Journal of Scientific Research
Banaras Hindu University, Varanasi

Vol. 55, 2011 : 25-34
ISSN : 0447-9483

MESOSCOPIC STRUCTURES FROM THE AREA AROUND SATENGAL, LESSER GARHWAL HIMALAYA

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ABSTRACT

The area around Satengal has been characterized by different types of mesoscopic planar, linear structures and folds. The detailed analysis of different planar linear structures and folds of the area reveals that the rocks of the area have suffered four phases of deformations D_1, D_2, D_3 and D_4 in chronological order. The detailed study of these mesoscopic structures reveal that first three phases of deformations are attributed to ductile deformation and the fourth phase of deformation is attributed to brittle deformation.

Key word : Deformation History, Mussoorie Synform, Lesser Garhwal Himalaya, Planar linear structures and folds.

Introduction :

The area around Satengal forms a part of Mussoorie Synform and falls in the survey of India topographical sheet no. 53J/3 and 53J/7 confined to the latitude 30°19'04" to 30°23'20"N and longitude 78°10' to 78° 18'11"E. The area is constituted of rocks of Krol nappe and Garhwal nappe. The Krol nappe rocks exhibit varied lithological units which range in age from Pre-cambrian to Eocene and consist generally of un-metamorphosed sedimentary formation. The rocks of Garhwal nappe consists of low-grade metamorphic rocks of slates and phyllites.

Regional mapping in and around Satengal has been carried out by earlier workers such as Middlemiss (1887) and Auden (1937). Recently Jain (1972), Shankar and Ganesan (1973) Saklani (1978), Valdiya (1975) and Sinha (1988) have discussed the major geological features, lithological boundaries, petrology of the rocks and fossil occurrences. However, not enough work has been carried out on the structures and deformation pattern of the area. In the present work an attempt has been made to study the deformational features and to establish the deformation history of the rocks of the area.

Geological Setting :

In the Lesser Garhwal Himalaya two major synforms i.e. Mussorrie synform and Garhwal synform occur in the form of doubly plunging synforms

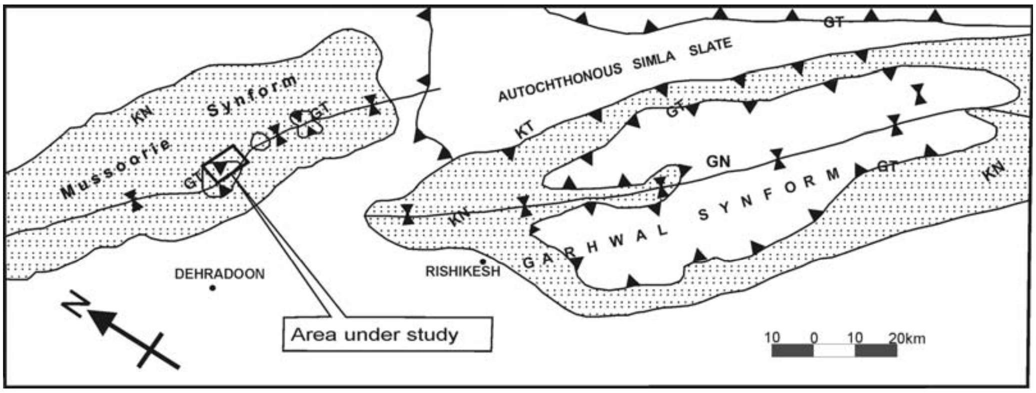

Fig.1 : Simplified tectonic map of Lesser Garhwal Himalaya. KN- Krol nappe; GN-Garhwal nappe; GT- Garhwal thrust; KT- Krol thrust.

(Fig.1). The longer axis of Mussoorie synform is running in an approximately NW-SE direcction (Fig.1). In this regional synform the sedimentary sequence of Krol nappe is overlain by the less metamorphosed rocks of Garhwal nappe along Garhwal Thrust. The Krol nappe consist of six recognized formations i.e. Nagthat, Blaini, Infra Krol, Krol, Tal and Subathu Formations. However, in the Satengal area which forms a part of Mussoorie Synform only Krol (consists of carbonaceous rocks), Tal (consists of siliceous limestones and orthoquartzite) and Subathu Formations (consist of shale and and limonitic nodules) are exposed where the rocks of Krol Formation are at the base. The metamorphosed rocks of Garhwal Nappe forms the top most unit of the area (Fig. 2 and 3).

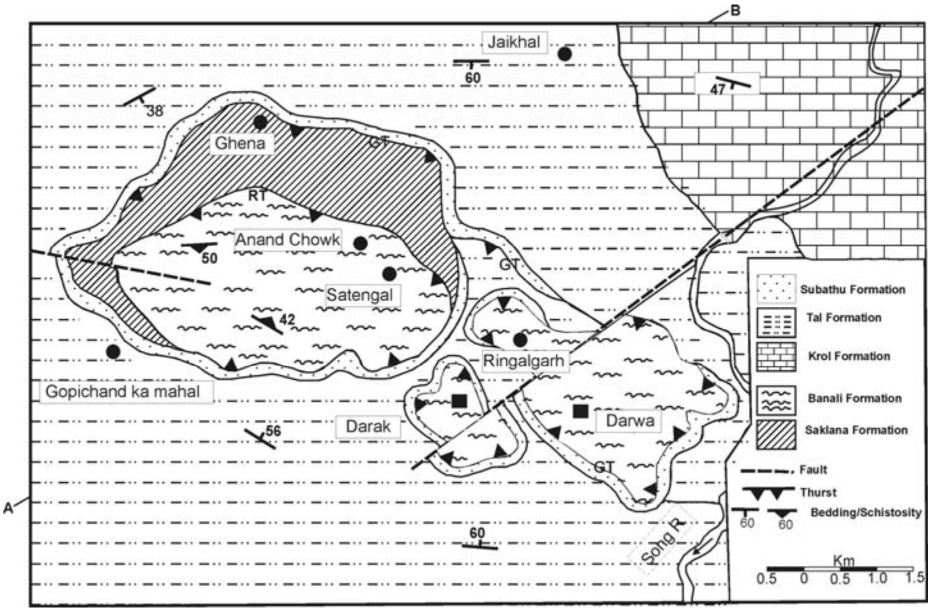

Fig. 2 : Litho-tectonic map of the area around Satengal form a part of northern limb of Mussoorie Synform.

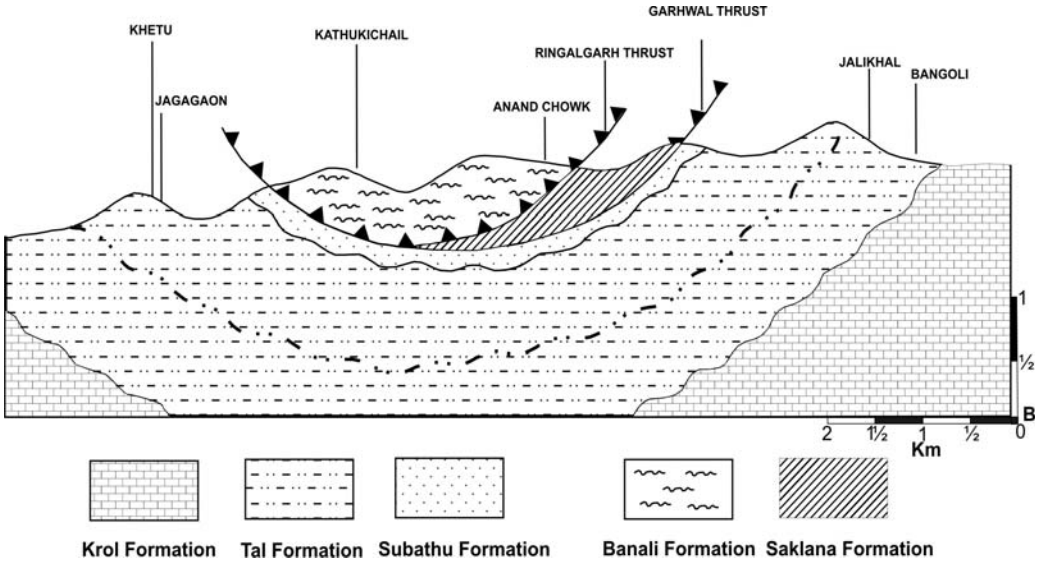

Fig. 3 : Schematic geological section of the area around Satengal

Auden (1934 and 1937) considered the Krol belt to be allocthon and Simla slate as autochthon, and designated the Krol belt as Krol Nappe. Auden (1937) considered Simla Slate as foundation of the Krol-Sain Dhar syncline, whereas the Mandhalies, Chandpurs and Nagthat formed the base of Nigali, Mussoorie, Garhwal and Naininta l syncline. The Simla slate are thrust over the Krol nappe rocks (represented by Chandpur, Nagthat, Blaini, Infra-krol, Krol, Tal and Subathu Formation in the ascending stratigraphic order) which has translated for about 8kms south wards along the Krol Thrust (Auden, 1937). Jain (1972) has recognized allocthonous nature of Krol Thrust and established Chandpur, Nagthat, Blaini, Krol, Tal normal sequence in Bidhalana and Pharat window. In Garhwal Himalaya the Krol nappe is overlain by another tectonic unit-the Garhwal nappe (Metamorphic equivalent of Chandpur Formation) along the Garhwal Thrust.

Auden (1937) has suggested the existence of two sub-units i.e. Amri and Bijni nappe separated by Amri thrust and has correlated the phyllite and quartzites of Amri nappe with Chandpurs and slates, limestone and quartzite of Bijni nappe as Mandhalies. Jain (1972) has given names to Banali Formation (consist of phyllite) and Saklana Formation (consist of slate, quartzite and limestones) for the rocks of Amri and Bijni nappe respectively. These two units are separated by Ringalgarh Thrust (Fig.2 & 3).

Table : Litho-Tectonic Sequence in the Northern limb of Mussoorie Synform (after Srivastava and Sinha, 1997)

Tectonic unit	Formation	Member
	Banali Formation	Phyllite
Garhwal nappe	-----------------------Ringalgarh Thrust-----------------------------------	
		Limestones
	Saklana Formation	Quartzite
		Slate
	---Garhwal Thrust------------------------------------	
	Subathu Formation	Subathu
Krol nappe	Tal Formation	Upper Tal
		Lower Tal
	Krol Formation	Krol B to E

STRUCTURE OF THE AREA

The structures of the area have been classified into mesoscopic structures and macroscopic structures. However, in the present work only mesoscopic structures have been dealt in detail.

Mesoscopic Structures :

All those structures studied on hand specimen to small out crop scale have been classified under mesoscopic structures. These structures have been found helpful in understanding the structural architecture and deformation behavior of the rocks in their internal domain, and all these, in turn, help in understanding the geology and deformation history of the area. The various mesoscopic structures of the area have been classified under small scale planar linear structures and folds. A structural map, of the area (Fig.4) showing the orientations of different types and generations of planar and linear structures, has been prepared.

Planar Structures :

All the mesoscopic structures that are penetrative in nature have been considered here as planar structures. The rocks of the area exhibit, development of planar structures such as primary bedding plane (S_1), Schistosity (S_2) and axial planes of different generations of mesoscopic folds. The primary bedding (S_1) has been recognized in the field by the lithological layering, sedimentary structures and color variation in the layers. Beddings planes are well characterized in the rocks of the Krol nappe which exhibit a dip from 20^o to 50^o towards southern and northern direction. In the area the schistosity has been observed in the phyllites and slates of the rocks of Garhwal nappe of the area. The strike of schistosity in Satengal and adjoining areas varies from NW-SE to NE-SW direction with low to moderate amount of dip in northern as well as in southern direction depending upon their position from the synformal axis (Fig.4).

In the area three generations of axial planes from three mesoscopic folds have been observed. The axial planes (S_3) associated with F_1 folding show a variation in their strike from NW-SE to N-S to NE-SW direction. The axial planes (S_4) which are related to F_2 folds exhibit a variation in strike from NE-SW to NW-SE to E-W direction. The axial planes (S_5) in F_3 folds strike in E-W direction. The local variation in the orientation of axial planes has been observed frequently throughout the area which is probably due to refolding faulting and thrusting in the area (Fig.4).

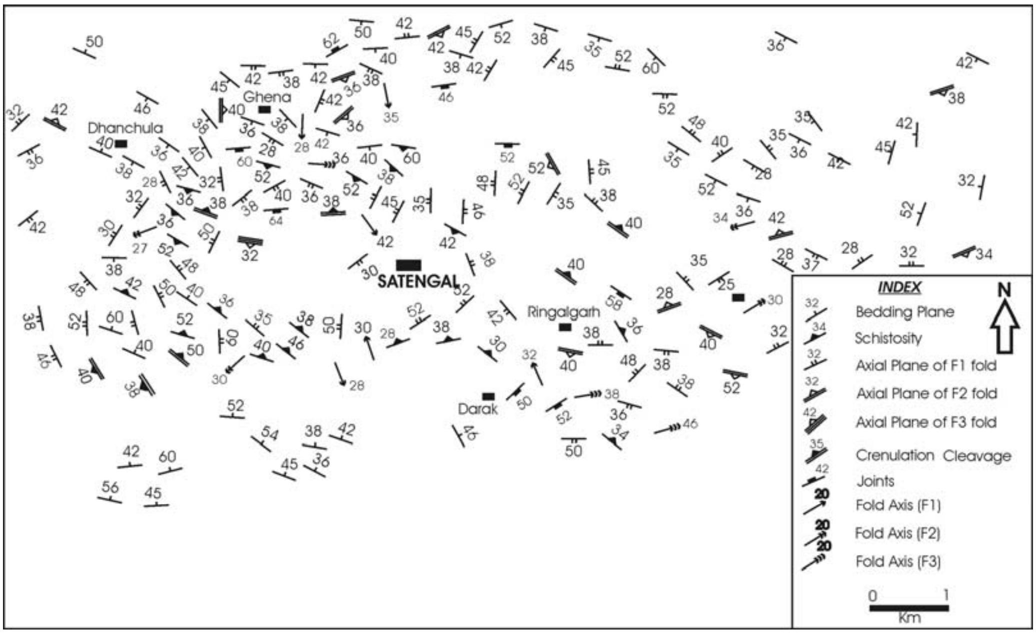

Fig. 4 : Structural map of the area showing different types and generations of planar and linear structures.

Linear Structures :

The linear structures shown in the area mainly include fold axes, stretching lineations, mineral lineations, slickensides and boudins. The mineral lineations include aligned elongate mineral grains and grain aggregates and are frequently developed in the rocks of the area. In the phyllites the mineral lineations show an average trend of NE-SW with an overall northern plunge for the southern limb of the syncline. Slickenside are also developed at number of places due to frictional sliding and frictional slip during local movement of beds past each other, and are commonly noticed on the surface of the fault, bedding and foliation planes. These appear as grooved or polished surfaces. Slickensides are commonly observed near Marora showing moderate amount of plunge towards south. Boudins commonly occur as an elongate mass of quartzo-feldspathic and calcite minerals (5C). Two generations of crenulations are present in the phyllites where later generation (L_2) of lineation is superimposed on earlier generation (L_1) of lineation (Fig. 6C).

In Satengal area it is being folded terrain, the hinge lines of different phases of folds define lineations which are penetrative even in mesoscopic scale. The lineation is much conspicuous in the rocks of Banali Formation near Satengal village, which forms the core of regional synclinal structure of the Mussoorie synform. In general, the hinge line of first generation of mesoscopic folds trend in NW-SE direction. The second generation of folds trend in NE-SW direction (Fig. 4). In the area the third generation of mesoscopic folds trend in E-W direction. However, locally the hinge lines of earlier folds do show variation in their direction and amount of plunge due to subsequent folding.

Folds :

The mesoscopic folds studied in the area range in size from a few cms to few meters. Study of fold geometry and their attitudes in the field suggest that the rocks of the area have under gone poly phased deformation. Each phase of fold is represented by a set of minor folds characterized by their typical fold geometry and attitudes (Fig. 5 & 6). The earliest fold F_1 – are tight isoclinal folds commonly shown in quartzo-feldspathic layers or by quartz veins. These folds are characterized by thin and occasionally boudinaged limbs and thickened hinges indicating mobilization of quartzo-feldspathic material from limbs to the hinge zone suggesting their formation under conditions of high ductile strains (Bhadauria et al. 2009). The F_1 folds mainly trend in NW-SE direction. The second generation of open to tight folds (F_2) developed on the limbs of F_1 (Fig.5 A&D and 6A & D) mainly trend in NE-SW direction with low to moderate amount of plunge. F_3 Chevron folds (Fig.6B) are developed in the phyllites of the Banali Formation of the area and trend in an E-W direction. The large folded structures of the area are characterized by trend of the strike of bedding and schistosity planes.

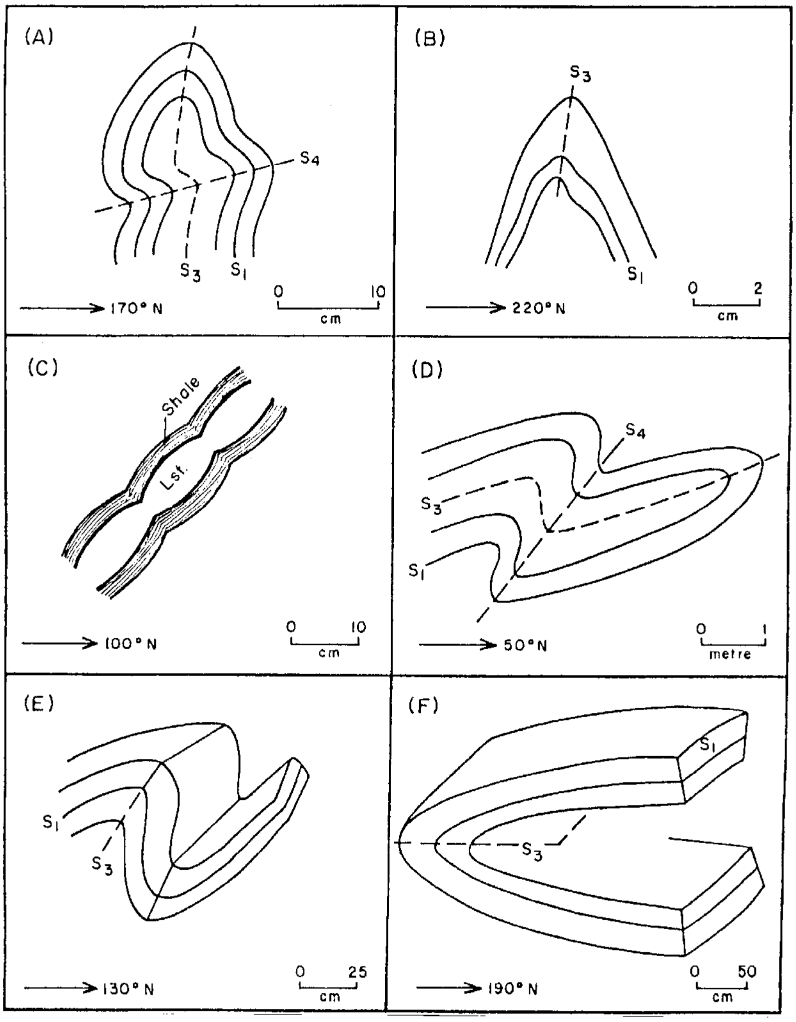

Fig. 5 : Hand sketches of the structures of the area

Deformation History :

The study of different planar and linear structures suggests that the rocks of the area have suffered four phases of deformation. The earliest phase of deformation is characterized by the presence of schistosity in the phyllites. However, no evidence of folding of bedding (S_1) with Schistosity (S_2) as axial plane in the phyllites have been observed. Schistosity parallel to bedding plane has been observed in different parts of Himalaya (Powell and Conaghan, 1973 and others) which has been attributed to isoclinals folding of S_1. If it is assumed that S_2 in the phyllite as axial plane cleavage of folds on S_1 then all the evidence of folding and other structural features are completely obliterated by later phases of tectonism. Therefore, this deformational feature has been called as Do and has not been discussed. The deformational episodes after the formation of schistosity have been discussed, for which ample evidences are available.

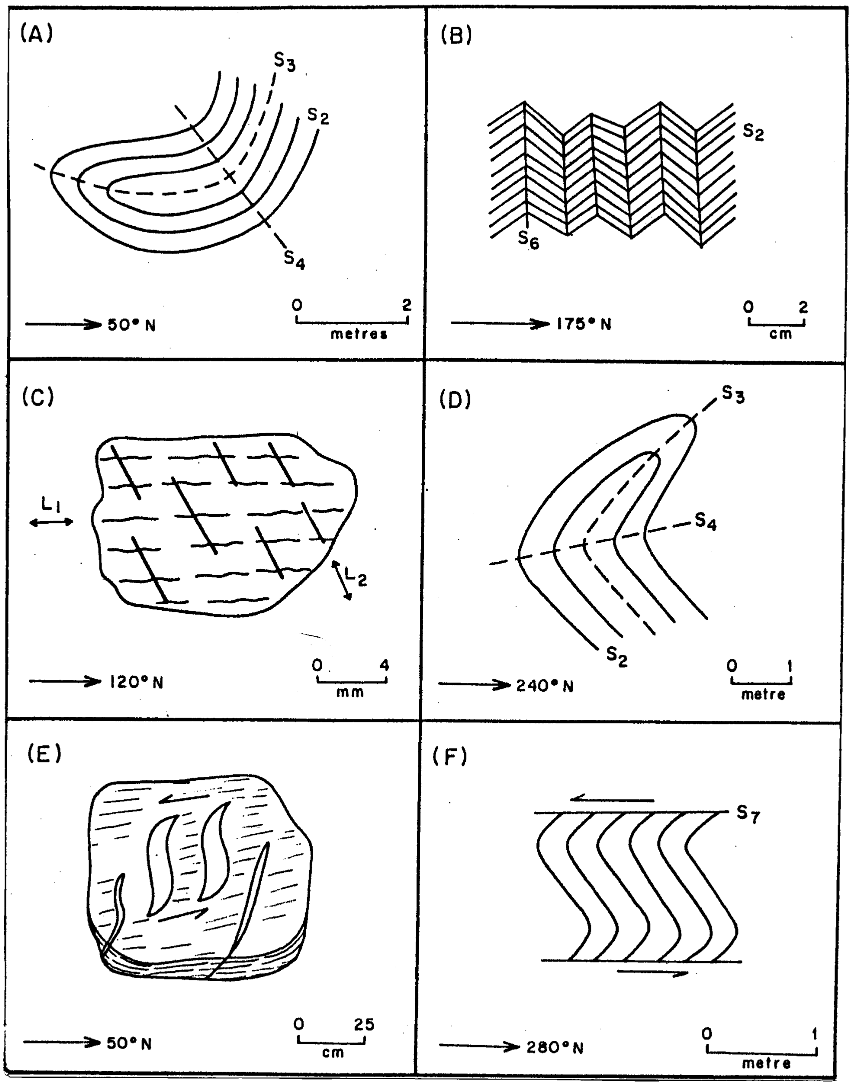

Fig. 6 : Hand sketches of the structures of the area

During D_1 phase of deformation bedding S_1 and schistosity (S_2) were subjected to folding (F_1), which trends in WNW-ESE to NNW-SSE direction mainly plunging towards either NW or SE direction. Pinch and swell and boudinage structures are developed during this phase of deformation. During D_2 phase of deformation the F_2 folds were developed on the limbs of F_1 folds. F_2 folds are open in style with rounded hinges mainly trending NNE-SSW to ENE-WSW directions. The late stage of D_2 deformation is attributed to ductile thrusting. During the D_3 phase of deformations F_3 chevron folds are developed which trends in E-W direction, further during this phase of deformation all the earlier structures were deformed. In the area under study the D_1, D_2 and D_3 phases are attributed to ductile deformation whereas the D_4 phase is attributed to brittle deformations during which the joints, fractures and transverse faults were developed.

Conclusion :

In the area around Satengal the phyllites of Garhwal nappe were thrust over the rocks of Krol nappe along the Garhwal thrust. The rocks of the area have suffered four phases of deformations. The first three phases of ductile deformation are synchronous to three phases of folding in the area. The fourth phase of deformation is brittle deformation and is responsible for the development of joints, fractures and faults in the area.

Acknowledgements :

Authors are thankful to Department of Science and Technology for the financial support.

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