Banas dislocation zone in Nathdwara–Khamnor area, Udaipur District, Rajasthan, and its significance on the basement–cover relations in the Aravalli fold belt

S. Sinha-Roy, M. Mohanty and D. B. Guha

Geological Survey of India, 15–16 Jhalana Dungri, Jaipur 302 004, India

The relationship of the Lower Proterozoic Aravalli fold belt of Rajasthan with the essentially Archaean Banded Gneissic Complex (BGC) has a significant bearing on the basement–cover relations. In major parts, the interface is a tectonized unconformity, but in the northern extremity of this fold belt this relationship is problematic. It is shown here that in the Nathdwara–Khamnor area a prominent dislocation, the Banas Dislocation Zone (BDZ), interpreted as a dextral strike-slip fault, separates the Aravalli fold belt and the BGC. The rocks of the Hammer-head syncline of Heron[1] belong to the basement BGC, and these are juxtaposed against the Aravalli fold belt along the BDZ. The BDZ might represent a reactivated boundary fault of the Aravalli rift basin, the earlier structures having been variably rotated and reoriented within the BDZ. The BDZ is linked with the thrust tectonics of the Aravalli fold belt.

In many strongly deformed Proterozoic fold belts, the basement–cover relationship is controversial. This relationship is complicated, as in Rajasthan, by extensive basement mobilization, ductile deformation of the interface and large scale dislocations. The low-grade rocks of the Lower Proterozoic Aravalli fold belt of Rajasthan are flanked by the amphibolite facies basement rocks of the Banded Gneissic Complex (BGC) in the east and by the Middle to Upper Proterozoic greenschist to lower amphibolite facies rocks of the Delhi fold belt in the west. The cover rocks of the Aravalli Supergroup unconformably overlie the gneisses and migmatites of the BGC, redesignated as the Mangalwar Complex[2]. A part of the Mangalwar Complex is suggested to represent a dismembered granite–greenstone ensemble[3]. It includes relicts of Archaean crustal materials, indicated by Sm/Nd age (3.3 Ga) of tonalite–granodiorite gneisses[4]. Although the Aravalli–BGC contact is tectonized at many places, an unconformable relation between the two can be established in the eastern part of the Aravalli fold belt. However, the basement and cover relation in the north of the Aravalli fold belt in areas north of Nathdwara and Khamnor is a matter of controversy mainly because of lack of adequate geochronological data, absence of recognizable unconformity and strong deformation at the interface. Moreover, a similarity in geochemical character of the basal Aravalli Delwara volcanics and the mafic enclaves within the BGC has been reported[5].

The BGC–Aravalli contact in Nathdwara–Khamnor area is suggested to represent a migmatite front[6]. On the basis of structural similarities between the BGC and the cover rocks in Nathdwara–Amet region, it has been suggested[7,8] that the BGC in this sector is the migmatized product of the Aravalli–Raialo rocks. However, mineral paragenesis and metamorphism of the BGC and the overlying rocks do not indicate that migmatization of the Aravalli cover rocks is responsible for the evolution of the BGC[9]. It is believed that the Raialo 'Series' of Heron[1] which is best exposed in the Hammer-head syncline area, north of Nathdwara, is a part of the Aravalli Supergroup[10]. The status of the Hammer-head syncline rocks is evaluated here to throw light on the problem of basement–cover relations in the Aravalli fold belt.

From photogeological studies, an east-west trending tectonic line, coinciding with the Banas river course, was identified and referred to as the Banas lineament[2]. This lineament has been indicated as a domain boundary, truncating the older tectonic grains[11]. The ductile shear zone (DSZ) in the basement rocks of the Mangalwar Complex was suggested to contain major strike-slip components. Sinha-Roy[12] suggested that the Nathdwara–Agucha strike-slip fault delimits the Aravalli basin in the north against the Mangalwar Complex of the Hammer-head syncline. This fault in the Nathdwara–Khamnor area is described here as the Banas Dislocation Zone (BDZ).

Basement–cover relations

The Hammer-head syncline lies to the north of the BDZ and is defined by the 'Raialo Series' with a fringe of Aravalli rocks and an inlier of BGC. Heron[1] did not recognize the Banas lineament and his map shows that the Raialo rocks, particularly the marble unit, extends from the Hammer-head syncline area into the Aravalli fold belt in the south from near Nathdwara down south to near Kabita. This marble unit within the Aravalli fold belt does not seem to belong to the Raialo, and is probably a part of the Aravalli sequence[8]. Thus, the continuity of the so-called Raialo rocks, south of the BDZ, with that to the north of it is not tenable. The BGC rocks in the west of the Hammer-head syncline are a southward continuation of the major BGC terrain, lying to the north of the Hammer-head syncline. Two greenstone-like sequences are identified within the BGC (Mangalwar Complex) in the north of the BDZ[13,14]. Utramafics (hornblendite and talc-chlorite schist), amphibolite (tholeiitic metabasalt), low-Mg marble, banded metachert, metagreywacke, metatuff, and metapelites comprise Greenstone Sequence-I (Sawadri group). Greenstone Sequence-II (Tanwan group) contains amphibolite, metagreywacke, marble, bedded chert and fuchsite-bearing quartzite. The contact between these two sequences is tectonic, being marked by an older DSZ. These sequences occur as ghost stratigraphy within the tonalite–granodiorite plutons (Ran Igneous Complex). The latter are responsible for migmatization and remobilization of the greenstones. The granulite facies rocks of the Sandmata Complex occur as tectonic slivers in this association.

The lithologic characters of the Hammer-head syncline suggest that its stratigraphy corresponds to Greenstone Sequence-II (Tanwan group). The major rock unit (Raialo mica schist[1]) of this sequence in the Hammer-head syncline area is a metagreywacke containing recrystallized quartz, plagioclase (10 to 15%), biotite, staurolite, garnet, sillimanite, with minor opaques and muscovite. The Aravalli mica schist, shown as a thin band, fringing the Hammer-head syncline, is petrographically similar to the metagreywacke. On the other hand, the major rock unit of the Aravalli sequence, south of the Hammer-head syncline across the BDZ, is a semipelite of the Debari Group (Figure 1), containing quartz, biotite, chlorite, muscovite, and at places, minor carbonates. The semipelite contains bands of meta-arkose, comprising quartz, heavily sericitised k-feldspar, and biotite.

The rocks of the Greenstone Sequence-II are metamorphosed in the amphibolite facies and contain evidences of polymetamorphic characters[14]. The paragenetic relationships of the metamorphic index minerals developed in the metagreywacke in relation to the first deformation structures suggest that the first metamorphic event (M_1) produced biotite–garnet assemblages. Similar relationships of the metamorphic mineral assemblages with structures of the second deformation suggest that muscovite, staurolite and sillimanite developed during a later metamorphic event (M_2). These relationships between deformation and metamorphic events are also substantiated by zoned garnets with core and rim having different S_i patterns. Two generations of staurolite signified by pseudomorphed idioblasts containing inclusions of staurolite and garnet of older metamorphic event (M_2) and rims of younger staurolite would suggest that the latter is the product of the last metamorphism (M_3).

The marble of this sequence is coarse-grained (0.08 to 1.30 mm), strongly crystallized and composed of ferroan calcite, chlorite, clinohumite and muscovite. The PT range of these rocks, estimated from mineral paragenesis is 550° to 670° at 5 to 6 kb. Contrary to the polymetamorphic character and medium PT metamorphism of the rocks of the Hammer-head syncline, the rocks of the Aravalli Supergroup in the south reached only biotite–chlorite–garnet grade of upper greenschist facies. The Aravalli dolomite is fine-grained (0.015 to 0.230 mm) and composed essentially of ferroan dolomite. The metabasalt of the basal Aravalli–Delwara sequence contains an assemblage of actinolite, chlorite, plagioclase, epidote and quartz. The PT range for metamorphism of the Aravalli rocks is estimated at 460° to 500° at 4 kb.

The greenschist facies rocks of the Aravalli Supergroup are tectonically juxtaposed along the BDZ against the amphibolite facies rocks of the BGC (Mangalwar Complex). The apparent continuity of the carbonate band across the BDZ, 1 km northeast of Nathdwara, is in fact due to the presence of two carbonate bands in two different lithotectonic units, namely, the Aravallis in the south and the BGC in the north, the two bands having contrasting metamorphic characters.

The rocks in the BDZ suggest a high strain nature of this zone. The metachert of the BGC shows a strong preferred dimensional and crystallographic orientation of quartz slivers. Larger quartz grains show prominent sutured outlines and subgrain formation, indicating an intermediate stage of recrystallization. Streaks of sericite exhibiting 'fish-scale' texture is parallel to mylonitic foliation. The angle between C and S bands is low (10 to 15°). The microfabric of the rocks in the BDZ indicates that this zone has developed essentially as a ductile deformation zone. However, in the eastern part of the BDZ, the deformation seems to be brittle-ductile transitional type, because the small bodies of deformed pink granite intrusive into the BGC rocks contain strained quartz and fractured perthite and plagioclase showing dislocated and bent twin lamelle. At places, pseudotachylite in ultramylonite groundmass is also present.

The Aravalli calcareous quartzite (Debari Quartzite) in the BDZ has developed a strong mylonitic fabric with partially recrystallized quartz slivers aligned

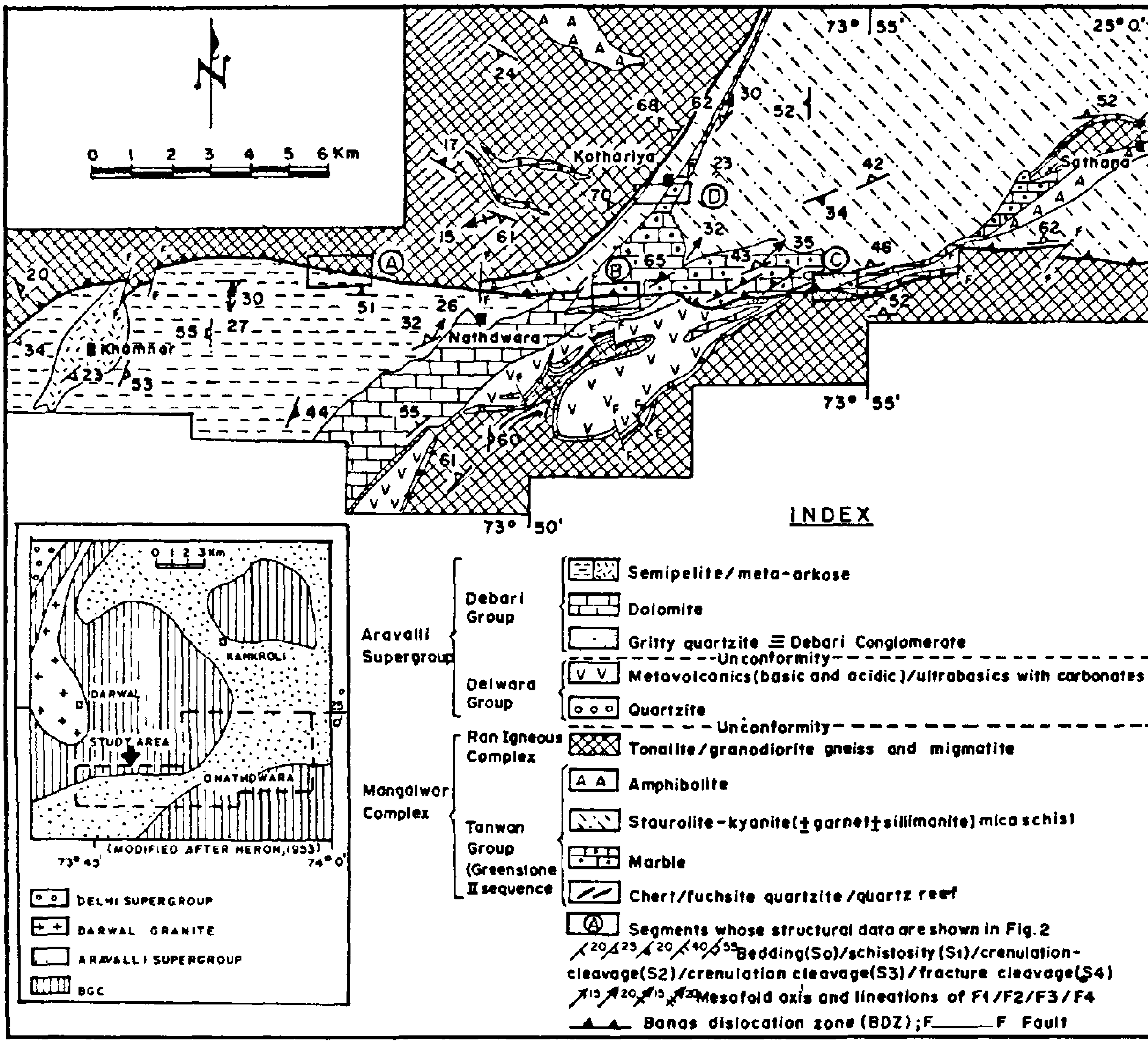

Figure 1. Geological map of Nathdwara–Khamnor area, Rajasthan, showing the Banas Dislocation Zone (BDZ) and its relationship with the different lithostratigraphies.

parallel to mylonitic banding, defined by quartz-rich and carbonate-rich layers. A two-stage development of the mylonite is indicated by an older secondary compositional banding parallel to the long axes of flattened quartz slivers which is intersected by discrete dislocation planes along which the quartz slivers show effects of granulation and microfaulting. This feature would suggest that the rocks in the BDZ are involved in an early ductile deformation and a late brittle deformation. The Aravalli sequence to the south of the BDZ, is represented by the older Delwara Group, dominated by basic volcanics, and the quartzite, carbonate and pelite assemblages of the younger Debari Group. The BDZ in the western part separates the BGC rocks in the north and the Debari Group in the south, while in the east the latter pinches out, except for a tectonized calcareous unit of this group that occurs between the BGC and the Delwara Group in the BDZ. The Debari Group has a strong unconformable relationship with the Delwara Group with a prominent conglomerate unit at the base of the Debari Group, outside the study area, and available evidences indicate a tectonic break between these two groups of the Aravalli sequence. From this, it may be inferred that the post-Debari development of the BDZ is probably related to the second or later deformation of the Aravalli sequence.

Structural relations

The rocks of the BGC and Aravalli Supergroup contain structures of multiple deformations. The planar structures (S_1) of the first deformation in the tonalite and granodiorite gneisses and migmatite of the Ran Igneous Complex is a gneissosity, and in the metasediments of the Tanwan Group it is schistosity almost parallel to bedding. The S_1 in the Aravalli rocks is also a schistosity. In both the cases S_1 is axial planar to the first recognizable isoclinal and reclined to steeply inclined mesoscopic folds (F_1). The second deformation produced a crenulation cleavage (S_2) and megascopic folds (F_2) in both the basement and the cover rocks. One such F_2 fold is defined by mica schist and marble unit of the Tanwan Group in north of the BDZ to the east of Kothariya. The S_2 shows variable attitudes because of F_3 folding which produced a crenulation cleavage (S_3) in the BDZ, the traces of the latter being parallel to S_3. The S_2 is intersected by minor shear planes and the S_2 in the BDZ, at places, swerves into parallelism with S_3 in the BDZ. Mineral fibre lineations, a stretching fabric, has developed on S_3 in the BDZ. The last deformation (F_4) produced warps and kink folds with N–S axial traces in both the basement and the cover rocks, and is also responsible for fault off-sets of the BDZ.

In order to establish the structural relations and their variability with respect to the BDZ, the structural details of four segments (Figure 1) are described below. Figure 2 gives the stereographic plots of the different structures of these segments. Segments A, B and C are within the BDZ and segment D is located within the BGC, ca. 2.5 km north of the BDZ. These diagrams show the relations between the BDZ, S_2, statistical F_2 axis, F_2 pucker lineation (L_2) and stretching lineation (L_3). Table 1 gives the data on the relations between these structural elements. These data and Figure 2 show that the angle between S_2 and the BDZ trace decreases from 68° outside the BDZ through 31° to 3° within the BDZ, signifying a rotation of the pre-existing S_2 into near parallelism with the BDZ. Within the BDZ, the angle between S_2 and BDZ trace is variable which would mean a strain heterogeneity within the dislocation zone. The rake of stretching lineation (L_3) within the BDZ is low (22° to 28°) in the centre and eastern segments (B and C) but in the western part of the BDZ (segment A) it is moderate (50°). This feature would corroborate the strain heterogeneity and a variation in strain geometry in the BDZ. Nonetheless, the low to moderate rake of L_3, signifying maximum elongation in the rocks, would suggest a dominant strike-slip component of movement along the BDZ. The regional map pattern and the map pattern of the study area (Figure 1) show significant swings in lithocontacts into near parallelism with the trace of the BDZ which

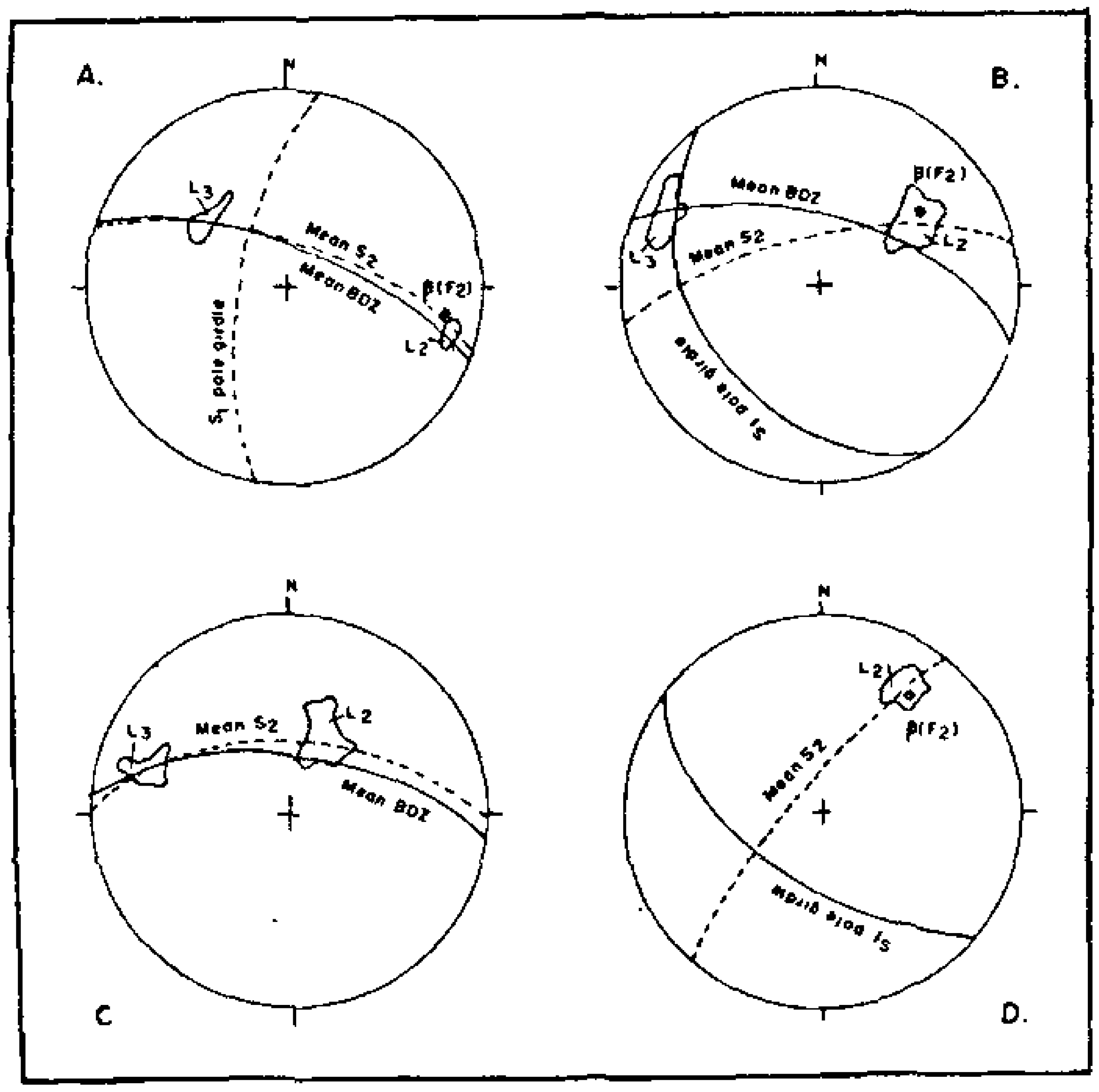

Figure 2. Stereographic (lower hemisphere) plots of different structural elements within and outside the Banas Dislocation Zone. A, B, C, D represent the segments whose locations are shown on Figure 1.

Table 1. Relations between different structural elements within and outside BDZ

Segment	Rake of mean L_2 on S_2 (Degrees)	Statistical F_2 axis (plunge amount in degrees/ direction)	Angle between S_2 and BDZ (Degrees)	Rake of mean L_3 on BDZ (Degrees)	Angle between mean L_2 and mean L_3 (Degrees)
Outside BDZ (D)	28	27/N34E	68	—	—
Within BDZ					
Eastern segment (C)	75	56/N30E	7	28	72
Central segment (B)	46	44/N58E	31	22	85
Western segment (A)	15	14/S74E	3	50	65

indicates a dextral sense of strike-slip movement along the BDZ. The statistical F_2 axis is almost parallel to L_2 which shows a variation in rake on S_2 with respect to the BDZ. L_2 has a low rake (28°) outside the BDZ (segment D), but increases to 46° and 75° in the central (B) and eastern (C) segments respectively. When this feature is considered together with the variation of the angle between the BDZ trace and S_2, it seems that L_2 has rotated to steeply inclined to nearly reclined attitudes within the BDZ. The western segment (A) of BDZ is an anomaly in this scheme because here the L_2 rake is low (15°) which again indicates that the deformation characteristics show a spatial variation along the BDZ. Interestingly, the reoriented L_2 in the BDZ makes an angle of 65° to 85° with L_3 which means that the pre-existing linear fabric has not rotated into parallelism with the direction of maximum elongation of F_3 deformation but L_2 rotation causing the rake variation is probably towards the direction of intermediate axis in a non-plane F_3 strain.

Conclusion

This study has revealed that the rocks of the Hammer-head syncline are a part of the BGC and that these do not physically extend into the Aravalli fold belt. The east-west trending BDZ truncates the rocks of the Hammer-head syncline and the associated other BGC rocks and marks the northern boundary of the Aravalli fold belt. Although the unconformable relationship between the Aravalli and the BGC rocks is discernible in the eastern margin of the Aravalli fold belt, the basement-cover relationship in the northern part is not straightforward. This contact is a tectonic one, being marked by the BDZ. It is difficult to determine whether the BDZ represents a reactivated fault zone that defined the northern limit of the Aravalli basin, although such a possibility cannot be ruled out in view of the fact that the available evidences indicate the evolution of the Aravalli basin through ensialic rifting processes[15]. On a regional scale, the BDZ is linked with the development of a number of tectonic zones in the Aravalli fold belt. The shear zones delimiting the BGC inlier within the Delwara Group, and their northward extension merge with the BDZ near Nathdwara. The Jharol–Gogunda ultramafic tectonic line which is considered to represent a segment of the Aravalli suture zone[16] merges with a strike swing from almost N–S to E–W with the BDZ near Fatehpur. This feature would link the strike-slip movement along the BDZ with the thrust movement in the possible suture zone, controlling the evolution of the Aravalli fold belt.

1. Heron, A. M., *Mem. Geol. Surv. India*, 1953, **79**(1), 389.
2. Gupta, S. N., Arora, Y. K., Mathur, R. K., Iqbaluddin, Balmiki Prasad, Sahai, T. N. and Sharma, S. B., *Lithostratigraphic Map of Aravalli Region*, Publ. Geol. Surv. India, 1980.
3. Sinha-Roy, S., *Bull. Geol. Min. Met. Soc. India*, 1985, **53**, 115–123.
4. Gopalan, K., MacDougall, J. D., Roy, A. B. and Murali, A. V., *Precambr. Res.*, 1990, **48**, 287–297.
5. Ahmed, T. and Rajamani, V., *Mem. Geol. Soc. India*, 1988, **7**, 318–327.
6. Naha, K. and Roy, A. B., *Precambr. Res.*, 1983, **19**, 217–223.
7. Naha, K., Choudhary, A. K. and Mukherji, P., *Contrib. Mineral. Petrol.*, 1967, **15**, 191–216.
8. Naha, K. and Halyburton, R. V., *Precambr. Res.*, 1974, **4**, 55–73.
9. Sharma, R. S., *Mem. Geol. Soc. India*, 1988, **7**, 33–76.
10. Roy, A. B., *Mem. Geol. Soc. India*, 1988, **7**, 3–32.
11. Bharktya, D. K. and Gupta, R. P., *Rec. Res. Geol.*, 1983, **10**, 186–192.
12. Sinha-Roy, S., *Indian Mineral.*, 1989, **43**, 226–240.
13. Sinha-Roy, S., Guha, D. B. and Bhattacharya, A. K., *Indian Mineral.*, 1992, **46**,
14. Mohanty, M. and Guha, D. B., *Rec. Geol. Surv. India*, 1990, **123**, 1.
15. Sinha-Roy, S., *Indian J. Earth Sci.*, 1984, CEISM vol., 84–91.
16. Sinha-Roy, S., *Mem. Geol. Soc. India*, 1988, **7**, 95–108.

ACKNOWLEDGEMENT. We thank the GEODATA Division GSI, WR for extending facilities.

Received 5 September 1991; revised accepted 30 January 1993