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Deformation Pattern as indicator of structural evolution: Ghatsila-Galudih-Tentuldanga fold belt, Tentuldanga, Jharkhand, Eastern India

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Fold of different generations formed due to different phases of deformation. Superposed folding may give rise different morphologies of the folded surface, which can be classified into three broad classes. In the studied area we have observed all these types of superposed folds.

Geological studies in the eastern Singhbhum part suggest that during Archaean times a volcanic arc was formed which is now known as Dalma volcanic. The geosynclinal trough in the southern, concave side of the arc was filled with Proterozoic argillaceous sediments. Ghatsila-Galudih-Tentuldanga fold belt occur within the central part of this Proterozoic mobile belt which is bordered by a volcanic series of Dalma in the north, and Shear zone in the south. This area is a zone of interest particularly for structural geologists, as the deformational history in this area is well preserved in mica schist rocks. The rheological contrast of the rock type has generated spectacular structural architecture in this region. Comparing to other two areas, Tentuldanga is more structurally complex and all three phases of deformation are vividly preserved where, in Ghatsila or Galudih the last deformation is poorly preserved. In this article, we will discuss the interesting structures those are preserved in Tentuldanga area and will try to understand the complex history of deformation. Some interesting photographs and schematics diagram are included to support the proposed geological history.

Geological Setup

A few kilometers towards the southeast of Ghatshila, a small outcrop atTentuldanga bears a signature of complex deformational history. Host rock of this area is kayanite mica schist, and metamorphosed at high pressure. This was confirmed by the presence of kayanite, which is essentially a high pressure mineral. History of deformation in Tentuldanga is more prolific. Here, at least three sets of deformation histories are clear, among which the last deformation is showing its maximum intensity. During superposition, early fold may tighten or open up and the final geometry of superposed buckling fold is depended on the initial tightness of the early fold. The classical model of interference was proposed by Ramsay (1967) that involves passive folding, but fails to explain superposed buckling. Later analytical and experimental modeling was proposed by various workers which need to be justified by observing field features. In that case, Tentuldanga is one of the best areas to compare the analytical and theoretical models with the field feature of superposed buckle fold.

Concept of Superposed Deformation

The superposed folds in Tentuldanga formed as a result of at least three sets of deformations. Three deformations generated three sets of schistosity.

In the mica schist intercalated host rock, the form surface was S_1 schistosity plane. S_0 plane was not discernible as it was almost parallel to S_1. Throughout this outcrop there is a well developed stripping lineation (marked by color variation, alternation of light and dark colored) on the S_1 surface. This lineation is associated with 1st generation of deformation or D_1. The F_1 fold axis formed due to D_1 deformation is parallel to this striping lineation. Since S_1 & S_0 both are parallel in all area except at hinge, F_1 is a tight isoclinal Fold. Therefore due to folding of S_0, S_1 forms during D_1 deformation.

S_1 forms enveloping surface which during latter deformation i.e.; during D_2 deformation is again folded to gives rise to S_2 axial plane cleavage which is almost vertical. The trace of S_2 on S_1 give rise to F_2 which is also parallel to F_1.But F_2 is an Open Fold.

Pucker axis is also formed during second stage of deformation & finally whole area suffered D_3 deformation for which antiformal & synformal structures are formed. The S_3 plane makes high angle with both S_1 &S_2 itself has a sub-vertical in nature. The traces of spaced cleavage on the S_2 surface form F_3 which is almost perpendicular to the F_1 & F_2.Since F_1 & F_2 are parallel, they are indistinguishable from each other.F_3 has a trend, which is at right angle to either of them and it has different plunge amount, depending on the orientation of the form surface.

The D_3 deformation produces a sidewise buckling of the earlier folds and superimposition of all these deformation and the folds have given rise to different fold interference pattern.

Types of Fold Interference

Fold of different generations formed due to different phases of deformation. Superposed folding may give rise different morphologies of the folded surface, which can be classified into three broad classes (Tuener and Weiss, 1963). In the studied area we have observed all these types of superposed folds (Fig 1 a, b, c).

Type 1 Fold interference:

Superimpositions of F_2& F_3, which are at high angle to each other, give rise to Type-1 fold interference pattern. The fold is Plane Non-cylindrical Fold, in which axial surface of early fold F_2 remains planar, but the hinge line is curved within that plane. The enveloping surface shows Dome and Basin structures. The outcrop pattern is EYE-shaped with Antiformal and Synformal culmination and depression (Fig 2, a).

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Fig 1: (a) F1 fold axis in the studied area, (b) Type 2 Interference in quartz schist rocks of Tentualdanga, (c) Type 3 interference in the area.

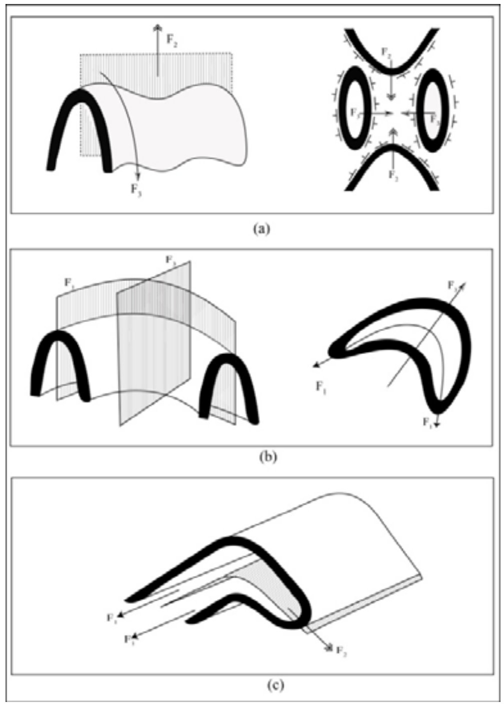

Fig 2: Schematic diagrams of (a) Type 1 interference of folds, (b) Type 2 interference of folds, (c) Type 3 interference of folds

Type 2 interference:

Superimpositions of F_1 & F_3, or F_2 & F_3 give rise to Type-2fold interference pattern. The fold is Non-plane, Non-cylindrical Fold, in which both the hinge line and axial surface of F_2 are curved. In mesoscopic scale it provides Mushroom or Crescent-shaped outcrop in horizontal section (Fig 2, b). These are often asymmetric with a long tail.

Type 3 interference:

Superimpositions of F_1 & F_2, which are parallel to each other, give rise Type-3 fold interference pattern. The fold is Non-plane, cylindrical Fold in which hinge of F_1 is straight, but axial surface is curved. This type of coaxial deformation gives rise to a Hook-shaped outcrop which can be found here (Fig 2, c).

Deformation of Lineation by Later Folds

When an early lineation is deformed by later folds, the pattern of the deformed lineation provides valuable information about the mechanism of folding.

The prominent lineations exposed in Tetuldanga outcrop were the mineral lineation and Striping lineation. They were parallel to F_2 fold axis, which has been affected by a letter phase of deformation, the generation of folding. They were traced out on cellophane paper, along the F_3 axis, the hinges of the folds. When the paper unrolled two situations arises;

A. Some of the lineation was straight implying that lineation makes equal angle with the fold axis on either limb in the mesoscopic fold. This indicates that the mechanism of folding is pure Flexural.

B. Some lineation were curved after unrolling indicates these lineation making different angle with the fold axis on two limbs i.e.; the fold has suffered some homogeneous strain.

Fig 3: Kink bands in the mica schist of Tentuldanga.

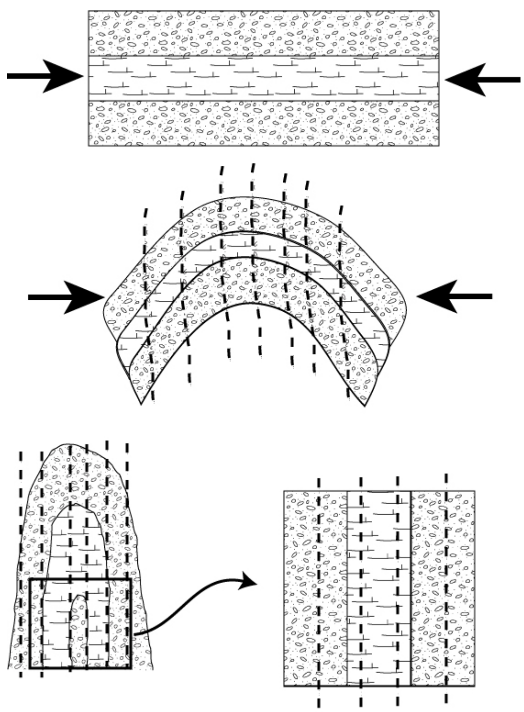

Fig 4: Schematic diagram of deformation history in the first phase.

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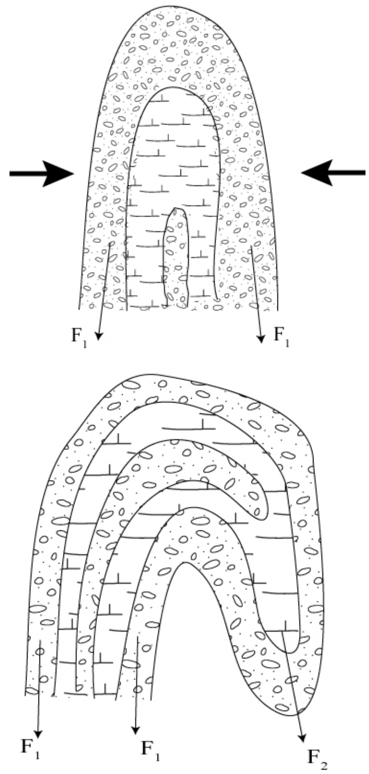

Fig 5: Schematic diagram of deformation history in the second phase.

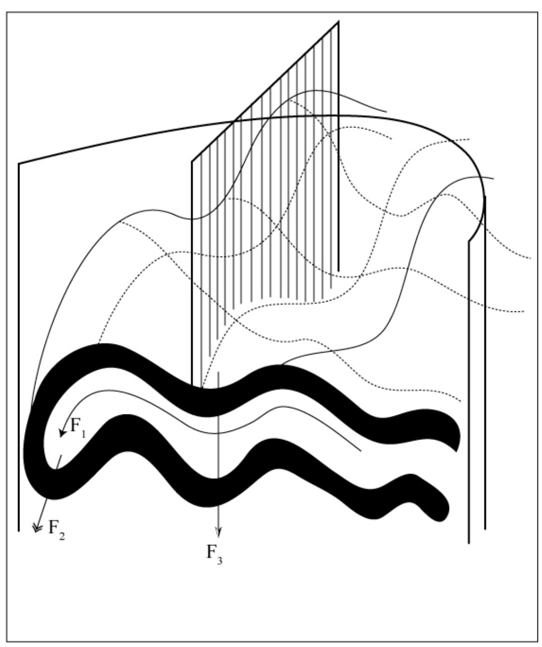

Fig 6: Schematic diagram of deformation history in the third phase.

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Kink bands:

There are some spectacular conjugate kink bands in a vertical section of quartzite - mica schist alternate layers exposed at Tentuldanga (Fig 3). Kink bands are defined by straight limbs (symmetric or asymmetric) and sharp angular hinges.Within the kink band, the layers are straight, and they are making a high angle with the outer layers. Outer layers bear a complex structural history, which is reflected in their fold patterns. Two conjugate sets of kink band (one dextral and one sinistral) have formed conjugate folds. In the kink bands mica is dominant, and the outer layers are quartz rich.

Kink bands are often formed in anisotropic multilayered rocks. In a continuous series deformation, kink bands are end members. Experimental studies have revealed that kink bands are originated at the initial phase of deformation in the anisotropic material. Deformation in mica schist layers probably initiated with formation of kink band, which became broad in the later stages of progressive deformation. Conjugate kink bands probably formed due to layer parallel compression. During deformation, quartz has migrated from the high strained banded area resulting relative increase in mica content within the kink bands.

Interpretation

First deformation:

The exposure at Tentuldanga area reveals the complex deformation history of the area. At least three sets of deformation are prominent in this area. Initially there was alternating bands of mica schist and quartzite. D_1 deformation lead to the folding of bedding planes and the S_1 schistosity was formed. This fold was tight isoclinals. So, the schistosity and bedding plane were parallel (Fig 4).

Second deformation:

In the D_2 deformation, the stress was coaxial. As the early fold was tight isoclinals, type 3 buckling took place. Interlimb angle was so tight, that it generated mode 4 buckling. Fold generated due to this deformation was open (Fig 5).

Final deformation:

In the final stage of deformation, two earlier fold was affected. This time stress direction was at high angle with the early two folds. As fold in the D2 deformation was open, it was superposed in the D3 and produced dome basin geometry. But the first fold was tight fold, so inspite being coaxial with second fold; it could not produce a dome basin structure in superposition. Rather, F1 and F3 interference gave rise to type 2 folding. Type 2 folding was also produced to superimposition of F2 and F3. But the modes of the two were different. Due to very small interlimb angle F1 and F3 gave rise mode 4 buckling, and F2 & F3 gave rise mode 3 buckling, where earlier hinge line shifted to a new material line. This was probably the last phase of deformation as strike line of S_3 did not change. Finally this deformation also result a broad synform in the rock unit, hence producing a complex outcrop of the region (Fig 6).

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Suggested Reading:

Ghosh., S. K. 1993. Structural Geology, Fundamentals and Modern Developments. Pergamon Press, Oxford.

Ramsay, J.G. 1967. Folding and Fracturing of rocks. McGraw-Hill, New York..

Sengupta S., Ghosh, S.K., Deb, S. K. and Khan, D., 2005, Opening and closing of folds in superposed deformation. Journal of Structural Geology 27, 1282-1299

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