RESTRICTED REPORT 221R

Division of

EXPLORATION GEOSCIENCE

CSIRO
AUSTRALIA

Institute of Minerals, Energy and Construction

MAGNETIC PROPERTIES OF MINERAL SANDS FROM BATHURST AND MELVILLE ISLANDS, NORTHERN TERRITORY

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SUMMARY

Mineral sands from Bathurst and Melville Island are only weakly magnetic. Apart from paramagnetic minerals (mainly ilmenite?), the magnetic mineral present is magnetite. Magnetite is present in a concentration of about 130 ppm and may carry a remanence. The magnitude of this remanence is difficult to determine but is low, about 10-20 mAm^{-1} (10-20 μG). This low remanence and the coercivity of about 240 Oe are consistent with coarse multidomain magnetite. The susceptibility of the sand is also low, ~0.00038 SI (30 $\mu G/Oe$), yielding a Königsberger ratio, Q = 0.7-1.3 (assuming a magnetic field of 50 μT or 0.5 Oe). Overall the sands could be expected to show a slight magnetic contrast with background.

DENSITY AND PACKING FRACTION

The density of mineral sand assemblage N1671 from Bathurst Island and Melville Island is 2.94 gm cm^{-3}, while that of the heavy mineral concentrate is 3.82 gm cm^{-3}. The packing fraction of both was measured as 0.62, i.e. 62% solid material.

SUSCEPTIBILITY VS TEMPERATURE

The variation of susceptibility with temperature (k-T), from -196°C to above 600°C, is highly diagnostic of the magnetic mineralogy of materials. Fig. 1a shows this variation for the mineral sand assemblage. The susceptibility is very low and approaches the noise limit of the CSIRO k-T bridge. On warming from -196°C (liquid nitrogen temperature) the susceptibility initially decreases hyperbolically. This is the classic signature of paramagnetic minerals and is discussed more fully by Schmidt *et al.* (1986) in a study of ilmenite bearing sands from Western Australia and Florida, USA. Between room temperature and about 400°C the susceptibility is flat, and as the temperature increases the susceptibility increases slightly before dropping rapidly at the ferrimagnetic Curie temperature (580°C). The slightly negative susceptibility at high temperature is due to instrument drift. On cooling the susceptibility is seen to be irreversible indicating some magnetic changes have occurred during the heating. The Curie temperature is that of pure end-member magnetite, magnetite *s.s.*.

Fig. 1b shows a k-T curve for the heavy mineral concentrate. This is similar in form to that of the sand sample, although the susceptibility is stronger and the ratio of magnetite to paramagnetic material is greater.

SUSCEPTIBILITY

The susceptibilty of the mineral sand assemblage is low, 0.00038 SI or 30 μG/Oe. These susceptibilty values are volume susceptibility where the volume is that of the sand plus air space.

The heavy mineral concentrate has a much higher susceptibilty, although still modest, of 176 μG/Oe or 0.0022 SI. The susceptibilities of the solid material is derived by dividing the above values by the packing fraction, 0.62.

Volume susceptibility is a function of concentration and grain-size and for magnetite varies between about 0.16 G/Oe (or 2 SI) for fine grained material (~0.1 μm) and 0.23 G/Oe (or 3 SI) for coarser material (~30 μm, O'Reilly, 1984, p.142). Assuming a grain-size >30 μm, a susceptibility of 30 μG/Oe

corresponds to a concentration of $30 \times 10^{-6}/0.23$ %, or 130 ppm. Likewise the magnetite content of the heavy mineral concentrate is only 770 ppm.

SUSCEPTIBILITY VS CONCENTRATION

Eight samples were prepared by mixing pure sand with varying portions of the heavy mineral concentrate. Table 1 lists the properties of these samples. The variation of susceptibility with both weight and volume percentage are plotted in Fig. 2. Fig. 2a is in SI units while Fig. 2b is in cgs units.

REMANENCE

The magnetic remanence that may be carried by the mineral sand could only be investigated crudely, since it is not practicable to make an *in situ* measurement. Following the procedure outlined by Schmidt *et al* (1986) a 10ml vial was filled with mineral sand in a magnetic field free space. The remanence was measured and the sample was then agitated in the Earth's magnetic field to simulate natural conditions. The remanence was again measured and the process repeated. Remanences observed were weak (~ 10 μG, or 0.001 Am^{-1}) and randomly directed. The remanence did not show a steady increase with successive agitations and nor did it appear to be aligned with the magnetic field direction. Further investigation showed that the magnetite was present in only a few large grains 100-500 μm in diameter. Extraction of these grains and measurement of their remanence showed individual grains to have much stronger remanences than the sample as a whole (up to 100 μG, or 0.01 Am^{-1}). Apparently the direction of remanence of individual grains tend to oppose each other, the Earth's field not being intense enough to provide a strong bias. Similar behaviour was observed when the sample was mixed with water into a slurry. The remanence of the mineral sand is therefore low, and probably does not exceed 10-20 mAm^{-1} (10-20 μG).

The remanence of the heavy mineral concentrate behaved similarly to that of the mineral sand, although the intensity was two orders of magnitude higher (~500-800 μG, or 0.5-0.8 Am^{-1}), the highest intensity being observed after mixing as a slurry. As the mineral sands become more highly concentrated it is possible that a remanence might become moderately large.

The stability of remanence was investigated by measuring its hysteresis, i.e. demagnetising an artificially induced (saturation) magnetisation. The heavy mineral concentrate was mixed with Plaster of Paris to fix the grains and exposed to a large magnetic pulse (10,000 Oe). This is sufficient to saturate multidomain magnetite. The remanence was measured and reverse fields applied, and the remanence measured each time. The resulting hysteresis plot (Fig. 3) yields a coercivity of remanence of 240 Oe. This is reasonably high and suggests that any depositional remanence carried by the natural mineral sand should be stable for a geologically long time.

REFERENCES

O'Reilly, W., 1984. *Rock and Mineral Magnetism*, Blackie, Glasgow and London, 220pp.

Schmidt, P.W., Clark, D.A. and Brown, H.E., 1986. Magnetic properties of some ilmenite bearing sands, CSIRO Restricted Investigation Report 1632R, North Ryde, NSW.

Table 1 Physical properties of artificial samples

No.	Min.Conc.(gm)	Sand(gm)	Vol.Susc. SI (μG/Oe)
1	1.53	11.40	0.000160 (13.1)
2	2.59	10.39	0.000400 (32.1)
3	3.61	8.96	0.000440 (34.7)
4	5.63	7.59	0.000750 (59.9)
5	7.12	7.36	0.000930 (74.1)
6	9.74	5.31	0.001200 (93.0)
7	11.91	4.62	0.001800 (141)
8	18.02	0.00	0.002200 (176)

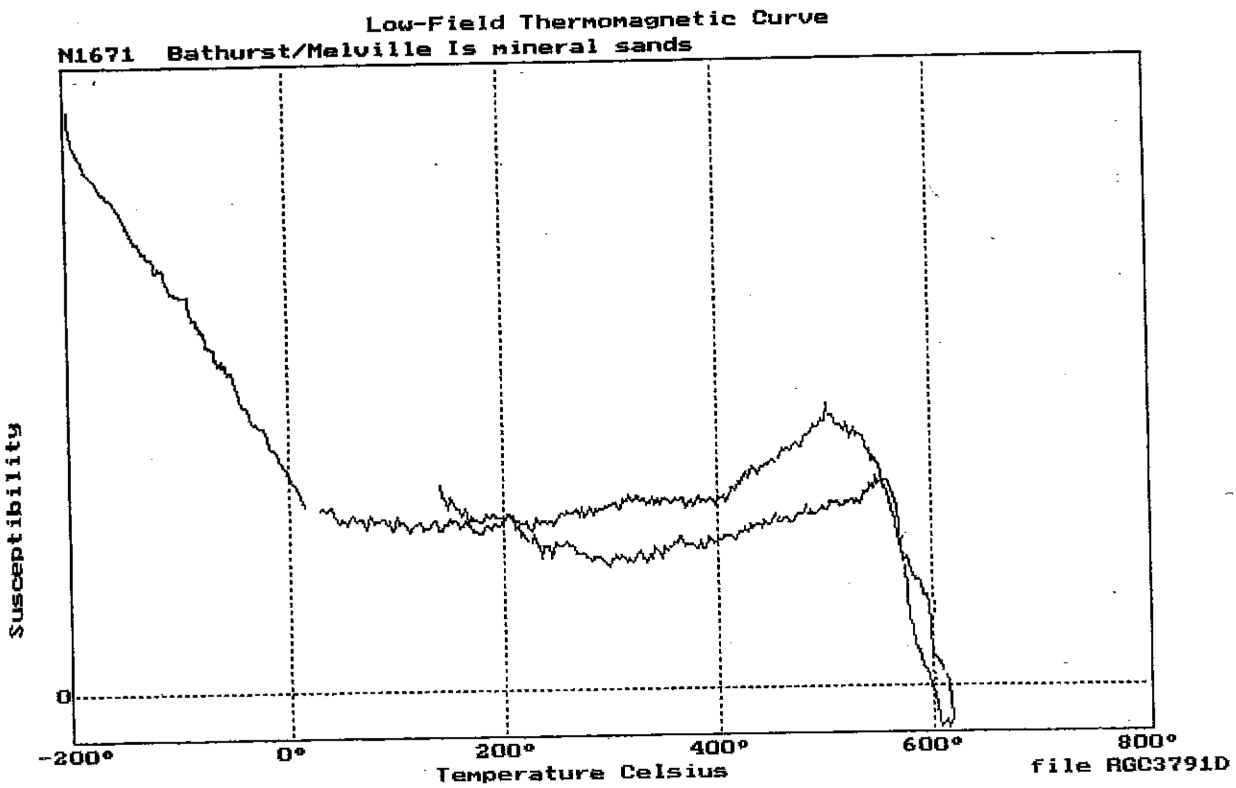
Low-Field Thermomagnetic Curve
N1671 Bathurst/Melville Is mineral sands
Susceptibility
0
-200°
0°
200°
400°
600°
800°
Temperature Celsius
file RGC3791D

Figure 1a

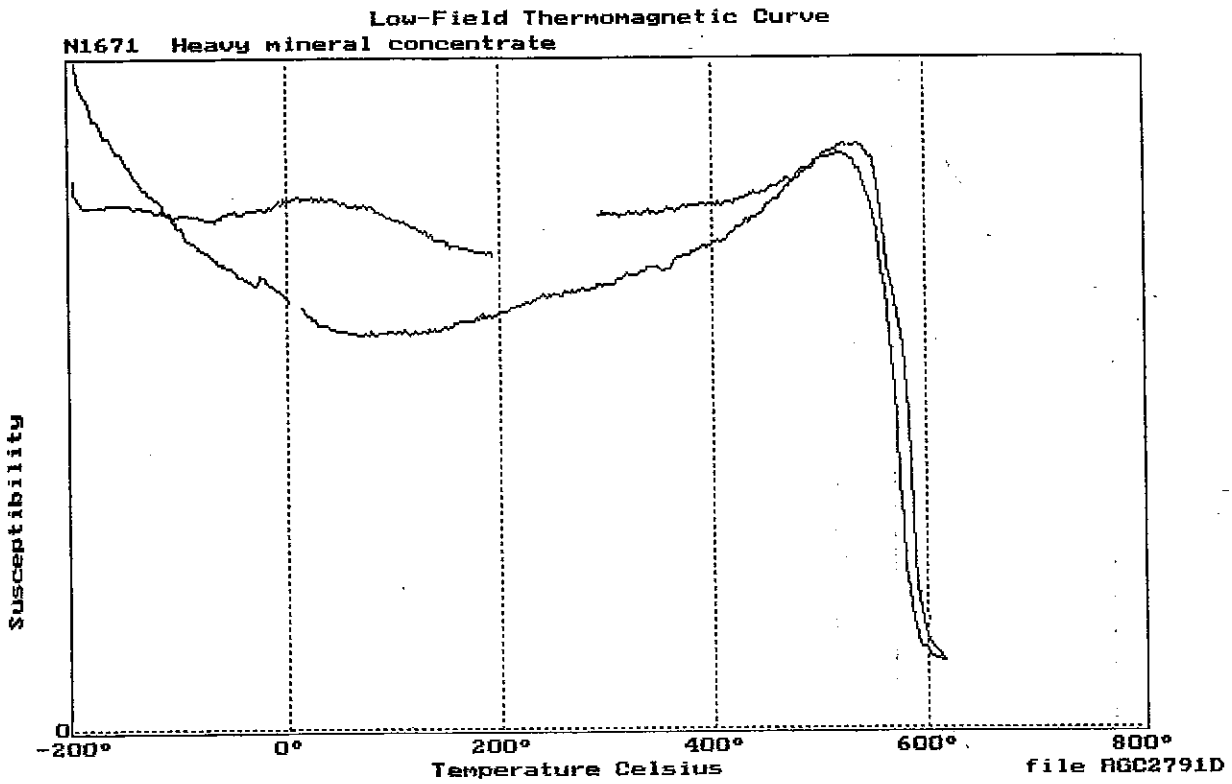
Low-Field Thermomagnetic Curve
N1671 Heavy mineral concentrate
Susceptibility
0
-200°
0°
200°
400°
600°
800°
Temperature Celsius
file AGC2791D

Figure 1b

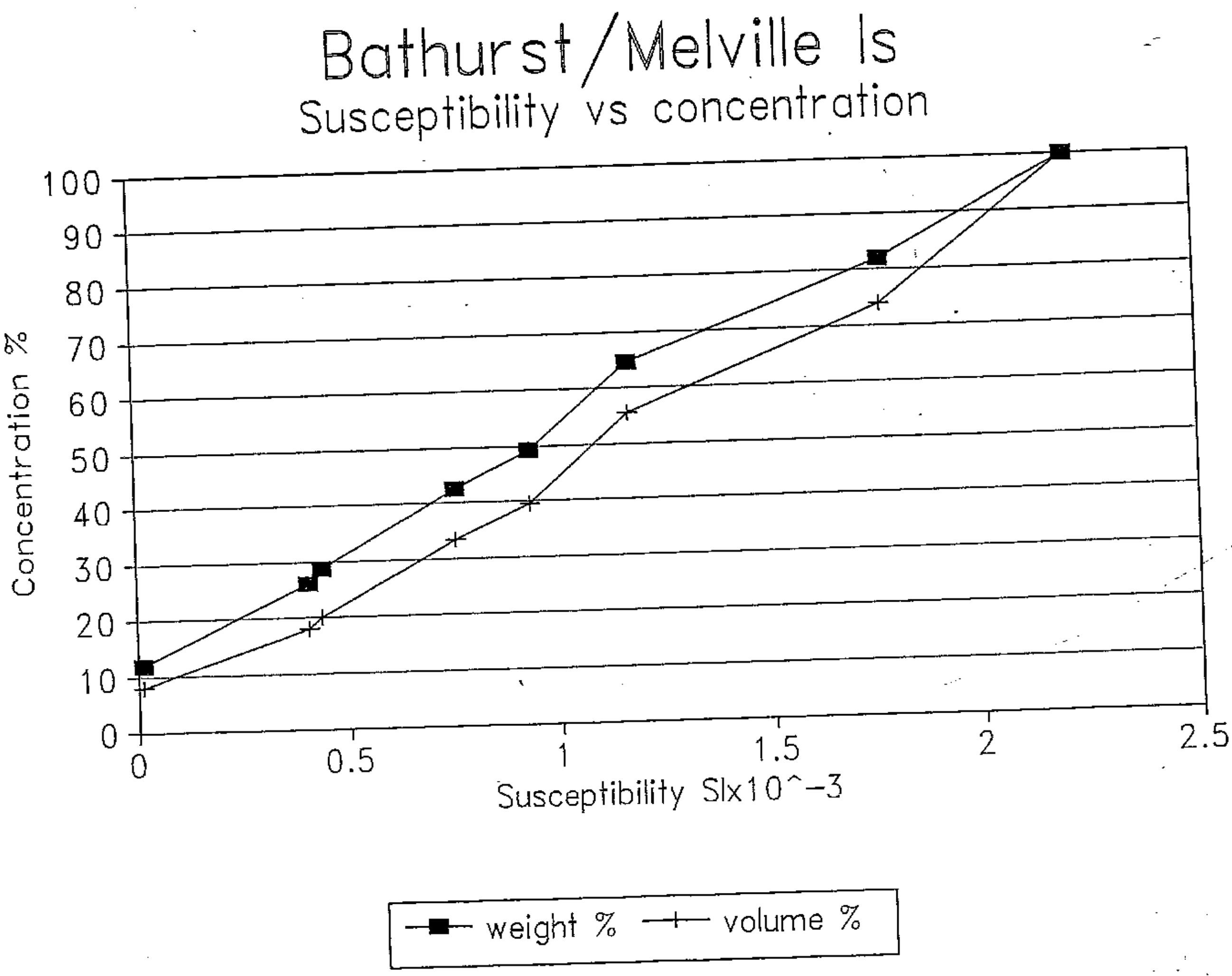
Bathurst/Melville Is
Susceptibility vs concentration
100
90
80
70
60
50
40
30
20
10
0
Concentration %
0
0.5
1
1.5
2
2.5
Susceptibility SIx10^-3
weight %
volume %

Figure 2a

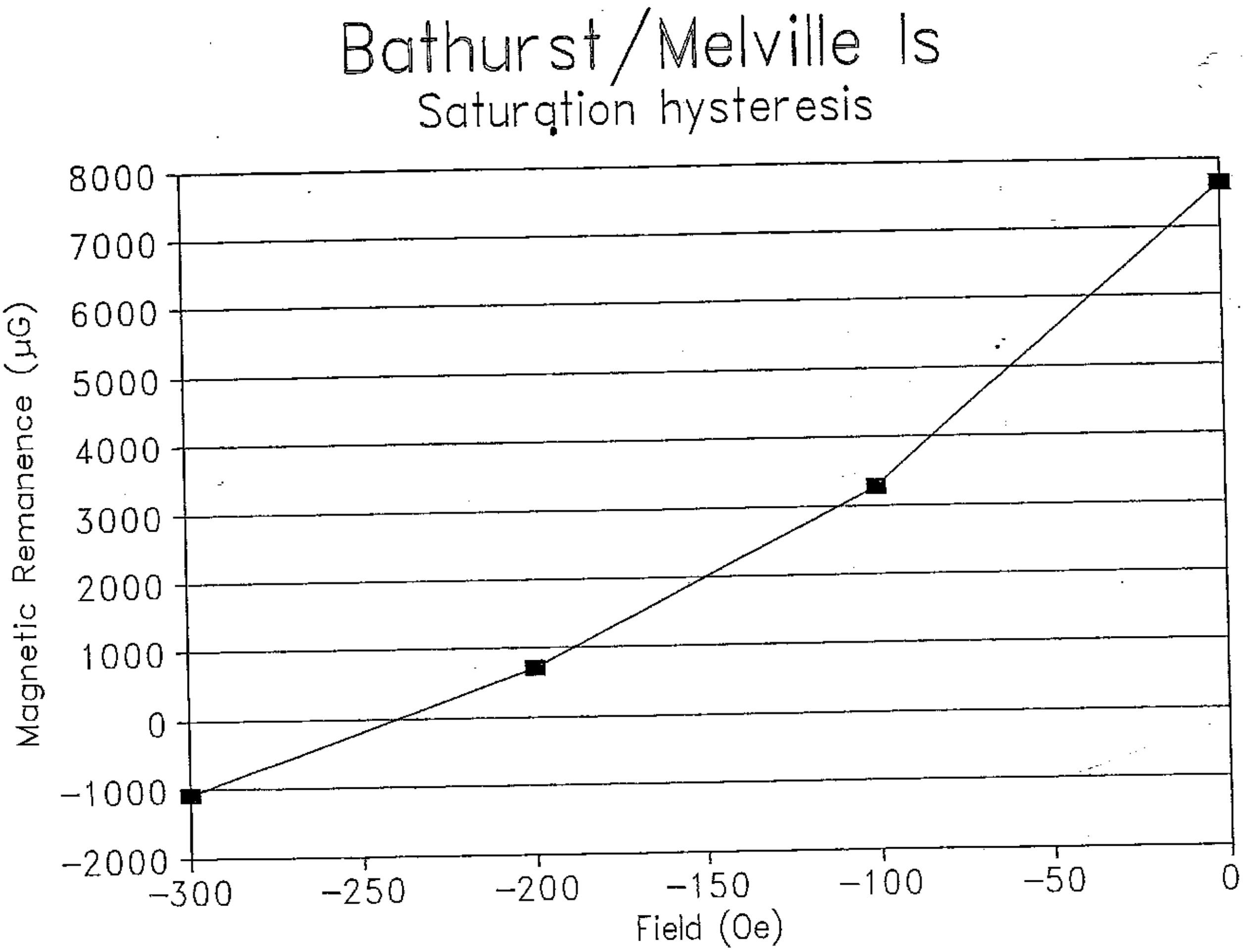
Bathurst/Melville Is
Saturation hysteresis
8000
7000
6000
5000
4000
3000
2000
1000
0
−1000
−2000
Magnetic Remanence (μG)
−300
−250
−200
−150
−100
−50
0
Field (Oe)

Figure 3