CHAPTER III

GEOLOGICAL SETTING

3.1. GEOLOGY OF METHALAYA

The Meghalaya Plateau is characterised by the presence of rock types belonging to different geological ages from Precambrian to Recent and Sub-Recent periods. Rocks of Precambrian age occupy most parts of the plateau in all the five districts of Meghalaya.

3.1.1. Stratigraphy

The oldest rocks forming the 'Basement Complex' cover the greater part of the plateau. It consists dominantly of quartzofeldspathic gneisses in which occur medium to high grade metamorphites such as varieties of schists, amphibolites, granulites, quartz-garnet-sillimanite rocks and also late intrusive granites. These rocks are named as 'Older Metamorphic Group' by the recent workers (Choudhury and Rao, 1975). The western part of the present Khasi Hills districts is considered the type area for this Group because the different varieties of rocks are best developed in this part. The rocks of this Group show wide lithological variations and evidences of complex metamorphic and tectonic history.

Deposited unconformably over the basement are the rocks of Shillong Group ('Series' of Medlicott, 1869), typi-
cally developed around Shillong (91°53' : 25°35') in the Khasi Hills.

This Group includes metasedimentary rocks that are pelitic at the base and quartzitic at the top. Rocks of this Group are separated at places by a conglomerate bed from the basement gneisses. These metasedimentary rocks suffered a very low grade (low Greenschist facies) metamorphism. Some sedimentary features like current bedding, ripple marks and graded bedding, which are still retained in the quartzites, are the clear evidences of their sedimentary origin.

The pelitic members of this Group, constituting the basal part, consists dominantly of biotite schist. In the schist occurs thin to thick bands of quartzite, grey actinolite schist, calc-silicate rock and isolated lenticular bands of conglomerate. The pelitic members are separated from the underlying 'Basement Complex' by a thin bands of sillimanite bearing conglomerate. Elsewhere, the contact between the two is marked by structural discordance and difference in their grades of metamorphism.

Quartzite is the most dominant rock type of the upper part of this Group. They are generally grey, white or buff coloured, compact and fine to medium grained. Sedimentary structures like current bedding, ripple marks and cross-beddings are present in these quartzites. Thin bands of pelitic rocks, now represented by phyllites and schists, occur in the
quartzites. There are many bands of conglomerate in the quartzites. The most consistent one is very thick and is composed of pebbles of vein quartz and a few quartzites. This band of conglomerate continue from east of Barapani (Ahmed, 1983) through Beadon-Bishop falls to west of Tyrssad.

The Shillong Group of rocks was intruded by basic intrusive rocks, called 'Greenstone' (Oldham, 1858) and later named the 'Khasi greenstone' (Medlicott, 1869). These occur as sills and dykes in the quartzites. The rocks are hornblende but rarely schistose.

Long after metamorphism and deformation, the Shillong Group of rocks are invaded by the pluton of porphyritic granite occurring around Mylliem town (91°49' : 25°29'). This was the earliest studied porphyritic granite in the plateau (Medlicott, 1869). Distinctly of younger in age, the Mylliem granite shows intrusive relationship with the Shillong Group and the Khasi greenstone and contain xenoliths of the latter (Das Gupta, 1934; Rahman, 1969). Similar type of porphyritic granite occur in different parts of the plateau of which the South Khasi batholith, the Nongpoh pluton, the Nongstoin granite are identified. The latter two occur within 'Basement Complex' in contrast with the Mylliem granite which occur in the Shillong Group of rocks.

The intrusion of the granites mark a definite phase in the development of the plateau, for, after the intrusion
neither sedimentation nor igneous activity took place in the plateau probably up to the Upper Jurassic time except in a small area in the Garo Hills where Lower Gondwana rocks are found. The Rb-Sr analysis of the Myllium granite has given it an age of 765 ± 10 m.y. (Crawford, 1969b).

Most of the Palaeozoic and Lower Mesozoic rocks are missing in the plateau region. In a narrow E-W strip along the southern border of the plateau occurs the trap rocks known as the Sylhet trap. The trap rocks are supposed to correspond with Rajmahal trap which is supposed to be of Jurassic age. These basaltic rocks lie unconformably on the Precambrian rocks.

The Cretaceous rocks developed in the plateau region are represented by Mahadek and Langpar Formations. The Cretaceous rests unconformably on the metamorphites, granites and the Sylhet trap.

The Tertiaries of the plateau belong to the self facies. The lower most members belonging to the Eocene are known as Jaintia series, which crop up on the southern slope of the plateau.

3.1.2. Structure

No earnest attempt has been made to study the geological structures of the plateau region as a whole. All the
published works on the plateau are confined to some specific areas or compilation of the works done by the early workers.

It is generally believed that the plateau is an autochthon of crystalline rocks that constitute the Foreland Spur of the Indian Shield and it has been overthrust from the north-west by the Himalayas and from the south-east by the Naga Hills (Bhattacharjee, 1968).

The regional structural trend of the Gneissic Group and the Shillong Group is NE-SW to ENE-WSW but a variation of it occurs in parts of Garo Hills where it swings to E-W (Bhattacharjee, 1968).

The Gneissic Group shows evidence of basement deformation. The dominant banding shown by the rocks was co-eval with amphibolite facies of metamorphism. Folds are generally tight and isoclinal but these may become increasingly folds of elasticus type in more and more metamorphic rocks. The dominant lineation in the rocks is defined by small-scale folds, quartz rods and by mineral parallelism. The plunge of the lineation is moderate to steep, at places it becomes vertical or nearly so.

The Shillong Group, however, shows the evidences of supracrustal deformation in relation to the basement tectonics of the Gneissic Group. Folds are not frequent. Those present are of small to moderate size. Folds present in the lower pelitic part contain only small-scale folds. The
folds are tight with steep to vertical axial plane and gentle plunge. The folds in the upper quartzitic part are open, asymmetrical folds with steep axial planes and gently plunging axes. The folds in the quartzites that occur surrounding the granite pluton, e.g. Mylliem granite, have their axes plunging as nearly as possible towards the pluton. These folds are generally of concentric type but smaller, similar type of folds also occur along the contact of the Shillong Group with the granite pluton. Rocks of the contact zone with the pluton differ not only structurally from the main mass but they are also more metamorphosed. Contact aureole is present and contact metamorphism has produced andalusite schist out of the phyllite wherever it is available.

The Cretaceous-Tertiary rocks of the plateau are horizontal to sub-horizontal and in the southern margin of the Khasi Hills plunge abruptly beneath the East Pakistan (now Bangladesh) alluvial plains along a monocline and fault (Krishnan, 1953; Mathur and Evans, 1964). The fault—the Dauki fault passes eastward into Haflong-Disang thrust. Evans (1964) postulated that the Dauki fault is a tear fault along which the plateau has moved eastward by 250 km relative to the Surma Valley. It is supposed that before the movement took place, the Rajmahal trap and Sylhet trap were parts of the same volcanic mass.
TABLE 2: The stratigraphy of the Meghalaya Plateau.

<table>
<thead>
<tr>
<th>Era</th>
<th>Formation</th>
<th>Rock Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eocene</td>
<td>Jaintia Group</td>
<td>Sandstones, limestone (nummulitic), shales (having phosphatic nodules), clays and coals.</td>
</tr>
<tr>
<td>Upper Cretaceous</td>
<td>Langpar and Mahadak Formations</td>
<td>Conglomerate, sandstone (arkosic), shales and fossiliferous limestones.</td>
</tr>
<tr>
<td>Jurassic (?)</td>
<td>Sylhet trap</td>
<td>Basaltic lava flows.</td>
</tr>
<tr>
<td></td>
<td>Shillong Group</td>
<td>Mylliem granite, Khasi greenstone, Quartzite, phyllite, shales, conglomerate, mica schist, calc-silicate rock, grey-wacke and sillimanite conglomerate etc.</td>
</tr>
<tr>
<td>Precambrian</td>
<td>Basement Complex</td>
<td>Gneisses, granites, schists (high grade), amphibolites and granulites.</td>
</tr>
</tbody>
</table>

3.2. GEOLGY OF THE AREA

The area studied consists of two distinct groups of rocks (Map 1). The lower group encompasses a varied assemblage of highly metamorphosed rocks that constitute the basement (Gneissic Series of Medlicott, 1869) on which the upper group consisting of metasediments are superposed. The lower group occupies the western part, while the upper group occurs in the eastern part of the area. Rocks of both the groups belong to the Precambrian age.
Gneisses predominate in the lower group. Of the gneisses, the quartzofeldspathic gneisses are the most abundant. The quartzofeldspathic gneisses, due to the variation in the amount of biotite contained in them, are either pink or grey in colour, the latter being richer in biotite.

Included in the quartzofeldspathic gneisses are various types of highly metamorphosed rocks. These include bands of garnetiferous gneisses containing sillimanite, bands and lenticles of hornblende gneiss, layer of quartz-sillimanite-garnet-feldspar granulites, bands of sillimanite-hornblende schist and bands of amphibolite.

The rocks of the lower group show both lithological and structural conformity amongst themselves. The layers in the gneisses and granulites are conformable with the boundary of the hornblende bands and lenticles. Same type of fold, foliation and lineation pervade all the rock types, showing no deviation at their lithological boundaries.

Small bodies of granitic rocks are emplaced into the rocks of the lower group. These include veins and dykes of aplite and pegmatite. A fine-grained granitic body occurring in the quartzofeldspathic gneiss about one km south-west of Mairang (Map 1) has gradational contact with quartzofeldspathic gneisses into which the granite body is emplaced. The granite resembles the aplite and may belong to the same source. The pegmatites do not belong to same age, some being younger than the rocks of the upper group.
The upper group consists wholly of metasedimentary rocks. This group can be divided into two parts: a basal part consisting mostly of schistose rocks and an upper part consisting mostly of quartzite. At the base of the lower part occurs a lenticular mass of sillimanite bearing conglomerate at Nongbri (Map 1). It is not found elsewhere in the area. The sillimanite bearing conglomerate often contains lenticular pockets of greywacke, which become a continuous layer above the conglomerate.

The rock types identified in this part are:
1. quartzite, 2. quartz-biotite schist, 3. quartz-biotite-muscovite schist, 4. calc-silicate rocks, 5. grey actinolite schist, 6. biotite schist, 7. sericite schist and 8. conglomerate.

The sillimanite bearing conglomerate rests on the 'Basement Complex'. The greywacke inside the conglomerate and above it are massive without internal bedding. The schistose rocks overlying the greywacke and the quartzites in the schists occur in thin layers. The layers become gradually thicker upwards from the base of the lower part of the upper group of rocks.

There is no distinct lithological break between the lower schistose and upper quartzitic part of the upper group of rocks. Both the parts together falls in the Shillong Group.
A small body of fine-grained grey granite occurs at Nongbri (Map 1). It is intrusive into the schistose part of the upper group of rocks.

The upper part consists mainly of massive quartzite. These are graded bedded. Thin layers of sericite schist and phyllites occur in between the quartzite layers. The upper part of the upper group of rocks are intruded by epidiorite as dykes and sills. These massive epidiorite is locally known as Khasi greenstone. No Khasi greenstone is observed in the schistose part of the upper group.

A new stratigraphic unit 'the Manai Group' has been proposed for the schistose part of the upper group so as to differentiate them from overlying quartzitic Shillong Group (series).

Both the lower and upper groups of rocks of the area were affected by polyphase deformations and polyphase metamorphism corresponding to greenschist to granulitic facies. The granites, aplites, pegmatites and other vein rocks escaped metamorphism as they were formed after the deformation and metamorphic episodes were over.

The geological setting of the area can now be summarized as:

(a) A lower (basal) group of polymetamorphosed, repeatedly deformed gneisses, in which quartzofeldspathic gneisses
predominate and include bands of various types of meta-
morphites.

(b) Resting on the lower group is an upper group of metasedi-
mentary rocks, which are predominantly schistose at the
lower part and quartzitic at upper part. The contact
between the lower group (a) and the upper group (b) is
not conformable: it is locally identified as an unconfor-
mity with occurrence of conglomerate on it and as a struc-
tural and lithological break in other places of their
contact.

(c) Emplacement of granitic bodies occurring in the form of
aplitic and pegmatitic veins and dykes and massive fine
grained granite. The aplites are confined to the lower
group (a) of rocks. The pegmatites are supposed to belong
to different ages. They are more numerous in the basal
group (a), but a few occur in the upper group (b) too.
Of the two granite bodies, one was emplaced in the gneisses
of the lower group (a) while the other was emplaced in the
schistose part of the upper group (b).

(d) Epidiorites, locally known as Khasi greenstones is intru-
sive into the upper part of the group (b).

For convenience of description, the area is sub-
divided into a western part in which the gneisses (Basement
Complex) are the most dominant rock types and an eastern part
in which the overlying psammo-pelitic metasedimentary rocks are prominent.

3.3. ROCK UNITS, THEIR DISTRIBUTIONS AND FIELD RELATIONS

3.3.1. Quartzofeldspathic Gneiss

The term quartzofeldspathic gneiss is used because the rock contains greater amount of quartz and feldspars and lesser amount of mica than in the pelitic schists. The term quartzofeldspathic gneiss of Heinrich (1956, p. 233) is appropriate in this case.

Quartzofeldspathic gneiss crops out over the greater part of the western part of the area (Map 1). The rocks are generally medium to fine-grained and are foliated to different degrees. Some of them show distinct compositional layerings, alternately rich in micaceous and quartzofeldspathic minerals. The gneissess are of two types: pink gneiss and grey gneiss. The distinction between the two types is not sharp; in all the cases one type passes gradually in to the other. The pink gneiss occurs at north-east of Bynther, at the vicinity of Mairang town and in the area west of Mongbri. The grey gneiss is the dominant type of the central part of the area and develop well at west and east of the Mairang town, around Mongbri and Wahlakhaw villages (Map 1).
3.3.1.1. Grey gneiss

The grey gneiss is well foliated and well-banded. The foliation is defined by the bands of biotite alternating with quartzofeldspathic bands. Veins, lenses and individual grains of pink feldspar impregnated the rock in the direction of foliation planes. Sometimes the foliation planes veers around the larger lensoids of feldspars. Elsewhere the foliation is obliterated by the concentration of feldspathic materials, which are irregular in shape and trend and criss-cross the body of the rock. Concentrations of biotite along the margin of the veins are noticed.

There is no clear-cut line of separation in the field between the pink and grey gneisses—the gradation from pink to grey gneiss and vice-versa is seen almost everywhere. Patches of grey gneiss occur in the areas where the pink gneiss is dominant, while the pink gneiss often continues in the areas dominated by the grey gneiss.

The study of contacts between the grey gneiss and pink gneiss reveal that the former passes imperceptibly in to the latter. In some cases there are clear indications that the grey gneiss is older than the pink gneiss, the latter cuts the former (Fig. 1). In certain areas the pink gneiss that cuts the grey gneiss, in its turn is cut by quartz veins (Fig. 1).
3.3.1.2. Pink gneiss

The pink gneiss is generally not well foliated. Wherever present, the foliation is made prominent either by fine quartz ribs alternating with feldspathic layers or by feldspathic bands alternating with bands richer in biotite (Pl. IA). Certain bands of the pink gneiss are rich in porphyroblasts of potash feldspar. The porphyroblasts are usually elliptical in nature and show rough parallelism with the foliation in the gneiss. Sub-rounded or well formed crystals are also seen. A few of the feldspar porphyroblasts show signs of rotation with a tail that meet the feldspathic veins, which probably acted as a feeders (Fig. 4). Some of the porphyroblasts measure more than 6 cm in length, e.g. in road cuttings 1 km east of Bynther.

Aplites and quartz veins impregnated the gneiss both concordantly and discordantly. Development of both irregular and regular bodies of pegmatite in the gneiss is widespread (Fig. 2,3, Pl. IB,C). The coarser, more pinkish variety contains irregular pockets of biotite.

3.3.2. Sillimanite-garnet schist

A band of sillimanite-garnet schist occurs west of the Mairang town (Map 1). It is 6 metres thick and can be followed along the strike for 30 metres. Another band occurs east of Bynther village in a stream section (Map 1). The
maximum thickness of the band is 3 metres and can be traced along the strike for 20 metres. These bands are well shown on the cuttings of Mairang-Nongstoin road. Elongated ridges and furrows are well developed on the weathered schistosity surfaces of the bands. The bands are often streaky with elongated patches of quartzofeldspathic materials.

These rocks are grey to pinkish brown in colour and are well foliated and lineated. The foliation is shown by flakes of biotite in the grey band and by small porphyroblasts of garnet and biotite in the pinkish bands. Large garnet porphyroblasts of about 5 cm in diameter disturbed the foliation in the rock. Rodded and mineral lineation predominate in the rock. Mineral lineation shown by fine needles of sillimanite is very prominently developed. Their dispositions are similar to those of the corresponding structural elements in the quartzofeldspathic gneisses.

The foliation in the rocks was deformed by flow folding causing their re-orientation. The lineation associated with the foliation was also affected. The folds produced are asymmetrical,ptygmatic in cases where the rock was impregnated by pegmatitic materials (Fig. 16). The foliation may also become wavy and thrown into small-scale folds. Small-scale isoclinal folds are associated with asymmetrical folds. These folds are similar in form.
Not infrequently open, comparatively large, gently asymmetrical folds with short steeper and long gentler limbs occur. These affected the sillimanite-garnet schist together with the associated quartzofeldspathic gneiss (Fig. 25). These folds deform all the structures described above.

3.3.3. Quartz-sillimanite-garnet-feldspar granulite

The quartz-sillimanite-garnet-feldspar rocks occur as thick bands in the quartzofeldspathic gneisses in a stream section 1 km east of the Bynther village (Map 1). The rocks are characterised by granulitic fabric and by distinctive high grade mineral assemblages. The granulitic fabric has planar foliation defined by alternation of parallel, highly flattened lenticles of coarse quartz with layers of finely crystalline quartz and feldspars. The rock is generally light coloured but gives a reddish brown colour due to scattered garnet crystals, which may often occur in regular bands in the rock.

3.3.4. Hornblendic rocks

Occurrences of hornblendic rocks in the western part of the area (Map 1) are many. These occur in the quartzofeldspathic (Pink) gneiss as elongate bands from less than a metre to more than twenty metres thick. These trend parallel to the trend of the foliation of the host rock. Only the
larger of these bands are shown on the map (Map 1). Hornblende-sillimanite schist, which has a well developed schistosity, occurs in the north-western part of the area. Some of the hornblende rocks, with the increase in grain size, disappearance of schistosity, and appearance of variable composition layers, gradually become hornblende gneisses. Lenticular bodies of nearly monomineralic hornblende and/or biotite may often develop in the gneisses. The main body of the hornblende rocks, with the development distinct lineation and planar foliation, gradually become amphibolitic on the western part of the area.

Some of the hornblende rocks derived from basic igneous masses, while others were probably of metasedimentary derivation. The structural deformation and metamorphic changes have modified many of the hornblende rocks resulting in the development of bands and lenses of fine to medium grained rocks rich in hornblende.

3.3.4.1. Hornblende-sillimanite schist

A thick body of hornblende-sillimanite schist trending N-S, parallel to the foliation of the pink quartzofeldspathic gneisses occur east of the Mairang town and continues over a limited distance. Another thick band of the rock occur between the pink gneiss and the hornblende gneiss mass e.g., between Bynther village and Mairang town (Map 1).
The prominent schistosity in the rock is defined mainly by the parallel orientation of hornblende together with fine, parallel bandings resulting from the alternation of hornblendic and quartzofeldspathic parts. It generally trends NE-SW with gentle to steep dip. Mineral lineation shown by hornblende and sillimanite needles are well developed and plunges gently towards NE.

Small-scale folds trending NE-SW are the most common structures. The folds are tight isoclinal and asymmetrical, have tightly appressed limbs and the NE-SW axial planes dip gently to the NE.

A thick hornblende rich layer interbanded with foliated gneiss is asymmetrically folded at east of Bynther bridge. The NW-SE trending fold measuring 4 metres across has a long and a short limb. The fold shows much thickening in hornblendic than in the gneissic layer (Fig. 12). Another fold occurring at a distance of 10 metres east refolded the earlier fold (Fig. 14).

3.3.4.2. Hornblende-sillimanite gneiss

Hornblende-sillimanite gneiss in thick and thin bands and lenticular bodies occurs at south-east of the Mairang town and intermittently within the quartzofeldspathic gneisses to the east of the Bynather village. The band cropping out at north of the Mawlong village is located near a horn-
blende schist mass and is 2 metres thick. Other bands of variable thickness crop out amongst the pink gneisses on the northern bank of the Kynshi stream, adjacent to a large amphibolite band.

The rocks lack or contain poorly developed planar foliation. Gneissosity is also poorly developed. The foliation trends NE-SW with gentle dip to the SE. Mineral lineation is shown by needles of hornblende and sillimanite. It plunges moderately to the NE. Whitish grey to pinkish grey streaks of feldspars are frequent in certain bands. Irregular pegmatitic veins cut across the main foliation and send out veinlets in all directions.

Minor folds that found in hornblende schist and quartzofeldspathic gneisses are also displayed in the hornblende-sillimanite gneiss. Isoclinal and asymmetrical folds with highly appressed limbs are much more pronounced than the open isoclinal box type folds. The attitude of the folds are identical to the folds occurring in the surrounding quartzofeldspathic gneisses.

3.3.4.3. Amphibolite

The basic metamorphic rocks of the basement complex is represented by the amphibolites. These rocks occur usually as conformable layers. Lenticular bodies with elongations parallel to the foliation of the quartzofeldspathic gneisses.
are also observed on the western part of the area (Map 1).

The amphibolites possess a distinct lineation and planar foliation. These may often be deformed by small scale folds. The foliation is defined by alternation of fine layers rich in quartzofeldspathic material and hornblende respectively. Mineral lineation produced by the parallelism of amphibole needles are common. The lenticular bodies and the foliation in them are parallel to the foliation in the enclosing gneisses. At places irregular pegmatitic veins cutting across the rock obliterated the foliation planes in the amphibolite. In spite of local minor variations, the amphibolites can be traced as regular bands and there is no evidence that the basic bands were in the form of a dyke, discordantly injected in the quartzofeldspathic gneisses. Though a good number of bands occur in the area, it is only possible to show the thicker bands on the map (Map 1).

Folds are not as common in the amphibolites as in the quartzofeldspathic gneiss. However, small-scale isoclinal folds with tightly appressed limbs are seen. The dominant foliation in the rock is axial planar to the folds.

3.3.5. Granite

Granite is the main variety of intrusive igneous rocks in the area that escaped metamorphism. Occurring as small plutons, it was emplaced into the quartzofeldspathic
gneisses in the western and the schists in the eastern part of the area. There are two common types: pink granite occurs in the vicinity of the Mairang town and the grey granite occurs near the Nongbri village.

3.3.5.1. Pink granite

Three elongated bodies of pink coloured, medium grained granites are noticed 1 km west of Mairang town (between 45 and 46 km posts), while porphyritic varieties borders the extreme western exposure of the bodies. The granite is generally massive. The foliation which is weakly developed, is marked by streaks of biotite and often by elongated grains of pink feldspar (microcline). Concentration of feldspar grains often produce feldspathic bodies in the granite. A typical field feature of the granite is the occurrence of spheroidal boulders due to weathering.

The granitic plutons cut across the earlier emplaced concordant pegmatites (Pl. IIA, Fig. 26) in the quartzofeldspathic gneiss. The rocks show gradational contact with the host rock. Small sinistral faults developed in the quartzofeldspathic gneiss are younger than the pegmatitic bodies and they seemed to help the intrusion of the granite (Pl. IIA).
3.3.6. Vein rocks

Vein rocks include pegmatites, quartz veins and aplites of which the former two are relatively abundant in the area. These veins vary in sizes from a few millimetres to a metre in thickness and several metres in length. They show both concordant as well as cross-cutting relationship to the foliation in the rock.

3.3.6.1. Pegmatitic veins

The pegmatitic veins which cut the first phase and second phase structures are coarse-grained, some containing microcline crystals measuring upto 6 cm in length. They occur throughout the Basement Complex, more particularly in the quartzofeldspathic gneisses and show both concordant and discordant relationship with the dominant foliation (S₁). Sometimes biotite rich lamellae of the gneisses bulge and swing around the pegmatitic bodies and produce corrugation on the foliation planes (Fig. 15). Some discordant veins send out veinlets along the S₁ foliation of the quartzofeldspathic gneisses that mimic the pre-existing folds (F₁) (Fig. 16).

A few pegmatites are emplaced into the asymmetrical folds (f₃) of the quartzites of the Manai Group.
3.3.6.2. Veins

The medium-grained aplitic veins occur in the quartzofeldspathic gneisses and schists. They bear both concordant and discordant relations to the foliation in the gneisses and the schists. Discordant veins send out veinlets along the foliation planes (Fig. 3). The aplitic veins vary in their thickness. Some of the veins are about a metre thick and concordant, being emplaced along the foliation plane in the quartz-biotite schist.

Quartz veins

Medium to coarse grained concordant and discordant veins abound in the area. The thickness of the veins are highly variable from a few cm to a metre. A prominent quartz vein trending N-S and cutting across the regional foliation and lithological layering is seen north of Nongbri village. It measures about 1 m thick and 5 m long and develops boudinage structure (Fig. 2). Small quartz veins intruded in to the quartz-muscovite-biotite schist. These were later in age than the folds in the schist. The veins are pytgmatically folded. The veins also mimic the fold of the host rock (Fig. 7). Inumerable small lense shaped quartz veins are also seen along the foliation of the schistose rocks of the area (Pl.IIc). At places these quartz veins intrude into the quartzofeldspathic gneisses along the dominant foliation (S1) and both are folded by F2 folds (Fig. 23).
3.3.7. Sillimanite-garnet conglomerate

Isolated outcrops of the conglomerate occur at Nongbri (91°40'18" : 25°32'48") on the southern side of the Shillong-Mairang road (Map 1). The village church is situated on the western most of the masses. The conglomerate occurs as a combination of lenses enclosed in a matrix of medium grained quartzofeldspathic metasediments. It separates the basement complex from the overlying metasedimentary rocks. The visible extent of the conglomerate lenses varies from 5 cm to 2 m. The pebbles are comparatively more resistant to weathering than the matrix and thus stand out prominently on the weathered surfaces (Pl. IIIA).

The pebbles in the conglomerate are composed of vein quartz. Most of the pebbles are very elongated and elliptical and flat in cross-section. Their long axes indicate a lineation and the flat surfaces show a well defined foliation. The foliation is generally wavy. The ground mass is composed of grains of quartz and feldspathic clay, which was metamorphosed to the sillimanite bearing ground mass.

3.3.8. Greywacke

Apart from the matrix to the sillimanite bearing conglomerate and the thick band over it, another band of greywacke occurs east of the basal conglomerate, at a distance of about 300 m from the Nongbri village. Another band
also occurs 1.5 km west of Mairang town. The rock still retain their clastic appearance and are medium to coarse grain in texture. The rocks are composed mainly of quartz and feldspar with little mica and they are loosely packed. Colour is from pinkish white to pale brown. Bedding is not well developed. The rock is rudely foliated. The trend of the foliation is variable from N-S to NE-SW.

3.3.9. Quartzite

Quartzite is one of the major rock types of the Manai Group of rocks that crops out in the eastern part of the area (Map 1). Because of its resistance to weathering, the area occupied by this rock shows high elevation mostly as NE-SW elongated hills.

The quartzites are of three types: massive quartzite, micaceous quartzite and feldspathic quartzite. In micaceous variety the content of mica is highly variable and this being the determining factor, they show varied degrees of foliation. The micaceous quartzite is susceptible to weathering and wears away easily.

Quartzites are frequently associated with the schistose rocks that occur as conformable layers of highly variable thickness varying from less than a metre to tens of metres.
In the Manai area, north of Um Dingshit stream, thin bands of quartzite alternating with biotite schist have developed small-scale open folds. The axial planes trend NE-SW, their axes plunge gently NE. About 500 metres northeast, three bands of quartzites each 10 m, 100 m and 30 m thick, occur with thin bands of grey actinolite schist in between the bands. The bands are folded into a large open fold with axial plane trending NE-SW and axis plunging gently to the NE.

In the Mawsaw area, a quartzite band about 40 m thick is slightly folded with asymmetrical folds with wide hinge zone. The axial planes trend NE-SW and the axes plunge gently to the NE. Thin bands of quartz-muscovite-biotite schist in the quartzites are open folded with axial planes plunging at low angle to the NE.

In the Mawmaram area, a 100 m thick and persistent band of quartzite is traced to a distance of 1.5 km. The quartzite is massive, well bedded and highly jointed (Pl IIIB). The biotite schist associated with the quartzite is folded into an open fold (Pl. IVB, Fig. 6). The gently NE plunging fold is of third phase deformation. The quartzite is intruded by a dyke of Khasi greenstone trending N-S.

An isolated outcrop of quartzite occurs at a road cutting on the western part of the Mairang town. The band, about 10 m across, lies above the quartzofeldspathic gneiss
The contact between the gneiss and the quartzite is found to be a tectonic one, as the structures and their trends in either of them are different. On the north of the stream, two massive quartzite bands are folded into open, asymmetrical folds (Pl. IVA). Portions of the rock is crushed where the quartzite has become thinly splintery. On the south of the stream, the quartzite shows regular bedding planes striking NW-SE. The quartzite is well lineated with rodded structures that plunges gently to the NE.

3.3.10. Quartz-biotite schist

Quartz-biotite schist occurs in thin bands south of the Shillong-Mairang road at west of Mawmaram and at south of Mawsaw. This metasedimentary unit is fine-grained, well foliated and dark grey in colour. The most dominant and pervasive planar structure in these rocks is the foliation ($S_1$) that developed during the first phase deformation ($d_1$). Small-scale asymmetrical folds are well preserved in the rocks. These folds have alternate long and short limbs with dominant foliation parallel to the axial planes of the folds.

3.3.11. Quartz-muscovite-biotite schist

Quartz-muscovite-biotite schist occurs as narrow wedges within the thicker quartzite bands at north of Mawsaw and at west of Mawmaram area. The biotite-rich variety is dark
grey, while quartz and muscovite rich variety is light grey in colour. The schistosity, which is defined mainly by the parallel orientation of biotite flakes together with fine banding resulting from alternation of quartz and micaceous minerals, trends NE-SW with moderate (60°) dip. The bands are a few millimetres to a few centimetres thick. Some bands occurring conformably with the lithological banding (or bedding) of quartzite have developed a foliation oblique to the regional foliation (S1) (Fig. 33).

Asymmetrical folds (f1) in the rocks have long and short limbs (Fig. 5), sometimes with thickened noses and thinned limbs (Fig. 5). The foliation (S1) of the rock is axial planar to these folds and the axes plunge gently to the SW. At places these folds (f1) are cut by quartz veins (Fig. 7).

3.3.12. Calc-silicate rocks

Calc-silicate rocks interlayered with other meta-sediments occur at east of Nanai. The layers vary in thickness and are persistent along the strike. A few elongated lenses are also observed.

The rocks show wide variation of colours in different bands, even in the same band, due to irregular mineral composition. Some of the rocks exhibit well defined foliation with well developed mesoscopic folds (f1) and others are non-
foliated and massive. The schistosity is marked. On weathering the rocks show characteristic pitted and rough appearance due to difference in hardness of constituent minerals.

A vertical fault trending NW-SE in the Um Dingshit river effects a band of calc-silicate rocks. The two faulted blocks show a simistral sense of movement. The north-eastern block is shifted along the fault plane to a distance of 100 m westward in relation to the south-western block.

3.3.13. Interbedded conglomerate

Isolated outcrops of conglomerate occur east of Manai. It is interbedded with pelitic rocks. The conglomerate is composed of quartzite, quartz and quartzofeldspathic pebbles. The pebbles are mostly angular fragments and they are poorly sorted. The pebbles vary in thickness from 2 cm to 5 cm. Since the pebbles are poorly sorted on lithological layerings, they show very poor lineation. The pebbles are comparatively more resistant to weathering than the matrix. The matrix is relatively more micaceous, schistose and weathers more easily than the pebbles.

3.3.14. Grey-actinolite schist

Bands of grey-actinolite schist occur mostly in north-eastern part of Manai. A few bands are also seen on the north-western bank of Um Dingshit, about 300 metres south of the Shillong-Nongstoin road (Map 1).
The rock is well foliated and well lineated. It has dark grey and grey laminations. The laminations are marked by alternating bands rich in quartz and micaeous minerals with feldspars. The S-surfaces are strewn with dark needles of actinolite which show a preferred orientation. Lithological banding is seen across as well as along the foliation \((O_1)\) due to the folding of the layers. The folds \((f_1)\) in the rocks vary in style from symmetrical isoclinal to asymmetrical open folds (Fig. 37). A fault is seen to effect a band of the rock. The NW-SE trending fault is vertical.

Small quartz veins intrude along the foliation and the apices of the folds. A massive quartz E-W vein, 2 m thick and 10 m long, is emplaced parallel to the foliation.

### 3.3.15. Biotite schist

Biotite schist occurs south of Nongti as conformable bands, some of which merge laterally with the adjacent sericite schist. A few bands also crop out amongst the quartz-muscovite-biotite schist and grey actinolite schist on the north-western bank of Um Dingshit stream. The colour of the rock is grey due mainly to the presence of abundant biotites. The parallel orientation of the biotite flakes, together with dark and light coloured bands, give the foliation of the rock. The foliation generally trends NE-SW and dips steeply to the SE. Rodded lineation is prominently developed and plunges
moderately to the SE. Small-scale folds ($f_1$) of the first phase deformation ($d_1$) are noticed in the rock (Fig. 8). Drag folds of the lensoid quartz veins occurring in the fine-grained rock are seen (Fig. 20). Lithological layerings which cannot be easily detected at most of the outcrops are prominently seen under the microscope (Pl. XXB).

3.3.16. Sericite schist

Sericite schist occurs as bands at south-east of Mawmaram and continues at intervals upto south of Nongti. These bands alternate with bands of quartzite. The rocks are well foliated and lineated. The finely foliated schist develops cleavages oblique to the composition layerings ($s_0$) resulting in development of local secondary foliation ($s_2$) (Fig. 30). Well developed mineral lineation plunges $\pm 60^\circ$ to the SE. Crinolines on the foliation planes post dated both the foliations $s_1$ and $s_2$.

Both concordant and discordant quartz veins are seen in the schist.

3.3.17. Khasi greenstone

The basic igneous rocks intrude the upper psammatic rocks of the Manai Group. These basic rocks are metamorphosed. They occur as dykes and sills. Although regionally concordant, the basic rocks occasionally trangressed into the host rocks.
Individual bands vary in thickness from less than a metre up to about 5 metres. One prominent, almost massive band of Khasi greenstone of about 5 m in thickness is found in a stream section east of Mawmaram village (Map 1). The N-S trending bands cuts across the lithological layering and regional foliation (s_i). A few bands also crop out near the south-eastern margin of the area under investigation. These bands measure 2 m to 5 m in thickness and are well shown in the cuttings on the Shillong-Mairang road. There are also thinner bands south-east of Mawsaw village.

The Khasi greenstones are less affected by weathering than the surrounding rocks. Intense weathering causes exfoliation and spheroidal boulders are produced.

3.3.18. Grey granite

The grey granite occurs south-east of Nongbri. It forms a 100 m by 20 m, E-W trending hillock. The granite cuts the quartzites and biotite schist that occur above the conglomerate. Due to jointing and spheroidal weathering, the outcrop is now a heap of boulders (Pl. IIB) which are quarried away. The contact of the intrusive with the surrounding rocks is sharp. The rock is medium grained and massive. The grey colour of the rock is due to high amount of biotite present in it.
PLATE I

A. Quartzofeldspathic gneiss with alternating quartz-rich and biotite-rich bands, showing well developed foliation ($S_1$).

B. Impregnation of concordant regular and irregular pegmatitic bodies in grey quartzofeldspathic gneiss.

C. Same as B in pink quartzofeldspathic gneiss.
PLATE II

A. Quartzofeldspathic gneiss impregnated by concordant pegmatites. Both are cut by a granitic body.

B. Spheroidal boulders of grey granite which cuts across the quartzite and biotite schist, east of Nongbri village.

C. Pink and grey concordant aplitic vein emplaced along the foliation in quartz-biotite schist. Small lens shaped quartz veins occur parallel to the foliation (s1); west of Mawmaram village.
PLATE III

A. Sillimanite-garnet conglomerate from Nongbri village. Quartz pebbles stand out prominently due to weathering.

B. Closely spaced joints in massive quartzite; west of Mawmaram village.

C. Well bedded quartzite; east of Manai village.
FIGURE 1. Grey gneiss with pink gneiss both of which are cut by quartz veins; from east of Mairang.

FIGURE 2. Large, concordant, boudinaged quartz vein in quartzofeldspathic gneiss; from west of Nongbri village.

FIGURE 3. Discordant aplitic vein sending out concordant branches, which gradually merge with surrounding quartzofeldspathic gneisses; from west of Nongbri village.

FIGURE 4. Microcline porphyroblast in pegmatite emplaced in quartzofeldspathic gneiss, the latter showing signs of rotation; from east of Bynther village.
FIGURE 5. Isoclinal folds ($f_1$) with long and short limbs occur in association with open asymmetrical folds in quartz-muscovite-biotite schist. Thickening of hinges and thinning of limbs of the folds are shown, from east of Mawsaw village.

FIGURE 6. Open fold ($f_1$) in biotite schist associated with quartzite; from east of Manai village.

FIGURE 7. Open fold ($f_1$) in quartz-muscovite-biotite schist. The concordant quartz-rich band is cut by late quartz veins; from Manai village.

FIGURE 8. Open asymmetrical fold ($f_1$) in biotite schist.