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MANGANESE DEPOSITS GREGORY RANGE - PILBARA GOLDFIELD, W.A.

by

J. N. Casey

A. T. Wells

With appendix by W.M.B. Roberts

CANBERRA. February, 1956.

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SUMMARY

Manganese deposits in the Gregory Range W.A., were sampled to determine whether they could be used for battery manufacture. The samples were sent to Metals and Ores, Alexandria, N.S.W., (subsidiary of Eveready Co.) for MnO_2 analysis, and samples with greater than 70% MnO_2 content were submitted to the "shelf and service" test; some deposits give ore suitable for battery manufacture and Eveready are arranging for a 10 ton sample of ore to carry out more exhaustive tests. The MnO_2 content ranged from 29.6% to 84.2%.

Twenty-five separate deposits were chip-sampled, and the investigation indicated a reserve of 107,000 tons of manganese ore (c.f. Owen, 1953 - 93,000 tons), based on a geological estimate from tape-measured outcrops.

The deposits occur as replacements of a siliceous chert breccia which formed from the weathering of upper Proterozoic dolomitic limestone containing chert nodules; the chert fragments collect in joints, sink holes, and basins formed in the limestone, and manganese replaces the silica in this position.

INTRODUCTION

Blatchford (1924) reports (Mn 43.5, 15.2 Fe) from Vanadium Ck. and it "occurs at top of a quartzite bed which overlies one of the limestone beds"; it has "laterite appearance of origin and was probably derived from the quartzite".

Manganese was first reported from the Baramine-Braeside area by Blatchford (1924). Finucane (1937) during a survey of the lead deposits at Braeside, reported that manganese occurred in the area and outcrops continued to the south. Owen (1953) with de la Hunty from the W.A. Geological Survey, plane-tabled, sampled and estimated reserves of manganese ore on the Woody Woody field.

The authors sampled the Woody Woody deposits from 23rd to 31st May 1955, and two collections were made; one was sent to Metals and Ores (Alexandria, N.S.W.) and the second to Mr. H. A. Ellis Chief Geologist of the W.A. Geological Survey. The sampling was specifically carried out to determine whether the ore could be used in the battery industry.

LOCALITY AND ACCESS

The manganese deposits occur in the south-east corner of Warrawagine Station, in an area that was once part of Braeside Station; the deposits are east of the Nullagine - Oakover River system and are within the Pilbara Goldfield area.

The most important deposits occur in a north-south belt, 25 miles long and 3 miles wide and it is part of the Gregory Range. It extends from Mt. Sydney in the north to about 6 miles south of Woody Woody Creek. The deposits are referred to as "Woody Woody" by the local people.

A weekly air service conducted by MacRobertson - Miller Aviation Pty. Ltd. connects Pt. Hedland to Ragged Hills airstrip which is 3 miles west of the northernmost deposit. A formed road connects Pt. Hedland to the Coongan turnoff, a distance of 90 miles; from here it becomes a good graded road to the actual manganese deposits, a total distance of 260 miles from Pt. Hedland. Three large rivers, the Coongan, Nullagine and Oakover have to be crossed as well as various smaller gullies and swampy areas; access to the field is therefore possible only during the dry season from April to December.

Pt. Hedland is the nearest port for shipment of ore from this district; the Marble Bar to Pt. Hedland railway was demolished in 1952; all bulk handling is now done by road transport. Carriers, using diesel trucks of 15-25 ton capacity, usually charge £5 per ton from the deposit to Pt. Hedland, where the ore is stored "on grass" until a vessel is available for further transport; the ore in 1954-55 was bought by B.H.P.; in 1953-54 9,000 tons of ore assaying about 53% Mn. was exported. About 4,000 to 8,000 tons is mined per year.

GEOLOGY

The Gregory Range trends north-south and consists of

Precambrian rocks; on the west these are flanked by Permian fluvio-glacials which crop out on the flat valley which continues west to the Oakover River and then north along the Nullagine - Oakover River System. Many boulders and pebbles from the fluvio-glacials litter the valley; in exposed sections the pebbles are set in a blue clay and sandstone matrix; 5 to 30 feet of marl, limestone and chalcedony forming the Tertiary Oakover Beds cap these Permian sediments. Glacial pavements are visible 2 miles north of Carawine gorge and south of Mother Uther Creek (2 miles south east of M.C.267); in both localities the glacier had moved towards the north west.

The earliest Precambrian rocks of the Gregory Range consist of Lower Proterozoic schists and greenstones, striking north-south. They are intruded by granite on the eastern side, and overlain by Upper Proterozoic (Nullagine) dolomitic limestone, chert breccia and sandstone on the western side. The contact of the Lower and Upper Proterozoic rocks is faulted in many places. The limestone in places is faulted and folded, and along the west scarp of the range it forms small structures with dips varying from 20° to 75°; the limestone has many beds and lenses of primary chert nodules and "biscuits" formed during deposition. Regionally, the limestone forms a syncline on the western margin of the greenstones; the trough of the syncline is occupied by the chert breccia and some sandstone; sandstone becomes predominant south of Woody Woody creek. The manganese deposits are wholly confined to this belt of limestone - chert breccia - sandstone. The chert breccia has been recognised as a mappable unit in other parts of the Pilbara area (Traves et al., 1955); it overlies the dolomitic limestone at Carawine Gorge, where it contains a trace of manganese and occurs at Pinjian Pool (south of Warrawagine) and near Yarrie Station

ORIGIN OF THE MANGANESE

A similarity exists between the two largest occurrences of manganese ore in W.A. i.e. that in the Gregory Range and that in the Teano Range - Horseshoe area. They are both associated with upper Proterozoic dolomitic limestones and are replacements of a siliceous chert breccia which has been derived from the limestone; in places a sandstone forms a lateral variation of the breccia.

The deposit in the Gregory Range has been regarded as a replacement body (Owen, 1953), but the chert breccia has not been recognised as a unit before. Owen regarded the manganese as "replacing silicified beds in the limestone and infilling joints and solution cavities". The chert breccia as a unit is not easily recognised near the ore deposits, but the authors had mapped the unit in other areas and its presence in the manganese field became obvious.

The brown, red brown, and yellowish dolomitic limestone containing many chert nodules and "biscuits" weathers easily, liberating the chert which either collected in cavities or joints in the limestone, or was transported to areas of low relief. The chert was probably poorly cemented by calcium and magnesium carbonates and it was later replaced by manganese and some iron. The manganese has probably been derived from the limestone and the neighbouring Lower Proterozoic basic volcanics (greenstones), or Upper Proterozoic basalts. Analysis of the dolomitic limestones shows 0.12 to 0.69% Mn and of the younger volcanics 0.16 to 0.67% Mn.

In the hand specimen chert pieces are interlaced with manganese veins, leaving only resistant patches of white chert; in some cases most of the varicoloured chert remains unreplaced by manganese. Microscopic examination of their sections show clearly that the chert has been replaced by manganese.

The deposits occur at the same general level, which would suggest that they formed on a level land surface with low relief and slow internal drainage. This would prevent the dispersal of manganese-bearing solutions.

The predominant mineral is pyrolusite, with small amounts of braunite and a trace of psilomelane; in some deposits (M.C.267) barytes, derived largely from the psilomelane, and siderite are quite common.

Mineragraphic examination by W.M.B. Roberts of the Bureau of Mineral Resources (see Appendix A) shows the sequence of events relating to the manganese deposition and bears out the theory postulated above.

Requirements for Battery Grade Ore

"Chemical" grade ore, as distinct from "metallurgical" ore, is purchased on the available MnO_2 content (minimum about 72-75%) as determined by standard methods of analysis.

Manganese is used as a depolariser in batteries; it is mixed with graphite or carbon black and solid ammonium chloride, and the whole moistened with a solution of ammonium chloride and zinc chloride. This mixture is compressed round the positive carbon cathode in dry batteries.

The following article by Camp (1938) gives a concise summary of the general occurrences and qualities of manganese dioxide suitable for dry batteries:

> "Manganese dioxide is probably the most important ingredient in dry cells, and its purity and condition have a vital effect upon the quality of the finished product. Because it is a natural material, purified only by mechanical processes, it is subject to wide variations depending upon its source and treatment. The principal types available are designated by the country of their origin and are listed as follows - Montana, Caucasian, African, Cuban, Porto Rican, Javanese, Brazilian, and Japanese. These all differ in regard to chemical composition, physical condition, and depolarizing power, and in addition they will often differ from lot to lot, so that great care in the selection and application of this ingredient must be used.
>
> "Manganese dioxide is used in the positive electrode of dry cells because of its depolarizing quality or ability to oxidize hydrogen to water. The extent of this power in manganese dioxide from different sources appears to be independent of its MnO_2 content. For instance, Phillipsburg (Montana) manganese of 70 per cent MnO_2 is a better depolarizer than Caucasian ore containing 86 per cent MnO_2. In different lots of the same type, however, the depolarizing quality is directly proportional to the MnO_2 content. The reason for this has never been definitely determined. The only way to find out is to try out the material in a standard-mix formula in a dry battery.
>
> "The natural ore, pyrolusite, usually occurs mixed with other minerals such as silica, clay, limestone, iron oxide, tramp iron, copper, lead, arsenic, silver, cobalt, lower oxides of manganese, and probably other ingredients. Outside of its depolarizing power, the fitness of a given ore for battery use is dependent on the quantity and kind of impurities present. The gangue minerals which are insoluble in boiling hydrochloric acid are innocuous, except as they dilute the active material. Ferric oxide, up to three or four per cent, as well as the lower oxides of manganese are also harmless, but metallic iron accidentally mixed in the ore is very deleterious, and usually all shipments are passed over magnetic separators to assure its removal. The other metallic elements, particularly

copper, lead, and silver in any soluble form, are active poison in a dry cell as they plate out on the zinc electrode and run the cell down by local short circuits. Their presence should be restricted therefore to mere traces, less than 0.02 per cent. Excessive lime causes gassing and low service".

The above article is typical of the literature on the subject, but criteria for the chemical requirements of the ore have been compiled by battery companies; these are:

(a) the ore must have crystal structure of gamma-MnO_2, cryptomelane or pyrolusite type;

(b) MnO_2 content to be a minimum of 70%, preferably 80% (equivalent to 45-50% Mn);

(c) nickel not to exceed 0.05% and cobalt not to exceed 0.15%;

(d) arsenic and antimony not to exceed 0.05%;

(e) copper not to exceed 0.05%;

(f) lead not to exceed 0.10%;

(g) iron as ferric oxide not to exceed 3%;

(h) moisture not to exceed 1%;

(i) must be low in phosphorus content;

(j) the silica content is not a limiting factor of the ore.

If the ore satisfies these chemical tests, it must be submitted for "shelf and service" testing to be sure the cell will hold its charge and not suffer polarisation effects; this latter test takes a period of weeks.

Skewes et al. (1952) determined that the crystal structure of gamma-MnO_2, identified by X-ray diffraction, was the most suitable for battery use; then followed cryptomelane and then pyrolusite. Cryptomelane is the "barium deficient psilomelane" and it, like pyrolusite, has a tetragonal crystal system; psilomelane is orthorhombic. Gamma-MnO_2 is thought to be a disordered form of the rare mineral ramsdellite.

It was also found that fine grinding of the oxide was detrimental to good cell performance; a relatively coarse oxide having the gamma-MnO_2 structure was best.

Ore from the Gold Coast, West Africa, is the biggest single source of high-grade battery ore in the world. Battery-grade ore is mined from Barraba, N.S.W., and it provides about 20% of Australia's 2,000 tons annual requirements; some ore comes from Eigo, Papua; most of the remaining requirements are filled by imports from the Gold Coast.

The price of the ore in May 1955, f.o.b. N.S.W., varied from £14.10.0 per ton for 75% MnO_2 to £17 per ton for 85% MnO_2. The price of the Peak Hill ore for metallurgical processes was £12 to £14 per ton f.o.b. Geraldton in 1954.

Broken Hill Pty. Ltd. in 1942 stipulated that for metallurgical processes the ore was to contain:

(a) 48% Mn;

(b) less than 8% SiO_2;

(c) less than 4% Fe;

Metals and Ores, who carried out tests on the samples, reported that certain ores, viz. MC271, MC211, MC54(2), MC273, MC57(2) and Southern Deposit (2) were worth evaluating completely by actually making them into dry cells; the Company is now investigating the possibility of obtaining a 10-ton parcel of any of the ores listed above.

METHOD OF SURVEYING AND SAMPLING

A flight was made over the field in a D.C.3 aircraft [illegible] flying at 1000 feet, and three north-south photographic flights were made at 10,000 feet, producing photos at a scale of 1800 feet to 1 inch (1 : 21,600). Photos at a scale of 1 : 37,500 have since become available to cover the whole Nullagine Four Mile area in which the manganese occurs.

An overlay was made from the uncontrolled matched photos and this was reduced photographically to a scale of 1 inch to 2 miles; manganese deposits and the regional geology were plotted on this overlay. The deposits generally are not very conspicuous on the air photos, but they stand out very clearly when viewed from an aircraft; many small isolated unpegged deposits were seen in this way extending north north west from MC268, past Mt. Sydney to a point east of Braeside; all these deposits were associated with the dolomitic limestone or the breccia.

Estimated tonnages were calculated by pacing the length and width of the deposit and measuring the height with a tape; a factor of 9 cubic foot of ore to the long ton was then used to estimate the tonnages. Due allowance was made for visible occurrences of siliceous manganese breccia within the deposit; all tonnages therefore represent a geological estimate based on measured exposures and the known tonnage may increase considerably when the deposits are drilled or open-cut; MC268 for example had an estimated reserve of 4,300 tons before it was open-cut in 1954; since then 4,000 tons have been removed and about 10,000 tons still remain.

Samples were taken by chipping from the surface of the outcrop and, where possible, blocks were broken to obtain a centre sample in case surface samples had been enriched. The chips were then mixed and divided, onehalf was sent to Metals and Ores for analysis, the other half to the State Geological Survey.

DESCRIPTION OF INDIVIDUAL DEPOSITS

These will be treated in numerical order, which has no relation to the north-south trend of the deposits. Unpegged deposits will be treated at the end.

"M.C." refers to Mineral Claim and the sufix "L" indicates the claim is within the Nullagine district of the Pilbara Goldfield.

M.C.53L (Northern Mineral Syndicate)

The deposits consist of a north-trending line of detached orebodies; the southern part of this line has already been worked. The sampled deposit (1) is exposed in a small gully and is 1600 feet north of the south-west corner datum peg of the deposit. The outcrop is irregular in shape and in places fills sink holes and joints in the underlying gently north-east dipping dolomite. The average thickness is 8 feet and the unworked deposit contains 2,300 tons of ore assaying 49.6% MnO_2.

Deposit (2) is 1,200 ft. N.N.W. of deposit (1). It has been partly mined but operations were selective because iron is found in pockets in the manganese. About 4,800 tons of ore assaying 52.3% MnO_2 are still available.

M.C.54L (Mineral claim held by Northern Mineral Syndicate) one bears 167° (mag.) from the northern deposit which was sampled as (1).

(1) The deposit averages 4 feet in thickness and contains 500 tons of poor grade manganese; there is much visible ferruginous breccia in the southern extremity of this northern deposit. Assay results gave 57.6% MnO_2.

(2) This southern deposit averages 6 feet thick and contains 6,800 tons of ore assaying 77.2% MnO_2.

<u>M.C.56L</u> (Northern Mineral Syndicate)

When this deposit was opened up a 12 foot face of manganese was exposed; the ore appears weathered and contains earthy wad and ferruginous material as well as white encrustations along joint planes. Ore reserves are 1,900 tons assaying 64.7% MnO_2.

<u>MC57L.</u> (Westralian Ores Pty. Ltd.)

The claim consists of two deposits; the northern one (sampled 1) is a conspicuous circular flat-topped deposit about 12 ft. thick. It contains siliceous manganese ore near the centre of the deposit and on its northern edge; pure laminated botryoidal hematite occurs in pockets in some parts on the top of the deposit; the siliceous ore may not persist with depth, but allowing for its persistence the reserves of ore are 10,000 tons assaying 64.1% MnO_2. The closest outcrop of dolomitic limestone is 500 ft. west of the mesa.

The second deposit (2) is 1000 ft. south of (1) and forms a small pimple of ore about 6 ft. thick giving 800 tons of ore assaying 70.1% MnO_2.

<u>MC211</u> (A. Rieck of Ragged Hills)

The deposit is ½ mile west of Mt. Sydney, and this claim is the most easterly of three deposits aligned east to west along a fault line. It overlies dolomitic limestone which dips SW at 20°. The limestone below the deposit is 40 ft. thick and it rests unconformably on indurated shale and crystalline schists. The deposit is 6 ft. thick, 120 ft. long, and 20 ft. wide giving 1800 tons of ore assaying 73.2% MnO_2. The other two deposits will be treated under "Unpegged deposits".

<u>MC247</u> (Broken Hill Pty. Co. Ltd.)

MC247 includes the largest group of orebodies on the field and forms the most conspicuous landmark, outcropping on the top of a hill of dolomitic limestone; the outcrop is elongated at 20°.

There are three separate deposits; the southern one (sampled A) measures 330 ft. by 90 ft. and is 4 ft. in visible thickness, giving a tonnage of 14,000 tons of ore assaying 76.9% MnO_2. The central deposit (sampled B) is small, measuring 30 ft. by 36 ft. and 8 ft. thick giving a tonnage of 1,100 tons of ore assaying 81% MnO_2. The northern deposit (sampled C) is 200 ft. long by 50 ft. wide and averages 9 ft. in thickness, giving 10,000 tons of ore assaying 76.4% MnO_2.

Siliceous breccia does occur on the surface with the manganese in this claim, but in view of the results seen after open-cutting MC268, this breccia is not expected to persist much below the surface.

<u>MC268.</u> (Northern Mineral Syndicate).

This deposit was open cut in 1954 and most of the ore mined in 1955 was expected to come from this claim. The ore is associated with dolomitic limestone, and traces of siliceous breccia are visible throughout the deposit. This breccia was very prevalent on the surface outcrop before open-cutting, but it was found to occur only as isolated patches that had no depth. They represent a fragment of the original breccia deposit that was not completely replaced by manganese.

The base of the deposit lies on dolomitic limestone that dips 12° to the E.S.E. The deposit is divided into three bodies; the southern one is separated from those immediately to the north by a small stream. It measures 45 ft. by 36 ft. and is 4 ft. 6 inches thick giving 800 tons of ore. The northern bodies are really one, but they are separated on the surface by a zone of siliceous breccia with some manganese; the more southerly of these northern deposits measures 80 ft. by 55 ft. and is 13 ft. 6 inches thick, giving 6500 tons of ore; the northern deposit (sampled A) is at present being worked and visible ore measures 36 ft. by 60 ft. and is 18 ft. thick giving 4,200 tons of ore assaying 56.9% MnO_2. The Syndicate has proved a further 14 ft. thickness of ore by drilling in the floor of the open cut, and this would give a minimum of 1,400 tons of ore. The total accessible and proved ore is thus 12,900 tons.

Another deposit (sampled B) outcrops ½ mile south-south-east of the main open cut; it is in a gully and the manganese replaces a joint filled with breccia in the dolomitic limestone, as well as lying directly on the bedding plane of the limestone which dips west at 10°. Total measured tonnage is 6,500 tons of ore assaying 57.5% MnO_2.

MC269 (Northern Mineral Syndicate)

This deposit was the first to be extensively worked on the field, and mining headquarters were made here in 1953-54. The high-grade bulk material has been mined, but there still remains much good ore distributed amongst siliceous and earthy manganese.

The westerly deposit (sample (1)) is about 2 ft. thick, irregular in plan, and contains some siliceous manganese ore on its southern part. 2,000 tons of ore assaying 70.0% MnO_2 are a visible reserve.

Sample (2) was taken from the worked deposit, but good ore still remains scattered through the irregular workings. Samples were taken from exposed faces and the ore had a maximum thickness of 12 ft. Reserves are estimated at 2,000 tons of ore which assayed 77.5% MnO_2. A further 800 tons have been proved by drilling. A smaller deposit of 1,000 tons crops out 200 feet to the north-north-east.

Total reserves for the claim are about 5,800 tons.

The manganese has replaced the siliceous breccia overlying the dolomite, and unreplaced blocks of breccia are numerous throughout the deposit; small patches of dolomite crop out near the deposit.

MC271. (Northern Mineral Syndicate)

Many small deposits occur in the vicinity of this claim, but they are either too small or have too much siliceous breccia with the manganese to be of present value.

The deposit sample measures 90 ft. by 15 ft. and is 12 ft. thick; the west end of the deposit grades into siliceous manganese. The 2,000 tons of ore assay 82.4% MnO_2, but if the silica does not persist with depth a further 2,000 tons may be expected.

MC272 (Northern Mineral Syndicate)

Two deposits within this claim were sampled; the eastern one (sample A) measured 45 ft. by 9 ft. and is 6 ft. thick giving 300 tons of ore assaying 76.9% MnO_2. The western deposit (sample B) measures 80 ft. by 15 ft. and is 9 ft. thick giving 1,200 tons of ore assaying 77.5% MnO_2; both deposits replace siliceous breccia and the second seems to dip at 5° to the east into the hillside with the breccia.

<u>MC273</u> (Northern Mineral Syndicate)

This claim is situated 2 miles at 60° from MC247 and consists of three adjacent deposits which have a visible tonnage of 1,000 tons of ore assaying 75.4% MnO_2.

<u>MC274</u> (Northern Mineral Syndicate)

This claim consists of five orebodies which are close to or in the side of a small gully. The largest deposit is 60 ft. by 40 ft. and is 15 ft. thick and is associated with dolomitic limestone dipping 25° to the west. An estimated 7,000 tons of ore assaying 75.0% MnO_2 is expected from the claim, but this could be increased considerably if the orebody penetrated the limestone down dip. The deposit may prove to be one of the best on the field.

<u>Southern Deposits</u>

These were pegged by R.G. Collins for Broken Hill Pty. Co. Ltd. in 1955, and the claim covers 104 acres and is 8.4 miles south of MC53. The deposits occur on the eastern slope of a prominent quartzitic sandstone hill, near the southern boundary of Warrawagine Station.

The northern of the two outcrops (sampled as Southern Deposit 1) varies greatly in depth; an average of 7 ft. in depth gives 10,500 tons of ore assaying 84.2% MnO_2.

The smaller southern outcrop (sampled as Southern Deposit 2) averages 4 ft. thick giving 2,500 tons of ore assaying 83.6% MnO_2.

Access to these deposits could prove difficult for heavy vehicles, but in view of the tonnage and quality of the ore available, the construction of a road would be practicable.

Several small deposits were seen in this area at distances from ½ to 4 miles south, south-east and west from the claim.

The country rock is quartzitic sandstone with small areas of dolomitic limestone forming inliers.

<u>Unpegged deposits</u>

Half a mile east of MC56L and 140° from MC57L are two small deposits; the larger is 6 ft. in thickness and contains 1800 tons of ore assaying 57.6% MnO_2. The smaller body contains 250 tons.

About 400 yards west of MC211 is a small deposit of 500 tons of ore assaying 70.4% MnO_2. There is much siliceous breccia scattered through the deposit, and this would require selective mining unless the silica did not persist at depth.

About ¾ mile west of MC211 is a small but concentrated deposit of 500 tons assaying 78.6% MnO_2. It is easily accessible and forms a prominent knob on the top of a dolomitic limestone hill; other scattered, poorer grade deposits occur associated with breccia which overlies the limestone, in this area.

SUMMARY OF RESERVES

Mineral Claim	Estimated Reserves from outcrop and limited drill holes	% MnO_2
MC53L	7,100 tons	49.6 and 52.3
MC54L	7,300 tons	57.6 and 77.2
MC56L	1,900 tons	64.7
MC57L	10,900 tons	64.1 and 70.1
MC211	1,800 tons	73.2
MC247	25,100 tons	76.9, 78.4 and 81.0
MC268	19,400 tons	56.9 and 57.5
MC269	5,600 tons	70.0 and 77.5
MC271	2,000 tons	82.4
MC272	1,500 tons	76.9 and 77.6
MC273	1,000 tons	75.4
MC274	7,000 tons	75.0
Southern Deposits (B.H.P.)	13,000 tons	84.2 and 83.6
Unpegged	3,000 tons	57.6, 70.4 and 78.6
TOTAL	106,700 tons	

An unpegged deposit mentioned by Owen (1953, p.4) estimated to contain 8,500 tons of ore which gave, on analysis, 54% of Mn., has been pegged MC267 and worked out.

About 20,000 tonshas already been mined from the field during 1953, 1954, and 1955.

ACKNOWLEDGEMENTS

The writers are indebted to Metals and Ores Pty. Ltd. (wholly owned subsidiary of Eveready Co.) who analysed the samples for possible use in the battery trade, and to Mr. Rod Fletcher of Northern Mineral Syndicate who explained the mineral claim locations and geographical names. Mr. A. Reich of Ragged Hills guided us to deposits near Mt. Sydney.

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APPENDIX A

by

W.M.B. ROBERTS

MINERAGRAPHIC EXAMINATION

Eight polished sections and two thin sections were made from the ore specimens submitted; x-ray diffraction was used to identify the minerals wherever it was possible to obtain a very nearly pure powder.

The principal manganese mineral in the ore is pyrolusite, which is present as very coarse grained aggregates with individual grains ranging up to 5.0 mm across; fine-grained masses, whose average grain size is 0.00045 mm, appear isotropic except when under extremely high magnifications. It also forms a few radiating fibrous aggregates which measure up to 0.35 mm across.

Braunite is the next most important mineral in the ore, forming approximately 10% of the total opaque manganese minerals. It is present as angular fragments, subhedral crystals and large irregular areas which have been strongly fractured, and which measure up to 1.5 mm across. It appears to be the earliest-deposited of the manganese minerals, and has been intersected by veins of pyrolusite and psilomelane. The angular fragments and subhedral crystals are recemented by finely crystalline pyrolusite and carbonate.

Psilomelane is of rare occurrence in the sections examined; it is present as one small crystalline vein cutting an area of braunite; its largest grain measured 0.15 mm across.

The major non-opaque constituent of the rock is chert breccia fragments which range up to 1 cm across; they consist of equi-granular quartz 0.016 mm across. Many fragments have a narrow rim of chalcedony.

Fractures cutting across the sections are filled with a second generation of quartz, the grainsize of which ranges from 0.17 to 0.01 mm.

One of the sections consisted of 75% carbonate in the form of large irregular masses and typical rhombohedral crystals, many showing zoning, and the largest measuring 0.65 mm across.

The edges of some of the crystals are moulded by rims of chalcedony, showing the carbonate to be earlier in the sequence than the second generation silica. In no place in the slide is the carbonate in contact with breccia fragments, but absence of twinning suggests that it is of later age than the brecciation of the chert (carbonate twinning readily with very slight deformation).

Thin veins of pyrolusite cut across carbonate and secondary quartz in one slide, and in a previously examined slide secondary quartz veins cut pyrolusite, suggesting an overlapping period of deposition for this mineral.

The angular fragments of braunite present in the ore indicate fairly clearly that this mineral had been formed in association with the chert bands in the original limestone, and has been shattered during the same period of brecciation. Its composition - $(3Mn, Fe)_2O_3 . MnSiO_3$ - also suggests a formation when there has been free silica available, possibly from the interaction of manganese from the limestone and the chert bands.

The following sequence of events is derived from the foregoing facts:

1. Brecciation of the limestone containing chert bands with associated braunite.

2. Chert rubble collects in suitable environment after removal of original limestone.

3. Partial recementation of the chert rubble by carbonate material possibly derived from the original limestone.

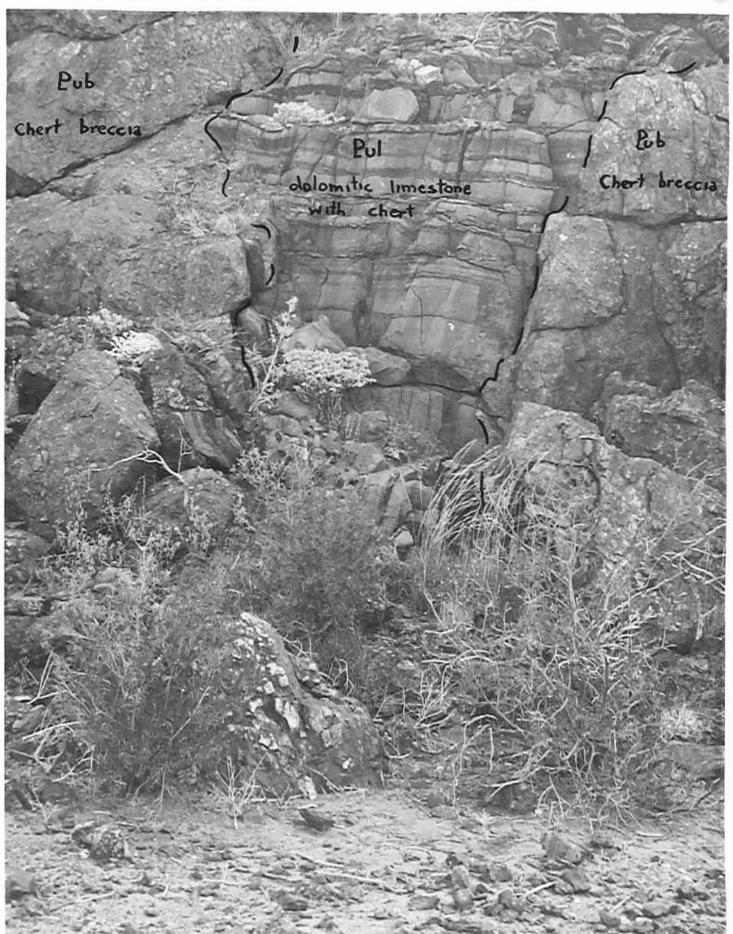
4. Secondary silicification in the form of chalcedony commences around chert and carbonate material.

5. Pyrolusite deposited - replacing chert breccia and carbonate.

6. Secondary silicification continues.

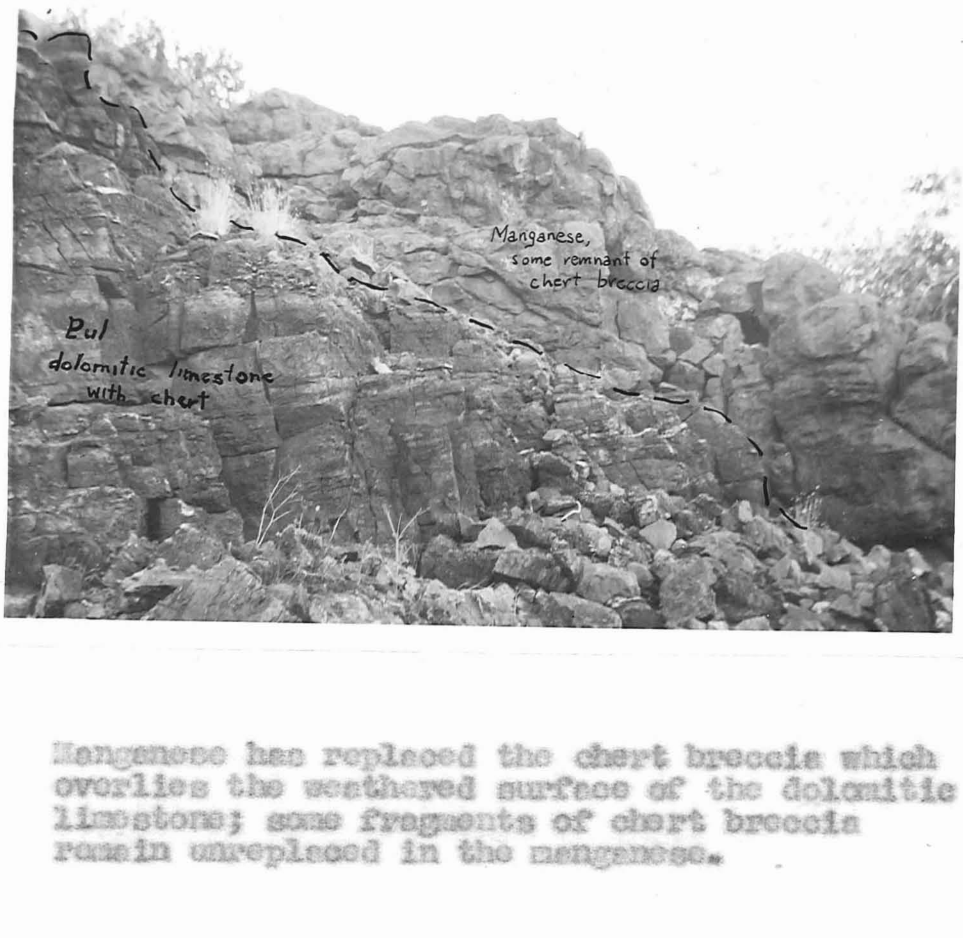
It is probable that the source of the manganese was the original limestone, wherein it was present as a mixed manganese-bearing carbonate, and from which it was freed during weathering.

Upper Proterozoic brown dolomitic limestone with bands and lenses of chert (light coloured).



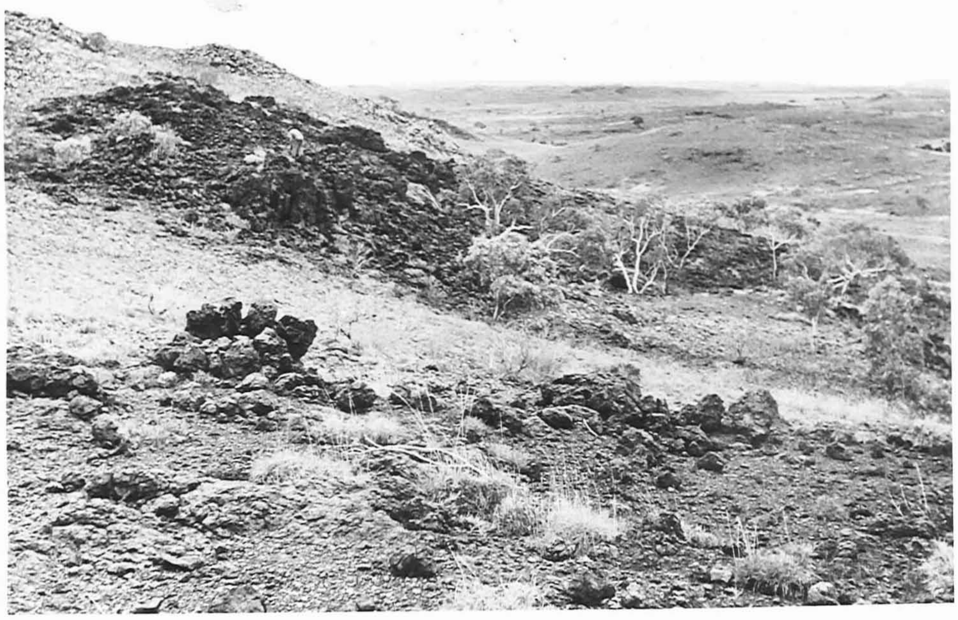
Dolomitic limestone with chert bands and chert breccia filling joints and cavities.

Close up of the siliceous chert breccia surface.



Manganese has replaced the chert breccia which overlies the weathered surface of the dolomitic limestone; some fragments of chert breccia remain unreplaced in the manganese.

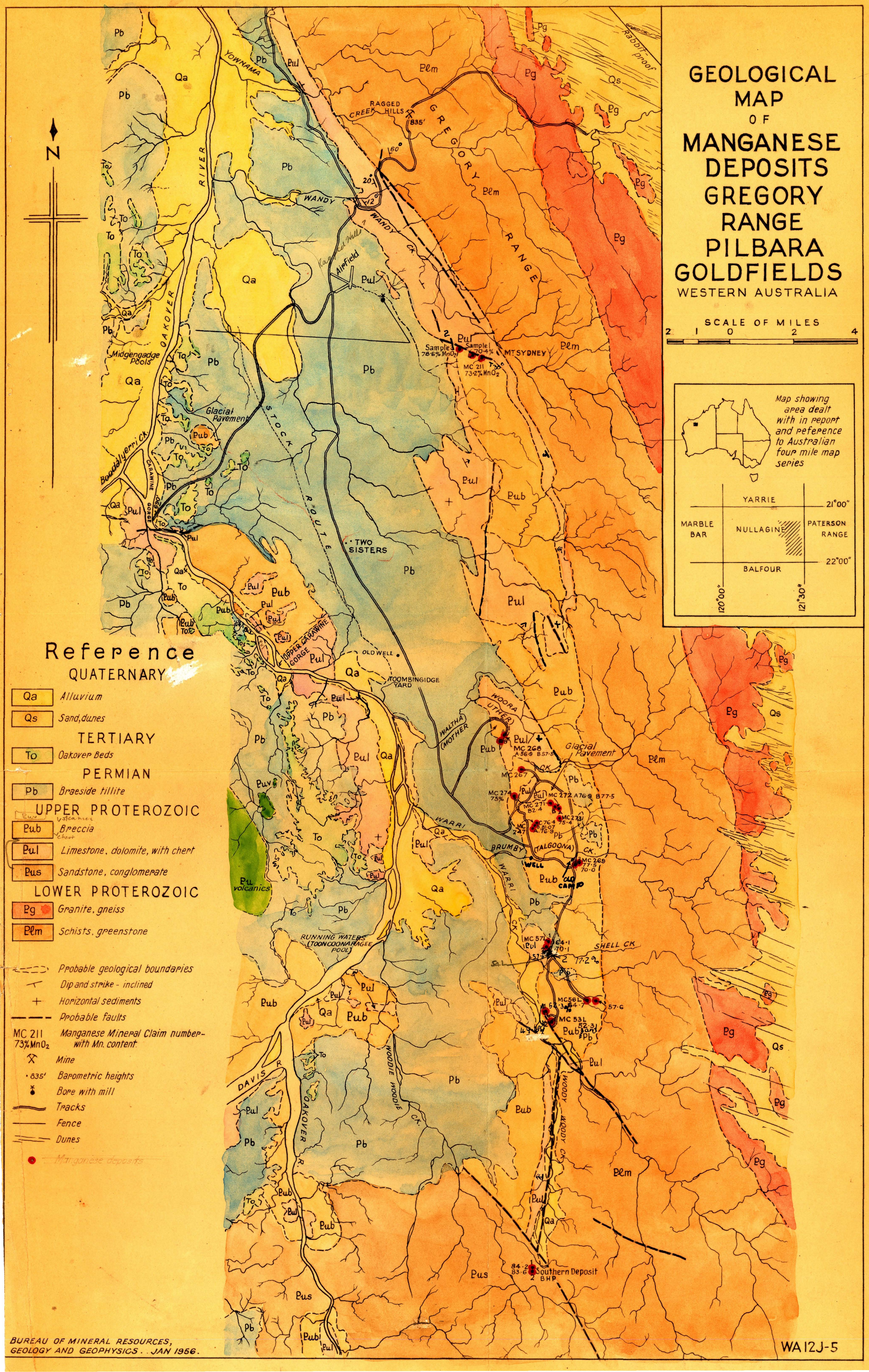
A manganese deposit; the white on boulders in the foreground represents some chert breccia not replaced by manganese.



Broken Hill Pty. Ltd. "Southern Deposit" of manganese. The view looks north from "Southern Deposit"(2), to "Southern Deposit"(1) (with person sampling). Sandstone hills on the left, limestone in the background.

A partly worked manganese deposit at MC269 (Northern Mineral Syndicate) with Westralian Ores MC57L deposit in the background. Smooth topography formed by limestone capped by breccia and covered with a scree of boulders and pebbles from Permian glacial sediments.

Northern Mineral Syndicate MC268 deposit showing the 18 foot face of manganese; drilling has proved another 14 feet in depth.


GEOLOGICAL MAP OF MANGANESE DEPOSITS GREGORY RANGE PILBARA GOLDFIELDS
WESTERN AUSTRALIA
SCALE OF MILES
2 1 0 2 4
Map showing area dealt with in report and reference to Australian four mile map series
YARRIE
MARBLE BAR
NULLAGINE
PATERSON RANGE
BALFOUR
21°00'
22°00'
120°00'
121°30'
N
Reference
QUATERNARY
Qa Alluvium
Qs Sand, dunes
TERTIARY
To Oakover Beds
PERMIAN
Pb Braeside tillite
UPPER PROTEROZOIC
Pub Breccia
Pul Limestone, dolomite, with chert
Pus Sandstone, conglomerate
LOWER PROTEROZOIC
Pg Granite, gneiss
Plm Schists, greenstone
Probable geological boundaries
Dip and strike - inclined
Horizontal sediments
Probable faults
MC 211 73% MnO2 Manganese Mineral Claim number with Mn. content
Mine
·835' Barometric heights
Bore with mill
Tracks
Fence
Dunes
Manganese deposits
GREGORY RANGE
OAKOVER RIVER
YOWNAMA
RAGGED HILLS
CREEK
WANDY CK
Airfield
MT SYDNEY
Midgengadge Pools
Glacial Pavement
STOCK ROUTE
CARAWINE GORGE
Boodalyerri CK
TWO SISTERS
UPPER CARAWINE GORGE
OLD WELL
TOOMBINGIDGE YARD
WOORA UTHER
WALTHA (MOTHER
WARRI
BRUMBY WELL
TALGOONA
CK
CAMP
SHELL CK
RUNNING WATERS (TOONCOONARAGEE POOL)
Pu volcanics
DAVIS R
OAKOVER R
WOODIE WOODIE CK
WOODY CK
Southern Deposit BHP
Rabbit proof
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS . JAN 1956.
WA 12J-5