STRUCTURAL FEATURES IN THE GHORIAJOR MANGANESE BELT, SUNDARGARH DISTRICT, ORISSA

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Introduction: The Ghoriajor manganese belt falls in Survey of India toposheet No. 73 B/SW and is located in the west-central part of Sundargarh district, Orissa. The prominent village of Ghoriajor (22°03′ : 84°08′), around which mining for manganese ore was active in the past, is situated at about 11 km from Dharuadihi railway station on the South-Eastern Railway. Besides Fermor, Krishnan (1937), investigated the economic potentiality of this belt during his mapping of the 'Gangpur Series'. Other workers who studied the 'Gangpur Series' include Sarkar and Dutt (1958), Mukherjee (1961), Kanungo and Mahalik (1967) and Banerjee (1969). The Ghoriajor manganese belt had been hitherto studied from economic angle only, but no detailed study of the structures present in the rocks was attempted. The present work has been undertaken mainly to study the salient structural features of this belt with a view to understand the controls of manganese ore mineralization. A total area of 60 sq km in three selected sectors falling between lat. 22°01′55″ and 22°09′25″ and long. 84°07′52″ and 84°13′47″ was mapped by the author on the scale 1 : 15,840. (Fig. 1).

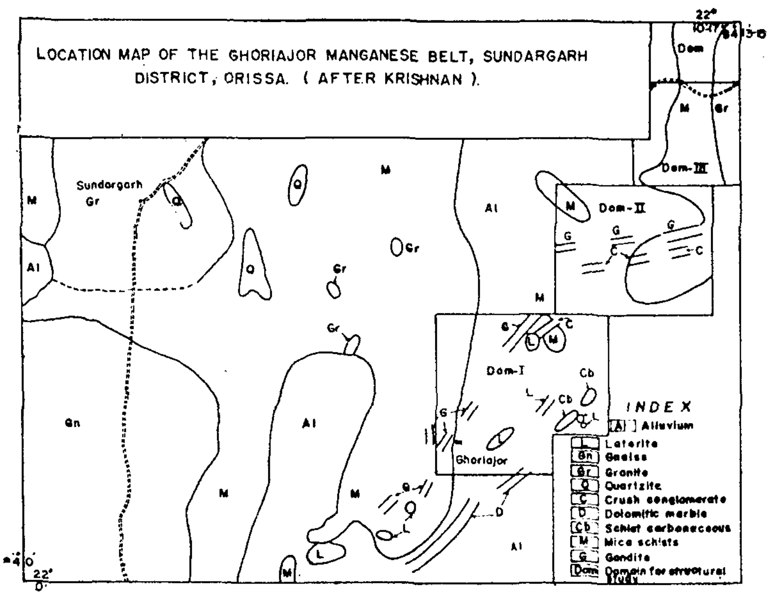

Figure 1.

Geological setting: The Ghoriajor manganese belt forms the central part of Gangpur Group of metamorphosed calcareous, pelitic, psammitic and manganiferous sediments. The characteristic rocks of this belt are the gondites, which occur as impersistent bands and lenses within the mica schists and phyllites of 'Ghoriajor Stage' of Krishnan. The principal rock formations include dolomitic marbles, banded carbon quartzites and carbon phyllites interbedded with mica schist bands, sheared quartzite/conglomerate, mica schists intercalated with impersistent bands of gondite and manganiferous bodies, garnetiferous mica schists and coarse-grained whitish quartzite.

Domain classification: For purposes of structural study, the area has been divided into three domains based on the strikingly different foliation trends within the rocks. In the domain-I (named Ghoriajor domain), enclosed by the parallels of latitude 22°01′55″ and 22°05′00″ and longitude 84°07′52″ and 84°11′08″, the foliation of the rocks strikes NE-SW to ENE-WSW. In the domain-II (named Ghantbur domain), bounded by the parallels of latitude 22°05′00″ and 22°07′05″ and longitude 84°11′04″ and 84°13′30″, the foliation of the rocks strikes WNW-ESE. In the domain-III (named Itma domain), bounded by the parallels of latitude 22°07′05″ and 22°09′25″ and longitude 84°13′06″ and 84°13′47″, the foliation of the rocks strikes NNW-SSE.

Structural elements and analysis: The principal structural elements studied by the author in the above three domains are: (1) bedding, (2) foliation, (3) fracture cleavage, (4) lineations, (5) mesoscopic folds and (6) joints.

Bedding is noticed in the carbonaceous horizons, gondites and quartzites and is mostly defined by colour and compositional bands, the gross lithological contacts being generally parallel to them. The *foliation and bedding* are sub-parallel in the area, dipping due southeast and southwest respectively in the three domains. The axial planes of folds in this area have NE-SW trends with subvertical dips or steep dips towards southeast (Banerjee, 1969). The parallelism of foliation and fold axial planes in the belt suggests the foliation to be of 'axial-plane' type. The foliation is generally shown by parallel layers of flaky or flattened minerals like sericite, chlorite, muscovite, biotite and quartz. A plot of the foliation poles from the three domains is shown in Fig. 2.

It is seen in Fig. 2 that the folds with S40° – 50°E axes are prominent in the domains I and II, whereas in domain-III, the fold with southerly axis is distinct. Two sets of *fracture cleavage* are quite conspicuous in the area, (i) NNW-SSE to NW-SE trend and (ii) NE-SW to NNE-SSW trend, both dipping at steep angles, the former towards SW and the latter towards SE. These two sets are related to the two folds mentioned earlier. The poles of the two sets of fracture cleavages are plotted in Fig. 3.

It is distinctly seen in the plot that the axial planes of the folds in the present area strike NE-SW and NNW-SSE, both dipping at steeper angles of 70°. Two prominent crinkle and mineral *lineations* marked by the alignment of biotite streaks and sericite flakes, termed L_1 and L_2, are well developed in the mica schists of the region. The L_1 is always found warped and refolded by the relatively rectilinear L_2 lineation. That the L_2 lineation is younger to L_1 is further corroborated in the field by unrolling. A striation (grooving) lineation in banded carbon quartzites and phyllites, quartz rodding in mica schists and a pebble elongation lineation in a sheared quartzite/conglomerate horizon observed in domains D-I and D-II are parallel to L_2. The lineation formed by the trace of fracture cleavage along NNW-SSE trend on the foliation plane, which is observed frequently, coincides with the L_2 lineation.

The plots of L_1 and L_2 lineations for the three domains are shown individually in Fig. 4 and striation and pebble elongation lineation for the domains I and II in Fig. 5.

The following interesting features emerge from the above plots: (i) two very prominent lineations viz. S50°E and S11° – 15°E are brought out by the plots. These two directions are respectively parallel to the Betas obtained by Pi-pole plot of the foliation planes (Fig. 2). It would, therefore, seem that at best two folds exist in the area on the foliation, both the folds being paralleled by crinkle and mineral lineations. The L_2 and L_1 directions are parallel to the axis of the folds due S10° – 15°E (termed F_2 folds) and S50°E (termed F_1 folds) respectively. (ii) As has already been mentioned, the L_2 lineations consistently refold the L_1 lineations indicating that F_2 folds are younger to F_1 folds. This is further corroborated by the L_1 plot of domain-III, where the L_1 lineation is seen plunging due S40°W. The refolded F_1 folds lie at approximately equal angular distance from the F_2 folds, which agrees with the angle between

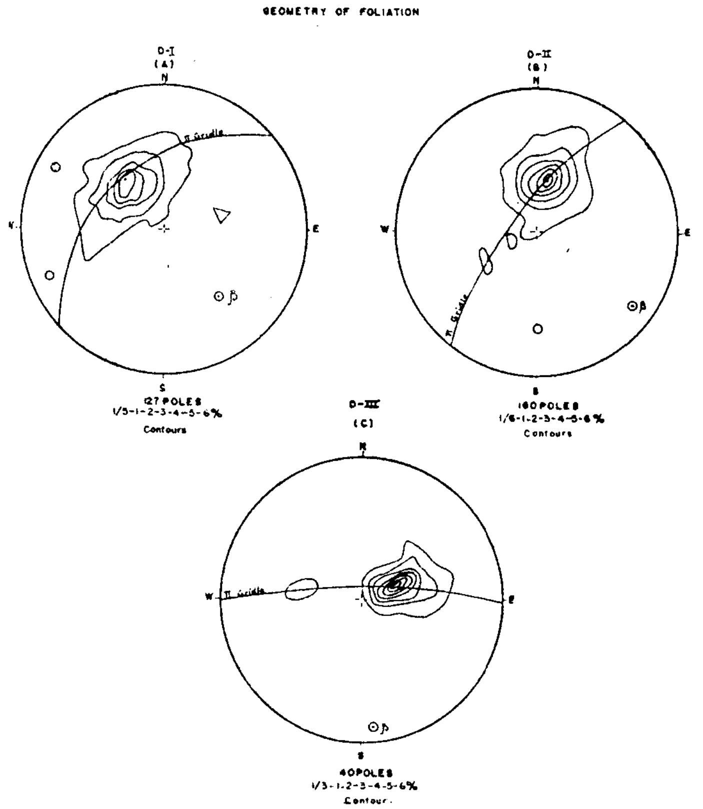

Figure 2.

L_1 and L_2 measured in hand specimens. (iii) The L_2 lineations show variations in the amounts of the plunge from 21° – 31° in domains I and II to sub-horizontal in domain-III. The lower (sub-horizontal) plunge of the L_2 lineations in the domain-III might indicate the presence of the hinge zone of F_1 fold, on which the former is superimposed.

A plot of the *mesoscopic fold* axes collected from the area is shown in Fig. 3. A distinct concentration in the SE quadrant and an ill-defined scattered concentration due east and west (and due SW also) are seen in the plot. All these appear to represent the first east-west fold described by Mukherjee (1961) and Banerjee (1969) in the eastern Gangpur. The former has also mentioned the presence of diagonal cross folds with their axes plunging due south in the southeastern part of Sundargarh district. The relative rarity of mesoscopic folds plunging due south in the present area suggests that the second folds (cross folds) are represented only on the macro- and micro-scales as seen by the arcuate swinging of the quartzite and gondite bands at places, the fine crenulations of small wavelength and amplitude and the broad warping of the schistosity planes in mica schists in thin sections.

A plot of the poles of *joints* in the domains I and II is shown in Fig. 6. A study of the figure reveals that the trend N50°W is characteristic of all the domains and this is parallel to the second fold present in this area. The trends N20° – 25°W are also parallel to the second cross fold in the area. The trends N40° – 70°E and N80°W are longitudinal joints.

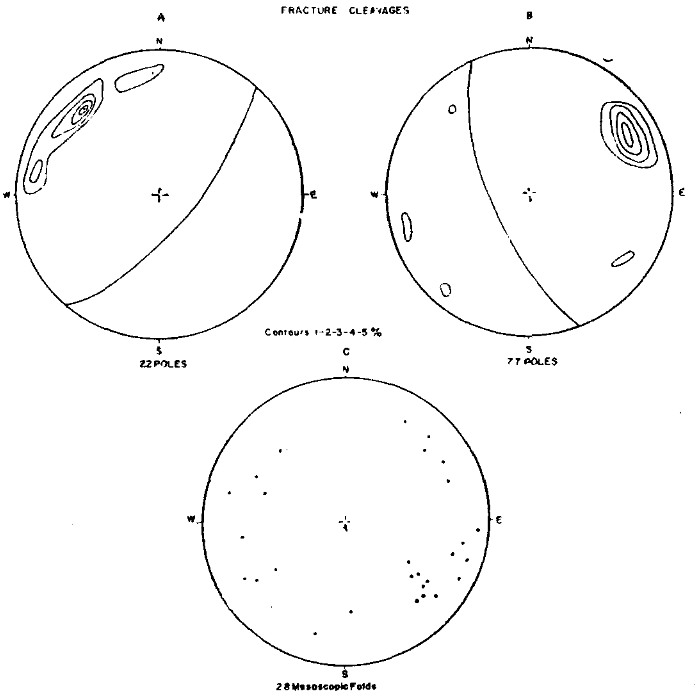

Figure 3. Plot of fracture cleavages and mesoscopic folds.

A few shears with trends along NW-SE to NNW-SSE and WNW-ESE, marked by ubiquity of silicification, are also noticed in the mapped area.

The analysis of the different structural elements in the three domains may now be summarised as follows:

(i) The rocks examined in all the three domains of the Ghoriajor belt were folded about two axial trends namely, S50°E- and S10° – S15°E. The two folds are respectively labelled as F_1 and F_2 folds.

(ii) The F_1 folds plunge at low to moderately steep angles due S50°E, while the F_2 folds have sub-horizontal to low axial plunge due S10° – 15°E.

(iii) Both the folds have mineral and crinkle lineations (L_1 and L_2) parallel to their axes. The lineation L_1 is found to be older to L_2. as evidenced by the rotation of the former by the latter, which is further confirmed by unrolling method in the field.

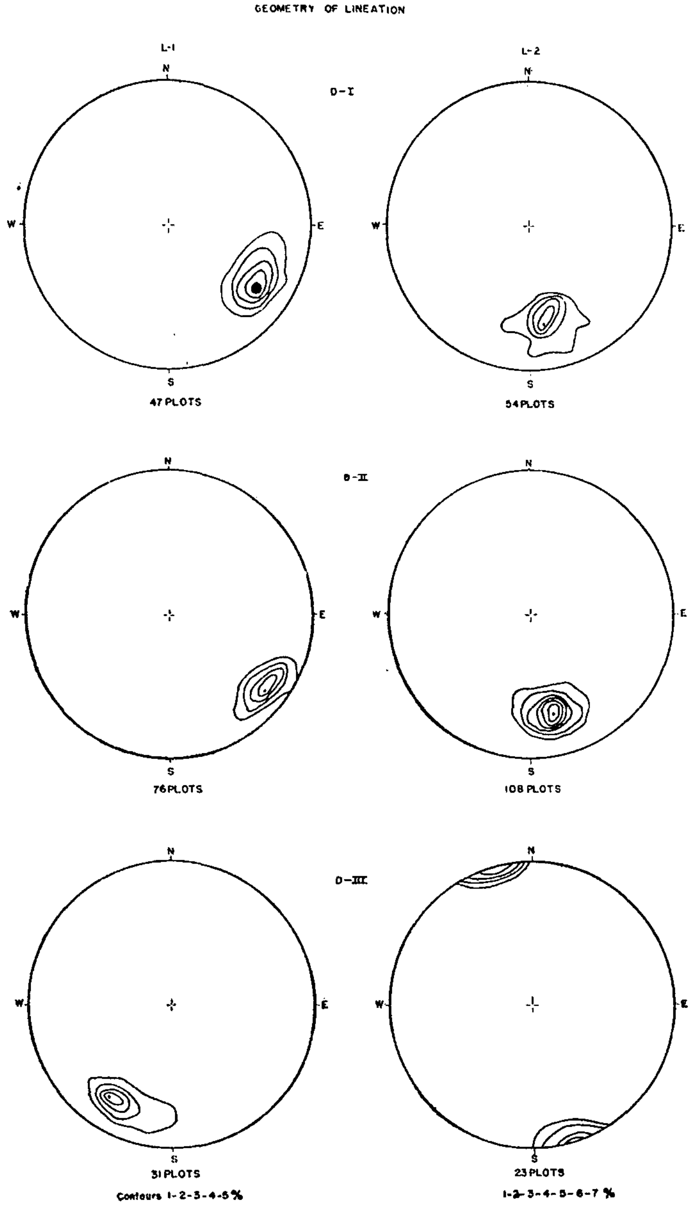

Figure 4.

(iv) Thus it is clear that F_1 folds, which are paralleled by the L_1 lineation are older than the F_2 folds, whose axes are paralleled by the L_2 lineation. The above age relationship is also further confirmed by the rotation of the F_1 fold on a regional scale, as brought out by the plot of L_1 and L_2 lineations for the three domains

(Fig. 4). The L_1 lineations show two unique maxima for Domains D-I and D-III, the former in the south-eastern quadrant and the latter in the south-western quadrant, which are presumed to be due to the rotation of the same L_1 lineation (F_1 fold) by the L_2 lineation (F_2 fold). It is significant to note that the latter maintains a more or less consistent trend in all the domains.

(v) The F_1 folds are represented mesoscopically by the minor folds in the carbonaceous quartzite, which are tightly appressed, often isoclinal and sometimes overturned to the north.

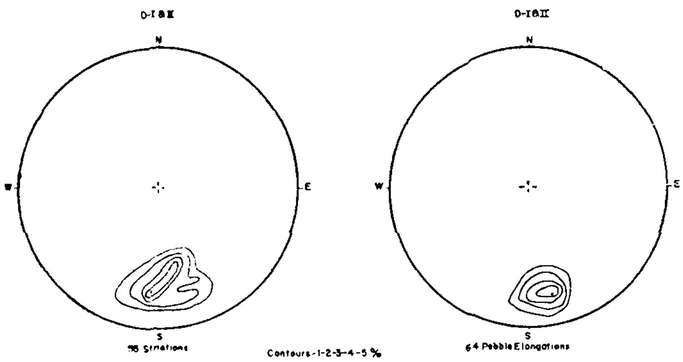

Figure 5. Plot of striation and pebble elongation lineations.

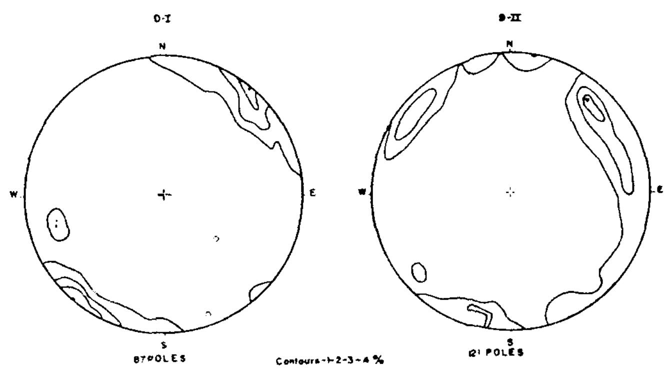

Figure 6. Point diagrams.

(vi) The F_2 folds represented only as small puckers and major warps are imprinted obliquely on the F_1 fold axis. The angle between the two lineations parallel to these folds, is consistently found to be about 45° in all the domains. Fig. 4 shows the rotation of the L_1 lineation around L_2 with approximately a similar angle.

(vii) The F_1 folds appear to be the first folds of the area under consideration for no other fold is noticed predating the F_1 fold. This fold may probably represent a local manifestation of the regional E-W fold described by other workers in adjacent areas (D. Mukherjee, 1961 and P. K. Banerjee, 1969).

(viii) The first fold (F_1) in the area is shown to be a fold on foliation plane, as seen by the plot of the foliation poles in Fig. 2. Bedding in the area is essentially parallel to the foliation, implying that the folds of the former are of isoclinal type.

(ix) The F_1 folding typically shows tightly appressed folds, often with attenuated limbs and thickened hinges. Besides, the foliation planes, showing extreme recrystallization of platy and tabular minerals flattened on the planes, are axial planar to these folds, as established by other workers in the adjacent areas. Thus the F_1 folds might have developed due to slip on foliation planes.

(x) The second fold (F_2) has also developed with a distinct axial plane cleavage. But slip on this plane is very limited. The rotation of the F_1 fold, which is a fold on the foliation plane, by the F_2 fold is consistent with flexural slip folds (Weiss, 1959). Thus it is inferred that the F_2 folds in the area are essentially flexural slip type, involving very little slip parallel to the axial planes.

(xi) It is interesting to note that the longer axes of pebbles and downdip striation lineations are parallel to the F_2 fold axes (Fig. 5). Moreover, several NNW-SSE trending shears have been traced in the area parallel to the axial plane trends of the F_2 folds. The gondite bands in the belt likewise show sinistral and dextral displacements about similar planes. All these suggest that there were movements parallel or sub-parallel to the trend of the axial planes of F_2 folds. The significance of these movements with respect to the F_2 fold formation is not clearly understood. The F_2 folds, might have developed during the penetrative cross fold movement connected with the 'forceful emplacement of the Itma tonalite pluton' (Banerjee, 1969). The configuration of the latter is seen to be distinctly controlled by the F_2 fold trends. In other words, the pluton is seen elongated parallel to the axial planes of the F_2 folds. Further field work supported by petrofabric studies on the minerals like quartz, mica etc., will be necessary to confirm the above hypothesis.

A careful study of the gondite bodies in this belt has revealed an interesting fact that the ore zones within the gondite occur as supergene oxide enrichments, which appear to have been concentrated as elongate pipe like lenses and worked in the past along S10° – 20°E direction, which is the direction of the plunge of the drags due to F_2 folds in the gondite bands. The prominent crinkle lineation along S10° – 20°E direction in the mica schists of this region is also parallel to the above drag folds. Thus it appears that the axial regions of the F_2 folds have served as effective loci for secondary enrichment of the gonditic bands to give rise to manganese ore bodies.

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