Alternating field demagnetization of manganese ores and related rock types of Vizianagaram District, Andhra Pradesh

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Alternating field demagnetization tests were carried out, on manganese ores and related rock types of Vizianagaram District, Andhra Pradesh. Protores and ores containing ferrimagnetic minerals undergo small changes in direction until the demagnetizing field exceeds their coercivity, the former showing random changes thereafter. The decay of intensity in ores is less rapid than in protores. Protores with ferrimagnetic minerals have the lowest MDF. The response of replacement-ores is suggestive of CRM. Differences in mineralogy and texture are reflected in the results of demagnetization.

MANGANESE ores, in the Vizianagaram District of Andhra Pradesh, are in close association with Khondalites[1]. The Khondalite suite consists of garnet–sillimanite–graphite gneiss, quartzite, calc–granulite and carbonatites. Samples of manganese protore, the ore, lithomarge, chert and wad were collected from the localities Garbham, Kottakarra, Garividi, Sadanandapuram, Devada, Chipurupalle, Avagudem and Gadabavalasa. The samples of protore and the ore were divided into ferrimagnetic and paramagnetic based on their magnetic properties and magnetic mineral content as estimated by magnetic separation of the pulverised samples. Protore–F and ore–F contain magnetic minerals of 1–37% by volume. Their volume magnetic susceptibility (K) and NRM intensity (J_n) were high. Protore–P and ore–P contain very few grams or total absence of the magnetic mineral and their K and J_n were low. The ferrimagnetic minerals in the suite of rocks were jacobsite and magnetite. They were identified by optical examination and X-ray diffraction analysis. The results of alternating field (AF) demagnetization are discussed here.

About 60 representative specimens of all the rock types were subjected to AF demagnetization in progressively increasing peak alternating fields of 2.5, 5, 10, 15, 20, 30, 40, 60, 80 and 100 mT. After each step the remanent intensity was measured on a spinner magnetometer.

During AF demagnetization the direction of magnetization gets scattered in random directions when its coercivity is exceeded[2]. Using this criterion the coercivities (H_c) of the specimens under test were estimated. The median destructive field (MDF) was also determined from AF decay curves. It is the strength of alternating magnetic field required to eliminate one-half of the original NRM of a specimen.

The response to AF demagnetization of each rock type has some broad characteristics distinct from other formations. Samples of protore–F undergo small and systematic changes in direction until their coercivities are exceeded and thereafter the changes are large and random (Figure 1 *a*). The changes in protore–P are more or less random even from the beginning of progressive demagnetization (Figure 1 *b*). In both types the decay in intensity is rapid. The protores under study are granular in texture with grains of 2 mm being common. Protore–F contains ferrimagnetic minerals, jacobsite and magnetite. Some samples of protore–P are from localities Gadabavalasa and Garbham. As far as magnetic minerals are concerned these samples contain only hausmannite. The rapid decay in intensity of protores seems to be due to the spinel group of minerals which are likely to be in the multidomain state.

The magnetizations of ore–F undergo small changes below their coercivities like protore–F (Figure 1 *c*). In ore–P coercivity stops are less evident (Figure 1 *d*). In both types the changes in direction are less random than in protores. The decay of intensity is also less rapid. It is more gradual in ores between the demagnetization fields of 2.5 and 30 mT. Transformation of the primary minerals in protore into manganese–rich secondary minerals by supergene oxidation results in ore formation. The domain structure in ores is very different from that of protores. Meteoric waters dissolving the primary minerals act along grain boundaries and cleavage planes and consequently the grain size of primary minerals in the ores is likely to be smaller than in protores.

The magnetizations that did not undergo considerable changes with demagnetization are depicted in Figure 10 *e* as a separate category. Samples are from the localities, Chipurupalle, Garividi and Avagudem. The ore at Chipurupalle is believed to be formed by replacement of the country rock by manganiferous solutions[1]. Such a process may result in single domain ferrimagnetic particles or the ferrimagnetic minerals like jacobsite may get martitised (to hematite). Hematite was found in samples collected from Garividi. The response to AFD and the process of ore formation are suggestive of a chemical remanent magnetization (CRM).

Some samples of chert undergo random changes in direction (Figure 1 *f*). Decay in intensity seems to be complete below 5 or 10 mT. Cherts in the ore deposits under discussion were formed through the replacement of paragneisses by the silica and manganese liberated from manganese garnets[3]. They contain soft manganese oxides. Even if magnetic minerals are present they are likely to be in superparamagnetic size because the replacement is gradual preserving the original texture.

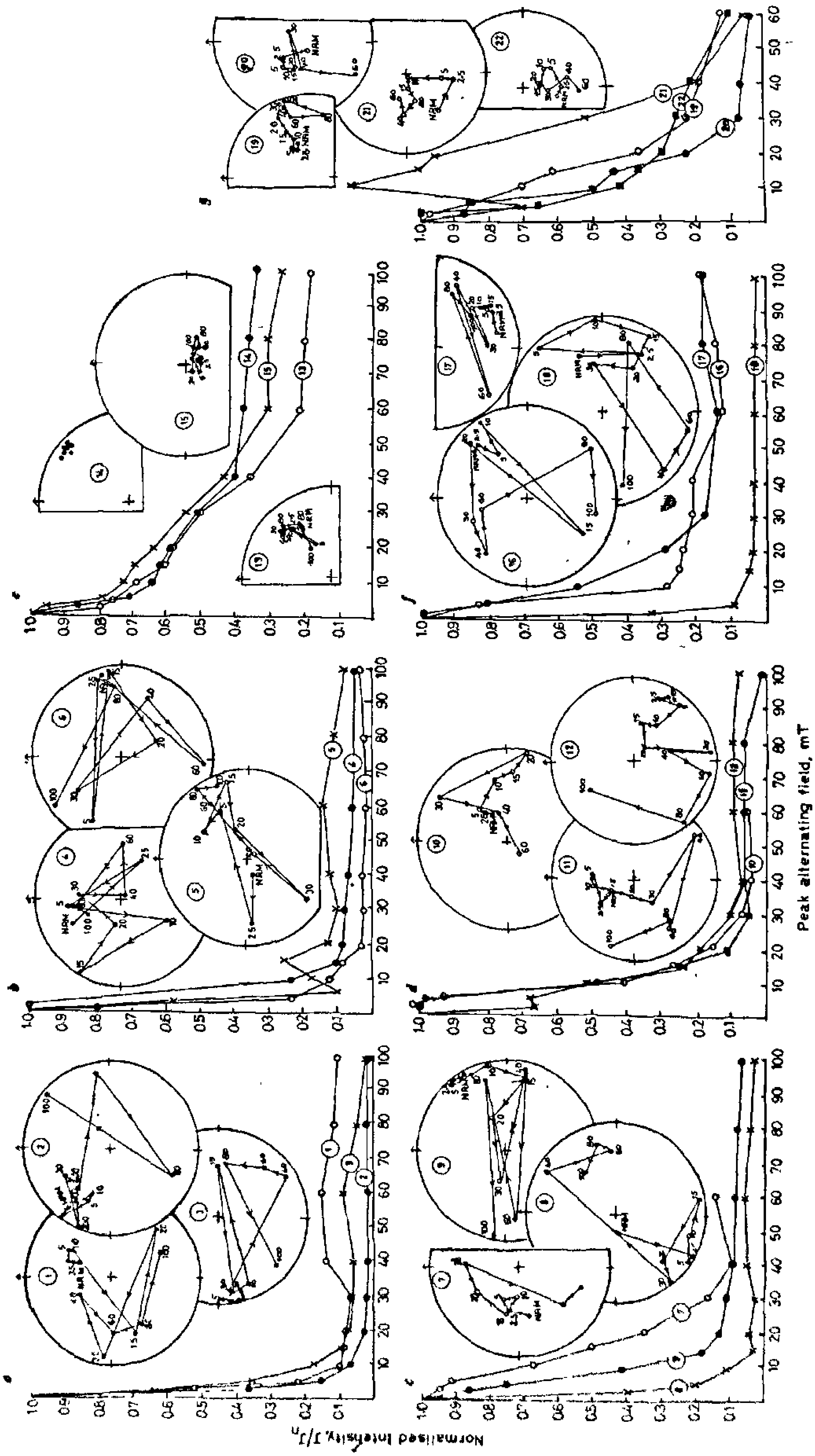

Figure 1. Behaviour of manganese ores and related rocktypes during progressive alternating field demagnetization.

Lithomarge and wad undergo steady changes in direction and intensity without indications of coercivity stops (Figure 1 *g*). Lithomarge is lateritized, kaolinized, crushed and altered paragneiss. Wad is an *in situ* remanent of paragneiss or protore after the primary minerals are leached by meteoric waters. These two rock types contain, among other minerals, manganese oxide in the form of paramagnetic minerals, pyrolusite or romanechite, and hydroxides of iron like limonite. Their response seems to be characteristic of their mineralogy.

Random changes in direction, at magnetic fields exceeding the coercivities, seem to be characteristic of protores. A common feature of ores, lithomarge and wad is the steady or more or less systematic variation in direction even at fields exceeding coercivities.

MDF and $\tilde{H}_c$ of different rock types are summarized in Table 1. They are shown plotted against the Koenigsburger ratio, Q_n, in Figure 2. $\tilde{H}_c$ and Q_n seem to have a systematic relationship with each other. A linear trend between them was fitted and is shown in the figure. The two parameters seem to reflect the relative hardness of magnetizations in different samples which in turn probably reflects differences in magnetic mineralogy and other aspects.

MDF values are distributed in two groups (Figure 2 *b*). Although such a division can also be seen in the $\tilde{H}_c$–Q_n plot, it is pronounced and distinct in the MDF–Q_n plot. Magnetizations in group II (Table 1) with high MDF are those in which changes in direction could not be brought about by AF demagnetization. MDF or $\tilde{H}_c$ of this group pertains only to the soft part and the coercivity of the really hard component may not have been exceeded in the demagnetization procedure. Most samples in group I with low values of MDF are of protore and ore samples containing the primary minerals, jacobsite and magnetite. It seems that MDF is a good parameter for resolving relatively soft magnetizations from the hard ones. It may be that different parts of coercivity spectrum are addressed by MDF and $\tilde{H}_c$. Magnetizations with lower values of MDF and $\tilde{H}_c$ may be attributed to primary ferrimagnetic minerals, while higher values to changes in grain size and mineral composition brought about by supergene processes.

Table 1. MDF and $\tilde{H}_c$ of rocks in the manganese ore deposits

	MDF	$\tilde{H}_c$
Rock type		
Protore-F	1.5–4.5	10–30
Protore-P	2.5–7.5	5–20
Ore-F	2–33	5–40
Ore-P	4–9	5–30
Chert	2–11.5	5–20
Lithomarge	10–27	2.5–20
Wad	6–31	10–40
Group I	1.0–12.5	2.5–20
Group II	24–33	30–40

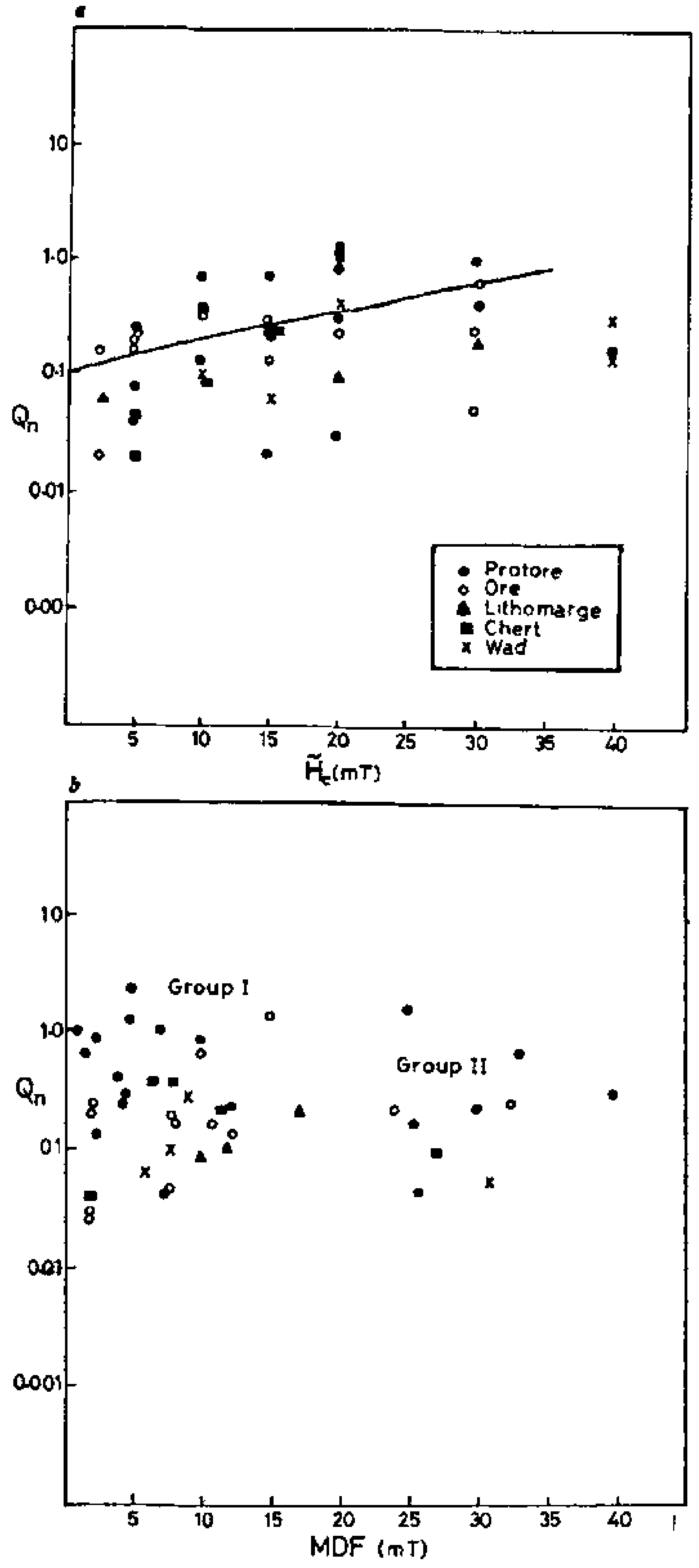

Figure 2. Plots of $\bar{H}_c$ (*a*) and MDF (*b*) against Q_n

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