GSMR6

Tasmania

DEPARTMENT OF MINES

GEOLOGICAL SURVEY

MINERAL RESOURCES

No. 6

The Iron Ore Deposits of Tasmania

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Issued under the authority of

The Honourable Sir NEIL ELLIOTT LEWIS, K.C.M.G.
Minister for Mines for Tasmania

Tasmania:
T. G. PRIOR, ACTING GOVERNMENT PRINTER

1919

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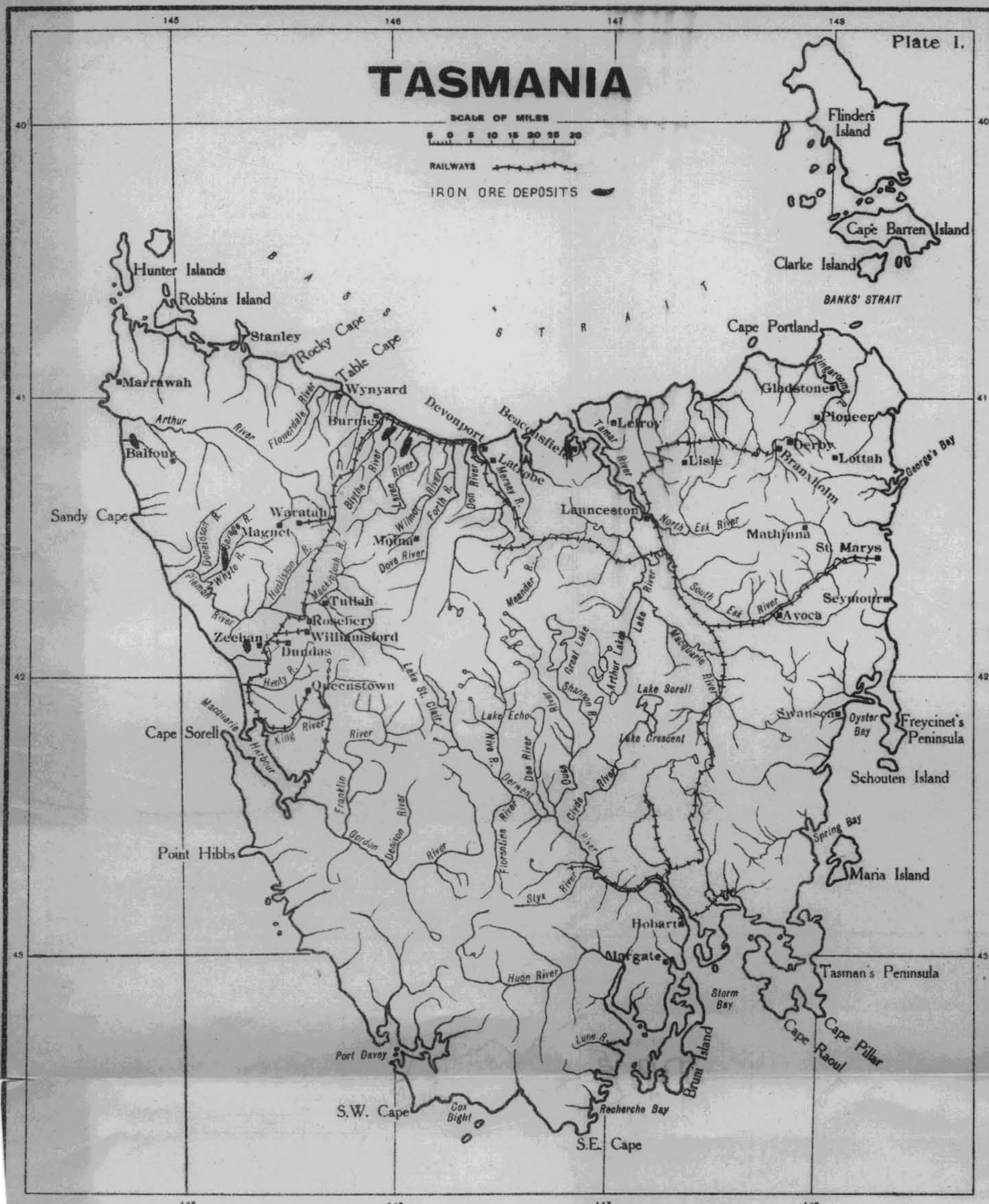

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The Iron Ore Deposits of Tasmania.

I.—INTRODUCTION.

The growing attention and interest surrounding the question of the initiation of the iron industry in this island has led to the preparation of this publication. An endeavour has been made to collect in one volume the various items of information with regard to iron ore deposts in Tasmania, which at present can only be obtained by referring to scattered descriptions, many of which are not easily accessible, and some, indeed, out of print. Some of the more important deposits have been revisited and subjected to renewed examination.

The chapter on iron ore in Long Plain and Zeehan Districts has been contributed by Mr. A. McIntosh Reid, who has lately examined the occurrences. Each author, while cognisant of the other's work, is responsible only for the contents of his own chapters.

Iron is one of the most essential metals which minister to the wants of civilised man, and, singularly enough, has at the same time perhaps the least unit value of any of the commercial metals. Statistically its output stands at the head of that of all the other useful metals; indeed, the figures representing the combined world production of all other metals are negligible compared with those referring to iron. This means that its use enters into all the departments of modern life, national and individual, and that the country which possesses large deposits of its ores, and the means of reducing them to metal, occupies an enviable position. History and experience teach that valuable iron and coal deposits are the foundations of a nation's material prosperity. The industry of iron and steel is the factor which dominates the manufacturing world.

Various attempts have been made from time to time to estimate the iron ore reserves of the world, but the data in many countries are very uncertain, and the figures put forward must be regarded as partaking somewhat of the nature of arithmetical feats, although for the moment nothing else expresses the possibilities.

The world output of pig iron annually amounts to between 60,000,000 and 70,000,000 tons. It has been thought that actual and potential reserves of ore amount to over 150,000,000,000 tons, which may contain between 60,000,000,000 and 70,000,000,000 tons of iron. In addition, there are enormous possibilities, in the shape of undiscovered deposits, which must be taken into account when considering the future of the world's supplies. Anyone who delights in making arithmetical calculations of dubious value can, by using these figures in a free way, make a show of forecasting the exhaustion of the world's iron deposits at the end of a determinate period. But there are so many uncertain and elusive factors in the problem that the conclusion, which seems so obvious, is unsafe.

The report of the International Geological Congress of Stockholm in 1910 on the "Iron Ore Resources of the World" estimated the world's reserves as follow:—

	Actual Tons.	Potential Tons.
Europe............	12,032,000,000	41,029,000,000 plus considerable
America	9,855,000,000	81,822,000,000 plus enormous
Australia	136,000,000	69,000,000 plus considerable
Asia..............	260,000,000	457,000,000 plus enormous
Africa	125,000,000	many million tons
Total	22,408,000,000	123,377,000,000 plus enormous

It is almost certain that the actual reserves are still greater than indicated in the above figures. The modest position occupied by Australia in this epitome of the world's resources is apparent, and causes one to think seriously of the future.

It emphasises, however, the necessity for making the most of the deposits available; that is to say, for testing them thoroughly, and utilising the raw material with the utmost care and to the last degree.

The iron ore deposits in Tasmania are still in an undeveloped state, and this makes it unsafe to calculate their extent on any other basis than that of potential reserves, On this basis the following figures represent an attempt to roughly estimate the possibilities of the island:—

	Potential Tons.
Blythe River lode	17,000,000
Dial Range and Penguin	700,000
Beaconsfield and Anderson's Creek..	1,300,000
Long Plain	20,000,000
Zeehan District	2,900,000
Nelson River	Unknown
Total	41,900,000

A recent report by engineers engaged by the Commonwealth for the examination of the Blythe River lode is referred to later in this bulletin. In their opinion, the lode-matter as a whole is too siliceous for a commercial iron ore. The view taken in the present publication is that until the ore-body has been effectively tested or developed, this opinion can be neither substantiated nor entirely disproved. In the meantime, the above provisional estimate is retained.

The various deposits will be described in a conservative spirit, with the view of being helpful to readers anxious to learn the facts and possibilities in connection with the iron resources of the island.

II.—IRON ORE IN THE BEACONSFIELD DISTRICT.

(1)—INTRODUCTION.

Deposits of brown hematite and magnetic iron oxide have long been known to exist in the vicinity of Beaconsfield, namely, on Brandy Creek, at the Sugar Loaf, and at Mt. Vulcan, Scott's Hill, and Barnes' Hill, on Anderson's Creek.

The first allusion on record is to the ore at the Ironstone Hills (Mt. Vulcan and Scott's Hill), a few tons of which were taken away by Colonel Paterson's "Lady Nelson" in 1805, which brought stores from Port Jackson to the new settlement at York Town in 1804. In 1865 or 1866 Mr. Charles Gould, then Government Geological Surveyor, spent some months on Anderson's Creek, opening up trenches and examining the deposits of ore. His report expressed the opinion that in the future the district would become highly important on account of the abundance of iron ore of good quality, and favourably situated for working.

In 1872, in May, Mr. T. C. Just and Mr. Jas. Scott, M.H.A., visited York Town and the Iron Hills, with the result that they induced Melbourne investors to come into a smelting enterprise, and the Tasmanian Charcoal Iron Company was floated, on 400 acres of leased land, with a capital of £80,000, in 40,000 shares of £2 each. Mr. W. Leonard was provisional manager. The present surveyed township north of the Iron Hills is called Leonardsburgh. The plan was to begin on a small scale, and make charcoal iron by the direct process in open Catalan forges, producing malleable iron blooms, to be forged into rough shaftings, &c., for the Victorian market. A jetty was built 310 feet out into the West Arm, and a wooden tramway constructed up Anderson's Creek to the mine, 5 to 6 miles distant. The company purchased 800 acres of land, with a frontage on West Arm for a township, called Port Lemprière, after a leading Victorian shareholder.

The first attempt appears to have been in a furnace designed to reduce the ore by a process invented by Mr. W. H. Harrison. Its foundation-stone was laid December 6, 1872, but the trial was not persisted in. Mr. Harrison communicated to the writer in 1902 the following information respecting what was done at the time of this trial:—

"About 30 years ago I was approached by the directors of that company, and engaged to erect a small trial plant (of a process which I patented) to see if a direct reduction of the company's valuable iron ores could be effected on a commercial basis. I accordingly put up a furnace on the mine, and, if I remember rightly, had only two or three days running, resulting in a considerable quantity of high-grade steel, from some of which a Mr. Grayson, a Sheffield cutler, of Melbourne, made a quantity of tools possessing very remarkable qualities. The tensile strength was far in excess of similar plates made from the then best manufactured steel procurable from Europe and America. From my steel, Mr. Grayson, under the hammer, made ribbons which could be tied into knots, and would nearly straighten out again to their original form. He made chisels to cut a groove along the course of a bastard file, the hammer-head of the chisel being so soft that it could be notched with a knife by hand. A bar of this steel could be cut and welded in the forge, like common wrought iron, without burning or losing its splendid qualities. So much for the kind of steel which your iron ores can be made to produce. At the time I was erecting this plant, the directors made the acquaintance of a Mr. Gray, a blast-furnace man, from Melbourne. At his suggestion my researches were discontinued in favour of the old blast-furnace operations. The chrome in these iron ores was blamed as a factor of failure. As a matter of fact, chromic acid is a factor going largely to give the splendid qualities named above."

The company, having spent £10,000 to £12,000 in preliminary work, was refloated in Victoria as the British and Tasmanian Charcoal Iron Company (capital £100,000), and a blast-furnace plant was ordered from Messrs. A. Barclay and Sons, Kilmarnock, R. Scott being appointed manager. The iron-cased cupola was put up at Port Lemprière. The bricks for the chimney-stack of blowing-engine were specially made and imported from Victoria. All the common bricks used were made at the works, the clay being ground in a steam-clay mill. On June 17, 1876, Governor Sir F. A. Weld inaugurated the new works by blowing the furnace in. Although the company was registered under the name of a charcoal-iron company, the fuel used was coke. The imported coke, which had to be lightered ashore, cost £3 per ton, so it was decided to import the coal and convert it into coke, which would then cost 25s. per ton. A range of 40 coke ovens was constructed, with a capacity of 1 ton each of coke per day. A trial charge of 20 of these was made with Bulli coal on September 4, 1876, and the results proved satisfactory.

A new deep-water jetty, 600 feet long, was built at a cost of £1500, for accommodating vessels of any draught. A line to the mines, 6 miles long, of 4 ft. 8½ in. gauge, was laid, with rails 50 lb. to the yard, and completed in May, 1876. Twenty wagons, each to carry 5 or 6 tons, were built on the works for the transport of ore, &c.

After the usual preliminary hitches, smelting fairly commenced on the 25th October, 1876. For flux, Silurian blue limestone was brought by steamer from the River Don. The furnace was blown out about Christmas, having in two months put out between 2000 and 3000 tons of pig iron, or between 250 and 300 tons per week. Some of the softer sorts realised in Melbourne, £6 10s. per ton. On the 5th February, 1877, the furnace was again in blast, and was working well. It was cast three times daily, yielding about 13 tons of pig iron at each tapping.

The presence of chrome appears by this time to have forced itself on the attention of those carrying on the enterprise. The first assays of the ore showed only small quantities of oxide of chromium. One assay yielded only traces, another 1·2 per cent., but when large quantities of ore were put through the furnace the objectionable element began to be noted in larger proportions, and the pig was found to contain from 2 to 10 per cent. of chrome. However, excellent cast steel was made in Melbourne from the purest varieties of this iron; a good deal of pig was used at Langford's foundry, and some splendid castings were produced. For such articles as stamper-heads and shoes, and for all purposes requiring a combination of hardness and toughness, the iron was looked upon as the best that had come into the Victorian market. But it was soon seen that the local market for these purposes was essentially limited; and endeavours were made to secure an outlet for the product in England. Numerous experiments and trials, made at the large iron and steel works in England and Scotland, have been detailed by Mr. T. C. Just, in his "Notes on the Iron Ore Deposits of the River

Tamar District." [1] It was mixed with other irons, tried for tools, wire, castings, chrome steel, &c.; but the net results of trials made by the largest ironmasters in the United Kingdom proved unsatisfactory, the product being too hard and brittle. The iron could not be worked by itself, was high in sulphur, was alloyed with irregular proportions of chrome, and produced brittle castings and excessively hard tool steel. The splendid appearance of the iron exhibited to the Iron and Steel Institute excited such unqualified expressions of admiration that the result of these trials caused deep disappointment. The company continued its shipments to Melbourne, but the realisations dropped to about £5 5s. per ton for the soft grey pig, which was produced in small quantities. Trials were made with charcoal fuel; the fluxes also were varied, but without success. The bulk of the iron was white and hard, and as the Australian market was too limited for the output of the furnace, it was decided, in August, 1877, to suspend operations indefinitely. At that time 4000 to 5000 tons of iron were awaiting shipment. There was some idea of procuring a complete foundry plant from England, and establishing a foundry in Melbourne for making gas and waterpipes, but this project apparently was not carried out.

As far as can be gathered from the records of the time, the total output of the furnace was about 10,000 tons of pig iron, and the quantity of ore taken from the mine may be approximately reckoned as 20,000 tons. Mr. Just, who was a director of the company, strikes a melancholy note in his report of the operations. He says [2]:—

> "Need I say that before admitting a failure we exhausted every known possible means of manipulation. Mr. Robert Scott, the manager, was an old experienced ironworks manager in Scotland, and was largely interested in the success of the enterprise. Whilst the furnace was in blast, I spent weeks with him at the works, and discussed with him night and day the experiments which were put in operation. We had a skilled analytical chemist there for some time, carefully examining what went into the furnace and what came out of it. The closest supervision was given, and details watched most minutely, but we never could get the iron sufficiently

(1) Tasmanian Official Record, by R. M. Johnston, 1891 (pp. 464-469).

(2) Tasmanian Official Record, by R. M. Johnston, 1891 (p. 470).

grey or soft, nor could we secure uniformity of quality. A great deal of iron was made equal to the best Scotch pig, but this would represent but a small proportion of a tapping, the bulk being white, crystalline, and hard. The ores for the furnace were carefully selected, and charged both raw and calcined; the quality of the limestone was watched narrowly, as also other fluxes which were tried. The fuel used was chiefly coal from Bulli Bulli, New South Wales, which was carefully coked on the works, and the coke seemed of excellent quality—at least, experts declared it could not be better. I should mention that Bulli Bulli coal was decided on after exhaustive trials of the coal from the Newcastle mines, none of which produced anything like as good coke. Operations were not confined to smelting with coke. Charcoal made from the native wood growing around was tried on several occasions, also mixtures of fuel, but all to no purpose; the product remained hard and unmarketable in quantities such as were produced. I should mention here that as an alloy the pig iron was found very valuable in the colonies for particular purposes, and the foundry masters would have become regular customers for small quantities for mixing with other irons. In the production of such articles as stamper-heads and false bottoms for quartz mills, or anything where extra hardness is required, the chromium pig was found excellent when used in the correct proportion with ordinary pig iron; but, of course, a demand of this kind would have been quite insufficient to dispose of the output of a furnace such as ours. Reluctantly, and with bitter disappointment, we had to declare ourselves beaten in the endeavour to make saleable pig iron out of the iron ores of the Ilfracombe district, and the splendid plant had to be broken up and sold. The large circular water-tanks seen along the Main Line Railway were once the shell of the first great blast-furnace erected in Tasmania, and the iron columns on which they are supported once formed the elevator by which the ores and other materials were hoisted to the tunnel-head or mouth of the furnace. ' 'Tis an ill-wind that blows nobody good,' and Mr. Grant got a great bargain in those materials."

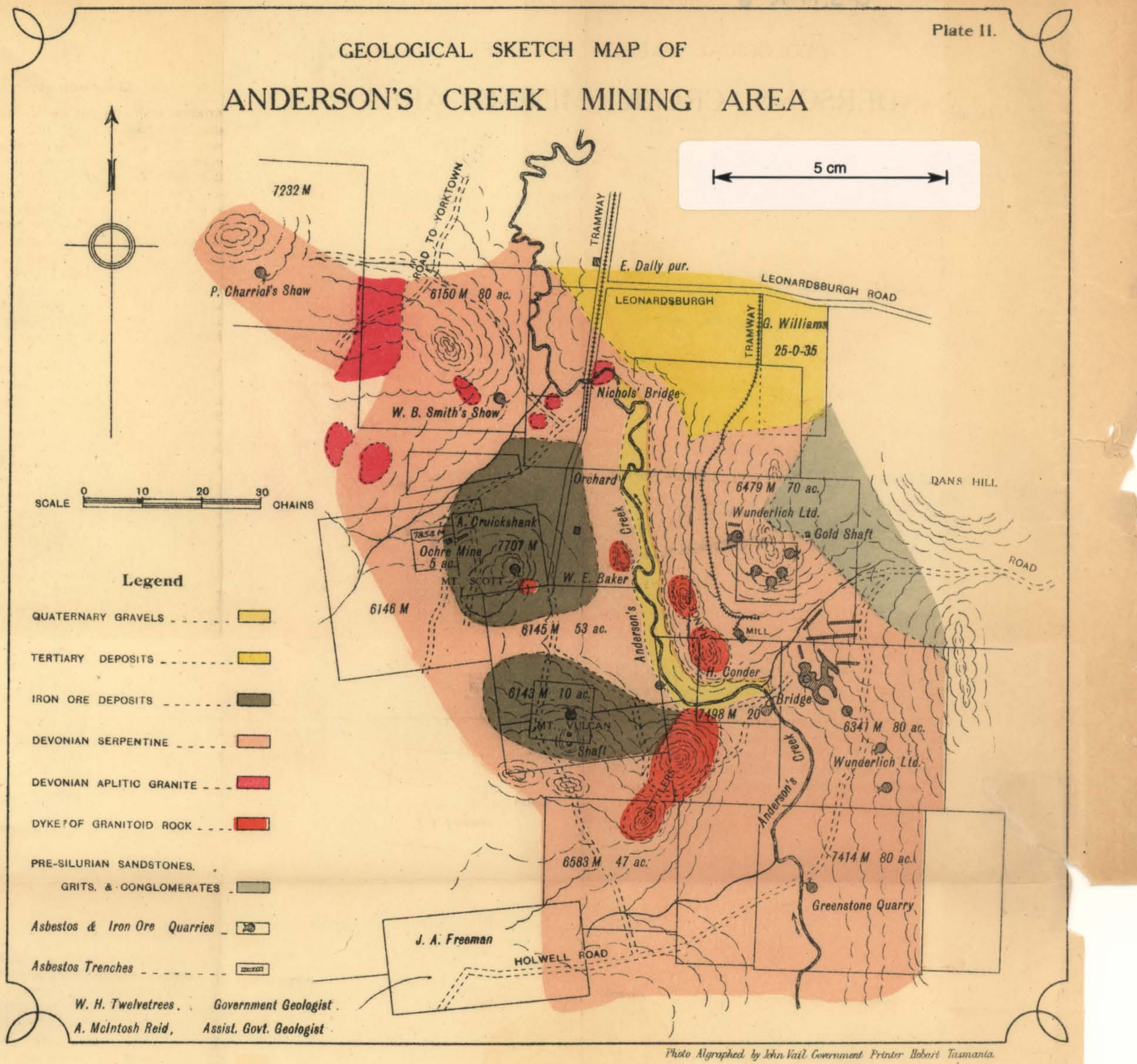


Photo Algraphed by John Vail Government Printer Hobart Tasmania.

(2)—Geology.

In accordance with the nature of this report, the geological features of the area will only be referred to in a general way. The geology of the Beaconsfield district, it may be mentioned, is very varied, and deserves a report devoted exclusively to it. Perhaps it may be possible in the near future for the Geological Survey to undertake a complete examination of the geology and topography of the entire district, and elucidate the various bearings and effects of these features on the economic deposits and the mineral industry generally. The gold, iron, asbestos, and limestone resources of the district, even making allowance for all that has been done in the way of gold-mining, still, it may confidently be affirmed, await their full development, and will no doubt sooner or later receive the attention to which they are entitled, by reason of their intrinsic value.

The country from the Tamar River to a line some 5 or 6 miles west of Beaconsfield ranges itself in a general way into separate zones of industrial geology. Speaking broadly, there is the gold belt of Beaconsfield, succeeded by the asbestos belt of the serpentine rocks bordering Anderson's Creek; associated with the serpentine is a chromiferous ironstone zone; and, finally, the lofty Asbestos Range, which forms a majestic line of mountain heights bounding the western horizon, and terminating to the north at Badger Head, on Bass Strait, is the imperfectly prospected home of copper ores. It may be here pointed out that the name "Asbestos Range" is a misnomer, for geologically it is composed of micaceous schists, grits, slates, and clays, in which asbestos is not present. These are among the most ancient strata in the island (Pre-Cambrian), and are the foundation rocks on whch the succeeding strata have been laid down. The following beds here are the Ordovician and Silurian strata of Beaconsfield (sandstones, slates, conglomerates, limestone), the most westerly occurrences of which occur at Dan's Hill, 2 miles west of the township. Between here and the Asbestos Range there is an intrusion of serpentinised ultra-basic rocks, forming the asbestos and iron belt on each side of Anderson's Creek, about 1½ mile in width and some 4 miles in length. The original rocks of this igneous intrusion were the felspar-less varieties known as peridotite and pyroxenite. These have undergone serpentinisation, and are traversed by veins of asbestos (chrysotile and amphibole asbestos). Veins of fibrous magnetite occur in the serpentine, especially on the meridian of the Ironstone Hills.

In the serpentine area are several small exposures of granite. In nearly every instance the granite is of pegmatitic character, sometimes showing a graphic structure. Mica is subordinate in these granites, but amphibole in long-bladed forms is seen occasionally. These occurrences suggest the proximity of an underlying granite mass, which has originated the serpentinisation of the ultra-basic rock and caused the formation of veins of asbestos and magnetite. The points at which the intruding granite has been observed are the following:—

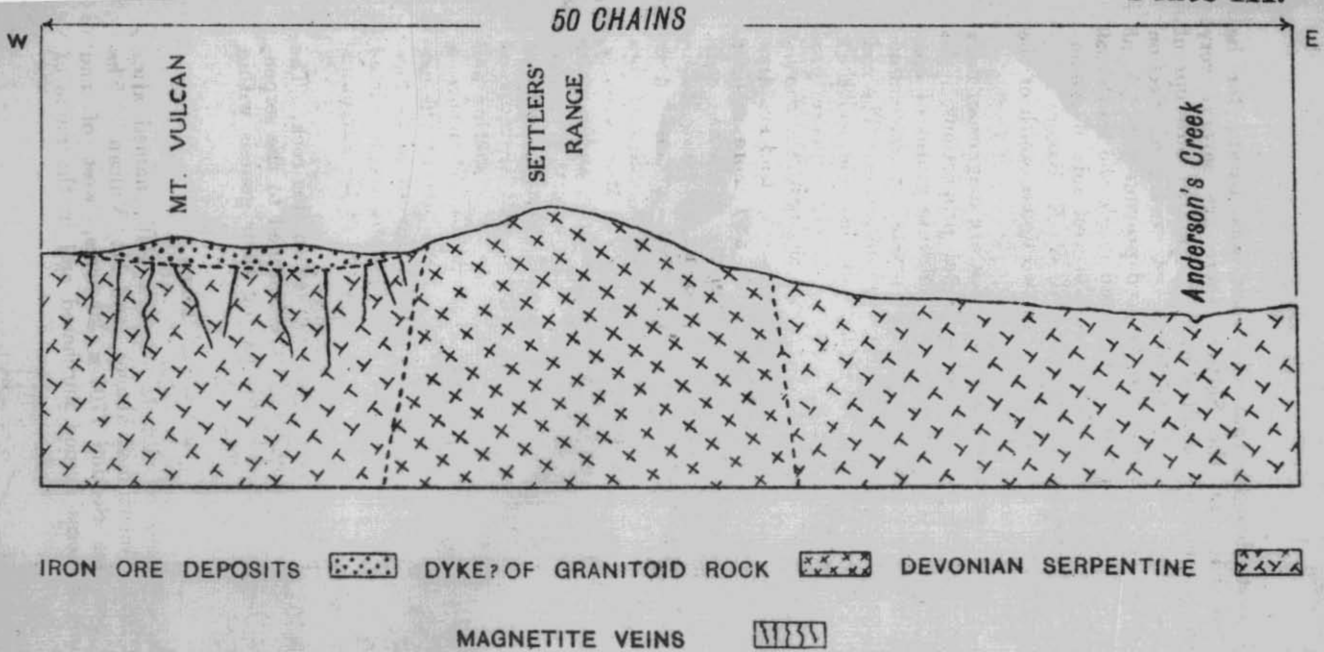
(1) On Charriol's asbestos section (7232-M, 80 acres), along the east boundary-line, and extending eastwards into the adjoining section (6150-M, 80 acres). Hornblende common in this rock.
(2) Another exposure ½-mile north-west of the above.
(3) East of Section 5116-93M, 10 acres.
(4) About a couple of hundred yards south-west of Nichol's Bridge.
(5) On the north bank of Anderson's Creek, east of Nichol's Bridge.
(6) Associated with scapolite in the old hill quarry in the north-east corner of the asbestos section (6340-M, 10 acres), near Dan's Hill. The vein is now hidden by talus, but loose white boulders lie about the entrance to the quarry.
(7) On Lot 730, W. Barnes, 640 acres. Shown by a few stones at the foot of a tree 5 or 6 chains east of Anderson's Creek, and 2 chains south of what used to be Gale's gate, on the northern boundary-line of the land. Now difficult to find, as fence and gate have been destroyed by fire.

It is interesting to note that similar occurrences of aplitic and hornblendic granite are met with in the serpentine asbestos fields in Canada near the mines at Thetford and Black Lake.

(3)—The Settlers.

A ridge of dark granular, igneous-looking rock, ¾-mile long by 10 or 12 chains wide, rising into four domes or rounded summits, pursues a roughly north and south direction on Sections 6583-M, 7498-M, and 6479-M. These summits used to be known locally as the Settlers. Mr.

Plate III.



Ideal Section through Mt. Vulcan & Settlers' Range

T. C. Just thought that the rock was basalt, for he reported that "at the Settlers there are several very curious mounds of basaltic rock." Parallel outcrops of identical rock occur at the south-east corner of Section 7707-M, 20 acres (formerly 6144, and previously 6143), at the southern foot of Scott's Hill; and inside the south-east corner of Mr. Williams' land, on the west side of Anderson's Creek (charted in the name of W. E. Baker).

The crest of the main ridge has two domes south of the creek, and two north of it.

The constituent minerals of the rock are magnesian mica (biotite), quartz and felspar in equal proportions. The felspar is thoroughly decomposed. Minute grains of apatite are present, and an occasional crystal of tourmaline. Indications of strain and pressure are noticeable. The rock has a massive, igneous appearance in the field, with an occasional tendency to schistosity, which is more pronounced in microscopic slides. From the first, the Survey regarded it as being some modification of an acid eruptive though it has become gradually more and more inclined to interpret its characters as evidencing a crushed sedimentary of the greywacke type. The late Professor Rosenbusch, to whom a sample was submitted, professed himself unable to recognise in the microscopic slide any sign of the normal structure of an igneous rock. More recently, Dr. E. W. Skeats examined it very carefully, and came to the conclusion that it was originally a rather coarse-grained sedimentary rock, consisting of quartz, aluminous and argillaceous material, and some partly decomposed felspars; *i.e.*, such a rock as an arkose or felspathic and argillaceous sandstone, and that its present structure is the result of contact metamorphism. At present the evidence, though not decisive, is rather in favour of its having been a sediment which was crushed and reconstructed as a consequence of the heat and pressure of the surrounding serpentine.

No mineral veins have been observed in this rock. The magnetite veins of the district are confined to the serpentine, both iron and asbestos, having their genesis within the latter.

(4)—Ironstone Hills.

These are two in number—Scott's Hill, named after Robert Scott (mentioned above); and Mt. Vulcan. The former occupies Section 7707-M, 20 acres, west of and adjoining 36 acres 1 rood purchased and in the name of

W. E. Baker (now owned by Mr. Williams). Mt. Vulcan is between 20 and 30 chains S.S.E., occupying the 10-acre Section 6143-M.

Mt. Vulcan.—This hill supplied practically all the iron ore for the old furnace at Port Lempriere, very little, if any, having been used from Scott's Hill. The whole width of the belt of red soil which indicates the iron formation is about 1500 feet, and it continues through the entire section of 10 acres. At the foot of the northern slope is the principal quarry, which has been cut into the hill for a little over a chain, showing a fence 170 feet in length. A chain and a half east of this is a smaller quarry in the same formation.

The precise nature of the deposit has been somewhat puzzling ever since Mr. C. Gould reported on it in 1866. He says: (3)

> "In each case the main part of the deposit commences on the crown of a hill, and consists of large rounded boulders heaped on one another, or protruding from the surface of the soil. On fracture they are found to consist of alternate layers of brown hematite and earthy matter, the richness varying, of course, with the relative portions of these two, and varying so much that it would be unsafe from surface knowledge to offer any estimate of the total amount or proportion of rich ore. I have contented myself with charting as accurately as I could the whole area within which these boulders occurred. It will be seen that in the one instance this area is about 360 yards long by 70 broad, and is of an elongated form extending to the north-east. In the other it is sub-rectangular. To a cursory observer the appearance of these deposits is very anomalous, presenting, as I before said, that of a capping on the summit of each hill of from 15 to 20 feet in thickness of large rounded boulders, ranging up to one or two tons in weight, all more or less good ore. How it got there, or where it came from is, then, the question. On extended examination I found that although the boulders cropped more or less over the area included in No. 1 and No. 2, yet they occurred in chief abundance in the direction of certain lines indicated on the charts by the small oval marking, and could be traced in those directions

(3) Geological Surveyor's Report of the Country near Ilfracombe, in the West Tamar District, by Chas. Gould, August, 1866, House of Assembly Paper No. 76.

down the hills into the adjoining flat, and that many contained fragments of the magnetic oxide, together with other indications of their being of a derivative character. I therefore infer that the value of these deposits is very imperfectly represented by the surface masses, which I look upon as having been derived from the destruction of rich iron ores, such as magnetic oxide or crystallised hematite (probably the former). It is also likely that they are nothing more or less than what miners call the back of strong lodes of magnetic oxide of iron, which would in that case be discoverable by mining operations conducted beneath the hills indicated on that vein. In fact, the drift below points to the existence of veins of magnetic oxide of some size, while the magnitude of the surface deposit renders it probable that that size would be considerable. I consider that eventually these spots will become of great value."

The red hill drift or soil consists of loose earthy-brown hematite mixed with a certain proportion of red hematite and magnetite. The writer described it in 1903 as follows:—(4)

"The slopes of the hills, as well as most of the country between them, are strewn with red hill-drift, consisting of brown hematite and magnetite. The drift passes downwards into layers of soft earthy hematite, sometimes hard and cellular, or partially crystallised and nodular, and into serpentine clay, the whole resting ultimately on solid serpentine, which may in places be bedrock, in others wall-rock. Pieces of crystallised columnar magnetite are found in the red ochreous drift, and veins of the same mineral exist in the serpentine. Some of the iron ochre on the hill flanks is now being screened and shipped to Melbourne in small quantities. The tops of the hills show large boulders of iron ore lying upon and embedded in the ochreous clay and drift. This is a common feature of all the deposits; the boulders are no doubt concretionary, and are exposed to the denudation of the surrounding soil. The quarries which have been cut in the hills show similar boulders at different depths, forming part of deposits of red and yellow earthy hematite."

Particular search was made on this visit for pebbles or foreign rocks in the deposit, and especially in the boulders, as a little silica had been observed in them previously, sug-

(4) "Report on the Mineral Resources of the Districts of Beaconsfield and Salisbury," by W. H. Twelvetrees, 8th May, 1903.

gesting transport, particularly as the country to the north has a thin covering of alluvial lying on the serpentine rock. The difficulty experienced in obtaining satisfactory evidence leads the writer to the belief that the grains of silica which have been noticed in the boulders may have been chalcedonic and pertaining to the serpentine bedrock.

Little nodules of magnetite and flakes of bronzite are occasionally seen, but none of these inclusions seem to be water-worn. The analyses reveal nothing which would indicate bog or lake ore. Bog ore is always limonite, hydrated oxide of iron, whereas this has an admixture of anhydrous ores (hematite and magnetite). It is also without the phosphorus content which characterises bog iron ores, and the silica content is lower than is usual in the latter.

All the evidence points to the deposit being a residual mantle of ore resulting from the decay of the serpentine rock *in situ*. In this process the iron ores in the parent rock were in the main converted into limonite, some of them, however, surviving as hematite and magnetite. The chrome contents have been derived from the serpentinised rock, in which chromite is an original rock-forming constituent. Some dehydrating action has induced the formation of concretionary and cemented masses within the deposit, met with as boulders or flat tabular bodies harder than the surrounding unconsolidated granular pulverulent or clay-like material.

In some parts of the serpentine area, especially in the parts where asbestos is abundant, veins of fibrous magnetite are very frequent. Sometimes magnetite and chrysotile asbestos are present, intimately associated in the same vein, leading the casual observer to conclude that one material is a replacement form of the other. Minutely examined, however, the connections are seen to be abrupt, and cases of partial substitution are absent. The identical habit of the two minerals in such veins suggests that the fibrous crystallisation of both was contemporaneous. Other veins consist of pure fibrous magnetite. These veins exist from the size of mere threads to a width of inches. The veins both of chrysotile and magnetite in all probability were genetically associated with the serpentinisation of the peridotite rock.

The present quarry is in a semi-ruined state owing to its long abandonment and the walls having fallen in to some extent. Visitors from the mainland occasionally view it, having heard of the iron deposits, but in its present condition it is not calculated to give a good impression of one of the iron shows of the State. It would probably be good policy on the part of the Government to pay a couple of men for three or four weeks to clean down the old faces and clear the floor of fallen overburden. The quarry would then be in a fit state for inspection.

About 170 feet south of the main quarry is a small shaft some 20 feet deep in the soft limonite and ochreous formation of which the hill consists; and 120 feet still farther south is Scott's shaft, on the crown of Mt. Vulcan. In this belt boulders of loose, and embedded boulders of consolidated, limonite, with enclosed fragments of fibrous (needle iron) magnetite, are plentiful.

The summit of Mt. Vulcan is 200 feet above creek-level. As regards the persistence of the ore in depth down to the level of the creek, the old bores are really the only data which can be produced. Three bores were put down at the time of the British and Tasmanian Charcoal Iron Company—two on the hill and a third one somewhere at its base. The No. 1 or Scott's bore at the shaft was put down 176 feet, and the serpentine bedrock struck at 52 feet from surface. The register is as follows:—

	ft.	in.
Ironstone	24	0
Hematite	6	6
Ironstone	5	6
Heavy black sand, mostly iron	4	0
Soft ironstone	2	0
Heavy hard ironstone	2	6
Brown hematite	7	6
Decomposed serpentine	30	6
Hard serpentine	5	6
Serpentine mixed with asbestos	6	6
Serpentine and asbestos with magnetite...	2	0
Very hard serpentine and asbestos	0	6
Hard serpentine	2	6
Very hard serpentine	1	6
Very hard serpentine with magnetite veins	9	0
Ironstone	5	6
Greenstone	14	0
Serpentine with asbestos	13	0
Serpentine with asbesos and iron ore	9	0
Iron ore	0	2
Serpentine with veins of magnetite	16	4
Iron ore, very hard, dense, and pure	6	5
Serpentine with asbestos	1	6
Serpentine	2	1
Total (feet)	178	0

No. 2 bore, also put down by Mr. Scott, showed much the same features. Its register is the following:—

Bore No. 2.

	ft.	in.
Ironstone	19	0
Sand with ironstone pebbles	5	6
Magnetite	8	6
Decomposed greenstone	24	6
Serpentine	12	6
Total (feet)	70	0

Water prevented further boring.

Bore No. 3.

	ft.	in.
Ironstone	19	6
Clay with iron pebbles	19	0
Oxidised conglomerate and magnetite	10	6
Pure magnetite	1	6
Decomposed greenstone	29	0
Hard rock, supposed to be ironstone, broke auger	8	0
Total (feet)	87	6

These bores support the view that the brown iron ore-body consists of a mantle about 50 feet in thickness, lying at that depth on serpentine rock veined with magnetite, from which it has been derived by decomposition.

A good many fragments of fibrous magnetite can be picked up on the surface of these hills, and veins of the same mineral may be seen in the serpentine which has been worked for asbestos by Mr. W. B. Smith west of Nichols' Bridge over Anderson's Creek. Whether the magnetite veins below the ironstone deposit are sufficiently numerous or wide enough to permit of profitable working once the oxide mantle has been removed is, however, problematical. For the present, at all events, this mantle must be regarded as the commercial asset of the proposition.

The dimensions of this mantle, horizontal and vertical, need to be ascertained and verified before any sound calculation of quantities can be made. The surface indications on Mt. Vulcan embrace the whole of the area of the 10-acre section; and on Scott's Hill the whole of the original

40-acre section. But from the width of the belt along which the surface boulders are most numerous, one would judge that the best part of the Mt. Vulcan deposit is from 200 to 300 feet wide—that is, if the boulder-bearing part of the deposit is taken as being the most solid and concentrated. But it is very evident that the carrying out of a comprehensive boring scheme, which need not be very expensive, is necessary to define the limits of the whole deposit.

The 10-acre lease could be quickly bored with a hand-drill with auger bits, drilling holes 100 feet apart along meridians and lines of latitude. Where necessary the distance could be reduced to 50 feet. The depths to bedrock would no doubt be variable, but would probably not exceed 50 feet. Sampling results from these holes would furnish reliable data for calculating tonnages and values; and until some such work is accomplished, estimates can be no other than speculative guesses.

Mr. Robert Scott made an estimate of furnace ore derivable from Mt. Vulcan in the following terms:—

> "By further explorations and borings I found that the quantity of hematite ore might safely be estimated at one million tons, or sufficient to produce 20,000 tons of cast iron annually for the next 25 years."

This might well be if the hill consisted of iron ore down to creek level, but for the reasons mentioned above the writer is of the opinion that it is highly probable that the mantle of ore is not more than 50 or 60 feet thick, in which case a generous estimate of the Mt. Vulcan deposit would not exceed half a million tons. The same quantity possibly exists on Scott's Hill, so it is likely that nearly one million tons of ore cover these two hills.

The bulk of this consists of fines, only a small proportion being consolidated, and the quality is far from being uniform throughout. The deposit no doubt rests on a mass of serpentine containing veins of magnetite, but, as said above, for the present the commercial value of the ore resides in the mantle deposit.

Scott's Hill.—A small cut or two may be seen on the low elevation known as Scott's Hill, 30 chains north of Mt. Vulcan. These were only trial excavations, and it does not appear that any supplies from this hill were taken to the furnace.

The ore is red and yellow soft limonite, very little of it really hard. The hill is low, from 80 to 100 feet high, about 25 chains in length from north to south, and 10 chains wide. The general occurrence is similar to that on Mt. Vulcan, though the ore is generally softer and more inclined to be ochreous. On the west side is a long open drive, from which material has been taken by the Serpentine Paint Company for its factory in Launceston, but this enterprise will be discussed later in the present report.

(5)—Quality of Ore.

Samples of iron ore from Mt. Vulcan were submitted by the writer in 1903 to Mr. W. F. Ward, the Government Analyst, who reported as follows:—

	Per Cent.
Iron as peroxide ...	75·80 = 53·06 metallic iron
Silica	5·40
Sulphur	0·13
Phosphorus	Minute trace
Chromium oxide ...	5·90
Alumina	4·30
Loss on ignition ...	7·30
Total	98·83 per cent.

Mr. Just reports an analysis of the pig iron from Mt. Vulcan ore made by Dr. R. C. Moffat as follows:—

	No. 1. Per Cent.	No. 2. Per Cent.
Metallic iron	89·72	97·82
Metallic chromium	9·27	1·43
Sulphur and phosphorus ...	Traces	Traces
Nickel, cobalt, manganese..	—	None
Tin, antimony, molybdenum	—	Traces
Nitride of titanium .... / Titanic acid .... / Silica .... / Oxides of vanadium and carbon	1·01	0·75
	100·00	100·00
Specific gravity	7·55	6·10

The same year (1877) analyses of the Mt. Vulcan pig iron were also made by Mr. E. Riley, London, who was considered one of the best authorities on iron in England. The figures were as under:—

	No. 1. Per Cent.	No. 2. Per Cent.
Carbon	4·200	3·270
Silicum	·976	·124
Sulphur	·207	·562
Phosphorus	·055	·054
Iron	88·343	91·362
Chromium	6·287	4·143
Manganese	Nil	Nil
Copper	Traces	Traces
	100·068	99·515

Samples taken by the writer on this visit have been assayed by Mr. W. D. Reid in the Geological Survey Laboratory, Launceston, as follows:—

	Mt. Vulcan (cemented material).	Mt. Vulcan (loose material).	Scott's Hill.
	Per Cent.	Per Cent.	Per Cent.
Iron	54·2	40·1	56·3
Alumina	6·93	19·22	5·87
Silica	3·30	7·60	2·96
Chromic oxide	2·53	2·71	1·80
Sulphur	0·16	0·09	0·12
Phosphorus	Trace	Trace	Trace
Loss on ignition	9·80	13·30	8·60

In chromiferous ores the oxide of chromium is reduced in the smelting process, and the chromium passes into the pig iron, uniting with the carbon and iron and forming a double carbide of those elements, very hard and brittle. One per cent. of chromium is stated to have the effect of making the iron quite hard, and 2 per cent. unfitting it for foundry purposes, leaving a market outlet only for certain steel works purposes.(5) As the chrome content rises, more of it enters the slag.

In 1903 the writer sent the analyses of some of the Mt. Vulcan ores to some of the large ironmasters of the United

(5) But see what is reported later respecting foundry iron from the Mayari chromiferous ore. (Cuba)

Kingdom, who replied with their opinions. Messrs. John Brown & Co., of the Atlas Works, Sheffield, reported that the composition is too variable for any reliable work to be done with it, but that if the pig were as good as Swedish, and with a regular percentage of chrome, armourplate makers could use it. Krupp's agent in London at that time stated that it was not suitable for their works. Messrs. Cammell & Co., Cyclops Works, Sheffield, wrote that the results of the smelting of such ores had not been very satisfactory, owing to the irregularity and great density of the iron produced; also to the great expense of smelting. The Barrow Hematite Steel Co. Ltd. stated that they were not aware that any great advance had been made during recent years in the way of utilising ores which contained a percentage of chromium. The previous year they had made experiments with an ore containing from 2 to 4 per cent. of chromium, with the object of using some ores of this class from Greece, but the result was most unsatisfactory, for they had to give up all ideas of using ores of that kind, even in small quantities.

In 1897 Mr. W. C. Dauncey, C.E., in a paper on the iron deposits of Tasmania, read before the Royal Society of Tasmania, suggested that a mixture of two ores—chromiferous and non-chromiferous—might be made in smelting, or a percentage of the chromium pig could be added to the pure pig when melting for the production of steel. The latter could be done by melting pure pig in the Bessemer converter, and adding the necessaary quantity of chromiferous pig; then agitate to ensure perfect mixing, and cast into ingot moulds. He considered that a ready sale could be got for the produce, "providing buyers knew that they could buy such material, and could rely upon getting a steel containing the necessary percentage of chromium, and not varying between a maximum and a minimum with a wide range."

It must be admitted that the outlook some years ago was not promising with respect to the possibility of utilising the Anderson's Creek ores. The writer, however, is of opinion that at the present time the position has become more favourable. This view is founded on the fact that iron ores containing low percentages of chromium are now being mined and marketed in different parts of the world.

This particular Tasmanian type of iron deposit is not quite unique. Elsewhere there are also occurrences of iron ore with a low percentage of chromium, and what is more to the point, some of them are being utilised. The Anderson's Creek deposits may be particularly compared with the brown ore-bodies of the island of Cuba. Residual masses of ore, described as mantle or blanket deposits, occur in that island, forming a bed derived from the decomposition of serpentine rock, into which it passes at depths varying up to fifty or (in a few cases) a hundred feet. It consists of red and yellow iron oxides, hydrated and anhydrous, with a certain proportion of magnetite. These are in a loose and finely divided condition, with abundance of shot-like concretions in the upper parts of the mass. Disseminated through the mantle are concretionary and pisolitic recemented masses. The lower part of the ore-body is largely composed of yellow oxides of a clayey appearance, but it is described as a commercial iron ore from the grass roots down to the surface of the unaltered rock. The estimated tonnages are enormous, amounting to nearly two thousand million tons of ore. Like our Anderson's Creek deposits, these Cuban ore-bodies contain a small percentage of chrome—1·7 per cent., 1·8 per cent., 2 per cent., and 2·39 per cent.—a somewhat lower content than that of the Tasmanian ore.

In a paper on "The Characteristics and Origin of the Brown Iron Ores of Camaguey and Moa, Cuba," by W. L. Cummings and B. L. Miller, 1911 (see Trans. Amer Inst. Min. Eng., 1912, Vol. XLII., p. 137), it is stated that the Pennsylvania Steel Company and the Maryland Steel Company have successfully used the chromiferous Cuban ores and established their value. Further, in a paper in the same volume on the "Iron Ore Deposits of the Moa District, Oriente Province, Island of Cuba," by J. S. Cox, Jun., the author makes the following interesting remarks:—

> "In the furnace the high alumina content complicated the slag calculations, and, since pig iron was produced, the elimination of the chromium was essential to the production of satisfactory steel. A detailed description of how these several problems have been met would form a paper of some length. It is sufficient here to say that the Pennsylvania Steel Company, the parent company of the Spanish-American Iron Company, has worked out practical solutions of all these difficulties in the case of the Mayari ores, and the results are applicable to the similar Moa ores" (p. 87). . . . . .
>
> "Partial or complete elimination of the chromium and the production of a satisfactory steel were accom-

plished after patient experiment. Steel rails made from this ore have demonstrated their superiority over ordinary rails by actual use on the Horseshoe Curve of the Pennsylvania railroad. For more than a year the Pennsylvania Steel Company and the Maryland Steel Company have manufactured commercially from Mayari ore a steel which, by reason of its nickel content and low phosphorus, is superior to the ordinary Bessemer and open-hearth products " (p. 88).

An average result of 59 analyses of the Mayari ore referred to is given at page 111 of the volume quoted from, as follows:—

	Per Cent
Silica	3·72
Alumina	9·63
Iron	47·60
Chromium, nickel, and cobalt	2·95

A works analysis of the ore as mined is as follows:—

	Per Cent.
Iron, natural	36·5
Iron, dry	50·34
Silica	3·75
Alumina	10·0
Phosphorus	0·01
Sulphur	0·18
Moisture	27·50
Combined H_2O	10·50
Manganese	0·64
Chromium	1·40
Nickel and cobalt	0·72

The Anderson's Creek ore differs from the above in containing less alumina, more chromium, and no nickel. The nickel of the Cuban ore has no doubt contributed to the high quality of its steel, and the chrome remaining in it has probably assisted in the same direction to a less extent. The absence of nickel from the Tasmanian ore may be a disadvantage.

In the " Mineral Industry for 1912 " (p. 495) it was stated that a new and natural alloy of iron, nickel, and chromium attracted much attention, and was being sold under the name of " Mayari Steel." The product was essentially pig iron smelted from the Mayari ores of Cuba, and then purified in an open-hearth furnace. This steel is being used where extreme strength or hardness combined with ductility is desired, and has been in demand for rails, shafts, tools, springs, &c.

Some of the iron ore deposits in Greece are in the form of beds resting on a floor of serpentine rock, and the ore contains from 2 to 3½ per cent. of chromium. Grecian ores are exported to European furnaces, but there is only a limited demand for the chromiferous varieties.

Other occurrences of chromiferous iron ore are mentioned in the literature of the subject. Thus the Clealum iron ores of Washington are lenses of hematite and magnetite lying on an old eroded surface of serpentine rock, from which it is supposed to have been derived; the occurrence, however, is not strictly parallel, as the formation is believed to be sedimentary. A feature in its composition, however, is that it carries from 1·9 to 5·2 per cent. of chromic oxide.(6)

Another occurrence is on Staten Island, New York, where some small deposits have been described as consisting of brown iron ore resting on serpentine rock, from which it has been derived as the result of subaerial decay. It, too, contains from 1 to 2·81 per cent. of chromic oxide. It was reported as being mined in 1886.(7)

The writer has been in communication with the Bethlehem Steel Company, Bethlehem, Pennsylvania, which a few years ago took over the Pennsylvania Steel Company, which latter company in turn controlled the Maryland Steel Company. The one operation on the Mayari ore is now being directed from the office of the Bethlehem Steel Company. Some interesting information has been received from the latter company with reference to this ore. The company's Cuban deposits are being worked at the rate of about 350,000 tons of nodules per annum, though just at present there is a temporary stoppage of operations in consequence of a scarcity of shipping. Steel rails are not at present made from Mayari ore, its use being generally confined to steel that can be heat treated. It is claimed that by a slight modification of the open-hearth process this steel is produced without the necessity of adding the alloying elements in the furnace or ladle, hence insuring uniformity in their distribution throughout any heat.

(6) "Contributions to Economic Geology, 1907," United States Geol. Surv. Bulletin 340 (p. 325).

(7) *Ibid.* (p. 326).

The pig iron produced from the ore is a chrome-nickel iron having the following general composition:—

	Per Cent.
Carbon	4·67
Manganese	·9
Phosphorus	·047
Sulphur	·011
Nickel	1·3
Chromium	2·66
Vanadium	·05
Titanium	·18
Copper	·035
Silicon	·80

It is a hard, dense, and brittle metal, a little heavier than ordinary pig iron. It has a large crystalline structure, somewhat similar to spiegel iron, cannot be drilled, and breaks up considerably when handled. In practice it is mixed with the different foundry irons in order to obtain the composition required. The makers state that in the general run of foundry work for miscellaneous castings an addition of 10 to 15 per cent. of the pig to the regular foundry mixture will produce excellent castings. They state that chilled rolls containing 20 to 30 per cent. of Mayari pig have given three to four times the service of ordinary chilled rolls, and that the presence of chromium and nickel in the iron give it a peculiar adaptibility for chilled work of any character. It is not recommended for all purposes, but for castings where closeness of grain, chill, strength, or service is essential.

The raw ore is described as being very similar to a loose non-plastic clay, a description which might also be applied to the Anderson's Creek ore. The best furnace results have so far been obtained by submitting the ore to a preliminary treatment. Nodulising it in kilns is the process principally employed, though it is believed that sintering will eventually be found more satisfactory, on account of saving in fuel and the more open and porous character of the material produced. The nodulising kilns are 125 feet long, 10 feet in diameter, and turn out about 8 tons of finished product per hour. Powdered coal is used as a fuel, about 400 lb. being required to produce a ton of the nodules.

(6)—Barnes' Hill.

This hill is on the 640-acre Lot No. 730, about 1½ mile south-east from Mt. Vulcan, and ½-mile east of Anderson's Creek. A fair bush road connects with the main road to Beaconsfield. All round the base of the hill, and ascending its slopes, is the familiar red ironstone soil. The hill itself evidently has a subtratum of serpentine rock, intersected here and there by veins of asbestos and fibrous magnetite. It is flat-topped, and in the limonite soil, both on the hill flanks and at its summit, soft boulders of iron ore are abundant. The strongest line of these appears to run north and south for a distance of 1200 feet, with a width of 300 to 400 feet. Outside these limits the stones of iron ore are scattered more sparsely, but the belt of red soil is still wider, and it is probable that the whole area of the occurrence is as much as 1000 feet square. The nature of the occurrence is similar to that at Mt. Vulcan. Some solid boulders of concretionary ore have been exposed by shallow excavations, and cuts a few feet deep have been put into the ground without showing any change in the character of the deposit. There are no proper data available for estimating the thickness of the mantle of ore, and in the absence of these it will be best to refrain from attempts to calculate tonnages. Quarries can be opened out with ease on the western brow of the hill, and the output sent down by tram to any level selected for the horizontal tramway to connect with Mt. Vulcan; or, if desired, a connection can be effected with the Sugar Loaf. When operations are resumed in the neighbourhood, this orebody ought to form an essential part of any scheme.

The ore is chromium-bearing, as will be gathered from the following analyses:—

(No. 1 analysis was made by Mr. W. F. Ward, Government Analyst, of samples taken by the writer in 1903; No. 2 was made by Mr. W. D. Reid, Government Assayer, of samples taken on the present visit.)

	No. 1. Per Cent.	No. 2. Per Cent.
Iron	50·54	47·80
Silica...	6·50	3·80
Sulphur	0·14	0·11
Phosphorus...	Traces	Traces
Chromium oxide	6·90	4·25
Alumina	4·00	11·88
Loss on ignition	8·70	11·81

Judging from the fine body of iron ore on this hill, the veins of magnetite whence it was derived must be unusually numerous, but to what extent they are developed can only be ascertained when the works bottom on the serpentine.

(7)—Concluding Remarks on the Anderson's Creek Deposits.

That the chromium content offers a difficulty has to be conceded, but a similar difficulty has apparently been overcome in other parts of the world, and with the approaching establishment of the iron industry in Australia and Tasmania, these fine deposits of ore, surrounded by abundant timber, near ample supplies of limestone flux, and within easy reach of deep water, ought not to be suffered to lie neglected just because some trials many years ago were not successful. With new trials, based on the most recent advances in metallurgical technique, the result might now be very different, and the undertaking is commended to any who are prepared to go thoroughly into the matter and assist the State to turn these ores to practical account.

The location of the furnace will depend largely on what plan of work is finally adopted. If it is intended to reduce the chromium content to some extent by blending with the Sugar Loaf chrome-free ores, the furnace would probably be erected where the old Ilfracombe Company's furnace still stands on Hind's farm, at the base of the Sugar Loaf (Lot 571, 640 acres, John Munro), close to the Sugar Loaf iron lode. The Anderson's Creek ores would then be trammed to that locality. Inexhaustible supplies of high-grade limestone exist about 1½ mile to the south. A tramway-line would have to be constructed from the furnace to Beauty Point for the transport of the iron to the port.

If, however, work is started at Mt. Vulcan, the furnace will probably be again erected on the shore of the West Arm. In this case it would be open to use coke as fuel if desired; while at the Sugar Loaf considerations of cost would most likely dictate the employment of charcoal. In either case, the State hydro-electric current would be a valuable asset in the process of reduction to metal.

(8)—Sugar Loaf.

Two miles south-east of the Barnes' Hill deposit is the Blue Peaked Hill, or Sugar Loaf, where there is a well-known lode of brown hematite, which was worked in 1872-3 by the Ilfracombe Iron Company, and was known by the name of the Ilfracombe Iron Mine.

The old Ilfracombe Sawmill Company had a tramway passing this spot, and this probably gave rise to the name "Ilfracombe" being adopted by the mining company, and attaching to the ore. In Mr. J. Hines' field, on Lot 571, 640 acres, in the charted name of John Munro, is the shell of the company's blast furnace, which appears to have been the oldest furnace in the district. It was erected under the direction of a manager from Victoria, but it is said that as a consequence of faulty construction, the metal could not be got to flow. After abortive attempts, and spending nearly £10,000, the company suspended operations in 1873.

At the foot of the range is an old ore pile, indicating that open heap calcination of the ore was resorted to, with a view of driving off the contained water previous to smelting

The lode courses up the hill in a direction N. 30 degrees E., and the outcrop shows some very large masses and boulders protruding through the rather dense scrub. The latter prevents the actual width of the lode from being ascertained on an ordinary visit of inspection. Mr. Gould, who reported on it in 1866, estimated the horizontal length of the outcrop as 286 yards, and its average width 66 feet. He calculated the tonnage above water-level as 705,800 tons, or, deducting half for inferior quality, a net quantity of 350,000 tons of rich ore. The average quality of the ore over a large portion of the lode he estimated as being from 55 to 60 per cent. The quality deteriorates towards the upper end of the outcrop, and the lode also seems to be breaking up in that direction. Facilities exist for open-cut working, and the ore could be broken out cheaply. The country-rock being sandstone and grits, the ore is, as might be expected, free from chromium. Samples taken by the writer on his previous visit, when analysed by the Government Analyst, yielded 56·8 per cent. metallic iron, and contained no appreciable titanium. The

Government Assayer's report of assay of samples taken on the present inspection is as follows:—

	Per Cent.	
Ferric oxide	78·84	= Iron 55·2%
Alumina	3·28	
Silica	6·20	
Chromic oxide	Nil	
Sulphur	0·08	
Phosphorus	Trace	
Loss on ignition	11·40	
	99·80	

It is difficult to forecast what plan of working the Anderson's Creek deposits will be found the most suitable, and as they are the governing factor in the initiation of work, and the tonnages available at the Sugar Loaf are not large, it is somewhat premature to attempt to outline what part the latter will play in the general industry of the district. Possibly the ore may be utilised in blending with the chromiferous ores, eventually pressing into the service tonnages below water-level, which Mr. Gould estimated would increase the quantity available at the rate of 20,000 tons for every yard in depth. In that case, the choice would lie between erecting the furnace at the Sugar Loaf and bringing the Anderson's Creek ores to it, and putting up the smelter at the West Arm and transporting the Sugar Loaf ore to it.

(9)—Dr. Thompson's Iron Lode.

At the base of Adams' Hill, at Flowery Gully, is Johnston's Creek, on the east bank of which are two lots, owned by Dr. L. Grey Thompson, 29 acres and 24 acres respectively.

Already in Mr. Gould's time an occurrence of brown iron ore on the 29 acres was known, which was judged by Mr. Gould to be in the form of a lode running east and west, and having a width of 5 or 6 feet. It is not easy to verify the accuracy of this statement, as the ore lies scattered about the hill in loose boulders, and forms small cliffs of impure ore mixed with country-rock, with steep faces to the valley on the west.

The ore may be characterised as an impure brown hematite, not sufficiently high in grade to be profitable by itself, and probably in insufficient quantity for separate treatment; but if smelting is started at the Sugar Loaf, some of it might be tried in the furnace there, with a view of ascertaining its practical value.

Samples of the best-looking ore were taken and assayed by Mr. W. D. Reid, Government Assayer, as follows:—

	Per Cent.	
Ferric oxide	78·98	= Iron 55·30 %
Alumina	4·02	
Silica	8·05	
Chromic oxide	Nil	
Sulphur	0·10	
Phosphorus	Trace	
Loss on ignition	9·00	
	100·15	

(10)—Swift's Hematite (now H. J. Windred).

This deposit is on a 14-acre section (No. 7988-M), east of Brandy Creek, Beaconsfield, held under lease by H. J. Windred. In the eastern portion of the lease are the old excavations made by the Tamar Hematite Iron Company in 1874-5. The history of this undertaking is of interest as showing what was done at that time in the way of smelting on a small scale for a short period.

The company extracted about 1000 tons of concretionary brown hematite and impure ironstone from shallow trenches and excavations in the surface beds, and smelted the ore in a charcoal furnace which was erected on the shore of Middle Arm (Swift's Jetty). The furnace was lighted on the 1st January, 1875, and after a few initial mishaps, was soon got into satisfactory running, showing an output capacity of about 5 tons of iron per day. Five hundred tons of excellent pig was produced during the first half of 1875. A trial casting of the iron was made at Peters' foundry, in Launceston. Two tons of it were run into moulds of fly-wheels for chaffcutters; tramway wheels, small wheels for the Launceston and Western railway, panels and rails for palisading, various parts of ovens, &c. It proved easy to melt, presented no sulphur trouble, and was pronounced soft and highly creditable in respect of fracture and grain. It was considered tougher than the Scotch iron, which was tested at the same time. In these trials the pig was sorted so as to separate the very hard or white iron. The softest was selected for the castings, and was smelted without any mixture with other irons. When run, it proved soft enough to take the finest impressions in the moulds. The castings made in Melbourne were also stated to be superior to those obtained from the ordinary Scotch pig, but as the Company could not obtain superior prices in Melbourne, they shipped a couple of hundred tons to Glasgow to try the home market. It was estimated that they could produce and land pig iron in London at a cost of from £4 to £4 10s. per ton. The parcel sent home was sold at £6 7s. 6d., and was reported "of good quality, though rather tough." The analysis was—

	Per Cent.
Iron	94·40
Combined carbon...	0·96
Graphite	3·08
Silicon	0·89
Sulphur	0·22
Phosphorus	0·09
Manganese	0·24
Loss	0·12
	100·00

A drop in the market value of pig iron to the extent of 50 per cent. took place, and the furnace was blown out in June, 1875. The published reasons for suspension were various. The depression in the iron trade was one; another was that it was intended to raise fresh capital and add to the plant. Mr. A. H. Swift, the manager, died in February, 1876, and work was never resumed. No doubt the fall in prices affected the enterprise materially, added to which was the small scale on which work was conducted. The deposit was never opened up extensively, and it is still impossible to say what quantities are available beyond the limited exposures in the shallow workings.

From the excavations, all that one is able to judge is that a bed of about 5 feet of impure brown hematite, passing below into 2 feet of denser ore, rests on a couple of feet of pebbly wash, which goes down into pipeclay. The 2-feet bed seems to have been taken for the furnace, and most of the impure overburden thrown aside.

The ore of this deposit is a brown hematite or limonite; its occurrence is manifestly in the form of a bed laid down in a lake or estuarine basin, which at one time may have stretched away as far as the Middle Arm. Its downward extension is evidently limited by the wash and pipeclay which is met with beneath it.

The northern part of the lease shows a widespread covering of unconsolidated iron oxide. The Native Paint and Oxide Proprietary in 1890-2 shipped 1000 tons of oxide from this ground to Melbourne. It was largely used for gas-purifying, and at that time realised from 27s. 6d. to 42s. 6d. per ton.

Between the road and the northern boundary a good many holes have been sunk in the material, disclosing flat tabular masses of hydrated iron ore at different horizons in the loose oxide. The deposit passes northwards beyond the boundary of the section. It is not to be supposed that the iron formation covers the whole area of the lease, but it may possibly extend over a third or more.

Mr. Windred is at present endeavouring to exploit the deposit for ochre and iron ore. If smelting works are erected for the Anderson's Creek ores on the West Arm it might be arranged to supply moderate quantities of this ore to supplement them, as there would be only a short road connection with the tramway.

Samples taken on the present visit have been assayed in the Geological Survey laboratory, with the following results:—

	Old Workings.	Unconsolidated Stratum.
	Per Cent.	Per Cent.
Ferric oxide	66·84 = Iron 46·8 %	43·56 = Iron 30·5 %
Alumina	5·20	15·32
Silicia	17·20	31·20
Chromic oxide	0·07	Nil
Sulphur	0·13	0·14
Phosphorus	Nil	Trace
Loss on ignition	10·40	9·60
	99·84	99·82

The loose ferruginous deposit is of a colour which is suggestive of a possible value for paintmaking. Some tests would be necessary to ascertain whether the bulk of the material is free enough from grit to permit of its use for this purpose. Excessive silica in a paint impairs its opacity or body, and excessive alumina impairs its brilliancy. The varying assay results indicate the necessity for a careful examination of the quality of the deposit as a whole. The property is very conveniently situated for working and transport to Beauty Point, the shipping port.

(11)—WINDRED'S OXIDE DEPOSIT.

This has been referred to in my report on iron ores. It is west of Brandy Creek, on the ground worked by the old Tamar Hematite Iron Company for the production of pig iron. On a portion of the lease is a covering a few feet thick of loose red iron oxide, of a colour-shade which suggests that it might be of use for paint-making.

(12)—SERPENTINE PAINT COMPANY'S DEPOSIT.

This company holds a 20-acre mining lease (7707-M) on Scott's Hill, and a 5-acre machinery site (7854-M) west of and adjoining the former. The hill (which, in fact, is little more than a gently rising ridge from the valley on the west) consists to all appearances of soft red and yellow limonite, resting on and derived from serpentine rock. The subaerial decay of this rock, with its contained veins of fibrous magnetite, has led to the conversion of the latter to the hydrated iron oxide, which is so useful for the manufacture of paint. The oxide forms a bedded or blanket deposit of essentially the same nature as that present on Mt. Vulcan to the south. Associated with it also is a similar chrome content, derived in like manner from the chromite veins existing in the serpentine. Embedded in the red soil on the flat top of the hill are consolidated concretionary stones and boulders of limonite, somewhat harder than the surrounding material, but identical in composition. Here and there scattered fragments of the familiar fibrous "needle iron" are noticeable on the surface.

The history of work on these deposits extends back to over 30 years ago. The Chromate, Asbestos, Paint, and Gold Mining Company operated previous to 1888, and the Native Paint and Oxide Proprietary in 1890-2.

The latter company shipped about 500 tons of iron oxide from here, principally for gas-purifying. The present company has extended the old open drive from the west side-line of the 20-acre section in a south-easterly direction into the hill to a total length of 250 feet. The maximum depth attained in the course of this drive is 25 feet, and the deposit has been tested to a further depth of 14 feet, making about 40 feet thickness proved. In driving further into the hill this thickness will increase. It will probably be comparable with that of the deposit on Mt. Vulcan. As the deposit is a bed, and not a lode, its width is not limited to the width of the cutting, and far greater quantities will be obtainable than are likely to be required by the present enterprise. If iron-smelting is initiated in connection with the deposits on these hills, there is no reason why the two industries should not be carried on concurrently, as the tonnages necessary for the paint requirements will be infinitesimal in comparison with the ore supplies taken by the iron furnace. It is not surprising that various attempts have been made to turn the paint deposit to account at different times, for the variety of permanent oxide colours in the material is striking. Yellow, red, green, and brown are elements of the colour scheme presented by the components of this bed. These metallic oxides form the basis of the iron pigments of commerce. Among the chocolate and dark-red varieties are to be found some of the most stable types of ferric oxide. Native oxides, unlike manufactured or calcined materials, possess the character of permanency, and, with suitable blending, lend themselves to the preparation of pigments with any desired degree of opacity and staining power. The present company controls three mines with different raw materials in each, which has the advantage of enabling it to command a market for varying types of product.

The Serpentine Paint Company, in founding a new Tasmanian industry, has established a paint factory on the wharf in Launceston, where it makes, not only the oxide paints, but lead and chemical paints as well, meeting the requirements of the entire paint industry. The following account of the process of manufacture is extracted from a communication emanating from the Company:—

"The crude oxides are purified by levigation or air separation, the specific gravity being made use of to separate the various grades of colour. In the levigating process the slimes are furnace-dried, and then ground to a very fine powder. This passes to a pug mill, and is incorporated with pure linseed oil; it then goes through the granite rolling machine, thus precluding any chance of burning the pigment and changing the colour; thence it passes through steel roller mills, where it is reduced to the consistency of stiff paste, and finally emerges as paste paint of the very finest quality.

"This paste is conveyed to the mixing-vat and the necessary quantity of linseed oil, turpentine, and a very small proportion of drier added to make it liquid paint. Rotary planes, electrically driven, thoroughly mix the paint, which is taken to the finishing cone mills, whence it is run directly to the containers, ready for market. This thorough mixing secures perfect suspension and absence of deposit on the bottom of the tin. The company guarantees that no adulterant of any kind is used in the manufacture."

The following is an analysis of the raw oxide from the cutting:—

	Per Cent.	
Ferric oxide	75·98	= Iron 53·2
Alumina	4·94	per cent.
Silica	5·25	
Chromic oxide	3·62	
Sulphur	0·09	
Phosphorus	Trace	
Loss on ignition	9·96	
	99·84	

The absence of grit in the raw material is highly favourable for easy grinding and ready conversion into paint. Another point which may be remarked is the non-existence in the ore of chemically active elements which would be apt to impair the permanence of the paint. It is practically an inert substance, and with due attention to the quality of the oil can yield a pigment permanently resistant to moisture, light, and climatic changes. Satisfactory tests of permanence and spreading power and other necessary qualities have been made of the manufactured paints, and the whole process of manufacture is under the supervision of a trained works chemist of repute in the paint world. It is to be hoped that the placing of a good local article on the market will meet with general support in Tasmania, and that Government departments will not be backward in encouraging the new industry with their orders.

(13)—Conclusion.

It behoves the Government to do all in its power to support and foster the development of a new industry such as paint-making, particularly as it is essentially based on the use of our natural resources. We have the suitable raw material, but it cannot be reckoned as an item of our mineral wealth unless it is profitably employed. Success in this enterprise depends largely upon what amount of patronage and support it can secure, and especially upon how far the local support will obviate the necessity for seeking trade outside the State. We have now an opportunity for testing the genuineness of the demand for local manufactures.

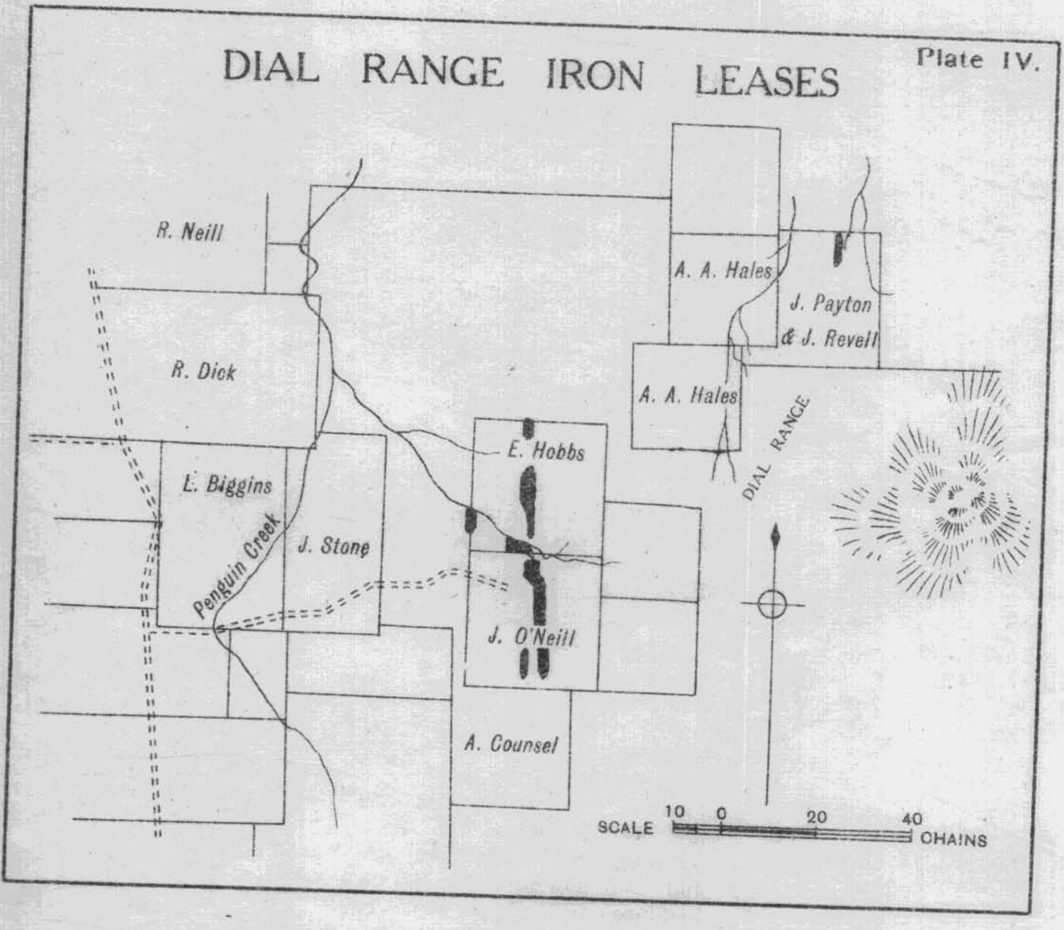
III.—DIAL RANGE IRON LEASES.

(1)—Lease 8038-M, 80 Acres, E. Hobbs; and Lease 8039-M, 80 Acres, J. O'Neill.

These leases cover the old leases 5088-93M, 50 acres, W. Jones, and 5089-93M, 50 acres, F. S. Denney.

They are situate high up on the steep western flank of the Dial Range, within a couple of hundred feet of the crest, towards the south end of the range, and about 6 miles from the sea-coast at Penguin. They are approached by a good metalled road running from Penguin to Riana through the farms occupying the fertile basaltic tableland which everywhere skirts the North-West Coast line, and is the source of prosperity of this part of the island. Incidentally, the question is sometimes put in respect of the comparative qualities of the soil derived from basaltic lava—the so-called chocolate soil—and that produced by the disintegration of the diabase rock of the Tasmanian Tiers. The latter soil forms large tracts of relatively poor land, while the former is renowned for its fertility throughout the State. Yet the chemical composition of both is nearly identical. The probable explanation is that the basalt, with its loose glassy base, breaks up into its constituent elements with sufficient rapidity to admit of the formation of a deep soft soil before wind and weather agencies have time to carry the disintegration products away; while the physically resistant diabase rock weathers so slowly that the resultant soil is carried off almost as soon as it is formed, leaving behind a thinly-covered surface of hard solid rock.

The surface of the Penguin tableland rises gradually towards the south until, at about 800 feet above sea-level, the southern boundary of the 100 acres charted in the name of L. Biggins (now Stone's farm) is reached, where the main road is left and the ascent of the range is commenced by means of a zig-zag foot-track, which leads direct to the iron leases. The air-line to the ore-outcrop is about 1 mile from the road in an easterly direction; the actual ascent begins at about half a mile. The Penguin Creek is crossed at the foot of the mountain. The footpath has been well cut, and the grade is easy. At the base the basalt soil gives place to the Silurian conglomerate rock of the range.


DIAL RANGE IRON LEASES
Plate IV.
R. Neill
R. Dick
L. Biggins
Penguin Creek
J. Stone
E. Hobbs
J. O'Neill
A. Counsel
A. A. Hales
J. Payton
& J. Revell
A. A. Hales
DIAL RANGE
SCALE
10
0
20
40
CHAINS

Some stones of iron ore are present in the conglomerate on the track before reaching the west side-line of the leases, but the main body of the deposit is situate a few hundred feet inside the lease boundary. The ore-body consists of red hematite (ferric oxide), non-magnetic, and appears to be a replacement of the conglomerate-bedded rock. It has a linear direction extending north and south, and showing outcrops at intervals through both leases. Its surface has not been exposed sufficiently to admit of accurate measurements of its width. A good deal of it seems to be 3 or 4 chains wide, and on the northern lease its width may be greater, as ferruginous soil is noticeable for several hundred feet.

The exposures on the northern lease, 8038-M, may be described as follow:—

Some ironstone is seen loose in the soil on the northern boundary-line of the section. Following a southerly direction from this across the lease through dense scrub in the valley, one ascends a hill which is crowned with a knob of hard iron ore.

Numerous boulders show ore of variable quality, some of it very massive and good, but mixed with other stone of lower grade. The surface indications here are very encouraging, and a good deal of ore could no doubt be got from this point. Its position, too, is favourable for transport down the creek to works or rail.

South of the creek, but still on the same lease, is a short adit which has been driven into the steep hillside, where there was formerly a small excavation. Ironstone boulders occur at surface, some of them consisting of very pure ore, while in others the replacement of the conglomerate has been imperfect, showing partly-changed pebbles.

Another little tunnel has been driven near the dividing-line between the two sections for some 50 feet in a south-westerly direction, but the formation in the end is somewhat indifferent in quality; some of it consists of fair iron ore, but the rest is stony. In this part of the lease the surface is ferruginous for a width of about 500 feet, but the scrub requires to be cleared and the ground examined by trenching in order to establish the nature and value of the formation.

There is evidently a parallel ironstone formation on this lease, exposed in a creek bank on the western side-line at about 7 or 8 chains from the south-west corner peg. The extent of this has not been ascertained.

Passing now to Lease 8039-M on the saddle or flat crest of the hill south of the boundary between the two sections, a large flat outcrop of great boulders of iron ore occurs in the surface-soil. The ore is of excellent quality; a good deal of it is massive, but shows the replacement process. Being at the summit of the spur, it could be quarried in either direction, and transported either down the creek to the east or to the tableland on the west, according to the working plan adopted. It is difficult to say what width the formation has at this spot, but it is probably at least 2 or 3 chains.

Further south, half-way through the section, and on the same ore-line, boulders of dense hematite appear, showing occasionally specular iron ore. Judging by the stone at surface, the usual width seems to be maintained.

The ore will break in mining into good lump-ore suitable for the furnaces, and the usual deleterious ingredients of many iron ores are distinctly low. The proportion of phosphorus on the whole does not exceed the Bessemer limit, and the sulphur percentage is quite low.

Owing, however, to the ore-body being the result of replacement of conglomerate, which has taken place to a variable extent throughout the ore-belt, some of it showing a complete substitution, while in other parts the substitution is only partial, the relative proportions of iron oxide and silica vary irregularly. The result is that the grade is far from uniform throughout the formation, and if any of the imperfectly transmuted stone is included in sampling, the silica percentage is at once augmented and the iron percentage diminished.

Siliceous boulders of ironstone are scattered in the soil between the different outcrops and cuttings. Towards the edges of the formation the conglomerate is seen to have suffered very little alteration, and in calculating the quantities of ore for smelting allowance will have to be made for this. Still several of the outcrops seem to carry a proportion of good-grade ore, and in working the deposits favourable places in the belt would have to be selected.

The scrub or overburden, or both, covering the ore-body for such a great part of its length makes it impossible to take an average sample; and some expenditure is necessary in the way of trenching down into the solid formation before an approximate idea can be formed of values. All that one can do for the moment is, on the one hand, to select some good samples, showing what the formation is capable of yielding in more or less quantity, and on the other hand to take such general samples where there happen to be exposures as may be judged to correspond with what will be met with in bulk.

Selected samples were taken by the writer in 1903 and assayed by Mr. W. F. Ward, Government Analyst, with the following results:—

	Iron. Per Cent.	Silica. Per Cent.	Phosphorus. Per Cent.	Sulphur. Per Cent.
Northern lease	68	0·5	traces	traces
Ditto	66	1·6	traces	traces
Southern lease	69	0·8	traces	0·15
Ditto	58	6·8	traces	traces

General samples taken on this occasion indifferently from all parts of the formation have been assayed by Mr. W. D. Reid, Government Assayer, as follows:—

	Iron. Per Cent.	Silica Per Cent.	Phosphorus. Per Cent.	Sulphur. Per Cent.	Moisture at 110° C. Per Cent.
Northern lease ...	50·86	23·40	0·05	0·095	0·15
Southern lease ...	63·84	8·60	0·08	0·03	0·02
Ditto	54·50	19·20	0·001	0·085	0·12

The highest grade on the southern lease was from the outcrop at the top of the hill where the track leads up to the formation, and this leaves nothing to be desired. The other samples show an excess of silica. A grab sample from the Knob outcrop on the northern lease resulted in a very siliceous assay, viz.:—

	Per Cent.
Iron	42·56
Silica	30·90
Phosphorus...	0·032
Sulphur...	0·10
Moisture at 110° C.	0·21

In fact, any variety of ironstone may be obtained, according to the more or less perfect replacement of the conglomerate. The more siliceous ore would require to be prepared for smelting by crushing and washing. It is impossible to say what proportion the siliceous ore bears to the quantity of ore of standard quality; this can only be ascertained by systematic trial work and sampling.

It would seem that in mining a selection would have to be made as far as could be judged of ores of 50 per cent.

and upwards. A certain amount of improvement could probably be effected by the use of picking belts. Between 50 and 60 per cent. ore is good grade, and if the Dial Range ore can be raised to that extent a little extra cost in selection will be remunerative.

Further south, and not far from the southern boundary-line, the ore outcrop again appears overlooking the valley which descends to A. Counsel's 60 acres. Indications of the continuation of the belt are said to occur on Mr. Counsel's land, which is very likely.

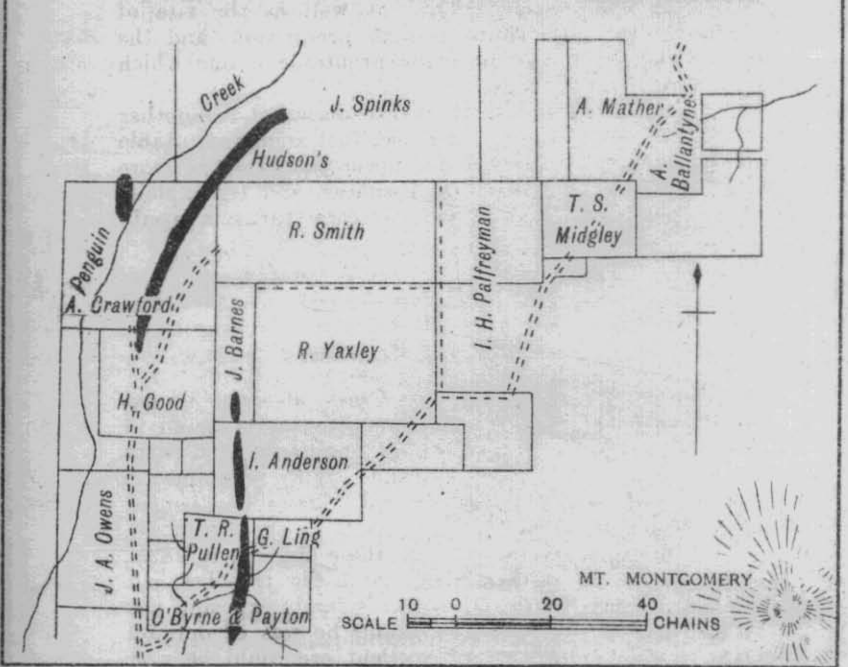
The ore at this southern end of the section seems either to widen out considerably, or else parallel belts exist. Some very good stones of ore may be picked out from here, but on the whole it looks as if the grade might not prove to be so high as at the northern end.

As regards the quantities available for the furnace, no commercial calculation can be made until the actual width of the formation is ascertained, and the whole length exposed by clearing off the scrub from the surface and testing the outcrop all along by means of trenches and pits. Even then its behaviour in depth will be only imperfectly known. At present only a very rough idea can be formed of its possibilities, and even in order to do this some vital assumptions have to be made. The length and width of the belt of smeltable ore have to be assumed, also the grade. If it turns out that a belt of workable ore 200 feet wide exists for a third of the total length through the two sections, the quantity of ore down to a depth of 50 feet would total about 600,000 tons. This, at 50 per cent. iron, would be equivalent to 300,000 tons metal, or, if at 60 per cent., 360,000 tons. These figures cannot, however, be used until the data are established.

The way in which the iron industry will be initiated on the North-West Coast is at present so uncertain that any forecast of the exploitation of the Dial deposits must be attended with uncertainty. The latest developments suggest that they will be worked as an independent enterprise. Operations will no doubt be commenced on a moderate scale. The smelter would probably be near Penguin, the creek route being the one used for transporting ore to the furnace. This route would permit of the Penguin Creek iron deposits being tapped, and contributing moderate quantities of high-grade ore to the general output. A route across to the Leven, and so to Ulverstone, has been mentioned, but the advantage of this is not apparent, except for shipping purposes. The natural fall for the output is down the Penguin Creek valley.

Plate V.

PENGUIN IRON LEASES



The whole subject of starting work is bound up with questions of competing works, fuel, and power, as well as the class of product aimed at. The future of these properties will inevitably be governed and regulated by the result of expert investigation of these conditions. The decision as to what class of iron will be specialised in—iron for steel-making, foundry or cast-iron, or iron for puddling or wrought-iron—will influence the scale of operations. Operations for making steel on a large scale will not be contemplated, and work will be restricted to the manufacture of some special lines of iron and steel, for which a market can be secured without having to deal with any ruinous competition. This, as well as the size of the deposit, will necessitate a small production, and the question whether it can be made profitable is one which will require careful study.

The questions of fuel and flux are discussed in another part of this publication. Charcoal fuel is more suitable for small furnaces using electric power than for the more trying conditions of large blast furnaces, and for exploiting these moderate-sized deposits electric furnaces would be eminently adapted.

(2)—Penguin Creek Deposits.

Along the course of the Penguin Creek, at about 3 miles from its mouth, a good deal of hematite ore is found in the stratified Silurian quartzite or sandstone and slate west and north-west of the Dial Range. The creek appears to have formed its channel in this wide ferruginous belt of country for about a mile or so.

Mr. A. Montgomery reported on these deposits in 1895. He noticed already at that time that a few trenches had been made on Hudson's and Brown's land, exposing the quartzite bedrock on the former, and he was of opinion that very large quantities of excellent ore could be won at small cost. He considered that the deposit had no connection with the Iron Cliffs lode, though it is almost on the line where the latter might be expected to be met with. The Iron Cliffs ore is a brown hematite, while the Penguin Creek ore is an anhydrous red hematite. Mr. Montgomery's samples, chipped here and there from the best-looking blocks of ore, yielded on assay 98 per cent. of peroxide of iron (68·60 per cent. metallic iron), 1·6 per cent. silica, and 0·2 per cent. sulphur, which is a pure iron well adapted for making high-quality steel. When Mr. Harcourt Smith visited the deposits in 1898 he found them being operated by the Tasmanian Iron Company (Mr. J. C. Ellis), who were shipping ore from the formations on Hudson's and Good's properties. In 1903 the writer examined the workings, and visited them again in 1905, at which time, owing to severe Australian competition, the output, which was being shipped to New South Wales for flux in smelting-furnaces, had been temporarily reduced to about 150 tons per week. Mr. Ellis worked the quarries from 1897 to 1909. At the end of that period the smelters got their main supplies elsewhere, and Mr. Ellis had difficulty in retaining a market for his full output. In addition, dispute with landholders resulted in his being deprived of his tramway facilities, and this led to the abandonment of the enterprise, after sending away altogether 40,000 tons of ore.

A horse-tram, two-thirds of it steel and the remainder wood with steel strips, had been laid down from the quarries to the wharf, a distance of 3½ miles, along the creek, which it crossed and recrossed several times by means of little bridges. Thirty tons of ore a day were carried in two trips, and the ore was loaded into lighters for transmission at Devonport into boats for New South Wales. The ore was selected so as not to assay less than 66 per cent., and it mostly ran from 66 per cent. to 68 per cent., with 2 to 3 per cent. silica.

Samples taken in 1903 from the various quarries then in work were assayed in the Government laboratories, as follows:—

	(1) Surface Work (side of tramway).	(2) Hudson's Quarry.	(3) Good's Cutting (above road).
Iron	69·00	68·00	68·5
Silica...	0·4	0·6	0·6
Sulphur...	Trace	—	—
Phosphorus... ...	Trace	—	—

Attention was called at that time to the remarkable freedom from detrimental impurities, such as sulphur and phosphorus, and the low silica content. On the present occasion there was hardly the same opportunity of taking samples which would do justice to the deposits, as work has ceased, and only abandoned and more or less worked-out quarries were available for inspection. The samples taken showed, nevertheless, a remarkably pure ore. They were assayed by Mr. W. D. Reid, Government Assayer, as follows:—

	Hudson's Quarry. Per Cent.	Good & Crawford's Quarry. Per Cent.
Iron	67·71	65·24
Silica	2·20	1·90
Sulphur...	0·025	0·098
Phosphorus	0·026	0·03
Moisture at 110° C. ...	0·13	0·13

The worked deposits extend for 1¼ mile along the creek in the form of replacement bodies of ore and boulders and nodules in a less pure soft ferruginous matrix extending from creek-level up to the surface of the basaltic tableland. The boulders sometimes attain a great size, some having been found weighing as much as 25 tons. The softer matrix in which they lie is often clayey, and was too impure for shipment. The working plan followed was to open out quarries at selected points where pure boulders or other solid ore occurred. To illustrate the irregular occurrence of the best hard ore, from a cut south of No. 1 quarry, only just below the soil, half a dozen boulders yielded 100 tons of ore. Further up the creek, too, on the east side, about 508 tons of ore were taken out of the surface-soil, boulders of 5 and 10 tons first-class hematite being very common.

The structure of the deposit indicates that the ore has replaced sandstone or conglomerate, and, as might be expected, the quality varies from place to place, a good deal of it being earthy and siliceous and associated with limonite. Occurring with the ore is a white friable saccharoidal sandstone which has here and there been converted into quartzite. A kernel of this stone was found in a boulder of iron ore. Signs exist of the conversion of sandstone into the ore of the deposit, and the nodular form in which some of the ore occurs suggests an original pebbly sandstone or conglomerate. This excludes any relation with the Iron Cliffs outcrop, which is that of a lode.

It is extremely difficult to form an opinion as to the quantities of workable ore still available. Of course, Mr. Ellis selected for his purpose only the very best ores, and the consequence is the workings are patchy and irregular. A good deal of the ore which he rejected would be suitable for the furnace; but even so, the irregularity of the deposit militates against laying out work with any reliance on continuity. There is no doubt a good deal of ore which is still accessible, and prospecting would disclose further points of attack. The value of the proposition seems to consist in its capacity as an adjunct to the Dial Range enterprise. Ore could be broken from it to augment the output of the latter and bring the total up to a higher grade. Additional assistance in the direction of increase of output could be looked for from the Iron Cliffs lode, the gossan of which might, in bulk, be expected to yield 50 per cent. iron. In fact, it almost seems as if the most desirable way of establishing the Dial Range and Penguin iron industry would be to amalgamate all the interests and start with united resources.

There are one or two other deposits in the district which tend to show that the iron country is rather extensive. An old quarry near the Iron Cliff-road, and south-west of the rifle-range, shows some iron ore 20 or 30 feet in width. Mr. Ellis worked here for a time, and shipped some of the ore. Some of it is siliceous, but in parts it is very pure. A sample taken on the present visit assayed in the Geological Survey laboratory yielded as follows:—

	Per Cent.
Iron	68·82
Silica	0·84
Sulphur...	0·021
Phosphorus...	0·001
Moisture at 110° C.	0·14

This is an excellent sample, of unsurpassable quality.

Traces of iron deposition are seen for about a mile further north. The quality of all these scattered occurrences varies from point to point, and the quantities available in any one spot are limited, but it might be possible to utilise the various deposits in the way mentioned above if the industry is started in the neighbourhood.

(3)—Iron Cliffs Lode.

This is a huge outcrop of brown hematite, about 150 feet in width, on the fall to McBride's Creek. Northwards the deposit or lode passes through Anderson's 60 acres, covered by basaltic soil, except where exposed in a creek, and into Barnes' 23 acres, where the ore has an admixture of quartz and barytes, and is sometimes manganiferous. Samples taken from the surface on this land assayed 59 per cent. iron, 5 per cent. silica, and only traces of sulphur and phosphorus. Southwards from Anderson's the lode passes into the sections held by Pullen and Mitchell, O'Byrne, and Paton. Samples from the large outcrop on Pullen's, assayed by Mr. W. F. Ward, Government Analyst, yielded:—

	Sample No. 1. Per Cent.	Sample No. 2. Per Cent.
Iron	48·0	57·0
Silica	18·4	7·2
Sulphur	0·15	Traces
Phosphorus	Traces	Traces

Samples from the deep tunnel (about 450 feet below the outcrop), and where a clayey iron gossan has been driven into, were assayed by Mr. W. F. Ward, Government Analyst, and appear to have yielded 16 grains gold per ton, with traces of silver and copper. It is evidently a lode formation, and the hydrated oxide, which forms the part of the lode now accessible, is most probably the result of oxidation of some metallic sulphide. As a brown iron ore its grade and quality are good. Mr. Ellis sent away some shipments from it, but the silica content, though not at all too high for iron-smelting, was too high for his requirements, and, being limonite, the contained water made it not sufficiently remunerative for his purpose, as only the very highest grade was suitable for his market.

The utilisation of this ore-body will, no doubt, eventually lie in supplementing ore-supplies to smelting-furnaces in the Penguin Creek valley. Taking the whole ore-body as it exists on Pullen's and O'Byrne's leases, there is no doubt that quantities of ore could be easily mined and delivered to furnaces in the Penguin Creek valley. As far as can be judged at present, a 50 per cent. grade might be obtained, and the output would belong to a class of ore easily reducible. The whole of these cliff and creek deposits are capable of forming valuable auxiliaries to the Dial Range proposition.

The local conditions for smelting works somewhere along the creek are excellent; Penguin itself is on the sea-board; it would be necessary to restore shipping facilities by repairing the breakwater, and with the iron industry started, the district would be a busy centre.

The writer is indebted to Mr. Richardson for accompanying him over the Penguin deposits.

(4)—Manganese Ore at Dial Range and Penguin.

(*a*) *Dial Range*.

A deposit of manganese ore occurs on the 63-acre lease, 7162-m, at the northern base of Mt. Duncan, charted in the names of J. Payton and J. Revell. It appears to have been discovered by Mr. Robert Revell in 1905. A belt of boulders and stones of ore runs up the hill in a southerly direction or a little east of south, and an open drive has been put in on the formation for a distance of about ½-chain, and 5 to 6 feet in depth. The ore is covered by about 2 or 3 feet of surface overburden, and its extent cannot be indicated until it is further prospected and opened out. It appears to be a stratified rock, but its exact mode of occurrence cannot be diagnosed until it is better exposed. The indications are that the ore-body will be found to be of a fair size. It consists of a mixture of various manganese oxides (manganite and other oxides) and manganiferous iron ore. A great deal of its commercial value will depend on the relative proportions of these. Samples may be gathered of a medium to low grade manganese ore, and again other specimens show a manganiferous iron ore.

Specimens brought in to Mr. Reid, Government Assayer, by the owners assayed 53·78 per cent. manganese oxide, and similar specimens sent to Melbourne yielded assay return as follows:—

	Per Cent.	
Iron oxide	21·93	
Manganese oxide	54·39	(34·36 per cent. manganese)
Siliceous matter	8·20	
Alumina	6·67	
Lime, magnesia, &c.	6·81	
Moisture	2·00	
	100·00	

Fairly solid looking samples from different parts of the occurrence—from the walls of the open drive and from scattered stones further up the hill—were assayed by the Government Assayer as follow:—

	Per Cent.
Iron	40·74
Manganese	16·23
Silica	4·00
Sulphur	0·17
Phosphorus	0·082
Moisture at 100° C.	0·80

From the above one may conclude that the deposit contains a low-grade manganese ore grading into a manganiferous iron ore. Just how to deal with these so as to obtain a higher grade manganese concentrate will be the special problem to be solved. If the ore proves to lie in a clayey matrix, the grade could be improved by washing, so as to free the oxide from some of the clay. This would be done by means of an American log-washer, which is a shaft fitted with arms or paddles arranged spirally, rotating in a trough in a slightly inclined position, which enables the ore to be gradually pushed up the trough till it passes out of the higher end, where it meets a flow of water carrying the lighter waste down the trough. The purer lumps of ore are thus saved. If these are too siliceous for the market, they must be crushed and jigged. In some mills the crude ore is first crushed in a jaw stone-breaker, then delivered to the log-washer, and afterwards sized in a trommel to three sizes, two of which are treated in jigs, the coarse product being re-ground between rolls and added to the jig feed. But the details of dressing are governed by the nature of the ore in each case. It may be, however, that the Dial ore will have to be treated purely and simply as a manganiferous iron ore, and the crude ore taken direct to the smelters.

The bulk of the world's output of manganese ore is from 40 to 50 per cent. grade, and the aggregate output at present is about 1,500,000 tons. This comes principally from India, Brazil, and Russia, in the order named. To give a general idea of the grade mined and sold throughout the world, the following particulars are given:—

United States: Ores below 40 per cent. subject to refusal or acceptance at buyers' option

Russia: Ores sold on a basis of 50 per cent. manganese.

Turkey: Ores sold on a basis of 45 per cent.

Japan: Ores sold on a basis of 44 per cent. to 56 per cent.

Germany: Ores sold on a basis of 50 per cent.

Brazil: Ores sold on a basis averaging 53 per cent. to 55 per cent.

Cuba: Ores about 43 per cent.

India: Ores run about 50 per cent. manganese, though in times of special demand 30 to 40 per cent. grades are drawn on.

England: Ores sold on a general basis of 50 per cent. Ores of 40 per cent. are not marketable.

We may take it as a general guide to prices that a 50 per cent. basis is the most usual, *i.e.*, the price is calculated per unit on 50 units, with a slight increase for each unit above the 50, and a penalty for each unit below it. A unit means 1 per cent.

It must be borne in mind that though ore containing less than 40 per cent. manganese may be saleable, it is only so in small quantities and at low prices. In disposing of a manganiferous iron ore to smelters, the contained manganese will only command a low rate, and in fact may not realise more per unit than the unit of iron.

The latest American prices quoted (at the beginning of the present year) for 50 per cent. ore, with silica under 5 per cent., were equivalent to £12 10s. per ton. British prices have varied the last few years from 9d. per unit to 3s., *i.e.*, for metallurgical purposes; much higher rates ruled for the non-ferriferous 75 per cent. ore required for the electrical, chemical, and other industries. Such industries are responsible for the small and irregular Australian demand for high-grade ores. A demand for the lower grade ores will probably set in with increasing steel manufacture in the Commonwealth. At present out of 1,500,000 tons raised throughout the world annually, Australia produces about 3000 tons, contributed by New South Wales, Queensland, and South Australia.

With the exception of comparatively small quantities used for the requirements of paint, glass, chemical industries, &c., the manganese ore output of the world is absorbed in the manufacture of steel. For the needs of this industry the ferro-alloys, spiegel iron, and ferro-manganese are produced; the former averaging about 20 per cent. manganese and the latter containing about 70 per cent. or 80 per cent.

Ferro-manganese is the standard deoxidising and dephosphorising agent added to molten Bessemer and open-hearth steel in small proportions ½ to 1 per cent., and spiegel iron is used as a substitute. The latter is a blast-furnace product from manganiferous iron ore; the other product needs greater heat, and consequently a hot blast, for which it is possible to utilise the electric furnace. Manganiferous iron ores are being used now, to a greater extent than formerly, in the production in the blast furnace of a high manganese pig iron, containing 2 or 3 per cent. manganese, for making basic steel.

Manganese steel containing from 10 to 14 per cent. manganese has tough and slow wearing properties, and is sought after for heavy duty plant, stone-breakers, and the hard parts of mill machinery, tram wheels, steel shovels, burglar-proof safes, &c.

Sir Robert Hadfield first broke new ground in the field of iron alloys by producing manganese steel, which ranks as one of the important discoveries of modern times. In the late war manganese-steel helmets, resisting shrapnel bullets striking at a velocity of 750 to 900 feet per second, saved tens of thousands of lives.

When the Dial Range deposit has been more thoroughly tested by prospecting, its owners will be in a position to see what quantities are present and whether the grade can be made to suit the requirements of export trade, or whether they will have to fall back on local production of spiegel iron or ordinary manganiferous iron with the aid of the State hydro-electric current, or sale to neighbouring smelting works, which the samples so far seem to indicate may be the trend of the future development of the property. In the last resort the ore will be saleable as a flux.

(*b*) *Penguin.*

A deposit of impure manganese oxides is seen half buried in the sand on the beach at the east end of the township. It occurs in the form of a line of apparent boulders, though it is not quite clear that what is really seen is not the loosened outcrop of strata replaced by the mineral. Until some work has been done this point cannot be regarded as settled. A good many years ago a small quantity of ore is said to have been broken out and shipped, but from what I can learn the market price at that time was not satisfactory, and the quality of the ore mined did not come up to expectations. Nearly thirty different varieties of manganese oxide exist in nature, and possibly more than one variety is present in this outcrop. Some of it consists of the hydrous dioxide known as psilomelane. It possesses a botryoidal exterior covered with a thin coating of hematite. Some ore has been recently broken from the deposit, and is now lying in the grass on a low sea-bank in front of the township; apparently it has been found to be too poor to send away at a profit. I took samplings from the ore at grass, and the assay result given by Mr. Reid, Government Assayer, is as follows:—

	Per Cent.
Iron	2·08
Manganese	34·50
Silica	32·60
Phosphorus	0·07
Sulphur	0·15
Moisture at 100° C.	0·75

It is evidently a partial replacement of a siliceous rock, resulting in a low-grade manganese ore, the usual grade of shipping ore required being in the neighbourhood of 50 per cent. The silica percentage is excessive, as the rejection limit of buyers is about 12 per cent. The other ingredients are satisfactory, but to fit the ore for the market it would have to be concentrated, and in doing this almost insuperable difficulties would be encountered. The manganese oxide is distributed through the rock matrix in such a finely divided state that any separation process by ordinary dressing methods would be largely experimental, and with small chance of success, and even if practicable would involve heavy additional cost. Further, seeing that the visible outcrop is of such a limited size, the quantity of ore available is likely to be very small.

IV.—THE BLYTHE RIVER IRON ORE DEPOSIT.

(1)—INTRODUCTION.

This is on a property held under mining lease from the Tasmanian Government by the Blythe River Iron Mines Limited.

It was visited by the writer first in June, 1900; again in January, 1901; and finally in 1918. Reports on it which have been issued are the following:—

Report on a Deposit of Iron Ore at the Blythe River, by A. Montgomery, M.A., 5th March, 1894.

Report on the Blythe River Iron Mines, by Mr. John H. Darby, M.I.C.E., 7th December, 1900.

Report on the Blythe River Iron Ore Deposit, by W. H. Twelvetrees, 30th January, 1901.

The leases at present held by the company are:—Nos. 1061-91M, 40 acres; 1009-91M, 73 acres; 851-91M, 78 acres; 4185-93M, 20 acres; 4066-93M, 40 acres; 7999-M, 91 acres; 8007-M, 50 acres; 8001-M, 184 acres; 1985-W, 2 acres; 7812-M, 40 acres; 7996-M, 40 acres; 7998-M, 12 acres; 7997-M, 68 acres; besides some freehold property and mining rights on C. O'Keefe's land, 50 acres.

In a report made for the owners of the property by the late Mr. J. H. Darby in 1900, he recommended work on a scale which would involve an ore output of upwards of 6000 tons weekly.

On his advice two test adits were driven into the lode below the outcrop on the northern side of the river, in order to obtain information as to the continuity and uniform quality of the ore. One was driven into the outcrop near the bridge over the Blythe River (since destroyed), and the other nearly 80 feet below one of the northern outcrops on the 40-acre section, No. 1061-91M. These adits are at points about 50 chains distant from one another along the strike, and the vertical difference between them is about 600 feet.

In possession of the results of these drives and of the information gained by his personal examinations, Mr. Darby arrived at conclusions which can be summarised as follow:—

1. There are overwhelming indications at many points over a mile of country of an immense deposit of

hematite, probably sufficient for the manufacture of 3000 tons of finished steel weekly for many years to come.

2. The ore can easily be reduced to pig iron. Its quality is excellent, and rarely surpassed by any in Europe or America.
3. A sample of ore taken over the whole deposit (63 per cent. iron, 0·024 per cent. sulphur, and 0·036 per cent. phosphorus) showed it to be capable of producing, with good coke and limestone, very superior hematite pig iron suitable for the manufacture of high-class steel.

(2)—Situation.

The River Blythe, a non-navigable stream, rising in the Surrey Hills, has at between 6 and 7 miles from its mouth at Heybridge intersected this large lode of hematite ore, excavating its channel and exposing the intersected lode down to over 600 feet below the general level of the tableland. Its bearing is north 27 degrees east and south 27 degrees west for an observed distance of fully 1 mile, and signs of its continuation are visible for a further distance.

North of the river it extends through part of Section 851, 78 acres, through Section 1009, 73 acres, C. O'Keefe's purchased 50 acres, into Section 1061, 40 acres, and indications of its existence further north are to be seen on the east boundary of O. Allen's 100 acres.

South of the river it passes through Section 851, 78 acres, and Section 4185, 20 acres, into W. H. Atkinson's 186 acres, where it disappears beneath a covering of basalt of Tertiary age.

(3)—Description of the Lode.

The outcrop dips at a high angle to the south-east, and the lode appears to be conformable both in strike and dip with the enclosing sedimentary strata, which are of Silurian age. The surface-strike is slightly sinuous, following the direction of the edges of the encasing beds. These beds are fissile sandstones and slates. On O. Allen's 100 acres east of the iron lode, the country rock, iron-bearing in places, is evidently the conglomerate of the West Coast Range and the Dial, and the hardened sandstone beds in

Plate VI.

BLYTHE IRON FIELD

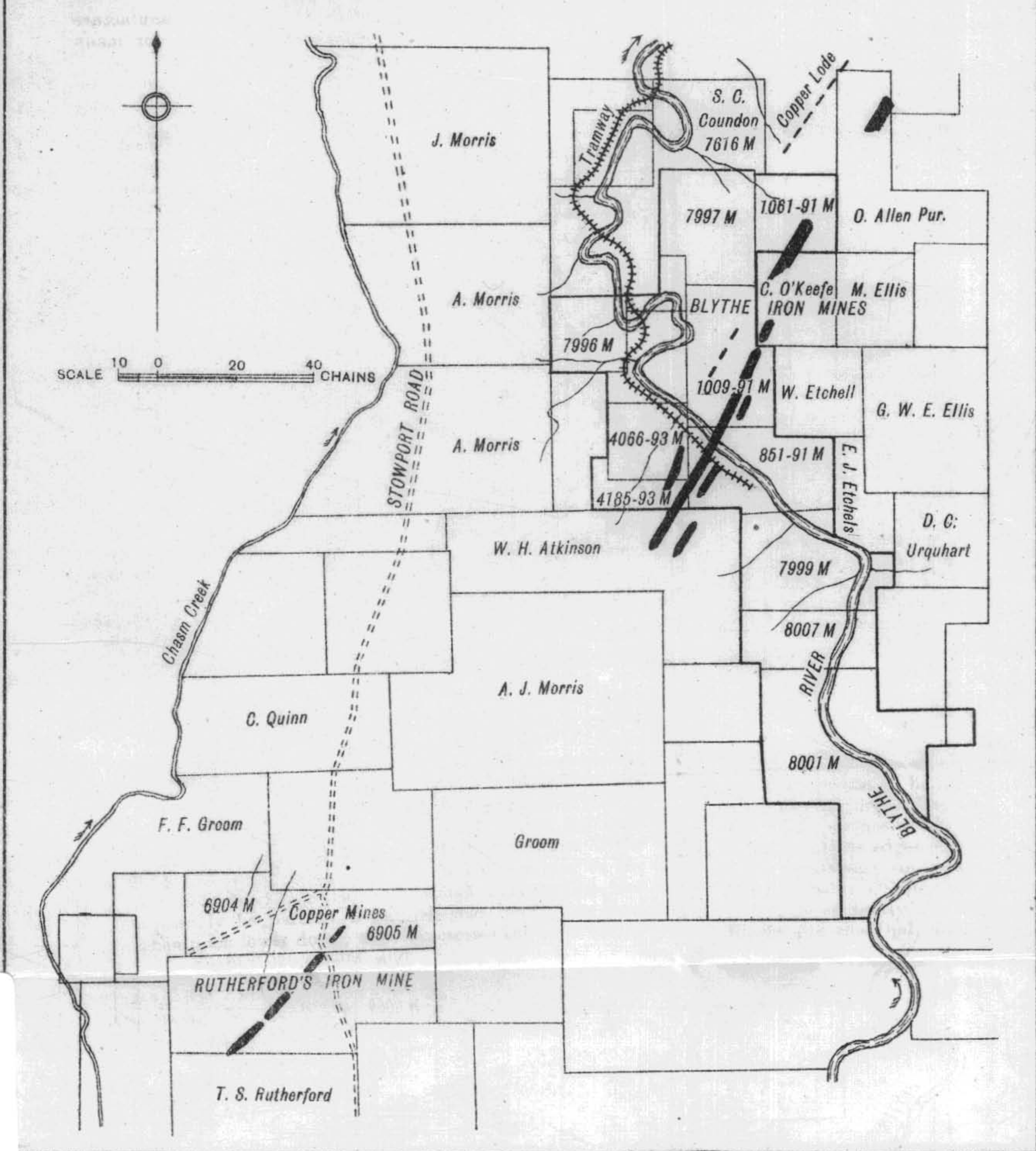


Photo Algraphed by John Vail Government Printer Hobart Tasmania.

immediate contact with the lode on its eastern side belong in all probability to the same series.

Mr. G. A. Waller, a former geological officer, adduced reasons for considering the West Coast Range conglomerate as the basal formation of the Silurian system in Tasmania. Owing to the accumulation of evidence, this view has lately been adopted by the Geological Survey, and the conglomerate removed from its provisional place in the Cambro-Ordovician to the Silurian.

A great deal has been said locally at one time or another about the possibility of the outcrop covering copper ore deposits. Of course, this question does not in the slightest degree affect the future of the Blythe Iron Mine as an iron ore property, for the huge outcrop continues to be non-cupriferous hematite-bearing material down to river-level. The absence of other lode minerals and the small proportion of limonite in the lode rather contra-indicate the existence of a copper lode in depth; a large number of analyses have been made without disclosing the presence of copper sulphides or any other ore. At the same time, there appears to have been a deposition of copper along parallel lines, and wherever the iron development is strong the parallel copper deposition is also pronounced. At the northern end of the iron lode the hard siliceous contact-rock is sparsely impregnated with specularite, iron, and copper pyrites. This strengthens a supposition that the deposition of both iron and copper ores formed part of one and the same physical process.

The lode at the Blythe has no doubt genetic associations with the granite which comes in at the southern boundary of Rutherford's land further south, or, more strictly speaking, with the acid magma, of which the granite is the manifestation and outcome. The relations, however, are not those of contact-metamorphism. The ore is not magnetic, and there are no characteristic minerals of a contact aureole. The deposition, it may be conjectured, has been by way of precipitation from solutions. Without speculating specifically on the successive stages of deposition, the process may be regarded as having been metasomatic.

The lode is prominently shown on each side of the river by a series of huge crags projecting from the slopes of the hill as they descend to the stream. The upper crag on the north side appears to be east of the main outcrop line, and may possibly be part of a parallel lens which has been trenched upon lower down, and also crosses the river east of the main line of outcrop. This eastern lens seems to be of a decidedly siliceous nature. Its continuation northerly is obscure. The main lode runs north from the river for about three-quarters of a mile, 26 chains of which are below a capping of olivine basalt of Tertiary age. This sheet of lava is between 100 and 150 feet in thickness. The lode emerges from below the northern edge of the lava and continues half-way through Section 1061.

The width of the lode north of the river and at different horizons varies a good deal. At the river itself it is not more than 30 feet wide, while higher up and some chains north of the river the width of outcrop is 50 feet, and north of O'Keefe's quarry the solid ore at surface at different points measures from 80 to 100 feet across, widest at the northern end.

The lode-width at the point where the river flows across the formation has been taken by the Commonwealth engineers(8) as an indication that the lode is thinning out in depth along its entire course, but it is doubtful whether this assumption is sound. The explanation suggests itself that the river may mark the thin end of a lens, which was chosen by the stream as a path of least resistance.

On the south side of the river the lode occurs as lenses showing in the form of large crags, not always on the same line, and separated by areas of intervening country-rock. The base of the lowest crag is between 140 and 150 feet wide. At the top of the crag a trench exposes the ore and ore-ground for 4 chains.

Higher up is what is known as the "Purgle Crag," a mass of dense lumpy iron ore, projecting in a striking way from the hillside. The crag is over 100 feet in width, siliceous ore extending further west, concealed below the overburden of soil. In the crag itself is excellent ore. Still greater widths have been ascribed to the ore-deposit on this side of the river, but these probably include intervening bands of iron-stained country between parallel iron formations, of which there are some signs. Further, there is a siliceous upper crag to the east—possibly a parallel lens.

The origin of the Purple Crag is not quite clear. The view advanced that it is merely a surface formation deserves examination, although appearing somewhat improbable. Those familiar with the features of the Tas-

(8) In a recent examination on behalf of the Federal Government.

manian conglomerates and breccias of this age will recall similar occurrences of brecciated ore without adopting for them a recent origin. Such may alternate with other beds in which the replacement has been imperfect. Naturally, the view adopted in the present case will inevitably affect the tonnage-estimate considerably. Samples which the writer took from the Purple Crag in 1900 yielded on assay by the Government Analyst 68·6 per cent. iron, 1·8 per cent. silica, 0·09 per cent. phosphorus, and traces only of sulphur. The sampling carried out by the Commonwealth engineers in 5-feet sections shows results ranging from 57·96 per cent. iron and 12·92 per cent. silica to 66·56 per cent. iron and 2·26 per cent. silica.

Speaking generally, there is so much siliceous lode-material and iron-stained country-rock on the south side of the river that a good deal of work is necessary in order to ascertain the boundaries and actual average quality of the ore-bodies. The old estimates and the present Commonwealth estimates have, in the absence of this work, merely a partial and tentative value. But the apparent lenses in this area cannot be excluded from the consideration of the Blythe River lode as a whole. The development of high-grade hematite ore on Rutherford's property further south shows that the ore-belt is not restricted to the north side of the river, but continues a considerable distance beyond the limits of the Company's leases.

The tunnels which have been driven into the lode on the north side of the river are three in number, viz.:—The old Central tunnel at between 500 and 600 feet from the river and 280 feet above the level of the water (aneroid measurement); Mr. Darby's lower tunnel at the river; and his upper tunnel below one of the northern outcrops.

The central tunnel, as was pointed out by the writer in a previous report, was driven in a badly-chosen spot, in a poor-looking part of the line between two large crags of ore which project from the surface on this side of the hill. It is a crosscut tunnel through the ore-bed, which is here 54 feet across. The tunnel is only 50 feet below the outcrop, which had nothing to recommend it, consisting of soft to stony material. The ore cut was of inferior grade, the impression left on the writer's mind being that perhaps 10 per cent. might be good ore, the rest being earthy and siliceous. The best ore assayed 56·7 per cent. iron and 18·8 per cent. silica. Going southwards from here the outcrop increases in width, till at a point about 400 feet above the river it is about 80 feet wide.

The lower tunnel was driven opposite to the old bridge which used to cross the river at that spot, and was put into the hill 225 feet on the western or footwall side of the lode, which latter has been tapped by seven crosscuts. The lode underlies to the south-east, passing beneath about 40 feet of soft slate country, which is succeeded by a jaspery ridge, and 80 feet of siliceous and brecciated iron ore, most of which is earthy and stony, though some of it looks of fair quality. This may be taken to be the eastern parallel lode.

Outside the entrance on the writer's previous visit was an old pile of ore broken from the outcrop, consisting of solid hematite free from visible silica. There were also piles of good ore from the crosscuts, especially from the 77-feet crosscut.

The first crosscut has been driven at 30 feet from the tunnel-mouth for a distance of 12 feet, the last six of which were in dense ore without visible silica.

The second crosscut, at 45 feet, was driven east 6 feet to the ore, and then stopped.

The third crosscut, at 66 feet, was driven 6 feet in ore of a jaspery and stony nature, the assay showing 46 per cent. iron and 34·2 per cent. silica.

The fourth crosscut, at 77 feet, was driven 17 feet in hard solid ore, assaying 65 per cent. iron and 7 per cent. silica.

The fifth crosscut, at 142 feet, cut into ore for 6 feet, assaying 67·2 per cent. iron and 3·8 per cent. silica.

The sixth crosscut, at 167 feet, was 25 feet in ore. Some good ore can be got from this crosscut, assaying 68·1 per cent. iron and 2·4 per cent. silica, but patchy. On the whole, the material is impure and lumpy, and in the face cherty with a hackly fracture.

At 189 feet the ore was merely cut into for a foot, and appeared good and solid.

At 199 feet good-looking ore was just exposed by a cut into the wall of level (assay 65·5 per cent. iron and 2 per cent. silica). Siliceous material showed on the western wall.

The seventh crosscut, at 225 feet, was driven in ore 13 feet. Some of this was good, assaying 68·7 per cent. iron and 1·6 per cent. silica, but most of it was lumpy and suspiciously hackly with a short fracture. Some of the lode-matter is rather fine, and would have to be cautiously mixed with other ores.

It will be noticed that in no instance has a crosscut been driven right through the lode; the latter has sometimes been tapped for a few feet only, or even merely exposed by a cut. The object appears to have been to obtain assurance that the lode was descending from surface in strength. Some good payable ore has been disclosed, but associated with siliceous material. The assays of samples taken by the Commonwealth experts across the lode at entrance to the tunnel yielded 54 per cent. iron and 31 per cent. silica. Such results are possible from a given section of the lode if in a cherty zone.

The upper tunnel is situate in the northern part of the lode, about 600 feet vertically above the lower one. It has cut the lode at about 80 feet below the outcrop, and has traversed the ore-body for 84 feet without passing through it. A few yards more driving would probably have taken it through the lode. The ore is solid, and has the appearance of being good, though the writer's samples did not yield the best results, giving 59·8 per cent. iron and 14·4 per cent. silica. Soft siliceous and earthy patches occur, and one of these has been entered at the end of tunnel. This tunnel also shows that the surface outcrop is not an encrusting capping, but that the lode descends with the enclosing strata. The trenches north of the tunnel show dense ore associated with silica. The Commonwealth experts formed the opinion that the ore in this tunnel is very cherty and siliceous throughout, though they say some of the ore looked fairly good, and some nice clean ore is showing in one or two places on the surface immediately over the tunnel. The results, they say, go a long way towards proving the irregularity and non-continuity of the better grade of ore exposed on the surface. Their complete sampling showed 54·3 per cent. iron and 25 per cent. silica.

A small quarry in the northern part of O'Keefe's 50 acres shows some very good-looking hard hematite, from which the writer got samples assaying as much as 68·4 per cent. iron, with only 2·2 per cent. silica. The thousand tons of ore which were sent away by the company are said to have been broken from this quarry. As usual, there is some mottled siliceous ore with the higher-grade hematite, and the samples taken by the Commonwealth experts averaged 56·4 per cent. iron and 19·11 per cent. silica.

If the fine outcrops are worth anything as an indication, they encourage the hope that actual work will show that all along the line adequate quantities of payable ore will be found available for many years to come. It is true that the trench work and close sampling carried out by the visiting experts in certain parts of the lode seem to justify the opinion that the average silica contents are unduly high, so far as those samples and trenches are concerned, but the real question is what proportions obtain in the lode as a whole. This must remain a matter of opinion until the lode is thoroughly tested and opened up in the course of working. It will then be possible also to determine how far it is practicable to reject excessively siliceous and waste stuff without going to too great expense. Mr. Darby's opinion was that there may be half a ton of refuse in 1 ton of ore, or equal bulk of each.

Mr. Darby gives the results of analysis of an average surface-sample taken from the whole deposit, and these may be placed by the side of an analysis given by the Commonwealth experts of a composite sample from proportional parts of 23 samples of fairly-good ore from different parts of the lode, as follow:—

	Mr. Darby. Per Cent.		Commonwealth Experts. Per Cent.	
Ferric oxide	86·954	= iron 63·259%	89·68	= iron 63 71%
Ferrous oxide	3·074		1·2	
Silica	7·312		7·76	
Alumina	1·756		0·620	
Lime	0·068		0·165	
Magnesia	0·071		Trace	
Sulphur trioxide	0·060	= sulphur 0·024%	0·135	= sulphur 0·054%
Phosphorus pentoxide	0·083	= % phosphorus 0·036%	0·119	= phosphorus 0·052%
Titanic acid	0·03		Nil	
Copper.........	Trace		Trace	
Arsenic	Trace		—	
Manganese ...	Trace		0·078 manganous oxide	
Chromium ...	Absent		Nil	
Combined water	0·324		0·54	
Moisture	0·160		0·13	

These analyses of the good ore at the Blythe do not differ essentially from each other. The crucial question after all is one of tonnage.

The writer, on his recent visit, took samples of good hematite exposed at and near the quarry on O'Keefe's section in the northern part of the lode, and from the southern end of the outcrop. These were assayed by Mr.

W. D. Reid, Government Assayer, with the following results:—

	Northern Samples.	South of River.	River Bank, South Side.
	Per Cent.	Per Cent.	Per Cent.
Iron	66·10	69·00	64·36
Silica...	5·20	1·20	6·20
Sulphur...	0·063	0·057	0·07
Phosphorus...	0·002	0·02	0·002
Moisture at 110° C.	0·12	0·14	0·08

Some of the more siliceous ore on the south side of the river was taken for assay, and yielded the following result:—

	Per Cent.
Iron	44·63
Silica	32·80
Sulphur	0·04
Phosphorus	0·001
Moisture at 110° C.	0·16

Such stone is too impure for treatment in the furnace.

From various reports it can be gathered that some of the ore is of excellent quality. Mr. J. R. M. Robertson, of Sydney, reported in 1891 to Messrs. Henry Law and Co.:—

> "I know of no deposit of iron ore so pure, and consequently so admirably fitted for producing the highest and best brands of iron and steel."

The "Australian Mining Standard" of July 20, 1891, contains an account of experiments made at Halliday's Engine Works, 20 Erskine-street, Sydney, with a 4-cwt. sample of Blythe River ore:—

> "Mr. Brazenhall informs us that he charged an ordinary foundry furnace with 3 cwt. of the Tasmanian iron ore and about 14 lb. of limestone, and ran the iron smelted into pigs. He afterwards made castings of various descriptions from the pigs thus produced, and had a cast mandrill put into the lathe to show that the iron was not too hard for machining. The iron proved of the very highest quality, of exceedingly fine and close grain, and very tough. In addition to the cast-iron, a small quantity of puddle bar-iron was secured, owing to the furnace not being entirely adapted for producing cast-iron, and wrought-iron has been worked up with the most satisfactory results."

Mr. A. Montgomery, M.A., Government Geologist for Tasmania, in 1894 reported in that year as follows:—

"As it was quite impossible for me in the undeveloped state of the mine to obtain a sample of the ore which would at all fairly represent its average bulk value, and as such a sample would indeed be of no particular use, inasmuch as in actual working a lot of lean ore would be necessarily rejected, I only took a few samples of the best-looking boulders in the river for analysis. They may be looked upon as fairly representing the best ore, but from inspection I should judge that many thousands of tons of equally good stuff could be readily obtained. What the average yield of such first-class ore from the bulk of the deposit would be is, as already remarked, only to be ascertained after it has been opened out by trenches and cuttings.

"The samples taken were forwarded to Mr. W. F. Ward, Government Analyst, in Hobart, with instructions to have them carefully examined for all impurities likely to interfere with the quality of the iron to be made from the ore. He reports the analysis as follows:—

	Per Cent.
Iron peroxide...	95·2% = iron 66·4%
Silica	4·8%
Phosphoric acid	Traces

This ore is of excellent quality, being practically free from all impurities with the exception of the silica. It resembles the well-known Cumberland red hematite, so long used for the production of steel by the Bessemer process."

Mr. Montgomery goes on to say that, according to these analyses, the Blythe River hematite is one of the finest and purest in the world.

The estimates of quantity which have been made by various observers at different times must be regarded as subject to the limitations which inevitably attach to the consideration of imperfectly tested properties. They are as follow:—

1894, Mr. A. Montgomery, 30,000,000 tons gross.
1900, Mr. J. H. Darby, 24,500,000 tons net.
1901, Mr. W. H. Twelvetrees, from 17,000,000 to 23,000,000 tons net.

1919, Messrs. Boyd, Gibson, & Young, 9,000,000 tons, the bulk of which is regarded as being too siliceous for an iron ore at the present day.

The following will indicate the bases adopted for these estimates:—

Mr. Montgomery says:—

"The deposit must be one of the largest also, containing many millions of tons. The data for calculating its size are very insufficient, but taking them such as they are, a rough calculation may be made which will serve to give some idea of it. On the south side of the river, the ore is seen for a horizontal distance of about 8½ chains, and rises to a height of 280 feet above the stream; on the north side it rises to 500 feet above the river in about 50 chains horizontal distance, and then falls a little, say to 400 feet, for another 16 chains. Taking the width of the ore-body at 66 yards, these measurements give the cubic contents of the deposit under the visible outcrop down to the level of the Blythe River as slightly over 10,000,000 cubic yards, or, at 3 tons to the cubic yard, 30,000,000 tons. It is not to be supposed that the ore terminates where the outcrop disappears under the superficial basalt, or that it only goes down to the level of the Blythe River."(9)

A good deal of the bush has been cleared away since the above report, and the width of the lode has been ascertained to be less than was surmised.

Mr. Darby reported that as he only saw the crosscut of the deposit made by the Blythe River and the solid ore blasted out in a few places, he was unable to state how many million tons are actually to be obtained, but could say that after thoroughly examining the surface, there are overwhelming indications at many points in over a mile of country of an immense deposit of hematite.

He proceeds:—

"In estimating the probable quantity of ore, I have taken the river bed as the bottom, although it is nearly certain to extend down much further, and have measured the width of the deposit where the sides are well defined. The cubical content of the deposit, which

(9) Report of the Secretary for Mines, 1893-4 (p. xxii.).

I have thought it advisable to divide by two, at 3 tons per cubic yard, yields 24,500,000 tons of selected ore."

The estimate of 17,000,000 tons marketable ore made by the writer was based on a horizontal lode length of 90 chains, and average widths and height above river level for separate sections, deducting 50 per cent. for waste rock. Taking the lode length as a mile, and the width as 100 feet, nearly the same result is obtained.

These three estimates, it will be observed, are rough and tentative, and assume the existence of concealed sections of the ore-body, besides involving personal opinions as to the average nature and quality of the ore. The estimate of Messrs. Boyd, Gibson, and Young, however, belongs to a different category, being confined to segments of the lode, on which some prospecting, however imperfect, has been carried out, and making some pretension to the valuation of definite blocks of ore. Being a buyers' valuation, all portions of the lode which cannot be demonstrated to contain sufficient usable ore are cut out, and, of course, potentialities and so on are not admissible. These necessary limitations, while meeting the requirements of an intending purchaser preclude the consideration of the general prospects and possibilities of the lode from the standpoint of its eventual contribution to the iron resources of the State. The additional trenches and excavations made under the direction of the Commonwealth experts have, as far as they have gone, given results not altogether reassuring; that is to say, they have shown the existence of more siliceous ore than was expected, and they indicate the necessity for the lessees to exercise care in deciding where they will open out in starting production. The company's advising engineers will, no doubt, in the first instance, lay out a well-considered prospecting scheme, and then locate the sites for their quarries. It is possible that a quarter of the whole tonnage exists to the south of the river, but very little is really known of the ore-bodies on that side of the Blythe, and they suffer under the disadvantage of being less accessible than the northern part of the lode. The lessees will probably look ahead for 20 or 25 years, and, if aiming at a moderate metal production with the aid of the State hydro-electric current, say, perhaps, 100,000 tons annually, they will require to assure themselves of an ore-supply to the extent of 4,000,000 to 5,000,000 tons, or double that quantity if they desire to double the production. It is regrettable that so many years have elapsed without opening up and practically establishing the value of the property.

The possibility of reducing the average silica content by selection and blending will have to be investigated. The mere presence of siliceous ores does not invalidate the claims of an iron property to serious attention. Some of the Lake Superior ores, as shipped, contain as much as 34 to 40 per cent. silica, but the proportion is brought down by mixing with the purer grades to an average of under 10 per cent.(10).

The facilities for ore-raising are good. Points for open-cut workings can be easily selected in the solid crags and outcrops of ore standing out on the hill-sides, and the ore sent down at no unusual expense to river-level for despatch to works. If the smelters are erected at the mouth of the Blythe, the old tramway route from the mine (some 6½ miles) can be used for laying down rails and connecting with the Government line at the coast. There would be a further transport of the finished product over a distance of 5 miles to Burnie, where interstate vessels can load with ease.

(10) "The Geology of the Lake Superior Region," by C. R. V. Hise and C. K. Leith. United States Monograph, Vol. LII., 1911 (p. 273).

V.—RUTHERFORD IRON LODE.

This is situated about 2 miles south-west of the most southerly exposure of the Blythe iron lode. It is on the northern half of 320 acres purchased land charted in the name of T. S. Rutherford, a block which as been recently subdivided. The northern subdivision comprises 158 acres, and it is in this part that the lode outcrops occur.

Between here and the Blythe River lode are undulating farm lands, with the exception of two mineral leases of 60 and 47 acres respectively, which have been worked by the Price Copper Mining Company, No Liability, with indifferent results. The farm lands have the basaltic soil characteristic of much of the North-West Coast.

The Rutherford main outcrop unquestionably marks the general continuation of the Blythe ore line. The southern outcrop of the latter disappears below the covering of basalt inside W. H. Atkinson's 186 acres, and, on this interpretation, reappears in the central knob of ore in Rutherford's 158 acres.

The cutting on the Main-road has intersected a soft ferruginous formation about 10 feet wide, south of which is a knob of ground strewn with boulders of rather soft brown hematite. A shaft has been sunk 40 or 50 feet without getting anything very solid; there is a possibility that it was put down a little too far east to strike the lode exposed in the cutting. This cutting lode may not actually be the continuation of the main Blythe lode, or, again, despite its dissimilarity, it may be the tail end of one of the Blythe lenses.

Further south, on lower ground, are some boulders of hard hematite, indicating an outcrop, and still further south, in about the centre of the block, the lode rises to a hill some 60 feet above the creek-level. This part of the outcrop shows an excellent hard hematite, in appearance indistinguishable from that of the Blythe. The outcrop appears as if it might be slightly off the Blythe line of lode, but this may possibly be due to difference of level or to the development of the ore-bodies in the form of more or less discontinuous lenses. There is an old shaft near the top of the outcrop on this knob, but the bottom of it is not now accessible. Reports are to the effect that this shaft was not very satisfactory; it seems to have been sunk in somewhat soft ground, which may have been outside the edge of one of the ore lenses. It would be desirable to prospect the whole line of country with a view of establishing the nature and extent of the ore-body. The hill at the base is 9 or 10 chains across, but in the absence of work it is impossible to state the true width of the lode. At present the width of the boulder-strewn surface is the only criterion, and may lead to erroneous conclusions.

Some crystallised and micaceous hematite of excellent quality occurs on this line a few chains further south, and stones of iron ore are met with in the soil right up to the south boundary of the 158 acres.

The lode-line, therefore, shows signs of traversing the block for over ¼-mile, and in addition there is the doubtful section of the lode near the road. As the solid outcrops are marked by hard knobs of ore only at intervals, it may well be that the lode is of unequal value at different points, especially if the general occurrence is lenticular.

Typical specimens of good ore were broken from different parts of the lode, and these have been assayed by the Government Assayer in the Geological Survey laboratory with the following results:—

	No. 1. Typical Ore.	No. 2. Micaceous Ore.
	Per Cent.	Per Cent.
Iron	68·94	67·06
Silica	1·53	2·16
Sulphur	0·01	0·03
Phosphorus...	0·05	0·06

A sample taken in 1903, and assayed by Mr. W. F. Ward, Government Analyst, gave the following results:—

	Per Cent.
Iron	58·00
Silica	2·40
Sulphur	Traces
Phosphorus	0·05

From the assays it will be seen that the ore has a high metallic value, and is specially low in silica and sulphur. The phosphorus is not excessive for an ore of that grade.

The pieces of Sample No. 1 were chipped off the solid outcrop on the central hill. In all probability it will be found that there exists a good solid mass of approximately this quality. Sample No. 2 comes from a little distance to the south, and all one can say is that it looks as if the lode were continuous between the two points. This is also a very good-quality ore. A systematic sampling, however, can be carried out only when the lode is cut into at regular intervals. The above, nevertheless, are sufficient to indicate a deposit which contains ore of exceptional purity.

The property is connected with the coast by a good road, the distance being a little over 7 miles to Wivenhoe railway-station. If work is started at the Blythe, the best way of developing the Rutherford ore-body, if prospecting results are satisfactory, would probably be to mine the ore and deliver it to the Blythe furnaces.

VI.—IRON ORE IN LONG PLAIN AND ZEEHAN DISTRICTS.

(By A. McIntosh Reid.)

(1)—Introduction.

In the following pages an account is given of the results of an investigation into the origin, nature, and extent of the magnetic iron ore deposits of the Western Division. It has been deemed advisable to present this account in two parts. One paper deals with the ore-bodies of the Long Plain district, the other with those in the vicinity of Mt. Heemskirk, in the district of Zeehan. Only the easily accessible of the commercially important deposits were examined, and of these the largest only in detail.

Several examinations of the ores of these fields have already been made by the Geological Survey. The early investigations of these occurrences were in relation to the associated silver and gold bearing copper, lead, and zinc ores, and not as to their value as sources of iron; but in later reports consideration was given to the economic features of the iron-bearing portions of the deposits. The last official examination of the Rio Tinto and Rocky River ore-bodies, in the Long Plain district, was made by W. H. Twelvetrees in 1903; and G. A. Waller, in 1902, investigated the large magnetite ore-bodies on the Tenth Legion property, and also the magnetic iron outcrops on Davern's leases, both of which lie in the western part of the Zeehan district.

Long Plain district is in the County of Russell, between Waratah and the sea-coast; Zeehan district lies in the County of Montagu, 25 miles southward from Long Plain.

(2)—Long Plain Iron-ore Field.

The deposits of magnetite described in these pages, as well as many others smaller in extent occurring in this locality, have been known for many years. They were originally discovered by Surveyor-General Sprent on one of his early expeditions through the western districts. It was considered at the time that the huge outcrops were cappings of tinstone deposits, and when this anticipation was not realised, the prospects were abandoned. However, several years later prospecting was resumed on the associated pyritic ore-bodies, which were found to contain chalcopyrite, gold, and silver. Subsequently large exploratory works were undertaken by wealthy mining companies at Rio Tinto, Rocky River, and at intermediate points; but in no occurrence were the metals sought after sufficiently concentrated to be of economic value. These immense magnetic deposits have been repeatedly noted by the Geological Survey, but their possibilities as sources of iron have not been fully realised until recent time. This investigation has shown that the extent of high-grade magnetic iron is much larger, both in the Rio Tinto and Rocky River areas, than anyone had reason to anticipate.

The Rio Tinto portion of the iron field lies 25 miles by road south-westward from Waratah, and 20 miles from the port of Corinna, on the Pieman River. A fairly well-graded road has been constructed from Waratah over the Magnet Range to the edge of Long Plain, whence it is connected with the terminus of the road leading from Corinna by a 10-mile track.

The iron ore occurs in disconnected masses contained in a belt of metamorphosed gabbro-amphibolite, ½-mile wide by 25 miles long, running 8 degrees west of north and south of east. They lie for the most part on the eastern side of Savage River, but cross the valley at Rio Tinto, and extend northward to Specimen Reef goldfield. Southward they continue on the western confines of Long Plain, cross the Whyte and Rocky Rivers near their confluence, and extend beyond Paradise River. The surface of this area is a tableland (Long Plain), 1100 to 1200 feet above sea-level, which is portion of an old Tertiary erosion channel. Much of the surface is gently undulating, with shallow serrated stream valleys, but in the vicinity of Savage River the effects of erosion are more pronounced.

A.—PETROLOGY.

Although the rocks which contain the magnetite deposits of the Long Plain and Zeehan districts differ in composition and in structure, as well as in age, yet in many respects they are remarkably similar. The former are described as hornblendic, serpentinous, quartzose, and talcose schists belonging to the Pre-Cambrian, while the latter are gabbro-amphibolites of Devonian age. Generally the metamorphosis of the Pre-Cambrian schists of Long

Plain has been intense; but in certain parts the hornblendic rock occurs devoid of banding, foliation, or schistosity, having the macroscopic appearance of gabbro-amphibolite. These formations were examined by W. H. Twelvetrees, Government Geologist, who makes the following comments:—(11)

> "The gneissose gabbro-amphibolite is enclosed in talc schists, into which it apparently passes. In places it is a pale banded gneiss; at other spots it is fissile and compact, passing into a hornblendic schist; or, again, it is coarse and gabbroid in texture. its colours are green and grey in various shades. It consists of a fibrous green hornblende, with large gabbroid-like plates of plagioclastic felspar, apatite, quartz, and a good deal of epidote. Talc, hornblende (actinolite), asbestos, calcite, dolomite, and serpentine occur in its more decomposed portions. The hornblende is often in streaks or bands, giving the rock its gneissose character."

The associated secondary minerals enumerated are typical metamorphic products of the original components of basic igneous rocks.

The absolute age of these hornblendic, talcose, and quartzose schists has not been determined. They have been tentatively ascribed to the Pre-Cambrian, because—(1) their extreme metamorphism compared with the Devonian gabbros, pyroxenites, and peridotites occurring in the neighbourhood, suggests an extreme age; and (2), because of the conformity of the planes of scistosity with the cleavage planes of contiguous strata, which on lithological grounds are considered to belong to the Pre-Cambrian.

B.—GEOLOGY.

The oldest rock-formations in this area are the hornblendic, serpentinous, and talcose schists of igneous origin, and the adjacent metamorphosed slates and sandstones, which are tentatively ascribed to the Pre-Cambrian. It is noteworthy that the trend of the structural planes of the schists is a little east of north, whereas the strike of the schist zone is north-westerly. Further east, in the Heazlewood area, fossiliferous Silurian slates and sandstones

(11) *Vide* W. H. Twelvetrees: "Report on Mineral Fields between Waratah and Corinna"—Report of the Secretary for Mines, Tasmania, 1900-01.

appear. These latter have been intruded by large masses of gabbro and peridotite rock, followed in this period (Devonian) by granites and syenites, which penetrated both slates and gabbros. The Devonian intrusives (gabbro and granite) outcrop 3 to 5 miles from the Rio Tinto ore-deposits.

All of the rock-formations occurring on Long Plain are more or less covered by unconsolidated and partly consolidated alluvial and detrital material. Near the goldfields occurs conglomerate, made up of angular to subangular and rounded quartz pebbles firmly cemented together. It has the appearance at first sight of an old consolidated rock, but it is evidently Tertiary.

Along the line of lode between Long Plain and Specimen Reef, patches of Tertiary basalt occupy the ridges. This eruptive rock is posterior to the Tertiary stream gravels and conglomerates.

C.—ECONOMIC GEOLOGY.

The solutions of the problems relating to the genesis of the magnetite deposits occurring in conformity with the hornblende schists in which they are contained appear difficult at first sight; but a closer investigation reveals the fact that, like those of the later occurrences in gabbro-amphibolite dyke rocks near Mt. Heemskirk, in the Zeehan district, they are largely the result of magmatic segregation. The conformity of the lenticular deposits with the planes of schistosity, and the banded structure exhibited by the magnetite ore, were formerly regarded as evidences of metasomatism. This evidence is inconclusive, for magnetite naturally assumes this banded form in conformity with the structural planes developed in the rock during the solidification of the basic magma; and, again, schistosity may have been developed in it during the transformation of the igneous rock. It has already been pointed out that the igneous schists of Long Plain and the gabbro-amphibolite rocks of the Zeehan district are widely separated in age, but they are, nevertheless, closely related types. In general, the old igneous schists have been subjected to extreme metamorphosis, but in certain parts comparatively little alteration has taken place, and the rock exhibits the appearance of a normal gabbro-amphibolite. As the dyke rocks in both cases are identical, not only in regard to their composition, but also to the nature of their occurrence, so are the contained ore-bodies regarded as having been formed under essentially similar conditions.

It is well known that iron minerals, such as magnetite, pyrite, and pyrrhotite, are frequent and almost universal constituents of basic irruptive rocks. Again, nickel and cobalt are pronounced basic elements, and are almost without exception found genetically associated with rocks of the gabbro and peridotite types. Nickel minerals are often found mechanically contained in pyrrhotite, and chalcopyrite is one of their common associates. Minerals, such as magnetite, pyrite, pyrrhotite, and chalcopyrite, with accompanying nickel and cobalt compounds, being less soluble than other substances present in the magma, crystallise out first. During this crystallisation the particles of ferrous oxide (in the form of magnetite), of ferrous sulphide (in the form of pyrrhotite), and ferric pyrite were aggregated, in the order of the degree of their insolubility, in irregular bodies called lenses. Thus are found sulphide segregations associated with massive magnetite deposits. At the Long Plain the bulk of the ore was deposited as ferrous oxide rather than as sulphide, for perfectly crystallised magnetite in the form of rhombic dodecahedra has been frequently noted in the massive ore-bodies, and the alteration of pyrite to magnetite has not been observed. The segregation of magnetite in gabbro magmas is analogous to that of chromite in peridotite.

Evidence of their origin by magmatic differentiation is contained in the following particulars:—

(1) The deposits are invariably associated with basic irruptive rocks, usually gabbro.
(2) A feature of these ore-concentrations is their occurrence in enormous lenticular bodies, almost without exception along the peripheral margins of the irruptive masses.
(3) In all cases observed, the strikes and dips coincide with the direction of the line of contact of the intrusive with the sedimentary formations, and not necessarily in conformity with the structural planes of the latter.
(4) The ore-bodies are contained in igneous rocks.
(5) There is generally a gradual transition of ore to rock as the borders of the deposit are approached.
(6) Pneumatolytic minerals are not present
(7) The ore-bodies sometimes enclose masses of igneous material.

(8) The associated dolomite is derived from basic igneous rocks, and does not contain an appreci able amount of magnetite.

(9) Limestone does not occur in the vicinity.

(10) Nickel and cobalt minerals are associated with the pyrite component.

Since the banded nature of the pyrite, hematite, and magnetite suggests a metasomatic replacement of the crystalline schists, it is probable, especially in the case of the pyrite component, that the deposits may in part be due to contact metamorphosis, or that they are older deposits which have undergone change subsequent to their original formation. This alternative is quite possible, as great masses of gabbro and granite occur in the neighbourhood Limonite, hematite, and pyrite, replacing hornblende schists, have been commonly noted, and hematite containing cores of pyrite has been repeatedly observed, showing a possible derivation of hematite ore from pyrite. The mineralising solutions responsible for the later ore-deposits have been largely composed of carbonic and sulphurous acids.

Although the evidence relating to their origin is admittedly inconclusive, it is considered that the iron ore-bodies here to be described occur in the main as magmatic segregations.

D.—THE MINES.

(1)—*Rio Tinto Deposits.*

(*a*) Preliminary Statement.

The properties enclosing these deposits, between the Long Plain and Specimen Reef goldfields, are now held under lease by a Waratah syndicate, for which L. Vardy of that town is the secretary. The members of this syndicate, recognising that the enormous consumption and the increased cost of production of iron and steel in other countries during the last few years, would lead to the establishment of extensive works in Australia, have been energetically engaged upon exploratory work, with a view to the early exploitation of the Rio Tinto deposits.

(*b*) The Ore-bodies.

This magnetite ore-field is the largest in Tasmania. It consists of a number of enormous disconnected lenticular masses, extending almost continuously for 3 miles, with

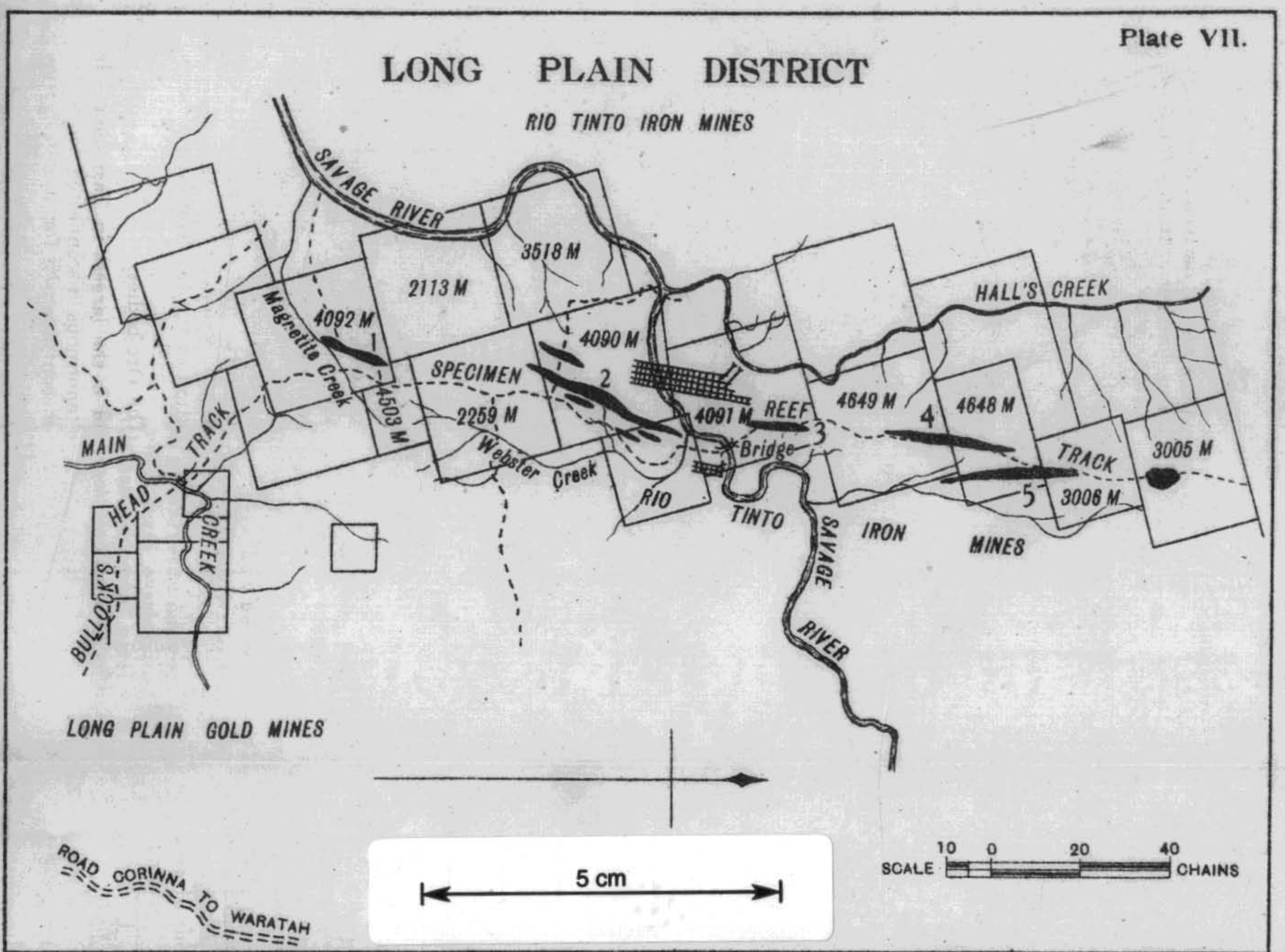


Photo Algraphed by John Vail Government Printer Hobart Tasmania.

other lenses at long intervals. The deposits are found in a zone of talcose, hornblendic, and quartzose schists, which strike N.N.W., and dip 60 to 80 degrees to the east.

These lenses occupy the summits of a series of high steep-walled ridges, trending in a general meridional direction, which stand out prominently above their surroundings in consequence of the greater power of resistance which the magnetite material affords to the denuding effect of erosive agencies. Erosion has, nevertheless, reduced the ore-deposits considerably, as shown by the deep and wide taluses of iron ore on the hill slopes.

The ore consists chiefly of magnetite, and subordinately of hematite. Associated with some of the deposits are small quantities of pyrite, pyrrhotite, chalcopyrite, and ores of nickel and cobalt, with also a little gold and silver. No trace of sulphidic minerals, however, has been observed at the outcrops, and they do not appear to become prominent within 200 feet of the surface. Moreover, they do not occur intimately admixed with the magnetite in the main ore-bodies, but are found usually in separate bands adjacent thereto.

The ore, as a rule, is fairly coarse-grained, very compact, and hard. In the massive portions of the ore-bodies magnetite commonly occurs in perfectly-formed rhombic dodecahedra, and, more rarely, in octahedra. Towards the centre of the deposits the ore presents an extremely dense crystalline appearance. At many points in the outcrops, however, alteration to hematite and limonite has taken place.

The deposits are in great part steeply inclined, and are conformable to the schists; while the ore, especially the hematite and limonite components thereof, exhibits the structure of the enclosing rock. In some lenses hematite is the dominant mineral, and magnetite is in unimportant amount; but, generally, the ore almost exclusively consists of magnetite. Sulphidic minerals increase with depth, and effect the schistose appearance of the country-rock.

The length of the largest lens is 2000 feet, and the width about 100 feet. Others extend along the strike 1500 feet, for over 400 feet along the dip, and are from 40 to 60 feet thick.

No. 1 ore-body is a lenticualr mass of magnetite outcropping on Section 4502-M in conspicuous crags overlooking Magnetite Creek. It courses a little east of north, parallel to and about 300 feet west of the track leading to Specimen Reef goldfield. Beyond Magnetite Creek it has not been traced southward, but it continues along the ridge in the opposite direction for 800 feet. As seen in the massive outcrop it is 50 feet wide, and is composed of very dense, clean magnetite and hematite. Samples 7, 8, and 9 were taken from this ore-body.

The main lens of No. 2 group is a very large massive body of ore extending almost unbroken through Section 4090-M, and through the north-west corner of Section 4092-M, a distance of fully 2000 feet. It is 450 feet above sea-level in Savage River valley, whence it rises up the steep ridge southward to an elevation of 1100 feet, showing clean magnetite and hematite all the way. The width of this ore-body varies from point to point, being greatest on the ridge near the centre of the lens, and tapering gradually towards the ends. Float or detrital ore broken from the capping covers the hill slopes on both sides for 200 feet; but the actual width, which is very difficult to determine, appears to be from 40 to 60 feet. In the centre the ore is very dense and massive; on the sides hematitic and limonitic replacements of the schists, and the associated dolomite, are conspicuously in evidence. Analyses of samples 1 to 6, and 12, 14, and 15, convey an idea of the nature of this ore.

On the west side of this ore-body, near its southern extremity, occurs another lens, much smaller in extent, and separated from the larger ore-body by a band of schist 250 feet wide.

The analysis of sample 13 shows the ore to be similar to that contained in the other lodes. The extent of this lens has not been determined.

South of Webster Creek, on the east side of the northern extremity of the main ore-body, are two parallel lenses of very clean magnetite-hematite ore. Their actual dimensions are impossible of determination until developmental works have laid bare the unbroken lodes. A great quantity of float ore is strewn over the surface in this locality, completely obliterating the outlines of the ore-bodies. Pyritic ores have not been detected in any of the deposits already described.

Across a parallel formation, composed largely of semi-oxidised pyrite contained in graphitic-looking serpentinous schist, a tunnel has been driven eastward from the bank for 200 feet. A little gold has been detected in the pyritic ore, and also in quartz which occurs as irregular veinlets in the schists.

On the north bank of the river, 30 chains westwards from the bridge, two parallel tunnels 30 feet apart have been driven northerly on the course of an immense formation of hematite and magnetite, containing siderite, pyrite, pyrrhotite, and a little chalcopyrite, associated with asbestos, tremolite, serpentine, and dolomite. As seen in the bank of the river, the lode is fully 100 feet wide, and extends up the hillside 700 feet higher. The magnetite usually occurs in distinct bands 10 to 20 feet thick, but in parts it is seamed with veinlets of pyrite and other sulphidic ores. Here hematite blocks were found with cores of fine-grained pyrite: the magnetite, however, is primary and anterior to the pyrite. Later cross-fractures, dipping south-easterly at 45 degrees, in the sulphidic ore-body, are filled with dense pyrite. Sample 10, from this ore-body, consists of pyrite and hematite, and 11 is of fairly clean hematite.

On the other side of the river No. 3 tunnel was driven southward 178 feet through similar material. No. 4, ½-mile above the confluence of Savage River and Hall's Creek, was driven from the east bank of the latter 172 feet in a south-easterly direction. Ore is cut at 147 feet, and a few feet farther ahead is a band of chalcopyrite. From this point the tunnel passes through actinolite schist containing magnetite and pyrites. No. 2 lode lies east of No. 1, and has an outcrop of hematite and magnetite. A tunnel driven 386 feet along its course shows the lode 17 feet wide, composed of gossan, with native copper and cuprite and much siderite.

Between these two pyritic ore-bodies, 12 chains north of the bridge, another lens (No. 3) of clean magnetite is exposed on the ridge of the steep hill leading towards Specimen Reef. The surface outlines are obscured by clayey material and vegetation, so that its size could not be ascertained.

Ore-bodies Nos. 4 and 5, which follow, are the most extensive and richest of them all. No. 4 commences at ⅜-mile north of the bridge in Section 4649-M, at an elevation of 1000 feet above sea-level, and continues through Section 4648-M along the ridge of a steep hill in a general meridional course for 2000 feet. It is fully 100 feet wide, and consists of clean magnetite of an extremely dense texture. No impurities of any kind could be detected by eye in this ore, and its quality is shown by analysis No. 17.

No. 5 ore-body is of equal quality, and is perhaps even greater than its predecessor, from which it is separated by a band of schist 200 feet wide. It lies a little eastward of No. 4, following the ridge northward for 1500 feet and southward into Savage River valley. The western fall of the hill to Hall's Creek slopes at a very high angle, exposing a very long face of massive magnetite. In some cases the ore occurs in aggregates of almost perfect octahedra, in others rhombic dodecahedra are common. A remarkable feature of this outcrop is the quantity of float ore strewn over the surface, in pieces about 4 inches in diameter, of extraordinary regularity. Sample No. 16 was taken from this ore-body.

North of this outcrop basalt occupies the surface, but 30 chains farther on still another occurrence is found. This is a dome-shaped mass of considerable extent, essentially similar in composition and nature to those already described.

Several other deposits are known in this locality, but they are not of any considerable extent, and were not examined.

(*c*) Analyses.

The composition of the ore may be gathered from the following analyses made by Mr. W. D. Reid, Government Assayer, in the Geological Survey Laboratory:—

No.	Kind of Ore	Iron.	Manganese Dioxide.	Titanic Oxide.	Silica.	Alumina.	Phosphoric Acid.	Sulphur
		%	%	%	%	%	%	%
1	Magnetite ...	67·0	2·37	Trace	1·50	0·12	0·02	0 05
2	Magnetite ...	68·5	...	...	1·68	0·18	0·02	0·07
3	Magnetite ...	69·2	...	...	0·86	0·07	0·03	0·06
4	Magnetite ...	68·1	...	...	2·40	0·22	0·04	0·13
5	Magnetite ...	69·25	...	...	0·94	0·03	0·01	0·02
6	Magnetite ...	69·5	...	...	0·63	0·02	Nil	0 01
7	Hematite......	63·1	...	...	0·50	...	0·38	0·03
8	Hematite......	64·3	...	...	0·46	...	0·29	0·02
9	Hematite......	63·4	...	...	0·52	...	0·16	0·02
10	Magnetite & pyrite	64·00	...	...	1·73	...	0·04	3·66
11	Magnetite & Hematite...	68·30	...	...	0·84	...	0·06	...
12	Magnetite ...	69·20	...	...	0·50	...	0·02	...
13	Magnetite ...	69·13	...	...	0·52	...	Trace	...
14	Magnetite ...	68·80	..	...	0·83	...	0·09	...
15	Magnetite ...	68·68	...	...	0·91	...	0·08	...
16	Hematite......	63·4	...	...	0·40	...	0·04	...
17	Magnetite ...	69·31	...	...	0·38	...	Trace	..

Under working conditions it is considered that the average grade will not exceed 65 per cent. iron.

All these samples were taken from surface outcrops. There are no underground openings in the main magnetite ore-bodies, and consequently no means are available for ascertaining their extent and their nature at depth.

Very little silica and alumina, and traces only of magnesia and lime, are present in the body of the deposit. As the bounds of the lenses are approached the last impurities mentioned (magnesia and lime) increase in amounts until the ore becomes too poor to work. The manganese content is low, titanium occurs only in traces, and sulphur and phosphorus are in negligible quantities. The phosphorus is below the Bessemer limit; it is dependent upon the original apatite component of the igneous rock. It may be remarked that the increasing presence of magnesium and calcium silicates towards the walls is detrimental only in reducing the percentage of iron. The only impurities likely to cause anxiety are the sulphides—pyrite, pyrrhotite, and chalcopyrite—but these appear in large quantities only near the walls of the magnetite bodies at a considerable depth below the surface. If the Savage River valley be considered a trench, then the ore-bodies have been intersected to a depth of 700 feet below the outcrops on the ridges. The river has carved its channel through the soft schists between two lenses, but the ends of the magnetite bodies show on both sides of the valley.

(*d*) Estimation of Quantities.

Although a considerable amount of developmental work is necessary before precise estimates can be arrived at relating to the quantities of the higher grades of ore obtainable by open-cut methods of exploitation, there is nevertheless sufficient information available to serve as a basis for safe calculation. It is probable that the quantities given here are much too small, for the estimates are based on a vertical extent of only 300 feet, and care has been exercised in restricting the superficial dimensions to the outlines of the unbroken ore-bodies. The large quantity of float ore strewn over the surface, therefore has not been taken into the consideration of the available supplies. The determination of the actual sizes of the ore-bodies has been attended with considerable difficulty. In the first place, the width of the ore-bodies could not be defined with precision because of the deep taluses of magnetite ore extending on both sides of the outcrops. Furthermore, they have not been intersected at depth by tunnelling, save in those places where pyritic bodies were known to occur. Consequently, a true valuation is impossible, and an approximate estimate only has been attempted. In the following statement no account has been taken of the quantities available from those deposits containing pyritic ore-bodies. Under these conditions the probable high-grade ore amounts to:—

	Tons.
No. 1 ore-body	1,100,000
No. 2 ore-body	4,000,000
Associated ore-bodies	1,500,000
No. 3 ore-body	400,000
No. 4 ore-body	6,500,000
No. 5 ore-body	7,000,000
	20,500,000

(2)—*Rocky River Deposits.*

At the Rocky River Mine,([12]) situated in the angle formed by the junction of the Whyte and Rocky Rivers, and about 10 miles south of the Rio Tinto, extensive underground workings have been made into large copper-bearing magnetite deposits contained in the southern portion of the igneous schist belt. The ore-body outcrops on the ridge of a high hill in a series of large lenticular masses of magnetic iron, and appears to be of remarkable purity. It has been developed for its copper-gold content by an adit sent in from river bank for 800 feet in a direction 12 degrees east of south. From the adit several crosscuts have been sent in at intervals to determine the extent and nature of the magnetite ore-body. These works, 360 feet below the outcrop, show it to be a lenticular mass of magnetite, attaining a maximum diameter of 30 feet, and coinciding in strike and dip with the schists. Associated minerals are ores of copper, nickel, iron, barium, and cobalt, with also asbestos, gold, and silver—none of them in payable quantity.

In this locality are many other deposits of lesser extent, some of which are difficult of access, and are not considered of sufficient importance to warrant an elaborate description.

([12]) *Vide* W. H. Twelvetrees: "Report on Mineral Fields between Waratah and Corinna"—Report of the Secretary for Mines, 1900-1901.

E.—TRANSPORT AND COMMUNICATION.

The fact that the Long Plain ironfield is comparatively difficult of access is the main reason why the deposits have not received more attention. As most of the large mines in Australia are far removed from the seaboard, and not more favourably situated, this disadvantage is more apparent than real.

The area lies about midway between Waratah—which is connected by rail with the seaport of Burnie—and the port of Corinna on the Pieman River. There are, then, two possible outlets for the products of this district. At the present time access is had from Burnie by rail to Waratah, a distance of 48 miles, thence by road over Magnet Range for 21 miles, and by pack-track for 9 miles across Long Plain. Magnet Range presents an almost insurmountable barrier to the westward extension of the Waratah branch railway. From the lowest saddle the road descends to Luina settlement on Whyte River, 950 feet in 3 miles. Not only are the engineering difficulties encountered on this route hard to overcome, but haulage against the grade would be very costly. The more natural outlet, not only for these mines, but for all the districts west of Magnet Range, is through Corinna. A 25-mile railway from Corinna would reach the most remote deposits, and pass by all others on the way. A further and distinct advantage is that the load is with the grade. In this rough, mountainous region naturally there are many obstacles to be overcome in the construction of railways, but they do not present very serious engineering difficulties. It is necessary that the line follow the east bank of Savage River, which falls at the rate of 30 feet to the mile, for on this side are the most important iron deposits and the most productive gold and osmiridium diggings and silver-lead and tin lodes. Perhaps the greatest difficulty encountered on this route is found near the confluence of Main Creek and Savage River. Here the creek flows in a tremendous gorge, steep-walled and rugged near the base and very broad higher up. It will be necessary to ascend from Corinna on the maximum grade to surmount this obstacle.

The Pieman at Corinna is a magnificent stream, 450 feet wide and 40 feet deep, with a tidal rise of 5 feet. At this point the banks slope so steeply that vessels can be moored alongside. A little higher up stream the river widens considerably, providing a splendid swinging-basin for vessels of large size. Three miles down stream, where the river cuts through the Donaldson Range, it is 80 feet deep, and not more than 150 feet wide; thence to the heads it presents a fine broad expanse of deep water. The entrance, 11 miles from Corinna, is very broad, with a large accumulation of sand on the south side. This sandbar extends up to some rocks which lie right in the fairway, 40 chains beyond the entrance. It has been suggested that the removal of these rocks would create a strong scour on the bar, but it is doubtful whether any lasting benefit would result. These rocks form a natural breakwater on the north side, and the bar between them and the mainland is always clear. It is stated that there is 16 feet of water over the bar at low tide. Captain Madden, who many times during the last 40 years navigated vessels to this port, considered the north passage safer than was the entrance to Macquarie Harbour before improvements were effected. It is significant that up to the present time not one vessel has been lost at the entrance.

In concluding these remarks, it may be mentioned that, during the boom period of the Corinna goldfields, sea freight from Launceston was only 30s. per ton, whereas railway freight from Burnie to Waratah amounted to £3 per ton.

F.—GENERAL REMARKS.

Many of the large deposits of magnetite were originally regarded as being too pyritic to prove of commercial value as sources of iron, but this opinion has been dispelled by later developments. It is true that the pyrite impurity has been found in some of the ore-bodies to increase with depth, but the writer feels safe in assuming that the sulphidic content will not become prominent within 300 feet from the surface.

An important consideration in the exploitation of these ore-bodies is that the greater part of the ore occurs under such conditions that it can be mined by open-cut methods, and loaded for shipment without preliminary treatment.

In this and in neighbouring districts there is an abundance of timber eminently suitable for fuel and mining purposes, and, it is reported, large formations of fairly pure limestone occur within 1 mile of Corinna and also in Middleton Creek valley.

From the foregoing account it will be seen that the economic conditions are decidedly favourable, either for the establishment of works at Corinna or for the exportation of ore overseas.

(3)—Iron-ore Deposits in the Zeehan District.

These deposits have been known since the first discoveries of silver-lead and zinc ores in this field, but up to the present time they have remained undeveloped. The most important are the Tenth Legion, Davern and Reynolds', a large deposit in Section 1812-M, and Davern's Prospect, on the south-east slope of Mt. Agnew; others occur all round the fringe of the Heemskirk Range, and some nearly as far north as Granville Harbour.

The main road from Zeehan to Reminé (the settlement at Trial Harbour) passes on the south side within a mile of the iron-ore field. The latter is easily accessible also by means of the Zeehan-Comstock tramway, the terminus of which is a little over a mile east of the Tenth Legion Mine.

All of the deposits examined on this occasion are contained in a small area lying near the western boundary of the Zeehan district, at the foot of Mt. Agnew, the most easterly peak of Heemskirk Range. Zeehan township is 5 miles distant to the east.

The iron ores occur in discontinuous, lenticular masses along the peripheries of gabbro-amphibolite dykes. Magnetite deposits occur likewise at comparatively short intervals all round the granite, either at the contact with slates and quartzites or else in the vicinity, but none has been observed in granite. The disintegrated material of the outcrops supports heavy vegetation. Wooded hillocks standing out prominently on the button-grass plains almost certainly indicate isolated masses of magnetic iron ore.

A.—Geology.

The outstanding geological features of this district are the granite massif of the Heemskirk Range and the gabbro-amphibolite and serpentine which fringe the eastern and southern sides. These Devonian intrusives penetrate Ordovician slates, sandstones, and keratophyric tuffs. No actual contact of the granite with the basic rocks has been observed here,(13) and the latter, although sensibly uniform in structure, have undergone some degree of metamorphism. It is evident that there was a brief interval between between the ascent of the basic material and the

(13) *Vide* W. H. Twelvetrees and L. K. Ward: "The Ore Bodies of the Zeehan Field," Tas. Geol. Surv. Bulletin No. 8 (p. 31).

acidic. It would appear, then, that out of the stock magma a gabbro differentiate was first separated, from which by further differentiation the magnetite ore-deposits were formed, and that the remaining acidic (granitic) portion of the magma followed almost immediately.

B.—PETROLOGY.

(1)—*Gabbro.*

These rocks, consisting essentially of plagioclase felspar (anorthite, bytownite, or labradorite) and pyroxene, but usually containing various accessory minerals, are the granitoid analogues of diabases and basalts. Gabbros are the plutonic members of the series; diabases usually comprise the hypabyssal, and basalts the volcanic members.

The pyroxene component of the gabbro may be monoclinic, as augite or diallage, or orthorhombic, as enstatite, bronzite, or hypersthene. Normal gabbros pass by insensible gradations into varieties which are composed dominantly of ferro-magnesian minerals. Thus at one end of the series labradorite, composed almost entirely of felspar, predominates; while at the other end felspar is absent, and the rock becomes ultra-basic in character. This variation in composition of the igneous mass is due to the differential concentration of the magmatic components, and the segregation of the basic and ultra-basic towards the cooler parts. In the cases under consideration, the gabbro dyke-rock penetrates slates and sandstones, and the basic components of the magma are found near the periphery of the igneous mass. Ferrous oxide in the form of magnetite is one of the first to separate, because it is insoluble in the basic magma; the remaining components of the molten mass crystallise out in the inverse order of their solubility, the last to solidify being those of maximum fusibility. Thus, the composition of the rock in the centre of the dyke varies greatly from that in the outer part.

In the coarser varieties on the Heemskirk Range, the hornblende component occurs in stout blades ¼-inch to 1 inch long; but in the fine-grained, the amphibole resulting from uralitisation of pyroxene appears in fibrous radiating fans in the form called malite. Felspar is abundant in large crystals, commonly as labradorite. Saussuritisation of the felspar has been followed by further change, until it has been transformed into an indeterminate kaolinised variety.

(2)—*Serpentine.*

At the northern end of the Tenth Legion magnetite ore-body a mass of serpentine outcrops above the detrital material occupying the plain at the east end of Mt. Agnew. It is a compact massive rock with well-developed conchoidal fracture of a peculiar opaline appearance. Its normal colours are black, dark-green, olive green to yellowish-green, and on weathered surfaces it appears bluish-white to white. It often exhibits stains due to magnetite, pyrite, or pyrrhotite, of which veinlets traverse the rock parallel to the structural planes. The most peculiar attributes of this rock are its brittleness and its sharply-developed conchoidal fracture. Serpentine commonly occurs also in large masses as a compact apple-green mineral, and occasionally with a fibrous and radiating structure associated with the magnetite deposits and various basic silicates.

(3)—*Diopside (Lime-Magnesia Pyroxene).*

Crystallised diopside is a constituent of the rock in which the Tenth Legion ore-bodies are contained. It occurs in occasional patches of irregular shape, merging gradually into the dense white rock, which appears to be massive diopside. A comparison of the chemical composition of these rocks is contained in the following table of analyses:—

	Crystallised Diopside. Per Cent.	White Rock. Per Cent.
Silica (SiO_2)	52·1	49·90
Alumina (Al_2O_3)	3·0	2·56
Magnesia (MgO)	15·0	17·80
Calcium oxide (CaO)	27·7	26·00
Ferrous oxide (FeO)	2·3	3·76
	100·1	100·02

C.—THE EFFECTS OF CONTACT-METAMORPHISM.

Basic magmas do not contain any appreciable amount of mineralisers in the form of gases and vapours. They had little but a baking effect, therefore, on the sedimentary rocks with which they were brought into contact. The greater change has taken place, not in the intruded slates and sandstones, but in the peripheral portion of the igneous rock. In places, slates have been transformed into hornstones, and sandstones into quartzites, while the ferro-magnesian dyke-rock also has undergone physical change. The igneous contact-rock is of an extremely dense felsitic character, largely made up of diopside, which is usually the type of pyroxene developed under such conditions. The development of diopside is partly due to chemical change of ferro-magnesian minerals by the loss of iron. The iron content evidently went to swell the bulk of the segregated ore. A further transformation of the constitution of the basic contact-rocks is shown by the occurrence of tremolite, actinolite, asbestos, serpentine, talc, steatite, chlorite, epidote, quartz, garnet, calcite, and dolomite. All of these are secondary minerals, most of them typical metamorphic products of the effect of carbonated waters on calcium-magnesian silicates.

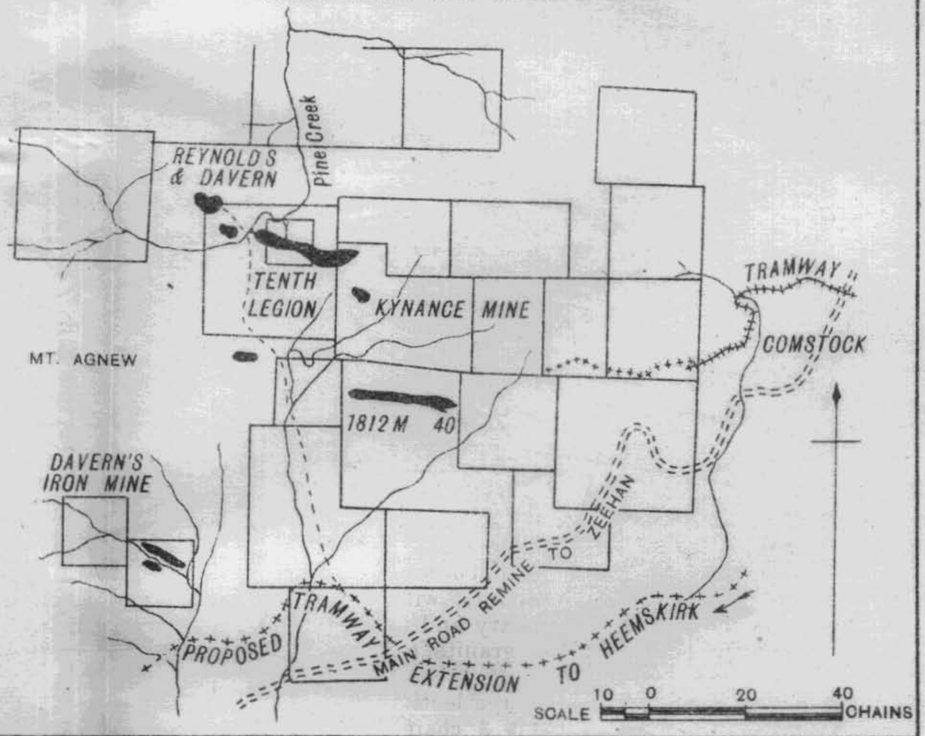
An interesting phenomenon in connection with the metamorphic contact effects in these ultra-basic rocks is the development of large bodies of crystalline dolomite. In all cases noted the dolomite occurs either in the igneous rock near the outer part or actually at the point of contact with sedimentary formations. In the vicinity of the dolomite the basic rocks are completely decomposed, and are recognisable only by the gradual transition to the unaltered, massive, dark-green gabbros, the pyroxenites, or allied rocks. The metamorphosed material consists of talc, serpentine, tremolite, asbestos, actinolite, dolomite, magnesite, calcite, epidote, zoisite, quartz, magnetite, &c., arranged according to the condition of metamorphism the rock has undergone.

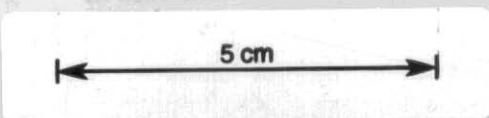
Crystalline dolomite of similar character occurs in several other localities in Tasmania associated with similar rocks. Thus, at the Comet and South Comet Mines, at Dundas, large bodies of dolomite are associated with serpentine; the gangue of the galena ore contained in serpentine and gabbro at the Madame Melba and Kapi Mines is dolomite; at the Magnet silver-lead mine a large portion of the Websterite dyke-rock has been completely dolomitised. Similar occurrences have been noted at the Victory Mine, Arthur River, showing its derivation from pyroxenite, and at the Rocky River Mine, near the border of the hornblende schist belt. This association of dolomite with ultra-basic rocks rich in magnesia and lime appears general in Tasmania.

Plate VIII.

ZEEHAN DISTRICT

TENTH LEGION IRON MINES





It is noteworthy that in all cases the dolomite is practically free from magnetite, and that it frequently contains silver-lead, zinc, and copper ore-bodies. From this it follows that the magnetite deposits were formed prior to the dolomitisation of the original ferro-magnesian igneous rocks. The alteration was effected by the agency of carbonated waters derived from the granitic magma, the intrusion of which immediately succeeded the basic differentiate. The zinc and silver-lead ores contained in the dolomitic rock are also of granitic origin.

The following analyses give an idea of the variation of the composition of this dolomitic rock:—

	Rio Tinto. Per Cent.	Magnet. Per Cent.
Magnesium carbonate... ...	88·31	32·76
Calcium carbonate...	3·01	56·64
Silica	3·34	—
Iron carbonate	4·50	8·26
Manganese carbonate	—	3·76
Alumina	0·96	

Ores of lead, zinc, copper, and iron are found replacing these dolomitic rocks at Rio Tinto, Rocky River, Magnet, Comstock, Silver Stream, and other mines.

D.—THE MINES.

(1) *Tenth Legion Deposits (Section* 7925-M, 10 *Acres: W. Thomas, Lessee).*

This is portion of the original Tenth Legion property, which consisted of a 70-acre section situated west of and adjoining the Kynance Silver-lead, Copper, and Zinc Mine. It is occupied largely by gabbro-amphibolite and diopside rocks containing the magnetite deposits, with slates and quartzites along the northern boundary and in the northeast quarter. The border of the granite outcrop is 35 chains to the westward.

The ore-body consists of a very large lenticular mass of magnetite, extending from a point 3 chains inside the Kynance boundary, through Section 7925-M, to the bank of Pine Creek. It occupies the crest of a sharp ridge, 250 feet high, trending north 60 degrees west. Near the centre of the section the lens contracts, and below this point a tunnel has been driven southwards from Pine

Creek, a distance of 312 feet, completely intersecting the ore-body at 120 feet below the outcrop. The tunnel passes through quartzites and slates for 182 feet, intersecting a narrow chlorite vein containing idiomorphic crystals of pyrite at 132 feet, and entering magnetite-diopside rock at 185 feet. The magnetite-bearing rock gives place to massive diopside at 239 feet, and continues for 36 feet, after which it passes through a second band of magnetite, 20 feet thick, finally entering diopside rock again. There is a gradual transition from ore to rock in this ore-body, but only thin bands of clean ore occur. Associated with the magnetite are tremolite, serpentine, diopside, calcite, actinolite, epidote, chlorite, and a little vesuvianite and garnet. This ore-body could be easily explored by driving east and west from the crosscut.

The length of this lens along the outcrop is 1400 feet, and the actual width about 50 feet. The apparent width, as determined by the talus material, is much greater. In some parts the ore is coarse-grained; in others, it is hard and dense, and remarkably pure. Very large octahedral and rhombic dodecahedral crystals of magnetite are developed in the massive ore-body. An idea of the quality of the ore may be gathered from the following analyses:—

No.	Kind of Ore.	Iron.	Phosphoric Acid.	Sulphur.	Titanium.	Silica.
		%	%	%	%	%
1	Magnetite	60·18	Trace	0·20	Nil	2·12
2	Magnetite	70·7	Trace	0·10	Nil	...
3	Magnetite	69·6	Trace	...	...	0·47

No. 1 sample was taken from the tunnel below the oxidised zone; Nos. 2 and 3 are representative of the massive ore at the outcrop. Phosphorus occurs only in traces, sulphur in negligible quantity, and titanium is entirely absent. Tests for silica show a very low content. It is noteworthy that there is little or no increase of sulphur in the ore at depth.

It is impossible to arrive at a close estimate of the quantity of ore extractable by quarrying, for there are no reliable data upon which a safe calculation can be based. Under the circumstances, it has been decided to consider the amount recoverable from the ore-body to a depth of only 200 feet. At this depth the quantity works out at 1,900,000 tons.

Eastward, in the Kynance property, are several smaller ore-bodies; and westward, just over Pine Creek, another deposit projects above the level of the plain. They are not important.

(2)—*Davern and Reynolds' Section.*

This is a 10-acre section situate 15 chains north-west from the Tenth Legion. It encloses a large dome-shaped mass of magnetite-hematite ore standing out 60 feet above the level of the button-grass plain. The hill, 350 feet long and 250 feet wide, is composed wholly of hard, dense ore of remarkable purity. The quantity of ore recoverable above drainage level is 160,000 tons. A branch from the Zeehan-Comstock tramway extension could be constructed very cheaply and on easy grades right up to the base of the hill. Thus the ore could be loaded direct and shipped without preliminary treatment. A grab sample of pieces of ore taken indiscriminately from the outcrop contained:—

	Per Cent.
Iron	66·72
Alumina	1·37
Phosphoric acid	Trace
Sulphur	0·49
Silica	2·57

(3)—*Section* 1812-M, 40 *Acres.*

This is a vacant section lying ½-mile south-eastward from the Tenth Legion Mine, and adjoining the Kynance Mine on the south. This deposit appears to be of precisely the same type as those already described. It occurs under similar conditions, and follows the northern boundary of the gabbro dyke, trending a little south of east. Like the others, it occupies a sharp narrow ridge, which extends westwards to the edge of the plain. This ore-body is about 40 feet wide, and fully 1000 feet long. Above the 150-feet contour it is computed there are 800,000 tons of high-grade ore.

(4)—*Davern's Prospect (Sections* 7611-M *and* 7296-M, *both of* 20 *Acres).*

These properties are situated about a mile west of south of the Tenth Legion. The margin of the gabbro passes through the south-eastern corner of the section, while that of the granite passes through the north-western. Between them the country consists of intensely indurated slates and hornstones. On the north side of a creek, which flows diagonally through the section from the north-west corner to the south-east, a large body of massive magnetite is exposed. The dimensions of this deposit have not been ascertained, owing partly to the heavy vegetable cover; but it outcrops prominently here and there for 1000 feet, and appears to be fully 40 feet wide. Float ore forms a deep talus over a far greater area. This ore-body can be easily exploited to a depth of 200 feet, at which level there exists 850,000 tons of fairly high-grade magnetite.

On the south side of the creek a number of trenches and open-cuts have been put in on irregular masses of sphalerite (zinc-blende) and magnetite which occur in the gabbro marginal rock associated with chlorite, phlogopite, tremolite, actinolite, &c. In some places the sphalerite is almost pure for several feet in width, and then it changes abruptly to magnetite without any distinct parting dividing the two; in others blebs occur sporadically distributed throughout the igneous rock.

The facilities for the exploitation of the ore-bodies are excellent, and very little development is necessary to prepare the mine for continuous operation.

E.—GENERAL REMARKS.

These mines possess decided advantages over those in neighbouring districts, in that they are easily accessible and can be operated without any considerable outlay on developmental works. By means of a short branch from the Comstock Tramway, rail connection with the seaport of Strahan, 35 miles distant, can be obtained. The route of the proposed extension of the Zeehan-Comstock Tramway to South Heemskirk district passes within a mile of these mines, all of which could be linked with the main tramway by means of short spur lines. A trial survey was made three years ago by the writer for the purpose of ascertaining the most economical and advantageous route to the South Heemskirk tinfields. Leaving the Zeehan-Comstock Tramway at the Summit, 2½ miles from Zeehan, this route follows the Colonel North line for a half-mile, from which point it deviates south-westerly, passing by the Tasmania Mine, thence north-westerly along the old tramway towards the T.L.E. property, thence south-westerly parallel to

Trial Harbour-road to the foot of the steep incline, whence it crosses the road and passes below the iron mines on the south side of Heemskirk Range.

The aggregate tonnage of magnetite, figured on the basis of actual ore in sight and available by quarrying methods of extraction, is probably far too small rather than too large. Exploration has not yet demonstrated the size and the nature of the deposits at depth, but it is considered that their vertical extension is beyond that at which economical mining can be carried on. The outstanding feature of the ore-deposits is the almost entire absence of deleterious impurities in the ores. Occurring in basic igneous rocks, the percentage of silica is naturally low; phosphorus and sulphur also are present in only insignificant amounts; traces only of chromium and titanium occur; and copper is entirely absent. So far as exploration has yet gone, there seems to be no evidence of increased sulphur at depth.

These deposits are conveniently situated to supply the immediate demand for high-grade iron ore, and they are of sufficient magnitude to meet all the requirements of the market for many years. The ore can be produced at a minimum cost without the necessity for heavy initial expenditure in the preparation of the deposits for exploitation. Thus all the essentials are here for the economical production of high-grade iron ore on a large scale.

VII.—THE IRON LODE ON THE NELSON RIVER.

Mr. L. Keith Ward, B.A., in Geological Survey Bulletin No. 10, on "The Mount Balfour Mining Field" (1911), describes a massive iron lode some 6 miles north-east of Whale's Head, Boat Harbour, on a group of sections situate on the Nelson River.

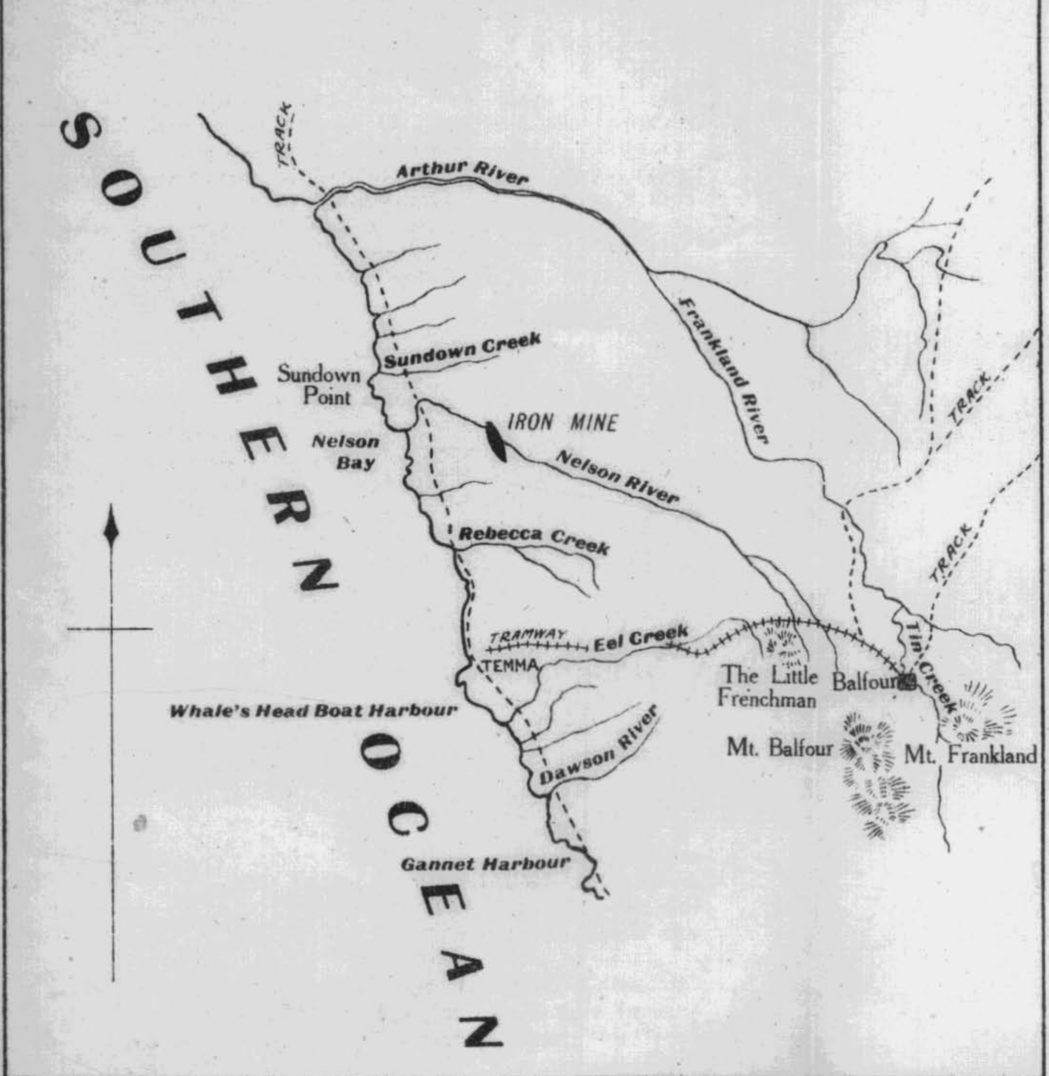
The mineral sections from north to south are 2760-M, 40 acres; 2923-M, 40 acres; 2942-M, 35 acres; and 2731-M, 40 acres. Mr. Ward states that in the central portion of 2923-M the outcrop is over 100 feet in width, and consists of gossanous material containing much hematite. The hematite becomes rapidly the most abundant constituent as the lode is followed southwards along its course. The outcrop may be traced through Section 2942-M without interruption. Mr. Ward says it is here massive, and consists of hematite mixed with crystalline magnetite and a small amount of quartz, for many chains maintaining a high degree of purity.

He concludes by remarking that as an ore of iron this lode merits systematic prospecting; trenches could be cut across it at regularly-spaced intervals, in such a manner that the width could be accurately ascertained at a number of points, and an opportunity exists for a tunnel across the lode from the Nelson River gorge.

The outcrop is said to be 300 feet above sea-level, and no engineering difficulties of any magnitude would prevent the ore from being carried by rail to Whale's Head Boat Harbour.

Plate IX

NELSON RIVER IRON FIELD



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VIII.—MISCELLANEOUS DEPOSITS.

Numerous occurrences of iron ore, but none of them of great importance at present, have been recorded from various other parts of the island.

Deposits of brown iron ore exist in the swampy button-grass land in the Florentine Valley. The large deposit marked on the Buckingham charts as "Iron Blow" on Frodsham's track, 2 miles east of the Florentine River, is an impure yellow hydrated oxide of iron, mixed with quartz and quartzite wash, with a N.W.-S.E. course, and a width of several chains. It has been trenched upon in ferruginous swamp clay and drift to a depth of from 5 to 10 feet. At the bottom of the deepest excavation the material is very clayey and contains stones of quartz and kaolin. Boulders of the ore are strewn over the soil.

(1)—Mt. Mueller or High Rocky.

On the plain crossed by the Gordon River track south-west of Mt. Mueller and half a mile from one of the streams which form the headwaters of the Styx River, boulders of brown iron ore are profusely scattered over the surface. About 150 feet north of the track the Great Western Railway Company opened a trench 40 feet long, 2 to 5 feet wide, and 6 feet deep, exposing concretionary limonite in yellow sand. The ore cut into is impure, and the bed is irregularly arched and has in it both vertical and horizontal partings. The trench is in soft sandy material, but boulders of hard limonite lie on the surface. South-west of the track is a knoll of limonite boulders, some of which enclose patches of soft sandstone or even unconsolidated sand. Below the knoll to the west are large boulders of conglomerate and white sandstone similar in character to the patches in the ore. These sandstone boulders are water-worn into fantastic shapes, with pot-holes. The sand in the ore must have been derived from the strata from which the boulders were dislodged, and was probably deposited in a lake, the water of which drained into the valley of the Upper Weld, which lies here in a panorama below the track.

Lower down the hill to the west, boulders of iron ore continue to occur in the soil, and for half a mile further west, where, in the myrtle and horizontal forest, the Great

Western Railway Company trenched and drove an abortive adit for about a chain to test the formation underground. The adit is driven in from the track in a south-easterly direction across ferruginous chocolate-coloured greasy clay slate, dipping about 45 degrees south-easterly. At 10 feet behind the end soft white clayey slate was passed through, and white indurated sandstone forms the face. No iron ore appears to have been met with.

Some loose specimens of limonite on the track show veins of quartz traversing them, and may possibly belong to the Silurian conglomerate beds, but the iron blows generally in this part of the country are, as far as the writer is able to judge, deposits of bog ore, and too impure to be used for the production of iron.

(2)—Lewisham.

A development of impure iron ore occurs here, but the quantity is unimportant, and though samples may be collected with an assay value of 50 per cent. and upwards the bulk is too low in iron to be of use.

(3)—West Coast Range.

Hematite ore-bodies exist at various points on the West Coast Range, but are apt to be contaminated with iron and copper pyrites, and have at present hardly any value as sources of iron.

IX.—ELECTRIC SMELTING.

European and American reports suggest that electric processes for smelting iron ore and producing pig are not universally applicable in a commercial sense. but that they may be adopted with advantage where the conditions are favourable, that is to say, where cheap hydro-electric power is available and coke economy is desirable.

Mr. J. Bibby, in a paper on "Iron and Steel Electric Furnaces," read in January this year before the Manchester Association of Engineers, says:—

> "On the average, the blast furnace consumes one ton of coke per ton of pig iron produced. The electric furnace consumes one-third of a ton of coke, and requires one-third horsepower year per ton of pig produced. For the cost of the two systems to balance, we must be able to supply one horsepower per year at the cost of two tons of coke."

Judging by this, the conditions in Tasmania would appear to be eminently favourable for the new process.

The history of attempts at electric smelting does not go further back than twenty years. The first experiments were in Italy in 1898-1901, with the Stassano furnace. Then during 1901-5 tests were carried out in the Keller furnace in France; and in 1904-6, with the Heroult furnace at Saulte Sainte Marie in Canada. This furnace was also in operation at Heroult in California from 1907 onwards. In 1907 came the experiments of the Electro-Metal Company of Domnarfvet in Sweden, followed by trials in Norway, and commercial operations in Sweden in 1910-11.

The following references will illustrate the gradual progress made since these dates in the electric smelting of iron ores:—

Rodenhauser, in his work on "Electric Furnaces in the Iron and Steel Industry" in 1912, quotes (p. 372) Crawford, of the Noble Electric Steel Company, of Heroult, California, as follows:—

> "While it is hardly agreed with the prophecies made by some that electric furnaces for producing pig iron will eventually be competitors of blast furnaces, even in the regions where economic conditions make the latter possible, Crawford feels that where electric

> power can be obtained cheaply, and where coke and freight rates are high, and for making superior grades of iron, electric furnaces will enable many large bodies of iron ore to be worked which would otherwise remain idle, and that the electric iron furnace, both of the shaft type and of the long and narrow type, each in the field best adapted for it, will make steady progress."

In the "Mineral Industry for 1913," Mr. Stoughton (p. 429), while noting that the commercial manufacture of ferro-alloys in the electric furnace continues to increase, admits that the smelting of iron ore to produce pig iron has not yet justified the early expectations of its advocates.

In the "Mineral Industry for 1914," Mr. James Aston succeeds Mr. Stoughton as author of the iron and steel articles of that work, and gives some hint of the reasons for the very slight advance made in electric iron smelting. He says (p. 438):—

> "For the production of pig iron from the ore the electric furnace has proved rather disappointing during the past year. Development proceeded to the point where with charcoal available as a reducing agent, and electrical energy at reasonable cost, pig iron could be produced at profit in competition with existing supplies.
>
> "However, developments of any magnitude, or outside of zones of special local conditions, pointed to the necessity of large furnaces, and especially of a type adapted to the use of coke as a reducing agent."

The dependence of successful electric smelting on the price of coal or coke and freight charges is emphasised by J. B. C. Kershaw in his "Electro-thermal Methods of Iron and Steel Production" (1913, p. 42): —

> "Though the electric iron smelting processes may therefore make headway in those localities where all the conditions favour their development, and where the price of pig-iron is artificially increased by freight charges, they are unlikely to undergo extension or development in other lands or localities so long as cheap supplies of coal and coke are available for the ordinary blast furnace process of manufacture."

The general position of electric smelting in Scandinavia in 1914 has been described by Dr. A. Stansfield in his bulletin entitled "Electro-thermic Smelting of Iron Ore in

Sweden" (1915), published by the Department of Mines, Canada. From his remarks it appears that at that time most of the iron ore in Sweden was smelted in small blast furnaces with charcoal fuel. The excellent quality of the iron produced has resulted in high prices being obtained, and consequently in the development of a profitable industry. The Electro-Metals furnace was well established in Sweden, and was replacing the charcoal blast furnace. The 4000-horsepower furnace at Domnarfvet was putting out about 30 tons iron daily, using charcoal fuel; attempts to employ coke were, up to that date, not very successful. He proceeds to remark:—

> "The smallness of the scale on which these furnaces operate may not be harmful in the charcoal-iron industry, because quality rather than quantity is aimed at, and because charcoal furnaces must always be of moderate dimensions. Such furnaces, however, cannot compete commercially with a modern coke blast-furnace of 400 or 500 tons daily output. It must also be remembered that attempts to use coke instead of charcoal in the Electro-Metal furnace have so far been unsuccessful, though it is expected that the difficulties encountered may be overcome by building the furnace shaft somewhat wider and lower. This change is needed, because coke is far less bulky than charcoal, and the charge is therefore less open and obstructs the passage of the gases up the shaft" (p. 7).

Dr. Stansfield describes the small Tinfos furnace operating in Norway as one of the few types in which the use of coke was possible. A gas coke was imported from England, containing 1·2 per cent. sulphur, but the furnace capacity is small, the output of pig being only 10 tons daily.

This author, in reporting on the outlook with regard to electric smelting in Canada (p. 8), comes to the conclusion that there is no evidence to show that it can be undertaken on a large scale in competition with existing blast-furnace industry. The reasons for this are stated as (1) the high cost of production, (2) the difficulties connected with the use of coke as a fuel in the Swedish furnaces, and (3) the small size and output of these furnaces. He adds that much of the Swedish metal is used to produce special qualities of steel and wrought iron, and that the possibility of developing a high-grade charcoal iron industry would have to be investigated before beginning in Canada a large production of a rather expensive product.

The statements reproduced above with reference to electric iron reduction furnaces represent the outlook up to 1915. Since then experiments have continued to be made, and the electric process has been substantially improved. It is perhaps still true to say that unless coke is costly and power cheap, the electric furnace will not compete with the blast furnace, but when the reverse is the case, it comes into its own. One great advance which appears to have been made in the interval is the adaptation of the furnace to the use of coke. The Electro-Metals furnace no longer suffers the disadvantage of being restricted to the use of charcoal fuel, but some more precise information on this point is still desirable.

Coke would be the best material to use in the electric furnace if it were not for the impurities which it contains, but that charcoal suffers from crushing more readily than coke, and that the size of charcoal blast furnaces in Sweden is limited by this drawback. One of the important improvements which have been introduced in this furnace is the possibility of securing a very uniform development of heat across the whole section of the furnace by transformer arrangements, making it practicable to increase the maximum size of the units which can be built with commercial success. This type of furnace is making headway in Sweden, and is also being installed in Italy and Japan. It seems, therefore, that a standard type is now being evolved, in which the shaft and charging arrangements are not very different in character from those of the ordinary blast-furnace. There is a wide hearth or crucible, as it is called, into which the iron in a spongy condition descends together with the flux, fuel, and gangue. Powdered ores are apt to clog, and the furnace works best with crushed ore 1 inch to 2 inches in diameter. Electrodes of amorphous carbon enter the crucible through its roof and are embedded in the charge. In the large furnaces a three-phase current is supplied from three transformers, and each transformer is connected to two opposite electrodes. The resistance of the charge to the electric current which passes between the pairs of electrodes creates the heat. The consumption of electrodes is met in a simple way by dropping them a little further into the charge at intervals of a few days; it has been found that from six to nine kilos per ton of pig are consumed gross. The role of the current is strictly to provide the heat which brings the charge to the temperature necessary for reduction and melting. Thus this process permits the coke consumption to be decreased to the quantity requisite for reduction, namely, one-third of a ton per ton of pig produced, in lieu of one ton as already mentioned. Thus at the outset two-thirds of the sulphur and other impurities in the fuel are excluded from the furnace charge. It may be added here that the higher temperature obtainable in the electric furnace admits of a more basic slag, which facilitates the elimination of sulphur from the iron, a circumstance of high value in connection with steel-making. Electric pig iron, whether made with coke or charcoal, is consequently superior in quality to blast furnace pig.

The above remarks refer to furnaces for producing iron from iron ore, and not to electric steel furnaces for making steel from pig or scrap or for refining steel. The latter are in widespread use, and are being continuously improved and otherwise developed. The possibility of producing pig steel direct from iron ore in the modern electric furnace seems to have been established, and if there is a demand for steel the question of adopting this process instead of converting the pig iron to steel in a second furnace would have to be considered.

Sir John McCall, the late Agent-General for Tasmania in London, went into the question of making steel direct from Tasmanian ores, using coke as fuel. He suggested restriction of manufacture to some special class of article, such as wire-fencing steel, &c. One gathers that the capital expenditure for plant would be £200,000. This is on the assumption that work will be initiated on a fairly large scale.

A bulletin on the commercial feasibility of the electric smelting of iron ores in British Columbia, by Dr. A. Stansfield, has been issued this year by the Department of Mines in that province, and is replete with valuable information on the whole question of electric smelting. The author reports that this process has passed the experimental stage, and that the furnace adopted in Sweden and elsewhere as the standard commercial type is that of the Electro-Metals Limited. In Sweden the normal product is a white or low-silicon iron, though the company consider that a foundry iron can be made, at a somewhat higher cost. Moreover, Dr. Stansfield is of opinion that this type of furnace can be used, as the white iron can be made suitable for the foundry by adding ferro-silicon. He remarks that coke and charcoal can be used as fuel if desired, mixed in certain proportions. Attention is drawn to the circumstance that commercial electric furnaces happen to have run nearly entirely on magnetites (with a slight admixture of hematite to facilitate smelting), but it is thought likely that hematite ores will be found to smelt more readily. The author's final conclusion is that with the present methods of electric smelting the industry in British Columbia may be expected to prove successful commercially, but that it will depend ultimately on the production of special qualities of iron and steel, and will be unable to compete with the blast furnace in the production of ordinary grades of pig iron.(14)

(14) "The Commercial Feasibility of the Electric Smelting of Iron Ores in British Columbia," by A. Stansfield Brit. Col. Dept. of Mines, Bulletin No. 2, 1919.

X.—COST OF PLANT.

This in Tasmania will vary considerably according to the locality in which works are erected, and will be further influenced by the scale on which the mineowners propose to work. All that is useful for the moment is to cast an eye over costs in other countries and States.

A well-known American author says:—(15)

> "As a general thing a furnace is not built unless its projector can see a profit of 1·50 dollars as a minimum, for a 500 tons furnace costs, with its site and all complete, about 1,000,000 dollars (£200,000) in normal times; its output is, say, 170,000 tons per year, and 1·50 dollars per ton profit on this is 255,000 dollars (£51,000) per year, equal to 25½ per cent. Capital can scarcely be raised for a smaller return than this in so variable a business."

The following estimate may be quoted as giving some idea of what a smaller blast furnace would cost. The Royal Commission on State Iron and Steel Works in Queensland recommended last year that the Government proceed with the erection of a blast furnace having a capacity of 150 tons of iron ore per day, together with by-product recovery, coke ovens, and mine equipment, the initial cost not to exceed £150,000, and further sums to be expended if circumstances warrant an extension of the works.

Mr. E. C. Saint-Smith, of the Geological Survey of Queensland, estimated also for this Commission that a smelting plant designed to handle only 100 tons of ore per day would not cost more than £100,000, including by-products, coke ovens with a limited surplus coke production, and mine equipment.

Thus, with £150,000 outlay, 60 per cent ore ought to produce 27,000 tons of pig iron per annum, working 300 days in the year; or, in the case of 50 per cent. ore, 22,500 tons. With £100,000 outlay, the yield would be 18,000 and 15,000 tons respectively.

Turning now to the cost of an electric smelting plant, some late information is that received from the Electro-Metals Limited, kindly placed at the writer's disposal by

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(15) J. E. Johnson, Jr.: "The Principles, Operation, and Products of the Blast Furnace," 1918 (p. 515).

Mr. J. H. Butters, General Manager of the Tasmanian Government hydro-electric enterprise. This is to the effect that the cost of a 4000-horsepower furnace, capable of an output of over 12,000 tons pig iron per annum, would (excluding buildings) be about £25,000 f.o.b. London or other English port; but this is for the furnace only, and would be exclusive of crushing plant, coke ovens, storehouses, tramways, &c.

Information from another source is to the effect that there are several single-unit furnaces working satisfactorily in Sweden, and the cost of the iron produced is not seriously greater than from the larger plant.

Dr. Stansfield, in his 1919 bulletin, gives an estimate of the cost of a three-furnace plant producing 27,000 tons per annum at from £70,000 to £80,000, inclusive of land, wharf, tracks, and rolling stock. Half of this quantity would probably be for steel-making and the remainder for foundry iron. Dr. Stansfield states that the Swedish furnaces do not seem to have been used regularly for the production of foundry iron, and that there is some doubt regarding their suitability for this purpose. They produce usually a white pig iron suitable for chilled castings or for steel making.

XI.—COST OF PRODUCTION.

At the present stage this cannot be definitely stated, as all the factors stand in need of investigation. Basic figures as to the cost of producing the iron can only be arrived at after decisions have been made as to the site of smelting furnaces, means of transport from mine, whether blast furnace or electric smelting is to be adopted, whether charcoal or coke is to be used as fuel, and whence the supplies of fuel will be derived, what deposit of limestone will be utilised. The figures will vary, too, sightly with the locality of the ore which is to be mined.

For such a universal article as pig iron the cost of production is practically standard. In present blast-furnace practice pig costs between £4 and £4 10s. per ton. Mr. E. C. Saint-Smith estimates that it could be produced in Queensland for £4 5s. At present this figure has the value of an estimate, and may possibly be exceeded a little in actual practice.

The matter of most interest in this connection, so far as Tasmania is concerned, is what prospect electric smelting has of competing successfully with the blast-furnace method.

The items of cost are comprised in four groups, viz.:—Raw materials, electric current and consumption of electrodes, labour, and overhead charges.

In a general estimate of the cost of the ore, fuel, and flux, allowance must be made for different local conditions. Thus ore from the Blythe lode, delivered to the mouth of the river, will cost less than Rio Tinto ore delivered to the Pieman; and ore from near the summit of the Dial Range, delivered to furnaces on the Penguin Creek or at Ulverstone, will cost more than ore from Anderson's Creek, delivered to the West Arm. Then the percentage of the ore will also make a difference. Sixty per cent. ore, at 6s. per ton, would mean 10s. per ton of pig iron; while 50 per cent. ore would enter for 12s. These possibilities must be taken into account when considering ths figures put forward below.

The cost of the electric current in Tasmania cannot yet be definitely stated as delivered to points on the North-West Coast, but at the outset it will be safe to assume that it will be in the neighbourhood of £4 per horsepower year; and the consumption per ton of pig may be estimated at from 0·3 to 0·4 horsepower. Dr. Stansfield, in his bulletin,[16] gives Gronwall's estimate in 1914 as 0·39 HPY per ton of electric white (coke) pig iron, and 0·42 HPY per ton of electric grey (coke) pig iron for 60 per cent. ore. Apparently Electro-Metals have brought down the consumption, as they quote 0·3 HPY for their present furnaces. This would make the cost £1 4s. per ton of iron prduced. As for the electrodes, Gronwall in 1914 estimated their consumption at from eight to nine kilogrammes per metric ton of iron. No quote is obtainable for Tasmania at the present time; the price would probably be not less than £30 per ton of electrodes; say, 5s. per ton of pig. Electro-Metals state that the electrode situation is at present abnormal, but that it is expected that prices will fall to an extent which will reduce the cost to, say, 2s. per ton of pig.

Prices of coal and coke are also at present exceptional and unstable. The furnace-owners would probably make their own coke in coke ovens near the works. Coke, at present prices, would cost from 55s. to £3 per ton; but some reduction of these figures may be expected.

Limestone flux may be reckoned at 12s. 6d. to 15s. per ton of stone delivered. The remaining items are labour, repairs, and general charges. Labour at English rates of wages is estimated at 5s. per ton, which may be doubled for this country.

Summarising the foregoing figures, the following general result is reached as the cost of a ton of pig iron to be produced by electric smelting in Tasmania:—

	Per Metric Ton.		
	£	s.	d.
60 per cent. ore, or 1·6 ton, at 6s. per ton at furnace	0	10	0
7 cwt. coke at 55s. per ton at furnace	0	19	0
4 cwt. limestone at 15s. per ton at furnace	0	3	0
Electric energy, 0·3 horsepower at £4 per horsepower year	1	4	0
9 kilos. electrodes at £30	0	5	0
Labour, repairs, and general charges	1	5	0
Total	£4	6	0

Some items may be found to be slightly different in actual working; and, as said above, mine-owners will have to adjust the figures for raw materials according to the situation of their mines, but it is extremely probable that the

(16) "Electrothermic Smelting of Iron Ores in Sweden," by A. Stansfield: Canada, Dept. Mines, 1915 (pp. 48-49).

cost will prove to lie somewhere between £4 5s. and £4 10s. per ton. If it is possible subsequently to obtain a reduction in the price of the electric current, so much the better.(17)

These costs may be regarded as satisfactory from the point of view of the utilisation of the hydro-electric supply of current, and even if they were higher, the adoption of electric furnaces for steel making would still dictate the use of electric energy.

If a properly organised charcoal-burning industry could be established, and regular and adequate supplies assured, one unit of the smelting plant might be run on charcoal fuel and special brands of iron produced.

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(17) With power at £2 per horsepower year, and ore at 10s. per ton, and the cost of electrodes reduced to 4 cents a lb., Dr. Stansfield is of opinion that foundry iron could be produced in British Columbia by the electric process for about £4 16s. per ton. The quantity of limestone will vary with the ore; in some cases it may amount to as much as 10 cwt. per ton of pig. In British Columbia Dr. Stansfield considers 8 cwt. of charcoal would be required for foundry iron.

XII.—FUEL.

Whether smelting in connection with the Beaconsfield deposits is being considered, or along the North-West Coast, or at Corinna, or Balfour, Zeehan, &c., the fuel question is an important one, for it is the heat cost which in the last instance determines the site for the works. The reports indicate that there is no doubt about the commercial applicability of the electro-thermal process where conditions are favourable, and these may be taken to be eminently so in Tasmania. Accordingly, blast-furnace smelting is a subject which will be discarded from this report.

Mr. J. Bibby, in a paper on "Iron and Steel Electric Furnaces," read in January this year before the Manchester Association of Engineers, says:—

> "On the average a blast furnace consumes one ton of coke per ton of pig iron produced. The electric furnace consumes one-third of a ton of coke and requires one-third horsepower year per ton of pig produced. For the cost of the two systems to balance we must be able to supply one horsepower per year at the cost of two tons of coke."

The lay reader may wonder why coke or charcoal should be necessary when electric energy is employed, but this question may be answered at once by calling to mind that the electric current supplies only the heat, while the carbon is required as the reducing agent; that is, an agent which will separate the iron from the oxygen with which it is combined. Consequently, coke or charcoal is always necessary.

(1)—CHARCOAL.

The Savage River and Heemskirk deposits, by reason of their remoteness, are at a disadvantage as regards coke supplies compared with Beaconsfield and North-West Coast properties, and the employment of charcoal may well be taken into consideration.

For electric-smelting furnaces charcoal is an excellent fuel, and has always an advantage over coke in one respect, namely, in that it is almost free from sulphur; though it may be mentioned here that with these furnaces the sulphur, if in moderate proportions, whether in coke or charcoal, is practically eliminated and an almost sulphur-free pig produced. At present the cost of charcoal in Tasmania seems to be a trifle higher than the cost of coke; but if quality of iron rather than quantity be aimed at, the selling price which the product will command will admit of a somewhat high fuel cost. This matter is dealt with in Sweden in the most thorough manner. The large iron companies have their own forests, and exploit them in the most scientific and systematic way. The best timber is utilised for pulp, the next best is used for building purposes, and the balance for charcoal-making. The large forests do not consist of large trees: the size is usually 8 or 10 inches in diameter. The branches and twigs too small for charcoal burning are gasified and the gas used in the manufacture of special steel. The very high-grade products which give Sweden a special position in the iron market of the world are based upon its pure iron ores, its hydro-electric power, and charcoal fuel. The conditions for a similar specialised high-class industry exist in Tasmania; it is worth while investigating them and seeing how far they can be taken advantage of.

One drawback to the use of charcoal is the acreage of land required for the growth of timber within easy reach of the smelting works. Although Tasmania is locally endowed with abundant forest growth, a steady depletion in any one district would make it necessary to continually go further back for supplies till at last the cost would tend to become prohibitive.

The yield of wood suitable for charcoal burning obtainable from Tasmanian forest lands naturally varies in different parts of the island. Mr. Robert Sticht, General Manager of the Mt. Lyell Mining and Railway Company, states that the average timbered portions of the West Coast will cut from 60 to 80 tons of 80 cubic feet each of 6 feet split firewood per acre. The experience of some burners points to a yield of 20 tons wood per acre in some localities. As about 50 per cent. of the wood consists of water and 25 per cent. of volatile matter, only about 25 per cent. of it will be represented by the charcoal which is obtainable, and perhaps it will be safe to say that the charcoal yield will be about 20 per cent. Thus the yield of charcoal per acre may be estimated as ranging from 4 or 5 tons to 15 or 16 tons, according to the forest growth.

The ruling costs for charcoal in comparatively small quantities appear to figure out at about 6d. per bushel of 15 lb. weight, which is equivalent to £3 15s. per ton. There are, however, considerable differences in the quotations, charcoal at Moina costing £3 14s. per ton; at Ben Lomond, £3 12s.; on the north coast, £3; on the east coast, £5; and on the west coast, from £3 to £6. Of course, these prices must be understood as being based on trivial quantities and on the usual primitive pit or stack method of burning, in which the yield is admittedly poor. Kiln or retort burning, with an output of by-products, would probably make charcoal available at works for something below £2 per ton. Incidentally, it may be mentioned that if charcoal fuel were adopted it might mean the starting of an imporant charcoal industry. At present it is difficult to forecast what choice of fuel will be made in the case of individual enterprises.

(2)—Coke.

Good iron furnace coke must be low in sulphur and ash. The presence of much sulphur in it involves the production of a sulphurous pig iron, to avoid which more limestone flux is needed in smelting, and necessarily more fuel. A satisfactory coke will contain from 0·5 to over 1 per cent. sulphur, and furnace-owners generally are averse to the use of a fuel which exceeds 2 per cent. or so of this objectionable element. At the same time a good deal of iron is made with inferior coke. Despite manipulation of fluxes, and though some of the sulphur is certainly driven off by the heat of the furnace, it may be accepted that the total quantity contained in ore, fuel, and flux is not substantially reduced in the blast furnace. Here the electric furnace has the advantage.

A good coke for blast furnace use has to be sufficiently hard to resist the unavoidable pressure in the furnace, but the electric furnace is not so exacting in this respect. It would be desirable to institute some experiments with a view of seeing whether any of the Tasmanian coals can yield a coke which would be suitable for electric smelting. Among the coals to be tested would be the coals from the Mersey seams, that from the Preolenna field, the coal from Catamaran in Southern Tasmania, and the East Coast coals. As a rule, the latter do not yield a firm, coherent coke, though their sulphur content is very satisfactory, the Nicholas Range coal having not more than from 0·5 to 0·6 per cent. There are great irregularities in the coking properties of the East Coast coals, some of them coking well in the laboratory. Such tests, however, are insufficient. It might be possible to achieve some result by mixing coal from different fields, say, the Preolenna and Mt. Nicholas fields; and again it is well known that coking in the by-product oven instead of the bee-hive oven has often converted non-coking coal to a coking variety, partly because in the former the coal is closely confined, while in the latter it lies loosely. Some of the Denison River coal has yielded a very firm coke on assay, and the Launceston Gas Company has obtained an excellent marketable coke from it. On the other hand, a small sample from the same seams was tested at the Thornhill Collieries in England, and yielded only a very soft and friable coke.

The Mt. Nicholas and Cornwall coal has been assayed at various times with indifferent results. A laboratory coke has recently been obtained by assay from coal at the west end of the Mt. Nicholas Range (the old Durham seam, now Silkstone); and the coal in the seams at Mt. Rex gives a coke which is described in the assay reports as good and firm. The Dalmayne coal, too, yields a good assay coke.

Trials have been made lately in the United States and Canada with pulverised coal in copper and nickel blast furnaces, and, it is reported, with satisfactory results. If this can be applied to the electric shaft furnace, it will mean much for Tasmania, as even if the coal of this island should not prove capable of yielding a suitable metallurgical coke, it could still be utilised in the furnace. It is indeed said that almost any coal can be used for this purpose. The progress of the trials which are proceeding on the American continent will no doubt be carefully watched. Electro-Metals Limited state that they have not yet used pulverised coal in lieu of coke, as the necessity has not arisen, but one of their patents covers the employment of it to convert the CO^2 into CO on its introduction to the crucible in the gas circulation system. A number of their furnaces are now working on coke most satisfactorily, and they are now completing a plant for Genoa where six furnaces will work entirely on coke.

The older coal in Tasmania, that of the Mersey and Preolenna seams, suffers under the drawbacks of a high sulphur content, though making good coke That of the Mersey basin contains about 3 per cent. sulphur; the Preolenna ranges up to 4 and 5 per cent., while the East Coast coal carries only from 0·5 to 0·6 per cent. If it is desired to draw on the firstmentioned fields for supplies, trials will have to be instituted to see how far and at what cost the sulphur contents could be reduced. Coal-washing plants are on the increase, and nuts and slack and dirty coal generally are frequently washed with a recovery of 75 per cent. Although the primary object in washing is to reduce the quantity of dirt, the process involves incidentally the elimination of part of the sulphur. A further reduction of sulphur takes place during coking, but how far the sulphur content in the Tasmanian high-sulphur coal can be reduced before employment in the furnace is a subject which invites study. If anything approaching to a normal content can be obtained, the remaining sulphur can be eliminated during the electric smelting process. It may be recalled that with electric smelting two-thirds less sulphur enters the charge than is the case in ordinary furnace practice, for only one-third of the fuel is needed, and this makes the work of elimination easier.

The possibility of mixing native coal with coke for the furnace charge has likewise to be considered. While a positive opinion on the applicability of Tasmanian coal to iron ore smelting by the electric process cannot be expressed, there is some possibility in this direction, and there exist strong reasons and encouragement for investigating the whole question.

XIII.—LIMESTONE FLUX.

Tasmania abounds in good limestone suitable for use in smelting, and it is believed that all the large deposits of iron ore likely to attract the attention of ironmasters are not far from limestone occurrences. This substance produces lime in the furnace, which acts as a base, forming a fusible slag. The quantity required will vary with the impurity of the ore, and may fluctuate between 4 and 9 cwt. per ton of pig. It is claimed that the Electro-Metals type of electric furnace, with average quality ores, may be assumed to take 350 lb. per ton of pig. On the other hand, other inquiries give figures up to 9 cwt.

The sources of supply in each case will be a matter for the works owners to consider. The Rio Tinto mines would derive their flux from limestone beds which are said to exist near Corinna; these occurrences have not yet been officially verified. The limestone near Zeehan would conveniently supply furnaces treating the ores from the Tenth Legion and that vicinity. The ores of the Beaconsfield district would easily draw supplies from the large deposits at Flowery Gully; while the great limestone properties at Gunn's Pains are the nearest to the Dial Range and the Blythe. Some limestone is being worked in the Don Valley by the Broken Hill Proprietary, connecting with the Government coast railway. Purchase or exploitation would depend on what arrangements are possible with the Broken Hill Company. At Mole Creek are unlimited quantities of limestone, and near the Government western line of railway. Freight to the Blythe would be over 72 miles by rail.

The Flowery Gully limestone is quite near to the Sugar Loaf iron lode, and is about 8 miles from Beauty Point on the Tamar, where at present deliveries in small quantity cost about 14s. a ton. This rate could no doubt be greatly reduced. A steel tramway exists for over 3 miles of the distance between the deposit and the port on the river: a connection for the remainder of the distance would have to be effected by the construction of a tramway. Dally's quarries, in the neighbourhood of Beaconsfield, could also supply a certain quantity of good-grade limestone for a furnace on the West Arm. Average analyses of the

Flowery Gully stone by the Government Assayer show the following composition:—

	Per Cent.
Calcium carbonate	95·26
Magnesium carbonate	1·07
Iron and alumina	2·10
Silica	1·34
Moisture	0·17

The nearest limestone to the Blythe River lode is that reported at the Upper Blythe Bridge, on Addison's purchased land west of the bridge, and an examination was made by the writer recently of the spot where some of it had been uncovered in the road bank and used for metalling the road. The rock is now buried below the soil, and only a few loose boulders can be seen. Notwithstanding this, judging from the surface contour, it is probable that the hill does contain beds of limestone concealed by a heavy overburden of basaltic soil. Since the visit referred to, an occurrence of limestone has been reported further up the road on Grealey's land.

An occurrence further east, in the valley of the Leven, is that at Gunn's Plains, at the mouth of Walloa Creek. This place is 4 miles south-east of Riana township, or 9 miles south-east of the Blythe River in a direct line. After leaving Riana there is a good road for a couple of miles to Kaine's farm, and a pack track thence to the mouth of Walloa Creek, which flows into the Leven at the north end of Gunn's Plains. Or one can motor all the way from Ulverstone on a good road. The limestone covers about 100 acres of Wells' land and about 60 acres of Rogers' land, part of the lot charted in the name of Mary Kent. These beds form part of a broad belt of this stone crossing the plains in a south-easterly direction. The actual strike of the strata seems to be N.W.-S.E., and the dip to the north-east.

The beds on Wells' land are exposed along the side of the road west of the creek. They can be worked cheaply, and are conveniently situated for loading the stone for transport. When Wells' stone is finally exhausted, the solid mass of rock on Rogers' land up the creek, where it is exposed in lofty vertical cliffs, will be available for supplies. Altogether there are 120 or 130 acres of limestone land on these lots, which would supply the rquirements of any smelting works indefinitely.

Samples of the rock have been assayed by the Government Assayer in the Geological Survey Laboratory, with the following results:—

	Per Cent.
Calcium carbonate	90·25
Magnesium carbonate	0·19
Silica	8·30
Ferric oxide and alumina	1·17
Moisture	0·18
	100·09

A high-class lime is being made from it by Mr. Wellard, and finds a ready market in quantities at 1s. 6d. per bag.

A disadvantage which the locality possesses as a source for outside supply is the present cost of getting the stone to the railway. By the new road it will probably cost 6s. or 7s. a ton to carry it to Preston, and thence by rail to Penguin from 2s. 6d. to 3s. Works in the Penguin Valley would most likely find the stone costing them, delivered, in the neighbourhood of 10s. per ton. At present rates the railway freight from Penguin to the mouth of the Blythe is 2s. 11d. per ton, but this would no doubt be considerably reduced for quantities. The present motor transport to Ulverstone from the plains is 10s. per ton, but it is questioned whether that could be made to compete with the railway. With modern quarrying methods and reduced transport rates, the conditions point to the selection of the great deposits of limestone at Gunn's Plains as a source of supply for any furnaces erected along the North-West Coast between Burnie and Ulverstone; and the costs may not be more than 2s. or 3s. per ton of pig iron.

XIV.—CONCLUSION.

From the preceding it will be gathered that Tasmania possesses deposits of iron ore of a varied nature in different parts of the island. With three exceptions, however, no commercial use has so far been made of them. These are the chromiferous ores of Anderson's Creek, the brown hematites of Brandy Creek, and the high-grade hematites of the Penguin Creek Valley. The metal from the Anderson's Creek beds was placed on the market for a short time, until the increasing chromium content interfered with the sales. Small quantities of the Brandy Creek iron were disposed of satisfactorily, but, with a drop in the market, the outlook was not encouraging enough for the owners to continue their venture. The demand for the Penguin ores fell off when the buyers found more convenient sources of supplies of flux on the mainland, and the difficulties with landowners hastened the suspension of operations. The remaining deposits have so far not been exploited for one reason or another. Either they are not sufficiently near shipping ports, or are unfavourably situated for deliveries of fuel and flux, or the desired capital has not been forthcoming. Doubtless the absence of serious attempts to prospect and open up the properties, with a view of disclosing their actual value, has to some extent discouraged the approach of investors. It may in fact be said that all the properties referred to are in this undeveloped state. While there is much in their visible features to support a hopeful view of their possibilities, an entirely inadequate amount of work has been done on them for establishing a basis for commercial calculations. Their values, therefore, may be characterised as latent and potential. In this sense the iron resources of Tasmania are of no mean order.

This becomes apparent when one takes into account the area of the island and compares this and the extent of the deposits with the average of those of the iron-bearing countries of the world. Professor Hj. Sjogren, in his summary of the Stockholm Congress reports, works out a ton-mile factor for the world's reserves. Striking a mean between different estimates of the supposed actual and potential supplies of iron ore throughout the world, ranging from 90,000,000,000 to 130,000,000,000 tons, there emerges approximately a total of 110,000,000,000 tons, which, over an area of 50,554,630 square miles, is equivalent to 2175 tons per square mile. In this total, Tasmania, with an area of 26,000 square miles and potential reserves of 42,000,000 tons, figures with 1615 ton-miles. This, therefore, is below the world average, but not depressingly so.

In the utilisation of these potential stocks the provision of electric energy by means of the State hydro-electric installation must always be regarded as an indispensable factor, as the future of the deposits is inextricably bound up with electric smelting and electric steel production. Electric furnace units of moderate size can easily be installed at various centres, thus responding to the needs of widely separated deposits. The Savage River and Zeehan magnetites are above all most suitable for electric smelting, for nearly all electric iron furnaces so far have been run on magnetic ores, and the commercial feasibility of the process has been practically and absolutely demonstrated. As hematites smelt in the blast furnace more easily than magnetites, they also will be readily reducible in the electric furnace. The Government is prepared to arrange for the delivery of power at reasonable prices. The costs of fuel and flux will not be prohibitive, though the question of fuel will involve anxious consideration. Electrodes will by and by be purchasable at normal prices. Labour will probably not fall below its present level. Taking all these factors into account, electric iron ore smelting presents itself as a workable proposition. The quantities required for electric furnaces do not necessitate the enormous tonnages customary in blast-furnace practice, and in one locality or another, according to all appearances, it is safe to say that enough ore exists to support the industry in Tasmania for very many years. Moreover, the intimate relation which is admitted to exist between the manufacture of iron and steel and the economic status and future of a nation or country justifies any attempt to exploit the deposits wherever the indications and conditions promise a reasonable chance of success.

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Geological Survey,
Launceston, 4th November, 1919.