Structural set up in northern part of Kumaun Himalaya

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Abstract. The Main Central Thrust (MCT) and the Main Boundary Thrust (MBT) are the two major thrusts in Kumaun, the MCT forming the boundary between highly sheared, deformed and mylonitized rocks of the Great Himalayan Central Crystallines and the Lesser Himalayan metasedimentaries. While in the Central Crystallines four-folding episodes are observed of which two are of the Precambrian age, the Lesser Himalayan rocks show only two phases of folding. MCT has its own distinctive structural history and the crystalline mass comprises an integral part of peninsular India.

Keywords. Structure; Central Crystallines; MCT; Kumaun Himalaya.

1. Introduction

The tectonic plane, separating the Lesser Himalaya from the Higher Himalaya and known as the Main Central Thrust (MCT) has thrown up the Precambrian basement rocks. The rocks of the Higher Himalaya forming a part of the 'Central Crystallines' of Heim and Gansser (1939) are sandwiched between the Trans Himadri Fault (THF) in the north and MCT in the south (Valdiya 1988). Between these two tectonic boundaries occur varied assemblages of schistose and gneissose rocks. These form basement for the sediments of Tethys Himalaya in the north and to the south occur feebly metamorphosed quartzites, slates, phyllites and limestones (Chamyal 1991). However, according to Valdiya (1977, 1988, 1989, 1991, 1993) the real MCT occurs at a higher stratigraphic level than that cited by all other workers and has designated this delimiting boundary as Vaikrita Thrust.

On a regional scale considerable structural data has been generated on the MCT and the overlying and underlying rocks and only the broad details of the structural set up of the area are available (Misra and Bhattacharya 1976; Valdiya 1978, 1979, 1980, 1987, 1988; Thakur 1981; Chamyal 1987; Roy and Valdiya 1988; Chamyal and Vashi 1989). The paper presents a broad synthesis of the work done by the authors in the valleys of Pindar, Sarju, Ramganga and Goriganga of Higher Kumaun Himalaya.

2. Lithostratigraphy

In the northern Kumaun, the Lesser Himalayan metasedimentaries are tectonically overlain by a great thickness of metamorphics forming the 'Central Crystalline'

Figure 1. Generalised geological map of northern part of Kumaun Himalaya.

Table 1. Structural sequence of the crystalline rocks in northern Higher Kumaun Himalaya.

Pindar and Sarju valley	Ramganga valley	Goriganga valley
Psammitic gneisses with pegmatitic and aplitic granites.		Trans Himadri Thrust
Sericitic quartzites.		Staurolite schists.
Kyanite schists and gneisses.		Leucogranite, pegmatitic and aplitic tourmaline granites, garnetiferous kyanite gneisses.
Gneissic granites, augen gneisses with micaceous quartzites.	Quartzites and calc silicate.	Calc silicatefels.
		Micaceous quartzites.
Augen and porphyroblastic gneisses.	Kyanite gneiss.	Garnet kyanite gneiss.
Schistose biotite gneiss.	Sericite and staurolite schists.	Augen and porphyroblastic gneisses with sericite, staurolite schists.
Augen and migmatite and gneissose siliceous feldspathic mica schists.	Migmatites and porphyroblastic gneisses.	Augen and migmatites with micaceous quartzites and staurolite schists.
Garnetiferous mica schists, chlo- rite and sericite schists with interbedded amphibolite lenses.	Garnet mica schists, chlorite and sericite schists with amphibolite lenses.	Garnetiferous mica schists, chlo- rite and sericite schists.
Main Central Thrust	Main Central Thrust	Main Central Thrust
Loharkhet quartzites, Saling slates, Deoban carbonates	Hokara quartzites, Deoban carbonates	Girgaon quartzites, Deoban carbonates.

(figure 1). Various kinds of granitoids and schists form the dominant rock types, besides lenses of micaceous quartzites, calcsilicate rocks and amphibolites. The MCT zone is characterised by the presence of phyllonites on supra thrust and the sheared quartzites on infra thrust side. Though it is very difficult to precisely demarcate the various lithological types, a broad sequence of rocks seen in the valleys of Pindar, Sarju, Ramganga and Goriganga is given in table 1.

3. Structure

The generalized geological map, structural trend map of the area, geological cross section of the MCT zone and across Kumaun (figures 1, 2, 3A, B, C and 4) provide insight into the structure of Kumaun Higher Himalaya. The rocks of the Central Crystallines have been subjected to tremendous compression as evident from tight folds and polyphase deformation. There exists marked difference in the structural

Figure 2. Structural trend map.

Figure 3. Detailed geological cross-sections (a) Goriganga valley, (b) Ramganga valley, (c) Pindar-Sarju valley.

BC – Balj Nath Crystallines, AC – Almora Crystallines (Pre-Cambrian), BQ – Blaini Quartzite, JU – Jaunsar, DE – Daoban, SP – Blaini Spillite, IK – Infra Krol, KL – Krol, KR – Keratophyres, SW – Siwalik, MCT – Main Central Thrust, NAT – North Almora Thrust, SAT – South Almora Thrust, MBT – Main Boundary Thrust.

Figure 4. Generalised cross-section across Kumaun Himalaya (after Chamyal 1991).

characteristics of the rocks on the two sides of the MCT. The fold history of the northern part of Kumaun Himalaya can be summarised as follows:

Event	Nature	Pindar/Sarju/Ramganga Goriganga valleys		Trend
		Central Crystallines	Lesser Himalayan rocks	
F ₁	Isoclinal/ Reclined	Present	Absent	NNE-NE/ SSW-SW
F ₂	Isoclinal/ Reclined	Present	Absent	NNE-NE/ SSW-SW
F ₃	Synformal folding	Present	Present	NW-SE
F ₄	Flexural folding	Present	Present	NE-SW

The first two foldings (F₁ and F₂) are recorded only in the Central Crystallines and are of Precambrian age (Merh 1984; Chamyal and Vashi 1989). These are co-axial, having identical geometry with variable plunges towards NNE/SSW and are represented by tight isoclinal/reclined folds. The main schistosity of the rocks is generally seen to represent axial plane cleavage of F₂, though relicts of the earliest axial plane foliation related to F₁ are abundantly recorded. Most of the gneissic bands occurring within the schists as well as layers of quartzites ideally show F₁ and F₂ folds at mesoscopic as well as microscopic scales. The gneissic bands are involved in F₁ and F₂ and it is likely that they constitute F₁ fold cores refolded on F₂. The hinge portions of the mesoscopic folds are generally thick and the limbs are thin. The rootless and tight folds of F₁ and F₂ generation are more intense in the thrust zone. However, the two tectonic units (Vaikrita and Munsiri) of Valdiya (1977) according to Roy and Valdiya (1988) show different structural patterns.

A thrust movement along the pre-existing lineament (MCT) pushed the crystallines over the Lesser Himalayan rocks (Chamyal and Vashi 1989). The MCT is characterised by a narrow zone striking E-W to NW-SE dipping due N to NE. The movement along this thrust has not only sheared the rocks but has also given rise to a new set of folds (related to the drag effect) superimposed over the Precambrian deformation. The drag folds also show a NNE to NE axes, and it appears that the major movement along the MCT was from NW. The axes of the drag folds mark the thrust related linear structure (L_T) while the phyllonitic cleavage represents the planar structure. Besides the drag folds also observed, rootless and tight folds in the vicinity of the thrust with their plunge in the same direction NNE to NE or SSW to SW. It is just a coincidence or identical nature of movement directions that F₁ and F₂ folds and the thrust related drag folds show similar trends. The 'a' lineation (striation) which is the effect of flexural slip during a later folding (F₃) also show a northeasterly trend.

The F₃ folds trend NW/SE and are open in nature, related to this are various

mesoscopic synformal nappes with asymmetrical and symmetrical parasitic folds. This folding is found in both the tectonic units and is almost right angles to F_1 and F_2 . The planar structure related to F_3 include the axial plane cleavage S_3 trending NW/SE dipping moderately ($20-30^\circ$) towards NW. The F_4 is also common in both the units, marking the last fold event, has imparted waviness to the regional foliation trends. The folds are open to chevron trending NNE-NE/SSW-SW. The planar and linear elements related to F_4 include the axial plane cleavage (S_4) trending NE-SW and crenulation axes (L_4) trending NE/NNE-SW/SSW with deviations towards N-S direction.

Roy and Valdiya (1988) while describing the tectonometamorphic evolution of the Kumaun Himalaya classified the small scale structures into two types – (i) folds parallel to lineation and (ii) folds at high angles to lineation. According to them F_1 and F_2 folds (and their subtypes) have formed under different tectonic conditions and the terms F_1 and F_2 do not imply the chronological order of their formation, but are descriptive terms indicating the orientation of the axes and axial planes of the folds in relation to the direction of tectonic transport. However Chamyal and Vashi (1989) do not think so and have assigned Precambrian age to F_1 and F_2 and Himalayan to Late-Himalayan ages to F_3 and F_4 .

The microstructural studies of the metasedimentaries lying below the MCT show that the carbonates have developed only a poor cleavage, the intensity of which decreases southward. Fractures and veins are abundant and the carbonates are recrystallized with grain sizes varying from 1 mm to 10 mm. The overlying slates and phyllites are characterised by a penetrative cleavage. Later kinks and crenulation folds are very intense and well developed. The deformation intensity is much more in the quartzites lying immediately below the MCT. The quartz grains exhibit undulose extinction, overgrowths, sutured grain boundaries and several overprinting schistosity are observed in the chlorite schists intercalated with quartzites. All these characteristics indicate that the increasing amount of internal deformation northward is due to the nearness of MCT.

4. Discussion

The existence of the MCT in the northern part of Kumaun Himalaya has been quite vital in working out the overall tectonic framework. The rocks of Higher Himalaya have atleast undergone effects of deformation and metamorphism of two generations- Precambrian and Tertiary. The rocks overlying and underlying the MCT show metamorphic and structural features quite distinct from each other. The Central Crystallines comprise a part of the Precambrian Indian Shield (Gansser 1964; Naqvi *et al* 1974; Crawford 1974; Chamyal and Vashi 1989). According to Chamyal *et al* (1984) the MCT is a pre-Himalayan tectonic feature that developed during the waning phase of the Hercynian orogeny on account of crustal stretching and rifting, the mechanism related to process of abduction along the northern flank of the subducted mid-oceanic ridges, the spreading centre of the proto-Tethys ocean. The Central Crystallines comprise a tectonic flake demarcated by the MCT. It thus neither marks a simple overthrust nor does it represent a major plate boundary but it is an intracrustal boundary thrust (Valdiya 1981).

The tectonic weak zone that developed in pre-Himalayan times was obviously

reactivated during the initial stages of the Himalayan orogeny (Chamyal *et al* 1984), pushing the older crystallines over the Lesser Himalayan rocks. The drag fold axes related to this early Himalayan thrusting point to a strike-slip movement along the pre-existing fracture in a NW-SE direction. The lateral displacement was caused due to the NE movement of the Indian plate whose stress was trending WNW-ESE and right laterally directed towards east (Sythanavong and Shah 1980). The MCT thus could very well be compared to a right lateral transcurrent fault.

Of the four folding episodes the most obvious event expressed by the rocks of Higher Himalaya has been F_2 which produced wide spread cleavage. According to Chamyal (1987) the first deformation (F_1) produced Quartz-oligoclase-muscovite-biotite-garnet-staurolite and metamorphosed the pelitic rocks to garnet (staurolite) mica schists. Karanth (1985) has also observed similar features in the rocks of Almora nappe. The next deformational event (F_2) recrystallized the rocks, to produce a crenulation cleavage (S_2). The metamorphism reached upto Sillimanite grade of upper amphibolite facies.

During the next major deformational episode (F_3) the crystalline thrust sheet was folded into numerous synforms, the relicts of which are seen as crystalline nappes in the Lesser Himalaya. A strong striation lineation of the nature of slickensides and mineral stretching developed along the thrust plane on account of intense flexural slip movement. All over the northern part of Kumaun Himalaya the last deformational episode is characterised by transverse faults. The transverse faults trending NNW-SSE or NNE-SSW show considerable crushing, shearing, displacement in the MCT and rock formations, offsetting of drainage pattern etc. These faults have right laterally displaced MCT by as much as 50 to 100 m and has dissected the Lesser Himalayan rocks as well.

It is beyond doubt that the Central Crystallines have over-ridden the Lesser Himalayan rocks in northern Kumaun along MCT. Gansser (1964) stated that the crystallines form the basement for the Tethyan sequence. The present authors however feel that the crystalline mass comprise an integral part of peninsular India as is also believed by many others. Having been affected by pre-Himalayan orogenies the frontal portion of the Indian shield was shattered and MCT geofracture was developed, which was reactivated during the Himalayan orogeny. The crystalline block (upthrust block) might have undergone drastic deformation and transformation at depth during this orogeny.

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