THE UNIVERSITY OF ADELAIDE
DEPARTMENT OF ECONOMIC GEOLOGY

A STUDY, MAINLY OF HEMATITE QUARTZITES FROM THE MIDDLEBACK RANGES, WITH SOME REMARKS ON THEIR MAGNETIC PROPERTIES.

HONOURS THESIS, 1956

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INTRODUCTION

As originally intended, my project may have been described as, "a study of the magnetic properties of the rocks of the Middleback Ranges, and the application of the results obtained to the interpretation of the aeromagnetic maps of the said area". But due to the nature of the predominant rocks of the area, the hematite quartzites, the study of the magnetic properties became rather difficult. The hematite quartzites were just too hard and tough to do very much with. For this reason the study was rather sidetracked towards a mineragraphic one, and on account of this both may have suffered.

In a paper delivered during a Symposium on Mining Geophysics held under the auspices of the Society of Exploration Geophysicists, C.A. Heiland (13) suggested some pointers that geophysicists should keep in mind and endeavour to apply. They were -

a. Limit the size of the prospecting area by geologic reasoning.
b. Examine the possibility of mineral associations.
c. Give more attention to physical tests of rock specimens.
d. Plan surveys that they tie in with known areas, that is overlap into areas where the general geology is known.
e. Conduct geophysical investigations from underground. workings.

Although you may not be convinced after reading this paper, it has more to do with pointer (c) mentioned above than anything else. The geophysical method in question is the magnetic one, or more exactly the aeromagnetic method, and thus the most important physical properties are the magnetic ones.

I like to feel that I have made some attempt to integrate the two approaches, the mineragraphic and the geophysical, in the interpretation of the aeromagnetic maps. Actually the interpretation done, rather than being of a general nature, is more strictly confined to that area nath of Iron Monarch - the Race Course area. In this area, aeromagnetic maps plotted from the results of two surveys flown at different altitudes, namely 500 and 1500' were made available to me. Also gravity plans were forthcoming, so that I felt justified in restricting my remarks more specifically to this place.

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MINERAGRAPHIC APPROACH

General

During the long vacation of 1955-1956 I was employed by the B.H.P. Co. Ltd. as a student member of their geological section at Whyalla. While at Whyalla I was able to collect a number of specimens of hematite quartzite - these consisted of both surface and sub-surface specimens; the latter were taken entirely from DDH 20 which is situated at Iron Monarch (See locality plan).

Specimens of drill core were taken for microscopic examination at about every 10'. At somewhat longer and more irregular intervals larger specimens were collected. These larger specimens were taken with the thought of later magnetic tests in mind. The disappointing feature was that very much of the core had been split for assaying, and only a few whole pieces remained. As was proved later, the broken hematite quartzite was just too hard to core again to produce specimens for magnetic tests. The job would have been much easier if whole pieces of the original core had been available at frequent intervals along the drill hole, for these would have only needed trimming at each end by diamond saw cuts. A new holder for the larger diameter core could easily have been constructed for the magnetometer used in measuring the magnetic properties. As it was there were too few whole pieces to warrant this.

Surface specimens were also collected. These were taken in conjunction with assay samples (for B.H.P.). They were collected from Iron Baron South during the commencement of the Taconite Survey there. Others were taken too - some from the surface near DDH 20 & 25.

Polished sections of many of these specimens were made. The specimens used here were those surface and subsurface specimens taken from DDH 20. These were examined and the descriptions follow. The descriptions may appear rather sketchy, but perhaps the overall picture is more important. Any variations with depth were looked for, particularly with regards to the magnetite content. It was thought that the specimens taken at the surface of DDH 20 might provide some control in this.

Details of specimens collected

a. Specimens taken from DDH 20.

No.	Depth	Remarks.
1	9'	Leached quartzite. Limonite staining.
2	15'	Leached spec.
3	23'	Porous siliceous material.
4	30"6"	cf. 2 Veined by red ochre.
5	33'8"	Banded H.Q.
6	42'7"	Mashed H.Q.

No.	Depth	Remarks.
7	52'	H.Q.
7a	62'	Banded H.Q.
8	65'6"	H.Q.
9	75'	Well banded H.Q. veined by quartz.
10	85'	H.Q.
11	95'	Banded H.Q. Quartz veining.
12	105'	Contorted H.Q.
13	114'6"	Well banded H.Q.
14	119'	Crumpled H.Q. Quartz veining.
15	125'	H.Q.
16	132'8"	Banded H.Q. Quartz veining.
16a	139'7"	Well brecciated H.Q. Ferruginous cement.
17	170'	H.Q. Brecciated.
18	158'8"	Banded H.Q. Quartz veining.
19	168'3"	Banded H.Q. Brecciated and crumpled.
20	170'8"	H.Q. Rich contorted hematite bands.
21	178'6"	See 20 Locally brecciated.
22	186'	H.Q. Crushed.
23	200'9"	Sheared out H.Q.
24	209'	Banded H.Q. Locally contorted.
25	218'	Siliceous H.Q. veined.
26	222'6"	Banded H.Q. Brecciated. Quartz cement.
27	225'6"	Banded H.Q. Veined.
28	232'	H.Q. Veined.
29	242'	Banded H.Q. Veined.
30	252'	H.Q.
31	259'	Extremely siliceous H.Q. Two large bands of hematite.
32.	260'	H.Q.
33	269'9"	H.Q. Brecciated and veined.
34	272'	Brecciated H.Q. Cherty quartz cement.
35	274'	Brecciated. Ochrous cement. See 16a.
36	284'	Banded H.Q.

No.	Depth	Remarks.
37	294'	Brecciated hematite rich rock.
38	304'	Hematite rich material containing quartz. The quartz is surrounded by a rim of jasper.
39	314'	Porous hematite rich material. See 37
40	315'	See 39. Not so porous. Veined.
41	325'	Hematite rich. See 40.
42	335'	Banded H.Q. Wavey banding. Rich in hematite.
43	345'	Oxidised H.Q. Ochre.
44	359'	Oxidised H.Q. The oxidation seems to be progressing along the banding.
45	369'9"	Brecciated hematite rich material. Oxidised in part. Slightly porous. Quartz veining.
46	378'	Sil. H.Q. Contorted and veined.
47		
48	398'	Brecciated H.Q.
49	406'	Banded H.Q. Intense local contortion.
50	408'	Brecciated hematite rich material.
51	412'9"	Banded H.Q. contortion.
52	420'	Banded H.Q. Veined.
53	424'	Very sil. material. Thin hematite bands offset by fractures. Same oxidation effect as 44.
54	428'	Oxidised ochrous material.
55	434'	Brecciated. Oxidised hematite cemented by quartz.
56	437'	Sil. H.Q. Veined.
57	441'6"	H.Q. being oxidised and leached.
58	443'6"	Rich banded H.Q. with large quartz veins. These contain limonite.
59	426'6"	H.Q. Well recrystallised.
60	455'	H.Q. containing irregular quartz patches.

No.	Depth	Remarks.
61	461'10"	Banded H.Q. Wide banding which is offet.
62	474'	Hematite rich material.
63	480'	Hematite rich. Quartz is jaspery.
64	485'	Wide banded H.Q. Veined.
65	487'	H.Q.
66	490'	Brecciated and contorted.
67	494'	Brecciated (cf 66). Quartz rich masses engulfed by hematite.
68	506'	H.Q. Slightly porous.
69	512'6"	Hematite bands contorted. Cherty quartz.
70	522'9"	Porous oxidised specimen.
71	532'11"	Cherty specimen. Veins containing red ochre.
72	542'	Hematite rich. Slightly oxidised.
73	557'10"	H.Q.
74	582'	Red ochre present mainly.
75	592'6"	Porous oxidised specimen.
76	602'3"	Leached oxidised cherty specimen.
77	612'	Cherty material.
78	640'	Oxidised specimen. Red ochre and quartz.
79	653'	" " More quartz.
80	655'	Brecciated quartz in oxidised hematite.
81	664'	Cherty sil. specimen. Veined by hematite.
82	668'3"	Banded H.Q. Leached and oxidised.
83	671'	Banded H.Q.
84	676'	Banded H.Q.
85	686'	H.Q. Brecciated.
86	695'9"	Banded H.Q.
87	699'6"	" "
88	706'	Cherty specimen. Ochre present in fractures.
89	707'3"	Oxidised. Ochre and quartz.
90	715'	See 80.
91 ,	725'	Oxidised leached specimen. A little hematite.

No.	Depth	Remarks.
92	721'	Oxidised leached specimen. Not much hematite.
93	733'	Very sil. cherty specimen. Not much hematite.
94	742'	Hematite blocks isolated in quartz (jaspery). Slightly leached and oxidised.
95	752'6"	Recrystallised H.Q.
96	760'	Hematite bands in red jaspery quartz.
97	771'	Banded H.Q. Sil. bands which are cherty.
98	777'	Banded H.Q. Large hematite rich bands.
99	787'6"	Oxidised specimen. Little residual hematite.
100	791'3"	Similar 99.
101	797'	" . More hematite.
102	807'	Cherty specimen.
103	811'9"	Brecciated quartz. Hematite infilling fractures.
104	814'6"	Recrystallised specimen of H.Q. Oxidised.
105	901'8"	Graphite schist.
106	1015'	Altered dolerite.
107	1077'	?

b. Surface specimens collected south of DDH 20.

These were collected for mineragraphic examination, every 10'. They were taken from what appeared to be solid outcrop.

No.	Distance South.
1	56'
2	66'
3	76'
4	86'
5	96'
6	106'

No.	Distance South
7	116'
8	126'
9	136'
10	146'
11	156'
12	227'
13	237'
14	246'
15	259'
16	269'
17	279'
18	289'
19	301'

There was solid outcrop neither within 56' of the drill hole nor for 71' south of specimen No. 11.

All specimens were typical of banded hematite quartzite.

Details of Specimens used in examination

A list of those specimens chosen for mineragraphic study is,

From DDH 20.

No. (on briquette)	Depth
5	33'8"
7	52'
7a	62'
12	105'
17	150'
23	200'9"
29	242'
36	284'
37	294'
41	325'
43	345'

No. (on briquette)	Depth
49	406'
52	420'
57	441'6"
61	464'10"
62	474'
64	485'
66	490'
73	557'10"
82	668'3"
83	671'
84	676'
86	695'9"
91	725'
95	752'6"
98	777'
101	797'
104	814'6"
105	901'8"

From south of DDH 20.

No. (on briquette)	Distance south.
2	66'
4	86'
6	106'
7	116'
8	126'
9 = 19	301'
9a = 9	136'
10	146'
11 = 12	227
14	246'
16	269'
18	289'

In addition a few of the camp set specimens of the Middleback Ranges were chosen as suitable material. Specimens mainly of iron ore were taken. These are,

No.	
MBR 5	Manganiferous hematite.
" 8	" "
" 11	Typical hematite ore.
" 17	H.Q.
" 24	Banded amphibole magnetite rock.
" 26	H.Q. (a pebble from Corunna Congl.)
" 33	Magnetic hematite ore.

Also several thin sections were made. The specimens used came from the subsurface ones of DDH 20.

No.	Depth
7a	62'
23	200' 9"
49	406'
64	485'
66	490'
101	797'
106	1015'

The descriptions of all polished and thin sections follow.

Descriptions of specimens exmined.

a. Polished Sections

DD20/5

Poor banding. Some quartz veining. Less than half of the section is hematite. The hematite does not take on good crystalline shapes. Most of the crystals are small and irregular. The larger crystals are composite - hematite is well intergrown in these.

A little magnetite is found.

DD20/7

Certain sections where less hematite is found and where the crystals of it are smaller, show good banding. Quartz veining. In the hematite rich areas the hematite crystals are composite and intergrown. Most are elongated.

Little magnetite.

DD20/7a

Banding is noticeable. A rather large and hematite rich one traverses the section. It is offset by minute fractures in places. Cross-cutting veins of quartz are found.

Magnetite is present in reasonable quantities. It seems to be confined to the hematite rich bands.

DD20/12

Banding and cross-cutting veins of quartz are seen. Throughout most of the section the hematite is equidimensional. In the richer portions it takes on elongated shapes.

Magnetite is present.

DD20/17

Banding not so good. Cross-cutting quartz veins.

Quartz predominates in the section. The hematite crystals seem to be mostly equidimensional.

Magnetite is present throughout the section.

DD20/23

Reasonably good banding. Quartz veins with hematite spicules extending towards their centres.

Much the same story, the larger hematite crystals are composite.

Magnetite is present.

Goethite is seen replacing the central areas of some hematite crystals.

DD20/29

Banding is prominent. Cross-cutting quartz veins.

Little magnetite is present.

DD20/36

Banding is obvious. Small cross-cutting veins of quartz are present. Also fractures.

The larger crystals of hematite are equidimensional for the most part, the smaller are needle like.

Magnetite is present under the usual circumstances. Goethite occurs, it may be replacing magnetite.

DD20/37

Banding can be seen. Quartz veining.

Magnetite is found in the section, it is not abundant.

Goethite is present too.

DD20/41

Again only a little banding. The section is broken up - quartz veining is prominant. Hematite crystals are sometimes enclosed in these quartz veins.

Crystals of hematite invaded by quartz are to be found.

Only little magnetite is present.

DD20/43

Another well broken up specimen.

Areas of greater hematite concentration are set in a finer grained groundmass.

Magnetite is rare.

DD20/49

Banding. Quartz veining.

Hematite occurs in cracks around quartz crystals. Migration?

Not much magnetite. Some goethite.

DD20/52

Some banding. Little magnetite.

DD20/57

Banding.

Hematite is ragged. It is also pitted. Sometimes one gains the impression that hematite has oxidised and moved on.

A little magnetite is present.

DD20/61

Banding not good. The specimen is fractured and veined in many directions. Elongated crystals of hematite grow transverse to the vein.

In this section "lattice twinning" is to be seen.

Magnetite is present.

What may be rutile is seen in one patch. It encloses small hematite crystals.

DD20/62

Hematite rich. Quartz veining. The hematite is well intergrown.

A little magnetite.

DD20/64

Another section showing brecciation. Hematite rich blocks are enclosed by quartz.

Magnetite is not abundant.

DD20/66

Banding. Hematite is present as blocky crystals. These are composite.

The section is rich in hematite.

Cross-cutting quartz veins occur in several directions. Some of these contain included hematite crystals.

Magnetite is abundant in the section. This is probably the richest yet (but still only about 2-3%).

It is becoming increasingly noticeable that magnetite is not necessarily confined to the interior of the hematite crystals. It occurs freely on the boundaries. However in occurring near the edge it still forms the core of a smaller crystal which goes to make up the larger composite one.

DD20/73

Banding. Quartz veins and fractures offset the banding.

Little or no magnetite is present.

DD20/82

Hematite rich. Large areas of intergrown hematite crystals. Little magnetite.

DD20/83

Good banding. The hematite is fine grained.

Magnetite occurs. What might be goethite seems to occur in the central areas of hematite crystals, as does magnetite. Does this replace magnetite?

DD20/86

Banding. Cross-cutting quartz veins.

Not a lot of hematite is present and what is, is fine grained and needle like.

A little magnetite is present.

DD20/91

Oxidation? Is hematite being removed or is it that introduced goethite is replacing quartz?

Lattice twinning.

Very little magnetite.

Also, a small crystal of pyrite is present.

DD20/95

Large blocks of hematite occur throughout the section. Elsewhere the hematite is fine grained and needle shaped.

Pyrite (?) is present - both isolated and enclosed in hematite.

Is goethite replacing fine grained magnetite or quartz?

DD20/98

Reasonably rich in hematite. Some magnetite.

DD20/101

NO banding. The hematite is concentrated into irregularly shaped masses. A few crystals of pyrite (?) are present this time enclosed by quartz.

Magnetite not abundant.

DD20/104

See 101. Spikey crystals of hematite are sometimes arranged in an intesecting pattern. They are intergrowth.

Pyrite (?) is present. The similarity of these sections containing pyrite is noteworthy.

Magnetite is rare.

DD20/105

A foliated specimen. Seems to contain tiny elongated crystals of hematite between the lamellae of graphite (?).

SDD20/2

Banding. Hematite is mostly fine grained. The larger crystals are composite. Magnetite occurs as irregular blebs throughout the hematite. It is generally confined to the larger masses of hematite.

SDD20/4

Banding is not so good. Quartz veins. Rutile or is it goethite occurs. This encloses hematite.

Magnetite is present.

SDD20/6

Banding. Cross-cutting quartz veins.

Magnetite is present but not too much of it.

SDD20/7

Banding. Quartz veining.

Magnetite is difficult to find. Rutile?

SDD20/8

Rich in hematite. Quartz veins. Hematite may dominate 60-40.

Many hematite crystals are straight edged.

Magnetite. Also rutile (?)

Banding and quartz veins. The veins contain small crystals of hematite.

Reasonably large magnetite crystals.

SDD20/9a

Indistinct banding.

No magnetite could be found although the section is rich in hematite.

SDD20/10

Very little magnetite. Not much hematite anyway.

SDD20/11

Banding. Much hematite. Quartz veins.

A criss-cross arrangement of hematite crystals is noticeable. Twinning (not lattice) is seen in the hematite, Magnetite is found more in the hematite rich areas.

SDD20/14

Banding. Brecciation and quartz veining.

Little magnetite.

SDD20/16

Banding. Within individual bands the quartz and hematite are equidimensional.

Magnetite is found, much more easily in the hematite rich areas.

SDD20/18

Banding and hematite veins are seen.

Little magnetite.

MBR/5

Larger hematite crystals are surrounded and cemented by pyrolusite.

Veins containing pyrolusite are seen. The hematite occurs both as large and small crystals - the larger are composite.

Associated with the pyrolusite in the veins is another mineral which may be goethite.

MBR/8

Hematite in quite large crystals is surrounded and cemented by goethite (which in turn contains smaller hematite crystals).

Some of the hematite shows lamellar twinning.

Could it be that magnetite was the original cementing medium, which has since been oxidised to goethite? A little of what could well be magnetite associated with pyrolusite is seen in the section. Magnetite also occurs as cores.

MBR/11

Principally hematite, surrounded by oxidised material. This black powder could be forming from goethite. A few magnetite " "Cores" are seen.

This could be a stage further than 8. There may be a transition from magnetite to goethite to powdery hydrated material.

MBR/17

Fine grained hematite, which emphasizes the banding.

Magnetite occurs as cores. Ocasionally goethite is seen replacing the central areas of hematite crystals (the magnetite).

MBR/24

Banding.

The presence of magnetite is obvious. Hematite is seen replacing the magnetite along the III planes. The fingers of hematite encroach from the outer edges of the magnetite crystals. Good lattice twinning is seen too. Nothing like this has been observed to date in any of the other sections (except once). All stages of the replacement can be examined.

MBR/26

Banding is excellent. This is H.Q. Very little magnetite.

Good lamellar twinning.

MBR/33

Hematite is cemented by magnetite and a little pyrolusite. The magnetite seems to be giving away to goethite. Magnetite is also seen as cores - two generations.

b. Thin sections

These merely showed the banded nature of the hematite quartzites. The well recrystallised behaviour was also demonstrated.

Conclusions drawn from results

a. Previous thoughts.

Quite a deal of discussion as to the relations between magnetite,martite, hematite and "limonite" went on back in the

1920's 30's when the first doubts against the supergene mode of formation of the large iron ore deposits of the Lake Superior type were raised. Gruner (who incidently originally advocated a supergene formation for the hematite from pre-existing magnetite, but later, swung over completely to the hydrothermal mode of formation) played a big part in this conflict. As indicated above he was the first to really suggest the hydrothermal type of formation. Van Hise and later Leith pumped unhesitatingly for the supergene method of formation.

Broderick (1), then Gilbert(15), wrote papers on the relations between magnetite and hematite occurring in ores together, Gilbert claimed that in the case of magnetite being the older mineral from which hematite formed through oxidation, then the hematite could either replace the magnetite, working inward with a smooth front which showed no relationship to or dependence on the internal structure of the pre-existing magnetite, or it could form as small clean cut plates running in several directions, undoubtedly, he claimed, oriented by the III planes of the magnatite host. He also advanced the possibility of magnetite replacing hematite in some cases.

As far as the supergene formation of hematite from magntite was concerned, Gilbert felt that considering the inertness that magnetite showed to oxidising conditions at the surface, it seemed unreasonable that such a formation could take place. "Of the hematite which replaces magnetite, I think that overwhelmingly the greater part is hypogene".

Gilbert also claimed that magnetite, which is actually less resistant than hematite, would rather produce "limonite" under surface or supergene conditions. In those cases where magnetite crystals have their interiors replaced by "limonite", and their borders by hematite he felt that the hematite was hypogene, the "limonite" supergene, replacing the magnetite selectively.

Gruner (8) followed this up with a paper on the magnetite - martite - hematite relationships. He carried out oxidation experiments on magnetite at atmospheric pressures and at temperatures up to 200°C and found that hematite formed but only after quite long periods of time, and then only at the surface as a thin film. This hematite replaced the magnetite along the octahedral planes. He argued that the oxygen atoms that must be added into the lattice of the magnetite.could only be added along the octahedral planes. This he deduced from a study of the structure of magnetite. For this reason it should become easy to understand why oxidation should proceed along these III planes. The "smooth front" replacement he felt might result if the minute rods of hematite (oriented along III) during shallow penetration on oxidation, fused as they became thicker. In such a way the hematite would offer a solid front before penetrating to a greater depth.

Gruner also indicated that, to produce magnetite from hematite, oxygen would have to be removed from the structure, so that, in this case, magnetite would form at the centre of crystals and should grow from the inside outwards. Apparently he looked upon this as a mass migration of oxygen, so that the central portions of a crystal would first be depleted. On this matter he agreed with Gilbert.

In this paper Gruner claims that the evidence for the existence of solid solutions of magnetite and hematite seem doubtful. They are now known to exist.

Gruner (6) also carried out hydrothermal leaching experiments on magnetite. He concluded that martite forms at higher temperatures.than those under which supergene processes are generally believed to take place.

On this (and other evidence) Gruner based his argument against the secondary enrichment theory for the formation of the iron ores. He met with a great deal of opposition from Leith and others who argued mainly from the point of view of field evidence.

Gruner (7) proposed that meteoric waters, generally stagnant, when heated due to intermingling with gaseous emanations from large intrusions became active solutions dissolving silica from the banded iron formations, so commonly associated with the iron ore deposits of this kind. They rose to the surface carrying with them this silica where it was deposited as a siliceous sinter, which was later removed by erosion. He introduced the idea of both lateral and vertical movement of the hydrothermal waters, as opposed to the downward (and also lateral) movement of the meteoric waters as suggested in the secondary enrichment theory.

It would seem that Miles (10) has taken up this idea of Gruner and introduced it into the Middleback Ranges. Miles has suggested that the formation of the ore bodies involves the movement of iron from the surrounding hematite quartzites - the carriers being hydrothermal solutions. He acknowledges the original sedimentary formation of the hematite quartzites as proposed by Edwards. These sediments were subjected to a moderate grade of metamorphism to produce the hematite quartzites which were then composed of magnetite and quartz. The conversion of magnetite to martite (hematite formed through the oxidation of magnetite) and "limonite" was probably a later supergene process, but he does think that Gruner's experiments indicate that magnetite is one of the more stable minerals under cold water oxidising conditions and it's martitisation could demand the presence of heated solutions. Later he develops this with regard to the leaching of the hematite by the hydrothermal solutions to form the ore bodies. Thus actually he seems to want it both ways! "The conversion of the magnetite to martite was probably a later supergene process". And later ...." partial oxidation of the magnetite was probably contemporaneous with the localisation of the high grade ores".

Edwards (3), examined specimens of hematite quartzite. These were from the surface. Regarding those from Iron Monarch South he mentions that in a few specimens, although the outlines of the hematite grains indicate that the martite has replaced magnetite, there is no evidence of lattice twinning. He seems to make nothing of this (if there is anything to make of it), but he does suggest that the development of "limonite", as related to the present cycle of weathering, in it's selective replacement of magnetite, raises doubts as to whether the martitisation of the magnetite can be attributed to supergene processes.

Whittle (12) of the specimens he examined from the Katunga Hills drill-hole Nos. 1 & 2 suggests that while of a similar grain size to the magnetite, the hematite does not appear to have been derived from it, for no evidence of progressive martitisation can be seen from a study of the polished sections. Discounting the possibility of a general recrystallisation of the whole rock during which the features indicative of martitisation have become obliterated (III replacement for Whittle), the hematite must be considered as an original constituent or as an introduced mineral. The elongated textural nature of the hematite suggests to Whittle a metasomatic origin for this hematite. Whittle says "hematite at deeper levels may be metasomatic in origin, but it is secondary after magnetite in near surface beds".

b. Personal thoughts.

The thing which struck me was the lack of evidence for any startling increase of the amount of magnetite with depth. The specimens taken from the drill core of DDH20 remained reasonably constant in the amount of magnetite present. This amount was very small (1-2%) too. The amount of magnetite varied little from that which was found in the specimens from the surface. I was surprised at this as I had gained the idea from reading, that because the hematite was secondary after magnetite it was to be found mainly near the surface. However, for over 800' of drill core from which some 29 specimens were examined hematite remained the predominant mineral by far. Magnetite was rare and the amount of it present did not vary much with depth - it always remained small.

This magnetite occurs as small irregularly shaped blebs in the larger hematite crystals. It does not occur only towards the centre of these larger hematite crystals (composite), but could be found near their borders. However, the larger hematite crystals were composite, consisting of many intergrown smaller crystals making up the larger mass, a fact noticeable under crossed nicols. Magnetite always occurs towards the centre of these smaller crystals making up the larger composite mass however. Thus even though the magnetite blebs might occur near the borders of the larger composite mass, they were cores of one of the smaller hematite crystals making up the larger one.

Except for one rare occasion there was no evidence of lattice twinning to be seen in any of the sections examined from DDH20 either surface or subsurface. One specimen namely MBR/24, a banded amphibole magnetite rock which was collected from Kimba Gap did show this lattice twinning, an after effect of III replacement of magnetite by hematite, remarkably well. Thus it was not as if I did not know what I was looking for, it just was not there.

The replacement of the pre-existing magnetite, now preserved in the cores as I mentioned above therefore took place as the "smooth front "type in those specimens from DDH20. Why this should be so is difficult to imagine. There was obviously some difference in the circumstances under which the replacement of magnetite by hematite through III replacement took place and those under which the "smooth front" type took place. Perhaps one explanation could be that the physical make up of the rocks are different. That is the grain size of the pre-existing magnetite differed in the two cases. In the specimen MBR/24 the magnetite may have been of a larger grain size - it does appear this way in polished section. Also it could be that the crystals were whole, unlike the composite intergrown crystals seen in those specimens taken from DDH20. The composite nature of the hematite masses in the specimens from DDH20 is easily recognisable now. Originally these may have been masses of smaller intergrown magnetite crystals. From the nature of the MBR/24 it is equally reasonable to say that the original crystals of magnetite, now largely replaced by martite showing strong lattice twinning, were once large whole crystals.

The above is some sort of explanation as to why you should get martitisation of former magnetite progressing along a "smooth front" in one case and as a "lattice replacement" in another. What causes the martitisation of the magnetite is perhaps more difficult to answer. From my examination of the specimens at the surface of DDH20 and those odd ones down to approximately 800', I feel that it is reasonable to suggest that the martitisation of the magnetite bears no relation to the present surface of erosion, for in this case an increase in the amount of magnetite with depth should be in order. This increase as I have indicated is just not the case. Also the examination of the sections seems to indicate that magnetite under surface oxidising conditions tends to be replaced by limonite in preference to hematite. While hematite replaced the magnetite originally, under the present conditions it would seem that magnetite is more likely to be replaced by limonite. Examples are seen where the outer rim of hematite remains unaltered though the central region, presumably originally a core of magnetite, has been replaced by limonite.

The formation of both hematite and limonite from magnetite require oxidising conditions - to produce limonite you need the presence of water.

The experiments carried out by Gruner would indicate that somewhat higher temperatures than those usually connected with supergene processes would be necessary for the formation of hematite (martite) from magnetite. Also the fact remains, as I have now mentioned several times, that the replacement of magnetite by hematite in those specimens from DDH20 bears no relation at all to the present erosion surface.

This sensibly constant, and rather large ratio of hematite: magnetite over a depth of some 800' and the seemingly obvious preference for magnetite to form limonite, while the replacement by hematite may require higher temperatures would thus seem to need a different explanation than that which suggests that supergene processes are at play.

One possible explanation would be that our original thought that the hematite has replaced magnetite is at fault. The hematite and magnetite may have existed together as a solid solution.

Another explanation is that the replacement of magnetite by hematite was an expression of a late retrogressive phase in the matamorphism of the hematite quartzites. The magnetite may have been retrograded to hematite which replaced it during the final uplift of the folded and metamorphosed sediments.

The martitisation may have been caused by high temperature hydrothermal solutions. This is the explanation as per Gruner and Miles.

A few remarks can be made concerning the polished sections of iron ore that were examined, too. These were specimens of maganiferous and magnetic iron ore. In all cases larger crystals of hematite were collected in a cementmof some sort or other. In the manganiferous type pyrolusite is an important constituent of this cement. Goethite also appears to be of some importance too. In the magnetic iron ore the cement is magnetite. Also in this ore we find magnetite present as cores, indicating two generations of magnetite.

The cementing magnetite can be traced and be seen to give away to goethite in some sections. In other sections goethite is seen giving away to a much more powdery material. Thus we seem to have this transition from magnetite to goethite to a finally very powdery hydrated material. This can be traced from several sections not just the one.

The impression gained therefore is that magnetite plus a certain amount of pyrolusite has been introduced as a cement perhaps replacing quartz and then the magnetite has been oxidised and hydrated to produce goethite and finally a very powdery hydrate which is now found as an infilling between the original hematite grains.

This is not to be regarded as an explanation of the formation of the hematite ore bodies - it merely supports Edwards in his claim that magnetite and pyrolusite have been introduced into the orebodies as cementing materials at some time or other. Edwards (4) thinks that this magnetite of the second generation is secondary due to its relation to the manganiferous material.

Too few specimens were examined for any statements concerning the iron ores to be put forward with confidence. In the manganiferous and magnetic specimens, mineral identification, apart from the abundant hematite, and the cement of pyrolusite and magnetite, in some cases was difficult. The hydrous iron oxides to which the magnetite cement seems to be breaking down were not absolutely identified as such.

An X-ray carried out on typical hematite ore (MBR11) did not give much information about the mineral content, except to confirm the presence of hematite! It did suggest the presence of quartz, though not definitely. Goethite, or such if present, was not so in sufficient amounts to register (of course, another possibility is that goethite was not present). The sample used was a bulk one, for it was impossible to dig out any of the interstitial powdery material which was thought to be a hydrous iron oxide of some sort.

In this specimen of typical iron ore (MBR11), the amount of hematite present was high. These crystals were surrounded by the powder I have mentioned. If this iron ore is supposed to represent original H.Q. in which quartz has been replaced, (as Miles would have), then the H.Q. must have been extremely rich in hematite, if only the interstitial material was introduced. If however other hematite has been introduced too, then it is indistinguishable from any hematite that was present originally. No relic banding suggesting the replacement of H.Q. was seen.

GEOPHYSICAL APPROACH

General

The Middleback Ranges have been flown several times aeromagnetically. The first comprehensive survey was carried out by the Bureau of Mineral Resources during November 1951. This was flown at an altitude of 1500'. The Latest survey, organised by the S.A. Dept. of Mines was flown at 500', and constant terrain methods were used. The S.A. Dept. of Mines has also done much gravity work in the area. The aim of these surveys is to delineate magnetic and gravity anomalies in order to indicate the extent and distribution of probable ore bodies.

Naturally in the interpretation of the aeromagnetic maps a knowledge of the magnetite properties of the rocks surveyed is important. The two main ones to be considered are -

a. The magnetic susceptibility.
b. The permanent or residual magnetism possessed by the rock.

The magnetic susceptibility is a property of a magnetic material which determines the amount of magnetisation induced in it by a given magnetic field.

$$K = \frac{I}{H}$$

K = magnetic suscept.
I = intensity of magnotisation
H = inducing field, in this case, the earth's.

I, is the factor which determines the size of the magnetic anomaly. In size and direction it depends on the inducing magnetic field.

The permanent or residual magnetisation is a property of rocks which they take when they originally form (and cool). The magnetite grains in the rock act as little magnets, which become lined up, and thus the whole rock has associated with itself a magnetisation which is constant in size and direction - it does not depend upon the present earth's field at all.

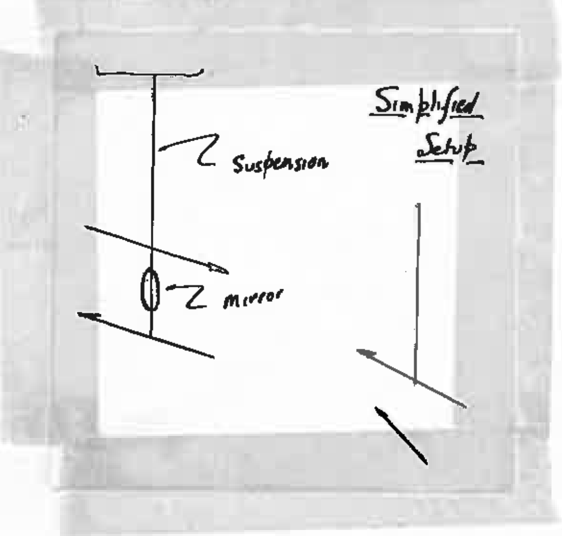
Dr. Sutton of the Physics Dept. has recently built a magnetometer with which these two properties can be accurately measured. To carry out an investigation properly many samples taken from known positions over quite a wide area would have to be measared. I had collected a number of hematite quartzites specimens from Iron Baron South during the commencement of the Taconite Survey there. Also it was originally intended to carry out measurements on specimens taken from DDH20 to see if any big variation with depth of either of the properties mentioned could be traced. The specimens taken at the surface again would have provided control. Those which were measured would have been examined in polished section. All this fell rather flat when was found that the hematite quartzites were too hard to core for specimens which must be shaped as cylinders if they are to be used and measured in the magnetometer. A few were measured though and some conclusions were drawn from the results obtained.

Notes on the Magnetometer.

a. Method of use.

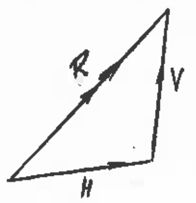
The specimen is regarded as a magnetic dipole - it is cut into the shape of a cylinder. This dipole has a certain directional orientation in space.

The magnetometer is made up of two small magnets. These are mounted on a rigid former such that they are 10 cms apart. The magnets are of equal moment and are so arranged that these moments act in opposite directions. For this reason a uniform horizontal field has no effect on the sensitive element - only a horizontal field with a gradient can cause rotation. (A vertical field has no effect whatsoever, it cannot cause rotation in a horizontal plane).



The specimen is mounted below the element, and because the field of a dipole dies off as $\frac{1}{z^3}$ the effect of the specimen on the upper magnet of the sensitive element is conveniently neglected.

The set up can thus be reduced to that in the figure opposite.



The field of the dipole has an effect on the element, it causes rotation.

The specimen (dipole) can be represented as a vector in space. It has both a horizontal and a vertical component. To find the resultant you must measure these two components Both of these components have associated fields.

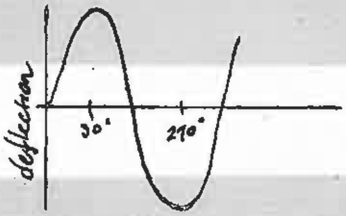
Consider the specimen to be placed directly below the sensitive element:

the horizontal component.

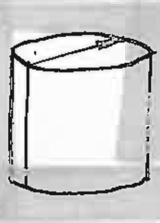
When this is in the same direction as that of the element its horizontal field causes no effect.

When it is at 90° it causes a positive or negative effect which is maximum.

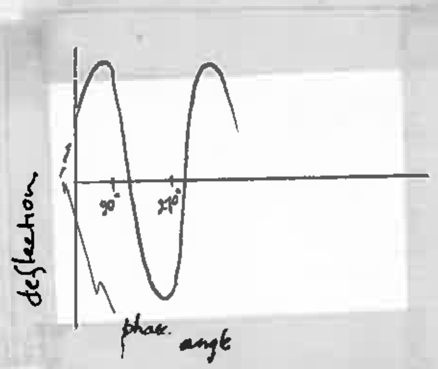
The variation as you rotate the specimen through 360° is sinisoidal and may be represented thus.



or, depending on where you begin your rotation with respect to the horizontal compoent.



On the specimen is marked a reference line with the aid of which you can determine the original orientation of the rock in the field. This and the



horizontal component need not be parallel. You start measuring with the specimen m mounted such that this reference arrow and the 0° position coincide - hence the phase angle. By noting this angle you thus determine the direction of the horizontal component with respect to the reference line whose position you know.

the vertical component

This will have no effect as it's field is everywhere perpendicular to the element's field, and so cannot cause rotation in a horizontal plane.

Consider the specimen not to be placed directly below the sensitive element:

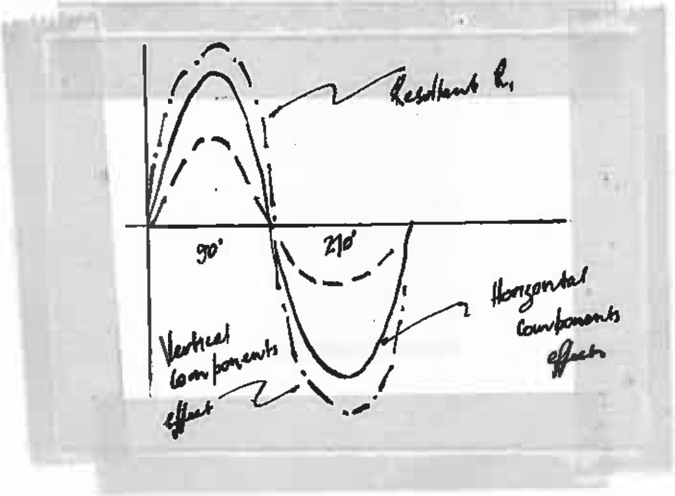
the horizontal component

This again has no effect when in the same direction as the element. The maximum effect occurs at 90°, 270°. Again if the reference line on the specimen and the horizontal component do not coincide, the phase angle will be involved.

the vertical component.

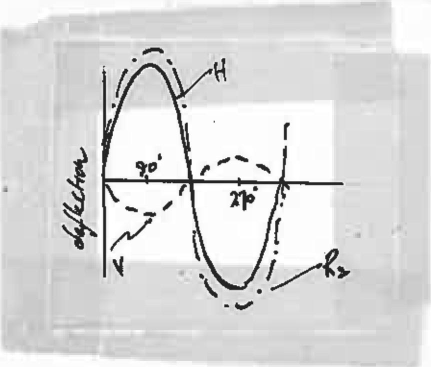
This will now have effect. Maximum effect (or min.) is at 90° and 270°. Zero effect is at 0°, 180°. This is regardless of phase angle.

Hence with the specimen offset, on rotation through 360°, you not only get the effect of the horizontal component which causes it's sinusoidal variation, but added to this you have the effect of the vertical component (actually the horizontal field associated with the vertical component). You thus have the sum of two sinusoidal variations acting on the sensitive element.



Now if you invert the specimen and again rotate, then in this case the effect of the vertical component is reversed. Of course you must reverse the order of taking readings - the effect of the horizontal field of the horizontal component in the 90° position when the specimen has been inverted is equivalent to it's effect in the 270° position before the inversion took place.

The variations caused by the horizontal fields of the horizontal and vertical components this time are represented thus,



i.e. $R_I = H + V$

$R_2 = H - V$

whence $R_I + R_2 = 2H$

$R_I - R_2 = 2V$

Actually all readings are taken with the specimen off centre.

b. Mathematics and Theory

a. The horizontal field due to the horizontal component of a dipole.

H is the horizontal component. This can be resolved into two further components, one in the "r" direction, the other in the "θ" direction.

Thus,

$$H = H_r \cos\theta + H_\theta \sin\theta$$

but $H_r = \dfrac{2M_A \cos\theta}{r^3}$

$H_\theta = \dfrac{M_h \sin\theta}{r^3}$

} see later c. & d.

thus,

$$H = \frac{2M_h \cos\theta \cos\theta}{r^3} + \frac{M_h \sin\theta \sin\theta}{r^3}$$

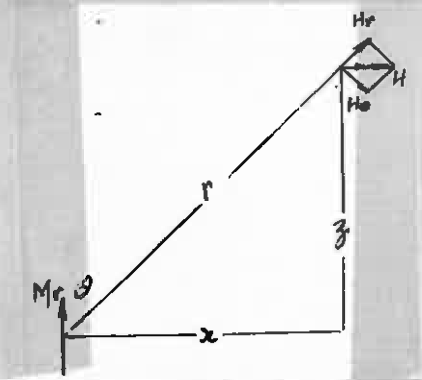
but, $\frac{z}{r} = \sin\theta$

so that the field $= \dfrac{M_h}{z^3} \; (I + \cos^2\theta)\sin^3\theta$

if however θ is quite large as it will be, then

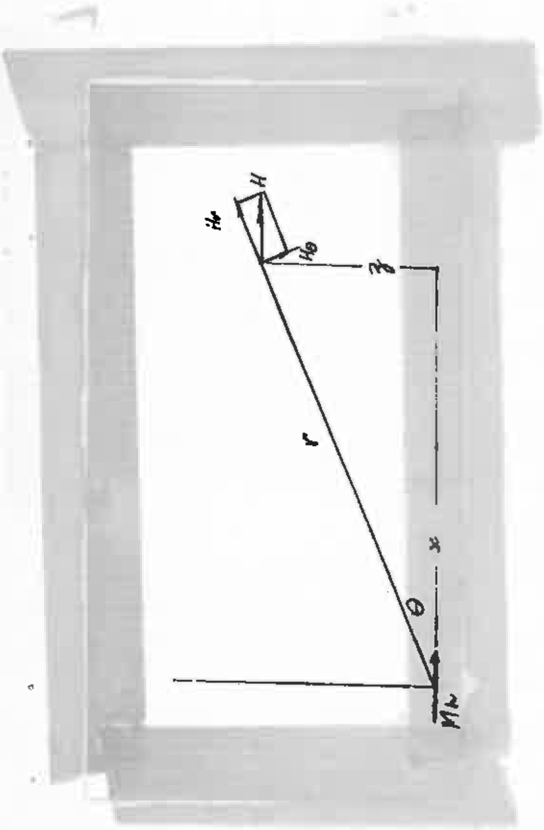
$\cos^2\theta$ 0

$\sin^3\theta$ I



i.e. the horizontal field of the dipole $= \dfrac{M_h}{z^3}$

b. The horizontal field due to the vertical component of a dipole.



$$H_r = \frac{2M_v \cos\theta}{r^3}$$

$$H_\theta = \frac{M_v \sin\theta}{r^3}$$

Now the horizontal field of the vertical component in this case is the thing which has effect.

This

$$= H_r \sin\theta + H_\theta \cos\theta$$

$$= \frac{2Mv}{r^3} \cos\theta \sin\theta + \frac{M}{r^3} \sin\theta \cos\theta$$

$$= \frac{Mv}{r^3} (2 \cos\theta \sin\theta + \cos\theta \sin\theta)$$

$$= \frac{3Mv}{r^3} (\cos\theta \sin\theta)$$

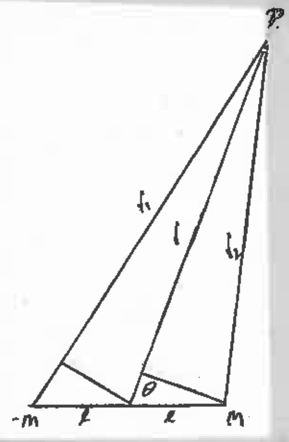
but again, $r = \frac{z}{\cos\theta}$

$$H = \frac{3Mv}{z^3} \cos^4\theta \sin\theta$$

$$\frac{3Mvx}{z^4} \quad \theta \text{ small, thus cos, } \theta^4 \; I$$

Thus knowing the horizontal fields due to the horizontal and vertical components of the dipole (M_h & Mv), you can find these two components.

c. The potential of a magnetic dipole.



potential at P

$$= -\frac{m}{r_1} + \frac{m}{r_2}$$

$$= m\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$$

$$= m\,\frac{(r_1 - r_2)}{r_1 r_2}$$

now, $r_1 = r + l\cos\theta$

$r_2 = r - l\cos\theta$

thus the potential $= \dfrac{m.\,2l\cos\theta}{(r + l\cos\theta)(r - l\cos\theta)}$

$$= \frac{m.\,2l\cos\theta}{r^2} \qquad (l^2\cos^2\theta \text{ small})$$

$$= \frac{M\cos\theta}{r^2} \qquad 2lm = M$$

d. Field of a dipole.

P the potential $= \dfrac{M\cos\theta}{r^2}$

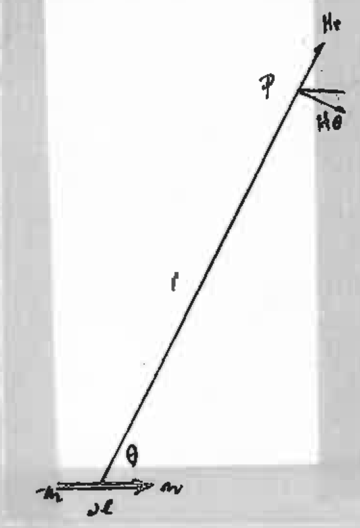
now, H the field strength

$= -$ grad. P

thus, $H_r = -\dfrac{dP}{dr}$

$$H_\theta = -\frac{1}{r}\frac{dP}{d\theta}$$

i.e.
$$\left.\begin{aligned} H_r &= \frac{2M\cos\theta}{r^3} \\ H_\theta &= \frac{M\sin\theta}{r^3} \end{aligned}\right)$$
see back a. & b.



c. Method of calculation of Magnetic susceptibility and Permanent magnetisation

Now a field of $7\text{x}10^{-7}$ oersted at the bottom magnet comprising the sensitive element causes a deflection of I mm on the scale provided. (the magnetometer is calibrated thus).

The horizontal field at the bottom magnet due to the horizontal component of the specimen dipole

$$= \frac{P_H}{z^3} \qquad (1)$$

(Ph = horizontal dipole moment)

The horizontal field at the bottom magnet due to the vertical component of the specimen dipole

$$= \frac{3 \times P_z}{z^4} \qquad (2)$$

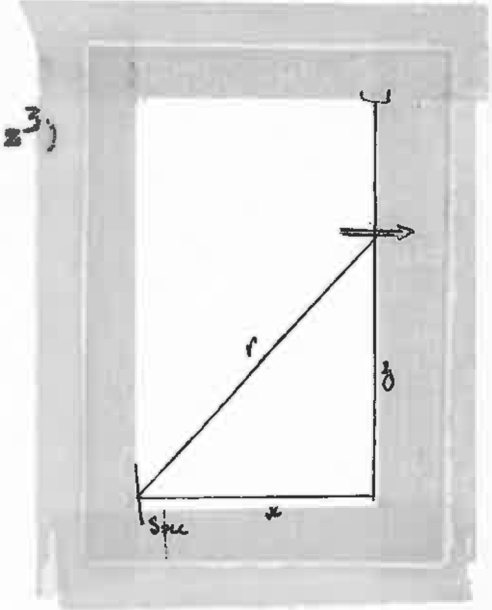
(P_z = Vertical dipole moment)

deflection due to I = d_H cms

deflection due to 2 = d_V cms

Thus, field I = $d_H\ (7 \times 10^{-7})$ oersted i.e. $P_H = d_H \, (z^3 \times 7 \times 10^{-6})$ oersted

$$= k \, d_H \qquad (K = 7 \times 10^{-6} \times z^3)$$



similarly,

$$p_z = d_v \left(\frac{z}{3x}\right) k$$

so that the total moment,

$$= \sqrt{p_h^2 + p_z^2}$$

$$= k \sqrt{d_H^2 + d_v^2 \, \frac{z}{x}^2}$$

$$= k \sqrt{a^2 + b^2 + d_v^2 \, (\frac{z}{3x}^2}$$

$d_H^2 = a^2 + b^2$

(a & b are the average deflections taken in the 0° & 90° posns. if a phase angle is involved)

the susceptibility,

this is measured when the specimen is in the 90° or 270° posn. The horizontal field of the vertical component of the spec. dipole is then having maximum effect.

Suppose the difference in deflection with a vertical field, equal to the vertical component of the earth's field, switched on and off

$$= d_s \text{ cms}$$

this will be the deflection due to a vertical dipole p_s, induced by this vertical field, a distance x cms. off axis

$$\text{Field} = \frac{3xp_s}{z^4} = d_s \times 7 \times 10^{-6}$$

$$p_s = d_s \, (7 \times 10^{-6}) \, z^3 \, \frac{z}{3x}$$

$$= k \; d_s \; \genfrac{}{}{0pt}{}{z}{3x} \qquad K = z^3 \times 7 \times 10^{-6}$$

I = moment / unit volume

$$= \frac{p_s}{\text{vol}} = K.\,H \qquad \text{vertical component of earth's field} = .6 \text{ oersted}$$

$$\text{thus } K, \text{ suscept.} = \frac{p_2}{\text{vol.} \times .6}$$

d. Results of measurements

Specimen	Dipole moment	Suscept	Remarks.
Moonabie porphyry			
	2.993×10^{-3}	2.182×10^{-3}	same spec. measured.
	2.99×10^{-3}		
Amphibolite	8.999×10^{-5}	1.272×10^{-4}	
Tor granite	3.638×10^{-3}	7.328×10^{-4}	
Cooks Gap Schist	1.502×10^{-4}	8.681×10^{-5}	
DD20/80	9.036×10^{-5}	9.979×10^{-5}	Hematite Quartzite.
DD20/98	1.127×10^{-3}	1.185×10^{-4}	
SDD20/16	2.577 x 10-2	5.549×10^{-4}	
DD20/91	1.324×10^{-3}	2.326×10^{-4}	
MBR 11	8.748×10^{-3}	2.365×10^{-4}	Hematite ore
Corunna sste.			No measurable effect.

Note: Dipole moment (e.s.u. system) = e.m.u. cms.
Susceptibility = e.m.u. / cms.^2 oersted.

Further remarks and conclusions

Only a very small number of specimens were measured, so that any conclusions or remarks made on the results must bear this serious limitation in mind. Specimen preparation was the bugbear.

The hematite quartzites vary in their values, but they are among those which give the highest. In fact they provide the highest value obtained for the permanent magnetism, and this specimen when viewed in polished section did not reveal outstanding amounts of magnetite.

A point worthy of note is the high values obtained for the hematite specimen. This contains a little residual magnetite- ideally it is claimed that hematite is almost non magnetic. This shows just what a little magnetite can do.

Also interesting are the low values obtained for the amphibolite. This was a reasonably fresh specimen as they go. Apparently little magnetite was present.

Perhaps one conclusion that can be put forward with a little confidence, for it applies to almost every specimen measured is that the value of the dipole moment is larger than that induced by the earth's field. That is, the permanent magnetism possessed by the rocks is larger than that induced by the earth's magnetic field. For this very reason the direction of this permanent magnetism is important. For instance if it were that the permanent magnetism was in the opposite direction to the induced magnetism, to take the most extreme case, then magnetic lows would result over highly magnetic rocks.

The magnetisation J of a rock mass in situ can be expressed by the sum of the reversible magnetisation KH_o induced by the geomagnetic field H_o, and the natural magnetisation J_n, namely

$$J = KH_o + J_n$$

The estimation of J_n may be difficult since it's intensity may differ from point to point.

The possibilities are that,

$$J_n < KH_o$$

$$J_n = KH_o$$

$$J_n > KH_o$$

In most cases the directions of J_n and H_o are the same or nearly so. Thus the apparent susceptibility k_a can be defined by

$$J = K_a H_o$$

$$\text{where } K_a = K + \frac{J_n}{H_o}$$

But in other cases, the direction J_n differs appreciably from that of H_o; they may even be opposed, as I mentioned above. If such were the case and if $J_n > KH_o$ then J_n would be of more significance in the interpretation of the aeromagnetic maps than would K, the susceptibility.

Apparently this would not seem to have an effect of any importance as far as the Middleback Ranges are concerned, for the magnetic anomalies are associated with the more magnetic rocks, where these outcrop anyway. Further study along these lines might prove interesting though. Oriented specimens would have to be collected in this case.

Application to the problem of the Middlebacks

a. General Problem

It is fairly obvious from the results obtained that the only rocks of the Middleback Range area that are capable of producing sizable magnetic anomalies are the hematite quartzites. This is also obvious from the aeromagnetic maps anyway. The large anomalies run north-south and they coincide with the ranges themselves. At odd places along the line the anomalous values are much larger than the usual, for instance, the anomaly over Camel Hill. This effect is partly due to fact that the hematite quartzites contain more magnetite in such places. Thus it would seem that any big anomaly can, if no otherevidence is forthcoming, be put down as being caused by hematite quartzites-this would be one logical explanation. The actual size of the anomaly would depend on the depth of the cause, and if it were hematite quartzite, the magnetite content.

The maps show very clearly the general trend of the ranges. Where the hematite quartzites have been eroded in such places as Kimba Gap magnetic lows are found.

The Camel Hill line is also well delineated - it would seem that it dies out to the west down dip.

As far as the 1" = 1 mile aeromagnetic sheets are concerned, I feel that they must be looked upon as reconnaissance sheets only. They indicate trends of the ranges very well and may show the areas where the basement complex nears the surface away from the ranges, but the large scale and the high altitude of flight, 1500', impose limitations. Smaller scales are necessary, lower levels of flight: in general more detailed maps. They do perhaps give a good indication as to which places, where the surface geology is masked, warrant further investigation. No doubt the officials of the Department of Mines linking the outcropping ore north of Iron Monarch with the large anomaly there, followed this up to prove the Race Course ore body. Another anomaly still further north centering on the Corunna Hills is also interesting. The Corunna Conglomerate would not be capable of producing such a large effect, and anyway, the cause lies at a fair depth.

As far as depth estimates are concerned, they are not necessary where the hematite quartzites outcrop. An important feature must be borne in mind, I feel, in those estimates based on the assumption that the responsible object is an isolated point pole. Here where the hematite quartzites, which are so very magnetic, have limited depth, the lower pole is only a short distance below the upper, and this distance is comparable with the altitude of flight. Thus it might not be possible to neglect the effect of the lower pole. It would have an effect along with that of the upper pole, thus rather influencing depth estimates based on the isolated pole theory. Thus estimates using two level flight testing prove better because they do provide a little control. The depth of the race course anomaly when worked through by such a method gave an answer of 1300': the Katunga Hills anomaly 400', and this would appear to be about the mark too, for drilling at this spot in the Katunga Hills revealed magnetic material from about 350' (to 1800').

If the value for the race course anomaly is correct then this means that it is due to material at depth. I do not know how deep drilling progressed in the area but the iron ore outcropped at the surface. The magnetic anomaly is probably due to more magnetic material, such as hematite quartzite, associated with the iron ore and which occurs at depth.

b. The problem confined to the Race Course area.

Several plans are submitted for inspection. Both gravity and aeromagnetic plots are available. From these, second derivative plots have been constructed. In the drawing of these second derivative plots, the formula as derived by Henderson and Zeitz (9) has been used.

The Mines Department has done a lot of drilling in this area and a plan showing the original outcrops of iron ore and the boundaries as inferred by drilling is also submitted.

The gravity plan clearly indicates the position of the larger mass of ore. An anomaly of 3.2 milligals is associated with this. The second derivative plot serves to focus attention more rigidly to this spot. The smaller mass of ore to the west is also outlined by both of these maps, although the anomalies associated with this mass are rather smaller.

As far as magnetic plans are concerned, again there is a straight out total intensity plot from which has been constructed a second derivative plan. The total intensity plan shows a large anomaly - the Race Course Anomaly - of peak value 4500 gammas. The second derivative plot again confines attention more strictly to the area (that bounded by the zero curvature contour). A large value of 1000 gammas/500'^{2} coincides almost with the gravity high, although I think that this is due to magnetic material at depth rather than the iron ore. Other values as high as 800 gammas/ 500'^{2} occur which do not bear any relation to the iron ore (or so it seems from the drilling, which was very thoroughly done).

All this may appear rather weak in that I have obviously come at the problem forearmed. However it does prove the point that magnetic work alone would not have been sufficient, in fact it may have been downright misleading in that such a large magnetic anomaly should be obtained over a hematite ore body. When it is used in conjunction with the gravity method it makes a little more sense. Actually the gravity plans, particularly the second derivative, would have served quite well in outlining the boundary of the northern extension of the ore which outcrops at 00, 00. It also gives some idea of the limits of the western body.

The gravity method would appear to be the only reasonably sure method of outlining the iron ore deposits then. The hematite ore may vary in it's magnetic properties but it is always of a higher density than the surrounding rocks. It does not seem reasonable to say that the hematite is nonmagnetic, or nearly so, for it does contain a certain amount of residual magnetite, and although only one specimen was measured, high values for the magnetic susceptibility and residual magnetisation were obtained.

Prospecting for iron ore by magnetic methods is thus limited by this factor of variable magnetic properties. The hematite quartzites are much more magnetic anyway: the largest anomalies are associated with these and this effect would tend to swamp out any produced by the hematite ore, as I feel has happened in the race course area.

Conclusions

I have brought out many of the points I wished to mention here already. The original 1 mile sheets as put out by the Bureau were flown at much too high an altitude to be any good for detailed work. That this fact has been realised or that this was the real intention - that they should be reconnaissance sheets - is obvious, because certain parts of the area have since been flown at lower elevations. These maps are thus now definitely useful for determining depths by two level method. They do give an indication where hematite quartzites or related magnetic rocks may lie at depth. Iron ore could be associated with this material but further drilling and gravity work would have to be done. Sensible use of gravity plans could save expensive drilling costs.

The large anomaly further north of the race course over the Corunna Hills would appear to warrant investigation. Considering the amount of drilling done in the race course area, it seems that at least one hole could have been put down. This is a deep seated type and I think is not due to the Corunna Conglomerate.

Those south of the Charleston Granite on the Wilton sheet are interesting too. They show well elongated trends, almost in line with the ranges. In longitudinal section they show marked breaks in peak intensity. The area has not been mapped (there is no Wilton geological sheet, nor Cowell Sheet for that matter), but it could be that much of the area is covered by alluvium. These too appear to be due to deep seated effects. Actually, I am at a bit of a loss, in that I do not know just how much work has been done by the Mines Department in such areas. Those anomalies down south would warrant investigation as they stand. Perhaps something has already been done and the area has proved uninteresting, although answers to enquiries seem to indicate little activity except in the race course area and about Iron Monarch. Certainly recent aeromagnetic plans have not been plotted for this area.

SUMMARY

Some sort of study of the rocks of the Middleback Ranges has been attempted. This has been rather limited to the hematite quartzites, the most prominent rocks in the ranges proper. These were examined in polished section - the specimens used came mainly from DDH20. They were both surface and subsurface specimens. In tying this mineragraphic approach in with the later study of the magnetic properties (again mainly of the hematite quartzites) note was taken of the magnetite content of the rocks. This it was estimated was limited to only about 1-2% of the total minerals present - the predominant ones being hematite and quartz. This small amount of magnetite, it was found, did not vary much with depth (over about 800'), and it was also nearly the same as the amount present in those specimens taken at the surface at DDH20. This would suggest that the amount of magnetite present in the hematite quartzites need not be dependent on the present erosion level, thus indicating that the conversion of the original magnetite of the hematite quartzites to hematite, is perhaps not dependent on supergene processes as much as others (for instance hypogene).

The hematite quartzites from DDH20 possess consistently high magnetic properties: this even in view of the fact that they contain relatively little magnetite compared with others found in the range area. This suggests the fact, which has been obvious anyway, that large magnetic anomalies will be more so associated with these rocks than any others.

The 1 mile aeromagnetic sheets are good for large scale reconnaissance investigation, and when used in conjunction with lower level maps, and ground gravimetric plots, become distinctly useful.

The anomaly north of the race course area, in the vicinity of the Corunna Hills, and those southern elongated types on the Wilton sheet would bear further investigation on the surface.

The large anomalies to the side of the ranges warrant thought too. They could be put down to basement highs (this outcrops in many such places), or concentrations of magnetic material in the same. Sometimes the basement where it outcrops seems to be associated with magnetic highs, other times, for instance on the Roopena sheet, the outcropping basement does not bear any such relation to marked magnetic highs.

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