Chapter 1

INTRODUCTION

Nagaland, the sixteenth state of the Indian Union lies in the extreme northeast with a geographic area of 16,579 km$^2$. It is bounded by Myanmar in the east, Manipur in the south, Arunachal Pradesh on the northwest, and Assam in the west.

The Naga Hills represents part of the Assam-Arakan Yoma basin where copious accumulations of Cenozoic and Mesozoic sediments have taken place. The sediments of the Assam-Arakan basin are broadly categorized into two distinct facies, the shelf and basin (Mathur and Evans, 1964). Cenozoic sediments of the Naga Hills forms part of a basinal facies represented by the Disang Group (Upper Cretaceous-Upper Eocene), Barail Group (Upper Eocene-Oligocene), Surma Group (Lower Miocene), Tipam Group (Middle to Late Miocene), Namsang Beds (Upper Miocene-Pliocene), Dihing Group (Plio-Pleistocene) and the Naga Hills Ophiolite (NHO) of Upper Cretaceous-Lower Eocene age. The basinal facies marked by strong folding and overthrusting (Ghose and Singh, 1981) are encountered in the Inner Fold Belt (IFB). These sediments, however, lack in reliable criteria for stratigraphic correlations such as age-diagnostic fauna, marker horizons and widespread lateral litho-facies variation. In consequence Mathur and Evans (1964) have given the Cenozoic stratigraphic succession of the region on the basis of lithological variation. Thus this has provided a challenging task to have proper insight of the basinal evolution and necessitates the establishment of high-resolution stratigraphy and its correlation to different sequences within the basin. Ganguly (1993) opines that the regional stratigraphy of these sediments is yet to be established.

Paleomagnetism is a proven robust tool for documenting and more precisely dating rocks for stratigraphic correlation. The earth’s magnetic field has been switching over its polarity at irregular intervals, resulting in alternating periods of normal and reverse polarity. This arbitrary reversal pattern of the earth's polarity provides a unique record - the key to paleomagnetism. Charting the long term history of the earth's geomagnetic field by recording fossil magnetism in rocks and sediments, enables dating of sediment formed over geologic time. Magnetic polarity reversal is a global event that provides for correlation and is the basis for chronostratigraphy.
Paleomagnetic stratigraphy or magnetostratigraphy is a recent technique that has been effectively used throughout the world in varied depositional environments for stratigraphic correlation (Harsland et al., 1990; Opdyke and Channel, 1996). Magnetic polarity is independent of lithogenic constraints such as lateral litho-facies variations, permitting good correlation amongst Cenozoic successions (Tauxe and Opdyke, 1982; Tandon et al., 1984; Johnson et al., 1985; Raynold and Johnson, 1985; Appel, et al., 1991; Tandon, 1991; Rao, 1993; Sangode et al., 1996, 1999; Brozovik and Burbank, 2000; Kotlia et al., 2002; Sangode and Kumar, 2003; Sangode and Bloemendal, 2004).

Very limited studies have been carried out on paleomagnetism and magnetostratigraphy in the north-eastern region. This has created a wide gap in our understanding of the geology of this terrain. Hence, the present study is an attempt at a detailed paleomagnetic study to establish magnetic properties of the rocks, pattern of polarity zone and its correlation with global polarity time scale (GPTS) to construct the magnetic polarity stratigraphy of the study area. The study will throw light on the rate of sediment deposition and magnetomineralogy.

However, in recent years some attention has been directed to petrographic and geochemical studies of various types of rocks of the region. The present study is devoted to paleomagnetism, petrography and geochemistry of select rocks of the study area including basalt and Upper Disang shale and sandstone. Other rock types in the region include the Lower Disang shale and various rock types of the ophiolite complex. The Lower Disang have not been considered for the present study as they comprise highly jointed and brittle shales at various stages of weathering that are difficult to sample for paleomagnetic studies. Most of the other rocks of the ophiolite complex are metamorphosed and so are also not suitable for the same as also much of the basalts that are altered to spilite.

1.1 Aims and Objectives of the Study

The study includes petrographic, geochemical and paleomagnetic studies of the basalt of the NHO and sandstone and shale of the Upper Disang rocks. However, for magnetostratigraphic correlation the Laisong sediments have also been sampled and analysed. The aims and objectives of the present study may be summarized in brief as follows:
i) Petrographic studies of basalt to understand their characteristics.

ii) Petrographic studies of Upper Disang sandstone for their classification provenance.

iii) Heavy mineral analyses for determination of provenance of the Upper Disang sediments.

iv) Geochemical studies to establish petrogenesis and tectonic setting of the basalt.

v) Geochemical studies of the Upper Disang sandstone and shale to decode their provenance, tectonic setup, sorting and recycling effects, weathering history, paleoclimate and depositional environment.

vi) Magnetic mineral studies to infer magnetic carriers of characteristic remanent magnetization (ChRM) in the basalt.

vii) Magnetic mineral studies to infer magnetic carriers of ChRM in the Upper Disang and Laisong sediments.

viii) To establish the rate of deposition of the Upper Disang and Laisong sediments of the study area through paleomagnetic means.

ix) To construct high-resolution stratigraphy of the study area through paleomagnetic means.

1.2 Location and Accessibility

The study area, including parts of central and eastern Nagaland, falls in Kohima and Phek districts. The basalt areas under study are incorporated in the Survey of India (SoI) toposheet 83 K/13 and lies within 25°33' & 25°41' north latitude and between 94°42' & 94°49' east longitudes. The Upper Disang lies between east longitudes 94°07' & 94°30' and north latitudes 25°30' & 25°41' in SoI toposheet 83 K/2 and K/6.

The area is well connected to the rest of the region by the NH 150 and AH 1. Several metalled and un-metalled roads connect the numerous small towns and villages. The nearest airport and railhead are located at Dimapur. Helipads at Chakhabama, Lacham, Waziho and Ziphu facilitate military and exploratory reconnaissance.

Lithostratigraphic columns of Paleogene sediments for magnetostratigraphic studies have been constructed at Leshimi and Viswema in Phek and Kohima districts.
respectively. The Leshimi section lies at 25°31'39"N latitude and 94°13'57.30"E longitude while the Viswema section lies between 25°34'13.11"N and 94°7'22.94"E.

1.3 Physiography

The study area is highly dissected and immature, depicting a second order topography with synclinal ridges and anticlinal valleys. High hills, narrow valleys, steep cliffs, deep gorges devoid of any plateau or tableland are the common physiographic features. The countryside, as a whole, commands a majestic landscape.

1.4 Climate and Rainfall

The study area enjoys sub-temperate to temperate type of climate. Summers are warm and humid while winters are dry and cold. January is the coldest month of the year. In winter the temperature falls normally to 5°C or less and in summer it rises up to 32°C. The area receives abundant rainfall during the monsoon which commences from May and continues till September. Maximum rainfall, which is contributed by the south-west monsoon, is noted during July-August. Cloudbursts and thunderstorms are common phenomena in this part of the country. The average annual rainfall varies within wide limits from 2000 to 2800 mm.

1.5 Drainage

The terrain is highly dissected by a number of perennial and seasonal streams which have excavated ‘V’ shaped valleys and gorges. The drainage is topographically, lithologically and structurally controlled. There are two main trends, viz., NE-SW and NW-SE. These are mainly dendritic and trellis with occasional parallel or sub-parallel patterns. The drainage density is higher in the Disang shale dominated areas. The major perennial streams are Sedzü, Zungki, Tizü, Lanyi and Layoti.

1.6 Flora

Variations in altitude, physiography, rainfall and soil coupled with the geology have given rise to diverse vegetation in the region. Besides, the intensity of biotic interference, either singly or in combination, creates a striking variety in the ecological situation. Exposed to the heavy rainfall, the area is endowed with rich flora. The terrain
is adorned majestically with both indigenous and exotic flora (angiosperm and non-angiosperm) and includes Bauhinia variegata, Erythrina indica, Bombax ceiba, Gmelina arborea (gamari), Alnus nepalensis (alder), Tectona grandis (teak), Terminalia myriocarpa (hollock), Juglans regia (walnut), Spondias pinonata, Sapindus rarak (soapberry tree), Schima wallichii (needle tree), Mangifera indica (mango), Quercus sp. (oak), Emblica officinalis (gooseberry), Rhus semialata (Naga tenga), Ficus cunia (fig), Ficus auriculata (fig), Docynia indica (wild apple), etc. Cyphomandra betacea (tree tomato), Zanthoxylum sp. (mechinga), Rubus ellipticus (raspberry), Curculigo capitulate, Centella asiatica (Indian pennywort), Colacassia sp., Zingiber officinale (ginger), Elettaria cardamomum (cardamom), Phrynum pubinerve, Thysanolaena maxima (broom), Musa sp. (banana), etc. are some of the common shrubs and herbs available in the study area. Climbers include such as Passiflora edulis (passion flower), Sechium edule (chow chow), Diascorea sp. (yam), Calamus tenius (cane), etc. A large variety of bamboo is also found (Bambusa balcooa, Bamnusa tulda, etc). A myriad species of orchids and lichens splendidly clad the natural forest adding brilliance to nature. Pine forests (Pinus sp.) abound along the higher hills and ridges in the eastern-most fringe. Jhum cultivation, unrestrained forest fire and indiscriminate felling of trees for timber and firewood are the major factors for large scale deforestation in the region.

1.7 Fauna

Major parts of the study area are uninhabited, being adorned with thick forests that provide an ideal habitat for a numerous and diverse faunal species. The mammals include Melursus ursinus (bear), Muntaiqus muntjak (barking deer), Bos frontalis (mithun), Canis sp. (fox), Talpa (guinea pig), Panthera pardus (leopard), Herpester sp. (mongoose), Hystrix bengalensis (porcupine), Callosciuras sp. (squirrel), Sus scrofa (wild boar), Filis chaus (wild cat), Cynoptirius sphinx (bat), etc. The reptiles are represented by a number of species of poisonous and non-poisonous snakes and lizards. The forests also provide habitat for numerous species of birds like Bubo nepalensis (owl), Dicrurus sp. (tailed drongo), Pycnouotus jocosus (whiskered bulbul), Passer domesticus (sparrow), Gallus gallus (jungle fowl), Mengalaima sp. (barbet), Psittacula krameri (parakeet), woodpecker, pigeon and the endangered Tragopan blythii, etc. Innumerable species of insects, bees, snails, frogs, fish, etc., abound in the region.
1.8 Previous Literature

Geological studies of the Naga Hills commenced with attempts for locating and evaluating Tertiary coal deposits by Mallet (1876). Oldham (1883) discussed the geology of parts of Kohima and Manipur. Hayden (1910) described some coal fields of Nagaland while Pascoe (1912) conducted a geological traverse from Dimapur to Saramati. Evans (1932) and Mathur and Evans (1964) proposed a lithostratigraphic classification and described the structures and tectonic framework of parts of NE India. Goswami (1960) referred to Nagaland while describing the geology of Assam. Brunnschweiler (1966, 1974) described the regional geology and tectonic history of the Indo-Burman ranges. The geological evolution of the rocks of the Upper Cretaceous-Tertiary basin has been dealt with in detail by Raju (1968) and Bhandari et al. (1973). Krishnan (1968) gave a general description of the geology and tectonic framework of Nagaland. The Directorate of Geology & Mining, Nagaland (DGM, 1978) gave importance in unravelling the geology and mineral resources of parts of the state leading to refinement of the stratigraphy of the rocks of Nagaland.

Systematic geological mapping of the NHO belt was undertaken by geologists of the Geological Survey of India (GSI) and DGM (Chattopadhyay and Roy, 1975; Singh and Adiga, 1976; Agrawal, 1977; Srivastava et al., 1978; Agrawal and Kacker, 1980; Roy and Kacker, 1980). Geological details of the NHO belt were synthesized in several publications by Sen and Chattopadhyay (1978), Chattopadhyay et al. (1983) and Kacker et al. (1984). Based on paleontological records the age of the Ophiolite has been placed at Upper Cretaceous-Eocene (Brunnschweiler, 1966; Chattopadhyay et al., 1983). Bhattacharjee (1997) dealt with the tectonism of the Indo-Burman area.

Petrography and geochemistry of the Ophiolites, particularly the mafics and ultramafics, was initiated by Ghose (1979), Singh (1979), Ghose and Singh (1980), Agrawal (1985), Agrawal and Ghose (1986) and Chattopadhyay et al. (1983). All these workers have distinguished the existence of litho-assemblages of dismembered bodies of the ophiolite. In recent years Rao et al. (2003), Subba Rao et al. (2004, 2005) and Srikanth et al. (2004) contributed to the geology of the NHO. Ezung (2007) undertook detailed geochemical and petrographic studies of the basalt and spilite of the NHO.

Sporadic studies have been carried out in the IFB comprising Upper Cretaceous-Tertiary sediments in the last few decades. Sarmah (1983) gave a detailed account of the Disang and Barail sandstones of Kohima town and its surroundings.

1.8.1 Paleomagnetic Studies

Though several workers contributed to the geology of Nagaland, very little interest was given to paleomagnetism. During the late 1980s, the GSI attempted paleomagnetic investigations on the magnetite of the NHO of Phokpur and Kiphire districts. The very first work on magnetostratigraphic attributes of the Tertiary rocks of the northeastern region was along the Hari River section in Meghalaya (Tiwari et al., 2006). A 3500 m thick succession of Cenozoic sediments comprising Sylhet limestone, Kopili, Laisong, Jenam, Renji and Lower, Middle and Upper Bhuban formations has been studied. This entire sequence has been inferred to have been deposited in a time span of 30 Ma. Tiwari et al. (2007) worked in parts of the Middle Bhuban sequence in Aizawl for magnetostratigraphic attributes where a total of seven normal and reverse magneto zones have been delineated. Recently, magnetostratigraphy of the Neogene sediments of the eastern Himalaya in Arunachal Pradesh has been investigated by Chirouze et al. (2012). In parts of the Indian subcontinent paleomagnetic and magnetostratigraphic studies have been extensively carried out by several workers but in the northeastern region such studies are far from expectation although there is scope for such studies.