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Geometry of mesoscopic folds in the vicinity of Disang and Piphima thrusts in Kohima district, Nagaland

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Abstract

The schuppen belt of Nagaland and Kohima synclinorium are multiply deformed regions in the NE India. The study of structures in the vicinity of Disang Thrust and Piphima Thrusts of the Schuppen belt reveals at least four phases of tectonic deformations. Based in the geometric analyses in the folded rock layers, the present study reveals that the majority of the folds of the study area are developed due to flexure slip mechanism and modified due to later deformations.

Introduction

In Northeast India the Assam – Arakan Orogenic province consists of three segments namely the Naga Hills, Chin Hills and Arakan Yoma segments. Two orogenic belts namely, the Himalayan belt to the north and the Assam – Arakan belt to the southeast mark a zone of plate convergence (Acharyya, 1991). A north-south convergence of India and Tibet has resulted in a straight collision while northwest-southeast convergence of the Indo-Sinian plate culminated into an oblique collision (Dewey et al., 1989; Burchfiel, 1993; Uddin and Lundburg, 1998a & b, Naik, 1998). In the Assam-Arakan belt, suturing of plates extended progressively southwestwards like a zipper as the two continental plates converged obliquely with a pole in the Naga Hills region (Biswas and Agarwal, 1990). The Naga Hills, reaching a height of about 3840 meters, is quite narrow (average width of orogen=250 km) and lie on the border of India (Nagaland & Manipur states) and Myanmar. Most of the earlier workers have related the stratigraphic inconsistencies and along-strike changes in the crustal nature with those of the varied and complicated nature of tectonic regimes in the region. Despite the fact that the Nagaland and the adjoining areas in the vicinity of Assam plains hold good potentialities for petroleum and natural gas, the region could not receive due attention of the geological community; may be because of its remoteness and disturbed socio- political conditions. The pioneering works of Evans (1932, 1964) and Mathur & Evans (1964) and some works done by GSI, ONGC, Oil India Limited and the state Directorate of Geology and Mining are the only bases for any type of geological studies in the region. The lithostratigraphy, structure and regional correlations have been attempted by workers like Bhandari et al., (1973), Dasgupta (1977), Banerjee (1979), Sinha and Chatterjee (1982), Rao (1983), Murthy (1983), Gangu and Khar (1985), and Naik et al., (1991), Acharyya (1986, 1991, 2007), Naik et al., (1991) and Nandy (1983, 2000).

Study Area

Geologically, the present area of investigation forms parts of the Schuppen Belt and Kohima Synclinorium. The Schuppen belt with its over thrust masses of varying width (10 – 40 km); extends all along the western margin of Nagaland state for about 200 kilometer trending NE-SW. Evans (1964), described the Schuppen belt as consisting of eight or more over thrust slices of Tertiary sediments that have over ridden each other from east to west.

The area under study falls between latitudes 25°43′35″ N and 25°47′29″ N, and longitudes 93°55′00″ E and 94°02′10″ (Fig.1) and covers nearly 85 sq. kms including areas lying near Kiruphema, Piphima & Pherima villages. It is located at a distance of 20 kms northwest of Kohima -the capital town of Nagaland state. The average height of the area is 1045 meters above mean sea level. As a whole, the Tertiary rocks in the study area present an immature geomorphology (Chakrabarti and Banerjee, 1988).

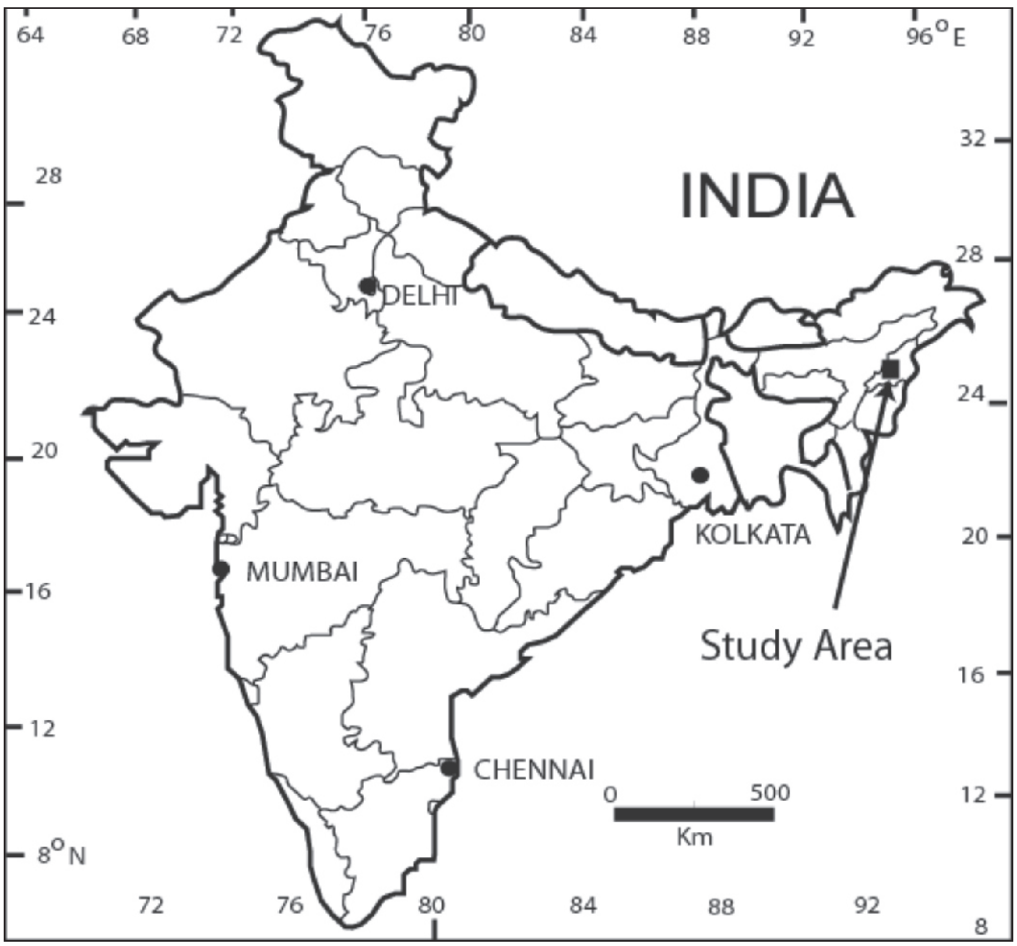

Fig.1 Location of the study area

Geological Setting

The rocks of the present study area belong to Disang Group, Barail Group and the transition sediments in between, named as Disang Barail Transition Sediments (DBTS) (Fig.2). The lithology of these geological formations have been studied in detail by different workers including Evans (1932, 1964); Mathur and Evans (1964); and Rao (1983) and Nakhro (2009). The dominant geological units in the present study area are briefly described below:

Disang – Barail Transitional Sequences (DBTS): The Disang Group occupies a tract between the Naga Ophiolite Complex and the Disang thrust in Nagaland and Manipur. Disang Group comprises dark to black carbonaceous, ferruginous, concretionary shales with a few interbeds of siltstones and sandstones. The lower most contact of this group is not exposed. It passes conformably upwards into the Barail Group in regions other than Schuppen belt. In present area of study, a part of the Disang Group is not exposed in its characteristic forms as described elsewhere, rather is shows the mixed characters of Disang and overlying Barail Group rocks. Therefore in the present work, those rocks in the study area which have mixed characteristics of Disang and Barail sequences have been described as Disang- Barail- Transition Sequences (DBTS) and their characteristics have been described separately. These beds have shown large variation in their orientation which may vary between 08º-74º towards SW & SE because of high degree of deformation.

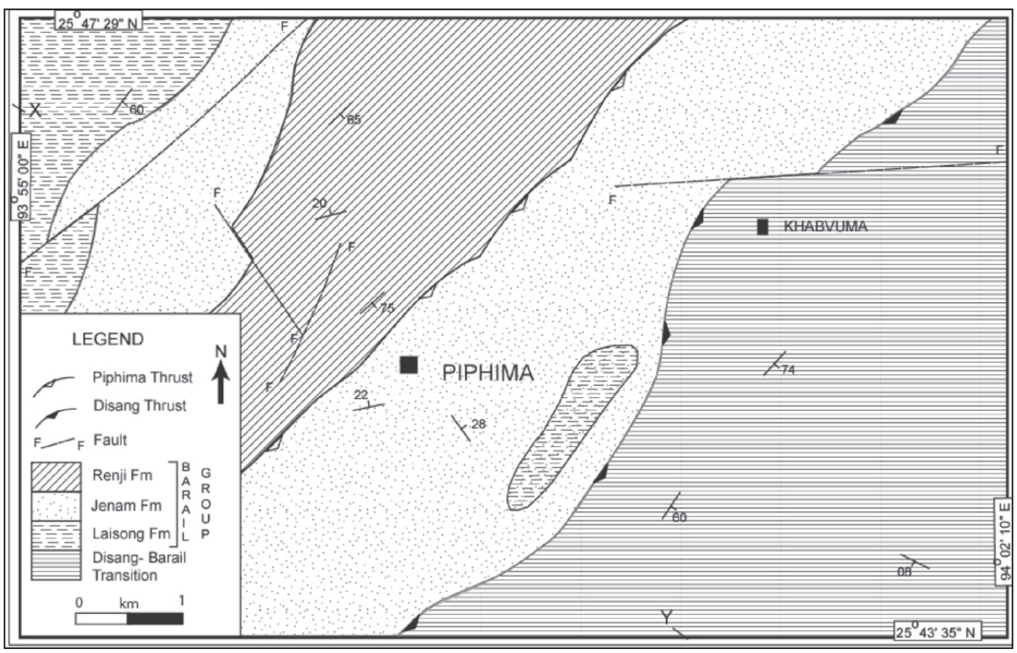

Fig.2 Geological Map of the study area, Kohima district, Nagaland

Barail Group: The Barail Group of rocks possesses a basic character of being arenaceous with the consistent development of carbonaceous facies. These occur as sub-parallel thrust slices in the western part of the area beginning with the Disang-Haflong Thrust.The part of the study area lying in the Schuppen Belt is characterized by Laisong, Jenam and Renji Formations of the Barail Group. Due to thrusted nature of lower contacts, the thickness of different Barail strips is found to be variable. The general dip of beds varies between 20º - 75º towards NW & SE respectively except for the locations having high degree of deformations. The geological map of the study area (Fig. 2) shows the distribution of various litho-units comprising Disang-Barail Transition and Barail Group. A brief account of the geology is given in Table 1.

Table 1. Geological succession of study area

		Renji Formation
Oligocene------------------------------------	Barail Group----------------------------	Jenum Formation
		Lisong Formation
---		Tectonic Contact – Disang Thrust
Upper Cretaceous to Eocene	Disang- Barail Transition Sediments(DBTS)	
	Disang Group	

Folds

The study area falls in the Schuppen belt of Nagaland which comprises of a number of thrust sheets, however our study is concentrated on the folds found in the vicinity of two thrusts namely Piphima thrust and Disang thrusts (Fig.2). The Disang thrust makes the tectonic contact of Schuppen belt with the Kohima synclinorium, while the Piphima thrust is nearest thrust to this tectonic contact in the schuppen zone, and thus these two together make a thrust slice in the schuppen belt. Mesoscopic structures in one thrust slice may or may not be same as in other slices of the belt. The study area is structurally very complex and exhibits multiple deformations. These deformations are reflected in the rocks of the study area in the form of folds, faults, thrust, joints and other planar and linear features at varying scales. The structures which can be observed on the hand specimen size to size of an outcrop on the hills are known as mesoscopic structures. Folds are important mesoscopic structures which are formed due to ductile deformation in the rocks and thus they record the most intense phases of deformation. Therefore In present work the detailed study and analysis of mesoscopic folds have been taken up.

The mesoscopic folds observed in the area belong to isoclinal (Fig.3C), tight (Fig.3D), close (Fig.3A), open (Fig 3D) and chevron types. Often, these folds do not exhibit their ideal form possibly due to the affect of later deformational episodes i.e. refolding. The chevron folds and kink bands have been developed characteristically in the vicinity of fault zone in the thinly foliated rocks such as shale of DBTS. These folds, which are developed on some prominent S-surfaces (S_1 or S_2), have also shown superposition of one style over another. At times, presence of thin incompetent layers between the competent ones has prompted development of drag folds especially in the vicinity of fault zone. The observations on superposition of folds in the present area lead to the genetic interpretations of fold types whereby isoclinal and tight isoclinal folds can be assigned to the first phase of folding (F_1), the tight and close folds to the second (F_2) and the open folds to the third generation (F_3). The sharp hinged chevron folds or kink bands and drag folds may be assigned to the fourth generation (F_4) of folding (Nakhro 2009).

Nevertheless, one should bear in mind that all the above folds (F_1, F_2, F_3 & F_4) are liable to change their shape and style as well in their multilayered structure due to successive tectonism of the later phases. The variation in the fold style may also relate to compositional variations among layers. For example, the thicker quartz rich sandstone layers in a F_2 fold may show an open fold style, while the thinly bedded shale shows the close style .

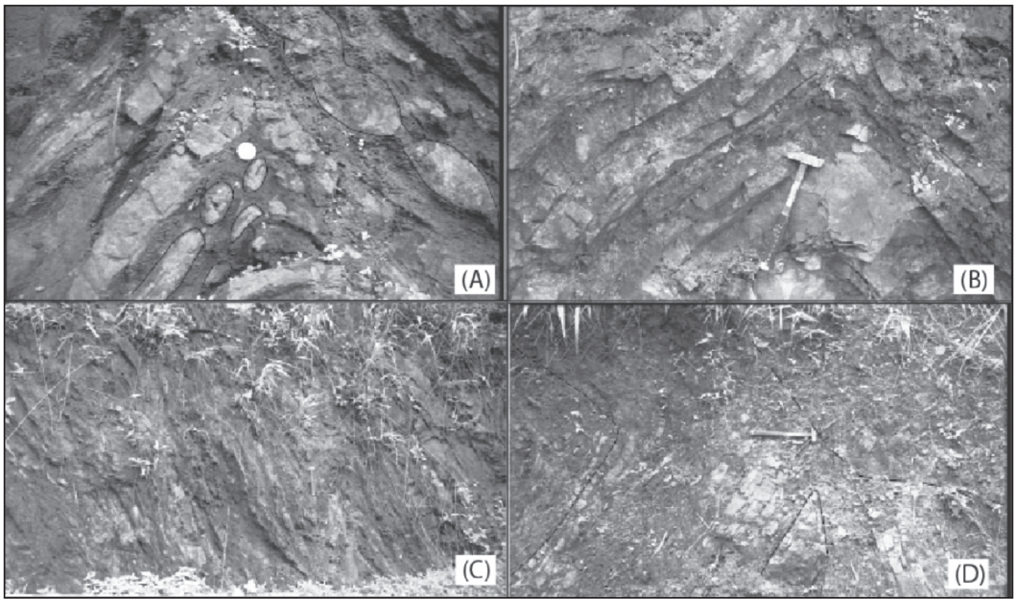

Fig.3 (A) Close folds in the Renji Formation (B) Open fold in Renji Formation (C) Isoclinal fold in thinly bedded Jenam Formation (d) Open recumbent and tight fold in Lisong Formation

Fold Profile Geometry

The development of a geometrical classification of the folded layer is based on dip isogon pattern, variation of the relative orthogonal and axial surface-parallel thicknesses on the profile section (Hudelston, 1973; Ramsay and Huber, 1987). Such a classification plays an important role in the study of fold morphology and in elucidating the principal folding mechanism (Ramsay, 1967). It is also possible to study the changes in the shape of different folded layers on the fold profile. The shape of any one layer in the folded structure depends on the relationship of bounding surfaces of the layer and in particular, the relative rates of change of the inclination of these bounding surfaces. Therefore, study of several profile sections of the fold will not only give a better idea about fold morphology in three dimensions, but also in understanding the possible mechanism involved in its evolution. The geometrical classification of fold morphology is also significant in terms of strain (Hobbs, 1971).

For the geometrical classification of the folds of study area, tracings of the fold profiles have been used. The fold profiles were obtained either directly from the field, field photographs or hand specimen folds. Care was taken in each case so that the sections (Fig 4) under analysis, as far as possible, were perpendicular to the fold hinge.

Thickness Measurements

The thickness parameters, which involves measurement of data on the orthogonal distance (called as orthogonal thickness (`t′) and along the axial surface (`T′) between the tangents drawn at equal dip angle (α) on the fold profile, were introduce by Ramsay (1967). He (1967) utilised the ratios t'_α (= t_α/t_o) and T'_α (=T_α/T_o) and the dip angle α for graphically classifying the folds (cf. Ramsay 1967; Ramsay and Huber, 1987).

In order to geometrically classify the folds of the area 3 multilayered folds comprising of four to five layers (Fig.4) have been chosen. The thickness parameters on the profile section of these folds have been measured along the dip isogons as described by Ramsay and Huber (1987). The orthogonal thickness ratios t'_α (= t_α/t_o) were calculated from those data. The t'_α value against change of angle (α) has been plotted for each fold to represent the variation in geometry of each layer of folds with change in α values. Thus, the t'_α vs α plots (Fig.4) which have been joined by a free hand curve describe the change in geometry of the individual folded layer.

The t'_α vs α plots of folds of the area (Fig.4) suggest that majority of the layers are not restricted to any particular class of Ramsay and Huber (1983) and they show change in their geometry from one class to another. The plots of these folds (Fig. 4) reveal that most of the folds of study area belong to class 1C geometry. However fold geometries belonging to 1A, 1B, 2 & 3 are also present.

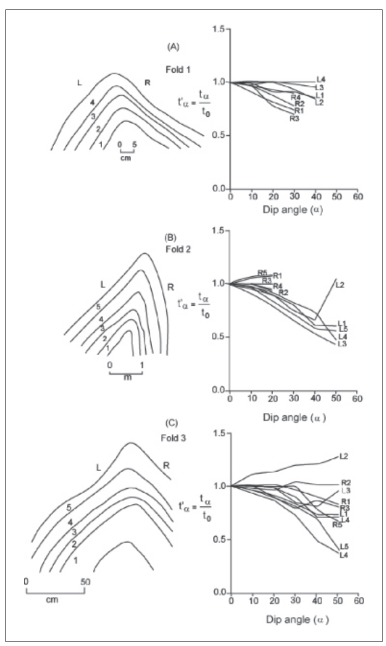

Fig.4 Fold profile traces and their orthogonal thickness parameters plots.

Variation in Multilayer Fold Geometry

In order to understand the variation in the fold profile geometry in a multilayer sequence of fold, the classification scheme of Srivastava and Gairola (1999) has been applied on the folds of the study area. The folds on which the scheme has been applied are shown in Fig. 4 and their plotting in $\sigma_n(t'_\alpha)$ vs α diagrams is depicted in Fig.5. $\sigma_n(t'_\alpha)$ represents the population standard deviation of the orthogonal thickness parameter t'_α for n number of layers in a multilayered sequence of fold and α represents the dip angle for the isogons on which the thickness measurements for t'_α were done. In this diagrams, the variation in fold geometry have been shown in quarter wave sectors. The L and R (Fig. 5) attached with fold number represents the left and right quarter wave sector of the fold numbered 1, 2 or 3 (Fig.4). From the plots, it is evident that no fold of the study area is analogous or isodeviatoric in true sense. The folds show variations in their geometry from one class to another which may range from sub-analogous to non-analogous fold.

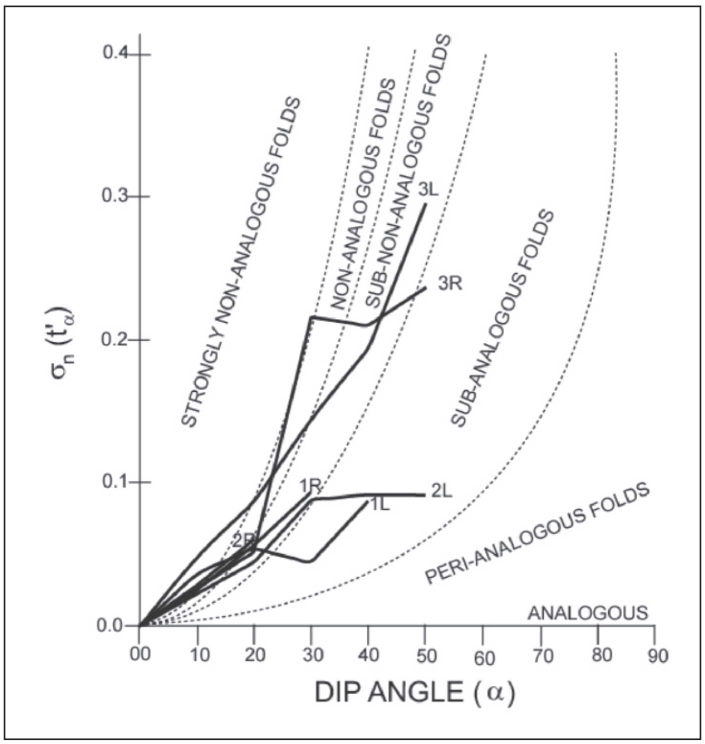

Fig. 5 Plotting of multilayered folds in Srivastava and Gairola (1999) diagram.

SUMMARY AND CONCLUSIONS

The Palaeogene sequences of the study area comprise parts of the Fold – Thrust Belt stretching NE – SW along western margin of a collision orogen in Naga Hills. The Naga Hills constitute northern extension of the Indo-Burman Ranges (IBR) which is considered to be an ideal setting for understanding the geodynamic processes involved in the evolution of the northeast Indian crustal block through late Mesozoic - Cenozoic period. The present investigation is an attempt to understand the deformational phases of the Palaeogene sequences developed in parts of the Kohima synclinorium and the schuppen belt of Nagaland. Structurally, the study area is made up of very complex structures on mesoscopic and macroscopic scales. For the purpose of systematic study, mesoscopic structures were studied as planar fabrics, linear fabrics and folds. The detailed geometric analysis of the mesoscopic folds is done in the present work in order to understand the possible kinematics and mechanism of the fold development in this geologically complex region of NE India.

The detailed study of these structures reveals that the region has suffered at least four phases of the deposition namely D_1, D_2, D_3 and D_4 (Nakharo, 2009). These deformational phases have brought about intricate patterns of distribution of rocks types of the region in the form of folding, faulting and thrusting of complex nature. The D_1 and D_2 deformational phases were mainly of ductile nature while the D_3 and D_4 have been mainly of brittle nature which has resulted in many fractures, faults and imbricate thrusting in the Schuppen Belt of Nagaland.

The geometrical analysis of the folds of the study area has been done which reveals that most of the folds of the area belong to class 1C geometry. However fold geometries belonging to 1A, 1B, 2 & 3 are also present. The geometry of the folded layer is an important criterion for study of fold morphology and also in describing the principal folding mechanisms involved in the development of the folds. According to Ramsay and Huber (1983), the folds of class 1A and 3 indicate differential compression in their evolution while class 1B and 1C suggest a flexure-slip mechanism, and class 2 suggests a slip mechanism in the fold formation. Therefore a flexure slip mechanism is the most dominant mechanism involved in the development of folds of these rocks occurring in the study area. The later deformations have modified the geometry of these folds and therefore they have shown much variation in the Srivatava and Gairola plots for multilayered folds.

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