CHAPTER VI

STRUCTURAL ANALYSES

1. INTRODUCTION

Various structural elements, which have been critically reviewed in the previous chapter, are the result of polyphased tectonic movements (Chapter VII). To understand the nature of these movements, the configuration of dominant S-surfaces of the Halog area have been analysed for macroscopic structures. In the present chapter an attempt has been made to draw a clear picture of the macroscopic folds and their order of superposition.

Microfabric analyses of ten selected tectonites from the Halog area have also been performed with the help of universal stage. The quartz optic axis and mica cleavage pole orientations have been plotted and contoured on equal area net. These diagrams elucidate the symmetry of the microfabric and nature of deformation.

The variegated group of para-autochthon has been observed to be highly folded in three localities of the map area, viz. east of Halog, around chayyan and south of Rup-ki-Ber (Chapter III). The fold systems have been superimposed over each other and they show a complicated geometry of the folds. These have also been analysed and have been dealt at the end of this chapter.
(a) DOMAIN I -
Pi & BETA DIAGRAMS
CONTOURS OF BETA-
DIAGRAM - 18%, 12% & 6% PER 1% AREA

(b) DOMAIN II -
Pi-AND BETA-DIAGRAMS
CONTOURS OF BETA-
DIAGRAM - 8%, 6% & 4%
PER 1% AREA

(c) DOMAIN III -
Pi- & BETA-DIAGRAMS
CONTOURS OF BETA-
DIAGRAM 12%, 8% &
4% PER 1% AREA
2. MACROSCOPIC ANALYSIS

The procedure for macroscopic analysis of the area has been based on the hypothetical examples given by Tinner & Weiss (1963 pp. 175-181). The above hypothetical account is based on superimposition of two fold systems. However, the map area is characterised by three fold systems superimposed over each other, which have further complicated the geometry of the folds.

The configuration of dominant S-surfaces has been analysed with the help of pi-diagrams. Beta-diagrams, in each case, have also been supplemented. It has been observed in the present diagrams that B-axis inferred from pi-circle coincides with beta-axis but some of the beta-axes do not have any geological significance (Ramsay, 1964).

The tectonic history of the allochthon unit is different from that of the para-autochthon unit (see Chapter VII) and, as a result the structures produced are markedly different. The rocks of the allochthon unit have developed secondary S-surfaces related to recumbent folds as the dominant foliation, whereas the para-autochthon rocks have developed the bedding cleavage into the dominant S-surfaces (see Chapter V). Thus in the allochthon rocks the configuration of S-surfaces reflects the folds after recumbent folding and they represent the set of cross folds, whereas the para-autochthon rocks are characterised by isoclinal folds which have been coaxially folded in the second phase and further have been cross folded during the third phase (see Chapter VII).

The area has been divided into seventeen domains (numbered
FIG.-20

(a) DOMAIN IV -
Pi- & BETA-DIAGRAMS
CONTOURS OF BETA-
DIAGRAM - 8 % & 4 %
PER 1 % AREA

(b) DOMAIN V -
Pi- & BETA-DIAGRAMS
CONTOURS OF BETA-
DIAGRAM - 9 %, 6 % &
3 % PER 1 % AREA

(c) DOMAIN VI
Pi- & BETA-DIAGRAMS
CONTOURS OF BETA-
DIAGRAM - 21 %, 14 % &
7 % PER 1 % AREA
by roman letters in appendix 'E'), the first seven corresponding to Jutogh formations, from VIII to XI corresponding to Chail formation while the remaining six domains correspond to the para-autochthon unit. A true homogeneous domain on the macroscopic scale in the area is not possible and these domains represent quasi-homogeneous characters which are characterised by either a single dominant fold system or equally dominant two fold structures.

A. Allochthon Unit

The present configuration of $S_2$-surfaces in the allochthon rocks is the result of superimposed fabric of close folds ($F_{d_3}$) and open folds ($F_{d_4}$) (Chapter V). The $\pi$-axes corresponding to $F_{d_3}$ folds in the $\pi$-diagrams (Fig. 19, to 21) have been denoted as $B_3$ and $\pi$-axes corresponding to $F_{d_4}$ folds have been denoted as $B_4$. These $\pi$-axes correspond to $B$-fabric axes of the fold systems (Turner & Weiss, op. cit.).

The domains, which are characterised by a single dominant macroscopic fold system, have well defined $\pi$-circles and beta-axes (Figs. 19c, 20c, 22a, 22b and 22c). The beta-axes in these cases correspond to $B$-axes of the macroscopic fold. However, some of the domains, which are also characterised by a single dominant macroscopic fold system, do not show the coinciding $\pi$-axes and beta-axes (Figs. 19a and 20b). The diverging poles of $S_2$-surfaces have given rise to this shift in beta-axes which may be attributed to the cross-folding. Domain IV (Fig. 20a); and probably domain V (Fig. 20b) are characterised by bodily rotation of macroscopic fold system ($F_{d_3}$) into two slightly
(a) DOMAIN VII
Pi- & BETA-DIAGRAMS
CONTOURS OF BETA-DIAGRAM - 9%, 6% & 3% PER 1% AREA

(b) SYNOPTIC BETA-AXIS
DIAGRAM FOR JUTOGH FORMATIONS

(c) DOMAIN VIII
Pi- & BETA-DIAGRAMS
CONTOURS OF BETA-DIAGRAM - 9%, 6% & 3% PER 1% AREA
reoriented folds of the same system, i.e. close folds ($F_{d3}$).

The domains, which are characterised by equally dominant macroscopic folds have also well defined $\pi$-circles and beta-axes corresponding to two cross-folds (Figs. 19b, 21a and 21c). The beta-diagrams have developed a number of subsidiary beta-concentrations probably of no geological significance.

The $\pi$- and beta-diagrams of the allochthon unit define B-macroscopic fabric corresponding to $F_{d3}$ and $F_{d4}$ folds. The synoptic B-axes diagrams for Jutogh formations (Fig. 21b) and Chail formations (Fig. 23a) differ, but very little. The surface area in the map is larger in the former case than that of Chail formation.

The synoptic B-axes diagram for allochthon unit, taking the two sub-units together, (Fig. 23b) shows the following four interesting features.

(i) Some of the $B_3$-axes fall on a great circle which may define a mean axial plane of macroscopic $F_{d3}$ fold. The axial plane dips $50^\circ$ due NE.

(ii) Some of the $B_3$-axes fall on a small circle which may show the character of superposed macroscopic $F_{d4}$-fold. The early linear structures, which may also be defined by $B_3$-axes, are deformed and reoriented on a small circle of the stereogram as a result of flexure folding (Ramsay, 1960).

(iii) The macroscopic $F_{d3}$-folds may have been broken up into two symmetrical parts each plunging opposite across the axis of
(a) Domain IX - Pi- & Beta-Diagrams
Contours of Beta-Diagram 15%, 10% & 5% per 1% area

(b) Domain X - Pi- & Beta-Diagrams
Contours of Beta-Diagram 9%, 6% & 3% per 1% area

(c) Domain XI - Pi- & Beta-Diagrams
Contours of Beta-Diagram 15%, 10% & 5% per 1% area
FIG.- 23

(a) SYNOPTIC BETA-AXES DIAGRAM FOR CHAIL FORMATION

(b) SYNOPTIC BETA-AXES DIAGRAM OF ALLOCHTHON UNIT ALONG WITH AXIAL PLANES OF MACROSCOPIC FOLDS

(c) DOMAIN XII - Pi- & BETA-DIAGRAMS CONTOURS OF BETA-DIAGRAM - 9%, 6% & 3% PER 1% AREA
cross folds.

(iv) A few B-axes have been oriented away from the main-fold axes direction which may be attributed to bodily rotation of macroscopic folds as a result of cross folding.

The axial plane of the cross-fold in the synoptic diagram (Fig. 23b) has been transposed from the synoptic diagram of the para-autochthon unit (Fig. 25c).

B. Para-autochthon Unit

The present configuration of $S_2$-surfaces (bedding cleavage) in the para-autochthon unit is the result of superimposed folds belonging to three generations, viz. $F_{d2}$, $F_{d3}$ and $F_{d4}$ folds (Chapter V). The isoclinal folds ($F_{d2}$) have their independent macroscopic characters only in domains XVI and XVII. The other domains are characterised by $F_{d3}$ and $F_{d4}$ cross-fold systems.

The nature of superposed folding in the para-autochthon unit is different from those of the allochthon unit. In most of the domains of para-autochthon unit, the $F_{d3}$-folds are broken into two macroscopic folds across the axis of $F_{d3}$-fold, thus the independent $F_{d4}$ folds could not be recognised with the help of pi-diagrams. In these cases, the pi-diagrams (Fig. 23c, 24b and 24c) are characterised by two pi-circles which intersect at a point defining $B_4$-axis. The beta-axes of these domains, although some of them coincide with the pi-axes, show many deflections and geologically insignificant directions.

However, some of the domains in para-autochthon unit have
(a) DOMAIN XIII -
Pi- & BETA-DIAGRAMS
CONTOURS OF BETA-
DIAGRAM - 10%, 7% &
4% PER 1% AREA

(b) DOMAIN XIV -
Pi- & BETA-DIAGRAMS
CONTOURS OF BETA-
DIAGRAM - 9%, 6% &
3% PER 1% AREA

(c) DOMAIN XV -
Pi- & BETA-DIAGRAMS
CONTOURS OF BETA-
DIAGRAM - 10%, 7% &
4% PER 1% AREA
Fig. 25

(a) Domain XVI - Pi- & Beta-Diagrams
Contours of Beta-Diagram - 12%, 8% & 4% per 1% area

(b) Domain XVII - Pi- & Beta-Diagrams
Contours of Beta-Diagram - 7%, 5% & 3% per 1% area

(c) Synoptic Beta-Axes
Diagram for Parautochthon Unit
Along with Axial Planes of Macroscopic Folds
developed independent pi-circles corresponding to $Fd_4$-folds (Figs. 24a, 25a, and 25b). The beta-diagram of domain XIII (Fig. 24a) shows coinciding beta- and pi-axes with only one spurious beta concentration.

The domains XVI & XVII are characterised by all the three superposed folds. The pi-diagrams (Fig. 25a and 25b) show pi-circles corresponding to three generations of folds. The $Fd_2$-isoclinal folds have been represented as relict fabric ($B_2$ in the diagrams). The beta concentrations for $Fd_2$-folds are not important in the beta-diagrams. A few spurious beta concentrations are also present in these diagrams.

The synoptic B-axes diagram for para-autochthon unit (Fig. 25c) show similar characters as in the case of allochthon unit (Fig. 23b). However, the axial plane of $Fd_3$-fold is nearly vertical with similar NW-SE trend. The small circle in this case is not well defined. The breaking up of macroscopic folds and thus, giving two macroscopic fold axes in opposite directions is also well marked. The bodily rotation of macroscopic fold is also observed.

The synoptic B-axes diagram (Fig. 25c) show a wide distribution of $B_4$-axes which fall on a great circle. This great circle may define the mean axial plane of $Fd_4$ folds which trend in NE-SW direction.

3. MICRO-FABRIC ANALYSIS

The polymorphites of the area (Chapter IV) have yielded to deformative forces resulting in a preferred orientation. This
preferred orientation has been analysed for quartz and micaceous minerals in the tectonites of Halog area.

A. Procedure

Ten specimens were selected from the map area, out of which five belong to Jutogh formation, three belong to Chail formation and remaining two have been selected from banded group of para-autochthon unit. These specimens have been located on the reference structural map appended at the end as Appendix 'E'. The specimens were away from the local heterogeneities, as for example the apex of the mesoscopic folds and local faults in the area. Thus these specimens will represent the deformation at microscopic stage under homogeneous deformative conditions.

Each specimen was cut perpendicular to the linear structures in the tectonite and oriented their sections were prepared. The section was mounted on four axial universal stage. Optic axis orientations of quartz and cleavage pole orientations of micaceous minerals were measured according to the procedure described by Turner & Weiss (op. cit., p. 197). The data thus collected were plotted on equal area net of 20 cm. diameter. The planes of these diagram represent the planes of thin sections which are oriented in different positions in the space. Each diagram was rotated to bring it on a common horizontal plane of projection. The diagrams were reduced to stereograms of 10 cm dia. (Figs. 26 to 32).

B. Description of the diagrams

SPECIMEN NO. 1: The specimen has been selected from
FIG. 26

(a) 200 QUARTZ OPTIC AXES ORIENTATION FOR Sp. No. 1. CONTOURS -4%, 3%, 2% & 1% PER 1% AREA

(b) 100 POLES OF MICA (001) FOR Sp. No. 1. CONTOURS - 9%, 6%, 3% & 1% PER 1% AREA

(c) INTERSECTIONS OF BASAL PLANES OF QUARTZ GRAINS WITH WAVY EXTINCTION. Sp. No. 1. CONTOURS - 16%, 12%, 8% & 4% PER 1% AREA
psamonic bands of banded graphitic schist (b3) exposed in the west of Chandal (Appendix 'E'). The tectonite has a foliation and micro-crenulation lineation. The thin section is characterised by over 90% of medium grained (about 0.3 mm.) quartz. The grains frequently show wavy extinction.

The quartz optic axis orientation diagram (Fig. 26a) is characterised by a well defined girdle which makes about 20°-30° angle with the 'bc' plane of the tectonite. The symmetry of the diagram is monoclinic and it has been apparently controlled by the rotation axis of the tectonite, i.e. the micro-crenulation lineation. The major maxima makes about 30° angle with the foliation.

The cleavage pole orientation diagram (Fig. 26b) shows monoclinic symmetry. The major maxima corresponds to the foliation. There are three other sub-maxima which may be due to crystalloblastic growth of quartz.

The quartz grains showing wavy extinction have been treated separately to relate the cause of wavy extinction. The two optic axes of a single quartz grain have been plotted and joined by dashed lines (Fig. 26c). The optic axis, being also the poles of the near basal faces (0001) of the quartz crystal, give two such faces which intersect along the line of deformation. These intersection points for various grains were plotted and contoured. This contour diagram (Fig. 26c) also shows a monoclinic symmetry and a well defined maxima. The maxima nearly coincides with g-fabric axis of the tectonite. The b-fabric axis of the tectonite has controlled the rotation of the monoclinic symmetry.
(a) 150 quartz optic axes orientations for Sp. No. 2
contours - 7%, 5%, 3%,
& 1% per 1% area

(b) 100 poles of mica
(001) for Sp. No. 2.
contours - 8%, 4%, 2%
& 1% per 1% area

(c) 200 quartz optic axes
orientations for Sp. No. 3
contours - 4%, 3%, 2%
& 1% per 1% area
SPECIMEN NO. 2: The specimen belongs to sericite-chlorite schist (a4) exposed in the west of Chandal (Appendix 'E'). The tectonite is characterised by schistosity ($S_2$) and $S_3$-surface. The oriented thin section shows augens of quartz aggregates (averaging in size of about 0.2 to 0.3 mm.). The quartz grains have often been fractured along $S_3$-surfaces.

The quartz optic axis orientation diagram (Fig. 27a) shows a triclinic symmetry, the maxima lying very near to the schistosity. There are two subsidiary maxima which lie near the 'ac' plane of the tectonite, possibly defining the girdle. The diagram shows a distinction of preferred orientation as a result of some superposed fabric.

The cleavage poles of mica (Fig. 27b) show three maxima. The diagram has retained earlier monoclinic symmetry with 'ac' plane as the plane of symmetry. The superposed fabric, in this case, seems to have been influenced by cross folds (Fc) with NW-SE and NE-SW trends. $S_3$-surfaces is indistinguishable from the diagram although a subsidiary maxima in NW quadrant may represent the same.

SPECIMEN NO. 3: The specimen has been selected from the garnetiferous graphitic-schist (b2) exposed in the east of Chandal (Appendix 'E'). Dark grey tectonite with specks of garnet and limonite is characterised by a well defined mineral lineation with apparently no planar element. The thin section is characterised by a few quartz rich bands. The grain size measures in average about 0.3 mm. $S_3$-surfaces are observed in traces.
(a) 100 POLES OF MICA (001)
FOR Sp. No. 3
CONTOURS - 12%, 8%, 4%,
& 2% PER 1% AREA

(b) 150 QUARTZ OPTIC AXES
ORIENTATIONS FOR Sp. No. 4
CONTOURS - 4%, 3%, 2% &
1% PER 1% AREA

(c) 100 POLES OF MICA (001)
FOR Sp. No. 4
CONTOURS - 8%, 6%, 4%,
& 2% PER 1% AREA
The quartz optic axis orientation diagram (Fig. 57c) shows a girdle which makes an angle of about 30° with 'ac' plane of the tectonite. The stereogram has also been affected by the superposed fabric which has disfigured the symmetry of the diagram. It shows two major maxima in the symmetry plane and two subsidiary maxima.

The cleavage pole orientation diagram (Fig. 28a) has a well developed girdle with b-fabric axis of the tectonite as axis of rotation. The diagram shows one strong maxima and two subsidiary maxima in the 'ac' plane.

**SPECIMEN NO. 4**  
The specimen has been selected from white quartzite (al) exposed in the north of Ratanpur (Appendix 'E'). The specimen is characterised by a linear structure. Under microscope the rock is composed of over 60% quartz and rest meta-oolites and minor minerals. The average grain size of quartz is 0.1 mm.

The quartz optic axis orientation diagram (Fig. 28b) shows a triclinic symmetry. A comparison of cleavage pole diagram of the specimen (Fig. 28c) shows that the partial girdle inclined to 'ac' plane of the tectonite might have developed but later on it was destroyed as a result of superposed fabric.

The cleavage pole orientation diagram (Fig. 28c) has developed a well defined girdle with axis of rotation coinciding with the lineation in the tectonite. The diagram shows one major maxima and two subsidiary maxima.

**SPECIMEN NO. 5**  
The specimen has been selected from
FIG. 29

(a) 150 QUARTZ OPTIC AXES ORIENTATION FOR Sp. No. 5.
CONTOURS - 6%, 4%, 2% & 1% PER 1% AREA.

(b) 100 POLES OF MICA (001)
FOR Sp. No. 5.
CONTOURS - 10%, 7%, 4% & 1% PER 1% AREA.

(c) 150 QUARTZ OPTIC AXES ORIENTATION
FOR Sp. No. 6.
CONTOURS - 5%, 4%, 3% & 1% PER 1% AREA.
pink quartzite (a2) exposed in the west of Ratanpur (Appendix ‘E’).
The tectonite has a well developed foliation and a pucker lineation.
The thin section is characterised by over 60% quartz which measures
0.2 to 0.3 mm. in average grain size. It shows two rude foliations
defined by biotite, sericite and chlorite flakes.

The quartz optic axis orientation diagram (Fig. 29a) shows
a triclinic symmetry. The partial girdle of early generation may be
traced as relict making small angle of inclination with the ‘ac’ plane
of the tectonite. The diagram shows a major maxima which lies in the
plane of subsidiary foliation defined by cleavage pole diagram.

The cleavage pole diagram (Fig. 29b) has a well defined
girdle in ‘ac’ plane of the tectonite. It shows a strong maxima
defining the schistosity (s2) in the rock. The subsidiary maxima
may define S3-surfaces.

SPECIMEN NO. 6  : The specimen has been selected from
quartz mica flag (c2) of Chail formation exposed in the west of Halog
(Appendix ‘E’). The tectonite has a well developed foliation (slaty
cleavage S1) and lineation due to intersection of bedding schistosity
(S2) and slaty cleavage (S3). Thin section is characterised by about
40% of quartz and rest micaceous minerals, felspar and minor minerals.
The average grain size of quartz is 0.08 mm. which often shows the
development of quartz lamellae.

The quartz optic axes orientation diagram (Fig. 22c) shows
a triclinic symmetry. The major maxima is inclined to ‘ab’ plane at
FIG. 30

(a) 100 POLES OF MICA (001) FOR Sp.No. 6. CONTOURS-12%, 8%, 4% & 1% PER 1% AREA.

(b) 100 QUARTZ OPTIC AXES ORIENTATION FOR Sp.No. 7. CONTOURS- 6%, 4%, 2% & 1% PER 1% AREA.

(c) 100 POLES OF MICA (001) FOR Sp.No. 7. CONTOURS- 8%, 4%, 2% & 1% PER 1% AREA.
an angle of about 30°. The diagram also shows four other sub-maxima.

The cleavage pole orientation diagram (Fig. 30a) is characterized by a well defined girdle and a strong maxima which correspond to intersection lineation as axis of rotation and the slaty cleavage (S₂) respectively.

**SPECIMEN NO. 7**: The specimen has been selected from sheeny phyllite (cl) of Chail formation exposed near Galog (Appendix 'E'). The tectonite is characterized by kink folds and axial plane cleavage. Thin section shows over 30% of quartz with average grain size of 0.08 mm. The quartz has been frequently, mylonitized with the development of deformation lamellae.

The cleavage pole orientation diagram (Fig. 30c) is characterized by two major maxima and a well defined plane of symmetry. These maxima correspond to sharply defined kink folds. The monoclinic symmetry of the diagram corresponds to the superposed fabric which has completely obliterated the fabric observed in specimen No. 6.

**SPECIMEN NO. 8**: The specimen has been selected from sheeny phyllite (cl) of Chail formation exposed near Ha'log village (Appendix 'E'). The tectonite has a well defined foliation plane and an intersection lineation. The microscopic characters are similar to those of specimen No. 7.

The quartz optic axes orientation diagram (Fig. 31a) shows a poorly defined girdle which makes a small angle with 'ac' plane.
(a) 100 Quartz optic axes orientation for Sp. No. 8. Contours - 4%, 3%, 2% & 1% per 1% area.

(b) 100 poles of mica (001) for Sp. No. 8. Contours - 8%, 4%, 2% & 1% per 1% area.

(c) 200 Quartz optic axes orientation for Sp. No. 9. Contours - 4%, 3%, 2% & 1% per 1% area.
of the tectonite. The major maxima is inclined at an angle of about 20° with the slaty cleavage ($S_2$) in the tectonite.

The cleavage pole orientation diagram (Fig. 31b) shows a well defined maxima corresponding to slaty cleavage ($S_2$). The diagram shows monoclinic symmetry with the axis of rotation coinciding with the intersection lineation.

**SPECIMEN No. 9**: The specimen has been selected from banded phyllite (d1) of param-autochthon unit exposed near Tangeesh (Appendix 'E'). The specimen is characterised by a pucker lineation and bedding cleavage ($S_1$). Thin section is characterised by quartz rich bands. The average grain size of quartz is 0.2 mm.

The quartz optic axes diagram (Fig. 31c) shows a triclinic symmetry. The major maxima lies in the plane of bedding cleavage.

The cleavage pole orientation diagram (Fig. 32a) shows a well defined girdle corresponding to the pucker lineation of the tectonite. The major maxima in the diagram corresponds to the bedding cleavage.

**SPECIMEN No. 10**: The specimen has been selected from the banded phyllite (d1) exposed in the north of Karaunri (Appendix 'E'). The mesoscopic and microscopic characters are similar to those of specimen No. 9.

The quartz optic axes diagram (Fig. 32b) shows a triclinic
(a) 100 POLES OF MICA (001) FOR Sp. No. 9
CONTOURS - 8%, 4%, 2% & 1% PER 1% AREA.

(b) 150 QUARTZ OPTIC AXES ORIENTATION FOR Sp. No. 10
CONTOURS - 4%, 3%, 2% & 1% PER 1% AREA

(c) 100 POLES OF MICA (O01)
FOR Sp. No. 10
CONTOURS - 8%, 4%, 2% & 1% PER 1% AREA
symmetry. The major maxima is inclined to the cleavage plane.

The cleavage pole orientation diagram (Fig. 32c) shows a well defined girdle corresponding to pucker lineation. The major maxima in the diagram defines the bedding cleavage.

C. Discussion

The above micro-fabric diagrams show varying symmetry elements and, therefore, the overall microfabric of the Halog area is characterised by triclinic symmetry. The monoclinic symmetry observed in quartz micro-fabric corresponds to the phase when schistosity was developed, whereas the monoclinic symmetry in mica micro-fabric is related with later phases of the orogeny also.

The following inferences may be drawn as regards to the deformation of rocks of Jutogh formation, Chail formation and para-autochthon unit.

(i) The quartz micro-fabric is well defined only in the tectonites of Jutogh formation. The preferred orientation is reflected in a girdle which is inclined to 'ac' plane of the tectonite at an angle of about 20° to 30°.

The quartz preferred orientation and wavy extinction in Jutogh tectonites are related to lineation of Phase-I (Chapter VII). The quartz micro-fabric has also been affected by a superposed deformation which has a distinctive effect on the preferred orientation. This may be related with the S3-surfaces in the tectonite during thrusting
FOLD STYLES IN VARIEGATED SLATES

SCALE: 1 cm. = 0.2 mtr. Approx.
(a) SUPERPOSED FOLDING

(b) SUPERPOSED FOLDING

(c) CONCENTRIC FOLDING
of the rocks (Chapter VII).

(ii) The quartz micro-fabric in the tectonites of Chail formation has been obliterated to a greater extent. However, the quartz-fabric girdle may be recognized as relict. The girdle is inclined to 'ac' plane with a small angle of inclination.

(iii) The quartz micro-fabric in banded phyllite (di) of para-autochthon unit has no apparent relation with the fabric elements of the tectonites. The preferred orientation, which has been reflected as maxima, may not be related with the tectonic history of the area and probably it reflects the sedimentary features.

3. DETAILED MESOSCOPIC ANALYSIS OF THE AREA EAST OF HALOG

The styles of mesoscopic folding (Fig. 33) in the highly folded variegated group exposed in the east of Halog (Appendix 'F' vide reference structural map Appendix 'E') have been controlled by many factors.

The wavelength of folded competent beds is generally larger resulting into open flexures (Fig. 33 a and c) while the wavelength in the incompetent slates is smaller resulting in tight flexure folds (Fig. 33 d).

The wavelength of the folds have also been controlled by the location of the fold in macroscopic structure. Thus single flexure is observed (Fig. 33, c, d and f) at the limbs of the macroscopic folds while the same beds have been folded to smaller wavelengths near the apex of macroscopic folds (Fig. 33 a and b).
(b) CONCENTRIC FOLDING OF SANDSTONE BED

FIG. 35
FIG.-36

EXPOSURES ON HORIZONTAL SURFACE

FAULT PLANE

N

FOLD AXIS (A.P. 60-240)

SHEAR FRACTURES

SLATES

FOLD AXIS (A.P. 100-280)

FAULT PLANE

N

FOLD AXIS (A.P. 20-200)

SLATES

FAULT PLANE (A.P. 160-340)
The wavelength has also been controlled by the phase of folding. Broad open flexures (34 h and 34 a and b) are in association with close flexures. The two fold styles belong to two different generations as is further revealed by the orientation of their fold axes and axial planes (Fig. 34 a and b). It is also possible to find out the relative ages of the folds. The earlier fold axes of close flexures have been bent and folded (Fig. 34a).

The competent quartzitic sandstone bed has been often tightly apressed resulting in close flexure. These tight folds (Fig. 34c) have developed secondary fractures both parallel to the axial plane and perpendicular to it which are equally prominent to the bedding cleavage in the rock.

The competent quartzitic sandstone folded along with the incompetent slates show interesting features. The folds developed in the quartzitic sandstone has been controlled by the band of quartzitic sandstone (Fig. 35). The slates have developed drag folds resulting into the minor thrust near the apex of the fold. Cross fractures in the slates are developed which run parallel to the tension cracks in the competent band. Small scale conjugate folds have also developed near the apex of the fold (Fig. 35a).

The mesoscopic strike-slip faults, which are related to the tight folds have developed drag folds in the incompetent slates near the thrust zones (Fig. 36a). The competent beds have been thickened near the fault plane and they have developed tension cracks parallel to the strike-slip fault. The incompetent beds are deformed into zones.
HYPOTHETICAL FOLD DIAGRAMS AS ORIENTED IN THE AREA EAST OF HALOG
HYPOTHETICAL FOLD DIAGRAMS AS ORIENTED IN THE AREA EAST OF HALOG
FIG.-39

HYPOTHETICAL FOLD DIAGRAMS AS ORIENTED IN THE AREA EAST OF HALOG
The zone just near to the competent bed have been cleaved with thinner bedding cleavage while a little away from it the slates have been cross-fractured. The cross fractures may be related with the two fracture planes in the deformation ellipsoid. These shear planes die out away from the fault plane.

The competent beds, when cross folded into open flexures, seems to have caused the developed subsidiary fault plane jetting out from the main strike slip-fault (Fig. 36b).

About 136 mesoscopic folds, which were recorded, have been studied critically from their orientation point of view. These folds can be grouped into eight classes so that the axial plane and axis of the folds of each class can be taken to be the same. These eight classes seem to have some relation with the phases of superposed folding. They were arranged in order and hypothetical diagrams along with stereograms were prepared (Figs. 37, 38 and 39).

Class 1 and 2 (Fig. 37a and b) have shallow dipping axial planes. These may belong to earliest generation of fold which were co-axially folded resulting in isoclinal folds. Classes 3, 4 and 5 (Figs. 38a, b and c) may probably belong to Phase-II (Chapter VII). The axial planes in all these cases are near vertical with varying amount of plunge. Classes 6, 7 and 8 (Fig. 39a, b and c) may belong to the generation which resulted in cross-folding of early folds. The axial plane trend is variable although the fold axes trend nearly coincides.