STRUCTURAL HISTORY OF BAROTIA GROUP NEAR BAR,
PALI DISTRICT OF RAJASTHAN

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ABSTRACT

The Delhi Supergroup of rocks near Bar in the Pali District of Rajasthan rests over the basement, Banded Gneissic Complex with a pronounced erosional unconformity at the base. This erosional unconformity is marked by the formation of a thick conglomeratic horizon. The overlying Delhi metasediments are classified into older Barotia Group and younger Sendra Group. The contact between these two groups is faulted. The rocks of Barotia Group exhibit three stages of folding. The first set of folds, F1, are isoclinal and reclined with the axis plunging in E-W/NE-SW direction to recumbent. The second set of folds, F2, are open and upright with axial plane striking in NNE-SSW direction. The superimposition of F2 on F1 has produced mirror-image pattern. The third set of folds, F3, occur locally as broad warps with the axial plane striking in E-W direction. The above structural pattern does not match with the common structures of Delhi Supergroup. Rather it resembles the structures of Aravalli Supergroup.

INTRODUCTION

On the basis of basal conglomerate, Heron (1953) mapped the Delhi rocks in the central Rajasthan of the Aravalli mountain range as a NNE-SSW striking belt flanked by the basement, Banded Gneissic Complex (BGC), on either sides. This belt is divided into two synclinoria (NW and SE) by an inflex of BGC near Beawar (Fig. 1a). The NW synclinorium is classified into two Groups, the lower Barotia Group and upper Sendra Group (Fig. 1b). The present author mapped the rocks of Barotia Group near Bar (26°03’
32°06’) in the Pali district of Rajasthan (Fig. 2).

LITHOLOGY

Barotia Group is represented by conglomerate, micaceous schist, calc-schist, orthoamphibolite, metachert and metabasalt. The conglomerate consists of pebbles of grey quartzite (80%) and granite gneiss. These are well-rounded, ellipsoidal and unsorted. They are extremely flattened with their three axes showing a ratio of 1:3:5 (Fig. 3a). The mica schist consists of biotite, quartz and K-feldspar. Calc-schist is constituted of diopside, hornblende, Plagioclase feldspar, chlorite-epidote and calcite. Epidote, hornblende, biotite and plagioclase feldspar constitute the orthoamphibolite. The metahyolite shows the presence of quartz, K-feldspar and muscovite. Quartz and pegmatite veins are emplaced profusely into the mica schist.

STRUCTURE

Small-scale structures:

F1 Fold

The Barotia Group shows three phases of folding described as F1, F2, and F3. F1 folds are developed on all scales from thin section through hand specimen to outcrop on the bedding planes (S0). These are tight to isoclinal folds with very high amplitude/wavelength ratio (Fig. 3b). Parallel folds are developed in competent layers (Fig. 3c). Due to the crystallisation of the flaky and prismatic minerals such as micas, hornblende and epidote parallel to their axial plane, the axial plane cleavage, S1, is developed ubiquitously. This cleavage shows refraction across different layers (Fig. 3c). Fold hinges, boudin lines and intersection lineations (between S0 and S1) near the F1 fold hinges (F1 lineations) are present in the area. F1 folds are recumbent to reclined in nature. Majority of its axial planes strike NNE-SSW and dip to ESE (Fig. 4a) and axis plunges to ESE (Fig. 4b). Variation in this orientation is caused by F2 folding (Fig. 4c and 4d). F1 folding is accompanied by flattening which has resulted in the for-
formation of boudins (Fig. 3d) in orthoamphibolite and mica schist. The quartzite pebbles in conglomerate are flattened and their longest axis remains parallel to the F₁ fold axis (Fig. 3e). Parasitic F₁ folds are developed in calc gneiss (Fig. 3b).

**F₂ fold**

The bedding, S₁ cleavage and F₁ axis are involved in a system of open to tight upright F₂ folding (Fig. 3f). The axial plane strikes NNE-SSW and axis plunges gently in these directions (Fig. 4e and 4f). Fig. 4c shows a complete girdle indicating rotation of S₁ plane by F₂ folding. The β axis plunges 10⁰N 19⁰E. The orientation of F₂ axis depends upon the orientation of the pre-existing surface such as bedding plane and S₁ cleavage. But the bedding-parallel S₁ cleavage shows uniform orientation because of least variation in the initial orientation of the F₁ isoclinal fold. The hinge portion of the F₁ isoclinal folds, where the bedding and S₁ cleavage are at right angle to each other, is of smaller areal extent. So by and large F₂ folds are developed on uniformly oriented surfaces. As a result the F₂ axes show little variation in orientation. Very little spread in contours in F₂ and coincidence of β axis of Fig. 4e with maximum in Fig. 4f prove the above fact. The variation in the plunge of F₂ fold ranging from 0⁰ to 10⁰ is caused by F₂ folding. Crenulation cleavage S₂ parallel to the axial plane of F₂ fold is developed due to sharp crinkling of S₁ cleavage. Crystallization of muscovite and development of fractures in competent layers are seen parallel to this cleavage. S₂ cleavage shows flaring across different layers of the S₁. Subhorizontal mineral lineations are developed parallel to the F₂ fold axis in the area. Parallel folds in competent layers and disharmonic folding in incompetent layers of contrasting competence are associated with F₂ folding (Fig. 3d). This suggests the effect of folding. Evidence of flattening and formation of boudins is absent in this stage of folding.

**F₃ fold**

F₃ folds are locally developed as open warped
Fig 2: Geological map of Barotia Group of rocks near Bar, Pali district of Rajasthan.

Folds are mostly parallel in shape. The axial planes of these folds strike E-W and the axis shows NE orientation.

Interference structures

Three phases of folding have developed interference pattern of different types on small to intermediate to outcrop scales.

1. The most conspicuous pattern is due to interference of F₁ and F₂ folds. Axial directions of F₁ and F₂ folds are nearly at right angle to each other. Superimposition of F₂ fold on F₁ fold has resulted in the rotation of axial plane and axis of F₁ fold, with F₂ axial plane as the plane of symmetry. The resultant pattern is the Type 2
Fig 3: Features in Barotia Group.

a: Half of the pebble of basal conglomerate is seen in the subvertical S1 plane. The maximum elongation of the pebble is parallel to the F1 lineation, seen as striation on the schistosity surface at Bar.

b: Trace of isoclinal F1 fold with NNE-striking subvertical axial plane (parallel to the scale) noted on subhorizontal surface of cale greis, 2 km NE of Bar. Parasitic F1 folds are present on thin layers.

c: S1 cleavage shows refraction across different litholayers in cale greis, 2 km NE of Bar. Scale parallel to the F1 axial plane.

d: Boudin (scale parallel to the longest axis) developed in the epidote + plagioclase + fol + quartz layer of orthoamphibolite; 2 km NE of Bar.

e: Upright open F2 fold with NNE-SSW-nor axial plane (scale parallel) and subhorizontal is seen on the subvertical face of the cale greis. Parasitic F2 folds and curved F1 lineations are on the folded S1 surfaces, 3.5 km east of Bar.
Fig. 4: Synoptic diagrams of structural elements of Barotia Group near Bar.

a: Polca to 310 F1 axial planes and cleavages of subarea 1. Contours: 1.0 - 2.0 - 3.0 - 4.0 - 5.0 - 7.0 %.

b: 105 F1 axes, lineations and longest axes of the pebbles of subarea 1. Contours: 1.0 - 2.0 - 4.0 - 6.0 - 9.0 %

c: Polca to 85 F1 axial planes and cleavage of subarea 2. Contours: 1.0 - 2.0 - 3.0 %.

d: 77 F1 axes and lineations of subarea 2. Contours: 1.0 - 2.0 - 4.0 %

e: Polca to 78 F2 axial planes and cleavages. Contours: 1.0 - 3.0 - 6.0 %

f: Polca to 56 F2 axes and lineations. Contours: 1.0 - 3.0 %
interference pattern (mirror image) of Ramsay (1967). The most widespread effect of this interference is that the F1 axial plane and cleavage have acquired subvertical attitude in NNE-SSW direction, parallel to the axial plane of F2 fold, and F1 axis plunges steeply in ESE-WNW direction. But they remain subhorizontal in E-W/ENE-WNW direction at the hinge of the F2 fold (Fig. 5a).

2. The second type of interference pattern is seen between F1 and F3 folds. The F1 fold is reclined and the axis of the fold trends E-W/ENE-WNW. The axial plane of F3 is E-W. Therefore F1 fold is coaxially refolded by F3 folding producing Type 3 interference pattern of Ramsay (1967) (Fig. 5b).

3. The effect of F3 folding on F2 folds is seen in the form of bending of the F2 fold axis producing Type 1 interference pattern of Ramsay (1967). The axial plane of F2 fold remains planar (Fig. 5c).

Large-scale structure:

Heron (1953) has brought out striking linear and steep-dipping nature of the Barotia Group lithounits around Bar (Fig. 1b). This Group has unconformable contact with the BGC towards west and has a faulted contact with the Sendra Group to the east. This fault is marked by mylonites and cataclasites (eastern most) of the Barotia Group.

The study of distribution pattern of small-scale structures in Barotia Group reveals the fact that small-scale F1 folds are distributed over almost all parts whereas the small-scale F2 folds are dominant to the easternmost rock units only. Therefore...
The study area is divided into two subareas (Fig. 2). The subarea I shows steep NNE-SSW striking S1 planes and steep ESE-plunging fold axes (Figs. 4a and 4b). The subarea 2 shows gentle S1 planes and F1 fold axes in E-W/WNW-ESE direction (Figs. 4c and 4d). This variation is due to F2 folding as proved by the complete girdle obtained in Fig. 4c. The β axis of this girdle which coincides with F2 fold axis (Fig. 4e) plunges 10°/N 19°E. If the structures of the two subareas are seen together, a synformal structure of Barotia Group would be apparent (A-B section, Fig. 2). Subarea 1 represents the limb and subarea 2 represents the hinge portion of the synform. Because of falling along the axial plane of this synform the eastern half of the hinge is in contact with the Sendra Group. This synform is an F2 fold as the S1 cleavage shows rotation at the hinge (Fig. 4c). The limb portion of the subarea 1 occupies greater part of Barotia Group. The lithounits in the limb strike NNE-SSW and dip steeply to ESE. Steepness of the lithounits has provided striking linearity to the map pattern (Fig 2).

Large-scale F1 folds are discernible in the map at 1 km and 5 km NE of bar (Fig. 2). The bedding plane and S1 cleavage are at right angle to each other at the hinge portion of these fold. The axial trace strikes NNE-SSW and axis plunges steeply to ESE.

GENESIS OF FOLDS

The F3 folds are very much localised in the area. The F3 folds which are nearly free from the effect of F2 folding are found low-plunging, upright with axial plane striking NNE-SSW. When these folds are unfolded the F1 fold emerged to be recumbent/reclined with axis trending in E-W direction. This direction is believed to be initial orientation of E-W fold axis before F2 folding. F1 folds are recumbent/reclined and are associated with features of buckling like parasitic folding in competent layers, flattening perpendicular to the axial plane, refraction of axial plane cleavage across layers of different composition, etc. Therefore a NNE-SSW directed sub-horizontal compression with rotation (simple shear) has generated the F1 folds (Naha et al., 1987). Flattening followed buckling. The upright nature of F2 folding indicates pure shear i.e., horizontal squeezing in WNW-ESE direction has generated the F2 folding. A N-S subhorizontal compression is responsible for F3 folding.

CONCLUSION

The structural history of rocks of Delhi Supergroup is studied by many workers at different parts of the Aravalli mountain range (Gangopadhyay, 1967; Dasgupta, 1968; Naha et al., 1987 and Biswal, 1988). Their works reveal a common pattern of deformation of Delhi rocks. Three major folds are identified. The first two folds are coaxial along NNE-SSW axis and the third fold is NW-SE. The earlier study of the structures of Barotia Group by Sen (1981), Gupta et al. (1988) and Dasgupta and Bhatnacharya (1989) does not differ much from the above observation. But the present work shows a completely different nature of deformation of Barotia Group. The first two folds, instead of being coaxial, are at right angle to each other. F1 folds are in E-W direction whereas F2 folds are in NNE-SSW direction. This type of structural pattern is characteristically found in rocks of Aravalli Supergroup (Roy et al., 1981; Mohanty, 1982 and Naha et al., 1984).

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"The reasonable man adapts himself to the world, the unreasonable one persists in trying to adapt the world to himself. Therefore, all progress depends on the unreasonable man."

—Bernard Shaw