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STRUCTURAL SETTING AND POST-GRANULITE MODIFICATION IN AN AREA IN THE NORTH EASTERN SECTOR OF EASTERN GHATS

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ABSTRACT

The granulites occurring in the north-eastern sector of the Eastern Ghats terrain comprise pyroxene granulite suite, metapelites and minor granites, and bear the imprint of three phases of deformation. S_1 (gneissic banding) is the most pervasive foliation. S_2 (leptynitic foliation) is regionally parallel to S_1. Compared to the regional tectonic trend of the Eastern Ghats, the trend in the present area (Jenapore, near the northern boundary of the Eastern Ghats) suggests a rigid body rotation near its boundary with the Singhbhum belt. Characteristic fold interference pattern between F_1 and F_2 is arrowhead, unlike the coaxial relation described from other parts of the Eastern Ghats.

Basic granulite bands are folded by early (F_1) folds and the S_1 fabric is impressed on them. Field relations and modal mineralogy of the pyroxene-granulites suggest that they are components of a differentiated suite. Khondalite (also called garnet-sillimanite gneiss) and quartzite are the two variants of metapelites. Leptynite and porphyritic granite were emplaced at the hinge zones of the F_2 folds. The granulite assemblages (orthopyroxene $\pm$ garnet in charnockites and sillimanite + garnet + K-feldspar in metapelites) define the S_1 fabric. These assemblages were modified by retrograde reactions synkinematically related to F_2 deformation.

Key-words : Eastern Ghats, granulites, structural setting.

INTRODUCTION

The rocks around Jenapore in the northeastern sector of the Eastern Ghats (Fig. 1) comprise dominantly of charnockites and metapelitic granulites with local patchy occurrence of leucocratic garnetiferous granite gneiss (leptynite) and minor bodies of porphyritic granite.

The present area did not attract much attention except the work of Banerjee (1987), who mainly concentrated on the nature of the northern boundary of the Eastern Ghats. Three phases of deformation in the Eastern Ghats have been reported by Bhattacharya *et al.* (1993, 1994) from the Chilka area.

The present study is aimed at structural analysis and petrographic studies which have helped to relate metamorphic changes with deformation fabrics.

ROCK TYPES AND FIELD RELATIONS

Pyroxene granulites, metapelitic granulites associated with patchy leptynite and

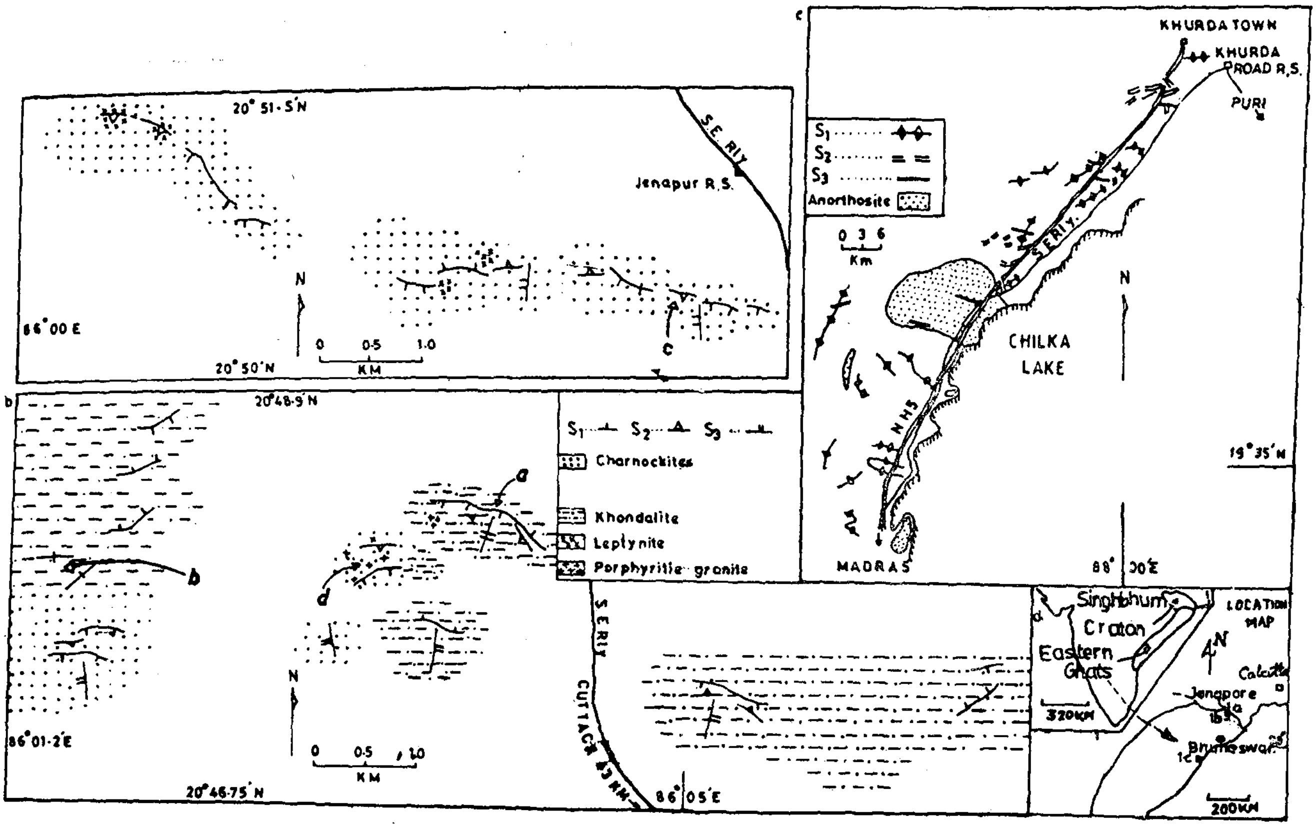

Fig. 1. Lithostructural map of different sectors (a and b) :- a. latitude [20°50'N to 20°51.5'N] and longitude [86°E to 86°4.35'E]. b. latitude [20°46.75'N to 20°48.9'N] and longitude [86°1.2'E to 86°6.3'E). c. Tectonic trend map of Chilka lake region (after Bhattacharya *et al.*, 1994). d. Location map.

minor bodies of porphyritic granite (Figs. 1a, 1b) are the principal rock types.

Pyroxene granulites

These include the following members. Mineral phases (given in bracket) are presented in order of abundance :

i) Acid charnockite (quartz + K-feldspar + plagioclase + orthopyroxene ± garnet ± opaque), ii) intermediate charnockite (quartz + K-feldspar + plagioclase + orthopyroxene ± garnet ± biotite ± opaque), iii) basic granulite (orthopyroxene + plagioclase + K-feldspar + clinopyroxene + quartz ± garnet ± hornblende ± biotite ± opaque), iv) ultrabasic granulite (orthopyroxene + clinopyroxene + hornblende + plagioclase ± biotite ± opaque).

The pyroxene granulites appear to represent a differentiated suite with acid, intermediate and basic varieties, defined on the twin basis of feldspar ratio and content of ferromagnesian phases (Streckeisen, 1976). The acid charnockites have alkali feldspar/plagioclase ratio greater than one and ferromagnesian phases less than 5%. The intermediate charnockites (enderbites) have equal proportions of alkali feldspar and plagioclase and ferromagnesian phases between 10 to 20%. The basic granulites normally do not have alkali feldspar ; feldspars are mostly plagioclase; the ferromagnesian phases constitute more than 30%. In addition, the basic granulites are characterised by the presence of clinopyroxene and amphibole. The ultrabasic variety has more than 60% ferromagnesian phases and the rest is plagioclase ; quartz is absent.

Acid charnockites occur as large bodies (Figs. 1a, 1b). Intermediate and basic varieties occur as lensoid patches (Fig. 3a) and bands enclosed in acidic varieties (Fig. 2c). The ultrabasic variety occurs as minor lensoid patches (<1m in length).

Metapelitic granulites

These comprise khondalite (quartz + K-feldspar + garnet + sillimanite ± opaque), also described as garnet - sillimanite gneiss, cordierite granulite (quartz + K-feldspar + garnet + sillimanite + cordierite ± perthite ± plagioclase ± opaque) and quartzite (quartz + garnet + sillimanite ± K-feldspar ± opaque).

Khondalite is the dominant variety. Quartzite occurs as bands and cordierite granulite occurs as patches (<10m in dimension) enclosed in khondalite.

Leptynite and granite

Leptynite (quartz + K-feldspar + plagioclase ± biotite ± garnet ± opaque) occurs as minor bodies associated with charnockites. Porphyritic granite (quartz + K-feldspar + biotite + hornblende + garnet ±opaque) occurs as minor bodies at the F_2 fold hinges (Fig. 2d). Intrusive veins from porphyritic granite extend both into charnockites and metapelites.

DEFORMATION STRUCTURES

Three phases of deformation (F_1, F_2, F_3) have been observed in the area and are associated with development of planar and linear fabrics deignated as S_1, S_2, S_3 and L_1, L_2 respectively.

Original (prior to first deformation) banding (S_0) is defined by the lithoboundaries of basic granulite bands (Fig. 2c) and by the quartzofeldspathic bands in acid to

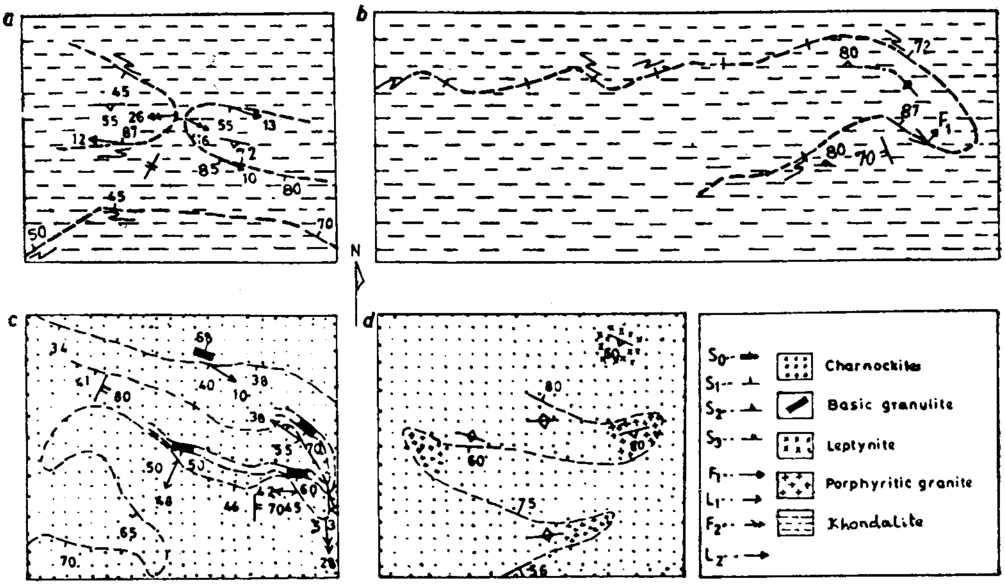

Fig. 2. Field sketches ; locations in Figs. 1a, 1b :- a. hour-glass interference pattern generated by F_2-F_3 superposition in khondalite. b. hook-shaped interference pattern generated by F_2-F_3 superposition in khondalite. c. hook-shaped interference pattern generated by F_2-F_3 in charnockite with mappable basic granulite bands (S_0) showing macroscopic F_1 fold. d. disposition of porphyritic granite at the hinges of microscopic F_2 folds. Foliation in granite is parallel to regional S_2 in charnockite.

intermediate charnockites (Fig. 3c). In metapelites S_0 is recognised by discontinuous quartzite bands, often forming intrafolial folds. S_1 is the most pervasive foliation throughout the area. In charnockites a gneissic banding (S_1) is defined by orthopyroxene $\pm$ garnet seggregations, which pass through the basic granulite bands at an angle to the lithologic boundary (S_0). Metapelites have garnet-sillimanite seggregations parallel to S_1 foliation in all the varieties. S_2 is recognised by characteristic quartz ribbons in all the rock types (Figs. 3a, 4a, 4b). S_3 is defined by fracture cleavages near the hinges of F_3 warps (Fig. 3d) in all the rock types. In the charnockites these fractures are locally filled with coarse grained quartz-muscovite aggregates and garnet seggregations.

Linear fabrics are mostly generated due to intersection of two planar fabrics. L_1 is defined by intersection of basic granulite bands with S_1 in the charnockites. In metapelites L_1 is defined by intersection of quartzite bands with S_1. L_2 is defined by elongate quartz ribbons on S_2. In metapelites L_2 is defined by sillimanite growth along the intersection of S_1 and S_2 planes.

F_1 folds are tight to isoclinal with steep

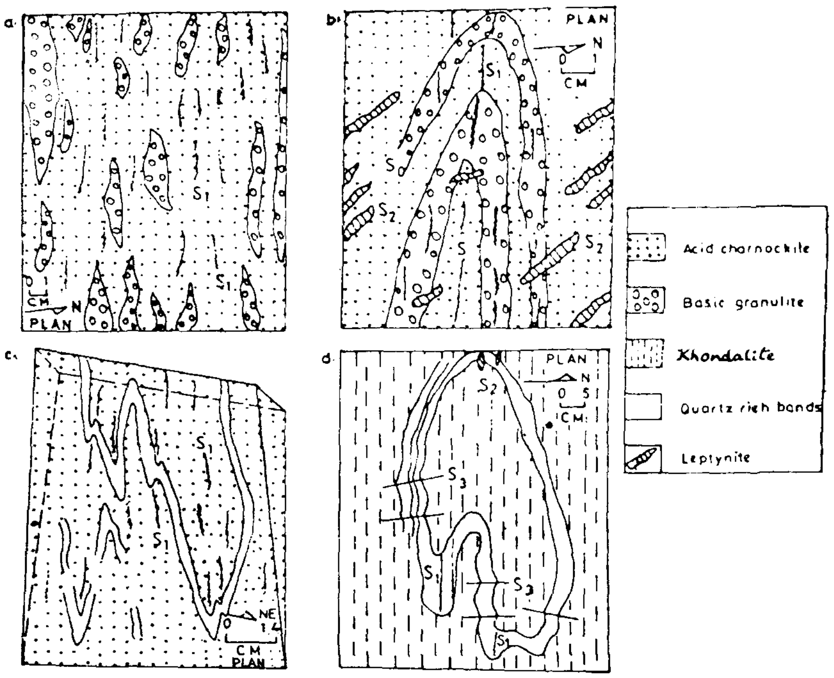

Fig. 3. Sketches from field photographs. a. lensoid patches (parallel to S_1) of enderbite and basic granulite enclosed in acid charnockite. b. F_1 fold defined by basic granulite bands (S_0) in acid charnockite with axial planar S_1 foliation. Foliation passes through the bands in the limbs. S_2 foliation cuts both S_0 and S_1 at an angle. c. F_1 folds of quartzofeldspathic bands (S_0) in acid charnockite with axial planar S_1 gneissosity. d. arrowhead interference pattern of F_1-F_2 folds in khondalite defined by quartzite bands (S_0) with axial planar S_1 and S_2 foliation respectively.

plunges (Figs. 3b, 3c). F_1 axes are reoriented by later folds and hence have diverse orientation. A number of macroscopic F_1 folds defined by bands of basic granulite are depicted in the field sketch (Fig. 2c).

F_2 folds occur on various scales and are commonly tight, with gentle plunge either towards ESE or towards WNW. The axial planes of F_2 folds (S_2) have variable inclinations (Fig. 4a, 4b,5b).

F_3 folds are broad warps with steep diping axial planar fabric (S_3).

STRUCTURAL ANALYSIS

The poles to foliations and lineations are plotted on equal area projection. S_1 poles define a great circle, the L_2 (F_2) lineations plot around the pole (β) of the great circle (Fig. 5a). However, the scatter across this great circle can only be interpreted as the effect of later folding (F_3), which have bent the earlier foliations (S_1 and S_2). This is also evident from the plot of S_2 (Fig. 5b). S_2 poles are widely scattered and two great circles may be conceived representing F_3

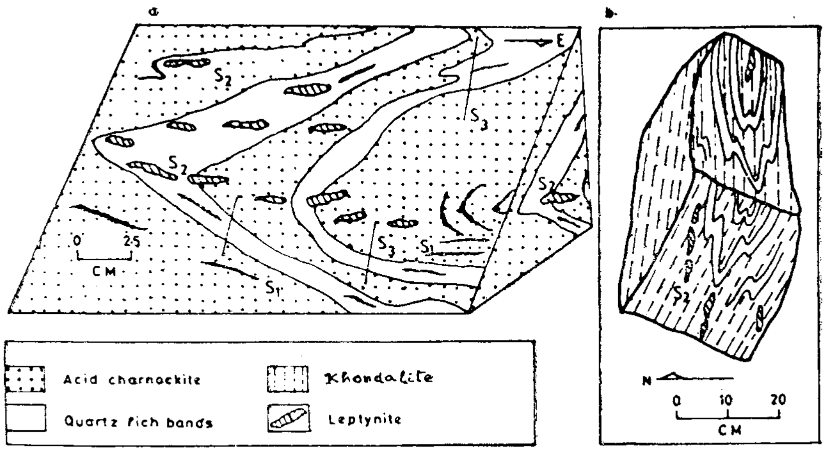

Fig. 4. Sketches from field photographs showing F_2 folds defined by quartzofeldspathic bands and S_1 foliation along with axial planar S_2 foliation : (a) in acid charnockite, (b) in khondalite.

folds on differently oriented pre-existing foliations (S_2). The S_3 poles show diverse orientation (Fig. 5c). The distribution of S_2 poles on two great circles can be explained as due to the variation of S_2 (possibly due to polyclinal nature of F_2 folds) prior to F_3 folding.

FOLD INTERFERENCE

All the three types of interference pattern of Ramsay (1967) have been observed in the study area on different scales.

Mappable hour-glass (type I) interference pattern (F_2-F_3 superposition) defined by S_1 is recognised in the metapelites (Fig. 2a). This type of interference is due to a high angle between S_2 and S_3 combined with high angle between F_2 and F_3 axes, the axial planes of both F_2 and F_3 folds remaining planar.

Mesoscopic arrowhead (type II) interference pattern (F_1-F_2 superposition) defined by quartzite bands is recognised in metapelites (Fig. 3d). This pattern results from high angle between the axes and axial planes of F_1 and F_2 folds, the axes and axial planes of F_1 being bent by F_2 folds.

Mesoscopic hook-shaped (type III) interference pattern (F_2-F_3 superposition) defined by S_1 is recognised in charnockites (Fig, 2c) and metapelites (Fig. 2b). This pattern results from high angle between S_2 and S_3 combined with low angle between F_2 and F_3 axes.

TECTONIC TREND

In the study area S_1 pervasive foliation trends E-W to ESE-WNW (Figs. 1a, 1b). S_1 and S_2 foliations are parallel except at the hinges of large F_2 folds. S_3 foliation is at high angle to S_1 and S_2, and trends nearly N-S.

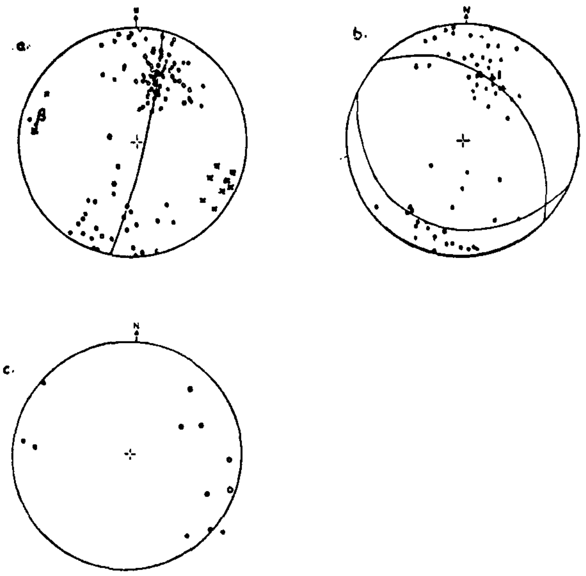

Fig. 5. Equal area projection diagrams:- a. poles to S_1 lie on great circle with pole β; L_3 lineations (crosses); b. poles to S_2 lie on two great circles ; and c. poles to S_3.

Bhattacharya *et al.* (1994) demonstrated that the main Eastern Ghats trend represented by S_1 is NE-SW while the less prominent trend represented by S_3 is nearly E-W (Fig. 1c).

By comparing the Eastern Ghats trends with the trends of the study area, it appears that the trend got rotated near the northern boundary of the Eastern Ghats with the Singhbhum belt. The rotation of tectonic trend may be ascribed to regional F_3 and the present area represents the limb of a major F_3 fold. But the evidence from the present area shows that S_3 is also rotated.

The above observations indicate a post-S_3 rotation of the whole package in the present area. An oblique collision during the juxtaposition of the two belts (Eastern Ghats in the south and Singhbhum belt in the north) was proposed by Bhattacharya (1994), and this is thought to be responsible for the bodily rotation.

TIME RELATION BETWEEN CHARNOCKITE AND LEPTYNITE

The tight, rootless F_1 folds defined by S_0 bands (Figs. 4, 5) in charnockites are absent in leptynite and porphyritic granite. The characteristic leptynitic foliation passes undeviated into the adjacent charnockites and is either axial planar to folded S_1 (Fig. 4a) or cross-cuts S_1 foliation (Fig. 3b) in the charnockites, and it is, hence, designated as S_2. The gneissic foliation of porphyritic granite is parallel to regional S_2 in metapelites and charnockites (Fig. 2d).

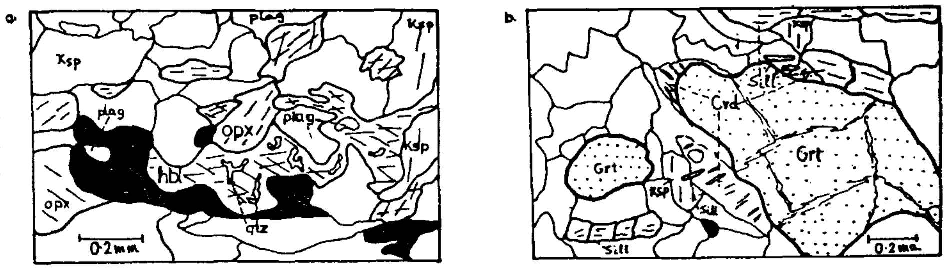

Fig. 6. Sketches from photomicrograph. a. Reaction texture showing hornblende (hbl)-quartz (qtz) symplectite around orthopyroxene (opx) and plagioclase (plag) in enderbite; ksp -K-felspar. b. Reaction texture showing cordierite (crd) and relict sillimanite (sill) adjacent to garnet (grt) in cordierite granulite; ksp - K-feldspar; plag - plagioclase.

Moreover, porphyritic granite bodies occur at F_2 fold hinges. Such evidence clearly points out the later origin of leptynite and porphyritic granite as compared to granulites.

DEFORMATION IN RELATION TO METAMORPHISM

The granulite assemblages, namely orthopyroxene$\pm$garnet in charnockitic rocks and garnet + sillimanite + K-feldspar in metapelitic rocks occur as seggregations defining the gneissic banding, S_1.

Following retrograde reactions are commonly observed in charnockites and metapelites.

In charnockitic rocks, the presence of hornblende-quartz symplectite with inclusion of plagioclase and/or orthopyroxene (Fig. 6a) suggests the reaction :

$$\text{plagioclase} + \text{orthopyroxene} \rightarrow \text{hornblende} + \text{quartz}.$$

In metapelitic rocks, the reaction texture (Fig. 6b) suggests the appearance of cordierite via the reaction :

$$\text{garnet} + \text{sillimanite} + \text{quartz} \rightarrow \text{cordierite}.$$

It should be noted that the domains of such retrograde reactions have a strong S_2 fabric with occasional relict S_1 fabric. S_2 fabric (sometimes as garnet seggregation bands) has developed across these reaction domains. Hence, the retrograde reactions (modification of granulite assemblages) are thought to be coeval with S_2.

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