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Evidences of three phases of deformation in the Pre-Cambrian rocks of Raisindri Pahar, Singhbhum, Bihar

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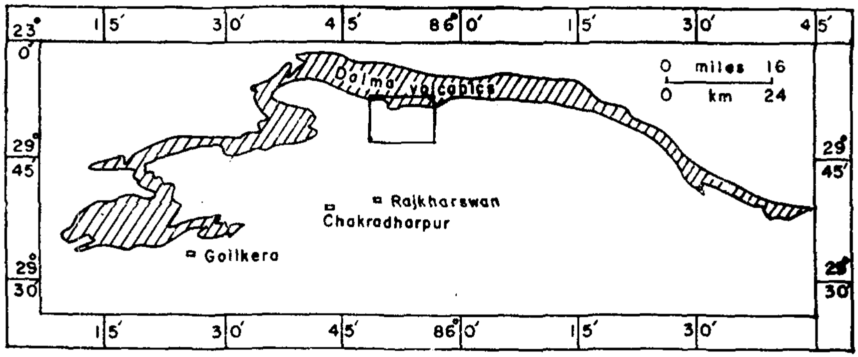
Abstract

Earlier workers recognised two phases of deformation. Evidences are presented here which indicate three phases of deformation. The imprint of the last phase of deformation is strongest.

Introduction and previous work:

The area covers approximately 150 km^2 in the Singhbhum district of Bihar, Eastern India. The rocks are mostly pelitic schists and phyllites with epidiorites belonging to the Iron Ore Series of Dunn (1929). According to Dunn, these rocks underwent two phases of deformation: the first phase corresponds to that of the Dalma syncline; the second phase corresponds to regional folds culminating in an extensive thrusting (the Singhbhum thrust) in which the northern block moved over the southern block. Later, Sarkar and Saha (1962) revised the stratigraphy of this region but essentially retained the above picture given by Dunn. None of these workers, however, carried out any detailed structural analysis of this area.



Location map.

Structural history:

Detailed structural analysis reveals that there are three distinct phases of deformation. The first phase of deformation produced isoclinal folds on bedding with a perfectly developed axial plane schistosity (S_1). Bedding and the first fold features are not preserved on a regional scale. The second phase of deformation involved folding on S_1 along with bedding and was accompanied by the development of a second axial plane schistosity (S_2). Structures of the second phase are predominantly preserved in the western and central part of this area. In the northern regions S_2 was not develeped, so that the third phase deformation structures were directly superposed on the deformed S_1-planes.

The thtrd phase deformation features were then superposed on both S_1 and S_2 planes (also on bedding wherever preserved). It caused folding predominantly by flexural slip. Development of third axial plane schistosity (S_3) is scanty except in the shear zones. The third folding movement culminated in shearing along the third axial plane schistosity (S_3) within the shear zones in which there is a reversed sense of movement i.e. northern block riding over the southern block.

Structural features:

The planar structures include bedding (S_0) and three consequentive axial plane schistosities (S_1, S_2 and S_3). Bedding is preserved in only few localities but is important in revealing the nature of the S_1-planes. S_1-planes are perfect mineral schistosity planes which both parallel and cross-cut bedding planes and hence are axial plane schistosities parallel to the axial planes of isoclinal folds on bedding. This is confirmed by direct observation, in some of the exposures, of iscolinal folds on bedding with S_1-planes along their axial planes.

The second generation axial plane schistosity (S_2) is most widespread in this area except in the extreme north. This is also a mineral schistosity which has often obliterated the earlier S_1-planes. The relationship of S_2 to S_1 is very important and subtle. The following points are important in this respect:

(1) S_2-planes parallel the axial planes of folds on S_1-planes which may parallel or cross-cut S_0-planes. Thus, in the same exposures three intersecting S-planes (S_0, S_1 and S_2) are seen to coexist.

(2) S_2-planes look coarser than S_1-planes where the two co-exist.

(3) S_2-planes are often throughly developed to the exclusion of S_1-planes megascopically. The latter can still be recognised, in a microscope, as relict fold hinges with S_2-planes as transposition structures.

(4) S_1-planes show the effect of two later deformations in the form of two axes of folds on this plane whereas S_2-planes show the effect of a single later deformation. As a result S_1-planes bear two co-existing crinkle axes and S_2-planes only one.

Both S_1 and S_2 planes have widely changing orientations throughout the area, whereas the S_3-planes have approximately constant orientation. S_3-planes appear as fracture cleavages outside the shear zones and are scanty. Within the shear zone, S_3-planes are dominant schistosity planes and appear as slip schistosity with a strongly developed striation.

S_1 is a mineral schistosity, defined by flaky minerals like muscovite, biotite and chlorite. S_1-planes are fine and closely spaced. S_2-planes are also defined by flaky minerals like muscovite and biotite but are less thoroughly developed than S_1-planes. S_3-planes are mostly fracture cleavages and transposition schistosity, frequently paralleled by flaky minerals. S_3-planes are more widely spaced than S_1 and S_2 planes. Evidences of transposition are very well seen in thin sections under the microscope.

The linear features include axes of crinkles and fold, intersections of planes, mineral lineations and striations. Bedding plane bears commonly three intersection lineations corresponding to the traces of S_1, S_2 and S_3 planes. These directions are also commonly paralleled by crinkle axes on bedding. S_1-planes bear two intersection lineations corresponding to the traces of S_2 and S_3 planes. These are also parallelled by crinkle axes. S_2-planes bear commonly one intersection lineation corresponding to the traces of S_3-planes. This is again paralleled by a crinkle axis. At times near or within the shear zones, the S_2-planes have acted as the shear planes along with the S_3-planes. Both bear strong striation lines which may be paralleled by mineral lineation and crinkle axis.

Thus, apparently, there are diverse linear features belonging to different generations of folding movements. Their relative ages were fixed by unrolling in the exposures as also from their patterns on stereograms.

Folds:

Majority of the mesoscopic and macroscopic folds belong to the third phase of deformation. These are invariably highly asymmetric, overturned to the south. Most of the folds are of flexural slip type except in the thin shear zones. where

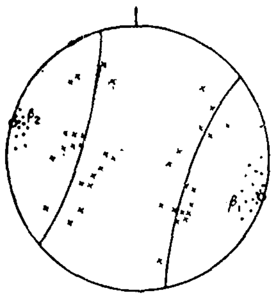


FIG. 1

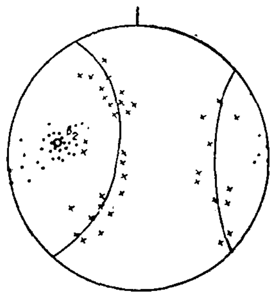


FIG. 2

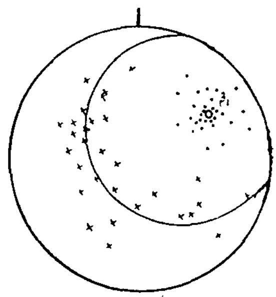


FIG. 3

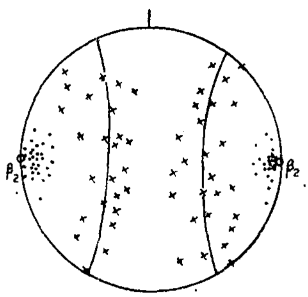


FIG. 4

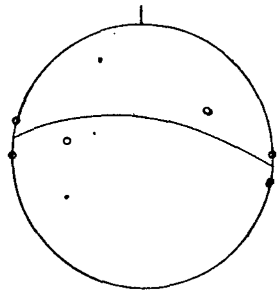


FIG. 5

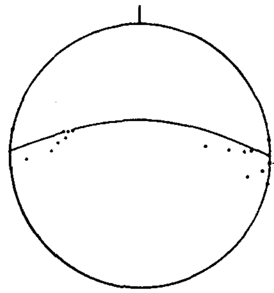


FIG. 6

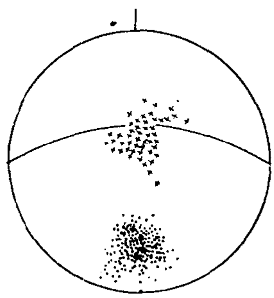


FIG. 7

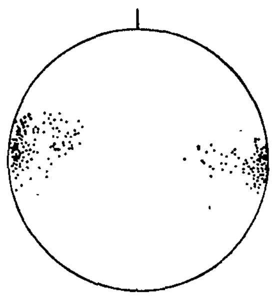


FIG. 8

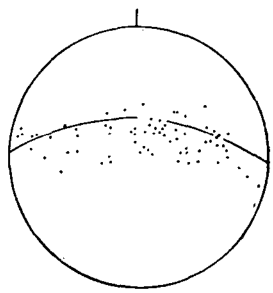


FIG. 9

Figures 1 to 9.

intense slip folding is common. Both concentric and similar geometry of the folds are present. The overall deformation plan presented by these folds represent southward movement of the northern segments along steeply northerly dipping planes. The regional fold pattern (Fig. 10) exhibited by the Dalma epidiorites, quartzites, phyllites and carbon phyllites in the north are in fact third generation folds with axes plunging towards northeast. This gigantic regional fold is a regional drag fold with a long northern limb, showing a drag sense closely comparable to the drag sense exhibited by the majority of the mesoscopic folds.

Structural analysis:

For analysis of structural geometry, the area has been subdivided into 4 subareas. In most of the subareas, S_1 and S_2 poles show each single great circle distribution; there is a general concentration of poles in the southern parts of the stereograms; this reflects the general overturning of the folds towards south.

The β-poles of such great circles, however, change in orientation. When all the β-poles of S_1 planes (Fig. 5) and of S_2 planes are plotted together it is seen that:

(1) β_1-poles for S_1-planes change widely in attitude from one subarea to another and lie on a great circle which represents the average orientation of S_3-planes throughout the whole area. S_3-planes of the whole area have practically constant orientation (Fig. 7). Thus, all these β_1-poles correspond to the third generation of folds superposed on the second generation of folds on S_1 (Fig. 5).

(2) β_2-poles of S_2-planes show little scattering and are subhorizontal to low plunging. This is caused by the single folding episode (i.e. third generation folds) affecting the S_2-planes (Fig. 6).

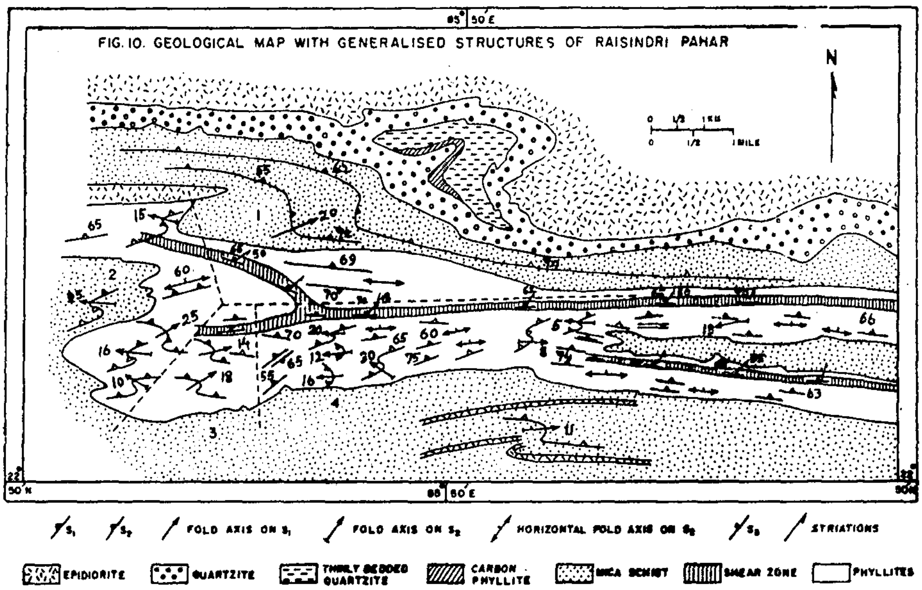


Figure 10.

There are innumerable linear features in these rocks, which present a very complex pattern even in any one subarea. These lineations have been classified according to their ages i.e. successive phases of deformations. Fig. 7 represents a simple picture of striations mostly on S_3-planes and sometimes on S_2-planes also. The folds on S_2 are highly asymmetrical with the northerly dipping limb very long and hence majority of the striations are noticed on this limb and are subparallel to the striations on S_3. Fig. 7 represents all striations observed throughout the whole area and gives a uniform northerly direction of slip which is almost downdip. Fig. 8 represents all S_2-S_3 intersection lineations (which are commonly paralleled by a crinkle axis on S_2) throughout the whole area. This also represents a simple picture of subhorizontal to low-plunging ESE-WNW axes of third generation folds on S_2. Fig. 9 represents traces of S_0 and S_1 planes on S_3 for the whole area. These lineations are commonly paralleled by axes of crinkles on S_0 and S_1 planes. The pattern shows a scattering along a great circle which represents the average orientation of S_3 planes. Superposition of S_3-planes on the already folded S_1 and S_0 planes obviously caused this geometrical scattering of the third generation fold axes on S_0 and S_1 planes. Besides these, there are a host of lineations which show interesting patterns:

(a) axes of crinkles on S_2 and S_2-S_3 intersection lineations which are parallel to the β-poles of the subareas and are hence uniform in plunge. These represent the third generation fold axes.

(b) S_1-S_2 intersections which are spread along small circle around the corresponding β-pole of each subarea (Figs. 1-4).

Regional Synthesis:

The present structural analysis establishes three phases of deformation, hitherto unrecognised in the earlier works. Each phase of deformation is accompanied by the development of characteristic planar and linear features; each of the earlier features are deformed by the later ones. Since the deformation of the third phase is most wide-spread and its features thoroughly preserved, its kinematic pattern could be faithfully unravelled. Within the shear zones, which are products of the third phase of deformation, northerly dipping shear planes (S_3) are developed with an almost down-dip slip direction. Outside the shear zones, the third phase deformation structures include drag folds of sizes ranging from microscopic crinkles to regional folds, all overturned towards south. Thus, the overall deformation represents a reversed sense of movement, i.e. the northern hanging block riding over the southern foot block. This picture closely corresponds to the concept of thrusting in the Singhbhum Copper Belt of the earlier workers. Similar structural sequences and kinematic patterns are also obtained in the recent structural investigations of areas to the west and southwest of the present area (Bhattacharyya, 1966; Bhattacharyya and Pasayat, 1971).

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