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TASMANIA

DEPARTMENT OF MINES

GEOLOGICAL SURVEY

MINERAL RESOURCES

THE CHROMIUM RESOURCES OF TASMANIA

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TASMANIA

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SUMMARY

The most important of the known deposits of chromium in Tasmania are the chromium-bearing iron ores lying a few miles west of Beaconsfield. Although not of present economic value these deposits are destined to play an important part in the industrial development of the district. Exploration will follow advances in the metallurgy of chromium, the extension of markets, and the increase in the price of the metal. Of recent years the great increase in demand has not materially affected prices because of the present relative abundance of the mineral in certain countries and the great latent resources thereof. Prices probably are maintained at a fairly constant figure because of the knowledge that these resources can be drawn upon as desired to supply the world's immediate requirements. However, since 1923 a gradual progressive increase in price gives the impression of a stable market with possible possibilities of improvement. Having that in mind it was deemed advisable to investigate our resources of both chromite and chromium-bearing iron ores. The results of those investigations, clearly set out in the following pages, show that Tasmania possesses considerable deposits of chromiferous-iron ore and of chromite in alluvial concentrations, the latter of high quality and particularly suitable for use in the manufacture of cement brick for lining kilns and in the chemical trade. However, the alluvial deposits of chromite lie off main lines of transport, therefore the costs of producing and marketing prevent successful operation at present prices. Serpentine rock bodies with disseminated chromite may become of importance when Australian markets are open for this mineral, but under present conditions cannot be drawn upon for foreign markets. Samples of chromite submitted for analysis to the Government Chemist & Assayer gave results of 55 to 64 per cent chromic oxide. Ore of that grade would find a ready market in Australia.

We have then in Tasmania important deposits of chromite and chrome iron ore which, however, at the ruling prices and costs of transport are not marketable at present, but which would become of considerable importance in the near future.

THE CHROMIUM RESOURCES OF TASMANIA

INTRODUCTION

The world's demand for chromium for use in the manufacture of non-corrosive steels, as a refractory for open-hearth furnaces, for stainless metal coatings and many other uses accounts for the extraordinary growth in the metallurgy of this metal. Its applications have been so greatly extended that it has of late been regarded as among the essential metals.

An enquiry therefore into our resources, not only of chromite, but of chromiferous iron ores, also, seems justifiable at this time. The attention given in other countries to the investigation of all sources of supply led the Mines Department of this State as a first work to undertake the drilling of the chromiferous iron ores of Mts. Scott and Vulcan and Barnes Hill near Beaconsfield. The results of that work appear in the following report. In addition, brief accounts are given of the more important deposits of chromite.

A compendium from the works of other investigators is given for the further information of those interested in this branch of the mineral industry.

BIBLIOGRAPHY AND ACKNOWLEDGEMENTS

In 1866 Charles Gould, Geological Surveyor, published a report of his investigations into the deposits of Mts. Scott and Vulcan in House of Assembly Paper No. 76. W.H. Twelvetrees in 1903 described those deposits in "Report on the Mineral Resources of the Districts of Beaconsfield and Salisbury".

In "The Iron Ore Deposits of Tasmania" by W.H. Twelvetrees and A. McIntosh Reid (1919) the first-mentioned presents a sketch of the history of development and an interesting account of the geology of the deposits.

In addition to those sources, which have been freely drawn upon, information has been obtained from Mineral Resources of the United States 1925, in which an article on Chromite appears by J.W. Furness. From The Mineral Industry 1926 McQuiggs' Table of Commercial Application of Chromium Alloys has been drawn and reproduced herein.

THE MARKET VALUES OF CHROMITE AND CHROMIFEROUS IRON ORE

Chromite, the commercial source at present of all chromium products, contains 68 per cent Cr_2O_3, but owing to impurities inherent in the ore the Cr_2O_3 content of marketed material ranges between 35 and 55 per cent. Although chromium cannot be regarded as a common metal, singularly enough it has a low unit value. This is the more striking when it is realised that the ore-bodies are very irregular. In consequence cheap production and transport to market are pre-requisites.

Market prices in Europe and America of ores of 45 to 50 per cent grade range from £4 to £4.10.0 per long ton, and of ores of 50 to 54 per cent grade from £4.10.0 to £5 per long ton. In Australia prices of the better grades are much higher, but the markets are limited to small lots. It is used here instead of magnesite as a refractory in open-hearth furnaces.

The outlook for the marketing of chromite in Australia in the immediate future cannot therefore be regarded as encouraging. In fact Australia is an exporting country. The demand for chromium, however, is expanding so rapidly that Australia should soon provide a large market capable of absorbing the local production.

As regards chromiferous iron ores, like those of Mt. Vulcan and Mt. Scott, such are too poor for export and can have a local value only even allowing for important advances in the metallurgy of chromium.

WORLD'S PRODUCTION

The subjoined table shows the production of crude chromite, 1921-1926, by countries, in metric tons. Although the potential reserve is high the rapidly increasing demand will take heavy toll of the resources. Its greatest application in the future will be as a preventive of rust the direct and indirect loss by which is estimated at £500,000,000 per annum. The need for the conservation of iron becomes more and more evident as the rich ore deposits show indications of depletion. Any alloy therefore that will increase the life of steel will materially assist in postponing the day when the world's reserves of low grade iron ore will be drawn upon for supplies. The corollary to that is the prevention of waste of chromium. It becomes evident that any of the uses which rapidly dissipate chromium should be eliminated. Its use as a refractory at once comes up for question. The desired end can be accomplished only by research work for the purpose of finding a satisfactory substitute as a refractory. In this use the service rendered by chromite is of but short duration therefore the ultimate loss is very heavy.

Country	1921	1922	1923	1924	1925	1926	1927
Australia	63	537	1211	785	978	607	
Brasil	-	-	-	-	-	1500	1820
Canada	2538	696	3228	-	-	-	-
Cuba	610	-	10587	19881	29830	36598	16983
Cyprus	-	-	-	-	2021	524	711
Great Britain	-	605	555	1060	455	-	384
Greece	8029	9213	14828	14651	9363	20049	15051
India	35320	23143	55113	46192	38053	33918	58207
Japan	3368	3757	4526	5362	5815	7052	-
New Caledonia	29458	19374	23220	23021	34732	34267	42885
Rhodesia	45529	84799	87702	156692	135828	164376	218016
Russia	4013	847	3004	7266	30670	30362	18060
Asia Minor	10000	2540	-	-	6209	4418	16609
South Africa	1078	87	-	4572	13756	12042	16959
United States	287	361	231	293	110	143	204
Yugo-Slavia	10	15	-	300	12160	15983	8757
Others	407	30	60	197	440	71	-
Total	130710	146004	204265	280075	321020	361910	414655

Rhodesia today supplies more than 50 per cent of the world's production and is capable of great expansion in the rate of output. Some of the deposits are reported to be of extraordinary extent.

Baluchistan produces the bulk of the India output,

some deposits, however, are showing signs of depletion. Statistics regarding the output of New Caledonia show increases over the 1924 production. Increases are reported also from Russia, Transvaal, Rhodesia, Asia Minor and India. In 1918 the United States was the leading producer shipping 82,430 long tons, mostly from the State of Maryland.

Today Russia produces sufficient for her requirements; England and France, through their colonies and dependencies, produce their needs; but the United States and Germany depend largely upon foreign sources of supply. Most of the producing countries have very small domestic consumptions and export the bulk of their ores.

COMMERCIAL CONTROL

The commercial control of chromite rests largely in the hands of Chrome Co. (Ltd.) of London who have arranged sales contracts with important Rhodesian producers and also with Companies operating in New Caledonia. Moreover, Chrome Co. (Ltd.) some time ago took over the largest mines in Baluchistan.

The Brasa deposits of Anatolia were operated in pre-war days by J.W. Whittall & Co., an English firm, as lessees. Now they are in the hands of a German Company.

A number of important producers in the British Dominions now operate independent of Chrome Co. (Ltd.), whose influence in some quarters is on the wane.

PROPERTIES AND ORES OF CHROMIUM

Chromium may be regarded as one of the rare components of the earth for it constitutes less than one-half per cent of the whole. Nevertheless, it is widely distributed and in many places naturally concentrated in commercial deposits.

This metal belongs to the oxygen group of the periodic system which includes such other acid-forming metals as molybdenum, uranium and tungsten.

Chromium is not found native, but in combination with iron as chromite, with lead as crocoite, with magnesium and iron as stichtite, with aluminium and magnesium as picotite or chrome spinel, and with silica, alumina and the sesquioxides of chromium and iron as chrome ochre and selwynite. All these minerals are found in Tasmania, but chromite and chromic iron ore are the only commercial ores of chromium.

Chromite is a blackish brown mineral, gives a brown streak, has a sub-metallic lustre, a hardness of 5.5, and a specific gravity of 4.3 to 4.6. Its crystal form is octahedral. The theoretical composition, if chromite were found pure, would be chromium sesquioxide (Cr_2O_3) 68 per cent and iron protoxide (FeO) 32 per cent; but in nature part of the iron is replaced by magnesium and part of the chromium by aluminium. It follows that an average high grade ore in bulk seldom contains more than 45 per cent chromium sesquioxide. The "verde antique" serpentine used for ornamental purposes derives its green colour mainly from chromium, which also gives the green colour to chrome mica and the emerald, and the lilac colour to stichtite. It is found also as chrome ochre (Cr_2O_3) and chromium garnet ($CaO\ Cr_2O_3\ SiO_2$).

Stichtite, a beautiful lilac-coloured amorphous mineral occurs in the serpentines of Dundas district. It is a derivative of chromite, a nucleus of which reveals its origin. An analysis gave the following composition:-

Cr_2O_3	-	11.5 per cent
Fe_2O_3	-	9.0 " "
MgO	-	36.0 " "
CO_2	-	7.2 " "
H_2O	-	36.1 " "

answering to the formula $(CrFe_2)\ O_3\ 6MgO\ CO_2 13H_2O$. The hardness is 1.5 and the specific gravity 2.20.

Crocoite ($PbCrO_4$) Chromate of Lead. The mineral found at Dundas is one of the most beautiful in colouration and at the same time one of the most perfect in crystallographic growth, surpassing that of the classic deposits of Siberia.

NATURE OF OCCURRENCE

Chromium ores in Tasmania, as elsewhere throughout the world, occur in rocks of ultra-basic character such as peridotite, olivine-pyroxenite, bronzitite, etc., and their serpentine derivatives. Chromite deposits are formed by magmatic segregations from the ultra-basic fractions of the magmas, and, in Tasmania, are closely associated with osmiridium. sometimes chromite is found massive in the forms of lenses or tabular bodies, more commonly, however, as octahedral crystals and blebs scattered through the rock and in fine grain blending with its serpentine container. Chromite deposits, therefore, as a rule are very irregular in their outlines and erratic in their destribution. This mineral does not occur in lodes (used in the strictest sense) but sometimes in well-defined lines of segregation as in Rhodesia where, for instance, an individual seam extends over six miles along the outcrop.

Deposits may be found as segregations in ultra-basic rocks in the forms of:-

1. irregular bodies, often lens-shaped.
2. thin regular seams in narrow dykes of serpentine.
3. disseminations in serpentine.

Chromite, with its associate osmiridium, is one of the first minerals to crystallise in the magma and segregates early in the cooling process.

In Tasmania, detrital and alluvial deposits, the result of disintegration of chromite-bearing serpentines form the bulk of the commercial bodies. The chromiferous iron ores of Mts. Scott and Vulcan containing up to 16 per cent Cr_2O_3 are, however, the most important of the known deposits.

METALLURGY OF CHROMIUM

Chromite is the only ore used at the present time in the preparation of chromium for industrial use. Its application depends upon the relative proportions of iron and chromium and the ratios of chromium to alumina, magnesia and silica. If the iron content predominates the ore becomes difficult of conversion into ferrochrome Ordinary chrome steels contain about 2 per cent of chromium, at present are manufactured only by the use of ferrochrome because of the cost in overcoming the difficulties referred to in making chrome steels direct from chromiferous iron ores. Research is now directed to the separation of chromium direct from chrome ore in order to eliminate the wasteful step of manufacturing ferrochrome.

In the manufacture of chrome steels ferrochrome (an alloy of iron, carbon and chrome) containing not less than 60 per cent chromium is used. Ferrochrome is made by reducing the crude ore or concentrate in an electric furnace. The alloy tends to take up much carbon, which is regarded as an undesirable element, therefore the quality depends inversely upon the proportion of carbon. In the electric furnace the reduction of chromite to ferrochrome is brought about by the use of anthracite according to the reaction -

$$FeOCr_2O_3 + 4C = Fe2Cr + 4CO.$$

The reducing action begins at 1185^0 centigrade.

The amount of carbon necessary for reduction greatly exceeds the theoretical quantity, therefore an excessive amount of carbon enters into the ferrochrome. To decarbonise the high-carbon ferrochrome, the alloy is melted with a lime slag, chromite ore and fluorspar. Chromiferous iron ores are treated by the gas reduction process with subsequent melting to produce the alloy. The high cost at present is restricting sales.

UTILIZATION

The consumption of chromium in 1928 was apportioned approximately as follows:-

1. in the manufacture of ferrochrome - 46 per cent
2. in the manufacture of chemicals - 13 per cent and
3. its use as a refractory - 41 per cent

Chromium has come into general use for coating metals and a considerable proportion is now applied to that branch of industry.

1. Chrome steels have many uses including the manufacture of axles, springs, parts of gun carriages, automobiles, safe steel, tyres, cutlery, armour plate and projectiles. These steels possess the quality of great hardness combined with toughness; they can be bent cold, and can be welded to iron to form either a surface or a core capable of resisting attack by the use of any but the finest drilling tools. Vanadium, nickel, tungsten and manganese, together with chromium, are alloyed with steel for use against abrasive action.

Rustless steel, containing 13 to 14 per cent chromium, 1 per cent nickel and little carbon, is used chiefly in the manufacture of cutlery. An alloy known as stellite (essentially cobalt, chromium, tungsten and molybdenum) is especially suitable for highspeed tools. Nichrome, which contains 60 per cent nickel, 14 per cent chromium and 15 per cent iron is a high temperature alloy used for annealing boxes and conveyor chains.

Stainless steels are used also for exhaust valves, turbine blades, pump rods, rollers for bearings in electric heating stoves and utensils.

Chromium is now coming into general use for coating metals. The coating is hard and white; it resists the action of ammonia, hydrogen sulphide and nitric acid, and is not attacked by molten zinc, tin or brass. It is non-corrodible by vegetable and fruit acids and may therefore supplant tine in the canning trade.

2. Chromium in the forms of chromates and bichromates has a wide application in the chemical industries. Chrome pigments - yellow, green and red - are extensively used. The soluble chromates and bichromates are used as mordants in the dye industry, in the tanning of chrome leathers, in the bleaching of fats and oils, and in the ceramic industry.

3. As a refractory, chromite remains unchallenged. Its most important use is as a liner for the open-hearth furnace in the manufacture of steel. About 2½ lb. of chromite is used for every ton of steel manufactured. It has a decided advantage over magnesite and silica-alumina mixtures in that it resists corrosion and withstands rapid changes of temperature and in high-temperature metallurgy, it has no substitute. In paper-pulp mills chromite brick fulfils a need in the lining of the kilns used for the drying of pulp in the sulphide process, as they resist corrosion caused by the literated gases in the kiln. The usefulness of chromite as a refractory depends in part upon the physical structure. The most important requirements, however, is the ratio of the chromium and aluminium to the iron and silica. A refractory suitable to the requirements must have the following physical and chemical properties:-

1. Resistance to chemical reaction with fused metals, slags, vapours, etc.;

2. Resistance to deformation caused by a wide range of temperatures;

3. Strength to withstand blows, shocks, loads etc, in wide range of temperatures;

4. Thermal conductivity;

5. Durability (length of service);

6. Uniformity;

7. Resistance to erosion, spalling etc;

8. Capability of conforming to accurate measure when moulded.

TABLE OF COMMERCIAL CLASSIFICATION OF CHROMIUM ALLOYS

Characteristic Chromium Range	Principal Properties	Some Typical Applications
0 to 5 per cent Cr. with or without one or more alloying metals as nickel, vanadium, molybdenum, etc.	High strength, ductility and toughness and (or) hardness.	Ball-bearings, tools, armour, armour-piercing shells, high-speed cutting tools, automibile and aeroplane parts, stamp shoes, crusher and roll parts, grinding machinery, saws, files, etc.
14 to 16 per cent Cr. added to cast iron.	Resistance to oxidation where the physical properties of cast iron are satisfactory.	Annealing boxes for malleable cast-iron foundries, roasting or muffle furnaces for temperatures up to 800° C. (1475° Fahr.)
12 to 16 per cent Cr. carbon content carefully controlled.	Resistance to corrosion together with excellent physical properties.	Cutlery, kitchen utensils, chemical plant apparatus to resist nitric acid and many other chemicals. Resists oxidation up to 800°C. Turbine blades, internal combustion engine valves, marine equipment, builders' hardware and decorative parts, sporting goods, etc.
10 up to 20 per cent or more Cr. with other alloying metals, especially nickel. Silicon and manganese present sometimes up to several per cent.	High electrical resistivity and non-oxidising. High tensile strength at high temperatures. Some have hot and cold working properties.	Electrical heating elements. Case carbonising boxes, annealing boxes, pyrometer tubes, furnace parts.
20 per cent Cr. and upward; no appreciable alloying elements other than carbon.	Resistance to oxidation and to many forms of chemical attack, especially nitrates and sulphur. Softness and workability in low carbon ranges; hardness.	All types of apparatus subjected to oxidation up to 1100°C. such as stills, muffles, retorts. Crushing and grinding equipment. Nitric acid plant equipment. Mine pumps.

The following table, prepared by J.W. Furness of the Bureau of Mines, U.S.A., gives the general characteristics of the chromite imported into the United States from the several sources of supply, and shows the reported average analysis of the material as marketed:-

Country	Physical Structure & Nature	Chemical Analysis	Per cent.	
			Low Grade	High Grade
Cuba	Amorphous and sandy, fine; some lump with tendency to soften and disintegrate.	Chromic oxide	34.14	43.97
		Magnesia	15.14	18.95
		Alumina	30.18	10.78
		Ferric oxide	16.07	13.97
		Silica	3.08	8.92
		Ignition Loss	1.40	3.34
			Average Grade	
Greece	Crystalline, good structure	Chromic oxide	38.83	
		Magnesia	16.33	
		Alumina	21.18	
		Ferric oxide	17.01	
		Silica	4.70	
		Ignition Loss	2.44	
			Medium Grade	
India	Mostly crystalline, but not so closely knit structurally as desired for refractory purposes.	Chromic oxide	42.38	
		Magnesia	13.78	
		Alumina	14.34	
		Ferric oxide	23.96	
		Silica	6.03	
		Ignition Loss	2.13	
			High Grade	
New Caledonia	Crystalline dense, also sandy and friable. One of the sources of high-grade chemical ore due to high-chromium low-silica content.	Chromic oxide	55.02	
		Magnesia	8.00	
		Alumina	11.10	
		Ferric oxide	12.77	
		Silica	3.00	
			Medium Grade	High Grade
Rhodesia	Crystalline dense, also sandy and friable; refractory grade from this source known as Imperial is a selected grade and must withstand the severest uses to which chromite is subject as a refractory; several grades are produced.	Chromic oxide	42.38	49.43
		Magnesia	8.88	13.95
		Alumina	15.16	13.60
		Ferric oxide	29.67	19.47
		Silica	4.12	5.59
		Ignition Loss	0.92	1.67
			Average Grade	
Turkey (Anatolia)	Semi-crystalline and sandy; fair percentage of lump when mined; has a tendency to disintegrate when exposed to agents of weathering.	Chromic oxide	44.55	
		Magnesia	19.10	
		Alumina	15.20	
		Ferric Oxide	15.25	
		Silica	5.40	
		Ignition Loss	0.30	

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Country	Physical Structure & Nature	Chemical Analysis	Per cent
			Average Grade
Selukwe (Rhodesia)	More or less friable (used in steel trade)	Chromic oxide	51.10
		Ferrous oxide	11.40
		Ferric oxide	1.40
		Manganese oxide	0.50
		Alumina	15.20
		Magnesia	12.70
		Lime	0.90
		Phosphorus pentoxide	0.50
		Silica	4.80
		Ignition Loss	1.97
Transvaal	Hard and massive (carries platinoids in minute quantities).	Chromic oxide	42.00
		Ferric oxide	20 to 25
		Silica	3 to 4

Although the use of chromite as a refractory depends in part upon the physical structure, the most important requirement of the mineral is the ratio of the chromium and aluminium content to the iron and silica, the range of which, as shown, is rather wide.

Some Trade Brands of chromite for refractories are:-

Imperial - Cr_2O_3 45 to 50 per cent

Plymouth - " 38 to 45 " "

Grecian High Grade - " 36 to 42 " " , Al_2O_3 18 to 25 per cent

Larco - " 32 to 37 " " , " 27 to 33 " "

GEOGRAPHICAL DISTRIBUTION

Chromiferous iron ores or chromite bodies are found in Tasmania wherever ultra-basic rocks, especially those of Devonian age, outcrop; but some bodies are too small to be of any considerable commercial value. Those only therefore that are likely to have a future value will be dealt with in this report, namely:

1. The Chromiferous Iron Ores of Mts. Vulcan, Scott and Barnes Land near Beaconsfield.

Other deposits of no present commercial value are :-

1. The Chromite deposits of Heazlewood, in primary bodies and alluvial deposits;
2. The Chromite deposits of Adamsfield;
3. The Chromite seams in serpentine near Hamilton-on-Forth;
4. The alluvial deposits of Harmon Rivulet;
5. The alluvial deposits of Huskisson River;
6. The alluvial deposits of Arthur River;
7. The Chromite Chromiferous iron, Crocoite, and Stichtite bodies of Dundas.
8. The Chromite deposits of New Rinu area.

THE CHROMIFEROUS IRON ORES OF MTS. VULCAN AND SCOTT AND BARNE'S LAND.

HISTORICAL SKETCH

The earliest record of chromiferous iron ore at Mts. Vulcan and Scott shows that a few tons were shipped by Colonel Paterson in the "Lady Nelson" to New South Wales in 1805 for testing. The results of the tests are not on record.

In 1865 Charles Gould, then Government Geological Surveyor, after a careful investigation, expressed the opinion that the deposits of ore would at a future time become of considerable commercial value. This report created public interest in the occurrence, but no action was taken until 1872 when the late T.C. Just and Jas. Scott visited the area, and as a result decided to place a scheme of development before Melbourne investors.

The history ofthe mining of these chromiferous iron ores and of the smelting of the ores at Port Lempriere is of particular interest in the light of our present-day knowledge of the metallurgy of chromium and the application of this metal to industrial use. The difficulties that beset the early smelting companies in finding markets for the product are clearly set out in the communications from the smelter managers as given hereunder.

In 1872 the Tasmanian Charcoal Iron Company was organised in Melbourne for the purpose of smelting the chromiferous iron ores by direct process in open Catalan forges to produce malleable iron blooms for shaftings, etc. for the Victorian market. The first attempt was made in a furnace designed to reduce the ore by a process

invented by W.H. Harrison, who in a communication to the Department stated inter alia: "I erected the furnace and as a result of two or three days' running produced a "considerable quantity of high grade steel from which "a number of tools were made that possessed very remarkable "qualitites. The tensile strength was far in excess "of similar materials made from the then best manufactured "steel in Europe and America. From my steel, under the "hammer, ribbons were made which could be tied into knots "and would nearly straighten to their original form. "Chisels were made that could cut a groove in a 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. Under "instructions from the Directors my researches were dis- "continued to favour of the old blast-furnace methods. "The chrome in these ores was regarded as a factor of "failure. As a matter of fact chromic acid is the factor "giving the splendid qualities to the product."

The Company, after spending £12000 on these works, sold their assets to the British and Tasmanian Charcoal Iron Company of Melbourne, who erected a blast-furnace and an iron-cased cupola at Port Lempriere. A range of 40 coke ovens, each ofone ton capacity, was erected in 1876, and Bulli coal was used. Limestone flux was obtained from the Melrose quarries. During the last two months of 1876 the Company produced between 2000 and 3000 tons of pig iron, the softer sorts selling in Melbourne at £6.10.0 per ton. Soon, however, the objectionable element chromium manifested itself, some of the pig containing 10 per cent. For such articles as stamp heads and shoes, and for all purposes requiring a combination of hardness and toughness, the iron was looked upon as the best on the market. The local market however proved too small and no other outlet could be found. Mixed with other irons and tried for tools, wire, castings, etc. it proved unsatisfactory, the product being too hard and brittle. The iron could not be worked by itself, and, containing chromium in irregular proportion, unformity of quality could not be guaranteed.

In 1877, in consequence of their failure to market the whole of the output, the company closed the works and sold the plant.

Apparently the enterprise started 50 years before its time. Harrison's furnace seems to have given the best results. However, some of the difficulties met with in those days still prove troublesome.

PRODUCTION

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 reckoned at 20,000 tons.

Analyses of Pig Iron smelted many years ago from Mt. Vulcan ore showed contents as given hereunder :

No.	Authority	Metallic Iron	Metallic Chromium	Silica	Carbon	Sulphur	Specific Gravity
		(per cent)					
1	R.C. Moffatt	89.72	9.27	1.01			7.55
2	" "	97.82	1.43	0.75			6.10
3	E. Riley	88.343	6.287	0.976	4.20	0.207	
4	" "	91.362	4.143	0.124	3.27	0.562	

Note : Traces only of phosphoric acid detected in the pig iron.

These analyses show a very variable content of Chromium; but it must be borne in mind that the aim of the operators was to exclude the chrome-rich ore and get rid of as much chromium as possible per medium of the slag. However, the composition of the pig iron is a fair reflection of the ore content. In practice it is mixed with the different foundry irons in such proportion as to obtain the desired composition, therefore no attempt need be made to sort the ore in preparation for smelting.

SITUATION AND ACCESS

The ore-bodies lie five to six miles south-west of Beauty Point, a deep-water port on Tamar River. In the old days the port of shipment was at Red Bill Point about half a mile north-west of Beauty Point. From that base a jetty was built 310 feet into West Arm and a tramway was constructed between the mine and the port.

The tramway now forms the foundation for a road, and passes through thinly-wooded gently undulating country all the way to the mines.

Beauty Point is now the chief port on the west bank of Tamar River.

GEOLOGICAL RELATIONS

The foundation rocks ofthe district consist of the Pre-Cambrian series of micaceous and quartz schists of the so-called Asbestos Range. Unconformably overlying those rocks on the east side are Cambro-Ordovician conglomerates, grits, quartzites, sandstones, slates and limestones. Intruding the Cambro-Ordovician appears a dyke-like outcrop of serpentinised ultra-basic rock of Devonian age about 1½ mile in width and over 4 miles in lergth. Peridotite and pyroxenites composed the original ultra-basic rocks, the conversion of which into serpentine and into chrysotile and amphibole asbestos has been ascribed to a later intrusion of granite of pegmatitic character from the same stock magma. No doubt the carbonic acid emanations from the invading granite brought about the serpentinisation of the ultra-basic rocks and the formation therein of veins of chrysotile and asbestos and of fibrous magnetite.

The constituent minerals of the granite are biotite, quartz and felspar in equal proportions. Accessory minerals are apatite in minute grains and black tourmaline. The rock shows marked evidence of strain which undoubtedly resulted from the effects of internal stresses induced in the containing ultra-basic rock is a direct result of increase in volume during the processes of serpentinisation. The alteration of olivine, one of the components of peridotite, to serpentine has been estimated to result in an increase of volume amounting to 30 per cent. There must have been therefore a very great expansion during serpentinisation, even allowing for the removal of iron, silica and alumina in the process, and this expansion was certainly sufficient to effect a complete change in the structure of the encased granitic rock. Its schistosity and its appearance generally of a rock which has been subjected to intense strain has a parallel in the evidences of great movement exhibited in the serpentine itself by the intricate arrangement of slickensided surfaces and gliding-planes.

Small intrusions of aplitic varieties of granite appear here and there and at Nicholls Bridge outcrops a granitoid rock consisting of hornblende set in a groundmass of turbid felspar and a little quartz.

Intrusions of granitic rocks lie close to every chromiferous iron ore deposit and to every chrysotile and asbestos vein, indicating a definite causal connection between them.

THE ORIGIN OF THE CHROMIFEROUS IRON ORE AND OF THE ASSOCIATED ASBESTOS DEPOSITS

In dealing with this phase of the subject, it is necessary to first inquire into the origin of the magnetite and chrysotile because both were formed under the same conditions and by the same agents at the same time, and it will be shown that the chromiferous iron ores are in part alteration products of magnetite and chromite.

Chrysotile is a crystallised variety of serpentine and like all asbestiform minerals is secondary. It follows that serpentine is an alteration product and not a primary rock. Serpentine commonly results from the action of carbonic acid solutions on peridotite, the probable reaction being :

olivine serpentine magnesite

$$2\ Mg_2SiO_4 + 2H_2O + CO_2 = Mg_3H_4Si_2O_9 + Mg\ CO_3$$

Under the action of hot carbonated waters containing silica part of the iron component of the peridotite is converted into magnetite and part carried off. In this case the change from olivine into serpentine is effected in the following manner:-

olivine serpentine

$$3\ Mg_2SiO_4 + 4H_2O + SiO_2 = 2H_4Mg_3SiO_2O_9$$

Pyroxene are also converted into serpentine under similar conditions, as shown in the following equation:-

diopside serpentine calcide quartz

$$3\ MgCaSi_2O6 + 3CO_2 + 2H_2O = Mg_3H_4Si_2O_9 + 3CaCO_3 + 4SiO_2$$

Peridotite consists of pyroxenes and olivine; pyroxenite consists of pyroxenes alone.

As already remarked, the range of the field of these secondary minerals is determined by the lineal extent of the granitic dykes intruding the serpentine. The hot carbonated waters emanating therefrom strongly attacked the basic rocks, breaking down their mineral structure, converting a portion of the iron constituent into magnetite and a portion into other oxides; converting the alumina constituent into aluminium silicate or clay; and collecting the chromite and precipitating it with the iron oxides and aluminium silicate.

Thus were formed the chromiferous iron ore-bodies of this district.

THE NATURE OF THE ORE-BODIES

All bodies in the area under examination exhibit like features. They occupy the summits and slopes of low hills of no great extent. The waste of them, covering the intervening spaces, gives an exaggerated impression of their size. At surface the material consists essentially of loose hematite, magnetite and limonite. This detritus rests upon layers of soft earthy hematite alternating with thinner layers of hard and cellular hematite, which in turn gives place to loose non-plastic ironstone clay and ultimately to solid serpentine veined with fibrous magnetite. Pieces of crystallised columnar magnetite appear in the detritus and veins of that mineral appear also in the serpentine, thus exhibiting a causal connection. Boulders of chromiferous iron ore of concretionary structure lie loose in the detritus and imbedded in the layers of red and yellow earthy hematite. Nodules of magnetite and flakes of bronzitite may be seen in the hematite and limonite detritus.

In the log of the old No. 1 bore drilled from a point near the shaft at the summit of Mt. Vulcan an account appears of several beds of iron ore cut far below the base of the outcropping body. This iron ore is contained in serpentine veined with magnetite and doubtless

represents a portion of the iron content of the original pyroxenite concentrated there during the process of serpentinisation. Its association with veins of magentite in serpentine provides no evidence of derivation ffom that ore, but shows it to be of con-temporaneous formation.

Samples of fibrous magnetite by analysis were found to contain chromium in considerable proportion, thus providing evidence of the collecting and concentrating actions of the solutions.

These residual mantles, resting upon serpentine no doubt represent the subaerial decay of beds of chromiferous iron ore contained in magnetite-bearing serpentine. The results reveal beds of red and yellow iron oxides, hydrons and anhydrons, loose and in finely divided condition in the middle layers, concretionary boulders and recemented masses in the upper layers and clayey material in the lowest. Unconfined silica, evidently pertaining either to the original basic parent rocks of the serpentine or to solutions from the intruding granitic magma generally invisible to the eye with that combined with alumina in the form of clay, forms a not inconsiderable portion of the ore.

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Driller: British and Tasmanian Charcoal Iron Company.

Locality: Mt. Vulcan.

No. of Bore: 1A.

Nature of Material	Depth in feet.	Thickness in feet.
Ironstone	24.0	24.0
Hematite	30.5	6.5
Ironstone	36.0	5.5
Iron sand	40.0	4.0
Soft Ironstone	42.0	2.0
Heavy hard ironstone	44.5	2.5
Brown hematite	52.0	7.5
Decomposed serpentine	82.5	30.5
Hard serpentine	88.0	5.5
Serpentine veined with asbestos	94.5	6.5
Serpentine with asbestos and magnetite ...	96.5	2.0
Hard serpentine and asbestos	97.0	0.5
Hard serpentine	99.5	2.5
Hard serpentine	101.0	1.5
Hard serpentine veined with magnetite	110.0	9.0
Ironstone	115.5	5.5
Serpentine	129.5	14.0
Serpentine veined with asbestos	142.5	13.0
Serpentine veined with asbestos and iron ore	151.5	9.0
Iron ore	151.7	0.2
Serpentine veined with magnetite	168.0	16.3
Iron ore, hard, dense and pure	174.4	6.4
Serpentine veined with asbestos	175.9	1.5
Serpentine	178.0	2.1

This bore was drilled from a point near the shaft on Mt. Vulcan.

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Driller: British and Tasmanian Charcoal Iron Company.

Locality: Mt. Vulcan.

No. of Bore: 1B.

Nature of Material	Depth in feet.	Thickness in feet.
Ironstone	19.0	19.0
Black sand with ironstone pebbles ...	24.5	5.5
Magnetite	33.0	8.5
Decomposed serpentine	57.5	24.5
Serpentine	70.0	12.5

Driller: British and Tasmanian Charcoal Iron Company.

Locality: Mt. Vulcan

No. of Bore: 1C.

Nature of Material	Depth in feet.	Thickness in feet.
Ironstone	19.5	19.5
Clay with iron pebbles	38.5	19.0
Iron conglomerate and magnetite	49.0	10.5
Pure magnetite	50.5	1.5
Decomposed serpentine	79.5	29.0
Hard rock, supposed to be ironstone	87.5	8.0

(Note: This hole was discontinued because of the breaking of the auger.)

QUALITY OF THE ORE

The records show that in the early days the smelters preferred the lump or hard ore. Friable and clayey ores were dumped as useless for their purposes, more because of the physical properties of the materials than the chemical composition. This will be apparent on reference to the analyses which do not in many cases show a wide variation in grade between the several layers of ore. Lump ore composes the greater part.

Although a certain degree of sorting might be put into practice with advantage, in this investigation samples representative of the material as a whole have been taken into account in arriving at a basis of value. These bulk samples were made up of the whole drill cuttings in five to ten feet sections.

The analyses reveal a chrome iron ore of fairly high average grade, containing little of oxides of titanium phosphorus, manganese and nickel, traces only of sulphur and lime, not much magnesia but rather much of silica and alumina which are more prominent in the clayey layers. The chromic oxide content is valuable ranging from one to sixteen per cent. Limonite forms a considerable portion of the iron ore as indicated by the amount of loss on ignition, but the anhydrous iron ores hematite and magnetite together make up the greater part.

047 B
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TABLE I OF ANALYSES

MT. VULCAN CHROME IRON ORE

LINE A - BORE No.1

Reg. No.	No. of sample	Sectional depth in ft. of sample	SiO_2	FeO Fe_2O_3	Cr_2O_3	Al_2O_3	MgO	CaO	TiO_2	P_2O_5	S	NiO	MnO & MnO_2	H_2O etc.	Nature of Material.
329	1	0 to 10	14.40	51.05	3.58		0.72	Nil	0.80	0.037	0.027	Trace	0.12	11.00	
330	2	10 to 15	17.20	47.66	3.53		0.72	Nil	1.00	0.037	0.027	Trace	0.24	11.7	
331	3	15 to 27	24.00	43.36	4.23		2.32	Nil	0.20	0.037	0.096	0.34	1.29	10.5	
	4	27 to 34													
332	5	34 to 40	25.00	38.53	1.88		1.80	Nil	0.60	0.037	0.068	0.18	0.98	12.40	

LINE A - BORE No.2

333	1	0 to 10	12.52	64.18	4.98		8.60	Nil	Trace	0.01	0.10	Nil	Nil	10.20	
334	2	10 to 15	10.40	70.14	6.52		1.44	Nil	Trace	0.005	0.08	Trace	Nil	6.26	
335	3	15 to 20	9.60	66.12	11.78		0.94	Nil	Trace	0.004	0.09	Trace	0.76	5.80	
336	4	20 to 25	9.40	68.44	10.26		1.01	Nil	Trace	Nil	0.08	0.10	Nil	6.50	
337	5	25 to 30	19.60	53.75	2.12		2.53	Nil	Nil	Trace	Trace	0.59	0.75	8.20	
338	6	30 to 35	15.00	53.77	3.65		2.53	Nil	Nil	0.007	Trace	0.13	1.00	9.80	

LINE A - BORE No.3

348	1	0 to 12	10.60	61.92	1.64		0.86	Nil	0.20	Trace	0.07	Nil	0.29	10.30	
349	2	12 to 17	11.60	67.59	3.15		1.08	Nil	Nil	0.002	0.05	0.15	0.59	7.40	
350	3	17 to 22	17.00	63.04	9.40		1.16	Nil	Nil	Trace	0.04	0.54	1.00	6.20	
351	4	22 to 27	9.20	73.28	7.40		1.88	Nil	Nil	Trace	0.03	0.35	1.10	5.16	

LINE A - BORE No.4

352	1	0 to 12	3.40	75.00	9.64		1.38	Nil	Nil	0.018	0.034	Trace	1.40	5.10	
353	2	12 to 17	3.20	79.30	16.00		1.73	Nil	Nil	0.003	Trace	0.25	1.75	1.20	
354	3	17 to 22	7.60	75.80	11.88		2.18	Nil	Nil	0.003	0.027	0.29	1.05	2.40	
355	4	22 to 26	5.20	76.95	7.05				Nil	0.005	0.09	0.37	1.05	3.90	

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BORE No.5

Reg. No.	No. of sample	Sectional depth in ft. of sample	SiO_2	FeO Fe_2O_3	Cr_2O_3	Al_2O_3	MgO	CaO	TiO_2	P_2O_5	S	NiO	MnO & MnO_2	H_2O etc.	Nature of Material
	1														
358	2	12 to 17	3.0	79.52	13.66		1.16	Nil	Nil	0.005	0.13	Trace	Nil	2.60	
359	3	17 to 22	5.36	77.24	6.06		0.94	Nil	Nil	0.003	0.05	0.29	3.84	5.30	
360	4	22 to 27	2.60	88.00	7.34		0.64	Nil	Nil	Trace	0.055	0.22	1.62	2.54	
361	5	27 to 30	5.68	76.12	8.70		0.72	Nil	Nil	0.005	0.11	0.23	1.18	6.64	
362	6		15.2	57.35	3.66		1.30	Nil	Nil	Nil	0.027	0.32	1.00	12.40	
						BORE No.6									
423	1		5.00	65.04	4.65	14.59	Trace	Nil	Nil	Nil	0.12	Trace	Nil	10.60	
424	2		3.20	63.39	2.13	20.67	Trace	Nil	Nil	Nil	0.11	Nil	Trace	10.50	
425	3		3.80	53.65	3.00	26.54	Trace	Nil	Nil	Nil	0.11	Nil	Nil	12.90	
426	4		6.00	59.30	3.60	19.70	0.72	Nil	Nil	Nil	0.027	0.07	0.29	10.30	
427	5		9.80	57.14	7.48	14.93	0.72	Nil	Nil	Nil	0.013	0.04	0.58	9.30	
428	6		6.80	71.51	5.78	8.89	0.72	Nil	Nil	Nil	0.013	0.12	0.87	5.30	
429	7		6.20	69.40	6.24	9.88	0.50	Nil	Nil	Nil	0.013	0.17	1.30	6.30	
430	8		9.00	63.18	5.16	12.63	0.50	Nil	Nil	Nil	0.068	Nil	0.87	8.60	
						BORE No.7									
431	1		17.88	54.01	3.60	12.51	0.14	Nil	Nil	Nil	0.068	Nil	Trace	11.80	
432	2	0 to 5	17.80	54.78	3.45	12.66	0.25	Nil	Nil	Nil	0.068	Nil	Trace	11.00	
433	3	5 to 10	9.60	63.93	6.06	10.01	0.20	Nil	Nil	Nil	0.20	Nil	Trace	10.00	
434	4	10 to 15	5.40	71.76	4.75	6.58	Trace	Nil	Nil	Nil	0.23	Trace	Trace	11.30	
435	5	15 to 20	7.20	63.31	4.56	14.26	0.14	Nil	Trace	Nil	0.23	Trace	Trace	10.30	
436	6	20 to 25	2.60	73.28	5.19	10.20	0.28	Nil	Trace	Nil	0.15	Trace	Trace	8.30	
437	7	25 to 30	10.20	58.66	6.57	13.29	0.87	Nil	Trace	Nil	0.11	Trace	Trace	10.30	
438	8	30 to 35	13.80	53.78	4.02	15.62	0.36	Nil	Trace	0.007	0.13	Trace	0.29	12.00	
439	9	35 to 40	13.00	57.41	3.90	15.87	0.36	Nil	Trace	0.014	0.13	Trace	0.22	9.10	
440	10	40 to 45	10.00	62.19	6.18	12.84	0.50	Nil	Trace	Trace	0.065	Trace	0.22	8.00	
441	11	45 to 49	11.20	64.16	6.30	8.67	1.08	Nil	Trace	Trace	0.065	Trace	0.22	8.30	

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BORE No.8

Reg. No.	No. of sample	Sectional Depth in ft. of sample	SiO_2	FeO Fe_2O_3	Cr_2O_3	Al_2O_3	MgO	CaO	TiO_2	P_2O_5	S	NiO	MnO & MnO_2	H_2O etc.	Nature of Material
679	1	1 to 6	15.60	63.49	3.84	2.94	0.20	Nil	0.40	Trace	0.13	Nil	Nil	13.40	
680	2	0 to 3	19.00	61.10	3.12	3.10	0.36	Nil	0.4	Trace	0.08	Nil	Nil	13.20	
681	3	3 to 10	16.00	62.63	2.49	2.01	Trace	Nil	0.40	Trace	0.17	Nil	Nil	16.30	
682	4	10 to 15	11.20	61.41	5.28	6.55	0.36	Nil	0.20	Trace	0.20	Nil	Nil	14.80	
683	5	15 to 20	12.20	62.48	5.73	7.97	1.50	Nil	Trace	Nil	0.15	0.07	Nil	9.90	
684	6	20 to 25	12.60	61.90	6.70	9.29	1.15	Nil	Trace	Trace	0.14	0.06	Nil	8.16	
685	7	25 to 30	15.08	59.07	6.18	9.67	1.15	Nil	Nil	Trace	0.13	0.12	Nil	8.60	
686	8	30 to 35	18.80	45.98	6.36	17.46	1.15	Nil	Nil	Nil	0.15	Trace	Trace	10.10	
687	9	35 to 40	32.00	22.32	3.00	27.77	0.36	Nil	0.30	Nil	0.05	Nil	Nil	14.50	
688	10	40 to 45	12.40	62.41	5.82	7.95	0.36	Nil	Trace	Nil	0.034	0.17	2.32	8.90	
689	11	45 to 50	4.20	83.43	5.61	1.53	0.36	Nil	Trace	Nil	0.034	0.11	1.83	2.90	
690	12	50 to 55	10.20	68.15	5.65	7.96	0.36	Nil	0.2	Nil	0.034	0.10	1.05	6.30	
691	13	55 to 60.6	9.20	61.71	6.63	7.83	0.21	Nil	Trace	Nil	0.065	0.58	4.38	9.40	

BORE No.9

692	1	0 to 12	9.00	60.40	5.12	10.44	0.21	Nil	0.20	Nil	0.13	Nil	Trace	14.50	
693	2	12 to 17	7.00	60.30	4.98		0.21	Nil	Trace	Nil	0.13	Nil	Trace	14.70	
694	3	17 to 22	6.60	79.03	4.50	1.16	0.21	Nil	Trace	Nil	0.10	Nil	Trace	8.40	
695	4	22 to 27	6.00	79.68	5.16	0.80		Nil	Trace	Trace	0.065	Nil	0.22	7.50	
696	5	27 to 30	7.00	71.89	5.08	7.96	0.58	Nil	Trace	0.007	0.065	Nil	0.22	7.20	
697	6	30 to 35	16.80	61.01	4.23	5.92	2.50	Nil	0.20	0.018	0.02	0.31	1.00	8.00	
698	7	35 to 40	13.20	70.34	3.78	2.07	1.45	Nil	Trace	Trace	0.032	0.33	1.00	7.80	
599	8	40 to 45	26.00	51.04	3.75	4.01	2.90	Nil	Trace	Trace	Trace	0.70	Trace	11.60	

BORE No.10

700	1	0 to 3	18.40	54.26	3.78	16.02	0.22	Nil	Trace	Nil	0.027	Trace	Trace	7.30	
701	2	3 to 10	17.60	55.31	4.08	13.33	0.22	Nil	0.20	Nil	0.065	Trace	Trace	9.20	
702	3	10 to 25	12.80	52.37	4.20	20.46	0.22	Nil	0.60	Nil	0.050	Trace	Trace	9.30	

BORE No.11

878	1	0 to 10	11.00	71.38	3.33	6.47	0.22	Nil	Trace	Trace	0.02	0.10	Trace	7.50	
879	2	10 to 20	10.00	75.43	3.45	5.33	0.22	Nil	Trace	Trace	0.02	0.15	Trace	5.40	
880	3	20 to 30	20.00	64.32	3.42	1.26	2.20	Nil	Trace	Trace	0.02	0.80	Trace	7.80	

BORE No.12

Reg. No.	No. of sample	Sectional depth in ft. of sample	SiO_2	FeO Fe_2O_3	Cr_2O_3	Al_2O_3	MgO	CaO	TiO_2	P_2O_5	S	NiO	MnO & MnO_2	H_2O etc.	Nature of Material
881	1	0 to 10	22.40	61.07	3.90	1.69	0.22	Nil	Trace	Trace	0.02	0.10	Trace	10.60	

BORE No.13

882	1	0 to 12	27.80	32.94	2.95	22.52	0.72	Nil	1.70	0.015	0.12	0.04	Nil	11.70	
883	2	12 to 24'2½"	18.60	47.14	3.36	18.15	0.80	Nil	0.80	0.018	0.17	0.03	Nil	10.94	
884		24 to 35	25.00	44.88	5.19	14.90	1.40	Nil	Trace	Trace	0.13	0.10	0.30	8.10	

MT. SCOTT AREA. - BORE No.1

885	1	0 to 13	13.00	59.07	9.84	8.91	1.40	Nil	Trace	Trace	0.12	0.05	0.21	7.40	
886	2	12 to 20	12.60	58.28	7.20	13.63	0.36	Nil	Trace	Nil	0.089	Nil	0.15	7.80	
887	3	20 to 30	5.20	68.99	6.69	12.35	0.36	Nil	Trace	Nil	0.065	Trace	0.15	6.20	
888	4	30 to 40	10.00	76.83	4.20	1.65	0.36	Nil	Trace	Nil	0.089	0.03	0.15	6.70	
889	5	40 to 45	23.60	48.83	2.67	10.83	1.59	Nil	Trace	Nil	0.065	0.32	0.30	11.80	
890	6	45 to 50	16.60	54.58	3.03	15.45	0.36	Nil	Trace	Nil	0.13	0.05	Trace	9.80	

MT. SCOTT AREA - BORE No.2

891	1	0 to 15	39.00	25.78	2.52	23.20	0.57	Nil	0.20	Nil	0.13	Trace	Nil	8.60	
892	2	15 to 30	19.40	52.57	4.32	16.24	0.32	Nil	Trace	Nil	0.15	Trace	Nil	7.00	
893	3	34 to 40	8.56	61.58	9.06	13.06	0.36	Nil	Trace	Nil	0.18	Trace	Nil	7.20	
894	4	40 to 50	10.20	59.94	8.31	13.33	0.22	Nil	Trace	Trace	0.19	Trace	Nil	7.80	
895	5	50 to 60	27.60	44.75	3.09	13.09	0.22	Nil	0.40	Trace	0.15	Trace	Nil	10.70	

TABLE I OF ANALYSES

MT. VULCAN CHROME IRON ORE

Reg. No.	No. of Sample	Sectional depth in ft. of sample.	SiO_2	Fe_2O_3	FeO	Cr_2O_3	Al_2O_3	MgO	CaO	TiO_2	P_2O_5	S	NiO	MnO & MnO_2	H_2O etc.
		Line A - Bore No.1													
329	1	0 to 10	14.40	49.50	1.55	3.58	18.27	0.72	Nil	0.80	0.037	0.027	Trace	0.12	11.00
330	2	10 to 15	17.20	46.90	0.76	3.53	17.89	0.72	"	1.00	0.037	0.027	"	0.24	11.7
331	3	15 to 27	24.00	42.60	0.76	4.23	13.63	2.32	"	0.20	0.037	0.096	0.34	1.29	10.5
332	5	34 to 40	25.00	37.50	1.03	1.88	18.53	1.80	"	0.60	0.037	0.068	0.18	0.98	12.40
		Line A - Bore No.2													
333	1	0.to 10	12.52	64.18	Nil	4.98	7.15	0.86	Nil	Trace	0.01	0.10	Nil	Nil	10.20
334	2	10 to 15	10.40	70.14	"	6.52	5.16	1.44	"	"	0.005	0.08	Trace	"	6.26
335	3	15 to 20	9.60	66.12	"	11.78	4.91	0.94	"	"	0.004	0.09	"	0.76	5.80
336	4	20 to 25	9.40	68.44	"	10.26	4.21	1.01	"	"	Nil	0.08	0.10	Nil	6.50
337	5	25 to 30	19.60	51.05	2.70	2.12	12.46	2.53	"	Nil	Trace	Trace	0.59	0.75	8.20
338	6	30 to 35	15.00	52.48	1.29	3.65	14.12	2.53	"	"	0.007	"	0.13	1.00	9.80
		Line A - Bore No.3													
348	1	0 to 12	10.60	61.92	Nil	1.64	14.12	0.86	Nil	0.20	Trace	0.07	Nil	0.29	10.30
349	2	12 to 17	11.60	67.59	"	3.15	8.39	1.08	"	Nil	0.002	0.05	0.15	0.59	7.40
350	3	17 to 22	17.00	63.04	"	9.40	1.62	1.16	"	"	Trace	0.04	0.54	1.00	6.20
351	4	22 to 27	9.20	73.28	"	7.40	1.60	1.88	"	"	"	0.03	0.35	1.10	5.16
		Line A - Bore No.4													
352	1	0.to 12	3.40	72.00	3.00	9.64	4.03	1.38	Nil	Nil	0.018	0.034	Trace	1.40	5.10
353	2	12 to 17	3.20	74.30	3.00	16.00	-	1.73	Nil	Nil	0.003	Trace	0.25	1.75	1.20
354	3	17 to 22	7.60	65.60	10.20	11.88	-	2.18	Nil	Nil	0.003	0.027	0.29	1.05	2.40
355	4	22 to 26	5.20	63.51	13.44	7.05	3.58	1.81	Nil	Nil	0.005	0.09	0.37	1.05	3.90

Bore No.5

Reg. No.	No. of Sample	Sectional depth in ft. of sample	SiO_2	Fe_2O_3	FeO	Cr_2O_3	Al_2O_3	MgO	CaO	TiO_2	P_2O_5	S	NiO	MnO & MnO_2	H_2O etc.
358	2	12 to 17	3.0	79.52	Nil	13.66	-	1.16	Nil	Nil	0.005	0.13	Trace	Nil	2.60
359	3	17 to 22	5.36	77.24	"	6.06	0.92	0.94	"	"	0.003	0.05	0.29	3.84	5.30
360	4	22 to 27	2.60	85.00	"	7.34	-	0.64	"	"	Trace	0.055	0.22	1.62	2.54
361	5	27 to 30	5.68	76.12	"	8.70	0.62	0.72	"	"	0.005	0.11	0.23	1.18	6.64

Bore No.6

423	1	- to 12	5.00	63.49	1.55	4.65	14.59	Trace	Nil	Nil	Nil	0.12	Trace	Nil	10.60
424	2	12 to 17	3.20	59.78	3.61	2.13	20.67	"	"	"	"	0.11	Nil	Trace	10.50
425	3	17 to 20	3.80	51.33	2.32	3.00	26.54	"	"	"	"	0.11	"	Nil	12.90
426	4	20 to 25	6.00	55.30	4.00	3.60	19.70	0.72	"	"	"	0.027	0.07	0.29	10.30
427	5	25 to 30	9.80	52.73	4.41	7.48	14.93	0.72	"	"	"	0.013	0.04	0.58	9.30
428	6	30 to 35	6.80	66.35	5.16	5.78	8.89	0.72	"	"	"	0.013	0.12	0.87	5.30
429	7	35 to 40	6.20	64.63	4.77	6.24	9.88	0.50	"	"	"	0.013	0.17	1.30	6.30
430	8	40 to 45	9.00	78.70	4.38	5.16	12.63	0.50	"	"	"	0.068	Nil	0.87	8.60

Bore No.7

432	2	- to 5	17.80	51.30	3.48	3.45	12.66	0.25	Nil	Nil	Nil	0.068	Nil	Trace	11.00
433	3	5 to 10	9.60	61.35	2.58	6.06	10.01	0.20	Nil	Nil	Nil	0.20	Nil	"	10.00
434	4	10.to 15	5.40	68.93	2.83	4.75	6.58	Trace	Nil	Nil	Nil	0.23	Trace	Trace	11.30
435	5	15 to 20	7.20	60.48	2.83	4.56	14.26	0.14	Nil	Trace	Nil	0.23	Trace	Trace	10.30
436	6	20 to 25	2.60	70.18	3.10	5.19	10.20	0.28	"	"	"	0.15	"	"	8.30
437	7	25.to 30	10.20	57.11	1.55	6.57	13.29	0.87	"	"	"	0.11	"	"	10.30
438	8	30 to 35	13.80	53.78	Nil	4.02	15.62	0.36	"	"	0.007	0.13	"	0.29	12.00
439	9	35 to 40	13.00	57.41	"	3.90	15.87	0.36	"	"	0.014	0.13	"	0.22	9.10
440	10	40.to 45	10.00	62.19	"	6.18	12.84	0.50	"	"	Trace	0.065	"	0.22	8.00
441	11	45 to 49	11.20	64.16	"	6.30	8.67	1.08	"	"	"	0.065	"	0.22	8.30

BORE No.8

Reg. No.	No. of Sample	Sectional Depth in ft. of Sample	SiO_2	Fe_2O_3	FeO	Cr_2O_3	Al_2O_3	MgO	CaO	TiO_2	P_2O_5	S	NiO	MnO & MnO_2	H_2O etc.
680	2	0 to 3	19.00	58.27	2.83	3.12	3.10	0.36	Nil	0.4	Trace	0.08	Nil	Nil	13.20
681	3	3 to 10	16.00	61.60	1.03	2.49	2.01	Trace	Nil	0.40	Trace	0.17	Nil	Nil	16.30
682	4	10 to 15	11.20	59.35	2.06	5.28	6.55	0.36	Nil	0.20	Trace	0.20	Nil	Nil	14.80
683	5	15 to 20	12.20	62.48	Nil	5.73	7.97	1.50	Nil	Trace	Nil	0.15	0.07	Nil	9.90
684	6	20 to 25	12.60	61.90	"	6.70	9.29	1.15	Nil	Trace	Trace	0.14	0.06	Nil	8.16
685	7	25 to 30	15.08	59.07	"	6.18	9.67	1.15	Nil	Nil	Trace	0.13	0.12	Nil	8.60
686	8	30 to 35	18.80	45.98	"	6.36	17.46	1.15	Nil	Nil	Nil	0.15	Trace	Trace	10.10
687	9	35 to 40	32.00	20.00	2.32	3.00	27.77	0.36	Nil	0.30	Nil	0.05	Nil	Nil	14.50
688	10	40 to 45	12.40	58.80	3.61	5.82	7.95	0.36	Nil	Trace	Nil	0.034	0.17	2.32	8.90
689	11	45 to 50	4.20	80.08	3.35	5.61	1.53	0.36	Nil	Trace	Nil	0.034	0.11	1.83	2.90
690	12	50 to 55	10.20	64.80	3.35	5.65	7.96	0.36	Nil	0.2	Nil	0.034	0.10	1.05	6.30
691	13	55 to 60.6	9.20	59.52	2.19	6.63	7.83	0.21	Nil	Trace	Nil	0.065	0.58	4.38	9.40
		BORE No.9													
692	1	0 to 12	9.00	58.60	1.80	5.12	10.44	0.21	Nil	0.20	Nil	0.13	Nil	Trace	14.50
693	2	12 to 17	7.00	58.50	1.80	4.98	2.68	0.21	Nil	Trace	Nil	0.13	Nil	Trace	14.70
694	3	17 to 22	6.60	74.90	4.13	4.50	1.16	0.21	Nil	Trace	Nil	0.10	Nil	Trace	8.40
695	4	22 to 27	6.00	74.00	5.68	5.16	0.80	0.58	Nil	Trace	Trace	0.065	Nil	0.22	7.50
696	5	27 to 30	7.00	67.50	4.39	5.08	7.96	0.58	Nil	Trace	0.007	0.065	Nil	0.22	7.20
697	6	30 to 35	16.80	54.17	6.84	4.23	5.92	2.50	Nil	0.20	0.018	0.02	0.31	1.00	8.00
698	7	35 to 40	13.20	63.37	6.97	3.78	2.07	1.45	Nil	Trace	Trace	0.032	0.33	1.00	7.80
699	8	40 to 45	26.00	46.40	4.64	3.75	4.01	2.90	Nil	Trace	Trace	Trace	0.70	Trace	11.60
		Bore No.10													
700	1	0 to 3	18.40	50.65	3.61	3.78	16.02	0.22	Nil	Trace	Nil	0.027	Trace	Trace	7.30
701	2	3 to 10	17.60	50.23	4.38	4.08	13.33	0.22	Nil	0.20	Nil	0.065	"	"	9.20
702	3	10 to 25	12.80	48.50	3.87	4.20	20.46	0.22	Nil	0.60	Nil	0.050	"	"	9.30
		Bore No.11													
878	1	0 to 10	11.00	66.58	5.80	3.33	6.47	0.22	Nil	Trace	Trace	0.02	0.10	Trace	7.50
879	2	10 to 20	10.00	69.37	6.06	3.45	5.33	0.22	Nil	Trace	Trace	0.02	0.15	Trace	5.40
880	3	20 to 30	20.20	60.20	4.12	3.42	1.26	2.20	Nil	Trace	Trace	0.02	0.80	Trace	7.80

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Reg. No.	No. of Sample	Sectional depth in ft. of sample	SiO_2	Fe_2O_3	FeO	Cr_2O_3	Al_2O_3	MgO	CaO	TiO_2	P_2O_5	S	NiO	MnO & MnO_2	H_2O etc.
881	1	0 to 10	22.40	56.95	4.12	3.90	1.69	0.22	Nil	Trace	Trace	0.02	0.10	Trace	10.60
					Bore No.13										
882	1	0 to 12	27.80	32.94	Nil	2.95	22.515	0.72	Nil	1.20	0.015	0.12	0.04	Nil	11.70
883	2	12 to 24	18.60	47.14	"	3.36	18.15	0.80	"	0.80	0.018	0.17	0.03	Nil	10.94
884	3	24 to 35	25.00	44.88	"	5.19	14.90	1.40	"	Trace	Trace	0.13	0.10	0.30	8.10
		Mt. Scott Area			Bore No. 1										
885	1	0 to 12	13.00	59.07	Nil	9.84	8.91	1.40	Nil	Trace	Trace	0.12	0.05	0.21	7.40
886	2	12 to 20	12.60	55.70	2.58	7.20	13.63	0.36	"	"	Nil	0.089	Nil	0.15	7.80
887	3	20 to 30	5.20	66.41	2.58	6.69	12.35	0.36	"	"	"	0.065	Trace	0.15	6.20
888	4	30 to 40	10.00	74.01	2.82	4.20	1.65	0.36		"	"	0.089	0.03	0.15	6.70
889	5	40 to 45	23.60	44.70	4.13	2.67	10.83	1.59	"	"	"	0.065	0.32	0.30	11.80
890	6	45 to 50	16.60	51.20	3.38	3.03	15.45	0.36	"	"	"	0.13	0.05	Trace	9.80
		Mt. Scott Area			Bore No. 2										
891	1	0 to 15	39.00	22.40	3.38	2.52	23.20	0.57	Nil	0.20	Nil	0.13	Trace	Nil	8.60
892	2	15 to 30	19.40	40.19	3.38	4.32	16.24	0.32	"	Trace	"	0.15	"	"	7.00
893	3	30 to 40	8.56	57.20	4.38	9.06	13.06	0.36	"	"	"	0.18	"	"	7.20
894	4	40 to 50	10.20	56.56	3.38	8.31	13.33	0.22	"	"	Trace	0.19	"	"	7.80
895	5	50 to 60	27.60	41.37	3.38	3.09	13.09	0.22	"	0.40	"	0.15	"	"	10.70

TABLE OF ANALYSES

BARNES HILL CHROME IRON ORES

Bore No. 1

Reg. No.	No. of Samples	Sectional Depth in ft. of samples	SiO_2	Fe_2O_3	FeO	C_2O_3	Al_2O_3	MgO	CaO	TiO_2	P_2O_5	S	NiO	MnO & MnO_2	H_2O etc.
1300	1	Surface to 10	4.00	62.92	4.65	6.00	10.47	0.30	Nil	Nil	0.03	0.13	Trace	Nil	11.50
1301	2	10 to 19	4.00	61.63	4.13	6.42	9.95	0.79	"	"	0.017	0.13	0.04	"	12.90
						Bore No. 2									
1302	1	Surface to 10	17.96	40.61	6.19	5.19	18.37	0.65	"	"	0.034	0.10	Nil	"	10.9
1303	2	10 to 20	6.60	54.05	5.67	7.68	13.03	0.72	"	"	0.053	0.20	"	"	12.00
1304	3	25 to 30	7.40	62.62	1.90	5.97	11.04	0.21	"	Trace	Trace	0.068	Trace	"	10.80
1305	4	30 to 38	5.00	69.78	3.09	6.15	8.30	0.21	"	"	0.017	0.062	0.10	"	8.30
						Bore No. 3									
1332	1	0 to 10	31.40	36.30	2.58	5.07	13.78	0.14	"	0.40	Trace	0.20	Nil	"	10.10
1333	2	10 to 20	15.92	54.12	2.20	7.60	11.63	1.08	"	0.48	Trace	0.11	"	"	6.86
1334	3	20 to 30	11.12	56.58	1.36	9.64	12.57	1.30	"	0.66	"	0.062	0.16	Trace	6.50
1335	4	30 to 40	19.00	44.48	2.40	6.72	16.25	0.86	"	0.72	0.015	0.08	0.18	Nil	9.30
1336	5	40 to 50	16.20	45.64	1.80	8.40	18.96	1.10	"	0.48	0.004	0.06	Trace	Trace	7.36
1337	6	50 to 60	19.00	51.33	1.55	9.96	4.17	2.03	"	Trace	Trace	0.08	0.38	1.70	9.80
1338	7	60 to 70	29.20	40.30	1.80	6.99	5.66	2.03	"	"	"	0.032	0.66	1.93	11.40

Bore No. 4

Reg. No.	No. of Sample	Sectional depth in ft. of samples	SiO_2	Fe_2O_3	FeO	Cr_2O_3	Al_2O_3	MgO	CaO	TiO_2	P_2O_5	S	NiO	MnO & MnO_2	H_2O etc.
1362	1	Surface to 7	17.80	49.93	1.55	6.45	10.06	0.72	Nil	0.20	0.062	0.13	Nil	Nil	13.10
1363	2	7 to 17	18.00	52.19	2.15	8.73	6.53	0.72	"	0.15	Trace	0.13	"	"	11.00
1364	3	17 to 26	16.12	39.52	1.78	9.60	19.53	0.64	"	0.84	Nil	0.13	0.04	"	11.80
1365	4	26 to 35	8.28	54.78	1.78	12.09	15.04	0.86	"	Nil	"	0.10	0.14	0.37	6.56
1366	5	35 to 40	21.32	42.78	2.20	8.56	13.27	0.94	"	0.24	"	0.09	0.48	0.92	9.20
									"						
						Bore No.5									
1437	1	Surface to 7	28.52	35.64	1.80	6.39	15.87	1.16	Nil	1.08	0.01	0.07	Nil	Nil	9.46
1438	2	7 to 17	7.56	73.54	2.82	5.13	5.93	0.58	"	0.54	0.03	0.07	"	"	3.80
1439	3	17 to 27	14.46	57.42	2.30	6.84	8.42	0.78	"	0.84	Trace	0.18	Trace	"	8.76
1440	4	27 to 37	14.80	56.41	2.05	7.27	10.40	1.44	"	0.90	0.016	0.12	Nil	Trace	6.60
1441	5	37 to 47	13.80	51.36	1.80	7.99	10.51	2.38	"	0.72	0.008	0.15	0.11	"	11.18
1442	6	47 to 57	10.68	57.52	1.54	10.83	9.63	1.52	"	0.48	Nil	0.12	0.12	"	7.56
1443	7	57 to 60	5.40	71.20	2.30	9.03	4.95	1.66	"	Nil	"	0.06	0.19	0.41	4.80
						Bore No.6									
1445	1	Surface to 10	29.08	26.23	2.05	2.79	24.09	0.58	Nil	1.50	0.034	0.15	Nil	Nil	13.50
1447	2	10 to 20	7.40	61.15	2.05	7.44	7.77	0.72	"	0.72	0.05	0.20	Trace	"	12.50
1448	3	20 to 30	17.00	52.22	1.54	7.58	10.27	0.43	"	1.14	0.04	0.18	"	"	9.60
1449	4	30 to 40	8.60	60.34	1.00	9.93	7.84	0.43	"	0.60	0.078	0.19	"	"	11.00
1450	5	40 to 50	9.40	61.44	1.28	13.14	3.35	2.46	"	0.60	0.046	0.19	"	"	8.10
1451	6	50 to 60	21.12	46.38	1.00	11.30	5.88	2.16	"	1.20	0.047	0.18	"	"	10.74
1452	7	60 to 70	18.20	42.98	1.80	8.13	15.11	0.94	"	0.96	0.03	0.14	0.12	0.29	11.30
1453	8	70 to 76	16.88	43.86	1.80	5.07	17.47	0.94	"	0.96	0.03	0.13	0.13	0.29	12.34

TABLE OF ANALYSES

BARNES HILL CHROME IRON ORES

BORE No. 1

Reg. No.	No. of Sample	Sectional depth in feet of samples	SiO_2	FeO & Fe_2O_3	C_2O_3	Al_2O_3	MgO	CaO	TiO_2	P_2O_5	S	NiO	MnO & MnO_2	H_2O etc.
1300	1	Surface to 10	4.00	67.57	6.00	10.47	0.30	Nil	Nil	0.03	0.13	Trace	Nil	11.50
1301	2	10 to 19	4.00	65.76	6.42	9.95	0.79	"	"	0.017	0.13	0.04	"	12.90
						BORE No. 2								
1302	1	Surface to 10	17.96	46.80	5.19	18.37	0.65	Nil	Nil	0.034	0.10	Nil	Nil	10.9
1303	2	10 to 20	6.60	59.72	7.68	13.03	0.72	"	"	0.053	0.20	"	"	12.00
1304	3	25 " 30	7.40	64.52	5.97	11.04	0.21	"	Trace	Trace	0.068	Trace	"	10.80
1305	4	30 " 38	5.00	72.87	6.15	8.30	0.21	"	"	0.017	0.062	0.10	"	8.30
						BORE No. 3								
1332	1	0 to 10	31.40	38.88	5.07	13.78	0.14	Nil	0.40	Trace	0.20	Nil	Nil	10.10
1333	2	10 " 20	15.92	56.32	7.60	11.63	1.08	"	0.48	Trace	0.11	"	"	6.86
1334	3	20 " 30	11.12	57.94	9.64	12.57	1.30	"	0.66	"	0.062	0.16	Trace	6.50
1335	4	30 " 40	19,00	46.88	6.72	16.25	0.86	"	0.72	0.015	0.08	0.18	Nil	9.30
1336	5	40 " 50	16.20	47.44	8.40	18.96	1.10	"	0.48	0.004	0.06	Trace	Trace	7.36
1337	6	50 " 60	19.00	52.88	9.96	4.17	2.03	"	Trace	Trace	0.08	0.38	1.70	9.80
1338	7	60 " 70	29.20	42.10	6.99	5.66	2.03	"	"	"	0.032	0.66	1.93	11.40

CONTINUED ON PAGE NO. 4.

BORE NO. 4.

Reg. No.	No. of sample	Sectional depth in feet of samples.	SiO_2	FeO & Fe_2O_3	C_2O_3	Al_2O_3	MgO	CaO	TiO_2	P_2O_5	S	NiO	MnO & MnO_2	H_2O etc.	Nature of Material.
1362	1	Surface to 7	17.80	51.48	6.45	10.06	0.72	NIL	0.20	0.062	0.13	NIL	NIL	13.10	
1363	2	7 " 17	18.00	54.34	8.73	6.53	0.72	"	0.15	TRACE	0.13	"	"	11.00	
1364	3	17 " 26	16.12	41.30	9.60	19.53	0.64	"	0.84	NIL	0.13	0.04	"	11.80	
1365	4	26 " 35	8.28	56.56	12.09	15.04	0.86	"	NIL	"	0.10	0.14	0.37	6.56	
1366	5	35 " 40	21.32	44.98	8.56	13.27	0.94	"	0.24	"	0.09	0.48	0.92	9.20	
							BORE NO. 5.								
1437	1	Surface to 7	28.52	37.44	6.39	15.87	1.16	NIL	1.08	0.01	0.07	NIL	NIL	9.46	
1438	2	7 " 17	7.56	76.36	5.13	5.93	0.58	"	0.54	0.03	0.07	"	"	3.80	
1439	3	17 " 27	14.46	59.72	6.84	8.42	0.78	"	0.84	TRACE	0.18	TRACE	"	8.76	
1440	4	27 " 37	14.80	58.46	7.27	10.40	1.44	"	0.90	0.016	0.12	NIL	TRACE	6.60	
1441	5	37 " 47	13.80	53.16	7.99	10.51	2.38	"	0.72	0.008	0.15	0.11	"	11.18	
1442	6	47 " 57	10.68	59.06	10.83	9.63	1.52	"	0.48	NIL	0.12	0.12	"	7.56	
1443	7	57 " 60	5.40	73.50	9.03	4.95	1.66	"	NIL	"	0.06	0.19	0.41	4.80	
							BORE NO. 6.								
1445	1	Surface to 10	29.08	28.28	2.79	24.09	0.58	NIL	1.50	0.034	0.15	NIL	NIL	13.50	
1447	2	10 " 20	7.40	68.20	7.44	7.77	0.72	"	0.72	0.05	0.20	TRACE	"	12.50	
1448	3	20 " 30	17.00	53.76	7.58	10.27	0.43	"	1.14	0.04	0.18	"	"	9.60	
1449	4	30 " 40	8.60	61.34	9.93	7.84	0.43	"	0.60	0.078	0.19	"	"	11.00	
1450	5	40 " 50	9.40	62.72	13.14	3.35	2.46	"	0.60	0.046	0.19	"	"	8.10	
1451	6	50 " 60	21.12	47.38	11.30	5.88	2.16	"	1.20	0.047	0.18	"	"	10.74	
1452	7	60 " 70	18.20	44.78	8.13	15.11	0.94	"	0.96	0.03	0.14	0.12	0.29	11.30	
1453	8	70 " 76	16.88	45.66	5.07	17.47	0.94	"	0.96	0.03	0.13	0.13	0.29	12.34	