CHAPTER IV

STRUCTURAL GEOLOGY

OUTLINE OF THE STRUCTURAL PATTERN:

The rocks of Majkhali area contain structural evidences of an interesting tectonic history comprising a series of deformational episodes, and the author has been able to construct the structural geology of the area with the help of the following:-

(i) A very systematic and detailed mapping of the lithology and the various macroscopic and mesoscopic structures.

(ii) A critical analyses of all the structural elements - both planar and linear.

(iii) Structural patterns of the neighbouring areas of Ranikhet and Almora, as worked out by previous workers.

A major portion of the Majkhali area is situated on the southern limb of the E-W synformal structure into which the Almora Nappe has been folded (Heim and Gansser, 1939; Merh, 1968). For the most part, the rocks in the area show a north-dipping foliation, and the fold axis lies about 2 km. further north of the area. However, on account of a major faulting, this synformal fold axis is met with in the north-eastern part of the area. Here, a small part of the northern limb of the synform is very clearly recorded. A.N. Shah (oral communication), who is mapping the neighbouring area of Almora, has traced this synformal fold axis further east for several kilometres. There are numerous evidences in the form of tight recumbent folds and other related minor structures to indicate the existence of a very early folding, which took place prior to the formation of the synform. This early isoclinal folding has been ideally studied and described by Vashi (1966) and Vashi and Merh (1965) in the neighbouring

Ranikhet area. It is seen that the foliation strikes almost NW-SE in the western part of the area, but swings to as much as NE-SW in the eastern part, and this swing in the foliation trend indicates a subsequent N-S cross-folding. Minor structures related to the various fold episodes are amply recorded.

Before proceeding with the description and discussion of the various structural elements of the area, the author has preferred to give briefly and chronologically, the main events of the area's structural history so that the structural geology of the area is better understood. The sequence of various structural episodes, as built up by the author has been summarized below:

(1) Deposition of sediments under geosynclinal conditions and then subsequent metamorphism under vertically directed load, giving rise to a bedding schistosity (S).

(2) Folding of the metamorphosed sediments into a number of recumbent isoclinal folds (F_1); development of the axial plane foliation (S_1) and the related (fold axis or 'b') lineation (L_1). Culmination of one such overfold into Almora Thrust and the formation of Almora Nappe (Episode I).

(3) Folding of the Almora Nappe into an E-W synform. This folding affected both Almora as well as Krol Nappes and resulted into the formation of anticline at Someshwar in the north and Bhowali in the south; development of chevron microfolds and crinkles with associated strain-slip cleavage (S_2). The fold axes of these crinkles, puckers and the intersection of S_1 and S_2 have resulted into the widespread development of lineation (L_2) (Episode II).

(4) Superimposition of open NS flexures (F_3) on the synform, resulting into a synformal folding of the north dipping rocks, and the development of a faint crinkling of the foliation and the related puckers (L_3) (Episode III).

(5) Development of numerous faults.

STRUCTURAL ELEMENTS STUDIED:

Planar structures:

(1) Bedding and Bedding foliation: Though very much obscured and obliterated, traces of original sedimentary bedding have been frequently recorded in the form of surfaces of folded quartzites. At some places, the lithological boundaries between pelites and semipelites or quartzites also indicate the bedding. More conspicuous,

is the schistosity developed parallel to the stratification-perhaps due to load. This bedding schistosity has a fragmentary preservation. For example calc-silicate bands and some semipelites show traces of this foliation. More often, it is seen tightly folded to give rise to a late (axial plane) cleavage.

(2) Axial plane cleavage: The main foliation of the pelites, semipelites and migmatites, belong to this type. Characteristically, it shows an axial plane relationship with the recumbent quartzite structures,which were obviously produced at the time of the large scale isoclinal folding of the rocks. A careful scrutiny of this foliation has revealed that it has evolved at least at some places, by the tight microfolding of the early bedding foliation.

(3) Strain-slip cleavage: Crinkles and fracturing of the hinges of the microfolds and drag folding along parallel shear planes, have given rise to conspicuous strain-slip cleavage at many places all over the area.

Linear structures:

(1) Axes of minor folds: These include the axes of small folds in quartzites, microfolds in pelites and puckers. Very often fold axes mullions have developed in quartzites. With the decrease in size, the fold axes, especially in pelites have changed over to puckers.

(2) Quartz rods: These are imperfectly preserved cores of folded quartz veins in micaceous rocks. These occur as distinct rods in pelites.

(3) S-surface intersections: This type of lineation is best seen in flaggy quartzites and semipelites wherein the intersection of cleavage with bedding planes has given rise to a fine stripping or ribbons. Generally, the recrystallization has obliterated the intersection, and only an ill-defined but conspicuous striation is seen developed all over. At many places, recrystallization and orientation of minerals along the intersection has resulted into a distinct lineation due to preferred shape orientation of minerals (mica, quartz, tourmaline, felspar). The intersection of early schistosity with late strain-slip cleavage has also given rise to this type of lineation.

Various minor structures - both planar as well as linear, almost always show a genetic relationship with the major structures and in the present area too, a careful study of all the minor structures has helped in establishing and understanding the regional tectonic pattern of the area.

STRUCTURAL ELEMENTS RELATED TO VARIOUS EPISODES:

Minor structures related to load:

Planar structures:

(i) Bedding and Bedding schistosity (S)

Minor structures related to the isoclinal folding (Episode I):

Planar structures:

(i) Schistosity and gneissic foliation
(ii) Axial planes of minor folds

(S_1)

Linear structures:

(i) Axes of minor folds in quartzites
(ii) Quartz rods
(iii) Mineral orientation
(iv) Stripping or ribbons
(v) Striations

(L_1)

<u>Minor structures related to the folding of the Almora Nappe (Episode II)</u>:

<u>Planar structures</u>:

(i)	Axial planes of the herringbone type chevron folds	(S_2)
(ii)	Related strain-slip cleavage	

<u>Linear structures</u>:

(i)	Axes of the chevron folds and the puckers	(L_2)
(ii)	Axes of folded quartz veins	
(iii)	Intersection of S_1 by S_2	
(iv)	Boudinages	

<u>Minor structures related to the open N-S folding (Episode III)</u>:

<u>Planar structures</u>:

(i)	Axial planes of the herringbone type folds	(S_3)
(ii)	Related strain-slip cleavage	

<u>Linear structures</u>:

(i)	Faint puckering lineation	(L_3)
(ii)	Fold axes of minor folds in quartzites	

Minor structures related to the load:

Bedding and Bedding schistosity (S): Before the main orogenic upheaval, the geosynclinal sediments appear to have undergone load metamorphism under conditions of vertically directed pressure due to overlying rocks, giving rise to a bedding schistosity. The main schistosity (S_1) has been superimposed on and derived from this early bedding foliation. The parallelism between the pelitic layers and the psammitic layers indicates this early bedding schistosity. At several spots the main schistosity (S_1) is seen showing a slightly oblique relation with the bedding schistosity (S).

Minor structures related to the recumbent isoclinal folding - F_1 (Episode I):

Planar structures: The present schistosity (S_1) of the rocks, which constitutes the main foliation, is seen to be connected with the large scale isoclinal folding that accompanied the progressive regional metamorphism. The schistosity typically shows axial plane relation with the small quartzite folds. At several places, this axial plane cleavage (S_1) appears to be a tightly folded and much obliterated early foliation (S).

The apparent parallelism between lithological banding and the schistosity (S_1) can likely be confused with the bedding schistosity. It is only by a careful investigation that the true nature of this axial plane schistosity is understood. In fact the parallelism is on account of the tight isoclinal folding. Petrographic studies have also revealed that the metamorphic foliation is not a phenomenon of simple compression but shearing stresses have also played a role in its development. Dominance of shearing stress is shown by snowball garnets in schists. The rolled garnet indicates differential slipping along the foliation during its crystallization. As this dynamic phase of regional metamorphism synchronized with the migmatisation, the schists were gradually transformed into gneisses. Thus, it is clear that the gneissic foliation is in fact, the schistosity (S_1), and genetically both are identical. A number of folds, related to this major recumbent folding, have been recorded from the area. These are usually seen as small folded psammitic layers and quartz veins in the schists. In both the above types the schistosity shows an axial plane relationship with the minor folds.

Linear structures: Lineations recorded in the rocks of the Majkhali area show a clear genetic relationship with the major folding. They are mostly parallel to the fold axis and can be considered as 'b' lineation. The different lineations described below are seen plunging with variable angles due NE to NW.

(i) The most conspicuous linear structures related to this episode are the minor folds in quartzites and quartzitic bands in pelitic and semipelitic schists. In the nala south of Upat, in the western extremity of the area, well developed mullions formed by repeated folding of quartzite bands are seen.

(ii) The lineation (L_1) is also represented by a dimensional orientation of minerals in rocks. In quartzites, it is characterized by a fine linear arrangement of quartz granules which imparts a peculiar streakiness to the foliation surface. In schists, it is somewhat coarse and consists of elongated particles of mica in schists and of tourmaline needles in migmatites. This lineation due to mineral growth also parallels the fold axis lineation.

(iii) Distinct ribbons, stripes and striations are often recorded in the psammitic rocks of Majkhali area.

The intersection of cleavage (S_1) and bedding (S) has possibly given rise to this lineation with the result that the quartzite surface (S) is marked by narrow flat stripes. Very often the recrystallisation has obscured the cleavage, and a prominent stripping or striation has survived.

<u>Minor structures related to the folding of the Almora Nappe (Episode II)</u>:

<u>Planar structures</u>:

<u>Axial planes of the herringbone type chevron folding and the related strain-slip cleavage (S_2)</u>: The author has observed intense crinkling of S_1 and development of herringbone and chevron type of microfolds on the schistosity. At some places folding is so sharp that the hinges of the folds have broken and slipped giving rise to a characteristic strain-slip cleavage along the axial plane of the folds. This cleavage is seen to be nearly vertical and strikes EW to WNW-ESE. In a broad way the strike of this strain-slip cleavage (S_2) is almost parallel to the axial plane schistosity (S_1).

<u>Linear structures</u>: The fold axes of the herringbone and chevron folds mark the lineation (L_2). This lineation

is marked by a strong puckering on the schistosity surface or as folded quartz veins as mullions or as boudinages. Sometimes a streakiness due to intersection between S_1 and S_2, characterises this L_2. This lineation is very predominant in the central region of the area. Generally, this lineation plunges very gently in various directions between NW and NE. Sometimes it is subhorizontal.

Minor structures related to the late N-S synformal folding F_3 (Episode III):

Planar structures:

Axial planes of the herringbone type chevron folding and the related strain-slip cleavage (S_3): On account of this last folding (F_3) that the area witnessed, the schists have developed scattered N-S crinkles and a related strain-slip cleavage (S_3) at various places. This cleavage is seen to be moderately dipping due W. It is this folding that has caused the variation in the amount and direction of plunge of lineations (L_1 and L_2).

Linear structures: Crinkling of the schistosity (S_1) during this folding has given rise to faint puckers. These puckers show a plunge due N to NNW and are recorded sporadically in the pelites and semipelites. Axes of a few minor folds developed in quartzite bands also constitute this linear structure.

STRUCTURAL ANALYSIS:

The scope of this structural analysis, as ideally put by Turner and Weiss (1963, p. 144) "embraces lithological configurations too large to be observed directly in a single exposure, and it deals with the spatial arrangement of mesoscopic structures within large tectonic bodies. On this scale we are concerned mainly with three topics.

(1) Form, orientation, geometric relations, and relative age of macroscopic structures, notably folds.

(2) Preferred orientation of mesoscopic structures - particularly S-surfaces, lineations, and fold elements - that are penetrative with respect to macroscopic domains.

(3) Homogeneity and symmetry of macroscopic domains."

For the purpose of the detailed geometrical analysis of the various mesoscopic structures to a considerable extent, the technique adopted by Ramsay (1958,1960) in investigating the areas of superimposed folding has been followed. The author has divided the whole study area into 10 sub-areas (or domains). It was only a very critical and painstaking study of the various structural elements of the different sub-areas, that revealed the correct tectonic pattern of the area affected by several fold episodes.

All the linear and planar structures of different generations, met with in the various sub-areas were plotted on Schmidt's Equal area net, and a number of stereograms (mainly π , β , and collective diagrams) prepared. These stereographic diagrams have borne out the structural characteristics of the respective sub-areas very well and prooved very useful in working out the tectonic pattern and the structural history of the area.

Subarea 1: Lying in the northwestern extremity of the map, this sub-area (Fig. 19) mostly includes varieties of schists and migmatitic gneisses. The schistosity surface shows the lineation (L_1) - a faint striation plunging between NNE and NE at angles of about 35° - 40°. The gneisses contain considerable tourmaline and show a lineation characterised by the orientation of tourmaline needles. This lineation due to mineral orientation has the same plunge as that of striations. The second lineation (L_2) represented by a puckering plunges due NW to WNW with variable angles. This is in fact the axes of fine crinkles and chevron folds developed on S_1 during F_2. Though not very conspicuous, these crinkles show axial planes (S_2) trending WNW-ESE. A third lineation (L_3) is marked by faint puckers that plunge at angles of about 25° to 30° due NNW. This folding which has given rise to the lineation (L_3), has also sporadically developed a N-S trending crinkling. A prominent lateral fault in this sub-area is seen to run almost N-S with a dextral displacement of about 1000 metres.

Subarea 2: This sub-area (Fig. 19) includes the exposures in the southern and southwestern corner of the map. Minor structures belonging to all the three generations are present. The early folding (F_1) is represented by the lineation (L_1) as fold mullions in quartzites and as stripping due to cleavage-bedding intersection (Plate 11). In this part the L_1 shows considerable fluctuation in its direction and amount of plunge. Broadly, it is seen to

PLATE 11

Lineation due to stripping in quartzites plunge in directions between N 15° E to as much as N 50° E, the amount of plunge varying between 20° and 30°. The schists show an axial-plane relationship with the isoclinally folded quartzites ~~(Plate 11)~~. The lineation (L_2) is seen as prominent puckers in schists and its direction of plunge varies between W to NW. The amount of plunge is also seen varying between 30° to 40°. A faint puckering indicates the lineation (L_3) which is seen plunging 35° due NNW.

Subarea 3: This sub-area (Fig. 19) includes the exposures N, NW and NNE of Majkhali, the schists of which show marked crinkling and widespread development of herringbones and chevron folds. The early (F_1) folds are scarce though the related lineation (L_1) is frequently recorded. The surfaces of the quartzites show this lineation due to the oblique orientation of mica flakes. The direction of its plunge varies between N 30° E to N 55° E, the amount fluctuating from 30° to as much as 50°. The dominant structures are those related to F_2. The lineations(L_2) characterised by puckering and axes of crinkles show varying orientation. In the eastern part of the sub-area, this lineation shows a variable plunge ranging from 15° to 40° due W to NNW, while some of these lineations in the western part plunge due ESE at angles of 35° to 40°. Perhaps, the variation in the plunge reflects the original orientation (subhorizontal) of the fold axes of F_2 folds. A few quartz veins (folded on F_2) in these schists also plunge at about 10° due WNW. A major fault (Jaurasi nala fault) striking N-S follows the Jaurasi nala and has laterally displaced all the formations, showing a dextral movement.

Subarea 4: This sub-area (Fig. 19) comprises the ground to the south of Majkhali. The lineation (L_1) as usual shows a plunge varying from 30° to 45° in all directions between NE and ENE. It mainly consists of (1) folded quartz veins forming quartz rods, (2) as faint striations on quartzites and (3) as the orientation of tourmaline needles and the felspar porphyroblasts in migmatitic gneisses. The pucker lineations (L_2) are seen plunging both in the NW and SE quadrants with variable angles. In this area, the axial planes (S_2) of the chevron folds strike almost EW with steep dips due N (dipping as much as 65° to 80°). The lineation (L_3) in quartzites (minor fold axis) plunges 30° in NNW direction. The fault encountered in the sub-area (3) in the north is seen to continue in this sub-area also.

<u>Subarea 5</u> : This sub-area (Fig. 19) includes the outcrops to the east and northeast of Majkhali i.e. to the north of the road going to Almora. The schists in this region show intense microfolding and frequent strain-slip cleavages developed on account of F_2. The effect of F_1 folding is not very conspicuous and when present, it is a lineation due to cleavage-bedding intersection plunging due NNE to NE at angles of as much as 30° to 45°. The axial planes of crinkles and the related strain-slip cleavage (S_2) strike roughly WNW-ESE and is almost vertical. Its intersection with the schistosity (S_1) has given rise to a lineation (L_2) which plunges rather variably (10° to 35°) due W to NW and E to SE. The calc-silicate bands which are quite numerous in this sub-area are quite often boudinaged and show typical saussage-shaped lenses. The axes of these boudinages coincide with the lineation (L_2) and it is thus obvious that they have resulted on account of stretching during the second folding. The third folding (F_3) is responsible for the swing of the regional foliation in this sub-area from WNW-ESE (in the west) to as much as

EW (in the east). A superimposed NNW plunging lineation (L_3) is also recorded in these schists in the form of faint puckers.

Subarea 6 : This sub-area (Fig. 19) includes the exposures of pelites and semipelites to the south and southeast of Majkhali right upto the Kathpudia village. Here the foliation trend is WNW-ESE with a few E-W strikes in the east. The dips also accordingly change to NNE with variable angles. No F_1 folds are seen and only lineation (L_1) is recorded. Due to the change in the strike of the foliation, this lineation also shows a little change in the direction and amount of plunge. It is seen plunging between N to NE with angles of 20° to 50°. The axial planes of the crinkles (S_2) almost strike E-W to ESE-WNW with dips of about 70°-75° towards N. It is significant to note here that the related fold axes and pucker lineations (L_2) which are very prominent, show a relatively large plunge of about 40° due WNW. The third lineation (L_3) that has been observed in this area mostly plunges between 30° to 35° in a direction NNW to N.

Subarea 7: This sub-area (Fig. 19) includes the exposures to the N and NE of the village Kathpudia. The schists show a fair amount of crinkling on F_2. The strike of the foliation here has swung to as much as ENE-WSW with dips of 30° to 40° towards NNW. The lineation (L_1) of the usual striation type shows a marked change in the orientation and is seen plunging in the NW quadrant, with variable angles. Similarly the lineation (L_2) shows a change and plunges NE with angles of 10° to 20°. The lineation (L_3) continues to be due NNW and plunges at angles of about 20°.

Subarea 8: In this sub-area (Fig. 19) comprising the south and southeast of Kathpudia, the rocks are mica schists, siliceous mica schists and graphite schists. These show the change of strike to NE-SW with dips towards NW. Wherever the siliceous mica schists are encountered, the intensity of crinkling is certainly less, but the garnet mica schists do show fair amount of crinkling. The lineation (L_1) fluctuates between WNW to NW plunging at angles of 15° to 30°. The lineation (L_2) shows a plunge of 10° to 30° towards NE. The lineation (L_3) has a plunge of about 30° towards NW.

Subarea 9: This sub-area (Fig. 19) includes the exposures of schists and gneisses in the northeastern extremity of the area, and constitutes a part of the core of the synformal structure (F_2). On account of a major NNE-SSW fault (Daulagad nala fault), this synform is truncated to the west. The trace of the axial plane of this major structure runs WSW-ENE and foliations to its north dip due S while those to its south dip the other way. It is this synform, whose geometry is reflected in the chevron folds so abundant in the sub-areas in the west. On account of this folding (F_2), the lineation (L_1) shows a plunge due SE on its northern limb. The lineation (L_2) shows a plunge of 10° to 30° in the direction SW.

Subarea 10: This sub-area (Fig. 19) includes the exposures mostly in the southeastern corner, north of the road leading to Almora. The rocks are as usual schists. In this part, is recorded a NW-SE fault (Nana Kosi fault) running along the Nana Kosi river which truncates the major NNE-SSW fault (Daulagad nala fault) in the sub-area 9. The foliation trend is approximately NE-SW with its dip to the NW. L_1 lineation is seen plunging at angles 25° to 30° due NW. The lineations (L_2) plunge due N 30° E with angles of about 20°. A few NNW lineations (L_3) are also seen in the siliceous schists which plunge at angles 35° to 40°.

STRUCTURAL SYNTHESIS:

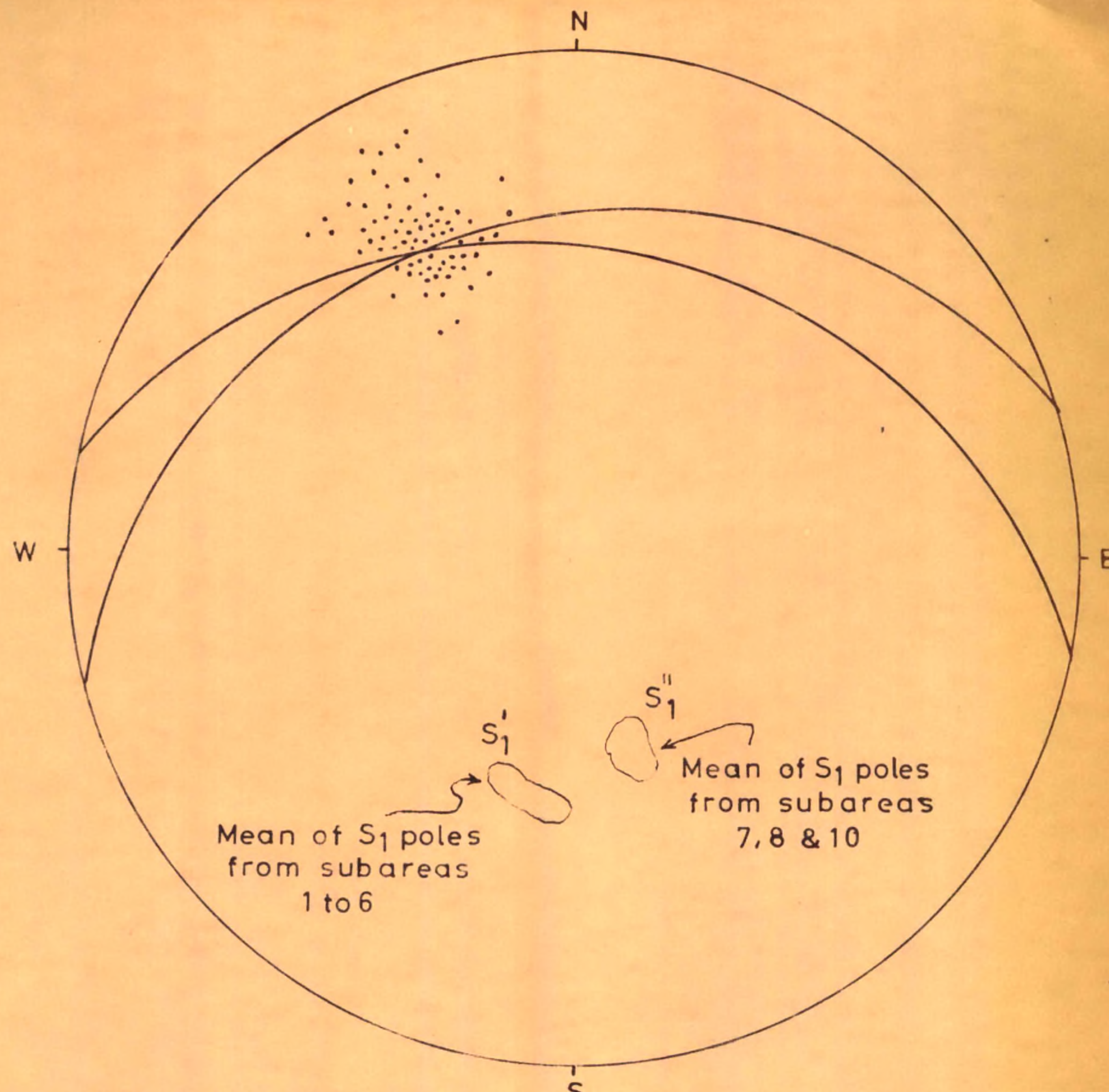
The above analysis has thrown much light on the sequence and nature of the various structural events and has enabled the author to explain the effects of the superimposition of various deformations. It is obvious that after the development of bedding schistosity, the first deformational event was a recumbent isoclinal folding (F_1). It is this folding that was responsible for the development of the metamorphic foliation (S_1) in the present area. The second folding (F_2) which resulted into an E-W synform gave rise to most of the chevron folds and crinkles and the related strain-slip cleavage (S_2) with the fold axes and pucker lineations. The third N-S folding (F_3) was responsible for the present swing in the foliation trend, and it is on account of this folding that the area shows a sort of very open synformal structure, with NS axial plane and a NNW fold axis. (Fig. 20).

Deformation of structures:

Having established the above sequence of tectonic events, the author now proposes to consider the effects of the superimposition of one structure on the other as per following:-

Fig.20

Stereogram showing the effect of F_3 on S_1



• Lineation L_3 (80)

S_1' Mean of S_1 poles from subareas 1 to 6

S_1'' Mean of S_1 poles from subareas 7, 8 & 10

I. Deformation of early (load) structures:

(i) by first folding (F_1)

(ii) by second and third folding (F_2 and F_3)

II. Deformation of first structures (F_1):

(i) by second folding (F_2)

(ii) by third folding (F_3)

III. Deformation of second structures (F_2)

(i) by third folding (F_3).

I. Deformation of early (load) structures

(i) by first folding (F_1): After the development of load schistosity (S) parallel to the lithological bedding, the recumbent folding (F_1) of the geosynclinal sediments took place. This folding, responsible for the development of metamorphic foliation (S_1) parallel to the axial plane of the folds almost completely obliterated the early foliation (S). The sedimentary bedding as preserved in quartzitic layers, is seen folded into recumbent structures. The early schistosity in micaceous layers is almost obliterated and (on a very close scrutiny) is recorded to show its very tight microfolding and ultimately merging into (S_1).

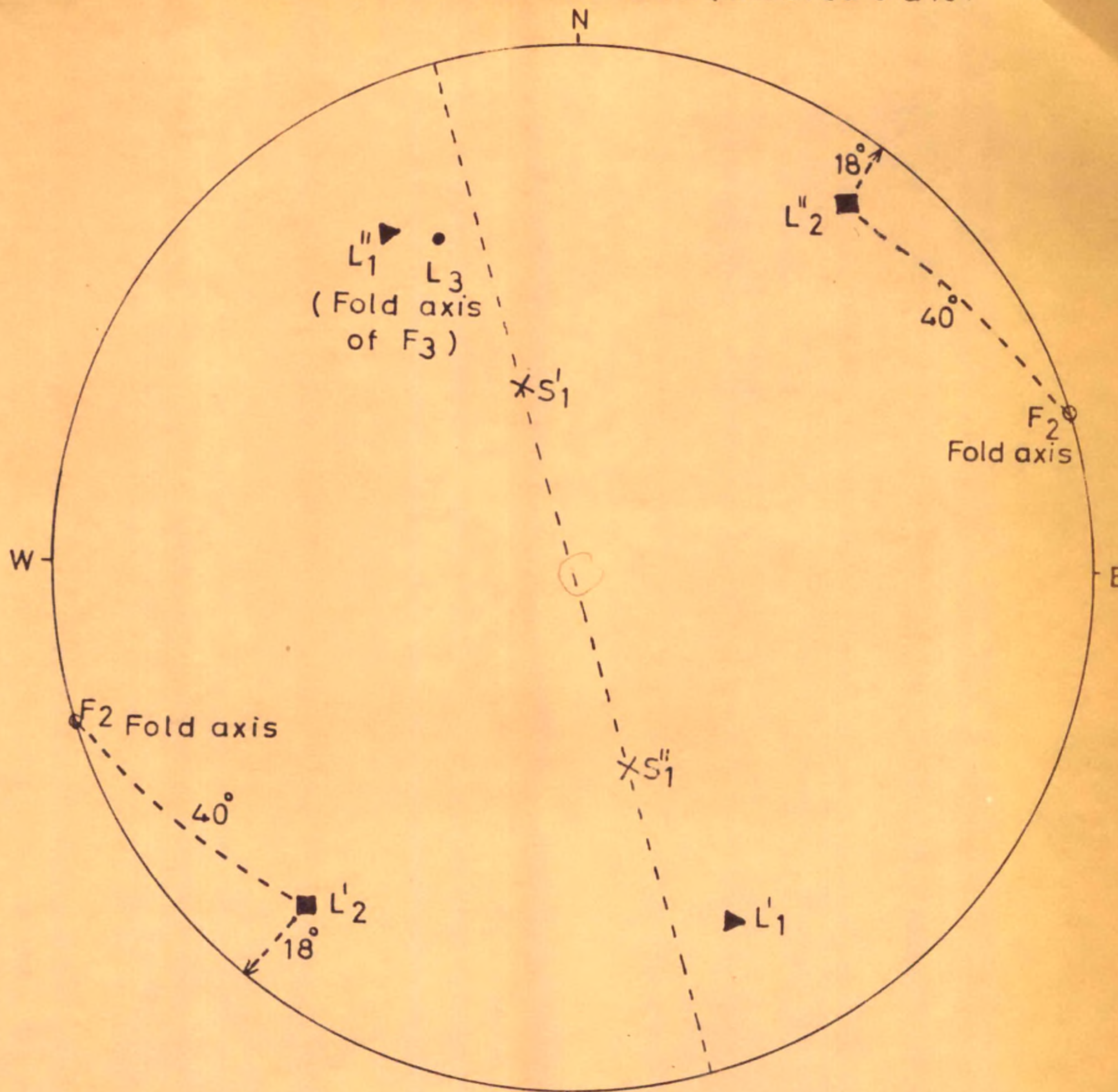
(ii) by second (F_2) and third folding (F_3): No special study of the effects of the second and third folding can be made. Whatever holds good for the deformation of F_1 structures by F_2 or F_3, can broadly be considered applicable for the early foliation also, as in the existing state, the two foliations 'S' and 'S_1' are almost coinciding.

II. Deformation of first structures (F_1)

(i) by second folding (F_2): The schistosity (S_1) has developed herringbone type chevron folds and the frequent strain-slip cleavage (S_2). This effect is more prominent in the central part of the area. The regional effect of this F_2 folding is seen in the formation of a synform in the NE corner. In addition, it is this folding which is responsible for the variation in amount of dips of the foliation (S_1) in most of the area. The plunge of the lineation (L_1) has also become very variable. On account of this folding, L_1 on the northern limb of the synform as seen in sub-area 9, is plunging due SSE while on its southern limb (sub-area 10) it is plunging in the northwestern quadrant (Fig.21).

Fig. 21

Stereogram showing interference of F_1 F_2 & F_3 in eastern part of the area (subarea 9 & 10)



▲ Lineation L'_1 from subarea 9

▲ Lineation L''_1 from subarea 10

■ Lineation L'_2 from subarea 9

■ Lineation L''_2 from subarea 10

• Lineation L_3 from entire area (except subarea 9)

○ Fold axis of F_2 synform

• Fold axis of F_3 synform

× Poles of foliation S'_1 from subarea 9

× Poles of foliation S''_1 from subarea 10

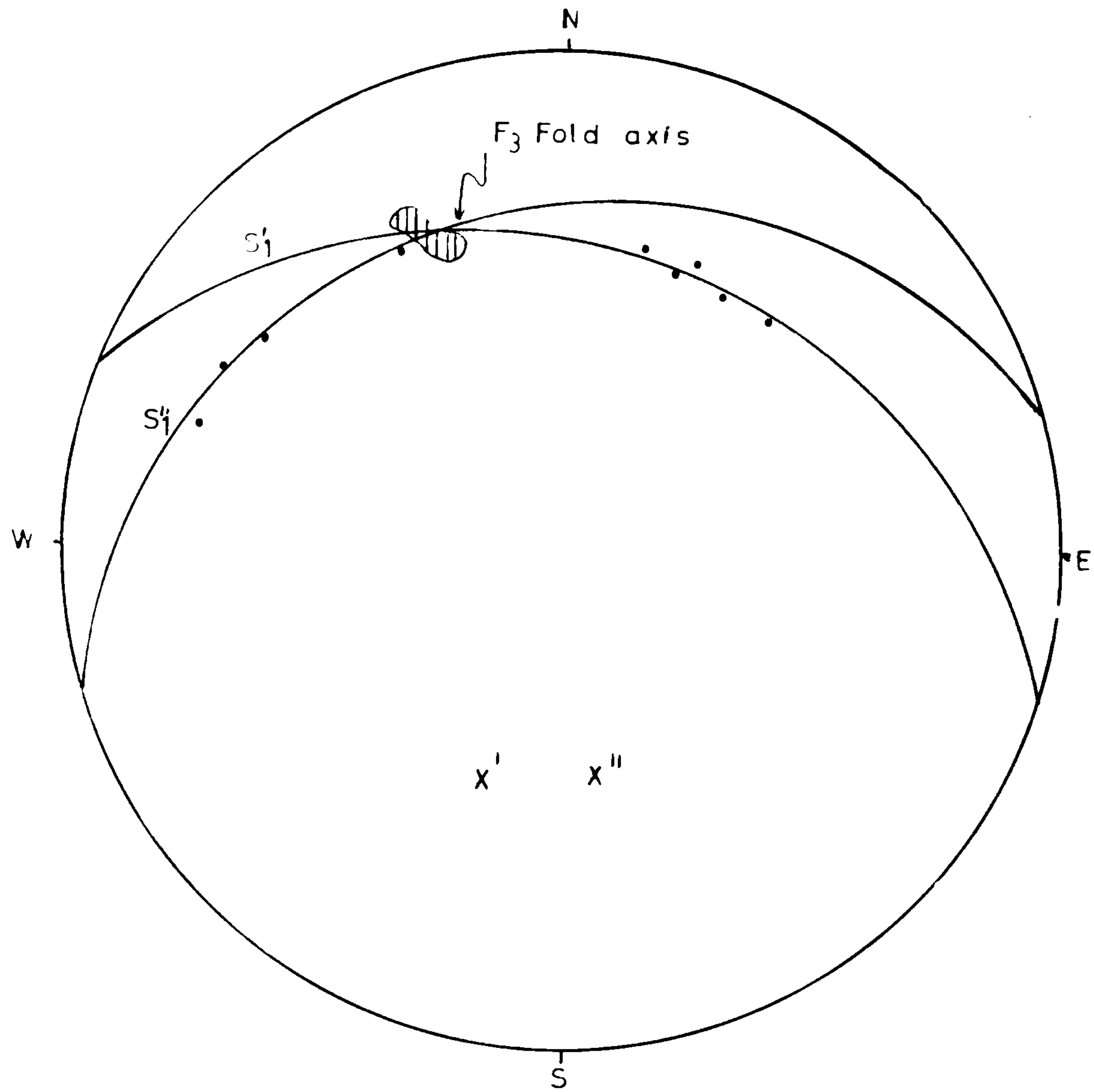
(ii) by third folding (F_3): The swing in the trend of the foliation (S_1) from WNW-ESE in the west to NE-SW in the east giving rise to an open N-S synformal structure is the effect of third and the last folding (F_3). The effect of F_3 on the orientation of L_1 is very clearly represented by plotting the L_1, L_3 and S_1 from sub-areas 1 and 10 (Fig. 22). It is seen that the L_3 lineations have the same orientation as the axis of the NS synform and this folding has twisted the orientation of L_1 in such a manner that in the west it is seen plunging due NE while in the east it shows a NW plunge.

III. Deformation of second structures (F_2)

(i) by third folding (F_3): This folding has caused a variation in the trends of the axial plane (S_2) from place to place (Fig. 3) and has also changed the direction and amount of plunge of the L_2, so that it plunges with gentle to moderate dips either towards WNW or NE. An interesting relationship between L_3 and L_2 is seen to exist in the form of a gradual increase of the included angle between the two lineations, so characteristically noted in the field and also ideally seen in the stereogram showing L_3 and the locus of L_2 (Fig. 23). In the subareas

Fig 22

Stereogram showing the effect of F_3 on L_1

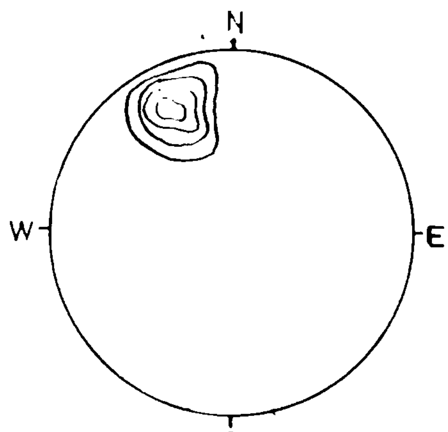


- Mean of L_1 from areas 1-8,10
- Mean of L_3 from entire area

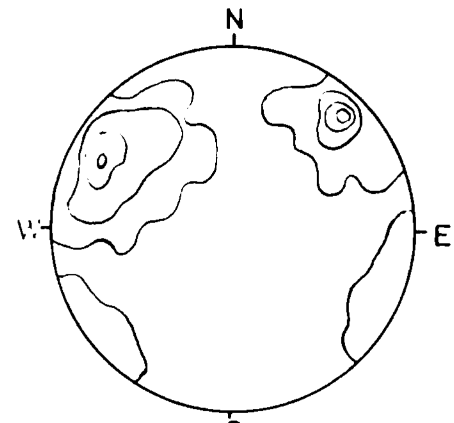
X' Mean of S_1 poles (subarea 1)
X'' Mean of S_1 poles (subarea 10)
S_1' Western limb of F_3 synform (subarea 1)
S_1'' Eastern limb of F_3 synform (subarea 10)

Fig. 23

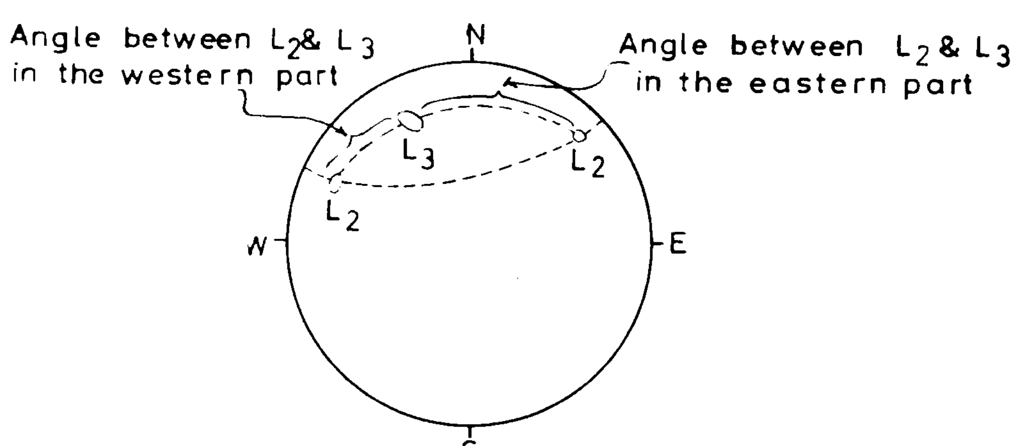
Stereogram showing the effect of F_3 on L_2



Lineation L_3(80)
from subareas 1 to 8 10
contours, 1,4,8,12 %



Lineation L_2(230)
from subareas 1 to 8,10
contours 1,4,8,12 %



9 (which in includes the core of the synform) and 10, it is seen that the axis of the synform (F_2) (which is more or less horizontal) and the lineation (L_2) do not coincide but show a twisting of about 40° in the direction and about 18° in plunge (both towards NE and SW). Obviously this is an effect of F_3, but in the absence of adequate data, it is not possible to explain the exact cause of this anomaly.

FRACTURE PATTERN:

Four major faults have been recorded in the area.

(i) Nagoti-Mauna fault: This fault in the NW quadrant is approximately N-S and follows a major nala, and cuts through the migmatitic gneisses, siliceous mica schists and garnetiferous mica schists. The fault shows a strike-slip movement and is essentially a dextral fault. The western side has shifted by 1000 metres to the north, with reference to the eastern side.

(ii) Jaurasi nala fault: This fault also strikes almost N-S and a conspicuous (Jaurasi nala) stream occupies most of the fault zone. This dislocation can be traced from Majethi in north to as far as Bhatulya and further south, and perhaps extends beyonds the area. This fault cuts through all the formations and is again identical to the Nagoti-Mauna fault, showing a dextral slip. Some downthrow of the eastern side also appears to have occurred.

(iii) Daulagad nala fault: The fault striking NNE-SSW mostly follows the Daulagad nala and shows clearcut lateral displacement of several kilometres, the eastern side having been pushed southward. This is a regional fault and has brought southward the axial portion of the major E-W synform (F_2).

(iv) Nana Kosi river fault: This is WNW-ESE trending fault roughly following the course of the river Nana Kosi. This fault mostly passes through the schists and has caused a lateral displacement of siliceous mica schists.

Out of the above four dislocations, the first three appear to be genetically related. Perhaps the Daulagad nala fault is the most dominant one, causing regional displacement, while Jaurasi nala fault and the first one to its west are the related subsidiary dislocations, each showing lateral slip dextrally. The

Nana Kosi river fault is obviously of later date as it is cutting and truncating the Daulagad nala fault.

All this faulting appear to have taken place after the third folding episode ceased to be effective.

Joints:

No special study of the joint was made. Only a few readings were taken from place to place to get a general idea of the joint pattern. On the whole, pelites show little jointing, while the psammites are ideally jointed. The semipelites also show good jointing. In a broad way, the joint pattern comprises of two sets - one striking WNW-ESE and the other NNE-SSW. The former dips 50° to 60° due ENE and is the most dominant. The other set dips 40° to 50° due WNW, and is not so well developed.