd's shaft on the Associated Gold Mines lease, is stated to be 1327 feet above sea-level; the Great Boulder is about 1227; and Kalgoorlie is 1240.

† Obtainable through the *Financial Times*, 72 Coleman Street, E.C.

‡ Published as a supplement by the *Bullionist*, June 25, 1898.

with in Chapters IV. and V., in which their geological features and mineralisation are discussed at length.

It may be remarked, however, that the "lode-formations," on

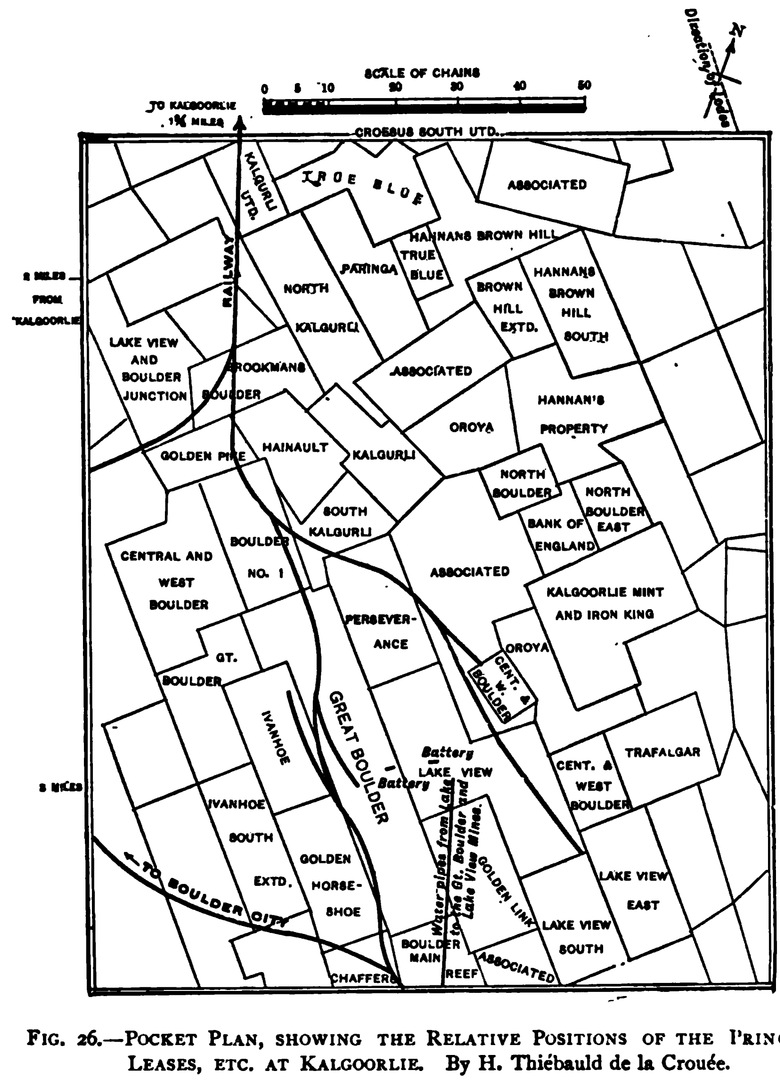


FIG. 26.—POCKET PLAN, SHOWING THE RELATIVE POSITIONS OF THE PRINCIPAL LEASES, ETC. AT KALGOORLIE. By H. Thiébauld de la Crouée.
(Reproduced by permission.)

the extreme eastern side of the field, present certain features which seem more or less to distinguish them from those on the western side; as they follow a different "course," and the ore-bodies they carry are of a more isolated character; partaking, it would appear in some cases, more of the character of "pipes" or "chimneys" than of a succession of lenses. Moreover, the lode-formations on the western side of the field, comprising the Ivanhoe, Golden Horse-shoe, and Boulder, or what are known as the Western Reefs, present considerable differences to the belt of country lying immediately east of them, in the centre of this auriferous area. The chief points of difference seem to be (1) that the country rock in the Australia, Kalgurli, and other leases is frequently of a greyish colour and felsitic character, whilst in the mines further west it is, generally speaking, of the dark-green, porphyritic, or granitic type found in other parts of the gold-belt (which may be regarded as the more characteristic of the two); (2) that whilst the Western Reef formations are as a rule narrower, the ore-bodies they carry, generally speaking, seem to possess greater continuity, and to partake more of the character of the gold-shoots in an ordinary lode; whilst their "gangue" has all along been more quartzose than that of the "formations" east of them, and seems to be becoming increasingly so; for these reasons the future of the western formations in depth appears to be the more assured. Conversely, the ore-bodies in the middle series of formations, termed the Eastern Reefs, present rather the character of a succession of lenses, which are often individually of very large dimensions, but are of a more isolated and irregular character.

These differences may possibly be due to the fact that some of the ore-deposits were formed at different periods and under different geological conditions, and that the eruptive dykes, to which they appear to owe their origin, were in some cases of a more acid, in others of a more basic character; so that the conditions under which the ore-bodies were formed and the gold was deposited in them, were not altogether the same.

Prospecting.—In the early history of the field, an immense amount of money was wasted in sinking small prospecting-shafts. The leases held by any one company varied in size from 10 acres up to 85 acres, but seldom exceeded 50 acres, and leases of only 24 acres in area were frequently found dotted with half-a-dozen or more shallow pot-holes,* notwithstanding the fact that most of the

* The small prospecting-shafts sunk in search of alluvial only measure about 2 by 4 feet as a rule, one reason being that as they are untimbered (except for being "logged-up," and perhaps "lagged" with a few poles, *near the surface*) they are less liable to cave, and sinking can be carried on with a windlass and "hide bucket" to some depth.

lode-formations dip at high angles (approaching the vertical) and the surface-zone is much unsettled; consequently, even to-day, many properties are by no means thoroughly explored.

A great deal of capital may, it is true, be easily squandered in objectless prospecting, whether by sinking shafts where they are not required, or by cross-cutting long distances where there are no indications to warrant outlay of the kind; but at Kalgoorlie, it must be recollected, you have a succession of parallel "formations," some of which may be termed "blind lodes" that never reach the surface at all. Moreover, the ore-bodies in the different "formations," recurring as they do in large isolated lenticular masses (containing perhaps, individually, thousands of tons of rich ore, separated along the course of the deposits by many feet of barren ground), are split up into vertical bands by parallel sheets or "horses" of worthless lode-matter, whilst the ore-bodies themselves are liable to be faulted and in part displaced, and "subsidiary lenses" are often found as outlying "bunches" in the walls of the principal formations. Under such circumstances as these, before a lease can be said to be thoroughly tested, it requires to be *well cross-cut* at various levels. The length and direction which such cross-cuts should take is, however, by no means altogether arbitrary, being governed by the discoveries on the surface and developments made under ground, as well as by the position that each property occupies in relation to the course of the "formations" discovered in neighbouring leases; assuming that they may be expected to traverse the adjoining properties in a certain direction, unless any faults or breaks seem likely to throw any particular "formation" out of its proper course. Exploratory work of this kind, in fact, requires to be based on indications and rational assumptions, which point to the probabilities or otherwise of finding a body of pay-ore in a particular part of the ground; and if waste of money is to be avoided, the point to be determined is the shortest and least expensive way to reach it, either by cross-cutting or boring from existing workings, or by sinking or boring from surface in a new place.

Where the width of a lease is considerable, it would seem to be the best policy, under ordinary conditions, to sink an independent prospecting-shaft, for cross-cutting the shallow ground when looking for "a formation"; but if considerable depth has been reached, it would be cheaper, as a rule, to put out exploratory bore-holes or cross-cuts from the main shaft in search of a "blind lode," to prospect for lateral ore-bodies; or in order to see if (as has not unfrequently happened) any improvement has taken place in depth in "a formation" known to traverse the lease, but which has proved more or less barren at surface.

An instance of a "blind ore-body" is given* by Mr. D. H. Lawrance, who mentions that at Hannan's Crœsus a "shute" of ore averaging 14 oz. to the ton was discovered in the early days, at a depth of 120 feet, whereas 60 feet below the surface no trace of the ore-body occurred. The *Financial Times* correspondent at Kalgoorlie, writing on August 10, 1901, said: "The Crœsus Proprietary has proved the existence of the Eclipse lode at a depth of 500 feet, and for a width of about 3 feet the body shows good values and would certainly pay to treat. He adds: "Development work lately carried on in the Eclipse lease proves that the same lode does not live above the 300-feet level." To the foregoing instances might be added the discovery of a "caunter-lode" in the Great Boulder main shaft at 898½ feet, reported to be 6 feet wide, dipping south, and assaying 18 dwt.; whilst it may also be observed that the new make to the west of the "west lode," as shown on a section (given in the *Statist* of July 28, 1900) which is taken through the cross-cuts from the main shaft, does not appear to run much above the 500-feet level. In the letter already referred to of the correspondent of the *Financial Times*, dated August 10, 1901, he remarked, "The cutting of a totally new ore-body at the 1300-feet level in the Great Boulder also bears out the argument in favour of deeper work, and where the ore occurs in lenses, as on the Kalgoorlie field, it is impossible to say, until much deeper work is done, what the future of the mines is to be. Mr. Hamilton is greatly impressed with the value of the discovery at the Great Boulder at 1300 feet,† and he is of opinion that the ore will be found to live to very great depth." In the Associated Gold Mines lease, a cross-cut from Tetley's 600-feet level, run to connect with Judd's shaft, was reported in September 1900 to have

* 'The Kalgoorlie Mines of the Great Western Australian Gold Backbone,' *Trans. Inst. of Mining Engineers*, vol. xv.

† It appears from the Company's Annual Report to December 31, 1901, that this discovery was made in cutting the "plat" on the west side of the shaft, where a lode having a width of 4 feet 6 inches and a value of 20 dwt. was found, dipping west 1 foot 6 inches in 6 feet.

cut a new ore-body (the No. 2 Cross-Lode) 300 feet to the east, 9 feet wide, worth about 23 dwt. A more recent case that came under the Author's notice was described in a cable to the *Statist* of October 5, 1901, as follows :—" South Kalgurli, at a depth of 723 feet, a body of ore has been intersected, the width being, as far as can be seen, 3 feet, assaying 30 dwt. In the manager's opinion it is an entirely new deposit."

Other instances might be given where the surface indications have been slight, and yet *valuable "ore-bodies" have been discovered by sinking*, a notable one being the North Boulder, where the existence of a wide lode formation, which was afterwards found averaging 1½ to 2 oz. to the ton, remained unsuspected during the first eighteen months' prospecting; and in August 1901 a bore-hole from the 600-feet level passed through a formation in the same lease 12 inches wide (100 feet east of the main shaft), an assay of which gave 3 oz. per ton. Again, the Kalgurli gold-mine, in which the prospectors merely discovered a small patch of rich ore near the surface, was proved afterwards by developments at the 200-feet level to contain an ore-body which is stated to have been 60 feet in width, in one place averaging some 4 oz. per ton; whilst an important new discovery of oxidised ore (averaging 1 oz. 5 dwt.) was made in 1902 in the North Kalgurli.

On these grounds, the evidence strongly favours the assumption that judicious *cross-cutting in depth* in some of the leases within the *main gold-belt* may probably result hereafter from time to time in making important discoveries.

In support of this view, I may quote the remarks of the special correspondent of the *Financial Times*, in a letter dated July 27, 1901 :—" A development of very great importance to the Kalgoorlie field occurred in the early part of this week on the North Block of Hannan's Oroya, the diamond drill having cut the Associated Northern's run of ore, at a depth of 555 feet. The drill travelled through 20 feet of lode matter, and values for that distance averaged 8 oz. per ton, but one section of the core gave an assay of something like 50 oz." *

* A cross-cut subsequently put out at the No. 6 level east from Pomeroy shaft, to prove this discovery, passed through 42 feet of lode-formation assaying 55 dwt. per ton; and for a width of 30 feet assayed 3½ oz. to the ton. A drive (No. 5) started north on the hanging-wall of this ore-body (8 feet wide) and advanced 75 feet, is stated to have shown an average assay value of 10 oz. 15 dwt. per ton. Company's report to March 31, 1902.

To avoid long and expensive cross-cuts, and save time, *long* single exploratory "bore-holes" are not unfrequently run out with diamond-drills, to cross-cut the ground, and valuable discoveries have certainly been made in this manner. But it is rather doubtful whether such a plan, speaking generally, is always satisfactory for mere prospecting purposes, since the results are sometimes misleading, should a "formation" be intersected in an exceptionally rich or poor spot, the section of a bore-hole being very different from a section that can be inspected and tested from a drive; and even if a rich formation happen to be discovered, time and money are lost in getting at it to open it up. The conditions are in fact totally different from those on the Rand, and in other places, where deep exploratory bore-holes have been, no doubt, sunk with great advantage.

A leading article in the *Financial Times* of October 2, 1901, on the Tarquah bore-holes, which I venture to quote, puts the case in a very plain and practical manner, as regards "*banket-beds*," which any business man can perfectly easily understand; and what is true of West Africa and the Rand applies with far greater force in the case of the Western Australian "formations":—

"As to the value of the ore, when a bore-hole does penetrate the reef, the market is apt to attach exaggerated importance to the matter. The demonstration of the continuance of the banket-beds is of the highest consequence; the value at a given point is of no significance whatever.

"From the way in which the assays of the cores taken are either extolled or sneered at, it might be supposed that a reef is of the uniform quality of a cheese. But although banket—as demonstrated on the Rand—usually contains a certain average quantity of gold throughout a considerable stretch of reef, in contradistinction to quartz bodies, in which the precious metal runs in "chutes," the value within a small radius is very variable. Here the gold may lie thick; a few inches away the stone may be poor, and then may come another rich splash. If on the Tarquah field, the ore is rich here and poor there, it must be the merest chance whether a bore sunk strikes a good or a bad section. Of much greater concern is the width of the reef shown. This also would naturally be variable, although not in the same degree, and inferences drawn from the core extracted may be somewhat misleading, owing to uncertainty as to the dip of the reef, and possibly a deflection * of the bore. Exploration by means of bore-holes is useful, because it roughly demonstrates general conditions; but exaggerated importance should not be attached to any particular result."

No better system can be employed, however, at Kalgoorlie or elsewhere, for testing the ground on either side of a level following "a formation" (particularly when it happens to be a wide one and carries irregular lenses and bunches of ore), than by putting in *a number of short cross-cut holes* for distances up to 100 or even 150 feet in length. Still, even these at times prove disappointing, and, as a case in point, the discovery reported in the Great Boulder in a bore-hole put out west in the vicinity of No. 2 air-shaft (478 feet north of Robertson's 100-feet cross-cut east) on Robertson's lode may be cited, an oxidised ore-body having been cut, reported to be 2 feet 6 inches wide, assaying 5 oz. It was, however, subsequently stated † that further trials had failed up to date to locate any valuable extension of this; and, under the head of "diamond drilling," Messrs. John Taylor and Sons remarked:—"A great deal of evidence disclosing information of geological interest was obtained, but we regret that in only a few cases discoveries of commercial value were made." During the year 1898 the Great Boulder did 1250 feet of diamond drilling; 4802 feet in 1899; and no less than 6977 feet in 1900; whilst 4328 feet 6 inches were bored in 1901. In the year ending March 31, 1901, the Associated put in 4088½ feet of diamond-drill holes, or an average of 340 feet per month; and 5458 feet up to the same date in 1902, an average of 455 feet per month.

Boring is done on "day-pay" and contract, the cost varying with the size of hole, nature of the ground, price of "carbons," etc.,‡ but I believe 17*s.* 6*d.* to 22*s.* a foot (compressed air being supplied by the company) will cover the cost of most of the ordinary size deep holes put in up to date; whilst under favourable conditions, small size holes may be drilled for 5*s.* 6*d.* per foot. Power (steam) for

* By the use of special instruments the dip and deflection can be ascertained, and the results checked.

† *Annual Report*, 1900, p. 48.

‡ The price of carbons per carat in London, in July 1900, reached, I have been informed, the high figure of 14*l.* 10*s.*; but in September 1901, carbons (1 to 6 carats) were quoted at the low price of 7*l.* 5*s.*; an average price being probably in the neighbourhood of 9*l.* to 10*l.* per carat. Borts could be bought for 2*l.* to 3*l.* 5*s.*; 6 to 8 stones of 1½ to 3½ carats are required per bit of ordinary size. The wear is reckoned on the Rand at about 1 carat per 15 ft. bored.

supplying air is reckoned to cost from 1*s.* 6*d.* to 2*s.* a foot all round; whilst the cost for electric power is said to run about 6*d.* a foot. At the Great Boulder, power is supplied by an oil engine.

The Author is informed that the cost of some of the *large size* "plants" employed for drilling long-holes runs from about 800*l.* to 1200*l.* on the spot. Sullivan's H-drill giving a 1⅛-inch diameter core is, as far as he knows, about the largest size in general use on the field, but for short holes (up to 300 or 400 feet) the smaller machines are almost equally effective, and handier to work underground. Owing to the liability of breaking up the softer parts of the core,* which are often the richest, the fine material washed out of the bore-hole should be settled and assayed. Compressed air is expensive for running drills of this kind, and the Sullivan Company have lately designed an electric drill, for which certain advantages are claimed. At a depth of about 600 feet in the North Boulder mine, drilling through hard ground, an electric drill made the satisfactory record of 231 feet bored on contract in five working days; and the cost of power was reported to be less than using compressed air.

Development by Shafts, etc.—Baron van Oldruitenborgh † expressed the opinion that a great mistake was committed by several companies in the early days, by sinking nearly all their vertical or main shafts within the "hanging-wall country" of the lodes, to reduce the expense of cross-cutting; notwithstanding that this item in the cost of development is liable to constantly increase with depth, if the shaft is sunk in the footwall, unless the underlie of the "formation" changes. It is true that the former course is justifiable in most cases, if the "hade" of the lode departs much from the vertical; but when, as at Kalgoorlie, the "formations" dip usually at a very high angle, no doubt it would have been better, speaking generally, to sink on the "footwall" side.

The trouble, however, no doubt was that no one could tell at the start, what alteration might take place in depth in the inclination of the lodes, and if they had gone off flat in depth, a shaft in the footwall might have added considerably to working charges, which few managers would care to risk. The situation of some of the shafts, however, entailed in certain cases danger of

* This is particularly liable to happen with the smaller sized drills.

† 'Technical Observations upon the Coolgardie Gold Fields,' *The Mining Journal*, London.

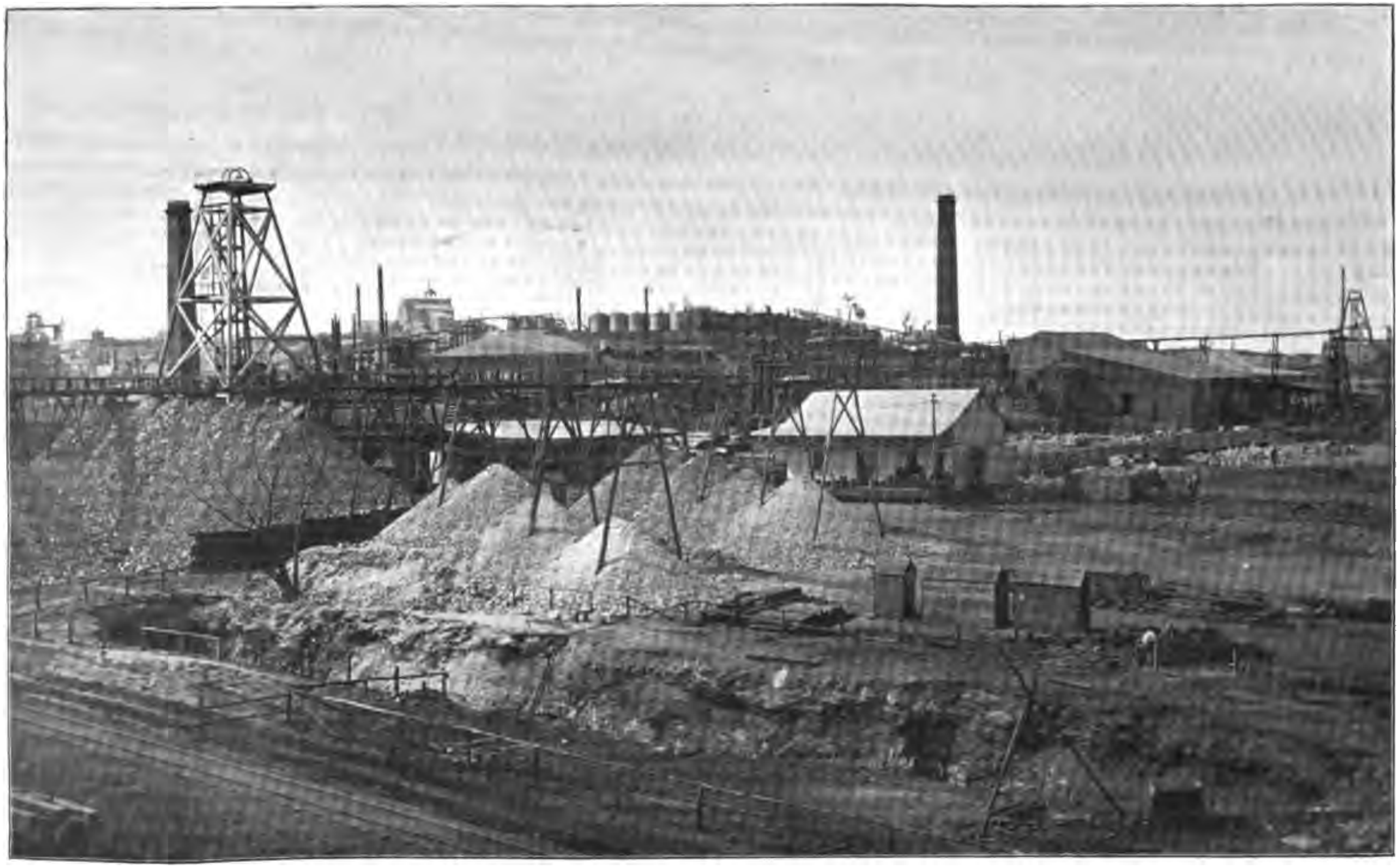


Fig. 27.—General View of the Great Boulder Mine and Works in 1889.

serious injury, when they were not left surrounded by sufficiently large "protection blocks" of solid ground; and in view of this fact, there can be no question, as Baron Oldruitenborgh said, that it was a great pity to have sunk some of the main shafts in the hanging-wall, facing by preference the richest and strongest "ore-shoots," thus entailing either danger of settlement around the shaft, or the loss of a block of stoping-ground 10 feet to 30 feet wide, carrying from one up to several ounces of gold per ton. A worse mistake, however, was, I believe, committed by locating some of the reduction-works and surface-plant on the hanging-wall side of the reefs, close to the line of "outcrop," where the foundations are liable to risk of settlement, and buildings and machinery to injury by removal of the ore below. It is also doubtful in certain instances how far the question of the most advantageous disposition of surface-plant was considered in the early days of the field, in reference to the location of the main working shafts, steam economy, etc.

Shaft Equipment.—The accompanying illustrations (Figs. 27 and 28) show the "poppet-heads" and dumps of the Great Boulder, and the "head-gear" erected at the Ivanhoe mines. Some of the older "head-gears" were both antiquated in design and shaky in construction; but it must be recollected that the same facilities for "haulage" are not even now required as obtain on the Rand and in other districts, where the chief object is to be able to handle *immense quantities* of comparatively low-grade ore, raised from great depths, in the shortest possible time.

The day will, however, no doubt arrive when this will be done at Kalgoorlie; but it cannot be attempted until fresh water is available on the field in sufficient quantity, and the "sulphide question" has been settled—that is to say, "sulphide-ore" can be treated at a lower figure than at present, with absolute assurance of metallurgical success.

Whilst, on the one hand, the great width of some of the Kalgoorlie ore-bodies favours large output, on the other hand, the uncertainty and irregularity in the distribution of the ore (more particularly in some of the "formations") operates the other way, making medium-outputs the rule for the time being. Hence the powerful, but necessarily costly, installations for winding purposes, which are common on the Rand, would, even in its present stage of development, be money thrown away in Western Aus-

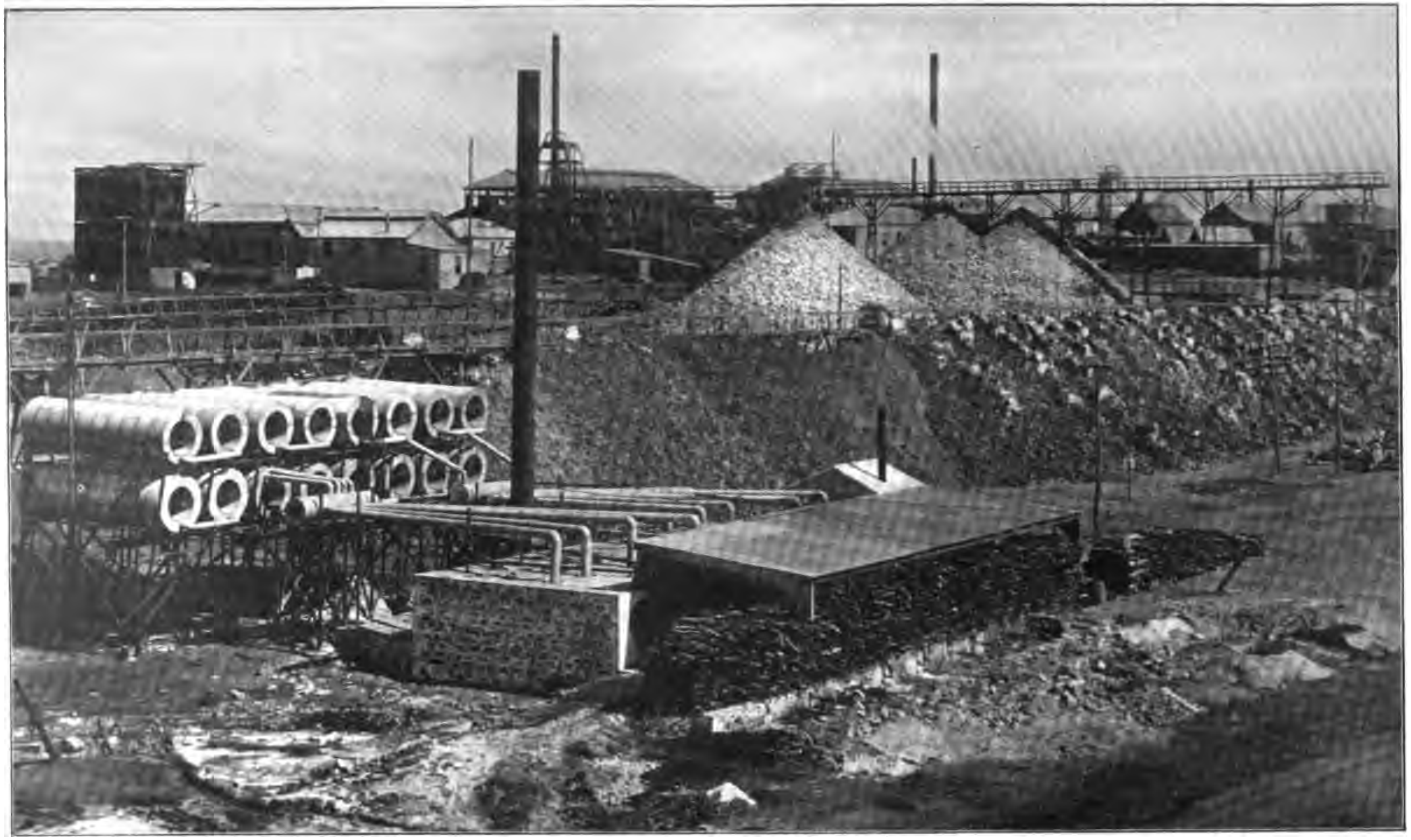


Fig. 28.—General View of the Ivanhoe Mine and Works, 1889.

tralia—a point adverse critics of Westralian management seem to overlook. Heavier loads might, however, be hoisted in some cases no doubt with advantage.* The winding-engine recently erected at the Associated, at Judd's shaft, is stated to be capable of hauling from 3000 feet.

The winding-plant at the Great Boulder main shaft (which is also equipped as a pump-shaft) consists of a first-motion horizontal engine, with a pair of 14-inch cylinders, 3-feet stroke, and 7-feet

FIG. 29.—HEAD-GEAR, AND DUMPS, AT THE GREAT BOULDER MAIN SHAFT.

drums, steam for the engine and compressors being supplied by a set of four high-pressure 6 feet by 24 feet Cornish boilers; two similar boilers were added in 1899.

Mr. Hamilton informed the Author that the "poppet-legs," 85 feet in height, shown in the illustration (Fig. 29), are of karri timber, the legs consisting of four single sticks of round timber, whilst the rest of the framing (which is 15 feet in height) is of sawn timber; there is a landing-stage for the mine-trucks, at a level

* At the Lake View mine, the main shaft is equipped with a Risdon direct-acting engine, and a small Martin's winding-engine for hoisting men, timber, etc.; the load of ore formerly hoisted was 14 cwt., but with proper loading arrangements in the shaft and automatic dumping-skips, it is stated that 800 to 1000 tons of ore could be handled daily. *Report*, Bewick, Moreing and Co., April 3, 1902.

sufficiently high to give good dump-room. Lane's Shaft was equipped in 1899 with a 14-inch by 36-inch double cylinder direct winding-engine, and the engine-shed contains two steam pumps with compound cylinders respectively 9 inches and 16 inches in diameter, and 12-inch water-cylinders, with a 15-inch stroke; these are used to pump the salt water required by the mine to the top of the hill behind the mill.

I am indebted to Mr. Thos. Hewitson for the information that the Ivanhoe main shaft (Patterson's), which was enlarged in 1901 to 13 feet by 5 feet, was equipped with an 18-inch by 42-inch first-motion engine, with 8-feet drums; new exhaust steam-condensers being subsequently added to this plant. Drysdale's shaft is fitted with an 8-inch Cornish lift-pump, which is operated by an 18-inch by 42-inch engine; they have also a geared (2 to 1) 12-inch by 30-inch slide-valve engine, with 6-feet diameter double-drums in the engine-shed. This shaft, which was originally 9½ feet by 4 feet, has been enlarged to 12 feet by 4 feet 6 inches to a depth of 537 feet 6 inches, and below that level is the same size as Patterson's.

The head-gear at Patterson's shaft originally consisted of iron poppet-legs 60 feet high, but new 90-feet poppet-legs have since been erected, and the stone raised is crushed in a No. 5 Gates' rock-breaker, and run into bins which possessed a nominal capacity of 342 tons, from the shoots of which the ore could be trucked direct to the mill. In 1900, on an output of 74,750 tons, hoisting cost 8·838*d.* per ton and ore breaking 1*s.* 2·213*d.*

At the Associated the cost of hauling (charged to ore-extraction) was reckoned at 3*s.* 8·61*d.* per ton on 41,384 tons handled in the year ending March 31, 1902.

When tarred and set in solid blocks of concrete (a plan the Author employed in Queensland), wooden poppet-legs are perfectly safe from the attacks of white ants, which is sometimes put forward as an objection to their use.

At the Lake View mine the four posts of the main "frame-work" are set vertical and strutted with back-struts; but the legs of most of the head-gears are spread outward, requiring no back "struts" with the engine set close to them.

As fuel and condensed water are both expensive items, high-pressure boilers * are mostly employed, and the exhaust steam used to be generally condensed in surface-condensers of the Wheeler class.

* The "water-tube" boilers used at the Associated mine are stated to have given satisfactory results, *Annual Report*, July 1901.

Lately, however, other forms of vacuum-condensers have been employed, as mentioned in the preceding chapter.

Towards the end of 1899 the depths which the principal main shafts had reached were given by the *Statist* (Oct. 21) as follows :—

Associated G. M. Co., Tetley shaft (Australia lease), 500 feet.
Associated G. M. Co., No. 4 shaft ("Adelaide" lease), 700 feet.
Chaffers, 500 feet.
Golden Horse-shoe, 505 feet.
Golden Link Consols, 800 feet.
Great Boulder Proprietary, 900 feet.
Great Boulder Main Reef, 400 feet.
Great Boulder Perseverance, 536 feet.
Hannan's Brown Hill, 498 feet.
Ivanhoe (Patterson's), 500 feet.
Kalgurli, 420 feet (winze from 420 level sunk to 520).
Kalgoorlie Mint, 500 feet.
Lake View and Boulder Junction, 607 feet.
Lake View Consols, 500 feet.
Lake View South, 768 feet.

etc.

The depths that these and other shafts are reported to have attained at the end of 1900 (unless otherwise stated) are shown in the following table :—

—	Depth. ft.	Depth. in.	Date.
			1900
Great Boulder Main Reef G. M. Co. (main shaft)	800	0	Sept. 30
Kalgurli G. M. Co. (main shaft)	660	0	July 31
Lake View Consols G. M. Co. (main shaft)	700	0*	Aug. 31
Golden Horse-shoe Estates (main shaft)	730	0†	Dec. 31
Golden Link G. M. Co. (main shaft)	930	0	Dec. 31
Great Boulder Proprietary G. M. Co. (main shaft)	1209	0	Dec. 31
Great Boulder Perseverance G. M. Co. (main shaft)	700	0	Dec. 31
Hannan's Star G. M. Co. (main shaft)	471	5	Dec. 31
Do. (Donoughmore shaft)	492	2	Dec. 31
Ivanhoe G. M. Co. (Patterson's shaft)	573	0‡	Dec. 31
Do. (Drysdale's shaft)	525	0	Dec. 31
North Boulder G. M. Co. (main shaft)	548	0§	Dec. 31
South Kalgurli	614	0‖	Sept 30
			1901
Associated G. M. Co. (Judd's shaft)	708	6¶	March 31
Do. (Tetley's)	621	0**	March 31

* On August 31, 1901, this shaft had reached a depth of 972 feet, and was down to 1000 feet in September, when driving was commenced. It had reached 1127 feet at the end of March 1902. † Total depth December 31, 1901, 830 feet.

‡ Total depth December 31, 1901, 732 feet. § Since sunk to 648 feet.

‖ Sept. 30, 1901, 723 feet. ¶ Since sunk to 1073 feet, March 31, 1902.

** Tenders called to sink another 200 feet in September 1901 ; March 31, 1902, depth 822 feet.

Writing on August 3rd, 1901, the manager of the Golden Link mine, referring to No. 3 shaft (12 feet by 4 feet 6 inches in the clear), said it should be sunk to the 1080 feet level as soon as possible, and in order to carry out this work, he proposed to install a first-motion winding-engine and two boilers, of similar design to the plant at the main shaft, but with 20-inch cylinders instead of 16-inch, and 5-feet stroke instead of 4-feet, to ensure rapid hauling from a depth of 2000 feet, as it would be false economy to put in a smaller engine and have to replace it with a larger one in two or three years' time. He added: "The cost of machinery and boilers is considerably greater than it was when the winding plant at our main shaft was procured, and I estimate the total cost of purchase, transport, and erection of winding-engine, two boilers and stack, including two lengths of steel wire-rope 1⅛-inch diameter and 2000 feet long each, and also two pit-head pulleys 10 feet in diameter, but not including new poppet-head gear, at 4600*l*."

This plant would, it is stated, form the principal hoisting machinery for supplying the reduction works. Being the deepest shaft but one (the Great Boulder) on the field, these particulars may be of interest.

At the end of July 1901 the Golden Link main shaft (10 feet by 4 feet in the clear) was down to 1100 feet, and the Great Boulder Proprietary to 1371 feet 6 inches, these being the greatest depths reached on the field up to that date. A *British Australasian* cablegram of October 9, 1901, said: "On the Great Boulder Proprietary Company's mine at the 1400-feet level, the bore has cut the lode 100 feet west of the shaft. At the point of intersection, it is 7 feet wide,* and assays 28 dwt. to the ton. The discovery is of immense importance, as demonstrating the continuance in size and value of the Kalgoorlie lodes in depth. Cross-cutting at the 1300-feet level has been commenced." According to a cable dated October 31, the 1200-feet level was opening up splendidly, both faces showing values equal to any of the higher levels. At the end of 1901, the total depth of this shaft was 1431 feet; and at the end of 1902 it had reached over 1600 feet in depth.

It must be confessed that the depths of the majority of the shafts, considering the age of the field, are by no means extra-

* Four feet of schist assaying 5 dwt. per ton, and 6 feet of quartz assaying 28 dwt.

ordinary, and some properties would undoubtedly have benefited by more energetic sinking; but, notwithstanding, various mines in the early days of the field were able to block out reserves of ore considerably in advance of their mill capacity, and they no doubt awaited a settlement of the water and sulphide difficulties before inaugurating a more active policy of development,—since, although it would probably have benefited their "shares" from an investment point of view, a large sum of capital would thus have been temporarily locked up.

On the other hand, the effect of developing large reserves of ore, without having the machinery necessary to deal with a correspondingly large output, would assuredly have resulted in an early demand for the immediate installation of sulphide-reduction machinery, regardless of the difficulties which faced its erection; and, consequently, vastly larger sums of capital would probably have been thrown away on unsuitable "plant" than have been actually lost in this manner, to the detriment of the field, and investors in West Australian mines.

The chief cause operating against deep-sinking, however, was undoubtedly the fear lest these deposits should prove to "peter out" suddenly in depth, and people were afraid of spoiling a good show, and ruining the market at the time being, by running risks on mining chances (which are liable to be fickle though they may seem most fair), sooner than circumstances compelled them to do.

Interesting no doubt from a general mining stand-point as proofs regarding the permanency or otherwise of the "telluride formations" in depth might be, in all probability, no one felt particularly anxious, individually, to face either the "bulls" or the "bears" in the Stock Exchange arena earlier than was absolutely necessary, and not unnaturally perhaps preferred to leave that honour to somebody else!

Like many other engineers, the Author, after seeing the developments of most of the principal mines of the Field in 1898, felt but little doubt, upon geological grounds, as to their immediate future; familiarity, however, with the risks run in opening up ore-deposits in *new* fields, instead of breeding contempt (as many kinds of risk do), has generally exactly the opposite effect on the large majority of people brought in close contact with them; which no doubt explains the general hesitation there was at first to sink.

Mr. Hamilton, M. Inst. M.M., of the Great Boulder mine, and other managers, however, with commendable nerve, in the belief that the "formations" would hold down,* led the way where others feared to tread, for which they are now reaping well-deserved credit. Had they been mistaken, however, it would have blackened more than one professional reputation for a decade at least, and as the reward of their enterprise, they would assuredly have been anything but blessed by some unreasonable people, who crop up like daisies, as a matter of course, if their hopes happen to be disappointed.

Judging by my own experience, shareholders in mines, as a rule, treat their engineers with every possible consideration, but when, not unnaturally perhaps, irritated by want of success—if I may be excused for saying so under the circumstances—they are apt at times, perhaps, to forget that engineers are neither responsible for, nor always able to forecast the vagaries of ore-deposits. This is unreasonable, because people who go in for mining must be well aware of the speculative risks with which it is surrounded; but it is these very risks that allow of corresponding chances of large profits, which are its chief attraction to people who are in a position to speculate. All that the mining engineer can do is to place the actual facts before his employers, and take every precaution to reduce the inevitable risks to the smallest possible dimensions.

It is manifestly, indeed, to the interest of investors in mines, and purchasers of mining property in particular, to know the true state of things, whether palatable at the moment or not; and engineers act wisely in refusing to forecast events, unless they have the necessary data upon which to form an opinion; a view that is, I believe, gaining ground in commercial circles.

Shaft Dimensions, Speed and Cost of Sinking, etc., compared with other Districts:—Mr. E. S. Simpson † states, that the main

* In this connection it is interesting to note that the Great Boulder had reached a depth of 1000 feet in June 1900; whilst in a report dated July 20, 1901 (*Financial Times*, August 29, 1901), the manager of the Golden Link reported that at 502 feet south of the main shaft at the 930 feet level, "the feather edge of a new lap of ore starts to come in on the east side of the lode," adding, "there is a narrow streak 6 inches wide of heavy pyritic ore on the footwall side of the new lap, which in the face (505 feet) is worth slightly over 5 oz. of fine gold per ton. What this lap will eventually prove to be I cannot say, but at present, appearances are distinctly favourable. The length of ore driven on within our east boundary at this level gives promise of excellent results at the 1080-foot level."

† Discussion of Mr. Bancroft's paper, *Trans. Am. Inst. of Mining Engineers*, vol. xxviii. p. 810.

shaft of the Associated, 12 feet 6 inches by 4 feet 6 inches section, was sunk 32 feet through hard diorite in one week; and I am told that the Lake View and Boulder Junction shaft was put down between the 200 and 520 feet levels, at an average of 60 feet a month under Mr. Frank Grace, the best sink being 44 feet in 12 days. These, so far as I know, are about the highest records that can yet be shown; but as a rule, it may be said (when compared with the Rand,* and even with other places in Australia) the speed in shaft-sinking is not very rapid.

Whilst reasons that may have accounted for this, in the early days of the field, have already been explained, the slow rate of sinking that has obtained, was doubtless to some extent due to want of skill on the part of some of the men employed, few of whom possessed experience in "machine-work"; and may also be partly attributable to the "blue-ground" being no doubt harder to drill, and not such good breaking-ground, as the quartzite and sandstone formations of the Rand; added to which the comparatively small size of the principal shafts at Kalgoorlie militated against record speeds. They were most frequently (unless mere prospecting shafts, which are mostly 8 feet by 4 feet) 10 feet by 4 feet inside lining-timbers, and an ordinary contract price for sinking and timbering (covering labour only), was about 5*l.* a foot.

The Author is informed that the contract price for sinking shafts (10 feet by 4 feet up to 12 feet by 4 feet) in 1897 might be usually

* The rate of sinking in South Africa in the outcrop mines ranged as a rule from 60 to 96 per month, but as high a rate as 141 feet a month sunk (using machine-drills) and 147 feet timbered, was reached in December 1896, in the Vogelstruis Deep 3-compartment vertical shaft; whilst in July 1897 the Clement shaft (5-compartment) of the South Rose Deep was sunk 156 feet with hand labour, and timbered 147 feet; and the Angelo Deep (4-compartment) West shaft was put down 164 feet and timbered 150 feet in August; the drilling being done by hand. The highest record of any belongs however to the Howard deep-level shaft of the Consolidated Gold Fields (where 203 feet were sunk in one month), and the Howard and Catlin shafts averaged for 12 months $146\frac{1}{4}$ and $145\frac{3}{8}$ feet a month, respectively. It seems therefore safe to assume that 120 feet a month or more, including cutting pump-stations, may be looked upon as a safe average rate on the Rand in the future (down to a depth of 2000 to 3000 feet), and the cost may be taken at about 22*l.* per foot. In a deep Queensland shaft the Author has made speeds in hard Charters Towers syenite varying from 63 feet to 72 feet per month timbered, at a cost of about 11*l.* 10*s.* 6*d.* a foot, including hoisting charges, air-supply and everything. This shaft was laid out and started 14 feet $7\frac{1}{2}$ inches by 3 feet 6 inches inside before I took charge: had it been a handier shape, the above speeds could probably have been exceeded. The sinking of deep level shafts on the Witwatersrand has been very fully and admirably described by T. H. Leggett, M. Inst. M.M., *Trans. Am. Inst. of Mining Engineers*, vol. xxx.

reckoned according to size, etc., at 5*l.* to 7*l.* per foot. Mr. Hoover gave the cost of shaft-sinking in 1898 as $30 (6*l.*) to $60 (12*l.*) per foot (including timber); the average for 12 feet by 4 feet shafts being $35 (7*l.*).* The Author believes that in most cases at the present time about 5*l.* per foot may be reckoned for labour, tools, etc., 30*s.* for cutting plats, air and haulage, and 10*s.* to 22*s.* for explosives; allowing therefore 3*l.* for timber and timbering and 12*s.* for general costs, the total would come to about 10*l.* 12*s.* or 12*l.* a foot, if other development work is in progress.†

At the Ivanhoe mine the shafts run up to 13 feet by 5 feet,‡ timbered with Karri, joggled at the ends. The cost of sinking 12 feet by 4 feet shafts with machines was given me by Mr. Hewitson, in 1899, as 7*l.* 10*s.* per foot, and the average rate of sinking as 42 feet per month.

At the Great Boulder mine, Mr. Hamilton informed me the cost for labour only, in shaft-sinking with rock-drills, in shafts 10 feet by 4 feet in the clear (inclusive of labour timbering) ranged from 5*l.* to 7*l.* per foot in 1899, and the rate of sinking reached about 40 feet a fortnight. The timbering consists of 8 feet by 2 feet sawn timber (Salmon-gut or Jarrah) joggled at intersection of ends and centres, with 2 inch spaces between the sets.

The North Boulder mine No. 3 or main shaft, which is 11 feet by 4 feet, divided into two 4-feet hoisting compartments and a 3-feet ladder-way, down to 400 feet, cost 4*l.* 15*s.* a foot, not including of course timber, tools, and general charges for air and steam. Below the 450 feet level it has been enlarged to 12 feet by 4 feet, and was sunk to a depth of 548 feet in 1899; the last 178 feet cost on the average 6*l.* 5*s.* 6½*d.* per foot, including contractor's wages and supplies, timbering and mullocking, and cutting plats. The greatest speed attained in any one month was 43 feet.

It will therefore be seen that, although the rate of sinking at Kalgoorlie is slow (and one reason for this has been that sinking and development have generally gone on concurrently), these small-

* *Eng. and Mining Journal*, December 17, 1898. In *Mineral Industry*, vol. vi. p. 335, Mr. Hoover mentions that at Menzies, in much harder rock, the cost is about ($100) 20*l.* per foot, and in the East Murchison District as much as ($125) 25*l.* per foot.

† If sinking alone is going on, it may cost between 13*l.* and 14*l.* per foot.

‡ Patterson's shaft below the 500-feet level has been increased to 13 feet by 5 feet; when connection is made with Drysdale's shaft it will be stripped to the surface, at the altered size, so as to admit of larger cages carrying all-round tipping trucks of 16 cubic feet capacity.

size shafts are far less expensive to sink and equip than those of the Rand, where many of the main shafts have cost from 17*l.* to 28*l.* 12*s.* per foot, and, when much water has been met with, to as much as 41*l.* 8*s.*,* an outlay justified, however, by the paramount necessity that exists often on the Witwatersrand, to provide for large outputs and to open up a large area of ground in depth from a single shaft with the utmost possible speed; whilst in laying out these deep shafts it is necessary to provide space to allow of proper ventilation, as well as to give room for air-pipes, etc., in the pump and ladder-ways.

Some of the West Australian shafts are "box-lined" for the sake of cheapness, like most Queensland shafts; † in other cases, as at Lake View, where the ground is perhaps heavier, "square-set" timbering is used, with "lagging driven behind the wall and end plates."

The small area of West Australian leases, and the fact that several shafts have been put down on many of them, also accounts in some measure for the divergencies in practice in one locality as compared with another, upon the merits of which I will not attempt to offer an opinion, as they depend on financial considerations, and other circumstances which vary in each individual case.

Whilst record speeds are liable to entail record costs, it may be said in a general way, that whatever the size of the shaft may be, the quicker it is sunk with a given party of men, the cheaper the cost per foot will work out; and, therefore, the attainment of the highest possible rate of speed, that the local conditions in each case admit of, is a matter of the first importance.

The vertical dip of the "formations," and the irregularity of the ore-bodies, do not favour incline-shafts, though in some instances the lode formations have been followed for some distance on the underlay, as for example in the main incline-shaft at Hannan's Brown Hill.

Hoisting, Cages, Plats and Pumps.—Owing to the small size of the shafts, the average weight of ore generally raised at each hoist was formerly only about 7 cwt.; the hoisting is done at Kalgoorlie, as at Charters Towers and elsewhere in Australia, in

* 'Deep-level Shafts of the Witwatersrand,' by T. H. Leggett, M. Inst. M.M., *Trans. Am. Inst. of Mining Engineers*, vol. xxx. The average cost for a shaft 2000 to 3000 feet deep may be estimated at 22*l.* per foot.

† The shaft at Charters Towers, referred to in the previous footnote, cost 1*l.* 13*s.* 7*d.* per foot "close-timbered," for hardwood (including bearer-sets every 50 feet, and wedges) as well as labour in preparing the timber.

single-deck cages. In collieries there is no doubt that hoisting with multiple-deck cages possesses distinct advantages, but in metal mines, it is questionable whether in a suitably-arranged shaft, with underground "plats" for storage, self-dumping "skips," such as are mostly employed on the Rand, are not preferable to cages, saving dead-weight and time in handling, both underground and by the "brace-men." Skips in incline-shafts are mounted on wheels; the large size skips generally have a capacity of 20 to 60 cubic feet or more (an ordinary load on the Rand averaging about 3 tons).* In vertical shafts smaller skips are carried on frames, running upon the shaft-guides, and usually possess a capacity at Johannesburg of about 30 cubic feet. One advantage of a skip-road is that a "water-tank" can be easily employed for baling if there is no great quantity of water to be raised, and skips are of course indispensable if a shaft turns off from the vertical on to the underlie.

The single-deck cages used in Western Australia, which carry the trucks, are fitted with the ordinary safety appliances and hooks to prevent overwinding, and are usually balanced in the two hoisting compartments of the shaft by leading the winding-ropes over one drum of the engine and under the other.

The end-tipping steel trucks used underground in some mines measure only 8 cubic feet (holding 6 to 7 cwt., according to the size to which the stone is broken and the way the truck is filled, with a "tare" of about 2½ cwt.); in other cases, however, the trucks, as in the Great Boulder mine, have a capacity of 13 cubic feet, and contain three-quarters of a ton or more, which, from the point of view of economy in haulage and transport, is a step in the right direction; the pattern I saw in use, however, in one or two mines, struck me as somewhat cumbersome, and likely to give trouble in handling on "flat-sheets," or if a truck became derailed in a level.

At the various levels, "plats" are "chambered out" the height of the "opening-out set" for the full width of the long side of the shaft, and carried straight in or sloped up from the drive, which is commenced about 20 feet or so beyond. In some of the larger mines the floor is boarded and covered with flat-sheets, and (as shown in the accompanying illustration, Fig. 30, taken under-

* In some of the deep-level mines skips of similar capacity have a tare of about 2½ tons; loads of 5 to 6 tons will, no doubt, be hoisted in the future in the deep vertical shafts.

ground in the Lake View Consols, which shows a landing-place of the kind) they are lighted with electric glow-lamps; in other cases, with oil-lamps. Plats of this kind (12 × 12 feet) cost about 5*l.* to 7*l.* a foot. Pumps are but little needed, it being generally possible to dam back most of the water which comes from the

FIG. 30.—"PLAT," 200-FEET LEVEL, LAKE VIEW CONSOLS.

surface in the upper levels, and syphon it off into skips or water-tanks. Nasty sores are caused if men are much exposed to the salt underground waters.

Air-Compressors and Rock-Drills.—In the soft upper ground hand-labour was necessarily extensively employed. In the hard igneous rocks at a greater depth machine-work is, however, undoubtedly, not only the cheapest, but has become necessary for making rapid progress, although its schistose and jointy nature at times gives trouble with the drills "fitchering." These facts explain why the introduction of machine-work on the field has not been more universal, and appears to have been somewhat backward.

The Associated Gold Mine was formerly equipped with a large Rand compressor at Judd's shaft and a small Ingersoll-Sergeant machine at Tetley's, but the company subsequently erected a very fine new 60-drill air-compressing plant, built by Walker Bros., at their main shaft.

The Lake View mine was originally provided with a compound air-compressor of 22-drill capacity, with 17-inch and 27-inch steam cylinders, 18-inch and 28-inch air cylinders, 4-feet stroke, and Reidler valves; which was supplied with steam by Babcock and Wilcox boilers at 125 lb. per square inch. A new 30-drill Rand compressor was erected, however, in 1901, by which the air-compressing plant was duplicated.

The Great Boulder mine plant originally consisted of one duplex 8-drill compressor; subsequently two compound-steam duplex-air 12-drill compressors were erected; in 1901 an 18-drill air-compressor, with condensing machinery, was installed at the main shaft.

The Ivanhoe mine plant originally consisted of a 12-drill Ingersoll-Sergeant type compound steam and air compressor, with piston-inlet, and Corliss valve-gear; steam cylinders 12 inches and 22 inches; air cylinders $11\frac{1}{4}$ inches and $18\frac{1}{4}$ inches; with a 42-inch stroke. The air being delivered to a 24-feet by 6-feet 6-inch diameter "receiver," of $\frac{5}{8}$-inch steel at 80 lb. pressure, and conveyed by 4-inch pipes below ground. In 1901 a new 20-drill Rand air-compressor was erected, with three Cornish boilers, condensers, etc.

The ordinary air-pressure used at most of the mines varies from 70 to 80 lb. per square inch; but there seems no reason why, given suitable machinery, higher pressures of 90 to 100 lb. should not be employed to accelerate speed.

At the North Boulder the plant consists of a 10-drill Rand air-compressor, and Ingersoll-Sergeant drills are used underground; the plant, including boilers complete, cost (including freight and insurance) about 3900*l*., erected and housed.

Rand $3\frac{1}{3}$-inch and Ingersoll-Sergeant $3\frac{1}{4}$-inch drills, are most in favour on "the field," the latter giving very satisfactory results; but Mr. Hamilton informed me that at the Great Boulder they used both "Ingersoll-Sergeant," and "Bendigo" $3\frac{1}{4}$-inch machines, and find them equally efficient. It is stated * that an electric drill has been tried at the Perseverance with satisfactory results, requiring only 2 horse-power to drive it compared with say 12 horse-power for an ordinary air-drill.

I have no information as to whether the "Climax," which is largely employed in India, or other types of drill in use elsewhere have been tried. Compressed air is used to operate air-winches

* Letter of the correspondent of the *Financial Times*, dated April 12, 1902.

and small pumps underground at times, but pumps are expensive to operate in this way.

FIG. 31.—MACHINE DRILLS AT FACE, 200-FEET LEVEL, LAKE VIEW CONSOLS.

Drives and Levels.—In most of the mines the ordinary levels are run 7 feet by 5 feet, but they are frequently much wider, and are driven at intervals of 100 feet or less, connected by "rises" and "winzes," but in many instances the winzes are sunk straight and are not kept to the underlay of the ore-bodies; "passes" 4 feet by 4 feet in the clear are put up generally about every 50 feet, timbered with 8-inch by 2-inch sawn timber, and closed at the bottom with sliding doors.

In machine-drilling, about 18 holes are drilled in the face to a depth of 4 feet or so, the centre-cut holes converging, and the outer ones radiating at an angle outwards, so as to "square-up" the "face," in the usual manner; $3\frac{1}{8}$-inch and $3\frac{1}{4}$-inch "star, or cross-bits" are used in driving in the "formation"; and chisel-edge bits in cross-cutting.

The employment of machine drills increases speed, but, according to various managers, makes little difference in cost per foot. The accompanying illustration, Fig. 31, shows the face of the 200-

FIG. 32.—LAKE VIEW CONSOLS, 300-FEET LEVEL, FACE OF RICH TELLURIDE ORE.

feet level of the Lake View Consols mine in course of being driven by rock-drill; Fig. 32, a level and "face" of rich telluride-ore; and Figs. 33, 34 and 35, views of some of the levels in the Golden Horse-shoe, which I have kindly been permitted by the Company to reproduce.

Drives of ordinary size, 7 feet by 5 feet, used to cost $11 (2*l.* 5*s.* 10*d.*) to $16 (3*l.* 6*s.* 8*d.*), according to Mr. Bancroft; Mr. Hoover estimated the cost of driving and cross-cutting in 1898 at from 2*l.* to 6*l.*

FIG. 33.—SOUTH DRIVE, NO. 2 LEVEL, NO. 4 LODE (30 FEET WIDE), GOLDEN HORSE-SHOE.

The cost of driving levels in the softer oxidised-formation by "hand" of late years, however, I believe may be reckoned at 1*l.* 5*s.* to 1*l.* 15*s.* per foot, and can be done for less than 20*s.* in some cases. In the deeper harder ground, the cost of driving with machines generally comes to about 2*l.* 10*s.* per foot, including explosives and sharpening drills; but under favourable circumstances levels can be driven on contract (the contractors finding all supplies and doing their own trucking) for 1*l.* 18*s.* upwards. At one mine, according to Mr. H. F. Bulman,* they used to give a bonus to each man of 1*l.* per week if 16 feet was exceeded, whilst 2*l.* a foot extra was paid in another case for rates exceeding 19 feet a week. Mr. Bulman mentions that a cross-cut 7 feet by 5 feet at the 300-feet level was driven 40 feet in a fortnight by 6 men (2 per shift) with machines, doing their own trucking to the shaft 500 feet. He adds that in levels in hard sulphide ore, 12 feet a week is considered a fair rate of speed with three pairs of men, drilling by hand.

I was informed by Mr. Hewitson that at the Ivanhoe mine, in

FIG. 34.—SOUTH DRIVE, 350-FEET LEVEL, SOUTH NO. 4 LODE (LOOKING SOUTH), GOLDEN HORSE-SHOE.

1899, they reckoned 85 feet an average rate of progress per month, in levels driven with machines, and 100 feet has been driven in hard ground† in the North Boulder mine. Mr. Hamilton, at the Great Boulder, puts the average length of holes drilled per shift at about 50 feet, varying with the rock. It will be seen, therefore, that the speed of driving, as might be expected, compares much more

* 'The Kalgoorlie Gold Mines, Western Australia,' by W. F. Bulman, *Trans. Inst. of Mining Engineers*, vol. xxvii.

† July 8 to August 9, 1901, in No. 6 level.

favourably than shaft-sinking with the Rand, where the average rate of progress in driving levels with machines is stated to be

FIG. 35.—SOUTH DRIVE, 35C-FEET LEVEL, SOUTH NO. 4 LODE (LOOKING NORTH), GOLDEN HORSE-SHOE.

between 70 and 100 feet a month;* but existing rates might probably be improved upon in Kalgoorlie by adopting a squarer section of drive with its greatest width in the middle (6½ feet high by 6 feet wide for a single track, or 7 to 8 feet high and 9 to 10 feet wide for a double track); and giving greater attention to the method of placing the holes, so as to obtain the same effect with a smaller number, say fourteen,—the "face" being apt to be "burnt out" instead of being properly blasted out, if an excessive number of holes are put in.

On "The Rand" the prices paid for driving to contractors, who provide labour, explosives, lights and lubricants, and shift the dirt back from the face, but do not tram it, generally runs, it is said, from 35*s.* to 47*s.* 6*d.* per foot,† which is cheaper, on the whole, than in the Kalgoorlie district. This may be partly owing to a somewhat higher average rate of speed: in the one field, however, you have, no doubt, easier ground, and cheap, but efficient "Kaffir boys"; in the other you are dealing mostly with hard igneous rocks in the deeper levels, and more highly skilled but much more costly labour, although explosives are less expensive.

Mr. Hoover‡ in 1897 reckoned that about 80 per cent. of the cost of driving in Western Australia was paid for wages.

Explosives.—These consist, principally, of gelignite, blasting-gelatine and gelatine-dynamite.

A "ring" in dynamite is said to keep up the price, although it certainly costs less than in South Africa, where the dynamite monopoly was formerly a notorious grievance, blasting-gelatin costing 105*s.* and dynamite No. 1[A] 85*s.* per case just before the war;§ but the same materials could be purchased, I believe, at the end of

* Record instances under favourable conditions are said to reach to 150 feet. *The Klerksdorp Gold Fields*, by G. A. Denny, M. Inst. M.M., p. 222. H. W. Webb, M. Inst. M.M., and Pope Yeatman, M. Inst. M.M., reckon that the progress in single drives where one machine is used runs from 60 to 100 feet, and in double drives, where two drills are operated, from 90 to 120 feet per month; the work being let on contract at 2*l.* to 2*l.* 10*s.* per foot for single drives and 3*l.* to 3*l.* 10*s.* for double drives; the contractor supplying labour, candles and explosives. *Engineering Magazine*, April 1898, p. 46.

† *The Witwatersrand Gold Fields*, by S. J. Truscott, A.R.S.M., p. 292.

‡ *The Mineral Industry*, vol. vi. p. 335.

§ In 1896 the consumption of nitro-glycerine explosives (usually referred to as dynamite) in the Transvaal, amounted, I am informed, to 143,456 cases, of 50 lb. each; and the importance of a reduction in price of this particular article may be gathered from the fact that in 1898 the Robinson Company alone paid, it is said, 24,532*l.* for its supply, representing a cost of 2*s.* 7·9*d.* per ton milled.

1901, at 67*s.* 6*d.* and 60*s.* per case respectively at the local factory, as compared with 97*s.* 6*d.* and 75*s.* in 1899.

The ruling prices at Kalgoorlie were given * in the earlier days of the field as being, for dynamite and gelignite 3*l.* 6*s.* 9*d.*; gelatine-dynamite, 4*l.* 1*s.* 3*d.*; and blasting-gelatine, 4*l.* 13*s.* per case of 50 lb.; but at the beginning of 1900 I am informed they had fallen to: dynamite and gelignite, 3*l.* 1*s.* 6*d.* per case; gelatine-dynamite, 3*l.* 16*s.* 6*d.*; and blasting-gelatine, 4*l.* 8*s.* 6*d.* There being no duty on dynamite, taking the price at say 60*l.* per ton, f.o.b. Glasgow, freight to Fremantle † at 12*l.* per ton (Liverpool and Hamburg), and charges from Freemantle to Kalgoorlie at 8*l.* 10*s.*,‡ reckoning 40 cases to the ton, the total cost per case delivered at Kalgoorlie would work out at 2*l.* 0*s.* 3*d.* Gelatine also, in large quantities, costs approximately, I understand, at present only 40*s.* per case, f.o.b. English, American, or Continental ports. The mining companies are apparently, therefore, still paying for explosives at a somewhat heavy rate compared with the price at which they could be delivered.

To obviate this, it has been suggested that the companies might combine, and import direct to a central depôt, from which each could draw its supplies as required.

It may be added that the cost of detonators at Kalgoorlie in 1900 could be reckoned at about 1*l.* 11*s.* per 1000, and fuze at 3*l.* 6*s.* per 100 coils.

Timber.—Good mining timber is very scarce, and whilst native woods, such as Jarrah and Karri, which are found along the coast, are largely employed underground, more particularly if required in long lengths, for various reasons they are not so much used for general purposes as Oregon pine, which, I was informed, in 1900 cost about 27*s.* 6*d.* per hundred at Kalgoorlie.

The native woods are brittle, double the weight of pine, shrink greatly, and are very difficult to work, carpenters' tools requiring to be specially tempered for the purpose.

Boards (native or imported), sawn, cost at railway stations 12*s.* 6*d.* to 16*s.* per 100 feet,§ "board-measure." In the Mulga-

* *Financial Times*, 'A Manager's Views on the General Conditions.'

† The cost of explosives at Fremantle in 1902 is given in Chapter X.

‡ Railway freight alone, in September 1899, was 7*l.* 12*s.* 7*d.* and it was afterwards raised (May 1902) to 8*l.* 3*s.* 9*d.* per ton, but has since been reduced, a rebate of 10 per cent. being granted on August 4, 1902, on truckloads consigned to one consignee, for distances of 150 miles or over.

§ Mr. Bancroft gives as high a price as \$6·25 (26*s.*) for boards per 100 feet superbush, sticks 8 feet long and 6 inches in diameter are difficult to find, and are charged for at the rate of 3*d.* per running foot. Eucalyptus is said* to cost about 6*d.* per running foot for props 10 inches in diameter, but on the average the price a short time ago might be reckoned at from 2½*d.* to 5*d.* per running foot, according to size. T. and G. pine 6 inches by ⅞ inches costs 16*s.* per 100 running feet, in 1900.

Stopes.—"Overhand stoping" and rock-filling is the method almost universally employed in removing the ore, but it is more than probable that in the wider ore-bodies a considerable saving in expense might be effected by "cross-stoping" them, by some one of the systems employed in mining wide deposits.† The only other departure from ordinary practice that has come under the Author's notice is the plan that was first adopted at Lake View, of running the waste tailings from the cyanide-vats through surface-passes into the "stopes" for "filling." At first this produced an injurious effect on the men, owing to the cyanide left in them, the fumes of which, in badly-ventilated parts of the workings, caused the miners to suffer from dizziness. To overcome this trouble, the tailings are now washed with water, before being sent underground; but unless washed with a cyanicide, which would be expensive and inconvenient, it seems open to some question how far this treatment ensures absolute safety, though the use of salt water is no doubt more effective in destroying traces of cyanide than fresh water would be. It was also said, in the early days of the field, that in some instances the tailings contained sufficient gold to make it rather an expensive matter. Moreover, it appears doubtful, unless "pack-walls," or "pig-styes" filled with rock, are used in conjunction with "sand packing," whether the latter, even when dry, form a safe "filling" by themselves for wide stopes, although they are reported not to "run," as freely as one would expect them to do. The dryness of the stopes, no doubt, renders this method more practicable, in fact, than it otherwise would be, as there is less danger of water charged with cyanide finding its way down into the lower levels, or of the tailings shifting, than would be the case in a wet mine.

If tailings can be safely employed on a large scale, as ex-

ficial; and 11 cents (5½*d.*) per running foot for round sticks. *Op. cit.*, p. 100. In the early days, sawn hardwood 2-inch planks, for shaft-lining, cost, I believe, as much as 60*s.* to 65*s.* per 100 feet superficial.

* H. C. Hoover, *Eng. and Mining Journal*, December 17, 1898.

† "Pyramidal stoping" has recently been introduced at the Ivanhoe.

perience in this case seems to show, this method certainly appears to achieve two useful objects; getting rid of surface accumulations,

FIG. 36.—"STULL"-TIMBERING, LAKE VIEW CONSOLS.

which on leases of small area are liable to block them up inconveniently; and obviating the expense of driving cross-cuts to quarry "mullock" for filling underground, as sometimes has to be done. I may add that it appears probable, that one of the directions in which mining costs will be most cheapened hereafter, will be by the use of light "Baby" machine-drills, in stoping these wide "formations."

Timbering.—So long as the levels in the "sulphide zone" are kept narrow they require very little timber, but when they are reached by the stopes from below, and the full width of the lode comes to be removed, the case is different, and the "caps" and "posts," which are of round timber, frequently run up to 15 inches in diameter, forming "four-piece sets" (that is to say, with a post in the middle) where the width is great.

Sometimes a line of posts is set to one side of a level, forming a "man-way," with a double line of rails laid on the other and wider side, and in the Kalgoorlie mine a kind of "saddle back" system of timbering is employed, consisting of "stulls" fixed opposite one another in "hitches" in the floor, butting like the rafters of a roof against a central longitudinal "ridge-piece" under the centre of "the back" of the level; the triangular spaces behind on each side being packed with mullock resting on "lagging." The idea of this is to economise timber, and the method referred to * will be found depicted in the *Engineering and Mining Journal*, of August 18, 1900.

For ordinary "stulls" and in levels which do not require such massive timbering 8-inch timber is used. The "salmon-gum," which grows plentifully in the district, makes, it is said, the best mine

FIG. 37.—A LEVEL AND STOPE, COMMENCED IN RICH TELLURIDE ORE.

timber, becoming so hard that holes cannot be bored in it by hand. The illustration (Fig. 36) shows the "stulling" of one of the levels in the Lake View Consols mine.

* A modified form of timbering of this kind is employed in the Calumet and Hecla mine in Michigan; it is figured by Mr. Park Channing on p. 261 of the Mining and Metallurgical number of *Cassier's Magazine*, July 1902.

In the stopes, posts with "head-boards" and "cribs," or "pig-styes," are employed to prevent "caves"; and at the Golden Horse-shoe mine, owing to the heavy nature of the ground in wide gunnies, they use "square-sets." The timbering and "filling" of the "stopes" is one of the main items of cost in mining at Kalgoorlie, in fact Mr. Hoover * states it costs as much as the actual breaking and handling of the ore.

The cost of timber at the Lake View Consols in 1898, for instance, appears to have amounted to 13,610*l.* 13*s.* 1*d.*, or 4*s.* 8·4*d.* per ton

FIG. 38.—SOUTH DRIVE NO. 2 LEVEL, NO. 4 LODE (SHOWING TIMBERING), GOLDEN HORSE-SHOE.

raised and treated, but a large part of this was no doubt chargeable to development, and 50 per cent. of the above sum was charged to Profit and Loss account, and written off, whilst the balance was charged to Capital Account.

The illustrations Figs. 36 and 37 show "the back" of two of the levels, with "stulls" and setts being put in for stoping; and Figs. 38, 39 and 40 show the timbering of a level and cross cut in the Golden Horse-shoe, and "square-set" timber work.

Underground Tramming.—Men are exclusively employed in

* *Eng. and Mining Journal*, December 17, 1898.

trucking. I do not know whether the question of electric traction for such a purpose has been considered; but mechanical haulage seems only capable of profitable application where the main levels are fairly straight, of exceptional lengths, and suitable size.

At the Great Boulder mine the principal drives are laid with steel rails, with a 17-inch gauge track. At the smaller mines, if the roads are of any considerable length, the cost of trucking is necessarily high, but might no doubt be cheapened by better organisation in some cases; 9 to 10 tons per man per shift, including stone broken

FIG. 39.—JUNCTION OF CROSS-CUT AND NO. 3 LODE NO 1 LEVEL, GOLDEN HORSE-SHOE.

in development, is reckoned, I believe, a fair day's work; this represented a cost of 1*s.* 1·33*d.* per ton shifted, in a case that came under the Author's notice, or 1*s.* 6*d.* or 2*s.* per ton of ore milled, taking into account stone shifted for "filling"—as much as 15 to 17½ tons under favourable conditions can, however, be handled per man.

At the Ivanhoe, in 1900, on an output of 74,750 tons, trucking cost 2*s.* 0·671*d.* per ton; and in 1901, on an output of 90,423 tons, it cost 1*s.* 6·820*d.* per ton.*

* For the year ending August 31, 1901, on an output of 76,571 tons "treated," trucking and mullocking cost 2*s.* 10·468*d.* at Lake View Consols.

Ventilation is entirely natural, and is assisted by the difference in temperature between the surface and below ground.

Underground Lighting.—As already mentioned, the "plats" are lighted by electricity, or with large oil-lamps, but since the question of safety has no bearing on the matter (as in collieries), candles are chiefly used underground; and just as the Saxon miner in the silver-lead mines has stuck to his "blende," * and the Scotchman to his blend of whisky; so the Australian, like the

FIG. 40.—SILL-FLOOR NO. 2 LEVEL NO. 4 LODE (SHOWING SQUARE-SET TIMBERING), GOLDEN HORSE-SHOE.

Cornishman, as a rule prefers his "dip" thrust in a lump of well-kneaded red-clay, or an American steel candle-holder (which he can stick or hang anywhere), to any other; as it gives him the best, though a more expensive, light to work by.

As either oil or tallow would, if dropped amongst the ore, seriously interfere with amalgamation, and might cause loss of gold out of all proportion to the saving effected by the using of a cheaper

* The following description of it is given by W. Leo, which shows its antiquity, and the same kind of lamp is in use to-day in Saxony: "'Blende' ist ein hölzernes oder blechernes Gestell, gleich einer Lanterne, in welcher der Bergmann, an vielen Orten, sein Grübenlicht führt"—*Bergbaukunde*, W. Leo, 1861.

illuminant; stearine, paraffin, or composite candles are, however, mostly employed. Price's candles are put up in 25-lb. boxes of about three-quarter cubic feet capacity, in blue packets, each holding 1 lb.; and they give less smoke, and do not gutter like "dips," although they do not stand strong draught or drops of water so well. Mr. Truscott* reckons that on the Rand, illumination costs about 4*d.* per ton of ore raised.

The cost of illumination, as might be expected, is less in "stopes" than in levels, reckoned on the tonnage broken; but the light being more diffused and exposed to draughts, more candles are used per man. As showing this, it may be stated that at the North Boulder, in 1898, 13,691 tons of ore were stoped in 5802 shifts, with a consumption of 3578 lb. of candles, which at eight to the pound, represents 28,624 candles used, equal to about 2·1 candles per ton, or nearly five candles per man per shift. Whilst in driving, etc., it may be reckoned that about 8117 tons were broken in 8000 shifts, and 3457 lb. of candles were consumed, which, reckoning eight to the pound, represents 27,656 candles, equal to about 3½ candles per ton, or 3½ candles per man per shift.

Sorting.—On the Rand, Mr. Truscott, M.Inst.M.M., has pointed out that there is a direct saving of gold effected by sorting, in addition to a saving in milling expenses, as the waste sorted out often does not assay 1½ dwt., whereas the residues from different reduction-works generally assay more.

If therefore the waste, instead of being sorted out, were crushed and treated as presently explained, it would arrive at the residue dumps with a higher assay value than it originally had. The capacity of the mills and reduction plants is also increased proportionately to the amount of stone thus got rid of, and the waste sorted out underground saves expense in providing mullock for "packing" the stopes.

The tailings which result from reduction have an assay value proportionate to the value of the ore treated, and this being the case, the value of any ore may be so increased by sorting that the resultant tailings might be treated at a profit; whereas if not so treated, they might be of too low a value. Another advantage is that hammer and pick-heads, and pieces of iron or wood, are picked out, and damage to machinery is thereby averted.

So long, therefore, as the value of the "waste" sorted out is less than that of the residues from the reduction processes, and the

* *The Witwatersrand Gold Fields,* S. J. Truscott, A.R.S.M., p. 393.

cost of sorting a ton of waste rock is less than the cost of reducing it, it presents obvious advantages.

In Kalgoorlie, little or no sorting is attempted, and the justification for this lies in the fact that, unlike ore on the Rand, it is frequently impossible to distinguish between a piece of ore rich in gold and a bit of mullock; and there is no doubt that the ore brought to the surface, owing to insufficiency of light underground, and the dirt and smoke with which much of the ore is covered, carries a considerable proportion of waste.

If this waste could be got rid of, it would be of distinct advantage, but what little sorting is attempted at Kalgoorlie is done mostly on the "dumps," and to do it properly would involve the erection of elaborate washing and sorting plant on surface, and with rich telluride ore put temptation in the sorters' way.

It is doubtful, therefore, whether the loss and cost would not greatly exceed the gain, unless the distinction between rich and poor ore becomes more marked in the lower levels of some of the mines, as may perhaps happen; in which event, surface-sorting with adequate safeguards will become a question for serious consideration.

In some mines there is, however, a good deal of barren stone, which by paying more careful attention to the matter, might possibly be separated with advantage underground, saving the expense of raising it; and leaving it as is done in other cases, where it would be most useful, in the working-places for "filling."

At Hannan's Star mine, in the Company's report for 1899, it is stated that 100,700 cubic feet of ground were broken in the stopes at the 75-feet level on the main lode, representing 6713 tons, which yielded 4185 tons of (oxidised) milling ore; in 1900, at the 175-feet level, 32,144 cubic feet of ground were broken on the main lode, representing about 2296 tons, which yielded 1250 tons of ore; and at the 275-feet level, 18,382 cubic feet of ground were stoped, representing about 1313 tons, which yielded 543 tons of ore.

Sampling.—This brings me to the subject of "sampling," and I do not think I am wrong in stating that sampling an ordinary quartz vein or Johannesburg "banket" is child's-play compared with the difficulties of sampling the Kalgoorlie "formations."

When you come to consider the following facts:—(1) That the appearance of the ore affords little indication of its value, and that it is frequently indistinguishable from mullock; (2) That it varies in width as much as it does in value; possesses frequently no well-defined walls, and is at times payable over great widths; (3) That minute seams of rich telluride are apt to run through it in all directions, bringing up the value of a foot or two of almost worthless stone, to a payable grade; and (4) That a given width of formation, owing to patches of rich telluride, will alter in average value from a few dwt. to 20 or 30 oz. to the ton, in a run of level, not exceeding a few feet in length,—it is evident that the question of accurate "sampling," so as to arrive at reliable results, is a very different affair to sampling a well-defined deposit, with values fairly evenly distributed through it.

By sampling the drives at regular and close intervals, as they advance, and taking "check-samples" from the "passes" and trucks delivered on surface, an approximate idea can, no doubt, be formed of the value of a "block of ground" whilst it is being laid open for stoping; but it is practically *impossible* to figure with *absolute certainty* what any *large block* of ground will yield until a considerable amount of stoping has been done upon it, indeed one might almost say *until it is actually stoped out,* as it is apt to contain surprises, equally pleasant or otherwise, in the shape of "unexpected" bunches of rich telluride, or blank patches of ground, which set the most careful calculations at defiance; and however great the "sampler's" experience, care, and rectitude may be, he is liable to make unavoidable mistakes, in estimates of the kind, based on "ore in sight," using the term in its strict technical meaning.

At the Ivanhoe and other mines, in calculating "ore reserves," only ore that is exposed on three sides at least is taken into account;* and as the winzes do not always follow the ore down, a certain margin is allowed on the safe side, which is no doubt a prudent precaution, that makes up for irregularities in individual blocks of ground.

Of course, some ore-shoots are comparatively speaking more regular than others, and give their lucky managers less trouble to figure upon than is oftentimes the case; but I believe the only way in which it is possible to calculate "values in reserve" with any *near* approach to certainty, would be to sample each level and winze at short intervals, so as to obtain a knowledge of its relative value in cross-section; and after sorting out any "waste" that would usually be picked out underground, pass the balance of the ore got from drives and winzes from day to day through a mechanical,

* The Ivanhoe Company's Report, 1900, p. 18.

automatic sampler, of the Vezin,* Brunton, or Bridgman class, in order to obtain an average bulk sample from each main level, etc., for assay.

Even this, however, would only partly meet the difficulty, and although it might be worth while in some cases, in others it would, probably, scarcely pay; and I believe the safest guide to depend on (which serves incidentally as a check on the sampling) is to so organise the sampling and plan the stoping, that the stope-samples and battery-crushings shall serve as an aid to guide the manager in figuring on the value of each block of ground whilst it is in course of removal. In any event, however, samples taken for assay from any particular "block of ground" or lot of ore should be as large as possible, and the final assay sample, when check-assays are to be made, should be pulverised to 120 mesh or finer,† instead of 60 or 80, as is the usual custom with ordinary ores.

At the Great Boulder mine, in mining the oxidised ore, the practice used to be (as a rough test) to keep a man constantly "panning" ore from the drives and "stopes," and estimating values, as it has been customary to do at the Homestake mines in Dakota, and in other cases where the ore is free-milling.

The foregoing facts may possibly, in some measure, explain the discrepancies that have occurred in estimating "ore in sight";‡ but in other cases they appear quite unaccountable, one of the most notable being where the manager of a company, it was stated, calculated the reserves at 739,296 tons, valued at 1 oz. 16 dwt.; whilst, according to the report of the mining engineers who inspected the property about six months later, they only amounted to 37,740 tons, valued approximately at 1 oz. 8·33 dwt.

The assaying of telluride ore is not, however, as simple as that of an ordinary gold-ore, and unless proper precautions are taken (as described by Messrs. C. H. Fulton,§ F. C. Smith,‖ E. A. Smith, A.R.S.M.,¶ and others), the assayer is liable to

* *Mineral Industry*, vol. vi. p. 369. An excellent description of this machine and a great deal of interesting information upon the subject of the mechanical sampling of telluride-ores is given by Mr. P. Argall, M. Inst. M.M., in a paper on 'Sampling and Dry-Crushing in Colorado,' *Trans. Inst. of Mining and Metallurgy*, vol. x.

† When tellurides are present and the ore is rich, Lodge recommends crushing to 140 mesh or even finer, *Mineral Industry*, vol. viii. p. 397.

‡ This subject is discussed in a paper by J. D. Kendall, M.Inst.M.M., read before the Institution of Mining and Metallurgy, 1902, and certain recommendations on the subject have been made by a committee of that Institution. It has also been recently discussed in the *Denver Mining Reporter*, October 1902, *et seq.*, and in the *Engineering and Mining Journal*, February 1903, *et seq.*

§ *N. Y. School of Mines Quarterly*, vol. xix. p. 419; and *The Mineral Industry*, vol. vii. p. 451. ‖ *Trans. Am. Inst. of Mining Engineers*, vol. xxvi. p. 487.

¶ 'The Assaying of Complex Gold Ores,' *Trans. Inst. of Mining and Metallurgy*, vol. ix.

fall into error. But the sampling is the real crux in figuring upon values.

Development Work.—As Mr. Hoover points out,* owing to the width of the lodes (6 to 30 feet), the tonnage developed per foot of opening (drivage, etc.) is very great.

Sufficient has been said to show that in order to maintain a large output, with a regular "mill-average," whilst adding gradually to reserves, it is necessary to keep "development work" pushed well ahead at different levels; and the amount of development required is liable to vary in different mines under different conditions.

The following table, compiled from official reports, giving the records of several mines in 1899, may serve to illustrate this.

Name of Mine.	Authority.	Scale of Treatment. 1899.	Estimated Reserves, Dec. 31, 1899.		Sunk. †	Developments in 1899. Driven.	Cross-cut.	Total.	Development. Grand Total to Dec. 31, 1899.	Ore Crushed. Grand Total to Dec. 31, 1899.
		tons		tons	feet	feet	feet	feet	feet	tons
Gt. Boulder Proprietary	Company's Report	51,835	Oxidised ore	17,266	2579	5195	1750	9524	41,927	143,361
			Sulphide ore	131,878						
			Total .	149,144‡						
Ivanhoe	Do.	59,664	Oxidised ore	128,273	1436	3371	1542	6349	12,444§	§88,429
			Sulphide ore	83,600						
			Total .	211,873						
Gold Horse-shoe Estates	Do.	39,191	Oxidised ore	129,809‖	..	..	..	..	9,774	49,141¶
Lake View Consols	Do.	..	..		1235	3221		4456	..	181,325
N. Boulder	Do.	12,060	Sulphide ore	5,000**	1222	1488	1419	4129	9,751	30,162

Corresponding particulars embracing most of the principal producing mines on "the fields" in 1900, are furnished in the table on next page.

* *Engineering and Mining Journal*, Dec. 17, 1898.

† Shafts, winzes and rises, but chiefly the two latter.

‡ No ore included below the 600-feet level, nor 20,652 tons of ore "at grass."

§ From December 7, 1897.

‖ Exclusive of 22,000 tons of oxidised ore, of low grade. The figures under scale of treatment are based on the average of 10 months crushing only, from March 1, 1899, the amount actually crushed being 32,659 tons. The figures under "development" represent the total amount of work done on the Golden Horse-shoe lease from the inception up to December 31, 1899.

¶ From opening of mine in 1896. ** March 2, 1900.

If rises and winzes are included, the general average cost of development, according to Mr. Hoover, has been about 4*s.* 6*d.* ($1·08) per ton of ore developed; he adds, "this figure, however, must be taken with a grain of salt"; the cost being liable to be largely increased by the necessary "prospecting work" that has to be done in cross-cutting, etc., looking for new ore-bodies. Were it not for this, the development of a given tonnage of ore would not

Name of Company.	Date. Year ending	Scale of Treatment.	Estimated Reserves.		Developments.			Total.
					Sunk.†	Driven.	Cross-cut.	
		tons of ore	tons of ore	av. value	feet	feet	feet	feet
LakeView Consols	Aug. 31, 1900	11,994 oxidised 25,738 sulphide	65,000* 55,000 120,000	oz. dwt. 1 12 8–15 dwt.	1535½	3752	1084½	6372
Gt. Boulder Proprietary	Dec. 31, 1900	37,484 oxidised 17,196 sulphide	22,028 143,800 165,828 ‡	"at grass" oz. dwt. gr. 1 9 9	2586	2872	1339	6797
Ivanhoe	Do.	74,750	227,827 ‡	not stated	1861½	3964	1283½	7109
Golden Horse Shoe Estates	Do.	67,095 oxidised 9,437 sulphide	112,925 20,000 100,340 233.265	oxidised low grade sulphide	3318	5531		8849
Gt. Boulder Perseverance	Do.	21,880 oxidised 21,418 sulphide		--	889	2821	1598	5308
Associated Gold Mines	March 31, 1901	35.524 sulphide and oxidised	122,794 §	oz. dwt. gr. 1 3 7	1230½	5396	2397½	9024

be such an expensive item, and the drivage on the actual ore-bodies could be kept at a comparatively small figure, without fear of reserves falling suddenly short.

The following table, compiled from the Reports of various Companies, and other sources, might of course be largely extended

* January 15, 1901 = 71,000 tons sulpho-telluride ore.
† Chiefly winzes and rises. ‡ Including ore "at grass."
§ No ore bulking below 14 dwt. included.

and perhaps made more sensational; but it affords, I think, a fair idea of the size and value of some of the individual ore-bodies in a number of the principal mines of the district, at various depths, so far as they had been developed at the dates given.

Report for the Year.	Name of Mine, and Level at which the Ore-body was reported as developed.			Length of Ore Reported Exposed.		Average Width.		Assay Value per Ton.		
				ft.	in.	ft.	in.	oz.	dwt.	gr.
1899	Great Boulder, West lode . . at	400 ft.	level	698	0	4	7	2	6	0
"	" " . .	400 "	winze	..		3	10	8	2	0
"	" " . . .	500 "	north	349	6	4	11	7	5	0
"	" " . .	500 "	south	360	0	4	2	1	3	0
"	" " . .	600 "	north	339	0	5	1	1	6	0
"	" " . .	600 "	south	345	0	4	4	1	16	0
"	" New discovery .	600 "	N. & S.	145	0	4	8	1	19	0
1900	" West lode, . .	700 "		255	0	5	4	1	17	0
"	" " . .	800 "		264	0	5	8	1	7	0
"	" " . .	900 "		241	6	6	9	1	13	0
"	" " . .	1000 "		154	6	6	6	1	17	0
1901	" " . .	1100 "		463	0	4	5	1	1	0
"	" " . .	1200 "		420	0	6	7	1	19	0
1899	Ivanhoe, Middle lode . .	300 "	north	251	0	5	0	5	10	0
"	" " . .	200 "	south	373	0	6	0	1	5	0
"	" " (Patterson's shaft)	400 "	west	cross-cut		8	0	4	0	0
"	" " "	500 "	"	"		8	0	6	0	0
1900	" " (Drysdale shaft)	400 "	"	"		6	6	3	0	0
"	" " "	500 "	"	"		6	0	1	10	0
1899	" East lode . .	300 "	north	285	0	9	0	2	12	0
"	" " . .	300 "	south	281	0	15	0	3	10	0
1900	" " (Patterson's shaft)	500 "	east	cross-cut		8	0	2	1	0
1899	" New lode . .	100 "	south	176	0	3	0	6	10	0
"	" " . .	200 "	north	196	0	2	0	2	4	0
"	" " . .	200 "	south	144	0	3	0	2	2	0
1900	" " . .	400 "	east	cross-cut		2	0	2	0	0
1899	" Boulder lode . .	200 "	north	100	0	3	6	4	9	0
"	" " . .	200 "	south	67	0	3	6	8	15	0
"	Lake View, East lode . .	100 "		80	0	4	6	2	13	0
1898	" Main lode . .	200 "	north	242	0	6	0	1	10	0
"	" " . .	200 "	"	205	0	8	0	1	12	0
"	" " . .	"	"	234	0	15	0	2	18	0
"	" " (above) .	200 "	south	186	0	12	0	3	10	0

Report for the Year.	Name of Mine, at Level at which the Ore-body was reported as developed.		Length of Ore Reported Exposed. ft.	in.	Average Width. ft.	in.	Assay Value per Ton. oz.	dwt.	gr.
1898	Lake View, Main Lode (below) .	200 ft. level south	620	0	15	0	1	0	0
,,	,, ,, . .	300 ,, ,,	42	0	8	0	34	9	0
1899	,, ,, . .	300 ,, north	720	0	*13	0	1	7	12
,,	,, † ,, . .	300 ,, south	320	0	6	0	‡38	19	9
,,	,, † ,, . .	300 ,, ,,	79	0	§17	6	1	10	0
,,	,, † ,, . .	300 ,, ,,	182	0	‖30	0	0	10	0
1900	,, ,, . .	400 ,, ,,	350	0	6	0	1	15	0
,,	,, ,, . .	400 ,, ,,	406	0	..		4 to 15 dwt.		
,,	,, ,, . .	500 ,, north	840	0	..		0	7	0
,,	,, ,, . .	500 ,, ,,	20	0	3	0	5	0	0
,,	,, ,, . .	500 ,, ,,	200	0	6	0	1	10	0
1900¶	Great Boulder Main Reef Co., Main lode .	385 ,, north	180	0	8	0	††1	10	0
,, ¶	Do. West lode . .	385 ,, ,,	175	0	2	6	2	0	0
,, **	Do. Main lode . . .	485 ,, ,,	60	0	4	0	3	10	0
,, **	Do. do. . . .	585 ,, ,,	‡‡37	0	5	0	40	0	0
1901	Do. do. 5th Ann. Rep. .	793 ,, south	15	0	2	6	2	0	0
,,	Do. do. do. . .	793 ,, ,,	20	0	3	0	0	15	0
1900	Associated G. M. Co. Tetley's ore-body	200 ,, northern section	180	0	11	0	§§1	16	0
1901	,, ,, ,,	416 ,, sec. A 15 & 16	195	0	15	0	1	10	0
		& B 16	135	0					
1900	,, ,, ,,	500 ,, central section	80	0	14	0	1	13	0
1901	,, ,, Main lode	136 ,, sec. C, 11 & 12	100	0	12	0	2	0	14
,,	,, ,, ,,	250 ,, sec. C, 11, 12,	127	0	10	0	0	15	0
		13 & 14	125	0	8	0			

* 6 to 20 feet wide.

† In the section from 400 feet to 900 feet south of the main shaft, between the second and third levels, the high-grade ore was stated to have varied from 10 oz. to 120 oz. per ton; whilst outside of the rich ore, the general average was 1 oz. per ton.

‡ Estimated from yield of 2620 tons shipped from this section and smelted.

§ 15 to 20 feet wide. ‖ 20 to 40 feet wide.

¶ Mr. L. Gilson's Report, March 2, 1900. ** Circular, Oct. 11, 1900.

†† 25 to 35 dwt. ‡‡ After driving 60 feet in the ore body.

§§ Mr. R. J. Frecheville's Report, dated April 5, 1900, figured on 1370 tons of sulphide ore of this value remaining here; the length and width given are the dimensions of part of this ore-body that had previously been stoped away. At the 300-feet level, he remarks, "The ore-body had also a length of 180 feet with an average width of 13 feet. At its N.W. limit there is standing about 1150 tons of 25-dwt. ore, and at its S.E. limit 500 tons of about 15-dwt. ore."

Report for the Year.	Name of Mine, at Level at which the Ore-body was reported as developed.	Length of Ore Reported Exposed. ft.	in.	Average Width. ft.	in.	Assay Value per Ton. oz. dwt. gr.
1900	Associated G. M. Co. {Austialia East, northern section} 100 ft. level north	120	0	15	0	†0 7 0
,,	,, ,, central ,, 100 ,, south	200	0	30	0	†0 7 0
1901	,, ,, No. 2 Cross lode between No. 2 & No. 6 levels	390	0	9	0	1 3 1
1901*	Associated Northern Blocks, Ltd. (Iron Duke) Lease No. 5 level, winze	..		15	0	6 5 0 (nearly)
,, ‡	Associated Northern Blocks, 450 ft. level, "west shoot" .	64	0	7	6	3 0 0
	,, ,, 500 ,, "No. 1c shoot".	40	0	5	9	2 17 0
1900	Kalgurli G. M. Co., Middle lode 100 ft. level {north of Main shaft}	13	0	..		1 9 0
,,	,, ,, 100 ,, ,,	22	0	..		0 15 0
,,	,, ,, 100 ,, {north of Howell shaft}	39	0	..		1 7 0
,,	,, East lode 200 ,, {north of Main shaft}	13	0	23	0	2 10 0
,,	,, Middle lode 540 ,, 520-ft. winze	cross-cut		30	0	1 12 0
,,	,, ,, 640 ,, 21 ft. {west of Main shaft}	cross-cut		13	0	1 0 0 (approximately)
				4	0	5 0 0 (approximately)
				9	0	0 14 0 (approximately)
				9	0	country
				6	0	1 6 0 (approximately)
,,	,, ,, 640 ,, Drive at 36 ft. from shaft north	27	0	..		1 15 0
	south	32	0			

1900 Golden Horse-shoe:
The average value of the ore extracted from No. 1 lode was given as 0·50 oz.
,, ,, ,, No. 2 ,, ,, 0·55 ,,
,, ,, ,, No. 3 ,, ,, 0·88 ,,
,, ,, ,, No. 4 ,, ,, 2·74 ,,

Six feet south of the East Cross-cut on No. 4 lode at the 500 ft. level (No. 5) a winze was reported sunk 88 feet in extraordinarily rich ore, 5 to 7 feet in width.

* Prof. E. H. Liveing's Report, dated April 5, 1900; he mentions that in the southern section the best portion of a body of oxidised ore had been stoped out by open-cut, to a width of 40 feet; and about 21,400 tons were left of low grade (7 dwt.) in the central section; and 3850 tons in the northern sections of similar grade.

† In a letter of the special correspondent to the *Financial Times*, dated July 27, he mentioned that 2000 odd tons treated from this mine, averaged a little over 8 oz. per ton.

‡ Mr. A. E. Thomas's Report, dated November 23, 1901, stated that between the No. 7 level (550 feet) and the No. 6 (500 feet), he estimated 10,338 tons in sight of an average value of 6 oz. 11 dwt.

The phenomenal width and richness which the ore-bodies in this district frequently attain, in places, has been referred to in a previous chapter. Thus, in the Great Boulder Perseverance mine, what is known as the Lake View Lode, it is stated,* was stoped in one place, between the surface and the 100-feet level, for a width of 100 feet; whilst at the 200-feet level, it was still 30 feet in width. At the Southern end of the mine in the 500-feet level at one point the lode was estimated to have been 40 feet wide, valued 35 dwt.; and again, where cut at 600 feet it was reported to be 12 feet wide, valued at 25 to 35 dwt. The average width of the West lode, which is said to be richer but more irregular than the Lake View lode, was estimated by the manager in 1901 at 8 feet; and a formation intersected by a cross-cut from No. 6 shaft, was reported to be 5 feet wide at this point, valued at 4½ oz. per ton. For reasons already stated, however, the quantities of ore crushed by the various mining companies, and the average returns they have yielded, considered in conjunction with the amount of development-work effected, and the "reserves of ore" blocked-out in each mine, are safer guides to go by in estimating the capabilities of "the field" as a whole, or of any particular property, than the value of this or that "ore-body."

In consequence of the lenticular shape which characterises most of the Kalgoorlie ore-deposits, they frequently "splice in and out," and in sinking and driving on them they generally lengthen and widen until a certain point is reached, when they commence to contract and wedge out lengthways and underfoot; but new bodies fortunately, as before explained, frequently "re-make," to take the place of the old ones that have been worked out.

The principal "*formations*" indeed, may be said to be fairly persistent in their "course," and some of the mine-workings, like those of the Great Boulder, give a visitor the impression of considerable regularity, whilst others impress him more with the great width of their stopes. Still, a 4-feet or 6-feet ore-body when of any considerable length, is a splendid average width on which to work, and is in some respects handier, and at times cheaper to mine, than a very wide one. Generalisations of this kind cannot, however, be carried too far, the profit a mine will yield depending on various surrounding circumstances, and very largely upon the business organisation of each concern.

In the Great Boulder and other mines, one notices that two

* *Statist*, September 1, 1900.

"formations" sometimes run parallel for some distance, and then unite, enclosing a patch or "horse" of barren ground between them; and it would not be at all surprising, judging by their converging dip, if what appear to be separate lodes in some of the mines (seen in horizontal-section at the upper levels) prove to be branches of one and the same "formation," and united in depth, forming more regular and well-defined ore-bodies. Unfortunately, their erratic mode of occurrence and the sudden jumps in values, up as well as down, to which the ore-bodies in this field are subject, just as in localities like the Comstock and Leadville (where somewhat similar conditions obtained), have presented many opportunities for speculative manipulation.

Development, Mining and General Mining Costs.—Mr. Hoover, in 1898, stated * that if we include under the head of extraction, pumping, winding and tramming, the average cost of mining was about $2·70, or say, 11*s.* 3*d.* per ton; it seems somewhat doubtful, however, whether this figure would entirely cover all these items, in all cases.

Taking the various items of expenditure on mining, milling and development that were debited to Profit and Loss account or charged to Capital account, and re-grouping them, it would appear from the annual reports of different companies in 1898, local costs (based on tonnage milled in each case) stood about as follows; exclusive of course of capital charges, for the purchase and erection of new plant.

Year 1898.	Total amount of Development work.	Output in tons milled.	Development. Cost per ton.	Mining. Cost per ton.	Milling. Cost per ton.	Average Total Mine Costs per ton.†	Cyanide Treatment per ton milled.
	feet.		*s.* *d.*	*s.* *d.*	*s.* *d.*	£ *s.* *d.*	*s.* *d.*
Lake View	5,512	57,920	12 2¾ ‡	13 3	10 1	2 0 11	5 6
Great Boulder	13,541	41,043	23 11 ‖	12 5	9 6	2 12 4⅜	nil
Ivanhoe	6,095	28,765§	15 2¾ ¶	10 7¼ **	7 5¾	2 5 11¼	3 2
North Boulder	2,682	10,150	23 11¼ ††	7 3¾ ‡‡	8 6	2 6 8½	nil

* *Eng. and Mining Journal*, Dec. 17, 1898.

† Including general charges (such as local office expenses, etc.), but excluding capital charges (other than development), cyaniding tailings, depreciation of machinery (written off), and London expenses.

‡ Inclusive of mine timber (charged to capital account), which is reckoned to have cost 2*s.* 4·199*d.* per ton; and a similar sum written off "extraction" for timber.

§ Thirteen months (including December 1897).

‖ Calculated upon 49,909 tons *mined* (part of which was not crushed); the expenditure under this head may be reckoned at about 19*s.* 8*d.* per ton.

¶ Includes 16,833*l.* 10*s.* 11*d.* charged to capital account, and 5067*l.* 10*s.* 5*d.* charged to profit and loss account.

** Covers stoping, hauling and trucking.

†† Includes general mine charges, mine timber, and mine maintenance; the actual cost of development (sinking, driving, etc.), amounted to 10*s.* 3·4*d.* per ton mined.

‡‡ Covers merely the cost of "getting ore." The cost of stoping, based on the tonnage mined, was only 7*s.* 0·317*d.*

It is interesting to note that, notwithstanding the difference in the amounts of ore crushed (a factor which, generally speaking, largely influences the cost of treatment), the total costs above shown (which may be reckoned as representing the average cost on the spot of winning and treating oxidised ore in 1898) in all these four cases show close uniformity, if allowance is made for the different amounts that different companies spent upon "development." The figures in the fifth column include general charges and maintenance, but are exclusive of such sums as were written off for depreciation of machinery,* London expenses, capital expenditure (other than development) and cyaniding tailings, etc.

The higher cost of development at the North Boulder mine resulted from its comparatively small output, which was due to the fact that the shoots of ore were neither as wide nor as regular as in the larger mines; whilst in the case of the Great Boulder, it is explained by heavier sinking charges and the relatively large amount of development work done, compared with some of the other mines.

The following table gives the Author's estimate of the cost of production at four of the leading mines at Kalgoorlie in 1899, when the output and treatment of the oxidised ores on this field had attained its maximum, from which it appears that the pay-yield ranged from about 11 to 19 dwt. (bullion value) per ton. In compiling this table, so far as the subdivision of the accounts and statements of the various companies permit of doing, the Author has endeavoured in each case to group similar charges together under one or other of the nine or ten headings into which the table is divided: "Development" includes sums charged to

* The Great Boulder "wrote off" 8000*l.* = 3*s.* 10¾*d.* per ton, from the balance of profit and loss account at December 31, 1897; on account of development in 1898, which is not included under cost of development in the table; and 10,000*l.* = 4*s* 10½*d.* per ton, on account of depreciation of plant, buildings, etc.

The Ivanhoe "wrote off" 5067*l.* 10*s.* 5*d.* = 3*s.* 6*d* per ton, on account of development, and 5595*l.* 1*s.* 6*d.* = 3*s.* 10*d.* per ton, on account of depreciation of plant, buildings, etc.

The Lake View Consols "wrote off" 4508*l.* 9*s.* 7*d.* = 1*s.* 6·682*d.* per ton, on account of development; 13,077*l.* 3*s.* 5*d.* = 4*s.* 6·187*d.* per ton, on account of depreciation of plant, buildings, etc.; and 6805*l.* 6*s.* 8*d.* = 2*s.* 4·199*d.* per ton, on account of mine-timbering, charged to cost of extraction. The first and last of these items are included under development in the table on p. 195.

The principles of calculating the "depreciation of machinery" have been very fully discussed in an article by Prof. Robert H. Smith, in *Fielden's Magazine*, March 1900, and in a series of articles in *Engineering*, July 5, 12 and 19, 190·.

General Table of Costs in 1899.

Name of Company.	(1) Lake View Consols, Limited. Total (£ s. d.)	Per ton (£ s. d.)	(2) Ivanhoe Gold Corporation, Limited. Total (£ s. d.)	Per ton (£ s. d.)	(3) Golden Horse-Shoe Estates Co., Limited. Total (£ s. d.)	Per ton (£ s. d.)	(4) Gt. Boulder Proprietary Gold Mines, Limited. Total (£ s. d.)	Per ton (£ s. d.)
Tons of Ore treated.	85,889 tons.†		59,664 tons. ‖		32,659 tons. ‖		51,835 tons. ‖	
Development *	‡43,376 8 4	0 10 1·207	23,665 15 0	0 7 11·196	25,531 10 4	0 15 7·622	74,072 14 8	1 8 6·962
Mining	51,571 14 10	0 12 0·107	37,501 3 9	0 12 6·850	21,053 8 3	0 12 10·714	30,463 13 8	0 11 9·049
Milling	28,526 15 6	0 6 7·713	17,117 11 0	0 5 8·855	15,432 19 10	0 9 5·412	24,476 5 10	0 9 5·327
Treatment of sulphide ore	24,308 17 1	0 5 7·926	..	..	..	..	..	..
Tailings treatment	§ 26,313 18 3	0 6 1·529	¶ 18,839 6 9	0 6 3·782	** 7,295 2 0	0 4 5·609	†† 13,946 14 2	0 5 4·574
General expenses, etc.	8,128 1 11	0 1 10·712	14,536 15 0	0 4 10·473	4,276 7 10	0 2 7·426	13,021 4 9	0 5 0·289
Taxes (income & dividend)	14,639 18 8	0 3 4·908	8,750 0 0	0 2 11·197	15,424 0 0	0 9 5·346	12,209 18 5	0 4 8·533
Depreciation (written off)	15,064 5 5	0 3 6·094	7,731 14 10	0 2 7·101	5,639 19 5	0 3 5·446	20,000 0 0	0 7 8·601
Maintenance	3,914 1 1	0 0 10·937	4,361 8 6	0 1 5·545	1,700 16 6	0 1 0·499	5,773 17 1	0 2 2·733
London & Adelaide expenses	4,381 0 8	0 1 0·241	3,597 10 6	0 1 2·471	7,394 13 10	0 4 6·341	9,242 7 7	0 3 6·793
Totals	220,225 1 9	2 11 3·374	136,101 5 4	2 5 7·470	103,748 18 0	3 3 6·415	203,206 16 2	3 18 4·861

	(1) Lake View Consols, Limited. (£ s. d.)	(s. d.)	(2) Ivanhoe Gold Corporation, Limited. (£ s. d.)	(s. d.)	(3) Golden Horse-Shoe Estates Co., Limited. (£ s. d.)	(s. d.)	(4) Gt. Boulder Proprietary Gold Mines, Limited. (£ s. d.)	(£ s. d.)
* Amount expended charged to capital account.	17,604 8 4	6 0·014	13,740 5 2	4 7·270	18,440 5 10	11 3·511	54,072 14 8	1 0 10·361
Amount charged profit and loss ac. (written off)	‡25,772 0 0	4 1·193	9,925 9 10	3 3·926	7,091 4 6	4 4·111	20,000 0 0	0 7 8·601
	43,376 8 4	10 1·207	23,665 15 0	7 11·196	25,531 10 4	15 7·622	74,072 14 8	1 8 6·962

† Of this amount, 4023 tons consisted of sulphide ore, which was raised and treated; 1403 tons were dealt with at the mine, at a cost of 3*l.* 16*s.* 9*d.* per ton; and 2620 tons were shipped and smelted at Illawarra, at a cost of 7*l.* 4*s.* 5¾*d.* per ton.

‡ Includes 6855*l.* 18*s.* 6*d.* = 1*s.* 7·157*d.* "written off" for mine timbering that was debited to extraction.

§ 44,323 tons of sands and 35,136 tons of slimes were dealt with by cyanide, and 90 tons of concentrates were treated.

‖ All oxidised ore.

¶ 37,369 tons of sands and 31,685 tons of slimes were dealt with in the cyanide works.

** 15,408 tons of tailings were treated by cyanide, and 410 tons of concentrates were shipped to the smelters; 1243*l.* 8*s.* 6*d.* = 9·138*d.* being charged to reduction (milling), on this latter account.

†† 23,707 tons of tailings were dealt with in the cyanide works.

development, shaft-sinking, etc., under Capital Account or Profit and Loss Account, whether written off entirely or in part or not. Apart from Development charges and sums written off for depreciation of machinery, no other capital charges are included in the table. Special items debited to Revenue Account, or Profit and Loss Account, such as "Expenditure on Cyanide law suit," "Experiments with Sulphide Ore," "Adapting the Boulder Milling Company's plant and running the same," "Preliminary Expenses" (in connection with the liquidation of the old, and formation of the new Golden Horse-shoe Company), etc., have been also excluded, as in a table of this kind they would be out of place.

In connection with the table just given, and that on pp. 210, 211, which deals with costs in 1900), it is to be observed that whilst some companies treat "development" and "depreciation" as *working expenses*, others charge these items to *capital*, and write them off in whole or in part.

As it was necessary, however, to do so in some instances, the Author has treated them as if they were a working charge in all cases; and even supposing them to be simply book-entries, he is of opinion that there is ample justification for adopting this principle, since any such charges must be deducted in one way or another from profits. Income tax, dividend-taxes, and London expenses, are similarly included in both tables as charges against revenue.

If mining companies, when fully equipped and developed, in the preparation of their "cost-sheets" (whilst keeping capital and profit and loss account charges separate) were to treat all current expenditure, including improvements, etc., as working costs, the cost per ton milled might frequently appear, perhaps, considerably greater than would otherwise be the case; but it seems the most rational and practical way of dealing with mine costs, in order to arrive at the ultimate question the business-man and mine shareholder wants to know: viz. the *actual divisible profit*, after all necessary charges are covered. This may be made more or less clear or otherwise, but no arrangement of figures can make it greater or less than it is, when the accounts for the year are closed. It will always remain, however, a more or less open question, to which fixed rules are difficult to apply, how much ought to be written off for depreciation on different classes of machinery, what proportion of the expenditure on plant and development should properly be considered as an actual asset, and what proportion should be "written off," from time to time, on account of "mine-development redemption."

The table on next page, which may be of interest, shows how the mining and mine-development costs were subdivided in 1898 and 1899, at the North Boulder mine; based upon the *tonnage of ore mined and raised*, viz. 10,556 tons in 1898, and 12,097 tons raised in 1899, under the management in Australia of Messrs. C. B. Kingston, M. Inst. M.M., and G. Browne, Assoc. M. Inst. C.E. (the local agents of the company) and Mr. Roger Lisle, the mine manager in charge.

The higher percentage in "cost of development" in 1899 as compared with 1898, shown in the table, is explained by the larger amount of sinking and cross-cutting done, in proportion to driving, during the period in question; the substitution of machine-work to a large extent, in place of hand-labour; and the increased hardness of the ground in depth.

In 1898 some 2682 feet 6 inches were sunk and driven in course of development, with an expenditure of 5427*l.* 13*s.* 10*d.*, representing a cost of only 2*l.* 0*s.* 5½*d.* per lineal foot for the whole of the work done. Estimating this as representing about 101,813 cubic feet in place (say 7832 tons),* this works out at a cost of about 13*s.* 10·3*d.* per ton of stone broken in shafts, levels, etc.; this only allows, however, for bare dimensions and average weight, the actual tonnage may have been considerably greater, and the cost per ton correspondingly less.

"*Stoping.*"—As a certain amount of "waste" is broken with the mill-rock and left in the stopes, the cost of "stoping" is liable to appear higher than it really is, when calculated on the *tonnage of ore* mined and raised.† The cost of "stoping," in fact, fluctuates with the width of pay-ore the stopes yield, the ease with which the ground breaks, its "cleat," and other factors, such as the number and depth of the holes, the way in which they are placed, whether hand or machine-drilled, the strength of the explosives used, and the proportion of "misfires."

In 1898, it may be estimated that at the North Boulder mine *at least* 13,691 tons of ore and mullock were broken in the "stopes,"

* Estimated at 13 cubic feet per ton; the weight of the Kalgoorlie ore being variously calculated at between 12 and 14 cubic feet per ton, according as it happens to be oxidised, or unaltered formation, the quantity of "mineral" present, and other circumstances, on which it depends.

† *Vide* remarks under the head of Sorting, p. 186.

—	Development. 1898.* Cost per ton.		Development. 1898.* Percentage of Cost.	Development. 1899. Cost per ton.		Development. 1899. Percentage of Cost.	Mining. 1898.* Cost per ton.		Mining. 1898.* Percentage of Cost.	Mining. 1899. Cost per ton.		Mining. 1899. Percentage of Cost.
	s.	d.		s.	d.		s.	d.		s.	d.	
Labour	9	0·472	87·89	11	1·920	82·74	6	4·479	90·72	6	5·480	91·45
Supplies—												
Explosives	0	10·799	12·08	1	11·319	17·25	0	5·155	9·28	0	5·301	8·55
Caps and fuze	0	1·688		0	2·097		0	0·895		0	0·512	
Candles	0	1·884		0	2·144		0	1·410		0	1·185	
Miscellaneous	0	0·558		0	0·358		0	0·375		0	0·246	
	10	3·401	99·97	13	5·838	99·99	7	0·314	100·00	7	0·724	100 00

—	General Mine Charges. 1898.* Cost per ton.		1898.* Percentage of Cost.	1899. Cost per ton.		1899. Percentage of Cost.
	s.	d.		s.	d.	
Labour (including shift-bosses, engine-drivers, brace-men, blacksmiths, tool-sharpener, timbermen, condenser, mullocking, trucking, bagging-ore, and hauling)	9	1·383	71·59	7	7·850	64·91
Fuel	2	4·803	18·84	2	2·280	18·57
Supplies—						
Mine timber	0	6·876	7·51	0	9·352	9·79
,, rails	0	0·840		0	1·070	
Oil and light	0	0·776		0	0·650	
,, lubricating	0	0·477		0	0·759	
Charcoal	0	0·335			..	
Ore bags	0	0·333			..	
Miscellaneous	0	1·857		0	2·030	
Tools	0	0·899	0·59	0	2·780	1·96
Repairs	0	2·214	1·45	0	6·710	4·74
	12	8·793	99·98	11	9·481	99 97

* Excerpt from the Company's Annual Report.

in 5802 shifts, which represents probably not less than 2·5 tons broken per man per shift, with a total consumption of 3687 lb. of gelignite, or 0·27 lb. per ton of stone broken; 62 boxes of caps and 831 coils of fuze were used in stoping this ground out.

In the same period, 8000 shifts were employed on development-work, and it may be calculated, by cubing the ground opened up, that some 7832 tons were broken in sinking, driving, etc., which represents approximately one ton broken per man per shift, with an expenditure of about 7600 lb. or ·98 lb. of gelignite and 336 lb. or 0·043 lb. of black powder per ton of stone mined; and a total of 120 boxes of caps, and 1490 coils of fuze consumed. During the early part of 1901, 672 feet 6 inches were driven, sunk and risen (with the exception of 40 feet) "in blue and sulphide stone," with a consumption of 128 cases of gelignite, representing 2 tons 17 cwt. 16 lb. used.

From particulars given by Mr. S. J. Truscott, A.R.S.M., it appears that on the Rand they mostly use from ½-lb. to 1¼ lb. of gelatine per ton broken in stopes, and 2 to 3½ lb. per ton broken in drives, and though Transvaal "banket" is probably harder to break than the ground in the oxidised zone at Kalgoorlie (to which the above figures for 1898 above given apply), it is probably easier to mine than some of the Kalgoorlie "blue ground"; consequently these figures do not seem excessive.

In 1896, dynamite was costing in the Transvaal 91*s.* 10*d.* per case, and gelatine 107*s.* 4*d.*, and Messrs. Webb and Pope Yeatman,* in this connection, say that the cost of explosives per ton probably averaged at least 9 per cent. of the total working costs, amounting at the period in question to from 2*s.* to 3*s.* per ton of ore mined. In shaft-sinking, an average of nine shafts 25 feet by 6 feet in the clear showed the cost of explosives as 5·12 per cent. of total working costs, and a cost per ton of rock broken of 1*s.* $8\frac{3}{10}$*d.* for explosives.

In stoping in two large mines adjoining each other, the cost for explosives per ton of ore milled † was 1*s.* 4*d.* in the one, and from 3*s.* 3*d.* to 3*s.* 6*d.* in the other, the difference in the latter case being probably due to the use of air-drills. In driving and development-work generally, the cost in opening up a well-managed deep level

* *Engineering Magazine*, May 1898, p. 262.

† G. A. Denny gives the average quantity of dynamite required per ton of ore milled as 1·3 lb.; representing at 75*s.* per case 1·95*s.* per ton.—*Deep Level Mines of the Rand*, p. 161.

mine, preparatory to milling, has averaged from 4*s*. 6*d*. to 6*s*. per ton of rock taken out.

Mr. H. C. Hoover states* that one of the most difficult problems in West Australian mines is the inefficiency of the labour

FIG. 41.—OXIDISED-ORE STOPE, NO. 1 LEVEL NO. 4 LODE, GOLDEN HORSE-SHOE.

(wages, he reckons, representing about 80 per cent.† of the cost of sinking and driving). This factor, he remarked, is improving with time, "but even now the amount of work accomplished per man per day is astoundingly small." In one mine, the men stoped quartz, in a body 20 feet wide, at the rate of 1·8 ton per man per diem; and in another mine, in soft lode-matter, under best conditions, 2·7 tons per man per diem. It may be added that each foot of thickness of ore (reckoning it at 12 to 14 cubic feet to the ton in place) may be estimated to yield about 2½ to 3 tons per square fathom (6 feet by 6 feet) stoped. The cost of mining (stoping or

* *Mineral Industry*, vol. vi., p. 335.

† As shown by the foregoing data, it appears nearer 85 per cent. on the average in some instances.

getting ore) as shown in the accounts furnished by different mines, if calculated upon the gross tonnage of ore got, cannot be accurately ascertained, or compared, unless the proportion which "ore got in course of development" bears to the actual quantity "stoped"

FIG. 42.—STOPE, NO. 3 LEVEL NO. 4 LODE, GOLDEN HORSE-SHOE.

is known and taken into account. The illustrations, Figs. 41, 42 and 43 show several of the "stopes" (in oxidised and sulphide-ore) in the Golden Horse-shoe mine.

Mr. Hoover mentions that the mining costs at the East Murchison United, Limited (in the East Murchison district), managed by D. P. Mitchell, of California, in December 1897 were as follows:—Mine development, \$1·86 (7*s.* 9*d.*); stoping, \$1·94

FIG. 43.—SULPHIDE-ORE STOPE, NO. 3 LEVEL NO. 4 LODE, GOLDEN HORSE-SHOE.

(8*s.* 1*d.*); timbering, \$0·20 (10*d.*); hoisting, \$0·49 (2*s.* ½*d.*); tramming, \$0·29 (1*s.* 2½*d.*); milling, \$1·20 (5*s.*); and general expenses, \$1·70 (7*s.* 1*d.*); total, \$7·68 (32*s.*); and they serve as an example of cheap costs in Western Australia.

From information kindly supplied to me by Mr. Ed. Skews, it appears that the mining (stoping) costs at the Boulder Main Reef, in June 1898—subdivided under the various heads of labour, (stoping), trucking, hoisting, explosives, candles and other stores—were as follows:—

	Cost per ton. s.	d.
Mining	6	9·3
Hoisting	1	2·2
Trucking	1	1·8
Explosives	0	3·4
Candles	0	0·7
Other stores and management	0	5·6
	9	11

At Lake View Consols, the cost of mining (stoping) for twelve months, in 1898–9, and 1899-1900, is given upon an output of 85,889 tons, and 37,732 tons respectively, as shown in the table.

Lake View Consols.	Expenditure. £	s.	d.	Cost per ton. s.	d.	Expenditure. £	s.	d.	Cost per ton. s.	d.
Mining	28,252	13	10	6	6·947	30,117	12	9	15	11·568
Trucking and mullocking	8,822	15	6	2	0·653	7,123	12	3	3	9·311
Hoisting	3,833	16	7	0	10·713	4,603	8	2	2	5·281
Timbering	3,800	13	5	0	10·620	3,753	5	5	1	11·873
General stores and charges	1,771	2	9	0	4·949	1,625	1	6	0	10·336
Tool sharpening and repairs	975	8	7	0	2·726	956	12	6	0	6·085
Assaying expenses	683	13	10	0	1·910	789	14	11	0	5·023
Tools, powder, and sample-bags	1,150	7	5	0	3·215	1,206	16	1	0	7·676
Superintendence	2,281	2	11	0	6·374	1,963	7	1	1	0·488
	51,571	14	10	12	0·107	52,139	10	8	27	7·641

The cost of stoping at the Lake View Consols for the year ending August 31, 1901, on an output of 76,571 tons, is also given as follows :—

Lake View Consols.	Expenditure. £	s.	d.	Cost per ton. s.	d.
Mining	26,703	7	11	6	11·698
Trucking and mullocking	10,996	18	2	2	10·468
Hoisting	6,887	11	2	1	9·588
Timbering	1,552	17	7	0	4·867
Underground charges	1,072	12	6	0	3·362
Tool sharpening and repairs	545	19	10	0	1·711
Assaying	436	14	2	0	1·369
Tools, powder, and sample-bags	1,138	6	8	0	3·568
Superintendence	1,321	10	5	0	4·142
	50,655	18	5	13	2·773

At the Golden Horse-shoe 32,659 tons of oxidised ore were raised in 1899, and the cost of mining (stoping) came to 12*s.* 10·714*d.*, whilst 76,532 tons of oxidised and sulphide ore were raised in 1900, and the cost of mining (stoping) came to 12*s.* 8·610*d.*

At the Ivanhoe, in 1900, calculated upon the basis of 74,750 tons treated, stoping cost 9*s.* 0·388*d.*; hauling, 8·838*d.*; trucking, 2*s.* 0·671*d.*; and development, 8*s.* 3·205*d.* per ton (charged to profit and loss account) written off in the Balance Sheet. In 1901, upon the basis of 90,423 tons treated, stoping cost 10*s.* 0·207*d.*; hauling, 11·542*d.*; and trucking, 1*s.* 6·820*d.* per ton.

At the Associated, the cost of ore extraction for the year ending March 31, 1901, based on 35,524 tons raised, was as follows:—

	Cost per ton. *s.*	*d.*
Management	0	1·689
Wages	11	3·568
Mining timber	0	3·313
Explosives	0	9·605
Candles	0	2·695
Coal	0	0·359
Firewood	0	7·068
Timber	0	0·210
Water	0	5·377
Compressed air	0	2·825
Stores	0	1·112
General underground maintenance	1	4·661
Total	15	6·482

For the year ending March 31, 1902, on 41,384 tons treated, stoping and trucking cost 13*s.* 7·31*d.*; 3·83*d.* extra was charged to ore-extraction for superintendence; and hauling cost 3*s.* 8·61*d.*

At Hannan's Oroya, the cost of mining (stoping, etc.), came to 7*s.* 3·7*d.* in 1900; and for the year ending March 31, 1901 (on an output of 7684 tons) amounted to: wages (2125*l.* 14*s.* 10*d.*) = 5*s.* 6·394*d.*; assays (61*l.* 9*s.*) = 1·919*d.*; explosives (138*l.* 13*s.* 2*d.*) = 4·330*d.*; fuel (99*l.* 12*s.* 5*d.*) = 3·111*d.*; fodder (9*l.* 1*s.* 8*d.*) = 0·268*d.*; plant, repairs, etc. (18*l.* 18*s.*) = 0·590*d.*; stores (130*l.* 9*s.* 8*d.*) = 4·075*d.*; timber (90*l.* 0*s.* 8*d.*) = 2·812*d.*; water (54*l.*) = 1·686*d.*; total, 7*s.* 1·185*d.* per ton milled.

At the Great Boulder, the cost of mine expenses (stoping) in

1898 and 1899, upon an output of (crushed) 41,043 tons and 51,835 tons respectively, was subdivided as follows:—

Great Boulder Proprietary.	1898.					1899.				
	Expenditure.			Cost per ton.		Expenditure.			Cost per ton.	
	£	s.	d.	s.	d.	£	s.	d.	s.	d.
Wages	21,041	13	0	10	3·041	25,938	17	2	10	0·099
Stores	1,247	10	4	0	7·295	1,639	13	11	0	7·592
Timber	1,341	5	4	0	7·843	613	13	2	0	2·841
Firewood	754	18	5	0	4·414	878	3	8	0	4·066
Condensed water	415	5	9	0	2·427	419	15	7	0	1·944
Proportion of horse-keep	13	19	7	0	4·289	200	8	10	0	4·507
Ore carting	719	11	3			773	1	4		
	25,534	3	8	12	5·309	30,463	13	8	11	9·049

In 1900, 54,680 tons were stoped; and in 1901, 89,121 tons; and the cost came to:—

Great Boulder Proprietary.	1900.					1901.				
	Expenditure.			Cost per ton.		Expenditure.			Cost per ton.	
	£	s.	d.	s.	d.	£	s.	d.	s.	d.
Wages	28,939	16	3	10	7·022	26,542	3	2	5	11·477
Contracts	2,103	11	3	0	9·233	5,470	19	2	1	2·703
Stores	2,728	17	7	0	11·978	4,460	7	4	1	0·012
Timber	1,239	0	4	0	5·438	2,085	7	6	0	5·616
Firewood	1,619	11	6	0	7·109	1,970	9	3	0	5·306
Condensed water	969	18	6	0	4·257	1,401	19	2	0	3·775
Proportion of horse-keep	330	18	4	0	6·480	244	17	5	0	0·659
Ore carting	1,145	10	2			1,398	8	2	0	3·766
Assay expenses	227	15	4	0	0·599	215	13	10	0	0·581
Fuel (charcoal, etc.)	45	16	11	0	0·201	31	3	1	0	0·084
Sampling	290	6	4	0	1·274	295	13	10	0	0·796
Tool sharpening	861	13	0	0	3·782	1,039	3	11	0	2·799
Compressed air	..				..	1,316	14	0	0	3·546
	40,502	15	6	14	9·773	46,472	19	10	10	5·120

At the Kalgurli Gold-Mines, the mine costs for the year ending July 26, 1901, are shown on the following cost-sheet.

Kalgurli Gold-Mines, Ltd.	Total Costs for the Year. Broken and raised . 15,583 tons; Shipped to London . 12 ,,; Total . 15,595 ,,			Average Cost for the Year. Cost per ton.	
	£	s.	d.	s.	d.
Labour—					
Breaking ore	2838	9	4	3	7·68
Loading and trucking	1055	16	3	1	4·25
Repairing and sharpening tools	251	7	4	0	3·87
Sundries	138	17	2	0	2·14
	4284	10	1	5	5·94
Stores—					
Tools	74	5	5	0	1·14
Candles	74	16	5	0	1·15
Explosives	691	11	8	0	10·64
Assaying	161	0	0	0	2·48
Sundries	111	12	3	0	1·72
	1113	5	9	1	5·13
Hauling and rock-drills	1746	6	4	2	2·87
Development—					
Redemption on account of surface ore	1501	6	4	1	11·10
Total cost of ore at shaft's mouth	8645	8	6	11	1·04
Proportion of administration and general expenses in Western Australia	930	7	3	1	2·32
	9575	15	9	12	3·36
Less cost of ore shipped to London	6	3	3		
As per profit and loss account	9569	12	6		

Costs at Kalgoorlie in 1900.

The table on pp. 210 and 211 gives the Author's estimate of general costs in 1900, at seven of the principal mines, based upon the "*tonnage treated*" in each case.

The considerable variations which appear in the total costs may be explained partly by differences in output, which is more or less dependent upon the capacity of the reduction-plants; but is governed as well as by the relative length, width, regularity, and frequency of occurrence of the ore-bodies in each mine, these latter factors all influencing the "cost of development."

Variations in cost are, however, partly due to the systems of treatment employed at different mines (more particularly for dealing with sulphide ore), partly to the proportions which the quantities of *oxidised* and *sulphide ore* mined and treated in each case bear to one another; and partly (as regards the details) to the way in which development, maintenance and other charges are treated by the different companies.

Under the head of "development," all sums are included that are charged to "development," "diamond drilling," or "shaft-sinking"—whether treated as capital charges, or debited to "revenue" or "profit and loss account," and written off in the Balance Sheet.

Although some mines spent considerably more than others on "development," it must be borne in mind that by so doing they presumably added to their "reserves" of ore to a more or less large extent; and whilst some companies wrote off larger sums than others, they thus as it were provided a "reserve" fund for *future* requirements; and thereby strengthened their financial position for the time being.

The same items in the table have been grouped, as far as possible, together under each head, but it is impossible to do so with absolute exactness, owing to the different way in which the accounts at several mines are subdivided and presented; it will, however, I believe, be found sufficiently accurate for all practical purposes.

The general rise in costs in 1900 compared with 1899 is explained by the fact that the table covers *a transition period*, viz. from mining and treating oxidised ore and tailings to dealing with a combination of both oxidised and sulphide ores in greater or less proportion; and there is every reason to suppose that the cost of handling sulphide ores on a large scale will be considerably reduced, at some if not all of the mines, in the near future, for reasons elsewhere explained.

In the following table (except in the case of the Kalgurli) the tonnage of ore *treated* is taken as a basis of calculation because it offers the best if not the only uniform basis of comparison; the profits of each mine being determined by scale of treatment, and not by the quantity of ore *mined.*

The figures therein given do not, however, show the cost of mining, milling, cyaniding, etc., when calculated upon the actual quantities mined, milled or cyanided, in each case. These details in

GENERAL TABLE

Name of Company.	Basis of Calculation, Tons of Ore Milled.	Development.	Mining.	Reduction.‖	Maintenance.
		£ s. d.	£ s. d.	£ s. d.	£ s. d.
(1) Lake View Consols.		A 26,009 12 9			
		B 20,645 9 3			
gross cost	37,732 (about 68 % sulphide treated)	46,655 2 0	52,139 10 8	112,749 5 3	4,462 3 8
		A 0 13 9·437			
		B 0 10 11·319			
cost per ton		1 4 8·756	1 7 7·641	2 19 9·159	2s. 4·382d.
(2) Associated Gold Mines					
gross cost	35,524 (about 97 % sulphide treated)	A 41,185 3 11	27,762 7 2	52,995 3 10	13,586 17 7
cost per ton		1 3 2·247	0 15 7·562	1 9 10·036	7s. 7·793d.
(3) Great Boulder Proprietary.		A 54,797 0 10		C 42,973 3 8	
		B 20,000 0 0		D 25,128 3 10	
gross cost	54,680 (about 31 % sulphide treated)	74,797 0 10	40,502 15 6	68,101 7 6	6,814 2 6
		A 1 0 0·513		C 0 15 8·617	
		B 0 7 3·783		D 0 9 2·292	
cost per ton		1 7 4·296	0 14 9·773	1 4 10·909	2s. 5·908d.
(4) Kalgurli Gold Mines.		A 8,163 0 9			
		B 1,574 0 0			
gross cost	12,133 (all sulphide) made up of: ore raised 8000 tons, ore treated 4133 tons	9,737 0 9	3,150 9 4	8,228 7 3	1,350 14 1
		A 0 13 5·471			
		B 0 2 7·135			
cost per ton		*0 16 0·606	†0 15 2·945	†1 19 9·812	*2s. 2·718d.
(5) Great Boulder Perseverance.					
gross cost	‡43,298 (about 49 % sulphide treated and smelted)	A 28,338 0 11	25,390 13 3	68,042 17 5	4,131 1 4
cost per ton		0 13 1·077	0 11 8·739	1 11 5·160	1s. 10·898d.
(6) Golden Horseshoe Estates.		A 24,000 2 1			
		B 12,439 1 2			
gross cost	§76,532 (about 12 % sulphide treated and smelted)	36,439 3 3	48,664 16 10	86,093 2 5	1,633 1 11
		A 0 6 3·263			
		B 0 3 3·008			
cost per ton		0 9 6·271	0 12 8·610	1 2 5·983	5·121d.
(7) Ivanhoe Corporation.					
gross cost	74,750 (about 35 % sulphide)	A 30,898 8 2	44,195 16 0	54,966 6 6	9,758 3 7
cost per ton		0 8 3·205	0 11 9·899	0 14 8·481	2s. 7·330d.

* Calculated upon 12,133 tons mined.
† Calculated upon 4133 tons crushed, the remaining 8000 tons being got in course of development.
C Calculated upon 54,680 tons of oxidised and sulphide ore.
D Estimated on the average cost of treating 93,726 tons of tailings dealt with in 1900, which cost 43,072*l.* 2*s.* 5*d.*
E Exclusive of cyanide, law-suit expenses, compensation for accidents, and sums spent on Capital Account other than upon "Development" and shaft sinking.
F Exclusive of visit of experts to mine, and capital charges other than Development, shaft sinking and drilling.
G Exclusive of capital expenditure other than upon "Development."
H Exclusive of expenditure on Capital Account other than upon "Development."
I Exclusive of expenditure on Capital Account, other than upon "Development"; and interest on loans.
J Exclusive of capital expenditure other than upon Development.

Management and General Mine Expenses.	Depreciation, written off Plant, Machinery and Buildings.	Taxes on Dividends and Income.	London and Adelaide Office Expenses.	Totals.	Remarks.
£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	
12,015 8 7	48,471 14 5	15,030 0 0	5,495 14 0	E 297,018 18 7	A Charged as Capital Expendit .re. B Charged to Profit and Loss Account (written off Balance Sheet). ‖ Includes milling, cyanide, slimes and sulphide-ore treatment, concentrates, and ore shipping expenses.
6s. 4·425d.	1 5 8·310	7s. 11·600d.	2s. 10·956d.	7 17 5·229	(Year ending August 31, 1900.)
20,929 5 7	..	8,172 7 8	8,385 17 10	F 173,017 3 7	A Charged as Capital Expenditure. ‖ Includes battery and sulphide-ore treatment, ore shipping and freight, insurance, and bank commission on bullion, which latter items cost 1847*l.* 9*s.* 11*d.*
11s. 9·398d.	..	4s. 7·212d.	4s. 8·655d.	4 17 4·903	(Year ending March 31, 1901.) Maintenance does not include "General underground maintenance."
15,292 18 7	20,300 0 0	23,453 18 1	9,119 3 2	H 258,381 6 2	A Expenditure partly charged to Capital, partly to Revenue Account. B Written off Profit and Loss Account in Balance Sheet. ‖ Includes battery and sulphide treatment, cartage, and the cyaniding of 54,680 tons of tailings.
5s. 7·123d.	0 7 5·100	8s. 6·943d.	3s. 4·025d.	4 14 6·077	(Year ending December 31, 1900.)
2,625 9 5	5,055 0 7	122 3 8	2,409 18 1	G 32,679 3 2	A Charged as Capital Expenditure. B Charged to Profit and Loss Account. ‖ Includes all treatment charges, calculated upon 4133 *tons crushed*. (Year ending July 31, 1900.)
*4s. 3·934d.	*0 8 3·992	*2·417d.	*3s. 11·669d.	4 10 2·093	
4,484 13 11	7,614 16 6	1,486 6 2	1,602 0 3	I 141,090 9 9	A Charged to Profit and Loss Account. ‖ Includes all treatment charges on oxidised and sulphide ores, and tailings treatment.
2s. 0·859d.	0 3 6·209	8·239d.	8·880d.	3 5 2·061	(Year ending December 31, 1900.)
7,125 4 0	6,856 2 1	21,119 5 7	10,202 16 2	J 218,133 12 3	A Charged as Capital Expenditure B Charged to Revenue Account (written off Balance Sheet). ‖ Includes battery expenses, cyanide treatment of sands and slimes, and treatment of sulphide ore.
1s. 10·344d.	0 1 9·500	5s. 6·229d.	2s. 7·995d.	2 17 0·053	(Year ending December 31, 1900.)
14,251 2 4	26,477 1 8	14,555 18 1	4,312 10 11	K 199,415 7 3	A Charged to Profit and Loss Account (written off Balance Sheet). ‖ Includes ore breaking, battery expenses, cyanide treatment (sands and slimes), and sulphide treatment.
3s. 9·756d.	0 7 1·010	3s. 10·734d.	1s. 1·846d.	2 13 4·261	(Year ending December 31, 1900.)

K Practically speaking includes all capital expenditure both on Development and Plant, but was exclusive of cyanide, law-suit charges, extra remuneration of Directors voted by shareholders, loss of live stock, and Western Australia Federation Fund.

‡ Oxidised ore—Tons mined 24,142; cost 7*s.* 10·61*d.* Tons treated 21,880; cost 18*s.* 5·22*d.*[1] Sulphide ore—Tons mined 22,777; cost 13*s.* 11·22*d.* Tons treated[2] 20,257; cost 34*s.* 11·31*d.*

§ Oxidised ore—Tons mined 67,095; cost 12*s.* 3·359*d.* Tons treated[3] 67,095; cost 15*s.* 10·188*d.* Sulphide ore—Tons mined 9437; cost 15*s.* 9·956*d.* Tons treated 9437; cost 69*s.* 9·309*d.*

[1] 25,990 tons of tailings treated cost 8*s.* 8·62*d.* extra, making the total cost of the reduction of the oxidised ore about 27*s.* per ton.
[2] The balance of 1161 tons being smelted.
[3] Including cyanidation of 33,418 tons of "sands"; 25,929 tons of "slimes"; and treatment of 586 tons of concentrates.

Name of Company.	Basis of Calculation, Tons of Ore Milled.	Development. £ s. d.	Mining. £ s. d.	Reduction.‖ £ s. d.	Maintenance. £ s. d.
(1) Lake View Consols.		A 26,009 12 9 B 20,645 9 3			
gross cost	37,732 (about 68 % sulphide treated)	46,655 2 0	52,139 10 8	112,749 5 3	4,462 3 8
		A 0 13 9·437 B 0 10 11·319			
cost per ton		1 4 8·756	1 7 7·641	2 19 9·159	2s. 4·382d.
(2) Associated Gold Mines					
gross cost	35,524 (about 97 % sulphide treated)	A 41,185 3 11	27,762 7 2	52,995 3 10	13,586 17 7
cost per ton		1 3 2·247	0 15 7·562	1 9 10·036	7s. 7·793d.
(3) Great Boulder Proprietary.		A 54,797 0 10 B 20,000 0 0		C 42,973 3 8 D 25,128 3 10	
gross cost	54,680 (about 31 % sulphide treated)	74,797 0 10	40,502 15 6	68,101 7 6	6,814 2 6
		A 1 0 0·513 B 0 7 3·783		C 0 15 8·617 D 0 9 2·292	
cost per ton		1 7 4·296	0 14 9·773	1 4 10·909	2s. 5·908d.
(4) Kalgurli Gold Mines.		A 8,163 0 9 B 1,574 0 0			
gross cost	12,133 (all sulphide) made up of: ore raised 8000 tons, ore treated 4133 tons	9,737 0 9	3,150 9 4	8,228 7 3	1,350 14 1
		A 0 13 5·471 B 0 2 7·135			
cost per ton		*0 16 0·606	†0 15 2·945	†1 19 9·812	*2s. 2·718d.
(5) Great Boulder Perseverance.					
gross cost	‡43,298 (about 49 % sulphide treated and smelted)	A 28,338 0 11	25,390 13 3	68,042 17 5	4,131 1 4
cost per ton		0 13 1·077	0 11 8·739	1 11 5·160	1s. 10·898d.
(6) Golden Horseshoe Estates.		A 24,000 2 1 B 12,439 1 2			
gross cost	§76,532 (about 12 % sulphide treated and smelted)	36,439 3 3	48,664 16 10	86,093 2 5	1,633 1 11
		A 0 6 3·263 B 0 3 3·008			
cost per ton		0 9 6·271	0 12 8·610	1 2 5·983	5·121d.
(7) Ivanhoe Corporation.					
gross cost	74,750 (about 35 % sulphide)	A 30,898 8 2	44,195 16 0	54,966 6 6	9,758 3 7
cost per ton		0 8 3·205	0 11 9·899	0 14 8·481	2s. 7·330d.

* Calculated upon 12,133 tons mined.
† Calculated upon 4133 tons crushed, the remaining 8000 tons being got in course of development.
C Calculated upon 54,680 tons of oxidised and sulphide ore.
D Estimated on the average cost of treating 93,726 tons of tailings dealt with in 1900, which cost 43,072*l.* 2*s.* 5*d.*
E Exclusive of cyanide, law-suit expenses, compensation for accidents, and sums spent on Capital Account other than upon "Development" and shaft sinking.
F Exclusive of visit of experts to mine, and capital charges other than Development, shaft sinking and drilling.
G Exclusive of capital expenditure other than upon "Development."
H Exclusive of expenditure on Capital Account other than upon "Development."
I Exclusive of expenditure on Capital Account, other than upon "Development"; and interest on loans.
J Exclusive of capital expenditure other than upon Development.

Management and General Mine Expenses.	Depreciation, written off Plant, Machinery and Buildings.	Taxes on Dividends and Income.	London and Adelaide Office Expenses.	Totals.	Remarks.
£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	
12,015 8 7	48,471 14 5	15,030 0 0	5,495 14 0	E 297,018 18 7	A Charged as Capital Expenditure. B Charged to Profit and Loss Account (written off Balance Sheet). ‖ Includes milling, cyanide, slimes and sulphide-ore treatment, concentrates, and ore shipping expenses. (Year ending August 31, 1900.)
6s. 4·425d.	1 5 8·310	7s. 11·600d.	2s. 10·956d.	7 17 5·229	
20,929 5 7	..	8,172 7 8	8,385 17 10	F 173,017 3 7	A Charged as Capital Expenditure. ‖ Includes battery and sulphide-ore treatment, ore shipping and freight, insurance, and bank commission on bullion, which latter items cost 1847*l.* 9*s.* 11*d.* (Year ending March 31, 1901.) Maintenance does not include "General underground maintenance."
11s. 9·398d.	..	4s. 7·212d.	4s. 8·655d.	4 17 4·903	
15,292 18 7	20,300 0 0	23,453 18 1	9,119 3 2	H 258,381 6 2	A Expenditure partly charged to Capital, partly to Revenue Account. B Written off Profit and Loss Account in Balance Sheet. ‖ Includes battery and sulphide treatment, cartage, and the cyaniding of 54,680 tons of tailings. (Year ending December 31, 1900.)
5s. 7·123d.	0 7 5·100	8s. 6·943d.	3s. 4·025d.	4 14 6·077	
2,625 9 5	5,055 0 7	122 3 8	2,409 18 1	G 32,679 3 2	A Charged as Capital Expenditure. B Charged to Profit and Loss Account. ‖ Includes all treatment charges, calculated upon 4133 *tons crushed.* (Year ending July 31, 1900.)
*4s. 3·934d.	*0 8 3·992	*2·417d.	*3s. 11·669d.	4 10 2·093	
4,484 13 11	7,614 16 6	1,486 6 2	1,602 0 3	I 141,090 9 9	A Charged to Profit and Loss Account. ‖ Includes all treatment charges on oxidised and sulphide ores, and tailings treatment. (Year ending December 31, 1900.)
2s. 0·859d.	0 3 6·209	8·239d.	8·880d.	3 5 2·061	
7,125 4 0	6,856 2 1	21,119 5 7	10,202 16 2	J 218,133 12 3	A Charged as Capital Expenditure. B Charged to Revenue Account (written off Balance Sheet). ‖ Includes battery expenses, cyanide treatment of sands and slimes, and treatment of sulphide ore. (Year ending December 31, 1900.)
1s. 10·344d.	0 1 9·500	5s. 6·229d.	2s. 7·995d.	2 17 0·053	
14,251 2 4	26,477 1 8	14,555 18 1	4,312 10 11	K 199,415 7 3	A Charged to Profit and Loss Account (written off Balance Sheet). ‖ Includes ore breaking, battery expenses, cyanide treatment (sands and slimes), and sulphide treatment. (Year ending December 31, 1900.)
3s. 9·756d.	0 7 1·010	3s. 10·734d.	1s. 1·846d.	2 13 4·261	

K Practically speaking includes all capital expenditure both on Development and Plant, but was exclusive of cyanide, law-suit charges, extra remuneration of Directors voted by shareholders, loss of live stock, and Western Australia Federation Fund.

‡ Oxidised ore—Tons mined 24,142; cost 7*s.* 10·61*d.* Sulphide ore—Tons mined 22,777; cost 13*s.* 11·22*d.*
Tons treated 21,880; cost 18*s.* 5·22*d.*[1] Tons treated[2] 20,257; cost 34*s.* 11·31*d.*

§ Oxidised ore—Tons mined 67,095; cost 12*s.* 3·359*d.* Sulphide ore—Tons mined 9437; cost 15*s.* 9·956*d.*
Tons treated[3] 67,095; cost 15*s.* 10·188*d.* Tons treated 9437; cost 69*s.* 9·309*d.*

[1] 25,990 tons of tailings treated cost 8*s.* 8·62*d.* extra, making the total cost of the reduction of the oxidised ore about 27*s.* per ton. [2] The balance of 1161 tons being smelted.

[3] Including cyanidation of 33,418 tons of "sands"; 25,929 tons of "slimes"; and treatment of 586 tons of concentrates.

the case of the Golden Horse-shoe and Perseverance Companies are furnished in the footnotes, and full particulars in other cases are given in separate tables, in which the details are minutely dissected.

For the sake of illustration however, the Great Boulder Proprietary may be taken to show how the result is liable to be influenced by these different methods of calculation ; the figures given, which all relate to the same period (viz. 1900), it should be pointed out, are exclusive of depreciation, taxes, or London office expenses.

Basis of Calculation.	Character of the Ore, Oxidised.	Cost per Ton.	
tons.		s.	d.
56,056 (extracted) .	Development (54,797*l.* 0*s.* 10*d.* expended) .	19	6·609
54,680 (stoped) .	Mining	14	9·773
37,484 (milled) .	Milling	11	0·697
93,726 (tailings) .	Cyaniding	9	2·292
54,680 (oxidised and sulphide ore mined and treated) .	Maintenance	2	5·908
54,680 ,, .	Management and general charges . .	5	7·123
	Total . . .	62	8·402

Basis of Calculation.	Character of the Ore, Oxidised and Sulphide.	Cost per Ton.	
tons.		s.	d.
54,680 (treated) .	Development (54,797*l.* 0*s.* 10*d.* expended) .	20	0·513
,, ,, .	Mining	14	9·773
,, ,, .	Reduction (including tailings treatment) .	24	10·909
,, ,, .	Maintenance	2	5·908
,, ,, .	Management and general expenses . .	5	7·123
	Total . . .	67	10·226

Basis of Calculation.	Character of the Ore, Sulphide.	Cost per Ton.	
tons.		s.	d.
56,056 (extracted) .	Development (54,797*l.* 0*s.* 10*d.* expended) .	19	6·609
54,680 (stoped) .	Mining	14	9·773
17,196 (milled) .	Milling, Roasting and Cyaniding . .	25	10·509
,, ,, .	Tailings treatment (proportion of cost) .	9	2·292
54,680 (oxidised and sulphide ore mined and treated) .	Maintenance	2	5·908
54,680 ,, .	Management and general charges . .	5	7·123
	Total . . .	77	6·214

The difference between the cost of treating oxidised and sulphide ore, as above shown, is not perhaps as great as one would at first expect; but it must be recollected that the costs of development and mining are calculated on one basis, viz. the gross quantity of oxidised and sulphide ore extracted and stoped; and it is possible, that to develop and mine similar quantities of sulphide ore alone might add somewhat to these items.

At the Great Boulder Perseverance, for example, the cost of mining oxidised ore in 1900 came to 7*s.* 10·61*d.*, calculated upon 24,142 tons mined, and to 7*s.* 1·44*d.* in 1901; whilst the cost of mining sulphide ore in 1900 came to 13*s.* 11·22*d.*, calculated upon 22,777 tons mined; and to 11*s.* 11·85*d.* in 1901.

At the South Kalgurli Gold Mine, the costs for July were given in a cable from the manager, dated September 16, 1901, as:—oxidised ore mining, 11*s.* $7\frac{3}{8}$*d.*; sulphide ore mining, 19*s.* $8\frac{3}{16}$*d.* per ton; transport, $5\frac{3}{16}$*d.* The quantities treated (as cabled on September 9) being, oxidised 340 tons, sulphide ore 1600 tons.

The annual *expenditure* upon development (disregarding sums written off, which are purely arbitrary) is a charge more or less likely to increase with depth, as in the harder ground more explosives are required for a given footage sunk or driven; besides which the cost of tramming is liable to grow larger as the number of levels increases, and in proportion to the extra distances that the ore has to be trucked and hoisted. The larger amount of water that is liable to collect in the workings, and the greater height to which it has to be pumped, must also be taken into account; whilst, as is well known, the substitution of rock-drills frequently tends to add to costs per foot driven, as compared with hand-labour. On the other hand, however, there are compensating causes which tend to neutralise and sometimes reverse this upward tendency in cost, for as time goes on, the labour employed becomes better organised and more highly skilled; so that better progress is made per man per shift. The more rapid development rendered possible with rock-drills reduces the cost of all standing charges per ton mined; and as the workings extend, less prospecting work requires to be done, larger outputs become possible, and larger and more economical winding-engines and other machinery take the place of the less efficient plant, with which smaller mines, in their earlier stages, are of necessity equipped.

The cost of mining (stoping) in the deeper ground, one might expect would also tend to become more expensive than in the upper levels, as the oxidised ore-bodies were, as a rule, of greater thickness, and the oxidised ore is much softer than the sulphide ore; but a good deal depends on the explosive used, the way in which the holes are placed, the method of stoping, and other local governing circumstances; and as the pay-ore in this field is, as a rule, better defined (i.e. more readily distinguishable from mullock) in the sulphide than in the oxidised zone, less worthless formation has to be broken in shooting down the ore, a circumstance which frequently unavoidably adds considerably to the cost of mining the oxidised ore; although the "mullock" broken with it may be useful for packing. Besides this, labour each year, as before said, tends to become more efficient, whilst the formations in the deeper levels in this district are in some cases a handier width to timber and mine than they were near the surface; and the cost of mining (stoping), like the cost of development, with increased outputs is more likely to fall than to rise, if the tonnage treated is taken as a basis to figure on.

For the year ending December 31, 1901,* the mining costs at the Golden Horse-shoe were subdivided as follows:—

—	Oxidised Ore. 68,479 tons.		Sulphide Ore. 31,928 tons.	
	Cost per ton.		Cost per ton.	
	s.	*d.*	*s.*	*d.*
Superintendence, etc.	0	4·37	0	4·67
Miners, stoping	4	2·78	3	11·53
„ winzes, rises, etc.	0	7·93	3	5·78
„ gangways and repairs	0	5·02	0	1·43
Trucking	0	8·90	0	4·44
Mullocking	1	4·03	0	11·71
Brace and platmen	0	2·44	0	2·10
Hoisting expenses	0	11·40	0	10·61
Timbering and timber charges	3	6·95	1	5·19
Rock-drills, tool-sharpening, etc.	0	5·03	1	10·4
Assaying and sampling	0	3·66	0	4·59
Explosives	0	5·65	1	2·40
Compressed air	0	1·16	0	9·13
General mining expenses and stores	0	11·43	0	11·98
Total	14	8·75	16	2·60

* The cost of driving and stoping in sulphide ore in August and September 1902 is shown analysed in Table XXXIII.

Surface Haulage. — Several of the mines at Kalgoorlie are connected by sidings with the Government steam tram-line. At the Associated, which stands on a hill, an endless wire-rope tramway has been built to haul firewood from the railway to the main boiler-floor, but drays and horse-teams are still extensively employed; overhead tramways on trestle-work, operated by manual labour, are laid to the waste-dumps. These latter and the tailings-heaps are frequently connected by tramways with small shafts sunk along the "outcrops" of the "formations," which are used for passing down "mullock," etc., for "filling" in the stopes.

At the Lake View Consols, the ore hoisted from the main shaft, broken in the stone-breaker, is raised from storage-bins beneath, by an endless wire-rope bucket tramway, to the top of the mill. At the Lake View South, the mill, which stands on rising ground, is connected with the main shaft in an ingenious way, by a tramway laid on trestles, set at such a grade that the trucks landed on the top landing-stage of the head-gear will run by gravity slowly down to the mill rock-breaker-floor, and can be returned on a reverse grade to a lower platform on the poppet-legs, which are built sufficiently high to allow of this being done.

Surface Illumination.—The mills and surface-works are mostly lighted with arc-lamps by electricity, generated at the mines, or supplied by the Kalgoorlie Electric Power and Lighting Company. At the Ivanhoe mine, Mr. Hewitson informed me, they had a dynamo of the direct-driven type, manufactured by the General Electric Company, of New York, driven at 560 revolutions per minute, with duplex steam-cylinders 6½ inches diameter by 5-inch stroke. This dynamo is a 20,000-watt machine (furnishing 182 amperes, at 110 volts), which supplied forty-three 32-candle-power lamps, one hundred and sixty-four 16-candle-power lamps, and two 1000-candle-power arc-lights. The total cost of running, maintenance and wages averaged, I believe, in 1900 about 4*l.* per diem.

Shops.—The larger mines do their own repairs, and are provided with lathes, punching, shearing, slotting and drilling machines, and wood-working machinery. At the Lake View Consols they have a moulding-shop; and a steam-hammer in the blacksmith's shop; and at the Great Boulder they have erected a small iron foundry. At Hannan's Star the changing house is 40 by 15 feet (capable of accommodating 150 men), and is fitted with steam clothes-drier, washing troughs, etc.; whilst other mines are provided with similar accommodation for their men.

CHAPTER VIII.

MILLING PRACTICE AT KALGOORLIE.

THIS embraces Stamp-batteries and Mills for wet-crushing and amalgamation, with supplementary cyanide works for the treatment of "tailings," consisting of "sands" and "slimes"; Dry-crushing Cyanide Works, for the treatment of oxidised ore and tailings; and Sulphide Works.

Oxidised Ore Treatment.

No particular difficulty has been experienced in handling this class of stone; although, owing to small and inefficient installations, scarcity of water, and high prices, it entailed considerable cost in the early days of the field; and no doubt, in some cases, there were heavy losses of gold in the "tailings." Much of this gold, however, has since been recovered in the cyanide works.

In recent years, with larger and better-equipped mills, improved management, and cheaper means of communication, the cost of milling by wet crushing and amalgamation has been brought down to more reasonable figures, the reduction being probably even greater than it appears on paper; as when the fields were first opened, it is probable that the tonnage of ore crushed was not always as accurately estimated as it might have been, a larger tonnage being sometimes milled than was reported as put through the batteries.

The principal metallurgical difficulty in dealing with this kind of stone arose from the sliminess of the ore, caused by the presence of silicate of magnesium, alumina, and hydrated oxides of iron, which Mr. H. P. Woodward stated* have been estimated to amount to over 40 per cent. of the entire lode-stuff. He has also expressed the opinion that the tailings of the more modern mills carried, as a rule, not more than 8 dwt. of gold per ton, which in some instances was probably the case; and in view of the nature of the ore, its richness, the fine state of division of the gold, and the quality of the water used, this cannot be considered a bad showing.

* *Trans. Inst. of Mining and Metallurgy*, vol. vi. p. 20.

Speaking of an earlier date, however, Baron Sloet van Oldruitenborgh remarked that several existing heaps of tailings carried "¾ of an oz. to 2 oz. of gold per ton"; and where they crushed *rich* ore, the tailings of some of even the more modern mills undoubtedly ran much above 8 dwt.

Some interesting experiments made by my friend, Mr. A. C. Claudet, M. Inst. M.M.,* seem to show that the percentage of extraction largely depends on the fineness to which the ore is crushed, as whilst he obtained an average extraction of 77 per cent. by the amalgamation, without grinding, of 3½ lb. of ore (which originally assayed 3 oz. 5 dwt. 12 gr. per ton) in a pan with mercury; 7·5 per cent. of the ore left on a 40-mesh sieve only yielded 1·9 per cent. of its gold; 12·6 per cent. left on a 60-mesh sieve yielded 15 per cent.; 21·3 per cent. left on a 120-mesh sieve yielded 70 per cent.; and 58·6 per cent. of the sample which passed a 120-mesh sieve yielded 93·3 per cent.

With fine crushing, therefore, it is not unreasonable to suppose that 80 to 85 per cent. of the gold in the "brown-stone" could, in certain cases, be extracted by amalgamation alone, and dealing with a low-grade ore, it might no doubt answer better than allowing the gold to escape the "battery" and "plates," if the extra recovery warranted the extra cost of finer crushing, and paid better than cyaniding the "tailings"; but with an oxidised ore originally worth say, 1½ oz. or upwards, as the tailings would be still worth retreating, even with an 85 per cent. extraction, it would scarcely pay to crush too fine, as the extra sliminess of the tailings would increase the difficulties in the cyanide works, and involve the use of filter-presses, which are always expensive.

Mr. G. J. Bancroft† gives a screen analysis of what he regarded as a typical milling-ore in this camp:—

Out of 100 parts—

0·8	remain on a	24	mesh screen.
0·98	"	30	"
9·34	"	40	"
16·63	"	60	"
17·43	"	80	"
5·50	"	100	"
49·32	passed through	100	"

* 'Notes on the Experimental Treatment of a Gold Ore from the Hannan's District, Western Australia,' by A. C. Claudet, A.R.S.M., *Trans. Inst. of Mining and Metallurgy*, vol. v.

† 'Kalgoorlie, Western Australia, and its Surroundings,' by Geo. J. Bancroft, *Trans. Am. Inst. of Min. Engs.*, vol. xxviii.

Following which, he gives a chemical analysis of a similar ore :—

		Per cent.
	Silica	48·43
	Iron	10·24
	Alumina	1·98
	Lime	9·86
	Magnesia	2·03
	Sulphur	3·66
	Copper	0·35
Calculated	Carbonic acid	7·75
Calculated	Oxygen in oxide of iron	3·05
Calculated	Alkalies, etc., undetermined	12·65
		100·00

From this he draws the deductions :—(1) That the 50 per cent. of "slimes" present would cause trouble in leaching (by packing), and (2) that the 10 per cent. of lime present (irrespective of magnesia) places chlorination out of the question.

A more recent analysis of a sample of oxidised ore from the Great Boulder mine, air-dried, is given as follows, by Mr. Robert Allen :—*

	Per cent.
Silica	66·80
Alumina	8·44
Ferric oxide	17·39
Magnetic oxide of iron	0·46
Lime	0·37
Magnesia	0·13
Chloride of sodium	0·50
Water (combined)	5·15
Water (moisture) balance	0·76
	100·00

The grade of the ore milled, as well as the fineness to which it is crushed, no doubt, to some extent, influence the grade of the tailings ; and the character of the water, when pumped back over and over again, as it used sometimes to be, in a more and more muddy condition (owing to its not being properly "settled"), apart from any injurious action the salts in the water might have, contributed to the losses referred to when mining was first started.

Bergrath Schmeisser appears to have been of the opinion that only about 55 to 60 per cent. of the gold was saved in the older

* 'Reduction Plants and Processes of Reduction, etc.' Pamphlet, Royal Commission, Glasgow International Exhibition, 1901, p. 17.

mills; and Baron Oldruitenborgh remarked that they hardly ever extracted more than 65 per cent., and then only when dealing with the most perfectly oxidised ores, the average being probably about 50 per cent. These losses may be ascribed to the amorphous unamalgamable (rusty) state of some of the ochreous ore, and "float gold" which escaped the plates, in addition to a certain proportion of gold locked up in sulphides, which the ores, even in the upper levels, carried. To obviate losses of this sort, some of the mining companies erected Berdan or other "pans," by which they succeeded in saving an additional 10 to 20 per cent. of the gold the ore originally contained; whilst "blankets" were also put in, to save the coarsest sulphides and tellurides that escaped, as well as some of the amorphous gold. By these means, they caught a certain quantity of concentrates, worth from 2 to 40 oz. of gold per ton, which were shipped to smelters.

The largest batteries at this period contained 30 stamps, more often only 4 or 8, or 5 to 10 heads, which crushed from 1½ to 2½ tons per stamp-head, per day—a small showing compared with 3½ to 6 tons per stamp-head crushed in recent years in South Africa in mills containing from 50 to 280 stamps each; there are various reasons, however, why it would not pay, as a rule, to put through *the soft "brown-stone"* found in Western Australia, so rapidly; partly because its exceptionally clayey nature* which tended either to clog the mortar and plates, or involved a heavy consumption of that most expensive commodity—water, partly because its much higher grade (when compared with "banket"), mixed as it is with clay, would be liable to entail a large escape of fine free gold with the tailings. This affords an excellent illustration of the fact that all ores cannot be treated alike, even for the extraction of the "free" gold, but require the method adopted to be modified to suit special circumstances.

The following table, given by H. C. Hoover,† shows the gradual growth of the mining industry in Western Australia, as indicated by the size and number of the then existing mills in each district, the tons of ore crushed, and the yield in 1897; but, as will be seen

* Discussing slimes-treatment in South Africa in the *Mineral Industry*, vol. vi. p. 345, Mr. W. R. Ingalls says that formerly (crushing the ore through 20-mesh screens) the proportion of slimes in the mill pulp was 20 per cent., whereas using 32-mesh screens, it amounts to about 30 per cent.

† 'The Working Cost of West Australian Mines,' *Mineral Industry*, vol. vi. p. 335.

later, as the tonnage crushed has increased, the grade of the ore milled has naturally fallen.

District.	No. of Stamps.	No. of Mills.	Average No. of Stamps per Mill.	Tons of Ore Crushed.	Total Yield.	Bullion. Average per Ton.
					oz.	dwt.
Coolgardie	329	24	13·3	9,196¾	8,684¼	18⅞
East Coolgardie (Kalgoorlie) .	265	15	17·6	18,402½	31,735	34½*
North East Coolgardie . .	182	16	11·4	4,123¼	3,729¾	18
Broad Arrow . . .	206	15	13·7	2,632	1,791¾	13⅓
North Coolgardie . . .	318	24	13·2	2,665	5,284	39⅝
Mount Magnet . . .	128	13	9·8	2,752¾	5,145¾	37½
Yilgarn	125	7	17·8	2,855¾	1,148¾	8
Dundas	186	16	11·6	2,631	2,797½	21¼
Murchison	445	33	13·4	6,788½	7,802½	22⅞
East Murchison . . .	48	4	12·0	1,949½	2,907¼	29¾
Yalgoo	40	5	8·0	516	644½	24⅞
Pilbarra	15	2	7·5	407½	603¾	29¾
Peak Hill	20	2	10·0	447	1,734	77⅓
Northam	80	1	80·0	..	..	..
Totals . .	2,387	177	13·4	55,367½	74,008¾	26¾

In addition to "dry-crushing" mills, two somewhat different types of wet crushing and amalgamating machinery have been employed in milling, viz. ordinary stamp-batteries, and Huntington mills.

Huntington Mills have done excellent work, both at the North Boulder mine where they were first introduced, and at the Oroya, which latter "plant," consisting of three "mills," crushed 26,715 tons in 1899 for a yield of 9829 oz. of bullion. Between September 1, 1896 (when crushing commenced) and November 30, 1896, the North Boulder Company treated in its old original mill 785 tons of ore for a yield of 1789 oz. 18 dwt., giving an extraction of 2 oz. 5 dwt. 14 gr. per ton, with a loss as shown by assay of 10 to 14 dwt. in the tailings, representing a yield of 69 to 78 per cent.

* The average yield of the East Coolgardie field, up to December 1896, is reported to have been 3 oz. 5 dwt. 23 gr. per ton; whilst the total production from quartz mines in West Australia is given as 323,091 tons, stated to have yielded 494,038 oz. and 16,873 oz. from an unknown quantity of stone crushed; being an average of 1 oz. 8 dwt. 21 gr. per ton.

The results of this trial were deemed so satisfactory in point of extraction and cost, that another 5-feet "mill" was bought, and this, together with the old one, continued to be employed, with the "stamps" which were afterwards added to the "plant."

The comparative slowness of its discharge, and the rubbing action, to which the "free-gold," and "gold-in-combination" with other minerals, is subjected in a Huntington mill, the Author is inclined to think, give it an advantage over stamps so far as regards "extraction," when treating an ore like the Kalgoorlie "brown-stone."

To sum up their merits: Mills of this type are excellent amalgamators, are comparatively cheap and simple to erect, and take less time to put up than "stamps"; enabling a mine when in the stage of a "prospect" to get to work quickly, prove its value on a milling basis, and earn profits when it could not perhaps afford to stand the cost and delay which would be entailed by erecting a large "battery": moreover mills of this kind require little power, and are cheap to run. They are not, however, to be compared with "stamps" for large outputs, or for dealing with *hard-ores*, as the capacity of a 5-feet mill may be reckoned at between 12 and 14 tons per 24 hours, if fine screens are used, when any considerable quantity of unoxidised ore is mixed with the stone crushed. A Huntington mill will, however, put through 17 or 18 tons of softer mill-rock; and would probably crush more, with careful feeding and coarser screens, if the stone is first broken in the rock-breaker to a fine size.

At the North Boulder, the Huntington mills are provided with automatic feeders (the ore being previously broken in a stone-breaker, and passed through a grizzly). The ore, after it is crushed, passes over a length of 9 to 10 feet of silver-plated copper tables, 5 feet in width; one table is broken by a "drop" of 2 inches and a shallow "well"; whilst the other has a double-drop "well" in the middle, and a drop of 6 inches at the foot of the second plate. The "plates" have an inclination of about 1·3 inches per running foot, and additional clear water is supplied by a perforated pipe at the head.

Below both mills, there are a set of blanket-tables, 11 feet in length and 5 feet in width, each divided into four strakes, pitched on a grade of about 1·4 inches per foot; which are used to collect any free gold or amalgam that might escape the mills. The screens mostly used are No. 40 diagonal-slot, without any "burr," and the mills are run at 65 to 70 revolutions per minute; they are charged with about 70 lb. of mercury.

The cheapness with which mills of this class can be operated is shown by the results that are said to have been achieved at the Spanish mine, Nevada County, California,* and the cost at the Oroya mine at Kalgoorlie is shown in the table below:—

	Twelve Months to September 30, 1899.	Six Months to March 31, 1900.
Tons crushed . . .	25,234	13,601
	s. *d.*	*s.* *d.*
Wages, cost per ton . .	3 8	4 0
Water ,, . .	2 0	1 8¾
Wood ,, . .	1 5½	1 6¾
Supplies, etc. ,, . .	0 10	1 5½
	7 11½	8 9

	Twelve Months to March 31, 1901.	
Tons crushed . . .	7,684	
	Mill Expenses.	Cost per Ton.
	£ *s.* *d.*	*s.* *d.*
Wages	1,362 15 10	3 6·565
Water	673 7 10	1 9·032
Fuel	630 16 9	1 7·703
Assays	53 2 7	0 1·659
Plant repairs, etc. . .	85 8 3	0 2·667
Timber, fodder, etc. .	14 9 4	0 0·451
Stores	365 16 4	0 11·425
	3185 16 11	8 3·502

The cost of treatment in Huntington mills on a large scale at North Boulder cannot be given exactly, as being "a composite mill" (containing, as previously mentioned, "stamps" as well as Huntington mills) the cost of labour, water, fuel, etc., used separately by each class of machinery, can only be estimated approximately.

The following particulars will serve to illustrate the different features of milling practice in the district.

Typical Milling Plants.

The Lake View 50-stamp battery † (Fig. 44), which the Author saw in 1898, seemed a well erected and arranged plant, besides being at that time the largest on the field. The ore was crushed in a "Gates

* 'The Choice of Coarse and Fine-Crushing Machinery and Processes of Ore Treatment,' by the Author, *Trans. Federated Inst. of Mining Engineers*, vol. vi.

† This battery has recently (1901) been re-modelled for treatment of sulphide ore by the Diehl process, as described in the next chapter.

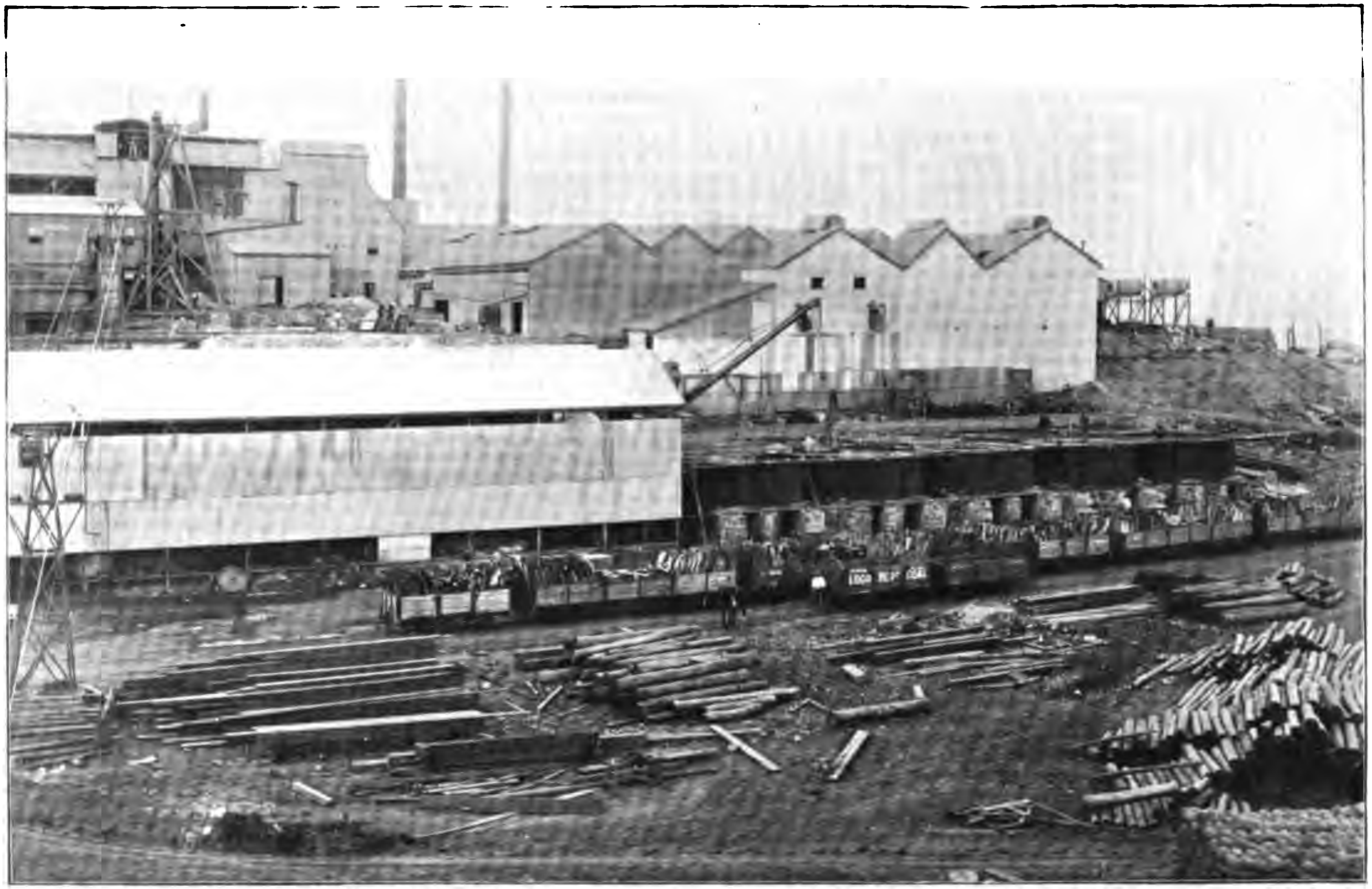


FIG. 44.—GENERAL VIEW OF THE LAKE VIEW CONSOLS MILL AND CYANIDE WORKS.

LAKE VIEW CONSOLS.

—	Twelve Months to August 31, 1898.	Twelve Months to August 31, 1899.	Six Months, Sept. 1899 to Feb. 1900.
Tons treated . .	57,725	81,866	11,994
	oz.	oz.	oz.
Bullion produced . .	64,695·625	56,506·475	6,385·130
Fine gold . .	62,721·293	54,910·279	5,995·481
Standard gold .	68,472·315	59,902·121	6,540·527
Fine silver . .	594·51	658·580	104·38
	oz. dwt. gr.	dwt. gr.	dwt. gr.
Yield per ton . .	1 2 9·6	13 19	10 16
	£ s. d.	£ s. d.	£ s. d.
Total value . .	265,939 13 6	232,478 12 9	25,431 4 3
Value per ton. .	4 12 1·68	2 16 9·5	2 2 4·8
,, oz. . .	4 2 2·44	4 2 3·4	3 19 7·8
Cost per oz. . .	0 9 0·16	0 9 11·4	1 0 2·3

Lake View Consols.	Total Cost.			Cost per Ton.		Total Cost.			Cost per Ton.		Total Cost.			Cost per Ton.	
	£	s.	d.	s.	d.	£	s.	d.	s.	d.	£	s.	d.	s.	d.
Superintendence and amalgamation .	1,795	7	0	0	7·464	1,717	16	4	0	5·036	568	18	9	0	11·384
Engine driving and firing . . .	1,808	15	5	0	7·520	983	7	4	0	2·883	467	13	3	0	9·358
Feeding. . .	1,008	5	5	0	4·192	511	0	0	0	1·498	158	15	0	0	3·176
Attending concentrates . . .	1,424	12	8	0	5·923	1,363	15	6	0	3·988	268	4	0	0	5·367
Handling tailings .	1,754	19	5	0	7·297	1,271	16	1	0	3·728	250	1	2	0	5·004
General repairs .	1,378	11	7	0	5·732	1,595	5	3	0	4·677	246	5	4	0	4·928
Assaying, retorting and melting .	300	0	9	0	1·248	291	9	11	0	0·854	76	4	6	0	1·525
Breaking and tramming . . .	3,469	13	0	1	2·425	5,336	10	0	1	3·645	1396	13	2	2	3·947
Pumping return-water . .	2,335	4	6	0	9·709	3,369	5	5	0	9·877	416	5	4	0	8·329
Mercury . .	349	0	11	0	1·451	298	3	6	0	0·874	25	11	6	0	0·512
Water, salt . .	4,513	12	2	1	6·766	5,939 (salt and condensed)	2	4	1	5·411	1138	17	3	1	10·788
,, condensed .	1,165	7	8	0	4·845										
Fuel . . .	3,282	2	2	1	1·646	1,548	17	1	0	4·541	535	7	2	0	10·712
Screens, shoes and dies . . .	..			..		490	0	6	0	1·437	133	13	6	0	2·675
General stores .	891	15	2	0	3·708	215	6	4	0	0·631	41	7	2	0	0·828
Electric light . .	603	13	6	0	2·510	776	17	9	0	2·277	271	18	7	0	5·442
Cleaning up . .	..			..		..			..		172	14	0	0	3·456
Realisation charges.	3,075	16	9	1	0·788	2,420	6	7	0	7·096	278	2	4	0	5·565
Totals . .	29,156	18	1	10	1·224	28,128	19	11	6	10·463	6446	12	0	10	8·996*

* A small portion of these costs were incurred in cleaning up in March and April.

type " crusher at the shaft, and elevated by a travelling wire rope-way with buckets to the top of the battery building, where it was trammed and dumped into a line of bins at the back of the stamps. The stamps weighed 900 lb., had a fall of 6 inches, and were run at 90 drops per minute. They were driven by a compound engine with cotton ropes running in grooved pulleys. The ore-feeders were of the Challenge pattern, and it is stated that 4 tons per stamp head or 200 tons per diem were being crushed in the autumn of 1898. The gold was caught on amalgamated copper plates and canvas strakes, whilst the tailings which were saved were treated by cyanide, as described later.

It may be added that this *combined* treatment is stated to have saved 90 per cent. of the gold the "brown-stone" contained. Results and details are given in the accompanying tabular statement, covering the period from August 1897 to February 1900.

The Ivanhoe Battery (Fig. 45), for a description of which I am largely indebted to Mr. Hewitson through the courtesy of the Directors of the Company, originally contained 60 stamps driven by toothed gearing, provided with clutches for every 10 heads. The oxidised ore was crushed in a No. 5 Gates crusher, having a nominal capacity of 400 tons, and was delivered by an overhead tramway to the battery bins, from which it was fed to the stamps by Challenge feeders, the feeding stamp being No. 5. The ore was crushed through punched 16-mesh Russia-iron screens (i.e. 256 holes per square inch), and the "pulp" passed over 12 feet of amalgamated copper plates with a fall of $\frac{3}{4}$ inch to the foot; a distributing launder thence conveyed it to canvas strakes 40 feet in length and 22 inches wide, with a fall of $1\frac{1}{2}$ inches per foot, which were swept down every hour with clean water, two men being thus kept fully employed. The concentrates thus collected, representing about 2·00 per cent. of the original ore, and assaying 12 oz. per ton, were stored and dried for subsequent treatment. The mill-tailings were handled by a double 12-inch plunger "tailings-pump." Mercury was added inside the mortar-boxes.

The mortar-boxes weighed 2 tons 17 cwt., were 4 feet 6 inches long, 14 inches wide, and 9 inches deep at the point of discharge.

The stamp stems were 13 feet long, $3\frac{1}{4}$ inches diameter, tapered at both ends, fitted with screw-tappets, and weighed 372 lb. The heads were 15 inches by $9\frac{1}{2}$ inches, and weighed 246 lb.

The tappets were 9 inches in diameter, and weighed 98 lb.

FIG. 45.—THE IVANHOE STAMP BATTERY (INTERIOR).

The shoes were 10 inches by 9 inches, and weighed 184 lb., making the total weight of the stamp 900 lb. The dies were 9 inches by 7 inches, which gave a 4-inch discharge when new, and they weighed 168 lb.

The wear on the shoes was reckoned at ·19 oz., and on dies ·14 oz. of metal; representing a cost of 1·16*d.* per ton crushed.

The duty in 1900 amounted to 3·7 tons of ore crushed per head, per 24 hours.

The mill-engine is a compound steam-engine, with Prell valve-gear, made by Martin and Co., of Gawler, South Australia, the cylinders being 12 inches by 20 inches diameter, with a 36-inch stroke, and was supplied with steam by four Cornish boilers 24 feet by 6 feet 6 inches, provided with eight Galloway tubes, and tested to 220 lb. pressure per square inch, the usual working pressure being 100 lb. per square inch. Power is transmitted by ten hemp ropes, each $1\frac{7}{8}$ inches diameter.

The labour employed per shift consisted of one battery-feeder, one man looking after the "tables" and general mill-work, and two men on the canvas strakes.

The screens, which measure 4 feet 7 inches by 1 foot, lasted about one week, using Russia sheet-iron, 16 mesh.

The cost of mercury was reckoned at 0·658*d.* to 2*d.* per ton milled.

The relative proportion of sands and slimes in the battery pulp was approximately 50 per cent. sands, 48 per cent. slimes, and 2 per cent. concentrates, in 1899; and 51 per cent. sands, and 49 per cent. slimes, in 1900.

The recovery by *battery-amalgamation* in 1898 was estimated at 64·89 to 70·2 per cent. of the total gold contents of the ore; in 1899, at 66·35 per cent. of the fine gold contents, 2·07 per cent. additional being recovered in the concentrates; whilst in 1900 the fine gold recovered in the mill amounted to 58·85 per cent., and 6·24 per cent. additional was obtained from concentrates and sulphides. The cost of milling in 1899 is officially stated to have been 5*s.* 0·836*d.* per ton of ore (4*s.* 3·285*d.* per oz. of bullion), exclusive of ore-breaking, which cost 1*s.* 3·463*d.* per ton; calculated upon 59,664 tons milled, which yielded 70,774 oz. 10 dwt. 12 gr., or an average of 1 oz. 3 dwt. 17 gr. per ton. In 1900, 74,372 tons of ore were crushed for a return of 64,921 oz. 15 dwt. of bullion, or an average of 17 dwt. 11 gr. per ton. The cost of milling came to 5*s*. 5·335*d*. per ton of ore crushed, or 6*s*. 2·845*d*. per oz. of bullion recovered, ore-breaking costing 1*s*. 2·213*d*. additional. Thirty-five per cent. of the ore crushed came from the lower levels of the mine, and the amount of concentrates caught increased 50 per cent., as compared with 1899, viz. from 15 cwt. to 30 cwt. per diem. The above-mentioned costs were distributed as follows :—

—	1899. Total Cost. £ s. d.	1899. Cost per Ton Milled. s. d.	1900. Total Cost. £ s. d.	1900. Cost per Ton Milled. s. d.
Labour	4,807 11 11	1 7·338	4,837 12 0	1 3·611
Condensed water	1,530 0 6	0 6·155	2,131 12 1	0 6·879
Salt water	1,869 14 9	0 7·521	2,660 11 9	0 8·585
Tailings and returning water	1,090 15 9	0 4·388	1,205 1 1	0 3·889
Fuel	3,445 1 5	1 1·858	4,960 19 0	1 4·009
Quicksilver	301 13 5	0 1·213	203 16 11	0 0·658
Stores	228 10 7	0 0·919	472 2 1	0 1·523
Repairs and renewals	1,850 8 10	0 7·444	3,774 10 11	1 0·181
	15,123 17 2	5 0·836	20,246 5 10	5 5·335

The milling practice at these works, it will be seen, was more or less the same as the treatment of the oxidised ore at Lake View.

The Golden Horse-shoe Battery (Fig. 46) originally contained 20 heads of 950-lb. stamps, but was increased in 1899 to 30 heads, to enable it to cope with the larger tonnage the mine was found capable of producing; whilst in 1900 it was further enlarged to 50 heads. The duty of the stamps was 4·404 tons per head in 1899 and 4·695 tons per head in 1900, and the capacity of the plant was estimated at 6000 to 7000 tons per month. Experiments made in 1899 were stated to have proved that an undue proportion of gold was locked up in the tailings leaving the mill, and that fine grinding was necessary, before the maximum extraction could be obtained.

The following line of treatment was therefore decided upon :—

The ore delivered to the mill was dumped upon two grizzlies with bars set 2 inches apart, and the coarse portion was crushed in two No. 3 Gates rock-breakers. The breaker-product, and the "fines" from the grizzlies, passed into a storage-bin holding about

200 tons, and were thence trucked to the supply bins behind the batteries, from which the ore was delivered automatically by Challenge feeders to the stamps; 30 of these were of Fraser and Chalmers' pattern, and the remaining 20 were built by Martin and Co. of Gawler. They had a 7-inch drop, falling 95 times per minute. The contents of a truck was dumped half-hourly from the battery-bin floor into a sampling-machine, which sampled about 24 tons per diem down to about 7½ cwt., making six equal cuts.

FIG. 46.—THE GOLDEN HORSE-SHOE 50-STAMP BATTERY (INTERIOR).

This bulk sample was broken down by a laboratory breaker and rolls, from which a final assay sample was obtained. Amalgamation took place both inside and outside the mortar-boxes.

The pulp discharged from the stamps, passing through 24-mesh woven wire screens (according to a sizing test given by Mr. Robert Allen),* had the following composition:—

Remaining on a 50-mesh screen . .	1·8 per cent.
,, 100 ,, . .	6·1 ,,
Passing through 100 ,, . .	92·1 ,,

* 'A Description of the Reduction Plants and Processes of Reduction in some of the Principal Kalgoorlie Gold Mines,' by Robert Allen, M.A., B.Sc., Royal Commission, Glasgow International Exhibition, 1901, Western Australia.

It was then distributed over the copper plates and a set of canvas strakes below them, which were the full width of the batteries.

These strakes, which were 25 feet long, caught any fine sulphurets (representing about 1 per cent. of the ore) that the stone contains.

The tailings (sand and slimes) were elevated after this treatment by four Cornish tailings-pumps (working two at a time), to ten 5-feet Wheeler-type grinding-pans, having a continuous overflow, in which the battery tailings were ground finer, and the gold was amalgamated before being discharged into five 5-feet diameter settlers, which collected the escaping mercury and amalgam, prior to the general clean-up.

The pans were fitted with amalgamated copper plates, but most of the gold was caught by the mercury with which they were charged.

Of the total gold recovered, 58 per cent. was reckoned to be saved by amalgamation, and the balance in about equal proportions from the sands and slimes treated by cyanide, as described later on. The average total extraction was about 90 per cent.

The cost and results in 1900 are given in detail in the accompanying tables:—

Battery Treatment, 1900.

Tons treated	67,095
Bullion produced, oz.	67,219·575
Fine gold	63,921·173
Standard gold	69,732·183
Value	£271,123 7 10
Yield per ton (bullion) oz.	1·002
Value per ton	£4 0 9·840
Value per oz.	4 0 7·920
Cost per oz.	0 7 9·120

	Gross cost. £	s.	d.	Cost per ton. s.	d.
Superintendence and amalgamation	1,770	16	8	0	6·334
Engine-driving, firing, etc.	2,195	9	6	0	7·853
Feeding	485	17	1	0	1·738
Concentrates	1,252	8	3	0	4·478
Tailings wheel	518	7	3	0	1·854
Assaying, retorting and melting	230	13	1	0	0·825
Breaking and tramming	1,842	13	9	0	6·593
Return water	1,897	0	0	0	6·786
Mercury	487	10	6	0	1·744
Fuel	3,871	5	9	1	1·848
Water, salt	2,627	12	5	0	9·399
,, fresh	2,688	9	9	0	9·617
Screens, shoes and dies	509	12	5	0	1·823
Electric light	464	2	8	0	1·660
Compressed air	215	15	10	0	0·772
General maintenance and repairs	2,037	11	7	0	7·288
Pan amalgamation	305	18	10*	0	1·094
Realisation charges	2,682	2	10	0	9·595
	26,083	8	2	7	9·301

* Four months' cost only.

The North Boulder 10-*head Battery* (Fig. 47), besides the Huntington mills already described, contains an improved Blake stone-breaker, which cubes the ore to 2 inches, the grizzlies being

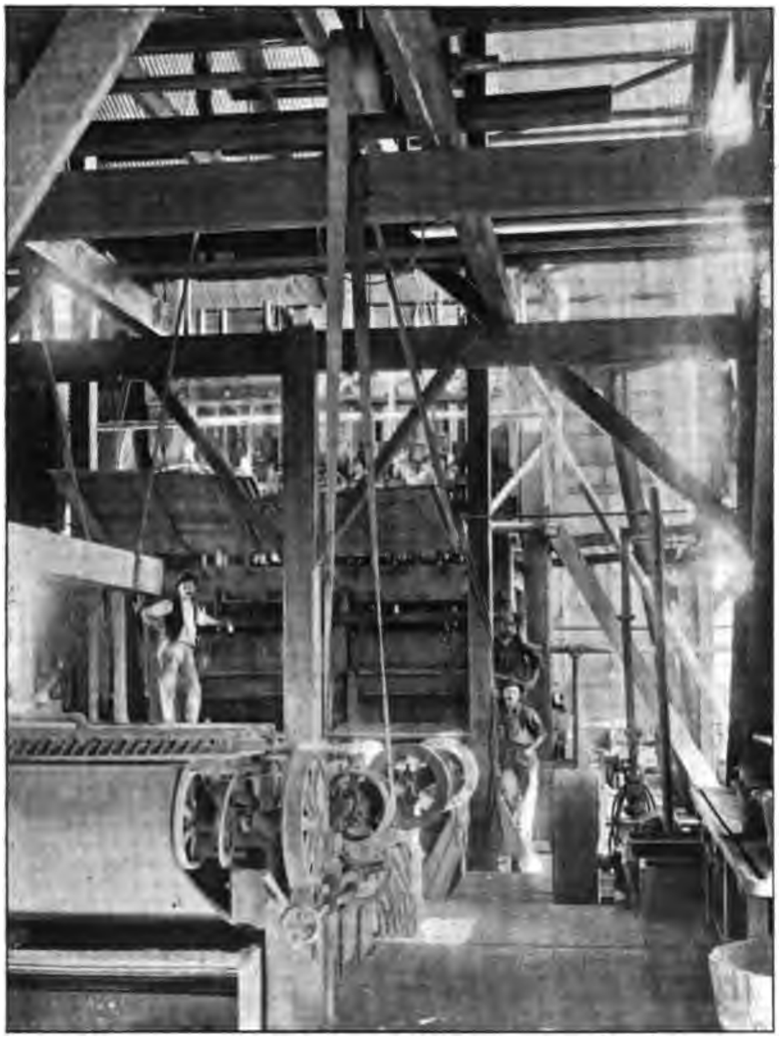


FIG. 47.—NORTH BOULDER MILL (BATTERY AND FRUE-VANNERS).

arranged to correspond; also ore-bins, two Challenge feeders, and ten 950-lb. stamps of Fraser and Chalmers' pattern, ordinarily run at 80 drops a minute, with a drop of 4 inches to 6 inches.

They put through, on the average, about 2 tons per head per diem under these conditions, but if the output of the mine had been on a larger scale, by increasing the speed to 85 and the drop to 8 inches, keeping the discharge low, and using coarser screens, their capacity could, without doubt, have been largely increased.

The explanation why, apart from other reasons, early advantage was not taken of this obvious means of cheapening the cost of milling, was the fact that with slower drops and high discharge, a higher battery extraction was secured; which, before the Company possessed cyanide works, was a matter for consideration when dealing with rich ore.

The stamps, it may be mentioned, are furnished with gib-tappets. The mortars are provided with false bottoms for regulating the discharge, and with "chuck-blocks" of suitable height to compensate for the wear of the dies. They are fitted with copper plates front and back, and the top panels of the screen-frames were intended to be left open, and hung with a strip of canvas, to allow the amalgamator to remove chips of wood accumulating behind the screens. The screens are planished Russia-iron, reckoned at 300 holes to the inch.

The ten stamps and the Huntington mills formerly used about 4000 gallons of water per hour, which is high, considering the low "duty" of the battery; but this is partly attributable to the clayey nature of the "brown-stone" and the small screen-mesh, and partly to the use of blankets.

The apron-plates, which are electro-plated, are 12 inches in length, and the pulp at the end drops about 6 inches through a grating on to the head of the tables. The plates on these latter are also electro-plated, 12 feet in length, and the same width as the top ones, divided in the middle by a double-drop mercury-well, and provided with a similar "well" at the end. They are set on a grade of about 1½ inches per foot, which is steeper than usual.* Following these amalgamating-tables, a set of blanket-tables 8 feet 4 inches long, set on a grade of 1¼ inches to the foot, were used to catch the "pyrites," which the stone carries in small quantities; but were afterwards replaced by Frue vanners, and the

* Dana Harmon, *Proc. Technical Society of the Pacific Coast*, September 7, 1900, advocates even steeper tables, viz. a grade of 2·5 inches per foot, with a 0·5 step drop every 2 feet, and lip-plates set on a grade of 4 inches. — *Mining and Sc. Press*, December 1, 1900.

tailings are elevated and passed through spitzkasten or hydraulic classifiers, to separate the sands treated in the cyanide works, from the slimes.

This machinery, including the Huntington mills, is driven by a 65 horse-power Fraser and Chalmers 14-inch diameter single-cylinder engine with a 28-inch stroke, which was designed to supply surplus power if the battery should be enlarged. Steam is supplied by a pair of Fraser and Chalmers' 4 feet by 14 feet multitubular boilers, and a large Cornish boiler, built by Martin and Co., of Gawler. The exhaust steam from the engines passes into the bottom of a "superheater" 2-feet 6-inch diameter, and 8 feet high, containing a number of 2-inch tubes, which heat the water circulating outside of them, before allowing it to pass to the mud-drums of the boilers. The steam which issues from the "superheater" is partly used for driving the mill-water supply-pump; whilst the remainder goes to a Wheeler condenser. The water from the Wheeler condenser, with the addition of water from the fresh-water condenser-plant, is pumped by a Knowles No. 4 pump (3¾ inch by 7 inch) through the "superheater" and mud-drums to the boilers.

The mill-water (salt) is pumped up to a large supply-tank, with a capacity of about 8000 gallons, by a couple of Knowles pumps, one having a 7½-inch plunger with a 10-inch stroke, the other a 4½-inch plunger and 8-inch stroke. This water, however, became over-heated in passing (as part of it does), through the Wheeler condenser, and to obviate this it was proposed to erect a Barnard "cooling-tower," with the object of producing a better vacuum in the condenser, and regulating the temperature of the battery-water, which is liable to get much too hot; a temperature of about 65° F. being generally considered the best to keep it at.

From samples the Author took in 1898, the "blanketings" from this mill may be reckoned to have assayed from 9 dwt. 14 gr. to 3 oz. 5 dwt. 8 gr., and even as high as 7 oz. 9 dwt. 11 gr.; the first were from the Huntington mills, whilst the two higher returns were from the stamps, and this difference is no doubt explained by the fact, that whilst the mills were exclusively used for crushing "brown-stone," the stamps put through a good deal of stone containing a certain amount of sulphide, and doubtless tellurides.

An average sample of tailings, obtained from the settling-pits outside the mill, in 1898, assayed 8 dwt. 19 gr.

North Boulder. Tons crushed 10,150.	1898. Gross Cost.			Cost per ton of Ore Milled.			
	£	s.	d.		s.	d.	per cent.
Labour	1882	8	3		3	8·510	43·61
Fuel	937	18	9		1	10·179	21·72
Water	1005	11	6		1	11·777	23·27
Supplies :—				d.			
Screens	125	11	1	2·968	..		..
Lubricating oils	19	13	4	0·465	..		..
Mercury	73	12	6	1·740	..		..
Chemicals	15	17	9	0·375	..		..
Blankets	16	11	0	0·391	..		..
Miscellaneous	84	3	1	1·999	..		..
				——	0	7·931	7·76
Tools	6	10	1		0	0·153	0·13
Repairs	151	0	0		0	3·570	3·49
	4318	16	11		8	6·120	

North Boulder. Tons crushed 9772.	1899. Gross Cost.			Cost per ton of Ore Milled.			
	£	s.	d.		s.	d.	per cent.
Labour	1753	3	9		3	7·060	36·91
Fuel	1190	9	10		2	5·240	25·00
Water	1092	10	3		2	2·830	22·94
Supplies :—				d.			
Screens	121	15	9	2·991	..		..
Lubricating oils	29	2	10	0·609	..		..
Lighting oil	24	16	7	0·715	..		..
Mercury	51	0	6	1·253	..		..
Chemicals	9	18	4	0·243	..		..
Blankets	17	1	6	0·419	..		..
Miscellaneous	22	11	6	0·555	...		..
				——	0	6·785	5·80
Tools	20	11	10		0	0·505	0·43
Repairs	427	4	3		0	10·490	8·97
	4760	6	11		9	8·910	

In 1898 the average yield of bullion per ton of ore milled was 19 dwt. 8 gr., and the average assay of tailings 7 dwt. 6 gr., showing an extraction by milling of 72·7 per cent.; and as experiment has shown that about 16 per cent. of the gold remaining in the coarser sands is amalgamable, no doubt the extraction by amalgamation could have been raised, with fine crushing, to between 80 and 85 per cent. of the total gold contents in the ore; but this would have entailed disproportionately increased cost, and the gold was consequently recovered more cheaply by cyanide.

The mill costs, which amounted to 1*l.* 19*s.* 1½*d.* in July 1897, milling 349 tons, dropped to 14*s.* 11¾*d.* in December, when 675 tons were crushed, and the preceding table shows the mill costs in detail in 1898 and 1899, when 10,150 and 9772 tons were treated respectively.

Milling 1224 tons in October 1899, the cost was, however, below these averages, being estimated at 7*s.* 9·82*d.* per ton, showing how largely the quantity milled affects the cost.

The higher cost in 1899, as compared with 1898, it will be noticed, was due principally to the extra cost of repairs, fuel and water, partly attributable to the fact that the mill-boilers supplied steam for other purposes, which ought not properly to be charged to milling, and make the mill costs appear greater than they really were; 8*s.* 11*d.* would probably, therefore, be nearer the actual figure for milling, the difference between which and the cost in 1898, is explained by the smaller tonnage crushed.

With a 20-stamp mill of this type, putting through 3 to 4 tons per head per day, and the engine running with the full load it is designed to carry, so as to economise steam, it is probable that costs could have been reduced to a still lower figure. In a properly-arranged mill of this size, two men and a boy, with an engine-driver on each shift, are able to attend to the crushing of the ore and its concentration, if mechanical concentrators are used.

The Great Boulder Main Reef 10-head Battery, for the treatment of oxidised-ore,* contains a crusher and rock-bins, and 10 head of 950-lb. Fraser and Chalmers' stamps provided with automatic feeders. The cam-shaft was fitted with Blanton cams, and the battery was furnished with blanket-tables for concentration.

The arrangement of the crusher below the ground-floor, requiring the rock to be scraped by manual labour to the elevator

* The sulphide mill is described in the next chapter.

(a job requiring the labour of two men) was its weak feature, but this arrangement was improved in December 1897. In 1898 the mill costs varied, I believe, between 10*s.* and 14*s.* a ton.

The machinery was driven by a non-condensing engine capable of developing 60 horse-power, running under 80 lb. steam-pressure. The boilers were of Lancashire pattern, 22 feet by 6 feet 6 inches diameter, fitted with Galloway-tubes. The loss of mercury, I am informed by Mr. Skews, was reckoned at ·519 oz. per ton of ore milled, but from 5 to 10 lb. were recovered at every clean-up in cyaniding the tailings, and he estimated the actual loss to have been about ·410 oz. per ton. The wear of shoes and dies figured out at ·490 lb. per ton of mill-rock.

Mr. Ed. Skews informed the Author in 1900 that for five months, by way of a test, No. 1 battery was worked without a front-plate, whilst No. 2 battery was worked with both front and back-plates in the mortar. Both batteries were furnished with lip-plates. From the lip and back-plates of No. 1, as much amalgam was obtained as from No. 2 battery. There was a marked improvement in the appearance of the lip-plate of No. 1 battery without the front-plate. The amalgam obtained from No. 1 battery, prior to the removal of the front-plate, save on three occasions, was from one-tenth to one-fifteenth more than from No. 2 battery.

The distribution of the mill-costs shown in one month's run were as follows :—Mill, 3*s.* 8·6*d.*; steam, 4*s.* 6*d.*; water, 1*s.* 9·3*d.*; handling slimes, 1*s.* 4·1*d.*: total 11*s.* 4*d.*

The Great Boulder 30-head Battery,* for details of which I am indebted to Mr. Hamilton, through the courtesy of the Directors of the Company, originally contained 30 head of stamps, with copper-plate tables, six amalgamating and grinding pans, three "settlers," and canvas concentrating-tables, the system of treatment being somewhat similar to that in use at the Lake View South, the next mill to be described.

The stamps were in sets of five, and weighed 750 lb. They were run at 80 drops per minute with an 8-inch fall, the order of drop being 1, 3, 5, 2, 4, and the capacity per head per diem was reckoned at 4·5 tons of oxidised ore.

* At the end of 1900 (the oxidised ore being exhausted) this mill was engaged in crushing the lower-grade sulphide ores, free from tellurides, which the mine produced, but it required to be remodelled to economically treat this hard ore. The present method of dealing with stone of this class will be found described in the next chapter, under Sulphide-ore Treatment.

The mortars weigh 2 tons 5 cwt., and most of the gold is caught inside.

The grinding-pans employed to amalgamate the coarser particles of gold and gold in pyrites which escaped the battery were of the Watson-Denny type, and were run at 50 revolutions per minute, and charged with two bottles of mercury each. The "settlers," which collect any amalgam or mercury that escapes from the pans, were run at 25 revolutions per minute.

The tailings passed over "canvas-tables," and were pumped into settling-dams for collection and subsequent cyanidation.

The loss of mercury varied from 0·425 to 0·536 oz. per ton of ore milled.

Punched screens, with 225 holes per square inch, were used in the mortar-boxes. Of the "pulp" passing through them, Mr. Hamilton informed me that 69 per cent. would pass through a sieve with 150 meshes to the *linear* inch, and after leaving the grinding and amalgamating pans 89 per cent. was reduced below this degree of fineness. Of the balance (11 per cent.) 80 per cent. would pass a 100-mesh, and all the remainder a 60-mesh screen. The battery-screens lasted from five to seven days, and according to figures given in the Company's Annual Report, milling and pan-amalgamation in this mill (inclusive of power, but exclusive of assay-expenses, horse-keep, etc.) may be calculated to have cost 8*s.* 2·75*d.* in 1898, on an output of 37,810 tons; 8*s.* 0·29*d.* in 1899 on 46,826 tons milled; and 10*s.* 2·71*d.* in 1900 on 36,276 tons milled; subdivided as follows:—

—	1899. Total Cost.			1899. Cost per ton.		—	1900. Total Cost.			1900. Cost per ton.	
	£	s.	d.	s.	d.		£	s.	d.	s.	d.
Wages	8974	17	7	3	10·02	Wages	8408	13	10	4	7·63
Stores	2143	11	11	0	10·98	Stores	2022	17	2	1	1·38
Firewood	2870	17	4	1	2·70	Firewood	3320	8	4	1	9·96
Salt water	3396	3	1	1	5·41	Salt water and track	3292	19	0	1	9·78
Condensed water	1401	11	7	0	7·18	Condensed water	1506	1	6	0	9·96
	18787	1	6	8	0·29		18550	19	10	10	2·71

The percentage of extraction was given as 84·27 in 1898, and 82·7 in 1899. The average assay of the tailings was 8 dwt. in 1898, 6 dwt. in 1899, and 5·5 dwt. in 1900. 137 tons of concentrates smelted, yielded 1864 oz.; and 228 tons treated in the new sulphide-mill yielded 1170 oz. in 1900.

The Lake View South 20-stamp battery, is of a somewhat similar type to the one just described, mechanical concentration taking the place of canvas tables. It is built on a graded mill-site, on the hill behind the mine, in five floors upon which are set (1) the Blake crushers, ore-bins, Challenge-feeders, stamps, and amalgamating-tables; (2) grinding-pans; (3) Frue vanners; (4) amalgamating-pans; (5) settlers. The ore passes automatically from one stage in the process to another. The stamps weigh 900 lb. each, and the mortar-boxes were fitted with "inside-plates," and use coarse screens, to secure rapid discharge. The battery tables are 11 feet long, with a step of about 2 inches every 17 inches, a metal plate being set across the table at each "drop," to throw the pulp down vertically on the head of the plate below. The slope of the tables can be regulated by means of adjusting screws.

From the "plates" the pulp is conveyed by launders, fitted with corrugated copper riffles, to 6 Watson and Denny grinding-pans standing on a floor 5 feet below the tables, which grind the pulp to a finer size; and their discharge passes to four Frue vanners on the next floor, which is 4 feet lower. The Frues yield concentrates containing 2 to 3 oz. of gold per ton which are subsequently treated by cyanidation, whilst the Frue-tailings pass through launders to four amalgamating-pans, of the Wheeler class, which discharge into 8-feet diameter "settlers," set 3 feet below the pans; the overflow-slime from these latter goes to settling pits, from which the clear water is pumped back into the battery storage tanks.

The cyanide plant for treating the concentrates from the vanners consists of two solution-tanks and two leaching-vats, with zinc boxes; and the cost of cyanide treatment is stated * to have been 8*s.* 9*d.* a ton. Mr. Bulman adds that actual figures over five months' working showed an extraction of 90·8 per cent. of gold contents. The average assay value of ore milled (crushed chiefly for outside parties) was 2 oz. 3 dwt. 3 gr. per ton, and of the residual slimes, 3 dwt. 23 gr., whilst the cost of "milling" (plate-

* H. F. Bulman, *Trans. of the Inst. of Mining Engineers*, vol. xxviii.

amalgamation, concentration and pan-amalgamation) ran from 14*s*. to 15*s*. a ton.

The Great Boulder Perseverance 20-head battery, I am informed, was provided with copper tables and canvas "strakes," the tailings from which were separated into sands and slimes by spitzkasten. The sands were leached with cyanide in four rectangular vats holding 100 tons each, and the slimes were agitated with the necessary cyanide solution, and filter-pressed in four Dehne 4-ton presses.

The concentrates collected on the canvas tables were shipped to smelters, and the gold was recovered from the cyanide liquors in the usual way in zinc extractor-boxes.

*The Associated Mill** for the treatment of oxidised-ore represented a type differing entirely from the preceding ones, the oxidised ore being treated by dry crushing and cyanidation. The stone from the mine was delivered to a rock-breaker at the top of the building and thence into a sizing-trommel, which separated the "fines" from the coarse mill-rock.

The "fines" were raised by a bucket-elevator into a "bin," and the coarse ore was delivered by automatic feeders to four Krupp ball-mills, the product of which was raised by an elevator, and joined the "fines."

The contents of the bin were discharged through canvas spouts into steel trucks (holding about one ton of crushed ore) which had W-shaped bottoms, the sides forming flap-doors; four or five of these trucks placed end to end were set on a carriage, drawn over the rails alongside the line of cyanide vats by an endless-rope, which could be started or stopped by a lever, shifting the driving belt from a fast to a loose pulley.

It was claimed that by this arrangement the contents of the trucks were deposited more evenly over each vat, and no trimming was required. Two men could fill a 160-ton vat in eight or ten hours. The residues were discharged through bottom doors into trucks below, and the charge was kept under cyanide treatment (percolation) ten days. During the year ending August 1, 1898, it is stated† that 20,519 tons of ore were treated in this mill, which yielded 22,174 oz., or 1 oz. 1 dwt. 14 gr. per ton, obtained at a cost of 18*s*. 2½*d*. a ton; of which 5*s*. 6*d*. a ton was chargeable

* The new sulphide mill is described in the next chapter.

† H. F. Bulman, *Trans. of the Inst. of Mining Engineers*, vol. xxviii.

to cyanide treatment. The returns of oxidised ore crushed for the years 1897 to 1900 are given * as under :—

1897.	13,369†	tons produced	29,480	oz., or an average yield of	44·1 dwt.
1898.	28,431	"	42,170 ‡ "	"	29·6 "
1899.	33,700	"	31,213 "	"	18·5 "
1900.	5,860 §	"	3,479 "	"	11·8 "

During the 12 months ending March 31, 1901, 1080 tons appear to have been treated at a cost of 14*s.* 6·3*d.* per ton.

The Hannan's Star Mill.—The process at these works was the same in general principle as that last described. The machinery consisted of a 200 I.H.P. compound condensing engine, with evaporative condenser and circulating pumps, a Blake stone-breaker, two 30-ton Krupp ball-mills, a revolving drier, elevators, and conveyors to pass the ore automatically through the various operations; and a complete cyanide plant, consisting of eight leaching vats, etc.

At first when the mill started, the leaching was reported to be unsatisfactory, *owing to the large proportion of slime* in the crushed product, but in September 1899, the leachability of the ore began to show signs of improvement, and towards the end of that month the rotatory drier was done away with. In the beginning of October, it was found possible to fill up the vats to a depth of 3 feet 3 inches, whilst towards the end of the run, a fair leaching was obtained with full charges. This improvement was attributable to an admixture of ore from Morison's lode, which is stated to be of a less clayey nature than that of the main lode.

The mill ran (about 8 hours per diem) 1509 hours, and during this period 5305 tons of oxidised ore were crushed. The average value of the ore cyanided (5285 tons) was 14 dwt. 7½ gr., and that of the residues, after treatment, 4 dwt. 8·2 gr.; an actual extraction of 71 per cent. of the gold being obtained. The cost of milling appears to have worked out at 7*s.* 2·4*d.*, and the cost of cyaniding at 6*s.* 11·77*d.* per ton. The bullion was over ·908 fine on the average.

The South Kalgurli Mill was laid out on a somewhat different system, being originally designed to treat both oxidised and sulphide ores. The stone delivered from the mine was first passed through a No. 2 Gates crusher, that broke it to 2½ inches,

* *The Mining Year Book*, 1901. † Including ore shipped to smelters.
‡ Including yield from a small quantity of tailings. § 11 months.

and then through a pair of Cornish rolls 3 feet 6 inches diam. which further reduced the ore to about 1-inch cube. Here the treatment of the two classes of stone, which were kept separate in two different 70-ton bins, diverged, the oxidised ore being fed from the bins of the rolls by means of automatic feeders to two wet-crushing Griffin mills. The issuing pulp passed from these mills over two amalgamated copper tables, 8 by 4, where part of the gold was recovered by amalgamation; the tailings were afterwards run into six Forwood, Down & Co.'s grinding and amalgamating pans, which completed this branch of the process, some 66 per cent. of the gold in the oxidised ore being thus recovered. The pulp overflowing (continuously) from the pans, was distributed over a series of canvas-tables, which concentrated out the fine pyrites the ore contained. The tailings of the canvas-tables were pumped up and delivered to eight large spitzkasten in series, which yield a sands and concentrates "underflow" from the first two, and a slimes "underflow" from the last six; the excess water being eliminated with the "overflow" from the eighth spitzkasten.

The sands were elevated by a tailings-wheel and sent back to the pans for regrinding, and the concentrates saved from the canvas-tables were shipped to Fremantle to be smelted.

The slimes passed to one of five agitation-vats, in which the pulp was agitated, after the necessary addition of cyanide, for about 18 hours. The pulp was then forced by means of two montejus into four Dehne filter-presses, each holding 3 tons of pulp. The slime residues from these were "dumped," and the gold solutions, after settling in an intermediate solution tank, were delivered to the zinc extractor-boxes. The sulphide ore, after leaving the Cornish rolls, was formerly delivered to a 70-ton bin, passed through a rotatory-drier, and thence into five dry-crushing Griffin mills, but it was subsequently fed direct from the bins of the rolls to the mills, the ore being afterwards elevated by five bucket elevators, to the hoppers of the Brown roasting-furnaces, and desulphurised.

It was at first intended, I believe, to grind the roasted ore in pans, and treat the slimed "pan-pulp," ***both of the sulphide and oxidised ores***, by agitation with cyanide, forcing it, after agitation in vats, through filter-presses. This method of extraction was, however, given up in favour of the Riecken process, and the sulphide ore, having been found to preponderate in quantity over the oxidised ore, to a larger extent than had originally been anticipated, special attention was subsequently directed to its treatment. The present

(Riecken) process for dealing with this class of stone will be described in its proper place in the next chapter.

The original plant was estimated to have a capacity of 60 tons per diem,* and an estimate of the cost of treatment (exclusive of mining charges)† was given by Mr. John M. Iles in his Annual Report to September 30, 1899, as follows:—

	s.	d.
Power (steam), fuel and fresh water	6	5
Wear and tear	2	3
Labour	6	10
Fuel for roasting and drying	1	9
Stores	1	0
Cyanide	1	6
Salt water	0	10
Incidental and superintendence	1	6
Total	22	1

The Brownhill Mill.—The mill erected by this company (for the treatment of its oxidised ores), which was under construction when I saw it in February 1898, like the mill last described, employed the same general method of treatment, viz. dry crushing ‡ and cyanide, for the treatment of "brown-stone," but applied it in quite a different manner.

It struck me as being extremely well designed and built, wrought-iron and steel taking the place of wood for the framework of the building.

Broadly speaking, the process as explained to me by Dr. Pape (who kindly took me over the works) was to be as follows: after it left the No. 6 Krupp stone-breaker, which crushed it to 1-inch size, it was to be passed through a trommel, and further reduced in $21\frac{5}{8}$ by $10\frac{7}{8}$ inches high-speed rolls, which would bring it down to $\frac{1}{2}$-inch size; dried in cylinder-dryers ($3\frac{1}{2}$ by 41 feet), crushed fine in three Krupp No. 5 ball-mills,§ and sized into three grades with (fan) air-separators, which, judging by the product I saw in the laboratory, effected this object very satisfactorily, yielding three products: "coarse," "medium," and "fine." The "coarse" products of this classification that contained coarse gold, after cyanidation,

* Its capacity was subsequently, however, I believe, duplicated, by which the cost of treatment was expected to be reduced considerably.

† These were figured at, mining and hauling, 12*s.*, and development, 3*s.* $8\frac{1}{2}$*d.* per ton.

‡ It has been pointed out that in dry-crushing ores in New Zealand, it is a curious and interesting circumstance that "the finer the dust, the higher its value," and the same thing has been remarked in dry-crushing some of the Kalgoorlie ores.—'Cyaniding in New Zealand,' by James Parke, *Trans. Am. Inst. of Mining Engineers*, vol. xxix.

§ Room was left for a fourth mill. The mills were to be fed automatically from a 25-ton iron bin, and were to crush the ore through 25-mesh screens; the fines below that size being previously screened out, after passing through the drying cylinders.

were to be ground and amalgamated in four Wheeler pans connected with two settlers, and sluices fitted wirh amalgamated plates below the level of the cyanide leaching vats, and the "slimes" produced were to be agitated with cyanide, and filter-pressed. The "sands" were to be cyanided in a series of ten steel vats (21 feet 4 inches by 6 feet 7 inches) holding 79 tons of coarse sands or 72 tons of medium sands, by percolation in the ordinary way; and the "fine" product with the slimes from "the pans," after being thoroughly mixed in a "mixer" with cyanide-solution, was to be passed through two sets of three agitation-vats set one slightly below the other, so that the "slimes" would run continuously through them; giving time, however, to dissolve the gold. From the last vat of each series, the pulp was to be collected in one of two storage-reservoirs of 40 tons capacity (alternately filled and emptied), agitated to prevent it from settling, and delivered from the reservoirs as required to one of three "montejus," by which it was to be forced through one of three filter-presses, under a pressure of about 60 lb. of air. Each filter-press was to be provided with a separate montejus for weak solution and wash-water. The sand-leaching plant was to be furnished with four elevated storage tanks of 8600 gallons capacity for strong solution, weak solution and washing water, one being kept in reserve. The gold was to be precipitated in zinc in extractor boxes in the usual way.* Power for running this mill was furnished by a 250 horse-power Davey-Paxman engine, and five 7 by 21 Cornish boilers under a pressure of 135 lb., one being kept in reserve.

A marked point of difference between the Associated and Brownhill methods of treatment was that in the latter mill bromo-cyanide was employed as a solvent, in place of ordinary cyanide, and it is stated† that no mine on the field obtains a closer extraction than the Brownhill.

By the addition of roasting-furnaces it was expected that this plant could be adapted to the treatment either of oxidised ore or telluride, but the new sulphide mill is designed to do away with roasting, and employs the Diehl process.

The ore crushed from October 1898 to September 1899, inclusive, amounted to 42,025 tons, which yielded 87,762 oz. 3 dwt. 9 gr., and in the profit and loss account 25,049*l.* 12*s.* 10*d.* appears charged to milling, and 25,906*l.* 10*s.* 4*d.* to extraction. As it is not stated,

* The line of treatment described was, I believe, practically the one adopted, with the addition of a fourth press, a third sludge storage tank and other plant, by which the capacity of the plant was afterwards, I understand, increased.

† J. K. Wilson, *Mineral Industry*, vol. ix. p. 781.

however, in the Report in which these figures are given, whether any portion of the quantity of ore dealt with was "sulphide," the cost of "milling" at these works (dealing with "brown-stone" alone) cannot be exactly stated. On an average monthly output of 3502 tons the cost of milling and extraction appears, however, to work out at 24*s.* 3*d.* per ton, exclusive of royalty. During the 15 months ending December 31, 1900, 76,027 tons of ore were treated, which returned 105,615 oz. 1 dwt. No data are available showing the average percentage of extraction, but in January 1899, it is stated * that the slimes yielded 93·62 per cent., the sands (by cyaniding and amalgamating the coarse sands) 90·c8 per cent., and the total ore 91·47 per cent. The company's laboratory equipment was the finest I saw on the field, and it possessed a very neat and well-arranged "experimental plant" for carrying out working-tests.

Some Special Points in Milling Practice in this District may be noticed, supplementing the general remarks at the commencement of this chapter. As will be seen from the description already given of the different milling-plants, very considerable variation exists both in the general methods used for the reduction of the ore and the recovery of the gold, and in the details of the machinery employed for these purposes.

The scarcity of water in the early days of "the field," and its consequent cost, coupled with its saline nature; the large percentages of "slimes" produced in wet-crushing the ore; the minute subdivision of a large part of the gold in the "brown-stone," favouring extraction by means of cyanide; the presence of decomposed or partially decomposed tellurides; and other reasons, early led to the application of "dry crushing" for the reduction of the oxidised ores. Dry crushing may, in fact, be regarded, despite sundry disadvantages, as the proper form of treatment, where scarcity of water renders wet crushing too expensive; the ore requires to be reduced to a *very* fine state of division, in one continuous operation, for its subsequent treatment; or when it has to be roasted, preparatory to chlorination or cyanidation. There is small doubt, however, that in addition to other inherent objections, compared with ordinary wet crushing, it is, generally speaking, expensive, so long as *the ore does not require to be "slimed"* in pans or "tube-mills," after crushing in the stamp-battery. Partly on this account, and doubtless for other reasons, a disposition may be noticed at Kalgoorlie to revert to wet crushing for the crushing of sulphide ore; just as happened in New Zealand, where dry pulverisers were

* *Financial Times* Supplement, May 29, 1899.

DRY CRUSHING COSTS.

Description.	First Arrangement—Crusher and Dryer and Four Sets of Rolls (experimental).	Second Arrangement—Two Crushers, Two Dryers and Eight Sets of Rolls. 45,844 long tons crushed to 1/8 inch.	Arrangement during 12 months' run ending May 31, 1899. New West Works, containing Four Crushers, Four Dryers and Sixteen No. 5 Krupp Ball Mills, crushing 130,776 long tons, to pass a 20-mesh, i.e. 1/20-inch screen.					
			Stone-Breakers.	Dryers and Elevators.	Ball Mills.	Engines.	Boilers.	Totals.
	s. *d.*	*s.* *d.*	*d.*	*d.*	*d.*	*d.*	*d.*	*d.*
Running expenses—								
Wages	2 6·40	2 6·20	3·420	2·370	2·790	1·850	1·604	12·034
Stores	0 2·80	0 3·90	0·446	0·620	0·904	0·486	0·310	2·766
General expenses	0 1·18	0 0·57	0·066	0·036	0·066	0·027	0·028	0·223
Electric light	0 1·43	0 0·59	0·035	0·125	0·069	0·068	0·035	0·332
Cartage	0 2·30	..	..	0·106	0·003	..	0·126	0·235
Inclined tram	..	..	..	0·517	..	..	0·800	1·317
Firewood	1 2·50	2 0·50	..	3·979	..	..	5·559	9·538
Coal	..	..	..	1·150	..	..	2·667	3·817
Water supply	0 0·57	0 0·52	..	..	..	..	0·068	0·068
Totals	4 5·18	5 0·28	3·967	8·903	3·832	2·431	11·197	30·330
Maintenance (repairs)—								
Wages	0 3·52	0 5·20	0·277	0·475	1·190	0·340	1·043	3·325
Stores	0 10·67	0 10·80	0·242	0·228	9·750	0·108	0·165	10·493
Cartage	..	..	0·002	0·007	0·004	..	0·025	0·038
Mechanics' work	0 6·28	0 5·21	0·183	1·527	0·755	0·044	0·397	2·906
Timber	0 0·22	0 0·18	..	0·013	0·002	..	..	0·015
Totals	1 8·69	1 9·39	0·704	2·250	11·701	0·492	1·630	16·777
Grand totals	6 1·87	6 9·67	4·671	11·153	15·533	2·923	12·827	47·107 *

* Total, 3*s.* 11·107*d.*

tried on a large scale, but, owing no doubt to the exceptional hardness of the stone, the tendency there has since been to employ wet or even dry stamps. The above figures given by Mr. N. F. White,* show the cost of dry crushing at Mount Morgan, Queensland, Australia, and are of interest in this connection.

It would appear from the preceding table, that although dry crushing is expensive for the reasons that have been explained, when it cannot be avoided it is cheaper to crush the ore *in one continuous operation to a fine size*, using ball-mills, than it is to reduce it gradually in a series of operations with rolls. It is generally considered on the fields, moreover, that the use of "ball-mills," which is a marked feature of Kalgoorlie practice, is the best method to adopt for dry crushing under existing circumstances, and can only be improved upon in so far as one type of "mill" may possess some slight advantage over another.

Mr. Ph. Argall † referring to these Mount Morgan tests, points out, however, that they cannot be considered conclusive evidence of the general superiority of ball-mills over rolls, so far as concerns *general practice*, partly because of the much greater capacity of the ball-mill plant, which was greatly in its favour, and partly because it was new, whilst the roll-plant was old and does not appear to have been of the latest improved type.

He argues, with considerable justice indeed, that as far as regards cost of crushing, "had this latter plant consisted of modern improved rolls, constructed and arranged in accordance with the best current practice, the results would no doubt have been very different." After very careful and elaborate trials which Mr. Argall details, that he made in Colorado, he arrived at the conclusion that a properly arranged plant, consisting of modern high-speed rolls, crushing the ore down gradually, for large capacities (say 60 tons per diem upwards) would be superior to ball-mills when the object aimed at is to prepare an ore for roasting, or direct lixiviation, and to obtain a *granular* product of the desired fineness to give a high extraction, free from much fine dust; dust being liable to make the ordinary leaching process slow and laborious.

He remarks that 62 lb. per horse-power hour is about the maximum output of dry-stamps, crushing the ore to 30-mesh, and that first class rolls will give four times this output with the same

* N. F. White, *Trans. Australasian Inst. of Mining Engineers*, vol. vi.

† 'Sampling and Dry Crushing in Colorado,' by Ph. Argall, M.Inst.M.M., *Trans. Inst. of Mining and Metallurgy*, vol. x. (1902).

expenditure of power. In a two-unit plant, having a capacity of 400 tons per diem, crushing to $\frac{1}{30}$ inch, and with the ore delivered at the "breakers," he estimates that ore can be crushed in Colorado for $0·50 (2*s.* 1*d.*) per ton, including all expenses for breaking, drying, operating, maintenance and sampling, but exclusive of management, rates and taxes, insurance, water supply (if any), and depreciation.

It is most difficult in reality to institute a comparison between different types of crushing machinery, as no two mills are built alike, and operate on exactly similar ore, under precisely the same conditions; and the character of the ore, and the process by which it is to be afterwards treated, largely decide the question of choice.

Rolls, for example, should deliver a product in the most granular and consequently in the most suitable condition possible for leaching; ball-mills, on the other hand, serving as pulverisers, are, I believe, better machines, when it is necessary to reduce the ore to a very fine state of division, and they are more suitable for *moderately hard*, than for *very* hard, or soft ores, which latter rolls are well adapted to deal with, so long as the stone is not *moist* and clayey; on the other hand, the presence of much *coarse* gold in an ore favours the employment of wet stamps.

The duty of a ball-mill, quite apart from the hardness and character of the ore, seems to depend to a large extent upon the speed at which it is run. If too fast, the centrifugal force drives the balls to the periphery and they do not drop properly. If too slow, the balls fall back before arriving at the top, and they are ineffective. The ball-mills at the Great Boulder Main Reef, I understand, used to be run at 22 to 23 revolutions* per minute, the screens used were 900 to the square inch, and 60 per cent. of the product, it is stated, would pass a 90-mesh screen. Under these conditions the cost of crushing (exclusive of power), came to a little under 1*s.* 6*d.* per ton; and Mr. Alfred James,† quoting Mr. Moss, states that crushing with these mills at Kalgoorlie, costs 9*d.* per ton for renewals, and 5*d.* per ton for labour (power is extra); and under good working conditions their "duty" is stated to amount to about 2 tons per horse-power.

* For the large sizes, 24 revolutions is said to be the best rate of speed.

† *Cyanide Practice*, by Alfred James, M.Inst.M.M., p. 109. (E & F. N. Spon, Ltd.) In the third edition (3p) 23, the same author states that recent results show 2110 tons of ore crushed in one month (670 hours) at Hannan's Star by two No. 5 mills, each using 16 horse-power, i.e. over 3 tons per hour for 32 horse-power or $\frac{1}{10}$ of a ton per horse-power hour, using 30 and 40 mesh screens. Messrs. James Brothers state that the mills are now turning out over 80 tons per 24 hours. One set of liners lasts 8½ months with the usual Kalgoorlie ores, but the best liners last 5½ months with the extremely hard Hannan's Star ore.

The output of a No. 3 ball-mill is estimated at 12–15 tons per diem, and of a No. 8 mill 50–60 tons.

Griffin-mills are also extensively used at Kalgoorlie, in connection with sulphide-ore treatment; it appears important that the material fed to them should be crushed down to not larger than 1-inch cube, and that it should be fed regularly.

Mr. Alfred James states that "recent practice at Kalgoorlie gives an output of 21½ tons per mill per diem crushed from 1-inch gauge through a 15-mesh screen, at a cost for wages and repairs (power not included) of 1*s.* 10*d.* per ton."

Dry pulverisers of these types are, it must be confessed, excellent *pulverisers*, and their compact form, admitting of grinding, screening and elevating in one machine, enables them to give a finished product in one operation—a feature that commends them in cases where small crushing units are required.

At Hannan's Star, in 1899, Mr. Robson stated* that the 30-ton Krupp mills used for dry-crushing the oxidised ore put through 5305 tons in 1509 hours, an average of 1·75 tons per hour per mill, and the average loss in weight of the balls was 0·5 lb. per ton of ore crushed. The iron abraded from the machine † is detrimental if bromo-cyanide is used.

The extensive employment of dry-crushing machinery on these fields involves one serious disadvantage, that of producing a very considerable quantity of dust,‡ which is not only bad for the workmen and bad for the machinery, but is often so rich as to represent, if allowed to escape, a serious gold loss.§ In America more attention appears to have been paid to this matter than in Australia, and in the Cripple Creek mills "dust-collectors" are extensively used. An arrangement adopted in a mill recently built is described and figured by Mr. J. E. Rothwell,‖ in which the dust is exhausted from the rolls, elevators and screen casings by a large exhaust-fan, and is blown into a series of cotton bags, located above the pulp ore-storage bins, the arrangement permitting any line of bags to be cleaned without interfering with the others.

* Annual Report, Hannan's Star Gold Mines, 1899.

† *Gold Milling*, by C. G. Warnford Lock, M. Inst. M.M., p. 301.

‡ Mr. Geo. Robson, M. Inst. M.M., estimates the "*aerial loss*," as it may be termed, at about 5 per cent. of the ore milled, so that on 5627 tons crushed in 1899, it amounted to 282 tons; whilst 342 tons extra of "dust" were collected from the rotatory-dryer.

§ Some interesting experiments on this subject were made by Mr. E. G. Banks in New Zealand, detailed in the *Trans. Am. Inst. of Mining Engineers*, vol. xxix. p. 671.

‖ 'The Barrel Chlorination Process,' *The Mineral Industry*, vol. ix. p. 363.

"A machine largely used in flour-mills is now being used in some of the new mills, in which a number of small bags are carried radially on a horizontal cylinder, and arranged so as to collect the dust blown into it, discharging it automatically to a screw conveyor, which in turn carries it to the main pulp-elevator or chute leading to the storage bins."

"Systems of hopper-bottomed storage bins in flues are also used, into which the dust is blown and settled. These, however, involve labour to empty, and require attention, besides giving the dust in quantity at a single time, which causes difficulties in its after treatment."

The method favoured by Mr. Rothwell is to mix the dust with the pulp continuously, treating the mixture in the usual manner, though some of the mills separate and ship the dust to smelters, who briquette and treat it, with the object of getting over the difficulty of treating it separately, as its removal gives a better leaching product, and increases in consequence the capacity of the plant. Mr. Argall lays special stress on the need of properly "*housing-in*" the crushing and screening machinery.

In the wet-crushing mills, at Kalgoorlie, the general use of "blankets," has been partly dictated by Australian custom, partly by the fact that the gold in the brown-stone is "free" and not unfrequently coarse; but no doubt mechanical concentrators, like the Wilfley table, which have been since introduced, do better work at a cheaper cost, and save a good deal of the mercury, which has unquestionably been lost in the "tailings," carrying gold with it. With sulphide ores the tendency lately has been to carefully classify the "pulp" as a preliminary step to concentration; and to put in canvas tables after the mechanical tables to save fine and rich sulphurets.

Mr. Skews informed the author that he found the stamp-stems were exceptionally liable to breakage at Kalgoorlie, although the stamps did not seem to have been unduly "pounding." The average speed of the battery was approximately 90 (varying between 83 and 97 seven-inch drops per minute), and he has suggested as a *possible* explanation the effect of the salt water.

He also informed me, that although the water must have had an average temperature of 100° F. during the day, the amalgam was so hard it was impossible to clean the "plate" with an ordinary rubber or scraper; which *may* perhaps have been due to the same cause. It would be interesting to know whether experience in other cases supports either of these suppositions, as other explanations are of course possible.

If salt water is used for condensation in Wheeler or other similar condensers, it is a heavy source of expense, and in one mill I am informed they had to drill out every pipe with augers weekly, necessitating a stoppage of 8 to 16 hours per week. Fresh or condensed circulating water should therefore be used for "condensing" purposes. Hot salt water will form an incrustation on pipes at the rate of 1 inch a month, destroying their efficiency; and has been found to incrust flumes to a depth of over 4 inches. The water in some of the mines is corrosive, due to the presence of free acid which destroys pipe-joints, especially if they happen to be of two different metals.

A further difficulty which steam-users have to cope with is the fact that some Australian hard-woods appear to have an unusual tendency to coat the boilers with soot and oily products of combustion, which affect their efficiency, and are liable to cause the plates to get "burnt" unless the boilers are constantly cleaned out, tubular boilers being particularly liable to suffer in this respect, especially if of the vertical type. This no doubt partly results from imperfect combustion in the fire-box, and can be mitigated by constructing it so as to admit a sufficient amount of air, and by careful "firing."

High-pressure water-tube boilers are giving satisfactory results, I am informed, but special attention has to be given to the filtration and removal of oil from the feed-water.

The cost of milling, it may be noted, shows wide variations, as in other fields, being determined (1) by output; (2) by the machinery that the process employed demands to recover the gold; (3) by the cost and organisation of the labour in each mill, depending to some extent on the arrangement of the plant; (4) by economy in the use of power and supplies, which results from the class of power employed, and the way in which it is applied; the size and type of boilers and mill machinery used; the quality and cost of fuel and water (if steam is used); and the care with which the machinery, wood, water, and supplies are looked after.

To determine whether the best is being done that can be done with the means at any particular manager's disposal, the surrounding circumstances in each case must be exactly known, and carefully studied from a technical standpoint, which no one except a professional man can possibly do, with any chance of arriving at a true conclusion, except by accident.

Tailings Treatment.

Whilst the battery tailings varied considerably in value, it was soon found that it would pay handsomely, as a rule, to "cyanide" them, consequently most of the wet-crushing mills were early equipped with "cyanide-plant" for this purpose. The tailings not unfrequently contained some pyrites and a considerable quantity of "black sand," and carried up to 2½ per cent. or more of soluble salts (chloride of sodium and magnesium) derived from the mill water. The addition of a small quantity of slaked lime to the mill-launders conveying the tailings to the dams is at times found beneficial to neutralise acidity, and a preliminary wash of weak caustic soda (say 0·1 per cent. strength) is often used to diminish the consumption of cyanide; the "extractor-boxes" are not, however, kept in this latter way, in as good condition as by using lime.

In some cases, large heaps of battery-tailings (sands and slimes) were accumulated in the early days, as was the case in South Africa, in which case they needed to be trucked from the heaps to the cyanide-works; but most mills subsequently came to treat their raw or "green" tailings direct, as they come from the battery. In the dams, where they still carry a lot of water after settling, they present a dirty, muddy, grey appearance; but when dried, the oxidised tailings are, as a rule, of a red-brown colour.

At the Great Boulder the average assay of the battery-tailings, as already stated, was 8 dwt. in 1898, 6 dwt. in 1899, and 5·5 dwt. in 1900. The fineness of the pulp, after *crushing* and *grinding* by the process previously described (which is no doubt due in a large measure to the argillaceous and calcareous nature of the ore, apart from its schistose structure), may be judged by the following figures, given in the company's reports for 1898 and 1899:—

	1898. per cent.	1899. per cent.
Passed through a sieve having 22,500 holes per sq. in.	81·2	85·8
,, ,, 10,000 ,,	9·0	5·7
,, ,, 6,400 ,,	..	6·5
,, ,, 3,600 ,,	9·2	1·4
,, ,, 2,500 ,,	0·6	0·6
	100·0	100·0

Experiments * made on a sample of North Boulder mill-tailings (crushed in the Huntington mills) assaying 12 dwt. 16 gr. of gold,

* A number of useful notes and suggestions are given by Mr. Alfred James, in regard to the investigation of samples, in *Cyanide Practice*, 3rd edition, pp. (3p) 32–36.

consisting of some of the richer and coarser sands separated from the "slimes" by settlement, showed that:—

Per cent.			
15	remained on a 40-mesh sieve	.	Assaying about 1 oz. of gold per ton.
15	„ 60 „	.	
23	„ 90 „	.	„ 10 dwt. „
47	passed 90 „	.	The slimes represented about 30 per cent. of the tailings and assayed 6 dwt. of gold.
100			

Whether mostly owing to some difference in the character of the ore, as I am inclined to think is the case, or partly in consequence of the different treatment it has previously undergone, it is a well-established fact that whilst in some instances "the slimes" in the battery-tailings were so poor as not to be worth treating, in other cases they were comparatively high-grade (running as they frequently did from 8 dwt. to over an ounce in value),* and this led to two radically different lines being pursued, in dealing with them.

In the one case, as at the North Boulder and Boulder Main Reef, the sands, which represent between 40 and 50 per cent. of the total ore crushed, were separated from the slimes, by settlement in one dam, and the "slimes" were collected in a second dam; the clear water which flowed to a "sump," being pumped back to be used over again. The "sands" thus collected were generally speaking *the more valuable portion of the "tailings,"* and were hauled to the cyanide plant, and treated by simple "percolation"; the bulk of the slimes at North Boulder were, in fact, too low grade to be profitably treated, generally assaying below 3 dwt. It may be remarked, however, that the Boulder Main Reef Company stated in their fifth annual report (July 30, 1901), that in the seventeen months (from January 1, 1900, to May 31, 1901), 14,333 tons of slimes from the oxidised ore, and sands from the first sulphide plant, yielded 7585 oz.; and the cost of tailings treatment is reported to have been 18*s.* 6½*d.* per ton.

In the other case, as at the Great Boulder, the tailings from the settling dams, after having been exposed to the air and weather for a long time, having lost much of their moisture and being mostly in the form of "slime," were trucked to the cyanide-plant, which had a capacity of 200 to 300 tons per 24 hours, and after being broken up in a "disintegrator" were run into a "sump," pumped into a vat with radial arms, and agitated with cyanide, in agitation vats, to dissolve the gold. After this was done, the pulp

* J. K. Wilson, *The Mineral Industry*, vol. ix.

was discharged into a montejus,* and filter-pressed, and the solution was passed through the extractor-boxes, and returned to the sump. In 1900, a Lidgerwood hoist handling 300 tons a day was installed to dispose of the residues. The cost of this method of treatment in 1899, dealing with 23,707 tons, appears to have been 11*s.* 9*d.* per ton, as set out in detail in the table below :—

	£	s.	d.	
Wages	6,195	7	6	
Stores	4,885	1	3	
Trucking	1,308	13	6	
Smelting expenses	20	14	0	
Firewood and fuel	599	18	5	
Lime	89	10	1	
Condensed water	262	19	2	
Proportion compressed air	496	2	5	
" stable expenses	88	7	10	
				Per ton.
	13,946	14	2	= 11*s.* 9·19*d.*

There was also another group of mines, such as the Lake View Consols, Ivanhoe, and Golden Horse-shoe, where crushing through 30-mesh screens, producing about an equal proportion of "sand" and "slimes," *a third system of treatment* has been pursued ; *both* battery products being sufficiently valuable to demand separate treatment, they were dealt with direct (without previous settling in a dam), and the gold was recovered from the sands by "percolation," and from the "slimes" by filter-pressing.

Percolation treatment, as generally applied on this field, presents no particular novelty, but a few special points in connection therewith may be noted here.

In practice in this district, a tendency may be noticed to use large-diameter shallow vats, rather than deep ones, on account of the difficulty experienced in percolation. At Waihi, in New Zealand, in the same way, it is stated by Mr. James Park † that a greater depth of charge than 24 inches was found impracticable for economical working, and even ‡ with the most favourable silicious material it seldom exceeds 3 feet. The gold is more readily dissolved the finer the ore is crushed, but this advantage is neutralised by the mechanical troubles caused by "sliming" the ore.

* A good description of montejus is given in *The Mineral Industry*, vol. v. p. 279, and in the Report of the Under-Secretary of Mines, Queensland, 1899, p. 200. In the newest type an air-jet is employed to agitate the contents, and prevent the coarsest portion of the pulp settling.

† 'Cyaniding in New Zealand,' by James Park, F.G.S., M. Inst. M.M., *Trans. Am. Inst. of Mining Engineers*, vol. xxix. p. 672.

‡ *The Cyanide Process*, by Park, p. 65. (Chas. Griffin & Co.)

The gold, I am informed, is quite as readily soluble in Western Australia as in the South African ores; but "slimes" require longer to settle, and the comparative coarseness of the gold in the sands no doubt serves to explain the length of time sometimes needed to obtain a high percentage of extraction.

The riveting of the steel vats, which are largely used on this field, costs about 1*l.* 3*s.* 10¾*d.* to 1*l.* 4*s.* 3*d.* per 100 rivets, the rivets being snapped or hammered, and the joints caulked. If tested with *salt water*, unless thoroughly washed out to remove the salt, the paint does not properly adhere to the steel.

Cotton-twill vacuum cloths, common house canvas, hessian and jute, have been tried; the hessian did not last more than two months; the canvas between three and four; whilst the twill lasted longest;* the jute also giving satisfaction.

Mr. Robert Allen considers New Zealand kauri pine, American redwood, or Queensland cedar (grown north of Rockhampton) more suitable woods than teak, as a material for extractor-boxes, and informs me that a good tight joint may be made with $\frac{1}{16}$-inch thick rubber-tape insertion; instead of painting them, the inside of the boxes can be treated with paraffin wax (melting point 120° F.), rubbed in with a hot "iron." A zinc capacity of 5 cubic feet per box, with three boxes, was found sufficient to precipitate the gold at North Boulder; but with richer tailings this would need to be increased, and sufficient slime-capacity is not always allowed underneath the trays for the accumulation of the "zinc slimes."

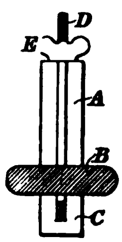


FIG. 47A.

Wooden plugs working in iron openings in the extractor-box launders do not seem to answer well, and Mr. Robert Allen suggested to the Author, that a better arrangement in place of plugs would be in the form of a pickle-bottle stopper, as per sketch (Fig. 47A). A C being cylinders of wood, smaller in diameter than the hole to be plugged; B, a rubber cylinder, just less than the size of the hole to be closed; D, a pin screwed into C, passing through A and B, freely, and threaded at the outer end; E, a thumb-screw which, when turned brings A and C together, compressing B, and expanding it in the hole to be stopped.

In some cases, when steel distributor-boxes are used to collect the liquors issuing from the vats, to avoid straining the boxes,

* Mr. Alfred James states, that treating about 1700 tons of slimes a month 70 yards of cloth are required, which at 1*s.* 9*d.* per yard represents ⅛*d.* per ton; 1 yard treating 24 tons.

causing danger of leakage, a liquor-distributing box might be used, divided longitudinally into as many compartments as necessary (corresponding with the number of boxes), with pipe connections to the boxes at each end of each compartment, and with a short length of hose placed at the end of the main delivery pipe, enabling the liquor to be easily diverted into the several compartments of the distributing box.

Zinc discs cost about 4½*d.* per lb. f.o.b. the works, and cutting say 30 lb. in eight hours adds over 4*d.* per lb. to the price, not allowing for loss of zinc and cost of power. Zinc in sheet form, wrapped round a wooden mandril, can be turned in a screw-cutting lathe, with a forward movement of $\frac{1}{500}$ inch at each revolution, at a cost of 8·71*d.* per lb. for "shavings."

Patent zinc-cutting machines are used on some large works, but are too expensive in first cost for small mines.

It would appear that a fine state of division of the gold does not *always* render it amenable to cyanide, as at Cooke, in Montana, Mr. Packard * mentions that the free-gold present in the ore, although so fine as to pass a 60-mesh screen, could not be extracted in the length of time usually allowed for leaching, by ordinary weak cyanide solutions, and it would not pay to use stronger ones, or extend the time of treatment.

As regards the use of lime, Mr. Merrill † has pointed out that the consumption of cyanide occasioned by the presence in the ore of certain compounds of iron and manganese can frequently be obviated to a large extent by mixing lime with ores of this class; but at other times, particularly in leaching partially-oxidised pyritic ore, there is a consumption of cyanide which the use of lime will not overcome. A standard of alkalinity should be maintained in sump-solutions, but any excess of alkali is detrimental with ores containing sulphides, and is also said to cause waste of zinc. Alfred James (3p) p. 43, 3rd edition of *Cyanide Practice.*

Experiments also made by Mr. Packard indicate that the loss of cyanide in the zinc-boxes may be very high with a strong (1 per cent.) cyanide solution if an impure lime (containing alumina and magnesia) is mixed with the ore in the tanks; but the loss is less as a rule when lime is used than when the acidity in certain ores is neutralised with caustic soda, the excess of lime or caustic

* 'The Cyanide Process in the United States,' by Geo. A. Packard, *Trans. Am. Inst. of Mining Engineers*, vol. xxvi.

† 'The Present Limitations of the Cyanide Process,' by C. W. Merrill, *Trans. Am. Inst. Mining Engineers*, vol. xxv., p. 104.

soda, and resulting salts, not being washed out before the cyanide solution is added. He states, however, that he found the consumption of zinc was slightly less when soda was used. In some cases, it has been claimed that a freshly-made solution of sodium dioxide added to the cyanide solution (Kendall's process), or the dioxide mixed with the ore dry by furnishing "nascent" oxygen, which liberates cyanogen, decreases the time required for leaching; and at the Commercial mill in Utah a preliminary treatment with a solution of sodium dioxide in water is stated * to have given better results in neutralising acidity in the ore than either lime or caustic soda; but the action of this reagent in hastening the reaction does not appear to last for more than 24 to 48 hours, and at the end of a long time it does not seem to accelerate the action of ordinary cyanide.

Mr. Merrill has remarked that as the solutions become fouled by the presence of base metals, their extractive power becomes weakened, even when the normal percentage of active cyanogen is maintained by the addition of fresh quantities of cyanide, which may be due to the fact pointed out by Mr. Maclaurin, in the *Journal* of the Chemical Society (February 1895), that the rate of dissolution of the gold decreases as the viscosity of such solutions increases, and as the absorption co-efficient of oxygen decreases.

This fact has been commented upon by Mr. James,† who remarks that sump-solutions "contain amongst other matters, salts of zinc, iron, occasionally copper, alkalies, and alkaline carbonates, ammonia, and sulpho-cyanides;" and "unless these constituents are prevented from accumulating in the solutions, the solvent power on the precious metals of any added cyanide must sooner or later be impaired." He found that the addition of lime improved the extraction in the case of quartzose tailings carrying free gold; but as before noted, it has a deteriorating effect on ores containing sulphides. Where lime failed, he found, however, that treatment with sodium sulphide (taking care to avoid an excess) followed by the addition of a small quantity of soluble lead-salt (acetate or chloride), in excess, was efficacious. Time must, however, be given in both cases for any precipitated sulphides to separate out and subside.

Although it costs rather more, Mr. James advocates the use of

* 'The Cyanide Process in the United States,' by Geo. A. Packard, *Trans. Am. Inst. of Mining Engineers*, vol. xxvi.

† 'Notes on Sump-Solutions, Extractor-Box Work, and Cleaning-up in the Cyanide Process,' by Alf. James, M. Inst. M.M., *Trans. Inst. of Mining and Metallurgy*, vol. vi.

lead-free zinc, partly in order to avoid the fine of from 3*d.* to 1*s.* 8*d* (averaging about 9*d.*) per ounce of fine gold, imposed by the London refiners on base bullion containing lead, partly because experiments he made demonstrated that the loss of gold in the treatment of the "gold-slimes" is reduced by about 0·2 per cent. when compared with the loss that obtains, if ordinary zinc is used; and also because it reduces the quantity of material (slimes) to be treated. Mr. James mentions that "an experiment with lead-free zinc gave a total loss of only 0·52 per cent. with direct fusion of the sieved slimes, the coarse zinc being treated with sulphuric acid, and the residue added to the slimes."

Mr. Leggett * has pointed out a fact deserving notice, that where the sulphuric acid method is used, all the disagreeable and loss-provoking sulphate of zinc (in the subsequent melting), are eliminated by means of hot-water washes pumped through the "gold-slimes," at a pressure of 60 to 80 lb. to the square inch in the apparatus which he describes.

Mr. Alfred James states † that "a comparison between melting direct and a preliminary treatment with sulphuric acid, gave results depending on the purity of the slimes; when these had been passed through a 40-mesh sieve, to free them from coarse zinc, melting direct gave a fairly pure bullion, and at least as good results as with acid treatment; but with scrap and coarse zinc included, the advantage lay with the latter method." Fabre du Faure tilting-furnaces are used in some cases for smelting the "gold-slimes." ‡

Cyanide naturally varies in price at Kalgoorlie; freight charges adding from ⅞*d.* to 1*d.* per lb. to the cost in London, so that at 12⅝*d.* it would cost about 13½*d.* delivered. §

* 'Additional Notes on the Treatment of Zinc-Box Precipitates (Slimes) from the Cyanide Process,' by T. H. Leggett, M. Inst. M.M., *Trans. Inst. of Mining and Metallurgy*, vol. v.

† *Op. cit.*

‡ An improved method of cleaning-up gold-slimes (precipitate) by direct fluxing with litharge (for which a considerable saving over other methods is claimed), is described by Mr. R. S. Taverner of the Bonanza, in a "paper" recently read before the Chemical and Metallurgical Society of South Africa, of which particulars are given in the *Mining Journal*, December 6, 1902. This process is dealt with in *Cyanide Practice*, 3rd edition, from which it appears that Mr. Taverner estimates the cost of cleaning-up by this method at 3*d.* per fine oz. of gold recovered, as compared with 1*s.* to 1*s.* 3*d.* by the acid or the roasting-process used on the Rand, and it is stated to show 10 per cent. greater recovery; the losses in cleaning-up averaging formerly over 6 per cent.

§ In *Cyanide Practice*, 3rd edition (3p) p. 7, it is stated that soda cyanide is now made of great purity 127–129 per cent. (in terms of KCy), but it is proportionately more expensive, and requires the use of more alkali to solutions than the ordinary double-cyanide. The cost of this latter chemical may be materially cheapened by new processes of manufacture.

Filter-press treatment * is more or less peculiar to Kalgoorlie, and has been brought to the high state of perfection it has attained through the exigencies of local requirements and conditions. At the end of 1901 there were 95 filter-presses in operation on the East Coolgardie gold-fields. The first filter-presses introduced into Western Australia were built by Jas. Martin and Co., of Gawler, South Australia, and were employed at the 25-mile cement claims, near Coolgardie. The comparatively large proportion of slimes produced, whether in crushing the oxidised ores or milling the sulphide ores in this particular district, gives special importance to the slimes branch of the tailings treatment, which is accentuated by the actual as well as the relatively high value of the slimes that the Kalgoorlie tailings carry. Under the conditions that obtain on this field ("decantation" † being impracticable), a more expensive method of gold-recovery can be employed than would ordinarily be permissible; provided it ensures close and rapid extraction, and admits of expeditiously handling large quantities of material. Moreover, the difficulty and cost of obtaining water in Western Australia render it important that it should be conserved with as little loss as possible from waste and evaporation; and this influences the question in some degree.

The suitability of the filter-press for coping with the difficulties presented by the treatment of slimes (whether oxidised or sulphide), under the combination of circumstances described, is now generally recognised; and the subject has been admirably and very fully dealt with by Mr. Wilson,‡ to whom the Author is much indebted for information incorporated in the following description. It must be recollected, however, that the material dealt with contains a certain proportion of fine "sands," and does not correspond in fineness with "slimes," as the term is understood in South Africa.

Filter-pressing was first introduced at the Lake View Consols at Kalgoorlie early in 1898, when the company experimented with one of the Dehne presses on some oxidised slimes from the old

* A paper on this subject was read before the Institution of Mining and Metallurgy in London, by Wm. McNeill, M. Inst. M.M., in 1898 (*Trans.*, vol. vi.), which gives a number of interesting particulars of the early application of this system of treatment as practised in Western Australia. Filter-pressing is also dealt with by C. G. Warnford Lock, in *Gold Milling*, E. & F. N. Spon, Ltd.; and Alfred James in *Cyanide Practice*, 3rd edition (3p) pp. 32–36, gives very full instructions for operating filter-presses

† The relative merits of "filter-press treatment" and "decantation" for the treatment of Rand slimes has recently been discussed, 'Notes on the Treatment of Slimes by Filter-Presses,' by Chas. Dixon, A.I.M.M., a paper read before the Chemical and Metallurgical Society of South Africa, an abstract of which and the discussion is given in the *Mining Journal*, London, October 4, 18, 25, and November 15 and 22, 1902.

‡ 'The Filter-press Treatment of Slime in Western Australia,' by J. K. Wilson, *The Mineral Industry*, vol. ix.

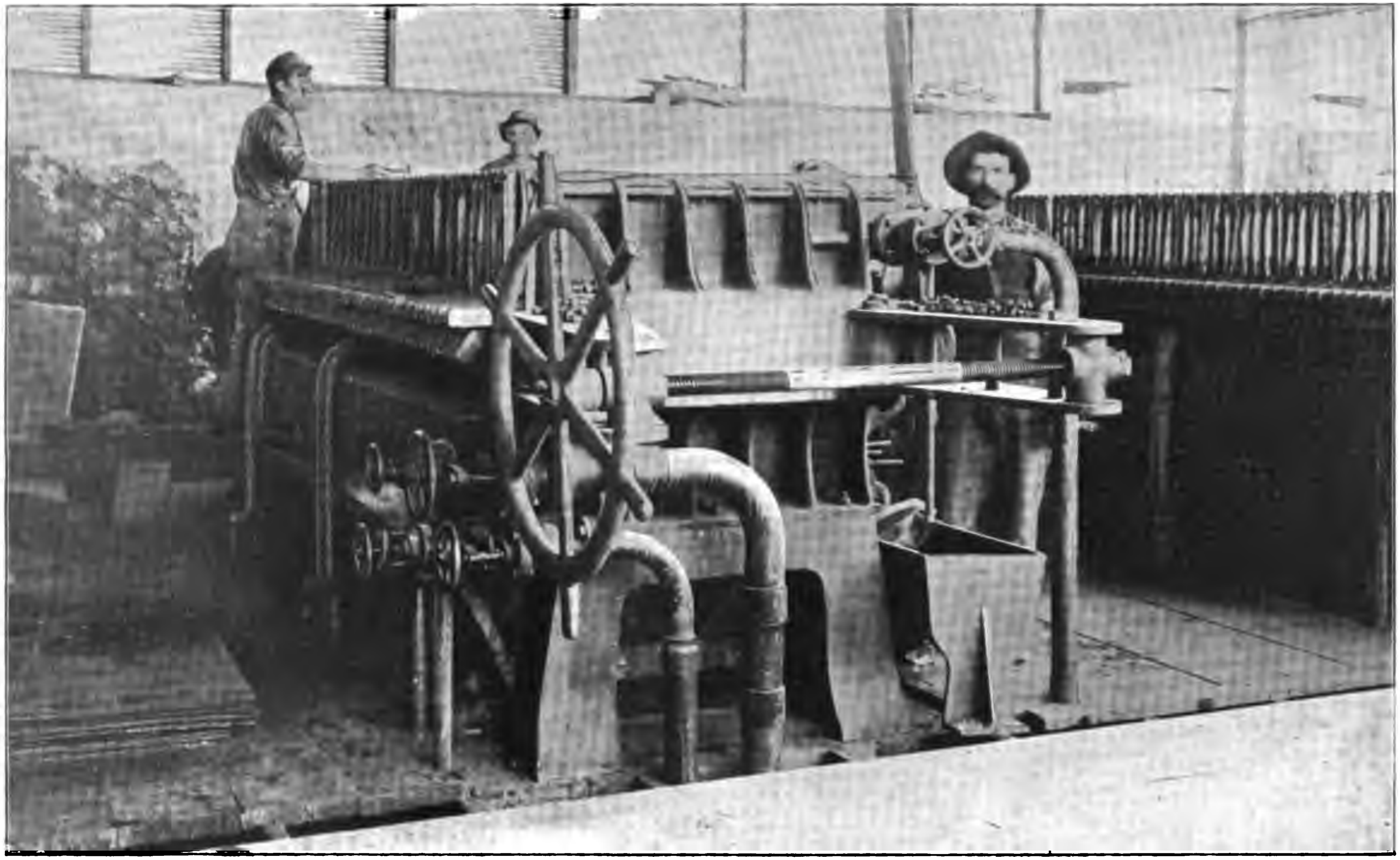


FIG. 48.—A "FILTER-PRESS" AT LAKE VIEW CONSOLS.

battery, and subsequently commenced to work oxidised slimes on a large scale; whilst to the Great Boulder Main Reef Co. belongs the credit, I believe, of being the first to successfully treat roasted sulphide and telluride slimes in filter-presses. The illustration (Fig. 48), shows a filter-press in use at the Lake View Consols. As the result of experiments carried out by various other companies, it has been found that the time occupied in thoroughly washing the large bodies of rich slime that have to be dealt with is too great to enable *decantation* to compete as an alternative method with the more rapid work of the filter-press, although the latter is the more costly of the two, in consequence of which it has so far been unable to take the place of *decantation* elsewhere for the treatment of low-grade slimes. Mr. Wilson classifies filter-press plants, broadly speaking, under two heads, "single" and "double-pressing."

The method of "Single-pressing."—This method, he remarks, "is applicable for the treatment of (*a*) slime containing gold so readily soluble that it may be dissolved in the press, and (*b*) slime from a dry-crushed ore, or one that has been lying exposed to the sun and the weather, and contains but little moisture.

"At Kalgoorlie single-pressing is carried out in two ways: (1) where the gold is brought into solution in the presses themselves as at the Lake View and Golden Horse-shoe mines; (2) * where it is dissolved in agitation vats prior to entering the presses—the press being used merely as a filtering medium, as at the Brown Hill, Ivanhoe, and Great Boulder mines.

"The *modus operandi* is as follows:—The slime, on leaving the distributing vats where the bulk of the sand has been settled, is passed through a series of pointed boxes, or spitzkasten, and any sand which may have escaped the distributors is caught. The true slime, 98 per cent. of which will pass a 150-mesh screen, flows into settling tanks, and the excess of muddy water is drawn off and pumped through two presses set apart for this purpose. When these presses become full of slime, they are dealt with in the same manner as the others, the water being returned to the mill.

"As the slime settles in the tanks, it is run out from the bottom into the montejus-tank and forced into presses by means of compressed air, the pressure required being from 30 to 60 lb. per square inch, according to the thickness of the cake. The clear water is returned to the battery, and a solution containing about

* This method is the one most generally adopted, and seems to be the better practice of the two.—AUTHOR.

0·2 per cent. KCy is pumped through the press; compressed air also being forced through the charge, at intervals of five minutes or so, until the gold is dissolved. The wash, either of weaker cyanide solution or water, then follows, and the charge is dried to a certain extent with compressed air, after which the press is opened and discharged. It is found that all the gold passes into solution in about twenty minutes, and the whole operation of treatment is completed in about two hours."

Mr. Wilson adds, that it is a remarkable fact with certain Kalgoorlie ores, that a prior agitation in vats for three or four hours gives no better extraction than is effected in the press with aërations, as described, and he concludes that air under pressure has a remarkably beneficial effect in aiding the solution of the gold, as shown by the fact that "whenever air has been forced through the charge, the exuding liquors are of increased gold content."

The disadvantages of this system of treatment, as compared with agitation previous to filter-pressing, seem to be that it requires a greater number of presses to treat a given quantity of material, involving a larger capital outlay on plant than would be needed with agitation. On the other hand, Mr. Wilson claims that it is the cheaper of the two to operate; whilst the water is returned direct to the mill, and there is no accumulation of liquors.

The second method of single-pressing differs from the preceding one, in that the gold is dissolved in agitation vats—the presses are merely used as a filtering medium.

This method is applicable, Mr. Wilson observes, "for the treatment of slime from an ore which has been dry-crushed, or which contains but little water, and consequently requires a longer contact with cyanide solution in order to extract the gold. It cannot, however, be recommended for the treatment of slimes coming direct from a wet-crushing mill and carrying much water, as in this case the cyanide liquors accumulate to a large extent, and have consequently to be run to waste, causing loss of cyanide liquor, and to a certain extent, gold." This latter class of "slime" is, therefore, more suitably dealt with by "double filter-pressing," as it requires longer contact with cyanide to extract the gold. Agitation and single filter-pressing is employed at the Brown Hill, Ivanhoe and Great Boulder plants in the treatment of their slimes.

Though the next process would come more properly, perhaps, under the head of "sulphide treatment," it may be discussed here, as it occupies a sort of intermediate position; being used for both oxidised and sulphide ores.

Double filter-pressing.—To quote Mr. Wilson, this method "is the one employed for the treatment of 'slime' which has been wet-crushed, and consequently requires a long contact with cyanide in order to dissolve the gold. Although slightly more costly as regards working expenses than single-pressing, it is to be recommended as the one most generally suitable to all classes of ore, as well as the one most likely to give the highest extraction. With regard to the treatment of sulphide-slime at Kalgoorlie, there is little doubt but that the double-pressing method will be the one eventually adopted.

"The method of procedure is as follows: The finely-pulverised slime is forced by means of compressed air or pumps alternately into one of two presses set above two large agitation vats (which serve to a great extent also as sumps) where the water is separated from the slime and returned to the mill or the pans as the case may be. The press being full of slime containing about 30 per cent. of moisture is now opened, and the slime is discharged into the vat below, where it is quickly disintegrated by means of agitation arms kept in continuous slow motion, and becomes thoroughly mixed with cyanide solution in the vat, causing the gold to be dissolved. From these vats the pulp, which now consists of slime and solution in about equal parts, flows into two montejus tanks, from which it is forced into a second series of four presses, where the cyanide solution is separated from the 'slime.'

"The charge is washed and dried in the press, and discharged into trucks and dumped, whilst the auriferous cyanide liquor and washes are conveyed through the zinc precipitation-boxes back to the agitation-vats, or to a small sump which is attached to the plant for washing purposes." The extra cost of "double" over "single" pressing is in filling and discharging the two first presses and separating the water, which Mr. Wilson estimated would not exceed 1*s.* a ton (two men per shift and two presses being able to deal with the moisture of 100 tons daily), whilst it presents the advantages of saving cyanide and conserving water, the recovery of which, in addition to the probable recovery of a few more grains of gold per ton, Mr. Wilson considered would soon defray this cost; in recent practice, however, single-pressing seems to have more than held its place.

Double filter-pressing as formerly applied to the treatment of Roasted Sulphide Ores is discussed in the next chapter; the plant used is substantially the same as that just described, its chief object being to wash out the soluble salts produced in roasting. The directions in which filter-press treatment seems most likely to be cheapened are by enlarging the capacity of the presses and by increasing *the thickness of the "cakes of slime"* they hold, provided that mechanical difficulties are not met with in the construction and operation of these large size presses.

Presses holding 1½ tons (having a capacity of about 10 tons of slime per diem) were used in some of the older mills, but most of the "presses" at present in use take 3 to 4½ tons of dry slime, and the limit of size so far reached successfully is stated to be 6 tons. I am informed that experiments recently carried out at Kalgoorlie have demonstrated that in place of cakes 2½ or 3 inches thick, it has been found feasible to work them up to 6 inches or even more, with satisfactory results as regards leaching. This ought therefore to reduce the time taken in filter-pressing a charge; if leaching these thicker cakes does not take proportionately longer; and at any rate, it should expedite the operation of emptying the presses, and save wear of filter-cloths, and so reduce expense, provided that mechanical difficulties are not met with in the construction and operation of these large-size presses. A correspondent of the *London Mining Journal* (October 12, 1901) said: "Filter-presses for roasted ore should be made stronger; no cake should be less than 48 inches square by 6 inches thick. By the adoption of the above, together with hydraulic pressure, the cost of filter-cloths, labour, etc., would be reduced 50 per cent. Now the largest cake on the field is 40 inches square by 3 inches thick, which is ample for oxidised slimes, necessitating an air pressure of from 60 to 80 lb., whereas the 3-inch cake for roasted slimes requires a pressure of only 10 to 15 lb."

Mr. James describes * a special filter-press used for "cleaning-up" purposes, which has plates 12 inches to 24 inches square, machined on the edges to prevent leakage of "gold slimes," by the use of which, he remarks, the clean-up is greatly simplified.

The average number of charges put through a press does not exceed ten to twelve per 24 hours, although the cycle of charging, pressing, washing and discharging may be completed in from 1 to 1¼ hour; and the discharging alone occupies about 20 minutes.

Mr. James † describes several improvements recently made in the construction of filter-presses.‡

Handling the Battery-Tailings.—To conserve the battery-tailings, owing to the general flatness of the country,§ whether they are stored or treated direct, the sands and slimes have usually

* *Cyanide Practice*, p. 33. † *Op. cit.*, pp. 73 and 163.

‡ The details and cost of a complete filter-press plant are given in the *Mining Journal*, London, November 15, 1902.

§ The slope of the ground in the Boulder Main Reef dam I am informed is 8 in 100.

to be elevated, and this is accomplished at the Great Boulder Main Reef and North Boulder mills by means of "tailings-wheels"; whilst at other plants, like the Ivanhoe, they use "tailings-pumps."

The dams are formed of banks of dry tailings, faced with "sludge," if the tailings are sandy, and are cheap to construct; but the arrrangements for settling and clarifying the water were not, as far as the Author observed, when he visited the field in 1898, generally carried to as high a pitch of perfection as in some other localities, notably Charters Towers in Queensland.

The "Tailings-Wheels" illustrated in Fig. 49, which shows the Golden Horse-shoe wheel, are mostly, I believe, constructed with

FIG. 49.—THE GOLDEN HORSE-SHOE WORKS (SHOWING TAILINGS-WHEEL).

outside buckets; the one at the Great Boulder Main Reef mill (which was, I am informed, the first to be built in Western Australia) elevates the tailings about 18 feet. The German type, with inside buckets, appears, however, to possess several features to recommend it. At the Ferreira Deep on the Rand, there is a fine double-bucket wheel, 60 feet in diameter, of which an illustration given in *Fielden's Magazine*, November 1900.

The "Tailings-Pumps," which are in common use for the same purpose, are able when necessary (as is sometimes the case) to lift the tailings to a much greater height than the tailings-wheels. They are of the usual Australian pattern, of which the pump at the Ivanhoe may be described as an example.

It is furnished, as I was informed by Mr. Hewitson, with a 12-inch plunger, with a 5- to 6-feet stroke, and lifts the battery-tailings a height of 50 feet to deliver them to the cyanide plant; it is actuated by a pinion, spur-wheel and sweep-rod, driven by rope-gear from a 16-inch by 22-inch stroke high-pressure slide-valve engine, built by Fraser and Chalmers. Indiarubber valves resting on cast-iron seating are used throughout the pump, and answer well. The pole-cases are fitted with outside packed glands, and Laidlaw's patent "water-rings." The usual stroke is 5 feet, and the speed of the plunger is 100 feet per minute. The special feature of this class of pump is the introduction of water, under extra high pressure, below the stuffing-box of the plunger-case, to prevent the sand from rising and cutting the packing to pieces, as otherwise would happen. I am not aware whether inclined Archimedean-screw centrifugal pumps have been tried for low lifts in this field, although they have been used for this purpose at Freiberg, at the New Central Dressing Works.

Air-lifts (inverted syphons) worked on the principle of the hydraulic-elevator, used in hydraulic mining, I am informed, are employed at Mount Malcolm on the Northern Gold-fields,* and there seems no reason why pumping machinery, worked on the principle of Pohlé air-lift pumps, should not be employed for work of this kind.

The Treatment of the old accumulated Heaps of Tailings.

After what has been already said, it will suffice if I describe the plant and process adopted at the North Boulder works, as an example of the method of dealing with "old-tailings," and give a few particulars of the cost and method of treatment, etc., at the Great Boulder Proprietary works.

At the North Boulder, exhaustive preliminary laboratory experiments were made locally by Mr. Robert Allen, the company's metallurgist, to whose careful work I am indebted for much information, and were carried out, not only in the ordinary way, but by treating bulk samples of 150 lb. in large-diameter pipes, of the same depth as the leaching-vats; the time of treatment lasting eight days. Extractions were thus obtained varying from 80 to 94 per cent.,† depending on the proportion of "slimes" present, whilst other experiments, made at the same time, went to prove that no

* A pump of this kind is figured in *The Mineral Industry*, vol. ix. p. 367.

† Higher extractions were got in the laboratory, owing to the slimes in the charges being more finely and evenly distributed through the samples.

advantage, but rather the reverse, resulted with this particular ore from using solutions of a greater strength than 0·3 per cent.

To quote one example: A laboratory test made on seven samples of the same composition and value (viz. assaying 9 dwt. per ton) with solutions of 0·3, 0·35, 0·4, 0·45, 0·5, 0·55, and 0·6 per cent. strength, showed that the extraction was practically the same (viz. 93 per cent.), and the residues after treatment assayed 12, 11, 10, 13, 13, 12, and 9 grains respectively; whilst on treating a duplicate sample of these tailings in bulk, with 0·4 and 0·5 per cent. solutions, the residues were practically of the same value, but the extraction was lower, averaging 80 per cent. This was probably partly due to the slimes present in the bulk samples (amounting to 13 per cent.) not being broken up, in order to imitate the conditions of treatment on a large scale; since lumps of this kind assaying 3 dwt. 8 gr. per ton before, assayed after treatment 2 dwt. 17 gr. per ton.

The presence of "slimes" *in lumps* consequently reduced the percentage of extraction, and when the total percentage of slimes (passing through a 90-mesh sieve) reached about 65 the leaching was very slow, amounting only to about ½ inch per hour.

The average percentage of 90-mesh slimes present in the coarser tailings, settled in the "dams," was found to be about 60 per cent.* (the maximum being 64 per cent.), but in no case fell below 50 per cent.; the value of the "slimes" was generally below 3 dwt. and, owing to the considerable proportion of "slime" that was present, a vacuum of 4 to 5 inches was used, to accelerate the rate of filtration at the conclusion of the treatment.

The battery-tailings banked for treatment contained about 6 per cent. of moisture, and the cyanide tailings, after treatment and draining twelve hours, generally carried 16 to 24 per cent. moisture. The cyanide consumption, as shown by tests, made by the shaking method, varied between 1·3 and 2 lb. per ton, using a 0·3 per cent. solution,† but the strength of the strong solution used was reduced afterwards in practice to 0·25 per cent.

The majority of tailings samples showed no acidity, but a small

* See footnote, p. 219, which shows the difference in the conditions in South Africa.

† Mr. H. H. Greenway, M. Inst. M.M., observes (*Trans. Inst. of Mining and Metallurgy*, vol. viii. p. 114) that, theoretically, an ideal solution of cyanide of potassium would be one that (presuming the solution to be able to contain eight parts of oxygen per million throughout the operation, always contained 0·013 per cent. KCN; but in the discussion of the paper Mr. Sulman observed that Maclaurin has pointed out that in practice a solution of ·25 to 0·3 has the highest solvent power on gold.

quantity of lime, added to the charges,* assisted precipitation of the gold in the extractor-boxes. The liquor entering the boxes was kept at a strength of not less than 0·025 per cent. KCN by bringing up the strength if necessary, previous to entering the boxes, with cyanide dissolved in the sand-settling tanks.

The salt water used had specific gravities of 1·0375 to 1·0386, the amount of solids present being 8·87 oz. per gallon. The alkalinity of the liquors, Mr. Allen informed the Author, was kept at about equivalent to 0·02 NaHO as tested by $\frac{n}{10}$ H_2SO_4 and methyl-orange.

The following sizing tests made on some specially rich tailings caught in a settling pit, which assayed 17 dwt., showed that the coarser sands carried the highest values, and a progressive decrease in value was apparent as the material became finer:—

Per cent.			oz.	dwt.	gr.
8·2	remained on a	40-mesh screen and assayed . .	1	15	22
17·6	,,	60 ,, ,, . .	1	6	14
8·6	,,	80 ,, ,, . .	0	14	11
3·0	,,	90 ,, ,, . .	0	13	0
62·6	passed a	90 ,, ,, . .	0	12	10
100·0					

To obviate the trouble caused by lumps of "slime" in a part of the coarser material dealt with, "sun-drying" was first tried; this has, I am informed, been successful in India, but, owing to the highly argillaceous nature of the ore, failed to give satisfactory results in this case.

The remedy afterwards adopted, was to "screen" † the tailings thus breaking up the lumps and aerating them, before putting them into the cyanide-vats; done on contract, this costs from 1*s.* to 1*s.* 3*d.* per cubic yard. It had an excellent effect in the way already mentioned, and also brought up the (bullion) value of the tailings from an average of between 7 and 8 dwt. as shown by assay, to between 13 and 15 dwt.

Whilst most of the old slime-heaps were too poor to pay for cyanidation, some of the tailings and "screenings," though of low average value, contained a certain proportion of fairly rich "sand,"

* With Kalgoorlie slimes that were treated by agitation and decantation, experimentally, lime, I am informed, in some cases seems to prejudicially affect their rate of settlement, although it has been found generally beneficial in South Africa.

† The screens used were ⅜-inch mesh, and it is a noteworthy fact that it was mostly "tailings" which had been crushed by the stamps that required screening; probably owing to the fact that they contained a larger percentage of "slimes" than the tailings from the Huntington mills. After screening, the sands contained still 48·4 per cent. or more of slimes.

and it was therefore found necessary to subject them to hydraulic classification, by agitating them in a rotatory mixer, and passing the sludge through a spitzkasten; an enriched product was thus obtained, between 50 and 60 per cent. of practically worthless slimes being eliminated.

About 47,444 cubic feet were dealt with in this manner, and 1079 tons of leachable sand were recovered, from some 2370 tons of tailings.

A little copper and a considerable amount of mercury were present in some of the "slimes."

The cyanide-plant (Figs. 50 and 51), which was supplied by the Cyanide Plant Supply Co., has a nominal capacity of 1200 tons a month; but allowing eight days' treatment, it is able to treat rather more, and is constructed on the most modern lines, with a view to economical handling.

It consists of eight 50-ton percolator-vats, 22 feet 6 inches by 4 feet 6 inches, built of steel, coated with protective paint, and fitted

FIG. 50.—THE NORTH BOULDER CYANIDE WORKS.

with false-bottoms and bottom-discharge doors to each vat; three sumps, 17 feet 6 inches by 6 feet; one solution-reservoir, 16 feet by 5 feet; one vacuum-tank, 6 feet by 4 feet; one Clobb belt-driven (5-inch air-cylinder) vacuum-pump; three sand settling-vats, 5 feet by 4 feet, with automatic decanters for equalising the flow of solution through boxes; three extractor-boxes; lathe, etc.

FIG. 51.—THE NORTH BOULDER CYANIDE VATS.

The vats are mounted on substantial masonry foundations (Fig. 51), supporting the wood framing and timber decking on which they stand, and wire-rope haulage was employed for raising the material from the "old tailing-dumps" to the works.

The waggons used were side-tipping, of about 16 cubic feet capacity, running on 14-lb. portable rails, and were carried across the vats on "travellers" (of lighter construction than is generally used in the field) which were designed by Mr. R. Allen.

It was found necessary, however, with this arrangement, to lower the trunnion-frames of the trucks, so as to raise their centre of gravity, otherwise one man could not discharge a 16-cubic feet truck properly. To control the tipping and ensure safety from overturning, a pair of straps was riveted to one end of the truck, through which a bent lever was passed, serving to tip it.

Trucks of larger size (20 cubic feet) seem too large for a man to handle comfortably.

A 4-B.H.P. engine and 6-N.H.P. return-tube steel boiler are used for running the pumps and zinc lathe, and a separate air-winch was used for haulage.

The operation of the plant presents no special features calling for remark, except that it was found preferable to bring the solutions up to their proper strength in the sumps by adding a weighed quantity of cyanide cake in an iron bird-cage, rather than by using a special dissolving-tank, as the storing of strong solutions appears to account for an avoidable loss. The cyanide is dissolved rapidly by allowing the stream from the pump to impinge on it. The precipitation of the magnesium hydrate by the caustic alkali of the commercial cyanide in the liquor apparently causes no trouble, the bulk of it being pumped on to the vats, and left in the sands.

As the foot-valves in the sumps did not always hold, and the priming of the centrifugal pumps was thereby apt to be lost, solid bottom-plug cocks packed at the top by a gland were substituted for patent valves, and, properly lubricated with black-lead and oil, gave more satisfaction; as they were found not to leak, so long as they were turned in one direction, to avoid the formation of quadrant grooves.

The rubber seatings of the discharge doors of the tanks were kept in good condition with grease, applied previous to re-closing them.

Up to the end of June 1899, 4634 tons were cyanided in these works, yielding 2802·28 oz. of bullion, and an extraction of 12 dwt. 2 gr. per ton, and the residues assayed 1½ to 2 dwt. Some of the vat-residues were higher than they would otherwise have been, owing to the presence of some fairly coarse gold, or sand not reduced fine enough for the gold to be quickly attacked by the solution; but the actual extraction, as shown by the bullion recovered, was better than the theoretical extraction indicated by preliminary assays; as, owing to the presence of free mercury and amalgam in the tailings, it was most difficult to get fair representative samples.

The consumption of cyanide varied during this period from 1·75 to 1·50 lb., and the cyanide bullion ranged from 850 to 880 fine.* In the following six months (to December 1899) 7470 tons were cyanided, giving a bullion return of 5291 oz. 15 dwt., representing an average of 14 dwt. 4 gr. extracted per ton; the residues assayed from 1·67 dwt. to 2 dwt.,† and the extractions ranged from 84·38 to 87·8 per cent., whilst the cyanide consumption was reduced to 1·361 lb. per ton, and even as low as 1·23 lb. The costs in detail were as follows:—

* On the average about 855.

† Mr. Geo. Robson, M. Inst. M.M., remarks, "On this field it has hitherto been considered very good work to reduce amalgamated battery sands to as low as 3 dwt. per ton by cyaniding."—*Report*, Hannan's Star Gold Mines, 1899, p 17.

Tons cyanided 1899, 12,104.

	s.	d.	Per cent.
Labour—			
Attendance and supervision	1	6·02	
Filling and emptying	1	7·45	50·98
Hauling and pumping	0	8·82	
Screening and carting	1	0·06	13·29
Water	0	1·97	2·17
Cyanide	1	8·64	32·52
Supplies, etc.	0	8·89	
General charges	0	0·41	1·03
Repairs	0	0·53	
	7	6·79	99·99

Estimating that the above 12,104 tons cyanided in 1899 represented about 50 per cent.* of the original battery-tailings; eliminating the valueless "slimes" reduced the cost of cyanidation to about 3*s.* 9·39*d.* per ton of ore crushed; and reckoning that the average grade of the whole of the ore crushed was about 1 oz. 7 dwt. 10 gr., the bullion extraction by milling and cyanide, etc., viz. 1 oz. 4 dwt. 22 gr. (including, say 2·5 dwt. (estimated) recovered from concentrates) † may be calculated to represent approximately 91 per cent. of the total bullion contents of the ore recovered, of which cyanide should be credited with recovering 6 dwt. 16 gr., or about 26·7 per cent. The loss was chiefly in "battery slimes" which were eliminated, and were too poor to treat at a profit on a small scale, assaying about 3 dwt. only. The subsequent results in 1899–1900, on sands separated by screening and hydraulic separation, the plant being worked intermittently, are shown in the table below:—

1896 tons cyanided.

	Total Cost. £	s.	d.	Cost per Ton. s.	d.
Supervision and attending solution	283	7	4	2	11·87
Filling and discharging vats, and extra labour	205	5	6	2	1·98
Classifying sands	43	0	3	0	5·45
Hauling and pumping	83	5	0	0	10·54
Cyanide	150	1	8	1	6·99
Zinc	11	2	5	0	1·40
Lime	21	1	7	0	2·67
Assaying and smelting material	44	18	7	0	5·69
Water	15	7	6	0	1·94
Lighting and lubricants	2	8	4	0	0·37
General repairs	5	3	9	0	0·66
General charges	10	8	9	0	1·32
	876	0	8	9	2·88

* This is very close to the actual fact, as the 14,000 tons cyanided were the product 27,874 tons milled.

† Excluding this gold the local mill extraction would appear slightly lower, as the percentage of extraction by smelting is over 91 per cent.

The 1896 tons of sands separated by "screening" and hydraulic-classification, and cyanided in 1899 to 1900 gave a bullion return of 1205·112 oz. = 12·7 dwt. per ton, and the bullion was 774 fine; they still contained 50·7 per cent. of 90-mesh slimes.

The average assay value of these tailings (sands) was 10·48 dwt. (fine gold), and the residues assayed 1·64 dwt., corresponding with a theoretical extraction of 86·4 per cent. 18,553 tons (224 gallons each) of liquor were used in the treatment of about 14,000 tons of "sands" cyanided in 1899 and 1900, which, on the average, returned 13 dwt. 7 gr. per ton in bullion. This quantity of liquor was precipitated with 4278 lb. of zinc, the bullion precipitated amounted to 9306·062 oz., and represented 7685·271 oz. of fine gold. The yield of bullion from the zinc-slime was between 55 and 65 per cent., and sulphuric-acid treatment was employed for the "gold-slimes," using a barrel provided with a hood to carry off the fumes.

The staff of the works consisted of one manager, acting as chemist, one foreman, two assistants, and one engine-driver.

The "green-tailings" going direct from the battery to the cyanide plant can now be separated into worthless slimes and "sands," by passing them at once through spitzkasten, instead of "settling" the "sands" in tanks excavated in the ground, as was formerly done.

At the Great Boulder, the cost of treatment in 1899 (dealing with 23,707 tons, which returned 10,193 oz. of bullion, of a fineness of ·850) came to 11*s.* 9*d.* per ton, which may be itemised as follows:—

TAILINGS-TREATMENT COST IN 1899.

Great Boulder Proprietary.	Total Cost. £	s.	d.	Cost per Ton. s.	d.
Wages	6,195	7	6	5	2·72
Stores	4,885	1	3	4	1·45
Trucking	1,308	13	6	1	1·25
Firewood and fuel	599	18	5	0	6·07
Condensed water	262	19	2	0	2·66
Proportion compressed air	496	2	5	0	5·06
,, stable expenses	88	7	10	0	0·89
Lime	89	10	1	0	0·90
Smelting expenses	20	14	0	0	0·21
	13,946	14	2	11	9·21

The consumption of cyanide came to 2·2 lb. per ton, and the average loss of gold in residues amounted to 39 gr., i.e. 1·62 dwt. per ton.

In 1900 the cost of treating 93,726 tons, which returned 46,748 oz. 10 dwt. 14 gr. of bullion, came to 9*s.* 2*d.*, itemised as follows:—

TAILINGS-TREATMENT COST IN 1900.

Great Boulder Proprietary.		Total Cost.	Cost per Ton.
		£ s. d.	s. d.
Wages and salaries		17,299 12 6	3 8·29
Stores		15,184 19 6	3 2·88
Contract trucking-in		5,131 13 4	1 1·14
Cable-way expenses (4 months)		572 8 3	0 1·46
Firewood		1,647 17 8	0 4·22
Condensed water		1,248 8 4	0 3·19
Compressed air		769 3 5	0 1·97
	£ s. d.		
Assays	352 0 1		
Bricks	6 2 5		
Timber	94 6 11	893 17 6	0 2·29
Stable, etc.	441 8 1		
Fuel		162 13 3	0 0·41
Lime		161 8 8	0 0·41
		43,072 2 5	9 2·26

The consumption of cyanide came to 2·35 lb. per ton of tailings, and the average loss of gold in the residues amounted to 1·78 dwt. per ton.

The Direct Treatment of Battery Tailings.

At the Lake View, the "battery-tailings," which, I am informed, contained as much as 80 per cent. of slime,* passed to a spitzkasten; the sands discharged from which were elevated by a tailings-wheel to a set of six collecting-tanks (Fig. 52), fitted with Butters and Mein's "distributors," carrying eight or more hollow radial arms, rotating in a horizontal plane above the tank on a central spindle. The stream of tailings delivered to these "distributors," falling into a cup-shaped receptacle, flows from the centre along the arms, and issuing at their ends (which are bent),

* The percentage of slime now produced is said to be 85 per cent. S. J. Truscott, A.R.S.M., *Mining Journal*, London, October 18, 1902.

causes them to rotate. The arms being of varying lengths (alternately long and short), the pulp is distributed evenly over the tank. The heavier sands, which fall to the bottom, still contained

FIG. 52.—THE LAKE VIEW CONSOLS CYANIDE PLANT (SHOWING VATS WITH BUTTERS AND MEIN'S DISTRIBUTORS).

at Lake View, 40 to 50 per cent. of 100-mesh slime, and the lighter slimes escaped through openings at the side, which are closed by slats as the level of the contents of the tank rises.

The sands thus settled and collected were trucked to a set of 16 leaching-vats, erected under cover, with the necessary solution-tanks, in a separate building, at a lower level, where they underwent, according to Mr. H. F. Bulman, about ten days' treatment, and the gold was precipitated on zinc shavings in the extractor-house. The precipitation-boxes contain a depth of about 16 inches of zinc, and are divided by transverse partitions into some ten consecutive compartments.

The results of this treatment are shown in the table on p. 275.

The "slimes" from the distributors, together with the "slimes" overflowing from the spitzkasten, were settled in "settling-tanks," and forced by a couple of "montejus" pressure-tanks, working under a pressure of 70 to 80 lb. per square inch, by compressed air, supplied by a 4-drill compressor, into ten * Dehne filter-presses

* Four additional presses were erected in 1899 for the treatment of sulphide-slimes, and the works were equipped (at the end of 1901) with twenty-two presses altogether.

with frames ranging from 2·5 to 3 inches in width. The cyanide leaching-solution was pumped through the cakes of slime, which were subsequently washed with water, two Excelsior (gravitation) filters being used to clear the liquors before they passed to the

LAKE VIEW CONSOLS. SANDS CYANIDED.

—	1898.	1899.	1900.
Tons treated	36,182	44,323	10,867
Bullion won oz.	29,209·475	23,628·650	4,577·912
Fine gold	26,505·090	21,030·593	4,080·697
Standard gold	28,914·639	22,942·467	4,451·424
Fine silver	1,720·740	982·340	180·97
Yield per ton, oz.	0·807	0·533	0·421
	£ s. d.	£ s. d.	£ s. d.
Total value	112,439 11 11	89,107 10 7	17,289 13 8
Value per ton	3 2 1·82	2 0 2·4	1 11 9·8
" oz.	3 16 11·60	3 15 5·07	3 15 6·4
Cost per oz.	0 8 2·72	0 11 1·6	0 17 0·8
	Cost per Ton	Cost per Ton.	Cost per Ton.
	s. d.	s. d.	s. d.
Superintendence and attending solution	0 5·153	0 5·858	1 1·109
Filling and emptying vats	2 0·859	1 10·629	1 9·641
General repairs	0 2·423	0 1·511	0 3·419
Assaying, retorting and melting	0 1·776	0 2·236	0 3·735
Zinc	0 0·5·5	0 0·941	0 1·896
" turning	0 0·830	..	0 0·772
Fuel	0 3·103	0 0·394	0 5·104
Water	0 1·376	0 1·004	0 2·894
Lime	0 3·516	0 1·604	0 1·486
Cyanide of potassium	1 11·881	1 7·166	1 11·665
General stores and charges	0 0·797	0 1·636	0 1·230
Electric light	0 1·324	0 1·179	0 2·337
Compressed air	0 0·939	0 7·841	..
Sulphuric acid	..	..	0 0·849
Realisation charges	0 9·167	0 5·246	0 4·163
Total	6 7·699	5 11·245	7 2·300

precipitation-boxes. The process, Mr. Bulman states, occupied about four hours; this part of the plant was capable of treating some 4000 tons of slime a month, at a cost of treatment varying from 7*s*. 5·866*d*. to 15*s*. 1·394*d*. The results are shown in the table overleaf.

SLIME TREATMENT.

Lake View Consols.	1898.	1899.	1900.	1901.	
Tons treated	7,423	35,136	35,919	15,733	
Bullion produced, oz.	2,794·070	11,665·375	12,662·802	6,793·275	
Fine gold do.	2,252·300	9,825·932	11,317·855	6,074·233	
Standard gold do.	2,457·053	10,719·196	12,346·750	6,626·435	
Fine silver do.	143·490	462·790	539·33	430·390	
Yield per ton, oz.	0·376 : 0·600	0·332	0·352	0·432	
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	
Value	9,549 5 9	41,616 5 6	47,936 10 9	25,795 10 0	
„ per ton	1 5 8·74	1 3 8·2	1 6 8·2	1 12 9·5	
„ per oz.	3 8 4·25	3 11 4·2	3 15 8·5	3 15 11·6	
Cost per oz.	1 8 5·22	1 2 6·6	1 18 0·6	1 15 0·1	
—	Cost per Ton.	Cost per Ton.	Cost per Ton.	Gross Cost.	Cost per Ton.
	s. d.	s. d.	s. d.	£ s. d.	s. d.
Superintendence and attending solution	1 0·967	0 6·614	0 5·939	403 11 10	0 6·156
Discharging presses	5 0·856	3 0·931	3 3·244	2,821 18 5	3 7·047
Compressed air	0 8·071	0 10·123	0 6·297	1,304 18 3	1 7·905
Zinc	0·466 } 0 0·948	0 1·147	0 1·450	127 10 6	0 1·945
Turning zinc	0·482		0 0·628	46 3 9	0 0·705
General repairs	0 4·025	0 4·148	0 7·325	603 3 10	0 9·201
Assaying, retorting and melting	0 8·160	0 4·193	0 6·870	424 1 3	0 6·469
Fuel	0 0·302	0 0·521	0 5·441	251 15 7	0 3·841
Sulphuric acid	..	..	0 0·731	..	..
Filter cloth	0 5·478	0 2·240	0 3·784	134 15 0	0 2·056
Cyanide of potassium	1 6·586	1 1·896	2 1·883	1,702 3 9	2 1·966
General stores and charges	0 1·952	0 2·492	0 1·548	96 0 6	0 1·468
Electric light maintenance	0 3·237	0 2·815	0 4·145	303 2 11	0 4·624
Water	..	..	0 0·805	112 10 8	0 1·716
Realisation charges	0 3·870	0 3·201	0 3·426	..	..
Breaking down old slime	..	0 1·545	3 10·977	3,221 11 5	*4 1·144
Agitation	..	..	0 0·474	263 13 6	0 4·022
Lime (chemical)	..	..	0 0·024	74 1 1	†0 1·129
	10 8·452	7 5·866	13 4·991	11,891 2 3	15 1·394

* Includes hauling. † Chemicals.

At the Ivanhoe plant,* the general arrangement of which is shown in Fig. 53, the battery-tailings were first lifted by two 12-inch tailings-pumps to a "hydraulic classifier," that served to separate the *coarsest* "sands," which were delivered to four grinding and amalgamating pans. After grinding and amalgamating, the tailings that were continuously discharged from the pans, were re-elevated to the hydraulic classifier; the overflowing pulp from which (carrying medium and fine sands and slimes), went to the cyanide-vats, whilst any coarse sands re-discharged were returned to the pans to be re-ground. The cyanide plant shown in Fig. 53, which was originally designed to handle the product of 60 stamps, was arranged somewhat on the same lines as at some of the works in S. Africa, where "the direct-filling process" is employed, and consisted of sixteen 80-ton vats in two tiers, set directly above one another; each tier contained two rows of four vats, 21 feet in diameter and 6 feet 6 inches deep; the top ones being 5 feet below the bottom ones, which were 22 feet in diameter and 6 feet 6 inches deep. The upper series were provided with Butters and Mein's distributors, and were used both as settling and "leaching-tanks" for the *medium* and fine *size* "sands" discharged from the hydraulic classifier; whilst the "slimes," which overflowed from the "tanks" through adjustable sluice-gates (representing, it is said, some 40 per cent. of the battery-tailings), as they contained a small percentage of fine sands, went to a spitzkasten, which eliminated as an under-flow whatever "sands" escaped the collecting-vats (to which they were pumped back); whilst the overflowing slimes passed to the slimes-plant.

The medium and fine sands, after the top-vats had been filled to the required depth, were drained fairly dry and leached for four days in the upper series of vats, then dropped through bottom-discharge doors to the lower series, again leached for four days, and were finally dumped through bottom doors into trucks underneath, and trucked to the mine for "filling."

It is claimed for this "double treatment" that it shortened the time of leaching from 10 to 8 days, the tailings being oxygenated and loosened in passing from one set of vats to the other.

The solution leaving the vats ran by a separate pipe from each vat to distributing launders, which delivered it to a double set of zinc-boxes built of kauri pine, each 20 feet long by 2½ feet

* The plant has been enlarged, on much the same lines, since the erection of forty new stamps, as described in the next chapter.

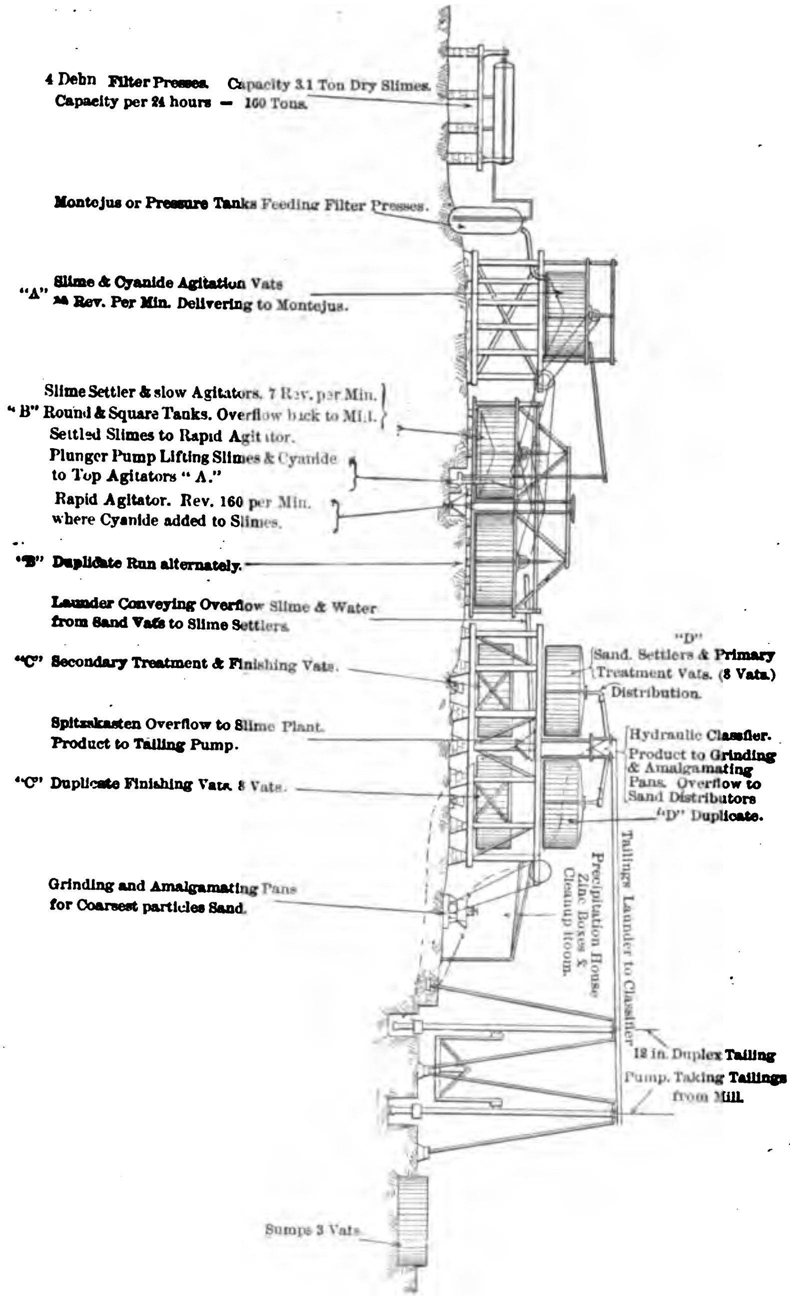


Fig. 53.—The Ivanhoe Treatment Plant (Elevation).

wide by 2½ feet deep. Mr. Bulman states that in October 1898, 120 to 140 tons of sands were being treated daily in this plant, with a staff of 13 men; and its average capacity, Mr. Hewitson informed the Author in 1900, was reckoned to be about 120 tons per diem.

The average cost of the "sands" treatment may be estimated at about 5*s.* 4*d.* per ton, including grinding and amalgamating the coarse sands in pans. The actual costs in 1899 and 1900 are set out in detail below:—

1899.

Sands cyanided, 37,369 tons.
Bullion produced, 21,795 oz. 16 dwt.
Cost per oz., 9*s.* 0·505*d.*

	Cost per Ton. *s.*	*d.*
Superintendence	0	6·287
Engine-driving	0	2·599
Filling and emptying vats	1	7·309
Removal of old tailings	0	5·254
Zinc	0	0·462
Cutting zinc	0	0·332
Cyanide of potassium	1	1·737
Lime	0	2·011
Fuel	0	5·139
Stores	0	1·785
Repairs and renewals	0	3·846
Smelting	0	0·141
Salt water	0	0·166
Condensed water	0	2·219
Total	5	3·287

1900.

Sands cyanided, 41,481 tons.
Bullion produced, 18,483 oz. 10 dwt.
Cost per oz., 12*s.* 3·380*d.*

	Total Cost. £	*s.*	*d.*	Cost per Ton. *s.*	*d.*
Superintendence	647	9	9	0	3·746
Engine-driving	386	12	5	0	2·237
Filling and emptying vats	3,211	13	9	1	6·582
Removal of old tailings	859	9	5	0	4·973
Zinc	116	2	3	0	0·672
Cutting zinc	48	2	6	0	0·278
Cyanide of potassium	2,971	19	4	1	5·195
Lime	331	18	0	0	1·920
Fuel	901	18	11	0	5·219
Stores	201	14	1	0	1·167
Repairs and renewals	1,205	11	7	0	6·975
Smelting	72	0	5	0	0·417
Condensed water	395	17	0	0	2·290
Total	11,350	9	5	5	5·671

The Slimes-Plant.—The slimes and water from the second spitzkasten, which received the discharge from the Butters distributors, were run to a series of five slime-settlers, fitted with agitator-paddles, to get rid of some of the excess water, the water after the slimes had settled being run off; the thickened pulp (of about a consistence of one part slime to one of water) was then delivered to a mixer fitted with a propeller-shaped agitator, where a stream of KCy liquor was delivered simultaneously with it. The cyanide pulp was then pumped up by an 8-inch plunger-pump to one of six agitators (20 feet in diameter and 10 feet deep), where it was agitated with cyanide solution till the gold was dissolved, the length of agitation being about eight hours. The slime and solution were then forced by one of two montejus, under a pressure of about 45 lb. per square inch, into filter-presses of Dehne pattern.

There were four of these presses of the frame-type, with fifty chambers in each, 40 inches square, forming cakes of slime two inches thick. The slime thus collected, after leaching with solution, was washed with spent liquors whilst in the press, to displace any remaining gold solution, and this was again pumped through a smaller Johnston's filter-press, containing forty chambers 24 inches square, to clarify it before it passed to the precipitation department. The zinc-boxes consisted of a double set, each being 20 feet long, 3¾ feet wide by 2¼ feet deep. The cakes in the filter-presses, after the gold had been dissolved out, contained about 16 per cent. of moisture (spent solution or water), and were discharged into V-shaped side-tipping trucks, running underneath the presses, and were trucked to the waste dump.

The capacity of the slimes-plant was about 200 tons per diem, and the extraction of gold, I am informed, ranged from 80 to 90 per cent. of the contents. The actual costs in 1899 and 1900 are set out in detail in the table opposite.

For cleaning up, sulphuric acid was used, and the gold was collected in a small clean-up "filter-press."

The "gold-slimes" were melted in a tilting-furnace, in salamander retorts, 36 inches high by 23 inches in diameter, with a capacity of about 450 lb. weight of "gold-slimes," and the whole clean-up (usually over 3000 oz.) was melted and run into "bars," in about four hours.

1899.

Slimes cyanided, 31,685 tons.
Bullion produced, 11,438 oz. 15 dwt. 12 gr.
Cost per oz., 17*s.* 4·383*d.*

	Cost per Ton.	
	s.	*d.*
Labour	1	7·835
Trucking	0	10·916
Engine-driving	0	2·547
Compressed air	0	3·841
Smelting	0	0·165
Renewals and repairs	0	2·634
Cyanide of potassium	1	3·332
Lime	0	2·001
Zinc	0	0·639
Turning zinc	0	0·368
Fuel	0	5·384
Filter-cloth	0	0·634
General stores	0	1·876
Condensed water	0	2·191
Removal of old slimes	0	5·526
Salt water	0	1·340
Total	6	3·229

1900.

Slimes cyanided, 47,489 tons.
Bullion produced, 16,317 oz. 12 dwt. 12 gr.
Cost per oz., 18*s.* 2·678*d.*

	Total Cost.			Cost per Ton.	
	£	*s.*	*d.*	*s.*	*d.*
Labour	3,670	10	3	1	6·550
Trucking	1,995	15	9	0	10·086
Engine-driving	396	18	1	0	2·006
Compressed air	761	18	1	0	3·851
Smelting	83	11	4	0	0·422
Renewals and repairs	917	6	8	0	4·636
Cyanide of potassium	3,564	17	6	1	6·016
Lime	360	5	0	0	1·821
Zinc	118	1	0	0	0·596
Turning zinc	48	2	9	0	0·243
Fuel	901	18	11	0	4·558
Filter-cloth	214	0	6	0	1·082
General stores	232	6	5	0	1·174
Condensed water	395	17	0	0	2·001
Removal of old slimes	831	16	4	0	4·204
Salt water	374	14	3	0	1·894
Total	14,867	19	10	6	3·140

The extraction, calculated on the "fine gold" recovered by the Ivanhoe process, is estimated as follows:—

—	Average Extraction of Fine Gold per Ton.					
	1898.		1899.		1900.	
	dwt.	%	dwt.	%	dwt.	%
By battery amalgamation	27·7916	64·8	22·7825	66·35	16·7384	58·85
,, concentrates treated (and sulphides in 1900) . . .	..	..	0·7123	2·07	1·7739	6·24
,, cyanide treatment .	7·7084	18·0	Sands 4·7566	13·85	4·0794	14·34
			Slimes 2·9081	8·46	3·4755	12·22
Total extraction .	35·5000	82·8	31·1595	90·73	26·0672	91·65

Total recovery—
1898. Bullion 50,660 oz. 15 dwt.
1899. ,, 104,009 oz. 2 dwt.
1900. ,, 107,050 oz. 19 dwt.

Of the gold (fine) unrecovered in 1899, 3·0412 dwt. per ton or 8·85 per cent. was calculated as remaining in the residues, and 0·1342 dwt. per ton or 0·38 per cent. in solutions and zinc-boxes; total 9·23 per cent. The gold unrecovered in 1900 was estimated at 2·3748 dwt. per ton or 8·35 per cent.

Mr. J. K. Wilson states* that this method of treatment gives good results, and the only exception that can be taken to it is the treatment of the "slime," which should be "double" instead of "single-pressed." He adds that the slime as it comes from the mill, though partially settled, is about half water, whilst that leaving the presses contains only 30 per cent.; as a result, the liquors accumulated to the extent of about 70 per cent., and had to be run to waste, causing a loss.

At the Great Boulder Perseverance, the accumulated "slimes," being too fine to treat by "percolation," were treated by agitation in vats and filter-pressed; the capacity of the plant is reckoned at about 80 tons a day, and slimes that will yield 4 to 5 dwt. are stated to have been thus dealt with.

The Golden Horse-shoe.—After grinding and passing through the "settlers," the pan-pulp from the stamp-battery is classified in these works (Figs. 54 and 55) in a spitzkasten (No. 1) with the

* *Mineral Industry*, vol. ix. p. 781.

"underflow" so controlled, as to yield a slimes "overflow" and a sand "underflow" in proper proportions. The sands thus separated are elevated by a 42-feet diameter tailings-wheel, and pass into collecting vats, fitted with Butters' distributors.

The slimes from these vats, together with the slimes from No. 1 spitzkasten, go to a second spitzkasten (No. 2) which eliminates (as an "underflow") any fine sands that may have escaped No. 1.

These sands pass back to the tailings-wheel, where they are mixed with the others. The slimes "overflow" from No. 2 spitzkasten is distributed over 16 canvas strakes, 31 feet long and 20½ inches wide, which eliminate a small quantity of very fine concentrates.

These, with the concentrates from the canvas tables, below the battery, pass through launders to a sump, and, by means of a tail-

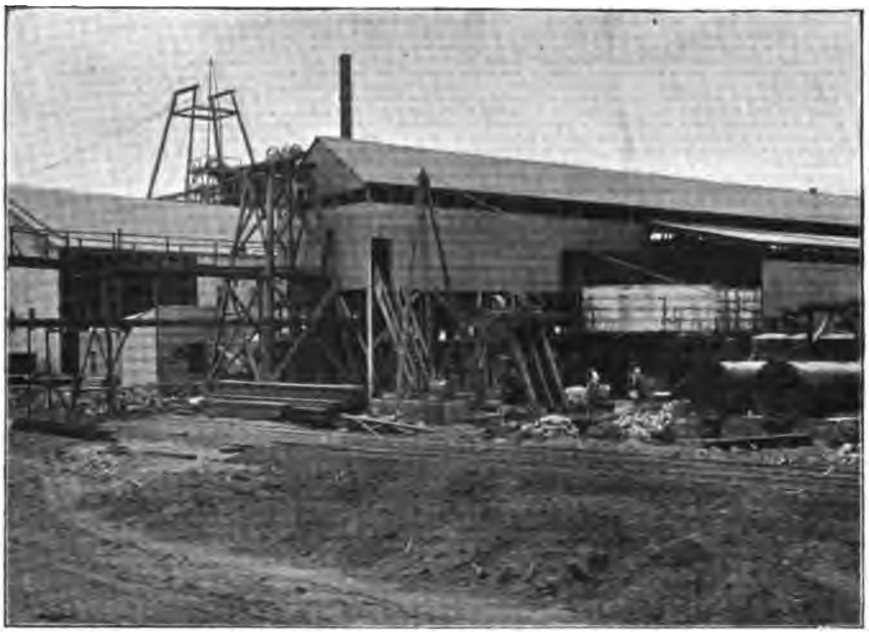


FIG. 54.—GOLDEN HORSE-SHOE CYANIDE PLANT.

ings pump, are raised to a bin at the railway siding, for shipment to Fremantle, where they are smelted.

The collecting-vats, in which "the sands" are first treated with cyanide, are 20 feet in diameter and 7 feet deep, and each contains a 74-ton charge (net) of sands.

FIG. 55.—GOLDEN HORSE-SHOE SLIMES PLANT.

The treatment of the sands is completed in a second similar-size set of vats, below; the usual time of treatment of each charge being between 7 and 10 days.

A sizing analysis of the sands given by Mr. Robert Allen * shows :—

Remaining on a 50-mesh screen	. .	24·7 per cent.
,, 100 ,,	. .	31·4 ,,
Passing through 100 ,,	. .	43·9 ,,

The slimes escaping from the second set of "canvas tables" go to a slimes-sump, from which they are raised by two plunger-pumps † and forced through nine Dehne filter-presses of 4 tons capacity, each holding fifty 3-inch cakes, three presses being usually filled at a time; there are, it may be added, three montejus

* *Op. cit.*

† Mr. Alfred James states that there is reason to believe that pumps are more economical for filtering presses than the montejus, *Cyanide Practice*, 3rd edition (3p) 24.

available for use should the filter-press capacity of the plant be increased.

The slimes, which will all pass a 150-mesh sieve, are not agitated, but leached with cyanide solution in the filter-presses, and the gold solution is clarified by passing it through three Excelsior filter-presses, from which it runs through four slimes zinc extractor-boxes.

The clear water leaving the presses is conducted to large surface condensers,* and used for breaking down steam coming from the engines, air-compressors, pumps, etc.

The zinc-sludge from the sands and slimes treatment is treated by the sulphuric-acid method, and a "tilting furnace" is employed to smelt the gold-slimes.

CYANIDE (VAT) TREATMENT OF SANDS, 1900.

Tons treated	33,418
Bullion produced, oz.	24,613·025
Fine gold	18,941·247
Standard gold	20,633·265
Value	£80,499 19 2
Yield per ton (bullion) oz.	·736
Value per ton	£2 8 2·160
Value per oz.	3 5 4·800
Cost per oz.	0 8 4·560

	Gross cost. £	s.	d.	Cost per ton. s.	d.
Superintendence, etc.	188	5	0	0	1·352
Solutionists, pumping, etc.	1,129	13	1	0	8·113
Filling and emptying vats	2,152	18	3	1	3·462
Engine-driving, firing, etc.	266	2	3	0	1·911
Turning zinc	131	13	3	0	0·945
Assaying, retorting and melting	587	17	10	0	4·222
Repairs and extension of tramways	354	11	9	0	2·547
Zinc	160	7	3	0	1·152
Fuel	208	8	4	0	1·497
Water (salt)	246	13	6	0	1·771
,, (fresh)	180	8	11	0	1·296
Lime	42	6	11	0	0·304
Cyanide	2,483	13	1	1	5·837
Electric light	133	19	7	0	0·962
General maintenance	872	6	9	0	6·265
Classification	†47	14	9	0	0·343
Grinding slimes	‡140	14	9	0	1·011
Re-handling sands	§50	1	17	0	0·359
Realisation charges (including insurance)	957	5	4	0	6·875
	10,335	2	6	6	2·224

* An excellent illustration of the surface condensers at Lake View Consols is given in the 1901 *Report* of the Department of Mines of Western Australia.

† Five months only. ‡ Six months only. § Two months only.

CYANIDE (FILTER-PRESS) TREATMENT OF SLIMES, 1900.

(8 months.)

Tons treated	25,929
Bullion produced, oz.	13,159·000
Fine gold	10,308·199
Standard gold	11,245·206
Value	£43,811 8 2
Yield per ton (bullion), oz.	·507
Value per ton	£1 13 9·360
Value per oz.	3 6 6·960
Cost per oz.	1 0 0·960

	Gross cost. £	s.	d.	Cost per ton. s.	d.
Superintendence and preparing solutions	738	9	9	0	6·835
Mechanics and helpers	514	5	1	0	4·760
Discharging presses	1,574	13	5	1	2·575
Handling residues, etc.	1,134	12	0	0	10·502
Turning zinc	67	18	7	0	0·629
Assays and melting	408	15	0	0	3·783
Cyanide	2,600	19	5	2	0·075
Filter-cloths	417	19	2	0	3·869
Zinc	112	15	2	0	1·044
Fuel	1,128	16	9	0	10·449
Salt water	486	9	8	0	4·503
Maintenance and repairs	1,310	2	5	1	0·126
Compressed air	†569	16	2	0	5·274
Electric light	272	3	9	0	2·519
Fresh water	†843	18	11	0	7·811
Classification	*113	4	0	0	1·048
Grinding slimes	†427	0	9	0	3·953
Realisation charges	494	7	7	0	4·576
	13,216	7	7	10	2·331

In the early days of the Fields, it appears from a statement in the *Australian Mail*,‡ that it cost the Lake View nearly 40*s*. a ton to treat its ore in June 1896; and in September 1897, it was still costing in its old mill 21*s*. 8·141*d*.§ a ton; whilst even at the Great Boulder, the average cost of battery treatment was, I believe, 21*s*. 7*d*. in 1896, but it came down to 10*s*. 8*d*. in 1897.

The foregoing particulars therefore show that a great decrease took place in the following four years, in the cost of treating the oxidised ores of this field, which no doubt would have been carried

* Only six months. † Only seven months. ‡ June 16, 1898.

§ It fell, however, to 14*s*. 6·848*d*. in October 1897, and to 8*s*. 6·754*d*. in January 1898, in the new battery.

further, had the supply of stone of this class not become practically speaking exhausted in most of the older mines.

Value and Fineness of the Gold.—Baron Oldruitenborgh has pointed out that the value of West Australian gold varies within broad limits. Gold produced from quartz veins, which is, as a rule, more or less argentiferous, is worth from 3*l.* 8*s.* to 4*l.* 2*s.* per oz., whilst the gold obtained from the "formations" has a value of 3*l.* 18*s.* to 4*l.* 4*s.* per oz. The Author does not know, however, of any actual case where it exceeded 4*l.* 2*s.* 5·7*d.* Mr. Wm. Frecheville estimated the average value of Kalgoorlie reef-gold as being a little over 4*l.* per oz., but this was some years ago; the average is now very much lower, the bullion produced varying considerably in "fineness," depending largely on the method employed in its extraction and refining.* The average value of West Australian bullion was reckoned at 3*l.* 17*s.* 1½*d.* per oz. in 1899, 3*l.* 14*s.* 9¾*d.* in 1900, and 3*l.* 12*s.* 11½*d.* in 1901. Mr. Wm. Frecheville gave the figures for Ballarat and Bendigo (Victoria) as 4*l.* per oz., and for Charters Towers (Queensland) as 3*l.* 6*s.* per oz. in 1896.

The Great Boulder mill-bullion was 970 fine (worth 4*l.* 2*s.* 4·87*d.* per oz.) in 1898; and 967 (worth 4*l.* 2*s.* 1·81*d.* per oz.) in 1899; whilst the cyanide bullion in 1899 was only 850 fine (worth 3*l.* 12*s.* 2·53*d.* per oz.). In 1900 the sulphide-mill bullion was 886 fine; and in 1901, the bullion recovered from sulphide ore by amalgamation was 848 fine, and by cyanide 719 fine.

The Lake View Consols mill-bullion was valued at 4*l.* 2*s.* 2·44*d.*; the cyanide bullion from "sands" at 3*l.* 16*s.* 11·60*d.*; and from "slimes" at 3*l.* 8*s.* 4·25*d.* per oz. in 1897–1898. In 1900–1901 the roasting-process yielded bullion worth 3*l.* 13*s.* 7·2*d.*; and by the Diehl process 3*l.* 15*s.* 0·6*d.* per oz.; and in the six months ending February 1902, 3*l.* 12*s.* 0·80*d.* and 3*l.* 11*s.* 2·91*d.* respectively.

The North Boulder mill-bullion was worth 4*l.* 2*s.* 5·7*d.* in 1898, and the cyanide bullion in 1899 mostly varied from 855 (worth 3*l.* 12*s.* 7·63*d.* per oz.) to 860 fine (worth 3*l.* 13*s.* 0·73*d.* per oz.), although it was occasionally as high as 880 fine.

The Oroya Company's mill-bullion for the six months ending March 31, 1900, was reckoned at 3*l.* 16*s.* 7*d.* net.

The Associated bullion obtained in 1899–1900 from the treat-

* The value is more or less liable to fluctuate from year to year, depending upon the relative proportions of mill and cyanide bullion produced, changes in the fineness of the gold in individual mines, and variations in the relative output of different properties and districts.

ment of sulphide ore was valued at 3*l.* 16*s.* 7*d.** ; and for the year ending March 1901, its average value (mostly from the treatment of sulphide ore) is given as having been 3*l.* 14*s.* 11·2*d.* It rose to 3*l.* 16*s.* 8·3*d.* in the year ending March 31, 1902.

I am informed that in some of the mines with depth there is a notable increase in silver in the bullion, some of it containing as much as 20 per cent.

In 1899 assays were made in the Government laboratory of carefully picked and cleaned metal from various districts, the results of which are given in the following table, excerpt from the Annual Progress Report of the Geological Survey, 1899:—

COMPOSITION OF WEST AUSTRALIAN NATIVE GOLD.

Locality.	Description of Sample.	Specific Gravity.	Gold.	Silver.	Copper and Iron.
1. Hall's Creek, Kimberley	Small alluvial nuggets	16·62	933·0	66·0	1·0
2. " "	3 oz. alluvial nugget carrying quartz	16·80	883·9	116·1	..
3. Shark's Gully, Pilbarra	"Bobby Dazzler" nugget, 480 oz.	14·66	768·1	230·4	1·5
4. Talga Talga, Pilbarra	Gold from quartz boulders	16·20	844·6	155·4	..
5. Nullagine, Pilbarra	" conglomerate bed	..	912·1	87·9	..
6. Bamboo Creek, Pilbarra	" quartz reef	..	940·0	60·0	..
7. Towranna, Pilbarra	" "	..	945·3	54·7	..
8. Peak Hill, Peak Hill	" "	17·16	965·4	34·6	..
9. Nannine, Murchison	Coarse gold from quartz reef	15·75	894·5	105·0	0·5
10. Boulder, East Coolgardie	Sponge-gold from lode stuff	..	999·1	0·9	..
11. Block 50, Hampton Plains	Coarse gold from ironstone pebbles	18·91	994·6	6·4	..
12. Red Hill, Coolgardie	Crystalline gold from calcite vein	18·00	933·1	67·2	0·7

"Where no figures are shown under the column headed 'copper and iron,' the percentage of these metals was not determined, owing to an insufficient quantity of the sample being available. In these cases, the figure in the column headed 'silver' includes all metal other than gold.

"The gold from Mount Morgan, Queensland, stated by Prof. Liversidge to be 997 fine, has up to the present been thought to

* *Report*, April 5, 1900, by R. J. Frecheville, A.R.S.M., M. Inst. C.E.

be the purest of all native gold; it will, however, be seen in the above table that some of the gold from the Kalgoorlie district is very considerably purer, some "sponge-gold," resulting probably from the natural oxidation of calaverite (telluride of gold), being 999·1 fine, or practically pure.

"The gold from ironstone pebbles at Hampton Plains is also more than ordinarily pure, assaying 994·6 parts of gold per thousand. The average fineness of the twelve samples of gold analysed is 917·7, having a mint value of 3*l.* 17*s.* 11½*d.*"

CHAPTER IX.

SULPHO-TELLURIDE ORE TREATMENT.

IN the previous chapter I dealt with the milling and cyanide treatment of the "brown-stone" or oxidised ore at Kalgoorlie, which is distinguished by considerable variety of practice, as well as by certain differences in the details of the several processes employed.

The question of treating the unoxidised sulphide and telluride ores is a yet wider subject, and one upon which considerable diversities of opinion still exist amongst metallurgists as to what will ultimately prove to be the best line to adopt.

Sufficient practical experience on a working basis (by which alone the matter can be set at rest) does not appear, in fact, to have been gained, or at any rate, has not been published, to enable any conclusive opinion to be yet expressed on this much-disputed question.

The unoxidised ore in this field carries a great deal of the gold it contains in combination with sulphides.

It must be remembered, however, that owing to variations in the character of the ore in different mines, and even in different parts of the same mine, a process that may answer very well in some cases is not always equally applicable in others; whilst, as time goes on, means may be found to surmount the numerous chemical and mechanical difficulties which have been found to cause trouble and expense; so that, when we look back a few years hence, to practice in 1900 and 1901, the various processes now under trial may have become so modified and improved, as to give entirely different relative, as well as actual results, on a large scale.

The solution of the problem may therefore be worked out on the lines already adopted, with improvements in details, employing either amalgamation and cyanide, or cyanide and bromo-cyanide, by merely applying these well-known methods in such a manner as to best suit the special circumstances of each mine; or, it may be, that a new line of treatment may come into use, in which oil-concentration, and chlorine, or possibly bromine, may play important parts.

For instance, should any large quantity of fairly high-grade concentrates have to be dealt with, as a by-product of one or other of the several systems of treatment hereafter described, when fresh water is available for milling purposes, it might be practicable to chlorinate them on the spot instead of shipping them away to be smelted; if it is not found cheaper to roast and cyanide them, as is now being largely done.

Vat-chlorination of the ore, as practised at Mount Morgan,* might also be rendered possible if, after roasting, the bulk of the artificially formed soluble salts that have prevented the profitable application of chlorine to these ores, could be cheaply removed † by washing with fresh water; or should the composition of the gangue of the sulpho-telluride ores change materially in depth, and there certainly appears lately to have been a marked increase in some mines in depth in the siliceousness of the ore, accompanied by an increase in the silver present, which may be derived from some of the tellurides such as sylvanite or petzite; but this latter element in the case, coupled with the poor leaching character of the ore on the whole, would seem to render the extensive use of chlorine on this field improbable. Mr. Alfred James observes,‡ however, that "it remains to be seen whether bleaching powder or chlorine might not be used for the treatment of sulphide tailings, from which the concentrates have been separated in plants where bromo-cyanide is used."

In speaking of the ***sulphide problem***, it must be understood that the term is used strictly in a commercial sense, ***not metallurgically***, since there is no difficulty whatever in obtaining a recovery of over 90 per cent. of the gold these ores carry by several processes in actual use; for example, by smelting large quantities in admixture with silver-lead ores. The tellurium can of course be saved by such methods as Schrötter's,§ which was once applied on a small scale in Hungary to the treatment of tellurium "gold-slimes."

The cost has unfortunately, however, to be considered, and the sulphide problem is really a question of how to extract the largest percentage of gold at the cheapest all-round rate; a rate which,

* Mr. C. G. Warnford Lock, M. Inst. M.M., gives the following particulars and results in *Gold Milling*, p. 462. Extraction from 16-dwt. sulphide ore, 94 per cent.; in 1899, on the basis of chlorinating 200,000 tons of ore per annum, the oxidised ore cost 3*s*. 1½*d*., of which chemicals amounted to 11½*d*. and labour and fuel to 2*s*. 2*d*. The sulphuretted ore absorbed 3*s*. 10*d*. of chemicals per ton.

† The difficulty of getting rid of the soluble metallic salts in this way is discussed on p. 311.

‡ *Cyanide Practice*, 3rd edition (3p) 47.

§ 'The Occurrence and Behaviour of Tellurium in Gold Ores,' by F. C. Smith, *Trans. Am. Inst. of Mining Engineers*, vol. xxvi. p. 500.

practically speaking, needs to be reduced to say 15*s.* per ton, when dealing with these ores on a large scale, before the sulphide problem can be said to be really *satisfactorily* solved, as there are large bodies of low-grade sulphide ores on the field (below 15 dwt. in value) which must otherwise remain unworked. I see no reason, however, why treatment costs should not be ultimately lowered by combined metallurgical and mechanical improvements to this figure, or even less, in course of time.

It may be of interest to mention here that, according to Mr. T. A. Rickard,* treatment by barrel-chlorination, which is even more largely employed than cyanide, for dealing with telluride ores in Colorado, at one of the large Cripple Creek mills (which has a capacity of 3000 tons per month), cost $3·46 (14*s.* 5*d.*) per ton of ore treated; whilst side by side is given a later estimate† by Mr. John E. Rothwell, which closely agrees with it:—

T. A. Rickard.	$	*John E. Rothwell.*	$
Labour and salaries	1·20	Labour and office salaries	1·34
Chemicals and supplies	0·78	Chemicals and supplies	0·72
Fuel	0·65	Fuel for roasting and power	0·70
Wear and tear	0·55	Renewals and repairs	0·45
Incidentals	0·28	Miscellaneous	0·32
Total	3·46	Total	3·53

Adding interest on investment, general expenses, and deterioration of plant, the total cost approximates $4·00 per ton. Mr. Rickard's figures are based on chloride of lime costing $2·40, and sulphuric acid $1·25 per 100 lb.; the roasting costs‡ alone amounting to 45 to 60 cents per ton; this item has tended to grow heavier as the Colorado mines have become deeper, as the sulphur contents has increased from an average of 1 per cent., it is said, in 1895, to 2½ per cent. or more.

It must also be recollected that both the local conditions and the prices in Western Australia differ from those in Colorado.

Mr. H. Knutsen considers § that iron-spar is the most characteristic mineral in the Kalgoorlie ores.

* *Mining and Scientific Press*, December 30, 1899.

† *The Mineral Industry*, vol. ix. p. 370.

‡ Mr. Alfred James, M. Inst. M.M., stated in 1900 that the roasting costs at Cripple Creek on telluride ores were under 2*s.* per ton, including fuel, cooling, conveying, labour and lubricants; the chief item being for fuel (160 lb. of slack-coal at 8*s.* per short ton), which amounts to, say 7¾*d.* per short ton, or 8½*d.* per long ton of ore roasted. *Trans. Inst. of Mining and Metallurgy*, vol. viii. p. 514.

§ 'The Diehl Process,' by H. Knutsen, M. Inst. M.M. A paper read before the Institution of Mining and Metallurgy, June 1902.

An interesting comparison of the characters of the ores in these two localities, which is given by Mr. T. A. Rickard,* explains the causes of difference in practice in the two districts that has hitherto obtained. "In both cases we have to deal with altered eruptives as the matrix of the ore, but the much older rock of Kalgoorlie has undergone more decomposition than that of Cripple Creek. To the metallurgist, the difference is of great importance, especially in the milling of the low-grade ores.

"The Kalgoorlie lodes carry only a small amount (2 to 12 per cent.) of alumina, the replacement of the felspar having advanced very far; while, on the other hand, the impregnation of secondary carbonates of lime and magnesia, aggregating from 5 to 15 per cent., gives the ore a strong dolomitic ingredient. The silica contents average between 45 and 60 per cent.† Titaniferous iron accounts for the presence of 1 to 2·5 per cent of titanic acid.

"The Cripple Creek ore has a composition which approximates that of the prevailing rocks, and therefore the alumina is very high, from 15 per cent. in the granitic ores to 25 per cent. in those occurring with phonolite and its allied dyke rocks. Of lime and magnesia, there is only a trace of the latter to 4 per cent. of the former. The silica ranges from 55 to 70 per cent., being highest in the granitic ores. In sulphur and iron the two districts present no very marked difference, although there is more pyrite disseminated through the ore at Kalgoorlie than at Cripple Creek, the average percentage of sulphur being from 4 to 8 at Kalgoorlie.

"From a smelter's standpoint the Kalgoorlie ore is the better, being less siliceous, and (what is more important) carrying a much smaller percentage of alumina." It would be interesting, however, to know what losses of gold have actually been incurred through volatilisation, or in other ways, in smelting these particular telluride ores, and other details bearing on this subject, in regard to which nothing so far as I know has ever been published.

"It is the practice in Colorado to limit the amount of alumina in the charge of the lead-smelting furnaces to about 5 per cent. The Cripple Creek ores, which carry four times this proportion, are smelted only in limited quantities, mixed with other ores, so as not to impair the fusibility of the slag.

"The absence of copper and lead in the ores of both dis-

* 'The Telluride Ores of Cripple Creek and Kalgoorlie,' by T. A. Rickard, A.R.S.M., *Trans. Am. Inst. of Mining Engineers*, vol. xxx.

† This seems, as already said, to be increasing with depth.

tricts does not affect the reduction by smelting, but it obviates difficulties which might otherwise arise in the wet treatment at the mills.

"The dolomite in the Kalgoorlie lodes renders chlorination unsuitable as a method of treatment, on account of the fact that the lime and magnesia, resulting from the roasting of the carbonates, absorb the chlorine before it can unite with the gold, and thus prevent any solvent action upon the precious metal until the former elements have been satisfied.

"On the other hand, the presence of the carbonates tends to neutralise the acidity due to the sulphatisation of pyrites and renders the ore very amenable to cyanidation, the process now employed at Kalgoorlie.

"The schistose character of the lode-stuff causes it to slime easily in wet crushing, and the mechanical difficulties arising from this fact promoted the general adoption of dry crushing, in order to expedite subsequent leaching and filtration." Experience has, however, proved that in treating the *sulphide ores*, whether wet- or dry-crushed, the production of "slimes" cannot be avoided—in fact, *the eventual sliming of the ore is aimed at*, both in the Diehl and Boulder Main Reef processes.

"The Cripple Creek ores are docile to cyanidation and chlorination alike. The latter process requires, of course, a 'dead-roast'; and for this reason the cyanide process, which does not necessarily require the roasting of oxidised and partially-oxidised ores, had an advantage in the early days of the district.

"Now, however, it is recognised that, apart from chemical reasons, it is economical to subject the oxidised ores (at Cripple Creek) to roasting, on account of the resulting betterment in the leaching and filtering of the pulp."

During 1899, Cripple Creek is credited with an output of 425,590 tons of ore, of a gross value of $15,658,254; whilst comparing the two fields, in the same year Kalgoorlie may be estimated to have produced 466,759 tons of ore, of a gross value of $16,172,532.

During 1900 the production of Cripple Creek amounted to $18,073,539, in gold, and $18,550,859 in 1901.

Mr. H. L. Sulman * has remarked that bismuth is of very

* *Trans. Inst. of Mining and Metallurgy*, vol. viii. p. 513.

general occurrence in these ores, occasionally in quite appreciable quantity, and usually in association with tellurium; vanadate of lead is found in the Associated ore, whilst antimony, as shown by the analysis given on p. 298, is also sometimes present; and, as pointed out by Mr. Sulman, molybdenum, antimony, bismuth, vanadium and tellurium all render gold ores refractory of treatment, even when present in small amount, which may account under ordinary circumstances for the non-extraction of several pennyweights of gold.

Smelting.—In the earlier days of the Kalgoorlie field, this was the only means by which the richer "telluride ores" could be dealt with, and it cost the mines (including freight and shipment charges) somewhere in the neighbourhood of 5*l.* 10*s.* a ton, and sometimes considerably more,* to recover some 95 per cent. of the gold the Kalgoorlie ores contained.

Later on, however, the smelters seemed to recognise the expediency of lowering their rates, and the "returning charges" came down to about 2*l.* a ton, being, in exceptional cases, perhaps 5*s.* a ton lower, in others higher, according to variations in the character of the ore; but subsequently they again raised their charges.

Depending on the "returning charge" and the value of the ore,† some works allow the mines 92½ per cent. to 95 per cent. of the assay value of the gold in the stone, paying for the gold contents at the rate of 4*l.* per oz. fine; in other cases, they pay for it in full, at this rate, making a deduction of 1½ to 2 dwt. per oz., according as it runs under or over a certain specified assay value.

The silver present is generally paid for, if in excess of 3 to 5 oz., at the current rate of the day for standard silver.

Lead, copper, zinc, arsenic, antimony, or bismuth, if present, subject the "returning charges" mentioned to material modification; but as these elements are not generally found in the Kalgoorlie ores in large amount, this is outside the question.

It is clear, however, that with the one item alone of bagging

* In 1898–9 the Lake View Consols shipped 2620 tons to smelting works in New South Wales, which produced 102,117·410 oz., being an average of 38·976 oz. per ton, upon which the cost of shipping, smelting and realisation of bullion is stated to have been 7*l.* 4*s.* 5¼*d.* per ton.—*Annual Report*, p. 12.

† The smelters prefer not to treat ore of exceptionally "high grade," owing to its attendant risks.

the ore, representing, as it did, say 5*s.* to 6*s.* a ton (bags * costing from 1*s.* 10*d.* to 3*s.* a dozen), allowing for mining, development and general expenses, crushing, cartage, freight, insurance, wharfage, agency † and export charges, with the utmost economy, sulphide ore to be treated in this way had to be worth at least 25 to 27½ dwt. per ton, or say 5*l.* to 5*l.* 10*s.*, to pay for shipping and treating, if the ore was smelted outside of the Colony.

The smelting works in the Colony, apart from special contracts (made for lots exceeding 200 tons, having special fluxing value, or ore of exceptionally high grade, and concentrates), at one time purchased gold-ores, I am informed, on the following tariff basis:—

Gold contents—

	%	
If the ore assayed under 2 oz.	92	of assay value paid for at the rate of 4*l.* per oz. fine.
,, 2 oz. to 3 oz.	94	
,, 3 ,, to 6 ,,	95	
,, 6 ,, and over	96	

All silver, less 3 oz. per ton, paid for according to tariff for silver ores.

Treatment charges, 45*s.*‡ per ton of 2240 lb., varying according to the chemical composition and physical nature of the ore. Oxidised ores, carrying an appreciable amount of iron or lime, being subject to a lower charge than ores containing a large percentage of silica or alumina.

The advantages of smelting in the Colony were specified as follows:—

1. Saving of sea freight, with wharfage, demurrage, storage, agency fees, and delays at port of shipment and landing.

2. Saving the export duty placed on all gold-ores, of 5*s.* or 10*s.* per ton, if shipped outside the Colony, according as their assay value is under or over 10 oz. per ton.

3. Avoiding bagging, as the Government supply light trucks for handling ore in bulk; and bags are returned free of charge.

4. A rebate on the freight rate of ½*d.* a ton per mile, conceded by the railway department, on all ores smelted in Western Australia, not exceeding 10 oz. in value.

5. The ore need not be broken smaller than to pass a 4-inch ring, doing away with the necessity of the seller "spalling" it.

* Of a size to contain 70 to 75 lb. of ore.

† Wharfage and agency charges may be reckoned at 3*s.* 6*d.* to 4*s.*; and there is a Government export charge levied on ore smelted outside of the Colony of 5*s.* a ton.

‡ On sulphide ore, say about 50*s.* per ton.

6. The seller or his agent can be personally present, to see the ore sampled.

The following were the Western Australia Railway rates, at ½*d.* per ton * per mile, to Owen's Anchorage (two miles from Fremantle), on consignments of not less than 5 tons, and of a declared value of under 10 oz. per ton.

Miles.		£ s. d.	Miles.		£ s. d.
363	Coolgardie . .	0 15 2½	467	Menzies . . .	0 19 6½
387	Kalgoorlie . .	0 16 2½	518	Mount Magnet .	1 1 8
399	Kanowna . .	0 16 8½		Boulder City . .	0 16 4½

According to the railway tariff (May 1902) these rates were raised to 8*s.* 4*d.* for the first 100 miles and ½*d.* per ton beyond that distance.

In a letter to the *Financial Times*, dated February 26, 1901, Messrs. James Bros. mention that at the annual meeting of the Associated Northern Blocks, the chairman of the company stated that the expense of shipping sulphide ore came to something like 3*l.* 10*s.* per ton,† which is no doubt approximately what it cost (exclusive of mining charges) to deliver and smelt ores of this class in the Colony under the most favourable conditions in 1901. A water-jacket furnace was erected some time back at the Golden Horse-Shoe mine to smelt the ore on the spot. In the last five months of 1900, 9437 tons of sulphide ore from this mine were smelted at Fremantle, and returned 23,748 oz., giving an average extraction of 94 per cent., at an average cost of 3*l.* 13*s.* 2 731*d.*, including breaking, sampling, proportion of management and general charges, transport, and smelting costs. In 1901, 21,048 tons of sulphide ore were treated by the Mine-smelter and Fremantle Works, which returned 75,285·088 oz. of gold.

The first of the two following analyses may be taken as an example of the class of ore on this field that was formerly smelted; the second ‡ as being typical of the sulphide ores, dealt with by cyanide up till recently:—

* Efforts were made to get this reduced to ¼*d.* per ton.

† Mr. A. E. Thomas, in a report dated November 23, 1901, stated that smelting charges, including carriage, from Golden Gate Station to Fremantle, formerly cost 3*l.* 11*s.* 4*d.* The current charge being 3*l.* 16*s.* 4*d.*, whilst "sorting" and "breaking" at surface cost 4*s.* extra. Total, 4*l.* 0*s.* 4*d.*

‡ 'The Treatment of West Australian Sulphide Ores,' by Alfred James, M.Inst.M.M., *Trans. Inst. of Mining and Metallurgy*, vol. viii.

	*No. 1. per cent.	No. 2. per cent.
Silica	48·43	about 50
Iron	10·24	10
Alumina	1·98	5 to 20 or more
Lime	9·86 (calcite)	6 to 17 ,,
Magnesia	2·03	1 to 5 ,,
Sulphur	3·66	3 to 7 ,,
Copper	0·33	0·1 to 0·3 ,,
CO_2	7·75 (calculated)	..
Lead	.. (calculated)	traces
Zinc	.. (calculated)	0·02
Oxygen (combined)	3·05 (calculated)	..
Arsenic	.. (calculated)	traces
Antimony	.. (calculated)	about 0·02
Alkalies, etc. (undetermined)	12·65 (calculated)	..
† Tellurium	..	0·03 to 0·1
	99·98	
Assaying in gold	6·5 oz.	
,, ,, silver	2·5 oz.	

A more recent analysis is given by Mr. Robt. Allen, M.Inst.M.M.,‡ showing the composition of a sample of air-dried sulphide ore from the 1100 feet level of the Great Boulder.

	Per cent.
Silica	74·95
Alumina	1·75
Sulphide of iron	5·40
Carbonate of iron	3·22
,, of calcium	7·03
,, of magnesium	4·76
Alkalies	1·40
Water (combined)	0·25
,, (moisture) balance	1·24
	100·00

The increased percentage of silica with depth is to be noted; and the presence of selenium is not uncommon. Selenious acid being a solvent of gold, it may give rise to loss if sulphuric acid is used for cleaning up "gold-slimes"; and selenium is also said § to

* An analysis of 100 tons of Great Boulder Main Reef ore given by Mr. Edward Skewes, *Mining Journal*, 1898, No. 3264, p. 312.

† Mr. H. L. Sulman, M. Inst. M.M., states that he has found as much as 0·15 per cent. of tellurium present in samples, and that probably about one-third only of the gold is combined with the tellurium, the rest being "free." Considerable manganese is likewise present in the oxidised ores. *Trans. Inst. of Mining and Metallurgy*, vol. viii. pp. 495–496.

‡ 'A Description of the Reduction Plants and Processes of Reduction on Some of the Principal Kalgoorlie Gold Mines,' by Robt. Allen, M.A., B.Sc., Royal Commission, Glasgow, 1901, p. 17. § Alfred James, *Cyanide Practice*, 3rd ed. (3p) 17.

cause trouble in melting cyanide bullion, as at Redjang Labong in Sumatra it forms a matte which appears to consist principally of selenide of silver.

Ore of the grade shown in No. 1 analysis of course left a handsome profit on smelting it, notwithstanding the expense, and this mode of treatment was necessitated under the circumstances, in order to realise any immediate returns, in the earlier days of the field.

The obvious need of a cheaper process, however, which would admit of the ore being treated on a large scale on the spot, speedily brought out of retirement a number of inventors, with patent processes to offer, each one claiming, and doubtless believing his own particular method to be the best; but with one or two exceptions, none of them ever reached the stage of being applied on a working-scale, and at the present time there are only four main lines of treatment in use for dealing with these sulphide ores. Still, as I have said before, this by no means excludes other inventors from the field of competition, as it does not follow that because there have been numberless failures in the past, some one may not find a key that will exactly fit the lock, and prove that it is a simpler one to open than it seems. It is a question, however, that chiefly concerns the wakeful metallurgist engaged in experimental research, who, if he is of an inquiring disposition, can turn it over in his brain when he cannot get to sleep; and, whilst venturing to indicate a few points to which investigation might perhaps be profitably directed, all that the Author has attempted has been to describe what has been done up to the present, following the evolution of each process, step by step, to the point it has so far reached.

The first attempts to deal with "sulphide ores" *locally* (which was a step in the right direction) commenced with the erection of the Lake View Consols and the Associated Gold Mines works, in the early autumn of 1898.

The Lake View Consols (old) Sulphide Works, as the result of previous experiments, originally adopted the following plan of treatment. The ore, broken at the main shaft in a No. 5 Gates rock-breaker, was conveyed by the aerial wire ropeway to the mill, where it was further crushed in two No. 2 Gates crushers, dried in a rotatory dryer, and passed through two sets of Chilian mills;* after this it was screened in a trommel, and the unfinished pro-

* Replaced in 1899 by the two No. 5 Krupp mills.

duct was delivered to two No. 5 Krupp ball-mills with a capacity of 50 tons a day each, fitted with 20-mesh discharge screens, that is to say, having 400 holes to the square inch. The crushed ore from the mills was conveyed to storage bins, and thence passed through automatic feeders, to two mechanical reverberatory straight-line furnaces, having 180 by 10 feet hearths,* with four fire-boxes on each side. The roasted ore, discharged from the furnace, after having passed through inclined iron cooling-cylinders † (revolving in a tank of water), was stored on a "cooling-floor," from which it was intended to deliver it to the steel cyanide-vats by a steam grab-crane, and leach it in the ordinary way.

The original capacity of this plant was estimated at 100 tons a day.

Unfortunately, although experiments on a small scale were reported to have proved satisfactory, defects very soon manifested themselves in this proposed system of treatment when operated on a working scale. The first trouble was caused by the wire-rope haulage of the furnace rapidly giving out, although by substituting chain-haulage for operating the rabbles this difficulty was partially remedied.

Owing, further, to the heat of the furnace with wood fuel not being able to be kept properly under control, the discharge doors at the end of the furnace also, it was reported, "burnt out"; a trouble which was met by suspending them from a water-jacketed carrier, and moving them further back from the fire. Finally a self-feeder had to be added to the furnace, to overcome irregularities in charging, and under the circumstances it is perhaps scarcely to be wondered at, that the results of the roasting were so poor ‡ that the sands had to be set on one side for retreatment; but the

* At the Golden Reward works in Dakota the hearth of a furnace of similar type is 180 × 8 feet.

† The Argall ore-cooler (a multitubular cylindrical cooler) is calculated to be able to handle 300 tons of roasted ore a day, and to cool it effectively in about 25 minutes from the time it has left the furnaces.

‡ The Swansea expert, subsequently engaged, got the furnaces, I am informed, into better running order, the ore being roasted fairly "sweet," each furnace turning out about 30 tons in 24 hours, and the sulphur being brought down to 0·15 per cent.; and it was stated that the output of the furnaces could be increased to 40 or 45 tons without seriously affecting the roast. It was afterwards decided, I believe, to abandon air-separation in favour of water-classification, as the imperfect separation of the sands and slimes had, it was reported, a decidedly adverse effect on the rate of extraction by subsequent lixiviation and filter-pressing, and proper separation into sands and slimes was expected to yield better results in both departments.

slimes, treated by agitation and filter-presses, showed, it was stated, as good an extraction as 95 per cent.

It was thought at first that by crushing the ore to pass a 20-mesh screen, and roasting it, the gold could be extracted by ordinary vat-leaching; but it was found in practice to require a much longer time than had been anticipated, consequently it was decided to crush it to 30-mesh size, two No. 8 and two No. 5 Krupp ball-mills being added to the plant in 1899. The coarse sands, after crushing in the mills, were separated from the "fines," in pneumatic separators,* the idea of this being to leach the sands apart in vats, whilst the "slimes" were to be agitated in agitators and filter-pressed. For this purpose four Dehne filter-presses † were added to the mill; and two additional furnaces and ten 100-ton steel vats were erected, whilst other necessary alterations were made with a view, it is stated, to increase the capacity of the plant up to between 300 and 350 tons per diem. Two No. 8 Krupp ball-mills with ore-bins and conveyors were erected, and two 200-ton lixiviation vats for sulphide sands were added to the plant in 1900.

Working under the difficulties that have been mentioned, 1403 tons were treated in 1899, which produced 4487·075 oz., at a cost of 3*l.* 16*s.* 9*d.* per ton.

The results for the year ending August 31st, 1900, may be summarised as follows:—

Sulphide sands treated	18,014 tons.			
	oz.	dwt.	gr.	
Gold won	28,690	19	16	
Average yield per ton	1	11	21	
,, value of sands	1	19	3	
,, ,, of residues	0	7	6	(reduced in the last 3 months to 4 dwt. 15 gr.)

Average amount of sulphur in the roasted ore	0·15 per cent.
Extraction	81 ,,
Consumption of cyanide	6·66 lb. per ton of ore.

Lixiviation.—The treatment of the sands in vats by percolation was not satisfactory, the presence of 7 per cent. of lime in the

* See note ‡, p. 300.

† Mr. H. Knutsen says that "It will surprise most, to learn that Dr. L. Diehl, of the London and Hamburg G. R. Co., Ltd., in 1896, in Hamburg actually demonstrated the efficiency of filter-presses on a large scale on ore from Kalgoorlie." The construction and operation of filter-presses is described by William McNeill, M. Inst. M.M., 'Filter-press Treatment of Gold Ore Slimes,' *Trans. Inst. of Mining and Metallurgy*, vol. vi.; by C. G. Warnford Lock in *Gold Milling*; and others.

roasted ore (which renders it liable to set when wetted) making percolation slow and imperfect, and this, combined with the presence of coarse gold (formed in roasting) accounts for the high value of the residues and the length of time (three weeks) occupied in leaching. In consequence of this a heavy consumption of cyanide was involved, though it was reduced to 3·29 lb. during the last three months of the year.

Sulphide slimes treated	3960 tons.
Gold won	8821 oz. 1 dwt. 2 gr.
Average value of slimes	2 oz. 4 dwt. 13 gr.
Extraction	90 per cent.
Consumption of cyanide	10·95 lb. per ton of ore.

Agitation and Filter-pressing.—With proper separation of sands and slimes, this portion of the process would, it was stated, show a very satisfactory rate of extraction. The high average value of the residues (4 dwt. 23 gr.) was due to the presence of "sands." During the last three months they were, however, reduced to 3 dwt. 8 gr. The abnormally heavy consumption of cyanide was explained by imperfect roasting in the early part of the year, and the consumption was reduced at the end of the period (August 1900) covered by the official report I have quoted, to 3·70 lb. per ton of ore.

During the last four months of the period in question the average cost of treating sulphide ore was brought down from 43*s.* 5*d.* to 32*s.* 10*d.* per ton.

	s.	*d.*
Crushing and transit	9	5
Roasting	17	1
Leaching and filter-pressing	16	11
Total	43	5

The results obtained from experimental trials with the Diehl process in 1900 are stated to have been as follows :—

Ore treated	217 tons.
Gold won	232 oz. 17 dwt. 8 gr.
Average value of slimes	1 oz. 3 dwt. 2 gr.
,, yield per ton	1 oz. 1 dwt. 11 gr.
,, value of residues	1 dwt. 15 gr.
Extraction	92·82 per cent.
Consumption of bromo-cyanide	1·18 lb. per ton of ore.

The quantity of sulphide ore that was shipped to smelters amounted to 3764 tons, which yielded 95,093 oz., or at the rate of 25 oz. 5 dwt. 5 gr. per ton.

The results of treatment in the sulphide works (which were closed down in 1902) and the costs in 1901, are given in a supplementary table at the end of this chapter; and a description of the Diehl mill, and method of treatment, is given later on p. 379.

The Associated Gold Mines of Western Australia.—The system of sulphide treatment first adopted at these works appears to have been modelled on much the same lines as that originally employed at the Great Boulder Main Reef (in 1899), and at the Lake View Consols mill, with the exception that "Stearns-Roger" rolls and ball-mills were employed for crushing the ore, and four Ropp furnaces were put in, each with a hearth 150 feet in length by 14 feet in width.

The mill was started in October 1899, and at first the metallurgical results seemed satisfactory (owing, apparently, to imperfect sampling of the tailings in the vats), but the actual extraction proved disappointing, as from October 20, 1899, to March 5, 1900, it appears * that 12,303 tons of ore were treated, containing, according to assay, 13,011 oz. of fine gold, which should, therefore, have been worth, at 4*l.* 4*s.* 11½*d.* per oz., 55,269*l.* 13*s.* In point of fact, however, during the same period, 8567 oz. of bullion were actually produced, of an average value, according to assay, of 3*l.* 16*s.* 7*d.* per oz., representing a money value of 32,804*l.* 9*s.*, showing a saving of only 59·35 per cent.,† and a loss in the tailings of 8·5 dwt. per ton.

Many vats, after over a month's treatment, still seem to have assayed 15 to 16 dwt., and the consumption of cyanide varied from 9 to 10 lb. per ton; but was reduced in 1900 to 6½ lb.

Estimating the capacity of the Ropp furnaces at 70 tons a day each, it was calculated that the maximum output of the complete mill would not exceed 280 tons of ore per diem; but, whilst advising a complete change in the system of treatment, the opinion was expressed by one of the engineers who reported on the mine early in 1900, that the extraction results might be improved upon by the addition of the air-separators, agitators, and filter-presses,

* Report by Mr. R. J. Frecheville, M. Inst. C.E., April 5, 1900, p. 5.

† Mr. J. Angove mentions that the average extraction in February 1900 was 64·12 per cent., leaving 10·5 dwt. in the tailings.—*Report*, April 6, 1900. The Author was subsequently informed, on what he believes to be good authority, that extractions of 70 per cent. were got, at the expense, however, of a high consumption of cyanide.

which it was proposed to employ. The cost of treatment, however, even if modified, would, it was feared, always be heavy; the figure of 30*s*. a ton being mentioned as a probable minimum.

During the year ending March 31, 1901, several changes were made; the arches of the Ropp furnaces were lowered, and the fire-boxes made smaller, which it was estimated would effect a saving of some 25 per cent. in fuel; and the use of push-conveyors and distributing tanks, in place of the former cooling arrangement, was expected to result in a further economy.

As the result of experiments (referred to in the Company's Annual Report, March 31, 1901), amalgamating and filter-pressing plant was put in, consisting of ten 5-feet grinding-pans (Wheeler type), five settlers, settling-vats, six agitating vats (18 feet in diameter by 5 feet deep), plunger tailings-pumps, montejus, and four Dehne filter-presses, each of which is able to handle a charge of about 4½ tons of slime. The mill was extended, and the second half was built, in 1901–1902.

The altered method of treatment these changes involved may be gathered from Mr. Rob. Allen's description of the first half of the works (which were under construction), from which it appears that the ore was delivered at the top of the feed-floor, dumped upon four grizzlies with 2-inch spaces between the bars, and the coarser portion was broken down in four No. C. Comet crushers, the product of which, together with the fines from the screens, was distributed between two bins of 200 tons capacity each, and was thence fed to four sets of Roger rolls (36 inches in diameter) by automatic feeders set to deliver a 1-inch product. The crushed ore then passed through four Howell-White revolving dryers (heated by means of the waste gases of the roasting furnaces), and was elevated by four chain and bucket elevators to four small bins which delivered it through automatic "grass-hopper" feeders to ten No. 5 Krupp ball-mills having a capacity of about 22 tons each per diem, crushing through a 30-mesh wire screen.

The pulverised ore, which was discharged with screw-conveyors, was then raised by four belt elevators to two 200-ton bins, from which it was delivered by screw-conveyors to the head of four 60-ton Ropp roasting-furnaces. After roasting, the ore (which was stated to contain ·25 per cent. of insoluble sulphur) was distributed by a couple of push-conveyors to 20 grinding and amalgamating pans, charged with mercury, into which the ore and water were introduced through a set of (20) four-inch diameter shoots. The overflow from the pans, consisting of fine pulp, passed next through ten settlers, so as to thoroughly slime it, and collect the amalgam. Mr. R. Allen remarked in this connection that until recently there was little or no free gold in the raw sulphide ore.

The slimed pulp, escaping from the settlers through two launders, was raised to two large 35-feet settling-vats by the tailings-pumps, and, after settlement, the supernatant liquors which contain cyanicides were drawn off. The "pulp" thus thickened then passed through bottom-discharge valves into twelve agitating-vats (each holding about 100 tons of slime), fitted with suspended paddle-agitators, and, after about sixteen hours' agitation with cyanide solution, it was delivered to four montejus, which served to fill eight Dehne filter-presses. The gold solution from these presses was clarified before going through a set of six extractor-boxes, by passing through a small auxiliary Dehne press and intermediate solution tank; whilst the residues from the presses were trucked to the dump.

From April 1900 to March 1901 inclusive, the treatment of 35,524 tons of ore, mostly sulphide (including, however, 1080 tons of oxidised ore) yielded 29,912 oz., an average of 17 dwt. per ton.

The tailings assayed 8 dwt., and the extraction amounted to 67·5 per cent.,* whilst the milling costs for the same period were as follows:—

	£	s.	d.	
Management and wages . .	20,175	0	10	
Stores, cyanide, coal, firewood, water, etc.	30,191	0	11	
Maintenance	10,987	2	9	
Total . .	61,353	4	6	= 35*s.* 7·498*d.* per ton.

During the year ending March 31st, 1902, the total cost of treating 7558 tons of sulphide ore by the percolation process (in the old half of the mill) came to 16,101*l.* 4*s.* 2*d.*, representing an average cost of 2*l.* 2*s.* 7·28*d.* per ton; details of which are given in the supplementary tables at the end of this chapter. During this same period it appears that the "percolation process" was entirely given up (the vats being discarded), and the grinding capacity of the plant was increased by the addition of (20) extra

* More recently, in an article in the *London Mining Journal* (October 12, 1901, p. 1268), the extraction was estimated at about 75 per cent., on 20 to 30-dwt. ore.

pans, and the agitating vats and filter-presses, required to complete the second half of the mill and remodel the works as before described. Besides this machinery, however, twelve large and eight small spitzkasten were put in, and three Wilfley concentrating tables, and some further modifications, I understand, were made in the original design with a view to deliver the ore direct from the Comet crushers to the ball-mills by a Robins' belt-conveyor; thus doing away with the rolls, dryers and elevators. After the ore has been ground in the pans it was also intended to pass the pan-pulp over the Wilfley tables and elevate the tailings of the concentrators by an air-lift to the spitzkasten; the coarse sands eliminated by this latter apparatus being returned to the pans; but the treatment in other respects appears to be the same as described on pp. 304–305.

During the year ending March 31st, 1902, the total cost of the sulphide ore treatment, dealing with 33,826 tons of ore, came to 55,033*l.* 3*s.* 10*d.*, representing an average cost of 1*l.* 12*s.* 6·46*d.* per ton; and during January, February and March from 5077 to 5325 tons were dealt with monthly.

Details of cost are given in the supplementary tables at the end of this chapter. The Chairman at the Annual Meeting last July, mentioned that considerable saving was anticipated in the cost of milling, by the erection of a Robins' conveyor and firewood tramway, which will deliver the firewood to the works, instead of carting it up the hill.

In the early days of Kalgoorlie a patent process was installed by the owners of the patent rights at the Great Boulder, the inventor of which ascribed* its non-success to the machinery which was intended to take the place of filter-presses. This appears to have been caused by the foliated character of the particles of ore, which made it pack, so that the slimes required some ten hours' leaching, and would have required ten hours more to wash, in spite of the fact he mentions, viz. that the same machine treating Transvaal and other slimes handled them successfully in 2½ hours to 4 hours.

The settling qualities of the slimes, however, appeared to be made more pronounced by roasting.

It is always easy, of course, to be wise after the event, but whilst the various early disappointments experienced were matters

* *Financial Times*, Letter, dated March 2, 1900.

for much regret, it must be recollected that practically the same general method of treatment, viz. roasting, and ordinary cyanidation by percolation in vats, answers admirably with certain telluride ores, like those of Cripple Creek, affording an excellent illustration of the need for careful preliminary investigation by specialists before embarking on the treatment of a new ore in a new district; which should serve as a warning to business people not to attempt to rush matters of this kind too rapidly.

Notwithstanding that time may be lost in getting returns, and considerable expense may be involved in making laboratory and working tests, more haste often results in less speed.

Unfortunate indeed as the failure of the vat-process and others that were proposed (for dealing with the sulpho-telluride ores) was, it gave an impetus to fresh efforts, which have resulted in the application of the several methods now employed, which give vastly better results.

There are four distinct main lines of treatment which claim attention, that may be described as—

(1) The dry-crushing and roasting, amalgamation and ordinary cyanide method, after removal of the soluble salts by double filter-pressing or otherwise, and zinc precipitation, which is generally known as the Boulder Main Reef process. This is, more or less, the system already described on pp. 304–306, adopted in the new sulphide plant at the Associated Gold Mines; double filter-pressing being now usually dispensed with.

(2) The wet-crushing and concentration, bromo-cyanide and filter-press method, which is applicable to raw ores, when slimed, and is known as the Diehl process.

(3) The dry-crushing, roasting, and combined amalgamation and cyanide method, with electrical precipitation, known as the Riecken process.

(4) The wet-crushing, amalgamation, and concentration method followed by separate treatment of the sands and slimes contained in the tailings with ordinary cyanide, the former in vats and the latter in presses, known as the Ivanhoe process.

The relative efficiency of these four methods of treatment from a commercial standpoint can, of course, only be decided by actual working results, on a large scale, with different ores, extending over a considerable period of time; and all that can be said at present, is that three at least of them seem to possess certain advantages which tend to more or less counterbalance one another, and it may be that more than one will be found to fill a particular sphere of its own. Trials on a working-scale place the *metallurgical success* of all four processes, practically speaking, beyond question: their ability to extract a large percentage of the gold, which the sulpho-telluride ores carry, having been demonstrated.

The General Principles on which Methods of Sulpho-Telluride Treatment are based.

Mr. H. Knutsen has pointed out* that in the Kalgoorlie sulpho-telluride ores "the slimes in all cases are richer in gold than the sands," a fact generally recognised, but which is of importance to bear in mind in connection with their treatment. He adds:—"In most cases less than 20 per cent. of the total gold is contained in the sands;" and he gives† the following interesting table, which shows the distribution of the gold in these ores, the gold being partly "free," but the greater portion "combined" in tellurides and sulphides.

DISTRIBUTION OF THE GOLD.

ORE.	No. 1.		No. 2.		No. 3.		No. 4.		No. 5.		No. 6.	
Assay, Fine Gold	oz. dwt. gr. 0 17 12		oz. dwt. gr. 2 5 7		oz. dwt. gr. 3 10 10		oz. dwt. gr. 2 10 12		oz. dwt. gr. 1 12 0		oz. dwt. gr. 3 5 10	
PRODUCTS.	Product % of Total Ore.	Cont. % of Gold.	Product % of Ore.	Cont. % of Gold.	Product % of Ore.	Cont. % of Gold.	Product % of Ore.	Cont. % of Gold.	Product % of Ore.	Cont. % of Gold.	Product % of Ore.	Cont. % of Gold.
Amal. Gold	—	0·88	—	2·85	—	1·75	—	4·82	—	11·53	—	11·62
Concentrates	10·57	37·51	6·88	45·90	9·45	48·58	6·26	43·32	7·36	34·49	8·94	38·49
Sand	50·00	26·24	48·23	16·15	46·21	16·62	44·77	17·14	53·36	19·91	42·93	20·27
Slimes	39·43	35·37	44·89	35·10	44·34	33·05	48·97	34·72	39·28	34·07	48·13	29·62
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

Mr. Knutsen likewise gives the following analyses of bulk samples from a number of the principal mines on the field, with the accompanying explanatory remarks upon the method of estimation he adopted:—

* 'The Diehl Process,' by H. Knutsen, *Trans. Inst. of Mining and Metallurgy, op. cit.*, footnote, p. 292. † *Ibid.*

"These samples represent parcels of ore varying from 2 to more than 200 tons. They were treated with very dilute hydrochloric acid, and determination was made of the carbonic acid, insolubles, and of protoxide of iron. The lime was, in a few instances, directly estimated; but as a rule I calculated the CO_2 necessary to form $FeCO_3$. This CO_2 was then deducted from the total CO_2. I then calculated the CaO necessary to form $CaCO_3$ with the rest of the CO_2. In all these ores there is more or less magnesia as $MgCO_3$, but the percentage is small in comparison with the lime.

"To simplify matters, I have calculated it all as $CaCO_3$."

ANALYSES OF KALGOORLIE ORES.

No.	Name of Mine.	Assay. Fine Gold.			Analysis.			Total Sum.
		oz.	dwt.	gr.	Insolubles.	$FeCO_3$.	$CaCO_3$.	
1	Hannan's Brown Hill, I.	1	13	20	57·98	19·29	22·55	99·82
2	" " II.	1	14	10	56·62	23·06	19·78	99·46
3	" " III.	2	19	7	50·81	30·21	19·64	100·66
4	" " IV.	3	2	2	52·73	24·56	22·57	99·86
5	" " V.	3	6	2	65·67	15·08	19·02	99·77
6	" " VI.	4	1	6	62·30	22·77	14·68	99·75
7	" " VII.	5	6	19	59·61	13·94	26·73	100·28
8	Lake View Consols I.	2	3	0	72·63	10·59	16·11	99·33
9	" " II.	2	6	8	73·77	12·76	14·23	100·76
10	" " III.	3	11	0	72·67	13·92	13·00	99·59
11	Hannan's Star I.	0	16	2	77·78	11·24	10·94	99·96
12	" II.	1	2	1	68·27	14·72	17·32	100·31
13	Associated (Australia)	0	18	9	76·91	12·11	9·18	98·20
14	Boulder Main Reef.	1	15	9	65·62	12·57	20·98	99·17
15	Brown Hill Central (English)	2	4	1	40·73	21·72	38·78	101·23
16	North Boulder	2	6	1	74·22	10·52	15·45	100·19
17	Kalgoorlie	2	6	7	73·81	11·16	14·61	99·58
18	Brown Hill Extended	3	2	6	66·11	12·62	21·50	100·23

Mr. C. W. Merrill in a paper on 'The Present Limitations of the Cyanide Process,' long ago pointed out* that "ores containing *coarse gold*, which is not easily soluble in potassium cyanide,

* *Trans. Am. Inst. of Mining Engineers*, vol. xxv.

should always have that portion of the gold extracted by *amalgamation or concentration* * before leaching,"—features which we find embodied, in the one case, in the Boulder Main Reef and Riecken, in the other, in the Diehl and Ivanhoe processes.

I may also call attention to several interesting points that bear on the question of sulphide treatment which were dealt with in an article † by Mr. R. Recknagel. He mentioned, for example, that in some experiments he made with mixed telluride and sulphide ores of Boulder County, Colorado, the results seemed to prove that "*some* tellurides ‡ containing gold do not yield their gold readily to cyanide," although others have been proved to do so; whilst he further observed that certain classes of sulphides are acted upon by cyanide in different degrees, altogether apart from the question of the influence which the common admixture of minerals one with another (for instance zinc-blende, containing as it frequently does, FeS in its pure natural state) may exercise upon their solubility. Thus, for instance, he observed that marcasite, FeS_2, which crystallises in the rhombic system, is attacked by cyanide to a considerable degree, whereas pyrites, FeS_2 (the natural bi-sulphide), which is isometric, is not at all or very little acted on.§

The conclusion the writer drew is that neither the same mineralogical character, nor the same chemical composition, as proved by analysis, can be taken as a safe guide to foretell the actual behaviour of natural sulphides towards cyanide solutions, and only actual experiment with any particular ore will set the question at rest. He also called attention to the fact that the gold in the pyrites may in some cases be present as an insoluble natural sulphide or silicate; but in others that a *finer pulverisation* ‖ might give a better extraction (one of the main features of the Diehl process); on the other hand, for different reasons, too fine a state of division may have the same effect as a too coarse one, viz. a low extraction, and particles of gold may still remain inclosed in the gangue even after it is pulverised to the greatest practical degree of fineness.

* The italics are the Author's.

† 'Cyaniding Sulphide Gold Ores,' *Engineering and Mining Journal*, November 13, 1897.

‡ *Vide* footnote, p. 317.

§ An explanation of this singular circumstance is perhaps afforded by the investigations of Mr. A. P. Brown, in the *Proceedings of the American Philosophical Society*, Philadelphia, 1894, vol. xxxiii. pp. 225–243, to which Mr. Recknagel refers.

‖ The italics are the Author's.

Mr. Recknagel strongly advocated roasting on the following grounds :—(1) An alteration of harmful compounds into indifferent ones; * (2) the removal of sulphur, by which the ore grains become porous, and with it the fine gold and silver particles are rendered accessible to solvents; and (3) a certain amount of "fritting" of the fine ore grains, which accelerates leaching.

If the ore is not roasted "dead," the effects of course will be different, as instead of insoluble oxides, a mixture of sulphates and oxides, as well as undecomposed sulphides, is produced, and a less porous product.

If all sulphides could be transformed into sulphates at the same time, as the soluble sulphates could be removed by a simple water-washing preparatory to cyanidation, the considerable gain in time and saving in fuel over a "dead roast," would, Mr. Recknagel considered, be in favour of such a method.

The fact is, however, that (apart from the impossibility of removing the more insoluble metallic sulphates by washing), in roasting sulphide ores, the complete conversion of sulphides into sulphates is an ideal state never reached, and the nearest approach to it is only gained in the course of a thorough "dead-roast." If roasting be interrupted when the bulk of the sulphides have been turned into sulphates, usually quite an appreciable amount of sulphides in the finest state of division, enclosed by gangue, or sulphates and oxides, remain unaltered; and in the subsequent leaching by cyanide it will be found not only that the consumption of cyanide will be higher, but also that the percentage of extraction will not be as high, as with "dead-roasted" ore; consequently it is of the utmost importance for the ore to be roasted as "sweet" as possible; whilst certain cyanicides can be and are washed out (previous to cyanidation) in the Boulder Main Reef process.

The cyaniding of (roasted) telluride ores in Colorado was very fully discussed and described in an interesting article by Mr. Ph. Argall, M. Inst. M.M., in *The Mineral Industry*, vol. vi. The presence of zinc in the mill solutions (so long at any rate as it does not exceed 0·55 per cent.† in the strong solution), although it lowers the extraction slightly, is, he points out, of benefit in reducing the consumption of cyanide; and he concludes from this,

* Unfortunately, in practice, this result is not in most cases fully achieved.

† A number of tests made by Mr. Argall, extending over two years, showed an average to be about 0·312 per cent.

that the zinc is largely precipitated in the charges of fresh ore in the lixiviation tanks, rendering part of the cyanide combined with the zinc available for dissolving gold.

Summarising his views, he expressed the opinion :—

(1) That mill-solutions will give equally as good extraction as purer solutions, but they require some 10 per cent. longer contact with the ore.

(2) That mill-solutions will give the same extraction as pure solutions, with about 25 per cent. less consumption of cyanide.

(3) That the lower consumption is probably in part due to the mixed cyanides in mill-solutions being less sensitive to cyanicides; and partly to the potassium, sodium, and other cyanides regenerated after the zinc is precipitated in the ore.

Mr. Argall also points out that solutions rich in gold precipitate far more readily than weak ones, other things being equal. When the solutions carry over 1·5 oz. per ton, the gold on the shavings presents a yellow colour; and if the solution contains over 2 oz., the shavings in the first compartment of the zinc-boxes assume a golden-yellow tint, shading off in the following ones to the usual black-coloured deposit that collects on the zinc in ordinary precipitation from poor solutions.

The essential conditions for good precipitation, Mr. Argall adds, are: 1st, Clear solutions; 2nd, *moderately* alkaline solutions containing *free* cyanide of potassium; and 3rd, boxes properly packed * with zinc, and frequently cleaned up (cleaning them up completely once a week), so as to keep them free from deposits of lime, manganese, and other substances that are apt to deposit on them. Lime judiciously used helps to keep the solutions free from accumulations of metallic salts, whilst matter in suspension can be got rid of by the use of settling-tanks, from which the solutions can be conveniently distributed to the zinc-boxes.

Early experiments with amalgamation, concentration, and cyanide treatment on Kalgoorlie ores do not appear to have met with much success; for example, in an interesting article in the *London Mining Journal* of October 5, 1901, on Telluride Treatment

* "When properly packed the shavings will occupy but 3 per cent. of the space, leaving 97 per cent. interstitial space for passage of solution," provided the shavings are pressed down evenly with some little force. To an experienced eye the evolution of hydrogen from the solution passing through the boxes clearly indicates the condition of the precipitation, but continuous samples of the solutions entering and leaving the boxes should be taken and assayed every 12 hours. The shavings should be in as fine threads as possible having sufficient substance to hold together, and not break in handling.

at Kalgoorlie, it is stated that Mr. Scrymgour, a local chemist, made, amongst hundreds of others, the following tests :—

No. of Test.	Value per ton of Ore.	Mesh.	Amalgamation. Per ton.	Amalgamation. Percentage Saved.	Concentration. Average Weight Saved.	Concentration. Value.	Cyanide. Residue.	Cyanide. Tailings.	Cyanide. Percentage Saved.
	oz. dwt. gr.		dwt.			oz. dwt. gr.	oz. dwt. gr.	oz. dwt. gr.	
1	7 11 6	900	8	5·29	6·17	31 2 6	5 17 0	2 9 12	57·70
2	7 11 6	1600	9	5·95	4·54	43 2 0	5 7 0	2 13 12	50·92
3	7 11 6	900	7	4·62	9·74	19 12 12	5 2 12	2 11 12	49·76
4	7 11 6	1600	11	7·28	7·17	28 10 0	4 18 12	2 14 0	45·18

The average total extraction of the four samples was :—

	Per cent.
Amalgamation (10 dwt. saved)	6·67
Concentration	22·20
Cyanide, an extraction of 50 per cent. from at the most 82 per cent. of original weight of ore as tailings .	28·70
Total extraction . .	57·57

In the above tests, 6 days' treatment with cyanide was given.

I may preface a brief description of the four processes which are at present being applied to the treatment of the Kalgoorlie ores on a working scale by a few further particulars of what has been more recently done in an experimental line, which will serve to explain the principal mechanical and chemical difficulties that metallurgists have had to face, and how they have been surmounted.

One of the chief mechanical troubles referred to results from the character of the ore, and to illustrate this it may be mentioned that a sample of sulphide ore,* when ground in a ball-mill to pass a 30-mesh sieve, gave 22 per cent. retained on a 40-mesh, and 49 per cent. which passed a 90-mesh screen; when ground to pass through a 60-mesh sieve, 24 per cent. was retained on a 90-mesh, the balance passing through; the finest portions were found to assay highest, which is not a matter for surprise.

It may consequently be inferred, from these and other similar tests, that owing to the concentration of the extremely friable tellurides in that portion of the sample which will pass a 90-mesh sieve, when telluride ores are dry-crushed *fine*, the "dry slimes"

* 'Notes on the Treatment of Kalgoorlie Sulpho-Telluride Ores,' by Alfred James, *Trans. Inst. Mining and Metallurgy*, vol. viii.

(dusts) will be richer than the "sands," and will consequently require extra careful handling to avoid loss.

An amalgamation test made by Mr. Alfred James on raw, finely-ground sulpho-telluride ore (slightly oxidised), containing about 12 per cent. of pyrites and 0·03 per cent. of tellurium, showed that only 20 per cent. of the gold was recoverable by ordinary amalgamation; but by roasting the ore and treatment in pans, the extraction was increased to 44 per cent., preliminary treatment with strong alkali, and also with nitric acid (with a view to dissolve any tellurous acid coating from the gold) failing to improve the extraction. Mr. H. L. Sulman has remarked,* however, that any such coating would probably consist of tellurite of iron, and if treated with hydrochloric acid experimentally, it could be readily rendered amalgamable.

In consequence of the volatile nature of the tellurium minerals, it seems surprising (even assuming there is no salt present) that a number of experiments carried out by Mr. James showed that roasting could be conducted with practically no loss of gold, except what is mechanically carried away in the dust (amounting, I believe, sometimes to as much as 2 per cent. of the ore, or more) † which is caught in the dust-chambers; this fact is, however, confirmed by the experience of Mr. Ph. Argall. ‡ The loss in weight due to roasting was found in some tests made by Mr. Alfred James to amount to about 4 per cent., § but is liable to vary with the nature of the ore. Ordinary mechanical concentration presents the difficulty of saving the rich, finely-divided, flaky tellurides, that are carried into the tailings, and this necessitates their subsequent treatment by an auxiliary process,‖ to recover the gold in the mineral that escapes; but where the tailings are subjected to further treat-

* Discussion, *op. cit.*

† Mr. T. A. Rickard points out ('The Telluride Ores of Cripple Creek and Kalgoorlie,' *Trans. Am. Inst. of Mining Engineers*, vol. xxx.), that in roasting these ores the tellurium is not driven off with the sulphur, but as soon as it has volatilised it becomes oxidised to TeO_2, and is fixed in the roasted charge by combining with the oxide of iron, due to the calcination of the pyrites in the ore, tellurite of iron being formed. What tellurium does escape is carried away mechanically by the draft, and is found in the flue dust. Laboratory tests made by Mr. Richard Pearce showed that as much as 96·4 per cent. of the tellurium remained in Cripple Creek ore, after roasting.

‡ *Op. cit.*

§ It is stated that the loss in weight by roasting at the Great Boulder Main Reef amounted to from 10 to 12·5 per cent. *The London Mining Journal*, Oct. 12, 1901.

‖ Mr. Trewartha James, M. Inst. M.M., has stated, that at Hannan's Star they succeeded in concentrating upwards of 40 per cent. of the total gold contents of a sulphide ore, of less than 1 oz. value per ton, into 4 per cent. of the original bulk. *Trans. Inst. of Mining and Metallurgy*, vol. viii. p. 501.

ment (as in the Diehl process) this is not a matter of serious moment. It was also found by Mr. James that the removal of the concentrates (16 per cent. of which carried 23 per cent. of the total gold) did not render the tailings any more readily amenable to ordinary cyanide treatment.

Ordinary bottle-tests which Mr. Alfred James made on raw ore, employing ordinary cyanide, showed an extraction of 60 to 77 per cent., with 16½ hours' agitation, and the residues of the 60 per cent. experiment, when roasted, yielded a further extraction of 33 per cent.; total, 93 per cent.

By percolation of the raw ore with cyanide solution, and double treatment for ten days and seven days respectively, 81 per cent. was extracted altogether, but at the cost of a heavy loss of cyanide, mainly due to the large percentage of copper (0·029 per cent.) and iron (0·04 per cent.) taken up by the solution; and all Mr. James' experiments went to show that fine grinding (to pass a sieve of 8100 holes per square inch) was essential to success, together with subsequent agitation, or intimate contact with the solution.

The deductions drawn by Mr. James from these experiments are:—

(1) * "That agitation of the finely-ground raw ores with ordinary cyanide solutions should be effective for ores containing even large quantities of sulphides," provided they carry but a fractional percentage of tellurium, and of a value of 1 oz. of gold or under, as, with ore of this value, high percentage extractions are not of such moment as low working costs.

(2) "That still lower-grade ores could be profitably treated by percolation, with re-treatment, provided it is found feasible in practice to keep the cyanide consumption, due to the copper and iron, at a low point, as, for instance, by the use of dilute solutions." This was aided by employing the system (without the air) adopted for treating the South African spitz-concentrates which contain about 7 per cent. of sulphides; freshly precipitated lead salt being added to counteract the retarding action of the soluble sulphides formed, that result from the effect of the alkaline solutions on the pyrites or other sulphides, during the long treatment necessary.

A further set of experiments, carried out by Mr. Alfred James

* This conclusion is criticised, p. 497, *Trans. Inst. of Mining and Metallurgy*, vol. viii., but the success of the Ivanhoe process would seem to confirm it, in a large measure, if the sulphides are not in *excessive* amount.

on ores containing a higher percentage of tellurium, went to prove that the results obtained depended on the amount of gold-carrying telluride, as contrasted with the iron pyrites present; and also on the hardness of the vein-material; whilst, speaking in general, they showed that sulpho-telluride ore of this class either required roasting, or else finer grinding, combined with the employment of an "accelerator" and agitation.

The blowing of air into the vats between the filter-bottoms did not appear to hasten or improve the extraction, on either raw or roasted ores, provided the solutions were circulated with ordinary rapidity; the advantages claimed for the Kalgurli method of treatment (see note, p. 357) are of interest in this connection.

If the method adopted for the extraction of the gold from the richer class of ores be that of employing an "accelerator" (in the shape of, say, bromo-cyanide), the chief point necessary to secure success, so far as extraction is concerned, seems to be *fine* preliminary grinding, as Mr. James observes that in comparative trials on raw telluride ore ground to pass a sieve of 14,400 holes to the square inch (120 mesh) * bromo-cyanide (0·4 cyanide solution + 0·04 bromo-cyanide) extracted 91·5 per cent. in a treatment of 23 hours, the final residues assaying 11 dwt.; † whilst with ore ground to pass a sieve of only 1600 holes per square inch, bromo-cyanide failed, with similar treatment, to extract more than 78 per cent.

It would appear from Mr. James' experiments that the consumption of cyanide is rather less with bromo-cyanide than in the longer treatment with simple cyanide, an advantage which is, unfortunately, more or less neutralised by the extra cost of bromo-cyanide. He remarked, however, "It is evident from the above results that even without the separate treatment of the concentrates, Dr. Diehl may be able, with a very fine grinding (120 mesh) and agitation with bromo-cyanide, to obtain the 90 per cent. extraction on this ore (Hannan's Star), as claimed by him." This claim has since been practically demonstrated.

There is, however, the important question yet to be settled, whether the Diehl process can reduce the tailings of high-grade ores carrying tellurides in considerable quantity, in all cases, to as

* Mr. H. L. Sulman observes that Mr. J. K. Wilson's experiments prove that reduction to 150 mesh is sometimes necessary for direct extraction. *Trans. Inst. of Mining and Metallurgy*, vol. viii. p. 512.

† The residues could not be lowered further in value, and treating a similar sample of the same ore with plain cyanide, after four treatments of 23 hours each, an extraction of 68 per cent. only was got, the residues still carrying over 2 oz.

low a point as those yielded by the Boulder Main Reef process,* at a cheaper cost. This, as Mr. James points out, with low-grade ores of under 1 oz. in value, is not of considerable moment,† but becomes of importance with richer ones.

This factor in the question explains why concentration would appear to be an important feature of the process proposed by Dr. Diehl, since apart from other reasons calling for it, the elimination of the rich and refractory long-treatment product (which can be set aside to be dealt with by some suitable method) would certainly seem likely to simplify the problem of treating the remaining pulp by this method.

It is true that great difficulties have hitherto been met with in concentrating tellurides in many cases. For example, it is stated in the article in the *London Mining Journal* of October 5, 1901, previously quoted, that the milling of telluride ores in Boulder County, Colorado, in the early seventies, was not a success. At the Savanne mine, Jackfish Lake, Western Ontario, Canada, not more than 30 per cent. of the value was obtained from the 10-stamp mill; whilst at the Dalton Mine, Utah, less than 50 per cent. of the value was recovered. The Peck mill erected on Stratton's Independence, Victor, Colorado, was specially designed, and erected at a cost of 20,000*l.*, to concentrate telluride ores, but it only worked long enough to prove its uselessness.

These facts do not, however, prove that, under other and more favourable conditions, "mechanical concentration" may not be successfully applied in certain cases (as at Kalgoorlie) *as an auxiliary method* for the treatment of telluride ores ‡; indeed, it is now being so employed at Kalgoorlie, but everything depends, of course, on the method adopted and the class of concentrating machinery employed.

The use of bromo-cyanide, judging from Mr. Alfred James' experiments, in some cases at any rate, does not seem to have a proportionately accelerating effect in dissolving out the gold in these Kalgoorlie ores *when roasted*, as compared with its action on

* Mr. H. L. Sulman suggested that the high residues in some of Mr. James' laboratory experiments might have been due to the ore not being ground sufficiently fine; but there must necessarily be a limit of fine grinding *on a large scale*, on account of the expense, and the difficulty of "screening it." Discussion, *op. cit.*, p. 512.

† Owing to the comparatively high cost of bromo-cyanide there is necessarily a limit to the use of this reagent with ore below a certain grade.

‡ Mr. Alfred James remarks in *Cyanide Practice*, 3rd edition (1903), "Concentration has most unmistakably loomed prominently forward during the past year, as a factor bulking largely in future cyanide practice," (3p) 17.

the unroasted telluride ores, its effects upon which appear, in this respect, very strongly marked.*

It is this special feature which appears to be the strong point about the Diehl process, as by avoiding dry crushing and roasting, expenses are saved which form very heavy items in the working costs of the Boulder Main Reef process and other proposed methods of treatment, whilst it opens the possibility of utilising "wet stamps" (which have generally proved to be the most economical kind of crushing machinery); and thus saving some of the batteries, which have cost a lot of money, from ultimately becoming valueless. In fact, as a rule, a wet process is, for many reasons, preferable to a dry process.

A difficulty, however, that may arise, to which Mr. A. C. Claudet has drawn attention,† is occasioned by the fact that if the telluride of gold be attacked by cyanide, tellurium will go into solution with the gold and may cause trouble in refining the zinc precipitate. Mr. H. L. Sulman expressed the belief,‡ however, that this is more or less overcome in practice, and that the tellurium in solution as a soluble tellurite can be gradually eliminated from the working solution, as an insoluble compound, probably as tellurite of iron.

The advocates of dry crushing and roasting, it must further be pointed out, have demonstrated that they are able, with the Boulder Main Reef process, to deal successfully (possibly, in some instances, better than by any other system) with the richer sulpho-telluride ores, using merely ordinary cyanide, with pan-grinding and amalgamation; the need for employing this latter auxiliary depending on the nature of the gold in the roasted material.

Owing to the fact that the ores *after roasting* contain a large percentage of soluble salts, which involve a wasteful consumption of cyanide in the Boulder Main Reef process, it was found necessary, before cyaniding them, to wash out these objectionable compounds as far as possible by pan-grinding and filter-pressing the roasted ore, as a preliminary step; but spitzkasten have now generally taken the place of presses.

* Mr. Ph. Argall, M. Inst. M.M., states that he has found the calaverite and sylvanite in the Cripple Creek ores are almost insoluble in 0·5 ordinary cyanide solutions (*The Mineral Industry*, vol. vi.); and Mr. Sulman confirms this (*Trans. Inst. of Mining and Metallurgy*, vol. viii. p. 498), but remarks that the former mineral is easily soluble in bromo-cyanide; Mr. Henry Cassel has also stated that experiments made by him show that sylvanite will not go into solution, unless decomposed by roasting. *Op. cit.*, discussion, p. 508; Mr. H. Knutsen states that coloradoite is easily attacked by KCy, but so far as I am aware, no experiments have yet been published showing to what extent other tellurides are relatively acted upon by bromo-cyanide.

† Mr. James' paper, *Op. cit.*, discussion, p. 507. ‡ *Ibid.*

Mr. Alfred James found by experiment that after roasting no benefit was gained, but rather the reverse, by extending the leaching time beyond a certain limit, although the tailings still carried high values; and this led him to the conclusion that practically the whole of the gold that had not been extracted was in the *coarse sand residues*; consequently, as might be anticipated, by grinding these residues finer, a much better and quicker extraction was obtained, and Mr. James mentions a case in which the "slimes" of a 6-oz. ore, after being subjected to only three days' cyanide treatment, were reduced to under 2 dwt.

He goes on to add: "It was thus clearly shown that, given roasting and sliming, even rich ores could be readily and rapidly treated (with ordinary cyanide), provided mechanical means were adopted to overcome the difficulty of leaching a mass of slimes." In all the tests he made, the "agitation" method, it may be remarked, showed much higher results than "percolation"; and he describes one most interesting experiment, viz. the treatment of a roasted sample of ore, which gave an extraction of 88 per cent. in 16 hours simply by agitation, and 96 per cent. when the treatment was prolonged to 41 hours. The residues from a previous (raw) agitation test when roasted and ground to pass a 90-mesh sieve, and amalgamated, yielded 19 per cent., and the subsequent cyanide-treatment of the pan tailings returned 71 per cent. additional. The final residues of an ore which originally assayed 7 oz. were thus brought down to 2¼ dwt. As already remarked, pan-grinding forms a most important feature of the Boulder Main Reef process. Its special functions are:—

1. To slime any coarse particles of roasted ore.

2. To rescue by amalgamation any coarse gold (such as often "sweats" or "blisters" out, in partially-fused globules,* in roasting tellurides,† if the furnace temperature rises above the melting-point of tellurium), which, provided proper precautions are taken, is readily extracted by amalgamation and is unsuitable to cyanide treatment; it being most important to prevent any coarse particles finding their way into the filter-presses.

3. To thoroughly levigate and leach out the abnormal quantity

* Mr. Alfred James points out that some coarse particles of gold are recovered from the pans with the mercury, that have not amalgamated properly. *Trans. Inst. of Mining and Metallurgy*, vol. viii. p. 509.

† Ores containing "selenide of gold," like the ore of a mine in Shoshone County, Idaho, are said to act in the same way. 'The Amalgamation of Free Milling Gold Ores,' by Louis Janin, Jun., *Mineral Industry*, vol. iii. p. 345.

of soluble salts that are present in the roasted ore, before the pulp passes to the filter-presses. The proportion of pans needed is stated to be about 1 for every 10 tons of roasted ore or concentrates treated.

The strong points of the Boulder Main Reef process appear to lie in its almost certain and complete extraction of the gold from high-grade ores, if the roasting and other branches of the process be properly conducted; *assuring* low-grade tailings; whilst a large percentage of the gold is recovered right-away by amalgamation; consequently, as Mr. Von Gernet, M. Inst. M.M., has pointed out,* the cyanide liquors are comparatively poor, and have not got to be handled with such extreme care as when dealing with very rich ones.

In all cases where roasting forms part of any metallurgical process, the ore obviously needs to be crushed dry; a point which there is *special* need to emphasise in this instance, as otherwise, owing to the presence of salt (chloride of sodium) *in the water*, the gold would be partially chloridised, and enormous losses would be incurred in roasting through volatilisation. It is not by any means unlikely, notwithstanding what has been said on p. 314, that certain losses do in fact arise from this cause, in roasting these Kalgoorlie ores, even when dry-crushed, as there must be a small amount of chloride of sodium in the moisture, in the ore in most cases.

In this connection, the results of some interesting experiments will be found in the *London Mining Journal* of October 5, 1901.

On p. 1237 it is stated that a well-known London chemist found that, by roasting the ore alone at a very low temperature, it could be done with a loss of 8 per. cent. of the bullion. He next attempted to lessen this loss by roasting with a small proportion of powdered charcoal, but did not succeed in doing so. The same result followed roasting with crushed anthracite. In both cases, the loss of gold was greater than when the ore was roasted alone.

Three tests (made in October in the previous year) may also be quoted from the same article.

Test 1.—The ore assayed 5 oz. 7 dwt. 19 gr. per ton in gold, and 1 oz. 1 dwt. 5 gr. in silver per ton. This ore was dry-crushed, and roasted, reducing the sulphur to 1 per cent., with the loss of 0·36 per cent. gold, and 20 per cent. silver. Another portion of the sample was wet-crushed and roasted, and the loss was found to be 81·5 per cent. gold and 66·6 per cent. silver.

Test 2.—Ore assaying 7 oz. 11 dwt. 22 gr. gold, and 2 oz. 10 dwt. 11 gr. silver was, as in No. 1 experiment, dry-crushed and

* *Trans. Inst. of Mining and Metallurgy*, vol. viii. p. 498.

roasted with the loss of 0·7 per cent. gold and 31 per cent. silver. By wet-crushing and roasting, the loss was 79·16 per cent. gold and 89 per cent. silver.

Test 3.—This experiment was carried out upon ore having an assay value of 4 oz. 11 dwt. 11 gr. gold and 2 oz. 4 dwt. 2 gr. silver. Dry-crushing and roasting showed a loss of 0·4 per cent. of the gold and 20 per cent. of silver. A portion of the pulp was then crushed and mixed with distilled water, to which 0·05 per cent. of common salt had been added; and after roasting, a loss of 20 per cent. of the gold and 80·6 per cent. of the silver was shown.

The same article adds, "Cripple Creek tellurides are more volatile than the Kalgoorlie ores, but the latter milling ores are richer, averaging roughly about 30 dwt. as against 22 dwt. of the former."

The loss of cyanide due to the quality of the water used in making up the solutions is said * to have been another reason why ***ordinary percolation treatment after roasting*** was given up after trial at the Boulder Main Reef and other mines. "All the water on the field carries more or less sodium chloride; even that from Hannan's Main Reef, the purest water on the field, carried 4·75 per cent. and nearly 1 per cent. of magnesium sulphate. The chlorides contained in the water † decompose approximately 1 per cent. of their weight of KCy in making up solutions; or in other words, it represents a loss of 0·5 lb. of KCy for every ton of ore treated, reckoning about 2½ lb. per ton of water and 20 per cent. of the amount of water added for wash purposes.

"Another cause of the loss is the action of the atmosphere on the KCy solutions.

"This decomposition is much more rapid with salt water than with fresh. Prof. E. H. Liveing, at the Associated Mines, made the following experiments ‡:—

"Two basins, each containing 1 kilo of ·265 per cent. KCy solution, the one being filled with distilled water, and the other with

* *The London Mining Journal*, October 12, 1901.

† This statement is supported by W. W. Ince, F.I.C., who says: "Magnesium sulphate, and chlorides of magnesium and calcium in the presence of air and carbonic acid are direct cyanicides, and their removal is therefore of the greatest importance in cases where cyanide treatment obtains; for which purpose he proposed to use either sodium or potassium carbonate. 'The Treatment of Highly Mineralised Waters,' Report of Chamber of Mines of Western Australia, July, August, September 1902. Also a series of interesting experiments by Mr. G. M. Roberts at the Great Boulder, *ibid.*, September, p. 314.

‡ Experiments of a somewhat similar kind were made at the Great Boulder Perseverance in 1900, with solutions made up to a strength of 0·2 per cent. The available cyanide, it is stated, was completely destroyed by agitation with the salt water in two days, but a similar solution with lime-water added to it and left in an open beaker was the same as when first made up.—*Annual Report*, p. 8.

ordinary mine water, were exposed to the air with the following results:—

—	August 13.	August 14.	August 15.	August 17.
	per cent.	per cent.	per cent.	per cent.
Distilled water solution .	·265	·23	·18	·08 KCy
Ordinary mine water . .	·265	·23	·07	·04 ,,

"It may readily be imagined, what the loss would mean over an extensive vat area, not to mention the sump-vats and zinc-boxes, etc.

"With oxidised ores, there was scarcely any appreciable difference between distilled and salt water on the KCy solution, as the consumption of KCy on such ores was less than 0·5 lb. per ton of ore;" but doubtless the chief part of the loss in treating roasted ores, as already said, arises from the presence of salts formed in roasting, and from imperfect calcination of the furnace product.

Instead of being cooled on an ordinary cooling-floor, the roasted ore is usually dumped hot, either into a tank or, as used often to be done, into a V-shaped launder, through which it was sluiced to the pans. The principal object of chilling it suddenly is, it is stated, to break up the hard superficial coating of tellurite of iron that is liable to form on the particles of free-gold during roasting, which artificially "rusts" them, and prevents or at any rate retards amalgamation.

The difficulty of percolating and filtering the solutions through ore ground as fine as is found to be necessary, has been met by the use of agitators and filter-presses, which are employed* in the same way as in the treatment of oxidised slimes described in the last chapter.

As pointed out by Mr. Alfred James, it must not, however, be supposed that because filter-pressing was reckoned† to have cost from 6*s.* to 8*s.* per ton, "double filter-pressing," as originally employed in the Boulder Main Reef process, doubled this item. The sum mentioned covered superintendence and settling solutions, 6·832*d.*; discharging and filling presses, 2*s.* 10·353*d.*; compressed

* Mr. J. K. Wilson expressed the opinion that filter-pressing answered better than agitation in a vat for dissolving the gold, whether the ore is roasted or raw (in the latter case, because of the rapidity with which bromo-cyanide decomposes), since the solvent solution is brought into quicker contact with the ore in a "press" under pressure. *Trans. Inst of Mining and Metallurgy*, vol. viii. p. 499. The extraction of the gold-values from slimes that are partially oxidised or not excessively refractory takes place, it is said, in a period of about 20 minutes.

† *Trans. Inst. of Mining and Metallurgy*, vol. viii. pp. 490 and 515.

air, 9·663*d.*; zinc turning, 0·196*d.*; repairs, 3·037*d.*; assaying, retorting and melting, 2·956*d.*; zinc, 0·528*d.*; filter-cloth, 3·121*d.*; cyanide, 10·748*d.*; general stores and charges, 4·403*d.*; and electric light, 3·488*d.*; total, 6*s.* 7·325*d.*; whilst the "preliminary filter-pressing" is merely required to express the superfluous water carrying the soluble salts. When spitzkasten are used in place of presses for the removal of the salts in solution, the cost is of course merely nominal; but some authorities seem to have held the opinion that this may be partly off-set by saving in cyanide, due to the more thorough and rapid removal of the soluble salts in the press.

According to a statement furnished to Mr. Alfred James by Mr. J. K Wilson, of the Golden Horse-shoe, it appears that two men per shift and two presses will readily express the moisture of 100 tons daily, and that the extra cost should not add more than 1*s.* a ton to the cost of the subsequent leaching by filter-press; and the Author is personally informed that from 7*d.* to 1*s.* 4*d.* per ton will cover the cost of this branch of the work.

The removal of the soluble cyanicides, such as sulphate of magnesia and alumina, is of great importance; since not only are they liable to form hydrates, which interfere with the precipitation of the gold, but an enormous saving of cyanide * is thereby effected.

The actual consumption in the Boulder Main Reef process is stated to have been reduced from 3 to 1½ lb. per ton, and was reported to have been lowered in 1901 to slightly over a pound. A peculiar difficulty encountered in attempting to treat *roasted* ores by *percolation*, in the early days of the field, arose from the fact that the carbonate of lime † present in the ore is converted into sulphate by roasting with the pyrites, if the roasting temperature does not exceed 500° F. (260° C.),‡ and this anhydrous sulphate of lime when wetted forms plaster-of-Paris, which causes the contents of the vats to swell, not only rendering percolation difficult, but, if left long enough exposed to this action, in some cases actually setting so hard as to require the use of wedges and even pickaxes to remove the tailings from the tanks; the usual method being to undercut, and pinch the blocks down. This

* Prof. E. H. Liveing, A.R.S.M., has stated that at some works the soluble salts caused a consumption of 10 lb. of cyanide per ton of ore treated; and it may sometimes run even higher.

† Mr. H. Knutsen observes that the finely crushed carbonate of iron with the carbonate of lime present in the ore, forms an "iron cement" which sets hard when wetted. *Trans. Inst. of Mining and Metallurgy, op. cit.*

‡ If heated to redness, it becomes denser, assumes a crystalline s ructure, and is said to lose the power of setting or solidifying. *Elements of Chemistry*, W. A. Miller, part ii. p. 469.

hardening is said to have added fully 6*d.* per ton to the cost of discharging the vats.

To get over this difficulty, attempts were at first made, I believe, to slake the plaster-of-Paris, by transferring the roasted ore from the "coolers" to a "floor," where it was watered with hoses, and turned over several times, ***before putting it in the vats***; but this required a great amount of labour, and was anything but satisfactory.

The weak points of the Boulder Main Reef process are the cost of dry-crushing, roasting and pan-grinding the ore; the mechanical rehandling it has to undergo; and losses that may be incurred in roasting, or through the ore not being properly roasted, which sometimes involved re-roasting it.

The Principles and Practical Application of the Boulder Main Reef Process.

This method of treatment has been called by Mr. James the "Marriner"* or "roasting and sliming process"; but it might perhaps be more fully described as the dry-crushing, roasting, pan-amalgamation and washing, or double filter-pressing (using ordinary cyanide) extraction process, in order to depict in sequence the essential features of this system of dealing with sulpho-telluride ores, which I will endeavour to describe in detail.

By dry-crushing the ore is ground fine and prepared for the furnaces. Roasting renders the gold susceptible to amalgamation and extraction by ordinary cyanide solutions; the pan treatment, as far as possible, slimes any coarse particles of ore carrying free gold, amalgamates gold of a coarse nature, or that may have assumed a lump-form by fusion in the furnace, and enables the soluble salts to be taken up into solution;† the first "leaching" in the filter-presses, spitzkasten, or agitating vats extracts these harmful soluble salts, and the second "leaching" with ordinary cyanide in "presses" dissolves most of the remaining fine gold. Considered as a whole, it therefore appears to be a method of treating sulpho-

* Mr. J. T. Marriner was the metallurgist who first applied it at the Boulder Main Reef Company's works.

† In this connection, Mr. S. Gilson, commenting upon the effect of "double filter-pressing," said: "It is found in practice that the consumption of cyanide (in the percolation process) is equal to 8 or 9 lb. per ton, which represents approximately 10*s.* per ton for cyanide of potassium alone. Also that occasionally, owing to a bad roast, salts form in the process of roasting, together with occluded reducing gases. When this occurs, the solvent action of the cyanide is greatly retarded." The "double filter-pressing" has for its object the elimination of these salts. The sulphates of iron and the sulphuric acid present due to the decomposition of the iron sulphates—the moisture in the hot ore supplying the hydrogen—decompose the KCy immediately.

telluride ores of this class which one cannot doubt is capable of achieving a high measure of metallurgical success, i.e. a high extraction, provided proper attention is paid in all departments to ordinary working requirements, whilst giving due regard to any chemical and mechanical modifications, which special circumstances may demand.

The Great Boulder Main Reef Sulphide Works.

The Author is indebted to the Company, for their courtesy in placing at his disposal the photographs from which the accompanying view of the works (Fig. 56) and the shaft furnace (Fig. 57) have been reproduced.

The earliest attempt made to treat sulphide ore in these works (from April to December 1899) is described in *The London Mining Journal* of October 12, 1901, and consisted in crushing the ore as it was delivered from the mine in a No. 3 Gates crusher (which worked only on one shift) to pass a 2-inch ring. From the storage bin the ore then went to a revolving drier, and from the drier it was raised by a chain and bucket elevator to another bin. The cost of drying in April and May 1899 is stated to have been 3·685*d.* per ton, and in the following June the practice of drying was given up, the ore being delivered from the storage bin of the stone-breaker direct on to a rubber belt, and thence to the hoppers of two No. 5 Krupp ball-mills. After leaving the ball-mills, the ore was raised to the top of the Richards' type roasting furnace (hereafter fully described) by a belt elevator, and after roasting, it was conveyed to a small room where it was damped and cooled, filled into side-tipping trucks, and trammed to the (eight) leaching vats 20 feet in diameter by 7 feet deep, in which it was treated with cyanide *by percolation*, and the gold was extracted in the usual manner in zinc extractor-boxes. The residues contained 20 per cent. of moisture. Difficulties arose, however, owing to the charges setting, and in other ways, and the extraction percentage was not increased, which led to the works being remodelled.

The average costs per ton from April to December 1899, during which time 12,210 tons are stated to have been treated in this manner, are given as follows:—

	s.	*d.*		*s.*	*d.*
Crusher	0	4·380	Smelting . . .	0	6·048
Ball-mill	1	5·819	Water and horse-hire	0	7·163
Furnace	6	6·167	Blacksmith . . .	0	1·042
Cyanide	9	4·145	Assays	0	1·665
Steam	4	2·378	Management . . .	0	5·793

Total average cost . . 1*l.* 3*s.* 8·6*d.*

The item cyanide includes various component costs. For instance, in September (1899) the consumption of cyanide is stated to have been 6720 lb., or at the rate of 4·46 lb. per ton, costing 4*s*. 8·73*d*.; chloride of lime, 5·94 lb. per ton, costing 1*s*. 0·74*d*.; zinc, 1·11 lb. per ton, costing 4·78*d*.; sundries costing 0·92*d*. per ton of ore.

To these items must also be added wages, as follows:—

Charging vats, 2*s*. 0·94*d*.; discharging vats, 1*s*. 0·47*d*.; treatment, 0*s*. 4·72*d*. per ton.

The furnace costs in September, roasting 1506 tons, were subdivided, I understand, as follows:—

—	Total Cost.	Cost per Ton.
	£ s. d.	s. d.
Wood consumed, 56 cords	61 12 0	0 9·81
Sundries	5 5 3	0 0·85
Wages	257 12 7	3 5·05
	324 9 10	4 3·71

In October 1899, 1255 tons are stated to have been roasted, at a cost of 4*s*. 3*d*. per ton, but it would appear that the average cost of roasting 12,210 tons amounted to 6*s*. 6·167*d*. per ton, as above.

The pioneer plant, afterwards designed and installed to carry out what is now generally known as the Great Boulder Main Reef process, also called the Marriner process, originally possessed a nominal capacity of about 40 tons a day (1200 tons per month); but has since been increased by the addition of five Edwards' roasters (three of which, I believe, started work at the beginning of April 1901), by which the capacity of the works was nearly doubled.

The crushing plant was the same as in the original mill and consisted of a No. 3 Gates crusher, which yielded a 1½-inch product; this was fed from a 200-ton bin below, by a Challenge feeder, on to a Robins' belt-conveyor which delivered it to two No. 5 ball-mills, from which the ore was elevated to the multiple-hearth Richards' type shaft-furnace; in addition to which the machinery included a tailings-wheel, six 5-feet diameter pans; filter-presses for leaching; four agitation-vats; two pressure-tanks; filter-presses for cyaniding; and zinc precipitation-boxes. In the period ending May 31, 1901, in addition to the Edwards furnaces, two plunger-pumps, and other necessary plant to deal with the increased output of the works was installed.

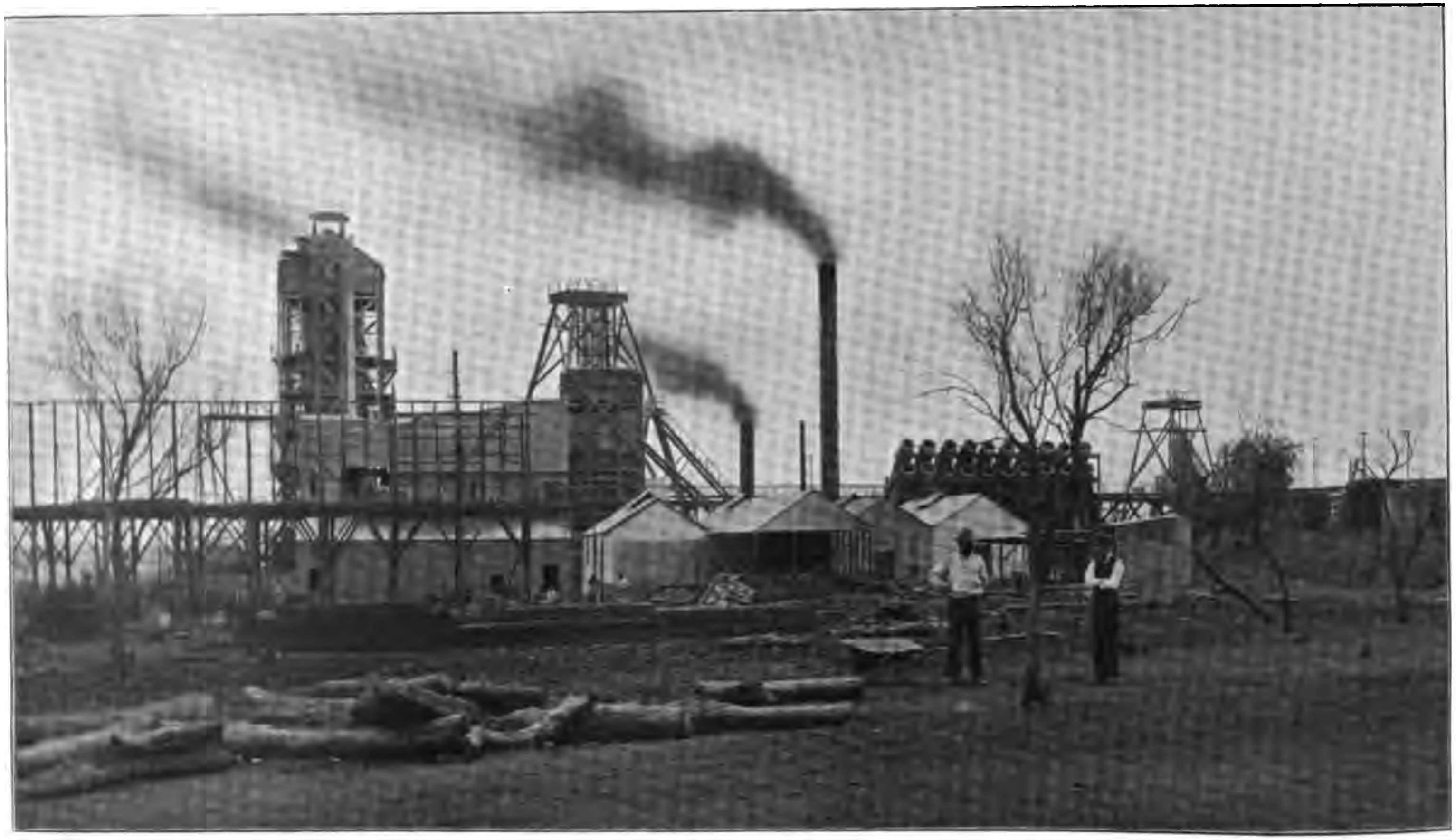


Fig. 56.—General View of the Great Boulder Main Reef Works.

Double Filter-pressing.—Formerly, after the sands had been roasted and slimed in the pans, the "pulp" was delivered to the first set of presses, and water was forced through the cakes of slime until the salts were washed out. The slimes then fell into a "mixer" and were agitated with cyanide solution; but spitzkasten are now employed to get rid of the soluble salts.

The Ball-mills are reckoned to have a capacity of about 30 tons a day each, crushing through a (900 per square inch) 30-mesh sieve Ball, and Griffin mills (which are also largely used), are generally preferred to rolls or Chilian-mills for dry-crushing at Kalgoorlie,* as they reduce the product when discharged to a much finer mesh in one operation.

The wear and tear on the balls is stated to amount to about 0·3 lb. per ton crushed, and with damp schistose ore about 80 per cent. of the product will pass through a 100-mesh screen whilst with dry quartzose ore, about 50 per cent. does so.

After the ore has been crushed, a bucket-elevator raises the ball-mill product to a point where, by means of an adjustable sliding door, it is split into two parts; one part passes down a shoot to a screw-conveyor, which delivers it through shoots to the Edwards' furnaces that were added to the plant, whilst the other portion is delivered to the boot of a second belt and bucket-elevator, by which it is raised to the feed-floor of the shaft-furnace

The Multiple-hearth Furnace (Fig. 57) is built on the lines of the Richards shaft-kiln erected at Mount Morgan,† in Queensland, with several (eleven) arched horizontal-hearths (resting on iron girders with an 18-inch web), superimposed vertically one above another. It is provided with one fire-place only, at the bottom of the shaft, and the hot air circulates backwards and forwards through flues at opposite ends of every alternate hearth, while the ore is allowed to bank up on each hearth till it forms a natural slope, off which it slides across the furnace, zigzagging from side to side (like in a shelf-kiln) till it reaches the bottom, where it is drawn out.

The furnace tower or shaft is 65 feet in height, and of rectangular shape, measuring 30 by 12 feet in horizontal section, with a fire-place at the bottom; and the ore, which is introduced at the top through a row of holes, by means of a screw-conveyor which distributes it over the whole length of the uppermost floor, starts roasting at a low heat, with a gradually increasing temperature;

* A discussion of this matter will be found in Chapter VIII., pp. 246–247.

† Particulars of this furnace are given by C. G. W. Lock in *Gold Milling*, p. 380.

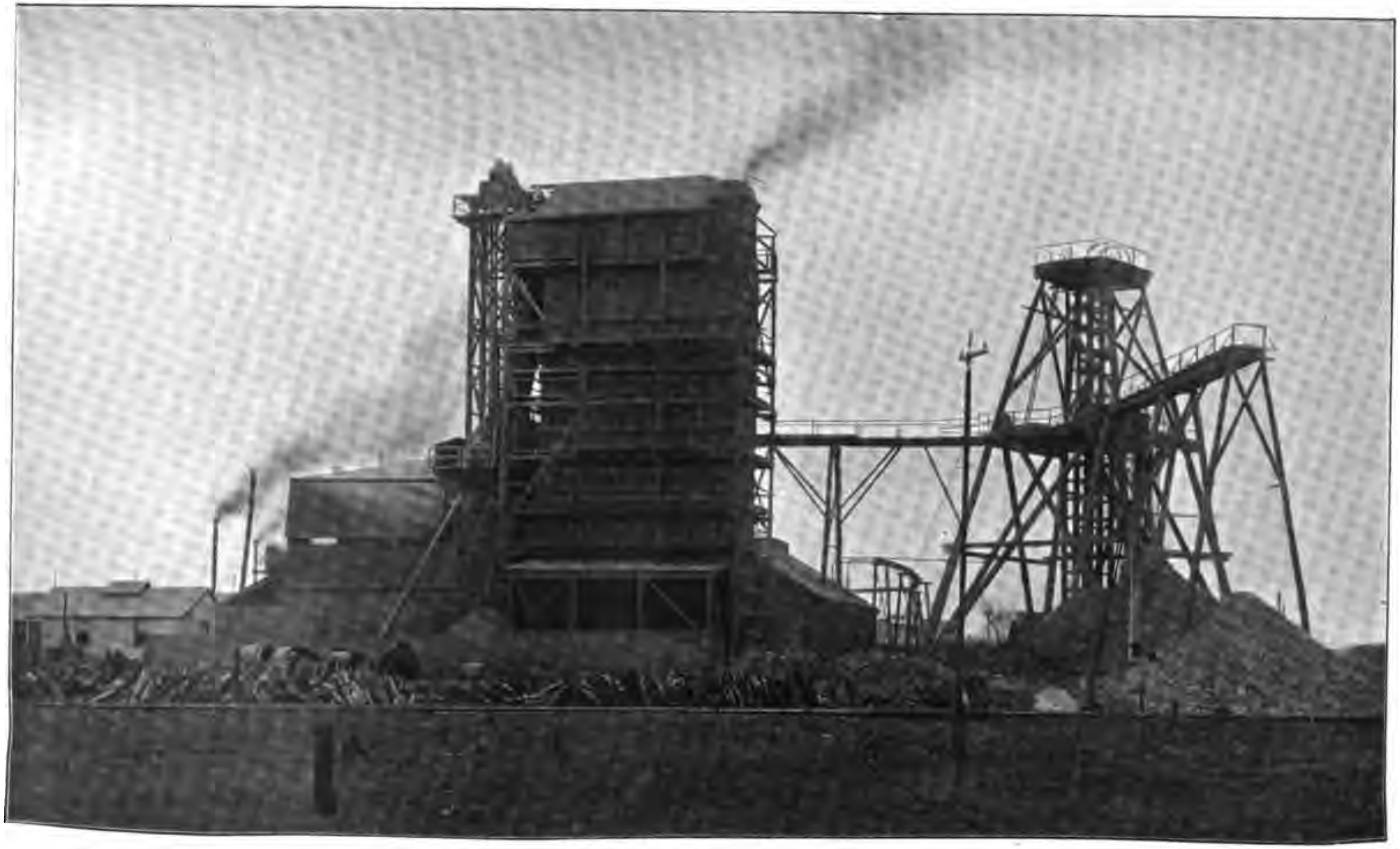


FIG. 57.—MULTIPLE-HEARTH FURNACE (ROASTING) AT THE GREAT BOULDER MAIN REEF.

a principle which is undoubtedly sound. This furnace is said to have cost 3700*l.* to erect. The fire-bricks used, which were all imported, had to pay a duty of 20 per cent.

The ore in its downward course is reckoned to travel some 200 feet, and it is claimed that the consumption of fuel is small as compared with other furnaces, which have several fire-places to a much shorter length of hearth. The escaping gases have a temperature, I am informed, of about 300° C. (572° F.). Its working capacity appears to be about 35 to 40 tons per 24 hours; whilst that of the Edwards' furnaces is reckoned at 12 to 15 tons per day each.

With wood fuel the consumption in the shaft-furnace is stated to be about 10 per cent., and that in an Edwards' furnace 15 per cent. of the weight of ore roasted. Mr. Robert Allen states that roasting causes a loss of weight of about 15 per cent. of the raw ore with a corresponding increase in assay value.

The chief difficulties in operating the furnace, if I am correctly informed, have been the tendency of the ore at times to stick on the shelves,* and the necessity of drawing it by hand off the bottom hearth, a contingency which was not contemplated originally; whilst at other times, a charge of "green" (unroasted) or partially roasted ore was liable to glissade and shoot down on top of the roasted charge in the lower part of the furnace. With the experience gained, these troubles seem, however, to have been overcome by structural alterations in the details of the furnace.

It is claimed, notwithstanding the difficulties that have been mentioned, that the multiple-hearth furnace has been one of the cheapest and simplest to operate of any on the "field"; and, taking into account the amount of labour and fuel which one might expect would be required to "sweet-roast" the ore, judging from the figures previously given, it seems not unreasonable to suppose that when run up to its full capacity the cost of roasting should not exceed 4*s.* 3*d.* a ton.

When discharged from the furnace, the ore is stated to be roasted down to about 0·8 per cent.† of sulphur, and is conveyed by a stream of "plant water" (forming a thin pulp) to a "tailings-wheel," which elevates it to a large spitzkasten, the object of which

* This difficulty was overcome, I understand, by piercing the walls of the furnace with three holes on each floor (12 inches square) and erecting stages or platforms outside, rom which the ore could be scraped down, but too much cold air was admitted in this way, and they had to be bricked up; internal alterations were consequently made in the furnace, and a dust chamber was built on top of it, raising it to 75 feet in height.

† A statement by Mr. Ed. Skewes to Mr. Henry Cassel, *Trans. Inst. of Mining and Metallurgy*, vol. viii. p. 509.

is partly to thicken the pulp, and partly to get rid of the soluble salts. The clear-water overflow is returned to a storage tank; whilst the underflow is divided by five jets into a slimes product and a coarse sands product.

The slimes product of the spitzkasten is pumped into four agitation-vats fitted with paddle agitators, each 21 feet in diameter and 6 feet deep, where, after the addition of the requisite cyanide, the pulp is agitated for eight hours; each of these vats holds about 20 tons of slime.

The sandy product of the spitzkasten is distributed between six 5-feet diameter Wheeler pans, which grind it finer, the gold being caught by the mercury charged into them; but no amalgamated copper-plates are used. The pans have a continuous overflow.

The Tailings-wheel and Pans need no special comment, except that I may mention, in connection with this part of the process, that the temperature of the water in the pans would seem to be a matter worth studying, since (to take merely two examples) it is well known that calcium sulphate is more soluble in water at 38° C. (100° F.) than it is in boiling water (150 gr. per gallon, or 2·143 grm. per litre, being dissolved at ordinary temperatures), whilst magnesium sulphate is soluble in three times its weight of water at 15° C. (59° F.) and in half that quantity at 100° C. (212° F.).

The temperature of the water in the pans appears, therefore, likely to materially influence the quantity of water required, and the rapidity with which the various deleterious salts are dissolved, depending upon the relative proportions in which they happen to be present.

Any coarse sands left after grinding in the overflow of the pans are separated by a spitzkasten, and returned to the pans for regrinding; whilst the slimes are pumped up to the agitation-vats, to be agitated with the other slimes.

The Agitators.—These are the only other part of the plant which needs more detailed description, and I may borrow the following particulars of their construction from Mr. James' "paper," which I have already quoted.

It may be observed that when old slimes are treated, these are broken up in a special tank called a breaker or mixer. It is about 4 feet deep by 5 feet in diameter, with a pierced (perforated) internal cone, fitted with a revolving blade or vane at the bottom. The pulp is thus drawn through the cone, past the rapidly circulating vanes, and discharged through an overflow at the side of the upper portion of the vat.

The agitators, before referred to, are much larger than this, running, as already said, up to 21 feet in diameter, and are provided with a vertical shaft (revolved by bevel-gearing at the top at from 5 to 10 revolutions per minute), carrying two sets of radial arms at the bottom. Agitation continues for 8–12 hours or more, depending on the capacity of the agitators and filter-presses. The KCy solution is strengthened in the agitators and brought up to normal strength by the addition of KCy. The liquor, after agitation has ceased, can be decanted or allowed to flow to the pressure tanks with the slimes. "Other methods of agitation that might be employed for the same purpose are a swiftly-revolving pipe, of say 18 inches diameter, filled with internal helical-curved vanes, which force all the pulp against an iron plate on the bottom of the vat. Another most efficient method is to use a centrifugal pump."

After treatment in the agitation-vats is complete, the (slimes) pulp is drawn off into one of two montejus, and then filter-pressed in four Dehne presses, holding about 3 tons 15 cwt. each. The issuing gold solutions, after passing through an additional press, to clarify them, are led into three zinc extractor-boxes. About 90 per cent. of the gold recovered is stated to be obtained by cyanide, the remainder being caught in the form of amalgam. By the addition of the new furnaces, etc., the capacity of the plant was gradually raised up to between 1800 and 2100 tons per month, in 1901.

Particulars of cost and extraction results are given on pp. 342–3, and in the supplementary tables, pp. 434–435.

The Great Boulder Sulphide Works.

The accompanying views of the works, Figs. 58, 59 and 60, are reproduced from the *Colonial Mining News* of May 1, 1902, by the courtesy of the proprietors of the paper.

This mill, which was the next to be erected, is an excellent example of the type under review; and the following particulars are excerpt from description given by Mr. Robert Allen,* and more recently by Mr. G. M. Roberts, in the Reports of the Chambers of Mines of Western Australia, July, August and September 1902.

The ore starts by being hand sorted, 3 to 4 per cent. of the mine-ore being thus eliminated, whilst the balance is crushed to

* *Op. cit*, Royal Commission, Glasgow.

2-inch size, in a No. 5 Gates breaker, "D" type,* the product of which is passed through a trommel with 1 inch diameter perforations. The coarser portion of the ore which this trommel rejects is then delivered by a pair of grasshopper conveyors with adjustable discharge doors, 6 feet apart, and distributed over a 500-ton bin supplying three No. H Gates fine breakers, which are fed by means of automatic Gates roll-feeders; these can each crush about 100 tons per diem to 1 inch size.

The product of the fine-breakers is then carried to the Griffin

FIG. 58.—THE GREAT BOULDER SULPHIDE MILL.

mill-bin by two 14-inch Robins' belt conveyors,† and distributed over it by grasshopper conveyors, whilst "the fines" from the trommel, if dry, are taken by a 14-inch belt conveyor direct to the same bin. If wet, however, they are first dried by being passed through a Howell-White drier, and are afterwards elevated to the bin. The ore, it may be mentioned, contains on the average some 3 per cent. of moisture, and, if it do not exceed this amount, does

* The capacity of this machine is 170 tons per eight hours, and it is fitted with a manganese-steel mantle, the life of which is said to be three times as great as the ordinary chilled solid head.

† One horizontal, the other set at an angle of 21°.

not require drying for dry-crushing. Very wet ores, containing up to 10 per cent. of moisture, are stored in a paddock, where they serve as a reserve, and the surplus moisture dries off in the sun. Shoots from the Griffin mill-bin lead to ten hoppers, fitted with automatic feeders, by which the ore is fed to ten * Griffin mills.

Each Griffin mill requires 20 to 25 horse-power and has a capacity of 26 to 30·5 tons per diem; crushing through 15-mesh woven-wire cloth, according to the character of the ore, 75 to 85 per cent. of the product will, it is stated, pass through a 120-mesh screen, and crushing through 18-mesh, 75 per cent. will pass a 150-mesh screen. The cost of crushing in these mills, based on 60,396 tons crushed, is given by Mr. Roberts as 2*s*. 10·631*d*.†

The Griffin mill dies are usually turned partly round four times before they are worn out; the wear and tear is about 13 oz. of metal per ton of ore crushed; the cast-iron bottoms, which weigh about 2 tons and cost 70*l*. each, are protected from explosions of small pieces of dynamite that occasionally get into the ore by a false bottom of $\frac{1}{16}$ inch wrought-iron plate.

Dust from the mills is drawn off by a fan and collected in a large settling chamber, from which it is withdrawn at intervals and roasted.

Screw-conveyors carry the ore as it is crushed to a double push conveyor, 190 feet long, with scrapers 12 inches apart, by which it is distributed through a series of 4 by 3-inch shoots to twelve ‡ Edwards' roasting furnaces, fed by Ridgeway patent feeders, which Mr. Roberts describes.

The Edwards furnaces have each a capacity of 12 tons per diem, if fired with wood, or 15 to 17·5 tons when fired with gas. Each is essentially a box-girder, lined on the inside for the greater part of its length with common brick, but with fire-brick at the bridge end. It is supported on the cantilever principle on a pivot at its centre, and, by means of a screw-jack at the discharge end, the inclination of the hearth can be adjusted, in practice being usually set at about 15 inches on its total length, i.e. 64 feet; § its inside width is 6 feet 6 inches.

The ore is stirred and carried forward in each furnace by fifteen

* Two additional mills were erected in 1902, and were running in December.

† Made up of labour, 4·885*d*.; oil, 0·265*d*.; power, 1*s*. 3·736*d*.; maintenance (labour), 4·718*d*.; duplicate parts and stores, 9·027*d*.

‡ In a letter dated Kalgoorlie, November 2, 1901, the correspondent of the *Financial Times* said that six furnaces were to be added to the plant, increasing the furnace capacity 50 per cent., and he anticipated that it would result in "a higher extraction with a decrease in costs." It would appear, from later information, that the output should be increased thereby to the extent of about 70 tons per diem, *vide* footnote, p. 342.

§ The dimensions of the Brownhill furnace are given by H. Knutsen as 60 feet by 6 feet, with six to eight rabble arms cooled by a water-circuit.

rabbles, the arms of which are at right angles to shafts passing through the roof of the furnace. The shafts, actuated by bevel gearing externally, rotate alternately in opposite directions, and absorb about 1 horse-power per furnace.

The first thirteen rabbles rotate at the rate of 1½ revolutions, the fourteenth at 4 revolutions, and the fifteenth or discharge rabble at 6 revolutions per minute.

FIG. 59.—THE SULPHIDE PLANT IN COURSE OF ERECTION, EDWARDS' FURNACES AND PANS.

The first ten rabbles consist each of a blade at right angles to the rotating shaft. They were in use ten months without needing repair.

The last five rabbles are each carried by a water-jacketed carrier, the rabbles sliding on the carrier; the wear and tear, which is extremely small, is confined to the lower end of the furnace, the worn-out castings being replaced by new ones cast on the mine.

The wood fuel burnt amounts to 15 per cent. of the weight of the ore, some of the furnaces being fired with wood; the others are, however, fired by producer-gas, made in three Dowson producers of cylindrical type (15 feet high by 6 feet in diameter) fed by bell-hoppers, with a mixture of Collie (Western Australia) and Newcastle (New South Wales) coals, equal parts giving good results. A mixture of Newcastle coal and saw-dust has been found, however, to answer even better. The necessary air for combustion with the gas is introduced by a Sturtevant fan, which in the absence of a gasometer, forces it into the furnace under slight pressure.

Screened Collie coal (free from dust) can be used alone, but unscreened requires an admixture of some Newcastle with it. Collie coal costs about 32*s.* per ton; Newcastle costs from 58*s.* to 60*s.* per ton on the mine.

For producer-gas, 8 cwt. of Newcastle are equivalent to about 15 tons of Collie coal, so that having regard to their relative price and efficiency their value is about the same. It was proposed to introduce automatic feeders in connection with the producers.

The producer-gas was formerly led direct to the furnaces, but coolers and washers are to be erected to extract the ammonia from the gas, and prevent the accumulation of pitch and tar in the pipes. The gas is delivered to each furnace at the feed-end by a 6-inch pipe, from a 20-inch galvanised iron main, and distributed by smaller piping to any desired point in the furnace.

By the introduction of gas-firing the capacity of each furnace is said to be increased 20 per cent.; a considerable economy was effected in labour and fuel, and it was anticipated that the roasting cost would be reduced from 4*s.* 6*d.** to 3*s.* per ton.

In roasting, the ore loses in weight about 6 per cent., with a corresponding rise in assay value. When roasted it contains about 0·16 per cent. of residual sulphur as sulphide, and 2·5 per cent. as sulphate, though these percentages are liable to vary slightly with the nature of the ore, and its rate of passage through the furnace.

At the discharge end of the furnace, two push-conveyors feeding two cross push-conveyors carry the ore to two Krupp chain and bucket elevators, which raise it to two closed-in "mixers"; a sample of the ore is cut out by means of a pipe, at the discharge end of the elevators. The mixers are each 4 feet in diameter, and 2 feet deep, fitted with suspended paddle agitators, consisting of

* Based upon a 12 months' run the costs given by Mr. Roberts are:—Supervision, 0·857*d.*; attending and firing, 6·400*d.*; firewood, 1*s.* 5·316*d.*; maintenance, stores and labour, 1·763*d.*; circulating-water, 5·714*d.*; horse-power, 2·057*d.*; gas-generator coal, 1*s.* 2·644*d.*; attendance and firing, 4·876*d.*; total, 4*s.* 5·627*d.*

two arms at right angles. The dust produced in elevating the ore is exhausted by a Sturtevant fan, collected in a dust chamber, and trucked to the cyanide works.

Return water from the spitzkasten or any surplus liquor from the cyanide works introduced with the ore into the "mixers" forms a thin pulp with it.

From each mixer the pulp is delivered to six Wheeler-type 5-feet grinding and amalgamating pans without copper plates, which are employed to reduce the 20 per cent. of coarse material that escapes the Griffin mills to a still finer state of division and amalgamate the coarse gold. The shoes and dies are cast on the mine and last 12 to 16 weeks.

The pans overflow continuously, and each set of three pans was formerly connected with a large diameter "settler," in which the sliming of the ore was completed and any escaping amalgam was caught.

Between 30 and 60 per cent. of the gold recovered from the roasted sulphide ore is caught by amalgamation, and from 40 to over 65 per cent. by cyanide treatment subsequently, depending on the character of the ore. The pans are cleaned up fortnightly, employing a clean-up barrel, in which the amalgam is ground for 24 hours, discharged into a box, and "washed" over riffles.

About 98 per cent. of the pulp overflowing from the "settlers" would pass a 120-mesh screen, and the remainder a 100-mesh.

The settlers discharged into a dam, separated into five divisions (used in turn), holding 250 tons of slime, where the pulp was settled for thirty hours, when it was sufficiently compact to handle and truck to the cyanide works. The excess of liquor from the dams was returned to the mill, and contained the greater part of the soluble salts which are deleterious to subsequent cyaniding.

Instead of passing through the settlers, the pan-pulp now passes direct through a 12-inch by 12-inch iron launder to the pump-sump, and is raised by a pair of 9 feet by 2 feet 4 inches to 2 feet 10 inches stroke plunger pumps to a height of 45 feet and delivered to two distributing tanks. Each tank has four holes leading to four sets of classifiers, which deliver in turn to four spitzkasten. The classifiers separate any coarse sands or quicksilver that may have escaped the pans, and return them to be reground. The spitzkasten clarify the solutions, and thicken the pulp to a consistency of about 45 per cent. of solution and 55 per cent. of ore, and it gravitates to the cyanide plant; the overflow water being returned to the mixers.

The Old Stamp Battery (remodelled).

This forms a separate section of the works, and was formerly used for the treatment of oxidised ore (as described in Chapter VIII.), but has been employed till recently to crush raw sulphide ore. To avoid crushing telluride-ore, it was set apart for the treatment of low-grade stone. The ore, after it had been crushed in the rock-breaker, was reduced to pulp by the stamps (thirty in number), and the gold was caught by inside and outside amalgamation, employing 24-mesh screens in the mortar-boxes.

The issuing pulp was distributed between six Wheeler-type pans, from which it overflowed continuously into three large settling-pans.

Between 88 and 96 per cent. of the pulp escaping from the settlers would pass through a 100-mesh screen; it flowed over four sets of "canvas tables," which caught some 9 tons of concentrates per 24 hours. The tailings from the canvas tables were caught in one of three 700-ton dams, where they were settled, and the clarified water was returned to the battery.

These tailings, when sufficiently drained to be shovelled, were trucked to the cyanide works.

The concentrates from the "canvas tables" were dried in a cylindrical Howell-White dryer, and roasted in one of the Edwards furnaces, after which they could be treated in the same way as roasted sulphide ore.

The gold extracted by amalgamation from the raw sulphide ore varied from 30 to 40 per cent., according to circumstances, and from 26 to over 50 per cent. of the balance of the gold contents of the ore was afterwards recovered by cyanide.

Owing to the recent enlargement of the sulphide works this mill would, it was stated, be reserved in future entirely for the treatment of oxidised ore.

The Cyanide Works.

This department of the works (Fig. 60) is independent of the battery and sulphide plant, and was set apart for the treatment of (1) raw sulphide tailings from the settling dams of the battery, (2) roasted pulp from the sulphide works, and (3) oxidised slimes from the dump. The first was treated separately, but the other two were mixed and received the same treatment.

The oxidised slimes were so fine that about 93 per cent. would pass a 120-mesh screen.

The capacity of the cyanide works is about 300 tons per day. As each truck of old slimes is received, it is dumped into a "vortex-mixer," fitted with a suspended agitator (propeller-shaped), and formed into a pulp, by mixing with a stream of cyanide liquor in the proportion of seven parts of slime to eight of solution.

From the mixer the pulp is raised by a 7-inch plunger-pump to one of two large storage tanks, 14 feet diameter by 16 feet deep, each holding 40 tons of slimes (net), one being formerly used for mixed oxidised and roasted ore slimes, and the other for raw sulphide ore slimes; the thickened pulp from the spitzkasten at

FIG. 60.—THE GREAT BOULDER CYANIDE PLANT (INTERIOR), FILTER-PRESSES AND AGITATORS.

the sulphide works is now, however, delivered to the storage tanks direct. Each is fitted with a suspended agitator to keep the pulp from settling.

From these storage tanks the pulp is drawn off into fifteen agitation vats, from 15 to 20 feet in diameter by 5 feet deep, driven by worm-gearing. Nine of these hold 20 tons net of slimes each, and the remaining six 30 tons each; lime is added to the slimes to neutralise any cyanicides.

If the material consists entirely of slime, 6 to 8 hours is generally sufficient agitation, but as some fine sand is frequently mixed with the "slimes," they are usually agitated for about 16 to 20 hours, the solution being strengthened up to 0·09 KCy.

The pulp, after treatment in this way, is delivered to the filter-presses by four montejus, each of 350 cubic feet capacity, two being used at a time, as they contain enough pulp to fill about three presses. This part of the plant contains four presses, which are of Dehne pattern, each holding 4·25 tons of raw ore, or 4 tons of roasted ore; and five Martin presses, each holding 3·4 tons of raw ore or 3·25 tons of roasted sulphide ore; all the presses make 3-inch cakes. The press is filled in about 15 minutes, the pressure running up to 75 lb. per square inch. After the charging valve is closed air is turned on for about two minutes to express the gold solution before washing, and washing occupies about 30 minutes. Three presses are filled, three are washed, and three are being emptied simultaneously, which requires five pairs of men.

The gold-bearing solution expressed is pumped up about 12 feet to a small tank, and after clarification in four Excelsior presses, is passed through a set of four ordinary zinc extractor-boxes, which are able to deal with about 200 tons of solution per diem.

Sulphuric acid treatment is used to clean the gold-zinc sludge, and a tilting furnace is employed to smelt the slimes, which are run into 400 oz. bars.

A Miller's chlorine plant has been installed to "part" the silver from the gold in the bullion.

The press-residues, which contain about 18 per cent. of moisture, after drying are hauled by horses in 25-cwt. trucks to a Lidgerwood "flying-fox," by which they are dumped; if they go to the stopes, they are given a final washing with salt water.

The extraction on raw (low-grade) sulphide ore is said to have varied from 86 to 90 per cent.; whilst on roasted ore (averaging about 30 dwt.) * and oxidised slimes, it has run from 93 to 94 per cent.

The total cost of extraction was formerly between 25*s.* and 26*s.* per ton, but has been gradually reduced, and the consumption of cyanide has fallen from 2·33 lb. of KCy in 1901 to 2 lb. per ton of ore treated.

The water used in the reduction works contains 7 to 13 per cent. solids, and has an alkaline reaction.

An analysis of a sample from the 1000-feet level in Lane's shaft,

* Mr. Roberts gives a more recent analysis (*op. cit*, August 1902) of an average sample of the Griffin mill product, which assayed 26 dwt. per ton gold and 19 dwt. silver. He estimates the extraction of the gold at 88 to 95 per cent. and the silver at 50 per cent.; the residues ranging from 1½ to 2½ dwt.

given by Mr. Robert Allen,* showed 7·20 per cent. of solids, made up as follows :—

	per cent.
Alkaline chlorides	5·675
Magnesium chloride	0·744
Sulphate of calcium	0·379
Oxide of calcium	0·402
	7·200

The presence of oxide of lime, Mr. Allen remarks, is possibly due to soakage from the settling-dams.

Mr. Alfred James states † that three-throw pumps, which are sometimes employed for filling the filter-presses, save cost of compressed air, but that the montejus tend to give better cakes; this appears to be owing to the fact, that should there be any coarse material in the pulp, *if pumped* up, it has time to separate in "the presses," giving a less homogeneous cake than is produced with compressed air, so that the cakes cannot be so uniformly washed.

In the year ending December 31, 1900, 17,196 tons of ore were crushed and treated in the sulphide works, and yielded by amalgamation and cyanidation 28,896 oz. of bullion, ·886 fine. The residues assayed 2·10 dwt. per ton, and the loss of mercury was ·558 oz. The costs, exclusive of cyaniding tailings, which averaged 9*s.* 2·292*d.* per ton, are given as follows :—

—				Total Cost.			Cost per ton.	
				£	*s.*	*d.*	*s.*	*d.*
Wages				10,689	10	2	12	5·19
Firewood				5,548	14	9	6	5·44
Stores				2,918	7	4	3	4·73
Condensed water				1,962	4	9	2	3·38
Salt water and maintenance pipe tracks				605	15	11	0	8·45
Fuel (charcoal, coal and coke)				270	13	11	0	3·78
Lime				12	9	0	0	0·17
	£	*s.*	*d.*					
Bricks	5	13	1					
Timber	39	0	10					
Stable expenses	89	0	8	240	4	10	0	3·35
Experiments	106	10	3					
				22,248	0	8	25	10·49

The cost of tailings treatment in the cyanide works in 1900 is given in detail in Chapter VIII. The costs in 1901 in the sulphide

* *Op. cit.* Royal Commission, Glasgow.

† *Op. cit. Trans. Inst. of Mining and Metallurgy*, vol. viii. p. 492. Mr. James has recently informed the Author that the liability to breakage which pumps of this kind were subject to, owing to sudden rise of pressure, or uneven filling of the presses, has been overcome by the use of an air-receiver to maintain a steady and low pressure.

works and cyanide works are given in the supplementary tables at the end of this chapter. Mr. Roberts estimates the value of the bullion from oxidised slimes at 76*s.* to 78*s.* per oz., and from roasted ore at 54*s.* to 72*s.*

In an interesting article on 'West Australian Sulphides,' the *Financial News* of October 1, 1901, said: "The Great Boulder Company is at present treating 165 tons per day, though the capacity of the plant is 200 tons,* with sufficient power for 250 tons; but to reach the latter figure a few alterations will probably have to be made. The average assay value of the sulphide ore at present being treated is 1⅝ oz., of which only 2·10 dwt., or roughly 6 per cent., is not recovered, leaving, say, 94 per cent. as the average extraction." "The figures for August were 17*s.* 10*d.* for milling and 8*s.* for cyaniding, or a total of 25*s.* 10*d.*" In September 1901, 5320 tons of sulphide ore were treated in these works: 9098 oz. being won by amalgamation, etc.; and 1498 oz. by the cyanidation of 9212 tons of tailings; and the costs were given as 24*s.* 2*d.* per ton. From more recent figures given by Mr. Roberts,† it appears that the cost in the sulphide plant was reduced in 1902 to 13*s.* 9·11*d.*, and in the cyanide works to 7*s.* 2·39*d.*; total, 20*s.* 11·50*d.*

General Summary of the Results of the Great Boulder Main Reef Process.

The following interesting particulars of results achieved by the Great Boulder Main Reef process were given by Prof. E. H. Liveing, as the result of an experiment on 15 tons of roasted ore from the Associated mine, treated at the Great Boulder Experimental works, before the erection of the new "Associated plant" was decided upon.

	per cent.
Gold obtained by amalgamation in grinding pan .	71·8 of assay value
,, ,, cyaniding and filter-pressing .	22·3 ,,
	94·1

The consumption of cyanide, Prof. Liveing remarked, amounted to less than 2 lb. per ton, and the materials worked well in filter-pressing.

Further experiments were made at the Associated mine itself,

* It was stated by the chairman, Mr. G. P. Doolette, at the Annual Meeting in May 1902, that this figure had now been reached, and by adding six more furnaces, and extending the sulphide plant, at a cost of about 10,000*l.*, Mr. Hamilton expected to increase the output by 70 tons per diem. These furnaces are of the type known as Merton's.

† *Report* of the Chamber of Mines of Western Australia, September 1902.

and in his report, dated May 2, 1901, Mr. Hewitson stated that a considerable amount of experimental work was done during the year ending March 31, 1901. A grinding pan was erected, together with an agitator and filter-press, so as to carry on experiments on a practical scale. These demonstrated that from 34 to 49 per cent. of the gold in the ore (varying with its coarseness) could be extracted by amalgamation, and the treatment of the finely-ground pulp in the filter-presses brought the extraction up to 92 to 94 per cent., with a loss of only 1½ lb. of cyanide per ton; whereas with a long treatment given in the leaching-vats, the loss of cyanide was about 6½ lb. per ton, due to its decomposition by the salts formed in roasting the ore.

To obviate this, it was at first proposed to filter-press the whole of the roasted product from the grinding-pans, but it was found that this double filter-pressing could be avoided by settling the ore in large vats, as it was proposed to do in the "new plant" before cyaniding them in "presses."

It may be of interest to add here, that the following are the totals of the fire assays and analytical tests done at the Associated during the twelve months ending March 31, 1901:—

Mill	6,500 fire assays
Mine	7,201 ,,
Laboratory	3,120 ,,
	16,821

and 4514 tests and analyses of various kinds were made in the laboratory. The cost of this work (assay expenses) amounted to 2264*l.* 10*s.* 1*d.*

Mr. Alfred James * states that the cyanide consumption in the Boulder Main Reef process may be calculated to vary from 1½ to 2 lb. per ton treated; the residues assay generally from 1 to 2 dwt., varying with the value of the original ore.

Mr. L. Gilson, in a special Report dated March 2, 1900, mentions that at Boulder Main Reef Mr. Marriner got extractions of from 93·6 per cent. to 96 per cent., the former figure being from "tailings"; but in the previous month the percentage was somewhat lower, as it was found that in dealing with material of this kind of low grade a larger profit could be made by putting through 40 per cent. more tailings, at a sacrifice of three or four points in extraction. The average extraction of the Boulder Main Reef process would appear on the whole to be between 91 and

* *Op. cit., Trans. Inst. of Mining and Metallurgy*, p. 491.

95 per cent.* of the gold contents of the ore, unless it is exceptionally high grade.

As regards cost, it has been estimated that about 4*s.* might be calculated for crushing, 4*s.* for roasting, and 12*s.*† for treatment, which would bring the total cost to 20*s.*, the figure Mr. James mentions it was originally officially estimated to cost.

Whilst this figure is below that at which the costs at first figured out, it seemed reasonable to suppose that by working on a larger scale, with lower roasting charges and general improvements in mechanical details and organisation, the costs at the Great Boulder Main Reef, which averaged 29*s.* 8·96*d.* per ton from July to December in 1900, although they only amounted to 26*s.* 7·58*d.*,‡ in August, might be considerably reduced, with the new furnaces in operation; since the plant was then running only up to about half its full cyanide capacity. The Company's Annual Report, July 30, 1901, in fact, shows that this was the case, and that the *average* costs for the 17 months ending May 31 came to 26*s.* 10*d.* per ton; but they were reduced in May to 20*s.* 9·88*d.*, with an extraction of 94·7 per cent.

In June 1901, 1815 tons were milled, which returned 2092 oz. The average assay of tailings being 1 dwt. 16 grs., the extraction figured out at 93 per cent.; and returns from bye-products smelted yielded 300 oz. extra, total 2392 oz. The return for July was 1977 tons treated for 2258 oz., the average value of the tailings being 1 dwt. 13 grs., and the extraction was estimated at 92·6 per cent.; 1935 tons of ore milled in August yielded 2274 oz. of bullion; the average assay of tailings being 1 dwt. 13 grs., the extraction was 92·7 per cent.; and the cost per ton for treatment, 22*s.* 10·99*d.*

The September costs amounted to 22*s.* 4·71*d.* The average cost for the twelve months ending September 1901, is given§ as 25*s.* 4½*d.*

Tables giving an analysis of the costs and particulars of extraction for the year ending December 31, 1901, will be found at the

* The Boulder Main Reef Company, in a circular dated October 11, 1900, stated that their extraction ran from 92 to 97 per cent.

† Deducting 7*s.* 6*d.* from 12*s.* (7*s.* 6*d.* being Mr. James' estimate of the approximate cost of double filter-pressing), leaves 4*s.* 6*d.* for pan-amalgamation, etc.

‡ The details were as follows:—Crusher, 3·33*d.*; ball-mill, 1*s.* 6·45*d.*; furnace, 8*s.* 3·41*d.*; grinding, 1*s.* 3·67*d.*; filter-press, 4*s.* 3·59*d.*; cyanide, 5*s.* 10·47*d.*; steam, 2*s.* 8·37*d.*; smelting, 3·62*d*; assays, 2·33*d.*; water and condenser, 10·11*d.*; management, 1*s.* 0·23*d.*; total, 1*l.* 6*s.* 7·58*d.* The Author is indebted for these figures to the courtesy of the company, who kindly placed them at his disposal.

§ 'Westralian Sulphide Treatment,' *Financial Times*, November 21, 1901.

end of this chapter. In July 1902, 2007 tons were crushed and the extraction was reported as 94 per cent.

The Great Boulder Perseverance and Kalgurli companies pursue a somewhat modified form of treatment, but on the same general lines as the Great Boulder and Boulder Main Reef.

The Great Boulder Perseverance Sulphide Works.

The Author is indebted to the company for their courtesy in placing at his disposal the photographs from which the accom-

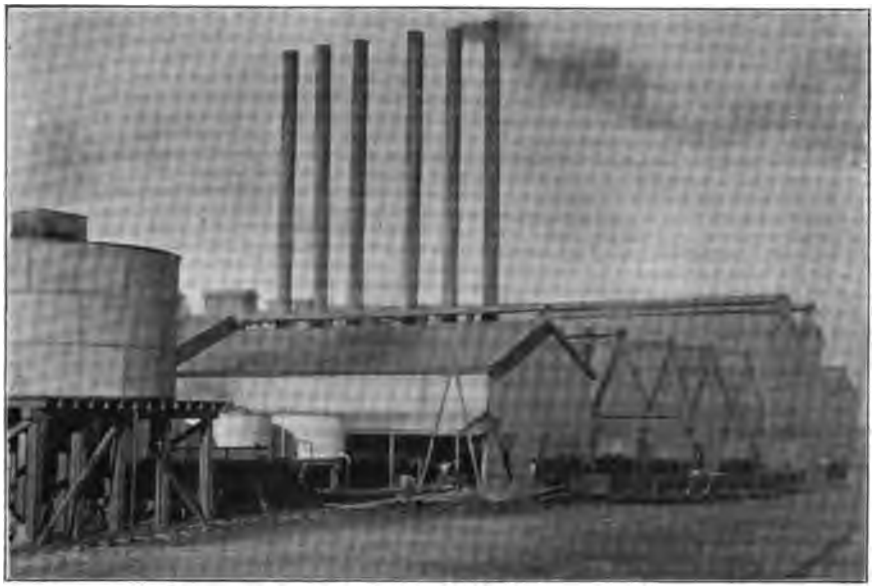


FIG. 61.—THE GREAT BOULDER PERSEVERANCE SULPHIDE WORKS.

panying views of the works, etc., Figs. 61, 62, 63 and 67 have been reproduced.

These works started regular operations in August 1900, and the following particulars are compiled from the descriptions given of it by Mr. Ralph Nichols in the *Financial Times*, in a letter dated August 24, 1900; an article in *Feilden's Magazine*, November 1900; the Company's Annual Report issued in July 1901; and by Mr. Robert Allen.*

The plant was originally designed to treat 260 tons per diem, or to average about 7500 tons per month.

* *Op. cit.*, Royal Commission, Glasgow.

The ore raised from the Main Shaft (known as No. 3 Shaft) is delivered about 60 feet above the surface, run in trucks across the Government Railway, and dumped on grizzlies, from which the coarser portion is fed into a No. 5 Gates rock-breaker.

The breaker-product, together with the previously-separated fines, are kept separate, each part passing over a second grizzly, and the coarser portion rejected here is fed into two No. 3 Gates crushers, the product of which, together with the fines from the second set of grizzlies, falls into a 1200-ton storage bin.

The crushing capacity of this portion of the plant, which is operated by a 60 horse-power electric motor, is equal to dealing with 400 tons a day, whilst, as just said, its storage capacity provides for 1200 tons, or a three days' supply of ore.

From the main storage bin, the ore is either elevated in cars, or raised by means of a belt elevator, fed by a Challenge-feeder, to a trestle-way, and delivered in trucks to a bin, from which (if wet) it passes through two cylindrical dryers, divided internally into quadrants, and heated by the waste-gases of the furnaces, and is re-elevated; otherwise (if dry) it is trucked direct to the feed-bins, that deliver it through automatic feeders to the hoppers of a set of ten * Griffin mills, fitted with 15-mesh screens, capable of crushing 30 to 40 tons each per diem. Generally, however, the ore is dry enough to be trucked direct to the Griffin mill bins.

The wear and tear of the Griffin mills (including renewals) is estimated to amount to *7d.* per ton, and they are said to require 25 horse-power each; crushing through 15-mesh screens, their capacity is rated † at about 40 tons each per diem.

A sizing analysis of the product is given by Mr. Robert Allen as follows:—

			per cent.				per cent.
Passing through a	120	mesh screen	72·6	Remaining on a	40	mesh screen .	4·1
Remaining on	120	,,	3·5	,,	30	,, .	3·2
,,	100	,,	2·3	,,	20	,, .	0·7
,,	80	,,	6·5	,,	10	,, .	nil
,,	60	,,	7·1				

The dust is drawn off by a Sturtevant fan, settled in cyclone arresters, and collected and delivered to the roasting furnaces.

The ore from the mills is delivered by screw conveyors and a cross-set conveying-belt to the boot of an elevator (fitted with 14-inch buckets), which raises it to an upper Robins belt-type

* Increased since to 12.

† The output is figured by Alfred James at 12 to 15 tons per diem in a No. 3, to 50 to 60 tons per diem in a No. 8, depending of course on the hardness of the ore and other things.—*Cyanide Practice*, p. 109. See also note p. 247.

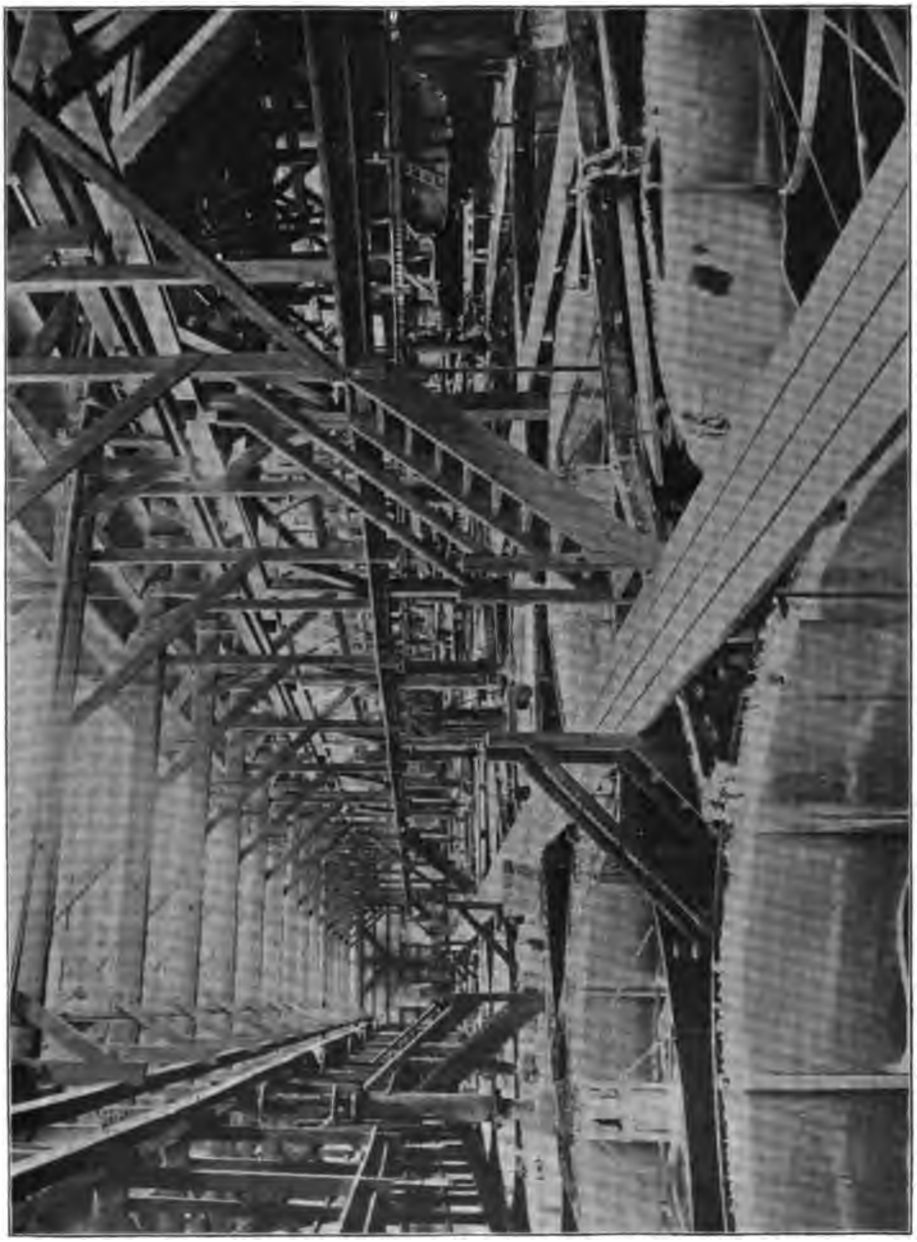


FIG. 62.—INTERIOR OF THE GREAT BOULDER PERSEVERANCE SULPHIDE WORKS.

conveyor, by which it is distributed to the feed-hoppers of six Holthoff-Wethey mechanical roasting furnaces * that have fixed horizontal hearths 120 feet long by 12 feet wide, possessing a capacity of 60 to 70 tons per 24 hours. Two of these furnaces only came into use in the latter part of 1901.

The ore is stirred and carried forward by means of eight travelling rabbles in each furnace, and less than ·02 per cent. of sulphur in undecomposed sulphides is left in the ore after roasting. The roasted ore is discharged on to a cooling-floor, below the bed of the furnace, and carried back along the whole length of the furnace by rabbles.

A large brick dust-chamber is provided to catch the dust, about 50 tons of dust per month, or about 1 per cent., being thus caught and re-roasted.

The cooled ore is taken by two screw-conveyors to an elevator which delivers it to a Robins conveyor feeding a closed-in 5 feet diameter "mixer," in which the ore, by the addition of plant-water, is formed into a pulp of a consistency of about 40 per cent.

The pulp overflowing from the "mixer" is distributed to grinding and amalgamating pans, eight of which are 8 feet in diameter, of Mr. Nichols' design, and three, which were to be replaced by four larger ones, were 5 feet in diameter.

These pans have a continuous overflow, and about 50 per cent. of the gold yield is recovered by them. The overflowing pulp discharged from the pans is led off to twenty-four agitation vats (20 feet in diameter and 4 feet 6 inches deep), which hold 16 to 17 tons of (dry) slime each, and are fitted with agitator-paddles of special design, and provided with 6-inch bottom-discharge gates.

The pulp is, it appears, first washed in these agitators to remove the soluble salts in solution, which are decanted off, and the residual pulp is agitated afterwards with strong cyanide solution, for from 2 to 4 hours. After each set of vats has been in use about six weeks it contains a small deposit of sands, which is shovelled out and put back into the pans.

Each set of six vats is connected with a montejus, the four being worked in turn, from which the pulp is forced by air-pressure into twelve Dehne 4½-ton filter-presses, each holding fifty 3-inch cakes.

Between 55 and 66 pressfuls can be treated in 24 hours

The gold-bearing liquor from the presses is finally pumped

* Described by H. O. Hofman in *The Mineral Industry*, vol. vi. p. 448, in an article on 'Recent Improvements in Lead-Smelting,' and in the *Engineering and Mining Journal*, May 29, 1897.

through a large Dehne clarifying press, and the gold is precipitated in seven ordinary zinc extractor-boxes, the gold being recovered from the zinc sludge in the usual way.

The residues are discharged from the presses upon a 24-inch horizontal belt conveyor below them, delivering upon an inclined belt conveyor, Fig. 63, from which they are dumped; the expense of handling being, it is said, thus reduced.

Power is furnished by a 450 horse-power engine * of the Corliss type (20 inches by 36 inches by 48 inches), with independent jet condenser, built by the E. P. Allis Company, of Milwaukee,

FIG. 63.—DUMPING RESIDUES, GREAT BOULDER PERSEVERANCE.

which was stated to develop 375 horse-power under its existing load.† Steam is supplied by ten Heine water-tube boilers, each developing 200 (maximum) horse-power at a working pressure of 125 lb., which were reported to be more economical of fuel, and to cost less for repairs than Cornish or Lancashire boilers; whilst the original cost of their installation was stated to be 30 to 40 per cent. less. Edmiston filters are used to free the feed-water from oil.

* As the main engine drives a 25-drill compressor and other machinery, it has been supplemented by a 250 horse-power engine and 250 kilowatt generator. The furnaces are operated by a 60 horse-power motor; and a 60 horse-power motor and two 20 horse-power motors were installed in the amalgamating and cyanide department in 1901.

† *Financial Times*, July 13, 1901. Report of the Annual Meeting.

The Holthoff-Wethey furnaces are reported to give an excellent roast, and seemed to be economical of fuel, although at the Mercur mine, Utah, where they are employed, Jackling * furnaces were installed for roasting base ore; they appear, however, to have given every satisfaction in Western Australia. The Robins conveyors seem to work well, provided attention is given to secure a proper feed; originally V-shaped launders conveyed the roasted pulp direct from a cooling-floor to the "pans," but they required such a large quantity of water to carry the ore that, to quote Mr. Nichols, it took them all their time "to decant the water that comes from the product of one furnace." At one time it was also thought, I believe, that Huntington mills would be preferable to Wheeler pans as amalgamators. Such mills would not, however, grind the ore fine enough to take the place of "pans"; and it is estimated that about 20 per cent. of the roasted ore required to be ground finer by the "pans."

It appears, in fact, that one of the early difficulties that was met with, was owing to the ore not being delivered to the filter-presses, finely enough ground, to admit of a proper extraction. Commenting upon this the local correspondent of the *Financial Times*, in a letter dated November 24, 1900, remarked that the pans were required to do work that should be done by the Griffin mills; and to remedy this, suggested crushing through finer screens. To overcome this trouble, additional pans were eventually put in, and their speed was increased; but when extra pans were erected, it was intended to run them slower, as too high a rate of speed is disadvantageous in various ways.

The "zinc-dust" method of precipitating the gold from the cyanide solutions as employed at De la Mar's Mercur mines, Utah, a description of which is given by Mr. D. C. Jackling in the *Mining and Scientific Press* of June 2, 1900, was, I believe, tried at first, but was abandoned in favour of ordinary zinc precipitation.

The arrangement of the works admits of elevating the tailings after treatment to a height of some 50 feet, with the object of distributing them over the lease; but as some of the residues in 1900 ran as high as 7 dwt. to the ton, they were too rich to be treated in this way as waste.

The reason for this was explained in the Annual Report for 1900 as being due to several causes besides the one already men-

* *Engineering and Mining Journal*, December 30, 1899. Not the "zinc-fume" method, devised by Mr. H. L. Sulman, *Trans. Inst. of Mining and Metallurgy*, vol. iii. p. 222.

tioned; viz. insufficient pan-capacity to enable the ore to be properly ground; it was also partly due to—

(1) The poor quality of the mill water available. (2) The formation of reducing agents in the roasted ore, resulting from imperfect roasting. (3) Inadequate filter-press capacity; resulting in imperfect washing of the filter-press residues.

As regards the *salt-water difficulty*, the presence of magnesia salts was stated by Mr. Nichols to have caused trouble in the zinc precipitation-boxes, a flocculent precipitate of hydrate of magnesia being formed,* which coated the zinc shavings and mixed with the zinc-sludge, from which it could not be removed, increasing the bulk of the material to be treated. In strongly alkaline solutions, most of the hydrate of magnesia is precipitated in the agitation vats, and is caught in the filter-presses and thrown out with the tailings, but it causes trouble with the filter-cloths, filling the pores of the cloth.

Certain constituents of this water, which is drawn from two mines at the north end of the field, were found to act as cyanicides, unless it was first treated with an alkali.

As regards *the roasting difficulty*, soluble salts are liable to result as a consequence of poor roasting, and both destroy cyanide, and precipitate gold in the agitation vats, which, being caught in the filter-presses, enriches the tailings. Mr. Nichols remarked, "The presence of a fraction of a per cent. of sulphides in solutions will seriously affect the extraction results. However, if the sulphides exist in small quantity, they can be removed by oxidising agents, such as bleaching-powder (chloride of lime); this we have tried from time to time with good results."

As regards *inadequate filter-press capacity*, Mr. Nichols said that extra presses were about to be installed, as "in turning out a large tonnage, sufficient time cannot now be taken to thoroughly wash presses before dumping tailings."

With a good roast, Mr. Nichols believed the extraction should be from 90 to 96 per cent., and he remarked that "there is no question about the efficiency of the metallurgical treatment." He also stated at the annual meeting in July 1901, that as soon as the new installation was completed the works would be able to treat 10,000 tons of ore a month, and this large tonnage would not affect the grade of the ore put through, so that the bullion yield should be augmented over 30 per cent.

It was stated in the Manager's Report for the year ending

* This has been referred to in Chapter VIII., and previously in this chapter.

December 31, 1900, that 75 per cent. of the bullion product was recovered by amalgamation, and was worth about 4*l.* per oz., whilst the cyanide bullion is worth from 3*l.* to 3*l.* 10*s.* per oz. The costs in September* 1900, were reckoned at 38*s.* 9*d.* per ton, whilst the average cost in 1900, treating 20,257 tons, was calculated at 34*s.* 11·31*d.* per ton. In 1901, the cost gradually came down, however, as shown below:—

	Tons treated.	Cost per ton. £ *s.* *d.*		Tons treated.	Cost per ton. £ *s.* *d.*
January . .	5258	1 15 4½	May . .	7200	1 3 9½
February . .	4810	1 11 7	June . .	7000	1 5 2½
March . .	6142	1 8 9½	July . .	7200	1 5 0½
April . .	6760	1 6 8	August . .	7200	1 4 0½

The corresponding yields were given as:—

	oz.		oz.		oz.		oz.
January .	4938	March	7281	May .	8,567	July .	11,107
February .	6822	April .	7395	June .	10,170	August .	10,791

In the last four months of 1901 the capacity of the sulphide plant ranged from 8000 to 8473 tons; and the average cost for the year was given in the Annual Report as 24*s.* 10·58*d.* per ton, but in September and October costs were stated † to have been reduced to 22*s.* 11*d.* and 21*s.* 1*d.* respectively.

In 1902 its output steadily rose from 8583 tons in January to 10,012 tons in June; yielding from 12,425 oz. to 14,198 oz. per month. In May, June and July, I am informed that the results were as follows:—

	May.	June.	July.
Tons treated	9,824	10,012	10,492
Yield, oz.	14,198	13,992	14,636
Cost per ton	24*s.* 3*d.*	22*s.* 4*d.*	21*s.* 4*d.*

The Kalgurli Sulphide Works.

The plant as originally designed was intended, I believe, to have a capacity of between 50 and 100 tons a day, and consisted of rock-breakers, ball-mills and one Ropp furnace. The roasted ore was elevated into a vat containing water, and then run over copper-plates and into amalgamating-pans, to catch any coarse gold; the sands, after amalgamation, being cyanided in vats, and the slimes going through filter-presses. The capacity of the furnace (which is no longer in use) appears to have amounted to about 50 tons a day (1500 tons a month); it was found, I believe, on trial that air-separation did not answer, and that in roasting the

* *Financial Times*, December 6, 1900.

† *Op. cit.*, 'West Australian Sulphides,' November 21, 1901.

ore the coarse gold was liable to become incrusted with an artificial coating which prevented it from amalgamating, so that it formed beads which escaped over the "plates";* for these and other reasons the general arrangement has since been modified on lines differing somewhat in details from the other sulphide plants on this "field."

The following interesting particulars of the present works as since rearranged are mainly excerpt from the description given of them by Mr. Frank A. Moss in the Company's reports 1900 and 1901; from Mr. Robt. Allen's more recent pamphlet; and details of the plant given in a letter dated March 15, 1902, by the local correspondent of the *Financial Times.*

The ore is raised to "the brace" at the main shaft (a height of 36 feet), tipped over grizzlies with bars set 1 inch apart, into a No. "C" Comet rock-breaker, which breaks it to 1½ inch size.

The product of the rock-breaker was formerly conveyed by an endless belt to a set of "Roger" rolls,† 16 inches face and 36 inches diameter, which reduced it to 1-inch gauge, and the stone crushed, together with the "fines" from the grizzly, fell into a bin, capable of holding about 200 tons. From this shaft-bin, the ore is carried by a Bleichert aërial tram to the mill, a distance of 570 feet (the buckets passing over a suspension weighing-machine, which registers their correct weight), and is delivered either into the "damp" or "dry" ore-bin, according as it happens to be wet or dry.

The capacity of the former of these bins is 200 tons, and from the damp ore-bin an automatic feeder delivers the stone into a revolving dryer, of the Howell-White type, 30 feet long.

After passing through "the dryer," the ore is carried by a short scraper-conveyor to a vertical chain-and-bucket Krupp elevator, by which it is elevated 50 feet, and dropped into a second shaking-conveyor, that delivers it to the bin of the ball-mills, which has a capacity of 100 tons. From this bin (into which the ore *when dry* is delivered direct) the dry-ore is fed into six No. 5 Krupp ball-mills ‡ by automatic feeders, fitted with an eccentric push-feed mechanism.

* *Financial Times*, letter of correspondent, April 17, 1900.

† From Mr. Allen's description it would appear that this part of the process has been modified, and the ore is simply crushed by the Comet rock-breaker to 2½-inch gauge (the grizzly being set with 2-inch spaces) and passes direct to the shaft-bin.

‡ A sizing analysis given by Mr. Robert Allen, *op. cit.*, shows :—

		per cent.
Passing a 120 mesh screen	. .	40 approximately
,, 80 ,,	. .	30 ,,
,, 35 ,,	. .	30 ,,

Mr. Moss mentions that the screen size used was 1600 meshes per square inch; from which it may be inferred that the ore is now being crushed rather coarser, but as Mr. Argall has pointed out ('Sampling and Dry Crushing in Colorado'), there are great variations in the *nominal* sizes of screens. The four original mills were gear-driven, but have been altered to belt-driven. *Financial Times*, letter of correspondent, March 15, 1902.

The mills crush the ore to pass a screen of No. 35 woven steel wire-cloth, crushing through which the mills are said to have a capacity of about 25 tons a day each. After it is crushed the ore is sampled at intervals and falls through shoots into a screw-conveyor, set at right angles to the end of the first conveyor, which delivers and distributes it over a 150-ton bin. From here the ore is fed by fluted rollers, to nine Edwards roasting furnaces, each having a capacity of about 15 tons per 24 hours. It was proposed, however, to employ gas-producers for firing the furnaces with gaseous fuel, in place of wood. The dust drawn off by the chimney draught is caught in dust-chambers. The dust from the ball-mills is collected by a 45-inch Sturtevant fan, and carried along pipes to three "Cyclone" dust-collectors. This dust, which is in the form of impalpable powder, and was formerly treated without roasting, by agitation with cyanide and filter-pressing, is now roasted with the remainder of the ore. The dust from the furnaces is caught in large settling chambers.

The roasted ore discharged from the furnaces falls into a push-conveyor delivering on to a second conveyor, and is raised to a height of 45 feet by means of two Krupp chain-and-bucket elevators, from the head of which it is dumped into a closed-in "mixer," provided with a propeller-shaped agitator, where it is formed with water into a thin pulp, and sluiced through a 3-inch pipe into seven sets of conical spitzkasten classifiers, each set consisting of three components, which separate "the sands" from the slimes by means of an ascending current of water.

The overflowing slimes pulp passes along a launder into four pyramidal spitzlütten, 13 feet long and 7 feet deep, from the bottom of which the slimes were discharged in a thickened condition (containing 35 per cent. of water only), and passed into nine agitation-vats,* 12 feet in diameter and 6 feet deep, holding about 11 tons of slime each, where they were agitated by paddle agitators, with a weak solution of cyanide, for 20 to 24 hours.

They were then emptied into two pressure-tanks worked alternately and forced into two filter-presses, each press holding fifty 3-inch cakes, or approximately 4 tons of dry slime. In the presses they are leached first with a weak solution of cyanide, and then washed with water, which is driven out by forcing compressed air through the cakes. The gold is recovered in two (slimes) zinc extractor-boxes.

* It appears from the statement in the footnote on p. 357, that this part of the process has since been modified.

The surplus water escaping from the spitzlütten goes back to the circulating-water storage tanks.

The heavy material which settles in the spitzkasten classifiers, consisting of gold, concentrates and sands, falls to the bottom and is delivered by 1-inch pipes to two copper-plate tables (10 feet by 5 feet), and then passes over four Halley (percussion) concentrating-tables. *The tailings* from these (consisting of clean sand) are treated in the cyanide vats.

The concentrates caught on the Halley tables, which are stated * to average about 5 oz. per ton, and to amount, according to the sweetness of the roast, to about 2½ per cent. of the ore, are ground and amalgamated in two 5 feet diameter Wheeler pans, which recover, it is said, about 65 to 75 per cent. of the gold the concentrates contain.

The pan-pulp, continuously overflowing, was thickened in a large pyramidal spitzkasten,† 10 feet long by 6 feet wide, and the thickened pulp, of a consistency of about 1 : 1 underflowing (before the process was modified as described in the footnote on p. 357), passes into two agitation-vats, each 10 feet in diameter and 6 feet deep, containing about 10 tons of slimes, and was agitated by paddles with cyanide solution, discharged into a montejus, and filter-pressed in a 4-ton Dehne press, the liquor from which goes through a special zinc extractor-box.

The sands (the tailings of the Halley concentrators) are caught in a sump, elevated by compressed air, and sluiced with water along a steel launder, through branch launders, into a series of twenty cyanide-vats of 100 tons capacity (22 feet diameter and 7 feet deep), where they are settled; the upper tier of vats are fitted with "distributors," which distribute the sands all over them; and the overflow water, containing a little slime, runs out at the top of the vat, along a launder, into the water-tank, from which it is pumped by two belt-driven 6-inch plunger-pumps to the overhead supply-tanks.

When a cyanide vat is full of sands (approximately 95 tons), it is discharged into the vat below, the water is drained off at the bottom, and the cyanide solution is run on; the time of treatment, including filling and emptying, occupies from 22 to 30 days for each charge; the strong solution first run on is drawn off below

* *Financial Times*, letter of correspondent, dated March 15, 1902.

† The overflow of this spitzkasten, consisting of clear water, is returned to the plant-water storage-tank, and the pan-slimes are now treated as described in the footnote on p. 357.

the filters for some time, and continuously delivered on the top of the sands by an air-lift, which aërates the solutions as well.

The gold solutions, both from the vats and filter-presses (previously clarified when necessary by means of an Excelsior press), pass through the pipes to the precipitating house, where the gold is precipitated on zinc-shavings in two (sand) zinc extractor-boxes, and is recovered in the usual way.

Handling ore yielding over 30 dwt., the consumption of cyanide was reduced to about 2 lb.

The extraction in 1901, is stated to have averaged 90·8 per cent., but an average approaching 93 per cent. was, I believe, anticipated for the future.

The machinery is operated by a 300 nominal horse-power cross compound Corliss engine; a 10 nominal horse-power engine, which works the aërial tram; a 12 nominal horse-power engine, which drives the separation and agitation machinery; and the electric-light engine and dynamo.

Steam is generated by three 120 horse-power multitubular boilers.

Air for the filter-presses and "circulators" of the cyanide vats is supplied by a three-drill belt-driven air-compressor, operated by the main engine, which also runs a belt-driven winch, for hauling fuel, as well as the machinery in the machine and fitting shops.

The ball-mills crush through extremely fine screens (as before said), and this reduces their capacity but increases the gold extraction.

The Ropp furnace which was at first installed was fed by means of two screw-conveyors fitted with differential pulleys to regulate the feed. Its hearth was 150 feet long and 14 feet wide, and the ore was carried along it by six sets of rabbles attached to carriages running on rails down the centre and returning on the outside. It was stated to have had a capacity up to 70 tons per diem, the roasted ore containing approximately 0·2 per cent. of sulphur remaining as sulphide. The time taken to roast "sweet" was found, however, to be longer than was at first anticipated.*

The air separators which were at first tried gave trouble in collecting the dust, in consequence of which the present system of wet-separation was adopted.

Two sets of three spitzkasten of the ordinary type were put

* In a letter dated July 27, 1901, the Kalgoorlie correspondent of the *Financial Times* said, five out of nine Edwards roasters were on their way, and the furnace that was in use would probably be dismantled in September.

in, built of wood, and worked well to start with, but a peculiar difficulty subsequently arose, as they are stated to have corroded up with a growth of sulphate of lime and magnesia.

Two sets of three cone-shaped spitzkasten made of sheet iron were then constructed, and are said to have done 30 per cent. more work, though only one-half the size of the wooden ones.

The spitzlütten put in to reduce the quantity of water in the slimes were also reported to answer this purpose well.

Mr. Moss further stated that the *air-lifts for circulating and aërating the cyanide solutions* in the cyanide-vats are applied in a manner which he claims is entirely novel,* and that their use has proved a success: not only keeping the solutions constantly moving through the sands, whereby fresh surfaces of gold are exposed to fresh solutions, but saving both cyanide and zinc, as only about 60 per cent. of the usual quantity of solutions is sent down to the zinc-boxes, and the ore can be washed more thoroughly without unduly increasing the quantity of solutions accumulated.

The ore is exceptionally pyritic and high-grade, and concentration and amalgamation form an important part of the process, as approximately 50 per cent.† of the total gold contents were formerly saved in this manner, and the slimes, free gold and concentrates having been separated from the sands, the latter are rendered almost as suitable for direct cyanidation as clean sands from oxidised ore.

By grinding the sands to a slime and filter-pressing, more gold could doubtless be extracted from them ; but against the increased

* In the company's report for the year ending July 31, 1901, the mine manager remarks, "In the matter of agitating the 'slimes' we have made a great improvemen in the process. Instead of mechanical agitation in large open vats we now run the slimes after separation into pressure-tanks connected with the filter-presses. In these they are agitated by compressed air at a low pressure for only three hours as against twenty-four hours in the open vats, and the extraction is invariably better, whilst there is a considerable economy in cyanide consumption, time and power." This modification of the original process is described by the Kalgoorlie correspondent of the *Financial Times*, in a letter dated March 15, 1902, as follows :—The thickened pulp from the hydraulic separators is run continuously into the agitation pressure-tanks (five in number), each having a capacity of 6 tons of dry slime. The cyanide solution is here added, the strength usually being 0·075 KCy. The whole is now agitated with compressed air (at about 20 lb. pressure per square inch) for three hours, when all the available gold is brought into solution. The residues in February assayed 1·4 dwt. The slimes from the pans, after thickening in a settler, are similarly dealt with (being agitated for four hours), and the residues in February assayed 2·2 dwt. It is not stated, however, whether the cost is less or more than with mechanical agitation.

† Mr. Robert Allen observes, "About 25 per cent. of the gold yield is recovered by the amalgamated copper-tables and the Wheeler pans, the remainder resulting from cyanide treatment of the sands and slimes."

return would have to be set the expense of grinding, and the higher costs of filter-pressing, and Mr. Moss therefore expresses the opinion that the extra gold recovered would not meet the extra cost involved. When in full operation, it was estimated that "the plant" would be able to treat a minimum of 2000 tons of sands and about 1200 tons of slimes monthly. The bullion produced has been of about 0·850 gold fineness.

The costs for the year ending July 20, 1901, are shown on the following cost-sheet.

Particulars.	Total tons treated . . 15,583 Total yield in standard gold 20,964 oz. 1 dwt. 17 gr. Average yield per ton . 1·34 oz. Average value of residues . 2·72 dwt. Average extraction . . 90·80 per cent.					
	Total Costs for Year.			Average Cost for Year.		
	£	s.	d.	£	s.	d.
Superintendence	1,240	0	0	0	1	7·10
Rock-breaker (including power)	887	6	10	0	1	1·67
Steam power	5,526	7	8	0	7	1·11
Aërial tram	224	8	4	0	0	3·46
Ore-dryer, conveyor and elevator	401	8	2	0	0	6·18
Ball-mills	1,187	11	4	0	1	6·29
Roaster	5,473	3	10	0	7	0·28
Separation, amalgamation, concentration, cyaniding and filter-pressing	9,714	13	1	0	12	5·62
Oiling and attendance	652	7	0	0	0	10·05
Electric lighting	388	2	0	0	0	5·98
Precipitation and smelting	1,110	8	9	0	1	5·10
Assaying	602	8	0	0	0	9·28
General	399	18	2	0	0	6·16
	27,808	3	2	1	15	8·28
Proportion of administration and general expenses in Western Australia	2,910	1	0	0	3	8·82
(As per profit and loss account)	30,718	4	6	1	19	5·10

At the company's annual meeting in December 1901, it was stated that the plant for the last four months had averaged 1450 tons, but with the additions being made to it, it was estimated to be capable of treating 3500 tons a month. The costs during the previous eight months, treating about 1500 tons per month, Mr. Black stated, had averaged about 32*s.* a ton, or, adding 3*s.* 6*d.* for general expenses, 35*s.* 6*d.* He hoped, however, to reduce the cost of 32*s.* to about 25*s.* per ton, and that the general expenses would be proportionately less. The extraction was expected to average over 90 per cent.

In February 1902, 1010 tons were treated for a return of 1265 oz., and the average of the residues was given * as 1·5 dwt. The staff of the works is stated to consist of one man on each shift to run the six ball-mills, and deliver the ore to the roaster-bin; two men to do all the work in connection with the nine roasters; and three men to attend to the separation of the slimes, concentration, amalgamation, and sands-treatment. In the General Manager's Report for the year ending July 26, 1902, the costs, reckoned upon 15,120 tons crushed, are stated to have averaged 23*s.* 6·23*d.*, or adding 1*s.* 8·12*d.* per ton for administration and general expenses, 25*s.* 2·35*d.* per ton.

The Diehl Process.

This has been called by Mr. Alfred James the concentration-sliming-bromo cyanide process, and the following is a general outline of the method adopted. The ore is first wet-crushed, the coarse gold is amalgamated, and the "sands" and "slimes" which constitute the battery pulp are classified in hydraulic classifiers. The richer tellurides and heavier sulphides contained in the coarse product of the "classifiers" are separated by concentration, whilst the tailings of the "concentrators" are ground in "tube-mills," provided with flint or agate balls, and the resulting product, consisting of "slimes," is agitated with cyanide in conjunction with bromo-cyanide,† and filter-pressed; the gold being precipitated on zinc shavings in the ordinary way. The details, however, as will be seen, differ somewhat in different mills, and no doubt experience will suggest modifications and improvements, as time goes on.

Mr. H. Knutsen explains the chemical principles of the process as follows ‡:—

"Reverting to the theory of cyaniding and the so-called Elsner formula, I would remark that in my opinion it is not pure oxygen which liberates cyanogen, but its allotropic form, ozone,

* *Financial Times*, April 14, 1902.

† The chemistry of the reaction taking place between bromo-cyanogen and finely pulverised tellurides of gold is however admitted to be somewhat obscure, *vide* Mr. H. L. Sulman's remarks on the subject, *Trans. Inst. of Mining and Metallurgy*, vol. viii. p. 507. The matter is dealt with by Mr. Sulman, *Ibid.* vol. iii.; C. G. Warnford Lock, in *Gold Milling*, and Alfred James in *Cyanide Practice*, also give additional information regarding bromo-cyanide and its applications, which is of great interest.

‡ *Op. cit.*, p. 292.

which is known to occur in water, and especially where water is evaporating. The effect of ozone on potassium iodide is well known, and I suppose it has an analogous effect on potassium cyanide. Adopting O_2O as the symbol for ozone, I think the reaction takes place according to the following formula :—

$$O_2O + \begin{cases} KCy + Au + KCy \\ KCy + Au + KCy \end{cases} = O_2 + O\begin{matrix} K \\ K \end{matrix} + \begin{cases} Cy - Au - KCy \\ Cy - Au - KCy \end{cases}$$

"This formula expresses the principle of the McArthur-Forest process. As oxygen acts as the liberator of cyanogen in this process, later inventors spoke of the oxidising effect of the oxygen,* and some proposed to add a strong oxidant, as sodium peroxide (Na_2O_2), potassium permanganate ($KMnO_4$), or potassium persulphate (KSO_4). According to my own results all these 'improvements,' especially on sulpho-telluride ores, are worse than valueless. About 1890, Dr. Roesler found that an addition of potassium ferricyanide to the solution of potassium cyanide materially assisted and increased the extraction. Moldenhauer has included this chemical in his process, and has described it as an 'artificial oxidising agent.' This is a most misleading designation of potassium ferricyanide, and can only be ascribed to a complete misunderstanding of the nature of this chemical. It is a splendid liberator of cyanogen, but its great faults are its expensiveness, and that it gives dirty precipitates in the zinc boxes. Its action may be seen from the following formula :—

$$K_6Fe_2Cy_{12} + \begin{cases} KCy + Au + KCy \\ KCy + Au + KCy \end{cases} = K_6Fe_2Cy_{12}\begin{matrix} K \\ K \end{matrix}\Big\} + \begin{matrix} AuKCy_2 \\ AuKCy_2 \end{matrix}$$
$$= 2K_4FeCy_6 + 2AuKCy_2$$

"Instead of an oxidation process, there is a reduction process, in which potassium ferricyanide takes up two atoms of K from the KCy, whereby two molecules of Cy are liberated to attack the gold. It is a well-known fact that old solutions which have circulated a few times through the plant, are more active, and give a

* Author's note. C. G. Warnford Lock remarks : "When dissolved oxidants are used, such as hydrogen peroxide, etc., the tendency is to oxidise other ore compounds also—the iron pyrites, copper sulphide, etc.—with fatal results to the potassium cyanide. In the case of the latter mineral, and in those of arsenical and antimonial compounds, the production of 'cyanicides' is intensified by the caustic potash produced in the solvent reaction giving rise to soluble sulphides."—*Gold Milling*, by C. G. Warnford Lock, p. 564.

better extraction with a less consumption of cyanide. The reason for this, I believe, is the content of potassium ferricyanide, always found in old solutions. In presence of gold and potassium cyanide this will again be reduced to ferrocyanide.

"In connection with this I may mention a fact which I do not remember to have noticed in any text-book, viz. that hydro-ferricyanic acid (i.e. potassium ferricyanide in an acid solution) will liberate iodine from potassium iodide according to the equations:—

$$(1)\ HCl + KI = HI + KCl.$$
$$(2)\ K_6Fe_2Cy_{12} + 6HCl = H_6Fe_6Cy_{12} + 6KCl.$$
$$(3)\ H_6Fe_2Cy_{12} + 2HI = 2H_4FeCy_6 + 2I.$$

"By addition of starch to the solution, the well-known blue colour will appear; this will disappear on addition of a solution of sodium thiosulphate.

"The credit of applying bromo-cyanide is due to Sulman and Teed,* and the process was fully described by them in *Transactions*, vol. 3 (ii.) p. 202. It has proved of great value in Kalgoorlie, making it possible to treat the ores in a cheap and effective manner without any complicated process. The following formula illustrates the reactions:—

$$\left.\begin{array}{l} KCy + Au + KCy \\ BrCy + Au + KCy \end{array}\right\} = KBr + 2AuKCy_2.$$

"Thus the cyanogen bromide not only liberates one molecule of cyanogen from the used KCy, but at the same time gives off its own cyanogen. Metallic gold is, as we know, insoluble in an air-free solution of KCy, as also in a solution of BrCy. It is, therefore, an exceedingly pretty laboratory experiment to have in one test-tube a solution of KCy, in which some leaf gold is put, and in another test-tube a solution of BrCy, also with some leaf gold. On shaking these two test-tubes up, no difference will be seen. If now the one test-tube is poured into the other, it will be seen that the leaf gold will dissolve instantaneously.

"One would think that chloro-cyanide would be just as effective as bromo-cyanide in liberating cyanogen, and thereby assisting the extraction. When I tried it I found that worse results were obtained with chloro-cyanide than with plain potassium cyanide solution.

"In the Table (p. 362) will be seen the results of treating slimes with plain cyanide solution, compared with treating them by a solution of KCy in combination with bromo-cyanide."

* The process being afterwards practically applied to the treatment of sulpho-telluride ores at Kalgoorlie by Dr. Diehl.—AUTHOR.

TABLE OF RESULTS OF TREATMENT WITH PLAIN KCY AND WITH BRCY ADDED.

Given by H. Knutsen (*Trans. Inst. of Mining and Metallurgy, Op. cit*).

Test No.	Proportion between		Hours of Treatment.	Strength of Solution before Treatment.		Strength of Solution after Treatment.		Consumption of Chemicals.		Slime Assay before Treatment.	Gold extracted per Ton of Ore.		Residue Assay.	
	Dry Slime.	Solution.		Per Cent. KCy.	Per Cent. BrCy.	Per Cent. KCy.	Per Cent. BrCy.	Per Cent. p. T. KCy.	Per Cent. p. T. BrCy.		Dwt.	Per Cent.	Dwt.	Per Cent.
1	1	1	24	0·10	nil.	0·065	..	12·25	..	37·33	15·00	41·18	22·33	58·82
2	1	1	24	0·15	nil.	0·102	..	16·80	..	37·33	16·63	44·64	20·70	55·36
3	1	1	24	0·20	nil.	0·134	..	23·10	..	37·33	19·88	53·24	17·45	46·76
4	1	1	24	0·25	nil.	0·164	..	30·10	..	37·33	21 12	56·59	16·21	43·41
5	1	1	24	0·30	nil.	0·208	..	32·20	..	37·33	23·80	62·51	13·53	37·49
6	1	1	24	0·10	0·025	0·076	..	8 4	8·75	37·33	28·83	77·23	8·50	22·77
7	1	1	24	0·15	0·0375	0·120	..	10·5	13·2	37·33	32·00	85·71	5·33	14·29
8	1	1	24	0·20	0·050	0·151	..	17·15	17·5	37·33	35·83	95·87	1·50	4·13
9	1	1	24	0·25	0·0625	0·178	..	25·2	21·9	37·33	35·63	95·43	1·70	4·57
10	1	1	24	0·30	0·075	0·206	..	32·9	26·25	37·33	36·10	96·65	1 23	3·35

RESULT OF EXPERIMENT ON LARGE SCALE, 1 TON SLIMES.

11	1	1	24	0·20	0·05	0·179	strong trace	7·4	17·5	37·33	36·25	97·1	1·08	2 9

Apart from the use of bromo-cyanide in the process (an application by Dr. Diehl of the original discovery made by Mr. H. L. Sulman and Dr. Teed), its principal feature, as already explained, depends upon fine-crushing the ore wet, thus avoiding the expense of roasting, by which, as Mr. Alfred James has pointed out,* a considerable saving (depending on the type of furnace used) is effected.

It would seem that there should also be a saving on the cost of wet- as compared with dry-crushing, and single as compared with double filter-pressing, or washing in spitzkasten, although this latter item would not represent a large amount in any case; but the fineness to which the ore must necessarily be reduced leaves it a somewhat open question still, whether fine crushing and grinding the raw ore in bulk, is not proportionately more expensive than sliming the roasted ore in continuous-working pans, notwithstanding the expense that always attends the use of machinery of the latter class.

The advantages claimed for the process † are, I believe, stated as follows:—

1. No loss of values in dust, or injury to the health of the workmen. 2. Highest extraction obtained from telluride ores, and no erratic results. 3. The gold is deposited in the zinc boxes ready to be taken out for smelting within three days after the ore enters the mill, and there is no dragging about of high values for weeks, and no retreatment of tailings, or repeated handling of the ore. 4. The roasting of the bulk of the ore is avoided; only the pyrites of the richer ore forming from 5 per cent. to 7 per cent. of the bulk is roasted, and as this is to a large extent self-burning, the costs of roasting are low; with low-grade ore the concentration and roasting are dispensed with, the ore merely being ground fine, and treated by chemicals.

Mr. Alfred James mentions several difficulties to be apprehended in pursuing this method of treatment, and comparing it with the Boulder Main Reef process, refers to royalty charges, and the extra expense of bromo-cyanide, which is a considerable item; ‡ he specially points out that finer grinding is likely to be found necessary than is needed in the roasting process, whilst he considered it probable that heavier cyanide consumption would be entailed in the Diehl process, owing to the reaction of bromo-

* *Trans. Inst. of Mining and Metallurgy*, vol. viii. p. 494.

† *Financial Times*, November 5 and November 19, 1901.

‡ Mr. F. K. Picard, M. Inst. M.M., estimated the consumption of bromo-cyanide at ½ lb. per ton, costing from 9*d*. to 1*s*. 6*d*. *Trans. Inst. of Mining and Metallurgy*, vol. viii. p. 504.

cyanide with the various sulphides, copper, and metallic iron, that are contained in the pulverised ore. It may also (if ordinary mine water is used), as Mr. James remarked, involve smelting charges on (4 per cent.* or more) concentrates, if risk of loss of gold, experienced in roasting ore charged with salts found in the Kalgoorlie waters, is to be avoided. Moreover, under certain circumstances it may happen that the residues might be considerably higher than those which the roasting process leaves behind, though this contention was traversed by Mr. H. L. Sulman, on the ground that the first trial run at Hannan's Star showed only 10 gr. of gold left in the tailings, and a later cable announced a 93¾ per cent. extraction on raw ore, originally assaying 16 dwt. 16 gr., which gave a residual value of but 15 gr. per ton.†

Mr. James adds, in discussing this question,‡ that, although as a rule the value of residues can be decreased by longer treatment, or finer grinding, "with unroasted tellurides, a point seems to be reached beyond which further treatment can do absolutely nothing at all in reducing the values of the unroasted fines." This, he said, is confirmed by official results of the Diehl process. "It will be seen that, with ore assaying 16 dwt. 14 gr. per ton, the final residues were 26 gr. It must be remembered, however, that of this 16 dwt. 14 gr. per ton we must allow for the amount extracted by the plates as well as by concentration. Thus, if we allow for a recovery of between 15 and 20 per cent., or say, 2 dwt. 14 gr. on the plates, and 40 per cent. of the remaining 14 dwt. in the 4 per cent. concentrates . . . this leaves the assay of the material treated by the Diehl process at 8½ dwt. per ton, and there must be some reason for the residues from these tailings being finally discharged at so high a figure as 26 gr. instead of 10 gr. per ton." "This is still more noticeable with recent work on Hannan's Brownhill ore. In this case, with richer ores the final residues are 2 dwt. 6 gr."

Difficulties may also occur in treating the "gold slimes," owing to the presence of precipitated tellurium in the zinc-boxes, to which Mr. A. C. Claudet called attention,§ as previously mentioned; but Mr. Sulman said he was inclined to think that there were compensating influences at work, and that tellurium in solution as a soluble tellurite was gradually eliminated from the working-solu-

* In the first period of working at Hannan's Star the quantity of concentrates obtained was less, viz. 2 per cent. of the ore (H. Knutsen, *op. cit.*), but this the Author believes to be a low average figure. † *Trans. Inst. of Mining and Metallurgy*, vol. viii. p. 513. ‡ *Ibid.*, p. 517. § *Vide* p. 318.

tions as an insoluble compound. It is important, I believe, that sulphide ore should be treated as it comes from the mine, so as not to have time to oxidise; and the process undoubtedly appears to be one likely to need the constant and particularly careful supervision of a skilled metallurgical chemist.

The company owning the Diehl patents guaranteed, it appears in the first instance, to extract 85 per cent. or more * from some of these telluride ores, and in actual practice it has considerably exceeded this percentage.† Its ultimate measure of success would, therefore, seem to hinge mainly on the question of the expense of securing as high an average relative standard of extraction as that obtained by other methods, a point, in the absence of conclusive evidence, that it must be left to time and results to determine.

Originally, I believe, it was anticipated that the cost was not likely to exceed 16*s.*‡ to 20*s.*§ a ton, and a well-recognised metallurgical authority some time since seemed to be of this opinion, as he estimated that on a large scale the Diehl process should not cost more than 15*s.* per ton. From particulars that have been made public, it would appear that in the case of the first trial lot of 250 tons treated at Hannan's Star, the actual cost of treatment came to 28*s.* 3*d.*‖ a ton (including realisation of the concentrates), whilst the original trial of the process at Lake View was reported locally to have cost about 25*s.* a ton, allowing for royalties.

In 1901 the costs at Hannan's Star were said to be 28*s.* per ton, with a saving of 93 per cent., and the company was reported ¶ to have entered into a contract to treat 1500 tons or more of telluride ore from the Oroya mine at 45*s.* a ton, with a guarantee to save 90 per cent. The cost of the process at Lake View has recently been brought down, I believe, to as low as 17*s.* 10*d.* in January 1903, or about the mean of what it was originally estimated to cost.

* *Statist*, August 18, 1900.

† The Secretary (as reported in the *Financial News* of March 16, 1900) stated that a trial lot of 200 tons of ore treated at Hannan's Brownhill gave an extraction of 97 per cent. A "British Australasian" telegram of the 19th referred to in the *Financial Times* announced that a month's trial at the Lake View Consols had proved a complete success, an extraction of 94 per cent. having been obtained. The *Statist* of August 18 mentioned that the trial run of Hannan's Star mill gave an extraction of 89 per cent.; but that whilst running on 60 tons a day of Brownhill sulphide ore for a couple of weeks, the Star plant effected an extraction of 97⅔ and 96¼ per cent. for the two respective weeks, and pointed out that the costs were likely to be reduced below 30*s.* per ton. The ore treated in the first week's run above referred to, I am informed, assayed 2 oz. 10 dwt., and the residues 1 dwt. 4 gr.

‡ *Financial Times*, May 7, 1900.

§ *Financial News*, March 16, 1900.

‖ *Financial Times*, October 16, 1900.

¶ *The Mining Journal*, 'Telluride Treatment in Kalgoorlie, Western Australia,' October 12, 1901.

The Brownhill Diehl Mill.

Milling was commenced in the Brownhill Diehl mill at the beginning of March 1901.

This plant, which was originally designed to treat 50 tons of ore per diem, has been recently very fully described by Mr. H. Knutsen,* who gives the following particulars of it.

The ore coming from the Brownhill main shaft is screened on a grizzly, through which the fines pass, and go to a storage bin.

The coarse pieces are put through a No. 6 Krupp rock-breaker, and the crushed ore joining the fines from the grizzly is drawn into trucks and hoisted to the battery bins.

The battery is a 20-head (four sets of five stamps). Each stamp weighs 1050 lb., and makes 105 drops of 7 inches per minute. The 20 heads crush about 75 tons per 24 hours.

The batteries are equipped with self-feeders, and both outside and inside amalgamation are employed to save the gold. The screens are of woven-wire cloth with 30 meshes per linear inch, and No. 1 battery is used for treating roasted concentrates, as well as for crushing raw ore.

The pulp discharged from the stamps passes over amalgamated copper plates, and then over Wilfley concentrators, and the tailings from the tables are elevated by a double tailings-wheel 32 feet in diameter, which discharges them into two classifiers, that thicken and deliver them as pulp to a pair of "flint mills."

These mills grind the ore to such a degree of fineness, that all but about 3 per cent. will pass through a sieve carrying 220 holes to the linear inch; and the whole will pass through a 200-mesh sieve; the pulp from the flint mills, generally carrying 3 to 5 per cent. of solids, is elevated and goes back to the classifiers, to re-separate any sand that is not finely enough ground, which is returned to the mills to be reground. The slimes from the first pair of classifiers are re-elevated on the other side of the tallings-wheel to a second classifier, which separates out the heavier (pyritic) particles which are returned to the Wilfley tables, whilst the remainder of the slimes go to a spitzkasten.

This eliminates the excess water, and the pulp discharged from the spitzkasten, which carries 40 to 45 per cent. of dry slimes, is delivered to one of five agitation vats 20 feet 6 inches diameter and

* 'The Diehl Process,' *op. cit.*, p. 292.

7 feet 6 inches deep,* which hold about 100 tons of sludge. When an agitator is filled it is charged with a strong solution of KCy and BrCy, and the pulp is usually agitated for about 24 hours. After 18 hours a sample is treated on a Büchner vacuum filter, the solution being completely removed, and the residue well washed and assayed. This takes 4 or 5 hours, and the results show whether the sludge has been sufficiently treated. The agitator then receives a charge of lime of 3 to 4 lb. per ton of dry slime and the sludge is ready to filter-press. The presses have a capacity of 5 tons of dry slime each, and they are each provided with a system of three "receivers" which saves considerable time, the operation being completed in less than two hours.

The auriferous solutions pass through a specially constructed filter to the zinc boxes, and the precipitated solutions go to an under storage-sump, where they are mixed with the overflow water from the spitzkasten (which is clarified of sludge by passing through an intermediate settling tank) and pumped back to the upper storage mill-tank.

The filter-press cakes when sent to the dump are reported to average 1 to 2 dwt., and Mr. Knutsen states that the grade of the ore treated does not seem to affect their tenor.

The admixture of the roasted concentrates, which contain only 0·02 per cent. of sulphur, has neither affected the extraction, nor increased the consumption of chemicals, which amounts to about 3 lb. KCy and 1¼ lb. BrCy per ton of ore.

The concentrates from the Wilfley tables containing 35 to 40 per cent. of sulphur are bagged, allowed to drain, and roasted in an Edwards furnace which roasts about 60 tons of pyrites per week. Mr. Knutsen adds, there is no loss of gold by volatilisation, as proved by a number of laboratory tests, any loss of gold being due to mechanical dusting; and Mr. J. T. Hollow, the manager of the works, informed him that the dust collected in the flue chambers did not assay higher in gold than the roasted material.

When cooled, the roasted concentrates are brought back to No. 1 battery in which, as before said, they are mixed with raw ore.

Mr. Knutsen adds that the Brownhill plant being entirely new, no old plant has had to be adapted, "the result being that no other plant has worked so smoothly, and in none has so high a rate of extraction been obtained with a lower working expense per ton."

* Sometimes the agitators are made larger (up to 25 feet in diam. and 8 feet in depth) holding up to about 125 tons of pulp.

Messrs. James Bros., in a letter dated February 26, 1901, observed:* "During the last five months of the past year, the Hannan's Brownhill Company treated at the Hannan's Star upwards of 8000 tons of refractory sulpho-telluride ore, averaging over 3 oz. of gold per ton, and obtained an extraction of fully 94 per cent. of the assay value, at a cost including crushing, treatment, realisation of products, and every charge from the time the ore was delivered on the mine until it was discharged as tailings to the dump, of less than 31*s.* per ton. In this case a still higher extraction could have been obtained at a cost not exceeding 26*s.* per ton, if it had not been necessary to force the capacity of the plant to the utmost."

A paragraph in the *Statist* of April 20, 1901, stated that a contract had been entered into (early in 1900) with Hannan's Brownhill Gold Mining Company "for the supply and erection of a plant for the treatment of their sulphide ores, capable of dealing with a minimum of 50 tons per day, with engine power equal to 100 tons per day, yielding a minimum extraction of 90 per cent. of the gold contents of the ore, at a cost not exceeding 30*s.* per ton. . . . The plant was completed at the end of February 1901, and the trial run of three weeks, provided for under the contract, commenced on March 4;" 1315 tons of sulphide ore being treated, which yielded 4091 oz. of gold. The plant was taken over by the Brownhill Company on April 1, and the following telegram was subsequently received from Kalgoorlie: "During month of March extraction has been 97 per cent. Cost per ton treatment is 24*s.* Now crushing 70 tons daily. Cost is estimated at 21*s.* during the month of April."

The details of cost in the Brownhill mill in July 1901 (as furnished to Mr. Knutsen by Mr. R. W. Feldtmann, Messrs. Bewick, Moreing & Co's. local representative) are given in a supplementary table at the end of this chapter, and also a "graphic" representation of the method of treatment, which Mr. Knutsen gives.

The Kalgoorlie correspondent of the *Financial Times* stated† that this plant had been running about seven months; during that period the monthly extraction had never been under 95½ per cent., whilst the treatment costs, including management, supervision, repairs and renewals, and general and office expenses, had amounted

* *Financial Times*, March 1, 1901. † *Ibid.*, November 5, 1901.

as nearly as possible to 24*s.* per ton; treating on an average about 70 tons per diem.

These costs could, however, it was believed, be reduced with a larger output, and the September costs were reported * to have been 22*s.* 11*d.*

At the company's annual meeting in July 1902, the chairman stated that 20,690 tons of ore had been treated for a yield of 45,977 oz., at an average cost of 24*s.* 8*d.* per ton, dealing with an output of only 70 tons a day.

The Author is informed that the costs for July and August were 25*s.* 3*d.* and 24*s.* 6*d.* respectively.

The Hannan's Star Mill.

The following particulars of these works have been excerpt from the description given of them by Mr. Robert Allen and Mr. H. Knutsen with some additional details furnished by the well informed local correspondent of the *Financial Times.*†

The plant, though somewhat more cramped for space than it would have been if the machinery had not required to be fitted into the old mill-building, is stated to be very compact and complete, allowing of economical work, even with a comparatively small output, which was rated at about 60 tons per day, or 1500 tons per month. Steam is supplied by a couple of Fraser and Chalmers two-flue 100 horse-power boilers, and as a stand-by a Lancashire boiler of equal capacity was provided. The horizontal steam engine is cross-compound and 200 horse-power. The engine-house also contains all necessary pumps, a small high-speed engine and dynamo for the electric light, and an air-compressor to provide air for the mill and filter-press work. The ore (which is said to average 10 to 15 dwt. per ton in gold), upon being hoisted from the shaft, is delivered by an overhead tram-line to the crusher-house, and is passed over a grizzly, with bars set 1½ inches apart. The coarser material, which is retained by the grizzly, is crushed in a Blake-Marsden rock-breaker. The broken ore, together with the fines from the grizzly, which fall into one bin, are then raised in cars by means of a double-cage lift, to a large double-compartment mill-bin, and from this bin, a couple of worm-feeders deliver it to two No. 5 Krupp ball-mills, previous drying having been discarded. The ball-mills require, when in full work, about 18 horse-power each,

* *Financial Times*, November 19, 1901.

† 'The Diehl Process,' *Financial Times*, November 7, 1900.

and were reported to crush between 30 * and 35 tons of sulphide ore every 24 hours, through a screen of 35 holes per lineal inch or 1225 per square inch.† The wear and tear on plates and balls is stated to be about half a pound avoirdupois per ton of ore crushed. With the softer oxidised ore the capacity of the mills rises to about 50 tons each, and the wear is considerably less.

The ore from the ball-mills is delivered to a bin by means of a belt-elevator, and a screw-conveyor transfers it to a second elevator which lifts it 30 feet, and discharges it through a second screw-conveyor into a "mixing machine," fitted with rotating paddles, into which plant-water containing a little free cyanide is introduced, so as to form a thin pulp.

An automatic sampler cuts out a sample for assay before the ore is mixed with water.

The pulp from the "mixing machine" goes to a spitzlutte (A) which separates the heavy mineral and sands (*a*) from the slimes (*b*), and the former products are passed over copper amalgamating tables to extract any coarse gold they carry (10 to 15 per cent. being thus recovered); whilst the slimes flow into four systems (B) of spitzkasten (three in each set) in which they are thickened.

The overflow water discharged from the spitzkasten (B) passes through a settling-tank where any remaining slimes are settled, and the water is pumped back to the mill-tanks which supply the mixing machine; the sediment collected in the settling-tank being occasionally cleared out and treated in the agitators.

Formerly, the pulp after passing over the copper plates was concentrated on Frue vanners, but this practice has been given up, and the whole of the sands which pass over the tables now go direct to a spitzkasten (C), which yields a thick pulp underflow (*c*) and a thin slimes overflow (*d*). The latter product goes to the pump-sump and is pumped into four spitzlutte, where any fine sands, that may have escaped with the slimes, are separated and sent back over the tables; whilst the slimes-overflow (*e*) passes back to the spitzkasten-system (B) which is connected with the

* *Financial Times*, Nov. 7, 1900.

† Mr. Robt. Allen states that (employing 30-mesh screens) which Mr. Knutsen also says are now used, 65 per cent. of the product will pass through a 100-mesh screen. See also *Mining Journal*, October 12, 1901.

spitzlutten (A) for treatment with the rest of the slime previously eliminated.

The thickened pulp underflow (*c*) from the spitzkasten (C) is delivered under a constant head to a "flint-mill"; and the product of this mill is raised by a bucket-elevator to a launder which returns it to the spitzkasten (C) that supplies the mills with pulp; any coarse particles that may have escaped grinding being thus caught and slimed.

The thickened slimes discharged from the spitzkasten (B) are converted in this apparatus into a sludge holding 40 to 50 per cent. of dry material, which is delivered to one of four agitation vats, each 21 feet 6 inches diameter and 7 feet 6 inches deep (provided with sheet-iron covers to prevent escape of bromine) in which they are agitated with cyanide and bromo-cyanide for 20 tc 26 hours. These vats hold about 100 tons of sludge, and conse quently take a charge of 40 to 50 tons of dry slime.

Mr. H. Knutsen, describing this part of the process, says: "The dry slimes assay before treatment 7 to 10 dwt. per ton. As soon as the agitator is sufficiently filled, the amount of KCy in the water is ascertained, and the tonnage of dry material in suspension. When this is ascertained a strong solution of KCy is allowed to flow in to make the quantity of KCy in solution up to 0·15 per cent. of the dry ore.

"As an example, suppose 100 tons of sludge contain 40 tons of dry material and 60 tons of water. The water carries 0·05 per cent. KCy or 17½ oz. KCy per ton of water. The total quantity is 1050 oz., which is equal to 26¼ oz. per ton of dry ore. The requisite is 0·15 per cent. or 52½ oz. per ton of dry ore. There is therefore needed an additional 26¼ oz. per ton, or a total of 1050 oz., or 65 lb. 10 oz. KCy, which must be added in the form of strong solution. Two hours after the KCy is added, the solution of BrCy is added at the rate of 0·04 per cent. of the dry tonnage. The whole is now agitated for 24 hours, when it is ready for filter-pressing. About two hours before filter-pressing lime is added to the agitator—about 3 to 4 lb. per dry ton."

After agitation the sludge is drawn off into the montejus and delivered into two Dehne filter-presses holding about 4½ tons of material, but only one system of receivers, viz. one unit each for sludge, for weak-solution, and for wash-water. The gold solution from the presses goes first into two vats which act as settlers, and is syphoned from them into two vats (fitted with filter-bottoms), from which it passes through the extractor boxes and is precipitated on zinc in the ordinary way.

The filter-press cakes after being treated with weak-solution and wash-water are discharged, and go to the dump ; very dry cakes are produced, the contained moisture being about 14 per cent.

In the article before referred to on the Diehl process the correspondent of the *Financial Times* * remarks : "Several mining men, not knowing the principles of the process, have expressed doubts as to the concentration of the telluride, but Dr. Diehl asserts that he only wishes to take the heavy pyrites from the pulp, mainly for mechanical reasons, and he does not attach much importance to a close concentration being obtained. † In fact, the more real telluride he can find in the pulp for chemical treatment the better is he pleased, for it can be easily dissolved when once in that state of fineness. The tailings from the vanners always carry a certain amount of mineral, mainly fine telluride, as before mentioned. The pulp now travels by gravitation to the fine milling department, and I might say that the work done in this department forms one of the most remarkable features of the Diehl process.

"Hitherto mill-men have always tried to prevent the production of slimes in milling ore, and doubtless many of them will be astonished to learn that Dr. Diehl has been compelled, by the peculiarities of the ore, to adopt an entirely new method, and, in fact, grinds the whole of the ore into slimes.

"As may be imagined, fine grinding in such large quantities did not at first appear to be an easy proposition, but by a really ingenious arrangement, the 65 tons of ore crushed per day in the ball-mills is now reduced by a single mill to such a state of fineness that it will pass through a screen carrying 62,500 meshes ‡ to the square inch. This is something which has never before been accomplished on a large working scale, and the careful preparation of the ore for treatment, combined with the specific effect of the bromo-cyanide solutions upon telluride of gold, . . . closely studied by Dr. Diehl, have made the success of

* 'The Diehl Process,' *Financial Times*, November 7, 1901.

† From what has previously been said this appears doubtful.

‡ As before observed, Mr. H. Knutsen says that the whole of the product of a flint-mill will pass a sieve with 200 meshes per linear inch, and less than 3 per cent. will remain on a sieve of 220 meshes per linear inch.

the process. The "fine mill" is of rather large dimensions, being* 17 feet long by 4 feet in diameter. It requires 25 horse-power, and is able to reduce 65 tons of ore into slimes every 24 hours. The mill works automatically, and the only attention it requires is the filling of the oil-glasses every three days. The power required is 0·425 horse-power per ton of ore, at 1*s.* 10*d.* per horse-power, which brings the costs of fine grinding up to 9·35*d.*, or, say, 10*d.* per ton. The wear and tear on the mill is reckoned at 1½*d.* per ton, so that the whole costs in the fine grinding do not exceed 1*s.* per ton, provided that an economically working plant is at disposal.

"The whole system of circulating the solutions and the ore is very ingeniously laid out, everything working automatically, and hand labour being avoided as much as possible. In fact, the ore is only handled twice—in the first instance to bring it to the mill bin, and secondly to dump the exhausted material on the tailings heap. It may be interesting to know that the whole of the mill work is done by eight men per shift—one foreman, one mill hand, two labourers, and four filter-press hands. The consumption of water, which is of paramount importance in this country, is very small, totalling 15 per cent. of the dry weight of the ore, which is equal to about 33 gallons per ton of ore treated, or, allowing for evaporation, the water used is not more than from 35 to 40 gallons per ton of ore. If worked with some care, the extraction is always over 93 per cent., and if the men in charge look carefully after their work, from 97 per cent. to 98 per cent. can generally be obtained. With ore from 1 oz. to 5 oz. assay value, the consumption of bromide of cyanogen is 1 lb. avoirdupois per ton, and for cyanide of potassium it varies from ½-lb. to 2 lb. The loss of the latter is mainly due to the dense salt water used, which contains from 8 per cent. to 20 per cent. of solid matters, including large quantities of magnesium salts, which act as cyanicides. Poorer ore than 1 oz. assay value gets proportionately smaller charges of chemicals, the extraction being equally good.

"The whole process is one of surprising simplicity, and, in a word, its chief principles are:—First, to disintegrate the ore by

* The *Mining Journal* of October 12 states that the flint-mill is filled with quartz pebbles from Norway in place of scraps of iron (as might have been seen in a machine working in Cornwall 20 years ago) as the iron acts injuriously on the bromine. It is usually charged with 4 tons of flint balls, and the usual standard size of the mill is 18 feet by 4 feet. It makes 28 to 30 revolutions per minute. Mr. Alfred James estimates the output of a mill of this kind at 70 tons per diem, through a 60-mesh screen (the size of the feed being 12 mesh), requiring 27 horse-power.

mechanical means, so that every particle of the precious metal can be attacked by the chemicals, . . . which have the power to dissolve the gold from its refractory combinations with tellurium, etc., just as easily as free gold can be dissolved by plain cyanide. The power required for the complete treatment of 1 ton of ore works out at 2½ horse-power in small plants, and will not be more than 2 horse-power in a large plant, to which costs the prices for chemicals and labour are to be added. This will show . . . that with a plant of, say, 150 to 200 tons capacity, the costs of milling and treating the ore should not exceed 20*s*. per ton, and, in fact, would probably be less. Given costs at 1*l*., with a high extraction, and taking into consideration the refractory nature of the Kalgoorlie telluride-sulphide ore, it may be fairly conceded that Dr. Diehl has achieved a brilliant success, and it is not too much to say that he and the London and Hamburg Company have conferred an immense boon on the Kalgoorlie field."

The Hannan's Star mill started work on March 15, 1900, and from that date to July 26 (when it was leased to the Brownhill Company for the remainder of the year) is stated to have treated 3630 tons of ore, of which 2129 tons were sulphide ore that yielded an average recovery value of 12 dwt. 20·8 gr. fine gold per ton ; and it appears from the report of Messrs. James Bros. (attached to the Company's Annual Report, July 9, 1901) that *the treatment costs*, as ascertained from continuous work in January, February, March, April and May of 1901, could be reckoned at 26*s*. 3*d*. per ton.

The residues, the Author is informed, assay 14 to 18 gr. fine gold per ton, from ore assaying about 14 dwt. per ton ; but with the richer ore, or ore from the settling-tank, may run up to 1 dwt. 6 gr. per ton.

The extractions for the first six months of 1901 were given (Report of the Annual Meeting) as 95 per cent.; 96 per cent.; 93 per cent.; 91 per cent.; 90 per cent.; and 93½ per cent.; and the treatment cost as 26*s*. 6*d*. on the average.

The results subsequently reported (cabled) were as follows :—

1901.	Hours run.	Sulphide Ore Treated.	Yield.	Extraction.
			oz. dwt.	per cent.
July	685	1355	901 0	92½
August	674	1635	1093 5	90
September . . .	650	1715	1146 0	92
October	692	1715	1204 0	92

Mr. H. Knutsen gives the following details of the cost of treatment in September 1901, furnished to him by Mr. G. E. B. Frood :—

COST OF POWER.

	£	s.	d.
Wages	126	19	11
Fuel	316	3	0
Salt water	37	17	5
Fresh water	90	3	9
Lubricants and waste	10	3	3
Stores	6	4	7
Electric light	—	—	—
Maintenance :—			
Wages	40	5	7
Stores	2	19	7
Total	630	17	1

This amount, 630*l.* 17*s.* 1*d.*, in the following analysis is divided between milling and ore treatment, two-thirds to milling, and one-third to treatment.

ANALYSIS OF COST ON 1718 TONS IN 1901.

—	Total Cost.			Cost per Ton.			
MILLING.	£	s.	d.	s.	d.	s.	d.
Wages	196	19	6	2	3·52		
Power and light	457	7	0	5	3·89		
Stores and sundries	13	5	3	0	1·85		
Lubricants and waste	6	8	4	0	0·88		
Ball metal	19	16	0	0	2·78		
Flints	10	5	0	0	1·43		
Wear on mill and crusher plates, large belts, etc.	70	0	0	0	9·78	9	0·13
	774	1	1				
ORE TREATMENT.							
Salaries	41	13	4	0	5·82		
Wages	280	16	8	3	3·22		
Power and light	188	10	5	2	2·33		
Stores and sundries	37	6	2	0	5·21		
Lubricants and waste	5	15	8	0	0·80		
Cyanide	200	15	8	2	6·90		
Cyanogen bromide	170	14	7	1	11·84		
Assays	23	16	3	0	3·32		
Fresh and salt water	11	1	7	0	1 54		
Maintenance	22	5	0	0	3·10		
Gold realisation	57	6	0	0	8·00	12	4·08
	1040	1	4			21	4·21

The returns were 1146 oz. 6 dwt. bullion, or 933 oz. 8 dwt. 14 gr. fine gold. This is equal to 10 dwt. 20·8 gr. per ton. The extraction (on basis of assay differences) was 92 per cent. There were consumed per ton of ore 2 lb. KCy and ½ lb. BrCy.

The results of treatment of the Brown Hill ore at the Hannan's Star mill are given in the following Table* :—

Month.	Ore treated.	Yield of Gold.		
1900.	tons	oz.	dwt.	gr.
August	1554	3,804	12	14
September	1867	4,554	12	12
October	1717	5,122	16	9
November	1698	4,684	9	19
December	1666	6,541	9	0
Total	8502	24,708	0	6

From a cable received from Mr. H. Trewatha James, dated August 7, 1902, and a subsequent cable in the *Financial Times* of August 11, 1902, giving the July returns, it appears that 1745 tons of sulphide ore from the Oroya were treated at Hannan's Star Mill which yielded 1711 oz. of fine gold, giving an extraction of 89½ per cent.; and during the first week in August 527 tons were treated, assaying 33 dwt. per ton, and an extraction of 92½ per cent. was obtained.

The Lake View Consols Sulphide Mill.

The Lake View sulphide-ore until recently was treated by two different methods—by roasting in the sulphide plant, and by the Diehl process without roasting. A general description of the original plant has already been given (p. 299); but as the works were subsequently more or less altered, the following account of the method of treatment pursued in them (until they were recently closed down), taken from the description given by Mr. Robert Allen, which furnishes additional particulars, may be given :—

The ore is dry-crushed and roasted, and the pulp is separated into sands and slimes, which are treated separately by cyanide.

The ore, as received on the brace, is first broken by two No. 5

* Hannan's Brownhill Gold Mining Company, Limited, Report No. 5.

Gates rock-breakers, set to produce a 1½-inch product, which drops into a 400-ton bin.

An aërial tramway (Otis system) delivers the ore from this bin to a 250-ton ball-mill bin. Containing very little moisture, it does not need drying.

This bin supplies four Krupp ball-mills, two of No. 5 size, driven at 25 revolutions per minute, each requiring 15 horse-power; the other two of No. 8 size, driven at 21 revolutions, requiring each 25 horse-power to drive them.

The screens used are 40-mesh woven wire, and with these screens, the capacity of each of the No. 5 mills is 25 tons per diem; that of each of the No. 8 mills is 40 tons per diem.

A sizing analysis of the ball-mill product is approximately as follows, the mill being full:—

			per cent.
Passing through a	150	mesh screen	63
Remaining on	150	"	6
"	100	"	27
"	80	"	4
			100

The dust, amounting to about 2½ per cent. of the weight of the ore, is removed by an exhaust-fan and deposited in a large settling-chamber, from which it is removed, as collected, to be roasted.

The ball-mills are discharged by screw-conveyors, the No. 5 mills delivering into a push-conveyor, which discharges into the boot of a 12-inch belt and bucket-elevator, the No. 8 mills discharging direct into the same elevator.

The elevator raises the ball-mill product to a screw-conveyor, which distributes it to shoots leading to four furnace-bins.

Sampling of the ore is done at regular intervals at the delivery of the screw-conveyor. The discharge from the bins is fed by fluted roll-feeds to four straight-line furnaces, each 180 feet long and 10 feet wide, which have a capacity of 30 tons a day each.

The ore is rabbled and pushed forward on the fixed hearth of each furnace by two travelling rabbles, which return over the top of the furnace; each rabble completes its circuit in 6 minutes. The furnaces have each four grates, in which wood fuel is burnt. The ore loses 10 per cent. of its weight in roasting, the residual sulphur, as sulphides, amounting to about 0·2 per cent. About 2 per cent. is reckoned to be carried away as dust.

The furnaces discharge between double discharge-doors into pits, and push-conveyors deliver the ore from the pits into a mill push-conveyor, which brings the roasted ore to the boot of a Krupp chain-and-bucket elevator.

This elevator discharges the pulp into one of a pair of "collecting agitator-vats," each holding about 50 tons net, and fitted with an ordinary suspended agitator that can be raised or lowered.

A stream of cyanide solution of 0·15 per cent. strength is delivered simultaneously with the roasted ore into the vat.

The vat gradually fills with sands, about 30 per cent of the ore treated being thus collected, whilst the remainder overflows as slime.

As the vat fills, the agitator-paddle is raised at intervals to keep it clear of the depositing sands.

When the vat is full (an operation which takes 16 to 20 hours) the sands are discharged into a pit.

From this they are raised in trucks by a crane, and sent to the leaching-vats, of which there are ten, each vat holding 60 tons of sands. The sands thus receive double treatment. The gold solution is precipitated in three sand zinc extractor-boxes.

The slimes which overflow from the "collecting agitator-vats" gravitate to three slime agitator-vats, each 20 feet in diameter and 6 feet deep, fitted with agitator paddles.

The pulp, containing 30 per cent of slime, is agitated in these until solution of the gold is complete, when the pulp is discharged through a bottom-discharge opening by raising a plug.

The contents gravitate to two montejus, used alternately, which fill four Dehne 4-ton presses worked in pairs.

The issuing gold solution from these gravitates to a settling-tank, from which it is siphoned to a second vat fitted with a filter-bottom. The liquor passing through this filter is run through two "slimes" extractor zinc boxes, and there exhausted.

The zinc sludge from the sands and slimes-extractor boxes is cleaned up, employing sulphuric acid treatment, and the resulting gold-slimes are smelted in a tilting-furnace.

The results during the year ending August 31, 1900, have been already given on page 301. During the year ending August 31, 1901, 35,517 tons were treated, at a cost of 31*s.* 7·996*d.* In the last four months of 1901, the cost is stated to have been 28*s.* 0·337*d.* per ton.

The capacity of the plant is between 3000 and 4000 tons per month.

The results and costs for the twelve months ending August 31, 1901, are given in detail below :—

Tons treated	35,517
Yield per ton oz.	1·499
Value per oz.	£3 13 7·2
" ton	£5 10 4·1
Total value	£195,963 5 3
Bullion produced oz.	53,250·650
Fine gold "	46,136·937
Standard gold "	50,331·203
Fine silver "	4,913·230
Cost per oz. "	£1 1 1·4

	Expenditure.			Cost per ton.	
	£	s.	d.	s.	d.
Superintendence	2,019	3	9	1	1·644
Electric light maintenance	967	2	1	0	6·535
Assaying, retorting and melting	1,611	14	10	0	10·890
Fuel	17,173	12	0	9	8·041
Water	6,951	1	6	3	10·968
Compressed air	1,717	8	9	0	11·605
Filling and emptying vats	3,026	12	1	1	8·450
Zinc	364	12	7	0	2·464
Cyanide of potassium	6,045	17	8	3	4·852
Separation	445	15	7	0	3·012
General repairs	4,327	13	10	2	5·242
Labour general	2781	0	7	1	6·791
Chemicals	265	5	5	0	1·792
General stores and charges	758	4	3	0	5·123
Filling and emptying presses	1,795	17	5	1	0·135
Filter-cloth	428	14	8	0	2·897
Engine-driving and firing	1,325	14	11	0	8·958
Firing roasters	2,420	0	10	1	4·352
Agitation	1,812	4	5	1	0·245
	56,237	17	2	31	7·996

The Lake View Consols Diehl Mill.

The Lake View Company, as previously mentioned, remodelled their old (oxidised-ore) battery at the end of 1900, with a view to give the Diehl process a thoroughly practical trial. The arrangement of "the plant" was altered as follows; the 50-head battery was enlarged, in 1901, to sixty stamps, and was increased to seventy-five, early in 1902. The ore from the mine first passes over a grizzly, and the coarser portion is crushed in a Gates crusher at the shaft to 1 inch diameter. From the shaft-bins it is carried by an aërial tramway to the battery ore-bins and fed to the batteries by Challenge feeders. The stamps each weigh 1100 lb., and are run with a 6-inch drop at 104 drops per minute. Punched-iron gratings used to be employed for oxidised ore (corresponding with 30-mesh wire screen), but wire-woven screens with 20 meshes per linear inch are now used. The capacity of the stamps with these screens is 4 to 4½ tons per head per 24 hours; very little gold can be recovered by amalgamation from this ore, so no copper plates are used. In place of going over tables the ore passes from each mortar-box direct into two small classifiers equal in length to the width of the mortar-boxes. The first of these is 8 inches deep, the other 18 inches, and they act as classifiers. The coarse sands (the product of 10 stamps) discharged from the first classifiers are delivered to a Wilfley concentrating table, and the finer sands from the second spitzkasten go to a second Wilfley. The tailings discharged from the Wilfleys are elevated 38 feet on the left side of a double tailings-wheel to a classifier which discharges their sand product into the flint-mills, 4 feet in diameter and 17 feet long, each charged with 4½ tons of flint balls.

Each tube-mill deals with the pulp delivered from three batteries (i.e fifteen stamps), which consists of sands and slimes mixed, and its discharge is re-elevated and returned to the classifier, the coarse sands from which are delivered in separate streams to the tube-mills, and passed through them again.

The finer sands and slimes discharged from the spitzkasten are elevated on the right side of the tailings-wheel, and passed through a "Krupp treble classifier"; and the heavy product this delivers goes back to separate concentrators, whilst the overflow passes into one of four or five systems (depending on the number of stamps running) of large spitzkasten, where it is concentrated to a sludge, holding 40 to 50 per cent. of dry material; the overflow water being finally settled in specially constructed settling tanks. The water, after the slimes have settled in these latter, is pumped back to the battery, and the slimes delivered by the spitzkasten and caught in the settling-tanks go to a series of large circular agitators (six being used with four flint-mills), 23 feet in diameter and 7 feet 6 inches deep, holding 110 to 120 tons of sludge when full.

Agitation takes place for 24 hours, first with a 0·2 per cent. solution of KCy equal to 4·4 lb. per ton of dry slimes (calculated in a similar way as at Hannan's Star), and two hours later each agitator is charged with 0·05 per cent. of cyanogen bromide per ton of dry material. One hour before the charge goes to the filter-presses 3 to 4 lb. of lime per ton of dry slimes is added. The cyanide consumption, I am informed, amounted to between 3 and 4 lb. per ton of ore; Mr. H. Knutsen states that 24 hours agitation under usual conditions will yield residues assaying only 1½ to 2½ dwt. fine gold per ton. The residues with shorter agitation and treatment will assay, however, as high as 4 dwt. fine gold per ton.

From the agitators the slime is delivered to filter-presses, and the solution expressed is forced through an empty filter-press to get it perfectly clear, before it goes to the zinc-boxes.

The process is essentially an agitation one all through, and considerable quantities of cyanide solution have to be kept in circulation, which no doubt partly accounts for the comparatively heavy consumption.

The concentrates produced in the 12 months ending August 31, 1901, amounted to nearly 4 per cent., which I understand, contained from 10 oz. to 15 oz. of gold; 1601 tons 3 cwt. 1 qr. 18 lb. having been recovered from 41,054 tons of ore crushed, which contained 21,217 oz. of gold. These concentrates were smelted in Fremantle, but they are now roasted and treated on the mine; the cost of shipping them away is stated* to have been 3*s.* 8·9*d.*; whilst the cost of treatment on the spot amounted to about 1*s.* 10·3*d.* Treating 1½-oz. ore in the early part of 1902, an extraction in both plants of about 90 per cent. appears to have been obtained,† but it was anticipated, I believe, that it would be brought up considerably, and that the cost of treatment in the Diehl plant would be reduced below 26*s.* 6*d*, which has since been effected.

During the eight months ending August 31, 1901, 41,054 tons were treated by the Diehl process, producing 40,120·975 oz. of bullion; and the concentrates produced contained 21,217·478 oz. The total value of the product was 230,180*l.* 10*s.* 4*d.* The average yield per ton amounted to 1·494 oz., valued at 5*l.* 12*s.* 1·6*d.* The value per oz. of bullion was 3*l.* 15*s.* 0·6*d.*, and the cost per oz. was 18*s.* 11·2*d.*

* Report of Messrs. Bewick, Moreing & Co., April 3, 1902.
† *Financial Times*, March 25, 1902. Report of R. W. Feldtmann.

The details of cost are given as follows:—

—	Expenditure.	Cost per ton.
	£ s. d.	s. d.
Superintendence	1,497 11 3	0 8·755
General stores and charges	1,283 6 4	0 7·502
Electric light maintenance	614 2 11	0 3·591
Assaying, retorting and melting	1,139 11 11	0 6·662
Fuel	7,791 17 9	3 9·553
Water	8,615 3 5	4 2·367
Labour, general	4,143 7 1	2 0·223
Engine-driving and firing	1,764 6 5	0 10·315
General repairs	3,527 19 7	1 8·625
Screens, shoes and dies	72 17 2	0 0·426
Elevating	715 13 5	0 4·184
Bromo-cyanide	9,349 10 7	4 6·660
Cyanide of potassium	7,108 18 4	3 5·560
Filling and emptying presses	5,786 16 5	2 9·831
Compressed air	3,795 18 0	1 10·192
Zinc	281 17 11	0 1·648
Chemicals	184 9 1	0 1·078
Filter-cloth	403 9 6	0 2·359
	58,076 17 1	28 3·531
Royalty	3,625 16 8	1 9·196
	61,702 13 9	30 0·727

The cost of treatment for the month of July 1902 was given * as 25*s.* per ton; and was brought down to 19*s.* 1·7*d.*† in November, and 18*s.* 4*d.* in December; an alteration having been made in the arrangement of the classifiers by which a finer slime is obtained, with less labour and power. A belt-driven pump for circulating salt water was also installed in place of the steam pumps, and a better vacuum was obtained in the condensers.

The Chairman at the Extraordinary General meeting of the Lake View Company held in July 1901, stated that when the arrangement is completed for taking over the plant erected by the London and Hamburg Company for adapting the mill to the Diehl process, in accordance with the contract, the total cost would approximate 24,000*l.*

Mr. H. Knutsen gives the following general particulars in regard to operating the Diehl process, which are of interest:—

Agitator treatment.—"When the agitator has received its full quantity of sludge, a strong solution of potassium cyanide is added. For slimes containing 1 to 3 oz. of gold per ton, we have found it

* *Financial Times*, August 12, 1902 (cable).

† The Author is informed that this was made up as follows:—Milled 6402 tons, cost per ton 4*s.* 10·6*d.*; concentrating, 1*s.* 1·3*d.*; bromo-cyaniding 6040 tons (12*l.* 4*s.* 2*d.*) 11*l.* 7*s.* 9*d.*; treatment of concentrates, 362 tons (26*l.* 4*s.* 3*d.*) 1*s.* 5·9*d.* Total per ton milled 19*s.* 1·7*d.*

sufficient to add so much cyanide that there will be 4·4 lb. KCy per ton of dry material. After the sludge has been agitated for 1 to 1½ hours, the solution of bromide of cyanogen is allowed to flow in, the quantity added being 1·1 lb. per ton of dry material. The agitator is kept going for 24 hours from the time the KCy solution was charged into it. In case the sludge should contain more than 3 oz. per ton, it may be advisable to add, after 6 to 8 hours' agitation, a further quantity of KCy and BrCy, to ensure a good extraction. On the other hand, if the sludge contains less gold than 1 oz. per ton, the quantity of KCy and BrCy can be considerably reduced.

"About 2 hours before the agitator is ready to discharge to the filter-press, lime is added to the sludge in quantity varying from 1 lb. to 4 lb. per ton of dry slimes. In most cases, I think, 3 to 4 lb. is used. A cleaner precipitate is thereby obtained in the zinc-boxes.

*Filter-presses and Filter-pressing.**—"The filter-presses used in the Diehl plants have a capacity of 4½ to 5 tons. They have as a rule 50 frames. The measurements of the cakes are 39½ inches square, with a thickness of 2½ inches (at Hannan's Star) to 3 inches (on Hannan's Brown Hill). The dry weight of such a filter-press cake will be 1¾ to 2 cwt. It is impracticable to use larger frames, as two men cannot handle them, and breakage might then be of more frequent occurrence. It has been found most advantageous for each filter-press to have its own system of receivers. One system consists of one receiver for sludge, one for weak solution, and one for wash-water. The sludge from the agitator flows into its receiver, which has sufficient capacity to fill one filter-press. When the receiver is full, the valve from the agitator is closed, and that to the filter-press is opened. The sludge is forced by compressed air into the filter-presses. At the beginning of the filling the air pressure will be 30 lb. per square inch. As the filter-press gradually fills, the air pressure increases to 50 lb., and even 75 lb.† When the filter-press is filled with sludge, the valve to the filter-press is closed, and the compressed air is turned off from the sludge receiver to the weak solution receiver. The cake is next washed with weak solution, and again with pure water.

* Mr. Knutsen points out that "in the Diehl process, the filter-press is absolutely indispensable," remarking, "It must be remembered that the slimes contain from 1 oz. up to 4 oz. or even 5 oz. per ton. The auriferous solution will thus contain about the same quantity of gold and any small remainder of solution left in the residue will cause considerable loss in the extraction. The treatment of slimes by the decantation method is therefore impossible at Kalgoorlie."

† The Author is informed by Mr. Alfred James that the ordinary pressure for filling may be estimated at 40 to 60 lb. to the inch, and 60 to 80 lb. for washing. The more impervious the slimes the *lower* the pressure to be used.

"For a charge of 5 tons dry slimes, 350 to 500 gal. of weak solution are used, and a similar quantity of wash-water. If the slimes be very poor, containing, say, 10 dwt. gold per ton, the use of weak solution is sometimes omitted. This has mostly been done where it is wished to put through as large a quantity of ore as possible. After the filter-press cakes are washed, a strong current of air is allowed to pass through them, at a pressure up to 80 lb. per square inch. This "dry-blowing" may last 10 to 15 minutes, but with a higher air-pressure the time taken is shorter. After this, the press is opened, the frames are emptied, and the cakes fall down into trucks standing ready below to receive them.

"When the frames are emptied they are cleaned. If any of the filter-cloths should be damaged they are mended or exchanged. The filter-press is then closed ready for a new charge. The whole time occupied from one charge to the next is about 2 hours.

Precipitation of the Gold.—"The auriferous solution is conducted to a storage tank, from which it must pass either through a filter-bottom or through a specially constructed plate-filter (sometimes a small filter-press) before it arrives at the zinc-boxes.

"The construction of the zinc-boxes and the work connected with them is so well known, that I need not go further into it here.

"The solution from the zinc-boxes flows to the same pump which receives the overflow water from the spitzkasten. From this the water is pumped back to the storage tank from which the battery or ore-mixer is fed. The solution from the zinc-boxes will contain KCy in varied percentage according to the ore which has been treated. It will contain ·05 per cent. to ·15 per cent., and sometimes more. As a result of this, the return water will contain KCy. In a new plant this will be very little; but as the work progresses the return water will grow in strength, until it reaches a figure ·03 to ·05 per cent. below the usual strength of the solutions from the zinc-boxes. In plants where no amalgamation is used, the KCy in the return water is of great advantage, as from the first moment the ore comes into the plant it is exposed to the action of the KCy. But even where amalgamation is used, the presence of KCy is not disadvantageous. The amalgamation will go on as usual, though the amalgam will be dry, and the plates will oftener need sprinkling with mercury. Some of the mercury will go into solution as $HgCy_2$, but this can easily be recovered by retorting the gold slimes from the zinc-boxes before roasting them. In doing this, I think more mercury may be recovered than has been used for amalgamation. The ore from the Kalgoorlie mines contains, amongst other minerals, coloradoite (HgTe), which is easily attacked by KCy. I have found in plants where no mercury has been used that the gold slimes in the first compartment of the zinc-box have contained a good percentage of mercury, which can only have come from the ore. The only drawback to the KCy in the return water is that the copper plates will wear out. After 18 months' or two years' continued use the copper plates must be replaced by new ones. The old ones will at this time be worn down to the thickness of paper. The return water will contain, after a time, a certain quantity of gold. This will not be lost, as in due time all return water, in one way or other, will pass through the zinc-boxes. Should the quantity of return water exceed the demand, the best way to get rid of the superfluous quantity is to use some of the precipitated solution from the zinc boxes, which will only contain a few grains of gold per ton, as wash-water in the filter-presses."

Mr. Knutsen has pointed out that, owing to the fact of one-third of the ore in the roasting process being treated in the form of sands, and only two-thirds as slimes, it has this advantage over the Diehl process in the matter of cost of compressed air, and filling and emptying the filter-presses.

On the other hand, the Diehl bullion at Lake View has been of higher value than that of the roasting plant. Another point claimed in favour of the Diehl process is that all ore can be dumped as exhausted residues within 48 hours of being raised from the mine, whilst with the "roasting process" the treatment is longer, often exceeding 10 days for *sands*.

Features that would also seem to most strongly recommend the Diehl process are its comparative simplicity and cleanliness. An estimate given by Mr. A. E. Thomas reckoned the cost of a Diehl plant with twenty stamps capable of crushing and treating 2250 tons per month erected at 35,000*l.* He calculated for depreciation at the rate of 10 per cent. per annum.

The relative amount of capital required to adapt existing "plants" or for erecting new works, for the installation of one or other of the processes that have been described, has, of course, to be considered; stamps, if of *heavy patterns*, can be utilised for the Diehl process, as well as "concentrators," and other mill machinery.

Judging from the facts that have been stated, it would appear that under the conditions hitherto obtaining, the cost of the Diehl process may be reckoned somewhere between the maximum and minimum figures that have ruled; and on a moderately large scale of treatment, it would seem quite possible to obtain by this means an average extraction from the Kalgoorlie ores of about 90 to 94 per cent. more or less, at a cost of between 17*s.* 10*d.* and 26*s.* 6*d.* per ton, depending upon the scale of treatment, arrangement of plant and other conditions. If therefore there is not any great difference in their relative average percentage of extraction, dealing with ores of similar grade and suitable character, it would certainly seem as if the Diehl process should be well able to hold its own with its earlier rival—the Boulder Main Reef process—in "plants" possessing about *the same capacity.* With cheaper *water* obtainable, treatment costs at Kalgoorlie would of course be materially reduced all round.

The Riecken Process.

The third process, of which mention has been made, was tested on a working scale by the owners of the patents at the South Kalgurli mine. The principles of the process on an experimental scale appeared metallurgically practicable, and it has attracted a larger amount of attention at Kalgoorlie than any other patent process except the Diehl; but it remains to be demonstrated that it can treat Kalgoorlie ore as cheaply and effectually as other processes in use.

The process is an electro-chemical one, and differs materially from both the Diehl and the Boulder Main Reef processes, as whilst any coarse gold is amalgamated, the fine gold is dissolved by the cyanide solution (ordinary) used, and the auro-cyanide being broken up, this portion of the gold is also recovered in the form of amalgam, being deposited on the amalgamated sides of an electro-vat instead of being precipitated on zinc. One advantage claimed is that the bullion produced is "finer,"* thus avoiding the deductions that are frequently made for refining cyanide bullion, which, if impure, may amount to ½ per cent. Any coarse particles of gold in the ore too

* The amalgam obtained is stated to be very finely divided, containing about 27 per cent. of fine gold; and results, after retorting and melting, when treating ores free from silver, in a bullion about 950 fine.

large to be dissolved by the solvent are also mechanically amalgamated. Thus three operations are performed simultaneously: (1) Amalgamation of the coarse gold; (2) solution by cyanide of the fine gold; (3) electrical precipitation of this dissolved gold.

In dealing with telluride ores, they have to be roasted as in the Boulder Main Reef process, but the Riecken system avoids the cost of pan amalgamation, and the expense of *double* filter-pressing, or otherwise eliminating the harmful salts, as it claims to effect the destruction of the cyanides by the action of the electric current on the salt bath, producing hyperchlorites, and so converting any ferrous salts that may be present into ferric salts, by which consumption of cyanide is reduced; and it is stated that it does not consume in practice more than about 2 lb. per ton.

As ordinary cyanide is employed, it seeks to escape the use of the more expensive chemicals required in the Diehl process, recovering the gold in one operation in place of two.

It seems comparatively simple to operate, and appears to require little power. Whilst, finally, one of its chief claims is that by the action of the electric current, the films formed on the gold in roasting, which act prejudicially in pan-amalgamation, are removed.

The ore to be treated must, of course, be first pulverised to such a degree of fineness as will allow of its being liberated by roasting, and freed from its enveloping matrix or gangue. The pulp in the "electro-vat" is made up of about equal weights of ore and solution, and, owing to the presence of salt in the water in Western Australia, its conductivity is excellent, so that a current of low potential suffices to precipitate the gold. The requisite current for each vat is stated to be about 250 amperes, of 2·5 volts potential, that is to say, $\frac{6}{7}$ of an electrical horse-power are sufficient to precipitate the gold in 18 tons of ore. The practical difficulty Mr. Von Gernet, M. Inst. M.M.,* has noticed, and which Dr. Kirke Rose, A.R.S.M., has described,† regarding the formation of hard black deposits on ordinary amalgamated copper plates when used as cathodes to separate gold from electrolysed auro-cyanide solutions, is apparently overcome by the thin stream of mercury kept constantly passing over the "plates," this forming a "flowing mercury cathode," which is one of the most interesting features of the process; and, in fact,

* *Proc. Chem. and Met. Soc.* of South Africa, vol. i. p. 30.

† 'The Electrical Precipitation of Gold on Amalgamated Copper Plates,' by T. Kirke Rose, B.Sc., etc., *Trans. Inst. of Mining and Metallurgy*, vol. viii.

A 0·05 per cent. to 0·075 per cent. solution of ordinary potassium cyanide will it is claimed, reduce the tailings of most ores down to 2 or 3 dwt.; and it is reckoned with high-grade ores of 2 oz. or over, that 18 hours' treatment will extract 90 to 95 per cent. of the gold; whilst with low-grade slimes carrying 3 or 4 dwt., it may be completed in about six hours. The probable loss of mercury is said not to exceed 2 oz. per ton.

The estimate originally given of the cost of treatment was as follows:—

	s.	*d.*
Cyanide (2 lb. at 1*s.* 2*d.* per lb.)	2	4
Mercury	0	3
Power, ½ horse-power (coal at 2*l.* per ton)	0	6
Labour	2	0
Water (200 gallons)	1	0
Lime	0	1
Labour and stores for engine and dynamo	0	6
Cost per ton treated	6	8

To the above must, of course, be added the extra expense of fine-crushing and roasting; but these, under favourable conditions, were not expected to cost more than 6*s.* 5*d.*, and adding 1*s.* extra for repairs the total cost, including general charges, was estimated, I believe, at about 16*s.* a ton.

Consequently, if the process should prove able to extract on a large working scale as high an average as, say 92 to 93 per cent. of the gold, even with an addition of 20 per cent. to these costs, it would no doubt be capable of competing with other methods of treating the *high-grade* sulpho-telluride ores of Western Australia.

A test made in London in 1901, under the supervision of Mr. A. C. Claudet and the Author, on a small trial lot of North Boulder sulpho-telluride ore assaying 2 oz. 6 dwt. gold, and 17 dwt. silver before roasting, and 2 oz. 19 dwt. gold, and 12 dwt. silver (per ton of 2240 lb.) after roasting, showed by assay an average extraction of 94 per cent. in 10¾ hours, using a ·03 per cent. solution which half-way through the run was brought up to ·069 per cent. strength.

The South Kalgurli (New) Sulphide Works.

The following particulars of this plant are taken from the description given of it by Mr. Robert Allen * and that of the local correspondent of the *Financial Times*.†

* *Op. cit.*, Royal Commission, Glasgow, 1901.

† *Financial Times*, letter dated January 19, 1901.

The ore trammed from the mine is crushed * in two No. 2 Gates crushers, which reduce it to about 2½-inch cubes. It then passes through a pair of 42-inch diameter Gates rolls, by which it is crushed to ⅜-inch cubes, and gravitates into two 70-ton bins.

From these bins the ore is distributed by screw-conveyors to five Griffin mills (run dry), after which † practically all the ore will pass a sieve of 80 meshes to the linear inch. It is then elevated by five belt-and-bucket elevators to hoppers, from which it is fed through fluted rollers, and roasted in two straight-line furnaces with hearths 147 feet long and 10 feet wide, which together are able to roast between 75 and 80 tons per diem, using wood fuel; whilst a third furnace, built in November 1901, increased the roasting capacity of the works, I understand, to 2800 tons per month.

The ore in the furnaces is stirred and carried forward by travelling rabbles, and discharged on to a push-conveyor, which carries the red-hot ore to a cooling-hearth of the same length as the furnace, where it is turned over by travelling rabbles, and carried to an underground bin.

A belt-and-bucket elevator lifts the ore from this bin to a covered mixing-vat, where it is mixed with an equal quantity, ·04 to ·07 per cent. strength, of cyanide liquor, so as to make it into a thick pulp (one part of ore to one of solution); and it is kept stirred by paddle-agitators, until the fine gold is dissolved, whilst the coarse gold is rendered readily amalgamable.

The four ‡ electro-vats, in which the pulp is agitated with paddle-agitators, are each 12 feet long, 11 feet deep, and 8 feet 6 inches wide, with sloping sides terminating in the rounded bottom of the tank, and vertical ends; these last support a horizontal shaft that carries the paddles.

Three of these tanks hold pulp equivalent to 20 tons of raw ore, the fourth holding 17 tons.

A current of electricity is supplied by one of a pair of plating dynamos of between 180 and 200 amperes, at between two and three volts, representing about two-thirds of an ampere per square foot of cathode surface; the copper plates are in removable sections, and cover the sides and bottom of the tank.

Agitation is continued for 16 to 18 hours for each charge.

* No. 3 Gates crusher was afterwards added to the plant, and a sixth Griffin mill.

† A screen-separator was put in below the Griffin mills early in 1902, to prevent any coarse particles going to the Riecken vats—in case of the breakage of a mill-screen—which is liable to interrupt the regular distribution of the mercury.

‡ An additional vat was added in January 1902.

The plates are kept bright by a constant stream of mercury distributed over them in jets by horizontal pipes parallel with the top of the plates, the pipes being pierced with a row of equidistant holes, and reciprocated backwards and forwards a couple of inches or so.

The mercury drawn off at the bottom of the tank is re-elevated to a small overhead reservoir for redistribution by an air-jet. The bulk of the gold is recovered as thin amalgam in the bottom of this reservoir.

The remainder of the gold is collected from the plates when sufficient amalgam has accumulated to warrant removal; and when a clean-up takes place, the "plates" are lifted from the tank by tackle, and removed on a trolley to the "clean-up room." The gold thus easily recovered is worth about 3*l.* 19*s.* 6*d.* an ounce.

After the pulp is exhausted, it is drawn off from the tank through a valve at the bottom of one of the vertical ends of the vat, and discharged into two storage vats, 12 feet in diameter and 6 feet deep, where it is kept agitated to prevent settling. It is drawn off as required into one of two montejus, and filter-pressed in the Dehne presses, to express the surplus liquor, so that the cakes can be dumped.

The plant started work on December 11, 1900, and is stated * to have treated 580 tons of ore in three weeks, which yielded 580 oz. 6 dwt., an extraction of 91 per cent., at a cost of 25*s.* 5*d.* The plant was taken over by the South Kalgurli Company in February 1901, after a month's trial, the results of which I am informed were as follows :—

Tons treated	700
Gold recovered, oz.	803
Gold contents ,,	863
Value of tailings	1 dwt. 16 gr. per ton
Extraction	93·28 per cent.

	Cost per ton. *s.*	*d.*
Labour	2	4·53
Cyanide	3	3·00
Water	0	2·46
Assays	1	3·24
Superintendence	0	7·08
Steam power	1	4·46
Mercury	0	4·03
	9	4·80

* *Financial Times*, letter dated January 19, 1901.

As before pointed out, these costs do not include the mechanical preparation of the ore, or roasting it. The Author was informed, however, that being a trial run, they covered certain incidental expenses which should not be ordinarily incurred in regular work, which it was anticipated would reduce the above figures: but judging from subsequent results, other charges have offset this expectation. Mr. Robert Allen estimated early in 1901 that "an extraction of 93 per cent. was being obtained by this process."

In his report for July 1901, Mr. John M. Iles, under the head of Milling, says:—

"The mill run for the month has been good, considering the new plant, and the different arrangement of appliances. The figures are as follows:—

1450	tons of sulphide	yielding	1473 oz.	=	1·0158 oz.	per ton
350	,, oxides	,,	250 ,,	=	0·7014	,,
1800			1723		0·957	

"The new roasting furnace did not deal with as many tons as I had anticipated. Owing to the arrangement for the draught not being sufficiently effective, other additions had to be made, and whilst this was being done only a moderate quantity could be roasted. Towards the end of the month the defects were remedied, and good results were obtained. A little delay also occurred through the mixer-shaft breaking.

"*Costs.*—In reviewing the milling cost-sheets, the cost of roasting is noticed. The amount, 8*s.* 7·92*d.* per ton, is heavier than usual. The chief reason for this increase is the faulty draught, because, to enable a proper heat to be maintained, extra fuel had to be consumed. The present altered conditions should lessen this charge in future.

"*Cyanide.*—Owing to the roast the cyanide consumption is heavier than it would have been under better circumstances.

"*Oxides.*—The quantity of oxides treated is smaller than usual. In future the operations on this class of ore will be irregular, as only at times, when circumstances are favourable, will the treatment be carried on.

"Under favourable circumstances, the mill as it stands at present is capable of dealing with 2000 tons of ore per month, and as the cost of treating this quantity will show only comparatively little increase on the total working expenses for the present month (July), there should be a marked improvement in the individual costs on such an output.

"The extension of the Riecken plant is practically complete. The copper plates are delivered, and the dynamo should be here in a week or so."

The returns for August were given in a subsequent cable, dated September 9, 1901.

"Have cleaned-up—worked 740 hours—sulphides 1600 tons yielding 1629 oz.—this includes 150 absorbed amalgamating fourth Riecken vat; oxides 340 tons, yielding 223 oz.—this includes concentrates to the value of 89 oz."

A cable, dated September 16, gave the costs as follows:—

"Sulphides, milling 1*l.* 8*s.* 1*d.*; extraction 92 per cent.; the gold is worth per oz. 3*l.* 14*s.* 9*d.* Oxides, milling 1*l.* 0*s.* 11*d.*; extraction 93 per cent.; the gold is worth per oz. 3*l.* 15*s.*"

In the Report of the Annual Meeting * the costs in October 1901, were stated to have been 27*s.* 6*d.* per ton.

It appears from the Annual Report of the Company that during the year ending September 30, 1901, 10,890 tons of sulphide ore were treated by the Riecken process, and the average extraction was about 92 per cent. The average cost was 34*s.* 0·33*d.*; but in the latter part of 1901, as already shown, this was considerably reduced; and in February 1902, treating 2670 tons of sulphide ore, which yielded 2777 oz. of bullion worth 3*l.* 11*s.* per oz., the cost is stated to have been brought down to 25*s.* 2*d.*; but it appears that the extraction fell concurrently to 90 per cent.

Referring to the Riecken process in his Annual Report dated October 1, 1901, Mr. Iles remarked, this method so far had given excellent results; plant of the extra capacity required to meet the increased output had been ordered and erected, and in future the whole treatment of sulphide ore would be completed by this process. Mr. Iles estimated that, on the basis of treating 2800 tons per month, costs could be reduced to 20*s.* 8·57*d.* per ton. Judging from the figures given on p. 392, this would appear possible with lower handling, crushing and roasting-charges (exclusive of any supplementary treatment); but in *Cyanide Practice*, third edition (1903), it is stated that the Riecken plant on the Great Boulder No. 1 mine has been shut down, and that filter-presses and zinc-precipitation are now employed at the South Kalgurli; and in a report dated January 23, 1903, Mr. Rich Hamilton advises altering the system of treatment, on very much

* *Financial Times*, January 23, 1902.

the same lines as that in use at the Great Boulder, by which he anticipates that the cost of handling and treating the ore from the main shaft to the residue dump should only amount to about 18*s*.

The Ivanhoe Sulphide Works.

A small plant was erected at these works in the first instance for the experimental treatment of sulphide ore, consisting of a small roasting-furnace * for roasting concentrates from the oxidised ores, and for treating small lots of rich sulphide ore ; the method of extraction pursued consisted in reducing the ore in ball-mills, elevating it to the furnace and roasting, then passing it through grinding-pans, agitating with cyanide solution, and filter-pressing ; much on the lines followed in the Boulder Main Reef process.

This plant started work in February 1900, and treated 601 tons of concentrates and 378 tons of sulpho-telluride ore for yields of 5939 oz. 12 dwt. and 1478 oz. 9 dwt. of bullion, showing averages of 9 oz. 17 dwt. 15 gr. and 3 oz. 18 dwt. 6 gr. per ton respectively ; and the costs, which came to 10*s*. 11·830*d*. per oz., are given below in detail :—

—	Total Cost.			Cost per ton.		
	£	*s*.	*d*.	£	*s*.	*d*.
Labour	1463	10	3	1	9	10·777
Water	323	13	3	0	6	7·345
Fuel	1333	17	9	1	7	3·000
Zinc	37	3	6	0	0	9·114
Cyanide of potassium	318	0	4	0	6	5·961
Stores	217	18	5	0	4	5·423
Filter-presses	204	19	4	0	4	2·247
Repairs and renewals	175	11	2	0	3	7·038
	4074	14	0	4	3	2·905

The Ivanhoe Process.

The fourth system of treatment adopted for dealing with sulphide ore, and which, for want of any better name, I have termed "the Ivanhoe sulphide process," proceeds on quite different lines from the process before described, being simply an adaptation of the old method of treating oxidised ore, and has so far successfully dealt with the ore from the different deep levels of the Ivanhoe mine.

In 1900 a series of experiments were made on ore from the 300, 400 and 500-feet levels, with five stamps set apart for the purpose.

* This multiple-hearth furnace was, I understand, provided with water-cooled mechanical rabbles.

The battery pulp, after it was crushed, was passed over a Wilfley concentrator, and the tailings were delivered to a 75-ton vat, where the slimes were separated from the sands.

The sands which settled were treated by percolation, and the slimes were agitated with KCy and filter-pressed.

The concentrates caught were roasted and cyanided.

Some 458 tons treated in this manner gave an 84 per cent. extraction.

The old oxidised battery, Fig. 64 (for a view of which I am in-

FIG. 64.—INTERIOR OF THE IVANHOE BATTERY. (Showing apron-plates and head of canvas tables.)

debted to the courtesy of the company), described in Chapter VIII., was remodelled, and particulars of the method of treatment employed are given by Mr. Robert Allen;* in the company's Annual Reports for 1900 and 1901; and in a Report by Messrs. Bewick, Moreing and Co., dated July 19, 1902, as follows:—

The ore (raised from Patterson's shaft) is first passed over a grizzly with 2-inch spaces, and the coarse portion is broken by a No. 5 Gates breaker, the product of which, with the previously-separated fines, falls into a 342-ton bin; a duplicate No. 5 Gates

* *Op. cit.*

breaker was installed and the bin-capacity was enlarged in 1901; but the present arrangement of the bins is, I believe, undergoing alteration, and the ore is to be passed through a double set of breakers, so as to deliver a finer product to the mill.

From the discharge-shoots of the shaft-bin the ore is trucked in 15-cwt. trucks to the stamp-mill, the stamps of which, in the old 60-head battery, weighed 900 lb., and were run at 90 drops per minute; their duty being about 3½ tons per 24 hours, using No. 16 punched screens.

The feeders are of the Challenge type. The pulp issuing from the boxes flows over apron-plates each 15 feet long by 5 feet wide and then over canvas tables 40 feet long and 22 feet wide. The concentrates which these latter appliances eliminated, represented about 1 per cent. of the ore (worth about 10 oz. per ton), and were shipped to Fremantle.

This part of the plant was remodelled, however, in 1901–1902 to correspond with the new 40-head battery, by putting in 12 Wilfley tables below the apron-plates to supplement the canvas strakes, as explained below, and heavier stamps, to correspond with the new battery, have been * put in. The sands and slimes which escape from the canvas tables are elevated by means of two 12-inch tailings pumps, and delivered to a spitzkasten.

This spitzkasten delivers a coarse-sand "underflow," and a fine sand and slime "overflow." The former is ground in four Wheeler pans which deal with about 35 tons of sands daily of an average value of say 13 dwt.; the gold set free (estimated at about 3 dwt. per ton of sands) is amalgamated, and the continuously-overflowing pulp is re-elevated by the pumps and returned to the spitzkasten. Pan-grinding is an important feature of the process, as gold is not only recovered as amalgam, but the gold that remains after re-grinding is said to be more easily attacked by cyanide. The overflow from the spitzkasten is delivered through Butters and Mein's distributors to one or other of twelve collecting-vats, each 21 feet in diameter and 6 feet 6 inches deep. The slime overflow from the vats is passed through a second spitzkasten, in order that any sands which may have escaped may be returned to the vats.

After draining in the collecting-vats, the sands which averaged

* The first ten were reported by cable on September 9, 1902, to have started work, and the others subsequently.

about 9·5 dwt. per ton in value for the six months ending June 30, 1902, receive a preliminary treatment with cyanide, and are then discharged into a second set of twelve vats below, 22 feet in diameter and 6 feet 6 inches deep, where their treatment is completed. The gold solution from these sands is precipitated in three zinc extractor-boxes. The residues for the six months ending June 30, 1902, are stated to have averaged 3·07 dwt., showing an extraction of 6·45 dwt. or 67·7 per cent.

The slimes overflowing from the second spitzkasten, which were reckoned to average 9·26 dwt., pass to one of eight settling-tanks, where they are thickened by settlement to about the consistence of one part slime to one part water, the supernatant liquor being drawn off. Agitator paddles, with which the tanks are provided, are then set in motion, and when the pulp is all fluid again, it is discharged into a small "mixing-tank," fitted with a propeller-shaped agitator, the necessary cyanide solution being introduced at the same time and incorporated with the pulp. An 8-inch plunger-pump delivers the cyanided pulp to one of six agitator vats, each 20 feet in diameter and 10 feet deep, where it is agitated for about 24 hours, after which, by means of one of two montejus, the pulp is forced into five Dehne filter-presses, each of a capacity of 3 tons of ore, holding 2-inch cakes. After treatment the residues are stated to have averaged, for the six months ending June 30, 1902, 2·33 dwt., showing an extraction of 6·93 dwt. or 74·8 per cent. The relative proportion of sands and slimes crushing 88,084 tons in 1901, was 49 per cent. and 51 per cent. respectively; but on hard sulphide ore, the proportions would more likely be 57 per cent. sands and 43 per cent. slimes.

The solution from the presses, after passing through a Dehne filter-press to clarify it, is deprived of its gold by passing through two slimes zinc-extractor boxes.

The original capacity of the Ivanhoe plant was about 6500 tons per month, but with the new 40-head battery of 1100 lb. of Fraser and Chalmers stamps (running at 93 drops per minute with a capacity of 3·97 tons per head) in operation,* it was calculated to be able to treat about 10,000 tons per month. The arrange-

* These were reported as having started work on September 29, 1901. The duty of the old 60-head battery in 1901 was 3·63 tons per stamp per 24 hours, and probably not more than 3·4 tons could be calculated upon with harder ore.

ment in the new mill differed at first slightly from that originally pursued in the old mill, until the old mill was remodelled to correspond with it. The pulp from all the batteries is now passed over amalgamated copper tables, then elevated to a spitzkasten, and the coarse and fine product of each set of ten stamps is treated separately on a pair of Wilfley tables.

The eight Wilfleys in the new mill were stated to have saved some 5 tons of concentrates per diem, worth about 4 oz. of gold per ton, in 1901; and with 12 tables to be added to the old mill, it was expected that 11 tons of concentrates of the above value would be caught daily; the actual quantity appears to have been about 13 tons, of an average value of 3½ oz.

The tailings of the tables are run over canvas strakes 30 feet in length and 22 inches wide, and pumped to the cyanide works, where they are dealt with in the manner already described.

The plant was increased in 1901 by the addition of eight out of the twenty-four collecting and leaching-vats, and the requisite auxiliary machinery was added to the cyanide works to cope with the extra output of the new stamps in the re-modelled (100-stamp) mill, including a new double-acting 15-inch plunger tailings-pump, which now lifts the whole of the battery tailings, the pump previously used being converted into a return water pump.

The "canvas tables" are an important feature in the scheme of treatment, as it is estimated that with the 100 stamps running full time they should save about 1½ ton of concentrates per diem, assaying say 12 oz. per ton in gold, the mineral being so exceedingly fine that canvas appears the only means of saving it.

The new 40-heads are driven by a 16 inches by 26 inches by 42 inches Fraser and Chalmers compound Corliss engine, provided with exhaust-steam condensers, the old engine driving the old battery, etc., as formerly; and four Cornish boilers supply steam for the new engine. The enlargement of the plant is stated to have cost about 38,000*l.*

The additions referred to enlarged the capacity of the cyanide works, so as to enable them to treat about 6000 tons of sands per month; and with four presses running 357 days, 170 tons of slime were dealt with daily in 1901; but with the whole six presses (one being used for clarifying purposes) 255 tons of slimes could be handled per diem.

Mr. Robert Allen gives * the following analysis of sulphide ore taken from the 500-feet level of the Ivanhoe:—

	per cent.
Silica	73·00
Sulphur	3·01
Alumina	2·50
Ferric oxide	10·70
Lime	5·40
Magnesia	3·90
Water	0·20
Undetermined soda, potash, etc.	1·29
	100·00

The concentrates were formerly shipped with the rich sulpho-telluride ore to Fremantle to be smelted; but as the result of the experiments before referred to made in 1900, it was decided to put in three Edwards furnaces and roast the concentrates on the spot after drying. The roasted material (representing about 13½ tons of Wilfley and table concentrates and 20 tons of telluride ore per day) is therefore at present dealt with by grinding and amalgamating it in (three) pans; the pan-sludge was at first fed into the battery-launder mixed with the ordinary mill-tailings and delivered to the cyanide works; but it is now elevated by a tailings-wheel to a spitzkasten, deposited in settling vats, transferred to agitators, and filter-pressed. The filter-press cakes assay about 3·3 dwt. per ton, and an extraction of about 96 per cent. is obtained, of which 40 per cent. is won by amalgamation and 56 per cent. by cyanide. The roasting and grinding plant is situated at the north-east end of the lease, near Drysdale's shaft and the 100-head mill, adjacent to the proposed new wood siding, so that there will be no necessity for double handling of fuel. Its cost was estimated † roughly at about 5200*l.* complete, and it includes besides the machinery already mentioned a No. 2 Gates crusher and two No. 4 Krupp ball-mills for crushing the "telluride-ore" for roasting, and an elevator which raises the crushed product to the furnace-bins, where it is mixed with the "concentrates" elevated from the drying-floor. It is thought, however, that the concentrates could be more economically slimed in grit-mills than in pans, and this alteration, I believe, is in contemplation.‡

The extension of the railway-siding to the condenser-plant is

* *Op. cit.*, Royal Commission, Glasgow, 1901.

† Report of the Mine Manager, October 16, 1901.

‡ The cost of treatment in this plant was given in the Mine Report of September 30, 1902 (with one furnace in operation), as 24*s.* per ton for telluride ore, and 26*s.* for concentrates.

stated to have saved considerable expense formerly incurred in carting fuel. In the Company's Annual Report for 1901, Mr. R. B. Nicolson observed:—

"The 100-head has now (December 31) been running three months for an actual extraction of 86 per cent., which is a fair guide to future results.

"When the 100-head mill is equipped with Wilfley tables, and the roasting-furnaces working, this extraction of 86 per cent. should be increased.

"For the last three months the costs of crushing, cyaniding and smelting charges have been about 15*s.* per ton, and we hope to reduce this to 13*s.* per ton when the roasting plant is in operation."

In 1901 some 46,459 tons of sands were treated in the cyanide works (including 4593 tons from accumulated heaps which were exhausted in July), which yielded on the average 8 dwt. 12 gr. *in bullion.* The average value of the sands before treatment was 10 dwt. 3 gr. per ton in fine gold, and after treatment 3 dwt. 12 gr., showing an actual extraction of 65·7 per cent. During the same period 60,624 tons of slimes were filter-pressed (including 17,412 tons from reserve heaps), yielding 8 dwt. 2 gr. per ton *in bullion*; the original value of these slimes was 8 dwt. 2 gr. in fine gold, and after treatment they assayed 1 dwt. 19 gr., representing an actual extraction of 77·8 per cent.

In 1901 the amount of ore treated on the mine, or shipped and smelted, was 90,423 tons, which yielded 108,767 oz. of bullion, containing 94,671 oz. of fine gold; and the loss in residues was 2 dwt. 14 gr. per ton, the amount of free gold in the ore decreased, and the amount of gold won from concentrates and tailings increased to about 40 per cent. of the whole quantity returned.

The correspondent of the *Financial Times*, early* in 1901, remarked:—

"Battery treatment will not, of course, apply to telluride ore; but the telluride on this field mostly occurs in "chutes," and the majority of managers are of opinion that it can be easily picked for smelting.

"All the sulphide ore taken from the "middle lode" (of the Ivanhoe) at the 500-feet level has been put through the stamps. The only telluride vein of any extent is at the Drysdale end of the property, and the management say that this can be sorted out with

* *Financial Times*, letters dated February 9 and March 9, 1901.

ease;" this, as will readily be seen, is the key-note of the Ivanhoe process.

The total extraction in 1901 from all sources came to 88·98 per cent. as shown in detail in the annexed table; and analyses of the cost of milling and cyanide treatment are given in the supplementary tables at the end of this chapter.

IVANHOE (1901).

—	Oz.	Dwt. per Ton.	Extraction per cent.
Fine gold won in mill	47,121	10·4223	44·28
,, from concentrates	6,852	1·5155	6·44
,, ,, sands	15,438	3·4146	14·51
,, ,, slimes	19,071	4·2181	17·93
,, ,, telluride ore	6,189	1·3688	5·82
	94,671	20·9393	88·98
Loss in residues	..	2·5946	11·02
	..	23·5339	100·00

During the six months ending June 30, 1902, 41·23 per cent. of the fine gold in the ore was recovered in the battery: 8·95 per cent. from concentrates; 16·67 per cent. from sands; 15·30 per cent. from slimes, and 3·47 per cent. from telluride ore; the gold recovered amounted to 56,133 oz. from 65,202 tons crushed.

In their Report dated July 19, 1902, Messrs. Bewick and Moreing (the Company's consulting engineers) pointed out that: "If the system at present in use of grinding 'coarse' sands were merely extended somewhat, so as to embrace a larger proportion of the sands, the effect would be to make a larger percentage of 'slimes,' and consequently to somewhat enhance the working costs, but also to obtain a better extraction from that portion of the fine sand treated as 'sands,' as well as from that portion which, ground to slime, would go through the slimes treatment. Probably a point would be reached at which the increase in the percentage of slimes would so raise the cost as to counterbalance the extra extraction obtainable; but when this would be reached it is impossible to foretell or to determine otherwise than by actual work."

They expressed confidence, however, that an economic improvement in the treatment of the "free-milling" ore would unquestionably be brought about, and add that: "Treatment on the lines suggested could also be modified or extended so as to deal with a larger proportion of the refractory material than naturally exists in the 'free-milling' ore,* possibly up to the ratio naturally existing in the mine."

They therefore suggested "replacing the grinding-pans at present grinding coarse sands by say three 30-tons (a day) flint-mills. These will grind a large proportion of the sands, coarse and medium coarse, to a fine sand and slime. It is estimated that provision will have to be made for the treatment of say 60 tons of slime per day more than are at present being dealt with."

In the event of the ore becoming more refractory in depth in the mine, so as to necessitate bromo-cyanide treatment, or on the other hand, in the event of the success of the "oil" process being established, these additions to plant would be of a nature, and would be so arranged, as to work in with either bromo-cyanide or "oil" treatment.

The Golden Horse-shoe Smelting Works.

A small plant for the treatment of *high grade* sulphide ore (for the accompanying views of which I am indebted to the courtesy of the company) was erected at the Golden Horse-shoe in 1900, consisting of an Edwards roasting furnace, fired with producer-gas, a water-jacket furnace, Fig. 65 (built by Martin and Co., of Gawler), and two American-type cupellation furnaces, Fig. 66, supplied with air by a Roots blower. A Miller's chlorination plant was also installed for refining and parting the resulting bullion.

The capacity of the water-jacket furnace is given by Mr. Robert Allen as 30 tons of ore and flux, per diem, 8 to 10 tons of ore being dealt with.

The fluxes consist of ironstone obtained locally, limestone procured from Southern Cross, and silver-lead ore imported from Broken Hill, New South Wales.

The reduced lead collects the gold and silver, scrap iron being used as a desulphurising agent.

The fuel used consists of 90 per cent. of coke and 10 per cent. of Collie coal.

The base-bullion thus produced is afterwards dealt with in the

* It would appear that for some time past "an undue proportion of 'free-milling' as against telluride ore had been mined," which called for some modification of the past system of treatment.

cupellation furnaces, Fig. 66, the litharge resulting being returned to the water-jacket. About 250 tons of high-grade ore were usually treated monthly on the mine with this plant.

FIG. 65.—WATER JACKET FURNACE, GOLDEN HORSE-SHOE WORKS.

The ordinary grade sulphide-ore is broken in a Blake-Marsden stone-breaker to 3-inch cubes, and shipped to Fremantle to be smelted with the concentrates; some 1800 to 2500 tons, containing 4700 to 6000 oz. of gold, being thus shipped away monthly.

The Golden Horse-shoe Sulphide Works.

So far as I am aware, no detailed description of these works has yet been published (since they have been erected), but I gather from particulars given in the company's last Annual Report that the line of treatment adopted differs somewhat from that of any of the other plants on this field; and writing under date of March 22, 1902, the correspondent of the *Financial Times* described the process as follows:—

"The new plant, which will probably start work at the end of this month, is designed for the complete reduction and treatment of at least 200 tons of sulphide ore per day, on the principle of preliminary breaking to an inch gauge, crushing in a stamp battery through fine screens, classification, concentration on Wilfley tables, reducing the sands to slimes in grit-mills, re-classification, withdrawing the water, collecting the slimes in agitating-vats, and agitating with cyanide of potassium, extraction of the gold by filter-pressing, and precipitation of the gold by means of zinc shavings.

"The battery is a 50-head Fraser-Chalmers, with 1250-lb.* stamps. The whole of the pulp coming from the battery will be laundered to a tailings-wheel and elevated into a system of fine classifiers. Each of these classifiers is divided into four compartments, forming inverted pyramids of successively increasing sizes. Each compartment is fitted with a flange, plug and spigot at the bottom, by which the graded product from the various compartments will be withdrawn.

"The openings in the spigots will be increased or decreased as

FIG. 66.—CUPELLATION FURNACES, GOLDEN HORSE-SHOE WORKS.

desired, so that the whole of the sands will be removed from the pulp in four different grades, and the overflow being slimes, will be conveyed to the near side of the tailings-wheel.

* 1275 lb. is the exact weight, according to the company's Report, 1901.

"The sands from Nos. 1, 2 and 3 spigots of the classifiers will be conveyed in separate launders to the Wilfley concentrators.

"Three of the concentrators will be set apart for the treatment of each of the grades from Nos. 1 and 2 spigots, and four tables for the product of No. 4 spigot.

"The concentrates will eventually be shipped to the smelters for further treatment.

"The tailings from the concentrators will be run in a launder to the tailings-wheel, and joining the slimes from the classifiers, the joint product will be elevated into three spitzlütten with an ascending current of water.

"These will trap all the sands and coarse particles, and the sands will then be conveyed to four grit-mills, where the greater portion will be reduced to slimes.

"After passing through the grit-mills the pulp will be returned to the launder and conveyed to the further side of the tailings-wheel, where it will join the pulp from the battery, and again undergo the process of classification and concentration.

"The overflow from the 'sand-traps,' being purely slimes, will be run over three separate slime-settlers." The slimes from the settlers will be conveyed to six agitation-vats, where the pulp will be mixed with cyanide solution, agitated, and the gold dissolved.

There are six filter-presses,* each of 5 tons capacity, for filter-pressing the slimes, and the solution from the presses will be run into four zinc-boxes and precipitated in the usual way.

The residues will be dumped by belt-conveyors on the tailings area at a height of 30 feet.

It is not stated whether bromo-cyanide is to be used in conjunction with ordinary cyanide or not, for the extraction of the gold, but the general principle followed appears to be to first remove the richer pyritic part of the ore by concentration, and slime the rest, as is done in other mills.

The total monthly output of the Golden Horse-shoe works was given in 1901 by Mr. Allen at between 15,000 and 15,500 oz. of gold.

In July 1902, with the old battery running 28 days and the new battery 25 days, 10,715 tons were crushed which (together with 107 tons smelted at the mine) returned 16,116 oz.

The costs of treatment in the old mill, in 1901, are given in the supplementary tables at the end of this chapter.

* Pumps are used to fill the presses in place of montejus at these works.

General Observations upon the Systems of Treatment described.

In the early part of 1898, the Author drew attention * to the probability of being able to deal successfully with these sulpho-telluride ores by concentration, employing wet classification † for the preparatory treatment of the battery pulp, and recent practice at Kalgoorlie certainly seems to be tending more and more in this direction. *Concentration*, in fact, now plays an important part in several processes now in operation on the field, and the results of the Elmore process of recovery by means of oil, that is about to be given a trial, with a view to the closer saving of flaky tellurides which are liable to escape table-concentrators, will be watched with very great interest; as if it meets with the success anticipated it may lead to important modifications being made in the present systems of reduction, and result in a considerable diminution in costs: if one estimates the average cost of sulpho-telluride treatment in the early part of 1901 at, say, about 26*s*. per ton. Costs have already come down considerably, and will probably be lowered still further in the near future, as they have shown a gradual tendency to do so; the various works that have been described having been improved and modified, so as to deal with these peculiar ores to better advantage, and handle them on a larger scale.

To gauge the relative *practical value* of different processes, however, not only must the cost of treatment (properly split up into its primary component units) and the percentage of extraction be known, but, in addition, it is most important to ascertain and compare the original value of the ore treated, the value of the tailings after treatment, the actual recovery value in ounces of bullion, and the fineness of the gold recovered, taking into account the concentrates, or other subsidiary products produced; the relative quantity of each by-product thus recovered; the cost its individual treatment entails; and the proportion of gold it returns, as compared with the gross amount recovered.

The mere *percentage of extraction* is often otherwise misleading, taken by itself, as gold is at times *extracted from an ore*, it is true, but remains locked up in solution or in other ways, and is never actually *recovered*, from a commercial point of view.

* Report upon the North Boulder Gold Mine, April 1898.

† Mr. Alfred James observes that it is recognised as fruitless to expect the same table to deal with coarse and fine together, and the newest plants provide for the separation of sizes as well as of equal falling particles.—*Cyanide Practice*, 3rd ed. (3p) 19.

The three leading processes which are at present employed at Kalgoorlie do not, however, exhaust the field which is being traversed in various directions to discover the best means of dealing with refractory ores in general, and sulpho-tellurides in particular. For wet-crushing a duty of 5 tons per diem has been reached with stamps, with an expenditure of about 3 horse-power per stamp; whilst in dry-crushing two ball-mills have shown themselves capable of handling 75 tons or more per diem with an expenditure of 32 horse-power.*

The Oil Concentration Process.

The oil concentration process, which was invented by Messrs. Elmore, being a new method of treatment, that appears to be applicable to various moderately mineralised ores (apart from its recent introduction at Kalgoorlie), a brief description of the principal features of the process cannot fail to be of interest. It was very fully described by Mr. Chas. M. Rolker† in a "paper" read before the Institution of Mining and Metallurgy, April 1900, in which he described the working and results of the process at Glasdir, Wales.

As certain modifications have, however, since been introduced into it, as will be seen, to adapt it to the treatment of telluride ores, I recently applied to my friend Mr. H. L. Sulman, for information on the subject, and he has not only been good enough to favour me with a general outline of the method pursued, but with the kind permission of the Australian Ore Concentration Syndicate, Ltd., he has given me particulars of the results of the trials made upon Kalgoorlie telluride ores.

Coming from the pen of a "specialist," who has personally studied the process, the following description, under date of August 25, 1902, possesses particular value, supplementing what the Author has already himself said in regard to the possibilities of the process.

"The successful results of large scale trials upon Kalgoorlie sulphide ores have attracted considerable attention of late from

* 'Metallurgical Progress in Western Australia,' by Alfred James, *Eng. and Min. Journal*, January 3, 1903.

† 'Notes on the Elmore Concentration Process,' by C. M. Rolker, M. Inst. M.M., *Trans. Inst. of Mining and Metallurgy*, vol. viii.

Westralian mining companies, and it is thought that this process will render possible the economical reduction of the large reserves of low-grade sulpho-telluride ores which are said to exist in the stopes of the several better developed mines.

"The process depends upon the fact that metallic sulphides and certain other minerals will attach themselves to oil in preference to water, but that oxides, silica and gangue-stuff generally are preferentially wetted by water, and so will not be taken up by the oil. Free metals and several non-metals, such as carbon in its various forms, sulphur, etc.; the insoluble metallic chlorides, tellurides, etc., behave in the same manner as the sulphides; but carbonates and silicates and oxidised products generally are rejected with the gangue. So marked is this selective action with certain oils, that it is only necessary to expose a battery pulp to sufficient contact with such an oil in suitable apparatus to effect an almost perfect recovery of the various non-oxidised minerals liberated from the gangue by crushing, as an 'oil concentrate.'

"The oil is employed in quantity sufficient to buoy up the entrapped heavy mineral particles, so that the concentrate-bearing oil-layer is separable by flotation from the treated pulps. The concentrates are recovered from the oil by passage through a specially designed centrifugal machine, whilst the valueless pulps are automatically rejected. When the separated oil is rapidly rotated in the centrifugal 'basket,' its contained mineral is piled up (through a layer of water) against the sides, the mineral-freed oil escaping over the return lip of the same, ready for re-use upon further pulp supplies. The process thus permits of continuous operation, the plant being practically automatic in action, of simple construction and having but few wearing parts; whilst the percentage of recovery is very high.

"Other inventors, notably Messrs. Robson and Crowder, had previously suggested the use of oil for the purpose of mineral concentration, but it was reserved for Messrs. Elmore to discover and work out the essential conditions for its application, especially as regards the necessity for employing thick mineral oils, such as the tarry residues from petroleum distillation, etc., after some of the volatile constituents have been distilled off. These inventors were also the first to devise a practical oil concentration plant, and to reduce vaguely known facts to a compact commercial process.

"The method was originally applied by Messrs. Elmore to the treatment of low-grade copper ores, where the float losses inseparable from water concentration, in even the most modern of vanning plants, were found to be prohibitive. At Glasdir, in North Wales, with a 2 per cent. copper ore (values being carried mainly in chalcopyrite and tetrahydrite), the most efficient wet concentration methods were found incapable of saving more than 15 per cent. of the copper, whereas on instituting oil-concentration it is claimed that from 80 to 85 per cent. of the copper was recovered.

"From this it was evident that the oil process had a wide scope of usefulness in application to the concentration of all non-oxidised minerals subject to heavy float losses during water dressing. Blende at present forms the only, though partial, exception.

"The Westralian sulpho-telluride ores are, of course, peculiarly incapable of wet concentration, owing to the great friability of the rich telluride minerals they contain, and to the no less marked tendency of these to 'float'; also to the extremely fine division of the values and their intimate dissemination through the ore.

"The fact that a direct solution process, such as the 'Diehl,' should require the ore to be opened up by crushing to a minimum mesh of 200 to the linear inch—in other words, that in order to 'expose' the values to a solvent it is necessary to grind the ore to absolute 'slimes,' will demonstrate the futility of any water concentration method for the close saving of such. But oil has no difficulty in collecting even the most finely divided mineral particles, provided these be clean and free from oxidation. For example, oil will readily recover the highly divided particles of metallic gold such as result from the precipitation of chlorination liquors, and have resisted subsidence and even filtration.

"Oil-concentration as applied to grit-mill pulps on the Hannan's field has been necessarily modified from the process originally designed for treating low-grade copper ores, i.e. where the mineral is sufficiently coarse to be liberated by crushing to a low mesh.

"In the latter case ample contact between ore-pulp and oil is secured by continuously passing the mixture through a series of two or more cylindrical drums. These are about 9 feet long and 3 feet in diameter; they revolve on friction rollers in a horizontal position, and are fitted internally with a helical fin some inches in depth. The rush of oil and pulp between the walls of the screw-shaped launder thus formed on rotating the cylinder is broken by the interposition of a certain number of baffle-plates, which stretch from rib to rib of the helix at uniform intervals. By this means sufficient agitation is assured to bring all mineral into contact with the free oil, whilst the baffles also serve to keep the heavier portions of the ore constantly dropping through the oily mass which continuously travels forward through the lower segment of the cylinder. The whole of the interior metal of the cylinder, the helix, baffles, etc., are normally covered with a layer of oil, which thus provides further catchment surface. The mineral-laden oil is separated by flotation from the partially treated pulp in a spitz-kast (trap) tank placed at the further end of the cylinder; the oil and mineral here obtained being run off to the continuously acting centrifugal plant, whilst the pulp flow is again mixed with a fresh supply of oil and sent through a second and even a third cylinder. Here, upon further contact with oil, the pulp is still again depleted of mineral values, and any 'overloaded' oil-globules which may have escaped separation in the first spitz-kast are retained and buoyed up by the second or third oil addition.

"At the end of the second cylinder the oil and concentrates are again separated, the pulp then usually traversing a third cylinder with fresh oil as before. After separation of this final oil addition the pulp is sufficiently depleted of mineral values as to be run to waste. Leaching and slime treatment methods are thus entirely eliminated, and all that remains is to 'bag' the sharp concentrates obtained from the centrifugal plant for smelting or other final recovery.

"The oil employed must possess physical characters, e.g. viscosity, agglomerative power, specific gravity, etc., which require careful choice in relation to the requirements of particular ores. That most usually used consists of certain of the heavier fractions and residuums resulting from the distillation of American petroleum.

"The loss of oil in the operation is small; a minute proportion is carried away by the rejected ore-pulps, while the well 'spun' concentrates also retain from 1 to 2 per cent. of their own weight of oil. The total loss may vary from ¾ to 1½ gallon per ton of ore crushed, an amount which costs approximately the same as the cyanide consumption upon a suitable 'cyaniding' ore, say *6d.* to 1*s.* per ton, according to the price of oil at the place where used.

"The oil process as applied to Kalgoorlie ores is considerably modified from the foregoing. The problem here is to catch all the values, and to leave behind a valueless pulp which shall require no further extraction, and thus to avoid all subsequent solvent treatment, filter-pressing, etc. It is therefore obvious that the ore must be so completely opened up by crushing as to liberate these values, i.e. it must be crushed down to the payable limit. This as before said, means reduction to slimes, or to the 220-mesh (linear inch) standard adopted by other processes on the field which depend upon similar mechanical exposure of the finely disseminated mineral.

"But in a pulp where the whole of the values have been reduced to absolute 'float' or slimes, mere rolling contact or gentle agitation with an oil is not sufficient for complete recovery. It is necessary to ensure more intimate admixture of oil and pulp, and to this end the flow of – 220 material from the grit-mill is passed through one or more centrifugal pumps, the necessary addition of oil being made immediately prior to this. The violent agitation thus effected breaks the oil into minute globules which are so thoroughly dispersed through the whole pulp that practically complete contact between oil and the finest divided mineral is assured. The mixture is then passed through cylinders so modified in construction as to act mainly as an oil coalescing (or agglomerating) plant, wherein the oil-entrapped values are separated from the exhausted ore pulps.

"Notwithstanding the minute subdivision of the oil employed by agitation, its subsequent collection may be as complete as in the former case, and losses are negligible.

"Unlike cyanide, the oil process is not dependent upon water free from dissolved mineral impurities; where oil is employed for extraction, mine waters can be freely used for ore crushing, indeed a faintly acid reaction of the milling water is even advantageous. The highly saline waters of Western Australia form admirable crushing media for oil-concentration, their high gravity aiding considerably in the flotation of the mineral-laden oil.

"Extensive tests have been made in London, by the Australian Ore Concentration Syndicate, upon ore parcels of from 2 to 15 tons from several Kalgoorlie mines. The Lake View Consols trials, which have resulted in the ordering of a 50 ton per day oil-concentration plant, showed that by crushing to only 100 mesh sulphide ore of 10½ dwt. original value, oil-concentrates containing over 82 per cent. of the gold were yielded, whilst the tailings averaged 1½ dwt. *per* *ton of original ore.* These residual (tailings) values were also found to be quite intractable to solvent, but on re-grinding to 200 mesh, in both this and other cases, a further reduction of values both by solvent and by oil was found possible. It is therefore evident that material coarser than 200 mesh contains 'enclosed' values inaccessible to oil or solvent, and that close recoveries and low tailings values are primarily dependent upon the grade of crushing employed. The payable limit of such crushing has been discussed elsewhere; all it is here necessary to point out is that whatever metal or sulphide or sulpho-telluride mineral is liberated by crushing is completely recovered by oil, no float loss of even the most intractable sulphides or tellurides being possible.

"Upon freshly crushed sulpho-telluride ores ranging from 8 to 30 dwt. originally, −220 mesh pulps yield tailings assaying 1 dwt. per ton or even less. With very rich ores the tailings values may be higher, the lowest limit attained in the case of a 5¼ oz. telluride parcel being 6 dwt. which, however, corresponded to an extraction of 94·2 per cent. of gold.

"In connection with this trial it is to be noted that the oil-concentration process fails to completely recover *partially oxidised mineral values.* It has already been noted that oxides are not caught by oil, and where samples of sulpho-telluride ores have been long exposed to the air, the weathering of the pyrites and of the various telluride minerals has been found to give rise to incomplete recoveries; doubtless owing to the films of oxide with which the minerals on the surface of the ore lumps become coated. In the case of the rich sample above referred to, ordinary cyanide was able in 30 hours to reduce the 6 dwt. tailings to 1½ dwt., from which it may fairly be inferred that oxidation had taken place to a considerable extent, unoxidised tellurides being intractable to plain cyanide. With the installation of an oil plant upon the Hannan's field the difficulty introduced by the partial oxidation of exported samples will disappear, aud no doubt is entertained that freshly crushed sulpho-tellurides, however rich, will yield extractions limited in completeness only by the crushing grade adopted.

"Oil-concentration has, of course, in common with other concentration methods (which, however, are inapplicable in this case), the advantage of effecting recoveries in an exceedingly short time. The pulp flow being continuous, within half an hour of crushing, the final tailings can be passed to the slimes dam ; or if an additional solid basket centrifugal separator be employed on these, the clear water can be returned to the crushing plant within an hour or so, undiminished by evaporation or soakage losses, and the nearly dry tailings dumped.

"On the basis of 100 tons of ore crushed per day and starting with – 220 (grit-mill) pulps, the total cost of obtaining all values as oil-concentrates (in about 10 per cent. of the original ore weight) is estimated at about 4*s.* per ton, inclusive of labour, power, oil loss and sundries ; these items being taken at Kalgurli prices.

"Smelting recovery of the concentrates (which according to the original value of the raw ore may vary from 3 to 10 oz. per ton) is unnecessary. The cost of such amounts at present to about 4*l.* 15*s.* per ton of concentrates, with payment for 95 per cent. of the gold. Trials on considerable quantities of the oil concentrates have shown that mechanical roasting followed by plain cyaniding (supplemented, if necessary, by intermediate pan-amalgamation) will recover from 97 to 98 per cent. of the gold. The costs of such treatment are, of course, well known. The superior richness of the concentrates appears to introduce no additional difficulty in calcining ; indeed, the 1 or 2 per cent. of oil adherent to the concentrates is of considerable advantage ; it prevents dusting during handling, charging and in the earlier stages of calcining ; on carbonising it provides a more or less reducing atmosphere during the elimination of tellurium, and tends to prevent the formation of the objectionable tellurous films over reduced gold ; it also aids in keeping the charge open, thereby promoting the final oxidation.

"Allowing 10 per cent. of concentrates to be dealt with at a cost of 35*s.* per ton, this means a concentrate-reduction cost of 3*s.* 6*d.* per ton upon the original ore ; adding 4*s.* per ton for oil concentration, 7*s.* 6*d.* would be the cost for complete recovery of values by the oil process, exclusive, of course, of mining and crushing expenses.

"Roasting, cyanide and filter-pressing operations, etc. are thus eliminated as regards the original ore, but portions of such plant will be still of value in dealing with the concentrates obtained, in the superseding of expensive smelting recoveries."

The author has been recently informed that certain modifications have been proposed in the oil-process, which it is claimed are improvements.

The Gilmour-Young Process.

My friend Mr. Alfred James some time ago drew attention* to a process which would seem to occupy a sort of intermediate position between the Boulder Main Reef and Riecken processes. It had been successfully applied by Messrs. Gilmour and Young to the treatment of the ore of the Santa Francisca mine, in Nicaragua, by which it appears that 90 per cent. of the gold, and 70 per cent. of the silver present were recovered from the "slimes." The ore, when ground to 30-mesh, carries a very large percentage of clay, which renders leaching a matter of extreme difficulty. The slimes assayed 1 oz. 10 dwt. gold and 4 oz. 10 dwt. silver. The "sands" gave lower results, but they are now separated with air-separators and treated separately by percolation, the entire extraction of the gold being brought up by re-treatment of the sands in this way to over 90 per cent., and bullion 800 fine was obtained. The slimes which the ore carries amount to about 70 per cent. of the ore, and although the ore could be treated as a whole with the aid of a vacuum in about seven days, it was found that the slimes were not satisfactorily leached and washed even after thirty days' percolation.

The method subsequently adopted, to which I have referred, has passed the experimental stage, some thousands of tons of ore having been treated by it, and over 10,000 oz. of bullion having been produced when Mr. James described it. The ore is crushed in No. 5 Krupp mills through a 30-mesh sieve, and the plant employed consisted of 5-feet pans, run on the well-known Boss system (used in silver mills), in which the gold is partly dissolved by cyanide in solution, and the whole of it (coarse and fine alike) is recovered by amalgamation, using a mixed zinc and copper amalgam, and caustic soda to keep the mercury in good condition.

In Nicaragua, the consumption and cost of chemicals is given by Mr. James as follows :—

						Cost per ton.	
	lb.		*s.*	*d.*		*s.*	*d.*
Cyanide . . .	1·67	at	1	3	per lb. . .	2	1·05
Caustic . . .	0·63	,,	0	1	,, . .	0	0·65
Copper sulphate .	1·16	,,	0	1¾	,, . .	0	2·03
Cast-iron turnings .	0·25	,,	0	0½	,, . .	0	0·12
Zinc . . .	0·39	,,	0	3	,, . .	0	1·17
Mercury . . .	0·40	,,	1	9	,, . .	0	7·81
					Total . .	3	0·83

* 'Notes on a Process for Treating Slimes without Filtration or Decantation,' by Alfred James, *Trans. Inst. of Mining and Metallurgy*, vol. vii. Further details of this interesting process are given by Mr. James in *Cyanide Practice*, pp. 79–81.

These costs are stated to have been for rich ore yielding about 3 oz. per ton; and with slimes, the consumption of reagents is much less; the consumption of cyanide being reduced to ½ lb. per ton.

Labour (in Nicaragua) cost 3*d.* per ton, and 24 horse-power was required for the treatment of 50 tons per diem, but Mr. James thinks this latter item could probably be reduced by using "barrels."

It appears therefore *possible*, although power is the chief item of cost in this process, when the expense of grinding has to be incurred (notwithstanding the total loss of the cyanide used), it might be profitably applied in a modified form to the treatment of roasted *telluride ores*, with a saving in expense, if after a preliminary washing, to get rid of the soluble salts, it sufficed to extract a sufficient percentage of the gold the Kalgoorlie ores carry.

To apply such a method, the ore might either be slimed completely, or else classified into the sands and slimes in air-separators * (after roasting); treating each class separately. Like the Riecken process, if it proved applicable to the treatment of roasted, or acted upon raw telluride ores, it might do away with the trouble and expense of filter-pressing and zinc-precipitation.

An efficient metallurgical process (yielding a high extraction) by which telluride ores can be treated *without the necessity for roasting*, would certainly seem, however, to be the most likely direction in which to look for a satisfactory solution of the Kalgoorlie "sulphide problem," from the point of view of cost. This ideal process has perhaps yet to be discovered, or at any rate has to prove its claims to universal recognition, although, owing to the nature of the ore and other special circumstances, the Ivanhoe method of treatment has up to the present given most satisfactory *all-round* commercial results, whilst the Diehl has made great advances in lowering costs.

Some points that may be noticed in Practice in Cyaniding and Roasting Sulpho-Telluride Ores in Colorado and Western Australia.

It is well to bear in mind that the tellurides are the long-treatment products, as well as by far the most valuable components of ores of this class, and their separation and elimination

* A new apparatus (a cone separator) for wet classification is described by M. D. Stackpole, and figured in the *Engineering and Mining Journal*, July 12, 1902. It has been installed at the new 300-ton mill at Sunshine in Utah, for the treatment of talcose ores, containing a large proportion of slimes, and it is claimed to possess special advantages for this purpose; for slimes that can be rapidly leached.

from the other metallic constituents of the ore (so far as it is feasible to do so) presents distinct advantages; with a view to treat them apart by special methods, which will insure the closest possible recovery.

Mr. Ph. Argall, in cyaniding tellurides at Cripple Creek, found that with normal solutions, carrying about 1 oz. of gold per ton in a 0·5 per cent. cyanide solution, not more than 0·33 lb. of zinc was dissolved for each ounce precipitated.

The distinction between the zinc dissolved and the total zinc used and precipitated should, however, be carefully noted.

He remarks,* in this connection, "Our general practice (at the Metallic Extraction Company's works) shows a consumption of 0·92 lb. of zinc for each ounce of fine bullion produced. Of this amount, more than 40 per cent. is dissolved, the remaining 60 per cent. being removed from the boxes with the precipitate at each weekly clean-up, and, owing to its finer state of division and richness in gold, we find it preferable to destroy the zinc and recover the gold."

It is an interesting fact commented upon by Mr. Argall that the alkalinity of the solutions rises rapidly with the precipitation of the gold in the zinc-boxes, and falls again towards the end of the box, usually leaving it about the strength it entered.

Average solutions, when entering the boxes, showed about 0·530 per cent., and a number of interesting tests, illustrated by "curve diagrams," are given by Mr. Argall; the alkalinity being reported in terms of sodium hydrate, using phenolpthalein as an indicator. On the other hand, in some experiments carried out by Mr. Alfred James, he failed to find any increase of free alkali in the zinc-boxes.

Mr. Alfred James mentions † that it costs 3*s.* 1*d.* for cyanide for every ounce of gold recovered in South African practice, whilst in Western Australia the returns from the Associated Gold Mine showed the cost in that case to be just under 3*s.* Mr. Ph. Argall stated ‡ (in 1897) that the sulphur in Cripple Creek ores averaged about 2 per cent., and satisfactory extractions were obtained by roasting down to 0·1 per cent. sulphur. It requires, however, a very high terminal heat to break up the sulphates.

Special stress requires to be laid upon *the importance of careful roasting*, in processes like the Boulder Main Reef and

* *Mineral Industry*, vol. vi. p. 378.
† *Trans. Inst. of Mining and Metallurgy*, vol. vii. p. 71.
‡ *Mineral Industry*, vol. vi. p. 371.

Riecken, as the results so far achieved at Kalgoorlie on the whole can scarcely be said to be entirely satisfactory, judged by practice elsewhere; in fact, in some cases the roasting has been admittedly bad, and in most if not in all, more expensive than one would anticipate.

In a letter to the *Financial Times*, dated January 19, 1901, a correspondent says that a number of mines are already roasting for 5*s*. a ton, and it will ultimately be done for 4*s*. a ton.* It would appear, however, that 4*s*. 6*d*. to 7*s*. a ton is nearer what the average has been, and in some cases it cost even more. This may be partly explained in several ways. (1) By the type of furnace used, or by faulty construction. (2) By the kind and quality of the fuel used. (3) By the nature of the ore, its previous mechanical preparation, and insufficient control of the temperature. (4) By inexperience on the part of the furnace men, and want of uniformity in the sulphur contents of the roasting-charges.

The Type of Furnace used.—It is hard to explain the high working cost and comparative small output of some of the furnaces that have been tried, except on the supposition that there have been faults in their construction,† coupled with inexperience in working them. Some metallurgists seem to think that the Brown "horse-shoe" would give better results than the "straight-line" type, which was erected at the South Kalgurli. Several automatic reverberatory calciners have also been employed, such as the Ropp,‡ Holthoff-Wethey,§ and Edwards furnaces, but it does not appear that revolving cylinder-roasters ‖ of the Brückner or Argall class, or circular revolving horizontal hearth furnaces, like the "Pearce turret" (which, I understand, have been extensively used in Colorado with satisfactory results) have as yet been given a trial at Kalgoorlie.

* The Author is informed that the cost of roasting with the Merton furnace at the present time is as low as 3*s*. a ton.

† The fact that the furnace installed by Mr. J. M. Iles at the South Kalgurli is reported to have given good results, would tend to confirm this supposition.

‡ The Associated furnaces were said formerly to be very heavy consumers of firewood; and the monthly fuel bill at one time for wood burnt on the mine (including the supply for boilers) was stated to have amounted to a very large sum, running only two furnaces.

§ A trouble seems to have been experienced with this furnace at the Boulder Perseverance, viz. that the small "slot doors" at the side became worn and torn off by the rabble carriages, thus admitting a large volume of cold air and seriously affecting the roast. To overcome this difficulty the carriages of the rabble arms were boxed in on No. 4 furnace, and it was reported to have subsequently done excellent work.

‖ The chief trouble with cylindrical furnaces is, I believe, the amount of "dust" they are liable to produce compared with mechanically rabbled hearth-furnaces.

As an illustration of the work done in a Pearce turret-furnace, Dr. Ed. Peters, jun.,* states that Gilpin County concentrates from a stamp mill, containing 79·5 per cent. of pyrites, representing 42·1 per cent. sulphur, were roasted down to 0·22 per cent. sulphur at the rate of 9·813 tons per furnace per day, and in 8½ days, 83·411 tons were calcined, at a cost of $1·045 per ton. Dr. Peters mentions that the cost of a "turret furnace" at Arago, as built by Mr. Pearce, was $5460·70, inclusive of royalties. At Pueblo, two furnaces cost $12,296 to erect. The fuel consumed with good, pyritic ores is said to be some 16 to 18 per cent. of the weight of the ore calcined. With a less pyritic ore to roast "sweet," the capacity would naturally be greater, and the costs correspondingly less, and one of its advantages for roasting rich gold ores seems to be in a comparatively small production of flue-dust. Argall's multitubular furnace also appears an excellent one, and is largely used for Cripple Creek ores, bringing the sulphur contents from 2 down to 0·10 per cent., and putting through about 48 tons per diem. Each charge requires about three hours' exposure, the furnace making one revolution in 4·8 minutes. During the first two hours the ore is gradually advanced to a dull-red heat, and for the last hour it is subjected to a good roasting heat, terminating at a bright-red close to the sintering point. An interesting description of this furnace† is given in the *Mineral Industry*, vol. vi. The performance of the 120 by 12 ft. Jackling furnace,‡ used at the Mercur mines in Utah, is likewise highly spoken of, as it is said to be capable of roasting 70 tons of base (arsenical) ore containing 2 to 5 per cent. sulphur, and 0·95 to 2·5 per cent. arsenic, down to 0·1 to 0·15 per cent. per 24 hours, with a consumption of about 7 tons of coal. The Holthoff-Wethey (100 by 12 feet) calciners in the same works roast, it is said, 145 tons of mixed ore in 24 hours, with a consumption of 8 tons of coal.

Edwards' mechanical furnace, which is used at Customs Works in Victoria, Australia, has been already referred to, p. 334, and is

* *Modern Copper Smelting*, 7th edition, p. 213.

† 'Cyaniding Telluride Ores,' p. 372. The author is informed that 40 to 50 tons of ore, containing 2½ per cent. of sulphur, can be reduced to 0·1 per cent. per diem; making one revolution in eight minutes, the capacity of the Argall furnace is rated at 23 tons per diem, or with one revolution in four minutes, 46 tons. The consumption of slack coal is reckoned at 150 to 160 lb. per ton of ore roasted, and with one furnace the cost of roasting in Colorado is reckoned to be 40 cents per ton; with three furnaces 28·7 cents. The cost of erecting a furnace is said to come to about 400 dollars in Colorado.

‡ *Mineral Industry*, vol. viii. pp. 304 and 400.

very fully described and illustrated in the *Engineering and Mining Journal*;* it seems well calculated to roast the ore "sweet," requiring but little manual labour. It is stated to give a very uniform product, and the Tasmania Gold Mining Company at Beaconsfield, Tasmania, *sweet* roast 200 tons a week of concentrates with their four furnaces; requiring only three men at 2*l.* 5*s.* = 6*l.* 15*s.* a week to look after them, which represents a cost of about 8*d.* a ton for labour. The amount of fuel each furnace consumes is reckoned at, say, 12 tons, to roast 50 tons of pyritic gold concentrates, which seems to be about the weekly capacity of the furnace when dealing with material of this class. The sulphur acts as fuel for the first half (more often for two-thirds) of its length, when the ore is no longer heat-sustaining, but is thus brought gradually under the influence of the fire with the furnace at a bright red heat, where the various sulphates are gradually oxidised. A special advantage claimed is the uniformity of the roasted product. A description of the Kalgoorlie furnace has been already given.

The Godfrey calciner,† a circular furnace with fixed rabbles and a revolving hearth, would seem to overcome one of the difficulties experienced with most mechanical furnaces, viz. injury to the rabbles by their exposure to too high a temperature inside the furnace. Almost all mechanical furnaces have, however, a certain disadvantage to contend against as compared with hand-rabbled furnaces, viz. that the ore particles are not afforded a sufficient period of rest for the sulphur to burn off properly before they are shifted, or turned over, and what seems needed is an adjustable mechanical movement of the charge on the hearth, with intervals of repose; whilst insufficient draught (owing to the flues and chimney not being properly proportioned) may result in failure to maintain a proper heat except at the cost of extra fuel. Unduly large grates not properly designed for the economical combustion of the fuel burned in them, or either an insufficient or unnecessary number of fire-places, may also in some instances have contributed to this result.

The Kind and Quality of Fuel used.—Consideration of this matter will, no doubt, explain in some measure the difficulties which have been met with, and the high cost of roasting, of which

* *Engineering and Mining Journal*, July 21, 1900.

† 'The Latest Type of Mechanical Calciner,' by W. Blackmore. *Trans. Inst. of Mining and Metallurgy*, vol. vii. p. 323.

mention has been made. The fuel used on the field is nearly all cord-wood, and consists of different varieties of eucalypti and mulga, the latter being the better wood of the two, having a steam efficiency, it is said, about equal to oak. As "the bush" has been largely denuded of trees around the various mining centres, wood-fuel is, however, getting scarce,* and there are very few cords of wood to the acre in most parts of the country. Besides, the growth of these hard-wood trees is slow, notwithstanding that certain areas of from 1000 to 10,000 acres are proclaimed as State "forest reserves" (chiefly in the S.W. districts of the colony), which are under a Conservator of Forests; and as there are no regulations enforced in regard to cutting or replanting trees on forest reserves, except that the timber-cutters have to take out a licence (which is simply a Government tax), it is only by railway extension that the supply can be kept up and prices kept down. Seeing, therefore, that some 800 tons a day (say 6000 tons a week) † were some time back being consumed at Kalgoorlie alone, cord-wood seems bound eventually to become even more expensive than it is now. All the wood burnt is not, moreover, of equally good quality as regards calorific value, and it is not unfrequently "piped" and badly stacked. Mr. H. C. Hoover quoted the price in Western Australia ‡ in 1897 as \$5·50 to \$7·50 per cord delivered; and the Author believes that the average price at Kalgoorlie in 1898 was about 25*s.* to 30*s.* a cord, depending on length,—the figure that Mr. G. J. Bancroft put it § at, viz. \$5 to \$6. He adds, that according to the manager of the Coolgardie Electric Light Company (where both coal and wood are used) one cord of bush-wood closely piled will produce as much steam as 1 ton of good coal, which was then costing \$11 (2*l.* 7*s.* 8*d.*) per ton. Mr. H. C. Hoover estimated ‖ that 2¾ cords per horse-power are burnt in operating ordinary engines on the average per month. Mr. H. F. Bulman mentions that the price of salmon-gum in 1899 was 18*s.* to 20*s.* a cord (128 cubic feet, or 35 cwt.), or, roughly speaking, 10*s.* 6*d.* per ton. A

* The woodcutters, finding that they have to go further afield for wood, demanded an increase of 6*d.* per ton on the old rates, at the beginning of 1901, and threatened "a strike" if it was not granted them.

† *Financial Times*, letters of correspondent, September 14, 1900; but a more recent estimate by H. Knutsen ('The Diehl Process') puts the consumption at 1700 tons per diem, or 50,000 tons per month.

‡ *Mineral Industry*, vol. vi. p. 334.

§ 'Kalgoorlie, Western Australia,' by J. G. Bancroft, *Trans. Am. Inst. of Mining Engineers*, vol. xxviii.

‖ *Mineral Industry*, vol. vi. p. 334.

little later the Author was informed that the price per cord ranged between 18*s.* 6*d.* and 25*s.* in 3 feet 6 inches to 5 feet lengths, though it may have been bought cheaper under exceptional circumstances about that time.

The West Australian Gold Fields Firewood Supply Company now deliver most (over 90 per cent.) of the wood consumed, to the mines, by a branch railway, and it is said * to cost the mines, under contract *at present* 14*s.* 6*d.* per ton on an average, though the Firewood Supply Company are stated to be able to deliver it at Golden Gate railway station at the Boulder Township, for 9*s.* per ton: 24*s.* a cord is probably, therefore, not an out-of-the-way price to pay for 4-feet wood; and stacking costs about 1*s.* extra. Mr. Alfred James estimating that a cord of Australian wood is equal to 1 ton of Collie coal, or 15 cwt. of Newcastle (Australia) coal, states that it should roast at least 9 (long) tons of Kalgoorlie ore, and taking the price at 22*s.* 6*d.* per cord, or 13*s.* a ton, the cost of fuel should not exceed 2*s.* 2*d.* per ton of ore roasted. He adds † that he was informed the actual consumption of fuel at the Great Boulder Main Reef was 1 ton of wood to 6 tons of ore roasted.

As regards the use of coal, Mr. H. C. Hoover expresses the opinion that, with a railway to Espérance, coal from the Eastern colonies could be imported at a comparatively cheap rate,‡ and would be equivalent to wood at $5 a cord, or possibly less; at any rate, there can be little doubt that, were railway rates cheaper, coal could be obtained at a figure which would enable it to compete against wood for steaming purposes. Most of the coal now used comes from Newcastle, in New South Wales, and the Author was informed in 1899 that it cost about 2*l.* 13*s.* per ton in Kalgoorlie. If the quality of the coal (which is said to have improved with depth) proves suitable for steam and roasting purposes, the opening up of the West Collie Coal-field near Bunbury, in Western Australia, may, however, provide a cheaper source of fuel supply, as this local coal could be bought in 1899 at 1*l.* 12*s.* 6*d.* a ton; but it is, I believe, admitted at present that powdered Collie coal, which was tried in firing steam-boilers and roasting-furnaces on a fairly large scale at Great Boulder, has not so far been found to be as satisfactory as wood fuel.

* *Financial Times*, letter of correspondent dated February 16, 1901.

† *Trans. Inst. of Mining and Metallurgy*, vol. viii. p. 515.

‡ H. Knutsen reckons it could be delivered for 36*s.* a ton, or less, *op. cit.*

For roasting purposes, however, the Australian hard-woods scarcely seem equal to coal *of good quality*, as I am informed that it is more difficult to regulate the firing, and notwithstanding that there is an excessive flame after firing, the heat is not steadily maintained, and does not reverberate properly along the furnace hearth, as it does with a coal fire ; this being particularly the case in furnaces with side-grates, where the flame is drawn sideways along the hearth, at right angles to the grate ; consequently the heat in a long furnace is not properly distributed, but it is apt to be concentrated too much near the fire-places, to remedy which extra grates have had to be put in in some cases. Another trouble seems to be that in some furnaces there is too much space between the arch and the hearth, and the fire-boxes were originally built too large. In the Edwards furnaces at Ballarat "producer-gas" is used ;* and six of the Great Boulder furnaces, as already mentioned, were provided some time since with supplementary gas-firing, which is stated to answer particularly well, and overcomes the difficulty of regulating the temperature.

The use of either oil-residuum or producer-gas † (if the former fuel could be got at a reasonable rate) is certainly worth considering, if the capacity of the roasting-furnaces can be thereby sufficiently increased, and the work performed materially improved, as I think has been proved to be the case by substituting other fuel (notably producer-gas) for wood. A letter in the *Bullionist*, dated Kalgoorlie, June 22, 1901, stated that the twelve Edwards roasters at the Great Boulder were then being all fired with "producer-gas," and it was stated that a mixture of Collie and Newcastle coal gave better results than Collie coal alone.

The Kalgoorlie correspondent of the *Financial Times*, writing on June 1, 1901, also remarked : "Of late the furnaces on the Great Boulder works have been doing excellent work ; the results attending the use of gas have been so satisfactory, that in all probability wood will shortly give place to coal in all furnace work."

In support of this opinion it is stated ‡ that the mills in

* "Plants" of this description are being installed at some of the Colorado mills, but have not been in operation long enough to furnish reliable data as to cost. The results, however, so far are reported to be satisfactory and favourable. *Mineral Industry*, vol. ix. p. 364.

† A large area is stated to have been taken up by the Mining and Oil Corporation recently (1902), to bore for oil on the Warren River, Western Australia.

‡ 'The Cripple Creek Gold Field,' by T. A. Rickard, A.R.S.M. *Mining and Scientific Press*, December 30, 1899.

Colorado enjoy an important advantage in being able to use oil-residuum in combination with coal in their roasting furnaces,—the coal in the first fire-boxes, or colder portion of the hearth, and the oil for the finish. The amount of fuel used in the different styles of furnaces varies slightly, according to Mr. John E. Rothwell,* a fair average consumption being from 90 to 100 lb. of coal, and from 14 to 18 gallons of oil, per ton of ore roasted. The coal used is semi-bituminous Colorado coal, and costs for "run of mine" from \$1·65 to \$2·25 per ton delivered at the works. The oil is from the Florence refineries. Florence is the oil-centre of Colorado, and the oil-residuum which is obtained from the distillation of petroleum costs from 75 cents to \$1·10 per barrel of 42 gallons. There is consequently stated to be an increased demand for it, although some metallurgists, I am told, still prefer to use coal alone of *first class* quality when it can be obtained. Oil, however, would certainly seem to afford, like gas, a fuel well adapted for roasting, as permitting a nice and quick adjustment of the heat of the furnace.

The Nature of the Ore, etc.—This may no doubt affect the working of the roasting furnaces in several ways. For instance, the comparatively high percentage of sulphur, and other volatile substances present in the Kalgoorlie ores, although of advantage in supplying and distributing the heat, which should tend to reduce the fuel-bill, adds to the cost in other directions, as it necessitates the charge remaining in the furnace longer than otherwise would be necessary in order to roast it "dead-sweet."

The risk of raising the temperature to too high a point, with the heat not thoroughly well under control, and so causing the ore to agglomerate and the gold in the tellurides to "sweat-out," combined with the fear of mechanical losses, or losses through volatilisation † (though this latter danger is almost *nil* with proper precautions), possibly also leads, in some cases, to the furnaces being kept too cold ‡ and to the charges being in some cases

* *Mineral Industry*, vol. ix. p. 364.

† John E. Rothwell, *Mineral Industry*, vol. ix. p. 364, says: "The gold losses by volatilisation, that is so much feared and discussed by metallurgists not familiar with recent practice, is practically *nil* in the Cripple Creek telluride ores, all losses being mechanical." There is, however, an essential difference in the composition of Cripple Creek and West Australian ores, and even if dry crushed there may be a certain amount of chloride of sodium in the latter class of ore, which may produce volatilisation of gold.

‡ Sulphur burns at between 235° and 260° C., = 455° and 500° F., and is vaporised at 446° C. = 836° F.

insufficiently rabbled, to do proper work. According to Mr. John E. Rothwell, the temperature at which roasting is done in Cripple Creek practice varies from the cold ore to 700° F. at the first fire-box (one-third the distance of the hearth), and from this it increases to 1100° F. (at two-thirds), the finishing heat being between 1500 and 1600° F. The usual time required to pass the ore through the furnace varies from 3·5 to 5 hours, depending on the amount fed in.

I should say, however, that in all probability the previous mechanical preparation of the ore has more than anything else to do with the small capacity of the roasting-furnaces, as it prevents the air from properly penetrating the charge, renders it difficult to rabble without causing excessive "dust," and, owing to the rapidity with which the oxidation of individual particles takes place, with a temperature generated above the fusion point of tellurium, it no doubt renders the telluride-ore liable to "frit," causing the formation of lumps; a fairly even and granular material, as free as possible from dust, if the ore is dry-crushed, being theoretically the most desirable condition to aim at.

It seems probable that the roasting temperature exercises an important effect on the extraction of the soluble salts in the Boulder Main Reef process, as some sulphates, should they happen to be formed, would be rendered anhydrous, and very likely insoluble in water, if heated above a certain point, whilst others would be unaffected. Sulphate of lime, it may be added, is stated to lose the power of setting and solidifying if heated above 260° C. (500° F.).

It must be borne in mind, moreover, that the time required for leaching with cyanide may be greatly prolonged by imperfect roasting, and the consumption of that chemical is liable to be enormously increased from this cause.

On the other hand, when the temperature is too high, and reducing gases are present, they impede the oxidation of the sulphides, and cause the formation of lower sulphides and basic sulphates, which may act injuriously on the cyanide-solutions; and, as Mr. C. W. Merrill has pointed out,* there is a class of roasted material (such as telluride ores) in the roasting of which the temperature may be high enough to fuse the minerals in which

* 'The Present Limitations of the Cyanide Process,' by C. W. Merrill. *Trans. Am. Inst. of Mining Engineers*, vol. xxv.

the gold occurs, so "imprisoning" it as to render it incapable of being dissolved by cyanide solutions; in consequence of which recourse must be had to grinding and amalgamation, as previously pointed out.

Mr. Philip Argall also lays stress on the fact, previously noticed, that to successfully roast telluride ores requires a very gentle and slow application of heat, with a very high terminal temperature (close to the sintering point) to break up the sulphates. With badly-roasted ore, sulphates of alumina and magnesia prove particularly troublesome, inasmuch as the hydrates precipitate on exposure of the solutions to the air, and also through mixing with solutions coming from other and more alkaline charges; coating the zinc in the precipitation-boxes with a gelatinous film, which effectually prevents the precipitation of the gold.

It would be interesting to know whether the water of hydration, which minerals in the ore are liable to contain, causes decrepitation, and influences the roasting of these ores to any appreciable extent.

Inexperience can only be remedied by taking time to train hands new to the work, and substituting experienced men.* A poor roast, carrying above 0·3 per cent. of sulphur as sulphide, upsets everything, and sends up the residues at once.† This may be partly due to *want of uniformity* in the sulphur contents in the furnace charges, the only remedy for which is to automatically sample in bulk, and mix the ore before it goes to the calciners; but whilst this is always done at Custom Works, where the ore is purchased and sampled on a large scale, it is rarely done at mines. The control over results which correct preliminary sampling gives would, however, frequently, I believe, cover unsuspected losses.

In Colorado the cost of crushing and sampling in this way may be estimated at from 50 cents to 75 cents per ton.

The practice at Cripple Creek,‡ Mr. John E. Rothwell states, is to mix the ores, so that the sulphur contents will be close to

* In Colorado, Mr. Alfred James states that "roasters" are paid 12*s.* per shift, and the cost of labour amounts to less than 6*d.* per ton roasted. With the best installations, lubricants cost 1*d.* per ton, and whilst repairs vary with the amount of ironwork exposed to heat in the interior of the furnace, in up-to-date plants this item has been reduced to less than 1*d.* per ton. *Trans. Inst. of Mining and Metallurgy*, vol. viii. p. 515.

† Owing to this cause a good many mines, I believe, have had to re-treat residues, and this has been a serious item of expense.

‡ *Mineral Industry*, vol. ix. p. 363.

1·5 per cent., in order to get a maximum capacity out of the furnaces.

The sulphur in the roasted ore is determined in both the soluble and insoluble states—the soluble being the sulphur in the sulphates soluble in hot water, and the insoluble the sulphur in sulphides or other forms insoluble in hot water. When a furnace is in good working condition, and the pulp is uniform in its sulphur contents, the sulphur left in the roasted ore should not exceed 0·1 per cent., of which for the best work the insoluble should not exceed 0·03 per cent.

In Colorado, considerable attention has been paid to methods of *cooling* the ore, after roasting it, and several systems of doing so are in use there.

In some cases, the return mechanism of the straight-line hearth-furnaces is used to move the pulp back along a hearth of light sheet-iron open to the air, above or below the roasting-hearth.

A form of cooling-hearth designed by Mr. John E. Rothwell has an annular sheet-iron bed, provided with suitable expansion joints, on which the hot-ore is distributed, ploughed up and pushed forward by rabbles attached to arms fixed to a central revolving shaft.

Argall's rotating cylinder-cooler has already been referred to, and Mr. John E. Rothwell has invented a vertical water-jacketed cooler (described in the *Engineering and Mining Journal*, July 29, 1899), which consists of a water-tight shell with a number of tubes in it, like the flues of a boiler, through which the ore is fed from a storage hopper, whilst it is withdrawn from below by a mechanical device like an ore-feeder, that is set so as to remove the pulp as fast as it comes from the furnace. Water circulates through the shell outside the tubes, and a cooler 11 feet high and 6 feet square is stated to have a capacity of 30 tons per 24 hours.

The troubles with all water-jacketed coolers are danger of leakage, and they must be provided either with a constant supply of water that can be allowed to run to waste, or the water must be cooled and pumped back.

Another device consists of a sheet-iron tower, containing a series of sheet-iron shelves over which the ore passes in a thin sheet, whilst cold air is forced through the interstitial spaces around the shelves, and carries off the heat.

In estimating the area required to cool ore on a hearth, Mr. John E. Rothwell says,* "It has been found that an area of 6 square feet of hearth surface is ample for 1 ton of ore in 24 hours, the ore

* *Mineral Industry*, vol. ix. p. 364.

being delivered to it at a temperature of about 800° F., and leaving it at about 100° F."

In conclusion, it may be pointed out that, although the past history of the treatment of the Kalgoorlie sulpho-telluride ores has not been free from mistakes, they have mostly been like those of the explorer who, finding himself in a new country, without maps or local guides, having to strike out a new line for himself, has sometimes taken a wrong path and had to retrace his steps.

The ultimate evolution of the problem must necessarily be watched with keen interest by miners and metallurgists who, profiting by past experience, are interested in seeing it settled on its merits, so as to secure the best and cheapest form of treatment applied to the ores of this district; and the Author ventures to think that if the Boulder Main Reef system could be somewhat modified, so as to enable the sulpho-tellurides to be roasted *coarser* than they are at present, and anything over 90 per cent. of the gold could be afterwards extracted, without having to resort to washing or double filter-pressing, that method might be cheapened.

If it did not appear to be requisite (for reasons previously explained) to chill the ore in a fine pulverised condition in water, as it leaves the furnace hot, I should be inclined, indeed, to think that it would pay better to "granulate" the ore before roasting with rolls, sending it to the furnaces in a coarser condition * than is now the practice, before "sliming" it in the pans; as it ought to be cheaper to roast, be better roasted, and entail less loss in dust when in a more or less sandy condition; and it should be easy to "slime" after roasting.

But it seems possible that the necessity of chilling the ore might be obviated by employing the Gilmour-Young process described by Mr. James, to which reference has been made, to secure the amalgamation of the gold, and if it worked as well with the Kalgoorlie ores as it seems to do in Central America (even supposing that the removal of the soluble sulphates by washing them out, as a preliminary step, could not be dispensed with), it would open the prospect in this connection of doing away with one of the more costly operations in the process, viz. the extraction of the gold by cyanide leaching in "the press" and the precipitation of the gold in the zinc-boxes. At any rate it

* In this connection, Dr. E. J. Peters, junr., remarks upon the preparation of ores for roasting, "The best size to which to crush varies with each individual ore, and is entirely a matter of trial and experience, etc."—*Modern Copper Smelting*, 7th edition, p. 96.

would not cost much to try it as an experiment, and see if it succeeds. It has also been suggested, I believe, that after the ore has been roasted and amalgamated, the residues might be thrown out into the open to weather, so as to obviate the necessity for such fine grinding, and secure a leachable product, which would give a high extraction.

As regards *wet crushing*, one direction in which costs may be cheapened (to which I have already referred) was foreshadowed by Mr. Govett, the chairman, at the last annual meeting of the Lake View Consols (December 13, 1901), at which he stated that they

FIG. 67.—POURING THE BULLION: THE GREAT BOULDER PERSEVERANCE.

had cabled for 30 tons of ore, and if the preliminary trials by the "oil process" proved a success, further tests on a large scale would be made at the mine.

He added that hope of great economy was held out, and apart from its application to high-grade ore, if they could concentrate 10-dwt. ore in the ratio of 10 to 1, and the estimates of cost are correct, they should show a good profit on 10-dwt. ore. If the ore is wet crushed, Mr. Alfred James states * that in practice it is found

* 'Metallurgical Progress in Western Australia,' by Alfred James, *Engineering and Mining Journal*, January 3, 1903.

that when the sulphides present amount to 0·5 per cent. extractions are unsatisfactory with cyanide.

This, he remarks, shows the extreme importance of close concentration, and he expresses himself in favour of wet-crushing (because of concentration), amalgamation on plates, concentration, roasting the concentrates with subsequent separate treatment on the lines of that given the tailings from the concentration tables, fine grinding in tube-mills, further concentration, the agitation of the tailings and slimes with cyanide solution, and filter-pressing.

In considering the general results of sulphide treatment at Kalgoorlie, the fact must not be overlooked that, whilst the cost is still undoubtedly high, the average percentage of gold reported as recovered, viz. 90 to 96 per cent., is considerably higher than has been the case in most instances where (comparatively speaking) free-gold ores are dealt with; the recovery in such cases ranging as a rule from 70 up to 87 per cent. at the outside, unless the tailings are re-treated.

G. A. Denny,* M. Inst. M.M., estimates the actual average recovery value in the Transvaal by milling and cyanide at 80 per cent., or 85 per cent. if the slimes as well as the sands are treated; stating that the losses will be found to figure as follows: 7 per cent. loss in tailings treatment (sands); 3 per cent. loss in slimes treatment; and 5 per cent. of loss unaccounted for.

Although a high extraction of gold may not be any gain to the individual mine owner, if his costs are so much higher, an extra 10 per cent. won, from an economic point of view, is of the greatest possible benefit to the industry at large, as it represents so much more gold put into circulation, that would otherwise be locked up and of no use to anyone. Moreover, with *rich ores*, like those of Kalgoorlie, the recovery or escape of a small extra percentage represents a far larger gross saving, or loss, than would be the case if a low-grade ore were being dealt with, and *a close saving* is therefore a matter of the first consequence. On the Rand the percentage of the total output paid in dividends as shown in a table given by T. K. Leggett,† rose from 12·3 per cent. in 1890 to 28 per cent. in 1895 (the boom year), then fell to 20·8 per cent. in 1896, and rose to 26·1 and 32 per cent. respectively in 1897 and 1898.

* 'Observations on Sampling Computation of Assay Averages, and relation of Assay value to Recovery value as applied to Banket Mining in the Transvaal,' by G. A. Denny. *Trans. Inst. of Mining Engineers*, vol. xix., and this subject is further treated by the same author in 'The Deep-Level Mines of the Rand.'

† *Trans. Am. Inst. of Mining Engineers*, vol. xxxi. p. 1035.

I venture, indeed, to regard it as being of the utmost importance for an engineer to consider carefully beforehand what line of treatment will return the greatest possible profit, and money is frequently saved by their allowing him sufficient time to consider this matter carefully, through not being in too great a hurry for big returns; for once the plans of works have been decided upon, he is bound to stick to a definite course of action and carry it through; and if he *starts* on the *wrong line*, initial mistakes are apt to be made, which are always costly, and often impossible to remedy. The remarks of the Chairman at a company meeting serve as an illustration of this. He is reported to have said:—"We cannot afford to spend any more money in experiments. Many of you will perhaps blame me for not recommending, when I originally went out to the mine, the doing away with all our plant; but I appeal to you, I had not the courage to condemn absolutely a forest of machinery which cost this company 500,000*l.*, and say, 'Do away with it all and erect something else.' I had not the courage, nor had the managers, nor the professional gentlemen I consulted; they all suggested that certain alterations should be made, by which we could utilise that vast machinery. Well, we are certainly succeeding in this, but very slowly."

I think, perhaps, this is one reason why more rapid progress has not been made in reducing the cost of treating sulphide ores on this field, and many errors might have been avoided if in its early days people had possessed the experience they now have to guide them. Variations in the cost of treatment, and percentage of extractions in different mills, using the same process, and even in the same mill at different times, show what an important part capacity of plant, as well as capacity of management, plays in the ultimate commercial result, and how it is liable to be influenced by the arrangement, class and design of the machinery employed, as well as by changes in the character of the ore treated, and other governing factors—matters that need to be carefully inquired into and *continually* watched and regulated.

It appears from a letter * of Mr. W. Bramall, Secretary of the Great Boulder Perseverance Gold Mining Company, Limited, that the Australian Gold Recovery Company abandoned their application for leave to amend their cyanide patents in Western Australia.

* *Financial Times*, letter dated October 18, 1901.

SUPPLEMENTARY TABLES.

No. I.—Cost of Sulphide Treatment at the Works of the Great Boulder Gold Mining Company, in 1902.*

—	Cost per Ton. Labour. s.	d.	Material. s.	d.	Total. s.	d.
Sulphide Works:—						
Supervision		..		..		4·43
Power, engines, boilers, condensers, etc.		10·91	2	9·32	3	8·23
Crushing, ore-breakers, Griffin mills, etc.	1	8·72	1	0·91	2	9·63
Roasting furnaces, gas generators, fuel, etc.	1	1·27	3	5·33	4	6·60
Amalgamating pans, spitzkasten, etc.		7·99		10·75	1	6·74
Drying crude ore and concentrates		0·67		0·78		1·45
Proportion assay expenses 0·50*d.*; electric lighting 2·11*d.*; condensed water 2·80*d.*; management and general expenses 2·62*d.*		..		..		8·03
					13	9·11
Cyanide Works:—						
Supervision		..		..		2·26
Power, engine, compressor, boiler, etc.		2·97		6·36		9·33
Cyaniding, agitation, filter-pressing, etc.	1	7·19	3	1·76	4	8·95
Disposal of residues		9·79		2·26	1	0·05
Zinc-boxes, precipitation and recovery of gold		..		..		1·84
Proportion assay expenses 0·68*d.*; electric lighting 1·20*d.*; condensed water 0·78*d.*; management and general expenses 1·30*d.*		..		..		3·96
					7	2·39

* Given by G. M. Roberts, excerpt from the *Report* of the Chamber of Mines of Western Australia, September 1902.

No. II.—The Great Boulder Gold Mining Company, Limited.

Results and Analysis of Cost of Treatment in 1901.

Sulphide Mill.

Tonnage treated	60,396 (ore)
Bullion returned by amalgamation (oz.)	34,718
Fineness of bullion	·848
Residues assayed (dwt. per ton)	2·45
Loss of mercury (oz.)	0·629

—		Total Cost. £ s. d.	Cost per ton. s. d.
Wages		22,063 10 0	7 3·673
Firewood		12,822 13 7	4 2·954
Stores		6,978 14 10	2 3·732
Condensed water		6,056 6 4	2 0·066
Salt water		1,637 18 9	0 6·509
Fuel		4,341 15 7	1 5·253
Lime		27 10 10	0 0·109
Bricks	£28 14 10		
Timber	162 16 3		
Stable expenses, proportion	210 0 2	548 18 2	0 2·181
Experiments	147 6 11		
		54,477 8 1	18 0·477

Tailings Mill.

		Assay of Residues per ton.
Tons of tailings from old heap, etc.	18,512	1·76
" " sulphide mill	60,396	2·45
" " old mill	28,725	3·68
	107,633	

—		Total Cost. £ s. d.	Cost per ton. s. d.
Wages and salaries		14,527 0 1	2 8·392
Cyanide		13,272 17 10	2 5·595
Stores		3,151 0 8	0 7·026
Trucking		4,850 16 11	0 10·816
Cableway expenses		3,285 8 2	0 7·326
Firewood		2,990 5 9	0 6·667
Condensed water		3,029 1 7	0 6·754
Compressed air		512 6 8	0 1·142
Lime	£1125 10 7		
Assays	550 11 7		
Bricks	24 5 4	2,577 7 2	0 5·747
Stable expenses, proportion	383 4 8		
Fuel	286 7 3		
Timber	207 7 9		
		48,196 4 10	8 11·465

No. III.—The Associated Gold Mines of Western Australia, Limited.

Results and Analysis of Cost of Reduction (Sulphide Mill Treatment) in 1901–1902.

Old Percolation Process.

—	April.		August.	
Tons treated	2394		863	
Bullion produced, oz.	2131		650	
Standard gold, oz.	2103·40		634	
Total value	£8190 2s. 6d.		£2468 12s. 11d.	
Value per ton	£3 8s. 5·06d.		£2 17s. 2·53d.	
Standard gold contents, per ton	·878		·734	
—	Total Cost.	Cost per Ton.	Total Cost.	Cost per Ton.
	£ s. d.	s. d.	£ s. d.	s. d.
Crusher, stone breaker, Roger rolls, Ball mills	783 5 1	6 6·52	266 12 1	6 2·14
Roasting, Ropp furnaces	826 8 7	6 10·85	270 18 3	6 3·34
Cyaniding	2010 17 1	16 9·59	878 19 5	20 4·44
Precipitation and clean-up	224 13 4	1 10·52	67 3 7	1 6·68
Electric light	56 12 3	0 5·68	15 1 5	0 4·19
Assaying	99 9 0	0 9·97	22 10 11	0 6·27
Maintenance	998 19 7	8 4·15	329 15 4	7 7·71
	5000 5 6	41 9·28	1851 1 0	42 10·77

New Process.

—	September.		January 1902.	
Tons treated	3034		5325	
Bullion produced, oz.	2553·04		4216·91	
Standard gold, oz.	2469·31		4142·08	
Total value.	£9614 14s. 8d.		£16,128 5s. 0d.	
Value per oz.	£3 3s. 4·55d.		£3 0s. 6·90d.	
Standard gold contents, per ton	·813		·777	
—	Total Cost.	Cost per Ton.	Total Cost.	Cost per Ton.
	£ s. d.	s. d.	£ s. d.	s. d.
Crusher, stone breaker, Roger rolls, Ball mills	1133 18 6	7 5·66	1479 8 11	5 6·68
Roasting, Ropp furnaces	819 17 7	5 4·84	1269 5 4	4 9·21
Grinding, agitating, filter-pressing, and concentrating	2067 10 0	13 7·54	2910 9 9	10 11·17
Recovering gold from concentrates	..	..	161 13 11	0 7·29
Precipitating and clean-up	238 8 5	1 6·86	171 18 6	0 7·75
Electric light	63 9 5	0 5·05	70 7 6	0 3·17
Assaying	82 7 6	0 6·52	82 2 2	0 3·70
Maintenance	983 8 11	6 5·79	1505 12 0	5 7·86
	5389 0 4	35 6·26	7650 18 1	28 8·83

No. IV.—Particulars of Extraction at the Great Boulder Main Reef.

(For the Year ended 31st December, 1901.)

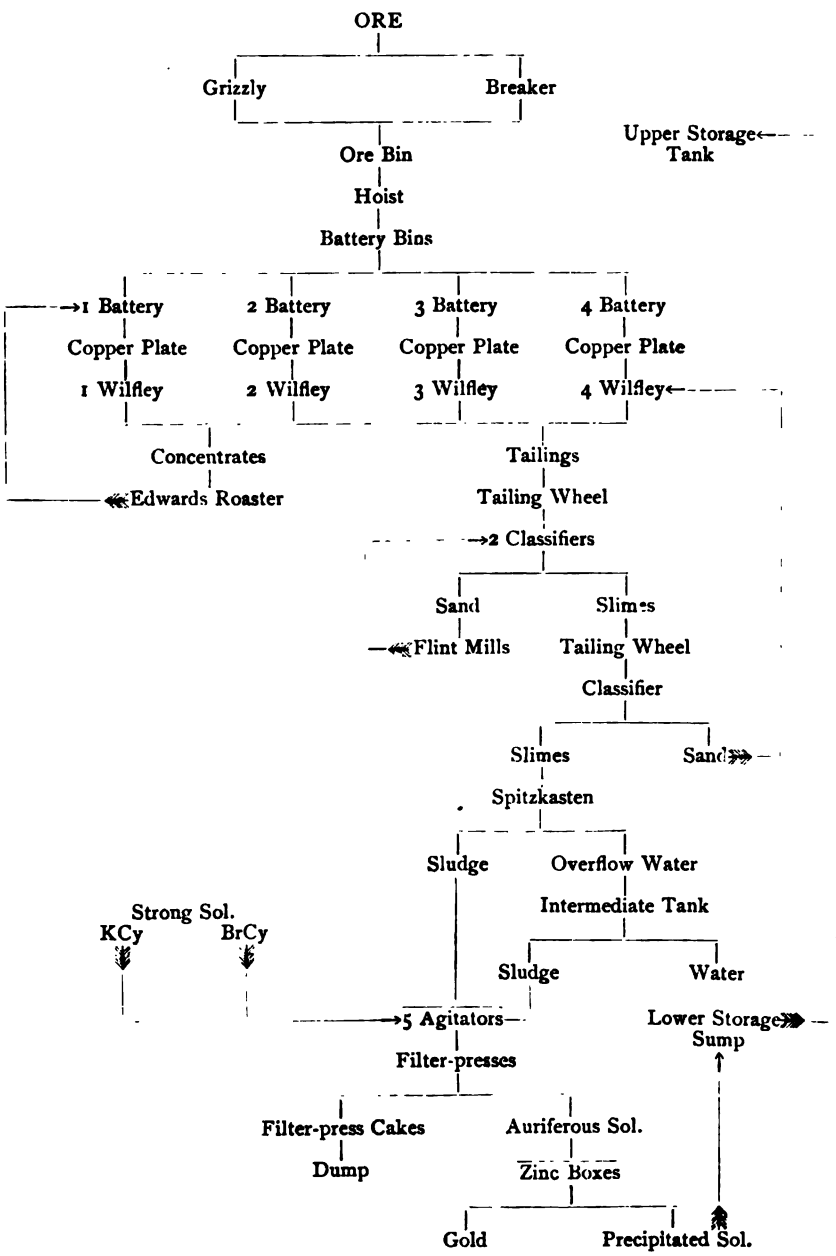
Month.	Bullion Recovered per Ton of		Average Value of Residues.	Extraction per Cent.		Consumption of Cyanide per Ton.
	Ore.	Sands.		Ore.	Sands.	
	oz. dwt. gr.	dwt. gr.	dwt. gr.			lb.
January	1 14 21	7 22	1 21	90·8	80·6	2·83
February	1 13 3	9 6	2 6	89·0	77·0	3·43
March	1 6 18	8 22	1 23	92·0	78·8	2·58
April	1 5 21	14 12	1 0	94·8	93·0	2·00
May	1 1 23	..	1 3	94·7	..	1·45
June	1 6 8	..	1 16	93·0	..	1·54
July	1 2 20	..	1 13	92·6	..	1·47
August	1 3 12	..	1 13	92·7	..	1·27
September	1 2 13	..	1 5	93·8	..	1·18
October	1 2 0	..	1 0	95·8	..	1·12
November	1 2 13	..	1 2	93·7	..	1·14
December	1 1 15	..	1 23	91·3	..	1·42
Averages for year	1 4 12	8 21	1 12	93·3	83·2	1·80

No. V.—The Great Boulder Main Reef, Limited.

Cost of Reduction, for the Year ended 31st December, 1901.

Month.	Tons Treated.	Crushing.	Milling.	Roasting.	Grinding.	Filterpress and Agitation.	Power and Air.	General Expenses and Maintenance.	Smelting and Assays.	Administration.	Total Cost.
		d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	d.	s. d.	£ s. d.
January	1079	4·86	1 9·08	9 4·08	0 11·66	7 5·19	4 2·24	1 1·62	3·88	1 0·20	1 6 6·81
February	1015	4·94	1 8·92	10 0·82	1 3·02	8 0·40	4 9·61	0 6·53	3·81	0 10·84	1 8 0·90
March	1319	3·35	4 7·30	9 2·47	0 9·08	7 1·12	4 3·64	0 5·64	3·44	0 10·01	1 7 10·05
April	1625	5·74	1 7·96	7 9·64	1 10·21	7 5·30	6 8·41	0 6·42	4·63	1 0·87	1 7 11·18
May	2077	4·05	1 2·65	6 4·63	0 8·53	5 9·66	4 5·74	0 6·41	4·26	1 0·05	1 0 9·88
June	1815	7·73	1 9·85	6 7·90	1 6·82	5 10·43	4 7·80	0 11·28	4·30	1 1·60	1 3 7·81
July	1977	7·57	2 6·57	6 4·53	1 2·60	5 6·04	4 5·88	1 5·92	4·27	1 1·26	1 3 2·64
August	1935	6·95	2 1·60	5 2·00	1 3·67	5 8·24	5 0·26	1 5·73	4·99	1 1·55	1 2 10·99
September	1968	5·68	1 1·85	5 3·61	1 1·84	5 3·09	5 4·57	2 1·47	4·60	1 2·00	1 2 4·71
October	2000	6·15	1 5·13	5 4·08	1 1·21	5 1·72	5 2·06	2 10·37	4·78	1 2·06	1 3 1·56
November	1864	8·87	2 8·28	5 6·66	1 1·04	5 1·49	5 8·88	3 7·91	4·90	1 2·03	1 6 2·06
December	1892	9·72	2 6·94	5 9·10	1 0·87	5 5·11	6 5·17	4 4·22	4·54	1 2·24	1 7 11·91
Averages for year		6·48	2 0·21	6 7·03	1 3·85	6 1·51	5 0·93	1 11·38	4·35	1 0·84	1 5 0·58

No. VI.—Hannan's Brownhill: Method of Working, as given by H. Knutsen.
(Excerpt from a paper read before the *Inst. of Mining and Metallurgy*, June 1902.)



No. VII.—Analysis of Costs at Hannan's Brownhill in July 1901, as given by H. Knutsen. (Excerpt from a paper read before the *Inst. of Mining and Metallurgy*, June 1902.)

Power.

	Total Cost £	s.	d.
Labour :—			
3 engine drivers	62	10	0
3 firemen	38	15	0
1 greaser	21	2	10
Sundry labour, etc.	27	3	10
Fire-wood	267	19	2
Fresh water	44	10	1
Sundry supplies and fodder	31	4	3
Repairs and salaries	30	2	5
	523	7	7
Proportioned as under :—			
Milling	236	18	5
Concentrates	54	12	5
Extraction	231	16	9
	523	7	7

Milling.

	Total Cost £	s.	d.	Cost per ton s.	d.
Labour :—					
3 battery hands	66	2	11		
2 breakers	32	19	10		
Sundry labour	1	18	9		
Proportion timekeeper	2	19	11		
" electrician	1	10	0		
" carter	3	0	0		
	108	11	5		
Ore Transport.					
Labour :—					
2 lift truckers	37	17	7		
Supplies :—					
Fresh water	1	12	2		
Sundries	4	6	10		
Administration	10	12	11		
Repairs	36	16	8		
Power	236	18	5		
Assaying	10	12	6	4	0·59
	338	17	1		
Concentration.					
Labour :—					
3 vanner hands	54	10	0		
1 trucker	17	4	4		
Sundry supplies	7	13	0		
Repairs	25	6	5		
Power (proportion)	54	12	5		
Assaying "	15	11	8		
Administration "	1	16	8	1	7·19
	176	14	6		

ANALYSIS OF COSTS AT HANNAN'S BROWNHILL—*continued.*

TREATMENT OF CONCENTRATES.

	Total Cost. £ s. d.	Cost per ton. s. d.
Labour :—		
3 drivers	63 16 8	
3 boys	31 0 0	
Electrician	1 10 0	
Fuel	45 4 0	
Sundry supplies	4 14 8	
Salaries	1 16 8	1 4·08
	148 2 0	

EXTRACTION.

	Total Cost. £ s. d.	Cost per ton. s. d.
Labour :—		
3 solution hands	79 16 6	
3 ,, (assistants)	58 6 8	
2 filter-press foremen	46 16 8	
4 ,, cleaners	75 7 8	
4 ,, truckers	64 8 7	
1 watchman	18 3 1	
2 rouse-abouts	43 5 6	
Proportion timekeeper	6 0 1	
,, electrician	1 10 0	
,, carters	3 0 0	
,, crushing lime	1 0 0	
Supplies :—		
Lime	26 10 0	
Zinc shavings	17 3 6	
Potassium cyanide	418 9 2	
Bromo-cyanide	457 0 0	
Sulphuric acid	20 13 6	
Fresh water	4 9 10	
Bromo salts	109 3 0	
Other supplies	78 9 7	
Repairs	64 9 2	
Power (proportion)	231 16 9	
Assaying ,,	45 6 8	
Administration ,,	16 11 8	17 1·02
	1887 17 7	

SUMMARY.

	Cost per ton. s. d.
Milling	4 0·59
Concentration	1 7·19
Treatment of concentrates	1 4·08
Extraction	17 1·02
	24 0·88

No. VIII.—The Ivanhoe Gold Corporation, Limited.

Results and Analysis of Cost of Treatment in 1901.

Battery Costs.

Old Mill (12 months).

Tons treated	74,226
Bullion produced	43,324 oz. 10 dwt.
Cost per oz.	11*s.* 8·688*d.*

	Total Cost. £	*s.*	*d.*	Cost per ton. *s.*	*d.*
Labour	5,586	17	10	1	6·064
Condensed water	3,419	9	11	0	11·056
Salt water	3,190	15	11	0	10·317
Tailings and return water	914	12	6	0	2·957
Fuel	6,436	4	3	1	8·811
Quicksilver	291	13	8	0	0·944
Stores	1,518	4	11	0	4·909
Repairs and renewals	3,893	13	3	1	0·590
Assays	145	7	1	0	0·470
	25,396	19	4	6	10·118

New Mill (3 months).

Tons treated	13,858
Bullion produced	7218 oz. 11 dwt. 12 gr.
Cost per oz.	12*s.* 0·834*d.*

	Total Cost. £	*s.*	*d.*	Cost per ton. *s.*	*d.*
Labour	606	15	11	0	10·509
Condensed water	563	12	0	0	9·761
Salt water	682	6	6	0	11·817
Tailings and return water	292	18	6	0	5·073
Fuel	1,247	13	1	1	9·608
Quicksilver	74	4	0	0	1·285
Stores	158	10	7	0	2·745
Repairs and renewals	31	14	9	0	0·550
Assays	15	9	9	0	0·268
Concentrating	683	2	1	0	11·830
	4,356	7	2	6	3·446

IVANHOE GOLD CORPORATION—*continued.*

TAILINGS TREATMENT.

Sands cyanided (12 *months*).

Tons treated	46,459
Bullion produced	19,763 oz.
Cost per oz.	12*s.* 3·653*d.*

	Total Cost. £	s.	d.	Cost per ton. s.	d.
Superintendence	408	18	1	0	2·112
Engine driving	450	10	11	0	2·327
Filling and emptying vats	2,891	15	5	1	2·937
Removal of old tailings	913	19	4	0	4·721
Cutting zinc	56	3	2	0	0·290
Zinc	135	16	1	0	0·702
Cyanide of potassium	3,424	3	8	1	5·689
Lime	471	14	0	0	2·437
Fuel	1,249	15	6	0	6·457
Stores	369	14	1	0	1·910
Repairs and renewals	710	6	5	0	3·669
Smelting	102	10	6	0	0·529
Condensed water	651	13	5	0	3·368
Assays	321	11	1	0	1·661
	12,158	11	8	5	2·809

Slimes cyanided (12 *months*).

Tons treated	60,624
Bullion produced	24,534 oz. 8 dwt. 12 gr.
Cost per oz.	16*s.* 4·064*d.*

	Total Cost. £	s.	d.	Cost per ton. s.	d.
Labour	4,126	14	8	1	4·337
Trucking	1,893	16	9	0	7·498
Engine driving	499	9	3	0	1·978
Compressed air	953	2	6	0	3·773
Smelting	151	2	9	0	0·599
Repairs and renewals	1,034	12	9	0	4·094
Cyanide of potassium	4,672	5	2	1	6·497
Lime	517	8	0	0	2·048
Zinc	135	15	8	0	0·538
Fuel	1,488	2	8	0	5·891
Filter cloth	219	7	0	0	0·868
Turning zinc	56	3	7	0	0·223
General stores	504	10	11	0	1·997
Condensed water	812	13	8	0	3·217
Removal of old slimes	2,014	13	7	0	7·976
Salt water	381	19	2	0	1·512
Assays	581	3	3	0	2·301
	20,043	1	4	6	7·347

No. IX.—The Golden Horse-Shoe Estates, Limited.

Results and Analysis of Treatment Charges, etc., in 1901.

Battery Treatment.

Tons treated	77,801		
Bullion produced, oz.	57,978·125		
Fine gold ,,	54,675·164		
Standard gold ,,	59,645·627		
Fine silver ,,	2,360·49		
Yield per ton ,,	0·745		
	£	s.	d.
Total value	231,832	0	10
Value per ton	2	19	7·152
Value per oz.	3	19	11·664
Cost per oz.	0	12	11·232

	Expenditure. £	s.	d.	Cost per ton. s.	d.
Superintendence and amalgamation	1,559	19	7	0	4·812
Engine driving, firing, etc.	2,479	3	1	0	7·648
Feeding	544	7	6	0	1·679
Handling concentrates	1,797	3	6	0	5·544
Tailings wheel	356	1	3	0	1·098
Assaying and retorting, etc.	215	8	8	0	0·665
Breaking and tramming	2,296	11	1	0	7·085
Return water	1,390	13	2	0	4·290
Mercury	519	4	3	0	1·602
Fuel	7,373	3	9	1	10·742
Water, salt	3,875	11	10	0	11·955
Water, fresh	5,794	6	1	1	5·874
Screens, shoes and dies	691	10	11	0	2·133
Electric light	524	15	3	0	1·619
Compressed air	1,101	6	4	0	3·397
General repairs and maintenance	3,640	16	10	0	11·231
Amalgamating pans	1,149	9	8	0	3·546
Concentrating tables	91	8	10	0	0·282
Realisation charges	2,103	9	1	0	6·489
	37,503	10	8	9	7·691

Sands Treatment.

Tons treated	40,108		
Bullion produced, oz.	21,481·100		
Fine gold ,,	16,786·347		
Standard gold ,,	18,312·373		
Fine silver ,,	2,437·580		
Yield per ton ,,	0·535		
	£	s.	d.
Total value	71,310	9	9
Value per ton	1	15	6·696
Value per oz.	3	6	4·704
Cost per oz.	0	11	6·720

GOLDEN HORSE-SHOE—*continued.*

	Expenditure. £	s.	d.	Cost per ton. s.	d.
Superintendence	191	13	4	0	1·147
Solutionists, pumping, etc.	889	7	9	0	5·322
Filling and emptying vats	2,408	17	9	1	2·414
Engine driving, firing, etc.	308	15	2	0	1·848
Turning zinc	176	13	8	0	1·057
Assaying and retorting, etc.	390	10	2	0	2·337
Extension of tramway and repairs	266	11	3	0	1·595
Zinc	158	2	6	0	0·946
Fuel	419	8	11	0	2·510
Water, salt	374	17	4	0	2·243
Water, fresh	360	11	0	0	2·158
Lime and chloride of lime	106	16	0	0	0·639
Cyanide	3,812	16	6	1	10·815
Electric light	175	7	8	0	1·050
General repairs and maintenance	949	15	7	0	5·683
Breaking slimes and sands	485	4	4	0	2·903
Re-handling sands from dump	171	7	11	0	1·026
Realisation charges	771	3	11	0	4·615
	12,418	0	9	6	2·308

SLIMES TREATMENT.

		£	s.	d.
Tons treated	51,588			
Bullion produced, oz.	22,971·250			
Fine gold ,,	17,888·926			
Standard gold ,,	19,515·187			
Fine silver ,,	2,622·68			
Yield per ton ,,	0·445			
Total value		75,995	13	5
Value per ton		1	9	5·544
Value per oz.		3	6	1·992
Cost per oz.		1	2	8·736

	Expenditure. £	s.	d.	Cost per ton. s.	d.
Superintendence and attending solutions	1,297	1	1	0	6·034
Engine driving and firing	1,000	12	4	0	4·655
Discharging presses	2,819	15	4	1	1·118
Dumping residues	1,927	13	2	0	8·968
Turning zinc	133	5	7	0	0·621
Assaying and retorting, etc.	626	6	1	0	2·914
Cyanide	4,951	0	2	1	11·033
Filter cloth	896	18	6	0	4·173
Zinc	205	9	3	0	0·954
Fuel	1,981	16	11	0	9·220
Water, salt	997	15	6	0	4·642
General stores, charges, repairs, etc.	3,381	2	11	1	3·730
Compressed air	1,503	1	0	0	6·993
Electric light	502	4	8	0	2·337
Water (condensed)	1,609	9	11	0	7·488
Breaking slimes and sands	1,455	14	3	0	6·772
Realisation charges	815	8	6	0	3·794
	26,104	15	2	10	1·446

CHAPTER X.

WESTERN AUSTRALIA, ECONOMICS AND STATISTICS.

Freight and Railway Rates.

RAILWAYS afford one of the most reliable indications of the state of prosperity and commercial activity of a country, since they are indispensable to the growth and development of industries of all kinds, and they form in process of time, as they gradually extend, a steel skeleton which gives the country backbone and support.

On a population basis, Western Australia is particularly well off in this respect, as in 1899 for every 133 inhabitants one mile of railway had been opened, and was being worked by the State; but railway extension needs to be pushed wherever practicable further afield, in order to open up new camps.

The capital cost per head of population amounted to 38*l.* 3*s.* 8*d.*, whilst the tonnage of goods carried per capita came to 6·82 tons. The train mileage open was 3,257,871 miles. The working expenses per cent. of revenue amounted to 70·91. The revenue per mile worked, came to 791*l.*; the working expenses per average mile amounted to 561*l*, and the profit per mile, to 230*l.* The working expenses per train mile came to 52·48*d.*,* the revenue per train mile to 74·01*d.*, and the profit per train mile to 21·53*d.*

The railway revenue per head of population amounted to 5*l.* 19*s.* 3*d.*; the number of passengers carried was 5,872,200, representing 312,685*l.* in receipts. The tonnage of goods carried

* In South Africa, Government tests are stated to have shown that the consumption of coal on the Cape railways varies, from 30 lb. of Welsh coal, and 38 lb. of Natal, to 64 lb. of Molteno per train mile. In October 1899 the railway charges per ton mile given by Mr. T. H. Leggett, M. Inst. M.M., varied from 2·34*d.* for *normal* goods on the Cape line, to 7·3*d.* on the *Netherlands* line to the Cape and Orange Free State. For *intermediate* goods, from 1·7*d.* to 6·15*d.*, and for *rough* goods from 1·6*d.* to 3·8*d.* 'Gold Mining in the Transvaal,' by J. H. Hammond, M. Inst. M.M., discussion, *Trans. Am. Inst. of Mining Engineers*, February 1901.

was 1,148,252, representing 582,315*l.* in receipts, and the dividend per 100*l.* of loan-capital which the profits represented was 4*l.* 11*s.* 0*d.**

There are two passenger classes only, with a maximum of six first and eight second class seats in each compartment. The basis of the ordinary fare is stated to be 2*d.* per mile for the first, and 1½*d.* per mile for second class passengers, outside of the metropolitan and suburban area; 112 lb. of baggage being carried free per first class, and 84 lb. per second class passenger.

Before the railway was opened to Coolgardie, the cost of transport from Fremantle amounted to about 100*l.* a ton; † and by the extension of the line from Southern Cross through Coolgardie to Kalgoorlie, the whole economic aspect of gold-mining became altered, as the following figures, given in the *Financial Times* of March 1, 1897, will serve to show.

On January 1, 1897, the section of the railway from Southern Cross being finished as far as Kalgoorlie, it was handed over by the contractors to the Government, materially lowering the cost of freight on goods to both places, as compared with the rates ruling immediately before. Thus, the charges on articles scheduled under Class A, as it is called, like chaff, fodder, vegetables, meal, flour, slates, etc., which cost previously 4*l.* 3*s.* 10*d.* per ton to deliver at Coolgardie from Fremantle, were reduced to 1*l.* 7*s.* 3*d.* per ton (gross weight of 2240 lb., or 40 cubic feet); a saving of 2*l.* 16*s.* 7*d.* being effected on every ton carried to Coolgardie; and 4*l.* 0*s.* 2*d.* on Kalgoorlie goods.

The B class of goods, which included mining trucks, buckets, pig-lead, fencing-wire, etc., were reduced from 4*l.* 9*s.* 10*d.* per ton to 1*l.* 14*s.* 4*d.* for Coolgardie, and from 5*l.* 14*s.* 10*d.* to 1*l.* 16*s.* 4*d.* per ton for Kalgoorlie.

Goods coming under first class rates, which included tinned meats, fruits, fresh meat, dairy produce, oils ‡ and candles, mining

* These particulars are taken from an interesting article on 'The Railways of Western Australia in 1899,' by John Davies, General Manager, in the *Handbook of Western Australia*, Perth, 1901.

† In 1889 it cost 30*l.* a ton to deliver goods by rail and ox or mule-waggon from the coast to Johannesburg; 8*l.* being for railway freight to Kimberley, some 300 miles distant, and the balance being for waggon-transport, loading, "off-loading," and agency charges. *The Gold Mines of the Rand*, p. 245.

‡ Viscolite, Arctic, Marine No. 1, Dark marine, Vacuum marine, Gas engine No. 1, 600 W. cylinder, Extra dark lubricating, Rochester machine, Cylinder, Pea-nut, Imperial, Colza and Castor, in four-ton lots at owner's risk; in smaller lots 'second class' at Commissioner's risk.

machinery,* corrugated-iron, nails, etc., that previously cost 5*l.* 7*s.* 8*d.* per ton to carry from Fremantle to Coolgardie, were reduced to 2*l.* 14*s.* 5*d.* per ton; a saving of 2*l.* 13*s.* 3*d.* to Coolgardie, and 3*l.* 15*s.* 3*d.* per ton on carriage to Kalgoorlie.

Goods coming under second class rates, such as groceries, hardware, clothing, etc., the rates for which originally amounted to 7*l.* 10*s.* 6*d.* per ton, were reduced for Coolgardie to 4*l.* 19*s.* 6*d.*; and from 8*l.* 15*s.* 6*d.* to 5*l.* 3*s.* 6*d.*, delivered at Kalgoorlie. Long timber requiring more than one truck (minimum 1 ton per waggon) was subsequently included in this class. Under the new regulations issued in May 1902, hardwood timber in lengths requiring three or more waggons, is charged by measurement or actual weight, up to 25 miles under class A, over 25 miles at M class rate, with 1*s.* 11*d.* per ton added; a minimum charge being made, as for 8 tons for two waggons, and 2 tons per waggon if more are required.

Imported timber is charged at first class rates, or, if carried at owner's risk, at B class rates plus 50 per cent.

Goods coming under third class rates, which included acids, spirits and glass-ware, when the railway was first opened to Coolgardie and Kalgoorlie, were reduced from 9*l.* 12*s.* to 7*l.* 6*s.* 4*d.* delivered at Coolgardie; the reduction to Kalgoorlie being from 10*l.* 17*s.* 10*d.* per ton to 7*l.* 12*s.* 4*d.*

The original rate of 2*l.* 14*s.* 5*d.* per ton (2240 lb.) fixed on mining machinery, it must be admitted, does not appear heavy, considering the distance between Fremantle and Coolgardie, 363 miles, when compared with what it used to cost in South Africa; as the gross cost of landing similar goods in Johannesburg from the coastal ports in 1894–1895 was † 6*l.* 15*s.* per ton from East London, and 9*l.* 3*s.* 4*d.* from Cape Town; 2*l.* more being charged on rough goods. In the one case, the distance to Cape Town by rail is, however, 1013 miles, whilst from East London it

* Mining machinery was subsequently carried at B class rates, plus 50 per cent., in full truck-loads of 5 and 10 tons per four and eight-wheeled trucks respectively, *vide* Reg., April 18, 1900. Mining cages, trucks and buckets, stone-breaking and quartz-crushing machinery, came under second class rates, with 10 per cent. added, unless carried at owner's risk, when 10 per cent. was taken off. By the tariff of May 1902, all mining machinery, unless otherwise specified, if packed, was carried at second class rates, plus 10 per cent. at company's risk; at owner's risk at second class rate if packed, or B class rate plus 50 per cent. unpacked. Copper matte was carried at B rates and conditions, subject to a minimum of 5 tons per waggon, but is now under class A, at owner's risk. Bromide of cyanogen was reduced from third to first class rate, January 18, 1901.

† *The Gold Mines of the Rand*, by Dr. F. Hatch and J. Chalmers, p. 246.

is 666 miles, and though the opening of the line to Delagoa Bay (394 miles) has tended to reduce rates, freight still remains one of the heaviest items in Johannesburg costs, as it is estimated * to represent 6 to 8 per cent. of the total operating expenses. Seventy-five items of machinery and plant shipped viâ East London, showed an average railway charge in 1896 of nearly 37 per cent. of their home cost; the highest being 469·5 per cent. in the case of Portland cement; and the percentage of importing charges on home cost upon these 75 items was 16½ per cent., a special duty of 3*s.* per 100 lb. being charged, for instance, on cement by the Transvaal Government.

Were it not that the policy of successive Colonial Governments seems to have been to concentrate trade and railway business as far as possible on Perth and Fremantle, the line that has been proposed from Espérance to Coolgardie, by saving some 200 miles of unnecessary distance, ought to reduce present freight costs by nearly 50 per cent., which would naturally be of great advantage to mine owners and people living on the Southern gold-fields,† and might possibly ultimately lead to the establishment of a smelter at Espérance, where it ought to be in a better position to compete for any Kalgoorlie ore not treated upon the fields. The only reason assigned so far as I am aware for the non-construction of this line has been want of funds, but one would think the money might have been found if need be privately without great difficulty.

On June 1, 1898, an increase of 43¾ per cent. of the rate previously charged for the conveyance of merchandise on the Fremantle-Kalgoorlie line, coming under Class I. category was made, whilst articles previously on a lower rating, were transferred to this and other higher classes; ‡ the lines of goods affected being for the

* Messrs. Webb and Pope Yeatman, *Eng. Magazine*, May 1898. Mr. G. A. Denny, M. Inst. M.M., calculates under the head of general expenditure, that materials and stores represent in the Rand a contribution of 15 per cent. of the total operating expenses of the mines. *Deep Level Mines of the Rand*, p. 151.

† In this connection the finding of the Committee of the Chamber of Mines of Western Australia (presented on August 5, 1902), a report of which is given in the *Financial Times* of September 9, 1902, is of interest.

‡ In the Official Table of Rates on the Western Australian Government Railways (June 1, 1898), the cost per ton (to Kalgoorlie), 387 miles, was given as follows: A class 1*l.* 8*s.* 9*d.*, B class 1*l.* 16*s.* 5*d.*, C class 1*l.* 18*s.* 11*d.*; first class 4*l.* 2*s.* 8*d.*, second class 5*l.* 3*s.* 8*d.*, third class 7*l.* 12*s.* 7*d.* In May 1902 these rates were raised, however, about 25 per cent. on the average, viz.: A class to 1*l.* 14*s.* 3*d.*; B class to 2*l.* 5*s.* 7*d.*; first class to 5*l.* 0*s.* 10*d.*; second class to 6*l.* 12*s.* 5*d.*; third class to 8*l.* 3*s.* 9*d.*; and M class to 1*l.* 2*s.* 10*d.* The increase on the carriage of local timber amounted to 80 per cent. C class was done away with in 1899.

most part mining requisites, building-materials, and provisions, a step which the Government Railway Department justified * on the grounds that the rates on the gold-fields lines having been originally 50 to 100 per cent. higher, had been assimilated with rates on the coastal railways, in the expectation of a large back traffic, which had not been realised; and since the assimilation of rates, the cost of working had risen from 47 to 80 per cent. of the receipts. Consequently, as the gold-fields lines were more expensive to operate, higher charges were necessary, and in any case they were lower than in the other Colonies, as shown by comparative tables.

It is true, as Mr. H. C. Hoover has pointed out, † that the railways, "like the mines, are run under severe conditions," but even under the late (1899) tariff, it appears that freight on machinery (packed) to Kalgoorlie, costs 5*l.* 14*s.* 0½*d.* per ton, or at the rate of 3·53*d.* per ton mile.

The mines being distant from the railways are very scattered, and goods at one time had to be delivered by waggon or on camels. ‡ By waggon the cost formerly averaged 2*s.* 1*d.* per ton-mile, and for such goods as camels can carry, somewhat less than half this amount, say $10 or 2*l.* 1*s.* 8*d.* per 50 miles.§

Since some important mines are as much as 200 to 300 miles from the railway, these freights amounted to an enormous sum annually, directly and indirectly adding from 10 to 20 per cent. to the working costs; in fact, Mr. Hoover said ‖ that a 60-stamp mill and corresponding mine equipment, would cost for transportation 100 miles beyond a railway terminus, about $75,000, i.e. 15,000*l.* ¶ The colony must therefore ultimately greatly benefit by the extension of railway communication internally; in fact it is indispensable to its prosperity, from a mining point of view.

As showing that the Government of Western Australia is not insensible of this, it is to be noted that the Menzies-Kookynie Railway has recently been completed and opened. This new district is reported to be highly auriferous, which no doubt led to the extension of the line from Menzies in that direction; and a

* Report, West Australian Chamber of Mines, London, 1898.

† *Eng. and Mining Journal*, December 17, 1898.

‡ The average load of a camel is about 846 lb. in Asia Minor. W. F. Wilkinson, M. Inst. M.M., *Trans. Inst. of Mining and Metallurgy*, vol. iii. p. 449.

§ H. C. Hoover, *Mineral Industry*, vol. vi. ‖ *Op. cit.*

¶ Mr. J. H. Hammond, M. Inst. M.M., estimates that generally speaking in the Rand the principal machinery will be found to cost erected two and a half times its home cost. *Op. cit.*

new find which appears to be of importance has recently been made in the neighbourhood, at Edjudina, 7 miles to the west, in *granite* country.

In old countries, owing to the continuous growth of capital charges without a corresponding increase in train-mileage, unnecessary tariff wars, labour difficulties and other causes, although the working expenses and rates of carriage * per train-mile may be comparatively low, and notwithstanding large gross traffic receipts, the natural tendency appears to be for the rate of interest on railway stocks (other than debentures and preference charges), to gradually decrease; as generally happens with undertakings which can borrow money cheaply, and the senior securities of which are consequently considered to be gilt-edged investments, except in cases where working expenses are reduced by exceptionally economical management. Railway lines in newer countries like Western Australia, are less affected in these respects, as there is greater room for extension of system and expansion of traffic, though its growth may be slower; but it is open to question, whether their construction and management are not better left to private enterprise than undertaken by Government.

The railway charge on ore carried in waggons which had been loaded on the up journey was fixed, on September 1, 1899, at ½*d.* per ton per mile, if conveyed at owners' risk, a distance of 150 miles and upwards, provided the value of the ore did not exceed 2 oz. per ton; an extra charge being made of 1*d.* per ton per mile for every additional ounce up to 5 oz. If over 5 oz. but under 15 oz. 1½*d.* extra, and if above 15 oz. ½*d.* per ton per mile was added for every additional 10 oz. of gold, or part thereof. If sent at company's risk 20 per cent. was added to these rates on ore exceeding 2 oz. in value, whilst a rebate of 10*s.* per ton was allowed on ores exceeding 2 oz. per ton if conveyed a distance of 300 miles or more, and *treated within the Colony.* On October 5, 1899, these rates were modified as follows: on 5-ton lots of ore per 4-wheeled waggons (loaded on the outward journey) if not exceeding 2 oz. of gold per ton, ½*d.* per ton per mile; exceeding 2 oz. in value, for each additional ounce or part of an ounce $\frac{1}{20}$*d.* per mile added to the rate for ore not exceeding 2 oz. of gold per ton; an additional

* An interesting comparison of the rates charged per ton per mile on English, American, French, German, Belgian, Dutch and African Railways for goods of different classes is given by G. A. Denny, M. Inst M.M., *The Deep Level Mines of the Rand*, pp. 153–155.

charge being levied of 5*s.* per ton on ores not exceeding in value 10 oz. of gold per ton, if exported; and 10*s.* per ton if exceeding 10 oz. in value.

The rates were altered on April 1, 1901, so that all ores and concentrates consigned to Fremantle up to 10 oz. per ton in value in lots of 5 tons or more, were it appears carried at the ½*d.* rate, an extra ¼*d.* per ton per mile being charged for each additional 10 oz. or part thereof, an alteration which was doubtless to the advantage of Colonial smelters; the necessity of importing fluxes, not to speak of fuel, making smelting in the Colony necessarily expensive. In May 1902,* the previously existing rates were again increased, on ore carried 150 miles and upwards, to 8*s.* 4*d.* (M rate) for the first 100 miles, and ½*d.* per ton beyond that distance, on ore not exceeding 2 oz. in value,† in lots of not less than 5 tons per waggon, if carried at owner's risk in waggons loaded with goods on the up journey. On ore exceeding 2 oz. per ton, for each additional ounce or part of an ounce, $\frac{1}{20}$*d.* per ton per mile is added to the above rate; special rates being charged under special conditions. Ironstone (flux) conveyed from Clack line to Owen's Anchorage for 5*s.* per ton, minimum 5 tons.

The trucks (iron) originally used for the conveyance of ore were designed to also serve as tanks, so that they were able to carry back water on the return journey from the coast.

Steamer freights, by coast steamer, were given by Mr. G. J. Bancroft in 1898 as $1·75 (7*s.* 3*d.*) to Port Pirie, and $3 (12*s.* 6*d.*) per ton of 2240 lb. to Dry Creek, exclusive of wharfage (50 cents), agency charges, and insurance; whilst freight from Fremantle to Adelaide (for Dry Creek) may now be reckoned, I believe, at 16*s.* 4*d.* to 17*s.* 6*d.* per ton.

Ocean freights on machinery from London to Fremantle (about 10,200 miles ‡), I am informed, cost 2*l.* 5*s.* (weight) or 2*l.* 10*s.* (measurement) per ton, plus 10 per cent. primage, in 1899. Whilst

* By a notice in the *Government Gazette*, these rates were again revised in August 1902 as follows. Ores not exceeding in value 2 oz. of gold per ton, loaded in waggons which have been loaded on the outward journey, ½*d.* per ton per mile: minimum 5 tons per four-wheel waggon. Ores and concentrates (consigned to Fremantle Smelting Works) not exceeding in value 10 oz. of gold per ton, loaded in waggons which have been loaded in the outward journey, ½*d.* per ton per mile: minimum 5 tons per four-wheeled waggon.

† If consigned to the Fremantle Smelting Works the same rate was to be charged up to 10 oz. of gold per ton.

‡ The distance from Tilbury to Fremantle is 10,208 miles, and from Plymouth to Freemantle 9914 miles.

freight from New York may be reckoned to have cost from 1*l.* 7*s.* 6*d.* to 2*l.* 2*s.* in 1898–1899, but subsequently rose to 2*l.* 12*s.* 6*d.**

The existing position of affairs in regard to ocean freights was very fully dealt with by the Melbourne correspondent of *The Financial Times* in a letter dated September 23, 1901, in an article entitled "Shipping Rings and British Trade" from which it appears that the *Suevic* (12,500 tons), sailing from New York to Australian ports viâ Liverpool, carried cargo to Adelaide wharf at 27*s.* 6*d.* net prepaid, general measurement, and Melbourne and Sydney at 25*s.* net prepaid freight; a New York commission house stating that they might be able to secure the 25*s.* rate to Adelaide for sufficiently large consignments, and for close-weight cargo a reduction of 5*s.* per ton on the above charges. Consequently it would seem that cargo could be carried from New York to Australia for 20*s.* a ton, and general cargo could be booked to Melbourne for 22*s.* 6*d.* per ton; although the rates for general cargo per the same line from Liverpool are stated to have been quoted in Melbourne at the same date) at 45*s.* to 50*s.* This rate-cutting on ocean freights is probably one reason why (as statistics indicate) British trade is said to have grown to the extent of 260 per cent. with foreign countries between 1881 and 1899, whilst it had only increased by 26 per cent. with British possessions.

In the matter of steamship rates, owing to shorter distance, South Africa, in its earlier days, appears to have possessed some advantage over Australia, as it is stated † that freights from England to Cape Town in 1894–1895 by the Castle and Union intermediate boats cost 32*s.* 6*d.* per ton, or to East London and Natal 40*s.* for machinery in pieces under 2 tons. The charge by mail steamers was, however, 1*s.* 3*d.* a ton more all round; and increased rates were charged on cases weighing over 40 cwt.; machinery freights from New York varied from 30*s.* to 150*s.* per ton, increased rates being charged for cases weighing over 30 cwt. The bulk of the goods were however landed at a cost of from 40*s.* to 50*s.* per ton.‡

* The rates in 1902 were, I am informed, substantially the same from London, and 42*s.* 6*d.* to 57*s.* 6*d.* per ton, plus 10 per cent. primage, from New York.

† *The Gold Mines of the Rand. Op. cit.* p. 246.

‡ G. A. Denny, M. Inst. M.M., gives some interesting tables, which show the cost of freight recently ruling, by different lines to South Africa, for different classes of goods. If not exceeding two tons in weight, the cost from New York direct to Cape Town was 32*s.* 6*d.*, or to East London or Port Natal 40*s.*; rising with increase of weight up to 97*s.* 6*d.* per ton to Cape Town, and 105*s.* per ton to East London; 10 per cent. primage being charged, which is returnable as a rebate. From London, Liverpool, or

Western Australia has not, therefore, really been so badly off in the matter of ocean carriage.

The Port of Fremantle, which is within 12 miles of Perth, with the improvements that have been made in it, provides a safe anchorage for the largest steamers, and now forms a port of call for the mail-boats. For 870 feet there was wharf accommodation with a depth of 30 feet of water, which was intended to be the average depth throughout the whole length of the wharf (4980 feet) along the south side of the inner basin, alongside the present railway-station yard.

The new harbour works constructed (since 1891) involved extensive blasting and dredging operations.*

About 54 acres had to be blasted out, and for this purpose trestle stages were erected, and from these stages holes 3 inches in diameter and 10 feet apart, were drilled in the rock to a depth of 33 feet below low water.

As each hole was completed, it was charged by means of a water-tight tin tube reaching from the bottom of the drilled hole to above sea-level with gelignite and dynamite, and each row of holes so charged, was exploded by means of time-fuses.

Owing to the proximity of the town of Fremantle, not more than 50 lb. of dynamite could be fired at one time, which rather impeded the progress of the work.

Before each row of shots was fired, the trestles were removed to the unblasted portion.

1,153,635 cubic yards have been blasted in this manner, at an average cost of 34·03*d.* per cubic yard. In addition to this, however, 247,058 cubic yards of rock were removed without blasting, which brings down the average for drilling and blasting, to 28·03*d.* per cubic yard of rock subsequently dredged.

Glasgow, freights to East London (on packages of under 3 tons) varied from 51*s.* 3*d.* to 55*s.* on machinery, boilers, etc.; they ran from 38*s.* 9*d.* to 41*s.* 3*d.* for trucks, piping, etc.; 32*s.* 6*d.* being charged on rails, earthen pipes, etc.; and 30*s.* per ton on bar-iron and steel, cement, etc. The corresponding charges on different goods to Algoa Bay, Port Elizabeth, were 42*s.* 6*d.* to 47*s.* 6*d.*; 31*s.* 3*d.* to 33*s.* 9*d.*; 25*s.*; and 22*s.* 6*d.*

Sea freight from New York to London may be reckoned at 12*s.* 6*d.* per ton, and through freight from Chicago to London on heavy goods (railway 1000 miles; sea distance about 3300 miles) about 40*s.* 6*d.* per ton of 2240 lb. *The Deep Level Mines of the Rand*, pp. 152–153.

* The following particulars are condensed from a description of the works given by Mr. C. Y. O'Connor, C.M.G., Engineer-in-Chief, in the *Handbook of Western Australia*, 1901.

Rock-Dredging.— This was done with bucket-ladder dredges, two being used, which were kept continuously at work by night and day, for 6 days per week, for the previous 3 years.

The total amount of rock dredged to the 31st December, 1899, was 1,400,693 cubic yards, including the 247,058 cubic yards of soft rock already mentioned.

Adding the cost of dredging, which averaged for rock-dredging 1*s.* 2*d.* per cubic yard, to the expenditure incurred in drilling and blasting, gives a total (approximate) of 3*s.* 6*d.* per cubic yard as the average cost of removing the rock. This includes the cost of explosives and all materials used.

Sand and Clay-Dredging.—Inside the rock bar, the material met with in the inner basin (which will have an area when completed of 109 acres) consisted chiefly of sand and clay, with a considerable amount of sea-weed in places. Two suction dredges were employed removing this; and 243,119 cubic yards of sand were pumped ashore, thus reclaiming 54 acres of land on the south side of the river; whilst the balance of the material removed to date, amounting to (approximate) 3,500,000 cubic yards, was carried to sea, a distance of 2½ miles; total journey 5 miles.

About 2,500,000 yards of sand, clay and sea-weed remained to be dredged. The cost of this work in the inner basin (including pumping some of it into the ground reclaimed) it is stated, in the article I have quoted, amounted on the average to about 7*d.* per cubic yard. It was anticipated, however, that what remained would be done cheaper.

Cost of Supplies.—Most mining requisites now have to pay a heavy duty; and although formerly it was not a high one, the cost of transportation brought the price of stores up to a high figure; and mine managers not long ago complained, that no firm of merchants stocked mining requisites, in sufficiently large quantity; consequently, if this "sample-room" style of business was not abandoned, it would become necessary for the larger mines to build depots of their own,* and keep large stocks of miscellaneous supplies on hand; since weeks and months often elapsed, before orders of the commonest kind could be executed.

Mr. H. C. Hoover † gave the following table, showing the cost

* The correspondent of the *Financial Times*, in a letter dated July 26, 1902, states that Messrs. Bewick, Moreing and Co. have decided to establish Co-operative Stores at Fremantle.

† *Eng. and Mining Journal*, December 17, 1898.

of ordinary supplies at Kalgoorlie in June 1898, compared with prices on the Witwatersrand at the end of June 1897.

—	Rand.	Kalgoorlie.
	$	$
Cement	11·04	5·64
Galvanised iron, per sq. ft.	0·09	0·09
Candles, per 25 lb. box	2·70	2·74
Dynamite, per case	*20·40	16·80
Blasting gelatine, per case	22·92	20·40
Detonators, per box of 100	0·62	0·96
Fuse, per coil	0·10	0·17
Shovels, each	0·72	0·68
Hammers, per lb.	0·09	0·04
Drill steel, per lb.	0·09	0·05
Rails, per ton	64·80	57·60
Bar iron, per lb.	0·04	0·02
Quicksilver, per flask	45·60	41·40

Between 1898 and 1901 † the price of sundry mine supplies delivered at the mines around the Boulder Township might be reckoned, I believe, on the average, at about the figures given in the first column of the following table; whilst those in the second column, are furnished to me from a most reliable source, as about the average local prices at Fremantle in the early part of 1902.

Explosives, etc.

	£	s.	d.		£	s.	d.
Dynamite, per case	3	1	6	per case	3	2	6
Gelignite ,,	3	1	6	,,	3	2	6
Blasting gelatine, per case	4	8	6	,,	4	7	9
Gelatine dynamite ,,	3	16	6	,,	4	3	0
Fuse, per 100 coils	3	6	0	per doz.	0	8	0
Detonators, per 1000	£1 11 0 to 1	13	4	per 1000	1	12	0
Candles, per 25-lb. box	0	13	3	per lb.	0	0	$6\frac{5}{8}$

* At Kimberley I believe dynamite only cost 50*s*. per case in 1900, inclusive of the Cape Government duty of 12*s*. 6*d*. per case.—*Statist*, June 30, 1900. In December 1901, prices at Johannesburg were fixed as follows: blasting gelatine, 67*s*. 6*d*.; gelatine, 50*s*.; dynamite No. 1A, 60*s*.; dynamite No. 1, 50*s*.; dynamite No. 2, 45*s*.—*Financial Times*, July 1, 1902: and it is stated that the British South African Explosives Co. have recently offered to supply gelatine at 55*s*. per case, and gelignite at 43*s*.

† In 1895 dynamite I am informed cost 5*l*. per case; detonators 5*s*. 6*d*. per 100; fuse, 1*s*. 1*d*. per coil; candles, 1*s*. per lb.

Timber, etc.

	£	s.	d.		£	s.	d.
Jarrah (hardwood), per 100 sup ft.	0	16	0	..	0	15	0
T. and G. pine (6" × ⅞"), per 100 running feet	0	16	0	..	..		
Oregon pine, per 100 sup. ft.	1	7	6	..	0	18	0
Galvanised iron (corr.), per ton	26	10	0	plain, per ton	20	0	0
				corr., ,,	21	0	0
Coal (N.S.W.), per ton	2	13	0	per ton	1	6	0
,, (Collie), per ton	1	12	6	..	..		
Firewood, per ton	0	14	6	..	..		
Coke (wholesale), per ton	5	4	2	per ton	4	0	0
Blacksmith's coal, ,,	3	18	4	,,	1	8	6
Charcoal, per sack	0	2	6	(Coolgardie) per ton	7	10	0
Rails, per ton	9	14	0	per ton	10	0	0
Nails (3-inch wire), per 100 lbs.	1	6	0	..	..		
Mercury, per bottle	9	16	0	per lb.	0	2	8
Cyanide, per lb.	0	1	1¼	,,	0	0	11¼

From a recent monthly Report of the Chamber of Mines of Western Australia it appears that as the result of endeavours to get the price of explosives reduced, a reduction of 16 per cent. had been obtained on blasting gelatine, 15 per cent. on gelatine dynamite and 10 per cent. on gelignite. Blasting gelatine has hitherto, I am informed, been found as a rule the most economical to use in the Kalgoorlie mines, in spite of its high cost. Western Australia consumes 4000 cases of explosives per month; South Africa about 40,000.—*Financial Times*, August 6, 1902.

ANAYSIS OF COSTS ON THE RAND.

	£	Total Cost per cent.
White labour	2,400,000	34·3
Kaffir ,,	2,000,000	28·6
Coal	700,000	10·0
Explosives (dynamite and gelatine)	600,000	8·6
Mining timber and sawn timber	300,000	4·3
Cyanide	240,000	3·4
Meat, mealies and mealie meal (being for most part food for Kaffirs)	250,000	3·6
Iron	85,000	1·2
Candles and paraffin	95,000	1·4
Tools	70,000	1·0
Steel	65,000	0·9
Mercury, zinc and other chemicals	45,000	0·6
Caps, fuse, ropes, cement, etc.	150,000	2·1
	7,000,000	100·0

The working costs on the Rand have been collected, classified and tabulated in a number of instances, and the preceding table prepared by State Mining Engineer Klimke, shows the percentage of the different items which constituted the working costs of all the mines on the Rand in 1895, excerpt from the article by Messrs. Webb and Pope Yeatman * previously referred to.

Mr. Hennen Jennings, M. Inst. M.M., in his evidence before the Industrial Commission, gave the following analysis of the working expenditure of six prominent companies in 1896, which enables an excellent idea to be formed of the relative importance of different items in the mining costs.

	Cost per Ton. s.	d.	Total Cost per cent.
White labour (salaries, etc.)	8	7·78	30·18
Native labour	6	9·62	23·73
,, food	1	2·24	4·14
Coal	2	4·35	8·24
Dynamite	2	10·13	9·92
Fuse and detonators		1·97	0·57
Cyanide		8·12	2·36
Zinc		0·62	0·18
Mining timber		2·98	0·87
Timber (deals, etc.)		4·05	1·18
Steel		4·21	1·22
Oil, grease and paraffin		3·73	1·09
Candles		4·15	1·21
Ropes (steel and manila)		0·93	0·27
Electric spares		1·47	0·43
Mill spares (shoes, dies, cams, cam-shafts, stems, mortar-boxes, screens, etc.)		4·59	1·34
Trucks, wheels, and rails		2·24	0·65
Sundry stores (bar-iron, bolts and nuts, pipes and pipe-fittings, buildings, machinery, assay chemicals, etc.)	2	0·73	7·19
General charges (insurance, licences, rent, printing and advertising, etc.)	1	5·99	5·23
	28	7·90	100·00

In the same evidence the average costs of twenty-nine companies were given as being 13*s*. 4*d*. per ton milled, for mining and 4*s*. 3·5*d*. for mine development and redemption ; the total average working cost per ton being put at 27*s*. 4*d*. ; 25*s*. being probably about the average before the war.

* 'Mining the Gold Ores of the Witwatersrand,' *Engineering Magazine*, May 1898.

The costs in some cases Messrs. Webb and Pope Yeatman state were, however, lower than this; for example, in 1897, at—

	s.	d.	
The Simmer and Jack	20	6·67	per ton
The Geldenhuis Deep	21	2·59	,,
The Meyer and Charlton	18	11·65	,,

Costs just before the war probably averaged about 25*s*.

An article on this subject, entitled 'Rand Economies,' appeared in the *Statist* of June 30, 1900; and Mr. T. H. Leggett in 1901 gave the following analysis of cost for several years preceding the war, in a tabulated form, presented in the accompanying footnote,* compiled from the State Mining Engineer's Reports.

Mr. G. A. Denny recently estimated,† that when the war was over and ocean freight and railway rates were reduced, more in keeping with those obtaining elsewhere, that mine costs would be somewhat less than they were formerly, and he anticipated a reduction somewhat as follows:—

	Representing a probable decrease per ton of s.	d.
In salaries and white wages	2	3
In native wages	1	8
In materials and stores (other than explosives)	0	5
In dynamite and explosives generally	0	45
In coal	0	61
	5	66

Labour.

As might naturally be expected, in a new mining camp, where "all sorts and conditions of men" are drawn together, and induced, either by an attack of "gold-fever," or to obtain the necessaries of life, to take to the hammer and drill (tools as unfamiliar to some of them as a sewing machine is to a sailor), a great deal of the labour available at first was incapable of fulfilling the duties it was called upon to perform; but willingness to learn, coupled with the experience thus purchased, and skilled miners coming to the fields from the Eastern Colonies and elsewhere in search of employment, have largely altered this state of affairs, although probably, taken as a whole, it may still be capable of improvement.

* White labour 31·22 per cent.; Native labour (including food) 29·83; explosives (dynamite, caps, fuse) 9·70 per cent.; coal 9·07; chemicals (cyanide, etc.) 3·22; tools steel, shoes, dies, etc. 3·29; mining timber and lumber 4·05; candles and lighting 1·38; sundries 8·24 per cent. = 100 per cent.—*Gold Mining in the Transvaal*, by J. H. Hammond, discussion, *op. cit.* p. 1039.

† *The Deep Level Mines of the Rand*, by G. A. Denny, p. 163.

As pointed out by Mr. G. J. Bancroft, the climate has an enervating effect on men not habituated to it, or who are physically unfitted to stand hard work in the tropical heat, and there is a certain class of "incurables," to whom idleness becomes a second nature, when they have been employed in merely "shepherding" a mining-lease to fulfil the necessary labour conditions; whilst every man who has done a little "dry-blowing" and fossicking calls himself a miner. He can scarcely, however, be considered representative of the class he claims to belong to, and I have met with a large number of as good miners in Australia as I have found in any part of the world.

The foregoing facts doubtless, however, explain, the statement made by such a competent judge as Mr. Hoover, in 1898, that in Western Australia, "a careful comparative record shows that, they accomplish about two-thirds the amount of work of a Californian miner, and only about 40 per cent. more than the Kaffirs of the Rand." He added, however, that the labour has greatly improved during the last two years, and there is reason to hope for further improvement.

In the above connection, the table opposite is of interest. It may be remarked that in forming an estimate of the cost of mining in South Africa, as compared with Western Australia, the scale of pay, in relation to the work done, explains the larger proportion of the total expense that labour represents in Western Australia; as it must be borne in mind, that the scale of native wages on the Rand, which came into force on June 1, 1897, ranged from 1*s*. 2*d*. to 2*s*. 6*d*. per shift of six * to nine hours underground; 1*s*. 4*d*. to 2*s*. 6*d*. on surface, and in the mills; 1*s*. 4*d*. to 1*s*. 9*d*. in cyanide works; and 1*s*. 2*d*. to 2*s*. 6*d*. for general employment. In addition to which, however, the Kaffir is usually supplied with "quarters" and food (2 lb. † of mealie-meal per diem, and 2 lb. of meat per week) which latter items represented about one-fourth of his wages (calculated at an average of 49*s*. 9*d*.), say 12*s*. 6*d*. a month additional, or approximately 4 per cent. of the total working cost. The average rate of pay to Kaffirs, in the year preceding the war, was, I believe,

* A "hammer boy" is expected to drill a hole 3 feet deep (which he can do in six hours), and can then quit work.—*The Witwatersrand Gold Fields*, by S. J. Truscott, A.R.S.M. It appears from a recent trial, that a first class "boy" can drill two 3-feet holes in 3 hrs. 55 min.; but the average time per hole appears to be about 3 hrs. 25 min.; and it is expected that under normal conditions *on contract*, 6 hrs. will suffice to drill two 3-feet holes.—*Financial Times*, Sept. 29, 1902.

† H. H. Webb, M. Inst. M.M. and Pope Yeatman, M. Inst. M.M. *op. cit.*; it was formerly I believe 2½ lb.

TABLE SHOWING AVERAGES OF GOLD ORE RAISED, AND OUNCES OF GOLD PRODUCED THEREFROM, PER MAN EMPLOYED ON THE SEVERAL GOLD-FIELDS OF THE STATE, DURING 1900 and 1901.*

Gold-field.	1900. Tons of Gold Ore raised. Per man employed under ground.	1900. Tons of Gold Ore raised. Per man employed above and under ground.	1900. Ounces of Gold produced. Per man employed under ground.	1900. Ounces of Gold produced. Per man employed above and under ground.	1901. Tons of Gold Ore raised. Per man employed under ground.	1901. Tons of Gold Ore raised. Per man employed above and under ground.	1901. Ounces of Gold produced. Per man employed under ground.	1901. Ounces of Gold produced. Per man employed above and under ground.
	tons.	tons.	oz.	oz.	tons.	tons.	oz.	oz.
1. Kimberley	146·50	83·71	60·00	34·28	61·66	30·83	44·35	22·17
2. Pilbarra	121·06	55·62	294·11	135·13	42·97	26·28	70·94	43·39
3. West Pilbarra	34·05	13·09	29·80	11·46	24·00	9·60	47·25	18·90
4. Ashburton	..	..	..	..	..	..	..	..
5. Gascoyne	..	..	..	..	..	..	..	..
6. Peak Hill	72·56	45·91	118·51	74·99	140·50	69·44	118·45	58·54
7. East Murchison	137·82	65·20	154·18	72·94	195·88	98·85	174·96	88·30
8. Murchison	128·03	67·17	134·82	70·74	144·40	73·14	184·08	93·23
9. Yalgoo	113·83	69·00	71·62	43·42	149·06	75·82	104·79	53·30
10. Mt. Margaret	137·49	71·75	149·49	78·02	196·48	115·98	149·97	88·53
11. North Coolgardie	111·05	60·08	129·05	69·82	111·85	61·76	151·91	83·89
12. Broad Arrow	204·71	113·76	141·21	78·47	200·63	109·39	149·26	81·38
13. North-East Coolgardie	138·92	82·22	98·27	58·16	113·25	69·12	107·96	65·90
14. East Coolgardie	178·87	83·30	266·88	124·28	242·76	109·90	345·97	156·63
15. Coolgardie	139·50	75·96	105·31	57·34	159·89	91·49	107·43	61·47
16. Yilgarn	227·62	109·46	121·98	58·66	217·45	90·23	217·74	90·35
17. Dundas	153·17	93·18	127·75	77·72	132·32	77·36	125·10	73·15
18. Phillips River	..	..	..	..	5·20	3·20	6·10	3·76
19. Donnybrook	8·37	4·50	10·53	5·66	1·05	0·59	0·08	0·05
Total averages	149·97	76·99	171·31	87·95	182·35	93·87	209·89	108·04

It will be seen from the above Table that the number of tons of gold ore raised and the number of ounces of gold produced per man employed above and under ground is 93·87 tons and 108·04 oz. respectively, as against 76·99 tons and 87·95 oz. in 1900. As the number of men employed in the mines is practically the same as for last year, it would appear that better work is being done by the miners, and that more systematic methods of mining and ore reducing are practised.

* Excerpt from the Report (preliminary) of the Department of Mines for the year 1901.

50*s.** for thirty shifts, exclusive of food. It has recently been proposed by the Chamber of Mines and Mine Managers' Association to pay the natives by "piece-work"; paying a standard wage of 35*s.* per month, for which they would be called upon to drill one 3-feet hole per diem.

For drilling two holes, the payment to be 70*s.* per month, or for one-and-a-half holes (4 ft. 6 in.) 52*s.* 6*d.* The effect is said to have been satisfactory and to have resulted in an increase of efficiency.

The attempt made to reduce the average rate of wages of "boys" on day-pay to 39*s.* 8*d.*, seems, however, to have proved a failure, owing to the scarcity of labour (resulting from the want of any incentive, or unwillingness of the Kaffir to work, so long as he can live in idleness), and the following new regulations have, I understand, now been adopted by the Chamber of Mines. (1) The rates fixed for natives on day-pay to be those of the Schedule of Oct. 25, 1900, viz. picaninnies 15*s.*, adults, minimum 30*s.*, maximum 35*s.* for thirty shifts; 7½ per cent. of the natives employed can be paid 45*s.* for thirty shifts as a maximum, and 5 per cent. can be paid any rate.

(2) Piece and task work may be extended at the discretion of the managers.

(3) The maximum rate of pay for work of this description (per foot, per ton, or per task) to be based on the work done on day-pay and the existing rates in force, mentioned in par. 1.

(4) The average earnings of all natives upon a mine not to exceed 50*s.* per thirty shifts.

The following may be given as examples showing how costs are distributed in Western Australia and South Africa, since magnitude of output does not affect a calculation of this kind to the same extent as it does cost per ton :—

Report of the North Boulder for 1898; Analysis of costs by the Author.

	Per cent.
Labour and supervision	71·99
Fuel	9·94
Supplies, explosives, etc.	8·33
Water	4·23
Office management and general expenses	3·82
Repairs	1·11
Tools	·28
Transport	·11
Assaying, etc.	·19
	100·00

* In the earlier days, (1890) the average pay of natives seems to have been as high as 63*s.* a month; and the keep of a Kaffir was reckoned at 8*s.* to 10*s.*, or say one-sixth of his wages; (Hatch and Chalmers, *op. cit.* p. 258, and S. J. Truscott, p. 456) but later on fell to 41*s.* 6*d.* rising again to 61*s.* in 1894. The keep of a Kaffir, however, at the *present time* if the Author is correctly informed amounts to nearly three times the sums named.

Report of the Consolidated Gold Fields of South Africa; Analysis of costs in 1897, by John Hays Hammond.

	Per cent.
Salaries to employees and wages to workmen	31·14
Wages and food to natives	27·83
Explosives (including fuse and detonators)	10·91
Fuel (coal and firewood)	8·98
Building material	3·79
Ironware, tools, shoes, etc.	3·47
Chemicals	2·55
Lighting (candles and paraffin)	1·35
Fodder	0·43
Sundries	9·55
	100·00

Mr. Hewitson informed the author that the distribution of labour at the Ivanhoe, in 1899, in different departments was as follows :—

Underground 58 per cent.; treatment including rock-breaking and repairs 25 per cent.; general, surface, erection, condensing, etc. 17 per cent.: total 100.

Men in Western Australia work, as a rule, 8-hour shifts, the effective week being equal to about 43 hours, viz. 7½ hours on 5 days, and 5½ hours on Saturdays, half an hour being allowed for "crib" (lunch) out of the 8-hours day; but a British Australasian telegram of September 9, 1902, reported that the leading Kalgoorlie mines have notified their intention to enforce the award of the Arbitration Court (as regards surface hands) for a full 48 hours weekly.*

Pay underground varies from 3*l.* 10*s.* to 4*l.* 10*s.* per week, with water free. In some mines, Italians have been tried, and found to accomplish, it is said,† excellent work, but they possess certain disqualifications. Coloured labour will never be tolerated in the Australian mines, nor does it appear desirable to employ such in mines when they can be run at a fair profit and afford employment to white men, except in countries like South Africa, where there is a large native population and men for mining work and skilled miners are scarce. But it is somewhat difficult to understand the objection to the properly regulated limited employment of coloured people (excepting Chinamen) in the capacity of "market-gardeners," and such avocations as they are adapted to, which are unsuitable for white men, or in which the remuneration is insufficient to attract the latter; when for instance, as in other Australian Colonies, they might supply the white population with garden produce and such like, which many people living on the gold-fields would probably be thankful to get in greater abundance at a reasonable price; but which they have to do without.

* *Financial Times*, Sept. 10, 1902.

† H. C. Hoover, *Eng. and Mining Journal*, December 17, 1898

Little "single-hand" work is done underground, not because it is not desired, but because many men are unable or unwilling to work at it; and good machine-men were formerly very hard to get.

The wages paid, although high, do not much exceed those currently earned in similar industries in countries like the United States; indeed, they are below the wage which white men can command in South Africa. From the official report compiled by Mr. Klimke, the State Mining Engineer, it appears * that the average ruling rates of wages at Johannesburg in December 1896, were as follows: Foremen, 38*l.* 11*s.* 10*d.*; shift-bosses, 27*l.* 1*s.*; miners and trammers, 22*l.* 9*s.* 10*d.*; machine-drillers, 27*l.* 9*s.* 5*d.*; pump-men, 25*l.* 2*s.* 9*d.*; pitmen, 18*l.* 7*s.* 9*d.*; engine-drivers, 25*l.* 2*s.* 9*d.*; stokers, 18*l.* 15*s.* 3*d.*; carpenters, 25*l.* 16*s.* 10*d.*; blacksmiths, 26*l.* 13*s.* 5*d.*; fitters and mechanics, 25*l.* 9*s.* 5*d.*; masons, 26*l.* 7*s.* 2*d.*; battery managers, 40*l.* 5*s.* 8*d.*; cyanide workers, 23*l.* 6*s.* 10*d.*; amalgamators, 22*l.* 7*s.* 3*d.*; concentrate workers, 21*l.* 16*s.*; vanner workers, 19*l.* 10*s.*; electricians, 26*l.* 9*s.* 4*d.*; clerks and store-keepers, 22*l.* 10*s.* 3*d.*; and labourers, 18*l.* 1*s.* 8*d.* per month (being 15 per cent. to 30 per cent. higher than in most mining centres in the United States); and as was shown in the evidence taken before the Industrial Commission, the average rate per man paid in a well

Articles.	Cost Price.	Traders' Price before the War.	Selling Price at Government Stores.	Percentage of Profits on Sales.
	s. *d.*	*s.* *d.*	*s.* *d.*	
Flour . .	15 7 per bag	17 0 per bag	29 2 per 100 lb.	87
Sugar . .	0 3½ ,, lb.	0 3½ ,, lb.	0 5 ,, lb.	43
Rice . .	0 2⅛ ,, lb.	0 3½ ,, lb.	0 5 ,, lb.	135
Jam . . .	10 0 ,, doz.	12 0 ,, doz.	15 0 ,, doz.	50
Butter . .	1 5⅝ ,, lb.	1 9 to 2*s.* lb.	2 3 ,, lb.	52
Paraffin . .	14 cents per gal.	14·6 cents per gal.	20 cents per gal.	43
Milk (condensed) .	6 2 ,, doz.	6 0 per doz.	9 0 per doz.	46
Quaker oats .	8 11½ ,, doz.	9 0 ,, doz.	15 0 ,, doz.	67½
Bacon . .	0 10¾ ,, lb.	0 11 ,, lb.	1 2 ,, lb.	30¼
Ham . .	1 1 ,, lb.	1 0 ,, lb.	1 4 ,, lb.	23
Candles . .	0 6⅓ ,, lb.	0 6 ,, lb.	0 9 ,, lb.	42
Salt, bag . .	0 1⅓ ,, lb.	0 2 ,, lb.	0 2 ,, lb.	50
,, table .	2 1 ,, doz.	2 9 ,, lb.	4 0 ,, doz.	92
Matches . .	0 6¼ ,, doz.	9*d.* per doz. or 7*s* 6*d.* per gross.	1 0 ,, doz.	92

* *Op. cit.*, S. J. Truscott, pp. 449–450, first edition.

managed developing mine was 19*s.* 6·6*d.* per shift, and in a working mine about 18*s.* 6*d.*; more skilled labour being required where construction work is going on. Against these rates, however, must be set the cheapness of ordinary (native) labour and the high cost of living, which amounted, I believe, at Johannesburg to about 19*l.* a month for a married man with a wife and two children, although single men could board for 5*l.* to 6*l.*

An article entitled 'On the Rand,' which was published in 1901, in the *Financial Times*, showed the cost at the coast of a number of articles sold in Johannesburg; the Natal share of railage; the Transvaal share of railage; the Transvaal Customs dues; the total cost landed in Johannesburg; the percentage of profits on sales; and current prices as given in the table on p. 462.

Mr. G. A. Denny gives* a most interesting "statement," compiled by Mr. F. Raleigh, which shows the cost of machinery, plant, etc., and the cost of importing it, via East London.

The cost of living in Western Australia in 1898 and 1901, may be judged from the prices † of the following commodities:—

	1898	
	$ $	*d.* *s.* *d.*
Beef (retail), per lb.	0·22 to 0·30	11 to 1 3
Bacon, per lb.	0·25	1 0½
Flour, per 100 lb.	4·75	19 9½
Butter, per lb.	0·60	2 6
Eggs, per dozen	0·60	2 6

Horse-keep may be reckoned at about 30*s.* to 35*s.* per week.

On the Coolgardie gold-fields in the early part of 1902, the following prices obtained:—

	s.	*d.*		*s.*	*d.*
Bread, per 2 lb. loaf	0	6	Sugar ,,	0	3
Meat, per lb.	0	10	Butter ,,	1	6
Bacon ,,	1	3	Potatoes ,,	0	2
Flour ,,	0	3	Water, per 100 gallons	8	0
Tea ,,	1	9			

Although the cost of living is much less now than it was before the construction of the railways, as Mr. Hoover has pointed out, it is still very high, ‡ owing to the high rates of transport by rail that still obtain, and the necessity that exists of importing most of the food supplies. Cheapening of production must therefore be looked for through reducing the cost of living and securing *efficiency* rather than from lowering the present wages rates. Single men pay, according to Mr. H. F. Bulman, 1*l.* to 1*l.* 10*s.* per week for board

* *The Deep Level Mines of the Rand*, p. 158.

† Given by G. J. Bancroft, *op. cit.*

‡ Mr. Francis F. Govett, at the Annual Meeting of the Ivanhoe Company, May 2, 1902, pointed out that under the existing conditions of living on the gold-fields, the current rate of wages could not be considered unreasonable.

and lodging, whilst Mr. H. C. Hoover stated in 1898 that a man could "batch" for $3 per week; the men living as a rule in rough-looking shanties of "hessian" stretched over a wooden framework (which in the hot, dry climate of Western Australia is not as uncomfortable as it seems), or in corrugated-iron huts, or small weather-board houses. In 1902, board and lodging at Coolgardie and Kalgoorlie cost from 18*s.* to 40*s.* per week; at Pilbarra 25*s.* to 30*s*; and on the Kimberley gold-fields 30*s.* upwards.

In a hot country like Australia it is particularly desirable to work with as few men as possible on *night* shift, as they cannot get proper sleep during the day.

The standard rates of pay at Kalgoorlie on an eight-hour basis were fixed formerly on the following scale:—Labourers, 1*s.* 3*d.*; brace-men, 1*s.* 4½*d.*; miners and stokers, 1*s.* 5½*d.*; machine-men (in dry ground) and engine-drivers, 1*s.* 8*d.*; and machine-men (in wet ground), blacksmiths, carpenters, masons and plumbers, 1*s.* 10½*d.* per hour.

At Fremantle, foremen roasters were paid 4*l.* per week; roaster hands, 8*s.* 4*d.* per shift; and electricians, 3*l.* per week. Tabulated in the ordinary way, for the sake of comparison, the following were the rates that obtained, I believe, at Kalgoorlie in 1900–1901:—

	Per 8-hour Shift. £ s. d.		Per Month. £ s. d.
Shift bosses			21 13 4

	Per 8-hour Shift. £ s. d.		Per Week. £ s. d.
Miners (dry)	0 11 8	or	3 10 0
,, (wet)*	0 13 4	,,	4 0 0
Machine-men in charge of the drill (dry) †	0 13 4	,,	4 0 0
,, ,, ,, (wet) *	0 15 0	,,	4 10 0
,, (assistants)	0 12 6	,,	3 15 0
Timber-men	0 13 4	,,	4 0 0
Pitmen	0 16 8	,,	5 0 0
Truckers ,,	0 10 6	,,	3 3 0
Bracemen and platmen	0 11 0	,,	3 6 0
Amalgamators	0 13 4	,,	4 0 0
Battery feeders and labourers	0 10 0	,,	3 0 0
,, lumpers and cyanide labourers	0 11 8	,,	3 10 0
Carpenters and fitters	0 15 0	,,	4 10 0
Blacksmiths	0 15 0	,,	4 10 0
Tool-sharpeners	0 13 4	,,	4 0 0
Strikers	0 11 0	,,	3 6 0
Masons, bricklayers and plumbers	0 15 0	,,	4 10 0
Engine-drivers (first class certificated)	0 13 4	,,	4 0 0
,, (second class and condenser men)	0 11 8	,,	3 10 0
Labourers (surface) ,, ,,	0 10 0	,,	3 0 0
Teamsters ,, ,,	0 11 8	,,	3 10 0
Boys	0 8 4	,,	2 10 0

* The term "wet ground" is understood to be when water is making at the rate of 1000 gallons per shift or more, but the men recently asked to have this reduced.

† Men at the "chuck" are not entitled to this rate.

The Australian Workers Association demanded a rise of wages in 1902 to 13*s.* 4*d.* for machine chuck-men and of 11*s.* 8*d.* for truckers, mullockers and labourers; that any men working on contract or piece work should receive not less than the current rate of wages; the time and a half be paid for Sunday labour; and that preference be given to the Union men. The matter was referred to the Conciliation Board.

The award of the Court of Arbitration, which was presided over by Justice Moorhead, Mr. W. E. Moxon and Mr. Lobstein, is given in the 'Report of the Chamber of Mines of Western Australia,' September 1902.

The Court has ordered that the minimum rate of wages paid by the employers on the East Coolgardie gold-fields is to be as follows:—

	Per Shift. *s.*	*d.*
Rock-drill men in shaft	14	4
,, in rises	13	10
,, driving, cross-cutting, stoping and winzes	13	4
Miners	11	8
Brace men and "plat" men	11	8
Mullockers and shovellers	10	6
Truckers, filling and trucking	10	6
Truckers from shoot	10	0
Men working at cyanide vats and filter-presses	11	8
Timbermen †	13	4
Surface labourers	10	0

The shift to consist of eight hours, including the customary allowance for "crib."

Surface men's shift to consist of eight hours, exclusive of "crib" time.

The Court decided that no sufficient reasons had been adduced to warrant interference with Sunday labour, which was already, except when necessary, absolutely prohibited by Act of Parliament.

Total Sunday closing, in the opinion of the Court, would mean an incalculable diminution in the production of the mines and largely increased expenses.

The Court declined to direct that the "contract system" should be totally abolished as proposed, but it directed that all agreements should be in writing, and should contain a clear specification of the work required to be done, the price to be paid, the price at which stores and explosives would be supplied to contractors, and the

* The men to be held jointly and severally responsible for the breakage of tools or injury to machinery.

† Working together, and directly in charge of and responsible to the underground manager for the work under their control.

dates of the progress payments to be made; notices of these terms to be posted one clear day before tenders are received.

The Court also strongly recommended that the form of agreement at present in use at the Great Boulder be adopted in other mines. Mine owners have the unrestricted right to employ non-unionists, and the Award applies to the East Coolgardie field for eighteen months.

A table showing the relative rates of wages in the different goldfields of the Colony in 1900 and 1901, will be found at the end of this chapter.

Cost of Disposal of Bullion.

A circular* issued by the Perth branch of the Royal Mint, shows the cost of the disposal of the gold raised in the Kalgoorlie District; from which the relative cost of treatment by refiners in London or at the Mint in Perth can be reckoned. The comparison is based on a consignment of 8000 oz., divided into three lots: (1) Battery gold, 5000 oz., assay of gold ·915, of silver 0·075: containing, therefore, 4575 oz. fine gold and 375 oz. fine silver; (2) cyanide bullion, 1500 oz., assay gold ·740, and of silver ·145: containing, therefore, 1110 oz. fine gold and 217·5 oz. fine silver; (3) gold from slimes, 1500 oz., assay gold ·740, of silver ·145: containing, therefore, 1110 oz. fine gold and 217·5 oz. fine silver.

Bullion sent through a bank to refiners in London.

	£	s.	d.
Boxes eight at 10s.	4	0	0
Cartage in Kalgoorlie	1	0	0
Railway carriage (ordinary rate), 6s. 6d. per 100 oz.	26	0	0
Police escort (ordinary rate), ½d. per oz.	16	13	4
Insurance (Kalgoorlie to London), 5s. per cent. on 29,000l.	72	10	0
Bank commission, 5s. per cent. on 29,000l.	72	10	0
Freight, 10s. per cent. on 29,000l.	145	0	0
Expenses in Fremantle, wharfage, cartage, etc.	2	10	0
Expenses in London, cartage, etc.	3	0	0
Refiners' charges, 8000 oz. at 2¾d. per oz.	91	13	4
	434	16	8
Less allowed for silver (810 oz. fine), 876 oz. standard, at 2s. 3d.	98	11	0
	336	5	8
To which must be added loss due to London market price for gold being 1¼d. per oz. standard less than Mint price (6795 oz. fine), 7413 oz. standard at 1¼d.	38	12	2
	374	17	10

* Given in a letter from Kalgoorlie, dated June 22, 1901, published in the *Bullionist*.

	£	s.	d.
If half the proceeds were required in Kalgoorlie to meet mine expenses, the money would have to be transmitted by "bill of exchange." If such bill could be obtained at a profit of ⅛ per cent., the above figures would be reduced by (14,500*l.* at ⅛ per cent.*) 18*l.* 2*s.* 6*d.*			
Lowering the total cost to	£356	15	4

Gold Bullion sent to Perth Mint.

	£	s.	d.
Expenses—Mine to Mint:			
Boxes, 8 at 10*s.*	4	0	0
Cartage in Kalgoorlie	1	0	0
Railway carriage (special rate), 6*s.* 6*d.* per 100 oz., less 25 per cent.	19	10	0
Police escort (special rate), ¾ per oz. . . .	8	6	8
Insurance (Kalgoorlie to Perth), 2*s.* per cent. on 29,000*l.*	29	0	0
	61	16	8
Mint charges	77	15	7
	139	12	3
Less allowed for silver	13	10	0
Net cost	126	2	3
If half the proceeds were required in London for dividends, etc., and half in Kalgoorlie for mine expenses, the above figures would be increased by (1) bank exchange, Perth to Kalgoorlie, 14,500*l.* at ⅛ per cent.* 18*l.* 2*s.* 6*d.*; ditto, Perth to London, 14,500*l.* at ½ per cent., 72*l.* 10*s.*	90	12	6
Increasing total cost to	£216	14	9

On June 20, 1899, His Excellency the Governor declared the Perth Branch of the Royal Mint to be open for the receipt of gold for coinage.

Subject to the Regulations, any person may deposit gold at the Mint in his own name. Those who cannot attend personally for the purpose may send the gold by an agent, through the post, or under police escort.

A circular can be obtained from the Deputy Master of the Mint giving all necessary information for intending depositors, conditions of the Escort Service, Coining Regulations, etc., etc.

Parcels up to 43 oz. gross may be sent through the post.

An Escort Service is provided by the Police Department for parcels of all sizes. The consignor pays for the carriage by coach or train, but the escort charges are collected by the Mint.

* Rates subject to alteration by the Banks.

Forms for use in connection with gold sent to the Mint by post or under police escort can be obtained at the Mint.

The charges for the conversion of gold into coin are as follows :—

1. *For Assaying and Refining:*

   A minimum charge of 4*s*. is made for all weights up to 48 oz.

   From 50 oz. to 500 oz. an addition at the rate of 10*d*. for every 10 oz. or part of 10 oz.

   From 501 oz. to 1000 oz. an addition at the rate of 1*s*. 8*d*. for every 20 oz. or part of 20 oz.

   From 1001 oz. and upwards an addition at the rate of 4*s*. 2*d*. for every 100 oz. or part of 100 oz.

2. *For Coining:*

   For deposits under 500 oz. standard . . 1½*d*. per oz.

   For deposits over 500 oz. standard . . 1*d*. „

The following table * illustrates the operations of these charges in cases of gold of the value of 3*l*. 17*s*. 10½*d*. an ounce :—

Weight of Deposit.	Rate of Charge per oz.			Amount of Charge.									Net Value of Deposit.		
	Assaying and Refining.	Coining.	Total Rate.	Assaying and Refining.			Coining.			Total Charge.					
oz.	*d.*	*d.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*
50	1·0	1·5	2·5	0	4	2	0	6	3	0	10	5	194	3	4
100	1·0	1·5	2·5	0	8	4	0	12	6	1	0	10	388	6	8
600	1·0	1·3	2·3	2	10	0	3	6	8	5	16	8	2,330	8	4
1,000	1·0	1·0	2·0	4	3	4	4	3	4	8	6	8	3,885	8	4
5,000	0·6	1·0	1·6	12	10	0	20	16	8	33	6	8	19,435	8	4
10,000	0·5	1·0	1·5	22	18	4	41	13	4	64	11	8	38,872	18	4

* GOLD ESCORT SERVICE—TABLE OF RATES.

From	To	Period.	Rate per cz.	Remarks.
			d.	
Abbotts	Perth	Monthly	5	
Australia United Mine .	„	„	2¾	Special rate for Perth Mint only.
Burbanks	„	Fortnightly	0¾	Ditto.
Coolgardie	„	„	0¼	Ditto.
Cosmopolitan Propy., Ltd. .	„	Monthly	1¼	Ditto.

* Excerpt from *Mining Statistics*, Department of Mines, Western Australia, 1900 and 1901.

TABLE OF RATES—*continued.*

From	To	Period.	Rate per oz.	Remarks.
			d.	
Cue	Perth	Monthly	3	Special rate for Perth Mint only.
Field's Find	,,	,,	4½	Ditto.
Geraldton	,,	,,	2	Ditto.
Kalgoorlie	,,	Fortnightly	0¼	Ditto.
Kanowna	,,	,,	0½	Ditto.
King of the Hills	,,	Monthly	2¼	Ditto.
Kookynie	,,	,,	1¼	Ditto.
Laverton	,,	,,	2¾	Ditto.
Lawlers	,,	,,	3¾ 2½	Ditto. Over 6000 oz. Special rate for Perth Mint only.
Leonora	,,	,,	1¼	Special rate for Perth Mint only.
Menzies	,,	,,	0¾	Ditto.
Mt. Malcolm	,,	,,	1¼	Ditto.
Mt. Morgans	,,	,,	2¼	Ditto.
Mt. Sir Samuel	,,	,,	4¼	Ditto.
Munara Gully	,,	,,	3½	
Nannine	,,	,,	4	
Niagara	,,	,,	1¼	Special rate for Perth Mint only.
Norseman	,,	,,	2¼	Ditto.
Northam	,,	Fortnightly	Nil	
Peak Hill	,,	Monthly	5½ 5 4¾	2000 oz. to 2500 oz. 2500 oz. to 3000 oz. Over 3000 oz.
Southern Cross	,,	Fortnightly	Nil	
Wiluna	,,	Monthly	6½ 6 3¾	1500 oz. to 2000 oz. Over 2000 oz. Over 6000 oz. Special rate for Perth Mint only.
Yalgoo	,,	,,	2½	
Yerilla	,,	,,	1¾	Special rate for Perth Mint only.

* RATES FOR CARRIAGE OF GOLD ON GOVERNMENT RAILWAYS.

—	Distance not over							
	25 miles.	50 miles.	100 miles.	150 miles.	200 miles.	250 miles.	300 miles.	350 miles.
	s. d.	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*
Gold dust and bullion per 100 oz.	1 0	2 0	3 0	3 9	4 6	5 0	5 6	6 0

6*d.* per 100 oz. for every additional 50 miles.

NOTE.—*A special reduction of 25 per cent. is made for all gold dust or bullion consigned to the Perth Mint.*

* Excerpt from *Mining Statistics*, Department of Mines, Western Australia, 1901.

*To find the value per ounce of gold sent from a mine to the Mint.** —Divide the standard gold by the weight before melting, and multiply the result by 3*l.* 17*s.* 10½*d.* For instance, supposing the Mint return to show:

	oz.
Weight before melting	47·41
Standard gold	38·19

The calculation would be as follows:—

```
4741)3819·0(·805        ·805 × £3 17s. 10½d.
     3792·8             ·805 × £3·894
     ------                     ·805
       26200                   ------
       23705                   19470
       -----                  311520
        2495                  ------
                             £3·134(670)
                                  20
                              ------
                             s. 2·680
                                  12
                              ------
                             d. 8·160 = £3 2s. 8d., value per ounce of gold as
                                            produced from the mine.
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Two letters in the *Financial Times* of October 16, 1901 and March 5, 1902, discuss the question of Australian coinage from a general stand-point.

Management.—The management of West Australian mines has at different times evoked a great deal of adverse comment, and as it is in a large measure the keystone upon which all else rests, several points of view from which it has been criticised, both from within and from without the profession, call for notice.

Some people, for instance, have argued in favour of what practically amounts to "dual control," in the shape of Australian direction on the spot, with a business man at the head of affairs, the departmental management being entrusted to mine and mill foremen. The disadvantages of this have been pointed out by Mr. J. H. Curle,† so I need not repeat them. Others have advocated vesting the supreme local power in the hands of a technical man, the latter arrangement being now the one most in favour, and which has worked on the whole the best, although both systems, it must be confessed, have occasionally broken down.

Another question which has given rise to no little discussion has been as to whether the general management of this or that company should be entrusted to a miner or a metallurgist, a point which it seems useless to argue, since it appears self-evident that

* Excerpt from *Mining Statistics*, Department of Mines, Western Australia, 1901.

† *The Gold Mines of the World*, by J. H. Curle, 1st ed., pp. 147–148.

anyone filling a post of the kind should possess a knowledge of both branches of the business he is called upon to look after. A worse bone of contention, however, over which rival advocates have got badly bitten at different times, has been fought over the most absurd, perhaps, of all questions, viz. the relative merits of American, Colonial and English engineers—a matter which, so far as regards outsiders (shareholders and others), has given rise to no little surprise and perplexity; and unfortunately one cannot, add that like the curse of the "Jackdaw of Rheims," "no one seemed one penny the worse."

The assertion is no doubt true, that it is impossible to defend the management of a number of properties in the earlier days of the field, but mistakes that were made do not appear to have been confined to any one particular branch of the profession, and it seems as foolish and ill-advised as it is unsportsmanlike, to raise discussion on such a purely abstract question as the capacity of a body of engineers sprung from one common stock, whether English, Colonial, or American, since the question turns on the experience and personality of each individual, which varies every case.

The list of engineers given in an article dealing with this subject in the *New York Mining Journal* of September 1, 1900, includes the names of a number of mining engineers, American and British, to which mining, both in South Africa and Western Australia, is undoubtedly largely indebted, and the article in question sums up the case in a nutshell by remarking that, "The wisdom and skill in the profession are not monopolised by the engineers of any one country: there are excellent men in all." Men of Anglo-Saxon blood can, in fact, surely well afford to admire success, which their colleagues and others have achieved, to whatever branch of the race they belong, and anything that tends to blunt the feeling of mutual esteem which generally animates them, and would tend to split them into different "camps," I cannot help thinking, is greatly to be deplored. Mining men by pulling together can accomplish far more for the welfare of their profession and the good of the industry, than by pulling "out of stroke" or against one another.

It is moreover but fair to managers of mines to draw attention to the fact (which business men are able to overlook) viz. that sometimes with a not unnatural, but unwise, desire to secure larger returns than a property is in a position to yield steadily, pressure may be brought to bear to force the output of a mine beyond what a manager judges to be wise. At other times he may have to suffer for mistakes made by his predecessors in office, for which he gets the blame if things go wrong, and occasionally he never gets the opportunity of carrying his ideas out in practice, and has to make shift as best he can with the means at his disposal. In fact it is, in all cases, most easy to criticise, and most difficult to allocate the exact measure of personal responsibility in any particular case without knowing exactly the different sides of the question.

Foresight in a business like mining, is an indispensable qualification for every mining engineer to possess who aspires to success, and lack of this natural gift is responsible for many mistakes; but it is always easy to moralise, and the profession on its own initiative has undoubtedly not only striven to advance, but has effected many necessary reforms.

One of the most common complaints which one hears brought against mine-management is "the reckless expenditure of capital," and in some instances, if the amount of capital placed at a manager's uncontrolled disposal is a large one, there may be temptation to extravagance; whilst, as Mr. S. H. Cox, M. Inst. M.M.,* has pointed out, it is a well-known fact that "working costs are generally greater on rich mines than on those which are poor." The measure of economy exercised in any particular case cannot, however, be judged simply from the gross outlay, which people are too apt to look at, without considering what it represents; and, if judiciously laid out, the larger the capital outlay the more it should make ultimately for economy, by supplying a property with the most perfect equipment possible, on a scale commensurate with its requirements and output: many a mine having been ruined or never having achieved the success which it ought and would have attained if properly equipped, simply because outlay has been stinted on its preliminary development and plant.

Leakage of information in regard to "important strikes" is another matter for which managers are not infrequently blamed, and although it can sometimes be checked, it is impossible, as a rule, to entirely prevent it, when it is encouraged from outside.

Gold-stealing, which has been a cause of trouble in the past when dealing with very rich ores, can only be stopped by combination, such as now obtains, amongst the mine-owners to detect and punish it; by the provision of properly-regulated "changing-rooms";

* Presidential Address, *Inst. of Mining and Metallurgy*, by S. H. Cox, M. Inst. MM., 1899, vol. vii. p. 219.

and by the enforcement of the Act that has been passed to register "gold dealers"; but the provision of the existing law, that the gold must be actually identified, has raised great difficulties in the way of punishing gold thefts; as pointed out by Mr. Hermann Landau, the Chairman at the Annual Meeting of the Associated Gold Mines, July 24, 1902; and the possession of gold which cannot be satisfactorily accounted for ought to suffice to secure punishment.*

In considering the question of management, the difficulties under which the fields have hitherto laboured, must be taken into account. It must be recollected, for example, as Mr. H. C. Hoover has pointed out,† that they cover an area of about 500 miles in diameter, and, as conditions vary greatly in different localities, a working cost of $25 per ton in one place may represent more efficient management than $10 in another.

Mr. Hoover in 1898 estimated that in well-managed mines employing wet-crushing mills, i.e. with free-milling ore exclusive of depreciation, London expenses, etc., the costs on different West Australia gold-fields averaged approximately as follows:—Kalgoorlie $10 per ton; Coolgardie $10; Menzies $20; Mt. Malcolm district $8; East Murchison district $7; Murchison $10; Yilgarn $7.

It is a fact, as he said, that, as a rule, $10 (10 dwt. ore) would not yield a profit, and it is therefore to the credit of their management that, despite the disadvantages under which mining suffers, under favourable circumstances and *with free-milling* ore considerably less than this has been made to pay.

To name a few mines, which I have selected, (1) as none of them shows an exceptionally large output; (2) they are situated (except as regards the two last) in different localities; and (3) because they were severally under Australian, American, and British management.

Fraser's Gold Mining Co. Southern Cross, in the Yilgarn goldfield, succeeded in paying dividends, dealing with a free-milling quartz ore averaging 10 dwt. 19 gr. per ton, the bullion being only worth 3*l.* 13*s.* an oz. The amount of stone crushed up to the end of 1898 is stated to have been 101,575 tons, which produced 54,966 oz. 10 dwt. in bullion.

* It appears that a "bill" with this object has recently been introducod by which any person found in possession of gold (meaning gold bullion, gold ores, amalgam, alluvial, concentrates, etc.), reasonably suspected of being stolen, and who does not prove that he came by it lawfully will be liable to a fine of not exceeding 50*l.*, or a term of imprisonment not exceeding six months.

† *Mineral Industry*, vol. vi. p. 334.

In a report of the Chamber of Mines of Western Australia Mr. V. F. Shallcross, M. Inst. M.M., gives * an interesting table showing that between May 16, 1890, and July 23, 1900, the total tonnage milled amounted to 138,701 tons, representing a yield of 1*l.* 16*s.* per ton, and that the total working costs per ton came to 1*l.* 11*s.* 7*d.*

During 17 months ending December 31, 1901, 35,206 tons were milled in Fraser's mill, which yielded 1*l.* 1*s.* 10*d.* per ton at a cost of 1*l.* 3*s.* 11·65*d.*, irrespective of returns from tailings; 102,516 tons being cyanided which returned 12*s.* 0·10*d.* per ton at a cost of 4*s.* 0·05*d.*

Mr. Shallcross points out that the shafts only permitted of hoisting trucks holding 7 cwt. and that the present batteries are old—the duty per stamp being only equal to 2·3 tons per diem, and he adds: "To some extent the economies effected are due to the installation of rock-breaker, ore-bins and automatic feeders, but a great deal is also due to *the system of accounts* which has been adopted at the mine, whereby the manager can see at a glance the cost of each particular piece of work as it progresses, and check any excessive expenditure."

The costs at the East Murchison United, in the East Murchison District, were given as only $7·68 (32*s.*) a ton. In 1898,† 12,431 tons were treated from this mine, for a yield of 13,641 oz. 13 dwt. 6 gr., and the average grade of the ore throughout, up to the end of 1898, was 1 oz. 7 dwt. 21 gr., the bullion being worth 3*l.* 15*s.* 6*d.* per oz. The Company paid 45,000*l.* in dividends during the years 1898 and 1899.

The costs at Bayley's United Gold Mines, Coolgardie, of mining, milling, and sands and slimes treatment combined, amounted to 1*l.* 11*s.* 4*d.*‡ in 1899, and to 1*l.* 11*s.* 1¼*d.*§ per ton in 1900. The quantity of ore crushed in the new battery in 1899 being 13,106 tons, and in 1900 28,227 tons, averaging 1 oz. 12 dwt. 7 gr. and 14 dwt. 23 gr. per ton respectively. In 1900 on a yield of 11 dwt. 23·77 gr., a profit of 14,986*l.* 18*s.* 3*d.* was earned after writing off 14,775*l.* 19*s.* 5*d.* for development, etc.

* *Vide* the *Mining Journal*, July 19, 1902, p. 1004.

† In 1898, 3284 tons crushed from the Donegal leases produced 2879 oz.; and 2004 tons crushed from the Waroonga yielded 2324 oz.; these leases being worked under a profit-sharing arrangement with the London and Western Australian Exploration Co., Ltd.—*Mining Year Book*, 1902.

‡ Report of the General Manager, Mr. G. W. W. Mackinnon, M. Inst. M.M.

§ Report of the General Manager, Mr. E. Davenport Cleland.

At the Norseman Gold Mines, in the Dundas District, 9584 tons of ore were crushed in 1898, yielding 10,148 oz. 5 dwt. 14 gr. in bullion, worth 3*l.* 12*s.* per oz., and I am informed that the cost came to 2*l.* 7*s.* 7½*d.* per ton (including mining 19*s.* 4*d.*, development 13*s.* 8*d.* and milling 14*s.* 7½*d.*), but Mr. R. M. Raymond, M. Inst. M.M. (the late General Manager), subsequently estimated, I believe, that, with sundry alterations and additions made to the plant, mining and milling could be covered by a return of about 5 dwt. per ton; and the costs for the year ending September 30, 1900, crushing 24,217 tons, came to 1*l.* 10*s.* 9*d.* per ton, mined, milled and cyanided, including 12*s.* 8·8*d.* for mining, 6*s.* 4·8*d.* for milling, 5*s.* 8*d.* for development, 5*s.* 5*d.* for cyaniding, and 6·4*d.* for sundry charges.

At Tindal's Mine, in the Coolgardie district, where the ore has been got by "open cast," ore yielding less than 4 dwt. is reported to be giving a profit.

It was stated, in fact, that 1013 tons were treated in April 1901 for a yield of 153 oz., or an average of just over 3 dwt., the total expenses being 489*l.* 16*s.* 2*d.* and the value of the gold 594*l.* 18*s.* 6*d.*

The costs at Hannan's Oroya (Kalgoorlie), exclusive of London and Adelaide charges, for the half-year ending March 31, 1900, milling 13,601 tons, which returned on an average 6 dwt. 11 gr. of bullion worth 3*l.* 16*s.* 7*d.* per oz., amounted to 19*s.* 11·1*d.* per ton for mining, milling, transport of ore smelted (526½ tons) at Fremantle (901*l.* 15*s.* 1*d.*) and general expenses, or including development (charged to capital account) the total expenses came to 1*l.* 18*s.* 9·8*d.* per ton milled. It should be mentioned, however, that the very low *mining* costs included in the above sum of 19*s.* 11·1*d.*, which amounted to 7*s.* 3·7*d.* per ton * of oxidised ore milled (inclusive of mining, trucking, hauling and filling in stopes), I am informed, was partly owing to the fact that some of the ore was mined "open-cast."

The costs at the North Boulder (Kalgoorlie), in October 1899, mining 1724 tons and crushing 1224 tons (the balance being sulphide ore), came to 1*l.* 17*s.* 5·05*d.* per ton, including general mining charges 8*s.* 8·80*d.*, stoping 4*s.* 2·07*d.*, development 7*s.* 0·22*d.*, milling 10*s.* 6·43*d.*, and general and surface expenses 6*s.* 11·53*d.*; and, charging a certain proportion of the milling costs to crushing the sulphide ore, to prepare it for shipment, it may be estimated on the above scale of treatment that mine general charges and mining were covered by 12*s.* 10·87*d.* per ton, and milling by 7*s.* 9·82*d.*; in

* Report of the Manager, Mr. J. V. Parkes.

other words, 1*l.* 0*s.* 8·69*d.*, or practically speaking 5 dwt. ore, all but covered these items; reckoning the bullion as being worth about 4*l.* 2*s.* per oz. Local general expenses and development added 13*s.* 11·75*d.*, making 1*l.* 14*s.* 8·44*d.* in all.

There are various other mines, no doubt, which can present a similar satisfactory showing, and I merely instance these, having the figures before me, to show that, under the circumstances with which the managers have had to deal, the management of West Australian Companies has not been perhaps so bad as some people painted it; the question of cost hinging largely on the quantity of ore that can be mined on the average monthly, and other matters which are outside of the possibility of individual control. It must also be recollected that the men who have tackled the problems which beset them at the commencement have had the incalculable advantage of later experience to guide them, which managers had at first to risk, in seeking a solution of difficulties, for which there was no precedent.

There are, however, one or two reforms which might, I think, be carried out, and would be of considerable advantage alike to shareholders and managers of companies. For instance, it would be a distinct gain if the reports of all companies were issued half-yearly or annually, brought up to the middle or end of the calendar year, and not at odd times.

Further, I believe it would be of advantage, not only to managers but to the companies they represent, if they would agree to adopt a more *uniform* system of subdivision, in which to present the various analyses of cost of mining, milling, etc., which are so admirably given in many of their reports; this would better enable them to see when and where *possible* economies could be effected. The high standard of general excellence and cheapness, which characterises mining on the Rand, is, in the Author's opinion, in a large measure due to the *uniformity* noticeable in the statistics of cost * furnished by the various large companies. A circumstance which tends, however, to complicate the presentation of returns and

* The importance of accurate "cost-keeping," a subject quite apart from ordinary "accountancy," was admirably dealt with by Mr. S. H. Cox, A.R.S.M., in his Presidential Address to the Institution of Mining and Metallurgy, in 1899, and Mr. J. H. Curle, referring to Western Australia, has also drawn attention to the subject (*The Gold Mines of the World*, first edition, p. 149); whilst the Author emphasised and explained the importance of "cost-sheets" and "mine-returns" in a paper read by him before the Institution of Mining and Metallurgy in 1897, and in the *Engineering Magazine* in an article on 'Mine Management' in January 1901.

cost-sheets in Western Australia is the fact that the treatment charges and yields of (1) oxidised ores, (2) sulphide ores, (3) concentrates as well as of (4) sands and (5) slimes, have to be kept separately; and the sulphide ores are sometimes dealt with by two different processes.

The form in which cost-sheets are represented is a matter, no doubt, which frequently rests with the Boards of Direction, Auditors and Consulting Engineers in London to decide, rather than with managers themselves; but the Chamber of Mines could do much to urge its advisability, and secure its adoption, and it would probably be possible for the Mine Managers' Associations in different districts to formulate a system which would be applicable to their general needs, subject to such modification as experience of its working might dictate. The Lake View Report and others, for 1901, in form and detail are most admirably arranged, and embody several features which the Author advocated in Chapter VII.

The tables in the Great Boulder reports showing the annual returns of crushing are also most excellently adapted for reference

The growing spirit of co-operation amongst managers in regard to such matters as "the sulphide question," and other technical subjects of common interest to all concerned in West Australian mines, as pointed out in the *Statist* * and in the *Australian Mail*,† will, I venture to think, materially aid in surmounting the principal difficulties with which they have had to contend, and this feeling seems to have been rapidly gaining ground of late.

As Mr. F. A. Govett remarked at the Annual Meeting of the Ivanhoe, May 2, 1902, "Hitherto there has been a great lack of combination amongst the great mines, but I hope we have changed all that. Our relations with the Great Boulder and Golden Horseshoe are of the most cordial nature, and I think that the policy initiated by my predecessor Mr. Rose, to ensure reciprocal information being given as to the developments of the Ivanhoe and Horseshoe lodes will be universally adopted, and will save many thousands of pounds.

"It only remains for us here in London to combine with a view to tackling all questions of common interest shoulder to shoulder, instead of leaving one company to fight a cause, as happened to the Ivanhoe and another company in the cyanide case; and further, of improving the conditions under which we all work, as, for instance, by the establishment of common mining stores, mutual insurances,

* March 10, 1900, p. 361; and September 29, 1900, p. 508. † May 10, 1900.

co-operation to meet the water supply, when it arrives, for its economical distribution. One special joint committee is actually in existence already, and I think some further joint action is likely to result from this apparently accidental beginning."

There are, practically speaking, it must be remembered, no longer any "trade secrets" in mining, such as used to be jealously guarded, by which the individual could benefit at the expense of the many; and whilst there must always be a certain amount of rivalry amongst every body of professional men, it should and can always be of a friendly and helpful character.

With a thoroughly efficient *technical man* (whether acting as manager of one large company, or as local consulting engineer of several smaller companies) at the head of affairs on the spot, coupled with periodical visits from a director or the secretary and the consulting engineer representing the company in London; so as to keep the business and technical management at home and abroad in proper touch with one another, which they cannot otherwise be; I believe that many of the troubles from which West Australian management has suffered in the past would be entirely removed.

As Mr. S. H. Cox* said in 1899, "The profession of a mining engineer has materially advanced during the last 25 years, and while mining to-day has by no means lost its speculative element, it has under more and more scientific methods assumed a position which it has probably never occupied before, at any rate, during the present generation.

"Not many years ago business men would have considered that holding shares in mines was a rather more pronounced form of gambling than betting or horse-racing. At present one seldom meets any one who is not interested to some extent in mining, and while the ventures of certain persons have resulted in the acquisition of wealth, and much self-appreciation of their own ability as financiers, others have lost money† and at the same time have had their belief in their genius for finance rudely shaken.

"It is the principal duty of a mining engineer to further establish mining as an industry and to eliminate the speculative element as much as possible."

* Presidential Address, *Trans. Inst. of Mining and Metallurgy*, vol. vii. p. 21.

† Mr. J. H. Curle devotes a chapter to the 'dangers of speculation' without discrimination, pointing but certain necessary precautions to be taken.—*The Gold Mines of the World*, Chap. II.

Its public importance is self-evident when one reflects that in countries like Australia, endowed with mineral riches, practically all other sources of employment depend upon the profitable and economical working of their mines; for the mines provide the sinews of all other industries.

The popular and picturesque idea of a mining engineer used to be, a bearded "digger" in a red flannel shirt, high boots and a wide-awake hat; but all that has been altered; the beard has disappeared through the intervention of the razor; the red shirt followed suit, possibly because it was found to irritate the "bulls" in the Stock Exchange; and of the quaint old picture only the wide-awakeness remains. Other people, who are addicted to drawing fancy portraits, picture mining engineers and capitalists as both being as black as that nigger of whom it was said, "that tar would have made a white mark on him;" but considering what capital and engineering combined have done to extend civilisation and the bounds of the British Empire this seems a rather rough portrait, and if such people knew the *many* good fellows in the profession with whom the Author has the privilege of being personally acquainted, they would come to exactly the opposite conclusion, viz. that any *ordinary* white paint would leave a smudge upon them.

Kalgoorlie possesses a Mine Managers' Association, a Chamber of Mines, and a capital Club; and it has been decided to establish a local School of Mines on the field.

Mining Laws. The Gold-Fields Act.

The original Laws and Regulations for the management of the gold-fields of the Colony (known as the Gold-fields Act and Mines Regulation Act of 1895) were found unsatisfactory, and the original law has been amended by two subsequent Acts, assented to on October 27, 1896, and October 28, 1898, and by a later one, known as the Amendment Act, 1900, which came into force on December 5, 1900; under which leases upon Crown land are now granted as Miners' Homesteads; all buyers of gold are compelled to hold a "Gold Dealer's Licence"; owners or managers of batteries are required, under penalty, to furnish certain regular returns; conditions were laid down for mining under railway or tramway reserves, and various details of the previous Acts were modified.

Alluvial Claims.

Under the provisions of the two first-named Acts and of the Gold-fields Regulations as amended to August 15, 1899, which I shall designate as the "Late Regulations," the size of ordinary alluvial claims varied from 70 feet by 70 feet for one miner, up to 200 feet by 200 feet for eight miners, with power to amalgamate adjoining claims whenever the natural difficulties of working the same, or other sufficient cause, was deemed to justify it.

Under the Amended Act of 1900 one miner is entitled to take up 25 yards by 25 yards, two miners 25 yards by 50 yards, three miners 25 yards by 75 yards, and so on in proportion for any number of men not exceeding eight; every claim being *if possible* laid out rectangular.

"Extended Claims" may also be taken up (1) on old abandoned alluvial ground (not being in a river, creek, or lake) or (2) in ground tested and found too poor to pay when worked in the ordinary way, which can be worked by puddling or sluicing, or (3) in wet ground where water exists and timbering is necessary throughout, or (4) in rocky ground where blasting for a depth of 50 feet is necessary in the sinking of the shaft.

The dimensions of these claims are for one man, half an acre; for two miners one acre; for three miners one acre and a half; and so on in proportion for any number of miners not exceeding eight.

River, creek, or lake "Alluvial Claims" taken up in new ground, must not exceed 120 feet along the course of the creek or river or shore of a lake for each miner, by a width extending from bank to bank, unless such width exceeds 300 feet; in which case the excess may be claimed by any other miner. In old abandoned ground, the length along the course of the river, creek, etc. is twice the above.

Before any discovery has been made, miners were formerly granted under the "Late Regulations" "Alluvial Prospecting Areas," which varied from 700 feet by 700 feet to 1000 feet by 1000 feet, according to the distance from the boundary of the nearest authorised holding producing gold at the time the "Prospecting Area" was marked off; and should gold be discovered and reported within seven clear days of the discovery, what was called a "Prospecting Reward Claim" might be marked off (within fourteen days from and after reporting the discovery as aforesaid), varying in size from 400 feet by 400 feet, to 600 feet by 600 feet, depending on the distance it was situated from the nearest holding producing payable gold.

Quartz Prospecting Protection Areas.

As a reward for the discovery of gold in apparently payable quantities on any "Quartz Prospecting Protection Area" (a term explained hereafter), in any new seam, vein, reef, or lode, a miner under the "Late Regulations" was granted a "Prospecting" or "Reward Claim"; upon proof, to the satisfaction of the Warden (if within a gold-field), or of the Minister of Mines (if the discovery were made outside of a gold-field) of such a discovery; double the length of an ordinary "Prospecting" or "Reward Claim" by 400 feet in width.

The length of a "Quartz Prospecting" or "Reward Claim" was limited to 400 feet, held to be efficiently worked by two men; and as a reward for reporting the discovery of gold in any new seam, vein, or lode therein discovered, miners were granted (according to the distance from the nearest boundary of any "mining tenement" producing gold) from 300 up to 600 feet in width from or across the base line (along which the length of the claim was measured), provided the claim was south of the Tropic of Capricorn; whilst if it was north of the Tropic, the size of the claim was doubled, i.e. extended from 600 up to 1200 feet in width. In addition to the "Reward Claim," each miner actually working in a "Prospecting Claim" was entitled to mark off and register one "Ordinary Claim" under Regulation 22, which could be worked conjointly with the "Reward Claim."

"Quartz Prospecting Protection Areas" within a proclaimed gold-field were of similar width, but were granted (as before mentioned) double the length of a "Reward Claim," which the miner was entitled to, under the above regulations; and outside of a proclaimed gold-field he might stake a "Prospecting Claim" of 400 yards by 400 yards.

Prospecting Areas.

These, under the amended Act of 1900 and Regulations, are now granted on Crown lands upon which a miner is desirous of prospecting for gold, and they may be taken up under the following conditions:—

	Yards.
If distant more than 10 miles from the nearest gold-mine on which operations are being at date of "pegging," or were carried on within the preceding period of six months	400 × 400
If distant more than 3 miles and less than 10 miles from such a mine	300 × 300
If distant more than 1 mile and less than 3 miles from such a mine	200 × 200
If distant more than 400 yards and less than 1 mile from such a mine	150 × 150

The Warden has the power to grant a "Prospecting Area" not exceeding 100 yards by 100 yards at a less distance.

Any miner prospecting in a locality distant over 50 miles from the nearest registered "claim" or "lease" may mark off a "Special Prospecting Area" of 400 yards by 800 yards.

These "Prospecting Areas" are registered for six months, when they lapse; but are renewable for a further term of six months at the discretion of the Warden of the gold-field. Every prospecting area must be worked continuously by a holder or man on his behalf, on every working day after three clear days from date of marking.

Reward Claims.

Under the amended Act of 1900 and Regulations, upon reporting the discovery of "payable gold" on a "Prospecting Area" to the Warden of the gold-field, within seven clear days of finding it, or within such time as he deems reasonable if the find is situated over 50 miles from the nearest Warden's Office, the prospector is entitled to take up a "Reward Claim" or a "Reward Lease" (in addition to the "Ordinary Claims" to which he may be entitled), whether it be on a lode or on alluvial, according to the distance from the nearest gold-mine (other than a "Prospecting Area"), on which operations are being or were carried on within the previous six months.

	Acres.
If less than 1 mile	1
Less than 3 but more than 1 mile	2
,, 10 ,, 3 miles	4
,, 50 ,, 10 ,, ...	8
Over 50 miles	12

As far as practicable the length of an "Alluvial Reward Claim" shall not exceed four times its width, and the length of a reefing "Reward Claim" shall not exceed twice its width across the line of reef. In localities north of the Tropic of Capricorn, the area of a reefing "Reward Claim" may be, but shall not exceed twice the area before specified.

The granting of an "Ordinary Claim" or "Lease," to the holder of a Reward Claim on land adjoining, cancels the obligation to work the "Reward Claim" (as must otherwise be done with one man); so long as the labour conditions prescribed for an "Ordinary Claim" or "Lease" are complied with, and the granting of a "Reward Claim" or "Lease" determines the title to a "Prospecting Area."

Reward Leases and Ordinary Lode Claims.

"Reward Leases" are granted to miners for discovering gold in apparently payable quantities, in any new reef or lode not within a distance of 3 miles from any gold-mining lease or quartz claim, that is being, or has been worked within six months preceding the date of application. The area of a "Reward Lease" is the same as that of an ordinary lease.

In lieu of rent or survey fees, the applicant for a "Reward Lease" is required to deposit a fee of 10*s.*, but in all other respects the regulations relating to ordinary leases must be complied with.

If a "Reward Lease" is granted, the rent may be remitted; for 5 years, if the Reward Lease is distant 50 miles from the nearest gold-mining lease or quartz claim worked within the previous six months; for 2 years, if distant over 10 miles and under 50; and for 1 year, if distant over 3 miles and under 10 miles. The rent to the end of the year then current must be paid within 30 days of the expiration of the term for which the rent has been remitted, or the lease is liable to forfeiture.

Under the "Late Regulations" an "Ordinary Quartz Claim" might not exceed 75 feet along or parallel to the base line, by a width of 400 feet in localities south of the Tropic of Capricorn; and 150 feet by 400 feet north of it; and not more than eight such claims could be worked conjointly.

Adjoining "Quartz Claims" might be amalgamated to an extent not exceeding sixteen men's ground, or 1200 feet along the base line from which they were laid off, where, owing to natural difficulties of working them separately, or for the sake of economy, it was deemed advisable; a regulation that still remains in force, given the consent of the owners holding a two-thirds interest.

If unpayable, the claims might be worked half-handed, that is to say, with one man for every 150 feet taken up along the base line south of the Tropic, or one man for every 300 feet north of it.

Under the amended Act of 1900 and Regulations the maximum dimensions of an ordinary "Reefing" or "Lode Claim" are:—

For one miner 25 yards along the line of the reef or lode by 130 yards across it; for two miners 50 yards by 130 yards; for three miners 75 yards by 130 yards; and so on in proportion for any number of men not exceeding eight. In localities north of the Tropic of Capricorn, these lengths may be doubled. The width must be marked off at right angles to the reef or base line, but the whole or any part of such width may be marked on either side of such line, at the option of the miner.

Labour Conditions on Claims.

Every "Lode" or "Reef Claim" when not payable, must at the expiration of 3 days from date of registration, be manned by one man for every two men's ground; but when apparently payable, one man must be employed for every one man's ground; as in the case of all other claims; unless "exemption," or. "partial exemption," has been applied for and granted.

Tunnelling Claims.

These "Protection Areas" were granted under the Late Regulations in localities where there was a height of at least 100 feet above the back of the tunnel; the protection area allowed being 800 feet on each side of the tunnel, with a length of half a mile across the hill or plateau.

The dimensions allowed for a "Quartz Claim" of this class was double the area of an "Ordinary Quartz Claim," provided any reef discovered in the "Protection Area" was at least 200 feet from the mouth of the tunnel; otherwise it is the same size as if "pegged" on the surface.

The "Reward Claim" for finding a payable quartz reef in any such tunnel, was, however, double the size of an ordinary "Reward Claim," with 50 feet additional along the line of reef for every 100 feet beyond 200 feet comprised in the length of the tunnel which led to its discovery. In the present "Regulations" they are not mentioned.

Leases.

The area of a "Lease" must not exceed 24 acres, measured, when practicable, in the form of a parallelogram with a maximum length along the line of reef not exceeding twice its width, and is granted from January 1 preceding the date of application, for any term not exceeding twenty-one years.

It gives no extra-lateral rights outside its side and end lines projected as vertical planes to an indefinite depth.

A yearly rental of 20*s*. per acre, or any fraction thereof, has to be paid to the Government, and certain labour conditions must be fulfilled to hold ground in this way.

In the case of a lease being granted, on ground not previously held wholly or in part as a gold-mining "Lease," for the first twelve months, within thirty days after the approval of the Governor has been notified in the Government Gazette, to efficiently work the lease (failing exemption), two men must be employed continuously on every working day, not being a bank or public holiday.

After the expiration of the first twelve months, one man* for every 6 acres, or fraction thereof, must be put on to man a lease effectively, unless "exemption" is granted by the Warden, or by the Minister of Mines, for specific and good reasons: such as want of capital (a fair sum having already been expended), time required for erection of machinery, influx or scarcity of water, scarcity of labour, the collapse of the working shaft, absence or illness of owners, disputed title, or for some other reason, rendering the mine, for the time being, unworkable. The Warden has power to grant exemption for any good and sufficient reason for one month, on posting an application at the Warden's office, and on the lease or claim for, three clear days before the application is heard; and he can grant fourteen days in case of sudden emergency without any notice being previously posted. In the case of land previously held wholly, or in part, as a gold-mining lease, the Regulations now require one man to be put on for every 6 acres or fraction within thirty days of notification in the Government Gazette, of the lease being approved, unless exemption or partial exemption from work for the reasons above stated has been granted. Men on "tribute" count in the

* Prior to 1897 the labour requirements demanded the constant employment of one man for every three acres. The Minister of Mines is reported to have recently stated the Government was determined to render every assistance to those companies which, having spent large sums in development work, required breathing space to enable them to prosecute further operations. *Brit. Australasian Cable*, Jan. 13, 1903.

representation of a lease, providing that a verified copy of the tribute contract is filed in the Warden's office wherein the lease is recorded, within 30 days of making such contract. Eight hours' ***bonâ fide*** work is required to be done by each man representing the ground, and "Leases" must be worked by not less than two men.

Leases cannot be taken up on public lands or lands granted in fee, or held under Government Lease or license other than pastoral and timber leases or licenses; or that consist exclusively of alluvial ground (unless owing to special circumstances such as abandonment, great depth, or excessive wetness, in the opinion of the Minister of Mines they ought not to be exempt from lease); or upon land lawfully occupied by the holder of a Miner's Right, or business area; or so as to endanger the safety of buildings, etc. on surface. Leases are liable to forfeiture at the will of the Governor, if the labour and other conditions under which they are granted are not complied with; but no plaint can be filed or proceedings be taken for an alleged breach of "labour conditions" unless such alleged breach took place within 30 days next preceding the date of filing such plaints. Proper notice, of intention to forfeit a lease, must first be given to the lessee, in the Government Gazette and by notice posted outside of the Warden's office for 14 days at least, specifying the breach complained of. In the case of a first breach of the labour conditions, it is lawful for the Governor (with whom the right of forfeiture rests), to impose a fine as an alternative penalty.

Any number of adjoining leases, if the total acreage does not exceed 96 acres, may be amalgamated, upon payment of a fee of 20*s*. for each lease so amalgamated, providing the labour to be employed in such amalgamated leases represents the sum of the labour conditions required in each separate lease.

Business, residence and machine areas, tailings areas, water rights, and dam sites are granted separately under special regulations, which are administered by the various Wardens of the goldfields, who represent the Minister of Mines and act as magistrates.

Anyone desiring to prospect or mine for gold must hold "a miner's right," which he can obtain (if not an Asiatic or African alien) on payment of a fee of 10*s*.; this permit holds good for twelve months from the date of issue, when it must be renewed.

The Government "Regulations" lay down rules for the "pegging," "survey," "registration," and taking possession of claims and leases. Objections against granting leases, application for forfeiture, transfer of claims, and other matters that are of importance, but which I need not enter into.

With the exception of two points, which have given rise to trouble and controversy, the Goldfields Act Amendment Acts and the Goldfields Regulations seem to have worked fairly well. The points to which I refer, are (1) the question of "dual title"; (2) the alleged insecurity of tenure involved in the regulations under which leases were held.

As regards the *dual title*: This trouble arose from the fact that by Regulation 103 of the former "Regulations" prior to November 16, 1898, any miner desirous of entering upon a lease for the purpose of searching for, and obtaining alluvial gold, could give notice in writing to the lessee, and within twenty-four hours the lease-holder was required to delineate on his land, the line of any reef or reefs situated thereon. This done, the alluvial miner was at liberty to enter on the lease, and work for gold, providing he did not approach within 50 feet of the reef or reefs marked thereon.

The result on small leases can be better imagined than described, although there is no doubt that the intention of the original Act was merely to permit the auriferous earth near the surface to be turned over by the "dry blowers," the trouble arising from the loose definition of the term alluvial.

Thus, in the original Act of 1895, alluvial was defined as "any loose soil earth or other substance, containing or supposed to contain gold not being a seam lode or quartz vein."

Under the Amendment Act, dated October 28, 1898, it is defined as "any earth containing or supposed to contain gold, not being a lode, dyke, reef, or vein"; earth being further defined as "clay, sand, soil, or other material of an alluvial character or origin."

A far better and more comprehensive definition of alluvial is given in the Queensland Act of 1898, viz.—ground containing gold, found in detritus, resulting from the disintegration of older deposits, whose constituents have been brought into their present position by mechanical agencies."

The discovery of the so-called "deep leads" at Kanowna and elsewhere, at depths varying from 50 to 150 feet, gave an impetus to explorations in search of similar deposits, and thus brought matters to a head; not merely threatening lease-holders with interference in the conduct of their operations, but with loss of part of their property.

The position thus created soon became recognised as intolerable, and it was proposed to limit the depth to which alluvial miners might go to 10 feet; but this aroused fierce opposition; the Regulation which subsequently came into force was merely a compromise, stating that any alluvial miner must refrain from undue interference with any *bonâ fide* lessee, or with any building or shafts, which might reasonably be required; all disputes to be determined by the Warden.

This Regulation had to be subsequently withdrawn by the Government, and Section 11 of the Amendment Act 1898 stated that "after the granting of any lease the lessee shall have the exclusive privilege of mining on the land demised and every part thereof. Section 87 of the Gold-fields Regulations in force provides, however, that any miner desiring to enter any land applied for as a lease, to search for alluvial, may do so, by serving the applicant for the lease with a proper notice of his intentions; and if within twenty-four hours of such service, the applicant for the lease shall not have marked off a portion of the lease applied for, not exceeding $\frac{1}{8}$ of the area thereof, for the purpose of his buildings, shafts and workings, any subsequent marking off by the applicant for a lease shall be subject to the rights acquired by any miner under Section 10 of the Gold-fields Act 1895 Amendment Act 1898. Any applicant for a lease who shall make, within the boundaries of the land applied for as a lease, a new discovery of alluvial gold, must report the same to the Warden of the gold-field within 7 days; and subject thereto is allowed 14 days from and after reporting the discovery, to mark off a "Reward claim," as provided by Regulation 15, on any portion of the land applied for as a lease, not being in lawful occupation by a miner under this Regulation.

The searching of every miner who enters upon any lease under Section 10 of the Gold-fields Act 1895 Amendment Act 1898, must be confined for the time being to an area not exceeding the area of an ordinary alluvial claim, and it must be marked out in like manner.

The correspondent of the *Financial Times*, in a letter dated November 18, 1899, summed the existing position up as follows:—

"The alluvial trouble at Kalgoorlie is still unsettled, but seems in a fair way to fizzle out. Whatever may be the rights of the question, the amending Act of last session effectually cuts the ground from under the feet of the alluvialists, who claimed the right to enter upon and peg out claims on leases. Every recent decision in the Supreme Court has gone in favour of the leaseholders, and now every point has been discussed that can be raised.

"The alluvial men, recognising their position, undertook to go off the leases if they were paid compensation for the work they had done. The leaseholders refused to pay because they said the work had been done in defiance of them.

"The Government was then approached and asked to pay, but the Premier declared that the dispute was one which the parties must settle between themselves in the Law Courts.

"On Monday last the alluvial men actually resumed work on the leases.

"Next day a body of police was sent out, and the men have not trespassed since."

As regards the *tenure of leases*, Mr. C. J. Alford, M. Inst. M.M., has pointed out in three letters which appeared in the *Sydney Daily Telegraph*, published in 1897, under the auspices of the New South Wales Chamber of Mines, that the first essential of a mining law is that, whilst it gives security to the investor, who finds the necessary funds, when he has fulfilled the conditions of his tenure, it on the other hand, obliges him to continue working the mine under all reasonable conditions, and this is secured in various countries, by various means, but usually by what are known as the "labour conditions."

1. In Australia it is effected by—

The permanent employment of a certain number of men on a certain area of ground.

2. In the United States, by the completion of a certain value of work on the ground.

3. In Rhodesia, by the completion of a certain amount of work on the ground.

Mr. Alford instances the minute of the Minister of Mines in New South Wales, regarding the suspension of labour conditions, during the "strike" some years ago, on the property of the Wentworth Proprietary Co. at Lucknow, to show that, although it is generally assumed that a mining lease would not be forfeited without just and good cause, the Australian law admitted of doing so, depending entirely on the individual view of each case taken by the Warden and Minister of Mines for the time being. Mr. Alford considers that the simple system of rental alone, without any other conditions, which has been adopted in the Transvaal is the best of any, but as this is scarcely practicable in Australia, he has suggested that, in order to overcome the difficulty, it would be better if a small annual rental were charged on locations of, say, 1*l.* per acre, and that, "during the first and each succeeding year after location, the holder should expend upon work and machinery on the ground a sum amounting to not less than, say, 100*l.* per acre of his location; and if this fails to be done, the rights are forfeited. In cases where the mine can best be developed by driving a tunnel, or doing other work, or erecting machinery outside the limits of the location, the expenditure on such should count as expenditure on the location.

"When the holder shall have expended on the ground in work and machinery, a sum equal to, say, 500*l.* per acre of his area, he should be entitled to apply for and obtain a permanent lease or title to the mine, with the obligation only to keep the boundaries adequately beaconed, and to pay an annual rental of, say, 10*l.* an acre; but these titles should not be granted to holders of less than 10-acre blocks." Carrying this idea a step further, it seems to me, that it would be more to the advantage of the miner, as well as of the capitalist, if instead of the present system of tenure and representation, the leaseholder were granted a "patent," as it is called in America, after, say, 500*l.* per acre has been spent on a lease (without increasing the rental) for the unexpired term of twenty-one years, as it certainly seems a hardship on the mine-owner that, after having spent, say, 10,000*l.* and exhausted his capital, on a 20-acre block which has turned out unpayable, although the circulation of this money locally has benefited the district, the ground should be forfeited beyond the chance of recovery, when by being allowed to hold it for a certain fixed period, either owing to the cheapening of the cost of working, which is always naturally brought about with the lapse of time, or by giving him time to find more capital, he might be able to recoup himself for his initial losses, and work the property with profit to the district and himself.

This suggestion might seem opposed to the object of the labour conditions, which are :—

1. To prevent the holding of areas of mining ground unworked.

2. To give employment to the working man (the one being the corollary of the other); but so far as the employment of labour is

concerned, I think it would have exactly the opposite effect, and increase the demand for it.

It is true, that the compulsory expenditure of money in the country benefits the working man to a certain degree, but his real interest lies in protecting capital, so that it may be turned as far as circumstances permit to profitable account; looking a little further ahead, it is obviously in fact a most unwise policy to kill the bird "that lays the golden egg;" and it is to the direct interest of labour, to encourage capital to come and remain in a colony, rather than to drive it away by harsh legislation; which must inevitably happen, if the principle of confiscating leases, on which large sums of money have been spent, is enforced.

Under the broader policy of permitting leases to be converted into freeholds for a term of years, as is done in the United States, it is probable that a great deal more money would be expended in testing new prospects, and re-opening abandoned mines (which money would otherwise be diverted to some other part of the world), than the amount of capital which would, as a rule, be spent after 500*l.* per acre has been expended on a property without some tangible result. And, as it must obviously be to the advantage, either of a company or an individual, to open up a good mine, or close down a worthless one as speedily as possible; it seems to me a reasonable view to take, that labour would benefit to a much greater extent, if such a principle were adopted, by encouraging capital to stay in the country, and fresh capital to flow in the same direction; since capital always follows the channels in which it finds itself made, most "at home." In other words, like every sensible working man, it gravitates naturally towards the places where it is best treated. The Government of Queensland, recognising this elementary fact, intend, for instance, I am informed, to bring in a new mining bill, which will provide an extension of time for commencing operations, in leases; and they propose to allow 200-acre leases to be taken up for sinking to 4000 feet or more.

The regulation and inspection of mines is governed by the amended Mines Regulation Act of 1895; which lays down various provisions for insuring the safety of the workmen and workings; Regulation 23 prescribes that clear and distinct signals shall be used in all metalliferous mines in the gold-fields, gold-fields districts and mining districts, to which the Mines Regulation Act applies. The following general code is one that is in use:—

Code of Signals.

1—Stop cage when in motion.	1 pause 1—Number 1 Level.
1—Hoist.	1 " 2— " 2 "
2—Lower.	1 " 3— " 3 "
3—Change to hoist from a different level.	1 " 4— " 4 "
4—Men on.	1 " 5— " 5 "
5—Cage at liberty.	2 " 1— " 6 "
6—Tools.	2 " 2— " 7 "
12—Accident.	2 " 3— " 8 "
	2 " 4— " 9 "
	2 " 5— " 10 "

In Queensland, one knock denotes to hoist; one knock to stop cage when in motion; two knocks to lower; three knocks to speak; four knocks men getting on, and others as arranged.

Government and the Industry.

The Government of Western Australia in past times, like all Governments, has had opponents, as well as adherents, who have attacked it in unmeasured terms on the grounds that its interests were focussed in Perth and the squatting industry, rather than in the gold-fields and the mining industry; the truth probably being, that either view is apt to be coloured according as a person looks at the legislator through blue or rose-toned spectacles; and this ordinarily depends a good deal no doubt upon the way in which he is affected by contemporary legislation; the people on the coast and elsewhere probably keeping their own particular interests in sight, as much as people on the gold-fields, and bringing all the influence they can to bear on them.

English shareholders in West Australian mines had, however, cause to complain of the passing of the Companies Act 1897 Amendment Act 1898; an Act to amend the Companies Act, 1893, as it was pointed out at the time that it would seriously impede the conduct of business; whilst some of the clauses were not only unworkable, but actually clashed with the provisions of the English Companies Acts.

It seems also unfair to mining companies that, according to Section 20 of the Mines and Collieries Regulation Act, 1895, "The occurrence of any accident in or on a mine shall be *prima facie* evidence of neglect on the part of the owner and the manager," placing mines on a different footing from other undertakings, and throwing the onus of proof on the *defendant*, a position contrary to the spirit of British law.

The imposition of a tax of 5 per cent. on all mining profits has not unnaturally been complained of by British investors, as a part of such profits is liable to be expended in the development of the mines; but it is stated that when the Dividend Duties Bill is re-enacted on January 1, 1903, provision is to be made that mining companies carrying on business in the State will pay 5 per cent. on the *dividends declared* alone; and if carrying on business elsewhere, 5 per cent. on all profits made in Western Australia; which seems a much more equitable arrangement; but the Queensland Act is, I believe, a more liberal one; so much of the dividends as are required to return to the shareholders the sum actually spent on the development of the mine, and three-fourths of the amount spent on machinery, being exempt from taxation.

Within the Colony much dissatisfaction has been caused by the *laissez-faire* attitude of the Government in the matter of the Espérance Bay Railroad; as it is thought that Western Australia would be benefited by being more closely connected with the Eastern Colonies (and no doubt some day a line will be built connecting Fremantle, Kalgoorlie, and Port Augusta); in consequence of the establishment of preferential railway rates on the coastal, as compared with the gold-fields lines (of which mention has already been made); as well as in regard to sundry duties that were levied on meat and other articles. An export tax of 5*s*. a ton was imposed * on ore smelted outside of the Colony, which was in the nature of "a bounty": but there was no duty on the export of "concentrates."

Federation with the various Australian Colonies (the Commonwealth Bill), which seems a step towards the idea of Imperial Federation, at one time bade fair to split the Colony in two, and the opposition it encountered promoted a demand for the separation of "the gold-fields" from the rest of Western Australia. Further, the miners have not unnaturally felt aggrieved that, whilst there were two gold-fields seats with, it was said, nearly 18,000 electors on the roll, there were 15 agricultural or semi agricultural seats, with a total of only 6678 electors.

Mine managers have complained, I believe, that the regulations in reference to boiler inspection are capable of improvement; and inconvenience was likely to be caused by a proposed new regulation relating to the number of men (viz. four) allowed to be lowered in a cage at one time; many of the mines having made adequate

* This duty has, I understand, been recently removed. *Statist*, October 18, 1902, p. 658.

provision for carrying six or more; the loss of time and power thus involved being a serious matter.

The action of the Government in proclaiming forest reserves along the branch railway used by the West Australian Gold-Fields Firewood Supply Company, also created grounds for protest amongst mine-owners, although it was supported by the smaller contractors, who bring most of their wood in by team.

"The Industrial Conciliation and Arbitration Act of 1900," was another legislative "bill" presented to mine-owners as a "bon-bon," for, whilst no one can question the value of Conciliation Boards, such as have been created in Great Britain, for smoothing differences that may from time to time arise between the labour Unions and employers of labour; this proposed Act, if I am rightly informed, contained provisions which seemed more calculated to cause trouble than to remove it; and therefore as originally drafted it was thought that it would be likely to have a most mischievous effect on the mining industry of the Colony.

For example, one of its clauses appears to have intended to set up the principle that seven workmen could form themselves into an association, for the purpose of contesting with employers any question in which they might consider their rights as workmen affected; and in case of an employer dismissing, for any good reason, any man in his employ, it is provided that he should be paid full wages, and could not be suspended or discharged until such time as the Board of Conciliation, and possibly the Court of Arbitration, dealt finally with the matter, any contravention of this provision laying the contravener open to a heavy fine.

Further, it was proposed, I believe, that no counsel or solicitor should be allowed to appear before a Board, and anyone armed with the authority of the Board might enter any mine or office, and inquire into and generally overhaul a company's affairs, dictating questions to anyone on the premises, or on any matter the inquirer might deem fit, refusal to answer such inquiries rendering the company liable to a fine of 50*l.* for every such refusal.

The "Workmen's Compensation Act" is also a new Act of so stringent a nature that the Insurance Companies, I am informed, raised their rates from 5*s.* 6*d.* per 100*l.* to 30*s.* per 100*l.* The "Industrial Conciliation and Arbitration Act of 1902" seems, however, to have worked satisfactorily.

On the other hand, however, it must be admitted that successive Governments have done a good deal to aid the mining industry, which is the real backbone of the Colony, and the following items must be placed to their credit.

An excellent telegraph system has been laid down throughout the fields; the Fremantle-Coolgardie railway has been extended to Kanowna, Menzies, and elsewhere; and several of the northern fields have been placed in railway communication with the coast. Large amounts have been expended all over the fields for reservoirs, schools, Government offices and buildings, and upon the Coolgardie water scheme.

Further than this, the Government has established "public crushing batteries" * with a view to enable working miners to develop the various small "shows" owned by parties of working men, scattered all over the country; although, as a general rule elsewhere, this is left to private enterprise; and it may be added generally works quite satisfactorily, in districts where a large number of small mines are grouped together.

It has established a Mint in Perth, and has done much to advance the mineral industries of the Colony, by subsidising "borings" and by spreading knowledge abroad regarding its mineral resources.

The improvement of the harbour of Fremantle, to enable mail-boats and large steamers to call there without difficulty, is also an object on which money has been well spent.

The Commonwealth Tariff introduced into the Federal House of Representatives on October 8, 1901, foreshadowed a moderate general policy of "protection," which it was said would not destroy existing industries, but would not foster exotic one-man industries; and would not make any sweeping changes in the rates that formerly obtained.

The Government proposed, also, to introduce a system of bonuses to encourage the establishment of new industries, especially on locally smelted iron and locally made machinery, upon the following lines:—

Pig iron, 12*s.* per ton, if manufactured from Australian ore; and on that made from ore containing 50 per cent. Australian, 6*s.* per ton.

On steel ingots made in Australia from Australian pig-iron it was proposed to offer 6*s.* per ton bonus.

The bonuses to commence in July 1902, and be payable only to works capable of producing 100,000 tons annually; to be limited to 150,000 tons of machinery.

* The idea has been recently mooted also, for the Government to provide "portable batteries," for testing new localities.

The *Financial Times* of October 11, gave a comparative table of the duties that formerly obtained in the different Australasian Colonies, and full details of the Federal tariff as originally submitted, and passed, were given in its issues of November 11 and 19, 1901.

The increased taxation upon mining operations is shown in the following table given in the *Financial Times* * which shows the difference in duty under the old and proposed tariffs upon material commonly used by mining companies; and it was proposed to make the duties retrospective to October 1901, which it has been pointed out would inflict a serious hardship on people who had entered into contracts for machinery prior to that date, which had not been delivered; it means that it would cost many mines largely increased sums for the erection of new plant, involving in one case mentioned, where designs for the erection of a plant were in course of preparation, 9700*l.*

Material.	Old Tariff.	Proposed New Tariff.
Mining machinery	5 per cent.	25 per cent.
Bar iron and steel	free	10 ,,
Tram rails	free	15 ,,
Coke	free	4*s.* per ton.
Nails	free	3*s.* per cwt.
Bolts and nuts	free	20 per cent.
Sheet lead and piping	free	2*s.* 6*d.* per cwt.
Plain iron	free	15*s.* per ton.
Fuse	free	1*s.* per doz. coils.

A substantial increase in duty was also proposed on building materials, notably on doors and iron.

The Kalgoorlie correspondent of the *Financial Times*, in a letter dated Oct. 19, 1901, pointed out that this increase in taxation would hit the mining industry of Western Australia very hard,† giving figures furnished by one of the biggest mines on the field, which, although only approximate, convey a very fair idea of what the increase in taxation would mean to a mine carrying on extensive operations. The figures are based on the mine's consumption for the previous six months.

	Consumption. £	*s.*	*d.*	Increase in Cost. £	*s.*	*d.*
Oils	605	4	9	60	10	5
Chemicals	759	17	9	152	0	0
Bolts and nuts	314	9	10	31	9	0
Tram rails	51	17	6	7	10	0
Pipes and fittings	2733	4	10	546	0	0
Galvanised iron	536	9	7	10	0	0
Iron and steel	896	11	5	90	0	0
Machinery	8866	7	7	1773	0	0
Filter cloth	488	0	0	24	8	0

* *Financial Times*, Nov. 19, 1901.

† This question is discussed in an article in the *Financial News* of Dec. 1, 1902, which gave the current duty on a number of different articles.

In this particular instance the management estimated that the increased cost all round on ore treated would be about 1*s.* 10*d.* per ton. "Taking all the Kalgoorlie mines, however, into consideration, a more conservative estimate would perhaps be 1*s.* 6*d.* per ton, and when it is considered that Kalgoorlie treats about 60,000 tons of ore per month, it will be seen that the tax is no light one."

"The heaviest item in the list is the 25 per cent. duty on imported machinery, and this, to a mining community where it is absolutely necessary to obtain the very best machinery, is a very stiff imposition.

"The idea is, of course, to give Colonial manufacturers a chance, but there is no getting away from the fact that, in the matter of certain mining machinery at any rate, the Colonial stuff cannot touch that manufactured in England or America." "The Colonial makers will take years before they can arrive at the standard reached by such a firm as Fraser and Chalmers, whose stamp mills are regarded out here as being the very best obtainable."

"The reason for this inferiority on the part of the Colonial stuff is that the Colonial manufacturers have not such a big output for their goods, and consequently cannot afford to retain the services of machinery experts, such as are to be found in the English and American factories. The mine managers and mining engineers on the field know the value of good machinery, and they will only have the very best, even if they have to pay a 25 per cent. duty on it. Apart from the heavy impost on imported machinery, the tariff is a fairly reasonable one, but at the same time it must necessarily increase the already high cost of living in this State."

The duty on mining machinery was subsequently fixed at 15 per cent., but an influential deputation which waited on Sir Edmund Barton on August 6 last, called attention to the need for a reduction * in this and other items on the tariff (such in particular as oil). As showing the importance of this matter, Mr. C. A. Moreing mentioned the fact, that the mines controlled by his firm alone, were paying some 300,000*l.* per annum for mining stores. The desirability of a uniform rate for cable messages and an accelerated mail service was also pointed out. The need of Government assistance in regard to railway rates and import duties, was dealt with in an article in the *Financial Times* of December 18, 1902, which amplifies several matters the Author has referred to.

* This present duty is 12½ per cent.

Western Australia is essentially democratic,* but its democracy is, perhaps, more largely tempered than some of the other Colonies by a recognition of the benefits which capital confers, and of the rights that it possesses in common with labour.

Furthermore, a strong undercurrent of loyalty and regard for the Old Country undoubtedly exists in Australia, as witnessed by the splendid way in which contingent after contingent of their sons were sent to South Africa during the war; and this feeling of reciprocal goodwill, backed by mutual necessity, will assuredly grow with Federation, provided British policy is shaped on clear and firm lines, and Colonial interest and susceptibilities are considered and studied with those of the Empire as a whole; as the masses of the people are becoming more highly educated, and are consequently less and less disposed, like people at home, to swallow large doses of political and social cant, administered by political cranks, and professional agitators.

Professing reformers have indeed so frequently failed to cure their ailments, that they prefer, I believe as a rule, to judge what is best for themselves, and take, on the whole, a wider view of their Imperial obligations than can be obtained from the mere spout of the "parish pump."

Moreover, I venture to think that capitalists and managers of works, all the world over, realise more generally than is supposed, that their duties and obligations towards their employees do not end with paying the workman a living wage and looking properly after his safety; and owners of mines and industrial undertakings happily recognise that the best means to promote cordial relations between capital and labour, which are vital to *both*, is to cultivate that spirit of mutual goodwill and friendly regard, which formerly so largely subsisted between landlord and tenant on almost all large estates in England; in consequence of the personal interest that the proprietor took in the advancement and welfare of his employees, who in return *voluntarily* did a fair day's work for a fair day's pay.

Drawbacks from which Mining suffers.

I have already enumerated a good many unavoidable difficulties that have been encountered, but the industry in Western Australia, if report is to be credited, has not been exempt from others of a preventable character with which mining elsewhere has been saddled in the past; amongst which might be named: the flotation

* So much is this the case that it was proposed, I believe, to place on the roll of electors every adult (male or female).

of companies on "salted" or "pickled samples" submitted to some so-called "expert," who perhaps never saw the property, or for that matter a mine, in his life. And, it may be added, the art of "salting" * covers as many tricks as a Chinaman is supposed to know!

Valuations based, in other cases, on the supposition that the richer outcrops represented the average value of quartz reefs in depth (which, as a rule, they do not); and estimates made upon crushings consisting of "sorted stone," in no way typical of the average value of the reef they were supposed to represent. The extraordinary demand on the part of European promoters for properties at any price, in order to form them into companies, to which middle-men have been apt to tack on a quite unjustifiable premium; properties hastily acquired without proper examination, and "shepherded" merely with a view to form subsidiary companies, before they have even been properly prospected; the premature abandonment of good "prospects"; the over-capitalisation of companies which could only hope to earn dividends if worked on a small scale in the most economical manner possible; insufficiency of working capital, and the assignment of an undue proportion of fully paid shares to vendors and others; the circulation of misleading reports, either of rich strikes, impoverishment in depth, flooding with water, or some other circumstance, affording an excuse to rig the market in some "bull" or "bear" interest; inadequate or too slow development; premature erection of machinery for the existing requirements of the mine, or the purchase of unsuitable plant; "picking the eyes" out of a property; understating the tonnage of ore milled for a given yield of gold; reporting ounces of bullion like ounces of gold; delay in some cases in publishing news from the mines, in others, circulating it prematurely; neglect to provide a sinking fund for the redemption of ore extracted, so as to keep sufficient capital in hand for future development, and distributing dividends up to the hilt; omitting not only to make provision for the amortisation of capital spent on development, but for depreciation of machinery; careless sampling and supervision of labour; over-optimistic reports in regard to developments, etc.; payment in some cases of inadequate salaries to men in responsible positions, inviting inefficient management and speculation on the part of highly placed employees; failure to ascertain what work has cost and is actually costing; managers trusting too much to subordinates; clinging to worthless properties, without sufficient prospect to

* *Vide* 'Mining Reports' and 'Mine Salting,' by W. McDermott, *Trans. and Inst. of Mining and Metallurgy*, vol. iii.

warrant a further expenditure of capital upon them; charging to capital, items of expenditure which ought to be properly charged against revenue:—such are some of the difficulties and evils that have been laid to the charge of mining in the past, against which industry and the profession have had to contend.

As Mr. S. Herbert Cox, A.R.S.M., has remarked:* "In a gold-mine we should know the value of the ore treated, the percentage saved by amalgamation, by cyaniding, by concentration, and by slime treatment, and the cost of each operation. We should also make ourselves acquainted with the losses which occur at each step in the process of extraction, and compare these with the final difference between the assay value of the ore sent to the mill, and the actual extraction." The quantities milled, cyanided, or otherwise treated should be known and kept separate; "calculating eventually, the average yield and value on the basis of the mill output."

"Economy in work should be the order of the day; machinery should replace hand-labour wherever it is possible, more especially where the cost of labour is high; piece-work should replace day-work wherever it is practicable; and in nearly every case, it should be the aim of a manager to develop and treat large quantities of low-grade ore, in preference to selecting small quantities of ore of high tenure."

"In a word, if we wish the best possible results to be obtained, we must practise economy, a constant supervision of costs in every department, and an everlasting investigation of weak points in our methods of treatment; we must adopt improvements as soon as we are convinced that the need for them exists; and, above all things, when we find that any process is a failure, we must discard it, even if it is difficult to admit that we have been wrong."

Mr. John Hays Hammond, M. Inst. M.M., shows the importance of large outputs in a statement he made in the Report of the Consolidated Gold-fields of South Africa, 1898, p. 14.

"The interests of mining companies are best subserved by working the lowest grade of ore compatible with the size of the batteries, the dividends required, etc.

"It is to the recognition of this fact, and the adoption of this policy by our mining companies, that the tonnage per claim has been greatly augmented, and, in spite of the seeming paradox involved, 'that the larger the batteries the longer the lives of the mines,' the statement has become an adage on the Rand. Of course this statement has its limitations.

* Presidential Address, *Trans. Inst. of Mining and Metallurgy*, vol vii.

"In accordance with this policy, therefore, ores of a grade heretofore too low to admit of working are now profitably exploited, with the result in some instances, of an apparent falling off in the value of the ore in certain mines." Care must, however, be taken to see that *unpayable* ore is not mined merely for the sake of securing a larger output.

A point also of much importance to mine shareholders is to so regulate the output as to avoid sudden and violent fluctuations in the mill-returns, the proper policy to aim at, being to raise them if possible, gradually but steadily.

In its issue of February 9, 1901, the *Statist* discussed several matters of general concern to mine-owners, pointing out the advantages which would result if an amalgamation of interests could in some instances be brought about; the main points in favour of such a policy being the saving in cost that would be effected (1) by reducing the number of shafts that have to be sunk to work a given area of ground which might be easily developed and mined from a lesser number if they were centrally situated; (2) by the centralisation of reduction works; (3) by the distribution and supply of power on the most economical lines; (4) by saving in management and administration expenses; and (5) by giving assurance of a longer lease of life to the various companies.

Owing to the small acreage of many of the West Australian leases, there is comparatively little room for surface works and tailings dumps,* and a judicious amalgamation of several properties would, no doubt, in some cases be of advantage to all concerned; as a large central mill and one main shaft might take the place of several small ones, and other economies could be effected by reducing the number of heads necessary for several independent concerns: permitting better salaries to be offered, and thus not only securing the best available technical skill, but taking the most effectual means to remove the desire which managers, like other people, are prone to—viz. to acquire a rapid fortune by private speculation. It would seem, however, inadvisable to extend the operations of one company over more than a certain area.

As Bergrath Schmeisser said: † "The European capitalist, who is desirous of investing his capital in Western Australian mines,

* It has been suggested, I believe, in this connection, that, given a sufficient supply of water, arrangements might be made by the different companies to construct a main ditch or flume through which valueless tailings could be sluiced away down towards the Lake; but without a proper survey it is impossible to say whether this would be feasible or not; apart from the question of cost, waste of water, and the use of tailings for filling.

† *The Present Position of the Gold Mining Industry of Western Australia*, p. 14.

should first weigh all the facts and statements in the most careful manner, before too confidently rushing into speculations which have been recommended by some *unknown* gentleman," who merely on his own *ipse dixit* poses as an " expert."

Managers of proved competency should be given as free a hand as possible, as it is a mistake to interfere too much in *local details* when a Board is situated in distant centres like London, or elsewhere, although the advice of any firm of London Consulting Engineers of standing (of which there are quite a number) would often save English companies from making costly mistakes, and be helpful to the management in explaining technical matters which a Board of Directors, although they may be first class business men (being but seldom possessed of professional knowledge) are not always able to follow without useless and lengthy correspondence, involving great loss of time ; hence it affords Boards of Directors the only possible means of protection against one of the most common dangers incurred in Joint Stock enterprises, upon which Mr. Geo. C. Brodrick commented, in the *Nineteenth Century.** An occasional visit of inspection by the Consulting Engineer is obviously, moreover, the most practical form of control that can be exercised over the conduct of an engineering undertaking, of a business character, such as a mine, situated abroad.

Expecting, as I do, to see many of the disabilities and disadvantages under which West Australian mines have had to contend in the past, removed in the future, I believe Western Australia offers every prospect of rewarding the pluck and confidence with which people have invested capital in many of its mines ; and it is sincerely to be hoped, for the sake of the mining industry in general, that the public will reap a golden harvest from many of them.

Ore Reserves and Lives of the Mines.

For reasons I have already explained (and people have had painful experience of the fact), it is an extremely difficult matter to arrive at figures, which afford a basis for close valuation, or for estimating the life of the mines in the Kalgoorlie field. It is true it can be done on the Rand,† thus enabling one to determine whether the market price placed on any particular share is above

* 'A Nation of Amateurs,' by the Hon. Geo. C. Brodrick. *Nineteenth Century*, Oct. 1900.

† An excellent " paper " on this subject has been recently contributed to the *Transactions* of the Institution of Mining and Metallurgy (Oct. 1902), entitled, ' An estimate of the Gold Production, and Life of the Main Reef Zones Witwatersrand down to 6000 ft.,' by Thomas Haight Leggett and Frederick H. Hatch.

or below its proper intrinsic value;* but apart from reasons of a technical nature which makes "sampling," a particularly difficult matter; an important difference which distinguishes the two cases, is that the Kalgoorlie formations are more or less vertical, whilst the "banket reefs" are comparatively "flat." This feature gives West Australian shares a speculative co-efficient of value which it is impossible to assess, as it affords prospects of an indefinite and possibly, in certain cases, a longer term of life, than some of the properties on the Rand, which have, so to speak, a fixed limit of existence; depending on the area of unworked ground each individual company holds, and the dip of the reef; but the larger mining areas, and the greater length and regularity of the gold shoots in the Witwatersrand generally counterbalances this advantage, although they have neither the width nor richness of some of the Kalgoorlie formations.

Another difference in the two cases is that, whilst on the Rand you can only figure on a certain number of payable auriferous reefs, which are known to traverse the various properties, the number of separate formations carrying ore-bodies of a payable nature which exist in different Kalgoorlie properties, cannot as yet be said to be definitely known. This, therefore, more or less favourably affects their "speculative co-efficient of value," by rendering the sudden and to some extent unexpected discovery of new and important bodies of ore, not only possible, but probable; although no actual allowance can be made for them, in reckoning the quantity of ore in sight and in actual reserve, which may be calculated upon at any given time.

I will merely take one example to illustrate this: under the head of ore-bodies partially developed. The report of the Lake View Consols for 1899 stated that a cross-cut run west at the 200-feet level through the north block (which adjoins the Perseverance boundary north of it) to the Great Boulder's east boundary (a distance of 670 feet) passed through the following ore-bodies.

The main reef at the point where the cross-cut started had a width of 40 feet and assayed 18 dwt. per ton.

44 ft.	west of the	main reef	an ore body	6 ft.	wide,	assaying	7 dwt.	per ton, was intersected.
109	,,	,,	,,	11	,,	,,	1 oz.	
155	,,	,,	,,	7	,,	,,	1 oz. 6 dwt.	
310	,,	,,	,,	6	,,	,,	7–18 dwt.	
633	,,	,,	,,	2	,,	,,	18 dwt.	

* The method of computing the present value of a mining share that may be considered as fairly certain to pay an estimated rate of dividend, for a fixed period is explained in *Mines of the Transvaal* and in an article 'The Yield on Mining Shares' in the *Statist* of July 26, 1902. It has been treated very fully by Frederick Hellman, M. Inst. M.M., in a paper entitled 'Determination of the Present Value of a Mine on the Rand.' *Trans. Inst. of Mining and Metallurgy*, vol. vi.

Company.	Issued Capital, Valued at 1*l*. Sterling.	Estimated Tons of Ore (Principally sulphide unless otherwise stated) in Sight, December 31 (if no other date given), 1899, 1900 and 1901.	Estimated Assay Value of Ore Reserves per Ton.	Average Estimated Per Cent. of Extraction.	Estimated Average Yield of Bullion, etc., per Ton of Ore.	
	£	tons.	oz. dwt. gr.	per cent.	oz. dwt. gr.	*s*. *d*.
Lake View . . .	250,000, increased Aug. 1902 to 350,000	1900. Aug. 31 55,000	8-15	81 (sands)		
		Dec. 31 71,000	1 12 0	90 (slimes)		
		August 31, 1903. [1] { 58,227	0 10 1 }	90 to 91·5	1 9 22	111 3
		42,772	0 15 10			
		77,798	1 10 2			
		September 1901. 90,000	1 4 0			
		1902. April 3 { 50,430	1 3 14 }	85·71	[10] { *1 4 10	
		June 30 { 37,833	1 3 0		†1 0 13·3	
Great Boulder . .	175,000 (1,750,000 2*s*.)	1899. [2] Sulphide . . 131,878	1 16 21			
		Oxidised . . 17,266	1 1 12			
		[2] 1900. 143,800	1 9 9	93 to 94	1 13 15	126 4
		[2] 1901. 240,816	1 7 14			
Golden Horse-shoe .	300,000 (5*l*. shares.)	1899. Oxidised . . { 129,809	1 13 9	90	1 14 17	132 5
		22,000	0 8 0			
		1900. Oxidised . . { 20,000	Est. by Author 0 8 0			
		112,925	} 1 18 4			
		Sulphide . . 100,340				
		1901. [4] Oxidised . . *88,674	0 17 0		1 17 6	
		Sulphide . . †189,970	2 0 14			
Kalgurli . . .	120,000	1899 [5] 100,000	1 7 4	92·5 to 90·8	‡1 10 0	116 10
		1900 [6] 120,000			‡1 6 21	
		1902. [7] 131,400				
Ivanhoe. . . .	1,000,000 (200,000 5*l*)	1899 Oxidised . . 128,273 }	Est. by Author 1 8 10	90·73	1 8 16	109 2
		[8] Sulphide . . 83,600				
		1900. Oxidised . . } *217,714	Est. by Author 1 3 13	91·65		
		Sulphide . .				
		1901. Oxidised . . } 303,971	1 6 0	88·98		
		Sulphide . .				
		July, 1902. 381,151	1 1 5	85·62		
Great Boulder Perseverance	175,000	1900. Oxidised . . } 250,000	1 10 0	90		
		[9] Sulphide . .				
		1901. Oxidised . . } 295,771	1 10 0	93	1 7 14	100 2
		Sulphide . .				
Associated . . .	495,408 (March 31, 1902)	April, 1900. 37,740	1 8 8			
		March 31, 1901. 122,794	1 3 7	**67·5	0 16 20	63 2
		March 31, 1902. [11] 91,210	1 6 0		0 17 14	

(1) Estimated by the late General Manager.

(2) Estimates by Messrs. Bewick, Moreing & Co. Exclusive of lower grade ore and ore not 'blocked out,' roughly estimated, September 25, 1902, at 29,000 tons: of which 15,000 were reckoned at an assay value of 12 dwt., and the whole at 13½ dwt.

(3) No account being taken of sulphide ore below the 600-feet level in 1899; the 1000-feet level in 1900; and 1000- to 1200-feet levels in 1901. Exclusive also of 20,652 tons at grass, estimated to contain 31 920 oz., in 1899: and 22,028 tons, estimated to contain 33,295 oz., in 1900. The reserves at the end of 1901 included, however, 13,306 tons at grass, estimated to contain 14,636 oz.

(4) *Exclusive of 23,688 tons, not blocked out for stoping, estimated at 9 dwt. per ton. †Exclusive of 245,996 tons, not blocked out for stoping, estimated at about 1 oz. 4 dwt. per ton. (5) *Fin. Times*, letter of correspondent, April 17, 1900. ‡ *Standard* gold.

(6) *Mining Year Book*, 1901. 7 Estimated on basis of three years supply, Report of Meeting, December 9, 1902.

(8) Exclusive of reserves in West and Middle lodes below the 200 and 300-feet levels. *Exclusive of 10,113 tons at grass in 1900; and †Exclusive of 10,000 tons at grass in 1901 similarly valued.

TABLE X.

Estimated Average Monthly Output in Tons Crushed, etc., and Recovery Value per Ton at the end of 1901, unless otherwise stated.			Estimated average Monthly Production in oz. of Bullion and Sterling Value at the end (fourth quarter) of 1901.	Estimated Monthly Scale of treatment in 1902.	Scale of Treatment and Gross Yields in 1902, compiled by the Author from published reports and information placed at his disposal.	Output* of Bullion in the first nine months of 1901 as compared with the first nine months of 1902. * As given in the *Statist* of October 25, 1902.		
tons.	s.	d.				1901.	1902.	Increase or Decrease.
						oz.	oz.	per cent.
Sulphide wks. 3622 Diehl . . 6211 9833	105	0	14,149 oz. 51,629*l.*	Tons. Sulphide works †. . . 253 Diehl plant . . . . 6300 6553 Tons 6697 to 6393 Oz. 6762 to 6646 £ 23,394 to 22,730 With the new stamps added to the Diehl plant, its output might be raised to about 10,000 tons, but it was only proposed to crush about 6000 tons, of a value of 21 dwt. for some time on from February 1902. † Shut down early in 1902. Capacity 3000 to 4000 tons per month.	Tons . 78,843 Oz. . 80,597 Value, £278,532 Dec. 1902: tons 6471, oz. 6638 £23,190 (cable)	113,821	60,447	− 47·0
Stamp battery 2487 Sulphide wks. 5526 8013	103	1	13,296 oz. 40,996*l.*	Stamp battery . 2463 to 2378 Sulphide works . 5899 to 6431 Tons . 8362 8809 Oz. . . 13,660 13,926 £ . . 43,228 43,798	Tons . 104,131 Oz. . 166,512 Value, £523,851 Dec. 1902: tons 9300, oz. 14,621 £44,975 (cable)	111,633	123,439	+ 9·6
Stamp battery 6706 Smelting wks. 1528 8234 Smelting concentrates 119 8353	144	1	15,350 oz. 59,340*l.*	Stamp battery 7147 Smelting works 1260 Tons . 8407 to 10,422 Oz. . . 15,589 to 16,105 £ . . 60,033 to 52,556 With the new (100-stamp) sulphide mill, the capacity of the battery may reach 13,000 tons or more.	Tons . 116,266 Oz. . 190,120 Value, £662,194 Dec. 1902: tons 11,165, oz. 16,131 £60,333 (cable)	138,162	141,849	+ 2·7
Sulphide wks. 1299 (12 months to July 31)	104	4	1747 oz. 6776*l.* to July 31	Sulphide works Tons . . } 2100 to 3650 Oz. . . 2291 to 3739 £ . . 8920 to 14558	Tons . 34,665 Oz. . 35,206 Value, £136,424 Dec. 1902: tons 3635, oz. 3639 £14,100 (cable)	15,483	24,962	+38·1
Stamp battery 10,607	73	4	11,118 oz. 40,766*l.*	Sulphide wks. Tons . . } 10,867 to 10,638 Oz. . . 11,244 to 12,204 £ . . 40,024 to 40,360 With the battery rearranged, its full capacity may be reckoned at 13,000 to 14,000.	Tons . 131,800 Oz. . 142,279 Value, £486,454 Dec. 1902: tons 12,039, oz. 13,140 £44,148 (cable)	75,409	104,067	+27·5
Stamp battery 2398 Sulphide wks. 8202 10,600	97	11	13,983 oz. 51,897*l.*	Battery (leased) oxide ore . } 2,420 to 1,974 Sulphide wks.[12] 9,342 to 10,432 [13] 11,799 to 12,287 Oz. . . 15,626 to 16,292 £ . . 57,030 to 56,121	Tons . 175,342 Oz. . 193,383 Value, £693,215 Dec. 1902: tons 10,651, oz. 17,310 £61,365 (cable)	92,393	142,634	+35·2
Sulphide wks. 3268	72	10	3088 oz. 11,910*l.*	Sulphide works Tons . } 4,879 to 4,959 Oz. . . 4,399 to 4,857 £ . . 16,742 to 18,224	Tons . 58,935[14] Oz. . 57,307[14] Value, £219,844[14] Dec. 1902: tons 5080, oz. 5585 £21,425 (cable) Value estimated by author.	22,260	40,363	+44·9

(9) The date of this estimate, given in the *Mining Year Book*, 1901, was the end of October 1901, and it only includes ore above the 500-feet level.
(10) Sulphide ore, treated in "roasting" and Diehl plants, September 1901 to June 1902 inclusive. * Estimated bullion contents. † Fine gold.
(11) Associated. Exclusive of ore below 15 dwt. in value, and 58,457 tons of tailings, estimated to contain 25,172 oz. of gold. ** Stated to have materially improved since stoppage of the old percolation process.
(12) When in full working order may be estimated at between 9000 and 11,000 tons, with six furnaces in operation.
(13) In January 1902:—The sulphide plant treated 8583 tons of ore, yielding 12,425 oz.
The battery „ 2548 „ „ 799 oz.
Slimes „ 3337 „ „ 1,374 oz.
} Total 14,598 oz., valued at 53,500*l.*
(14) Estimated by the author from published figures, cables, etc., valuing the bullion at 3*l.* 16*s.* 8·7*d.* per oz.

It seemed, therefore, reasonable to anticipate that some one or other of these various "formations" might produce a large tonnage of sulphide ore; but as they had not been driven upon or followed in depth obviously they could not be included in the reserves of ore estimated as being "developed," that is to say, "in sight" in the sense of being actually "blocked out."

The preceding table, No. X., compiled by the Author, furnishes particulars in regard to several leading Kalgoorlie mines (as far as they can be ascertained from published statements) that may be of interest. In column 2 will be found estimates of the tonnage of ore estimated as being in "sight" at different times, and when no other date is given, the estimate refers to *the end* of the year named; it will be, of course, some time before actual data are available as to the reserves of sulpho-telluride ore in the different mines at the end of 1902, but no doubt, in a number of instances, they will be found to have been added to rather than depleted.

Column 3 gives the estimated assay values of the "reserves," in 1899, 1900 and 1901, in oz. and dwt., and in sterling, per ton, based upon the estimates given in official reports or statements that have been published, but in a few cases where absolute figures are not available they have been calculated from the data given in columns 4 and 5, on the assumption that the yield of the ore milled during the year and in the following twelve months *plus* the average estimated mill-loss represented pretty nearly the average value of the ore-reserves at that time.

Column 4 shows the estimated percentage of extraction, as near as can be ascertained, and column 5 the estimated average yield, and sterling value of the ore milled during the year in column 2, opposite which it is set.

Columns 6 and 7 show the estimated average monthly tonnage of ore as reported treated during the last quarter, in 1901; the calculated average gross amount of gold produced therefrom in each case in oz. of bullion, its value, and the sterling value per ton recovered.

Column 8 gives what the Author reckoned in 1902 as the probable minimum and maximum monthly outputs, of the various plants at work on the field; and in several instances they have been exceeded.

Column 9 shows the actual reported results in 1902, and the returns in the last month of that year, and reads in conjunction with the figures in column 2, seems to indicate that there ought generally speaking to be no difficulty in maintaining this scale of treatment, if developments in depth keep pace with extraction, and several mines may be able to increase their output in 1893 without adding to their present plant. In column 10 a comparison is given of the returns in the first nine months of 1901 and 1902.

On the data in column 8 the Author had at first intended to endeavour to figure out the probable profit and dividend prospects for 1902–1903, but he abandoned this intention for several reasons.

In the first place, anyone who chooses to speculate upon them, can very well do so for himself by deducting the average cost of treatment per ton in each case, hitherto obtaining in each case (which has already been given) from the estimated average yield of gold per ton in sterling in 1902, and multiplying the difference by the tonnage treated, shown in column 9.

There are, however, certain practical difficulties in estimating on this basis.

For instance, whilst the sterling values in columns 6 and 7 no doubt represent about the average value of the quantities of ore, tailings, etc. treated at the end of 1901, a comparison of these figures with those in columns 8 and 9 indicate that most of the companies found it to their advantage in 1902 to treat ore of lower average grade, and to aim at larger outputs which the addition to their plant have rendered possible, so that no definite standard of mill values has yet been established in all cases, that would serve as a reliable guide to results in 1903; besides which, the variable proportions of ore smelted, and tailings treated monthly complicates any such attempt.

Moreover, on a larger scale of treatment, as I have pointed out, there will probably be found to have been a considerable all-round reduction in mining and milling costs in 1902–1903, as compared with 1901–1902. As regards Lake View costs, for instance, the Company's Annual Report for the ten months ending June 30, 1902, shows that the cost of mining (stoping) had been reduced to 13*s.* 6·42*d.* as against 27*s.* 7·64*d.* in the twelve months ending August 31, 1900, and the total working expenses, exclusive of development and capital charges, for the ten months ending June 30, 1902, is put at 2*l.* 11*s.* 0·296*d.* as compared with 2*l.* 18*s.* 5·184*d.* given in the previous Annual Report. The corresponding figure in September 1902 may be reckoned,* however, at 2*l.* 0*s.* 1*d.*; and similar economies seem likely to be effected in various directions in other cases.

Development, maintenance and depreciation are again very uncertain factors of cost; the former item depending on the footage

* Report Annual General Meeting, October 9, 1902.

driven and sunk, the proportion that driving and sinking bear to one another, and the gross output in any given period; all of which conditions are liable to vary.

The question that most concerns the mine shareholder or speculator, *probable dividends*, depends also to a certain extent on the balances brought forward and carried forward each year, which latter are unknown and purely arbitrary factors in each instance dictated by policy, depending upon a variety of circumstances.

Until capital charges are finished with, and the mines have settled down to regular business on a large scale (as they ought to do shortly) and the costs are published in 1903, it will be impossible in fact to estimate dividend prospects long in advance, and it is only by following what is being done from month to month, that it is safe to venture on speculations even for short periods ahead. The simplest rough method perhaps for people who choose to do so is described by a correspondent, a director of a dividend-paying Kalgoorlie mine, in a letter in the *Financial Times*, dated November 25, 1901, in which he says: "Taking into account all charges, including development, income tax (two), etc., the experience of many months' working proves that it costs (treating 30 dwt. ore) about 24,000*l.* to obtain 40,000*l.* worth of gold." This, valuing the ounce of gold at 4*l.* 2*s.*, would represent a cost of about 3*l.* 13*s.* 9½*d.* per ton, or if representing bullion at 3*l.* 16*s.* per oz. 3*l.* 8*s.* 4½*d.*; but variations in cost and grade of ore, etc., are liable to vitiate calculations of this kind. Unless, therefore, the gross working expenses are published monthly, estimates of this sort are best left to people of a speculative turn of mind, who possess the brains, knowledge, and money, necessary to speculate with; and speculation anyway is outside the legitimate business of an *engineer*, more particularly if he happens to be in a responsible executive position.

The accompanying "plan" (Plate I.), which by the kind permission of the proprietors of the *Statist* I am permitted to reproduce from its issue of February 2, 1901, gives the salient features of the Kalgoorlie field, showing the general "run" of the principal recognised formations, and the position of a number of the main ore-bodies located on them; and I may quote the following extracts from the explanatory remarks which the *Statist* made upon it, briefly summing up the then general position of affairs. "Of the many runs of reef the main payable ore-bodies of any continuous length so far opened up on the field are:—

1. The two Ivanhoe lodes—these lodes continue into the adjoining Horse-shoe area.

2. The two Boulder lodes, one in the Boulder and the other partly in the Horse-shoe and Ivanhoe areas.

3. The long ore-channel of the main lode of the Lake View Consols, which runs through the Lake View, the Perseverance, and into the South Kalgoorlie.

4. The West lode of the Perseverance.

"Outside these main lodes are many spurs and off-shoots, but no connected lodes of great length; there are also several isolated or detached bodies of payable ore of no great dimensions in any one direction.

"The Australia East ore-channel is not yet sufficiently defined, but the evidence, as far as it goes, would indicate a very promising future. The ore-bodies picked up in the Kalgoorlie Mint, Bank of England and North Boulder, are most likely spurs or off-throws from this lode.

"The pipes or chimneys of ore in the Kalgurli (and perhaps in a less degree the Tetley lode in the Australia lease) are somewhat similar to the isolated deposits in the Brownhill,* Brownhill Extended,* and Iron Duke * properties. . . . . Though they are rich, wide, and of great value, they apparently have no great length.

"The small runs of ore scattered about in the other parts of the field need only concern those directly interested. None have so far displayed any of the elements which go to make a big continuous ore-run.

"The future of the Ivanhoe and Perseverance as separate mines, especially the former, is more assured than is that of any of the other mines reviewed; both have their principal lodes well towards the centre of the leases, and the deep levels of the lodes well protected by the boundaries.

"The Perseverance management claims the deep levels of the Tetley ore-body of the Associated mine, by reason of its westerly dip; the Associated people claim the northern part of the Lake View lode, by reason of its easterly dip; † and the Golden Link claim the southern portion, by reason of its westerly dip. These claims remain to be proved, but there are grounds for their being put forward.

"In the Boulder, the West (as called by the company and

* Not shown in the plan.

† This appears to be slight in the lower levels.

shown on the map as the Boulder) lode at 800-foot level approaches so close to the western boundary, that confidence as to the future of the mine was at one time disturbed, though little notice appears to have been taken of this adverse inclination of the dip.

"The West Branch lode has already dipped into the Horse-shoe and Ivanhoe, the Horse-shoe drawing its richest ore from this West Branch, or as it is called in the Horse-shoe office the No. 4 lode, and so described on the map. The length of this lode possessed by the Ivanhoe, although short, is of great value.

"So far this No. 4 lode has in the Horse-shoe maintained its westerly dip, but in view of the easterly turn of the Boulder lode at the 1000-foot level, and the possibilities of the lodes conforming to one another, an easterly dip to this No. 4 lode would cause anxiety to the Horse-shoe."

This affords a good idea of the existing position of things in 1900–1901. But, as will be seen from the description of the different leading properties that follows, the situation has since undergone some considerable modification. For example, very important developments have recently taken place on the eastern side of the field, and the short run of rich ore marked on the plan of the Associated Northern Blocks* has been opened up and followed as far as the northern boundary of the north block of the Oroya,† and has already been proved for a considerable length in that property, affording evidence, it is reported, that in all probability the "formation" will be found to traverse the entire length of that lease. At this point I am inclined to think it bends round somewhat to the east, following the line of strike of the Friday lode, which runs through the western part of the old North Boulder lease, and into the "Bank of England," now amalgamated with it; but sufficient work has not yet been done to prove this conclusively, and the Friday lode *may* be a spur of the Australian East formation, as some think.

In any case, however, a succession of rich ore-bodies may be said to have been proved to extend (so far as development in length and depth have gone) from the Brownhill, through the Associated Northern Block and well into the Oroya.

Developments in these properties and in the North Boulder

* At date of November 23, 1901, Mr. A. E. Thomas estimated the ore "in sight" at 63,691 tons, valued at 775,345*l*., and "ore probably in sight" at 21,200 tons valued at 231,000*l*. At September 30, 1902, the ore available in reserve, at grass, and in transit was estimated by the manager at 99,795 tons, which he valued at 1,164,206*l*.

† This company has recently been amalgamated with the Brownhill.

have also shown that at least two other formations exist to the east of the line in question; these discoveries seem likely to have an important future bearing for the North Boulder, and other properties situated on the East side of the field; and a revival of interest and confidence in this section of the gold belt has lately been shown, which it is to be hoped will be rewarded by exploration in depth, which the Brownhill Extended, Oroya, North Boulder Gold-Mines and other properties, are, carrying on. The North Boulder Gold Mining Company, which has recently been reconstructed,* was the earliest company to pay dividends on the south-east side of the field, which it was enabled to do, owing to its good fortune in discovering the Friday "formation"; and with the new capital the present company possesses, to explore the ground, it is undoubtedly in an excellent position for making important discoveries in depth. The two "formations" west of the Friday are, in fact, so far practically unexplored, and it is possible that the Friday formation which dips west at surface may turn over on an easterly dip (as happened in the Kalgurli and other cases), which would enable it to be followed down in depth.

New and important developments have similarly taken place in the Lake View, Perseverance, Associated, Kalgurli and South Kalgurli, in the centre of the "golden mile," and in the Great Boulder, Ivanhoe, Central and West Boulder and other mines on the western side of the field. An excellent "plan" showing recent developments in the different properties in minute detail has lately been published (October 1902) by the Compagnie Belge des Mines d'Or Australiennes. The plans, etc. that follow and accompany the description of leading mines will serve to furnish a general idea of the position of the principal formations, the run of the main ore-shoots, and the workings, at the dates specified.

The only matter for regret is that no new discoveries have been made of any consequence, known to the Author, either north-west or south-east of the belt, which it may be observed crosses the principal formations diagonally, in a direction slightly east of north

* With a working capital of 30,000*l.* the old company paid back 27,454*l.* 17*s.* 6*d.* in dividends.

† In this connection the discovery in the Associated Northern Blocks (reported in a British Australasian telegram dated October 10, 1902), is worth noting. The diamond drill put down to a depth of 1172 feet cut a lode of the estimated width of 6 feet; the ore was of high grade averaging 1 oz. 18 dwt. 15 gr. (6 inches assaying 6 oz. 18 dwt). No. 2 bore from the 550 feet west crosscut put down afterwards diagonally 686 feet, intersected a formation 5 feet wide, averaging by assay 3 oz. 0 dwt. 14 gr.

and west of south. Capital has, however, naturally and wisely been absorbed for the moment in proving and developing the richer mines, and has left the development of "outside" shows as a legacy to the next generation, as the existing mining groups have probably enough to occupy their attention for the present looking after their own immediate affairs.

The accompanying table No. XI. on p. 514–517, published by the Kalgoorlie Chamber of Mines, shows the gold produced by the Kalgoorlie Mines in 1900 and their total production to December 31, 1900; following which I have appended a brief description of the history and position of the several leading mines, brought up to date as far as possible.

Lake View Consols.

Interesting details regarding this mine were given in articles in the *Statist*, dated September 15, 1900, and October 12 and 19, 1901, illustrated with a longitudinal section Plate II. which the proprietors have kindly allowed the Author to reproduce. The levels that are shaded represent work done during the year ending August 31, 1901.

The property it is stated was "pegged out" in 1893, by the Coolgardie Gold Mining and Prospecting Company, which had a capital of 225*l.*, but was subsequently sold to an Adelaide Company, called "The Lake View and Boulder East," with a capital of 40,000*l.*, divided into 80,000 shares of 10*s.* each. The property has an area of 48 acres.

Colonial speculators in 1894 used, it is said,* to "bear" the shares of the Adelaide Company at 3*s.* 6*d.*, and cover at 1*s.* 6*d.*, thus valuing the mine at about 6000*l.*! Towards the middle of 1899 it rose temporarily to the position, however, of being the largest gold-producing mine in the world, the output being over 30,000 oz. per † month.

This return was maintained for some time when dividends at the rate of 4*l.* per share per annum ‡ were being distributed, and the 1*l.* share rose to 28½*l.* The reasons for the subsequent fall in value, which took place, in common with the shares of all the

* *Statist*, September 15, 1900.

† The return in May 1899 was 33,160·405 oz.

‡ Dividends amounting to 20*s.* per share (250,000*l.*) or 100 per cent. were paid in 1897–1898; 30*s.* per share, 150 per cent., for 1898–1899; 45*s.* per share, 225 per cent., for 1899–1900; and 10*s.* per share, 50 per cent., for 1900–1901.

other Kalgoorlie mines, were partly due to differences in estimates given in regard to the amount of ore in sight and the falling off in returns, owing to the early troubles with the "sulphide plant"; but now that large quantities of sulphide ore can be dealt with, if new "ore-bodies" are discovered in depth anything like equal to what they proved to be in the upper levels, the company will no doubt once more take up a position in the front line of big producers.

The "formation" from which the bulk of the ore raised has been got runs north-west and south-east through the entire length of the property, some 2300 feet. On this "formation" (judging from the longitudinal sections of the mine) the principal shoot so far opened up lies south of the main shaft, in the neighbourhood of the shaft known as No. 2 South, as most of the "stoping" below the 200-feet level done during 1900–1901 and subsequently was in this section of the workings; but at June 1902 there was still a large area of ground below the 700-feet level apparently but partially explored to the north and south of the main shaft; though a block had been stoped for some length, at one point north of it, above and below the 700-feet level.

In addition to the main "formation," moreover, a cross-cut which was put out from the 200-feet level in 1899 to the western boundary in the northern block (referred to on p. 503) was reported to have intersected several promising "formations," and a cross-cut from No. 1 shaft at the northern end of the south block intersected a "formation" called the East reef (west section) at the 100-feet level, which was driven on for 65 feet, reported to be 3 to 6 feet wide, averaging 2 oz. 13 dwt.; and there appears to be a branch of this formation further west, on the "plan" close to the Oroya boundary; further discoveries may therefore yet be made on this side of the property; although the western block seems to offer the best immediate prospects.

During the year ending August 31, 1901, the main shaft was sunk to a depth of 972 feet,* and the following development work was reported to have been done:—

	Feet.		Feet.
Shafts	271½	Drives	3776½
Winzes	996½	Cross-cuts	1699½
Rises	166½	Plats	73
Total			6983½

* In March 1902, it was reported that "a plat" was being cut at the 1100-feet level, and the main shaft had reached a depth of over 1200 feet in June.

No.	Company.	Area of Leases	Capital.	Shares held in Reserve.
		acres.		
1	Associated Gold Mines, W.A., Ltd.	76	500,000—500,000 shares of 20s.	..
2	Associated Northern Blocks, W.A., Ltd.	78	350,000—350,000 ,, 20s.	..
3	Boulder Half-mile South, G.M. Co. (N.L.)	27	75,000—150,000 ,, 10s.	2,500
4	Brookman Bros.' Boulder G.M. Co., Ltd.	36	175,000—175,000 ,, 20s.	10,388
5	Brown Hill Central G.M. Co. (N.L.)	36	200,000—200,000 ,, 20s.	113
6	Brown Hill Extended, Ltd.	12	80,000— 80,000 ,, 20s.	..
7	Brown Hill Proprietary, Ltd.	24	125,000—125,000 ,, 20s.	..
8	Central and West Boulder G.M., W.A., Ltd.	54	250,000—250,000 ,, 20s.	..
9	Crœsus North No 1 G.M.	9	. . . . .	..
10	Crœsus Proprietary G.M. (N.L.)	12	40,000— 80,000 ,, 10s., 9s. 3d. paid up	..
11	Crœsus South G M. Co., Ltd	27	150,000—150,000 ,, 20s.	19,993
12	Devon Consols	24	. . . . .	..
13	Golden Horseshoe Estates Co., Ltd.	24	1,500,000—300,000 ,, 5l.	..
14	Golden Pike and Lake View East, Ltd.	38	250,000—250,000 ,, 20s., 18s. paid up	27,089
15	Golden Ridge G.M. Syndicate	72	. . . . .	..
16	Golden Zone G.M. Co, (N.L.)	22	30,000— 60,000 ,, 10s., 4s. paid up	..
17	Great Boulder Main Reef, Ltd.	25	130,000—260,000 ,, 10s.	..
18	Great Boulder No. 1, Ltd.	24	225,000—225,000 ,, 20s.	..
19	Great Boulder Perseverance G.M. Co., Ltd.	24	175,000—175,000 ,, 20s.	..
20	Great Boulder Proprietary G.M., Ltd.	85	175,000—1,750,000 ,, 2s.	..
21	Hainault G.M., Ltd.	20	130,000—130,000 ,, 20s.	20,000
22	Hampton Properties, Ltd. (Block 50)	8000	. . . . .	..
23	Hannans Block 45, Ltd.	18	230,000—230,000 ,, 20s.	7,000
24	Hannans Britannia G.M.	23	. . . . .	..
25	Hannans Brown Hill G.M. Co., Ltd.	54	225,000—225,000 ,, 20s.	82,000
26	Hannans Central G.M., Ltd.	48	230,000—230,000 ,, 20s.	65,000
27	Hannans Central Extended G.M. (N.L.)	24	100,000—100,000 ,, 20s., 13s. 6d. paid up	..
28	Hannans Consols, Ltd.	21	. . . . .	..
29	Hannans Crœsus, Ltd.	23	200,000—400,000 ,, 10s.	36,540
30	Hannans Excelsior	12	. . . . .	..
31	Hannans Main Reef, Ltd.	21	80,000—160,000 ,, 10s.	..
32	Hannans North G.M. Co., Ltd.	24	100,000—100,000 ,, 20s.	19,993
33	Hannans North Crœsus G.M.	24	. . . . .	..
34	Hannans Oroya G.M. Co., W.A., Ltd.	36	250,000—250,000 ,, 20s.	..
35	Hannans Proprietary Development Co., Ltd.	397	500,000—500,000 ,, 20s.	..
36	Hannans Reward, Ltd.	40	80,000— 80,000 ,, 20s.	5,000
37	Hannans Reward North G.M. (N.L.)	27	30,000 { 10,000 ,, 10s., fully paid up; 50,000 ,, 10s., 9s. paid up }	12,380

CHAMBER OF MINES (Incorporated).

Dividends Paid, 1900.		Gold Production for Year 1900.			Total Gold Production from all Sources to Date.			Remarks.
Per Share.	Amount.	Ore Treated.	Yield of Gold.	Yield per Ton.	Ore Treated.	Yield of Gold.	Yield per Ton.	
s. d.	£	tons.	oz.	oz.	tons.	oz.	oz.	
1 6	37,500	41,332	34,183·75	·82	150,810	216,168·9	1·43	
..	..	1,318·3	10,253·56	7·77	1,318·3	10,253·56	7·77	Including 34·65 oz. from dollied specimens.
..	..	..	..	..	80	20·3	·25	
..	..	3,157	4,050·05	1·28	9,493	10,206·15	1·07	Including gold won by Tributors.
..	..	340	432·55	1·27	3,114·5	2,650·5	·85	
..	..	735	3,531·98	4·80	837·75	4,572·48	5·45	
..	..	126	78·39	·62	440·25	437·44	·99	Including gold won by Tributors.
..	..	9,830	4,095·75	·41	23,158	15,767·65	·68	
..	..	421	206·1	·48	441·25	217·6	·49	
..	..	..	..	..	61	20·9	·34	
..	..	3,950	1,205·25	·30	4,120	1,337·4	·32	
..	..	185	84·37	·45	185	84·37	·45	
15 0	225,000	76,532	132,875·63	1·73	125,481	271,854·86	2·16	Less 69·97 oz. overstated 1899.
..	..	..	..	..	25	16·3	·65	
..	..	321	395·23	1·23	594·25	984·28	1·65	
..	..	86	38·72	·45	388	440·72	1·13	
1 0	13,000	9,777	22,050·47	2·25	34,553	61,579·27	1·78	
..	..	..	..	..	198	87·4	·44	
..	..	43,279·8	47,098·49	1·08	93,276·05	135,036·14	1·44	
*2 0	175,000	54,887	115,908·73	2·11	198,248	449,944·73	2·26	*Including 6*d.* declared Jan. 10, 1901.
..	..	..	..	..	12·5	50	4·00	
..	..	712	436·1	·61	712	436·1	·61	
..	..	719·5	865·96	1·20	1,016	1,354·96	1·33	Including gold won by Tributors
..	..	301	221·86	·73	322·5	242·86	·75	
27 6	191,500	61,795	80,756·75	1·30	137,486	252,885·85	1·83	
..	..	55	19·1	·34	55	19·1	·34	
..	..	57	51·75	·90	57	51·75	·90	
..	..	238	251·99	1·05	316	333·49	1·05	
..	..	..	..	..	3,643·5	3,301·7	·90	
..	..	..	..	..	103·5	52·95	·50	
..	..	145	62·85	·43	145	62·85	·43	
..	..	210	162·36	·77	1,130	1,608·01	1·42	
..	..	..	..	..	96	35·9	·37	
1 0	*9,491	15,170·5	5,825·46	·38	60,168	25,232·46	·41	*Feb. 1900, on 189,820 shares then issued.
..	..	9,205	5,805·89	·63	11,789·5	9,476·59	·80	Including gold won by Tributors.
..	..	2,475	3,092·87	1·24	8,596	8,458·02	·98	
..	..	..	..	..	218	174·2	·79	

No.	Company.	Area of Leases.	Capital.			Shares held in Reserve.
		acres.				
38	Hannans Sir John Forrest	6	. . . . .			..
39	Hannans Star G.M., Ltd.	18	225,000—225,000 shares of 20*s.*			33,000
40	Harquahala	..	. . . . .			..
41	Ironsides North G.M. Co. (N.L.)	25	100,000 { 45,000 / 55,000	,, / ,,	20*s.*, 11*s.* paid up / 20*s.*, fully paid up	..
42	Ivanhoe Gold Corporation, Ltd.	100	1,000,000—200,000	,,	5*l.*	..
43	Kalgoorlie Bank of England G.M. Co., Ltd.	10	26,250— 75,000	,,	7*s.*	20,000
44	Kalgoorlie Mining Development Co., Ltd.	115	. . . . .			..
45	Kalgoorlie Mint and Iron King G.M. Co., Ltd.	42	200,000 { 20,000 / 180,000	,, / ,,	20*s.*, 15*s.* paid up / 20*s.*, fully paid up	..
46	Kalgoorlie United G.M., Ltd.	12	100,000 { 30,000 / 70,000	,, / ,,	20*s.*, 5*s.* paid up / 20*s.*, fully paid up	10,000
47	Kalgurli Gold Mines, Ltd.	18	120,000—120,000	,,	20*s.*	..
48	Kalgurli Star Syndicate, Ltd.	36	15,000 { 40,000 / 20,000	,, / ,,	5*s.*, 2*s.* paid up / 5*s.*, fully paid up	..
49	Lake View Consols, Ltd.	48	250,000—250,000	,,	20*s.*	..
50	Lake View Extended G.M., W.A., Ltd.	24	175,000—175,000	,,	20*s.*	..
51	Lake View South G.M., W.A., Ltd.	20	200,000—200,000	,,	20*s.*	..
52	Leviathan Filter Press Cyaniding Co.	..	. . . . .			..
53	Maritana G.M. Co. (N.L.)	15	60,000— 60,000	,,	20*s.*, 10*s.* 6*d.* paid up	..
54	Maritana South G.M.	9	. . . . .			..
55	Mount Charlotte G.M. Co., Ltd.	68	75,000— 75,000	,,	20*s.*	..
56	North Boulder G.M. Co., Ltd.	9	110,000 -220,000	,,	10*s.*	40,000
57	North Kalgurli G.M., Ltd.	30	150,000—150,000	,,	20*s.*	25,000
58	North Mount Charlotte G.M., Ltd.	24	. . . . .			..
59	North Western Associated G.M, W.A., Ltd.	224	375,000—375,000	,,	20*s.*	..
60	Paringa Consolidated G.M. Co., Ltd.	60	500,000—1,000,000	,,	10*s.*	248,020
61	Phœnix G.M. Co., Ltd.	..	. . . . .			..
62	Reefers Eureka G.M. Co. (N.L.)	30	45,000 { 42,500 / 2,500	,, / ,,	20*s.*, 19*s.* 7½*d.* pd. up / 20*s.*, fully paid up	..
63	South Kalgurli G.M., Ltd.	16	150,000—150,000	,,	20*s.*	30,000
64	Public Crushings	..	. . . . .			..
65	Sundries	..	. . . . .			..
	Totals	..	. . . . .			..

The above return represents gold won from ore crushed, and does not include surface alluvial

February 28, 1901.

Dividends Paid, 1900. Per Share.	Amount.	Gold Production for Year 1900. Ore Treated.	Yield of Gold.	Yield per Ton.	Total Gold Production from all Sources to Date. Ore Treated.	Yield of Gold.	Yield per Ton.	Remarks.
s. d.	£	tons.	oz.	oz.	tons.	oz.	oz.	
..	..	..	..	..	194	181·5	·93	
..	..	4,055	2,373·58	·58	10,258·75	5,925·98	·57	
..	..	..	..	..	118	93·25	·78	
..	..	1,004	892·8	·88	1,004	892·8	·88	
20 0	200,000	74,750	107,050·85	1·43	181,711	304,848·6	1·67	
..	..	3,417	1,156·77	·33	11,626·5	5,434·67	·46	
..	..	1,317·35	1,278·85	·97	2,769·85	3,005·45	1·08	
..	..	395	2,439·28	6·17	3,338	7,848·13	2·35	
..	..	199	112·05	·56	199	112·05	·56	Including gold won by Tributors.
..	..	10,423	15,627·55	1·49	11,722	22,610·05	1·92	
..	..	829	543·86	·65	1,547·25	952·66	·61	Including gold won by Tributors.
25 0	312,500	28,642·8	98,771·45	3·44	210,071·8	532,083·7	2·53	
..	..	..	..	..	710	228	·32	
..	..	..	..	..	4,532	1,142·9	·25	
..	..	..	425·26	..	..	1,179·76	..	Late Kalgoorlie Filter Press Cyaniding Co.
..	..	129	134·4	1·04	485·5	483·85	·99	Including gold won by Tributors.
..	..	37	19·85	·54	125	336·5	2·69	
..	..	4,864	2,229·9	·45	11,601·5	4,974·7	·42	Including gold won by Tributors.
..	..	2,563·9	5,347·92	2·08	29,954·9	45,791·12	1·50	
..	..	298·55	1,468·27	4·9	298·55	1,468·27	4·90	
..	..	152	97·42	·64	669	339·22	·50	
..	..	..	..	..	29	51·65	1·78	
..	..	405·25	959·16	2·36	807·25	1,552·26	1·92	Including gold won by Tributors.
..	..	78	92·65	1·18	161	236·35	1·46	Including gold won by Tributors.
..	..	467	450·68	·96	995	1,084·23	1·08	
..	..	11,219	11,004·4	·98	11,219	11,004·4	·98	Including Boulder Central, Hannans Golden Group, Kalgoorlie Proprietary, Mount Charlotte East, True Blue and Binduli production, shown separately in previous returns.
..	..	9,282·75	7,044·81	·75	11,473	9,359·31	·81	
..	..	..	..	..	705·25	524·95	·74	
..	1,163,991	491,943·7	733,578·62	1·49	1,381,014·95	2,449,204·05	1·77	

(Signed) THOS. MAUGHAN, *Secretary.*

In the article referred to in the *Statist* of October 19, 1901, it was pointed out that in course of cross-cutting from the workings on the main "formation," an ore-body was discovered which at the north end of the 200-feet level proved to be 34 feet thick (6 feet being rich, and the remainder described as payable); whilst a body of ore was also reported to have been intersected in January 1901 south of the main shaft, at the 500-feet level, showing a width of 12 feet and a value of 30 dwt., which was apparently the extension in depth of the main shoot.

What has proved a most important discovery was referred to in the annual report for the year ending August 31, 1901, as having been made in a bore-hole put down from the 400-feet level (1000 feet north of the main shaft) to a depth of 850 feet; at about 1000 feet *vertical* from surface, this bore-hole was reported to have intersected a "formation," estimated as being about 14 feet thick, of an average value of 1 oz. of gold per ton. The 1000-feet level,* in course of drivage, was not, however, expected to reach the northern boundary before November (1902) at earliest.

The Table following gives particulars of ore treated, percentage of profits and expenditure, cost per ton of ore treated, profit per ton of ore treated, and cost per ounce of gold recovered, etc., during the year ending August 31, 1901.

Treated, 76,571 tons for 121,684 oz. Total receipts, 456,477*l*.

	Total Cost and Profit.	Per Ton of Ore Treated.	Per Oz. of Gold Recovered.	Percentage.
	£	£ s. d.	£ s. d.	
Expenditure	310,308	4 1 0	2 10 11	67·97
Profits	146,169	1 18 2	1 4 0	32·03

A cable report, dated December 7, 1901, was received from Mr. Hewitson, who was asked to report on the mine, in consequence of which it was decided to reduce the grade of output to about an average of 25 dwt.

The annexed Table on p. 519 shows the working cost and an analysis of the cost per ton for the year ending August 31, 1901, exclusive of capital expenditure on plant and other sums included in the preceding statement.

	Total Cost.			Cost per Ton.		
	£	s.	d.	£	s.	d.
Extraction of ore	50,655	18	5	0	13	2·773
Ore breaking	6,918	10	7	0	1	9·685
Oxidised slimes treatment	11,891	2	3	0	3	1·271
Sulphide ore treatment	56,237	17	2	0	14	8·269
Diehl process, expenses	61,702	13	9	0	16	1·397
Concentrates treatment, expenses	7,389	6	3	0	1	11·166
Charges on bullion	3,661	18	7	0	0	11·478
Slag treatment, expenses	150	18	3	0	0	0·473
Oxidised sands treatment	77	3	4	0	0	0·242
Maintenance	5,801	14	6	0	1	6·184
Management and general expenditure:						
Western Australia	12,339	17	1	0	3	2·675
London	6,207	5	2	0	1	7·455
Adelaide	675	7	5	0	0	2·116
	223,709	12	9	2	18	5·184
Add: development and sinking main shaft, which cost	42,951	12	3	0	11	2·625
Total working cost, exclusive of reserve for cyanide, law suit, and the other claims such as W. A. Government duties, capital charges for plant, etc.	266,661	5	0	3	9	7·809

The following Table gives the total returns of the mine in bullion.

	Ounces	Value
15 months ending August 31, 1897	46,588	£191,981
12 " " 1898	103,946	414,368
12 " " 1899	199,230	803,604
12 " " 1900	157,158	610,574
12 " " 1901	121,684	453,156
10 " June 30, 1902	97,497	348,354
	726,103	£2,822,037

The capacity of the reduction works at the end of 1901 was equal to dealing with some 9300 tons, representing a yield of about 14,276 oz., with ore of similar grade to that treated during July and August 1901. With the additional plant then in course of erection it was anticipated, however, that it would be possible to treat 12,000 tons monthly.

A considerable reduction was shown in the Annual Report to August 31, 1901, in the cost of mining, which was stated to have fallen from 27*s.* 7·641*d.* in 1900 to 13*s.* 2·773*d.*, and the cost of treatment in the sulphide works appears to have been reduced from 43*s.* 5*d.* to 31*s.* 7*d.*, and as each month brought heavy capital expenditure nearer to an end, it seemed reasonable to expect, as the General Manager remarked at the conclusion of his report, that as the work of re-organising and improving the various plants was nearing completion, a substantial reduction in the monthly expenditure could confidently be looked for.

In a special report* on the mine and plant, made by Mr. W. R. Feldtmann on behalf of Messrs. Bewick, Moreing and Co., he gave the following particulars of the position of affairs at the end of June 1902.

"Considered broadly the ore deposits hitherto worked may be divided into two chutes—a northern and a southern one—on the same ore-channel.

"The northern one appears to consist of a main body of low grade ore proved at the upper levels to extend from the north boundary for several hundred feet southward. Connected with this north cnute is a west vein or spur, proved down to the second level for a length of 150 feet. The north end of the company's property has not been so productive as that portion of the mine south of the main shaft, although a small length of the main ore-body and about 100 feet of the west vein appear to have yielded high values in the past.

"The southern chute in the upper levels has been worked for a length of about 1000 feet, and allowing for the usual eccentricities of ore-deposits on these fields, appears to have been fairly continuous and consistent for that length.

"A cursory examination of the relative position and shape of the stopes in the mine, including such stretches of ground as are, according to existing records, of sufficient value to warrant stoping, would convey the highly disconcerting impression that there is a distinct and alarming diminution in the length of the ore-bodies at each successive level.

"As instancing this, it may be mentioned here, that the lengths of pay-ore stoped or exposed on the first five levels on the south chute, are as follows:—

	Feet.		Feet.
No. 1 level	1050	No. 4 level	300
No. 2 ,, ...	1000	No. 5 ,, ...	250
No. 3 ,, ...	700		

"Now, while fluctuations in length from one level to another are common enough, and may very well be looked for in the local ore-chutes, such a progressive falling off as appears to be indicated here for a depth of 500 feet must necessarily arouse a suspicion that

* Published in the *Financial Times*, March 25, 1902.

somewhere an extension has been missed—indeed such a possibility should clearly have suggested itself at latest, when at No. 4 level the pay-chute contracted or appeared to contract to 300 feet in length.

"If such contraction in length in going down were peculiar to the district, and were locally a normal occurrence, there would be grounds for believing the logical sequence to be an almost complete disappearance of values in the deeper levels, and even if hitherto unprecedented, such a complete collapse in values as appears to have been encountered at the bottom levels, must be accepted as correct, providing every precaution has been taken to prove that the various levels have not departed from the line of the lode.

"On the other hand, a perpetuation of a faulty system of testing the ground at each level, would lead to the same apparent result, particularly if owing to the partial failure of operations at one level, the prospecting work at the next, were unduly hurried, as might happen.

"Before deciding, therefore, that there is a real failure in the ore-bodies in depth, the question has to be answered, Has every reasonable possibility been exhausted at each successive level? If every precaution has been taken to drive on the ore-channel, and keep on it, or, failing the latter, if a requisite number of cross-cuts have been put in at intervals east and west to a sufficient distance to determine its existence or non-existence on one side of the drive or the other, then the question may safely be answered in the affirmative."

Mr. Feldtmann, however, went on to show that neither of these conditions had been fulfilled, and that in places long stretches of ground had not been cross-cut sufficiently in the southern section of the mine, whilst at the northern end, No. 5 level, ostensibly driven to open up the main ore-body, was palpably off the line of the same, and insufficient cross-cutting has been done to rectify this.

The position of affairs was subsequently summarised in a cable * dated Boulder, W.A., March 24, 1902:—

"Examination by Messrs. Hoover, Feldtmann and Prichard. Result derived from 3200 samples and mill-trials. Main lode strong and well defined throughout future workings; average width of the lode is 30 feet; within it are bodies of high grade ore; outside of this, value of ore-bodies is too low ever to be profitable. Previous estimate a large number of tons of low grade ore based on erroneous assay plan.

* Published in the *Financial Times*, March 27, 1902.

"In the upper levels there are two main V-shaped ore-bodies; north ore-body reaches to 300-feet level, south ore-body reaches to 600-feet level. Large proportion of yield of the mine has been extracted from these ore-bodies. Estimated reserves blocked out in these ore-bodies 47,930 tons. Examination of drives and recent cross-cutting indicates moderate increase of reserves can be expected in this region.

"Isolated ore-bodies exposed in 500 feet, 700 feet and 800 feet levels; estimate amount of ore in sight 2500 tons should be increased considerably with development. Total estimated reserves 50,430 tons. Ore should yield 21 dwt. 12 gr.

"Confident can maintain present output twelve months from proved ore-bodies reported.

"Result, diamond drill 1000-feet level indicates ore-body there, it should be reached in another 600 feet of driving.

"There is every reason to believe further ore-bodies will be developed; prospect should give more encouragement to the shareholders. Perseverance lode has not been adequately prospected. Strongly recommend vigorous development of the mine in the lower levels and greater depth. Estimate working expenditure after thorough overhaul plant 11,500*l.* monthly. Estimate proper development will require an expenditure of 4000*l.* monthly."

In their report, which was subsequently received, dated April 3, 1902, the engineers estimated that, including all reserves of an average assay value of 13 dwt. upwards, there were 50,430 tons of ore in sight, of an average assay value of 23·6 dwt., which should yield a recovery value of 21·6 dwt. per ton.

They pointed out that the two principal ore-bodies referred to by Mr. Feldtmann have yielded some 310,000 tons of ore for 650,000 oz. of gold, an average of over 2 oz. per ton; and that, so far as is known, disconnected ore-bodies, of more limited extent, have been found at —

600 feet north	500 feet level
100 ,, ...	700 ,,
300 feet south	800 ,,

After giving various reasons in support of the probable permanence of the ore in depth, and opposed to the arguments advanced against it, they expressed the opinion that: "A large portion of the feeling of disappointment in the property existing at present is due to an exaggerated estimate formed when the richest ore-body at any time discovered on these fields was adopted as a standard of future values, instead of as a local aberration, to be accepted cheerfully, but without unduly sanguine hopes of speedy repetition.

"Other mines on the field have bottomed their ore-bodies, but have happily succeeded in finding successors in time to prevent any hiatus in their operations. The existence of a wider barren zone below the upper ore-bodies in this mine than in some others, whilst a fact that must be faced as materially affecting the value of the mine, should not extinguish confidence."

The mine had then been explored by 25,650 feet of levels and cross-cuts. The changes in progress in the Diehl plant, when complete, will give it a capacity of about 10,000 tons a month, and the dry-crushing plant has a capacity of about 3000 tons; that is to say the total capacity of the reduction plant may be reckoned at about 13,000 tons per month. The sulphide mill has, however, been since shut down, and only 50 stamps of the Diehl mill kept running, as they pointed out that the limited number of stoping faces in pay-ore precluded an output of more than 6000 to 6500 tons per month, without greatly increasing the mining costs; and moreover the reserves in hand did not warrant a depletion more rapid than this amount in order to give time for future development to provide further reserves.

The engineers also expressed the opinions that the Diehl mill was cheaper to operate* and being able to treat 10,000 tons of ore per month "will suffice for the mine's output permanently." By treating the concentrates on the mine (by roasting and cyanide) the cost has been reduced from 3*s.* 8·9*d.* per ton of ore treated to 1*s.* 10·3*d.* and a reduction of cost was foreshadowed in various directions; notably, in steam economy through a better disposition of the plant; by dispensing with all unnecessary manual labour; by sorting the ore so as to avoid crushing unpayable stone; by obtaining supplies in such quantities as may actually be required, and at the most favourable rates; and by careful administration and accurate cost-keeping.

The cost per month per horse-power in the mill boiler-plant of an aggregate rated capacity of over 1000 horse-power (which supplied about 400 horse-power) for instance, was 8*l.* 15*s.* against a possible cost with better plant of not over 4*l.* per horse-power

* At the Company's Meeting on Oct. 9, 1902, the Chairman, Mr. F. A. Govett, stated that on a smaller tonnage the costs of the Diehl process had been reduced to 1*l.* 6*s.* 7*d.* per ton in June, to 1*l.* 3*s.* in July, to 1*l.* 2*s.* 7*d.* in August, and to 1*l.* 1*s.* 2*d.* in September, whilst they have since been brought down to 18*s.* 4*d.* in December. Power costs had also fallen from 8300*l.* in January to 5000*l.* in June 1902

average. At the main shaft boiler-plant, of a rated capacity of 1000 horse-power (delivering up to 600 horse-power), it cost 4*l.* 12*s.* in February 1902.

It was proposed to maintain an output in 1902 of about 6000 tons per month, of an average value of 21 dwt., upon which a profit of 7500*l.* per month was expected to be earned; and the engineers expressed the belief that there was every reason for confidence that the recurrence of ore in depth would be proved, "and the continuance of a prosperous career to the company will become assured."

It is to be recollected that, in addition to the "Lake View Lode" upon which the operations of the company have been mainly concentrated in the past, there are the "Perseverance lode," the "East lode," and presumably "Tetley's lode" to be yet explored; and work has been directed to open up the "Perseverance lode" at the 1000-feet level, with all speed. At the meeting held on October 9, 1902, the Chairman referred to the discovery of the Perseverance lode at the 700-feet level as a strike of great importance and gave interesting particulars about this and other developments which appear to be of hopeful augury for the future. Thus the Perseverance lode had been driven on at the 700-feet level, and for 50 feet had an estimated average value of 30 dwt.;* a rich "seam" was struck in the shaft at 1245 feet, believed to be the Lake View Lode; and at the 1000-feet level the main formation was reported to be heavily mineralised, carrying ore in bunches which, though on the whole low grade, in one portion, for 20 feet, assayed 1 oz. 16 dwt.

A cable dated October 27, stated that a diamond-drill bore from the west cross-cut 1130 feet north, 700-feet level depressed 69°, at a depth of 400 feet, 5 feet of core assayed 2 oz. 7 dwt. per ton, containing telluride of gold, and at the depth of 440 feet which the borehole had reached, the core was still mineralised. An office note stated that the lode referred to lies between the Perseverance

* A drill-hole from the 630 feet west cross-cut at the 1000-feet level was reported in November 1902, to have passed at 346 feet through 2 feet of ore assaying 21 dwt. and 4 feet assaying 3 dwt.; considered to be the Perseverance lode. On December 11 the North drive, at the 1000-feet level from the 630 feet cross-cut, was reported (by cable) driven 47 feet showing 4 feet of ore in the face, the last 22 feet assaying 1 oz. per ton, and on January 15, 1903, a cab'e announced that 102 feet had been driven; and added, "estimate stope averagings over full width of the drive 2 oz. per ton last 20 feet driven," showing streaks of telluride.

and Lake View lodes, and it was calculated that it* had been intersected at a vertical depth of about 1050 feet.

A later cable (dated October 30) announced the strike of what appears to be Tetley's lode,† reading as follows: "diamond-drill bore from west cross-cut 1130 feet north, 1000-feet level. The core from 467 feet to 483 feet assays 2 oz. 3 dwt. per ton, containing telluride of gold. Apparently the dip of the lode is 70° west. . . . This gives location of lode 75 feet west of the Associated Gold Mines boundary at a vertical depth of 1090 feet." From 472 to 477 feet the average of the core was reported as high as 3 oz. 13 dwt.

These discoveries appear to be of great importance, and strengthen the opinion the Author has previously expressed.

At an extraordinary general meeting of the company held on August 1 last, it was resolved to authorise the increase of the capital of the company to 350,000*l.* by the creation of 100,000 new shares of 1*l.* each to rank *pari passu* with the existing shares; and to offer the new shares *pro rata* to the shareholders on the register on August 1 at the price of 25*s.* per share.

With this extra capital at the company's disposal it is intended to push on developments to 2000 feet in depth or more if need be.

In future the fiscal year will close on June 30 instead of August 31, and the returns are now given in fine gold.

It is intended to issue a quarterly statement of "ore reserves." The total at September 30, 1902,‡ was computed at 53,000 tons, assaying 23 dwt., exclusive of ore in the Perseverance lode, and ore partially developed estimated to amount to 38,000 tons; showing a net increase of 15,167 tons upon the quantity on June 30. On December 31, 1902, the estimated "reserves" amounted to 58,000 tons blocked out, assaying 18 dwt. 12 gr. per ton, and 33,000 tons partially proved assaying 12 dwt. 12 gr. per ton, not including the Perseverance lode, and lode 66 feet east of it on the 1000-feet level.

* From cables of January 5 and 15, 1903, it seems that this "formation" lies about 66 feet east of the Perseverance; that it has been struck at the 1000-feet level in a cross-cut west 830 feet north; and for 20 feet driven upon it north, carried telluride and had an estimated value of 1 oz. over the full width of the drive; whilst on January 15 the last 20 feet driven was reported to average 2 oz. per ton.

† A cable dated January 15, 1903, announced that this lode had been driven upon north at the 1000-feet level, and at a point 120 feet south of the Perseverance and 45 feet west of the Associated boundaries it was 15 feet wide, assaying 15 dwt. per ton and dipping west.

‡ *Statist*, Oct. 18, p. 658.

The Great Boulder.

This property was originally owned by the Coolgardie Gold-Mining and Prospecting Company (capital 225*l.*), which also owned the Lake View Consols; the present company was formed in June 1894, and it had formerly an area of 109 acres but, owing to the sale of the Boulder No. 1, at present comprises about 85 acres.

Out of profits, the company has applied considerable sums to expenditure on machinery, buildings, plant and development, and provided for depreciation. At the end of 1900, the balance carried forward to 1901 amounted to 51,200*l.* 3*s.* 6*d.*; and at the end of 1901, the sum of 22,942*l.* 7*s.* was carried forward to 1902.

The profits the mine has returned have been as follows :—

Shares Issued.		Net Revenue for the Year.	Dividends Paid.	Rate Per Share.	Rate Per Cent.
		£	£		
160,000	1895	83,284	64,000	8*s.*	40
	1896	167,542	160,000*	20*s.*	100
	1897 (shares split)	272,805	248,000	16*s.* per £1 share, and 1*s.* 6*d.* per 2*s.* share.	155
	1898	250,689	160,000	2*s.*	100
175,000	1899	213,436	174,800	2*s.*	100
	1900	255,919	175,000	2*s.*	100
	1901	254,928	175,000	2*s.*	100

Two masterly formations outcrop on the western side of the Great Boulder lease known as the West lode and West Branch lode. The West lode is intersected by several flat ore-courses or "caunter lodes" which carry rich ore. The West Branch lode splits in two in the middle of its course, forming an eastern and western loop; and in the same way the West lode is divided in the centre by a "horse" for about 300 feet, forming an east and west branch. The extension of the West lode from this point northwards goes by the name of the East lode. On the eastern side of the lease two formations known as Gamble North and Robertson's have been developed to some considerable extent, and have produced some good ore, more particularly the former

* One Boulder No. 1 share was paid in respect of each Great Boulder Proprietary share.

one, but as compared with the main lodes, are low grade and irregular. Gamble North lode has, however, a special historical interest (as elsewhere mentioned) as being the formation upon which the original location was made. The Ivanhoe East lode traverses the north end of the property in lease 102[E], west of the West Branch lode; and the Ivanhoe Middle lode crosses the south-west corner of lease 51[E] and produced some good ore in 1901; still further to the west at the north end of the property other formations have been prospected and opened up in leases 280[E] and 61[E].

In 1899, 9524 lineal feet of development work was executed in shaft sinking, levels, cross-cuts, rises and winzes, etc.; attention being chiefly directed to opening up the West lode; which, pending other developments, was expected to furnish the principal ore-supply in the immediate future.

Two new levels, the 500 and 600-feet, were started, and as well as the 400-feet level were driven north and south from the main shaft.

The widths and values of the lode in these levels were returned as follows:—

Level.		Length Driven.	Average Width of Lode.		Average Value of Lode.	
feet.		feet.	ft.	in.	oz.	dwt.
400	Total	698	4	7	2	6
500	North	349	4	11	7	5
500	South	360	4	2	1	3
600	North	339	5	1	1	6
600	South	345	4	4	1	16

In 1900, 6797 feet of development work was executed; the Main Shaft, Edwards and Lane, being altogether sunk 675 feet, and four new drives were commenced, viz. the 700, 800, 900 and 1000-feet levels, and extended north and south from the Main shaft.

The width and value of the lode in these levels, which were driven 915 feet on the principal ore-shoot, were set out in the report of the consulting engineers of the company, Messrs. John Taylor and Sons, as follows:—

	Lode Averaged.		Value.	
	ft.	in.	oz.	dwt.
700-feet level for a length of 255 feet	5	4	1	17
800 ,, ,, 264 ,,	5	8	1	7
900 ,, ,, 241½ ,,	6	9	1	13
1000 ,, ,, 154½ ,,	6	6	1	17

Some 1466 feet of winzes and rises were sunk and put up in 1900 and this work, besides greatly improving the ventilation in the deeper workings, it was stated threw clearer light on the lenticular splicing of the ore-bodies, and also on the breaks in their continuity.

At the end of the year all the main ends were stated to be in ore.

In the Directors' report it was pointed out, that during the year the sulphide reserves standing underground, had been increased by 11,922 tons; and 1376 tons had been added to the stock of ore at surface.

During 1901 several important developments were reported as follows :—

On May 13, a cable announced that * ore had been struck 1100-feet level, 87 feet west of shaft, the width of the formation proved to be 5 feet and the value 25 dwt.; and at 1200-feet level, 90 feet west of the shaft, the lode was struck 12 feet wide, assaying 17 dwt. per ton.

On May 20, a telegram said: † "1100-feet level last assay driving north, 2 oz. 5 dwt. per ton; driving south, 3 oz. 18 dwt. per ton. Have commenced to drive on the lode 1200-feet level, the value is improving, the average width is maintained."

An article in the *Statist* of August 24, 1901, speaking of the West lode near the Ivanhoe and Golden Horse-shoe areas, remarked :—

"From the end of 1900 to June 30, 1901, some additional driving was done, more especially at the 700 and 900-feet levels; the thickness and value being greatest in the southern extension of these two levels; and similarly at 1000, 1100 and 1200-feet levels. The developments to the date named have exposed, at the 700 and 900-feet levels, some 475 feet of a large ore-body, in parts stripped to a width of some 12 feet, with recent advices of ore worth 2 oz.

"Stoping in the 400-feet level south was reported (June 30) as in ore 13 feet thick, assay value 41 dwt., and at north of shaft in the same (400-feet) level, 7 feet, value 22 dwt. At the 300-feet level north 7 feet of ore being stoped, is reported as assaying 35 dwt.; 600-feet level south, 4 feet of ore, 31 dwt.; same level north, 7 feet of ore, 35 dwt.; at the 900-feet level—north and south—the stoping in sections is reported as in 8-feet of ore, 55 dwt."

"At 700-feet level advices reported: north driving at about 150 feet from shaft, had passed into rock of 'no value,' but the

* *Statist*, August 24, 1901. † *Ibid.*

GREAT BOULDER PROP.

WEST LODE SECTION.

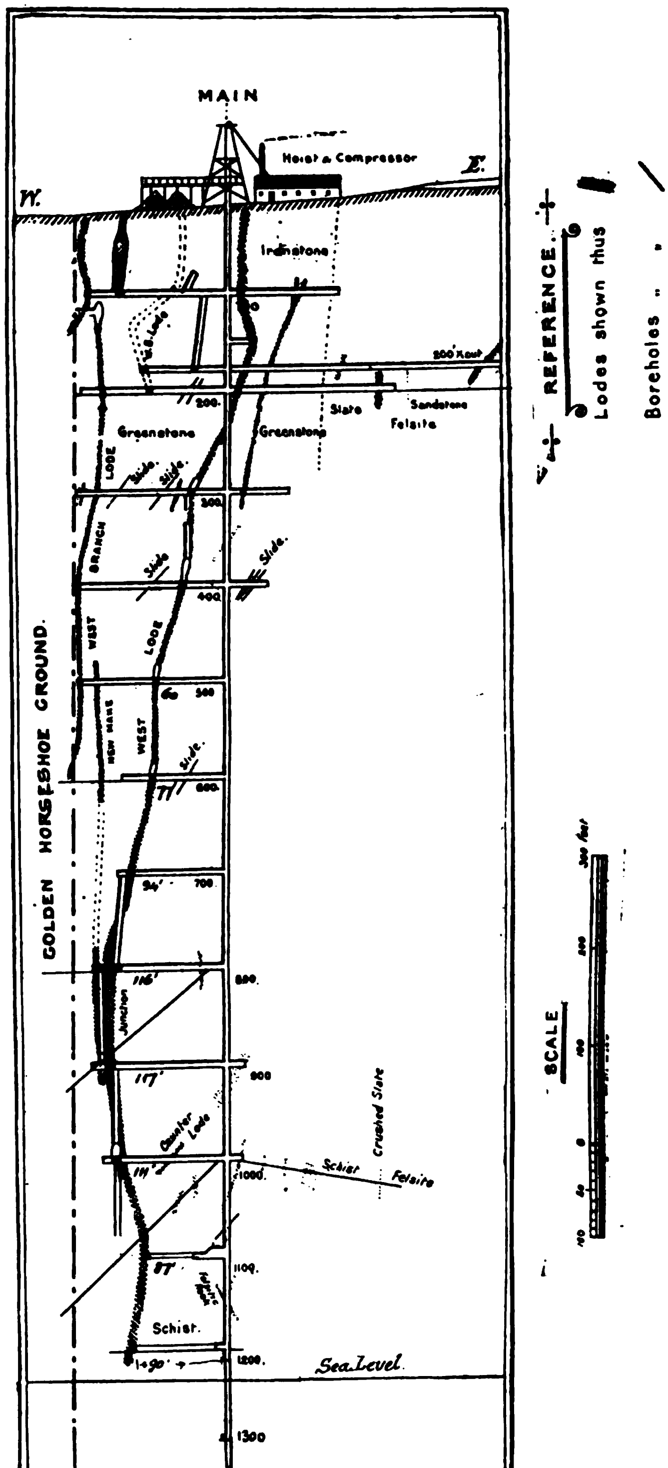


FIG. 68.

2 M

south drive at 302 feet from the shaft was in 4 feet 6 inches width of lode, value 31 dwt.

"At 1100-feet level, the driving north (June 30) was in 6-feet lode, value 23 dwt., and driving south in 4 feet 6 inches lode, value 16 dwt.

"At 1200-feet level north, ore 6 feet wide, value 12 dwt.; and south 7 feet, value 18 dwt."

On July 4, a cable reported: "Struck ore, assaying 15 dwt., 5 feet in width, cutting plat, 1300-feet level; about the centre of lode, 2 feet assays 25 dwt.; shows visible free gold and tellurides. The lode looks extremely promising; it is quite new."

By the kind permission of the proprietors of the *Statist*, the Author is permitted to reproduce a cross-section, Fig. 68, given in the article I have quoted (in their issue of August 24, 1901) upon which they made the following comments.

The distances of the lode from the main shaft at various levels are indicated in the small figures shown on the cross-cuts.

"At 1300 feet the cutting of a plat exposed the 5-feet reef referred to in the July 4 telegram." Reference to the diagram shows that the 5-feet lode come on so near the shaft, cannot be the same as that which is some 90 feet distant from the shaft at the level above, i.e. the 1200-feet level.

By telegram dated October 8, advice was received * that at 1400 feet in depth in the shaft, a diamond-drill west at 74 feet from shaft, cut a lode 4 feet thick, value 4 dwt.; and at 100 feet from shaft the main lode was intersected 7 feet thick, value 28 dwt.; at 1500 feet deep a bore-hole west, at a distance of 80 feet from the shaft, intersected the main body of ore 9 feet wide, value 15½ dwt.

A cable published in the *Financial Times* of November 26, 1901, read as follows:—

"800-feet level, 230 feet to the north of the western cross-cut, have cut a body of ore assaying 30 dwt., 4 feet in width; ore in the south end, 260 feet to the south of the western cross-cut, 8 feet in width, 2 oz. 10 dwt. per ton. The value of 1200-feet level has been gradually improving north and south of the shaft; level north driven 140 feet; average assays for last month are 46 dwt. 10 feet in width; the lode in the end is 10 feet wide, and carries visible free-gold—telluride of gold—not less than 5 oz.: level south driven 195 feet. Average assays for last month are 25 dwt., 8 feet in width; the lode in the end is 8 feet wide and carries 2 oz.; other

* *Statist*, Oct. 12, 1901.

levels developing satisfactorily. Mine promises exceedingly well for the future."

The correspondent of the *Financial Times*, in a letter dated Kalgoorlie, January 4, 1902, said:—

"The north end of the 1200-feet level is still in wonderfully rich ore, and the chute is apparently a very long one.

"The 1300-feet level had been rather disappointing, the ground having been apparently disturbed by a fault;" it was recently reported, however, that a horizontal bore, put out west, 140 feet north of the main cross-cut, came on 10 feet thickness of ore, value 24 dwt., about 83 feet from the west boundary.

"The western cross-cut at the 1400-feet level has intersected the main ore-body at a point 100 feet from the shaft. The first 4 feet of the lode is schist worth 5 dwt., the next 6 feet is quartz bulking 26 dwt."

A *British Australasian* telegram dated March 11, 1902, said:—

"At the 1200-feet level in the north face, the lode is 12 feet wide and worth 2 oz.; in the south face at the same level it is 10 feet wide and worth 3½ oz.

"At the 1400-feet level the ore maintains its width and is worth 26 dwt. per ton."

Early in July, the "plat" at the 1500-feet level was completed. At the 1200-feet level south drive the width of the ore was reported at 5 feet assaying 30 dwt.; as compared with 21 dwt. for the last half of June. For the half month to mid-August it was reported with reference to work in the lowest levels, that in Section 31 at the 1200-feet level north the considerable width of 20 feet was shown, assay values being 22 dwt. In the south drive the lode was 7 feet, value 87 dwt., compared with 29 dwt. during the last half of July.

At the 1400-feet level, the south drive at the date of this report showed 3 feet of ore assaying 14 dwt. as against 10 dwt. previously; although still low, values at this point had been steadily improving. A cable in Nov. 1902 reported that cross-cutting at the 1500-feet level 75 feet west of the shaft, the lode was found worth 35 dwt. per ton, 9 feet in width; drives were started on it, and the north drive showed a width of 6 feet, and an assay value of 40 dwt.

Although the Western lode at one time, it is said, gave occasion for anxiety in regard to its dip, owing to its proximity to the eastern boundary lines of the Ivanhoe and Golden Horse-shoe companies, the cross-section shows that from the 800 to the 1300-feet levels, notwithstanding a certain amount of sinuosity, its dip has been practically vertical.

In 1901, a total of 4746 feet of development work was executed; less attention being directed to sinking than to ascertaining the lateral extent of the main "shoot," but the main shaft was put down 222 feet to 1431 feet.

The 700, 800, 900 and 1000-feet levels were extended, and the 1100 and 1200-feet levels commenced.

The following figures show the length of the main shoot reported proved in 1901:—

700 feet level . . .	570 feet.	
800 ,, . . .	538 ,,	South level still productive.
900 ,, . . .	474¼ ,,	Both levels.
1000 ,, . . .	200 ,,	Lode faulted in both levels, but with ore above and below the slides.
1100 ,, . . .	463 ,,	Averages 4 feet 5 inches, assay 1 oz. 1 dwt.
1200 ,, . . .	420 ,,	Averages 6 feet 7 inches, assay 1 oz. 19 dwt.

The last two new levels were still in good ore, both to the north and to the south. In the 1200-feet level the lode it was estimated would average about 11 feet in width after stripping, and as regards both size and quality combined "opened up the best piece of ground seen for some time past."

An examination of the table of driving in 1900, on page 527 and the results of stoping in 1901, given below, shows that the initial development work does not indicate the full width available for stoping.

Stopes, 1901.

700-feet level	for a	length of	270	feet width . .	7½ feet.
800	,,	,,	220	,, . .	9½ ,,
900	,,	,,	310	,, . .	12⅓ ,,
1000	,,	,,	155	,, . .	9¾ ,,

The underground work at the end of 1901 aggregated 10⅓ miles, and 3¼ miles of exploratory boring had been done. The temperature at the 1400-feet level is fairly constant at 80° F.

The ore treated during the year showed besides ordinary iron pyrites, a notable quantity of tellurides, and contained gold, silver, copper, cadmium, besides some arsenical pyrites. The silica averaged 75 per cent., lime 7·5 per cent. and magnesia 4·75 per cent. in the ore obtained in the 1100 and 1200-feet levels.

The company up to June 1899 only dealt with free-milling oxidised ore, and that month commenced to deal with sulphide ore; since 1901, it has used its stamp-battery as well as its sulphide-plant, for crushing sulphide ore.

"The monthly average of gold produced in 1900 was about 35,900*l*." In 1901 it averaged about 39,821 net.

In the issue of the *Statist* already quoted, it was pointed out that the value of the bullion produced had fallen from about 4*l*. per oz. in 1899, to 3*l*. 4*s*. per oz. in July 1901;* and that this no doubt contributed to weaken the market price of the shares.

As a set-off against this, however, the quantity of ore treated in 1901 was larger, viz. 89,121 tons, or on the average 7426 tons per month; the tailings reserve stood at 51,643 tons as compared with 70,055 tons at the end of 1900.

Details of the tonnage of ore and tailings treated, and the bullion value from the commencement of operations to the end of December 1901, are given in the Company's Annual Report as tabulated below, and particulars of bullion output and working costs will be found in the various tables the Author has compiled.

Year.	Ore Treated.	Tailings Treated.	Value.
	Tons.	Tons.	£
1895 (9 months)	4,291	..	107,023
1896	16,729	..	223,705
1897	29,463	..	336,844
1898	41,043	..	334,123
1899	51,835	23,707	333,541
1900	54,680	93,726	430,783
1901	89,121	107,535	477,854

The shareholders in respect of profits earned up to the end of 1901 have received a return on their investment of 695 per cent.

At the end of 1901, the ore reserves were estimated by Mr. Hamilton down to the 1200-feet level in the main shaft, and the 1000-feet level in Lane Shaft (including 13,306 tons at grass), at 240,816 tons assaying in gold 332,503 oz.

At the Company's Annual Meeting† May 15, 1902, the Chairman, Mr. G. P. Doolette, pointed out that the tonnage treated in 1901 was 63 per cent. more, whilst the expenses had only increased 27½ per cent., and that whilst the daily output of the sulphide mill in September was 165 tons, it had reached 200 tons already per diem.

This had led Mr. Hamilton to obtain authority from the Board

* The value in October 1902, I am informed, was about 3*l*. 3*s*. 0*d*.

† *Financial Times*, May 16, 1902.

to erect six more furnaces at a cost of about 10,000*l*., and the output it was expected, would thereby be increased 70 tons per diem: an extraction of about 94 per cent., he also mentioned, was being obtained.

The battery, when these changes are made, will be exclusively reserved for the treatment of any oxidised ore discovered.

Mr. Hamilton, in his annual report for 1901, stated that "the present bottom level of the mine is the best below the 200-feet level, and its appearance justified an expectation of a long continuation of ore laterally and also in depth. He remarked that work at Lane's shaft had not discovered pay-ore at the 1000-feet level; but "the lode looks strong and promising and will very likely improve at greater depth."

The regularity and length of the ore-channels, and the first rate management that has characterised the undertaking from the start, hold out excellent prospects for the future; a formation presumed to be entirely new was recently encountered at the 1600-feet level 17 feet west of the shaft, bearing 35° west of north, and dipping 80°. It was reported to have a width of 2 feet and to average 17 dwt. per ton, showing values ranging from 8 to 50 dwt. per ton. The following cable of later date, which was reported in the *Statist* of October 25, 1902, said: "Prospecting with diamond-drill boring horizontally 1600-feet level; have struck ore 57 feet west of the shaft; first 11 feet is equal to an average of 27 dwt. per ton, remaining 5 feet is equal to an average of 10 dwt. per ton. The lode-stuff consists chiefly of quartz with schist." As the main formation is 100 feet west of the shaft at the 1400-feet level, it would appear to have a westerly underlie between these two levels. This development appears a most important one for the field.

In December, the formation was cross-cut at 57 feet 6 inches from the shaft and for a width of 16 feet was reported to average 22 dwt.

It is said to be the company's intention to prospect the north end of the property from Janson shaft.

At date of June 30, 1902, I am informed that the ore-reserves in sight (not including or below the 1200-feet level) were estimated by Mr. Hamilton at 249,000 tons.

The mine costs in 1902 are also stated to show a great reduction on 1900 and 1901, as given in the *Citizen* of February 7, 1903, viz. sulphide mill 11*s*. 4*d*., tailings 6*s*. 6*d*., general charges 8*d*., stoping 11*s*. 9*d*. and development 6*s*. 3*d*.; total, 1*l*. 16*s*. 6*d*. per ton.

The Ivanhoe.

This mine was "pegged out" in the autumn of 1893, and was at one time, it is said, offered for sale for* 40*l.*!

The capital of the first company formed in Melbourne to work the property was 15,000*l.*, with a working capital of 4000*l.*, but the company was subsequently reconstructed, and its capital was increased to 50,000*l.* which provided an additional 18,695*l.* In 1895, 1757 tons were crushed, yielding 3036 oz., or an average of 34·5 dwt. per ton. The property was taken over by the present company on October 14, 1897.

It was considered to have a larger reserve of oxidised ore than any other mine on the field; and owing to the several formations which traverse it being well in towards the centre of the property, as is the case with the Perseverance, both have been less troubled than some of the other mines by adverse rumours regarding the course and dip of their ore-bodies. Steady returns, and its excellent management, have therefore made it a favourite. The *Statist* gives various interesting particulars of this property in its issues of August 25, 1900, September 21 and October 5, 1901; and, by the kind permission of the proprietors, the Author is permitted to reproduce the accompanying plans and sections (Figs. 69, 70, 71, 72 and 73) that were given in the latest issue referred to.

The principal formations upon which work has been done are known as the East, Middle, and New lodes.

Several other "formations" (known as the West lode, Patterson's lode, and the Boulder lode) lie within the area the company possesses. The New lode and Patterson's lode, appear to be merely main branches respectively of the East and Middle lodes.

The Boulder lode crosses the Ivanhoe Company's lease at its south-east corner, and is expected to give a short run of very rich ore, carrying as it does high values for 150 to 200 feet in length; but the West lode, Patterson's, and the Boulder lode have not been developed to any extent. The East lode, which has been opened up like the Middle lode from boundary to boundary, is in places of great width, running up to 15 feet or more in thickness; but its average width is given† as being about 7 feet, in which payable values are practically continuous for a length of 1000 feet. The

* *Statist*, August 25, 1900.

† Report of the Consulting Engineers (Abstract) *Financial Times*, August 30, 1902.

Middle lode is comparatively narrow in the upper workings, except for a short section south of Patterson's shaft, where it is stated to run from 15 up to 22 feet * in width; but its average width is also

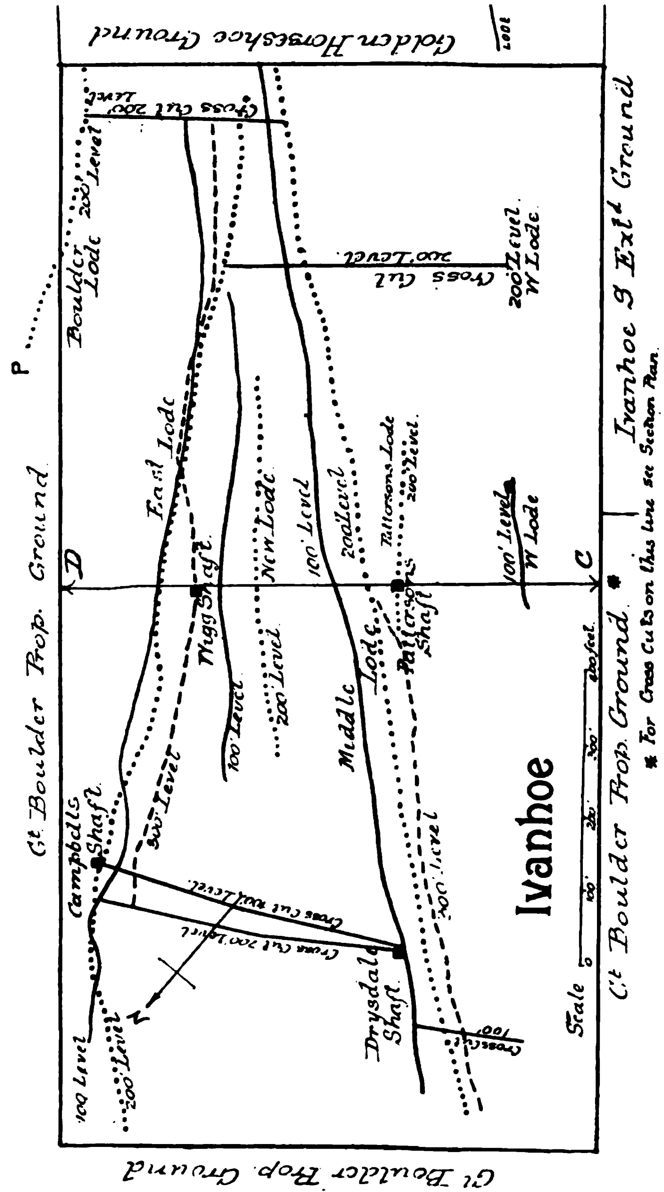


FIG. 69.

* *Statist*, October 5, 1901.

put * at about 7 feet, and it is likewise stated to carry payable values (practically continuous), for a length of about 1000 feet.

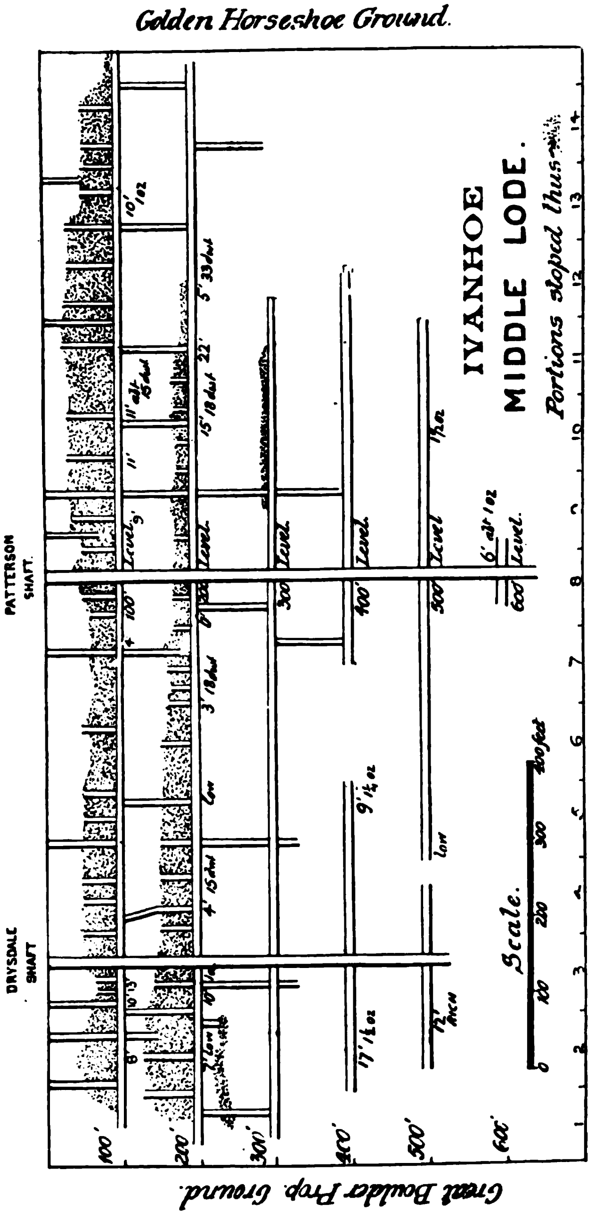


Fig. 70.

* Report of the Consulting Engineers (Abstract) *Financial Times*, August 30, 1902

In the lower workings at the 500-feet level north, it widens out in places, however, I believe to 8 or 9 feet. The New lode, so far as it has been developed, appears from the company's report to

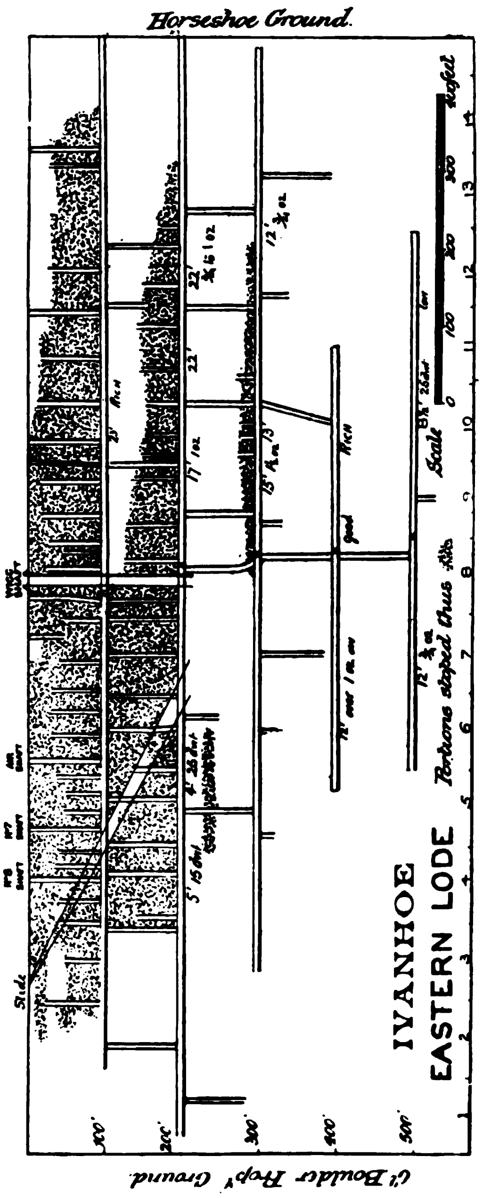


FIG. 71.

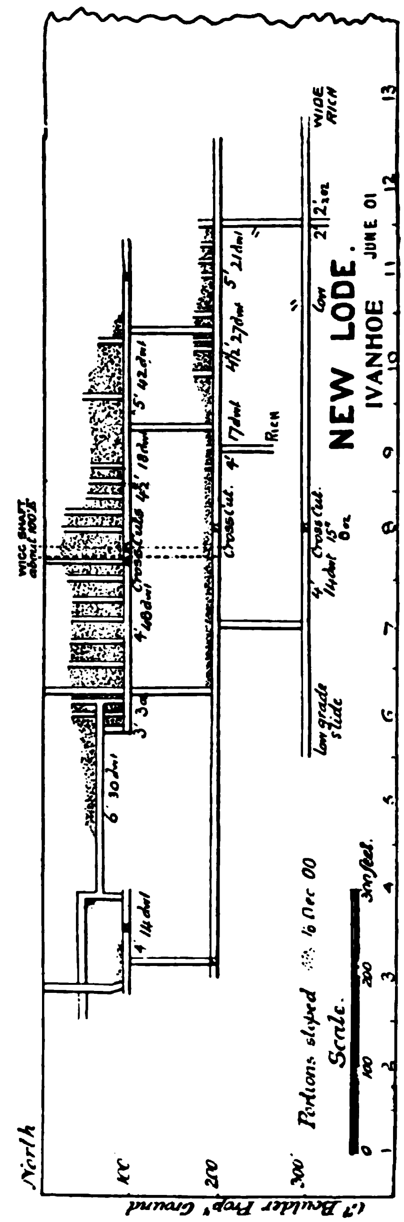
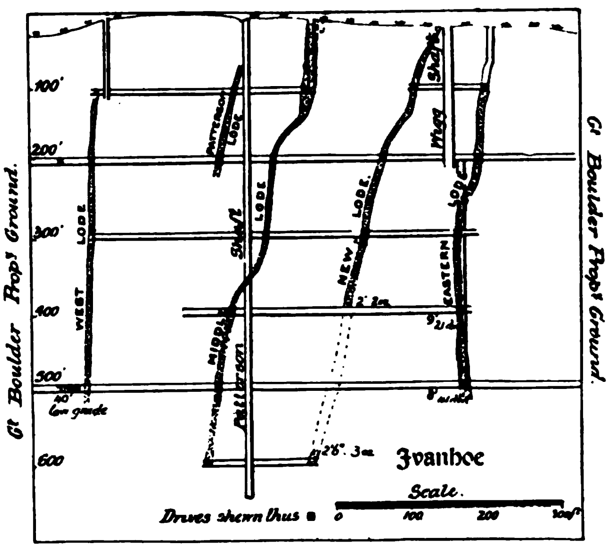


FIG. 72.

have ranged from 1½ to 5 feet in thickness, say 2 to 3 feet on the average (over a length of 400 to 600 feet). It is stated to be somewhat irregular and uncertain in value, but can be comparatively cheaply mined with a certain amount of selection in the stopes. The West lode appears to have been intersected in 1901 in the west cross-cut from Patterson's shaft at the 500-feet level at 266 feet from the shaft where driving was commenced on 21 inches of ore assaying 2 oz. per ton, but it is generally narrow—about 2 feet—and said to be patchy.



CROSS SECTION THROUGH WIGG & PATTERSON SHAFTS
SEE C—D ON SURFACE PLAN.

FIG. 73.

The trend of these various formations is shown on the "plan," which, to avoid complication, only gives the upper levels, and it may be noticed that the East and Middle lodes, which approach one another at the south end of the lease, branch off, going north, the one striking north-west, the other further to the west.

It is worth notice that both the Middle and New lodes show remarkable parallelism, down to the 400-feet level viewed in cross-section C D, Fig. 73, both exhibiting similar bends at the same horizon, as for instance, between the 100 and 200-feet levels, but they seem to approach closer together at the 600-feet level. During the first years of the company's existence, work was chiefly confined to the upper levels, but a large amount of development work at and below the 300-feet level has been done within the last two years, and in the middle of 1901, driving was commenced on the Middle lode at a depth of 600 feet. On the same lode, at the 500-feet level, nearly 1000 feet in all had then been driven. On the Eastern lode, at both the 400 and 500-feet levels, some 800 feet in the one and over 1000 of driving in the other had been executed at the end of 1901.

No development work had been done at the date referred to below the 500-feet level on the Eastern lode, beyond sinking to 600 feet, and commencing to open out at that depth, but the 600-feet level on the Middle lode was considerably advanced north and south of Patterson's shaft, which was put down to over 700 feet in depth.

In the early part of 1901 exploratory work at the 400-feet level is stated to have proved the New lode to be 2 feet thick, worth 2 oz. per ton, and where cross-cut at the 600-feet level it showed a thickness of 2 feet 6 inches, of a value of 3 oz.

In the northern part of the lease a cross-cut east from Drysdale's shaft at the 500-feet level, at 341 feet from the shaft, was stated to have cut the Eastern lode, 3½ feet thick, where it had a value of 1 oz. 4 dwt.

The progress report of February 15, 1902, referring to Drysdale's shaft, stated that at the 700-feet level, 40 feet east of the main shaft, an ore-body had been intersected which the managers took to be the "New lode," 2½ feet wide, average assay value 1 oz. per ton. A cable dated April 23 reported that the Middle lode had been cut at the 600-feet level in Drysdale's shaft, value over 2 oz. for a width of 7½ feet.

The progress report for the first half of May stated that the cross-cut west at the 700-feet level at 72 feet from Drysdale's shaft intersected an ore-body 15 inches thick assaying 2 oz. 4 dwt. per ton. This in the manager's opinion was the Middle lode * faulted west. In September a cable notified the cutting of the East lode at the 700-feet level; the full width given in a later cable being put at 9 feet, bulk assay 1 oz. 10 dwt. In December 1902, the east cross-cut from Patterson's shaft, No. 8 level (865 feet), cut the New lode at 47 feet width, 1¼ feet, assaying 1 oz. 5 dwt. per ton, and an office note stated that the lode between No. 7 and No. 8 levels has taken an easterly dip.

* The Middle lode in a winze below the 700-feet level has since been reported proved to have a width of 12 feet and an average value of 1 oz.

Several "faults" are stated to cross the "formations," but they do not appear to have "thrown" the main lodes appreciably out of their course, or "cut off" the ore-shoots, as frequently happens in other cases. The *Statist* observes that the Boulder lode has been brought into the Ivanhoe ground by a horizontal "slide" of this kind.

The widths and values of the formations shown in the three longitudinal sections given in the *Statist*, are indicated at different points by the figures upon them.

The shaded portion represents those parts of the formations that had been stoped out at the end of 1900, but the development work is carried up to June 30, 1901.

The tonnage of ore treated and amount of bullion won in 1899, 1900 and 1901 have been as follows:—

	Tons.	Contents, Oz.	Value, £ Sterling.
1898 *	28,765	53,727	208,292
1899	59,664	104,009	400,544
1900	74,750	107,141	408,065
1901	90,423	108,767	398,643

The dividends that the company paid up to January 28, 1902, amounted to 625,000*l.* and are shown in Table XII. p. 580; 38,000*l.* of the balance carried forward (after paying the final dividend for the year 1900) was set aside to be applied to additions to plant; an extra 40 stamps with accessories having been ordered. This has enlarged the battery to 100 heads at a cost of 38,825*l.*

In 1901, considerable sums were expended on capital account, chiefly with respect to the enlargement of Patterson's shaft, to provide for a larger output in connection with the increased capacity of the reduction works, and the decision of the Directors to press on with the development of the mine in depth.

The past heavy outlays on capital account should, however, gradually be greatly reduced; but the outlay upon development work may possibly be somewhat increased to correspond with the increased output.

The results that have been attained so far, are scarcely a fair

* Thirteen months.

criterion of what may be expected in the near future, assuming that now the full number of stamps (100) are in operation they should be able to deal with 12,000 tons a month, or more, as the alterations to the old battery were only completed towards the end of 1902.

All but a comparatively small proportion of the company's ore, both oxidised and sulphide, can be treated by the stamp-battery. The concentrates and any rich sulpho-telluride ore produced were formerly bagged and shipped to smelting-works, and as the bullion resulting from sales of ore to the smelters is returned, as is usually the rule, at its *net* value, the treatment charges upon it did not figure in the mine costs, as is the case with mines which do not ship ore to public smelting-works.

On December 31, 1900, there were reported to be 227,827 tons of ore in sight above the 500-feet level, and at grass; being 15,954 tons in excess of the amount on hand at the end of the previous year.

In 1901, the quantity of ore crushed and treated was 90,423 tons, which averaged 1 oz. 4 dwt. 1 gr. per ton. At the end of 1901, the ore in sight above the 600-feet level, including 10,000 tons at grass, was estimated at 313,971 tons of an average grade of 1 oz. 6 dwt. per ton, an increase of 86,144 tons over that in sight at the commencement of the year.

At the Annual Meeting of the Company on May 2, 1902, the Chairman, Mr. Francis F. Govett, is reported to have remarked :—

"Each of the main lodes appears as solid and good at the bottom as elsewhere, and I think I may fairly say there is no sign of the runs of ore shortening in depth.

"The length of the runs of ore and the regularity of the lodes are the great features of the mine, and this is where we have the pull over the rest of the field.

"We may not be so rich—even this has its advantages, as we are not so liable to robbery of rich ore—but we are regular, and where we drive a level, practically you may say we open up so much reserves. Now where lodes are long and regular, they are held to be more certain to continue in depth, and, unless something unlikely occurs, you may assume that our lodes do live down.

"I may not be able to bring home to you my convictions, but when I stood on the 1200-feet level of the Great Boulder—which is close alongside our East lode—and saw there a great solid lode

14 feet wide, with its magnificent run of ore, and reflected that this lode had been cut 300 feet below at the 1500-feet level, I can assure you it seemed impossible to have any doubt about the future of our mine."

Mr. Govett laid particular stress on the "efficiency of management," remarking: "I have studied report after report, and the lesson I have learned is, that the greatest economy is only obtained by the greatest efficiency.

"In England we find it difficult even to tear out worn-out machinery to replace by up-to-date."

The fact he mentioned, that the old stamps only crush 75 per cent. of the amount of ore the new ones are able to crush, coupled with the statement that repairs to the old mill cost about 4000*l.* per annum or over 1*s.* per ton, affords an admirable illustration why in America they re-model machinery when it gets out of date or when past services relegate it to the "scrap-heap." The old battery has therefore undergone alteration, and it is estimated that by a capital expenditure of 22,500*l.* by altering the old mill the net annual saving should amount to 35,000*l.*, without allowing for the additional economy of driving the battery with one engine in place of two; one of which is of an older type than the other. Mr. Govett further observed that "every mine has a scale up to which it can be legitimately worked, and the scale of 100 stamps is probably near the limit of the Ivanhoe, with its small area of 24 acres, notwithstanding its three main lodes.

"Anyway, before any extension can be considered, the first thing to be done is to make the equipment on the present scale absolutely *efficient and up to date*; in effect to crush the greatest number of tons with 100 stamps at the lowest possible cost.

"Slovenly machinery means bad work.

"Here in London we have perhaps not properly grasped the importance of getting absolutely the best work out of your machinery."

To do so Mr. Govett pointed out that a periodical inspection by a good mechanical engineer was requisite, and this in no way reflected on the staff, as but few mines are in a position to keep a first class man permanently engaged for this purpose. In other directions Mr. Govett foreshadowed a reduction in working expenses, such as :—

The introduction of two or three-ton skips automatically delivering the ore to the rock-breakers.

The installation some day perhaps of a central electric power station, in place of employing a number of small outlying engines. An alteration (under trial) in the old method of stoping, viz., "pyramidal stoping." The sale of sufficient gold in Perth to cover the monthly expenditure, and shipment of the balance to London to avoid borrowing against gold in transit for working expenses. Efforts initiated so as to secure legislation in order to reduce cost of living, supplies, etc.

The treatment of the concentrates on the mine by roasting and cyanide; reduction in the price of dynamite; the more extended use if found practicable of oil fuel; and the closing of the Melbourne office. The protection of the interests of Colonial shareholders by creating shares to bearer, the coupons on which are to be payable in Australia on the same date as the dividend is payable in London.

The progress reports are in future to be submitted in a different form, so as to make them clearer to the average shareholder.

The policy of "secrecy" about the operations of the mine, has been abolished, and friendly relations with other companies cultivated; and it was anticipated that economy will result by driving the main levels in future further apart.

No. 7 level is 125 feet below No. 6, and No. 8 will probably be driven 150 to 175 feet below No. 7, and ultimately they may be driven 200 feet apart.

The extraction in the sulphide works is reckoned at 86 per cent. and another 3 per cent is recovered by smelting, making a total of about 89 per cent.

Mr. Govett illustrating the difficulties of the conditions under which mining has to be carried on in Western Australia, mentioned that he believed that under the best conditions in England with water-power or gas, the cost of power per horse-power is about 4*l.* per annum; whilst the cost at the Ivanhoe was about 45*l.* per annum, which is "very nearly the cheapest on the field;" and it is certainly below the average; as Mr. Alfred James estimates * the average cost per horse-power at Kalgoorlie at between 50*l.* and 70*l.*† per annum, or 3*s.* to 4*s.* per diem.

As showing the effect of this he mentions that a cyanide plant treating 20 tons per diem and requiring 60 horse-power would cost

* *Cyanide Practice*, p. 103.

† The Author believes that with the best appliances 4*l.* per month is a low figure at Kalgoorlie, whilst at Cripple Creek the cost per horse-power per month may be reckoned at about 14*s.*

for this one item 180*s.* to 240*s.* per diem, or 9*s.* to 12*s.* per ton for horse-power alone.

Messrs. Bewick, Moreing and Co., who are the Consulting engineers to the company, in a report recently published,* to which reference has already been made, point out a fact the Author has laid stress upon, viz. that the Ivanhoe ore carries more quartz than most of the other Kalgoorlie mines, and that although it contains telluride, the distribution of the telluride is not, or at least has not hitherto, been found proportionate to the gold contents, but it occurs in isolated shoots or patches; for instance, as a stretch north of Drysdale's shaft on the Middle lode; the practical effect of this being to permit a large proportion of the ore being treated as a comparatively free-milling proposition; the proportion of the ore mined, which is of refractory nature, constituting, according to a careful estimate, about 14 to 15 per cent. of the whole. This more refractory portion on such levels as have been partially stoped, has hitherto been dealt with as already described by smelting, or treatment on a comparatively small scale at the mine; but the amount so treated has not been proportionate to the amount of free milling ore crushed, and the ratio of refractory to free milling ore, is therefore higher in the present and prospective ore-reserves, than originally in the mine.

The terms "refractory" and "free-milling" are, however, relative, as with the greatest possible care in sorting some proportion of refractory mineral is bound to be sent to the mill.

With the cessation of stoping in the oxidised zone, the difference between the two classes of ore is naturally becoming less marked than it was, and of late an occasional bunch of telluride ore has been found outside of the boundaries of the recognised telluride shoots.

The report states that steps will therefore have to be taken either to increase the proportion of refractory ore treated, or to so modify the existing treatment as to permit of dealing with the ore in bulk without seriously prejudicing the extractions obtained.

Another noteworthy feature is, that although the lodes seem to be practically vertical a series of step-faults occur, which successively throw the lodes in a westerly direction going down, producing the same effect as a westerly underlay.

These "slides," whilst they squeeze the lodes out of place, do

* Report dated Kalgoorlie, July 19, 1902.

not in every instance interrupt the continuity of ore-bodies, although as a rule there is a considerable impoverishment within the area of disturbance, and low values are met with.

A careful estimate of the ore-reserves made by Messrs. Feldtmann, Pritchard and Hollow, for Messrs. Bewick, Moreing and Co., showed the following ore-reserves:—

—	—	Gold Contents.	Av. Value.
	tons.	oz.	oz. dwt. gr.
Middle lode	171,350	206,589	1 4 2
East lode	155,150	158,209	1 0 9
Boulder lode	5,622	10,948	1 19 0
New lode	33,555	20,855	0 12 0
West lode	5·474	2,598	0 9 0
Surface	10,000	5,000	0 10 0
	381,151	404,199	1 1 5

A calculation made to determine the annual minimum rate of sinking to keep pace with the mill requirements showed that, taking No. 4 level for a basis of estimation, there were standing:—

	tons.
In the East and Middle lodes	84,550
In the New lode developed or to be developed	5,000
Stoped from the Middle and East lodes	22,000
	111,550

This is stated to be a conservative estimate (leaving out of account the West and Boulder lodes) of what, provided the lodes continue as productive as heretofore, they may be expected to produce per 100 feet in depth. Reckoning the output of 100 stamps at best at 170,000 tons per annum, a sinkage of 150 to 200 feet per annum should therefore keep the developments well abreast of the mill.

The report adds: "It is strongly to be recommended that the enterprise in development, and caution as regards crushing plant, which has characterised the company's policy in the past, be rigorously adhered to."

The equipment of the mine was detailed, and the treatment of the ore described, and as regards cost it was pointed out that in considering the cost of various operations there is no standard with which to compare them, except as regards mining, as the method of reduction has hitherto allowed of a simpler method of treatment than is generally applicable on the fields. Nevertheless, particularly as regards power costs, economies could proprobably be made; although with improved but increased complication in treatment, costs will tend to rise, to counterbalance which increased economy in other directions should be studied. In the mine report of September 30, 1902, it is stated that the consumption of water had been reduced to 10,900 gallons per diem, and the fuel burnt, to 97 tons. The mine report for October 1902, mentioned that on the East lode at the 700-feet level, there was 6 feet of solid stone in the north face worth 16 dwt., and a bore-hole to the west showed a value of 1 oz. 3 dwt. per ton. At the 600-feet level on the East lode the south drive was within 160 feet of the boundary in high grade ore, and the Report said:—"We have every reason to assume, that the shoot will continue right up to the Golden Horse-shoe, and if such proves to be the case, it will make the shoot practically 1250 feet long, and as proved by a cross-cut in Section 13, the lode was 18 feet wide worth 2 oz. 8 dwt. per ton, and bore-holes in every 15 feet showed the lode to be of considerable width for the greater part of the distance driven."

Further, it appears from the mine report for November, that at the 400-feet level, the East lode in Stope Section 6 opened out east on a flat ledge, making the ore body 30 feet wide, of an average value of 1 oz. 8 dwt. per ton. The report added "We are now stoping on this and have gone some 20 feet along the same, the width being maintained.

In the quarter ending September 30, 1902, an increase in the ore-reserves of 20,469 tons * was reported, which (on the basis of the yield of the ore crushed) may be reckoned to average about 26 dwt. In January 1903 a telegram stated † that in the West cross-cut 125 feet from Drysdale's shaft at the 700-feet level the Middle lode was intersected 2½ feet thick, assaying 32 dwt. per ton.

The Golden Horse-shoe Estates.

This property, which had an area of 24 acres, was acquired by the Golden Horse-shoe Gold Co. Ltd., December 31, 1894, from the Golden Link Company, the purchase price at first stipulated, being 7500*l.* in cash, and 57,500 fully paid shares of 1*l.* The shares at that time appear to have been considered less important than the cash, and the terms were after some negotiation reduced to 1000*l.* in cash and 64,000*l.* in fully paid shares; the shareholders subscribing for part of the balance of the shares (10,000) issued for working

* *Statist*, November 15, 1902, p. 859. † *Statist*, January 31, 1903.

capital, and the vendor company guaranteeing, it is stated, 5000*l.* additional for 5000 reserve shares, by which 11,500*l.* were provided. The authorised capital at this time was 80,000*l.*

On December 22, 1896, the capital was raised from 80,000*l.* to 100,000*l.*; 20,000 shares being issued at 10*s.* premium, which provided 30,000 additional, and the price of the shares having appreciated enormously (about 5000 per cent.), the present company was registered, February 28, 1899, each shareholder receiving three fully paid 5*l.* shares in exchange for his 1*l.* share. The present capitalisation is 300,000 shares of 5*l.* each, i.e. 1,500,000*l.*

In 1896 a few of the original 1*l.* shares were forfeited for non-payment of calls, and in the middle of 1899 these shares were valued at 50*l.*, the equivalent price in 1900 being about 37½*l.* The mine is an instance of great and unexpected results obtained on this field, largely owing to the pluck and pertinacity of a group of shareholders (some of whom were French) who stuck to it. The mine began crushing with a 20-stamp mill in September 1898, and the dividends paid in respect of 1898, 1899 and 1900, amounted to 675,000*l.*,* whilst in 1901 18*s.* per share was paid (=270,000*l.*).

The *Statist* in its issue of September 8, 1900, gave an excellent description of the then position of the company, from which some of the foregoing particulars are taken, and referred to a point which was formerly a matter of some speculation, if not apprehension, viz. the future ownership of what is known as "No. 4 lode," which lies near to the boundary of the Great Boulder. Fortunately, however, for the Golden Horse-shoe, the formation in question has so far gone down nearly vertical; and like the cry of "wolf," the theory that it might dip back into the Great Boulder has become too familiar to cause much uneasiness; a diagonal bore-hole put out from the Great Boulder from the 1400-feet level to the boundary of the Horse-shoe at 1600 feet failing so far to locate it.† The *Statist* of September 14, 1901, urged the desirability of pushing on with sinking. The management of the company appears to have been excellent, and the following table shows the quantity of ore crushed,

* Dividends of 15*s.* or 75 per cent. were paid in 1898 and 1899 by the old company, amounting to 150,000*l.*; whilst in 1899, although the dividends declared by the present company were at the same rate, owing to the increase in capital, they represented 225,000*l.*, and in 1900, 20*s.* or 100 per cent. which was paid per 5*l.* share, came to 300,000*l.*

† Winzes below the No. 7 level, sunk in 1901, indicated that it was again underlying west, though the lode it appears is nearer the boundary at No. 7 than at Nos. 5 and 6 levels.

oz. of bullion produced from all sources, and average yield per ton, at intervals of six months apart.

—		Tons Treated.	Oz. Produced.	Yield Per Ton.
				oz.
First Quarter, 1899		8,306	26,634	3·21
June ,,		2,608	8,577	3·28
January, 1900		4,071	7,189	1·77
June ,,		5,552	9,674	1·74
January, 1901	milled and cyanided	6,303	8,728	1·87
	smelted	1,857	6,573	
June ,,	milled and cyanided	6,590	8,980	1·85
	smelted	1,748	6,442	
December 1901.	milled and cyanided	6,922	8,264	1·85
	smelted	1,363	7,107	

The ground owned by the company until recently * consisted of a 24-acre block south of the Ivanhoe and west of a portion of the Great Boulder lease, and the position of the "formations" which traverse it and the mine workings are shown on the accompanying plan and sections (Figs. 74 to 77), which the Author has been permitted to reproduce by the courtesy of the proprietors, from the issues of the *Statist* of September 14 and 21, 1901.

The company's output is mainly drawn from what are known as No. 3 and No. 4 lodes, which are considered to be the principal ones; although other formations exist, which have not been opened up to any extent.

The richest "formation," known as No. 4, outcropped in the Great Boulder lease, but dipped into the Horse-shoe for a length of over 700 feet just above the 100-feet level, and has continued therein down to the No. 8 level. In parts this "formation" is extremely rich, 1500 tons milled in the early days at a public battery giving a return of 6 oz. per ton, of which 4 oz. is stated to have been caught on the "plates," and 2 oz. left in the tailings; and the pay-shoot apparently extends for some 700 feet, it having been stoped for about that length, at the first, second and third levels.

The *Statist*, in its article dated September 14, 1901, said:—

There was still some ore remaining between the first and second, and more between the second and third levels, yet to be taken out.

A little sulphide ore had also been stoped at the 400, 500, 600 and 700-feet levels. A considerable quantity of the sulphide ore between the 300 and 700-feet levels (the lowest level then driven) ranged from 3 to 10 oz. per ton.

* It has lately been increased to 86a. 3r. 24p. by the acquisition of five leases to the south of the original lease.

The cross-section Fig. 75 is taken through the main-shaft along the line marked A B on the plan, Fig. 74.

Fig. 77 gives a longitudinal section of the workings on No. 4 lode, and indicates the extent of the development work done upon

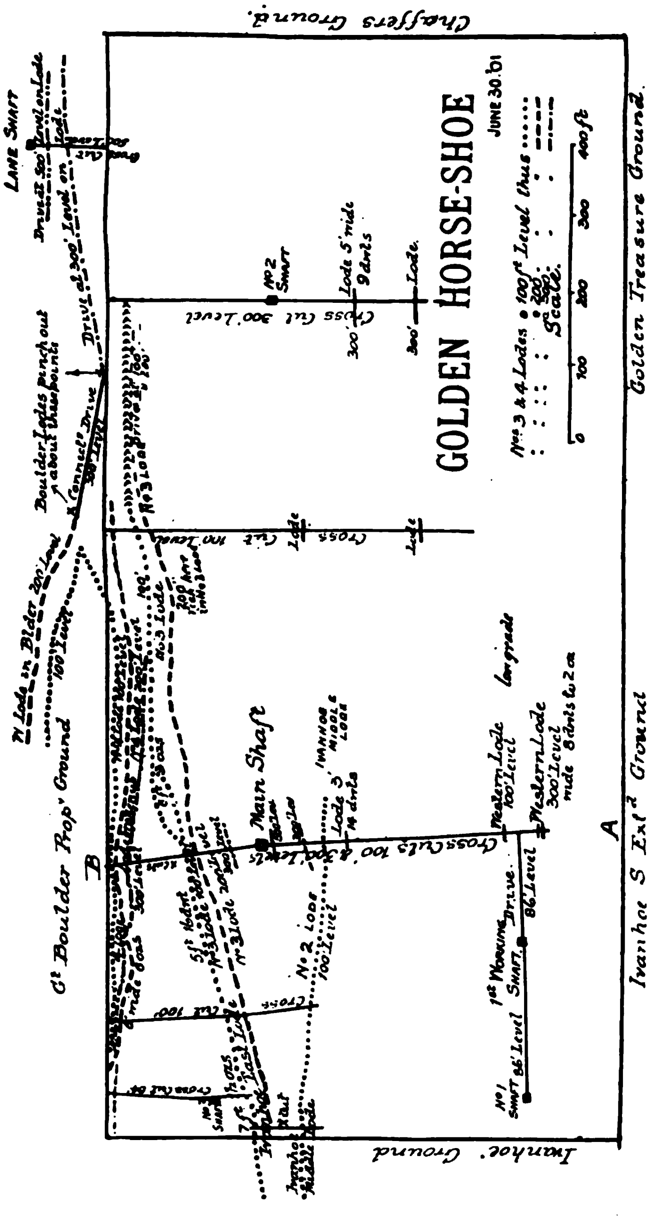


Fig. 74

it and the amount of ground "stoped out" up to June 30, 1901. This lode is reached by cross-cuts driven east from the main shaft, which had reached a depth of 730 feet at the end of 1900, and 830 feet at the end of 1901. The lowest level driven in 1901 on this formation was the 700-feet, but preparations were made for opening out at the 800-feet level. The distance from the main shaft to the western boundary of the lease, is about 220 feet.

GOLDEN HORSE-SHOE

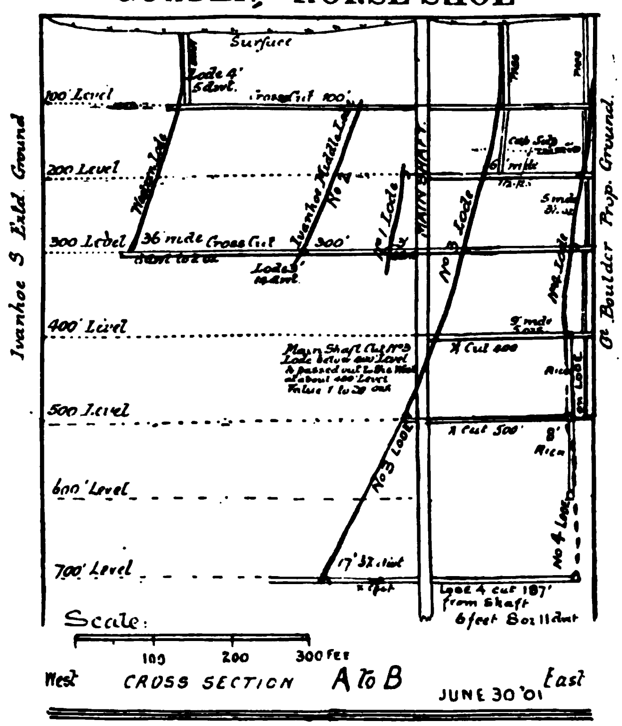


FIG. 75.

Another formation, known as No. 3, lies to the west of No. 4, and possesses a more distinct westerly "underlie" or "dip."

This formation had been proved from surface down to 700 feet in 1901, and was reported as being 17 feet thick, valued at 32 dwt. in the bottom.

Fig. 76 gives a longitudinal section of the workings on No. 3 lode, which down to the 400-feet level lies east of the main shaft; but crosses the shaft just before this point, and is intersected by cross-cuts driven west, at the 500 and 700-feet levels.

Except at the 100 and 200-feet levels no stoping and but little development work seems to have been done on this lode up to 1902, but the pay-shoot of ore at these levels, judging from the stopes, appears to have a length of 800 feet or more.

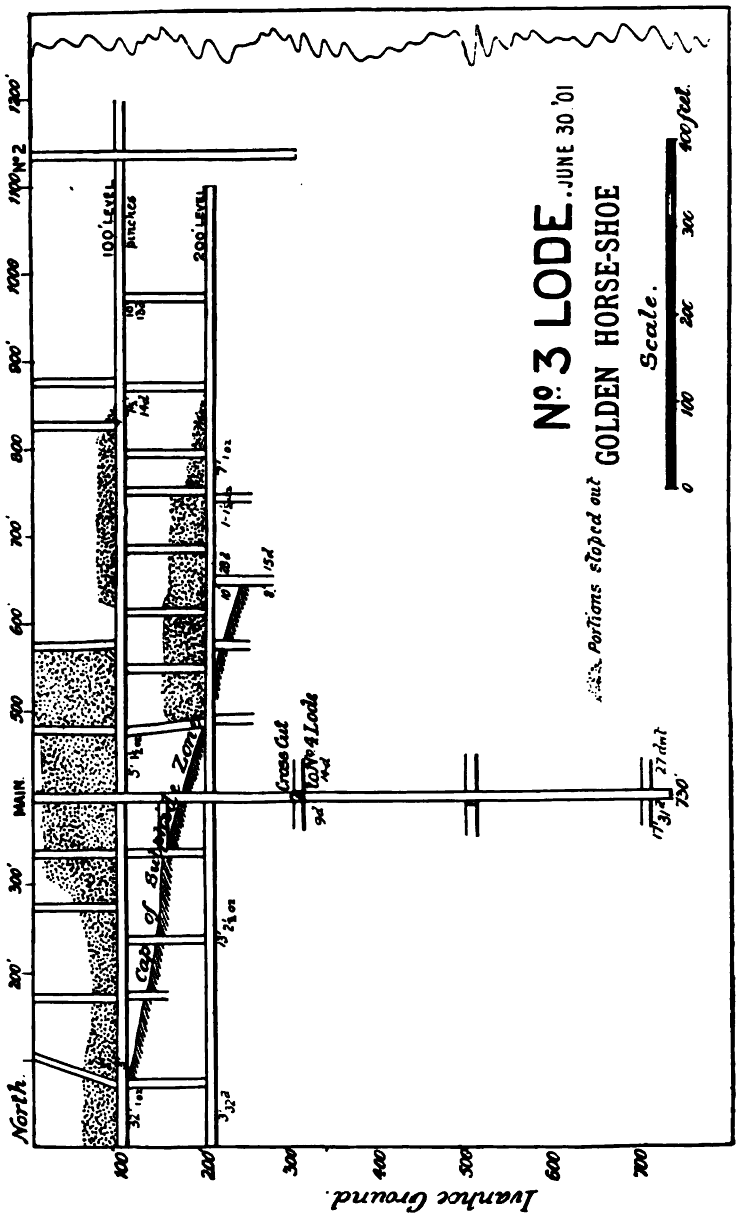


Fig. 76.

A third formation, known as No. 1, lies west of No. 3, but it had only been opened at the second and third levels, and was there of no great width or value.

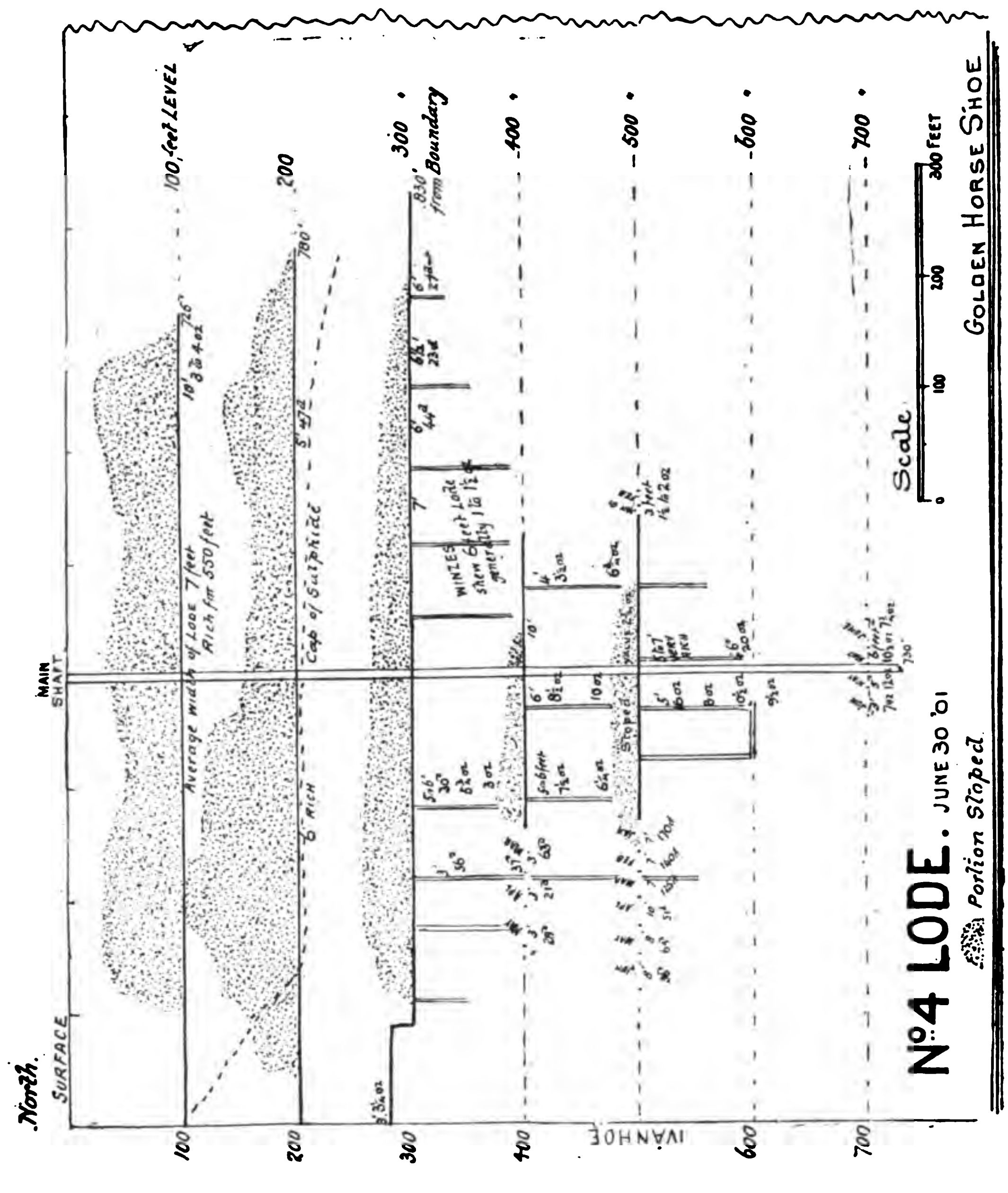


FIG. 77.

Still further west, the Ivanhoe Middle or No. 2 lode, had been opened on at the 100 and 300-feet levels, and in this latter level was, I believe, 3 feet wide, worth 14 dwt.; and 4286 tons removed in 1901 averaged ·69 oz.

On the western side of the lease, there is a large low-grade lode, known as the Western lode, which had been intersected by cross-cuts from the main shaft at the 100-feet and 300-feet levels. Near the surface this lode was driven upon some distance, but was comparatively narrow and low-grade; at the 300-feet level the *Statist* observed that "its value ranged from 8 dwt. to as much as 2 oz. over a width of 36 feet"; and expressed the opinion in this connection that there are great possibilities presented by it, although work has been mainly concentrated on No. 3 and No. 4 "formations." 351 tons removed in 1901 only averaged, however, ·33 oz. per ton. At the north end of the property the oxidised zone goes down about 100 feet; but south of the main shaft, it seems to go down about 200 feet on No. 3 lode.

A feature noticed in the case of the Ivanhoe is repeated also in the Horse-shoe, but reversed, the No. 3 and No. 4 lodes, which are a considerable distance apart where they cross the north boundary line of the Horse-shoe lease, approaching close together as they trend southward.

Driving at the 300-feet level had been commenced in 1901 on No. 3 lode, and values, it was stated, ranged between 9 and 14 dwt.

At the 700-feet level values were higher than at the 300-feet, averaging about 1½ oz. over a width of 17 feet for some distance.

The company till quite recently was crushing oxidised ore mixed with a certain amount of sulphide ore, whilst the richer sulpho-telluride ore is smelted, but a "sulphide plant" was erected at the mine in 1902.

The reports of December 31, 1899, 1900, and 1901 show the amount of ore standing in sight at those dates as estimated by Mr. J. W. Sutherland, the General Manager, as follows:—

—	Oxidised.	Sulphide.	Total.
	tons.	tons.	oz.
Ore in sight December 31, 1899	129,809 22,000	.. ..	216,785 8,800
" " 1900	*132,925	100,340	..
" " 1901	†112,562	†435,966	773,241

* Including 20,000 tons of lower grade stone.

† These figures included "estimated" ore not ready for stoping; viz. oxidised ore 23,888 tons, containing 10,666·40 oz., and 245,996 tons of sulphide ore, containing 301,850·04 oz.

The original 50-stamp battery seems to have attained its maximum capacity in July 1901, when it put through 7610 tons, its output during the previous six months ranging from 5507 to 6590 tons; but the mine output in bullion has been very constant, ranging from January to September 1901, from 15,300 oz. to 15,461 oz., and 15,371 oz. in December.

This gold represented a monthly revenue of about 59,450*l.*; and the company earned a sufficient profit to distribute 345,000*l.* during the calendar year 1901. The original battery of 30 stamps was increased to 50 in 1900; and an additional 50 stamps were erected in 1902, for dealing with sulphide ore; this should add largely to the revenue of the company in 1902–1903. Payment for this additional plant was provided for by borrowing 50,000*l.* on debentures at 6 per cent. repayable in three years,* to be written off out of revenue in that period. Under these conditions costs should be reduced in 1902–1903, and it should pay to treat ore that would at present be unpayable, although, crushing larger quantities of sulphide, a reduction in the average grade† of the ore seems not improbable, unless it is compensated for by crushing and smelting a larger proportion of rich sulpho-telluride ore, which would tend to maintain it. As less free-milling ore comes to be treated, some attendant increase in milling costs would also appear likely. The company possesses a small water jacket and refining furnace of its own on the mine.

An interesting cable, dated December 3, was published in the *Financial Times* of December 5, 1901, as follows: "Have resumed sinking main shaft; have started cross-cuts to the east and west on the 800-feet level. In the stope on No. 4 lode on the No. 6 level have struck a seam of thin almost solid gold, one piece (containing) 96 oz. of gold." New plant arriving rapidly.

A cable dated March 19, 1902, evidently referring to No. 3 lode reported, "800-feet level cross-cut to the west 66 feet, have cut a body of ore assaying 26 dwt. per ton of 2240 lb. 3 feet wide"; and the chairman of the company, Sir John Purcell, K.C.B., at the Annual Meeting (April 30, 1902) stated that No. 4 lode had just been cut at 800-feet level, 37 feet within the boundary dipping to the west, and it was reported 5 feet wide, assaying 2½ oz. per ton. The mine report for June 1902, recorded some

* 8000*l.* out of profits in 1901 was set aside for the redemption of these debentures.

† This was reckoned officially at the end of 1901 at 0·45 to 0·85 oz. per ton of oxidised ore, and from 1·23 to 2·03 oz. per ton for the sulphide; there being, it was calculated, 189,970 tons of the latter value in sight.

high assays in respect of the lowest levels. Thus, at level No. 6 the No. 4 lode was reported to average 3 oz. 9 dwt. in the north drive, and 2 oz. 10 dwt. in the south drive.

At the No. 7 level the No. 3 lode was the full width of the drive and averaged 1 oz. 3 dwt. On the No. 4 lode, a winze 25 feet south had been sunk 18 feet and the lode for the full width was reported to average 7 oz. 18 dwt.; a winze 95 feet south, which had reached the No. 8 level, gave 17 dwt.

At No. 8 level the north drive on No. 4 lode had been extended 39 feet, total 83 feet; the ore-body being the full width of the drive, and averaging 6 oz. 2 dwt. per ton. The south drive had been extended 35 feet, the lode being 4 feet wide and averaging 35 dwt. Driving on the lode met with 66 feet west of the shaft had been started. For 12 feet south the width averaged 5 feet, and the value 1 oz. 4 dwt., for 10 feet north a width of 5 feet and an average of 1 oz. 2 dwt. In November it was reported to be the full width of the drive, assaying 1 oz. 17 dwt., and a winze was being put down from No. 7 level to ascertain whether this formation is the same as No. 3 lode, which ought to be further west.

The total production of gold to December 31, 1901, amounted to 19 tons 1 cwt. 1 qr. 0 lb. 9 oz. (standard troy); and the dividends to the end of 1901, including those of the old company, totalled 945,000.

The ore reserves actually in sight and ready for stoping on June 30, 1902, are stated * to have amounted to 445,295 tons of ore containing 697,230 oz. of gold, as against 278,644 tons of ore, containing 460,725 oz. of gold on December 31, 1901.

The Great Boulder Perseverance.

This property was acquired in June 1895 by the British Westralia Syndicate, and in September of the same year was transferred to the present company (which has a capital of 175,000*l.*) for 125,000 fully paid 1*l.* shares; the parent syndicate subscribing for 30,000 shares at par to provide working capital, and the remaining 20,000 shares being afterwards issued. Owing to the want of system which was reported to characterise the underground workings of the mine in the early days of the field, it was irreverently spoken of I believe as a "rabbit-warren"; but all this has been

* Circular issued December 16, 1902.

changed under its present management, and it is a property which has generally been held to possess exceptional possibilities.

An interesting description of the property is given in the *Statist* of September 1, 1900, illustrated by a plan, Fig. 78, which the

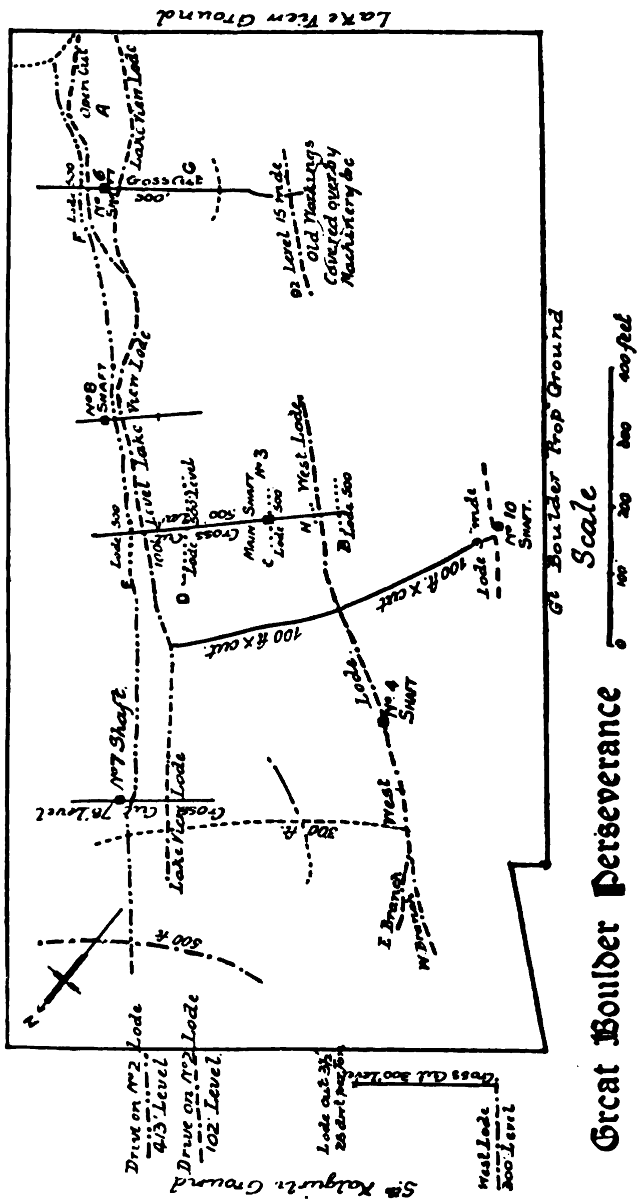


Fig. 78.

proprietors have kindly allowed me to reproduce, upon which I have plotted work since done; the results of operations in 1901 were dealt with in the *Statist* of March 15, 1902.

Crushings started in 1896, and for some time subsequently the grade of the ore milled was conspicuous for its variations; andowing to the small amount of water the mine yielded in the early days of its existence, the ore was hauled several miles by cart to a public battery, entailing considerable expense; but this was done away with later on, and arrangements were made to deliver it by rail.

The lease (which lies north-west of the Lake View and south-west of the Associated, with the South Kalgurli north and the Great Boulder south-west of it) has a length of some 1440 feet, and two masterly lodes are known to traverse it known as the Lake View lodes and the Perseverance lodes; judging from the plan, there appear however to be indications in the 500-feet cross-cut from the main shaft of the existence of four other formations (two in between and two to the south-west of what are considered to be the principal lodes) which so far have been scarcely touched.

The *Statist* in the article referred to, pointed out that the possibilities of the mine yielding large bodies of ore are undoubtedly very great, remarking however, that "the lodes as they traverse the property are not regular or uniform either in width or value, a fact which few mining investors stop to consider when dealing with the lodes of this gold-field."

"The uniformity of the returns from the various mines on the Rand is only obtained by sound scientific mining, and there is no reason why the same regularity should not be obtained from the Kalgoorlie mines, it is simply a question of having sufficient ore reserves to work from."

"The general manager of the Perseverance mine has called attention to the great care necessary in sampling a mine where the lodes are so irregular in width and so very variable in value, and until further work has been done, he did not feel justified in estimating the ore reserves.

"That there are certain difficulties in this direction is seen from the fact that at the point marked A on the plan the lode between the surface and the 100-feet level has been stoped (worked by open cast) and treated, for a width of no less than 100 feet, whereas at the 200-feet level it has narrowed to 30 feet, whilst further along the line to the north the lode has a width of a few feet only and is of low grade."

The two principal lodes which have been developed are known respectively as the Lake View, and the West or Perseverance lode. Their position is approximately shown on the plan, the broken lines tracing their course at the 100-feet levels, the dotted lines the driving done at the 500-feet level.

The Lake View lode has, apparently, a distinct easterly dip, the Perseverance less so, and they show a tendency to run together at the south-east corner of the property, and conversely to separate farther apart going north.

The Lake View lode comes in from the Lake View Consols, where it was both wide and rich, and shafts 6, 7 and 8 are located upon its course.

This formation is exceptionally wide at the south end of the property, where the ore proved of good grade, whilst at one point at the 500-feet level it is stated to have been 40 feet wide, valued at 35 dwt. At this end of the mine the formation splits into two branches, but these appear to be closing together as depth is attained. Its average width so far as it had been developed at the end of May 1901, was estimated by Mr. Nichols at 20 feet.* Its average width from the 200 to the 700-feet levels was, however, given in a circular published in the *Financial Times* of May 2, 1902, as being 14 feet valued at 1 to 2 oz. The upper levels in the northern section of the lease are said to be poor. The official plan carried up to December 31, 1901, shows that the Lake View lode has been driven upon for about 1300 feet at the 500-feet level to within some 150 feet of the north-west boundary. It was cross-cut at the 700-feet level in January 1901, and at the end of the year the 700-feet, which was the bottom level at that date, had been driven north about the same distance as the 500-feet level above; and 100 feet or more south of the cross-cut from the main shaft. A feature of some importance is that the Tetley lode in the Associated runs in the direction of the north end of the Perseverance lease, and the expectation entertained that it would traverse it in depth (as this vein has a strong westerly dip in its upper levels) has been confirmed by recent developments.

It would be rash to assume however, as other cases have shown, that because the Lake View lode in the Perseverance has an easterly dip, it will be carried into the Associated in depth; but it is probable, judging by their respective angles of dip, that the Lake View

* *Financial Times*, June 1, 1900. Report of the Annual Meeting.

and Tetley's lodes may junction in depth, at somewhere between 1000 and 1200 feet vertical, and this may lead to very important developments hereafter, in the Boulder Perseverance ground, whilst the question of the Associated ultimately getting the Lake View Perseverance lode in depth depends upon which formation masters the other, or whether they cross one another undisturbed. The discovery was reported in 1900 in the cross-cut, south-west of No. 6 shaft, at the 500-feet level, of what seems to be the extension southward of one of the middle formations before referred to, which was stated to be 5 feet wide, valued at 4½ oz. per ton; it is not clear, however, whether this is a branch of the Lake View formation or an entirely separate one; but it seems not unlikely that it may be the same as that discovered in the Lake View 66 feet east of the Perseverance.

The West or Perseverance lode which is worked from the Main (No. 3) and upon which No. 4 shaft is sunk, has a more vertical dip than the Lake View lode, though it "hades" somewhat to the east; owing to its "course," its deep levels are practically assured to the Perseverance, and on the whole it seems to have been so far more extensively opened up, and stoped upon to a greater extent than the Lake View formation; the deepest level shown on the published (1901) plans is the 500-feet.

The *Statist* in the article previously quoted (September 1901) remarked: "The lode is very irregular, both in value and width. The average width is set down by the manager at 8 feet* as against 20 feet for the Lake View lode; but the bulk of the richest ore developed in the mine is from this West lode.

All the five formations at B, H, C, D, and E, intersected by the cross-cut at the 500-feet level, were reported by the manager to be of "great strength and good values."

The formation near the Western boundary at No. 10 shaft has been only opened up superficially, and so far seems of little value.

At the company's annual meeting in 1901, the chairman, Mr. Frank Gardner, mentioned that Mr. Nichols had informed the Directors in October (1900) that whilst declining to estimate accurately the tonnage and value of the ore reserves he gave it as his opinion that down to the 500-feet level 250,000 tons† of sulphide ore of the average value of 1½ oz. might be reckoned on.

* It would appear from a circular issued in May 1902, that the average width from the 200 to the 700-feet level may be reckoned at 13 feet at the value of from 1¼ to 1½ oz.

† The oxidised ore is reckoned at 16 cubic feet per ton. The sulphide ore is reckoned at 13 cubic feet per ton.

With reference to the oxidised ore, Mr. Nichols in his Annual Report for the year ending December 31, 1900, said, "The oxidised ore at the present time is all coming from the open cut blocks L, 11, 12, 13, north of the mine office and in the workings down to the 100-feet level."

"It is impossible to say how much oxidised ore we have left in the mine, as the values occur in lenses in a wide vein formation."

"We have extracted during the past year 21,880 tons of oxidised ore, and to-day there is more ore in sight than there was a year ago."

The total amount of development work done on the property on December 31, 1900, in shafts, winzes, rises, cross-cuts and drives (not including stoping) was given as 16,956 feet; 5308 feet having been accomplished in the preceding twelve months.

In 1900, in addition to oxidised ore crushed, and sulphide ore treated and smelted, 25,990 tons of tailings were cyanided for a yield of 13,283 oz. 18 dwt. 7 gr., but the supply of tailings sands was stated to be becoming exhausted.

It appears from the Company's Annual Report to December 31, 1900, that most stoping was done on the Perseverance lode, in the sections of the mine lying to the north and south of No. 4 shaft above the 100 and 200-feet levels, and above the 300 and 500-feet levels north and south of the Main shaft. On the Lake View lode some ore was taken out above the 50-feet north, between No. 7 and No. 8 shafts; north of No. 6 shaft at the 40-feet level, and south of that shaft above the 200 and 400-feet levels.

The Perseverance lode, where the 700-feet cross-cut intersected it in November 1900, was reported to have a width of 6 feet of an average value of 1½ oz. per ton, and the Lake View lode in the same cross-cut (intersected in January 1901), had a width of 20 feet, 5 feet of which gave an average assay value of 2 oz., the remaining 15 feet being low grade, running from 2 dwt. to 1 oz.

At a point much further north, viz. the 300-feet level (reached by a cross-cut from No. 4 shaft) a diamond-drill bore-hole put down to intersect the Lake View lode, cut a formation 20 feet wide, which assayed 4 oz. 4 dwt. The Directors' Report in July 1901 stated that it was anticipated as driving on the course of this lode proceeded, which it was doing at the rate of about 10 feet per week, it would be found of much higher value than was so far shown. A paragraph in the *Statist* of November 23, 1901, said, "Developments at the 700-feet level continue of a satisfactory character. In the north drive off the east cross-cut from the main shaft the ore is reported to show an average value of over 2 oz., width not stated, while in the south drive the grade is fair, and improves as the drive is extended."

In the Directors' Report (for the year ending December 31, 1901) dated March 10, 1902, it is stated that Mr. Nichols, estimating on a most conservative basis, reckoned the reserves of ore down to the 700-feet level on December 31, 1901, at 295,771 tons of the average value of 1½ oz.

On January 30, he advised the Board by cable that:—

"The Tetley lode had been cut by diamond-drill at a depth of 835 feet for a width of 30 feet; and 2-feet section assaying 2 oz. 7 dwt., and a 6-feet section gave an average assay of 1 oz. 2 dwt. per ton. Four days later the same lode was proved at the 500-feet level for a width of 8 feet assaying 18 dwt., a 2-feet section assaying 1 oz. 7 dwt."

The point (Block P 24) where this strike was made, is at the southern end of the property about 250 feet from the Lake View boundary, and the chairman stated at the Annual Meeting (March 19), that they had learnt by cable since, that the Tetley lode had cross-cut at the 500-feet level near the bore-hole 5 feet wide assaying 24 dwt.

"The Lake View lode was located by diamond-drill boring at a depth of 900 feet on February 25, the width not being advised. A 2-feet section assayed 13 oz. This discovery was made in Block M 7, about 275 feet from the South Kalgurli boundary at the northern end of the property, and proves the continuance of the Lake View lode in depth for a distance of about 1100 feet through your lease.

"In Mr. Nichols' estimate of ore-reserves no account was taken of any ore on this lode below the 400-feet level at the south end of the property nor below the 700-feet level further north."

Mr. Nichols, in his Annual Report for 1901, referring to the Perseverance lode, said:—

"The estimated reserves of ore in this lode are practically all in one shoot, one of the longest and strongest ore-shoots that I know of on the Kalgoorlie field. During the past year we have stoped and milled from this lode nearly 51,000 tons of ore, and from the Lake View lode 33,000 tons.

"You will see from the estimated present reserves of 295,771 tons, 111,535 estimated in Lake View lode and 184,236 in Perseverance lode, that the ratio of ore taken from the two lodes during the past year and that now standing is about the same.

"It has been our aim to make a mixture from all parts of the mine so as to keep the grade of the ore uniform as nearly as possible. By mixing the ore as in the past we shall be able to maintain about the same average of 30 dwt., and this with present estimate should last about three years.

"Oxidised Ore.—We have more ore in sight than was exposed the first of last year, and we shall probably be able to keep the battery running for seven or eight months longer and possibly for the rest of the year.

"I think we are safe in counting upon from 12,000 to 15,000 tons of oxidised ore in sight, with a possibility of slightly increasing this amount."

The total amount of development work done on the property in shafts, rises, cross-cuts and drives on December 31, 1901, was given as 23,485 feet, 6529 feet of which was done during 1901.

2798 tons more of oxidised ore were treated in 1901 than in 1900, but 586 oz. less gold was recovered.

The total tonnage treated at the Lakeside Cyanide Plant amounted to 35,198 tons, and Mr. Nichols remarked that with the sands and slimes on hand, and produced during the year, they would have sufficient to keep the plant running on about the same grade of material as treated during the past year.

Some 70,000 tons of tailings at the sulphide works were estimated to contain about 17,000 oz., from which Mr. Nichols reckoned that 25,000*l.* to 30,000*l.* could be recovered at a cost of under 8*s.* a ton.

The tailings recently produced were stated, however, to be too low grade to pay for re-treatment.

Details of the returns from ore treated up to that date were given in the *Statist* of October 12, 1901, and it will be seen that from May to August from 7000 to 7200 tons of sulphide ore were dealt with monthly in the company's works; and in September they reached their full estimated capacity with four furnaces of 7500 tons; but in October they exceeded this, crushing 8000 tons,* for a yield of 11,529 oz. of bullion, which with 1779 oz. obtained from oxidised ore was valued at 48,740*l.*

The bullion produced from July to September stood very

* With the new engine and condensing appliances installed, Mr. Nichols in the Annual Report, December 31, 1901, said, that instead of having a capacity of 9000 tons per month, the works should be capable of treating 10,000 tons with the six furnaces in operation.

constant at between 12,629 oz. and 12,667 oz. per month, of an estimated value of 44,845*l.* to 46,580*l.*, and in January 1902, the returns reached an estimated value of 53,500*l.* Concurrently with an increased yield, the cost of treatment in the reduction works has also steadily fallen several shillings below the figure at which it formerly stood, and capital charges, which have been a heavy tax on revenue, appear to be nearly at an end.

The chairman of the company at the Annual Meeting, July 12, 1901, stated that Mr. Nichols had informed him, that when the outlay on plant came to an end and the new sulphide plant was in full working order, a monthly revenue of 42,000*l.* to 48,000*l.* with an expenditure of about 20,000*l.* might be anticipated; and at the Annual Meeting on March 19, 1902, he foreshadowed a yield of 15,000 to 17,000 oz. a month, or a revenue sufficient to more than pay dividends of 2*l.* per annum. The main shaft had been sunk to a depth of 908 feet on January 1, 1902. In their Report dated March 10, 1902, the Directors stated that they proposed to write off the items shown in the Appropriation Account to the exact amount of the original working capital and plant, machinery and buildings, which after allowing for depreciation written off in various years, appeared in the books as worth 230,956*l.* 15*s.* 2*d.* and would in future be shown at only 25,131*l.* 19*s.* This in itself is equivalent to the establishment of a very considerable reserve fund.

In April 1902, the Perseverance lode was cross-cut at the 900-feet level, the average width being given as "12 feet, assaying the same value as at the 500 and 700-feet levels."

The Lake View lode was also cross-cut at the 900-feet level towards the end of June 1902, width 15 feet, assay value same as where cut at the 700-feet level. At the latter level the width was 20 feet, the first 5 feet averaging 2 oz.*

COMPARATIVE SUMMARY, 1900–1901.

—	1900.	1901.
Revenue from bullion	£160,368	£487,734
Mining, treatment and management	103,626	223,510
Development	28,338	41,978
Depreciation	7,615	6,766
Equipment written off	..	44,425
Net profit	17,743	163,555
Dividend	..	87,500
Yield from all sources, oz.	48,102	134,219
Sulphide plant, average cost per ton	34*s.* 11*d.*	24*s.* 10*d.*

* *Statist*, June 21, 1902.

In its issue of March 15, 1902, the *Statist* gave a comparative summary of operations in 1900 and 1901. (See Table on preceding page.)

The company paid its first dividend of 10*s.* per share (i.e. 87,500*l.*) on January 10, 1902, and has since declared four dividends of 10*s.* each. From a cable in November 1902, it appears that the drive south on the Perseverance lode at the 700-feet level showed high values, the last 100 feet being reported to average over 1½ oz. A circular issued in October 1902, stated that the ore reserves were "more than they were on December 31, 1901."

Worked, on miner-like and economical lines, as it now appears to be, the future prospects of the mine certainly seem extremely bright, and it should be a large and regular dividend-payer.

The Associated Gold-Mines.

The position into which this company at one time fell was much to be regretted, as it was undoubtedly in the early days a mine which appeared to have possibilities second to none on the field by reason of the remarkable width and richness of some of the ore-bodies in its upper levels; indeed, I cannot but think that with more extensive development in depth it is likely to again take a good position. A description of this property was given in the *Statist* of October 6, 20, and 27, 1900, which gives a number of interesting particulars, that I have quoted and, by the kindness of the proprietors, I am able to reproduce the plan and sections (Figs. 79 to 81) that illustrated the articles referred to.

The leases comprised in the original area of about 198 acres which the company possessed, were pegged out in different parts of the field for the Coolgardie Gold Mining and Prospecting Company (original capital 225*l.*), and comprised the properties now owned by the Associated Northern Blocks (one of which is the Iron Duke); the Lake View South, the Lake View Extended, and the four leases the company still hold, viz. the Adelaide Lease (south of and adjoining the Lake View South, and Lake View Extended), and the principal "sett" which comprises three leases known as the Australia, Australia North, and Australia East, that form a compact block of about 52 acres, situated some distance north-west of the Adelaide.

The Associated Company was formed, I believe, in December 1894, the purchase consideration being 271,485 fully paid shares and

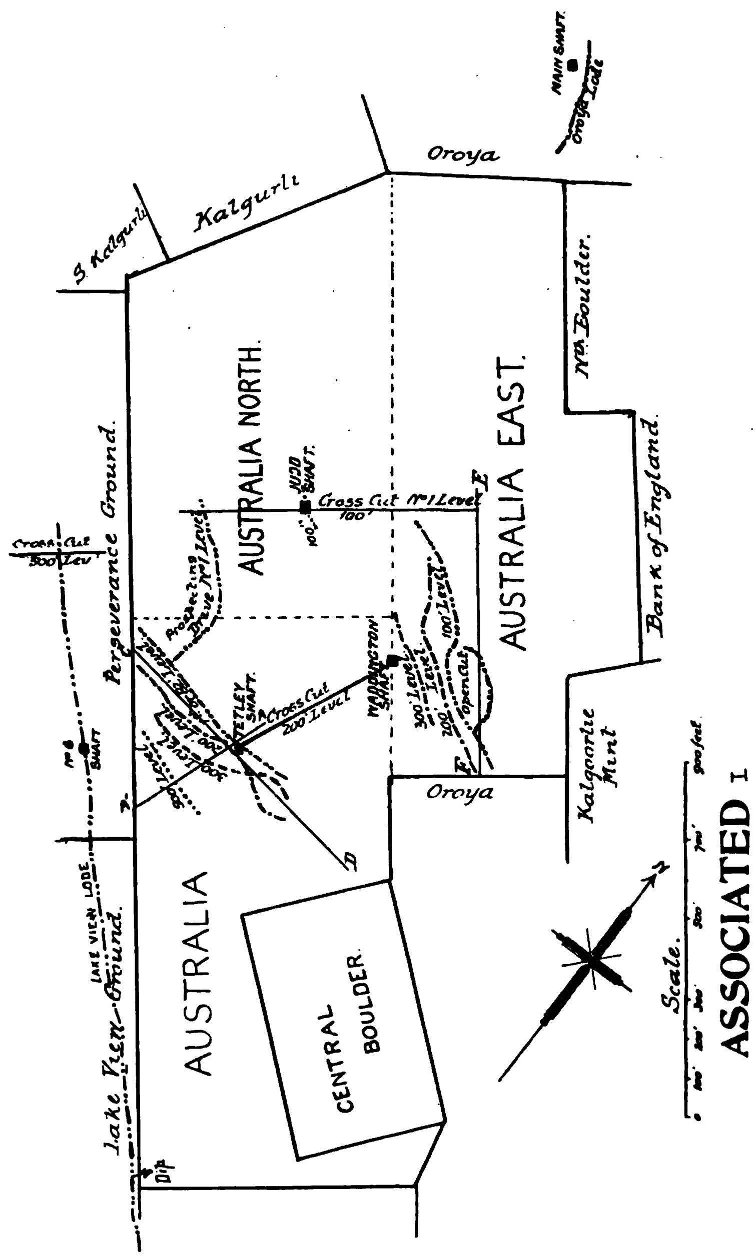
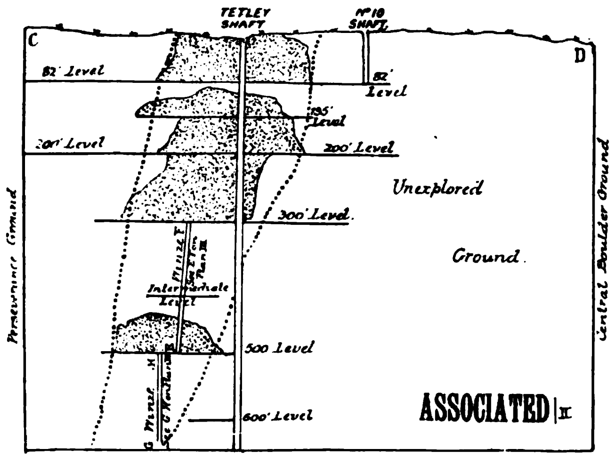

Kalgurli
S. Kalgurli
Oroya
Main Shaft
Oroya Lode
Nth. Boulder
Bank of England
AUSTRALIA NORTH.
AUSTRALIA EAST.
Judd Shaft
Cross Cut No 1 Level
Perseverance Ground.
Tetley Shaft
Cross Cut 200 Level
Waddington Shaft
Open Cut
Oroya
Kalgoorlie Mint
Lake View Lode
Lake View Ground.
AUSTRALIA
CENTRAL BOULDER.
Dip
Scale.
ASSOCIATED I

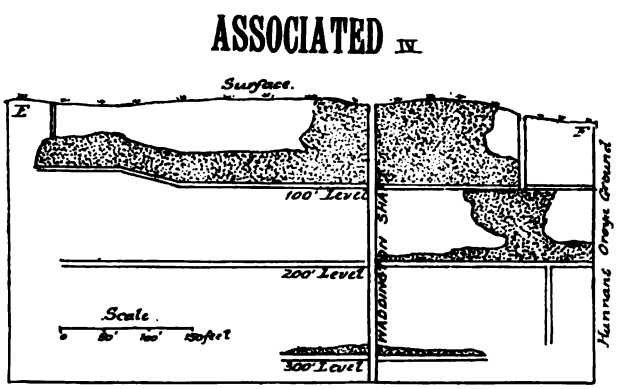
FIG. 79

53,515*l.* cash ; and 50,000*l.* was subscribed at par for working capital, making the original capital in 1*l.* shares 375,000*l.* Subsequently, in November 1897, power was taken to increase the capital by 125,000



Longitudinal Section . AUSTRALIA LEASE
See C-D on Plan I

FIG. 80.



Longitudinal Section Australia East Lode.
See E - F on Plan 1.

FIG. 81.

shares, bringing it up to the nominal sum of 500,000*l.*, of which 492,971*l.* had been issued on March 31, 1901, and 495,701 on March 31, 1902 : out of which a small number of shares (293) were forfeited.

In addition to the first issue of 50,000 shares at par, a second issue of 75,000 shares at $2\frac{1}{2}$ was made in November 1897, and a third issue in September 1899, of 42,971*l.* shares at 12*l.* each, which

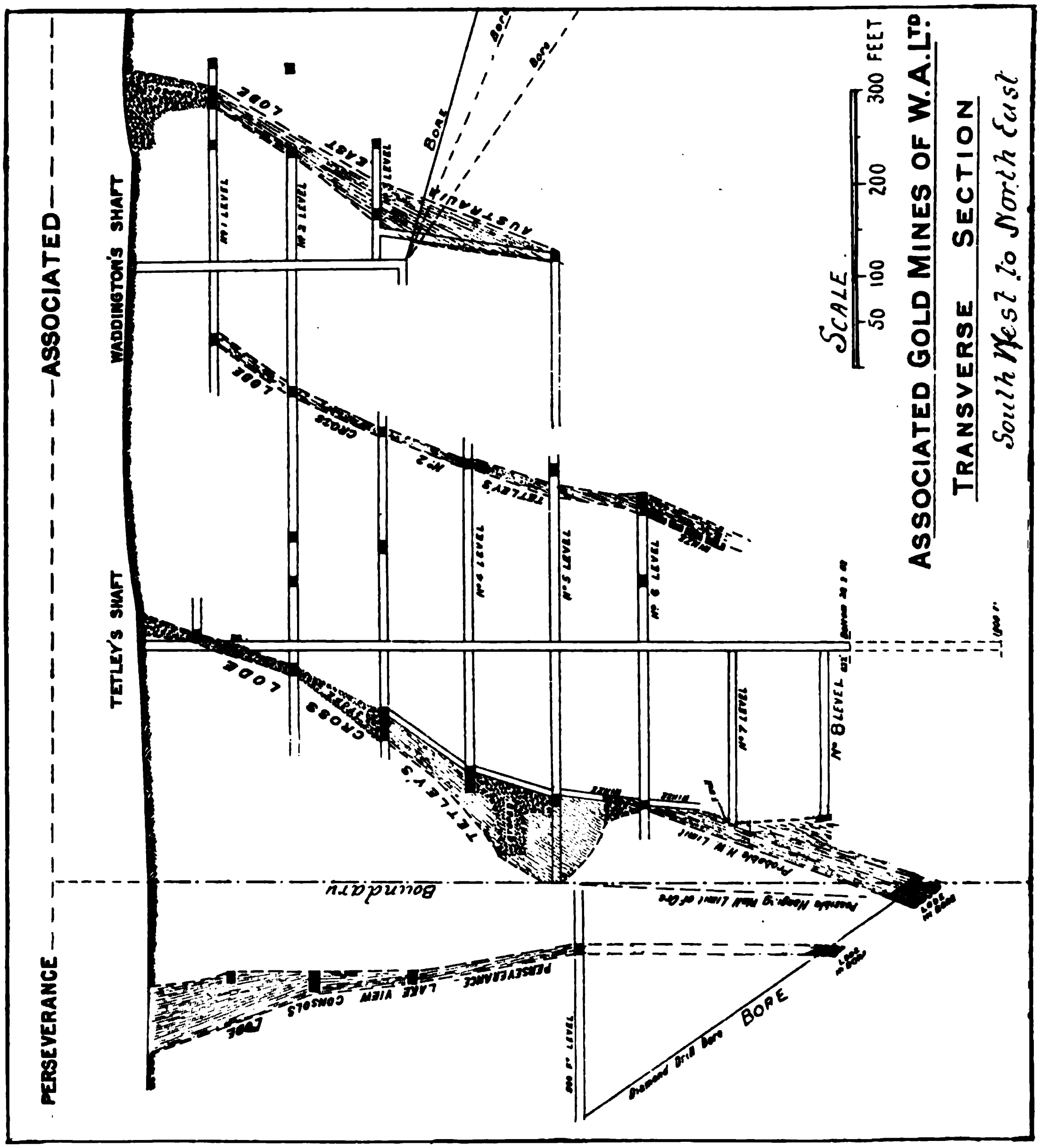


FIG. 82.

provided the company with a working capital of 753,152*l.*; a further sum of 39,500*l.* in cash being raised by the flotation of subsidiary companies, and 42,000*l.* by the sale of 35,000 shares in the Lake View South; which it appears altogether placed 834,652*l.* at its disposal.

The ore treated to the end of August 1900 amounted to 140,602 tons and returned 209,588 oz., valued at about 838,000*l.*

Dividends equal to 7*s.* 6*d.* per share have been paid, returning a total of 171,787*l.*, which with 4*s.* per share paid back to shareholders out of the last issue of reserve shares at 12*l.* each, makes a grand total of 11*s.* 6*d.* per share paid back, representing 270,392*l.*

The balance sheet of March 31, 1900, showed assets, comprising

	£	s.	d.
200,000*l.* Consols at cost	208,594	6	0
Sundry advances on securities	25,160	0	0
Advances to Subsidiary Companies	8,100	0	0
Cash	31,997	12	7
Bullion in transit	27,956	11	10
	301,808	10	5

In addition to which sundry investments, amounting to over 10,000*l.*, were referred to which should be added to the above amount, as well as stores on hand, etc.

The shareholders likewise received scrip dividends in the shape of 250,000 shares in the Associated Northern Blocks (being at the rate of one share of the latter company for each share in the Associated), and to any shareholders who may have realised their holdings, in 1900 at 3*l.* this would have meant a return of 30*s.* on Associated shares; they were recently (August 25, 1902) quoted at 3⅜ to 3½ and touched 4⅛ I believe in 1901.

75,000 shares in the Lake View South, and in the Lake View Extended, were also distributed amongst the Associated shareholders, and these shares at one time possessed a market value of 3⅜*l.* and 2*l.* respectively.

In the early part of 1900 the prospects of the company appeared anything but bright, the ore reserves then in sight being estimated at only 37,740 tons, valued at 1 oz. 8·33 dwt., but under control of Mr. Hewitson, the former manager of the Ivanhoe, the position of the company has since then vastly improved. The results for the year ending March 31, 1901, were 35,524 tons treated for a yield of 29,912 oz., valued at 112,072*l.* 10*s.* 9*d.*, and a very large increase in ore reserves was reported, as they were estimated at 122,794 tons, valued at 1 oz. 3 dwt. 7 gr. per ton, or containing 142,939 oz.

The sulphide mill has been remodelled and enlarged, and various general improvements have been made, with a view to reduce the high costs which formerly obtained; and the table following shows substantial progress made in this direction during the year ending March 31, 1902:—

Basis of Calculation 41,384 *tons.*

	Cost per ton. £ s. d.	Cost per ton. £ s. d.
Ore extraction :—		
Superintendence	0 0 3·83	
Stoping and trucking . . .	0 13 7·31	
Hauling	0 3 8·61	
		0 17 7·75
Reduction :—		
Percolation process	2 2 7·28	1 14 4·53
Modified process	1 12 6·46	
Management and general expenses		0 6 2·83
		2 18 3·11

50,650*l.* 14*s.* 4*d.* was spent upon development account and shaft sinking, and included in capital expenditure, which deducting several credit items came to 83,630*l.* 19*s.* 1*d.*; inclusive of 4068*l.* 15*s.* 9*d.* spent on diamond-drilling.

The following short description may be given of the three principal "setts" the company hold.

Two formations, known respectively as Tetley's and the Australia East lodes, have been those principally developed.

The plan Fig. 79 attached hereto, shows the general position of the underground workings on both formations; Fig. 80 is a longitudinal section of Tetley's lode along the line C D on the plan; the shaded portion shows the position of the stopes in 1900; most of the high-grade ore sent to the smelters came from this section of the mine.

Owing to the shortening of the length of the ore-shoot in the lower levels, as compared with the upper ones, it was feared that the pay-ore might cut out in depth, but, although no doubt an unfavourable factor to be reckoned with, an exaggerated importance appears to have been attached to it, partly because it is not uncommon for ore-shoots to contract and widen out again, and partly because it would appear that the 416-feet level at any rate was driven off the ore-body, *vide* report (quoted),* dated May 10, 1900:

* *Statist*, October, 20, 1900, p. 617.

"It is now clear that the intermediate level has been driven off the ore-body; hence the poor assays of samples taken from the southern (eastern) portion of the drive," and the Manager's Report, dated May 2,1901, shows this to have been the case, as, referring to this point, he remarked, "A drive was extended north from the point where the good ore was met with in the cross-cut, along the portion of the lode that had been missed, for a distance of 71 feet. All these workings are in good ore, the average of the truck samples from here being 1 oz. 9 dwt. 16 gr. The width of the lode is about 15 feet." And again, speaking of the 557-feet level, he said, "In Sect. A 16 (Tetley's lode) a cross-cut was driven into the west side of the south drive 19 feet, and from this point a rise put up 42 feet into the No. 5 stopes. This work proved a width of 10 feet of 30-dwt. ore which had been left in the wall." At the 600-feet level drives were extended upon the lode, north 83 feet and south 165 feet, and an ore-body was struck 11 feet wide, which had a length of 67 feet and an average value of 1 oz. 7 dwt. per ton. A winze was sunk in the south drive (Section A 16) 60 feet (below the 600-feet level), the bottom of which was however in low-grade ore. As the *Statist* observes: It is not yet quite clear whether the Tetley ore-body is to be regarded as being in the nature of a pipe or chimney, or whether it is one of a succession of lenses such as are met with in most of the other formations; but if the former, other similar bodies may be found further north in driving along the course of the formation. The south-west dip of the formation would appear to carry it in depth, into the Perseverance and Lake View ground, although the cross-section shows that its dip becomes more vertical as it goes down below No. 5 level.

The Australia East lode traverses the eastern side of the lease on a "course" that bears more to the north, unlike Tetley's, which crosses it diagonally.

The whole of the oxidised ore treated came from this formation, whilst Tetley's carried sulphide ore up to the surface, just as was the case in the Kalgurli, to which it bears some points of resemblance.

Fig. 81 also gives a longitudinal section of the Australia East formation, and shows the position of the stopes in 1900. At one point ore is said to have been taken out for a width of 90 feet, and to have yielded by treatment 16 dwt. per ton. To the south-east this lode runs into the South Block of the Oroya lease, where for over 200 feet it is stated to have had a value * of 30 dwt. per ton.

* *Statist*, October, 27, 1900.

Some 200 feet north (west) of Waddington's shaft, the "formation" in the Associated appears to be cut by a slide.

Up to date of April 1900, the total amount of development work done in the mine came to 2¼ miles, and up to the end of February of that year, it had produced 120,983 tons, which yielded 192,768 oz. of bullion.

During the year ending March 31, 1901, a considerable body of ore valued at about 17 dwt. was discovered above the 300-feet level, in course of prospecting from Waddington's shaft. The main cross-cut east, passed through 6 feet of ore assayed about 1 oz.; and No. 1 winze 42 feet east of the shaft (Section H 14) was sunk 108 feet, and the lode was reported 6 feet wide and slightly above 1 oz. in value. This, being apparently the deepest point then reached in this section of the workings, was a point of interest.

Work carried on from Judd's shaft, on the north-west extension of the Australia Main-lode, does not appear to have resulted in any new discoveries of great importance being made in 1900–1901, but speaking of the south drive at No. 5 level on the course of the Australia East lode Mr. Hewitson observed, "There are indications that the drive is not far away from better values."

The most important event of the year, was the discovery of an entirely new ore-body (the No. 2 Cross-lode as it is called) which was intersected by the main cross-cut started 50 feet west of Tetley's shaft at the 600-feet level, in a north-easterly direction towards Judd's shaft; the "Cross-lode" being met with in the cross-cut after driving it about 300 feet, where it intersected the Australia Main-lode (this latter being "a formation" lying more or less parallel with, but west of the Australia East lode).

Drives extended along the Main-lode, north-west 198 feet (where it holed through to Judd's shaft) and south-east 18 feet, exposed a body of ore 25 feet in length in the north drive, and 18 feet in length in the south drive, valued at 1 oz.; whilst drives started on No. 2 Cross-lode and run 235 feet north and 128 feet south, opened up 180 feet in length reported to average 9 feet in width, assaying 1 oz. 3 dwt. per ton. This appears to be a case of the enrichment of the Main-lode by the Cross-lode, where they intersect.

The following is a summary of development work during the twelve months 1900–1901 and 1901–1902.

	1900–1901. feet.			1901–1902. feet.		
Driving	5,396			4,828		
Cross-cutting	2,397½			3,061½		
Rises, winzes, etc.	1,060			1,106		
Shaft sinking	170½	Plats		139		
		Shaft sinking		565½		
		Average	feet.		Average	
Total	9,024	per month	752	9,700	per month	808⅓
Diamond drill holes	4,088½	,,	340¾	5458	,,	454⅚
Total for the year	13,112½	,,	1092¾			1263

Driving, cross-cutting, and rises and winzes cost on the average 4*l.* 15*s.* 6·66*d.* per foot. Shafts, "plats," etc., 10*l.* 17*s.* 9·60*d.*, and diamond-drilling 14*s.* 10·91*d.* per foot in 1901–1902. The mine was most carefully sampled in 1900–1901, 16,821 assays being made in the laboratory apart from 4514 tests and analyses of various kinds.

In 1901–1902, 6902 tests and analyses were made, and the fire assays comprised:—

Mill	7575
Mine	8358
Laboratory	3280
	19,213

During the year ending March 31, 1902, the No. 2 Cross-lode was intersected at the 400-feet level at 200 feet east of Tetley's shaft in Section E 15 where it was 12 feet wide, assaying 55½ dwt., and although this was not maintained it showed improved values upon being driven upon further north; the face at 98 feet from the cross-cut being reported in high-grade ore, telluride showing freely, and the last 16 feet, it is stated, averaged 32 dwt.

On Tetley's lode at the same level, ore averaging 30 dwt. was opened up in Section A 16, and close to the Great Boulder Perseverance boundary, "a large body of highly payable ore" was reported disclosed by a cross-cut in Section A 17, where ore stoped averaged 37 dwt.

An important strike of high-grade ore was also subsequently made in Section D 14 at No. 5 level, Tetley's shaft, which it was stated had "considerably brightened the outlook of the mine," and it appears from the May report, that in driving at this level on the Cross-lode, the level was carried 143 feet in ore averaging 3 oz. 10 dwt., where it was displaced by a slide.

On Tetley's lode ore was stoped in 1901–1902 averaging 21 dwt. in Section A 15 and 16.

On No. 2 Cross-lode a rise to No. 5 level in Section D 13 at the junction of No. 2 Cross-lode and the Australia Main lode, passed through rich ore averaging 40 dwt., and in prospecting to the east of No. 2 Cross-lode a parallel seam was discovered which proved to be 8 feet wide. Ore broken here and above the cross-cut averaged 33 dwt.

At date of March 31, 1902, the depth of the lowest "plats" in the mine measured from the "collar set" at Judd's shaft was as follows:—

		feet.	
Waddington's	No. 3 level	300	Connects with No. 5 level from Judd's shaft.
Tetley's	No. 7 level	692	
Judd's	No. 10 level	1047	

The most important developments during the years 1901–1902 were (1) a large make of ore in Tetley's lode on the western side of the old workings at Nos. 4 and 5 levels; (2) the discovery of the "footwall-seams" of No. 2 Cross-lode; (3) the shoot of ore in the Australia East lode at No. 3 level, Section F 10; and (4) a "bore" run 1025 feet from No. 2 level, Judd shaft, put down in Section C 5 No. 41, to a vertical depth of 1269 feet from surface, at a depth of 808 to 900 feet, passed through a large low-grade ore body, supposed to be the Northern Blocks Oroya lode; judging from position and the strike of the two formations, however, unless it makes a sharp bend to the north (which has yet to be proved), it seems scarcely likely that the Brownhill Oroya lode can correspond with the Australia East lode, as some suppose.

The following advices received subsequently, in 1902, may be of interest:—

Statist, May 3, 1902.—"Tetley's shaft: (north drive on No. 2 Cross-lode) at the 500-feet level the vein has been driven upon north for a distance of 40 feet showing an average width of 5 feet, and an average assay of 4 oz. per ton."

Statist, May 10.—"In the north drive on the No. 2 Cross-lode at the 500-feet level Tetley's shaft, the width of ore is now reported as 3 feet assaying 3 oz. per ton."

Advices were received at the end of July which would seem to indicate that Tetley's lode has gone down more vertically than was expected, it being reported by the manager that at the 800-feet level the "lode is dipping into our ground." This is discussed in the *Statist* of August 2, 1902, from which the transverse section Fig. 82) is produced.

It appears from the Report for October 1902, that at No. 6 level on Tetley's lode, a "rise" 74 feet south of the main west cross-cut was put up 26 feet, the first 16 feet averaging 3 oz. 9 dwt., and the last 10 feet being in high grade ore. At No. 8 level, the north drive on No. 2 Cross-lode had been advanced 45½ feet, the last 28 feet averaging 1 oz. 5 dwt. 15 gr., the lode showing for the full width of the drive; the last 17½ feet, however, was in ore of lower value.

The ore reserves at March 31, 1902, were estimated at 91,210 tons, containing 118,660 oz. bullion, and an independent examination since made by Mr. Griffiths* put the ore reserves at 100,000 tons valued at 26 dwt; 41,384 tons of the company's ore were treated for a yield of 36,399 oz. of bullion of an average value of 3*l.* 16*s.* 8·3*d.* per oz., and the extraction has improved since the old percolation process has been given up, whilst the cost of reduction has gone down.

A vigorous policy of development, coupled with the fact that with the works in full running order, they were expected to be able to treat 7000 to 8000 tons per month with an extraction of about 92 per cent., as compared with an output of 2000 to 3000 tons with a 60 to 70 per cent. extraction as formerly, seems likely to bear good fruit in the future if the additions to the ore-reserves keep pace with the extension of development work, in anything like the same ratio as in the period reviewed. In January, February and March of last year (1902) between 5077 and 5325 tons were treated monthly, which returned 3764 oz. to 4502 oz. per month of a total net value ranging from 14,309*l.* 10*s.* 3*d.* to 16,806*l.* 11*s.* in March. The Kalgoorlie correspondent of the *Financial Times*, in a letter dated December 24, 1901, remarked: "There now appears a probability that the mine will at last settle down into a regular produce of at least 5000 to 6000 oz. per month." Details of mining and milling costs will be found tabulated elsewhere. The total production of the mine to date of March 31, 1902, may be calculated to have amounted to 201,715 tons treated, that yielded 260,281 oz.

The Kalgurli Gold-Mines.

The property of this company consists of two adjoining leases, one of 12, the other of 6 acres, shown on the accompanying "plan," Fig. 83, which the proprietors of the *Statist* have kindly allowed the Author to reproduce.

* Chairman's speech at Ordinary Meeting of the Company, July 24, 1902.

The company was formed in June 1895,* the capital being apportioned as follows :—

	£
To the Vendors cash 15,000*l.* total purchase consideration	80,000
20,000 shares sold at par to provide working capital .	20,000
	100,000

The following subsequent issues being made to provide further working capital.

	£
10,000 shares at 3½*l.* per share . . .	35,000
5,500 shares at 6*l.* per share . . .	33,000
4,500 shares at 8*l.* per share . . .	36,000
	104,000

These issues, with the original amount raised, gave the company a working capital of 124,000*l.*

The total nominal capital issued is 120,000*l.* The mine commenced crushing in March 1900, the ore having been shipped previously to smelters, pending the results of the different methods of sulphide treatment under trial. The distance from the north-western to the south-eastern boundary is about 1460 feet, and the formations that traverse the lease strike in a general north-west and south-east direction.

The original discovery was made by a prospector named McLeay in the north block, but for some time no ore-bodies of value were found; but a small vein of rich telluride ore discovered at the 100-feet level led to the discovery of the rich and wide chimney which was met with at the 200-feet level.

The two principal formations so far developed are known as the Middle and West lodes, and owing to their different bearing cross one another (both dipping west in the upper levels) between the main shaft and Howell's. A formation further east is also known to exist called the East lode.

The Middle lode at the 100-feet level appears (as already stated) to have had but little value at surface, but at the 200-feet it is reported to have been 18 feet wide, and for a length of 70 feet had, it is said, a value of 2½ oz. per ton; at the 300-feet level the value was 1½ oz. for a length of 100 feet.

At the 420-feet level the formation apparently alters its dip from west to east, and a drive was extended 184 feet to the north and 283 feet south; at the 520-feet level an ore-body 30 feet wide valued at 1½ oz. per ton, was cut, showing a stretch of 100 feet of pay ore, south of the main shaft. The West lode at the 100-feet

* *Statist*, November 24, 1900.

level is stated to have been 30 feet wide, and for a length of 83 feet was valued at 3 oz. per ton.

At the 200-feet level it was valued at $1\frac{1}{4}$ oz. for a distance of 116 feet for the same width.

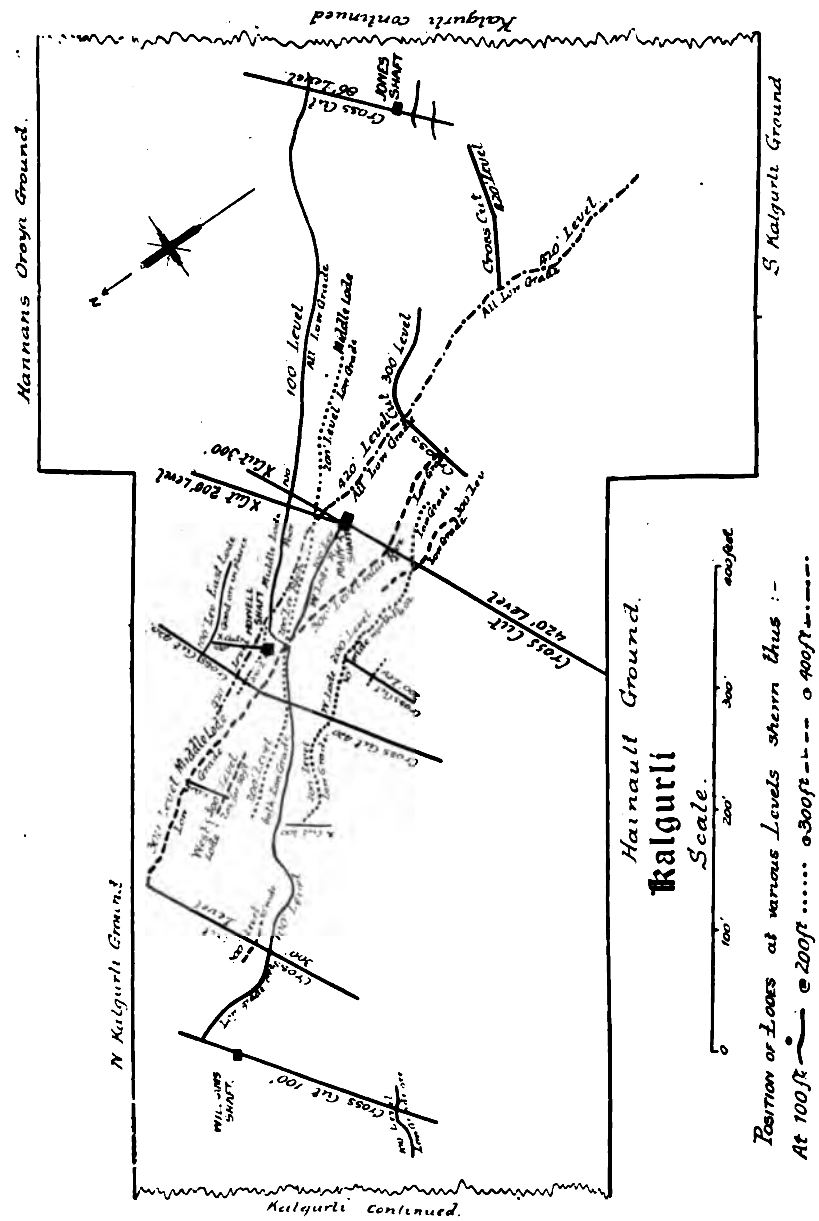


FIG. 83.

At the 300-feet level a small body of ore met with was valued at 2 oz. for a length of 50 feet.

The richest portion of the property appears to lie between the Main and Howell shafts; the extensions of the drives north and south running into low grade ore. The property has been extensively cross-cut practically from boundary to boundary in the centre, also from Williams' shaft at the north end, and from Jones' and Evans' shafts at the south end, where a bore-hole proved a low grade formation, 46 feet wide.

Extremely rich ore has been found in the main ore-chimney.

In 1897, 1016 tons smelted returned 4½ oz. per ton, 245 tons 8½ oz. per ton, and 2 tons of selected ore sent away was valued at 180 oz. per ton.

The ore in sight in November 1900 was estimated, I believe, at 100,000 tons, worth on the average 5*l.* 10*s.* per ton.

In the year ending July 26, 1901, the main shaft was carried down to 850 feet, and levels were opened at 750 and 850 feet.

In sinking the shaft at 805 feet a formation 6 feet in width apparently striking east and west with a flat underlie (35°) was passed through, assaying from 5 dwt. to 2 oz. per ton; again at 840 feet a well defined lode was intersected which continued for 10 feet; and in the cross-cut at the 850-feet level, had an average value of 8 dwt., small veins in it assaying up to 1 oz. per ton. At the 640-feet level, 36 feet west of the main shaft, 100 feet were driven south from the main cross-cut in ore of an average value of 30 dwt.; and north 32 feet, in ore of the same grade, followed by 27 feet in 15 dwt. ore.

At the south end of the south drive, cross-cuts driven west 10 feet and east 5 feet were reported in ore of an average value of 20 dwt. per ton. No. 2 south drive, started from the main west cross-cut at 61 feet from the shaft, was carried 32 feet in 20 dwt. ore, and north 11 feet in ore of a similar value per ton.

A "rise" put up to the 540-feet level, in No. 1 level 30 feet south of the main west cross-cut, was reported to have shown an average value of 2 oz. per ton for the whole height. The values quoted being mill values from ore broken out in development. At the 540-feet level, 26 feet south of the main west cross-cut for a length of 58 feet the drive was widened to 15 feet, "this work was all in high grade ore carrying telluride, and more free gold than had been met with in the sulphide ore in other parts of the mine."

The chairman at the Annual Meeting (December 10, 1901), quoting a cable just received, is reported to have said: "The west cross-cut at the 925-feet level exposed ore for a distance of 30 feet. For a distance of 25 feet the average assay of the ore was 25 dwt. per ton. At a distance of 18 feet from the main shaft, driving north and south had been carried a distance of 20 feet. The average assay of ore is 35 dwt. per ton, the gold is chiefly as telluride." Developments of an encouraging nature were reported in 1902; thus from 850 to 870 feet, the ore in the shaft carried telluride, the average value reported being 20 dwt. per ton; at 910 feet another ore-body was struck and carried down to 935 feet, assaying from 920 to 923 feet 2½ oz. per ton, and some small but high grade veins were struck at 1005 feet; at 1060 feet a rich vein varying in width from 3 to 15 inches was met with, reported to carry both telluride and free-gold. At 1065 feet another vein 12 to 18 inches wide was encountered valued at 29 dwt. per ton: most of these ore-bodies were reported to dip west, but the telluride vein at 1005 feet dips east. Various other developments in 1901–1902 are described in the company's report.

The main shaft reached a depth of 1078 feet early in 1902, 1149 feet of development work was done during 1900–1901, and 1439 feet in 1901–1902. The supply of ore for the mill was drawn from all parts of the mine, from the surface dumps to the 750-feet level; the greater part having been taken out in course of development and exploration work; the stopes on the 200-feet level were chiefly drawn upon for the balance required.

15,583 tons were treated in 1900–1901 for a return of 20,964 oz. of standard gold, an average of 1·34 oz. per ton; the extraction obtained being 90·8 per cent. The profit and loss account showed a net profit of 22,757*l.* 0*s.* 2*d.*; and after writing off 11,301*l.* 13*s.* 3*d.* for depreciation of plant, buildings and machinery, a balance of 25,542*l.* 1*s.* 6*d.* was left, out of which a dividend of 2*s.* 6*d.* per share was declared in December 1901. Since July 1902, two interim dividends of 2*s.* 6*d.* each have been declared, one paid on October 2, 1902, and the other on January 6, 1903.

The average working cost per ton for the year ending July 31, 1901, was given as 2*l.* 11*s.* 8·46*d.* but the ore treatment costs were stated to have been reduced in the last four months of the period covered by the Annual Report. For the year ending July 31, 1902; 22,060 tons were treated which returned 24,842·26 oz. of standard gold, an average of about 1·12 oz. per ton; the extraction being 91·38 per cent.

The new plant (a full description of which is given in the Chapter on Sulphide Treatment), is designed to handle a minimum quantity of 3500 tons per month, and 3500 to 3650 tons have been treated since July.

The General Manager expressed the opinion that the ore reserves on July 26, 1901, were larger than at the commencement of the year, and Mr. R. S. Black stated in July 1902, that developments had opened up a supply of ore sufficient to meet the present tonnage for three years.

The figures presented in the accompanying Table No. XII. have been compiled by the Author from the *Gold-Mining Statistics* of the West Australian Government, the *Mining Year Book, Skinner's Mining Manual* and other authorities, and he has to thank the secretaries of different companies for the kind assistance they have rendered him in placing such published information as they could furnish at his disposal.

The difficulties in the way of securing absolute accuracy in regard to figures of past production are, however, very considerable, as in all but one instance they are calculated on the basis of the calendar year and not on the period covered by the Annual Report of each company unless the two happen to correspond.

In the early days of the field, moreover, returns were difficult to obtain and statistical records could not be expected to be kept with the same exactness that now characterises them.

The fact that a large amount of ore has been treated outside of the Colony (the returns from which had, in many cases, to be estimated) further complicates the agreement of different figures; as the published returns in some cases represent the amount of bullion returned by the smelters (disregarding losses in smelting, etc.), in others, doubtless, the gross estimated contents of the ore based on assay values.

The Author believes, however, that the figures represent in a tabulated form, as nearly as can be ascertained, what the several mines he has described have produced; as allowing for the gold produced by the original companies, and gold from alluvials, tributes, etc., which is not included, the total tonnage crushed and bullion produced correspond practically with the total amount the various mines are credited with in the Government statistics, and the returns of the Kalgoorlie Chamber of Mines; and the individual returns of the different companies have been very carefully kept during the last few years.

Conclusion.

If space permitted, the Author might have dealt with various other mines, but circumstances will not allow him to do so; and he thinks that the properties he has described present a sufficiently good idea of the typical features of the field, to render further amplification unnecessary. Special points of interest in a number of instances have been touched upon in the chapters on Geology, Mining, and Ore-treatment.

The figures in Tables No. XII. and No. XIII. afford striking evidence that Kalgoorlie may boast of being one of the premier mining camps of the world, despite its peculiar difficulties.

Sulphi

	Ore.
...r.	tons.
...7	{ conc
La...	195
Con...	2620
...	3764
...	. .
...-02 (16	

...r.	
-96	.
...	.
...	.
...	.
Gre...	.
Pr...	.

issued in 1901.

¶ Including Barbank's Birthday Gift; East Murchison United; Lady Shenton; Peak Hill; Sons of Gwalia: and White Feather Main Reef.

TABLE No. XIII.

Name of Company. (1*l.* shares unless otherwise stated.)	Issued Capital 1900.	Issued Capital 1901.	Price of Shares.			Market Valuation of Capital.		Depreciation.	Price of Shares.					
			Highest 1899.	Make up March 26, 1900.	Aug. 14, 1900.	Make up March 26, 1900.	Make up Aug. 14, 1900.		Highest. 1900	Lowest, 1900.	Highest, 1901.	Lowest, 1901.	Mid Jan. Account, 1902.	Mid June Account, 1902
	£	£				£	£	£						
Associated.	500,000	492,678	13 13/16	5 1/8	3 1/16	2,562,500	1,531,250	1,031,250	7 5/8	2 1/16	3 1/8	1 7/8	2 5/16	1 7/16
Brown Hill Extended	80,000	80,000	7 1/2	3 1/8	1 7/8	250,000	150,000	100,000	3 7/8	1	1 9/16	5/8	3/4	
Central and West Boulder.	250,000	247,987	3 15/16	1 1/4	7/8	312,500	218,750	93,750	1 15/16	1/4	5*s.* 6*d.*	1*s.*	1/4	6*s.*
Chaffers 4*s.* (470,778)	* 92,135	94,155	42*s.*	20*s.* 6*d.*	10*s.* 9*d.*	465,006	247,712	217,294	26*s.* 3*d.*	5*s.*	10*s.*	3*s.* 6*d.*	5*s.* 6*d.*	7*s.*
Golden Horse-shoe 5*l.* (300,000).	1,500,000	1,500,000	17 7/8	14 1/8	12	4,237,500	3,600,000	637,500	15	9 1/2	13 3/4	8 3/8	11	9
Golden Link Consolidated.	* 347,183	348,183	5 1/8	2 13/16	2 1/4	906,139	781,162	124,977	3 1/8	1	1 5/8	1/2	13/16	15/32
Great Boulder Prop. 2*s.* (1,750,000).	175,000	175,000	41*s.* 3*d*	32*s.* 9*d.*	32*s.* 6*d.*	2,865,625	2,843,750	21,875	37*s.* 6*d.*	24*s.* 3*d.*	27*s.* 6*d.*	17*s.* 3*d.*	20*s.* 9*d.*	19*s.* 9*d.*
Great Boulder Main Reef 10*s.* (260,000)	130,000	130,000	2 11/16	1 1/2	1 3/8	390,000	357,500	32,500	2 7/8	1 1/16	2 3/16	1/2	11/16	3/4
Great Boulder Perseverance.	175,000	175,000	16	11 1/8	11 5/8	1,946,875	2,034,375	†87,500	13 1/4	7 7/8	10 3/16	5 3/8	10 5/8	11 7/16
Hannan's Brown Hill	143,000	155,000	14 1/4	9 11/16	8 7/16	1,385,312	1,206,563	178,749	11 1/4	4	4 13/16	2 3/4	3 1/4	3
Hannan's Oroya.	189,820	240,000	4 5/8	2 11/16	1 1/4	510,141	237,275	272,866	3 5/16	15/16	2 13/16	3/4	2 1/8	3 3/8
Hannan's Star.	* 184,500	202,000	2 1/2	1 1/2	1	266,250	184,500	81,750	1 11/16	11/16	1 1/16	3/16	3/8	5/16
Ivanhoe Gold 5*l.* (200 000).	1,000,000	1,000,000	18 9/16	13 3/8	9 5/8	2,675,000	1,925,000	750,000	15 1/2	8 3/8	10 1/8	6 1/4	7 13/16	7 5/16
Ivanhoe S. Extended ‡	100,000	150,000	6 1/4	3 1/4	2 3/8	325,000	237,500	87,500	4 3/8	7/8	2 1/4	5/8	3/4	1 9/32
Kalgurli.	120,000	120,000	13 1/2	7 3/4	6	930,000	720,000	210,000	9 5/8	3 3/4	5 1/8	3	3 15/16	3 3/8
Lake View Consols.	250,000	250,000	28 7/8	13 1/2	11 13/16	3,375,000	2,953,125	421,875	15 3/8	7 9/16	10 1/4	5 3/8	6 1/2	3 1/8
North Boulder 10*s.* § (260,000).	110,000	129,342	1 7/16	9/16	3/8	123,750	41,250	82,500	7/8	1/8	8*s.*	2*s.*	4*s.* 9*d.*	1*s.* 6*d.*
North Kalgurli. ‖	125,000	122,058	3	1 1/4	9/16	156,250	70,312	85,938	1 11/16	7/16	. .	. .	5*s.*	6*s.* 3*d.*
South Kalgurli.	120,000	132,000	7 1/2	5 5/8	4 1/2	630,000	540,000	90,000	6 1/8	2 5/8	3 3/16	1 11/16	2 1/4	1 5/8
Miscellaneous. ¶	. .	. .	. .	. .	. .	24,312,848	19,880,024	4,432,824						
						3,832,500	3,144,375	688,125						
						28,145,348	23,024,399	5,120,949						

The prices of the principal shares in this list at the mid-monthly settlements in July, September and October were given in the *Statist* of October 25, 1902. The principal changes since June being in Great Boulder Proprietary, Great Boulder Perseverance and Lake View, which were respectively quoted at 19/3, 10 3/4 and 2 3/8. On January 12, 1903, Associated were quoted at 1 1/4, Golden Horseshoe at 9 11/16, Lake View at 2 1/16, Great Boulder at 19/9, Great Boulder Perseverance at 9 11/16, Ivanhoe at 7 11/16 and Kalgurli at 3 3/4.

* The figures in the first column thus marked underwent slight capital changes in 1900; but the *Statist*, in the article from which they are taken, observes that they were unimportant, and therefore no account was taken of them in calculating the market valuation of the shares. † Appreciation.
‡ Reconstructed October 17, 1899. § Reconstructed August 1902; now the North Boulder Gold Mines, Limited.
‖ Amalgamated with Brookman Brothers, Boulder G. M. Co., Ltd. in 1901. The capital of the new company is 175,000*l.*, in 350,000 shares of 10*s.* 244,177 shares 8*s.* 6*d.* called up (103,750*l.*) issued in 1901. ¶ Including Barbank's Birthday Gift; East Murchison United; Lady Shenton; Peak Hill; Sons of Gwalia: and White Feather Main Reef.

A summary of the figures showing the market valuation* of the mines included in Table No. XIII. was given in the *Statist* of August 18, 1900 (from which it has been partly compiled), and shows the great fall that took place in the market value of West Australian shares at that period; no account being taken of some slight capital changes which occurred in the interval, as they were unimportant. The issued capital in 1901 and the highest and lowest prices of the shares in 1900, 1901, and 1902 have been added by the Author.

	Kalgoorlie Mines.	Miscellaneous.
	£	£
Market valuation, highest, 1899	41,161,795	5,653,125
,, March 26, 1900	24,312,848	3,832,500
,, August 14, 1900	19,880,024	3,144,375
	Per cent.	Per cent.
Decline, March 26, 1900, on highest, 1899 .	40·9	32·9
,, August 14, 1900 ,, ,, . .	51·7	44·3
,, ,, ,, on March 26, 1900 .	22·3	21·2

The fall in Associated alone, accounted for nearly a quarter of the total depreciation in 1900, and Lake Views dropped about 12½ per cent. The three Great Boulder mines, however, showed but little change.

It may further be pointed out that, according to figures compiled by the *Australian Trading World*, the market valuation of thirty-five West Australian mines which when issued represented 8,834,000*l.*, stood at 31,449,225*l.* on January 23, 1900; at 32,861,063*l.* on February 20, 1900; at 26,070,906*l.* on June 25, 1900; at 22,286,438*l.* on December 21, 1900; at 18,356,125*l.* on April 9, 1901; at 16,784,220*l.* on August 12, 1901; at 19,793,249*l.* on September 9, 1901; at 18,658,812*l.* on November 8, 1901; at 17,783,813*l.* on February 10, 1902; at 15,952,063*l.* on May 9, 1902; at 14,925,671*l.* on August 11, 1902; at 15,287,921*l.* on September 8, 1902; and at 14,494,796*l.* on October 10, 1902. Or, as calculated in the *Financial Times* in its issue of May 17, 1902, taking these 35 mines at par value:—

	Per cent.
On February 20, 1900, they stood at . .	439·95
January 13, 1902 ,, ...	219·59
February 10, ,, ,, ...	203·94
March 10, ,, ,, ...	201·74
April 8, ,, ,, ...	195·42
May 9, ,, ,, ...	172·91

Table No. XIV. gives the production and dividends of six Kalgoorlie companies in 1898, 1899 and 1901, which were not included in Table No. XII.

From the *Report* of the West Australian Chamber of Mines,

* Some interesting estimates, which bear on this subject, were given by Linkman in the *Financial Times* of July 16 and November 8, 1902.

TABLE No. XIV.

Name of Company.	Product.	Tonnage Treated.* 1898.	1899.	1900.	1901.	Bullion Obtained.* 1898.	1899.	1900.	1901.	Rate of Dividends Paid per Share. 1898.	1899.	1900.	1901.	Amount of Dividends Paid in each Year. 1898.	1899.	1900.	1901.
		tons.	tons.	tons.		oz.	oz.	oz.						£	£	£	£
Great Boulder Main Reef, Ltd.	Oxidised ore[1]	8,185	12,530	9,777[4]	20,649[4]	14,365[5]	12,708[5]	22,051[5]	26,649[5]	10%	10%	10%	10%	12,000	12,000	13,000	13,000
	Av. per ton dwt.	35·1	20·3	45·1	25·8					= 1s.	= 1s.	= 1s.	= 1s.				
Hannan's Oroya G.M. Co., Ltd.	Oxidised ore[2]	15,412	27,120	15,146	. .	6,453	11,715	5,801			5%				9491		
	Av. per ton dwt.	8·4	8·6	7·6							= 1s.						
South Kalgurli Gold-Mines, Ltd.	Oxidised ore	. .	. .	11,219	20,110	. .	. .	11,004	18,838								
	Av. per ton dwt.	. .	. .	19·6	18·7												
North Boulder G.M. Co.,† Ltd.	Oxidised ore[3]	10,150	9,772	. .	. .	9,824	7,838										
	Av. per ton dwt.	19·3	16·0														
	Sulphide ore	. .	2,228	1,527	A 1900 / B 506	. .	4,075[7]	2,278	A 856 / B 1828	1897. 7½%	17½%			1897. 8236	19,218		
	Av. per ton dwt.	. .	36·5[6]	29·9	9·0 / 72·2					=9d.	s. d. =1 9						
	Tailings	. .	14,104	1,952	828	. .	8,094	1,279	548								
	Av. per ton dwt.	. .	13·4	13·1	13·2												
Brownhill Extended, Ltd.	Sulphide ore (smelted)	. .	103	735	. .		1,040	3,532									
	Av. per ton dwt.	. .	201·9	94·7													
Associated Northern Blocks, W.A., Ltd.	Sulphide ore (smelted)	. .	. .	1,318	C 5840	. .	. .	10,219[8]	C 37,195				25%				87,500
	Av. per ton dwt.	. .	. .	155·0	127·4								= 5s.				

(1) Total previous to 1898, 3798 tons 13 cwt., produced 10,534 oz. 7 dwt. 21 gr. (2) Total previous to 1898, 2465 tons 17 cwt., produced 1239 oz. 15 dwt. 6 gr.
(3) " " 7952 tons, produced 12,430 oz. 14 dwt. 7 gr. (4) Including telluride ore smelted. (5) Including gold from tailings.
(6) Estimated from returns. (7) Calculated contents exclusive of 60 tons 3 cwt. smelted at Swansea, which yielded 518 oz. (8) Dollied specimens, 34·65 oz.
A Milled. B Smelted. C Dollied specimens 75·45 oz.

* The figures in these columns (excepting those relating to the North Boulder G.M. Co.) have been computed from the Government statistics.

† Reconstructed in 1902, the name of the new company being the North Boulder Gold-Mines, Ltd., capital 400,000 shares of 10s. each, 258,023 of which were to be issued to the shareholders of the old company, 55,000 to acquire the Bank of England lease of 10 acres, 7 to signatories, and the balance held in reserve.

December 1898, it would appear that 76·6 per cent. of the total gold product of West Australian mines was contributed by British-owned mines in 1897; and 68·5 per cent. in 1898.

A summary of the cabled returns from fifty *British-owned* mines operating in Western Australia, in December 1899 (given in the *Returns* of the West Australian Chamber of Mines), showed the following totals and averages, allowing for defective or abnormal returns:—

—	Tons Treated.	Gold Recovered.	Yield per Ton.
	—	oz.	oz. dwt.
Mill and smelting ore	61,575	69,714	1 2.6 *
Tailings	22,896	11,721	0 10 1 *
Slimes	6,025	2,224	0 7·4 *
Concentrates	235	1,147	4 13·8 *

The total gold production of West Australian mines in 1900, as shown by the *Mining Statistics* of the Department of Mines, amounted to 1,513,917·08 oz., which appears to have been obtained as follows:—

Ore milled 1,233,104·45 tons § yielded 997,570·57 oz.
Alluvial, yielded 27,689 46 oz.
Dollied and specimens yielded 13,237·08 oz.

Smelting Ore.	Concentrates.
56,242·55 tons yielded 125,359·74 oz.	7,522·81 tons yielded 30,531·87 oz.
Tailings.	**Slimes.**
747,560·86 tons yielded 288,157·21 oz.	79,041·00 tons yielded 31,371·15 oz.

Grand total † 1,513,917·08 oz.

The average per ton treated (inclusive of alluvial and specimen gold), was 1·14 oz. compared with 1·31 oz. in 1899.

Mr. H. C. Hoover expressed it as his opinion, ‡ in December 1898, that if the lodes at Kalgoorlie maintained their value with depth, the equipment in contemplation and course of erection should treble the output in four years, bringing it up to 75,000 oz. a month, a figure it nearly approached in 1900 (when it averaged 67,575 oz.) and exceeded in 1901, when it averaged 86,139 oz.

The outside mines, Mr. Hoover added, now furnish 75 per cent. of the production of Western Australia, and whilst the increase from them will not be so great, they may conservatively be expected to swell the total to 150,000 oz. monthly, a figure which has also already been exceeded, since April 1901, as shown by Table No. XV., which gives the total gold output of the different gold-fields of

* Total from all sources, 84,806 oz.

† This figure is given by Mr. Jas. Wallace (Government Statist) in his letter of transmittal to the Department of Mines dated May 31, 1901. *Gold Statistics*, 1900, and the figure marked § is estimated from the data therein given.

‡ *Eng. and Mining Journal*, December 17, 1898.

Western Australia as entered monthly for export and received at the Royal Mint, Perth, from January 1, 1897, to December 31, 1901.

In 1902 thirty-two companies are stated * to have produced 1,388,420 oz. of bullion from 1,276,842 tons of ore, yielding an average of 1·085 oz. per ton; and estimating the market value of the shares on December 1, 1902, at 15,375,315*l.*, the dividends declared last year amounted to over 8 per cent. or 1,279,225*l.* The total production of the State up to the end of December 1902 is calculated at 9,974,463 oz. valued at 37,670,313*l.* Kalgoorlie alone is credited † with a yield of 1,116,383 oz., and a grand total of 4,564,112 oz. produced. It is said to have returned 6,414,000*l.* in dividends; 1,086,250*l.* of that sum being distributed last year.

General Charges, Maintenance, etc.

At the end of 1898 ‡ Mr. Hoover said:—"It is impossible to estimate accurately expenditures for maintenance and general charges, from present cost. Because of the large excess of construction and development going forward; we may for present purposes, put it down at 72 cents (3*s.*) a ton"; it may be added, however, that it is liable to vary with output to a very considerable extent, as shown by the following table, which gives an estimate of the cost of maintenance, depreciation, etc., at several mines in 1898–1899, not taking into account any London or Adelaide expenses.

—	Lake View.		Great Boulder.		Ivanhoe.	
	1898.	1899.	1898.	1899.	1898.	1899.
Tonnage milled taken as the basis of calculation.	57,920	85,889	41,043	51,835	28,765	59,664
	Cost per ton.		Cost per ton.		Cost per ton.	
	s. *d.*	*s.* *d.*	*s.* *d.*	*s.* *d.*	*s.* *d.*	*s.* *d.*
General expenditure and management.	2 8·183	1 10·712	5 1·0	5 0·3	‖5 4·65	‖4 10·47
Maintenance (i.e. repairs, renewals, etc.).	2 1·254	0 10·937	1 5·1	2 2·7	¶7 2·78	1 5·54
Depreciation (plant etc.) . .	4 6·187	§3 6·094	§4 10·4	§7 8·6	3 10·68	§2 7·10

Owing, however, to the great influence that output and different variable factors exercise, and the different way in which the same items of expenditure are dealt with in the statements of cost pre-

* 'Gold Mining in Western Australia,' by H. C. Hoover, *Eng. and Mining Journal*, January 3, 1903.

† *Mining Journal*, London. Kalgoorlie correspondent letter, dated January 5, 1903.

‡ *Eng. and Mining Journal*, December 17, 1898.

§ Written off machinery, buildings and plant in balance sheet.

‖ Included gold shipment charges.

¶ This figure seems to have included "water-supply expenses," which, would seem more properly chargeable to "general expenses" if not split up.

TABLE No. XV.

RETURN SHOWING QUANTITY AND VALUE[a] OF GOLD, THE PRODUCE OF THE STATE, ENTERED MONTHLY FOR EXPORT AND RECEIVED AT THE ROYAL MINT,* PERTH, FROM JANUARY 1, 1896, TO DECEMBER 31, 1901.

Month.	1896. Quantity.			1896. Value.			1897. Quantity.			1897. Value.			1898. Quantity.			1898. Value.		
	oz.	dwt.	gr.	£	s.	d.	oz.	dwt	gr.	£	s.	d.	oz.	dwt.	gr	£	s.	d.
January	16,350	0	11	62,130	1	9	40,386	14	3	153,469	9	8	93,395	8	19	354,902	13	5
February	17,922	5	21	68,104	14	4	32,526	0	0	123,598	16	0	53,739	3	14	204,208	17	8
March	11,084	17	5	42,122	9	4	40,296	7	12	153,126	4	6	75,380	0	21	286,444	3	4
January 1 *to March* 31	45,357	3	13	172,357	5	5	113,209	1	15	430,194	10	2	222,514	13	6	845,555	14	5
April	16,772	12	14	63,735	19	10	39,660	7	12	150,709	8	6	84,082	12	16	319,514	0	2
May	22,266	1	6	84,611	0	9	59,111	15	3	224,624	13	6	83,346	18	18	316,718	7	3
June	27,933	14	0	106,148	1	2	53,348	14	20	202,725	4	4	80,749	12	20	306,848	12	[illegible]
January 1 *to June* 30	112,329	11	9	426,852	7	2	265,329	19	2	1,008,253	16	6	470,693	17	12	1,788,636	14	7
July	16,258	8	19	61,782	1	5	48,811	4	17	185,482	13	10	76,980	15	9	292,526	18	5
August	29,516	19	22	112,164	11	8	65,129	3	10	247,490	17	0	89,395	9	10	339,702	15	9
September	35,301	6	15	134,145	1	2	71,776	11	6	272,750	18	9	89,179	4	4	338,880	19	10
January 1 *to September* 30	193,406	6	17	734,944	1	5	451,046	18	11	1,713,978	6	1	726,249	6	11	2,759,747	8	7
October	27,331	2	13	103,858	5	8	75,690	3	15	287,622	13	10	116,824	12	5	443,933	10	4
November	30,874	7	12	117,322	12	6	75,845	0	15	288,211	2	5	111,793	2	9	424,813	17	0
December	29,653	9	18	112,683	5	1	72,411	14	9	275,164	10	7	95,316	10	22	362,202	17	6
Total	281,265	6	12	1,068,808	4	8	674,993	17	2	2,564,976	12	11	1,050,183	11	23	3,990,697	13	5
Fine contents, oz.	251,618·69						603,846·44						939,489·49					

TABLE No. XV.—*continued.*

Month.	1899.						1900.						1901.					
	Quantity.			Value.			Quantity.			Value.			Quantity.			Value.		
	oz.	dwt.	gr	£	s.	d.	oz.	dwt.	gr.	£	s.	d.	oz.	dwt.	gr.	£	s.	d.
January . . .	110,090	0	19	418,342	3	0	*b*143,819	16	23	546,515	8	5	138,696	17	9	533,982	18	11
February . . .	100,565	1	19	382,147	6	10	*c*117,849	4	11	447,827	0	11	*l*135,497	6	8	521,664	13	4
March . . .	106,098	12	19	403,174	16	7	*d*126,049	10	2	478,988	2	4	127,845	11	7	492,205	8	6
January 1 to March 31	316,753	15	9	1,203,664	6	5	387,718	11	12	1,473,330	11	8	402,039	15	0	1,547,853	0	9
April	116,466	7	7	442,572	3	8	*e*113,506	5	21	431,323	18	4	150,018	9	18	577,571	3	6
May	114,623	6	8	435,568	12	1	*f*120,312	10	17	457,187	12	8	*m*144,087	8	11	554,736	11	7
June	161,952	16	11	615,420	14	7	*g*136,767	4	19	519,715	10	3	*n*161,967	9	2	623,574	14	0
January 1 to June 30	709,796	5	11	2,697,225	16	9	758,304	12	21	2,881,557	12	11	858,113	2	7	3,303,735	9	10
July	137,931	18	18	524,141	7	3	*h*113,601	17	4	431,687	1	3	160,294	8	0	617,133	8	9
August. . . .	145,397	17	0	552,511	16	7	*i*131,485	11	0	499,645	1	9	161,770	10	16	622,816	11	1
September . .	167,076	9	17	634,890	12	11	148,305	9	7	563,560	15	4	180,662	18	6	695,552	4	3
January 1 to September 30	1,160,202	10	22	4,408,769	13	6	1,151,697	10	8	4,376,450	11	3	1,360,840	19	5	5,239,237	13	11
October . . .	205,186	8	4	779,708	7	1	133,285	19	4	506,486	12	10	169,270	1	21	651,689	17	3
November. . .	139,867	11	19	531,496	16	10	*j*146,635	1	13	557,213	5	10	*o*172,114	1	16	662,639	4	5
December . . .	138,620	3	10	526,756	13	0	*k*149,331	12	16	567,460	4	2	*p*177,165	7	9	682,086	13	5
Total . . .	1,643,876	14	7	6,246,731	10	5	1,580,950	3	17	6,007,610	14	1	1,879,390	10	3	7,235,653	9	0

	1899.	1900.	1901.
Fine contents, oz. . . .	1,470,604·66	1,414,310·86	1,703,416·52

(*a*) The Official Valuation to December 31, 1900, was 3*l.* 16*s.* per ounce. In 1901, 3*l.* 17*s.* (*b*) 2125 oz. 5 dwt. 7 gr. smelted New South Wales; 19,497 oz. 12 dwt. 16 gr. smelted South Australia. (*c*) 1,468 oz. 16 dwt. 21 gr. smelted South Australia; 9,602 oz. 8 dwt. smelted New South Wales. (*d*) 516 oz. 12 dwt. 10 gr. smelted South Australia; and 771 oz. 11 dwt. 14 gr. smelted England. (*e*) 21 oz. smelted England; 3,857 oz. 11 dwt South Australia; 8,153 oz. 17 dwt. 2 gr. New South Wales. (*f*) 4 oz. 15 dwt. 17 gr. smelted United Kingdom; 400 oz. 10 dwt 10 gr Victoria; 851 oz. 2 dwt. 17 gr. New South Wales. (*g*) 2,836 oz. 19 dwt. 9 gr. smelted South Australia; and 8,575 oz.; 4 dwt. 8 gr. New South Wales. (*h*) 853 oz. 6 dwt. 2 gr. smelted South Australia; 381 oz. 12 dwt. 14 gr. New South Wales. (*i*) 142 oz. 7 dwt. 2 gr. smelted South Australia and 1,718 oz. 4 dwt. New South Wales. (*j*) 216 oz. 12 dwt 7 gr. smelted South Australia. (*k*) 33 oz 7 dwt. smelted South Australia. (*l*) 180 oz 12 dwt. smelted South Australia. (*m*) 10 oz. smelted United Kingdom. (*n*) 134 oz. 19 dwt. 6 gr. smelted Victoria. (*o*) Deduction of 2,367 oz 4 dwt 19 gr. made from November total to adjust excess in September; 10 oz. 4 dwt. 17 gr. smelted United Kingdom; 30 oz. 8 dwt. 4 gr. Victoria; 6,334 oz. South Australia; 1,285 oz. 5 dwt. New South Wales. (*p*) 75 oz. smelted Victoria; 2,448 oz. 6 dwt. 16 gr. New South Wales; and specimens containing 26 oz. Denmark.

* The following amounts, included in the above figures, were received at the Royal Mint, Perth:—January, 1900, 28,754 oz. 14 dwt. 10 gr.: February, 31,486 oz. 7 dwt. 10 gr.; March, 53,524 oz. 4 dwt.; April, 35,646 oz. 16 dwt. 5 gr.; May, 38,464 oz. 14 dwt. 10 gr.; June, 51,561 oz. 10 dwt. 9 gr.; July, 49,408 oz. 18 dwt.; August, 57,886 oz. 17 dwt; September, 60,579 oz. 5 dwt. 9 gr.; October, 48,724 oz 4 dwt. 19 gr.; November, 63,376 oz 2 dwt, 9 gr.; December, 61,769 oz. 3 dwt. 19 gr. January 1901, 65,972 oz. 4 dwt. 19 gr.; February, 49,584 oz. 18 dwt.; March, 52,309 oz. 13 dwt.; April, 62,598 oz. 6 dwt. 5 gr; May, 57,300 oz. 18 dwt. 19 gr.; June, 67,810 oz. 6 dwt. 10 gr; July, 91,604 oz. 9 dwt. 5 gr.; August, 58,531 oz. 15 dwt. 5 gr.; September, 87,402 oz. 2 dwt.; October, 83,508 oz. 14 dwt. 9 gr.; November, 83,157 oz. 6 dwt. 5 gr; December, 94,500 oz 0 dwt 14 gr.

sented by different companies, it is practically out of the question to attempt to compare them with the data available so as to establish any standard coefficient of cost applicable to mines in general on this field.

Capital Charges.—Tables No. XVI. and No. XVII. given in the reports of the Lake View and Ivanhoe Companies, show what these charges amounted to in each case, spread over a number of years.

The *Statist* in its issue of June 28, 1902, published an interesting article on "Some points on Westralians" which shows in a tabular form the various amounts written off on account of development, plant, etc., by different companies, and strongly advocates following the example of Transvaal undertakings, viz. allocating a certain sum per ton crushed to "redemption of mine development charges," a practice which is unquestionably, in the Author's opinion, sound policy.

It must not be forgotten, however, that there is some difference in the two cases, as the tonnages and values in ground blocked out are not so easily arrived at for purposes of calculation in Western Australia as on the Rand; and wider margins would require to be allowed; but it might be dealt with as a "suspense account," pending the exhaustion of each block of ground when the difference between the original estimate and the actual returns could be adjusted, in calculating the allowance to be made in the ensuing year. The question of a company creating a "sinking-fund" for the redemption of the original company embarked in the undertaking by the time the property is worked out is quite another question, however, the pro's and con's of which are discussed in the *Financial Times* of January 27, 1903.

Mining and Treatment of Sulpho-Telluride Ore: General Cost at the present time, inclusive of Development.

Excluding mine development, construction, and depreciation, *local costs* in Western Australia probably range at the present time between 29*s*. and 50*s*. The Author is inclined to believe, however, that whilst in exceptional cases the gross cost when dealing with sulphide ore may not exceed 50*s*. to 60*s*. per ton treated in most instances, including development charges, depreciation, maintenance, London expenses, taxes on gold, etc.; it varies between 60*s*. and 93*s*., depending of course on size of ore-bodies, character of ore, general management, scale of treatment and other circumstances that have been mentioned. As Mr. Hoover has pointed out, however,* as the economic conditions of mining become more favourable, and the operations are conducted on a large scale with increased efficiency of

* *Eng. and Mining Journal*, December 17, 1898.

TABLE NO. XVI.

LAKE VIEW CONSOLS, LIMITED.

SCHEDULE OF EXPENDITURE ON BUILDINGS, PLANT, MACHINERY AND MINE DEVELOPMENT, REFERRED TO IN BALANCE SHEET OF AUGUST 31, 1901.

—	Purchased from Vendors.	15 Months to August 31, 1897.	1898.	1899.	1900.	1901.	Total.
	£ s. d	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Machinery and plant	5912 18 8	18,983 0 8	12,858 19 1	10,345 16 2	13,231 4 3	18,316 10 11	79,648 9 9
Horses, vehicles and harness .	370 4 8	327 4 11	155 11 3	244 6 0	309 13 3	145 14 0	1,552 14 1
Buildings	970 2 9	3,839 9 9	5,917 4 7	4,845 6 9	3,758 9 4	3,571 15 6	22,902 8 8
Battery plant	. .	16,174 8 5	14,728 16 0	334 9 6	3,261 18 5	. .	34,499 12 4
Cyanide plant	. .	2,829 10 3	6,883 18 9	1,422 4 11	549 2 5	221 14 5	11,906 10 9
Furniture and fittings (mine office)	. .	812 9 4	65 11 4	73 11 2	310 15 10	314 7 2	1,576 14 10
Ditto (London office)	. .	. .	. .	. .	. .	791 5 9	791 5 9
Scientific instruments	. .	40 0 4	75 5 7	21 5 9	. .	. .	136 11 8
Main shaft	. .	2,024 17 0	872 4 4	3,424 8 3	2,313 12 11	6,114 16 4	14,749 18 10
Mine development	. .	12,368 4 9	16,415 6 7	14,180 0 1	23,695 19 10	36,836 15 11	103,496 7 2
Slimes treatment plant . . .	. .	. .	9,643 10 4	2,912 11 3	1,292 0 10	827 18 10	14,676 1 3
Electric light plant	. .	. .	1,341 3 8	500 2 11	528 14 1	2,035 2 2	4,405 2 10
Air-compressor plant	. .	. .	6,462 8 7	166 14 4	88 2 5	5,313 6 10	12,030 12 2
Sulphide plant	. .	. .	13,249 0 3	39,965 7 4	11,142 2 2	1,729 4 8	66,355 14 5
Railway siding	. .	. .	1,127 11 6	214 11 11	. .	22 12 0	1,364 15 5
Water right, No. 145 . . .	. .	87 8 0	. .	. .	. .	. .	87 8 0
Diehl process plant	. .	. .	. .	. .	680 17 1	4,822 18 3	5,503 15 4
Forewood Down condenser plant	. .	. .	. .	. .	. .	6,302 14 0	6,302 14 0
Firewood siding, No. 1 . . .	. .	. .	. .	555 17 4	533 6 0	. .	1,089 3 4
,, ,, No. 2 . . .	. .	. .	. .	391 0 0	82 11 9	. .	473 11 9
						87,366 16 9	
Less value of stores included in above, charged to additional Capital Expenditure account at August 31, 1899	. .	. .	. .	. .	. .	9,824 10 7	. .
	7253 6 1	57,486 13 5	89,796 11 10	79,597 13 8	61,778 10 7	77,542 6 2	383,279 12 4

TABLE No. XVII.

IVANHOE GOLD CORPORATION, LIMITED.

SCHEDULE OF EXPENDITURE ON BUILDINGS, PLANT, MACHINERY AND MINE DEVELOPMENT, REFERRED TO IN BALANCE SHEET OF DECEMBER 31, 1901.

—	Purchased from Vendors.	1898.	1899.	1900.	1901.	Total.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Buildings	3,329 10 0	2,576 2 3	3,637 13 9	4,444 2 10	5,353 4 5	19,340 13 3
Battery plant	3,745 13 5	10,223 2 4	8,679 4 0	3,088 11 8	23,189 4 6	48,925 15 11
Fitting-shop equipment	400 0 0	. .	270 7 11	217 17 4	210 9 11	1,098 15 2
Machinery and plant (general)	200 0 0	5,776 3 1	1,806 9 2	6,153 13 11	9,170 5 6	23,106 11 8
Pumping and condensing plant	1,000 0 0	2,185 10 4	785 0 0	3,606 1 10	1,606 5 3	9,182 17 5
Winding plant	2 660 0 0	. .	2,024 8 11	1,514 14 0	1,727 12 1	7,926 15 0
Horses, vehicles and harness	255 0 0	88 0 0	17 17 6	323 8 0	58 0 0	742 5 6
Office and general furniture	200 0 0	26 1 0	21 0 9	363 19 11	13 14 2	62[illegible] 15 10
Scientific instruments	20 0 0	22 0 11	6 9 10	5 10 10	. .	54 1 7
Cyanide plant	. .	10,662 0 7	1,828 19 5	872 17 10	6,090 5 2	19,454 3 0
Tramways	. .	1,422 9 2	1,940 13 3	2,096 0 8	1,495 0 4	6,954 3 5
Electric light plant	. .	26 10 4	1,457 13 11	87 5 3	70 16 3	1,642 5 9
Slimes treatment plant	. .	5,434 16 4	3,937 13 11	2,873 3 9	4,908 3 7	17,153 17 7
Rock-drilling plant	. .	516 0 1	4,888 7 11	2,438 17 3	2,604 8 5	10,447 13 8
Sundry effects	. .	177 17 9	15 0 0	40 7 1	. .	233 4 10
Mine development	. .	16,833 10 11	13,740 5 2	30,898 8 2	46,464 8 3	107,936 12 6
Railway siding	. .	267 5 1	63 19 0	10 0 0	191 11 7	532 15 8
Experimental sulphide plant	. .	. .	2,958 9 6	1,501 10 7	. .	4,460 0 1
Water area plant	. .	. .	90 15 7	438 16 2	. .	529 11 9
Ore elevators	. .	. .	6 0 0	. .	. .	6 0 0
Compressor plant	. .	. .	. .	2,511 4 7	6,333 11 10	8,844 16 5
Diamond-drilling plant	. .	. .	. .	1,224 10 4	. .	1,224 10 4
Fencing	. .	. .	. .	164 7 10	66 3 6	230 11 4
Office furniture, London	. .	. .	. .	. .	809 7 3	809 7 3
Removals	. .	. .	. .	. .	1,917 7 8	1,917 7 8
Roasting plant	. .	. .	. .	. .	4,417 9 2	4,417 9 2
					116,697 8 10	297,797 1 9
Less amounts included in above transferred from Old Plant account	. .	. .	. .	. .	860 13 4	860 13 4
	11,810 3 5	56,237 10 2	48,176 9 6	64,875 9 10	115,836 15 6	296,936 8 5

management, the working costs will decrease and lower-grade ores become profitable. "Every country possesses more one-ounce than two-ounce ore, and more half-ounce than three-ounce ore. Still every decrease in working expenses means an increase in tonnage treated in the leading mines, and an increase in the number of profitable mines on the gold-field."

The rapid growth of the industry is shown by the Government returns, embodied in Table No. XVIII., which show the output of Western Australia in the aggregate from 1896 to the end of 1901.

The gold output of Western Australia, between 1886 and the end of 1899, as can be seen from Tables No. XV. and No. XVIII., in fact grew at the pace of sweet-corn in August, when the darkies say, "you can hear it grow at night"; and notwithstanding the set-back which the industry received in 1900, it seems to be fairly started again, and when the immense quantities of low grade sulphide ores the mines contain come to be treated (to borrow another quaint but appropriate simile from Julian Ralph), I think there is good reason to expect that it will "push up like a mango-sprout in the hands of an Indian juggler;" provided capital is forthcoming for their further development in old and new directions.

The future prospects of the field appear to be well summed up by the special correspondent of the *Financial Times* in the following extracts from two letters dated Kalgoorlie, March 2 and 9, 1901, which I may quote in conclusion :—

"Taken on the whole, the mines on the Kalgoorlie belt look better to-day than they have ever done. Moreover, we have some of the ablest metallurgists in the Colonies constantly experimenting on our sulphide ores, so that in the near future we may expect to see treatment costs very considerably reduced."

There is every reason to believe that in the near future half-ounce sulphide ore will be worked at a handsome profit. When this desideratum is attained, the Kalgoorlie field will be second to none in the world, for it possesses millions of tons of ore, ranging from pennyweights up to ounces, which are only awaiting cheap and economical treatment." That is the key to the whole business, although it may take some time to realise, and "the near future" must not, I think, be taken too literally.

A great deal will probably be done to cheapen costs in Western Australia by directing more attention to the organisation of labour underground, automatic handling of ore on surface, and steam economy which requires to be specially studied, both in laying out and operating plant.

In a tropical climate it is obviously more difficult to secure good condensation than in a colder one, and defective condensa-

TABLE No. XVIII. (*continued*).—RETURN OF GOLD, THE PRODUCE OF THE STATE, ETC.

Year	* Peak Hill. Quantity.	* Peak Hill. Value.	Murchison. Quantity.	Murchison. Value.	* East Murchison. Quantity.	* East Murchison. Value.	* Mt. Margaret. Quantity	* Mt. Margaret. Value.	† Yalgoo. Quantity.	† Yalgoo. Value.
	oz. dwt. gr.	£ s. d.	oz. dwt. gr.	£ s. d.	oz. dwt. gr.	£ s. d.	oz. dwt. gr.	£ s. d.	oz. dwt. gr.	£ s. d.
1886	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
1887	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
1888	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
1889	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
1890	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
1891	. .	. .	2,064 8 16	7,844 16 11	. .	. .	. .	. .	. .	. .
1892	. .	. .	24,356 9 12	92,554 12 1	. .	. .	. .	. .	. .	. .
1893	. .	. .	21,210 8 22	80,599 13 11	. .	. .	. .	. .	. .	. .
1894	. .	. .	52,946 6 11	201,196 0 7	. .	. .	. .	. .	. .	. .
1895	. .	. .	65,477 5 3	248,813 11 5	. .	. .	. .	. .	. .	. .
1896	. .	. .	71,282 13 17	270,824 4 1	. .	. .	. .	. .	. .	. .
1897	5,110 0 0	19,418 0 0	82,891 17 1	314,989 0 9	9,453 16 6	35,924 9 9	8,685 14 14	33,005 15 5	2,034 4 15	7,730 1 7
1898	13,736 17 1	52,200 0 9	93,667 3 6	355,935 4 4	39,563 7 0	150,340 14 7	43,266 13 20	164,413 8 7	3,756 7 16	14,274 5 1
1899	31,995 6 17	121,582 5 6	93,518 0 10	355,368 9 8	41,569 13 3	157,964 13 11	81,817 1 8	310,904 17 0	10,879 11 14	41,342 8 0
1900	28,669 17 4	108,945 9 3	108,696 11 13	413,046 19 10	58,369 10 1	221,804 2 1	141,522 19 21	537,787 7 6	9,368 11 9	35,600 11 3
1901	21,607 9 12	83,188 15 7	144,693 17 7	557,071 7 6	77,604 0 20	298,775 11 3	198,807 13 20	765,409 12 3	9,198 10 4	35,414 5 2
Total	101,119 10 10	385,334 11 1	760,805 1 22	2,898,294 1 1	226,560 7 6	864,809 11 7	474,100 3 11	1,811,521 0 9	35,237 5 10	134,361 11 1

* From August 1, 1897.

† Prior to April 1, 1897, included with Murchison.

TABLE No. XVIII. (*continued*).—RETURN OF GOLD, THE PRODUCE OF THE STATE, ETC.

Year.	Yilgarn. Quantity. oz. dwt. gr.	Yilgarn. Value. £ s. d.	* Coolgardie. Quantity. oz. dwt. gr.	* Coolgardie. Value. £ s. d.	† East Coolgardie. Quantity. oz. dwt. gr.	† East Coolgardie. Value. £ s. d.	† North Coolgardie. Quantity. oz. dwt. gr.	† North Coolgardie. Value. £ s. d.	† North-East Coolgardie. Quantity. oz. dwt. gr.	† North-East Coolgardie. Value. £ s. d.
1886	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
1887	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
1888	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
1889	1,858 10 0	7,062 6 0	. .	. .	. .	. .	. .	. .	. .	. .
1890	2,277 0 0	8,652 12 0	. .	. .	. .	. .	. .	. .	. .	. .
1891	12,833 5 23	48,766 10 8	. .	. .	. .	. .	. .	. .	. .	. .
1892	21,209 9 18	80,596 1 1	. .	. .	. .	. .	. .	. .	. .	. .
1893	75,744 10 23	287,829 5 8	. .	. .	. .	. .	. .	. .	. .	. .
1894	31,498 7 17	119,693 17 1	105,329 16 11	400,253 6 8	. .	. .	. .	. .	. .	. .
1895	19,747 15 2	75,041 9 4	125,105 18 18	475,402 11 3	. .	. .	. .	. .	. .	. .
1896	16,565 5 0	62,947 19 0	69,135 3 16	262,713 13 11	85,287 1 7	324,090 16 11	17,160 10 4	65,209 18 8	4,113 3 15	15,630 1 9
1897	17,994 9 13	68,379 0 3	104,306 7 9	396,364 4 0	300,037 4 18	1,140,141 10 0	74,556 2 12	283,313 5 5	32,905 16 8	125,042 2 1
1898	11,696 3 13	44,445 9 6	127,227 1 8	483,462 17 1	450,312 5 10	1,711,186 12 7	70,625 6 4	268,376 3 5	125,240 9 19	475,913 17 3
1899	16,805 0 23	63,859 3 8	141,170 1 15	536,446 6 2	923,617 14 4	3,509,747 5 10	105,688 15 10	401,617 6 8	81,171 3 15	308,450 9 9
1900	29,418 2 1	111,788 15 10	119,781 9 3	455,169 10 8	810,906 15 18	3,081,445 15 11	106,193 7 17	403,534 17 3	52,129 2 10	198,090 13 2
1901	29,488 1 11	113,529 1 7	88,600 10 20	341,112 1 9	1,033,669 12 19	3,979,628 2 3	142,798 1 19	549,772 12 11	50,566 10 14	194,642 12 9
Total	287,136 2 0	1,092,591 11 8	880,656 9 4	3,350,924 11 6	3,603,830 14 4	13,746,240 3 6	517,022 3 18	1,971,824 4 4	346,116 6 9	1,317,769 16 9

* Declared April 5, 1894, to which date included with Yilgarn.

† Prior to May 1, 1896, included with Coolgardie.

TABLE No. XVIII. (*continued*).—RETURN OF GOLD, THE PRODUCE OF THE STATE, ETC.

Year	* Peak Hill. Quantity. oz. dwt. gr.	* Peak Hill. Value. £ s. d.	Murchison. Quantity. oz. dwt. gr.	Murchison. Value. £ s. d.	* East Murchison. Quantity. oz. dwt. gr.	* East Murchison. Value. £ s. d.	* Mt. Margaret. Quantity oz. dwt. gr.	* Mt. Margaret. Value. £ s. d.	† Yalgoo. Quantity. oz. dwt. gr.	† Yalgoo. Value. £ s. d.
1886	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
1887	. .	. .	. .	. .	. .	. .	. .	. .	. .	.
1888	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
1889	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
1890	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
1891	. .	. .	2,064 8 16	7,844 16 11	. .	. .	. .	. .	. .	. .
1892	. .	. .	24,356 9 12	92,554 12 1	. .	. .	. .	. .	. .	. .
1893	. .	. .	21,210 8 22	80,599 13 11	. .	. .	. .	. .	. .	. .
1894	. .	. .	52,946 6 11	201,196 0 7	. .	. .	. .	. .	. .	. .
1895	. .	. .	65,477 5 3	248,813 11 5	. .	. .	. .	. .	. .	. .
1896	. .	. .	71,282 13 17	270,824 4 1	. .	. .	. .	. .	. .	. .
1897	5,110 0 0	19,418 0 0	82,891 17 1	314,989 0 9	9,453 16 6	35,924 9 9	8,685 14 14	33,005 15 5	2,034 4 15	7,730 1 7
1898	13,736 17 1	52,200 0 9	93,667 3 6	355,935 4 4	39,563 7 0	150,340 14 7	43,266 13 20	164,413 8 7	3,756 7 16	14,274 5 1
1899	31,995 6 17	121,582 5 6	93,518 0 10	355,368 9 8	41,569 13 3	157,964 13 11	81,817 1 8	310,904 17 0	10,879 11 14	41,342 8 0
1900	28,669 17 4	108,945 9 3	108,696 11 13	413,046 19 10	58,369 10 1	221,804 2 1	141,522 19 21	537,787 7 6	9,368 11 9	35,600 11 3
1901	21,607 9 12	83,188 15 7	144,693 17 7	557,071 7 6	77,604 0 20	298,775 11 3	198,807 13 20	765,409 12 3	9,198 10 4	35,414 5 2
Total	101,119 10 10	385,334 11 1	760,805 1 22	2,898,294 1 1	226,560 7 6	864,809 11 7	474,100 3 11	1,811,521 0 9	35,237 5 10	134,361 11 1

* From August 1, 1897.

† Prior to April 1, 1897, included with Murchison.

TABLE No. XVIII. (*continued*).—RETURN OF GOLD, THE PRODUCE OF THE STATE, ETC.

Year.	Yilgarn.		* Coolgardie.		† East Coolgardie.		† North Coolgardie.		† North-East Coolgardie.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	oz. dwt. gr.	£ s. d.	oz. dwt. gr.	£ s. d.	oz. dwt. gr.	£ s. d.	oz. dwt. gr.	£ s. d.	oz. dwt. gr.	£ s. d.
1886	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
1887	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
1888	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
1889	1,858 10 0	7,062 6 0	. .	. .	. .	. .	. .	. .	. .	. .
1890	2,277 0 0	8,652 12 0	. .	. .	. .	. .	. .	. .	. .	. .
1891	12,833 5 23	48,766 10 8	. .	. .	. .	. .	. .	. .	. .	. .
1892	21,209 9 18	80,596 1 1	. .	. .	. .	. .	. .	. .	. .	. .
1893	75,744 10 23	287,829 5 8	. .	. .	. .	. .	. .	. .	. .	. .
1894	31,498 7 17	119,693 17 1	105,329 16 11	400,253 6 8	. .	. .	. .	. .	. .	. .
1895	19,747 15 2	75,041 9 4	125,105 18 18	475,402 11 3	. .	. .	. .	. .	. .	. .
1896	16,565 5 0	62,947 19 0	69,135 3 16	262,713 13 11	85,287 1 7	324,090 16 11	17,160 10 4	65,209 18 8	4,113 3 15	15,630 1 9
1897	17,994 9 13	68,379 0 3	104,306 7 9	396,364 4 0	300,037 4 18	1,140,141 10 0	74,556 2 12	283,313 5 5	32,905 16 8	125,042 2 1
1898	11,696 3 13	44,445 9 6	127,227 1 8	483,462 17 1	450,312 5 10	1,711,186 12 7	70,625 6 4	268,376 3 5	125,240 9 19	475,913 17 3
1899	16,805 0 23	63,859 3 8	141,170 1 15	536,446 6 2	923,617 14 4	3,509,747 5 10	105,688 15 10	401,617 6 8	81,171 3 15	308,450 9 9
1900	29,418 2 1	111,788 15 10	119,781 9 3	455,169 10 8	810,906 15 18	3,081,445 15 11	106,193 7 17	403,534 17 3	52,129 2 10	198,090 13 2
1901	29,488 1 11	113,529 1 7	88,600 10 20	341,112 1 9	1,033,669 12 19	3,979,628 2 3	142,798 1 19	549,772 12 11	50,566 10 14	194,642 12 9
Total	287,136 2 0	1,092,591 11 8	880,656 9 4	3,350,924 11 6	3,603,830 14 4	13,746,240 3 6	517,022 3 18	1,971,824 4 4	346,116 6 9	1,317,769 16 9

* Declared April 5, 1894, to which date included with Yilgarn.

† Prior to May 1, 1896, included with Coolgardie.

TABLE No. XVIII. (*continued*).—RETURN OF GOLD, THE PRODUCE OF THE STATE, ETC.

Year.	* Broad Arrow.		† Dundas.		‡ Donnybrook.		Unspecified.		Totals.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	oz. dwt. gr.	£ s. d.	oz. dwt. gr.	£ s. d.	oz. dwt. gr.	£ s. d.	oz. dwt. gr.	£ s. d.	oz. dwt. gr.	£ s. d.
1886	. .	. .	. .	. .	. .	. .	. .	. .	302 0 0	1,147 12 0
1887	. .	. .	. .	. .	. .	. .	. .	. .	4,873 0 0	18,517 8 0
1888	. .	. .	. .	. .	. .	. .	. .	. .	3,493 0 0	13,273 8 0
1889	. .	. .	. .	. .	. .	. .	. .	. .	15,492 10 0	58,871 10 0
1890	. .	. .	. .	. .	. .	. .	. .	. .	22,806 6 6	86,663 19 9
1891	. .	. .	. .	. .	. .	. .	. .	. .	30,311 1 9	115,182 1 2
1892	. .	. .	. .	. .	. .	. .	. .	. .	59,548 6 4	226,283 11 5
1893	. .	. .	147 19 11	562 5 11	. .	. .	. .	. .	110,890 18 5	421,385 9 2
1894	. .	. .	228 7 12	867 16 6	. .	. .	. .	. .	207,131 6 6	787,098 19 10
1895	. .	. .	241 18 2	919 4 9	. .	. .	. .	. .	231,512 13 21	879,748 4 9
1896	. .	. .	4,350 6 6	16,531 3 9	. .	. .	. .	. .	281,265 6 12	1,068,808 4 8
1897	4,159 5 9	15,805 4 6	19,310 16 7	73,381 1 11	. .	. .	. .	. .	674,993 17 2	2,564,976 12 11
1898	24,631 8 20	93,599 9 6	32,031 16 6	121,720 17 9	. .	. .	. .	. .	1,050,183 11 23	3,990,697 13 5
1899	44,524 5 18	169,192 5 10	45,164 19 1	171,626 16 4	506 2 3	1,923 4 1	904 7 14	3,436 12 10	1,643,876 14 7	6,246,731 10 4
1900	47,860 11 23	181,870 5 5	40,687 11 2	154,612 14 1	265 11 1	1,009 2 0	7,930 17 3	30,137 5 1	1,580,950 3 17	6,007,610 14 1
1901	29,104 15 15	112,053 8 2	38,796 5 1	149,365 11 5	4 12 20	17 17 5	1,906 0 2	7,338 2 4	1,879,390 10 3	7,235,653 9 0
Total	150,280 7 13	572,520 13 5	180,959 19 0	689,587 12 5	776 6 0	2,950 3 6	10,741 4 19	40,912 0 3	7,797,021 5 19	29,722,650 8 6

* From September 1, 1897. † Prior to 1893 included with Yilgarn. ‡ From March 1, 1899.

TABLE No. XIX.

ALL MINES.—NUMBER OF DEATHS FROM ACCIDENTS IN THE DIFFERENT GOLDFIELDS, MINING DISTRICTS, AND COALFIELDS OF THE COLONY, DURING THE YEAR 1900.

Goldfields, Districts, Mining Districts, and Coalfield.	Number of Men employed.	By Explosives.	Falls in Mine				In Shafts.									Miscellaneous Underground.									On Surface.					Gross Total.
			Falls of Sides.	Falls of Roof.	Miscellaneous.	Total Falls.	Overwinding.	Ropes and Chains Breaking.	Whilst Ascending or Descending by Machinery.	Falling into Shafts from Surface.	Things Falling from Surface.	Falling from Part Way Down.	Things Falling from Part Way Down.	Miscellaneous.	Total in Shafts.	Suffocation.	Irruption of Water.	On Inclined and Engine Planes.	By trams and trucks.	By Machinery.	Ropes and Chains Breaking.	Falling into Water.	Sundries.	Total Miscellaneous Underground.	By Machinery.	Boilers Bursting.	Railways and Tramways.	Miscellaneous.	Total on Surface.	
Goldfield.																														
1. Kimberley	7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
2. Pilbarra	111	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
3. West Pilbarra	52	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
4. Ashburton	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
5. Gascoyne	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
6. Peak Hill	354	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
7. East Murchison	873	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
8. Murchison	1,441	..	..	..	..	..	..	1	..	1	..	1	..	..	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3
9. Yalgoo	226	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
10. Mt. Margaret	1,851	..	..	..	..	..	..	2	..	..	..	..	..	1	3	..	..	..	..	..	..	..	..	..	1	..	..	..	1	4
11. North Coolgardie	1,510	3	1	1	..	2	..	1	..	..	..	1	..	..	2	..	..	..	..	..	..	..	1	1	..	..	..	..	..	8
12. Broad Arrow	646	..	1	..	..	1	..	1	..	..	..	1	..	..	2	1	..	..	..	..	..	..	..	1	1	..	..	..	1	5
13. North-East Coolgardie	860	..	1	1	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	1	1	4
14. East Coolgardie	5,903	2	..	3	..	3	..	..	..	1	..	1	..	..	2	1	..	..	..	..	..	..	1	2	1	..	..	4	5	14
15. Coolgardie	1,752	..	1	1	..	2	..	..	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	..	1	..	..	..	1	4
16. Yilgarn	497	..	..	..	..	..	..	..	..	..	..	..	1	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
17. Dundas	526	..	..	1	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
18. Phillips River	58	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
19. Donnybrook	80	..	..	..	..	..	..	..	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
Tin . Greenbushes M.D.	306	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Tin . Marble Bar D.	49	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Copper Day Dawn D.	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Copper Mt. Malcolm D.	67	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Copper Phillips River G.F.	107	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Copper West Pilbarra G.F.	34	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Lead . Northampton and Yandanooka M.Ds.	8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Coal . Collie River Coal M.D.	400	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Limestone . Yilgarn G.F.	10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Diamonds . Nullagine D.	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total	17,735	5	4	7	..	11	..	5	..	4	..	4	1	1	15	2	..	..	..	..	..	..	3	5	4	..	..	5	9	45

Table No. XX.

All Mines.—Synopsis of ACCIDENTS, showing Killed and Injured, which have occurred During the Year 1900, and the Fields on which they have happened.

Class of Accident.		Kimberley.	Pilbarra.	West Pilbarra.	Ashburton.	Gascoyne.	Peak Hill.	East Murchison.	Murchison.	Yalgoo.	Mt. Margaret.	North Coolgardie.	Broad Arrow.	North-East Coolgardie.	East Coolgardie.	Coolgardie.	Yilgarn.	Dundas.	Phillips River.	Donnybrook.	Northampton.	Greenbushes.	Collie.	Total 1900.	Total 1899.	Comparison with previous Year
1. By explosives	Killed											3			2									5	14	-9
	Injured							1	2	1	1	3		1	1	3	1							14	21	-7
2. By falls of ground	Killed											2	1	2	3	2		1						11	9	*2
	Injured						6	1	1	2	2				5	4	1	4				1	1	28	27	*1
3. In shafts	Killed								3		3	2	2		2	1	1			1				15	14	*1
	Injured							2	5	2	4	4	1	1	13			4					1	37	24	*13
4. By miscellaneous underground	Killed											1	1	1	2									5	1	*4
	Injured							2	1		2	1	2		13	2	1	1						25	11	*14
5. On surface	Killed										1		1	1	5	1								9	7	*2
	Injured						1	3	1		1	2	2	3	12	2	1	2						30	18	*12
Total, 1900	**Killed**								**3**		**4**	**8**	**5**	**4**	**14**	**4**	**1**	**1**		**1**				**45**		
	Injured						**7**	**9**	**10**	**5**	**10**	**10**	**5**	**5**	**44**	**11**	**4**	**11**				**1**	**2**	**134**		
Total, 1899	Killed		1					1	3	4	6	2	3	3	14	5	2						1		45	
	Injured		1				2	5	9	1	4	14	6	8	29	6	3	7				1	5		101	
Comparison with previous year	Killed		-1					-1	=	-4	-2	*6	*2	*1	=	-1	-1	*1		*1			-1			=
	Injured		-1				*5	*4	*1	*4	*6	-4	-1	-3	*15	*5	*1	*4				=	-3			*33

* Represents *plus*.

Table No. XXI.

MONTHLY GOLD PRODUCTION.—Return of Gold, showing the Quantity reported Monthly to the Mines Department from the several Goldfields of the Colony during the Year 1900.

Goldfield.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.
Kimberley	60·00	150·30	30·00	30·00	46·40	20·00	25·00	81·65	. .	102·80	15·00	10·00	571·15
Pilbarra	627·00	844·05	2,628·35	1,629·13	856·50	867·85	2,640·85	1,232·10	1,048·58	1,681·87	1,156·48	1,404·09	16,616·85
West Pilbarra	130·03	7·75	76·96	22·25	21·46	38·16	331·00	16·52	45·77	79·30	5·53	178·92	953·65
Ashburton	. .	160·00	312·00	227·00	122·00	128·00	146·00	148·00	128·00	118·00	125·00	90·00	1,704·00
Gascoyne	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	74·00	. .	74·00
Peak Hill	2,666·00	245·15	2,085·25	4,564·04	4,164·41	543·51	3,981·17	2,293·50	1,522·35	1,644·30	1,671·90	1,190·05	26,571·63
East Murchison	3,891·52	3,431·10	5,619·91	2,896·80	6,097·74	4,564·36	6,584·89	5,810·49	6,847·60	5,830·93	6,834·32	6,288·37	64,698·03
Murchison	7,084·41	7,218·71	9,377·69	5,889·89	9,679·99	7,296·61	7,825·10	9,594·56	7,994·33	10,800·03	11,271·16	11,689·83	105,722·31
Yalgoo	897·32	782·25	898·30	231·05	912·50	948·80	340·90	1,293·20	1,384·12	511·90	1,041·16	860·36	10,101·86
Mount Margaret	7,996·16	8,942·00	10,335·08	9,344·02	14,284·35	12,138·37	12,990·23	12,786·91	12,804·37	13,274·71	10,384·80	20,407·75	145,688·75
North Coolgardie	7,530·79	9,039·32	8,756·29	7,090·29	8,238·37	9,360·64	9,028·25	9,918·39	8,223·46	10,892·02	8,534·12	10,162·03	106,773·97
Broad Arrow	2,640·91	6,041·39	5,055·62	4,497·64	3,061·41	2,251·42	2,926·88	4,239·58	5,310·74	5,575·29	4,916·45	5,915·99	52,433·32
North-East Coolgardie.	5,628·13	5,961·35	8,469·37	7,136·89	5,337·08	5,968·08	6,018·64	6,065·07	4,879·33	5,711·70	4,314·99	5,255·23	70,745·86
East Coolgardie	52,353·72	64,239·44	59,062·36	49,438·71	56,810·72	68,403·39	59,828·43	60,430·41	64,205·58	72,909·75	68,857·37	61,431·10	737,970·98
Coolgardie	7,737·85	8,892·19	9,382·37	8,190·55	8,471·16	11,502·18	8,102·18	8,282·98	8,494·24	9,574·50	7,795·11	5,987·70	102,413·01
Yilgarn	1,785·88	2,004·70	1,543·34	1,511·60	1,698·54	2,393·85	2,434·91	3,472·10	3,673·13	2,922·76	2,868·55	2,846·06	29,155·42
Dundas	2,646·57	2,925·96	3,872·32	3,440·61	3,236·47	3,381·68	3,393·48	3,826·50	3,349·82	4,314·67	3,215·35	3,480·20	41,083·63
Phillips River	. .	. .	. .	. .	. .	. .	5·00	. .	. .	. .	. .	34·00	39·00
Donnybrook	. .	176·10	. .	. .	. .	. .	. .	. .	94·50	135·60	. .	46·90	453·10
Goldfields generally.	. .	. .	95·80	. .	. .	. .	50·76	. .	. .	. .	. .	. .	146·56
Total	103,676·29	121,061·76	127,601·01	106,140·47	123,039·10	129,806·90	126,653·67	129,491·96	130,005·92	146,080·13	133,081·29	137,278·58	1,513.917·08

Table No. XXII.

HALF-YEARLY GOLD PRODUCTION.—Comparative Table, showing by Half-Years the Quantity of Gold reported to the Mines Department from the several Goldfields of the Colony to December 31, 1900.

Goldfield.	Previous to 1897.	1897. Jan.—June.	1897. July—Dec.	1898. Jan.—June.	1898. July—Dec.	1899. Jan.—June.	1899. July—Dec.	1900. Jan.—June.	1900. July—Dec.	Total to Date.
	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.
Kimberley	12,734·00	229·30	. .	222·42	217·75	752·15	165·00	336·70	234·45	14,891·77
Pilbarra	28,470·56	3,547·65	3,277·61	5,499·86	8,913·93	8,143·72	11,148·26	7,452·88	9,163·97	85,618·44
West Pilbarra	337·91	309·84	550·22	320·70	6·00	612·08	1,322·72	296·61	657·04	4,413·12
Ashburton	. .	. .	302·95	250·63	250·00	672·10	987·00	949·00	755·00	4,166·68
Gascoyne	. .	6·75	6·80	. .	13·50	262·65	71·12	. .	74·00	434·82
Peak Hill	11,070·16	. .	10,883·23	6,464·00	8,505·32	11,638·45	20,315·20	14,268·36	12,303·27	95,447·99
East Murchison	2,576·00	6,383·44	14,611·63	15,845·00	21,235·32	19,833·92	25,204·98	26,501·43	38,196·60	170,388·32
Murchison	140,432·28	20,597·53	41,718·66	39,417·68	39,838·71	36,825·30	43,723·41	46,547·30	59,175·01	468,275·88
Yalgoo	7,227·00	1,193·04	2,262·75	1,849·52	1,449·43	4,387·01	7,748·93	4,670·22	5,431·64	36,219·54
Mt. Margaret	4,992·10	6,897·85	15,694·24	20,649·79	29,067·98	34,889·72	45,034·00	63,039·98	82,648·77	302,914·43
North Coolgardie	26,962·85	32,419·14	28,943·68	30,859·30	42,019·58	51,473·12	65,495·02	50,015·70	56,758·27	384,946·66
Broad Arrow	9,129·25	6,377·86	8,086·68	11,064·62	16,661·81	20 509·75	27,684·63	23,548·39	28,884·93	151,947·92
North-East Coolgardie	8,975·95	11,984·95	28,468 15	77,102·88	93,338·85	64,344·44	48,481·01	38,500·90	32,244·96	403,442·09
East Coolgardie	143,828·70	120,036·23	176,727·88	165,322·71	257,069·15	337,539·19	517,865·68	350,308·34	387,662·64	2,456,360·52
Coolgardie	74,181·76	24,640·06	40,151·42	48,468·27	51,204·57	54,171·90	77,084·99	54,176·30	48,236·71	472,315·98
Yilgarn	94,194·60	8,989·22	8,083·60	6,045·41	5,723·99	6,431·72	9,940·06	10,937·91	18,217·51	168,564·02
Dundas	3,979·90	5,837·21	13,446·31	15,354·71	21,443·77	23,595·84	20,617·46	19,503·61	21,580·02	145,358·83
Phillips River	. .	. .	. .	. .	. .	. .	. .	. .	39·00	39·00
Donnybrook	. .	. .	. .	. .	14·65	132·00	379·49	176·10	277·00	979·24
Goldfields generally	. .	. .	. .	. .	. .	1,261·70	17·20	95·80	50·76	1,425·46
Total { Half-year	. .	249,450·07	393,215·81	444,737·50	596,974·31	677,476·76	923,286·16	711,325·53	802,591·55	. .
Total { Year	569,093·02	642,665·88		1,041,711·81		1,600,762·92		1,513,917·08		5,368,150·71

TABLE No. XXIII.

GENERAL RETURN SHOWING, FOR EACH GOLDFIELD AND GOLDFIELD DISTRICT, THE AREA IN SQUARE MILES, LEASES IN FORCE, PARTICULARS OF PLANT, AVERAGE NUMBER OF MEN EMPLOYED, THE QUANTITIES OF ALLUVIAL AS REPORTED, DOLLIED AND SPECIMEN GOLD AND ORE TREATED, WITH GOLD YIELD TO DECEMBER 31, 1900.

Geographical Division.	Goldfield.	District.	Warden's Head Quarters.	Date of Proclamation of Goldfield.				Area in Square Miles.		Leases in Force.		Particulars of Plant.				Average Number of Men Employed.	
				Proclamation Gazetted.	To take effect from	Latest Amendment of Boundaries Gazetted.	To take effect from	District.	Goldfield.	No.	Area in Acres.	Milling. Number Stamps.	Milling. Other Mills	Cyaniding. Leaching Vats.	Cyaniding. Filter Presses.	Above Ground.	Under Ground
Northern Goldfields	Kimberley	. .	Hall's Creek	20-5-86	20-5-86	. .	. .	. .	46,886	4	38	70	2	. .	. .	3	4
	Pilbarra	Marble Bar	Marble Bar	1-10-88	1-10-88	20-9-95	1-11-95	25,205	. .	43	379	80	2	4	. .	32	35
	,,	Nullagine	. .					9,675	34,880	16	150	35	. .	. .	. .	28	16
	West Pilbarra	. .	Roebourne	20-9-95	1-11-95	. .	. .	. .	9,480	13	161	30	1	. .	. .	32	20
	Ashburton	. .	Mt. Mortimer	11-12-90	11-12-90	25-6-97	15-4-97	. .	6,992	. .	. .	. .	. .	. .	. .	. .	. .
	Gascoyne	. .	Bangemall	25-6-97	15-4-97	. .	. .	. .	5,061	5	72	. .	1	. .	. .	. .	. .
Central Goldfields	Peak Hill	. .	Peak Hill	19-3-97	1-4-97	. .	. .	. .	12,194	120	1,744	40	. .	. .	. .	130	224
	East Murchison	. .	Lawlers	28-6-95	28-6-95	24-12-97	1-1-98	. .	28,242	147	2,064	155	5	12	. .	460	413
	Murchison	Cue	Cue					7,981	. .	70	678	175	2	20	. .	144	139
	,,	Nannine	. .	24-9-91	24-9-91	8-2-95	23-1-95	7,716	. .	110	1,266	153	. .	15	. .	182	206
	,,	Day Dawn	. .					728	. .	63	679	70	2	18	. .	126	117
	,,	Mt. Magnet	. .					4,088	20,513	95	906	115	2	19	. .	233	294
	Yalgoo	. .	Yalgoo	8-2-95	23-1-95	. .	. .	. .	18,921	39	480	60	5	. .	. .	89	137
Eastern Goldfields	Mt. Margaret	Mt. Malcolm	Mt. Malcolm	12-3-97	1-4-97	24-12-97	1-1-98	2,644	. .	154	2,990	258	5	52	. .	440	562
	,,	Mt. Margaret	. .					39,510	42,154	123	2,510	131	. .	31	. .	445	404
	North Coolgardie	Menzies	Menzies					3,268	.	86	1,183	148	2	42	4	282	283
	,, ,,	Ularring	. .	28-6-95	28-6-95	12-3-97	1-4-97	12,256	. .	133	1,707	60	. .	3	. .	143	212
	,, ,,	Niagara	. .					779	. .	88	1,028	105	1	17	. .	206	246
	,, ,,	Yerilla	. .					14,306	30,609	46	725	45	3	13	. .	62	76
	Broad Arrow	. .	Broad Arrow	17-11-96	20-11-96	. .	. .	. .	590	113	1,445	235	4	30	3	287	359
	North-East Coolgardie.	Kanowna	Kanowna					1,099	. .	133	1,625	175	21	11	. .	260	397
	,, ,,	Bulong	. .	20-3-96	15-4-96	13-11-96	20-11-96	991	. .	38	509	30	. .	. .	. .	76	102
	,, ,,	Kurnalpi	. .					19,452	21,542	8	133	10	1	. .	. .	15	10
	East Coolgardie	. .	Kalgoorlie	21-9-94	1-10-94	20-3-96	15-4-96	. .	632	382	6,368	360	87	184	76	3,154	2,749
	Coolgardie	Coolgardie	Coolgardie	6-4-94	6-4-94	20-3-96	15-4-96	9,221	. .	212	2,786	416	2	43	4	563	665
	,,	Kunanalling	. .					2,753	11,974	123	1,570	138	4	15	2	235	289
	Yilgarn	. .	Southern Cross	1-10-88	1-10-88	20-3-96	15-4-96	. .	15,593	48	765	175	5	52	. .	258	239
	Dundas	. .	Norseman	31-8-93	31-8-93	20-3-96	15-4-96	. .	17,848	93	1,164	150	8	35	. .	206	320
	Phillips River	. .	Ravensthorpe	21-9-00	14-9-00	. .	. .	. .	1,300	5	114	. .	. .	. .	. .	22	36
	Donnybrook	. .	Donnybrook	17-11-99	27-11-99	. .	. .	. .	102	51	785	5	2	. .	. .	37	43
	Goldfields generally.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	60	3	5	. .	. .	. .
			Total	. .	. .	. .	. .	. .	325,513	2,561	36,024	3,484	170	621	89	8,150	8,597

TABLE No. XXIII (*continued*).—GENERAL RETURN FOR EACH GOLDFIELD AND GOLDFIELD DISTRICT, ETC.

Geographical Division	Goldfield.	District.	First Quarter of 1900. Alluvial.	First Quarter of 1900. Dollied and Specimens.	First Quarter of 1900. Ore Treated.	First Quarter of 1900. Gold therefrom.	First Quarter of 1900. Average per ton Treated.	Second Quarter of 1900. Alluvial.	Second Quarter of 1900. Dollied and Specimens.	Second Quarter of 1900. Ore Treated.	Second Quarter of 1900. Gold therefrom.	Second Quarter of 1900. Average per ton Treated.
			oz.	oz.	tons.	oz.	oz.	oz.	oz.	tons.	oz.	oz.
Northern Goldfields	Kimberley	. . . . .	140·00	. .	291·00	100·30	·34	70·00	. .	100·00	26·40	·26
	Pilbarra	Marble Bar	255·00	. .	747·40	2,590·75	3·46	880·00	. .	1,195·55	1,788·38	1·49
	,,	Nullagine	27·00	4·00	470·30	1,222·65	2·59	. .	7·00	209·05	678·10	3·24
	West Pilbarra	. . . . .	146·93	. .	68·75	67·81	·98	81·87	. .	. .	. .	. .
	Ashburton	. . . . .	472·00	. .	. .	. .	. .	477·00	. .	. .	. .	. .
	Gascoyne	. . . . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Central Goldfields	Peak Hill	. . . . .	. .	. .	2,212·00	4,996·40	2·25	. .	. .	4,028·50	9,271·96	2·30
	East Murchison	. . . . .	200·00	96·00	13,786·50	12,646·53	·91	143·20	88·33	11,321·00	13,327·37	1·17
	Murchison	Cue	25·00	18·20	4,258·50	4,690·45	1·10	18·50	10·40	3,647·00	4,128·16	1·13
	,,	Nannine	. .	561·35	7,813·75	5,802·28	·74	. .	1,217·26	5,796·00	5,679·91	·98
	,,	Day Dawn	4·00	62·13	372·50	1,904·10	5·11	. .	5·05	1,114·00	2,351·85	2·11
	,,	Mt. Magnet	. .	22·30	9,273·50	10,591·00	1·14	. .	57·90	8,234·00	9,397·46	1·14
	Yalgoo	. . . . .	. .	. .	4,496·00	2,577·87	·57	. .	30·00	3,403·00	2,062·35	·60
Eastern Goldfields	Mt. Margaret	Mt. Malcolm	. .	48·00	13,728·30	17,178·49	1·25	1·20	. .	19,724·00	24,791·20	1·25
	,,	Mt. Margaret	. .	150·00	10,327·00	9,896·75	·95	. .	16·50	11,268·50	10,957·84	·97
	North Coolgardie	Menzies	6·99	7·21	11,091·50	11,520·85	1·03	31·14	4·08	9,128·00	11,887·84	1·30
	,, ,,	Ularring	. .	5·00	4,325·35	5,127·38	1·18	. .	. .	3,260·50	4,058·34	1·24
	,, ,,	Niagara	3·22	18·62	9,257·00	7,058·70	·76	. .	45·10	7,060·00	6,613·21	·93
	,, ,,	Yerilla	36·65	100·00	569·60	1,441·78	2·53	50·02	121·80	1,397·00	1,877·77	1·34
	Broad Arrow	. . . . .	220·00	33·65	20,172·50	13,484·27	·66	344·20	211·94	11,168·75	9,254·33	·83
	North-East Coolgardie	Kanowna {quartz	. .	388·80	11,569·80	7,789·54	·67	. .	489·16	10,536·00	6,253·44	·59
		Kanowna {cement	2,079·52	. .	5,408·00	3,209·71	·59	3,526·23	. .	3,892·75	2,258·24	·58
	,, ,,	Bulong	1,095·78	1,745·00	2,171·25	2,498·55	1·15	1,035·77	295·25	3,457·25	3,790·46	1·09
	,, ,,	Kurnalpi	1,035·00	92·45	92·00	124·50	1·35	579·00	64·80	192·00	149·70	·78
	East Coolgardie	. . . . .	1,384·85	·50	109,333·55	174,270·17	1·59	396·34	564·24	118,648·46	173,692·24	1·46
	Coolgardie	Coolgardie	353·24	41·71	23,530·85	19,628·70	·83	494·19	8·42	25,749·35	22,776·30	·81
	,,	Kunanalling	. .	44·75	7,329·00	5,944·01	·81	. .	48·93	5,980·50	4,836·05	·81
	Yilgarn	. . . . .	. .	. .	9,626·50	5,333·92	·55	. .	. .	9,920·00	5,603·99	·56
	Dundas	. . . . .	. .	21·97	11,494·00	9,422·88	·82	64·30	9·00	12,300·00	9,985·46	·81
	Phillips River	. . . . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
	Donnybrook	. . . . .	. .	. .	57·00	176·10	3·09	. .	. .	. .	. .	. .
	Goldfields generally	. . . . .	41·78	54·02	. .	. .	. .	. .	. .	. .	. .	. .
		Total	7,526·96	3,515·66	293,873·40	341,296·44	1·16	8,192·96	3,295·16	292,731·16	347,498·35	1·11

TABLE No. XXIII. (*continued*).—GENERAL RETURN FOR EACH GOLDFIELD AND GOLDFIELD DISTRICT, ETC.

Geographical Division.	Goldfield.	District.	Third Quarter of 1900. Alluvial.	Third Quarter of 1900. Dollied and Specimens.	Third Quarter of 1900. Ore Treated.	Third Quarter of 1900. Gold therefrom.	Third Quarter of 1900. Average per ton Treated.	Fourth Quarter of 1900. Alluvial.	Fourth Quarter of 1900. Dollied and Specimens.	Fourth Quarter of 1900. Ore Treated.	Fourth Quarter of 1900. Gold therefrom.	Fourth Quarter of 1900. Average per ton Treated.
			oz.	oz.	tons.	oz.	oz.	oz.	oz.	tons.	oz.	oz.
Northern Goldfields	Kimberley	. . . . .	65·00	. .	119·00	41·65	·35	56·00	. .	76·50	71·80	·93
	Pilbarra	Marble Bar	119·02	12·05	1,355·71	3,557·81	2·62	246·52	65·87	951·00	2,571·65	2·70
	,,	Nullagine	. .	. .	590·75	1,232·65	2·08	. .	. .	653·95	1,358·40	2·07
	West Pilbarra	. . . . .	3·97	. .	486·40	389·32	·80	124·69	. .	126·00	139·06	1·10
	Ashburton	. . . . .	422·00	. .	. .	. .	. .	333·00	. .	. .	. .	. .
	Gascoyne	. . . . .	. .	. .	. .	. .	. .	74·00	. .	. .	. .	. .
Central Goldfields	Peak Hill	. . . . .	. .	19·60	6,342·10	7,777·42	1·22	. .	5·25	3,672·00	4,501·00	1·22
	East Murchison	. . . . .	256·62	20·85	15,654·50	18,965·51	1·21	138·72	74·95	16,161·00	18,739·95	1·16
	Murchison	Cue	59·30	78·20	4,115·50	5,093·88	1·23	56·05	71·65	5,440·00	5,899·02	1·08
	,,	Nannine	. .	626·63	8,161·03	7,489·92	·91	350·00	66·20	8,564·50	8,363·72	·97
	,,	Day Dawn	. .	36·80	949·50	1,911·83	2·13	. .	34·60	5,665·00	8,336·50	1·47
	,,	Mt. Magnet	. .	229·38	11,701·00	9,888·05	·84	. .	175·24	11,685·25	10,408·04	·89
	Yalgoo	. . . . .	. .	250·00	4,436·00	2,768·22	·62	. .	9·00	3,261·20	2,404·42	·73
Eastern Goldfields	Mt. Margaret	Mt. Malcolm	. .	580·00	23,480·45	25,003·83	1·06	. .	336·19	24,563·75	25,093·96	1·02
	,,	Mt. Margaret	. .	110·85	12,867·25	12,886·83	1·00	4·00	30·25	16,862·00	18,602·86	1·10
	North Coolgardie	Menzies	71·97	6·96	8,519·50	12,510·17	1·46	442·78	20·82	9,308·39	13,262·26	1·42
	,, ,,	Ularring	. .	. .	4,822·90	5,455·88	1·13	. .	. .	4,411·25	5,638·36	1·27
	,, ,,	Niagara	·90	18·80	7,838·00	6,605·09	·84	. .	6·40	6,561·00	7,694·65	1·17
	,, ,,	Yerilla	30·43	109·93	1,697·00	2,359·97	1·39	15·95	184·60	1,481·00	2,322·35	1·57
	Broad Arrow	. . . . .	518·46	10·00	17,728·32	11,948·74	·67	387·60	12·85	24,423·60	16,007·28	·65
	North-East Coolgardie	Kanowna {quartz	. .	249·60	11,530·75	7,593·95	·65	. .	128·20	9,936·50	6,781·32	·68
		Kanowna {cement	1,374·88	. .	4,469·25	2,212·88	·49	1,951·20	. .	2,100·00	1,095·99	·52
	,, ,,	Bulong	1,273·83	4·50	2,596·75	3,181·53	1·22	906·86	425·61	2,605·75	2,885·93	1·10
	,, ,,	Kurnalpi	491·50	436·00	100·00	144·37	1·44	750·00	304·17	55·00	52·64	·95
	East Coolgardie	. . . . .	339·17	786·07	128,399·69	183,339·18	1·43	175·20	668·43	135,338·30	202,354·59	1·49
	Coolgardie	Coolgardie	310·16	13·75	25,588·50	19,535·33	·76	231·10	59·87	29,403·22	17,785·69	·60
	,,	Kunanalling	104·17	11·80	7,068·75	4,904·19	·69	131·90	90·83	8,437·58	5,057·92	·59
	Yilgarn	. . . . .	. .	. .	21,040·50	9,580·14	·45	. .	. .	13,816·10	8,637·37	·62
	Dundas	. . . . .	101·83	4·51	12,499·50	10,463·46	·83	. .	. .	12,721·00	11,010·22	·86
	Phillips River	. . . . .	. .	5·00	. .	. .	. .	. .	34·00	. .	. .	. .
	Donnybrook	. . . . .	. .	. .	130·00	94·50	·72	. .	. .	173·00	182·50	1·05
	Goldfields generally	. . . . .	50·76	. .	. .	. .	. .	. .	. .	. .	. .	. .
		Total	5,593·97	3,621·28	344,288·60	376,936·30	1·09	6,375·57	2,804·98	358,453·84	407,259·45	1·13

TABLE No. XXIII. (*continued*).—GENERAL RETURN FOR EACH GOLDFIELD AND GOLDFIELD DISTRICT, ETC.

Geographical Division.	Goldfield.	District.	Total for 1900. Alluvial.	Total for 1900. Dollied and Specimens	Total for 1900. Ore Treated.	Total for 1900. Gold therefrom.	Total for 1900. Average per ton Treated.	Total for 1900. Oz. from Unknown tons.	Total Previous to 1900. Alluvial.	Total Previous to 1900. Dollied and Specimen.	Total Previous to 1900. Ore Treated.	Total Previous to 1900. Gold therefrom.
			oz.	oz.	tons.	oz.	oz.	oz.	oz.	oz.	tons.	oz.
Northern Goldfields	Kimberley	. . . . .	331·00	. .	586·50	240·15	·40	. .	727·00	. .	14,452·00	13,593·62
	Pilbarra	Marble Bar	1,500·54	77·92	4,249·66	10,508·59	2·47	2,082·00	2,878·50	882·27	25,322·45	51,288·01
	,,	Nullagine	27·00	11·00	1,924·05	4,491·80	2·33	. .	1,729·79	53·45	5,224·65	10,087·57
	West Pilbarra	. . . . .	357·46	. .	681·15	596·19	·87	. .	735·07	. .	1,851·00	2,724·40
	Ashburton	. . . . .	1,704·00	. .	. .	. .	. .	. .	2,122·68	340·00	. .	. .
	Gascoyne	. . . . .	74·00	. .	. .	. .	. .	. .	119·43	20·30	236·70	221·09
Central Goldfields	Peak Hill	. . . . .	. .	24·85	16,254·60	26,546·78	1·63	4,551·60	. .	1,246·45	18,835·19	63,078·31
	East Murchison	. . . . .	738·54	280·13	56,923·00	63,679·36	1·11	. .	2,890·54	3,043·81	87,344·74	99,755·94
	Murchison	Cue	158·85	178·45	17,461·00	19,811·51	1·13	1,072·00	46·39	1,121·71	93,574·12	91,974·50
	,,	Nannine	350·00	2,471·44	30,335·28	27,335·83	·90	. .	1·90	1,177·47	77,323·50	76,347·45
	,,	Day Dawn	4·00	138·58	8,101·00	14,504·28	1·79	. .	63·31	1,739·79	82,125·60	99,898·20
	,,	Mt. Magnet	. .	484·82	40,893·75	40,284·55	·98	. .	87·53	3,666·32	88,738·25	85,357·00
	Yalgoo	. . . . .	. .	289·00	15,596·20	9,812·86	·62	. .	. .	16·50	28,512·98	26,101·18
Eastern Goldfields	Mt. Margaret	Mt. Malcolm	1·20	964·19	81,496·50	92,067·48	1·12	. .	1,571·62	2,799·61	102,629·81	119,818·70
	,,	Mt. Margaret	4·00	307·60	51,324·75	52,344·28	1·01	. .	37·52	507·50	23,892·95	32,490·73
	North Coolgardie	Menzies	552·88	39·07	38,047·39	49,181·12	1·29	. .	89·62	265·00	109,758·00	196,006·61
	,, ,,	Ularring	. .	5·00	16,820·00	20,279·96	1·20	. .	1·82	374·00	13,621·61	22,893·91
	,, ,,	Niagara	4·12	88·92	30,716·00	27,971·65	·91	. .	89·44	121·83	45,401·45	36,213·91
	,, ,,	Yerilla	133·05	516·33	5,144·60	8,001·87	1·55	275·00	735·90	4,573·72	13,580·23	16,531·93
	Broad Arrow	. . . . .	1,470·26	268·44	73,493·17	50,694·62	·69	250·00	1,597·80	495·55	113,152·96	97,171·25
	North-East Coolgardie	Kanowna {quartz	. .	1,255·76	43,573·05	28,418·25	·65	. .	. .	956·95	75,018·40	71,619·87
		Kanowna {cement	8,931·83	. .	15,870·00	8,776·82	·55	. .	93,615·73	1·00	87,413·18	103,677·85
	,, ,,	Bulong	4,312·24	2,470·36	10,831·00	12,356·47	1·14	. .	15,391·33	2,671·65	33,116·55	37,931·32
	,, ,,	Kurnalpi	2,855·50	897·42	439·00	471·21	1·07	. .	5,508·45	151·07	1,492·55	1,171·01
	East Coolgardie	. . . . .	2,295·56	2,019·24	491,720·00	733,656·18	1·49	500·00	590·25	223·71	895,675·91	1,717,075·58
	Coolgardie	Coolgardie	1,388·69	123·75	104,271·92	79,726·02	·76	. .	6,524·89	1,463·88	267,711·03	287,877·35
	,,	Kunanalling	236·07	196·31	28,815·83	20,742·17	·71	. .	4·22	1,645·47	82,518·11	72,387·12
	Yilgarn	. . . . .	. .	. .	54,403·10	29,155·42	·53	. .	. .	738·18	272,123·53	138,670·42
	Dundas	. . . . .	166·13	35·48	49,014·50	40,882·02	·83	. .	142·75	229·28	110,210·63	103,903·17
	Phillips River	. . . . .	. .	39·00	. .	. .	. .	. .	. .	. .	. .	. .
	Donnybrook	. . . . .	. .	. .	360·00	453·10	1·26	. .	32·10	. .	312·80	494·04
	Goldfields generally	. . . . .	92·54	54·02	. .	. .	. .	. .	23·90	21·10	. .	1,233·90
		Total	27,689·46	13,237·08	1,289,347·00	1,472,990·54	1·14	8,730·60	137,359·48	30,547·57	2,771,170·88	3,677,595·98

TABLE No. XXIII. (*continued*).—GENERAL RETURN FOR EACH GOLDFIELD AND GOLDFIELD DISTRICT, ETC.

Geographical Division.	Goldfield.	District.	Total Gold Production. Oz. from Unknown tons.	Alluvial.	Dollied and Specimens.	Ore Treated.	Gold therefrom.	Average per ton Treated.	Quantity of Gold Exported and Received at Royal Mint. During 1900.	Previous to 1900.	Total.	Value.* £	s.	d.
			oz.	oz.	oz.	tons.	oz.	oz.	oz.	oz.	oz.	£	s.	d.
Northern Goldfields	Kimberley	. .	. .	1,058·00	. .	15,038·50	13,833·77	·91	676·62	25,338·11	26,014·73	98,855	19	6
	Pilbarra	Marble Bar	2,082·00	4,379·04	960·19	29,572·11	61,796·60	2·08	17,140·51	155,423·25	172,563·76	655,742	5	9
	,,	Nullagine	. .	1,756·79	64·45	7,148·70	14,579·37	2·03						
	West Pilbarra	. .	. .	1,092·53	. .	2,532·15	3,320·59	1·31	721·68	3,983·78	[1]4,705·46	17,880	15	9
	Ashburton	. .	. .	3,826·68	340·00	. .	. .	. .	524·36	4,811·72	5,336·08	20,277	1	4
	Gascoyne	. .	. .	193·43	20·30	236·70	221·09	·93	86·10	418·72	[2]504·82	1,918	6	4
Central Goldfields	Peak Hill	. .	4,551·60	. .	1,271·30	35,089·79	89,625·09	2·55	28,669·86	50,842·19	[3]79,512·05	302,145	15	9
	East Murchison	. .	. .	3,629·08	3,323·94	144,267·74	163,435·30	1·13	58,369·50	90,586·82	[3]148,956·32	566,034	1	10
	Murchison	Cue	1,072·00	205·24	1,300·16	111,035·12	111,786·01	1·00	108,696·58	507,414·66	616,111·24	2,341,222	14	3
	,,	Nannine	. .	351·90	3,648·91	107,658·78	103,683·28	·96						
	,,	Day Dawn	. .	67·31	1,878·37	90,226·60	114,402·48	1·26						
	,,	Mt. Magnet	. .	87·53	4,151·14	129,632·00	125,641·55	·96						
	Yalgoo	. .	. .	. .	305·50	44,109·18	35,914·04	·81	9,368·57	16,670·19	[4]26,038·76	98,947	5	9
Eastern Goldfields	Mt. Margaret	Mt. Malcolm	. .	1,572·82	3,763·80	184,126·31	211,886·18	1·15	141,523·00	133,769·49	[5]275,292·49	1,046,111	9	3
	,,	Mt. Margaret	. .	41·52	815·10	75,217·70	84,835·01	1·12						
	North Coolgardie	Menzies	. .	642·50	304·07	147,805·39	245,187·73	1·65	106,193·38	268,030·71	[6]374,224·09	1,422,051	11	7
	,, ,,	Ularring	. .	1·82	379·00	30,441·61	43,173·87	1·41						
	,, ,,	Niagara	. .	93·56	210·75	76,117·45	64,185·56	·84						
	,, ,,	Yerilla	275·00	868·95	5,090·05	18,724·83	24,533·80	1·31						
	Broad Arrow	. .	250·00	3,068·06	763·99	186,646·13	147,865·87	·79	47,860·59	73,315·00	[6]121,175·59	460,467	3	4
	North-East Coolgardie.	Kanowna {quartz	. .	. .	2,212·71	118,591·45	100,038·12	·84	52,129·12	243,430·67	[6]295,559·79	1,123,127	4	10
		Kanowna {cement	. .	102,547·56	1·00	103,283·18	112,454·67	1·08						
	,, ,,	Bulong	. .	19,703·57	5,142·01	43,947·55	50,287·79	1·14						
	,, ,,	Kurnalpi	. .	8,363·95	1,048·49	1,931·55	1,642·22	·85						
	East Coolgardie	. .	500·00	2,885·81	2,242·95	1,387,395·91	2,450,731·76	1·76	810,906·78	1,759,254·27	[5]2,570,161·05	9,766,611	19	0
	Coolgardie	Coolgardie	. .	7,913·58	1,587·63	371,982·95	367,603·41	·98	119,781·46	672,274·46	[7]792,055·92	3,009,812	9	11
	,,	Kunanalling	. .	240·29	1,841·78	111,333·94	93,129·29	·83						
	Yilgarn	. .	. .	. .	738·18	326,526·63	167,825·84	·51	29,418·10	228,229·92	257,648·02	979,062	8	9
	Dundas	. .	. .	308·88	264·76	159,225·13	144,785·19	·90	40,687·56	101,476·14	[8]142,163·70	540,222	1	2
	Phillips River	. .	. .	. .	39·00	. .	. .	. .	. .	. .	. .	. .		
	Donnybrook	. .	. .	32·10	. .	672·80	947·14	1·40	265·55	506·11	[9]771·66	2,932	6	2
	Goldfields generally.	. .	. .	116·44	75·12	. .	1,233·90	. .	7,930·86	904·39	8,835·25	33,573	19	0
		Total	8,730·60	165,048·94	43,784·65	4,060,517·88	5,150,586·52	1·26	1,580,950·18	4,336,680·60	5,917,630·78	22,486,996	19	3

* Valuation at 3*l.* 16*s.* per oz. [1] Prior to May 1, 1898, included with Pilbarra. [2] Prior to March 1, 1899, included with Ashburton. [3] From August 1, 1897.
[4] Prior to April 1, 1897, included with Murchison. [5] Prior to May 1, 1896, included with Coolgardie. [6] From September 1, 1897. [7] Declared April 5, 1894, to which date included with Yilgarn.
[8] Prior to 1893, included with Yilgarn. [9] From March 1, 1899.

The tables that follow are excerpt from the *Report* (preliminary) of the Department of Mines of Western Australia for the year 1901.

They afford much valuable and interesting information.

TABLE No. XXIV.

SHOWING OUTPUT OF GOLD FROM THE SEVERAL STATES OF AUSTRALIA AND THE COLONIES OF NEW GUINEA AND NEW ZEALAND DURING 1901.*

	State.	Gross weight.	Fine contents.	Value.	Percentage of Value of Total Output.
		oz.	oz.	£	£
1.	Western Australia	1,879,390	1,703,416	7,235,653	45·29
2.	Queensland .	835,553	598,382	2,541,892	15·91
3.	Victoria . .	789,562	730,449	3,102,753	19·42
4.	New South Wales	267,061	216,888	921,282	5·77
5.	Tasmania . .	‡	69,491	295,176	1·85
6.	South Australia . and Northern Territory. .	4,918 / 22,581 } 27,499	3,911 / 18,035 } 21,946	16,613 / 76,609 } 93,222	·58
	New Guinea † .	9,188	7,685	32,646	·20
	New Zealand .	455,561	412,875	1,753,783	10·98
	Total .	4,263,814	3,761,132	15,976,407	100·00

* Excerpt from the *Report* (preliminary) of the Department of Mines for the year 1901.

† Financial year ended June 30, 1901.

‡ 54,113·50 oz., valued 202,926*l.*, and 21,718 oz. fine gold.

TABLE No. XXV.

SHOWING AVERAGE NUMBER OF MEN EMPLOYED AT GOLD MINES DURING 1901, CLASSIFIED ACCORDING TO THE SEVERAL GOLDFIELDS, AND THE PROPORTION OF MEN EMPLOYED IN EACH GOLDFIELD.*

	Goldfield.	Above Ground.	Under Ground.	Total.	Increase or decrease compared with 1900.	Percentage of total men employed.	
						1900.	1901.
1.	Kimberley	3	3	6	− 1	·04	·03
2.	Pilbarra	80	126	206	+ 95	·66	1·23
3.	West Pilbarra	3	2	5	− 47	·31	.03
4.	Ashburton	—	—	—	—	—	—
5.	Gascoyne	—	—	—	—	—	—
6.	Peek Hill	175	171	346	− 8	2·11	2·07
7.	East Murchison	424	432	856	− 17	5·21	5·11
8.	Murchison	764	784	1,548	+ 107	8·60	9·24
9.	Yalgoo	85	88	173	− 53	1·35	1·03
10.	Mt. Margaret	871	1,255	2,126	+ 275	11·05	12·69
11.	North Coolgardie	785	968	1,753	+ 243	9·02	10·46
12.	Broad Arrow	186	223	409	− 237	3·86	2·44
13.	North-East Coolgardie	293	459	752	− 108	5·14	4·49
14.	East Coolgardie	3,455	2,858	6,313	+ 410	35·25	37·68
15.	Coolgardie	569	761	1,330	− 422	10·46	7·94
16.	Yilgarn	172	122	294	− 203	2·97	1·75
17.	Dundas	206	290	496	− 30	3·14	2·96
18.	Phillips River	23	37	60	2	·35	·36
19.	Donnybrook	36	46	82	2	·48	·49
	Totals	8,130	8,625	16,755	+ 8	100·00	100·00

* Excerpt from the *Report* (preliminary) of the Department of Mines for the year 1901.

The East Coolgardie goldfield still continues to maintain a large proportion of the labour engaged on the goldfields of the State, over 37 per cent. of the men employed on gold-mines during 1901 having been employed on that field. Substantial increases in the number of men employed appear on the East Coolgardie, Mount Margaret, North Coolgardie, and the Murchison fields, while the Coolgardie, Broad Arrow, and Yilgarn fields show corresponding decreases.

Table No. XXVI.

Showing Average Rate of Wages per Week on the several Goldfields, Mining Districts, and Coalfields of the State during 1901, together with a Comparison of the Two Previous Years.*

—	Miners, above ground.	Miners, under ground.	Miners, wet ground.	Engine-drivers.	Mechanics.	Carpenters.	Labourers.	Average Wage. 1901.	Average Wage. 1900.	Average Wage. 1899.
Goldfields.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1. Kimberley	4 0 0	4 0 0	4 0 0	5 0 0	5 0 0	5 0 0	4 0 0	4 8 7	4 4 3	4 4 3
2. Pilbarra	4 0 0	4 0 0	4 10 0	4 10 0	5 0 0	5 0 0	4 0 0	4 8 7	4 8 7	4 10 0
3. West Pilbarra	3 0 0	3 10 0	4 0 0	4 0 0	4 0 0	4 0 0	3 0 0	3 12 10	3 12 10	3 12 10
4. Ashburton	4 0 0	4 0 0	. .	. .	. .	. .	3 10 0	3 16 8	3 16 8	3 13 4
5. Gascoyne	4 0 0	4 0 0	. .	. .	. .	. .	3 10 0	3 16 8	3 16 8	3 13 4
6. Peak Hill	4 0 0	4 0 0	. .	4 10 0	4 10 0	4 10 0	4 0 0	4 5 0	4 1 8	4 1 8
7. East Murchison	3 10 0	4 4 0	4 10 0	4 10 0	5 0 0	5 0 0	3 10 0	4 6 3	4 4 3	4 3 7
8. Murchison	3 12 6	3 12 6	4 5 0	4 5 0	4 10 0	4 10 0	3 10 0	4 2 2	3 14 3	3 14 3
9. Yalgoo	3 10 0	3 15 0	4 0 0	4 0 0	3 10 0	3 10 0	3 0 0	3 12 2	3 12 10	3 12 10
10. Mount Margaret	3 10 0	4 0 0	4 10 0	4 10 0	4 10 0	4 10 0	3 10 0	4 2 10	4 2 10	4 2 10
11. North Coolgardie	3 9 3	3 18 9	4 7 6	4 8 9	4 12 6	4 8 9	3 9 3	4 2 1	4 2 1	4 1 4
12. Broad Arrow	3 10 0	3 10 0	4 0 0	4 0 0	4 10 0	4 0 0	3 7 6	3 16 9	3 19 3	3 18 7
13. North-East Coolgardie	3 10 0	3 10 0	4 0 0	4 10 0	4 10 0	4 10 0	3 3 0	3 19 0	4 4 8	4 4 8
14. East Coolgardie	3 5 0	3 15 0	4 5 0	4 5 0	4 10 0	4 10 0	3 0 0	3 18 7	4 0 0	4 0 0
15. Coolgardie	3 5 0	3 10 0	4 0 0	4 0 0	4 0 0	4 0 0	3 5 0	3 14 3	3 14 3	3 14 3
16. Yilgarn	3 0 0	3 0 0	3 15 0	3 10 0	3 6 0	3 12 0	2 14 0	3 5 3	3 5 5	3 6 10
17. Dundas	3 5 0	3 15 0	4 0 0	4 0 0	4 10 0	4 0 0	3 5 0	3 16 5	3 16 5	3 16 5
18. Phillips River	3 0 0	3 10 0	4 0 0	4 0 0	3 15 0	3 15 0	3 0 0	3 11 5	3 12 10	
19. Donnybrook	2 14 0	3 0 0	3 6 0	3 10 0	3 10 0	3 6 0	2 14 0	3 2 10	3 8 7	3 6 3
Mining Districts.										
Northampton and Yandanooks	2 10 0	2 15 0	3 5 0	2 15 0	3 15 0	3 5 0	2 5 0	2 18 7	2 18 7	2 18 7
Greenbushes	2 14 0	3 0 0	3 0 0	3 6 0	3 6 0	3 6 0	2 14 0	3 0 10	2 15 0	2 13 0
Coalfield.										
20. Collie	2 15 0	4 0 0	†	3 0 0	3 6 0	3 6 0	2 15 0	3 3 8	3 3 8	3 2 0

* Excerpt from the *Report* (preliminary) of the Department of Mines for the year 1901.

† In some cases a bonus is given.

Table No. XXVII.

Showing Dividends paid by Western Australian Gold Mining Companies during 1900 and 1901.*

(Compiled in the Statistical Office, Registrar-General's Department.)

Goldfield.	Name of Company.	Par Value of Shares.	Paid up to	Nominal Capital.	No. of Shares issued.	1900. No. of Dividends Paid.	1900. Total Amount Paid.	1901. No. of Dividends paid.	1901. Total Amount paid.
		£ s. d.	£ s. d.	£			£		£
Peak Hill	Peak Hill Gold Fields, Ltd.	1 0 0	1 0 0	300,000	289,000	2	50,000	..	..
East Murchison	Lake Way Gold Fields, Ltd.	1 0 0	1 0 0	150,000	110,000	1	2,750	..	..
	East Murchison, United, Ltd.	1 0 0	1 0 0	150,000	150,000	1	7,500	..	..
Murchison	Great Fingall Consolidated Gold Mines, Ltd.	1 0 0	1 0 0	125,000	125,000	..	..	2	62,500
	Island Eureka G.M. Co., Ltd.	0 2 6	0 0 3½	10,000	80,000	..	..	8	4,333
	Long Reef G.M. Co., Ltd.	1 0 0	1 0 0	150,000	133,400	..	..	1	3,335
Mount Margaret	Sons of Gwalia G.M. Co., Ltd.	1 0 0	1 0 0	350,000	318,000	1	30,000	1	31,800
	Westralia Mt. Morgans G.M. Co., Ltd.	1 0 0	1 0 0	125,000	114,500	3	31,902	4	43,603
	Lancefield G.M. Co., Ltd.	1 0 0	1 0 0	25,000	21,600	4	1,440	12	4,320
North Coolgardie	Lady Shenton G.M., Ltd.	1 0 0	1 0 0	160,000	160,000	1	4,000	2	12,000
	Queensland Menzies G.M. Co., N.L.	0 5 0	0 4 6	33,000	132,000	2	3,300	3	9,900
	Cosmopolitan Proprietary G.M. Co., Ltd.	1 0 0	1 0 0	400,000	360,000	1	9,000	..	..
North-East Coolgardie	White Feather Main Reef, Ltd.	1 0 0	1 0 0	160,000	160,000	3	12,000	3	12,000
	Queen Margaret G.M. Co., Ltd.	1 0 0	1 0 0	100,000	95,050	2	4,752	1	3,564
East Coolgardie	Associated Gold Mines of W.A., Ltd.	1 0 0	1 0 0	500,000	500,000	1	33,750	..	..
	Hannan's Oroya G.M. Co., Ltd.	1 0 0	1 0 0	250,000	240,000	1	9,491	..	..
	Great Boulder Main Reef, Ltd.	0 10 0	0 10 0	130,000	260,000	1	13,000	1	13,000
	Great Boulder Proprietary G.M., Ltd.	0 2 0	0 2 0	175,000	1,750,000	3	131,250	3	175,000
	Hannan's Brownhill G.M. Co., Ltd.	1 0 0	1 0 0	225,000	155,000	4	193,625	1	37,000
	Ivanhoe Gold Corporation, Ltd.	5 0 0	5 0 0	1,000,000	200,000	5	250,000	3	95,000
	Lake View Consols, Ltd.	1 0 0	1 0 0	250,000	250,000	3	312,500	2	125,000
	Golden Horse-shoe Estates Co., Ltd.	5 0 0	5 0 0	1,500,000	300,000	3	225,000	4	345,000
	Associated Northern Blocks, Ltd.	1 0 0	1 0 0	350,000	350,000	..	..	1	87,500
	Kalgurli Gold Mines, Ltd.	1 0 0	1 0 0	120,000	120,000	..	..	1	15,000
Coolgardie	Burbanks Birthday Gift G.M., Ltd	1 0 0	1 0 0	180,000	180,000	1	9,000	..	..
	Premier G.M. Co., N.L.	1 0 0	0 13 6	50,000	50,000	5	6,250	..	..
	Bayley's United G.M. Co., Ltd.	0 5 0	0 4 3	155,000	620,000	2	31,000	..	..
	Vale of Coolgardie G.M. Co., Ltd.	1 0 0	1 0 0	90,000	75,000	3	5,625	..	..
Yilgarn	Fraser's South Extended G.M. Co., N.L.	1 0 0	1 0 0	100,000	99,489	3	3,731	..	..
Dundas	Princess Royal G.M. Co., Ltd.	0 10 0	†	40,000	80,000	3	12,000	3	12,000
	Total	..	..	..	..	..	£1,392,866	..	£1,091,855

* Excerpt from *Report* (preliminary) of the Department of Mines for the year 1901.

† 45,000 Shares up to 6*s*. 6*d*., and 35,000 up to 10*s*.

The preceding table gives only the dividends that have actually been paid during the year; several large dividends were declared towards the latter end of the year, but not payable until early in 1902. It is gratifying to note that five mines appear for the first time as dividend-paying mines.

TABLE NO. XXVIII.

QUANTITY AND VALUE OF ALL THE MINERALS PRODUCED DURING 1900 AND 1901.

Description of Mineral.	1900.		1901.		Increase or Decrease for Year compared with 1900.	
	Quantity.	Value at the Mines.	Quantity.	Value at the Mines.	Quantity.	Value at the Mines.
		£		£		£
1. Black tin (raised), statute tons . .	823	56,702	734	40,000	− 89	− 16,702
2. Coal (raised) ,, . .	118,410	54,835	117,836	68,561	− 574	+ 13,726
3. Copper ore (raised) ,, . .	6,183	43,673	10,157	75,246	+ 3,974	+ 31,573
4. Gold { Export, ounces, troy . . / Mint ,, . .	999,767 / 581,183	‡6,007,610	1,019,110 / 860,281	§7,235,653	+ 298,441	+ 1,228,043
5. Ironstone (raised), statute tons . .	12,251	9,258	20,569	13,246	+ 8,318	+ 3,988
6. Lead ore (raised) ,, . .	268	533	9	109	− 259	− 424
7. Limestone (raised) ,, . .	15,927	3,594	18,210	4,348	+ 2,283	+ 754
8. Mica (exported) ,, . .	†	3	..	..	..	− 3
9. Precious stones (exported), carats .	..	..	†	1,000	..	+ 1,000
10. Silver (exported), ounces, troy . .	28,749	3,594	60,869	7,609	+ 32,120	+ 4,015
Total Values . . .	..	6,179,802	..	7,445,772	..	+ 1,265,970

* Excerpt from *Report* (preliminary) of the Department of Mines for the year 1901. † Weight not stated. ‡ 3*l.* 16*s.* per ounce. § 3*l.* 17*s.* per ounce.

The preceding table shows a comparison between the mineral output of the years 1900 and 1901. The amount of limestone raised is much understated, as returns could only be obtained for limestone used for flux and that produced from mineral leases granted by the Crown.

The value of the gold produced bears practically the same proportion to the total value of minerals raised as it did in 1900, viz. 97·2 per cent.

No silver mines are being worked, the amount of silver given in the table having been obtained as a by-product.

The value of the minerals produced for the year 1901 exceeds that for any previous year, exceeding the value of the yield for 1899, the largest that has previously been recorded, by 1,098,064*l.*

TABLE NO. XXIX.

SUMMARY OF THE GOLD EXPORTED AND RECEIVED AT THE PERTH BRANCH OF THE ROYAL MINT DURING 1900 AND 1901, COMPARED WITH THE YIELDS REPORTED TO THE MINES DEPARTMENT; ALSO THE PERCENTAGE OF THE LATTER FOR THE SEVERAL GOLDFIELDS, AND THE AVERAGE YIELD PER TON OF ORE MILLED.

Goldfield.	Export and Mint.		Reported Yield.					
					Percentage for each Goldfield.		Average per ton of ore milled.	
	1900.	1901.	1900.	1901.	1900.	1901.	1900.	1901.
	oz.	oz	oz.	oz.			oz.	oz.
1. Kimberley	677	663	571	297	·04	·02	·40	·72
2. Pilbarra	17,140	11,320	16,617	10,265	1·10	·56	2·43	1·65
3. West Pilbarra . .	722	481	954	231	.06	·01	·87	1·97
4. Ashburton . . .	524	64	1,704	992	·11	·05	..	..
5. Gascoyne . . .	86	26	74	90	·01	·01	..	..
6. Peak Hill . . .	28,670	21,607	26,572	20,255	1·76	1·10	1·63	·84
7. East Murchison . .	58,369	77,604	64,698	76,236	4·27	4·14	1·11	·89
8. Murchison . . .	108,697	144,694	105,722	146,592	6·98	7·96	1·05	1·27
9. Yalgoo	9,369	9,198	10,102	9,238	·67	·50	·62	·70
10. Mount Margaret . .	141,523	198,808	145,689	190,032	9·62	10·32	1·09	·76
11. North Coolgardie . .	106,193	142,798	106,774	148,305	7·05	8·05	1·16	1·36
12. Broad Arrow . . .	47,861	29,105	52,433	34,675	3·46	1·88	·69	·74
13. North-East Coolgardie .	52,129	50,557	70,746	63,652	4·67	3·46	·71	·95
14. East Coolgardie . .	810,907	1,033,670	737,971	991,369	48·75	53·84	1·49	1·42
15. Coolgardie . . .	119,781	88,601	102,413	84,754	6·77	4·60	·75	·67
16. Yilgarn	29,418	29,488	29,155	26,587	1·93	1·44	·53	1·00
17. Dundas	40,687	38,796	41,084	37,084	2·71	2·01	·83	·94
18. Phillips River . .	..	..	39	713	..	·04	..	1·17
19. Donnybrook . . .	266	5	453	4	·03	..	1·26	·08
Goldfields generally .	7,931	1,906	146	127	·01	·01	..	..
Totals and Averages	1,580,950	1,879,391	1,513,917	1,841,498	100·00	100·00	1·14	1·15
Fine Contents .	1,414,311	1,703,417	1,354,343	1,669,072	..	..	..	..

* Excerpt from *Report* (preliminary) of the Department of Mines for the year 1901.

In comparing the outputs of the various fields, the figures given under the heading of "Reported Yield" should as a general rule be taken. Most of the gold produced finds its way to the Mint, or is exported from the State, and thus the result of the addition of the Mint and Customs returns can be taken to be the total production of the State.

The large discrepancy between the Export and the Mint figures for the East Coolgardie Goldfield is accounted for, to a great extent, by the fact of a good deal of ore from outlying centres being treated at Kalgoorlie, the resulting gold being banked there and entered for export as being the product of that centre.

The East Coolgardie Goldfield is still responsible for more than half the total yield of the State, it having produced nearly 54 per cent. of the total reported yield. The Mount Margaret Goldfield again takes second place with a yield of 190,032 oz., which shows an increase of about 30 per cent. as compared with the previous year, and represents slightly over 10 per cent. of the total output of the State. The North Coolgardie and the Murchison Goldfields follow with yields of 148,305 oz. and 146,592 oz. respectively, which shows the substantial increase of 39 per cent. in each case, as compared with the previous year.

It cannot but be regarded as satisfactory that the average return per ton of ore milled has been maintained during the year. Decreases in the average appear in the Mount Margaret and several of the other goldfields, while in others, such as the North Coolgardie and the Murchison, the average has improved.

TABLE No. XXX.

TABLE SHOWING QUANTITY AND VALUE OF BULLION, THE PRODUCE OF THE STATE IN 1902, ENTERED MONTHLY FOR EXPORT AND RECEIVED AT THE ROYAL MINT, PERTH; COMPILED BY THE AUTHOR FROM THE SUPPLEMENT TO THE GOVERNMENT GAZETTE, JANUARY 2, 1903, AND THE CABLED RETURN FOR DECEMBER, ESTIMATING THE VALUE OF THE LATTER BULLION AT 3*l.* 13*s.* PER OZ.

1902.

Month.	Estimated Quantity.	Estimated Value.		
	oz.	£	s.	d
January	168,159·03	599,916	14	6
February	152,692·56	546,434	10	7
March	177,505·60	638,348	2	1
January 1 to March 31	498,357·19	1,784,699	7	2
April	183,531·34	656,848	4	8
May	164,226·34	593,060	14	4
June	189,620·51	681,717	14	10
January 1 to June 30	1,035,735·38	3,716,326	1	0
July	184,227·67	661,357	3	11
August	187,971·55	672,493	10	11
September	188,167·63	669,412	2	10
January 1 to September 30	1,596.102·23	5,719,588	18	8
October	194,387·42	689,853	17	3
November	197,197·03	706,233	15	10
December	*189,755,00	*692,605	15	0
Total	2,177,441·68	7,808,282	6	9

TABLE No. XXXI.

NUMBER OF GOLD-PRODUCING MINES IN THE SEVERAL GOLDFIELDS AND DISTRICTS DURING 1900 AND 1901.

Goldfield.	District.	1900. District.	1900. Goldfield.	1901. District.	1901. Goldfield.
Kimberley	. .	. .	3	. .	1
Pilbarra	Marble Bar	30	45	22	37
	Nullagine	15		15	
West Pilbarra	. .	. .	5	. .	2
Ashburton	. .	. .	. .	. .	. .
Gascoyne	. .	. .	. .	. .	. .
Peak Hill	. .	. .	17	. .	8
East Murchison	. .	. .	54	. .	55
Murchison	Cue	63	188	52	189
	Nannine	39		47	
	Day Dawn	20		17	
	Mt. Magnet	66		73	
Yalgoo	. .	. .	17	. .	14
Mt. Margaret	Mt. Malcolm	69	117	52	116
	Mt. Margaret	48		64	
North Coolgardie	Menzies	47	221	58	226
	Ularring	91		72	
	Niagara	43		61	
	Yerilla	40		35	
Broad Arrow	. .	. .	47	. .	40
North-East Coolgardie	Kanowna	51	68	51	70
	Bulong	15		17	
	Kurnalpi	2		2	
East Coolgardie	. .	. .	50	. .	64
Coolgardie	Coolgardie	97	176	96	158
	Kunanalling	79		62	
Yilgarn	. .	. .	20	. .	17
Dundas	. .	. .	46	. .	45
Phillips River	. .	. .	2	. .	6
Donnybrook	. .	. .	3	. .	1
Total	. .	. .	1079	. .	1049

* Excerpt from *Report* (Preliminary) of the Department of Mines for the year 1901.

It will be seen from the above tables that the decrease of 30 in the number of producing mines is principally accounted for by the closing of 22 mines on the goldfields from Peak Hill northwards; the only other noticeable decreases in the producing mines occur in the Broad Arrow Goldfield and in the Kunanalling district of the Coolgardie Goldfield.

TABLE No. XXXII.

SHOWING INCREASE OR DECREASE IN OUTPUT OF CERTAIN LARGE PRODUCING MINES IN 1901, AS COMPARED WITH 1900.

	Goldfield.	District	Name of Mine.	Production. 1900.	Production. 1901.	Increase or Decrease for Year compared with 1900.
				oz.	oz.	oz.
1.	Peak Hill		Peak Hill Goldfields, Ltd.	24,488	19,884	− 4,604
2.	East Murchison		Yellow Aster	5,330	8,726	+ 3,396
3.	,,		Fingall Reefs Extended, Ltd.	. .	5,433	+ 5,433
4.	,,		East Murchison United, Ltd.	26,075	30,818	+ 4,743
5.	,,		Bellevue Consolidated, Ltd.	8,499	11,445	+ 2,946
6.	Murchison	Day Dawn	Great Fingall Consolidated, Ltd.	8,525	67,045	+ 58,520
7.	,,	Mt. Magnet	Long Reef G.M. Co., Ltd.	13,814	13,016	− 798
8.	,,	,,	Morning Star leases	6,233	6,949	+ 716
9.	Yalgoo		Field's Find G.Ms., Ltd.	5,852	7,392	+ 1,540
10.	Mt. Margaret	Mt. Malcolm	Sons of Gwalia, Ltd.	53,589	68,490	+ 14,901
11.	,,	,,	Merton's Reward North	8,085	10,450	+ 2,365
12.	,,	,,	Mt. Malcolm Mines, Ltd.	6,965	2,566	− 4,399
13.	,,	Mt. Margaret	Craiggiemore Proprietary, Ltd.	4,058	6,282	+ 2,224
14.	,,	,,	Golden Rhine G.Ms. (W.A.), Ltd.	538	6,251	+ 5,713
15.	,,	,,	Lancefield G.M. Co., Ltd.	6,624	7,827	+ 1,213
16.	,,	,,	Euro G.Ms., Ltd.	377	10,171	+ 9,794
17.	,,	,,	Westralia (Mt. Morgans) G.Ms. Co., Ltd.	25,868	37,364	+ 11,496
18.	North Coolgardie	Menzies	Lady Shenton G.M., Ltd.	20,579	24,572	+ 3,993
19.	,,	,,	Menzies Consolidated G.Ms., Ltd.	7,427	8,572	+ 1,145
20.	,,	,,	Queensland Menzies G.M. Co., N.L.	7,667	9,172	+ 1,505
21.	,,	Ularring	Mt. Ida Consols, Ltd.	1,746	6,088	+ 4,342
22.	,,	Niagara	Cumberland Niagara G.Ms. Ltd.	1,850	8,244	+ 6,394
23.	,,	,,	Cosmopolitan Proprietary, Ltd.	† 14,249	23,882	+ 9,633
24.	Broad Arrow		Golden Arrow Mine, Ltd.	1,577	5,196	+ 3,619
25.	,,		New Austral Co., Ltd.	10,279	6,902	− 3,377
26.	,,		Paddington Consols, Ltd.	16,956	4,960	− 11,996
27.	N.E. Coolgardie	Kanowna	White Feather Main Reefs, Ltd.	10,728	14,492	+ 3,764
28.	,,	Bulong	Queen Margaret G.M. Co., Ltd.	10,447	7,337	− 3,110

29.	East Coolgardie		Associated G.Ms. of W.A., Ltd.	34,183	31,524	− 2,659
30.	,,		Associated Northern Blocks (W.A.) Ltd.	10,218	37,270	+ 27,052
31.	,,		Golden Horse-shoe Estates Co., Ltd.	132,863	185,297	+ 52,434
32.	,,		Great Boulder Main Reef, Ltd.	22,050	26,649	+ 4,599
33.	,,		Great Boulder Perseverance G.M. Co., Ltd.	47,098	134,302	+ 87,204
34.	,,		Great Boulder Proprietary G.Ms. Ltd.	115,908	152,161	+ 36,253
35.	,,		Hannan's Central Extended G.M. Co., N.L.	. .	6,302	+ 6,302
36.	,,		Hannan's Star G.Ms., Ltd.	2,373	12,064	+ 9,691
37.	,,		Hannan's Oroya G.M. Co. (W.A.), Ltd.	5,800	. .	− 5,800
38.	,,		Ivanhoe Gold Corporation, Ltd.	107,051	108,767	+ 1,716
39.	,,		Kalgurli G.Ms., Ltd.	15,632	19,222	+ 3,590
40.	,,		Lake View Consols, Ltd.	98,770	153,858	+ 55,088
41.	,,		North Boulder G.M., Ltd.	5,347	2,773	− 2,574
42.	,,		South Kalgurli G.Ms., Ltd.	11,003	19,470	+ 8,467
43.	,,		Hannan's Brownhill G.M. Co., Ltd.	80,756	55,737	− 25,029
44.	,,		Hannan's Proprietary Development Co., Ltd.	4,344	2,826	− 1,518
45.	,,		Hannan's Reward, Ltd.	3,092	5,894	+ 2,802
46.	Coolgardie	Coolgardie	Vale of Coolgardie G.Ms., Ltd.	8,558	6,407	− 2,151
47.	,,	,,	Burbank's Birthday Gift G.M., Ltd.	19,072	19,734	+ 662
48.	,,	,,	Bayley's United G.Ms. Ltd.	23,145	5,617	− 17,528
49.	,,	,,	Lady Loch G.Ms., Ltd.	6,415	5,575	− 840
50.	Yilgarn		Mines Development Syndicate, Ltd. (late Fraser's G.M. Co., N.L.)	13,054	19,750	+ 6,696
51.	,,		Fraser's South Extended G.M. Co., Ltd.	6,152	532	− 5,620
52.	Dundas		Break-o'-Day	4,465	1,073	− 3,392
53.	,,		Lady Mary leases	1,935	2,548	+ 613
54.	,,		Norseman G.Ms., Ltd.	10,821	7,366	− 3,455
55.	,,		Princess Royal G.M. Co., N.L.	18,464	17,418	− 1,046
	Total			1,116,994	1,479,662	+ 362,668

* Excerpt from *Report* (preliminary) of the Department of Mines for the year 1901.

† Includes 247 oz. from Altona leases, omitted from 1900 Report.

Out of above 55 mines, 37 produced 462,564 oz. more and 18 produced 99,896 oz. less than in 1900, being a net increase of 362,668 oz.

TABLE No. XXXIII.—THE GOLDEN HORSESHOE ESTATES COMPANY, LIMITED.

(Excerpt from the September Report of the Chamber of Mines of Western Australia).

The subjoined schedules of costs, kindly supplied by the General Manager (Mr. F. W. Sutherland), are of considerable interest.

STATEMENT SHOWING WORK DONE STOPING (AND DRIVING) SULPHIDE ORE ON CONTRACT. PAYMENTS BASED ON LINEAL FOOTAGE BORED.

All Costs shown are exclusive of Superintendence and General Charges. For period August 1 to September 15, 1902.

Locality.	Party.	No. of Men per Shift of 8 Hours each.	Total No. of Shifts Worked.	Total No. of Holes Bored.	Average Depth of each Hole.	Footage Bored. Total.	Footage Bored. Average per Man per Shift.	Tons of Ore Broken. Total Weight.	Tons of Ore Broken. Average per Man per Shift.	Explosives Used (weight in lbs. avoir.). Total Weight.	Explosives Used. Average per Ton of Ore Broken.	Total Cost of Labour and Explosives.	Cost per Foot Bored. Labour.	Cost per Foot Bored. Explosives.	Cost per Foot Bored. Total.	Costs per Ton of Ore Broken. Labour.	Costs per Ton of Ore Broken. Explosives.	Costs per Ton of Ore Broken. Total.
					feet							£	s. d.	d.	s. d.	s. d.	s. d.	s. d.
No. 6 Level—No. 4 lode, north drive, and all stopes north and south .	No. 1	2	232	425	5·99	2,546	10·97	1,165	5·02	690	·59	262·160	1 4·50	8·21	2 0·71	3 0·06	1 5·95	4 6·01
No. 5 Level—No. 4 lode, north and south stopes	,, 2	2	230	359	5·75	2,064½	8·98	1,561	6·79	1000	·64	238·958	1 6·54	9·24	2 3·78	2 0·53	1 0·21	3 0·74
No. 7 Level—Nos. 3 and 4 lode, north and south stopes	,, 3	2	228	363	6·78	2,462½	10·80	1,515	6·64	1120	·74	239·825	1 3·42	7·95	1 11·37	2 1·07	1 0·93	3 2·00
No. 3 Level—Nos. 2 and 3 lode, north and south stopes	,, 4	2	232	452	6·11	2,762½	11·91	1,862	8·03	1150	·62	234·912	1 2·21	6·20	1 8·41	1 9·08	0 9·20	2 6·28
No. 3 Level—No. 4 lode, north and south stopes	,, 5	4	467½	834	6·13	5,115	10·94	3,710	7·94	2333	·63	461·256	1 3·09	6·56	1 9·65	1 8·80	0 9·04	2 5·84
No. 2 Level—No. 3 lode, north stope .	,, 6	2	231	382	6·32	2,414	10·45	1,303	5·64	859	·66	218·112	1 4·44	5·25	1 9·69	2 6·46	0 9·72	3 4·18
Totals	..	14	1620½	2815	..	17,364½	..	11,116	..	7152	..	1655·223	..	..	..	..	..	..
Averages . . .	..	..	..	..	6·17	..	10·72	..	6·86	..	·64	..	1 3·80	7·08	1 10·88	2 0·68	0 11·06	2 11·74

STATEMENT SHOWING WORK DONE AND COST OF TRUCKING ORE AND MULLOCK FOR PERIOD JUNE 15 TO AUGUST 31, 1902 (AS PER BRACE AND PLAT TABLES).

No. of Shifts Worked.	Tonnage Trucked. Ore.	Tonnage Trucked. Mullock.	Tonnage Trucked. Total.	Average Tonnage per Man per Shift. Ore.	Average Tonnage per Man per Shift. Ore and Mullock.	Cost per Ton. Based on Tonnage of Ore. (Labour only.)
						s. d.
1830½	28,512	3521	32,033	15·57	17·50	0 8·529

GENERAL INDEX.

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