CHAPTER - III

REGIONAL GEOLOGY OF THE AREA
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The Geological formations in the study area consist of highly metamorphosed to less metamorphosed Precambrian Gneissic Complex and the Shillong Group, intruded by both acid and basic intrusives of different ages. The Tertiary Group of rocks overlie unconformably on these rocks in the southern and south eastern parts of the area. The older and younger alluvium occur in the eastern and western part of the district (Fig. 7).

This chapter deals mainly with the broad lithological units, structure and tectonics and different types of lineaments in the area, which play a dominant role in the characteristics of hydrology in it.

3.1 Lithology

Because of the presence of diverse lithounits, aerial photographs and satellite imagery (IRS-IA LISS-II and LANDSAT-5 TM) data reveal of very complex geological set up in the district. All the lithounits are not easily identifiable from satellite imagery and aerial photographs. As most of the areas of the district are covered by thick forest, only a broad identification of the units can be made through different image characteristics. However, the lithological boundaries of some of the units are very distinct in the images (Photographs 2, 3 and 4 and Fig. 7).

The district under review comprises Precambrian metamorphic
Photograph 2: IRS-1D (LISS-III) imagery showing sharp lithological contact (C) between granite (G) and gneissic (Gn) rocks. The granite shows well developed lineaments.

Photograph 3: LANDSAT-5 (TM) imagery showing lithological contact between the Tertiary Group (T) and the Gneissic Complex (Gn).
Gneissic Complex (Krishnan, 1960) overlain successively first by the Shillong Group and then by the Tertiary Group of rocks. The field and photo character of the different lithological units are briefly discussed below.

3.1.1 The Gneisses

The gneissic rocks form the basement on which all the other groups of rocks were deposited. Gneissic Complex exhibits subdued to high relief, banded variable tone with coarse texture due to thick forest cover and moderate to highly jointed pattern. From the geomorphic expression and the foliation pattern (Photograph 5), these rocks can be separated from the other units. Drainage pattern is subdendritic to dendritic with medium density (Fig. 28b).

During the field verification, the Gneissic Complex, forming the oldest rock type of the district, is found to be highly metamorphosed comprising mainly of quartzofeldspathic gneiss, hypersthene gneiss, calc silicate rock, quartz- sillimanite- gneiss and schists, garnetiferous mica schists, occurring mostly in the central and northern part of the Diphu sub-division and in the south-western part of the Hamren sub-division. The gneisses occupy about 40% of the district. All possible textural and compositional gradations exist amongst these different lithounits.

The gneissosity in the rocks is defined by alternate biotite and quartz-feldspar rich layers. Biotite content generally decreases towards lesser gneissic variety.
Photograph 4: IRS-IA(LISS-II) imagery showing denudational hills of Gneissic Complex (Gn) and Tertiary Groups (T) of rocks.

Photograph 5: LANDSAT-5(TM) imagery showing sharp of contact between intrusive granite (G) and foliated gneissic (Gn) rocks.
3.1.2 The Shillong Group

The Shillong Group of rocks is expressed as structural (Photograph 6) and denudational (Photograph 7) hills maintaining almost uniform heights forming a plateau. The rock types are demarcated easily from satellite imagery and aerial photographs because of scanty vegetation cover on them and clear lithological banding, trellis and rectangular pattern of drainage, fine to medium texture and light to medium phototone. This group can be divided into two parts. The lower part shows medium texture, less developed bedding planes, moderately dissected dendritic drainage. The upper part shows fine to medium texture with well bedded, rectangular to trellis type of drainage. The Shillong Group of rocks are less metamorphosed and younger in age than the Gneissic Complex. It comprises mainly of feldspathic- biotite- gneiss, mica schists, carbonaceous slate, quartzite, quartz- mica- sillimanite- schists (Barooah and Goswami, 1972), feldspathic quartzite and phyllite at the lower part while sheared conglomerate, quartzite and phyllite are dominant in the upper part. These rocks occur in the northern parts of both the Diphu and Hamren sub-divisions. The individual lithological units are difficult to be separated from each other with the help of remotely sensed data.

The Precambrian Gneissic Complex and Shillong Group of rocks are intruded by various acid (Photograph 8) and basic intrusive rocks (Photograph 9) and are present as circular and semi-circular to linear outcrops. These are well recognised (mappable units) both on aerial photographs and satellite imagery by their tone, texture, pattern, size and shape.
Photograph 6: IRS-IA (LISS-II) imagery showing angular unconformity (U) between Upper and Lower Shillong Group of rocks.

Photograph 7: IRS-IA (LISS-II) imagery showing denudational hills of the Shillong Group of rocks in Hamren Sub-divisions.
Photograph 8: IRS-IA (LISS-II) imagery showing valley-fills on the well-bedded Shillong Group of rocks intruded by granite intrusions.

Photograph 9: IRS-IA (LISS-I) imagery showing denudational hills of the Gneissic Complex with circular basic intrusions (CS) at the centre and ENE-WSW shear zone followed by the Kaliyani Dikharu river.
3.1.3 Granitoids

About one-fourth of the Precambrian rocks consists of granitoids. On the imagery and on the aerial photographs this unit can be delineated from their lighter tone, coarse texture, dendritic and joint controlled drainage patterns. This unit is moderate to highly jointed and their contact is very sharp with the country rock (Photograph 11). On field verification, these are found to be leucocratic, pink to grey coloured and medium to coarse grained. Crude gneissosity at places are marked by mega crystals of potash feldspar. Biotites are also responsible for giving these rocks a faint gneissosity.

3.1.4 Carbonatite-Alkali Complex

These semi-circular intrusives, composed mainly of alkali syenites, basic rocks and carbonatites, form the carbonatite-alkali intrusive complex of the Karbi Anglong district (Photograph 10). Field verification indicates that there are two types of carbonatites present in the area. One is the grey carbonatite and the other one is the white carbonatite. They are mostly coarse grained and equigranular, containing mostly calcite with biotite, magnetite and apatite as accessories.

A semi-circular drainage pattern has formed because of the shape of the intrusions of this complex. Such a semi-circular body occurs one and a half kilometre SE of Samchamapi village (26°12'48"N : 93°23'0" E). It covers about 12 sq. km. area. It is marked by light
Photograph 10: LANDSAT-5 (TM) imagery showing intrusive bodies of alkali syenite (S) in the Gneissic Complex (Gn). The main intrusive is distinctly seen at the centre.

Photograph 11: IRS-IA (LISS-II) imagery showing the contact between granite (Gr) and quartzite (Q) rocks. NE-SW shear zone controls the course of the Barpani river.
grey phototone on aerial photographs and satellite imagery.

3.1.5 Basic and Ultrabasic Intrusives

The basic and ultrabasic intrusives occur at several places in the district. Most of the intrusives occur along the major fracture zones. A circular topographical depression occurs at the south-western part of Hima Parbat (26°26'10"N : 93°28'55"E), which appears to be a plug like basic intrusive surrounded by granitic rock (Photograph 9). Other intrusive bodies are met with during the traverses but because of their small size these intrusives are difficult to be demarcated from aerial photograph or imagery.

3.1.6 Trap Rocks

Trap rock occurs at various places in the district. At most places the traps are highly weathered, decomposed, lateritic and brown to brick red coloured. Such occurrences are seen close to the Jamuna river east of Jamuna falls, Disobal nala near Diphu and in the south western part of Hamren sub-division. On the imagery and aerial photographs, these occurrences are not very clear due to their small dimensions.

3.1.7 Tertiary Groups

The Tertiary Group of rocks occurs in the southern and south eastern parts of the district and can be very easily distinguished in the aerial photographs and satellite imagery from the Precambrian rocks by their smooth texture and light grey to dark grey tones
Within the Tertiary rocks, four different groups of rocks occur and they can be separated from their tone, texture, vegetation cover and drainage density and its pattern.

During the field verification, these four groups are identified as the Jaintia-Disang group, the Barail group, the Tipam-Surma group and the Dihing groups.

3.1.7.1 The Jaintia and Disang Group

The rocks of the Jaintia and Disang Group extend in a NE-SW direction from the north-eastern part of Nambar forest to south-eastern part of Sangot (south eastern part of Hamren sub-division) via Manja. The rocks are moderately compact, highly dissected and consist mainly of sandstone, sandyclay, shale, mudstone, fossiliferous limestone, carbonaceous shale and thin coal seams.

This group of rocks occurs directly over the Precambrian basement in the Diphu sub-division, while in the Hamren sub-division it occurs over the Shillong Group of rocks. On the aerial photographs and satellite imagery it shows smooth texture, light grey to grey tone, moderate to highly dissected zones.

3.1.7.2 The Barail Group

It occurs around Chotalongphar and in north-eastern and south-western parts of Diphu sub-divisions. The rock types consist mainly of buff coloured, fine to medium grained thinly bedded sandstone intercalated with shales.
3.1.7.3 The Tipam and Surma Group

Tipam and Surma group of rocks occur along the south eastern part of the district. The rocks are compact or moderately so. The rocks consist mainly of coarse to medium grained feldspathic sandstone, sandy shale and mottled clay. Wood fossils are very common in the rocks.

3.1.7.4 The Dihing Group

Dihing group of rocks occur at two different places in the district (Fig. 7). It occupies large areas on the south-east and north-east corners of the district. It consists mainly of boulder and pebble beds with subordinate amount of clay. On the photographs and satellite imagery it shows medium tones with smoothly rounded mounds with intermontane valleys.

3.1.8 The Alluvium

Recent alluvium occurs along the western part of Dhansiri (Photograph 12), Jamuna and Dikharu rivers and in the eastern part of Kopili river (Photograph 13). Older alluvium occurs at a slightly higher level than the younger alluvial plain and these are situated mostly along the foothills. On aerial photographs and satellite imagery they show light tone, patchy appearance of the cultivated fields. These have low drainage density with smooth and flat surfaces.

The tentative geological succession of the district has been determined by field traverses and verified through imagery and aerial
Photograph 12: IRS-IA(LISS-I) imagery showing alluvial plains on the highly meandering Dhansiri river and dinudational hills of Gneissic (Gn) and Tertiary Group (T) of rocks.

Photograph 13: IRS-IA(LISS-I) imagery showing alluvial plains of the Kopili and Jamuna rivers on the Gneissic Complex (Gn), Shillong Group (Sh) and Tertiary Groups of rocks.
<table>
<thead>
<tr>
<th>Age Group</th>
<th>Formation</th>
<th>Description of lithounits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent</td>
<td>Newer Alluvium</td>
<td>Shingles, sand, silt and clay</td>
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<tr>
<td></td>
<td>Unconformity</td>
<td></td>
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<tr>
<td>Pleistocene</td>
<td>Older Alluvium</td>
<td>Clay, coarse sand, gravels, boulders</td>
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<td></td>
<td>Unconformity</td>
<td></td>
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<tr>
<td>Pliocene</td>
<td>Dihing</td>
<td>Pebble bed, soft sandy clay and grit</td>
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<tr>
<td></td>
<td>Unconformity</td>
<td></td>
</tr>
<tr>
<td>Miocene</td>
<td>Tipam/ Surma</td>
<td>Feldspathic brownish sandstone, clay, shale with silicified and</td>
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<tr>
<td></td>
<td>Not differentiated</td>
<td>carbonised wood fossils</td>
</tr>
<tr>
<td></td>
<td>Unconformity</td>
<td></td>
</tr>
<tr>
<td>Oligocene</td>
<td>Barail</td>
<td>Ferruginous, thickly bedded fine to medium grained sandstone</td>
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<tr>
<td></td>
<td>Not differentiated</td>
<td>and shale</td>
</tr>
<tr>
<td></td>
<td>Unconformity</td>
<td></td>
</tr>
<tr>
<td>Eocene</td>
<td>Jaintia/ Disang</td>
<td>Fine to medium grained sandstone, limestone and shale</td>
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<td></td>
<td>Not differentiated</td>
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<tr>
<td></td>
<td>Unconformity</td>
<td></td>
</tr>
<tr>
<td>Upper Cretaceous</td>
<td>Carbonatite/ Alkali Complex</td>
<td>Basic intrusives including mafic, ultramafics and carbonatite and alkali-syenite intrusives</td>
</tr>
<tr>
<td></td>
<td>Unconformity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acidic intrusives</td>
<td>Granites and veins.</td>
</tr>
<tr>
<td></td>
<td>Basic intrusives</td>
<td>Epidiorite, diorite</td>
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<td>Shillong</td>
<td>Shillong formation: Quartzite with bands of phyllite and</td>
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<tr>
<td></td>
<td>Shillong</td>
<td>conglomerate</td>
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<tr>
<td></td>
<td>Unconformity</td>
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<tr>
<td></td>
<td>Mica schists/gneisses with feldspathic quartzite quartzite and quartz-mica-sillimanite-schists.</td>
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<td>Precambrian</td>
<td>Tyrsad</td>
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<td></td>
<td>Unconformity</td>
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<td></td>
<td>Gneissic Complex</td>
<td>Quartzo-feldspathic gneiss with amphibolite, granulite, mica-</td>
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<td></td>
<td></td>
<td>schist and calc silicate rocks.</td>
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<tr>
<td></td>
<td></td>
<td>Granite, aplitic and pegmatitic intrusives</td>
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photo interpretation and compared with earlier works carried out by Mathur and Evans (1964), Barooah and Goswami (1972) and Dasgupta (1977), as presented in Table 7.

3.2 Structures and Tectonics

Geologically the Karbi Anglong district is a part of the Shillong Plateau. It consists mostly of Precambrian rocks with a thin mantle of Tertiary rocks occurring along the southern and south-eastern parts of the district. The area seems to have been uplifted and faulted during the Tertiary period (Krishnan et al. 1960).

From the study it has become apparent that the area is tectonically disturbed giving rise to different structural patterns. These include both planar and linear structures, bedding planes foliation, joints, fractures, crush belts, folds and various types of lineations were recognised.

The gneisses are well foliated, which has a general NE-SW trend. Folds are not common and are confined to limited zone, where folds of plastic nature occur. These folds that refold the dominant foliations in the rocks are themselves not associated with axial planar foliation. According to Barooah (1972), the plastic nature of folds was due to higher mobility of the rocks during folding which might have been caused by deep burial. However, the frequent association of folds with pegmatitic granitoid materials indicates
that the folding might have also accompanied the mobilisation of the granitic material during migmatisation of the rocks.

The depositional stratification of the Shillong Group is well preserved. It strikes ENE-WSW. The rocks mainly the argillaceous parts are folded by small isoclinal folds, which are associated with axial planar foliation. The upper—mainly quartzitic rocks are infrequently folded by low plunging, open asymmetrical folds.

Due to the high presence of argillaceous content and thick vegetation cover the bedding planes in the Tertiary rocks are not very distinctly shown both in aerial photographs and in satellite imagery. However, these are well shown on the river and road cuttings.

Lineaments are observed almost in all the rock units (Fig. 8). Statistical analysis indicates that lineament density is maximum in the Gneissic Complex and least in the Shillong Group (Fig. 10). In the Tertiary rocks their occurrence is moderately higher than in the Shillong Group. Four main sets of lineaments are observed in the district. These trend in NNE-SSW, NE-SW, E-W and NW-SE (Fig. 10). The NW-SE lineaments are limited in numbers lineaments mentioned above primarily include joints, fractures, faults and shear planes.

3.2.1 Tectonic Evolution

To understand the lineament pattern, it is necessary to have a comprehensive view of the regional structural and tectonic setting of the terrain (Fig. 9). Karbi Anglong district consists of rocks
Figure 8.

LINEAMENT MAP OF KARBI ANGLONG DISTRICT, ASSAM
INTERPRETED FROM IRS-I A (LISS-II) LANDSAT(TM) & AERIAL PHOTOGRAPHS

LEGEND

Alumina
Tertiary Group
Granite
Shearing Group
Genetic Group
Shear Zone
Fault
Lineament Major
Lineament Minor
Lithological Boundary
River
State Boundary
District Boundary
Figure 9.
Rose diagram showing lineament direction in three different lithounits of Diphu sub-division based on Satellite imagery (TM) & Aerial photographs.

Figure 10.
belonging to the Precambrian, Mesozoic and Tertiary ages. These rocks cover about 87% of the total geographical area of the district. The remaining part is covered with both Older and Newer alluvium, most of which consist of river/stream borne sediments. The rocky terrain contains a thin cover of residual soil, the thickness of which varies from 1 m to 30 m.

The Precambrian rocks consist of the Gneissic Complex and the Shillong Group. The Gneissic Complex consists mainly of quartzofeldspathic gneisses, in which occur isolated enclaves of amphibolite, metadolerite, charnokitic rocks, mica schists and calc silicate rocks.

The quartzofeldspathic gneisses contain both planar and linear structure (Fig. 11). The planar structures include lithological layers (S\textsubscript{0}) and gneissocity (S\textsubscript{1}). The linear structures includes folds (F\textsubscript{1}, F\textsubscript{2}, F\textsubscript{3} Fig. 11) and lineation (L\textsubscript{1}, L\textsubscript{2}).

The lithological layering is marked by alternating layers of felsic and felsic bands. This lithological layering may represent original sedimentary layerings (Barooah, Goswami & Barman, 1983). All these structures were developed during different phases of deformation (D) developed in successive phases of D\textsubscript{1}, D\textsubscript{2} and D\textsubscript{3}.

3.2.1.1 The Gneissic Complex

Evidences of three phases of deformation exist in this Group
Figure 11. Geological structures on the Gneissic Complex showing three phases of deformation.
(a) First Phase of Deformation ($D_1$)

The lithological layering ($S_q$) was deformed by a set of tight isoclinal folds, $F_1$ (Fig. 11). The axial planes of these folds are sub-horizontal. Weak axial planar mineral growth defines the tectonic banding the dominant foliation ($S_1$) in the rocks. Because of isoclinal nature of the $F_1$ folds, the $S_1$ is parallel to $S_q$ on the limbs of the folds (Photograph 14). The lineation is poorly defined and represented by quartz rodding and intersection lineation.

(b) Second Phase of Deformation ($D_2$)

The second phase ($D_2$) is marked by the development of large, NE-SW trending monoclinal to asymmetrical folds, $F_2$ (Fig. 11). This set of macroscopic and mesoscopic folds affects both $S_o$ and $S_1$. The folds are not associated with the development of planar structure. For lineation associated with this set of folds is defined by quartzo-feldspathic rocks. The axial planes $S_2$ of the $F_2$ folds are sub-vertical and curved due to the effects of later deformation.

(c) Third phase of deformation ($D_3$)

The third phase ($D_3$) of deformation is marked by the development of $F_3$ folds. $D_3$ is associated with E-W to ESE-WSW trending shear zone and affects all the earlier structural elements described hitherto.

The Shillong Group consists of metamorphic rocks of sedimentary origin. It rests unconformably on the Gneissic Complex.
The unconformity is locally marked by a conglomerate. The rocks of the Shillong Group are divisible into a lower argillaceous and an upper arenaceous division, separated by a conglomerate bed. Bedding planes ($S_0$) are well recognised in both the divisions. The rocks are repeatedly deformed. Three phases of deformation $d_1$, $d_2$ and $d_3$ are recognised, where different planar and linear structures were developed.

3.2.1.2 The Shillong Group

Evidences of three phases of deformation exist in this Group.

(a) First phase of deformation ($d_1$)

The rocks of the lower division are mainly argillaceous. Lithological layering ($S_0$) are defined by layers rich in argillaceous alternating with layers rich in arenaceous material. These layers ($s_1$) are folded into small scale isoclinal folds ($f_1$) during the first stage of deformation $d_1$. The folds are associated with axial planar foliation ($s_1$). $s_1$ is parallel to $S_0$ except along the crest of the folds (Fig. 12e and f). Metamorphic differentiation has taken place parallel to $s_1$ and is better shown in the layers rich in argillaceous material.

Both $S_0$ and $s_1$ were thrown into open asymmetrical folds with sub-horizontal axes (Fig. 12e) during the 2nd phase of deformation. During the last phase ($d_3$) strain slip cleavages occur along foliation planes, producing kinking in the schistose rocks (Photograph 15).
Figure 12. Geological structures showing different phases of deformation in Karbi Anglong district.
Photograph 14: Field photograph of tight recumbent fold with lithological layering ($S_3$) parallel to the fold axis ($S_1$).

Photograph 15: Field photograph of open folds in quartz rich layers of metapelitic rocks. Foliation ($S_1$) in the schists is well developed, while the quartz rich layers show development of fracture cleavages.
(b) Second phase of deformation ($d_2$)

The rocks of the upper division were folded into open, asymmetrical, gently plunging folds ($f_2$). The rocks of the lower division are also affected. This folding led to the reorientation of the bedding planes ($s_0$) into their present disposition. The occurrences of these folds can be ascertained from aerial photographs and are confirmed during field checking. The fold ($f_2$) exerts strong control on the present structural configuration of the area. $f_2$ folds occur in macroscopic and mesoscopic scale (Fig. 12a,b,c) and affected $s_0$, $s_1$ and their associated linear fabrics. The ($f_2$) folds generally trend ENE-WSW. However, ($f_2$) folds trending N-S and E-W are also noticed. The plunge of folds is low in the dimension either the NE or SW. These variations are due to the effect of later tectonic activities. According to Rahman (1969), the shape and direction of plunge of folds on either side of the Mylliem granite is due to the intrusion of the granite into the already folded upper division of the Shillong formation. A similar mode of variation in the plunge direction on either side of the Hamren granite is also noticed. During field verification in the north western part of Samalangso, en-echelon pattern of occurrence of folds are seen.

(c) Third phase of deformation ($d_3$)

A set of tight, steeply plunging folds ($f_3$) occurs in close association with crush zones (Fig. 5 S-S). These folds affected the structural elements developed during the earlier phases of
deformations \(d_1\) and \(d_2\). These folds (\(f_3\)) are steeply plunging (Fig. 13) with parallel strike slip cleavages. Open to steeply plunging folds (\(f_3\)) with axial planar joints, are common in the area (Fig. 12-d and photograph 16). The amplitude of these folds varies from a few centimetres to several metres. The folds are of variable style and are well developed.

3.2.1.3 Later deformational episodes

Fractures of late deformation are recognised by their effects on earlier formed planar features, although the sequential development of all these late deformations is not always possible to be established. Most of these are the result of semibrittle to brittle types of deformation. At least four major sets of joints and several minor and major faults belonging to these late deformations occur in the area (See section 3.4).

3.2.1.4 Post Precambrian structural elements

Semicircular basic/alkaline igneous rock bodies occur in the area. These occur in a NE-SW trending structural depression. The depression extends south-westwards and meet the Sung valley graben in the Meghalaya (GSI Report). There are evidences of several episodes of igneous activities ranging from older granitic domes belonging to the Precambrian age to later alkaline plutons. The fission track ages of the alkaline rocks at the Sung valley is estimated at 106 m years by Acharjee (1986) and at 141 \(\pm\) 25 m years by Ghosh (1989), thus indicating their Cretaceous age. This is taken to indicate that the
Figure 13. Crush zone in the Shillong Group of rocks. The crushing is accompanied by the development of fractures along with the dominant foliation (s1) in the rocks were dragged parallel to the fractures to produce a strain slip cleavages (s2).
Photograph 16: Field photograph of well bedded quartzite open folded with the development of fracture cleavages axial planar to the folds.

Photograph 17: Field photograph of highly slickensided Shillong Group of rocks in Hamren sub-division.
alkaline rocks of Karbi Anglong occurring in the same structural continuation of the Sung valley also belong to the Cretaceous age.

The Tertiary Group, consisting of arenaceous, argillaceous and calcareous rocks, occur unconformably on the Precambrian rocks consisting of gneisses, quartzite, metapelite and granites. The Tertiary rocks are well bedded ($S_0$). Several unconformities (Table 7) occur in these rocks. The rocks show well developed cross bedding. The unconformities and the bedding planes between the diverse lithounits are visible even on the imageries. These rocks belonging to the shelf facies (Krishnan, 1960, pp 496-497) are separated from the geosynclined facies of rocks by the Naga Thrust, which falls south of the area under consideration.

3.2.1.5 Igneous activities and their relationship with the structures of the area.

Several episodes of igneous activities can be identified in the area. The first episode took place prior to the folding ($F_1$) and the development of axial planar foliations ($S_1$) in the Gneissic Complex (Fig. 11). These igneous rocks were of basic composition and were $F_1$ folded and $S_1$ foliated.

There were several episodes of emplacement of granitic rocks during the Precambrian times. However, all were younger than the $D_1$ phase of deformation. Apart from the post $D_2$ and post Shillong Group granitic rocks, the other episodes of emplacement can not be separately identified. The granitic rocks includes aplites, pegmatite
and granites. The granite bodies form small to huge stocks, bosses and batholiths of semicircular to circular shape. A few smaller bodies, elongated parallel to the structures in the host rocks are also seen. The shape of the granitic bodies can easily be ascertained from aerial photographs and imageries. These also influence the drainage pattern of the area.

Basic intrusive rocks include post Shillong Group, Precambrian Khasi Greenstone and Cretaceous (?) alkaline rocks. The Khasi Greenstone occurs as dykes and sills in the Shillong Group and also identified from aerial photographs and imageries, because these rocks are less resistant to erosion than the surrounding quartzite and thus form elongated depressions on the topography. The alkaline rocks together with carbonatite follow a structural lineament developed during the Cretaceous times.

The Precambrian rocks of the area show evidence of polyphase deformation and polymetamorphism. Although these Precambrian rocks are often correlated with the Dharwars (Krishnan 1960, Table 19, pp 151-155); however, their lithologies differ in detail. Recent age dating (Sarkar 1986, pp 26, Table 11; Talukdar et al. 1982) also showed that the rocks of Shillong Group are much younger by circa 1800 m.y. Accordingly, it is suggested that the rock of Shillong Group cannot be correlated with the Dharwar.
3.3 Lineaments

Since the advent of remote sensing technology various workers have emphasized the importance of aerial photographs and satellite imagery in structural analysis, specially in the lineament - tectonic mapping for ground water targeting. Boyer and Queen (1964), Lattman and Parizek (1964), Trainer and Elison (1967), Siddique and Parizek (1971) were some of the earlier workers who showed useful correlation between lineament detected on aerial photographs and the occurrence of ground water.

A lineament map of the Karbi Anglong district has been prepared from satellite imagery i.e. LANDSAT 5 (TM) FCC, IRS-1A (LISS-II) FCC and aerial photographs of 1:50,000 scale (Fig. 8). Lineaments can be easily identified both on satellite imagery and aerial photographs in the hilly terrain. On the alluvial plain it is difficult to identify them except in a very few cases with additional help from drainage characteristics and vegetation. The study of lineaments are mostly connected with the exploration of groundwater.

3.3.1 Lineaments: General concepts and definition

The term lineament has been used widely. However, the meaning of the term varies from worker to worker. O' Leary et al. (1976) defined lineaments as a mappable, simple or composite linear feature of a surface whose parts are aligned in a rectangular or slightly curvilinear relationship and which differ distinctly from the patterns of adjacent features and presumably reflects a surface phenomenon.
Hobbs (1911) considered lineaments as rectilinear earth features manifest in the landscapes by (i) crust or ridges of the boundaries of the elevated areas, (ii) the drainage lines, (iii) boundary lines of formations of photographic rock types or of lines of outcrops. Sondar (1947) expanded the concept of a lineament to a general regional designation to denote a definite direction which is contained in the tectonics, the joints and the relief. Gwinn (1964) drew lineament on the basis of old areas, culminations and transverse sedimentary facies changes deduced from sub-surface data, whereas Rosger (1970) drew lineaments from structural data on a geological map. Lattman (1958) defined photographic lineament as a natural linear feature consisting of topographic (including straight stream segments), vegetation and soil tonal alignments, visible primarily on aerial photographs or mosaic and expressed continuously or discontinuously for many kilometres. Qureshy et al. (1989) defined lineament as a regional scale linear or curvilinear feature, pattern or change in pattern that can be identified in a data set and attributed to a geologic formation or a structure.

Photolineaments generally represent the surface traces of fractures in bed rocks, projected more or less vertically upward to the erosion surface by various mechanisms. These linear features or lineaments are lines chosen from images on the assumption that they originate through geologic processes. If the lineaments originate through geologic processes, it is often a fracture (faults or joints) or a linear expression of fracture system or shear zones. The
fractures are reflected in many forms like topographic, relief lineaments. For example, there may occur straight lineaments of rivers and streams, straight fractures, valleys, straight and narrow valleys due to differential erosion by leaching or surface run off and vegetal lineaments (Srinivason, 1988).

The definition of O' Lary et al. (1976) and Qureshy et al. (1989) which are almost similar met the requirements of photo interpretation techniques and have been followed in the present work.

3.3.2 Scope of the work

The lineament analysis has been taken up with the following objectives:

1. To map all the lineaments observed on the aerial photographs and IRS-1A LISS-II FCC and LANDSAT-TM imagery (FCC) with a view to decipher lineament tectonic framework of the area.

2. To generate detailed information base that can be utilised for groundwater targeting.

3.3.3 Methodology of lineament analysis

Karbi Anglong district has experienced a complex tectonic evolution. Therefore, a detailed structural analysis is necessary to evaluate the structural history of the area. However, as the present study is primarily related to ground water exploration, a detailed structural analysis is beyond its scope. Emphasis has therefore been given on the detection and mapping of the lineaments. A detailed
The lineament tectonic map of the study area is shown in Fig. 9. Linear fractures such as joints, faults, fractures, schistosity plan and shear zones may occur as linear depressions or lines of weakness which are mapped up to as short as 0.25 km in length. Most of the major lineaments are 25 km or more in linear extent. The maximum length of lineament recorded is 165 km. The majority of lineaments are rectilinear; and the others are curvilinear. The lineaments generally cut across one another. Some of the major lineaments occur in the area have been described as faults and shear zones. The trace of bedding and foliation appear as closely spaced trend lines along a particular direction. The high density of trend lines having preferred orientation in one direction occur as thin discontinuous feather lines with wavy appearance on the imagery which is characteristics of foliation (schistosity and gneissosity). A brief description of the various major lineaments in terms of their trend, extension and expression on
Rose diagram showing the combined length of lineament in three different lithounits of Diphu & Hamren subdivision of Karbi Anglong district.

Figure 14.
<table>
<thead>
<tr>
<th>Preferred Orientation</th>
<th>Gneissic Complex</th>
<th>Shillong Group</th>
<th>Tertiary Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total No. of lineaments in Gneissic Complex</td>
<td>Total length in km</td>
<td>Average length in km</td>
</tr>
<tr>
<td>0°- 10°</td>
<td>299</td>
<td>310.3</td>
<td>1.03</td>
</tr>
<tr>
<td>10°- 20°</td>
<td>284</td>
<td>389.4</td>
<td>1.37</td>
</tr>
<tr>
<td>20°- 30°</td>
<td>222</td>
<td>354.6</td>
<td>1.59</td>
</tr>
<tr>
<td>30°- 40°</td>
<td>168</td>
<td>427.5</td>
<td>2.54</td>
</tr>
<tr>
<td>40°- 50°</td>
<td>255</td>
<td>453.1</td>
<td>1.77</td>
</tr>
<tr>
<td>50°- 60°</td>
<td>244</td>
<td>439.2</td>
<td>1.8</td>
</tr>
<tr>
<td>60°- 70°</td>
<td>236</td>
<td>526.4</td>
<td>2.23</td>
</tr>
<tr>
<td>70°- 80°</td>
<td>253</td>
<td>508.0</td>
<td>2.00</td>
</tr>
<tr>
<td>80°- 90°</td>
<td>256</td>
<td>481.6</td>
<td>1.88</td>
</tr>
<tr>
<td>90°-100°</td>
<td>276</td>
<td>457.5</td>
<td>1.65</td>
</tr>
<tr>
<td>280°-290°</td>
<td>54</td>
<td>106.8</td>
<td>1.97</td>
</tr>
<tr>
<td>290°-300°</td>
<td>88</td>
<td>150.9</td>
<td>1.70</td>
</tr>
<tr>
<td>300°-310°</td>
<td>49</td>
<td>71.7</td>
<td>1.48</td>
</tr>
<tr>
<td>310°-320°</td>
<td>27</td>
<td>42.7</td>
<td>1.58</td>
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<td>320°-330°</td>
<td>25</td>
<td>31.5</td>
<td>1.26</td>
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<td>330°-340°</td>
<td>38</td>
<td>53.6</td>
<td>1.41</td>
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<tr>
<td>340°-350°</td>
<td>76</td>
<td>114.7</td>
<td>1.50</td>
</tr>
<tr>
<td>350°-360°</td>
<td>173</td>
<td>204.2</td>
<td>1.18</td>
</tr>
<tr>
<td>Grand Total</td>
<td>3023</td>
<td>5124.7</td>
<td>964</td>
</tr>
</tbody>
</table>
### TABLE 8(b): ANALYSIS OF LINEAMENTS OF KARBI ANGLONG DISTRICT (HAMREN SUB-DIVISION)

<table>
<thead>
<tr>
<th>Preferred Orientation</th>
<th>Gneissic Complex</th>
<th>Shillong Group</th>
<th>Tertiary Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total No. of lineaments</td>
<td>Total length in km</td>
<td>Average length in km</td>
</tr>
<tr>
<td>0° - 10°</td>
<td>429</td>
<td>1521.0</td>
<td>3.54</td>
</tr>
<tr>
<td>10° - 20°</td>
<td>280</td>
<td>408.0</td>
<td>1.45</td>
</tr>
<tr>
<td>20° - 30°</td>
<td>198</td>
<td>363.3</td>
<td>1.83</td>
</tr>
<tr>
<td>30° - 40°</td>
<td>213</td>
<td>325.0</td>
<td>1.52</td>
</tr>
<tr>
<td>40° - 50°</td>
<td>211</td>
<td>426.3</td>
<td>2.02</td>
</tr>
<tr>
<td>50° - 60°</td>
<td>165</td>
<td>372.4</td>
<td>2.25</td>
</tr>
<tr>
<td>60° - 70°</td>
<td>142</td>
<td>277.2</td>
<td>1.6</td>
</tr>
<tr>
<td>70° - 80°</td>
<td>150</td>
<td>308.0</td>
<td>2.01</td>
</tr>
<tr>
<td>80° - 90°</td>
<td>227</td>
<td>315.0</td>
<td>1.38</td>
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<tr>
<td>90° - 100°</td>
<td>289</td>
<td>377.6</td>
<td>1.30</td>
</tr>
<tr>
<td>280° - 290°</td>
<td>80</td>
<td>91.5</td>
<td>1.14</td>
</tr>
<tr>
<td>290° - 300°</td>
<td>16</td>
<td>32.0</td>
<td>2.00</td>
</tr>
<tr>
<td>300° - 310°</td>
<td>12</td>
<td>10.8</td>
<td>0.9</td>
</tr>
<tr>
<td>310° - 320°</td>
<td>5</td>
<td>5.5</td>
<td>1.1</td>
</tr>
<tr>
<td>320° - 330°</td>
<td>5</td>
<td>3.6</td>
<td>0.72</td>
</tr>
<tr>
<td>330° - 340°</td>
<td>13</td>
<td>16.2</td>
<td>1.24</td>
</tr>
<tr>
<td>340° - 350°</td>
<td>36</td>
<td>47.7</td>
<td>1.32</td>
</tr>
<tr>
<td>350° - 360°</td>
<td>129</td>
<td>124.0</td>
<td>0.96</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>2600</strong></td>
<td><strong>5022.1</strong></td>
<td></td>
</tr>
</tbody>
</table>
the satellite imagery and aerial photographs as well as their interpretation is given in Table 8a,b.

Based on the style and trend of the features such as lineaments, fold axes and foliation observed on the satellite images and the topography, the study area can be divided into three major tectonic domains viz. (i) the Hamren division on the West, (ii) the Diphu division on the North and (iii) Diphu division on the South.

3.3.5 Control of lineaments on drainage pattern

Most of the streams and rivers (3rd order and above) of the study area are controlled by the lineaments i.e. joints, faults, bedding planes and shear zones. A description in this regard follows for the two sub-divisions.

3.3.5.1 Hamren division on the West

The area consists of Precambrian rocks belonging to both the Gneissic Complex and the Shillong Group. Topographic height varies from 225 to 1052 m.s.l. The foliation in the gneisses and the bedding planes in the Shillong Group strike NE-SW to ENE-WSW. The Shillong Group of rocks belonging to the lower divisions are schistose and gneissic while the upper division is quartzose. The minor granite bodies are nonfoliated. The rocks are weathered and the depressions on the rock surface are covered with soil varying in the thickness from 2 to 6 m.
The regional lineament tectonic pattern map prepared from satellite imagery and aerial photographs shows the NE-SW lineaments and structural trends in the Precambrian rocks are almost conformable.

Some of the major lineaments of the area represent faults or fault zones. The Kopili fault trends NW-SE. The Barpani fault trends NE-SW and is a shear zone which extends upto the Kaliyan in east Diphu division. It is marked by low elevation. This shear zone generally controls the drainage. All the drainage in this region are controlled by the joints, fractures, faults, lithological boundaries and shear belts. Therefore, it becomes apparent that structures occurring in the area are responsible for controlling the drainage pattern and promoting spring zones in the area. Rose diagrams show that the most predominant direction of lineament in Hamren division is N-S. This is followed in predominance by the E-W, ENE-WSW and NE-SW lineaments (Fig. 15).

3.3.5.2 Diphu division on the north (Samalangso, Rongnongwae, Milip)

The Diphu division on the north can also be divided into two zones;
(a) The denudo-structural hills on the north and (b) denudational hills of Gneissic Complex on the south.

The prominent rock types exposed in the area are the highly metamorphosed Precambrian Gneissic Complex and less metamorphosed Shillong Group comprising of quartzites, phyllites and conglomerates. The general trend of Shillong Group of rocks is mostly ENE-WSW and in
Rose diagram showing lineament directions in two different lithounits of Hamren Sub-division on Aerial photographs & Satellite imagery (TM).

Figure 15.
the Gneissic Complex mostly NE-SW. The denudostructural hills of the north form a plateau. The topographic height of the plateau ranges upto 1100 m above m.s.l. The metasediments show fold pattern which are conformable with the trend of bedding plane. Cuesta, fault, major joints, shear zone appears in this unit. The lineaments in this unit are found to be rather sparsely developed or poorly manifested as compared to the other rock units of the area. This is supposed to have been due to the lesser tectonic deformations of the rock. The major lineaments (joints) which trend NE-SW are similar to that of the Gneissic Complex. The length of the major joints ranges upto 40 km. These are definitely deep seated, open fractures caused by crustal movement of the region. Some of the lineaments are also developed along the strike of the bedding plane. The cuestas are developed along the strike of the foliation probably due to strike fault. A very limited number of lineaments are developed in NW-SE direction in this unit. Intrusions of basic dykes are also seen along the lineaments. The maximum length of lineament in this direction ranges upto 20 km. In the southern part of this unit there is a sheared zone along the Kaliyani river trending in ENE-WSW direction. Some of the lineaments cut across the sheared zone. Along this shear zone several springs both hot and cold occur. The shear zone generally controls the drainage of the Kaliyani.

The southern part of this unit is the denudational hills of Gneissic Complex consisting mostly of Precambrian quartzo-feldspathic gneiss with enclaves of hornblende-biotite gneiss, granite gneiss,
pyroxene-hornblende-granulite. The topographic height varies from 185 m to 1360 m above m.s.l. The structural trends are highly varied, though the rocks generally exhibit a NE-SW strike. The rocks are strongly deformed into tight plunging synform and antiforms with fold axes trending generally NE-SW and occasionally NW-SE.

The major lineaments trend ENE-WSW to NE-SW. Very few lineaments are trending in the NW-SE. The major lineaments are upto 50 km in length. Some of the lineaments trend NNE-SSW and WNW-ESE also. These are mostly developed in granitic rocks. From rose diagram (Fig. 10) it appears that most of the lineaments are developed in the NNE-SSW and ENE-WSW directions. The NE-SW lineaments are fewer in number.

3.3.5.3 The Diphu division on the south

The Diphu division on the south consists of Tertiary sedimentary rocks of low relief varying from 190 m to 600 m above m.s.l. The general strike of the bedding planes in the rock varies from NE-SW to E-W. The sedimentary rocks are folded along these directions. On aerial photographs and satellite imagery they appear as denudational hills with thick vegetation cover. The lineaments in these rocks are not as prominent as in the other rock units. It is probably due to the high argillaceous content and soft nature of the rocks. The maximum length of lineaments is upto 15 kms. A few major lineaments include the NNE-SSW Dhansiri fault and the WNW-ESE Jamuna fault. Rose diagram for the southern block, i.e. for Tertiary Groups
of rocks, shows that the majority of lineaments follow NE-SW direction, followed by those occurring in the NNE-SSW and WNW-ESE directions (Fig. 10). The NW-SE lineaments are of limited occurrence.

Considering on the basis of the lengths in the three different lithounits both in Hamren and Diphu divisions, it is seen that the NE-SW lineaments are the longest, followed by the NS and E-W lineaments for Gneissic Complex in the Diphu sub-division (Fig. 14); but in Hamren division the maximum length occurs in N-S direction. In the Shillong Group of rocks of Diphu sub-division maximum length occurs in ENE-WSW followed by NNE-SSW direction and in Hamren sub-division maximum length occurs in NS direction followed by NE-SW and WNW-ESE.

In the Tertiary Group of rocks maximum length occurs in NNE-SSW direction followed by NE-SW and WNW-ESE.

3.3.6 Control of lithounits on lineaments

The rose diagrams for all the three different lithounits i.e. for Gneissic Complex, Shillong Group and Tertiary Group of rocks show distinct variations in the lineament pattern. It is seen that the maximum number of lineaments occur in the Gneissic Complex, while they are at a minimum in the Shillong Group. In all the lithounits the number of lineaments trending NW-SE are limited. It is also noted that the Shillong Group of rocks of Diphu north division (Samalangso, Rongnongwae –Nilip) contain lesser number of lineaments compared to the Hamren division. High density of lineaments indicates high
secondary porosity and the intersecting nature of the lineaments indicates high permeability as well. The porosity and permeability that exist in the gneisses, Shillong Group of rocks, granitic and alkaline rocks of the area are the result of secondary openings such as fractures, faults and dislocations (cf Rasta Saugee et al. 1987). The study further reveals that, except in the Tertiary group and the Shillong Group of Diphu north division, the lineaments are mostly open in nature.

The intensity and linear persistence of the lineaments of different groups of rocks have been analysed statistically and also represented by rose diagrams (Fig. 10, 14, 15 and 16). These analyses show (Fig. 14) that the lineaments of the area belong to four major groups, trending NNE-SSW, NE-SW, E-W and NW-SE directions. The NE-SW and ENE-WSW lineaments conform with the structures in the basement, while the other two are younger and appears to have been superimposed on the basement structures. The lineaments described above primarily include joints, fractures (both major and minor) faults, shear planes, unconformity and lithological boundaries.

The preferred orientations obtained from rose diagram will be useful for prioritising groundwater exploration along certain lineaments. A few regional lineaments picked up during the course of present study are of great significance for groundwater exploration and have been described in the Chapter 3.4.4, Table 9.
Rose diagram (cumulative) showing lineament direction in the Diphu and the Hamren sub-division of Karbi Anglong district, Assam

Figure 16.
### TABLE 9: DESCRIPTION OF MAJOR LINEAMENTS IN THE AREA (REF. FIG. 9)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of the Lineament</th>
<th>Trend</th>
<th>Extension length in km</th>
<th>Evidence on AP Imagery</th>
<th>Interpretation</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jamuna Fault</td>
<td>WNW-ESE</td>
<td>33</td>
<td>Linear depression, change in landuse</td>
<td>Depress valley with high moisture</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Kopili Fault</td>
<td>NW-SE</td>
<td>35</td>
<td>Wide linear depression, major river course flowing along the depress zone</td>
<td>Wide valley, thick deposits of valley fills</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Dhansiri Fault</td>
<td>NNE-SSW</td>
<td>38</td>
<td>-do-</td>
<td>-do-</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>North of Burapahar</td>
<td>E-W</td>
<td>55</td>
<td>Linear depression, with braccia</td>
<td>Linear depress valley, high moisture, dark grey tone</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Rongpi Fault</td>
<td>NE-SW</td>
<td>27</td>
<td>-do-</td>
<td>Linear depression</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Kaliyani- Dikharu - Barpani Shear</td>
<td>NE-SW</td>
<td>165</td>
<td>Wide linear depression with shear plane, change in landuse pattern, valley fills zone</td>
<td>Moderately wide valley, dark grey tone on aerial photos. Interpreted as wide shear zone</td>
<td></td>
</tr>
</tbody>
</table>
3.3.6.1 Unconformity

Several unconformities occur in the area. However, it is not possible to identify all of them through visual interpretation. A few unconformities are very distinct, such as the one between the Gneissic Group and the Shillong Group, between the lower and upper divisions of the Shillong Group. The unconformities within the Tertiary rocks such as those between Jaintia-Disang and Barail, Barail and Tipam, Tipam and Dihing groups are not very distinct. Within the Shillong Group the unconformity between Shillong formation and Tyrsad formation is also very distinct (Photograph 6) and can be delineated with the help of interpretation technique on the basis of tone, texture and pattern. The angular unconformity between Tyrsad and Shillong formation in the north western corner of Hamren sub-division is very clear (Fig. 9).

3.3.6.2 Faults

Faults are structurally weak planes along which movement of geological sequence is observed. A limited number of faults are inferred from the imagery and aerial photographs. They are the WNW-ESE trending Jamuna fault, the NW-SE trending Kopili fault and the NNE-SSW trending Dhansiri fault. An E-W fault, named here as Burapahar fault, occurs along the foot-hills of the Burapahar, separating the rocks of plateau from the Brahmaputra alluvial plain (Fig. 9) on its north. There are also other small faults which can be recognised only by field verification. Some of these faults act as conduits for the intrusions of basic dykes. The faults inferred from aerial photographs are now occupied by the streams and rivers. These are revealed as depressional
valleys in the satellite imageries.

3.3.6.4 Joints and Fractures

Although joints are relatively discontinuous features, many of them are well defined and persistent over long distances, producing a mosaic of joints in the area.

The joints (both major and minor, more than 0.25 km in length) are easily identified through visual interpretations of the imageries. These features are developed in all the rock formations and are expressed as linear features. These are well reflected by streams and vegetation patterns. From field observation it is found that the dip of the joints varies from 30° to vertical, although the majority of them are vertical. The concentration of joints is dependent on the rock types. The Gneissic Complex shows the maximum concentration of joints in the area. Their length varies from those identifiable in the aerial photographs (0.25 km) up to a maximum of 60 km. Most of them are either NNE-SSW or NE-SW. Several other sets of joints are also identified, although these are of minor occurrence. These are NW-SE, E-W and ENE-WSW joints.

The concentration of joints in the Shillong Group of rocks varies in the two divisions. In the lower metapelitic division the concentration of joints is marginally higher than in the upper quartzitic division. The trend of joints in the lower division is NE-SW and E-W, while in the upper division the joints are mostly NE-SW and ESE-WNW. Moreover, as a whole, the concentration of lineaments
(joints) in the Shillong Group is lower than those in the Gneissic and Tertiary Groups.

In the granitic rocks the concentration of joints is the highest. Two sets of joints, trending NNE-SSW and NE-SW, are very distinct in granitic rocks. In other intrusive rocks joints are not very distinct on the imagery or on the aerial photos.

The concentration of joints and fractures in the Tertiary rocks are slightly higher than in the Shillong Group of rocks. Their lengths vary from 0.25 km to 15 km. Most of them are either NE-SW or E-W. Very few NW-SE joints occur in these rocks. Physical verification in the field shows that the joints are usually non-gapping; however, the drainage systems on the rocks conform with the joints. Therefore, the joints play an important part in determining the drainage pattern, at least in the initial stages, in the area covered by the Tertiary rocks.

### 3.3.6.4 Shear Zone

A zone in which shearing has occurred on a large scale so that the rock is crushed and brecciated is identified as a shear zone. A very distinct NE-SW trending shear zone, named as Kaliyani-Dikharu-Barpani shear zone (Fig. No.9) occurs in the area under study (Photograph 9,11). The strike length of the zone in Karbi Anglong is 165 kms. It is up to 2 km in breadth. The zone is characterised by crushing of the rocks through which it passes. The effect of crushing varies from rock type to rock type. The gneisses
along the zone are brecciated with mylonitation in which flinty crush rocks occur. It is composed essentially of cryptocrystalline quartz and looks almost like flint. At some places well developed crystals of quartz are also formed. Elsewhere, the gneisses are transformed to tectonic conglomerate. The Shillong Groups of rocks are folded along the zone. The limbs of the folds are dislocated along which strain slips, cleavages and slickensided occur (Photograph 17). The zone in the Shillong Group is associated with sulphide mineralization.

The shear zone, affecting only the Precambrian rocks, is easily identifiable on aerial photographs and imageries. It traverses the whole district in a NE-SW direction. A shift from NE-SW to ENE-WSW direction occurs at the western part of Diphu sub-division. There is no offset of the trend of the shear zone but the shear zone is intersected by joints, indicating younger age of the joints. The shear zone is followed by the Kaliyani-Dikharu and Barpani rivers (Photograph 1 and 4).

The structures described above exercise observable control over the aquifer characteristics of the different rocks formations. The structurally weak planes act as conduits for the occurrence and movement of groundwater. The fault zone generally acts as conduits for groundwater movement, although the groundwater conditions depend partly also on lithology and stratigraphy. The intensity of fracturing is also an important factor (cf. Reddy, 1991). In the massive and brittle rocks like the granites, quartzites and limestone of the area, fractures along fault zones act as good
aquifers. In the argillaceous rocks like the metapelites and the shales, fracturing is not much effective in improving the porosity and permeability of the rocks, because secondary openings are not clean to allow free movement of groundwater. As such, there is only limited improvement in the transmissivity - vis-a-vis groundwater conditions in these rocks - even along the fault zones. Thus, in hard rocks which lack primary porosity and permeability, faults, fractures and joints with associated weathering act as conduits for movement of groundwater and form very good aquifer.

3.4 Ground truth data analysis

Detailed structural mapping in selected areas, while corroborating remotely sensed data, revealed the presence of major fold. Systematic statistical analysis of the structural data also shows that the rocks of the area possesses an almost homogenous symmetry on the scales.

The statistical representation of the poles to foliation ($S_1$) of the north-western part of the area shows that the foliation ($S_1$) was refolded. The trend of the fold axes is slightly variable. However, a general E-W (Fig. 17a) or NE-SW (Fig. 17b, c and d) trend is maintained by the fold. The change in the trend of foliation might have been caused by deformation occurring after the development of the fold.

The contour diagrams (Fig. 18) were prepared from the polar projection of joints on the lower hemisphere of equal area net and
Figure 17. Contoured plots of the poles of 110 foliations of Karbi Anglong district
Figure 18. Contoured diagrams of the poles of joints of Karbi Anglong district.
contoured following conventional method as described by Regan (1973, p 113). The number of joints projected is indicated in each diagram. The contour interval is kept at 1%. By the method of best fit, five major sets were determined for each of the Hamren division, Diphu north (i.e. Samalangso-Rongmongwae-Nilip division) and Diphu south division. It is seen that the joints are N-S, NE-SW and NW-SE. A very prominent horizontal set of joints occur in both the areas.

The following are the details of the faults occurring in the areas mentioned below.

**Hamren sub-division**

1. Kopili fault : It is a NW-SE fault and is covered by alluvium. From the drainage anomalies it can be presumed that the Kopili river is controlled by the fault.
2. The Barpani shear zone : It is a NE-SW fault zone. It is marked by a depression along which the Barpani river flows from SE to NE.

**Diphu sub-division**

1. The Burapahar fault : It trends E-W along the foot hills of the Burapahar.
2. Kaliyani-Dikharu Shear Zone : It trends SW-NE to ENE and is marked by a depression along which the rivers Kaliyani and Dikharu flows.
3. Dhansiri fault : It is a NNE-SSW fault covered by alluvium. The fault can be identified from the controlled drainage characteristics and bracciation in the nearby areas.
4. The Jamuna fault : It trends from WNW to ESE directions.

There are also other minor faults like the NE-SW Amlokhi fault in the NW part of the Diphu sub-division and the E-W Longchalliet fault in the lower part of the Diphu division (Fig. 9).

An analysis of the acute bisectrices of the conjugate fractures shows that the direction of $P_1$ varies in the NE-SW direction from 18°-198° to 70°-250° (Fig. 19, 20). This arrangement of the stress field indicates, as explained by De Sitter (1956, p 55), to be due to a doming effect on the rocks of the plateau by a compressive stress acting at a NE-SW direction producing an broad anticlinal structure that trends SE-NW, that is, perpendicular to the direction of the compressive stress (Goswami, Bhattacharjee and Goswami, 1993). The compressive stress might have resulted either due to (a) forces acting in NE-SW direction, as a result of the north-eastward movement of the Indian plate and its collision with the Asian plate, (b) Epeirogenic movement of the plateau (the Meghalaya Craton) resulting in the pulling towards the plateau of rocks adjacent to it or (c) to both of these events.

From the study, it appears that the stress field in the Shillong plateau, of which the Karbi Anglong is a part, is dominantly related to the uparching due to motive force generated by upward material transport from below. Verma and Mukhopadhya (1976) indicate presence of higher-density material at depth below the plateau having a higher than normal density material (1.2 gm/cc). Dasgupta and Nandi
STRESS DIRECTIONS DETERMINED FROM CONJUGATE FRACTURES OF DIPHU DIVISION

Figure 19.
STRESS DIRECTIONS DETERMINED FROM CONJUGATE FRACTURES OF HAMREN DIVISION

Figure 20.
(1982) suggested that the seismicity of the plateau has linkage with the tensional fractures traversing it. On the other hand, Bhattacharjee (1978) has suggested that the uparching was caused due to the subduction of the Indian plate both below the Himalayas to the north and the Indo-Burman ranges to the south-east. This is supposed to have led to the formation of a WNW–ESE trending arch on the plateau. The southern limb of the arch is formed by a monocline (Mathur and Evans, 1964), eventually cut and separated from the Cachar-Tripura plains by the "Dawki Tear Fault" and the northern limb passes below the Himalayas cut, therefore, by the Main Boundary Fault. The eastern termination of the arch bends east and north eastward first below the Brahmaputra alluvium and below the Belt of Schuppen, then the Upper Cretaceous and Tertiary rocks were overthrusted over the plateau. The south eastern termination of the arch is again delineated by a fault, the Naga Thrust. Thus, the Shillong plateau as a whole forms a dome, elongated and parallel to the trend of the Himalayas, plunging below the Brahmaputra alluvium to the east and separated from the Bengal basin in the west by the Dhubri fault.