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ZONED SEDIMENTARY MAGNETITES FROM PRECAMBRIAN BANDED IRON FORMATION OF EASTERN INDIA

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Abstract

Electron microprobe study of low temperature zoned magnetite grains of primary sedimentary origin from the Precambrian banded iron formation (BIF) of Eastern India revealed alternate micro-bands rich in silica and iron, while minor concentration of magnesium is also found in silica-rich bands. X-ray data indicate a normal type of magnetite structure and trace element values support its primary sedimentary origin. Origin of the zoning in magnetite is attributed to enrichment of Si and Fe in alternate bands on a microscale simulating the alternate silica and iron rich bands of the host-rock—banded iron formation.

Introduction

Reports of compositional zoning in low temperature authigenic magnetite are rare, compared to those from magnetite of igneous and metasomatic origin (Davidson and Willie, 1965; Shcheka *et al.* 1977). During the study of the Precambrian banded iron formation of some Eastern Indian deposits, the authors observed zonal texture in magnetite grains. It is conspicuous after etching magnetite grains from the iron oxide mesobands that are believed to be of low temperature sedimentary origin.

The authors previously attributed the zoning either to differential distribution of elements like Al, Mg or Ti in trace quantities or to oxidation of iron to different valency states (Chakraborty and Majumder, 1971). With the availability of microprobe data, it is now possible to study the distribution of elements in the individual grains and suggest probable mechanisms for development of zoning.

Mineralogy of Zoned Magnetite

Samples of magnetites of primary sedimentary origin (Majumder and Chakraborty, 1977), collected from the Precambrian BIF of Orissa, on etching with HF (1 : 1) revealed zonal growth texture when viewed under reflected light in polished sections. The zonal growth in the individual magnetite grains consists of microbands which are alternately dark and light in colour (Fig. 1). The light-coloured bands obviously have slightly higher reflectance compared to the adjacent darker bands.

The individual bands are generally parallel and maintain more or less uniform thickness. In some grains the sequence of bands constituting zoning are normal to each other while in others they make angles of 75°–85° (Fig. 3a).

Under reflected light, total isotropism is shown by all the bands, X-ray study of a small extracted portion gave a cell parameter: $a = 8.394 \pm 0.005$Å, the standard ISTM value being 8.396Å. This indicates that these zoned magnetites are structurally similar to normal magnetite.

Trace element content of zoned magnetite determined by emission spectroscopy of an extracted portion is presented in Table I along with the values of unzoned normal magnetites, both the samples are from the same sedimentary environment and locality. Table I shows that there is no significant difference in trace element

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content between the zoned and unzoned magnetites. The characteristic low content of Ti (<10 ppm) and Co/Ni ratio below 0.1 substantiates the sedimentary origin of the zoned magnetites (Frietsch, 1970, Majumder *et al.* 1982) in the iron formations.

TABLE I. Distribution of trace elements (ppm) in zoned and normal sedimentary magnetite from banded iron formation of Orissa, India.

Element	Zoned Magnetite	Normal Magnetite
Ba	10	10
Co	<10	<10
Cr	<5	<5
Cu	20	10
Mn	1000	900
Mo	10	<5
Ni	140	60
Pb	<10	<10
Sr	<10	<10
Ti	<10	<10
V	30	20
Zr	<10	<10

Analyst ; Shri S. B. Das, Geological Survey of India) Calcutta.

TABLE II. Electron probe analysis of three spots of a primary sedimentary magnetite showing zoned structure, from banded iron formation of Orissa, India.

Oxide %	Spot 1	Spot 2	Spot 3
SiO_2	0.25	1.91	1.41
Al_2O_3	0.23	0.08	0.04
Fe_2O_3	96.07	96.77	97.19
MgO	0.17	0.71	0.56
MnO	0.12	0.19	0 20
CaO	0.10	0.01	0.00
TiO_2	0.00	0.00	0.00
Total	*96.94*	*99.67*	*99.39*

Fe_2O_3 represents total iron.
Spots 1, 2 and 3 are shown in Fig. 3(a).

Electron Probe Study

Electron probe analyses of some of the samples of zoned magnetite were carried out to decipher the distribution of elements and the cause of zoning. Figs. 2a and 3a show the secondary electron image of some of the zoned specimens. The bands are normal to each other in Fig. 2a, while in Fig. 3a, the bands are inclined to each other. The observed difference in the interfacial angle between the bands are possibly due to different orientation of the polished faces (Zimmermann and Amstutz, 1973). Partial major element analyses at three locations, as shown in Fig. 3a by electron probe of the core area and two adjacent bands in a single zoned magnetite grain are given in Table II. From Table II, it appears that cations other than Si and

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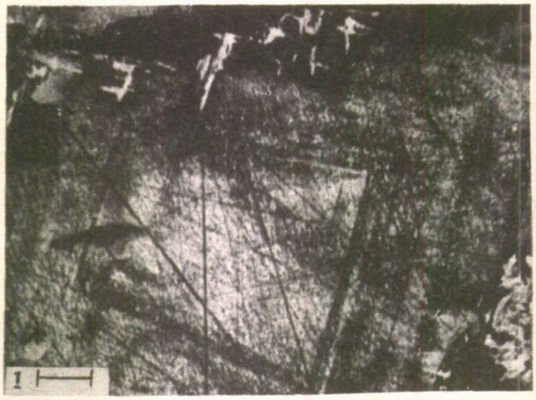
EXPLANATION OF FIGURES

Fig. 1. Photomicrograph of etched magnetite showing zoned structure under reflected light. One nicol, air, Bar equals 0.2 mm.

Fig. 2. (a) Secondary electron image of zoned magnetite with bands normal to each other. Bar equals 20 microns. (b) and (c) X-ray scanning photograph of grain as in Fig. 2 (a) showing the distribution of silica and magnesium in the bands. Note similar bands showing enrichment. Bar equals 20 microns.



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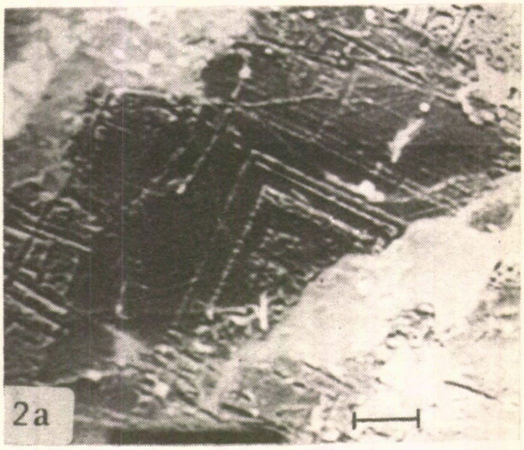

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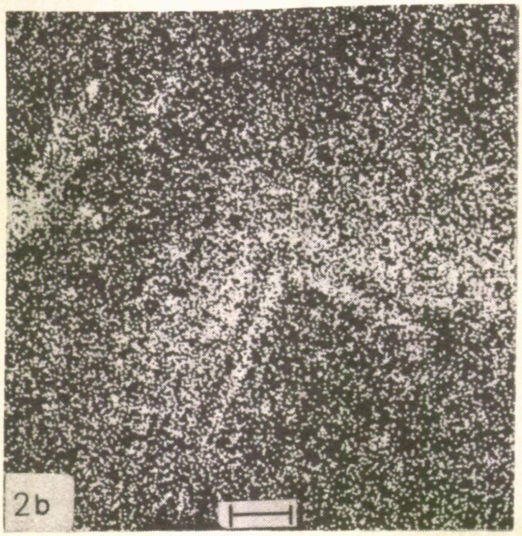

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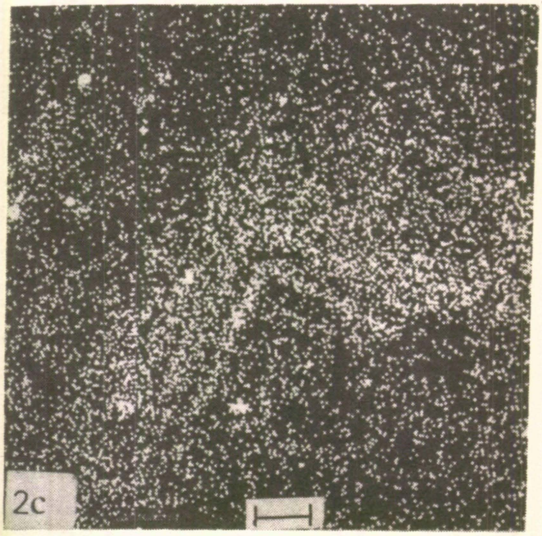

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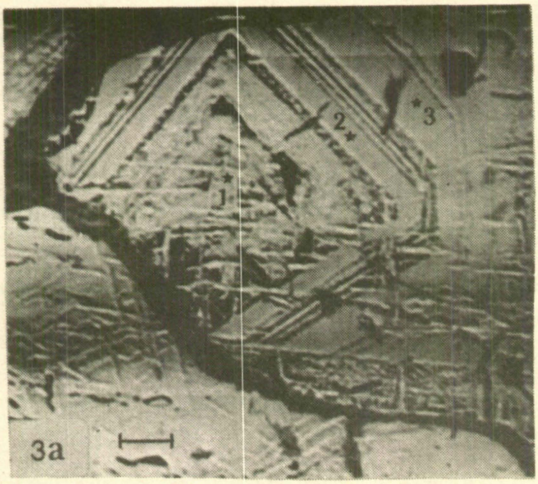

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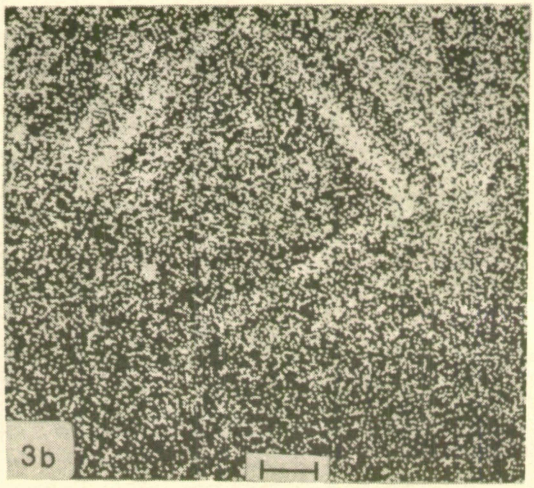

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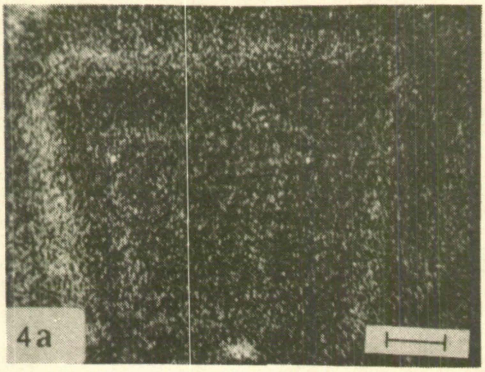

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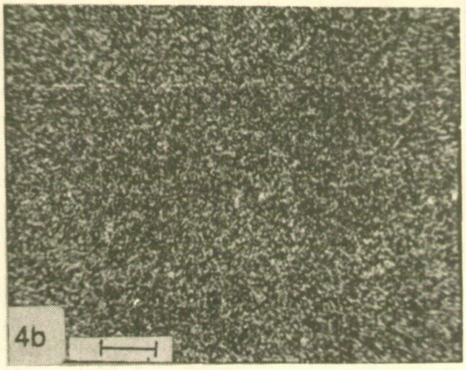

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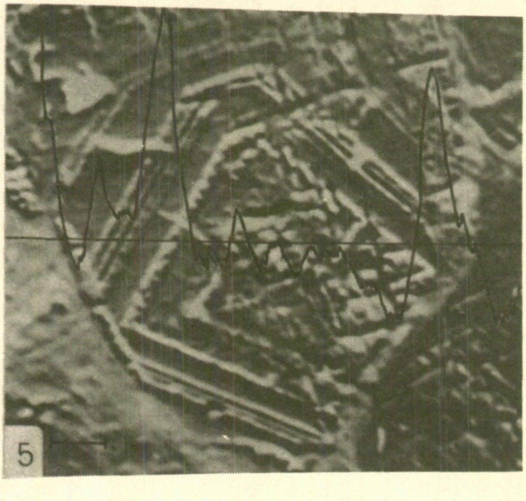

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Fe are not present in significant amount. The difference in total at Spot 2 is due to the presence of possible water molecule.

The development of zoning by differential oxidation of iron into bi- and trivalent states is ruled out in view of the nearly uniform distribution of oxygen as shown in Figure 4b of a zoned sample of magnetite. Figure 4a shows the distribution of silica in the sample, where alteration of silica enrichment in bands is visible. Such concentration of Si and Fe in alternate bands in individual zoned crystals is also seen in Figures 2b and 3b while Figure 5 shows the scan line for Si in one such zoned crystal. Mg is concentrated in Si-enriched bands (Fig. 2c) and is relatively depleted in the Fe-enriched bands.

The ionic radius of Mg^{+2} is 0.57Å in tetrahedral coordination while those of Si^{+4}, Fe^{+2} and Fe^{+3} are 0.26Å, 0.63Å and 0.55Å respectively (Henderson, 1982). Hence, according to thermodynamic principles, Mg cannot replace Si due to large difference in ionic radius exceeding 15% and valency exceeding by 1. Therefore, in all probability, Mg remained absorbed in the structure of magnetite. Further, as the magnetite under present study is considered to be of primary sedimentary origin as borne out by texture, environment and trace element data (Majumder and Chakraborty, 1979 ; Majumder *et al.* 1982) where cation substitution is not normally expected.

The sedimentary environment provides some guidance for possible explanation of zoning. In macroscale, the host rock for the magnetite is the BIF composed of alternate bands enriched in iron oxide and silica admixed with varying amounts of iron oxides. These chemically precipitated rocks were formed in low energy shallow water environment (Majumder and Chakraborty, 1979), where due to minor but significant change in the Eh and pH in the depositional environment, alternate bands rich in silica and iron oxide were precipitated.

From the above discussion and major element distribution in the zoned magnetite crystals as revealed by electron probe study, enrichment of silica and iron in alternate bands on a micro-scale, are presumably analogous to meso- and micro-bands in the banded iron formation.

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EXPLANATION OF FIGURES

Fig. 3. (a) Secondary electron image of zoned magnetite with bands at an angle to each other. 1, 2 and 3 are spots analysed as in Table II. Bar equals 20 microns. (b) X-ray scanning photograph of silica distribution in the grain of Fig. 3 (a). Bar equals 20 microns.

Fig. 4. (a) and (b) X-ray scanning photograph of silica and oxygen distribution in the grain of Fig. 3 (a). Bar equals 20 microns.

Fig. 5. Superposed scanline of silica on secondary electron image of the grain in Fig. 3 (a). Bar equals 20 microns.

References

CHAKRABORTY, K. L. and MAJUMDER, T., (1971) Zoning in sedimentary magnetites. Jour. Geol. Soc. India, v. 12, pp. 402-403.

DAVIDSON, A. K. and WILLIE, P. J., (1965) Zoned magnetite and platy magnetite in Cornwell' type ore deposit. Econ. Geol., v. 60, pp. 766-772.

FRIETSCH, R., (1970) Trace elements in magnetites and hematite. Sveriges Geol. Unders. Arsbok, v. 64, p. 136.

HENDERSON, P., (1982) Inorganic Geochemistry. Pergamon Press, London, 353 p.

MAJUMDER, T. and CHAKRABORTY, K. L., (1977) Primary sedimentary structures in the Banded Iron Formation of Orissa. Sedimentary Geology, v. 19, pp. 287-300.

——— (1979) Petrography and Petrology of the Precambrian Banded Iron Formation of Orissa, India and reformation of the bands. Sedimentary Geology, v. 22, pp. 243-265.

MAJUMDER, T., CHAKRABORTY, K. L. and BHATTACHARYA, A., (1982) Geochemistry of Banded Iron Formation of Orissa, India. Mineralium Deposita, v. 17, pp. 107-118.

SHCHEKA, S. A., ROMARENKO, I. M., CHUVAROV, V. M. and KORENTSAVA, N. A., (1977) Silica-bearing magnetite. Contrib. Mineral. Petro. v. 63, pp. 103-111.

ZIMMERMAN, R. A. and AMSTUTZ, G. C., (1973) Relation of section of cubes octahedra and pyritohedra. N. Jb. Mineral Abh., v. 120, pp. 15-30.

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