CONTRAST IN DEFORMATIONAL HISTORY OF 
ARAVALLI AND DELHI SUPERGROUP: 
A REAPPRAISAL

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ABSTRACT
The deformational history of the Aravalli and Delhi Supergroups differs principally with respect to their first fold. While the first fold in the Aravalli Supergroup (AF₁) is in NW-SE to E-W direction, the first fold in the Delhi Supergroup (DF₁) is at right angle to it along NNE-SSW direction. Further, that DF₁ fold has impressed upon Aravalli Supergroup as AF₁ folds and Delhi Supergroup is free from the effect of AF₁ folding, lead to the inference that the Aravalli rocks had undergone one more phase of deformation (Aravalli orogeny) prior to the deposition of the Delhi rocks. However, structures of Barotia Group is not consistent with other parts of Delhi Supergroup in that a distinctive set of tight isofinal reclined fold BF₁, with southeasterly dipping axial plane and down dip plunging axis resembling AF₁, fold of Aravalli Supergroup is present in it. This is superimposed by NNE-SSW oriented BF₁ fold and NW-SE trending BF₂ fold. In addition to this the Aravalli rocks exposed around Girnar and within the state of Gujarat do not carry E-W trending AF₁ fold, contrarily they accord with the deformational structures of the Delhi rocks. Hence, the E-W trending AF₁ fold which is described as a characteristic feature of Aravalli Supergroup has been interpreted in this paper as a restrictive feature confined to the contact zone between basement and cover rocks and genetically attributed to heterogeneous shear along the contact decoulement. These folds were originally in NNE-SSW direction resulting from NW-SE shortening of the basin and subsequently reoriented to E-W direction by inhomogeneous shear strain along the contact. Further, the third stage of folding represented by AF₁, and DF₁ folds are similarly oriented and are attributed to transpression resulted from strike slip shearing along the pre-existing thrust planes.

INTRODUCTION
In the Precambrians of the Aravalli mountain of Rajasthan and Gujarat (Fig. 1a), a first order unconformity between Delhi and pre-Delhi rocks has been visualised on the basis of basal conglomerate underlyingly Delhi Supergroup (Heron, 1953). Further, it is an angular unconformity, is supported by the variation in structural style between these groups (Naha and Halbyburton, 1974, 1977a, 1977b, Naha et al., 1984, Roy, 1988). The above variation is interpreted in the manner that the Aravalli rocks were deposited and subjected to AF₁ folding (Aravalli orogeny) along E-W axis; following which the Delhi rocks were deposited and deformed along NNE-SSW axis (Delhi orogeny) resulting in angular disposition.
of the rocks. Hence, two distinctive orogenies mark the evolution of Aravalli mountain. In this paper the author has emphasized on single orogeny for Delhi - Aravalli rocks (cf. Paliwal, 1992) and has explained the variation in folding style as due to inhomogeneity in finite strain along the contact between basement and cover. The above observation is based on structural analysis of the Delhi rocks belonging to Barotia and Sendra Groups near Bar (26° 05′ : 74° 06′) and Babra (26° 14′ : 74° 15′) in Pali district of Rajasthan (Fig. 1b) and few traverses across the contact in state of Gujarat.

**GEOLOGICAL SETTING**

The Delhi rocks in the central Rajasthan occur in a NNE-SSW striking belt flanked by Banded Gneissic Complex (BGC) on either sides (Heron, 1953). This linear belt has been divided into two synclinorium (NW and SE) by an inlier of BGC near Beawar (Fig. 1a). The NW synchirorium is further subdivided into two groups, the lower Barotia Group and upper Sendra Group (Fig. 1b). The Barotia Group rests over BGC with a prominent basal unconformity marked by conglomerate (Fig. 2).

**Structural pattern of Barotia Group**

The Barotia Group comprises a host of lithologies namely conglomerate (Plate 1 a), mica schist, calc gneiss, ortho-amphibolite, meta-rhyolite, meta-arkose and chert showing greenschist to lower amphibolite facies of metamorphism (Fig. 2). They have undergone three phases of folding such as BF₁, BF₂, and BF₃ (Biswal, 1993). The BF₁ folds are isoclinal and reclined with very high amplitude/wavelength ratio (Fig. 3b) which can be classified as Class IB to Class 2 fold after Ramsay (1967). These are associated with axial plane cleavage and intersection lineation (bedding plane and cleavage). Majority of them show NW vergence with SE dipping axial planes (Fig. 2a). Reclined nature of BF₁ fold has rendered the fold axis and intersection lineation, over large part of the area, down dip on cleavage planes (Fig. 2b). Extreme layer parallel stretching has boudinaged the competent plagioclase feldspar + epidote + quartz rich layers in ortho-amphibolite. The BF₂ folds show variation in geometry from reclined to recumbent towards the eastern margin of the Barotia Group as they are involved in open upright BF₂ folding. The axial plane of BF₂ fold is NNE-SSW (Fig. 2c) and plunge varies 10-15 degrees in NE and SW direction (Fig. 2d). The BF₃ folds are developed locally as warps with axial plane striking NW-SE. The superimposition of BF₂ on BF₁ has resulted in mirror image interference patterns. Occasional type 3 interference pattern is produced because of BF₁ and BF₂. Superimposition of open BF₂ on BF₃ has produced rare dome-and-basin structures.

WNW-ESE shortening has caused BF₁ and BF₂ buckle folds. The BF₃
fold hinges have been reoriented to down-dip of cleavage due to progressive deformation and therefore, have acquired reclined geometry. The rotation of BF\textsubscript{1} folds indicates transportation of material right angle to fold axis which is however absent during BF\textsubscript{2} folding. Hence the BF\textsubscript{2} folds maintain NNE-SSW axial trend. The BF\textsubscript{3} folds are generated due to NE-SW shortening.

![Geological map](image)

**Fig. 1.** Geological maps (a) Aravalli mountain and (b) of the area around Bar and Babra (after Heron, 1953).

On the basis of structural data the Barotia Group has been interpreted as constituting a half BF\textsubscript{2} synform whose other half possibly is concealed under Sendra Group due to faulting (Fig. 2, see the section). Since the half synform is dominated by the limb, the lithounits strike NNE-SSW consistent with the limb data and dip steeply towards ESE which therefore provides striking linearity to the map pattern. Repetition of similar units within the group is due to BF\textsubscript{1} folding.
Structural pattern of Sendra Group.

Sendra Group overlies Barotia Group with a fault at the base (Fig 3). Mica schist, calc schist, quartzite and granites constitute the Sendra group around Babra. Three phases of folding such as $SF_1$, $SF_2$, and $SF_3$ have been identified in these rocks.

A set of isoclinal and flattened parallel folds with very high amplitude/wave length ratio characterize the $SF_1$ fold (Plate 1 c) which is associated with penetrative axial planar schistosity. The $SF_2$ folds are coaxially refolded by open upright $SF_2$ fold in NNE-SSW direction.
PLATE 1
a. cigar shaped clast in conglomerate at the base of Barotia Group seen on the subvertical schistosity surface. Striaions (parallel to the scale) are BR lineations.
b. Isoclinal reclined fold with NNE-SSW striking axial plane (scale parallel) in calc gneiss NE of Bara.
c. Isoclinal recumbent SF, fold with NNE-SSW axial trend is seen on the subvertical face of the calc schist east of Babra. Pencil is parallel to the axial plane.
d. Open upright SF, fold in calc schist (Pencil, parallel to the axial plane). SF, boudins in the compositional layer are folded by SF, fold.
e. Open upright SF, folds in form of crenulation in calc schist (Pencil, parallel to the axial plane).
f. Type 3 interference pattern due to coaxial folding between SF, and SF, in calc schist SE of Babra.
thereby acquiring recumbent/reclined through inclined to upright geometry in different parts of SF₂ (Plate 1 d,e,f and Fig. 3 a,b,c,d). The SF₂ folds are represented by a set of polycrystal open warps to crenulations (Plate 1e) along NS, EW and NW-SE axis. The N-S trending SF₂ crenulations are more penetrative and are associated with anastomosing crenulation cleavages and mineral lineations. SF₂ conjugate folds along N-S and E-W axes are observed at places in thinly layered calc schists. The coaxial folding between SF₂ and SF₁ has resulted type 3 interference pattern (Ramsay, 1967) and irregular domes and basins are produced due to superimposition of SF₂ on SF₁.

Fig. 3. Geological map of Sendra group around Babra.

a. Poles to 780 SF₁ axial planes and cleavages. Contours: 0.5 - 1.0 - 1.5 - 2.0 - 3.0 - 5.0%. plunge plunges 30°/N35E.
b. 320 SF₁ axes and lineations. Contours: 0.5 - 1.0 - 2.0 - 3.0 - 6.0 - 8.0%.
c. Poles to 125 SF₂ axial planes and cleavages, contours 1.0 - 2.0 - 3.0 - 4.0 - 5.0%.
d. 98 SF₂ axes and lineations. Contours: 1.0 - 2.0 - 3.0 - 4.0 - 5.0%. g axes in 'a' and maxima in 'b' and 'd' are coincident indicating coaxial nature of SF₁ and SF₂ fold. The SF₁ folds have therefore attained recumbent/ reclined to inclined and upright geometry.

The elliptical outcrops of mica schist around Babra and east of Chadawata-ki-Dhani (Fig. 3) are the result of interference of three phases of folding as noted in small scale. The northeastern and southwestern closures are due to SF₂ folding as borne out by the rotation of SF₁ cleavage around these hinges. These hinges belong to major NNE-SSW trending SF₂ fold (A-B profile Fig. 3). The SF₂ has caused plunge reversal producing type 1 interference pattern e.g., a dome on large scale. The quartzite bed east of Chadawata-ki-Dhani shows the effect of SF₂ and SF₁ folds in large scale. Synkinematic granitic intrusions have developed widespread skarns in calc schist.
Association of parallel folding and disharmonic folding in the
compotent layer and refraction of axial plane cleavage through layers
of differing competence imply the buckling origin of \( SF_1 \), \( SF_2 \), and \( SF_3 \)
folds. The coaxial folding between \( SF_1 \) and \( SF_2 \) indicates a continuous
shearing along NW-SE direction which acted as a simple shear initially
to give rise to the \( SF_1 \) fold and later changed into a compression
producing the \( SF_2 \) folds. The \( SF_3 \) folds are due to NE-SW compression
(Naha et al., 1987; Biswal, 1988) resulted from length parallel
shortening of the orogen. The disposition of \( SF_1 \) and \( SF_2 \) fold axes
parallel to the length of the orogen lends support to lack of sufficient
amount of flow right angle to the axis synkinematic to their
development.

On summarizing the structures of Barotia and Sendra Groups, the
E-W to WNW-ESE trending \( BF_1 \) folding is evidently absent in rocks of
Sendra Group. Contrarily the NNE-SSW oriented \( SF_1 \) folds are imprinted
over Barotia Group as \( BF_2 \) folds. The third deformation in form of \( BF_3 \) and
\( SF_3 \) is identical in both the Groups, though its effect is more pronounced
in Sendra Group.

**DISCUSSION AND CONCLUSION**

The facts that the Aravalli and Delhi rocks could be distinguished
on basis of fold pattern seem to be over simplified. The present study
unequivocally illustrates the presence of E-W folds in Barotia Group of
Delhi Supergroup. A number of example can be quoted as to the absence
of E-W folding in Aravalli rocks too. For instance Jharol Group in Aravalli
Supergroup does not record E-W folding vividly. The E-W \( AF_1 \) folds are
hardly decipherable on mesoscopic scale in Aravalli rocks around Katar
(Mohanty, 1982) and Gorimari (Chauhan et al., 1996). An interpretation
to the effect that all \( AF_1 \) folds have been transposed by later deformation
is an exaggeration. A traverse across the Aravalli mountain in state of
Gujarat (unpublished work of the author) barely reveals any difference
in structural pattern between Godunda Group of Delhi Supergroup and
Jharol Group of Aravalli Supergroup. Hence, a review is necessary on
so called structural contrast between Delhi and pre-Delhi rocks.

If a close view is given to the early works on Aravalli mountain
(Naha and Halyburton, 1974, 1977a, 1977b, Naha et al., 1984, Roy, 1988) it
would be evident that the Aravalli Supergroup has been extensively
studied in proximity of the Banded Gneissic Complex which has acted as
basement to Aravalli-Delhi rocks. The contact acted as decollement
(Ramsay, 1967) during closure of the basin where large simple shear
strain produced greater flow of the material in E-W direction across
the zone of contact strain. This resulted in reorientation of folds from
NNE-SSW direction to E-W direction in those sectors only. Distribution of early lineations on a great circle coinciding with the axial
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plane of the AF, fold (Naha and Halyburton, 1971) and association of ductile shearing with AF; folding (Roy, 1988, Pailwal, 1988) bear testimony to this heterogeneous flow. Similar transformation has occurred in Delhi rocks within Barotia Group because of its closeness to the basement. The sectors which lie farther away from the contact obviously retained the NNE-SSW orientation due to lack of sufficient flow right angle to fold axis. Therefore, the rocks of Jharol group in Aravalli Supergroup and Sendra Group in Delhi Supergroup persist with NNE-SSW folding. Lack of any structural discordance between Delhi and Aravalli Supergroup is amply clear from within Gujarat understandably because of the above phenomena. Hence, the author holds the view that the presence of E-W folding in some parts of Aravalli Supergroup is not due to separate phase of deformation or orogeny but due to variation in finite strain during same orogeny. So it is opined that there was a single orogeny which can be named as Aravalli orogeny that has affected the Aravalli mountain during Proterozoic time.

The above contacts in addition to few others shown as lineaments (Geological Survey of India, 1980) have acted as major thrust planes during closure of the basin. However, in later event during third stage folding, these were rejuvenated as strike slip shears. Association of strike slip shearing during third stage of folding in Aravalli rocks is evident in Zawar area (Roy, 1995; Biswal et al., 1997). This shearing plausibly created third folds and effected strain neutralisation along the pre-existing thrust planes (Bhattacharya et al., 1995). It is, therefore, believed that strike slip shearing led to transgression in large scale across the Aravalli range effecting both Aravalli and Delhi rocks which gave rise to NW-SE trending AF, and DF, folding synchronously.

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