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MINES AND MINERALS OF THE BRITISH EMPIRE

PRIMITIVE CHINESE OPEN-CAST.

MINES AND MINERALS OF THE BRITISH EMPIRE

BEING A DESCRIPTION OF THE
HISTORICAL, PHYSICAL, & INDUSTRIAL FEATURES
OF THE
PRINCIPAL CENTRES OF MINERAL PRODUCTION
IN THE
BRITISH DOMINIONS BEYOND THE SEAS

BY

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WITH ILLUSTRATIONS

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1908

TO

THE PIONEERS

TECHNICAL AND FINANCIAL

OF THE

MINING INDUSTRY

WHOSE ENERGIES HAVE CONSTITUTED

THE CHIEF AWAKENING AND PROGRESSIVE INFLUENCE

IN THE

NATIONAL DEVELOPMENT

OF

THE BRITISH COLONIES

PREFACE

In the following pages, the author has endeavoured to present a brief, though comprehensive, review of those mines and minerals of the British Empire oversea, the industrial influence of which extends beyond their domestic sphere, and therefore entitles them to rank as factors of considerable moment in the mining world. So vast is the subject as a whole that in it there can be no specialists. So diverse are its bearings that no writer or reader can claim the qualification of full technical authority. The author's purport has been to deal with all the more salient industrial conditions obtaining in the mineral-producing sections of the Empire, and to describe the characteristics of ore occurrence and methods of exploitation in a form as lightly technical as is consistent with accuracy and lucidity of expression.

To the mining reader it may appear that restriction of discussion to the British Empire forms an arbitrary limitation, possibly suggestive of Imperial glorification, that is inapposite. It must be recognized, however, that, although mineral deposits may be more aptly classified by natural than national distinctions, mining fields are closely linked by the bonds of mutual interests, of similar administrative influences, of frequently related technical controls, and of a common motherhood in the great Metropolis, whose financial offspring, hale and sick, are established abundantly throughout the colonial mining world.

The bulk of this volume is based upon observations made and data collected during a tour of the Empire extending from January, 1906, to the beginning of 1908. On this journey, which the author undertook on behalf of the *Mining World*, Chicago ;

and the *Rand Daily Mail*, Johannesburg—and as an occasional contributor to the *Financial Times*, London; *Straits Times*, Singapore; and journals in India and Australia—a course was pursued from South Africa through Ceylon, India, Burma, Malay Peninsula, Australia, New Zealand, and Canada. In the period mentioned, when the mineral industry was at the zenith of its prosperity, it was clearly impracticable to visit every field of consequence; but the omissions—amongst which must be reckoned Mysore, Queensland, Klondike, and Rhodesia—have been rectified as far as possible by the inclusion of brief reports, founded on the publications of Governmental and other trustworthy authorities.

In practical illustration of the magnitude and importance of the British Empire from the mining standpoint, the peculiar personal experience of the writer, during his tour of over 35,000 miles, may be incidentally recorded. Only twice—and then but by way of stepping-stones—did he set foot upon foreign soil (to wit, in Java and Honolulu), and but once did his course carry him within a hundred miles of any noteworthy mining field unqualified for inclusion under the title of this volume.

In some chapters a proper sense of proportion may appear to be wanting, and attention to have been bestowed upon certain fields out of relation to their respective output records. This apparent lack of perspective springs from the adopted plan of most fully describing the notably distinctive mining fields of each country. Thus, the mica fields of India, the plumbago and gem pits of Ceylon, and the asbestos mines of Quebec, are discussed with further detail than, for example, some of the minor gold and copper fields of Australia, which may be responsible for more valuable contributions to the mineral yield of the Empire, but are unimportant in their particular spheres. Mica, plumbago, sapphires, and asbestos—like tin, nickel, gold, and diamonds—merit particular notice as products almost essentially British.

In concluding this prefatory note, explanatory of the range attempted, and apologetic for its inevitable deficiencies, the author would express the hope that this book (in no degree, let it be understood, a guide to investment) may be of service to those concerned in the practice and science of mining, and at the same time strengthen the public appreciation and knowledge of the great 'Foundation Industry,' which adds each year £200,000,000 to the Empire's wealth, supports several millions of British subjects, and the advent of which marked the dawn of national life in ten of our foremost colonial territories.

Acknowledgment of the assistance rendered by many friends and acquaintances in all parts of the Empire, and by those mining companies which provided all facilities necessary for the acquirement of facts relative to their undertakings—thus maintaining the high reputation enjoyed by the mining industry in virtue of the exceptional publicity of its methods and circumstances—is made in an Appendix recording the names of those to whom thanks are expressly due.

THE AUTHOR.

Johannesburg, South Africa,
February, 1908.

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MINES AND MINERALS OF THE BRITISH EMPIRE

INTRODUCTION

Only those who are acquainted with the active centres of industry in the mining world, and have knowledge of their early chronicles, can adequately realize how powerful and enduring has been the influence of mineral production in the economic development of the British Empire. Statistics, wonderful though their lessons may be, fail to provide a convincing record of the industry's practical accomplishments, of which the direct may be the less important, or to indicate the solid basis for prosperous trade and commerce it has established in distant colonies through its vitalizing forces.

Englishmen at home, and not a few abroad, are commonly inclined to view the mining world solely in the mirror of a Stock Exchange price list. Financial experiences have taught them in many instances to regard the mine flotation as a popular means of speculation, in which 'boom' and 'slump,' reconstruction and liquidation, constitute a usual sequence of events —diversified by an occasional 'trial crushing' or a 'bonanza discovery'—upon which to gamble with excessive funds. Owing, also, to the circulation of literature dealing with the romantic aspect of sensational discoveries, with the sudden acquisition of wealth by fortunate prospectors, and with the crashes of ill-conceived mining promotions, the true sense of perspective is apt to be driven from the public vision. General deductions are drawn from abnormal special cases. Thus, sight may readily be lost of the many fields of mineral production progressing upon steady, well-regulated principles with the industrial sobriety of 'Home Rails.'

It must be admitted, however, that no industry lends itself more readily to the purposes of the illegitimate company organizer than the exploitation of new mineral deposits, with which the greatest risk must inevitably be associated, and the rewards of which are at times so astoundingly rich. Only when the speculative phase has given place to the industrial; when the prospector and pioneer, the nervous gambler and man of quick finance, have withdrawn in favour of the scientific engineer and business manager, can the true merit and influence of the new-born industry be realized. But when the dust has settled, most probably the 'nine days' wonder' will have passed from the public mind. It is, in truth, the natural fate of almost every mining field to rise amidst such an excess of vague and optimistic expectations that few observers, attracted by the exciting circumstances of its early history, escape the dull reaction or carry their thoughts into the later chapter of tangible accomplishment. The Rand gold-field, the Kimberley diamond-mines, the Broken Hill silver-lead district—only in such El Dorados as these can a living interest be maintained, and even then, perhaps, political or other adventitious circumstances are in part responsible for their recollection.

The old-established mining-fields are for ever presenting features of industrial transition, but new discoveries of such good promise as to attract universal attention can be recorded but twice or thrice in a decade. Upon reviewing the chronology of twenty or thirty of the mining centres contributing most weightily to the mineral output of the British Empire, it is to be seen that longevity is a common blessing. The tin alluvial of Malay, the ruby and petroleum tracts of Burma, the gem-fields of Ceylon—regions in which the inception of industrial life was not coincident with the advent of the British pioneer—have been under exploitation from time immemorial. For other lands, the days of discovery run back to dates showing that, although mineral deposits are essentially exhaustible, their life of productiveness is often measurable by generations. Some may be seen visibly approaching the end of their resources; for others, long life appears to be assured and commercial extinction unforeseeable through the haze of future uncertainties.

A table of discovery dates for the greatest mining-fields upon the Empire's active list to-day is given on the opposite page.

Compared with preceding periods, and notably with the prospector's memorable decade of 1882–1891 (the first four years of which saw the birth of the Rand, Mount Morgan, Sudbury, Waihi, and Broken Hill), the past ten years have not been marked by a normal share of new discoveries. The Premier diamond-pipe and the silver veins of Cobalt, Ontario, have been the brilliant revelations of the new century, unique in their natural features, strong in their promise of industrial prosperity; but the world awaits the establishment of new mining regions to compensate for the steady impoverishment of the old. Antiquarians have roughly classified the past into the ages of stone, bronze, and iron. The present is the age of machinery, in which the miner must be called upon to provide the needs, growing in diversity and volume, of practical science and the means of its commercial application.

Field.	*Date.*	*Aggregate Yield to End of* 1906.
		£
Ballarat, Aust.	1851	276,500,000*
Bendigo, Aust.	1851	
Wallaroo and Moonta, Aust.	1860	12,000,000
Cariboo, Can.	1861	8,000,000
Kimberley, S.A.	1869	85,000,000
Mt. Bischoff, Tas.	1871	—
Charters Towers, Aust.	1872	23,000,000
Mysore, India†	1880	26,000,000
Mt. Morgan, Aust.	1882	13,000,000
Waihi, N.Z.	1882	5,500,000
Broken Hill, N.S.W.	1883	42,000,000
Sudbury, Can.	1883	15,000,000
Rand, S.A.	1885	162,000,000
Rossland, Can.	1890	7,000,000
Boundary, Can.	1891	6,000,000
Coolgardie, Aust.	1892	5,000,000
Kalgoorlie, Aust.	1893	37,000,000
Klondike, Can.	1896	24,500,000
Mt. Margaret, Aust.	1896	5,500,000
Premier (Diamonds), S.A.	1902	3,300,000
Cobalt (Silver), Can.	1903	1,100,000

The influence of the mining industry upon the growth and welfare of the British Empire is most fully exhibited by the history of the several colonial territories which it has raised to the forefront of commercial nations from the obscurity of sterile wildernesses. The influence of the Empire as a factor in the mining world, however, can be shown by more clearly defined and expressive testimony. In the first table given on p. 4, based upon statistics for 1906, obtained from various sources (including 'The Mineral Industry,' vol. xv.), the significance of the Empire as the producer of the most noteworthy metallic and non-metallic minerals is clearly indicated.

* Total for Victoria.

† Systematic development commenced in 1880, upon site of ancient workings.

	Percentage of World's Yield.
Gold	60
Silver	12
Tin	73
Copper	9
Lead	15
Pig-iron	18
Steel	15
*Nickel	60
*Manganese	40
*Coal	30
*Asbestos	90
Plumbago	45
†Mica	90
Diamonds	98

Outside the United Kingdom, whose prodigious yield of coal and iron has prompted the deliberate exclusion of its mines from the scope of this volume, the Empire is under the heaviest economic obligations—to-day as in the past—to gold, a metal found in deposits of unsurpassed richness or extent in Australia, the Transvaal, New Zealand, India, and Western Canada. So vast has been the production of the yellow metal, as indicated by the subjoined table, that it is hard for the mind to grasp the practical significance of the aggregate returns :

	Yield up to 1907.
	£
Victoria	276,500,000
Transvaal	170,000,000
West Australia	70,800,000
New Zealand	69,500,000
Queensland	64,300,000
New South Wales	54,300,000
Mysore (approximately)	26,000,000
Klondike	24,500,000
British Columbia	23,000,000
British Guiana	7,500,000
Rhodesia	6,500,000
Tasmania	6,000,000
‡West Africa	3,500,000
	802,400,000

To this table might be added very substantial contributions from Nova Scotia, Ontario, British New Guinea, Sarawak, Quebec, and Cape Colony. In these days of cash stringency, when more and more gold is being required to lubricate the wheels of expanding industry, the debt of the whole civilized world to the Empire's gold-producing regions demands no elaborate exposition.

* Approximations only.
† Very rough estimate. Reliable statistics unavailable. ‡ Since 1887 only.

The annual mineral yields of the most productive divisions of the Empire, so far as these are capable of compilation on a common basis of estimation, are given below in round figures for 1906. At the time of writing it is impossible to cover the year 1907, for reliable statistics are not available, as a rule, till six or nine months after the close of the period.

It may be noted that, of the aggregate valuation of £200,000,000, fully one-half is attributable to the coal-mines of the United Kingdom.

	Value.
	£
United Kingdom	105,850,000
Australia :	
West Australia	7,900,000
New South Wales	8,200,000
Queensland	4,200,000
Victoria	3,400,000
Tasmania	2,200,000
South Australia	800,000
South Africa :	
Transvaal	27,000,000
Cape Colony	7,620,000
Rhodesia	2,200,000
Orange River Colony	988,000
Natal	500,000
Federated Malay States	8,500,000
Canada	14,000,000
India	6,200,000
West Africa	850,000
Newfoundland	300,000
	200,708,000

It is, unfortunately, beyond the range of reliable inquiry to determine the proportionate allocation to wages, stores, and profits. Such an analysis would doubtless prove that returns on capital invested are generally far from being in accord with the glowing reports of the company promoter, anxious to encourage the faint-hearted, or of the trade-union agitator, who endeavours to disturb the mind of labour with invidious allusions to the greedy opulence of controlling shareholders.

In whatever direction and to whatever degree the popular conception of its financial aspect may be at fault, the mining industry unmistakably appears in a light that is favourable without reservation as the field of employment for highly remunerated workmen, and the support of the most prosperous labouring communities in the British Empire.

CHAPTER I

MINE LABOUR

1. Census of mine employees.—2. Socialistic Unionism.—3. Premium on inefficiency.—4. Retrograde influences.—5. Costly skilled labour.—6. Working conditions in the Transvaal.—7. Kalgoorlie, Westralia.—8. Broken Hill, N.S.W.—9. Bendigo and Ballarat.—10. Waihi, New Zealand.—11. Boundary, British Columbia.—12. Sudbury, Ontario.—13. Thetford, Quebec.—14. Malay States.—15. Burma.—16. Madras and Ceylon.—17. British Guiana.—18. West Africa.

1. THE vast population of British subjects who can claim to be dependent upon the mines of the Empire for their livelihood could never be computed with any claim to accuracy. In many mining-fields, where the cost of living is commonly expensive, workers are supporting absent families; and thousands of unnaturalized foreigners are employed. Of those, however, who draw their earnings directly from the Empire's mines and associated works, the yearly numberings are regularly forthcoming. For 1906 the roll of these employees—men, women, and children, white, black, and yellow—stood as follows:

	Total Employees.
United Kingdom	1,004,000
Federated Malay States	212,700
Transvaal	193,700
India (approximately)	150,000
New South Wales	42,500
Victoria	26,500
Cape Colony	23,000
South Rhodesia	22,000
West Australia	19,400
Queensland	18,200
Gold Coast, West Africa	14,100
New Zealand	12,800
Ontario	11,200
British Columbia	8,800
Orange River Colony	7,500
Tasmania	7,000
Natal	7,000
South Australia	6,500
Quebec	5,700

CHINESE COOLIES, MALAY STATES.

GRAPHITE MINERS, CEYLON.

Including the mine employees of colonies unspecified above, a grand total of 2,000,000 may be roundly estimated, producing £100 per head per annum.

2. During 1906 and 1907 the mining labour question assumed a position of exceptional importance—in South Africa largely because of the political principles involved, in Australasia and America because an inadequate supply of efficient workers constituted a check upon industrial progress. But apart from the scarcity of qualified miners and mechanics, the situation in Australia and Canada was further characterized by the aggressive dissatisfaction evinced by sections of their mining communities, aroused by the propagation of the specious doctrines of Socialism or of Industrial Unionism. With dire results to its proselytes, the gospel of discontent, malice, and suspicion has been assiduously spread by those 'altruistic' social reformers who are to be found in all mining camps sufficiently prosperous to provide the cost of maintaining a militant organization.

3. The abnormal growth of mining has frequently given rise to abnormal demands for experienced men, who cannot be recruited from other industries. The high-wage schedules prevailing in the mining world are calculated to attract workers from other fields of labour, but the capable miner is no sudden creation. The miner needs years of training to reach that grade which qualifies him for the distinction (and high reward) due to the experienced artisan in whose efficiency must be found the elements of pluck, judgment, strength, and perseverance. By some it is, indeed, contended that the inexperienced man of maturity can only in exceptional cases be turned into a competent miner—that the influence of youthful environment is virtually essential. This extreme view tends to emphasize the significance of one of the greatest difficulties with which the expanding industry has had to contend, under the levelling action of Socialistic Trade-unionism. The shortage of hands has been principally demonstrated in the higher grades of underground labour.

4. To meet the exigencies of the position, the industry has been disposed, in accordance with the primary laws of supply and demand, to make the remuneration of the efficient worker proportionately higher than that of his less serviceable and more abundant fellows, who, for lack of inducement to rise, from laziness or natural incompetence, remain in the ranks of the unskilled. It is in this connexion that the socialistic tendencies

of trade-unionism are most unfortunately manifested, wherever its power approaches dominance. On short-sighted principles, it opposes discrimination between the trained and untrained, the fit and the unfit, the zealous and the indolent, and thus prevents the industry from encouraging men to elevate themselves (through a ‘ learner ’ or apprentice system, or other means) in the scale of working utility. It may be taken as axiomatic that the upper grades in the mining occupation, for the manual labourer or the scientific engineer, can only be attained by mounting the ladder from the bottom rungs, and the lessons of practical experience prove that men will only make the effort of ascent (no light task even for the most active in mind and body) with the practical encouragement of commensurate reward. The obstacles in the way of putting this logical principle into operation have been responsible for many of the labour difficulties by which the colonial mining industry was harassed up to the close of 1907, when the metal market was disorganized by American difficulties, and the demands for workmen diminished.

5. In the Transvaal, where there is so sharp a line between skilled and unskilled labour, in regard to wage and other conditions, problems have been more complex. The necessity of paying white employees of the upper grades at a high rate (by wages or contract earnings) has forced the gold industry to depend upon low-waged Kaffirs or indentured Asiatic labour for the performance of the rough manual labour inseparable from the exploitation of the Rand's narrow and flatly inclined ore bodies.

For purposes of comparison, so far as such can be established between localities dissimilar in their working, geographical, and social features, a summary of labour conditions in various parts of the Empire may be given as under :

6. *Transvaal.*—In the Rand gold-mines the skilled labour is performed by whites (mostly Cornishmen and other immigrants of British stock), and the unskilled by Kaffirs and indentured Chinamen (now in course of repatriation). White miners are employed as machinemen (principally on contract), timbermen, supervisors of unskilled labourers, and in other positions of responsibility. Skilled men on wages, including mechanics, carpenters, etc., receive from 15s. to 21s. per day, and efficient machinemen on contract in stopes and development workings make from £20 to £50 per month. Formerly earnings up to £80 or £100 per month were to be recorded. The native and Chinese labourers, who are maintained in mine compounds, cost about 3s. per day, of which the wage represents about one-half.

7. *Kalgoorlie, Western Australia.*—This camp has attracted the best of Australian labour. Very few foreigners are employed. Out of 6,000 employees in and about the mines, 4,000 are unionists. Miners on pay receive 13s. 6d., and contractors make, on the average, 15s. 6d., per shift of eight hours. Unskilled labourers, below and on the surface, make about 11s.; mechanics, 13s. to 14s.; and mill-hands, 11s. 8d. per shift. The necessities of life for the single man cost about 27s. per week.

8. *Broken Hill, New South Wales.*—Here the standard of efficiency is below that prevailing in Kalgoorlie, but conditions of work are somewhat more unfavourable. Miners on pay receive 10s.; contractors, 13s. to 14s.; labourers, 8s. 7½d. (some on contracts substantially more); mill-hands, 8s. 7½d. to 9s. 6d.; and carpenters, blacksmiths, etc., 11s. 6d. per shift. The cost of living for a single man may be reckoned at 22s. per week.

9. *Bendigo and Ballarat, Victoria.*—Conditions in these old-established and well-favoured centres, where all the comforts of country home life may be enjoyed, differ radically from those marking the desert camps of Kalgoorlie and Broken Hill. Wages stand on a lower plane, and yet labour is generally abundant. Youths and learners are engaged on the mines at a small wage, growing commensurately with the increasing value of the services rendered. Miners, who are mostly on day's pay, receive 8s. per shift; labourers, 5s. to 7s.; lads and learners, 2s. 6d. to 5s.; mill-hands and mechanics, 7s. to 8s. 6d.

10. *Waihi, New Zealand.*—Nearly all underground work in the Waihi gold-mine is performed on contract, under which system miners make 10s. or 11s. per shift, and their sub-contracting truckers 8s. or 9s. Surface men are paid at Arbitration Award rates, working forty-five hours a week, of: Labourers, 7s. 6d.; vanner and stamp men, 8s. 6d.; amalgamators, 9s.; engine drivers, 9s. or 10s. per shift. Although nearly all employees are unionists, preference for them being demanded by law, the local organization is not aggressive. Industrial disputes are settled by an Arbitration Court, whose decisions are often rigidly enforced by Government, though inevitably more binding upon the employer than the labourer.

11. *Boundary District, British Columbia.*—Wages in the Boundary copper-field are apt to vary according to the strength of the metal market. In the middle of 1907, when copper was standing at £100 per ton, miners received 16s. 6d. per eight-hour

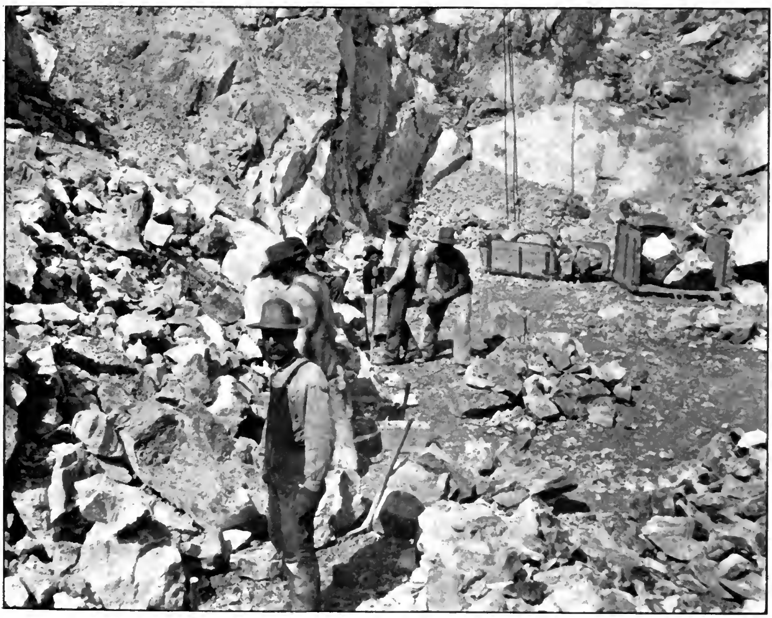
shift; underground labourers, 14s. 6d.; and surface labourers about 14s. The workers, who are for the most part single men, are boarded at one dollar (4s. 2d.) per day, and pay 30s. or 35s. per month for accommodation. The union, as a branch of the Western Federation of Miners, Colorado, is powerful. In the workers' ranks are a large number of foreigners, notably Americans, Austrians, Swedes, Finns, and Poles. At the copper smelters, a large proportion of the workmen are Italians. Such high wages could not be maintained with a weak copper market, and grave fluctuations are inevitable.

12. *Sudbury, Ontario.*—In the nickel-copper mines and smelters of Sudbury, Northern Ontario, we find a striking illustration of the labour policy followed in Canada, in direct contrariety to the exclusive principles of Australian immigration. The great majority of Sudbury's labouring community are continental Europeans—thrifty, contented, and hard-working. Their wages average 7s. or 8s. per day, out of which enough is commonly saved for a return to the homeland in a few years. There are no unions. These physically and mentally stolid foreigners appear to provide satisfaction and receive it. In their dread of strikes, likely to interrupt the steady rate of profit accumulation, they give the agitator meagre encouragement. The shift is of ten hours' duration, for which the workers—truckers and shovellers—in the district's principal mine receive 9½d. per hour. Drill-runners make 10s. or 11s. per shift. Few of these foreigners speak English, or even endeavour to learn. The Sudbury labour position, though industrially sound, is politically deplorable, and reflects one of the ugliest features of Canada's liberal immigration policy.

13. *Thetford Mines, Quebec.*—The employees of the Quebec asbestos mines are almost exclusively French-Canadians, industrious and contented. Ordinary labourers receive 7s. 6d. per shift of ten hours, and machine-men earn 9s. or 10s. In the cobbing sheds a number of boys and girls are employed at a few shillings per week. The seeds of unionism were planted in the district a few years ago, but the sickly growth arising was stamped out as a weed by these sturdily conservative *Habitants.* In the winter months, when mining is slack, the Thetford workers seek the shelter of the forests, where their exceptional skill with the axe can be turned to good account.

14. *Federated Malay States.*—The natives of the Peninsula constitute an inconsiderable proportion of the great population

KAFFIR COMPOUND, RAND, SOUTH AFRICA.



FRENCH CANADIANS, QUEBEC.

of the mine workers, of whom 200,000 are immigrant or Straits-born Chinamen. These signally efficient labourers prefer employment on a profit-sharing system ; many thousands, however, are on day's pay, receiving 1s. to 1s. 6d. for a shift of a few hours. The average coolie is very powerfully built, and, considering the trying nature of Malaya's moist equatorial climate, performs a remarkably good day's work. Chinese immigration having failed to keep pace with the development of the country's tin-mining and rubber-planting industries, a shortage of labour was experienced in 1906 and 1907. The importation of Indians is practised to a limited degree.

15. *Burma Ruby Mines.*—In Burma, as in Malaya, native labour supplies are totally inadequate for local needs. For the operation of their mines at Mogok, Upper Burma, the Ruby Company employs 2,000 to 2,500 *maingthas*, or Chinese Shans, drawn from the bordering State. The efficiency and conduct of these men, who receive one rupee (1s. 4d.) per day without board, have been favourably commented upon by all qualified observers. In the working of the country's oil-wells the intelligent Burmese are extensively employed.

16. *Madras.*—In the mica and manganese mines of Madras a wage schedule is in vogue lower than that of any other division of the British Empire. The average wage of the Telugu workers, whose homes are in the immediate vicinity of the mines, is approximately 3d. per day. Children earn 1½d., women 2d., and the men 2½d. to 4d., according to the class of labour performed. It cannot be claimed that the efficiency of these coolies, who are generally weak and inexperienced, stands at a high level. The remarkable powers of endurance possessed by the Indians, however, compensate to some extent for their lack of muscular energy. Though the wages mentioned may seem absurdly low, a thrifty family of workers are able to save a good proportion of their earnings for periods of distress, and, at the same time, live a life of the fullest indulgence according to their simple tastes. Madras labour conditions can by no means be justly regarded as typical of India, for in the Mysore gold and Bengal coal field the wage-earning standard is far higher than that found ample by the home-loving Telugu villagers.

In Ceylon the gem-pits and graphite mines give employment to a large number of Cingalese, who seem to hold a national monopoly of this field of labour, while the demands of the tea and rubber plantations are met by the importation in thousands of Tamils from Southern India.

17. *British Guiana.*—Labour conditions upon the gold-fields of British Guiana appear to be generally satisfactory. The secretary of the Institute of Mines and Forests has expressed himself enthusiastically upon the constitution and skill of the native negro, who works capably under strict and judicious management for a wage of 1s. 4d. to 2s. per diem, with food. It would be difficult, he says, to find a 'finer animal, a hardier, pluckier, cheerier mortal, than the first-class gold-digger.' Contracts are made with the labourer for a specified period, and should he desert, refuse to work, or misconduct himself, he is liable to a penalty of £5, or, in default, imprisonment.

18. *West Africa.*—Like those of South Africa, the gold-mines of the Gold Coast are served by whites and by coloured native labour; but there are certain fundamental distinctions between conditions of employment. The climate of the country, enervating and unhealthy (though the growth of knowledge and civilization is steadily reducing its dangers), is the very antithesis of that with which South Africa is favoured. White employees are consequently engaged in a more restricted degree, and, working for an average of 21s. per shift, are maintained by the companies. Native labourers, however (receiving 1s. 9d. per day on the average), keep themselves. On the Rand these conditions are reversed. A contrast of greater economic importance lies in the allocation of duties, for in West Africa the intelligent natives are under no restriction as to the scope of their duties, and are trained to perform the higher grades of labour, in mine, treatment plant, 'shops,' and office. There is no scarcity of native labour, but, with a view to greater security, districts have been tapped far from the centres of activity, even in the Northern Territory, four hundred miles to the north of Kumassi.

CHAPTER II

INDIAN EMPIRE

Mica and Manganese

1. A young mining country.—2. Iron and aluminium.—3. Geological survey.—4. Bengal coal.—5. Saltpetre.—6. ‘ Giant granites ’ of Madras.—7. Primitive methods.—8. Great producers.—9. Taxation and values.—10. Cheap labour.—11. Bengal mica.—12. Prevalence of thefts.—13. Classification of product.—14. Qualities of mica.—15. Strange Indian uses.—16. Manganese boom.—17. Two great fields.—18. Causes of activity.—19. Vizagapatam deposits.—20. Kodur Mines.—21. Central Provinces.—22. Origin of the ore.—23. Future prospects.

1. Though famed for generations past as the home of Golconda diamonds and Burmese rubies, and known to have been exploited for its gold and petroleum by ancient workers, India—as a mining country—has developed from the chrysalid stage in very recent times. Progress has of late been remarkable indeed. The yield of coal has been doubled, of manganese quadrupled, in eight years. The mica output has increased in an even greater ratio during the same term of industrial activity. In twenty years the gold-fields of Mysore have risen from insignificance to a position of world-wide importance. In twenty years, also, —since the British annexation—the gem and oil fields of Burma, found in the slough of native maladministration, have been established on a basis of commercial stability.

2. In addition to accomplishments, new projects of significance have been soundly formulated—plans for the fitting utilization of the country's iron and aluminium resources. Sini, where the large iron and steel works would operate, is situated on the Bengal-Nagpur Railway, 180 miles from Calcutta. Iron production has proceeded intermittently for many years at the *Barakar* works, now vigorously active, but the difficulties of steel production, technical and commercial, appear to have been insuperable under prevailing conditions. The exploitation of

the country's bauxite for aluminium is a further scheme, beyond the stage of primary investigation, in the advancement of which the Geological Survey Department has taken a vigorous part. In a recent address, Mr. T. H. Holland referred hopefully to the large bauxite deposits, suitable for the manufacture of pure alumina, occurring in India, and their industrial possibilities under enterprising exploitation.*

3. In 1897, Mr. T. T. Wynne, referring to a new ruby district in Burma, before the Institute of Mining and Metallurgy, remarked that information was scarce, the 'Government of India, in pursuance of its usual policy, having discouraged individual enterprise.' During recent years, however, under the régime of Mr. T. H. Holland, the Geological Survey has enlarged its sphere of work and influence to a striking degree. The staff has been strengthened by several trustworthy mining geologists, who stimulate private enterprise of the legitimate class, and whose knowledge is at the service of all willing to employ capital in the sound development of India's mineral resources. The vastness of the territory to be covered fully justifies the existence of so strongly organized a Geological Department, which is larger in relation to value of mineral yield than that supported by any other British Dependency.

4. The annual production of minerals in India and Burma exceeds £6,000,000, of which the Mysore or Kolar gold-fields contribute upwards of 40 per cent. Next in importance are the Bengal coal-fields, which have recorded extraordinary progress during the last few years, and have been made the basis of considerable financial speculation. The growth of the Indian coal industry can be shown at a glance by the following figures :

Year.	*Long Tons.*
1892	2,538,000
1897	4,006,000
1902	7,424,000
1905	7,762,800
1906	9,112,600

Bengal accounts for 95 per cent., and now holds high rank amongst coal-producing divisions of the British Empire. The coal-mining industry gives employment to 90,000 natives, of whom 28,500 are adult females, working above and below

* Presidential Address, Transactions of the Mining and Geological Institute of India, vol. ii.

ground, and 2,400 children under twelve years of age, mostly on light surface work. It is one of the incongruities of labour economy that the demand for workmen by industries in this land of teeming millions is nearly always in excess of the supply, and that the home-loving natives are willing to emigrate in thousands to the estates and coal-mines of Natal, to the plantations of Ceylon, Malaya, Fiji, and British Guiana.

5. India at one time enjoyed almost a monopoly of the saltpetre trade, and the supply of Europe was nearly all manufactured in the country. In Ball's 'Economic Geology of India' it is noted that, thirty years ago, the districts of Behar, Cawnpur, Allahabad, Benares, the Punjab, and Madura (Madras) were the most productive. By the collection of the impregnated soil, lixiviation, evaporation, and a simple process of refining which eliminates other salts, especially the sodium chloride, pure or nearly pure saltpetre was produced. At the present day there are 400 registered refineries (including 280 in Behar), yielding about 15,000 to 20,000 tons of saltpetre per annum. The product is valued at 15s. per 100 pounds.

MICA FIELDS.

6. The production of mica is one of India's most distinctive mining industries. The mineral occurs, as muscovite, in Madras and Bengal in deposits of exceptional richness, which satisfy a large proportion of the world's increasing demands. It is found in numerous parts of India, but the only producing districts of commercial importance are those of Nellore (Madras) and the Chota Nagpur (Bengal), which may be independently discussed. Unlike the Chota Nagpur field, 'hacked and hurt by time,' the Nellore mica district, 80 miles north of Madras, possesses a dreary monotony of feature. It comprises an area of about 100 by 30 miles to the west of Gudur, on the Madras Railway—a flat, low-lying, sandy, and unfertile plain, stretching from the Veligonda range to the Indian Ocean. The pegmatites, or giant granites, in which the great books or bundles of mica occur, have cut through an enormous belt of mica-gneiss and hornblende schists. The intrusions take the form of lenses, irregular masses, and sheets, dipping steeply, and generally parallel in trend to the foliation planes. The chief constituents of these bodies are quartz, felspar, and mica, commonly associated with apatite (occasionally in enormous blocks), garnets in abnormally large crystals, beryl, and schorl. Sometimes the books of mica are

found near the surface; often there is merely an outcrop of coarse greisen or milky-white quartz with clusters of small mica. The perfect six-sided tabular crystalline form of the great bundles extracted in the rich deposits is strikingly revealed upon their removal from the working faces, where one may see a perfect cast of the crystal edges as clearly defined as those observed in the clay encasing a ribbed fossil shell. The wide distribution of the known deposits and their frequent lack of prominent outcrop suggest that the mica resources of the field are inexhaustible, and that new finds may be constantly expected under the stimulative influence of a strong market.

7. Mining in the Nellore district commenced, in 1887, with a customary term of speculative excess. The local natives (essentially agriculturists) turned prospectors, and went out daily with pointed rod, pick, and basket in search of mica. The Madras gambler also visited the field, and many ill-advised propositions were undertaken, leading to a batch of failures and disappointments. The most successful pioneers were Messrs. Sargent, Wickham, A. Subba Naidu Garu, and A. M. Kuddus Badsha Sahib—the two latter, natives of high standing, still controlling a dozen of the best deposits.

Visitors to the Madras mica-mines cannot fail to criticize adversely the working methods of the past. In extenuation of their palpable faultiness, allowance must be made for the common lack of working capital, which necessitates a hand-to-mouth policy, and checks the accomplishment of preparatory work not immediately productive. Moreover, the early workers could not rely upon the permanence of the deposits. The brevity of the Government leases also prompted holders to ignore the demands of future economy. But to-day the same excuses cannot be advanced in apology for the offences against rudiments of scientific mining. Long leases are now obtainable. Experience has demonstrated the typical features of the pegmatite veins and bosses. Several of the controlling firms are financially strong. Nevertheless, one may observe work proceeding, even in many of the best properties, on inefficient, unmethodical lines. To as great a depth as safety will allow, the deposits are quarried. Sixty feet is about the maximum depth to which open cutting has been practised. Then follows irregular underground mining. Tunnels appear to be driven in without a vestige of exploratory system; the best indications of the day are followed, and the workings speedily spread into a sinuous tangle. Underhand stoping results in the destruction or excessive injury of the mica.

Some of the old mines of the district, not necessarily exhausted, are in such a state of chaos below ground that the extension of operations could only be undertaken with extreme difficulty. The problem is peculiar to this class of mining, wherein the shattering of the rock must be avoided as far as possible. The need of preserving the crystals, whose value is so greatly reduced by fracture or perforation, suggests the advisability of overhand stoping and waste-filling.

The inefficiency of native systems is unfavourably commented upon by all who examine the field. The Government Inspector of Mines has written : 'Primitive methods without much regard for safety and efficiency appear to be the rule, and "supervision" and "discipline" are almost unknown words.' The latter criticism refers, presumably, to the higher branches of supervision, for in matters of petty regulation, such as the precise relative positions of the coolies engaged in passing up the baskets of mineral and rock, the overseers, or 'maistries,' often appear to be rough and extravagantly exacting task-masters.

8. The greatest deposits of the field, now controlled by native operators, are known as the *Palimitta*, *Shah*, *Laksmienarayana*, '*D*' (*or Sargent's*), *Tellabodu*, *Kelly*, '*F*,' *Kodadad*, *Nuṇdalagunta*, *Mobarak*, and *Kalichedu*. The first five rank amongst the greatest mica deposits in the world. When visited by the author in 1906, the *Tellabodu* was turning out approximately 30,000 pounds of cut mica per month. As much as 60,000 pounds per month had been recorded. Its product is of fair quality, highly flexible, but inclined to be flawed by greenish spots. The *Palimitta*, controlled by Badsha Sahib and Co., is another enormous deposit, which has been producing for fifteen years, and declaring an annual yield of 250,000 to 300,000 pounds of mica of first-class quality. The '*D*' mine is one of exceptional interest, having been opened up with great success by an Englishman, Mr. Sargent. The deposit, a lens 350 feet long by 150 feet wide, has been carried to a depth of 60 feet by open-cut, and mined for a further 50 feet. Its yield was 1,000 pounds per diem in its more active days. On the northern side of the ellipse occurs a great boss of milky-white quartz, around which the excavation has been carried. The quality of the mica is first-class, and characteristically of a light greenish tinge.

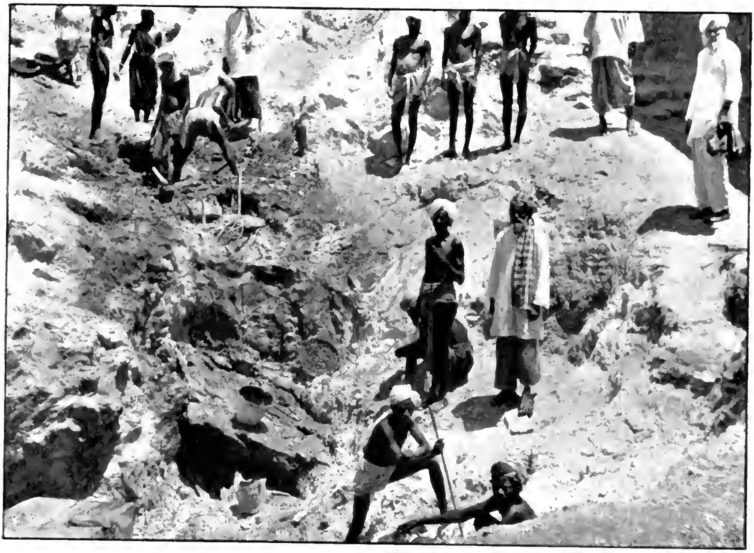
The mica from the district is (1) clear, (2) pale green, (3) stained, and (4) spotted. Madras mica is known widely by its clear and greenish varieties, just as 'ruby' mica is a typical product of the Bengal regions.

9. The native operators, though admittedly prosperous, are often loud in complaint against Government regulations and system of taxation. Upon acquisition of lease, a deposit of about £35 has to be made. Miners pay a dead rent of 1s. 4d. per acre, or 5 per cent. *ad valorem* duty on mica removed (whichever may be the greater), and a surface rent of 1s. 4d. per acre. No mica can be dispatched until passed by a Government inspector. It is the practice of Madras producers to cut their mica, after it has been delivered at the sheds or 'godowns' from the mine workings, with shears into the largest rectangular piece possible. Whether it is commercially advantageous to do this, instead of merely taking off the flawed sections or broken edges with a hand-sickle (as commonly practised in Bengal), is a debatable question.

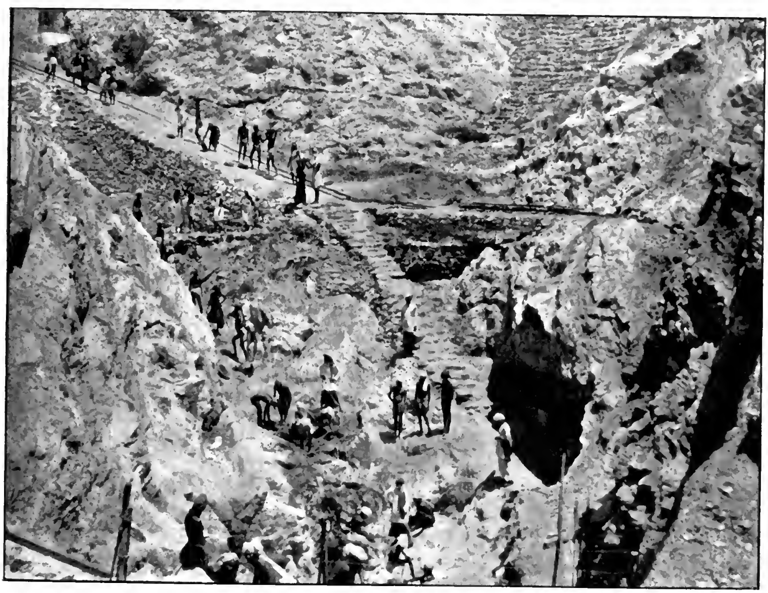
During recent years, the production of films or splittings for the production of micanite has enormously increased. Many of the old dumps of scrap and dirty mica in Madras and Bengal are now in the hands of the 'round' cutters, for division into the finest laminæ (clean and perfectly transparent), which are shipped to micanite manufacturers oversea. These splittings are made, by means of a powerfully adhesive substance, into micanite sheets of large size.

10. The success with which Madras mica mining has been prosecuted during the recent term of high market prices for mica and micanite has in due course led to an extension of operations. An influence tending to check overproduction has been a frequently prevalent shortage of labour, thickly populated though the country may be. From October to January work in the mines is checked by the monsoon rains. In good harvesting seasons labour is particularly scarce. Employment is found for 8,000 men, women, and children, in and about the mines. Being employed in the vicinity of their homes, these labourers are satisfied with wages much lower than those obtainable in other centres. Under proper supervision—which is rarely forthcoming—they become efficient workers.

The miners receive 3d. to 4d. per day, ordinary surface coolies (male and female) 2d. to 3d., and children 1½d. or 2d.—all classes 'finding themselves.' At the *Tellabodu* mine, the greatest producer, hammer-boys receive 4d. for a shift of seven hours (8 a.m. to noon, and 2 to 5 p.m.), with an opportunity of earning an additional 2d. for a supplementary two hours. With such a schedule of wages, and with deposits equalling in richness those in any part of the world, it is easy to understand how



MICA MINING, MADRAS.



PALLIMITTA MICA MINE, MADRAS.

strongly India maintains its position as the greatest producer of mica. Not only can the country command the European market, but it also invades the home markets of other producing countries, such as America. Quebec, Canada, produces considerable quantities of the mineral, but we find that the Indian product, delivered at Ottawa, costs no more than the domestic supply.

11. The Madras fields produce roughly half of India's mica yield, which aggregated 50,400 cwts. in 1906. Excepting 5,000 cwts. recovered in Rajputana, the remainder is attributable to operations in Bengal. The Hazaribagh district of Chota Nagpur (whose mica tract comprises a stretch of broken jungle-covered country, about 15 by 60 miles in extent, to the west of the Giridih coal-fields) has now been under exploitation since 1872, when Mr. F. F. Chrestien—still in control of many important properties—first realized the commercial possibilities of the industry. The pegmatites here occur, also in the form of lenses and veins, along the bedding planes of schists—generally striking east and west. The erratic and non-persistent character of the typical deposits has influenced the development of mining systems, which are very crude, but generally more efficient than those prevailing in Madras. Efforts made to open up these mines on high academic principles have ended disastrously. Small syndicates dare not risk too much in any one mine, but, working several, rely upon the law of averages to make good the losses of the failures of the group.

There are ten or twenty independent controls covering the best properties in the field, where the European influence is powerful, and the chief centres are Tesree, Koderma, Dabur, Dhab, Domchanch, Bendi, Gawan, Gharanchi, Charki, and Mahisri. Around Koderma is a large protected Government forest in which lie some of the most productive belts. Tesree, the home of the Bengal mica industry, is still the central station for the mines of Messrs. Chrestien, and the site of the largest trimming and splitting depot in India.

12. Although it may be noted that Madras mining has at times been checked by the prosecution of vicious lawsuits—a diversion beloved of the Asiatic mind—there is probably less industrial co-operation between the controllers of the Bengal field. Concerted action would tend to check the traffic in stolen mica, which has long been rampant.

The problem of its prevention has been one of the most serious difficulties facing managements, who, maybe, rely too implicitly upon Government assistance. Very few of the many thieves and their patrons are caught, and those found guilty have generally been punished with absurd leniency, tending to encourage others of wavering integrity to join the gang. Seeing that £50 to £100 worth of the best mica can be carried by a single bullock, the difficulties of the case are obvious. The lack of unity amongst managements is further demonstrated by the constant competition in the recruiting of labour.

While the rate of wages has increased, the standard of working efficiency has fallen. Frequent interruptions, of troublesome irregularity, are occasioned in the progress of work by funerals and wedding festivals (which apparently every cousin unto the hundredth degree must attend), as well as the established religious festivals. No weekly day of rest is observed. Enforced holidays occur in all mining districts from a wide diversity of causes, but the Chota Nagpur can claim to be affected by a surely unique factor of interruption, when the occasional visitation of a man-eating tiger throws terror into the hearts of the village miners, and not inexcusably deters them from making a journey to the pits through the invaded jungle.

13. Owing to the different classifications adopted by the several establishments, it is difficult to establish a representative schedule of valuations. To Mr. E. Lane, manager of the *Bengal* and *Chota Nagpur Mica Syndicates,* I am indebted for a statement relative to the strong market position in 1906, when the field was visited by the writer. This showed that sheets under 3 square inches were valued at 4½d. per pound ; between 3 and 6 square inches, 6d. to 1s. per pound ; between 6 and 10 inches, 1s. 1d. to 3s. ; 10 to 16 inches, 2s. to 4s. 3d. ; 16 to 24 inches, 3s. to 5s. per pound ; and in very large sizes, of best quality, even 15s. and 20s. per pound.

Splittings or films of good quality were valued at 2s. per pound for over 16 square inches, 1s. 6d. per pound for 10 to 16 square inches, 1s. 1d. to 1s. 3d. for 6 to 10 square inches, and 9d. to 1s. for smaller sizes.

These prices have been strongly maintained.

14. The commercial uses of mica—a transparent, flexible, incombustible, and durable mineral, with exceptional insulating properties, ready adaptability to any shape, and indifference to shock and changes of temperature—are numerous in the world of electricity and mechanics. Sheet mica is most extensively employed in the construction of dynamos, alternators, etc., for which it needs to be of high quality, free from impurities and

cracks, and of perfectly uniform cleavage. The earlier usage as 'Muscovy glass' for furnace and stove windows, lamp protectors, and other purposes, calling for a strong transparent substance little affected by heat, continues to account for a substantial demand. There are many other uses—and abuses—to which the mineral, in sheets or powder, is applied in the East. One of the mine-owning firms has established an exhibition store in Madras to advertise these minor products, some references to which will illustrate muscovite's commercial versatility.

15. Waste and powdered mica is utilized as a lining for roofs and walls in hot and cold climates; in the preparation of a whitewash to impart brilliancy; in the 'getting-up' of fine muslins; with grease or graphite as a lubricant; for the polishing of ballroom floors; and in the manufacture of boiler and steam-pipe coverings. Cut mica and micanite are also made, for the native market, into elaborate chandeliers; into 'ornamental' stamp, cash, betel-nut, spice, snuff, and match-boxes; cigar and cigarette cases, ice-chests, table-dishes, bowls, jugs, dessert services, teacups and saucers, butter-dishes, tumblers, trays, ladies' fans, caps, stationery cabinets, imitation bouquets, motor goggles, confetti, and curtains. But the culminating-point of Mohammedan commercial ingenuity, which might be more profitably directed toward the mining of the crude material, is seen in the 'ladies' mica hat, very elegant, decorated with flowers—10 rupees.'

A recently issued catalogue of these abnormal utilities closed with the significant statement that 'mica is used in the preparation of Indian medicines for about 230 diseases.' When one investigates the full prescriptions specified for these divers ailments, the impression formed is not one of surprise at the medicinal potency of potash mica, but of simple admiration for the strength of the patient surviving a dose of such abominable concoctions, of which mica appears to be the one solitary ingredient of a harmless character.

MANGANESE MINING.

16. While it is to be seen that almost every branch of Indian mining has evinced signs of steady progress, the records of expansion have been further marked by a sensational feature in the meteoric rise of the manganese industry. The 'boom' in the production of this metal, which has in a year or two carried India nearly to the head of the list of manganese-mining countries, has been of the most gratifying description. The

scramble and rush has been for mining profits, and not for the gains of stock-market manipulations.

As an illustration of the possibilities of India's less romantic mineral resources, no brighter page of her industrial history could be found. But, like other booms, the rapid progress has not been without some ill-consequences; for, in the feverish haste of ore-extraction, operations have in several instances been conducted on careless principles without due consideration for future economy.

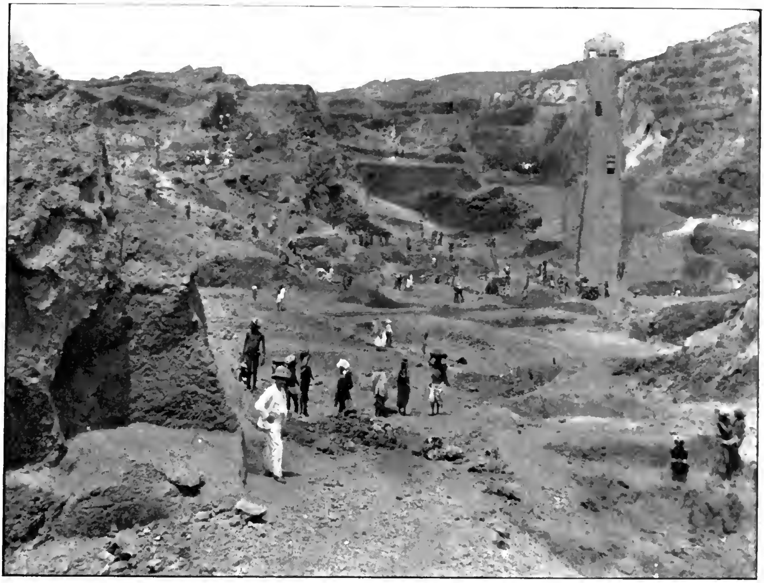
17. As in the case of mica, there are two widely separated manganese-producing areas—in Madras and the Central Provinces. The Madras deposits, in the Vizianagram district, have been worked since 1893, during which year 3,100 tons were exported. In 1899 the output had risen to 87,000 tons, and the Central Provinces then began to contribute their quota to the country's yield, the subsequent records of which are shown in the subjoined table:

Year.	*Yield.* Tons.
1900	92,458
1901	162,057
1902	144,037
1903	171,223
1904	138,733
1905	204,194
1906	436,442

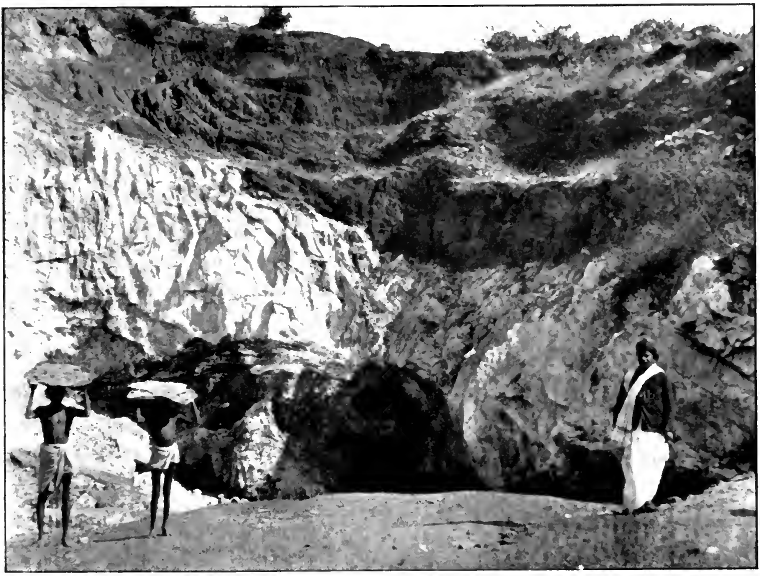
The ores of the Central Provinces, near Nagpur and to the north of the Bengal-Nagpur Railway, were first alluded to over thirty years ago by Captain Jenkins and Dr. Voysey.

When this field became fairly developed, it soon outstripped the Madras area in rate of production. Between the two fields there are several contrasting features—natural and industrial. In the Vizianagram belt the deposits occur in the flats between the ranges of gneiss; their psilomelane ore averages 46 to 50 per cent. manganese. Shipments have to be carried only sixty miles by rail to the port of Vizagapatam, and one firm has a practically monopolizing control. In the Central Provinces the occurrences are frequently in elevated places suitable for cheap ore-extraction and transportation by aerial gear; the percentage of manganese averages as much as 54 per cent.; ore for export has to be sent 500 miles to Bombay, or 700 to Calcutta; and there are many independent ventures at work.

18. The great activity of the last two or three years has been stimulated by the higher quotations for the mineral, for which



GARBHAM MANGANESE MINE, MADRAS.



TELLABODU MICA MINE, MADRAS.

the demand increased owing to the development of the steel industry. Thus, in 1904, the price in the United Kingdom was 9d. per unit, as compared with 1s. 1d. to 1s. 4d. per unit in 1906. The ore is exported in three grades, for which market quotations towards the close of 1907 were only 10½d., 9½d., and 8½d. per unit.

19. The Vizagapatam or Vizianagram manganese deposits are situated near Garavidi Station on the Madras Railway—the most productive body, the *Garbham*, being eleven miles distant, while the *Kodur*, second in importance, is within stone's-throw of the station. Psilomelane (manganese dioxide), commonly bluish-black and submetallic, is the most abundant mineral, with some braunite. The deposits occur as lenticular masses of great width in the gneiss formation, which strikes roughly east and west, dipping south. *Garbham*, which is very irregular in form and disposition of values, stands with a prominent outcrop in the middle of a broad and fertile plain. The mining excavation, measuring about 1,200 by 400 feet, appears the more irregular owing to the occurrence of portions containing comparatively high percentages of silica or iron, which have not been mined as extensively as the zones richer in manganese. Some low-grade sections are characterized by an abundance of jasper ; others, containing perhaps 20 per cent. iron and 35 per cent. manganese, have lately been mined in considerable quantities to meet market requirements. Only 25 to 35 per cent. of the rock and ore mined is shipped, the remainder being waste.

The ore is hand-drilled and blasted, carried in baskets to the surface, or raised by incline haulage. The cobbed ore is piled in stacks for measurement and sampling prior to its dispatch by water-buffalo and bullock-wagon to the railway at Garavidi. In the *Garbham* some 1,500 natives were employed in 1906, the majority being under private contractors on wages of 2d. or 3d. per shift. Though these natives are agriculturists by instinct and experience, they have taken well to their mining duties. The rise of this centre of steady employment has exercised a beneficial influence upon the life and prosperity of these simple villagers.

20. The *Kodur* mine, opened in 1892, is more regular than the *Garbham*, and has been terraced back with greater system. At a depth of 60 to 70 feet, its bottom area was 80,000 square feet. The ore is somewhat richer than that of the *Garbham*, averaging—manganese, 50 per cent. ; silica, 2 to 7 per cent. ; and phosphorus—of course an undesirable constituent to reach

the steel works—0·25 per cent. Up to the time of the writer's visit in May, 1906, the ore was carried by coolies up the zigzag paths to the stacking-yards; but mechanical haulage was being introduced, the pulsometers were being reinforced by a Worthington pump, and a scheme was under consideration for the commencement of underground mining. In course of time many of the Indian manganese producers will be forced to abandon open-cast working, and it is estimated that many, able to make a good profit under former favourable conditions—in the field and in the market—will be unable to operate underground payably. The Vizianagram mines are frequently hampered by water troubles, serious floods being experienced in the rainy seasons. Practically the entire tonnage of manganese ore for Madras is turned out by the Vizianagram Mining Company, which holds the exclusive right to mine on the great Samastharam Estate, or Vizianagram Zemindary, belonging to the Rajah. Other deposits exploited by the company are the *Parapi* and *Garuja*. Outside the Zemindary there are few mines of importance.

21. In the Central Provinces the leading enterprises are the Central Provinces Prospecting Syndicate, Central India Mining Company, and the Indian Manganese Company. The mines of this district, favoured in physical conditions, are severely handicapped by freight expenses, although the rate is only one-tenth of a pie per maund per mile (¼d. per ton-mile). This amounts, however, to 10s. per ton to Bombay, compared with which the cost of mining is small.

The simple methods of manganese mining adopted in India—and, indeed, with certain limitations, simplicity has been the wisest aim—have frequently been made a basis for controversy. Blindly following the best channels of ore, and ignoring the benefits of labour-saving devices, many operators have laid themselves open to severe criticism. Mr. Leigh Fermor, of the Geological Survey, who has studied the deposits more thoroughly than any other competent observer, has commented favourably upon the working of a big mine at *Kandri*, where, by means of a system of two aerial ropeways, an inclined plane, and some zigzag tramways, the labour of transportation is greatly reduced.

Mr. Fermor also cites the *Balaghat* deposit as being well developed, with the advantage of an incline haulage from the mine to the shoots on a branch-line connecting with the Bengal-Nagpur Railway.*

* Transactions of the Mining and Geological Institute of India.

22. Discussing Mr. Fermor's geological reports on the nature of Indian manganese, the Director of the Survey notes the advancement of a definite theory as to the origin of the manganese silicates (in the Vizagapatam district), from which the manganese ores are regarded as having been derived, at least in part, by chemical alteration.

This theory predicates formation by differentiation from an original magma which had a composition corresponding to a mixture of apatite, felspar, quartz, spessartite, and various manganese pyroxenes. Referring to the deposits of the Central Provinces, the hypothesis is expressed that the original manganese-bearing rock was there also intruded in the molten condition into the metamorphic schists and gneisses. 'The manganese ore of the Central Provinces, besides being less phosphoric than those of Vizagapatam, are much more largely braunite, and while the manganese ores of Vizagapatam are often cavernous, porous, and friable, those of the Central Province are almost invariably very compact, hard, and more or less crystalline.' *

23. While it is probable that too gloomy a view is often taken of the future of Indian manganese-mining, it is unquestionable that the prosperity of the last year or so cannot be maintained when the easily worked surface-levels are exhausted by open-cut, and the metal market fails to maintain its abnormal strength of 1906–1907. But it has been pointed out that the position of the industry could be greatly strengthened against the competition of countries still able to rely upon extensive surface deposits for cheap quarrying by the local manufacture of the ferro-manganese required in the Bessemer steel plants. As in the production of mica, India has the inestimable advantage over her rivals in the availability of cheap labour, which can be raised to a fair level of efficiency under sound administration.

* Indian Geological Survey Report, vol. xxxiii.

CHAPTER III

INDIAN EMPIRE—*Continued*

Burma Rubies and Petroleum

1. Title to distinction.—2. The ruby tract.—3. Historical events.—4. Native workings.—5. Burma Ruby Mines, Limited.—6. Stones recovered.—7. Shan workmen.—8. Burma oil-fields.—9. Productive beds.—10. Burmese methods.—11. Rate of production.—12. Character of the oil.

1. The work of mineral production in Burma is as yet practically confined to the recovery of rubies and petroleum.

From the commercial or technical point of view, the working methods and their results appear of small importance; but the great antiquity of its mining history, the occurrence of the world's most prolific ruby-field, and the establishment of the most prosperous petroleum industry in the British Empire, give the country certain distinctive features of interest, noteworthy even in comparison with colonies whose national welfare is wholly dependent upon the exploitation of mineral resources.

Ruby-mining in Burma has proceeded through many centuries. Unfortunately, its early conditions were enshrouded with the utmost secrecy by the Royal monopolists controlling the field, and travellers endeavouring to gather information in regard to the deposits found few facts available.

2. The most productive region to-day, as it has been from time immemorial, is in the vicinity of Mogok, which stands at an elevation of 4,000 feet, some ninety miles to the north-east of Mandalay, in Upper Burma. This district is intersected by ranges of mountains whose altitudes run up to 7,000 feet. The proximity of the Shan States of China has been a factor of particular importance in the development of the ruby tract, for from over its border are drawn the hardy Maingthas, or Chinese Shans, necessary for the performance of the hard manual labour.

Just as in Malaya, the independence or indolence of the natives has necessitated the introduction of Chinese muscle by those endeavouring to establish industrial enterprises. If the labouring classes of Burma have often missed their opportunities, it must at least be recorded, to the credit of native capitalistic discernment, that in the year 1597 the Burmese King obtained these rich ruby deposits from the neighbouring Shan ruler in exchange for an unimportant town on the Irrawaddy.

3. Notwithstanding the defects of early records, it is possible to divide the history of the Mogok mines into two distinct epochs, with the occupation of Upper Burma by the English and its incorporation with the Indian dominions in 1885 as the point of division. Before that date, the production of rubies was a jealously guarded Royal monopoly. King Mindon Min and his successor, King Thibaw (deposed upon British annexation), drew a substantial revenue from the field by parcelling it out to licensed miners (twin-tsas, or 'eaters of the mine'), and demanding possession of stones of a certain size. This rigid stipulation led to endless trouble, for large stones were occasionally split up by the miners to avoid this imposition, and more often licensees were charged with this offence unjustly. It is interesting, in regard to this speculative exactment, to note how few big rubies are to-day recovered, suggesting that the proportion of these stones was so small as to have justified the suspicions of the Royal owners.

In 1885 a flying column of British troops from Mandalay took possession of the mines, which were visited and examined by Mr. George Streeter, Mr. R. Beech, and Mr. Charles Bill, M.P., in the following year. In 1887, after complex negotiations, the *Burma Ruby Mines, Limited,* was formed, with a capital of £300,000.

This company has now for twenty years turned out the bulk of the world's ruby supply; but, despite its strong control, and the enterprise shown by its pioneers in commencing operations soon after British occupation, the venture has more often found itself in serious difficulties than enjoying the fruits of such prosperity as one would be inclined to associate with the production of this most precious stone.

The extent of the ruby-field around Mogok (the 'Ratnapura' of Burma) is about 400 square miles, of which only very limited sections consist of payable ground. The mother-rock of the gems is white granular limestone or calc-spar, in caves and crevices of which a disintegration product is often worked by natives. The bulk of the stones occur, however, in the valley accumulations of alluvial, which are generally shallow and dammed by a rock barrier at the lower end. The ruby-bearing ground, either that obtained in the flats or in the limestone caves and channels, is called 'byon,' and varies in character from gravel to tenacious clay. In the valleys it is commonly 4 or 5 feet thick, and lying at a depth of 15 to 20 feet. On the hill-sides it may be 15 to 20 feet thick.

4. The native methods of exploiting this ground are extremely primitive, and closely correspond with those adopted by the Chinese in working the smaller tin deposits of Malaya, and by the Cingalese in their gem-pit operations. These methods have been fully described by Mr. Trafford Wynne,* who classes native workings under three heads—'Loos,' or caves; 'hmyaws,' or open cuttings; and 'twinloos,' or pits.

The caves or fissures are operated quite unsystematically, the men working their way in as best they can, and bringing out the byon in mats or baskets. On the hill-sides, 'hmyaws' are frequently made, by which is meant that a stream of water is carried round by means of ditching and bamboo pipes to the working-place, and allowed to fall upon and sluice the broken ground. The heavy material is caught in a box, and subsequently washed in baskets for any precious stones it may contain. These 'hmyaws' remind one of many hill-side workings in Malaya, where, indeed, weather conditions are more favourable to the regular application of the system.

More important than either 'loos' or 'hmyaws' are the pits in the alluvial, which are worked very similarly to the Ceylon gem-pits for sapphires. In size they run up to about 9 feet square from a circular hole only capable of holding one man. The sides are kept back with poles, sticks, and leafy branches. The 'byon' extracted is washed in any neighbouring water. For dewatering the larger pits, balance cranes, with the ubiquitous oil-tin at one end and a weight at the other, are widely used in Burma, just as they will be found throughout the world wherever alluvial mining is performed by primitive means. In many regions, especially in the eastern tropics, the balance crane is the one conspicuous symbol of the science of mechanical engineering, although in hydraulics the native miners will often evince an untutored skill tantamount to genius.

Alluvial pits in the Mogok ruby region frequently attain a depth of 50 feet.

* Transactions of the Institution of Mining and Metallurgy, vol. v.

5. The advent of the *Burma Ruby Mines, Limited*, in 1887 did not immediately transform the industrial conditions of the field. The rights of the natives in the valleys suitable for exploitation, the density of the surrounding jungle, and the burden of Government dues long prevented the company from operating at a profit. Moreover, a false start was made, and attention turned to a section of the property called *Pingutaung* (' Hill of Spiders '), believed to be the source of the district's gems. The theory proved erroneous and the scheme costly. The year 1893 was a turning-point in the company's career. It was realized that work on a small scale would never bring success, and it was decided to attempt the exploitation of the large valley deposits by installing pumps in pits at their lower end, and thus, by draining the valleys, enabling the ground to be readily excavated and trammed to the washers. Experimental work at the *Tagoungnandaing Valley* was successful, and, as a result, similar operations were commenced in 1894 upon the main *Mogok Valley*. Since then several valleys have been worked in this way, and others still remain untouched. At first, power was generated for pumping by steam or by water-wheel, but now the centrifugal pumps are worked by electricity transmitted from neighbouring water-power.

The treatment of the ' byon ' is a simple process. From the mine-trucks it is tipped through grizzlies into trommels, from which the undersize passes into 14 - feet washing-pans, with ordinary revolving arms to stir up the dirt and allow the light valueless slime to overflow into a safety-pan. The heavy concentrates are drawn off twice daily, and passed through classifying trommels producing five sizes, of which the largest is sorted direct, and the four others are further treated in pulsators before being submitted to examination. The sorting is performed by Burmese under white supervision. Apart from the ruby,—spinels, sapphires, tourmalines, and Oriental topazes are found.

6. Large rubies are of rare occurrence. It is stated in a pamphlet written by Messrs. F. Atlay and A. H. Morgan, officials of the *Burma Ruby Mines, Limited*, that a stone found in the *Tagoungnandaing Valley*, weighing $18\frac{1}{2}$ carats in the rough, cut to 11 carats, and sold for £7,000, was the most valuable ruby yet found. Dr. Max Bauer, in his standard work on Precious Stones, remarks that the majority of the rubies are under $\frac{1}{8}$ carat in weight, and that about 500 rubies are found to one sapphire.

It is pointed out in the chapter on Ceylon that conditions in the gem-bearing deposits of that island are the reverse, sapphires being in the great preponderance, and rubies of comparative rarity. But the Ceylon ruby cannot be classed with the deep pure carmine ('pigeon's blood') red stones of Upper Burma, whose attempted imitation, at one time causing anxiety, has not exerted any seriously adverse influence upon the trade. The bulk of the Burma Ruby Company's yield is disposed of in London, but there is also a considerable traffic in stones at Mogok, where the diggers holding licences under the company (the fee is 20 rupees, or 26s. 8d. per man per month) dispose of their winnings, and where the company also sells its inferior stones. As a rule, there are about a thousand independent natives at work upon the tract. Like their Mohammedan fellows of Ratnapura, Ceylon, the Burman, Chinese, and Shan dealers of Mogok are inveterate gamblers, and the fortnightly auction sales frequently present scenes of the most extraordinary excitement.

The output of gems from *Burma Ruby Mines* for 1906 was declared at 324,410 carats, as compared with 217,420 carats for the preceding year. The grade of the ground worked by the Burma Company is low, and leaves a margin for profit so narrow that it does not suggest any excess of Government generosity in their assessment of profit tax at 30 per cent.

Returns for the last four financial years have been :

Year to June 1.	*Trucks washed.*	*Cost per Truck.*	*Yield per Truck.*
1904	1,500,124	8·0d.	14·9d.
1905	1,907,624	7·0d.	11·3d.
1906	1,773,129	8·4d.	11·9d.
1907	1,890,944	7·7d.	12·1d.

These figures represent a revenue from rubies of £87,000 to £95,000, and clearly prove that the ground under exploitation could be worked at a profit probably by no other means, and certainly on no smaller scale, than that obtaining. The company's income from miners' royalties is a fluctuating amount, and has varied from £13,000 to £23,000 per annum during the period covered.

7. The best workmen available for the heavy work of the pits are the Maingthas—a race of strong 'pig-tails' drawn from the Shan States, who are able to stand the trying and unpleasant variations of climate, and to perform duties for which the Bur-

mese are generally unfitted by natural disposition. These Shans constitute far the greater proportion of the company's 2,000 to 2,500 employees, and are paid at the uniform rate of 1s. 4d. per day, without any deductions and without any allowances for board. As labourers, these highly contented men receive commendation from all authorities—their one predominant failing being the characteristic Chinese passion for gambling. The Maingthas have the reputation of being expert thieves, but present systems of working obviously do not give them many opportunities of practising their skill at the expense of the company.

PETROLEUM.

8. To the oil-fields of Burma, as to its ruby-mines, belongs the distinction of exceptional antiquity. Both regions have been opened up by British capital, and raised from a basis of primitive inefficiency to a high level of industrial stability, since the annexation of the country twenty-two years ago. From the earliest records of the industry one may learn that the Burmese people in bygone days were in the grip of an 'oil monopoly,' in comparison with which the American Oil Trust of to-day appears a defenceless giant.

Prior to 1852 Burma's 'Standard Oil Company' comprised a group of twenty-four families, who held the exclusive right of digging oil-pits, and who, at one time, preserved the exclusiveness of their valuable monopoly by marrying solely amongst themselves. In the year mentioned, the supreme power of the Irrawaddy 'Rockefellers' was brought to an end, not by the imposition of a colossal fine or an outburst of democratic indignation against the 'octopus,' but by the more simple process of a Royal decree by King Mindon Min, who declared his intention of controlling the industry himself. According to reports, whose authenticity would appear to be as uncertain as those circulated with regard to the first discoveries of Burmese petroleum, the King enjoyed an annual revenue of 600,000 rupees from this source.

To-day there is no monopoly, although the *Burma Oil Company*, by reason of its selected holdings, its established pipe-lines, and refineries, and business organization, has so strong a footing in the country that the task of competitors must be signally difficult.

The oil-fields may be classed under two heads—coastal and interior. The latter, which occur along the banks of or near the Irrawaddy, to the south of Mandalay, are infinitely the more important. The two centres, *Akyab* and *Kyaukphyu*, which are ports of call for Calcutta-Rangoon coastal steamers, are now responsible for but a thousandth part of the country's production, which is almost entirely derived from the districts of *Yenangyaung* (Magwe), *Singu* (Myingyan), and *Yenangyat* (Pakokku). *Yenangyaung*, the premier region, whose scientific exploitation dates from the conquest of Burma by the English, but whose legendary history goes back as far as the conquest of England by the Normans, produces over half of the country's oil. In 1895 Dr. Fritz Noetling gave the field a thorough examination on behalf of the Indian Government, and presented his views in a Geological Survey memoir.

Several of the opinions expressed by this geologist have since been keenly debated, but his observations have proved of great value, and constitute the most comprehensive treatise upon the industry.

9. Dealing with the Yenangyaung area, Dr. Noetling points out that the petroleum is always associated with sandstone strata, with which clay-beds occur, acting as a hermetic seal. In no case is oil present in the argillaceous beds, or gathering in their cracks and fissures.

'This mode of occurrence,' he contends, 'renders it impossible that the petroleum should have originated at some other place, and migrated to its present receptacle. It is impossible to imagine how it could have penetrated a fairly thick layer of clay without leaving the slightest traces of the way it followed and eventually gathered in a sandy streak. . . . To me this seems convincing that either the substances eventually changed into petroleum, or the petroleum itself must have been absorbed by the sandy layers before the latter was hermetically sealed up and surrounded on all sides by a covering layer of clay.'

The layers of oil-sand occur at several horizons.

From the fact that the deeper wells are marked by a continuity of production, and that there is a periodic rise and fall within the season, it is argued that a certain amount of migration occurs within the bed.

10. The simple methods adopted by the Burmese have been unchanged for centuries. Even the earliest descriptions of their pits hold good to-day. The native pits have been compared with the *Fettlocher*, or fat-holes, of Northern Germany, where the country people used as an illuminant the crude oil collected from the small pools, on which floated a layer of petroleum.*

* 'Technology of Petroleum,' Neuburger and Noalhat, 1901.

Many Burmese wells, however, have been carried to depths that are truly remarkable under prevailing conditions.

The gaseous emanations not only prevent the use of a naked light, but also render it impossible for the miners to remain below for more than a very brief spell. As every miner knows, it takes a few minutes to 'find one's eyes' upon suddenly entering a dark working from bright daylight, so the Burmese, to save time, sit blindfold at the top of the pit for a while before descending, so as to have full advantage of the meagre light from above during their brief shifts underground.

During recent years the natives have hit upon the original idea of reflecting sunlight down to the working face with mirrors.

When the oil-bearing layer is reached, the petroleum quietly oozes into the pit accompanied by gas. In 1895, Dr. Noetling estimated that there were 519 productive and 671 unproductive wells open. Of the productive wells, 306 exceeded 200 feet in depth. It is difficult to arrive at fair figures in indication of the average yield of these native workings. In 1894, when these statistics were compiled for the Government, the production from the natives' reserves was about 4,000,000 gallons. In 1891 the petroleum recovered by means of drilled wells under European control exceeded the native supply, and since then the proportion attributable to boring has rapidly assumed a preponderating importance. Drilling was started in 1887, but with poor results. The *Burma Oil Company*, floated after the annexation with a capital of £120,000, purchased largely from the natives, and at the same time tested new areas. In a few years, however, it was independent of the native sources of yield.

11. The rapid increase of the oil-yield of Burma can be clearly shown by official figures :

Year.	*Gallons.*
1886	1,435,000
1891	5,791,044
1894	10,806,180
1902	56,607,700
1903	89,859,100
1904	115,903,804
1905	142,062,846
1906	137,654,261

The bulk of this supply is drawn from the *Yenangyaung* area and the newer field of *Singu.*

Burma not only exports crude and refined oil, but also paraffin wax. The oil is piped from the fields to reservoirs on the banks of the Irrawaddy, down which it is transported to the works at

Rangoon in tank steamers. In time it will be piped to the coast direct.

12. Rangoon oil has a wide reputation as a lubricant. In the crude state it is of a dirty dark-green appearance, with a specific gravity determined by Mr. T. H. Holland (Director of the Geological Survey of India) at from 0·863 to 0·892, differing considerably in the various centres of production.

The oil collected by the natives for their own use as an illuminant is subjected to no preliminary treatment, save that it is allowed to settle in earthenware jars for a considerable time to permit the separation of any earthy or aqueous impurities. Although the first attempts of Englishmen to work for oil in Burma do not date back further than 1877, when two companies prospected upon one of the Arakan Islands, using the gaseous emanations as a guide, exported oil had been known in England long previously. In 1850, Messrs. Price and Co., the famous candle manufacturers, made use of the Burmese product.

It is manifest, in view of the above statistical record of production, that admirable progress has been made by the pioneers of the petroleum industry in Burma during recent years. But it must be understood that the local market is still dependent, in a rapidly decreasing degree, upon imports from Russia, the States, and elsewhere. Moreover, if the figures for Burmese production be compared with the vast returns for America or the Baku region, the country's achievements appear, as a factor of the world's petroleum supply, of trivial significance. In 1887 the hope was freely expressed that *Yenangyaung* would one day be as famous as *Baku*. Such an anticipation was palpably extravagant. For comparative purposes, one can only turn to the Canadian petroleum-fields, which have been rapidly outstripped by the Burmese industry.

CHAPTER IV

INDIAN EMPIRE—*Continued*

Kolar Gold-Field

1. Ancient workings.—2. An old soldier's discernment.—3. Frustrated hopes.—4. Turn of fortune.—5. Nature of the schist band.—6. Gold in chutes.—7. Methods of exploitation.—8. Ore reduction.—9. Rate of production.—10. Cauvery power scheme.—11. Horse-power supplied.—12. Skilled native labourers.—13. Dharwar gold-field.

[All the great gold-producers of the Kolar field are under the control of Messrs. John Taylor and Sons, London, who did not permit the writer to inspect their properties. The close policy recently adopted, which may at times tend to protect shareholders from financially biased reports of pseudo-authority, contrasts strikingly with the open-door policy of the Rand, Kalgoorlie, and Waihi. Upon these latter fields reasonable criticisms are held to be of service, irrational opinions a cause of amusement rather than distress, and a free interchange of data and experiences to be the breath of technical life. The notes presented in this chapter are largely based upon the geological monographs of R. Bruce Foote, P. Bosworth Smith, W. F. Smeeth, F. H. Hatch, T. H. Holland, and J. W. Evans, and upon numerous reports kindly provided by Messrs. John Taylor and Sons.]

1. The Kolar district of Mysore, Southern India, to-day stands third upon the list of the Empire's most productive gold-fields, being surpassed by the Rand and Kalgoorlie alone. As of other less important fields in India, Egypt, Rhodesia—lands wherein the natives or immigrants of an early day detected and appreciated the occurrences of yellow metal—the history of Kolar falls into two widely distinct parts—an ancient and modern—whose intervening gap appears unbridged by record or tradition. The early history of the field was carved in stone upon its great quartz reefs, and workings, deep and extensive, remained to

mark the industry of a distant day. The chronicles of recent times present a tale—though but the story of prospectors and promoters, of shares and dividends, of mills and cyanide vats—no less romantic.

2. The true pioneer of the Kolar belt was a Mutiny veteran—an old Irish soldier, named Lavelle, who endeavoured to make use of a little knowledge of rocks and minerals, gained at some institution at home, by turning prospector. In 1871 he commenced work upon the ancient workings at Kolar, keeping the results of his investigation secret. Shortly afterwards Lavelle applied for, and eventually obtained, a concession for twenty years over a large tract of country around his workings, upon fair terms, granted in the belief that coal as much as gold was the mineral for which search was being made. In 1876, Lavelle, no longer shunning publicity, obtained assistance, and started to open up the ore-body with vigour and thoroughness. Two years later his rights were transferred to the Kolar Concessionaires—a syndicate of which Major (now General) Beresford was a leading spirit. Capital flowed freely to the field, and in 1880 the *Ooregum Company* was floated upon the block in which Lavelle's original workings were situated. Subsequently the *Mysore Gold-Mining Company* was formed, and then the *Nundydroog*.

3. The results obtained in the shafts and levels of these strongly supported companies were consistently unfavourable. Disappointment followed disappointment, and in the face of the poor showings, only a few retained their faith in the possibilities of the belt. Fortunately, there were some men of buoyant optimism—including Captain Plummer, Mr. Bell Davies, and Mr. John Taylor—who were determined at least to obtain decisive evidence as to the value or worthlessness of the mines.

At last the day arrived when the *Nundydroog* closed down for lack of funds, and the *Ooregum* was nearly at the end of its resources.

When things looked at their worst, the *Mysore Company* was urged 'not to attempt to make the mine pay with what could be got from shallow depths, which had already been denuded by the ancients.' This advice presented the key to the position; the salvation of the field lay in the possibilities of the deeper levels, of which the former workers had no knowledge. In its early misfortunes the Kolar gold-field stands almost unique amongst metalliferous districts of importance. On the Rand, Kalgoorlie, Rossland, Charters Towers, Ballarat, and Mount

Morgan fields, rich surface concentrations of gold enabled the earliest pioneers to enjoy the spell of greatest prosperity.

Doubtless at Kolar, too, the surface zones were once marked by exceptionally high values, but centuries before Prospector Lavelle appeared upon the scene the ' cream ' had been skimmed away.

4. Deep-sinking was therefore held—by the most sanguine or discerning—to be the only hope of salvation. A meeting of the *Ooregum Company* was called, and it was decided to spend the remaining funds (£18,000) upon the Taylor shaft, although appearances therein were at the time essentially unfavourable. In May, 1884, the tide of fortune turned, rich ore was encountered, and the deep-level theory conclusively established. Other companies then had no difficulty in obtaining money for continuing work, the results of which for the most part were a repetition of those obtained in the Taylor shaft. Up to the end of 1907 the line of lode covered by the *Mysore*, *Champion Reef*, *Ooregum*, and *Nundydroog* Companies—so nearly abandoned in 1883—has paid out in dividends £11,500,000, and produced gold to the value of about £25,500,000.

5. The schist belt of Kolar, which contains the lode formation, and belongs to the Dharwar system of ancient transition rocks, is, in the opinion of some authorities, of sedimentary origin. To quote Mr. Bruce Foote, 'the schistose band forms an elongated synclinal fold. . . . The dip of the rocks forming its basement, and therefore the boundaries of the synclinal fold, is easily traced on both sides.'

Mr. Bosworth Smith's report contains the opinion that the hornblende schists are largely sedimentary in character. Dr. J. W. Evans supports the same view, which is strongly and independently opposed by Drs. F. H. Hatch and W. F. Smeeth. The schist band has a width varying between one and four miles, and the section covered by the properties of gold-producing companies is approximately four miles. The principal reef, the mainstay of the camp, is the Champion Lode, which dips to the west with the confining schists at an angle of 50 to 55 degrees.

The rich gold ore occurs in chutes, which occasionally bulge, especially where folds occur in the schists, to a width of 30 or 40 feet.

The large bodies are often exceptionally rich. Dr. Hatch declares that the Kolar deposits are typical quartz veins, and can only be termed ' bedded ' in so far that the quartz has been deposited from mineralizing solutions along the foliation planes of the schists in which they lie. Dr. Smeeth calls them 'infiltrated quartz-veins occupying spaces of discission in the schists, with local enlargements probably due to a metasomatic action.'

Dr. Evans, on the other hand, has said of the occurrences: 'They conform to all the undulations of the schists, and are to be regarded as interstratified deposits rather than the infilling of fissure veins, though no doubt there has been a certain amount of redistribution of the quartz and gold through a process of gradual solution and redeposition by underground water.'*

6. The northerly pitching of the rich chutes within the vein is a marked characteristic, clearly reflected in plans of underground mine-workings. In some cases, shafts and winzes are sunk to follow the inclination of the chutes, between which the body may be represented by a few stringers or merely divisional planes between the wall rocks. The gold quartz is of a somewhat uncommon dark bluish-grey colour with a vitreous lustre, sometimes much broken up, crushed, and even banded, where it has been subjected to great stress. With the gold, which is rarely 'visible,' are associated small quantities of iron, magnetic and arsenical pyrites, blende, galena, and chalcopyrite. The non-metallic minerals include green hornblende, pale green pyroxene, brown mica, calcite, and chlorite.

The more important feature of the chutes is their exceptional richness, for in point of average yield the Kolar gold-fields are almost unsurpassed. For close comparison, only the records of the famous *Mount Morgan*, Queensland, can be noted. The returns of the four great Mysore gold-producers, given in their order from north to south, from their inception up to the beginning of 1907, may be summarized as follows:

Mine.	*Tons treated.*	*Yield Value.*	*Yield per Ton.*
		£	s. d.
Nundydroog ..	748,328	3,053,585	80 2
Ooregum	1,236,812	4,258,440	68 10
Champion Reef ..	1,551,205	7,295,826	94 1
Mysore	1,817,451	9,117,427	100 3
Totals	5,353,796	23,725,278	88 7†
Mount Morgan ..	2,917,876	13,139,740‡	90 0

* *Journal of the Society of Arts*, vol. xlix.
† Average yield per ton. ‡ Including £604,410 from copper.

The Queensland 'Mountain of Gold' commenced production within a year or two of the Kolar field, with the average yield of which its gold return presents so remarkable a similarity. But the *Mount Morgan's* wealth was largely attributable to wonderful surface or shallow concentrations. Had not the upper zones of the Kolar ore-bodies been exhausted by ancient miners, the true richness of the Indian deposits would probably be more conspicuously revealed by a comparison of recent industrial achievements.

7. Referring to the transformation effected by the mining industry at Kolar, Dr. Evans remarked before the Society of Arts: 'An industrial centre with a population of nearly 40,000 has arisen in the bleak undulating plateau. An irregular line of lofty chimneys and head-gears, square-built bungalows and rows of cottages and huts, extend for miles along the outcrop.' Head-gears do, indeed, constitute a very prominent feature, for the methods of exploitation adopted have involved the sinking of many shafts. Upon the *Mysore* and *Champion Reef* properties operations proceed in no less than seventeen shafts, mostly inclines. These shafts attain depths of over 3,500 feet, and average 2,500 to 3,000 feet.

Levels are driven every 100 feet, and the ore is blocked out by winzes averaging 150 to 250 feet apart. Development is performed for the most part by natives running machine-drills on contract. In the economy of the underground department few faults are found by technical observers, whose critical faculties are more commonly exercised over the systems of ore treatment. Mining costs, exclusive of administration, and total costs, including mining, administration, treatment, repairs, directors' fees, etc., were during the last fiscal years covered by reports available as follows (per long ton):

Mine.	*Tons treated.*	*Mining Costs.*	*Total Costs.*
		s. d.	s. d.
Champion Reef	203,174	19 3	30 1
Mysore	185,900	23 1	34 3
Ooregum	122,537	18 6	28 6
Nundydroog	81,750	23 9	36 1

Timbering forms a heavy item in Kolar underground cost-sheets. In the *Ooregum* the total mining expenditure includes: Timber, 2s. 5d.; European and native labour, electric power, etc., 11s. 1d.; fuel, 2s. 9d.; and explosives, 1s. 7d. per ton milled.

8. The skill and energy displayed by the Kolar companies in the application of efficient mining methods and in the distribution of electric power are, unfortunately, not matched by similar qualities in systems of metallurgical operation. The gradual development of the field, and the uncertainties of future results, which deterred financial controls from spending heavy sums upon large installations, are factors in part responsible for the apparent inefficiency of ore-reduction methods. In his report as mining specialist to the Geological Survey, Dr. Hatch pointed out a few years ago the backwardness of milling and cyanide systems in the light of Rand practice. He referred dubiously, as others have done, to the economy of exposing the sands to the influences of weathering before their cyanidation. Dr. Smeeth, in 1904, still more strongly criticized the work of the Kolar companies, and deplored the lack of adequate experimenting on satisfactory lines.

Kolar ore is not characterized by any large percentage of base material. Stamp duties are consistently low, and, from the limited data available, appear to average from 3 to 3½ tons per stamp per diem. The writer is unable, for reasons explained at the beginning of this chapter, to go beyond the information to be derived from published reports.

In their annual statements the managers of the great Kolar properties, one may note with astonishment, express small interest in metallurgical matters. Full and lucid are the reports upon the course of mining operations, but the work of ore-reduction is discussed with a scarcity of detail as to achievements and experiments that is scarcely suggestive of keenly progressive policies.

Kolar has, of course, its peculiar problems to solve in its own way. So have the Rand, Kalgoorlie, and the Waihi gold-fields, which, nevertheless, frankly and speedily profit by each other's failures and successes.

The scientific institutions and mining press of England and America constitute the great clearing-house for technical ideas, to which the sundry members of the mining world periodically transmit their claims for attention, and through whose agency mutual obligations are conveniently balanced.

Metallurgists in Mysore have yet to appreciate the facilities and practical advantages of this universal exchange.

9. Including the *Balaghat* mine, situated a mile to the north of the *Ooregum*, and also under Taylor control, the producers

of the Kolar belt are at present crushing a monthly tonnage of about 55,000 tons. Tonnages and yields for 1906 were as under :

Mine.	*Ore stamped.*	*Tailings cyanided.*	*Total Yield.*
	Tons.	Tons.	£
Balaghat	53,750	43,031	178,899
Nundydroog	81,750	83,850	272,384
Ooregum	122,537	113,222	259,250
Champion Reef ..	203,174	207,143	678,706
Mysore	185,900	158,848	809,413

The tailings are principally sand with a certain amount of slime. In some cases, notably at the *Champion Reef* and *Ooregum*, efforts have been made to treat a larger proportion of slime, together with the coarser pulp, by cyanide percolation. It is said that slime, under present conditions, cannot be profitably treated by itself. Prior to the introduction of the cyanide treatment of sands, Wheeler pan-amalgamation was widely practised.

10. After its extraordinary wealth of auriferous deposits, the Kolar field is most famed for its electric-power scheme, which is recognized to be a wonderful example of successful long-distance power transmission. The installation is a monumental tribute to the skill and foresight of its originators, whose accomplishment appears the more creditable and striking in the atmosphere of Oriental primitive conservatism pervading this region of the world.

The scheme for generating electricity at the Cauvery Falls, and transmitting it over a line 91½ miles long to Kolar, was decided upon in the year 1900, when the Mysore Government let contracts for the supply and erection of the plant for the generation, transmission, and distribution of the power to the General Electric Company of Schenectady, New York, and for the hydraulic plant to Messrs. Escher, Wyss and Co., of Zurich.

11. The original installation, since greatly enlarged, provided for the supply of 4,000 horse-power to the mines, transmitted at a pressure of 30,000 volts. The line is a double one throughout, each set of wires being capable of transmitting the whole power. So successful was the first installation, that arrangements were made in 1903 for the provision of an additional 2,000 horse-

power. Motors and compressors at the mines were also provided by the Government, and handed over to the mines after the first year. The price per horse-power per annum has been a variable amount, falling after the first five years to £10. On the 4,000 horse-power basis, with 30,000 volts, the loss of power in the lines was 13 per cent.*

The original cost of the scheme was estimated at £287,000, including electric, hydraulic, and distribution plant and works in the country. Extensive operations had to be undertaken upon the Cauvery, where the water from the east was diverted into the west branch at the Isle of Sivasamudram, and into channels leading to the turbines. In 1906, owing to an exceptionally dry season, and the consequent lowness of water in the Cauvery River, the full supply of electric power was not continuously available. The construction of storage reservoirs in the river should act as a safeguard against stoppages in times of drought. This daring Cauvery power scheme, undertaken by the Mysore Government for the benefit of the mining industry, is, in several aspects, comparable with the water scheme of Western Australia, by which the Government provides Kalgoorlie (the Kolar of that State) with water pumped for a distance of 300 miles from the coastal district. Both Governments have given us examples of long-distance transmission *in excelsis.*

12. Upon the five producing mines mentioned above approximately 30,000 persons are employed, and of these, only 4 per cent. are whites. Coloured employees not only undertake the duties of unskilled labourers, but, as in West Africa, are also employed as carpenters, smiths, engine-drivers, mining contractors, blasters, timbermen, firemen, landers, and 'maistries,' or overseers. Their wage averages about 30s. per month, that of the miners being about 38s., of underground coolies 20s., and of surface coolies 12s. per month. The European and Eurasian employees, including assistant-engineers, reduction officers, millmen, carpenters, smiths, engine-drivers, miners, blasters, timbermen, cyanide chemists, pitmen, etc., earn an average of £20 per month. They obtain various concessions under the three years' agreement commonly entered into with Messrs. John Taylor and Sons, rarely enjoyed by officials and workers upon other mining-fields which are able to recruit their employees locally.

13. Although the Dharwar gold-field, which has attracted considerable attention during recent years, does not fall under the

* Report of Chief Inspector of Mines, Mysore, 1903-1904.

head of this chapter, it may here be aptly referred to in view of its similarity of geological formation and of the part taken by the Kolar mine controllers in effecting its development. The Dharwar belt, situated about 250 miles north-west of Kolar, in the southern portion of the Bombay Presidency, is most widely known on account of its ancient workings. The reports made by Mr. Foote prompted Messrs. Huddleston, Puzey, and Oliver to commence prospecting operations in 1900, with the result that several strong companies have since been formed to exploit the district.

Great interest attaches to this field from the evidences presented of mining operations performed in a distant age. Dr. J. Malcolm Maclaren* states that the old workings are exceedingly numerous in the neighbourhood of and west of *Kabulayatkatti*, but generally nothing more than a slight depression serves to mark the site of an old pit that may be 80 to 100 feet in vertical depth. Many of the ancient pits are sunk within a few feet of each other, and in one case four pits occur within a radius of 10 feet. The probable explanation of this apparent waste of labour, Dr. Maclaren remarks, lies in the ancient method of breaking the quartz—by heating with fires, and suddenly dashing cold water on the heated rock. For effective combustion, at least two shafts were necessary, and probably each family worked independently. From the *Kabulayatkatti* ancient workings over 40,000 tons of ore were probably removed and treated. In the report quoted, reference is made to the abundant relics of 'mills' for crushing quartz, which are of three classes. First, 'rock-breakers'; then crushers, consisting of huge boulders rocking to and fro in depressions in a hard bed-rock; and, thirdly, a rarer type—with small crushing-stones—for more finely pulverizing the ore when necessary.

Though jaw-crushers, gravity-stamps, and tube-mills were things unknown, 'fine grinding'—the problem of to-day—thus appears to have been a subject for consideration and experiment even in these days of primordial metallurgy.

* Geological Survey of India: Records, vol. xxxiv.

CHAPTER V

CEYLON

Gems and Graphite

1. Mining a subordinate industry.—2. Fame of the island's precious stones.—3. Ratnapura, the 'City of Gems.'—4. Village speculators.—5. Typical alluvial pits.—6. River gemming.—7. Hill-side deposit.—8. Signs of exhaustion.—9. Disposal of stones.—10. Sapphires and rubies.—11. Chrysoberyls and moonstones.—12. Zircons and tourmaline.—13. Growth of plumbago-mining.—14. Export returns.—15. Problems of genesis.—16. Cingalese operators.—17. Preparations for market.—18. Value of grades.

1. The mineral industries of Ceylon give employment to many thousands of its natives, increase the value of annual exports by many lakhs of rupees, and yield products renowned for their unsurpassed quality throughout the mining world; yet they hold an essentially subordinate position amongst the factors maintaining the strong commercial prosperity of this, Britain's most beautiful colony. The prospects of mining are admittedly neglected by European property-holders and business companies, whose thoughts and ambitions are concentrated upon the greater assets of the vegetable kingdom, and who to-day care little for the resources of the land lower than the roots of tea-plant, rubber-tree, and cocoanut-palm. While, with almost frantic haste, the tea and rubber companies extend their areas of cultivation, and the clearing of the jungle proceeds noisily throughout the low country, the work of graphite-mining and gem-digging quietly goes on—as it has done for many decades—neither harassed by the scrutiny of an officious Government control nor favoured by the attention of an interested public. The prevalent apathy in regard to the mining and allied industries suits no sections of the community so admirably as those actively engaged in their pursuit. The mine and market operators of Cingalese plumbago desire nothing more fervently than freedom from the inconvenience and danger of close Government supervision, or the critical curiosity of the outside world. Anxious that their monopoly

should remain inviolate, the native mine-owners frequently circulate misleading reports as to their financial results, emphasize and exaggerate their working difficulties (the result, maybe, of unscientific methods), and proclaim far and wide that foreign enterprise must end in inevitable failure.

2. In the sphere of gem-production—the lesser of the island's mineral industries, but the best known by virtue of its antiquity and brilliant self-advertisement—there is no opening for the employment of European capital. Work must be left in the hands of the village diggers—whose Oriental love of speculation has led them to test every probable and improbable corner of the productive districts—and of the Moorman dealers, who shoulder the risk of purchasing the gems and preparing them for the Colombo market.

The beginnings of Ceylon gemming, as of the ruby industry of Upper Burma, belong to so remote a period of history as to be covered alone by the fragmentary allusions of tradition. The story-tellers of the 'Arabian Nights' drew upon the reports of early mariners for their fables of the gems of *Serendib*, and the travellers of the Middle Ages excited the interest of Europe with their tales of 'sapphires, topazes, amethysts, garnets, and other costly stones, and of the ruby which belonged to the King of the Island, one span in length, without a flaw, and brilliant beyond description.' Under the Kandyan kings, the right of gem-digging was held jealously by the Crown. Under British rule, the monopoly was abolished, and now for many years great numbers of natives have been engaged in the precarious industry—men whose energies might, in the majority of cases, be more profitably directed toward the cultivation of their paddy-fields, and whose gambling spirit is frequently deplored by politically squeamish observers as a retrograde influence.

3. The precious stones of Ceylon are found almost exclusively in alluvial deposits, which represent the detritus of the gneissic rocks extensively exposed throughout the island. Precious garnets (though not the cinnamon-stone variety), commonly, and 'moonstones' (an opalescent felspar), abundantly, are found *in situ*. The most productive alluvial district is that of Ratnapura, in the province of Sabaragamuwa, to the south-east of Colombo, whose glories of forest, mountain, and river scenery—indescribable by any save a master of the word-painter's art—appear to present a new scientific phenomenon in the form of landscape beauty at its 'saturation-point.' Ratnapura, in the neighbourhood of Adam's Peak—the celebrated mountain, cloaked with

forests of perpetual green, revered of Buddhist pilgrims—is the historical 'City of Gems'—and a gem amongst cities. Planted in the most peaceful of surroundings, without a blemish in its aspect, and seeming to have sprung from the earth with the palms that give it shade, this little centre of industry has received the notice of many generations of travellers. No engineer nor geologist could find himself on duty in happier environment. From Colombo, Ratnapura is easily accessible by train and coach, bullock 'hackery,' or 'padda' boat.

4. The most active gemming season is from November to March, at other times the water being generally too abundant to allow pit-working. In some sections of the island a rainfall of over 200 inches is recorded, so that the inability of the diggers to fight against the inflow during the wet seasons can be readily conceived. Nearly all the gemming is performed by poor natives with a speculative turn of mind, who either work their own small holdings or leases from Government, or else the ground of others for a share of the winnings. The latter 'joint-stock' system is especially popular. The owner of the property or his representative supervises operations, and collects the stones for disposal. A great deal of thieving and 'poaching' on Government ground unquestionably occur, but very little can apparently be done to check the trade in stolen gems. Apart from the exceptional hill-side deposits, there are two classes of working in common operation—the ordinary pit in the alluvial flats, and the river-bed washing. In the dry alluvial, the precious stones are generally found beneath an overburden of mud, sand, and clay, in a layer known as *illam*—the pay-gravel—which is characterized by well-worn pebbles and such minerals as ilmenite, zircon, spinel, cassiterite, garnet, and common corundum. The natives search for this pay-lead with a long-spiked iron rod, called an *illam kura*, which is rammed through the soil at promising spots in the hope of striking the pebbly deposit. The feel of the rod tells the experienced manipulator the general character of the ground passed through, and thus indicates its prospects. This appears, indeed, to be an eminently practical variety of 'divining-rod.' In some places the *illam* has been opened up to a depth of 100 feet.

5. The pit-working undertaken on some of the flats in the neighbourhood of Kuruwitta, Sabaragamuwa (eight miles from Adam's Peak), may be described as typical of common practice. The *illam* is found below a few feet of alluvium. Pits varying from about 10 to 20 feet square are sunk to the gravel, the sides

GEM-PITS, SABARAGAMUWA, CEYLON.

WASHING PIT, CEYLON GEM-FIELDS.

being kept back by means of bamboo poles with cross-sticks, branches, and leaves for lagging. The ground is thrown up in small wicker baskets about 18 inches in diameter. Water is kept down by means of the ubiquitous balance-crane of the simplest construction, with an oil-tin bucket at one end and a balancing-weight at the other. The *illam* recovered is washed in a neighbouring pit or stream, in which the washers stand with their rather deep conical bamboo and rattan baskets, with inturned rims, larger than the prospector's pan. Giving this basket a rotary movement, with one rim below or at the level of the water, the natives remove the lighter materials with skilful rapidity. After the operator has washed down the contents of about twenty of the small carrying-baskets, an inspection of the concentrates, or *nambu,* is made by the owner's representative. Sapphires form the most common finds of value in the deposits. The residue, sometimes containing minerals of scientific interest (such as thorite and thorianite), is dumped in the old pits. The gems are very irregularly distributed through these deposits, and after the sinking of several barren pits, a good patch may be encountered amply recouping the diggers for their previously fruitless labours. When the *illam* occurs at considerable depth, drifting will be practised between neighbouring pits, often to a dangerous extent.

6. River-washing is also carried on in the Ratnapura district during the so-called 'dry' months of the year. A row of natives may be seen standing knee-deep across the river, and with their long hoe-like *mamoties,* with flexible handles up to 20 feet in length, scooping up the bed in front of them as far as they can reach. Boulders are a frequent obstruction. The *illam* is scooped up to their feet, and eventually washed in baskets for its *nambu* contents. Work proceeds slowly up-stream. This class of venture is a speculative one for poor natives to attempt at their own risk, as unexpected floods are at all times liable to sweep down the river, check operations, and cover up the *illam* with a new layer of silt and mud.

7. At *Potgulkanda,* a few miles from Ratnapura, there is a deposit of a remarkable character, which is being worked by a wealthy Cingalese land-owner. The ground is situated in a slight depression high up on a hill-side, and it appears that the gem-bearing product must represent the disintegration of some neighbouring deposits in which the stones occurred in their original matrix. There is an overburden of varying thickness of sand, gravel, clay, and undecomposed boulders. Ground for treat-

ment is sent down to a washing-trough or sluice, fitted with grids or gratings from 1 inch in width of aperture down to a size allowing no valuable stone to pass. The ground is hand-puddled with a short *mamoty* under a small flow of water. The material caught by the last grating is examined on a sorting-table. The *Potgulkanda* pits are well known amongst local dealers as a source of pure, lustrous sapphires, generally lacking in serious flaws or 'silkiness.'

8. Wherever one travels through the valleys of this important mining district there are evidences of former workings. In some places the ground has been treated two or three times. Under the peculiar conditions of work, and in view of the seemingly unquenchable spirit of speculative greed which inspires the natives to forsake the sure rewards of labour in the fields or plantations for the lottery of the gem-pit, the absolute cessation of operations is impossible of prediction. But only a substantial rise in the price of Ceylon gems would make return to many of the old fields attractive even to the most adventurous. There are, of course, still many surprises to record in the exploitation of new areas, believed to have been without much promise. A year or two ago the Government sold a lease over five acres of ground in the Madampe district for 250 rupees. Half an acre was found to be gem-bearing, and yielded its holders 50,000 rupees in a few months.

9. The disposal of the valuable winnings is generally undertaken in the nearest village centre, where the uncut stones are purchased by the Moorman dealers and lapidaries, who keep the Colombo merchants supplied with cut and polished gems. There is very great risk, even for the most experienced buyers, in the acquisition of the uncut stone, not only on account of normal difficulties of valuation, but also because the flaws will frequently spread during the process of burning which is undertaken to improve the coloration. Some of the gem-field owners and workers have considered the feasibility of sending parcels of uncut stones to Europe, for it is the faulty tendency of native work, excellent though it may be in certain cases, to sacrifice too much to maximum size. The cutting and polishing are effected in the most primitive manner by the native lapidaries, who may be seen squatting at their work in many of the open *boutiques* of Ratnapura. After preliminary shaping, the stone is cut by means of a vertically revolving metal disc, on which corundum paste is used as the abrasive medium. The stone is fastened to a baton about 5 inches in length, with which, fixed

in a holder near the edge of the rotating disc, the lapidary is able to regulate the angle of the cutting face. Polishing is performed upon a flat rotating disc with a paste composed of ground rice and paddy husks.

The visitor to Ceylon who is anxious to obtain specimens of local gems will find it profitable to barter with these village dealers, but must be prepared for wilful or ignorant deception. Misleading local names are at times applied to the stones in all good faith, whilst the wholly inexperienced purchaser may discover his 'fancy stones' to have been classified by colour alone. The misfortunes of many tourists endeavouring to make profitable bargains at the centre of production have long thrown Ratnapura into disrepute, by which Colombo merchants doubtless profit. Ernst Haeckel, who paid the 'City of Gems' a visit in the early eighties, expressed the bold opinion that more European cut-glass was sold there than genuine stones. It is still declared by the more uncompromising assailants of the industry that people in need of a South African diamond, Brazilian topaz, or Persian turquoise, will be promptly supplied upon application to the Ratnapura gem-diggers.

10. The sapphire, or blue variety of precious corundum, is the most important of Ceylon gems, being found occasionally as large indigo-blue stones of perfect purity and lustre. Values range from a few pence to several pounds per carat. Statistics of production cannot be obtained from any reliable source. Another variety of corundum in gem form is the Oriental ruby, which is found sparingly in Ceylon just as sapphires occur rarely with the rubies in Burma. Ceylon rubies are generally lacking in the deep mulberry tint of the more valuable Burmese product, and are frequently flawed or discoloured. An uncut ruby of 42½ carats from Ceylon, exhibited in Paris in 1900, and valued at £2,000, is said to have been the finest produced in the island, though reduced in worth by a tinge of blue. Yellow sapphire, or Oriental topaz, is also found. Asterias—or 'silky' sapphires which present a stellar opalescence when cut *en cabochon*—are a characteristic Ceylon gem. It is a curious native belief that the precious stones 'grow' in the alluvial deposits, and that the flawed stones and those presenting the phenomenon of asterism have been in the ground too long; are, in short, merely 'over-ripe.'

11. The cat's-eye (of the chrysoberyl, as opposed to the quartz variety) is a national stone of some distinction, relying for its commendation upon the caprices of fashion. The finest known

specimen is in the possession of a Moorman dealer, who values his stone at the somewhat arbitrary figure of £3,000. Alexandrite, an emerald-green variety of chrysoberyl, at one time won exclusively in the Urals, is now found of exceptional quality in the Morawak Korale District of Ceylon.

One of the most abundant of Ceylon's commercially valuable gems is the well-known moonstone, which is found in its matrix near Kandy, and could be produced in large quantities. Unfortunately, its popularity is far from great. The stone, which is a variety of felspar, is low in the scale of hardness—a fact tending to restrict its usage—but its peculiar and often attractive opalescent reflections should place it above much of the showy trash finding favour with the manufacturers and users of cheap jewellery.

12. Other gem-stones essentially Cingalese from a commercial point of view are the red (hyacinth) and smoky-tinged (jargon) varieties of zircon. Tourmaline—a name originating from a corruption of the Ceylon word 'Turamali'—is found in several varieties—yellow, green, and red. Poor or indifferent specimens are almost valueless. The precious garnets are represented by cinnamon-stone, and, less frequently, almandine. Spinels, of divers colours, occur. Although there is found such a wide range of gem-stones, perplexing in scientific distinctions undeterminable by the native digger, the true emerald is almost unknown; the sea-green or bluish variety of beryl—aquamarine—is, however, occasionally met with. Topaz is also among the rarer of Ceylon's numerous gem-stones.

During the last few years the value of Ceylon fancy stones has increased substantially.

GRAPHITE, OR PLUMBAGO.

13. The mining of graphite in Ceylon, where this remarkable carbon product occurs in unrivalled quality, is the more important of the island's mineral industries, and is of comparatively modern development. It is on record that one of the Dutch Governor-Generals of Ceylon mentioned the existence of the mineral to his successor in the seventeenth century, but it remained for the efforts of the Cingalese pioneers of thirty or forty years ago—notably Jacob De Mel and W. A. Fernando—to elevate the industry from a position of commercial insignificance. The high value of Ceylon's graphite has been known far and wide, however, for nearly a century. Joseph Dixon, the founder of the

great American Crucible Company, which later competed in the island with the Morgan Crucible Company of Battersea, imported a shipment in 1829.

14. The United States have to this day remained the most important customers for the Ceylon mineral. For many years, with occasional harvests owing to market inflations, the pioneers were obliged to be content with small profits, and many failures were recorded. But the large number of mines to be opened up were responsible for a rapid increase of aggregate yield. In the fifties the annual output averaged 14,000 cwts., in the seventies 120,000 cwts., and for recent years export declarations made by the Chamber of Commerce have indicated the following satisfactory progress :

Year.	*Cwts.*
1900	383,350
1901	453,267
1902	495,501
1903	478,860
1904	515,752
1905	627,910
1906	703,666

These trustworthy returns demonstrate a 50 per cent. increase in production in four years. Upon subdividing the exports for 1905 and 1906 according to place of consumption, we find foreign countries to stand in the following order of importance :

	1906.	1905.
United States	309,898	262,328
United Kingdom	187,672	165,123
Germany	127,253	110,678
Belgium	64,024	55,362
Japan	2,617	23,108
Other countries	12,202	11,311
	703,666	627,910

For the production of these yields, there are about 200 or 300 active 'mines,' and an incalculable number of little pits barely attaining to the dignity of that title.

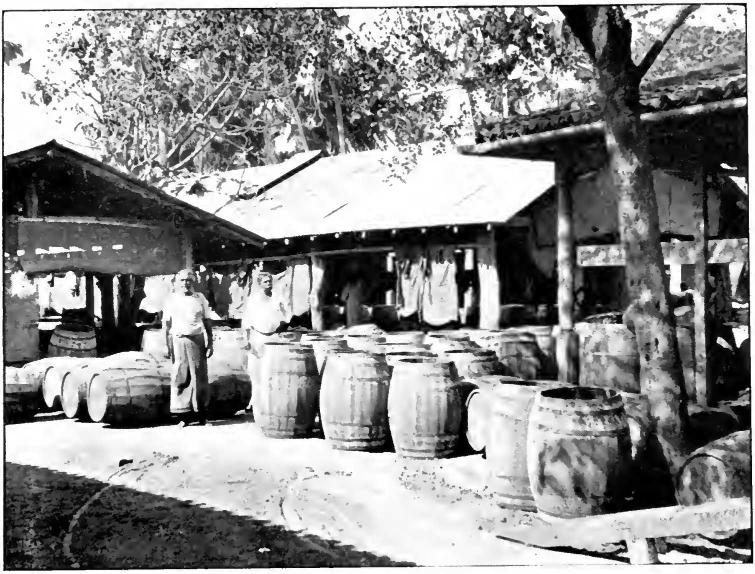
15. The veins occur in the 'Charnockite' series of gneissic rocks, which constitute the dominant geological feature of Ceylon and Southern India, and possess features of stratification, though recognized to be of igneous or highly metamorphic origin. Particularly noteworthy members of the series are the granulites or leptynites, marked by prominent foliations and of varying composition, with associations of orthoclase felspar, quartz augite,

hornblende, garnet, and some mica. These rocks come prominently to the visitor's notice upon his arrival at Colombo, where they are well exposed along the coast. In fracture planes, generally parallel to the strike of the country rock, the veins of graphite are believed to represent a fissure filling introduced in liquid or gaseous form, and not an extreme stage of carbonization of organic matter. The genesis of graphite is a matter so frequently discussed that a quotation may be given from the Ceylon Mineralogical Report for 1905, indicating the views of Dr. Coomaraswamy and his assistant, Mr. Parsons, F.G.S. : 'The data available are scanty. . . . It appears certain that the graphite was not aggregated in veins and pockets by a process of " excretion " from the immediately surrounding rocks. . . .

'. . . It is probable that it was introduced in the form of an unsaturated carbon compound, or a saturated compound which dissociated at a high temperature on the diminution of pressure due to the shrinkage and formation of cracks in the containing rocks.'

One of the mines visited by the author in the Kurunegalla district displayed interesting evidence of fissure-formation below the region of surface alteration, in the frequent occurrence of veinlets in the joint cracks at right angles to the vein, and the practical freedom of the walls, an inch or so from the mineral, from finely disseminated particles. Quartz and iron pyrites are most commonly associated with the vein graphite, and more rarely felspar. Quartz and graphite are often beautifully intergrown. When the mineral occurs in bunches, their trend usually coincides with the strike of the country rocks.

16. The most important plumbago-mining centres are *Kurunegalla* and *Kegalla*. Methods employed are of the utmost simplicity, and generally inefficient. Only where prospects appear manifestly excellent will the Cingalese incur the expenditure necessitated by such mechanical equipment as a pumping-plant. The best opening for foreign syndicates would be in the revival of mines abandoned on account of an influx of water, deemed a final check upon profitable operations by the native controllers. At the majority of workings the acme of mechanical ingenuity is reached in a hand-winch, or *dabare*, turned by seven or eight men. The deepest mine is about 700 feet. Generally the veins are clean and narrow, but they have been known to widen out to many feet. Everywhere evidences of faulty mining methods are to be found, but critics must always bear in mind the precariousness of the deposits.



GRAPHITE CURING YARDS, COLOMBO.

GRAPHITE MINE, NAMBAPANA, CEYLON.

The labourers are nearly all Cingalese, although the tea and rubber plantations are obliged to rely upon Tamils imported in thousands from Southern India. As miners, the natives can at least claim the benefits of long, if poorly directed, experience, but their empirical ideas at times prove dangerously misleading. It must at least be chronicled to their credit in the mining world that these Cingalese labourers (whether their numbers are largely increased by refugees from the law, glad of the seclusion of the underground workings and the disguise of a thorough 'black-leading,' is a question of no concern) are without rivals in their skilfulness in making their way through difficult workings, which are irregular, poorly equipped with means of transit, and as slippery as manufacturers of graphite lubricant could wish to observe.

17. The treatment of the mineral product, such as it is, generally is undertaken at the curing-yards in Colombo. At shaft-head, the mined rock and mineral are subjected to a rough sorting by hand-cobbers, and the valuable portion, of which 10 or 15 per cent. will probably be waste, is dispatched by bullock-wagon and rail to the city. The methods there in vogue vary considerably according to the inclinations of the managements and the trade requirements of the different establishments. There are two classifications to be effected, one by size (this being a matter of washing, breaking, picking, screening, and fine sifting), and another by quality, determined by some experienced tester. Variations of quality and price are based more upon peculiarities of physical condition and state of aggregation than chemical purity; the percentage of carbon may be the same in plumbago realizing £20 per ton as in that worth £40. Only by years of practice can the valuer become a rapid and efficient judge of qualities. His task is often rendered the more difficult by the mixture of grades in a parcel—the poor appearing bright and lustrous from its contact and friction with the good.

18. For commercial purposes, the sizes are graded as follows:

	Per Ton (Jan., 1907).	*Per Ton (Dec., 1907).*
	£	£
Large lumps	13–40	15–40
Ordinary lumps	12–40	16–41
Chips	10–28	10–30
Dust	3–14	3–18
Flying dust	2½–8	2½–9

The finest plumbago, soft, lustrous, and greasy to the touch, and often flaky in form, is termed 'X' and 'X B.' Quality 'B' stands below these two. Lower grades, down to the hard, brittle, dull, and stony forms, are indicated by various letterings. 'Dust' and 'flying dust' contain a considerable proportion of fine sand and other impurities.

Whether the world's consumption of plumbago is to increase to any remarkable degree is a problem governed by no easily determinable circumstances. In any of the fields of commercial utility—whether for crucibles and other refractory articles, lubricants, foundry-facings, pencil-leads, graphite 'greases,' steam-packing, and paints, or for time-honoured blacklead of domestic use—there must ever be a changing demand. With a general expansion of industries, the consumption should tend to increase, and minor fluctuations in the demand may arise through divers causes—from wars and rumours of war, to the fickle fancies of the grate-polisher, Mary Ann.

CHAPTER VI

MALAY STATES

Industrial and Geological Conditions

1. Sources of world's tin.—2. New industrial influences.—3. Geographical aspect of Malaya.—4. The active immigrant.—5. The idle native.—6. Output declarations.—7. Heavily taxed miners.—8. Desirable discrimination.—9. Assisting the capitalist.—10. Labour conditions.—11. Rock structures.—12. Origin of alluvial.—13. Tin-bearing veins.—14. Ore in limestone.—15. Classes of deposit.—16. Influence of market on production.

1. The unprecedented rise in the price of tin to £215 per ton in 1906 and the rapid fluctuations experienced in 1907—which give the charted curve-line of market quotations the appearance of the school-book diagram of Himalayan heights—have drawn unwonted attention throughout the world to the supply and demand of this ill-distributed metal. Qualified opinions may differ as to the prospects of a large increase in the aggregate production, in spite of the few sources of supply to which we must look for evidences of expansive influences; but it is at least conceded, universally and without hesitation, that Malaya holds to-day, as hitherto, the key to the situation. Seeing that the peninsula and the neighbouring isles of Banka and Billiton together account for 75 per cent. of the world's production, the recognition of this circumstance necessitates no extraordinary powers of perception. Bolivia, however, has rapidly asserted itself as a factor of considerable importance, as may be clearly indicated by the figures below, given in tons of 2,240 pounds :

	1897.	1901.	1906.
Malaya	44,884	52,580	58,443
Banka and Billiton ..	14,730	19,365	11,254
Bolivia	5,400	8,000	14,700
Australia	3,500	3,345	6,482
Cornwall	4,452	4,600	4,500
Total ..	72,966	87,890	95,379

In no fields is it more difficult to accurately determine the tendencies of changing condition than those of the Federated Malay States, 85 to 90 per cent. of whose yield is due to an innumerable host of Chinese producers.

2. The dominant factors of the industrial position calling for attention during the past two or three years have been the gradual exhaustion of the richer surface deposits, the high market price of tin, the standardization of the Straits dollar at 2s. 4d., the application of suction-dredging to the alluvial flats, and the growing percentage of ore won by European and Australian engineers backed by English capital. Producers of vast quantities of metal though the Chinese have been, these diligent immigrants may also be considered to have thoroughly prospected the land in readiness for the company equipped for the treatment of big yardages at low cost. To a large extent the Chinese have been 'eye-picking' the shallower deposits, and leaving the big low-grade bodies of alluvial for the attention of those able to apply efficient systems of engineering.

Upon its poorer deposits the prosperity of the Malay tin-fields must more and more largely depend. Light is shed upon this strengthening influence by an analysis of the yields and projects of the mines under European control; but extreme difficulty prevails in following the progress of the Chinese operators—of the vast agglomeration of private workings, from open-casts as big as a South African diamond mine to pits a few feet square, whose performances and prospects are perhaps determinable by inference alone, and whose aggregate yield is seven or eight millions per annum in sterling value.

3. Though 'Straits tin' is the common designation of the metal drawn from the Far East, the Straits Settlements themselves—Singapore, Malacca, Penang, Province Wellesley, and the Dindings—produce quite an insignificant tonnage. The metal is derived almost entirely from the four dependent Federated Malay States, Perak (Perah), Selangor, Negri Sembilan, and Pahang, which form the lower section of the great peninsula stretching for 900 miles from Burma down to within a degree of the Equator. Pahang, the largest State, is industrially the least important, and stands geographically divided from her more prosperous sisters to the West by a great granite range, which heights up to 7,000 and 8,000 feet, which run axially from north to south of the peninsula. The valleys and foothills support a dense jungle vegetation, giving place in many sections to the clearings of the alluvial miners and to plantations under cultiva-

tion for rubber, cocoa, spices, sago, tapioca, coffee, and cocoanut-palms. Rain is abundant, falling on about two hundred days in the year, and many of the low-lying districts are covered with impenetrable swamp. The climate of this equatorial land is very trying to the European resident, for, although the excessive temperatures experienced a thousand miles to the north are unknown, the unchanging range of 70° to 80° throughout the year, with a uniformly damp atmosphere, is a severe test of constitutional strength for any immigrant accustomed by nature to the relief of seasonal changes. The ill-effects of this green-house climate are felt to an exceptional degree by the white women and children residing in the country, but the good health frequently preserved by the Englishmen, who lead a life of mental and physical activity, is a practical contradiction of the extravagantly unfavourable reports so freely circulated by heedless travellers.

4. The population of the four States is estimated at 800,000 to 900,000, of whom the native Malays and immigrant Chinamen —roughly in equal numbers—comprise the great majority.

The balance of numbers, however, by no means reflects an equality of social, industrial, or political influence. From the earliest days of tin-mining in the country—and this branch of industry has long been the basis of its commercial existence—the national backbone has been provided by the hardworking aliens from China, enterprising, skilful, law-observing under British rule, peaceful when there were no laws to observe. The combination of Chinese energy and zeal and British administrative strength and integrity saved the country from the paralyzing influence of civil strife and disruption.

5. Now that good government is assured, and quarrels find their settlement in British courts of justice, the indolent but lovable Malay has lapsed into a state of quiet, contented, and proud retirement. Though fond of his country, he envies not the Chinamen their lion's share of the country's wealth. His ambitions are few and readily satisfied. However much the thoughts and habits of these sturdy and intelligent natives may be misinterpreted by the passing observer, their indolence as sons of toil—strangely contrasting with their activity in the sphere of sport—is conspicuous and unmistakable. Through this weakness in their character, this supine indifference to the rewards of steady labour, the fruits of their rich country have been won by alien hands. In the development of the tin-mines, which give direct employment to over 200,000 Chinamen, the

part played by the Malays has been insignificant. When labour problems arise, and the influx of coolies from China fails to keep pace with the growing demands of mine and plantation, small hope is entertained of finding relief in the availability of native workers. India is called upon for her less desirable recruits.

6. The standards of weight adopted upon the tin-fields are the *pikul* and *katti*, whose equivalents are 133⅓ pounds and 1⅓ pounds respectively; thus, 1 *pikul* equals 100 *katties*, and 16·8 *pikuls* equal 1 long ton.

The exchange value of the Straits dollar, divided into cents, is 2s. 4d. In noting records of mine production, it is necessary to bear in mind that, in common practice, quantities are stated in tin oxide or black tin, representing approximately 70 per cent. metallic tin, to which latter London market quotations refer. Exports from the Federated Malay States are half in the form of metal, which has been smelted by the Chinese operators, and half of cassiterite, for dispatch to the works of the smelting company at Pulo Brani, near Singapore.

The most productive of the four States is Perak, of which the Kinta district is the richest and the most efficiently worked. Some years ago Taiping, the present seat of State Government, was the leading centre of industry, but the exhaustion of the best surface deposits in that area has thrown the balance in favour of the more easterly division, where the town of Ipoh now stands as the commercial capital of the Federation. The output showings of the Federated Malay States for the year 1906 have been declared by the Warden of Mines as follows:

	Tons.	*Value.*
		£
Perak	25,990	4,557,000
Selangor	16,000	2,808,000
Negri Sembilan	4,630	813,000
Pahang	2,050	360,000
	48,670	8,538,000

Of the 48,670 tons produced, 18,250 tons were exported as block tin and 30,420 as tin oxide, for reduction to the metallic state in the Straits Settlements.

7. The taxation of the industry is exceptionally heavy. It is urged that the production of tin involves a corresponding impoverishment of the country's assets. Consequently an *ad valorem* duty of 14 per cent. (unless the price is abnormally low) is imposed, which brings in the greater part of the Treasury's extraordinarily large mining revenue of 10,000,000 dollars (over

£630,000). It need hardly be explained that protests against this heavy burden have been loud (in the Chinese and English tongues) and incessant; but they have been unavailing. Critics have assailed the inflexible Government on the grounds that the industry is made to contribute excessively to the public funds, and that the taxation should be more equitably applied. Present systems, it is contended, tend to discourage the outside capitalist from embarking his money in mining enterprises, where the means of taxation makes no allowance for his heavy capital expenditures in plant. It is said to be not only impolitic, but palpably absurd, for the venture whose equipment may have cost thousands of pounds to be taxed at the same rate as the Chinese enterprise, whose capital expenditure may be represented by a few sluice-boxes, a water race, and an endless-chain pump. Profit taxation, however, is wholly impracticable in view of the complex and inscrutable methods of financial regulation. It is difficult for the mining engineer to regard the matter in its true political aspect. The Chinese mine-owner, though spending little upon mechanical installations, may be circulating two or three times as much money in wages, per *pikul* produced, as his neighbour with dredge, steam navvy, incline haulage, or mechanical treatment plant. Due allowances are already made to those mines whose ore requires blasting or crushing. The rebate in these circumstances is decided by qualified authorities, and cannot exceed 50 per cent. The 'lode' qualification has been judiciously superseded by one of hardness.

8. Discrimination between the scientifically-equipped low-grade mine and the crude Chinese working in rich surface ground could not be easily made without engendering ill-feeling between the Chinese population (who, after all, have built up the mining industry) and the Administration. It might be held to savour of race favouritism, although the Chinamen would be at liberty to benefit by the concessions himself. But even at the risk of such a calamity as the annoyance of the influential 'Towkays,' the Government might advantageously evolve a new schedule of such elasticity as to make liberal allowance for the special claims of a proposition depending upon large, mechanically treated tonnages of poor-grade ground, which on a small scale of operation would be unprofitable.

9. The Federal and State Administration indirectly assist the capitalist by stringently enforcing the labour, or working, clause in the leaseholder's agreements, and thus tending to check the idle 'shepherding' of ground by the small Chinese holder, unable

or unwilling to work his property at a profit, and yet declining to negotiate for its transfer save on exorbitant terms. The difficulties experienced by the new company, anxious to obtain a stretch of alluvial for large-scale operations, are thus reduced. Nevertheless they are still serious. Mr. Chappel, of the leading European mining firm in the States (Messrs. Osborne and Chappel) informed the writer that the acquisition of the newly-floated *Penghalen* property involved negotiations extending over nearly eighteen months, with thirty or forty Chinese principals. By enforcing the operation or abandonment of holdings, the Government strives to encourage the working of the land alienated for mining purposes (over a quarter of a million acres) 'up to the hilt.' At times a complaint is heard against the expense of taking up new ground—the premium of 10 dollars (23s. 4d. per acre), survey charges, and prospecting expenses constituting a heavy charge for the pioneer to meet before returns are possible.

10. Though rarely as acute as those experienced in many other mining fields, labour difficulties are never wholly absent from the Malay tin-fields, especially from the view-point of the European operators, who are morally obliged to employ their workmen on the wage system. The Chinese immigrants—a happy, muscular, intelligent class of men who would compare admirably with the unskilled workers of any nation—are apt to favour, in their love of independence and speculation, the opportunities of tribute and contract working in the Chinese pits. By natural disposition, they prefer the risks and freedom of co-operative mining to the sure return and discipline of employment on the capitalist's mine.

The relative significance of the three systems may be shown by the following estimate for 1906 :

	No. of Labourers.
On contract	59,259
On wages	27,519
On tribute	125,882
	212,660

In Perak there were 8,000 labourers employed other than Chinese—mostly Tamils and a few Javanese. The Indians, being good head-carriers, are advantageously employed for truck-filling. To a small number of Malays—too few to influence the position—are relegated some of the lighter duties, especially hydraulicking, and positions of trust. They make good imitative learners, but their sphere of work is practically confined to service in the house and stables,or as boatmen and fishermen. The wages paid to the Chinese labourers is commonly 50 cents (1s. 2d.) per day, with rice and quarters, whilst contractors look to gain much higher remuneration. The demand for their labour has been of late increased—especially in Selangor and Negri Sembilan—by the great expansion of the rubber plantations, which have been absorbing all classes and quantities of labour they can obtain, and offering good rates of pay. A heavy fall in the price of tin would, of course, soon liberate a large number of coolies employed upon the many pits wavering above the line of unpayability.

11. The broader features of Malay geology are not remarkably complex, though minor problems of signal perplexity call for solution, and the work of detailed investigation is greatly hampered by jungle and swamps. Reliable structural markers are often unavailable, and beds of lesser prominence concealed beneath thick mantles of soil and vegetation leave much to conjecture. The main stratigraphical relations of the rock series of the peninsula not only prevail throughout its length, but continue into the islands to the south, once forming part of the mainland — just as Ceylon is geologically an extension of Southern India. From north to south there runs as a main axis or backbone a wide and massive range of granite mountains —the most prominent of the country's physical features. Chief interest attaches, however, to the marginal limits of the granites and to the flanking beds of gneiss, schist, quartzite, and crystalline limestone. These beds have been tilted up at high angles by the intrusive granite, and the limestones are especially conspicuous as foothills, often rising to an elevation of 1,000 feet. The steep limestones, with white precipitous faces devoid of vegetation, appear to have better withstood the agencies of weathering than the schists—agencies lacking in the potent aid afforded in many countries by sudden changes of temperature, by ice and grit-laden winds. Unconformably bordering the elevated formations are recent deposits of no significance, apart from the industrially all-important alluvial deposits filling the great plains.

12. Manifestly the most attractive question of economic geology for discussion is that of the nature and formation of these vast alluvial deposits, which have for so many years supplied the world with the bulk of its tin. The tin-bearing layer, or *Karong* —gravelly, sandy, or argillaceous—occurs from grass-roots down to considerable depths (rarely worked below 60 or 80 feet) below

an accumulation of barren overburden, and commonly lying on a bed-rock of limestone or granite. Associated with the cassiterite may be noted pyrite, mispickel, schorl, wolfram, and specular iron. The oxide crystals are usually black, but also occur brown (light and dark), straw-coloured, and of a resinous lustre, and nearly white, these latter varieties being frequently of remarkable purity.

It has been frequently suggested that these alluvial deposits represent vast ages—geologically—of denudation of the granite and the concentration of its detritus. Many deposits, however, have been traced to their source in neighbouring schists and pegmatites, in process of speedy decomposition and disintegration, and the evidence obtained in many of the flats—of buried tree-stumps and of recent flows of silt—does not favour the hypothesis of formation through very distant ages.

13. In a report issued by Mr. Scrivenor, the Government Geologist, the suggestive query is raised—'Is it not more probable [than the theory of the granite being the chief original repository] that the bulk of the detrital tin has been derived from masses of pegmatite, lodes and stockworks, which take part in the formation of the low rolling country at the foot of the high ranges?'

The best instances of tin-ore occurring under these circumstances are at *Jeher* and *Bruseh*, Southern Perak, two places about 30 miles apart along the same line of country on the granite contact. At *Jeher* tin is seen to occur in narrow quartz veinlets in a mass of highly decomposed schists. At *Bruseh* the veins occur in a similar decomposed schistose formation, whose bedding planes dip away from the granite at an angle of 50 degrees to the south-east; whilst the stringers, composed of quartz, cassiterite, pyrite, and tourmaline, dip at an angle of about 40 degrees slightly east of north. At the *Sipiau* and *Sudu Seremban*, in Negri Sembilan, veins and stockworks in pegmatite are being worked—the decomposed character of the ground having enabled the monitor jets to break it up with the occasional assistance of the pick or a few blasts of powder in the virgin face.

Tin is often found sparsely distributed throughout thick gravelly deposits, without restriction to any clearly definable *karong* layer, as is usual in the great flats comprising the bulk of the alluvial fields. As to be expected from the above references to the profitable source of the alluvial deposits, the productive fields stretch most abundantly along the plains and valleys parallel to the western ridge of the main granite range—through Perak, Selangor, and down into the State of Negri Sembilan.

14. There is a further form of occurrence, which has proved a difficult and interesting problem for scientific investigation, in the hard and rich deposits found in limestone. Some of these are true lodes, deposited in limestone fissures, just as they are more frequently in the impregnated zones closely bordering the granite. But one of more mysterious origin is seen at *Lahat*, on the property of the Société des Étains de Kinta, where a cylindrical pipe of ore dips vertically through the limestone. At surface it is 25 feet in diameter, but at 150 feet it makes into ramifications. Its calcite-cemented ore, unassociated with tourmaline, fluorite, or other commonly related tin-lode minerals, is of a reddish coloration, and marked by pyrites round its perimeter. When inspected by the author in 1906, the body appeared to fully maintain its strength to 160 feet, and was yielding ore worth 25 to 30 per cent. (and up to 40 per cent.) black tin. The Government Geologist, who has expressed the opinion that this *Lahat* mine is one of the most remarkable in the world, has recently summed up the evidence in support of its origin as a lode or as a detrital deposit, and declared the balance to be in favour of the latter hypothesis.

15. Dealing with the alluvial deposits from the industrial point of view—the lode and lode-like deposits being, comparatively, of purely geological interest—they may be classed as (1) surface deposits; (2) shallow alluvials, exploitable by open-cast methods upon the removal of, say, 10 or 25 feet of barren or unpayable overburden; and (3) the deep leads, operated by shafts and tunnels or very large open-pits. The surface deposits are commonly worked by a simple Chinese method, of conducting channels of water across the ground, for the rough concentration of the wash-dirt carried into them by tributary channels, and of sluicing the heavy material in the usual boxes, to be described in the following chapter in the reports on typical properties. This is called *lampan* working, and is responsible for a considerable proportion of the country's tin output. The relative significance of the three main systems of operation may be displayed by the following analysis of labour returns for the Federated Malay States:

	No. of Workers on Wages, Contract, and Tribute,	
	1906.	1905.
Open-cast	163,104	.. 159,447
Lampan	29,187	.. 25,970
Underground	20,369	.. 23,597
	212,660	209,014

Considered in greater detail, many subdivisions of system must be recognized, for only the crude Chinese methods will permit of broad classifications. With the growth of European influence, however, there has naturally arisen a greater complexity of practice, representing not only a perpetuation of Chinese methods, with mechanical innovations, but also suction-dredging and hydraulicking.

16. Whenever a substantial fluctuation occurs in the market quotation for tin, the query is raised, How will it affect the production in Malaya ? Experience shows that the body industrial is too weighty and strongly established to be influenced by the vicissitudes of the metal market speedily or momentously. The reason can be readily discovered, for tendencies of increasing or decreasing productiveness are almost automatically balanced by contrary influences. When the price of tin rises new producers may spring up, but many of the old, satisfied with the usual standard of profit, will not exert themselves to maintain the former level of production. On the other hand, when it falls, and weaker enterprises are forced to suspend operations, many of the Chinese tributers are induced to prosecute their work with greater vigour, and to record a compensative increase in the output tonnage.

CHAPTER VII

MALAY STATES—*Continued*

Chinese and European Mining Methods

1. The seeds of scientific engineering.—2. Chinese 'truck' system.—3. Primitive mining.—4. Frequent handling.—5. Dangerous shafting.—6. The Tambun's record.—7. Kamunting open pit.—8. European sphere of interest.—9. French company.—10. Tronoh mines.—11. Batu Gajah district.—12. Gopeng hydraulicking.—13. Pioneer dredges.—14. Backward Selangor.—15. Negri Sembilan.—16. Pahang, the lone sister.

1. Thirty years ago the British Resident at Perak, Sir Hugh Low, introduced the first steam-engine and pump into the Malay tin-fields, and installed them upon a Chinaman's property near Taiping. The innovation was successful, and prompted other operators to call in the aid of steam-power to enable them to more effectively cope with all-prevalent water troubles. The balance-crane and endless-chain pump thus found a formidable rival, and were ousted from many properties, whose owners were sufficiently alive to the economy of the change to be able to shake off the fetters of prejudice and conservatism. But the shock of this revolution was enough for one generation. We find the curator of the Perak Museum, Mr. L. Wray, recording the 'melancholy' fact, in 1894, that 'steam pumping is the only improvement that Europeans have been able to introduce into the Chinese system of mining. This is not because,' he added, 'the Chinese will not adopt improvements, but simply because, taking all the circumstances into consideration, their system is as good as, if not better than, the European system.'

But *tempora mutantur*—if not the Chinamen *in illis*; and European systems have advanced in efficiency so speedily under scientific direction that many properties now worked upon them would be idle under the old régime. It was too much to expect, however, that practices feasible under the control of British capitalists and engineers would be speedily adopted by the Chinese 'towkays,' whose fondness for speculation is rarely strong enough to bring heavy initial expenditures on plant and unproductive preparatory operations into a favoured programme. As Mr. Liong Fe, member of the Perak State Council and owner of Tambun mine (at one time the world's greatest tin-producer), declared to the author, 'Whether the industry expands or declines now depends largely upon outside capitalists and investors, to whom we look for the money to bring the deeper deposits to a producing stage with suitable mechanical appliances.'

Many of the rich Chinese mine-owners have the means of installing these equipments, and recognize their value, but fear the risk.

2. There is another consideration of even greater significance to be noted in explanation of the Chinaman's reluctance to employ extensive machinery—a reason to be found in the so-called 'truck' system, which is virtually (if not virtuously, in all respects) the foundation of Chinese mining business throughout the country. The working coolies are lent money for the prosecution of work by an independent advancer, who will guarantee wages, provide food—such as rice, fish, and vegetables—and recoup himself out of the tin returns, deducting loans—plus interest at a rate calculated to give the terms of their professional brothers in London the semblance of charity—and a large share of the profits. The powers of these advancers are considerable, including the right to inflict fines for derelictions of duty. Chinese mine-owners, too, commonly make a big revenue—not infrequently turning a loss on actual mining into a profit on the whole undertaking—by advancing money to the coolies, and by supplying them with all their requirements, necessary and luxurious, on a lucrative basis. Sir Frank Swettenham, formerly High Commissioner of the Federated States, than whom no man knows more of Malay conditions, declared in 1893 that 'the most successful Chinese miners do not owe the bulk of their wealth to tin, but to other adventitious circumstances.' Returning to the question of mechanical innovations, it is therefore easy to understand why the influence of working costs is not the governing factor. To the European manager, who does not find the wages paid to his coolies returning through commercial channels, machinery is economical. To the Chinaman the benefits of labour-saving, trade-destroying, client-losing devices are obviously less substantial.

3. Outside a few great mines held by Chinamen, the alluvial pits are all operated on very similar principles. Working with

picks and *changkols* (large hoe-like implements), the coolies break down the ground and carry it out in two baskets, supported by a yoke across one shoulder.

The sturdy coolies undertake this work with marvellous rapidity, carrying up these balanced loads of over 100 pounds at a pace nearing an amble. Some coolies will be on overburden, which requires dumping below the sluice-boxes or elsewhere out of the track of mining progress. Others are on the *karong*, which will be tipped in readiness for sluicing.

If the earth is clayey, preliminary puddling in a shallow square pit may be necessary. Otherwise, it is delivered into the hands of the coolie—of a superior grade—whose duty it is to feed the sluice-box to suit the prevailing conditions of water inflow and *karong* consistency. The boxes universally used for sluicing are called *lanchutes*, easily remembered in appearance by their likeness to a giant coffin. The sizes of these simple contrivances vary considerably, but are commonly about 10 feet long, 15 inches wide at top and bottom, and 30 inches wide at the maximum point, a few feet from the head. Larger boxes run up to 40 feet in length, and 5 feet at their greatest width. The stream of dirt is continually scraped up the box, which is graded at about 1 in 12, by coolies with small *changkols*, and the concentrates thus acted upon more thoroughly by the water. The black tin collected in these *lanchutes* is subsequently enriched by further sluicing and hand-washing, until raised to a value of 68 to 72 per cent. metal. Fortunately the oxide generally occurs in the *karong* in a coarse state; otherwise the freely circulated reports of the extreme wastefulness of Chinese sluicing methods would probably be near the truth. The average loss cannot be exactly specified. It has been estimated from under 3 per cent. up to 30 per cent. by sceptical extremists.

4. In some of the small and deep pits the Chinese, instead of carrying up the dirt in baskets, will puddle it at the bottom of the workings, and scoop up the sludge through a series of sumps cut in the pit-side. The sludge will perhaps be scooped up from one sump to another eight or ten times before reaching the sluice-boxes at the surface, reminding one involuntarily of India, another country where labour economy often seems to be no desideratum, and where the baskets of material from the mica mines are passed to the surface through the hands of a score of coolies, stationed at intervals up the zigzag side-tracks. For dewatering purposes, balance-cranes or endless-chain pumps, driven by water-power or tread-wheels, are generally used. As

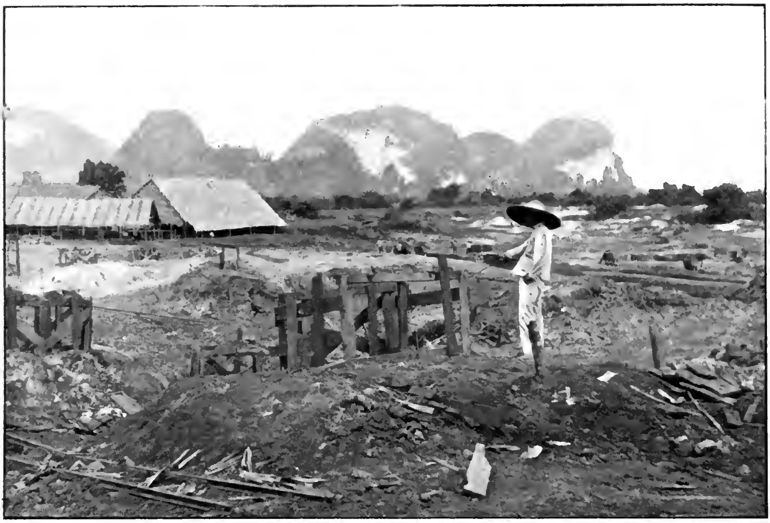
stated above, steam-pumping plants are utilized upon the larger Chinese properties. There are about 750 boilers and engines upon the Malay tin-mines, equivalent to 8,200 horse-power, and these are mostly connected with pumping operations, for mechanical haulage is meagrely adopted.

5. When the tin-carrying layer or layers occur below a depth of waste alluvium—over 30 or 40 feet—which it would be unprofitable to remove, the Chinese adopt a system of underground working. Shafts are sunk in squares, 40 feet apart, from which the daring miners block out the dirt, supporting (if possible) the soft and heavy roof of overburden with an abundance of timber props and cap-pieces, placed so close as to render access to the working faces a difficult matter. These workings are amongst the most dangerous shallow metalliferous mines in operation anywhere in the world. The 'premature burial' of a Chinaman in these death-traps (as some of the less methodically directed mines have proved to be) appears but an incident in the day's work to his fellows, perhaps even welcome as a break in the monotony of the common routine. As Mr. Dykes, Senior Warden of Mines, has said, 'the truth is that nothing but a violent death ever ends the readiness of the Chinese coolie to take preposterous risks with his own life.'

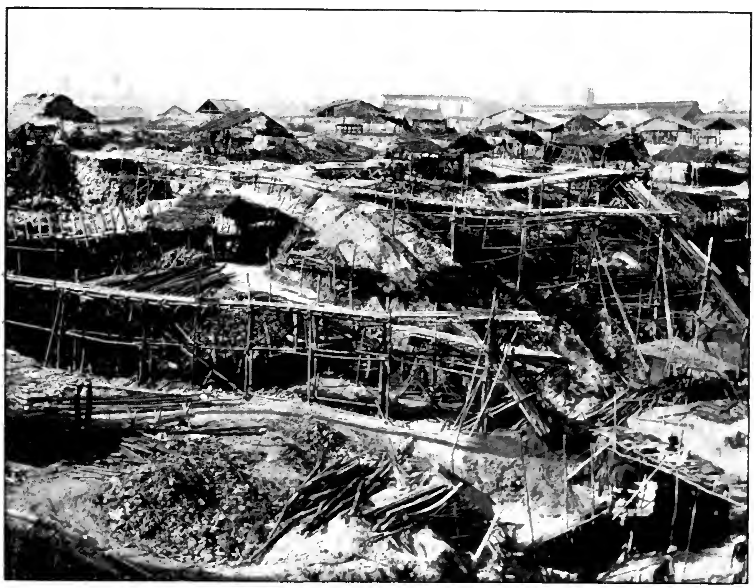
Shafting has enabled operators to work rich ground which would have been economically accessible by no other means; the defects of deep open-casts, as evinced by the *Tronoh* and *Sungei Besi* mines, are serious even when a large area is available and the sides can be given a moderate slope. The ground is always treacherous and liable to slips.

6. Specific reference may be made to two great properties—the *Tambun* and *Kamunting*—which represent, respectively, the most productive and the largest Chinese mines in the Federated Malay States. These mines being privately held, the writer feels especially indebted to their owners, Mr. Liong Fe, M.C., and Mr. Ng Boo Bee, for rendering him every facility to gain an insight into prevailing conditions.

Tambun, once the world's greatest tin-producer, whose 1903 record yield of 2,417 tons of metal was equivalent to half the production of all Australia or Cornwall, lies a few miles to the north of Ipoh, Perak. Not many years ago the ground is said to have been held for coffee-planting, and a part of it sold for the proverbial song. Prospecting revealed a very large deposit of high-grade *karong* below an overburden averaging 40 to 50 feet, and lying on an irregular limestone bed. This was exploited as



SUBSIDED WORKINGS, TAMBUN MINE, PERAK.



CHINESE SHAFTING, KAMPUR.

thoroughly as possible on the Chinese shafting system, on particularly daring principles. For, as a great subsidence over the old workings indicates, a big depth of the *karong* was removed, the gradual fall of ground having been profited by in underground excavation by the foolhardy miners, who allowed the well-capped, pointed props to sink into the soft floor of the working while they kept pace with the subsidence. The value of the ground washed during the record output year averaged 26 *katties* (34 pounds) per cubic yard.

Although the best days of the mine are surely past, it should still enjoy a life of some considerable duration. Shafting has been stopped and the proposition transformed into a large open-cast. For a Chinese mine *Tambun* is remarkably well equipped, having been wisely placed in the hands of competent engineers. The treatment plant comprises four 20-foot circular puddlers, from which the concentrates are delivered to a belt elevator, feeding a series of trommels and jigs. Rock fragments rejected by the first trommel are passed to a jaw-rockbreaker, Huntingdon mill and Wilfley table. An examination of tailings proves that a good extraction is certainly obtained. A subsidiary plant for treating a large quantity of low-grade ground has been installed, including a horizontal puddler and 300 feet of sluicing.

7. *Kamunting*, the largest open-cast mine in the country, situated in the languishing district of Taiping, presents a numerous contrast with the *Tambun*. It is owned by Towkay Ng Boo Bee, whose extreme conservatism is only matched by his hospitality and courtesy—virtues eminently characteristic of the Chinese mine-owner. The great pit is some 2,400 feet long by about 100 to 150 feet across, and the *karong* lies at a depth of from 30 to 40 feet. By ordinary *lanchute* washing, without preliminary puddling, a yield of 1,000 to 1,500 *pikuls* (85 to 90 tons) of black tin per month was recorded in 1906.

Between 3,000 and 4,000 coolies were on the labour roll, and wages represented over 80 per cent. of operating expenses.

The pit is being carried steadily across the property, where a large stretch of virgin ground is said to be yet available, the discarded overburden and wash-dirt tailings filling the exhausted area. The majority of the coolie labourers are on day's pay, but some are put on contract at the rate of 22s. per *chiang* (a unit equivalent to 50 cubic yards) for *karong*, and 17s. 6d. per *chiang* for overburden. Water is drained down into a central sump, and pumped out by centrifugals driven by steam-power. *Kamunting* is controlled on the ' truck ' system. The merchantproprietor expressed the opinion in 1906 that the absence of expansion in the Malay tin-mining industry, despite the good price of the metal, was due to labour shortage, attributable to increased prosperity and railway building activity in China.

THE EUROPEAN INFLUENCE

8. In considering the European 'sphere of interest' in Malay mining, marked distinction must be made between Perak, the richest and most progressive area, and the two southern States of Selangor and Negri Sembilan. For, in the two latter divisions, the yield of European concerns is yet inconsiderable, and the benefits of engineering skill have scarce been felt.

Yet, although Perak is the most advanced, there are only a dozen noteworthy ventures operating therein, under the control of Europeans. Apart from a few of more recent conception and unproven possibilities, we may tabulate the most important of these mines as follows, with their average monthly yields of black tin :

	Tons.
Société des Étains de Kinta	170
Tronoh	155
Pusing Lama	70
Gopeng, Limited	34
Bruseh Hydraulic	30
Jeher Hydraulic	30
New Gopeng	17
Kinta Tin Mines	16

With which may be compared—

Briseis, Tasmania	120
Dolcoath, Cornwall	130
Mount Bischoff, Tasmania	60
„ „ (in 1885)	230

We may assume that the monthly output of the European mines in Perak is 550 tons at the outside, or about 20 per cent. of the aggregate. For all the States combined, the European returns only represent 10 to 15 per cent.

9. The most important company, by virtue of its present yields, high profits, and long standing, is the Société des Étains de Kinta, usually known as the French Mining Company, with ten separate properties in various districts. Formed in Paris in 1880, with a capital of 3,000,000 francs, the company must be regarded as the pioneer of successful European mining enterprises in the country. Profits since 1890 have totalled about 11,000,000 francs. The two principal holdings are at *Lahat* and *Kampur*—the former comprising the marvellous cylindrical

deposit in limestone described in the geological section of the preceding chapter. The mine, which has been yielding 40 tons of black tin per month, is additionally noteworthy on account of its electrical equipment and gas-producer plant. Charcoal fuel is used. At *Kampur* the company wins an average of 120 tons of dressed tin ore from three extensive alluvial workings—two open-cast, and one shafted in Chinese fashion. To enable certain deeper deposits of *karong* (110 to 150 feet) to be exploited, the company has installed an electric pumping station, operated by power transmitted from a fall of water a mile and a half from the mines.

10. *Tronoh Mines*, Limited, whose rich deposit, 16 miles from Ipoh, is the greatest producer in the peninsula, repaid its capital in four years. Before 1902 it was worked by Mr. Foo Choo Choon, a wealthy Chinaman with progressive ideas, who floated the mine in conjunction with Messrs. E. G. and P. G. Edgar, with a capital of £160,000. The body of tin-bearing alluvial, of a somewhat tenacious gritty clay, occurs in a depression in the limestone formation, and is bordered on the western side by a hill of altered shales, slates, and other sedimentary beds. The length of the deposit appears to be about 2,000 to 3,000 feet, the bed-rock depth 70 to 100 feet, and the width of the payable portion under 200 feet. At first, open-cut or *lombong* working was attempted, but slides occurred and shafting was undertaken—not without great obstacles, such as mud-rushes. It is now intended to centralize plant, to sink a new hauling and pumping shaft in solid limestone as the main working artery, and to install an electric generating station of 2,000 horse-power capacity. For a large alluvial deposit, the grade of the *Tronoh* is exceptional, having averaged 25 to 30 *katties*, or 1½ per cent. The yields for the last few years have averaged 1,800 to 1,900 tons.

The ground, being clayey, requires thorough puddling. There are two treatment plants, each with four puddlers, 21 feet in diameter by 4 feet deep ; and four or five big *lanchutes*, 40 feet long by 5 feet wide at the top, and decreasing to 1¼ feet at the end. Upwards of 20,000 yards of dirt from the shafts, and up to November, 1905, from the open-cut, have been put through the puddling-machines per month.

11. Two properties of note in the vicinity of Batu Gajah, Perak, are the *Pusing Lama* and *Redhills*, whose areas adjoin. The company, under skilful management, has paid dividends amounting to 62½ per cent. from December, 1905, to July, 1907,

on a monthly yield of about 65 to 70 tons. With five puddlers and a light battery of fifteen heads for the rich fragments of quartz and conglomerate occurring in the hilly gravel deposit, a total yield of about 4 pounds per yard is recorded. Hydraulicking is also adopted for a section of the ground. On the *Redhills*, for the treatment of similar gravel, a steam navvy, Blondin conveyor, a 25-stamp mill, and horizontal puddlers, Wilfley and Buss tables, were installed in 1906. Transportation methods proved unsatisfactory, and rope-haulage is being substituted for the Blondin. A new property near this 'Red Hill,' lately taken over by English investors, is the *Pusing Baru*, whose deposit is estimated to yield over 5 pounds per cubic yard.

12. In the Gopeng district, south-west of Ipoh, there are three hydraulicking concerns under the control of Messrs. Osborne and Chappel, who, with Mr. Wickett, were the first to realize the possibilities of working the big low-grade deposits on a large scale by this system. The *Gopeng*, Limited, which commenced work with two monitors in 1892, has been paying dividends regularly since. This was the second hydraulicking venture in the country—a failure at *Changkat Pari* having been the first. With its tin yield of about 34 tons of black tin per month is recorded an interesting supplementary output of 2 tons of wolfram.

Perhaps the best-known hydraulicking enterprise in the country is the *Bruseh*, which deals economically with decomposed schistose formation, with included stringers of tin-stone already described. A cutting face of 220 feet high is taken in the hill deposit, the ground being broken with charges of powder and a jet of water (130 pounds pressure) from a 3-inch nozzle. Sluice-boxes are 300 to 400 feet long, 4 feet wide, 20 inches deep, inclined at 1 in 24, and riffled with inverted rails. Water service included seven miles of pipe-line. Being a 'lode' mine, though fortunately decomposed, *Bruseh* ranks as one of the cheapest of its class in the world. Working costs average 3d. to 3½d. per yard sluiced. The property is under the management of Mr. W. O'Brien, a Californian mining engineer. The *Jeher*, not far distant, is another economically operated hydraulicking venture, managed by an Australian engineer, and held largely by Chinese speculators, who deal actively in all mining stock negotiated in Singapore, Ipoh, and Penang.

13. The year 1906 saw the introduction of the first suction-dredge, of the type so successfully employed in the Tasmanian tin-fields, into Malaya—an innovation promising to constitute a new departure of far-reaching influence. The pioneer plant,

installed at *Tanjong Rambutan* by Mr. Toby, under Messrs. Osborne and Chappel's control, comprised a pontoon of 50 by 50 by 6 feet, carrying two large boilers, a centrifugal pump to supply two monitors breaking down the face of the gravelly alluvial, and a suction elevator (with 16-inch intake pipe) to raise 60 cubic yards per hour a vertical height of 60 feet to the sluice-boxes. In 1907 working costs were reduced to 15 or 20 cents (4½d. or 5½d.) per yard. The results of work by this dredge prompted the Dutch Government to investigate the possibilities of suction dredging in Banka and Billiton, where, it is probable, the practice will be adopted profitably on an extensive scale. In Malaya the innovation has not led to a wide introduction of similar plants, although there are doubtless extensive flats—which have merely been robbed of their richer concentrates by the Chinese pit-workers—suitable for their application. The Chinamen fear the initial expenditure, which was £12,000 in the case of the *Rambutan*. The English firm, Messrs. Osborne and Chappel, responsible for this pioneer dredging venture, have been guided by the experience gained in the equipment of two new properties—*Tekka* and *Pengkalen*. The system of working the latter property on the Lahat alluvial flats is to involve the operation of centrifugal suction elevators by means of power derived from a central generating-station, where the dynamos will be driven by power from boilers fired with crude oil. From this station all power up to 1,500 horse-power is to be transmitted to three dredging plants and the main pumping-station. This will be the first large plant of its kind worked with crude liquid fuel in the Federated Malay States. Oil from the fields of Burma or Sumatra will be conveyed in tank steamers to Teluk Anson, and thence by rail to Lahat—a distance of 40 miles.

14. In the State of Selangor there are very few European concerns of significance. At *Sungei Besi*, an exceptionally large open-cast mine is worked by a party closely identified with the *Tronoh* control. A depth of over 80 feet has been attained. The exploitation of such deep ground by open-pit methods was regarded as a very daring experiment by miners in the district. Also in Selangor, not far from the Federal capital—Kuala Lumpur—is a rich deposit, associated with much arsenical pyrites. At the time of the writer's visit to this mine (*Salak*) a remarkable bonanza was being extracted at 70 feet, worth 80 to 85 per cent. tin oxide, or, say, 55 per cent. metal. Mispickel, found with this concentration, is often a troublesome impurity. The Chinese used to calcine the ore for its removal, but the arsenical fumes

were seen to have such ill-effects—upon vegetation and perhaps live stock—that the practice was forbidden by Government.

15. In Negri Sembilan the chief mines under European control are hydraulicking in the neighbourhood of the capital, Seremban. These include the *Seremban* Tin Mining Company, a Cornish flotation, which was one of the first to operate in the State. This works a face of decomposed granitic ground, with sharp-edged tin particles unevenly distributed. In the decomposed rock quartz veins occur, but lode-mining appears impracticable. The *Sipiau* Tin Company, Limited, near the former, is profitably hydraulicking a mass of decomposed pegmatite and alluvium. Its main pipe-line (14-inch diameter) is 4½ miles long, preceded by 8 miles of ditching and fluming.

But the company intends to abandon its long ditch and pipe-line, introducing a 200-brake horse-power gas plant and pumps for supplying the head of water at the working faces. So, too, the *Temiang Syndicate* will operate by means of a Campbell 360-brake horse-power gas-engine for driving a Mather and Platt's pump, capable of delivering 250 cubic feet of water per minute against a total head equivalent to 400 feet, including pressure at the jets. The gas plant comprises three producers—one as a stand-by—using charcoal fuel, which costs 30s. per ton locally. Two other European companies are the *Setul Hydraulic* Tin Mining Company, operating two monitors on friable ground not exceeding 50 feet in depth ; and *Kinaboi*, Limited, 50 miles from Jelebu, yet in an early stage of exploitation. The introduction of pumps, operated by gas-engines, for hydraulicking is distinctly the most significant feature of recent mining development in Negri Sembilan. Mr. J. Tedlie, of the *Sipiau*, *Temiang*, and *Setul* Companies, must be given chief credit for this progressive innovation.

16. Pahang—the ‘ Cinderella ’ of the Federation—is the least known of the Federated Malay States, and probably the least worthy of notice, in spite of the reputation Rumour has given her as a mysterious field of unexploited riches. Pahang has failed to improve upon acquaintance. The tin has been ill-distributed by Nature between the two sections of the peninsula on each side of the great dividing range of granite, and although a gold-field was thrown in the way of make-weight on the east, the west has infinitely the better measure. Being poorly opened up and ill-supplied with transport facilities (so admirable in the Western States), Pahang may yet be found to contain rich sections un-

By favour of J. TEDLIE.

HYDRAULICKING AT SIPIAU, SEREMBAN.

THE PIONEER DREDGE AT RAMBUTAN.

tapped, but realizations in the past have not been conducive to the formation of highly optimistic anticipations.

The area under development by the *Pahang Consolidated* at *Kuantan*, however, is *sui generis*, and, despite heavy transport, fuel and labour difficulties, has attained considerable prosperity. The mine, whose several lodes run as fissures through granite and metamorphosed sediments associated with copper, tourmaline, chlorite, and mica, has recently been re-equipped for more economical working. Water is now utilized for the generation of electric power, and heavier stamps have been installed to deal efficiently with the unoxidized ore. The shares of *Pahang Consolidated* have been actively dealt in upon the London Stock Exchange, and the company is apt, in consequence, to be regarded as a representative undertaking, reflecting the progress of industrial affairs in the country. It would be difficult, however, to find an enterprise whose working conditions are less characteristic of Malay tin-mining.

CHAPTER VIII

VICTORIA

Bendigo and Ballarat

1. ' Infant splendour.'—2. Official version of early history.—3. Surface riches. —4. Aggregate yields.—5. Beautiful Bendigo.—6. ' Saddle Reefs.'—7. Succession of ore-bodies.—8. Rand and Bendigo at depth.—9. Critical visitors. —10. Working capital.—11. Example of methods.—12. Battery practice.— 13. Costs and values.—14. Labour and wages.—15. Ballarat gold-fields. —16. Alluvial and quartz.—17. The ' indicators.'—18. Chief producers.— 19. Geological features.—20. Deep leads.—21. Heavy pumping.—22. Government aid.—23. State batteries.

1. With reference to the Ballarat field in 1855, four years after the amazing discoveries which made Victoria the greatest gold-producing division of the British Empire, a contemporary writer observed : 'We always think, on entering these great old diggings, of the glorious sight presented to us the first time we visited them, when *Golden Point*, in all its infant splendour, first broke upon our view—its hundreds of cradles at work on the creek, and the diggers running upon the hill like busy ants.' And five years later thought was given to the probable exhaustion of the ' old ' fields of the State—Bendigo, Ballarat, and the many other regions of auriferous wealth within a hundred miles of Melbourne. Little did these writers of half a century ago foresee the strength and vitality of the new-born industry, then considered old and failing. Soon after the first few years of surface wealth production, the yield of gold, it is true, gradually decreased ; but the influence of the metal upon the national progress grew in force.

2. History will ever pay a glowing tribute to Victorian gold, and acknowledge the incalculable debt of the island continent to its stimulating powers ; but little of good does official history say of the troubled birth and infancy of the industry itself. The impressionist of 1855 recalled the ' glorious sight ' of busy diggers and the ' infant splendour ' of *Golden Point*. The political chronicler finds, however, the distant view obscured by less gratifying pictures.

Throughout that early period there flowed into the country a vast torrent of eager adventurers: experienced miners; sailors deserting from their ships; young Englishmen drawn from their homes by visions of abundant wealth; emigrants from America; undesirables, with convict taint, from Van Diemen's Land, thousands of that nomad tribe, homeless and disowned, for whom the land of new-found gold provides a rallying-point for general muster. By this great flood of humanity, all so-called pillars of authority were swept aside. The errors and embarrassments of a tactless, vacillating Government, the lawlessness of a few individuals, the vain attempts of a weak Administration to enforce impolitic demands from recalcitrant diggers, the long series of disputes and disorders culminating in riot and bloodshed on Bakery Hill—these are the events by which the 'splendid infancy' of the Victorian gold-fields are often shown to be conspicuously distinguished. After a few years of civil disorganization the industrial aspect of affairs speedily brightened; a stronger Government authority was instituted, and the mining communities were happily purged of their degrading elements, and had their genuine grievances redressed.

3. The surface alluvial of Ballarat and Bendigo kept the diggers engaged with cradles and other simple appliances for several years. At Ballarat the gold occurred in fine particles and nuggets, some of which were a great weight. The famous *Welcome* nugget realized over £9,000, and the *Lady Hotham* £3,000. Large numbers of diggers were able to record steady returns of £5 to £10 per diem, and there were, of course, numerous instances of more remarkably good fortune. Oft-recited tales are handed down—'of miners, poor to-day, sleeping at night with pillows of gold-dust under their heads; of saving wives who found abundance of pin-money in washing the soil off their husband's boots.'

Bendigo, whose rich flats were the scene of busy alluvial washing for some years, speedily entered its transition state. In 1861, ten years after discovery, it was noted that the alluvial of *Kangaroo Flat* had been 'worked over and over again,' and that, while Bendigo Flat was still the scene of puddling operations to a considerable extent, the 'numerous gullies running into those flats' were comparatively deserted. But quartz-mining, which has been the support of the camp for half a century, and promises to remain so for as long again, was rapidly proving that the true merit of the field did not lie in the detrital deposits at surface. In time, depth was gained, and 'illimitable Bendigo' now ranks with the Rand as one of the two deepest gold-fields in the world.

4. From the standpoint of gold-production the records of Victoria may be divided into three periods. During the decade from 1852 to 1861 an annual yield of between 2,000,000 and 3,000,000 ounces was declared; from 1862 to 1875, between 1,000,000 and 2,000,000, and thenceforward less than 1,000,000 ounces per annum. Although Western Australia now accounts for half of Australia's gold output, the long duration of mining activity in Victoria gives that State great pre-eminence in the records of aggregate production, which may be tabulated up to the end of 1906 as follows:

	Total Yield.
	£
Victoria	276,517,000
West Australia	69,645,000
New Zealand	69,501,000
Queensland	64,335,000
New South Wales	54,314,000
Tasmania	5,751,000
South Australia	2,609,000
	£542,672,000

From the commencement of mining in Victoria, Bendigo and Ballarat—almost simultaneously discovered—have been the leading producers. For the first two years the two camps maintained an honourable rivalry for pre-eminence, which was eventually claimed beyond dispute by the former field. In 1906 the several Victorian districts ranked in the following order of productiveness:

District.	*Yield.*
	Ozs.
Bendigo	221,187
Ballarat	164,065
Beechworth	134,812
Castlemaine	99,386
Gippsland	97,180
Marybrough	80,267
Ararat and Stawell	24,899

The Beechworth district relies for its yield largely upon contributions from alluvial deposits in the Chiltern, Rutherglen, Buckland, and Bright divisions.

5. Bendigo, which celebrated its golden jubilee—never was the term more applicable—in 1901, is one of the most beautiful mining cities in the world. Amongst the few surpassing it in scenic and municipal qualities stands its old-time rival Ballarat. Yet Bendigo remains *par excellence* a 'mining camp,' in spite of civic enterprise. It is intersected conspicuously by several lines of shafts and mine equipment. The headgear of one company rises prominently above the palms and trees of the public gardens,

By favour of THE MAYOR OF BENDIGO.

IN COMMEMORATION OF GOLD DISCOVERY AT BENDIGO, 1851.

alongside the city's leading thoroughfare, 'The Mall,' and within stone's-throw of the chief public buildings. It is common to find well-planted residential streets broken abruptly by active or deserted mining leases, or by huge tailing heaps, whose flying dust is a frequent subject of debate amongst municipal councillors, anxious to improve the living conditions of their attractive city. The district, though stripped of timber in the mining regions, is plentifully grown with varieties of eucalyptus, called descriptively iron bark, stringy bark, white gum-tree, red gum, grey, yellow, and red box.

6. The geology of the district is exceptional, and rock structural conditions have led to the occurrence of ore-deposits of such peculiar characteristics as to be renowned as much for their form as their gold-production. Scarce a college text-book on geology can be found without its references to the 'Saddle Reefs' of Bendigo, by whose standards the very definition of the term is commonly established. In the valuable reports made by Mr. E. J. Dunn for the Government of Victoria, the view is expressed that the quartzites, sandstones, and slates making up the mass of Silurian strata on the field were laid down horizontally in water, and were, in course of time, subjected to prodigious forces, buckling, bending, and folding them to an extraordinary degree. The rocks now present a corrugated form, with parallel anticlinal folds, trending north-west and south-east, from 400 to 1,000 feet apart, and with corresponding troughs or synclines between. The beds on each side of the anticlinal arches dip away at about 60 to 70 degrees, on the average, and there is also a distinct pitching of the strata along the axial lines. In the folding of these rocks, which is considered by Mr. Dunn to have occurred when the strata were in a state of flexibility no greater than to-day, open fissures were frequently formed at the crown of the anticlines or in the basin of the synclines, in which the auriferous quartz was deposited.

Sometimes the bodies thus produced have the distinct form of a saddle, with well-defined, tapering legs branching away from the wide crown, or as trough reefs (inverted saddles). Commonly, however, the saddle characteristics are unrecognizable, and the bodies consist of an irregular mass or channel of ore without a branching cross-section.

7. A vital point in connexion with Bendigo stratigraphy is the circumstance that, the country rocks comprising a series of great thickness, repetitions of the ore-filled fissures are found to occur in vertical succession. Thus a mine may contain five to ten

distinct saddle-reefs, one below the other. On the other hand, development may fail to reveal a lower deposit. These uncertainties, apart from the normal irregularities of value in proved ore-bodies, naturally constitute a speculative factor, and in part, though not fully, excuse the extreme cautiousness of expenditure and the policy of installing small plants, often unduly criticized by visitors from more progressive fields.

The quartz of Bendigo, commonly a milky white, contains most of its gold in a coarse and free condition, together with a small percentage in combination with pyrites. It is probable that the quartz and gold rose in solution at a high temperature and were deposited in the existing fissures, which were in time enlarged by the forces of crystallization. The hot mineralized solutions which are seen to rise into the deep workings to-day provide an illustration of the probable nature of the thermal waters whose influence, manifested through vast ages, resulted in the occurrences of ore as found to exist.

It will be understood from the nature of their deposition that individual reefs do not extend downwards for great distances; but the recurrence of fold fissures has enabled mining to proceed, from one cap to another, to depths exceeding 4,000 feet. Shafts in the deepest Bendigo mines had been carried, at the beginning of 1907, to—

	Depth. Feet.
New Chum Railway	4,320
Victoria Reef Quartz	4,260
Lazarus New Chum	3,780
North Johnson's	3,500

Nine others exceeded 3,000 feet, and fifty ranged between 2,000 and 3,000 feet.

8. There has always been a close rivalry between the shafts of the *Jupiter* and *Cinderella* deep mines of the Rand and the *New Chum* and *Victoria Quartz* of Bendigo, though the former, it must be noticed, are large five-compartment shafts as compared with Bendigo's small excavations of 10 by 4 or 4½ feet. Another striking contrast between deep-level operations in Victoria and the Transvaal is that of temperature. The mines on the South African high veld are blessed with a happily small rise of temperature with increase of depth, so that work can be comfortably undertaken between 4,000 and 5,000 feet without great difficulties of ventilation. The rock temperature at the bottom of the *New Chum Railway* averages 108 to 110 degrees, and the air 98,

without artificial ventilation. The rising water is sometimes over 112 degrees.

9. There are more than twelve industrially important anticlinal axial lines marking the structure of the field. Many of the deposits, especially at the crowns of the saddles, are of great width, which enables mining to be cheaply undertaken on a flat system, with waste rock or 'mullock' used for filling. In weak, treacherous ground, hand-drilling—double-handed almost invariably—is performed; elsewhere, moderately heavy machine-drills are used. The ore being satisfactorily free-milling, and the wages of skilled miners lower than the average elsewhere, working costs can be brought to a very low level. It is instructive and often amusing to note how consistently all engineers from abroad or from Western Australia who express an opinion of Bendigo mining, mechanical, and metallurgical methods, proclaim to the world the inefficiency of systems and the backward principles of the field's conservative management. They speak pitifully of labour and power wastages, and the lack of all efforts to march with the times in the application of new principles. Some of these technical critics leave the field with the impression that their strictures may cause surprise and consternation amongst local managements, who appear, however, to regard the condemnation by 'ignorant strangers,' filled with so many 'new-fangled notions,' with complete indifference. Certainly no suggestions of improvement can be made with any claim to brilliant originality. Fault-finding has proceeded without cessation for half a century. A guide-book of 1885 informs us: 'It was at Bendigo that the effort to crush quartz and extract the gold by amalgamation originated. The first steam-engine was started by Messrs. Walker and Smith, but the boilers unfortunately burst, in consequence of the ignorance or incompetence of the engineer.'

10. The apparent inability or disinclination of controls to depart from the established groove must be attributed to diverse circumstances. Not the least forcible obstruction in the way of mechanical progress is to be found in the system of finance favoured in Bendigo, which rarely lays at the disposal of local managements a sufficiency of working capital to enable a bold policy of equipment or exploration to be pursued. Capitalizations are usually moderate (of the *New Moon*, the largest producer, the capital is only £12,000), and it is customary to call upon shareholders for small contributions upon their shares as capital is required. The benefits of this call 'system' are several. Directors, probably not aware as to how further demands or

'calls' will be received, are forced to adopt economical principles, and shareholders, whose losses, in case of failure, are definitely limited, are able to keep a closer watch upon current expenditures. On the other hand, the dread of making unsuccessful 'calls' deters those in control from embarking in schemes necessitating large initial expenditure to ensure higher efficiency of operation or greater industrial security. Engineers attempting to preach progressive doctrines are often suppressed with the manager's argument: 'We have been mining here for fifty years, and should know best what suits our conditions. You are speaking with your head full of South African or Yankee ideas, but this is Bendigo.'

It must be observed, however, that there is frequently a lack of efficiency in power generation, deplorable under all circumstances, and that milling practice is rarely characterized by experimental innovations calculated to improve extraction or reduce costs. Many managers and directors—for local directors take an unusually active part in the control of affairs—stand loyally to the rule-of-thumb methods of their technical forefathers, and regard with suspicion all proposals of 'scientific' modification. It is satisfactory to record, however, a marked improvement in the types of winding engine installed upon the field during recent years, not as the necessary sequence of deeper mining operations, but as the result of a more general effort to attain higher efficiency in this important branch of work. The mechanical needs of Victorian mines are almost entirely satisfied by local foundries, and in this respect are fortunate in being uninfluenced by the Commonwealth's protective tariff, which now constitutes a deplorably heavy burden upon more progressive fields using special classes of imported machinery.

11. Metallurgical methods at Bendigo are of the utmost simplicity. There is no occasion for complexity. Common practice is to crush the ore in stamp batteries for the amalgamation of the free gold, and the collection of the small percentage of concentrates, for chlorination or cyaniding. There is no cyanide treatment of sands. For illustrative purposes, reference will be made to the system of gold extraction practised on the *New Moon*—a property on the Eaglehawk section of the field, which was the largest producer and the most up-to-date in methods at the time of the writer's visit.

The ore-bodies of the *New Moon*, which are irregular in form, and in some places attain a width of nearly 100 feet, yielded up to the beginning of 1907 approximately 400,000 tons of quartz and 180,000 ounces of gold. Formed in 1867, the company had paid two hundred dividends, exceeding £300,000 in total amount. These figures do not appear large in relation to the records of many other gold-fields, but for Bendigo they stand exceptionally high. In 1906, 32,340 tons of ore were treated for 15,493 ounces of gold, or 38s. 3d. per ton.

12. At shaft-head preliminary breaking is effected in a Gates crusher, whence the ore is transported by cable tramway to the mill-bins. Challenge ore-feeders are used for most of the mortar-boxes in this battery of 71 stamps (850 pounds), though hand-feeding is very common throughout the field. The screening is of 180 punched holes to the square inch; for Bendigo as a whole, the mesh averages from 140 to 240 holes. Below the copper plates, which are said to effect a high extraction, the pulp is run over tables for the collection of concentrates. At the *New Moon* modern types of table—such as the Wilfley, Card, and Phœnix-Weir—have been introduced.

In the past a percussion-table known as the 'Halley' was chiefly relied upon, but this demanded considerable attention and hand labour. A rotary concentrator called the 'Harrison' has also been employed. By these machines a sulphide product, representing about 2 per cent. of the pulp, and worth about £8 per ton, is obtained. The tailings from the tables pass over strakes of coarse sacking, yielding a small return, and then run to the settling dams and dumps. Upon many Bendigo properties Chinamen undertake the attention of tailings below the mill for what they can win from them. At one time the industrious Asiatics made excellent profits by their work, but now tailings are of very low grade, and these contractors require remuneration in addition to the gold won in concentrates by means of their blanket or sacking strakes.

13. With natural conditions of a favourable character, Bendigo is able to treat very low-grade ore at a profit. Working-costs on the *New Moon* may be shown to average as follows:

	Per Ton. s.	d.
Wages	8	3
Material, etc.	2	7
Firewood	0	9
Battery expenses	1	8
Office expenses	0	5
Pyrites treatment	0	9
	14	5

Wood, costing 7s. or 8s. per ton, is the standard fuel.

Published records of Bendigo working-costs are not, as a rule, overflowing with detailed information, and it is difficult to compile fair comparative statements. Numerous properties are operated for a return of 4 to 6 dwt. per ton. The chief dividend-payers, however, are treating considerably richer ore, as appears from the following table of results for 1906 :

	Tons treated.	*Yield per Ton.*	*Dividends.*
		dwt.	£
New Argus	11,124	25·0	37,500
New Moon	32,340	9·6	34,800
South New Moon	28,660	9·3	28,800
United Ulster	13,561	13·3	22,400
Virginia	12,872	8·7	22,275
Catherine Reef United	17,107	12·0	20,127
Red, White, and Blue	13,834	14·8	19,125

Though producing very little gold to-day, the *Garden Gully United* and *Great Extended Hustler's* were formerly two of Bendigo's most important mines, each accounting for over £1,000,000.

14. Labour and wage conditions on the Victorian gold-fields differ radically from those obtaining in the camps of the interior, such as Kalgoorlie and Broken Hill. On these latter fields there is a comparatively high minimum wage, below which not even a learner can be paid. At Bendigo an adult learner or boy is paid according to his worth. There is a regular standard of wage for those who are recognized to be efficient miners, or strong, capable labourers. Save in cross-cuts and drives, contract work is rarely performed. Current rates of pay may be scheduled as follows :

	Per Shift.
	s. d. s. d.
Foremen	8 3 to 9 0
Miners	7 6 ,, 8 6
Surface men	6 0 ,, 7 0
Boys	2 6 ,, 5 0
Carpenters, etc.	8 3 ,, 9 0

The higher officials, who have nearly all risen from the ranks, are similarly paid at a much lower rate than that recognized in Western Australia or other fields where a more scientific training is demanded. General managers receive from £5 to £10 per week ; legal or business managers, 10s. to £3 ; mining managers, £3 to £7 ; and engineers, £3 10s. to £4. The rational system of employing lads and inexperienced men on a graduated scale of wages has proved highly advantageous. As a rule the lads are given the lighter duties, enabling them to gain an experience which stands as a lasting asset to them through life. Such methods of training, beneficial from both the employers' and the skilled wage-earners' point of view, can only be adopted where the strength of Unionism is inadequate to enforce the payment of a competent man's wage to all ages and all classes, and where conditions of life and work are such as to make what is not much more than a living wage acceptable during the vaguely defined period of probation.

BALLARAT GOLD-FIELDS.

15. The old mining-camp of Ballarat recently regained a share of outside attention—not consistently favourable—owing to the exploitation of the deep alluvial deposits or 'Deep Leads,' constituting one of the most interesting geological features of the field. In the early days of Ballarat development, surface or shallow alluvial deposits were worked in the gullies and river-beds. The extensions of these deposits were often found to run beneath an increasing thickness of overburden, which eventually checked the advance of the mining party or syndicate without capital to permit of deeper sinking. This disappearance of the leads beneath a capping is explained by the disturbing influences of earth movements and volcanic eruptions, which completely revolutionized the river system of the district.

Sheets of basalt filled the old river channels, covering up the alluvial, and formed new water-courses. In the same way we find the tin alluvial deposits of North-Eastern Tasmania commonly protected by igneous cappings.

The early miners directed their energies towards the exposed alluvial or the ground available below a moderate thickness of basaltic overburden. The deep leads, owing to the expense involved in their dewatering and exploration prior to gold extraction, have been left for recent enterprise. The great middle period of Ballarat history is chiefly marked by the production of gold from the quartz-reefs of the field. After the exhaustion of the superficial deposits, work was performed on the leads lying beneath the clay and sands of the existing gullies, and in the opening up of this detrital ground, quartz ore-bodies were discovered.

16. Upon analyzing the official returns for 1906, it is to be seen that alluvial and quartz deposits in the six principal divisions

of the Ballarat district accounted for gold in the following relation :

Division.	*Alluvial.*	*Quartz.*
	ozs.	ozs.
Central	890	51,274
Southern	12,009	29,730
Creswick	22,350	308
Smythesdale	3,771	13,963
Clunes	10,133	336
Buningyong	1,020	6,894
Other divisions	1,707	9,678
Totals	51,890	112,183

The highly productive Ballarat central or eastern division has been made the subject of a lengthy report* by Professor J. W. Gregory, on behalf of the Geological Survey of Victoria. This monograph met with considerable local criticism (as did the same geologist's report on the Broken Hill silver-lead deposits), but nevertheless contains an abundance of interesting facts. In it appears a very lucid discussion of that prominent and important feature of Ballarat geology, the 'indicators.'

17. The plan of the gold distribution at Ballarat East was gradually unravelled as mining proceeded. 'The comparative poverty of most of the quartz was compensated for,' Professor Gregory notes, 'by the occurrence of irregularly scattered nuggets or rich nuggety patches. The distribution of these patches appeared at first erratic, but as the mines were worked the clue to their distribution was discovered. These rich patches occur where the flat quartz veins, or floors, intersect thin vertical lines of dark-coloured slate. . . . Accordingly, the miners, by following these vertical lines, were able to pick up these rich positions with a minimum of dead work. As these lines of slate indicated the direction which mining should follow, they were called "indicators."'

In a paper read before the American Institute of Mining Engineers (Trans., vol. xxvii.), Dr. J. R. Don states : 'Away from the indicator, the greater part of the vein-quartz is absolutely barren ; but at the intersection with the indicator large masses of gold (often more than 100 ounces in one piece) have been obtained, and the greater part of the gold extracted from this (*i.e.*, the indicator) belt has come from those parts of the quartz vein near some of the indicators.'

18. The chief vein material of Ballarat ore-bodies is quartz, occurring in 'coarse, irregular, crystalline aggregates, with no

* 'Memoirs of the Geological Survey of Victoria,' 1907.

defined crystal faces.' Compared with the saddle reefs of Bendigo, the Ballarat quartz deposits are of low grade, the yield of twenty-four producers in the central division in 1906 averaging only 24s. per ton crushed. The leading companies during that year were as follows :

	Tons treated.	*Yield Value.*	*Yield per Ton.*
		£	dwt.
Victoria United	32,775	42,445	6·0
New Normanby	27,785	28,030	4·9
North Woah Hawp ..	14,944	24,503	8·0
Llanberris, No. 1 ..	22,540	21,181	4·6
Band and Loch	7,210	15,501	10·4
First Chance	8,040	13,649	8·3

It will be seen that not only is the ore of low grade, but the scale of operations is small. This combination of circumstances, characterizing Victorian gold-mining in general, reflects credit upon managements who are able to obtain good results even with inefficient plants, and thus give a practical reply to the arguments of hypercritical observers.

19. Referring to the structure of the field, Professor Gregory, in the report previously mentioned, declares that 'it appears complex owing to the multiple series of indicators, the apparent capriciousness of the occurrences of the quartz masses, and the irregular distribution of the gold in them. But on further acquaintance with the field, it is seen to have a simple, fundamental plan. Reduced to its simplest elements, the field consists of alternate series of layers of slate and sandstone, which have been tilted into a highly inclined position, with a prevalent dip to the west. The rocks have been broken into a series of blocks, which have been displaced amongst themselves by a complex series of faults . . . dip-faults or cross courses, and strike-faults or slides. . . . Water containing silica and sulphides in solution then circulated through the fractures, and deposited great blows of quartz along the main slides; these blows occur where the country rocks were especially crushed, and thus were liable to permeation by the solutions flowing along the slides. The big quartz-blows along the main slides are the most important ore deposits in the field.'

Two notable exceptions to the general run of low or medium-grade mines of Victoria are the *Long Tunnel* and *Long Tunnel Extended* mines in the Walhalla division of Gippsland. The latter mine, with a yield of 25 dwt. per ton, is the leading dividend-payer in the State. The former treats a larger tonnage for a return of about 18 dwt. per ton.

20. Returning to the question of deep alluvial mining, it must be pointed out that the industrial destiny of the 'Deep Leads' is, at the time of writing, a matter of the most problematical character. Their development has been attended by very serious disappointments, but the conditions under which they are exploited or explored are nevertheless particularly interesting. The testing of the leads below a covering of 300 to 600 feet of basalt was undertaken several years ago by the Victorian Government, and the results of drilling encouraged London capitalists to form companies for the working of the *Madame Berry* deep-lead system, which extends for several miles from near Clunes and Creswick. The principal companies situated upon this line are *Loddon Valley Gold-fields, Ltd.*, *Moorlort Gold-fields*, and the *Victorian Deep Leads*, with which must be associated the administrative firm of Messrs. Bewick, Moreing and Co., who operate in several parts of Australia. As to the prospects of these concerns, and the wildly extravagant hopes expressed regarding their profit-making capabilities, no opinion need be here expressed. Chief interest attaches to the extreme working difficulties encountered.

21. In the case of the *Loddon* property, tunnels were cut below the lead, at a depth of about 400 feet, from a shaft sunk through basalt and bed-rock at a point outside the main channel. From these workings 3-inch steel tubes were forced up into the lead, through which the water made its way into the tunnel and to the shaft. The pumps required to be of the enormous capacity of up to 10½ million gallons per day.

When the lead had been dewatered, it was tapped by rises, and the alluvial cut out by a system of panels, 35 feet from centre to centre. It may be added that results of treatment fell very far short of anticipations, the absence of a deep rich gutter being the most serious disappointment to those interested in the undertaking. Instead of a narrow width of high grade wash-dirt, there was found to a be great width of very poor material.

22. The Victorian Government, recognizing the fact that the thorough exploration of the Deep Leads was a matter of national importance, and anxious to assist a company which had got into financial difficulties after spending £200,000 on costly plant and operations, allotted the company £8,000 on the pound-for-pound principle of the Mines Development Act, for the prosecution of

additional prospecting. The Government, demanding repayment out of the first profits, secured itself by a mortgage on the lease and one of the company's plants.

The financial assistance of deserving mining ventures by the State is one of the most noteworthy features of Australasian mining administration. State aid is liberally granted by Victoria and Western Australia for various purposes calculated to benefit the industry. The sums spent by the Western State in 1906, included advances in aid of mining work, of boring and of crushing plants, subsidies to private crushing plants, the purchasing of boring plants and various other subsidies, totalling £16,238.

23. Miners are also assisted by the many public batteries, cyanide plants, and, in Western Australia, smelting works, which are installed and controlled by the Government. These equipments, though run at a small loss, constitute a factor of great industrial value, and enable many small centres to become active producers which would lie dormant without Government support. In Western Australia, which is peculiarly suitable for the application of this class of Government aid owing to the abundance of small deposits failing to warrant the establishment of private mills, there are twenty-nine State batteries and twenty-four State cyanide plants. Under the system, about 500,000 tons of ore had been crushed, up to the end of 1907, for a yield of £2,000,000. The charges made for public ore treatment are regulated so that the year's current expenses for the whole State are approximately balanced by receipts. To the end of 1906 the capital expenditure on State batteries and tin-dressing plants in Western Australia totalled £225,680, and the working expenses exceeded the receipts by £8,210.

There are occasions, of course, when the policy of erecting State batteries may be carried to excess, and prove opposed to the true interests of the district served by discouraging permanent work and checking individual enterprise. A new reef or line of reefs may be discovered. Prospectors test it by their usual methods, put down a few small shafts, dump their ore at surface, and then clamour for the establishment of a State battery. When their request is granted, they will often gouge out the best patches or zones, make good profits from the oxidized ore, then leave the mine, commonly in a hopeless state of disorder, to its fate (the fate of the majority of mines bearing the stigma of abandonment), and the battery on the hands of the Government. Had the property been taken up by a syndicate or company, greater consideration would have necessarily been paid to the permanent prosperity of the undertaking.

In many districts of Australia, with a large number of erratic quartz-reefs, State batteries are essentially beneficial from all points of view. But the advantages and possibilities of the system must always be determined in the light of local conditions. Replying to a deputation in 1905, the West Australian Minister for Mines remarked : 'During the past five years £400,000 of public money has been spent on the gold-fields for the indirect benefit of prospectors, and £200,000 on public batteries. That shows how earnest the State has been to assist such men. . . . The results have not come up to our expectations. My idea is that some of the money won from the ground should be put back into it for development. I wish we could discover some means by which we could encourage people to do that.'

This contention clearly indicates one of the chief defects of the system, and the merits of company-owned mines, which are obliged, by reason of their expenditures on plant and development, to open up their holding upon well-regulated, scientific principles, and to give heed to the broader questions of future economy.

CHAPTER IX

QUEENSLAND

Gold and Copper

1. A country of distances.—2. Primarily a gold producer.—3. Futile rush of diggers.—4. Gympie's free-milling ore.—5. Charters Towers.—6. Ore Treatment.—7. Mount Morgan.—8. The first phase.—9. Geyser theory of origin.—10. Mr. Dunn's report.—11. Copper a growing factor.—12. Classes of ore.—13. New smelting works.—14. Aggregate results.—15. Walsh and Tinaroo.—16. A new copper camp.—17. Standard of wages.

1. Only by the lessons of hard travel is it possible to realize the isolation of many Australian centres of population, the wide distinctions of geographical and mineral condition obtaining in different localities, the vastness of the 'Never-Never Land' of the interior, and the striking contrasts in the country's most conspicuous features, which forbid description in general terms. Of a land so great and varied brief report is impossible; for Australia, though politically federated into one nation, still remains—geographically considered—a group of many countries.

Queensland, the youngest and second largest division of the Commonwealth, is a country of great distances, and is, in some aspects, the least typical of Australia. This single State, whose axial line from north to south would stretch from Sweden to Sicily, can be divided into three primary regions, each possessing distinctive physical and climatic characteristics. There is the tropical eastern side of the Great Dividing Range, covered with a profuse vegetation; the region round the Gulf of Carpentaria, abundantly watered pastoral land; and the south-western district—the famous Downs Country—whose fine climate and rich soil have been turned to good account through the plentiful supply of artesian water. Queensland grows sugar, cotton, and other products of the tropics (within which zone two-thirds of the country lies), and also all the grains, fruits, and plants of Europe. The variety of vegetable production is matched by a similarly wide range of mineral resources. Like New South Wales, which is also blessed with many forms of mineral wealth, Queensland ranks as a producer of gold, copper, silver-lead, tin, coal, antimony, opals, bismuth, and ironstone. In addition, wolfram, manganese, molybdenite, gems, scheelite, and graphite appear upon the output list.

2. From the time of its first mineral discoveries Queensland has been known primarily as a gold-producing country. Only within recent years the yellow metal has ceased to be the all-important factor of mineral production, and copper and tin have risen to a position demanding commensurate notice. This change of general aspect is not only due to the decline of many gold-fields and the rise of new copper-bearing regions, but to the remarkable transition of the *Mount Morgan*—which Karl Schmeisser described in 1898 as 'the mightiest deposit of gold that has been discovered in the world up to the present time'—from a great gold producer into greater producer of copper and gold. How wonderful has been the progress of base-metal and non-metallic mineral-mining in the State may best be demonstrated by the following figures, which are more convincing in their testimony than the most vivid description of latent potentialities :

	Yield (1896).	*Yield* (1906).	*Increase.*
	£	£	£
Copper	21,042	916,546	895,504
Lead	6,180	49,884	43,704
Tin	49,018	490,283	441,265
Antimony	—	6,917	6,917
Coal	154,987	173,282	18,295
Molybdenite ..	—	17,037	17,037
Gold	2,150,000	2,313,500	1,635
Silver	32,162	101,693	69,531

Distinction can only be gained in the mining world by the operation of some mineral field possessing extraordinary features of wealth or geological formation. The province or State recording a large output contributed by a host of small mines and districts—whose lessons are of little concern—will be ignored, while another, accounting, perhaps, for only half the yield, may enjoy universal renown by virtue of one distinctive centre. Queensland, though clearly endowed with great natural riches, was saved from the fate of mediocrity—in the eyes of busy outside observers—by the renowned 'Mountain of Gold,' as *Mount Morgan* is commonly termed in picturesque phraseology, discovered near Rockhampton in 1882. *Mount Morgan* has not only shed its glory upon the State in which its treasures have been realized and distributed. With the 'Golden Mile' in Western Australia and the Broken Hill lode in New South Wales, it stands in the front rank of the several mineral concentrations of marvellous richness for which the continent is rightly famous.

3. Gold-mining commenced in Queensland several years after its inception in Victoria and New South Wales, and under circumstances far less propitious. A futile rush of diggers occurred to the banks of the Fitzroy River in 1858, and many shiploads of men reached Canoona drawn by reports of rich alluvial deposits. But the rush, in which 15,000 diggers are said to have taken part, proved a disastrous failure, and 'for some time the Fitzroy River was the scene of wretchedness and starvation'—within a few miles, it was subsequently learnt, of the richest concentration of gold in the world. But *Mount Morgan* was reserved for a later generation. In 1867, following the discovery of gold at Gympie, another rush occurred. On this occasion good results followed, and a new field of permanent productiveness was established.

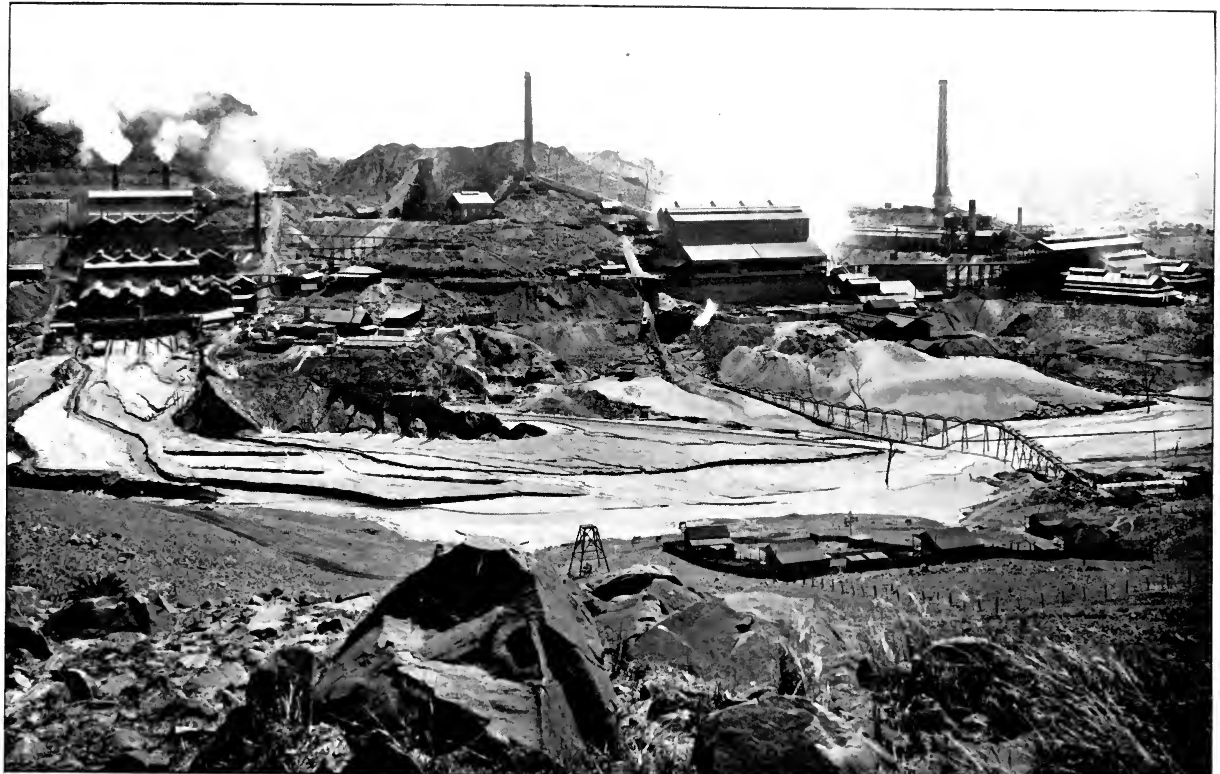
4. Gympie is situated 100 miles by rail to the north of Brisbane. Like Charters Towers, Mount Morgan, Ravenswood, Etheridge, Walsh, and Tinaroo, it lies, fortunately, near the coast, and has not suffered from that inaccessibility which has proved so serious an obstacle to the development of many other promising fields. With a steady yield of gold reaching a maximum of £627,000 in 1903, and recently tending to decline, the district has turned out over £10,000,000 in gold to date. Gympie is often called the Ballarat of Queensland, on account of the close relationship between the rich portions of the quartz reefs and certain beds of carbonaceous slates—the 'indicators.' The strata in which the auriferous reefs occur are highly altered sedimentary rocks, broken and complicated by numerous faults. The reefs are only found to be payable when cutting the slate-beds mentioned, and are widely displaced by certain cross-courses. The theory is advanced that these cross-courses played an important rôle in the deposition of the gold-deposits by acting as the main channels for the ascending mineral solutions, the vein matter in which was precipitated largely by the carbonaceous matter in the slates. It is said that the ore-bodies are more numerous and extensive, and increase in gold value upon approaching one or other of the main cross-courses.* It is the inestimable

* *Australian Mining Standard*, September 25, 1907.

good fortune of Gympie to possess an ore from which a high extraction of gold can be effected by the simplest of mechanical means. At Gympie, when the ore is in the mill-bins, the labours of gold production are practically at an end; at Kalgoorlie work has scarce begun. Although Gympie ore averages 13 or 14 dwts. in value, amalgamation obtains so high a proportion of the gold as to make the cyanidation or chlorination of tailings rarely profitable. There are to-day only two large producers in the district—the *Scottish Gympie* and the *No. 2 Great Eastern.* In 1906 these two properties contributed upwards of 60 per cent. to the total yield of £452,000 recorded by the Gympie and associated Glastonbury, Marodian, and Yabba gold-fields.

5. Of greater importance than Gympie—standing on a higher plane of technical efficiency and producing capacity—is the premier gold-field, Charters Towers, which was discovered in 1871-1872, and has since, together with the Cape River fields, turned out gold to the value of over £24,000,000. Charters Towers, situated on the northern spurs of the Towers Mountain, is 820 miles north-west of Brisbane, and is connected with Townsville on the coast by rail. The great depths to which mining is carried and the requirements of mill-tailing treatment necessitate heavier capital expenditures, underground and on surface, than Gympie is obliged—in its fortunate lack of mineralogical complexities—to consider. The quartz veins treated are for the most part of very good grade, vary in width from a few inches to many feet, and are characterized by a very flat dip, like that of the Rand in its deeper levels. The mines are generally dry. Occurring in a granitic formation, the veins are of quartz, with a small percentage of pyrites (iron and copper), galena, blende, and some mispickel. Miners in Charters Towers are well able to appreciate the difficulties and expense of working reefs dipping at a low angle, and their underground costs are heavy. Ventilation is an expensive item, and the comparatively small scale upon which operations are performed, gives the management no opportunity of distributing standing charges over a big tonnage.

6. The general system of ore-treatment in vogue is described by Mr. Donald Clark briefly as follows: 'The fines and crushed material (from the rock-breakers) are automatically picked up by buckets on an elevator chain-belt, and delivered either into trucks or emptied into a hopper. Thence it passes into an automatic feeder, which delivers it into the battery. . . . Mercury is usually fed into the box. The pulp passes through punched screens, passes over plates, sometimes absurdly short, then into



By favour of Mt. Morgan G. M. Co.

CHLORINATION AND SMELTING WORKS, MOUNT MORGAN.

an amalgamator. Leaving this, it goes to a Brown and Stansfield concentrator, the sands and slime passing away to be cyanided, while the concentrates are ground in Wheeler's or other pans running continuously. The ground material is further treated by fine grinding in Berdan basins, into which lime is fed. The pyritic slimes or sludges are then run into pits and settled as far as possible. These are then sold by tender to the cyanide firms.'*

The two chief lines of reef are the closely related Day Dawn and Brilliant, upon which the five leading producers are situated—namely, the *Mill's Day Dawn United, Brilliant Extended, Day Dawn Block and Wyndham, Brilliant and St. George*, and the *Brilliant Central.* These properties only crush from 20,000 to 45,000 tons each per annum. The record of treatment results for 1906, showing mill and cyanide returns, may be shown as under :

	Tons.	*Yield.*	*Per Ton.*
		£	s. d.
Mills	240,416	480,992	67 7·5
Cyanidation	223,173	167,069	34 8·9

During the last few years the mining outlook has been generally unfavourable, but it is, nevertheless, an encouraging sign that exploratory work has been advanced with unusual vigour, and that dividend reductions have been in many instances attributable to greater expenditures calculated to give greater stability to the mines. Increases of development and improvements in treatment plants have in part compensated for the declines of such prominent companies as the *Brilliant Extended* and the *Brilliant and St. George.* Rockhampton and Gympie do not stand alone amongst Queensland gold-fields upon the down grade, for almost every other important district—notably Ravenswood, Etheridge and Woolgar, Croydon—has failed to maintain its regular rate of yield.

7. The unique cupriferous gold deposit of *Mount Morgan* has been able to command and hold the attention of the mining world from the time of its discovery in 1882 steadfastly up to the present day. It is one of those few mining centres in the world which are never without new features of importance, whose fabulous records never fail to excite interest even outside technical circles, and whose unique natural conditions and efficient technical methods

* 'Australian Mining and Metallurgy,' Melbourne, 1904.

form a profitable study for all miners and metallurgists. The declining gold-yield of recent years might have tended to relegate the Mount to the comparative obscurity of past wonders; but gold is no longer the sole basis of prosperity, and now we find the enterprise passing rapidly into a greater producer of copper. This wonderful transition has made the years 1906 and 1907 as eventful (and astonishing to those who have followed the mine's career by records of production alone) as any since the opening period of its long and prosperous history. The *Mount Morgan Gold Mining Company*, from its formation in 1886 to the end of 1907, has produced £13,000,000 in gold—equivalent to over £4 per ton of ore treated—and paid £7,000,000 in dividends.

8. There is a fascination about the tales of great mine discoveries from which the most phlegmatic of philosophers rarely escape. In the story of *Mount Morgan* are to be found the strongest elements of romance and the strangest commingling of mischance and wondrous good fortune. The tale of events leading up to the discovery of the 'Mountain of Gold' may be taken from the *Sydney Morning Herald* of 1885, though there are other versions. In 1871 a young Scotchman named Donald Gordon took up two selections of land, each of 640 acres. One of these included the south-eastern portion of a hill more rough and rocky than the rest, with big dark metallic-looking boulders. Year after year passed away, and Gordon found himself steadily growing a poorer man. Droughts came, and his cattle died. Prospectors visited the district in search of gold, and day after day passed the boulders on the mountain, never suspecting that they might contain gold. Then Gordon caught the mining fever, and set out to find a copper-mine. He noticed the black metallic rocks of the mountain, and obtained advice about it. Opinions were condemnatory.

Gordon's hopes and spirits had been broken, and he went to work in the *Galawa* mine, Mount Wheeler. One day he offered to show the owners the mountain of ironstone, and, as a result, to his great surprise and gratification, was given £1 an acre for his selection, or £640 in all. The men who noted the possibilities of this remarkable mountain were the Morgan Brothers, who formed a private syndicate and worked the property secretly for some time. A company was formed, with an ultimate capital of £1,000,000, in £1 shares, which rose to a valuation of nearly £18 at the height of the boom.

9. The original cap of the Mount, mostly removed in course of mining operations, stood at a height of 580 feet above the River

Dee, which runs past the base of the elevation. How the great central mass of ore (of several distinct zones and classes) was formed has proved one of the most interesting problems of mineral deposition presented anywhere in the world. The well-known theory of geyser origin, propounded by Dr. Logan Jack, has been vigorously debated. Dr. Jack declared, after careful study of the whole formation, that, in his opinion, nothing but a thermal spring in the open air could have deposited the material under consideration, and that the 'frothy siliceous sinter' agreed in every respect with the deposits of New Zealand and Iceland geysers. Dr. Leibin, lecturing before the Royal Society of New South Wales in 1884, said that the mountain ridge appeared to be the result of a thermal-spring, which in past ages held quartz, iron, and gold in solution. Early investigators had, of course, no such data upon which to base their contentions as are now available in workings to a depth of over 900 feet from the original capping, but their views are still strongly supported by some of the best authorities.

10. A valuable report upon the *Mount Morgan* deposit is to be found in the Proceedings of the Royal Society of Victoria (vol. xvii.), before which body Mr. E. J. Dunn gave the results of his investigations. According to this geologist, the masses included a central core of soft red sandstone, surrounded with a belt of limonite and beds of sand rich in iron oxides. Again surrounding this came siliceous skeleton rocks from which the sulphides had been removed. Altered igneous rocks form the walls of the mine. The top of the Mount was occupied by this sandstone plug three-fifths of an acre in extent, almost the whole of which was dumped away as waste, so as to render the rich secondary ore below it accessible. The secondary ore formed a zone of enrichment, and the whole of this material was payably auriferous—running in places up to hundreds of ounces per ton.

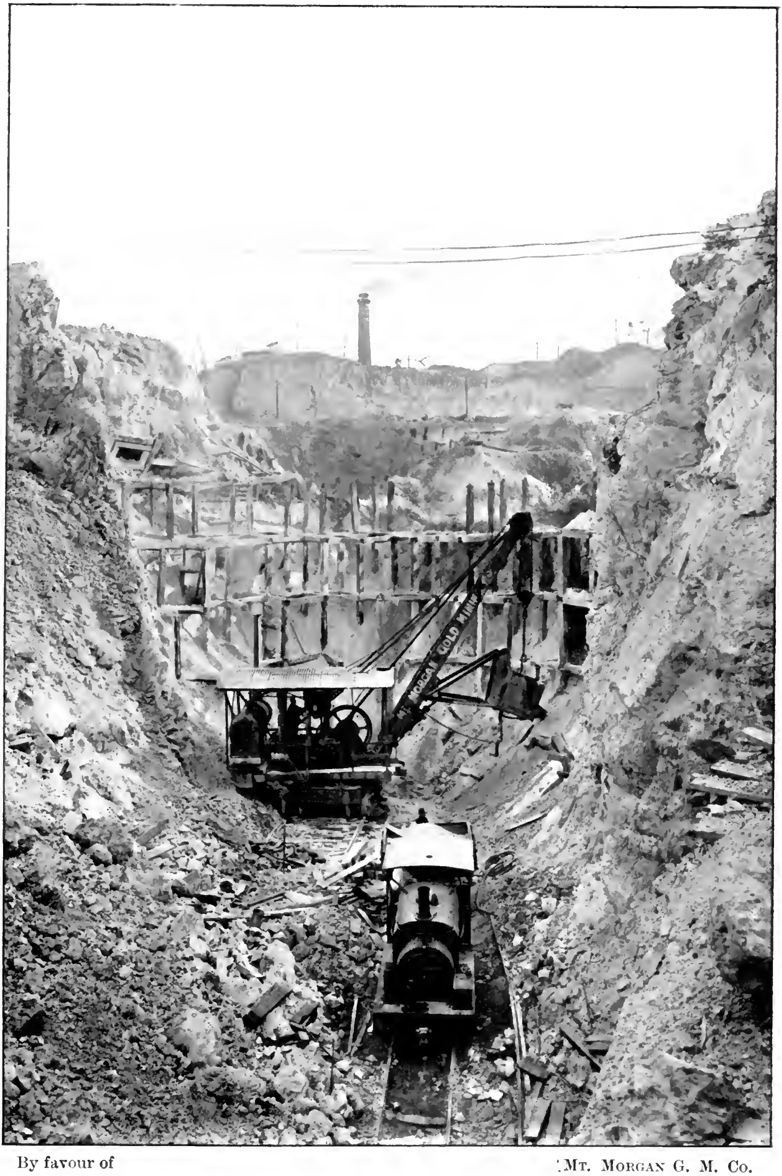
Underlying and almost surrounding the whole of the secondary ores is the great mass of siliceous and Kaolin ore, representing the upper and oxidized portion of the siliceous sulphide ore met with deeper in the mine. Through this the gold, which is phenomenally fine, occurs in a most irregular manner. The average contents of gold in this zone would probably be only pennyweights against ounces in the enriched zone. Everywhere in the mine as depth is attained this oxidized and leached ore is found to give place to sulphide ore—the unaltered zone. In the lower levels copper pyrites is met with, associated with the iron pyrites.

11. Mr. Dunn is of opinion that the siliceous sulphide body is undoubtedly the original source from which all the Mount gold has been derived. The indications of change suggested to him that the mine may eventually become a copper-mine, the gold being merely a by-product. As recent reports have shown, the transition is already in process, and a greater revenue is now derived from the copper smelters than from the gold chlorination works. The fall in the gold grade from the days when the marvellously rich secondary ore contributed principally or largely to the yield may be shown by the following selected figures :

Year ended	*Ore chlorinated.*	*Total Yield.*	*Yield per Ton.*	
	tons.	£	ozs.	dwt.
May 31, 1888	17,241	374,083	5	5
,, 1889	49,276	966,448	4	15½
,, 1891	74,741	828,974	2	14
,, 1893	62,190	495,536	1	19
,, 1896	91,597	578,678		11
,, 1899	204,502	664,143		16
,, 1903	262,919	566,401		11
,, 1907	246,022	413,553		8½

The tonnages for 1903 and 1907 include 29,000 and 10,000 tons of tailings. With the fall in gold yield is associated a corresponding decline in dividends from £866,667 in 1899-1900 to £162,500 in 1906–1907. It is no longer possible to view operations and results of treatment in so simple a table. There are independent plants for the production of gold by chlorination and of copper and gold by smelting.

12. The ore drawn from the mine, whence it is extracted by open cut (with steam shovels) and underground operations, is of several classes. But one common characteristic, which has been the predominant factor in determining metallurgical methods in the past, is the extremely fine state of subdivision in which its gold occurs. After long and costly experimenting, the successful issue of which was largely due to the ability of the gresent general manager, Mr. G. A. Richard, a special chlorination process—following a preliminary roast—was successfully evolved. The oxidized ore is dispatched to the 'West Works' and the sulphide ore to the 'Mundic Works,' while at lower sheds considerable tonnages of tailings are treated for gold and copper. Treatment costs at the Mundic Works have averaged lately about 13s. 6d. per ton, and at the West 10s. 6d.—a rising figure, owing to the greater refractoriness of the ore.



By favour of Mt. Morgan G. M. Co.

STEAM SHOVEL IN OPEN CUT, MOUNT MORGAN.

13. Chief interest now attaches to the large new copper-reduction or smelting works, whose erection in 1905 marked the commencement of a new era in the history of the *Mount Morgan* mine. The first of four blast-furnaces—190 by 48 inches at the tuyeres—was blown in on January 20, 1906. This section of the company's plant, designed for the treatment of the deep-level gold and copper-bearing pyritic ore, will clearly advance in industrial importance just as the chlorination works must tend to decline. Current practice, with three furnaces in operation, involves the production of a 40 per cent. matte, which is concentrated to blister copper in the converter plant. The blast for the furnaces is provided by Connersville blowers, and for the converters by Parsons turbo-blowers.

During the half-year ended May 31, 1907, when two furnaces were in blast, a yield of 1,972 tons of copper and 26,377 ounces of gold was recorded at the new smelting-works—a return equivalent in value to twice the output of the chlorination plant for the same period.

14. Illustrative of the magnitude of the *Mount Morgan* company's operations from 1886 to the middle of 1907, the following authentic aggregates are remarkable:

	Total. £
Gold yield	12,535,330
Blister copper yield	505,000
Wages and contracts	3,204,783
Machinery and plant	735,650
Stores, material, and timber	952,893
Firewood and charcoal	380,215
Dividends	6,841,667
Dividend duty and income tax	231,799
Coal and Coke	153,923

Such minor expenses as law costs, directors' fees, insurance, telegrams, postage, printing, etc., amount to tens of thousands sterling. And this was the famous Mount—the source and distributor of such vast wealth—which was sold by its needy owner at a pound an acre.

Parturiunt montes, nascetur ridiculus mus. However applicable may have been the metaphor in its usage by the Latin poet, the passage must indeed be quoted with discretion in Australia—the home of Mount Bischoff, Mount Lyell, and Mount Morgan, whose giant children have exerted an influence upon the prosperity of a continent.

15. A mining-field of great importance—as the leading producer of copper and tin—is the Walsh and Tinaroo, situated in

the North of Queensland, with Cairns as its coastal town. Not only has this district progressed admirably through the stimulative influences of a strong metal market, but it has also gained strength from the view-point of actual development. Noteworthy copper-producers in this region are the *Chillagoe*, *Mungana*, *Mount Molloy*, and *O.K.* mines, treating ore for a smelter return of from 4 to 11 per cent. copper. Tin-mining in the Walsh and Tinaroo field—which accounts for 80 per cent. of the State's yield—has progressed admirably. The three leading mines (lode propositions) recorded in 1906 the following returns :

	Ore treated.	*Yield Black Tin.*
	tons.	tons.
Vulcan	9,680	781
Stannary Hills	38,719	692
Smith's Creek	3,803	107

It is of interest to compare these figures with the yields of the two leading producers in Tasmania, which enjoy far wider fame in the mining world :

	Yield.
	tons.
Briseis	1,117
Mount Bischoff	1,050

Recently, however, the *Mount Bischoff* has fallen in producing capacity to 50 to 60 tons per month, and this world-famous mine has, therefore, fallen below the premier companies of Queensland.

16. There are many who look to the country's resources in silver-lead—which are by no means inconsiderable—to shortly develop into an industrial factor of far greater import. Only during the last four or five years have these metals in association sprung into economic significance in Queensland. Deposits of good promise, however, await exploitation in many districts.

Unquestionably the most remarkable new feature of Queensland mining has been the meteoric rise of the Cloncurry copper-field, which lies 200 miles to the south of the Gulf of Carpentaria, in the Burketown district. This new field, whose development will shortly be stimulated by the extension of railway sanctioned by Government in 1906, turned out copper ore to the value of £53,663 during the year, and is still to be considered merely in the prospecting stage. In his report for the Geological Survey, Mr. L. C. Ball states that the topographical features of the Cloncurry district are striking. Stretching away for hundreds of miles to the north-east and south-east are the famous rolling downs —vast black-soil plains, clothed with Mitchell and Flinders grasses, with lines of trees marking the course of river or creek. The temperature ranges between 55° and 115°. The ore deposits are of three kinds—rich lenticular bodies and impregnations of the strained rock in crush-zones, and poorer impregnations of originally porous bands of country. At present only the high-grade ore can be profitably shipped.

17. The annual reports issued by the Under-Secretary for Mines contain detailed statements relating to rates of wages paid in the State to various classes of mine-labour.

Taking the schedules of two districts—(1) Mount Morgan, Rockhampton, Mount Shamrock, etc., and (2) Charters Towers and Ravenswood—it is to be seen that rates average per shift:

	(1)		(2)	
	s.	d.	s.	d.
Machine drill men	10	5	11	7
Hand-drillers	8	7	10	7
Mullockers	7	8	7	9
Surface labourers	7	1	9	7
Blacksmiths	9	9	12	9
Carpenters	10	7	12	10

During the year 1906 and the greater part of 1907 there was a scarcity of skilled and unskilled labour in the several districts in which operations have been undertaken on an increasing scale, while many wage-earners left the settled camps to prospect for new deposits, and thus more fully participate in the benefits of Queensland's steady expansion as a field of mineral production.

CHAPTER X

NEW SOUTH WALES

Review of Mineral Production

1. Comparisons with Victoria.—2. Gold discovery in 1851.—3. Progressive totals.—4. Silver-lead.—5. Gold-mines.—6. Mount Boppy.—7. Cobar copper.—8. Tin-fields.—9. Newcastle coal.—10. Kerosene shale.—11. Precious opals.—12. Diamonds.

1. New South Wales, the oldest and most populous division of the Australian Commonwealth, is frequently submitted to comparison with the neighbouring State of Victoria. Comparative references are made to their wealth, population, resources, politics, and, more often still, to the merits of their great capitals—Sydney and Melbourne—which vie with each other for recognition as the grandest city of the Southern Hemisphere. From the mining standpoint the two States present remarkable contrasts, although the records of their primary development—of salvation from the depths of industrial depression—appear to be closely related. Gold was discovered in New South Wales before Ballarat and Bendigo were known—indeed, it was the exodus from the southern settlements in 1851 to newly proclaimed finds in New South Wales that prompted Victoria to offer inducements for the more vigorous search for fields of her own, which might serve as a counter-attraction. How marvellously successful were her efforts must be shown in the chapter upon the Victorian gold-fields. But it may be mentioned that, while gold has remained to this day almost the entire support of the mining industry of the Southern State, in New South Wales the yellow metal was speedily relegated to a position of subordinate importance amongst the mineral products of the country. Victoria and Western Australia are the great gold-producers. New South Wales and Queensland enjoy renown for the diversity of their mineral yield.

2. Gold had been officially recorded by a Government surveyor —James McBrian—in 1823, but not till 1851 was a find made of sufficient importance to warrant active development. This was

the discovery made by Edmund Hammond Hargraves, not accidentally, but as the result of a search conducted by him in the light of experience gained in California, to which land the great rush of gold-seekers occurred in 1848–1849. Nowhere in Australia, despite the surface richness of many of its gold deposits and its considerable population of aborigines, has the gold-prospector received guidance from ancient workings. The natives appear to belong to a degree of civilization too low for them to have appreciated the possibilities of the metal.

In 1852 the gold production of New South Wales reached £2,660,950—a high-water mark in the history of this branch of mineral industry. Falling to £317,240 in 1888, the production has of late years averaged £1,000,000. Copper became a product of industrial importance in 1869, tin in 1873, and silver-lead, with the rise of Broken Hill, in 1884. Coal-mining had been carried on long before the metal deposits were discovered, but its active development can only be said to commence about the time of Hargraves' find of gold.

3. The steady progress of the mineral industry of the State may be shown by the following official compilation of yields for the last five decades :

	Total Value.
	£
1887–1866	16,724,300
1867–1876	18,129,500
1877–1886	22,422,900
1887–1896	46,772,500
1897–1906	60,762,500

During the last three years the increase in value of output, in part due to the strength of the metal market, and in part to an augmentation of quantities, has been remarkably satisfactory. The aggregate valuation for 1906 was 28 per cent. higher than that for 1904.

Upon reviewing the list of minerals accounting for these totals, it is seen, taking the returns for 1906, that the numerous products stand in order of significance as under :

	Yield.
	£
Silver-lead	2,862,973
Coal	2,337,227
Gold	1,078,866
Copper	789,527
Zinc	292,806
Tin	255,744
Coke	110,607
Opals	56,500
Antimony	52,645
Oil shale	28,470
Bismuth	5,700

Also included in the list, upon which the statistics of the Mines Department are based, are iron (from scrap), Portland cement, alunite, diamonds, ironstone and limestone flux and marble.

4. Of the metallic minerals, silver and lead are seen to be far in advance of gold and copper. In the Broken Hill silver-lead-zinc-field (to which subsequent chapters are devoted), New South Wales can boast of the most famous producing centre for these three closely related metals in the world. Discovered in the desert interior some twenty-five years ago, the Broken Hill or Barrier silver-field has since recorded a yield of £50,000,000 and cash dividends amounting to £13,000,000. Its output shows no signs of reduction. Outside the Barrier, the production of silver and lead is comparatively insignificant, being limited to small contributions from the Peel and Uralla, Cobar, Lachlan, and New England mining districts.

5. Cobar, situated 460 miles by rail to the north-west of Sydney, is the chief centre of gold and copper mining in the State. The *Great Cobar* is the premier copper-mine of New South Wales, and *Mount Boppy*, 27 miles from Cobar, the chief gold-mine. The former also produces considerable quantities of gold, which is refined from the copper at its Lithgow works.

At one time the *Cobar Gold-Mines, Limited*, was a leading producer, but has recently entered the transition stage between free-milling and sulphide ore treatment. Other gold-producing fields of note, in their relation to Cobar, stand with their 1906 records as under:

	Quartz Gold.	*Alluvial Gold.*
	ozs.	ozs.
Cobar	48,091	—
Lachlan	33,113	3,345
Mudgee	18,301	3,533
Peel and Uralla	15,862	549
Bathurst	11,045	1,891

6. The *Mount Boppy* crushed 72,976 tons of quartz in 1906 for a yield worth £126,000, or 34s. 6d. per ton. This mine was discovered about eight years ago, and vigorously developed by an English company. In a report for the Government, Mr. J. B. Jaquet gave some interesting particulars of the deposit exploited, and stated that payable ore had been found in the upper levels for a distance of about 1,300 feet, the bodies varying in width from 6 to 50 feet. Certain irregularities in the form of the deposit, which occurs in altered Silurian slates and schists, led to the belief that the stopes in one section of the mine were terminated by a 'slide.' This is held to be a misleading misnomer by Mr.

Jaquet, who considers the deposit to be an inverted 'saddle,' and notes certain comparisons with the anticlinal silver-lead deposit of Broken Hill. The oxidized ore is composed essentially of quartz, with a small admixture of oxide of iron, and the unoxidized ore of quartz with iron and arsenical pyrites, galena, and zinc-blende. Gold is said to be always present in an extremely fine state of division. Copper is present only in insignificant quantities. The ore, which is more easily treated than that from many other Cobar mines, is crushed by gravity stamps, and subjected to amalgamation. Concentrates are roasted in Edwards duplex furnaces, while the sands are cyanided in ordinary leaching-vats, and the slimes by a filter-press process. The mine is under the control of the well-known firm of Messrs. John Taylor and Sons, whose interests are in India, Tasmania, Sudan, and other countries.

The Lachlan gold-mining district is one of a multitude of small producers, calling for no mention in this broad review. In the Mudgee district, *Mitchell's Creek* is the only noteworthy producer, treating ore worth approximately £2 per ton. This division will always possess great historical interest on account of the 'Kerr's Hundredweight,' which was found there in 1851 by a native in the employ of Dr. Kerr. It was this find—a mass of gold weighing 106 pounds—which greatly increased the rush of gold-seekers to New South Wales and excited the wild stampede, to check which Governor Sir Charles Fitzroy declared would be as futile an attempt 'as to try to stop the influx of the tide.' To-day operations upon the Mudgee fields are unimportant.

7. The mainstay of the copper-mining industry in New South Wales, which had produced this metal to the value of over £9,000,000 up to the end of 1907, is the *Great Cobar* mine, which was purchased for £800,000 cash by a London company in 1906. In some respects the Cobar district resembles that of Broken Hill, being subject to wide ranges of temperature, with a small, uncertain rainfall (which calls for careful conservation), and appears bare and unattractive. The *Great Cobar* mine, however, is fortunate in the possession of several remarkable qualities. Its deposits are wide, the ore is practically self-fluxing, and contains gold with the copper, providing a constant revenue unaffected by metal-market fluctuations. A depth of over 1,000 feet has been attained, and the ore, consisting chiefly of iron and copper pyrites, with gold and silver, occurs in chutes from 30 to 50 feet in thickness. An average value for the ore-reserves has been estimated at: Copper, 3·7 per cent.; gold, 1·78 dwts.; and silver, 11·2 dwts.

per ton. The *Great Cobar* has recently been the fourth producer of copper in Australia, standing below the *Mount Lyell, Wallaroo, and Moonta,* and *Mount Morgan.*

8. The bulk of the tin yield of the State is derived from the Tingha and Inverell divisions of the Peel and Uralla districts. Here there are about thirty pump dredges in operation, dealing with ground averaging from 2 to 2½ pounds per yard. There are also a large number of small working-parties 'fossicking' in the surface alluvial, in the hope of falling upon a rich patch to repay their labours; but, as a rule, the returns are low, and provide a poor exchange for the earnings to be made in less precarious pursuits.

9. Coal was discovered in New South Wales in 1797 in the Illawarra district, and later near the mouth of the River Hunter, where Newcastle now stands as the greatest coal-mining centre in Australasia. From the inception of the industry, which may be considered to date from 1825, to the end of 1907, roughly 140,000,000 tons of coal have been produced, with a value of £53,000,000. Recent progress may be shown as follows:

	Output.	*Value per Ton.*
	tons.	s. d.
1885	2,878,863	9 3·7
1890	3,060,876	8 4·3
1895	3,738,589	5 10·3
1900	5,507,497	6 0·7
1904	6,019,809	6 7·5
1905	6,632,138	6 0·5
1906	7,626,362	6 1·5

The coal-bearing districts, known as the Northern, Southern, and the comparatively unimportant Western fields, are of enormous extent. Their product is of high quality for steaming, domestic, and gas-producing purposes, and enjoys a wide Australasian and foreign trade. Shipments are made to the Straits Settlements, Chili, Mexico, and the Philippine Islands, and other distant lands.

10. The extensive deposits of kerosene shale, or torbanite, which have been worked in New South Wales for many years, are of peculiar interest. Although the value of yield has fallen of late, prospecting is still being vigorously performed in the *Capertee* and *Wolgan* valleys and other parts of the State about 100 miles to the east of Sydney. In his report upon the occurrences, Mr. J. E. Carne, F.G.S., states that the mineral (if strictly distinguished from cannel) is confined to Scotland, France, Australia, and probably New Zealand. Good kerosene shale ignites readily, and

throws off a smoky flame. It is brownish black, and is especially characterized by its conchoidal fracture. The products to be obtained by processes of distillation and refining range from heavy lubricating greases and solid paraffins to machine and illuminating oils, naphthaline, and gasoline. The exported shale gained an excellent name in the market in view of its exceptional purity.

11. The precious opal, which has found high favour as a gem for many centuries, in the past even more particularly than to-day, is now won almost exclusively from New South Wales. Stones to the value of over a million sterling have been exported.

The most productive region is *White Cliffs*, in the Albert mining district. Lately a new field has sprung up in the Walgett division, near the Queensland border, and the finds have inspired the hope that an expansion of operations may compensate for the decline of the former field. The value of the stone ranges from 10s. to £50, or even more, per ounce. Opal-digging is a hazardous venture, and good fortune can rarely be ascribed to any peculiar discernment on the part of the workers, who trench or sink for the stones to shallow depths, ' blindly,' or below a surface find. Opals of a poor class—termed ' candle-box stuff ' by the miners—are difficult to dispose of, but stones exhibiting fine qualities meet with a ready sale.

12. That New South Wales has been a small, though fairly regular, producer of diamonds for thirty or forty years is a fact but little known. The occurrence of the stone is widespread, but in quantities insufficiently abundant to form the basis of a remunerative industry. To date the yield has approximated 160,000 carats, worth £110,000, won from alluvial.

The stones are almost invariably of small size, so that the discovery of a flawless, straw-coloured diamond weighing 28 carats in 1905 occasioned great astonishment. But diamonds in New South Wales are of little more than scientific interest, and in the light of present knowledge this minor division of the State's varied mineral resources does not appear destined to gain greater commercial distinction.

CHAPTER XI

NEW SOUTH WALES—*Continued*

Broken Hill: Silver, Lead, and Zinc

1. A field of wide renown.—2. Unattractive township.—3. Boundary-rider's discovery.—4. Early disappointments.—5. Disputed formation.—6. Character of ore.—7. Associated Minerals.—8. Output statistics.—9. Meagre rainfall.—10. Coal and timber.—11. Four mining systems.—12. The 'open stope.'—13. Bulkheads.—14. Stope and block methods at Central Mine.

1. The Broken Hill or Barrier Range mining-field, situated in the desolate interior of Australia, some 350 miles to the north-north-east of Adelaide, constitutes the most important centre of silver-lead-zinc ore-production in the world. With an aggregate yield of £50,000,000 to date, and an annual output to the value of between £3,000,000 and £4,000,000, the industry holds a position of pre-eminence over all other mineral fields of Australasia, excepting Kalgoorlie. Being a popular field for European speculative investment, and now easily accessible by rail from the South Australian capital, Broken Hill has received a due share of outside attention from the financial world, whilst the great bulk of its ore-bodies, and the associated problems of exploitation, have drawn upon it the keen scrutiny of mining men. Metallurgical methods and practical details of working expenditure, however, have frequently been obscured under the veil of official secrecy.

2. The Barrier region of New South Wales is, in its natural features, as unattractive as the auriferous districts of Western Australia. The camp itself stands in a dreary stretch of rolling and slightly broken country near the boundary of South Australia. Being possessed of an insignificant rainfall ranging from 4 to 16 inches, and of an annual evaporation of no less than 7 feet, only a skimpy vegetation of dwarf native shrubs (mulga and salt-bush), and of stunted gums—rapidly cleared off for miles around the centres of population—is supported by the district. In some

seasons grasses spring up plentifully, while the hardy pepper-tree, cultivated about the town, relieves the dreary aspect with its monopoly of bright green foliage. The curse of the dust-storm is experienced in a form of more painful severity than even Kalgoorlie knows. Rising up with little warning, these hurricanes of grit and dust, with a front extending for many miles, become an affliction of no small economic significance, throwing over the camp the darkness of the densest London fog, and often so fierce in its onslaught as to necessitate a suspension of surface operations. Despite the natural discomforts and evil consequences of these sandy tornadoes and the tropical extremity of its summer heat, the climate is generally healthy, and remarkably pleasant at some seasons of the year. Broken Hill—or 'Silver City'—has a population of over 30,000 souls, of whom mine employees exceed 8,000 men. It is laid out with perfect symmetry, parallel to the line of lode, and is provided with trams, electric light, a telephone system, good club-house and hotels, a substantial town hall, and a daily newspaper. The concentration of business, mining, and residential centres gives the city an advantage of orderly compactness over the youngest desert-city of Kalgoorlie and its mining suburb, Boulder. Recognizing their foremost obligations to the industry, and, perhaps, with a view to familiarizing the visitor with the minerals of the belt, the early 'city fathers' of Broken Hill furnished the streets with names of apt selection. Through Blende, Argent, Crystal, Beryl, and Wolfram Streets cut Oxide, Chloride, Gossam, Sulphide, Iodide, and Bromide Streets—titles instructive and distinctive enough, but apt to raise in one's mind the possiblity of some startling new mineral compounds at the cross-roads.

3. Just as Coolgardie led to the discovery of Kalgoorlie—the magnet which drew away the mining population and occasioned the mother-field's neglect—and just as the Rand was responsible for the desertion of the older De Kaap gold-field, so was Broken Hill discovered and speedily opened up owing to the pre-existing Thackeringa and Silverton camps to the south-west, whose names soon fell from the list of prosperous mining centres. In 1883—or forty years after the discovery of the Barrier Range by the explorer Sturt—Siverton appeared to be a camp of great promise. The excitement of its rush fired the minds of all living in this desolate region with hopes of further discoveries. In September a boundary-rider named Charles Rasp,* guided by the dense, dark appearance of the ridge, pegged out an area of 40 acres on

* Mr. Rasp died in 1907.

what was subsequently shown to be the manganiferous ironstone capping of the famous Broken Hill lode. That he had found a great deposit of tin-ore was his fortunate misconception, for otherwise the mass might have been ignored as valueless. Rasp told the manager and his mates on Mount Gipps Station of his good fortune, and a small syndicate of seven, each subscribing £70, was formed to peg out an additional 258 acres along the deposit. Work was commenced, and assays made for tin—of course, with negative results. The little syndicate determined, however, to sink a shaft, but this failed to reveal the richness of the ground, whose values had been so extensively leached from the upper zone by surface-waters.

4. When the funds and patience of the party became nearly exhausted, the oft-recited incidents occurred which have given to the early records of the field an element of romance almost without parallel in chapters of mining history; for the tales are true. The shareholders had been raised to fourteen, and when the prospects were at their worst, many efforts were made by the less optimistic members to dispose of their interest for a few pounds. But the more picturesque illustration of the early vicissitudes of fortune—not infrequently cited to the faint-hearted speculator as an example of the opportunities of mining investment and the danger of losing hope—is presented by the game of euchre played by M'Cullock and Cox, of Mount Gipps Station, to decide whether the latter should pay £100 or £150 for a fourteenth share. M'Cullock won, and Cox was obliged to pay the bigger price for what represented, a few years later, a fortune of £1,500,000 sterling.

Eventually rich chloride of silver was discovered in Rasp's shaft by a native in the service of Mr. W. Jamieson, then manager, and in August, 1885, the *Broken Hill Proprietary* was formed, with a capital of 16,000 shares of £20 each. Of these, the original fourteen holders received 14,000. From the inception of this famous company, of which the *British, Block 10*, and *Block 14 Companies* were subsidiary flotations, the development of the field proceeded rapidly and, with occasional checks and periods of depression, successfully up to the present day.

5. The ridge along which run the massive ore bodies of the field, operated by ten producing companies, trends north-east and south-west for a distance of nearly 2 miles. Although the form of the ore deposit which crowns the ridge, and its mineralogical characteristics, have been abundantly revealed in mine-workings down to 1,300 feet, the question of genesis still remains a point of

PANORAMIC VIEW OF BROKEN HILL SILVER-LEAD MINES.

keen contention among geologists and miners. Messrs. Pitman and Jaquet, geologists in Government service, Mr. E. J. Horwood (mine manager of the *Proprietary*) and Mr. G. Hebbard (manager of the *Central*) favour the hypothesis that it is a segregated lode of 'saddle' type, as exemplified at Bendigo; while Professor Gregory, Mr. John Warren, and many others oppose the theory. The problem is considerably complicated by the metasomatic replacement which has indubitably occurred along the walls of the lode. Whatever the true interpretation, the term 'saddle' conveys a good impression of the form of the deposit in the upper levels, where a 'saddle-cap' (or Cornishman's 'wallow of ore,' according to the point of view) is observable with diverging branches of ore dipping away on either side. The downward continuation of the more persistent of these two bodies (the eastern leg, or the true fissure) is a point of vital importance which mining operations alone can decide. The western leg commonly takes the form of a bulging 'stump,' whereas the eastern dips down steeply—pinching and making, with a general tendency to decrease in width. The anticlinal axis diverges considerably from the horizontal in some sections of the line, so that the 'saddle' occurs at varying depths. In the *Central* mine the maximum width of the 'saddle' (nearly 400 feet) before the branching occurs appears at a depth of 500 or 600 feet below the surface. In the *South* mine a vast mass of ore, as wide and nearly as rich as that in the *Central*, has been opened up in the last year or so at greater depth.

6. The country rocks are chiefly crystalline gneisses (often greatly contorted), micaceous schists, quartzites, and garnetiferous sandstones, all so highly metamorphosed as to make it debatable whether they are igneous or altered sedimentary rocks. The alteration of the sulphide ores has occurred to great depth and to an advanced degree. The most noteworthy features of this zone are—or were (for little now remains)—(1) the inclusion of Kaolin masses; (2) the comparative poverty in zinc, which forms so important a constituent of the unaltered sulphide ore; and (3) the occurrence of rich silver and lead compounds, formed by chemical agencies during ages of water percolation. Carbonate of lead, the chlorides, bromides, and iodides of silver, and native silver, comprised the production of the early days, and even as late as 1892 'the mention of the term "sulphides"' (says Mr. Warren in his 'Reminiscences of Broken Hill') 'would cause a shock to the nervous system of most of the managers on the field.'*

* Transactions of the Australian Institute of Mining Engineers, vol. ix., part i.

In 1893, however, the treatment of the unaltered sulphides was attempted on a working scale, and mechanical concentration has been effected widely and profitably from that period, with a steady improvement of efficiency.

7. The argentiferous sulphides of lead and zinc occur intimately associated, as the operations necessary to effect their ample separation by fine grinding fully demonstrate. The gangue consists of rhodonite, quartz, garnet, and calcite; accessory minerals are iron and copper pyrites, and more rarely mispickel, wulfenite and fluorspar. It is generally found that the greater hardness of the rhodonite ore, as opposed to that characterized by calcite, is compensated by a higher value in silver and zinc. It drills and shoots badly, and is often met with in masses of such compact and resisting form as to damage drill and temper of the best machine-man. Between the oxidized and sulphide zones a layer of very valuable ore was found coating the sulphides where-ever the dry ore, rich in silver, came in contact with them. In reference to this curious class of ore, of more scientific than commercial importance, Mr. G. B. Jaquet has remarked: 'Resembling soot somewhat in appearance, it has been named "sooty sulphide" ore by the miners. . . . It contains up to 250 ozs. per ton, and frequently as much as 12 per cent. of copper.' * Another type of ore, more frequently encountered, is the argentiferous garnet-quartz rock, which contains 5 to 60 ozs. of silver per ton in sulphide, and a little lead and zinc.

8. The value of the ordinary sulphide ore, which occurs in this massive body running in width up to 400 feet, may best be shown in connexion with a broad review of the industry's achievements to date and the results of recent operations. Output statistics are complicated by the fact that the metallic contents of the major portion of the field's concentrate shipments are recovered outside New South Wales. The net values of the ore, concentrates, and bullion declared to the Customs Department for export by silver-lead-mines of the State (returns from districts other than Broken Hill being inconsiderable) for the years 1903190–6 are as follows:

Year.	*Net Value.* £
1903	1,626,576
1904	2,249,482
1905	2,717,864
1906	3,156,863

* 'Report on the Geology of the Broken Hill Lode,' Memoir Geological Survey, N.S.W., No. V., 1894.

The gross output value and tonnages of ore raised during 1905 and 1906 were:

	1905.	1906.
	£	£
Gross value	3,300,000	3,540,000
Sulphide tons	1,327,877	1,231,193
Oxidized tons	11,157	20,943

Dividends in 1906 totalled £868,327.

Although the ore contains from 10 to 18 per cent. of zinc, this metal at present only contributes a comparatively small share to the total output.

The milling capacities of the ten noteworthy mines run from 2,000 to 12,000 tons per week, and ore reserves aggregate about 12,000,000 tons, containing: Lead, 14·5 to 22 per cent.; silver, 4 to 14 ozs. (approximate average, 11 ozs.); and zinc, 10 to 18 per cent.

Numerous increases of plant were effected during the recent two years of high lead and zinc quotations, notably in the case of the *Central*, *South*, and *British* mines.

9. The Barrier mines have long been at the mercy of a small and precarious rainfall for their supply of water, but schemes have been formulated to place them in a position of greater security.

The chief source of supply is the Stephen's Creek reservoir, situated 9 miles from the town, which was completed in 1892. The creek's catchment area is upwards of 200 square miles, but with an average fall of 9 inches and an annual evaporation of 7 feet, it is rarely possible to claim a reserve of over eight or nine months' supply. A drought of five or six months is not exceptional. Charges for water from the creek were formerly on a sliding-scale, but now consumers pay uniformly 5s. per 1,000 gallons. Some companies draw upon underground and private dam supplies.

The average consumption of water per long ton milled is, for all purposes, 200 gallons. At the *Proprietary*, even when a considerable quantity was used for 'water curtains' to keep a smouldering mine-fire within limits, 170 gallons per ton milled was utilized.

10. Coal is an expensive item, the Newcastle, north-south-west product being delivered at the mines for 30s. per ton. Power costs may be estimated at 1d. to 1½d. per horse-power per hour. In 1906 about 115,000 tons of coal were used, and the total horse-power of engines, motors, etc., is estimated at 14,400. Only one

mill—the *Central*—is driven electrically. One of the outstanding features of Broken Hill mining economy has always been the enormous amount of imported timber used in underground operations. When the Nevada, or square-set, method of stoping was in vogue, the timber charge per ton was far greater than it is to-day under systems in which waste rock or residue filling is employed for purposes of mine support. Of present-day mining costs, from 1s. to 1s. 6d. per ton must be debited to timber. The Oregon pine is commonly used in pieces 10 by 10 inches, also 10 by 4 inches and 10 by 2 inches.

Over 16,000,000 superficial feet of this timber, whose well-known qualities have enabled it to withstand all competition from Australian products, were used by the industry in 1906. Though unable to bear heavy stress against the grain, it possesses exceptional powers of resistance to pressures in line with it, is light, and easily worked. The cost of the timber, which is dispatched from America ready squared, averages 15s. or 16s. per 100 superficial feet.

MINING SYSTEMS.

11. The divers difficulties of mining the immense vertical ore-bodies of Broken Hill have led to the adoption, at different times and under varying circumstances, of four main systems of exploitation, with numerous modifications. Upon the *Broken Hill Proprietary* an enormous bulk of surface ore and waste rock (used for stope-filling) has been excavated by open-cut operations. This work, by means of which the crown of the ridge, after which Broken Hill was named, has been entirely removed, reached the limits of economical application a few years ago. The open-cut system is, therefore, one of the past.

The careless and unscientific methods of underground stoping of the early days were superseded in 1887 by the 'square-set' or 'Nevada' system of timbering, which was introduced by American engineers. The merits and defects of this system, which converted the underground workings into veritable forests of timbering, have been widely debated. Despite the large amount of timber required, its frequent inability to withstand the enormous pressures of the walls and the dangers of fire, the method has no doubt served its purpose admirably in its application to the softer sections of the deposit. With 10 by 10 inch timber used exclusively, excepting the 10 by 2 inch laths for the floors, the sets are commonly built with 6-feet caps, 5-feet struts, and 7-feet legs. They are carried up as close to the working face as possible, allowing for the requirements of working space and the protection of timbering from the effects of blasting. Two prominent defects of the system, unless accompanied by waste filling, have been seriously illustrated by mine-fires and by a caving-in of vast masses of ground upon the hanging-wall side of the depleted ore-bodies.

The subsidences which have occurred, and are known as 'creeps,' have been rendered the more serious in their consequences by the primary fault of early engineers in constructing mills and works in dangerous proximity to the lode on its foot-wall side. The most critical of these 'earth movements' occurred at the *Central* mine in 1905, when a mass roughly of the shape of an inverted pyramid, and comprising some 9,000,000, or 10,000,000 tons of ore, rock, and filling, suffered movement, effecting the partial or complete destruction of gangways, shaft, etc., and the displacement of buildings and machinery. The subsidence of a few feet at the surface reflected chaos underground.

12. At the present day square-sets are employed only to a very limited extent; they are frequently employed where the ore is treacherously friable, and also in connexion with the 'stope and block' system. The practicability of introducing a cheaper method, better adapted to the dense sulphide ore, was first proved by Mr. Sampson, of the *British* mine, and is now very widely employed, with several modifications, along the lode, under the name of the 'open-stope system.' A drive is carried in ore along the lode, and a flat section of the body stoped out from wall to wall. To withstand the pressure of the sand filling to be subsequently introduced, the drive timbering is very strongly constructed.

The variation of drive timbering seen in the *Proprietary* mine, similarly aiming at a maximum restriction of pressure upon the legs and relief of the cap-pieces, involves the construction of short legs, shoulder and crown pieces within the main posts, relieving the outer timbering against all stress. The methods of timbering adopted have admirably withstood the test of time.

13. Over the whole of the sill-floor of the flat section stoped out are placed 10 by 4 inch 'bottoms' in 15-feet lengths, over which the filling is introduced. The stope is then carried up in horizontal strips, and the filling upon which the miners operate rises coincidently. To hold up the back, bulkheads or cribs of 10 by 10 inch timbering are temporarily erected, the old ones being displaced by new as the growth of filling necessitates. Upon nearing the level

above, ordinary diagonal stoping is commenced, by means of which it is easier and safer to approach the worked-out ground overhead, and to win every ton without mishap.

In some cases it is found advisable to carry the stopes on the 'rill' throughout, full advantage being taken thereby of the natural slope of the inpoured tailings, which in flat work demands more labour for its proper disposition. Bulkheads are, however, more difficult to erect on the sloping waste filling. Chutes and ladder-ways are constructed of a double square set of 10 by 10 inch timbers. In this system of operation the open spaces are small, and the chances of mine-fires, which have proved a serious factor in the past, are reduced to a minimum.

14. At the *Central* mine the manager, Mr. Hebbard, introduced a 'stope-and-block' system for working the immense widths of ore encountered in the property. In this case cross-cuts are driven from a main drive in the country-rock across the lode to the opposite wall every 50 feet, or at greater distances if conditions warrant. Alternate blocks are then stoped and filled, the others being left as a support until they can also be safely extracted.

A run of square-set timbering is carried up on each side adjoining the pillar, in order to assure greater security of the filling mass when the time arrives for the extraction of the intermediate blocks. Mr. Hebbard expressed the opinion to the writer that the pillar system is the most economical which can be applied to Broken Hill ore-bodies exceeding, say, 100 feet in width. Owing to the compression of the filling by the broken ore, the natural settlement of the mass, and the effect of water leaking through, it is anticipated that the pillar will be extracted as readily and safely as the original stopes on each side of it.

CHAPTER XII

NEW SOUTH WALES—*Continued*

BROKEN HILL: METHODS OF EXTRACTION

1. Difficulties of concentration.—2. Zinc recovery.—3. Broken Hill Proprietary.—4. Ore reduction.—5. Regrinding machines.—6. Tables and vanners.—7. Slime treatment.—8. Zinc processes.—9. Granulation.—10. Magnetic separation.—11. Acid flotation methods.—12. Zinc Corporation.—13. Unpopular labour field.—14. Standard of wages.

1. SMELTING operations at Broken Hill were suspended many years ago. It has been the primary object of the mining companies to win a high-grade silver-lead concentrate, and to leave the tailings, rich in zinc-blende, for independent or subsequent treatment. Companies dispatching to smelting works in South Australia or New South Wales are content with a concentrate of 60 per cent. lead, or less, whilst those shipping oversea may find it profitable to concentrate more closely. In the silver-lead product there is inevitably a considerable percentage of zinc, ranging from 6 to 10 per cent., for the association of the blende and galena, both argentiferous, is, unfortunately, very intimate. This percentage represents absolute loss to the producers, who are, indeed, penalized for an excess of 10 per cent.

The gangue minerals with which the blende and galena are intermixed vary materially in different sections of the lode, and ncessitate corresponding variations of treatment. Of greatest importance, from the metallurgist's point of view, are—

	Specific Gravity.	*Hardness.*
Rhodonite	3·5	5·5–6·5
Quartz	2·5	7·0
Garnet	4·0	7·0
Galena	7·25	2·5
Blende	4·0	4·0

Calcite, soft and light, is a constituent of some importance, whilst the quartz and rhodonite are nearly always present in the sulphide zone in varying proportions.

2. The great weight of the galena enables a clean concentration to be made by jigs, tables, and vanners, but the similar weights of the zinc-blende, rhodonite, and garnet make the separation of the valuable mineral by gravity methods a matter of economic impossibility. Up to recent years the blende product has consequently been dumped, and to the extent of several million tons.

A new mill has lately been erected by the Sulphide Corporation at the *Central* mine, which will be unique as the winner of both lead and zinc concentrates from the ore in one continuous series of processes, not excluding the sulphides in slime. The feed of the mill is to be crude ore and the residues true 'waste' in readiness for underground filling.

3. For illustrative purposes brief reference may be made to the 'New' mill of *Broken Hill Proprietary*, through which 6,000 tons of ore are passed weekly. The 'Old' mill puts through a similar tonnage, and represents a standard of efficiency little below that of the more recent installation. The two plants between them make the company the greatest silver-lead producer in the world, standing, in its relation to the next of importance, which are American, as follows:

Recent Yields for Fiscal Years.

	Silver.
	ozs.
Broken Hill Proprietary	4,615,000
Tonopah Mining Company, Nevada	3,194,000
Federal Mining and Smelting Company, Cœur d'Alene	3,920,000
Bunker Hill and Sullivan	1,598,000
Anaconda Copper Company	2,980,000
Nipissing, Canada	1,500,000

	Lead.
	tons.
Broken Hill Proprietary	57,248
Bunker and Sullivan	40,133
Federal Mining and Smelting	63,029

The *Federal* comprises a group of five consolidated properties.*

4. At the *Proprietary* the ore, hoisted through the Delprat shaft, is trucked by endless rope haulage to the mill bins, where the grizzly oversize is crushed in Gates gyratory breakers and thence delivered into the Cornish Roll section of the plant, whose efficiency is above the average for the field. In the *Proprietary* mill, where a product for feeding the jigs capable of passing through 3·32-inch diameter holes is aimed at, practice involves the scientifically sound principle of stage-crushing

* *Mining and Scientific Press*, June 22, 1907.

CONCENTRATES FROM DELPRAT ZINC PLANT.

HORSES GOING UNDERGROUND. PROPRIETARY MINE.

through three graduated sets of rolls, so that there is no return of coarse product to a machine through which it has already passed. Owing to the greater hardness of the low-grade rhodonite ore, the three sets of rolls effect a partial classification of the ore into value grades by distinctions of hardness.

The final roll product is passed through an upward current classifier—more efficient sizing classifiers are being introduced along the Hill—which removes the slime and fine sand for dispatch to the table and vanner sections. The underflow feeds coarse jigs of the May plunger type, with five compartments.

The first two hutches return a concentrate worth 60 per cent. lead. The third and fourth hutches make a middling (worth about 10 per cent. lead, 19 per cent. zinc, and 10 ounces silver) for regrinding. The tailings in the fifth contain 3 or 4 per cent. lead. On certain other mines coarse jigging produces a concentrate worth from 65 to 73 per cent. lead.

5. The middlings are reground in Ball Mills, whose pulp, with slime eliminated, passes to intermediate and fine jigs. Broken Hill has been keenly engaged in its problems of fine grinding, in company with many other centres of metallurgical progress during recent years, and the investigations conducted in this direction have been second in thoroughness and importance only to those made in respect of experimental zinc separation.

Grinding-pans, Chilean mills, Heberle disc-grinders, and tube mills have been extensively employed with varying success. Extreme fine grinding leads to the production of excessive slime, which is a difficult material to deal with.

6. Returning to *Proprietary* methods, it must be noted that the various overflows from the roll and jig plants run as a combined feed to the vanner and table department on a lower floor. The percentages of ore-recovery attributable to the various units have been stated as follows:*

	Per Cent.
Coarse jigs	47·5
Fine jigs	13·5
Wilfley tables	3·15
Luhrig tables	3·15

Fine tailings are dispatched to the zinc plant for the extraction of blende, and the slimes to sintering works, where the *Proprietary* is able to convert them into a valuable product for use at the company's smelters at Port Pirie, on the South Australian

* 'Ore Treatment at the Broken Hill Proprietary Mine,' G. D. Delprat, Transactions of the Australian Institute of Mining Engineers, September, 1906.

coast. Opinions differ as to the extent of work that should be thrown upon the Wilfley tables, and several metallurgists are in favour of reducing it, in conjunction with finer grinding and an extension of the vanner's sphere of utility. Much depends upon the subsequent disposal of slimes and tailings. At the *Proprietary*, where 12,000 tons of crude ore are treated per week, there are seventy-five Luhrig tables and thirty Wilfleys in the lead-mill. The recovery percentages recorded upon the field vary from 66 to 74 per cent. of the ore contents.

7. There are enormous accumulations of slimes along the lode. The *Proprietary* company adopts a treatment method only practicable in conjunction with its smelting works. The settled slimes, comprising 12½ per cent. of the crude ore, are dried and caked, then transferred to sintering works four miles from town, where the dry blocks of slime are built into kilns and partially desulphurized by the sintering or heap-roasting process. By this means sulphur is reduced from about 12·5 to 7 per cent., and a product formed, of value in furnace work.

The rich slimes of the *Central* and *Block 10* mines are treated by the 'Granulation' or Cattermole process, which is applicable to sand and slime.

8. With dumps of tailings to the amount of five or six million tons, and containing from 15 to 22 per cent. of zinc, standing defiantly along the ridge for many years, it will be readily understood that the minds of managements and metallurgists have long been exercised over the realization of these important assets. Many processes have been in time evolved, and yet the zinc concentrates so far produced represent an insignificant proportion of the mineral brought to the stage of reduction immediately or approximately preceding the final work of separation. The processes applied, of which some are peculiar to Broken Hill, may be tabulated as under :

Cattermole, Ballot, or granulation.
Delprat or salt-cake.
Potter or acid.
Elmore vacuum.
De Bavay or water flotation.
Magnetic (Mechernich).
Magnetic (Ullrich).

9. With the exception of work undertaken by Mr. Ullrich on magnetic principles, the Cattermole or 'granulation' process adopted by the *Central* mine was the first utilized commercially

upon the field. This method can treat slime and coarse sand. The tailings treated at the *Central* contain 21 to 22 per cent. zinc, 5 per cent. lead, and 6 ounces of silver, and are reground in pans (machines of growing popularity from north to south of the field). The pulp, sand, and slime is then elevated and fed into a series of six mixing or agitation boxes. In No. 1, sulphuric acid is added for the purpose of cleansing the particles. In the next four boxes, which are connected by holes at the bottom of the partitions, the charge is agitated with oleic acid, and in the sixth box with steam, which creates bubbles, further contributing to the flotation of the oil-coated sulphide grains and particles. The discharge from the agitation boxes runs into a spitzbox, from which the overflow of oil and bubble suspended concentrates passes into cloth-bottomed settling vats. Figures provided to the writer in 1906 showed the recovery of a concentrate worth 48 to 49 per cent. zinc, 8 to 9 per cent. lead, and 13 to 15 ounces silver; and tailings, 5 to 6 per cent. zinc, 2 to 3 per cent. lead, and 2·5 ounces silver. An extraction of up to 80 per cent. of the zinc is claimed for the plant.

10. Magnetic separation of the blende from old tailings has also been effected commercially for several years upon the *Central* mine. The first magnetic plant erected did good work, but it remained for the second installation, manufactured by the Electro-Magnetische Gessellschaft, Frankfort-on-Main, to demonstrate the full possibilities of the process. The tailings are dried and classified into three grades, and then passed between two powerful electro-magnetic poles, the upper one cylindrical in shape and revolving, the lower semi-cylindrical and stationary. This feed comprises rhodonite, quartz, blende, and galena, whose varying magnetic properties are utilized; it depends upon the degree to which they are influenced by the magnets into which little chute they fall upon the further side of the poles. Thus, the most highly magnetic minerals (the rhodonite and iron) are not able to drop so speedily as the galena and quartz, which fall into the first receptacle. Intermediate between these falls the moderately magnetic blende.

The rhodonite division is valueless, and can be used for mine-filling. The middle product is a rich blende concentrate, averaging 48 per cent. zinc, and the quartz-galena-blende division provides a product for jigging and table separation. In connexion with other processes of zinc separation, magnetic machines are sometimes used for an enrichment of the concentrate from, perhaps, 43 to 50 per cent. zinc.

11. Another process, which has for several years been utilized on a large scale, is the salt-cake or Delprat process, similar to the Potter acid process, but employing sodium sulphate to effect the flotation of the sulphides instead of sulphuric acid. The *modus operandi* is as follows: Zinc tailings are fed into the 'flotation-box,' which is an inverted pyramid with two pockets at the bottom. One of these is merely useful as a receptacle for any metal rubbish or stones chancing to be included in the feed, and the other is an outlet. Into the box is fed solution of sodium sulphate in excess of the outflow from the bottom, so that there is a constant overflow. The advantage of salt-cake over sulphuric acid alone, as in the Potter process, lies in its giving the liquor a greater density, and thus assisting the flotation of the sulphides. The acid acting upon the carbonates in the ore creates bubbles of carbonic acid gas, which possess a remarkable selective affinity for the sulphides, making them buoyant. Thus the heavy sulphides run off in the overflow, whilst the lighter quartz and rhodonite sink through the box. The properties of the gas-bubbles remind one of the oil in the Elmore and Ballot processes, and of the grease upon the tables of the South African diamond mine, which picks out the valuable diamond from the worthless garnet, olivine, and ilmenite with the infallibility of a calculating-machine.

The *Central* and *Proprietary* mines are shipping annually many thousands of tons of zinc concentrates.

12. Measured by practical results, the work done by the *Central* and *Proprietary* mines for the realization of their assets in zinc has been of the greatest significance. The formation of the Zinc Corporation in 1905, for the purchase and treatment of numerous dumps, has not led to the accomplishment of such practical results as were too forcibly predicted in early reports.

The prospects of a steady expansion of this important branch of the industry are nevertheless hopeful. A method of particular interest, unlike those already referred to, is the De Bavay at the *Broken Hill North Mine*. This process is one of water concentration by flotation, and depends upon the remarkable and delicate buoyancy of the fresh sulphide particles, which fail to overcome the surface tension of the water into which they flow, whilst the quartz, rhodonite, etc., speedily sink.

Although marked by many failures and disappointments, the evolution of zinc processes upon the Barrier during recent years has shown that the recovery of blende from current tailings can be performed by methods of assured economy, and that the production from this source alone, regardless of accumulations upon the dumps, should give New South Wales a high place amongst zinc-producing countries.

LABOUR DIFFICULTIES.

13. Since the disastrous strike of 1892, prosecuted with a bitter determination and attended by hardships and loss, the sorrowful memories of which die hard; since, also, the days of widely prevalent lead-poisoning due to the dust of lead carbonate ores and the fumes of local smelters, the Barrier has never been so popular in labour circles as the Golden West. To the good worker, the contract rates of Kalgoorlie have proved more highly attractive. Yet it is clear that the men upon the Boulder (excepting the few who regard gold-tellurides as a fitting medium for the practical application of communistic principles) are little better off than they would be on the Barrier to-day. Whereas there are certain contrasts between working conditions at Broken Hill and Kalgoorlie—the two chief centres of employment for metalliferous miners in the Commonwealth—there are striking resemblances of climatic and geographical features. Both fields are situated three or four hundred miles from the coast, isolated as islands in an ocean of drear and sandy desert. In neither camp can the miner feel tempted to settle permanently or to seek the comforts of home-life, such as they might enjoy in Victorian or Queensland fields. In the stretch of cheerless canvas 'camps' hugging the Boulder mines, suggestive of an industry that has arisen in a few months, with prospects of as speedy a downfall, and the prison-like barrenness of Broken Hill shanties, dust-stricken and miserable, can be seen the material expression of that spirit of restlessness characterizing the communities of both centres. But while the full-grown industry of Kalgoorlie, whose labour needs have been constant for many years, is able to draw upon a considerable surplusage of unemployed, to exercise discrimination in the selection of workers, to freely dismiss the incompetent and indolent, Broken Hill has been forced to receive with welcome all grades of labour available, good, bad, and indifferent, and has thus been unable to establish a high standard of efficiency.

14. The contract system in force in the Barrier mines has not been rigorous enough to ensure high efficiency.

Just as in 1906 the man who could saw a piece of wood and hammer in nails necessarily considered himself (and was accepted as) a competent carpenter, so have miners had frequently to be drawn from the ranks of other occupations or of the totally unskilled. The levelling influences of unionism prevent the remuneration of the many efficient hands at a rate fittingly in advance of that granted to the dangerously incompetent greenhorn. The obvious discomforts of life in Broken Hill are compensated by a good wage. Miners on day's pay received, when the metal market was strong, 10s. per shift, and contractors, on the average, 13s. 6d. Underground truckers made from 8s. 7½d. to 10s. 6d., and surface labourers 8s. 7½d. per shift. Mill hands average 9s., and carpenters, blacksmiths, etc., 11s. 6d. The bare necessities of life for the single man may be rated at a guinea per week.

In time, no doubt, the ill repute of the district will be dispelled. An extravagant dread of the field has been allowed to influence the mind of miners in outside camps, and to give the district the aspect of a huge death-trap. Having regard to the enormous size of the ore-bodies exploited, it cannot be said that the underground workings are operated on a dangerous system. The fatal accident rate of 2·25 per mille is conclusively proved to be due as much to the gross carelessness or ignorance of the victims as to the normal misadventures inseparable from the progress of underground mining.

CHAPTER XIII

TASMANIA

Mount Lyell Copper-Mine

1. Region of divers interests.—2. Climatic defects.—3. Historical associations. —4. Early exploration.—5. Rock formations.—6. Mount and North Lyell mines.—7. Properties amalgamated.—8. Irregular deposition.—9. Mineralized schist-bands.—10. Remarkable cupriferous clay.—11. Pyritic smelting.—12. Transportation of ore.—13. Furnace practice.—14. Metallurgical principles.—15. Analyses of products.—16. Matte conversion.—17. Operating results.—18. Labour position.

1. Geographically, industrially, and historically the Queenstown district of the wild and fertile west coast of Tasmania is one of the most remarkable sections of Australasia.

Queenstown itself is a bleak and unassuming red-roofed township lying about 3 miles from the *Mount Lyell* copper-mines, and within unpleasantly close range of the company's smelters. It is connected with the seaport of Strahan, on the Macquarie Harbour, by 20 miles of rail through broken, densely timbered and plenteously watered country, appearing all that is grand and peaceful to the well-accommodated travellers of to-day, just as it must have seemed forbiddingly ill-favoured to the railway pioneers, whose energies made easy journeying practicable.

In travelling from the coast to the *Lyell Mines* one catches many a fine glimpse of Macquarie Harbour and of the King River, gently flowing through evergreen woodlands, ineptly classed with the scrub-covered wastes of Central Australia under the comprehensive name of 'Bush.' In the distance are precipitous mountain peaks and ranges, often crowned with snow in the winter months.

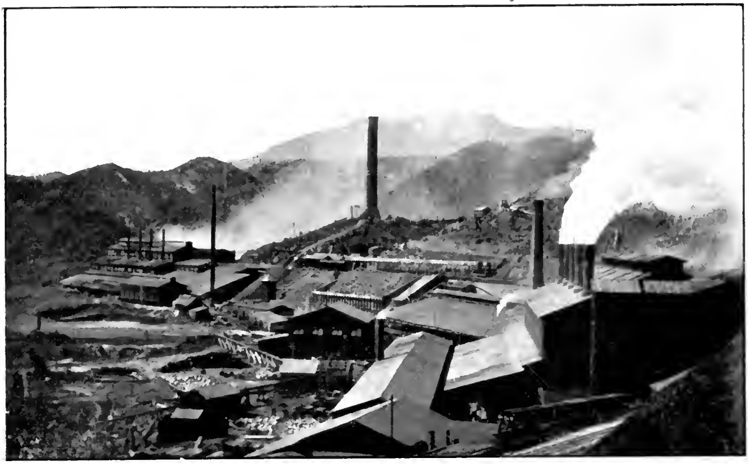
2. The climate of the district is generally distressing. With an occasional respite the place is cold and wet and miserable. At the mines about 120 inches of rain and 260 wet days are annually recorded; 20 or 30 inches may fall in a month. At

Queenstown a 'shower' is said to last for days. During the summer months a spell of hot, dry days is usually followed by a serious shortage of water, and by bush fires, which frequently occasion the loss of valuable timber and house property. Not merely do the broken branches, fallen trees, and the remaining small growth transmit the flames, but the 'soil,' a mass of peat, decaying roots, and timber, gets in a state of combustion, and throws off volumes of smoke and fumes from the sulphur it has collected from the smelter's outpourings. Most of the timber and shrubs have been destroyed for miles around the camp by the sulphurous fumes of the pyritic furnaces.

3. The district coastwards is of great historical interest—as historical associations go in this part of the world—in the grim records of its convict settlement (recalled in Marcus Clarke's book, 'For the Term of his Natural Life'), which was as sternly confined by sea and forest as any gaol by walls and riflemen. Escapes were many and desperate, but the majority of those who were successful in their initial efforts to reach the freedom of the woods gave their lives as the price of 'liberty.' Some of the fugitives, exchanging the bondage of civilization for the ruthlessness of the natural man, were killed and eaten by their starving comrades. Thus an island, now ranking amongst the summer health resorts of Melbourne people, made cannibals of Englishmen but eighty years ago.

4. Explorations were conducted through parts of this unhappy region in the early sixties, resulting, incidentally, in a small find of gold along the King River. Tin and silver-lead ores were discovered further north twenty years later, and drew many adventurous spirits to the west coast of the then languishing island.

In 1883, the 'Iron Blow'— a prominent body of hematite outcropping over the present *Mount Lyell* mine, though not actually part of it, and associated with auriferous limonite—attracted the attention of prospectors. In course of time the possibilities of the field for copper, as well as gold, were realized and deposits of three classes were revealed. In 1896, after the visit of influential capitalists from Melbourne, the *Mount Lyell Mining Company* was formed, and led to the exploitation of the field on scientific lines. It was not, however, until the *Mount Lyell Company* could utilize the great mass of pyritic ore, discovered beneath the 'Iron Blow,' in conjunction with the richer bornitic ore of the *North Lyell*, held by a formerly independent English company, that the district was placed on a basis of sound industrial stability. In the early days, when a number



MOUNT LYELL SMELTING WORKS.

Photo by SPURLING.

FURNACE CHARGE FLOOR, MOUNT LYELL.

of ill-conceived ventures were floated over a long stretch of country, the world spoke of the 'immense and inexhaustible' Lyell 'Field'; now one hears only of the *Mount Lyell* Company, outside whose boundaries there is little of importance, and whose prosperity has been as much due to metallurgical ingenuity as to natural riches.

5. The geology of the copper belt is problematical in many respects, and has been studied thoroughly by few. It is recognized that the soundest treatise on the field is that which Professor J. W. Gregory prepared for the Australian Institute of Mining Engineers. The salient features can be presented briefly. There are two great stratigraphical divisions of the country in a series of greatly altered schists (of doubtful origin), dipping at high angles, and overlying beds of enormous thickness of conglomerates and sandstone. The latter form the lofty summits of Mout Lyell and Mount Owen, along whose connecting ridge the chief ore-bodies are located. The relation of these two series is made conspicuous over large areas by the striking difference in superficial colour of the metamorphic and sedimentary formations.

The Conglomerate Series (the venerated gold-carriers of the Transvaal, the mountain-makers of the Queenstown district) comprise a great thickness of red sandstones and quartzites and of conglomerates, consisting of large, well-rounded pebbles and boulders in a sandstone or gritty matrix. It is clear that the conglomerates belong to an earlier geologic period than the unconformable underlying schists. But a complexity appears along the ridge, where the schists are found seemingly conformable to and overlying, steeply, sandstones and conglomerates identical with those forming the mountain-tops. All the best copper deposits are found along this contact. The question arises whether there are two distinct ages of conglomerate, or whether the series have been brought into this anomalous position by overthrust faulting. The latter hypothesis is most satisfactorily reconciled with prevailing phenomena. This contact between the conglomerate and schists is marked by a great longitudinal fault, complicated by numerous transverse dislocations, in whose bays and angles the richest ore masses have been found.

6. There are to-day two distinct sources from which ore for the *Mount Lyell's* smelters are drawn—the *Mount Lyell*, or *Big Mine*, and the *North Lyell*. All other occurrences are of comparative insignificance. The *Mount Lyell* mine comprises a vast deposit of iron pyrites, almost free from gangue, containing

small quantities of copper, gold, and silver. It has been worked by open cutting to a depth of 350 feet, the excavation, roughly oval, tapering down, in ten benches, from a size of 900 feet long by 650 broad. The mass, occurring on the fault-plane mentioned, is bounded on one side by the schists and the other by the sandstone conglomerates. There is a reduction in size and grade with increasing depth, and it was estimated in January, 1907, that about 4,000,000 tons of pyrites remained for extraction by open-cut and underground mining. The value of the ore at that time was under 1 per cent. copper, 1·8 ozs. of silver, and 1½ dwts. of gold.

Enrichments have occasionally been opened up—as, for example, upon the No. 4 level, where a mass of 850 tons, assaying 21 per cent. copper, 1,010 ozs. of silver, and a little gold, accounted for a yield of £106,000. In the lower levels of the mine, which has been worked underground to a depth of about 800 feet below the original outcrop, the copper value drops to about 0·5 per cent. On its own basis, the *Mount Lyell* would be an unpayable proposition, and its great importance lies in its utility as a smelting base, which contributes largely toward the metal output, and at the same time renders possible a system of cheap pyritic smelting in conjunction with the richer ores of the *North Lyell* mine. There is adequate ore available in the *Mount Lyell* to keep the smelters supplied for a further fifteen years, calculated upon present ratios of pyritic to *North Lyell* ore utilized. Approximately 1,000 tons of ore and overburden are broken in the *Big Mine* per day.

7. The *North Lyell* mine, though very rich in copper, was run independently until 1903 as a lamentable failure. Something like a million and a quarter sterling was spent by the company, largely in futile experimenting and showy expenditures upon lines of a ruinously extravagant and unprofitable character. It was fortunately realized, however, that whereas the future prosperity of the *Mount Lyell* and *North Lyell* Companies was, independently, a matter of small promise, their amalgamation would lead to metallurgical benefits of extreme importance to both concerns. Few mining amalgamations have been effected on more soundly scientific principles. The *Mount Lyell* held the pyritic base and a splendid administration under the control of Mr. Robert Sticht, one of the world's leading copper experts. The *North Lyell* held the rich siliceous copper ore, with which little good could be done without cheap copper-bearing pyrites for fuel and flux.

8. The *North Lyell* ore-bodies—or group of ore-bodies, associated genetically with many cross-faults breaking across the great Lyell fault about a mile from the ‘Big Blow’—resemble the *Mount Lyell* in but few points. Their origin may be similar, as bodies formed by the ascension of solutions along the lines of fault weakness, and, molecule by molecule, partially or entirely replacing the original rock; but pyrites at the north forms a constituent of no importance. The ore is highly siliceous, and the copper occurs principally as bornite, chalcocite (glance), and calcopyrite in veins, patches, chutes, and other enrichments. During the last few years the ore from this mine (and the closely connected, though more schistose, *Lyell Tharsis*) has averaged —copper, 6·0 per cent.; silver, 2·0 ozs.; and a few grains of gold. In the mass of *Mount Lyell* pyrites there is known to be ore available for many years, but conditions in the north would not permit of distant predictions, even if the course of the copper market was sufficiently assured to remove that dominating factor of uncertainty from anticipations. The *North Lyell* property is recognized to be more faulted and disturbed than any equal area in the district. There is, indeed, no need to turn to scientific hypotheses to learn the bearing of the fault system upon ore deposition. When the *North Crown Lyell*, also in the great Lyell fault, was prospected without promising results, the general manager reported: ‘The line of contact, followed for 1,185 feet, is evidently much too regular and undisturbed to warrant the existence of satisfactory deposits of ore.’ Thus, where the feature of irregularity is acknowledged to be a desideratum, the insecurity of the mining position without extensive development is manifest. The exploiters of the mine, in which eighteen to twenty ore-bodies or chutes have been proved, have experienced a big crop of surprises, favourable and otherwise, and realize the difficulty of establishing laws for future guidance. Well may the miner's profound saying, ‘Where it is, there it is,’ be applied to any of the *North Lyell's* lesser ore-bodies. Some of the stopes operated, however, are of considerable size, and warrant the employment of the square-set system with or without filling. At the 700-feet level the main ore-body—irregular in shape—presented a horizontal section equal to 12,500 square feet, and this has been proved to continue strongly to the bottom stoping level at about 850 feet. Exploration work is seriously retarded by occasional zones of extremely obstinate rock, and during one year difficulties of sinking were so great that the main shaft could only be deepened 120 feet.

9. In addition to these two important mines, which constitute the mainstay of the company, certain deposits of a different class are held for their utility in fluxing; but they can have no independent existence out of servitude to the pyritic smelters. These are the 'fahlband,' or mineralized bands of schist, which contain 1·5 per cent. or 2·0 per cent. of copper, and are consequently found to be valuable as metal-bearing flux.

The *South Tharsis* and *Royal Tharsis* are worked intermittently by the company. Efforts to exploit these bodies more extensively as independent concentration propositions resulted in failure, owing to the excessive production of unmanageable slime. Its highly siliceous character and schistosity prevent the employment of this class of ore, of which there are great quantities in the field, in more than a strictly limited degree.

10. There is yet another form of copper-ore occurrence (worked by the *Mount Lyell Blocks* Company) to which passing reference may be made on account of its probably unique geological features. The deposit, also near the junction between conglomerates and schists, is a wide interbedded body of clay, at first dipping east at a low angle, and subsequently turning steeply to the west. The section of the clay carrying values ranges in width from 2 to nearly 100 feet, and the copper occurs native in small slugs (both crystalline and worn) and particles, of which a proportion is so fine as to escape the concentrating tables and a large expanse of canvas strakes. So soft and yielding is the ore-body that the greatest difficulty prevails in keeping the development workings open. Pressures are slow but irresistible; the heaviest timbering is useless to support its burden. If the posts used do not break, they twist out of place. The policy has been adopted, therefore, of using small timber and replacing it frequently. The grade of the deposit has averaged 1·5 per cent., and by means of puddlers, table concentrators, and strakes, a recovery of about 70 per cent. is recorded.

PYRITIC SMELTING.

11. The term 'pyritic smelting' has been given such widely divergent interpretations as to suggest the advisability of its abolition from the technical glossary. But it is universally recognized by metallurgical authorities that 'pyritic smelting,' in its strictest application, involving the utilization of pyrites as a fuel with the addition of a negligible quantity of coke or other carbonaceous product, is exemplified in its highest degree

of efficiency and economy at the smelting works of the *Mount Lyell* Company, whose general manager, Mr. R. Sticht, has led the way in the development of this comparatively novel practice for the world to follow. The general scheme, involving few operations, appears one of essential simplicity; when viewed in close detail, however, it presents a number of perplexities, providing opportunities for constant experiment and modification. Only an outline of principles and methods need here be attempted.

12. The ore for the furnaces is drawn principally from the two sources already described—the copper, silver, and gold bearing pyrites coming from the *Mount Lyell*, and the rich siliceous bornitic ore from the North, which mines are connected with the works by aerial ropeway, steam-tram, and haulage. The top of the open pit is 1,450 feet above sea-level, while the works are over a mile distant, with an elevation of 850 feet less. Before delivery into the main bins a fractional portion of the ore—from one-tenth to one-twenty-fifth—is sent to the sampler house, where it is passed through Blake crushers, rolls, and Vezin samplers for the production of a representative parcel for analysis. The machinery for this plant is especially heavy, being utilized also for the crushing of the lowest-grade pyrites for dispatch to the company's chemical and superphosphate works at Yarraville, near Melbourne.

13. Smelting operations involve the production of matte containing 35 per cent. to 45 per cent. copper by effecting a single concentration of about 20 to 1, and the bessemerizing of this matter for blister copper over 98·5 per cent. fine. The plant used in this process includes five furnaces, of which four are continually employed. There are three floors, the uppermost being where the ores and fluxes are received and tipped into their appointed bins, from which they are drawn off, in proportions required, by the truckers on the charging-floor, 20 feet below. The truck-loads are tipped along either side of the furnace-top and shovelled in by hand. Automatic feeders have been lately introduced. Another 20 feet below is the tapping-floor. The furnaces themselves are rectangular, with a height of 16 feet from feed-opening to bottom plate. At the tuyeres, forty-eight in number, inside dimensions are 42 by 210 inches. Immediately below the top of the furnace is a downcast through which most of the heavy fumes are drawn away to the long flue and chimney-stack. In addition to Root's blowers, a Parsons' turbo-blower of 18,000 cubit feet per minute capacity has been installed with great success. At one time a hot blast was utilized, but now no

preliminary heating is effected, a greater blast pressure (42 to 48 ozs.) and the consequent increase of furnace activity compensating for the omission.

14. Great interest attaches to the charging of the furnaces and the process of fusion. The fundamental principle involved may be expressed as the utilization of the pyrites, forming the bulk of the charge, for the evolution of the heat necessary for the fusion of the ore and fluxes, instead of coke. The *Mount Lyell* pyrites not only furnishes the fuel and contributes its associated precious metals to the matte, but also provides the iron for combination with the silica of the *North Lyell* richer ores and the consequent formation of a readily fusible slag. The sulphur, also oxidized, escapes for the most part through the chimney-stack, and spreads its fumes over the district whose vegetation it has destroyed for miles around. The combustion is commenced by means of kindling chips, logs of wood, and coke, but once under way, intense furnace activity is maintained with the addition of a purely nominal percentage of coke.

15. A typical charge, whose proportions and analyses were kindly furnished by the chief metallurgist, may be given as under:

	Pounds.
Mount Lyell pyrites	2,240
North Lyell siliceous ore	1,200
Old slag	500
Limestone	250
Coke	60

Quartz and limestone are drawn from neighbouring quarries. The constituents of the *Mount Lyell*, *North Lyell*, and 'fahlband' ores have been stated by Mr. Sticht to average—

	Mount Lyell.	*North Lyell.*	*Fahlband.*
Iron	42 per cent.	6·8 per cent.	8·0 per cent.
Sulphur	48 ,,	6·5 ,,	5·0 ,,
Silica	2 ,,	66·6 ,,	6·5 ,,
Alumina	2 ,,	7·5 ,,	12·0 ,,
Barytes	1 ,,	1·0 ,,	—
Copper	8 ,,	6·5 ,,	1·6 ,,
Gold	1·5 dwts.	1·5 grains.	9 grains.
Silver	1·8 ozs.	2·0 ozs.	0·25 ozs.

So extraordinarily has the efficiency of smelting systems been increased, that of eleven furnaces once employed, six have been abandoned, and the remaining five been made to treat about

1,200 tons per day, or a greater tonnage than that dealt with previously by the whole plant. Economy has been instituted so stringently in every department that smelting operations have been conducted for about 7s. 6d. per ton and matte conversion 1s. 2d., bringing current expenditures both at mines and works to under 14s. 6d. per ton.

16. For the enrichment of the furnace matte to blister copper, pear-shaped steel vertical converters are used. The matte, trucked down from the smelters, is remelted in one of two furnaces on a floor commanding the converters, of which four are in operation for about five days per week.

Practice is here similar to that of copper-matte conversion elsewhere. The blast of air causes a vigorous ebullition of the charge, continued for upwards of an hour until the iron has combined with the silica of the lining to form a fluid slag, which is poured off for use in the blast-furnaces. The final elimination of the sulphur by oxidation is completed in another hour. Then nothing remains to be done but the pouring of the copper into flat moulds, in which it speedily solidifies into cakes (10 cwt.) for shipment, after sampling by drill, to America. The metals are electrolytically separated by the Baltimore Copper Smelting and Rolling Company, Maryland, U.S.A.

The visitor to smelters and converter-house is surprised that the men should be able to work efficiently in what is sometimes a chokingly dense sulphurous atmosphere without ill-effect ; some seem to thrive upon this pulmonary diet.

17. The magnitude of the company's operations may be demonstrated by some figures relating to the work for the financial year ended March 31, 1907. During that period the mines produced :

	Tons.
Mount Lyell pyrites	273,137
North Lyell and *Lyell Tharsis*	121,459
Metal-bearing fluxes, etc.	8,389
	402,985

These figures practically represent the product smelted for a yield of 8,330 tons of blister copper, equivalent to 2·07 per cent., and providing a net profit of £504,000. For the first half-year the average assay of the 'blister' was 98·96 per cent. copper, 73·30 ozs. silver, and 2·393 ozs. gold.

Ore reserves at the *Mount Lyell*, however, are valued at—copper, 0·55 per cent. ; silver, 1·95 ozs. ; and gold, 0·032 ozs. ;

at the *North Lyell*, copper, 5·5 per cent.; silver, 1·33 ozs.; and gold, 0·005 ozs.

The dividend-paying capacity of the company is primarily regulated by the situation of the copper market, though the gold and silver production of an annual £150,000 to £180,000 has constituted a gratifying support in times of weakness. For the financial year specified, dividends amounting to £400,000 were distributed upon the 1,200,000 £1 shares comprising the issued capital of the company. Since the amalgamation in 1903, £900,000 had been paid up to June, 1907. Even had the copper market maintained its recent level of inflation, the yields and profits of the company could not have been long continued at these standards in face of the decreasing grades, the increase of mining depth, and the augmentation of wages.

18. The *Mount Lyell* district was visited by the writer in 1907, at the time of exceptional prosperity throughout the country, when the labour position was inclined to be in an unstable state. With 2,000 men employed in mines and works, the district then experienced a considerable shortage.

Owing to the then prevailing strength of the copper market, and the supposed greater attractions of Broken Hill wages, an all-round increase of pay was granted by the *Mount Lyell* Company, bringing the scale to: Mining contractors, 12s. per shift; truckers and mullockers, 8s. 3d. to 8s. 9d.; smelter and converter hands, 8s. to 9s.; carpenters, 9s. 6d. to 11s. 6d.; and engine-drivers, 9s. to 11s. 6d. This schedule appears to be about 1s. below the Broken Hill standard, where the average standard of efficiency, however, is lower. The cost of living at Queenstown is fully 20 per cent. below the demands of the Barrier. In the Tasmanian field there are the annoyances of rain and snow and cold; in the Central Australian desert are dust-storms and tropical heat, intensified in their obnoxiousness to man by the isolation of the field from all centres of civilization and the absence of sheltering vegetation. An hour's run down the line from Queenstown will carry the worker on his holiday into the midst of the finest scenery in the Commonwealth. The average miner, it is true, cares little for the river or the tree-clad hill-side, save from the prospector's materialistic point of view; the water of mountain streams attracts him no more forcibly than pure water in a glass. But his wife and family appreciate the influences of smiling Nature, which tend to create a happier and more settled home-life than the most contented and buoyant of Broken Hill residents can hope to establish in their afflicted city.

CHAPTER XIV

TASMANIA—*Continued*

Mount Bischoff Tin-Mine

1. Hardships of pioneers.—2. First points of attack.—3. Dwindling yields.—4. Origin of the Mount.—5. Ore in depth.—6. Question of life.—7. Tin contents.—8. Ill-placed mill.—9. Stamps, jigs, and tables.—10. Slime-sheds.—11. Working costs.—12. Smelting at Launceston.

1. Discovered in 1871 by a prospector named James Smith, *Mount Bischoff* for several years accounted for half of the tin produced by Australia, and held foremost place among the tin-mines of the world. The many difficulties with which the pioneers of the Tasmanian west coast had long to contend were of extreme severity, but were the very antithesis of those encountered by the prospectors of Western Australia, where vast stretches of waterless and sun-scorched desert had to be traversed by those in search of mineral wealth.

The mountainous division of the 'Garden Isle' in which Mount Lyell, Mount Bischoff, and the Zeehan fields occur, a few hundred square miles in extent, suffers from a rainfall of volume and steady duration exceeded in few parts of the world, and the dense woodland vegetation, almost impenetrable, defied all save the most daring and experienced explorers. The wealth of its minerals, however, have resulted in the establishment of coaching roads and railways by Government and private enterprise, so that the visitor of to-day can travel conveniently through the chief mining centres, though not without being forced to appreciate the tremendous hardships under which it was necessary to labour in the first days of the country's development.

2. *Mount Bischoff* has an elevation of 2,500 feet, but, rising from a tableland to the east, does not stand very prominently above the surrounding country. Two years after 'Philosopher' Smith made his great discovery—that is to say, in 1873—the

Mount Bischoff Tin Mining Company was registered with a capital of £60,000 in shares of £5 each, of which the vendors received 4,400 fully paid up and £1,500 in cash. For several years the records of the mine, situated in an isolated region where transport by pack-horses was very costly and unreliable, were marked by a sequence of disappointments and failures which even shook the faith of the most steadfast believers in the possibilities of the venture. In 1875 Mr. H. W. F. Kayser was appointed general manager—a position held up to the end of 1907, which won for him the almost unique record of thirty-three years' continuous service in control of a great metalliferous mine. Upon a clearance of timber being effected and prospecting undertaken upon the Mount, above the discovery point, rich alluvial was found, and also ore-bodies, then called the north and south lodes.

The extraordinary surface richness of the mine made all things possible, and work was soon proceeding profitably on a fair scale. The alluvial or disintegration deposit of the 'White Face' kept the company employed for several years. By sluicing and dressing, a yield of no less than 250 tons of black tin per month was attained.

3. From its inception up to the middle of 1907 the *Mount Bischoff Company* had produced 66,173 tons of tin oxide, averaging 70 per cent. metal, and paid out in dividends £2,100,000. Going back to 1885, when the average yield began to decline, we find returns to have been as follows:

	Monthly Average Production.
	tons.
1885	229
1895	190
1901	120
1902	106
1905	106
1906 (January to June)	100
1906 (July to December)	76
1907 (January to June)	57

The rapidity of the decline, following a long succession of uniform declarations, has again brought the deposit into prominence, less favourable than formerly, and displayed many new problems whose solution must be effected before industrial stability can be regained.

4. The Mount was formed by the intrusion of great porphyry dykes through an older series of metamorphosed slaty rocks, which are now found, greatly contorted, dipping round the hill

or scattered about it in detached segments. The dykes, of topaz-quartz porphyry, are pyritic and stanniferous, and it is considered that the greater part of the rich tin deposit represents the disintegration of these intrusive bodies. The principal system of these dykes possesses a roughly rectangular outcrop, giving the eastern section of the Mount a basin-like form in which the ore has settled and concentrated during long ages of oxidation and weathering. Thus was formed the central 'Brown Face' deposit, which has been the mainstay of the mine for many years, and which was opened up soon after the 'White Face,' beneath a dense hematite gossan. The 'White Face' occurs on the southern slope, and on the opposite side is the 'North Alluvial,' from near which a rich non-pyritic tin lode dips down at a shallow angle towards the central 'Brown Face' body. In the gravelly, clayish, and gossany ground the strength of the company has always lain.

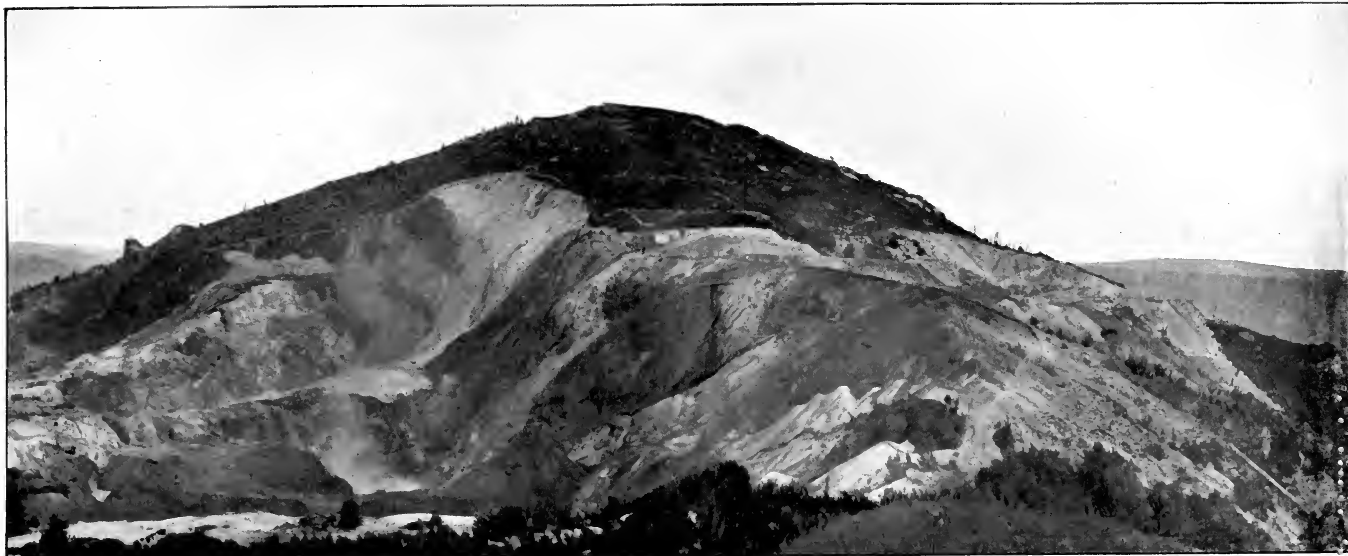
5. The stanniferous porphyry, in the solid, is generally of very low grade, and becomes pyritic and untreatable under present circumstances below the zone of oxidation. A large quantity of the white porphyry, from which the pyrites has weathered out, is sent to the mill, where it forms a good mixture with the softer dirt, though barely payable in itself. With the tin are found the commonly associated minerals—tourmaline, wolfram, fluorite, and arsenopyrite—seen also in Malay tin-veins. In the bodies of alluvial or disintegrated material blocks and boulders of the porphyry are frequently met with, from which the outside portions may be profitably broken off for contribution to the mill, while the pyritic 'kernels' are reserved for possible future treatment. The question of the profitable treatment by milling and calcination of the deeper porphyry, whose values are low, is a difficult one of the utmost importance in a consideration of future prospects, for the easily worked quarrying dirt is rapidly being exhausted, and new resources must be found outside the famous 'Brown' and 'White Faces,' the smaller intermediate deposit, called the 'Slaughter Yard' on account of its red, oxidized colour, and the 'North Alluvial.'

Not only do—or did—these sections contain abnormally rich layers and patches of concentrated mineral, but their excavation by simple pick and shovel work enabled mining costs to be kept at a low figure. When drawing from the easily worked formations, it was possible, moreover, to equalize outputs with perfect regularity by sending more or less of the rich patches to the mill. The previously given returns, showing a steady output of 106 to 120 tons of tin oxide per month for several years, do not indicate a constant tonnage and recovery, but merely the practicability of making up for deficiencies, or excess, by mine regulation. In 1906 the exhaustion of rich, readily accessible reserves occurred with unpleasant abruptness, for, although the walls containing the 'Brown Face' deposit were known to be gradually converging, and the occurrence of pyrites was rapidly increasing, shareholders did not adequately realize the significance of changing conditions. Extensive tunnelling and cross-cutting through the Mount, beneath the central deposit, which has been worked to a depth of 200 feet below the original capping, has given evidence almost consistently unfavourable. Though revealing generally pyritic and low-grade ore, the tunnels have been of value to facilitate the transportation of ore from the working faces to the mill, a mile and a quarter distant, which has been undertaken by steam locomotives.

6. The nearly exhausted 'Brown Face' has been responsible for a third of the mill tonnage for many years, but for a much higher proportion of the tin yield. At all other points of attack working results have been comparatively precarious, and subject to frequent changes. Sections of slate may unexpectedly appear, or the stanniferous porphyry turn pyritic and untreatable. The 'White Face' has always been a very important division of the Mount, but reserves are appreciably giving out in many of its benches.

The 'North Alluvial' has lately been a valuable, but limited, source of clay and crush dirt. The 'Queen' lode—a compact 3-foot body in the upper levels—has been practically worked out. So localized are the ore occurrences that Mr. Kayser did not consider outside prospecting to justify much attention, excepting in connexion with the *Wheal Bischoff* to the west, and a friable porphyry dyke near the 'North Alluvial.' When visited by the writer early in 1907, the outlook was consequently far from bright. Even by those best acquainted with *Mount Bischoff* conditions, estimates of ore reserves must be left largely to judgment and conjecture, but the general manager was able to express the opinion that ore to be safely depended upon would be enough to keep the mill in operation for about six or seven years, though the maintenance of yield at 55 or 60 tons per month could not be definitely assumed.

7. The grade of *Mount Bischoff* ore has been typically variable. During the first few years surface concentrations were found



PANORAMIC VIEW OF MOUNT BISCHOFF TIN MINE.

yielding enormous lumps and iron-cemented blocks of cassiterite, while big tonnages of weathered porphyry sent to the mill contained fractional percentages barely paying for treatment. For a few years prior to the decline of values the recovery averaged approximately 0·8 per cent., black tin falling to 0·65 per cent. in the early part of 1907.

The installation of an electric-power plant in 1907 revolutionized methods of ore transport and mill-driving. Previously the company relied upon steam locomotives, which drew sixteen $1\frac{3}{4}$ cubic yard trucks per journey, and several large water-wheels, for which even the West Coast rains occasionally failed to provide ample water for the operation of mill machinery.

8. The *Mount Bischoff* mill, cramped near the steep head of a small valley below the township of Waratah, has grown from small beginnings. Additions have been made to such an extent that the plant *in toto*, although benefiting by a good initial fall, now appears ill-ordered in design and unfortunate in its site. Moreover, the ore has changed in character, and shown a greatly increased tendency to slime. Consequently, a plant that may have been fairly efficient in the old days is now found to require modification. Mr. Kayser considered in 1907 that the recovery of tin represented 80 per cent., as compared with a previous 90 per cent. The first stamps, five in number, were erected in 1876; fifteen heads were added in 1879, and a further sixty, as a lower mill, a few years later.

9. The gossany and porphyritic ores were, when possible, mixed equally, and hand-fed into the boxes, which are provided with 14-mesh wire screens. The stamps (500 lbs.) drop through $7\frac{1}{2}$ inches at 75 per minute. Below the boxes are upward current classifiers, yielding coarse, medium, and fine (overflow) products. The first two run to coarse and fine jigs (winning a large proportion of the tin), whose final tailings go to the buddle department. The big overflow is delivered into spitzkasten, whose coarse product is treated on convex rotary concentrating-tables.

Hydraulic elevators effect the complex distribution and re-distribution of the several jig, table, and classifier products. The convex tables, 16 feet in diameter, are given a surface inclination of 1·1 inch per foot for a slow revolution. That these antiquated machines, introduced when practices were generally inefficient, should have found no superior substitute is frequently commented upon by technical visitors. Possibly adequate experimenting with newer types of slime concentrators has not been undertaken, but it has been pointed out that some of the most modern and most highly commended slime tables are practically the same in principle, though more in price. In the opinion of Mr. J. B. Lewis, manager of the *Anchor* tin-mine, they are cheaper in first cost and probably cheaper in upkeep than any of the other forms of slime-dressing tables, and as efficient as most.

The concave buddles, dealing with jig and table tails, are 18 feet in diameter, and are provided with arms or scrapers, revolving seven times per minute. When a thickness of several inches of sand has accumulated, the workmen dig out the buddle and feed the product into Chilean mills, by which it is (poorly) reground for reconcentration on lower tables, which again yield a buddle feed.

10. Below the milling section, and fed by the general overflow from numerous spitzkastens, are the slime sheds, which account for 13 to 15 per cent. of the total recovery. This department is commanded by three large V-boxes and a succession of seventy-two small pyramidal boxes, from which the convex tables are supplied. Apart from the jig-heads, concentrates only require treatment in the tossing-tub before dispatch to the smelters. The units in operation in the mill and slime sheds include: 75 stamps (for 100,000 tons, often of a soft clayey nature, per annum), 18 jigs, 34 rotary tables, 12 buddles, and 3 Chilean mills.

About a mile further down the gully another attempt is made to catch the more elusive particles in the stream of fine tailings. At the ‘ Ringtail Sheds,’ as they are called, 6 buddles, 2 Chilean mills, and 5 rotary tables are employed, for a yield of 20 to 30 tons per annum.

11. The cost of mining, crushing, and dressing a ton of crude ore has generally averaged 6s. to 7s. Variations have been due to the allowances necessary for development and progressive work, which were costly items when extensive tunnelling was being performed. Figures for the half-year ended June 30, 1907, stand as shown in table on next page.

During 1905 the crushing of 100,600 tons of ore was effected for a yield of 1,272 tons of black tin (1·26 per cent.) and a profit of £78,219, allowing the payment of £57,000 in dividends, or practically 100 per cent. During the first half of 1907 profits were being made at the rate of £50,000 per annum, and dividends were reduced to a monthly 5 per cent.

	Cost per Ton.	
	s.	d.
Mining, including new works, maintenance, etc.	2	5·9
Filling, hauling and emptying trucks	0	5·5
Crushing, dressing, and maintenance	0	7·4
Slime sheds	0	1·1
Ringtail sheds	0	2·0
Management and supervision	0	9·5
Plant, including all machinery	0	0·4
Development and progressive work	0	3·6
Stores	0	0·5
Wheal mine	0	1·6
Sundries	0	0·1
	5	1·6

12. The *Mount Bischoff Company* ships its concentrated ore by the Emu Bay Railway to Burnie, on the north-west coast, and thence by the Government line to Launceston, the commercial capital of Tasmania. The absence of any mineral in the ore liable to create offensive fumes enabled the company to establish its smelting works in a central section of the city, conveniently placed for the receipt of all the island's tin ore from east and west, and for the dispatch of the refined metal oversea. At this plant there are six reverberatory furnaces installed, of which four are constantly in use for the smelting of 5,000 tons of ore per annum (approximately 70 per cent. metal) in 50-cwt. charges. The furnace hearth is 13 by 9 feet in dimensions, with a 4-inch fall toward the tapping aperture, and the height 1 foot 6 inches. The metal tapped assays from 90 to 95 per cent. tin, and is ladled into refining 'kettles,' in which it is raised to an average purity of 99·89 per cent. In these kettles, which are heated from below, the molten tin is agitated by sinking therein billets of green-wood, the moisture or sap of which is converted rapidly into steam, bringing to the surface the impurities for skimming. Ingots are turned out in three sizes of 14, 28, and 78 lbs., the small being for colonial use, and the large—representing 75 per cent. of the production—for European shipment.

CHAPTER XV

TASMANIA—*Continued*

Gold and Silver-Lead

1. Zeehan, a field of small mines.—2. Silver-lead veins.—3. Types of ore.—4. Early misfortunes.—5. Mount Zeehan and Zeehan Montana.—6. Old-fashioned methods.—7. Concentration.—8. Custom smelters.—9. Rosebery and Mount Read low-grade mines.—10. Tasmania gold-mine.—11. Structural features.—12. Record pumping-plant.—13. Gold extraction.—14. Working expenditures.

1. Of the annual two and a quarter millions sterling represented by the mineral yield of Tasmania, upwards of one-half has been attributable to the operations of the *Mount Lyell Copper Company*. The tin-mines, holding a place of high distinction in the mining world, are rivalled in value of production by the silver-lead-field of Zeehan, one of the oldest of Tasmania's mining centres, yet one of the least known. Situated fifteen miles from the *Mount Lyell*, the Zeehan district presents a striking contrast with that copper-field, where the famous mining and railway company stands in glorious isolation. The *Mount Lyell Company* constitutes the greatest industry in the island, just as it is the most brilliant example of scientific enterprise. Emblematically, it is an oak; Zeehan, a bundle of sticks. The strength of the silver-lead-field is made up of a number of independently unimportant units. There are a score of producers and a hundred lodes scattered over the district of which Zeehan is the commercial and railway centre. Whereas *Mount Lyell* is supported by several enormous masses of low and medium grade ore, the best of the silver-lead-mines rely upon many small, erratic, and bunchy veins, rich but dubiously persistent. Another contrast appears in their salient geological features, which at the Mount are marked by a structural problem involving miles of country and the relationship of great formations. Questions of Zeehan's stratigraphy, none the less perplexing, are petty and 'parochial.'

2. Especially important are the strong influences of local faults and of variations of country rock upon ore deposition. The field is one of widespread disturbances and displacements. It is for the most part made up of Silurian slates and sandstones, very frequently—especially in the most productive areas—interbedded with sheets of melaphyre tuffs, mostly decomposed beyond recognition.

The mining geology is full of strange contradictions and irregularities. With danger will one recall the old German dictum—

'There is no lode like that
Which has an iron hat.'

Manganese Hill, the best-looking gossan 'hat' a wealthy lode could wish to don (a 'vuggy,' manganiferous limonite, with the prominence of the outcrop once marking Broken Hill), is declared to be a vain deceit. On the other hand, the main lode of the *Spray* mine, the richest ore-body worked by the *Mount Zeehan Silver-Lead Company*, is practically without surface indications. The miner's rule-of-thumb principles are similarly upset by anomalous circumstances. In one property hard, well-defined walls are the common associates of high values and big widths. In the next, a soft and broken country rock promises the best values.

3. There are three main types of lode in the district, of which pyrites, siderite, and stannite form the distinctive associates of the silver-bearing galena. Of chief commercial importance is an intermediate type containing both pyrites and siderite. The Zeehan district itself, as opposed to the 'Hinterland' or Mount Read-Rosebery division, is intersected by a multitude of small fissure lodes, rich in silver and lead. The deposits, commonly striking north-west and south-east with the strata, usually occur as chutes and patches linked up by poor vein matter. The uncertainties of ore deposition necessitate the performance of much dead-work and the exploitation of several lodes coincidently. To compensate for lack of persistence the field is favoured with some very rich ore.

From 175,000 tons raised by the *Zeehan Montana* in thirteen years were produced 37,226 tons of marketable ore (hand-picked and mill concentrates), assaying 64·9 per cent. lead and 79·4 ozs. silver, worth £484,100, or £2 15s. per ton raised. In this total is included a quantity of low-grade 'seconds' for concentration. Occasionally the lodes will show a face 10 or 12 feet wide of solid galena.

4. Industrially, Zeehan dates back a quarter of a century. Galena was first discovered there in 1882, and there was a period of great activity, technical and financial, for several years. In 1891 came a bank smash, but in 1892 a railway. The greater enterprise which should have followed the latter event was checked by the paralyzing results of the financial crisis. The best mines were obliged to win the capital for plant and development from the ground; the weaker were crippled. A spirit of extreme cautiousness, forced upon the field in the early stages, has remained to this day as the dominant influence of administrative policy, tending to restrict capital expenditures suggested by demands of legitimate innovation and engineering advancement. During the last five years annual returns have risen from 45,000 tons, worth £200,000, to about 90,000, worth £450,000, when the metal market was strong.

5. From the earliest days the London-controlled *Mount Zeehan Company* and its subsidiary, the *Zeehan Montana*, have been the leading producers. The *Mount Zeehan* comprises several holdings, but relies chiefly upon two mines—the *Spray* and *Argent*. The *Spray* lode is the most persistent on the field. Much of its ore is an antimonial variety (jamesonite), yielding high silver values. The width of the ore-body has been up to several feet, with a recent payable thickness averaging 2 to 3 feet. The *Zeehan Montana*, with workings to 900 feet, is the deepest in the district. Numerous veins are operated, the ore occurring in irregular independent zones which may easily pass unrevealed in development workings. For a period of two years, indeed, development was actively advanced in cross-cuts and in drives along the line of lode-formation without opening out any new ore-chutes, and yet stoping was successfully performed in intermediate blocks.

6. Working methods demand small notice, being generally old-fashioned and inefficient. An excuse lies in the precariousness of the mining position. Labour-saving contrivances are introduced only to a restricted degree. First-class ore is partly recovered below ground, the seconds hoisted for picking and concentration, and the waste used for stope-filling. All drill-work is performed by hand labour. Under American administration machines would undoubtedly be employed extensively.

Stoping is performed on a flat system, the waste-rock filling, covered over with sawn planks before the fracture of ore, being carried up close to the backs, with passes built through at intervals of about 25 feet.

7. Silver-lead concentration is performed on ordinary lines. In the *Montana's* mill the general manager, Mr. J. Craze, aims at the production of four sizings of marketable ore. Iron pyrites is the most troublesome constituent to eliminate; the other materials—siderite and slaty rock—being readily separated. The scheme includes a series of rolls, six trommels, with 13 down to 1·5-millimetre diameter holes, corresponding May jigs, re-crushing rolls, three secondary trommels (3, 2, and 1 millimetre), and jigs, Wilfley tables, and Bartsch rotary tables. On ore averaging 8·4 per cent. lead and 9·8 ozs. silver, mill tailings ran 1 per cent. lead and 2·4 ozs. silver.

8. With the exception of a small shipment by the *Zeehan Montana* to Antwerp, the district's entire output of firsts and concentrates is shipped to the Tasmanian Smelting Company, whose works lie two miles from town. This venture, according to its own declarations, is not remarkably prosperous; but it has exercised a beneficial influence upon the field, especially through its successful treatment of refractory low-grade zinc-iferous ores, which must be dealt with locally for any hope of profit. These low-grade bodies—at *Rosebery* and *Mount Read*—may be said to average 20 to 30 per cent. zinc, 10 per cent. lead, 10 to 15 ozs. of silver, and an appreciable amount of gold.

For the production of silver-lead bullion the percentage of zinc is detrimentally high, and hampers concentration.

9. Every year, however, greater attention is being directed towards the low-grade ores of the *Rosebery* and *Mount Read* district, and it is recognized that the needs of the region can only be satisfied fully by the erection of smelters within easier access of the group, operated under the direct control of the mining interests. The district, outside Zeehan itself, has the making of some large mines, which may well profit by the lessons of the *Mount Lyell*, fifteen or twenty miles away, and by a study of the benefits there exemplified of a scientifically directed alliance of properties, whose full success can only be attained by contributing to a common smelter.

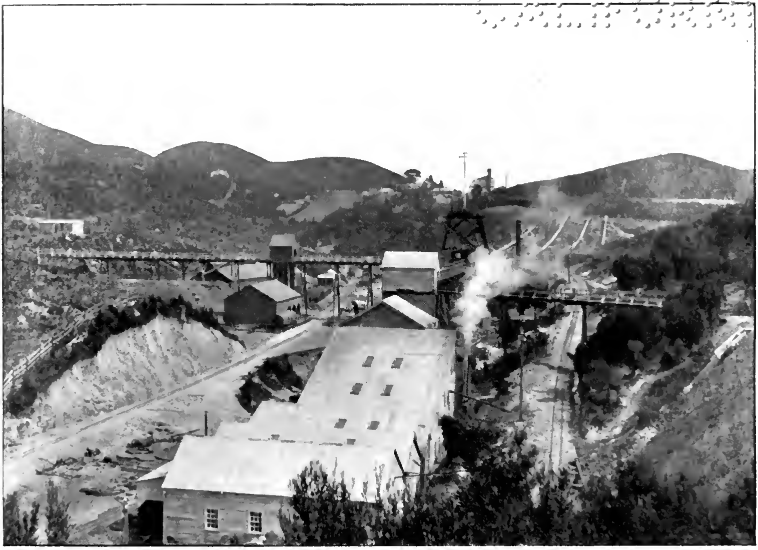
TASMANIA GOLD-MINE.

10. The *Tasmania* gold-mine, situated on the left bank of the Tamar, some thirty miles from Launceston, is amongst the richest in the world. From 690,000 tons crushed it has produced 700,000 ozs. of gold. Additional distinction falls to its lot as one of the wettest metalliferous mines in the world.

During a flood in 1906 some 8,100,000 gallons were raised daily from a depth of 1,000 feet; 5,000,000 gallons per day is the average duty.

11. In 1903 the *Tasmania* gold-mine was taken over by a new company, under the management of the well-known firm of Messrs. John Taylor and Sons. The mine stands practically alone, without productive neighbours, and supports the pleasantly situated little township of Beaconsfield. Geographically the property is well favoured, with a tramway of 3 miles connecting it with Beauty Point Wharf on the river. Geologically it is blessed by the possession of a fissure lode of exceptional richness, width, and good breaking qualities, but cursed by an abnormal influx of water through the limestone and sandstone strata constituting the country rocks of the deposit. The vein runs north-east and south-west, and dips to the south-east at an angle of 60 to 70 degrees, while the standstones, grits, conglomerates, and limestones strike north-west and south-east at a somewhat flatter angle. Thus the gold carrier runs across the beds almost at right angles. Detailed assay plans show that the gold is distributed with fair regularity, the patches of higher and lower values occurring without any zonal relationship. On the other hand, the different country rocks have a decided influence on the gold values of the lode, which tend to follow down the sandstones in their dip to the north-east, and to be reduced where the fissure cuts into the limestone on one side and a series of conglomerates and sandstones on the other. The ore—a milky-white quartz, with abundant pyrites and some chalcopyrite—is easily broken *in situ*; no machine-drills are employed. Pick-work can be extensively practised. Formerly flat stopes were carried from level to level, but now a system of rilling has been advantageously introduced. The company has three shafts, of which the new Grubb shaft is 32 feet 1 inch by 8 feet in the clear. Twelve hundred feet is the present maximum mining depth.

12. The enormous Cornish pumping plant is of three units, each operated by a horizontal compound-condensing pumping engine, with 50-inch high-pressure and 108-inch low-pressure cylinders. The plunger pumps are capable of raising 8,000,000 gallons per diem, or $2\frac{2}{3}$ millions each unit, working at 6·9 strokes (10 feet) per minute. To 500 feet the rods are 22 inches in diameter, from 500 to 1,000 feet 18 inches, and from 1,000 to 1,500 feet 16 inches. The total chamber capacity of the shaft is equivalent to 450 feet of ordinary sinking, 32 by 8 feet. Careful



ZEEHAN MONTANA MILL, ZEEHAN.

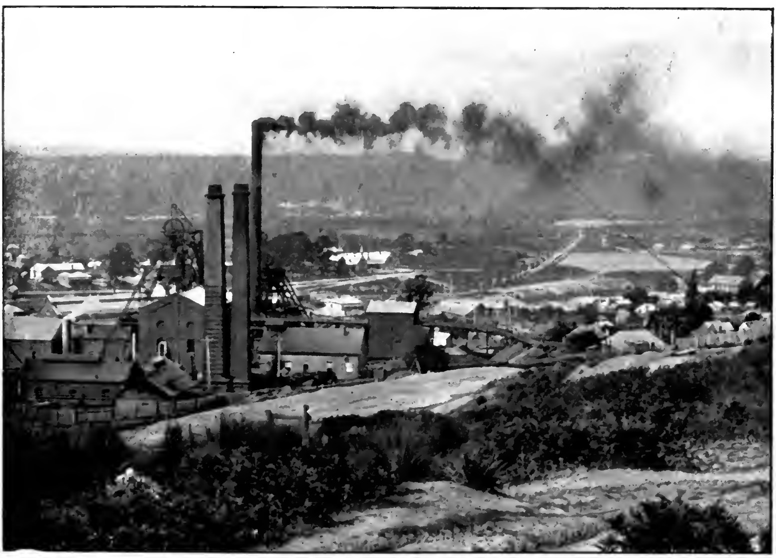


Photo by SPURLING.

TASMANIA GOLD MINE, BEACONSFIELD.

examinations of local stratigraphy and watercourses have been made to determine if anything could be done to check the serious influx of water into the mine. Caverns and channels are easily formed in the limestone beds, but these are believed, despite their disrepute, to be hardly more responsible for the passage of water than the associated sandstones. A fluming scheme to carry off flood-waters from the most receptive strata has lately been effected.

13. Owing to the heavy expenditures demanded in and about the mine, the milling department has been somewhat neglected. The battery comprises two sections, one of 40 stamps (1,000 lbs.) and an antiquated section of 65 light stamps, which the manager hopes to replace by 60 heavy stamps. Duties are low, being at the new section of the mill 3·4 tons per stamp-diem, with screening of 12 punched holes per linear inch.

The screen sand passes over amalgamating tables, and the pulp is classified into ten products by spitzkastens, which are concentrated by jigs, tables, and vanners.

It is found that the concentrates obtained represent 8 per cent. of the mill product. Their average value is about 1·5 ozs., and after roasting in Edward's furnaces and chlorination, the tailings, which run 4 dwts., are reserved for cyanidation. The tailings from the jigs and tables are elevated by a 40-foot wheel, and passed through a spitzkasten, whose slime overflow, valued at 2·7 dwts., runs to waste.

14. Of working costs, which are high, pumping accounts for 5s. or 6s. per ton of ore crushed. The item ' ventilation ' is also a substantial one, owing to the occasional inpouring of carbon dioxide into the workings, some of which can only be cleared with difficulty. The limestone beds appear, indeed, to be peculiarly pernicious neighbours, whose liberal donations of water and gas constitute a nuisance responsible for a charge of 7s. per ton against each ton of ore extracted. With the aid of a Root's blower and a thorough piping system to tap the most troubled sections, the gas evil is vigorously combated.

CHAPTER XVI

TASMANIA—*Continued*

North-Eastern Tin-Fields

1. Natural advantages and defects.—2. Types of deposit.—3. Briseis lead.—4. Drift values.—5. Sluicing methods.—6. Pioneer mine.—7. Nature of gravel.—8. River dredging.—9. Blue Tier District.—10. Working expenditures.—11. Quarrying and milling.—12. Results of work.—13. Chinese fossickers.—14. Government and taxation.—15. Disposal of tailings.

1. The eastern and western divisions of Tasmania differ very considerably in mineralogical as in climatic conditions. The mountainous and rainy west coast, where an insular climate is exemplified in all its most disagreeable features, is marked by great diversity of metal production. From three of its centres copper, gold, silver, lead, zinc, and tin are won. Its leading mines include *Mount Lyell* and *Mount Bischoff*, both world-famous for metallurgical or geological reasons. To the latter tin deposit, indeed, much of the island's renown as a region of concentrated mineral wealth has been due. But the maintenance of Tasmania's position as one of the chief factors outside Malaya in the supply of the world's tin must be attributed to the progress of the north-eastern division of the island. *Mount Bischoff* in the west has fallen from its high estate. The *Briseis*, *Pioneer*, *Anchor*, and *Arba* in the east, with a multitude of neighbouring ventures of lesser import, have commensurately gained in industrial strength, and are now responsible for 80 per cent. of the State's production.

The north-east tin-fields, with a warmer climate and with more moderate rains than the west, are well favoured for cheap alluvial working. The annual rainfall runs from 35 to 60 inches, and water-power, for hydraulicking or driving machinery, is widely available.

The winter is unpleasant, but there are no such unfavourable climatic conditions obtaining as to make a high wage necessary.

Even with the risk of occasional spells of enforced idleness men are well satisfied with a wage of 7s. to 8s. per shift. Living is cheap. The mining district, accessible from Launceston by rail and coach, is several hundred square miles in extent. It is generally hilly, and towards the east coast is marked by ranges up to 4,000 and 5,000 feet in elevation. Vegetation is remarkably thick and beautiful. Pines and gums are the most useful timbers, whilst magnificent tree-ferns provide the woods with some of the evergreen glories of a subtropical foliage. Bush-fires are a constant danger during periods of drought, whilst an evil to be feared during the rains appears in the torrents pouring down steep hill-sides and gullies. In January, 1907—to cite an exceptional instance—a storm of unprecedented severity broke over the Derby-Pioneer district, and 10 inches of rain fell upon the district (and, incidentally, upon the writer) in about six hours.

2. The several types of tin-bearing deposit under exploitation in the eastern fields may be broadly classified as ancient river deposits, with or without basaltic covering terraces; river flats; low-grade masses of altered granite; and unimportant fissure lodes.

The first type, which is of special significance, and includes many 'deep lead' deposits known to be of great size, may be dealt with in a description of the famous *Briseis* property at Derby.

3. The ancient lead upon which the *Briseis* and *New Brother's Home No. 1* are jointly working extends for about a mile south-east and north-west. The bed of the deposit or channel on which it was concentrated is the granite of the district. The drift or wash has an average thickness of over 100 feet, and the basaltic overburden of generally less. Whereas the drift is excellent hydraulicking ground, the removal of the overburden was a more difficult undertaking, owing to the occurrence of a considerable percentage of boulders (undecomposed basalt), whose removal by trucking was necessary.

At the lower end of the property the deposit is cut through by the Ringarooma River, on the further side of which there appears an extension of the old lead with a very thick over-burden. This extension is under exploitation by the *Briseis Company*, whose old property is rapidly nearing exhaustion.

4. Owing to the manifest difficulties of drift valuation and to the excessive optimism of controlling parties, the *Briseis* was at one time enormously overvalued. The ore-contents of

the ground must now be reckoned in pounds per cubic yard instead of in percentages, though they are still high for this class of deposit. During 1906 an average yield of 5·1 lbs. per yard for the whole property was recovered. Results for five years may be broadly shown in tabular form :

	Overburden removed.	*Drift sluiced.*	*Yield.*
	cubic yards.	cubic yards.	tons.
1902	247,575	122,298	316
1903	482,377	256,940	412
1904	755,424	173,440	425
1905	551,548	481,350	971
1906	519,262	615,990	1,408

Since its inception the *Briseis Company* has produced, up to September, 1907, 4,741 tons of tin oxide, containing approximately 75 per cent. metal.

The *Briseis* has an abundant water-supply, providing power for all purposes—for the nozzles, for hydraulic elevators, for electric-light generation, and for driving centrifugal pumps. There are three main water-races giving a head of 300 to 400 feet at the bottom of the workings. The average daily supply is 150 sluice-heads, the Tasmanian unit being 24·17 cubic feet per minute.

5. Work upon the *Briseis* lead involves the two operations of overburden removal and of cutting down the drift for the sluice. Excepting where boulders have necessitated the employment of tram-lines, the decomposed basalt is broken down with ‘ giants ’ or monitors into races, which carry off this waste product to the Ringarooma.

The drift is worked at four or five faces.

There are three main sluices in operation which are from 120 to 150 feet in length, 12 feet wide, and graded at 2 feet 3 inches to the chain.

The sluice concentrates are finally dressed to a value of 75 per cent. metal. Associated impurities are of small account. There is a little wolfram and tourmaline. In cleaning up the gutter or bottom of the lead, a small quantity of iron and arsenical pyrites, with rich tin, is obtained. Topaz is sometimes found.

Working on a large scale, the management of the *Briseis* has brought costs down to a low level. The removal of overburden in 1906 cost 4·1d. per cubic yard (including boulders to the extent of 2 per cent.), and 6d. per cubic yard in 1905 (boulders 12 per cent.). The cost of winning black tin and delivering it dressed and bagged for shipment at the mine-sheds is about £10 per ton produced, or 5½d. per yard of drift treated.

6. Following the *Briseis* in industrial importance is the *Pioneer*, which is another deposit of ancient river-drift, though not covered by any basaltic overflow. It lies ten miles to the east of the *Briseis* on the Derby-Gladstone road. The drift is deep and clean, and possesses in plan an S-like form. Determined to reduce the speculative element to a minimum, the management put down before production commenced a large number of bore-holes through the drift and well into the basement granite. It would appear that the estimate of 2·5 lbs. per cubic yard would be confirmed to within 0·1 or 0·2 lb. by actual working results.

The question of the reliability of boring for drift valuation is one upon which there is locally much diversity of opinion. The experience of the *Pioneer*, however, clearly shows that such a mode of testing, scientifically and widely undertaken, can be made in some cases to give a reliable average.

7. The *Pioneer* lead is of excellent width, and is being worked for 1,000 feet across the deposit, which is 70 to 75 feet deep in the central section. The average grade is apt to change considerably month by month, owing to the varying proportions of top and bottom ground dealt with. Owing to its depth, the lead is worked in two benches, the lower being served by a small auxiliary pumping plant and the upper by two big barges with 12-inch centrifugal pumps, lifting 96 and 84 feet respectively.

The tin oxide occurs in a satisfactory degree of coarseness, so that a high recovery is obtained in the sluice-boxes. Electricity is now to be utilized instead of steam-power. The quantities of drift treated up to the end of the year 1906 may be tabulated as under :

Fiscal Year to June 30.	*Yards.*	*Yield (Tons).*
1901	121,400	77
1902	237,900	217
1903	315,900	397
1904	351,100	371
1905	327,100	309
1906	439,400	423
1906, July to December	287,900	277

(Work in 1907 checked by flood.)

This shows that 2,080,700 cubic yards were treated for a return of 2,071 tons of black tin, equivalent to 2·23 lbs. per yard. No stripping having to be performed, expenses are low—7½d. to 8½d. per yard.

Barges and pumps of a similar type to those used upon the *Pioneer* are to be seen at the *Briseis Extended* and *Weldbrook*. At the *Briseis Extended* the drift contained a large percentage of pebbles and small boulders, allowing the runners and liners in the pumps a life of about two months. On comparatively boulder-free *Pioneer* ground they pass about 110,000 and 80,000 yards respectively without renewal.

8. The early results of dredging upon the Ringarooma River were not eminently successful, owing, it is considered, to the lack of experience in construction and operation. The outlook has, however, considerably improved. Primary difficulties experienced by the *Ringarooma Dredge* were chiefly associated with the large quantity of timber and boulders encountered in the alluvial, which is 16 or 17 feet thick. Adjoining the *Ringarooma*, a new venture—the *Dorset*—has built two large bucket dredges, capable of dealing with 3,000 cubic yards yer day. The pontoons are 124 feet long by 40 feet wide. Six-feet buckets are used, the ladder being 66 feet between centres, and capable of dredging to 38 feet. Table surfaces total 2,880 square feet. A 17-inch centrifugal pump provides water for sluicing. The *Dorset* bucket dredge is the largest employed in tin-alluvial practice in Australia, and probably in the world.

9. Although excelled in rate of production by the *Mount Bischoff*, *Briseis*, and *Pioneer*, the *Anchor* tin-mine at Lottah is widely known in the mining world on account of its low costs as a quarrying and milling proposition. The *Anchor* and neighbouring *Blue Tier* deposits of tin-granite are also of extreme geological interest, and comprise masses of tin-bearing rock, on the borderland of payability and unpayability, of unique extent. The granite of this region, which is somewhat mountainous, and crossed by a range rising to a height of 2,000 to 3,000 feet above sea-level, is a coarse porphyritic variety, with large crystals of felspar, biotite, and quartz. There is also a little muscovite mica. In this granite are great zones—a more specific term can scarcely be applied—of altered granite (carrying small quantities of cassiterite), which is not so porphyritic, and is apt to more readily decompose. Although in one section of the tier a narrow band of tin-granite is exposed, the dike theory

of origin finds small support, particularly in view of the irregular boundaries of the masses and the occurrence of 'floors.'

Mr. Twelvetrees, Government geologist, considers there are good reasons for believing that tin ascended as a fluorite, and, if so, that the resulting fluorine compounds formed powerful agents in the decomposition of granite and its conversion into the modified rock which carries the tin-ore.

10. The shapeless masses formed have been exploited, not only on the *Anchor* (where the rock can be most thoroughly studied), but on the *Australian*, *Liberator*, *Crystal Hill*, *Haley's* and *Moon* leases, where the *Mount Lyell Copper Company* made thorough investigations in 1906.

The ground is in all cases very low grade and of problematical value for mining. Formerly production was undertaken on an unfittingly small scale, and the best patches alone considered. Thus milling showed returns of ½ to 1 per cent. black tin. But the *Anchor*, which has alone approached success, has been recovering less than 3½ lbs. per ton, or 0·15 per cent. Its chief aim has been to reduce costs to an absolute minimum—an object well achieved in a cost-sheet showing the admirably low working expenditure of 2s. per ton treated.

A large quantity of rock finding its way to the mill is undoubtedly barren. But selection or picking is impossible under prevailing conditions. The work done in advance of the quarry faces is limited to hand-bores and stripping.

11. The ground drills and shoots well. Explosive costs work out at 2½d. per ton, and total quarrying, with labour at 7s. 6d. per shift, runs to 1s. 1½d. per ton on the basis of about 3,000 tons per week. The accessory minerals—molybdenite, copper pyrites, wolframite, and fluorite—are commonly found about the contact of the altered (tin-bearing) and unaltered porphyritic granites. From the quarries the ore is horse-trammed to gyratory crushers. Thence it is delivered to the 100-stamp mill, which is in two 50-stamp sections. Stamps are weighted to 800 lbs., and a high duty (6 tons per stamp-diem) is obtained by the use of coarse screening. The company's chief trouble—apart from the low tenor of its ore—has been a water scarcity in summer. A good extraction is obtained by means of jigs, tables, and vanners.

12. The results of operations by this unique tin-mine may be displayed in summarized form for three years, as follows:

	1904.*	1905.*	1906.*
Ore treated (tons) ..	135,860	118,634	122,364
Black tin (tons)	241½	190½	185½
Pounds per ton	3·97	3·59	3·40
Metallic percentage ..	71·8	69·1	70·4
Receipts per ton	2s. 8d.	2s. 7·2d.	3s. 1½d.
Costs per ton	2s. 6·5d.	2s. 5·2d.	2s. 5d.
Average stamps	91·3	74·2	73·0
Stamp duty	4·74	4·98	5·26

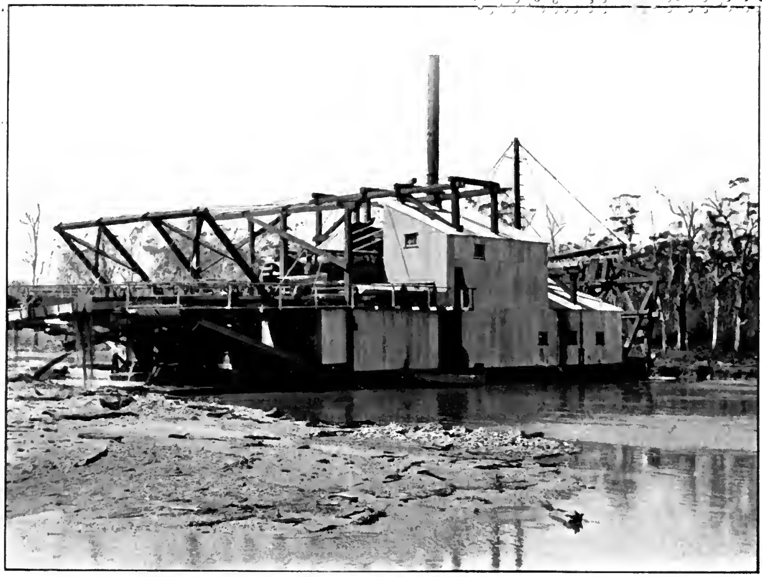
* Year to June.

Wages are responsible for about 77 per cent. of the working expenditure.

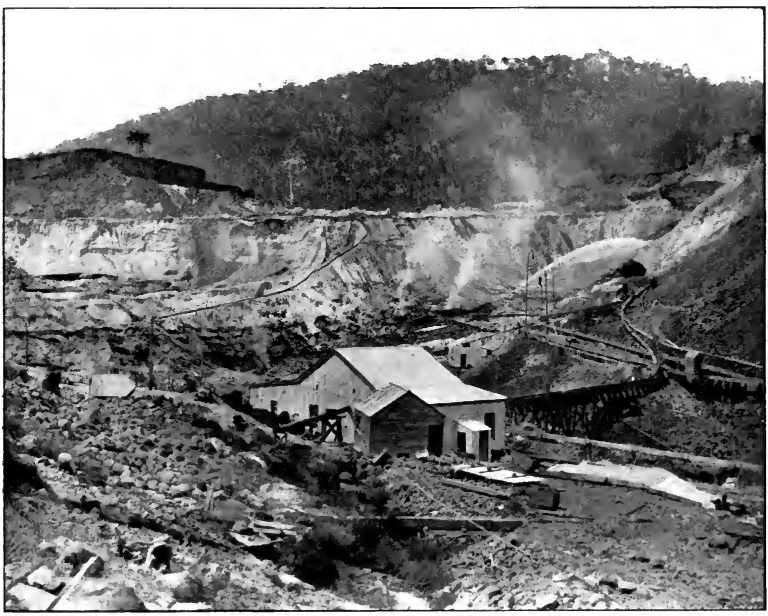
13. Outside the ventures mentioned above, to which the *Arba* may be added as a notable producer, there are numerous small concerns and private working-parties and fossickers contributing small parcels of ore to the total yield. Sixty of these are of sufficient importance to merit individual notice in the statistical reports of the Government geologist. Ten leading mines, however, are found to account for 80 per cent. of the north-eastern division's output, and three of them for upwards of 70 per cent. In several districts Chinese tributers are seen to be at work, assiduously squeezing a livelihood from tailings and forgotten patches. At one time these diligent Asiatics no doubt did very well in this precarious occupation, but of late their opportunities have decreased, and many an erstwhile miner has turned—or returned—to the safer profits of market-gardening, in the pursuit of which their exceptional business acumen can now be more beneficially employed.

14. Tasmania, or the Commonwealth of Australia generally, has often been quoted by the critics of the Government controlling the Malayan tin-fields as the country to which reference should be made for examples of all that is right and efficient in administrative policy. Though both these lands are producers of tin from alluvial deposits, and are under British influence, the vital distinctions between industrial systems and social conditions characterizing each country render it almost essential that problems of administration should be worked out independently and reforms effected, in the light of local experience and judgment.

The burdens of taxation falling upon Tasmanian tin-mines are comparatively light. There is no export tax, but dividends



RINGAROOMA BUCKET DREDGE.



BRISEIS TIN DEPOSIT.

are subject to an income-tax of 1s. in the £. Profits made by individual workers and classified as the result of personal effort are not taxed, unless in excess of £400 per annum.

15. An important advantage enjoyed by Tasmanian hydraulicking concerns is the fact that, in the disposal of tailings, they have not to concern themselves very deeply in its subsequent destination. Since the fighting of a lawsuit in regard to the damaging of plantation-ground near the mouth of the Ringarooma River—settled in favour of the mines—the 'pollution of rivers' has no longer been a cause of anxiety to companies. Broadly speaking, the needs of the industry are allowed to dominate in the north-eastern division, and the inhabitants of the field could no more reasonably complain of river pollution than could the residents of Queenstown on the West Coast protest against the sulphur fumes issuing from the pyritic smelters, which, directly or indirectly, provide the means of livelihood for all.

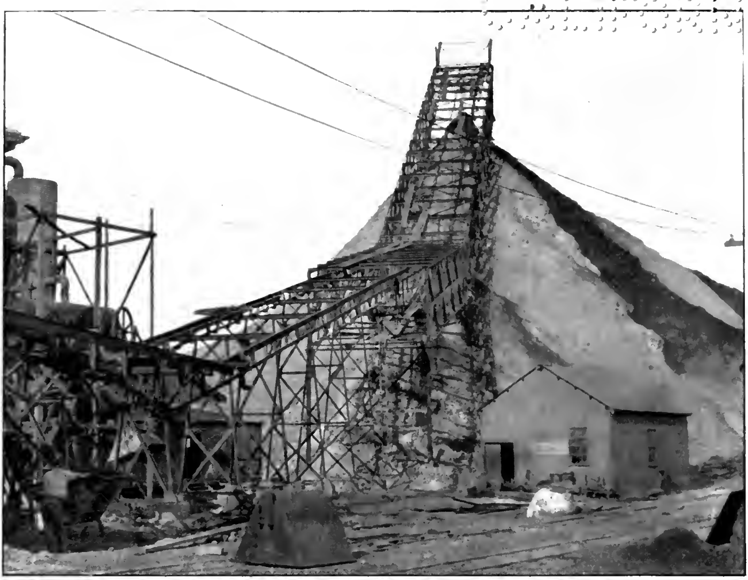
CHAPTER XVII

WESTERN AUSTRALIA

Growth of the Gold Industry

1. 'Cinderella' State.—2. Bold prospectors.—3. Discovery of Coolgardie.—4. Pat Hannan's find.—5. 'Golden Mile.'—6. Rocks of Kalgoorlie Belt.—7. Nature of rich deposits.—8. Their origin.—9. Value of ore.—10. Output to date.—11. Comparison with Rand.—12. Eastern group of mines.—13. Horseshoe, Ivanhoe, and Boulder.—14. Central line.—15. Water-supply.—16. Reduced expenditures.—17. Labour efficiency.—18. Current schedule of wages.—19. Managerial policy.

1. There are no divisions of the British Empire which present more forcible illustrations of the nation-building forces of metalliferous mining than Western Australia, Victoria, and the Transvaal. In each country gold was the lodestar of the vigorous people necessary for the development of the land and for the establishment of a progressive population. Not only has gold been the primary support and awakening factor in these colonies, but it has also provided the means of effecting a broader industrial expansion. Victoria now stands upon a commercial basis so wide and strong that mining no longer constitutes the paramount industry. The Transvaal and Western Australia, however, remain to this day primarily dependent for their existence as States of individual significance upon the success of their gold-mines. Prior to the discovery of the Coolgardie and Kalgoorlie fields Western Australia—the 'Cinderella State'—was little better than a bushy wilderness. With a few farmers along its more favoured coastal regions and half a dozen gold-fields of small importance, labouring under difficulties then almost insuperable, this vast sub-continent of 976,000 square miles boasted in pre-Kalgoorlie days a population of 60,000, and a gold yield of £226,000. In 1906 this isolated section of the Commonwealth contained a young nation of 260,000 souls, and was adding to the world's wealth an annual £8,000,000 in mineral products.



GREAT BOULDER TAILINGS ELEVATOR.

'BAYLEY'S REWARD CLAIM' TREE-MARK, COOLGARDIE.

2. The year 1893 may be taken as the starting-point of Westralia's mining, or national, history. Prior to that date the city of Perth was but the centre of a pastoral district and a base for the expeditions of the many intrepid explorers who endeavoured to cross the great and dreary *terra incognita* of the hinterland. The Kimberley, Yilgarn, Pilbarra, Ashburton, and the more important Murchison fields contributed small parcels of hard-earned gold to the colony's export list. Elsewhere centres of activity were few and feeble, in spite of the efforts of brave adventurers who explored the vast stretches of bushy desert or of waterless wastes. The prospector of those regions and those days was not of the class one sometimes finds to-day—a loafer and a braggart—in the mining city. The hardy and resourceful adventurers who have raised Westralia to its present status, ignorant and unscientific in method though they may have been, as mercenary in their aims as many pioneers of higher distinction, had battles to fight and hardships to endure which must always place them amongst the Empire's most useful servants.

3. In the early nineties Southern Cross, in the Yilgarn district, 250 miles east of Perth, was the base of operations for many prospectors whose eyes turned eastwards with vague hopes of wealth to be revealed. The proclamation of the Kimberley gold-field in 1886, the exploitation of which ended disastrously, had drawn to the country a considerable body of good prospectors. These scattered to the south, and became the pioneers of other fields. Late in 1892 two prospectors—Bayley and Ford—made that discovery of gold, at a point 350 miles to the east of Perth, which led to the establishment of mining-fields destined to revolutionize the industrial position of Western Australia. For some time secrecy was preserved, but upon the application at Southern Cross for a discovery claim, a stampede of great excitement occurred, and the 'mother city of the fields' was almost deserted. Events moved swiftly, and in a week parties of gold-seekers were scattered far and wide over the field around *Bayley's Reward Claim.* Many finds were made, but the prospectors in their desperate impatience were rarely content with their discoveries, and frequently struck out in search of 'pastures new.'

In November—a month after the discovery—the prospector was followed by the financier. Mr. Sylvester Brown, of Melbourne, travelled to Coolgardie, and purchased the *Reward Claim* from Bayley and Ford for £6,000 plus one-sixth interest. He is said to have paid down only £100, extracting the balance from the mine itself. Though the first discovery in the long Coolgardie belt, the *Reward Claim* has proved the richest, and its early yields, exhibited in Perth, acted as a brilliant advertisement for the new fields, to which adventurers arrived in due course from all parts of the world.

4. The fame of the district was even more widely established upon the discovery, next year, of rich alluvial ground by Pat Hannan some twenty-five miles further east. Hannan's find, located at the eastern extremity of Hannan Street in the Kalgoorlie of to-day, did not represent the best part of the new parallel belt. Its easily treated alluvial, however, still worked here and there by persevering 'dry-blowers,' who patiently rock their 'shakers' for a small precarious return, speedily yielded heavy parcels of nuggets to its early workers. This alluvial, representing the disintegration of a section of the Kalgoorlie belt, gave promise of no long life, and was soon left in search of better prospects. Four miles to the south of Hannan's original workings several prospectors—notably Brookman and Pearce—were soon at work on a different class of deposit, which rapidly was shown to be the surface of a true lode formation. These finds were the beginning of the famous *Golden Mile*, constituting the richest square-mile block of auriferous ground in the world.

A report dated December, 1893, stated that the chief claims then worked were the *Ivanhoe*, *Ivanhoe West*, *Great Boulder*, *Great Boulder East*, *Great Boulder Extended*, *Great Boulder South*, *Lake View*, and *Australia*. Several shafts on the *Ivanhoe* showed an 'average width of reef of 5 feet, the body of it going 80 to 100 ozs. per ton by prospect.'

Shafts also had then been commenced upon the *Great Boulder* and *Lake View*. By far the greatest difficulty with which these early workers had to contend was scarcity of water, which was selling normally at 6d. per gallon at Hannan's, and 1s. per gallon at Coolgardie. In course of time, as the needs of the mines extended, large condensing plants were installed.

5. During the first few years there prevailed a most extravagant and disastrous 'boom' at Coolgardie and Kalgoorlie, when English investors—largely relying upon the advice of interested parties or of hopelessly incompetent 'experts'—subscribed and lost millions of pounds in ventures doomed to failure from the moment of their inception.

Nevertheless, the experience of one small syndicate must hold place amongst the most dazzling stories of fortune-making in

Photo by Dwyer's Studio.

KALGOORLIE IN THE EARLY DAYS.

the history of mining, and can hardly be surpassed by the tales of Broken Hill, Johannesburg, or Kimberley. With a capital of ten £15 contributing shares and five fully paid-up shares, the Coolgardie Prospecting Company was floated in Adelaide in 1893 to equip Pearce and Brookman for the new fields. These fortunate prospectors, as told above, were the first to locate the ore-bodies on the *Golden Mile*. In 1898 the syndicate was wound up, and after having distributed £950,000 in shares and £3,421,000 in cash, found itself holding shares in eight mines—including the *Great Boulder*, *Lake View*, *Ivanhoe*, and *Associated*—to the value of £9,275,075, making aggregate assets of £13,646,750.

6. The Kalgoorlie belt constitutes four or five miles of fissured country, greatly varying in value, which stretches past Kalgoorlie City down to its bread-winner, the mining suburb of Boulder City on the Golden Mile.

The northern and middle sections are now virtually abandoned, though several efforts have lately been made to effect their resuscitation. Headgears or 'poppet-legs' stand in depressing abundance to mark, as tombstones, the graves of British fortunes. The great values of the camp appear to be closely confined to the Boulder square mile, which turns out over 50 per cent. of the West Australian gold yield, and comprises the second gold-producing centre in the world.

7. The rich deposits of this section are best known as 'lode-formations,' which occur, striking roughly north-east and south-west, as several parallel or branching bodies of great irregularity. The productive country comprises a varying range of amphibolite rocks and their derivatives, which have not only undergone extreme chemical change, but have also been subjected to great pressures, giving the rock a characteristic (and, from the mining point of view, eminently satisfactory) schistosity, and at the same time forming lines of weakness along which the mineral-bearing solutions found their way.

The principal constituents of the lode-formations in which the gold, silver, pyrites, and tellurides occur are quartz, felspar, hornblende, chlorite, sericite, ilmenite, and calcite—some primary and some secondary. Even in those mines where the walls are best defined, ore and country merge gradually one into the other, as is characteristic of replacement veins. The ore occurs in lenses, sometimes highly attenuated, and following in succession along the same line of strike, in wide independent masses, in fairly persistent chutes, in unsystematically disposed patches, or in continuous 'pipes' or channels.

For several years geological phenomena were misinterpreted. That the country rock was granite was suggested in high quarters; while Baron Sloet van Oldruitenburgh concluded that the lode-formations were 'neither fissure formations nor impregnated dykes, but eruptive dykes, the ore-contents of which were carried upwards by the masses of eruptive rocks themselves.' *

Whether the series of hornblendic rocks are eruptive flows or igneous intrusions is still a debatable matter, as Mr. Gibb Maitland, the present Government geologist, stated in June, 1906; but it is now virtually impossible for even the most ardent follower of the igneous school to regard the precious metals as primary constituents of the amphibolite masses.

8. The most noteworthy exposition of the replacement theory was first delivered to the outside world by Mr. H. P. Woodward, late Government geologist, whose paper before the Institution of Mining and Metallurgy in October, 1897, on 'The So-called Lode-formations of Hannan's and Telluride Deposits,' dispelled many erroneous ideas, and established a sound knowledge of true conditions. When no greater depth than 300 feet had been attained, Mr. Woodward said: 'There is only one theory tenable. This is that a series of fissures have been formed without any yawning, gaping, or faulting, up which highly heated mineral solutions were forced, which permeated the country rock on each side of these cracks, dissolving out certain of its constituents and replacing them by others, thus altering the nature of the rock to a large extent near the fissure, and gradually less further and further from it until no alteration at all took place, where the country rock remained in its original form.'

9. The zones found to characterize the lode-formations of the *Golden Mile* are: (1) Surface decomposed zone, rich in nuggety gold; (2) telluride zone, in which ore values are greatly increased by the inclusion of Calaverite, Kalgorlite, and other compounds of tellurium, gold, silver, and mercury; and (3) the deeper sulphides, marked by lower but fairly persistent and uniform values. To understand clearly the change of tenor one may note the ore reserve valuations for the *Great Boulder Proprietary*, which is generally regarded by reason of its historic associations, geological position, working depth, and acreage as the premier mine of the field. The main shaft has been carried to 2,200 feet.

Down to 2,000 feet values ranged from about 30 dwts. in the upper levels, through 40 and 50 dwts. for the 400-feet to 600-feet

* Translated by London *Mining Journal*, 1897.

levels, and gradually down to about 13 dwts. for the deepest workings, where the grade appears satisfactorily steady.

10. The first large output declaration made by the Kalgoorlie mines, which come officially under the title of 'East Coolgardie Gold-Field,' was for 1896, when 47,026 tons of ore were crushed for a return of 143,329 ozs., exclusive of the gold won from the alluvial workings. This was equivalent to 3 ozs. per ton, while the following year, when 117,560 tons were treated, the recovery was 2·5 ozs. per ton. Since then, however, Kalgoorlie has sobered down to a medium-grade field, dealing with large tonnages at low cost, and relying upon the persistence of values in its sulphide ore ranging between 10 and 15 dwts. The records of the field for the last few years more clearly evince this tendency than any discussion of the results of individual producers:

Year.	*Tons crushed.*	*Fine Ozs.*	*Yield per Ton.*
			dwts.
1904	1,147,270	1,048,262	18·3
1905	1,288,954	993,790	15·5
1906	1,478,917	984,351	13·3
Total from inception to end of 1906	7,805,455	8,146,233	20·9

It is indicative of the greater economy and efficiency of methods that, despite the reduction of grade, the dividend-paying capacity of the field has remained practically a constant figure. Distributions to Kalgoorlie shareholders have been as under:

Year.	*Amount.*
	£
1904	1,516,295
1905	1,584,281
1906	1,587,536

The chief dividend-payers and their records up to the end of June, 1907, may be shown in the following table:

	Authorized Capital.	*Total Dividends.*
	£	£
Great Boulder	175,000 ..	2,513,050
Golden Horseshoe	1,500,000 ..	2,355,000
Oroya Brownhill	450,000 ..	1,954,991
Ivanhoe	1,000,000 ..	1,768,750
Lake View	350,000 ..	1,378,750
Great Boulder Perseverance ..	1,500,000 ..	1,251,250
Kalgurli	120,000 ..	495,000
Associated Northern ..	350,000 ..	490,000
South Kalgurli	200,000 ..	50,000
Hainault	150,000 ..	46,613

11. On the different sections of the eight main lode-formations traversing this half square mile there are eleven profit-making mines in operation. These eleven producers are responsible for half of the Westralian yield and 27 per cent. of that for all Australia. Only to the Rand, whose pre-eminence as a whole is due to the immensity of its gold-bearing territory rather than the wealth of limited sections, can one turn for fair comparisons; even there the rate of production per acre from the central divisions is less than half that recorded on the West Australian field.

The vertical lode-formations of the Boulder group are closely centralized, and not readily separated. The mines may, however, be reasonably classed into three divisions—the Eastern, Middle, and Western lines.

12. The Eastern includes the two richest properties on the field, which still produce considerable quantities of telluride ore. These two—the *Oroya-Brownhill* and the *Associated Northern*—lie on the famous Oroya chute, which pitches as a channel at an angle of about 30 degrees from the *Brownhill* down to the *Associated*. The form of this pipe has been best described by its homely comparison with a string of sausages. An average cross-section may be estimated at 50 by 100 feet. When visited by the writer in 1906, the *Oroya-Brownhill* contained one stope, with 40,000 tons of 5-oz. ore developed, and was milling 11,000 tons per month for a yield of £5 per ton. Although the enormous value of this phenomenal chute, which stands amongst the richest in the world, has been well established, and exploratory work above, below, and on each side of it has been very extensive, the exact relation of the ore-body to the country rocks has not been satisfactorily explained. Some maintain that the deposit, which is more schistose and friable than its enclosing wall-rock, represents a filling in the fold of a disturbed formation, for an analogy to which we may turn to the saddle reefs of Bendigo.

The closely related *Associated* mine can only claim the tail end of the Oroya chute, and relies upon several distinct lode-formations, great in dimensions and low in grade.

13. The Western line of producers includes the famous *Great Boulder Proprietary*, which had, with £2,000,000 in ore reserves, produced up to the middle of 1907 £5,250,000 in gold, and paid out over £2,500,000 in dividends.

The 1906 returns for the Western group stood as under :

	Tons crushed.	*Ozs. won.*	*Dwts. per Ton.*
Golden Horseshoe	243,619	152,119	12·5
Great Boulder	149,943	130,542	17·4
Ivanhoe	185,985	122,460	13·2

The ore in these mines is generally harder and more quartzose than elsewhere upon the field.

14. The Central or Middle line of properties is of a lower grade, with the exception of the *Kalgurli*, whose great lenses of rich ore constitute a class of their own. On the other hand, the *Lake View*, *Perseverance*, and *South Kalgurli* are very closely allied, and through them run the exceptionally long and persistent Lake View lodes, at one time yielding considerable tonnages of ore as rich as any the field produced in its halcyon days. From 6,400 tons of *Lake View* ore over three-quarters of a million sterling was produced in a few months. That was in 1899. During 1907 the recovery was less than 25s. per ton.

The *South Kalgurli*, whose ore is particularly well favoured for extraction and treatment, is the most cheaply operated mine on the field, with the smallest labour complement relatively to tonnage crushed.

Upon summarizing, the following comparisons of 1906 yields and grades for the three divisions of the *Golden Mile* can be established :

	Tons crushed.	*Ozs. won.*	*Dwts. per Ton.*
Eastern	259,627	245,629	18·9
Western	579,547	405,121	14·0
Central	521,801	271,821	10·4
Totals and average	1,360,975	922,571	13·5

This average yield of 13·5 dwts. per ton is nearly twice the value of the ore mined from the comparatively flat and narrow banket-beds of the Witwatersrand.

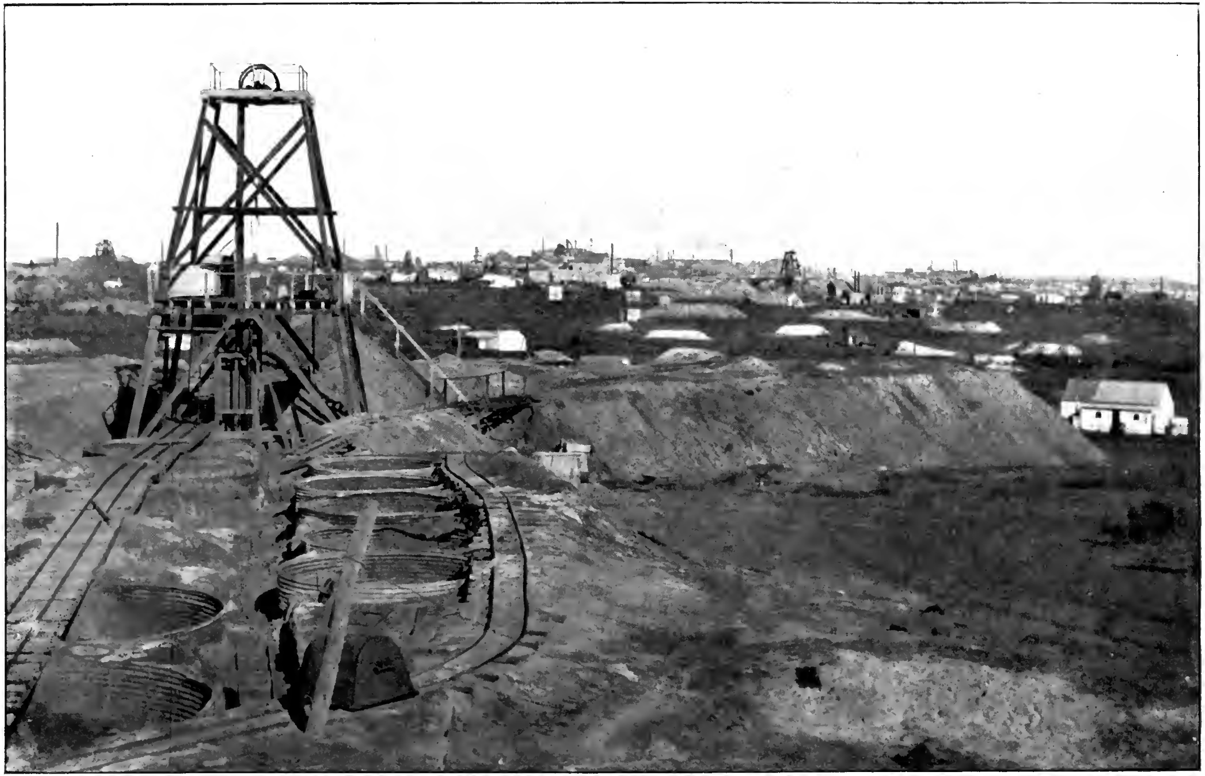
15. From the earliest days of Coolgardie's exploration the question of water-supply has been a formidable one. The

growing needs of the new industry, and the impracticability of relying upon local supplies of salt water and the output of private and public condensers, prompted the Premier, Sir John Forrest (even in 1895, when the possibilities of Coolgardie and Kalgoorlie were highly problematical), to consider one of the most daring engineering schemes ever undertaken by the Government of a young colony; at the time of its inception it was considered foolhardy. When it was first resolved to pump water (as much as 5,000,000 gallons per day if required) from the Mundaring Hills near Perth for a distance of 300 miles into the interior, the prospects of Coolgardie, which even now consumes but 100,000 gallons per day, developing into a great gold-field, provided the principal justification for the undertaking. The rise of Kalgoorlie made the Premier's bold enterprise a success.

At Kalgoorlie the Mines Trust (or Chamber of Mines) takes over its supply at 4s. per 1,000, and distributes it at 5s. per 1,000.

The Administration's scale of charges for water varies in accordance with the merits of the demand. At Coolgardie, for example, low-grade mines, recovering less than 8 dwts., pay 3s. 6d. per 1,000; higher grade mines 5s. 3d., if the scheme's water is used exclusively; 6s. 3d. when private supplies are utilized; and 7s. per 1,000 when the right of using any water is reserved. A company recently attempting to establish a dredging proposition at Coolgardie—a scheme which the thirst-stricken prospectors of that parched and waterless plain would have considered a few years before to stand at the highest pitch of impracticability—were supplied with water at 1s. 6d. per 1,000. In making these allowances the Water-Supply Administration acts entirely under the advice of the Mines Department, which determines the cases where the margin between revenue and expenditure can only be small, even under sound management, and where the good of the country can be served by granting reasonable assistance.

16. During the past few years expenses upon the *Golden Mile* have been very materially reduced in all departments by increasing the scale of operations, installing labour-saving devices wherever practicable, but, more significantly, by effecting radical changes in metallurgical practice. A few years ago working costs stood at such a figure that reductions of 10s. or 20s. per ton were speedily made when keen technical competition between managements became a dominant influence, and forced upon the industry a change of methods and policy. At the time when the introduction of Chinese labour into the Trans-



'GOLDEN MILE,' FROM THE NORTH.

vaal for work in the mines was a subject of wide (and wild) discussion, Kalgoorlie cost-sheets were frequently quoted in substantiation of the view that cheap indentured labour was unnecessary, and that the needs of the South African field could be economically satisfied by white miners. While the fundamental distinctions between the two fields, both in regard to underground conditions and surface requirements, render a close comparison of efficiencies useless for practical purposes, it must be acknowledged that the efficiency of the miner in West Australia is exceptionally high. The good wages draw men from all sections of the continent, and the Kalgoorlie mines have long been in a position to displace the indifferent worker by the good, owing to the large body of work-seekers generally in the camp.

17. An important circumstance in favour of Kalgoorlie underground economy is the rare occurrence of that dread scourge—miner's phthisis. The sturdy miner will endure a long, unbroken term of work with no ill-effects. Excellent ventilation has much to do with this gratifying condition; but more significant is the comparative innocuousness of the dust created by the breakage and handling of its rock. The conglomerates of Johannesburg and the quartz of Bendigo throw out jagged and spear-like particles of floating silica, eventually embedding themselves in the miner's lungs, whereas the amphibolite and sulphide ore of the Boulder yields no such dangerous discharge. The miner is able to continue his work for years with strength and confidence, while the employer can place men of long experience in all parts of the mine. There is, moreover, not the same loss incurred in the training of new men as there has necessarily been on a rapidly expanding industry like the Rand. The total labour force of Kalgoorlie has remained at about 6,000 for the last four or five years.

The improved and still improving efficiency of men and systems is reflected by statistics of tonnages raised and treated per man employed. For the last three years figures have been:

	Per Man Underground.	*Per Man employed.*
	tons.	tons.
1904	353	183
1905	384	206
1906	442	248

These coefficients include men upon several properties merely developing or reorganizing, and for several individual properties the ratio is very much greater. At the *South Kalgurli* the tonnage raised and treated per man employed underground is between 700 and 800 tons per annum.

The climate of Kalgoorlie, as compared with that of the Rand, is not a factor in its favour. The field's winter is ideal, but the frequently persistent dust-storms, during which whole dumps of residues apparently endeavour to solve the problem of aerial navigation, together with the trying discomforts of tropical heat, detrimentally affect the efficiency of surface labour to an appreciable degree. The trials of Broken Hill in this respect, however, are far more conspicuous.

18. Wages in Western Australia are, reasonably enough, higher than in other parts of the Commonwealth. The scale fixed by industrial agreement for Kalgoorlie includes the following rates :

	Per Eight-Hour Shift. s. d. s. d.
Rock drill men	13 4–14 4
Miners (hand-labour)	11 8
Bracemen and platmen	11 8
Mullockers, truckers, etc.	11 0
Timbermen	13 4
Labourers in cyanide vats	11 8
Filter-press men	11 8
Riggers	11 8
Firemen	11 8
Surface labourers (comprising pick-and-shovel men, battery feeders, slime, sand, and wood truckers, etc.)	11 0

Nearly all developmental work and considerable stoping is performed on contract, by which system good men make an average of 15s. to 16s. per day.

Mining companies, the majority of which are sorely cramped for space, make no attempt to provide for the comfort of employees by building, as on the Rand, cottages for occupation at nominal rents or recreation-halls for the leisure hour. The men live mostly in canvas 'camps.' After paying 22s. 6d. or 25s. per week for board, they very commonly dispatch their savings to relatives in the Eastern States. Kalgoorlie is not a particularly sober camp, like police-enthralled Broken Hill, but its most prominent weakness is a widespread passion for gambling. Kalgoorlie is a young city of many boasts ; its wide streets, its imposing post office, substantial houses of business, electric trams and public baths, are warmly eulogized by every judicious visitor, yet no feature can strike the stranger's eye more pleasantly, strange to relate, than the foundation of its 'unrighteousness'—two large race-courses, which comprise alluring oases, green and bright, in a desert of disorder and dreariness.

The life of Kalgoorlie is that of its mines. The miners clearly express their intention of making their residence on the field purely a temporary misfortune. Efforts by the Government to induce miners to bring over their wives and families from the Eastern States to Boulder City met with but limited success.

Turning from the managed to managements, the only point worthy of note, which cannot be inferred from subsequent records of working systems, is the usual independence of separate mine controls, as opposed to the group system, at one time carried to an excess upon the Rand. Nevertheless, the powerful firm of Messrs. Bewick, Moreing and Co. controls the *Lake View*, *South Kalgurli*, and *Oroya-Brownhill*, which are placed under a joint head-office management and resident superintendents, whose power extends little beyond the direction of current operations and normal development.

For many years Kalgoorlie has held the cream of Australian labour, just as it has attracted some of the country's best engineering and metallurgical talent.

In regard to working costs and mine conditions, the Boulder shares with the Rand the reputation of affording exceptional facilities for the acquisition of technical data by shareholders and other *bona fide* inquirers. Some years ago extreme secrecy and reticence were the rule. Agitations and criticisms led to a general change of policy, and it was even decided to freely admit all shareholders, and in some cases the general public, to the mine workings. Idle visitors became a nuisance. Consequently only one day a week was reserved for public inspection. Visitors were still a nuisance; then a charge of 3s. was imposed, in aid of some deserving charity. They visited no more.

CHAPTER XVIII

WESTERN AUSTRALIA—*Continued*

Ore Treatment at Kalgoorlie

1. Mining systems.—2. Filling and timbering.—3. ‘Shrinkage’ stopes.—4. Contract labour.—5. Timbers used.—6. Good machine ground.—7. Gold thefts.—8. Metallurgical status.—9. Complexity of methods.—10. Roasting versus Diehl process.—11. Types of plant.—12. Furnace operations.—13. Wet-crushing.—14. Filter-pressing.—15. Outside fields.—16. Coolgardie's destiny.

1. The wide, vertical lode-formations of the ‘Golden Mile’ present, despite their close relationship, considerable differences of trend and character, resulting in distinctions of mining and metallurgical practice. The principal variations are in the form of the deposits, which occur as chutes, lenses, channels, or fairly regular lodes, and in their degree of hardness, largely dependent on their schistosity and proportion of free quartz. A good width can nearly always be mined, good bulk and high values being commonly associated in these ‘replacement’ ore-bodies.

Although mine managers are frequently pressed for detailed estimates of reserves, the prevailing conditions of ore-deposition do not lend themselves to methods of exploitation, allowing precision in these calculations. It is not advisable to cut the ore into small blocks, as can be done in Rand mines in the course of normal development, for the purpose of satisfying investors' curiosity with figures of dangerous exactitude. Few Kalgoorlie mines can be fairly valued by their ‘positive’ ore-reserves, and any precision in the declaration of the ‘probable’ may easily give the shareholder a sense of false security.

2. There are three principal methods of stoping, the choice of which primarily depends upon the width of the ore-bodies and the strength of the walls. The most popular system is to run the stopes on the ‘rill,’ which means that they are carried up as

overhead stopes, worked from each side of a rise, and that they are filled naturally by the dry slime residues shot down from the surface, the working benches being regulated so as to conform to the angle of rest assumed by this filling.

Where the dip is regular and conditions otherwise suitable, the filling of stopes from surface can be performed at about 6d. per ton passed down.

Before stoping proper is commenced, a leading drive is carried along the lode with a height of some 20 feet. The timbermen follow the drills and build up the roof of the drive, which is to constitute the support for the stope-filling. Narrow widths are timbered with a single stull-piece hitched on the lower side and inclined at a moderate angle. A leg-post will often be added. In the wider levels ‘saddle-back’ timbering may be adopted, two heavy pieces of salmon-gum being set at an angle of about 60 degrees. Where the width is too great, or the walls are too insecure to stand the strain, the timbers may be supported by waste-rock packing penned up on either side. Full sets are also sometimes put in, but not as commonly as they were a few years ago.

A particular advantage of the saddle-back and single stull methods of timbering is that they enable the stopers to come up easily from the lower level and to get out every ton of ore without difficulty. Lagging poles are laid across the stulls to form a support for the residues or ‘mullock’ (waste rock). As the stope is carried higher and higher and the body of filling increases, the vertical passes and manways have to be steadily extended upwards. These passes are made at frequent intervals.

3. Another system of stoping highly favoured in mines with comparatively narrow lode-formations and fairly regular durable walls is locally known as the ‘shrinkage.’ As usual, the overhead stope is commenced from a winze (after the completion of the leading drive and its timbering) and carried up as an isosceles triangle. But no sand-filling is introduced. Throughout the breaking of the whole block the blasted ore constitutes the support for the miners, only the surplus (of about 40 per cent.) being sent down to the trucks. In this way the introduction of foreign filling is obviated (though it may eventually be required), and a large reserve of broken ore is accumulated, allowing the mill-grade to be well regulated. From these ore-filled stopes, whose broken contents represent 60 per cent. of the ore *in situ*, the rock can be drawn off as required. The loss of fines associated with other methods is prevented.

Three or four of the mines—notably those with large lenticular bodies (*e.g.*, the *Kalgurli* and *Great Boulder*)—adopt the system of flat-stoping or cross-work, by which the full width of the lode is dealt with in successive sections.

4. Half the mines of Kalgoorlie work their stopes on contract. It is often preferable to stope on day's pay for the reason that it enables a better check to be kept upon the ore filled into the trucks, of which much is apt to be unpayable rock when the distinction between ore and country is not conspicuous, and when miners are working for a maximum tonnage, without studying the economic requirements of the mine.

The *Golden Horseshoe* to some extent overcomes the difficulty, and at the same time gains the advantage of the contract system by paying 1s. 6d. to 1s. 9d. per foot drilled, instead of per cubic fathom extracted. Contract rates for stoping range from 40s. to 90s. per cubic fathom, with an average of about 60s. Development is performed almost entirely under contract.

5. Timber is clearly an important item in Kalgoorlie mining necessities, and in this respect the field is well favoured. The south-western division of Western Australia is the home of the giant Jarrah and Karri. More widely used for underground work, however, are the 'salmon-gum' (*Eucalyptus salmonophloia*—so named on account of the burnt reddish appearance of its somewhat smooth bark), and 'gimlet' gum, commonly associated with the salmon-gum, which has a strongly fluted or longitudinally twisted outer surface. Both these timbers are found plentifully in the region of the gold-fields, but their rapid consumption is driving the wood companies further afield each year and increasing the cost at the mines. Salmon-gum is hard, durable, and fairly heavy, and costs 1s. 4d. per linear foot up to 12 feet, 1s. 8d. up to 20 feet, and 2s. per foot for special pieces. The poorer trees and branches are used for firewood, and with this as a fuel the West Australian Collie coal-field near the coast cannot successfully compete.

6. The wide ore-bodies of the camp are essentially suited for cheap machine-drilling, the part played by hand-steel work being comparatively insignificant. Recently 2-inch and 2½-inch 'baby drills,' operated by one man, have been widely introduced with great economic success. In the Western mines the ground is too hard for these small machines, and it has been in the *Kalgurli*, *South Kalgurli*, *Oroya-Brownhill*, and *Lake View* that they have proved a factor of exceptional importance in reducing under-

ground costs. Upon an investigation of conditions underground made by the writer in August, 1906, it was found that the stoping of the industry's 130,000 tons per month and the accomplishment of corresponding development were effected by the constant use of 250 machine-drills, of which 86 were 'babies.'

Another circumstance in favour of the field is that the average ore is good breaking-ground, and gelignite a sufficiently powerful explosive, costing under £2 per 50-lb. case. Gelatine dynamite and blasting gelatine are used to some extent in development. Explosive costs average 9d. to 11d. per ton broken or milled, including consumption in development work and 'popping.'

The tonnage broken per employee ranges from 25 to 30 tons per month, and per mining man only 40 to 65 tons per month. A striking exception is the *South Kalgurli*, an easy property, of compactness and regularity, whose labour requirements are wonderfully low. From the self-dumping skip at shaft-head to the residue dump, treatment is all mechanically performed, and the working of the plant, equivalent to 55 or 60 head mill in capacity, called for less than forty men (of whom about half were on filter-presses), or thirteen men per shift. Yet every ton of its ore required roasting, and with this small force 8,500 tons of 8-dwt. rock were treated per month for a 92 per cent. extraction.

The amount of hand-drilling performed in regular mining practice is small. When adopted, it is double-handed, and the shift's work runs from 5 to 9 feet.

7. One of Kalgoorlie's industrial afflictions has always been the wide prevalence of gold-stealing from mines (where the tellurides are so rich in gold) and surface works. It has been the custom of the companies to do their utmost to check this evil by a thorough system of change-houses. But the many temptations to which employees were at one time submitted by illicit gold-buyers, and the laxity of Government supervision of the traffic in the metal, allowed the evil to attain alarming proportions. An agitation led to the appointment of a Royal Commission in 1906 to inquire into this flourishing 'business,' which was robbing shareholders of thousands and tens of thousands of pounds, and demoralizing the mine labourer. The strong recommendations of the Commission—that gold-dealers' licences should only be granted to the Mint and incorporated banks, that extra detectives be appointed with increased powers of

inspecting suspicious premises, that batteries and treatment of all descriptions should be open for official inspection, that punishment on conviction should be more severe, and that the court should have power to inspect and sample any mine—clearly proved the urgent necessity of reducing the dangers to which mine-owners had been long submitted.

The humorous impudence with which considerable parcels of gold had previously been sold and registered as the monthly or weekly production of such properties as the 'Hard to see' or 'Lost for ever' (if the recording of any specific source of production appeared advisable) gave this subsidiary industry an aspect of Gilbertian absurdity, only appreciated in that light, however, by those free from any interest in the prosperity of the Boulder mines.

METALLURGICAL METHODS.

8. It will often be remarked in metallurgical circles that 'the Rand is far behind Kalgoorlie,' and the remark is true. This comparative generalization can only be expressed with justice, however, when it is acknowledged that the Westralian field is so conditioned by Nature as to necessitate the adoption of several processes marked by great chemical and metallurgical ingenuity to overcome its peculiar difficulties, whereas the aim of the Transvaal metallurgist, with a reasonably disposed, if somewhat indigent, ore and cheap labour to deal with it, has most generally been to make simplicity more simple. But when we see, as during the last year or two, a gradual transformation of the fundamental principle of gold-ore reduction throughout the world, marked by the wide introduction of the tube-mill and more efficient means for treating increased tonnages of slime, the lead that has been long taken by the West Australian industry in this sphere of metallurgy must be allowed to reflect the highest credit upon technical leaders.

The Kalgoorlie metallurgist has been confronted by problems and intricacies, mechanical and chemical, upon every side. After several years of costly experiment for which the mines could once well afford to pay, two fundamentally distinct processes have been evolved upon this half square mile of gold territory, each characterized by lesser variations. The efforts made by different companies to solve problems, of which many have been common to all, has been in several respects divergent in their tendencies, but may now incline again to a uniformity in view of the indisputably established success of certain methods.

9. There are eleven noteworthy gold-producers at Kalgoorlie. Four of these crush their ore in Krupp ball-mills, one with Griffin mills, one with both Krupp and Griffin, one with stamps for further classification and fine grinding.

The ore is roasted in Merton, Edwards, or 'Perseverance' furnaces. Regrinding and sliming are performed in Wheeler pans and tube-mills.

The first mine to boldly attack the problem of treating the sulphide ore was the *Great Boulder Main Reef*, which, in 1899, roasted a fair tonnage by means of a shaft furnace, similar to those used at *Mount Morgan*, with poor results.

The many failures of the early days of telluride ore treatment, and the changes and processes necessarily effected by all the mines, are marked to-day by the relics of old and unserviceable plants standing alongside of, or intermixed with, the present installations, in odd connexion.

10. The two main processes evolved may be broadly classified as—

(*a*) Dry-crushing, all roasting and all sliming, for cyanide treatment.

(*b*) Wet-crushing, classifying, concentrate-roasting, and raw slime bromo-cyaniding.

The plants operated on the former system are very similar, although the primary crushers differ. Those of the second division either roast concentrates and slime all the rest, or eliminate a leachable sand product. Writing in 1907, Mr. Alfred James declared: 'The battle of the processes at Kalgoorlie is now over. It is admitted that the all-roasting process gives the most profitable extraction, but the good fight made by the wet-crushing bromo-cyanide party, and notably by the *Ivanhoe*, has been of the greatest service to the industry, and the *Ivanhoe's* costs are such as to reflect great credit upon the management and the staff; but the fine showing made by the *South Kalgurli*, the *Great Boulder*, the *Kalgurli*, and other companies, appears now to have convinced even the former advocates of bromo-cyanide.' *

Coming from Mr. James, who early identified himself with the introduction of the tube-mills in conjunction with the Diehl bromo-cyanide process, this testimony is significant.

* *Mining and Scientific Press*, January 7, 1907.

The plants in use in 1906, when the field was visited by the writer, were as under :

	Tons Monthly.	Mills used.
(1) All roasting :		
Associated	8,700	10 No. 5 Krupps
Associated Northern	3,500	3 No. 5 Krupps
Great Boulder	14,000	{ 2 No. 8 Krupps 12 Griffins
Kalgurli	11,000	9 No. 5 Krupps
Perseverance	15,000	16 Griffins
South Kalgurli	8,500	{ 2 No. 8 Krupps 1 No. 5 Krupps
(2) Wet-crushing :		
Golden Horseshoe	24,000	150 stamps
Ivanhoe	18,000	100 ,,
Lake View	11,000	70 ,,
Oroya-Brownhill	10,500	50 ,,

In addition to stamps, the *Golden Horseshoe* employed ten tube or grit mills, the *Lake View Consols* six, and the *Oroya-Brownhill* also six.

The cost of treatment by either method is comparatively high, in one case the roasting and in the other the bromo-cyaniding constituting a heavy charge. The average cost may be placed at 11s. to 12s. per ton milled.

11. Special features of the typical all-roasting proposition are its compactness and singleness of operation as compared with the plant relying upon several classifications of product.

MILLING.

The bulk of the ore treated by the all-roast plants passes, after preliminary breaking, through Krupp ball-mills, of which there are two sizes in use—Nos. 5 and 8. Sizing analyses show that these mills turn out a product of which 50 to 60 per cent. will pass 150-mesh screening. This fineness (minus 150) is classified as 'slime' in Kalgoorlie—an important point to remember when 'all-sliming' processes are under discussion.

Krupp ball-mills are in high favour on the field, and although they are not designed for the production of a discharge as fine as the Griffins, are more economical in supervision, repairs, and power. As a fine pulverizer the Griffin mill is, indeed, a most remarkably effective unit. Its action resembles that of the Huntingdon mill in the position of shafting, but there is only one roll or disk attached to the revolving shaft, which is free, like a pendulum, to swing within the die-ring. All wearing parts are made at the mine foundries, which constitute a most important and creditable department of Kalgoorlie surface works.

Working these mills on a well-reduced feed, and with 14-mesh screening, over 70 per cent. of the product is of a fineness under 200 mesh. The dust formed in the course of Krupp and Griffin mill operation is generally drawn off by the Sturtevant fans.

12. The milled ore, carefully transferred by screw conveyors to prevent loss of valuable dust, is delivered into the roasting furnaces, whose costs average 2s. 4d. to 2s. 8d. per ton milled.

Kalgoorlie ore contains an average of 3 to 4·5 per cent. sulphur, and the furnaces turn out a product with about 0·1 per cent. as sulphide and 2 per cent. as sulphate.

From the furnaces the roasted product is passed by a long series of push-conveyors, allowing it to cool down in transit, to mixers in which weak cyanide or plant solution is introduced. The next item is one of extreme importance in Kalgoorlie practice—the Wheeler grinding-pan, which is employed in the all-roast and wet-crushing plants, and in which amalgamation recovers, on the average, 28 per cent. of the gold.

The finally reduced or 'all-slimed' pulp (90 to 95 per cent. of which is minus 150 mesh) passes to the settlers and then to the agitation vats, wherein it is stirred by the ordinary rotating gear, or agitated pneumatically with cyanide. After agitation for ten to twenty hours comes filter-pressing, or vacuum-filtering, clarifying, gold extraction, and disposal of residues—branches of work common to all Kalgoorlie plants, wet or dry.

13. The several wet-crushing and concentrating plants in operation upon the Kalgoorlie field do not lend themselves to general description as readily as the more uniform installations roasting the entire mine product. Methods vary somewhat widely. Thus the *Oroya-Brownhill* and *Lake View Consols* roast their concentrates, and slime all the rest for raw bromo-cyanide treatment, with pans and tube-mills. The *Golden Horseshoe* also roasts and slimes its concentrates, but eliminates about 10 per cent. of the mill-pulp as a leachable sand product. The *Ivanhoe*, a steadfast opponent of tube-mills, treats as much as 45 per cent. of the mill-pulp by ordinary double leaching treatment. All these properties crush in the first instance with stamp batteries, generally using coarse mesh screens. The *Lake View's* duty is over 7 tons per stamp diem.

For classification of pulp Wilfley tables are principally used, and for regrinding, Wheeler pans and tube-mills.

The Diehl process was first put to practical test at the *Hannan's Star* mine. Here Dr. Diehl and the James Brothers installed the 'mother of tube-mills' in gold metallurgy.

Tube-mill practice changes in detail so frequently that figures bearing upon conditions and results speedily become out of date. It may be noted for the *Golden Horseshoe*—16 feet 4 inches by 4 feet mills—that, according to the data published by Mr. R. Allen on behalf of the West Australia Chamber of Mines, the power required, at thirty revolutions per minute, was 30 h.p., and the percentage of slime (minus 150 mesh) in the feed was 28·8 per cent., and in the discharge 39·5 per cent.

The agitation of the raw slime from the tube-mills with potassium and bromo-cyanide is effected in closed vats for safety, and is completed in about twelve hours.

14. Another weighty item of expenditure met by all companies on the *Golden Mile* is that of filter-pressing. For the treatment of slimes made by the milling of 120,000 tons per month about 90 presses and over 200 men were employed.

The large labour requirements of the filter-press have prompted Kalgoorlie metallurgists to experiment with automatic devices, and apparently the most successful innovation has been that made by Mr. Ridgeway, the assistant manager of the *Great Boulder Proprietary*, whose patent vacuum filter has proved highly satisfactory, and promises to widely displace the ordinary presses. By the adoption of vacuum filters there is the prospect of still further cost-reductions being speedily effected upon this metallurgically progressive field.

15. Outside the Kalgoorlie or East Coolgardie district there are a number of lesser fields and a few large mines which are of more than local importance. In order of productiveness these outside fields are the Day Dawn (Murchison gold-field), Mount Malcolm (Mount Margaret gold-field), Lawlers (East Murchison), Coolgardie, Mount Margaret, Kanowna, Niagara, and the recently progressive Black Range.

The greatest of West Australian mines outside the boundaries of East Coolgardie is the *Great Fingall Consolidated*, which had paid £1,563,900 in dividends up to September, 1907. This famous quartz-mine, situated at Day Dawn in the Murchison gold-field, has always been one of the most cheaply operated mines in the country. In 1906, 222,892 tons of ore were treated for a yield of 121,163 ozs., which compares poorly with 141,976 tons for 156,702 ozs., as registered in 1904. This mine, together with the *Sons of Gwalia* and *Cosmopolitan*, accounts for over a fourth of the Westralian yield outside Kalgoorlie.

16. The boom city of Coolgardie, raised in the 'Wild and Woolly' days of dazzling prosperity, when every man in the street was a mine-owner, every mine-owner a prospective millionaire, and the natural privilege of every millionaire was reckless and boisterous extravagance, soon lapsed into a state of lethargic respectability upon the rise of its unblessed offspring to the east. To Coolgardie the greater field of Kalgoorlie owes its industrial origin; to Kalgoorlie, Coolgardie attributes much of its misfortune and neglect. By no outside influences, however, is it reasonable to explain the fall of the older camp from its high distinction as the centre of a few magnificent discoveries and of more magnificent hopes. Not so soon, perhaps, would Coolgardie have found its proper level had not Kalgoorlie held out its more attractive offerings, but the fall itself was fated from the first days of its abuse by a host of visionary or fraudulent promoters. As a city Coolgardie—with a legacy of substantial buildings—has benefited by the prodigality of its youth; as a field for mining investment it has suffered keenly. From Burbanks in the South up to Bonnievale in the North, with *Bayley's Reward* claim as a central pivot, lies a 13-mile belt of gold territory still offering fair opportunities for companies of modest capitalization—if the past and its inept standards and practices be sunk in oblivion. The exploitation of the low-grade deposits on a larger scale is the chief hope of the field, whose quartz-reefs and lode-formations are to-day chiefly in the hands of small working parties. Coolgardie is a miniature Rhodesia. With a few producers of fair significance, such as the *Westralia* and *East Extension* mines at Bonnievale, *Bayley's*, *Griffith's* and *Tindal's* near the city, and two *Burbank* mines, the belt is for the most part in the hands of tributing parties and small syndicates, of which over a hundred contribute their quota to the 50,000 ozs. representing the annual production of the field.

CHAPTER XIX

SOUTH AUSTRALIA

Wallaroo and Moonta

1. Copper-mining, the paramount industry.—2. Burra Burra.—3. Discovery of Wallaroo.—4. Ore and its gangue.—5. Moonta lode system.—6. Smelting-works.—7. Miners on bonus system.—8. Blinman and Northern districts.

1. To the mining or metallurgical visitor South Australia presents two features of supreme interest—the *Wallaroo* and *Moonta* copper-mines, which have for nearly half a century comprised the greatest mineral asset of the State, and the Port Pirie smelting-works, reflecting the glory of the Barrier Range silver-field across the border.

The practical benefits of State aid to miners and prospectors have been well appreciated in the country since 1893, when the granting of subsidies was sanctioned by the Government authorities in Adelaide. Encouragement has not been wanting for the wider development of the mineral industry, and many are the occurrences of gold, silver-lead, iron, and other metals, in quantities large enough to warrant vigorous exploitation. But copper-mining has steadfastly remained the one important industry, and the *Wallaroo and Moonta* the one great enterprise upon which the fame of South Australia in the mining world depends. Of the current output, copper and copper ore account for 80 per cent.; of the aggregate yield to the end of 1907 (approximating £27,000,000), they represent £25,500,000.

2. The first noteworthy copper-mine to be opened up in South Australia was the *Burra Burra*, which lies 100 miles to the north of Adelaide, and has been unproductive for some years, though now and again attracting attention. The discovery of this deposit, made by a shepherd in 1845, put new life into the infant colony. During the mine's term of activity a yield of

234,650 tons of ore, containing 51,622 tons of copper (22 per cent.), was registered, with a value of £4,749,224.

Operations were suspended in 1877. Mr. H. Y. L. Brown, the Government geologist, investigated the mine thoroughly, with a view to determining the prospects of successful reorganization. His reports, promising from the industrial point of view, show that in the upper levels there is no appearance of lodes, the ore (blue and green carbonates) being deposited with the greatest irregularity. In the deeper workings regular lodes are met with, running north and south, containing very rich ores of malachite, red oxide, and grey sulphuret of copper. The blue carbonate often occurred in round nodules, with regularly formed crystals projecting from the surface. The malachite was formed in the form of stalactite, in slabs incrusting fissures, and irregularly shaped masses, which had been deposited in the rocks. Large quantities of native copper were also extracted. In a Government Report, dated 1901, the hope is expressed that 'ere long this mine will be the scene of a similar prosperous activity to that which existed in the past' in view of the evidence provided by boring operations of 'copper-bearing lodes at a considerably greater depth' than the mine-workings. It is in the natural order of things for the grade of copper-mines to fall with depth, but the Burra Burra could well afford to experience a diminution if the lodes continue. That the Government recommendations were not acted upon in time to allow the mine to benefit by the high metal market of 1906-1907 is to be deplored.

3. The *Wallaroo* and *Moonta* mines, situated on the shores of the Spencer Gulf, at the north-west of Yorke Peninsula, 80 miles from Adelaide, were discovered in 1860 and 1861 respectively, and until 1889 were operated as independent ventures. The *Wallaroo* company smelted its own ore and also the purchased product of the *Moonta* mines until amalgamation was effected. Up to that time the two companies had produced copper to the value of about £7,625,000. In all a yield approaching 250,000 tons of fine copper, worth over £13,000,000, must be accredited to these, the greatest copper deposits in Australasia.

The early discovery of these mines must be explained by their position on the coast and proximity to the more populous settlements. There were no prominent outcrops to mark the site of the ore-bodies in this flat, soil-covered section of the Yorke Peninsula. In a paper read before the Institution of Mining and Metallurgy in 1906 Mr. T. C. Cloud stated: 'The general characteristic was that the caps of the lodes were invariably covered by a deposit of calcareous marl, and that again by a layer of travertine limestone. The native wombat, a burrowing animal of the size of a small pig, had to be thanked for the discovery of these two mines. The travertine limestone crust was in places very thin, and the marl underlying it came to the surface in more or less rounded patches. The animal made its burrow by digging down into the marl and getting under the limestone crust.'

4. The following notes upon the mines and smelters, which the writer was unable to visit, are based upon reports by Mr. Cloud, Mr. Hancock (general manager), and Mr. H. Y. L. Brown, Government geologist, and upon data derived from other trustworthy sources. In the *Wallaroo* mine the main lode stands nearly vertical in a country of micaceous schist, and produces ore, principally chalcopyrite, of a value averaging from 3 to 10 per cent., with occasional enrichments. There are no regular chutes, and the width of the main and associated lodes ranges from a few inches to 12 feet or 14 feet. Above the zone characterized by chalcopyrite, red and black oxides, grey and black sulphides, with iron pyrites and a little malachite, were found; but these altered products were exhausted many years ago. The chief minerals forming the gangue of the ore in the *Wallaroo* and *Moonta* mines are quartz, felspar, biotite, hornblende, ankerite (carbonate of lime and iron), and calcite; while apatite, fluorite, and scheelite also occur in small quantities. Other metallic minerals found are zinc-blende, galena, molybdenite, cobaltite, gold, and pyrrhotite.

5. At the *Moonta* the lode system occurs in a quartz felspar porphyritic rock, and is composed of numerous ore-bodies, from a few inches up to 20 feet in width. Here also chalcopyrite is the predominant mineral below the upper zone of red oxide and atacamite ores. Bornite or peacock ore occasionally occurs as a distinctive and enriching factor. The peculiarity of this cupriferous district was disclosed by the removal of the green surface ores and the sinking of shafts—namely, that although the lodes maintained their regularity, no further ore was met with, and, as a rule, no stain of copper was seen until the depth of from 5 to 10 fathoms was reached, when rich oxide and other deposits were encountered. The chalcopyrite commenced at an average depth of 100 to 140 feet, and is now proved extensively in workings below 2,000 feet.

6. The ore from the mines is received at the smelting-works at Port Wallaroo in the form of a picked product—'Hancock jig,' concentrates, and slimes. Vein stuff as raised to surface runs from 3 to 4 per cent., and the dressed ore has shown the following average analysis :

	Wallaroo. per cent.	*Moonta.* per cent.
Copper	13·00 ..	19·00
Iron	26·10 ..	25·26
Sulphur	22·15 ..	17·82
Silica	25·19 ..	27·03

Recently, however, the copper contents have fallen considerably below these percentages.

At the smelting-works a matte containing 50 to 52 per cent. copper is produced in reverberatory furnaces. This is subsequently enriched to rough copper, about 90 per cent. fine, for the refinery. Immense accumulations of tailings and slimes from mechanical dressing plants have latterly been subjected *in situ* to treatment by a simple leaching process, affording good profits. The company manufactures sulphuric acid and sulphate of copper or bluestone.

The *Wallaroo* and *Moonta* mines have paid out in dividends over £2,000,000, and the *Moonta*, when an independent concern, gained the happy distinction of being the first mine in Australia to distribute over £1,000,000 amongst its shareholders. Statistics covering a period of forty-five years show that 1,540,180 tons of dressed ore (Cu 15½ per cent.) were produced at a cost of £6 15s. 4d. per ton, or £10,423,000. This great expenditure largely represents the wages of mine and smelter employees, numbering to-day about 3,000.

7. During the busy periods of 1906 and 1907, when, all the world over, copper-mines were eagerly pressing for a greater share of the good fortune enjoyed by producers of the red metal, the *Wallaroo* properties did not escape the common affliction of a labour shortage. But in a well-favoured centre such as this, with a considerable population of miners who have made the place their home, labour difficulties are only experienced in times of abnormal activity, and are speedily dispelled. There are various trade unions in the district, but none is recognized by the company. The greater part of stoping work is performed by contract, and bonuses, governed by the price of copper, are added to the standard rate of wages, as follows :

	Per Cent.
With copper over £60, bonus	10
" " " £65, ...	15
" " " £85, ...	20

Shifts are of eight or six hours, according to the class of duty performed, and overtime work is paid for at ordinary rates. Sunday work at the mines is restricted to repairs and special undertakings.

The fallacious precept of Barrier and Kalgoorlie unionism that skilled miners are born, not made, is discreetly ignored at Wallaroo, where the guidance of the inexperienced is not left to inspiration. Youths are encouraged to gain proficiency in their trade by attending technical classes and working as the hired helpers of underground contractors. Thus a new generation of trained men arises to fill the places of retiring veterans, and a high standard of efficiency, which the dangers and difficulties of the miner's work demand, can be more constantly maintained.

8. Outside the *Wallaroo* and *Moonta* there is only one active property of importance which has added to the State's yield of copper during recent years. This is the *Blinman*, situated in the Flinders Range, 272 miles from Adelaide and 110 miles north-north-east from Port Augusta. The prominent outcrop marking this deposit is said to have attracted the attention of a shepherd named Blinman forty-five years ago. The mine has experienced many changes of ownership and fortune, and is now being exploited on sound lines by the *Tasmanian Copper Company*. Smelting is undertaken upon the property in a 150-ton furnace, and results have shown an extraction of 4 to 5 per cent. copper. It is stated in a Government Report that a strong lode runs through the property, which, besides maintaining an equal percentage of copper, makes at intervals into extensive deposits of ore.

The company treats purchased parcels of ore at its smelter as well as the mine product. The opening up of this new market has been of great importance to the many copper-miners in this Northern district, where the lower-grade ores would not bear the burden of freight to Adelaide or Wallaroo.

CHAPTER XX

NEW ZEALAND

Chief Mineral Localities

1. Mining outlook.—2. Gold yields.—3. Bucket-dredging.—4. Home of the industry.—5. Pioneer steam plant.—6. Ill-conceived ventures.—7. Alluvial flats.—8. Present operations.—9. Sluicing and elevating.—10. Scientific exploration.—11. Quartz-mining. 12. Vicissitudes of fortune.—13. Coal-fields and coal yields.—14. 'Nationalize the industry.'—15. State coal-mine.

1. Although Government influences have been generally conducive to the active exploitation of the mineral resources of New Zealand, which are widespread and varied, the mines have not fully participated in the industrial expansion of this progressive dominion of the Southern Pacific. Public interest has been more keenly concentrated upon the pastoral, agricultural, and dairy industries, although mining has always constituted one of the prime factors in the country's welfare. It must be acknowledged, however, that the outlook has lately brightened. Signs are not wanting in the records of production of a notable revival in the mining of gold, which, with its associated silver, is the only metal won in quantities worthy of distinction. But this industry is only regaining, after a long period of weakness, the standard of production attained half a century ago. The output of coal—a mineral which is found to occur in New Zealand with a wide distribution that is geologically remarkable—has steadily increased, but at a rate no speedier than that recorded in other divisions of the Empire during a period of universal industrial activity. An interesting table can be compiled, indicating the position and progress of New Zealand as a coal-producer in its relation to other British fields (see p. 184).

The expansion of the Natal coal industry—like that of the Transvaal—is, of course, largely due to the cessation of hostilities in South Africa; for the Rand gold-fields provide the life-blood of all trade and commerce throughout the sub-continent.

	Output, 1902.	*Output*, 1906.	*Increase.*
	tons.	tons.	per cent.
New Zealand	1,365,040	1,729,536	27
India	6,790,507	9,112,663	34
New South Wales ..	5,942,011	7,626,362	28
Nova Scotia	3,900,000	5,200,000	33
Natal	592,821	1,238,713	109

2. A general indication of the course of the gold-mining industry may be given by the following figures for certain years, taken from official records:

	Value.
	£
1857	40,422
1861	751,873
1866	2,844,517
1871	2,787,520
1881	1,080,790
1891	1,007,488
1901	1,753,783
1905	2,093,936
1906	2,270,904

Up to the year 1871 the greater part of the colony's gold output was derived from the South Island, but after that date the North assumed a position of particular importance, and now, owing principally to the wonderful richness of the Waihi district, accounts for over half of the Dominion's yield. In the *Waihi* gold-mine the mineral industry presents its brightest aspect. Not only does the *Waihi* provide the one factor of strength raising the gold-fields above the commonplace, but it alone maintains for New Zealand the notable position in the mining world which was accorded to her many years ago as the home of alluvial bucket-dredging.

3. The dredges at work in the Otago and West Coast districts of the South Island are now productive of nearly 25 per cent. of the colony's gold output. As the outcome of many years' experimenting and modification, working expenditures have been reduced to a figure enabling exceptionally low-grade deposits to be profitably exploited. The practices inaugurated in the fields having since been applied—not always with similar success—in many other countries, it is of interest to briefly

trace the growth of the industry from its inception up to the present day. For much of the following data the writer is indebted to reports by Messrs. H. A. Gordon, R. Tennent, R. McIntosh, and other Government officials who are thoroughly acquainted with methods employed and their achievements.

4. The cradle of the dredging industry was the Clutha or Molyneux River, which joins the sea 50 miles to the south of Dunedin, the capital of the Otago district, South Island. In the year 1862 two Californian miners named Hartley and Reilly discovered gold along its beaches, then extensively exposed owing to the scarcity of water in the river. Their first efforts to treat the auriferous sands of the river-beds were made with 'spoon dredges,' worked by hand labour. These contrivances, slow in operation, achieved fair success owing to the high gold values encountered; but their principal service to the industry was in their exploratory indications of the extent and nature of the gravels tested. The next advance was marked by the introduction of current-wheel dredges, which were constructed of two pontoons, braced together, with current wheels outside operating an endless chain of buckets in the middle. The mooring-lines, to fix the position of the dredge, were operated by hand-winches. While this type of plant proved far more effective and economical than the spoon dredges (which are still employed in some parts of the world for testing operations), its manifest defects drove the engineers to attempt the application of advanced mechanical methods. Current dredges, by reason of their governing principle, could only be employed in a strong current.

Valuable runs of gravel could not be followed by them into the beaches or below eddies or still water.

5. After some years it was recognized that other methods of power generation would have to be employed to ensure the requisite independence of operation, and in 1881 the first efficient steam bucket-dredge—the *Dunedin*—was put to work on the Clutha River. From that time forward progress was rapid, and the industry expanded on satisfactory lines. Suction dredges were tried, amongst other systems, but the *Dunedin* represents the master type, after which, with numerous minor improvements, the most successful dredges have been designed up to the present day. Bucket-dredges can deal with enormous yardages of gravel from the river bottoms, and also from alluvial flats where water for floating the pontoons can be obtained. Soon after the inception of dredging in the Otago district atten-

tion was directed towards the river-beds on the West Coast of the island. Owing to the occurrence of large boulders and submerged timber the small Otago dredges proved inefficient, and operators had to experiment with several heavier types before success was achieved.

6. It was one of the early—and not exceptional—misfortunes of the New Zealand gold-dredging industry to suffer abuse at the hands of company promoters—fools and knaves—who traded upon the success of the legitimate ventures and the enormous extent of river ground upon which a dredge, with or without the possibility of success, could be placed in the 'auriferous region.' The boom found its origin, apparently, in the exceptional prosperity of a company formed in Dunedin in the year 1889 by a Chinaman named Sew Hoy, which worked three dredges on the *Shotover* beaches. Once aroused, excitement soon reached fever-heat, and the good name of the industry was ruined by the wild extravagance of financial aspirations. The functions of the promoter were limited to two floating operations: (1) The flotation of his syndicate, with a capital allowing £3,000 or £4,000 for plant, and (2) the flotation of a dredge—of any description and in any locality. Whether the bucket-ladder was sufficiently long to reach the bottom of the alluvial; whether the gravel, if reached, contained any gold; and whether the washing appliances, if gold existed, could profitably effect its extraction, were questions apparently considered too immaterial to merit previous investigation.

7. Another factor tending to check the development of the industry upon sound lines was the shortage of experienced men, due to the sudden increase in the demand. In many cases, certainly, the ignorance of the mechanics was considered a desirable factor, to which the absence of profitable returns could be conveniently ascribed by the financial sponsors. But in time men trained in the hard school of practical experience—the instruction of no other can avail—have raised the field to the highest standard of efficiency. Through the skill of constructing engineers and operating employees the sphere of application has been extended to flats and banks beyond the possibilities of successful treatment in the 'boom' days.

A most important event in the history of the industry was the installation of a dredge in 1894 with a tailings-elevator for the disposal of the waste gravel after treatment. This enabled the dredges to exploit much deeper ground and banks high above the water-level.

8. The magnitude of operations at the present day may be shown by figures for 1906 extracted from a Report by the Inspecting Engineer of Mines for New Zealand:

District.	*No. of Dredges.*	*Yield.*	*Dividends.*
		£	£
West Coast	31	86,082	24,086
Southern	136	415,117	79,636
Total	167	501,199	103,722

There were also thirty idle dredges upon the fields. The average yield per dredge was £3,000, and the expenditure £2,200.

While the tendency of recent construction has been to build still larger dredges, the pontoons commonly average from 80 to 100 feet in length, with a ladder capable of working to a depth of 25 to 35 feet. The buckets vary in capacity from 3 to 5 cubic feet, and are from twenty-five to fifty in number. On the *Alexandra Lead* a large dredge is in operation, with a pontoon 125 feet long, a ladder capable of dredging to 40 feet, and thirty-four buckets of 7 cubic feet capacity. Statistics available do not allow of the formation of an exact estimate of drift values, but an analysis of the returns of seventeen dredges, each dealing with from 200,000 to 750,000 cubic yards per annum, reveals an average production of less than 4d., or 2 grains of gold per cubic yard. By working on a large scale working costs can be reduced to a figure making a 1-grain proposition payable. In the last few years progress has been made in methods of driving dredge machinery, and electricity has in several instances been applied with economical results.

9. There are large alluvial deposits in New Zealand not possessing the favourable conditions essential for bucket-dredge working, which can be exploited profitably by hydraulic sluicing and elevating. The successful application of this system, even to flats apparently suitable for paddock-dredging, is to be noted particularly in the provinces of Otago and Southland, where remarkably cheap work has been recorded. Average costs for sluicing and elevating in the Southern and West Coast districts are estimated at 1¾d. and 2d. per cubic yard. Statistics compiled by the *Round Hill Gold-Mining Company*, and based upon the treatment of 2,250,000 cubic yards of ground, with an average depth of 45 feet, showed a yield of 2·363d. per cubic

yard, and an expenditure, including depreciation on plant, of 1·75d. per yard.

10. The highly creditable reduction of working costs has saved many deposits of very low-grade material, to which each year the miners are forced to pay more attention, from industrial neglect. While it may be necessary to deplore the fall in the rate of gold-production from dredging and hydraulicking during recent years, this branch of the industry has, in other respects, gained strength. Testing and operating have become a science, free from many of those highly speculative factors responsible for numerous early catastrophes. Professor J. Park, Director of the Otago School of Mines, has declared: 'The experience of gold-dredging and hydraulicking in New Zealand has proved conclusively that where the ground has been systematically sampled by an experienced engineer practically no failures are known.'*

11. The quartz-mines of New Zealand produce gold bullion to the value of £1,500,000 annually, representing a yield of 51s. per ton crushed. The mainstay of the group is the *Waihi* mine, whose brilliant record is made the subject of the following chapter. There are two noteworthy quartz-mining districts—the Northern and the West Coast of the South Island. The returns of the ten most significant producers stand relatively as follows:

	Yield for 1906.	*Yield per Ton.*
	£	s. d.
Northern district:		
Waihi	837,000	51 0
Waiotahi	223,678	248 6
Talisman	152,011	61 3½
Komata Reefs	45,448	44 2½
New Zealand Crown	40,735	35 0½
Grand Junction	13,794	33 10
West Coast district:		
Progress Mines	91,200	34 5
Consolidated Gold-Fields of New Zealand	36,307	37 5
Keep-it-Dark	18,887	26 10
Big River	7,904	77 10

12. Several of the colony's quartz-mines have been steady producers for many years. The *Keep-it-Dark* mine in the Reefton district, for instance, has happily belied its name by the declaration of 180 dividends during thirty-four years of activity. But it has been the destiny of many quartz-mines, in New Zealand, as elsewhere, to experience extreme vicissitudes of fortune upon the revelation or exhaustion of rich chutes and patches. Surprises, good and bad, often sensational, have been the dominant

* 'Text-book of Mining Geology,' 1906, p. 213.

feature of quartz-mining history in the Coromandel and Thames districts, upon which operations have proceeded for fifty years. Some of the early finds in the latter field were of amazing richness, and led to an excited rush of gold-seekers from all parts of the island. One claim—the *Caledonian*—paid shareholders £550,000 in dividends in a year. The lode was so rich that sometimes ‘ the gold had to be cut out with a chisel.’ Unfortunately, the rich zone was only a patch, and a speedy cessation of big profits came as a shock even to those best acquainted with the mine’s characteristics of ore deposition. A recent illustration of the highly speculative nature of work upon these quartz bodies, the unknown prospects of which more keenly attract daring investors than the safer alluvial ventures of limited possibilities, has been presented by the astonishing prosperity of the *Waiotahi* mine. The property has tended to restore the confidence of speculators in the Thames field, which was in former days one of the richest in Australasia, and from a narrow strip of which, only 1,000 yards long, some £7,000,000 sterling have been extracted. In 1906 the *Waiotahi* crushed 18,000 tons of ore, which produced—with additional specimen stone—gold to the value of £224,000, equivalent to the yield of £12 8s. 6d. per ton.

In the Reefton district, where the best mines of the South Island occur, the gold values are more evenly distributed in a free milling ore. Difficulties of prospecting and transportation, due to the thick vegetation and rough, mountainous nature of the field, have constantly retarded its development.

13. In the numerous coal-fields of New Zealand the mining geologist is not only perplexed by the variability of character observed in different beds, but also by the occurrence of the mineral under peculiar stratigraphical conditions. To the Carboniferous Age no New Zealand coal deposits can be accredited. According to the late Sir James Hector, Director of the Dominion’s Geological Survey, the coals of the colony belong to the Cretaceo-Tertiary Period ; whilst large bodies of lignite belong to still more recent formations. Official reports state that the coals ‘ vary in quality from a dull-burning brown coal of low evaporative power—suited only for use in the locality in which it is obtained—to a splendid coal equal to many of the best British coals for steaming, gas, and coking purposes.’ The beds of coal and lignite are so abundant and well distributed as to inspire the frequent hope, to which the Minister of Mines has, amongst others, given expression, that New Zealand may become the great manufacturing centre of the Pacific.

The output of 1,729,536 tons for 1906 comprised four classes of product, as follows:

Class of Coal.	*Tons.*
Bituminous	1,077,408
Pitch coal	24,961
Brown coal	521,003
Lignite	106,164

Far the most productive company is the *Westport*, in the South Island, which turned out 570,000 tons during the year.

14. Democratic New Zealand is famed for its daring legislative experiments, and has intrepidly led the way in many untrodden paths of economic politics. The aims of Australian labour parties, whose policies are divergent in many vital issues, have of late consistently tended towards the unseen goal of Socialism. Whenever it has appeared necessary for the advocates of this foggy principle to express in plain language, without the embellishment of platitudinous generalities, the means to be adopted for its practical application, the high-sounding formula, 'Nationalize the mining industry' is one commonly propounded. In the Australian federal elections of December, 1906, this was one of the cries most frequently raised by those of communistic tendencies. In New Zealand State-mining has been practised for many years.

15. The Act authorizing the Government to embark in coal-mining under the direct control of the Minister of Mines was passed in 1901, and 8,000 acres of coal-land near Greymouth (South Island) were reserved for State operation.

Financially these coal-mines—like many others under company control—have been a success.

The workers are registered as an industrial union, and work is carried on under an agreement entered into between this union and the manager. In this connexion conditions closely resemble those obtaining upon other fields where an 'association' of mine-owners and the trade union of employees arrive at a mutual understanding with regard to wages and other conditions of work.

With a view to the encouragement of the permanent settlement of employees the Government has set aside portions of the township for the erection of cottages on favourable terms, and many of the miners have built homes for themselves. A library and recreation-hall have also been established. This considera-tion for the social welfare of State coal-mine workers is suggestive of the more lavish efforts of the capitalistic mine-controllers of Johannesburg to satisfy the social needs of their white employees.

The New Zealand Minister of Mines is not alone amongst colonial officials of his position, upon whom the duties of mine management nominally fall. There are now Government tin-mines in the Transvaal and Government silver-mines in Ontario. Whether such undertakings can affect adversely the interests of independent controls must depend largely upon their scope of operation and the attitude adopted toward employees. In New Zealand the State coal-mine is politically of small moment, and, indeed, can scarce be called a 'stepping-stone' towards the 'nationalization of the mining industry,' which still seems to be far below the political horizon.

CHAPTER XXI

NEW ZEALAND—*Continued*

Waihi Gold-Mine

1. Australasia's premier gold-mine.—2. Situation of Waihi.—3. Twenty years' transformation.—4. Martha Hill.—5. Reef system.—6. Cherty quartz.—7. Silver exceeds gold.—8. Heavy pumping.—9. Stoping methods.—10. Ore treatment.—11. Three batteries.—12. Tube-mills.—13. Amalgamation.—14. Vacuum filters.—15. Power plant.—16. Working results.

1. No reader of the English or American mining press can have failed to note with interest the rapid advance of the *Waihi* gold-silver-mine during the last few years to a position of prominence among the world's most prolific metal-producers. By virtue of its yield, huge masses of ore, and progressive metallurgical policy the company has won renown far beyond the shores of New Zealand, in which colony it stands as the only mining enterprise of world-wide consequence.

A year or two ago the supporters of the *Waihi* were wont to measure its output with satisfaction against the chief declarations of the Rand, and note the mine's eminence even in relation to the foremost of the list. But the Transvaal mines have lately forged ahead so speedily as to make these comparisons no longer a cause for gratification. Amongst Australasian producers, however, the *Waihi* is shown by the following figures for 1906 to easily hold the lead:

	Yield.	*Dividends.*
	£	£
Waihi	840,000	297,544
Golden Horseshoe, W. A.	645,000	240,000
Oroya-Brownhill, W. A.	625,000	360,000
Great Boulder, W. A.	550,000	262,000
Ivanhoe, W. A.	520,000	240,000

A bonus of £74,386 was also paid by the *Waihi* in respect of the year's operations, bringing the total distribution to £371,930.

2. The township of Waihi is pleasantly situated amidst surroundings of hills, some rocky and bare, some plenteously wooded, in the Hauraki district of the North Island. The camp, built of wood and iron, is quiet and unpretentious. It is provided with four hotels, a daily newspaper, public library, an entertainment hall of good capacity, and other institutions naturally befitting a township of 6,000 inhabitants. Quite recently the Government railway terminus has been established at Waihi, making it accessible by rail from Thames or Auckland. The latter port—the most active in the Dominion—is only 70 or 80 miles from the mine as the crow flies, and the intermediate country is for the most part easy to traverse until the mountainous Te Aroha-Paeroa district is gained. But the railway route is circuitous, and the trains are slow. In the course of a wearisome eight-hour journey one is reminded of travel in Western Tasmania, where more ample excuses, however, can be found for deficiency of speed.

3. Huge and rich though its gold-carriers have proved to be, the *Waihi* did not shoot suddenly into eminence. Its expansion, marked by many changes of fortune, was slow and gradual. In the eighties the *Waihi* and adjoining *Martha* companies were independently at work, trying various means of ore-treatment with poor success. The needful vitality was infused into the former venture by Mr. Henry Russell, who arrived from England without practical mining experience, and who applied himself keenly and cleverly to local problems. As the result of his investigations the *Waihi Company* purchased the property of the *Martha Company* from its despondent shareholders for a nominal sum. This section has been solely responsible for the company's great prosperity. Dealing with the progress made, Mr. H. A. Gordon, F.G.S., has written : 'Several hundred thousands of pounds have been expended in machinery and development work. About 1,400 men are employed by the company. A flourishing town has sprung into existence ; good roads and streets have been constructed ; large, commodious buildings have been erected ; orchards and gardens gave a cheerful aspect to the place. Compare that with a solitary public-house (bleak and uninviting, a traveller was glad to reach that solitary habitation) in the year 1884, and note the gigantic strides due to the mining industry.'

It may be commented, however, that twenty-three years is a very considerable life for any gold-mining field. It is *Waihi*, the single mine—not Waihi the district—that properly calls forth expressions of praise and wonderment from new-comer or old visitor returned. As a metallurgical undertaking the company ever stands in the vanguard of the technical advance. As a mine, it holds a position of industrial stability probably unsurpassed by that of any gold-producer in Australia, America, or India, and equalled by few in South Africa.

4. Geologically, the Waihi section of the Hauraki district is of volcanic origin. The prevailing rocks are rhyolite and andesite, in a variety of forms and conditions, whereas sedimentary beds are scarcely represented. Geological conditions have a specially important bearing upon mining questions. At Waihi there is an upper flow of rhyolite, in which no productive lodes are found. Under this, and rising through it, at two points, is a mass of decomposed andesite, to which the gold-bearing quartz-filled fissures are restricted. Other bodies of andesite, of a different class, are also noted in the vicinity—but without the distinction of valuable fissures. Martha Hill—humbly named, indeed, for so opulent an eminence—is the most significant exposure of the decomposed andesite. It is lapped round by a flow of rhyolite, through which (and a body of hard andesite) the neighbouring *Grand Junction Company* had to sink for 500 feet before reaching the altered andesite and the contained Martha lode.

5. The reef system is a strong and complex one. The main group of ore-bodies consists of three parallel lodes, shown by cross-cutting at 850 feet to be 110, 30, and 17 feet wide. These are known as the Martha, Empire, and Royal lodes. Apart from these, there are eleven other bodies, distinct branches or connecting cross-lodes, all contributing to the mill-bins. So great are the widths of mineralized quartz that it is difficult to advance any simple hypotheses in explanation of the manner of deposition. It is surmised that fissures have probably been enlarged by faulting action. The wall rock has also, it appears, been to some extent replaced by the lode matter, which was carried into and precipitated in the fissures by thermal waters. Though such replacement has occurred in both Waihi and Kalgoorlie, there is little comparison between the vertical deposits of these two fields. In the former district quartz is an infinitely more abundant factor, and the walls of its lodes, though lacking, as a rule, a distinct parting, are fairly well defined.

6. The minerals found in association with the gold and quartz are pyrites, oxide of manganese (a favourable indicator), sulphide

of silver, blende, and galena. The quartz occurs in many varieties, the most abundant form being milky white, compact, and somewhat cherty. The best ore commonly possesses a distinctly banded structure, with the sulphides forming wavy lines parallel to the dip of the lode. In some places big sections of clean, hungry-looking quartz, with calcite, may be met with, forming treacherous ground to extract. Although manifestations of volcanic activity are so abundant throughout the district, faultings of the lodes are fortunately rare. A Rand or British Columbian gold-miner would consider them practically non-existent.

The main lodes strike through Martha Hill, east and west, and the cross-lodes run obliquely, often in a north-east and south-west direction, cutting the principal deposits at an angle of 45 degrees. All are vertical or very steep in dip.

7. Gold is, of course, the *Waihi Gold-Mining Company's* most important product; but it is by no means the weightiest. The yield of silver is seven times that of the yellow metal. The bullion produced resembles tin in appearance, and is worth only 12s. 3d. an ounce. The total contents and value of the ore per long ton, according to assay, have been proved during recent operations to be as follows :

	Ozs.	*Dwts.*	*Value.* s. d.
Gold	—	$11\frac{1}{2}$	48 4
Silver	4	14	9 4
			57 8

The grade has remained at about this figure for several years, revealing an inappreciable decrease with depth. So slight an impoverishment is satisfactory and exceptional. Moreover, the ore-bodies have increased substantially in bulk.

8. Of the ore derived from the company's many reefs—the Martha, Empire, Welcome, Royal, Regina, Albert, Princess, Victoria, Rex, and others—(the Waihi is loudly patriotic)—the Martha accounts for 40 to 50 per cent. This ore-body, with its width of 110 feet at a depth of 850 feet, and a grade of 50s. to 60s., may be regarded not only the backbone of the company, but is one of the greatest gold deposits under operation in the British Empire. The comparatively small Empire and Royal reefs, lying parallel thereto, would be 'enormous' in any other field. There are six vertical shafts upon the property, five of

13—2

which are in operation. Pumping is a heavy item, for the wide fissurings prove inconveniently receptive water-carriers. The Cornish pumps employed represent the most efficient installation of their class in Australasia, excepting the lifts in the *Tasmania* gold-mine, which are of similar type and manufacture. Their capacity is 135,000 gallons per hour.

9. In the development of the lodes, where the widths are moderate, drives are carried along the middle, and cross-cuts made every 50 or 100 feet, from wall to wall, for valuation. When desirable, a leading stope is commenced, and heavy, full-set timbering introduced for the protection of the drive and the support of the mullock-filling subsequently passed into the workings. In the case of very great widths, longitudinal sections of 30 feet are stoped and filled. In the narrow bodies the 'shrinkage' system is practised with success. The rising stope is filled with broken ore, only the surplus being passed through the chutes until the block is depleted, and the ore then tapped away as required. The timbers now most commonly used are the Rimu and kauri pine.

Nearly all underground work is performed on contract, the machine-men undertaking to deliver the ore at the plat for about 4s. per ton. Development is performed at 16s. or 17s. per foot, plus the 4s. per ton allowance.

Heavy machine-drills are employed. Winzing is generally undertaken by hand labour. Gelignite, purchased by contractors at 47s. 6d. per case, is the most common explosive. The ground drills and breaks well, and in driving a rate of 30 to 35 feet per week can be made without special urgency. As demonstrated by stamp duties in the mill, the quartz is particularly hard, but this circumstance is compensated for, in regard to drilling and ore-breaking, by the banded structure and the frequent occurrences of cracks and soft streaks. No surface sorting of ore is practised. The rate of extraction averages 325,000 tons per annum, and ore reserves exceed 1,000,000 tons, estimated on a thoroughly conservative basis.

10. Though the *Waihi* possesses in the Martha lode a gold deposit of marvellous resources, the proposition appeals to the metallurgist even more strongly than the miner. The progress made by this somewhat isolated venture and the high efficiency attained without excessive expenditures are features reflecting the highest credit upon the management. On the Rand or at Kalgoorlie metallurgists are able to benefit promptly by the

failures or successes of their neighbours, but on the *Waihi* improvements can only be effected as the result of independent trial. To-day, however, power and milling plants are being reorganized on a system likely to remain in force for some years in its salient principles, though perhaps to be regarded as a further stage in an advance to a process of reducing all the ore to a state of slime. The remarkable success obtained with tube-mills, after fair and conclusively unfavourable trials of grinding-pans and ball-mills (steadfastly honoured by Kalgoorlie controls), has been so conspicuous that thirteen of these machines will be in use, resulting in bigger mill tonnages and a higher gold extraction by 2 per cent. Even more creditable than the tube-mill progress, with the coincident introduction of a patent liner for the utilization of local rock instead of imported 'silex,' has been the construction and use of a highly efficient vacuum filter plant for slime treatment.

11. The *Waihi* company operates three independent mills—the Victoria of 200 heads at Waikino, the Waihi of 90 heads, and the Union of 40 heads, making 330 in all. Owing to the hardness of the cherty quartz, a low stamp duty of only 3½ tons per day is recorded; before the introduction of tube-mills and coarser mesh-screening the duty was as low as 2½ tons.

The tonnage dealt with by these batteries is therefore very small as compared with the *Simmer and Jack*, Transvaal, whose single mill of 320 heads deals with 750,000 tons per annum. For 1906 Waihi tonnages were only—

Mill.	*Stamps.*	*Tons.*
Victoria	200	189,260
Waihi	90	111,056
Union	40	28,550
	320	328,866

In New Zealand, however, no milling is performed on Sundays.

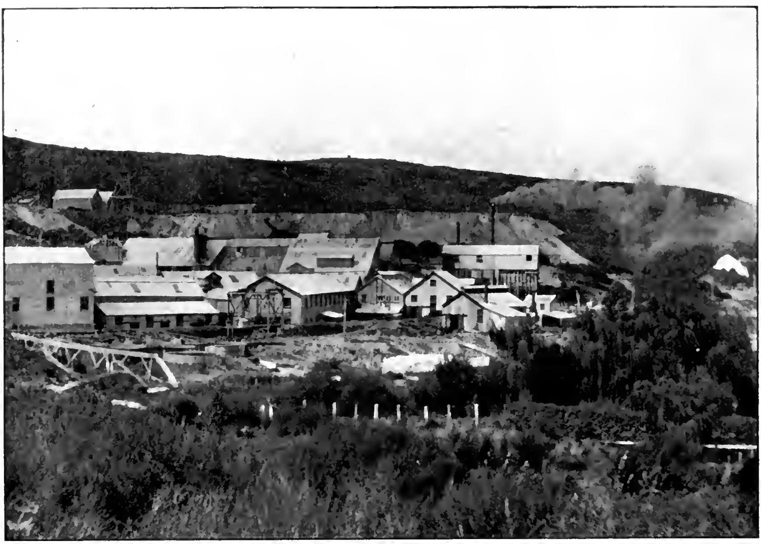
At the Waihi 90-stamp mill, where new practices are commonly tried before general application, treatment methods are as follows: The ore, after being weighed, passes through Gates crushers for reduction to a good stamping size. The stamps are of 960 lbs., and 20-mesh woven wire-screening is employed in place of the 40-mesh in use two or three years ago. The stamped product (42 per cent. of which will pass 150-mesh) is elevated and passed through spitzkastens, yielding a coarse settlement for the tube-mills, of which four are here employed.

12. Tube-mills have been in operation since May, 1905. Of the Davidson type, and 22 feet long, they are charged with $5\frac{1}{2}$ tons of flints, and revolved at $27\frac{1}{2}$ revolutions per minute. The most noteworthy point in connexion with Waihi tube-mill practice has been the invention of the Superintendent, Mr. H. P. Barry, of a liner of efficiency and economy, overcoming several difficulties met with in other parts of the world. For some time the 'silex' blocks were used, but by means of 'honeycomb' frames it was found possible to turn an equally hard local cherty quartz to good account without attempting to fashion it similarly into rectangular blocks. The frame is of cast-iron, $18\frac{1}{2}$ inches long by $15\frac{1}{2}$ inches wide, and $3\frac{1}{2}$ inches deep, divided into four compartments, wherein irregular lumps of the quartz are firmly packed with cement. The life of these liners, which can be speedily replaced, is said to be longer than that of the 'silex' blocks. The cost of running the tube-mills has averaged about 1s. 2d. per ton of sand treated, of which figure flints and liners account for 7d. Each mill passes nearly 80 tons per diem.

13. The discharge of the tube or grit mills, joined by the spitzkasten overflow, runs to a long V-box, commanding the amalgamation tables, the plates of which are Muntz's metal. The arrangement of this section of the works is exceptional. By a set of siphon-pipes the product is delivered evenly to tables, fifteen in number, in a house quite apart from the crushing and grinding sections. There is one pipe for each plate, and a perfect distribution of product is thus effected. Even when stamps are held up, the full table efficiency is constantly obtained. The cleanliness and quietude of the room are important factors, being conducive to careful work and to a thorough understanding of queries and orders, perhaps too trivial for expression in a shout, between operators. Dangers of theft are also reduced to a minimum. The amalgamating-room below the Waikino or Victoria 200-head mill is only entered by six men (two per shift), excepting the head amalgamator and staff officials, in ordinary routine.

The pulp is classified into coarse sand, fine sand, and slime. The two former products serve union vanners (frue type), yielding concentrates and tails, further classified into sands—submitted to ordinary cyanide treatment in 40 or 80 ton leaching-vats—and slimes. The concentrates from all mills are sent to Waikino, where they are reground in small tube-mills.

WAIHI GOLD MINE.



WAIHI MILL, WAIHI.

14. Slime treatment is the *Waihi Company's* technical forte. Even Kalgoorlie, where sliming is practised more extensively than in any other gold-field, has been surpassed in efficiency of methods by this mine. The costly hand-operated filter-presses have been displaced by a vacuum filter, of the Moore type, with results of the most satisfactory nature. The apparatus consists of a 'basket' of nine to eleven frames, 10 by 16 by 4½ feet in dimensions, over which are stretched the cloths acting as the filtering medium. Through this the cyanide solution is drawn by suction-pipes. The slime adheres to the outside of the cloth in a satisfactorily firm state. When drawn from its tank the basket holds tenaciously 4½ to 5 tons of slime in cakes 1¼ to 1½ inches thick on each side of the frame. Before introduction into the filtering-tanks, the slime has been treated in vats, mechanically or pneumatically agitated, for two or three days—the high silver values necessitating long agitation. A great economy of labour is effected by means of these vacuum filters, which operate at 6d. per ton of slime. The good combination of tube-milling and vacuum-filtering of slimes with a small percentage of fine sand has turned the thoughts of the company's advisers toward the oft-discussed goal of 'all-sliming.'

The gold obtained from all quarters is equivalent to an extraction of about 90 per cent., and the silver 75 per cent.

15. For mill-driving the company has relied till recently upon both steam and water power. Efforts were made a few years ago to obtain permission for the utilization of the Hora Hora Rapids on the Waikato River, fifty miles distant. But the New Zealand Ministry, ever zealous for the 'rights of the people,' would not entertain the favourable terms offered, and refused to grant the required sanction. While the rapids are still spending their power uselessly upon the river channel, the *Waihi Company* has turned to other means of economical power-generation. In 1907 a gas-producer plant of two units was installed, and gas-engines for operating the new tube-mill and other sections of the plant at Waikino. There will be five gas-engines, each of 200 horse-power, eventually in use.

16. The total working costs of the Waihi Company, including mining and development (8s. 5d.), milling, repairs, office expenses in New Zealand and London, directors' fees, etc., average 21s. per ton crushed.

Yields and dividends since inception have been as follows :

Year.	*Yield.*	*Dividends.*
	£	£
Up to 1899	1,202,224	470,863
1900	317,902	160,000
1901	461,205	166,425
1902	521,574	209,900
1903	658,393	297,544
1904	683,882	297,544
1905	728,521	322,340
1906	837,927	391,930
	5,411,628	2,296,548

The capital of the Waihi Gold-Mining Company is £500,000 in £1 shares, which are quoted in the Stock Exchange at a price giving the mine a valuation of over four millions sterling.

CHAPTER XXII

SOUTH AFRICA

Mineral Production in the Five States

1. To the Zambesi, and Beyond.—2. Industrial expansion.—3. Records of achievement.—4. Copper, the first important metal.—5. Little Namaqualand.—6. Two producing companies.—7. Methods of extraction.—8. Natal coal.—9. Orange River Colony.—10. Transvaal's minor fields.—11. Base metals.—12. Abundance of coal.—13. North-Western Rhodesia.—14. Rhodesia Broken Hill.—15. Copper production.—16. Mining progress and financial depression.

1. In the familiar usage of such trite phrases as 'from China to Peru,' or from 'Indus to the Pole,' the fitness of a literal application may well be allowed to pass unheeded. But in speaking of the territory 'from Zambesi to the Cape,' too often is the definite impression conveyed that this span embraces in its entirety the British sphere in Southern Africa. To the south, it is obvious, the final boundary is inevitably defined, but northwards the advance of civilization and industry, through the progressive forces of Charterland administration, stimulated by the development of newly exploited mineral deposits, has penetrated to the centre of wild territories traversed a few years ago by none save the daring explorer. To these distant regions of Northern Rhodesia, first prospected in 1894, the mining industry has stretched its vigorous limbs, and the fields have become a significant part of commercial 'South Africa,' even though separated by geographical distinctions. As the well-known review modified its title and became the *Nineteenth Century and After*, so in this great sub-continent must the changes now be recognized and the field of industry be surveyed 'from the Cape to the Zambesi, and Beyond.'

2. Since the cessation of hostilities in 1902 there has been evinced throughout South Africa—notably in the gold-mines of the Rand and Rhodesia, in the diamond-fields of Cape Colony,

Orange River Colony, and the Transvaal, and in the subsidiary coal-mines—enormous expansion, rapid in achievement and inherently sound. Production has been augmented far beyond the pre-war standards, and the basis of operations widened and diversified, in spite of the adverse financial conditions prevailing in every quarter, and in every branch of industry. The years 1906 and 1907 have been periods of record accomplishment—of record gold, diamond and coal yields; of record dividends and record wage distributions; also, as an anomalous sequence, of disastrous depression, contrasting unhappily indeed with the unparalleled wave of prosperity then benefiting other regions of the world.

3. The South African mineral yield stands high above the declarations of other divisions of the Empire. But the great bulk of the production must be accredited to a few rich concentrations, and not to the combined contributions from many fields. Regretfully may it be suggested that Nature, in distributing a bounteous share of useful minerals, shed them over the land with a partial hand, using, as it were, a big spoon instead of a pepper-pot.

Tabulating the figures for a recent year, the mineral returns may be shown as follows:

	Year ending	*Value.*
		£
Cape Colony	January 1, 1907	7,600,000
Orange River Colony	June 30, 1907	1,300,000
Transvaal	June 30, 1907	30,000,000
South Rhodesia	December 31, 1907	2,382,000
Natal	January 1, 1907	525,000

Of the South African aggregate the Rand gold-fields and the Kimberley and Premier diamond-mines account for 85 per cent. In succeeding chapters these great mineral-producing centres will be discussed in some detail, and it is here only necessary to mention briefly the regions of active exploration, such as the Cape and Northern Rhodesia copper-fields and Natal coal-fields, omitted from subsequent review.

The rise of several new centres of mining activity may be regarded as a cause of peculiar satisfaction in view of this ill-distribution of mineral wealth south of the Limpopo River. In the prevailing tendency toward excessive centralization, there naturally arises a factor of instability—of precarious dependence upon the support of two or three deposits, rendering the country the more liable to suffer from the changing moods of Fortune. Scattered mining camps, too, exert a more beneficial influence

KIMBERLEY DIAMOND MINE IN EARLY DAYS.

upon the general development of trade and agriculture by the establishment of markets in widely distributed regions.

4. South Africa has gained and held its place of eminence in the mining world by virtue of its wealth in gold and diamonds; it was copper, however, that provided the early prospectors with their first rich rewards, just as copper has lately been amongst the products attracting and encouraging the pioneers of Rhodesia northwards. The universal renown of the sub-continent as a mineral country was established upon the opening up of the Kimberley diamond-mines in the seventies, and was revived and strengthened when, in 1885, the Witwatersrand gold-field, following Lydenburg and Barberton, revealed its boundless treasure. The Natal coal-fields—the sole region of mineral production in the 'garden colony'—recorded their first substantial yield in 1889; while Rhodesian gold-mining, with an unchronicled history running back for centuries, can be said to date, in its modern aspect, from the occupation of the country by the Chartered Company in the early nineties. But even several years before the original discovery of diamonds near the Orange River copper-mining had become a promising industry in Little Namaqualand, on the north-west coast of Cape Colony. The extensive and remarkably rich deposits of this region were opened up between 1852 and 1855, amidst a flurry of speculative excitement, marked by the flotation of manifold syndicates—for exploration or development—and by the success of only two, from which were evolved the Cape Copper and the Namaqua Copper Companies of to-day. Little is now heard of these two old-established producers, which no longer possess much speculative interest, and which are situated in a part of the country—sterile and unattractive—far from the main arteries of South African life and commerce. Yet *O'okiep*, *Nababeep*, and *Tweefontein* hold place amongst the greatest copper deposits in the British Empire.

5. The Little Namaqualand copper district, of which O'okiep is the principal centre, and whose group of ore deposits includes a large number of related occurrences, is situated about 300 miles up the coast from Cape Town. The centre of operation lies inland from Port Nolloth on the Atlantic seaboard, with which connexion is made by a light railway 90 miles in length, belonging to the Cape Copper Company. The neighbouring country is described in unfavourable terms by all observers; the long droughts and very small annual rainfall give the region, which is broken by low ranges of hills, a dreary, sterile aspect. The

productive section of the field, beyond which for many miles indications of copper have been found to exist, though rarely leading to the development of profitable mines, is roughly defined by an area 10 miles wide by 30 miles long (east and west), made up almost wholly of granite and gneiss. The copper ore occurs in payable quantities at certain parts of an eruptive vein, running in lines or belts. The deposits are of fairly systematic aggregate relationship, but, individually regarded, are most erratic in disposition. Traces of copper occur throughout the intrusive rock, which consists, according to Mr. J. Kuntz, chiefly of plagioclase, but also contains hornblende and quartz, and in places biotite and augite. In mineralization, the deposits vary chiefly in point of value, for the classes of ore found are generally similar. Copper pyrites forms the bulk of the product, which is often enriched by bornite (peacock ore). The oxides of copper, black and red, are also found in the upper levels, and near the surface carbonates and silicates occur in abundance.

6. The two operating ventures—the Cape Copper (a powerful concern, under the control of Messrs. John Taylor and Sons, also holding enormous copper deposits in Newfoundland) and the Namaqua Copper Companies—have opened up a dozen deposits of more or less promise. By far the greatest mine has been the *O'okiep*, held by the Cape Copper Company, which has also worked the *Nababeep*, *O'okiep East*, *Specktakel*, *Koperberg*, *Narrap* and *Carolusberg East*. The *Nababeep* is now responsible for the biggest tonnage of ore. The important *Tweefontein* mine is the mainstay of the Namaqua Company.

According to report, the great *O'okiep* ore deposit was accidentally revealed by a wagon-rut. The occurrence is of great magnitude, measuring about 1,300 feet along the strike, and with a vertical thickness of 300 feet, but is of no great downward persistence. Referring to this deposit, Mr. Kuntz remarks: 'This huge mass of ore consisted to a great extent of copper ore, especially bornite and copper pyrites, partly pure ore, and partly intermixed with the other mineral contents of the eruptive vein. There are also large pieces of gneiss-granitic country rock, horses intermixed with the mass of the pocket; and smaller and larger veins of copper ore of secondary origin traverse the vein rock, as well as the country rock in its neighbourhood.'*

From 1883 up to the end of 1907 the *O'okiep* had produced upwards of 600,000 tons of copper ore containing 19½ per cent.

* Transactions of the Geological Society of South Africa, vol. vii.

of metal. On the same line as the *O'okiep* occur the *Narrap* and *Nababeep*; in both places the eruptive vein forming the ore-bearer is stated to be very conspicuous. From the latter mine over 200,000 tons of ore, containing 4·5 to 6 per cent. of metal, had been extracted up to the end of 1907. The Cape Copper Company operates smelters at *O'okiep* and *Nababeep*, in which the low and medium grade ore and 'raggings' are treated, whilst the rich 'firsts' are shipped to Swansea, where the regulus from the local cupolas is also dispatched. During the last fiscal year the Cape Copper Company made a profit of £379,910, principally on account of Namaqualand operations.

7. The *Tweefontein* ore-bodies are very similar to those of *O'okiep* and *Nababeep* in their irregularity and mineralogical features. In some notes read before the Geological Society of South Africa at the close of 1905, Mr. J. H. Ronaldson stated that three ore-bodies were being worked which had a slightly easterly dip in their longitudinal extension, and that each section terminated below in a bifurcated outline. Their greatest dimensions were from 540 to 760 feet in length and 40 to 75 feet in width. Mr. Ronaldson referred to the wonderful solidity of surrounding rocks in this and other mines in the neighbourhood, which has facilitated the adoption of simple working methods. 'Exploring drives and winzes,' he stated with regard to the O'okiep, 'define the workable ground; underhand stoping extracts the bulk of the ore; while pillars, irregularly spaced, but as far as possible one above the other in the different levels, support the roof. These pillars are at first of large size, and are gradually "robbed" till the spaces around them become caverns of great extent and height.' The amount of rock-filling utilized is small.

The Namaqua Copper Company smelts some of its ore, and also effects the concentration of a considerable tonnage by means of jigs and electro-magnetic separators. During 1906 the company produced 8,775 tons of dressed ore (16½ per cent. copper), and also 2,192 tons of matte (55 per cent.) from a furnace charge of 22,474 tons, including slimes, tailings, slags, and flue-dust. Copper sales during the year totalled £214,000 in value.

The recent advance in the market valuation of copper gave renewed strength to the Little Namaqualand fields, but the subsequent collapse of prices, the imposition of a tax of 2s. in the £ on profits of Cape diamond and copper companies exceeding £50,000 per annum, and the seeming lack of any great new mines to take the place of the famous producers when exhausted, has thrown a cloud over a district of high repute in the mining and financial world.

8. Minerals of economic importance found in Natal, generally in deposits of small magnitude, include gold, copper, graphite, mica, asbestos, iron, lead, silver, and coal. The only profitable mining industry so far established has been that of coal in the north of the colony, and this merits additional notice in view of its rapid progress. From a tonnage of 216,106 tons in 1896 the yield has now risen to over a million and a quarter tons. The Natal coal-measures occupy a large area of the upper part of the colony, chiefly in the Klip River county, between Elandslaagte and Newcastle—a district famous for its associations with the war. The formation containing the coal-seams is invariably horizontal, and the seams are found at a comparatively shallow depth below the surface. The workable portion of the Natal coal area may be divided into three districts, each working coals of various thicknesses and qualities, namely—

(1) Elandslaagte and Wessels Nek;
(2) Dundee and Hatting Spruit; and
(3) Newcastle.

The workable seams in the Elandslaagte or Wessels Nek district are two in number—the top seam, about 4 feet thick, being of moderate quality, and the second, about 2½ feet thick, of good quality. The *Elandslaagte Colliery* is the chief producer in this district, and is, indeed, near the head of the Natal list. From the Dundee and Hatting Spruit district the best quality of Natal coal is obtained. The Natal Government Railway is chiefly supplied from this source, whence are drawn contributions from the *Glencoe Collieries*, *Natal Navigation*, *St. George's Collieries*, and *Dundee Collieries*. Some of these mines possess high-class coal, and employ very superior cleaning and screening appliances. The collieries of Natal give employment to over 6,000 persons, of whom nearly half are immigrant Indians. Owing largely to the employment of mechanical coal-cutters since 1901, for operation by electricity or compressed air, the annual output of coal per man employed on productive work has risen from 150 to 200 tons. The paid-up capital represented by producing coal companies amounts to one and three-quarters millions sterling, upon which, during 1906, dividends totalled £50,000, or only 2·7 per cent.

9. The Orange River Colony, essentially an agricultural country, produces a little coal and many diamonds. During the last year or two it has been one of the most attractive fields for prospecting and for company promotion—legitimate or fraudulent—in South Africa. Deposits containing the precious stone and others merely expected to do so have been opened up over a very wide range of territory, in pipes and fissures, in alluvial and river-beds. New mines—such as the *Roberts Victor* and *Voorspoed*—have arisen to give impetus to the work of exploration; others—such as the *Lace, Monastery, O.F.S. and Transvaal*—have lapsed into a state of quiescence. Mines may come and mines may go, but the famous *Jagersfontein*—the one great pillar of strength in the colony's mineral industry—runs on 'for ever.' This pipe was the first to be discovered in South Africa, soon after the river diggings at Klip Drift and Old Pniel on the Vaal had attracted their host of eager adventurers. The find was made as far back as 1870, and yet during the last financial year—so strong and enduring has been the mining position—the dividends amounted to £425,000.

The geological features of the Orange River Colony are not favourable for the occurrence of gold deposits, for the exposures of the ancient formations with which the yellow metal is commonly associated in the Transvaal and Rhodesia are of limited range. Shaft-sinking and bore-hole prospecting has been undertaken to a certain extent, however, to the north of the colony, where the Rand formation is found to outcrop and to extend below more recent rock series. At present, however, the country is unfortunately dependent upon its diamonds for its status in the mining world, and is thus primarily at the mercy of a capricious market.

10. In the Transvaal, with the Rand gold-mines producing over 96 per cent. of the country's annual gold yield of 27½ millions and the *Premier* mine accounting for its diamonds, there is an obvious call for the exploitation of new mineral fields to provide a better industrial balance. At present the Rand is the *fons et origo* of all prosperity and of all adversity within the colony, and even far beyond its borders. The lesser mining districts have frequently received financial attention, but energy has been put into their development spasmodically, and often without consideration for permanent success and the requirements of practical mining. The Barberton (or De Kaap) and the Lydenburg gold-fields in the Eastern Transvaal—which were active scenes of industry and speculation before the 'banket'

of the Rand was known—have not evinced that degree of vitality which their resources would appear to warrant. Their stagnation or restriction of progress has been attributable in large measure to failures and disappointments; but the locking up of extensive areas of ground under company control has been a further obstacle to development. The Klerksdorp district, to the south-west of Johannesburg, and situated upon geological formations similar to those encountered across the Rand, possesses many banket mines, and may be considered one of moderate promise under economical management uninfluenced by dangerous theories of reef correlation with Johannesburg ore-bodies. The Pietersburg district, in the Northern Transvaal, is marked by an abundance of generally precarious gold-reefs. Few other distinct gold occurrences are worthy of note excepting those of Heidelberg (South Transvaal) and Schweizer-Reneke (West Transvaal).

11. Greater heed has recently been paid—no doubt under the influence of the high market quotations of 1906 and 1907, which set prospectors and pioneers on the track of investigation all the world over—to the base-metal deposits of the Transvaal. Compared with the fortunes lost in the exploration of this class of resources, returns have been paltry indeed. During ten months of 1907 the Government statistics show the value of production to have been:

	Value. £
Copper ore	53,275
Galena	15,472
Tin ore	42,753

The only copper-producer of significance—and the first in the colony—is the *Messina Development Company*, whose property lies 6 miles from the Limpopo River, 130 miles by road to the north of Pietersburg, via Louis Trichardt. The country belongs to the Low Veld, is flat, densely wooded, and feverish in the rainy season. Four lodes with gneissic walls, in the archæan granite country, are operated, and the ore is mostly bornite and glance, with carbonates down to 100 feet. Shipments, averaging 60 per cent. copper, have been made regularly for over two years, the ore as mined being valued at 23 per cent. A modern concentrating plant, with a full capacity of 1,500 tons per month, is, according to report, to be erected shortly.

The Transvaal has frequently been quoted as one of the world's important prospective tin-producers. On several occasions hopes have run very high of proving rich and extensive deposits, but the 'potentialities' have been seen to steadily diminish upon their attempted realization. There are, however, general occurrences of decided interest—not to be mentioned in the same industrial category as those of Malaya, Tasmania, or Queensland—in the Potgietersrust district, where a small stamp-mill is being erected, in the Warmbaths district, and in Swaziland. In the last-named Transvaal 'Dependency' the tinstone is obtained from alluvial, but in the two former districts it occurs *in situ*. Tin is also being recovered in small quantities, it may here be incidentally mentioned, at Kuils River, near Cape Town.

Galena ore, with and without associated silver and zinc, is found in the Pretoria (Edendale) and Zeerust districts, but the future of this industry is quite problematical. Large deposits of magnesite occur in the Eastern Transvaal toward the Portuguese border, and iron ore exists in abundance in the Middelburg, Lydenburg, and Northern Pretoria districts. Asbestos of good quality occurs in the Eastern Transvaal.

12. The position of the Transvaal coal-mining industry, in the main subsidiary to the Rand gold-mines, is characterized by two prominent features—the enormous extent of coal-bearing ground, for the full development of which market demands are inadequate, and the excessive competition amongst producers, with a consequent reduction of prices to a level rarely leaving a margin for fair return on capital invested. The existence of extensive coal-seams, yielding a highly serviceable product, within easy access of the Rand gold-field (which is even overlaid by coal deposits in its eastern extension), is one of the country's conspicuous natural blessings, whose benefits can be but ill appreciated by disappointed shareholders. The prices realized and the records of production may be shown as under for the last few years:

	Tons sold.	*Price at Pit's Mouth.* s. d.
1901-2	1,134,871	8 3
1902-3	1,969,089	8 0
1903-4	2,370,465	7 6
1904-5	2,513,824	7 0
1905-6	2,751,136	6 0
1906-7	2,912,083	5 5
1907 (half-year)	1,455,395	5 5

There are upwards of thirty collieries at work in the colony, of which the majority are operating in the Springs-Brakpan and Middelburg areas.

13. The base-metal deposits under development in North-Western Rhodesia, far to the north of the Zambesi River, possess national importance in their influence upon the occupation and settlement of a part of the African continent till recently of small concern amongst the younger members of the British Empire. It would seem that mining, supported by a bold policy of railway construction, is destined to do for the dark regions of Central Africa what it has already done for the Gold Coast and Ashanti. Three zones of fair promise are under attack—the *Rhodesia Broken Hill* zinc and lead, about 350 miles north-east of the Victoria Falls; the *Bwana N'Kubwa* group of copper deposits 100 miles to the north, near the Congo State border; and the extensive field of copper mines on both sides of the Kafue River to the west of Broken Hill.

The history of northern mining opens with a chapter of stirring adventure—with the exploits of Major Burnham, the famous scout, and his companion, Mr. Ingram, who in 1894 made their way into hostile territory, and after many weeks of arduous and exciting trekking, brought down to Bulawayo the news of important copper discoveries. Other expeditions followed, and in time a wide range of base-metal belts was revealed.

14. The *Rhodesian Broken Hill* mines, long the terminus of the Cape to Cairo Railway's southern section, were so named from their analogy to the famous Australian deposit (which is, however, rich in silver). They comprise two main kopjes, about 3,000 feet apart, largely composed of zinc and lead ores. There are numerous lesser outcrops. No. 1 kopje is an irregularly shaped hill, nearly square at the base, which measures about 250 feet each way. The ores of which the rise is composed are chiefly carbonates of lead and zinc, but there are patches of sulphide. Silicates and iron compounds of zinc are also present. Ore values are officially estimated at 26 per cent. lead and 22 per cent. zinc. The No. 2 kopje is of a different character to No. 1. It stands about 90 feet above the level of the flat. Through it runs a broad belt, 120 feet wide, of 'zinc ores carrying only a small percentage of lead (under 2 per cent.) and 27·72 per cent. of zinc.' Irregularities of formation render estimates of ore in sight difficult to compute. Deep prospecting—a most vital operation from the metallurgical as well as the financial point of view—has been undertaken by drilling. Eighteen calcining furnaces have been erected as a measure said to be preparatory to the installation of adequate treatment

plant. A serious disadvantage experienced by the Broken Hill mines, as by the copper deposits to the north and west, is the long distance from the port of Beira (1,330 miles) and from the Wankie collieries (444 miles). Freight charges are about 70s. or 80s. per ton to Beira, and the total cost of ore-production under present conditions, including mining, calcining, rail, shipping, freight, etc., amount to £6 or £6 10s. per ton. It will be readily understood that mining in Northern Rhodesia is yet in a highly speculative stage of development, and commercial success is largely dependent upon the satisfactory solution of extremely difficult metallurgical problems.

15. At *Bwana N'Kubwa* the Rhodesia Copper Company have undertaken vigorous development work upon ancient copper workings which extended over a length of 2,100 feet. Results have been reported as eminently promising. The mine is not connected with Broken Hill by rail, but the route has been surveyed. In 1907 it was estimated that 50,000 tons of ore exceeding 18 per cent. copper, and 500,000 tons of over 4 per cent., had been developed. The ore consists principally of the carbonate, associated with a little sulphide. Mining conditions are said to be generally favourable. Timber for fuel and underground work is available in ample quantities, and plenty of raw labour is forthcoming. The question of transport is one of vital importance to the northern copper-mines, many of which cannot be economically exploited without good railway facilities.

To the north and south of the Kafue River there is an extensive group of copper deposits, several of which occur as impregnations in limestone formation. At surface malachite occurs, followed by copper glance, copper pyrites, and bornite, often associated with fluorspar. High-grade deposits have been tested in several localities.

16. While it is manifest, from a review of South African mining in almost every aspect, that substantial progress has been the dominant feature of post-war history, it requires no labour of searching investigation to learn how ill-reflected this technical advancement has been in the welfare of the individual and in the attitude of the colony's financial supporters. At the close of the war those concerned in South African mining —from the standpoint of the investor or the wage-earner—conceived anticipations of profitable industrial expansion, even beyond the great natural resources of the land. The necessity of long recuperation after the crippling effects of the three years'

campaign was ignored. Imagination and eager hopes carried the optimistic to thoughts of the essentially inachievable. The mining 'boom' which followed the proclamation of peace established a false standard of prosperity. Over-capitalizations, unjustified flotations, and other Stock Exchange excesses, over-trading by merchants, a surfeiting influx of unskilled whites in search of occupation, the gradually intensifying acuteness of the cheap labour shortage, political insecurity, and a reduction of values in the deeper Rand gold-mines—these are circumstances which have all contributed to intensify recent suffering and disaster, and have shattered the confidence of an over-expectant public.

The gorgeous visions of five years ago have been dispelled. Realizations, solid and successful, can now alone avail—and then only if their permanence and reality are thoroughly assured. The disfavour or disrepute with which all South African projects have come to be regarded—symptomatic of the pendulum-swing which has carried public opinion from the extreme of optimism to that of pessimistic dread and displeasure—has, of course, tended to check the normal development of mineral resources. So, too, has it obscured from view the splendid succession of technical achievements.

On the Rand gold-production and dividend distributions have surpassed all records. In the greatly expanded diamond-fields new 'pipes' and other deposits have been opened up, and marvellous success has attended the operations of the old, where yields and values increased coincidently up to the time of the American industrial disorganization. In Rhodesia the gold-mines have in a few years advanced — rarely aided by the support of big capital—to a level of productiveness placing the country above India and Queensland as a producer of the yellow metal. But in spite of the many gratifying factors in the situation, which give strength to the hope, silent and subdued, of a flourishing future, a thickening gloom has settled over the colonies of South Africa, from the Limpopo to the Cape. Some years, perhaps, of strenuous effort—of financial reform and technical advancement—may yet be necessary to restore the confidence of the industry's supporters, whose allegiance has been so rudely shaken by the troubles and uncertainties of recent times.

CHAPTER XXIII

SOUTH AFRICA—*Continued*

CAPE COLONY, ORANGE RIVER COLONY, AND TRANSVAAL DIAMONDS

1. The power of De Beers.—2. Simple tale of discovery.—3. The alluvial diggings.—4. Opening of Kimberley mines.—5. Individual claim owners and suicidal competition.—6. The master minds.—7. Modern Kimberley.—8. Diamond 'pipes.'—9. Origin of blue ground and diamonds.—10. Record hoisting.—11. Mining methods.—12. Weathering of blue ground.—13. Washing and concentration.—14. Classes of stone.—15. Statistics of yield.—16. Native compound system.—17. Orange River Colony diamond deposits.—18. Jagersfontein.—19. Inception of Transvaal industry.—20. A daring purchase.—21. Character of Premier pipe.—22. Large direct-treatment plant.—23. Cheap mining proposition.—24. Decline in grade.—25. A factor of the State.

1. There is no mining corporation in the British Empire, probably in the world, which has exerted so powerful an influence upon the destiny of nations as the De Beers Consolidated of Kimberley. No company has been more loudly and persistently vilified; none ever contributed by its organization, which evolved strength and order out of industrial chaos, more materially to the welfare of a country. In its conception was the touch of financial genius; in its administration have been revealed the highest attributes of scientific and progressive mine management; in its records of achievement appear colossal figures suggestive of a Chancellor's Budget.

Not long ago 'De Beers' and the 'diamond-mining industry' were synonymous terms; the company's monopoly was virtually absolute. Angry murmurs were heard against the 'tyranny' of the 'rapacious octopus,' whose tentacles shot out relentlessly over the land to hold it against possible competitors. That De Beers should have endeavoured to maintain its security by obtaining control of prospective producers is a rudimentary principle clearly essential to the stability of the undertaking's controlling power. But the vast diamond resources of South

Africa have to some extent carried the position out of the company's hands, and the emptiness of the popular clamour (excepting in Rhodesia, where grievances are real indeed) has been proved by the discovery of new mines, which have yielded big profits to their unhampered proprietors, or into which speculators have been allowed to throw their money without check or embarrassment. De Beers is still, of course, the great predominant factor; but it is far from appearing the be-all and end-all of South African diamond-mining. Operations at Kimberley did not relax in vigour till recent months of over-production and American economic disorganization. Yields and profits reached a culminating-point in 1906-1907. It has been the advance of new producers, not the decline of De Beers, which is accountable for the change in the relative situation.

2. In every serviceable description of the Kimberley mines, in every report purporting to convey an adequate impression of the magnitude of operations, there appears the necessity of employing large figures and bulky statistics—figures to fix in mind the vast scale upon which work has proceeded, and to provide a broad review in true perspective. In striking contrast with these multifarious records and with the history of the camp at the time of amalgamation and of struggle for the control of the world's market, the first chronicles of South African diamond-mining present a tale of picturesque simplicity. The outline of the oft-told story may be repeated here, based on various records and upon the authority of Mr. Gardner F. Williams, late General Manager of De Beers, whose work upon the 'Diamond Fields of South Africa' is perhaps the most masterly and attractive volume ever compiled by a mining authority for the entertainment of the public and the instruction of the technical world.

Some forty years ago, Daniel Jacobs lived near the small settlement of Hopetown, on the banks of the Orange River. His children, ignorant of the happy creations of the Lowther Arcade, amused themselves by collecting the pretty stones and pebbles scattered along the river-bank. One of these stones, more brilliant than the rest, chanced to be seen by Jacobs' neighbour, Schalk van Niekerk, who took it away to ascertain if any value could be attached to it. The stone passed through many hands without determination of its value, until it was sent—with significant carelessness—to Dr. Guybon Atherstone at Grahamstown, who pronounced it to be a diamond of $21\frac{1}{4}$

carats, worth £500. A search over the locality of the find was soon instituted, but without reward. Theories were propounded (though strongly opposed by Dr. Atherstone) that this solitary stone had no importance in its indications, and had probably been carried to the Hopetown district in the gizzard of an ostrich. Doubts were dispelled, however, in March, 1869, when a perfect white diamond, weighing 83·5 carats, was found by a shepherd-boy on a farm called Zandfontein, near the Orange River. This gem, eventually sold to Earl Dudley for £25,000, was named the 'Star of South Africa'—the star which drew thousands from all parts of the Cape Colony and Natal, and from across the seas to this 'Golconda,' a greater treasure-store than is known even to Indian legends.

3. The disappointments of the early prospectors were many, but on looking back through the long vista of eventful years, the progress of work seems to have been swift, as it was brilliant in its outcome. The band of diggers assembled at Klip Drift (now Barkly West) opposite Pniel on the Vaal River rapidly grew in numbers, and comprised at all times a hard-working, orderly community. Operations were undertaken with the most primitive contrivances—simple 'cradles,' such as were employed in the first exploitation of Ballarat, Victoria. It is recorded that the first organized party of prospectors reached the Vaal from Maritzburg, Natal, in November, 1869, and commenced systematic washing. Results were extremely erratic, and to the majority unprofitable. The stones recovered were mostly white, and included some of superb quality. It is noticed to-day that river stones are, on the average, of higher value than those won from the pipes. The diggings spread from Klip Drift across the river to Pniel, but it was not upon finds in this spot nor of this character that the great South African diamond industry has been founded. Along the river beds and banks were merely found the overflow wash from deep-seated 'pipes,' which constitute the chief repository of the world's diamonds.

4. The rush to the Vaal had placed all upon the alert—old Dutch settlers as well as newly arrived immigrants—and it was followed in 1870 and 1871 by the epoch-making discoveries of the mines, whose production has continued up to the present day, and won for them fame throughout the world. In August, 1870, the overseer of C. J. Visser's farm, *Jagersfontein,* found some big diamonds, which led to the opening up of the famous property in the Orange River Colony, now controlled by the New Jagersfontein Mining and Exploration Company, closely allied

with De Beers. Very shortly after, the discovery of the mines of the great Kimberley group, about 20 miles south-east of the old Klip Drift pioneer diggings, was recorded. First came the finding of diamonds at *Dutoitspan*, then on *Bultfontein*, on Vooruitzigt (*De Beers*), and a month or two later at Colesberg Kopje (*Kimberley* mine). These new points soon drew the diggers away from Klip Drift and Pniel, and amply rewarded them for their former ill-recompensed labours.

It was in the deposit at Colesberg Kopje, discovered by Fleetwood Rawstone and T. B. Kisch, that the best results were obtained. This deposit, famous as the *Kimberley* mine, was consequently developed with greater speed. For some time it was believed that, as at Klip Drift, a shallow alluvial deposit was under exploitation; but the supposed bedrock was shown merely to be the capping over rich, yellowish, friable ground even more valuable than that above. In course of time, as sinking proceeded, many fortunes were made from the rich, easily treated ground. It rapidly became clear that a great circular deposit, of probable persistence, was being worked *in situ*. Thus was the first great diamond ' pipe ' or crater revealed to the world of industry and science.

5. The formation of the De Beers Consolidated was still afar off. Individual ownership of single claims, a meagre 30 feet square, or small group holdings were the order of the day. When considerable depth had been attained—a possibility at first not contemplated—difficulties naturally arose owing to the frequent occurrence of slides either from the side of the pipe or from the strips of ground between blocks of claims which had been left for roadways. The mining position was further complicated by the establishment of diverse systems of raising ground. Eventually the haulage lines down into the pit became so thick that it seemed to be ' covered by a monstrous web,' Mr. Williams tells us in his picturesque way, ' shining in the moonlight as if every filament was a silver strand.'

The difficulties arising from falls of ' reef ' (as the enclosing rocks of the pipe are called) and mine-floodings led to the formation of a Mining Board in 1874 to regulate matters of general concern; but the enormous slides of 1879, 1880, and 1881—when the *Kimberley* open pit was nearing a depth of 400 feet—proved beyond the effective powers of this organization. In 1883, it is recorded, work was greatly curtailed, and the practicability of individual operation almost ceased. Shortly after, open working was abandoned. The experiences of the *Kimberley* mine had been to some extent paralleled in the *De Beers*, but the former was at all times the most advanced mining proposition.

6. While matters were thus gradually lapsing into a state of disastrous inactivity, two men of wonderful perception and determination, Cecil Rhodes and Barney Barnato (Barnett Isaacs)—brilliant financial organizers differing widely in character and early attainments—were formulating schemes for the acquisition of a controlling interest in the four great Kimberley mines. Not only did they recognize the benefits of systematic deep-level exploitation on a large scale, but also the vital necessity of checking competition and of establishing an absolute control over the world's diamond market. The silent struggle for mastery between these two financial giants, who had both arrived upon the fields in 1873, appears to-day—now that the immensity of the prize is comprehended—as an incident of absorbing interest. Mr. Rhodes had effected, in alliance with Mr. C. D. Rudd, amalgamations in the *De Beers* mine, which led the way to the organization of the De Beers Mining Company—the parent of the Consolidated. But in the *Kimberley*, without which no projects for the regulation of the diamond output and market could be successfully carried into effect, there was a complex disposition of interests. Large blocks of claims were held by the French and Central Mining Companies. Mr. Barnato had heavy share interests in the Central and also other holdings. The De Beers Company obtained the French property. A bitter fight ensued between Mr. Rhodes and Mr. Barnato, whose differences were finally settled, and in 1888 De Beers Consolidated Mines, Limited, was formed, with control of the two great pipes. Subsequently *Dutoitspan* and *Bultfontein* were acquired. The *Wesselton* mine, which the diggers had crossed, all unconscious of the wealth beneath, for many years, was discovered in 1890, and became the fifth great pipe of the Kimberley group under De Beers control, all of which occur in a priceless belt some 5 miles in length.

7. The city of Kimberley to-day, reflecting in its substantial, though not pretentious, structures the strength and security of the industry when placed upon the basis of amalgamated control, is blessed with few natural advantages. Its locality was no matter of choice. Standing in the middle of a dreary plain, its corporate aspect can be surveyed from no commanding point. Extensive tree-planting has imparted a pleasant appearance to the main thoroughfares and side-walks. While the town is without features of special architectural significance, there are many

buildings of substance—such as the Town Hall, Government Buildings, the Club House, De Beers Offices, and the Sanatorium —which would do credit to any 'mining camp' in the world. A good electric tram service connects the town with Beaconsfield and with the pleasure resort of Alexandersfontein, where many attractions have been established to carry holiday-makers away from the scenes of their week-day toil. Through the influence of De Beers, Kimberley has risen to its present status, and upon it alone can it depend for support. The present collapse of the diamond market, necessitating the restriction of mining operations and vigorous retrenchment all round, has led to a period of unparalleled depression throughout every branch of trade and industry in the district.

Suddenly and unexpectedly, after a year of record achievements, the industry has been crippled by the disorganization of the peculiarly sensitive ganglion of the industrial world upon which the vitality of the diamond-fields depends. Johannesburg has had its years of agony, but there the process of transition has been gradual. The vast gold-field, at the mercy of no fickle market for its value of production, will bear small comparison with delicately balanced Kimberley, which must stand prepared at all times for swift reversions of fortune. Kimberley has seen bad times before the close of 1907, and the more optimistic of its supporters have not hesitated to express unshaken confidence in the ultimate issue of prevailing difficulties; but never before has the outlook appeared so eminently inauspicious.

It is frankly acknowledged that the world's luxury-buying capacity had been overestimated, and that South African producers must protect their mutual interests by stringent limitations of yield. The wealth of the sub-continent in diamonds is too vast for the needs of a single planet, and any attempt to aim at a maximum yield must end in inevitable disaster.

8. The five great pipes of Kimberley, which have all been vigorously exploited, revealed their existence by no prominent surface features. Lying in gently rolling ground at an altitude of 4,000 feet, the pipes were found without any indication of such crater elevations as commonly mark volcanic eruptions. Sub-aerial denudation has been a powerful levelling agency throughout the regions of South African diamond occurrence, and accounts readily for the obliteration of original surface irregularities. The walls of the diamond pipes, which vary in shape from a circle to an elongated oval in plan, comprise a series of flatly disposed igneous and sedimentary rocks. In the

case of the *Kimberley* mine itself, which is the deepest in South Africa, and is most crater-like in its features, there appears in the wall 300 feet of shale below the surface debris and dolerite. Next in succession comes a thickness of about 400 feet of melaphyre—a coarse-grained volcanic rock, which is seen very conspicuously in the open mine as the light-coloured, vertical wall below the sloping funnel section of black shale. Beneath this comes a series of quartzite, melaphyre, quartz porphyry, and at 2,520 feet Vaal River Conglomerate. The sequence of the rocks through which the intrusions occurred at the *De Beers, Bultfontein, Dutoitspan,* and *Wesselton* mines only presents variations of thickness. There are many 'pipes' in South Africa, lacking in the all-important gem, which are in other mineralogical features very similar to the Kimberley deposits. Most of the large craters, however, are found to contain diamonds in quantities above the average for the small occurrences. The pipes at Kimberley, though large, stand far below the *Premier* (Transvaal) mine in point of size. This crater has a surface area of 3,570 claims of 30 feet square, whereas the De Beers group present the following measurements :

Dutoitspan	1,440 claims.
Wesselton	1,162 ,,
Bultfontein	1,067 ,,
De Beers	622 ,,
Kimberley	470 ,,

(There are approximately 45·3 claims to an acre.)

9. The infilling matter of the diamond pipes of South Africa has been differently classified by geological writers, and is remarkable for the inclusion of a great variety of minerals. It was aptly termed Kimberlite by Professor Carvill Lewis, who classified the rock as 'porphyritic peridotite.' In a paper read before the Geological Society of South Africa, Mr. H. S. Harger expressed preference for the designation 'serpentine breccia,' while Mr. Gardner Williams stated in a scientific paper : 'The blue ground must be designated as a breccia. There is no doubt that it is of volcanic origin, and was forced up from below. It consists of olivine with fragments of other rocks. The blue ground from all of the five mines seems to be very similar. It consists of a clastic mass of rounded and angular olivine which is almost entirely converted into serpentine.'

The minerals found in the Kimberlite or 'blue ground' include ilmenite (titanic iron), augite, bronzite, calcite, chlorite, chrome-iron, cyanite, zircon, garnet, mica, and hornblende. Some of the associates of the diamond, caught in the concentrating pans and pulsators, but scorned as 'poor relations' by the snobbishly discriminating grease-tables, are of attractive appearance. The garnets especially are often of fine quality. From the many pipes and fissures, containing diamonds, which have been exploited in the country, a vast store of geological data has been in time accumulated, throwing light upon the oft-debated genesis of the 'indomitable' gem. The reported practicability of artificially making diamonds profitably on a commercial scale has at times drawn to this deeply scientific problem the light of public interest.

The two most widely accepted theories predicate the igneous origin of the 'blue ground'—which hypothesis has not escaped contradiction by other theorists, and yet differs radically upon the formation of the diamond itself. One school maintains that the precious stones crystallized at great depth prior to the eruption which resulted in the formation of the pipe. The other contends that the carbon, of which the diamonds are formed, was collected by the magma from surrounding strata during its ascent.

Of the trained scientists who have studied the question, none has given it more thorough practical investigation than Mr. Gardner Williams. Asked frequently for his theory, he has replied: 'I have none; for after seventeen years of thoughtful study coupled with practical research, I find that it is easier to "drive a coach-and-four" through most theories which have been propounded than to suggest one which would be based upon any more unassailable data.'

10. Though providing less scope for the exercise of the imagination and the labours of laboratory experiment, the more material questions of mining and recovery are of peculiar interest. Open mining, which was carried on in the early days of individual ownership under dangerously unfavourable conditions, is still practised in the *Wesselton* mine; but underground mining accounts for the great bulk of the ground hoisted, and all of it is passed through the shafts sunk in the rock outside the pipe. The cheapness of open working has naturally led to its application to depths as great as possible in each case, but reef falls constitute an ever-prevalent restrictive factor. Difficulties of applying common mine methods of stoping to the great pipe-formations of Kimberley, in which the ground occurs to a large extent in a state of hardness incapable of bearing great stress, have been overcome by the introduction of a system of mining peculiar to the field, by which the mass of broken reef and debris

falling to the bottom of the open excavations is utilized for filling. In spite of all difficulties, only a small percentage of the blue ground has to be regarded as beyond recovery.

Methods are generally similar in all the Kimberley mines. The following description is based upon observations made in the *Dutoitspan*, which is the biggest of the group, the most cheaply operated, and famed for its wonderfully rapid hoisting: The main shaft of the *Dutoitspan*, now 750 feet deep, was only commenced in October, 1901—when the market appeared capable of absorbing an increased production—and the property is the most recently equipped. Open working was stopped at a depth of 250 to 300 feet two years ago, and now all ground extracted from the several levels, which are 40 feet apart, is passed to the main haulage level at 750 feet. At this bottom tramming level, anticipated to serve the mine for several years at the normal rate of production, the ground is received through chutes, constructed of steel girders with the utmost durability. From the passes it is sent in trucks of one load (16 cubic feet) capacity to the shaft-bins. Traction in the *Dutoitspan*, *Wesselton*, and *Bultfontein* is by 5-ton Baldwin-Westinghouse electric locomotives, drawing twenty-four trucks. In hoisting, wonderful records are achieved. A few weeks before the writer's visit, some 5,240 loads had been raised through the double compartment shaft in a single eight-hour shift.

11. The system of breaking and filling employed in the Kimberley mines has been concisely described by the present General Manager of De Beers, Mr. Alpheus Williams, in the following words: 'Main tunnels are driven across the crater upon its longer axis, and, at right angles to this, smaller tunnels are driven out every 22½ feet until they reach the hard rock on the side of the mine. These tunnels are widened, first along the rock until they connect one with another, and, at the same time, the roofs or "backs" are stoped up until they are within a few feet of the loose ground above, thus forming long galleries, filled more or less with blue ground, upon which the men stand when drilling holes in the backs. The broken blue ground lying in the galleries is taken out, as a rule, before there are any signs of the roof giving way. At times this is impossible; the roofs cave upon the broken ground, and the blue ground is covered with reef. As the roofs cave or are blasted down, the blue ground is removed, and the loose reef lying above it comes down and fills the gallery. After the first cut near the rock is worked out, another cut is made, and in this manner the various levels are

worked back, the upper level in advance of the one below, forming terraces. Soft blue ground is drilled with long jumper drills sharpened at both ends. In hard blue ground, short drills and single-hand hammers are used. The native workers become very skilful in both methods of drilling.'

Illustrative of the relative hardness of the blue ground and the enclosing melaphyre, it may be mentioned that the boys are required to drill 10 feet in tunnels and 12 feet in chambers in the former, whereas 5 feet or less is considered a shift's work in the melaphyre.

The question of drainage is one of peculiar importance, owing to the danger of mud rushes resulting from the inflow of water into the debris filling. Some 60,000 to 70,000 gallons per hour are pumped from the five mines. Timbering in the main tunnels in blue ground is a heavy item of expenditure. Mining and depositing costs—covering operations from the breakage of the ground to its distribution on the floors—vary greatly in the different mines. Thus, the *Kimberley*, with workings to 3,000 feet and large quantities of very hard blue ground to deal with, is greatly more expensive to operate than the younger and larger mines of *Dutoitspan*, *Wesselton*, and *Bultfontein*. At the close of 1907 mining and depositing costs at the Dutoitspan had been reduced to 2s. 7d. per load—a figure only attainable as the reward of high-pressure work of an efficiency rarely known in mines working with coloured labour. There can be no doubt but that the standard of native labour efficiency at Kimberley is, on the average, higher than upon the Rand. The wage averages about 3s. 6d. per shift, and good drill-boys make 4s. or 4s. 6d. All classes feed themselves, but this allows a good margin for saving. The fact that the boys can never obtain drink, and are always available in the closed compounds when required, increases the opportunities of the management to raise the working unit to the highest pitch of efficiency.

12. The destination of the blue ground extracted from the mines, unless so hard as to require direct stage-crushing (as practised upon the Kimberley hard blue), is the pulverizing floor. Around Kimberley many square miles of level country are covered with blue ground in process of natural disintegration—in all some 10,000,000 loads of diamondiferous material, 'spread thin,' more or less in readiness for treatment. No mining corporation in the world can claim such a strength in mineral-bearing ground or ore, not only 'in sight' in the mining engineer's interpretation of the term, but actually visible on surface. The deposition of

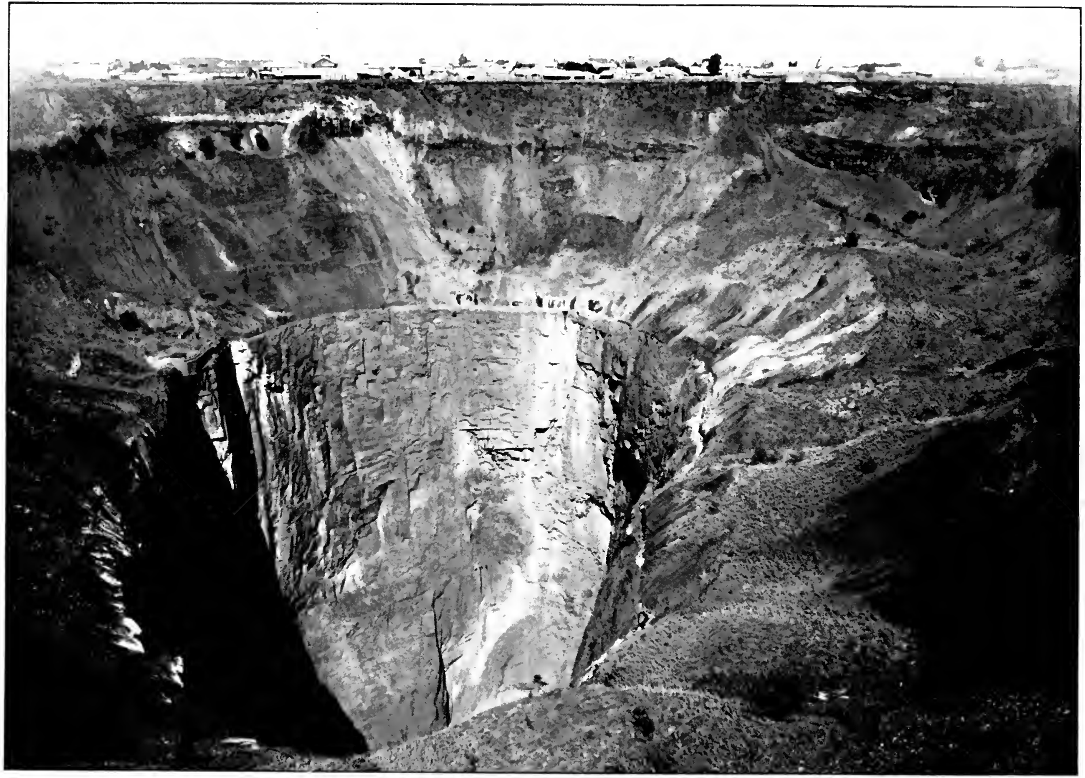


Photo by MIDDLEBROOK STUDIO.

KIMBERLEY MINE AT PRESENT DAY.

the ground on these floors is the simple operation by which it is reduced to a state of friability suitable for concentration in the washing-pans.

Instead of by means of the crushers and mills seen upon metalliferous properties, the reduction of the mine product is effected by sun and rain, by heat and cold—by the natural weathering agencies ever at work in modifying the conformation of the world's surface, aided by harrowing machines employed for turning the ground and exposing new faces to the sun. Not only are there variations in the time required for efficient disintegration in the case of different mines, but the influence of the season is a strong factor of uncertainty. Droughts, which are not of infrequent occurrence in the Kimberley district, have caused serious delays, for a thorough disintegration is essential for a high extraction.

13. The pulverized ground is conveyed by endless rope haulage —of which there is an aggregate length of over 150 miles in use between various points—to the washing department. This section of the treatment works, which wins a concentrate equivalent to one-hundredth part of the charge of blue ground, is of signal simplicity, and forms an important part of diamond-winning operations. The ground, from which the 'lumps' have been eliminated by revolving cylinders with holes $1\frac{1}{4}$ inches or less in diameter, is fed into pans, 14 feet in diameter, wherein it is swept round by rotating arms similar to the operation of a 'buddle.' The material is passed in with the thick slimy overflow from the pans on the 'puddle,' whose density, being greater than that of pure water, assists in the separation of the heavy minerals. In the rotating arms are blade-like teeth, extending nearly to the bottom of the pan, which are so arranged as to gradually work the heavy minerals to the outer rim of the pan, whilst the lighter particles flow away over the inner rim. The heavy deposit is drawn off occasionally in the day, and dispatched to the Central Pulsator. Here—at last—there is centralization. Around Kimberley there appears to be a remarkable multiplicity of operating places—of mines, floors, washing-plants, compounds, and tramming lines—but from all possible sources the concentrates are delivered in locked trucks to the Pulsators under the management of Mr. J. Stewart.

In this plant a further concentration is effected, and the product obtained is then subjected to treatment upon that most interesting appliance the grease-table, or 'greaser,' whose secret, revealed by chance some years ago, revolutionized methods of diamond-sorting. The 'greaser' consists of a shaking-table of five corrugated plates arranged in steps, and covered with a thick grease possessing a wonderful affinity for the diamonds only, which cling to it whilst the other minerals pass over unchecked. From the grease, which is scraped off the tables, the diamonds are easily recovered by steaming. The remarkable action of the grease is somewhat analogous to that of oil in metal recovery by the Elmore and other processes. An extraordinary feature of the system, pointed out to the writer by Mr. Stewart, is its fallibility in dealing with the concentrates from the yellow (or oxidized) ground. This circumstance was appreciated by the Premier Company of the Transvaal when the process was first applied by them below their crushing plant two or three years ago. Before the discovery of the grease-table's properties was made concentrates were laboriously sorted and resorted by hand.

14. The diamonds won are dispatched to the head office of the De Beers in Kimberley, thoroughly cleansed and then classified in the valuation department according to purity, size, and colour for delivery to the all-powerful Diamond Syndicate of London, in whose hands rests the task of market realization.

The five Kimberley mines produce characteristic varieties of stones, which have been classified by the late General Manager* as follows :

De Beers mine is noted for an exceptionally large percentage of ordinary 'yellows,' a very small percentage of very 'dark yellows,' a limited number of brilliant 'silver capes' of great lustre, and considerable 'light brown cleavage' (broken stones) of a delicate shade.

Kimberley mine yields a fair proportion of 'white crystals,' a good percentage of 'white cleavage,' and quite a remarkable percentage of 'maacles'—*i.e.*, flat crystals.

Dutoitspan produces some very fine blue-white stones, and ordinary 'white' stones and cleavage, together with large 'yellows,' showing an exceptional proportion of large stones.

Bultfontein yields principally white stones, generally small, and *Wesselton* diamonds are mostly octahedron crystals or fragments, with a large percentage of rubbish and boart.

15. The *De Beers* and *Kimberley* mines have since consolidation been the chief mainstay of the company, but as the strength of the diamond market increased, it was found that a greater output could be safely effected with profitable results. The other mines

* Gardner F. Williams, 'Diamond Mines of South Africa.'

—first the *Wesselton* in 1897, then the *Bultfontein* in 1901, and the *Dutoitspan* in 1904—have consequently been worked, and have contributed steadily increasing parcels to the total yield. So radically have conditions changed that the great *Dutoitspan* which Mr. Rhodes declared in 1888 to be too poor to work, but too rich to allow others to acquire possession of, has now risen to be the most valuable producer.

Since consolidation—which, it must be recalled, occurred after the mines had produced many millions of carats—the group has achieved the following (up to June 30, 1907) :

Mine.	*Loads of Blue washed.*	*Diamonds found.*	*Value of Diamonds.*
		carats.	£
De Beers and Kimberley ..	43,309,500	33,454,200	55,780,200
Wesselton ..	16,346,000	4,805,700	8,108,200
Bultfontein ..	4,144,600	1,371,900	2,714,500
Dutoitspan ..	2,246,500	537,300	2,134,200
	66,046,600	40,169,100	68,737,100

The figures appearing under the unit of measurement for ground washed and of weight for stones won fail to convey a full impression of the vast quantity of material treated by De Beers for a comparatively infinitesimal return of the precious mineral. On the one hand we have 1,056,000,000 cubic feet of ground, and on the other 10 tons of diamonds.

The average values of the stones won from the different mines varied, during the period of strong demand and good prices, from 41s. 1d. per carat in the *Wesselton* to 79s. 7d. per carat in the *Dutoitspan*. Interesting comparisons, indicative of the augmentation in value per carat in spite of increasing production, can be shown as follows for the years ended June 30, 1902 and 1907 :

Mine.	1902.		1907.	
	Carats per Load.	*Value per Cwt.*	*Carats per Load.*	*Value per Cwt.*
		s. d.		s. d.
De Beers and Kimberley	0·76	46 5·7	0·37	64 9·7
Wesselton	0·30	33 5·9	0·32	41 1·3
Bultfontein	0·21	30 4·7	0·32	43 6 3
Dutoitspan	0·26	69 10·9*	0·24	79 6·8

* Year ended June 30, 1905.

The magnitude of operations, from the standpoint of commercial prosperity, may be displayed by the official figures for the last two financial years—the most profitable in the company's history. Statements issued by the directors show revenue and expenditure, including depreciation, interest on debentures and obligations, etc., to have been :

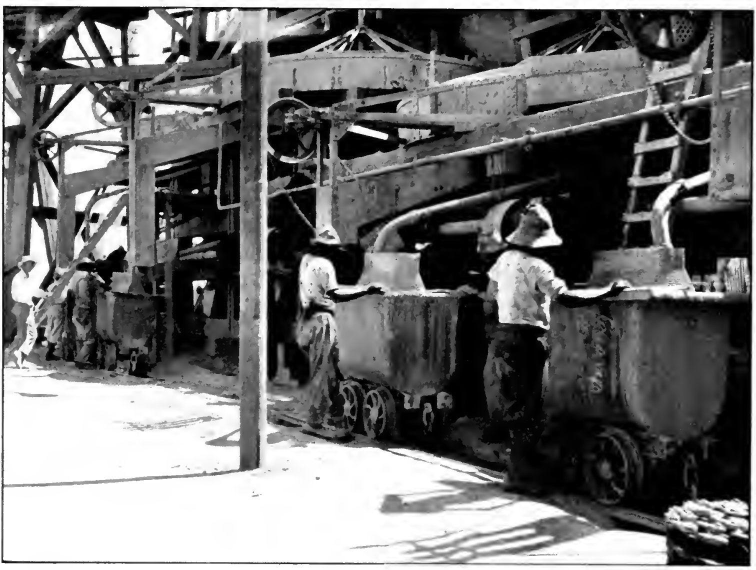
	Year to June 30, 1906.	*Year to June* 30, 1907.
	£	£
Revenue by diamonds ..	5,607,718	6,452,596
Expenditure	3,504,182	3,845,356
Leaving a profit of	2,103,536	2,607,240

How far it may be possible to regain the position of commercial strength evinced by these records is a problem beyond determination in the light of South African conditions. With 10,000,000 loads of blue ground upon the floors, with 50,000,000 loads in sight, with new washing plant and pulsator under erection, and with the mines thoroughly in shape for greater outputs than ever hitherto attained, the company is technically in a position to break all records in rate of production should the world's demand for the South African gem return to its former vigour.

16. Even in the early days of Kimberley mining, when records of production were ill-kept and the means of disposing of stolen diamonds manifold, the risks of illicit diamond-buying were heavy. The degree of I.D.B. was recognized as a past-master's in the art of roguery. But when it became practicable to institute a strict compound system, the losses of operators through criminal channels were reduced to a minimum. Although the Kimberley compound system is stringent in its effects, and boys are required to submit themselves to a term of, perhaps, 'six months' imprisonment,' life upon the De Beers mines has been as attractive to Kaffirs as any other existence of which toil forms a component part. The field is undoubtedly more popular than the Rand, and labour shortages have been rarely experienced. To-day, of course, the company's restricted requirements are fully satisfied.

In Kimberley, the boys—strictly confined to their compounds or working-places throughout the term of agreement—are paid good wages and are obliged to feed themselves. To the average native, the temporary restrictions of the compound are of small concern. For the time being, the natives have a not unpleasant world of their own, comparing agreeably with that of liberty in the kraal. To the company, the system is necessary from the

MINE COMPOUND HOSPITAL, DUTOITSPAN.



DRAWING OFF CONCENTRATES FROM PANS.

view-point of theft prevention, and highly advantageous from that of working efficiency.

The newest compound at Kimberley is the Dutoitspan, the low buildings of which—mostly comprising the living quarters—are arranged in the usual rectangular form, with an included space of 700 by 400 feet. Each living-room—27 by 19 feet—contains thirty bunks, is airy, and lit electrically. The boys are provided with light, wood, and water free, and are able to purchase stores at low rates. Blankets are supplied at cost price. Feeding themselves at a cost appearing to average 1s. 3d. to 1s. 6d. per day, the boys live chiefly on mealie and Boer meal, meat, fruit and vegetables, and buy largely such 'luxuries' as tinned foods, tea, cocoa, sauces, butter, eggs, milk, etc. Attached to the compound is an admirably regulated hospital, with 120 beds, dispensary, operating-theatre, and other departments, making it wholly self-contained.

To check any communication between mine-boys and those employed in other departments, an inclined tunnel leads from within the compound to the shaft. The boys going to work or returning from it pass through a turnstile at the head of this passage, where their pay-tickets are recorded. A feature of the labour system adding to the popularity of the field is in the payment of a bonus to boys finding stones in the course of their work. For such finds they are paid 5s. per carat, with a special percentage for stones of over 10 carats. Several hundred pounds are paid out monthly under this attractive system of speculative remuneration.

ORANGE RIVER COLONY.

17. A large number of diamond-pipes in the Orange River Colony have, at one time or another, risen to distinction in the world of speculation, but few have come to stay. There are 'indications of diamondiferous ground'—the phrase beloved of syndicate promoters—over enormous stretches of the country, and so difficult has been their interpretation that it has remained for the last few years to reveal several of the most important deposits. The proven diamond-bearing pipes now include the renowned *Jagersfontein*, the *Voorspoed*, *Roberts Victor*, *Koffyfontein*, *Monastery*, *O.F.S. and Transvaal*, *Lace*, and the *Ebenhaezer*. In addition to the mines, attention has occasionally been directed, with more or less energy and excitement, to the Vaal River diggings in the Orange River Colony, as in the Cape Colony. But this division of the industry, interesting in the human

aspect, is ephemeral and unimportant. Standing in the scale of value and security high above all other propositions in the colony is the *Jagersfontein* mine, which was discovered upon Cornelis J. Visser's farm in 1870. Not only is the pipe one of great size—the magnitude of its mouth (1,124 claims) having enabled open working to be continued to the present day at a depth of about 560 feet—but its product is of exceptional quality. The high value of *Jagersfontein* stones compensates for the comparatively low yield by weight of diamonds extracted. A varied sequence of misfortunes has visited the property since its inception, including falls of reef into the workings, droughts, floods, rinderpest amongst transport oxen, destruction of plant during the war, and now the commercial crisis affecting all diamond-producers. Nevertheless, few mining companies can claim to have achieved similar success. The mine has always sold its product to the same syndicate as De Beers, and its directorate includes several of the strongest members of the Kimberley corporation.

18. The *Jagersfontein* is situated near Fauresmith, about 100 miles south-west by south of Kimberley, and is in shape at surface an oval roughly 1,400 by 1,000 feet. The mine produces very fine diamonds, amongst which are exceptionally valuable 'blue-white' and 'white' stones. Until the *Dutoitspan* was reopened in 1906, the average value of the *Jagersfontein* product exceeded that of any other pipe in the country. The most famous of its big stones was the 'Excelsior,' weighing 969½ carats, with a length of 2½ inches, blue white, and of very fine quality. This was found in 1893, and remained till 1905, when the 'Cullinan' was unearthed in the Transvaal, the world's greatest diamond.

The performances of the company during the prosperous financial year ended March 31, 1907, may be tabulated as under :

Ground washed	2,405,581 loads.
Diamonds produced	219,275¼ carats.
Yield per 100 loads	9·78 carats.
Produced (value)	£784,636.
Value per carat	71s. 6·79d.

Working costs are very low (though an increase must shortly occur when underground mining is instituted), and enabled a profit of £429,373 to be made during the year covered by the above figures. The *Jagersfontein* is taxed only 7 per cent. of its profits—for the original owners of the farm were in possession of all mineral rights—as against the 40 per cent. assessment made upon the more recently established ventures.

Two newly discovered mines of interest, whose revelation led to a wild excess of speculative excitement throughout the colony, are the *Roberts Victor* and the *Voorspoed.* The former is a small pipe 20 miles north-east of Boshof (which is to the north-east of Kimberley), returning over 40 carats per 100 loads, worth —in the formerly strong market—60s. per carat. The latter, in the Kroonstad district, is, on the other hand, a very large mine, with yellow ground extending to 100 feet, but low in grade. The carats won per load and the value per carat are only half those recorded in the diminutive *Roberts Victor.*

TRANSVAAL DIAMONDS.

19. In 1902, the report that Prinsloo's portion of Elandsfontein, No. 85, 24 miles to the north-east of Pretoria, had been sold for £55,000 cash, and that prospecting operations had revealed indications pointing to the existence of a great diamond-mine of marvellous extent and richness, was received with a sympathetic smile for the rashness of the purchasers, and with ridicule for the wildness of their theoretical predictions. In 1907, the same property—developed into the largest diamond-mine in the world—had become so potent a factor in the diamond industry that it was economically necessary for an agreement to be made with De Beers for the joint regulation of the world's output, and to prevent a complete disorganization of the trade by competitive overproduction. Thus have the sceptics been put to rout by tangible accomplishment or driven to confine their attention to questions of recovery and valuation. Above all the cavilling, the *Premier*—as the mine was aptly named—stands as one of the greatest accumulations of mineral wealth in the world.

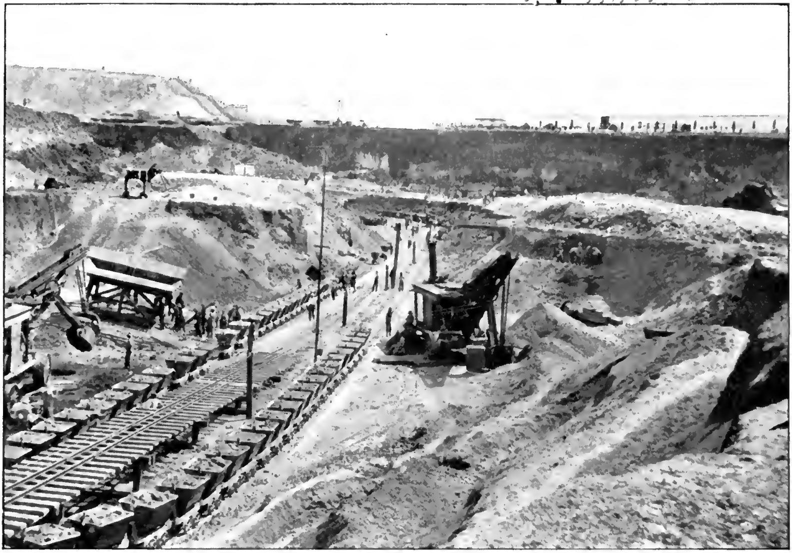
Industrially considered, diamond-mining commenced in the Transvaal with the discovery of the *Premier* late in 1902. Five years before, however, a true diamond-pipe had been found upon Rietfontein in the same district, in which operations proceeded, intermittently and unsuccessfully, up to 1905. The mine, about 80 yards in diameter, proved a failure, owing to the hardness of the blue ground and its low diamond contents. As the pioneer diamond-pipe in the Transvaal, its influence was nevertheless of great service. Other deposits—including rich alluvial from a source then unknown, but not unsuspected—were also located. Up to the time of the war, however, results had little more than opened the eyes of South African geologists and prospectors to the possibilities of another Kimberley far from the producing regions of Cape Colony.

It would be hard to find two mining districts in South Africa which have grown up under conditions more antithetical than those of Kimberley and the Premier. How the diggers in the early days commenced work over the *Kimberley* and *De Beers* mines in the belief that the ground was shallow alluvial; how many of the claim-holders made fortunes in a few months; how, in course of time, temporary disaster fell upon the camp, owing to the multiplicity of the individual workings; and how De Beers Consolidated was formed after years of hard financial contention and scheming, are facts which have been already recounted. The Premier Diamond Mining Company is the outcome of no such stirring and painful evolution, but stands to-day as a dazzling tribute to the determination of those who had the perception to read the riddles of a district's conformation and the pluck to back their deductions with a heavy stake. Few great mines in the world can claim a discovery less 'accidental.'

20. The results of work below Elandsfontein had turned the eyes of many toward the farm as the possible, or even probable, repository of the diamonds found in the alluvial. But the owner of the property was one Joachim Prinsloo, a man of dogged determination, who resolutely refused to permit prospecting under any terms whatsoever, or to transfer his freehold for less than £55,000. No bargaining, no conditional terms could be considered. Prinsloo, with characteristic Boer inflexibility, told inquirers to take his freehold at the price mentioned—or to leave it. Nevertheless, a purchaser appeared, and the sum was paid over in hard cash by Mr. T. M. Cullinan to the fortunate Dutchman for a property unstruck by the prospector's pick. In a few days Mr. Cullinan had pitched his tent near the centre of the ridge-encircled depression, and was winning diamonds from near surface. Up to the end of 1907, stones to the value of over £5,000,000 sterling have been produced from the holding; but, even so, the former owner, who so resolutely obstructed exploitation with a barrier of unreasonable terms, must be considered amongst the most fortunate of the numberless Boer farmers who have profited by the large expenditures of mining and prospecting syndicates since the war.

Mr. Cullinan immediately proceeded to erect the No. 1 gear, and this plant, comprising only three pans, has alone returned the company in diamonds about £750,000 sterling.

21. The *Premier* pipe lies in a depression, encircled by low rocky ridges, where it has intruded the quartzites of the Pretoria series. Felsite, however, constitutes the immediate wall of the mine. At surface the pipe appears roughly oval, approximately



PREMIER (TRANSVAAL) MINE IN 1905.

PREMIER NO. 3 WASHING PLANT.

2,900 feet by 1,400 feet in dimensions. Its outline in plan may be suggestively likened to the shape of Africa as depicted in the maps of the old navigators. At the surface of the mine a certain measure of natural concentration had occurred, by which early returns (exceeding 1·25 carat per load) were given a richness many times the pipe's true average, and subsequent operations on an extensive scale have shown the yield to average only 0·25 to 0·3 carat. Parts of the mine are covered by thick overburden, and there are also large sections of 'floating reef'—foreign rock which has become mingled with the volcanic magma—calling for removal. The yellow ground occurs to a depth of 30 to 50 feet, and is followed by 'blue ground' of a characteristically greenish tinge, which pulverizes well and rapidly upon exposure. The difficulties in the way of flooring the ground for natural disintegration and the consequent delays drove the company to resort to a practice of direct crushing. At first, when the possibilities of the mine were inadequately realized, a small gear of three washing-pans was erected at the south-east of the mine; later, a plant of eight 14-feet pans was installed. These worked the soft material without difficulty.

22. In 1905 an enormous new gear, No. 3, was erected at a commanding position about 150 feet above the elevation of the mine, with which it is connected by endless rope-incline haulage. This plant comprised five sets of 14-feet washing-pans, arranged in groups of eight for double treatment. Before charging into the pans, the hard lumps are crushed in gyratory crushers, and then further reduced by means of corrugated rolls before delivery into the first set of rotaries.

Below these upper pans come further rolls, and the concentrates from the lower pans were sent to pulsators for further concentration before delivery to the grease tables. At the older gears hand sorting was practised. Many processes have been experimentally instituted upon the property—including chemical methods of disintegration and tube-milling for concentration—and the sequence of treatment units to be finally employed is still *sub judice.* A notable feature of Premier mine concentrates is the great abundance of ilmenite or 'carbon.'

Amongst the several difficulties faced by the Premier Company upon its expansion to a producer of great magnitude was that of water scarcity. Supplies in the immediate vicinity of the mine were insufficient for the quenching of its Gargantuan thirst. To meet requirements the company was forced to turn to the Wilge River, where—at a point 22¾ miles from the mine—a reservoir has been constructed with a capacity of 1,100,000,000 gallons. Pumping costs have been reduced to a level comparing favourably with the expenditures of any other waterworks in South Africa.

23. An incalculable economic advantage arising from the great magnitude of the *Premier* diamond 'pipe' (apart from the primary consideration of available diamondiferous ground) will be demonstrated by the long period of open working practicable. The depth to which it can proceed is yet beyond prediction. A system of passes and tunnels carried underground proved costly, owing to the quantity of timbering required in greasy ground. Open cuttings will suffice for the future, and it is proposed to work the mine in levels 50 feet apart, each of which would represent roughly 17,000,000 loads. By working two or three levels simultaneously the utmost requirements of existing gear should be fully satisfied. The general manager, Mr. W. McHardy, estimated that the attainment of the extreme output of 12,000,000 loads would therefore only lower the average depth of mine workings 35 feet per annum. Calculations are strengthened by the fact that prospecting and boring operations have shown the walls of the mine to be vertical, without any indication of convergency. The 12,000,000-load basis of calculation was only advanced at a time when the diamond market appeared capable of absorbing the enormously increased output, and does not form part of present estimates necessarily framed on a more modest scale.

24. The steady fall in grade recorded by the Premier Company since its inception prompted the Board to seriously contemplate this enormously increased output, so that the smaller margin of average profit could be balanced by the greater amount produced. Only market conditions have prevented the fulfilment of these projects. At the time of writing the industrial position is still critical, and forbids all estimates of future results. Illustrative of the fallen grade, the following table may be presented :

Year ending	*Loads washed.*	*Carats won.*	*Cwts. per Load.*
October 31, 1903 ..	76,931	99,208	1·29
,, 1904 ..	939,265	749,653	0·798
,, 1905 ..	1,388,071	845,652	0·609
,, 1906 ..	2,988,471	899,746	0·301
,, 1907 ..	6,538,669	1,889,986	0·289

(A large quantity of overburden also treated.)

The average value of the stones won has fluctuated—leaving recent times of a surfeited market out of consideration—between about 22s. and 29s. per carat, which is, of course, substantially below the *De Beers* and *Jagersfontein* standard.

The *Premier* has produced many large diamonds, and the list of those exceeding 100 carats is of imposing length. In January, 1905, it may be remembered, a stone was found surpassing in size and value all gems known to history or tradition. Previously the 'Excelsior' diamond of *Jagersfontein*, weighing 969½ carats, had been the record for the world. But the Premier's stone, called the 'Cullinan' after the company's founder—who thus stands alone amongst Transvaal financiers with name immortalized—weighed 3,025 carats, or 1·37 pounds avoirdupois. Even so it constitutes only a portion—probably less than half—of a fractured crystal. The measurements are 4 by 2½ by 2 inches. Of a gem so unique in size and of a theoretical value, based on formulæ applicable to lesser stones, beyond all possible realization, the means of disposal was a question of extreme difficulty. In November, 1907, however, the stone was acquired by arrangement, and presented to the King by the Transvaal Government. The 'Cullinan'—the true 'Star of South Africa'—will henceforward rest among the Crown jewels in the Tower of London.

25. The influence of the *Premier* mine upon the welfare of the Transvaal, direct and indirect, has manifested itself in several ways. An exacting system of taxation deprives the company of 60 per cent. of its profits—a burden on mineral production without parallel elsewhere in the world. The profit taxes on diamond mines in the leading colonies of South Africa are: Cape Colony, 10 per cent. (till 1907, 5 per cent.); Orange River Colony, 40 per cent.; and Transvaal, 60 per cent. A director of the Premier Company, commenting upon these comparisons, once remarked that the statesmanship responsible appeared to be guided by latitude. 'Would it surprise you,' he facetiously added, 'if on the discovery of a mine nearer the Equator, the owners had to pay over the total profit plus 5 per cent. for administration?'

The profit tax is the most direct means by which the State has benefited, but more significant are the great distributions made in wages to white and coloured employees, in payment for stores obtained from local merchants and farmers, in support of the coal-mines and railways, and the dazzling instance it has provided of the country's mineral wealth. The *Premier* is an asset readily appreciated even by those with the smallest understanding of mining economics. In the long record of failures and disappointments in Transvaal exploration since the war, this exceptional discovery has indeed provided a redeeming feature of inestimable value.

CHAPTER XXIV

SOUTHERN RHODESIA

Mining Progress in Charterland

1. The occupation of Rhodesia.—2. Early tasks and responsibilities.—3. Faults of administration.—4. Systems of taxation.—5. Commencement of mining development.—6. The tale of progress.—7. Geological investigation.—8. Massive ore bodies.—9. Conglomerate reefs.—10. Classes of deposit.—11. Productive districts.—12. The low-grade wanderer.—13. Globe and Phœnix.—14. Giant mines.—15. El Dorado banket.—16. Operating methods and costs.—17. Power supply.—18. Victoria Falls scheme.—19. Transvaal and Rhodesian consumers.—20. Base metals.—21. Precious stones.—22. Gem production at Somabula.—23. Native labour.—24. Prospects of industrial expansion.

1. In October, 1889, the British South Africa Company was incorporated by Royal Charter. Steadily and thoroughly the company has laid the foundations of civilization and industry in Rhodesia—a vast unsettled country at the time of occupation, over four times as large as Germany.

In this great stretch of territory to the north of the Transvaal, both north and south of the Zambesi River, and blessed with a magnificent subtropical climate and enormous natural resources, Cecil Rhodes, the far-seeing idealist, and Alfred Beit, the shrewd financier, found full scope for their allied genius and for the materialization of the grand constructive projects, in the pursuit of which their wealth, acquired in Kimberley, provided the motive power.

2. Shareholders in the Chartered Company, with a natural appetite for dividends to recompense them for many years of weary waiting, are apt to view with impatience, sometimes loud in its expression, the broad results of Chartered administration. Even the keenest critics of company rule, and even the most exacting of shareholders must recognize, however, the onerous labours of the pioneer administrators under responsibilities that have been national in their scope and

gravity — labours performed in the face of extreme difficulties, and productive of results which mere balance-sheets can never reflect. While the exploitation of mineral and agricultural resources has been a foremost aim—for only by such industrial prosperity can the required white population be attracted to the land—other problems have called primarily for attention. First, the country had to be occupied, and sound government instituted in fulfilment of the obligations imposed by the original Charters. This work, providing for the security of the people, white and black, and an essential preliminary to the establishment of productive industries, involved heavy capital expenditures. Almost coincidently, and as a salient factor in the pioneer advance, railway construction had further to be accomplished upon a liberal scale, even without hope of immediate return, leading population as well as following it. The policy of trunk-line construction, urged by Mr. Rhodes and Mr. Beit, has been boldly followed, but not without occasioning loud complaints from mining districts of Southern Rhodesia that appeared to afford better opportunities for profitable branch-line services. The vital importance of facilitating means of communication was appreciated by none more readily than Mr. Beit, by whose will a fund to the value of over £1,200,000 was provided for the promotion of better means of communication in portions of Africa to be traversed by the Cape to Cairo railway or telegraph systems.

The first section of the railway from Kimberley to Vryburg (127 miles) was commenced in 1891 through the influence of Mr. Rhodes, in spite of Cape Government scepticism and alarm. In 1893 the line was started northwards, and carried in time on to Bulawayo, to the Victorian Falls, and still forward into Northern Rhodesia. A result of the heavy drain occasioned upon the resources of the Chartered Company, which, now in the industrial stage of its career, must pay more narrow consideration to commercial profits, has been a diminution of public confidence in Rhodesia's possibilities; the reputation of the mining industry has to some extent suffered in consequence.

3. While it has always been to the direct advantage of the British South Africa Company, whose assets include all land and minerals, and whose revenue is swelled by royalties and subsidiary share interests, to foster and stimulate active exploitation, there has been for many years a strong conviction held by those engaged in mining that an economically unsound policy has been pursued by the Administration. Viewed from a broad political

standpoint, the Chartered Company appears manifestly worthy of the Empire's gratitude. Regarded as a business organization, its methods have been marked by many faults of early judgment and weaknesses of executive policy. Directors, deplorably out of touch with local feeling, gained extreme unpopularity through their inscrutable indifference to the petitions and protests of soundly constituted representative organizations.

The visit of the British South Africa Company's Committee in 1907, which effected several radical changes of administrative system, constituted an event of far-reaching importance in the history of the country's mining development, not only on account of its practical issues, but also of the better understanding created between the Administration and the leaders of the industry. For several years there had been strife between these interests, although expansion has been their common aim. In the commendable desire to obtain the greatest possible benefit for their shareholders, the Chartered Company imposed a system of taxation that was heavy in its exactions and impolitic in its influence. Constant protests were raised by the Chambers of Mines at Bulawayo (Matabeleland) and Salisbury (Mashonaland), but without avail. Now that the Chartered Company has met the mine operators in a spirit of conciliation, and grievances have been effectively discussed, and in part dispelled, there is little need to enumerate in detail the troubles of the past. It must be recognized, however, that legislation has been of an exceptional character, and has played a leading part in the moulding of the mining industry.

4. Rhodesia is widely known as a country of small quartz-reef propositions. Performances have justified the reputation, but its possibilities are of wider range. Special encouragement has been afforded to the small worker crushing with five stamps or less, whereas the large mine, requiring flotation on a company basis, has been penalized by an enactment securing for the Chartered Company 30 per cent. of the vendor's interest. This has tended to check the inflow of capital, or else to lead to over-capitalization by promoters to satisfy the Company's demands. The small worker was allowed to treat for profit up to 750 tons per month without proceeding to flotation, but the royalty payable was on a sliding scale, increasing from $2\frac{1}{2}$ to $7\frac{1}{2}$ per cent. on the gross output according to the amount won.

In a statement issued by the Visiting Commission of Chartered Directors on October 20, 1907, the announcement was made that on and after January, 1908, mining locations producing gold are to be worked on a royalty basis, wisely allowing for those ventures working large low-grade tonnages for a narrow margin of profit. Normally, this royalty is fixed at 5 per cent., with special reductions to $2\frac{1}{2}$ or $3\frac{1}{2}$ per cent. for big propositions dealing with lean ore, and a surcharge of $2\frac{1}{2}$ per cent. (making $7\frac{1}{2}$ per cent. in all) for rich mines yielding over an ounce per ton. 'Small men,' who have lately been flocking to Rhodesia in gratifying numbers, are especially encouraged by being called upon to pay only $2\frac{1}{2}$ per cent. if their yield does not exceed £3,000 per month. Up to £100 per month no royalty at all is paid.

The system of taxation in vogue has been the burning question in the Rhodesian mining world for several years, and has constituted a dominant factor of uncertainty influencing the progress of development, thus having been comparable with the labour question in the Transvaal and the market position in the diamond-mines of Cape Calony.

5. Not till several years after the occupation of Rhodesia in 1890 did mining development begin to show substantial results. Native rebellions, lack of transport facilities, and inadequacy of working capital, all contributed toward a restriction of activity. In 1899 the industry started upon its course of unbroken progress, up to the record achievements of the present day. The widespread abundance of auriferous quartz reefs in Rhodesia renders the country open to comparison with regions of Western Australia, where, however, the early prospectors were frequently guided or arrested in their journeys of investigation by rich alluvial deposits. In Rhodesia, alluvial mining has been comparatively unimportant, and such occurrences have rarely proved of value as a marker to associated reef formations. 'Rubble' working is a notable feature of gold-mining operations in many districts, but this rubble includes the extensive waste dumps of the ancient workers as well as disintegration deposits. The abandoned pits of the ancient miners, who operated over an enormous extent of Rhodesia and neighbouring territories, were the points of first attack by the pioneer miners under Chartered rule, although very many rich virgin reefs and large low-grade deposits, which escaped notice or were considered unpayable in the bygone days, have been opened up. A large proportion of the Rhodesian gold yield is attributable to the operations of miners working small and rich ore-bodies of no great persistence—quartz reefs of the usual patchy type so suitable for speculative exploitation by practical working parties. Properties equipped for a large or moderately large tonnage are of special significance in view

of their greater industrial stability. During the year ended March 31, 1907, contributions of gold were received from about 250 sources, of which as many as 175 represented mines on a crushing basis of five stamps or less. Larger concerns, each accounting for over 15,000 tons of ore milled per annum, yielded approximately 63 per cent. of the aggregate output, and those treating over 30,000 tons per annum, 47 per cent.

6. The rapid advance in the rate of gold production during the last few years, demonstrated by the table given below, has been largely due to the increasing activity of the 'small men,' who deal chiefly with easily accessible ore, without much thought for conditions in depth or the 'shape' of their workings. The record of operations, revealing rapid increases in tonnages and amount of gold won, and a natural fall in average grade owing to the growth of low-grade mining, may be presented as under :

Period.	*Short Tons.*	*Yield Value.*	*Yield per Ton.*
		£	s.
Prior to September, 1898	—	23,465	—
Period to June, 1899 ..	80,252	176,447	43·97
,, ,, 1900 ..	98,364	209,682	42·63
,, March 31, 1901	139,685	335,043	47·97
,, ,, 1902	248,002	650,752	52·47
,, ,, 1903	336,718	713,909	42·43
,, ,, 1904	515,212	851,807	33·10
,, ,, 1905	784,649	1,120,528	28·56
,, ,, 1906	1,099,182	1,584,459	28·83
,, ,, 1907	1,412,822	2,054,877	29·08
	4,714,886	7,720,969	32·75

These official figures provide a striking indication of the uninterrupted progress of the industry, and prove that, although expansion has not been along the lines recommended, or of the measure whose possibilities are predicted by the critics of Chartered Company administration, it has nevertheless been rapid and substantial. Both India, with its famous Mysore fields, and Queensland, with Mount Morgan, Charters Towers, and Gympie, have been surpassed by Rhodesia in the list of the world's great gold-producing countries ; and this advance has been achieved under the cloud of financial depression which has overcast South Africa and checked the growth of young enterprises from the Zambesi to the Cape.

The tendency of recent prospecting, it may be noted with satisfaction, has been to investigate many belts of promising country untouched by the ancients. The common principle of searching for old workings rather than reefs has a decreasing band of followers in the field.

7. It is a grave reproach to the powers in control that Rhodesia —a country primarily dependent upon its mineral resources— has not been submitted to examination, systematic survey, and report by a properly constituted geological organization. Good work has been performed by private geologists, and also by Mr. F. P. Mennell, F.G.S., Curator of the Rhodesia Museum at Bulawayo, but the field is too vast and varied for individual effort.

The following notes upon the economic geology of the country as a whole are based principally upon the writings of Mr. Mennell, whose paper before the Rhodesia Scientific Association (vol. v., part iii., 1905) and report on 'The Mineral Wealth of Rhodesia' contain much valuable information upon Rhodesian rock structure and mining geological conditions. The old series of South African rocks, represented conspicuously in Rhodesia as in the Transvaal, are of particular importance on account of their contained ore deposits. The auriferous quartz veins are usually found in the metamorphic rocks as fissure and gash veins. In the 'basement schists' occur such notable deposits as the *Globe and Phœnix*, *Tebekwe*, *Bonsor*, *Surprise*, and *Geelong*. The later massive epidiorite and hornblende schists are the country rocks of many veins, as, for instance, in the case of the *Beatrice*, *Bernheim*, *Antenior*, *Dumbleton*, *Morven*, *Mohem*, *Nelly*, and *Sheba* reefs. The old sediments, Mr. Mennell declares, do not usually contain well-defined gold reefs. Their veins, when auriferous, are often rich, but usually very small. But both these sediments and the other metamorphic rocks contain large ore deposits of the nature of impregnations—mineralized zones of irregular shape grading off almost imperceptibly into the surrounding country. This class of deposit comprises the majority of the larger producing mines.

8. Among the impregnations of rocks of presumably igneous origin, the *Gaika* and the *Giant* mines are cited. In the former case the rock varies from serpentine to talc-dolerite schist, and even pure soapstone. The 'banded ironstone' rocks, which form the oldest sediments, contain some interesting deposits. The famous *Wanderer* mine, whose crushing capacity is far greater than that of any other mine in Rhodesia, and is equivalent to more than an eighth of the country's total, treats a much-crushed zone of banded ironstone for an extraction of only

about 10s. per ton. In the *Giant* mine there is a large lenticular ore body, partly of banded ironstone and partly of chlorite and talc schist, the ironstone being auriferous for a great width at surface.

9. Peculiar interest attaches to the 'conglomerate series' in Rhodesia, which has received an exceptional share of attention during the last few years, owing to the rich developments reported in the *El Dorado* mine, in the Lomagundi district, and to the vigorous discussions held in scientific circles as to the origin of the rock and its similarity to Rand banket. Conglomerates also occur in the Sebakwe district, but it is pointed out that, whereas the former has mostly granitic pebbles embedded in a recrystallized matrix of different material, the composition of the latter conglomerate is of banded jasper in both pebble and cement.

The ore of the great *Ayrshire* mine, not far from the *El Dorado*, is differently classified by various authorities. Mr. Mennell states that the schists round the granite boundary at this locality are a series of bands of rock of variable width, sometimes granular and sometimes foliated, and arranged more or less parallel to the edge of the igneous mass. The veinstone is stated to be 'probably a contact-altered rock of conglomerate series,' and 'no doubt a mixed rock resulting from the contact alteration and injection by granitic material of a zone of the surrounding schists.'*

10. The same authority has compiled an instructive summary, showing the varied geological conditions under which Rhodesian gold-mining is undertaken, as follows :

(1) Reefs.—(*a*) In the basement schists : *Globe and Phœnix, Surprise, Tebekwe.*

(*b*) In banded ironstone : *Camperdown* (upper reef), *Bristol, Veracity.*

(*c*) In conglomerate : *Bell.*

(*d*) In epidiorite, etc. : *Antenior, Beatrice, Killarney, Sheba.*

(2) Impregnations.—(*a*) In basement schists : *Gaika.*

(*b*) In banded ironstone : *Wanderer, Camperdown* (lower reef), *Concession Hill, Giant* (partly).

(*c*) In conglomerate : *El Dorado*, etc., *Riverlea.*

(*d*) In granulite : *Ayrshire.*

(*e*) In chlorite and talc schist : *Giant* (chiefly).

(*f*) In granite : *Commonwealth.*

The quartz reefs, it is remarked, need no special description. They yield medium grade ores, worked at a cost of 25s. to 30s. per ton in some typical cases.

* 'The Mineral Wealth of Rhodesia,' Museum Report, 1907.

11. A glance at the map of Southern Rhodesia shows that the most productive mining districts are well distributed throughout the country. The mines of Matabeleland can be classified into two large districts—Bulawayo and Gwelo—and those of Mashonaland into six—Salisbury, Umtali, Hartley, Lomagundi, Mazoe, and Victoria. Leading producers in each division, with their returns for the year ended March 31, 1907, appear as under :

	Tons treated.	*Value.*	*Per Ton.*
Bulawayo district :		£	s.
East Gwanda Mines ..	65,009	119,666	36·8
Rhodesia Consolidated, Ltd.	25,693	62,374	48·5
Killarney Hibernia ..	41,043	52,530	25·6
Rice-Hamilton	52,511	49,809	19·0
Willoughby's Consolidated (Queen's)	16,981	34,109	40·2
Bush Tick Mine ..	28,483	32,907	23·1
Matabele Mines ..	23,410	28,641	24·5
Antenior	14,127	24,810	35·1
Morven	14,013	22,145	31·6
Gwelo district :			
Globe and Phœnix ..	79,432	168,296	42·4
Wanderer	192,430	100,172	10·4
Selukwe	77,367	72,693	18·8
Surprise	35,866	65,155	36·3
Gaika	15,342	30,359	39·7
Rhodesia Gold-Fields (Bell)	17,449	28,013	32·1
Theta	9,492	25,071	52·8
Salisbury district :			
Beatrice	18,380	44,418	48·3
Umtali district :			
Penhalonga Proprietary ..	85,830	78,298	18·3
Rezende	36,600	51,193	28·0
Hartley district :			
Giant Mines	52,940	110,330	41·7
Battlefields	14,405	55,515	77·1
Inez	14,274	31,054	43·5
Indarama	12,735	22,699	35·7
Mashonaland Consolidated (Golden Valley) ..	13,870	21,035	30·3
Lomagundi district :			
Ayrshire	88,348	91,404	20·7
Mazoe district :			
Jumbo	19,158	54,220	56·6

In the Victoria district there are no producers of special importance. All ventures yielding over £20,000 in the year are included in the above list.

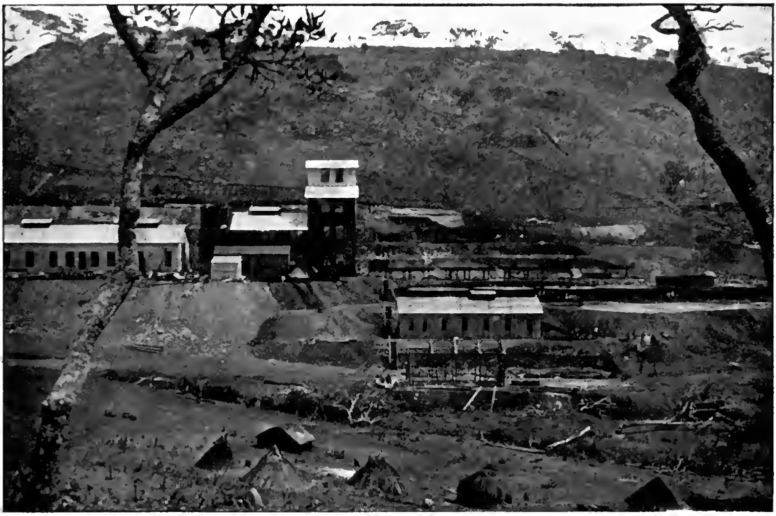
12. Individual reference to the leading gold-mines may be commenced with the *Wanderer*, in the *Selukwe* district, which enjoys peculiar distinction on account of its large tonnage and low working costs. The ore-body is one of those occurring as impregnations in the banded ironstone, and is on the junction with the conglomerate series. Mr. Mennell states that the rock is considerably disturbed, but not more so, nor is it more mineralized, than in many occurrences throughout the country. The gold contents rise with the increase in the amount of iron present (hematite and limonite). In places the workable width of ore is 50 or 60 feet. By a process of dry crushing with jaw-breakers and rolls for direct cyanidation, an output of 193,277 tons was treated during the year ended April 30, 1907, for a yield of no more than 10s. 4·4d. per ton, yet at a substantial profit. With an increasing tonnage, current expenditures have been steadily reduced, and may be given for the last two fiscal years as under :

	1906.	1907.
Tons treated	178,560	193,360
	Cost per Ton.	*Cost per Ton.*
	s. d.	s. d.
Mining	1 10·9	1 11·6
Tramming	0 4·3	0 4·7
Milling	1 9·3	1 7·8
Cyaniding	1 9·5	1 8·7
Maintenance	0 0·8	0 1·1
General expenses	0 1·6	0 1·4
Sundry charges	0 8·0	0 8·2
	6 8·4	6 7·5

These remarkably low costs are at about the minimum, except as regards fuel, in which item there is said to have been scope for reduction. The gold-extraction obtained by cyanidation approximates 80 per cent., the residues running 0·66 dwt. in value

13. The *Globe and Phœnix* in the Sebakwe district, though dealing with a smaller tonnage than the *Wanderer*, is the greatest producer of gold in Rhodesia. During the year ended March 31, 1907, the company milled 79,432 tons, and cyanided 52,724 tons for a yield worth £168,296, or 42s. 5d. per ton. The deposits are classed amongst the reefs occurring in the older basement schists —talc-quartz schists probably representing extremely ancient granites. Crushing commenced with a forty-stamp battery in 1900, and since then an aggregate yield of about £1,330,000 has been recorded, of which gross profits represent 45 per cent. Working costs total 27s. 3d. per ton, including mining, 8s. 7·9d. ; milling and maintenance, 4s. 11·7d. ; cyanide, 1s. 10·8d. ; and

RHODESIAN 'SMALL MAN' PROPOSITION.



By favour of B.S.A. Co.

WANDERER MINE, SOUTHERN RHODESIA.

mine development redemption, 4s. 5·7d. per ton. In mill practice concentrates are reground in Wheeler pans, and slimes are treated. Antimony occurs in the ore as a factor for consideration in metallurgical operations. The *Globe and Phœnix* stands high amongst Rhodesia's small group of mining dividend-payers.

14. A property which has advanced rapidly to a position of eminence is that of the *Giant Mines* in the Hartley district of Mashonaland. The deposit under exploitation is a large lenticular body partly of the 'banded ironstone' already referred to, and partly of chlorite and talc schist, these last being exceedingly heavily charged with pyrites and pyrrhotine. The banded ironstone is auriferous for a great width on the surface, but lower down is reported to be too poor to work, and stoping is confined to the schists. Only fifteen stamps and a tube-mill are employed, but the ore is about £2 per ton in recovery value; and with the remarkable stamp duty of 10½ tons per day, the battery treats ore at the rate of 55,000 tons per annum for a working profit of 21s. 9d. per ton. The *Giant Mines* are undoubtedly one of the strongest propositions in the country. Other profit-makers of note are the *Battlefields, Ayrshire, Jumbo, East Gwanda,* and *Penhalonga.* The *Selukwe* is a large producer, but the grade of ore treated is low, and conditions do not enable working costs to be reduced like those of the *Wanderer.*

15. The *El Dorado* mine, to the north-west of Salisbury, in the Lomagundi district, has for the last two or three years figured largely in reports upon Rhodesian mining prospects. The outcome of exploratory work in the ancient workings on the property has been the development of a 'conglomerate' ore-body (whose true character and origin have been keenly debated), with rich chutes of apparent persistence. A new field of such promise, with ore bearing a close resemblance to the Rand 'banket,' could not fail to cause a revival of interest in mining and prospecting. Crushing operations at the *El Dorado* were commenced in 1907, and at the close of the year it was arranged to duplicate the plant, including the regrinding section, making it equivalent to a sixty-stamp mill in capacity.

16. Upon the biggest mines of Rhodesia gravity stamps, with Huntingdon or tube mills as auxiliary grinders, are chiefly used. The crushing power in use on March 31, 1907, was estimated as equivalent to 1,348 stamps and 5 tube-mills. The small workers use Tremain, Huntingdon, Kincaed, or Pneumatic stamp-mills

in some cases. Tailing treatment by cyanide has increased in amount upon all classes of propositions, and during the statistical year already quoted 590,000 tons were dealt with for a yield of £339,000, or 11s. 6d. per ton. In his address reviewing the course of operations during the year ended March 31, 1907, the President of the Rhodesia Chamber of Mines gave some interesting figures regarding working costs in the country, based upon the returns of fourteen mines treating 752,478 tons, or half the Rhodesian total. For these expenses were :

	Per Ton. s.	d.
Mining, crushing, tramming, sorting, etc.	7	2·26
Milling	3	11·57
General expenses	2	8·77
	13	10·60
Cyaniding (477,846 tons)	1	4·54
Total (excluding redemption)	15	3·14

If the *Wanderer*, on account of its great tonnage and abnormally low costs, be eliminated from calculations, the figure for mining, crushing, milling, and general expenses rises to 19s. 6·44d. per ton. The labour complement is equivalent to 1·17 white men per stamp, and 17·33 coloured men.

17. Wood fuel being available in large quantities, the demand for coal for mining purposes is very small. The coal-fields of Rhodesia are, however, of large extent. The producing colliery—the *Wankie*—turns out roughly 100,000 tons of good steaming coal per annum for use on the railways and upon a few of the mines. The *Wankie* coal-field is situated 150 miles, in a direct north-north-west line from Bulawayo, in the direction of the Victoria Falls. Though the field has a market of limited magnitude, assured in the requirements of railway traffic, the possibilities of future expansion may perhaps be checked by the installation of an electric power generating-station at the Victoria Falls. This point raises for consideration the famous Zambesi Power Scheme, which has been hotly discussed in technical circles from England to New Zealand, from Germany to California, which is the boldest engineering project ever conceived in the colonial mining world, and the industrial influence of which, if the ultimate hopes of its sponsors can be fulfilled, would surpass all calculation. It is yet merely a 'scheme,' maybe impossible of economic achievement.

18. Whether the project is carried to its final fulfilment is a question complicated by difficulties other than scientific. But

it nevertheless appears a grand tribute to the energy and courage of the British pioneer that the great Victoria Falls, discovered by Livingstone in 'Darkest Africa' some fifty years ago, should now be held to be the potential means of moving the wheels of industry in Rhodesia and the Transvaal; that this region—with the glamour of mystery dispelled by the advent of train and tourist—should promise to become a source of power transmission, unequalled in point of distance and voltage, in a mighty alliance with the world's greatest gold-field (600 miles away); and that the administrators of a land whose entire white population is less than one-thirtieth of Melbourne or Sydney should support a project involving an expenditure of hundreds of thousands sterling with the spirit of dauntless enterprise of their early leader, Cecil Rhodes. The final goal proposed by those responsible for harnessing the Falls is the provision of power for the Rand gold-mines. Over the commercial practicability of this scheme the highest authorities have joined issue in academic debate. The numerous experts advising the African Concession Syndicate—the promoters of the undertaking, half of whose shares are held by the Chartered Company—affirmed its feasibility in the light of long-distance electrical transmission effected in America, and of known physical and commercial conditions in South Africa. Their opponents, however, are neither few in numbers nor weak in argument.

19. The Victoria Falls, about twice as wide as the Niagara and two and a half times as high, represent far the greatest force of natural water power in the world. Its practical utilization has been contemplated for many years, especially owing to the rapid advance in electrical science made in other parts of the world. Not till 1904, however, when the railhead reached the Zambesi, was the project carried from the dim light of hopeful conjecture, and critically investigated in its several aspects, scientific and commercial. The scheme stands so far above any similar undertakings, and so many hypothetical factors remain for practical test, that the opposing views expressed by eminent authorities upon its possibilities can occasion no surprise. Progress can only be effected with sure-footed deliberation; there is no precedent for guidance. In 1907 the Duke of Abercorn, President of the Chartered Company, addressed shareholders in the following words with reference to the formation of the Victoria Falls Power Company, Limited: 'Our action in this matter has not been taken without the fullest preliminary inquiry and consideration. . . . I think it important to emphasize again the fact that our

action has throughout been dictated with the sole object of bringing about an early development of power at the Victoria Falls under the most favourable commercial conditions. That object has now, we believe, been fully secured. Power from the Falls will be available for use in Rhodesia at an earlier date and at a cheaper price than would have been practicable had the enterprise been left to be dealt with by a smaller and purely local concern. At a later date we look forward to the realization of the project for the transmission of the Falls power to the Transvaal mines. That is the ultimate goal.'

The question of Rhodesian supply does not possess the same far-reaching interest as the problem of profitable transmission to the Rand, but it nevertheless is of the utmost significance from the local standpoint through its influence upon existing works and mining economics, and also in the possibility created of establishing new industries in the vicinity of the Falls.

20. A gratifying feature of recent mining development in Rhodesia is to be noted in the small quantities of lead, copper, chrome iron, wolframite, antimony, and precious stones appearing upon the output list. The lead is derived from the concentrates of the *Penhalonga Proprietary Mines, Limited*, and the copper from the same source and the *East Gwanda Mines*. The chrome iron is mined by the *Bechuanaland Exploration Company* on the Selukwe Commonage.

Northern Rhodesia, beyond the Zambesi, wherein copper, lead, and zinc occur in districts now within range of the Cape to Cairo Railway, promises to develop into an important field of base-metal production. Operations in this newly occupied section of the Dark Continent, now profiting incalculably by the influence of pioneer industries, are referred to in a previous chapter. The successful exploitation of the North-Eastern and North-Western territories would benefit Southern Rhodesia materially through the agency of the Chartered Company, whose administration extends both north and south of the Zambesi, through the Victoria Falls Power Company, which looks to the north for large customers, and through the railways, whose greater prosperity should enable reductions in freight charges to be made in the southern fields.

21. Throughout an enormous extent of the Transvaal, Orange River Colony, and Rhodesia prospecting for precious stones has proceeded vigorously, with a few splendid rewards and a host of disappointments, during the last five years. That Rhodesia should have failed to participate adequately in this widespread

campaign is attributable to the monopoly held by De Beers over the country's diamonds since 1892 and the lack of encouragement provided to prospectors under existing legislation. In 1903, however, powers were granted to a venture entitled the South African Option Syndicate, Limited, under Sir John Willoughby, to prospect for and locate areas containing precious stones. A find of importance, upon which recent energies have been concentrated, was made in the gravels of the *Somabula Forest*, near Gwelo.

22. Operations have not yet been prosecuted on a scale of any magnitude, but results have been sufficient to indicate the existence of a considerable extent of rich gem-bearing ground, and of an unusual variety of precious stones of good quality, including diamonds, chrysoberyls, topazes, sapphires, and rubies. The source of the gems, believed to be a pipe in the vicinity, has not been determined. In a report issued by Mr. F. P. Mennell, it is stated that the gravel is 'composed of beautifully rounded pebbles in a matrix of sandy clay, sometimes ferruginous. The pebbles are mostly of quartz, frequently rock crystal, but they also include jaspery banded ironstone, chert, agate, hard sandstone or quartzite. Apart from the gems, there are a number of interesting minerals found in the deposits.' These minerals include rutile, ilmenite, chromite, magnetite, hæmatite, limomite, psilomelane, and staurolite.

Up to the beginning of May, 1907, there had been won 3,600 carats of diamonds and 27,000 carats of other precious stones, including chrysoberyls (yellow), and cat's eyes, topazes (blue and white), sapphires, and a few rubies. The diamonds, which are considered to have travelled no great distance, are of fine quality. Test-washing was long hindered by mechanical irregularities and scarcity of water. Gradual increases in capacity of washing-gear have been made. It is of interest to note, in regard to the disputed origin of Rhodesian diamonds, that a true pipe—though diamondless or 'blind'—has been located some 40 or 50 miles west of *Somabula.*

23. The cry for an adequate supply of unskilled native labour has arisen from all divisions of the sub-continent, and Rhodesia has not escaped the ill consequences of a periodical shortage of 'boys' for service in the mines. But the problem has been less acute in its bearings upon the progress of industry than upon the Rand. Under 40 per cent. of the natives employed belong to Southern Rhodesia, the remainder being drawn from neighbouring Portuguese territory and the newer recruiting regions of

Northern Rhodesia. A Labour Bureau, supported by contributions from employers proportionate to their labour complement, has been organized to stimulate recruiting during the months of shortage, and to facilitate the work of fair distribution. The scarcity of boys prevails, as a rule, from October to January, owing, in large measure, to the increase of material prosperity amongst the native population since the institution of Chartered Company rule. During the months mentioned the natives are busy cultivating their lands, sowing and reaping their crops, and the extraordinary augmentation of native wealth, demonstrated mathematically by reliable statistics as to herds, flocks, and acres under cultivation in Mashonaland and Matabeleland, has furthermore reduced the number of natives requiring to work for wages. The standard rate of pay for hammer-boys in Rhodesia runs from 35s. to 45s. per month, with food. Generally, labourers sign on for a few months—a period too short for the attainment of proper working efficiency. The peacefulness and prosperity of Rhodesian natives unquestionably afford eloquent testimony to the manner in which the British South Africa Company have fulfilled the obligations assumed under their charter, and have carried out their 'civilizing mission.'

24. The Rhodesian mining industry will yet expand, and its demand for native labour—almost trebled in the last five years—must increase commensurately; but the question of supply is not a factor of insecurity calculated to dominate the position as in the Transvaal. Much may yet be done to remedy existing defects of labour organization, and to attract a larger stream of recruits from the northern territories. The problem of greatest urgency is one of administration and of law. Before the Rhodesia Chamber of Mines at Bulawayo Mr. Franklin White declared in 1907: 'In times gone by the country was invested in glamour and views of the great beyond. Those expectations have not been realized as the founders and those who took part in the early struggles of this country expected. We are now over the rise, and what do we find? We have a mining country which can give fair results—quartz-rock getting harder as it gets deeper—so that I think it can only be expected to bear a fair amount of burden of taxation. . . . If we are to get an increased production, it will have to be the result of hard work and the expenditure of a lot of money.'

The problem for consideration by those who endeavoured to readjust the basis of taxation was one of manifold intricacies. In their anxiety to be liberal to the exploiters of the mineral wealth under their ownership, without robbing their shareholders, and to gain for their shareholders the utmost benefit without curbing the progress of the foundation industry, the Chartered Company Committee found themselves between Scylla and Charybdis.

It is beyond dispute that legislative enactments have tended to divert the course of gold-mining progress into restricted channels, and that, through its laws and ordinances—gold, base metal, and diamond—Rhodesia must largely find the means of gaining that measure of prosperity for which its natural resources should provide an enduring basis.

CHAPTER XXV

TRANSVAAL GOLD

Discovery and Development of the Rand

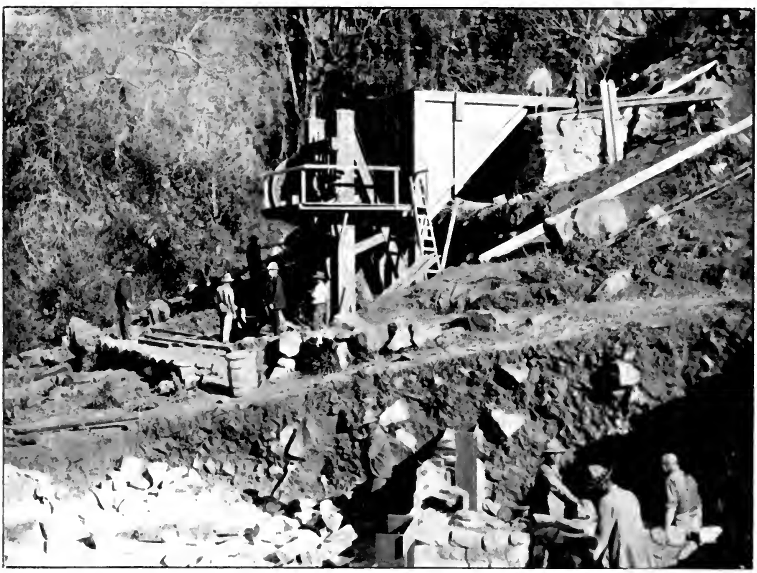
1. Production and prosperity.—2. Pioneer fields.—3. Pilgrim's Rest.—4. De Kaap gold-fields.—5. The salvation of the Republic.—6. Discovery of 'banket.'—7. Early difficulties.—8. The Rand's physical features.—9. Geology of the field.—10. Main Reef series.—11. Genetic problems.—12. Distribution of values.—13. Decrease in grade.—14. Augmented scale of operations.—15. Expansion or contraction ?—16. A common aim.

1. Gold to the value of £26,422,000 was produced by the Witwatersrand gold-fields in the year 1907. This enormous aggregate, equivalent to one-third of the world's output, not only eclipses all previous South African records, but is without parallel in the annals of gold-mining. During the same period the Transvaal and the two coastal colonies of Natal and the Cape, which sensitively reflect in several gauges of prosperity the conditions obtaining in the great inland State, have passed through a term of disastrous depression, also unparalleled in the country's history. This anomalous situation involves a wide range of complex factors—political, financial, industrial, and geological—beyond brief explanation, as the attendant distress is beyond all simple remedy.

Beneath the dazzling magnificence of its gold and diamonds the colony may be seen suffering untold agonies in the relentless hand of retrenchment, reorganization, and reform. Again, beneath this human aspect lies the unalterable picture of the Rand as the greatest centre of metal-production in the Empire, the employer of 175,000 workers, the source of £190,000,000 in twenty-two years of industrial activity, a field of unique persistence and indefinite life, the golden hub of the mining world.

2. Forty years ago the Transvaal was to the prospector a forbidden land. In 1868, however (about the period when the

CLUTHA MINE, DE KAAP GOLD-FIELDS.



SMALL BATTERY, SABI DISTRICT.

intrepid explorer Thomas Baines was searching Matabeleland for gold), the urgent necessity of putting vitality into the industrial life of the State became apparent to the Boer Government, and the obstacles were removed from the path of the mineral-seeker. The possibilities of the new field were at first ill appreciated, but the discoveries of diamonds along the Vaal River and at Kimberley fired the souls of many in the southern colonies with a desire for such quickly gotten wealth. A few adventurous prospectors—not realizing the greater offerings of Griqualand West—set northwards from Natal. It was not the unpromising plateau, grassy and undulating, of the High Veld which attracted these early pioneers, but the more mountainous regions of the North and Eastern Transvaal. In 1870 Mr. Edward Button found the first gold-reef in the rocks of the Archæan system, at Eersteling, in the Zoutpansberg district—an occurrence of more historic interest than industrial significance. Two or three years later notable finds of alluvial gold were made in the Lydenburg district—at Pilgrim's Rest, Mac-a-Mac, Spitzkop, Waterfall, and elsewhere in the Eastern Transvaal, near the mighty escarpment which commands the Low Veld. Some of the creeks, well stored with alluvial representing the disintegrated product of the many quartz veins in the dolomite, were of exceptional richness, and the good fortune of many diggers opened a brief era of excessive prosperity such as is often experienced in the young alluvial camp.

3. The surface wealth of Pilgrim's Rest was in time exhausted, though even to-day sluicing proceeds at Mac-a-Mac, and an occasional digger may be seen along the old forsaken creeks, grubbing his 'tucker,' and little more, from neglected pockets. The district recovered strength on account of its reef deposits. Many small mines, worked independently or under a central control, have proved most profitable sources of revenue. In 1907 the district turned out gold to the value of nearly £400,000, principally contributed by the Transvaal Gold Mining Estates, Limited (whose numerous mines encircle the 'dorp' of Pilgrim's Rest), and by Glynn's Lydenburg at Sabi. Both these concerns are under the control of the great Rand firm of Messrs. H. Eckstein and Co., whose activity in 'outside' ventures does not appear to add force to the oft-heard statement that the powerful financial houses would check the development of lesser fields for the 'benefit' of the Rand industry. While the Lydenburg district is one of great possibilities, its decided limitations must

be realized. With its quartz-reefs, often poor and patchy, sometimes enriched with extraordinary channels of high-grade ore where little suspected, it is essentially a region for small companies, syndicates, or private working-parties. There appear to be three principal ore-bodies—so far as correlations can be safely determined—the Theta, Beta, and Glynn's Lydenburg, lying at a flat angle, and frequently exposed where denudation has cut through the shale and dolomite series. Difficulties of transport are a retarding factor. Pilgrim's Rest lies 50 miles from Nelspruit on the Pretoria-Delagoa line, and its roads are difficult.

4. The next field of importance to be opened up after the Boer War of 1881 was that of De Kaap. An Australian digger discovered alluvial on the Devil's Kantoor, where some rich finds were made. A 'rush' occurred, and this was followed by the discovery of gold-reefs on Moodie's and elsewhere in the district. The wonderful *Sheba* mine—the most historic of the Transvaal's producers outside the Rand—was opened up in 1885, when the De Kaap gold-fields were proclaimed. If Pilgrim's Rest had led to excitement and excessive optimism, the finds in the De Kaap (or Barberton) district were fruitful of speculative mania. Moodie's and the Kantoor had roused the public interest to a high pitch of expectancy, but it remained for the *Sheba*, or Bray's '*Golden Quarry*,' with its 8-oz. ore, to add frenzy to the spirit of popular anticipation. Though very far from being a *Mount Morgan*, this South African 'mountain of gold' had an early life of wondrous good fortune. Shares were rushed from £1 up to £100—though at this time the barometric indications of a share-market price-list were of little reliability as a guide to intrinsic merits. The *Sheba's* big chute measured at its widest part 120 feet, with an extent of 300 feet along the strike. Up to 1904, a year of reconstruction, the *Sheba* had yielded £2,272,000, and dividends up to 1898 totalled £720,000. The company is still operating, in a more humble way. Ore is drawn from several sources, and now yields little more than a sovereign per ton milled. The history of the *Sheba* constitutes a varied tale of excessive prosperity, when money was frittered away with a lavishness commensurate with the wealth of its workings, and of subsequent laborious efforts —after Nature's strong-room had been rifled—to save the company from ruin. Other properties of interest in the De Kaap fields, now returning in all a few thousand pounds per month, are the *Worcester*, *Clutha*, and the *United Ivy*. The *Worcester* is

a comparatively young mine, acquired in 1898, which has been producing since 1904. The *United Ivy*, worked on lease for many years, is a wonderful instance of a quartz-vein formed along a fault-plane, the walls of which are often as smooth and polished as a ball-room floor. Although the De Kaap gold-fields are situated only 50 or 60 miles south of the Lydenburg dolomite region, the two districts are of fundamentally dissimilar geological features. Viewing the Barberton area from the heights of Moodie's, the impression is gained of a vast amphitheatre, whose walls are represented by the ranges of upturned shales, schists, quartzites, and sandstones of the ancient Swaziland system, fringing the flat, arena-like granite mass of the De Kaap Valley. The encircling mountains are of a broken and rugged nature. In extensive sections, the field is covered with a cloak of soil and vegetation barely disguising the angular form beneath. The rocks of Barberton, intruded by the granite which is the 'basement' formation to the north of Johannesburg, belong to an earlier geological age than the Witwatersrand beds.

5. Historically, too, Barberton can claim the distinction of priority, but only by a narrow margin. While the De Kaap gold-fields, 'boomed' to a pitch unequalled in South African gold-mining, were tottering to their fall, sound, well-conducted prospecting work was proceeding on the Witwatersrand (White Waters Range), 30 miles south of Pretoria, ultimately yielding results which could have saved the mining credit of the Republic from the ill-consequences of a far more demoralizing shock than the Barberton fiasco.

The honour of having discovered the gold-reefs of the Rand is accorded to the Struben brothers, whose claim for recognition in this distinguished light is not only indisputable, but followed the labours of scientifically directed investigation. It was no case of the happy fluke which has been the origin of many other famous fields of mineral industry. In 1884 the farm Sterkfontein, on the north-western end of the Witwatersrand, was prospected by Mr. F. Struben on behalf of his brother, who owned the property. Gold was soon found in a vein occurring in the Lower Witwatersrand beds. This body—the Confidence Reef—gave some phenomenally rich results, but in time proved to be of no great persistence.

6. In the same year Mr. Struben noted the conglomerate bed now known as the Main Reef—the wide and low-grade member of the famous productive series—but values were insufficiently high to draw him from the Confidence. In 1886, however, one

of his employees brought in samples from the farm Langlaagte, which were of great richness, and marked the true revelation of the possibilities of the line to the south of Sterkfontein workings. How well the pioneers of the field deserved this turn of fortune may be appreciated from the fact that £11,000 had been spent upon the Rand before a shilling of profit had been made.* The news of the discovery was speedily noised abroad—or as speedily as the means of communication in those days would allow—and the samples shown in Kimberley prompted several influential men to leave the diamond-fields in order to investigate the prospects of the new El Dorado. First Mr. J. B. Robinson, then Cecil Rhodes, Alfred Beit, and others whose names stand in the forefront of the band of successful pioneers, trekked hastily to the north-east, and acquired properties along the conglomerate line, paying prices which then seemed exorbitant to the sages who expressed their resolution to leave the 'cabbage patch' alone, but which to-day represent, maybe, no more than the profit of a week's operations. Langlaagte was at first the scene of the most active investigation. In 1886 this farm and Roodepoort, Vogelstruisfontein, Paardekraal, Turffontein, Doornfontein, Elandsfontein, Driefontein, and Randfontein, embracing about 30 miles of country, were proclaimed public diggings.

7. With such men as those mentioned above taking part in the early exploitation of the field—a party soon reinforced by many others from Kimberley experienced in the prosecution and financing of mining propositions—it is unnecessary to point out that the work of exploration, east and west, proceeded vigorously. In 1887 stamp-milling was commenced upon the oxidized ore, which yielded high returns—the loss in tailings was then a matter of small concern—by simple amalgamation. So long as the free-milling, weathered ore was under treatment, the only anxiety felt upon the camp was the question of persistence in the reefs; but upon the appearance of pyritic ore, the bugbear reigned in the metallurgical department. This class of ore is not refractory, as the term is understood in many parts of the world, but it nevertheless presented greater difficulties of economic treatment. At a moment most opportune for the industry the MacArthur-Forrest Cyanide Process for the extraction of gold was evolved in Glasgow, and in 1890 was introduced upon the Rand upon a commercial scale. This process speedily led to a proper appreciation of the value of tailings, and has,

* T. Reunert, 'Diamonds and Gold in South Africa,' 1893.

in subsequent current practice, constituted the most conspicuous support of the mining industry, contributing to its success benefits of incalculable importance.

8. Situated at an elevation of nearly 6,000 feet upon the High Veld of the Transvaal, the Witwatersrand enjoys a climate that is finer and healthier than that possessed by any other mining-field, without exception, in the British Empire. With a winter that is never too rigorous, with a summer rarely oppressive during its hottest spells, with a fair rainfall and long months of clear, unbroken weather, the country provides a striking example of the vital influence of altitude on climate and of climate upon the health and energy of man. By none can this factor, industrially of such importance, be better appreciated than by the traveller who journeys northwards, towards the Equator, from the sweltering districts of subtropical Natal to the cool, bracing air of the Transvaal plateau.

The White Waters Range stretches east and west, and is composed of the upturned edges of the wide series of quartzites, shales, and grits which form a prominent escarpment, bordering on a mass of granite which extends northwards towards Pretoria. This ridge, a prominent feature in a wide expanse of bare and generally rolling country, is the watershed dividing the streams which reach the Atlantic Ocean through the Vaal and Orange Rivers from those flowing into the Indian Ocean through the Limpopo.

9. The Witwatersrand System, which alone it is here necessary to discuss, is found to comprise a great synclinal basin, whose northern rim—containing the renowned 'banket' reefs in their richest section—dips away steeply from the granite. At Nigel, 30 miles south-east of Johannesburg (the centre of the Rand section), the other edge of the basin crops up. On the Vaal River, to the south-east of Potchefstroom, the series is again prominently exposed, and at Klerksdorp, 100 miles to the south-west of Johannesburg, there is a great extension of the beds. The Lower members of the series, which form the ridges to the north of Johannesburg, are principally of quartzite, grits, and shale, several thousand feet in thickness. The Upper division, commencing with the Main Reef 'banket,' comprises a further sequence of quartzites, sandstones, etc., marked by the occurrence of five distinct series of conglomerates, which are named in ascending order the Main Reef, Livingstone, Bird, Kimberley, and Elsburg series. It has been the lowest of these

—the Main Reef series—which has placed the Rand *facile princeps* amongst the gold-producing regions of the world. The other conglomerate beds, commonly containing small quantities of gold, have only in limited sections proved of industrial value, notably in the case of the Kimberley, which has been mined in the Krugersdorp or western end of the field. To convey an impression of the structure of the Rand syncline, comparison will frequently be made to the form of a ‘ broken-up plate ’; but a better simile may perhaps be found—still retaining a homely pattern—in a battered tablespoon. For the eastern end of the Rand syncline—extensively proved by bore-holes beneath a covering of more recent unconformable strata—flattens out as the end of a spoon, whilst the side-edges slope inwards more steeply. Mining operations, though carried to a depth of over 4,000 feet, can only be regarded as having fringed the edge of the conglomerate basin, as to the central conditions of which no reasonable hypothesis can be hazarded. The Main Reef series does not occur amongst the beds of the Witwatersrand system forming the ridge, but some distance south, where the country gradually slopes away until broken by the igneous rocks of the Klipriversberg.

10. Turning from the Witwatersrand system in general to the small division of economic significance, detailed reference must be made to the features of the Main Reef series, which comprises, as a rule, three or more distinct parallel members. Bearing in mind the origin of conglomerate beds, one would not expect to find these bodies in a similar relation or of uniform character throughout the great area of their Transvaal occurrence. The wonder is that correlations at widely separated points can be determined as closely as is found to be practicable, and that there should be found such enormous areas of a more or less similar character, with gold contents well above or around the margin of payability.

The auriferous conglomerate, commonly called ‘ banket,’ the Dutch name for almond-rock sweetmeat, which the oxidized ore resembles, consists of rounded pebbles of quartz, commonly white, but of many shades, encased in a quartzose matrix. Gold occurs in the matrix, often around the pebbles, in a fine state of division, rarely visible to the naked eye. The most noteworthy mineral constituent, apart from the gold, is iron pyrites—other metallic associates being quite insignificant. The occurrence of a considerable percentage of iron pyrites (say 2 to 4 per cent.) with which gold is very intimately mixed has been the cause of the very vigorous development of 'fine-grinding' practice (for the liberation of the noble metal), characterizing metallurgical progress on the field during the last three or four years.

11. The Main Reef series has been under exploitation for twenty-two years, and has been mined for many miles, and to a depth of 4,000 feet; visitors to the field have included the most eminent of scientists; learned geologists have lived for many years in Johannesburg, and specimens of its rocks have found their way into the cabinets of all the mining colleges and institutions of the world. Yet even to-day—such are the interminable paths of academic debate—no final conclusion has been established in regard to the origin of the banket's gold. The best discussion of the question, peculiarly interesting from the magnitude of its bearing and the simplicity of first premises, is that published by Drs. Hatch and Corstorphine,* who summarize the theories propounded as follows:

'(1) The gold was mechanically deposited with the pebbles of the conglomerate as the result of the denudation of some pre-existing auriferous rocks—that is to say, the conglomerates represent ancient alluvial or placer deposits.

'(2) The gold was present in solution in the waters by which the conglomerate was laid down, and while the pebbles were accumulating as a result of mechanical action, the gold itself was being chemically precipitated.

'(3) The gold, with the other minerals (quartz, chalcedony, pyrites, etc.), which now form the bulk of the matrix, was introduced by percolating water into the interstices of partially solidified conglomerates.

'Briefly the question is whether the gold was formed before, during, or after the deposition of the conglomerates.'

Drs. Hatch and Corstorphine, after carefully weighing the evidence, give their support to the third or infiltration theory. The question has not yet been allowed to rest, and only last year Professor J. W. Gregory reopened it before the London Institute of Mining and Metallurgy with a paper advancing the contention that the banket was a 'marine placer in which gold and black sand (magnetite with some titaniferous iron) were laid down in a series of shore deposits. The gold was in minute particles, and it was concentrated by the wash to and fro of the tide, sweeping away the light sand and silt, while the gold collected in sheltered places between the larger pebbles. The black sand deposited with the gold has been converted into

* 'The Geology of South Africa,' 1905.

pyrites, and at the same time the gold was dissolved and redeposited *in situ.*'

12. A problem far more profitable to investigate, though more restricted in its scope for lofty debate, is that of the disposition of the gold within the banket reefs. The miner from another field seeking information of Rand conditions would inquire, when he had learnt the average grade and widths, if the values ran in 'chutes' or channels. The cardinal feature of Rand gold distribution is, however, its uniformity over large areas, and the rarity of well-defined chutes of regular trend, such as commonly characterize quartz ore-bodies. There are rich sections and poor sections, high-grade patches and low; but, as a rule, it is impossible to count upon the trend of values in any specific direction. This is a point raised by those arguing against the infiltration theory of gold deposition. One contributor to the discussion, Mr. J. S. Curtis,* cites the conditions in the Robinson-Crown Deep and the Primrose-Rose Deep areas in support of the contention that chutes occur. It is largely a question of definition, so often the bane of ore-genesis controversies; for Mr. H. F. Marriott some years ago plotted out the values of the Main Reef series as proved in actual operations between Randfontein, at the extreme west of the Rand, and Modderfontein, at the east. The conclusions drawn were that there was not the slightest indication of any chute, and that where ore was being developed of a lower grade than the average of the surrounding country, sooner or later the values would improve, and the poor zone or patch be isolated.† This view does not run counter to the statement regarding the wonderful uniformity of values along the Rand, viewed in a general aspect.

13. Another question of great significance, closely related to that of zonal arrangement, is whether the average grade of the reef or reefs tends to diminish with depth. That mining is continually being practised on deeper and deeper ore, and that the average yield of gold per ton treated has steadily fallen, are facts beyond dispute. But there are several coincident circumstances militating against the simple deduction that there is a diminution of natural value commensurate with the drop in yield. While it must be admitted that the average tendency of the grade is to decline, this decrease is less conspicuous than upon the majority of other mineral fields, is marked by many satisfactory exceptions, and would be misrepresented by the

* *Journal of the Chem. Met. and Min. Soc. of S.A.*, January, 1908.
† Discussion, Institute of Mining and Metallurgy, 1907.

records of average recovery. Nevertheless, it is of interest to give these figures, with a subsequent explanation of their true significance.

Year.	*Value of Yield.*
	s. d.
1894	45 6 per ton milled.
1898	41 2 ,, ,,
1903	39 6 ,, ,,
1904	38 6 ,, ,,
1905	35 9 ,, ,,
1906	34 6 ,, ,,
1907	33 11 ,, ,,

(As these figures represent gold actually recovered, not the contents of ore treated, it must be borne in mind that the percentage of extraction has been an increasing proportion.)

Conceding the fact that many of the outcrop mines have yielded rich ore above the deeper average, the most important circumstance to be considered in relation to this tale of shrinking values is the recent practice of sending to the mills large tonnages of ore formerly neglected. Working costs have been satisfactorily reduced, and this has enabled managements to deal with sections of the mines once below the critical line of payability—isolated patches, divisions of the reef left in foot-wall or hanging, or some indigent ore-body away from the rich workings. Mr. Hennen Jennings once remarked before an assemblage of engineers: 'The golden stores for which man so strenuously battles are not guarded by dragon or by flaming sword, but merely an account-book.' Through the reduction of working costs to a level substantially below the anticipations of the soundest authorities, the lower-grade ore-bodies of the Rand have now been deprived of their only protection, and are eagerly ripped out from their position of former security to satisfy the growing appetites of modern stamp-batteries, to which tube-mills have been added as such potent aids to digestion. Rand batteries, fastidious epicures in the past, are now gluttons of the coarsest breed—once *gourmets*, now voracious *gourmands*.

14. The Rand has lately seen a striking change in systems and scale of mine equipment. In the early days small blocks of claims* were constituted into units for independent exploitation, and served by small mills, whereas it is the necessary tendency of recent progress, owing to the great cost of opening up deep-level ground and the economy of surface centralization, to operate enormous areas as one mine. Amalgamations of

* A reef claim is 155 × 413 English feet, or about 1½ acres.

smaller properties have been effected to achieve the same end. The consequently increased scale of operations has been a leading factor in the reduction of working expenses, and consequently in the tenor of the ore it is found profitable to extract. In illustration of the remarkable expansion of the big-mill operations, a simple comparison may be instituted between certain features of Rand mining statistics for December, 1907, and December 1898. The following table gives the number of properties dealing with specified tonnages during those months :

Mines Milling	*December,* 1898.	*December,* 1907.
Over 50,000 tons	Nil	1
From 40,000 to 50,000 tons	1	4
From 30,000 to 40,000 tons	Nil	10
From 20,000 to 30,000 tons	5	16
From 10,000 to 20,000 tons	21	21
Under 10,000 tons	42	14
	69	66

As the total numbers of mines at work are about equivalent for the two periods, the relative position is clear at a glance. It is to be seen that, whereas properties dealing with over 20,000 tons per month were in 1898 under 9 per cent. of the total number, such large operators now represent 47 per cent. of the list.

So great is the extent of the Main Reef series upon which mining operations proceed that, taking the *Ferreira* mine as the central point of the Rand, the *Geduld* company is seen to be developing the reef at a point nearly 25 miles due east, and the *Stubbs Randfontein* is working near the western extremity of the outcrop line, 20 miles due west. Between *Geduld* and *Stubbs Randfontein* there is an almost unbroken line of developing and producing mines, often two and three deep. But there are bends in the formation which bring the mileage of proven outcrop or sub-outcrop (hidden below more recent measures) to a much greater figure. In the Randfontein-Krugersdorp, or extreme western, area, the beds have changed their strike, indeed, to north and south, or at right angles to the general trend of the Rand series. Allowing for all irregularities, there is a stretch of approximately 60 miles of reef between Randfontein and Holfontein, beyond Geduld.

15. The field provides enormous scope for future expansion, for only in the rich central section has exploitation been carried to an advanced stage. Upon analyzing the gold returns for the close of 1907, it is found that, in spite of the field's 60 miles of reef, upwards of 70 per cent. of the total yield was contributed

by companies lying between the *Langlaagte Estate* and the *Glencairn Main Reef*—a distance of 12 or 13 miles. The fact that many of the good mines are nearing the end of their industrial existence, and that others are not coming forward adequately to replace them, is one of the most lamentable features of the present outlook. It is computed that between 1908 and 1915 over twenty companies, as at present constituted, will cease production.

16. The expansion of the industry upon sound principles can only be effected with the co-operation of the Government, the engineer, and the financier. The Prime Minister has given his assurance that the object of the Government 'is to see not only the present mines continue working, but also to see other mines open up in the near future.' Mr. Sydney Jennings, speaking as an engineering chief of Messrs. Eckstein and Co., declared: 'It is essential for the prosperity of the Transvaal, and incidentally of South Africa, that the mining industry should be expanded to the utmost limits of which it is capable.' With such identity of aims, the situation is relieved of a primary difficulty; but, unfortunately, great divergency of opinion exists as to the means by which the desired expansion can be most beneficially effected. As the world has frequently been told, a large force of Chinamen was imported to provide a constant supply of unskilled labour for the field. These coolies were neither a 'mob of murderous savages' nor the 'maltreated victims of legalized slavery,' but proved efficient and contented labourers. High political issues, however, were involved in the question of their employment, and in 1907 the Transvaal Government decreed that all the Chinese should be repatriated upon the termination of their contracts, without right of renewal. The leaders of the industry, recognizing the futility of fighting against the mandate of the Transvaal and Imperial Governments, have expressed their determination to 'loyally work and do their best under these altered circumstances.'

In order to thoroughly elucidate the mining conditions bearing upon the practicability of working the Rand under various systems, a Government Commission was held in 1907 to examine witnesses of all classes of experience and interest. Much good undoubtedly attended the investigation. Incidentally, the public was provided with a feast of facts, figures, and hypotheses, sufficiently divergent in their technical signification to enable every theorist, whether sound economist or political faddist, to find support for his particular combination of opinions.

CHAPTER XXVI

TRANSVAAL GOLD—*Continued*

Rand Ore Extraction and Treatment

1. Technical uniformity.—2. Typical reef-sections.—3. Dykes and faults.—4. Diamond-drilling.—5. Costly mine equipments.—6. Record shaft-sinking.—7. The deepest mines.—8. Mining methods.—9. Underground water.—10. Ore-conveying.—11. Metallurgical advancement.—12. Crusting, sorting, and milling.—13. Cyanide process.—14. Fine grinding in tube-mills.—15. The West Australian School of Ideas.

1. The general uniformity of reef conditions, structural and mineralogical, obtaining throughout the Witwatersrand is reflected in a corresponding uniformity of mining and metallurgical practice. Broadly considered, the best system of operation for one property is the best system for another. Some sections of the reef are marked by a peculiarly flat dip—as in the Far East Rand—or by an exceptionally narrow ore-body, as in the Roodepoort section ; again, opinions may differ as to the economy of various units in the treatment plants, one property being somewhat behind or ahead of its neighbours in current practice. But there is, as a rule, small scope for wide divergences of principle in this field, where group controls speedily transfer successful innovations from mine to mine, and where, above all other centres of industry in the world, there is a liberal interchange of ideas and experiences through the medium of technical societies and other channels.

The technical position may be compared, by a permissible metaphor, with that of a regiment drawn up in line from Krugersdorp to Modderfontein, with its head-quarter staff at Johannesburg. To this centre all information and observations calculated to be of service in the direction of the economic advance are fully reported. Thus do the flanks, 'dressing by the centre,' receive their guidance, and backward members are effectively brought into line. Units have occasionally ignored the technical alignment, have held back or ventured independently along untrodden paths of radical reform. The enterprise of the more daring pioneers has, indeed, often been fruitful of good results, positive or negative in their teaching. But many authorities now proclaim against revolutionary methods upon the Rand, and hold them to be no longer of service in the campaign against that 'account-book' which Mr. Hennen Jennings has declared alone protects from Man the golden stores of Nature.

2. It has been noted in the preceding chapter that the Main Reef series of 'banket' reefs has been followed along the strike between Randfontein and Holfontein—regardless of problematical extensions—for a distance of about 60 miles. In such a wide span the relationship of the ore-bodies is naturally marked by manifold changes. In the Central Rand, where the formation dips at outcrop 70 or 80 degrees south, flattening to about 30 degrees, there are typically three noteworthy members. The lowest is the wide, low-grade Main Reef itself, which assumes a thickness, including its quartzite partings, up to 10 or 12 feet. Overlying this, with a few feet of intervening quartzite, comes the important Main Reef Leader, the average thickness of which has been given by reliable authorities at 15 inches. Sometimes the Main Reef and Main Reef Leader are in contact. Enormous sections of the former body may be regarded as a reserve asset for realization upon the reduction of working costs to their estimated minimum. At a distance varying between 50 feet, or less, and 100 feet from these bodies, there occurs in the hanging wall side the South Reef, comprising two or three small members in close contiguity, of which the lowest is commonly of great richness, though perhaps only a few inches in width.

Westwards, in the Roodepoort district, the series is characterized by the occurrence of an exceptionally narrow and rich South Reef, which requires the most careful mining to check the impoverishment of the ore with waste. Beyond the Witpoortje fault the reefs correlated with the Main Reef series are known as the Botha series, followed by the Randfontein series, dipping very steeply to the east, which are worked by the several companies under the control of Mr. J. B. Robinson.

Eastwards of Johannesburg many changes occur in the relationship and names of the banket ore-bodies, which it is here unnecessary to describe in detail. In the Far East—on Geduld—the gold-carrier is a narrow body, lying almost flat on a slate footwall, averaging less than a foot in thickness. At Nigel, on the southern lip of the syncline, the reef is also narrow.

3. A prominent and disadvantageous feature of Rand physical conditions is the wide prevalence of dykes and faults, which in many properties detract from the value of the reef-bearing area, and add to the difficulties and expense of mining. Some of the intrusions displacing the Main Reef series are of great thickness. The system of longitudinal dykes, which are naturally more inclined to influence the progress of mining operations over extensive stretches of ground than transverse intrusions, constitutes an important factor in the consideration of mine valuation and development. Their occurrence is frequently associated with extensive throws of the formation intersected. Maps have been published showing the course of the main dykes encountered along the Rand, but these plans omit the numberless minor intrusions and simple faults to be found in many properties—lesser irregularities seeming of small concern, save to the men in control of underground operations, within whose sphere of work comes the recovery of aberrant ore-bodies. The only other significant gold-field in the British Empire, to the writer's knowledge, with which the Rand can be compared in this geologically troublous aspect is Rossland, British Columbia, where the lodes on Red Mountain are similarly cut and complicated by an aggressive system of igneous intrusions. At Gympie, Queensland, faults also constitute a factor of great importance in the relationship of the gold deposits.

4. Although notoriously unreliable for any purpose of extensive and accurate ore valuation, the diamond-drill has performed inestimably good service upon the fields in the testing of deep-level ground to the south of the Central section, in the tracing of western extensions under the dolomite, and in revealing the conformation of the East Rand basin as a necessary preliminary to the laying out of mining properties. Some of the most famous bore-holes of the Rand were those put down some years ago to the south of Johannesburg, which proved the downward persistence of the Main Reef series far on the dip of existing mine-workings, and bettered the prospects of large areas of deep-level ground. Mention may be made of the *Rand Victoria* and *Bezuidenville* bore-holes. The latter was located 5,800 feet on the dip of the outcrop of the *Meyer and Charlton*, and cut the series at 3,250 feet in 1895. More significant still were the two *Turffontein* holes, situated 8,600 feet on the dip of the Salisbury outcrop, which cut the reefs at about 4,800 feet, and yielded rich samples.

Since the war, deep drilling has been undertaken upon still more daring lines, and even at points on the dip appearing to provide small prospects of a successful strike of Main Reef, though, nevertheless of great possible importance in the unravelment of problems bearing upon the central structure of the syncline. On the *Santa Barbara* property, almost 2¾ miles on the dip of the *Simmer and Jack* outcrop line, a bore-hole was sunk 5,455 feet. Still more remarkable were the recent drilling operations of the New South Rand Company on the farm Reitfontein 308, 15 miles south of Johannesburg. Through diabase and quartzites the hole reached a depth of no less than 6,333 feet, or nearly 1¼ miles. An ordinary 'P' drill was used, with many of its parts specially strengthened. The American steel rods commonly employed were not satisfactory, and were replaced by Birmingham mild steel rods. No accident of any kind happened, and the occasional delays were not caused by the exceptional depth of hole, but by the nature of the rock drilled through. The diameter of the hole from surface to 1,260 feet was 2⅝ inches, and from there downwards 2 inches. The average footage made for the last 1,000 feet was 101 feet in quartzite formation.

The Far Eastern Rand basin, the geological features of which are now so well known, has been pierced by over 100 bore-holes, running to a maximum depth of 5,583 feet. In many of these holes there have been great deflections from the vertical, and accurate surveying has had to be performed before the true significance of the section could be safely determined.

5. In the laying out of the outcrop mines of the Rand, which are commonly served by incline shafts, there was, for obvious reasons, not the same scientific regard for permanent economic requirements as can now be exercised in the equipment of deep-level properties. Of comparatively small area, the outcrop mines represent in their disposition the first stages in the evolution which has resulted in making subsequent propositions world-famed examples of methodical arrangement. With the benefit of long-accumulated experience, with a knowledge of probable reef conditions allowed to the prospective exploiters of no other untested metalliferous properties in the world, the controlling heads of Rand deep-levels have been able to elaborate the best scheme of development and equipment before the ground has been touched by pick. It is known, with unusual reliability of estimate, when the vertical shaft will cut the reef, what capacity of battery will be needed to meet the requirements of most profitable life, and when adequate development will have been

undertaken to justify the commencement of milling with ore reserves, placing the concern in a position of industrial security. The enormous expense of equipping deep-level mines, and the necessity of working on a large scale, have forced the financial houses to work properties of 200, 400 or more claims as single units. The single deep-level Rand mine of to-day is equal in area to the whole of Kalgoorlie's famous 'Golden Mile,' which produces a fourth of Australia's gold-yield. The cost of equipment and development (up to the milling stage) of nine representative first-row deep-levels averaged £620,000; whilst upon others of greater depth over a million sterling must be spent before gold-production can be judiciously commenced.

6. Shaft-sinking accounts for a heavy proportion of this vast outlay on the deeper level, or 'deep-deep' mines. In this department of mining the Rand has achieved many notable records for speed, both in the sinking of incline and vertical shafts, with hand-labour and machines. The records for incline shaft-sinking are held by Mr. Way for 213 feet in a month at the *New Kleinfontein*, and by Mr. Britten for over 200 feet in the *Wolhuter*. A shaft 14 by 7 feet was put down 260 feet in one month at the *Nigel Deep*.

In vertical work, Mr. L. Simson sank the five-compartment shaft of the *Simmer West* 203 feet in one month, averaging 145 feet per month; whilst the sister shaft on the *Jupiter* was lowered an average of 146·6 feet. Although it is now considered that fewer vertical shafts of enormous depth will be sunk upon the Rand than at one time anticipated—the deep-deeps being more commonly exploited from the mines located above them—it must be noted that several shafts of remarkable dimensions are still in progress. In the sinking of seven-compartment shafts the field has attained records of world-wide distinction. Special reference may be made to the seven-compartment shafts of the *Brakpan Mines* in the East Rand. In No. 2, which is an excavation 42½ by 9½ feet, Mr. C. B. Brodigan made the following monthly footages from June, 1907, to January, 1908: 170, 204, 180, 148, 164, 120, 135, and 172 feet. The rate of 204 feet (from 1,690 to 1,894 feet) constitutes a world's record, in connexion with which the following notes on working conditions may be chronicled:

(1) Buckets of 1-ton capacity used throughout.

(2) Timber sets, of Tasmanian 'stringy-bark,' mostly 7 feet 6 inches apart; bearer sets about 100 feet apart.

(3) Three eight-hour shifts worked per day.

TRANSVAAL GOLD-MINING ESTATES, LYDENBURG DISTRICT.

OLD KAFFIR COMPOUND ON THE RAND.

(4) All hand-labour; eighty Kaffirs and two whites—sinker and helper—per shift. One shift of three timber-men per day.

(5) Bottom of shaft carried flat (no benches), with about forty holes, requiring case of gelignite per round.

(6) Natural ventilation good, allowing new shift to go down directly after the blast to clean timbers.

(7) Routine per shift: Cleaning timbers, 10 to 15 minutes; lowering boys, 20 to 30 minutes; cleaning out shaft, 2½ to 3½ or 4 hours; drilling, 3 to 4 hours; charging and getting drills and boys out, 40 to 45 minutes.

(8) Cost per foot, about £25. For record footage month (204 feet sunk and 210 feet timbered), cost £22 19s. 9d. per foot.

(9) Natives receive 2s. per shift, with bonus for good drilling. White men get standard wages, and bonus on sinking over 100 feet per month.

Efficient Rand shaft-sinkers are the highest-paid miners in the world.

The work performed in this *Brakpan* shaft, visited by the writer during a month of such speedy sinking that the timber-men were obliged to work double shifts to follow at regulation distance, provided decisive testimony as to the high working capacity of good Kaffir labourers under perfect organization.

7. Although rivalled in point of footage by the small shafts of the *New Chum Railway* and *Victoria Quartz* at Bendigo, Victoria, the Rand may well advance the claim of possessing the deepest gold-mines of the world; for not only do three great shafts exceed the 4,000 feet standard, but extensive development on reef has been undertaken below this depth. Data obtained from official sources in February, 1908, show that the Catlin five-compartment shaft of the *Jupiter* mine stood at a depth of 4,232½ feet below the collar; whilst the workings at the Howard shaft on the adjoining property were also below 4,000 feet.

Another mine of wonderful depth is the *Cinderella Deep*, whose shaft stood at 4,123 feet at the beginning of February, and the deepest workings at 4,188 feet vertical. The five-compartment shaft measures 30 feet 4 inches by 7 feet 6 inches outside timbers, with an excavation kept as nearly 32 by 9 feet as possible. In normal progress the rate of sinking averaged 90 to 100 feet per month, with a record of 120 feet. This shaft is served by a head-gear of steel, all solid sections, 105 feet high to the centre of the sheaves. It is important to note that ventilation was satisfactory to great depths, and the manager states that when at 3,900 feet there was only a difference of 4° between temperatures at the bottom of the shaft and at surface (84° as against 80°), with the division-wall 400 feet from the bottom.

In regard to the increase of rock-temperatures with depth, the Rand is particularly well-favoured. At 4,000 feet the temperature approximates 84°, and the calculated rate of increase would make it 92° at 6,000 feet. In a report on the *Turf Mines*, at whose northern and southern boundaries the reefs are estimated to lie at 4,000 and 6,000 feet respectively, it is stated that natural ventilation should reduce the rock temperatures in the vicinity of the workings 5 to 10°, so that, unaided by artificial ventilation, the average temperature throughout the mine should not rise above 80°.

8. Development practice on the fields has involved the driving of levels about 100 to 200 feet apart, and the blocking out of ore by winzes, which prepare the mine for stoping and enable ore-valuation to be effected. The present tendency is to greatly increase the distance between successive levels and winzes, so that properties can be more expeditiously opened up and a saving made in development costs. In stoping, the 'underhand,' 'overhand,' and 'breast' methods are practised—the underhand being particularly applicable and commonly adopted where the reefs are thin and steep in dip. Where, as in the deeper mines, the angle of inclination is lower, it is found economical to employ the 'overhand' and 'breast' methods, which allow the broken rock to be cleared more readily from the working faces. In 'breast' stopes the line of the working faces is more nearly parallel to the winzes than in the true 'overhand' stope. One great advantage of 'underhand' stoping is the fact that the hammer-boys are able to work in a more effective position, though in all three methods the holes are drilled almost exclusively downwards as 'wet holes.' The range of applicability of each method varies conspicuously along the Rand, according to the dip and width of the ore-bodies and to the opinions of the management. Efficient hand-labour is the most economical means of stoping in narrow reefs, which, to prevent the fracture of a large proportion of waste rock with the ore, have to be carried in small stopes; but in many sections of the field the comparative economy of hand and machine stoping is a matter of debate.

The repatriation of Chinese labourers and the uncertainty of the native supply has driven engineers to devise a small stope-drill which can be economically employed in narrow workings. A competitive trial of such machines, organized by the *South*

African Mining Journal of Johannesburg, was held recently, under the control of Professors Yates and Orr, with results proving conclusively that the manufacturers of small machines for operation by one man have realized their opportunities, and are solving one of the Rand's most urgent problems. One small drill of the hammer type revealed exceptional merits, but the evolution of the field's efficient one-man drill is considered to be yet at an embryonic stage. In ordinary practice with heavy machines, one white miner directs the work of two or more drills, run by coloured—often by no means unskilled—labourers. At the close of 1907 there were upwards of 2,000 machine-drills in use upon the Rand.

In hand-drill work, a gang of perhaps thirty or more 'boys' are under the supervision of a white miner. A hole of 3 feet is regarded as a day's work for the hammer-boy, who can rarely be encouraged to perform more work by the inducement of extra pay, though well capable of undertaking it. The Chinese labourers, with a greater appreciation of good wages, often took advantage of the bonus of ½d. per inch offered for drilling beyond this standard. High explosives are used in blasting, gelatine in development faces, and gelignite largely in stopes. A satisfactory feature of Rand conditions is the comparatively small demand for timber. Long pillars of ore are left to protect the drives, and others where necessary in the stopes to support the roof. During the last few years numerous cases of 'caving in' have occurred along the outcrop row of mines, where inadequate allowance was made in the early days to prevent subsidence of the overlying beds. The question of ventilation, particularly in the deeper mines, is one of increasing importance, and bears forcibly on that of the worker's health and efficiency, whether regarded from the humane or economic point of view. In the shallower mines, which are served by a multiplicity of openings, natural ventilation is generally good. Comparatively little has been done by way of artificial ventilation on the fields.

9. In regard to underground water, the mines are not, as a rule, seriously troubled. Comparing the Rand with other notable fields in the Empire, its mines are wetter than those of Kalgoorlie and Broken Hill, and drier than the *Waihi* and *Tasmania* gold-mines. Estimates quoted by Mr. S. J. Truscott* give the averages for 15 miles of Central Rand at 50,000 gallons per shaft per day for outcrop mines—45,000 for the first row of deep-levels, and 2,500 to 5,000 gallons only for the second row.

* 'The Witwatersrand Gold-Fields Banket and Mining Practice.'

A notoriously wet mine, upon which pumping charges were at one time equivalent to over 4s. per ton of ore milled, is the *Knight's Deep* at Germiston. The quantities of water pumped through two shafts have been :

Year ended	*Gallons.*
July 31, 1905	859,974,000
,, 1906	614,132,600
,, 1907	542,714,500
Subsequent monthly average	39,000,000

These records are suggestive of operations at the *Tasmania Gold-Mine*, where, however, Cornish pumps are used, as opposed to electrically driven plunger and centrifugal pumps at the *Knight's Deep.* Cornish pumps have done splendid service upon the Rand outcrop mines.

10. A division of underground operations to which special attention has of late years been turned with a view to decreasing costs and requirements of unskilled labour is that of ore transportation from the working faces to the loading stations—both in regard to conveying ore to the levels and from the boxes to the shaft. Although the scope for the introduction of mechanical contrivances is in some mines confined to narrow limits, their field of utility is certainly being satisfactorily extended. The common method of dealing with the broken rock is by simple hand-shovelling in the stopes, the poorest class of labour being employed, and hand-trucking to the shaft. In many mines shaking - chutes and aerial - gears have been adopted with economical results for conveying ore to the levels, and a monorail system has also been successfully introduced. Shovelling and tramming account for over 20 per cent. of underground costs. For hoisting rock to the head-gear bins, self-dumping skips are most extensively used.

EXTRACTION OF THE GOLD.

11. In 1903 Mr. H. H. Webb, of the Consolidated Gold-Fields, asserted that it is underground where one must look for chief economies in the future. In 1906 Mr. Drummond Chaplin, as retiring president of the Chamber of Mines, reaffirmed this view, the truth of which has been well confirmed by the tangible results of experience. But it must not be inferred that surface methods —of ore-handling, reduction, treatment, and tailings disposal— were considered to have reached finality in point of economy. Even though the scope for reduction of costs and increase of

efficiency may not have been as manifest in surface departments, there has been no lack of 'hustling' effort around mill and cyanide works to save the proverbial 'extra grain' of gold from residues and the extra farthing from cost-sheets. To clearly note the several lines upon which progress has been most satisfactorily accomplished it is necessary to outline briefly the common sequence of treatment operations on the Rand, with incidental references to modifications of practice instituted during recent years. Primarily it must be understood that the installation of very large plants has followed, as a natural sequence, the operation of greater claim areas or of adjacent properties under joint control. The day is predicted when stamp-batteries of 800, or even 1,200, heads will be established on the fields. Already we see in operation large mills upon the *Simmer East*, *Knight's Deep* (400-stamp joint-mill), *Simmer and Jack* (320), and *Robinson Deep* (310 stamps). Thirteen properties employ batteries of from 200 to 300 head capacity. Comparatively small equipments, such as those constructed on a basis of 60 to 120 stamps to serve the outcrop mines, can no longer form part of the Rand's industrial designs.

12. The ore has already been followed from its original position *in situ* to the head-gear bins. The first operation then to be performed is the separation, by means of grizzly bars, of the coarse and 'fines,' of which the former is subjected to crushing in gyratory or jaw breakers prior to 'sorting.' On revolving sorting-tables or travelling-belts, the waste rock, which has been mixed with the 'banket' in process of mining, is extensively picked out, and thus saved from the treatment-works, where barren or very low-grade rock would involve expenditure for no adequate return. To what extent the practice of sorting should be carried is a question dependent chiefly on individual conditions; with mills working at full pressure, its close application becomes of greater importance. On the average, 15 or 16 per cent. of the ore hoisted is discarded, though in some properties 30 per cent. or more may be found the best economic proportion. Sorting is a practice followed on the Rand with exceptional thoroughness.

The ore for treatment (the remaining 85 per cent.) is recrushed in preparation for the gravity stamp-mills—time-honoured machines which appear destined (in spite of commendable efforts to relegate them to the scrap-heap in favour of more economical substitutes of a different type) to serve the Rand to the end of its days as steadily as they have done since the erection of

Struben's five-stamp battery in 1884. In December, 1907, no less than 8,373 stamps were engaged upon the fields.

The dominant aims of the best battery practice upon the Rand have undergone of late so remarkable a transition that it may be here advisable to first cursorily review the methods of a few years ago, and to add references to the principal departures. With stamps weighing 850 to 1,350 lbs., and wire screens of a mesh varying from 400 to 1,000, a duty averaging 4·9 tons per stamp per day was recorded. Amalgamation on copper plates resulted in the recovery of about 63 per cent. of the gold won from all sources. The subsequently classified pulp was mostly treated by cyanide, though several mines merely accumulated their slimes, and a few found it profitable to make a close concentration of the pyritic constituents of the ore by mechanical means, selling the resultant product to chlorination works. The problem involved in the economical recovery of the gold encased in pyrites has been the principal factor influencing modern progress in Rand metallurgy. The treatment of clean sands, containing their gold in a state satisfactorily amenable to the attack of cyanide solution, was successfully accomplished upon the field some years before slimes had been made to yield a profitable return. In the methods of dealing with slimes and concentrates to best advantage, notable changes and improvements have been and are still being introduced. Chlorination of concentrates having been entirely abandoned on the field, all the gold won from below the copper plates is obtained by means of cyanide solution. Brilliant indeed has been the record of this chemical process. It was evolved in a Glasgow laboratory by Messrs. MacArthur and Forrest with happy opportuneness, when the Rand industry, which it saved from disastrous stagnation inevitable under pre-existent conditions, was beginning to call eagerly for the aid of Science. The greatest deposit of gold ore and the greatest process, after amalgamation, of gold-ore treatment were twin discoveries, to which the world is now indebted for a grand proportion of its revenue from the yellow metal. Without the cyanide process gold to the value of tens of millions, now in circulation, would to-day be lying in virgin reefs, abandoned mines, or tailings run to waste.

13. MacArthur and Forrest's methods were first applied successfully under working conditions upon the Rand, where Mr. Alfred James conducted tests in 1890 at the *Salisbury* mine, resulting in the establishment of works at the *Robinson* later in the same year. Even by its promoters the commercial possi-

bilities of the process upon the field were at first estimated at not a tithe of their true significance. In 1891 about 35,000 ozs., or 5 per cent. of the Rand's gold yield, was attributable to this innovation of the Gold Recovery Syndicate. In 1894 the extraction from tailings exceeded 28 per cent., or 1¾ millions sterling in value. To-day the average proportion is approximately 35 per cent. More striking is the fact that cyaniding operations on the Rand during the last five years only have resulted in the production of *thirty-five millions sterling.*

Returning to common practice of three or four years ago, the pulp from the mills was elevated by tailings wheels or other means (for mill-sites on the Rand are insufficiently steep to allow a natural flow from the plates to a point commanding the cyanide works), and classified by spitzlutten and spitzkasten into a heavy pyritous or concentrate product, sands and slimes. The sands were delivered by means of Butters and Mein's distributors, or of a hand-operated hose, into settling-vats, from which they were transferred to treatment-vats with filter bottoms, and subjected to about six days' treatment with strong, medium, and weak solutions of cyanide of potassium. The resultant gold solutions were passed through extractor boxes containing fine shavings of zinc, upon which precipitation forms 'gold-slimes,' requiring to be dried, roasted, and fused with fluxes for the production of bullion. The leached sands were transported in trucks or by means of belt-conveyors (appliances of greatly increased popularity along the reef for shifting ore and sands in all departments) to the residue dumps. Efforts have been made—most successfully in the case of one rich dump—to extract some of the remaining gold from these dumps by a process of leaching *in situ.* The difficulties of cyaniding slimes with commercial success were first overcome by Mr. J. R. Williams on the *Crown Reef* in 1896, and the decantation method of dealing with this overflow product, troublesome on account of its extremely fine state of division and of its grade being too low to permit of profitable filter-pressing, has since added several millions to the Rand's output. During the last five years slimes have accounted for the following yields :

Year.	*Value.* £	*Percentage of Total Output.*
1903	417,032	3·3
1904	684,837	4·4
1905	993,003	5·0
1906	1,443,812	6·1
1907	1,766,177	6·7

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The rapid increase in the percentage of gold attributable to gold from slimes, which is associated with a corresponding decrease of from 5·4 per cent. to 1·6 per cent. for gold from concentrates, strikingly reflects the most significant change in Rand metallurgical practice—viz., the regrinding of the concentrates in tube-mills, so that the gold locked up in the pyritic particles can be liberated for ordinary treatment on auxiliary amalgamating-tables and in the sands and slimes plant. Vats used to-day for sand and slime treatment are of enormous capacity, some being installed by the Consolidated Gold-Fields (under whose controls are the largest batteries, the heaviest stamps, and the highest stamp-duties), having a diameter of 50 feet for the former and 70 feet for the latter product.

14. Tube, grit, or flint mills (as the same type of revolving grinding-drum is termed in different countries) were introduced from Kalgoorlie, their birthplace in gold-milling, in 1903. By means of this machine the technical advisers of Messrs. Eckstein and Co., the General Mining and Finance Corporation, and the Consolidated Gold-Fields (Messrs. J. R. Williams, S. H. Pearce, W. Betty, G. A. and H. S. Denny, and W. A. Caldecott), first put into successful practice the system of regrinding, which has placed a different aspect upon Rand metallurgical records. The introduction of tube-mills has resulted, at a cost of small account in relation to benefits derived, in two great achievements:

(1) Increase of tonnage milled per stamp.
(2) Increase of total gold-extraction.

It is obviously to the advantage of mines to obtain from their existing stamp-batteries a maximum duty, provided that efficiency is maintained. Great increases in this direction have been effected with the aid of regrinding machines, owing to the lesser need of finely pulverizing the ore in the mortar-boxes. Larger mesh screens have been introduced, with the result that a greater quantity of pulp leaves the plates that is too coarse for ordinary cyanide treatment. With auxiliary grinders to reduce this heavy product, which includes the metallic constituents of the ore, the stamps are thus called upon to perform, as it were, more work less thoroughly. In current practice, a battery of 200 stamps is served by three tube-mills, though in some cases the ratio is higher. Bearing upon this factor of increased tonnage, the significance of progress may be exhibited by a few simple figures. The stamp duty or tonnage of ore crushed per stamp per diem for the whole Rand was—

	Tons.
In 1904	4·90
,, 1905	5·05
,, 1906	5·34
,, 1907	5·60
,, 1907 (December only)	5·72

But these Rand averages have been raised by the achievements of a few companies. For December, 1907, the stamp duty recorded by the twenty-eight companies using tube-mills was over 6½ tons, with a maximum of 8·9 tons for the *Luipaard's Vlei Estate.* At the *New Modderfontein*, under Messrs. Eckstein's control, a duty approaching 10 tons is anticipated. These figures demonstrate that a great proportion of the increase in rate of gold-production is attributable to metallurgical progress. On 1904 standards of stamp duty, the Rand output for last year, assuming the number of stamps employed to be as recorded, would have been 23 instead of 26½ millions sterling. But even this conclusion fails to adequately indicate the benefits of the new system of auxiliary fine grinding, for, just as working expenses have been reduced upon the field, so has the percentage of gold-recovery been increased to a figure beyond all favourable anticipations of a few years ago.

Several of the mines employing tube-mills have attained a total extraction of 96 per cent. of the ore's gold contents, and as the average recovery of all the mines equipped with regrinding appliances may be placed at approximately 93 per cent., an increase of 3 or 4 per cent. can be further placed to the credit of the innovation beyond that of augmented tonnage.

Another tendency of modern progress has been the utilization of weightier stamps, and from a recent maximum of 1,300 lbs. these have been raised to 1,650 lbs. Upon the property of the *Simmer Deep* a battery of 300 heads is now under erection (for the service of that company and the adjoining *Jupiter*) in which the stamps are to be 1,670 lbs. in weight, with mortar-boxes allowing an increase to 1,800 lbs. This battery, to be served by four large tube-mills, will be further noteworthy as an example of advanced Rand practice in the fact that it is to be operated by electric power, and is to be constructed, with the exception of battery framing, bin-lining, floors, and wall-framing, of steel.

15. The necessity of finely grinding the pyritic 'banket' for the recovery of a high percentage of its gold has turned the thoughts of several engineers to the West Australian practice of converting all the ore into a state of slime, and dealing with the same by some uniform continuous process. This proposition

was advanced before tube-mill practice had been carried to its present high level of efficiency. The proportion of slime now dealt with is larger than formerly, as previously noted, but the bulk of authoritative opinion is still strongly opposed to 'all sliming.' In the treatment of the slime-product, however, notable advances have been lately effected upon the field, without recourse to pressing or vacuum filtration. The adoption of the Usher process upon twenty or twenty-five mines, with a view to improving and expediting gold-recovery, has indeed provided another instance of the recognition of merit by Rand mining controls, and of their readiness to seize all opportunities for the profitable amendment of working methods, which, even though providing no field for radical change, never have been, and probably never will be, held incapable of improvement in some degree.

CHAPTER XXVII

TRANSVAAL GOLD—*Continued*

Questions of Administration, Labour, and Working Costs

1. The troubled times.—2. Technical progress.—3. Head office controls.—4. Government influences.—5. Transvaal Chamber of Mines.—6. Exceptional richness of Central Rand.—7. The great mining groups.—8. Vast producers.—9. Yields and dividends.—10. Reduced working costs.—11. Steam and electrical power.—12. Water-supply.—13. Labour: White, Black, and Yellow.—14. A charge recalled.—15. Chinese and trade.—16. A 'white man's country.'—17. Total labour force and wages.—18. Skilled labourers.—19. Conditions of work.—20. Native labour supply.—21. The future.

1. To those acquainted with the tranquil progress of great mining-fields in other parts of the world, where an occasional strike of labourers or a sudden fluctuation in the metal market may provide the sum total of disturbing eventualities, the Rand must have appeared in recent times a centre of strange disquietude. Military operations were concluded six years ago, but strife and controversy—political, industrial, and technical—have since proceeded with unabated vigour. The crippled industry has regained its strength and risen to a place of pre-eminence amongst the fields of gold-production amidst a storm of disturbing influences. The post-war chapter of its history has been full indeed of notable episodes. Troubled times have been marked by endless changes and agitations, and even upon the settlement of transient problems there has ever hung upon the horizon a heavy cloud of future uncertainties.

The loss of support in financial circles, and the return of the Dutch to political ascendancy are occurrences of yet indeterminable influence upon the economic development of the industry; labour questions to-day, as hitherto, press most urgently for solution. The trial of unskilled whites, the restricting shortage of Kaffirs for work in the mines, the introduction of indentured Chinese labour, and all the antecedent commotion in England

and South Africa; the strike of white miners, the repatriation of the Asiatics, the question of their replacement by white machine-drill runners—these several matters for political and industrial debate have been far-reaching in their bearing. Even has their influence extended from the Council-room in Downing Street to the lowermost winze in the *Jupiter* mine.

2. Though politics necessarily constitute a wellnigh inseparable factor in the industrial concerns of the Rand, so intimately allied are the fortunes of mines and State, many changes have been effected solely at the call of technical economy. There has been interminable strife in the political and semi-political arena, but there has also been a coincident war of methods and systems in the field of mining and metallurgical engineering for the achievement of higher efficiency. A keenness of competition has been evinced in technical life without equal in other parts of the mining world. The loudest cry has been for a reduction of working costs, and in this direction achievements have been more substantial and gratifying than the most sanguine dared to predict some years ago. Well-informed critics have contended that in the struggle for maximum efficiency upon the mines the controllers of surface departments have most nearly attained their goal, but that underground can still be found the means of bringing down the average costs for the Witwatersrand.

A very important part is played in the establishment of a high standard of skill by the technical societies, whose periodical meetings in Johannesburg are the occasion of keen discussions as to the means of improving methods in all divisions of work, and who actively stimulate the advancement of new ideas of benefit to the industry at large. This free circulation of experiences and information can in many cases be accredited with having resulted in improvements and reforms of great importance. The aim of the members is one of mutual enlightenment, so that those who have advanced upon any particular line of investigation are able, not without indirect benefit to themselves, to give their fellows the advantage of the special knowledge gained. The Chemical, Metallurgical and Mining Society (founded in 1894), the South African Association of Engineers, the Transvaal Institute of Mechanical Engineers, and the Geological Society of South Africa, with large memberships, are able to apply themselves to different spheres of utility without undue encroachment upon each other's preserves. While professional controversies are often of a lively nature suggestive of competitive zeal, a spirit of good-nature most commonly prevails throughout the meetings. The writer once asked a West Australian mine manager why a society for periodical debates had not been instituted at Kalgoorlie, where a sufficient membership could doubtless be maintained, and where conspicuous distinctions of treatment method suggest the advisability of a wider interchange of opinions. One reason advanced was that the fear prevailed, in so limited a field, of engendering ill-feeling between individuals and interests. On the Rand the needs of the industry have overcome such delicate scruples, and the risk of serious enmities has not so far been a conspicuous danger.

3. A noteworthy feature characterizing the administrative system of Rand mining and distinguishing it from other fields—and upon few would it be applicable—is that of central technical controls, under which groups of mines are placed for purposes of general economy. Nearly all the mines of the field are financially directed by eight Houses, with directorates in Johannesburg. Thus, under the control of Messrs. Wernher, Beit, Eckstein and Co. fall no less than twenty-three producing mines, accounting for upwards of 45 per cent. of the Rand's gold output. Under the Consolidated Gold-Fields of South Africa, Limited, fall five mines, producing about 13 per cent. But the degree to which technical operations are controlled at head office or by resident managers, and to which comparative statistical records are kept with a view to standardization and improvement of systems, differs considerably in respective instances. The Rand Mines group of deep-levels were controlled by one general management, with results prompting Messrs. Eckstein and Co. to extend the scheme to other companies in 1904. It has been claimed that the subsequent reduction in average working costs for this latter group, known as the Eckstein Central Administration, from 21s. 3d. to 17s. 7d. per ton milled, can be partly attributed to its influence. Mr. C. J. Price, its general manager, pointed out in evidence before the Mining Commission that the resident manager does not in consequence lose his personality, nor is he deprived of his initiative and reduced to a mere figure-head, as some critics have stated. Kalgoorlie, Western Australia, it may be remarked, has its 'central administration' in the firm of Messrs. Bewick, Moreing and Co., whose mines, the *Oroya-Brownhill*, *South Kalgurli*, and *Lake View*, are under a general manager at the local head office.

4. The majority of Rand mines are controlled under an open policy allowing all concerned to obtain ample particulars as

to progress and conditions. Few mines are not accessible to visitors holding *bona fide* reasons for seeking knowledge of underground developments, and periodical reports generally provide an abundance of technical data relative to all features of the position. Broad industrial statistics are compiled—with unnecessary minuteness some contend—by the Government Mines Department and the Transvaal Chamber of Mines. The publications of these bodies provide a detailed picture of the mining situation, and enable one to observe precisely every changing tendency, whether knowledge be required for the guidance of the engineer, the investor, or the political student. Statistical records issued by the Mines Department include details of metal-production, mines at work, operations performed, explosives and rock-drills used, labourers employed, accidents, wages, stores, and a long miscellany of other facts and figures. But these published data do not indicate the full range of technical information which the mining companies are called upon to supply. The functions of the excellently administered Mines Department also include, of course, the enforcement of the divers regulations which managements are compelled to observe. These regulations mainly provide for the safety, health, and comfort of employees by the institution of innumerable precautionary and other measures; for the thorough accuracy of detailed plans and records; for the efficiency of men in various responsible positions, by whom Government certificates are required; and for the restriction of coloured labour to the lower grades of employment. The burdens imposed upon the industry, direct and indirect, take the form of claim licenses, profits' tax, high railway rates from the coast over Government lines, import duties, and other less easily defined charges. Profits are taxed at the rate of 10 per cent. (as compared with 5 per cent. before the war), after allowance for amortization of capital, which means that a fund bearing compound interest at 3 per cent. is assumed to be set apart for the redemption of capital by the time that the property is exhausted.

Upon a field dependent so largely upon imported supplies, owing to the scarcity of local factories and the necessity of using the highest class of machinery, etc., distance from the coast is a serious penalty. Johannesburg is distant from the chief South African ports as follows: Lourenço Marques, 394 miles; Durban, 482; East London, 665; Port Elizabeth, 712; and Cape Town, 956 miles. All these lines, with the exception of the short section in Portuguese territory from Delagoa Bay, are under the control of the Colonial Governments, and are of narrow (3 feet

6 inches) gauge. As an instance of freight charges, it may be noted that the rate for machinery and component parts, undamageable, is 5s. 9d. per 100 lbs. from Durban, and 5s. from Lourenço Marques. Timber is carried at 0·2 shilling per ton per mile; coal—from the local collieries—at half that rate. It has been estimated by Mr. Ross Browne that railway charges account for 1s. 10d. per ton of ore milled in working costs.

5. The interests of the gold-mining industry are watched and protected by the Transvaal Chamber of Mines, which was founded in 1889 under the presidency of Mr. Herman Eckstein, and has frequently been compelled to adopt the attitude of a militant organization to defend the mines against antagonistic influences. An office is maintained in London for the benefit of European shareholders. The principal aims of the Chamber are to advance and protect the mining interests of the Transvaal by the consideration of all associated questions, and by the circulation of statistics and information; to promote any legislative measures, or to petition Government on matters of concern to the industry; to maintain a library and museum; to grant subsidies to any institutions connected with the industry; and to act as arbitrators in cases of dispute. As instances of its wider functions may be mentioned the offer of prizes in competitions calculated to assist in the solution of technical problems, such as those awarded to the inventor of the best device for preventing the dust responsible for miner's phthisis, and those now offered, in conjunction with the Government, for the most economical small stope-drill likely to be of value in the replacement of unskilled labour. The valedictory address of retiring presidents of the Chamber must always be regarded as the most authoritative expression of opinion made by leaders of the industry regarding the progress and prospects of the field.

6. If we classify the Rand into geographical sections, we find the division extending from the *Crown Reef* in the west to the *Jubilee* and *Village Main Reef* in the east—that upon which the keenest activity was displayed in the earliest days of the field's development—to be of far the greatest richness and importance. Their preponderating interest in this comparatively small section of the reef has given the firm of Messrs. Eckstein and Co. their greatest strength. Between the limits mentioned, a distance of only 2½ miles, the famous *Bonanza*, *Pioneer*, *Worcester*, and *Wemmer* mines, to-day exhausted or absorbed by neighbouring companies, are located, and the remaining eleven active mines of the section now produce gold at the rate of £7,000,000 per

annum. Their dividends for 1907 totalled £2,826,500, or 40 per cent. of the aggregate for the Rand. Since inception, they have distributed 21 millions sterling amongst shareholders. These remarkable figures, indicating the large measure of prosperity attributable to less than a twentieth part of the proven line of reef, demonstrate how irrational it is, despite the general uniformity of mineralogical conditions upon the field, to deduce from the achievements of this premier group industrial standards for universal application. Yet how often have not inspired members of the British Parliament based elaborate arguments as to the possibility of Rand expansion—under labour conditions of their own fanciful conception—upon the 200 and 300 per cent. dividends of the *Crown Reef* and *Ferreira* companies! As reasonably might we attempt to gauge the intellectual level of the House of Commons by the lofty standards of sagacity established by these pre-eminent reformers.

7. There are between sixty and seventy gold-producing companies upon the Rand. It is consequently beyond the scope of this review to give any record of individual performances, even in form of the briefest summary. An instructive table can be presented, however, dealing with the operations of the several groups of mines which fall under the control of the eight leading financial houses, outside of which there are only half a dozen producing properties of note. The interests of the eight firms may be shown as follows, with the aggregate tonnages milled and gold yields for one month (November, 1907):

Interest.	*No. of Mines.*	*Tons milled.*	*Yield.*
			£
Wernher-Beit-Eckstein	23	509,766	913,740
Consolidated Gold-fields	5	198,036	307,391
Farrar-Anglo-French ..	5	151,035	256,546
Barnato	7	135,134	198,182
Robinson	5	97,089	156,473
Neumann	4	81,557	126,816
Albu	4	72,266	117,684
Goerz	6	72,765	101,921
Various controls ..	7	40,918	60,598
Totals	66	1,358,566	2,252,208*

These figures give a ready indication of the importance of the Rand's 'big mining houses,' of which the first two upon the list account for nearly one-fifth of the world's gold-production.

* Includes £12,857 declared through local banks.

8. Not only do the Eckstein and the Consolidated Gold-Fields groups show the greatest aggregates, but they also include the greatest individual mines—indeed, the greatest gold-producers in the world. The *Robinson*, with 210 stamps in operation, heads the list, whilst the *Simmer and Jack* comes second with 320 stamps, treating ore of very much lower grade than the premier producer. The achievements of the leading five Transvaal mines for the year 1907 may be summarized as under :

	Tons milled.	*Yield.*	*Dividends.*
		£	£
Robinson	410,927	1,290,461	660,000
Simmer and Jack ..	736,930	1,189,634	450,000
Robinson Deep ..	614,289	941,944	343,000
Cason	440,278	811,211	341,250
Crown Deep ..	437,036	781,923	330,000

Following these come the *Angelo*, *Ferreira Deep*, *Witwatersrand Deep*, *Village Main Reef*, *Ferreira*, and *Robinson Central Deep*.

The *Robinson* mine is not only the greatest producer, but it is also the richest mine. Again, analyzing the returns for November, 1907 (which provide a conservative basis owing to the non-declaration of gold from the reserves commonly maintained for purposes of industrial security), we find that the *Robinson* obtained 56s. from every ton milled. The average for the Rand was 32s. 8d. per ton. Classified by grades, there were—

6	mines	yielding	over 40s. per ton.
11	,,	,,	from 35s. to 40s. per ton.
19	,,	,,	from 30s. to 35s. per ton.
22	,,	,,	from 25s. to 30s. per ton.
8	,,	,,	under 25s. per ton.

To obtain these results, it is necessary to discard an average of 15 per cent. of the ore mined as waste rock; and yet the records given above stamp the Rand as an essentially low-grade mining centre when compared with the leading gold-fields of West Australia, Queensland, New Zealand, Tasmania, India, British Columbia and the Western States of America, where, in most instances, the ore can be delivered into the treatment plants without preliminary waste-rock elimination.

9. In May, 1905, after the influence of the Chinese labourers had been reflected in growing outputs for several months, the Rand regained the standard of outputting capacity attained

prior to the war. How this pre-war record has since been exceeded by many millions, and dividends have almost proportionately risen, may be gathered from the following table, based on statistics for the Transvaal, compiled by the Chamber of Mines:

Year.	*Yield.*	*Dividends.*
Up to 1897	53,987,973	10,777,000
1898	16,240,630	4,848,238
1899	15,452,025	2,946,358
1900	1,481,442	—
1901	1,096,051	415,813
1902	7,301,501	2,121,126
1903	12,628,057	3,345,502
1904	16,028,883	3,877,624
1905	20,854,440	4,832,436
1906	24,616,704	5,735,161
1907	27,403,738	7,131,212

(The war lasted from October, 1899, till May, 1902.)

Bearing upon the financial aspect of the Rand, it is of interest to note that the 1907 dividends were equivalent to a return of about 7½ per cent. on the market valuation of the shares involved, after allowance of 4 per cent. for redemption of capital.

With its gold, which as bullion possesses an average fineness of 870 to 880, the Rand produces a substantial quantity of silver, equal by weight to approximately 10 per cent. of the gold. This comparatively insignificant source of revenue brings in £80,000 to £90,000 per annum.

10. No feature of Rand mining progress has been scrutinized with wider interest, no effort has been attended with greater success, than the lowering of current working expenditures. In some cases, no doubt, this aim has been pursued to the excessive detriment of grade or with the aid of uneconomical capital outlays,* but, broadly reviewed, the achievements of controlling heads have been indicative of the highest skill. With the reduction of working costs to between 14s. and 15s. per ton milled, as on the *Robinson* (14s. 1d., Dec. '07) the means are demonstrated by which enormous reserves of low-grade ore can be transferred to the sphere of payability. 'Working costs' are understood to include all current expenses on the property, directors' fees, head-office charges, and an allowance for 'mine development redemption,' by which the cost of development should be wiped off before the close of the mine's life. On this basis of calculation, average Rand costs (equal to the yield minus declared

* For a highly critical analysis of this important question readers may refer to Mr. G. A. Denny's 'Commercial Aspect of Rand "Profits,"' published by the London *Mining Journal*.

working profits) have fallen to 20s. per ton milled, and upon many mines to 17s., 16s., and 15s. per ton. Before the war the corresponding figure was 24s., according to an estimate based on the operations of thirty-six companies.

To indicate the segregation of the various items of expenditure, we may here append the costs of two of the greatest producers for the quarter ended December 31, 1907:

	Robinson Deep. per ton.		*Simmer and Jack.* per ton.	
	s.	d.	s.	d.
Mining and pumping ..	12	2	9	9
Sorting, crushing, etc. ..	0	5½	0	6
Milling	1	11	1	7
Tube-mill	0	4	0	9
Cyaniding	1	2	1	2
Slimes	0	6½	0	6
General charges	1	1	1	4
Development redemption ..	2	6	2	0
	20	2	17	7

Classifying Rand costs on a different basis, an average distribution may be shown as under:

Supplies	35·5 per cent. of total.
Labour	59·0 „ „
Management, etc.	5·5 „ „

Since the war the cost of supplies has been very materially reduced, owing principally to a cheapening of coal, explosives, and railway rates. The most important stores consumed on the Rand (apart from native and Chinese food-stuffs) were, during the year ended June 30, 1907, as follows (tons of ore milled, 14,867,046):*

	£
Explosives—Blasting gelatine	946,917
Gelignite	231,901
Others	22,661
Coal—Steam	1,109,537
Smithy	26,668
Machinery and machine tools	726,968
Timber—Deal	90,564
Pitch pine, Oregon, etc.	221,560
Poles and lagging	83,694
Cyanide	338,373
Candles	221,500
Rock-drill spares	103,508
Zinc and zinc discs	100,167
Battery shoes and dies	99,949
Fuse	92,443

The value of all stores consumed during the year totalled £7,464,470.

* Report of the Government Mining Engineers for 1906–1907.

11. The cost of power has been estimated for the nine subsidiaries of the Rand Mines, Limited, using local coal for all power developed, at £27 per indicated horse-power per annum, of which half is accounted for by fuel. This estimate includes 'all running costs of boiler and engine rooms, with repairs and renewals, but without redemption of capital expenditure.'

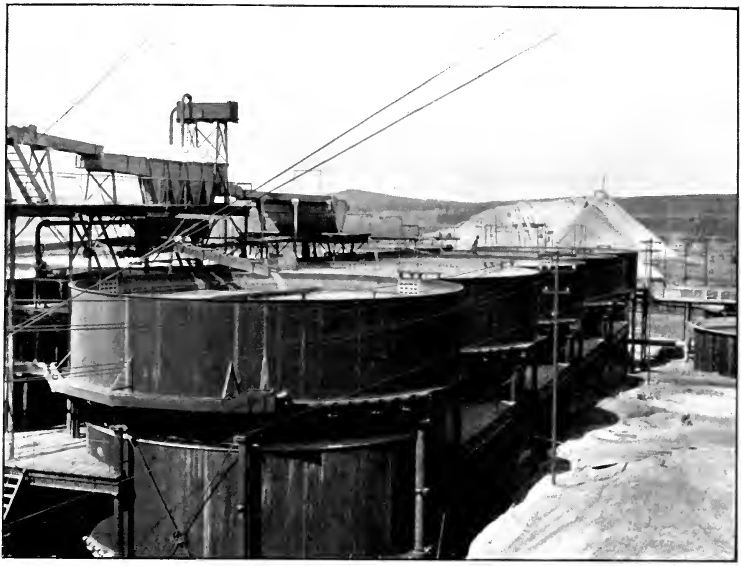
The application of electricity has been greatly extended upon the fields, and is rapidly attaining a much greater degree of industrial importance. An electrical engineer of high standing has favoured the writer with the following note upon this aspect of Rand economics :

'Although the first equipment of our gold-mines, for many reasons, was laid out on a purely mechanical basis, the adoption of electricity as an illuminant and a motive power was soon admitted, and to-day there is not one mine that has not found it of advantage to utilize electricity for driving its various appliances on the surface and underground. It is evident that a gold-mine, with the high value of its product, should, in the first instance, rather look to a rapid development than to minute details of economic working ; and the favourable positions of the Rand, surrounded by good coal-fields, whence cheap fuel could be obtained, naturally tended to start the mine with direct steam-driven motors. But gradually, as development increased and greater depths were reached, electricity had to be resorted to, and when once introduced, it soon found its way to all parts of the mine, and was readily adopted for driving pumps, haulages, locomotives, winches, and other auxiliaries, and gradually introduced for the main devices such as crushers, stamp batteries, underground winding engines, etc.

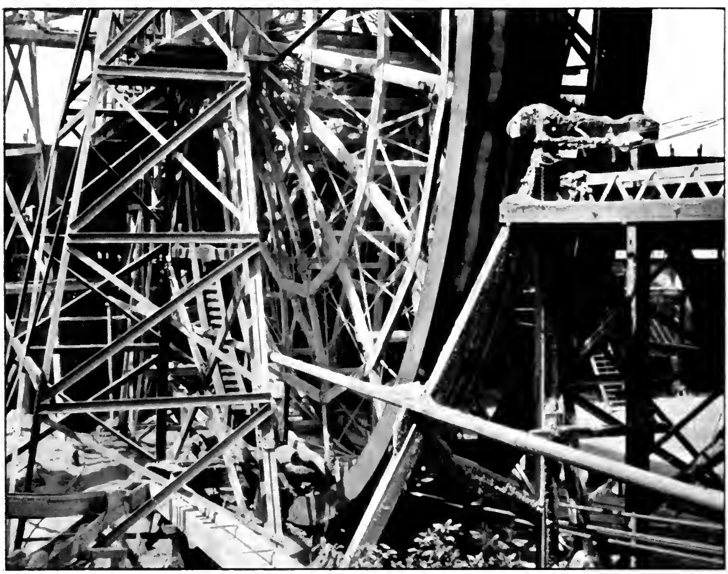
'One of the problems which every deep-level mine will soon have to contend with is the question of underground hoisting—that is, bringing the rock along the incline shaft to the bottom of the vertical, from where it will be taken to the surface by the main hoisting engine. The electrically driven hoist erected at the top of, and hauling along the incline will undoubtedly be resorted to.

'The adoption of rock-drills, driven by compressed air, in large quantities—which, apparently, can soon be expected—will demand extensions of compressor plants, and the tendency will most probably be to erect electrically driven compressors underground, one or more at each level. The driving of stamp-batteries by electric motors has already been proved a success.

'An interesting application of electricity has lately been



RAND CYANIDE VATS.



WHEEL FOR TAILINGS ELEVATION.

introduced on these fields in the shape of an electric furnace for heating the drills and sharpening the same underground.

'In the above notes only a few of the many applications to which electricity lends itself have been mentioned, but those items undoubtedly constitute the principal lines upon which the mines will tend to extend their electrical plant in the near future. The peculiar position of the Witwatersrand Gold-Fields, being situated in an almost uninterrupted line extending many miles east and west of Johannesburg, makes it an ideal ground for electric transmission from one or more centres.'

The Victorian Falls Power Company is establishing two power stations with initial capacities of 18,000 and 6,000 kilowatts, and will soon be ready to supply the rapidly increasing demand for electric current. This power, it must be added, will be generated locally, and not at the Zambesi River, as the name suggests.

12. In regard to water-supply, a factor of great importance in a wet-crushing field of such magnitude, the Rand is well favoured. Mine-dams provide the bulk of the companies' requirements for milling, etc., but a position of perfect security is established by the works of the Rand Water Board, which is capable of pumping 12,000,000 gallons a day to its reservoirs. A rainfall of about 25 inches per annum is recorded in the district. The Water Board draws its supply from the dolomite formation on farms 10 to 15 miles to the south and south-west of Johannesburg. On a basis of 3,000,000 gallons per day, pumping costs are estimated at 4¾d. per 1,000 gallons, exclusive of maintenance, renewals, etc., and the uniform charge for water to mines and other customers is 3s. per 1,000 gallons. It is estimated that 1,600 gallons of water are used by the mines per ton crushed, but by repumping the actual loss is reduced to 413 gallons per ton.*

LABOUR: WHITE, BLACK, AND YELLOW.

13. The Witwatersrand labour question, ranging in its influence from high political issues affecting the relationship of the white and coloured populations of South Africa down to the pettiest problems of mine operation, promises once again to assert itself, in a new aspect, as the foremost problem dominating the future progress of the gold industry.

The Chinese labour 'experiment' was undertaken on a

* Proceedings of the South African Association of Engineers, 1907.

'working scale' which involved the introduction of some 50,000 to 60,000 coolies from the East. From the standpoint of working efficiency the indentured Asiatics amply justified their introduction, for, owing to their higher intelligence and longer contract of service, they raised themselves to a plane of utility well above that of the more tractable Kaffir. But the final outcome of the 'experiment' has not depended upon the teachings of mine account-books, nor upon the feelings and inclinations of the indentured coolies. By the decision of the Imperial and Transvaal Governments, the 'yellow phase' of the labour question is being brought to a speedy conclusion. The Labour Importation Ordinance came into force in 1904, and on May 25 the first batch of Chinamen arrived. By the end of the year 20,918 were employed upon the Rand; in December, 1905, some 47,000; and twelve months later, 53,000. During 1907 the work of repatriation commenced, and at the close of the year the complement had fallen to 37,000 coolies. In December of this year, 1908, there should only remain 14,000 Chinese labourers upon the field, nearly all of whom will have returned to the Celestial Empire before the following Christmas. Thus the Rand is called upon to work out its own salvation—to seek its labour in South African territories, and, if all required is not forthcoming, to still further introduce mechanical appliances as a substitute for muscle power. How far success will attend these localized efforts no engineer nor politician can yet foretell. Even though a curtailment of constructive and mining enterprise outside the Rand, and other adventitious circumstances, have recently led to an augmentation of the available supply of Kaffirs, the withdrawal of the constant force of Chinese labourers, accounting for 30 to 40 per cent. of the gold-production in 1907, cannot fail to create an upheaval of working conditions. Having, as needs they must, accepted the new situation, the leaders of the industry are unquestionably straining every nerve to make the utmost of prevailing conditions; there is no sulking over the defeat.

14. Amongst the sundry cries raised by the expert traducers who flourished during the home elections of 1906 none was so loud as that of Chinese 'slavery.' The baselessness of the accusation that the labourers were imported under conditions purposely misrepresented to them, and when upon the field were forced, even with brutality, to work against their will, has been demonstrated so repeatedly and so forcibly that those who most deeply committed themselves to the allegation have been obliged

to acknowledge their 'misconception' of the facts. Even when permitted to return to China before the termination of their contracts, only a small party—a remarkably small percentage under any circumstances—availed themselves of the opportunity. The Chinese labourers have been eminently contented and happy, and have found their duties generally congenial. It has been urged in criticism that their wants have been far better cared for than those of the native labourers; though the very conditions of their long engagement in a foreign land justified this greater consideration. All who have inspected the mine compounds have been able to bear testimony to the thorough satisfaction of the Chinese labourers with their treatment and environment. But if mere personal observations are held to be untrustworthy, further proof is surely provided by the records of labour efficiency. The unwilling hand is never a good working unit. Statistics compiled over a long period for the *Simmer and Jack*, where about 4,000 coolies were employed, showed that the 1,500 hammer-boys at work in the mine drilled an average of 39½ inches per shift for a wage of 1s. 10½d.

15. One of the strongest arguments raised by objectors to Chinese importation was that their enormous earnings would be sent out of the country. The fears entertained in this connexion were soon dispelled by the somewhat surprising thriftlessness of the coolies and their remarkable weakness for costly luxuries and display. It is true that their innate love of gambling has been responsible for an ill distribution of cash in circulation, and that a large number of more provident Chinamen have wisely treasured their savings for use in the homeland; but, nevertheless, Transvaal trade has benefited enormously by the great addition to the body of wage-earners. The displeasure of the farming community was aroused by the fact that, instead of South African mealies, the Chinamen required imported rice for their staple diet. Though calling upon local producers less than do the natives, the Chinese consumed large quantities of other food-stuffs, to the advantage of Transvaal markets.

The importation of Chinese for the mines was, from the employers' standpoint, a very costly proceeding, and involved an expenditure of about £17 10s. per head, of which £10 went in sea transportation charges for the double journey.

16. There have been many opponents of Chinese labour, resorting to no exaggeration of its recognized disadvantages nor to the familiar calumnies to support their case, who have sincerely and consistently maintained that the 'experiment'

constituted a curse which no industrial emergency could justify even as a 'final and last resource;' and that the absence of proportionate increase in white employees, whatever the economic reasons, condemns it finally. Their arguments lie chiefly within the realms of higher politics. However laudable the hope of emulating other divisions of the Empire with an 'exclusive' policy may be, South Africa, with its preponderating population of five or six million natives, can never be a 'White Man's Country' such as the statesmen of Australia, New Zealand, and Canada can make of their dominions. In Australia the native population is a negligible factor; in New Zealand the Maori community has risen to a high level of civilization and prosperity, but it is small and unambitious; in Canada, with its 7,000,000 whites, the question of competition with immigrants from the Far East is to-day of minor significance.

The problem confronted by the Transvaal Government is one of degree. In what measure shall the native be allowed to develop his faculties as mine labourer, and where shall the barrier be maintained between the spheres of white and coloured employment? Those responsible for the introduction of Chinese labourers contend that their action did not affect this fundamental problem. The Chamber of Mines declared that the seizure of trade by Chinese, and their ousting of whites from positions such as carpenters, fitters, engine-drivers, etc., would have been a 'national catastrophe.' Upon this point, at least, the views of the whole Transvaal white population, with the lessons of Natal before them, have been in strong unanimity.

17. The great increase in the labour force employed upon the Rand and the variations in its disposition are indicated by the following returns:

Year.	*Whites.*	*Coloured.*	*Chinese.*
January, 1904	12,118	62,092	—
January, 1905	14,873	82,847	27,222
January, 1906	17,696	83,955	47,166
January, 1907	17,198	94,221	53,856
December, 1907 ..	17,050	119,988	37,118

More instructive than the numerical proportions of the roll is the relative allocation of wages to the three classes of employees. Although the coloured and Chinese workers outnumber the white by nine to one, their aggregate wages are only equivalent to two-thirds of the earnings of the superior class; such is the significance of 'cheap, unskilled labour' on the Rand. Allowance must be made for the fact that the whites are obliged to support themselves, whereas the Kaffirs and Chinese are kept free in the mine compounds, but the contrast is none the less remarkable. Wages for the statistical year to June 30, 1907, totalled for the Transvaal gold-mines (the figures being increased only a small percentage by returns for companies outside the Rand) as under:

	£
Salaries to whites	948,508
Wages to whites	5,407,850
,, 'Kaffirs'	2,906,098
,, Chinese	1,217,130
	10,479,586

18. The whites, who perform all the higher and more responsible duties, such as those of machine-drill and hammer-boy direction, timbering, engine-driving, carpentering, general mechanical work and supervision, etc (which the natives are forbidden by law to undertake), are mostly of British birth. A recent analysis showed the South African-born white employees to equal 20 per cent. of the aggregate; other colonials, 6 per cent.; and aliens, 6 per cent. Before the war, and for some time after it, the efficient miner was able to earn on contract in stope or development working a rate of pay very substantially higher than that obtainable in any other field in the world. But that was in the days of great actual or apparent prosperity, and the scope for earning big cheques after the monthly 'measure up,' though still above the Australian or Canadian standard, has in recent times of depression been sternly reduced. So sweeping have been the changes underground in the standards of contract prices that a fair average return is now hard to arrive at. Good miners may still be said to draw £30 or £40 per month. The cost of living in Johannesburg is notoriously high, owing principally to the heavy railway rates on imported goods. A married man with wife and two or three children can live comfortably on £20 to £25 a month, and the single man for £10.

19. Operations in the treatment works proceed continuously throughout the week, and allowing for stoppages due to repairs and other causes, a running record of 340 days per annum is usually accredited to the full mill. Underground there is no Sunday mining, and the shifts are of about ten hours' duration. Eight-hour shifts have been instituted in a few mines. Unlike

the mining fields of America, where the incidence of strikes often appears to be a factor in industrial calculations on a par with the uncertainties of water-supply or lode-persistence, the Rand has been remarkably and happily free from difficulties on account of organized refusal to work by white miners. Its labour troubles have been of a different order. In May, 1907, however, the long record of industrial peace was broken by a serious strike, which for some time threatened to disorganize the industry, but terminated in favour of the mining companies after an acrimonious struggle.

The serious prevalence of that dread disease, miner's phthisis, due to the fine particles of quartzite dust which are inhaled by the miner in the underground workings, particularly at the development faces, must be taken into account in the rating of a fair day's pay. Many efforts have been made to combat this danger, and large prizes offered for the best means of allaying the noxious dust. The most effective system is by the employment of water-sprays and atomizers, but these are strenuously objected to by the workers as equally harmful, owing to the saturation of the atmosphere, which is liable to cause other complaints. When water can be delivered at the drill's striking-point in the hole, the trouble is checked; but this necessitates the use of hollow steel. The mitigation of the siliceous evil is a question still receiving investigation by engineers and Government authorities.

20. The coloured native workers, recruited from a number of tribes in different parts of South Africa, who form the great bulk of the unskilled labour force, are generally strong, tractable, contented, and sufficiently intelligent for the duties they are called upon to perform. Though lacking in all initiative, they make excellent imitative or routine workers. Seeing that their cost in wages, food, keep, and recruiting expenses works out at less than 3s. per shift, and that a very large measure of unskilled labour forms an economic necessity in the exploitation of narrow low-grade reefs, the mining industry is manifestly fortunate in being able to retain a supply of 100,000 natives in its service. Two noteworthy circumstances, however, tend to reduce the actual value of the Kaffir as a working unit as compared with the white or Chinese labourer. Firstly, his term of service, varying from about four to twelve months, is too short, and the raw native fresh from the kraal requires several months' experience before full efficiency is attained. Secondly, the standard of day's work established is far below his full capacity.

FERREIRA DEEP.

CHINESE LABOURERS AT SHAFT HEAD.

In hammer-work the boy is at liberty to return to his compound upon the completion of a 3-feet hole, which a good worker can drill in half a day. Inducements offered to him for the accomplishment of extra footage are not often considered acceptable. Yet we find that in shaft-sinking by hand-labour, when work is performed at high pressure, under the most rigorous supervision, the natives not only achieve the drilling footage expected from them in stopes, but previously clear out the broken rock—a task of three or four hours' hard pick and shovel work. Thus one of the subordinate labour questions, growing in significance with the expulsion of the Chinese, is that of the means to be adopted for obtaining a full day's work from the happily independent Kaffir.

The recruiting and fair distribution of the coloured labour-supply is undertaken by the Witwatersrand Native Labour Association, an organization subsidiary to the Transvaal Chamber of Mines, formed to substitute co-operation for competition among employers. Many divisions of South and Central Africa are partially or wholly closed against the association's recruiting agents. From 45 to 50 per cent. of the natives brought to the Rand are drawn from Portuguese East Africa, with the administrators of which foreign territory the most friendly relations have always been maintained by the controllers of the Transvaal mining industry.

21. With the Far East closed for purposes of recruiting, and with a native labour-supply (of late happily abundant) ever constituting a factor of dangerous instability, the Rand is now compelled to turn more earnestly to the aid of labour-saving devices. The idea can claim no feature of novelty. In every department wherever an opportunity has appeared for mechanical innovation—and often where there has not—new appliances have been installed. The utilization of the automatic can be easily carried to excess under South African conditions. It is allowed by all, however, that in the field of rock-drilling—in the development of a small stope-drill capable of operation by one man as a substitute for hammer-boys—there is promising scope for economic advancement.

Fortunately, the day of the Rand's exhaustion is yet far distant. It stands beyond prediction. Divers estimates, necessarily based upon factors determinable with no precision, and liable to constant modification in this land of kaleidoscopic changes, have been advanced to indicate the probable measure of gold still to be recovered from the banket reefs. The resources of payable ore to be opened up at a profit have been computed at a value of 800 to 1,000 millions sterling; some prophesy in larger figures. But all these estimates are based upon our present standards of economy, applied down to a reasonable mining depth. Where the limit of payability will lie a decade hence none can determine.

A long future of activity is assured by the great expanse of reef-bearing territory of highly probable or proven payability. So, too, there is the region of undoubted poverty and excessive depth, with commercial possibilities too meagre for consideration; and between these indefinable spheres there lies the vast 'borderland' of uncertainty, holding out the promise of incalculable reward for those devoting to its needs the highest faculties of scientific skill and industrial statesmanship.

CHAPTER XXVIII

CANADA

Progress of Mineral Industry

1. Status of mining industry.—2. Records of yield.—3. Minerals produced.—4. Principal centres.—5. Coal-fields.—6. Iron and steel.—7. Petroleum and natural gas.—8. Nova Scotia gold.—9. Non-metallic minerals.—10. Administrative influences.

1. The two colonial Dominions, Canada and New Zealand, have risen to a high degree of commercial distinction and prosperity under small obligations to the progressive influences of mining, and thus differ vitally from the sister colonies of Australia and South Africa, whose mineral wealth provided the national foundation.

For generations past Canada has drawn upon herself the eyes of the financial world, to which have been revealed the innumerable opportunities of profitable participation in the progress of a young and growing nation in a boundless land. Year by year the soundness of its industrial offerings is more forcibly evinced by plenteous returns, and to-day the Dominion affords one of the world's most attractive fields for the employment of capital, growing speedily in popularity and promise. From the days of Charles II., when the 'Honourable Company of Adventurers from England, trading into Hudson's Bay,' established the 'rule of the fur-traders,' down to the present era of railroad suzerainty, when the transcontinental lines of Canadian Pacific and Grand Trunk provide the main arteries for the inward flow of men and money, there has been no phase of industrial development during which the miner's work has appeared of aught but subordinate significance amongst the factors responsible for the country's strength. Fortunately for the enduring stability of the nation, agriculture has been made the backbone of its trade and commerce, and in the exploitation of this branch of natural resources, successive Governments have consistently applied their foremost energies.

On this account, and not as a consequence of mineral poverty, has the Dominion failed to win a lofty place amongst great mining countries. The prominent trade-sign of Canada, proclaiming to the world the opportunities for farmers in its prairie regions, has tended to obscure the lesser industries of mine and smelter. Occasionally the announcement of great mineral finds has awakened the country's neighbours to the possibilities of wealth beneath the soil. The fame of Yukon placers, of Rossland gold and Cobalt silver, spread swiftly as a nine days' wonder round the globe, but the true forces of expansion bringing the country to the forefront of the mining world are little known.

For many years British Columbia—the 'mineral province'—could be credited with the bulk of the Dominion's mineral production. With the rise of the Klondike diggings in 1896 the balance of output was still more conspicuously in favour of the Western regions. The most noteworthy transformation of recent years, however, has been the rapid growth of the Eastern fields, leading to the establishment of better industrial equilibrium between the East and West. Ontario no longer bends the knee to British Columbia, but justly advances its claim to the distinction of recognition as the leading 'mineral province.'

2. The dissimilar methods of ore-valuation adopted by the statists of the Dominion and provincial mining departments, particularly regrettable in these days of universal standardization, put difficulties in the way of closely comparing returns for each division, and of noting the significance of each source of mineral supply relatively to the aggregate yield. For example, the Ontario Bureau of Mines takes credit only for the spot value of mineral products, such as copper-nickel matte; while the Ottawa Department estimates the value of the metal contents, which are recovered, maybe, outside the country. This leads to discrepancies of a magnitude perplexing to the casual student of Canadian statistics.

Figures for representative years, reflecting the progress of two decades, and covering the total mineral yield of Canada (metallic and non-metallic products and structural materials), may be tabulated as under :

Year.	*Value.*
	£
1886	2,090,000
1890	3,400,000
1895	4,200,000
1900	13,200,000
1904	12,300,000
1905	14,000,000
1906	16,000,000

In aggregate value the mineral production from 1886 to the end of 1906 substantially exceeds £155,000,000.

The apparent stagnation of the industry as a whole between 1900 and 1904 was in large measure due to the steady decline in gold-yield from the Klondike gravels. Reaching its zenith in 1900, when an output of £4,550,000 was recorded, the famous Yukon district has since gradually decreased in yearly out-putting capacity by upwards of half a million sterling per annum, declaring a yield of only £1,140,000 for 1906.

3. The total yearly production for Canada, tabulated above, may be further subdivided according to classes of product and sources of yield :

Metals.	1905.	1906.
	£	£
Gold	2,956,000	2,454,000
Copper	1,514,000	2,243,000
Nickel	1,540,000	1,826,000
Silver	735,000	1,168,000
Lead	537,000	625,000
Pig-iron from Canadian ore ..	214,000	351,000
Iron ore	25,000	30,000
Cobalt, zinc, etc.	57,000	72,000
Totals	7,578,000	8,769,000

Of the non-metallic minerals, coal is vastly the most important, but there are also several other products of considerable value :

	1905.	1906.
	£	£
Coal	3,602,000	4,070,000
Asbestos	303,000	402,000
Petroleum	173,000	155,000
Gypsum	119,000	121,000
Natural gas	64,000	108,000
Salt	62,000	67,000
Limestone (flux)	53,000	55,000
Mica	34,000	119,000
Corundum	30,000	42,000
Pyrites	25,000	32,000
Various	75,000	78,000
Totals	4,540,000	5,249,000

Under the head of 'Various' fall chromite, ochres, mineral water, phosphate, grindstones, asbestic, felspar, graphite, manganese, barytes, tripolite, and talc.

4. A particularly favourable feature of Canada as a mining country is the lack of excessive centralization ; its productive fields are diverse in character and wide in distribution. Amongst

the land's mineral occurrences are the greatest deposits of nickel, asbestos, and placer gold, and the richest silver-field in the world.

As a producer of coal Canada holds precedence among the self-governing colonies of Great Britain, and is but narrowly surpassed by India; its yield of mica constitutes a substantial percentage of the world's supply, and the petroleum production exceeds that of all other colonies. There are six centres of activity in the Dominion which stand out prominently above the rest, and are responsible for 80 per cent. of the aggregate yield of metals, as follows:

	1906 *Output.* £
Boundary, British Columbia	1,753,000
Cobalt, Ontario	730,000
Rossland, British Columbia	648,000
Sudbury, Ontario	2,243,000
Yukon	1,140,000
British Columbia silver-lead	696,000
Total	7,210,000

The chrysotile mines of Quebec, upon which the world relies for fully 90 to 95 per cent. of its supply of asbestos, have also a unique importance of their own.

5. The greatest coal-fields of Canada occur in British Columbia and Nova Scotia. Out of the Dominion's total yield of 9,916,177 short tons in 1906, the Western Province accounted for 2,127,000 tons, and the Eastern for 6,570,000 tons. The Sydney coal-field, in the county of Cape Breton, Nova Scotia, was the first opened in Canada, and has a high reputation for its excellent bituminous coals, largely used for coke-making, steaming, and domestic purposes. The principal producers are the *Dominion Coal Company*, with an annual output of 3,500,000 to 4,000,000 tons, and the *Nova Scotia Steel and Coal Company*, with 750,000 tons. At the Glace Bay section of the Sydney coal-fields the *Dominion Company* works the Phalen (8 feet) and Harbour (6 feet) seams on a large scale. The great Phalen seam yields a very valuable coal, showing the following analysis:

	Per Cent.
Volatile combustible matter	31–32
Fixed carbon	62–63
Sulphur	1·8–2·3
Ash	4·6–6·4
Moisture	0·7–0·9

In British Columbia, the *Crow's Nest Pass Coal Company* is the leading producer, with a nominal capacity of 2,000,000 tons of coal and 500,000 tons of coke. The collieries are situated on the western slope of the Rocky Mountains, within convenient distance of the Boundary and Rossland smelters, which have provided an expanding market for their coke. For steam and domestic coal the demand is always keen, and frequently in excess of the supply. The coast is served by collieries on Vancouver Island, whose annual yield exceeds 1,000,000 long tons.

6. Though frequently described as the most backward of the colonies in mining development, Canada is the only country of the Empire outside Great Britain which has established an iron and steel industry of any considerable prosperity and magnitude. India, Australia, and South Africa have all the essentials in the form of iron-ore, coal, and limestone, but have hitherto been unable to attain (whatever recent enterprise may lead to in India and Australia) any high degree of importance as the producers of this industrially stimulative metal. The country's happy distinction has been largely attributable to the wisdom of the Dominion Parliament in 1897, whose Bounty Act provided for the payment of liberal bounties on steel and iron made in the Dominion from home or imported ores.

The rapid advance of pig-iron production following this policy may be learnt from the official records :

	Output. tons.
1895	37,829
1898	68,755
1900	86,090
1901	244,976
1902	319,557
1903	265,418
1904	270,942
1905	468,003
1906	541,957

In five years the output has been practically doubled. The soundness of the bounty system, so well demonstrated in Canada, has been realized by India and Natal, where, however, the practical benefits have yet to be gained. The iron and steel of Canada, of which less than a quarter is made from domestic ores, is smelted on the coal-fields of Nova Scotia by the *Dominion* and *Nova Scotia Companies*, and in Ontario, at Hamilton, Deseronto, Midland and Sault Ste Maria. The *Dominion Steel and Iron Company* is the greatest producer, drawing exceptionally cheap ore from Bell Island, Newfoundland. More satisfactory has been the advance of the Ontario industry during the last few years, for in that province Canadian ores are to be more and more extensively utilized. The exploitation of its enormous iron-ore deposits is one of the most encouraging features of the province's economic development. Recent statistics have shown the production of pig-iron for Ontario to be :

Year.	*Pig-Iron.*	*Value.*
	tons.	£
1903	87,004	305,000
1904	127,845	370,000
1905	256,704	800,000
1906	275,558	930,000

At the beginning of 1907 there were fifteen completed blast-furnaces in Canada, of which eight were in blast. Four more were under construction.

7. Petroleum and natural gas are two mineral products of significance for which Ontario is almost entirely responsible. Oil has been produced since 1862, when numerous spouting wells were opened up. For several years the petroleum yield of the south-western division of Ontario, immediately between Lakes Huron and Erie, exceeded that of Burma. In 1904 the industry was aided by the grant of a bounty by the Dominion Government of $1\frac{1}{2}$ cents ($\frac{3}{4}$d.) per imperial gallon, but the production has remained fairly constant since 1900 at about 20,000,000 gallons. In illustration of the various products turned out by the Canadian refineries, the following schedule may be given for 1905 (from 33,821,998 gallons of crude oil, Canadian or imported from Ohio) :

Product.	*Quantity.*	
Illuminating oil	16,433,600	gallons.
Lubricating oil	3,403,000	,,
Benzine and naphtha	2,828,000	,,
Gas and fuel oils, and tar	5,788,000	,,
Paraffin wax and candles	4,078,000	pounds.
Total value	£448,000	

The production of natural gas, by which several towns in the same division of the province are supplied, has made a rapid advance. There are over 300 wells, producing gas to the value of over £100,000 per annum.

8. Gold-mining in Nova Scotia, during its erratic progress since the commencement of operations in 1860, has frequently risen to prominence in the public eye and as frequently slipped back into the region of obscurity to which all unsuccessful mining-fields depart. The fields cover 3,000 square miles.

Gold occurs in free quartz, associated with various sulphides. The remarkable vicissitudes through which the industry has passed, and the low ebb at which it stands to-day, may be demonstrated as follows :

Year.	*Yield.*
	ozs.
1867	27,000
1874	10,000
1889	24,000
1893	15,000
1898	31,000
1905	15,000
1906	13,000

The cause of the field's retrogression is more freely attributed to inefficient mining methods, to the unsound influences of granting small claim areas, and to the lack of any laws compelling holders to operate their mines, than to the deficiencies of mineralization.

9. In addition to the essentially Canadian product—asbestos—three non-metallic minerals produced in Canada to a considerable extent are mica, graphite, and corundum. Mica is derived principally from Ontario and Quebec, where work has been satisfactorily stimulated by the good prices lately ruling for films, owing to the multiplication of their uses in the electrical world. As of nickel, asbestos, and cobalt, Canada possesses unlimited quantities of corundum, whose concentration forms a distinctive industry.

At Craigmont, in an out-of-the-way part of Ontario, the *Canadian Corundum Company* is treating about 200 tons a day of gneissic syenite, in layers of which, from a few inches to 20 feet thick, the hard mineral occurs in irregularly distributed crystals up to 60 lbs. in weight. In 1906 the mill produced 2,900 tons of finished grain corundum, of the highest abrasive power, which has to compete in the commercial world with time-honoured emery and with the artificial products carborundum and alundum.

10. The interests of mining are well served by Government departments, federal and provincial. In 1907 a Dominion 'Department of Mines' was formed, with 'mining' and 'geological' branches, to facilitate and extend the work previously carried on by the Geological Survey and its mining section. The functions of the mines branch of the new department comprise the compilation of full statistics and reports on mineral production, and the general investigation of all phases and factors of

mining progress throughout the Dominion. The Geological Survey will carry on its highly efficient work as hitherto. While there had previously been a manifest want of an administrative organization to adequately record the tendencies of Canadian mining in general, the provinces individually have been eminently well served by their own Mining Bureaux. The reports annually compiled by the Governments of British Columbia and Ontario are open to few criticisms. Provincial geologists have time and time again provided ample proof of the practical value of disinterested expert reports upon the economic possibilities and geological features of new mineral regions.

The virtual necessity of widely circulating reliable information in regard to mining prospects in this rapidly expanding country has been realized by the Governments of every province, whose many reports and maps, as also the elaborate and trustworthy publications of the Geological Survey, are issued free to all *bona fide* applicants. By this practice, and by the public advertisement of mining resources, opportunities, and laws, the progressive Dominion has created a precedent which other colonies might follow with prudence and advantage. On sound principles are the prospector and pioneer thus assisted in their work, and the investor encouraged to embark his capital in the better classes of mineral enterprise.

CHAPTER XXIX

ONTARIO

Cobalt Silver

1. The discovery of the century.—2. Railway construction.—3. Ore found in 1903.—4. Rush for claims.—5. Frenzied flotations.—6. Geology.—7. Unique richness of ore.—8. Nervous administration.—9. Mining conditions.—10. Estimation of values.—11. Light equipments.—12. Smelters.—13. Milling schemes.—14. Score of leading mines.—15. Early industrial warfare.—16. A mushroom city.

1. Rumours of great mineral discoveries, emanating from the bands of explorers and prospectors who form the scouts and advance guard of the mining industry in its forward march, are frequently received from the less-known regions of the world. Too often these 'discoveries' are rumour, and nothing more substantial. Only three or four times in a decade does there chance to be revealed a new district of far-reaching significance, destined to hold place in the constellation of great mining centres, to provide a new lode-star for the multitude of restless spirits, and to constitute a disturbing, yet progressive, influence in the affairs of a people. During the present century three new mining fields of world-wide fame have sprung into life, with an infancy of dazzling splendour. This trio of discoveries comprises the Premier diamond-mine in the Transvaal, the Gold-field-Tonopah district of Nevada, and the Cobalt silver-field of Northern Ontario. For universal notoriety amongst miners, geologists, and speculators the unique finds in the last-named district of Canada have unquestionably attained a leading place. Its foremost distinction has not been due to the greater magnitude of its industrial prospects, but to a combination of other favourable circumstances. The value of Cobalt's silver veins was marvellous at surface ; their display of metallic richness was even ostentatious. The finds were made in a densely wooded region scarcely known to the prospector. Mineralogical characteristics found no parallel in any part of the world. Ore-values were

speedily turned to commercial account, and the possibilities of such easily exploited deposits forcibly appealed even to men wholly unacquainted with scientific mining. Cobalt, moreover, lay within a few hundred miles of large and prosperous populations (ripe for an epidemic of speculative fever), whose agents, investigators, and reporters were carried to the very heart of the field in the course of a few hours' easy train journey.

2. Like Sudbury, the other great metal-field of Ontario, Cobalt was found incidentally during the construction of a new railroad. The building of the Temiskaming and Northern Ontario Railway, which joins the Canadian Pacific Railway at North Bay, was commenced for the purpose of serving the great 'clay belt,' which is said to constitute some 24,000 square miles of land well adapted for cultivation upon the clearance of timber, stretching across the North of New Ontario.

The course of this railway from North Bay to Lake Temiskaming had been determined long before the existence of a silver-vein was known; yet not only did the line cut the Cobalt district centrally, but it divided into equally productive halves the richest square mile of the camp, which has been responsible for 70 or 80 per cent. of its yield. Had the mines come first and the railway after, the track would not have deviated one chain from its present course. The significance of this circumstance lies in the fact that Cobalt has thus always enjoyed the best railway facilities at its very heart, and has consequently avoided the serious delays marking the early development of nearly every new mining-field, due to lack of cheap and rapid transport. The Temiskaming district, hilly, thickly wooded, and broken up by a system of lakes and watercourses, that add greatly to the beauty of the region, and assist the prospector to penetrate an otherwise difficult country, had been crossed by travellers to the North for many years before railway construction was considered commercially practicable.

3. While it is somewhat difficult to determine the first discovery of silver ore, owing to the failure of the railway-men to recognize the value of their finds, it is unquestionable that the veins to the south and north of Long or Cobalt Lake, now covered by the *McKinley-Darragh* and *La Rose* properties, were the first to be located and worked.

Messrs. McKinley and Darragh were lumber-men with some knowledge of mining, and as a result of their observations and finds, made their location in February, 1903. Very shortly after, La Rose, a French-Canadian blacksmith working at the railway construction camp, recorded a find of promising mineral at the further end of the lake. It is illustrative of the common inaccuracy of many of the more romantic episodes of mining history that, although La Rose was a prominent figure in the early days of Cobalt, and is still alive, three radically different stories are current as to the chance by which the blacksmith first detected the mineral upon the claim now bearing his name, and which has been proved to contain fabulously rich ore to the value of many millions of dollars. According to one authority, a piece of attractive-looking mineral was thrown at his feet after a blast of rock along the new railway track, was pocketed, and in time proved to be rich in silver. According to another authority, gifted with a far finer conception of the picturesque, La Rose was at his forge, when he perceived a red fox in the bush near by, whose impudent curiosity was so great as to prompt the blacksmith to fling his hammer at it. He missed the fox, and nearly lost his hammer ; the missile was of value, however, and had to be recovered. Upon searching the bush, he found that the hammer-head 'had struck a rock, and that the bruise gave a bright metallic streak.' Another version of the affair is that he struck his foot against an exposure of ore, whose 'scar' attracted attention to its metal contents.

It is quite probable that all these stories are equally erroneous.

In October, 1903, a piece of niccolite, mistaken for an ore of copper, was sent to Mr. T. W. Gibson, Director of the Ontario Bureau of Mines, who recognized its value, and recommended the Government geologist, Professor W. G. Miller, to visit the locality of the discovery. Towards the close of November the result of the early investigations of this official became known, and a collection of specimens was made and sent down to Toronto for exhibition. It was a considerable time before the public of Eastern Canada, naturally suspicious of mining investments, began to interest themselves in the new district. In time, however, as more claims were taken up, new discoveries were made of veins carrying native silver, cobalt, nickel, and arsenic, and the weighty argument of output became more convincing; the field attracted large numbers of prospectors—professional and amateur—miners, and speculators ; there was a rush, and subsequently a wild stock-market boom. So wonderful were the values obtained in divers sections of the camp that the excitement marking the first two or three years of development was as normal a phase of growth as the following spell of disgust and disappointment. In 1904 half a dozen properties shipped 158 tons of ore, the silver contents of which were valued at

20

£27,800; and in 1905, when about a score of mines contributed, 2,144 tons were shipped for a return of £277,000, equivalent to almost £130 per ton. The ore produced included some enormous nuggety blocks, very largely composed of native silver. Such returns as these would be likely to intoxicate alike the old prospector and the mining novice of the most phlegmatic and sober-minded disposition. How little amazing, then, the excitement and extravagant optimism of the keen and impetuous people of a young country!

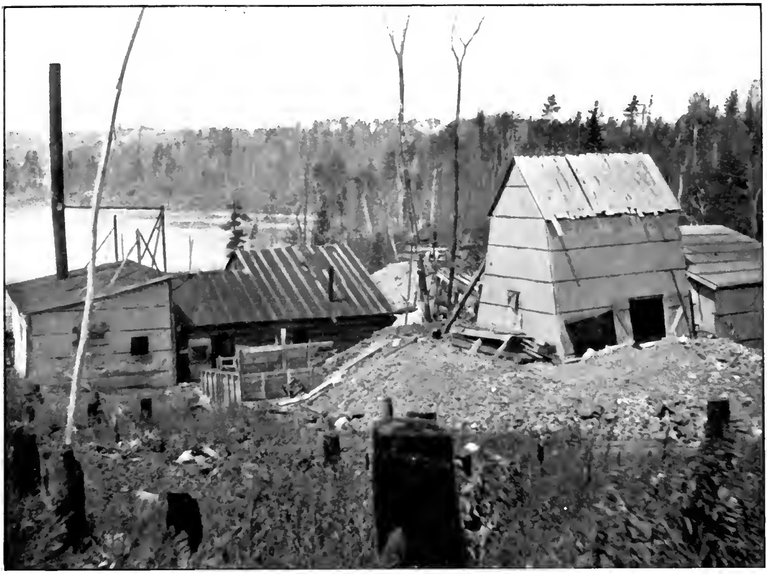
4. Upon the announcement of a rapid sequence of new discoveries in various parts of the field there came a wild rush for claims. Ground with only the smallest indication of mineral *in situ* was greedily snapped up, and dumped into the share-market hampered with a millstone of excessive capital.

No indiscretion or carelessness on the part of the public can excuse the unbusinesslike methods of reputable company promoters and the deliberate deceptions of the unscrupulous scrip-manufacturers, who reaped so abundant a harvest during the third year of the camp's exploitation.

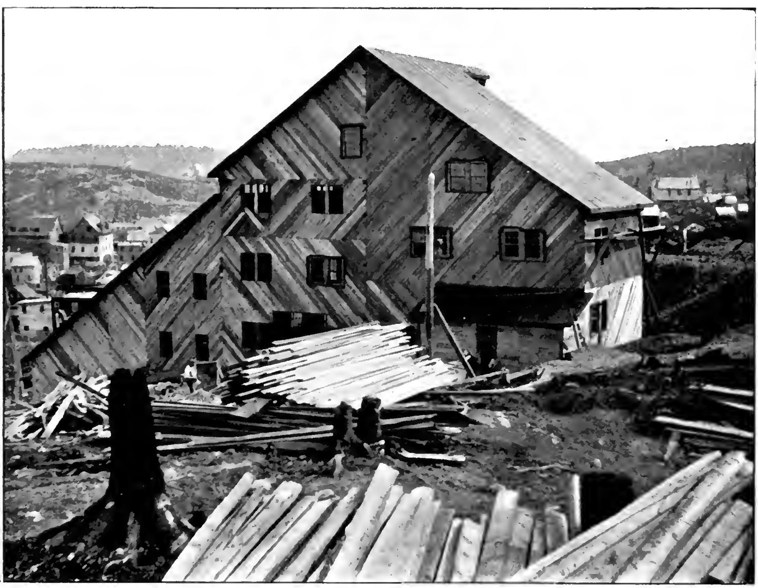
In Cobalt were seen a number of narrow, rich veins, generally unpersistent, constituting a perfect 'poor man's paradise,' in the exceptional facilities obtaining for the speedy realization of its widely distributed mineral assets. So boundless was the brazen audacity of the wild-cat promoters in the field that up to the middle of 1907 some 15,000 to 20,000 acres of Coleman, Lorrain, and Bucke townships, Cobalt district, had been formed into companies with an aggregate capitalization of £50,000,000.

Reviewing 140 of these flotations, one finds that 87 were capitalized at $1,000,000 or more, while only 11 (despite the modesty of their mechanical needs) figured below $500,000. In nearly all cases the remarkable anxiety of the vendors and promoters (who customarily received their 70 to 80 per cent. of the capital in cash and stock) to off-load their holdings before their possibilities could to any degree be tested was significantly evident. By naming exorbitant terms, the promoters bluffed the credulous public into the belief that the value of the property was *de facto* established and understood, and that company flotation was merely expedient as an aid to exploitation on a scale of appropriate magnificence.

5. It was quite in accordance with recognized practice to place before the public a 'prospect' (perhaps without any vein in



NOVA SCOTIA MINE, COBALT.



CONIAGAS MILL, COBALT.

evidence) upon the strength of the bare opinion expressed by an interested party that its possibilities, or, better still, its 'potentialities,' were 'enormous.' In some cases promoters would introduce their venture with a pamphlet describing in dazzling terms the success of 'neighbouring' Cobalt mines, or even of great dividend-payers in other parts of the world. But investors have now grown sorely tired of predictions and anticipations, and look impatiently for more solid realizations and returns commensurate with the many millions of dollars absorbed by Cobalt stock. After the extravagant enthusiasm of 1906 there came in due course the swing of the pendulum to intolerant disgust. From this reactionary feeling the camp has of late to some extent suffered. The glamour of novelty and mystery have gradually passed from the field—to its advantage as a mining industrial centre—and a painful purging of the body financial has been in process.

6. The district has provided remarkable problems for investigation by the field geologist and the mineralogist—problems which possess great importance in their direct bearing upon mining prospects. The three chief formations represented in the field are the Keewatin series of igneous rocks (including greenstones and some granites and porphyries); the Lower Huronian series of conglomerates, breccias and slates; and sheets and masses of diabase, which have been intruded through both these older formations.

After the formation of the Keewatin there was a long period of subsidence and erosion, during which these fragmental Huronian beds accumulated. The subsequent intrusions of diabase and gabbro, to which the formation of the veins is generally accredited, spread over the Keewatin and Huronian, and formed sheets between them or pipes of indefinite downward persistence. The veins of the district, which occur abundantly in the Huronian conglomerates, frequently in the diabase, and rarely in the Keewatin, are narrow vertical fissures with contents of smaltite (diarsenide of cobalt), niccolite (arsenide of nickel), silver—native or as a sulphide—and other related minerals. The proportions of these minerals vary remarkably, silver being absent almost entirely in some deposits. The walls of the veins are typically well defined, though they are characteristically shot with metallic silver, or, in the rich mines, cut by sheets and films of native silver which fill the joint-cracks in the country formation at right angles to the vein. Ore-bodies also frequently split up into a number of stringers, branching and rejoining with marked irregularity. It is believed that the flows of igneous rocks, upon cooling and contracting, led to the formation of fissures in the older series over and between which the magma spread. The petrographical character of the Huronian was more favourable to the influence of this force than the more compact Keewatin, in which strong fissure veins are rarely found. At the close of the volcanic eruptions, or as immediate after-actions, there rose the mineral-bearing solutions responsible for the filling of the receptive fissures.

Professor Miller contends, however, that the genesis of the veins belongs to different periods of fracturing and mineral precipitation.*

Some of the strongest veins, available evidence demonstrates, may extend with their valuable contents through the Huronian—a flat or undulating series of small thicknesses—down into the Keewatin, but, broadly, it would appear that the mainstay of Cobalt will be in the abundance and richness of its small veins, workable to quite moderate depths of 100 to 300 feet.

The average width of the deposits found to date may be given reservedly at about 4 inches. At surface, where the veins have been affected by chemical agencies, the proportion of metallic silver is above the average.

It is not, however, in this form that all the silver is found. In some veins—notably one upon the *La Rose*—the most valuable metal is largely represented by argentite. Most commonly the silver occurs in association with smaltite or niccolite, which frequently proclaim their presence by the formation of decomposition products at surface—cobalt and nickel-bloom (erythrite and annabergite)—whose beautiful pink and green tints promptly arrest attention. The minerals found at Cobalt in greater or less abundance are :

Silver.—Native, argentite, dyscrasite, and pyrargyrite.
Cobalt.—Smaltite, erythrite, and cobaltite.
Nickel.—Niccolite, chloanthite, annabergite, millerite.
Bismuth.
Iron.—Pyrites, mispickel.
Copper.—Copper pyrites, tetrahedrite, and bornite.
Graphite, zinc blende, manganese, and other minerals.

7. Ore running below 100 ozs. to the ton is barely profitable to send to the smelters, and this is allowed to accumulate for future treatment, either when smelting costs are lower, or when it can be conveniently used for the enrichment of the ore fed into

* *Canadian Mining Journal*, March 15, 1907.

concentrating-mills. The yields declared by the Cobalt district have been as under :

Year.	*Tons.*	*Value.*
		£
1904	158	27,800
1905	2,144	277,000
1906	5,129	800,000
1907 (approximate)	14,000	—

These values represent almost entirely silver returns, for no allowance has been made for nickel, and only in some cases is cobalt, and never if under 6 per cent., paid for by the smelters. The most systematic testing of Cobalt ores for their principal contents was undertaken by Dr. Ledoux, of New York, who described his results before the Canadian Mining Institute. This trustworthy metallurgist sampled 394 lots of ore received from all parts of the camp. The highest values obtained were 7,402, 6,909, 6,413, 6,163, and 5,950 ozs. of silver per ton. Of his samples, 1 per cent. exceeded 6,000 ozs. per ton, 0·75 per cent. exceeded 5,000, and 3 per cent., 4,000 ozs.

Nearly 40 per cent. of the ore sampled exceeded 1,000 ozs. of silver in value. Dr. Ledoux also made analyses for cobalt, nickel, and arsenic, his results showing the average percentage of cobalt in the ore to be 5·99 per cent. (highest, 11·96 per cent.), and the average nickel 3·66 per cent. (highest, 12·49 per cent.). Arsenic averaged 27·12 per cent. In one lot the amount of this remarkably abundant element equalled 59·32 per cent.

8. With ore of such high silver contents, and with geological features, as already explained, of a character adding greatly to the precariousness of vein conditions, the recent clamour of shareholders for knowledge of ore values at depth can be readily understood and justified.

When the field was visited by the writer in July and August, 1907, the *Nipissing Company*, always regarded as the premier concern of the district, and the 'bell-wether' of the Cobalt market, had proved eighty-three veins over 120 acres, but had sunk no shaft deeper than 130 feet in any of its mines. The *Coniagas*, as another leading property, was ingeniously called after its four minerals (Co, Ni, Ag, As), with upwards of £1,000,000 worth of ore said to be in sight as the result of development responsible for an output of £200,000, had no working below 75 feet.

9. Up to the time of the miners' strike in July, 1907, the leading twenty-one companies of the Cobalt field were employing

1,900 to 2,000 men, and 132 machine-drills. Two had shafts over 300 feet, and fourteen others, over 100 feet. Their total underground development approximated 5 miles—little enough, considering the many points of attack—and an average shaft-depth of only 130 feet.

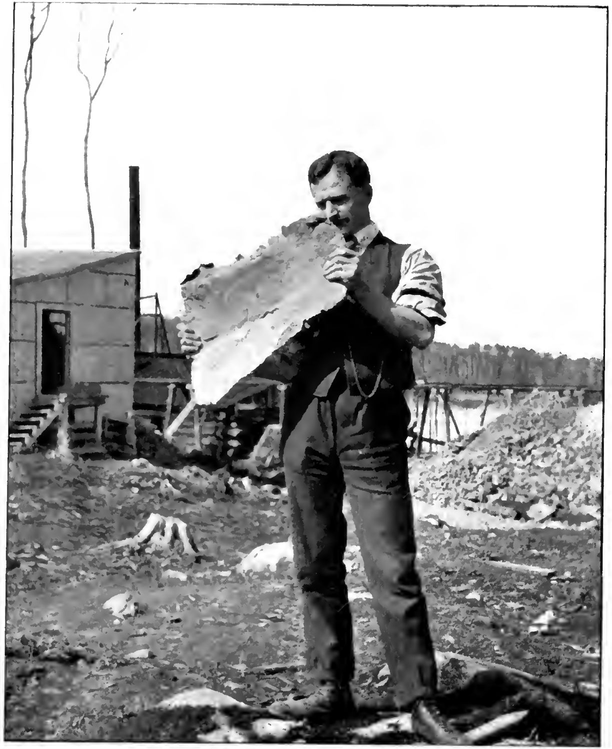
The two properties whose shafts exceed 300 feet—the *La Rose* and *O'Brien*—are both closely controlled without regard for Stock Exchange susceptibilities. Of conditions in the latter privately held property authentic data are unavailable. The *La Rose* reveals a change with depth of a striking nature. That this is characteristic of the field cannot be suggested; the facts are significant, however, in that they relate to the strongest, richest, and most continuous ore-body proved in Cobalt camp. Commencing in the conglomerates, the vein, which has been followed for 1,000 feet at the 100-feet level, passes into the slates of the same Huronian series. In the bottom level these slates are greatly disturbed.

The conspicuous alteration in the character of the veins is that, with increasing depth and change of country, they split and re-split until at 300 feet the ore-body—at 100 feet represented by three parallel veins—is made up of a number of stringers across a width of 2 to 25 feet. This subdivision of ore-bodies will materially affect the requirements of surface equipment, and increase the ratio of milling to crude shipment ore.

In regard to the lateral course of the veins, not only are faults prevalent, but a wavy and branching trend is typical. Frequently a **Y**-shaped divergence will be encountered in the face of the drive; the strong arm, perhaps, will be found to pinch out and the narrow stringer make into the main body. Another curious feature of irregularity is strikingly evinced in a journey along the level. Occasionally one will reach a drive at right angles, running on what would naturally be taken for a cross-vein. But in reality, as the plans at once indicate, this turn at right angles represents the mean strike of the vein, of which one is liable to lose bearing owing to the tortuous nature of the level.

So much remains in doubt as to the prospects of vein persistence in depth upon Cobalt properties that the lack of vigorous shaft-sinking elsewhere in the camp is particularly regrettable. The confidence of the outside world can only be won by such a policy of determination to learn and publish the truth.

10. Another circumstance adding to the speculativeness of Cobalt mines, which distant shareholders are most liable to



NATURAL SHEET OF SILVER, COBALT.

METALLIC OUTCROP OF SILVER ORE, COBALT.

recognize, is the extreme difficulty of making authoritative estimates of ore reserves. The erratic and deceptive nature of the veins, and, in some cases, the blind methods of working them, militate strongly against the formulation of trustworthy predictions. Veins pinch and make typically. In a few mines development has been sufficiently advanced to allow of a rough calculation of ore blocked out, on the hypothesis that irregularities of an unfavourable character may be balanced by others favourable. But in dealing with such narrow widths, normal errors of sampling and other small misjudgments in the basis of calculation will produce serious errors in final conclusions. The majority of companies, relying so largely upon open-cut veins and mere surface exposures, cannot apply any trustworthy method of computation.

The only reliable method of prospecting Cobalt properties is that of systematic trenching. The cloak of subsoil is thick in all parts of this hilly, wooded district. The *Nipissing Company*, whose properties total 846 acres, prospected a seventh part of its holdings by means of over 40,000 feet of trenching. Experimentally, this company put into practice, in 1905, the novel method of clearing the bed-rock of its soil by means of hydraulic jets, for which the water-pressure was provided by pumping-plant on the shore of Peterson Lake. By this means several outcrops were disclosed, but the area to which the system was economically applicable was limited, and the use of 'giants' for this purpose has been long discontinued. For testing the continuation of veins or general prospecting, the diamond-drill may occasionally be employed with significant results, but, as a rule, a small core is not to be trusted for the location or valuation of such narrow, erratic veins as are found in this field. Costeaning must always be the soundest method of exploring new territory, accompanied, where possible, by underground cross-cutting, as upon the *La Rose* and *Townsite* properties.

11. There are few mining-fields in the world which have been brought to a producing and dividend-paying stage for so small an outlay in capital expenditure as Cobalt. To commence production on a small scale, a 5 by 5 hoist, head-gear, one-drill steam-plant, accommodation for men, and other necessaries, can be installed for £500 to £600. For another £2,000 equipment could be completed on the basis of three or four machine-drills and requisite air-compressor. For a representative group of important mines, whose development footages run up to 2,000 feet, expenditures on equipment have ranged from £5,000 to £14,000.

The plants installed, however, only provide for the exploitation of the mine and the shipment of rich silver ore, which is usually classified into two or three grades.

In course of time Cobalt will become more largely dependent upon the treatment of low-grade ore (low in a comparative aspect) by milling and concentration. Very considerable quantities of ore and country rock shot with silver have been dumped for reduction. Only one mine regards its immediate country rock as absolute waste—*i.e.*, the *Drummond*—whose walls are so exceptionally clean that non-shipping ore is dumped into the lake as a matter of convenience.

12. The requirements of the Cobalt district for better smelting facilities than those hitherto obtaining comprise one of the dominant factors in the industrial position. Past shipments have almost entirely gone to the Orford Company's works at Copper Cliff, Ontario, and to New Jersey, to which places freight-charges were £1 2s. and £2 per ton respectively. German and Welsh smelters have endeavoured to obtain business in the field, but such distant companies are generally disfavoured for obvious reasons. The Orford Company paid for the cobalt as well as the silver contents, no allowance for nickel or arsenic being made. Cobalt-silver ores were received on these terms (short tons):

Payment	for	94	per cent.	of silver,	if over	4,000	ozs.	per ton.
,,	,,	92	,,	,,	,,	1,200	,,	,,
,,	,,	92	,,	,,	,,	800	,,	,,
,,	,,	90	,,	,,	,,	500	,,	,,
,,	,,	85	,,	,,	,,	300	,,	,,
,,	,,	80	,,	,,	,,	150	,,	,,

For cobalt in the ore £6 per ton was paid for 12 per cent. and over, £4 for 8 per cent., and £2 for 6 per cent. cobalt. At the close of 1907 serious smelting difficulties arose (owing to the industrial upheaval in the U.S.A.), whose outcome cannot be foreseen at the time of writing. Ontario will certainly be forced to rely more fully upon locally controlled plants for metal-production.

13. Hitherto cobalt has not assumed a position of any importance in the mechanical or metallurgical world. Gradually, however, the scope of its requirements is expanding. Problems of concentration cannot yet be discussed in the light of experience, though probable difficulties are not inconsiderable. The cobalt and nickel minerals, with which the silver is closely associated, are, fortunately, of high specific gravity, approximating that of galena—smaltite running from 6·5 to 7·2, and

niccolite 7·3 to 7·6. Most of the mills are being designed with the object of obtaining a good extraction by jigs before fine grinding. Plants constructed or under construction are those of the *Coniagas, Cobalt Central, Buffalo, McKinley-Darragh, Muggly Concentrators, Limited* (on the *Townsite* property).

14. The Cobalt mining district, covering twelve square miles of the townships of Coleman, Bucke, and Lorrain, may be conveniently divided into the Cobalt and Kerr Lake sections, outside which arbitrarily defined divisions there are few producing mines. The properties in the vicinity of the Cobalt Lake, comprising little more than a square mile in aggregate area, constitute the heart of the field, and have produced over three-fourths of the yield recorded to date. The largest company is the Nipissing, with a capital of $6,000,000 in $5 shares, and controlled from New York. This company's shares at one time reached £7 per share, making the market valuation of the property over £8,000,000.

The fluctuations of market quotation experienced by this company have marked the financial records of many lesser undertakings. From May 1, 1906, to August 1, 1907, the company produced 1,250 tons of first-class ore, 1,800 tons of second-class, and 100 tons of cobalt ore, valued at £300,000. At the end of the period £20,000 worth of ore was ready for shipment, and £230,000 worth of ore believed to be in sight in the several mines.

Other important properties in the Cobalt section are : *La Rose*, whose exceptionally rich main vein has been traced for one-third of a mile, and extends into the Right of Way property ; *O'Brien*, a privately held mine, of whose output the Provincial Government receives 25 per cent., and which yielded up to August, 1907, ore worth £125,000 from 1,500 feet of development and a little stoping ; *Coniagas*, *Buffalo*, and *Trethewey*, lying along the hill immediately to the west of Cobalt ' City,' and numerous veins running typically east and west ; *McKinley-Darragh*, *Townsite*, and *Silver Queen*, near the south of the lake. All these mines are situated upon the Huronian series, through which, however, the less kindly Keewatin has been reached in several places.

In the neighbourhood of Kerr Lake, 3 miles to the south-east of Cobalt, is another important group of mines, including the *Drummond* (of which the late Dr. W. H. Drummond, the Canadian poet, was the pioneer), the *Foster*, *Kerr Lake*, *Cobalt Central*, *Silver Leaf*, *Lawson*, and *University*. Two of these—the *Kerr*

Lake and *Cobalt Central*—work veins in the diabase, which are generally less persistent than those in the Huronian conglomerates. The *Kerr Lake* diabase vein (No. 3) is, however, one of the strongest in the field, with little cobalt and nickel. Upwards of 1,000,000 ozs. of silver had been derived therefrom up to the autumn of 1907.

Outside the two centres named the chief properties remaining for notice are the *Nova Scotia*, *Green Meehan*, *Temiskaming*, *Colonial*, and *Hudson Bay*. Sub-lake operations are a feature of cobalt-mining. The right to work under the Cobalt Lake, whose depth of water and mud is 76 feet, was sold by the Provincial Government for £220,000. The purchasers have been shaft-sinking on their shore allowance of 33 feet. Similarly, rights were sold in respect of a portion of Kerr Lake, where a campany, capitalized at the characteristically excessive figure of $2,000,000, is at work.

15. Cobalt is frequently mentioned as the infant prodigy of New Ontario. It is truly a precocious infant, speedily pushed into the turmoil of industrial hostilities. Four years after the discovery of the first vein the veterans of Western trade unionism waged war upon the camp, and endeavoured to gain a station of power, which would have enabled them to hold permanent control of the field's labour position and to govern the relations between companies and their employees. Cobalt managers were determined, however, that questions arising between themselves and the workers should be decided in Canada, and in the light of Canadian conditions, not settled by mandate from the Western Federation of Miners in Denver, Colorado.

Cobalt wages for ten-hour shifts were standardized at 13s. 6d. for machine-men, 11s. 6d. for helpers; engineers, 1s. 3d. per hour; firemen, 1s. per hour; and ordinary labour, 9s. per shift. The men, at a fixed charge of 2s. 6d. per day, are accommodated in 'bunk-houses,' and well fed at the mine boarding-house. Owing to the sudden demand for mine labourers and drill-men, and the prevailing shortage in many other mining camps, it was once necessary for Cobalt to employ many green-hands—farmers and 'lumber-jacks'—who have gradually become fairly efficient workers and thoroughly familiar with the simple duties of prospector and miner in the district.

16. Of the city of Cobalt little need be said. Aught in praise would be unfitting. Disparagement would savour of the hyper-

critical. This mushroom camp has all the defects common to its kind, untidy in detail, sprawling and unsightly in its corporate aspect, raised without thought of beauty, convenience, or sanitation. Its situation upon the shore of Cobalt Lake is not unfavourable, though some of its streets are almost too rough and steep for the wagons, loaded with machinery, stores, or building materials, comprising the bulk of the limited local traffic. In the centre of the camp are a few pretentious structures, by which the average habitation, in sorry contrast, is made to look the more miserable. The town is completely built of timber, and stands at the mercy of the first keen blaze to windward. A danger almost as serious lies in the all-pervading filth, which has been allowed to accumulate in masses of tins, bottles, old clothes, food-scraps, and decaying offal around the houses of people whose indifference to the claims of the public duty appears to be unshaken by the dread of pestilence. It must at least be recorded to the credit of the camp that, for public orderliness and safety of person and property, it stands below no centre of population in the Dominion. If we compare, in this respect, Cobalt with a Western mining-camp, such as Rossland, it must be admitted, however, that the British Columbian miner is subjected to greater temptations by the availability of drinking saloons, whose doors are open seven days in the week. This common incentive to rowdiness—the bar—is entirely absent from the Ontario camp, save for the dispensing of fruit-juices or of Laurentian water at 1s. per bottle. The refuge of those whose thirsty needs are beyond satisfaction by such mild forms of liquid, and whose standard of respectability or economy forbids them to patronize the many unlicensed victuallers in private business, is the senior town of Haileybury, 5 miles distant, on the Lake Temiskaming. Haileybury is the business and social centre of the Cobalt district, and has been made the home of many who desire to watch the progress of their mining interests without completely forfeiting the minor comforts of established civilization.

CHAPTER XXX

ONTARIO—*Continued*

Sudbury Nickel

1. Control of world's supply.—2. Lack of advertisement.—3. Accidental discovery.—4. Detection of nickel.—5. Crop of failures.—6. International Nickel Company.—7. Debated origin of deposits.—8. The mining belt.—9. Ore values.—10. Greatest nickel mine.—11. Heap-roasting of ore.—12. Production of matte.—13. Mond Nickel Company.—14. New Caledonia's competition.—15. An ancient metal.—16. Nickel steel.—17. Expanding market.—18. Foreign labour.

1. Canada is to nickel as Malaya is to tin. These divisions of the British Empire are the predominant producers of the two metals, which, though dissimilar in form of occurrence, properties, and uses, are curiously linked by several relationships. The superficial metallic resemblance, the frequently close equality of price, the erratic and rare distribution of their ores over the earth's surface, are considerations inspiring a kindred interest. But as an industrial factor in the colonial mining-world, tin—which gives employment to tens of thousands before it reaches the smelter—is of vastly greater significance.

The Sudbury district of Northern Ontario now yields over 60 per cent. of the world's nickel. This great proportion is drawn from four deposits, and closely controlled by an American company, which constitutes the most productive and most profitable metal-mining company operating in the British Empire.

2. Operations upon the field are undertaken without much regard for the tendencies of public opinion. General information regarding practice and results are provided as a matter of courtesy to *bona fide* inquirers, but no effort is made to proclaim achievements to the outside world. The impracticability of successful competition with those who already have the grip-hand of the nickel market is widely accepted as the necessary

deduction from past experiences. This, no doubt, accounts for the comparative lack of advertisement accorded to the industry by the propounders of the Dominion's national blessings. No mineral asset yet revealed between Vancouver and Quebec, however, can give the country greater distinction than these Sudbury deposits, or demonstrate more brilliantly the rewards to be reaped by foreign capital in Canada.

3. The discovery of the field dates back to 1883. A magistrate of Sudbury, the story runs, chanced to get lost in the woods. A party, including Dr. Howey, went out in search, and found the missing stipendiary about 4 miles to the west of the township, seated upon a rock. The ore-like appearance of the stone (afterwards proved to be the outcrop of the *Murray* mine) attracted the attention of the doctor, who took a sample home for investigation. Reports on the find proved condemnatory. In the following year the Canadian Pacific Railway, then forging the great steel link between the East Coast and the West, put a cutting through the ridge near the point of Dr. Howey's find, and revealed an unmistakable lode. A rush to the district followed, and prospectors discovered a number of copper-bearing deposits (nickel was unsuspected), all marked by good 'gossan' cappings or 'ironhats.' In 1886 some shrewd Americans came over from the States, realized (as the Canadians had unfortunately failed to do) the great possibilities of the field, and formed the Canadian Copper Company, with a capital of $2,000,000 to work three big deposits for copper.

4. The ore was shipped green to New Jersey, U.S.A., for treatment. Here, upon the investigation of the slag obtained from furnace treatment, the presence of nickel—and in excellent quantities—was almost accidentally discovered.

A long term of difficult experimenting followed, and a process for the economical separation of the nickel and copper was in time evolved. In 1888 smelting was commenced at Copper Cliff, the head-quarters of the Canadian Copper Company, 5 miles from Sudbury.

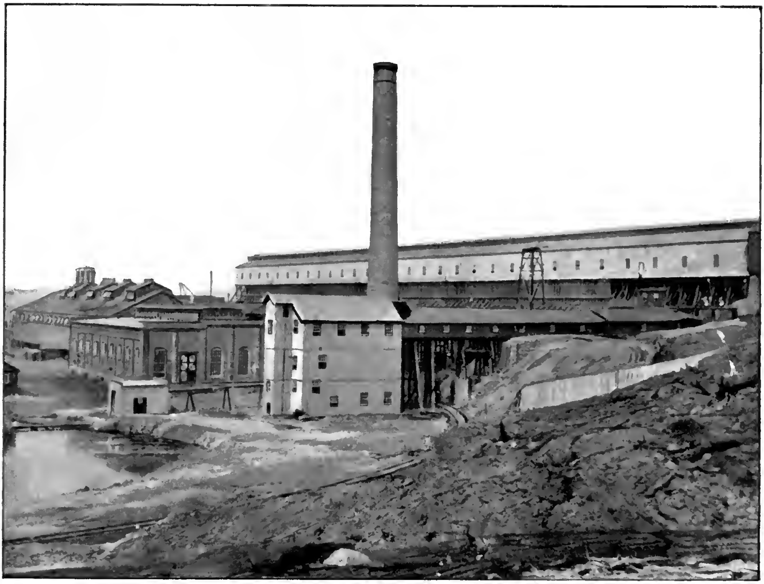
5. About this time several new companies sprang up in the district, including one formed under the control of the famous smelting firm of South Wales, H. Vivian and Co. Most of these enterprises were ill-administered, and came to grief. The few able to reach the stage of matte production were unable to give consumers the promise of the steady, substantial supply which is essential to the successful marketing of the metal.

Apart from the pioneering Canadian Copper Company, only one venture—the Mond Nickel Company—stands in the field to-day as a profitable producer. The history of this London company presents a striking contrast to that of the American concern, which first secured the mines, then found the nickel, and subsequently evolved the process to win it from the associated metals.

The Mond Company, on the other hand, found its origin in an English laboratory, where Dr. Ludwig Mond discovered the 'carbon monoxide process' for separating copper and nickel. On the strength of this patented process he acquired mines in the Sudbury region and floated them, in conjunction with his English rights, into the Mond Nickel Company, with a capital of £600,000. After frequent checks and difficulties, this concern was placed on a steady producing basis in 1904, and now treats 50,000 tons of ore per annum.

6. In 1902 the International Nickel Company was formed in New York, for the consolidation of the Canadian Copper Company, several works in the States, and extensive New Caledonian nickel interests. The greater object of this amalgamation was to control the nickel-supply of the world—a purpose it has achieved. With assets valued at £6,500,000 at the time of formation, its business has since been enormously extended. In 1906 alone the Canadian Copper Company—the most important constituent enterprise—dispatched to the New Jersey smelters nickel-copper matte containing metal worth one and three-quarter millions sterling. The International Nickel Company is backed by some of the strongest financiers of New York, and ambitious competitors must be prepared for serious difficulties, although there are large deposits of nickel ore still unexploited.

7. The Sudbury nickel-field has been a keen, and even wrathful, battling-ground for the opposing schools of American geology. Throughout the long discussion following Posepny's famous treatise on the 'Genesis of Ore Deposits,' scientific debate, in a specific relation, has never been more keenly evinced than over the mystifying sulphide accumulations of this rich Ontario region. The salient feature of its rock structure is a great synclinal basin, some 35 miles long (east and west) and 15 miles across, whose lip—especially the southern—is marked by the occurrence of ore-deposits, containing chalcopyrite, pyrrhotite (magnetic iron pyrites), with pentlandite—a nickel-iron sulphide—and pyrite. Cobalt, platinum, and palladium are rare but



NICKEL-COPPER SMELTERS, COPPER CLIFF.

POURING SLAG, COPPER CLIFF.

distinctive associated elements. The occurrences, which are commonly in the form of lenses or channels, are remarkably well distributed along the base of a synclinal sheet of quartz-norite, from which—according to one school of geologists—the heavy sulphides have separated out by process of magmatic differentiation, akin to settlement of matte from slag in smelting operations. Those in opposition to this theory refuse to recognize such genetic relationship, and consider the deposits to be of secondary and aqueous origin, occurring as replacements along crushed and faulted zones. The strongest advocate of magmatic origin is Dr. A. P. Coleman, the strongest opponent Dr. C. W. Dickson. Dr. A. E. Barlow, who supports the magmatic theory, deprecates the extremity of opposing views.*

8. Whatever the undetermined truth, the theory of segregation from the norite appears a good working hypothesis, for the mines and prospects nearly all occur along, or closely associated with, this traceable elliptical rim. Most of the deposits exploited lie along the southern contract, but the Northern belt would prove highly productive under favourable industrial conditions. The various mines, abandoned or under exploitation, occur along a 30-mile line of formation which is 3 miles from Sudbury — the railway and commercial centre — at its nearest point. The district, which lies immediately to the north of Lake Huron and to the east of Lake Superior, is broken by many ranges of low glaciated hills, bare and rocky, or covered with a close, though slender, growth of poplar and birch. At one time a heavier vegetation cloaked the district, but forest-fires have now destroyed the stoutest timber. The whole of this part of Ontario is marked by a complex system of lakes and water-courses.

9. The metal-production of the Sudbury field has increased steadily since 1896, with the exception of 1904—a year of misfortune. From 1886 to the middle of 1907 there has been an aggregate yield of 74,500 tons of nickel and 55,500 tons of copper, with a valuation of about £16,000,000, based on the price of metal recovered in the Welsh or American refineries. In 1906 340,060 tons of ore were smelted for the production of 20,364 tons of Bessemer matte, containing 10,776 tons of nickel (52·9 per cent.) and 5,260 tons of copper (25·8 per cent.).

The value and character of the ore in the several mines vary within limits that are very narrow considering the wide range of

* 'Geological Survey of Canada,' vol. xiv., Part H.

deposition. As a rule the nickel contents exceed those of copper. The extraction value of the roasted ore from the *Creighton* appears, from matte statistics, to be about 3½ per cent. nickel and 1½ per cent. copper, and losses in roasting and smelting are reported at 15 to 20 per cent. The *Creighton* may be roughly termed a 5 per cent. nickel and 2 per cent. copper proposition. Ore dealt with by the Mond Company from the *Victoria* mines contains equal quantities of the two metals (2·8 per cent. of each). In the early days copper was a more important constituent.

Mines of importance in the past were the *Frood*, *Copper Cliff*, *No. 2*, and *Stobie*; the *Blezard*, *Murray*, *Elsie* and *Gertrude* have also been extensively exploited. These have been closed down in favour of the cheaper open-pits, or have 'joined the majority' through the failure of controlling companies.

10. The chief producer of to-day—the world's greatest nickel-mine—is the *Creighton*, which is situated, at the lower edge of the norite sheet, 12 miles from Sudbury and 8 from the smelters at Copper Cliff. Work was commenced by the Canadian Copper Company in this deposit eight years ago. The open pit is now about 600 feet long by 300 feet across, and 140 feet deep. With a dip of 40 to 50 degrees to the north-west (below the norite), the mass has been proved by diamond-drilling to extend along the strike for a long distance beyond the wall of the open-cast working. The deposit is largely composed of pyrrhotite, sometimes with visible pentlandite—though this valuable nickel-iron sulphide is generally too finely disseminated to be perceptible by the naked eye. There is also a considerable proportion of chalcopyrite and iron pyrites.

11. The ore from the workings is crushed at shaft-head, classified by trommels and hand-picking into 'coarse,' 'medium,' and 'fines,' and then transported in flat trucks to the roast-yard near Copper Cliff. Here it is bedded into heaps of 1,500 to 3,000 tons, with the fines outside, and the process of 'heap-roasting' commenced by the kindling of wood laid below in suitable air channels. Once the oxidation of the sulphides is well started, the roast continues by reason of the heat evolved by the action, without the addition of further carbonaceous fuel. In three or four months the operation is completed, and the sulphur contents are reduced from 28 to 10 or 12 per cent. A steam-shovel fills dump-cars with this roasted product, which is ready for charging into the furnaces with the necessary additions of fuel, siliceous flux, and green ore.

12. At Copper Cliff three large blast-furnaces—50 by 204 inches at the tuyeres—are employed. The coke-charge varies from 7 to 14 per cent., and the cold air-blast from 30 up to 45 ozs. in pressure. The object is to obtain a matte of 40 per cent. metal, for subsequent enrichment in a Bessemer converter-plant to about 80 per cent. This final matte, ready for shipment, contains approximately 57 per cent. nickel and 22 per cent. copper. The converter slag is returned to the furnaces, and the matte poured into long flat moulds, broken up and dispatched to New Jersey, U.S.A.

The process of refining, which involves resmelting with sodium sulphate, is kept secret in its practical details, and represents in its present highly efficient state one of the company's most valuable assets.

13. The Mond Nickel Company operates the Victoria mines, which lie 23 miles to the west of Sudbury on the Sault branch of the Canadian Pacific Railway. The two main and closely associated ore-bodies are funnel-like in form, dipping at about 70 degrees. According to Dr. Coleman,* they belong to the class termed 'off-set' deposits, or dike-like projections from the basic edge of the norite, as opposed to the marginal deposits. The manager, Mr. Hiram W. Hixon, however, only recognizes the results of aqueous deposition along contracts, and the replacement of those rocks least able to resist the chemical action—viz., the 'greenstones.' The chutes are of large dimensions, yielding 200 to 250 tons of ore per foot a sinking. A vertical depth of 800 feet has been attained. Ore is transported from mine to roast-yard, and thence to smelters by aerial ropeway. Prior to recent extensions the company utilized one of two small furnaces, 44 by 120 inches at the tuyeres. Coke is added to the extent of 11 per cent., and the average blast-pressure is 24 ozs. Here, as at Copper Cliff, an 80 per cent. matte is produced, but the two metals occur in equal proportions. The final matte is shipped to South Wales for the separation of the metals.

14. Canada's only competitor in the production of nickel is New Caledonia. In 1889 this Pacific island yielded ore containing 1,330 tons of nickel; the output increased to 5,210 tons in 1901. In the following year Sudbury gained the lead over the French penal settlement, although the latter held the industrial advantage of cheap labour, of deposits near the coast, and of higher grade ore, in the form of silicate, simple to treat. To-day the Dominion turns out nearly twice as much nickel as

* Report of the Ontario Bureau of Mines, vol. xiv., Part III.

its rival, and the extension of plants being effected at Sudbury should still more firmly establish its predominant position.

15. Although figures of nickel consumption indicate that the metal is comparatively young in the industrial world, and that it is only to-day gaining a place in the group of 'necessary' metals, the element has been used to some extent from time immemorial. Dr. Austen, in his 'Historical Sketch of Nickel,' mentions the employment of a nickel alloy, similar in composition to the American five-cent piece, by a Bactrian King some 2,000 years ago; while the Chinese used a copper-zinc-nickel product called *pakfong* (the German silver of to-day) long centuries before Confucius. The early utilization of the metal in Europe was in the manufacture of 'German silver,' and of coins, by Switzerland, Hungary, France, Austria, and Italy. The high merits possessed by the pure metal for purposes of coinage, as compared with soft and evil-smelling copper, are so manifest as to suggest the desirability of far wider usage, even where silver coins are largely circulated. Nickel coins long maintain their brightness, and, being exceptionally hard, are difficult to counterfeit.

16. To the manifold applications of nickel-steel it is necessary to turn for knowledge of the main support of the industry and the opportunities of further expansion. The story of the early recognition of the peculiar properties manifested by this alloy, originally suggested by the composition and attributes of meteorites, is too complex to be briefly summarized. Suffice it to note that a paper read by Mr. James Riley in 1889 before the Iron and Steel Institute of Great Britain drew the world's attention to the wonderful qualities of nickel-steel, with the result that a great demand for the rarer element was rapidly established. The nickel yield of Sudbury in 1907 was ten or eleven times that of the whole world for the year preceding Mr. Riley's address.

17. How far the demand may be further augmented is a question governed by factors difficult to determine. Nickel-steel possesses, according to the ratio of combination, the several qualities of hardness, high tensile strength, and elastic limit, power of resistance to 'fatigue' and corrosion, good polishing capabilities, and peculiar homogeneousness. By virtue of these characteristics, it is advantageously utilized for armour-plates and heavy ordnance (in which application the merits of the alloy were first practically demonstrated and turned to account by

the United States Navy Department), rails, engine and propeller shafts, cables, piston-rods, axles, and many other machinery parts subjected to extreme severity of usage. To-day the outlook is favourable for the more extensive employment of nickel-steel rails, whose strength and durability are factors, in the opinion of high authorities, calculated under certain circumstances to more than balance the increase of prime cost. It must be understood, however, that the scope of trade expansion is strictly confined to narrow limits by the high price of 1s. 9d. to 2s. per lb. at which nickel has been maintained. In the field of commercial competition, manufacturers often find this cost prohibitive.

18. In Sudbury the visitor perceives a restful instance of a colonial mineral region undisturbed by labour difficulties, 'strikes,' or shortages, which are the element of danger most commonly weakening the industrial status of mining enterprises abroad. The quietude of the labour position seems imperturbable. Italians, Finns, Polanders, and Austrians form the bulk of the district's working force. Working in ten-hour shifts, the miners receive an average wage of 8s. per day. In the smelters Italians are largely employed. The Finns—keen, muscular, hard-working men—and the Polanders, with whom cleanliness is not a cardinal virtue, prefer work in the mines. Statistics in illustration of the magnitude of this alien invasion are desirable for a scientific investigation of the situation, but the writer is tempted to recall the verbal lesson of a single pay-sheet. On this the names appeared—'Yoasi Puskala, Nik Pera Korpi, Niko Kalmari, Kustaa Wutasaari, Petyn Juriczuk, Oska Lehikainen, Szimen Hung, Jou Chytrowski,' with one significant 'John Johnson' in the roll, looking serenely calm in the midst of this lawless mob of struggling syllables.

CHAPTER XXXI

QUEBEC

ASBESTOS FIELDS

1. Growth of industry.—2. Properties of asbestos.—3. Records of production.—4. Form of occurrence.—5. Percentage of recoverable fibre.—6. Leading producers.—7. Quarrying of Serpentine.—8. Fiberizing practice.—9. Cyclone pulverizer.—10. Limitations of supply.—11. Land of content.

1. Owing to its wonderful crystalline form and fire-resisting properties, the mineral asbestos or amianthus has been widely known for many centuries. The ancients wrapped dead bodies for the funeral pile in cloth woven of its fibres. Pliny the Elder referred to the mineral, expressively if erroneously, as 'incombustible flax,' just as the miners of to-day commonly speak of it as 'rock cotton.'

It has remained for the great industrial expansion of recent years, however, to raise the product from the level almost of a mineralogical freak to that of an extensively utilized article of commerce. Even to-day the asbestos industry, whose progress has been due to the unique and valuable attributes of the mineral rather than the influences of commercial advertisement, still appears to be merely in its infancy.

Applications of asbestos once deemed simply advisable are now regarded as essential, and new spheres of utility are being constantly revealed. The characteristics and uses of few economic minerals are more widely recognized; nevertheless, the form of occurrence, methods of winning, and the classification of product are strangely misconceived in the world of mining by those not particularly concerned in its primary exploitation.

Asbestos, either of the chrysotile or amphibole variety, occurs in noteworthy quantities in Canada, Italy, Russia, United States, Newfoundland, Australia, and South Africa. Its distribution is, however, irregular, and the productive areas of Eastern Canada to-day yield almost the entire supply. Asbestos will bear strangely close comparison with two other non-metallic minerals of economic importance—mica and graphite. In each case the production is virtually controlled by countries of the British Empire, the asbestos of Quebec, the mica of India and Canada, and the graphite of Ceylon supplying the bulk of the needs of their respective world-wide markets. In each case, an abnormal industrial expansion has been recorded during the last few years, aggregate yields and average valuations coincidently rising. Each mineral possesses unique features protecting it, in its main usages, against the serious competition of any known substitutes. Though characterized by exceptional power of heat resistance, their marked dissimilarity of form and composition prevents any extensive overlapping of commercial application.

2. Of the three minerals mentioned, asbestos is most essentially a British production, and has advanced the most rapidly in significance during recent years. The uses of the mineral have been so multiplied and widened that the output tonnage has been more than doubled in four years without satisfying the demands of manufacturers.

The manifold uses of asbestos now enable the mining companies to readily dispose of all classes of product, from the long silky crude down to the poorest floury fibre, or even 'asbetic,' a mill by-product of asbestos and pulverized serpentine. Well-known applications of the textiles made are for stage curtains, firemen's clothing and hose, and various fire-proof clothes. For spinning the best long fibres are naturally required, and even with these many difficulties of manipulation have always presented themselves. The insulating properties of asbestos have created a considerable market for medium grades, which are mixed with some binding material for steam-pipe and boiler coverings. Other manufactures of note are mill-board, packing and wall-papers, stove-lining, filter-paper (owing to the mineral's power of resisting acids), and building materials. The production of low-grade fibre by milling has been greatly stimulated by the comparatively new asbestos 'lumber' industry. Building sheets, plain or corrugated, are easily cut and handled, and with asbestos slates or shingles should eventually attain high favour with the constructors of smelting or mechanical works, where valuable plant has to be protected against fire. It is probable, however, that the electrical world offers the best openings to-day for the increase of trade. Employment has been found for several grades of mineral in connexion with the insulation of electric wires, and for switchboards, fuses, cut-outs, etc. Dr. Mattison, president of a leading company of American asbestos manufacturers which controls the *Bell* asbestos mines, Quebec, informed the writer that 'the electrical field offers the largest scope for the use of asbestos of from fair to most excellent qualities, and is the one that should be most cultivated by persons who are interested in extending the usefulness of asbestos in the arts and manufactures.'

3. The Canadian asbestos fields are situated in the province of Quebec, some 60 miles to the south of the old capital. In order of importance, the centres are those of Thetford, Blacklake, East Broughton, and Danville—all in the eastern townships. The two former areas are of the greatest significance, and have been worked steadily since 1878. Since the early days, a complete change of methods has overtaken the industry, which for many years was dependent solely upon the returns of the hand-cobbers. Gradually, since the year 1890, machinery has been more and more extensively introduced, until the crude hand-picked product represents only 25 per cent. of the yield by valuation, or 6 per cent. by weight. The rate of progress attained by the Quebec industry can be demonstrated by the following selection of official figures for annual tonnages of marketable asbestos (crude and fibre) and their valuation :

Year.	*Tons.*	*Value.*
		£
1880	380	5,100
1885	2,440	30,000
1899	17,790	97,000
1903	29,261	190,000
1905	48,960	310,000
1906	61,315	438,000

Up to the middle of 1907 the Quebec fields had accounted for a yield to the value of £3,500,000. The average value is seen to have remained at about £7 to £8 per ton for the last few years, but the true course of market quotations can only be observed by a classification of the different grades. Taking the returns for 1902 and 1906, when average prices were substantially below the 1907 valuations for Thetford and Blacklake, we note :

	1903.	1906.
(1) Crude (first class) ..	930 tons.	1,461 tons.
Value per ton.. ..	£26.	£45.
(2) Crude (second class) ..	2,354 tons.	2,456 tons.
Value per ton.. ..	£20.	£26.
(3) Fibre	950 tons.	18,068 tons.
Value per ton.. ..	£6 10s.	£9.
(4) Paper stock	16,327 tons.	39,330 tons.
Value per ton.. ..	£3 6s.	£3 10s.

BELL ASBESTOS PIT, QUEBEC.

In this period the output of good fibre and 'paper stock' (lowest grade of mill product) has thus increased from 26,000 tons to over 57,000 tons. The four classifications given do not indicate the divisions adopted by Quebec producers, which vary considerably upon each mine, and are here bulked for statistical purposes.

4. The asbestos veins of Quebec are found traversing, in all directions and without systematic disposition, certain masses of serpentine which occur in the eastern townships in association with surrounding schists and slates. Without going closely into the several problems of relationship between the serpentine (an alteration product) and the country rocks, or between the asbestos and the enclosing serpentine, which is of similar chemical composition, it may be noted that the origin of the valuable veins is a controversial matter of greater scientific than commercial interest. The type of serpentine promising to repay examination is readily determinable by the prospector of empirical knowledge, whose experience of the hard and 'dry' barren variety may be based on wide exposures of rock in the vicinity of the productive areas. The great bodies of serpentine so profitably exploited at Thetford and Blacklake have now been mined and quarried to an extent providing a wonderful exhibition of the forms in which the veins and stringers of asbestos occur *in situ.* At first the visitor is amazed by the great magnitude of the pits. The second feature to attract attention is the abundance and irregularity of the asbestos veins, which lie at all angles, are of widths ranging from mere threads up to 3 or 4 inches, are rarely of a length exceeding a few yards, and whose reticulated appearance is complicated by the results of severe crushing and faulting.

Unlike the Italian amphibole variety of asbestos, the Quebec mineral crystallizes at right angles to its walls, and rarely exceeds 5 inches in vein width. Shearing action is frequently marked, however, by the formation of brittle asbestos or picrolite, running longitudinally with the fault-plane, which contributes meagrely to the stock of fibre won in the mills, and mostly splinters up or passes off with the tailings and dust. Not infrequently faulting is seen to have occurred actually along a vein, spoiling the fibres or sometimes creating a polished slickenside surface apt to give a barren appearance to rock capable of yielding a good percentage in the mill.

The fissuring of the serpentine occasionally is exemplified by a regular series of minute veinlets. In one face in the underground workings of the *Bell* mine the writer counted seventy distinct parallel threads—perfect veins in miniature—across a width of 2 feet. The fibres of the wider veins are often flawed by particles of iron ore or a line of division without such inclusions. The most productive serpentine, of a fresh greyish-green appearance, weathering light brown, as opposed to the dense and darker type unfavourable to vein-formation, may be ranked as a soft mining rock, whose drilling and shooting qualities are increased by a tendency towards schistosity. The mines of East Broughton are specially favoured in this respect.

5. A close estimation of the recoverable asbestos in these great serpentine masses is difficult, owing to the irregularity of barren rock extraction and occasional laxity of records. Writing in 1890, Mr. Obalski, Quebec Government Mining Engineer, expressed the opinion that 1 per cent. of asbestos then represented an average of all rock extracted, and was the limit of profitable working, an extraction of 2 or 3 per cent. being very advantageous, and above 4 per cent. exceptional. This estimate, of course, only covered the asbestos won by the old methods of hand-cobbing, which was, however, carried to a further degree of thoroughness than is now necessary with supplementary milling. At the present time it is probable that crude and fibre represent an average of 8 to 10 per cent. of the rock milled, which constitutes about 50 per cent. of the rock actually mined. Mr. Fritz Cirkel, in his monograph for the Dominion Government, dated 1905, estimated the milling rock furnished by the mines at from 30 to 60 per cent. of all the rock mined, and the fibre extraction (excluding crude) 6 to 10 per cent. of the rock passed through the mills. Since that report was written the production of low-grade fibre has developed into a more important branch of operations.

6. The leading producers of asbestos in Quebec are the following :

King Brothers Company, Thetford.—This concern, controlled by Mr. H. M. Whitney, has for several years been the world's greatest producer of asbestos. The main deposit, worked by open cast, measures 1,100 feet by 600 feet, and the depth of the pit is 180 feet. Apart from the asbestos won by hand-picking, between 800 and 1,000 tons of serpentine are crushed in the mills per day for an average return of 8 per cent. in fibre. Each producer adopts his own system of fibre classification, the lack of uniformity in this respect being of small importance owing to the close relations between the mines and consumers, whose special requirements are satisfied. The grading employed by the *King*, together with the 1907 valuation, may be shown as follows:

	Per Ton.
	£
Crude (first class)	60
Crude (second class)	35
Fibre ('X')	12–14
Fibre ('XX')	7–8
Fibre ('C')	4–5

The two mills operated by the *King* are the most efficient upon the field.

Bell Asbestos Mines.—This famous property, formerly held by the Bell Asbestos Company of London, and now controlled by Messrs. Keasby, Mattison and Company, asbestos manufacturers of Ambler, Pennsylvania, U.S.A., has been worked for thirty years.

A new section of the mine is being opened up by means of incline tunnels and drifts, and will be mined on the pillar-and-stope system so long as the demands of safety will allow. The *Bell* constitutes the only underground asbestos mine of any consequence in the world, and presents an unexampled exhibit of asbestos *in situ*.

The capacity of the *Bell* mill—one of the first to do satisfactory work—is nominally 500 tons of rock per day. A new plant, with three or four times this duty, is to be constructed for use early in 1909. The products now turned out include No. 1 Crude, worth £60 to £70 per ton, and equivalent to 10 per cent. of total yield by value. Fibre is sold in four grades, running from £3 to £25 per ton.

Johnson Asbestos Company.—The property adjoining the *Bell* has long been held by the Johnson Brothers, and is the most profitable asbestos concern in operation in Quebec. At Thetford, this close corporation works two large quarries opening out from the *Bell* open-pit, and at Blacklake another valuable mine. It was the first producer, and appears to have been consistently conservative in its method and policy. The *Johnson* mine at Thetford is exceptionally rich in veins suitable for hand-cobbing.

The *Beaver Asbestos Company* is situated nearly half a mile from the Bell-Johnson deposit, and is essentially of a lower industrial status than that held by the three great central mines already mentioned, whose aggregate yield represents three-fourths of the world's supply of asbestos.

American Asbestos Company.—This new company, controlled by the owner of the *King* mine, is the leading Blacklake enterprise, and derives most of its output from two pits each about 300 feet in diameter. There is also a series of quarries situated along the hill of serpentine which forms the commanding feature of Blacklake scenery. The tonnage treated averages 75,000 to 100,000 per annum. During one typical month in 1907 5,800 tons were milled at a cost of 2s. 2d. per ton, out of 12,000 tons mined at 3s. 2d. per ton. During the period there were produced :

	Tons.	*Per Cent.*
Crude (firsts)	5	1·4
Crude (seconds)	55	14·6
Fibre (ordinary)	305	81·1
Fibre (poor)	11	2·9
	376	100·0

The American Company does not subdivide its fibre into many grades, but disposes of it nearly all in bulk as ‘run of mine,’ worth £11 per ton.

Other Blacklake propositions of some significance are the *Standard* and *Dominion Companies*. Also worthy of mention are the *Glasgow and Montreal*, and the *Manhattan* (now forming part of the American Company) at Blacklake; the *Broughton* and *Quebec Asbestos* Companies, working the easily mined bodies of serpentine at East Broughton, 22 miles north-east of Thetford; and the *Asbestos and Asbestic Company* at Danville, 38 miles to the south-west.

METHODS OF TREATMENT.

7. The uniformity of mining and milling practice at the chief properties enables this subject to be covered broadly. With the exception of the new *Bell* mine, the deposits are worked by open-cast methods. The mine labourers at the faces fill flat pit-boxes, carrying about 1 ton, which are hoisted by means of cable derricks, operated with an incline carrier-rope or on the horizontal tail-rope system. The lumps of serpentine containing the long-fibred asbestos (over ½ inch) are picked out in the mines and separately dispatched to the cobbing-sheds, where men, boys, and girls, commonly working on contract, liberate the mineral from its encasing rock. This simple operation was formerly responsible for the entire yield. It must be observed, however, that the crude represents to-day only 5 or 6 per cent. of the total yield by weight, but its very high value raises it to the equivalent of 25 to 30 per cent. of the revenue.

8. Quebec fiberizing mills have now been steadily increasing their volume for over twelve years. The proposition before the pioneers of this mechanical innovation was an original one, and a multitude of experiments have had to be undertaken in working practice.

The first need of the rock, which sometimes contains the asbestos in a form difficult to detect upon superficial examination, is preliminary reduction through jaw-breakers, preferably in two stages. Then follows an operation of drying, if sun and wind have not been able to perform this function. Wet rock, whose inclusion in the feed would greatly reduce the efficiency of the separating-machines and discolour the fibre, is usually passed through mechanical driers—either the simple rotary, with a 30 or 36-inch cylinder, or the Campbell tubular drier, with five 14 or 18 inch tubes. These machines are not entirely satisfactory, and involve a heavy consumption of fuel. To overcome these defects, the manager of the *Bell* (Mr. G. R. Smith, M.P.) uses a drying-floor of 2-inch piping, through which exhaust steam is circulated. This simple scheme is costly in labour.

9. After drying comes the section of treatment providing the greatest scope for further experiment and technical debate. The aim is to finely pulverize the rock, so as to enable the clean fibres to be easily removed by suction fans. The machine most widely considered to efficiently liberate the fibres, without unduly breaking them up and thus reducing their value, is the cyclone pulverizer. This mechanically faulty apparatus has for its most important parts two 'beaters' of chilled iron, weighing 160 lbs. each, which are driven at 1,800 to 2,200 revolutions per minute in opposite directions. These beaters stand vertically like three-bladed propellers, about 3 inches apart, breaking up the pieces of rock by their impact, and throwing the fragments against each other at terrific speed. As may be expected, the fibre suffers very considerably in the process. The beaters, costing 25s. each, need constant balancing, and only last from sixty to one hundred hours.

Ordinary crushing rolls have several strong supporters, including the management of the *Bell* mine, whose new plant is to be constructed without cyclones. Opponents of the principle contend that rolls tend to crush the rock particles into the fibre, thus reducing the efficiency of subsequent shaking screens and fans.

Below the cylcones or rolls, greater uniformity of method prevails. The dominant distinctions are principally indicative of varying marketing requirements. The sequence includes a series of shaking-screens, from which the fibre is drawn off by suction fans through a hood to settling-chambers, and further classified by means of screens, shaking or revolving, for different grades or lengths. The grit passes through the screening, and the fibre is delivered into collectors, whose whirling current of air allows only the heavy and valuable material to drop. The floury dust floats out at the top of the mill, and spreads as a white haze over the district.

Cheap electric power has lately been introduced upon the field, and has widely displaced its venerable competitors. Several properties have already undergone the final agonies of transition.

10. Several new mills are under construction in the Quebec asbestos fields, but there appear to be no preparations for increasing production beyond the rate of the market's expansion. New factories for the production of asbestos goods would not improbably be established in America and Europe if the sources of supply were not so limited and closely controlled. In all parts of the world, pioneers of industry should turn their attention to any promising occurrences of asbestos, in the ready disposal of which no market difficulties should present themselves.

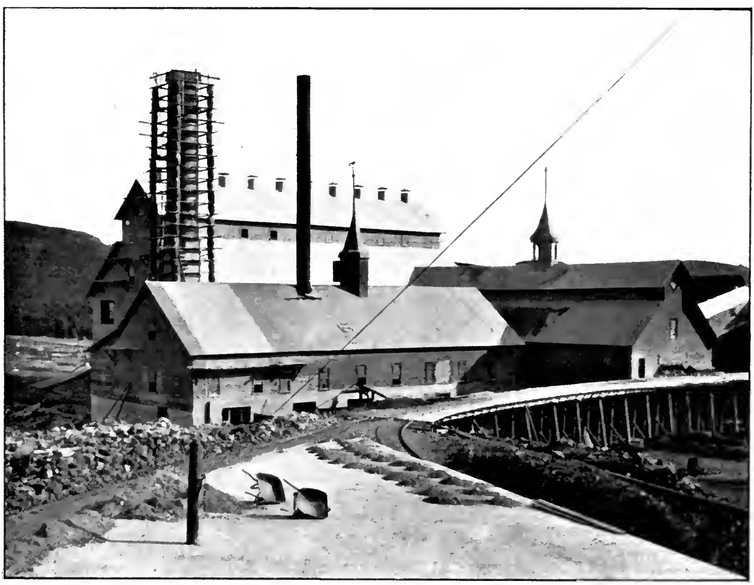
11. Like the majority of mining districts, the Quebec asbestos field has experienced its labour shortage. The majority of the 2,000 men employed are French-Canadians, whose settled homes are in the vicinity—men happy and contented by natural disposition, undisturbed and undisturbable by the influences of Socialistic agitators. Their interests are protected by the laws of supply and demand.

In 1907 the average wage stood at 7s. 6d. per shift of ten hours, drill-men making 8s. to 10s. per shift. During the cold winter months, when the bleak quarries present no alluring aspect, these French-Canadians betake themselves in large numbers to the woods, where they can make good money with the axe in sheltered regions. They are, indeed, more expert axemen than mine labourers, though their cheerful temperament and ready adaptability render them more valuable working units than many a Western miner, reared in an atmosphere of blasting fumes, and familiar with all the tricks and exigencies of his trade through the influence of long environment.

There are no trade unions. The men comprise the happiest and most contented body of mine-workers to be seen in any

By favour of G. SMITH, M.P.

ASBESTOS VEINS, BELL MINE, QUEBEC.



JOHNSON'S ASBESTOS MILL, QUEBEC.

mining camp. How far to associate the two circumstances is a question unprofitable to debate, for the personal element—the buoyant French disposition—is a strong and indefinable factor. Maybe, if the apostles of the Western Federation of Miners could obtain a hearing at Thetford mines, the 'poor misguided wage-slaves' might discover that they were really in the last stage of destitution and misery, that their plump bodies were proof positive of insufficient nourishment, and their high spirits a sign of mental and physical decay. Theirs may be a 'fool's paradise'; that is a question of terms. But the people are certainly blissful in their 'ignorance,' and there appear to be times when even a plethora of brains to the square inch (proverbial on the Rand) can provide a land with no solid comfort.

The eastern townships at the close of summer leave upon the visitor's mind a pleasing memory. The random reminiscence of an old mining field presents a picture of barren country with its ugliness accentuated by rude, untidy shanties, by rubbish and litter, by waste-rock piles and rusty scrap-heaps, by smoke and tailings' dust floating away from the active works, and by a scene of neglect and dilapidation on the abandoned claim, by flying grit and long-abiding grime. Mining is a despoiler of Nature, and the layman is loath to pardon its ravages.

Of Thetford one's memories are marred by no such harsh features. There is noise, one must admit—the racket of the dry-crushing mills; the whistles of many steam locomotives drawing their burdens between pits and crushers; the detonation of blasting at Thetford and on the Black Lake Hill, 3 miles distant, sounding like the challenge and response of opposing artillery—where even competition barely exists. But for the rest, all features spell tranquillity. The streets display no evidence of the mining camp. Even the men returning from the pits seem to carry with them no badge of occupation. The 'three-decker,' or dinner-tin, is not in evidence. The large-brimmed straw hats so commonly worn in summer would better befit the market-gardener in a subtropic land. Underground workers with the brand of candle-grease are few. The mill-hands, as white as millers from the fibrous flour of the screens and settlers, suggest no acquaintance with Blake crushers and cyclone rock pulverizers; while the girls from the cobbing-shed, smart in their large-peaked caps and coloured blouses, returning from their day's work with 3-lb. hammers at the cobbing-block, might be on their way to a choir practice or an evening class. And all around the little township there stretches a rolling expanse of pastoral and agricultural land spotted with 'Brittany' farm-houses, and of woodlands whose autumn carpet is a boundless spread of blueberries.

The cardinal habitude of this flourishing district is not that of the rough and strenuous mining camp—of the active centre of mineral production. To figure its true social complexion, we should borrow rather the picturesque, if unscientific, phrases of simple folk or of an earlier day, and think of it as a rural cultivating ground of ' rock cotton ' or incombustible ' flax.'

CHAPTER XXXII

BRITISH COLUMBIA

Rossland Gold and Copper

1. Establishment of 'Mineral Province.'—2. Rise of lode-mining.—3. Silver-lead production.—4. Discovery of Red Mountain.—5. Natural features of district.—6. Attractive mining camp.—7. Geological problems.—8. Origin and form of deposits.—9. Main lodes.—10. Decrease in grade and costs.—11. Tenor of ore.—12. Stoping and timbering.—13. Ore shipment.—14. Miners and Sunday labour.

1. The sequence of events marking the early chronicles of British Columbian mining will find many a parallel in the histories of individual fields. As frequently happens where the importance of a mineral find is not fully realized until a time when records are difficult to verify and correlate, the honour of the first discovery has been accredited to several claimants. It is at least beyond dispute that gold discoveries made upon the Thompson, Fraser, and Columbian rivers between 1855 and 1857 were the primary cause of establishing British Columbia in the eyes of the mining world as a promising new field for exploration.

In 1858 commenced a stampede of diggers and fortune-hunters from San Francisco. The influx of adventurers from all parts of the world was only surpassed in volume and excitement by the Californian gold-rush of a decade before. But the flood of immigration was premature, and many disappointed prospectors returned to California. Subsequent discoveries of greater value occurred, giving rise to further augmentation and redistribution of the country's floating population, and with the opening up of the Cariboo district, placer gold-mining speedily became an industry of firmly established importance. In ten years, from 1859, £6,000,000 in gold was won from the alluvial deposits. Between the discovery of the British Columbian placers (some of which were shown to be of enormous richness) and the commencement of lode-mining, a term of almost thirty years elapsed. Not till 1895, however, when the star of ill-fated Rossland was in the ascendant, can the yield of lode-mines be considered to have gained noteworthy proportions.

The output of alluvial fell off abruptly in 1869, and for thirteen years fluctuated around a value of £350,000.

During the past ten years the gold from this source, now won scientifically from low-grade ground, has averaged £200,000 per annum, and to-day constitutes only 5 per cent. of the province's metallic production.

2. Gold made British Columbia the 'Mineral Province,' but only through the rapid progress of its copper and silver-lead industries has this western division of the Dominion been able lately to hold its premier right to that title against the claims of Ontario. In surveying the records of production to-day, we find that the copper-gold mines of the Boundary, the gold-copper mines of Rossland, and the silver-lead mines of the Fort Steel division, all dependent upon lodes for their ore and smelters for its treatment, are responsible for 75 per cent. of the province's metallic output.

3. Silver-lead production is almost confined to the Fort Steele division, the ore of which is mostly drawn from two groups of mines—the *St. Eugene* at Moyie and the *Sullivan and North Star* at Kimberley. In 1903 the silver-lead yield in British Columbia fell to a vanishing-point on account of prevailing market difficulties. The subsequent revival of the metal industries of the world acted so beneficially upon the progress of mining that the *St. Eugene*, whose vertical fissure lodes cut a steep hill at Lake Moyie, on the Crow's Nest branch of the Canadian Pacific Railway, soon ranked as one of the most profitable mines in Western Canada. Its two veins, connected by a complex series of cross-lodes or 'avenues,' run about 200 feet apart in a country of dense, slaty quartzite. The ore, argentiferous galena with about 4 per cent. of zinc, occurs in chutes, zones, and bunches, sometimes attaining a width of 30 to 40 feet. One exceptionally rich stope averaged 12 feet in width, and extended for 800 feet, with a height of 50 to 150 feet. The mill treats 10,000 to 15,000 tons of ore per month for a yield of 2,000 to 2,500 tons of concentrates, containing 60 per cent. lead and 30 ozs. of silver. From the outcrop on the hill-top to the bottom level is 2,200 feet vertical. The *St. Eugene* was discovered in 1895.

The silver-lead concentrates are smelted at the Trail smelters, where the bullion is refined electrolytically. This British Columbian electrolytic lead refinery was the first in the world to be worked on a commercial scale. Practice resembles that followed in copper work, and the valuable secret of what is known as Betts's process lay in the discovery of a suitable electrolyte—viz., hydrofluosilicic acid, cheaply made from quartz, fluorspar, and sulphuric acid. The cathodes, which are melted and run into bars of 100 lbs. (or 200 lbs. for the Chinese market), possess a fineness of 99·995. From the anode slime, silver, gold, and antimony are recovered.

ROSSLAND GOLD-FIELD.

4. To the British and Canadian mining investor no district in the Western Province is more intimately known than the unfortunate Trail Creek division of West Kootenay. Rossland, its active centre, is situated upon the Gold Range of the Western Cordillera, and commands the beautiful valley of the Columbia River. It became famous in 1896, when railway and smelting facilities permitted the exploitation of the rich auriferous iron and copper sulphide deposits to be commenced on a fitting scale, and, three years later, it became correspondingly infamous upon the collapse of a share-market boom, which had marked an epidemic of financial delirium only surpassed in Canadian mining history by the speculative outbreak at Cobalt, Ontario, during recent years.

The Red Mountain, upon which the mines and town of Rossland now stand, had attracted attention of occasional travellers before any serious thought was given to the location of claims. In 1890, however, two prospectors, Bourjois and Morris, visited this gossany region, and pegged out in one day almost the entire rich section, covering the *Centre Star*, *War Eagle*, *Idaho*, *Virginia*, and *Le Roi*.

Colonel E. S. Topping was given the *Le Roi* claim, which has yielded about five millions sterling in gold, copper, and silver for paying the registration fees of £2 12s. The function of pegging, however, was not the sole task of these early workers, who were obliged to labour under many difficulties, physical and financial. According to Geological Survey records, the first shipment of ore was made in 1893. With the erection of a smelter at Trail, on the Columbia River, 5 miles from the camp, by the copper magnate of Butte, F. A. Heinze, the production of metal began, in 1895, to reach substantial proportions. The field reached the height of its productiveness in 1902, when £1,000,000 was recorded. From its inception up to the end of

1907 the industry has turned out 2,800,000 tons of ore for a smelter return of £8,000,000, or £2 17s. per ton.

5. The Rossland district possesses topographical features of great beauty, its pine-clad ranges, attaining maximum heights of 6,000 to 7,000 feet, being divided by abundant mountain creeks, contributing their measure to the great Columbia River, which finds the sea 500 miles below at Portland, Oregon. To the north and north-east are the long and narrow mountain lakes of Kootenay, Arrow, and Slocan, whose steam-boat traffic fortunately lightens the difficulties of travel and transport in this division of the province. The Gold Range lacks the wild magnificence of the more elevated Selkirks and Rockies to the east, and in its comparative tameness reveals the influence of an important epoch in its recent geological history, when the Cordilleran glaciers filled its valleys and imparted a tedious rotundity to all prominent features of the land.

For a Canadian climate, that of Rossland and the neighbouring copper-field of the Boundary must be regarded with exceptional favour. The seasons are somewhat abruptly divided into winter and summer—the latter being a period of unquestionable charm in its frequently long spell of warm, sunny days. Fair proof of its physical reality can be observed in the gardens and orchards, wherein all the fruits of the temperate zone—apples, pears, plums, cherries, peaches, and grapes—are successfully cultivated. Of the winters too much should not be said. Though delightful in their moderation to the resident of the prairie or of Eastern Canada, they still must appear essentially unpleasant in severity and duration to the native of other lands. As an industrial factor, however, the keenest winter rarely exercises any adverse influence.

6. The city of Rossland, served by branch-lines of the Canadian Pacific and Great Northern Railways, is, for its population, one of the best-favoured mining camps in the world. To some extent it owes its municipal merits to the abortive boom of 1896, when the population of the city rose to 6,000, and its industrial aspirations were South African in their range and loftiness. To-day the inhabitants barely number 4,000. The place is overbuilt, and ‘suburban’ rents are nominal. Columbia Avenue, with its substantial post-office, Government buildings, well-appointed club-house, and long rows of shop-buildings, is apt, indeed, to give the visitor, unacquainted with Rossland's chequered career, a false impression of the camp's importance and prosperity.

The little town of Trail, on the other hand, which is supported by the smelting-works on the Columbia River, where the greater part of the Rossland ore is treated, presents an appearance of the utmost dilapidation and instability. Ramshackly even amongst smelter towns, Trail has one incongruous boast in its possession of an opera-house with a seating capacity equivalent to its entire population.

7. The geology of Rossland is complex and problematical, not only in regard to the origin of its sulphides—always a fruitful basis for scientific controversy—but also as to the relation of its rock masses. The field has been admirably covered by members of the Geological Survey—Messrs. R. G. McConnell and R. W. Brock, who worked independently in different years—and has also been geologically discussed before the Canadian Mining Institute by several authorities. The abundant occurrence of pyrrhotite (magnetic pyrites) and chalcopyrite, which comprise the most distinctive ore constituents both at Rossland and Sudbury, Ontario, has frequently prompted geologists to draw analogies between the nature and origin of these distant deposits. Both nickel and cobalt, forming important associates of the Sudbury copper ores, have been detected in the Rossland pyrrhotite. Both groups of ore deposits have been attributed to igneous and aqueous agencies by the opposing schools of modern geology, but whereas the consensus of opinion places the Sudbury sulphides in the magmatic segregation class, the genesis of Rossland ore-bodies is more generally considered to have been in the replacement of fissure or channel walls by ore, through the agency of mineral-bearing waters.

8. The Rossland district is volcanic. In the vicinity of the camp there appears an oval mass of monzonite (orthoclase, felspar and augite) about 5 miles long by 2 miles across, near whose western edge the township is situated. This volcanic plug is bordered to the north-west by a porphyritic rock composed mainly of augite and plagioclase felspar, in which the irregular, faulted, though closely grouped system of ore—bodies of the Red Mountain occurs.

The formation of the sulphide deposits is generally considered to have been due to several distinct, long-continued operations. It is contended that the fissures in the monzonite, made by volcanic disturbances, were first partly filled by the pyrrhotite, which was followed at a later period by the chalcopyrite and pyrite with gold. It is certain that faulting occurred during, and after, the period of mineralization. Not only are the ore-bodies frequently displaced by dykes of simple thrusts—occasionally to the despair of the bewildered miner—but instrusive sheets, cutting through the lodes, are also seen to have acted as barriers to the hydrothermal solutions, and resulted in causing a special enrichment about the plane of intersection. So complex and erratic are the dykes and faults breaking and confusing the normal trend and disposition of Rossland ore-bodies, that only miners of considerable local experience can hope to successfully solve the multitudinous problems presented in the course of development and exploration.

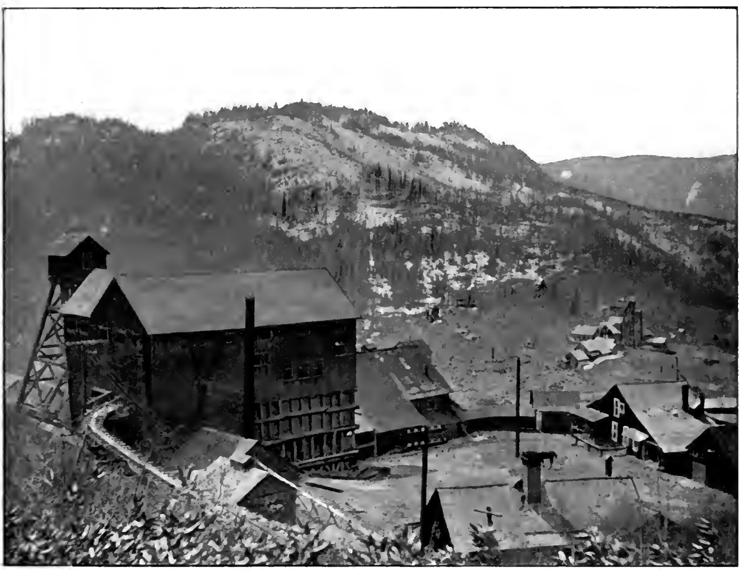
An additional factor of irregularity is provided by the indefinite character of the lode-walls. The process of metasomatic replacement has in many places extended far from the probable main channel of ascending waters, and is indicated by large masses of ore, whose limitations, in foot and hanging, can only be determined by commercial considerations as to the line between the payable and unpayable. True country rock may apparently be reached and regarded as the barren wall of the stope, only for the discovery to be made later of valuable ore beyond.

9. The main lodes of the Red Mountain area are four in number. Of primary importance is the Le Roi-Centre Star, consisting of two parallel members (main and south), which has been developed for upwards of a mile, and proved to a depth of about 2,000 feet. This series strikes approximately east and west, with a dip to the north of 60 to 70 degrees. The ore occurs in chutes—commonly lenticular—and as an illustration of their dimensions, it may be mentioned that on the 1,500 feet level of the *Centre Star* four stopes were commenced in 1907, with lower measurements of 15 by 125 feet, 40 by 90 feet, 20 by 60 feet, and 10 by 90 feet. One exceptional chute in *Le Roi* is recorded, with an average size of 150 feet long by 60 feet wide, and extending downwards for several levels.

Other important lodes are the War Eagle (to the north of the Le Roi-Centre Star), the Iron Mask, and the Josie, 800 feet to the north of the Le Roi. The great dyke system is characterized by a number of parallel intrusions running north and south, directly across the lodes, and dipping at various angles. The most prominent dyke is the Josie, whose average width exceeds 50 feet, and whose course is signally persistent.

The conspicuous eccentricity of Rossland ore-deposition is not only reflected in mining systems, but also in administrative policies. The estimation of ore reserves or the prediction of future accomplishments is a risky undertaking, which few

LE ROI MINE, RED MOUNTAIN.



SHAFT HEAD, LE ROI NO. 2, ROSSLAND.

engineers to-day, mindful of past blunders and false prophecies, dare to attempt. The mines can never be submitted to valuation formulæ based on actual profits in sight, for the elements of speculation and the opportunities for miscalculation in the establishment of first premises are too manifold. The prevailing cautiousness, reflecting the precariousness of mineral conditions and the creditable desire of those in control to avoid misrepresentations to any degree, is unquestionably discreet. But it is not calculated to satisfy that embodiment of troublesome curiosity—the shareholder—who may hope, especially in regard to a fully-fledged gold-field like Rossland, to gain some definite knowledge of the prospective value of his holdings, and of the extent to which his risks are reduced by proven resources.

10. The question of decreasing trade, as in the majority of metalliferous mining camps, is one of special moment. In a report of the *Centre Star Company*, the general manager declared that the mine had experienced the same general change in the character of its ore deposits as had occurred in all other productive mines of Rossland, and which is the general rule throughout the mining districts of the world. 'This is the transition,' he remarked, 'from the occurrence of high-grade bonanza ore-bodies, capable of profit under the expensive process of smelting, to masses of lower grade, requiring a cheaper treatment of milling.'

In regard to this statement, it may be added that mechanical concentration did not prove as successful as anticipated, but the lower-grade ore has nevertheless been profitably exploited owing to the great reduction of smelting costs.

If guidance be sought in the records of production as to the tendencies of falling grade, allowance must be made for the changing policy of recent years, when it has been possible, owing to the lower smelting changes and more economical working in general, to handle ore of poor value at a profit which would otherwise have been left alone. There has, however, apart from these influences, been a pronounced falling-off in average value. In 1895 smelter returns showed a yield of £7 per ton, in 1901 approximately 67s., and to-day the average recovery is 45s. to 50s. per long ton.

11. The values to-day being principally in gold, Rossland is not so much at the mercy of fluctuating metal markets as the neighbouring Boundary district, where conditions are reversed and copper forms the staple product. The average copper value is below 1 per cent., and gold accounts for approximately £2 per ton in Rossland smelter returns. The ore, which, again, may

be contrasted with the Boundary sulphides, is not of a self-fluxing character.

The gangue associated with the sulphide minerals—pyrrhotite, chalcopyrite, and pyrite—is essentially country rock with occasional occurrences of quartz and calcite. Masses of clean sulphide are frequently found. The ore value in the early days, revealed by surface and shallow workings, was comparatively high, as shown by the above output record. For the first three years shipment averaged approximately 1·5 ozs. of gold, 2 ozs. of silver, and 1·75 per cent. copper. During 1906 recoveries averaged :

Gold	0·38 oz.
Silver	0·45 oz.
Copper	0·75 per cent.

Even the most experienced of Rossland miners have the greatest difficulty in judging from the appearance of a well-mineralized face its gold value, and are obliged to rely upon the results of sampling and assay. Generally, however, the presence of chalcopyrite is a favourable indication of gold, whilst pyrrhotite is as commonly unaccompanied by the precious metals.

MINING AND ORE TREATMENT.

12. In the mining of these large ore bodies, Rossland managers have adopted the Nevada, or square set, and the 'shrinkage' systems, which are understood to be more economical than any practice involving the utilization of waste-filling introduced from surface. The irregularity of stopes between level and level greatly increases the difficulties of operation, and prevents the adoption of a uniform system of exploitation. A stope may be commenced on single stulls hitched across the drive, and then open out to an extent necessitating the introduction of square sets. In narrow stopes the broken ore is allowed to accumulate on the stulls, and only the excess is drawn off till the stope is depleted, unless an additional row of stulls is added at an intermediate level. Stulls up to 16 inches in diameter and 15 feet long are utilized.

The square set system has been favoured in view of the strength of the 'commercial' walls, the moderate cost of timber, and the frequent need of returning to old workings to follow up newly discovered extensions. Round pieces of local red fir—of good quality, though less efficient than the world-famed Douglas fir or Oregon pine — are generally employed, and are set at

5 feet or 5 feet 4 inches centres, with 9-feet posts. As a support against great side pressures the system is of small service. The timber is cut with long tenons, to relieve the caps and struts of downward stress against the grain. Lagging poles for rock support are also of fir, though spruce and cedar are sometimes used. Drilling faces often being extremely hard (indeed, it would truly seem that some of the world's mines demand the institution of a new scale of hardness, running up to 15, with the diamond still at 10 !), it is necessary to use heavy machine-drills. Very little work is performed on contract. The *Le Roi* operates its drives on this system, whereas the *Centre Star* favours the bonus, and grants machine-men 4s. 2d. per foot driven beyond 120 feet per month. The rate of 140 feet is considered a good, though not remarkable, standard of progress.

13. Rossland ores are shipped for treatment to smelters at Trail, on the Columbia River, or Northport, a few miles to the south, in the United States. The average ore of Rossland shows, upon analysis :

	Per Cent.
Silica	48·5
Iron	12·0
Sulphur	8·0
Alumina	16·0
Calcite	8·0

It is found necessary to effect a double concentration, producing a first matte of 7 to 12 per cent. copper and 4 ozs. gold, which, resmelted with additional ore, fuel, and fluxes, for a matte containing 40 to 50 per cent. copper. This product is shipped for conversion and refining to Tacoma, U.S.A.

14. Rossland miners include representatives of many European races in their ranks. Wages and living conditions place the field at a high level. The miner earns, in good times, 14s. or 15s. per shift, the labourer 12s. 6d., and the skilled mechanic 16s. 6d. It is a strange feature of working conditions at Rossland, particularly astonishing to the visitor acquainted with South African and Australasian mining, that, despite the strength of Unionism and the suggested interference of the Dominion Government, ordinary underground operations are undertaken every other Sunday. The men could easily revolt against the system if inclined to do so, but they prefer to pass the Sabbath in honest toil. To openly advocate Sunday work on surface in Australia—below ground it is not for a moment contemplated, save for the customary 'emergencies and repairs'—would almost qualify the miner for degradation to the ranks of the 'scab' or 'blackleg.'

CHAPTER XXXIII

BRITISH COLUMBIA—*Continued*

BOUNDARY COPPER DISTRICT

1. Steady expansion.—2. Genesis of deposits.—3. Composition of ore.—4. Principal mines.—5. Granby's enormous mass.—6. Mining difficulties.—7. Big tonnages.—8. From mine to smelters.—9. Yields and costs.—10. Cheap power.—11. Labour conditions.—12. Smelting capacities.—13. Large blast-furnaces.—14. Problematical future.

1. THE substantial progress of the Boundary copper district, by which name that rich portion of the Yale or Kettle River mining division lying a few miles to the north of the international boundary is generally known, has constituted, with the exception of the more meteoric rise of Cobalt, the most significant feature of recent mineral development in Canada. That the progress of industrial expansion has been marked by few sensational events and meagre public appreciation places the field in a light of creditable distinction when compared with the senior mining camp of Rossland, 50 or 60 miles to the east. These two districts, both producing copper, gold, and silver, both dependent solely upon smelting for metal recovery, situated in similar topographical surroundings, served by electric power from the same source, closely comparable in regard to railway facilities, labour conditions, and fuel requirements, have, despite their proximity, grown up under eminently dissimilar influences. While the early history of Rossland is notoriously one of financial aberration, speculative mania, and managerial extravagance under English and Canadian control, the Boundary copper-field has steadily progressed, under the unemotional direction of capitalists in the United States and Eastern Canada, slowly and surely to a position of sound industrial prosperity, only menaced by metal market conditions beyond its control, and to a standard of productiveness till recently unsurpassed by any other metal field in the Dominion. To draw a fair deduction from this comparison, it

must be remembered, however, that the Rossland debacle so disgusted European investors with British Columbian mineral enterprises that the reports of the neighbouring low-grade copper deposits were either ignored or discredited. At that time London would have turned its back upon a Mount Morgan or a Broken Hill in this part of the world.

Several mineral deposits had been known in the Boundary district prior to the discovery of the mines for which it is now famous. The first of the distinctive ore-bodies to be located was the *Mother Lode* at Deadwood, pegged in May, 1891; two months later Henry White and Mathew Hotter found the more important Old Ironsides and Knob Hill deposit, which ranks amongst the greatest low-grade copper ore bodies in the world.

Mr. G. W. Rumberger, one of the pioneers of the field, has favoured the writer with the following references to his experiences in the days of discovery: 'The distance from our base at Marcus, U.S.A., was about 75 miles, which we made with pack-horses going up Kettle River, only used by the Indians travelling to Grand Prairie, now Grand Forks. From there we crossed Boundary Mountain by Dewdney trail to Boundary Creek, where we met the discoverer of the Knob Hill. We immediately proceeded thither, and located the *Brooklyn* and the *Monarch-Rawhide* section of the field. Results were disappointing, and we dropped all our prospects except the *Brooklyn*. In those days we found many difficulties in our way. . . . We had to make our own trails through a very heavy growth of timber under brush and fallen trees. For the first few years it required about one-third of our time in keeping the trails open. . . . Prosperity came to this field when Mr. Jay P. Graves started development in 1896, and when Mr. Keffer prospected the *Mother Lode*.'

2. The geology of the Boundary copper-field, signally complex in its range of volcanic and plutonic rocks and associated occurrences of displaced sedimentary beds, has been thoroughly investigated by Professor R. W. Brock, who also examined the Rossland field for the Dominion Geological Survey. The principal copper deposits of commercial value in the district—masses running up to 300 feet in width—are very similar in character and mineralogical composition.

In 1906 Mr. W. L. Austin, metallurgist and geologist of New York, reported on the field for private interests, covering the *Granby*, *Mother Lode*, and other mines.

His views are not available in such form as to allow of close comparison with those of Professor Brock. One general conclusion formed was that: 'The ores are impregnations by vapours and mineral solutions of lava flows, tuffs and ash-beds, formed by previous volcanic activity. . . . Pockets of limestone are scattered through the *Granby* deposit, but these are of a wholly secondary importance. The lava flows and ash-beds at Phœnix were (after eruption) impregnated with mineral, forced into them by intense pressure, and probably under great heat. . . . It is probable the ash-beds would be more easily permeable than the lavas.'

Professor Brock, in his report dated 1903, after classifying the ore-bodies of the district into three groups, declares that the most important, which are characterized by much magnetite and chalcopyrite, with pyrite and specular iron, are replacements of country rock. 'On the outskirts of an ore-body this substitution can often be seen in all stages of development, the individual constituents of the rock being one by one replaced. There very often appears nothing resembling walls, the ore being irregular in form and shading off into country rock. Sometimes a fracture plane, sometimes an impervious rock such as a dyke of diorite, porphyrite, or contact of compact crystalline limestone will form a containing wall to the deposit. . . . All the minerals in the deposit appear to have been formed almost contemporaneously. They are often banded. The minerals are not evenly distributed, but while sometimes mixed are often bunchy. . . . The deposits are most numerous, are largest and most valuable in those parts of the districts most disturbed by Tertiary volcanism. Limestone in such cases seems favourable to the deposition of ores. In a few instances the ore occurs in the limestone itself, but more frequently it is found in rock along its contact with limestone. . . . That the contacts between limestone and other rocks should be favourable may have been due in part to the chemical influence of the lime in precipitating the mineral contents of the solutions, but it was also due to the lack of firm cementing between the limestone and the contact rock, which left free channels for the solutions. . . .'*

3. The similarity of ores obtained from the major deposits is demonstrated by the uniformity of practice at the smelting-works, each dependent upon its own sources of supply, operated by the three companies in control of the field. An average

* Geological Survey of Canada, Report for 1902.

analysis of these self-fluxing ores, based on figures elicited by the writer from the working companies, shows :

Silica	38–40 per cent.
Sulphur	3–4·5 „ „
Iron	15–17 „ „
Lime	18–22 „ „
Alumina	6–7 „ „
Magnesia	6–7 „ „
Copper	22–28 lbs.
Gold	0·06 ozs.
Silver	0·40 „

A tendency to turn somewhat more siliceous in depth has been noted in some mines, though not to a degree to prevent the ready adaptability of ores to smelting without foreign fluxes.

The ore masses are typically irregular in width, dip, and form, though occasionally they assume—as in the *Brooklyn* mine—normal lode-like features. At the *Knobhill-Ironsides* or *Granby* mine it was long before the true nature and trend of the deposit could be determined. The *Rawhide* is another mass whose relation to the country rocks is yet ill-defined, and the *Mother Lode* is continually surprising its exploiters by unexpected and erratic lateral developments.

In all the mines one will see abundant evidences of slides, which in the smaller deposits bear detrimentally upon mining economy, but in the large bodies these slips, marked by movement planes with or without secondary filling, are of small commercial importance. These fracturings are often helpful in rock-breaking.

4. The mines upon which the three mining and smelting companies depend for their principal supplies of ore may be grouped as follows :

Granby Consolidated :
    **Granby Group*, Phœnix.
    Gold Drop Group, Phœnix.

British Columbia Copper :
    **Mother Lode*, Deadwood.
    Emma, Summit.
    B. C. Mine, Summit.
    Oro Denoro, Summit.

Dominion Copper :
    **Brooklyn Stemwinder*, Phœnix.
    **Rawhide*, Phœnix.
    Sunset, Deadwood.

The four mines marked with an asterisk have accounted for 75 or 85 per cent. of the district's yield.

Another property of note is the *Snowshoe*, leased by the Consolidated Mining and Smelting Company of Canada from its English owners, and made to contribute 600 tons of ore per day, containing 1·4 per cent. of copper and 7s. per ton in gold and silver, to the company's smelting works near Rossland.

The Boundary district, possessing such huge low-grade deposits, which must be worked on a large scale to enable costs to be brought to the phenomenally low level in spite of costly labour, has evolved a system of ore-extraction that is in many respects *sui generis.*

5. For illustrative purposes, reference may be made to the *Granby* mines, which, in point of tonnage, has ranked among the foremost copper-producers of the world, although holding a subordinate place upon the list in metal yields. All descriptive matter in this chapter refers to conditions in July, 1907, before the temporary cessation of work necessitated by the high wages and the low price of copper obtaining towards the close of the year.

The *Granby* ore-body is situated immediately to the south of Phœnix township, at an elevation of 5,000 feet, outcropping on the *Knobhill* and *Old Ironsides* claims, and dipping into the *Ætna* and *Victoria* claims to the east at a variable angle of from 60 to 25 degrees. The strike is almost due north and south, cutting into a hill rising steeply to the south. In the lower levels the average dip is of 35 to 40 degrees. Combining this circumstance with an enormous width, measuring horizontally from 200 to 400 feet, it will be understood that the safe and economical extraction of ore is a problem presenting peculiar difficulties. The methods adopted involve the employment of no rock-filling, and only timbering in the levels and ore-shoots. By a peculiar application of the pillar and stope system, the mine superintendent at Phœnix anticipates an eventual recovery of 90 to 95 per cent. of the ore.

In the surface workings enormous quantities of ore have been won by 'glory-holes,' or quarrying. Steam-shovelling is no longer practised in these workings, all the rock therefrom gravitating to a tunnel, of which four are run from the hill-side into the ore-body, in length 1,500, 2,600, 2,400, and 2,500 feet. These tunnels almost represent the length of the deposit on these four levels. Not only does the deposit dip to the east, but the chutes comprising the payable section also pitch to the north, giving them a north-easterly trend in plan. The deposit has been opened up to a depth of 900 feet from the *Knobhill* outcrop.

6. On each level drives are carried along the deposit at varying distances apart (on the same horizontal plane), according

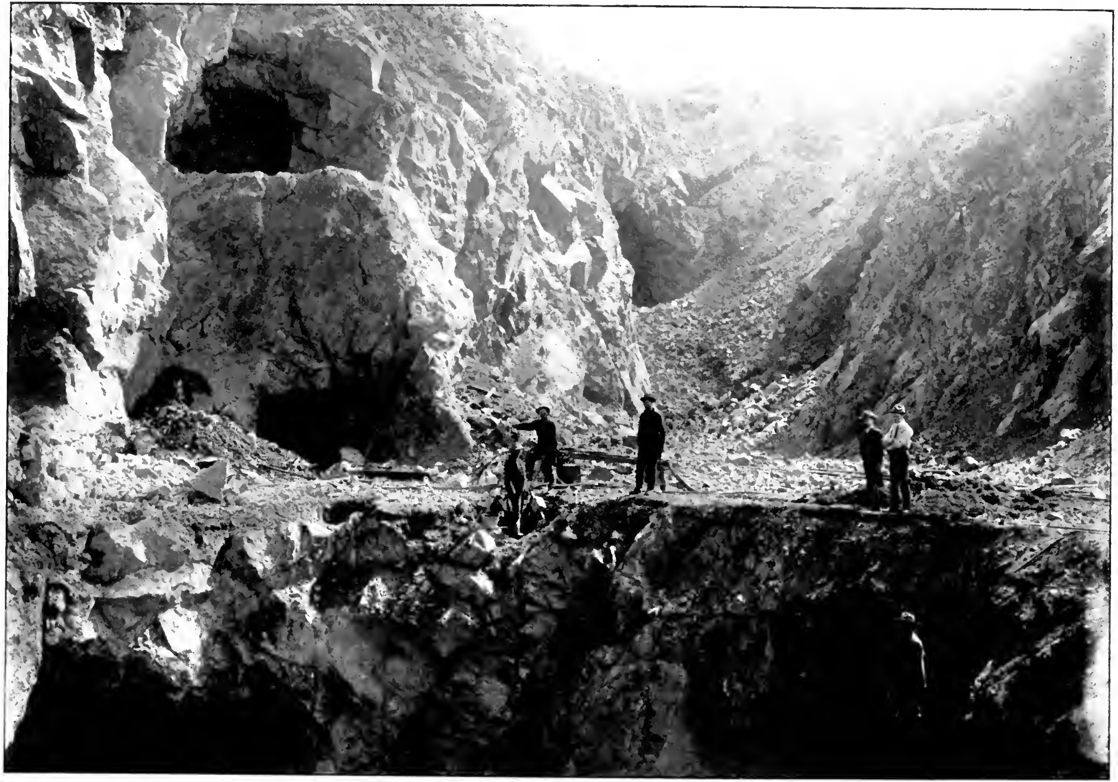


Photo by McRae Bros.

OPEN WORKINGS, GRANBY MINES.

to the width and requirements of the body. Typically they are placed at 65 to 75 feet apart, so that, on a horizontal width of about 200 feet, there would be one at the foot, one at the hanging wall side, and two centrally located. Main tramming levels are 12 by 9 feet, and ordinary working drives and cross-cuts 7 by 9 feet.

Where the dip is comparatively flat—less than permits of the ore gravitating to the passes on the foot-wall level—a drive or drives will be carried below in the country rock to serve the stopes above. A commencement is made by putting up raises every 30 to 35 feet along the level; from these are formed the pillars over and protecting the level, between which heavily timbered ore-shoots are then built. When a distance of about 15 feet has been risen, the working is opened out into a stope (the pillars being naturally formed in the operation), which is carried up and widened out to extensive limits. Central stope pillars are left according to the demands of the formation. Upon nearing the level above, a rise is put through and the machines turned, working back, so that, rigged up on the solid, it is possible, upon opening out, to put in highly effective down holes, and shoot down big burdens into the stope below. The mine eventually becomes a network of pillars and arches. Some of the pillars left are enormous, being up to 50 or 60 feet high and 40 feet long.

7. Comparatively little use is now made of the broken ore as a support for the miners. Although the rock stands well, workers must exercise more than usual caution to guard against accidents. When the time comes for drawing pillars, subsidences will inevitably occur. These will be incidental; accidental collapses can only be guarded against by the maintenance of a liberal factor of safety in mine support and by eternal vigilance, which is the price of safety, indeed, in many of the world's great mines.

Barring down or scaling is an important operation at all times and in all sections of the mine; but it is particularly urgent in the upper levels at early spring, when the ice in cracks and crannies is melting away and leaving great slabs in a perilous state of 'animated suspension.'

As will be readily believed, in workings of this magnitude, and with ore traversed by many joints and slide-planes, high tonnages can be credited to drills employed. In driving on a 9 by 7 feet face, about 120 to 140 feet a month will be made. To ore-extraction figures one must turn for the coefficients indicating—apart from cost-sheets—the economy of prevailing systems. The salient consideration is that for the production of 3,000 tons a day, and the accomplishment of current development, only forty machine-drills were used. In underground workings it is common to use drills of 12 to 14 feet long.

The *Granby* sometimes employs steel of nearly 25 feet in length. These long holes are started with a 3-inch star bit, and are customarily 'sprung' or chambered at the end, so that, for the final blast (for the throwing of perhaps several hundred tons), a space may perhaps be formed capable of holding a case of high explosive.

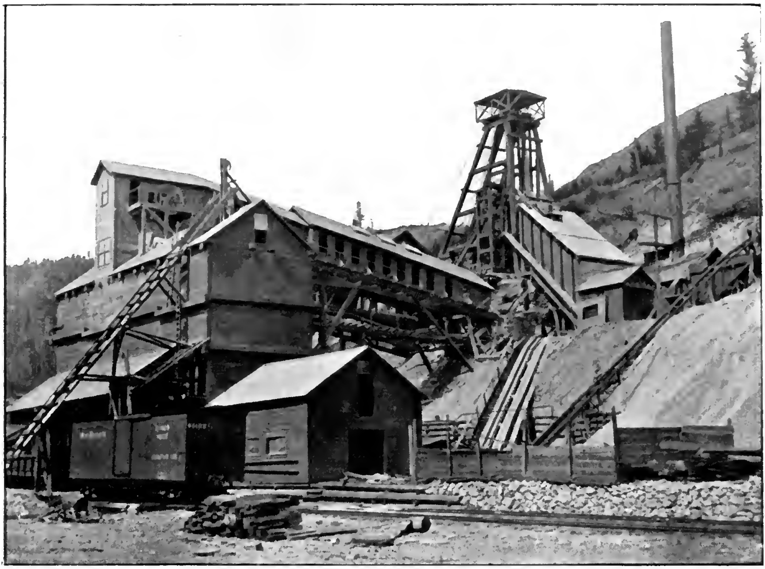
The average consumption of dynamite is slightly over $\frac{2}{3}$ lb. per ton extracted, equivalent to a cost of approximately sixpence. It must be noted, however, that most of this cost does not go in charging drill-holes, but in 'bull-dozing' or breaking up, without further drilling if possible, the great blocks of ore cast down by these fertile shots.

8. The *Mother Lode* mine at Deadwood, 3 miles to the north-west of Greenwood—the head-quarters of mining men, trade, and officialdom in the Boundary, and of the British Columbia Copper Company's smelter which it feeds—is the second largest deposit in the district. With the bottom stoping level at 400 feet, 900,000 tons of ore had been extracted up to the middle of 1907, with 2,000,000 tons reported to be in sight.

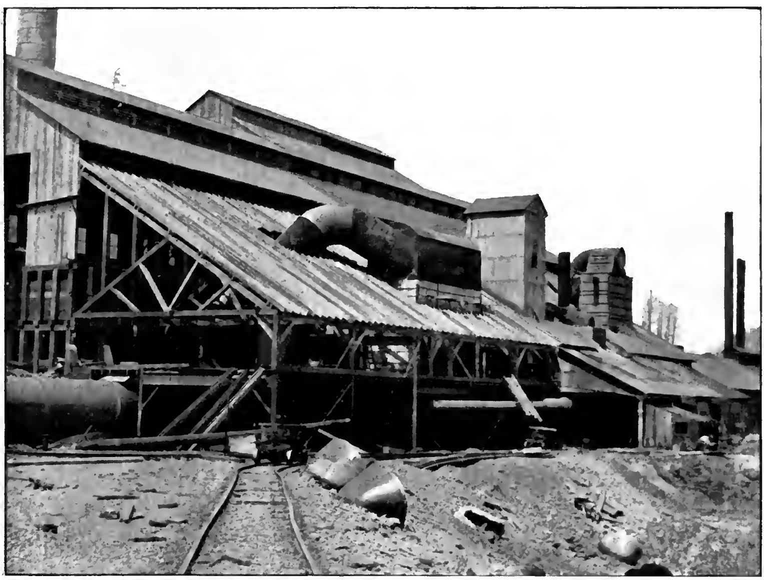
The foot-wall country of the *Mother Lode* is a pure crystalline limestone, as in the *Brooklyn* at Phœnix. Average values are estimated at 1·25 to 1·50 per cent. copper, 4s. in gold, and 1s. in silver.

The two mines from which the Dominion Copper Company has drawn the bulk of the ore for its smelter at Boundary Falls are the *Rawhide* and *Brooklyn.*

From the shaft or tunnel bins, the ore from the Phœnix, Deadwood, or Summit mines is carried in 30 or 40 ton cars to the smelters, the various points of ore supply and ore-treatment being served by an excellent railway system, controlled by the competing Canadian Pacific and Great Northern railway companies. Coal and car shortages have frequently prevented a fitting utilization of these well-constructed lines. The two companies wisely do not enter into any freight-war for the acquisition of Boundary traffic, of which in normal times there is abundant to engage the attention of both corporations, but a fortunate rivalry of service prevails. Few mining companies in the world dependent upon ore shipment for their returns find themselves in the happily independent position of the *Granby*, at whose shaft-head is a double set of bins, delivering on one



MOTHER LODE HEAD-GEAR, BOUNDARY.



LARGE SMELTING FURNACE, DOMINION COMPANY.

side into cars of the Canadian Pacific Railway and on the other, of the Great Northern.

9. The last few years have been a period of smelter enlargement. The miner has been continually treading upon the heels of the metallurgist; the position of the metal market and the concentrating capacity of the furnaces, not the outputting capacity of the mines, have been the limiting factor. To perceive the extent to which yields are capable of speedy augmentation, reference must be made to the work and projects of the three corporations exploiting the chief deposits. Before entering into these individual records the achievements of the district may be summarized (so far as available figures allow) as under :

Year.	*Tons smelted.*	*Copper.* lbs.
1900 (six months)	96,600	275,000
1901	390,800	11,170,000
1902	508,876	15,000,000
1903	690,419	20,700,000
1904	829,808	24,900,000
1905	933,548	28,500,000
1906	1,158,991	35,000,000
1907	—	—
Totals	4,609,042	135,545,000

The aggregate value of this yield, with its gold and silver, may be roundly placed at £6,000,000. The average recovery of copper is seen to have been 29·4 pounds per ton.

Of the tonnage shown above, over 3,000,000 tons have been treated by the *Granby Consolidated*, the leading company of the district, and, indeed, the greatest copper-smelting enterprise in the British Empire.

When wages, which were substantially increased in 1907, owing to the then abnormally high value of copper, ranged from 12s. 6d. to 14s. 6d. per shift, and coke stood at 27s. per ton, mining costs in the Boundary averaged about 6s. 6d. per ton, and smelting costs very little more. The *Granby Consolidated*, during a recent fiscal year, operated at a total cost of 13s. 9d. per ton of ore smelted. This excellent record was achieved upon a basis of upwards of 3,000 tons per day.

Having regard to the enormous variations in the price of copper from one period to another, it is significant to note that the Boundary can produce the metal at, roughly, £35 per ton. Like the *Mount Lyell*, these mines possess a valuable factor of support in the occurrence of some gold and silver, which, as a small though constant source of revenue, establish the producers in greater security against the changes of the commercial situation.

10. The creditable reduction of expenditure has been possible by the introduction of cheap electric power, more efficient systems of mine exploration, improved transportation facilities, and by the augmentation of the scale of operations. Since the general adoption of electric power, generated at the Bonnington Falls on the Kootenay River, 70 to 80 miles distant, and at the Cascade on the Kettle River, the cost per horse-power per annum has fallen approximately to £6 from wellnigh three times that amount. The increased tonnages, demonstrated by preceding tables, have naturally tended to reduce the cost per ton for all standing charges, and also for many of the more variable expenditures. But in average furnace work coke represents 12 per cent. of the charge by weight, and unless this can be reduced by enlargement of furnace dimensions or by the advantageous use of the hot blast, tried by the Dominion Copper Company, in fuel alone there is a virtually fixed charge of 3s. 4d. per ton smelted, or over 50 per cent. of the smelting expenses. Enlargement of capacity should beneficially influence the trend of mining costs, though the increase of working depths must prove an adverse factor of growing importance.

11. In 1906 and 1907, during the transient spell of great industrial activity, the labour question assumed a position of unusual importance. Not only had the Boundary and Rossland districts to consider the soundest means of preserving industrial peace within their own limits without entering into suicidal competition, but they were also dependent, for the very means of maintaining operations at the smelters, upon the miners of the Crow's Nest coal-field, at one time in a chronic state of subdued or active agitation. Labour on the Boundary is notably migratory, and speedily departs to other fields in the province, or over the Washington border, upon any cessation of work or cause of dissatisfaction, returning tardily upon the settlement of difficulties. The 'family life,' so valuable a bond between man and district, is poorly developed. The majority of labourers live a somewhat comfortless life in single rooms or boarding-houses at a cost of one dollar (4s. 2d.) per day for board and £1 13s. per month for lodging. At Phœnix the *Granby Company* built a commodious hotel for its employees at a cost of £6,000. Accommodation is provided for over 200 men, who pay £1 10s. a week. Generally, on British Columbian mines, there is a central boarding-house under official control, and 'bunk-houses' or scattered quarters for living accommodation. Neither in Canada

nor Australia does one find the mine employees provided for with the practical consideration evinced by Rand mining companies.

Boundary wages, on which an all-round advance was made by employers in May, 1907, ranged from 13s. 9d. for surface hands up to 16s. 6d. for skilled miners. A remarkable variety of nationalities is represented—Canadians, Englishmen, Americans (generally constituting the most turbulent element in local Unionism), Poles, Scandinavians, Austrians, and a motley crowd of Southern Europeans. The Italians most frequently hold employment at the smelters. Although this polyglot gathering is welcomed into the fold of local Unionism, the mining camp of Phœnix—as orderly a centre as one could wish to find—is held in mortal dread by the Asiatic labourer. He harbours the strong conviction that if ever rashly impelled to visit that forbidden land, common duty to his next-of-kin should deter him from taking any luggage or purchasing a return ticket.

12. So enormous are the low-grade copper deposits of the district that the mines may be said to be dependent on the market and smelters, just as, at Rossland, the smelters are dependent on the mines.

The achievements of the smelting plants hitherto in operation may be demonstrated by the tonnage for three years.

Plant.	1904.	1905.	1906.
	tons.	tons.	tons.
Granby	596,252	665,097	830,000
British Columbia Copper	210,484	194,056	130,000
Dominion	30,930	82,664	220,000
Totals	837,666	941,817	1,180,000

It will be seen, however, that present capacities—always rendered liable to reduction by the inability of the *Crow's Nest Collieries* to supply fuel—are considerably in excess of these recorded tonnages, the individual furnace capacities being :

Plant.	*Furnaces.*	*Size at Tuyeres.*	*Daily Capacity.*
		inches.	tons.
Granby	8	44 × 218	3,000
British Columbia Copper	3	48 × 240	1,800
Dominion	1	46 × 255	800
Dominion	2	40 × 170	650
Totals	14		6,250

The composition of the Boundary ores is generally uniform, and contains the needful percentages of silica, iron, sulphur, and lime to obviate the necessity of seeking foreign admixtures for fluxing, and to place the chief producers in a position of independence as regards all the factors for the economical production of a 40 to 50 per cent. matte for the converters in a single operation. The same problems have had to be faced by each smelter, and, with minor exceptions, the divergences of practice seen to exist only reflect the ever variant personal element.

Tht *Granby* smelter, treating 62,387 tons in 1900, was the first put in commission. Eight furnaces have recently been employed. The ore, drawn by electric motors from bins to furnaces, is, in normal practice, introduced in large lumps. Coke is added to the extent of 10 to 12 per cent. Blast pressure is supplied at 16 to 18 ozs. through twenty-four tuyeres of 4 inches, provided by a large blower-plant of three units with a capacity of 30,000 cubic feet per minute each, and seven of 13,000 cubic feet per minute. Each furnace requires 20,000 cubic feet. A matte is formed with a value of 40 to 45 per cent. for the plant of three stands with hydraulically tilted horizontal converters, turning out blister copper approximately 99 per cent. fine. The slag, which cannot be granulated owing to defects of elevation, shows an average analysis of : Silica, 45 per cent. ; lime 23 per cent. ; iron, 15 per cent. ; alumina, 7·5 per cent. ; magnesia, 1·5 per cent.

13. The three 600-ton furnaces of the B.C. Copper Company's smelter at Greenwood were the largest in Canada when erected, but are now surpassed by the Dominion Company's new plant. The furnaces are supplied with a 22 to 24 oz. blast by Root's blowers with a capacity of 25,500 cubic feet per minute. Large single forehearths are used, 10 feet by 16 feet by 4 feet deep, and lined with 12 inches of chrome brick. Slag disposal is most efficiently performed by 25-ton slag cars, electrically hauled and tilted. These cars are of standard gauge, and were transported from the Pennsylvania factory, some 3,000 miles distant, on their own wheels.

The most noteworthy feature marking the newly organized plant of the Dominion Company is the application of the Giroux hot-blast top to their 800-ton furnace. This constitutes the first attempt made in British Columbia to effect economies by the heating of the blast by any means.

14. The question of future production is dependent upon a variety of circumstances, apart from furnace capacities, which

render predictions essentially dangerous. Tonnages and profits are at the mercy of a fluctuating copper market. Viewed apart from this extraneous though dominant influence, the Boundary copper-field assumes the appearance of a most unsensational industry, comprising three copper factories secure in the possession of immense stores of rough material.

The profitable exploitation of copper deposits worth under 1·5 per cent. places the Boundary in a unique position. The enormous bulk of its deposits, the self-fluxing character of the ore, and the existence of neighbouring water-power for the generation of cheap electricity, are the favourable conditions, of which the utmost advantage has been taken by the skilful administrators of this progressive industry.

CHAPTER XXXIV

YUKON TERRITORY

KLONDIKE ALLUVIAL GOLD

1. A renowned field.—2. Climate.—3. Conformation of district.—4. History of diggings.—5. Classes of deposit.—6. Value of drift.—7. White Channel gravels.—8. Aggregate wealth of field.—9. Systems of exploitation.—10. Lode-mining.

1. THE Klondike is one of the few mining-fields, sharing universal renown with the Rand, Kalgoorlie, Kimberley, Mount Morgan, and Rio Tinto, of which every newspaper reader in the world can claim some general knowledge. Possessed of striking geographical features, climatic conditions of manifest intensity, auriferous deposits whose character and richness can be readily described, and a history from which no elements of interest and romance are lacking, the field can also claim the more exceptional distinction of being commonly pictured with some measure of accuracy.

The early tales of hardship endured by the great band of immigrants in 1896 and 1897—some, experienced old Northerners, others manifestly unsuited to undertake the arduous task of pioneering on the outskirts of the Arctic region, all alike smitten with insatiable *auri sacra fames*—have been narrated so frequently in mining literature of the romantic kind that there can be no call for reiteration. Events move with kaleidoscopic rapidity in the world of mining, and records of ten years ago form part of ancient history; but so unexampled were the incidents of the Klondike's discovery, so vivid were the pictures presented by reports sent down by participators in the rush, that the good fortune of the few and the afflictions of the many are still fresh in the public memory. Though it would be hard to exaggerate the difficulties faced by the eager thousands who struggled to the Northern Land of Promise in 1897-1898, or the bitter hardship of the winter trails, their recollection may give an imperfect impression of the fields to-day, over which the forces of industry have effected a remarkable transformation.

2. Save in the winter season, the journey from Vancouver to Dawson City can now be made in less than a week, the most difficult section across the White Pass (of sorrowful memory to the pioneer) being comfortably traversed by railroad to the foot of the White Horse Rapids, whence river-steamboat traffic is established with the camp. Of the Yukon's summer climate misconceptions are more prevalent than of any other of its natural features. The winter is fully as severe as it is commonly reported ; commencing in October, frost closes the Yukon River from early in the following month to the middle of May.

During this season the thermometer will range from zero to 70 degrees below. The country is covered with two or three feet of snow on the plains, with deep drifts in the mountain regions. In the month of May the climatic pendulum gives a startling swing. The extremes of temperature in winter and earlysummer represent a difference of 150 degrees, with a variation of about 80 degrees between the means. In June there comes a period of heavy rains. The district supports a vegetation of surprising abundance considering the altitude, principally of spruce, birch, and poplar. Possibilities of garden cultivation are also considerable, and it is recorded that even up at Fort Yukon, on the Arctic Circle, many miles to the north of Dawson City, potatoes and other vegetables have been successfully raised, and barley ripened. The visitor to the Klondike will often be astonished to experience the summer pest of innumerable mosquitoes, said to be smaller than their partners in wickedness infesting tropical climes, but no less provokingly voracious.

3. The Klondike district, or that section of an extensive plateau which is bounded on three sides by the Yukon River and its parallel tributaries, the Klondike and Indian Rivers, is topographically dominated by an elevation of 4,250 feet, standing with no particular prominence above the surrounding country, called the Dome. From this mount, situated between the Indian and Klondike Rivers, about 10 miles from each and 25 miles to the east of the Yukon, spring the *Hunker*, *Gold-Bottom*, *Boundary*, *Sulphur*, and *Quartz Creeks*, all famous as the most productive channels of auriferous gravel. The landscape features are essentially tame and monotonous, bearing the aspect of a region whose irregularities have been worn away —as in Southern British Columbia—by glacial action ; the region has, however, been submitted to no such levelling in-

fluence. The hill-slopes are gradual, and the valleys correspondingly flat and wide, except in their upper sections. The yellow metal being almost exclusively recovered from the alluvial deposits, and rarely found *in situ* in amounts adequate to repay exploitation, the geology of the field is of less interest and importance than that of the average lode-mining district. The group of rocks from which the bulk of the alluvial has been formed by processes of disintegration and concentration in the creeks and valleys is the Klondike series of light-coloured sericite schists and greenish chloritic schists. In this formation, quartz veins are abundant, but are generally small and not persistent. A parallel to Klondike vein conditions may be found in the world of tin-mining. In Malaya occur vast stretches of rich alluvial, formed by the disintegration of narrow veins, whose ore contents have only been made of commercial value by their natural concentration in valley drifts.

4. Although the Yukon only gained a position of industrial importance in 1896, gold had been known in the district many years before. The Stewart and Forty Mile Rivers, south and north of the Klondike, supported two or three hundred diggers in 1885. Forty Mile Creek, which was the head-quarters of the district up to the establishment of Dawson City, 50 miles further up the Yukon River, had proved a veritable bonanza to the prospectors of 1887, which no doubt prepared their minds for the greater discoveries to be recorded to the south ten years later.

In the winter of 1895 Robert Henderson found gold on *Gold-Bottom Creek*, a tributary of *Hunker Creek*. After visiting him in 1896, Carmack discovered on his way home the still more famous *Bonanza Creek*, whose gravels have already yielded £10,000,000. The news of the finds soon spread throughout the field, attracted all the northern population, and when the district's fame had reached the outside world, set adventurers in all parts of the continent heading for the new El Dorado. Before the close of the century the population had arisen to 30,000, of whom a large proportion were unfit for the work to be performed, and after wasting their time up and down the chief waterways, left the field in disgust with less gold than was in their pockets upon arrival. Efficient prospectors were nevertheless on the spot in large numbers. The operations of the more fortunate speedily resulted in the recovery of enormous parcels of gold, and established the reputation of the diggings as the richest the world has ever known. The wonderful rapidity of gold-production, which reached its maximum in 1900, and the subsequent decline, largely due to the gradual exhaustion of the richest claims along the *El Dorado* and *Bonanza* creeks, is shown in the following table of returns :

Year.	*Value of Yield.* £
1896	61,000
1897	510,000
1898	2,040,000
1899	3,265,000
1900	4,550,000
1901	3,670,000
1902	2,959,000
1903	2,550,000
1904	2,000,000
1905	1,700,000
1906	1,140,000
Total	24,445,000

It is interesting, in the light of these achievements, to recall the coincident discovery and development of the Kalgoorlie field in Western Australia. The Klondike and Kalgoorlie—the two greatest gold-fields in the Empire, outside the Rand—both made their first substantial declarations in 1896. While the easily exploited alluvial field shot up with signal rapidity, and reached the highest degree of productiveness in 1900, with its output of £4,550,000, the lode-formations of Westralia, with a maximum yield, strangely enough, of the same value in 1903, have maintained the more uniform rate of production to be expected from an industry dependent upon the results of chemical and mechanical plants. To the sun-parched, waterless desert of West Australia as to its geographical antithesis, the Arctic, snow-covered regions of the Yukon, some thirty thousand men were drawn by the golden magnet. By her twin prodigies of twelve years old the world has been enriched to the score of £63,000,000.

5. The alluvial of the Klondike is well distributed in the creeks of a large extent of schistose rocks, but infinitely the most productive creeks have been the *Hunker*, *Bonanza* and *El Dorado Creeks*, which are tributaries of the Klondike River. According to sound estimates by Government authorities, these three creeks, inclusive of the associated hill gravels, have produced 75 per cent. of the district's yield. Others of noteworthy importance are the *Bear*, *Dominion*, *Gold Run*, *Sulphur*, *Quartz*, numerous subsidiary creeks and gulches, and the *Klondike River Flats*. The gravels of the several creeks will bear close

comparison. They are divided into six classes by Mr. R. G. McConnell, as follows:

Low-level gravels	Gulch gravels. Creek gravels. River gravels.
Intermediate gravels	Terrace gravels.
High-level gravels	Klondike gravels. 'White Channel' gravels.

The most important of these are the low-level or recent gravels, which lie on the valley bottoms of decomposed and broken schist, are commonly from 4 to 10 feet thick, and are overlaid by a sheet of black 'muck' from 2 to 30 feet in thickness. In description of these gravels, Mr. McConnell writes:* 'They are local in origin, and consist entirely of the schists and other rocks outcropping along the valleys. The schist pebbles are usually flat, round-edged discs, measuring 1 or 2 inches in thickness and 2 to 6 inches in length. They constitute the greater part of the deposit, but are associated with a varying proportion of rounded and subangular quartz pebbles and boulders. The pebbles are loosely stratified, and usually embedded in a matrix of coarse reddish sand, and alternated in places with thin beds of sand and muck. The gulch gravels occupy the upper portions of the main creek valleys and small tributary valleys. They differ from the creek gravels in being coarser and more angular.

'The only river gravels of the district proved, so far, to contain gold in paying quantities occur in the wide flats bordering the lower portion of the Klondike River below the mouth of Hunker Valley.' In these the pebbles, having travelled further, are better rounded than those of the creeks.

6. The richness of these gravels is estimated for the best creeks to show up to £100,000, or even £200,000 per claim of 500 feet along the creek, or £200 to £400 per foot of valley. A stretch of 80 feet some way above the *Discovery Claim* in the *Bonanza Creek* turned out £60,000. The *El Dorado Creek* was even higher in average value than the *Bonanza*, and is considered to have been the richest section of placed ground ever discovered. From the claims covering 3½ miles of its course, £5,000,000 to £6,000,000 have been won. *Hunker Creek* is reported to have yielded £200,000 per claim in its best sections.

As of the other creeks, its gravels are of local origin, with subangular quartz pebbles and boulders, and have a thickness of 4 to 10 feet. The gold in these comparatively recent deposits

* Geological Survey of Canada Annual Report, Part B, vol. xiv.

is generally coarse and very little 'worn,' and averages in value from £3 3s. to £3 14s. per oz.

Returns for 1905 from the United States Mint showed an average value of all bullion from the camp of £3 6s. 9d. in gold and 5·47d. in silver per oz. Though bulbs and discs of gold of considerable size are often found, the Klondike has not revealed any wonders in the shape of very large nuggets. Considering the enormous amount of gold produced, and the fact that the precipitation of gold from solution has probably occurred in the gravels to some extent, this absence is surprising. Large nuggets, however, appear to be no criterion of great richness in alluvial deposits. It is of interest, in this context, to quote two official reports in parallel. In *El Dorado Creek*, it has been pointed out, the gold is 'very coarse,' and in it 'nuggets are more plentiful than on the *Bonanza*.' Several valued at 'from £80 to £200' have been obtained. The *El Dorado* has turned out £5,000,000. Compare with this the record of Australia's recent gold rush to *Tarnagulla*, Victoria, a field of no industrial importance, with a past and prospective yield that is insignificant, where, however, nuggets of 387 ozs., 953 ozs. (£2,880), 306 ozs., 675 ozs., and 502 ozs. were obtained from the surface soil in the course of a few weeks and within a distance of 90 feet.

7. After the creek deposits, the White Channel gravels are of the greatest economic importance. These were formed prior to an elevation of the country, which, it is assumed, gave existing streams a grade enabling them to cut their way through these deposits and deep into the underlying schists. These older deposits have not been worked as extensively as the creek gravels, but their great importance has been well established.

Their characteristics are quite distinctive. Mr. McConnell describes them as consisting of 'a compact matrix of small, little-worn, and often sharply angular grains of quartz, and scales of sericite thickly packed with rounded quartz pebbles, and rounded and subangular and wedge-shaped quartz boulders often 2 or 3 feet in diameter. . . . The deposits are always stratified . . . but the composition is very uniform throughout. They are to be regarded as stream gravels deposited under somewhat peculiar conditions, chief among which was an exceedingly slow accumulation in streams of easy grades and comparatively slack currents.'

8. Their values, and incidentally those of the other deposits, have been made the subject of a special report by the Dominion Geological Survey, from which some remarkable figures, demon-

strating the amount of gold which was concentrated in the Klondike alluvials, can be quoted :

LOW-LEVEL GRAVELS.

	Estimated Past Yield.	*Estimated Future Yield.*
	£	£
El Dorado Creek	5,100,000	530,000
Upper Bonanza	3,160,000	658,000
Lower Bonanza	2,240,000	2,350,000
Bear	200,000	122,000
Hunker	2,857,000	1,522,000
Klondike River Flats	200,000	1,326,000
	13,757,000	6,508,000

HIGH-LEVEL GRAVELS.

	Past.	*Future.*
	£	£
Upper Bonanza and El Dorado Hills	4,900,000	1,675,000
Lower Bonanza Hills	153,000	1,530,000
Klondike River Hill	Small	195,000
Hunker Creek Hills	510,000	1,020,000
Totals	5,563,000	4,420,000
Grand totals	19,320,000	10,928,000

These estimates, made in 1907, do not include the creeks flowing southwards into the Indian River, from which £5,000,000 has been extracted, leaving a probable £2,000,000. Truly the store of gold for which so many thousands united in a perilous stampede in 1896-1897 was a prize well worth the risk and hardships borne. Some 40,000,000 sterling lay hidden in the surface beds.

9. Mining methods in the Klondike, without parallel in other parts of the world, have been evolved to meet the exceptional demands of local 'conditions,' whose tyranny is known too well by mining men, too little by directors and shareholders in many lands, but which in the frost-bound Yukon gravels are all-powerful. So vigorous are the winter frosts and so brief is the summer that the auriferous gravel is constantly frozen into a compact, adamantine mass, on which the pick is unavailing. In summer the unprotected ground thaws to a few feet, but if excavating operations had to be confined to the gravels released by natural warmth, the returns of the district would have been small indeed. In the early days, however, necessity mothered a scheme by which it was possible for the diggers to extract

their gravel during winter in readiness for the summer sluicing. At first large wood fires were lit upon the selected part of the claim which, after burning for twelve hours, enabled the operator to shovel up perhaps a foot of thawed dirt. These fires were continued until the gold-drift was reached, when driving was commenced. In a few years, however, this primitive method was superseded by the use of steam or hot water for melting what may be termed the 'matrix' of ice. Steam is most commonly employed, the application being made by means of hose and pointed steel tubes which are run into the gravel. These 'hypodermic injections' act upon 1 to 3 cubic yards per shift. Where the drift is worked out from below an overburden of muck, the ice so tenaciously binds the fragmental material that no timbering supports are required. In one case an unsupported roof is said to have covered a vault measuring 140 feet by 230 feet, and held up till midsummer.

In some parts of the district an open-cut method is applicable. As this involves the removal of the barren overburden, it is essential to success that the drift does not lie at any great depth. Where possible, streams are diverted across the claim in springtime, and thus made to carry off the overlying muck. Water for sluicing is now often pumped to the head of the boxes, and the introduction of steam for divers purposes has placed the field on a higher level of efficiency than that maintained for several years after the inception of the industry.

10. The prospects of lode-mining in the district are not generally regarded with favour on any large scale owing to the lack of persistence characterizing the great majority of the quartz veins in the Klondike schists. Mr. McConnell has described the veins in these words:

'They vary in size from mere threads up to masses of quartz 1 to 200 feet in length and from 4 to 6 feet in width. Large veins occasionally occur. . . . The common vein of the district is generally lenticular in outline . . . following the planes of schistosity, as a rule, or cutting them at right angles. The gold occurs mostly at or near the surface, very little being found in the interior of the vein.'

It is stated that work in the district will be supplemented in the future by river-dredging on a greater scale than at present practised, and that the influence of the financial corporation, as opposed to the small working syndicate or party, will be an industrial factor of steadily increasing importance.

CHAPTER XXXV

WEST AFRICA AND THE SUDAN

1. A mythical El Dorado.—2. Modern advancement.—3. Climate and transport.—4. Division of fields.—5. Tarkwa banket.—6. High working costs.—7. Quartz-mines.—8. Egypt and Sudan.—9. The distant past.—10. Rock formation.—11. Economic and financial difficulties.—12. A new Sudan mill.

1. The Gold Coast Colony, West Africa, is one of the oldest gold-producing divisions of the Empire, and although its name has been apt, in the past, to convey an extravagant impression of its productiveness, it ranks to-day amongst the most progressive of the minor gold-fields of the world. Four or five hundred years ago, the gold-dust used by the natives for money and the vague rumours of unlimited deposits in the unknown hinterland awakened the Portuguese, who were the pioneers of the region, to its possibilities as a great producer of the yellow metal. We read that in 1441 two Moorish captives were exchanged by the Portuguese for 'ten negro slaves and some gold-dust.' But England has rarely left the dangers and rewards of pioneering to other races, and when the West African Coast became the struggling-ground for Portuguese, English, French, and Dutch adventurers, expeditions were dispatched from London to search for the supposed El Dorado.

2. But results, sometimes disastrous, nearly always disappointing, led to no remarkable development of the gold industry, which was thrown into insignificance by the prosperous slave-trade and other commercial pursuits. In the report of the Committee of the Privy Council on African trade in 1789 gold does not appear in the list of exports from West Africa to Great Britain. Only in the last five or six years, which have been marked by the operations, in face of extreme natural difficulties, of strongly constituted London companies working under secure Government, has the yield of gold reached large

proportions. Recent progress, however, has been steady and substantial, and we find the rate of production has increased ten-fold in six years, as shown by the following table for the Gold Coast and Ashanti mines :

Year.	*Ozs.*	*Value.*
		£
1902	26,911	96,880
1903	70,775	254,790
1904	104,460	378,480
1905	171,149	653,820
1906	230,957	892,291

3. The principal difficulties with which the pioneers have had to contend, reflected in the comparatively high cost of working, have been those necessarily associated with the unhealthy tropical climate and inadequate transport facilities. White labour demands high remuneration, but, as an offset against this, many of the natives available can be trained to undertake the higher grades of labour in mine and works, and also in the clerical departments. Thus the ratio of white to coloured employees is only about one-half or one-third of that obtaining on the Rand, where the average wage of the native is nevertheless substantially higher. It is, however, to the difficulties of transport and the heavy burden of railway rates that Gold Coast companies now point as the chief obstacle in the path of normal progress. On machinery, the rate is 2s. per ton per mile, and the transportation of coal from the port of Sekondi to Tarkwa, the centre of the principal field, 40 miles inland, is 7s. per ton—a charge which, on the Rand, more than covers its price at the gold-mine bunkers. At present, it is true, local wood-fuel, costing 12s. to 15s. per cord at Tarkwa, can be utilized, but this is becoming more difficult and costly to obtain, and consequently the necessity of turning to imported products grows more conspicuous.

4. The gold-fields of West Africa, apart from the rivers upon which dredging is performed, may be conveniently classified as the Tarkwa 'banket,' Prestea quartz, and the Ashanti quartz groups. In 1906 the Tarkwa mines crushed approximately 136,000 tons for a yield of 13 to 14 dwts.; the Prestea, 29,000 tons for nearly 18 dwts.; and the Ashanti (and Bibiani) 126,000 tons for 14 to 15 dwts.

The Tarkwa line of auriferous conglomerates, called 'banket' reefs owing to their great similarity to the famous gold-carriers of South Africa, is connected with Sekondi on the coast by a narrow-gauge railway, which extends inland northwards to Ashanti. The Prestea quartz belt parallel to the Tarkwa range is not yet served by railway, but obtains its stores by a route from Axim port by river transport of 44 miles to Fura, and thence by 23 miles of light railway through difficult country to the mines.

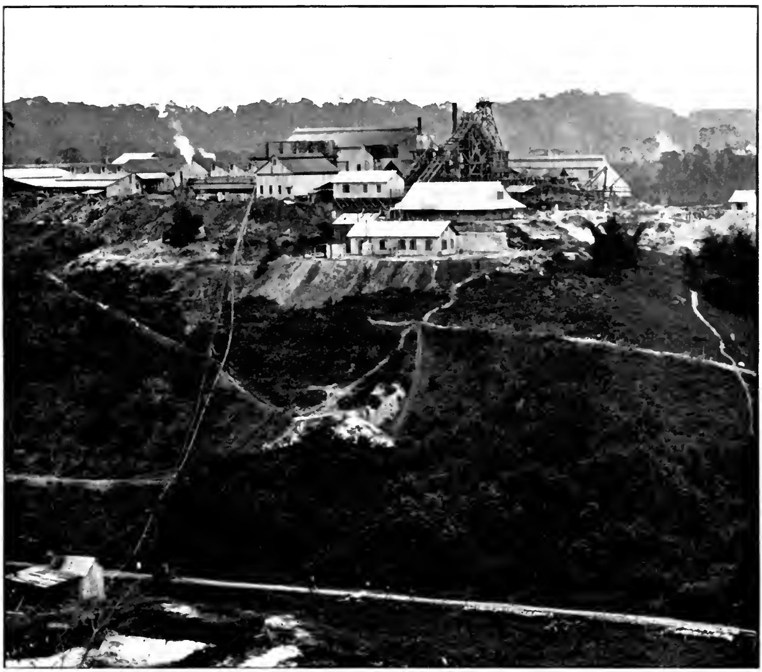
5. The Tarkwa reefs, which extend in payable and unpayable sections for 20 miles and support several producers, are noteworthy for their close resemblance to Rand banket, their good average grade and persistence, and non-pyritic character even at great depth. Occurring in sandstone and quartzite formation, the conglomerates consist of pebbles, mostly of white quartz, and of varying size up to 8 inches long, in a matrix consisting near the surface of a sandstone of quartz grains, white mica, and iron oxide, which becomes compact and quartzitic in depth.* Occasionally gold occurs in the pebbles. Down to the bottom of the *Abosso* (1,300 feet) there is not a trace of sulphide, though iron oxide is abundant. A bore-hole has proved the reef on the deep level of the *Abosso* mine at a depth of 2,483 feet.

The reefs, which run more or less parallel to the coast, were marked at surface by numerous old workings, extending, however, to no great depth.

6. The close similarity of West and South African 'banket' prompts a comparison of Tarkwa and the Rand in other aspects. In a discussion of working costs it must be understood that the mills of Gold Coast companies are of small capacity, comprising from 10 or 20 to 50 head of stamps. The *Abosso*, however, contemplates a duplication of its 50-stamp mill. Even allowing for the comparatively small duties practicable under these conditions, expenses are heavy, but steadily decreasing. For illustrative purposes, reference may be made to the well-classified returns of the *Abosso Gold-Mining Company* for the fiscal year ending June 30, 1907, when a mill of only 30-stamp capacity was in operation. After sorting out 17 per cent. of waste rock (1·4 dwts.), 36,880 tons of ore, worth 15·57 dwts., was crushed for a 91·8 per cent. recovery, the mill returns representing 70·4 per cent. of the gold contents. Costs, on this basis, averaged :

* A. R. Sawyer, Transactions of the Federated Institute of Mining Engineers, vol. xxii.

BREAKDOWN OF TRANSPORT IN EGYPTIAN DESERT.



By favour of TAQUAH AND ABOSSO CO.

TAQUAH MINE, GOLD COAST.

	Per Ton of 2,000 *lbs.* s. d.
Mining	13 6·4
Milling	5 7·4
Cyaniding	2 8·9
Maintenance	2 0·1
General charges	7 1·9
Development redemption	5 9·0
London expenditure	1 5·4
Total	38 3·1

The manager contends that, with an increased mill, he can reduce costs to the Transvaal standard. Working on a small scale, however, the Gold Coast mines are able to maintain a higher yield, approaching £3 per ton. Other noteworthy mines on the Tarkwa line are the *Abbontiakoon Block* 1, *Limited*, which recently tried dry-crushing without success, and now mills over 5,000 tons per month for £2 per ton, the *Tarquah and Abosso*, and the *Wassau*.

7. On the Prestea quartz belt, in which gold values are higher but less persistent, the two important companies are the *Prestea A* and the rich *Broomassie*, equipped with batteries of 50 and 20 stamps respectively. During the latter part of 1907, these companies were between them crushing 8,000 to 8,500 tons per month, for a return of about £23,000. Other quartz mines of considerable importance, outside the Prestea belt, are *Akrokerri*, *Sansu*, and *Ashanti Gold-Fields Corporation* in the Ashanti district, and the *Bibiani* and *Atassi* ; all are working quartz reefs. The *Bibiani* was in 1906 a very rich producer, treating 40,500 tons of quartz for 29,214 ozs., but its recent fall in value of ore treated has emphasized the need of extensive development in these quartz ore-bodies, and the greater industrial stability of the enterprises operating upon the Tarkwa conglomerates.

While there have been disappointments in West African quartz-mining, and the disposition of the rich zones and patches often appears to be characteristically precarious, this class of enterprise nevertheless continues to present good opportunities for the employment of soundly administered capital. As auriferous quartz belts, the Prestea and Ashanti deposits are of an extent that is geologically remarkable. Their industrial stability can only be established by a policy of thorough exploitation in advance of the mill requirements. From the administrative standpoint a reduction of railway rates is the Gold Coast industry's most pressing need.

SUDAN GOLD-FIELDS.

8. The romance and mystery with which the ancient gold-mines of Egypt and Sudan were enshrouded by the lore of archæologists proved dangerously attractive a few years ago to London speculative investors. The reopening of ancient workings, operated and abandoned many centuries before amalgamation and cyanide practice, is a task essentially fascinating in its possibilities, and if the operations fail to produce tangible results comparable with the conception of a fertile imagination, some compensative satisfaction can always be found in the assured production of historic data. Although the Sudan provinces alone fall strictly within the scope of this volume, it is unnecessary here to differentiate between the two geographical sections of the field—the Egyptian and Sudan—which have during the last few years secured (and to a large extent lost) the attention of English speculators.

Some of the companies formed between 1900–1904 (whose aggregate capitalization exceeded £2,000,000) obtained the support of very influential mining capitalists, such as Messrs. John Taylor and Sons of Mysore fame, and Mr. J. B. Robinson of South Africa. The tract of country, over which large concessions, conveniently bounded by lines of latitude and longitude, were granted, extends from near Cairo in the north to Abyssinia in the south, between the Nile and the Red Sea.

9. What is known of early Egyptian gold-mining, from the historical standpoint, has been graphically recorded by Professor A. H. Sayce, who states that for several centuries Egypt was the California of the ancient civilized world of the East. In the writings of this well-known Egyptologist, we read: 'The gold so largely used in Western Asia was derived from it, while, at home, the Pharaohs had at their disposal enormous stores of the precious metal. . . . Egypt, it would seem, possessed sufficient gold to supply the whole world. . . . The gold-mines of the desert must have been worked from a very early period. A high official, who lived in the Twelfth Dynasty (*cir.* B.C. 2500), tells us in his biography that he had escorted the gold procured from the mines between Keneh and Kosseir to Coptes. . . . It is clear, however, from the ancient evidence that the Eastern desert of Egypt is peculiarly rich in gold. Immense quantities of the precious metal have been taken from it in the past, and there is every reason to believe that equally large quantities are still to be found there. Whenever Egypt fell into a state of

feebleness and decay, or was overrun by a foreign enemy, the Bedouin at once became masters of the desert, the mining settlements were destroyed, and the roads to them rendered impassable.' Professor Sayce attributes the desertion of the mines to the insecurity of the ancient operators rather than to an exhaustion of the precious metal.

10. The field as it appears to-day to the technical observer has been ably described by Mr. C. J. Alford, who, acting on behalf of the Victoria Investment Corporation, inspected the auriferous belt several years ago. In a paper before the Institution of Mining and Metallurgy, of which he is vice-president, Mr. Alford stated that to the east of the sandy belt between Keneh and Assouan, and bordering the coast of the Red Sea, is a chain of lofty and rugged mountains, 50 miles wide, in which the mining belt (under his notice) is situated. The crystalline rocks which constitute the mountain districts are the oldest geological series met with in Egypt. In the lower ranges, and covering very extensive areas, is a rather fine-grained grey granite, passing in places into gneiss, and that into mica schist, traversed by dikes and instrusions of greenstone, felsite, porphyry, and a very fine-grained white elvan granite. It is in these rocks, Mr. Alford stated, that most of the auriferous quartz veins are found to occur.

11. Economic difficulties met with in the exploitation of Egyptian and Sudan mines are notably the want of timber and fuel, and the scarcity of water. The fellaheen or working men of the Nile are described, in the capacity of mine employees, as 'industrious, hardworking, and civil.' The climate is characterized by excessive heat in summer and occasional deluges of rain, but is otherwise admirable. In Egypt some of the chief mines reopened have been the *Um Rus*, *Eridia*, *Semma*, and *Atallah*, and in the Sudan several old workings have been resuscitated. Whatever the true import of the results obtained, it is certain that English capital has lost confidence in the possibilities of Egyptian mining, which was revived with an excess of enthusiasm. At the same time, there are men of high standing in the mining world who retain their faith in the prospects of the field. In a letter of reply dated November 20, 1907, Mr. Alford informed the writer that work had been going on very slowly at all the mines owing to want of funds, that the workings still looked promising, and that he had by no means lost faith in their future. 'But large working capitals will be required,' he declared, 'owing to the necessity of transporting the ore to

the water, there being insufficient for milling purposes.' Speaking of the properties of the *Egyptian Mines Exploration Company*, which has, with its subsidiaries, performed considerable mining work upon the Egyptian section of the field, Mr. Alford remarked that it would indeed be unfortunate if such 'promising prospects' were lost for want of money to carry on development, but that the financial outlook was not hopeful.

12. It is particularly satisfactory, therefore, to find that the developments on the *Om Nabardi* property in the Sudan have been sufficiently promising to prompt the controlling company (*Sudan Gold-Fields, Limited*) to erect a small battery. The fact that the Stock Exchange is dead to all influences of mere prospective import, and that this construction work is undertaken upon the advice of Messrs. John Taylor and Sons, clearly indicates that actual mine conditions fully warrant this expenditure.

Several mines in Egypt and Sudan have been well reported upon by consulting engineers, but in many of the old workings the ancients—with their slave labour—appear to have left little of value for their successors of the present generation.

CHAPTER XXXVI

OTHER BRITISH DEPENDENCIES

1. British North Borneo, Labuan, and Sarawak.—2. Fiji Islands.—3. British New Guinea.—4. Cyprus.—5. Nigeria.—6. British Central Africa.—7. British East Africa.—8. Uganda Protectorate.—9. Newfoundland.—10. British Honduras.—11. Leeward Islands.—12. Barbados.—13. British Guiana.—14. Trinidad.

1. *British North Borneo.*—The north-eastern section of Borneo, comprising some 31,000 square miles, is under the control—industrial and political—of the British North Borneo Company, which is granted by charter absolute authority over the internal affairs of the country. Supported by some influential British statesmen and financiers, this chartered company—like those which have operated in India and Africa—has constituted, while primarily endeavouring to advance its own commercial prosperity, one of the great constructive forces in the general expansion of the Imperial influence. Amongst the various resources of the company, minerals—in the form of manganese and coal—are rapidly increasing in importance. From the first, these minerals and iron have been declared to be latent assets of great value, though their exploitation has necessarily been a slow and difficult undertaking in a jungle-covered land, for which the chartered company has been obliged to provide all the primary necessities of civilization and sound administration. Railway construction has for a long while drawn heavily upon the resources of the company. Mining has, nevertheless, been keenly encouraged, and in December, 1906, the country's first shipment of manganese ore—of which enormous deposits are said to be available—was received in England. Average ore is reported to contain 49 to 51 per cent. manganese, 15 per cent. silica, and very little sulphur and phosphorus.*

The mines are situated at Tanjong Batu, near Kudat (at the north of the island). Coal-mining is also undertaken at Seru-

* Bulletin of the Imperial Institute, vol. iii.

dong, Tawao, near Cowie Harbour (south-east of the territory), whence it is exported. Iron ore may be considered a valuable reserve. Gold is known to occur, but so far this metal has proved signally elusive. Copper, diamonds, chromite, and oil are amongst the Company's industrial 'possibilities.'

Labuan.—In the island of Labuan, near Borneo, which falls under the administration of the Straits Settlements, an extensive coal-field is operated.

Sarawak.—The mineral sources of Sarawak include deposits of antimony ore, coal, diamonds, gold, and petroleum. Coal-mines are worked by the Government at Sadong and Brooketon. A gold yield of 40,000 to 50,000 ozs. per annum is recorded by the *Borneo Company, Limited,* which, in the neighbourhood of Bau and Bidi, has been treating a milled product worth 4 to 8 dwts. per ton by direct cyanidation.

2. *Fiji Islands.*—The Fiji Islands, which lie about 17 degrees south of the Equator, are of volcanic formation. In these southern Pacific islands very little has been done in the way of mineral development, although discoveries have frequently led to strong hopes for the establishment of profitable mining. Difficulties of rock investigation, the lack of any population of mining experience, and the alleged neglect of Government to encourage prospectors, are circumstances combining to check systematic exploration. Recently, however, the Government policy has been more liberal, and the discoverers of a deposit of copper ore in the principal island of Viti Levua have been granted a large concession, for prospecting and mining, upon favourable terms. Some of the copper ore is said to be rich. Gold is also known to occur in the island of Vanua Levu, but has not, it seems, yet been found *in situ.*

3. *British New Guinea.*—Gold-mining in British New Guinea is reported to give employment to between 300 and 350 persons, and to account for a yield to the value of over £50,000. The several fields in the possession are enumerated in recent Government reports as the Louisiade, Sudest, and Misima Islands, Gira, Yodda, Murua or Woodlark Island, Milne Bay, Cloudy Bay, and Musa River. In their report on the geology of Queensland and British New Guinea, dated 1892, Dr. R. L. Jack and R. Etheridge jun. noted alluvial workings in several regions, and reefs exploited in the Sudest Island. A great part of New Guinea, the largest island in the world after the Australian Continent, is a *terra incognita*—mountainous and covered with the densest vegetation.

4. *Cyprus.*—Professor Dunstan of the Imperial Institute visited Cyprus in 1904 on behalf of the Colonial Office, and the collection of minerals made was of importance 'as indicating the possibility of the occurrence of deposits of some commercial value, which might be discovered if a careful and systematic search were made for them.' Copper was worked in the island by the ancients, by whom the rich concentrations were apparently exhausted. Until recently the red metal was obtained from an old copper-mine at *Lymni*, in Papho.

There are some small asbestos workings in the island. Gypsum is produced to the value of a few thousand pounds annually.

5. *Nigeria.*—The British Protectorates of Northern and Southern Nigeria have recently been examined by a mineral survey on behalf of the Colonial Office. In Southern Nigeria an alluvial tin deposit in the Akwa-Ibama district appeared of possible commercial importance. The values are said to average about 3 lbs. of cassiterite per ton. Lignite has been observed in the country, and lead ore, containing silver, is worked and smelted by the natives near Omoso. On the subject of tin in the Northern territory, the *Niger Company, Limited*, has favoured the writer with the following memorandum, dated December 12, 1907:

'The existence of tin in what is now called Northern Nigeria has been known for many years. Tin from local sources was used by native metal-workers for lining the bowls and other vessels which they manufactured, and metallic tin in faggots was a regular article of trade.

'Exploration on the high plateau to the north of the Benue, the great tributary of the Niger, has revealed the existence of rich alluvial deposits of the metal in the province of Bautchi at a height of 3,000 to 4,000 feet above sea-level. Active workings have been carried on during the past two years, under mining leases granted by the Northern Nigerian Government, and upwards of 150 tons of tin have been shipped to Europe, some of it smelted at the mines, and the rest in the form of black oxide yielding about 73 per cent. metal. The chief obstacle to rapid development is the distance from water-carriage, but the light railways recently authorized will reach a point much nearer to the mines than the present shipping station on the Benue.'

6. *British Central Africa.*—The occurrence of numerous minerals, including coal, gold, copper, silver-lead, and iron, has been noted in the British Central African Protectorate by reliable

authorities. Reports made the Commissioner, Sir Alfred Sharpe, indicate that copper ore exists in the Ruo, Lower Shiré, and the Shiré Highlands district; in the latter area gold quartz is found. Bog iron ore in Northern Angoniland was once smelted and utilized by the natives for making weapons and various implements. In a bulletin issued by the Imperial Institute the opinion is expressed that, to judge by specimens examined, the country merits such systematic exploration for valuable minerals as already accorded to German East Africa. Special attention is drawn to the pegmatites (which yield valuable mica in German East Africa), coal, limestone, alluvial gold, graphite, and iron ores.

7. *British East Africa.*—The mineral resources of the Protectorate have not yet been fully ascertained, but iron is known to occur abundantly in most districts; mica and graphite are to be found in Ukamba; limestone is worked near Kitui, Makindu, and Lake Victoria; opals are plentiful in the Rift Valley; a large deposit of carbonate of soda has been discovered in the southern part of Ukamba, and gold-mining has been commenced, but discontinued.*

8. *Uganda Protectorate.*—The compiler of mining statistics for the Home Office summed up the knowledge of mineral resources of Uganda in 1906 as follows:

'Fragments of coal are found in the bed of the streams all around Mount Elgon; there are traces of copper in Busoga; iron ore is abundant in the Protectorate; alluvial gold is known to exist in parts lying far from the railway, and there are deposits of salt at Toro and Kibero.'

More recent discoveries have yet failed to prove deposits of sufficient value or extent to provide a basis for a sound mining industry.

9. *Newfoundland.*—This island—the oldest British colony—is an important mining-field, but one whose industrial development cannot be regarded with satisfaction commensurate with its record of yield; for an export of raw minerals—crude ores of both iron and copper—is the principal basis of activity. All mining involves an impoverishment of assets impossible to reproduce, but the results are more gratifying in countries that treat the ores or produce therefrom manufactured goods. Dividends come out of capital. In 1906 Newfoundland exported

* Home Office Report, 'Mines and Quarries, Colonial and Foreign Statistics,' 1907.

884,986 tons of iron ore from *Bell Island*, Conception Bay, principally to the iron and steel works of Nova Scotia. The *Tilt Cove* copper-mines, producing the greater part of the island's output of 75,000 tons of copper ore, are operated by the *Cape Copper Company*. Tilt Cove is situated on the north shore of the island. The mines have been worked more or less continuously for thirty-six years. The largest mass was 350 feet by 280 feet at the surface, and 220 feet deep. Economic conditions are said to be unique; labour is cheap and fuel expensive, so that the mine is operated practically without machinery.*

The total mineral production of the island, of which iron and copper ore exceed 90 per cent., is valued at £275,000 to £300,000 per annum, and includes some antimony, gold, and iron pyrites.

10. *British Honduras.*—With reference to the mineral prospects of British Honduras, the following minute was kindly forwarded to the writer by the Colonial Secretary at Belize, for whom it had been written by the Surveyor-General:

'Practically nothing has been done as yet in prospecting for mineral deposits in the colony by experienced men. Untrained persons have tried to locate mines, which on assay have turned out to be unworkable. I believe that mines will some day be found in the interior of the colony, and for preference would indicate the Cockscomb Mountains as the most likely locality in which gold and silver mines might be found. The presence of coal has been more than suspected. In Mr. Fowler's report on his journey across part of the colony, he appears to have made mention of gold-bearing formations. . . .

'H. I. PERKINS,
'*Surveyor-General.*'

9/10/07.

The omitted section of Mr. Perkins' minute is a quotation from Mr. Alfred G. Lock's book, 'Gold: Its Occurrence and Extraction,' 1882, pp. 101, 102, wherein reference is made to the prospects and production of the country.

11. *Leeward Islands.*—Mines containing molybdenum and copper are stated to exist upon the Virgin Islands. The island of Redonda supports a small phosphate industry. There is a sulphur-mine in Dominica Island.

12. *Barbados.*—The most important mineral product of Barbados, in the West Indies, is glance pitch or 'manjak,' which

* W. Spencer Hutchinson, 'Mineral Industry,' vol. xv.

is principally exported to the United States. An American authority states that this mineral, which has a lower melting-point than elaterite, is particularly valuable on account of its jet-black colour, whereby the necessity for mixing any black pigment with it is avoided when it is used as a basis for black varnish or japan. In Barbados there are also several wells yielding petroleum.

13. *British Guiana.*—In the colony of British Guiana—a magnificent province, with an area exceeding that of the United Kingdom, in the little-developed north-eastern part of South America—gold and diamonds have been won by natives for many years. From 1884 up to the end of 1907 the production of yellow metal has reached an aggregate value of £7,450,000. The output has lately declined, owing largely, it is said, to the lack of capital necessary for the advancement of exploration and other operations. Professor J. B. Harrison, Director of Science and Agriculture in the colony, has on several occasions made valuable reports upon the mineral resources of British Guiana. He maintains that the exploitation of gold and diamonds has been due primarily to the black section of the colony's inhabitants, to the smaller landowners, the artisans and the labourers of the race, although much capital has been supplied by the other sections. Negroes first proved the existence of payable deposits of gold and diamonds, have expended their energies and not infrequently their small capitals in working them, and several thousands of them still spend their time in the forest districts prospecting for and working placer deposits of gold. Vast tracts of land still remain unexamined. Gold is obtained from quartz reefs, from ordinary alluvial, and from disintegration deposits held *in situ* by the forest growths. Most of the gold has been won from placers, worked by hand labour and sluicing. Hydraulicking and dredging have also been practised. The two leading quartz-mines are the *Peters*, on the Puruni River, and the *Barima*, equipped with a stamp and Huntingdon mill respectively. In a recently issued Government report, the secretary of the Institute of Mines and Forests expressed the opinion that good results could be anticipated from quartz-mining, when taken in hand scientifically. He deplored the lack of properly trained mining men, and declared that, 'with very few exceptions, the people working alluvial gold in British Guiana know gold from pyrites, and that is about all.' The gold yield of the colony is now 50,000 to 70,000 ozs. per annum, or only half of the amount recorded ten years ago.

Diamonds in considerable quantities were first discovered near the Putareng Creek of the Mazaruni River by an 'exceptionally intelligent negro prospector' named Gilkes. Professor Harrison states that since that time placers in the neighbourhood of the creek have been more or less diligently worked for a return of 740,000 stones, weighing 49,000 carats and worth £68,000. Only the Putareng district and its neighbourhood can fairly claim to be a recognized diamond-field. The exploitation of the district should receive a great impetus whenever the excessively high costs of transport are reduced.

14. *Trinidad.*—This island, the most southerly of the British West India Islands, has long been celebrated for its valuable yield of asphalt, and the remarkable occurrence of this mineral in the *Pitch Lake.* The yields for 1904, 1905, and 1906 were 133,000, 100,600, and 114,800 long tons respectively, valued at about £1 per ton, and including the three classes of asphalt—crude, refined, and dried. For refinement the crude asphalt is boiled in open vats, by means of which the water and some of the more volatile oils are removed, reducing the weight by about a third. The famous *Pitch Lake* at La Brea, the area of which has been shown by survey to be 137 acres, has been well described by Mr. Cunningham Craig. This geologist stated before the Colonial Institute* that the pitch itself is an emulsion consisting of, roughly, 30 per cent. water, 25 per cent. fine clay, and sand, and about 45 per cent. bitumen. 'It has been formed,' he said, 'on the outcrop of the La Brea oil-sand by the gradual oozing out of oil which evaporates and oxidizes in contact with the air. So rich is the rock in petroleum that its cohesion breaks down on exposure, and sand and sticky asphalt ooze out in an intimate mixture, thus gradually forming the wide and deep hollow occupied by the lake. The material is sufficiently viscous to ensure in the course of ages an almost perfect mingling of all the various constituents.' The *Pitch Lake* accounts for 85 to 90 per cent. of the island's asphalt yield. It is stated that the level of the lake has fallen 7·1 feet by the extraction of 1,500,000 tons of pitch.

Explorations have lately been conducted in various parts of Trinidad, under extreme difficulties, for the opening up of a petroleum field. Drilling for oil has met with considerable success. The prospects of the field were discussed by Mr. Randolph Rust—one of the pioneers of the industry—before the West India Committee in 1906, when Professor Carmody, Govern-

* Journal for July, 1906.

ment Analyst of Trinidad, subsequently expressed the opinion that Trinidad petroleum was of the very highest quality. Mr. Craig, in the geological paper quoted above, stated that in the island there was an oil-field of at least 500 square miles, and that it had never been adequately tested. Over a large part of this area a production of oil could be confidently expected. 'At the least,' he added, 'a new and valuable asset of the Empire is waiting for exploitation. . . . Even with only moderately successful results, the development of these untouched sources of mineral wealth should have the effect of placing the colony in a position of far greater importance than it has ever hitherto attained.'

APPENDICES

APPENDIX A.—MINERALS OF THE EMPIRE

PRINCIPAL SOURCES OF YIELD

A record, in summarized form, is given below of the chief mineral products of the British Empire and the particular countries from which they are derived. The localities are named, as far as available statistics allow, *in order of productiveness*, and are only chronicled when their output of the mineral specified exceeds £1,000 in value per annum.

Gold.

Transvaal; Western Australia; Victoria; Canada*; New Zealand; Rhodesia; Queensland; India; New South Wales; West Africa; Tasmania; British Guiana; Sarawak; South Australia; British New Guinea; Federated Malay States; United Kingdom; Cape Colony.

Tin.

Federated Malay States; United Kingdom; Tasmania; Queensland; New South Wales; Western Australia; Transvaal; Victoria; India; Cape Colony; Nigeria.

Copper.

Canada; Queensland; Tasmania; New South Wales; South Australia; Cape Colony; Newfoundland; Transvaal; Western Australia; United Kingdom; Rhodesia.

* Canada, New Zealand, Rhodesia, Queensland, and India have been close competitors. New Zealand and Rhodesia are the most progressive.

Silver and Silver-Lead.

New South Wales; Canada; Tasmania; United Kingdom; Queensland; New Zealand; Transvaal; Western Australia; Rhodesia; Victoria.

Zinc.

New South Wales; United Kingdom; Canada.

Nickel.

Canada.

Manganese.

India; United Kingdom; Queensland; British North Borneo.

Iron.

United Kingdom; Newfoundland; Canada; New South Wales; South Australia; Queensland; India.

Antimony.

New South Wales; Queensland; Victoria; Rhodesia; Newfoundland.

Bismuth.

New South Wales; Queensland.

Molybdenum.

Queensland; New South Wales.

Tungsten (Wolfram or Scheelite).

Queensland; United Kingdom; New South Wales; Federated Malay States; Tasmania.

Coal.

United Kingdom; India; Canada; New South Wales; Transvaal; New Zealand; Natal; Queensland; Orange River Colony; Victoria; Western Australia; Cape Colony; Rhodesia; Tasmania; Sarawak; Labuan.

Oil-Shale and Petroleum.

United Kingdom; India (chiefly Burma); Canada; New South Wales.

Mica.

India; Canada; United Kingdom.

Plumbago.

Ceylon; Canada; India.

Asbestos.

Canada; Transvaal; Cape Colony.

Diamonds.

Cape Colony; Transvaal; Orange River Colony; Rhodesia; India; New South Wales.

Precious Stones (other than Diamonds).

Burma (chiefly rubies); New South Wales (opals); Ceylon (sapphires, chrysoberyls, moonstones, etc.); Queensland; Rhodesia.

APPENDIX B.—GEOLOGICAL SURVEY ADMINISTRATION

The recent institution in Canada of a Dominion Department of Mines, with mining and geological branches, to extend the functions previously performed by the Geological Survey, has revived interest in the question of the economic advisability of forming a similar federal organization to serve the Commonwealth of Australia. The question is also one which may assume practical importance in South Africa should unification or federation of its colonies be accomplished. The trend of opinion in Australia upon the matter is expressed in the following note, courteously contributed by Mr. W. H. Twelvetrees, Government geologist of Tasmania :

'In reply to the question about the prospects of a Federal Survey and Mines Department being established, the natural response would be that this is not one of the departments unified by the Federated States, and present forecasts of future political developments are impossible. It may be at some future date that the States will delegate additional powers to the central Government, but at present the straws of political opinion in the different States are blowing in the other direction. The intervening distances of the States and the different conditions prevailing in each tend to show that there is not yet sufficient community of interest to make it advantageous to proceed further in unifying experiments.

'As for the Mines Department, mining leases and water rights are closely connected with land and forest leases, and to divorce the authorities regulating these would be inconvenient. Mining is necessarily carried on under widely different conditions in the different States, and uniform regulations for working would be impracticable, and would dislocate the industry. The geological surveys of the different States have their own officers, whose geological knowledge and experience are of greater use to their State under present conditions than they would be under the control of a federal regime with the liability to removal or transfer, etc. The maps of each State are available to the Commonwealth statistician, and each State is gradually improving them. A system is being started in Tasmania under which its mining-fields are being geologically surveyed one by one, and its methods of disseminating useful knowledge relating to its mining industry improved. An assistant geologist has been appointed, and other measures taken to place the work on a satisfactory basis. Under these circumstances, a gigantic federal geological survey, which would take half a century to complete, and entail an enormous expenditure, does not seem to be within the range of practical politics. Moreover, most of the advantages of federalizing mines can be inexpensively obtained by mutual inter-State agreement on all matters upon which it is desirable that there should be agreement.'

'W. H. Twelvetrees,
'*Government Geologist.*

'Launceston, Tasmania,
'*October* 26, 1907.'

It must be pointed out that in Canada, while the Survey undertakes nearly all the important work of geological investigation, the Dominion Mines Department only supplements the duties of the several 'Bureaux of Mines' under provincial control, and in no respect reduces their individual power or utility.

On the question of federation and the functions of colonial geological surveys, Mr. A. Gibb Maitland, Government Geologist of Western Australia, and formerly of the Queensland Survey, has kindly favoured the writer with the following weighty opinions :

'I am not aware that the Federation of the Geological Surveys of Australia has been considered by the individual States or the Commonwealth, but I think it is merely a matter of time before it is thought of.

'Personally, I am not much in favour of the establishment of a Federated Department of Mines, as distinct from the Geological Survey, as is done in Canada. As may be seen by their reports, there is a marked tendency to a duplication of work. There is already a mining division in the Canadian Survey. To create a Geological Survey and call it a Mines Department, or to make it subsidiary thereto, is to imply that the Survey's functions are solely to deal with mining questions, which seriously hamper and restrict the organization's utility.

'A properly constituted Geological Survey *ought* to be capable and permitted to deal with geology as applied to subterranean water-supplies, agricultural and other industrial pursuits, in which important geological considerations are involved.

'In such a colony as the Cape of Good Hope, where agricultural and pastoral interests are paramount, the Survey would naturally, while not, of course, neglecting scientific questions, devote its energies to the mapping and investigation of those formations which might be expected to yield supplies of artesian water and good soils, etc. On the other hand, in such a colony as the Transvaal, the Survey would naturally first devote its energies to the investigation of the geological structure of the mining districts, or those in which there seemed to be a likelihood of developing into such.

'In Australia the Geological Surveys are placed as an act of administrative convenience under the control of the Minister of Mines, for obvious reasons.

'While the Geological Survey of any country would naturally deal with investigations connected with those industries upon which the public welfare principally depended, I do not think that if it neglected other matters it would be fulfilling those wide functions which the taxpayer expects. In partially explored countries, like most of the British Dominions and Colonies (to use the new-fangled phraseology), a Geological Survey is established, not for the purpose of purely scientific research for its own sake, but with the hope that science will be made of some material benefit to the proper utilization of the country's resources. By this I do not mean that in a purely mining country a Geological Survey should become a mere prospecting machine, but that it should deal in the broadest sense with all those considerations which would lead to direct prospecting and mining in legitimate directions, but should only deal with matters which come properly within the functions of a Government department. To eyes educated to their proper use geological maps occupy to the landsman (whatever his calling in life may be) the same position and serve the same purpose as the Admiralty charts do to the seaman, and their production should be a national work.

'In Western Australia, although a mining country *par excellence*, the Geological Survey, as may be seen by its reports, has not neglected the question of subterranean water-supplies in the agricultural and pastoral districts. As a result of geological investigations, large areas of excellent pastoral country (which since the inception of the colony could not be utilized) have now been proved to be underlaid by artesian water. After the geological mapping and the experimental boring, private enterprise has followed, and is now busy in taking up pastoral holdings, and boring for water in those areas which have been defined as artesian-water carrying. The importance of Geological Surveys to the pastoral areas of a country like Australia, where the last season's wool-clip alone is stated to be worth £23,615,000 (or equal to 170 tons of gold), is not to be overestimated.

'A Geological Survey ought to deal with the geological structure, mineral resources, mining industries, soils, and underground water-supplies of the country, using these terms in their widest sense consistent with geological considerations.

'A. Gibb Maitland.

'Geological Survey Camp,
'Windalea Pool,
'Lyndon River, W.A.
'*November* 27, 1907.'

APPENDIX C.—RAND DIVIDENDS

The aggregate distributions made to shareholders up to the end of 1907 by the principal dividend-payers of the Rand may be tabulated as follows:

	£
Robinson	5,724,688
Ferreira	2,589,250
Crown Reef	2,477,900
Langlaagte estate	1,880,880
Simmer and Jack	1,791,461
City and Suburban	1,768,913
Robinson Deep	1,590,686
New Primrose	1,513,775
Geldenhuis estate	1,490,750
Bonanza	1,365,000
Crown Deep	1,357,500
Village Main	1,330,343

Several other mines have exceeded a million sterling in total dividends. It is of interest to compare these figures with the records of the greatest Australasian gold-mines, as under:

	£
Mount Morgan, Queensland (to June, 1907)	6,904,166
Waihi, New Zealand (to January, 1907)	2,296,548
Great Boulder, Western Australia (to June, 1907)	2,513,050
Golden Horseshoe (to June, 1907)	2,355,000
Oroya-Brownhill (to June, 1907)	1,954,991
Ivanhoe (to June, 1907)	1,768,750
Great Fingall Consolidated (to June, 1907)	1,475,000
Lake View (to June, 1907)	1,378,750
Great Boulder Perseverance (to June, 1907)	1,251,250

Vastly the greatest dividend-payer amongst all classes of mining enterprise in the Empire is the De Beers Consolidated, which paid out £4,350,000 during the last two financial years. The Broken Hill Proprietary, Wallaroo and Moonta, Mount Bischoff, Cape Copper Company, New Jagersfontein, Mysore, Champion Reef, Ooregum, and Canadian Copper Company have all declared dividends amounting to over a million, and in some instances to two or three millions sterling, since their inception.

APPENDIX D.—MINING IN NATAL

(*Kindly contributed by the Commissioner of Mines*)

Coal-Fields.—The principal Natal coal-fields are: The Klip River coal-field (approximately 1,650 square miles), the Utrecht and Vryheid coal-field (approximately 550 square miles), and the

Somkeli coal-field (area doubtful). There are several other coal-bearing areas at present less important. The collieries on the Klip River field produced 1,521,747 tons (2,240 lbs.)—*i.e.*, 99·45 per cent. of the total coal output (1,530,043 tons) of the colony in 1907. They are distributed from Elandslaagte to Newcastle, being from 206 to 269 miles by rail from Durban. The single colliery on the Somkeli field in Zululand, 168 miles from Durban, put out 7,974 tons during the year. Though, in the absence of the railway now being constructed, the output from the Utrecht and Vryheid field was negligible, the coal-field will become important in the near future, owing to the extent, number, and thickness of seams, and the high quality of much of its coal.

All classes of coal—bituminous, semi-bituminous, and anthracite—are met with in different Natal collieries, and, indeed, frequently in the same colliery, as a result of igneous intrusions in the strata, but at the present time the Zululand Colliery at Somkeli and the Woodlands Colliery near Glencoe alone place anthracitic coal on the market.

There is no present danger of exhaustion of the colony's coal-supply. I estimate that at least 280,000,000 tons of semi-bituminous coal of quality equal or superior to that of the coals now sold can be extracted from ground which has been already practically proved, while, allowing for anthracite coals, and coal areas only partially proved, the amount of available coal becomes at least 1,500,000,000 tons, and is probably much greater.

Working Conditions.—On the Klip River coal-field mining is carried on from the surface to a maximum depth of 700 feet, but most of the output comes from about 250 feet deep. The seams worked are practically horizontal, and generally from 3 feet to 6 feet thick, but there are frequently two seams, and these are so close together near Hatting Spruit and Dannhauser that they are, in places, worked as one seam. Roofs are, as a rule, good. The mines are usually dry. Fire-damp is found in the deeper collieries, and is occasionally met with in the shallower.*

The system of working is generally pillar and stall, but there are also examples of double and single stall and long-wall. The most striking feature of mining practice is the extensive use of mechanical coal-cutters, 62·5 per cent. of the output being

* A few hours after the completion of this report the Commissioner of Mines was summoned urgently to Glencoe, owing to the occurrence of a series of disastrous fire-damp explosions, which resulted in the death of seventy persons. Most of these victims, amongst whom was the Deputy-Commissioner of Mines, belonged to rescue parties gallantly endeavouring, with a full knowledge of the extreme danger of their action, to save the lives of those previously entombed.

mechanically undercut in 1907. The excellent surface equipment for coal-sorting and washing is also noteworthy.

In the Zululand Colliery the seam dips at an angle of 22 degrees, and in a typical section shows 37 feet of coal in a seam thickness of 47 feet.

The collieries depend on natives and indentured and unindentured Indians for manual labour. The output of the producing collieries per man employed in 1907 was 213 tons, or 327 tons per man employed underground. Working costs are not made public, but may be said to run from 4s. per ton upwards.

Minerals other than Coal.—Though coal is at the present time by far the most important Natal mineral, many others of economic value have attracted attention, among which may be mentioned asbestos, chromite, fire-clay, gold, graphite, gypsum, kaolin, limestone, magnesite, marble, mica, nitre, phosphates, and slate, and the ores of copper, iron, lead, and silver, manganese, molybdenum, nickel, and tin.

Of these minerals and ores, most energetic investigation is at present being directed to fire-clay, gold, and graphite, lime and clay for cement-making, and the ores of copper, iron, and silver-lead.

Excellent fire-bricks are being manufactured at Gezubuso, on the Natal-Cape Railway. Gold is very widely distributed in both banket and quartz reefs. The gold output in 1907 was 878 ozs. Several deposits of graphite, which is found in both crystalline and amorphous form, are receiving attention. Many copper deposits are being worked upon, principally in the Vryheid and Nqutu districts and the Tugela Valley. Galena is being extracted from a quartz vein in the Mfongosi Valley. More than one project for establishing iron-smelting works in the colony is being actively pressed forward.

Mining Prospects.—Prospects of mineral development in Natal are decidedly bright. Natal coal has now obtained a footing on markets from Buenos Ayres to Singapore. It is more probable that this footing will be made good, and the export trade extended, than that it will be lost. Recent discoveries and local economic conditions apparently render possible the establishment of an iron-smelting industry, exporting to the East as well as supplying South African demands.

Probably the attention being devoted to gold and copper and other mineral deposits will in some cases be rewarded.

CHARLES J. GRAY,
Commissioner of Mines, Natal.

PIETERMARITZBURG,
February 13, 1908.

APPENDIX E.—DISCOVERY OF THE KLONDIKE

The early history of the Klondike, the richest alluvial gold-field in the world, has long been marked by points of controversy. To whom the full honour of discovery should be rightly accorded has been debated in many quarters, but careful investigation has proved Robert Henderson, of Nova Scotia, to be worthy of foremost distinction. The rights of his claim have lately been officially recognized by the Geological Survey of Canada. Peculiar interest, therefore, attaches to the following rough notes, specially contributed to this volume by Mr. Henderson (who is still working in the Yukon) upon his first experiences in the famous fields. In 1894, after an adventurous life in New Zealand, Australia, Cape Colony, Colorado, and elsewhere, 'Bob' Henderson struck north for the Klondike. From this point the narrative may be continued in his own words:

'I packed my outfit over Chilkote Pass to Lake Linderman, where I arrived on June 1, 1894, and went down the river to 60-mile post. I then went to Indian River, 18 miles below the 60-mile. I prospected along the river bars, also the creeks coming in to Indian River, finding fine gold at every place, but not enough to pay. I made up my mind that there must be coarse gold somewhere up in the creeks flowing into Indian River, so I continued up to what is now called Quartz Creek. At the head of it I found 10 cents to the pan. In the winter of 1894-1895 I prospected on the lower part of Quartz Creek till February, when I went further up Indian River to the head of Australia Creek. I found fine gold anywhere I panned.'

At this time Mr. Henderson suffered from a series of misfortunes, vividly exemplifying the risks and hardships falling to the lot of the pioneer in this Arctic borderland. Amongst other accidents was an injury which prevented him from prospecting for some time.

'I went down the river to 60-mile post to have my leg attended to and to obtain supplies. I got a small outfit, and started back to Quartz Creek, where I stayed all winter, sinking holes. In spring I made a trip up Indian River to the head of Australia Creek, but finding very little gold, I returned down to Quartz Creek, and crossed over the summit to the creek I named Gold Bottom, finding 2-cents dirt. When I got back to Quartz Creek, there were eighteen men there. I tried to get them to come over to Gold Bottom Creek, for us all to work together. They all agreed to the proposition, but after starting with our packs over the mountains, they thought it was too hard, and all left except four, who stayed with me. We sluiced 750 dollars, and then the others went their way. Some became very rich afterwards. I, on the other hand, had no luck at all. During the time I was working Gold Bottom, I made a discovery on what is now known as Hunker Creek. I then had to go to 40-mile post to record my claim. I staked No. 12 on Bear Creek on my way down the Klondike River.'

Difficulties were placed in the way of Mr. Henderson's recording his claims, and he remarks :

'I have now been ten years trying to get the matter settled. One claim alone paid royalty on 450,000 dollars, and was then sold for 200,000 dollars. Many thousands were taken out before royalty had been paid. At present I receive 200 dollars a month until my compensation is settled.

'Regarding the discovery of gold on Bonanza Creek by George Carmack, I was working on Gold Bottom, and we got short of food. I went down the Indian and up the Yukon River to 60-mile post. I returned by the Klondike River, where I met Carmack, who was catching salmon with nets. I told him that I had found fairly good dirt on Quartz Creek and Gold Bottom Creek; also on Gold Run, afterwards named Hunker Creek, and advised him to go over. He said he would if he could get Indians to attend him.

'Arriving at the Discovery claim two days later, I found Carmack had got there the same evening. He stayed there that day, leaving the second. He and the Indians each staked a claim. I told him on his departure that if he did any prospecting on his way back and found anything good, to let me know by sending one of his Indians back. On their way home they went over the mountain, and followed Rabbit Creek, now called Bonanza. About a mile below the forks of the El Dorado and Bonanza they stopped to rest and have lunch. While Carmack was having a nap, one of the Indians—"Skookum Jim"—climbed up the rim bed-rock, scraped up some dirt, and found on panning coarse gold. He showed it to Carmack. They panned out about 13 dollars, staked claims, and then went down to the mouth of the Klondike.'

Three weeks after this Mr. Henderson heard for the first time, and then by chance, that the new 'Bonanza Creek' was the 'biggest thing in the world,' and was mortified to learn that it had already been 'staked from head to foot.'

APPENDIX F.—PERSONAL ACKNOWLEDGMENTS

THROUGHOUT his tour the author received invaluable assistance in his studies and observations from those in financial or technical control of mining operations, to whom he has been unable to acknowledge his indebtedness in the body of this work. He therefore takes this opportunity of expressing his gratitude for services courteously rendered by the following gentlemen in countries outside South Africa, in which land he is under obligations to friends and acquaintances too numerous for individual mention.

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ALLEN, M. A. V., Assistant Warden of Mines, Perak, Malaya.

ASHMORE,* Sir A. M., Lieutenant-Governor, Ceylon.

ATKINSON, J. H., Board of Revenue, Madras.

BADSHA SAHIB, M. A. Kuddus, mica mine-owner, Madras.

BEAUCHAMP,* H., editor, *Madras Mail*, Madras.

BEE, Ng Boo, mine-owner, Taiping, Malaya.

CAPLIN, T., manager, manganese mines, Madras.

CHAPPEL, W. R. (Messrs. Osborne and Chappel), Perak, Malaya.

CHOON, Foo Choo, mine-owner, Perak, Malaya.

CHRESTIEN, H., mica mine-owner, Bengal.

CLAYTON, L. H., Chinese Protectorate, Penang.

COOMARASWAMY, Dr. A. K., director, Mineral Survey, Ceylon.

COWAN, —, Chinese Protectorate, Perak, Malaya.

CUMMING, H., Kuala Lumpur, Malaya.

EDGAR, P. C., director, Tronoh Mine, Malaya.

EDGAR, Dr. P. G., director, Tronoh Mine, Malaya.

EDGAR, C., Sungei Besi, Selangor, Malaya.

ELLIOT, W. T., Messrs. Macneill and Co., Calcutta.

EVANS, Hon. W., Treasurer, Straits Settlements.

FERGUSSON, R., editor, *Ceylon Observer*, Colombo.

FERMOR, L., Geological Survey of India, Calcutta.

FI, LIONG, member of State Council, Perak, Malaya.

HAMPSHIRE, A. K. E., Kuala Lumpur, Malaya.

HAYDEN, H., Geological Survey of India, Calcutta.

* Since deceased.

Holland, T. H., director, Geological Survey of India.
Hughes, G. E., Assistant Warden of Mines, Seremban, Malaya.
Jayatellike, —, mine-owner, Ratnapura, Ceylon.
Jones, S. R., mining inspector, Gopeng, Malaya.
Lane, E., manager, mica mines, Bengal.
McFadyen, —, mica mine manager, Bengal.
Mackie, Grant, Sungei Besi Mine, Malaya.
Mel, H. de, graphite merchant and miner, Ceylon.
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Nicholls, H. E., superintendent, Pahang Consolidated, Malaya.
Nutter, H. F., mining engineer, Ipoh, Malaya.
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Soysa, W. H. C. de, estate and mine owner, Ceylon.
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Mica Inspector, Nellore District, Madras.
Secretary, Chamber of Commerce, Colombo.
Secretary, Royal Asiatic Society, Colombo.
Secretary, Institute of Mining and Geology, Calcutta.

AUSTRALASIA.

Abraham, W., mining inspector, Bendigo, Victoria.
Agnew, J. A., Messrs. Bewick, Moreing and Co., Kalgoorlie, Western Australia.
Aitken, —, ex-Mayor of Coolgardie, Western Australia.
Andrews, H., director, Griffiths and Tindal's mines, Coolgardie, Western Australia.
Banks, E. G., chief metallurgist, Waihi, New Zealand.
Barry, W. P., superintendent, Waihi, New Zealand.
Beal, R., British Broken Hill, New South Wales.
Beaumont, —, manager, Broken Hill, New South Wales.
Borrowe, G. W., manager, Boulder Perseverance, Western Australia.
Carthew, J., Inspector of Mines, Broken Hill, New South Wales.

Cecil, H. P., South Mount Cameron, Tasmania.

Clark, Lindesay, manager, Briseis Tasmania Mining Company, Tasmania.

Clarke, A. Z., Queen Street, Melbourne.

Craze, J., manager, Zeehan Montana, Tasmania.

Cundy, W., Queenstown, Tasmania.

Deane, E., chief metallurgist, Mount Lyell, Tasmania.

Delprat, G. D., general manager, Broken Hill Proprietary, New South Wales.

Dewar, F. M., New Moon, Bendigo, Victoria.

Dickenson, F. M., secretary, Broken Hill Proprietary.

Evans, S., Kalgurli Gold-mining Company, Kalgoorlie, Western Australia.

Evers, H., secretary, Tasmania Gold-mine, Tasmania.

Finch, C. D. (Messrs. Gibbs, Bright, and Co.), Melbourne.

Gardener, W. E., Central Mine, Broken Hill, New South Wales.

Hamilton, R., general manager, Great Boulder, Western Australia.

Hancock, H. L., general manager, Wallaroo and Moonta, South Australia.

Harkness, A., Victoria Foundry, Bendigo, Victoria.

Hart, W., director, Mount Bischoff Tin-mine, Tasmania.

Hay, —, mill manager, Hainault, Western Australia.

Hebbard, G., manager, Central Mine, Broken Hill.

Hooper, —, manager, Virginia Mine, Bendigo, Victoria.

Horwood, E. J., mine manager, Broken Hill Proprietary, New South Wales.

Howard, F. C., managing director, Broken Hill South, New South Wales.

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Jackson, F. B., Mount Bischoff smelters, Tasmania.

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Jones, H. E., New Moon, Bendigo, Victoria.

Kapp, T., manager, Tasmanian Smelting Company, Tasmania.

Kayser, F., late manager, Mount Bischoff, Tasmania.

King, H. S., Secretary, Mines Department, Western Australia.

Knox, Hon. W., M.H.R., Melbourne.

Leahy, J., Broken Hill Proprietary, New South Wales.

Lewis, J. B., manager, Anchor Tin-mine, Tasmania.

Loring, W. J., manager, Messrs. Bewick, Moreing, and Co., Melbourne.

Low, V. F. Stanley, general manager, Broken Hill Block 10, New South Wales.

McColl, J., Bendigo, Victoria.

Maitland, A. Gibb, Government Geologist, Western Australia.

Mathews, H., Queen Street, Melbourne.

Maughan, T., secretary, Chamber of Mines, Western Australia.

Mellor, A., secretary, Mount Lyell Company, Melbourne.

Mitchell, H., manager, Arba Tin-mine, Tasmania.

Mitchell, —, late manager, Oroya Brownhill, Western Australia.

Moore, A. J., surveyor, Broken Hill, Block 10, New South Wales.

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