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STRUCTURAL ARCHITECTURE AND DEFORMATION PATTERN OF THE MAIN CENTRAL THRUST ZONE OF THE GUPTAKASHI-GAURIKUND AREA, GARHWAL HIMALAYA

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ABSTRACT

In the Guptakshi-Gaurikund area of Garhwal Himalaya, the Main Central Thrust (MCT) separates the Central Crystalline Zone of the Greater Himalaya from the sedimentary belt (Garhwal Group) of the Lesser Himalaya. The MCT constitutes a huge shear zone of about 10-12 km width. The Central Crystalline Zone has been subdivided into three formations, from base to top, these are : (1) *Guptakshi Formation* (dominantly with mylonties and subordinate quartz- muscovite gneiss and chlorite schist), (2) *Barasu Formation* (mylonites, garnetiferous gnesis, muscovite- biotite gneiss, granite gneiss and quartzite), and (3) *Gaurikund Formation* (garnetiferous biotite gneiss, granite gneiss and quartzite). The *Garhwal Group* is mainly represented by a sequence of quartz arenite, dolomite (locally) and amphibolite. A thick zone of mylonites is dveloped at the base of the crystalline pile, i.e. in the vicinity of the MCT. Megascopically, the rocks of the area are disposed as a homocline showing persistently north- dipping strata. The rocks are affected by a number of megascopic faults mostly trending NE-SW. On the mesoscopic scale, the rocks show at least three phases of folding, and a NE-SW trending stretching lineation that becomes progressively stronger towards the MCT. A variety of planar and linear strcutres are also developed in both the crystalline and sedimentary rocks of the area. Structural/microstructural studies indicate a complex deformation pattern in the internal domain of the shear zone.

Keywords: Main Central Thrust, Garhwal Himalaya, Central Crystalline Zone.

INTRODUCTION

The Main Central Thrust (MCT) (fig.1) is an important geotectonic element of the Himalaya. It separates the crystalline rocks of the sedimentary belt of the Lesser Himalaya (Gansser, 1964). The crystalline rocks of the Greater Himalaya have been thrust over the less- to non-metamorphosed sedimentary rocks of the Lesser Himalaya along the MCT. The effects of strong shear deformation are observed not only in a wide zone of the crystalline rocks (hanging wall) exposed along, and structurally above, the MCT but also in the sedimentary rocks (footwall). As such, the MCT occurs as a wide zone of 10-12 km extent in the Himalayan domain. The various structural/microstrucural elements of the MCT zone and the deformation pattern shown by the rocks of the MCT, zone, therefore, hold significant bearing on the deformation history of the MCT zone in particular and the evolutionary pattern of the Himalaya, in general.

Earlier, the area was referred to in the work of Auden (1937) on a regional basis. Tewari and Setti (1960) presented an account of the geology and structural set-up of the Mandakini and Bhilangana valleys. Dungrakoti *et al.* (1976) demarcated the position of the MCT between Kund Chatti and Guptkashi. Naithani and Prasad (1997) presented a landslide hazard zonation map of the Okhimath-Kedarnath area.

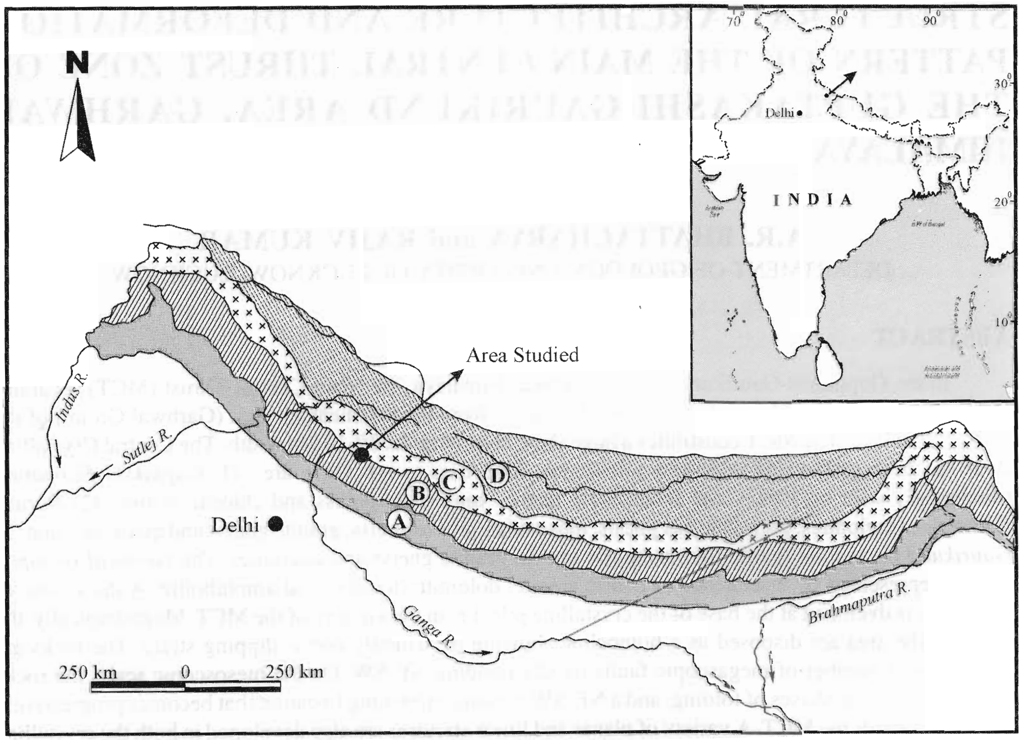

Fig. 1. Generalised geological sketch map of the Himalaya (after Gansser, 1964) showing the location of the study area. A- Outer Himalaya, B- Lesser Himalaya, C- Greater Himalaya, D- Tethys Himalaya. The contact of C and D defines the Main Central Thrust.

GEOLOGY OF THE AREA

Two major lithotectonic subdivisions of the Himalaya are exposed in the study area (fig. 2): one, lying to the north with medium to high grade metamorphic rocks belonging to the Central Crystalline Zone of the Greater Himalaya, while the other lying to the south with a thick pile of younger (sedimentary) rocks of the Lesser Himalaya and is referred to as the Garhwal Group. These two subdivisions are separated by the MCT.

(A) Central Crystalline Zone

The Central Crystalline Zone (CCZ) constitutes a massive pile of crystalline-metamorphic rocks, mainly gneisses and quartzites. Due to the effects of marked shearing along the MCT, the crystalline rocks have been mylonitised to varying degrees, and as such, the gneissic rocks of the area can be described as mylonitic gneisses. In the present area, the CCZ has been subdivided into three formations: (1) Guptakshi Formation (2) Barasu Formatin, and (3) Gaurikund Formation. The lithology and structural disposition of the rock types of the CCZ are given in the geological cross sections (figs. 3-5).

1. Guptakashi Formation

The lowermost rock unit of the Central Crystalline Zone of the area has been named as the Guptakashi Formation, after the name of this place. The southern contact of this

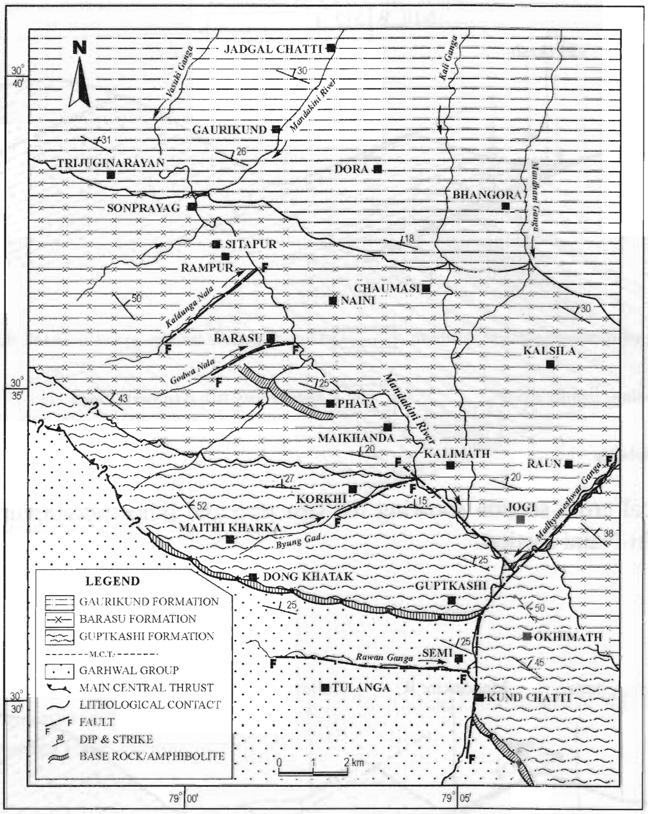

Fig. 2. Geological map of the Guptakshi-Gaurikund area, Garhwal Himalaya

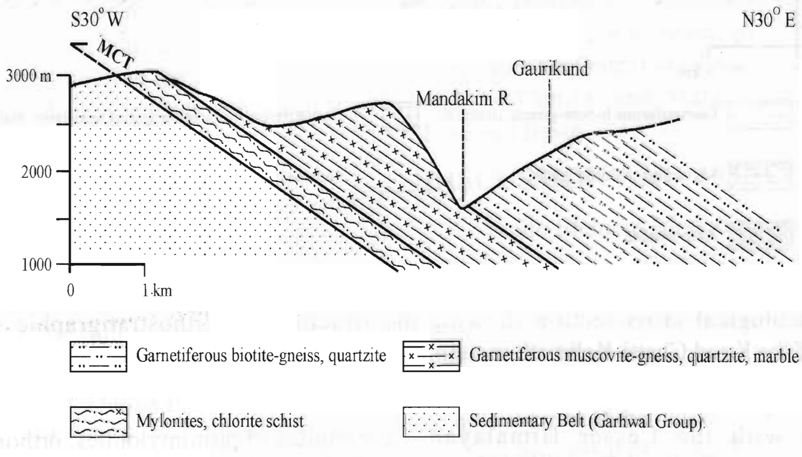

Fig. 3. Geological cross-section showing the strcuture and lithostratigraphic sequence of the Gaurikund-Sonprayag section.

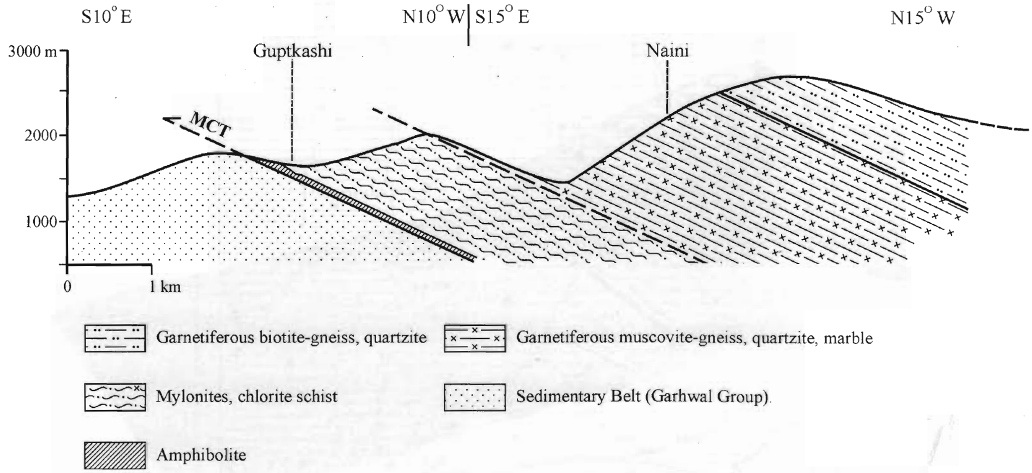

Fig. 4. Geological cross-section showing the structure and lithostratigraphic sequence of the Guptkashi-Naini section.

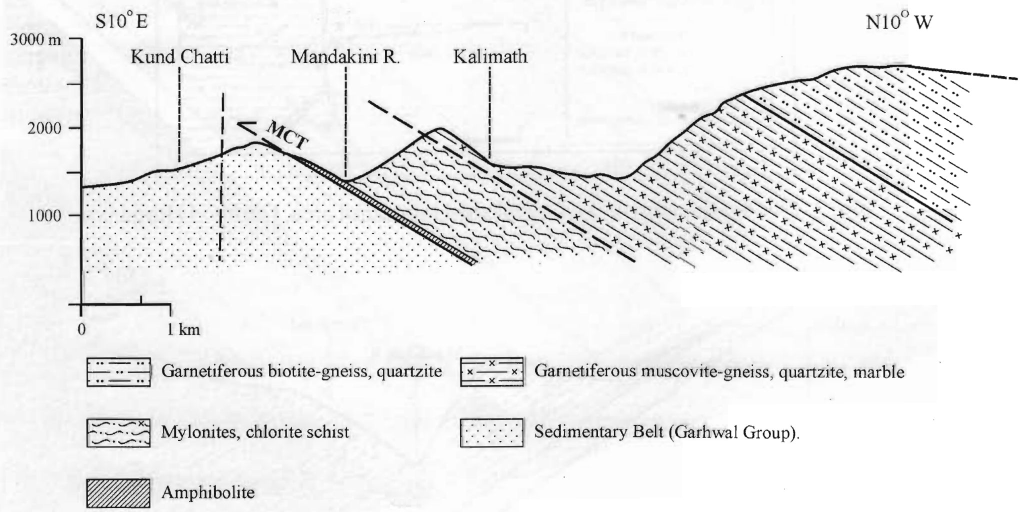

Fig. 5. Geological cross-section showing the structure and lithostratigraphic sequence of the Kund Chatti-Kalimath section.

formation with the Lesser Himalayan sedimentaries (i.e. Garhwal Group) is tectonic (MCT) while the northern contact with the overlying Barasu Formation is mainly constituted of protomylonites, orthomylonites and ultramylonites, and the major lithological units include chlorite schist, quartz-muscovite gneiss, quartz-sericite gneiss, quartzite, marble and actinolite schist. All these rock types have been mylonitised to varying degrees. Basic rocks variedly altered to amphibolite and chlorite schist, are commonly noticed all along the trace of the MCT. Effects of mylonitisation, shearing and pulverisation of rocks are relatively more common in the rock types of the lower part of this formation. The general dip of foliation varies from 5^0 to 55^0 towards N to NE.

2. Barasu Formation

The sequence of rocks overlying the Guptakashi Formation has been named here as Barasu Formation after the name of this village in the Mandakini valley. This formation is, in general, constituted of medium to high grade metamorphic rocks that are mylonitized at several structural levels thus giving rise to the development of proto-, ortho- and ultramylonites. The major constitutents of the Barasu Formation include mylonite, quartzite, marble and calcsilicate, muscovite, gneiss, biotite gneiss and garnetiferous schist/gneiss. Garnet is commonly present in the majority of rock types and the occurrence of garnet is important mainly because this mineral is prcatically absent (to rare) in the lowermost unit (Guptakashi Formation) of the Central Crystalline Zone. As such, the very occurrence of garnet has been considered in this work as the major distinguishing feature of the Barasu Formation against the Guptakashi Formation.

3. Gaurikund Formation

The uppermost unit of the Central Crystalline Zone of the study area includes a north-dipping sequence of garnetiferous gneiss and various types of schists. This unit has been named as Gaurikund Formation after the name of this place. The major rock types include garnetiferous biotite-muscovite gneiss, hornblende-quartz gneiss, garnetiferous biotite gneiss (with tourmaline), quartzite, quartz-muscovite gneiss, and amphibolite. The quartzite is well bedded, banded and grey in colour. Mylonites (protomylonite and orthomylonite) are also occasionally developed especially at the lower horizons of this formation. In general, the degree of mylonitization decreases northwards, i.e. towards the higher stratigraphic horizons, and as such the rocks located farther north, e.g. around Rambara and Kedarnath areas, do not exhibit mylonitic texture. Also, the effects of shearing in the rocks sympathetically decrease northward.

(B) SEDIMENTARY BELT

Garhwal Group

The Lesser Himalayan Sedimentary belt, as mentioned earlier, is known as the Garhwal Group. In the study area, only a small part of this group is exposed to the south and possibly represents the upper stratigraphic units of this group. Due to tectonic emplacement/overriding of the massive pile of the Central Crystalline Zone over this group along the MCT, the rocks of this group have undergone (low to moderate degree of) recrystallisation and also show effects of shering in their internal domain. This sedimetary belt is represented by a sequence of quartz-arenite, slate, amphibolite and dolomite (locally). In general, quartz-arenite occurs almost all along the thrust contact, and shows a vareity of colours (white, purple, brown and green) and is well bedded to massive, medium to coarse grained. Sedimentary structures, mainly current bedding and ripple marks, are comonly noticed in the quartz-arenite.

STRUCTURE OF THE AREA

In the present work, the structural architecture of the area hs been discussed under (a) megascopic strcutures and (b) mesoscopic structures.

(A) MEGASCOPIC STRUCTURES

(I) Thrusts

Main Central Thrust: The northern contact of the sedimentary belt (Garhwal Group) of the Lesser Himalaya with the Central Crystalline Zone is a low-to moderately dipping tectonic plane along which the crystalling rocks of the Greater Himalaya are thrust over the sedimentaries. This tectonic plane was first designated as the Main Central Thrust (MCT) by Heim and Gansser (1939) and Gansser (1964). In the present area, the MCT has a more or less WNW-ESE trend which, south of Kund Chatti, swings to NE-SW due to intervention of the Mandakini Fault.

The trace of the thrust is characterised by the presence of basic rocks, altered to amphibolite and chlorite schist. Profuse development of silica lenses and veins, occurrence of highly stretched ellipsoidal bodies of quartzo-feldspathic minerals, effects of marked shearing and crushing of rocks, pulverisation and mylonitisation are common features all along the thrust. Effects of retrograde metamorphism in the crystalline rocks are also noticed all along the thrust zone. The amphibolite occasionally shows bundinage structure due to continued streching along the thrust plane. On the mesocopic and microscopic scales, the rocks of the thrust zone show a variety of complex structural features that clearly suggest that the MCT zone has a long and complicated history of intense deformation in its internal domain (cf. Bhattacharya, 1987, 1990, 1999; Bhattacharya and Siawal, 1985).

The MCT zone is also characterised by the occurrence of landslides at a number of places, e.g. in the Guptakashi and Kalimath areas, suggesting that the MCT zone is neotectonically active.

(II) Faults

Although the rocks of the area have been affected by a large number of faults on various scales, only those which are mappable on 1 : 50,000 scale are described here.

Mandakini Fault: Between Kund and Guptakashi, the general trend of the MCT (i.e. WNW-ESE) is offset along the Mandakini river. This is due to the presence of a fault along the river, and has been named here as the Mandakini Fault (fig. 2). For most parts, the valley shows steep walls and the strata show steep to vertical attitude at several places. The fault trends approximately N-S and appears to have caused an offset to the MCT by about 3 km along the fault. North of Kund, the fault swings to NE and extends along the Madhyameshwar Ganga for 4 km (as measured from the confluence of the Mandakini and Madhyameshwar Ganga rivers). Effects of intense fracturing and shearing of rocks are commonly noticed all along this fault.

Rawan Ganga Fault: The Rawan Ganga appears to follow a fault, as indicated by the following : (a) the river follows a straight course south of Guptakashi (fig. 2), (b) the prominent topographic break marked by the low-lying cultivated land on the southern side of the river, and (c) prominent escarpment on the northern side. All these suggest the presence of a fault. This E-W trending fault has been named here as the Rawan Ganga Fault.

Byungad Fault : The rocks exposed along the NE-SW trending Byungad also appear to be associated with a fault, named here as *Byungad Fault* (fig. 2). Fracturing and crushing of rocks are commonly noticed along Byungad. A number of landslides occur all along this fault causing blockade and collapse of the road at a number of places.

Godwanala Fault: Along the NE-SW trending Godwanala (fig. 2), south of Barasu, the rocks appear to follow a fault plane, named here as *Godwanala Fault*. The rocks in the vicinity of this fault show prominent effects of silicification, high degree of crushing of rocks and development of gouge. This tract is also associated with a large number of landslides.

Kaldungnala Fault: The Kaldungnala, south of Rampur, also appear to follow a fault trending NE-SW, named here as *Kaldungnala Fault* (fig. 2). This fault zone is characterised by local steepening of strata and high degree of silicification in the associated rocks. A number of landslides occur along this fault.

(B) MESOSCOPIC STRUCTURES

All those strcutures studied on local and small outcrop scales as well as in hand specimens are categorised here under mesoscopic structures. The various mesoscopic structures of the area have been classified here under the following three categories : (a) Minor folds, (b) Planar structures and (c) Linear structures.

(I) Minor Folds

Study of fold geometry and their attitudes clearly indicate that the rocks of the area have undergone at least three phases of folding. Each phase is represented, in addition to other types of structures, by a set of minor folds charcterised by their typical fold geometry and attitudes. In general, the area appears to have been affected by at least three generations of folds as prominently refleced on mesoscopic scale.

The first generation folds (F_1) are tight isoclinal, recumbent type of folds with their axes usually trending N/NW-S/SE with low plunge upto 25^0. These folds are mostly formed due to folding of the original S_1 planes and as such their axes give rise to the S_2 planes in the area. The F_1 folds are noticed in the crystalline rocks especially in the areas around Sonprayag, Rampur and Barasu. The wavelength - amplitude ratio (cf. Bhattacharya, 1986) of these folds ranges from 0.15 to 0.33. The hinge thickness of the F_1 folds is always greater than the limb thickness. It has been observed that away from the MCT, the trend of the axis of F_1 folds generally remains NW-SE which, towards the MCT, gradually changes approximately to NE-SW, i.e. nearly parallel to the trend of the stretching lineation. It is therefore quite possible that with progressive shear, the F_1 fold axes may have undergone rotation in response to progressive shear movement associated with the MCT.

The second generation folds (F_2) are generally coaxial to the F_1 folds. The F_2 folds include steeply to moderately inclined as well as asymmetrical folds and are commonly developed on the limbs of F_1 folds. As compared to the F_1 folds, the F_2 folds are open imlying that they represent a weaker deformation phase in comparision to that of the F_1 folds.

The folds of the third generation (F_3 folds) are open folds with their axial planes dipping at high angles and are mostly in the form of upright and vertical folds. These folds appear to have developed during some later phase(s) of deformation. The F_3 folds also occur as kink bands, re-oriented, repeated, disharmonic and conjugate folds in the vicinity of the MCT, e.g. in the quartz sericite gneisses around Semi and Kund Chatti areas. The axial trend of F_3 folds varies from E-W to NE-SW and are thus more or less normal to the folds of earlier (F_1 and F_2) generations. Plunge of the F_3 folds is relatively high, upto 50^0.

In addition to the above, some specific fold types - mainly *sheath folds* - are also developed in the area, e.g. in the vicinity of Sonprayag and Kalimath areas. These folds generally occur in zones of high shearing (cf. Cobbold and Quinquis, 1980; Malavielle, 1987) and occur as extended tube-shaped folds in the lithic layers.

The axial trend of the sheath folds in Sonprayag area is NNE-SSW while in Kalimath

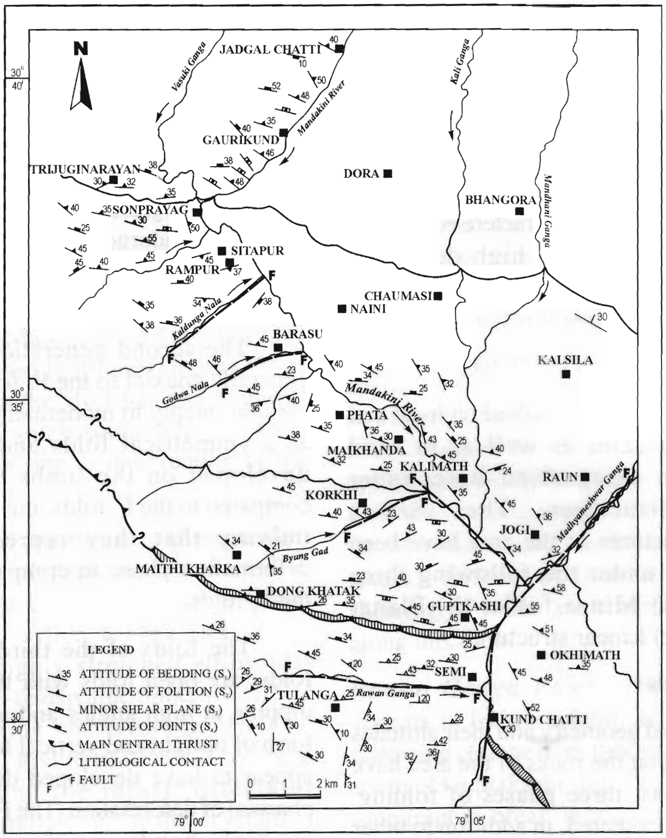

Fig. 6. Planar structural map of the Guptakashi-Gaurikund area, Garhwal Himalaya.

area, i.e. in the vicinity of MCT, it is ESE-WNW.

(B) PLANAR STRUCTURES

The mesocopic structures that are of penetrative nature have been categorised here as planar structures. Attitudes of various planar structures have been noted in the field and have been plotted on a map (fig. 6). The following types of planar structures are developed in the area.

Primary bedding plane (S_1): The primary bedding plane, designated here as S_1, is recognised in the field by lithological characters, compositional layering, primary sedimentary structures and colour variation. Development of S_1 planes have been observed in the various rock types of the Garhwal Group. Dip of S_1 generally varies from 5^0 to as much as about 70^0 betwen NW to NE with strike varying from NE-SW to NW-SE.

Schistosity plane (S_2): Schistosity (S_2) plane is commonly developed due to the first phase of deformation and is shown by preferred orientation of sericite, chlorite, mica and stretched grains of quartz. S_2 planes are commonly noticed in the rocks of the Central Crystalline Zone. In the gneissic rocks, the S_2 planes are defined by the gneissosity as identified by the development of colour bands of mafic and felsic minerals.

In the crystalline rocks, the general strike of the S_2 planes varies between NE-SW to NW-SE with dips of 5^0 to 48^0 N/NE.

Minor Shear Planes (S_3): The shear planes, designated here as S_3 planes, have been given a special category in the present work and are mostly defined by displacement of silica venis on the limb of a fold along a shear plane. The S_3 planes are prominently seen developed in the vicinity of the MCT, away from which their occurrence become relatively poorer. Trend of these minor shear planes remains between WNW-ESE to NW-SE.

Jonts (S_4): The joint planes, designated here as S_4 planes are developed in both the sedimentary and crystalline rocks and commonly show two dominant sets, though other, subordinate, sets are also noticed. In the sedimentary rocks of Garhwal Group, the most dominant strike of the S_4 planes is NW-SE with dips of 15^0 to 50^0 due N to NE, while in the crystalline rocks, the strike of the S_4 planes varies between WNW/NW and ESE/SE with dips of 10^0 to 55^0 due NE to NW.

(c) Linear Strucutres: In the area, linear structures are rather more comonly developed in the crystalline rocks than in the sedimentary rocks. A common observation is that the attitude of the linear strucutres of crystalline rocks is more or less systematically related to the proxmity of the MCT plane. The is also valid for the linear features of the sedimentary rocks occurring in the vicinity of the MCT. As such, all linear features of the crystalline rocks have been broadly considered here as *stretching lineation*, which is developed as a very common structure in the MCT Zone. This lineation is mainly defined by elongation of feldspar, mica aggregates, stretching of porphyroclasts and elongation of recrystallised trails of quartz and quartzo-feldspathic minerals.

In the vicinity of the MCT, the trend of the stretching lineation in the crystalline rocks has been observed to be more or less constant, i.e. N/NNE-S/SSW. Away from the MCT, this common trend gradually deviates up to NE-SW. Therefore, the common direction of stretching lineation, which is nearly perpendicular to the general trace of the MCT, can be considered as the direction of overall tectonic transport for the crystalline mass.

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