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REPORT ON THE GEOLOGY
AND ORE RESERVES TR 3358H
ROY HILL, WESTERN AUSTRALIA

VOLUME I

BY

G. MAGUIRE

KWYNANA

DECEMBER, 1971



THE ENGINE

ORIGINAL

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AND ORE RESERVES TR 3358H
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S U M M A R Y

TR 3358, Roy Hill was geologically mapped between the months of February 1971 and July 1971. The mapping was done on new aerial photography at a scale of 1: 40,000.

A total of 50 boreholes were drilled, for a total of 4,255 feet.

The maximum potential ore reserves of TR 3358H is 593×10^6 tons, with a grade of 58.3% Fe and a L.O.I. of 5.3%. Much of this is thin and covered by substantial thicknesses of overburden.

1. INTRODUCTION

1.1. LOCATION

TR 3358H lies along the southern slopes of the Chichester Hills and extends from approximately $118^{\circ} 30'E$ to $120^{\circ} 10'E$ in longitude, and in latitude it lies approximately between $22^{\circ} 05'S$ and $22^{\circ} 40'S$. The reserve is approximately 110 miles long and is 600 square miles in area.

The reserve is crossed by two main roads, the Wittenoom - Port Hedland road towards the western end, and the Great Northern Highway near the eastern end. The reserve is also crossed by the Mt. Newman Railway, which has a good maintenance road.

Parts of three pastoral leases fall within TR 3358H. These are Mulga Downs, Roy Hill and Warrie.

1.2 TITLE

TR 3358H is held under the Iron Ore (The Broken Hill Proprietary Company Limited) Agreement Act. 1864, of Western Australia, which gives The B.H.P. Co. Ltd. tenure from the 24th November, 1964 to the 31st November, 2014.

Prior to this act being passed, the area covered by TR 3358H was held by the company in the form of 12 Temporary Reserves. These were TR 2022H - TR 2029H and TR 2352H - TR 2355H.

TR 2022H - TR 2029H were granted to the Company prior to 1961 and TR 2342H - TR 2355H were granted in April, 1962.

1.3 HISTORICAL

The iron ore in the Roy Hill area was first reported by R.G. Collins in 1958. In 1961 a helicopter survey of the area was carried out by geologists: J.E. Harms, B.D. Morgan and W.A. Winter. They estimated that the Temporary Reserves held at that time, TR 2022H - TR 2029H, had potential reserves of $200-400 \times 10^6$ tons, averaging about 62% calcined Fe, and that Temporary Reserves 2352 - 2355, which had been applied for, held potential reserves of 100×10^6 tons averaging about 60% calcined Fe.

In 1962 the area was examined by W.A. Winter, and 68 percussion boreholes and 13 diamond boreholes were drilled. Mapping was carried out largely by photo interpretation, with spot checking. The drilling was done in the eight eastern reserves, TR 2022H - TR 2029 and it indicated a minimum of 350×10^6 tons of 50% to 55% Fe.

In 1963 the four western reserves, TR 2352H - TR 2355H, were examined by G. McLellan. Thirty-one percussion boreholes were drilled and these indicated an aggregate tonnage of 25×10^6 tons of +62% Fe.

In 1970 S. V. Bell sited 3 percussion drill holes to test the suggestion that the iron ore extended below the alluvium of the Fortescue Valley. The results were not conclusive.

1.4 ACCESS

Access to TR 3358H is by the Great Northern Highway, the Wittenoom - Port Hedland road and the maintenance road along the Mt. Newman Railway.

Within the area access is by means of station tracks, and tracks bulldozed or graded by the Company.

During the 1971 programme most of the old tracks in the western areas were improved by a grader, and later another grader was used to make new access tracks and drill sites in these areas. Before drilling in the eastern areas was started, a Cat D5 bulldozer was brought in to upgrade existing tracks, and to make new access tracks and drill sites. There is now reasonably good access to most parts of TR 3358H.

1.5 1971 PROGRAMME

The purpose of the present programme was initially to map TR 3358H using new Government aerial photography at a scale of 1: 40,000. The desirability of further boreholes was to be examined in the light of this mapping and, after this drilling had been carried out, the total potential reserves of TR 3358H were to be calculated using all available information.

Three geologists and several other employees took part in the work on this area, with a maximum of seven at any one time. The mapping was carried out by three geologists and one trainee geologist.

These were:	G. MAGUIRE	Geologist.
	B. FAKHRY	Geologist.
	N. G. SEKAR	Geologist.
	J. NELSON	Trainee Geologist.

The work on the western part of the area was carried out from Mt. Newman Railway Line Maintenance Camp 127. No more than four personnel were based here at any one time. The eastern part of the reserve was mapped from a camp set up at Parker's Bore, on Roy Hill Station.

Work on TR 3358H started when the party moved to Camp 127 on the 2nd February, 1971. Parker's Bore camp was set up on the 11th May and operations were transferred from Camp 127 to Parker's Bore on the 16th May. Work on TR 3358H was completed on the 23rd July, 1971.

It was found that either one or two of the old Temporary Reserve areas formed convenient sized mapping areas, so that old Temporary Reserve areas and numbers have been retained during this programme.

1.6 DRILLING CONTRACTORS

The drilling in the western areas was done by Seidel Bros., Welldrilling Co. Pty. Ltd., and that in the eastern areas by W. H. Drilling Pty. Ltd. A total of 50 percussion boreholes were drilled.

1.7 EQUIPMENT

While the party was based at Camp 127 it's equipment consisted of two Land Rovers. The equipment at Parker's Bore camp consisted of the following:-

- 4 Land Rovers
- 1 10KVa Generator Set
- 1 Office Caravan
- 2 15' x 15' tents
- 1 500 gal. tank, and tank stand
- 1 12 cu. ft. Electric Refrigerator
- 1 200 gal. tank and pump, trailer mounted

1.8 WATER

There are several bores on Mulga Downs in the Fortescue Valley, a few miles south of Chichester Hills and these mostly produce drinkable, though slightly saline, water. There is less water available in the eastern areas. Warrie Station had been abandoned for several years and none of it's bores or wells close to the Temporary Reserve are pumping; however Warrie Station has recently been taken over by the Lessees of Hillside Station, and it is therefore probable that these bores will be repaired.

On Roy Hill Station, Parker's Bore had to be repaired by Company personnel before the camp could be set up, but it later stopped working: it appears that a complete, new pump is required. For part of the time, water for the Parker's Bore camp was obtained from pools in a nearby creek.

2. GEOLOGY

2.1. REGIONAL STRATIGRAPHY

<u>SUPERGROUP</u>	<u>GROUP</u>	<u>FORMATION</u>	<u>MEMBER</u>
Mount Bruce	Hamersley	Boolgeeda Iron Formation	
		Woongarra Volcanics	
		Weeli Wolli Formation	
		Brockman Iron Formation	
		Mt. McRae Shale	
		Mt. Sylvia Formation	
		Wittenoom Dolomite	
	Fortescue	Marra Mamba Iron Formation	
			Roy Hill Shale
			Warrie.
		Jeerinah	Woodiana Sandstone
			Maddina Basalt.
			Kuruna Siltstone
		Mt. Jope Volcanics	Nymerina Basalt
			Tumbiana Pisolite
			Kylene Basalt
		Hardey Sandstone	

The regional stratigraphy is shown above. The stratigraphy within TR 3358 is as follows:-

<u>FORMATION</u>	<u>MEMBER</u>
Recent Alluvium, Colluvium, etc.	
Marra Mamba Iron Formation	
Jeerinah.	Roy Hill Shale Member. Warrie Member.
Unconformity	
Mt. Jope Volcanics.	Maddina Basalt Member.

The Mt. Jope Volcanics cover only a very small part of the Temporary Reserve, and the Jeerinah Formation and the Marra Mamba Iron Formation are the most important formations in the area. The three major units are the Warrie Member, the Roy Hill Shale Member and the Marra Member Iron Formation. In a few localities these three can be seen in one section (Plate 1).

2.2 DETAILED STRATIGRAPHY

Mt. Jope Volcanics Formation

The topmost member of this formation, the Maddina Basalt Member, outcrops in the north of Areas 2022 and 2023. The outcrop is of small areal extent and of no importance in the economic geology of the area.

Jeerinah Formation

(a) Woodiana Sandstone Member

This is the lowermost member of the Jeerinah Formation. It was not recognised during the mapping of Areas 2022 and 2023 and also it is not shown in this locality in the 1965 edition of the Geological Survey of Western Australia's Map Roy Hill, Sheet SF50-12.

It therefore seems that there is an unconformity between the Maddina Basalt Member and the Warrie Member.

During the 1971 mapping programme no great attention was paid to the Warrie Member, and as it is noted that both the Woodiana Sandstone Member and the Warrie Member consist of mixed sediments, the writer considers it possible that the Woodiana Sandstone Member does exist in this area, but has not been observed. It is therefore thought possible that the full sequence exists.

(b) Warrie Member

The Warrie Member outcrops in Area 2352, but its main outcrop is in the eastern areas. In particular it covers large parts of Areas 2026, 2027 and 2029.

The Warrie Member consists of shale, chert and mudstone. At the top there is a hard dolomitic limestone. No attempt was made to measure the thickness of this member.

There is a narrow transition zone between the Warrie and Roy Hill Shale Members. This boundary was not mapped in detail, and there are many outliers of Roy Hill Shale on the Warrie Member which are not shown on the maps.

(c) Roy Hill Shale Member

The Roy Hill Shale Member is the most distinctive geological unit in TR 3358H. It consists of a well bedded white shale, sometimes with a purplish tinge. The bedding varies from about 1/2" to 2" in thickness. There are a few thin bands of mudstone at least one of which is slightly calcareous. Hill slopes of Roy Hill Shale usually have a pinkish brown colour, but on the aerial photographs the shale is distinctively white.

The Roy Hill Shale appears to thin slightly from west to east in the Temporary Reserve. In the western and central areas it is between 100 ft. and 150 ft. thick, but in area 2029 it seems to be no more than 100 ft. thick.

The shale contains abundant small iron rich nodules. These nodules have a porous structure, and they are about 1/2" in diameter.

In boreholes and wells unweathered Roy Hill Shale is dark grey, almost black, with a slightly greasy feel. This is probably due to a high carbonaceous content. The unweathered shale contains pyrite nodules and some of these and some iron rich nodules were collected and analysed. The results obtained are:

	<u>IRON RICH NODULES</u>		<u>PYRITE NODULES</u>	
	%		%	
Fe		59.9		43.2
S		0.0		44.0
P		0.17		-
SiO ₂		4.1		-
Al ₂ O ₃		1.7		-
Cu		0.075		0.020
Zn	Less than	0.005	Less than	0.005
Pb		0.01		0.005

In a few localities a transition zone between the Roy Hill Shale and the overlying Marra Mamba Iron Formation has been observed. The best section is near the western end of Area 2353. At the base there is the normal white, well bedded shale, in the upper part of which there are a few thin yellow cherty bands. There are then a few bands, about six inches thick, of chert which has been replaced by hematite-goethite; these are interbedded with purplish shale.

Above this there is again a few feet of white shale, though the bedding is not so well developed as usual, and then more and thicker chert bands come in (Plate 4) until one has typical Marra Mamba chert. About 30 feet of this section is exposed.

The Roy Hill Shale is uniform in lithology throughout TR 3358H, the only variation being the slight change of thickness.

Marra Mamba Iron Formation

The Marra Mamba Iron Formation is the most important unit in this sequence. It lies conformably on the Roy Hill Shale and it is a result of its resistance to erosion that the Chichester Hills have been formed. The iron ore of the Roy Hill Area is the result of enrichment of the Marra Mamba Iron Formation.

The Marra Mamba consists almost entirely of chert, with some jaspilite and thin shale bands. There are occasional chert breccias, which are probably auto-breccias formed during diagenesis.

The chert generally has a creamy-yellow colour; it is hard and usually well bedded. (Plate 5 and 6). Most of the chert exhibits pronounced "pinch and swell" structure. The elongate pods produced by this vary in size, but in section they are usually from 3 to 6 inches across. This podding is probably the result of the pressure of overlying sediments during diagenesis of the chert. (Plates 7 and 8).

Jaspilite forms only a minor part of the Marra Mamba. It was noted by McLellan (1963) that jaspilite often underlies the iron ore and he concluded that it represents an intermediate stage between chert and ore. The writer agrees with this conclusion.

The shale bands in the Marra Mamba were originally observed in boreholes and it was some time before any were found in surface exposure. These shale bands outcrop in only a few localities.

In boreholes the unweathered shale bands within the Marra Mamba and also those in the transition zone were observed to be white in distinction to the Roy Hill Shale, which is black. This suggests that the carbonaceous content of the shale bands is low. The shale bands are almost all found in the lower part of the Marra Mamba. They have not been found in all boreholes and the wide spacing of the drilling makes correlation impossible. Most shale bands are only a few inches thick, but in several boreholes there are whole five foot sections consisting almost entirely of shale.

The fact that these thick bands have not been found in all boreholes suggests that they may be lenticles in the thinner bands; however, as only a few boreholes reached the base of the Marra Mamba it is impossible to be sure of this.

In borehole R112, in Area 2354, some of the 'shale' would more correctly be called mudstone. The colour of the shale bands varies from white to medium grey.

Two cores of shale within the Marra Mamba were obtained. These show that the shale is sometimes interbedded with chert and iron ore. The shale in one gives the appearance of being slightly brecciated and it has a greasy feel.

The shale bands seen in exposure are thin. They are always seen in cliff sections and they can be traced for the full length of the cliff face. The shale is finely laminated, soft and white or slightly purplish; it closely resembles surface exposures of Roy Hill Shale. In detail, the shale beds are slightly contorted by the podding which has affected the chert. Differential erosion of the shale bands sometimes produces distinct overhangs in the cliff faces (Plates 9 and 10).

The transition between the Roy Hill Shale and the Marra Mamba was described in the section on the Roy Hill Shale. In many places, however, this transition appears to be absent. In these cases, the base of the Marra Mamba is a hard white chert containing nodules, about two or three inches in diameter, of a dark chert and it rests directly on Roy Hill Shale. This situation is found to exist mainly where the Marra Mamba higher up the sequence has undergone iron enrichment.

The writer believes that during the movement of silica in solution, which must have taken place in the process of iron enrichment of the Marra Mamba, the shale in the transition zone was silicified to produce a pseudo-chert and the original chert bands became altered and formed the dark chert nodules (cf. Plate 4). Where this white chert with dark nodules is found in the absence of iron enriched Marra Mamba, it is considered probable that the latter has been removed by erosion.

A borehole in Area 2354, R112, passed through 120 feet of Marra Mamba before reaching Roy Hill Shale. This is the thickest intersection of Marra Mamba in any of the boreholes and it is thought unlikely that the Marra Mamba Iron Formation is much thicker than this anywhere in the Roy Hill area. The natural sections suggest a thickness of not more than 100 feet.

Within the limits described, the Marra Mamba Iron Formation shows little variation throughout the length of TR 3358H.

The Formation above the Marra Mamba, the Wittenoom Dolomite, does not outcrop anywhere within the Roy Hill Reserve, and therefore the full thickness of the Marra Mamba cannot be estimated.

An idealised section (Fig. 10) shows the stratigraphy of the Chichester Hills, and the estimated thickness of the various units.

Superficial Deposits

The superficial deposits, which have mostly been grouped together on the geological maps, are alluvium towards the centre of the Fortescue Valley, and ill-sorted scree and outwash fans nearer the hills. These are also found along some of the larger creeks in the hills.

There is also some scree ore down dip from the Marra Mamba outcrop, and some consolidated pisolitic scree in the hills. These will be discussed later.

2.3 STRUCTURE

With the exception of areas 2026, 2027 and 2028 where the strike is almost due N-S, the sediments of TR 3358H strike about 105° with a dip of about 10° south. In effect, the Marra Mamba has been regionally deformed into a very large Z fold.

Within the southward dip there are minor undulations, and there is also gentle folding on a N-S axis. The folding on both the N-S and E-W axis is occasionally much more severe, but the places where this can be observed are scattered and there is no apparent pattern in their distribution.

Five small domes have been observed in different parts of the Temporary Reserve. The dips in these domes are steep, and some are vertical. All observed domes bring up the Roy Hill Shale through the Marra Mamba and some are almost diapiric in structure. (Plate 11). It is possible that other similar structures exist in the area, but have not been recognised.

The intensity of folding of these domes in a region of generally low dips is surprising. Two occur in the west of Area 2353 and there are two close together in Area 2355. One of these in Area 2353 is in an area of strong folding and it is considered certain that the domes are the result of the interaction of sharp folds on both axes. In at least one of the domes the E-W axis is longer than the N-S axis.

There is little faulting within the area. One of the longest faults in the region cuts the eastern end of Area 2353 and

goes through the west of Area 2354; it has a total length of over 30 miles and has a north-easterly trend.

Although it is so long and forms a very prominent feature, it has very little displacement. It would appear to have a very small downthrow to the south, perhaps about ten feet.

This fault, and some of the folding, seem to have occurred after the iron enrichment. It is thought that this apparent post-ore movement is, in fact, enrichment along selected horizons.

There are a number of other faults in the Roy Hill area, most of them with a north-easterly trend and few of them with any significant movement. One exception is in the extreme east of Area 2029, where a north-easterly fault has cut out the Roy Hill Shale, and brought the Warrie Member against the Marra Mamba. Figure 10 shows the general structure of the Chichester Hills.

2.4 GEOMORPHOLOGY

The Chichester Hills are essentially formed by a scarp and dip slope of the Marra Mamba Iron Formation. The northern edge of the main mass of the Chichester consists of a scarp of Roy Hill Shale capped by hard resistant Marra Mamba, which dips gently southwards until it is covered by the alluvium of the Fortescue Valley. (Plate 2).

To the north of the main parts of the Chichester Hills there is a wide band of mesaform terrain (Plate 3). These mesas consist of Roy Hill Shale, which is easily eroded, capped by Marra Mamba. There are also conical hills of Roy Hill Shale in this area.

The northern parts of the Chichester hills are deeply dissected, and near vertical sided gorges are produced. However, this is less common in the western areas. The hills are all drained southwards into the Fortescue and in the eastern areas many of the larger creeks originate several miles north of the hills. A short distance south of the hills the creeks spread out and form alluvial flood fans.

In some northern parts of the reserve the Warrie Member forms low lying country, with small hills caused by hard bands within it.

2.5 VEGETATION

Over the main part of the Chichester the Marra Mamba is covered mainly by spinifex, with scattered trees and bushes, such as scrub oak, white gum and mallee. The Roy Hill Shale has a sparse vegetation cover and the main growth on the Warrie Member is spinifex.

There are abundant river gums along the creeks and on the alluvium south of the hills there is normally dense mulga.

3. IRON ORE

The iron enrichment of the Marra Member is extremely variable in thickness and iron content, but most of it does not reach ore grade. Where it does, the iron ore consists mainly of goethite and some hematite and limonite.

There are few boreholes with average grades of +60% Fe, but grades of individual 5 foot drill samples can reach 65% Fe. It is usual for the greatest enrichment to occur at the out-cropping surfaces of orebodies.

It is only thin but frequently produces grades of +60% and, invariably gives a mis-leading impression of the grade of the deposits. Surface samples almost always have higher average grades than those of drill samples in the same deposit. The close relationship between the superficial enrichment and the present land surface suggests that it is of recent origin.

The enriched Marra Mamba generally lies above unenriched chert (Plate 12), but occasionally in boreholes, and rarely in surface exposure, zones of enrichment can be seen with chert above and below. The areas of enrichment are scattered, apparently at random and vary considerably in size down to thin patches too small to warrant mapping. They are erosion remnants of a previously more extensive area but nevertheless, there are areas where clearly there has been little or no iron enrichment. Although locally the enrichment seems to follow stratigraphic horizons, it is apparent overall that its base has a transgressive relationship with the bedding. The enrichment can go down to the base of the Marra Mamba, and rest directly on the Roy Hill Shale (Plate 13). Yet, within a few miles, sections of 50 feet or more of enriched chert can be seen (Plate 5). Despite this, boreholes in some of the thicker deposits indicate that there may be some measure of stratigraphic influence on the ore. Figure 10 shows typical distribution of the ore.

3.1 THICKNESS AND GRADE OF THE ORE

Examination of all the borehole assays shows that the average thickness of the ore is about 40 feet. Several thicknesses of more than 60 feet have been recorded and one borehole had 75 feet of ore with a grade of 62% Fe. The maximum recorded thickness is 100 feet of ore averaging 55.7% Fe.

A graph (Figure 14) of average grade against the thickness of +45% Fe in boreholes shows that there is a distinct increase in grade in thicknesses greater than 50 feet. The optimum thickness appears to be 55-60 feet and above this there seems to be some decrease in grade. There are few thicknesses of more than 70 feet, so in the range above that, the graph is unreliable. Figure 14 also indicates that ore less than 25 feet thick normally has a grade of less than 52% Fe.

3.2 STRATIGRAPHIC AND STRUCTURAL CONTROL OF ORE DEPOSITS

In many of the thicker ore deposits there is a high grade zone, usually +60% Fe, towards the base, but in several cases there is a zone of lower grade ore, perhaps 5 to 15 feet thick at the base of the ore zone. Typically, in these cases, the ore stops at a thick shale band or a group of shale bands and the lower grade of ore above this is due to minor amounts of shale in the ore. Below the shale bands there is sometimes more ore, up to about 15 feet thick, but usually with a grade of less than 55% Fe. This shale can be up to five feet thick, and it is usually interbedded with unenriched chert.

Most of the best ore intersections in the Roy Hill area follow this pattern and it is thought by the writer that the thick shale bands bear a causal relationship to the good ore above them. It is not known if the shale below the ore is the same band, or bands, in every instance and could only be decided by drilling. However, the writer considers that more than one shale horizon is involved. One reason for this is the occasional absence of thin shale bands above the thick shale, but more importantly, it is thought that the thick shale bands are not continuous horizons.

The rather distorted bedding of much of the ore makes the structure of most deposits difficult to determine. In general, the ore tends to dip into hillsides, but this is by no means invariably so. It is considered that ore was preferentially formed in gentle synclines, and the thickest and best ore was formed where shale bands provided an impervious trap for circulating iron-bearing solutions.

Boreholes in some of the most extensive areas of enrichment sometimes show shale at the base of the enriched zone, but clearly the shale has had much less influence in these extensive areas than it has had in the few small areas of ore grade enrichment. It seems probable that structural traps have to coincide with thick bands of shale to produce more than 50 feet of +60% Fe.

There are large areas of ore 30 to 50 feet thick, ranging from 50% to 55% Fe, but there are no obvious reasons why these areas should be enriched. There are even larger areas of chert which show no sign of ever having been enriched.

3.3. DOWN DIP EXTENSIONS OF THE ORE

The lack of large extensions of the ore below the alluvium of the Fortescue Valley clearly demonstrates the relationship between the ore and the present topography. In a series of boreholes down dip of Fe 9 in Area 2354, R105 is the last hole to show any substantial thickness of ore, in this case 65 feet. It is 2,400 feet south of Fe 9, but only about 1,600 feet from a lobe of this deposit. In area 2028, R142, which is down dip from the exposure of Fe 61, has 100 feet of 55% ore. Like R105, R142 is in an embayment in the hills, and it is probable that this is the only situation in which down dip extensions of +55% Fe of more than 30 feet thick can be found.

It also seems that 2,000 feet is about the maximum distance which the ore extends below the alluvium.

3.4 AGE OF THE ORE

The alluvium which covers the ore is along the edge of the Fortescue Valley, and will be the most recently deposited. It therefore seems clear that the ore conforms closely to a recently existing land surface. This very strongly suggests that the ore was formed more or less contemporaneously with the present landform.

3.5 SOURCE OF THE ORE

Assays of borehole samples logged as consisting entirely of chert, or chert with shale, rarely drop below 10% Fe and normally vary between 10% and 20% Fe. It is therefore considered that the source of the iron ore lies in iron oxides finely disseminated throughout the Marra Mamba chert.

3.6 FOLDING AND FAULTING OF THE ORE

It was mentioned in the section on structure that it seems that some folding and faulting has occurred after the iron enrichment.

In view of the recent origin of the ore, it is thought that apparent folding of the ore is, in fact, selective enrichment of particular horizons around folds. As the faults are of small displacement it is possible that their origin is post-ore, though it is more probable that here also selective stratigraphic enrichment has taken place.

3.7 FORMATION OF THE ORE

From all of this it is considered that, during Tertiary times, and contemporaneous with the formation of the present land surface, iron enrichment of the Marra Mamba Iron Formation took place over large parts of the Chichester Hills. It is not clear why this occurred in some areas and not in others. This enrichment must have involved selective leaching of silica and deposition of iron oxides; these iron oxides most probably coming from other parts of the Marra Mamba. It is uncertain where all the leached silica went to, but some, at least, was probably re-deposited within the Marra Mamba.

Within limited areas, the iron enrichment sometimes follows bedding units in the chert. However, regionally it is transgressive across the bedding, and the base of the zone of enrichment can be anywhere from the base of the Marra Mamba upwards. In apparent contradiction to this, thick bands of shale can give some degree of stratigraphic control of the enrichment by forming a layer impervious to circulating fluids.

Before erosion removed much of it, the typical thickness of the ore was probably in excess of 50 feet, with an average grade of 50% - 55% Fe. In a few localities a combination of synclines or structural basins and thick shale bands formed traps for the iron-bearing fluids. In these areas, thicknesses of originally well over 50 feet of +60% Fe were deposited.

It can be seen from the graph (Figure 14) that there is, in general, a slight decrease in grade when the ore exceeds 60 feet in thickness. It is suggested that these large thicknesses of lower grade ore may represent structural basins which lacked a sedimentary trap to concentrate the ore.

3.8 ORE TYPE

Most of the ore is platy, biscuit type ore, with many small cavities (Plate 14); remnants of the original podded structure of the chert are only rarely observed (c.f. Plate 8). The principal ore mineral in typical ore is goethite, with some hematite, and varying amounts of limonite. In boreholes in the high grade ore hematite is the major mineral.

A core of typical ore from R129, in Fe22 in Area 2353, consists of a banded goethite-hematite ore, with minor limonite. This ore is brown and has large numbers of small cavities. A core of high grade ore, from R143 in Fe 61, in Area 2028, consists of massive hematite. The ore is hard and dark blue, with a purplish tinge, and it has very few cavities.

3.9 SECONDARY ORE DEPOSITS

In a number of boreholes scree ore or pisolitic scree was encountered. These were found either down dip from the outcrop or in valleys in the hills. The scree ore is cemented, and consists mainly of goethite. These deposits are of small areal extent and do not exceed 20 feet in thickness. At the moment, they have no economic importance.

In the hills, especially in the eastern areas, there are several pisolitic deposits. It is difficult to determine whether these are pisolitic scree or true pisolites, but fragments of fossilised wood indicate that some of it may be pisolite. These deposits are probably thin and are of no economic significance.

They have not been differentiated from the normal ore on the maps, but notes have been made where this type of ore is abundant.

Lateritisation has commonly affected the ore, and the laterite seems to grade into normal ore. Occasionally there is thin laterite on the chert.

3.1 MANGANIFEROUS IRON ORE

Small patches of manganese enrichment are common throughout the iron enriched areas of the Marra Mamba (Plate 15). These patches of manganese enrichment are particularly abundant in some areas and they have a strong tendency to be concentrated within stratigraphic units. However, drilling shows that manganese enrichment is rarely more than 15 feet thick.

Areas where manganese is particularly common are marked on the maps. The two best areas of manganese are not far apart, in Area 2354. There is extensive manganese enrichment on Fe5, and R115 intersected 15 feet of 17% Mn. Further west, in Fe 7 R100 intersected 40 feet of 18% Mn. This is the best manganese intersection of any borehole in TR 3358H. However, lateral continuity of these high values cannot be assumed, as two other boreholes on Fe 5 did not intersect any significant values. As happens in other places, these show that manganese enrichment at the surface can have almost no extension in depth.

One other deposit where good manganese values were obtained is Fe 23 in Area 2353. R130 has 20 feet of 4.5% Mn, and R113 has 10 feet of 9.5% Mn.

In R115 one sample assayed 28% Mn, which is higher than the Fe value.

It is considered unlikely that mineable amounts of high grade Mn ore can be found, but it is possible that large quantities of lower grade ore could exist and could be located by further drilling

Small patches of manganese bloom can occasionally be found in unenriched Marra Mamba. It is probable that manganese oxides were originally disseminated through the Marra Mamba in the same way as iron oxides. It may originally have been richer along some horizons, which could be those where it is now largely concentrated. It is assumed that the process of manganese enrichment is similar to that of iron.

4. DRILLING

4.1 PREVIOUS DRILLING

The drilling in 1962 was entirely in the eight eastern areas 2022-2029. It consisted of 68 percussion drill holes, renumbered R1-R68, with a total footage of 3259 feet and 12 diamond drill holes renumbered RD1-RD13, with a total footage of 937 feet.

During the 1963 programme 31 holes, renumbered R69-R99, were drilled, with a total of 2364 feet. A Halco-Stenuik Mark III Percussion Rig was used, with an Ingersoll-Rand 365 cfm compressor. This drilling was carried out in the three western areas, 2352, 2353 and 2354. Difficult drilling conditions were encountered during this programme and approximately 50% of the holes required cementing. The average footage was 34 feet per day.

In 1970 three percussion drill holes, R100-R102, were drilled in Areas 2353 and 2354. They had a combined footage of 295 feet. The drilling contractors were W.H. Drilling, who used an Ingersoll-Rand TRUCM-3 1200 Drillmaster.

4.2 RE-NUMBERING OF BOREHOLES

The 1962 and 1963 boreholes have been re-numbered. The old and new numbers are listed in Appendix 2.

4.3 1971 PROGRAMME

A total of 50 boreholes were drilled during the present programme, with numbers R103 and R152. They have a total footage of 4,255 feet.

The drilling in the three western areas, 2352, 2353 and 2354 was done by Seidel Bros., Well Drilling Co.Pty.Ltd., who used an Ingersoll-Rand TRUCM-3 600 Drillmaster.

They used an Ingersoll-Rand 1060B hammer and 6½" Carset bits, and also an Ingersoll-Rand 275 hammer, with 5½" Carset bits.

Seidel Bros. drilled 37 boreholes for a total footage of 3478 feet. The work was done in two periods, with a total of 33 working days. The drilling average 105 feet/day. No serious drilling problems were encountered and only 7 boreholes required casing or cementing. Three cores were taken, one each from R129, R131 and R133.

The drilling in the eastern areas, 2024 and 2028 was done by W. H. Drilling Pty. Ltd., who used an Ingersoll-Rand TRUCM-3 1200 Drillmaster, with an Ingersoll-Rand 275 hammer and 5½" Carset bits.

W.H. Drilling completed 13 boreholes with a total footage of 881 feet. This was done in 7 working days, at an average rate of 125 feet/day. No casing or cementing was required, but one borehole, R146, had to be abandoned when the core barrel was jammed in the hole. It was found to be impossible to retrieve this barrel. Earlier three cores had been taken, one each from R141, R143 and R145.

The difficult drilling conditions mentioned in the report on the 1963 programme were not encountered during drilling in 1970 and 1971. This is probably partially due to better drilling equipment used in the later programmes.

The total footage drilled in the Roy Hill areas, including the diamond drilling, is 11,110 feet.

4.4 SAMPLING

In the 1970 and 1971 programmes the boreholes were sampled in 5 foot intervals. Dry samples were divided by riffing, and wet samples by coning and quartering.

5. ORE RESERVES

<u>Bore Type</u>	(a) Percussion
	(b) Diamond
<u>Sample Interval</u>	(a) 1962-1963. Variable 1970-1971. 5 ft.
	(b) Variable.
	<u>Area x average thickness</u>
<u>Formula</u>	Tonnage Factor.

5.1 SCHEME 1.

Ore	- Definition	- All samples 55% Fe.
	Thickness in Bore	- All ore plus included waste with a minimum thickness of 30 ft. Weighted average grade to be not less than 55% Fe.
	Bore Grade	- Weighted average of ore thickness defined above.
Area	- Definition	- Mapped extent of deposit less estimated portion represented by barren holes.
	Measurement	- Counting Squares.
Tonnage Factor	-	- 11 c.ft/ton for both ore and overburden. See Appendix 1.
Reserves	- Category	- Potential Ore.
	Tonnage	- 593 million tons ore, (Table 1).
		- 232 million tons overburden (Table 1).
	Average Grade	- 58.3% Fe, 5.3% L.O.I., 61.6% Fe cin. (Table 2).

COMMENTS

Only deposits for which borehole information is available were included in calculations on this scheme.

Normally, results from percussion boreholes only were used, but in deposits where there are none, the results of any diamond drill holes were used.

Average values for SiO_2 , Al_2O_3 and P were calculated where possible. Analyses for these are given for the 1970 and 1971 drilling, but they are not recorded for many of the 1962 and 1963 boreholes. Some of those which have analyses for SiO_2 and Al_2O_3 have no values for P. The average grades and analyses for each deposit and the number of boreholes from which results were obtained are listed in Table 2.

Down dip extensions, even when they are known to exist, have not been included in these calculations, as their extent is largely unknown.

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TABLE 1

Thickness and tonnages of +55% ore, and of overburden

Deposit No.	Area sq.ft. $\times 10^3$	Ore thickness feet.	Overburden thickness feet.	Ore tons $\times 10^6$	Overburden tons $\times 10^6$
<u>Area 2352</u>					
Fe 28	2,788	55	5	14	1
Fe 29	5,556	30	0	15	Nil
Fe 64	1,667	55	0	8	Nil
<u>Area 2353</u>					
Fe 22	40,000	32	12	116	61
Fe 23	23,333	43	26	91	55
<u>Area 2354</u>					
Fe 5	16,000	50	40	72	58
Fe 7	2,556	40	45	9	10
(Top 40' of overburden of Fe 7 is rich in Manganese).					
Fe 8	8,889	34	0	26	Nil
Fe 9	31,000	40	7	112	19
Fe 13	7,541	32	17	21	11
<u>Area 2028</u>					
Fe 61	38,889	31	5	109	17
<u>TOTAL</u>				<u>593</u>	<u>232</u>

TR 3358 TABLE 2
AVERAGE GRADES OF +55% ORE

Deposit No.	Tons x 10 ⁶	Fe %	L.O.I %	SiO ₂ %	Al ₂ O ₃ %	P %	No. of Boreholes Fe & L.O.I.	No. of Boreholes SiO ₂ & Al ₂ O ₃	No. of Boreholes P
<u>Area 2352</u>									
Fe 28	14	58.8	6.1	4.8	2.5	.073	1	1	1
Fe 29	15	57.6	6.3	n/a	n/a	n/a	2	Nil	Nil
Fe 64	8	56.8	6.2	9.7	1.9	.039	1	1	1
<u>Area 2353</u>									
Fe 22	116	56.8	7.0	9.6	1.8	.046	2	2	2
Fe 23	91	60.5	3.9	5.7	2.1	.045	3	3	3
<u>Area 2354</u>									
Fe 5	72	58.5	7.0	5.6	1.7	.070	2	2	2
Fe 7	9	58.5	7.6	4.6	2.4	.080	1	1	1
(40 ft. of the overburden of Fe 7 has the following grades:-									
		34.1	11.6	9.1	4.6	.046 (Plus 18.0% Mn).			
Fe 8	26	57.0	6.3	9.3	2.5	.040	3	1	1
Fe 9	112	58.7	4.3	7.3	2.4	.040	11	3	3
Fe 13	21	61.1	2.1	6.7	1.4	.023	5	3	3
<u>Area 2028</u>									
Fe 61	109	57.4	4.3	9.2	3.2	.060	3	3	3
TOTAL	593	58.3	5.3	7.7	2.3	.050			

n/a = no information available

5.2 SCHEME 2

Ore	- Definition	- Individual Bore samples 50% Fe Bore intersections 55% Fe.
	Thickness in Bore	- Minimum of 30 ft. provided that weighted average grade is not less than 55% Fe and that no individual assays are less than 50% Fe.
	Bore Grade	- Weighted average ore thick- ness as defined above.
Area	- Definition	- 800'x 800' around bore.
	Measurement	- Calculated.
<u>Tonnage Factor.</u>		- 11 c.ft/ton for both ore and overburden.
<u>Reserves</u>	- Category	- Inferred ore
	Tonnage	- 99.2 million tons of ore (Table 3)
	Average Grade	- 58.5% Fe, 5.4% L.O.I., 61.8% Fe cln. (Table 3)

COMMENTS

Boreholes in down dip extensions were included in this scheme. It was noticed that diamond drill holes in ore appear to give higher assays than percussion boreholes, and for the sake of uniformity, diamond drill hole assays were excluded.

The overall averages for SiO_2 , Al_2O_3 and P were calculated for the ore included in this scheme. They are given in the Summary of Total Ore Reserves on page

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TABLE 3

+55% Fe ore reserves, with a minimum 30 feet intersection and an 800 feet square area of influence for each borehole.

Deposit No.	Tonnage x 10 ⁶	Fe %	L.O.I. %	No. of Boreholes
<u>Area 2352</u>				
Fe 28	3.2	58.8	6.1	1
Fe 29	2.8	58.0	5.5	1
Fe 64	3.2	56.8	6.2	1
<u>Area 2353</u>				
Fe 21	4.5	58.6	4.5	2
Fe 22	3.2	56.7	6.0	1
Fe 23	6.6	61.0	3.8	2
<u>Area 2354</u>				
Fe 5	5.7	58.5	6.9	2
Fe 6	1.7	59.2	5.6	1
Fe 7	2.3	58.5	4.6	1
Fe 8	3.5	57.8	6.0	1
Fe 9	31.3	58.6	5.4	11
Fe 13	6.6	60.9	1.7	2
<u>Area 2026</u>				
Fe 50	3.3	59.1	5.6	1
Fe 51	5.8	56.8	9.9	3
Fe 52	2.9	58.7	8.3	1
Fe 53	1.7	59.6	2.9	1
<u>Area 2028</u>				
Fe 61	10.7	56.7	6.6	3
TOTAL	99.0	58.5	5.6	

5.3 TOPOGRAPHIC INFLUENCE

The ore tonnages have not been discounted to allow for the amount removed by erosion. Such a topographic factor is difficult to estimate with any accuracy, and it will vary considerably from one deposit to another. It is probable that it ranges from 30% to 50%, with an average figure of about 40%. Therefore, the quoted reserves of potential ore should be reduced by this amount to give a more realistic figure for the ore reserves.

However, the reserves calculated in Scheme 2 will not be greatly influenced by topography.

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SUMMARY OF TOTAL ORE RESERVES

Scheme 1. Potential reserves +55% Fe with a 55% cut-off in each borehole. Tonnage calculated as tons per vertical foot, but no allowance made for topography.

Tons x 10 ⁶	Fe %	L.O.I. %	SiO ₂ %	Al ₂ O ₃ %	P%	Fe _{cln} %
593	58.3	5.3	7.7	2.3	.050	61.6

By this scheme there are 947 x 10⁶ tons overburden.

Scheme 2 Inferred reserves +55% Fe with an average assay of 55% Fe over a minimum of 30 feet and an 800 feet square area of influence in each borehole. No significant allowance necessary for topography.

Tons x 10 ⁶	Fe %	L.O.I. %	SiO ₂ %	Al ₂ O ₃ %	P%	Fe _{cln} %
99	58.5	5.6	6.9	2.4	.058	62.0

6. RECOMMENDATIONS

It is recommended that consideration be given to relinquishing some 400 square miles of TR 3358H. The ore within this area is of low tonnage and grade and occurs in small scattered deposits.

Plans showing the areas which are recommended for retention have been prepared, and a composite plan of these areas (Fig.15) at a scale of 1:250,000, is included in this report.

The areas containing all significant deposits of +55% Fe have also been delineated in Figure 15. These areas total slightly under 65 square miles.

The best deposits on Scheme 1 in grade and tonnage are:-

Deposit No.	Tonnage x 10 ⁶	Fe %	L.O.I. %	SiO ₂	Al ₂ O ₃ %	P %	Overburden Tons x 10 ⁶
<u>Area 2352</u>							
Fe 22	116	56.8	7.0	9.6	1.8	.046	61
Fe 23	91	60.6	3.9	5.7	2.1	.045	55
<u>Area 2354</u>							
Fe 5	72	58.5	7.0	5.6	1.7	.070	58
Fe 9	112	58.7	4.3	7.3	2.4	.040	19
<u>Area 2028</u>							
Fe 61	109	57.4	4.3	9.2	3.2	.060	17
TOTAL	500	58.3	5.2	7.7	2.3	.051	210
TONNAGE	Average Grade						

It is recommended that any future work on TR 3358H be concentrated on these deposits.