CHAPTER 2

GEOLOGY OF NAGALAND

2.1 GEOLOGICAL SETTING

Nagaland tectonic hills are part of the Arakan-Yoma ranges of Cretaceous-Tertiary age. The subduction of the Indian Plate beneath the Burma Plate began during the Cretaceous. Large negative isostatic anomalies to the east of Arakan-Yoma, high seismicity and depth of foci are evidences of continuing subduction (Nandy, 1976; Verma, 1985; Bhattacharjee, 1991). This susceptible region consists of high hills and deep valleys which forms an integral part of the northern extension of the Indo-Myanmar Range (IMR). The IMR is an arc-shaped tectonic belt that is convex towards the west. The IMR is divided longitudinally into three segments such as the Naga Hills, Chin Hills and Arakan-Yoma Hills (Brunnschweiler, 1974).

The state is dominantly made up of undulating hills and sharp crested ridges with narrow elongated valleys and steep gorges. The alluvial plain of Dimapur is a continuation of the Brahmaputra valley of Assam. The mountain ranges are high with peaks such as Saramati (3826m) along the Nagaland-Myanmar border.

Naga Hills

The northernmost segment of the IMR constitutes the Naga Hills, which trends approximately NE-SW. This segment is constituted primarily by the Naga-Patkai Hills of Nagaland and northern part of Manipur. Brunnschweiler (1974) classified this region into three major lithostratigraphic units, the Naga Metamorphic Complex, Naga Hills Flysch and the Upper Chindwin Molasse of the Chindwin Basin. Acharyya (1986) classified this section on the basis of geologic and tectonic setting into two distinct longitudinal belts, namely the Central Naga Hills Paleogene flysch and the Naga-Chin Hills ophiolite belt.

Chin Hills

The Chin Hills is positioned amid the Naga Hills on the north and Arakan-Yoma segment in the south. They are chiefly composed of flysch sediments with minor

igneous and metamorphic rocks. On the south identified as Kanpetlet schist which belongs to a group of schistose rocks overthrusts the Lower Tertiary unmetamorphosed shales and sandstones with conglomeratic layers to the west. Brunnschweiler (1974) explained this fragment of the IMR without ophiolites but with exotics in the flysch sediments. Probably resulting to be the basis on which the two segments, the Naga Hills and Chin Hills were detached.

Arakan-Yoma Range

The Arakan- Yoma- Range lies to the south of the Chin Hills and encompasses low hills and covers the coastal areas of Myanmar. Though moderately less, Ophiolite rocks, are identified on the eastern side as small outcrops. The entire strike of the tectonic lineaments is NNW-SSE and the tectonic position of this segment is more or less than the other two segments.

2.2 STRATIGRAPHY

The NH 39 runs through a terrain of diverse features. The mountains trending NE-SW, are more or less, parallel to each other. Part of this terrain is made up of tough sedimentary rocks such as sandstone while others are made up of broken shales. This region is representative of major Cretaceous-Tertiary orogenic upheavals. The stratigraphy of Nagaland (Imchen et al., 2014) is given in Table 2.1.

Metamorphic Complex

Metamorphic complex is an isolated section of the Pre-Tertiary Burmese continental crust possibly of Pre-Mesozoic age and is a part of the eastern fringe of Nagaland (DGM, 1978). Metamorphic complex consist of a cover of meta-sediments which are primarily members of calc-psammopelitic sequences. Mica schist, granitoid gneiss and feldspathic metagreywacke with tectonic slices of ophiolite of variable dimensions form the main litho-units of the Naga Metamorphics. These occur as a klippe above a thrust plane dipping east and overlying the younger mélange zone. Whereby the formation is overlain by the Nimi Formation consisting of interbands of phyllite, quartzite, limestone and quartz-sericite schist.

Zepuhu Formation

This linear belt of Upper Cretaceous age that trends NE-SW, and is about 90 km in length and varies from 5 to 15 km in breadth. The Zepuhu formation representing the Ophiolite Complex of Nagaland lies between the Nimi Formation in the east and the Disang Group of rocks on the west and are distinguished by dismembered tectonic slices of serpentinite, cumulates and volcanics. They are often associated with pelagic sediments such as chert and limestone, found interbedded with the volcanic rocks. The Cherts are usually bedded and bear radiolarian. Fossil records in limestones indicate an Upper Cretaceous-Lower Eocene age.

Jopi / Phokphur Formation

The ophiolite suite of rocks is unconformably overlain by an open marine to paralic sedimentary cover which has been designated as the Phokphur Formation. These are essentially ophiolite-derived volcano-clastics. This formation comprises tuffaceous shale, sandstone, greywacke, grit and conglomerate and is considered equivalent to the Barail. Carbonaceous matter added with minor limestone is eminent in these rocks.

Disang Group

The Disang Group of rocks ranging in age from Upper Cretaceous to Eocene, is the oldest of the Tertiary in Nagaland. Made up of a thick sequence of shales intercalated with very fine grained, flaggy sandstone and siltstone have been categorised as a basal argillaceous and an upper arenaceous horizon or as Lower and Upper Disang formations respectively (Sinha et al., 1982).

The Disang shales are distinguished for their organic content which gives the shales their characteristic dark gray to black colour. Box-work and spheroidal weathering (Plate 2.1) are common and the presence of pyrite in the Disang indicates that they were deposited under reducing conditions. Studies indicate that these rocks belong to a deep basinal set-up (Imchen, et al., 2014) and were deposited in a marine environment, probably at great depths where anoxic conditions prevailed. At a later date these sediments were uplifted. Ultimately weathering and erosion of the overlying rocks has exposed the present area. The Disang represents a flysch facies, they are found over more than half the surface area of Nagaland. As it goes higher up the stratigraphic coloumn the volume of shales decreases and the presence of sandstone become more prominent. The Disang grade vertically and laterally into the

Barail Group of rocks where at numerous places reddish to brownish Disang are noted due to oxidation of pyrite. Ferruginous concretions and nodules are common features in red soils. Two main processes namely, air breakage and the dispersion of colloidal material brings about weathering of shale (Badger et al., 1956). Consequently, talus and scree form at the base of slopes and thick columns of soil are formed on slopes, rendering the Disang dominated areas vulnerable to various forms of slope failure, which includes landslides. Disang are splintery by nature having very low shearing strength. This splintery nature is practically due to the intersection of bedding and a prominent fracture cleavage (Soibam, 1998). Areas of steep slopes and thick overburden are sites for slope failure. A number of landslides are noted due to intensive weathering of shales together with jointing, faulting, etc. Most of the highway running over Disang is affected where shaly silts, silty shales and bedded siltstones are found. This extensive displacement in the rocks is the result of numerous faults and possibly thrusts.

This part of the region receives abundant rainfall and cloudburst is common. Taking all this factors into consideration and not forgetting the anthropogenic activity, it is but natural to see instability in the area. In Disang country a number of present day landslides have occurred in paleoslide zones reminding us of continued instability of the region.

Barail Group

The Barail, named after the Barail Range in the North Cachar Hills of Assam, is an arenaceous suite of flysch sediments. These rocks of Upper Eocene-Oligocene age, conformably overlie the Disang and comprise of thick sequences of sandstones intercalated with thin shale. They are found scattered all over Nagaland. The Barail may be divided in the south and southwest of Nagaland into three formations including Laisong, Jenam and Renji. In the northern intermediate hills of Nagaland they are recognized as Tikak Parbat, Baragolai and Naogaon formations.

The Barail exposed in the study area belong to the Laisong Formation where it conformably overlies the Upper Disang. They are made up of well-bedded quartzose-sandstones alternating with hard, sandy shale. The greywacke are weakened by two to three sets of joints at most places, commonly finely laminated, very tough and

greyish in colour. Occasionally, massive sandstones with intercalations of carbonaceous shale and thin streaks of coal are noted. The Jenam is made up of massive sandstones with intercalations of shale, sandy shale and calcareous and iron stained shale. The youngest member, the Renji are essentially sandstones that are hard, massive, ferruginous and very thick bedded, with intercalations of minor shales. This formation has thick forest cover forming high peaks such as Japfü (3015 m) in southern Nagaland which lengthens along the southwest of Nagaland into Assam and south into Manipur. These rocks limited to the Schuppen belt along the western margin of Nagaland, are of marine to estuarine origin occasionally exposed as inliers due to strike faulting. Fossils and sedimentary structures are rare but structures such as ripple marks, load casts, flute marks and current bedding are noted.

In the north-eastern parts of Nagaland, the Naogaon Formation is extensively exposed as high ranges which are hard, grey, thin bedded and fine to medium grained and often intercalated with some shale and carbonaceous shale. Concretionary structures are also sporadically seen. Further towards the south the sandstones are thick and massive with thin shale partings. The Tikak Parbat and Baragolai formations are made up of sandstone, shale, carbonaceous shale and coal which include workable coal reserves. Towards the south these rocks branch out in northern Manipur.

Surma Group

The Surma are subdivided into the Bhuban and Boka Bil formations. The surmas are characterized by the presence of conglomerate which unconformably overlies the Barail. They consist of Lower Miocene molasse and alternations of well-bedded sandstones, shaly sandstones, mudstones, sandy shales and thin conglomerate. On the western margin almost along the entire length of Nagaland, the rocks are exposed in the form of a number of long narrow strips running along the schuppen belt which gradually thins out towards the north.

Tipam Group

The Tipam molasse belonging to Mio-Pliocene group unconformably overlies the Surma. Tipam Group includes the older Tipam Sandstone and the younger Girujan

Clay which are exposed along the western border of Nagaland in the schuppen belt as long, narrow strips due to strike faulting.

They include massive, highly friable with subordinate clay and shale where the sandstones are generally coarse grained, occasionally gritty and ferruginous. Due to presence of chlorite they are commonly green in colour but weather to different shades of brown. The argillaceous Girujan Clay Formation consisting of mottled clays, sandy clays and sandstones in subordinate amounts overlie the Tipam Sandstone. These clays are exposed in the schuppen belt and also along the western section of Nagaland. The formation encloses bluish-gray mottled clays with minor sandstones.

Namsang Beds

Lying unconformably over the Girujan Clay, the Namsang Beds of Mio-Pliocene age, belong to the Dupi Tila Group. They are confined to the schuppen belt and comprise of sandstone, pebbles of lignite, conglomerate, grit, mottled clay and lenticular seams of lignite.

Dihing Group

The Dihing Group of Plio-Pleistocene age unconformably overlies the Namsang Beds. They consist of an unconsolidated mass of Barail cobbles and pebbles mixed together in a matrix of clay and soft sand. The deposits are found as few patches in the schuppen belt.

Alluvium and High-level Terraces

Alluvium and high-level terraces are common features observed in many parts of Nagaland. High-level terraces are mainly boulder beds consisting of coarse sand, gravel and clay at a range of levels above the present rivers. The older alluvium is composed mainly of cobbles and boulders with considerable amounts of clay, silt and sand occupying the northeastern tract of the Naga-Patkai ranges. The newer alluvium covers the western border of Nagaland and is mainly composed of dark gray to black clay, silt and sand deposits and they occur as recent deposits of rivers and streams.

Table 2.1. Stratigraphy of Nagaland (after Imchen et al., 2014)

<table>
<tr><th rowspan="2">Age</th><th rowspan="2">Group</th><th colspan="3">Litho-formations</th></tr>
<tr><th colspan="2">Outer and Intermediate Hills</th><th>Eastern Hills</th></tr>
<tr><td rowspan="2">Recent - Pleistocene</td><td></td><td colspan="2">Alluvium and high level terraces</td><td rowspan="2"></td></tr>
<tr><td>Dihing</td><td colspan="2">Boulder beds</td></tr>
<tr><td colspan="5">--------Unconformity---------</td></tr>
<tr><td>Mio-Pliocene</td><td>Dupi Tila</td><td colspan="2">Namsang Beds</td><td></td></tr>
<tr><td colspan="5">--------Unconformity---------</td></tr>
<tr><td rowspan="2">Miocene</td><td>Tipam</td><td colspan="2">Girujan Clay
Tipam Sandstone</td><td></td></tr>
<tr><td>Surma</td><td colspan="2">Upper Bhuban
Lower Bhuban</td><td></td></tr>
<tr><td colspan="5">--------Unconformity---------</td></tr>
<tr><td rowspan="3">Oligocene</td><td rowspan="3">Barail</td><td>Renji</td><td>Tikak Parbat</td><td rowspan="3"><u>Jopi / Phokphur Formation</u>
Tuffaceous shale, sandstone, greywacke, grit and conglomerate. Minor limestone and carbonaceous matter</td></tr>
<tr><td>Jenam</td><td>Baragolai</td></tr>
<tr><td>Laisong</td><td>Naogaon</td></tr>
<tr><td rowspan="2">Upper Cretaceous - Eocene</td><td rowspan="2">Disang</td><td colspan="2">Upper</td><td></td></tr>
<tr><td colspan="2">Lower</td><td>Shale/slate/phyllite with calcareous lenses in basal sections and invertebrate and plant fossils in upper sections with brine springs</td></tr>
<tr><td colspan="3">-------Base not seen-------</td><td>-------Fault/Thrust-------</td></tr>
<tr><td>Upper Jurassic - Upper Cretaceous</td><td colspan="2">Ophiolite Complex</td><td>Zepuhu Formation
Marine sediments (shale, phyllite, greywacke, iron-rich sediments, chert and limestone with radiolaria and coccoliths), volcanics (basalt, spilite, volcaniclastics), metabasics greenschist, glaucophane schist/ glaucophane-bearing metachert, eclogite), layered cumulate sequence (peridotite, pyroxenite, gabbroids, plagiogranite, anorthosite), and peridotite tectonite and serpentinite associated with deposits of podiform chromite and nickeliferous magnetite, minor Cu-Mo sulphides associated with late felsic intrusions and some dolerite dykes</td></tr>
<tr><td colspan="3"></td><td>------Fault/Thrust-------</td></tr>
<tr><td>Pre-Mesozoic (?)</td><td colspan="2">Naga Metamorphic Complex</td><td>Nimi Formation
Weakly metamorphosed limestone, phyllite, quartzite and quartz-sericite schist
Naga Metamorphics
Mica schist, granitoid gneiss and feldspathic metagreywacke with tectonic slices of ophiolite in variable dimensions</td></tr>
</table>

2.3 MAJOR STRUCTURAL UNITS

Major structural features of Northeast India and Myanmar emerged as a result of collision of the India subcontinent with the Eurasian and Burma plates. Desikachar (1974) and Nandy (1976) have clarified the evolution of major features relating to a plate tectonic model. They justified that during the Mesozoic the Andaman-Arakan-Assam basin existed between the Burmese landmass and the Indian plate and had extended from 5° to 27° N latitudes. When Gondwanaland rifted the eastern margin of the Indian Peninsula was at latitude 50° S and got positioned in an E-W direction (Chatterjee and Hotton, 1986). Ever since the Cretaceous, the Indian plate has moved northward and the eastern continental passive margin rotated 20° in a clockwise direction until the Late Eocene when it collided with Eurasia (Gordon et al., 1990). This theory is supporteded by oceanic magnetic anomalies (McKenzie and Sclater, 1971) and palaeomagnetic studies of the Indian rocks (McElhinny, 1973). The considerable relationship between high seismicity, depth of foci and large negative isostatic anomalies to the east of the Arakan-Yoma suggests that the subduction process is still continuing (Verma, 1985).

Nagaland portrays part of the mobile morphotectonic unit of the Indian Plate that collided with Burma Plate (Bhattacharjee, 1991). These stresses are responsible for the major structural units of Nagaland where the major lineaments trends NE-SW and a NW-SE compression direction. Ultimately, all the structures like reverse faults and folds are parallel to the regional NE-SW trend. But some of the joints, Normal faults, and tensile fractures are parallel to the NW-SE compression direction. The crustal rocks of this mobile belt have gone through much compression which resulted to large-scale surface deformation. Subsequent to the three orogenic events of the rising Himalayas these section has undergone three deformational episodes F_1, F_2 and F_3. F_1 signifies an early Alpine-Himalayan incident. The surface rocks of Nagaland do not show signs of this orogenic movement. F_2 produced large NE-SW, low to moderately plunging asymmetric open folds and some major NE-SW thrust planes signifing a Late Alpine-Himalayan event. The F_3 Pliocene-Quaternary open folds trends NW-SE / WNW-ESE which are small and moderate to high plunging and partially asymmetrical. Roy and Kacker (1986) is of the opinion that F_2 and F_3 deformations are post-collisional features. Aier, et al., (2011a) suggest that neotectonic features in the region are a result of ongoing F_3 movements. Looking

from the tectonic and structural point, Nagaland is geologically very complicated. Basing on morphotectonic elements, Nagaland can be longitudinally separated into three distinctive units, the “Schuppen Belt”, the “Inner Fold Belt” and the “Ophiolite Complex” from west to east (Goswami, 1960; Mathur and Evans, 1964; DGM, 1978). All of these major structures have NE-SW trends.

Schuppen Belt

Schuppen Belt forms a very complex pattern and runs from the northwestern margin of Nagaland embracing eight to ten NE-SW trending overthrusts. Along the western margin of this belt, juxtaposing parts of the Tipam and Barail against the Sub-Recent to Recent alluvium, an en-echelon fault system known as the Naga Thrust is erratically exposed. This thrust is composed of a succession of six thrusts where the uppermost member is the persistent Disang Thrust, which occupies the southeast.

Inner Fold Belt

Inner Fold Belt inhabits the central portion of the Naga Hills. Distinguishing feature is a large spread of Disang capped with isolated outliers of Barail. These Palaeogene rocks folded into a series of anticlines and synclines are restricted within the Disang Thrust on the west and ophiolite belt to the east. Kohima Synclinorium in the south and Patkai Synclinorium to the north are two major synclinoria of the Inner Fold Belt. This synclinorium is positioned SSW of the Patkai Synclinorium and is situated southwest of Kohima Town consisting of broad synclines and narrow, sharp-crested anticlines, with faults trending approximately N-S. This synclinorium is flanked on all sides by the Disang and the younger groups of rocks in this structural unit lie towards the Surma Valley. It is alligned in the northwest by the Disang Thrust and in the south it merges into the eastern Surma Valley.

Corresponding to the first, second and third phases of the Himalayan orogenies, three generations of folds are recorded in the litho-units (DGM, 1978) with each generation punctuated by an interval of comparative quiescence. Formed due to orthotectonic movements during the Upper Cretaceous-Eocene period, the first set of folds is isoclinal with low plunges on both the sides with N-S to NNE-SSW axial trends forming reversal of plunge by folding later on. In combination with the first generation folds the second set of folds has NE-SW axial trends with steeply

inclined axial surfaces and low plunges and directs the topographic morphometry of Nagaland. These folds perhaps correspond to the second phase of the Alpine-Himalayan Orogeny. The third set of folds is broad and open with steeply dipping axial planes and moderate plunges and trends is E-W to ESE-WNW direction. These folds are attributed to Pleistocene movements. Two sets of characteristic faults have been accounted (DGM, 1978). The earlier set, trending NE-SW, shows a conformity with the regional trend of the early folds while the later has WNW-ESE trend. These two sets interfer each other resulting in the development of large tectonic blocks.

Patkai Synclinorium

Patkai Synclinorium forms the intermediate elevated hill range of Nagaland made up of Barails and with the Disangs exposed on either side. It is observed that strike faults have affected the rocks. The Disang Thrust separates it from the schuppen belt on its northwestern flank.

Ophiolite Complex

The litho-tectonic framework implies convergence of plates whereby the Indian Plate plunge below the Burma Plate (Shan Massif) eastward forming the Indo-Burma ranges along the Ophiolite Complex of Nagaland (DGM, 1978; Imchen et al., 2014). As a result of large scale compression and faulting is distinguished whereby the drainage too is structurally controlled (Chattopadhyay et al., 1993).