

5. This is a point on a variety where it is impossible to find local holomorphic coordinates i.e. a point where the variety is not a complex manifold.
6. More general results are obtained in Srinivas, V., *J. Reine Angew. Math.*, 1985, **359**, 90; 1985, **362**, 4.
7. i.e. every term  $x^i y^j k^k$  which occurs in  $f$  with a non-zero coefficient has  $i+j+k=d$ .
8. Murthy, M. P. and Swan, R. G., *Invent. Math.*, 1976, **36**, 125.
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10. These identities may remind the reader of the rules for adding and multiplying complex numbers  $a+ib$ , where  $a, b$  are real numbers, and  $i^2 = -1$ ; here, polynomials in  $x$  and  $y$  play the role of real numbers, while  $z$  plays the role of  $i$ .
11. A matrix of complex numbers, whose determinant is 1, can always be reduced to the identity matrix by row and column operations with complex coefficients; an  $n \times n$  matrix of polynomials in  $m$  variables (i.e. algebraic functions on  $\mathbb{C}^m$ ), with  $n \geq 3$ , and determinant 1, can be reduced to the identity by row and column operations with polynomial coefficients; this is a result of Suslin, A. A., *Izv. Akad. Nauk S.S.S.R.*, 1977, **41**, 235.
12. Srinivas, V., *J. Reine Angew. Math.*, 1987, **381**, 37-50.
13. See Quillen, D., *Lect. Notes in Math. No. 341*, Springer-Verlag, New York, 1973; Grayson, D., *Lect. Notes in Math. No. 551*, Springer-Verlag, New York, 1976; Srinivas, V., *Algebraic K-theory*, a book based on lectures at Bombay, due to appear shortly.
14. This is not standard terminology.
15. i.e. there are sub-bundles  $F_1 \subset F_2 \subset F$ , together with an isomorphism of  $E$  with the quotient  $F_2/F_1$ .
16. To be precise, define  $K_i(Y) = \pi_{i+1}(K(Y))$ .
17. i.e. the homotopy groups of the homotopy fibre of the mapping  $K(Y) \rightarrow K(C)$ , induced by restriction of vector bundles from  $Y$  to  $C$ .

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## Magnetic properties of manganese ores of Vizianagaram district of Andhra Pradesh

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Natural remanent magnetization (NRM) and magnetic susceptibility of manganese ores from the Vizianagaram district of Andhra Pradesh were measured. The NRM values are in the range  $0.1 \times 10^{-5}$ – $118 \times 10^{-3}$  e.m.u. while the susceptibility values are between  $3 \times 10^{-5}$  and  $18 \times 10^{-3}$  c.g.s. Samples containing minerals like jacobsonite and vredenburgerite have high values. Increase in NRM, in general, is associated with an increase in susceptibility. The koenigsburger ratios range between 0.02 and 61.7, with most of them below unity. Multidomain magnetic grains in the unaltered ores and the effect of supergene processes in the case of secondary ores may account for the koenigsburger ratios.

MANGANESE ore deposits in the Vizianagaram district of Andhra Pradesh are distributed in a belt between north

latitudes  $18^\circ 13'$  to  $18^\circ 30'$  and east longitudes  $83^\circ 13'$  to  $83^\circ 45'$ . The geological formations in the area belong to the khondalite group comprising of quartzites, garnetiferous quartzites, quartz-garnet-sillimanite gneisses, graphite-sillimanite-gneisses, calc-granulites, calciphyres, crystalline limestones, manganese silicates and manganese ores. Manganese ore occurs in close association with calc-granulites and garnetiferous quartzite. The metamorphosed manganese silicate-carbonate, commonly known as protore, occurs within and conformable to the khondalite group of formations.

The manganese ores in Eastern Ghats are of sedimentary origin. During regional metamorphism subsequent to their deposition, the manganese sediments are reconstituted to protore. Epigenic activity resulted in the formation of secondary ore deposits conformable with the associated rock types.

Geological aspects of the deposits have been reported earlier<sup>1-5</sup>. Prospecting for some of these ore deposits by magnetic method and a study of the magnetic properties were attempted by Bhimasankaram<sup>6,7</sup>.

For the present study manganese ore samples were collected, on a pilot scale, from different localities (Table 1). The intensity of natural remanent magnetism (NRM) and magnetic susceptibility was measured. A total of 23 samples were collected and cylindrical specimens (2.5 cm diameter and of even length) were drilled out of them. These specimens were used in the determination of magnetic properties. NRM intensity was measured with an astatic magnetometer of appropriate sensitivity. A susceptibility meter<sup>8</sup> was used for measuring the magnetic susceptibility at a field strength of 0.5 Oe.

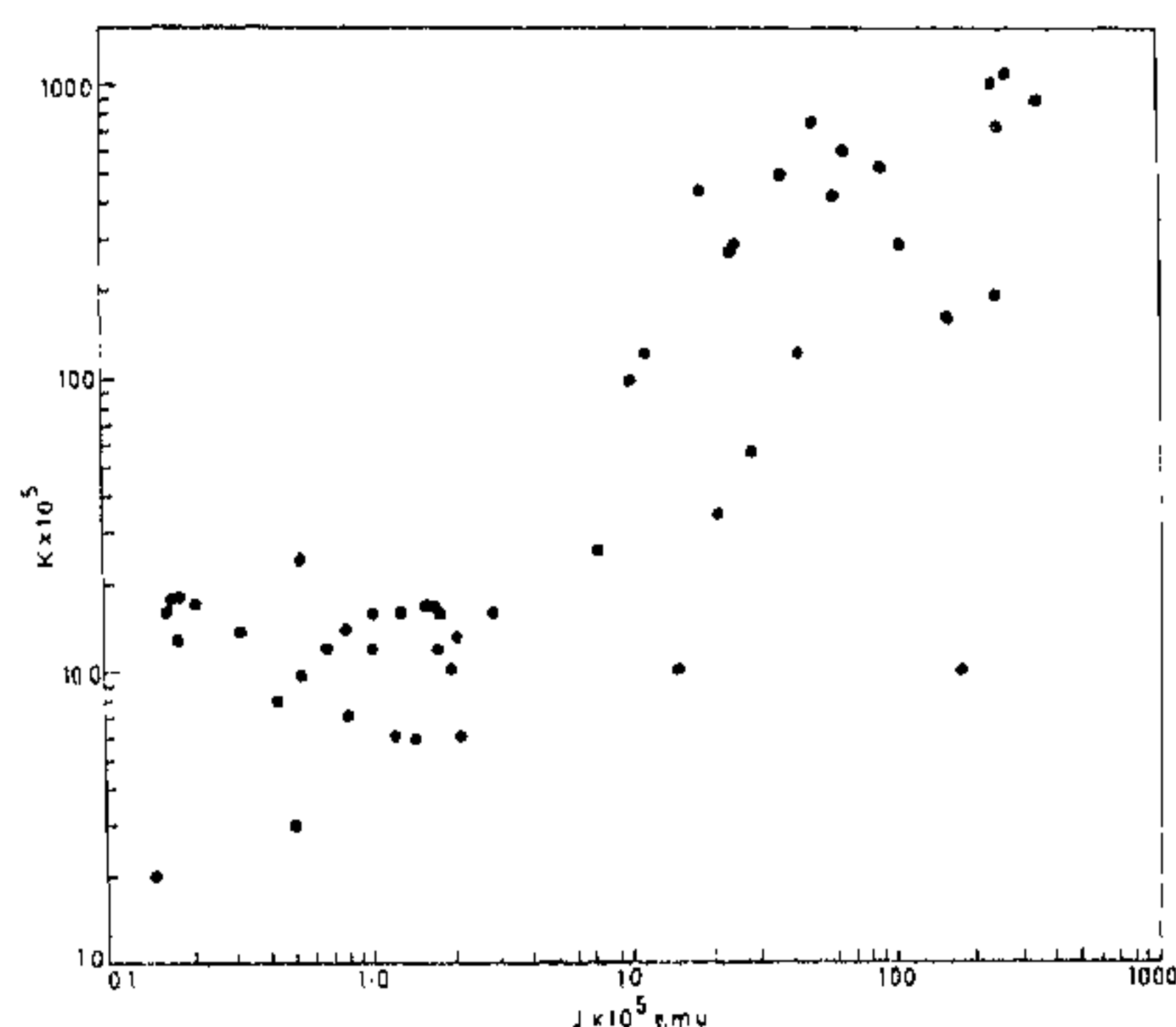
The measured values of NRM intensities were in the range  $0.1 \times 10^{-5}$  to  $118 \times 10^{-3}$  e.m.u. while the magnetic susceptibility values range between  $3 \times 10^{-5}$  and  $18 \times 10^{-3}$  c.g.s. The average values for different sites are given in Table 1. Koenigsburger ratios,  $Q_n = J_n/KH$  for  $H = 0.5$  Oe., were calculated using the measured values of  $J_n$  and  $K$ . They range between 0.02 and 61.7. The ranges and average values are also listed in Table 1. Samples from Sadanandapuram have the highest NRM intensity and  $Q_n$  values. In the case of magnetic susceptibility, samples from Chipurupalle have the highest values followed by those from Sadanandapuram. Samples from Gadabavalasa have low  $Q_n$  values.

The samples, in general, contain pyrolusite and psilomelane. Some of them from Sadanandapuram contain, in addition, jacobsonite, braunite, bixbyite, limonite, hausmanite and traces of vredenburgerite and magnetite probably accounting for the high values of NRM intensity and susceptibility. The ore samples from Chipurupalle, having high susceptibilities, are in the relict stage. Sivaprakash<sup>9</sup> observed that primary minerals at Devada are far less than at Sadanandapuram and Chipurupalle. Therefore, there appears to be a

**Table 1.** Magnetic properties of manganese ores.

Site	Number of samples	Number of measurements	$J_n (\times 10^{-5})$		$K (\times 10^{-5})$		$Q_n$	
			Range	Average	Range	Average	Range	Average
Sadanandapuram	5	18	0.32–11815	1.24(9) 35.5(6) 9370(3)	10.0–1800	12.1(9) 366.0(9)	0.11–0.71 33.3–61.7	0.25(15) 51.31(3)
Devada	2	4	0.4–181	—	3.0–10	7.7	0.11–3.12	1.19
Garbham	8	13	0.16–30	7.0	12.0–156	46.5	0.02–1.27	0.26
Gadabavalasa	4	7	0.1–2.9	1.7	8.0–26	12.3	0.02–0.57	0.17
Chipurupalle	4	13	0.16–356	79.0	2.0–1114	638.0	0.16–0.81	0.41

Numbers in parentheses indicate the number of observations averaged.

**Figure 1.** Plot of NRM intensity ( $J_n$ ) against susceptibility ( $K$ ).

relationship between mineralogy and the magnetic properties. In Figure 1, NRM intensities are plotted against magnetic susceptibilities. Increase in NRM intensity, in general, is associated with an increase in susceptibility. Such a relationship was observed for massive haematite (containing no other iron-bearing mineral)<sup>10</sup>. Bhimasankaram<sup>6</sup> observed an approximate linear relationship between magnetic susceptibility and normative amount of (Mn,  $\text{Fe}_3\text{O}_4$ ). From Figure 1, it appears that the magnetic minerals responsible for an increase in susceptibility are also likely to enhance NRM as far as the samples under study are concerned.

The ratio  $Q_n$  is generally used as an indicator of magnetic stability in palaeomagnetic work. In igneous and volcanic rocks magnetizations with high  $Q_n$  are considered stable. A criterion, based on  $Q_n$ , for assessing the stability in sedimentary rocks was earlier formulated and used<sup>11</sup>.  $Q_n$  values also reflect the grain size or the domain structure of ferrimagnetic minerals. Usually, the values for multidomain grains range<sup>12</sup> between 0.2 and 1.0. Values for sediments may be close to zero<sup>13</sup>. A high  $Q_n$  value indicates the presence of fine grains. The values in Table 1 indicate that in most cases the magnetic grains are multidomain in nature. In some of

the manganese ores under consideration the primary minerals were altered to secondary oxides by supergene processes. Therefore, minerals deposited after being transported by meteoric waters may resemble sediments, in general, as far as  $Q_n$  values are concerned thereby accounting for the low values. The three high values of  $J_n$  and  $Q_n$  in the case of Sadanandapuram, seem to be due to an isothermal component of magnetization.

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