Rep.Bk.No. 57/14
G.S.No. 2669
D.M. 130/63.
18th July, 1963

DEPARTMENT OF MINES
SOUTH AUSTRALIA

Report

on

VISIT TO WEST AUSTRALIAN IRON & MANGANESE DEPOSITS IN MAY 1963

by

T.A. Barnes, Director of Mines & G.F. Whitten, Senior Geologist

Collated by

G. F. Whitten
Senior Geologist

CONTENTS

PLAN REFERENCES

63-307	Western Australia - Distribution of Jasper Bar Belts.	1" = 100 M.
S 3453	Route followed and Deposits visited in Hamersley Iron Province, W.A.	1" = 40 M.
S 3454	Pre-Cambrian Shields and The Iron Ore Resources of the World.	
S 3455	Pangea showing Shield Areas and Superior Type Iron Ore Deposits	
S 3456	Mt. Goldsworthy Iron Ore Deposit West Australia	1" = 5000' 1" = 500'
S 3457	Pisolitic Iron Ore Deposits Robe Riv. Valley W.A.	1" = 10 M. 1" = 40 CH.
S 3458	Hematite Iron Ore Deposits Mt. Brockman & Mt. Turner Synclines W.A.	1" = 10 M. 1" = 2 M.
S 3459	Asbestos & Iron Ore Wittenoom & Yampire Gorges W.A.	-
S 3460	Roy Hill Area and Ophthalmia Range	1" = 10 M.
S 3461	Balfour Downs & Mt. Cooke Manganese Deposits, W.A.	Sketch
S 3462	Woodie Woodie & Mt. Sydney Manganese Deposits, W.A.	1" = 100'

DEPARTMENT OF MINES
SOUTH AUSTRALIA

Report

on

VISIT TO WEST AUSTRALIAN IRON & MANGANESE DEPOSITS

IN MAY 1963.

ABSTRACT

A comparison of West Australia and South Australia suggests that large high grade iron orebodies occur in flatly dipping favourable horizons which have a leached and oxidised appearance; siliceous steeply dipping iron formations oxidise less easily and produce few relatively small orebodies.

Faulted or jointed carbonate rocks can contain deep high grade manganese orebodies; shales form blanket deposits of lower grade.

Combination rigs using rotary holes in overburden, down-the-hole hammers in hard rock or diamonds with soluble oil in the circulating water offer best progress and economy in exploration drilling.

1. INTRODUCTION

The following observations are based on a brief visit of inspection to the Hamersley Iron Province of Western Australia by the South Australian Director of Mines, Mr. T.A. Barnes, and the Senior Geologist (Iron Exploration) from 29th April to 15th May, 1963.

These observations are a follow up to those made by the above from 14th to 29th April, 1958 when they inspected iron ore deposits at Yampi Sound, Koolyanobbing, Tallering Peak etc. with the late .M. Willington, Mining Engineer.

In these two inspections virtually all the major known iron bearing areas of Western Australia within 300 miles of the coast have been visited. As a total of 16,000 miles was travelled in 32 days on the two trips, time for inspection of each deposit was limited. Wherever possible visual estimates of tonnage and grade were made and checked by examination of field maps, drill logs etc. and compared with figures quoted by guides.

An examination of the literature on return gave a further check. If anything, published figures are conservative; however all figures quoted in this report have been published. The Western Australian Minister of Mines has announced that the Hamersley Iron Province contains reserves of 8,000 million tons viz. 3,000 million tons of "hard hematite" and 5,000 million tons of "Pisolite" ore. By comparison Barrie (1961) quotes high grade reserves in the Middleback Ranges as 163.0M tons "Demonstrated" and 18.1M tons "Inferred".

Production has taken place from Yampi Sound and Koolyanobbing and is proposed for Mt. Goldsworthy and Tallering Peak. No firm title has yet been given over any of the other deposits in the state. Government policy is to let out large areas to suitable organisations for testing after which negotiations are entered into with a view to development and production virtually on a "company-pays-all" policy. Thus Mt. Goldsworthy Mining Associates are to provide all government buildings both at their deposit and at the port.

Thanks are due to the Western Australian Department of Mines and several private companies, in particular the Broken Hill Pty. Co. Ltd. (B.H.P.) and Conzinc Riotinto of Australia Ltd. (C.R.A.) for facilitating the trips, supplying transport and guides.

2. ITINERARY

Mon. 29 April	Depart Adelaide for Perth.
Tues. 30 April	W. Australian Geol. Survey.
Wed. 1 May	Depart Perth for Port Hedland.
Thur. 2 May	Inspect Mt. Goldsworthy (iron) Whim Creek (copper)
Fri. 3 May) Sat. 4 May)	Inspect Robe River Deposits (iron)

Sun.	5 May	Travel to Beolgeeda
Mon.	6 May	Inspect Hamersley Deposits (iron)
Tues.	7 May	Inspect drilling Wittenoom (asbestos) T.A. Barnes returned to Perth Inspect Yampire Gorge (asbestos)
Wed.	8 May	Inspect Dayles Gorge (iron) " Roy Hill (iron)
Thur.	9 May	Inspect Ophthalmia Ra. (iron)
Fri.	10 May	Inspect Balfour Downs (manganese)
Sat.	11 May	Inspect Mt. Cooke (manganese) " Woodie Woodie (manganese)
Sun.	12 May	Inspect Moolyella (tin) " Marble Bar Return to Perth.
Mon.	13 May	W. Aust. Geol. Survey Inspect Toodyay (foundations)
Tues.	14 May	Main Roads Board Inspect Laboratories (foundations)
Wed.	15 May	Return to Adelaide

Plan S 3453 shows the route taken by the Director and the writer through the Hamersley Iron Province and the route taken by the writer to the manganese deposits further east.

3. REFERENCES

Barnes, T.A., Whitton, G.P. & Willington, C.M. - 1958 - The Principal Iron Ore Deposits of West. Australia. Geol. Surv. S. Aust. Rept. 46/133

Barrie, J., 1961 - Australian Sources of Iron Ore. Bur. Min. Resour. Aust. Rec. 1961-85.

Carey, S.W., 1958 - "CONTINENTAL DRIFT; A SYMPOSIUM", Hobart, Univ. of Tas., Geol. Dept.

Casey, J.N., 1956 - Manganese in Australia. In Symposium Sobre Yacimientos de Manganeso. XX Cong. Geol. Int. IV.

Connolly, R.R., 1959 - Iron Ores in Western Australia. Geol. Surv. W.Aust., Min. Res. Bull. 7 (1959).

Connolly, R.R., 1960 - Report on the Exploratory Drilling of the Tallering Range Iron Deposits. Ann. Rept. Geol. Surv. W.Aust. 1959 p. 86.

Danielsson, ., & Ivarsson, S., 1963 - Iron Ore Developments Surge in West Africa. Min. Eng. 15 (3).

Ellis, H.A., 1956 - The Exploratory Diamond Drilling of the Koolyanobbing Iron Deposits for Pyrite. Geol. Surv. W. Aust. Bull. 111. (1958).

de la Hunty, L.E., 1960 - Final Progress Report on the Regional Survey of the Balfour Downs 4-Mile Sheet, Pilbara Goldfield, W.A. Ann. Rept. Geol. Surv. W.Aust. 1960.

de la Hunty, L.E., 1961 - Some Limonitic Iron Ore Deposits in the Vicinity of Port Hedland, W.A. Ann. Rept. Geol. Surv. W. Aust. 1960.

de la Hunty, L.E., 1962 - Report on New Iron Deposits in the North West Division W.A., Ann. Rept. Geol. Surv. W. Aust. 1961.

de la Hunty, L.E., 1961 - Report on a deposit of bog iron ore at the Scott River, S.W. Land Division, W.A. Ann. Rep. Geol. Surv. W. Aust. 1960. 71-72.

de la Hunty, L.E., 1963(?) - Geology of Manganese Deposits of W. Aust. Geol. Surv. W. Aust. Bull. 116.

Hyde, R.W., Lamb, B.M. & Glaser, W.W., 1962 - Iron Ore Resources of the World. Eng. Min. Jour. 163 (12) p. 84-88.

Johns, R.K., 1958 - Report on Visit to West Australian Manganese and Beryl Deposits. Geol. Surv. S. Aust. Rept. 46/222.

Johnson, W., 1950 - A Geological Reconnaissance Survey of Parts of the Yalgoo, Murchison, Peak Hill and Gascoyne Goldfields. Geol. Surv. W. Aust. Bull. 106.

Jones, W.R., 1963 - The iron ore deposits of the Weld Range, Murchison Goldfield. Ann. Rep. Geol. Surv. W. Aust. 1963 (in press).

Low, G.H., 1960 - Report on the Exploratory Diamond Drilling of part of the Mt. Goldsworthy (Ellerine Hills) Hematite Iron Ore Deposits, Pilbara Goldfield, W.A. Ann. Rept. Geol. Surv. W.Aust. 1960.

McWhae, J.R.H. et al. 1956 - The Stratigraphy of Western Australia. Jour. Geol. Soc. Aust. 4 (2).

Miles, K.R., 1942 - The Blue Asbestos Bearing Banded Iron Formations of the Hamersley Ranges, W.A. - Geol. Surv. W. Aust. Bull. 100.

Miles, K.R., 1946 - Metamorphism of the Jasper Bars of Western Australia. Quart. Journ. Geol. Soc. C II (2) pp. 115-156.

Miles, K.R., 1953 - Wilgie Mia, Weld Range iron ore deposits, in GEOLOGY OF AUSTRALIAN ORE DEPOSITS, 5th Emp. Min. Metall. Congr. I, 242.

Noldart, A.J., & Wyatt, J.D., 1961 - The Geology of Portion of the Pilbara Goldfield. Geol. Surv. W.Aust. Bull. 115 (1963?).

Park, C.F., 1956 - On the Origin of Manganese. In Symposium Sobre Yacimientos de Manganeso. XX Cong. Geol. Int. I.

Park, C.F., Jnr., 1959 - "The origin of hard haematite in Itabirite. Econ. Geol. 54, p. 573.

Rao, M. Suba, 1962 - "Manganese in the Shelf Sediments of east coast of India". Proc. Ind. Acad. Sci., Sec. A, 56 (5) Nov. 274-284.

Reid, I.W., 1958 - The geology of Cockatoo Is., Yampi Sd., W.A. Stillwell Anniv. Vol. Aust. Inst. Min. Metall. 213-239.

Ruckmick, J.C., 1963 - The Iron Ores of Cerro Bolivar, Venezuela Econ. Geol. 58, (2) p. 218.

Skinner, H. C., Skinner, B.J. & Rubin, M. 1963 - Age and Accumulation Rate of Dolomite-Bearing Carbonate Sediments in South Australia. Science 139 (3552) p. 335-336.

Sofoulis, J., 1957 - Report on Iron Ore Deposits, Bungalbin - Mt. Walton Areas, Yilgarn - Coolgardie Goldfields, W.A., Geol. Surv. W. Aust. Bull. 114 (1960).

Sofoulis, J., 1960 - Report on Iron Deposits, Six Miles North of Roy Hill Station, Nullagine District, Pilbara Goldfield, Ann. Rept. Geol. Surv. W. Aust. 1959, p. 58.

Timmermans, C.E.B., 1963 - Making the Best of Manganese Deposits. S. Afr. Min. Eng. Jour. Feb. 1963.

Trueman, N.A., 1963. "Some Observations on the mineralogy and paragenesis of the crocidolite veins at Wittenoom Gorge, W.A., Technical Paper, Aust. Inst. Min. Met., Adelaide Conference 1963 (unpublished).

-- -- Minerals in 1961. Min. Chem. Eng. Rev. 54 (4) 1962.

-- -- 1962. Enormous Iron Ore Discoveries Spur Western Australian Boom. Eng. Min. Jour. 163 (12)

Included in the above are references to iron ore deposits in Western Australia which were visited in 1958.

4. GENERAL GEOLOGY

The Western Australian Geological Survey has been mapping in the Pilbara on various projects for some years, but it was only during the winter of 1962 that more than one regional mapping party was available. Two parties each of one geologist and a driver spent a 6 months field season in the area, while another two parties spent 6 months between them. These parties, members of the Mineral Resources Section, produced the equivalent of 4 x 4-mile sheets in 18 man-months.

It is understood that one sheet, the Balfour Sheet, is being printed at the moment. A regional map of the Hamersley Iron Province will soon be available to the public on a scale of 1" to 15 miles, and will be reproduced in the Annual Report for 1962, available in August, 1963.

The Stratigraphic Column of the Hamersley Iron Province shown below, was provided by the Western Australian Geological Survey and a summary will be reproduced in the Annual Report for 1962.

TABLE 1

CAINOZOIC

Valley fill, scree, alluvium.

TERTIARY

Pisolitic Ore, Conglomerates, etc.

Unconformity v v v v v v v

PROTEROZOIC

Unconformity v v v v v v (?)	) Exposed east and south of the	
Unconformity v v v v v v (?)	) Hamersley Iron Province	

WYLOO GROUP			(11000')
	Greywacke	2000	
Duck Creek	Dolomite	1000	
	Conglomerate	1300	
	Dark Shale	100	
Cheela Spring	Basalt	5000	
	Siltstone & Quartzite	200	
Beasley River Quartzite		300	
Turree Creek Formation		1000	
HAMERSLEY GROUP			(8000')
Boolgeeda Iron Formation		700	
Woongarra Dacite		1900	
Weeli Wolli Formation		1600	
Brockman Iron Formation		2200	
Mt. McRae Shale		300	
Mt. Sylvia Formation		110	
Wittenoom Dolomite		500	
Marra Mamba Iron Formation		600	
FORTESCUE GROUP			(14000')
Jeerinah Formation		3000	
Mt. Jope Basalt etc.		7000	
Hardey Sandstone		4000	
(TOTAL in PROTEROZOIC)			(33000')

Unconformity v v v v v v v

ARCHAEAN

Granite, Greenstone, Jaspilite

N.B. Formations underlined are predominantly iron formations
" underlined contain thin iron formations.

The Archaean Mosquito Creek System is made up of granites, greenstones and jaspilites. It outcrops as inliers in the southern part of the Hamersleys and near Pt. Hedland and as large areas to the south east and north east of the Hamersley Ranges. The Archaean where seen dips steeply (e.g. Mt. Goldsworthy, Whim Creek?) and contain the jaspilite of the southern gold fields and Mt. Goldsworthy, and also base metal deposits.

Unconformably overlying the Mosquito Creek System is the Fortescue Group (Proterozoic) made up of pebble and felspar sandstones (4,000'), pillow lavas (7,000') and shales (3,000'). The Mt. Jope Basalt has been traced for 90 miles. The Jeerinah Shale Formation is characterised by fine bedding with chert nodules near the top.

Conformably overlying the Fortescue Group is the Hamersley Group, mainly chemical sediments with some volcanics and shales. It begins with the Marra Mamba Iron Formation which is characterised by boudinage and has been traced for 300 miles. This formation has produced numerous usually small and thin high grade iron ore bodies and is one of the economically significant horizons. The Wittenoom Dolomite is massive, finely bedded and with chert bands to 12". It usually forms the valley floors. The Mt. Sylvia Formation is characterised by three jaspilite bands; the upper one (Bruno's Band) varying from 17'11" to 18'3", has been traced over 300 miles. One inch of chert 42" from the top of this band has been traced for 105 miles and may also have been recognised over 300 miles. Further work is proceeding to divide this 1" of chert and the writer was able to recognise two iron oxide bands from specimens taken over 100 miles apart. The McRae Shales are dolomitic in part and, where inspected at Dayle's Gorge, were distinctly cherty.

The Brockman Iron Formation is 2,200' thick; it may be shaley near the top. Approximately 1000' from the base are two or three zones rich in blue asbestos (crocidolite) and riebeckite. These have been traced over a length of at least 30 miles; they are adjacent to an horizon containing possible jelly fish. The bottom half of the Brockman Iron Formation where inspected may become the host for the high grade hematite ore bodies (see next section). The Weeli Wolli Formation contains dolomites and thin jaspilites and is overlain by dacite. The Boolgeeda Iron Formation is somewhat shaley and is not distinguished by significant iron ore deposits.

Conformably overlying the Hamersley Group is the Wyloo Group, mainly clastic sediments, fossiliferous in part and with a thick basalt horizon.

Note that there are two unconformities above the Wyloo Group, still in the Proterozoic. The Fortescue, Hamersley and Wyloo Groups in the Hamersley Ranges are relatively undisturbed. They form a syncline trending E.S.E. with dips of $3^\circ - 10^\circ$ on the north edge, with dips becoming steeper on the south edge and towards the south-east, where steep dips occur in en echelon dome-basin structures.

During Tertiary times, jaspilite scree produced mainly from the Hamersley Group was deposited as gravels in closed drainage areas, e.g. Yampire and Dayle's Gorge, and along river valleys, e.g. Duck Creek, Boolgeeda Creek and Robe River. There have been at least two, and possibly as many as five, periods of oscillation since during which time, further clastic sediments were laid down. The base of the ferruginous gravel deposits (see pisolitic iron ore) is now 30' below sea level.

The present cycle of erosion has dissected the Tertiary ferruginous gravel forming mesas of iron ore and produced a drainage system like the Tertiary one, not only in location and distribution, but also in slope. Later jaspilite scree deposits of ore grade in places may be related to this cycle of erosion.

In the Balfour Downs syncline, equivalent rocks occur but unlike the Hamersley Range, the Balfour Downs area is rich in manganese. A summarised stratigraphic column is as follows:-

TABLE 2

CAINOZOIC

Valley fill, scree, alluvium

TERTIARY

Calcrete

Oakover Beds (chalcedony and limestone breccias).

PERMIAN

Braeside Tillite etc.

Various Sandstones and Shales

Unconformity v v v v v v v v v v v v v v v v v v v

PROTEROZOIC

?

Davis Dolerite

?

MANGANESE GROUP

Noreena Shale (manganiferous)

Balfour Shale

Bee Hill Sandstone

Coondoon (Basal) Conglomerate 30'

Angular Unconformity v v v v v v v v v v v v v v v

(= HAMERSLEY GROUP)

Boolgeeda Iron Formation and Pinjian Chert Breccia

?

?

Carawine Dolomite (= Wittenoom Dolomite)

(= FORTESCUE GROUP)

Lewin Shale (incl. Marra Mamba Iron Formation)

Basalt (and pisolitic limestone)(= Mt. Jope Basalt?)

Basal Conglomerate (= Hardy Sandstone?)

Unconformity v v v v v v v v v v v v v v v v v v v

ARCHAEAN

etc.

The above tabulation modifies that to be published as Explanatory Notes to the Balfour 4-mile Sheet as it is more detailed in places and includes the result of this season's work.

There is general correlation between the Balfour Downs Area and the Hamersley Iron Province. However, the iron formations are not as well developed and the middle portion of the Hamersley Group is missing or does not outcrop. The top of this group is represented either by the Boolgeeda Iron Formation (1 location only) or by the Pinjian Chert Breccia, a terrestrial deposit possibly a Precambrian Duricrust which was glaciated in the Permian.

In the Manganese Group, the Bee Hill Sandstone contains thin bedded quartzites and is glauconitic, while the Balfour Shales are green, dolomitic and cherty or micaceous. The Noreena Shale, the host rock for many of the manganese deposits, is a chocolate shale and contains numerous braunite pellets, averaging 32% manganese.

The Davis Dolerite contains pillow lavas and is amygdaloidal producing agate.

The Oakover Beds form mesas but where continuous, this formation is an important aquifer.

All the above are liable to modifications to accommodate current work. In particular, mapping of two unconformities in the Upper Proterozoic south of the Hamersleys should enable better correlation with the Adelaide System. The ages currently favoured namely uppermost Proterozoic for the Fortescue, Hamersley and Wyloo Groups do not appear to allow sufficient room, for two unconformities below the Cambrian or the addition of the clastic iron formations of Yampi Sound and the glacials elsewhere which may be the equivalent of the Aldgate Sandstone and the Sturt glacials respectively.

3. GENERAL COMMENTS ON IRON

3.1. DEPOSITION OF PRE-CAMBRIAN IRON FORMATIONS

While the chemical and geological theories behind the deposition of jaspilite are thought to be known, there are many factors which can only be guessed at. Some are not only not understood but are actually misunderstood.

Many workers for example contrast the common occurrence of jaspilite in the Pre-Cambrian with their absence in later rocks and suggest that the environmental conditions were very different (e.g. Danielsson & Ivarsson, 1963). This ignores geological time. The base of the Cambrian is approximately 560 million years; there are age determinations available in excess of 2,500 million years and Runcorn is insistent that the earth is 4,600 million years old. Thus Pre-Cambrian time is at least three to possibly seven times longer than Post-Cambrian time, with presumably three to seven times more opportunity for iron formation to be deposited.

Moreover there were at least three and probably more different periods in which iron formations were deposited chemically in the Pre-Cambrian, just as there have been a number of periods during which other chemical sediments, e.g. dolomite, were deposited. In some of these, for example in the Braemar iron formation, dolomite is intimately interbedded with iron formation.

Recent estimates of metallic iron in High Grade Direct Shipping Ore, in Concentrating Ore and in the Potential (that is potentially economic) Resources of the world vary between 81,170 and 127,055 million tons of metallic iron. Of this Brazil and Venezuela in South America, the Guinea Coast, South Africa and Tanganyika in Africa, India and Australia have 35,734 million tons, that is approximately one-third of the world's resources, most of which are in Pre-Cambrian jaspilites.

Plan S 3434 shows the known jaspilite and other iron occurrences in the world. Included in the reserves of the older developed countries are large quantities of extremely low grade material not considered ore in the newly developed countries. This gives an undue bias to reserves in the northern hemisphere particularly North of the Tropic of Cancer.

Plan S 3433 shows the Lake Superior Type jaspilites in the countries mentioned in the previous paragraph on a base map taken from Carey (1958) and suggests that in Precambrian times there may well have been a contiguous environment of iron deposition in the Southern Hemisphere. There is also some evidence of a similar environment in the Northern Hemisphere ranging through the Lake District of the United States of America and the Labrador Trough of Canada and extending via Scandanavia into Russia and possibly to Manchuria. The jaspilites of the southern group contain anomalous amounts of soda. Thus the crocidolite (blue asbestos) and riebeckite of Wittenoom Gorge, W.A., the Bababudanite from Mysore, India, the blue asbestos of S. Africa (Miles, 1942) and the magnesioriebeckite of Cerro Bolivar, Venezuela (Ruckmick, 1963) represent soda rich jaspilites not reported from the Northern Hemisphere.

Tremendous amounts of these chemical sediments were deposited. In the Hamersley Group, jaspilites make up over 3,000 feet of the column. These rocks occur over an area of 300 miles East-west by 100 miles North-south, necessitating the deposition of nearly 20,000 cubic miles of iron formation. Assuming an average grade of 25 to 30% iron, this requires the deposition of about 5,000 cubic miles of METALLIC IRON, i.e. sufficient to form an AXLE of rotation for the earth nearly one mile in diameter.

Recent research (Skinner 1963) on dolomite sedimentation being carried out at the University of Adelaide suggests accretion rates of 0.2 to 0.4 millimetres per year. While the writer knows of no correlation between dolomite deposition and iron deposition (though they do occur interbedded), if rates of deposition are comparable the 3,000 feet of iron formation would require 3 million years, for the iron in a group which contains in addition dolomite and chert.

In the Mt. Sylvia formation, the uppermost jaspilite band is being studied in detail. Forty two inches from the top is a one inch band of chert containing a large number (more than 200) of very fine chemically precipitated beds. Groups of these can be recognised by eye in specimens collected up to 100 miles apart and possibly 300 miles apart. Extrapolating Skinner's data (strictly speaking there may be no basis for this), it appears of the order of 1,000 years would be necessary for the deposition of this one inch band. Fossil evidence and ripple marks in other jaspilites e.g. Wilgena Hill suggest shallow water conditions are necessary for deposition. Thus this one inch band would seem to require quiescent conditions and no clastic additions over a period of 1,000 years in an area 300 miles by 100 miles.

3.2. LEACHING AND ENRICHMENT OF PRE-CAMBRIAN IRON FORMATIONS

No significant petrological work has been done by the Western Australian Geological Survey during the current programme on iron formation in the Hamersley Ranges. However, Miles (1942, 1946) has carried out extensive field and petrological work on these rocks and the map of W.A. (63-507) accompanying this report is taken from Miles (1942) with the locations considered by the present writer added.

The primary ore minerals are not known but magnetite with lesser hematite together with chert and minor ferruginous silicates are present in the unweathered rock. Apart from the flat dips the most striking feature of the outcropping rocks is their "oxidised" appearance. This terminology, of common usage by iron ore geologists, refers to the reddish slightly soft and weathered appearance of what was a magnetite or hematite jaspilite which has started to lose silica by leaching and in which the iron oxide has been converted to hematite or goethite. It indicates immediately and macroscopically the leaching of silica and iron and suggests through further enrichment the possible occurrence of ore bodies in the neighbourhood.

In the writer's experience this occurs almost solely in relatively flatly dipping favourable horizons in an area which has experienced abundant "downward-percolating-surface-waters".

The only area in Australia where this has been seen in a wholesale way is in the Hamersley Ranges where the jaspilite is flatly dipping, but relatively minor occurrences in steeply dipping rocks occur in the Ord Ranges and at Wilga Mia, Koolyanobbing etc.

The "oxidised" appearance of the flat lying jaspilite contrasts with the "siliceous" or "silicified" appearance of jaspilites in the Ophthalmia Range, Tallering Range, and Middleback Ranges, Wilgena Hill etc. where black "unoxidised" iron "oxide" bands (magnetite, martite or even hematite) occur in a siliceous matrix. Here wholesale leaching or transport of iron is not evident even though individual bands on the surface may have been etched for a few millimetres. All the areas mentioned in this paragraph have steep dips and relatively few and small high grade ore bodies.

The leaching of any mineral is a factor amongst other things of the surface area of the mineral grains exposed. In addition to jointing etc. grain size is thus critical so that a fine grained jaspilite is more likely to be leached than a coarse grained or a recrystallised jaspilite.

The organic content of the water is also important. Iron is soluble in water containing organic compounds and is redeposited as goethite on evaporation. During periods of heavy rainfall silica is more soluble, especially in more acid water. Ruckmick (1963) quotes springs of pH 7.2 - 6.1 issuing from the orebody at Cerro Bolivar and containing 150-200 times more silica than iron. He suggests that 9 TONS of silica per year are removed from the orebody producing 18 tons of average grade ore and calculates that the Cerro Bolivar orebody could be produced by existing climatic conditions in 20 million years, ignoring ordinary erosional processes.

It is thus impossible to ignore the common occurrence of large orebodies in unmetamorphosed "oxidised" iron formations of low dips and to contrast this with the scarcity and smallness of ore bodies in siliceous iron formations in areas of high dips or in areas of high grade metamorphism. It is in areas of high grade metamorphism and usually in areas of high dips however, that recrystalisation has produced coarse grained iron formations suitable for beneficiation and which because they can produce higher grade and more uniform furnace feeds are preferred in highly developed countries to crude direct shipping ore of less than premium grade.

It is unfortunate that South Australia has no known deposits of "oxidised" iron formation of low dips while the metamorphosed recrystallised iron formations with the exception of Greenpatch are not only too small but too far from the coast for development. The high grade ore bodies of the Middleback Ranges being close to the coast have been and will continue to be developed but current thinking makes it unlikely that the fine grained unmagnetic and very siliceous jaspilite of the Middleback Ranges will be developed within a lifetime.

3.3. ENRICHMENT OF IRON FORMATION IN THE HAMERSLEYS RANGES

The leaching referred to above has allowed the enrichment of iron formation to form blanket deposits of high grade iron over favourable iron horizons and all the tabular high grade hematite deposits of the Hamersley Iron Province are of this type. These seldom exceed 100 feet in thickness and possibly average 50 feet. However such leaching is facilitated by faulting, strong joints, minor folds etc., and where these occur the orebodies are a great deal thicker, 200 ft., occasionally up to 300 feet thick. Thus they resemble closely the classical orebodies of the Mesabi Range and the Labrador Trough.

Apart from shape these ore bodies are of two mineralogical types - biscuit ores and hard hematite. In the biscuit ore silica has been leached leaving a porous mass, somewhat similar in drill core to a packet of biscuits. The spaces between the biscuits represent the siliceous bands removed while the porous biscuits represent the leached ferruginous bands. Such ore in the Mesabi Range grades into

(1) "Wash Ore" where the silica is partially leached, the remaining silica occurring as separate grains which are easily washed out during beneficiation. Wash ore may grade into oxidised and then unoxidised iron formation.

(2) "Slump Ore", in thick deposits where the weight of the overlying ore, scree or glacials has compacted the leached material.

(3) "Hard Ore", where secondary iron oxides, goethite or hematite leached from nearer the surface are deposited lower down infilling leached material to produce hard dense black ore.

In the Hamersley and Ophthalmia Ranges such hematite is the main cementing material and such hard ores occur as deposits over or in iron formations or occasionally over cemented scree on iron formation. Topographically now and during enrichment these appear to have existed in elevated free draining positions. Enrichment appears to have occurred during the Tertiary but it is likely that leaching is still going on in some places.

The biscuit ore and hard hematite ore bodies are almost wholly restricted to the bottom of the Brockman Formation and to the Marra Mamba Iron Formation. In the case of the Marra Mamba Formation the ore bodies are frequently small thin discontinuous manganiferous and erratic in grade both in plan and section. Almost all of very large ore beds occur where the bottom half of the Boolgeeda Iron Formation is exposed to allow access to downward-percolating-surface-waters and where minor structures have opened up the rock.

3.4. EXPLORATION OF IRON FORMATION

Initially exploration was not co-ordinated geologically. At present it is largely restricted to the Boolgeeda Iron Formation but complete cover of all the thicker iron formations and favourable structures will follow eventually. Large scale exploration was carried out by helicopter surveys. Usually two geological parties used one helicopter and were leapfrogged forward alternatively. All known ore bodies outcrop and were recognised by geologists walking outcrops which are not recognised differentially in the air from the ferruginous occurrences referred to above.

Costeaning has not been necessary and testing generally has been confined to wagon drills, cutting being logged by hand lens and assayed. Diamond drilling, say every 5th to 8th hole is done to confirm structure. Lines vary, 800, 1000, ¼ mile apart with drill holes at 200' to 800' centres. The standard of drilling is generally high. Assaying is carried out locally (For details see later).

3.5. EROSION OF IRON FORMATION

Presumably in Tertiary times when the ferruginous skin was forming over the Hamersley peneplain considerable detritus was shed from the outcropping iron formations. Some was caught in closed basins, some deposited in river channels. Drainage initiating from headwaters in the Boolgeeda iron formation received the greatest supply forming trapped equidimensional deposits possibly in lakes in the Dayle's Gorge area etc. and sinuous elongate deposits in river valleys now occupied by Duck Creek, Boolgeeda Creek and Robe River. The former remain as tableland areas and the latter as terraces and mesas along present day water courses.

There is no question that the material deposited in the upper edges or reaches of these deposits is jaspilite scree. Coarse detritus, microcrystalline chert fragments and jaspilite fragments are recognisable. Since Tertiary times however considerable changes have taken place especially in the lower reaches. Silica has been leached out completely and the iron has been reconstituted to form pisolites of goethite so that the grade has been enriched and almost all traces of original structures are lost. The only clastic material remaining are occasional coarse quartz grains.

In the Robe River channel the ore now reaches to 50 feet below sea level at the westward end and indicates at least two periods of oscillation. The slope of the bottom of the sinuous deposit is identical with the present slope of the Robe River which is rather sluggish. During deposition a great deal of wood, mainly fragments ¼" to ½" in diameter and ½" to 1" long now recognisable in hand specimen was deposited but a great deal of smaller material invisible to the naked eye is said to be included. Larger pieces are rare. The shallow slope, the abundant wood and the lack of clastic material have been taken by some workers to suggest a bog iron deposited in a stagnant river system.

6. IRON DEPOSITS VISITED IN 1963

6.1. MT. GOLDSWORTHY (A ORD RANGE)

Location: 85 road miles east of Pt. Hedland and 20 miles from the coast. See Location 3, plan 63.507.

Access: 120 miles from Depuch Is., the nearest suitable possible port site. If dredging of Pt. Hedland is possible rail route may be reduced to about 80 miles.

Held by: Mt. Goldsworthy Mining Associates, i.e. Consolidated Gold Fields (Australia) Pty. Ltd., Cyprus Mines Corporation and Utah Construction & Mining Co. M.G.M.A. have a licence to export and have entered into an agreement with the W.A. Govt. to build a railway.

port facilities and two towns, exporting to begin within 5 years.

Geology: At Mt. Goldsworthy the ore occurs in jaspilites of the Archaean Mosquito Creek Series, on the southern limb of a major syncline plunging east-north-east at 80°. Two to three miles southerly these have been invaded by granite. Immediately north of the orebodies drag on an east-west fault has produced minor syncline plunging 40-50° westerly. The ore occurs in favourable beds where they abut on the fault, in the keel of the syncline and tailing out along the southerly limb. Five ore bodies exist (See Plan S 3456).

Testing: During 1959 and 1960 the West Australian Government diamond drilled the main lens and then called tenders to develop the deposit. M.G.M.A. have continued drilling mainly by wagon drill (20,000'+) and have put in 4 adits. Two of these (Nos. 1 & 4) testing No. 1 Lens were mapped by the writer(See Plan S 3456).

Mineralogy: The high grade massive ore is hard black, dense, shows remnant bedding and with micaceous hematite deposited to fill up the voids. (Est. Grade 65% +). Elsewhere fragments or remnants of hard black hematite are cemented in a ground mass of softer red clayey looking hematite (Est. grade 60-62%?). There is some soft red ore with white flecks, possibly a foundry ore high in phosphorus (Est. grade less than 60% Fe). The footwall of No. 1 Lens is made up of very oxidized and leached jaspilite too low grade to be considered ore but indicating the process of enrichment.

Reserves & Grade: Published figures are 66 million tons averaging 62% Fe. The No. 1 lens has been quoted (E. & M. J. 163 (12)) as 30 million tons grading 64.23% Fe. Other deposits are held by M.G.M.A. in the Ord Ranges but were not visited.

Remarks: M.O.M.A. have 3 years to establish a market and to begin production. Cost is estimated at $23M; royalties as 7½% of f.o.b. value of the ore plus 28/ per ton after 21 years. Considering the 120 mile railway required along a coastline with numerous rivers, also the difficulty of establishing a port, the reserves appear somewhat small and the capital suggested inadequate.

References: Barrie (1961), Connolly (1959), Low (1960) Plan S 3436

6.2. **ROBE RIVER** etc.

Location: 40-100 miles east of Onslow. See Locations 4,5,6, Plan 63-307.

Access: A large number of railway routes and possible port sites are being considered. All rail routes involve crossing large seasonal rivers; all port sites are troubled by low swampy coastlines, shallow seas, unprotected moorings, high tides and annual cyclones. Maud Landing is being investigated by B.H.P.

Held By: The Lower Robe Deposits are held by the Broken Hill Pty. Coy. Ltd. (Location 4). The upper Robe Deposits (Location 5) are held by Basic Materials (Howe Sound, Garrick Agnew Pty. Ltd., W.A., & Cleveland Cliffs). Duck Creek and Boolgeeda Creek are held by Conzinc Riotinto of Aust. Pty. Ltd. in association with Kaiser Steel (Location 6).

All the above titles are by Ministerial Reserves which give the companies 2 years to explore the deposits. After this negotiations with the W.A. Govt. will be entered into to determine conditions for exploitation.

Geology: All these deposits are sinuous deposits along the Old Robe River which have been exposed by erosion to form mesas or terraces. See Section 5 for details of this process.

Plan S 3457 1" = 10 miles shows the location of those inspected in the Lower Robe River Valley. Two of the deposits continue under recent alluvium. The Diagrammatic Cross Section shows theoretical sections through the Upper and Lower Robe River Channels while Cross Section AB shows an area inspected. The deposits vary to approx. 150' with cover from 0-100'.

<u>Testing</u>: Main testing is by wagon drills with minor diamond drilling. The excellent exposures mean that detailed mapping is not required, nor costeaning. Testing is mainly for sampling purposes.

<u>Mineralogy</u>: The ore is pisolitic limonite with more than 10% water. First suggested as being bog iron deposits they are now thought to be channel fillings leached of silica and with the iron leached and redeposited as pisolites.

<u>Reserves & Grade</u>: Published Reserves are 3000M tons grading 55-58% Fe, 9.01 to 11.60% H_2O, and with low silica alumina, titanium and phosphorus. (See especially de la Hunty, 1961).

<u>Remarks</u>: Only two of B.H.P's deposits were inspected on the ground. However an aerial reconnaissance of parts of Duck Creek and Beasley River was made. Total exposures are in excess of 200 linear miles and reserves are often discussed in terms of square-miles-feet. With upgrading by simple roasting the area has enormous potential.

<u>References</u>: de la Hunty (1961), de la Hunty (1962). Plan S 3457.

6.3. MT. BROCKMAN & MT. TURNER SYNCLINES etc.

Location: 50-200 air miles east of Onslow; Locations 7 & 8, Plan 63-507.

Access: Railway routes south of the Hamersleys westerly towards the Onslow coast and through the Ranges northerly towards the Roebourne coast are being considered.

Held by: Conzinc - Riotinto Australia and Kaiser Steel under temporary reserves with 2 years available for prospecting.

Geology: Essentially all these deposits are in the lower part of the Brockman Iron Formation where cross faults, jointing or minor folds has allowed oxidation and leaching of the iron formation. Plan S 3438 shows the regional picture and the relation of ore beds to the Brockman Iron Formation and to structures. Generalised Cross Section AB shows the stratigraphic control of the hematite ore bodies (H) and the relation of the Pisolite orebodies (P) to streams with headwaters in the Brockman Iron Formation. Section CD shows the stratigraphic column and the topographic relationship of beds and orebodies from the Archaean to the top of the Brockman I.F.

Testing: Testing has been carried out by wagon drilling and diamond drilling. Some of the orebodies are very large so that little really detailed work has yet been done.

Mineralogy: These orebodies are formed from iron formation in situ by leaching. In general hard hematite occurs at the surface, passing down through biscuit ore and partially leached and oxidized jaspilite to unleached iron formation at depths ranging from 50 to 400'. (c.f. Park, 1959). Hematite is the predominant ore mineral but hydrated oxides also occur.

Reserves & Grade: The W.A. Minister of Mines has announced reserves of 3000M tons in this general area. A grade of 60.62% Fe is anticipated.

Remarks: This is one of the most outstanding groups of iron ore bodies in the world. While similar deposits may exist in India, S. Africa and Brazil none have been worked on a large scale as yet.

References: Eng. & Min. Jour. 163 (12), 1962.

6.4. YAMPIRE & DAYLES GORGES

Location: 25-30 miles east of Wittenoom.

Title: National Park.

Geology: The Brockman Iron Formation which is here flat lying forms a tableland area which in Tertiary times may have formed a lake. A large areal extent of pisolitic iron ore occurs. Plan S 3439 shows how the Yampire Gorge Area is being dissected by the present cycle of weathering leaving tablelands, terraces and mesas of pisolitic iron ore. In the gorges the existing streams have cut down below the old stream level exposing the lowermost part of the Brockman Iron Formation which contains the asbestos (See Section of Yampire Gorge).

Testing: For iron - Nil. Yampire Gorge has been worked for asbestos.

Mineralogy: As for the Robe River Deposits (See 6.2.)

Reserves & Grade: At least several hundred and possibly several thousand million tons grading 55% Fe +.

Remarks: As this is in a National Park no exploration has been allowed.

References: Miles (1942).

6.5. ROY HILL

Location: Chichester Range between Roy Hill and Wittenoom; Location 9, Plan 63-507.

Access: 100-230 miles from the coast along the Fortescue River Valley.

Held by: In part by B.H.P. under a 2 year prospecting reserve.

Geology: Hard hematite occurs on outcropping Marra Mamba Iron Formation. As the formation is thin the orebodies are thinner and less continuous than equivalent orebodies on the Brockman Iron Formation. Biscuit Ore also occurs, see plan S 3460, Sec. AB, for the area visited by the writer.

Testing: Drilling, details not known.

Reserves & Grade: The Marra Mamba outcrops for over 100 miles with the same topographic expression so that reserves in excess of 100CM tons are likely. Published grade is 62.6% acid soluble iron, 2.72% SiO_2, 1.62% Mn with low P, Ti, MgO and S.

Remarks: The distance from the coast and lack of large orebodies suggests that this area will not have priority of development.

References: Sofoulis - 1960.

6.6. OPHTHALMIA RANGE

Location: 60 miles south of Roy Hill, Location 10 Plan 63-507.

Access: Approx. 300 miles from the coast along the Ashburton River Valley.

Held by: Hilditch A.S. and Wharman, E.H. under a 2 year prospecting reserve.

Geology: The Ophthalmia Range lies in the SE of the Hamersley Iron Province where both the Brockman and Marra Mamba Iron Formations are isoclinally folded into narrow synclines. Ore is related to fold structures, faulting etc. The jaspilite appears less oxidised and more siliceous than in the Hamersley Ranges and more like that in the Middleback Ranges.

Section D, Plan S 3460 shows the orebodies inspected by the writer. Here a flatter than usual dip has sponsored a very large orebody. Both the Archaean Rocks and Tertiary or Recent Scree have been converted to iron ore.

__Testing__: Nil

__Mineralogy__: Hard hematite.

__Reserves & Grade__: Probably a great deal more than 1000M tons grading over 62% Fe.

__Remarks__: Possibly the higher than average grade may be related to the steeply dipping source beds. The distance from the coast make it unlikely that this area will be developed in the immediate future.

__References__: Nil.

The other deposits inspected in 1958 are shown on plan 63-307 and covered by Barnes et al. (1958) and other more recent references e.g. Barrie (1961), Connolly (1959, 1960), Jones (1963), Reid (1958), Sofoulis (1957).

7. GENERAL COMMENTS ON MANGANESE

Bedded manganese oxide deposits form either under marine or fresh water conditions. Manganese leached from rocks during normal weathering processes is transported in stream waters and precipitated by electrolytes such as are present in saline waters. Park (1956) quotes from Chile a manganese oxide zone averaging 20 centimeters thick which has been followed almost continuously for nearly 30 Kilometers but is only 1 kilometer wide. This suggests a stream, lake deposit or ancient shoreline. Recent work in India (Rao - 1962) shows that bottom sediments off the mouths of rivers contain ten times as much manganese as sediments between river mouths. Dredging of manganese nodules from the sea floor is being suggested more frequently in the technical press as a potential source of manganese ore.

However it is necessary to explain the general association of iron and manganese in the same formation though usually in different beds. In Sweden and Finland iron and manganese are precipitated separately with a single lake or within a single inlet. It is thought that this separation depends directly on pH. The rocks of the Hamersley Ranges contain no significant manganese yet further east similar but not identical beds contain numerous syngenetic manganese oxide pellets and form supergene manganese orebodies in outcrop. The shales may average to 13.2% Mn in the unleached condition and pellets as high as 32% Mn. See de la Hunty (1960 & 1963?).

In S. Australia manganese occurrences in jaspilite is not widespread though the Iron Monarch is highly manganiferous in places. In the Proterozoic and basal Cambrian manganese occurs at Pernatty Lagoon (Upper Tillite?) and Donnelly's Comstock but has not been recognised from the Braemar Iron Formation. Park suggested that Pernatty Lagoon deposits may be in tuffaceous sediments but this is not yet confirmed.

All the deposits inspected in W.A. result from supergene enrichment; they often were associated with faulting and usually with dolomite. Most are small; almost all are several hundred miles from the coast.

Commonwealth Government regulations allow lease holders to export one third of reserves proved since 1956. This enables operators to highgrade a group of claims, mining only the best material, hand picking high grade lumps and leaving lower grade material in dumps or in the ground. Prices have fallen from £24/ton maximum in 1958 to £15/ton in 1963 and the grade requirements are now more stringent. South Africa has been a serious competitor with Japan the main market.

Minimum grade required is 40% Mn with a preference for 50% Mn. Timmermans (1963) figures the steep increase in price per pound of contained manganese with the increase in the percentage of manganese in the ore. Thus in 50% ore manganese is worth twice as much as in 40% ore and in 60% ore three times as much as in 40% ore.

Timmermans also summarises the main beneficiation methods recommended in S. Africa. Of six methods viz hand sorting, screening and washing, gravity, high intensity magnetic, low intensity magnetic and flotation only hand sorting is used in West Australia. Hydro-metallurgical processes are also possible where cheap acid or pickling solutions are available to produce battery grade ore.

8. MANGANESE DEPOSITS VISITED

8.1. BALFOUR DOWNS MANGANESE

Location: 100 road miles easterly from Roy Hill.

Access: Roy Hill is 260 road miles from Port Hedland.

Held by: D.F.D. Rhodes has 4 x 100 ac. leases.

Geology: The Balfour (manganiferous) shales form mesas here outcropping as a shallow syncline trending E-W with limbs dipping less than 5° (See Plan S 3461). The shales are exposed in a gully up the axis of the structure and around the edge of the mesa.

The ore is hard and dense and has a distinctly bedded appearance within 2' of the surface. It is formed by supergene enrichment and the removal firstly of Ca, Mg and SiO_2 and finally of Fe. In costeans rubble ore and pisolitic ore show the physical and chemical breakdown which has occurred (See Cross Section S 3461).

<u>Testing</u>: The area which is 1 mile EW by ¾ mile NS has been mapped by plane table on a scale of 100' to 1". The deposit has been costeaned on an 800' grid and sampled.

<u>Reserves & Grade</u>: Average thickness is 12' and average grade 36% Mn; too low to be mined under existing conditions. Reserves could be as much as 5M tons certainly sufficient to justify a metallurgical project.

<u>Remarks</u>: This is probably the most outstanding manganese resource of Australia. <u>Should it be amenable to beneficiation it is likely to take the market for all except the highest or battery grade ore</u>.

Surrounding the deposit are flats covered by rubble 2' and more thick. This assays 26% Mn. Of 50 pebbles, 45 were manganese pisolites, 4 iron and 1 quartz. Reserves are possibly 1 M tons per square mile.

Ore from this deposit is characterised by a brown limonitic surface coating.

<u>References</u>: de la Hunty (1960), de la Hunty (1963?).

8.2. <u>NOREENA SHALES</u>

Four miles east of Mt. Cooke an outcrop of Noreena Shales was inspected. In general these are soft chocolate shales or dense chocolate mudstones containing Braunite Pellets. These assay as high as 32% Manganese and range in size from less than 1 mm to 20 mm averaging possibly 10 mm. There are occasional doublets; one triplet was seen. They occur at 5 to 10 mm spacings throughout the rock. They are evenly distributed although in some bedding planes they may almost touch. Where inspected the ground was covered by these pellets and such occurrences are not uncommon.

There can be no question that these are compacted manganiferous concretions formed on a sea floor and the source of many of the deposits now being worked. A small high grade body (50 tons? of 50% + Mn) outcropped in the vicinity and this horizon could be traced for half a mile.

8.3. MT. COOKE (DAVIS RIV.) MANGANESE

Location: 40 miles ESE of Nullagine

Access: Nullagine is 200 miles from Pt. Hedland.

Held by: D.F.D. Rhodes under MC 194L.

Geology: The orebody occurs as a surficial enrichment of the Mosquito Shales, here subhorizontal and underlying a chert breccia. The higher grade material in the East Quarry seems related to a fault. See Plan S 3461. Manganiferous scree occurs and has been worked. The ore occurs as a blanket deposit 400-500' EW and 10'-30' deep, averaging possibly 15'. At the fault plane the ore has been worked over a NS distance of 200' at right angles to the general strike and to a depth of over 30'

Reserves & Grade: Production has been approx. 20,000 tons; it is apparently worked out. However large quantities of ore, possibly in excess of 20,000 tons remain in the dumps. Grade was 50% Mn.

Remarks: The deposit inspected was only one of several in the district.

This ore is dense blue-black and hard and is very distinctive.

References: de la Hunty (1960, 1963 in press).

8.4. WOODIE WOODIE MANGANESE

Location: Approx. 80 air miles east of Nullagine.

Access: Approx. 260 road miles from Port Hedland.

Held By: Northern Minerals Syndicate - MC 269.

Worked By: D.F.D. Rhodes who has a power plant, crusher, trommel, picking belt and bins on separate trailers forming a road train which is moved from deposit to deposit.

Geology: The district structure is a syncline in dolomitic limestone. This limestone contains lenses and nodules of chert which as a result of weathering now blankets the limestone. The main deposit occurs near the axis of the syncline (dips 5-10°) and appears to follow the bedding where it has been opened up by joints. See Plan S 3462.

The main quarry has been open cut to 50' and has been proved to 90'. Strong joints are common in the quarry and appear to control the replacement. Breccias resembling sinkhole fillings were seen in two places on the NW wall of the main quarry.

In the Manganese Outcrop to the SW remnant bedding is defined by ferruginous bands and lines of chert breccia similar to that seen at Donnelly's Gemstock near Quorn S.A. A series of wagon holes drilled at 10' and 25' centres on lines 25' apart has proved ore to 60'.

The ore is high grade and white in colour. Some light coloured mineral (clay or carbonate ?) is deposited in joints and cloaks the faces of the quarry and the broken ore so that it is impossible to determine ore from waste in the quarry without chipping pieces or assessing their weight. The outcrop is the typical dark colour of manganiferous outcrops.

Reserves & Grade: Originally quoted as 4000 and later as 5800 tons production approximates 50,000 tons. Grade is possibly 50% Mn.

Remarks: This is one of the largest deposits in West Australia and is remarkable because of its depth extent which presumably is related to strong jointing. Note the mobile treatment plant.

References: Casey (1956), de la Hunty (1960, 1963 in press).

8.5. MT. SYDNEY MANGANESE

Refer Plan & Section S 3462.

This deposit is also remarkable because of its depth extent. Dolomite along a fault is replaced by hausmannite and psilomelane. One of a number of pods with limited surficial exposure enlarged in depth either along tension joints or minor faults to form a body 70' x 30' x 30' deep under 10' of dolomite. See Sketch Section AB. A second lens also had a small pod attached to it.

Both these 2 deposits show the difficulty of assessing reserves of manganese orebodies especially in carbonate rocks opened up by jointing or faulting. Deposits formed in or from shales appear to be more blanket-like in form.

9. OTHER ASPECTS CONSIDERED

9.1. WHIM CREEK COPPER MINE

Location: Halfway between Port Hedland and Roebourne. W.A.

Access: On main road.

Held by: Depuch Shipping and Mining Co. Ltd. which is controlled by Japanese interests.

Geology: The country rock is said to be made up of slates and metasediments of Archaean age. An oxidized copper lode, dipping 15° near the surface and 45° in depth was worked more than 50 years ago. The present interests are putting up a plant to treat oxidized copper ore in dumps and in the oxidized zone.

An after-dark surface inspection by the writer using lamplight identified tuffs in the host rock, black slate at one shaft and primary zinc ore in pyrite on thedump of another shaft in the hanging wall of the orebody. The sphalerite is almost certainly marmatite as is common with pyritic zinc ores.

Testing: A number of old shafts are being cleaned out. A diamond drilling programme using a Mindrill F 20 machine with an A-hydraulic head and a Longyear equivalent machine is in progress. Most holes were drilled at - 70° and penetrated flatly dipping "slate" to 500 ft., then passed into "quartsite" and bottomed in "gneiss". Core is "AX" or "EX".

Japanese impregnated bits (11 carats) at £12.5.0 each are preferred to Australian equivalents quoted at £17.0.0 each. A Japanese core barrel was said to give 30% more core; core recovery was seen to be good and probably not difficult with any type of bit or barrel.

Reserves & Grade: Reserves of oxidized copper ore are estimated at 250,000 tons assaying possibly 8-9% copper but more probably 5-6% copper.

The West Australian Geological Survey knew of no zinc mineralization being reported and had no access to drilling records or assays of core. They have a regional mapping party working in the area this winter.

Remarks: Many sulphide deposits worked 50-70 years ago in the oxidized zone for copper stopped in the zone of secondary enrichment when complex sulphides were reached.

This deposit needs examination for a possible zinc orebody.

9.2. WITTENOOM ASBESTOS

Location: Wittenoom Gorge 5-6 miles south of Wittenoom and Yampire Gorge 26 miles easterly.

Access: Wittenoom is 181 miles from Roebourne and 193 miles from Point Samson.

Held by: Australian Blue Asbestos Pty. Ltd., a subsidiary of Colonial Sugar Refining Co. Ltd.

Geology: The "ore horizon" is in the lower half of the Brockman Iron Formation. See Plan S 3459. There are two and occasionally three zones of blue asbestos (crocidolite), each of a number of thin beds conformably enclosed in banded ironstone. Usually, and especially in the case of the thicker crocidolite beds, there is a bed of riebeckite adjacent to the crocidolite. These bluish bands (up to 6") can be recognised from many yards in the gorges and serve to distinguish the asbestos horizons. The riebeckite exists as an interlocking mass of minute fibres with bedding rarely visible.

The crocidolite forms cross fibres at right angles to the bedding and varies to approx. 2" in length though most bands are thinner. For the thicker asbestos bands a thin band of fibrous quartz with fibres oriented at 60° to the bedding may cap one side of the crocidolite band. In all cases thin magnetite beds (less than 1 mm) form the actual boundary of the asbestos. Frequently especially in the thinner bands wisps of magnetite bands remain in the fibre suggesting growth of the crocidolite and displacement of magnetite. See sketch of specimen Plan S 3459. This may also account for crimps in the longer fibre or cone structures in some thinner beds.

At Vampire Gorge fossils occur adjacent to the asbestos horizon. These fossils are typically numerous concentric rings with an outside diameter approaching 6". Groups of 2 and 3 of these occur on single slabs suggesting colonies of algae or jellyfish. Other structures rather like raised lumps and said to be fossils were not convincing. The age is probably Proterozoic.

Deposits: Yampire Gorge was the site of the original mine where one horizon worked by a room and pillar method used, numerous openings in a promontory between the main gorge and a branch.

Recent production has come from Wittenoom Gorge where a "slope" below the ore zone has enabled two horizons to be worked by a mechanised room and pillar method. Changing prices and greater mechanisation has affected mine layout resulting in a large cave-in which has disrupted production.

Each ore horizon is 3'-4' high and in the drill holes seen contains less than 10% asbestos. For details of drilling See below.

Milling: Asbestos milling is a dry process, basically crushing sufficiently to break the fibres from the rock followed by air elutriation. It is thus a dusty process and recovery is low - of the order of 50%.

At Wittenoom the presence of magnetite in the fibres affects both crushing and collection. See Trueman (1963).

Reserves: As the asbestos is bedded reserves are very large, production depending on accessibility and market price.

Remarks: Sec. 3.1. refers to the occurrence of blue asbestos only in jaspilites of the southern hemisphere. In Western Australia the jaspilites are known to be of 2 ages; Wittenoom occurs in the younger jaspilites.

Weak asbestos mineralisation is associated with dolomite adjacent to an iron formation near Tumby Bay. No details are available. Other occurrences in S. Aust. are of the serpentine variety.

Considering the low percentage of asbestos at Wittenoom it seems desirable that all asbestos occurrences in S.Aust. should be reassessed, especially those near the coast.

References: Miles (1942, 1946). Trueman (1963).

9.3. MOOLYELLA TIN

Location: 10-15 miles east of Marble Bar.

Access: Approx. 130 miles from Pt. Hedland.

Held By: Mineral Concentrates Ltd. which company owns the major leases.

Geology: The area is granite which contains cassiterite, generally in non economic veins. Weathering has produced tin leads, which were "high-graded" by up to 1500 men before 1904.

Overburden is usually 3'-6'. Three miles of leads have been worked averaging 50' wide; 18" of wash at the bottom containing the cassiterite.

Workings: Present prospecting methods are to follow old workings. Originally bulldozers removed the overburden (5'-6') but as this may contain 4 lbs./yard it is now being put through a mobile upgrader - see later. The wash containing high values in clay is then stacked and allowed to dry out in the "dry" with occasional restacking to facilitate drying. This is then picked up by a front end loader and trucked to the concentrating plant.

Water: Shortage of water (average 13' evaporation/year) prevented production from 1904 to 1953. Nowadays surface runoff during the wet is directed into old workings and used early in the "dry". Main reserves come from bores which were selected by photographing the area from the air with colour film and selecting bore sites in better vegetated country where major joints or faults run out of the granite. Water is not being reused although with a ponding system this should be possible.

Mobile Upgrader: Sun dried low grade material which has been restacked or run over by bulldozers is trommelled in the field rejecting over half as coarse material (+ 3/16 Even the high grade ore is loaded through a portable grizzly to reject lump (+ 2"?) material. Maximum cassiterite size is possibly ⅛ inch.

Treatment Plant: The trucked material passes from a bin via a belt through a mixing box to a trommel (10' x 2'6") with ½" punched screen (8') followed by 2' of woven screen. Oversize is passed to a truck for dumping. Undersize falls to a sump pump which delivers it at 35% solids to two primary cones which catch the coarse tin on the first pass. A minimum of water is used; 35% solids is the maximum the pumps will handle.

The tailings from these cones is pumped to a scavenger cone which produces a final tailing and returns a low grade concentrate to the primary cones for cleaning. This additional mixing and pumping breaks up small clay balls releasing fine tin, increasing recovery and producing a cleaner concentrate. All the concentrate is produced by the primary cones.

The cones: The cones are made of ¼" mild steel checker plate with the apex supported and the body running on small solid rubber tyres. Included angle approximates 110°, diameter is 10' for the primary cones and 12' for the scavenger cone. Each has a 1" internal lip parallel to the axis. An external lip at right angles to the cone surface removes drips. The axis is inclined at approximately 50° so that the cone dips out at 2½° (for scavenger), 5° (for primary) or 7½° (for beach sands) from the apex.

Delivery of feed is half way between the apex and lip on the rising side and directed towards the lip. They are fed at a minimum rate of 15 cubic yards/cone/hour but have been used as high as 30 cubic yards/cone/hour. As dense a feed as possible is desirable; the fresh feed pushes the light material out. Rotation causes the feed to "wind-in" towards the apex. Rotational speed is approx. 8 revolutions/minute. It must not be too high else a centrifugal action results. Wash water is applied on edge of the cone half way up on the rising side. Total water use is 130 galls/cubic yard compared with 1000 galls/cubic yard with jigs.

The concentrate comes out about 18" from the apex and is drawn off the back of the cone at intervals through a 1" spigot on the axis while the cone is revolving. It is cleaned up by sluicing or tubbing sundried and packed in 44 gal. drums containing 17 cwt.

__Reserves:__ Probably 20 years.

__Grade:__ Recovery has averaged 11.5 lbs/yard. Tin loss is less than 1% of tin fed.

__Remarks:__ This plant currently treats 300 c. yds. per 10 hour day producing a drum of cassiterite weighing 17 cwt. and valued at approx. £600. Similar equipment is used for beach sands and could be used for gold. Cones down to 4' diameter are in use, these being simply mounted on posts.

__Native Yandying:__ The mechanical working of deep leads means that bulldozers frequently leave small pockets of very rich ore on the floor of the lead or in crevices in the bedrock. Native women sweep these clean with small brooms made from spinifex and recover the tin by yandying.

This is vaguely similar to panning for gold except that the feed must be dry, preferably evenly sized and the dish is boat shaped. Originally made of bark, galvanised iron 2' long by 15-18" wide is curved into a hemicylinder with rounded ends. Rhythmic shaking forces the cassiterite to one end while the gangue overflows at the other. One 2'6 jam tin of cassiterite can be collected in a day and is worth six shillings.

9.4. SCOTT RIVER (IRON)

This is a Quaternary Bog Iron Ore deposit. As it has had much publicity it was originally planned to visit the area, especially as it could possibly resemble laterites near Victor Harbour. However the W.A. Geological Survey advised that the deposit is not significant.

Location: Near Albany in the south west.

Access: Less than 10 miles from coast.

Held By: Mineral Mining & Exports (W.A.) Pty. Ltd. who have a licence to beneficiate the material and to export it. This may be a subsidiary of Heine Bros.

Geology: The iron has been introduced laterally into a swamp. It rests on sand and has sand pockets and contains sand cemented by limonite. The silica content is high.

Reserves: At least 200 acres exist, averaging 4' - 11' thick and assaying 40-45% Fe.

Remarks: Of no economic significance.

References: de la Hunty (1961).

9.5. DRILLING TECHNIQUES

As drilling plays such a large part in exploration this was assessed at each prospect. The more geological aspects such as hole spacing, logging techniques etc. have been mentioned briefly under the pertinent deposits.

Iron exploration overseas has tended to avoid diamond drilling and this trend has been recommended in the Department by the writer as far as available equipment allows. Thus diamond drilling accounted for only 16% of the drilling done at Warramboo where average cost per foot was £1. 7. 9., somewhat less than at Cowell and in the Middleback Ranges.

Wagon Drills

In the Hamersley Iron Province the trend is towards wagon drills. At Mt. Goldsworthy, a crawler mounted Gardner-Denver Air-Trac Drill was used with a 2-2½" bit to 230'. A four-wheeled compressor was towed by the crawler during shifting. This is a "down-the-hole" drill. Progress has been as high as 200' per shift but with stoppages had averaged only 200' per week recently. Cuttings are laid in heaps beside the hole for each run and are collected by a sampler or geologist. Costs are 15-40% contract diamond drilling rates. Assays for iron are carried out in Pt. Hedland with composites for each hole assayed for other elements in Perth.

The Broken Hill Pty. Ltd. use a Halco-Stenuick down-the-hole drill, truck mounted and with a truck mounted A.C. compressor supplying air. Cuttings are laid out on the ground in 6' runs. An excellent drilling record is maintained; in particular the colour is logged using a Munsel colour chart. The system is somewhat similar to that used at Warramboo but no attempt is made to record mineral content accurately. However assaying is done locally so that grade can be checked quickly.

Con-zinc Rio-tinto Australia have a contractor using a Reich Drill (B.H.P. use one of these at Koolyanobbing) which has a larger hammer and produces more cuttings than the Halco-Stenuick which they consider unsatisfactory. Of the cuttings, 75-95% being the coarsest are collected at the collar of the hole by an inverted cone placed over the casing. The fines (5-25%) are collected by fan in a dust box. Average progress is 75' per day; elsewhere it has been 150' per day. Direct costs are 15-25% of diamond drilling costs at three times the speed. However a geologist or sampler is required at the drill site. Every tenth hole is duplicated by diamond drilling. Assaying is done locally.

From the above it seems that penetration rates and costs per foot for a wagon drill approximate that for a rotary plant in overburden or soft rock. A wagon drill could possibly replace a diamond drill for short holes in hard material. Logging and interpretation is more difficult but the techniques used at Warramboo could suffice and could make savings if properly used.

Diamond Drilling

Mt. Goldsworthy Mining Associates and Conzinc Rio-tinto Australia used contract diamond drillers. The costs quoted where comparable with drilling in the Middleback Ranges and somewhat higher than recent Departmental drilling in iron formation.

At Whim Creek (See Section 9.1) drilling conditions were excellent. AX and EX holes were drilled and Japanese equipment was regarded as better than the Australian equivalent. Never-the-less the figure quoted for diamond loss per foot was extremely low and total cost per feet so low as to suggest that supervision, overhead and fuel were not included. However some investigation of Japanese equipment seems desirable and may be rewarding.

Combination Rigs

At Warramboo a combination rotary (diamond) - percussion (cable tool) plant, the Failing WW 1 with a geologist and/or sampler attached turned in a very good performance, both from the drilling and geological aspects. Total cost including geological logging is estimated at approximately £1.15.0 per foot.

At Wittenoom John Kitching is achieving remarkable results with a "250 Pneumatractor Self-Propelled Schramm Rotadrill" for 3 reasons:-

(1) Type of plant. This plant is mounted on a pneumatic tyred tractor and can go almost anywhere under its own power thus reducing the transport costs. It will drill a 3"-6" hole with a down-the-hole hammer to 500' using 250 c.f.m. of air at 100 p.s.i. This requires no water. Using the same N drill rods it can convert to diamond drilling with water and continue. There is no rotary table or kelly, rotation being by an hydraulic motor on the mast. It can only drill vertically. Cost of plant was £22,000 (Refer

D.M. 1197/63).

(2) Supervision and organisation. Each hole is prepared by excavating to 3' and filling with concrete. Collaring is done with a roller bit to bedrock and 6"(?) casing is then inserted. A 4" Halco Stemwick hammer (4½" bit) is then used as far as possible or to near the asbestos seam, after which the hole is continued by diamond drilling. The rig arrives on the site self contained and with enough gear for 2 days drilling.

Using a smaller down-the-hole hammer it should be possible to follow with AX or BX equipment. Kitching is getting rods with a tapered seismic thread to speed up progress.

Almost all personnel have been on the job for more than 2 years and there is a good esprit de corps. Kitching's enthusiasm, knowledge and questioning approach stamp him as an unusually good type of supervisor.

(3) Diamond Drilling. This is done by Mindrill Spiral Set NX Core Bits, containing 8-10 carats with best quality ("Hard core") stones, 80-110 per carat. Slow revolutions (80-120 per minute) are used with 2-300 lb. bit pressure (Mindrill 750/1200 pump).

Shell Dromus B Soluble Oil (£22/44 gal.) is added to the circulating water at a ratio of 1 oil : 80 water. Recently 2 drums were used for 350' of diamond drilling in 12 shifts. This is approx. 2/6 per foot for oil.

Footage per bit has increased from 18" to 70'. Diamond recovery on bits used from 30-70' is estimated at 80% and these bits were to be used on the next hole. A target of 130 ft./bit has been set for an iron formation as hard as much in the Middle-backs.

The increased efficiency appears more than can be expected by the addition of a small amount of cutting oil to the circulating fluid. Possibly a type of "oil-flotation" occurs by which metallic mineral particles are floated away from the bit, thus preventing regrinding. It would appear that a small project could be initiated with A.M.D.L. to determine if this occurs, to compare flotation of metallic minerals such as ores with any quartz and to test if any conditioning agent such as is used in mineral flotation might help this effect. It is also necessary to see if the oil can be used with "mud".

It would appear that the smaller "125 Pneumatic-Tractor-Mounted Schramm Drill" capable of down-the-hole, rotary, diamond and auger (?) drilling may have a useful application for the Department in mineral exploration. Do-it-yourself kits i.e. a "125" or "250" plant for mounting on your own vehicle are also available. Any such increase in drilling efficiency must be matched by an increase in geological efficiency. A suitable programme must be available and logging and interpretation as at Warramboo must keep pace with the drilling.

9.6. MOBILE PLANTS

Apart from the iron, the Hamersley Province contains a large number of small mineral deposits, each too small to amortize equipment on their own. With relative easy access and a suitable climate operators are tending towards mobile plants. These are not plants that can be dismantled and re-erected elsewhere as some quarry operators use in South Australia but plants made up of units on trailers which can be towed from place to place.

At Woodie Woodie (Section 8.4), a prime mover, made in Perth, carried diesel-electric generators and towed 150 tons. This comprised 3 or 4 trailers carrying respectively crude ore bin and jaw breaker, stacker conveyor, picking belts and final ore bins. At Moolyella (Section 9.3) a mobile upgrader consisting of a trommel and stacking belts and also a portable grizzly were used to reduce transport of crude ore. The cone treatment plant itself could be dismantled and shifted cheaply and cones down to 4' diameter are used elsewhere.

Such plants in South Australia have potential for testing or treating heavy minerals such as tin, gold, diamonds, lead and copper and in testing prospects may be just as much an exploration plant as a diamond drill.

10. CONCLUSION

The Hamersley Iron Province quoted by the West Australian Minister of Mines as containing 8000 M tons of direct shipping iron ore is one of the major iron provinces of the world and is certain to be developed.

The flat dips, the leaching and oxidation and minor structures such as faults, folds and joints have produced a large number of large high grade iron ore bodies in the classical sense. South Australia with steeply dipping siliceous, unoxidised iron formation by contrast has few relatively small iron orebodies; it seems unlikely that any equivalent field of high grade iron ore will be found here. Metamorphosed iron formations capable of providing ore for beneficiation is our best target providing it is close to the coast. In this respect Greenpatch warrants testing.

In the northwest of Western Australia railway and port facilities though non-existent at present are sure to be provided. One of the major points to be considered in development is Government policy. This restricts title initially to 2 years Prospecting Reserves which enables a prospecting organisation and the Government to assess potential but does not give the prospector any real rights to any deposits found. In addition the Government requires the future lease holder to supply all township facilities, including buildings for Government purposes and all rail and port facilities. The royalty charges are high especially as some of the facilities e.g. ports eventually revert to the Government.

The manganese deposits seen in Western Australia are either thick high grade bodies in carbonate rocks or tabular low grade bodies in shales. The former are small in area and the latter large in area. The manganese potential is limited by the distance of the deposits from the coast. However if Balfour Downs is amenable to upgrading its large potential will dominate the Australian market. Therefore if any exploration programme for manganese is envisaged in South Australia it should have priority or through beneficiation be aimed at a market not available to the Balfour Downs ore.

The variety of mineral deposits in the Hamersley Province show that Pre-Cambrian and preferably Archaean terranes are those that contain the best exploration targets. For this reason the Olary Province, the Central Province and Eyre Peninsula in South Australia require most attention here and the development of an up-to-date exploration philosophy is desirable for these areas.

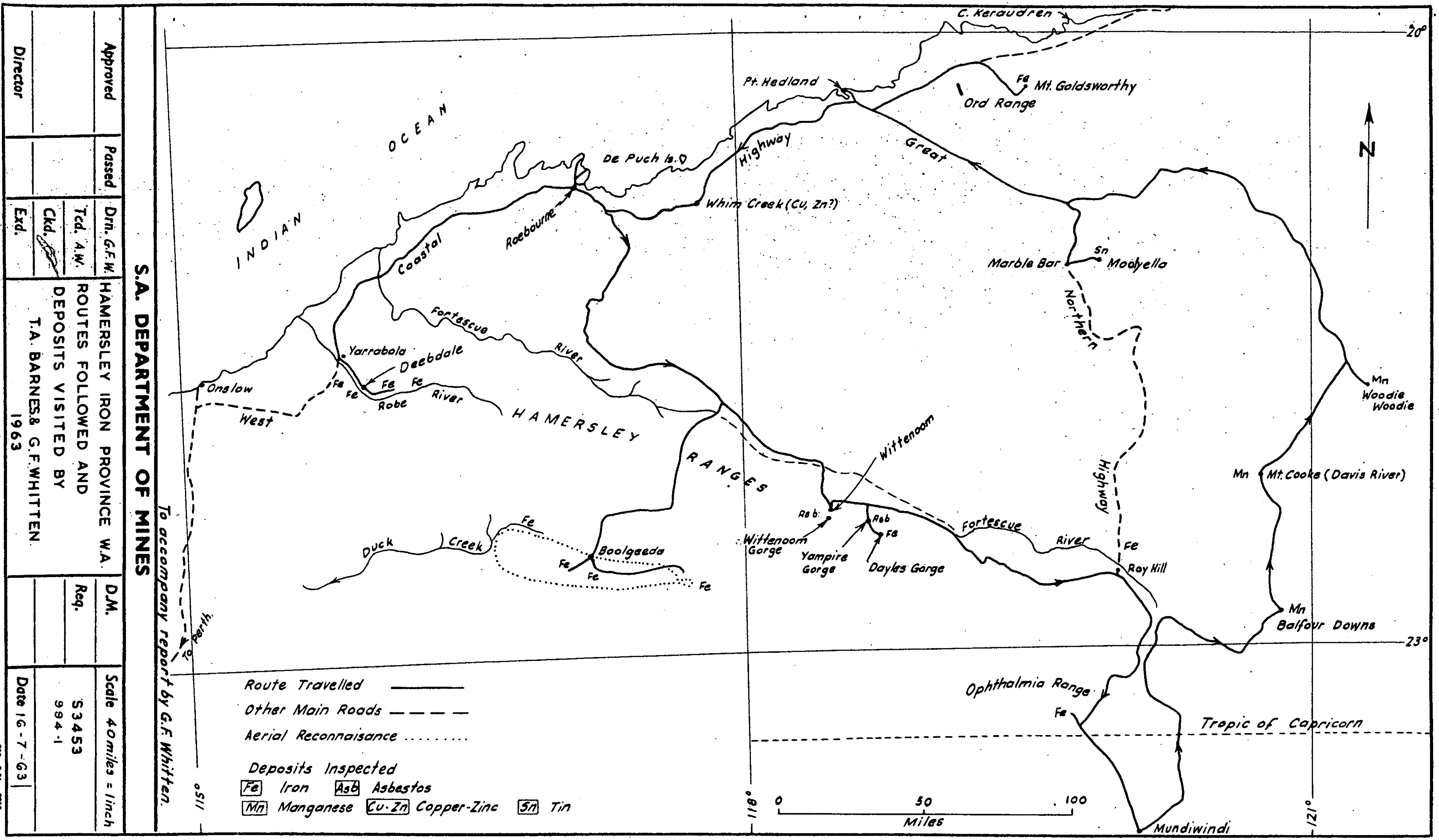
As testing is a necessary follow up in the development of mineral deposits in these areas the use of combination rigs and mobile treatment plants should be investigated.

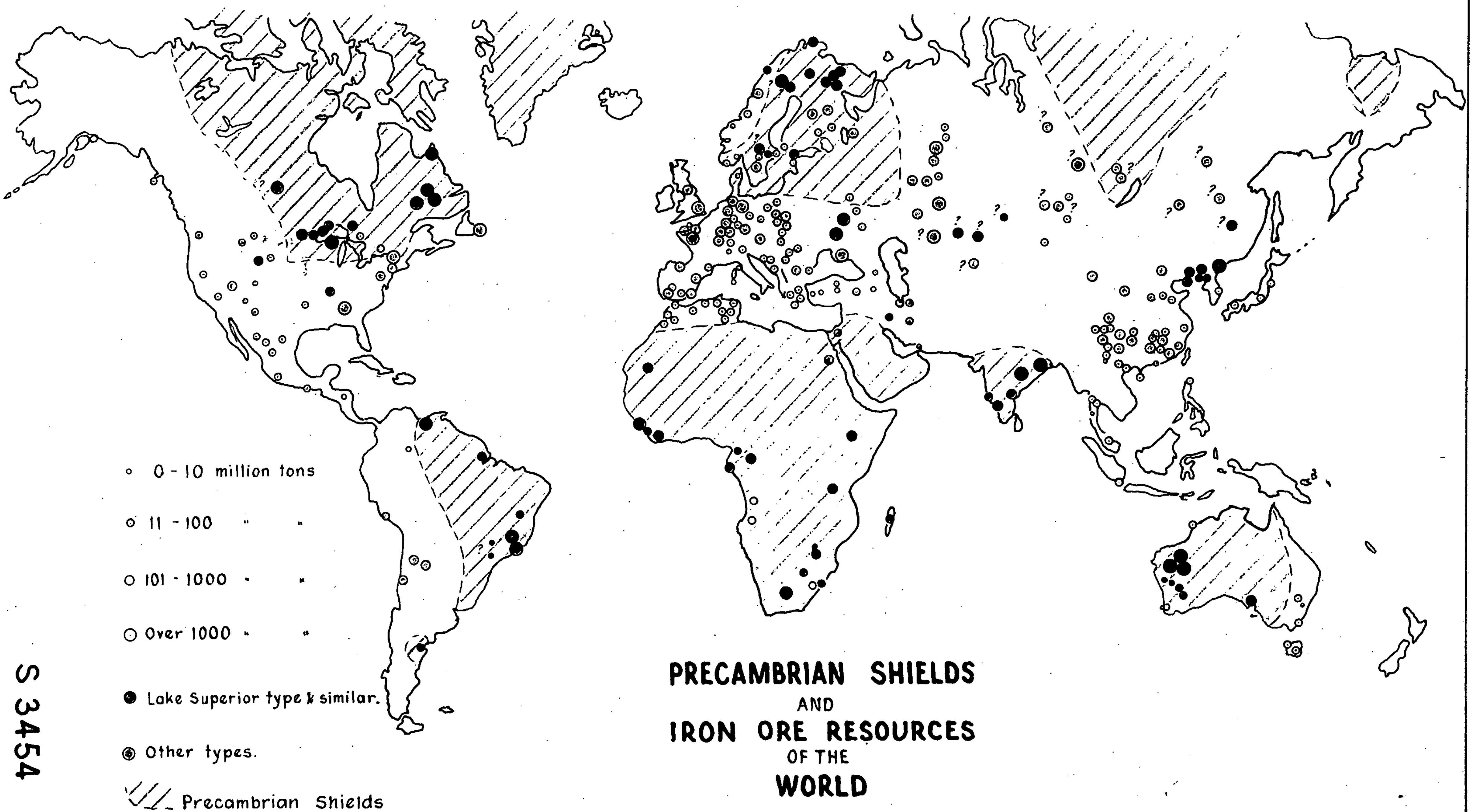
It is only by a virile exploration programme based on scientific assessment that new deposits will be found in areas with such a long history of prospecting.

G. F. Whitten
Senior Geologist
IRON EXPLORATION SECTION

GFW:AGK
18/7/63

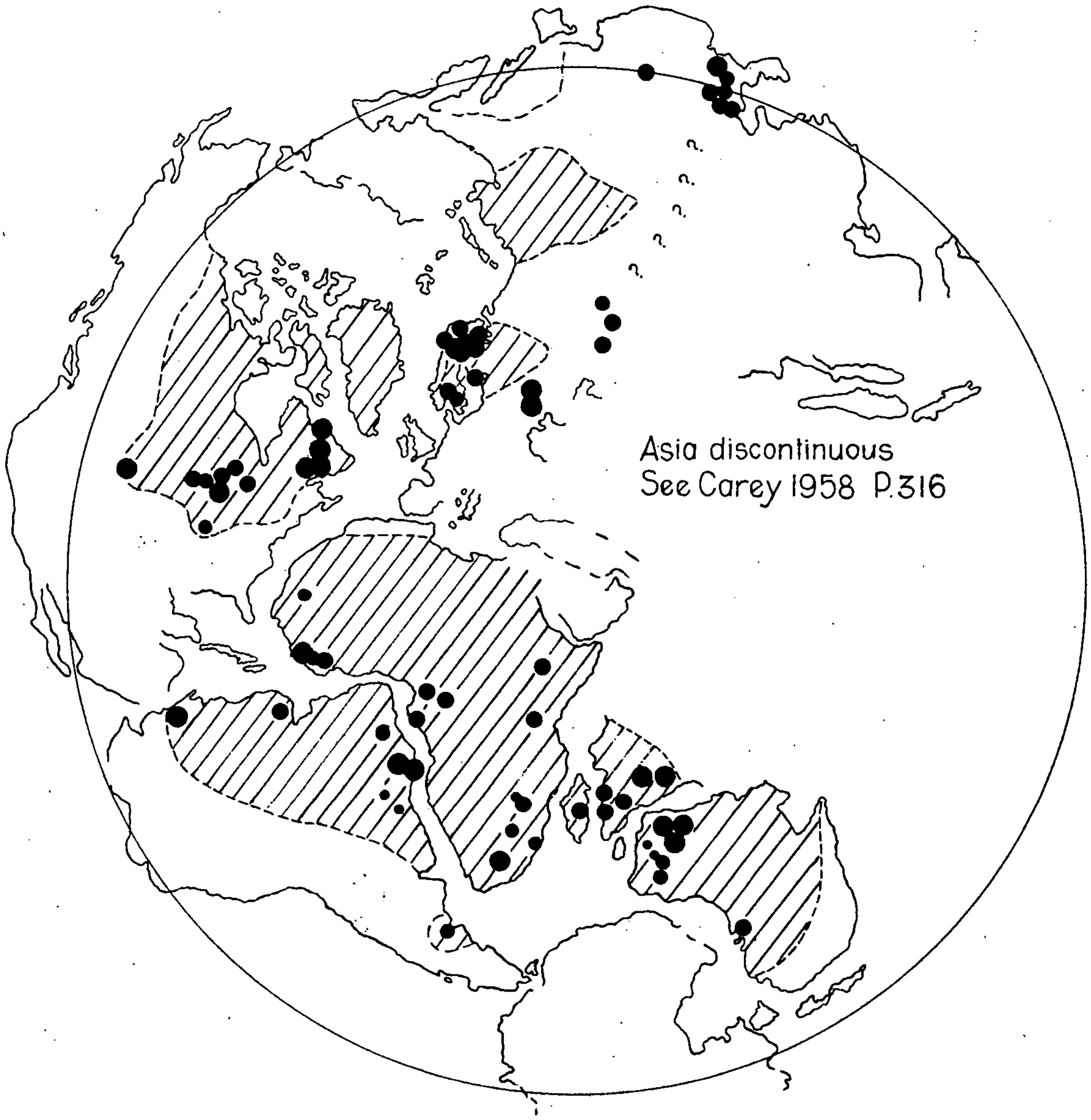
FIGURE 63-307 IS MISSING


S.A. DEPARTMENT OF MINES
HAMERSLEY IRON PROVINCE W.A.
ROUTES FOLLOWED AND
DEPOSITS VISITED BY
T.A. BARNES & G.F. WHITTEN.
1963
Approved
Director
Passed
Drn. G.F.W.
Tcd. A.W.
Ckd.
Exd.
D.M.
Req.
S3453
994-1
Scale 40 miles = 1 inch
Date 16-7-63
To accompany report by G.F. Whitten.
C. Keraudren
20°
Pt. Hedland
Mt. Goldsworthy
Ord Range
OCEAN
INDIAN
De Puch Is.
Highway
Great
Whim Creek (Cu, Zn?)
Roebourne
Coastal
Marble Bar
Moolyella
Sn
Northern
Fortescue
River
Yarrabola
Deebdale
Onslow
Fe
Robe
River
West
HAMERSLEY
RANGES
Wittenoom
Mn
Woodie Woodie
Mt. Cooke (Davis River)
Highway
Asb
Wittenoom Gorge
Yampire Gorge
Dayles Gorge
Fortescue
River
Roy Hill
Duck
Creek
Boolgeeda
Mn
Balfour Downs
To Perth.
23°
Ophthalmia Range
Tropic of Capricorn
Route Travelled
Other Main Roads
Aerial Reconnaisance
Deposits Inspected
Fe Iron
Asb Asbestos
Mn Manganese
Cu-Zn Copper-Zinc
Sn Tin
115°
118°
121°
0
50
100
Miles
Mundiwindi
N



PRECAMBRIAN SHIELDS AND IRON ORE RESOURCES OF THE WORLD

S 3454



LEGEND

Lake Superior Type iron ore deposits

- 0 – 10 Million tons
- 11 – 100 " "
- 101-1000 " "
- over 1000 " "

Precambrian Shields

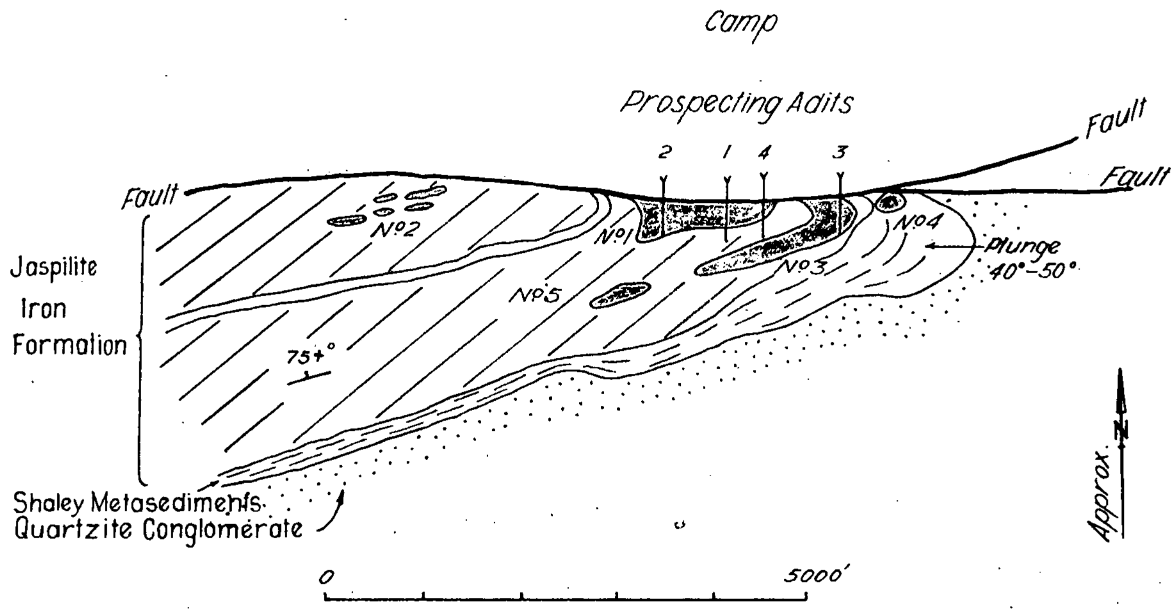
To accompany report by G.F.Whitten

S.A. DEPARTMENT OF MINES

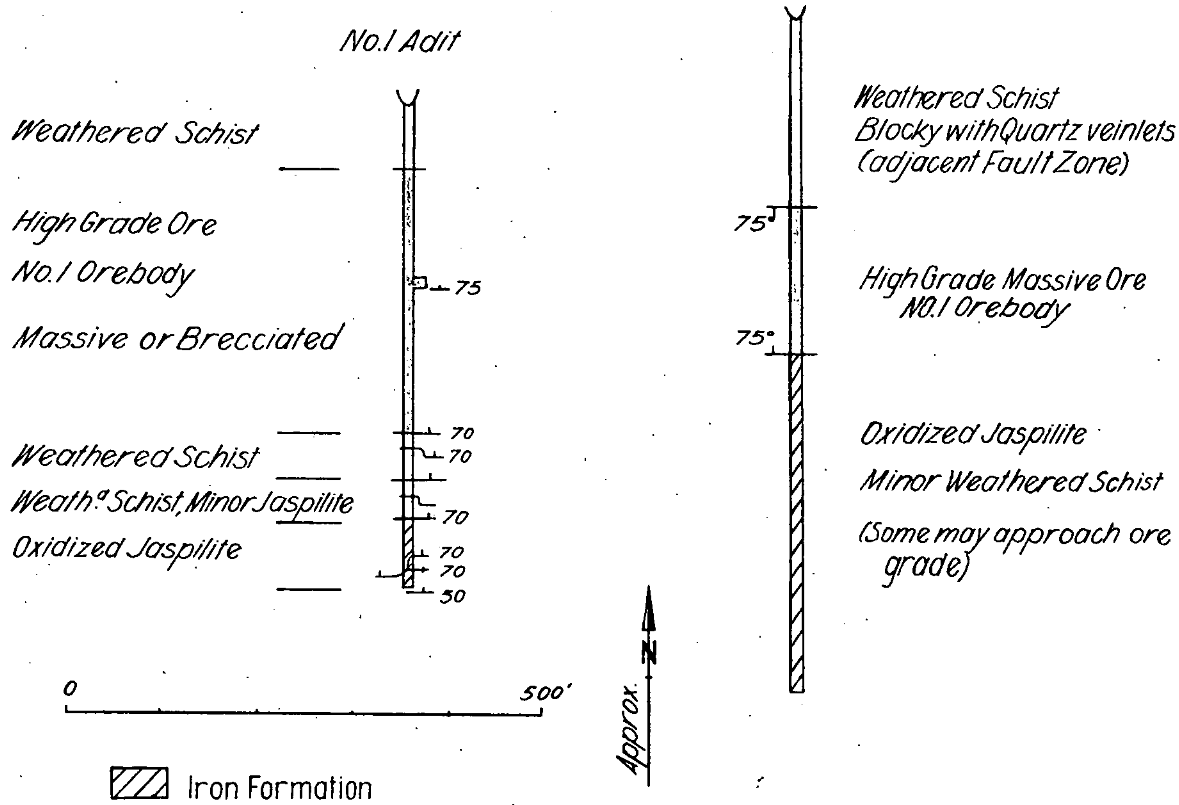
Approved	Passed	Drn. G.F.W.	PANGAEA	D.M.	Scale
		Tcd. G.M.	SHOWING SHIELD AREAS AND	Req.	S3455
		Ckd.	SUPERIOR TYPE IRON ORE DEPOSITS		910
Director		Exd.			Date 26·7·63

200—2·61 3805

DISTRICT PLAN



UNDERGROUND PLANS



- Iron Formation
- Hematite Orebodies
- Quartzite
- Metasediments

Location No 3 Vide Plan 63:507

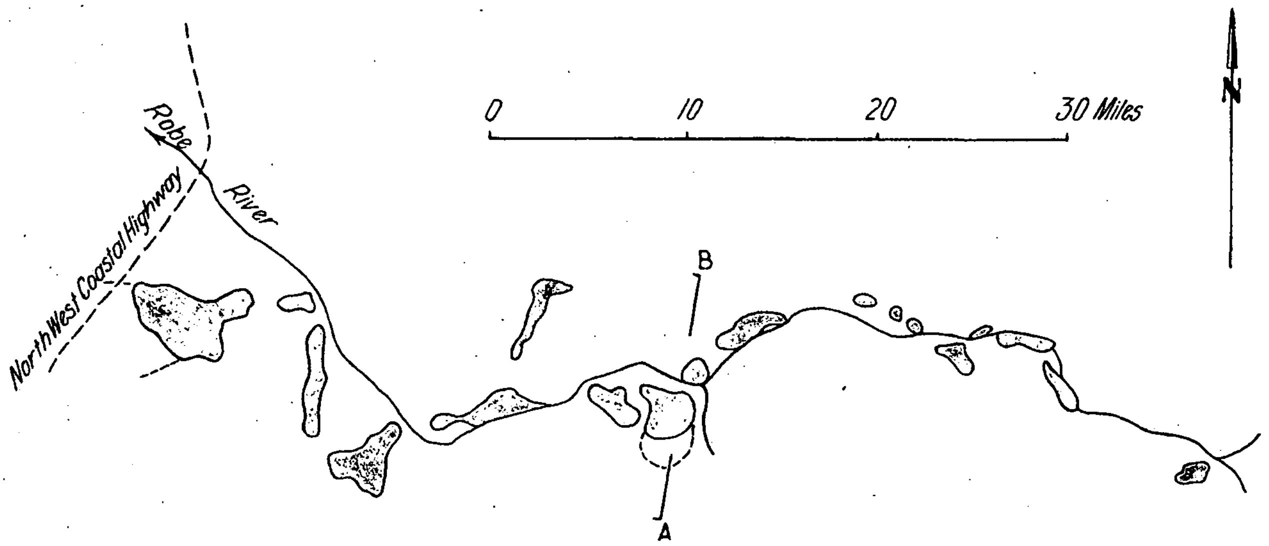
To accompany report by G.F. Whitten

S.A. DEPARTMENT OF MINES

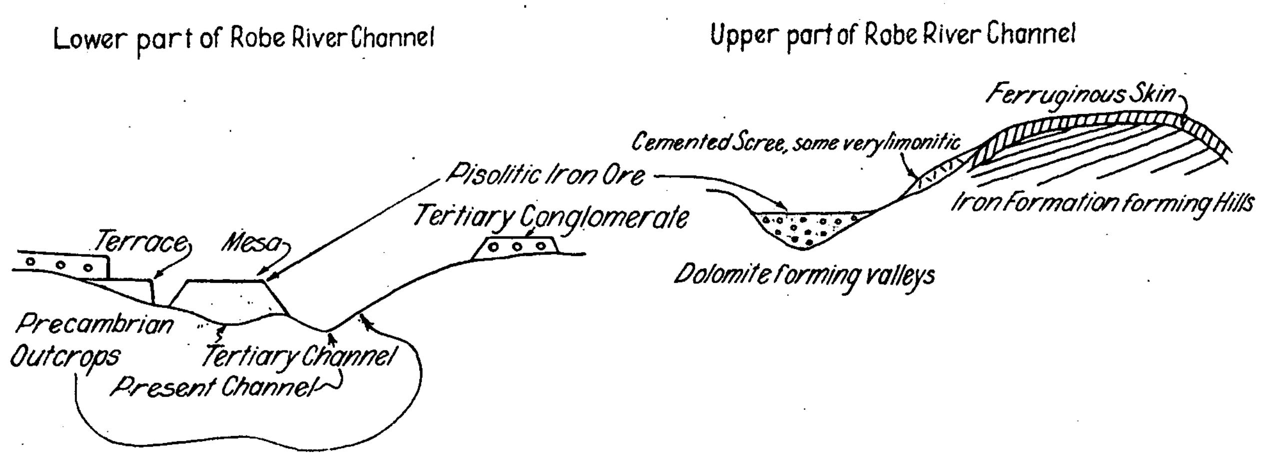
Approved	Passed	Drn. G.F.W.	MT. GOLDSWORTHY	D.M.	Scale As above
		Tcd. G.M.	IRON ORE DEPOSITS	Req.	S3456
		Ckd.	WESTERN AUSTRALIA		994·1
Director		Exd.			Date 24·7·63

200—2·61 5805

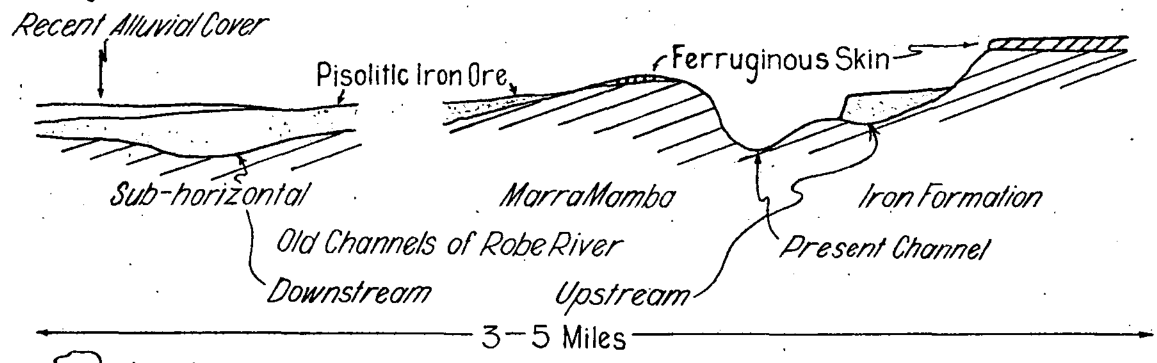
GENERALISED PLAN



DIAGRAMATIC CROSS SECTIONS



CROSS SECTION AB, ROBE RIVER
(Looking westerly)



- Alluvium
- Cemented Scree
- Tertiary Ferruginous Skin
- Tertiary Conglomerate
- High Grade Pisolitic Iron Ore
- Precambrian Iron Formation

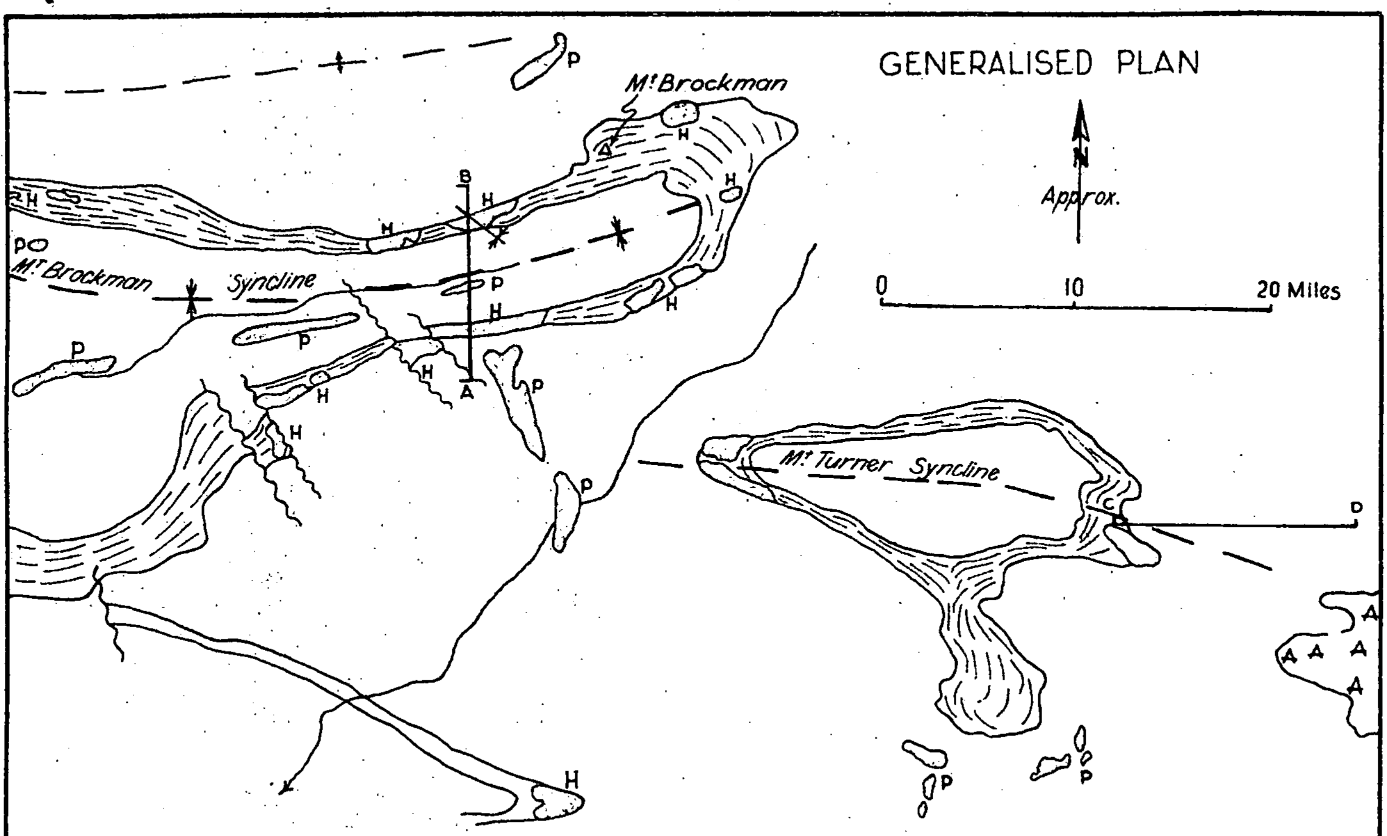
Locations 4&5 Plan 63:507

S.A. DEPARTMENT OF MINES

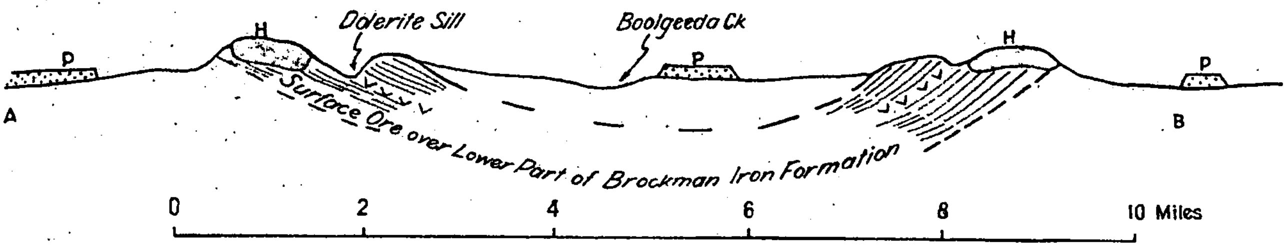
Approved	Passed	Drn. G.F.W.	PISOLITIC IRON ORE DEPOSITS	D.M.	Scale As Above
		Tcd. G.M.	ROBE RIVER VALLEY	Req.	S3457
		Ckd.			994·1
Director		Exd.	WESTERN AUSTRALIA		Date 29·7·63

200—2·61 8803

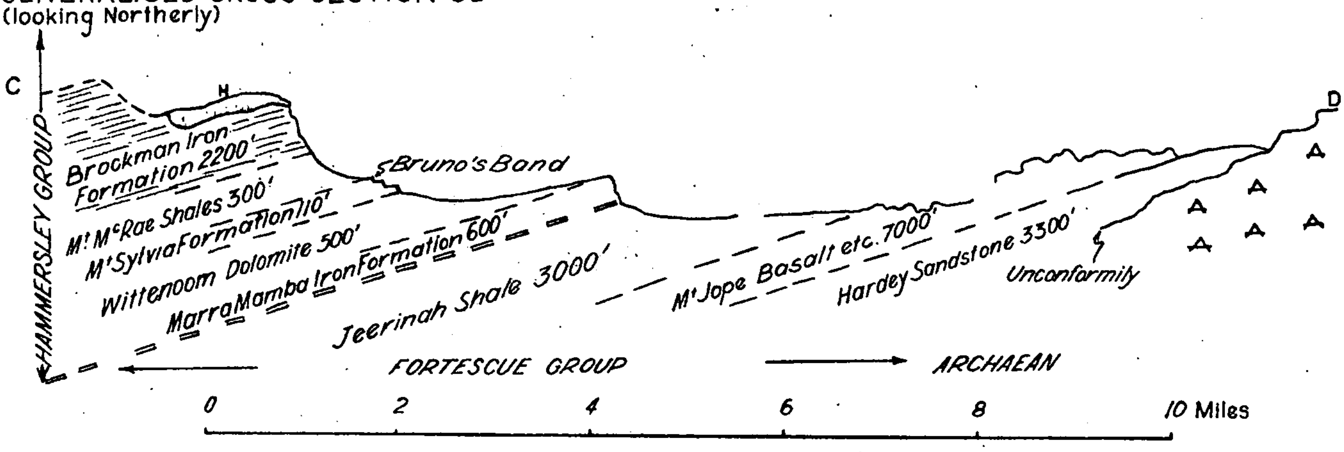
GENERALISED PLAN

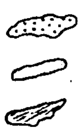


GENERALISED CROSS SECTION AB ACROSS MT BROCKMAN SYNCLINE
(looking Westerly)



GENERALISED CROSS SECTION CD
(looking Northerly)





Pisolitic Iron Ore
Hematite Iron Ore
Brockman Iron Formation

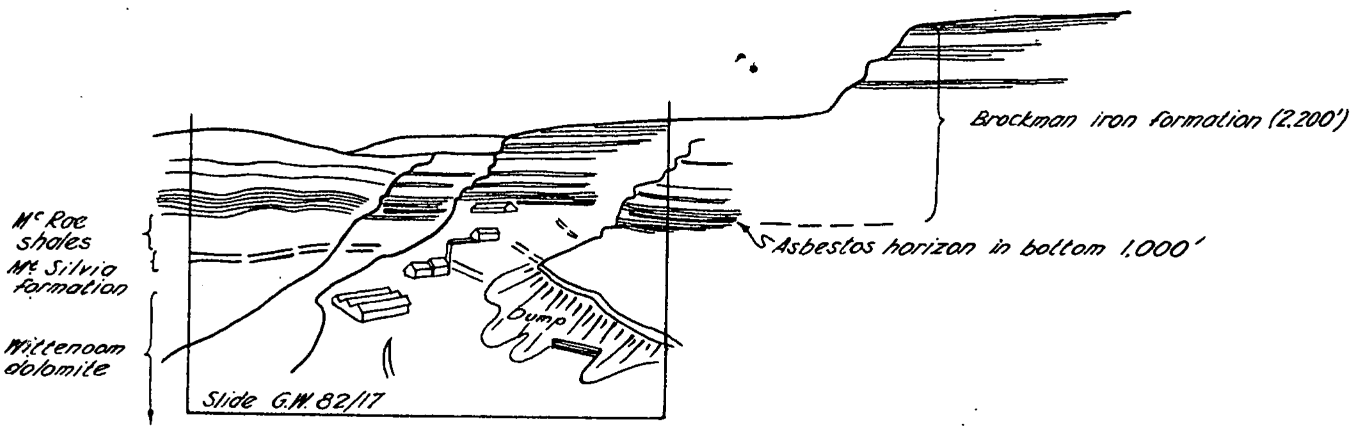
Locations 7&8 Plan 63·507

S.A. DEPARTMENT OF MINES

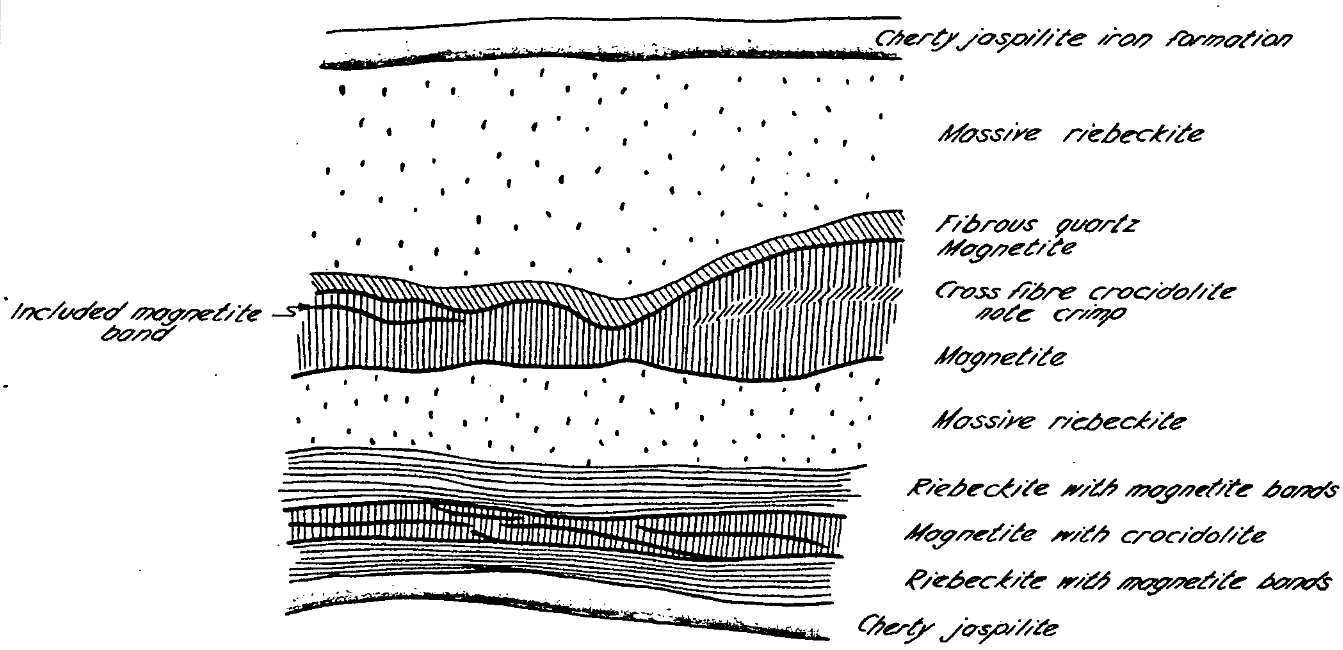
Approved	Passed	Drn. G.F.W.	HEMATITE ORE DEPOSITS	D.M.	Scale AS ABOVE
		Tcd. G.M.	MT BROCKMAN & MT TURNER SYNCLINES	Req.	S 3458
		Ckd.	WEST AUSTRALIA		994·1
Director		Exd.			Date 1·8·63

200—2·61 3305

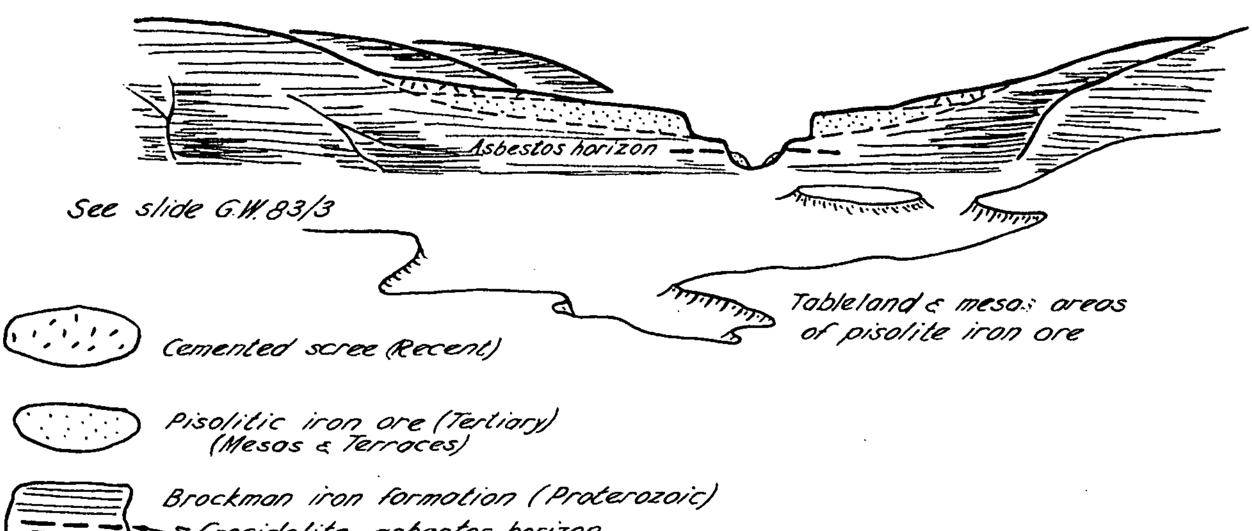
GENERAL VIEW OF WITTENOOM GEORGE
(looking southerly)



TYPICAL SPECIMEN OF ASBESTOS–YAMPIRE GEORGE



TYPICAL SECTION OF YAMPIRE GEORGE
(looking northerly)

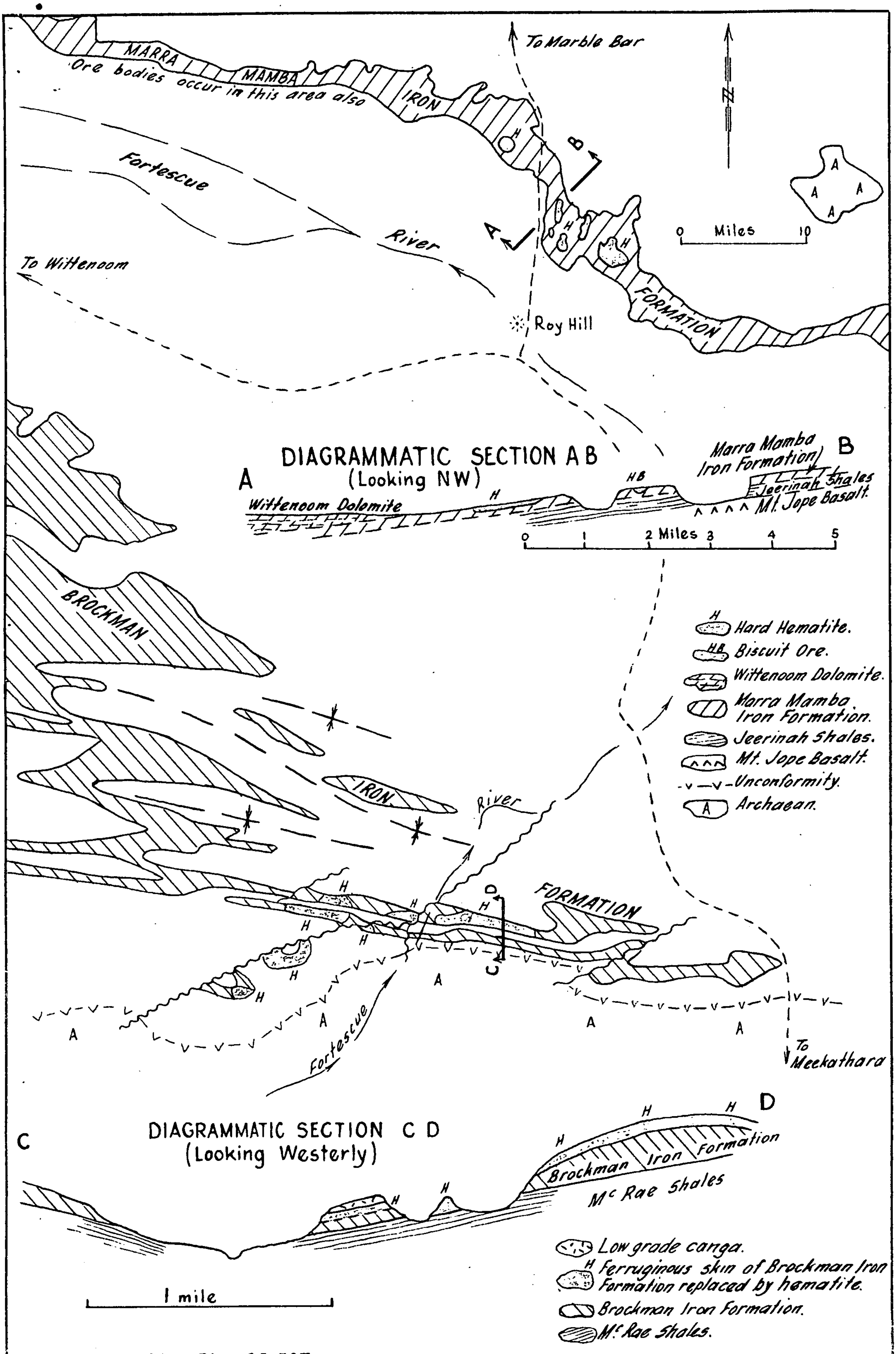


To accompany report by G.F. Whitten

S.A. DEPARTMENT OF MINES

Approved	Passed	Drn. G.F.W.	ASBESTOS & IRON ORE WITTENOOM & YAMPIRE GORGES WEST AUSTRALIA	D.M.	Scale Sketch
		Tcd. RJ		Req.	S 3459 994·1
		Ckd.			
Director		Exd.			Date 2·8·63

200—2·61 3805



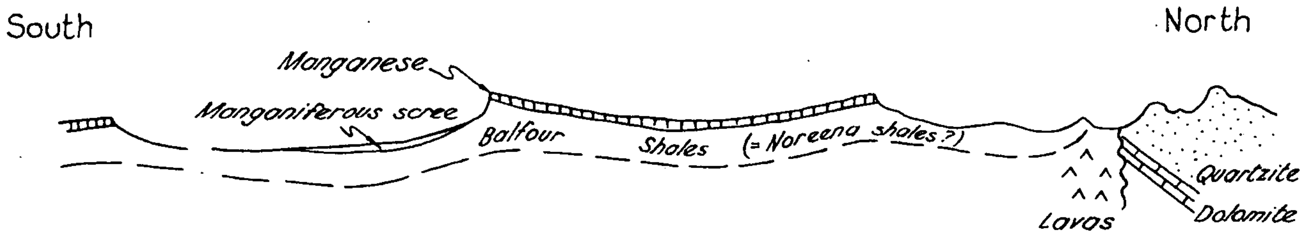
Locations 9 & 10, Plan 63-507.

To accompany report by G.F. Whitten.

S.A. DEPARTMENT OF MINES

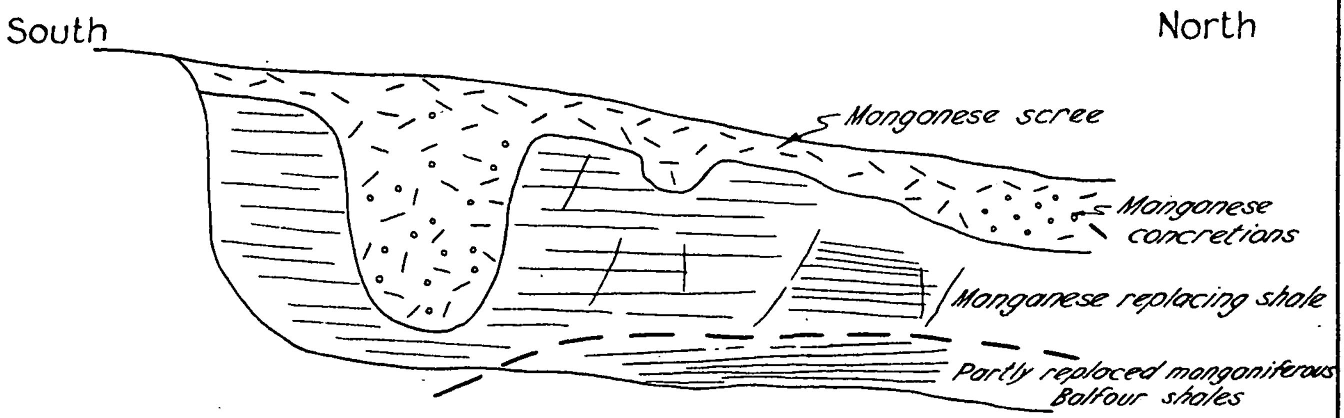
Approved	Passed	Drn. G.F.W.	ROY HILL AREA AND OPHTHALMIA RANGE IRON ORE WESTERN AUSTRALIA	D.M.	Scale As above.
		Tcd. M.B.L.		Req.	S 3460 994·1
		Ckd.			
Director		Exd.			Date 31·7·63

200—2·61 3805



Cross Section of Deposit
(looking west)

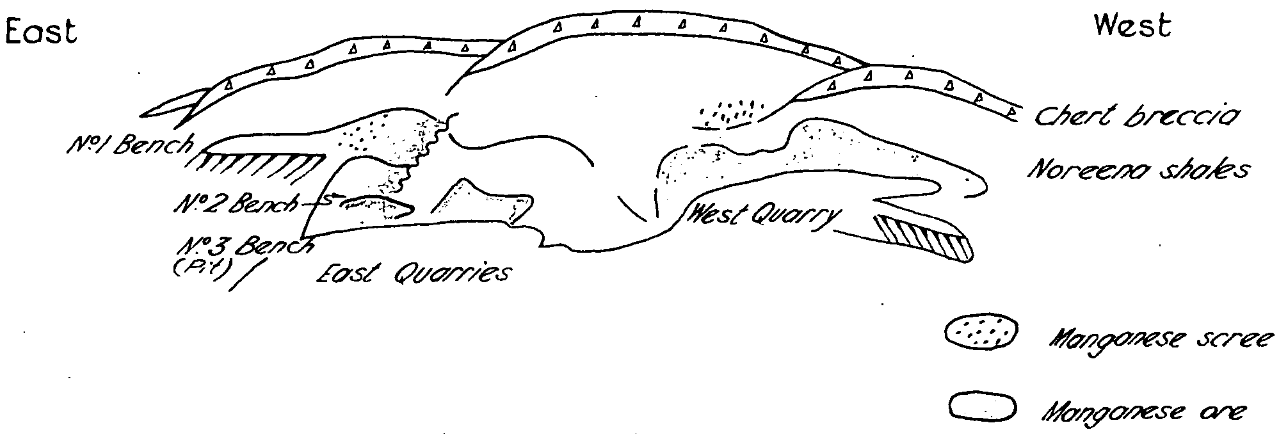
Scale
1 mile (approx.)



Cross Section of Costean
(looking west)

BALFOUR DOWNS MANGANESE
4 x 100 acre claims D.F.D. Rhodes

Scale
10 feet



Mt COOKE (DAVIS RIV.) MANGANESE
General view looking south
M.C. 1944 D.F.D. Rhodes

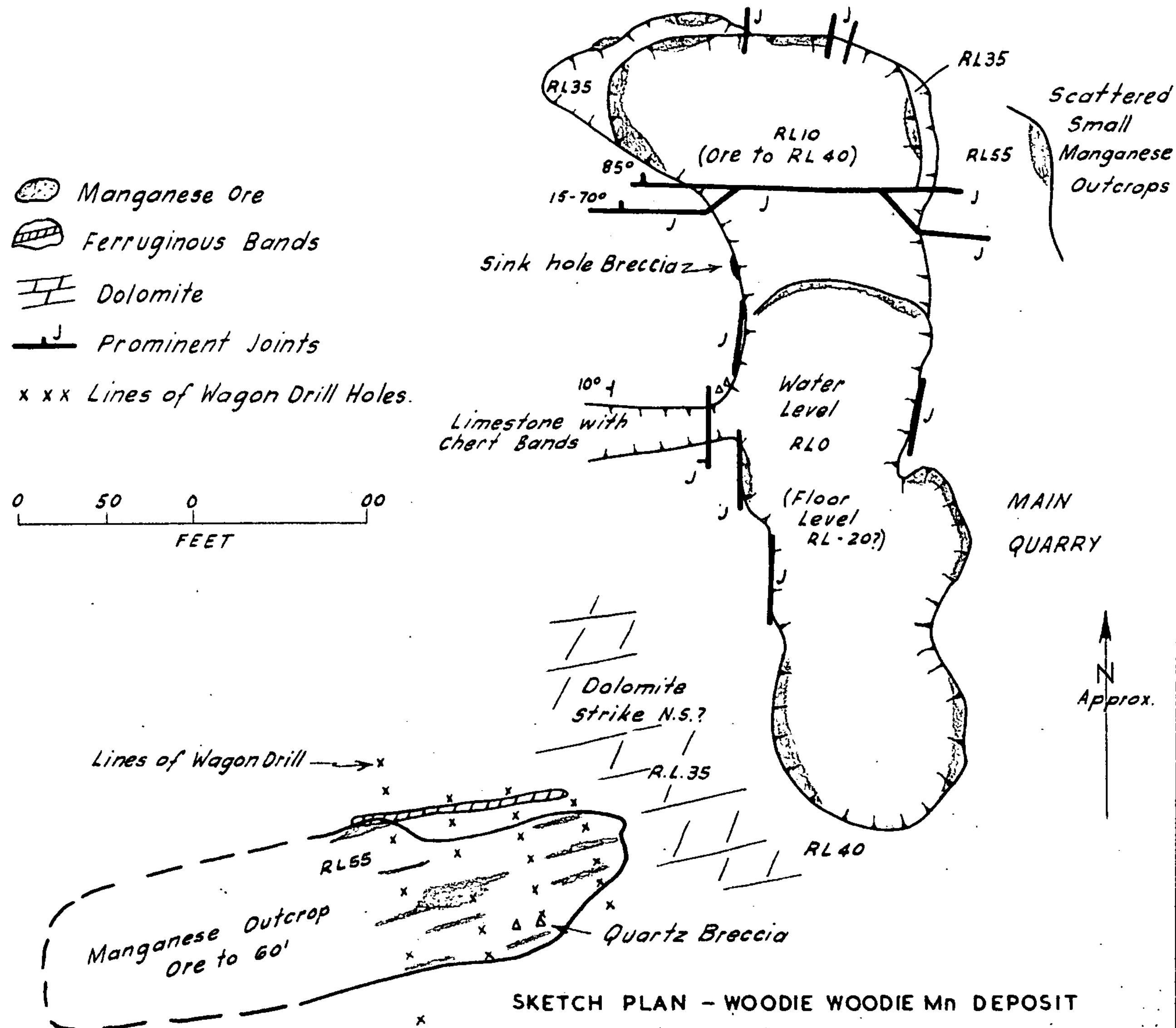
Scale
0 100′ 200′

To accompany report by G.F. Whitten

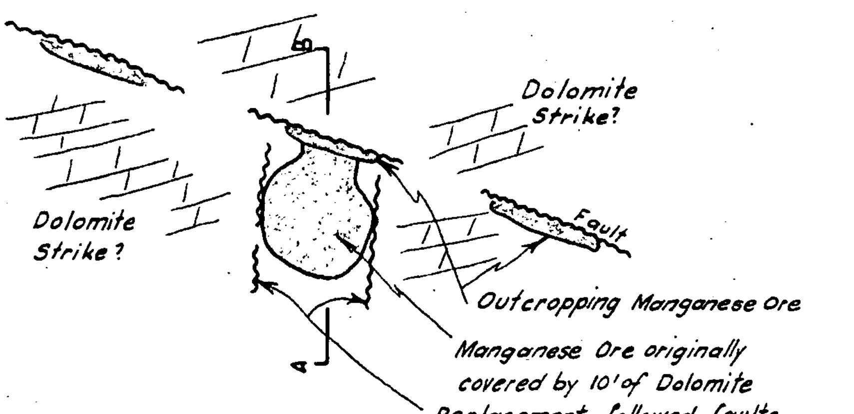
S.A. DEPARTMENT OF MINES

Approved	Passed	Drn. G.F.W.	BALFOUR DOWNS & Mt COOKE MANGANESE DEPOSITS WEST AUSTRALIA	D.M.	Scale
		Tcd. RA		Req.	S 3461
		Ckd.			994·1
Director		Exd.			Date 1·8·63

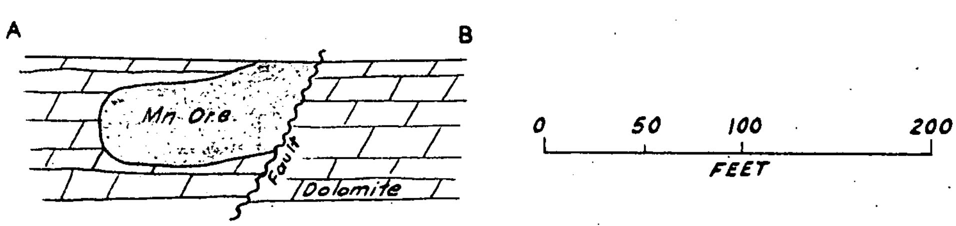
200—2·61 3805



SKETCH PLAN – WOODIE WOODIE Mn DEPOSIT
M.C. 269 NORTHERN MINERALS SYNDICATE



SKETCH PLAN
MT. SYDNEY Mn DEPOSIT



A–B SKETCH SECTION LOOKING WEST

To accompany report by G.F Whitten.

S.A. DEPARTMENT OF MINES

Approved	Passed	Drn. G.F.W.	WOODIE WOODIE AND MT SYDNEY MANGANESE DEPOSITS WEST AUSTRALIA	D.M.	Scale 100' to 1"
		Tcd. A.W.		Req.	S3462 994·1
		Ckd.			
Director		Exd.			Date 29-7-63

200—9·61 8805