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DEPARTMENT OF MINES
SOUTH AUSTRALIA

GEOLOGICAL SURVEY

IRON EXPLORATION SECTION

GEOLOGICAL REPORT

ON

KNOWN IRON ORE DEPOSITS
in
SOUTH AUSTRALIA

Outside the Middleback Ranges

by

Graham Whitten
Senior Geologist

January, 1963.

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PLAN

No.	Title
62-710	South Australia showing Known Iron Ore Deposits.

January, 1963.

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*Footnote 1. Published by permission of the Mines Department, South Australia.

*Footnote 2. Senior Geologist, Iron Exploration, Geological Survey of South Australia.

INTRODUCTION:

The high grade orebodies and the jaspilites of the Middleback Group (Archaean) in the Middleback Ranges ((Loc. 1))*

* Numbers in brackets (( )) refer to Localities on Plan.

constitute the largest reserves of iron ore in South Australia. Most of the numerous deposits elsewhere in the state, especially the high grade ones, are small. Exploration by the South Australian Mines Department outside the Middleback Ranges has enabled a reassessment of all the known significant deposits. Details of this work are available in unpublished reports by the writer in the files of the Department. In most cases this reappraisal has resulted in new opinions as to origin, age, reserves and metallurgy.

For present purposes, the term "iron ore" is used to describe material which can be used to feed a furnace directly (direct shipping or high grade ore) or can be beneficiated to produce a blast furnace feed (concentrating or low grade ore). "Iron formation" is used as a general term for formations containing iron rock members but usually containing in addition shale, quartzite, carbonate rocks etc. or their metamorphosed equivalents. Pyritic slate because of its facies relationship to more typical varieties of iron formation is included in this term. "Jaspilite" refers to a rock consisting essentially of interbedded layers in widely varying proportions of iron oxide and silica (chert), both chemically precipitated. Martite is here used to describe Fe_2O_3 whose origin from magnetite by supergene oxidation can be recognised microscopically and to distinguish it from hematite of primary or unknown origin.

Modern blast furnace practice required extremely high grade feeds. As this can be supplied by a variety of ores through beneficiation no appraisal of an iron ore prospect today is complete without some assessment of metallurgy. The metallurgical comments herein are based on experimental work carried out by the Australian Mineral Development Laboratories for the South Australian Department of Mines. A.M.D.L. also carried out the petrological examinations.

ARCHAEAN IRON FORMATIONS

Eyre Peninsula

In Southern Eyre Peninsula the Archaean rocks of the Middleback Ranges are represented in the Lincoln Uplands ((Loc. 2)) and in the Kimba-Cleve Uplands ((Loc. 3)) by the Hutchison Schists. These contain iron formations of the magnetite-jaspilite type which appear over a length of approximately 80 miles. The beds usually consist of alternating ¼" to ½" bands of recrystallised grey chert and iron oxide. In outcrop the magnetite is usually leached completely or altered to martite or limonite; manganese staining is common. The beds average 50' wide, seldom being more than 100'. There are usually 2 but occasionally up to 4 beds forming an iron rich zone less than 1000' thick. Selected bands assay up to 61% Fe but the overall grade would be about 30% Fe.

On the narrow Eastern Coastal Plains east of the Uplands occur a number of aeromagnetic anomalies. Two near Cowell ((Loc. 4)) and a third near Port Neill ((Loc. 5)) have been drilled intersecting in each case iron formations of the oxide facies under 0-300' (average 100') of Recent and Tertiary cover. Strike length aggregates possibly 8 miles. The iron formations contain too much clastic material to be considered simple jaspilites. They have suffered thermal metamorphism (550°C - amphibolite facies) and magnesian, potash and soda metasomatism resulting in the formation of anthophyllite, cordierite, cummingtonite, diopside and garnet. The formations are medium grained and carry approximately 28% acid soluble iron as magnetite.

All the above iron formations are too low grade to be worked under present economic conditions; they are considered as potential resources because of their possible ease of upgrading and their proximity to the sea coast.

In Central Eyre Peninsula exploration of the Warramboo Aeromagnetic Anomaly ((Loc. 6)) and the Kopi Group of Anomalies ((Loc. 7)) has disclosed approximately 30-40 miles of non-outcropping metamorphosed Archaean iron formation 50 miles from

the nearest known outcrop of comparable material. Bed width varies to possibly 1000' with a cover of Recent sands and clays ranging in thickness from 0 to 100'. The top 100' of the iron formation is weathered and contains martite; below this, coarse grained magnetite is the ore mineral. The other minerals present are similar to those found in the anomalies of the eastern coastal plain and indicate the sillimanite-almandine subfacies of the almandine-amphibolite facies.

Prospecting is still in the early stage. Grade of drillhole intersections to date is low but preliminary metallurgical work suggests that beneficiation will not be difficult. Thus there is a potential tonnage possibly of the order of 1000 M tons (equivalent to say 250 M tons of concentrate).

All the anomalies referred to above are elongate with asymmetrical and/or serrated profiles which are indicative of stratiform bodies. Three equidimensional anomalies with symmetrical profiles investigated in Western Eyre Peninsula disclosed basic igneous rocks viz. gabbros carrying minor magnetite.

Yorke Peninsula.

Three groups of elongate asymmetric aeromagnetic anomalies have been tested at North Kadina, Weetulta and at Balgowan in the Wallaroo-Moonta District ((Loc. 8)). Here there are no Archaean outcrops but drilling disclosed a succession similar to that outcropping in the Lincoln Uplands. Best intersections have been at Weetulta - 100' zone in 2 holes assaying 17.5% Fe and at Balgowan - 85' zone in 2 holes assaying 24.9% Fe (alternately 265' assaying 20.7% Fe). At Kadina a drill hole testing an anomaly with a value of 40,000 gammas above background intersected only 23' of iron formation assaying 24.7% Fe.

The correlation between Yorke and Eyre Peninsula is strengthened by the presence of magnetic shoals in Spencer's Gulf east of Cowell and northerly from Balgowan through Tiparra Reef to Middle Reef north of Kadina.

Central Province.

In the Central Province the jaspilites of the Middleback Ranges are represented by fine grained jaspilites of the Tarcoola

District (e.g. Wilgena Hill) ((Loc. 9)) and the coarse grained metajaspilites of the Mt. Christie District ((Loc.10)). The sediments around Tarcoola were considered previously to be Cambrian or later while the metamorphics near Mt. Christie were thought to be Archaean. The latest work suggests that they all occur at or near the one stratigraphic horizon in the Archaean, and that the age difference ascribed to the enclosing "metamorphics" and "sediments" by previous workers is more strictly a difference in degree of metamorphism only. This opinion is strengthened by the discovery of medium grained jaspilite east of Mulgathing Homestead intermediate in geographic position and in petrology to the two types found at Mt. Christie and Wilgena Hill.

East of Tarcoola occur several small outcrops of fine grained (5-45 microns) hematite-jaspilite. In polished section the hematite shows no evidence such as lattice twinning to indicate alteration from magnetite. This suggests that hematite was the primary oxide and that the depositional environment was shallow water. Although these deposits are of no economic significance, they are important geologically as they define a hematite facies not recognised in other Archaean provinces in South Australia.

Further west, near Tarcoola, Wilgena Hill consists of one large hill of jaspilite (5000'+NW-SE by 2000'+SW-NE by 200' high), and three small ones (maximum, 2000' by 1000' by 100'). The jaspilite consists of $\frac{1}{4}$" to 1" (usually $\frac{1}{4}$" to $\frac{1}{2}$") bands of red jasper separated by similar sized bands of siliceous hematite. Magnetite is present only as traces and the hematite lies in the 2-10 microns size range. Minor limonite occurs and there are occasional $\frac{1}{8}$" veins of secondary hematite. In the jaspilite are found perfectly preserved and very persistent current ripple marks attesting to the shallow water origin of such hematite - jaspilite and the lack of metamorphism since.

Fossils have also been found (R.C. Whitehead pers. com.). The single exposure has been inspected by the writer and was found to contain twelve complete and 4 incomplete almost circular

impressions ranging from 2 to 12 c.m. in diameter, the majority ranging from 3 to 6 c.m. They are slightly oval, the short diameter being approx. 80% of the large diameter. In profile there is a central raised portion reddish in colour covered by small knobs 0,5 m.m. high and distributed at 2 m.m. centres. The central area is surrounded by a depression 2-3 m.m. deep. This ring and the surrounding rock is blue-black in colour. The ring has a fine radial structure. No classification has been made as yet and no other exposure has been found.

The jaspilite beds are 5-80' wide (usually 20'-40') separated by 10-200' (usually 30-50') zones of poor outcrops. On the main hill are wide zones of no outcrop covered by canga. "Canga " here refers to cemented scree or soil adjacent to an iron formation and made up of fragments of the iron formation in a ferruginous cement. One dyke of Gawler Range Porphyry occurs. One third to one quarter of the hill is outcropping jaspilite. Chip samples across the hill averaged 40.9% Fe and 41.3% insoluble; no waste material was sampled. Reserves lie in the range 60-200 M tons depending on the nature of the non-outcropping material. Both cationic and anionic flotation of -200 mesh material produced concentrates grading 60% Fe approximately with recoveries in the range 60-80%. Cationic flotation proved to be faster than anionic flotation and no recleaning was necessary.

In the Mt. Christie District 60 miles NW of Tarcoola metajaspilites aggregating perhaps 10-15 miles occur as discontinuous outcrops in an area 20 miles square. The main deposits are Mt. Christie itself and Fingerpost Hill, one mile north west, which have been drilled. The drillhole intersections were 230' and 257' of ore respectively. The rock is coarsely lenticular with iron oxide lenticles 1-6 mm. across. They contain magnetite (100-500 microns) enclosed in and penetrated by martite and separated by quartz (mean size 500 microns). The enclosing rocks are very coarse grained granitised metasediments containing metamorphic minerals of the pyroxene granulite facies. This agrees with the metamorphic zoning deter-

mined from the grain size of the metachert in the iron formation.

The mean grade of 11 chip samples across outcrops in the Mt. Christie area is 55.8% iron, 6 at Mt. Christie itself averaging 52.0% iron. However, one diamond drill hole testing centrally under Mt. Christie averaged 38.2% Fe over 180', alternately 33.9% Fe over 230' indicating considerable surface enrichment. This is a problem always to be considered in the examination of this type of material. Proved reserves approach 20 M tons, with possible reserves in the range of 20-100 M tons. Both dry magnetic separation and Humphreys-spirals produced concentrates grading over 60% Fe. with recoveries over 85% using feed ground to pass 18 mesh BSS and with middlings reground to pass 72 mesh BSS.

Olary Province

In the Olary Province the Archaean has suffered metamorphism no less intense than that at Mt. Christie in the Central Province. At Billeroo ((Loc. 11)) there are five separate groups of iron ore outcrops consisting of a number of parallel bands of medium to coarse grained magnetite-meta-jaspilite in an iron formation 400' in stratigraphic thickness. The beds dip near vertically. Outcrop length aggregates 4,500' over a distance of 3½ miles. Some highly magnetic zones exist between outcrops. The iron ore occurs in Archaean metasediments varying from felspathic schists to granite gneisses and these are intruded by abundant pegmatites and granite dykes. There is one small high grade body (65.5% Fe, 100,000 tons (?) to 100 feet depth). The remainder averages 48.4% Fe and aggregates 1½ M. tons per 100 vertical feet. Dry magnetic separation and Humphreys-spirals produce concentrates grading in excess of 60% Fe with recoveries of 80-90% at - 36 mesh B.S.S.

At Koolka ((Loc. 12)) the orebodies appear to be recrystallised iron formations of the jaspilite type with concentrations formed at noses of folds probably during metamorphism. Two large pinnacles and a number of smaller ones outcrop and are enclosed in and are conformable with Archaean metasediments,

mainly epidote quartzites. Magnetite, altered to martite near the surface is the dominant iron mineral and varies from 0.4 mm to 2 mm or more across, averaging 0.6 mm. Grade averages 66.3% Fe with reserves of the order of 330,000 tons per 100 vertical feet.

Plumbago and Old Toraminga Dam are high grade deposits similar to Koolka and in the same district ((i.e. Loc. 12)) but with geological relationships to the surrounding rocks less clearly defined. Reserves for each are possibly of the order of 200,000 tons per 100 vertical feet grading 66.6% and 64.6% Fe respectively.

Mt. Lofty Ranges.

In the Archaean of the Mt. Lofty Ranges occur a number of small (5-50,000 tons) titaniferous replacement type deposits. In the Mt. Compass - Yankalilla Inlier ((Loc. 13)), Mt. Jagged, an irregular magnetite-ilmenite body (65.2% Fe 4.9% TiO_2) in felspathic schists is of historical interest having produced the first pig iron in South Australia (1873). Wenhams, in the same inlier, though lower grade is of interest as it is unusually low in Titanium (44.3% Fe, 0.16% TiO_2).

PROTEROZOIC IRON FORMATIONS

Olary Province

In the Olary Province south of the railway the iron deposits are mainly Proterozoic. Here glacial sediments of the Sturtian Series in the Adelaide System contain hematite and magnetite siltstones (i.e. bedded iron formation) and hematite and magnetite tillite (tillitic iron formation) formed by chemical deposition of magnetite euhedra (40 microns) in a finer grained hematite (1-10 microns) ground mass. In the near surface material the magnetite euhedra are oxidized to martite . These rocks are not jaspilites as they contain no chemically precipitated silica. In the bedded iron formation the iron oxides are contaminated by fine clastic material. The tillitic iron formation includes erratics in varying proportions in addition to the fine clastic material and lamination is not visible.

These rocks are the Braemar Iron Formation of Mawson,

which occurs at the one horizon over a length of more than 70 miles in various parts of the Olary Province. The major known deposit is Razorback Ridge ((Loc. 14)), where beds dipping 30-40° aggregate up to 500' in thickness over a length of up to 12,000'. Grade of the bedded iron formation is 35.4% Fe, of the tillitic iron formation 23.7% Fe, the average possibly being 25.5% Fe. Reserves are 100 M tons above plain level plus 35 M tons per 100' below plain level. Exposures are excellent and reserves and grade are related directly to ore type which has been mapped in outcrops.

Beneficiation of surface and underground material by various methods has been tried, most methods recovering the magnetite euhedra (40 microns) and either losing the hematite flakes (1-10 microns) or recovering them in "composites" which lower the grade of the finished product. Best results have been obtained by reducing all the iron oxide to magnetite by heating in an 85% CO_2 - 15% CO atmosphere followed by fine grinding (-300 mesh) and magnetic separation. A grade of 60.4% Fe with a recovery of 80% + has been achieved on Bedded Iron Formation.

Similar material is known from Cutana Nos. 1, 2 and 3 Quarries, from the bedrock underlying and near Grants Quarries and from Maldorky Hill, all in the Radium Hill District ((Loc. 15)) These latter can not possibly be considered as sources of iron ore until the metallurgical problems related to the fine grained nature of the Braemar Iron Formation are solved. Even then larger deposits of this formation will have priority in development.

Flinders Ranges

In the Flinders Ranges, diapirs (i.e. piercement fold structures) which are known to have been active during the Upper Proterozoic and Lower Palaeozoic frequently contain small bodies of high grade iron ore. The origin of the ore is not known with certainty, though since it occurs in association with dolerites, it is thought to be deepseated. The primary iron ore mineral is magnetite. The Iron King deposit (Worumba diapir) ((Loc. 16)) is the largest of this type (30-50,000 tons, grade 66% Fe) while

others occur in the Blinman and Moralana diapirs. Elsewhere small bodies of micaceous hematite occur, the micaceous nature of the ore possibly being related to faulting.

On the eastern flanks of the Enorama and Worumba diapirs, narrow hematite siltstones and tillitic iron formations form part of the lower glacial sequence (Sturtian) and are to be correlated with the Braemar Iron Formation of the Olary Province. Another occurrence is known in an anticlinal core on the Willippa 1-mile sheet. To date these formations have not been recognised on the western flanks of the ranges.

Also occurring in Proterozoic rocks in the Flinders Ranges and possibly related to diapirism are numerous veinlets and lode channels of siderite. Of these Nicols Nob Copper Mine, 22 miles NE of Leigh Creek, is the largest and best known.

Mt. Lofty Ranges etc.

In the northern Mt. Lofty Ranges, Hick's Quarry near Gladstone ((Loc. 17)) produced approx. 70,000 tons of flux for Port Pirie from a replacement in an environment of steeply dipping Proterozoic sediments. The ore mineral is magnetite almost wholly altered first to martite and then in part to goethite. The rock replaced has not been identified but the presence in the quarry of weathered dolerite, a decomposed basic volcanic rock and a diapiric breccia prove a diapiric association. Reserves may lie in the range 30,000-100,000 tons grading 60.2% acid soluble iron. The micaceous hematite of the Devil's Chimney deposit 26 miles north east of Orroroo may also occur in a diapir or a fault.

In the southern Mt. Lofty Ranges the Basal Grits of the Torrensian Series contain heavy minerals (Aldgate Sandstone). These have been traced around the Houghton-Barossa Inlier ((Loc. 18)), for over 30 miles and here they are particularly ferruginous. Shearing along the unconformity during the Lower Palaeozoic Orogeny has converted most of the iron oxide to micaceous hematite. Thus the Mt. Bessemer Mine has produced 40,000 tons of micaceous hematite for use as flux and more recently for use as a filler in industrial paint. Resources

approximate 500,000 tons containing 40-62% iron, high in titanium. However, as the deposit is within the South Para Reservoir it is no longer available for mining.

Immediately to the south however the same bed outcrops in Malcolm Creek where it averages 50' in thickness and dips 50°E. The best outcrop is 1500' in length rising to about 100' above creek level. Discontinuous outcrops occur to the south over a distance of two miles. Resources are estimated at half a million tons above creek level averaging 35.3% Fe, 50.0% insoluble and 0.6% TiO_2. The bed could possibly supply half to one million tons per 100' below creek level. Both dry magnetic separation and flotation have recpvered 92-97% of the iron in concentrates grading 62-65% Fe.

South of Williamstown where the basal beds are lower grade (7.7% Fe and 0.74% TiO_2) but where a large area has been exposed on the crest of an anticline, they have been investigated mainly for their titanium content. Mapped resources are 45 M tons with latent resources possibly in excess of 1000 M tons. These rocks have been referred to informally as "The Williamstown Grits". The equivalent unit of heavy mineral sandstone has been found near Rhynie and extends northwards.

Elsewhere in the state very thin Proterozoic iron formations of no possible economic significance outcrop in quartzites at Woocalla (Central Province) and with ferruginous grits and siltstones at Corraberra and Pt. Lowly (Eyre Peninsula).

PALAEOZOIC & MESOIC IRON FORMATIONS

In the Mt. Lofty Ranges the Nairne Pyrite Horizon (Cambrian) which is treated elsewhere requires mention here because of its facies relationship to the more usual oxide facies.

At Leigh Creek in the Triassic Coal Measures narrow (1'-2') beds of siderite (capped by limonite) identify the carbonate as a sedimentary iron facies which has not been reported elsewhere in South Australia. However, siderite replacing Archaeocyatha limestone (Cambrian) occurs at the Copper King Ochre Mine 15 miles south of Leigh Creek.

TERTIARY (?) SURFICIAL DEPOSITS, ETC.

The surficial deposits known in South Australia are of three types viz.

(1) Laterites, either residual or transported, which occur as near horizontal remnants, usually on the tops of low rises, Where laterites are thickest or richest they appear to be formed from older iron formations nearby.

(2) Limonites, more or less massive, replacing steeply dipping shales or breccia zones. Remnants of unreplaced country rock occur. The ore usually requires sorting or selective mining and tends to grade out in depth.

(3) Hematites. Where identified the replaced rock has been marble.

All three types may be related to Tertiary or perhaps later weathering cycles. The variation in ore type appears to depend on the material replaced. While a number of such deposits produced small tonnages of ironstone flux for base metal smelting near the turn of the century, all are either too small, too low grade, too difficult to concentrate or too isolated to be exploited under present economic conditions.

Olary Province

In the Olary Province production of flux has been made from two areas of laterite 8-10 miles south of the Broken Hill railway in the Radium Hill district. ((Loc. 15)). Recent sampling of Grants Quarries suggests grades of 43.2% and 39.5% acid soluble iron for two workings in laterite overlying Braemar Iron Formation. In Alberta Quarries 3 miles S.E., secondary hematite is more plentiful and Jack records a grade of 57.1% iron from hand-picked material. Resources may approximate 1 million tons per deposit. Beneficiation of ore from Grants Quarries is not economic.

At Donnelly's Comstock Mine, ((Loc. 19)) near Quorn, shales, limey shales, sedimentary breccias and sandy siltstones of basal Cambrian age have been replaced near outcrop by limonite

Minor hematite and manganese oxides also occur. The deposit is made up of a large number of small bodies arranged in four groups around the keel of a syncline in an area $\frac{3}{4}$ mile NS by $\frac{1}{2}$ mile EW. Resources approximate 300,000 tons grading 50% Fe.

Mt. Lofty Ranges etc.

At Oodla Wirra on the Broken Hill railway ((Loc. 20)) limonite replaces breccia zones in steeply dipping limey shales of Upper Proterozoic age. These breccias may be related to a diapiric structure, containing basic rocks, immediately to the north. Production to 1903 was 18,000 tons of hand picked ore grading 51% iron. Resources suitable for smelting are limited to a few thousands tons which would require hand picking. Ochre for use in red oxide paints may be available from underground workings.

In the Angaston District small bodies of hematite form replacements in Cambrian limestone and have been worked for cement manufacture. Where exposed the cut off at the base of the ore is sharp and appears to represent the karst surface of the limestone. Resources are limited to a few thousand tons per deposit.

At Peeralilla Hill ((Loc. 21)) near Victor Harbour laterite formed on rocks adjacent to the Nairne Pyrite Horizon (?) has produced 9-10,000 tons of flux. Reserves may lie in the range 100,000 - 400,000 tons grading 39.3% Fe. Upgrading is not practicable. Other lateritic bodies of still lower grade occur in this area as Tertiary remnants.

A number of small deposits, mainly limonite, also occur e.g. Hundreds of Pekina, Clinton, Campoona, Kapunda, Moorooroo. Some of these have been worked for flux but are of no economic significance today.

GFW/EMD
January, 1963

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S. A. DEPT. OF MINES

SOUTH AUSTRALIA

SHOWING

KNOWN IRON ORE DEPOSITS

and Geological Provinces

1 Middleback Ranges
2 Lincoln Uplands
3 Kimba-Cleave Uplands
4 Cowell Anomalies
5 Port Neill Anomaly
6 Warramboo Anomaly
7 Kopi group of Anomalies
8 North Kaaina, Balgowan & Weetulta Anomalies
9 Wilgena Hill etc
10 Mt Christie & District
11 Billeroo
12 Koolka, Plumbago, Old Toraminga Dam
13 Mt Jagged, Wenhams
14 Razorback Ridge (Braemar)
15 Cutana, Grants, Alberts Quarries, Maldorky Hill
16 Iron King
17 Hicks Quarry
18 Mt Bessemer Mine, Malcolm Creek, Williamstown Grits
19 Donnelly's (Comstock) Quarries
20 Oodla Wirra
21 Peeralilla Hill
22 Greenpatch

SCALE IN MILES

50 0 50 100

62-710A