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# Influence of differential basement mobility on contrasting structural styles in the cover rocks: An example from Early Precambrian rocks east of Udaipur, Rajasthan

A B ROY and D K NAGORI

Department of Geology, M L Sukhadia University, 51 Saraswati Marg, Udaipur 313 001, India

**Abstract.** Detailed structural and lithological mapping of the Aravalli rocks overlying the Mewar Gneiss in the area east of Udaipur, Rajasthan, suggests presence of blocks bounded by faults, showing a contrasting structural pattern. The contrast is reflected in the differential development and in the orientation of AF1, AF2 and AF4 folds in different blocks. In the central Umra block, the rocks constitute a virtually homoclinal sequence showing one dominant orientation of bedding and axial planar schistosity. Fold axes, lineations and $\beta$ orientations indicate presence of reclined folds of AF1 generation. AF2 folds are either absent or have developed only locally. The two other blocks which border the Umra block show development of large AF2 synforms and local minor antiforms having N–S or NNE–SSW trend. The folds interfere with AF4 folds producing irregular domes and basins in the western Kanpur-Kalarwas Block and minor plunge reversals in Bagdara-Dhamdhar Block. It is argued that the constituents of the different blocks which formed a collage of rift basins and horsts during sedimentation, responded differentially to deforming forces because of differential mobility of the underlying basement.

**Keywords.** Differential basement mobility; Early Precambrian rocks; structural mapping; lithological mapping; tectonic synthesis.

## 1. Introduction

Studies carried out during the last 25 years in the area between Amet and Salumber have helped in elucidating a complex history of deformation in the Aravalli Supergroup of Early Proterozoic age. In addition to three or four phases of folding which produced intricate outcrop patterns in different scales of study (*see* Naha and Chaudhuri 1968; Mukhopadhyay and Sengupta 1979), more recent studies have revealed the role of ductile shear zones and faults in the structural evolution of the rocks of the region (Roy *et al* 1980, 1985; Paliwal 1988; Roy and Bejarniya 1990). Many of these dislocations occur along the interface of the Aravalli cover rocks and the pre-Aravalli basement (Mewar Gneiss; Roy 1988). From the nature and distribution of lithological units and the relationship between their sedimentary facies, it appears that at least a few of these were initiated as basin margin faults.

Although structural investigations in a number of regions confirmed involvement of basement during deformation of cover rocks (Naha and Mohanty 1988; Naha and Roy 1983; Sharma *et al* 1988), analysis of isotopic data of Choudhary *et al* (1984) indicates differential response of basement 'blocks' during later orogenic cycles (see Roy 1988). The contrasting behaviour of the basement is also strongly reflected in the strain and fold geometry of the cover rocks (Roy *et al* 1980; Roy and Bejarniya 1990). The present paper deals with one such case, and suggests how a contrasting structural pattern in the cover rocks could have resulted because of differential mobility of the underlying basement blocks during different phases of deformation.

## 2. Geological setting

The present area of investigation lies east of Udaipur (figure 1) where a low grade metasedimentary sequence representing a shallow water shelf facies rocks (Roy and Paliwal 1981; Roy *et al* 1984, 1988; Choudhuri and Roy 1986; Nagori 1988) unconformably overlies biotite gneisses, amphibolites and metasediments. Recent Sm-Nd isotopic studies indicate 3·28 Ga whole rock age of the biotite gneisses of the area (Gopalan *et al* 1990). The youngest age recorded in these rocks is 2·45 Ga which is the date of mineral scale re-equilibration of Sm-Nd isotopes (*op. cit.*). The cover sequence belongs to the Aravalli Supergroup which comprises three groups, each separated from the other by an unconformity.

The present study is based on structural and lithological maps prepared by the authors (figures 2 and 3). Several important stratigraphical revisions have been proposed on the basis of field relations and map pattern.

(i) The Udaisagar granite of Heron (1953) is physically continuous with the Banded Gneissic Complex, and constitutes the basement of the Aravalli (Supergroup) rocks.
(ii) The conglomerate-arkose-quartzite unit which Heron (1953) thought to be an outlier of the Delhi system forms a part of the Aravalli succession (Roy *et al* 1988).
(iii) There is a single phosphorite horizon (bed) which, because of its characteristic stromatolitic structures, persistently narrow outcrop width and continuity, constitutes a prominent marker bed not only for determining the correct stratigraphic order of rocks but also in elucidating the structural history.

Stratigraphic relationship and sedimentary attributes of the Aravalli formations suggest their deposition in linear, discontinuous basins which developed as a system of complex grabens separated by horsts (Roy and Paliwal 1981; Nagori 1988). Periodic subsidence of faulted blocks has been considered to be the primary factors controlling sedimentation in the Aravalli basins (Roy and Paliwal 1981).

## 3. Chronology of structural elements

Four phases of folding (AF1, AF2, AF3 and AF4) and the corresponding planar and linear structures have been identified in the field. AF1 folds, which are the earliest structures developed in the Aravalli rocks, are generally isoclinal in nature, having high but variable amplitude-wavelength ratio. It is, however, difficult to express this ratio quantitatively because of two reasons: (i) these folds have commonly approached the condition of coalesced limbs; and (ii) the limbs of these folds have also been affected by later folding.

AF1 folds, particularly in the carbonates, show extremely variable profile shapes due to thickening of hinges and thining of limbs. In certain cases detached hinges of AF1 folds appear as 'fish-hooks' (Ramsay and Huber 1987) bounded by zones of penetrative axial planar cleavage (or schistosity). AF1 folds do not seem to have

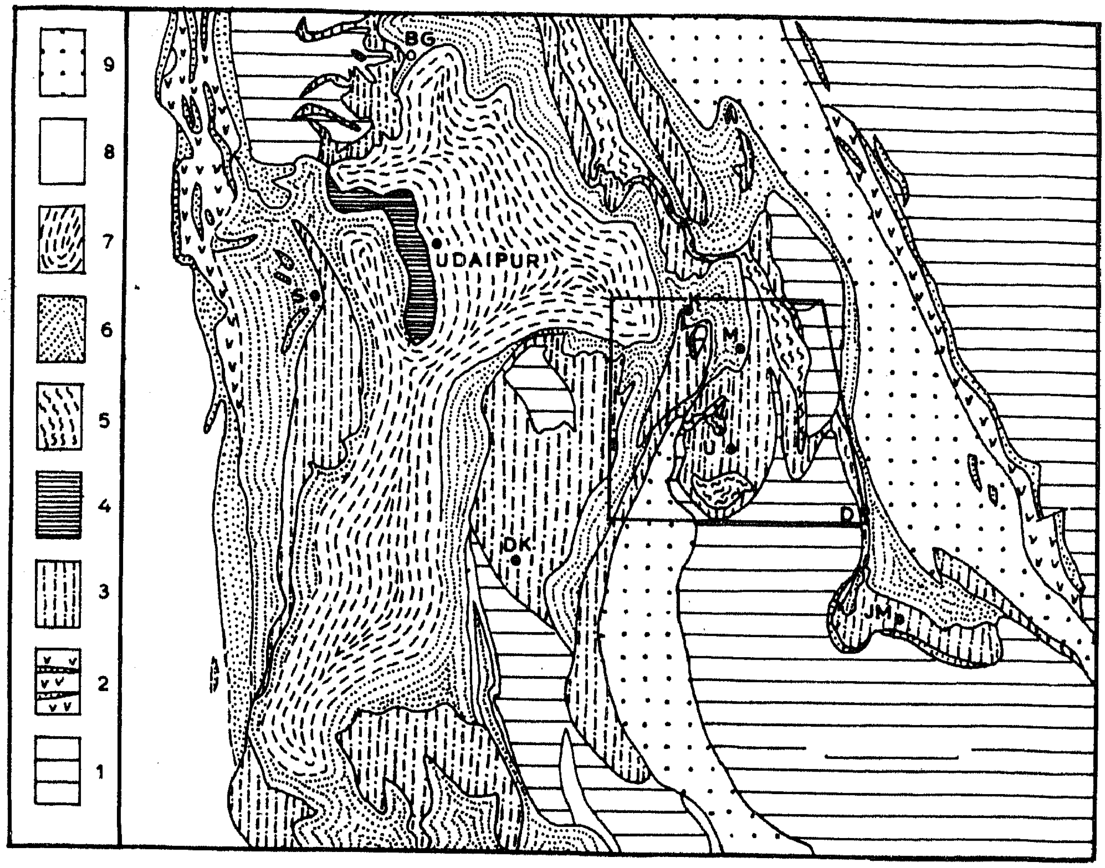


**Figure 1.** Geological Map of Udaipur region showing area of investigation (Modified after Heron 1953). Explanations: 1. Mewar gneiss; 2. Basal volcanics, and quartzite-grit-conglomerate; 3. Carbonate association with phosphorite; 4. Orthoquartzite silty arenite; 5. Carbonaceous slate; 6. Phyllite and mica schist; 7. Greywacke-phyllite and lithic arenite; 8. Mica schist-phyllite with bands of quartzite; 9. Conglomerate-arkose and quartzite. JM—Jhamarkotra, D—Dhamdhar, U—Umra, M—Maton, K—Kanpur, BG—Bargaon, S—Sisarma, DK—Dakan Kotra.

developed uniformly over the whole region. These folds are most common in the Umra region. By contrast, very few folds of this generation have developed in the eastern and western areas around Kanpur, Bagdara and Dhamdhar. In parts of the Kanpur area, even the schistosity does not seem to have developed in the rocks.

In the Umra region, AF1 folds are almost invariably reclined in geometry. In other areas the folds show variable attitude, from gently inclined (showing low pitch angle between the fold axis and the strike of the axial plane) to almost reclined.

Folds with subvertical-to-steep axial planes (AF2) have been overprinted on the earlier structures. Most of these second generation folds have high interlimb angles (gentle or open in geometry); a few, however, are tight or even isoclinal in nature. Usually AF2 folds show well-developed axial planar crenulation cleavage. AF2 folds show variable trend of fold axis; the majority of these, however, have northeast-southwest trend. Variation in trend of AF2 fold axis is due to variation in the attitude of axial plane, and superimposition of AF4 folding on these folds. Plunge variation ranges from low to moderate. Locally steeply plunging AF2 folds, varying from reclined to upright geometry, are observed. In general, the axes of AF2 folds are at high angles to those of AF1 folds (and lineations). Intersection of the two fold systems

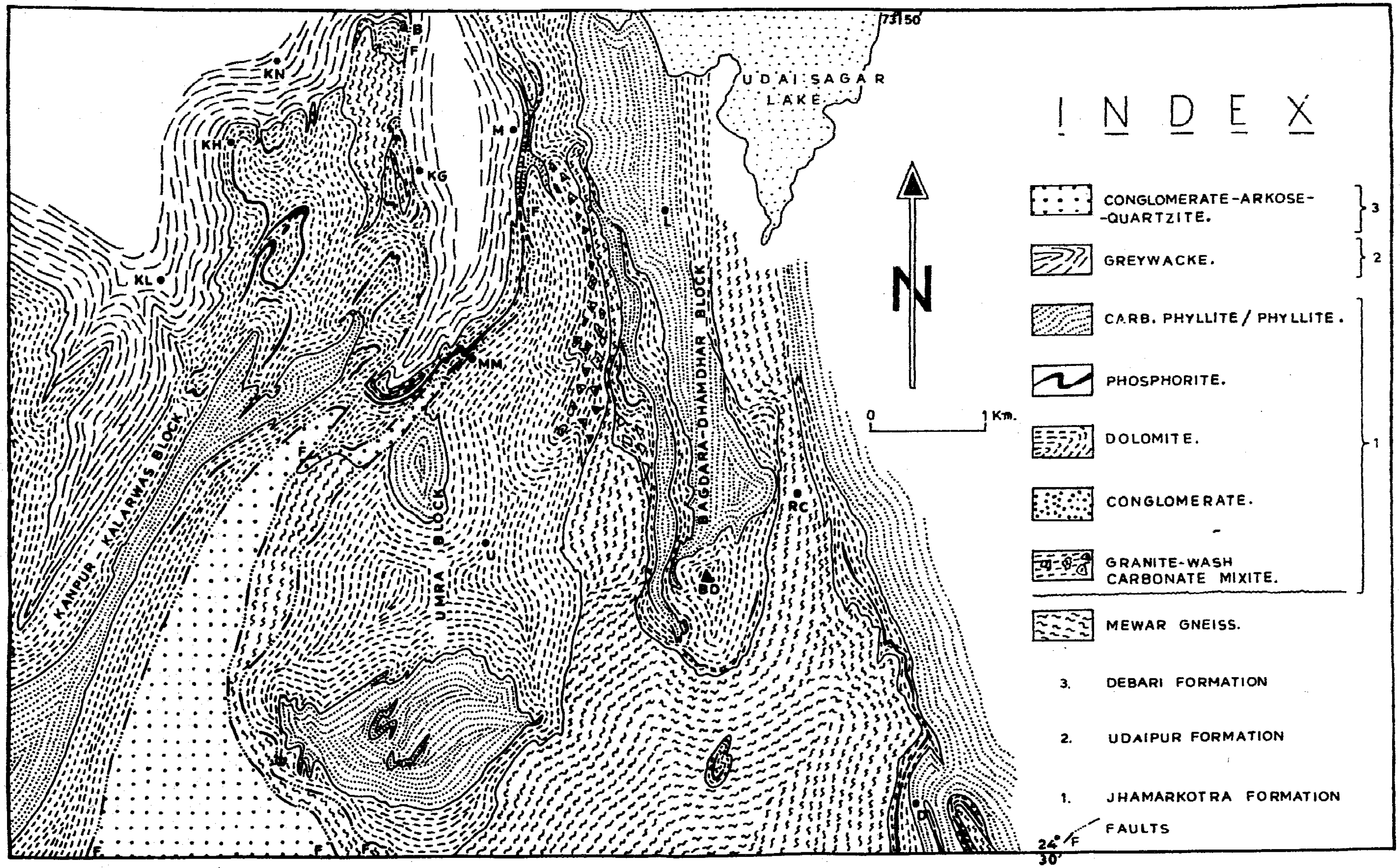


**Figure 2.** Lithological map of the area east of Udaipur. D—Dhamdhar; RC—Rock Crusher; BD—Bagdara hill; L—Lakarwas; M—Maton; MM—Maton Mines; U—Umra; KG—Kharbaria ka Gurha; B—Bhoion ki Pacholi; KN—Kanpur; KL—Kalarwas.

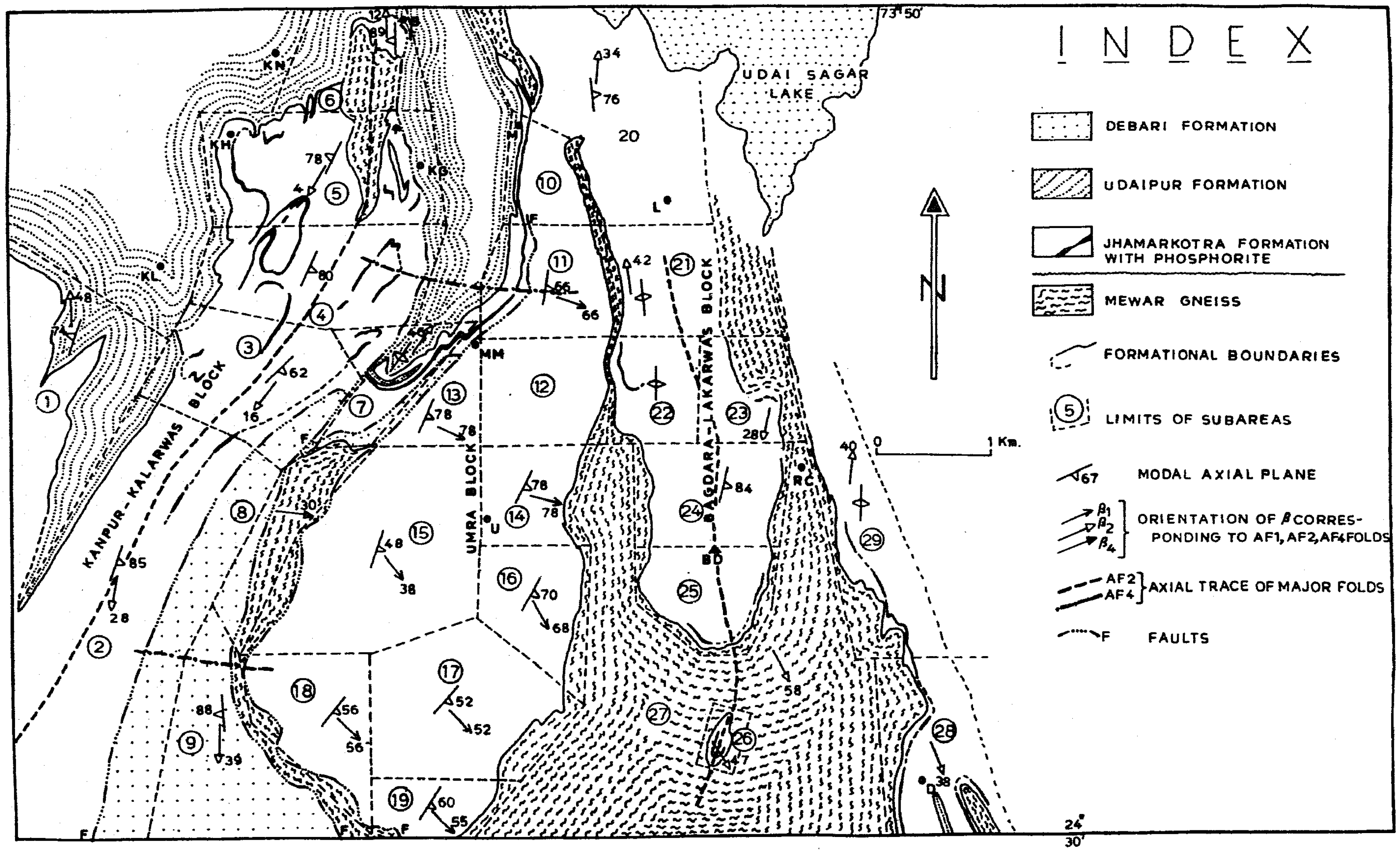


**Figure 3.** Synoptic structural map of the area east of Udaipur showing major structural features. D—Dhamdhar; RC—Rock Crusher; BD—Bagdara hill; L—Lakarwas; M—Maton; MM—Maton Mines; U—Umra; KG—Kharbaria ka Gurha; B—Bhoion ki Pacholi; KN—Kanpur; KL—Kalarwas.

at low angles, becoming virtually coaxial at a few places, has been observed in the area around Maton village.

AF3 folds having subhorizontal axial planes commonly occur on steeply dipping bedding and schistosity planes. Unlike the two earlier fold phases, the folds of this generation developed only in small scales. A set of well-developed crenulation cleavage generally accompanies these folds showing fanning of the axial planes.

Refolding of AF1 and AF2 folds by AF4 folds having steep, east-west striking axial planes is a common feature both in small and large scales. In outcrops, most of these folds appear as warps in different parts of the study area. Associated with AF4 folds are axial planar fracture cleavage which developed sporadically in mica schists, phyllites and carbonates.

Besides different generations of folds, a number of faults and slides (*sensu* Bailey 1910) have affected the rocks of the region. Most of the faults follow the lithological contacts. Locally, however, these have produced offsets in the outcrop pattern. The presence of conglomerate, showing characteristics of steep-slope origin, along some of the fault planes suggests that a few of these are synsedimentary faults defining margins of sub-basins ("growth faults") which later participated in the deformation of rocks.

## 4. Structural analysis

### 4.1 *Structural subareas and synoptic diagrams*

For preparing synoptic diagrams for planar and linear structures, the entire area was divided into twentynine subareas. Although the main purpose was to divide the map area showing effects of the polyphase deformation into domains of cylindrical folding, this was effectively not possible because of the complexity of deformation. Even then, the diagrams are useful for visualizing the variation in orientation of bedding and other planar and linear structures over the whole region (figures 5A, B and C). Together with the map pattern of the marked beds and evidence of younging, these diagrams helped in elucidation of large-scale structural pattern. A summary of interpretation of the synoptic diagrams from different subareas is given in tables 1, 2 and 3.

### 4.2 *Large scale structural pattern*

For convenience, the entire area has been divided into three blocks, viz, (a) Kanpur-Kalarwas Block, (b) Umra Block, and (c) Bagdara-Dhamdhar Block. Each of the blocks shows a distinctive structural pattern.

4.2a *Kanpur-Kalarwas Block*: Map patterns of formational boundaries and younging data suggest that the carbonate sequence south of Kanpur is folded into a large synform of AF2 generation. In the south, the fold is virtually isoclinal having gentle plunge to south. The fold geometry changes northward, and north of the Railway line the synform splits into two with an antiform appearing in the middle. The plunge of the antiform, which is towards south in the southern part, shows reversal to north in the northern part. Unroofing in the culmination zone thus formed exposed the granitic basement (figure 3).

**Table 1.** Structural Geometry in different subareas in the Kanpur-Kalarwas Block.

| Sub area No. | Nature of S-pole diagram | Plunge and trend of beta | Modal axial plunge (dip and direction) | Remarks |
|---|---|---|---|---|
| 1. | Single maximum spread along a girdle | 48 to N4E | 74 to N65W | Antiformal $AF_2$ fold, lineations scattered along the modal plane. |
| 2. | Strong peripheral maximal spread along a girdle | 28 to S22W | 85 to S63E | Isoclinal anticlinal folds with pinched in syncline. $L_2$ around beta. |
| 3. | Strong maximum and weekly defined partial girdle. | 16 to S33W | 62 to S49E | Tight and isoclinal $AF_2$ folds weakly cylindrical fold geometry. Lineations widely scattered. |
| 4. | Conjugate maxima with wide scattering of poles | —— | 80 to S59E | $AF_2$ folds showing continuous variation in plunge because of fold interference. |
| 5. | Several weak maxima spread along weakly defined girdle. | 4 to S24W | 78 to N67W | Open $AF_2$ folds. $L_2$ lineations widely scattered |
| 6. | Fairly well-defined girdle. | 12 to N2W | 89 to S88W | Open $AF_2$ antiformal fold. $L_2$ lineations around beta. |

**Table 2.** Structural geometry in different subareas in Umra Block.

| Sub area No. | Nature of S-pole diagram | Plunge and trend of beta | Modal axial plunge (dip and direction) | Remarks |
|---|---|---|---|---|
| 7. | Scattered maximum weakly defined girdle. | 46 to N49E | N49E/90 | Fairly open $AF_2$ synformal folding. |
| 8. | Partial girdle with single maximum | 30 to S81E | —— | Gentle $AF_4$ folding. |
| 9. | Symmetrically arranged pair of maxima lying on a well-defined girdle. | 39 to S2E | 88 to S87W | Open synformal $AF_2$ folds. $L_1$ Lineations around beta. |
| 10. | Wide scattering of poles | — | — | Noncylindrical fold geometry. |
| 11. | Scattered poles defining a weak girdle | 66 to S64E | 66 to S70E | Reclined $AF_1$ folding. Early lineations around beta, $L_2$ moderate to low plunging to NNE–SSW. |
| 12. | Peripheral distribution of poles; weak girdle in other directions. | — | — | Steep and vertical plunging folds. Lineations widely scattered. |
| 13. | Strong maximum spread along a partial girdle. | 78 to S66E | 78 to S65E | Reclined folding of $AF_1$ generation. Lineations widely scattered. |
| 14. | Well spread out poles with a single maximum | 78 to S79E | 78 to S61E | Reclined $AF_1$ folding. $L_1$ around beta. |
| 15. | Very strong maximum and wide scattering of lower concentration points. | 38 to S25E | 48 to S68E | Lineations scattered around beta. Inclined $AF_1$ folding and effects latter deformation. |

(*Continued*)

**Table 2.** (*Continued*)

| Sub area No. | Nature of S-pole diagram | Plunge and trend of beta | Modal axial plunge (dip and direction) | Remarks |
|---|---|---|---|---|
| 16. | Strong maximum and peripheral spread. | 68 to S33E | 70 to S60E | Lineations around beta. Near reclined geometry of $AF_1$ fold. |
| 17. | Strong maximum spread along partial girdle. | 52 to S47E | 52 to S57E | Lineations scattered around beta. Reclined $AF_1$ geometry. |
| 18. | Strong maximum spread along partial girdle. | 56 to S49E | 56 to S49E | Reclined geometry of folding. |
| 19. | Pair of closely spaced maxima and widely spread out pole distribution. | 55 to S27E | 60 to S59E | Steeply inclined $AF_1$ folding. Lineations scattered around beta. |

**Table 3.** Structural geometry in different subareas in Bagdara Dhamdhar.

| Sub area No. | Nature of S-pole diagram | Plunge and trend of beta | Modal axial plunge (dip and direction) | Remarks |
|---|---|---|---|---|
| 20. | Single maximum fairly well spread along a girdle. | 34 to N4E | 76 to N86E | $AF_2$ folding. Single maximum may indicate isoclinal folding. |
| 21. | Strong peripheral maximum and well-defined girdle. | 42 to N10W | N10W/90 | Upright $AF_2$ folding with isoclinal geometry. |
| 22. | Symmetrical disposed pair of maxima. Tendency towards a small circle girdle. | — | N–S/90 | Upright folding with conical geometry. |
| 23. | Single maximum spread along partial girdle. | 28 to S13W | — | Majority of data from hinge region only. |
| 24. | Fairly strong peripheral maximum and wide scattering of poles. Weak tendency towards small circle girdle. | — | 84 to S74E | Noncylindrical geometry. Scattering of lineations. |
| 25. | Widely scattered poles with a weak maximum. | — | — | Concentration suggests moderate plunge of fold axis to south. |
| 26. | Fairly well-defined girdle with a pair of unbalanced maxima. | 47 to S26E | 82 to S56W | Sheath fold showing practically cylindrical fold geometry. |
| 27. | Annular pattern of poles with several maxima lying on a weakly defined girdle. | 58 to S24E | — | Folding of steep planes having diverse attitudes. |
| 28. | Well-defined partial girdle Lineations are scattered. | 38 to S19E | 80° to N80E | Southerly plunging $AF_2$ folding. |
| 29. | Peripheral maximum spread into a partial girdle. | 40 to 77°E | 90 to N7E | Upright northerly plunging $AF_2$ folding. |

The complex outcrop pattern brought out by the thin phosphorite bed in the region north of the Railway line is the result of superimposition of AF4 folds on the AF2 folds (figure 4). The interference caused (i) variation in the plunge of AF2 fold (figure 5A, 1–6), (ii) arcuation in the axial planar orientation of AF2 antiforms and synforms, and

(iii) rotation of AF2 axial planes from almost vertical to steeply dipping towards east or west. These effects have been spectacularly brought out by the outcrop pattern of the phosphorite bed. Giving allowances for the lateral discontinuities in the outcrop of the bed, the phosphorite bed defines a series of irregular domes and basins showing shallow plunge of fold hinges varying through horizontal, with consequent changes in trend from south-southeast to north-northeast.

South of Kalarwas, the carbonate rocks and the overlying greywacke-slate-phyllite sequence (figure 3) form a series of antiforms and synforms plunging at moderate angles to north. Small-scale folds show a wide range of variation in plunge and trend. Unlike the folds south of Kanpur, the folds in this area show easterly vergence.

Two major subparallel faults showing significant strikeslip displacement have been traced close to the north eastern margin of the Kanpur-Kalarwas Block (figure 3). The eastern-most Maton Fault which borders the eastern margin of the Maton Synform shows a sinistral sense of movement. It is a basin margin fault which participated in later deformations. The western Kharbaria Fault, which is dextral in character, is post-AF2 in age, and has truncated the Maton Synform defined by the phosphorite bed. This fault may also in part be a basin margin growth fault.

4.2b *Umra Block*: The Umra block, sandwiched between synformal fold systems of Kanpur-Kalarwas Block in the west and the Bagdara-Dhamdhar Block in the east, represents a distinctive structural entity. Stratigraphically, there are three units occurring as subparallel broadly homoclinal sequences. The units are the carbonate-carbonaceous phylite association without phosphorite, and the conglomerate-arkose-quartzite separated by an intervening 'slice' of sheared basement rock. Unlike other blocks, all the subareas within this block, except one, show one dominant orientation of bedding and schistosity, expressed as a single point maximum in an S-pole diagram (table 2, figures 5A, 7–9; 5B, 1–10). The spread in each diagram describes a partial girdle around a $\beta$ which defines the plunge and trend of reclined (or steeply inclined) folds. Concentration of early lineations and AF1 fold axis around $\beta$ suggests that the orientation of bedding in these subareas shows influence of AF1 folds only. The study of S-pole diagrams also reveals a distinct swing in the strike of the modal axial planes from NNE–SSW in the northern part of the Umra Block to almost N–S in the southern part. This swing in modal axial plane is possible the effect of AF4 folding. The only subarea in this block which shows the effect of AF2 folding is that which covers the southeastern part of the outcrop of the conglomerate-arkose-quartzite. The S-pole diagram prepared for this subarea defines a $\beta$ which plunges 39° to S2°E (figure 5A, 9). Apart from this, there is no indication of any major AF2 folding in the entire Umra Block. Even in small scale, folds, of AF2 generations have developed only locally. A symmetry of AF2 folds (in small scales) and their westerly vergence are indicative of westward tectonic transport during AF2 fold movement.

4.2c *Bagdara-Dhamdhar Block*: The Aravalli rocks in this block occur as linear outcrops between granitic gneisses and amphibolite. Besides the lenses of carbonate mixed with granite-wash and local wedges of conglomerate indicating unconformity between phosphorite-bearing metasediments and the gneisses and amphibolite, there is a sharp contrast in the grade of metamorphism between the two stratigraphic units. At many places, almost unmetamorphozed carbonate rocks (dolostones) are seen to overlie medium-to-high grade paragneisses (marbles and calc-silicate rock),

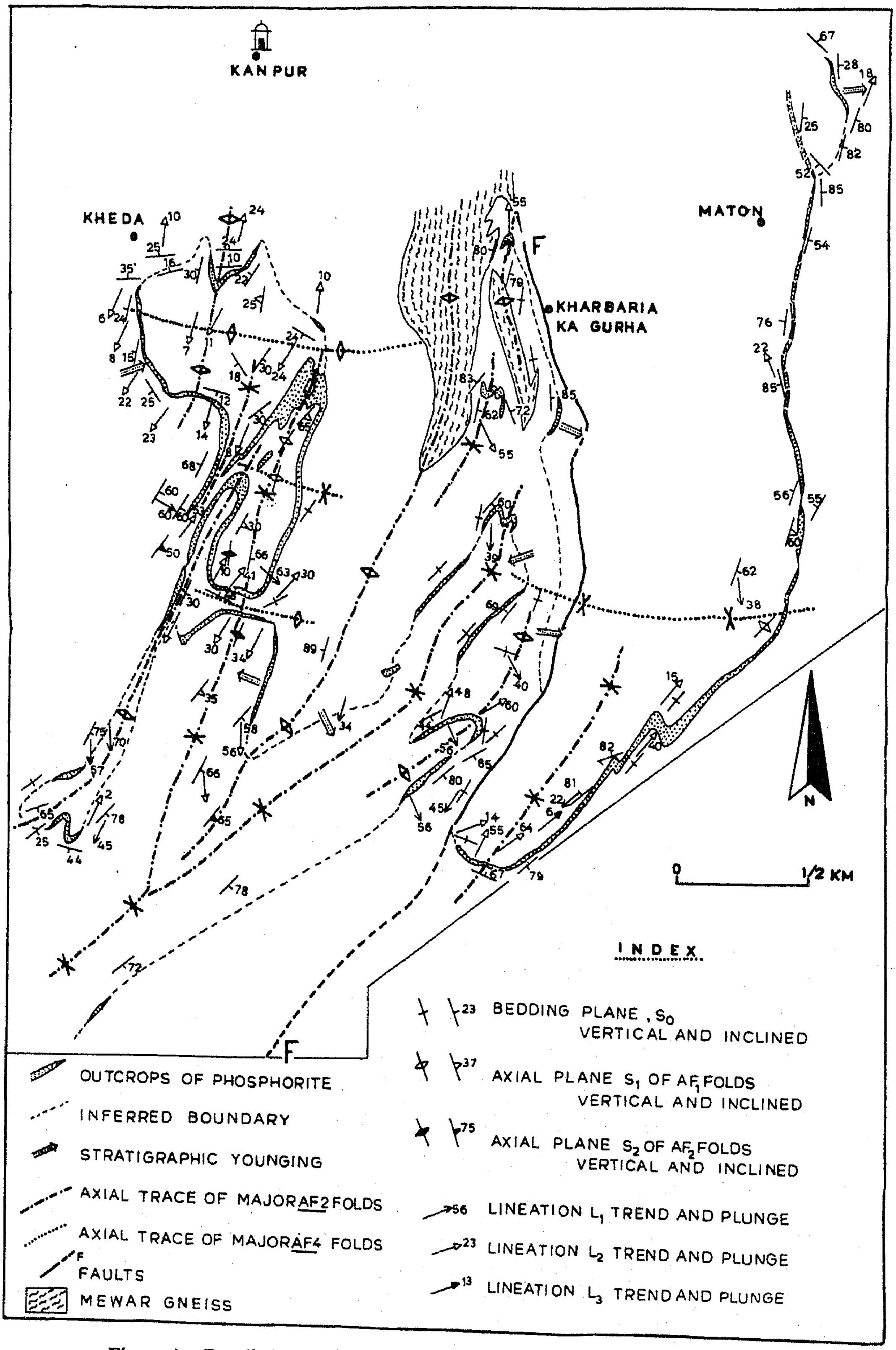


**Figure 4.** Detailed structural map of a small area south of Kanpur and Maton.

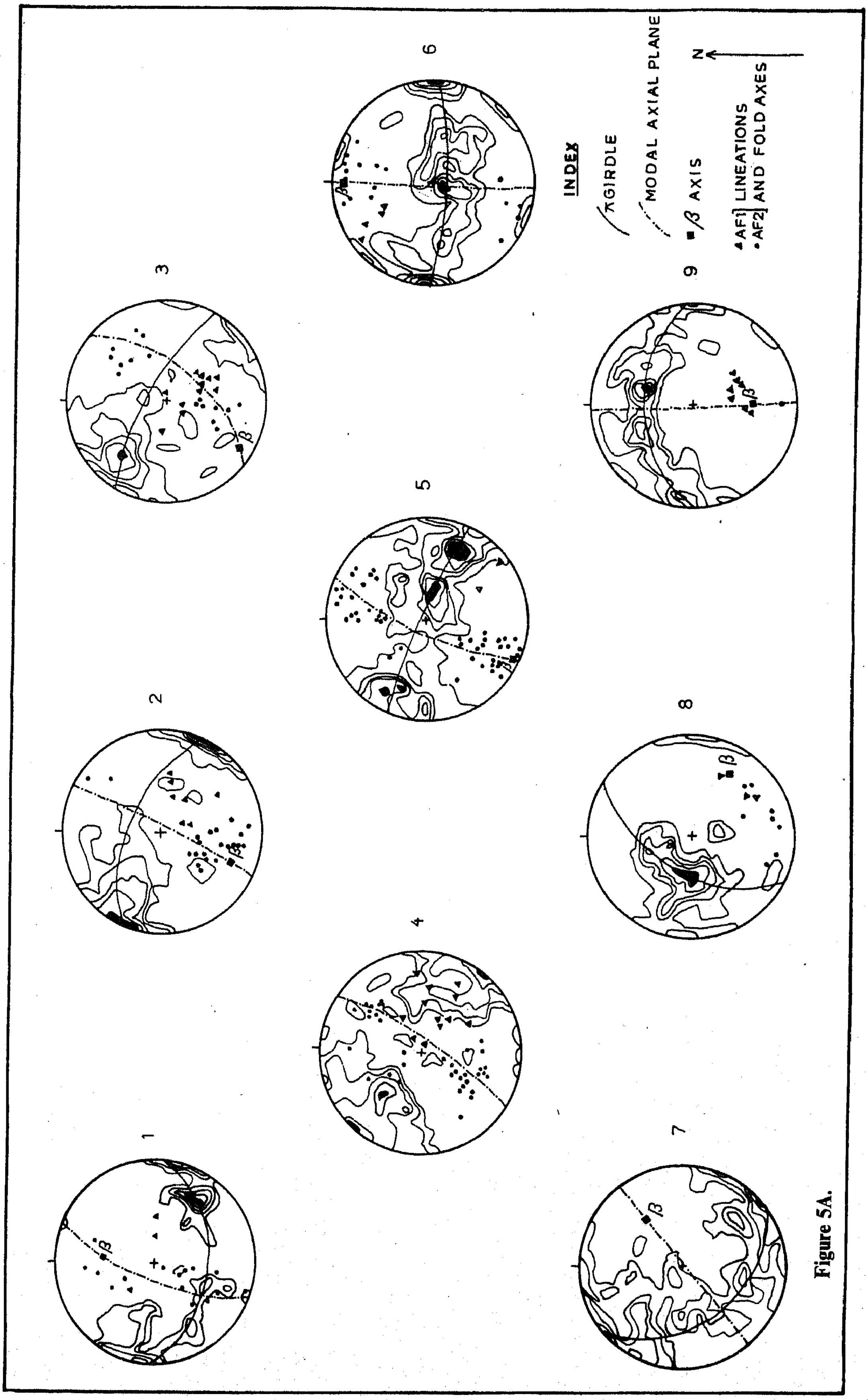
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Figure 5A.

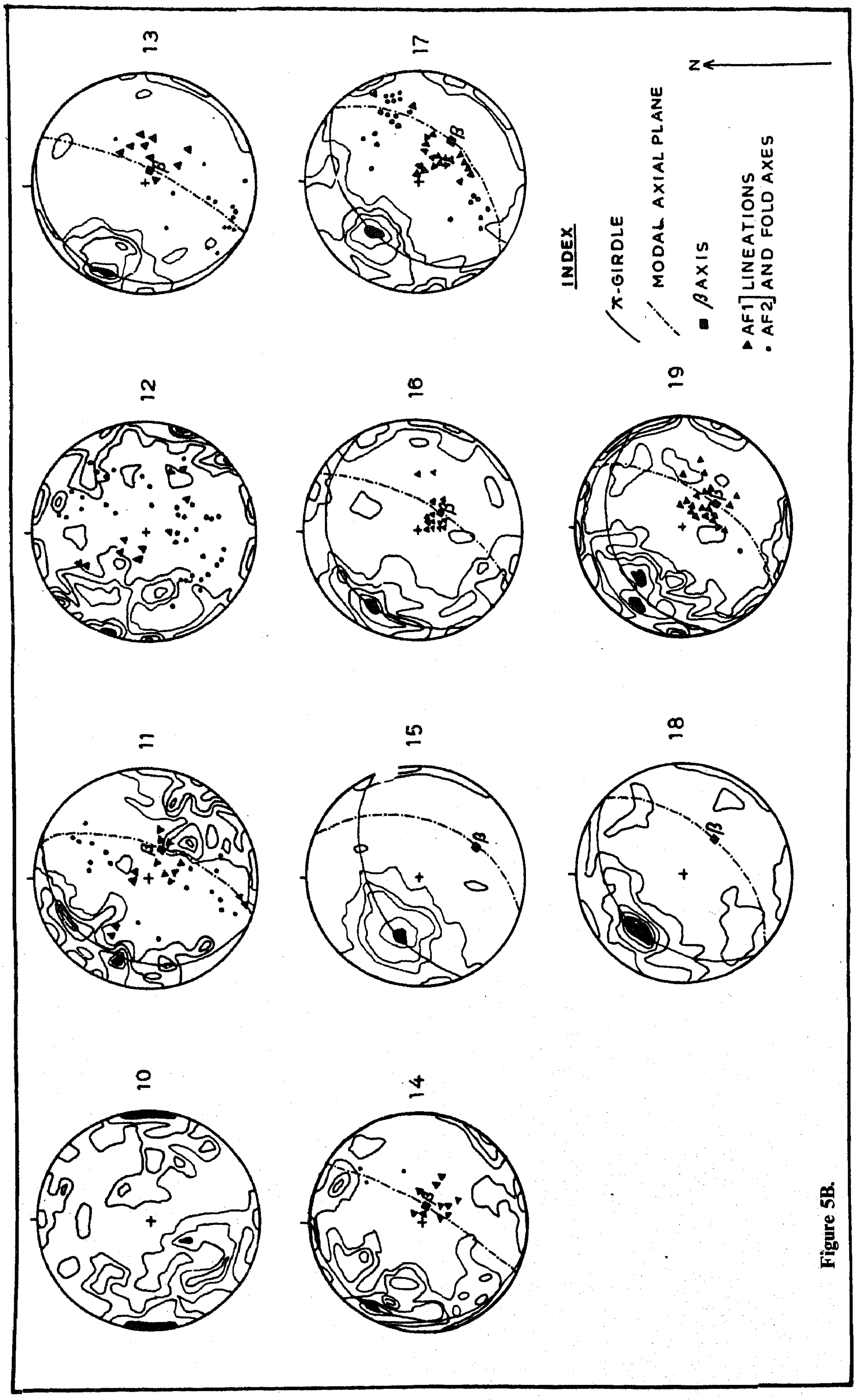
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Figure 5B.

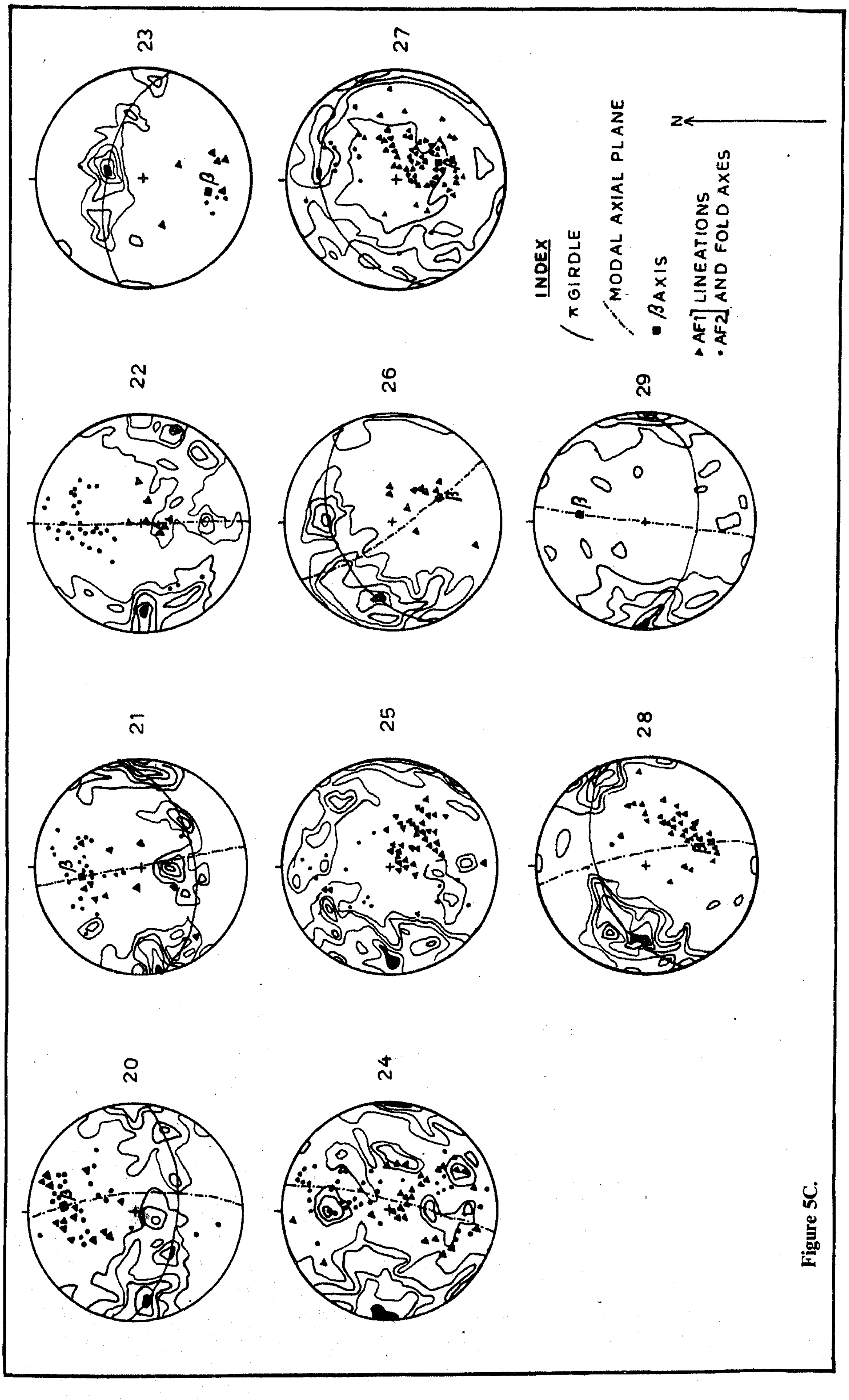


**Figure 5C.**

**Figure 5(A–C).** Orientation of planar and linear structures in different sub areas (1–29).

Details of different stereograms (figures 5A, B, C)

| Sub area number | Total poles | Contour values (% per unit area) | Maximum (%) |
|---|---|---|---|
| *Kanpur-Kalarwas Block* | | | |
| 1 | 93 | 1·61–2·68–3·76–4·83–5·91 | 6·45 |
| 2 | 123 | 0·4–2·03–5·2–8·4–12·13 | 17·60 |
| 3 | 180 | 0·83–2·5–4·2–5·8–10·8 | 11·50 |
| 4 | 259 | 0·59–0·98–2·15–4·49–6·05 | 6·54 |
| 5 | 249 | 0·6–1·81–2·2–3·0–3·8 | 4·80 |
| 6 | 71 | 0·7–2·1–3·5–4·9–6·3 | 8·45 |
| *Umra Block* | | | |
| 7 | 83 | 0·60–1·80–3·01–5·42–9·03 | 9·80 |
| 8 | 52 | 0·26–0·78–1·3–1·82–2·86 | 3·12 |
| 9 | 64 | 0·78–2·34–5·46–7·03–11·71 | 14·06 |
| 10 | 90 | 0·55–1·66–2·77 | 3·33 |
| 11 | 127 | 1·18–1·96–2·75–3·54–5·11 | 5·51 |
| 12 | 149 | 1·00–1·67–3·02–3·69–5·70 | 6·04 |
| 13 | 94 | 1·6–3·7–5·8–7·9–10·07 | 12·80 |
| 14 | 64 | 0·78–2·34–3·90–7·03–10·15 | 10·93 |
| 15 | 303 | 0·8–2·47–3·47–8·6–9·8 | 12·80 |
| 16 | 58 | 0·86–2·58–4·31–6·03–12·93 | 15·51 |
| 17 | 199 | 0·75–2·76–4·27–7·28–10·30 | 11·05 |
| 18 | 97 | 0·52–2·57–5·67–8·76–9·79 | 14·43 |
| 19 | 123 | 0·40–1·21–2·03–4·47–6·09 | 8·13 |
| *Bagdara-Lakarwas Block* | | | |
| 20 | 149 | 1·0–2·34–3·0–4·6–7·7 | 8·04 |
| 21 | 106 | 0·47–2·35–3·30–4·24–8·96 | 10·38 |
| 22 | 171 | 0·87–2·03–2·60–3·8–4·4 | 4·64 |
| 23 | 46 | 3·26–5·43–9·78–11·95–14·13 | 15·21 |
| 24 | 194 | 0·77–1·28–2·31–3·35–4·38 | 5·15 |
| 25 | 149 | 0·87–1·46–2·04–3·21–4·38 | 5·84 |
| 26 | 69 | 1·45–2·17–3·62–5·07–6·52 | 7·25 |
| 27 | 478 | 0·31–1·35–1·98–2·82–3·45 | 3·55 |
| 28 | 107 | 1·40–2·33–3·27–4·2–6·0 | 9·30 |
| 29 | 162 | 0·92–3·39–5·25–7·09–8·95 | 9·26 |

amphibolite and tonalitic-trondhjemite gneiss. Bedding planes in the carbonate rocks are at places at high angles to the foliation in the gneissic units.

The main body of the Aravalli rocks forms a linear U-shaped outcrop closing south of Bagdara Hill, Further south, there is a small oval outlier of carbonate and phosphorite amidst granitic gneisses and amphibolites. The carbonate, its facies variants, and phyllites also occur in the eastern margin of the map area as the northward continuation of the Jhamarkotra outcrop of the Aravalli rocks (see Roy *et al* 1980).

Stratigraphic relationship of rocks, as evidenced by the younging data, clearly suggests the synclinal nature of the Bagdara fold. The fact that schistosity (S1) planes along with bedding constitute the form surface of upright N–S trending folds proves that the Bagdara fold is a second generation (AF2) structure. No first generation folding in the scale of map is present in the cover unit.

From north to south, the fold axis shows variation in plunge from almost northerly in the north to south-easterly in the south near the closure (figure 3). A continuous change in the orientation of AF2 fold axis is also noticeable in the orientation of linear structures and axis of small scale folds of the AF2 generation.

Axial surface of the synform as indicated by the modal plane (figure 3) dips steeply to east in the north and is almost vertical in the south.

Judging purely from the shape of the outcrop, the southern outlier can be described as a typical 'eyed fold' (Ramsay 1967; Ramsay and Huber 1987). S-pole diagram prepared for this sub-area indicates that fold geometry is statistically cylindrical. The $\beta$ plunges 47° to S26°E, and the modal axial plane dips steeply (82°) to S56°W (figure 5C, 26). The overall three-dimensional geometry of this fold, therefore, is similar to that of a sheath fold defined by Cobbold and Quinquis (1980).

It is difficult to presume that the sheath fold geometry of the outlier unit is the result of superimposition of AF2 on a large AF1 fold. No large scale AF1 fold is present in the entire eastern block, and the swing in the orientation of AF2 fold axis as reflected in the orientation in the S-pole diagrams can be explained by superimposition of AF4 folding on AF2. AF1 structures are mainly represented by lineations (bedding-cleavage, S1, intersection, mullions and small scale folds).

In the easternmost block, the metasedimentary (Aravalli) units are folded into a large AF2 synform which shows plunge reversal from southerly around Dhamdhar to northerly further north. This reversal of plunge is due to interference of AF4 fold. The overall geometry of the fold is upright as indicated by the dip of modal axial planes which is about 80° to east-northeast near Dhamdhar to vertical and north-south striking further north (figure 5C, 27–29).

Large scale structural geometry of the basement gneisses is difficult to decipher because of the absence of any key horizon. However, judging from the attitudes of foliation planes, it appears that the structure is more complex than that shown by the bedding planes in the overlying metasediments. In small scales, the foliations in the gneisses and amphibolites show complex fold patterns, which do not have corresponding analogue in the cover units. The S-pole diagram prepared for the gneissic foliation shows an annular pattern with a void in the central part (figure 5C, 27). This signifies that the foliation planes are moderate to steeply dipping with their strikes in all directions. However, if only 3·5% population is considered, then a $\beta$ is definable with 58° plunge to S24°E. The Majority of linear structures shows scattered distribution around the poorly defined $\beta$. The plunge and trend of $\beta$ can be correlated with that in the outlier, suggesting simultaneous folding of the two units during AF2 deformation. The sheath fold geometry of the outlier as mentioned earlier indicates that this is a zone of 'high strain'. There is, however, no evidence of any shear zone passing through this zone. It may thus be taken as an example of development of sheath fold in an environment outside shear zone (cf. Ramsay and Huber 1987).

## 5. Tectonic synthesis and discussion

The analysis of large scale structures summarized above clearly brings out the contrasting style of deformation in different blocks. Out of the four phases of deformation producing successive generations of folding in the rocks, the earliest one (AF1) is the most intense and pervasive in the Umra Block, producing mesoscopic folds, a penetrative axial planar schistosity, and a steeply plunging lineation. In the other two blocks, this deformation did not seem to have produced much effect. Though the rocks became schistose and lineated, folds are rather elusive.

In strong contrast AF2 folds are best developed in the Kanpur-Kalarwas Block as well as in the Bagdara-Dhamdhar Block. In the Umra Block, AF2 folds are rare. The structural contrast between the different blocks is illustrated in an east-west cross-section drawn on the basis of structural and stratigraphic data (figure 6). The virtual absence of AF2 folding in the Central Block suggests that the units comprising this block responded by rotation and reverse-faulting on steep easterly dipping fault planes during the east-west shortening which produced north-south trending upright folds in the adjacent blocks. The reverse faulting possibly produced some amount of stacking of units, resulting in slightly higher grade of metamorphism of rocks in the region.

Earlier Roy *et al* (1988) and Roy and Bejarniya (1990) suggested how the conglomerate-arkose-quartzite (Debari Formation) underwent rotation by listric normal (basin margin) faulting. The same process also seems to have operated here. Because of rotation (anti-clockwise, viewing south to north), the beds dip steeply, with NNE–SSW or N–S strikes. Deformation during AF1 folding produced mesoscopic isoclinal folds and penetrative axial planar schistosity by simple shear movement which resulted in left lateral movements along bedding planes. During later east-west shortening, the beds suffered further rotation and stacking by reverse faulting on steeply dipping planes.

In the Kanpur-Kalarwas and Bagdara-Dhamdhar Blocks on the other hand, the east-west shortening during AF2 deformation produced moderately plunging folds with steeply dipping or vertical axial planes, because the attitude of beds prior to folding was either horizontal or gently dipping. Thus the difference in the structural pattern seems to be a reflection of initial attitude of beds prior to AF2 folding.

AF4 folds which interfered with AF2 to produce irregular domes and basins in the Kanpur-Kalarwas Block, did not have much effect in the Umra and Bagdara-Dhamdhar Blocks. The arcuations in the faults, which either border the western margin of the Umra Block or pass through the conglomerate-arkose-quartzite unit, are possibly the result of AF4 deformation.

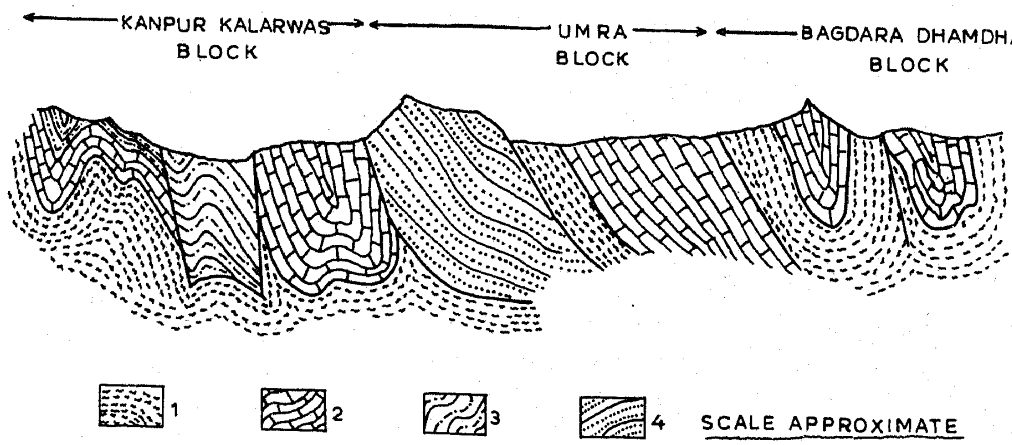


**Figure 6.** East-west cross-section showing constrasting structural pattern in different blocks. Explanations: 1. Mewar gneiss, basement rocks; 2. Carbonate association with phosphorite; 3. Greywacke-slate-phyllite; 4. Conglomerate-arkose-quartzite.

One possible explanation for the contrasting structural pattern could be the differential mobility of the Archaean basement blocks which floored the linear sedimentary basins (*see* Morey 1983 and Sims and Paterman 1983 for similar examples from the Great Lakes Region). The collage of rift basins (grabens) and horsts which represented the depositional setting of the Aravalli Supergroup not only influenced the divergent sedimentary associations (Nagori 1988; Roy and Paliwal 1981), but also controlled the structural pattern by responding differentially to deformations during different phases.

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