

## CONTRASTS ACROSS THE SHEAR ZONE IN THE PRECAMBRIAN ROCKS OF WESTERN SINGHBHUM<sup>1</sup>

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### ABSTRACT

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A prominent shear zone runs E-W across Singhbhum. Structural analysis indicates three phases of folding, all with E-W axial planes dipping northerly or subvertically to the north of the shear zone. South of this shear zone there are two phases of folding consisting of earlier folds with NNE striking axial planes, overprinted by later E-W folds. This marked structural contrast, along with other contrasting characteristics, indicates a large horizontal displacement that juxtaposed the two separate orogenic belts. Kinematic patterns indicate that such a large horizontal displacement could have been brought about by a sinistral transcurrent shear during the second phase of deformation seen in the north. The changes in kinematic patterns from N-S compression to transcurrent movement to N-S compression again during the same Singhbhum orogeny are of great interest.

### INTRODUCTION

The famous Singhbhum shear zone stretches in a curvilinear belt (more than 100 km long), convex towards north, across the Precambrian terrain of Singhbhum (Fig. 1). These Precambrian rocks were classified by DUNN (1929) into the following subdivisions:

Iron Ore Series: { Iron Ore stage  
Chaibasha stage

According to Dunn the rocks to the north of the shear zone belong mainly to the Chaibasha stage and those to the south to the Iron Ore stage. Later SARKAR & SAHA (1959) revised the stratigraphy of this region in the following manner:

Singhbhum Series (950 m.y.)

Iron Ore Series (2000 m.y.)

Thus it was recognised that rocks to the north of the shear zone belong to the Singhbhum series and those to the south to an earlier Iron Ore Series. All these workers believed that mo-

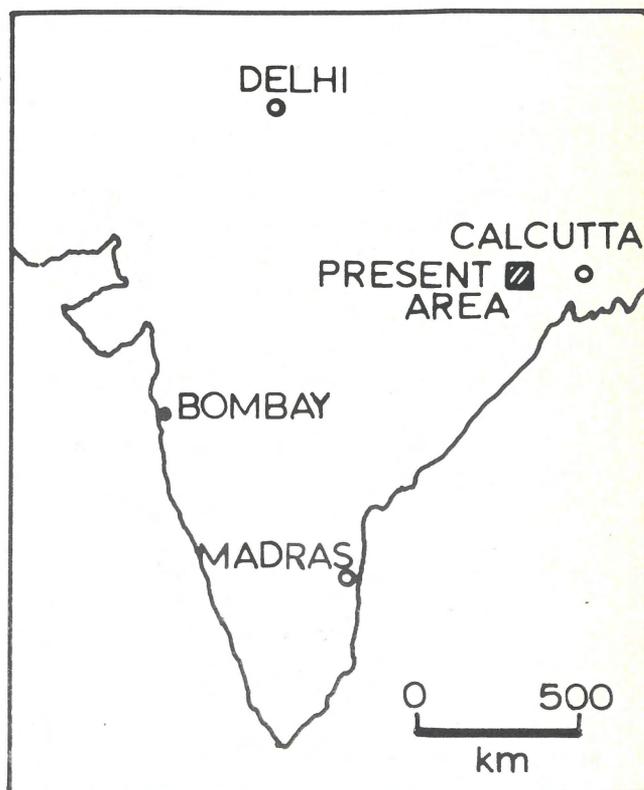


Fig. 1  
Location map.

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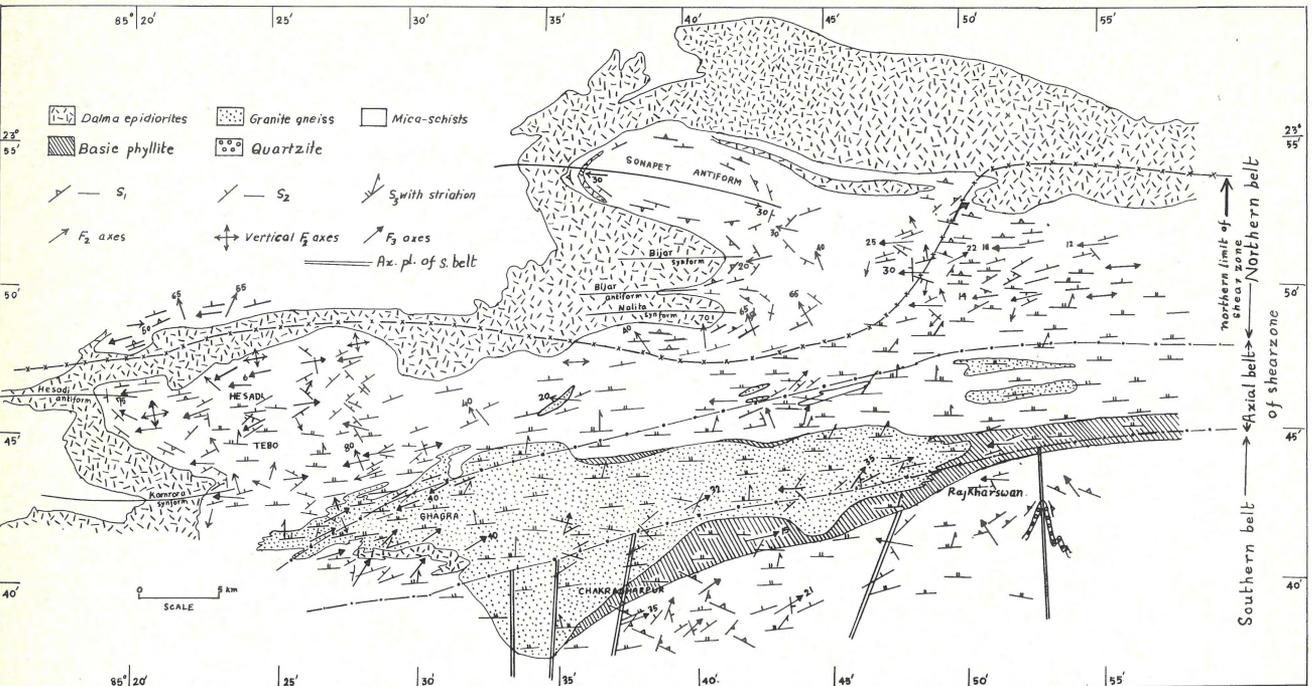


Fig. 2 Geological map of western Singhbhum with interpretative features. The Dalma epidiorites define six macroscopic fold closures which belong to the F<sub>2</sub>-folding phase. S<sub>1</sub> and S<sub>2</sub> are regionally parallel but S<sub>2</sub> is, in fact, the axial plane schistosity belonging to the F<sub>1</sub>-folding phase. The region is divided into a northern belt (with F<sub>1</sub>, F<sub>2</sub> and F<sub>3</sub>-folds, one superposed on the other), an axial belt (which is the Singhbhum shear zone and contains the F<sub>3</sub>'shear' folds, all earlier structures being obliterated) and a southern belt (with F<sub>3</sub>-folds superposed on earlier folds with NNE striking axial planes). Earlier NNE striking axial planes of folds are marked on the map. The northern belt contains rocks of the Singhbhum series and those of the southern belt rocks of the Iron Ore Series of Sarkar & Saha (1959).

vement along the shear zone brought about the juxtaposition of these two different stratigraphic belts.

In Precambrian terrains, where rocks are unfossiliferous and strongly metamorphosed, it is difficult to prove the occurrence of large-scale displacements and the consequent juxtaposition of once widely separated orogenic belts (KNOPF, 1935; NAHA, 1971) which may be the case here. One conclusive line of approach, in such cases, is a structural analysis to establish the structural contrasts across the shear zone and the dénouement of the kinematic evolution of these structures. The results presented below are from five years of field and laboratory investigations.

STRUCTURES NORTH OF THE SHEAR ZONE

North of the shear zone, structural analysis of the rocks by BHATTACHARYYA and co-workers (BHATTACHARYYA, 1966a, 1966b; PASAYAT & BHATTACHARYYA, 1977; SARKAR & BHATTACHARYYA, in press) indicates the presence of three major phases of deformation.

(1) The earliest (F<sub>1</sub>) phase consists of isoclinal folds on bedding (S<sub>1</sub>) with strongly developed axial plane schistosity. This

is seen in the rocks by a perfect schistosity (S<sub>2</sub>) generally parallel to bedding and cross-cutting the latter at the hinges of the isoclinal folds. Isoclinal folds are also indicated by diametrically opposed younging directions even where the bedding planes dip uniformly.

(2) The second phase (F<sub>2</sub>) consists essentially of flexural slip folds (without any axial plane schistosity) on S<sub>1</sub> and S<sub>2</sub>, refolding the earlier structures. This refolding is displayed on the map by six macroscopic antiforms and synforms (Fig. 2). The F<sub>2</sub>-folds were developed on steeply dipping planes of F<sub>1</sub>-folds and consequently around steep plunging axes which were synchronously cross-folded, at places, into low plunging attitudes. F<sub>1</sub>-axes were rotated by F<sub>2</sub>-axes along great circle girdles (Fig. 3a & 3b). F<sub>2</sub>-folds range from open folds in the north to compressed isoclinal folds in the south.

(3) The third phase (F<sub>3</sub>) consists of both flexural slip and 'shear' folds superposed on F<sub>1</sub> and F<sub>2</sub>-folds. The F<sub>3</sub> 'shear' folds in the south constitute the Singhbhum shear zone. The F<sub>3</sub>-folds are characteristically asymmetric folds displaying a consistent sense of movement of the northern block riding over the southern block. The F<sub>3</sub>-folds mostly have low plunging axes trending E-W and have refolded the F<sub>2</sub>-axes (Fig. 3c, d, e) along wide small circles and great circle girdles. The F<sub>3</sub>-folds are seen as flexural slip folds in the north and gra-

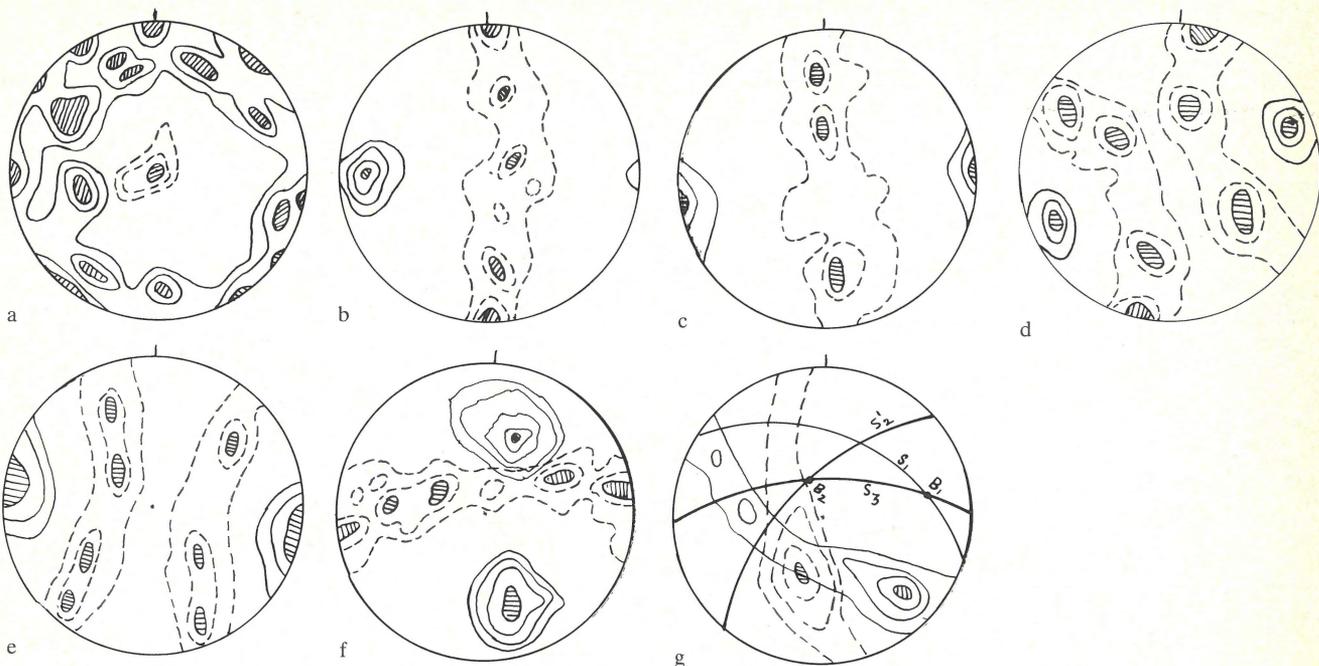


Fig. 3

Equal area projection diagrams of structural features.

- Rotation of  $F_1$ -axes around  $F_2$ -axes in the western part of the Hesadi antiform. The dashed contour represents the  $F_2$ -axes (1-6-12-18%).
- Rotation of  $F_1$ -axes around  $F_2$ -axes in the western part of the Sonapet antiform. The dashed contour represents  $F_1$ -axes (1-6-12-18%). The continuous contour represents  $F_2$ -axes (1-7-14-21%).
- Rotation of  $F_2$ -axes (dashed contours) around the  $F_3$ -axis (continuous contour; 1-7-14-21%) in the Hesadi antiform and the Kamrora synform.
- Rotation of  $F_2$ -axes (dashed contours; 1-6-12-18%) around the  $F_3$ -axes (continuous contours; 1-7-14-21%) at Ghagra.
- Rotation of  $F_2$ -axes (dashed contours; 1-6-12-18%) around  $F_1$ -axes (continuous contours; 1-7-14-21%) at Raisindri.
- $F_3$ -axes (dashed contours; 1-7-14-21%),  $S_3$ -poles (thick continuous contour; 1-6-12-18%), and striations, mineral lineations and lineated pebbles (thin continuous contours; 1-6-12-18%).

dually give way to 'shear' folds in the south until, within the Singhbhum shear zone, these are intense 'shear' folds with strongly developed axial plane schistosity ( $S_3$ ) which is moderately to steeply dipping towards the north and contains an almost downdip mineral lineation and striation (Fig. 3f). The  $F_3$ -axes are scattered along a great circle (representing the average  $S_3$ -plane) as a consequence of its superposition on the earlier  $S_1$  and  $S_2$ -planes (which were already folded by previous deformations).

#### STRUCTURES SOUTH OF THE SHEAR ZONE

The shear zone is quite thick in some places and frequently all the earlier structures are completely obliterated at the core. South of the shear zone, the structures consist of an earlier set of folds, with axial plane schistosity ( $S_2'$ ) striking NNE-SSW and dipping steeply, on which the shear planes ( $S_3$ ) are superposed. The line of intersection of  $S_3$  and  $S_2'$  commonly has a large pitch and often coincides with the downdip striation on  $S_3$  in which case  $S_2'$  does not show any folding but constitutes,

with  $S_3$ , a pair of intersecting S-planes. Further south, the  $F_3$ -shear folds give way to  $F_3$ -flexural slip folds with highly asymmetric profiles, indicating a consistent sense of movement with the northern block riding over the southern block.

Both bedding and schistosity ( $S_2'$ ) show highly asymmetric  $F_3$ -folds; these are shown on the stereogram (Fig. 3g) by the spread of poles along great circles (with zones of concentrations corresponding to the longer limbs) whose axes lie on the average  $S_3$ -great circle at the points where bedding and schistosity ( $S_2'$ ) (corresponding to the maxima on the stereogram) intersect.

#### CONTRASTS ACROSS THE SHEAR ZONE

Structural analysis reveals the superposition of three generations of folds, all with E-W striking and northerly dipping axial planes, to the north of the shear zone, and superposition of two generations of folds ( $F_3$ -folds on earlier folds with NNE striking axial planes) to the south of the shear zone. This presents a sharp contrast in both the number of phases of

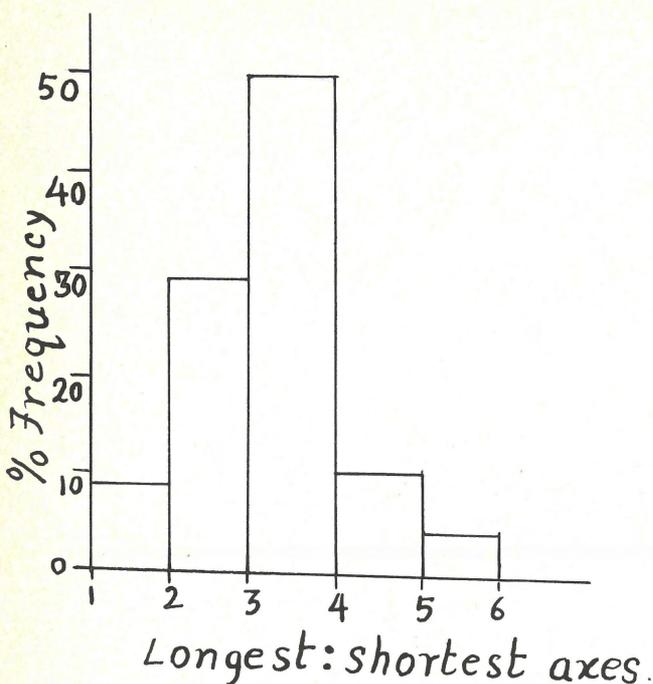


Fig. 4  
Histogram showing the frequency of the relation between the longest and shortest pebble axes.

deformation and the orientation of pre- $F_3$ -folds concerned.

Besides the contrast in structure, there is also a contrast in metamorphism (DUNN, 1929). Detailed investigations (BHATTACHARYYA et al., 1976) indicate that north of the shear zone rocks contain imprints of three phases of high-grade metamorphism (with the development of almandine, staurolite, andalusite and fibrolite) whereas south of the shear zone rocks are metamorphosed in the green schist facies only.

A third aspect of contrasting characteristics is the radiometric ages of the rocks. Available age data (SARKAR & SAHA, 1959) indicate that the rocks to the north of the shear zone belong to a younger orogeny (the Singhbhum orogeny: 950 m.y.) and those to the south to an earlier orogeny (the Iron Ore Orogeny: 2000 m.y.).

### KINEMATIC EVOLUTION

All the three generations of folds ( $F_1$ ,  $F_2$  and  $F_3$ ) seen to the north of the shear zone have approximately the same axial plane, with an E-W strike and northerly or subvertical dip. The  $F_1$ -folds initially had a broad E-W trend convex towards the north (Fig. 6). These were refolded during  $F_2$ -folding by a subhorizontal sinistral shear into asymmetric folds with steeply plunging fold axes (sometimes rotated synchronously into shallower plunges). This subhorizontal sinistral shear is presumed to have developed into a transcurrent shear zone, now masked by the later shear zone.

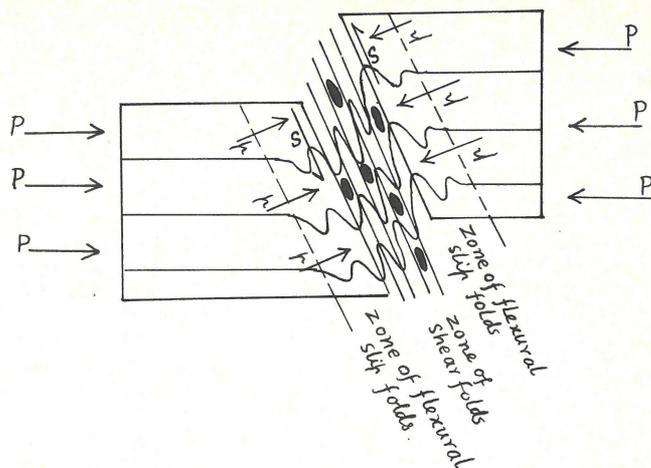


Fig. 5  
Diagram illustrating the nature of the shear zone, which zone lies squeezed between two blocks of which one overrides the other.

The movement pattern during the  $F_3$ -folding (culminating in the shear zone) can be reconstructed from the following lines of evidence. As the shear planes ( $S_2$ ) dip at  $55^\circ - 70^\circ$  towards the north, it is unlikely that large horizontal displacement occurred by downdip movement along these planes; the shear planes are basically planes of flattening as these are parallel to the axial planes of flattened concentric and similar folds; this is also borne out by the deformed ellipsoidal pebbles which are flattened on  $S_3$ -planes and elongated along the downdip striations; the ratio of the longest to shortest axes of the pebbles is commonly 3.5 (Fig. 4) and indicates a major downdip flow; no large horizontal component of displacement is indicated. The only element of shear is indicated by the highly asymmetric profiles of all the  $F_3$ -folds with a constant sense of movement of the northern block riding over the southern block. These features lead to the conclusion that during  $F_3$ -folding (and shearing) the major movement was a north south flattening with a subordinate shear around a subhorizontal axis, as shown in Fig. 5.

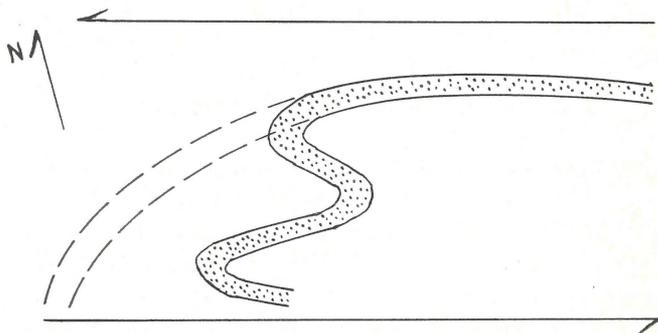


Fig. 6  
Plan view of the subhorizontal sinistral shear producing the  $F_2$ -folds.

It is thus apparent that  $F_3$ -structures and their kinematic evolution do not in any way indicate a large horizontal displacement, required to bring about the structural contrasts across the shear zone. Hence it is concluded that the observed contrasts were brought about by the sinistral transcurrent shear during  $F_2$ -folding movement and were later heavily deformed by the  $F_3$ -folding.

Rocks to the north of the shear zone belong to the Singhbhum orogenic cycle (950 m.y.) (SARKAR & SAHA, 1959). The changes in the kinematic pattern during this orogeny, from a N-S compression to a sub-horizontal sinistral transcurrent movement and to a further N-S compression reflect deep-seated changes in the mechanism driving the orogenic movements.

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