Chapter-2

Regional Geology, Field Observation and Petrography
2.1. An Overview of the Geology of Northeast India

North eastern India is arguably the most bewitching part of India. Its valley and razor sharp high hills, snow clad mountains, meandering rivers, flat high lands, plateau, deep gorge and waterfalls form a very fascinating landscape. The region is known as the land of blue hills and red rivers due to its misty forested hills and silt laden river water during the monsoons.

Northeastern India and its adjoining territories display tectonically distinct geological domains occurring in intimate spatial association with each other. Rocks representing the entire time span, from Archaean to recent, occur in this very small region.

The distinctive tectono-geological provinces of this region under consideration can be divided into the following domains (Nandy, 2001):

1. The eastern Himalayan collision belt including the trans-Himalayan Tethyan zone, the Tsangpo suture zone (with ophiolites) and the Andean type granodioritic margin to the north
2. Mishmi block (Diorite-granodiorite complex) with the frontal folded and thrusted metamorphic belt
3. Indo-Myanmar (Burmese) mobile belt
4. Meghalaya Plateau with platform sediments to the south and east and the Mikir Hills
5. Brahmaputra Valley with cover of alluvium, and Tertiary sub-crop sediments.
6. Bengal basin covering almost whole of West Bengal and Bangladesh with Cretaceous to recent sediments
The Eastern Himalaya: The Himalayas form the most complex orogenic belt of the world. The eastern Himalayan mobile belt comprises the tract of the Himalayas from eastern Nepal to Subanshiri district of Arunachal Pradesh. The eastern Himalayan mobile belt has a narrow foreland basin along its southern margin making it a unique orogen (Yin, 2006). As a result, basement rocks of the Indian craton are exposed as close as 30 km from the Himalayan frontal thrust zone (Gansser, 1983 and Yin et al., 2010). As shown in Yin et. al., (2010), the
Arunachal Himalaya and the NE Indian craton share a common geologic history from Paleoproterozoic to Late Cambrian/Early Ordovician time. From south to north, the succession comprise of: 1) Neogene Molasse accumulating in the foredeep (the Siwalik Hills), ii) Gondwana sediments of both continental and marine derivation, structurally overlain by an older sequence of carbonate, orthoquartzite and low grade schist (the Lesser Himalaya) and iii) high grade schists, gneisses and patch of granite forming the Central crystalline sequences (the higher Himalaya). The general trend of the successions and the thrust separating them are E-W dipping towards north regardless of whether these are of sedimentary, metamorphic or thrust origin (Nandy, 2001). Further east, the E-W trend gradually swerves northward from NE to NNE and eventually to N-S in Siang District, apparently terminating against the N-S Siang fracture zone (Nandy, 1980) or Bame fault (Kumar, et al., 1989) or Tuting Guru tear fault (Acharya, 1997) running parallel to the Siang/Dihing river in Arunachal Pradesh.

**Mishmi Block:** It lies in the north eastern corner of India bordering Myanmar and China. Mishmi block is tectonically the linkage between Eastern Himalaya and Indo-Myanmar Mobile belt as it separates the two (Nandy, 1976). The rocks of Mishmi block has suffered four different phases of fold movement (Thakur and Jain, 1975). All the lithotectonic units are trending in NW-SE direction and dipping towards NE. Geologically and petrologically the rock units can be broadly divided into three distinct belts, from southwest to northeast, each separated from the other by NW trending steeply dipping thrusts (Talukdar and Nandy, 1976 and Nandy, 2001).

**The Indo Myanmar Mobile Belt:** It is geologically and tectonically bordering the Indian subcontinent from the east. It has been resulted from the northeastward drift of Indian subcontinent and its collision with Shan-Tenesserim block of the Asian landmass by the early mid-Eocene. The Patkoi–Naga-Manipur-Chin-Arakan-Yoma regions representing the Indo-Myanmar Mobile belt is a westerly
convex arcuate belt which is NW-SE trending at its southern extreme and ENE-WSW trending at its northern end. Eastern Boundary Thrust is the back bone of the arcuate shaped belt. Along the eastern boundary thrust, a narrow strip of older Palaeozoic-Mesozoic sediments, patches of metamorphics and dismembered ophiolites. This eastern boundary thrust is the eastern extremity or leading edge of the Indian plate. To the east of the eastern boundary thrust, Palaeogene-Neogene central Myanmar sedimentary basin occurs. This basin is medially traversed by a westerly convex volcanic arc that divides the basin into western fore-arc and eastern back-arc. Sediments in both the basin were deposited with pronounced unconformity at the base (Nandy, 2001).

The Meghalaya Plateau (Shillong Plateau) and the Mikir Hills: It occurs in between the E-W trending eastern Himalaya in the north and the broadly NNE-SSW Indo-Myanmar mobile belt to the east. The detailed geology of the plateau is described in the later part of this chapter.

Bengal Basin: It occupies most of the West Bengal, Bangladesh and northern part of Bay of Bengal. It is situated to the south of Shillong Plateau. The Bengal basin became a remnant ocean basin (Ingersoll et al., 1995) at the beginning of Miocene because of the continuing oblique subduction of India beneath and southeast extrusion of Burma (West Burma Block). The Bengal Basin is well known for the development of a thick Early Cretaceous–Holocene sedimentary succession (Curray, 1991a; Curray and Munasinghe, 1991) that has long been of interest from the hydrocarbon exploration point of view.

Brahmaputra Valley: It is a narrow valley trending NNE to SSW. Mishmi block lies to the northeast of the valley. Eastern Himalaya and Assam Arakan Yoma mobile belt lies to the north and east of the valley (Nandy, 2001). This valley is covered by thick quaternary sediments. The northern extremity of the Shillong Plateau represents Assam-Meghalaya Gneissic Complex as inselbergs, rising
over the plains of Quaternary sediments, belonging to Chapar, Sorbhog, Hauli and Barpeta Formations (Sinha, 1985).

2.2. Regional Geology of the Study Area

Shillong Plateau is the only Precambrian cratonic block of the North Eastern India. Evans (1964) considered the Shillong plateau as a detached part of the Indian shield. It is the north-eastern extremity of the Indian Peninsular Shield (Ghosh, et al., 1991). As per the interpretation of Crawford (1974), this Precambrian block is a continuation of the Eastern Ghat Charnockite Terrain. Shillong plateau, which is a continuation of the Chhotanagpur Gneissic Complex, is separated from the later by the Garo-Rajmahal Gap (Desikachar, 1974). Shillong Plateau is covering an area of about 104x4 km$^2$. This horst like plateau is roughly rectangular in shape. Evans (1964) earlier put a view that right-lateral shear faulting was the cause of Shillong Plateau, which is a detached block of Indian crust, found some 250 km eastward from the Rajmahal hills of India. In contrast to earlier view, vertical or dip-slip fault has been suggested for the upliftment of the Shillong Plateau (Desikachar, 1974; Hiller and Elahi, 1984). It was uplifted due to E-W trending high angle reverse Dauki fault in the south and Brahmaputra fault in the north (Rajendran et al., 2004). The north and south bounded reverse faults raised the Plateau as a ‘pop-up’ structure (Bilham and England, 2001). Kopili-Bomdila Fault zone and Brahmaputra River, termed the Jamuna River in Bangladesh part, are considered as the eastern and western mark of the Shillong plateau (Biswas and Grasemann, 2005; Dasgupta and Biswas, 2000). Despite the Dauki Fault being a high-angle reverse fault at greater depth, it appears as an apparent right lateral strike-slip fault near the surface (Lohmann, 1995). Dauki fault-I, Dauki fault-II and Dauki fault-III are the three major E-W trending faults which have been mapped between Jadukata river and Therriaghat (N25°11'00"; E91°45'20")). So the Dauki fault is actually
an imbricate system of E-W trending faults. Repeated uplift along the E-W trending Dauki fault system over long span of time caused the Meghalaya plateau to attain its present height (Murthy, et al., 1969). The throw of the Dauki fault system has been estimated to be 13 km (Evan, 1964). However, the differences in the relief (pointed out from seismic surveys) between the top of the Sylhet Limestone and the Shillong Plateau on either side of the Dauki fault at Sylhet trough is about 15 km (Hiller, 1988). The overall relief between the Meghalaya Plateau and the basement of the sylhet trough on either side of the fault system is about 20 km (Shamsuddin. et al., 1997).

Shillong Plateau shows a complex structural history. Five generation of folding can be deciphered in Shillong plateau (Khongla et al., 2008). Many major structural features are observed in Shillong Plateau. Kopili fault is one of the major faults found in Shillong Plateau. The alluvium tract of the Kopili River flowing along the NE-SW trending Kopili fault separates the Mikir Hills from the Shillong Plateau (Nandy and Dasgupta, 1986). Nongchram fault, Um Ngot and Dudhnoi Fault are N-S trending major structures traversing the plateau (Golani, 1991; Kayal, 1987). The NE-SW trending Badapani-Tyrsad shear zone is another important structure observed in the Shillong Plateau (Kumar et al., 1996). Beside these, a number of N-S, E-W and NW-SE lineaments cross the plateau. Many of the north-south to northeast-southwest trending folds in the Shillong Plateau is thought to have been developed dominantly by the component of east-west directed compressional force associated with plate collision and crustal shortening (Hiller and Elahi, 1984). Rifting of India from the combined Gondwana land was a striking event in the geological history of the shillong plateau (Alam, 1989; Acharyya, 1980).
The present physiographic configuration of the plateau was attained through different geological events since Mesozoic upto the present day, as indicated by the polycyclic erosional surfaces at various levels (Anon, 1974). The Meghalaya Plateau and the Mikir Hills are occupied by Archaean-Proterozoic gneissic complex with basic intrusive, Proterozoic Shillong Group of rocks with basic intrusives, Proterozoic-Palaeozoic porphyritic granite plutons with small outcrops of Lower Gondwana rocks at its western edge Jurassic-Cretaceous to Neogene platform sediments.

Many earlier workers attempted to establish stratigraphy of Shillong Plateau based on field relationships, contact relation between the litho units,
correlation and isotopic dating. The stratigraphy of Shillong Plateau is given below:

Table 2.1. Stratigraphic succession of Shillong plateau (Khonglah et al., 2008)

<table>
<thead>
<tr>
<th>Majumdar (1986)</th>
<th>Khonglah et al., 2008</th>
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<tbody>
<tr>
<td>Mesozoic-Tertiary</td>
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<tr>
<td>Jaintia Group Tertiary</td>
<td>Shella Formation (?)</td>
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<tr>
<td>Khasi Group Cretaceous</td>
<td>Mahadek Formation (?)</td>
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<tr>
<td></td>
<td>Bottom Conglomerate</td>
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<td></td>
<td>Sandstone Conglomerate</td>
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<td>Sylhet Trap</td>
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<tr>
<td>Porphyritic Granite with pegmatoid variation</td>
<td>South Khasi, Nongpoh, Mylliem and Kyrdem Plutons</td>
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<td>Porphyritic Granite</td>
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<tr>
<td>Khasi Greenstone</td>
<td>Late Proterozoic</td>
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<td>Basic Intrusives</td>
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<td>Meta gabbro/ Dolerite</td>
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<td>Shillong Group - Slate/Phyllite</td>
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<tr>
<td>Sandstone/Quartzite, Conglomerate/Pseuso</td>
<td>Nongpiur</td>
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<td>Conglomerate</td>
<td>Arkoasic quartzite, Conglomerate</td>
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<td>Shillong Group (Late Proterozoic)</td>
<td>Umiam</td>
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<td>Phyllite with thin quartzite intercalations and quartzo</td>
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<td>feldspathic meta-volcanics</td>
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<td>Bedded white quartzite, basal polymictic conglomerate</td>
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<tr>
<td>Gneissic Complex</td>
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<tr>
<td>Migmatitic Granitoids, Augen Gneiss,</td>
<td>Umsning Schist Belt (Early to Middle Proterozoic)</td>
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<td>Gneissose Members Schistose Members</td>
<td>Quartz muscovite schist, carbonaceous phylite, micaceous</td>
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<td></td>
<td>quartz, quartz feldspathic mica schist, quartz hornblende</td>
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<td>biotite schist, quartz biotite schist, Quartz sericite</td>
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<td></td>
<td>sillimanite schist</td>
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<td></td>
<td>1150±26 and 1714±44 Ma intrusive granitoid into the</td>
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<td></td>
<td>Umsning Schist Belt</td>
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<td></td>
<td>Granite gneiss, migmatites with enclaves of biotite schist,</td>
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<td></td>
<td>quartz hornblende - biotite schist, sillimanite schist and</td>
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<td></td>
<td>quartzite.</td>
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---------Basement not exposed----------
Gneissic Complex

The gneissic complex is the country rock of the area. It is the basement of the all rock types exposed in Shillong Plateau. This gneissic complex was classified into two parts as older metamorphic group and granitic gneiss. The older metamorphic groups include variety of pelitic, basic, impure calcareous and ferrugineous rocks which have undergone medium to high grade of metamorphism and which are closely associated with the granitic rocks of the region. This older metamorphic group shows mineral assemblage suggestive of recrystallisation under amphibolite facies conditions (Choudhury and Rao, 1975).

The Granite gneiss, which is a part of the gneissic complex, is the most extensively developed rock, covering large areas of the plateau. Megascopically, gneissic banding is well developed and defined by alternate biotite and quartzofeldspathic rich layers. Migmatites and ptigmatic folding are very common in the granite gneiss. This litho unit of Shillong Plateau comprises of biotite gneiss, quartz feldspathic gneiss and diorite gneiss. The typical granite gneiss is characterized by hypidiomorphic texture with mineral assemblage of quartz, microcline, oligoclase, biotite and accessories (Mazumdar, 1976).

Shillong Group

The Shillong Group of rocks comprises psammo-pelitic metasedimentary rocks. These metasediments were deposited over the floor of the Gneissic Complex. The basal conglomerates of the Shillong Group of rocks mark the unconformity between Gneissic Complex and the overlying Shillong Group of rocks. This group has undergone a low grade metamorphism. The metasediments of the Shillong Group still retain primary features like current bedding ripple marks etc (Choudhury and Rao, 1975).

The Khasi Greenstone

The Khasi Greenstone is a group of basic intrusive rocks. They are weakly foliated, dark green to black, fine to medium grained basic intrusive rocks of
doleritic to gabbroic compositions and have undergone low grade metamorphism (Rao et al., 2009). It shows both concordant and discordant relationship with Shillong Group of rocks.

**Porphyritic Granite**

Many isolated granite plutons are found in the Shillong plateau. They intrude the basement Gneissic Complex and the Shillong Group of rocks. They are very coarse grained and are porphyritic enclosing large phenocryst of mainly K-feldspar (Choudhury and Rao, 1975). Enclaves or caught up patches of other Precambrian rocks of Shillong Plateau is very common in the porphyritic granite. The porphyritic granite intrudes all Precambrian rocks of Shillong plateau. The Mylliem and Kyrdem plutons intrude the Shillong Group of rocks. The Nongpoh pluton intrudes the gneissic complex and the South Khasi Batholith intrudes into both, the basement Gneissis Complex and Shillong metasediments (Khongla et al., 2008). South Khasi Batholith (690±19 Ma), Mylliem Pluton (607±19Ma), Kyrdem Pluton (479±26Ma) and the Nongpoh Batholith (550±15Ma) apparently show younging in the age of plutons from south west to northeast (Kumar, 1998).

**Sylhet Traps**

The Sylhet traps are exposed in a narrow 80 km long and 4 km wide E-W belt along the southern margin of the Meghalaya plateau. They are plateau basalts of both ‘aa’ type and block lava type. This basaltic rocks of Shillong plateau include both quartz and olivine tholeiite with minor alkali basalts, rhyolites and acidic tuffs. The Sylhet Traps, apparently overlying the eroded Precambrian basement complex, are overlain by Cretaceous-Tertiary shelf sediments of Shillong plateau (Talukdar and Murthy, 1971). This plateau basalts of Shillong plateau is exposed to the north of Dauki fault system and to the south of Raibah fault and entirely absent to the north of Raibah fault. Thus the Raibah fault to the north and the Dauki fault system to the south would have been the controlling factor on the effusion of this Plateau basalt (Talukdar and Murthy, 1971 Murthy, 1981).
Cretaceous-Tertiary Shelf Sediments

The cretaceous-tertiary shelf sediments overlying the Sylhet traps occupy the southern part of the Shillong Plateau. Sandstone and Shale affected by mostly faults are the main lithounits of these shelf sediments. These sediments are broadly classified into three groups namely; Cretaceous Khasi Group, Palaeocene-Eocene Jaintia Group and Oligocene-Miocene-Pliocene Garo Group (Anon, 1974). The lower most unit of these Cretaceous-Tertiary shelf sediments is the Jadukata Formation of Khasi Group. This Jadukata Formation comprises of conglomerate and sandstone which are unconformably overlying the Sylhet Trap in the southern part of the Shillong plateau (Chakraborty, 1972 and Nandy, 2001).

2.3. Sample Details and Field Observation

This section describes the sampling procedure and sample details used in this study (Appendix-I) along with field observations made during the field work.

2.3.1. Sample Details

The samples in this study were collected during three field seasons. The geological maps after Mazumdar, (1976) and Khonglah et al. (2008) (Fig.2.2) was used along with the Survey of India topo-sheets (1:50,000 scale) for the field work. The sample locations are listed in Appendix-I. The fieldwork was conducted with the aim of sampling the Kyllang Pluton, Moudoh Pluton and the basement gneisses exposed around Kyllang and Moudoh plutons in Shillong plateau.

The basement gneiss consists of common grey and pink gneisses, migmatites and banded gneisses with rare augen gneisses at few places. There are massive porphyritic granite and pegmatite veins, probably representing the last phase of magmatic activity. The exposures and outcrops were located in new road cutting sections. As most of the area is covered by the thick soil cover and growth of luxuriant vegetation the exposures of basement are rare and
infrequent. Taking fresh sample was the main difficulty during the field work. Throughout the study area construction of new roads were going on to connect the village nearby. The new road cutting surfaces made collection of fresh samples easier. A brief discussion of some of the field observations made during field investigations are discussed below.

2.3.2. Field Observation and Sampling

The area under investigation forms a part of Shillong Plateau which in turn is a north easterly extension of Chotanagpur Gneissic Complex of Indian peninsula separated by well known Garo- Rajmahal Gap (Desikachar, 1974).

Porphyritic granite is exposed at Kyllang and Moudoh plutons. Two types of granite can be observed at Kyllang pluton as Pink granite (Plate-2.1a) and Grey granite (Plate-2.2c). Pink porphyritic granite is observed at Moudoh pluton too. Both Kyllang Pluton and Moudoh plutons are intrusive granite plutons within the basement gneiss (which is exposed around the Kyllang and Moudoh plutons). Different rock units observed in the study area are described below.

Amphibolite: These are dark greyish to green; medium grained and well foliated rocks. The exposure of these amphibolites is found as either caught up patches, enclaves or xenoliths in both basement gneiss and porphyritic granite at many places (Plate-2.1e). At some place amphibolite enclaves are observed as elongations along the gneissosity. Some sample was collected during the second field work. Geochemical analysis was not carried out as the objective of this study is mainly on granitoids.

Gneiss: They are medium grained pink to grey colored streaky gneisses. The gneissosity is shown by alignment of mafic minerals. Enclaves of this unit are observed in porphyritic granite (Plate-2.2a). These Precambrian rocks form the country rocks, they have a general trend of ENE-WSW and 75° - 80° dipping towards NW. Amphibolite enclaves is very often seen in this rock unit giving a clue of the age relations between them.
Granite: Next to gneisses porphyritic granite predominate the area. Granite is the main igneous rocks which show no signs of metamorphism. In the study area, Kyllang and Moudoh plutons are the two granite plutons. Kyllang pluton is the bigger pluton. It is nearly 15 km away from Mairang town towards north. Grey and pink granite are the two types seen in Kyllang pluton. No difference could be seen in these two types except for the colour. Pink granite and grey granite are shown on plate-2.1a and plate-2.1b respectively. The rocks are coarse grained and characterized by large phenocrysts of k-feldspar. The individual phenocryst ranges (in size) from few cm to 10 cm. The feldspar phenocrysts are generally tabular and elongated. The tabular crystals are more or less euhedral. Spheroidal weathering is very common in the granite of this area. The intrusion of porphyritic granite in gneissic body seen in the field is an indication of the granite being younger than the gneiss. Alignment of phenocrysts is seen in pink porphyritic granite near Kyllang area (Plate-2.1c) and the alignment of the phenocrysts is almost parallel to the boundary of the pluton. The contact between gneiss and porphyritic granite is very sharp with no mineral fringe (Plate-2.2b).

Pegmatite and quartz veins: Pegmatite veins are very common in the area. Many pegmatite veins have intruded almost all type of rock units in the area. Pegmatite that are exposed in the mapped area dominantly constitutes of quartz and k-feldspar with little amount of muscovite (Plate-2.3a).

5 mm to 30 cm thick quartz veins are frequently encountered. Quartz veins have intruded most of the country rock including pegmatites (Plate-2.2d). The pegmatite and quartz veins had intruded into the gneisses both along and across the foliation plane.

2.3.3. Contact Relationship

Basement gneiss is having sharp contact with porphyritic granite (Plate-2.2e). Pink porphyritic granite is more dominant than grey porphyritic granite in Kyllang pluton. Porphyritic granite and basement gneiss show sharp contact as
observed at many places on way from Nongstoin Road to Masar through Nongjilak and also on the road from Kyllang to Riangman. The boundary is discordant with gneissosity. Many veins of porphyritic granite intruding the basement gneiss are also observed frequently. The amphibolites found in the study area occur as enclaves and xenoliths within the granites and gneisses. The size of the enclaves ranges from few cm to meters. The foliation of the amphibolites shows no continuity with the gneissosity of the gneiss but show discordant relation with porphyritic granite. The contact between amphibolites and other rock unite are very sharp. Some amphibolites enclaves are elongated parallel to gneissosity (Plate-2.1f). Quartzite veins are also observed in this rock unit. At one place near Mawsmai, quartz veins of nearly 3 cm thick are intruding the porphyritic granite (Plate-2.2d). At some places the porphyritic granite is so coarse that it passes into pegmatite. Near Nongjilak quartz vein of 30 cm thick is found cutting a pegmatite body (Plate-2.2c). This quartz veins might be the last stage of the granitic intrusion. The quartz vein maintains both concordant and discordant relationship with the host rock. In granite and gneiss, quartz vein are found mostly along weak plane like joint plane. Majority of the quartz vein are discontinuous. Some quartz veins, intrusive to the gneiss, exhibit pinch and swell structure before dying out within a strike length of 1m to 2 m.

2.3.4. Structure

The structural features observed during the field work include foliation, fold, joints and other megascopic structure. A systematic description of the different structural unit present in the rock units are given below:

Planar Structures: Foliation, Joints and Faults.
Other structures: Fold

Planar Structures: Foliation is most common planar structure found in this area. The foliation in the area is defined by the parallel arrangement of the flaky and prismatic minerals like micas and the amphiboles. The parallel arrangement of
biotite in the mafic layers separating them from quartzo-feldspathic layers defines gneissic texture of the gneiss. The general trend of the dominant foliation on Nongstoin Road is N60°E with subvertical dip (Plate-2.1d).

**Joints:** All the rock units exhibit different sets of joints. Joints in porphyritic granite and gneiss are very well developed. Near Nongjilak village grey porphyritic granite usually show two sets of joints. They are subvertical trending N25°W dipping 70° towards NE and N30°E dipping towards 78° towards NW (Plate-2.3c). Sheet joint is one of the most striking features seen in this area. It has shallow dip at places, sometimes having the trend N20E/40°→SE (Plate-2.3b).

**Fault:** A small scale fault has been seen on the road, 30 m north of Mairang-Nongstoin road crossing near Nongstoin. The quartz vein intruded in gneiss had been faulted having an attitude of N355°/80°→W. Here the dip separation is 5 cm (Plate-2.3e). The quartz veins form very shallow angle to the gneissosity of the host rock.

**Folds:** Ptigmatic folding is quite common in gneiss in the study area (Plate-2.3d).

### 2.4. Petrography of the Rock Samples

Petrography is the art of visual study of the rocks, the branch of geology that describes and classifies rocks, usually after microscopic study, the description of rocks with goals of classification and interpretation of its origin. Most schemes for the classification of rocks are based on the size of the grains and the proportions of various minerals with their interrelationship with each other. The study of petrography is incomplete without the study of field relations, structure, texture, and chemical composition as well as sizes and proportions of different kinds of grains. The conditions of formation of a rock can be understood from the types and textures of its constituent minerals.

#### 2.4.1. Sampling and thin Section Preparation

Oriented rock samples were collected, the orientation was perpendicular to the foliation and parallel to the stretching lineation, which is supposed to show
best strain variation, fabric development and shear sense. For preparation of thin section samples were cut parallel to the orientation line marked on the sample with a bueller rock cutting saw then these cut samples were mounted on the glass slide and polished to reduce the thickness to 0.03 mm. After attaining the required thickness the thin section are ready for petrographic study. Petrographic and textural (micro-structural) study was carried out in the petrological laboratory of the Department of Geology, Delhi University, under Leica Orthoplan microscope fitted with image analyzer.

2.4.2. Petrographic Description of Selected Samples

For the study of petrography seventy samples were selected from the above mentioned study areas. Detail petrographic and textural (micro-structural) study was carried out in the petrological laboratory at the Department of Geology, Delhi University, under Leica Orthoplan microscope.

On the basis of colour, type of rock and place of occurrence the samples under study have been classified into four groups. These groups are (A) Group I-Pink porphyritic granite of Kyllang pluton, (B) Group II- Grey porphyritic granite of Kyllang pluton, (C) Group III-Porphyritic granite of Moudoh pluton and (D) Group IV-Basement gneiss exposed around Kyllang and Moudoh pluton. Few samples are described from each group:

Petrographic Description of Group I

F24-This is a coarse grained holocrystalline and hypidiomorphic rock. K-feldspar, plagioclase and quartz are abundant. Lesser amounts of biotite and hornblende are also observed. Very few grains of clinopyroxene are also present in the section. Orthoclase is most abundant. Carlsbad twinning and lamellar twinning are present in plagioclase. Quartz is anhedral in shape and is present as inclusions in other big grains of biotite and feldspar. Myrmekite texture is shown
at the boundary of the k-feldspar. Overall the section shows porphyritic granitic texture.

**S46**-This section shows medium to coarse grained, inequigranular and holocrystalline texture. It is composed essentially of K-feldspar, plagioclase, quartz and biotite. Orthoclase is more abundant than microcline. Muscovite is present in very less amount. Apatite, sphene and opaque minerals are present as accessory minerals. Feldspar is highly fractured and broken into small grains and exhibit variable degree of alteration. Quartz is medium to coarse, anhedral in shape exhibiting undulose extinction. Biotite is the main mafic mineral and they are highly elongated. Myrmekite and perthitic texture is observed.

**Petrographic Description of Group II**

**F44**-The thin section shows coarse grained, inequigranular and holocrystalline texture. Like samples of group-I, it also shows K-feldspar, plagioclase, quartz, biotite and hornblende as essential minerals. Microcline shows well developed cross-hatch twinning. K-feldspar phenocrysts are surrounded by finer grains of other minerals like quartz and biotite showing a porphyritic texture. Here, three types of quartz grains can be observed. Bigger grains of quartz are present as phenocryst in the rock. Finer grains of quartz are also present in the interstices of other bigger grains. The third type is drop like quartz grains present as inclusions in bigger grains of feldspar and biotite. Irregular fractures in the feldspar are filed by other silicates.

**S514**-It is coarse grained porphyritic and hypidiomorphic texture. Major minerals are K-feldspar, quartz, plagioclase, biotite and hornblende. Sphene, apatite and iron opaque minerals are present as accessory minerals. Perthitic texture is observed in k-feldspar. Biotite is generally associated with hornblende and sphene. Biotite grains are tabular in most of the case. No deformation of any type is seen.
Petrographic Description of Group III

S4- The section shows inequigranular, coarse grained texture. It has abundant plagioclase, quartz, K-feldspar and biotite. Muscovite is present in lesser amount. Plagioclase phenocrysts are tabular in shape and randomly oriented. Carlsbad twinning, lamellar twinning and cross hatch twinning are observed. Myrmekite and perthitic texture are notable textures present in the section. Quartz is fine to medium grained and anhedral in shape. Biotite is also elongated and altered to chlorite in some cases. Small grains of sphene are present as accessory minerals. They are anhedral in shape.

S410- This rock shows almost similar petrographic character to the samples described above. It shows porphyritic texture. K-feldspar, quartz, plagioclase are major minerals. Biotite and hornblende are the main mafic minerals. No sign of deformation is present. Sphene and iron oxide minerals are present as accessory minerals.

After analyzing the petrographic studies of the above samples of Group-I, Group-II and Group-III, we can concluded that the samples of these three groups (Granite from Kyllang and Moudoh pluton) have similar petrographic characters in broad sense. The petrography of the samples collectively can be described as follows:

Granites from Kyllang and Moudoh plutons show coarse grained, holocrystalline and hypidiomorphic granular texture. Quartz, K-feldspar, plagioclase, Biotite, muscovite and hornblende are seen as essential minerals. Iron oxides, apatite and sphene are seen as the accessory mineral phases.

K-feldspar and plagioclase are subhedral and large upto 5cm. Medium to small grains are also seen. Carlsbad and cross-hatch twinning are quite common in the k-feldspar and microcline. Perthitic texture is also seen in microcline. Inclusion of biotite and quartz like droplets present within k-feldspar phenocryst. Myrmekite texture is very common at the outlines of the k-feldspar which is resulted by the intergrowth of quartz and plagioclase. In some cases, microcline...
occurs as large phenocrysts surrounded by matrix of quartz and biotite which exhibit the porphyritic texture of the rock.

Quartz grains are very big and subhedral to anhedral in size. Two types of quartz grains are seen. One is phenocryst sized, ranging from large to medium. And the other is very small drop like inclusion within other minerals. Larger quartz grains have irregular boundaries and show wavy extinction in some cases. Almost all the quartz grains occur as inclusion within K-feldspar have rounded shapes.

Biotite is less abundant, anhedral, medium to fine grained. Some grains are equidimensional and some are elongated. Small grains of drop like intrusion are also seen within feldspar. On the other hand small drop like grains of quartz are also seen as intrusion within big grains of biotite.

Muscovite and hornblende are very less; most hornblende grains are interlocking with biotite grains. Muscovite grains are anhedral and medium to fine grained. Hornblende shows two sets of cleavage. Some hornblende grains are very altered showing indications of weathering.

Iron minerals are also present. They occur as fine grains. Most of them are rounded and found within other minerals of large dimensions. Apatite and sphene are also seen but very less. Apatite grains are fine grains and euhedral to subhedral and are of medium size. Some of apatite grains are present as inclusion within big grains of Biotite.

**Petrographic Description of Group IV**

**S21**-This is medium grained rock composed of microcline, plagioclase, quartz, biotite and hornblende. The variation in the amount of microcline and biotite show different appearance from pink to grey in the outcrop or hand specimen. Muscovite, apatite, zircon, sphene, chlorite, sercite and iron minerals are the accessory minerals. Microcline occurs as relatively larger grain with irregular lobed outlines. Most grains are microperthitic. Plagioclase grains are sub-
idioblastic to xenoblastic in nature. Carlsbad and lamellar twinning are present. 
Three type of plagioclase can be recognised. Biotite generally occurs as thin 
flakes. The grain boundaries are generally smooth and straight.

**S210**-The rock is inequigranular and essentially composed of plagioclase, quartz, 
biotite, k-feldspar and hornblende. Apatite and sphene are noticed as accessory 
minerals. Hypidiomorphic texture is seen. Development of myrmekite is noticed 
at places. Quartz grains are anhedral and showing wavy extinction. Most of the 
plagioclase show characteristic lamellar twinning. At places the lamellar twinning 
is distorted and displaced indicating the rock is deformed. Further, the presence 
of a deformed biotite grain also proves that the rock is deformed.

**S45**-The rock is inequigranular, coarse to medium grained, composed of mainly 
quartz, k-feldspar, plagioclase and biotite. Iron minerals, sphene and apatite are 
main accessory minerals. Biotite is the predominant mafic minerals exhibiting 
pleochroic colours from light to dark brown. One set cleavage with straight 
extinction is its characteristic. Elongated biotite grains show alignment forming 
definite bands of biotite. Graphic texture is also common in the section.

**Overall Petrographic Description of Group-IV Samples:** The rock contains 
abundant amount of plagioclase, quartz, biotite and microcline. Accessory 
minerals are magnetite, apatite, zircon and sphene.

Plagioclase occurs as both large and small subhedral grains. Large grains 
predominate over small. Grains are partly altered, in which the core of the grains 
are altered and the borders remain as fresh. Inclusions of quartz are present in 
plagioclase. Some of the grains are fractured. Larger grains contain inclusions of 
smaller grains of quartz and biotite. The boundary of the grains in inclusions is 
almost rounded and in certain cases irregular. Albite twinning is always present.

Quartz occurs as fine to coarse grained. Larger grains predominate. Smaller grains occur either as inclusions in plagioclase or as aggregates in the 
interstices of other grains.
Biotite occurs usually as subhedral, elongated grains of light brown color. Alignment of the grains is observed in many samples. They form definite band in the grey gneiss while in the pinkish variety most of the biotite are disseminated over the whole rock. They show pleochroism from light to dark brown color. One set cleavage with straight extinction is its characteristic. Inclusions of small plagioclase grains are found in biotite. Deformed biotite grains (bent grains) are also observed indicating the sample had undergone deformation in the past (Plate-2.6f). Some grains are altered to chlorite which shows pale green color.

Microcline occurs as fine to medium grains. Cross hatched twinning is its characteristic feature. Larger grains of microcline contain inclusions of quartz and biotite. The boundary of the grain with quartz grains is almost rounded and with biotite is straight in most of the cases.

Muscovite, hornblende and clinopyroxene are anhedral, very altered and present in very less amount. Muscovite grains are more elongated and show proper alignment. Iron minerals are opaque and rounded in shape. Sphene is present as fine grains and anhedral in shape. Apatite is equidimensional and round in shape. They are very fine grained in the studied sections.
Plate-2.1
Plate 2.2
Plate-2.3
Plate-2.4
Plate-2.5
Plate-2.6. [Qtz- quartz, Plg- plagioclase, Kf- K-feldspar, Bt-biotite, Ms-muscovite, Zr-zircon, Am-amphibole]