Figure 6. Interacting ring vortices The younger vortices overtake the older ones and slip through them.

Figure 7. A pattern generated when successive drops are released and the resulting vortices are allowed to be influenced by convection currents or wakes in the pool

situation where a number of drop-generated vortices have overtaken one another to form the pattern shown. Note that the smallest ring is about to overtake the previous ring below. If convection currents or asymmetric wakes are present when a number of vortices are released, beautiful patterns may be generated (Figure 7).

In conclusion, we would like to express the opinion that the drop mechanism is a compact, convenient, reliable and inexpensive method to generate and study toroidal vortices. So far, we have only studied the rings generated by water drops contacting pools of water. Even this has been limited to a small part of the $\mathcal{B}^{-1}$- Re plane. We are confident that many interesting and beautiful phenomena are waiting to be investigated outside this limited domain.

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ACKNOWLEDGEMENTS We thank our colleagues in the EAD, NTAF and Propulsion Divisions for the loan of equipment All the pictures displayed here were obtained with the skilled help of our colleague Mr M R Padmaraju We thank him and his assistant Mr T. Baburajan for all their help.

Received 4 December 1993, accepted 15 December 1993

Magnetic properties of different rock types associated with the manganese ore deposits of Vizianagaram District, Andhra Pradesh

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We have measured the intensity of natural remanent magnetization (J_n) and volume magnetic susceptibility (K) of samples collected from the manganese ore deposits of Vizianagaram District, Andhra Pradesh. The two magnetic properties of protore and the ore are distributed in the ferrimagnetic and paramagnetic range. Those of lithomarge, chert and wad are mostly in the lower range. The distribution of each magnetic property of all the rock types together is lognormal. Jacobsite, magnetite and vredenburgite are the ferrimagnetic minerals among the many manganese minerals in the samples. We found by magnetic separation that samples with high values of J_n and K contained ferrimagnetic minerals in varying proportions. Those with low values contained few grains or none at all. Like susceptibility, J_n of the samples also seems to be systematically related to magnetic fraction. From this relationship, we inferred that a substantial part of NRM is viscous or isothermal in nature. Though a relationship between magnetic fraction and susceptibility is common, it has a special significance in this context. In manganese deposits the primary ferrimagnetic minerals in protore are transformed into secondary paramagnetic minerals by the process of supergene oxidation. The differences in magnetic properties, among different samples of a deposit or formation, reflect differences in magnetic content and in turn the relative states of oxidation.

GEOLOGICAL aspects of manganese ore deposits in the Vizianagaram District of Andhra Pradesh are well studied[1–4]. Bhimasankaram and Rao[5] reported magneto

Table 1. Magnetic properties of different rock types

Rock type	$K \times 10^3$ (SI) Range	$K \times 10^3$ (SI) Average	$J_n \times 10^3$ A/m Range	$J_n \times 10^3$ A/m Average	Q_n Range	Q_n Average
(a) Protore-F	30–226	81.3	160–9400	908	0.08–0.95	0.27
(b) Protore-P	0.63–4.4	1.69	2.2–25.6	7.1	0.001–0.42	0.05
(a) Ore-F	63.0–713	286	100–2910	811	0.003–12.4	0.23
(b) Ore-P	0.42–2.26	1.23	0.7–66.9	16.8	0.003–2.86	0.06
Chert	0.38–3.27	1.33	1.7–100	24.8	0.007–1.95	0.13
Lithomarge	0.47–1.28	0.86	1.5–26.4	7.0	0.04–1.15	0.18
Wad	0.6–6.81	1.8	2.0–76.9	13.2	0.05–0.73	0.19
All types*						
(a) Mean	(i) – 0.0947 (ii) – 2.8168		– 0.8637		– 0.795	
(b) Median	(i) – 0.9545 (ii) – 2.8303		– 2.1008		– 0.766	
(c) Mode	(i) – 0.9737 (ii) – 2.8255		– 2.1909		– 0.658	
(d) Skewness	(i) + 0.0159 (ii) + 0.0335		+ 0.7968		– 0.038	
(e) Kurtosis	(i) Mesokurtic (ii) Leptokurtic		Platykurtic		Leptokurtic	

*Statistical estimates for lognormal distribution

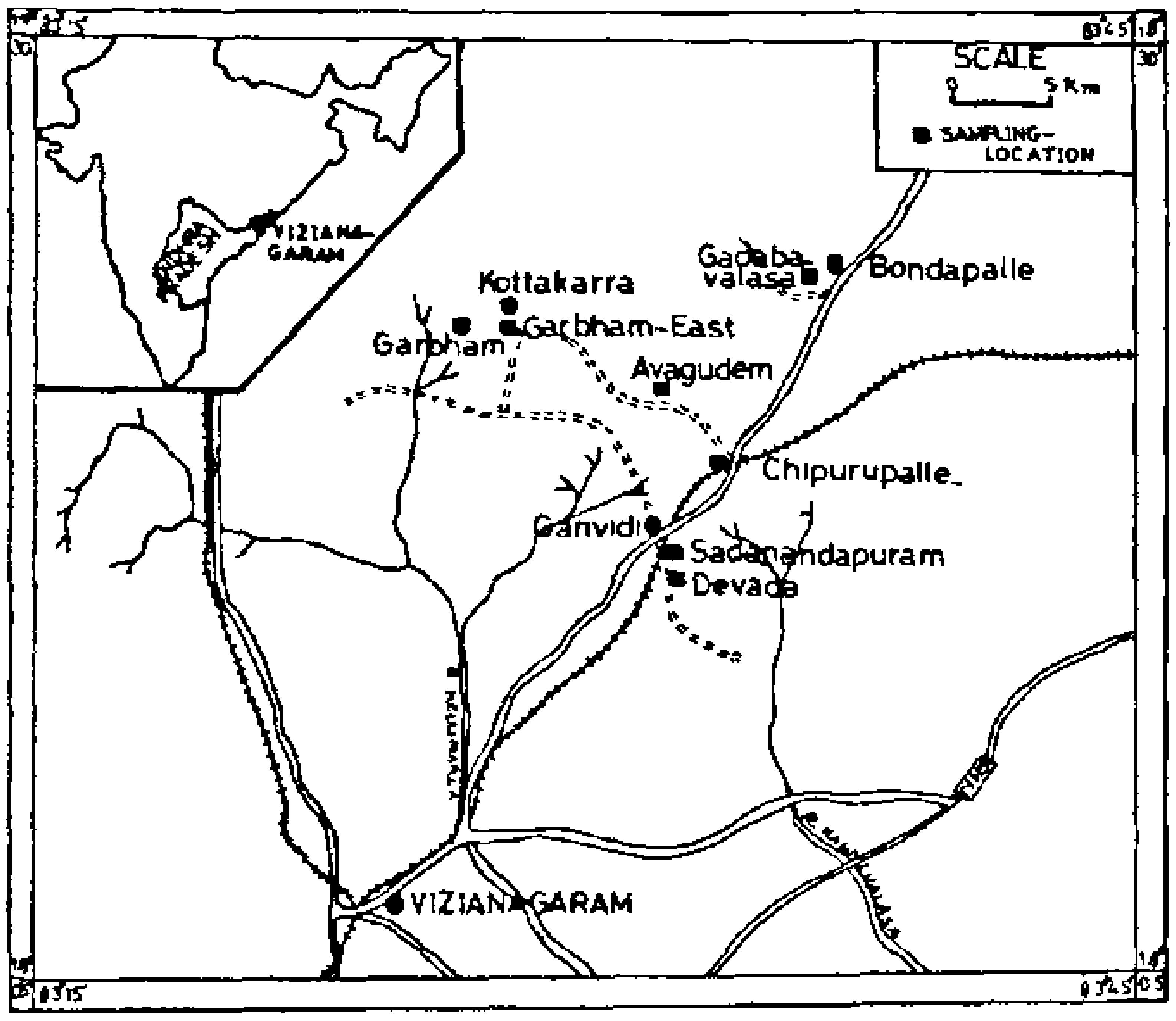

Figure 1. Location map

metric surveys over some of these deposits and correlated magnetic susceptibility with normative amounts of $(MnFe)_3O_4$. One of their observations is that some ore bodies caused large magnetic anomalies while some others, though of higher grade, caused small anomalies. We have studied magnetic properties of the constituent rock types of these deposits to identify the factors affecting magnetic properties. The correlation found between the magnetic properties and the mineralogy is presented here.

About 300 block samples of protore, ore, lithomarge, chert and wad, were collected from the deposits at Sadanandapuram, Devada, Garividi, Chipurupalle, Garbham, Kottakarra, Avagudem, Gadabavalasa and Bondapalle (Figure 1). Cylindrical specimens measuring 2.5 cm in diameter and 2.2 cm in length were prepared in the laboratory by drilling the block samples with a diamond drill. Roughly spherical specimens were prepared from the few samples which could not be drilled either because of their hardness or because they do not withstand drilling. Intensity of natural remanent magnetisation (J_n) of the specimens was measured on a spinner magnetometer. Volume magnetic susceptibility (K) was measured on a low field susceptibility meter[6] at a field strength of 0.05 mT (H). The Koenigsburger ratio Q_n was calculated for all the specimens using the J_n and K values. $Q_n = J_n / KH$. Bulk density (ρ) of the specimens was determined by the conventional method using loss of weight in water. In the present context ρ was used as a parameter against which J_n and K can be plotted.

The values of J_n, K and Q_n of all the rock types measured are summarized in Table 1 and presented as frequency histograms in Figure 2. The susceptibilities of both protore and ore are high ($30–712 \times 10^{-3}$ (SI)) as well as low ($0.38–12 \times 10^{-3}$) while those of other rock types are mostly in the lower range. J_n of the five different rock types covers a wide range of 0.7 to 9400 $\times 10^{-3}$ A/m. The values of both protore and ore show central tendencies in the two ranges $0.7–67 \times 10^{-3}$ A/m

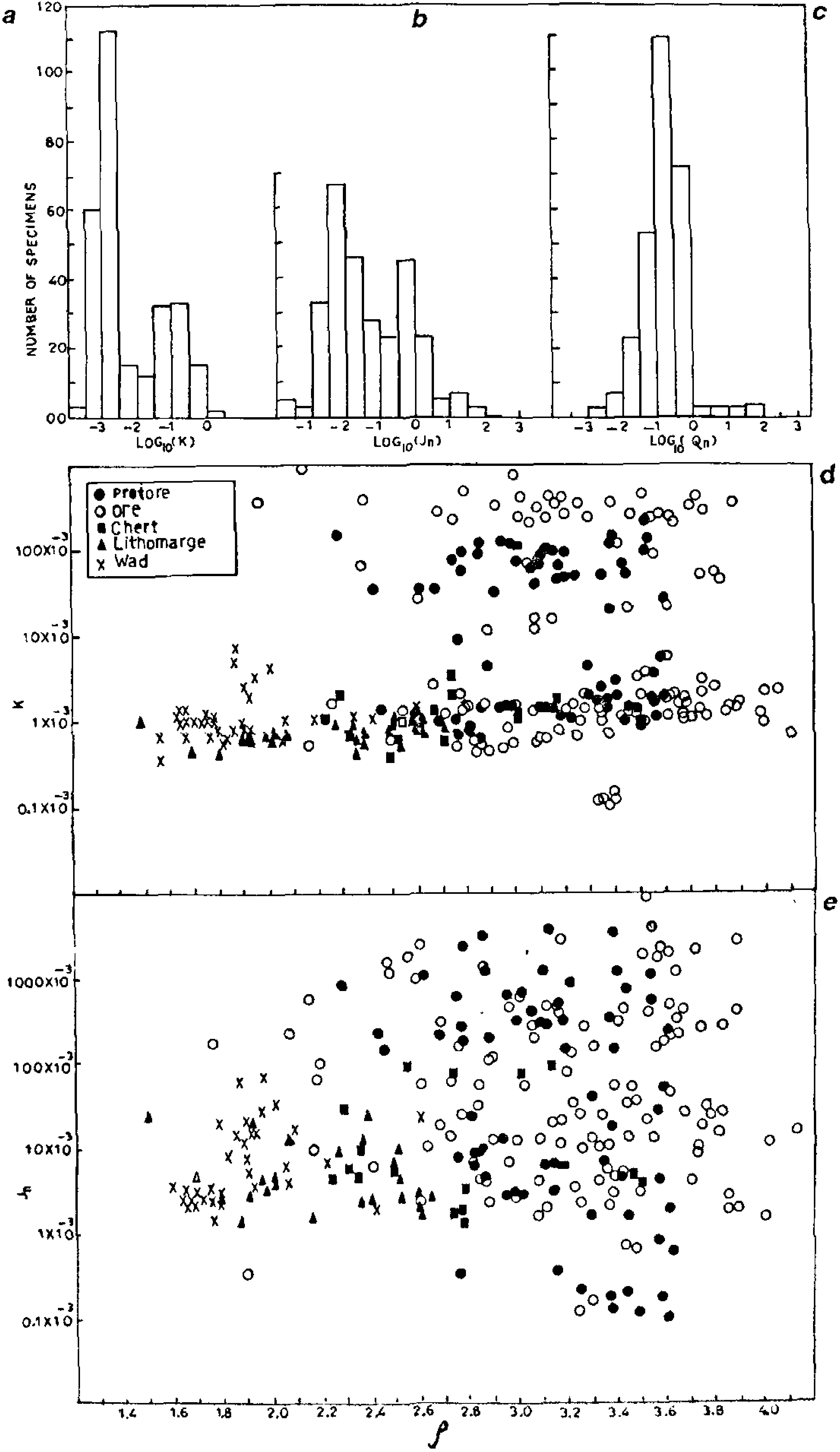

Figure 2. *a–c*, Frequency histograms of K, J_n and Q_n; *d*, plot of K against ρ and *e*, plot of J_n against ρ.

and 100–9400 × 10^{-3} A/m. J_n of the other three rock types are mostly in the lower range. From the frequency histograms of K and J_n (Figure 2, *a* and *b*) the data seem to conform to lognormal distribution with a bimodal nature. The corresponding modes, means etc. are listed in Table 1. The bimodal nature of the combined histograms of all the rock types seems to be due to the predominance of values of protore and ore. This is also evident from the $\rho - K$ and $\rho - J_n$ plots (Figure 2). The Q_n values of all the rock types are between 0.001 and 12.4. The distribution seems to be lognormal and is unimodal with a small negative skewness.

The manganese protore is a metamorphosed product of the original manganiferous argillaceous, arenaceous and calcareous sediments. The manganese in it is in the form of primary oxides, silicates and carbonates. The constituent manganese minerals of the different rock types under study were identified by examination of polished and thin sections and by X-ray diffraction analysis. As far as magnetic properties are concerned the Mn–Fe oxides are of importance. The primary oxide minerals identified in manganese protores are: bixbyite, braunite, haematite, hausmannite, jacobsite, magnetite, manganite, etc. In the zone of oxidation, they were subjected to weathering, leading to enrichment of manganese and resulting in the formation of ore. They are dissolved by meteoric waters in the process of supergene oxidation. The higher mobility of Mn than that of Fe leads to remobilization and deposition of Mn and Fe ions under favourable conditions of pH and Eh. Through this process the primary Mn–Fe oxides of lower valence state are converted into their corresponding higher oxides. On complete oxidation they are transformed into one of the higher oxides like pyrolusite or cryptomelane. Other secondary oxide minerals identified in the ores under study are romanechite, ramsdellite etc. Primary minerals also occur in the ores[3, 7–9]. Those identified in some of the ore samples under discussion are braunite, hausmannite, jacobsite, magnetite and vredenburgite. Their presence is due to either incomplete oxidation or transportation by meteoric waters.

Among the primary and secondary oxide minerals jacobsite, magnetite and vredenburgite are ferrimagnetic. The former two belong to the magnetite–hausmannite solid solution. The intermediate member jacobsite is iso-structural with magnetite[10] and it is even more magnetic than the latter. The saturation magnetization of jacobsite can be as high as 1.5 times that of pure magnetite[11]. Vredenburgite is a two-phase intergrowth of jacobsite and hausmannite. Most of the other manganese minerals are paramagnetic[12].

Specimens with their susceptibilities in the higher range (Table 1), among protores as well as the ores, were found to contain jacobsite and magnetite. Vredenburgite was found in a few ore specimens. Because of their values in the ferrimagnetic range and because of their content of ferrimagnetic minerals they are named as protore-F and ore-F. Those with susceptibilities in the range 0.42–4.4 × 10^{-3} (SI) do not contain ferrimagnetic minerals except an occasional grain of jacobsite or magnetite in a stray specimen. They are accordingly named as protore-P and ore-P. The J_n values of these two classes of specimens (ferrimagnetic and paramagnetic) are not as distinctly separate as their corresponding K values. It may be due to the fact that J_n is more complex in nature than K. In protores it may be a vector sum of TRM, VRM etc. In the ores and the other altered rock types it can be the vector sum of IRM, CRM, TRM of relic ferrimagnetic grains and any other possible components. The high values of K and J_n in protore-F and Ore-F are obviously due to the presence of ferrimagnetic minerals. The low values in protore-P and ore-P are ascribed to the paucity of ferrimagnetic minerals possibly due to leaching or oxidation in the former and complete transformation in the latter.

Lithomarge is a product of *in-situ* disintegration of protores and paragneisses. It is composed of pyrolusite, cryptomelane, ilmenite, goethite and clay. The formation of chert is by the process of chertification – the alteration of manganese silicate and deposition of the secondary silica in a colloidal state. Wad is the *in-situ* remanent of the paragneisses and/or protore. It consists of garnet, limonite, goethite and clay. It may also contain pyrolusite and cryptomelane or romanechite. The K values of these three rock types are in the general range 0.38–3.27 × 10^{-3} (SI). J_n is between 2 and 66 × 10^{-3} A/m. Few samples of the three rock types from the contact zone with ore or protore showed higher values. These ranges of J_n and K overlap those of the ore-P. The separate ranges for individual rock types are listed in Table 1. The low values of chert, lithomarge and wad may be due to the depletion of primary ferrimagnetic minerals during oxidation and leaching.

The presence or otherwise of ferrimagnetic minerals in the samples, as made out from the mineralogical study, was verified by magnetic separation. About 50 specimens, of all the rock types studied, were pulverized to –230 mesh size and the magnetic component was separated with a magnet. The volume percentage in specimens with high susceptibility and J_n is 1–37%. Specimens in the paramagnetic range yielded few grains, that could be picked up by a magnet, or none at all. The magnetic fractions thus estimated are plotted against K in Figure 3*a* and against J_n in Figure 3*b*. Values of K less than 30 × 10^{-3} (SI) plot near the ordinate and higher values are against percentages of one and above. It seems that the distribution of magnetic properties in two different ranges is because of differences in the ferrimagnetic mineral content.

The plot of J_n against magnetic content is similar to that of K and the relationship appears to be more systematic. Magnitude of NRM need not necessarily be

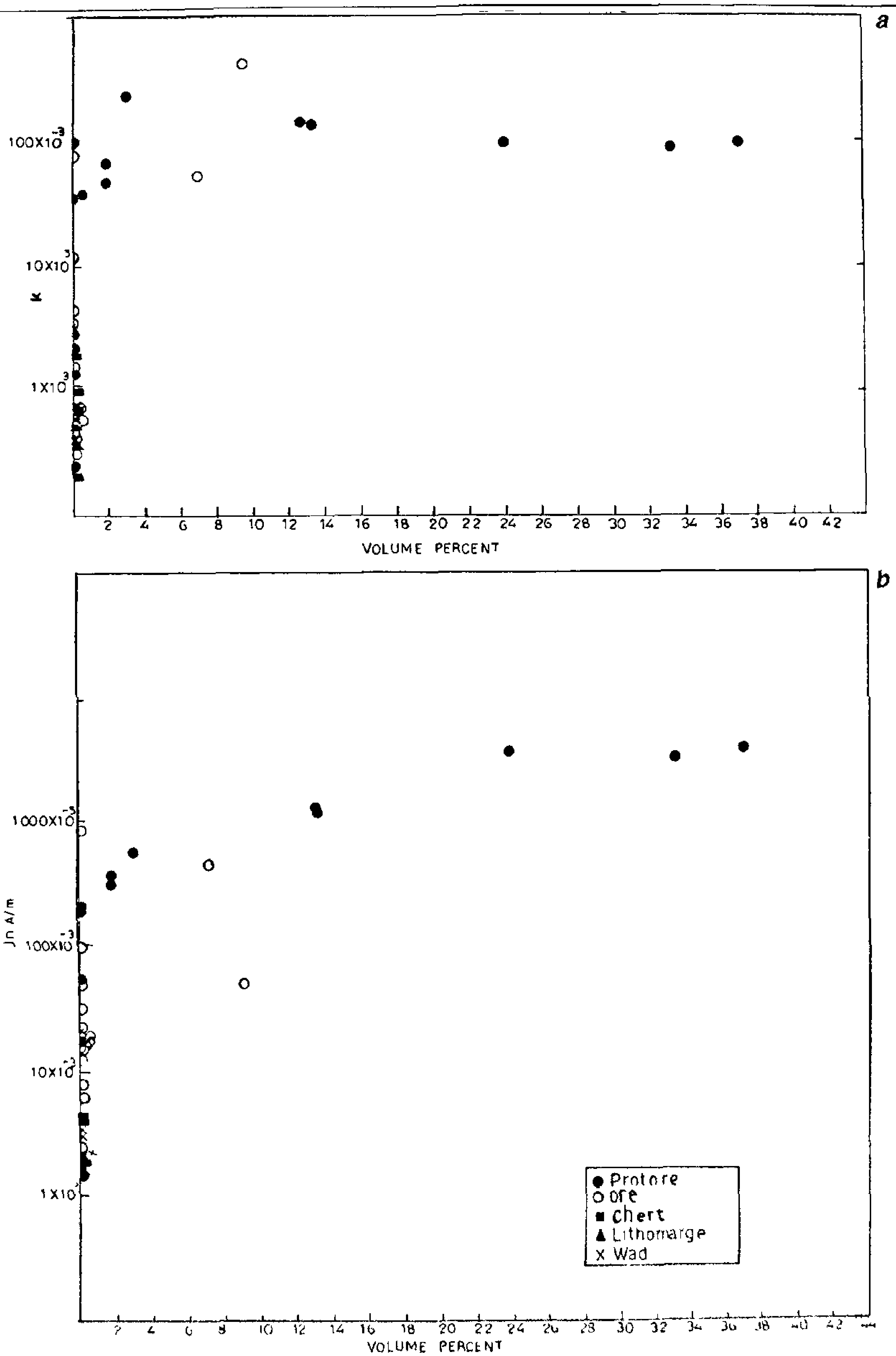

Figure 3. Plots of K (*a*) and J_n (*b*) against vol% of the magnetic fraction

related to the magnetic fraction. In addition, it depends on the composition of the magnetic minerals, nature of magnetization, domain states, the number of domains aligned along a common direction etc. It may possibly be the vector sum of many components of magnetization acquired at different times. But its dependence on magnetic fraction (Figure 3 *b*) leads one to infer that a large part of the magnetization is viscous (VRM) or isothermal (IRM) in nature. The Q_n values, which are sometimes used to assess magnetic stability, seem to corroborate this inference. The values of all the rock types are in the same broad range with a lognormal and unimodal distribution. This is consistent with the fact that magnetizations are controlled by minerals of the spinel group only. The average values of all the rock types (Table 1) are less than 0.5. Rocks with such values are dominated by MD (multi domain) grains[19]. The protores under study are coarse-grained with grain sizes of 2 mm or more being common[14]. The other rock types are the altered products of protore or paragneisses. From these considerations, the magnetizations in all the rock types seem to be soft. Such natural remanent magnetizations are not likely to be much different in direction from the induced magnetization. Direction of the latter normally coincides with that of the ambient geomagnetic field. These inferences lead to the conclusion that the contributions of these two components of magnetization to the magnetic anomalies are likely to be complementary to each other. Differences in magnetic properties caused by differences in the concentration of magnetic minerals are indicative of the extent of leaching and oxidation in these rock types rather than their original composition.

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ACKNOWLEDGEMENTS. The measurements were made at the National Geophysical Research Institute, Hyderabad The authors thank the Director, NGRI for providing the facilities The cooperation extended by Dr M S Bhalla and Dr G V S Poornachandra Rao of the Palaeomagnetic Division, NGRI is thankfully acknowledged The help of Sri T Kameswara Rao, Faculty Member, Training Institute, Geological Survey of India, Hyderabad, in the mineralogical examination of the samples is gratefully acknowledged

Received 20 July 1993; revised accepted 20 November 1993

Occurrence of monazite in some alluvial soils of North Bihar

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Monazite, a thorium-bearing mineral, has been identified in the heavy mineral fractions of the fine sands from the alluvial soil profiles at Barpalia and Gyaspur of Siwan district in north Bihar. The amount of monazite varied from 14.29 to 15.40% and 6.25 to 9.38% of the heavy minerals in the fine sands of Barpalia and Gyaspur, respectively. Monazite could have been derived from the granite pegmatite and gneissic metamorphic rocks in association with feldspar, zircon and apatite from the Himalayan orogan. The amount of ^{232}Th present in monazite originally ranges from a few wt% ThO_2 to 10–12%[1]. Even in the east coast of India, monazite contains 9.05% ThO_2.

MONAZITE, a (Ce, La, Th) (PO_4), occurs only in the finer fraction of the sediments[2]. Compared to Kerala coast[3], Chilka lake coast contains monazite only in a small amount (0.16–0.88%)[2] in the heavy minerals of the fine sand fraction. Even in the east-coast, its percentage in the coastal sediments was estimated to range from 0.5 to 3.0% (ref. 2), while in the Travancore coast, its percentage was as high as 10.22% (ref. 1). Although thorium is present in monazite in substitution for cesium and lanthanum, thorium-free monazite is rare[1]. It is, moreover, observed that the intensity of radioactivity is proportional to the average monazite content and the level of radioactive intensity in the region may be due to occurrence of monazite even in traces. The present investigation was accordingly undertaken to identify the presence of monazite in some alluvial soils of the Indo-Gangetic plain of north Bihar quantitatively. No data on these aspects for all alluvial soils, particularly of north Bihar, are available. However, in India, monazite is known to occur in Travancore, Gaya and Ratnagiri[1] besides coastal sediments near Chilka lake[2].