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LINEAMENTS FROM THE GARHWAL HIMALAYA, INDIA

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Abstract: The lineament study from a large part of Garhwal Himalaya India, exhibits four prominent trends, mainly NE - SW; NW - SE; N - S and E - W directions. The trends of lineaments were traced from LANDSAT imagery and have been correlated with results of structural analysis (based on the field data on planar and linear fabrics and on folds), from two important sections of Garhwal Himalaya. The study reveals that the lineaments of the area are parallel or subparallel to the axial directions of major folds, and regional strike trends of faults and thrusts.

Key words: LANDSAT imagery, lineaments, thrusts, faults, Garhwal Himalaya.

Introduction

Continent-continent collision in the Himalaya is well documented by Late Cenozoic intracontinental crustal shortening and southward thrusting along the Main Central Thrust (MCT) and associated thrusts over the Lesser Himalayan sediments (Searle 1986; Coward et al. 1986, Pecher & LeFort 1986). Post-collision deformational processes in the Himalaya are reflected by the development of large scale lineaments with the help of LANDSAT imagery from a large part of Garhwal Himalaya, India. Further, the study is supplemented by detailed structural analysis of mesoscopic planar and linear fabrics and folds, present in the rocks of different sections of Garhwal Himalaya.

Geological framework

Garhwal Himalaya exposes from south to north all the four typical lithotectonic subdivisions (Fig. 1), viz Sub-Himalaya or Outer Himalaya, Lesser Himalaya and Tethys Himalaya (Gansser 1964). However, in the area under study only the first three tectonic subdivisions are exposed, which are characterized by their distinct geological sequences of different ages, tectonic styles and geomorphic features. A brief summary of their geological and structural characters are presented in the following lines.

Sub-Himalaya

The outermost part of Garhwal Himalaya (Molassic Siwalik Supergroup of Mio - Pliocene age), is demarcated in the north by NW - SE striking Main Boundary Fault and is separated from the rocks of Lesser Garhwal Himalaya. The Siwalik tectonic zone consists of folded, fluvial and lacustrine deposits showing typical development of cycles, coarsening upwards. Its structure is characterized by broad open anticlines and synclines trending parallel to the length of Himalaya.

Lesser Himalaya

The highly folded Lesser Himalayan rocks ranging in age from Late Precambrian to Eocene, are demarcated in the north by Main Central Thrust and in the south by Main Boundary Fault. In the core of NW - SE trending Garhwal and Mussoorie Synforms the rocks of Garhwal Nappe are thrust over the rocks of Krol Nappe (Auden 1937) along the Garhwal Thrust. Further in the north, near Sprinagar the phyllites of Chandpur Formation are thrust over the rocks of Garhwal Group (Jain 1971) along NW - SE striking North Almora Thrust.

Higher Himalaya

Further, in the north, medium to high grade metamorphic rocks are thrust over the rocks of Lesser Himalaya, along Main Central Thrust. The crystalline rocks of Higher Himalaya have been named variously depending upon locality and workers. In the Garhwal Himalaya these metamorphic rocks have been called as Central Crystallines (Heim & Gansser 1939). In the Joshimath area these crystalline rocks are thrust over the unmetamorphosed quartzites and limestones of Garhwal Group along Main Central Thrust. The F_1 folds in these crystalline rocks trend in NW - SE direction (Gairola & Srivastava 1987).

Method of study

The lineament study was done in an area of 157 x 128 km lying between 77°45' East longitude and 29°30' to 30°45' North latitude (Fig. 1). The area was covered by two LANDSAT scene (Row 039 - 040; Path 46 - 47) in the orbit. The lineaments were traced from the enlarged prints (paper print and false colour composite of band 4, 5 and 7) by using rectilinear trends of morphological features, structural alignments and river courses, textural and tonal contrast. Two types of lineaments viz. minor (< km) and major (>20 km) have been identified on the scale of imagery. The lineament study was made to understand their geological, tectonic and structural correlations.

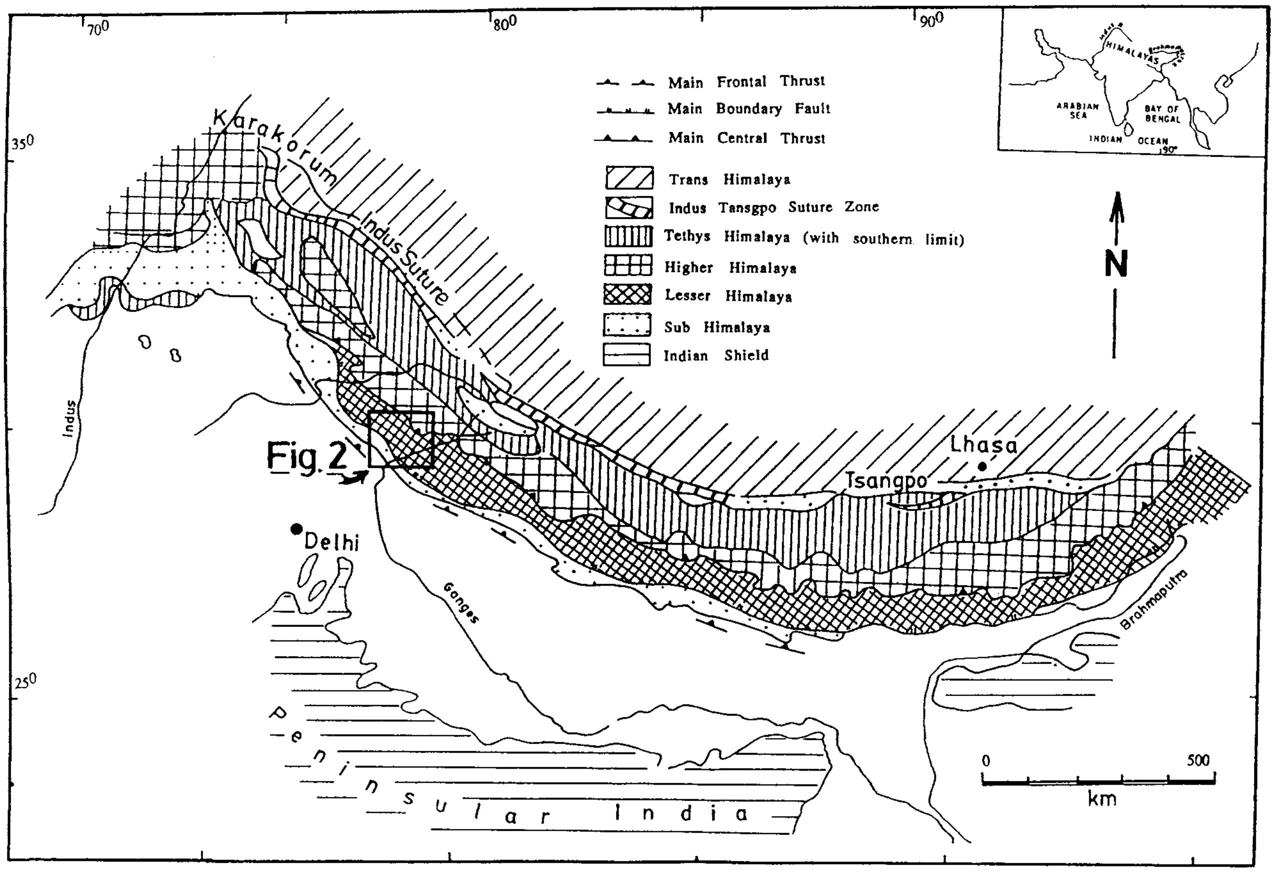

Fig. 1. Outline of Himalaya showing the broad lithotectonic subdivisions (modified after Gansser 1964).

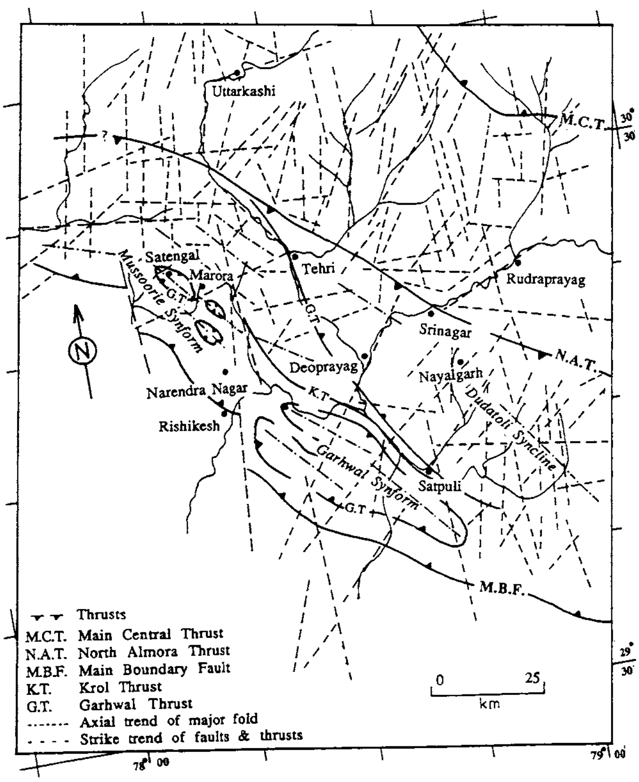

Fig. 2. Map showing lineaments of a part of the Garhwal Himalaya.

Lineaments and their structural correlations

A lineament map provides sufficient information for the detailed tectonic and structural studies when it is prepared in conjunction with regional geological map (Goel et al. 1987). Approximately 120 lineaments, traced from this part of Garhwal Himalaya (Fig. 2), were used to evaluate the regional pattern of lineaments. These lineaments were analysed statistically in terms of frequency (Fig. 3A) as well as in length and a synoptic rose diagram of frequency has been prepared (Fig. 3B). The prominent lineament pattern in this region of the Garhwal Himalaya is N - S both in regard to frequency and length. However, the NE - SW and NW - SE lineaments, which are little less as compared to N - S lineaments, correspond to the major Himalayan trends. Similar trends of lineaments have also been observed by Goel et al. (1987) while interpreting the regional structures of the Kumaon Garhwal Himalaya.

The main purpose of deciphering the lineaments on regional scale was to make a comprehensive study of the field observations recorded in different parts of the Garhwal Himalaya and to correlate them with the results of LANDSAT imagery. A detailed structural analysis of two different sections, viz. Satengal - Marora section and Srinagar - Nayalgarh section have been carried out, and the regional structures are correlated with the lineament trends deciphered from the LANDSAT imagery.

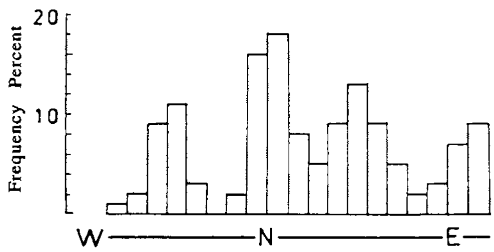

Fig. 3A. Frequency diagram of lineaments.

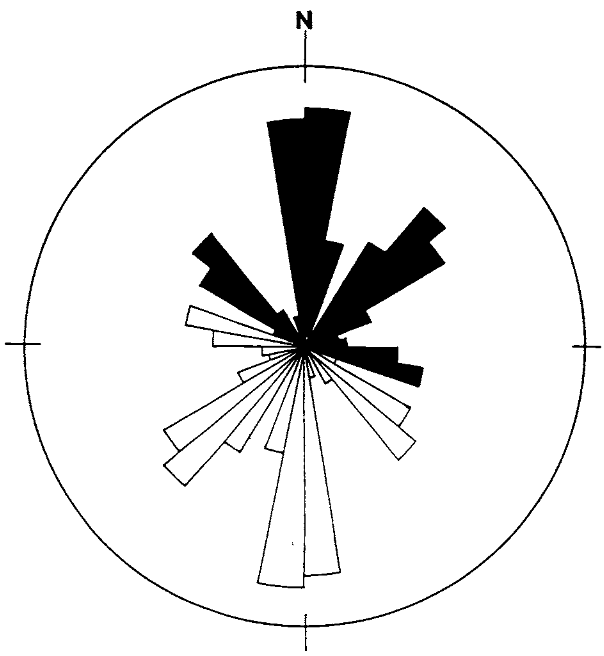

Fig. 3B. Rose diagram indicating frequency distribution of lineaments.

Satengal - Marora section

The Satengal - Marora section forms a part of northern limb of the Mussoorie Synform and consists of two tectonic units, i.e. Garhwal Nappe and Krol Nappe. The rocks of the Garhwal Nappe (Precambrian in age) are thrust over the rocks of Krol Nappe (Precambrian to Eocene in age) along Garhwal Thrust.

The mesoscopic structural studies reveal that the area has suffered three phases of successive foldings (Srivastava & Sinha 1989). The F_1 folds, developed during first phase of deformation, are tight isoclinal folds and exhibit trend from NNW - SSE to WNW - ESE directions. This variation in the orientation of F_1 folds is probably due to the subsequent phase of folding. The F_2 folds, developed during second phase of deformation, are open folds with rounded hinges and generally plunge, at low to moderate angles, towards NE or SW directions. The trends of F_2 fold axes range from NNE - WSW to ENE - WSW directions. The F_3 chevron folds are characterized by the presence of crenulation and strainslip cleavages, mainly trend in an E - W direction.

To determine the structural history of the area different generations of mesoscopic structures were plotted on the lower hemisphere of equal area net and contoured. In Fig. 4A the pole to the schistosity ($S_1=S_2$) and the associated lineations were plotted for the Satengal area. The diagram shows a single elongated maxima near the center suggests an isoclinal F_1 folding. The partial girdle through elongation of S-poles reveals a NW plunging β_1 axis. The cluster of lineations (L_1) around β_1 indicate their genetic relation to F_1 folds.

The axial planes of first generation of folding (S_3) showed variation in their orientation when they were studied in mesoscopic refolded structures. Therefore, to obtain the macroscopic folding of second generation, the pole to S_3-planes (axial planes of first generation of folds) were plotted on the lower hemisphere of equal area net contoured and β_2 obtained. The β_2 trends in a NE - SW direction (Fig. 4B). The poles to S_4 planes i.e. axial planes of second generation of folds (data obtained from refolded structures), were also plotted on the lower hemisphere of equal area net and the β_3 trends in an eastern direction (Fig. 4C). The lineations L_2 and L_3 around β_2 and β_3 respectively, indicate their genetic relations to F_2 and F_3 folds (Fig. 4B and C).

Srinagar - Nayalgarh Section

Srinagar area forms a part of northwestern extension of Dudatoli Group (Mehdi et al. 1972) and eastern extension of Garhwal Group (Jain 1971), where the rocks of Dudatoli Group are thrust over the rocks of Garhwal Group along NW - SE striking North Almora Thrust (Heim & Gansser 1939). The analysis of mesoscopic and macroscopic structures in Srinagar and Nayalgarh areas reveal that the rocks of these areas have suffered four phases of deformations.

The first phase of deformation is represented by tight isoclinal folds and exhibits a variations in the trend from NNW - SSE to WNW - ESE directions in the quartzites associated with phyllites of Dudatoli Group. The first phase of deformation is followed by a second phase of deformation and is represented by F_2 folds which show a variation in its trend from SSE - NNW to SSW - NNE direction in Nayalgarh area. This great variation in the orientation of F_2 folds is probably due to its refolded nature. The third phase of folding is characterized by the presence of chevron folds and exhibits its trend towards E - W direction. The last phase of folding has resulted into a broad open (F_4) regional fold and is coaxial to F_3 (Srivastava & Sahai 1989).

In order to reveal the geometry of large scale folding the data of various planar and linear structures were plotted on the lower hemisphere of equal area net and contoured. In Fig. 5A the pole to S-surfaces (S1=S2) were plotted and the β_1 (pole to π-S_2 girdle) obtained. The lineations around β_1 indicate their genetic relation to F_1 folds. To obtain the macroscopic folding of second and third generations of folds, the pole to S_3 (axial plane of first generation of fold) and S_4-plane (axial plane of second generation of fold) of Nayalgarh area, were plotted and the β_2 and β_3 axes were obtained. The L_2 and L_3 lineations are related to β_2 and β_3 axes of area respectively (Fig. 5B and C).

Conclusions

Four major lineament trends i.e. NW - SE; NE - SW; E - W and N - S have been deciphered from this large part of Garhwal Himalaya. The NW - SE and NE - SW trends of the lineaments (Fig. 2) are parallel or subparallel to the axial trends of most of the regional folds (Garhwal Synform, Mussoorie Synform and Dudatoli Synform) and strike trends of major thrusts and faults (i.e. Main Boundary Fault, Krol Thrust, Garhwal

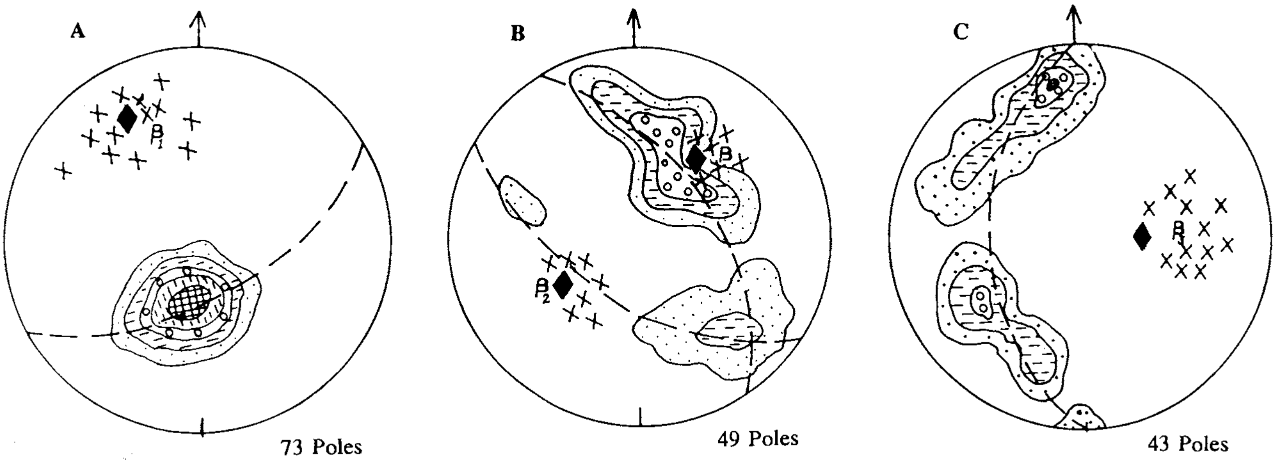

Fig. 4A. Lower hemisphere equal area projection of 73 poles of S_1 and S_2 (S_1=S_2). β_1 (◆) is surrounded by L_1 (X) lineations indicating genetic relationship of β_1 with L_1. Contour intervals: 3, 6, 9, 12, 15 and 15 % per 1 % area.
Fig. 4B. Stereogram showing 49 poles of S_3 planes. β_2 (◆) is surrounded by L_2 (X). Contour intervals: 2, 4, 6, 8 and 8 % per 1 % area.
Fig. 4C. Stereogram showing 43 poles of S_4 planes. β_3 (◆) is surrounded by L_3 (X) lineations.

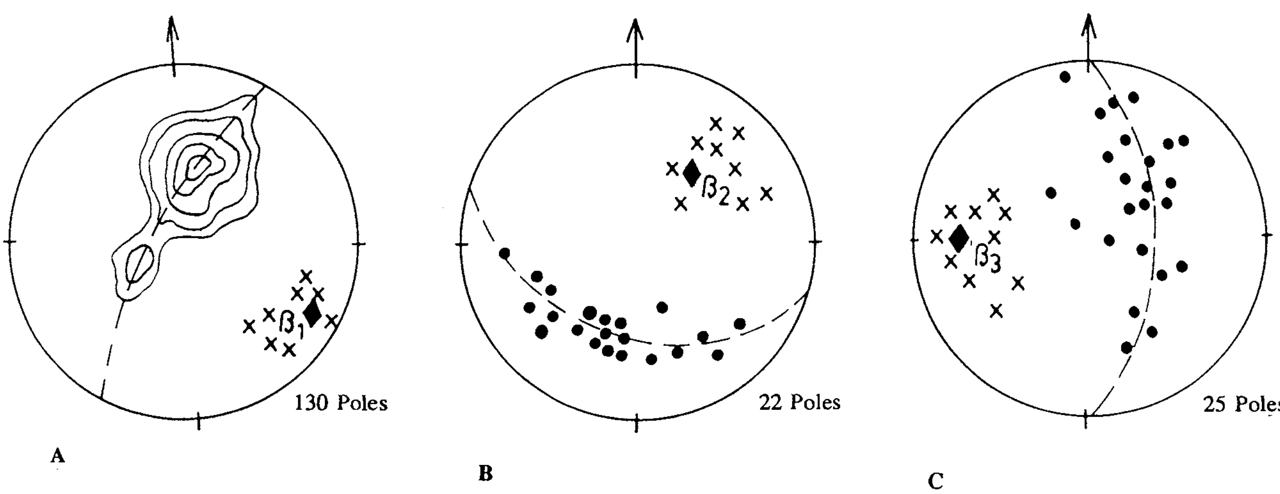

Fig. 5A. Lower hemisphere equal area projection of 130 poles of S_1 and S_2 (S_1=S_2) from the Srinagar area. β_1 (◆) is surrounded by L_1 (X) lineations, indicating genetic relationship of β_1 with L_1. Contour intervals: 2, 4, 6, 8, 8 % per 1 % area.
Fig. 5B. Stereogram showing 22 poles of S_3 planes. β_2 indicate genetic relationship of L_2.
Fig. 5C. Stereogram showing 25 poles of S_4 planes of Nayalgarh area. β_3 (◆) is related with L_3 (X).

Thrust and North Almora Thrust) of Garhwal Himalaya (Fig. 2). The NE - SW and NW - SE trends of these lineaments correspond to the major Himalayan trends. However, the N - S lineament pattern (Fig. 3) is probably because of development of transverse faults and fractures, whereas, the E - W patterns of the lineaments are due to the development of oblique fractures which may take place at the oblique angle of 10° - 40° with the earlier lineaments.

Few prominent lineations (L_1, L_2 and L_3) belonging to different phases of foldings have been plotted along with the few dominant trends of lineaments (Fig. 6) from this part of Garhwal Himalaya. It is evident from the figure that the trends of axes of major folds, faults and thrusts are parallel to the dominant trends of lineaments. All the lineaments are therefore parallel, or subparallel to the axial directions of major folds, faults and thrusts in the discussed region of Garhwal Himalaya. While describing the geology, structures and tectonics of different parts of Garhwal Himalaya, different workers (Kumar & Dhaundiyal 1979; Rawat & Varadrajan 1979; Virdi 1979; Doval & Saklani 1980; Gairola & Saxena 1980; Negi et al. 1980; Rao & Pati 1980; Schwan 1980; Jain 1972; Pachauri 1972) have deciphered different orientations of various generations of fold trends and strike trends of thrust and fault planes. However, the orientation of the structural features of the lineaments exhibit good to perfect matching with one another.

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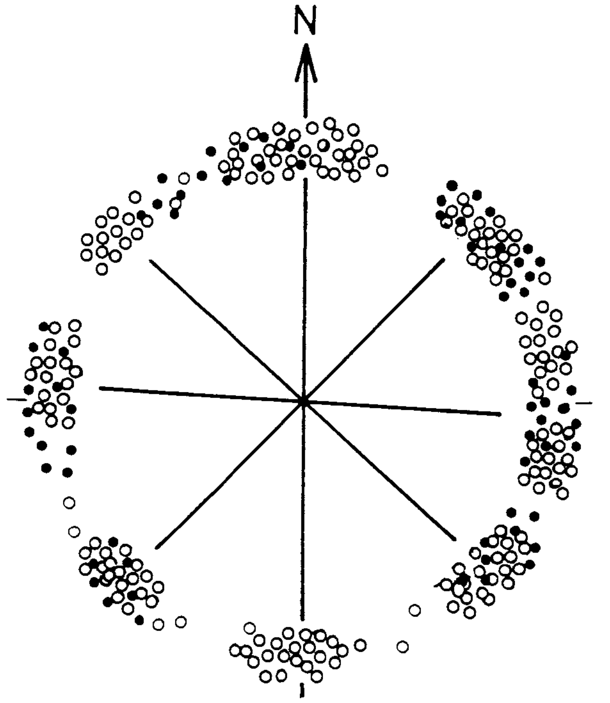

Fig. 6. Diagram showing the plots of few prominent trends of lineaments (o) and lineations (•) form both the sections of Garhwal Himalaya.

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