1959

WESTERN AUSTRALIA

GEOLOGICAL SURVEY

MINERAL RESOURCES OF WESTERN AUSTRALIA

BULLETIN No. 7

IRON ORES IN WESTERN AUSTRALIA

COLLATED BY

R. R. CONNOLLY

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

Issued under the authority of the Hon. A. F. Griffith, Minister for Mines.

By Authority: ALEX. B. DAVIES, Government Printer,
1959

28227/8/59—750

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PREFATORY NOTE

This Mineral Resources Bulletin gives an account of the Geological Survey's present knowledge of the Iron Ore Resources of the State as at June, 1959.

The deposits at Koolan Island and Cockatoo Island situated close to the Mainland some 80 miles north of Derby in the north-western part of the State, and owned by The Broken Hill Proprietary Limited Company, are the only two deposits on which sufficient exploratory work has been done to enable reliable estimates of tonnage and grade of ore to be made.

Some exploration by diamond drilling has been done on the deposits at Tallering Range and Koolyanobbing, but the nature and extent of this work is totally inadequate for the purposes of assessing the grades and quantities of ore of varying types available from these deposits.

With the exception of the Cockatoo and Koolan Islands deposits, which are of a younger geological age and continue in depth as hematite deposits, available information proves that mainland hematite and limonite deposits which are associated with Banded Iron Formations (jaspilites or ferruginous quartzites) change in depth below the surface to magnetite at Tallering Range and Koolyanobbing, and will certainly do so in all the other deposits described in this Bulletin as being associated with Banded Iron Formations.

The assumptions made by the authors in arriving at ore-reserve estimates and grades, are clearly stated in the text, and should be heeded by anyone quoting this publication as an authority. The whole of such data as it applies to Mainland deposits is of a reconnaissance nature and is of value as a *guide to surface dimensions and surface grades only*. Until each deposit is adequately explored in both its oxidized and unoxidized portions. no reliable estimates of quantity and quality of the iron ore available in Western Australia can be made.

It can be safely accepted that there are hundred of millions of tons of limonite-hematite-magnetite ore with a 20 to 30 per cent. metallic iron content associated with the Banded Iron Formations in the western half of the State southwards from Port Hedland.

It can be also confidently stated that some of the Mainland deposits would be found to be capable of providing high grade limonite-hematite iron ore in quantities commensurable with the needs of a steel industry if they were adequately tested.

As at June, 1959, all desposits of iron-ore on the Mainland of Western Australia are reserved to the Crown, and consequently no deposit is available for pegging as a mining tenement under the Mining Act.

Reserves.

The deposits described in this Bulletin and on which qualified ore reserve estimates have been made along the lines mentioned above and in the text, give an inferred reserve as follows :—

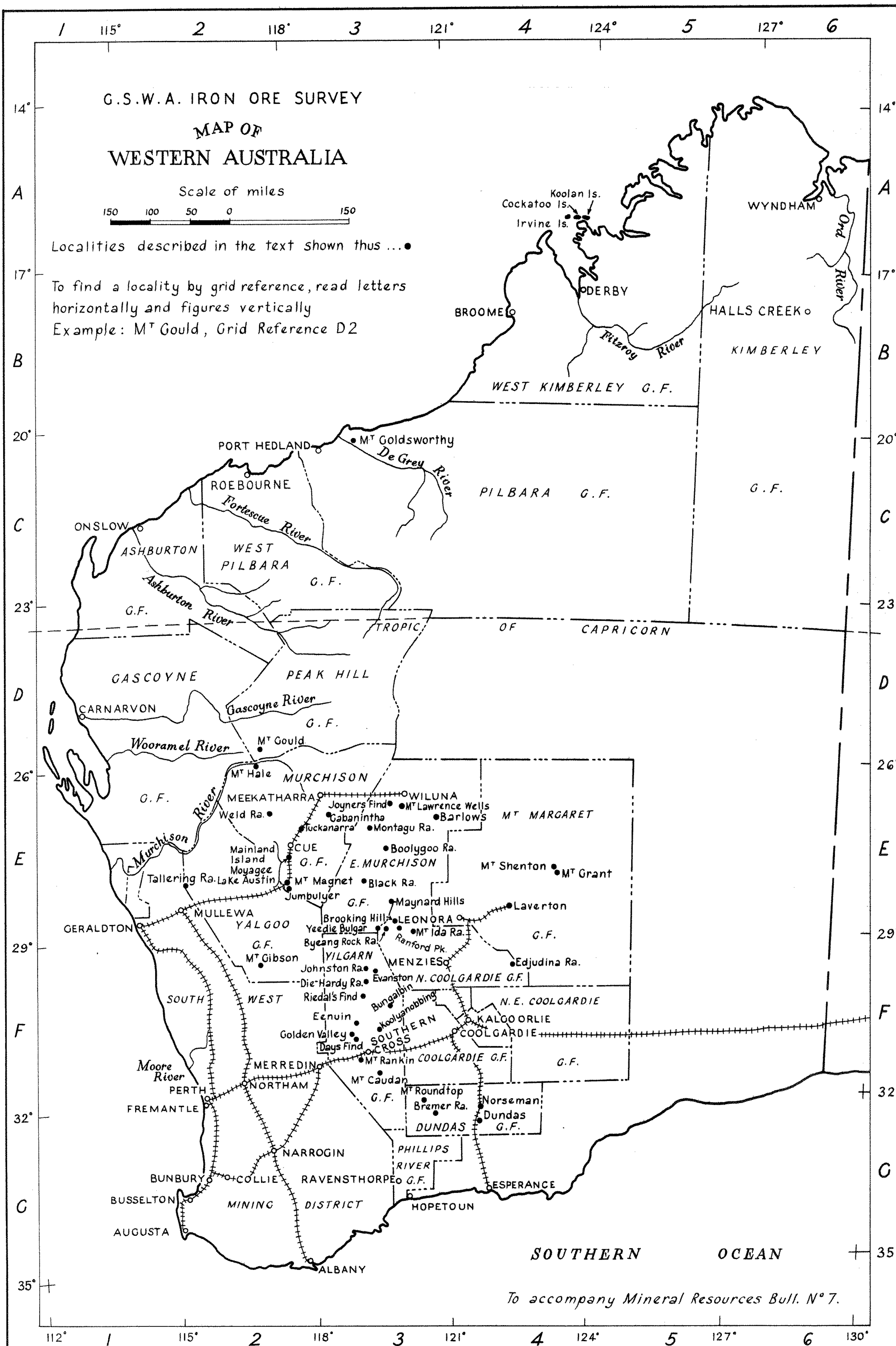
HIGH GRADE ORE (above plain level), 60%+ Metallic Iron: 275,000,000 long tons.

LOW GRADE ORE (above plain level), 30-45% Metallic Iron: 223,000,000 long tons.

LOW GRADE ORE, under 30% Metallic Iron: Probably many hundreds of millions of tons.

H. A. ELLIS,
Government Geologist.

4th June, 1959.



G.S.W.A. IRON ORE SURVEY
MAP OF
WESTERN AUSTRALIA
Scale of miles
150 100 50 0 150
Localities described in the text shown thus ...●
To find a locality by grid reference, read letters horizontally and figures vertically
Example: Mt Gould, Grid Reference D2
Koolan Is.
Cockatoo Is.
Irvine Is.
WYNDHAM
Ord River
DERBY
BROOME
HALLS CREEK
Fitzroy River
KIMBERLEY
WEST KIMBERLEY G.F.
PORT HEDLAND
Mt Goldsworthy
De Grey River
PILBARA G.F.
G.F.
ROEBOURNE
Fortescue River
ONSLOW
ASHBURTON
WEST PILBARA
G.F.
Ashburton River
G.F.
TROPIC OF CAPRICORN
GASCOYNE
PEAK HILL
CARNARVON
Gascoyne River
G.F.
Wooramel River
Mt Gould
Mt Hale
MURCHISON
G.F.
MEEKATHARRA
WILUNA
Joyners Find
Mt Lawrence Wells
Weld Ra.
Gabanintha
Barlows
Mt MARGARET
Tuckanarra
Montagu Ra.
Murchison River
CUE
Boolygoo Ra.
Mainland Island
Moyagee
G.F.
E. MURCHISON
Mt Shenton
Mt Grant
Lake Austin
Tallering Ra.
Mt Magnet
Black Ra.
Jumbulyer
Maynard Hills
G.F.
Laverton
MULLEWA
Brooking Hill
LEONORA
GERALDTON
YALGOO
Yeedie Bulgar
Mt Ida Ra.
G.F.
Byeang Rock Ra.
Ranford Pk.
G.F.
YILGARN
Mt Gibson
MENZIES
Edjudina Ra.
Johnston Ra.
Die-Hardy Ra.
Evanston
N. COOLGARDIE G.F.
Riedal's Find
Bungalbin
N.E. COOLGARDIE
SOUTH
WEST
Koolyanobbing
Eenuin
SOUTHERN
KALGOORLIE
Golden Valley
CROSS
COOLGARDIE
Days Find
Moore River
MERREDIN
Mt Rankin
COOLGARDIE G.F.
G.F.
PERTH
NORTHAM
Mt Caudan
Mt Roundtop
G.F.
FREMANTLE
Bremer Ra.
Norseman
Dundas
DUNDAS
G.F.
NARROGIN
PHILLIPS RIVER G.F.
BUNBURY
COLLIE
RAVENSTHORPE
ESPERANCE
BUSSELTON
MINING DISTRICT
HOPETOUN
AUGUSTA
SOUTHERN OCEAN
ALBANY
To accompany Mineral Resources Bull. No 7.

CONTENTS

MAPS

CHAPTER I

GENERAL INFORMATION

INTRODUCTION

Iron, as the major constituent of steel, ranks as one of the most essential elements to our modern civilization, and in fact, a country's production of iron and steel is often used as a measure of its living standards. This most useful element is the fourth most abundant in the earth's crust, but only a small proportion of the total occurs in a sufficiently concentrated form to be available to man, the greater part being widely disseminated and locked in chemical combination with other elements in many rock forming minerals. Western Australia is liberally endowed with iron rich deposits, one of which at Yampi Sound, is among the world's best. However, of the many iron rich deposits which will be described later in this Bulletin, only two, viz. Koolan Island and Cockatoo Island can be said to constitute iron ORE in the strict definition of the term which is as follows: "Ore is that part of a geologic body from which the metal(s) that it contains may be extracted profitably."[1] The profit need not necessarily be a monetary gain but may be the broader benefit of satisfaction of a national need to produce the metal or to encourage industries dependant on that production. Nevertheless, for a deposit to be termed an ore it must be capable of being mined and if necessary transported to a point where the metal can be extracted and disposed of gainfully. At the present time in Western Australia, only the two deposits previously mentioned have been proved to be ORE as correctly defined. All other deposits lack the exhaustive examination of mining costs, transport costs and marketability necessary to prove them as ORE.

However, for convenience throughout the remainder of this bulletin all of the iron rich bodies as delineated shall be referred to as iron ore bodies.

[1]1948 McKINSTRY, H. E.: Mining Geology, p. 461, New York.

PURPOSE OF THE SURVEY

The need to know the iron resources of the State must be apparent in view of the importance of the metal and has always been recognized. However, until the present survey, as instigated by the Government Geologist (H. A. Ellis) in 1955, no State wide assessment had been completed. The Commonwealth Government in 1938, following the placing of an export embargo on iron ores, commenced such a survey with the co-operation of the State Geological Survey as part of a commonwealth wide assessment of iron ore reserves. However, after the detailed examination of the Koolan Island deposits and the contouring and surface mapping of the Koolyanobbing deposits had been completed, the project lapsed for reasons of commonwealth political expediency. The report on the investigation of the Koolan Island deposits compiled by Moss and Forman was confidential to Australian Iron and Steel Limited, and never published. That on the Koolyanobbing investigation was published by the Geological Survey.[2]

Simultaneously, as part of the Aerial, Geological and Geophysical Survey of Northern Australia, the iron deposits of Yampi Sound, Ellarine Hills and Andover were mapped and sampled, and reports published.[3], [4]

Prior to these immediate pre-war investigations, many of the individual iron deposits throughout the State had been noted, and in some cases mapped and specimens analysed. The most notable of these was an early survey of the trigonometrical station deposit at Koolyanobbing by H. W. B. Talbot, reported on by Gibb Maitland.[5]

Post war work on iron deposits prior to the commencement of the present survey consists essentially of measurement and sampling of such deposits as occur within the area covered by Bulletin No. 106[6] and a drilling programme at Koolyanobbing[7] which, although primarily designed to explore for pyritic ore bodies, yielded in addition information on the behaviour of jaspilitic iron ores in depth.

It can be seen therefore, that while a considerable amount of work has been done on the obviously high grade deposits, no previous attempt had been made to assess the resources of iron on a State wide basis.

The purpose of the present survey was therefore to gain a comprehensive appreciation of the iron ore potential of the State by examination, sampling and measurement of all known occurrences with the exception of those deposits which had already been authoratively reported on.

Accordingly, all available literature on reputed iron occurrences in the State was searched and examination of the localities thus found commenced in August, 1955, and continued, with some interruptions due to other commitments, until April, 1958.

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[2]1946 HOBSON, R. A.: Koolyanobbing (Trig. Station MY1) Iron Ore Deposits, Summary Report. *G.S.W.A. Ann. Prog. Rep.* 1945, pp. 10–12.

[3]1941 FINUCANE, K. J.: The Iron Deposits of Yampi Sound, Western Australia. *A.G. and G.S.N.A. Report, W.A., No.* 50.

[4]1941 FINUCANE, K. J. and TELFORD, R. J.: The Ellarine Hills and Andover Iron Deposits. *A.G. and G.S.N.A. Report, W.A., No.* 56.

[5]1919 MAITLAND, A. G.: The Iron Deposits of Western Australia. *G.S.W.A. Mining Handbook.* Memoir No. 1, Chapter II, Part III, Section 5, p. 9.

[6]1950 JOHNSON, W.: A Geological Reconnaissance Survey of Part of the Area Included between the Limits Lat. 24° 0′ S. and Lat. 29° 0′ S. and between Long. 115° 30′ E. and Long. 118° 30′ E. *G.S.W.A. Bull.* 106, pp. 82–89.

[7]ELLIS, H. A.: The Exploratory Drilling of the Koolyanobbing Iron Ore Deposits for Pyrite. *G.S.W.A. Bull.* 111.

ACKNOWLEDGMENTS

For various administrative reasons, the field work for and the compilation of this Bulletin have been entrusted to several officers, namely K. Berliat, D.Sc., J. Sofoulis, B.Sc., and R. R. Connolly. At the inception of the survey, Dr. Berliat compiled the list of localities to be examined and carried out the field work for the majority of these localities, assisted in the field at various times by Mr. Sofoulis and Mr. Connolly. Late in 1957, Mr. Sofoulis conducted a reconnaissance survey in the Bungalbin locality assisted in the field by survey hand—motor driver K. Grimbly. From the beginning of 1958 until the completion of the programme, the field work was carried out by Mr. Connolly assisted by Mr. Grimbly.

Individual reports on the localities examined have been compiled by the officer in charge of the field work at the time, and Chapter II of this Bulletin presents these reports under the authority of the respective investigating officer(s).

Some localities were not examined in the course of this survey and the reports thereon are extracts from previously published reports. In each such case the authority for the information has been clearly shown.

In addition to the field work, Dr. Berliat also compiled much of the information presented in this Chapter I and, although the final preparation of the manuscript has been the responsibility of Mr. Connolly, liberal use was made of notes prepared by Dr. Berliat.

The Government Geologist (Mr. H. A. Ellis), assisted from time to time with advice on field methods, history of past investigations and manner of presentation of the publication.

In the field, all manner of people, too numerous to mention individually, readily gave information concerning tracks, water supplies, etc., in the more remote areas and in so doing considerably assisted the field investigations.

NATURE OF INVESTIGATIONS

As mentioned earlier, a list of all known occurrences of iron ore within the State was initially prepared, the main source of information being Simpson.[8] Some of these localities had already been examined in a more comprehensive manner than was required for the purposes of the present survey, and these localities were not re-examined. The remaining localities on which either no information or insufficient information existed were inspected in the field and, unless the deposit was obviously of no significance by reason of grade or size, the examination was conducted in the following manner:—

Field Methods.

Initially the ore body was outlined by walking the outcrop and fixing the limits by obvious change in grade or topographic prominence.

Wherever possible, outcrop dimensions were measured using a 100 feet linen tape. Heights were measured with an aneroid barometer unless other height information was available (*e.g.*, Trig. station—railway line, etc.). Notes were made on the attitude of the ore body (strike, dip, plunge), access from existing communications and topography.

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[8]1948 SIMPSON, E. S.: Minerals of Western Australia, W.A. Govt. Printer.

Sampling.

The only sampling undertaken was by chip sampling at the surface across the strike of the ore body, this, because of the extremely tough nature of the outcrops, being the only practical method of sampling without the use of rock breaking machinery. Ordinary geological hammers were used, chips of one half to one cubic inch being taken at intervals of one foot or less in a line at right angles to the strike. Where necessary, samples were crushed to one quarter of an inch or less and reduced by quartering to give a final sample of approximately four lb. weight. Sample intervals along the strike were dependant on the size of the ore body, the topographic expression and in some cases accessibility, details of which are given in the reports on the individual deposits.

As the survey progressed, these samples were submitted to the Government Chemical Laboratories for determination of acid soluble iron (on dry basis). In addition, specific gravity determinations and partial analyses for Iron (Fe), Silica (SiO_2), Titanium (Ti), Manganese Oxide (MnO), Sulphur (S) and Phosphorus (P), were made for group samples made up of equal parts by weight of specified individual samples, covering a particular ore body or part thereof. In all, 263 samples were analysed for iron and 51 groups partially analysed for the constituents listed above.

Ore Estimate Calculations.

In assessing the ore reserves of any particular deposit, the procedure has been to calculate the volume of the body in cubic feet and divide by a conversion factor expressed in cubic feet per ton. This conversion factor may vary from one deposit to the next within the range 7 to 12 cubic feet per ton, dependant on grade and physical nature of the ore, but in each individual report the factor used is specified. Unless otherwise stated, the length of the body is as measured, width is true (*i.e.*, horizontal or measured width reduced to allow for the dip) and height is the average height above the level of the surrounding country. This last dimension presupposes that the ore will persist unchanged to the general level of the surrounding country which would be the highest level of the water table in any particular locality. It is generally accepted that the zone of oxidation extends vertically at least to the water table and Ellis[9] has shown that the zone of oxidation in jaspilitic iron ores may extend to a level considerably below that of the water table. Furthermore, in this same work it has been shown that bedded limonitic and hematitic iron ores, where structurally continuous from above to below the zone of oxidation, pass from limonite-hematite to magnetite which behaviour has also been demonstrated in deep goldmining and drilling in jaspilites in other fields. The assumption of continuity in depth of jaspilitic iron ores to the level of the surrounding plain is therefore a reasonable one providing that there is no evidence of structural discontinuity in depth.

Limitations of Methods Used.

In a state wide mineral resources survey of this nature, accuracy of method must be to some extent sacrificed in favour of coverage where the number of potential deposits to be investigated is large. The aim is therefore to provide accuracy

[9]ELLIS, H. A.: The Exploratory Drilling of the Koolyanobbing Iron Ore Deposits for Pyrite. *G.S.W.A. Bull. No.* 111.

within the limits imposed by such factors as availability of time-manpower and equipment. A further examination of the sampling and ore estimate calculation methods will give an apprecia, tion of the reliability of the quantative data presented in Chapter II of the bulletin.

As stated earlier sampling was limited to chips taken across the strike and at the surface. The banded nature of jaspilitic iron ores, in which alternating bands of silica and hematite varying in thickness between one sixteenth and one half of an inch are presented at the surface, leads in some cases to a differential weathering action which results in biscuit like combs of residual silica or hematite projecting above the general surface of the outcrop.

In general it appeared that the minor constituent by volume was the most easily weathered out, so that any sampling done on such a surface would give a false impression of the overall grade. Such weathered parts of the outcrop were therefore avoided where possible and sample lines located where possible to take in mostly fresh, in situ exposures. However, rather than attack a smooth, massive exposed face there was a tendency to break the chip from an angular projection which may have existed as such by virtue of a slight difference in composition from the bulk. However, it is considered that the main cause of angularity in outcrop on this scale is the joint, fracture and bedding plane patterns and the effect of composition difference in determining shape of outcrop is considered negligible.

Another type of weathering appeared to distribute a "skin" or "bloom" of iron oxides of uniform composition over the exposed surface of the rock, and although this "skin" was seen in section to be microscopically thin, an attempt was made to avoid such small scale surface concentrations by trimming off the outside or originally exposed inch of any one chip. A similar process of surface enrichment on a much larger scale is almost inevitably present, but such a condition could not be provided for by any method of surface sampling.

In deposits where the alternating layers of silica and hematite attained individual thicknesses of one eighth of an inch or more, particular care had to be exercised to ensure that the greatest dimension of each chip was across the bedding and not parallel with it. This precaution was generally observed even with very finely banded ores where the diluent effect of accidentally taking an odd number of bands, the extra one in each case being say silica, for each chip, being less. This chance is also minimised by taking a large number of chips per sample.

In a sampling programme at Koolyanobbing[10] using the same method of chip sampling across the strike at the surface, the grade figure arrived at by calculation from analyses of individual samples on ore body "A" was 63·4 per cent. Fe.

The grade of approximately 100,000 tons ore actually quarried from ore body "A" has been 61·76 per cent. Fe, the quarry floor now being some 50 feet below the outcrop level. The same ore body has been penetrated about 800 feet along the strike to the north-west at a vertical depth of 750 feet below the outcrop in D.D.H. No. 12 from site A2[11], and several hundred feet below the level of the water table. Here the grade over the 132 feet true width of iron ore is 53 per cent. Fe, which shows

[10] 1950 HOBSON, R. A.: Koolyanobbing (Trig. Station MY1) Iron Ore Deposits, Summary Report. *G.S.W.A. Ann. Rep.* 1945, p. 10.

[11] ELLIS, H. A. Op. Cit. p. 8.

unmistakably the effect of enrichment towards the surface or impoverishment at depth of ore bodies of this nature. However, the abovementioned results also show that chip sampling at the surface in the manner used in the present survey is capable of accuracy within one per cent. of the true surface grade and is certainly sufficiently accurate for this type of survey, bearing in mind the proven behaviour of weakening grade below the surface. By the same token, analyses for surface samples must be regarded as maxima for iron.

As regards the limitations of the method of calculating the ore quantity figures, the nature of the dimensions used has already been outlined (p. 9) and needs no further elaboration. However, the category in which the reserves thus calculated lie bears further examination.

The United Nations Department of Economic and Social Affairs[12] in its appraisal of world iron ore resources has recommended the use of the term " reserves " to describe quantities of ore which are, or could be mined under present day economic conditions, and the term " potential ore " to material which may be exploited at some future date under more favourable economic conditions. The sum of these two broad categories is regarded as the known " resources " of ore for the area under consideration.

" Reserves " and " potential ores " may be further classified in terms of the reliability of the estimate, the three degrees of reliability most commonly used in regional appraisals being " measured," " indicated " and " inferred " ore.

As the classification of the resources is dependant on these terms it is worth while to present the full definition of each which is as follows :[13]

> *Measured Ore* is ore for which tonnage is computed from dimensions revealed in outcrops, trenches, workings and drill holes and for which the grade is computed from the results of detailed sampling. The sites for inspection, sampling and measurements are so closely spaced, and the geologic character is defined so well, that the size, shape and mineral content are well established. The computed tonnage and grade are judged to be accurate within limits which are stated, and no such limit is judged to differ from the computed tonnage or grade by more than 20 per cent.
>
> *Indicated Ore* is ore for which tonnage and grade are computed partly from specific measurements, samples or production data and partly from projection for a reasonable distance on geologic evidence. The sites available for measurement, inspection or sampling are too widely spaced or otherwise inappropriately spaced to outline the ore completely, or to establish its grade throughout.
>
> *Inferred Ore* is ore for which quantitative estimates are based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on an assumed continuity or repetition for which there is geologic evidence ; this evidence may include comparison with deposits of similar type. Bodies that are

[12]Survey of World Iron Ore Resources—Occurrence, Appraisal and Use. United Nations Department of Economic and Social Affairs, New York, 1955.

[13]1948 McKINSTRY, H. E. : Mining Geology, p. 472. Prentice-Hall Inc., New York.

completely concealed may be included if there is specific geologic evidence of their presence. Estimates of inferred ore should include a statement of the spacial limits within which the inferred ore may lie.

Only two deposits, viz., Cockatoo and Koolan Island may be regarded as having *measured reserves.* A few other deposits, viz., Koolyanobbing, Irvine Island and perhaps Tallering Peak may be classed as *indicated reserves* and the remainder of the deposits described in Chapter II are classed as *indicated potential ore.*

IRON ORES

While the main purpose of this Bulletin is the presentation of factual data on Western Australian iron deposits, some further information on iron ores in general will assist the reader in any assessment of the value of any particular deposit described in Chapter II.

Economic Considerations.

The economic factors affecting the mining and treatment of iron ores are fundamentally different from those which apply to other mining propositions. Most iron and steel concerns possess their own iron mines or have long term contracts with known suppliers, so that there is less opportunity for the free marketing of iron ores than for other minerals. On the other hand, the capital outlay involved in the development of an iron and steel industry is so great that only large companies or groups of companies can undertake it.

The possibility of exploiting a deposit with a view of establishing an iron and steel industry depends on a great many factors, particularly on its accessibility, geographic location with respect to existing transport systems, water, flux and fuel supply and proximity of markets. Other factors of equal importance concern the grade of ore, its chemical and physical characteristics and the size of the deposit. For economical operation, large deposits of a specific uniform composition must be assured. A single modern 800 tons per day blast furnace requires annually about half a million tons of 50 per cent. iron ore. This would require a deposit of 10 to 15 million tons of ore to amortise investment in the treatment plant over a period of say twenty years.

If the essential conditions for the establishment of a local iron and steel industry do not exist, it may be possible to export iron ore, assuming that port and shipping facilities make such an operation profitable.

Smaller deposits with less rigid specifications may be economically worked if the production of foundry pig alone is contemplated.

Classification.

Briefly, the commercial classification of iron ores is based both on chemical or physical characteristics. " Direct shipping " ores are usable in the blast furnace as mined, while " concentrating ores " must be beneficiated before use in the furnace. Before such beneficiation these may be classed as " raw " or " crude " ores.

On the basis of the phosphorus content, which is of paramount importance in the steel making process, iron ores are further designated as " Bessemer " or " non-Bessemer " ores, the former being limited to a few hundredths of one per cent. of phosphorus.

Ores are also specified as "lump," "rubble" or "fines" according to the size of the pieces as finally delivered for treatment.

Uses.

Apart from use as ochres and road dressing aggregate, iron ores are used for production of steel, production of foundry pig, and as a flux in the smelting of other metals from their ores.

Steel Making.

This process requires two stages, first the reduction in the blast furnace of iron ore to pig iron, and secondly, the treatment of pig iron to make steel. In principal, the blast furnace is a refractory lined vertical shaft into the top of which is charged the iron ore together with coke and limestone. The coke (or other suitable solid fuel) which is burnt by blowing preheated air through Tuyeres near the bottom of the furnace, reduces the ore to metallic iron which is withdrawn in the molten state from the bottom of the furnace from time to time. The limestone under these conditions reacts chemically with the silica, magnesia and other acid impurities to form a liquid slag which floats on top of the molten iron and which is withdrawn separately. The process is a continuous one, the rate of feed being limited by the furnace capacity.

The type of pig iron produced by the blast furnace, and in particular the phosphorus content of that pig determines the type of process which must be used in the second stage of steel manufacture. The acid Bessemer and the acid open hearth processes require pig iron of low phosphorus and low sulphur content. Pig iron for the basic open hearth process can have a phosphorus content of 1·5 per cent. or more, and the basic Bessemer process uses pig of approximately two per cent. phosphorus content.

Foundry Pig.

Iron ores for the manufacture of foundry pig only may have variable phosphorus contents according to the special use intended for the pig.

Flux.

Iron ores used as a flux for the reduction of lead or copper ores should have an iron content of not less than 50 per cent. and be comparatively free from silica.

Nature of Ores.

The iron content of ores used in blast furnaces varies between about 20 per cent. and 71 per cent. The value of an iron ore is not, however, exclusively determined by the iron content. Other important factors to be considered include the amount and nature of impurities and the nature of combination of iron in the ore. Hematite ores for instance, the mainstay of the iron industry, are easier to reduce in the blast furnace than magnetite ores.

The main impurities in iron ores and their action in the furnace are described below :—

Silica.

High silica ores are uneconomical to use in ordinary blast furnaces by reason of the high fuel consumption caused by the excessive amount of slag obtained. Furthermore, such ores require large quantities of lime to neutralize the silica. Such low iron-high silica ores should therefore be beneficiated prior to smelting or sweetened in smelting with high grade ore or scrap iron.

Phosphorus.

Phosphorus present in the iron ore cannot be removed in the slag and nearly all goes into the pig iron on smelting. The amount of phosphorus in the pig then ultimately determines the process to be adopted in the manufacture of steel.

As mentioned earlier, the phosphorus content of iron ores divides the ores into "Bessemer" and "non-Bessemer" types, a Bessemer ore being one with less than 0·0009 per cent. of phosphorus for each per cent. of iron[14]. Thus if the iron content of an ore is 50 per cent., the "Bessemer limit" for the phosphorus content of the *ore* is about 0·045 per cent. The figures quoted below show the limits of allowable phosphorus in *pig iron* for the various steel manufacturing processes:—

Acid open hearth—less than 0·05 per cent.

Acid Bessemer—less than 0·1 per cent.

Basic open hearth—not over 1·5 per cent. and preferably not over 1 per cent.; for special process 1·5 per cent. and over is permissible.

Basic Bessemer—at least 1·5 per cent. and preferably over 2 per cent.

Foundry iron—wide range according to the ultimate use intended for the product.

Sulphur.

The sulphur content of iron ores, although usually small, is deleterious because of the difficulty of removal. A small percentage of sulphur in a blast furnace burden is eliminated with the gas, but the rest is divided between the slag and the pig iron.

Manganese.

Specialized pig iron, high in manganese, is deliberately produced for certain purposes. If the manganese content of the ore is sufficiently high, speigel iron (or ferromanganese) with 10 to 30 per cent. manganese can be produced in the blast furnace. The allowable manganese content of pig iron for the production of steel however, varies between 0·5 per cent. and 2·5 per cent.

Titanium.

Iron ores carrying more than one per cent. of titanium are undesirable because such ores require an excessive amount of fuel to reduce them. In addition the titanium tends to make the slag more viscous and may ultimately choke the furnace.

Ore Minerals.

As far as the Western Australian iron ore deposits are concerned, only some of the following minerals are sufficiently abundant in large masses to be sources from which metallic iron may be obtained.

Hematite (Fe_2O_3).

This is the predominant iron ore mineral in both high and low grade ore bodies. In its pure state the mineral contains 70 per cent. of iron and 30 per cent. of oxygen. When developed

[14]Survey of World Iron Ore Resources—Occurrence, Appraisal and Use. United Nations Department of Economic and Social Affairs, New York, 1955.

with a metallic lustre and/or splendent crystals it is called specular iron. Micaceous hematite has a foliated or micaceous structure. Martite is a pseudomorph of hematite after magnetite.

Magnetite (Fe_3O_4).

Frequently occurs in various subordinate percentages with hematite. In jaspilitic type ore bodies, hematite in the zone of oxidation gives way to magnetite at depth and such bodies render the use of the compass at the surface, unreliable. The iron content of pure magnetite is 72 per cent., the balance being oxygen.

Limonite ($2Fe_2O_3$-$3H_2O$).

Essentially a superficial weathering product of hematite, limonite is of common occurrence in most ore bodies and in certain instances, where it forms a gossan over pyritic ore bodies at depth, it is the predominant ore mineral and forms deposits of considerable magnitude. Goethite is similar in composition to limonite, but is distinguished from it by being crystalline. The iron content of limonite is 60 per cent.

Siderite ($FeCO_3$).

Also called spathic iron, this mineral is occasionally found in association with other ore minerals. In other parts of the world it is also known to form solid lodes of considerable thickness. It contains 48 per cent. of iron.

Pyrite (FeS_2).

This sulphide of iron occurs in bodies of some magnitude in this State and is mined from one locality (Norseman) for its sulphur content. It contains 47 per cent. of iron but is not considered as a source for that metal.

Nature of Iron Deposits in Western Australia.

In Western Australia, by far the greater number of iron ore deposits of actual or potential economic significance are associated with banded iron formations or, as they are widely known throughout Australia, jaspilites. These rocks, similar in composition to the taconites in the Lake Superior District of North America, the itabirites of Brazil and the calico rocks of Southern Africa, are of sedimentary origin and are considered to represent the result of a rhythmic chemical precipitation of colloidal silica and iron compounds in shallow basins. Their formation may possibly be ascribed to the action of meteoric waters which have dissolved iron and silica from the rocks of an old continental area.

The jaspilites are composed essentially of alternating layers of fine granular or dense silica, or chert and iron oxides. They are interbedded with highly metamorphosed sedimentary and volcanic rocks and are of widespread occurrence within the area of the Western Australian Pre-Cambrian shield.

The iron oxides at the surface are usually in the form of hematite with accessory magnetite and limonite. Below the zone of oxidation however, the hematite is replaced by magnetite and accessory pyrite. The presence of abundant limonite at the surface is an indication that a sulphide body may exist at depth as demonstrated at Koolyanobbing and Mt. Caudan where "brown iron ore" at the surface gives way to pyritic bodies at depth.

On many occasions the beds are covered by a layer of secondary iron formation, the so called "laterite." Lateritization is usually ascribed to selective weathering under tropical and sub-tropical conditions which causes the leaching of silica and the regrouping of iron and aluminium oxides in a pisolitic form. The common products of this weathering are limonitic minerals which in some cases form a covering mantle obscuring the jaspilitic outcrop. This type of limonitic capping should not be confused however, with the limonitic ore which forms the surface expression of a pyritic body, although the distinction in the field may be difficult.

The jaspilites vary widely in their relative proportions of ferruginous to siliceous material. They range from banded cherts with no, or insignificant, iron compounds to high grade iron ores containing up to 67 per cent. of metallic iron and as little as one per cent. silica. Between the two, all transitional stages are found. The average content of a typical ferruginous jaspilite, or banded iron formation, varies between 30 per cent. and 40 per cent. metallic iron and the silica fraction is between 40 per cent. and 55 per cent. Titanium is present in quantities of less than 0·01 per cent. while manganese oxide, sulphur and phosphorus are usually each below 0·1 per cent.

The jaspilites of exceptionally high iron content mentioned above, form irregular bodies surrounded by the more usual low grade formation. The contacts are as a rule not sharp and the laminations of the normal jaspilite may be followed gradually into a high grade ore body.

Various theories have been advanced to explain the concentration of the ore, but no single one is of universal application. It is probable however, that the ore is of syngenetic origin, the iron being derived from within the original jaspilite beds, but the mobilizing agent has not been identified.

In the field, the banded iron formations being more resistant to weathering than other sediments, often stand up in well defined ridges, which can be followed for many miles along the strike. When tectonically undisturbed, the thickness of the individual bands may range from a few feet to over 100 feet.

Often however, the jaspilites are disturbed by folding and thrusting resulting in repetition and thickening of the strata.

Apart from the jaspilitic iron ore deposits and the Yampi Sound deposits (*see* report on Koolan Island, Chapter II), mention is made of two other modes of occurrence, although these cannot be considered as being of economic significance so far as the iron and steel industry is concerned.

The first type is the lateritic type deposits. These have formed at or near the surface as a result of certain climatic conditions applied to rocks with a small and disseminated original iron content, such as basic igneous rocks, gneisses, etc. Although these ferruginous laterites are widespread over the State, they are only of a superficial nature, are small and scattered in occurrence and subject to large variations in iron content and chemical composition in general. In 1950, the Geological Survey carried out, with negative economic results, a reconnaissance investigation of deposits of this nature in an area within a radius of 50 miles of Bunbury, and it is highly probable that similar conclusions would be arrived at in any other part of the State. Originally, the State Charcoal Iron Industry's Wundowie furnace operated on lateritic type ore, but deposits fell far short of the planner's expectations, and ore for this industry is now drawn from Koolyanobbing (a banded iron formation).

The second additional mode of occurrence is that of certain titaniferous iron ore deposits in Western Australia which are clearly derived from an igneous source and must be regarded as magmatic segregations and intrusives into their host rocks. Deposits of this nature are relatively small, lenticular and of irregular extent and distribution. Furthermore, their high titanium content makes them unsuitable as an iron ore.

GEOPHYSICAL EXPLORATION TECHNIQUES AND THEIR LIMITATIONS*

The principles governing the exploration for iron ore deposits do not differ essentially from those relating to other mineral deposits. In the first instance, geological mapping for the purpose of obtaining some knowledge of the general geology of the area to be explored is essential. Regional mapping is the prerequisite to which all geophysical exploration methods may be considered subsidiary.

Geophysical prospecting is based on certain physical characteristics of iron ore minerals, such as magnetism, contrast in density or electrical conductivity. These characteristics permit widespread use of modern scientific techniques which can be carried out from the air or on the ground.

In iron ore exploration the most widely used geophysical techniques have been based on the magnetic properties of iron ore minerals. The method has proved to be a useful accessory to geological exploration, but in very few instances has been directly instrumental in the discovery of iron ore deposits.

Gravimetrical, electrical and other geophysical techniques have been much less widely used. Although they have been of limited value in some instances, in others they have proved valueless.

Magnetic Surveying.

Magnetic Surveying both on the ground and from the air, is based on the magnetic properties of ore and the surrounding material, and the observations are compiled into magnetic contour maps and magnetic profiles. The sensitivity and accuracy of the best airborne and ground magnetometers are comparable. The two methods do not compete, but complement each other, each having a distinct place in the exploration for iron ore.

In aeromagnetic surveys, flying is usually done at an elevation of 500 feet. The spacing of the lines, at right angles to the magnetic trends, may vary between one quarter of a mile and one mile, and the magnetometer is recording a continuous profile along these lines of flight.

The limitations inherent in this method are firstly the errors incurred in locating the exact positions of the aero-profiles with respect to the ground. This may be due either to poor base maps on which the control points are plotted, or in mountainous areas, to the necessary violent manoeuvring of the 'plane when attempting to maintain a constant elevation above ground. The accuracy of position of an aeromagnetic

* For further details on this subject:
GILBERT C. MONTURE: Techniques of the Exploration and Discovery of Iron Ore Deposits. Survey of World Iron Ore Resources, United Nations, New York, 1955.

map is only in rare cases within 50 feet, and the error may be as great as a quarter of a mile. Furthermore, the crest of an aeroprofile may not necessarily be vertically above the source of the anomaly, its location depending largely on the orientation of the magnetic body with respect to the inclination of the earth's magnetic field. In the second place, as an anomaly varies inversely as some function of the distance from the magnetic source, small anomalies will disappear in the aeroprofiles. On the other hand, because of the " fanning out " of an anomaly with increasing height, two or more separate ground anomalies may merge into one major peak at a higher altitude, causing a composite character of most of the aeroanomalies.

The instruments used in ground magnetic surveying are the dip needle, the superdip, a more intensive modification of the dip needle, and the magnetometer. A ground survey is made by a system of station measurements with interpolations between the stations, the position of which can be accurately determined by conventional surveying methods. The main advantage of the technique lies in the greater degree of resolution of individual anomalies. The profile is closer to the source of magnetic disturbance and therefore small anomalies and separate magnetic crests will be recorded that would pass unnoticed at greater height. In contrast, ground determinations are influenced to a much greater extent by extraneous magnetic fields, such as pipe lines, rails or boulders of basic rocks.

The difficulty encountered in both airborne and ground magnetic surveys is that some ore bodies contain magnetite, whereas others contain none. Similarly, the formation enclosing the ore body may vary in magnetic content, from strongly magnetic material to non-magnetic material. Also, magnetite may occur at some horizon within the iron ore formation, but these bands may not be continuous along the strike. It is possible therefore, that there may exist at depth ore bodies which do not produce recognizable anomalies because they are essentially non-magnetic. These remarks apply in particular to banded iron formations where the magnetite has been oxidised above the water table to hematite and limonite. In many cases these oxidised formations, containing but a small amount of magnetite, will not give readings any higher than adjacent areas underlain by basic greenstones. It is evident therefore, that whereas magnetic surveys over magnetite ore bodies can be made with good prospects of success, there is no prospect of carrying out similar work over hematitic or limonitic ore bodies.

On the other hand, the real extent and "strength" of a magnetic anomaly do not provide an indication of the commercial possibilities of the material causing the anomaly. For example, magnetite bearing rock of non-commercial grade may give readings far greater than the total quantity of magnetite present in the rock would indicate. This may possibly be the result of either residual magnetism or the parallel orientation of individual magnetic grains within the deposits. In contrast, the "strength" of an anomaly may be less than the total quantity of magnetite in the rock would indicate. Individual anomalies must therefore be regarded only as a guide for further investigation.

In conclusion, magnetic surveying techniques, although not sufficient in themselves to discover commerical ore bodies are nevertheless most useful in iron ore exploration. They are most profitably used to eliminate areas of no potential interest and detailed geological mapping can be planned to include a closer examination of pronounced anomalies.

Gravimetric Surveying.

Another characteristic of iron ores that may be an aid in searching for deposits is that the ore commonly has a greater weight than an equal volume of adjacent rock material. Consequently, the application of gravimetric surveying methods to the search for iron ore is related to these differences in specific gravity. The variations of gravity encountered in practice are extremely small, and the instruments used for measurement have to be of great sensitivity. For exploration work mechanical gravimeters are most widely used. These instruments use the elastic force of springs and the torsion of wires to measure gravity with an accuracy of one in ten million. The pendulum method and the torsion balance consume considerable time and are not widely used for ordinary field mapping. The sensitivity of gravity instruments frequently results in complications in the interpretation of gravimetric readings.

Gravimetric work carried out in recent years over a number of Canadian deposits were generally inconclusive and gave no definite indications of the location of ore bodies. The main reason for the erratic results was to be found in the great porosity variations and their resultant reflection in ore densities.

The criterion to be used in judging whether gravitational exploration might be used successfully under a certain set of field conditions is whether the ore body to be detected or delineated possesses an average specific gravity appreciably and consistently different from the surrounding rocks; the greater this difference, the greater the possibilities of locating small ore bodies.

Electrical Surveying.

Electrical methods of exploration, depending on the difference in electrical properties of certain rocks and minerals, are of limited application and value in iron ore exploration. In certain cases differences in electrical resistivity may be used to indicate the possible presence of hematite. Considered in detail, however, the results cannot be considered very accurate, apart from the fact that the method is too expensive for preliminary examination.

BENEFICIATION OF LOW GRADE ORE

Beneficiation is a metallurgical process by which poor ores are sufficiently improved in grade to yield an economic burden for the blast furnace. The vast reserves of banded iron formations in this State have a relatively low iron content, varying between about 30 per cent. and 40 per cent. Also their high percentage of silica would require great amounts of fuel and limestone flux if fed to the blast furnace as mined. It is therefore essential for these ores to be upgraded to such a degree as to make them a suitable blast furnace feed.

Beneficiation methods using low grade magnetic ores are already largely practised outside Australia, particularly in the United States of America, and vast sums are being spent in developing new techniques for concentrating low grade hematitic ores identical to our Western Australian jaspilites. There are no insurmountable obstacles to the solution of the problem.

The first step in the beneficiation procedure consists in the liberation of the iron minerals from the gangue, requiring grinding to about 150 mesh. Next, the iron minerals must be separated from the gangue minerals and concentrated. This can be effected by conventional methods, such as flotation, gravity concentration or magnetic separation. Flotation involves the reagent-coating of certain mineral assemblages, enabling them to adhere to a froth of air bubbles, carrying them upward into a collecting trough. The non-adherent particles remain in suspension.

In magnetic concentration the finely crushed material is carried in suspension over a revolving magnetized drum. The magnetizeable mineral particles adhere to the drum and are removed by a scraper, whereas water and waste are eliminated at the front of the drum.

Obviously this method is only applicable to ores in which the iron is present in the form of magnetite. In the zone of oxidation the Western Australian jaspilites consist essentially of hematite and limonite, both non-magnetic minerals. The problem may be overcome, at additional cost, by magnetic roasting, converting hematite and limonite into magnetite. Investigations along these lines are being actively carried out.

The gravity concentration method is based on the fact that minerals of different specific gravities move differently in a certain medium. The medium may be water or a substance of higher specific gravity than water (heavy media separation).

The final step in the beneficiation process is agglomeration. In order to produce a feed suitable for the blast furnace, the concentrates have to be joined and reconsolidated into larger aggregates. This is accomplished by the methods of sintering, briquetting or nodulising. A large bibliography on each process is available.

Economic considerations are as important as technical factors when deciding whether a low grade ore can be beneficiated to a useful product. Since it takes between two and a half and three tons of low grade ore to the equivalent of one ton of high grade ore, the mining costs of the concentrate will be proportionately higher. This, in conjunction with the large scale operations necessary to produce low grade concentrates equivalent to the normal high grade ore production, necessitates the development of new techniques for cheaper mining. It also requires enormous tonnages of ore, favourably situated to existing transport facilities.

Unfortunately, a number of vast deposits are situated in remote areas in the interior of the State, and it would appear that these occurrences will be untouched for some considerable time yet. However, with the gradual exhaustion of the known high grade deposits, and an ever expanding steel industry, the time will arrive when these huge reserves will have to be exploited as sources of iron ore. The experience already gained in the Lake Superior region of the United States, and intense research work carried out at present leave little doubt that the problems of large scale mining and beneficiation of low grade ores will be satisfactorily solved.

IRON ORE PRODUCTION IN WESTERN AUSTRALIA

As Reported to the Department of Mines

Tabulated in accordance with purposes used— for (a) FLUX, (b) EXPORT, and (c) PIG IRON

Iron Ore for Flux

Year	Tons	Value	Centre	Goldfield or Mineral Field
		£		
Prior to 1899	100·00	300·00	Whim Creek	West Pilbara
1899	2,000·00	1,391·00	Greenbushes	Greenbushes
	1,540·00	1,071·00	Clackline	Outside Proclaimed
	4,600·00	3,200·00	Werribee	Outside Proclaimed
	4,712·00	3,277·00	Coates Paddock	Outside Proclaimed
1900	12,251·00	9,258·00	Avon (Wundowie)	Outside Proclaimed
1901	450·00	247·00	Boulder	East Coolgardie
	2,725·00	2,086·00	Greenbushes	Greenbushes
	9,972·00	6,983·00	Avon (Wundowie)	Outside Proclaimed
	7,422·00	3,930·00	Clackline	Outside Proclaimed
1902	1,955·00	831·00	Greenbushes	Greenbushes
	2,845·00	1,209·00	Clackline	Outside Proclaimed
1903	220·00	88·00	Greenbushes	Greenbushes
1904	581·00	233·00	Greenbushes	Greenbushes
	860·50	344·00	Clackline	Outside Proclaimed
1905	3,212·60	1,285·00	Clackline	Outside Proclaimed
1906	1,279·87	512·00	Clackline	Outside Proclaimed
1907	1,093·53	438·00	Clackline	Outside Proclaimed
1910	10·50	12·00	Yampi	West Kimberley
1942	150·00	225·00	Clackline	Outside Proclaimed
1943	84·35	128·00	Koolyanobbing	Yilgarn
Total	58,064·35	37,048·00		

Iron Ore for Export

(Cockatoo Island, Yampi Sound, West Kimberley Goldfield)

Year	Ore	Assay Fe	Assayed Fe Content	Reported Value (nominal)
	Tons	%	Tons	£
1951	10,384	62·60	6,500·38	10,297·00
1952	204,945	62·53	128,156·57	203,238·00
1953	687,895	63·39	436,084·00	682,161·69
1954	634,514	63·08	400,261·89	629,325·00
1955	496,882	61·57	305,930·02	492,741·00
1956	327,815	62·64	205,343·22	323,923·00
1957	389,686	63·09	245,846·14	386,440·00
1958	536,713	63·98	343,386·64	532,355·00
Total	3,288,834	Av. 62·99	2,071,501·86	3,260,480·69

Iron Ore for Pig Iron

Koolyanobbing—Yilgarn Goldfield

Wundowie—Outside Proclaimed Goldfields

(Smelted by Charcoal Iron and Steel Industry at Wundowie)

Year	Wundowie Ore		Koolyanobbing Ore		Pig-Iron Produced	Value at Works
	Tons	Assay Fe	Tons	Assay Fe		
		%		%	Tons	£
1948	7,222·20	*	....	*	3,332·98	26,164·97
1949	12,524·13	*	....	*	6,609·17	66,295·92
1950	11,825·25	*	3,069·98	*	7,725·64	82,682·37
1951	5,493·19	*	13,629·08	*	11,014·36	181,135·65
1952	4,708·55	43·56	12,994·90	60·94	10,641·63	226,843·82
1953	3,675·89	42·55	13,175·88	62·11	10,045·72	221,005·85
1954	1,633·30	41·89	16,664·99	62·46	11,160·96	209,027·22
1955	426·06	43·60	16,876·82	62·00	11,590·22	220,558·48
1956	....	....	19,853·60	61·78	13,413·13	278,845·62
1957	....	....	21,838·50	62·88	13,968·27	324,646·16
1958	....	....	30,075·00	60·54	19,307·00	458,561·00
Total	47,508·57	Av. 42·95	148,178·75	Av. 61·74	118,809·08	2,295,767·06

* Not available.

Compiled by Mr. E. Lester,
Compiler, Statistics Branch,
W.A. Mines Department.

CHAPTER II

THE IRON DEPOSITS

THE IRON DEPOSITS (continued)

INTRODUCTION AND ARRANGEMENT

In all, 49 localities are described in the following reports, the majority of which localities were examined in the course of the present survey. Some however, which had already been examined in sufficient detail for the purposes of this Bulletin, were not re-examined, and the reports presented thereon are precis of previously published works. In such cases the title and authorship of the original publication is clearly shown.

The arrangement of the reports is in Goldfields commencing from the north and working to the south in east to west strips. The deposit localities may conveniently be identified on the locality map at the front of the Bulletin. The map reference system is shown on this map.

THE DEPOSITS

WEST KIMBERLEY GOLDFIELD

In the course of the present survey, no field work was undertaken in this area and the following summaries are based on previous reports.

KOOLAN ISLAND

(Map Ref. A.4.)

Precis by K. Berliat, D.Sc., from the references listed at the end of this report.

General Information.

Koolan Island, the easternmost and largest of the Yampi Sound group, is situated off the Kimberley coast, approximately at south latitude 16° 8′ and east longitude 123° 45′. The island is seven miles long in an east-west direction and has a width of two and one half miles at its widest point. The topography is rugged and there are a series of mountainous ridges striking in a general east-west direction. Elevations range up to 560 feet.

On the south side of the island there is a navigable deep water channel, permitting large vessels to approach to within easy loading distance of the coast. The nearest mainland port is Derby, 90 miles to the south.

Geological Occurrence.

The rocks in which the deposits occur are reported, in the available literature, as being members of the Pre-Cambrian Mosquito Creek Series, and consist of a sedimentary succession of slates, schists, sandstones, quartzites and hematite quartzites that have been folded into a major syncline and a complementary anticline. Both folds are overturned towards the north and have a regional plunge of eight degrees to the west. The strike of their axes ranges from north-west to west-north-west.

There are five principal hematite ore bodies conformable to the bedding of the enclosing sediments. They occur stratigraphically in the lower part of the succession.

Current thought at the Geological Survey (H. A. Ellis: verbal communication) suggests that the ore-bearing rock succession is more likely to be *post*-Archaeozoic in age and, as such, should not be correlated with the jaspilitic type ores found elsewhere within the State. Furthermore, there is no evidence to suggest that the hematite bodies should not persist virtually unchanged below the zone of oxidation, as distinct from jaspilite type ores which pass from hematite to magnetite. (Recent diamond drilling by Broken Hill Pty., Ltd., shows hematite still at 1,200 feet vertical depth: H. A. Ellis, 19/5/1959.)

The Ore Bodies.

1. The southern, or main ore body occurs on the overturned south limb of the major syncline, its outcrop forming a high ridge on the southern side of the island. The average dip is 50° south with local variations ranging from 35° to 65°. The dimensions of the ore body are as follows :—

	feet
Length	6,250
Average true width	100
Average horizontal width	134
Mean height above high water level	525

2. The northern ore bodies occur on both limbs of the major anticline thus forming north and south branches, each of which consists of an east lens and a west lens. The western lenses are approximately 3,500 feet north, and the eastern lenses approximately 10,000 feet east of the central part of the main ore body. Dimensions are as follows :—

	feet
(a) South branch, west lens—	
Length	3,950
Average true width	54
Average horizontal width	81
The mean dip is 35° to the south.	
(b) South branch, east lens—	
Length	3,600
Average true width	50
Average horizontal width	64
The mean dip is 35° to the south.	
(c) North branch, west lens—	
Length	2,650
Average true width	48
Average horizontal width	59
The average dip is 50° to the south.	

(d) North branch, east lens—	feet
Length	2,950
Average true width	47
Average horizontal width	56

The average dip is 50° to the south.

3. *Lateritic and Detrital Ore.*—Immediately north of the central part of the main ore body there are occurrences of limonitic laterite and detrital hematite. The area has a total length of 1,250 feet in an east-west direction and is 430 feet wide. Two vertical shafts showed the depth of the ore to be 82·5 feet and 78·5 feet respectively. The average exposed thickness along the northern boundary is 40 feet.

Another area of lateritic ore lies south of the east lens of the south branch of the northern ore body. Its length in a south-east north-west direction is roughly 2,800 feet, but no information as to its width is on record. An inclined shaft showed a thickness of 27 feet of lateritic and detrital ore without reaching its base.

Exploratory Work.

1. *Surface Sampling.*—Systematic surface sampling of the main and northern ore bodies was carried out prior to 1941 by the Yampi Sound Mining Co., Ltd. On the main lode sample channels were cut across parts of the outcrop, namely over a length of 2,000 feet in the north-western portion and over a similar length in the south-east, the number of channels totalling 30. On the northern ore bodies, sample channels were cut at an average distance of 100 feet. The metallic iron content of each of these samples was determined, and partial analyses were made of group samples.

2. *Underground Exploration.*—To test the nature and dimensions of the ore bodies at depth, six cross cut adits were driven into the main lode and one into the west lens of the south branch of the northern ore body. Adits Nos. 1 and 2 on the main body were at high water level, while the other four ranged in elevation between 340 and 405 feet above that level. The adit into the west lens was at an elevation of 272 feet.

In order to expose the hanging wall contact of the main ore body which was not located in No. 3 and No. 6 adits, a vertical shaft was sunk to a depth of 33 feet at the measuring point of No. 6 adit. The contact was not located, but was exposed in a number of test pits dug into the hill slope east and south-west of the portal of No. 3 adit.

In the No. 1 adit a winze was sunk to a depth of 27 feet at a point 52 feet south of the hanging wall. It encountered highly oxidized material throughout its depth.

An inclined shaft on the east lens of the south branch of the northern ore body had not reached the ore when operations were suspended.

The three exploratory shafts sunk in the lateritic and detrital ore have already been mentioned.

Grade of Ore.

1. *Main Ore Body.*—The average iron (Fe) content based on the average of all adit group samples, weighted for width sampled, is stated to be 67·2 per cent. The range of the principal con-

stituents as determined by partial analyses of group samples taken across the full width of the ore body in adits Nos. 1, 4 and 5 is as follows :—

	%		%
Iron Fe	67·13	to	68·8
Silica SiO_2	0·51	to	1·81
Titanium dioxide TiO_2	0·13	to	0·19
Phosphorus P	0·025	to	0·13
Sulphur S	Nil	to	0·005
Water H_2O	0·25	to	0·66

Results of complete analyses of ore made on two groups of surface samples regarded as representative are given below :—

	No. 1	No. 2
	%	%
Fe_2O_3	92·89	96·04
FeO	not determined	
SiO_2	1·11	0·73
Al_2O_3	2·56	1·50
MgO	0·06	Nil
CaO	Nil	Nil
Na_2O	Nil	Nil
K_2O	Nil	Nil
H_2O+	2·45	1·22
H_2O-	0·39	0·22
TiO_2	0·21	0·14
P_2O_5	0·31	0·13
MnO	Nil	Nil
CO_2	0·02	0·03
Cl	0·01	0·02
Cr_2O_3, V_2O_3	Nil	Nil
(Ni, Co)O, BaO	Nil	Nil
ZnO, PbO, CuO	Nil	Nil
As, Sb, Sn	Nil	Nil
C	0·09	0·05
S	Nil	Trace
Totals	100·10	100·06

2. *Northern Ore Bodies.*—As a general indication of the composition of the surface ore in the four ore bodies, the following group analyses are quoted :—

Constituent	North Branch East lens	North Branch West lens	South Branch East lens	South Branch West lens
	%	%	%	%
Iron Fe	62·81	65·76	64·27	66·76
Silica SiO_2	3·44	4·67	2·15	1·87
Titanium Dioxide TiO_2	0·255	0·072	0·191	0·085
Phosphorus P	0·067	0·022	0·063	0·062
Sulphur S	Nil	Nil	Trace	Nil
Water H_2O	2·73	0·35	2·61	0·95

3. *Lateritic and Detrital Ore.*—The following is a partial analysis of a group sample of ore north of the central part of the main ore body :—

	%
Iron Fe	57·92
Silica SiO_2	4·61
Titanium Dioxide TiO_2	0·715
Phosphorus P	0·136
Sulphur S	0·047
Water H_2O	5·93

Ore Reserves.

The estimated tonnages of ore available in the various ore bodies are set out in the accompanying table.

ORE RESERVE ESTIMATES, KOOLAN ISLAND

Ore Body	Estimated Reserves above high water level	Prospective tonnage to 500 feet below high water level	Long tons per vertical foot of depth
	Long tons	Long tons	
Main Ore Body	45,300,000	46,500,000	93,000
Northern Ore Bodies—			
South Branch :			
West Lens	15,400,000	18,200,000	36,400
East Lens	12,600,000	12,850,000	25,700
North Branch :			
West Lens	4,700,000	8,750,000	17,500
East Lens	9,000,000	9,250,000	18,500
Totals	87,000,000	95,550,000	
Lateritic and Detrital Ore	3,000,000	....	
Miscellaneous Sections of Hematite Ore	1,850,000	....	
Totals	91,850,000	95,550,000	
Grand Total	187,400,000	Long tons	

Production.

There has been no production so far from any of the ore bodies of the island.

References.

The following is a list of the works consulted in the compilation of this summary :—

MOSS, F. A. and FORMAN, F. G. : The Iron Ore Deposits of Koolan Island, Yampi Sound, Western Australia, 1941. Unpublished report on G.S.W.A. file 41/1939.

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ANONYMOUS: Yampi Sound Iron Ore Deposits; Queensland Government Mining Journal, December, 1920.

CAVANAN, F. and EDWARDS, J. B.: The Iron Ores of Yampi Sound, Western Australia; Proceedings of the Australian Institute of Mining and Metallurgy, New Series No. 110, 1938.

COCKATOO ISLAND

(Map Ref. A.4.)

Precis by K. Berliat, D.Sc., from the references quoted in the previous report on Koolan Island.

General Information.

Cockatoo Island is situated about two miles west of the western extremity of Koolan Island. It is approximately three miles long and varies in width from six chains to one mile. The greater portion of the island is between 300 feet and 400 feet above sea level, but elevations up to 490 feet are found in the eastern part of the island. The southern coastline is more or less a linear cliff with minor indentations, while the northern coast slopes down more gently and is broken by three bays.

Access to the island from the sea is good. The approach can be safely negotiated by larger vessels and there are well sheltered anchorage and wharf sites on the south side of the island.

Geology.

The shales, slates, sandstones and hematite quartzites outcropping on Cockatoo Island are lithologically identical with those on Koolan Island and belong to the same stratigraphical succession. Structurally, the main feature is a major synclinal axis that extends through the centre of the island, and which can be traced over its whole length. The plunge at the eastern end of the syncline is 14 degrees to the west, and at the western end, five degrees to the east. Subsidiary folding along the southern limits of the structure has caused a minor anticline and syncline in the south-eastern portion of the island.

North of the synclinal axis there is a complementary major anticlinal fold, and another syncline and anticline can be traced at the extreme northern side of the island.

As at Koolan Island, all the folds are overturned to the north. The average dip is about 50 degrees to the south, but there are variations ranging from 35 degrees to 75 degrees.

Ore Deposits.

1. *The Main Deposit.*—The main deposit occurs as a single conformable bed in the overturned south limb of the main synclinal structure, and outcrops along the southern coast of the island where it forms a steeply dipping cliff. At high water level the ore body has a length of 7,000 feet and rises to a maximum height of 400 feet. Its average horizontal width is 70 feet with variations ranging between 20 feet and 148 feet. The minimum width is found over the westernmost 1,200 feet of the deposit.

At the surface the ore is hard, steel grey hematite.

2. *Brown Iron Ore.*—Adjoining the central portion of the main deposit in the north are two areas of limonitic ore. The dimensions of these areas are as follows :—

	Length feet	Width feet
Eastern Area (located East of No. 1 gully)	1,100	200
Western Area (Located West of No. 1 gully)	1,200	150

No information as to the downward extension of these bodies is on record.

3. *Northern Ore Body.*—Several smaller parallel bands of hematite and hematite quartzite extend from the isthmus on Cockatoo Island to the western end of the island. They vary in thickness from four feet to 56 feet and dip at approximately 55 degrees to the south. These beds are highly siliceous in places and must be regarded as a doubtful source of commerical ore.

Surface Sampling.

Surface sampling across the main ore body and across beds of the northern ore body was carried out in 1920, on behalf of the Queensland Government. No details of the sampling procedure are on record.

Surface samples on both ore bodies were also taken by Montgomery.

Underground Exploration.

In 1920 two diamond drill holes were put through the main ore body on behalf of the Queensland Government. No. 1 hole, which penetrated 86 feet of hematite, was at a distance of 50 chains east of the western end of the ore body. No. 2 hole, 15 chains from the western end, went through 21 feet of hematite. The two drill holes were four feet and five feet respectively above high water level, and both located the footwall of the ore.

Further exploratory work includes four tunnels driven through the main bed four feet to 12 feet above high water level, and two other tunnels, 300 feet and 330 feet above high water level, driven with the object of testing the two areas of brown ore immediately to the north of the main deposit.

Grade of Ore.

1. *Main Deposit.*—The grade of the main bed is illustrated by the following analysis of a composite sample taken from bore cores obtained in the two diamond drill holes :—

	%
Iron Fe	69·6
Fe_2O_3	99·5
Silica SiO_2	0·1
Alumina Al_2O_3	0·1
Lime CaO	Nil
Magnesia MgO	Nil
Manganese Oxide MnO	Nil
Titanium Dioxide TiO_2	Nil
Phosphorus P	0·01
Arsenic As	Nil
Sulphur S	0·005
Moisture at 105°	0·2
Further loss on ignition	Nil

A composite sample from surface samples of sections measured across the width of the ore body gave results as follows:—

	%
Iron Fe	69·2
Fe_2O_3	98·9
Silica SiO_2	0·4
Alumina Al_2O_3	0·39
Lime CaO	Nil
Magnesia MgO	Nil
Manganese Oxide	Nil
Titanium Dioxide	Nil
Phosphorus P	0·024
Arsenic	Nil
Sulphur S	0·007
Moisture at 105°C.	0·2
Further loss on ignition	0·2

2. *Brown Iron Ore.*—These beds have not been sampled and no analytical data is on record.

3. *Northern Ore Body.*—Three surface samples from the northern beds analysed on behalf of the Queensland Government (1920) yielded :—

	Sample 1	Sample 2	Sample 3
	%	%	%
Iron Fe	48·3	42·0	47·0
Fe_2O_3	69·0	60·0	67·1
Silica SiO_2	29·2	38·2	31·2

A sample collected by Montgomery from the northern bed at the isthmus on the western end of the island gave :—

	%
Iron Fe	51·70
Sulphur S	0·05
Phosphorus P	0·010

Ore Reserves.

Estimates by K. J. Finucane based on a theodolite survey along the hanging wall, a survey along the footwall and abney level cross sections at intervals of 500 feet, together with information from the four tunnels, indicate 18,782,000 tons of ore for the main ore body down to high water level. A factor of eight cubic feet of ore per ton was adopted.

No reserve estimates have been made for the limonitic and northern deposits.

Production.

Production by Broken Hill Pty., from the main ore body between July, 1951 and June, 1955, amounted to 1,757,698 long tons of ore containing 1,110,473 long tons of metallic iron valued at £A1,743,148. The average content of metallic iron from all ore mined to December, 1954 was 63·76 per cent.

References.

See references listed in the previous report on Koolan Island (p. 29).

IRVINE ISLAND

(Map Ref. A4)

Precis by K. Berliat, D.Sc., from the references quoted in the report on Koolan Island.

Irvine Island is one and one-half miles west of Cockatoo Island, and has a maximum east-west and north-south width of two and one-half miles in each direction. Intensive folding has taken place on the isthmus in the north-eastern corner of the island, where shales, slates and hematite quartzites have been thrown into a number of minor south-westerly dipping, overturned folds, which are subsidiary to a broad anticlinal overfold whose axis extends in a general north-westerly direction. The minor folds comprise a thin and much crumpled bed of hematite. To the south, this bed dips below water level, but emerges again in the extreme south-eastern part of the island, where it forms a gentle arch 3,300 feet long in the cliff face above high water level. Wherever exposed, the hematite bed is covered by a considerable thickness of overburden.

No sampling has been done and no estimates of reserves have been attempted. It appears that the general average grade of the ore is fairly low, and that the deposits are of limited economic significance.

PILBARA GOLDFIELD

(Map Ref. C2 and C3)

Field work by K. Berliat, D.Sc., and J. Sofoulis, B.Sc. Reports by K. Berliat, D.Sc.

The main hematitic jaspilite deposits mentioned in the earlier literature (G.S.W.A. Bulletin No. 40) may be divided into the following three structural zones :—

1. Bamboo
   Coppin's Gap
   Kitty's Gap
   Talga Peak
   Coongan River-Marble Bar area

2. Gorge Creek
   Lalla Rookh
   Strelley Gorge

3. Tabba Tabba

These zones will be described individually.

Zone 1

Wrapped around the Talga-Mt. Edgar-Limestone granite mass the five occurrences, listed in this group, form part of a continuous belt striking in a general east-west direction from Bamboo Creek in the east to the Coongan River in the west, and from there in a south-easterly direction through the Marble Bar to Warrawoona. With one exception, all these reported " deposits " have been found to consist very predominantly of highly siliceous banded cherts and quartzites with only subordinate layers and lenses of more ferruginous material.

Their value as a source of iron ore is nil.

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Coppin's Gap

The exception mentioned above occurs at Coppin's Gap in the Talga Ranges 30 miles in a direction N. 45° E. from Marble Bar, which is 104 miles by road from Port Hedland. Access is gained from the Eginbah-Ragged Hills road, or from the south by station tracks from Talga Talga Homestead.

The water gap is most conspicuous topographically, visible for many miles both from the north and the south. It is carved out of east and west striking jaspilites, the walls rising to a height of 400 feet above the level of the creek. The section is about 1,000 feet long, the distance from wall to wall at the bottom of the gorge being approximately one chain. The deposit would be eminently suitable for quarrying.

The jaspilites are lithologically quite uniform and show regular red and steel-grey banding. An analysis of a composite sample made up of five individual samples, each representing about a 200 feet section gave the following results :—

	%
Acid Soluble Iron Fe	29·51
Silica SiO_2	51·91
Phosphorus P	0·08
Sulphur S	0·02
Manganese Oxide MnO	0·44
Titanium Ti	0·01

Unfortunately the ferruginous jaspilites as exposed in the gorge give way along the strike, both to the east and west, to highly siliceous varieties that would be useless even as a low grade ore.

At Kitty's Gap, a similar gorge less than two miles further to the west, the exposures exhibit a very predominantly siliceous section with only a few thin ferruginous layers near the southern approaches. A similar gradation into banded cherts is noticeable along the eastern continuation of the range.

The exact extent of the ferruginous material at Coppin's Gap east and west of the gorge is difficult to ascertain on account of superficial alteration—laterisation and or silicification—of the outcrops on top of the range. However, it would appear safe to assume a length equal to the width (800 feet) of the ferruginous variety. On this assumption, and using a conversion factor of 12 cubic feet to the ton, the tonnage above plain level has been calculated at 22,000,000 tons.

Zone 2

Gorge Creek-Lalla Rookh-Strelley Gorge

These localities have been mentioned in the earlier literature as containing large developments of ferruginous jaspilites. They form part of a belt that extends from Gorge Creek in a south-westerly direction for 40 miles. Gorge Creek is adjacent to the main road from Marble Bar to Port Hedland. An investigation of the three occurrences gave entirely negative results. The jaspilite formations, although topographically very prominent, are predominantly siliceous and useless as a source of even low grade iron ore. A. Gibb Maitland reported (G.S.W.A. Bulletin 40, p. 29) that the "laminated jaspers," notably those in the Lalla Rookh zone, could be readily concentrated to high grade ore.

The occurrences at Lalla Rookh have been found, in this investigation, to contain an average of 28·75 per cent. metallic iron and the actual deposits to be of small dimensions consisting of a number of small lenticular bodies, usually not more than 15 feet wide. The deposits, although in places 80 to 100 feet high, would therefore afford only a very limited tonnage and be of no interest as a source of iron ore.

Zone 3

Tabba Tabba

A narrow ridge several miles long, rising to a height of 300 feet above the plain and composed of " laminated iron bearing jaspers " was mentioned by A. Gibb Maitland (G.S.W.A. Bulletin No. 40, p. 10) about five or six miles east of Box Creek Well. The well is situated about seven miles east from Red Hill trigonometrical station and about five miles north of Tabba Tabba homestead. The northern end of the ridge is slightly less than one mile south of the Strelley mine workings, which are right on the Port Hedland-Marble Bar road, 37 miles from Port Hedland.

At this point the ridge is made up of two bands, the western one of which is the widest, having a true thickness of 25 feet. The beds are dipping at 70 degrees to the east. The main band extends in a general south-south-westerly direction for at least two miles, forming a line of low discontinuous hills of an average height of 50 feet.

The following analysis is indicative of the average grade :—

	%
Acid Soluble Iron Fe	29·47
Silica SiO_2	53·10
Phosphorus P	0·10
Sulphur S	0·06
Manganese Oxide MnO	0·04
Titanium Ti	0·01

The tonnage above plain level, calculated at 550,000 tons (conversion factor 12 cubic feet per ton) is not within economic range. The tonnage figure is based on an estimated total length of half a mile of the individual ridges.

ELLARINE HILLS (MT. GOLDSWORTHY)

(Map Ref. C.3)

Precis of North Australian Survey report No. 56, K. J. Finucane, M.Sc., and R. J. Telford, by K. Berliat, D.Sc.

General Information.

The Ellarine Hills deposits are located under Mt. Goldsworthy Trig. Station on the eastern side of the de Grey River, approximately in latitude 20° 20′ S. and longitude 119° 30′ E. The shortest distance to the coast is 20 miles, but the nearest port suitable for large vessels is Port Hedland, from whence the deposit is accessible by the West Coastal and Great Northern Highways.

Geological Occurrence.

The iron ore consists of three hematite lenses in east-west striking steeply dipping beds of quartzite and hematite quartzite, contained in Banded Iron Formations of Archaean age.

The Deposits.

The No. 1 or main lens occurs along the top of an east-west striking ridge rising to approximately 180 feet above the general level of the surrounding country. It consists partly of solid hematite and partly of shaley material with a high iron content. The lens is 2,200 feet long and has a total average width of 230 feet.

No. 2 lens, 2,200 feet farther to the west of the ridge, has a length of 1,200 feet and an average width of 150 feet. It is also made up of massive and slatey portions.

No. 3 lens adjoins No. 1 lens to the east. It consists of ferruginous slates and quartzites but appears to be very siliceous. The length is 850 feet and the average width 40 feet.

Sampling.

Only the main lens was sampled by Finucane and Telford. Twelve sample channels, approximately 200 feet apart were cut across the outcrop of the solid hematite. The iron rich shaley portions between the solid hematite were not sampled. A total of 14 samples were taken over an average width of 142·5 feet.

Grade.

A complete analysis of a composite sample made up of the 14 individual samples gave the following results:—

	%		%
SiO_2	.... 3·02		
Al_2O_3	.... 1·42		
Fe_2O_3	.... 91·84	Fe	.... 64·23
FeO	.... Nil		
MnO	.... 0·72	Mn	.... 0·56
MgO	.... 0·12		
CaO	.... 0·15		
Na_2O	.... Trace		
K_2O	.... Trace		
H_2O—	.... 0·24		
H_2O	.... 1·83		
TiO_2	.... 0·008		
P_2O_5	.... 0·22	P	.... 0·096
SO_3	.... 0·22	S	.... 0·09
BaO	.... 0·05		
Cr_2O_3	.... 0·02		
V_2O_3	.... Trace		
Pb	.... Nil		
Cu	.... 0·004		
As	.... Nil		
Co	.... Trace		
Ni	.... Trace		
Zn	.... Nil		
Au	.... Trace		
Ag	.... Nil		
	99·862		

Tonnage.

Using a factor of eight cubic feet per ton, Finucane and Telford arrived at the following preliminary estimates of iron ore contained in the main (No. 1) ore body above plain level :—

(a) Assuming a mean width of 142·5 feet of solid outcrop *only:* 6,662,000 tons.

(b) Assuming a total mean width of 230 feet (solid and slatey portions): 10,750,000 tons.

WEST PILBARA GOLDFIELD

(Map Ref. C.2)

Field work by K. Berliat, D.Sc., and J. Sofoulis, B.Sc. Reports by K. Berliat, D.Sc.

In the course of the present survey no commercial deposits of iron ore were found to exist within the boundaries of this goldfield. The main occurrences of potentially iron bearing rocks occur to the north and west of Roebourne, where a number of jaspilite bands extend in a south-westerly direction from Cape Lambert and Point Sampson to beyond Mt. Prinsep, a distance of 30 miles. Nowhere along the strike did these beds develop sufficiently large concentrations of ferruginous material to warrant further attention.

E. S. Simpson (Minerals of Western Australia, Vol. 2) mentioned the presence of hematite ore on Dolphin Island, 25 miles west-north-west of Point Sampson. He writes : "A large deposit of hematite associated with Pre-Cambrian greenstones and jaspilites is said to exist on this island. A temporary prospecting reserve, 392H, was gazetted in 1925, but no ore was ever raised."

A number of traverses from coast to coast on Dolphin Island failed to reveal the presence of any jaspilites or other type of iron ore.

ANDOVER

(Map Ref. C.2)

The Andover deposits are situated six miles west of Andover station, which is 12 miles by road south of Roebourne. They were mapped and described by K. J. Finucane and R. J. Telford in 1939[15].

The deposit, a magmatic segregation product, is stated by these authors to occur in seven large and 17 smaller lenses, associated with granodiorites, diorites and gabbros. The dimensions of the larger lenses are given as follows:—

Lens	Mean Length	Mean Width
	feet	feet
No. 1	2,260	140
No. 2	720	96
No. 3	600	283
No. 4	570	150
No. 5	240	192
No. 6	500	175
No. 7	700	138

[15]FINUCANE, K. J. and TELFORD, R. J. : The Ellarine Hills and Andover Iron Deposits. Aerial, Geological and Geophysical Survey of Northern Australia, Report Western Australia No. 56, 1939.

A partial analysis of a composite sample from these lenses, reported to consist of hematite, ilmenite, limonite and a little quartz, gave the following results:—

	%
Total Iron Fe	51·6
Titanium Oxide TiO_2	18·04
Silica SiO_2	1·75
Sulphur S	0·08
Phosphorus P	0·05

No information is given as to the tonnage available, but Finucane and Telford conclude that the ore is of too low a grade for use as ferro-titanium ore, and that its titanium content makes it valueless as an iron ore.

While in the district, an inspection of this deposit was made with the view of obtaining a further representative sample and getting some tonnage information. The sampling showed the average quality of ore to be as follows :—

	%
Acid Soluble Iron Fe	50·63
Silica SiO_2	1·66
Phosphorus P	0·02
Sulphur S	0·06
Manganese Oxide MnO	0·37
Titanium Ti	12·78

The tonnage available by quarrying was found to be negligible, only small portions of the outcrop protruding to any height above the hilly surroundings. The ore lenses are, as a rule, sandwiched between the massive country rocks and are not recoverable by cheap mining methods. This fact alone, quite apart from the chemical composition of the ore, deprives the deposit of economic significance.

Peak Hill Goldfield

MOUNT GOULD

(Map Ref. D2)

Precis by K. Berliat, D.Sc., from G.S.W.A. Bulletin 106, by W. Johnson, B.Sc. (Hons.).

General Information.

Mount Gould, one of the most conspicuous landmarks in the upper reaches of the Murchison Valley, rising to nearly 1,000 feet above the surrounding country, is located approximately in latitude 25° 48′ S. and longitude 117° 19′ E. The mountain is a double peak with the highest point and trigonometrical station on the eastern peak. It is about 200 miles from the nearest point of coast. The nearest town, Meekatharra, is approximately 100 miles by road to the south-east.

Geological Occurrence.

Mount Gould is composed of metamorphosed sediments, attributed to the Pre-Cambrian Whitestone complex. The principal rock types are gneisses, mica schists, ferruginous jaspilites and quartzites, which have been folded into a broad anticlinal fold, plunging 80° S.E. The limb, upon which the trigonometrical station is located, strikes due north and dips vertically, whilst the other limb has a strike in an east-north-east direction and a dip of 60° to the south. The ore bodies are well defined lenses of almost pure micaceous hematite in banded ferruginous jaspilites. The four major lenses occur in a jaspilite horizon on the north striking limb of the anticline.

The Ore Bodies.

No. 1 *Lens.*—This lens is approximately 2,000 feet north of Mt. Gould trigonometrical station. Its average height above the surrounding country is 555 feet, its length 700 feet and its average width 75 feet.

No. 2 *Lens.*—This lens is about 600 feet south of No. 1. The average height above the plain is 355 feet, the length 500 feet and the average width 55 feet.

No. 3 *Lens.*—The north end of the lens is approximately 30 feet west of the trigonometrical station. It has an average height above the plains of 790 feet, a length of 770 feet and an average width of 54 feet.

No. 4 *Lens.*—This is the largest lens and is close to the nose of the fold. The north end is approximately 150 feet to the south-east of the south end of No. 3. The lens has an average height of 555 feet, a length of 1,170 feet and an average width of 97 feet.

Surface Sampling.

A limited amount of sampling was carried out by R. A. Hobson and W. Johnson in 1946–47. The locations of the samples taken are described as follows :—

No. 1 : 200 feet from south end of No. 1 lens
No. 2 : 600 feet from south end of No. 1 lens
No. 3 : Middle of No. 2 lens
No. 4 : 300 feet from north end of No. 3 lens
No. 5 : 600 feet from north end of No. 3 lens
No. 6 : 300 feet from north end of No. 4 lens
No. 7 : 800 feet from north end of No. 4 lens.

Grade of Ore.

Partial analyses of the samples gave the following results :—

Sample No.	1	2	3	4	5	6	7
	%	%	%	%	%	%	%
Iron Fe	66·19	64·83	68·70	68·62	68·88	66·98	65·18
Silica SiO_2	2·43	4·02	0·52	0·60	0·35	1·56	2·41
Water H_2O	1·36	1·19	1·19	0·26	0·24	1·52	2·07
Titania TiO_2	0·02	0·02	0·03	0·01	0·02	0·03	0·06
Phosphorus P	0·06	0·13	0·04	Nil	0·01	0·07	0·07
Sulphur S	0·05	0·12	Nil	Nil	Nil	Nil	0·02

Tonnage.

Using a conversion factor of 9 cubic feet or ore per ton and assuming that the ore bodies maintain their dimensions down to the level of the surrounding plain, W. Johnson arrived at the following tonnages of ore :—

Ore Body	Volume	Tonnage
	cubic feet	long tons
No. 1 lens	29,138,000	3,238,000
No. 2 lens	9,763,000	1,085,000
No. 3 lens	32,848,000	3,649,000
No. 4 lens	62,987,000	6,998,000
Totals	134,736,000	14,970,000

Production.

The deposit has not at any time been worked.

MOUNT MARGARET GOLDFIELD

MOUNT SHENTON-MOUNT GRANT

(Map Ref. E4)

Field work by R. Connolly and K. Grimbly, report by R. Connolly.

General Information.

Mount Shenton is located 73 miles north-east of Laverton and is reached by a reasonably good track passing through the Cosmo Newberry Native Mission, the total distance from Laverton by road being 95 miles.

Mount Shenton and Mount Grant are approximately ten miles apart in a direction N. 30° W. and are centrally situated in a narrow greenstone belt oriented in the same direction and some 20 miles long.

Occurrence.

The central core of both mounts is a succession of jaspilite beds striking generally N. 25° W. and dipping at 60° to the east, with reversals in some places, in particular at Mount Shenton where the dip is 60° and steeper to the west. At the summit of Mount Shenton (Cairn M6) the jaspilites are highly contorted and predominantly siliceous with evidence of some interbedded greenstone schists.

Due to the obviously poor nature of the jaspilites with respect to iron content, no samples were taken, and although some time was spent examining the jaspilites along their strike, nothing resembling an economic grade of ore was seen.

LAVERTON AREA

(Map Ref. E4)

Field work and report by K. Berliat, D.Sc., assisted in the field by R. R. Connolly.

General Information.

The deposits described are centred about the old Gladiator mine, three miles west of Laverton, Mount Margaret goldfield.

They are close to and very easily accessible from the main road to Leonora. Laverton is approximately 68 miles by road from Malcolm, the nearest rail served town which is in turn 403 miles by rail from Esperance, the nearest port.

Occurrence.

A double line of ferruginous jaspilites striking north and dipping 65° east, extends on both sides of the Gladiator mine. The outcrop forms a number of low, discontinuous ridges, not exceeding 20 feet in height, and 50 chains in combined length. The western, or main band has a horizontal width of 50 feet, and the eastern bed, which is a chain or less away, of 12 feet. The jaspilites show coarse, regular white or yellow and grey or black banding and there is a strong development of siliceous layers.

A second occurrence, a quarter of a mile to the east, and about 10 chains south of the Leonora road, is within the limits of the old G.M.L. 1868T (" Sheila "). Here, a strong, tightly dragfolded jaspilite band, forms a prominent ridge some 40 feet high, striking in a general north-easterly direction for a distance of about 15 chains. At the northern end, due to folding, the horizontal width is about 100 feet, while the overall average width is approximately half that figure.

Sampling.

Owing to the uniform lithological development of the formation, only four representative samples were collected, two (Nos. 1 and 2) from the beds traversing the Gladiator mine and the other two from the " Sheila " horizon. The analytical results are given below :—

Sample No.	Per cent. Fe	Remarks
1	31·32	5 chains south from Leonora Road.
2	29·02	25 feet north of "Augusta Shaft," Gladiator Mine.
3	29·25	North end of "Sheila" horizon.
4	34·36	South end of "Sheila" horizon.

Partial analyses of group samples are as follows:—

Constituent	Gladiator Horizon	Sheila Horizon
	%	%
Acid soluble Iron Fe	30·34	32·02
Silica SiO_2	52·59	48·87
Phosphorus P	Trace	0·13
Total Sulphur S	0·03	0·04
Manganese Oxide MnO	0·02	0·06
Titanium Ti	Trace	Trace

Tonnage.

A factor of 11 cubic feet to the ton gives the following approximate tonnages:—

	long tons
Gladiator horizons	173,000
Sheila horizon	148,000
Total	321,000

Remarks.

A large development of jaspilites is found both to the north and to the south of Laverton. In the Cox's Find-Erliston area, 40 to 45 miles north, the jaspilites deserve mention because of their areal continuity and topographic prominence. The ridges can be followed in the field for long distances, in the order of tens of miles. They rise up to 200 feet above plain level, the major bands having a horizontal thickness of 40 to 50 feet. Lithologically, they are white and grey banded cherts with localized thin and lenticular ferruginous layers. At Mt. Clarke trigonometrical station for instance, there is a limited development of red and black banded ironstones of no commercial significance.

Similarly, the prominent ranges culminating in Mount Crawford and Mt. Weld, three miles north and 10 miles south of Laverton respectively, consist essentially of quartzites and banded cherts.

Between Laverton and Mt. Enniskillen, one mile south, there is a narrow low ridge, 20 to 25 feet high consisting of highly contorted and dragfolded banded ironstones. The quality of the material is generally poor, the siliceous fraction being far in excess of the ferruginous. A sample taken across the richest looking portion of the outcrop assayed only 28·54 per cent. Fe.

The same remarks apply to a number of parallel bands further to the west.

East Murchison Goldfield

MT. LAWRENCE-WELLS, BARLOWS

(Map Ref. E.3)

Field work by R. R. Connolly assisted by K. Grimbly.

General Information.

In the course of the present survey, both of these localities were examined for possible commercial iron ore deposits. From the flats to the east and south of Mt. Lawrence-Wells, high grade ore has been reported, a small quantity being reputed as having been smelted in Wiluna to yield "an excellent tool steel." At Barlows, ferruginous jaspilites were reported by H. W. B. Talbot (G.S.W.A. Bulletin No. 83).

Mt. Lawrence-Wells.

Mt. Lawrence-Wells is a prominent topographic feature 15 miles south of Wiluna and five miles west of the Wiluna-Leonora road. A signposted track from the Leonora road to a Lakeway Station outcamp passes a few miles to the south of the mount. The mount itself is made up of highly siliceous jaspilites (or banded cherts) striking north-west and dipping steeply to the south-west. It forms the southern extremity of a 10 miles long range running to the north-west.

In a reconnaissance of the low relief area to the south and east of Mt. Lawrence-Wells, only one occurrence of a predominantly hematitic rock was located. This was alongside the previously mentioned track to the outcamp at a distance of 1·9 miles from the Leonora road. The outcrop is on a small rise only a few feet above the general plain level and the area of outcrop is small. The strike extension of the body is obscured by soil, but eluvial material showed that the ore body rapidly reverts to a low grade ferruginous jaspilite. In view of the small size of the lens, no further attention was warranted.

Barlows.

This gold mining centre has now lost its original identity but is located in a mining reserve now known as the New England area, some six miles north-east of Barwidgee Station homestead. There is no existing mining activity on the reserve although the remains of old workings may still be seen.

In this area, several low jaspilite ridges were examined, some of which in places showed superficial capping of iron rich "cement." Down dip, it was obvious from natural outcrops and some small workings, that the capping passed into a weathered low grade ferruginous jaspilite.

The economic potentialities of this area, with respect to iron ore, are nil.

JOYNER'S FIND

(Map Ref. E.3)

Field work by R. R. Connolly assisted by K. G. Grimbly.

General Information.

Reports have in recent years reached this office of a "natural steel" deposit south-west of Wiluna, and in 1956 a brief inspection of the occurrence was made. From this preliminary inspection it was obvious that a quantity of high grade ore was available, and in 1958, in the course of the present survey a more detailed examination was made.

Specimens of this ore have also been smelted in Wiluna by a Mr. Jones, who was of the impression that the earlier reports of "natural steel" occurrences attributed to the Mt. Lawrence-Wells area were actually from the Joyner's Find deposit.

Location and Access.

The Lyndon goldmine at Joyner's Find is located some two miles north of the Wiluna-Sandstone road, from a point on that road 23 miles from Wiluna. The iron ore deposit is situated immediately to the east of the goldmine (abandoned). Road access from the deposit to Wiluna is reasonable, and from Wiluna to Meekatharra (the nearest functioning railway) the road distance is approximately 120 miles.

The Ore Deposit.

The iron ore deposit consists essentially of four iron rich jaspilite beds, interbedded with schistose greenstones. The jaspilites, together with the enclosed greenstone bands, form a prominent ridge with a north-westerly trend, the maximum height above the surrounding country level being 150 feet. The jaspilites are now represented at the surface by almost pure hematite.

The strike of the iron rich jaspilites is N. 20° W. and their dip is to the west at 60° and in some places steeper. The thickness of any one jaspilite bed may vary from four to 40 feet along the strike and, in a like manner, the thickness of the interbedded greenstone mullock varies from 10 to 100 feet.

A total length of 5,800 feet was measured, there being no topographically prominent exposures beyond these points. Within this length, the outcrop of the four main bands was not continuous, and for the purpose of quantity estimates only actual outcrop measurements were taken.

The eastern edge of the ridge is precipitous, while the western side slopes more gradually down to a valley wherein lie the old Lyndon goldmine workings. To the west again of the valley and approximately three-quarters of a mile from the deposit, another prominent ridge made up of a number of thin (15 feet) bands of poor to medium grade ferruginous jaspilite with interbedded greenstones, runs to the north for some miles. It was followed for some distance, but no further likely ore deposits were found.

Quantity Estimate.

In view of the outcrop discontinuities and the variable exposed width of the individual bands comprising the ore body, the total quantity of iron ore was calculated by summation of a series of ore blocks along the strike, assuming the dimensions at the outcrop persisted to the general level of the surrounding plain. A conversion factor of 7·6 cubic feet of ore to the ton, based on a specific gravity determination of a composite sample, was used throughout.

The figure thus determined was 2,275,000 tons of iron ore above the level of the surrounding plain.

Grade and Nature of the Ore.

The ore at this deposit is very nearly pure hematite as shown by analysis. In places the ore is quite massive, having lost all bedding characteristics, but this is probably a surface redistribution effect. Mainly, bedding is apparent on breaking a boulder, fine bands of splendent crystals showing up under certain conditions of light incidence.

Four samples taken across the strike, and omitting the interspersed greenstone bands, at intervals of 1,000 feet gave on analysis the following results :—

Lab. No.	G.S.W.A. Sample No.	Location of Sample	Acid Soluble Fe % on dry basis
3116/58	1	500 feet from south end	68·45
3117/58	2	1,500 feet from south end	68·28
3118/58	3	2,500 feet from south end	69·36
3119/58	4	3,500 feet from south end	69·18

A composite sample prepared by mixing equal parts by weight of the individual samples gave the following partial analysis :—

	%
Acid Soluble Iron Fe	68·81
Silica SiO_2	0·93
Phosphorus P	less than 0·01
Sulphur S	not detected
Manganese Oxide MnO	0·06
Titanium Ti	not detected

The grade of iron ore as exposed at the surface may therefore be accepted as being 68 per cent. metallic iron.

Summary and Conclusions.

In the vicinity of the Lyndon goldmine, a small, rich iron ore body exists which may contain 2¼ million tons of 68 per cent. iron ore down to plain level. Further extensive work by way of diamond drilling or tunnelling would be needed to positively establish the existence of even this tonnage. The ore occurs in four parallel bands, each band being separated from the others by greenstone schists. This manner of occurrence presents obvious mining difficulties and in view of this and the remote inland location, it is doubtful if this ore will be utilized in the near future.

BOOLYGOO RANGE

(Map Ref. E3)

Field work and report by K. Berliat, D.Sc.

General Information.

The southern extremity of this range is in latitude 28° 0′ S. and longitude 120° 0′ E., from which point it extends in a direction slightly west of north for a distance of 25 miles. The road from Sandstone to Lawlers goes past the south end of the range, 44 miles east of Sandstone. The latter town is 100 miles by road east of Mount Magnet, the nearest railhead.

With the exception of the central part, the range is relatively easily accessible by station tracks, the northern section from Boolygoo station homestead, and the south end from the Sandstone-Lawlers road.

Occurrence.

In the south the ore body forms a prominent ridge rising fairly abruptly to a height of 100 to 150 feet, and continuing without interruption for about one mile. The banded iron formations are very finely banded, bluish grey in colour, and expose intercalations of coarse, steel grey and yellow banded beds which appear to be particularly high in iron content. *Magnetite* is present in appreciable quantities.

The ridge is made up of one single bed having a true width of not less than 250 feet. It strikes north and dips at an angle of 55° to the west.

In the north the range is made up of a number of sub-parallel jaspilite bands, separated by hilly greenstone ridges. The jaspilites are similar to those in the south, but in the field appear to be richer in iron. Only a cursory inspection was made of this part of the deposit whilst the central parts were not inspected at all. From such observations as could be made there appears to be little doubt however, that the jaspilites form a continuous line of interrupted ridges from south to north.

Sampling.

The only systematic sampling was carried out over a length of one mile at the southern end of the range. Owing to the uniform nature of the deposit, the sample lines were spaced 500 feet apart and five composite samples, each made up of two individual samples, were submitted for analyses. From the north end, two representative samples from two individual bands approximately one mile south of Boolygoo station homestead were analysed.

Grade.

(a) South End—intervals 500 feet—

Sample No.	Iron, Fe Acid Soluble %
No. 1 South	39·79
2	40·13
3	39·69
4	39·96
5 North	39·22

(b) North End—

No. 1	36·39
2	43·21

Partial analysis of group sample, south end—

	%
Iron Fe	39·71
Silica SiO_2	39·95
Phosphorus P	0·09
Total Sulphur S	0·03
Manganese Oxide MnO	0·06
Titanium Ti	Trace

Tonnage.

Huge reserves of ore, in the order of tens of millions of tons, are available in this deposit, but such limited investigations as were carried out are quite insufficient to arrive at even a very vague approximation. A figure of 13 million tons alone has been arrived at for that portion at the southern end sampled in more detail.

MAYNARD HILLS

(Map Ref. E3)

Field work by R. R. Connolly and K. Grimbly, report by R. R. Connolly.

General Information.

The Maynard Hills lie immediately to the east of the Sandstone-Menzies road in the vicinity of Bulga Downs station homestead and extending in a general south-easterly direction to Mount Richardson.

The nearest accessible railway is at Menzies, a distance of approximately 130 miles from Bulga Downs of good track and formed earth road. Actual entry to the range over the few miles that separate it from the Menzies-Sandstone road is very limited, the only negotiable track to the southern part of the range being the station track to Fly Mill. This track leaves the main road some 17 miles south of the homestead and first cuts the hills 3·5 miles from the road.

Northwards from a point on the range approximately six miles north-west of Mount Richardson, granitic terrain is encountered, while still further north and immediately to the east of the Bulga Downs homestead, the Maynard Hills are composed of banded quartzites with little or no iron content.

Attention was accordingly confined to the section running from two miles north of the Fly Mill track to Mount Richardson, a total distance of some six miles. Here the hills are composed of finely banded ferruginous jaspilites.

Occurrence.

The ferruginous jaspilites form two prominent ridges which converge at a point some two miles north of the Fly Mill track. Each ridge is made up of four to six jaspilite bands separated by greenstones. The west ridge, from the point of convergence runs south-south-east for a distance of 3½ miles through Mt. Forest, then gradually loses topographic prominence. The east ridge runs approximately south-south-west for three miles then swings south and terminates a short distance past Mount Richardson. To the east, granitic terrain is in close proximity, but the actual contact is obscured by soil cover.

The strike of the jaspilite beds controls the trend of the ridges, and the dip of both ridges is generally to the west at between 70 degrees and 85 degrees. Whereas the east ridge invariably dipped to the west, some parts of the west limb dipped at steep angles to the east, indicating along with the arcuate outcrop line a possible south plunging syncline.

At the southern extremity of the eastern ridge a small lens of high grade hematite was discovered on the north-west slope of Mount Richardson. This material was blue-black when broken, of medium to fine grain size and somewhat granular in texture. It was very slightly friable. Some freshly broken surfaces showed a fine breccia structure, but the mode of formation and relationship to the flanking ferruginous jaspilites was not elucidated. Blocky scree from this ore made assessment of the size of the body very difficult as no positively " in situ " outcrop could be identified.

Sampling.

With the exception of the one high grade deposit, the remainder of the jaspilites were quite uniform in appearance. Six samples of the ferruginous jaspilite were taken, three on the west ridge and three on the east ridge at, as well as could be estimated, equal distances apart. Each sample was a composite, taken from across the jaspilite beds and omitting the interbedded greenstones. The jaspilites and greenstones were generally of equal proportions on the ridge top outcrops.

One sample (No. 6) was taken from across the width of the Mount Richardson high grade ore. As mentioned earlier, no " in situ " ore was identified and the sample was therefore taken from blocky eluvial material.

Grade.

On analysis, the following results were obtained :—

Lab. No.	G.S.W.A. No.	Locality (approx.)	Acid Soluble Iron Fe
			%
6539/58	1	East Ridge : At Fly Mill Fence	33·96
6540/58	2	1 mile south of Fly Mill fence	37·76
6541/58	3	2 miles south of Fly Mill fence	39·37
6542/58	4	West Ridge : 1 mile north of Fly Mill fence	36·41
6543/58	4A	At Fly Mill fence	37·99
6544/58	5	1 mile south of Fly Mill fence	39·84
6545/58	6	North-west slope Mount Richardson	67·45

A group sample, prepared by taking equal parts by weight of samples 1–5 (excluding 4A which was erroneously assessed in the field to be of lower grade), gave on partial analysis the following results :—

	% on dry basis
Iron Fe	37·41
Silica SiO_2	43·92
Sulphur S	0·01
Phosphorus P	0·04
Titanium Ti	0·01
Manganese Oxide MnO	0·02

Specific gravity 3·20

Tonnage.

So far as the medium grade ferruginous jaspilites are concerned, the inferred tonnage is so large that approximations may safely be made with the dimensions.

The average aggregate width of the multiple jaspilite bands (minimum of 4, maximum of 6) is taken at 140 feet. The average height is 100 feet and a total length of 9½ miles (west ridge 3½ miles, east ridge 6 miles), is assumed. A conversion factor of 11·2 cubic feet per ton, based on the specific gravity of the composite sample, has been used.

On these assumptions, a figure of approximately 61,000,000 tons of 37 per cent. iron content is obtained.

For the high grade lens at Mount Richardson, the following approximate dimensions have been assumed :—

Length : 350 feet

Width : 30 feet

Height : 175 feet

Conversion factor : 8·0 cubic feet per ton.

This gives 230,000 tons of high grade (67 per cent.) iron ore.

Summary.

Huge reserves of 37 per cent. iron ore exist in the southern part of the Maynard Hills, and one small deposit of high grade ore was noted. Under present day conditions however, neither the low nor the high grade ores in this locality are of economic importance.

Note.—H. W. B. Talbot, plate 1, Bulletin 45 includes the area described above in the Brooking Hills. Current nomenclature however, confines the Brooking Hills to that portion of the range to the south and west of the Menzies-Sandstone road. North and east of the road is known as the Maynard Hills.

MONTAGUE RANGE

(Map Ref. E3)

Field work by R. R. Connolly and K. Grimbly, report by R. R. Connolly.

General Information.

The Montague Range is a line of hills with a north-north-westerly trend cut near the southern end by the Wiluna-Sandstone road at a point on that road approximately 60 miles from Sandstone.

The most prominent topographic features of the range are the twin hills of Mt. Townsend in the north and Mt. Marion approximately 6 miles to the south-south-east, both situated in the northern part of the range and visible for long distances.

An early report by Blatchford (G.S.W.A. Annual Report, 1898) mentioned the occurrence of ferruginous jaspilites at both Mt. Townsend and Mt. Marion and along the hills connecting the two. Simpson (Minerals of W.A., Vol. II) records figures of 43 per cent. and 48 per cent. hematite content, based on specific gravity determinations, for specimens from Mt. Townsend and Mt. Marion respectively. These figures correspond to metallic iron contents of 30·1 per cent. and 33·6 per cent.

There is no record of higher grade ores in this locality.

Access.

Access to the southern part of the range is via the Sandstone-Wiluna road. Mt. Townsend is reached via Gidgee station homestead (now located at the old mining centre of Jonesville) using station tracks and finally a long disused track eastward past Townsend Well (now collapsed) to the north-west slopes of the mount. The last three miles of this track are barely negotiable.

Occurrence.

A very thick bed (140 feet measured width) of brown, coarse banded jaspilite striking N. 25° W. and dipping variously vertical or steeply to the west, forms the backbone of both mounts. Highly weathered greenstones (?) flank the jaspilites.

The two mounts were traversed on foot, following the strike of the jaspilites and no improvement in grade was noticed. Between Mt. Townsend and Mt. Marion the ridge is only about 50 feet high and the jaspilite appears to thin out to approximately 40 feet in width.

Sampling and measurement was confined to the top of both mounts and the following outcrop dimensions were recorded :—

Mt. Townsend :
Length : 1,900 feet
Width : 140 feet
Average height : 300 feet

Mt. Marion :
Length : 1,700 feet
Width : 120 feet
Average height : 250 feet.

The total approximate tonnage to plain level in the two main exposures is therefore 12,000,000 tons, using a conversion factor of 11 cubic feet per ton.

In view of the uniform nature of the jaspilite, only one sample was submitted for analysis. This was a composite of two samples, one from across the strike at the top of Mr. Townsend and the other likewise from Mt. Marion. The metallic iron content was 34·02 per cent. (Lab. No. 6553/58).

In the south-eastern portion of the range the jaspilites are thin and the outcrops scattered. There is a large tonnage of ferruginous jaspilite in the area, but none of workable concentration was seen. Four samples were taken from this area at one mile intervals on either side of the Sandstone-Wiluna Road and the following results of a partial analysis of a group sample indicate the composition of the ore.

	% on dry basis
Acid Soluble Fe	35·44
Silica SiO_2	45·86
Phosphorus P	0·03
Total Sulphur S	0·06
Manganese Oxide MnO	Nil
Titanium Ti	Trace

BLACK RANGE DISTRICT

(Map Ref. E.3)

Field work and report by K. Berliat, D.Sc.

General Information.

The area described includes the country around Sandstone and the old goldmining centres of Nungarra and Handcocks, seven miles south-south-west and four miles south-east respectively therefrom. Sandstone township is 104 miles east of Mt. Magnet, the nearest rail head.

Occurrence and Nature of Jaspilites.

East and west striking jaspilites are met with in all three centres. Although all are of the ferruginous variety and in places appear to be very rich in iron content, they are of very little economic value as iron ore deposits because of their limited extent, thinness, and in most cases, topographical insignificance.

At the old Handcocks' diggings there are over a dozen short, lenticular, parallel bands spread over a section of slightly over one mile. They are individually less than 10 feet wide and protrude only a few feet, or not at all, above the surrounding country. Lithographically all identical and highly ferruginous, they are of the red and black banded variety. A representative sample assayed 52·29 per cent. metallic iron.

About half a mile north of the old townsite of Nungarra and immediately west of the road to Sandstone there is a rather prominent ridge, up to 50 feet high, formed by a jaspilite band dipping 45° north and of an average true width of 30 feet. As the red and black banded bed appeared to be high in iron content, four representative samples were taken. They assayed 57·51 per cent., 39·81 per cent., 37·22 per cent. and 35·18 per cent. of metallic iron. The total tonnage available is probably not more than 275,000 tons.

The jaspilites slightly south and south-east of Sandstone are in all respects similar to those at Hancocks and have hardly any topographic expression.

Murchison Goldfield

In addition to the occurrences described later in this section, two other localities, *viz.*, Stakewell and Meekatharra were inspected as jaspilites were known to occur at these places. At neither locality was any iron rich body of commerial significance seen, the jaspilites being of poor grade and lacking topographic prominence.

GABANINTHA

(Map Ref. E.3)

Field work by K. Berliat, D.Sc. and R. R. Connolly, report by K. Berliat, D.Sc.

General Information.

A. Gibb Maitland in 1904 first drew attention to what he called "a large deposit of titaniferous magnetite about half way between Gabanintha and the Star of the East Goldmine." He estimated the tonnage above the general level of the plain to be approximately 1,500,000 tons.

The deposit is situated 25 miles by road south-south-east from Meekatharra. It is also accessible from Nannine, a mining centre 21 miles by road to the west.

Occurrence.

The lode strikes between north and N. 20° W. and forms a number of low discontinuous ridges, the most prominent of which has a length of 1,500 feet and an average height above plain level of about 40 feet. The lode can be followed for a total length of 9,000 feet, but in outcrop only about half of that distance stands above the general level of the country. The gaps between the hills are up to a quarter of a mile long and most of the hills stand no more than 30 feet above plain level.

The ore is uniformly massive without any traces of banding. The high percentage of ilmenite would suggest that the outcrop represents the gossan of a basic dyke-like body.

The dip of the ore body cannot be ascertained with certainty from surface examination. Only in one instance could a dip of 50° to the east be suggested.

Sampling.

Wherever possible, chip samples across the strike were taken every 100 feet and five composite samples, made up by a number of these individual samples, were assayed for iron.

No. 1 sample consisted of 14 individual samples taken over the most northern portion of the lode. (Total length of discontinuous outcrop 1,400 feet.)

No. 2 sample comprised eight individual samples from outcrops further to the south.

Samples Nos. 3 and 4 are representative of the ore exposed in the most continuous outcrops (1,500 feet long) and consist of eight and seven individual samples respectively.

No. 5 sample is made up of 10 individual samples collected over the southern, discontinuous portion of the outcrop (1,000 feet).

Grade.

The grade of the iron ore is illustrated by the following analytical data:—

Sample No.	Iron, Fe Acid Soluble on dry basis %
1	53·80
2	53·27
3	53·76
4	53·68
5	54·08

A composite of the five samples listed above gave the following results on partial analysis :—

	%
Acid Soluble Iron Fe	53·77
Silica SiO_2	1·73
Titanium Ti	8·88
Manganese Oxide MnO	0·06
Sulphur S	0·04
Phosphorus P	Trace
Specific gravity	4·66

Reserves.

Taking the combined length of the various hills as being 4,500 feet, the mean width of the lode as 15 feet, and the average height above the plain as 25 feet, and applying a conversion factor of 8·5 cubic feet per long ton, the reserves have been calculated at 200,000 tons above plain level.

Remarks.

This deposit is of no value as a source of iron ore, both on account of the low tonnage and the high titanium content.

TUCKANARRA

(Map Ref. E.2)

Field work and report by K. Berliat, D.Sc.

General Information.

The small settlement and railway siding of Tuckanarra is situated on the Great Northern Highway and railway 26 miles north of Cue, the administrative centre of the Murchison Goldfield. Cue lies approximately 400 miles by rail or road north of Perth and 300 miles east of Geraldton, the nearest port.

Potable water in the district is drawn from rainwater tanks, supplemented for other purposes by limited well supplies.

Occurrence.

C. G. Gibson, who first mapped the district in 1904, commented on banded iron formations as follows : "Traversing the greenstones are numerous parallel bands of hematite bearing quartzites. North of the railway line these run in a general north-north-easterly direction, but south of it they take a sudden turn to the east and run on a bearing varying from south-east to almost due east . . . . .they run in narrow parallel belts, occasionally passing imperceptibly into foliated greenstone, from two to three feet to as much as a chain or two in width, and from one to five chains apart, and can be followed on the surface for a considerable distance."

Gibson's mapping indicates that the jaspilites are near a structural nose, forming the two limbs of a south-westerly plunging anticline. The northern limb, north of the railway line, consists of two belts, separated by a stretch of alluvium. Each belt is approximately half a mile wide, one containing 13 and the other 18 individual lenses over a total length of about one and one half miles and one mile respectively.

The corresponding members of the southern limb are found outcropping to the south of the railway line.

The only belt which could possibly be of economic interest is north of the railway line, approximately a mile and one half east-north-east from Tuckanarra townsite. Here, a great number of japilite bands (Gibson mapped 18) form a broad north striking ridge, 60 to 70 feet in height and about one mile long. As far as the outcrops go, the bands are individually thin, in in the order of 10 feet or less. However, their actual thickness cannot be determined as the intervening strips of country are covered by ironstone rubble which may or may not be underlain by jaspilites. No outcrops of the usual greenstone rocks could be observed between the jaspilite formations.

Grade.

All the bands are lithologically identical, the steel grey, iron rich layers predominating over the yellowish brown siliceous layers. Analysis of samples of similar material collected by Gibson from a locality eight and a half miles north-east of the townsite gave 40·5 and 38·1 per cent. metallic iron.

Tonnage.

The tonnage depends on the nature of the rocks between the jaspilite bands in situ. If these strips consist predominantly of banded ironstones the deposit may prove to be of economic significance. On the other hand, if the intervening horizons are made up of greenstones, the occurrence is commercially useless. A certain amount of surface exploration by costeening should clear the matter up. Prior to this it would be futile to attempt the computation of ore reserves.

LAKE AUSTIN AREA

(Mainland, Island, Moyagee)

(Map Ref. E2)

General Information.

Occurrences of ferruginous jaspilites are found at Lake Austin in the three old goldmining centres of Mainland, Island and Moyagee. They are part of the same belt, separated from each other by saline lake flats. All the deposits are adjacent to the road and railway line from Mt. Magnet to Cue. The old Austin townsite, on the Island, is 14 miles south of Cue. Mainland and Moyagee form the north-eastern and south-western extensions respectively. All occurrences are easily accessible.

The Island.

Field work and report by K. Berliat, D.Sc.

The Island, a positive relief element surrounded by the salt flats of Lake Austin, lies immediately to the east of the road and railway line from Mt. Magnet to Cue. It has a length of three miles in a north-south direction and a width of 60 chains at its widest point.

Occurrence.

The Island consists of medium to coarse grained hornblende and hornblende-feldspar rocks traversed by a number of ferruginous jaspilite bands striking N. 25° E. and dipping at high angles to the west. Most of the bands are thin, lenticular and topographically of little prominence. The most conspicuous band is that on which the Austin trigonometrical station is located. It extends for a distance of nearly two miles and protrudes over half that length to about 30 feet above its immediate surroundings. Its width would be nowhere greater than 30 feet.

Three samples taken at approximately equal intervals along the strike of the main band gave on analysis 30·42, 39·87 and 37·46 per cent. metallic iron respectively.

The Mainland.

Field work and report by K. Berliat, D.Sc.

This occurrence is in an area located about five miles north-east from the old Austin townsite. The geological conditions are identical with those at the Island, a number of low, interrupted jaspilite ridges traversing medium to coarse grained greenstones in a general east-north-easterly direction. The trigonometrical station is located on what may be considered as the main band which has a length of some two miles and forms a number of hills, 30 to 40 feet high north-east of the cairn.

Two samples taken across the strike over widths of 20 feet gave an analysis 37·91 and 34·06 per cent. metallic iron respectively.

Moyagee.

Field work and report by R. R. Connolly assisted in the field by K. Grimbly.

The ferruginous jaspilites which form the south-west extension of the Austin beds outcrop in a series of low hills immediately to the south-east of the old Moyagee mining centre. This centre is reached by a track leaving the main highway about one mile south of Austin siding.

Occurrence.

Four parallel bands of jaspilite striking N. 40° E. and vertical, or dipping steeply to the west, can be traced for 2¼ miles along the strike. The main band which has a maximum width of 20 feet is flanked on the south-east by two thinner bands and to the north-west by one smaller band. The main band forms the crest of the ridge which reaches a maximum height of 50 feet above the surrounding plain at an unmarked cairn, half a mile from the northern limit of the ridge.

Highly weathered greenstone schists separate the jaspilite beds, these intervening strips being up to 300 feet wide and generally covered with loose jaspilite fragments.

As the flanking bands are thin and of much less topographic significance, attention was confined to the main bed. This was found to be uniform in grade throughout its length, varied in height from 20 to 50 feet above the surrounding general level, and in width from 10 to 20 feet. A composite sample made up of two individual samples taken one mile and one and three-quarter miles from the southern end (at the cairn) assayed 32·65 per cent. iron, confirming the visual estimate of poor grade apparent in the field.

Based on length of 11,000 feet, width of 15 feet average and height of 35 feet and using a conversion factor of 10 cubic feet per ton for this grade of ore, a quantity of 577,500 tons above plain level is obtained.

In view of the attenuate nature of this, and the extension deposits of the Island and Mainland, and the overall low grade, no economic significance can be placed on these deposits.

MOUNT MAGNET

(*Warramboo*)

(Map Ref. E2)

Field work by K. Berliat, D.Sc., and R. R. Connolly. Report by K. Berliat, D.Sc.

General Information.

Mount Magnet (trigonometrical station K5) is a prominent landmark 2½ miles north-west of Mt. Magnet townsite. The town (population 900) lies on the northern railway, 400 miles from Perth. It is also on the Great Northern Highway, 350 miles from Perth via Wubin and Payne's Find. The nearest port is Geraldton, 200 miles by rail or road from Mt. Magnet.

The deposit is easily accessible, a number of tracks leading right to the foot of the mountain.

Occurrence.

Structurally, the banded ironstones forming the deposit are located on the overturned eastern limb of a major synclinal structure (Boogardie Syncline). They form a tightly compressed southerly plunging dragfold exhibiting steep easterly dips (70° to 80°).

The jaspilites, which appear to be rich in iron are predominantly steel grey to black, the hematite rich layers being interbedded with red or white siliceous layers. The length of the beds, in a north-south direction, that could be profitably worked by quarrying methods, is approximately 2,000 feet, with an average true width of 150 feet and an average height above plain level of 300 feet.

Grade.

Five representative samples were analysed with the following results :—

Locality—	Metallic Iron %
400 feet south of trig. station	31·74
At trig. station	36·05
400 feet north of trig. station	35·90
800 feet north of trig. station	38·37
1,200 feet north of trig. station	37·31

A composite sample, made up from the above five individual samples showed on partial analysis the following composition :—

	%
Iron Fe	35·65
Silica SiO_2	46·38
Titanium Ti	Trace
Manganese Oxide	0·02
Sulphur S	0·01
Phosphorus P	0·05

Tonnage.

On a basis of 10 cubic feet of ore per long ton and using the dimensions of the deposit as described, the inferred ore reserves amount to 9,000,000 tons.

JUMBULYER

(Map Ref. E2)

Field work by K. Berliat, D.Sc., and R. R. Connolly, report by K. Berliat, D.Sc.

General Information.

Access to the banded iron formations forming the Jumbulyer Range is gained from Mt. Magnet by a station track which leads close to Jumbulyer trigonometrical station K14, approximately 10 miles south-south-west from the townsite.

Occurrence.

In the vicinity of Jumbulyer trigonometrical station there are three distinct jaspilite bands, but the main band is the one on which the trigonometrical station is located. This band, dipping 70° E., extends in a north-north-westerly direction from one mile south of the trigonometrical station to 2¼ miles north of it, at which point it is cut off and laterally displaced by a major fault.

The average horizontal width of the band is 100 feet, and a height of approximately 80 feet above the plain is reached.

Sampling.

Due to the uniform lithological nature of the outcrop, samples were taken at intervals of approximately a quarter of a mile, three composite samples, each consisting of four individual samples being submitted for analysis. No. 1 sample is representative of the quality south of the trigonometrical station; No. 2 and No. 3 going north are representative of the quality to the north of the trigonometrical station.

Grade.

On analysis the samples showed the following metallic iron (Fe) content :—

	%
No. 1	36·78
2	40·11
3	32·22

Partial analysis of a group sample from the three samples above gave the following results :—

	%
Iron Fe	36·30
Silica SiO_2	30·29
Titanium Ti	Trace
Manganese Oxide MnO	Trace
Sulphur S	0·03
Phosphorus P	0·02

Tonnage.

Taking a total outcrop length of 2½ miles (to allow for various gaps) and using a factor of 11 cubic feet per ton, the tonnage above plain level for the main band is estimated to be 10,000,000 tons.

WELD RANGE

(Map Ref. E2)

Precis by K. Berliat, D.Sc., from G.S.W.A. Bulletin 106.

General Information.

The Weld Range deposits (approximate latitude 26° 56′ S. and longitude 117° 42′ E.) are situated 35 miles in a direction N. 15° W. from Cue which is about 265 miles by road or rail from the port of Geraldton. From Cue, the deposits are easily accessible by road and station tracks.

The Weld Range deposits contain the famous Native Wilgie Mia red ochre cave. This cave is situated two miles south of Mt. Lulworth and five miles east of the Weld Hercules Goldmine. It has been opened out in the softer portions of the hematite, the excavations measuring 15,000 cubic yards. Over the centuries, many tons of " Wilgie " (war paint) have been traded by the aborigines all over Australia.

Geological Occurrence.

The general trend of the Weld Range is parallel to two major jaspilite horizons striking N. 50° E. The jaspilites are both of the ferruginous and siliceous variety and form two lines of hills, two to four miles apart, along the northern and southern fringe of the range. The central part consists of intermediate to basic intrusives.

The ore bodies are associated with ferruginous jaspilites, and consists of six high grade lenses of massive to specular hematite with local earthy or ochreous varieties. With one exception, the lenses occur along the southern line of jaspilite hills. Conformably with the jaspilites, their dips vary between vertical and 80° S.E.

The Deposits.

Ore bodies Nos. 1 to 5 are located in a straight line along the strike of the southern jaspilite.

No. 1 Ore Body.—This body is located in the south-west end of the old M.C. 20, and contains the Wilgie Mia ochre cave. It has a length of 1,900 feet and an average width of 58 feet. The average height above the surrounding plain is 400 feet.

No. 2 Ore Body.—Situated in the north-eastern portion of M.C. 21 (now surrendered), this ore body forms the south-westerly continuation of No. 1. The length is 800 feet, the average width 33 feet and the average height 300 feet.

No. 3 Ore Body.—This ore body is located at the north-east end of M.C. 27, and has a length of 1,700 feet. The average width and height are 76 feet and 400 feet respectively.

No. 4 Ore Body.—This lens contains the "Little Wilgie Mia" ochre deposit and lies in the south-west corner of M.C. 27. The length is 700 feet, the average width 124 feet and the average height 400 feet.

No. 5 Ore Body.—Located 1½ miles N. 50° E. from the north-east corner of M.C. 20, this ore body is 900 feet long, averages 45 feet in width and has an average height of 420 feet.

No. 6 Ore Body.—This body occurs on the northern jaspilite horizon, approximately two miles in a direction N. 10° E. from Mt. Lulworth. It is 1,300 feet long, 31 feet wide and has an average height of 400 feet above plain level.

Sampling.

W. Johnson (G.S.W.A. Bulletin 106) gives the following locations of samples submitted by him for analyses :—

No. 1 : 700 feet from east end of No. 1 ore body
2 : 1,100 feet from east end of No. 1 ore body
3 : 1,500 feet from east end of No. 1 ore body
4 : 1,900 feet from east end of No. 1 ore body
5 : 400 feet from east end of No. 2 ore body
6 : 800 feet from east end of No. 2 ore body
7 : 400 feet from east end of No. 3 ore body
8 : 1,000 feet from east end of No. 3 ore body
9 : Centre of No. 4 ore body
10 : Across north-east end of No. 5 ore body
11 : 400 feet from north-east end of No. 5 ore body
12 : 880 feet from north-east end of No. 5 ore body
13 : 400 feet from north-east end of No. 6 ore body
14 : 800 feet from north-east end of No. 6 ore body

Grade of Ore.

The results of partial analyses of the above samples are given in the following table :—

Constituent	Sample No.								Sample No.					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Iron, Fe Acid Soluble	63·69	62·72	62·02	62·59	57·34	57·47	62·58	66·30	60·73	66·28	66·44	63·57	56·49	64·28
Silica SiO_2	1·78	2·35	2·45	3·85	4·62	4·58	4·47	2·08	6·07	2·49	1·89	4·29	15·68	2·11
Water H_2O	5·17	5·98	5·87	2·05	10·63	10·35	3·41	1·06	2·83	1·00	1·17	2·22	2·47	4·32
Titania TiO_2	0·02	0·02	0·04	0·02	0·05	0·02	0·03	0·03	0·10	0·05	0·03	0·05	Trace	Trace
Phosphorus P	0·27	0·18	0·31	0·15	0·27	0·09	0·16	0·11	0·22	0·11	0·08	0·07	0·07	0·12
Sulphur S	0·08	0·06	0·09	0·11	0·07	0·02	0·09	0·05	0·14	Trace	Trace	0·02	0·05	0·02

Tonnage.

Using a conversion factor of 9 cubic feet per ton, W. Johnson arrived at a figure of 18,810,000 long tons, as representing the total reserves of all ore bodies down to the level of the surrounding plains.

The inferred reserves for the individual ore bodies are as follows :—

	Long tons
No. 1 Ore Body	4,890,000
No. 2 Ore Body	880,000
No. 3 Ore Body	5,740,000
No. 4 Ore Body	3,730,000
No. 5 Ore Body	1,890,000
No. 6 Ore Body	1,680,000
Total, All Bodies	18,810,000

Production.

There has been no commercial production of iron ore from any of the ore bodies in this group.

MOUNT HALE

(Map Ref. D.2)

Precis by K. Berliat, D.Sc., from G.S.W.A. Bulletin 106, by W. Johnson, B.Sc.

General Information.

Mt. Hale, a peak in the Jack Hills, is located approximately in latitude 26° 21′ S. and longitude 117° 16′ E. Access from the southern part of the State is gained via Meekatharra, which is about 95 miles to the south-east from the occurrence.

Geological Occurrence.

Mt. Hale is formed of strongly dragfolded ferruginous and siliceous jaspilites, striking N. 40° W. and dipping steeply to the south-east. A high grade hematite lens occurs in the crest of a large dragfold in ferruginous jaspilites at the summit of the mount.

The Deposit.

The lens is two chains south-west of Mt. Hale trigonometrical station and its dimensions are stated to be as follows :—

	feet
Length	500
Average Width	31
Average height above surrounding plains	800

Grade.

A sample taken across the centre of the lens assayed as follows:—

	%
Iron Fe	67·77
Silica SiO_2	0·48
Water H_2O	0·69
Titanium Oxide TiO_2	0·02
Phosphorus	0·28
Sulphur S	Trace

Tonnage.

According to W. Johnson, the inferred reserves above plain level are 1,380,000 tons.

YALGOO GOLDFIELD

TALLERING RANGE

(Map Ref. E.2)

Precis of previous work (mainly G.S.W.A. Bulletin 106, by W. Johnson, B.Sc.), by K. Berliat, DSc., supplemented by later work by G. H. Low, B.Sc., and R. Connolly.

General Information.

Tallering Peak (approximate latitute 28° 7′ S. and longitude 115° 28′ E.), the highest peak in the short Tallering Range, lies 31 miles N. 14° E. from Mullewa and is accessible from that town by road following the northern telegraph line for 35 miles and thence westerly for five miles by fence track. Mullewa is 71 miles by rail from Geraldton, the nearest port.

Geological Occurrence.

The Tallering Range is made up of highly folded Pre-Cambrian rocks of probable Whitestone age. The main rock types include basic ingeous rocks, sandstones, conglomerates and japilites. The regional strike is N. 50° E. and dips are vertical or steeply to the north-west. In places the low grade ferruginous jaspilites comprising the backbone of the range pass, at the surface, into lenses of apparently dense, finely granular hematite which form the Tallering ore bodies.

The Ore Bodies.

There are three lenticular ore bodies which will be referred to as the Numbers 1, 2 and 3 lenses, the numbering being from north to south.

The No. 1, or main lens is at the summit of Tallering Peak, approximately one and a quarter miles in a direction N. 30° E. from Tallering trigonometrical station. The dimensions (G. H. Low, 1958) are as follows:—

	feet
Length	540
Average width	75
Average height	480

The No. 2, or middle lens is approximately half way between Tallering Peak and the Tallering trig. station. Its dimensions are as follows:—

	feet
Length	220
Average width	40
Average height	380

The No. 3, or Trig. Hill lens is located at the trigonometrical station and its approximate dimensions are as follows:—

	feet
Length	290
Average width	25
Average height	600

Sampling.

The ore bodies were sampled by W. Johnson in 1947, the sample locations being as follows:—

Sample No. 1: 100 feet from north-east end of No. 1 lens.
Sample No. 2: 100 feet from south-west end of No. 1 lens.
Sample No. 3: Centre of No. 2 lens.
Sample No. 4: 100 feet from north-east end of No. 3 lens.
Sample No. 5: 100 feet from south-west end of No. 3 lens.

Grade.

Partial analyses of the above samples gave the following results:—

Sample No.	1	2	3	4	5
	%	%	%	%	%
Iron Fe	63·27	62·34	59·96	68·66	64·90
Silica SiO_2	7·23	8·82	12·87	0·43	4·41
Water H_2O	1·62	1·39	0·94	0·38	0·96
Titania TiO_2	0·01	0·01	Trace	0·03	Trace
Phosphorus P	0·13	0·15	0·19	0·09	0·10
Sulphur S	0·04	0·05	0·03	0·08	0·06

Tonnage.

On the basis of nine cubic feet of ore per long ton and the previously listed dimensions, the following estimates of ore reserves above plain level are arrived at:—

	long tons
No. 1 Lens	2,160,000
No. 2 Lens	371,000
No. 3 Lens	483,333

Present Exploration.

At the time of writing, a diamond drilling programme of four holes designed to test the downward continuation of the three lenses is in progress (May, 1959). Although a full report on the drilling programme will not be available until the completion of the remaining two holes on the No. 2 and No. 3 lenses respectively, two facts concerning the No. 1 lens are immediately recognizable, *viz.*,: firstly the ore at depth changes in character from hematite rich to magnetite rich and secondly the grade is poorer at depth. This the established behaviour of all explored *jaspilitic* iron ore bodies in Western Australia.

Production.

There has been no production from the Tallering Range deposits although, prior to the current diamond drilling exploration programme, the Western Australian State Government sought from the Commonwealth Government an export permit with the view of exploiting the deposits for overseas sale.

MOUNT GIBSON

(Map Ref. F.2)

Field work by K. Berliat, D.Sc., and R. R. Connolly. Report by K. Berliat, D.Sc.

General Information.

Situated between Lake Monger and Lake Moore, approximately in latitute 29° 35′ S. and longitude 117° 10′ E., Mt. Gibson is accessible from the Great Northern Highway via Ninghan station, some 60 miles north-east of Wubin. A rough station track leads from the homestead to the deposit, the distance being about 14 miles. The road or rail distance from Wubin to the ports of Fremantle or Geraldton is in the vicinity of 220 miles.

A. Gibb Maitland (G.S.W.A. Ann. Rep. 1916) described the deposit as a large lens about 2,000 feet in length, 200 feet wide and rising to a height of 300 feet above the general level of the surrounding country. According to him, there is not less than 10,000,000 tons of iron ore in the deposit.

Occurrence.

Mt. Gibson forms part of a range of hills made up of jaspilites striking N. 30° W. and dipping at high angles to the east. The average exposed horizontal width of the beds is about 60 feet, but no doubt they are considerably wider in many places, particularly in the vicinity of the conspicuous hematite monolith at the southern end of the deposit, where they measure not less than 350 to 400 feet. The jaspilites enclose two high grade hematite lenses.

The main lens, on which is situated the monolith already mentioned, consists of massive hematite and has a length of 700 feet and a horizontal width of 55 feet.

The second lens, 300 feet further to the north is 500 feet long and its exposed width varies between 33 feet and 80 feet.

The two lenses are separated by red and grey banded jaspilites which, in the field, appear to be of much inferior quality. Jaspilites of similar appearance can also be observed between the north lens and Mt. Gibson trigonometrical station. North of this point and south of the south lens, siliceous varieties become increasingly prominent.

Sampling.

Three samples were collected from each high grade lens and a further six samples were taken to show the iron content of the jaspilites between the lenses and to the north of the No. 2 lens.

Grade.

The following results of analyses show the grade of ore at the surface of the No. 1 (south) lens and the No. 2 (north) lens :—

Location of Sample	Iron Fe, acid Soluble on dry basis
	%
No. 1 lens—	
North end	65·70
Middle	64·75
South end	67·29
No. 2 lens—	
North end	65·29
Middle	64·56
South end	65·04

A sample taken from between the two lenses assayed 39·93 per cent. metallic iron, and the five samples taken from between the north end of the No. 2 lens and Mt. Gibson trigonometrical station 1,500 feet to the north, yielded metallic iron contents varying between 37·26 per cent. and 41·96 per cent.

Details of analysis of a group sample made up from the individual samples from the ore lenses are as follows:—

	%
Iron Fe acid soluble	66·22
Silica SiO_2	0·90
Titanium	Trace
Manganese Oxide MnO	0·01
Sulphur S	Trace
Phosphorus P	Trace

Tonnage.

Calculations of tonnage for the two ore lenses have been made on a basis of eight cubic feet of ore per ton, an average true width of 50 feet, and an average height above plain level of 300 feet.

Inferred reserves are thus as follows:—

	tons
No. 1 (south) lens (700 feet long)	1,312,000
No. 2 (north) lens (500 feet long)	938,000
Total for both bodies	2,250,000

The combined reserves of low grade ore existing between the trigonometrical station and the No. 2 lens and between the two lenses are estimated at approximately 2,220,000 tons based on dimensions of 1,800 feet length, 80 feet average width and 200 feet average height.

North Coolgardie Goldfield

EDJUDINA RANGES

(Map Ref. F.4)

Field work and report by K. Berliat, D.Sc.

General Information.

The Edjudina Ranges form portion of a large jaspilite belt, extending from Lake Carey in the north to Pinjin in the south a total length of over 70 miles. The outcrops form a number of conspicuous landmarks such as Yabboo Hill in the south, and Mt. Millicent, Mt. Howe, Mt. Hornett and Mt. Florence in the north between Lake Raeside and Lake Carey. As it was obviously not within the scope of this reconnaissance survey to examine the formations along their total length of strike, a limited sector had to be chosen for investigation.

The Edjudina section described hereunder was mentioned by A. Gibb Maitland (G.S.W.A. Bulletin No. 11) as far back as 1903 as a possible source of iron ore. It forms a most prominent, almost uninterrupted ridge, five miles long and culminating near the southern end in Yabboo Hill. This Hill (trig. station E36) is about five miles south-east from the old goldmining centre of Edjudina, which is in turn approximately seven miles east of Yarri. Edjudina is reached from Yarri by a station track via the old "Paget" mine. The ranges are intersected about three miles further east and over that distance are of difficult accessibility. Apart from station bores and dams there are no water supplies in the area.

The road distance from Kalgoorlie to Yarri via Kanowna is 108 miles.

Occurrence.

Dip evidence favours the interpretation that the three parallel jaspilite bands forming the Edjudina Ranges are but one horizon, and that folding has caused a repetition of the beds within a width of about 15 chains. The bands have a regional strike of N. 40°-45° W. and a regional dip of 75° E. to vertical. Their average true thickness is approximately 25 feet and the mean height above plain level, somewhere in the vicinity of 200 feet.

Within the area examined, the three bands are very similar lithologically. There are local compositional variations, but as a whole the formation is remarkably uniform along the strike.

Sampling.

Sampling was carried out over a total length of five miles starting in the south at a point half a mile south of Yabboo Hill. Samples were taken alternatively along each band at intervals of approximately 20 chains.

Grade.

The results of analyses of the samples are shown in the following table :—

	Iron, Fe acid soluble on dry basis %
No. 1—Lab. No. 2737/56	35·29
No. 2—Lab. No. 2738/56	31·75
No. 3—Lab. No. 2739/56	34·93
No. 4—Lab. No. 2740/56	37·68
No. 5—Lab. No. 2741/56	35·92
No. 6—Lab. No. 2742/56	40·06
No. 7—Lab. No. 2743/56	39·65
No. 8—Lab. No. 2744/56	42·92
No. 9—Lab. No. 2745/56	36·95

	Iron Fe acid soluble on dry basis %
No. 10—Lab. No. 2746/56	39·42
No. 11—Lab. No. 2747/56	36·49
No. 12—Lab. No. 2748/56	41·94
No. 13—Lab. No. 2749/56	40·44
No. 14—Lab. No. 2750/56	38·11
No. 15—Lab. No. 2751/56	42·05
No. 16—Lab. No. 2752/56	43·90
No. 17—Lab. No. 2753/56	33·26
No. 18—Lab. No. 2754/56	40·55
No. 19—Lab. No. 2755/56	40·40

Partial analysis of a group sample prepared by taking equal weights of individual samples gave the following results:—

	%
Acid Soluble Iron Fe	38·09
Silica SiO_2	43·88
Phosphorus P	0·03
Total Sulphur S	0·03
Manganese Oxide MnO	0·01
Titanium Ti	Trace

Specific gravity 3·55

Tonnage.

From the specific gravity determination a conversion factor of 10 cubic feet to the ton of ore is obtained. On this basis, one single band would contain 13,200,000 tons in a length of five miles. To allow for discontinuities and lenticularity (developed mostly in the third band) only two major bands will be taken into account. The total tonnage is therefore 26,400,000 tons.

Remarks.

It is probable that very substantial additional ore reserves of similar quality are available for many miles both to the north and south of the area examined. However, in the northern portion of the belt, i.e., in the area west of Linden and south of Lake Carey, the jaspilites are predominantly of siliceous variety and although topographically prominent in places, can hardly be considered as large scale sources of iron ore.

IDA RANGE

(Map Ref. F3)

Field work and reports by K. Berliat and R. R. Connolly.

General Information.

The range, formed by banded iron formations, extends from Mt. Bevon (latitude 29° 5′ S. and longitude 120° 20′ E.), through Mt. Mason to Mt. Ida (latitude 29° 15′ S. and longitude 120° 25′ E.) in the south. Its central part, near Mt. Mason, is accessible by an old partly washed out track from the Timoni goldmine at Copperfield, seven miles to the east. The northern part is reached by a long disused track which proceeds eastwards from the Menzies-Sandstone road, just south of Perrin Vale station, to Mitchell Rocks (granite), three miles to the west of Mt. Bevon. The southern part is reached on foot from Piantos, an abandoned mining show just west of the Copperfield-Menzies road.

Copperfield, the nearest mining centre to the range, is 62 miles by road north-west of Menzies, the nearest rail centre. The distance by rail from Menzies to the port of Esperance is 337 miles.

With the exception of the tracks mentioned above, the range is not accessible to motor transport and must be reached on foot over several miles of dense scrub country. A limited amount of domestic water is obtainable from well supplies around Copperfield.

Between Mt. Bevon and Mt. Ida the total length of the range is approximately 15 miles. Its backbone is formed by a variable number of parallel jaspilite bands spread over a width of 10 or 15 chains. The average strike is N. 25° to 30° W. and the dip 60° E.

H. W. B. Talbot (G.S.W.A. Bulletin 45) mentioned " a large mass of very fine iron ore " in the Mt. Mason locality and also recorded a large thickness of ferruginous jaspilites at Mt. Ida.

Owing to the great areal extent and inaccessibility of the range, attention was confined to the three most topographically prominent sectors of Mt. Bevon, Mt. Mason and Mt. Ida.

Mount Bevon

Report by R. R. Connolly.

General.

The trigonometrical station cairn AN16 on Mt. Bevon has been obscured by regrowth of dense scrub and is not visible from the lower ground to the west. The mount itself, which has a long rounded outline, is made up of a maximum of three jaspilite bands with interbedded greenstones. It is flanked on the west by granite which approaches to within half a mile of the mount, and to the east the greenstone extends for a considerable distance.

The jaspilites strike at N. 30° W., and dips between 30° and 45° to the east were recorded. On the mount, which is approximately 2,100 feet long and averages 100 feet above the level of the plain to the west, three ferruginous jaspilite bands aggregate 320 feet in apparent thickness. Samples 1 and 2 taken from 182 feet north and 800 feet south of the trigonometrical station respectively, gave an analyses the following results :—

	Acid Soluble Fe %
No. 1—Lab. No. 6557/58	39·45
No. 2—Lab. No. 6558/58	40·86

Sample No. 3 (Lab. No. 6556/58), taken from across the top of the next ridge to the south (half a mile from the trigonometrical station) is representative of the single exposed jaspilite band of 120 feet apparent width. Sample No. 3 gave 39·30 per cent. metallic iron.

One mile south of the trigonometrical cairn the single exposed band had an apparent width of only 58 feet and appeared to be more siliceous than those samples taken from Mt. Bevon. Sample No. 4 (Lab. No. 6555/58), taken from this point, gave on analysis 35·06 per cent. metallic iron.

Further south along the range exposures were poorer, and the grade was assessed by eye as being from 30 per cent. to 35 per cent. metallic iron.

Using equal parts by weight of the individual samples, a composite on partial analysis gave the following results :—

	On dry basis %
Iron Fe	38·86
Silica SiO_2	43·57
Sulphur S	0·01
Phosphorus P	0·04
Titanium Ti	Trace
Manganese Oxide MnO	0·02

Calculation of inferred reserves or ore containing more than 36 per cent. metallic iron is made on the following assumptions :

Length : 2,500 feet

Average aggregate width : 225 feet

Average height : 100 feet

Conversion factor : 10 cubic feet per ton.

The figure thus obtained is 5,625,000 tons.

Mount Mason

High Grade Body.

The " large mass of very fine iron ore " mentioned by Talbot as occurring in this locality, is a high grade hematite lens of approximately the following dimensions :—

Length : 1,200 feet

True Width : 30 feet

Height above plain level : 100 feet.

To the north and south the lens passes into the normal ferruginous jaspilitic facies.

Samples were taken at 200 feet intervals, the grade of ore being illustrated by the following two composite samples :—

	Acid Soluble Iron Fe %
No. 1—Lab. No. 16956/56	66·64
No. 2—Lab. No. 16957/56	66·70

Partial analysis of a group sample showed :—

	% on dry basis
Acid Soluble Iron Fe	67·12
Silica SiO_2	1·31
Phosphorus P	0·05
Total Sulphur S	0·03
Manganese Oxide MnO	Nil
Titanium Ti	Trace

Using a factor of eight cubic feet of ore per ton, the quantity above plain level works out at 450,000 tons.

Lower Grade Ores.

Seven typical samples at 20 chain intervals south of the high grade iron ore lens at Mt. Mason, assayed as follows:—

		Acid Soluble Iron Fe %
No. 1—Lab. No. 16958/56	....	39·45
No. 2—Lab. No. 16959/56	....	33·73
No. 3—Lab. No. 16960/56	....	42·05
No. 4—Lab. No. 16961/56	....	37·17
No. 5—Lab. No. 16962/56	....	42·46
No. 6—Lab. No. 16963/56	....	37·74
No. 7—Lab. No. 16964/56	....	31·87

A group sample from these individual samples gave the following results on partial analysis:—

		%
Acid Soluble Iron Fe	....	39·90
Silica SiO_2	....	43·51
Phosphorus P	....	0·04
Total Sulphur S	....	0·01
Manganese Oxide MnO	....	Nil
Titanium Ti	....	Trace

Mount Ida

The Mt. Ida trigonometrical cairn is located on a short north-easterly trending spur of the range. In this locality the jaspilites are highly folded and largely obscured by laterization. On the western side of the range almost vertical cliffs drop away to a granitic plain about 200 feet below. Where exposed, the jaspilites appear to be of low grade with respect to iron content, with the exception of one body in the immediate vicinity of the trig. station, which was assessed by eye in the field to contain approximately 40 per cent. metallic iron.

This body, striking N. 20° E. and dipping at 45° to the west commenced at a point 245 feet south-west of the trig. station and extended north-easterly for approximately 1,000 feet with an average apparent width of 125 feet. A sample taken across the centre of this body (Lab. No. 6559/58), showed 38·47 per cent. metallic iron. The amount above the level of the plain to the west is calculated at 2,500,000 tons, using a conversion factor of 10 cubic feet per ton. It is probable however, that at least one-third of this tonnage has already been lost by erosion in a steep gully parallel to the body to the north-west, and a figure of 1,600,000 tons is probably nearer the true figure.

Remarks.

An accurate assessment of the overall tonnage existing in the Ida Range is not possible, due to the limited work carried out in three localities. However, allowing a 50 feet average aggregate thickness of ferruginous jaspilite over a length of 15 miles at an average height of 80 feet, some 30 million tons of 30 to 35 per cent. metallic iron content material would exist in addition to some slightly higher grade lenses, and one lens of approximately half a million tons of 67 per cent. iron ore.

LAKE BARLEE AREA

(Map Ref. E.3)

Field work by R. R. Connolly and K. Grimbly, report by R. R. Connolly.

General Information.

Three main greenstone belts have been outlined by Talbot (G.S.W.A. Bulletin No. 45) in the Lake Barlee Area. All contain numerous beds of ferruginous jaspilite striking in a general northerly direction.

The Brooking Hills are immediately to the east of the north-eastern arm of Lake Barlee, and the present Menzies-Sandstone road runs alongside these hills over their length of approximately 10 miles. Ranford Peak is at the south end of the range, and to the north the range loses topographic prominence for some five miles before making again at Mt. Alfred.

An unnamed tract of hilly greenstone country some four miles to the east of Byeang Rock is reached by station track from Perrin Vale homestead, terminating at a stock well on the eastern flank of the hills. Some time was spent in this locality examining a large number of small sharp jaspilite ridges for possible commercial concentrations of iron. The jaspilites in this area were found to be thin, lenticular and of obviously poor grade with respect to iron content and no samples were taken. The abundance of intrusive quartz in the area was the only noteworthy feature.

A third greenstone area commencing in the south at Yeedie Bulgar Hill (trigonometrical station NB33) and extending to the north for some 20 miles, was similarly examined with no positive results. Here the jaspilites are better defined and more continuous in strike, but the beds have a siliceous "biscuity" appearance and offer no possibilities as ores of iron. Access to the area is gained by a limited number of station tracks on the Cashmere Downs spread.

Brooking Hills.

Ranford Peak, an isolated hill approximately 200 feet high is the southernmost prominence of the Brooking Hills. At Ranford Peak, three parallel jaspilite bands, each approximately 25 feet wide and separated by schistose greenstones, strike at N. 20° W. and dip to the west at 75°. The jaspilites here are poor in iron content and were not sampled. Following this direction of strike to the north over two miles of low, soil covered, thickly timbered country the Brooking Hills proper commence.

Generally the range consists of two parallel ridges approximately 1,000 feet apart running due north. Neither ridge is continuous, but the east ridge is the stronger of the two. Both are made up of one or two ferruginous jaspilite bands with some interbedded greenstone. The dip is uniform over the length of the range at 75° to the west. The maximum height above the surrounding level is 250 feet, but in many places heights of only 50 feet are attained. An average height of 95 feet has been assumed for the range.

Across the strike of the beds, considerable variation in iron content was noted and sampling and measurement was therefore confined to the more iron rich beds. The remainder of the jaspilite was of the pale coloured "biscuity" variety noted elsewhere in the Lake Barlee area.

The west band was continuous for approximately two and a half miles commencing at the southern end. Widths varied along the strike and an average of 50 feet has been assumed. Going north, the iron rich beds in the jaspilite succession gradually thin out and at the last point sampled, only 13 feet of the 95 feet wide band was sampled for iron. The three samples taken at approximately equal distances from south to north on the western band assayed as follows:—

	Acid Soluble Fe %
No. 1—Lab. No. 6546/58	43·11
No. 2—Lab. No. 6547/58	48·09
No. 4—Lab. No. 6549/58	33·49

The east band, which does not run quite so far to the south as the other, can be followed more or less continuously for six miles with an average width of iron bearing jaspilite of 65 feet. The four samples taken from south to north along this band assayed as follows:—

	Acid Soluble Fe %
No. 3—Lab. No. 6548/58	32·60
No. 5—Lab. No. 6550/58	36·77
No. 6—Lab. No. 6551/58	35·22
No. 7—Lab. No. 6552/58	37·59

A partial analysis of a group sample, composed of equal parts by weight of the individual samples from both bands, gave the following results:—

	%
Iron Fe	38·28
Silica SiO_2	43·08
Sulphur S	Trace
Phosphorus P	0·05
Titanium Ti	0·01
Manganese Oxide MnO	0·02

Quantity Estimates.

West Band—	feet
Length	13,000
Average width	50
Average height	95
Conversion factor	11 cubic feet per ton
Quantity above plain level	5,614,000 tons

East Band—	feet
Length	31,000
Average width	65
Average height	95
Conversion factor	11 cubic feet per ton
Quantity above plain level	17,402,000 tons
Total	23,016,000 tons

BUNGALBIN-MOUNT WALTON

(Map Ref. F3)

Precis by K. Berliat, D.Sc.

General Information.

The deposits are centred about latitude 30° 25′ S. and longitude 119 40′ E. Access to Mt. Bungalbin is best gained from Southern Cross via Koolyanobbing by a track which branches off at the latter locality. The distance from Koolyanobbing to Bungalbin, via Glen Rhyn rocks, is 42 miles.

The shortest route (45 miles) to Mt. Walton is by a north trending track from Boorabbin (on the Great Eastern Highway), passing through both Ryan's and Breakaway Finds, to meet the old Yellowdine-Menzies road at Iron Knob. Other access roads to this locaity are from Karalee (65 miles) or Carbine (58 miles).

The deposits are located in rugged, undeveloped, generally heavily timbered country devoid of permanent, natural water supplies. No mining activities are being carried out in the area.

Work of a reconnaissance nature on the deposits was undertaken in the first instance by K. Berliat and R. R. Connolly, and later by J. Sofoulis, accompanied by a field assistant, (K. Grimbly).

The present report has been compiled from the following publications, to which special reference is made :—

(1) JOHN SOFOULIS : Report on a Geological Reconnaissance of a Greenstone Belt extending from Jackson in the Yilgarn Goldfield to Ryan's Find in the Coolgardie Goldfield, W.A. G.S.W.A. Bulletin No. 114 (Miscellaneous Reports for 1957).

(2) JOHN SOFOULIS : Report on Iron Ore Deposits, Bungalbin-Mt. Walton Areas, Yilgarn-Coolgardie Goldfields, W.A. G.S.W.A. Bulletin No. 114 (Miscellaneous Reports for 1957).

Geological Occurrence.

The iron ore deposits occur in jaspilitic rocks, which form the backbone of an arched greenstone belt varying 5 to 12 miles in width, and extending from Mt. Jackson in the north-west to Ryan's Find in the south-east, a total length of approximately 100 miles. In the Bungalbin sector the jaspilite hills present a bold and rugged appearance, ranging up to 500 feet above the general surrounding level. Elsewhere these hills vary from 100 feet to 200 feet above the general level and occasionally may rise up to 300 feet. In some sections (e.g., between East Bungalbin and Mt. Walton) the range feature becomes very subdued, and is represented by a low line of hills containing only a few isolated hills of higher elevation. In the Bungalbin sector the jaspilites exhibit steep northerly dips, which, following the strike deflection east of Bungalbin, turn to steep easterly at Mt. Walton. Subsidiary bands of jaspilites, appearing as low discontinuous hills parallel to the main belt are possibly the result of structural repetition.

The ore deposits appear as regional trending high grade hematite lenses, localised in the more highly contorted and disturbed sections of the jaspilites. Where noted, the highest iron concentrations seldom exceed 100 feet in width, although in some Bungalbin sections up to 600 feet in width may be observed. The length of such iron rich lenses may approach a mile or so, but usually they are of a restricted size only, and rapidly pass to more siliceous forms. It is frequent therefore, to have a highly siliceous jaspilite adjoin an iron rich type, or else have large blocks of siliceous jaspilite enclosed in a highly ferruginous section and vice versa.

The Ore Deposits.

There are four high grade hematitic ore bodies, three of which occur at Bungalbin. The fourth is near Mt. Walton- The regional location and the slope of these ore bodies is shown on the sketch maps appended to John Sofoulis' reports men. tioned above.

Bungalbin Sector.

Central Ore Body.

This ore body, approximately one mile north of Bungalbin trigonometrical station occurs in north-south striking, steeply easterly dipping jaspilites. The assumed dimensions are as follows :—

Average Width : 200 feet
Average Height above plain level : 250 feet
Length : 2,000 feet.

Eastern Ore Body.

This ore body is at the eastern end of the prominent jaspilitic ridge on which the Bungalbin trigonometrical station is located. It is centred about four miles east-north-east from that point. The assumed dimensions are :—

Average Width : 50 feet
Average Height above plain level : 360 feet
Length : 7,920 feet.

Western Ore Body.

This ore body is located at the eastern end of an east-west trending jaspilite ridge, approximately two miles north of Bungalbin trigonometrical station. It has the following assumed dimensions :—

Average Width : 130 feet
Average Height above plain level : 130 feet
Length : 2,800 feet.

Mt. Walton Sector

The Walton ore body is located approximately five miles north-west of Mt. Walton and its assumed dimensions are as follows :—

Average Width : 83 feet
Average Height above plain level : 90 feet
Length : 2,600 feet.

Sampling.

All the samples taken were "chip samples" across the strike and over the widths given below. The sampling locations for each ore body are shown in the sketch plans attached to John Sofoulis' report on the Bungalbin-Mt. Walton iron ore deposits. (op. cit.).

Grade

Bungalbin Sector

Central Ore Body.

Sample No.	Chemical Lab. No.	Width Sampled Feet	Acid Soluble Fe dry basis %
12	12305	300	59·76
13	12306	300	64·72

Weighted average grade = 62·24 per cent. Fe.

A composite sample (No. 12309) prepared by mixing equal weights of the individual samples 12 and 13 gave the following partial analysis :—

	%
Acid Soluble Iron (Fe)	63·06
Silica (SiO_2)	1·86
Phosphorus (P)	0·09
Total Sulphur (S)	0·03
Manganese Oxide (MnO)	0·08
Titanium (Ti)	0·03

Specific gravity 4·73.

Results are moisture free, i.e., on dry basis.

Eastern Ore Body.

Sample No.	Chemical Lab. No.	Width Sampled Feet	Acid Soluble Fe dry basis %
1	12294	50	60·64
2	12295	50	60·83
3	12296	320	61·86
5	12298	66	61·94
6	12299	25	62·84
7	12300	30	59·53
28	17882	250	55·21

Weighted average grade = 59·5 per cent. Fe.

A composite sample (No. 12308) prepared by mixing equal weights of the individual samples 1 to 3 and 5 to 7 inclusive, gave the following partial analysis :—

	%
Acid Soluble Iron (Fe)	61·25
Silica (SiO_2)	2·55
Phosphorus (P)	0·10
Total Sulphur (S)	0·07
Manganese Oxide (MnO)	0·17
Titanium (Ti)	0·10
Specific gravity	4·73

Results are moisture free, *i.e.*, on dry basis.

Western Ore Body.

Sample No.	Chemical Lab. No.	Width Sampled feet	Acid Soluble Fe, dry basis %
8	12301	100	67·08
9	12302	75	66·46
14	12303	100	65·93
52	17903	155	59·01
53	17904	90	61·51
54	17905	80	59·63
55	17906	95	60·71
56	17907	150	64·54
57	17908	280	65·48
60	17911	210	45·77
61	17912	138	63·90

Weighted average grade = 60·9 per cent. Fe.

Composite samples (Nos. 12310 and 19639) prepared by mixing equal weights of the individual samples Nos. 8, 9, 14 and 52 to 57, inclusive, respectively gave the following partial analysis:—

	12310 %	19639 %
Acid Soluble Iron (Fe)	66·56	61·81
Silica (SiO_2)	0·94	4·90
Phosphorus (P)	0·15	0·13
Total Sulphur (S)	0·08	0·01
Manganese Oxide (MnO)	0·04	0·02
Titanium (Ti)	0·01	0·04
Specific gravity	4·73	3·89

Results are moisture free, *i.e.*, on dry basis.

Mt. Walton Sector

Walton Ore Body.

Sample No.	Chemical Lab. No.	Width Sampled feet	Acid Soluble Fe, dry basis %
45	17896	115	62·03
46	17897	90	60·62
47	17898	85	60·37
48	17899	112	59·37
49	17900	120	59·13
50	17901	80	60·89
51	17902	100	61·65

Weighted average grade = 60·5 per cent. Fe.

A composite sample (No. 19638) prepared by mixing equal weights of individual samples Nos. 45 to 51, inclusive, gave the following partial analysis :—

	%
Acid Soluble Iron (Fe)	60·06
Silica (SiO_2)	2·85
Phosphorus (P)	0·10
Total Sulphur (S)	0·02
Manganese Oxide (MnO)	0·08
Titanium (Ti)	0·02
Specific gravity	3·62

Results are moisture free, *i.e.*, on dry basis.

Tonnage.

The inferred tonnages available from the four ore bodies above plain level are based on the dimensions given above. A conversion factor of eight cubic feet of ore per ton has been used.

	tons
Bungalbin Central Ore Body	12,500,000
Bungalbin Eastern Ore Body	22,500,000
Bungalbin Western Ore Body	5,915,000
Mt. Walton Ore Body	2,500,000
Total available above plain level	43,415,000

In addition to the four high grade deposits, the iron bearing jaspilite zone of this belt contains millions of tons of lower grade iron deposits (30 to 50 per cent. Fe) which could be of some potential should an iron ore centre be established in the area.

EVANSTON

(Map Ref. F.3)

Field work by K. Berliat, D.Sc. and R. R. Connolly, report by K. Berliat, D.Sc.

Location and Access.

Access from Bullfinch is gained by road via Marda, the distance being 102 miles. The Pidgeon Rocks well, source of water for domestic purposes is 22 road miles distant. An old bore, about one and a half miles south of Evanston locality, reported to be capable of supplying 10,000 gallons of stock water per day, was out of order and partly fallen in at the time of inspection.

Occurrence.

There are two main zones of ferruginous jaspilites approximately one half of a mile apart. Each zone is made up of several bands separated by basic greenstone schists. The regional strike is north-east with dips varying between 20° and 60° to the north.

The southern zone consists of two main bands which are highly contorted and dragfolded over a length of about a mile. To the south and south-east of the old mine workings these bands form a number of hills rising to a height of about 80 feet above the level of the surrounding plains. Their width varies generally between 25 feet and 50 feet, but in some places greatly increased thicknesses due to repetition by intense drag-folding, have been observed.

The northern zone forms a continuous ridge immediately to the north of the old Evanston battery. The more prominent sector of this ridge is about 60 chains long and about 10 chains wide, rising at the western end to a height of approximately 100 feet above the level of the surrounding plain.

Detailed mapping by R. S. Matheson, showed the presence of four to six closely spaced individual bands separated by greenstone schists. The width of any one band is rarely more than 30 feet and all are of identical composition.

Sampling.

Samples Nos. 1 to 5 were taken from four prominent hills formed by the jaspilites of the southern zone. Each sample is a composite one representative of both bands.

The northern zone could only be sampled at both ends, where outcrop conditions are more favourable than in the central sector.

Sample No. 6 comes from the western and No. 7 from the eastern end. Both samples are again composites, including all the bands outcropping across the ridge.

Grade.

Results of analyses of the samples are as follows:—

Sample No.	Iron Fe on dry basis %
1	33·41
2	34·61
3	32·31
4	29·21
5	35·03
6	27·75
7	26·75

Details of a partial analysis of a group sample, made up from equal parts by weight of these seven samples, are as follows:—

	%
Iron (Fe)	30·94
Silica (SiO_2)	52·38
Phosphorus (P)	0·05
Sulphur (S)	0·02
Manganese Oxide (MnO)	0·09
Titanium (Ti)	Trace

Tonnage.

For the southern jaspilite zone the following assumptions have been made:—

	feet
Length of the more prominent portion of the outcrop	4,000
Average true width of each band	30
Average height above plain level	50

By using a conversion factor of 11 cubic feet per ton of ore, the inferred tonnage above plain level thus arrived at is approximately one million tons.

The northern zone, owing to the poor quality of the ore, the thin horizontal development of the individual bands and the interspersed greenstone country, is hardly of any economic significance.

KOOLYANOBBING

(Map Ref. F3)

Precis by K. Berliat, D.Sc.

General Information.

The Koolyanobbing iron ore deposits are situated approximately 34 miles N. 26° E. from Southern Cross railway station, and are readily accessible from that township by a good natural surface road capable of carrying heavy loads.

There are no natural water supplies in the area and in the event of it ever being developed, potable water would have to be obtained from the goldfields water supply line which passes through Southern Cross.

The iron ore deposits were mapped and surface sampled by the Geological Survey in 1938, and the results of this work appeared in the Annual Report of the Geological Survey for the year 1945[16].

A diamond drilling programme to test-drill the iron ore deposits for pyritic material below the zone of oxidation was carried out by the Mines Department between 1952 and 1955. Twelve holes were drilled for a total of 9,524 feet. Two tabular bodies of high grade pyritic ore of potentially large tonnages were proved to occur on the footwall side of the iron ore lenses at Dowd's Hill, and ore body " A " in the Koolyanobbing Hills respectively.

Detailed results of the drilling operations were published in Bulletin No. 111 of the Geological Survey[17].

The present report has been compiled from the above two publications.

Geological Occurrence.

The ore bodies occur in discontinuous lenses in a banded iron formation similar to those occurring throughout Western Australia. It varies from the typical black and red jaspilite, with about 50 per cent. iron oxides, to a siliceous jaspilite containing very little iron oxide. The outcrop forms a series of bold hills and short ranges, extending in a north-west south-east direction from trigonometrical station MY1 in the Koolyanobbing Hills. The regional dip is north-east at about 60°, but there are numerous steeper dips. The hanging wall and footwall of the jaspilite are similar, and consist of weathered greenstone schist.

The ore bodies form a series of irregularly shaped lenses, generally with the larger axes parallel to the strike of the jaspilite. At the surface they consist, with one exception (Dowd's Hill), of massive and banded brown (limonitic) iron ore, with varying proportions of fine grained hematite or coarse grained specular hematite—the brown ore being in excess of the hematite. In the Dowd's Hill ore body the proportion of hematite exceeds that of the brown ore.

The specular hematite occurs in vein quartz and also lenses and veinlets in the jaspilite. It is of intrusive origin, and of later age than the hematite of the jaspilite.

[16]HOBSON, R. A.: Koolyanobbing (Trig. Station MY1) Iron Ore Deposits, Summary Report. *G.S.W.A. Ann. Rep.*, pp. 10–12, 1945.

[17]ELLIS, H. A.: The Exploratory Diamond Drilling of the Koolyanobbing Iron Ore Deposits for Pyrite. *G.S.W.A. Bull.* 111, 1958.

In some places the jaspilites are much folded, while elsewhere they have a steady strike. Major faulting is absent, but minor faulting has been observed locally.

The Ore Bodies.

The geological map accompanying R. A. Hobson's report (*op. cit.*) shows in detail the outlines of five individual ore bodies, and the approximate dimensions given below have been measured on that map. The ore bodies are arranged in order of their size.

Ore Body "E" (Dowd's Hill).

This ore body is situated 3·8 miles in a direction N. 31° W. of trigonometrical station MY1.

As already mentioned this ore body contains much more hematite than any of the other ore bodies. It consists of fine grained banded and massive hematite, abundant micaceous hematite, and an appreciable quantity of brown iron ore.

The approximate dimensions are :—

Length : 3,200 feet
Width : Irregular, varying between 200 feet and 800 feet
Height above plain level : 100 feet to 260 feet.

Ore Body "C" (Koolyanobbing Hills).

This ore body is centred about 500 feet south of MY1 trigonometrical station. It consists of massive brown ore with a very minor quantity of banded brown ore, and has the following approximate dimensions :—

Length : 1,800 feet
Width : Irregular, varying from 50 feet to 800 feet
Height above plain level : 20 feet to 360 feet.

Ore Body "D" (Koolyanobbing Hills).

This ore body is located about 2,000 feet east-south-east from MY1 trigonometrical station and extends from there in a general east-south-easterly direction. It consists of banded and massive brown iron ore with an appreciable quantity of micaceous hematite.

Length : 1,300 feet
Width : 300 feet
Height above plain level : 50 feet to 200 feet.

Ore Body "A" (Koolyanobbing Hills).

This ore body extends in a general north-westerly direction from a point about 4,500 feet north-west of Koolyanobbing trigonometrical station. It consists of massive and banded brown ore, with an appreciable quantity of fine grained crystalline hematite. This ore body is second to ore body "E" in the amount of hematite it contains.

Length : 2,300 feet
Width : 150 feet
Height above plain level : 0 to 200 feet.

Ore Body "B" (Koolyanobbing Hills).

This ore body located half a mile north-west of Koolyanobbing trigonometrical station, consists of massive brown ore with a minor quantity of banded brown ore.

Length : 330 feet
Width : 600 feet
Height above plain level : 100 feet to 280 feet.

Sampling.

The ore bodies were surface sampled in 1938 (Ref. 16 op.cit.). The sample lines were spaced at intervals of approximately 100 feet and chip samples were taken across the strike of the ore bodies over the widths exposed. A total of 425 individual samples were obtained, all of which were assayed for metallic iron. Partial analyses were also made on 20 group samples. Full details of the analytical results are available at the Geological Survey.

Grade

The following summary of the analytical results is given in R. A. Hobson's report :—

Locality	Ore Body	Iron calculated from analyses of individual samples	Range of principal constituents from partial analyses of Group Samples						Specific Gravity
			Fe	SiO_2	H_2O	TiO_2	P	S	
		%	%	%	%	%	%	%	
Koolyanobbing Hills	A	63·4	63·24 63·66	1·42 2·67	4·89 6·56	Trace 0·03	0·04 0·13	0·03 0·04	4·39
	B	60·3	60·30	4·60	7·40	0·02	0·05	0·02	4·14
	C	58·5	57·93 59·15	3·11 7·06	6·39 7·82	0·20 0·50	0·04 0·08	0·08 0·11	4·02
	D	59·1	55·53 60·48	3·93 8·70	7·30 8·61	0·05 0·15	0·05	0·04 0·07	4·05
Dowd's Hill	E	62·7	61·23 64·05	1·40 4·44	3·10 8·09	0·02 0·03	0·11 0·22	0·01 0·04	4·34

In the course of the diamond drilling programme initiated by the Department in 1952, six penetrations of iron ore bodies over their full widths were made below the zone of oxidation. The drilling proved the unoxidized ore to be magnetite. Only the coarse grained specular hematite, occurring as fresh massive lenses at the surface, notably in ore body " E " at Dowd's Hill was found to continue downwards still as coarse grained specular hematite. Detailed core logs, assay data and mineral determinations for each iron ore sample are given by H. A. Ellis in Bulletin No. 111. The following group assays for the six penetrations are taken from that publication :—

Ore Body "E" (Dowd's Hill).

Diamond Drill Hole No. 2—Site E1.

Ore: Mainly massive magnetite and banded talc-magnetite lode, with some specular hematite.

Assay Data
(Moisture free basis)

Sample Length	Fe (Total)	Fe (acid soluble)	Ti	Mn	SiO_2	S	P
	%	%	%	%	%	%	%
552′– 651′	41·50	39·36	0·02	0·01	31·51	0·59	0·02
651′– 750′	36·29	33·35	0·01	Trace	39·58	0·55	0·09
759′– 852′	36·79	32·88	0·01	0·01	36·04	0·53	0·10
873′– 976′	29·74	25·31	0·02	Trace	43·58	1·27	0·08
980′–1,075′	21·72	18·64	0·02	Trace	59·46	1·15	0·05
1,075′–1,162′	15·89	13·49	0·02	Trace	68·88	1·11	0·04

Note: 750′ to 759′ }
852′ to 873′ } not sampled (greenstone)
976′ to 980′ }

Ore Body "E" (Dowd's Hill).

Diamond Drill Hole No. 4—Site E3.

Ore: Mainly massive magnetite and banded talc-magnetite lode.

Assay Data
(Moisture free basis)

Sample Length	Fe (Total)	Fe (acid soluble)	Ti	Mn	SiO_2	S	P
	%	%	%	%	%	%	%
409′–563′	58·68	58·13	Trace	0·15	10·02	0·50	0·27
563′–651′	24·03	19·63	Trace	0·84	48·46	0·49	0·08

Ore Body "A" (Koolyanobbing Hills).

Diamond Drill Hole No. 6—Site A1.

Ore body penetrated 670′ to 814′.

Assay Data
(Moisture free basis)

Sample Length	Fe (Total)	Fe (acid soluble)	Ti	Mn	SiO_2	S	P
ft. in.	%	%	%	%	%	%	%
76 6	43·36	41·87	Nil	0·09	24·62	0·59	0·19
65 6	34·73	32·36	Trace	0·15	30·70	1·56	0·12

Ore Body "A" (Koolyanobbing Hills).

Diamond Drill Hole No. 12—Site A2.

Magnetite iron ore from 735′ to 867′.

True width: 132′.

Assay Data
(Moisture free basis)

Sample Length	Fe (Total)	Fe (acid soluble)	Ti	Mn	SiO_2	S	P
ft. in.	%	%	%	%	%	%	%
71 6	61·72	60·93	Trace	0·02	1·55	1·20	0·10
60 6	42·86	41·80	Trace	0·21	1·93	2·05	0·03

Ore Body "A" (Koolyanobbing Hills).

Diamond Drill Hole No. 11—Site A3.

Magnetite iron ore from 739′ to 955′

Assay Data
(Moisture free basis)

Sample Length	Fe (Total)	Fe (acid soluble)	Ti	Mn	SiO_2	S	P
ft. in.	%	%	%	%	%	%	%
70 0	59·33	57·87	Trace	0·29	5·93	1·67	0·20
65 6	59·21	58·02	Trace	0·43	4·27	1·88	0·22
22 0	43·34	41·93	Trace	0·90	6·92	1·72	0·08
22 6	44·08	41·67	Trace	0·93	3·53	2·86	0·26

Note: 874′ to 889′ } not sampled (greenstone)
911′ to 932′ }

Ore Body "C" (Koolyanobbing Hills)

Diamond Drill Hole No. 7—Site C2.

Ore: Massive magnetite, banded magnetite jaspilite talc-magnetite schist, pink banded magnetite jaspilite, some massive talc.

Footwall section only of ore body penetrated between 850′ and 1,106′ 6″.

Assay Data
(moisture free basis)

Sample Length	Fe (Total)	Fe (acid soluble)	Ti	Mn	SiO_2	S	P
ft. in.	%	%	%	%	%	%	%
81 6	45·58	43·23	Trace	Trace	22·09	0·08	0·12
90 0	37·86	34·94	Trace	Trace	32·23	0·06	0·01
84 6	36·96	33·67	Trace	0·05	28·25	0·08	0·02

It will be seen from these six intersections that the overall grade of the iron ore at depth is considerably lower than that of the outcrop ore.

Tonnage.

Preliminary estimates of iron ore reserves by R. A. Hobson were based on the assumption that the lower limit of oxidized ore was approximately at the water table, which was assumed to be 180 feet below the base contour at both Dowd's Hill and the Koolyanobbing Hills deposits. However, H. A. Ellis pointed out that the drilling logs show decomposed ground much deeper than this everywhere, and as all of the holes were planned to cut unoxidized ground, no further information about the actual depth below the outcrop of oxidized ore was obtained in this drilling programme.

The inferred tonnage estimates to water level by R. A. Hobson are given below:—

Locality	Ore Body	Inferred Tonnage to Water level
		(2,240 lb.)
Koolyanobbing Hills....	A	7,500,000
	B	4,750,000
	C	16,000,000
	D	9,000,000
Dowd's Hill	E	32,000,000
Total	....	69,250,000

The drilling programme carried out by the Mines Department was designed to test the mineral content of the surface iron ore bodies below the zone of oxidation, and *not* to outline the limits of these ore bodies. No ore reserve estimates can therefore be computed from this type of drilling. It can only be inferred that large tonnages of magnetite ore are available below the zone of oxidation.

MOUNT CAUDAN

(Map Ref. F3)

Report by K. Berliat, D.Sc.

General Information.

Mount Caudan (Kings Cairn trigonometrical station), the summit of the prominent ridge which forms the Mt. Caudan lode, is situated approximately in latitude 31° 35′ S. and longitude 119° 20′ E. The track from the old mining centre of Parkers Range to Moorine Rock crosses the ridge about two miles west of Parkers Range and 12 chains south of Mt. Caudan trigonometrical station. Parkers Range is approximately 37 miles by road from Southern Cross via Marvel Loch and Burbidge. The distance by road or rail from Southern Cross to Perth is 232 miles.

The Mt. Caudan lode was first mentioned by C. G. Gibson, was later described and mapped by Montgomery and Blatchford, and more recently by H. A. Ellis. In 1952, detailed mapping of the lode on a scale of 5 chains to an inch was carried out by L. E. de la Hunty and the author, and exploratory drill hole sites laid out. At the present time the area is covered by a Government Reserve. No exploratory drilling has been done in recent years.

Geological Occurrence.

The lode, conformably interbedded with metamorphosed sediments of the Whitestone Series (Pre-Cambrian), has a regional strike of N. 5° E. and a dip varying between 55° and 65° to the west. The hanging wall of the lode is obscured by outcrops of massive laterite or lateritic soil, whilst the footwall, particularly in the vicinity of the trigonometrical station, forms an abrupt cliff up to 60 feet high. Highly siliceous jaspilites are frequently observed along the footwall. Granitic rocks occupy large areas of country to the west and in places approach closely to the ridge.

The Ore Body.

The outcrop of the Mt. Caudan lode represents the gossan of a pyritic ore body and consists of massive brown Goethite (limonite) including various amounts of hydrated manganese oxides (psilomelane), particularly in the central portion. The outcrop is remarkably consistent in strike and can be followed on the surface for a distance of some 8,000 feet. The ridge, topographically most prominent in the vicinity of Kings Cairn, gradually flattens out in a northerly, and to a lesser extent in a southerly, direction. At the southern end the lode passes gradually into low grade siliceous ironstones while its northern extremity is obscured by a thick mantle of yellow loamy soil.

Owing to the excessive amount of talus and lateritic cover along the hanging and footwalls, it is difficult to determine the actual width of the lode. The average horizontal width of the outcrop is approximately 100 feet, but north of the trigonometrical station it is as much as 300 feet.

Surface Sampling.

Blatchford took four samples across the outcrop at the following positions :—

No. 1 Sample : Approximately 420 feet south of the trigonometrical station

No. 2 Sample : At Kings Cairn trigonometrical station

No. 3 Sample : Approximately 1,500 feet north of the trigonometrical station

No. 4 Sample : Approximately 2,500 feet north of the trigonometrical station.

In the course of the iron survey, the author took a further four samples, but the results of these did not differ materially from those collected by Blatchford.

Underground Exploration.

Following recommendations by Montgomery, two diamond drill holes were put down.

No. 1 bore was located about 620 feet south-west from the trigonometrical station, at a point some 40 feet lower than the crest of the ridge. The bore was inclined at an angle of 60° from the horizontal and reached a depth of 304 feet. The lode was intersected from 203 feet to the bottom of the hole.

The bore log between these limits is given below :—

Borehole Depth	Description
Feet	
203–210	Limonite and very little quartz
210–218	do.
218–221	Limonite with a little quartz and some combined silica
221–224	do.
224–226	Limonite and little combined silica
226–230	do.
230–232	Limonite and very little quartz and combined silica
232–266	Limonite and about 20 per cent. siliceous matter
266–290	Limonite and about 30 per cent. siliceous matter
290–300	Cellular and ironstained quartz and limonite with about 30 per cent. siliceous matter
300–304	Cellular ironstained quartz and limonite with about 75 per cent. siliceous matter

No. 1 Bore having not penetrated below the zone of oxidation, a second bore was put down at a point approximately 580 feet west of the trigonometrical station. It attained a depth of 831 feet from the surface and passed through over 100 feet of massive *pyrrhotite* between 603 and 707 feet. A feature of considerable interest was the occurrence of a 30 feet thick lode of siderite between 495 and 525 feet, and of two horizons (between 535 and 539 feet, and 547 and 559 feet) composed essentially of magnetite.

Grade.

The four samples taken by Blatchford across the outcrop of the lode, were analysed with the following results :—

	Sample 1	Sample 2	Sample 3	Sample 4
	%	%	%	%
Iron	60·22	55·51	50·70	61·84
Total Manganese	0·43	4·17	7·90	0·19
as MnO	....	....	2·17	....
as MnO_2	....	....	9·85	....
Silica	1·90	2·83	3·25	1·92
Phosphorus	0·056	0·070	0·048	0·018
Sulphur	0·026	0·058	0·031	0·018

Analyses of three samples from the lode of siderite between 495 and 525 feet in the No. 2 bore gave the following results :—

	495–505 feet	505–515 feet	515–525 feet
	%	%	%
Iron	44·25	42·14	38·92
Manganese	3·55	3·07	3·21
Sulphur	0·24	1·60	2·96
Insolubles	2·52	5·00	12·0
Lime	Nil	Nil	Nil
Magnesia	Trace	Nil	Nil

The magnetite horizons met with in No. 2 the bore have the following average compositions :—

	535–539 feet	547–559 feet
Iron	41·77	43·33
Sulphur	1·45	2·85
Silica and Silicates	32·86	22·90

An average bulk sample of the whole core section through the sulphide (pyrrhotite) lode in the No. 2 bore (603–707 feet) is given below :—

		%
Insoluble in dilute hydrochloric and nitric acids—total 9·25%	Silica SiO_2	5·91
	Alumina Al_2O_3	0·23
	Ferrous oxide FeO	0·66
	Lime CaO	0·56
	Magnesia MgO	1·35
	Manganese oxide MnO	0·42
	Potash K_2O	0·09
	Soda Na_2O	0·03
	Water H_2O	0·75
	Carbon dioxide Co_2	7·54
	Titanium dioxide TiO_2	0·16
	Phosphoric oxide P_2O_5	0·08
Mostly magnetite	Alumina Al_2O_3	2·40
	Magnetic Iron oxide Fe_3O_4	10·46
Pyrrhotite	Iron Fe_{11}	36·54
	Sulphur S_{12}	22·78
	Lime CaO	5·27
	Magnesia MgO	3·55
	Manganese oxide MnO	1·86

The total metallic iron content in the bulk sample is 44·63 per cent. The proportions of pyrrhotite and magnetite have been approximately determined by Montgomery as follows :—

Magnetite .... 14 per cent.

Pyrrhotite .... 82 per cent.

Other materials .... 4 per cent.

Reserves.

No estimates of iron ore reserves have been attempted. The tonnage available above the level of the surrounding country is limited and the downward continuation of the surface iron ores is a completely unknown factor. It appears likely that the Mt. Caudan lode is rather a mining proposition for pyrrhotite than as a source of iron ores.

JOHNSTON RANGE

(Map Ref. F.3)

Field work by K. Berliat, D.Sc., and R. R. Connolly, report by K. Berliat, D.Sc.

General Information.

The central part of the Johnston Range is situated approximately in south latitude 29° 40′ and east longitude 119° 25′. It is a large north-easterly striking structure, approximately 10 miles long, between the old gold diggings of Diemel's Find in the west and Broadbent's Find in the east. The first locality is 19 miles by road north of Pidgeon Rocks, the nearest water supply, and 106 miles north of Bullfinch. Broadbent's Find is some 10 miles by road north of Evanston. Both extremities of the range are relatively easy of access from these centres, while the central portion is in thick scrub country not negotiable by motor vehicles.

Occurrence.

The banded iron formations making up the range form an interrupted line of hills and ridges rising to 200 feet above the level of the surrounding plain. They dip either vertically or steeply to the north or south. At the western end, two miles south of Diemel's Find there are three parallel bands spread over a distance of 20 chains. The central band is the most prominent one and varies in thickness between 50 feet and 100 feet. In this sector the jaspilites are of the steel grey and red banded variety, highly contorted and magnetic. To the north and west of Broadbent's Find only one major band 50 to 100 feet thick is seen outcropping.

Sampling.

For reasons given above, only the ends of the range were investigated. Samples were taken over a length of two miles in the west, and one mile in the east. Six composite representative samples have been analysed.

Grade.

The four western samples (approximately one half of a mile intervals) gave on analysis the following metallic iron contents :—

	Acid Soluble Iron Fe %
No. 1—Lab. No. 5950/56	34·91
No. 2—Lab. No. 5951/56	36·35
No. 3—Lab. No. 5952/56	36·23
No. 4—Lab. No. 5953/56	38·45

The two samples from the eastern end gave results as follows:—

	Acid Soluble Iron Fe %
No. 5—Lab. No. 5954/56	37·15
No. 6—Lab. No. 5955/56	38·19

A group sample taken from the six individual samples showed the ore to have the following composition:—

	%
Acid Soluble Iron Fe	36·84
Silica SiO_2	44·57
Phosphorus P	0·05
Total Sulphur S	0·02
Manganese Oxide MnO	0·01
Titanium Ti	Trace

Tonnage.

The computation of reserves is handicapped by the fact that nothing is known about the central part of the range. However, considering only the major band observed at both ends and assuming a total length of seven miles (thus making allowance for gaps along the strike), an average true thickness of 50 feet, and a mean height of 70 feet, the reserves above plain level have been calculated at approximately 13,000,000 tons (conversion factor 10 cubic feet per ton).

DIE HARDY RANGE

(Map Ref. F.3)

Field work by K. Berliat, D.Sc., and R. R. Connolly. Report by K. Berliat, D.Sc.

Location and Access.

The old "Die Hardy" goldmining leases are situated in rugged country some 15 miles south of Evanston. They adjoin the main Bullfinch-Evanston track 85 miles north of Bullfinch. The Pidgeon Rocks well is nine miles distant and can be reached by motor track.

Occurrence.

Two ferruginous jaspilite horizons run in a general north-westerly direction through the leases. They dip at 60° to the south-west and both form prominent ridges, each approximately three-quarters of a mile long. The average height of these ridges is about 50 to 60 feet and the beds have horizontal widths of 75 feet.

Grade.

The average iron content of the two horizons is indicated by the following analyses:—

	Acid Soluble Iron Fe %
No. 1—Lab. No. 5956/56	35·90
No. 2—Lab. No. 5957/56	37·44
No. 3—Lab. No. 5958/56	37·11
No. 4—Lab. No. 5959/56	38·53
No. 5—Lab. No. 5960/56	38·71
No. 6—Lab. No. 5961/56	36·69
No. 7—Lab. No. 5962/56	34·01

Results of partial analysis of a group sample made up of equal parts of weight of the above individual samples are as follows:—

	%
Iron Fe	36·64
Silica SiO_2	45·91
Phosphorus P	0·05
Sulphur S	Trace
Manganese Oxide MnO	0·02
Titanium Ti	Trace

Reserves.

The tonnage above a base contour representing plain level is calculated at 1,625,000 tons, and the amount above water level (150 feet below the base contour) at 4,875,000 tons. The following assumptions have been made in arriving at these figures:—

	feet
Length of ore bodies (where topographically prominent)	6,500
Mean height above base contour	50
Mean true width	50

Remarks.

As far as could be ascertained, the banded iron formations of the Die Hardy Range continue as a broken line of prominent ridges as far north as Evanston, a distance of not less than 15 miles. Huge quantities of iron ore, similar in grade to that at Die Hardy and Evanston can be expected to exist in this belt.

RIEDEL'S FIND

(Map Ref. F.3)

Location.

Riedel's Find is an old goldmining centre half a mile south of Marda, which is 64 miles by road north of Bullfinch, and 22 miles south of Pidgeon Rock well. Water for domestic and mining purposes can also be obtained from a government tank (capacity 500,000 gallons) about two miles south-west from the old workings.

Occurrence.

Of the numerous red and black jaspilite lenses in this area, only those immediately to the west of the late G.M.L. 3931 ("Dolly Pot Hill") are worth mentioning. They form a conspicuous hog-backed ridge about half a mile long and rising to 70 or 80 feet at the highest point. The jaspilites, highly contorted and dragfolded, strike broadly east and west, and dip vertically. There are three sub-parallel bands of which the northern one is by far the most important, having a thickness of not less than 200 feet. The central band, five chains to the south, has a width of 50 to 60 feet and the southern band is still thinner and without topographic prominence.

Sampling.

The central and southern bands were sampled at intervals of 10 chains and one composite representative sample from each band submitted for analysis.

Grade.

	Acid Soluble Iron Fe %
Northern Band—Lab. No. 5963/56	38·73
Central Band—Lab. No. 5964/56	35·82

A partial anlaysis of a group sample representing both bands is given below:—

	%
Iron Fe	37·46
Silica SiO_2	43·94
Phosphorus P	0·01
Sulphur S	0·01
Manganese Oxide MnO	0·01
Titanium Ti	Trace

Reserves.

	tons
Northern (main) Lens: Tonnage above base contour	1,200,000
Tonnage to water level	4,200,000
Central Lens: Tonnage above base contour	240,000
Tonnage to water level	800,000
Total tonnage	5000,000 long tons

The above figures have been arrived at by making the following assumptions:—

	Northern Lens feet	Central Lens feet
Length of ore body	2,000	1,500
Mean width of ore body	150	40
Height above base contour	40	40

Conversion factor: 10 cubic feet per ton.

MOUNT RANKIN

(Map Ref. F3)

Field work by K. Berliat, D.Sc., and R. R. Connolly, report by K. Berliat.

General Information.

Mount Rankin is situated eight miles as the crow flies, south-west of the mining town of Southern Cross, which is 330 miles by road and 296 miles by rail from Perth. The deposit is reached by a track which branches off the Great Eastern Highway southwards from near the 221 mile peg, the total road distance from Southern Cross being about 15 miles.

Occurrence.

H. A. Ellis' (G.S.W.A. Bulletin No. 97) mapping shows that the greenstone-jaspilite belt, running in a south-easterly direction from Keane railway siding through Mt. Rankin for a distance of about seven miles, forms the western limb of an anticlinal structure. The jaspilites along this line exhibit steep north-easterly dips and numerous dragfolds suggest a strong plunge to the south.

The jaspilites are topographically most prominent in the Mt. Rankin sector. There are two parallel bands 1 to 3 chains apart. They have an average dip of 70° N.E., and each band has an average horizontal width of about 35 feet with local variations ranging from 28 feet to 45 feet. Although they rise to a maximum height of about 100 feet above plain level, the average altitude is nearer to half that figure.

The beds are well exposed over a length of half a mile. To the north of Mt. Rankin their topographic prominence gradually disappears. To the south a dip fault causes a marked lateral displacement of the outcrop. South of the fault, both bands form again prominent ridges and are reasonably well exposed for a length of about 1,000 feet. However, further to the south the lithological nature of the beds cannot be ascertained owing to widespread lateritization.

Sampling.

At Mt. Rankin itself, samples were taken along both bands at intervals of roughly 500 feet. South of the fault one representative sample was collected from each band.

Grade.

The grade of ore is illustrated by the following analyses :—

	Acid Soluble Iron Fe %
Western Band—	
No. 1 North end—Lab. No. 17992/55	38·17
No. 2 North end—Lab. No. 17991/55	44·06
No. 3 North end—Lab. No. 17990/55	44·68
No. 4 North end—Lab. No. 17986/55	42·99
No. 5 South end—Lab. No. 17987/55	45·84
Eastern Band—	
No. 6 North end—Lab. No. 17995/55	38·54
No. 7 North end—Lab. No. 17994/55	42·93
No. 8 North end—Lab. No. 17993/55	49·65
No. 9 North end—Lab. No. 17988/55	47·77
No. 10 South end—Lab. No. 17989/55	53·40

The samples collected south of the fault showed :—

	Fe %
Western Band—Lab. No. 17996/55	44·56
Eastern Band—Lab. No. 17997/55	36·75

The partial analyses of two group samples made up from the individual samples taken along the western and eastern bands gave the following results :—

	Western Band %	Eastern Band %
Iron Fe	43·16	46·56
Silica SiO_2	30·34	28·56
Titanium Ti	Trace	Trace
Manganese Oxide MnO	Trace	0·01
Sulphur S	Nil	0·07
Phosphorus P	0·08	0·04

Tonnage.

Inferred tonnage estimates above plain level for the two bands at Mt. Rankin proper (combined length one mile) are based on an average height of 60 feet and an average true width of 30 feet. By using a conversion factor of 10 cubic feet of ore per ton, the figure arrived at is approximately one million tons.

Considerable additional reserves, of a grade similar to that illustrated by the two analyses mentioned earlier, may exist in the laterite capped hills south of Mt. Rankin.

EENUIN

(Map Ref. F3)

General Information.

A large development of ferruginous jaspilites forming prominent topographic features, is found at the old goldmining centre of Eenuin, 18 miles by road north-north-west from Bullfinch. Access is gained by a motor track that branches off the old Jackson road north of Lake Deborah, about 16 miles north from Bullfinch. Bullfinch is connected with the Goldfields water supply line and is 250 miles by rail or road from Perth.

Occurrence.

Between Lake Deborah and Eenuin there are four main jaspilite horizons striking N. 25° W. and dipping vertically. The two western bands extend from trigonometrical station HK48 in the south to G.M.L. 1847 in the north. They are topographically prominent only in these two localities.

The largest development of hematite ore is found in the two eastern horizons which are about 10 chains east from trigonometrical station HK48, and form an almost continuous ridge, up to 150 feet high, extending in a northerly direction for one mile. The thickness of the two bands varies, but the average true thickness of one single band is nowhere less than 50 feet.

The two eastern bands can be followed for about a further two miles to the north, but they gradually become more siliceous, thinner and topographically less prominent.

Sampling.

The eastern bands were sampled over a length of one mile between trigonometrical station HK48 in the south and G.M.L. 1791 (Great Gorman South) in the north. Samples were taken from south to north at intervals of 500 feet.

Sampling on the western bands was confined to the two prominent hills already mentioned.

Grade.

The iron content of the two eastern bands is illustrated by the following analyses :—

	Iron Acid Soluble Fe %
West Band—	
Lab. No. 17983/55	33·10
Lab. No. 17982/55	37·25
Lab. No. 17981/55	34·92
Lab. No. 17980/55	35·91
Lab. No. 17979/55	34·39

East Band—

Lab. No. 17985/55	37·73
Lab. No. 17977/55	38·00
Lab. No. 17974/55	36·66
Lab. No. 17975/55	36·18
Lab. No. 17978/55	28·48

Two samples taken from the abovementioned prominent hills to the south and north of the western bands, assayed as follows :—

	Metallic iron %
South (Trig. Station HK48)—Lab. No. 17984/55	36·55
North (G.M.L. 1847)—Lab. No. 17976/55	30·46

Partial analysis of ore from the eastern and western bands gave the following reults :—

	Eastern Bands %	Western Bands %
Iron Fe	34·90	33·38
Silica SiO_2	46·15	48·47
Titanium Ti	Trace	Trace
Manganese Oxide MnO	0·01	0·01
Sulphur S	0·09	0·07
Phosphorus P	0·06	0·05
Specific Gravity	3·36	3·27

Reserves.

Taking into consideration only one band with an average thickness of 50 feet and a mean height of 80 feet above plain level, the ore reserves in the main eastern zone down to water level are estimated at 4,000,000 tons. A conversion factor of 11 cubic feet per ton has been used.

GOLDEN VALLEY

(Map Ref. F3)

Field work by K. Berliat, D.Sc., and R. R. Connolly, report by K. Berliat, D.Sc.

Location.

The Golden Valley Mining Group is situated in hilly country, nine miles by road north-west from Bullfinch.

Occurrence.

With one exception, the several bands of jaspilite in this group are of the siliceous variety. The only ferruginous band is about one quarter of a mile east of Colreavy's Dam, between G.M.L. 863 (Violet South) in the south to slightly beyond G.M.L. 1387 (May North) in the north. It strikes N. 20° W. and has a general dip of 70° eastward. The average width is 30 feet and the mean height above the surrounding country is 25 feet.

Sampling and Grade.

Samples were taken from north to south at approximately 10 chain intervals. Analytical results are given in the table below :—

	Iron Fe %
No. 1—Lab. No. 17969/55	34·59
No. 2—Lab. No. 17968/55	33·07
No. 3—Lab. No. 17967/55	39·38
No. 4—Lab. No. 17966/55	35·96
No. 5—Lab. No. 17965/55	40·30
No. 6—Lab. No. 17970/55	37·94
No. 7—Lab. No. 17971/55	35·61
No. 8—Lab. No. 17972/55	33·15

A composite sample made up from the above individual samples gave the following composition :—

	%
Iron Fe	36·78
Silica SiO_2	44·93
Titanium Ti	Trace
Manganese Oxide MnO	Trace
Sulphur S	0·06
Phosphorus P	0·07

Specific gravity, 3·61.

Reserves.

The tonnage, calculated on a basis of 10 cubic feet per ton is estimated at 2,200,000 tons.

DAY'S FIND

(The Sisters Trig.)

(Map Ref. F3)

Field work by K. Berliat, D.Sc., and R. R. Connolly, report by K. Berliat, D.Sc.

General Information.

Day's Find, a group of old goldmining leases ("One Under," G.M.L. 3933; "Mistletoe," G.M.L. 3825; "Albatross," G.M.L. 3932), is reached by a track which branches off the main Bullfinch-Marie's Find road, one mile from Bullfinch. The distance is approximately five miles. Water for domestic and mining purposes has to be carted from Bullfinch.

Occurrence.

R. S. Matheson has mapped and described two belts of jaspilites forming prominent lines of hills on the eastern and western side of the leases. The western zone consists of one strong major band dipping 70° south-west. In the vicinity of the Sisters Trig., this band is tightly folded and forms three conspicuous hills. The trig. is situated on one of these hills. The band 40 to 45 feet wide rises to a maximum height of 100 feet in the Sisters Trig. sector, but rapidly loses its prominence to the south.

In the eastern zone, repetition by folding has produced three strong individual bands varying in width from 30 feet to 70 feet. The dips vary from 40° N.E. to 70° S.W. In the north, for a total distance of half a mile north and south of the track joining the old Jackson road with the "Radio" mine, the three bands reach a maximum height of about 80 feet. Further to the south they are 30 to 40 feet high, or even less.

Sampling.

Both bands were sampled in the topographically prominent portions of the outcrop, the eastern zone north and south of the track leading to the "Radio" Mine, and the western band in the vicinity of the Sisters Trig. Samples were taken at approximately 200 feet intervals and seven composite samples submitted for analysis.

Grade.

Samples Nos. 1–4 were taken from the western band while the other three are representative of the eastern bands :—

	Acid Soluble Iron Fe on dry basis %
No. 1—Lab. No. 17958/55	29·61
No. 2—Lab. No. 17959/55	22·64
No. 3—Lab. No. 17960/55	28·83
No. 4—Lab. No. 17961/55	26·75
No. 5—Lab. No. 17962/55	26·99
No. 6—Lab. No. 17963/55	37·55
No. 7—Lab. No. 17964/55	38·17

Partial analyses of group samples gave the following results :—

	West Band %	East Band %
Acid soluble Iron Fe	27·35	34·30
Silica SiO_2	55·86	46·85
Titanium Ti	Trace	Trace
Manganese Oxide MnO	0·01	Trace
Total Sulphur S	0·07	0·02
Phosphorus P	0·08	0·07

Tonnage.

Tonnage calculations have been restricted to those portions of the outcrop that were sampled. The figures are based on the following estimates :—

Western Band—

Total Length	40 chains
Average height above plain level	80 feet
Average true width	35 feet

Eastern Bands—		
Total length of the three bands	120 chains	
Average height above plain level	60 feet	
Average true width	40 feet	

	Tons
Tonnage above plain level for Western Band using factor of 13 cubic feet per ton	560,000
Tonnage above plain level for Eastern Bands using factor of 11·5 cubic feet per ton	1,648,000
Total tonnage	2,208,000

DUNDAS GOLDFIELD

NORSEMAN-DUNDAS

(Map Ref. G4)

Field work and report by K. Berliat, D.Sc.

General Information.

The mining town of Norseman is 450 miles by rail from Perth and 125 miles by rail from Esperance, the nearest port. Water for domestic and mining purposes is obtained from the Coolgardie-Norseman pipeline which is a branch line from the main Eastern Goldfields water supply scheme.

The occurrences described below are centred in an area approximately four miles south-south-east from the town, and are easily accessible from the old road to Dundas.

Occurrence.

A number of discontinuous, parallel repetitions of jaspilite beds extend from just north of Timberlana Hill, approximately four miles north-west of Norseman to beyond the old gold-mining centre of Dundas in the south, a distance of some 25 miles. A reconnaissance examination revealed that they have the most conspicuous outcrops and appear to be highest in iron content, in a three mile long hilly strip of country between the "Iron King" mine in the north and the old "Lady Mary" mining group in the south. In this sector, there are from two to four major bands, striking north and dipping 50° to 60° west. They are interbedded with metamorphosed sediments and volcanics, the whole succession being on the western limb of a northerly plunging anticline. Wherever exposed, the eastern bands are predominantly banded quartzites while the two western bands are, in places, moderately rich in iron. The westernmost bed is immediately to the east of the main shaft of the "Iron King" pyrite mine and the other one, on an average, 10 chains further to the east.

Unfortunately, exposures of fresh rock are intermittent, large portions of the outcrop being entirely covered by gossan of quartz and secondary limonite. Nevertheless, such observations as could be made point to the probability that the hematite rich fractions are either lenticular, or confined to selected horizons within the jaspilitic succession. The westernmost band for instance consists of moderately high grade ore along the footwall while the hanging wall side is of poor quality.

Sampling.

Outcrop conditions along the two western bands permitted sampling in two localities, *viz.*:—

(a) In an area approximately 25 chains north from the main shaft of the "Iron King" mine, and

(b) In the "Lady Mary" area.

Due to lateritic covering, no representative samples were obtainable in the one and half mile long intervening portion.

Grade.

The great compositional variations of the two bands are reflected in the following analytical results:—

Sample No.	Lab. No., 1956	Acid Soluble Iron Fe	Remarks
		%	
1	9138	32·81	Eastern Band, 5 chains north from "Lady Mary Deeps," G.M.L. 1402.
2	9139	31·44	Eastern Band, 10 chains north from "Lady Mary Deeps," G.M.L. 1402.
3	9140	46·74	Western Band, west of "Lady Mary" main shaft.
4	9141	43·42	Eastern Band, near south limit of "Lady Mary Deeps."
5	9142	21·32	Eastern Band, 20 chains south from No. 4.
6	9143	33·76	Eastern Band, 25 chains north from main shaft "Iron King" mine.
7	9144	47·24	Western Band, 25 chains north from main shaft "Iron King" mine.
8	9145	23·86	Western Band, 25 chains north from main shaft "Iron King" mine.

Sample No. 7 was from the footwall side and No. 8 from the hanging wall side of the western band.

Partial analyses of group samples from the western and eastern bands showed average percentages of iron and impurities as follows:—

	Western Band	Eastern Band
	%	%
Iron Fe Acid Soluble	39·18	32·70
Silica SiO_2	39·58	49·46
Phosphorus P	0·06	0·03
Manganese Oxide MnO	0·02	0·03
Sulphur S	0·02	0·02
Titanium Ti	Trace	Trace

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Tonnage.

Tonnage estimates are based on a length of three miles, an average height of 50 feet and true widths of 150 feet and 100 feet for the eastern and western bands respectively. The total true width of the western band is approximately 200 feet, but only the iron rich footwall side is considered here. Using a factor of 11 cubic feet per ton, the following figures are obtained:—

	tons
Eastern Band	10,800,000
Western Band	7,200,000
Total	18,000,000

It is imperative to keep in mind that these figures have been arrived at by assuming that the iron content over the whole length of about three miles would be essentially similar to that ascertained in the "Iron King" and "Lady Mary" areas. This may or may not be so—with the emphasis on the second alternative. As already pointed out, the composition of the jaspilite in this area is subject to very great variations and there is a distinct possibility that, in the central portion of the belt, where no sampling was possible, they are too highly siliceous to be even considered as a source for iron ore.

Remarks.

The jaspilites near the western side of Lake Kirk, four miles south-west of Norseman, and mentioned in earlier reports, have been found to be essentially banded quartzites, and useless as a source of iron ore.

Bibliography.

CAMPBELL, W. D.: The Geology and Mineral Resources of the Norseman District, Dundas Goldfield. G.S. Bulletin, No. 21, 1906.

BREMER RANGE

(Map Ref. G.3)

Field work by R. R. Connolly and G. Bartram, B.Sc., report by R. R. Connolly.

General Information.

The Bremer Range is located at the western end of the Dundas Goldfield and within a greenstone belt outlined by Honman (G.S.W.A. Bulletin No. 59, report No. 46). To the north of the range an unformed but cleared road running between Hyden and Mt. Thirsty, passes four miles to the south of Mt. Roundtop. There is no track connecting Mt. Roundtop with the road.

The Lake King-Norseman road passes approximately 14 miles south of Mt. Glasse and it is from this road that access by rough track to the central part of the range is obtained. The interesection of the track with the road at a point 44·6 miles westerly from Daniell Siding is not very distinct. From this point to the main jaspilite outcrop, the distance is 32·4 miles of slow track. The main outcrop is therefore 77 miles from rail (Daniell Siding) and a further 96 miles by rail to the port of Esperance.

Potable water is extremely scarce, being limited to small seasonal supplies in rock catchments.

Occurrence.

Within the Bremer Range greenstone area, only in two localities are the jaspilites of sufficient topographic prominence and grade to warrant attention as possible iron ores.

At Mt. Roundtop, one, or possibly two jaspilite bands have been tightly folded to give an ore body 750 feet long, 60 feet wide and 150 feet above the surrounding country, striking N. 20° W., dipping at 45° to the east and plunging to the south at 30°. Within the body there are some infolded greenstone schists in bands of a few feet thick, and one quarter of the total volume has been subtracted in ore reserve calculations to allow for this material.

In the main body of the range, where it bisects Lake Johnson, some six miles north of Mt. Glasse, two jaspilite bands, each of 25 feet true width, outcrop prominently over a total length of 4·4 miles. For the greater part of this outcrop length the two bands are separated by 70 feet of schistose greenstones, but at the northern extremity they converge and become tightly folded with a steep southerly plunge. The strike is constant at N. 30° W. and the dip varies between 60° and 75° to the east. The average height of the range is this locality is 70 feet above the bed of Lake Johnson.

Grade.

At Mt. Roundtop, a representative sample taken from across the strike and omitting the narrow bands of infolded greenstone, assayed as follows:—

		Acid Soluble Iron %
Sample 1—Lab. No. 2330	....	38·23

At the main deposit, five samples were taken, each one embracing both bands but omitting the greentone between. Samples were taken from south to north at approximately one mile intervals. No change in grade was noted along the strike of the beds. Analyses of these samples were as follows:—

Sample No.	Lab. No.	Acid Soluble Iron Fe on dry basis %
2	2331	43·89
3	2332	38·70
4	2333	39·51
5	2334	38·17
6	2335	39·94

Results of a partial analysis of a group sample, prepared by mixing equal parts by weight of samples 2 to 6, inclusive, were as follows:—

	%
Acid Soluble Iron Fe	40·33
Silica SiO_2	40·01
Phosphorus P	0·04
Sulphur S	0·02
Manganese Oxide MnO	0·03
Titanium Ti	Trace

Reserves.

Mt. Roundtop—	feet
Length	750
Width	60
Height	150
Conversion factor	10 cubic feet per ton
Apparent Tonnage	675,000 tons
Less one quarter for infolded greenstones.	
Total Tonnage	506,000 tons

Main Deposit—	feet
Length	23,000
Average aggregate thickness	100
Average height	70
Conversion factor	10 cubic feet per ton
Hence Total Tonnage	16,000,000 tons

Remarks.

The attenuated nature of the main deposit at Bremer Range renders the future use of the ore a remote possibility.

INDEX

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