Chapter 1

Introduction

“Wonder is the feeling of the philosopher, and philosophy begins in wonder.”

-Plato

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The Earth itself is a dynamic system. All its constituent layers are subjected to continuous changes and in continuous motion. Convection in the liquid outer core generates the magnetic field of the earth providing an electromagnetic shield to protect the living world from harmful cosmic rays. Convection in the mantle layers generate the forces required for movement of the blocks of the lithosphere, the outermost layer of the solid earth. The crust is subjected to cycles of creation, preservation and destruction. Newborn crust starts its venture from a mid oceanic ridge (divergent boundary), wander a long way off to become older, reach a subduction zone (destructive boundary), and end up merging down to the mantle for a next cycle. During these cycles, the crustal material on top of the crustal blocks undergoes deformations, leading to generate topographic features on the surface of the Earth. Such topography, in turn takes part in the various dynamic activities on the hydrosphere, biosphere and atmosphere, inducing the rock cycle, water cycle, oxygen, carbon cycle, etc.

When the lithosphere together with some part of the crust has been consumed in a destructive margin, the net extent of the crustal materials, in the regional scale, will be reduced either by overlapping or by elastic and plastic deformations which is described as crustal shortening. Lateral compression, which exerts on the crustal materials, is generally compensated by vertical thickening of the crust within the extent of the stress field developed due to that
compression. Such huge compression force is generated by tectonic movements involving lithospheric plates.

The Indo Myanmar Ranges (IMR) runs along the eastern margin of the Indian sub-continent passing through the states of Nagaland, Manipur and Mizoram, and continues along the Chin Hills of Myanmar (Burma), as an arcuate body convexing westward (fig. 1.1). It extends approximately in the north south direction along the political boundary of north-east Indian states with Sagaing division and Chin state of Myanmar. Part of the Indo-Myanmar Ranges in India falls within the territorial boundaries of Nagaland, Manipur and Mizoram states. The whole range had been broadly divided into three major segments by former workers accordingly with the change in the trending axes orientation (Brunschweiller, 1966, 1974; Acharyya, 1991; Acharyya, et al., 1986; Mitchel, 1993; Mitchel & Mc Kerrow, 1975, Nandy, 2001). However, there was no sharp demarcation of these segments.

IMR is probably the northern prolongation of the Indonesian Island Arc system. The northern end of this arcuate belt joins with the eastern margin of the Himalayas, along the Tidding Suture Zone and extends up to the southern end of the Arakan Yoma in the Andaman Sea. Probably it has been evolved as an accretionary prism due to collision and subduction of India plate, underthrusting Myanmar (Eurasian) plate (Brunschweiler, 1966; Curray et al, 1979; Bender, 1983). It has the characteristics of a typical island arc system inside the continental landmass (Soibam, 2001, 2006). The line of the eastern foothills is assumed to be the margin of the Myanmar plate. The Surma basin, IMR, and the Chindwin basin, extending up to the Myanmar volcanic arc system constitute the accretionary prism. The Irrawady basin is the back arc basin (Kayal, 1995; Soibam, 2000). The process of subduction is still believed to be active (Satyabala, 1998; Khan, 2005). The subduction of the Indian plate below the Myanmar
plate is directly responsible for the structural and tectonic evolution of the Indo-Myanmar Ranges rather than that of the collision of the Indian and Eurasian plates under a dextral shear coupling deformation mechanism as contended by Soibam (2006).

The present work is a regional scale study on the tectonic aspects of the Indo-Myanmar ranges (IMR), with the observation of various controlling factors. The part of the crust in this region is along the destructive margin of the collision and subduction of Indian plate and Eurasian plate, enclosing the Myanmar micro-plate (Curray et al., 1978; Soibam, 2006). Field observations in various part of the region show many high degree compression features with compression direction perpendicular to the regional trend. But the regional trend is more or less aligning with the direction of motion of the Indian plate with respect to Eurasian plate. The relationship between the shortening direction and plate motion direction has something to explain the mechanism of the stress field controlling the geodynamics in this region. Conception of the present work was inspired by these observations.

An overview of the drainages from third and higher orders shows a systematic pattern, which seem to be related with the degree of compression and regional tectonic setting. The streams on the eastern margin of the ranges show an oblique pattern aligned with the synthetic or antithetic strike slip directions of the regional shear couple mechanism. Some part of the drainages, very few, are likely to be controlled by tension fractures but majority of them follow the synthetic strike slip direction. Only the major streams run parallel to the regional trend. When the compression stress is high enough the thrust planes are not open but tension along the orthogonal direction may induce the weak zones of the normal and/or strike slip faults, at the same time erosional activity is more there. On the western side of the ranges, the streams are more or less parallel or sub-parallel
following the regional trend. Farther to the west, higher order streams follow the synclinal valleys of the regional fold system.

Crustal shortening across this region is calculated at selective profile lines, taken perpendicularly to the regional trend. Variation in the shortening shows a uniform pattern, decreasing northward and southward from a zone of maximum shortening. The results are compared with the outcome through various perspectives, mainly from structural, morphological, global tectonics and Paleomagnetic viewpoints. Regional shortening is compared with compression structures found along the respective profile lines such as minor folds.

Assuming the vertical thickening of the crust varies directly as the amount of shortening, the degree of shortening can be computed by measuring original width and final width of a deformed crustal segment. Such a crustal segment is generally accompanied by geosynclinal basin with sedimentary strata exhibiting the deformation features. Thickening of the crust may be due to folding of strata, thrust nappes and overlapping thrust sheets in the form of imbricate slices or duplex horse.

Shortening in a region is exhibited by elevation in the topography with fold, thrust and other compression structures in the associated rock strata. In an ideal condition of rock cycle, within the region itself, if the crustal rock materials are not lost outside during the process of weathering and erosion, the average topographic elevation in the regional scale compensates the horizontal shortening. Curvature of folded strata expresses the degree of shortening of the same strata. Relative movement of the crustal blocks along a thrust plane, displacement of roof sheets in a duplex system and such similar features may also be used for determination of regional scale shortening of the crustal masses.
Balanced cross-section techniques are used to reconstruct the original forms of the presently deformed structures observed or inferred in the field. Methods used by Gibbs (1990), Hossack (1979), Woodward et al, (1989), are adopted in the present work to find out the horizontal dispositions of the crustal masses.

In a subduction zone, subducting crustal plates together with the lithosphere dips down below the obducting or overriding plate towards the mantle layer; the juncture at which the cycle ends. The outer layer of the crust along with the sedimentary strata on top of it may be pushed up by the margin of the overriding plate. As the subduction continues compressive force is generated and consequently, stress field is developed within the rock strata leading to various deformations compensating the implied pressure. Stress is more at the nearer end of the overriding plate margin and dies out at the points farther away from it.

According to the field observations of the structural and tectonic features found in this region, evolution of the IMR may not be concluded as simple accretionary wedge (Mitchel, et al, 2010). Mode of emplacement of the Ophiolite, longitudinally parallel thrust systems, inversion of tectono-stratigraphic sequences, and north-south extensional regime in the part of the Manipur Hills segment, etc. are some of the inspiring ideas leading to the conception of the present work.

The general trend of the hill ranges of the IMR follows a curvature, northeast-southwest in the northern part to NNW-SSE in the southern part. Axes of the major folds also follow the same trend. Many regional scale thrusts are found parallel to this trend as well as parallel to each other. The degree of compression is found to be more on the northern side showing a maximum shortening around Manipur-Nagaland boundary, gradually reducing towards the north as well as
southward. This variation in the degree of compression is supposed to bear a direct relationship with the relative motion of the Indian plate with respect to the Myanmar plate.

Fig. 1.1: IMR States of the Northeast India (Nagaland, Manipur and Mizoram)
The rotation vectors of this relative plate motion can be deduced by calculating the amount of shortening, along different lines across the range perpendicular to the regional trend. The line of maximum shortening will be aligned with the equatorial line correspond to the pole of the rotation and the pole will be at a distance of 90° away from this line. At the pole of rotation, the shortening is zero or at the end nearer to the pole of rotation, the shortening is minimum. It will be maximum at the farther end or at a distance of ninety degree away from the pole of rotation. Shortening is calculated along a chosen line across the ranges perpendicular to the general trend. Methods used in this work are adapted from the techniques introduced and applied by Dahlstrom (1969), Gwinn (1970), Coward (1992) and Woodward (2000). Yakovlev et al., (2001), in a case study in the Tien Shan Mountain, observed that thickening in the crust had not been contributed by the horizontal shortening alone. Thickening due to under plating of new crustal material under the influence of a mantle plume also has some contribution in the process. However, in the case of the IMR, it seems that thickening in the crust has a closer relationship with the horizontal shortening.

As reveal by the data from various sources, Indian plate is moving towards northeast direction (De Mets et al., 1990; Vigny, et al, 2003; Curray, 2005). At the same time Myanmar micro plate is moving northward with a strike slip movement along Sagaing fault (Satyabala, 2003; Vigny et al, 2003; Mitchell et al., 2010). Due to the configuration of the margin of the overriding plate, that is the Myanmar plate, and the direction of motion of the Indian plate, a resultant compression along the direction, approximately in the east-west, is produced. This compression stress might have been responsible for the evolution of the IMR. As well, a shear couple might have been developed by the different rate of movements of the plate pair. This shear couple can be used to explain the structural lineaments associated with the rocks and other topographic features in
this region. Further, comparison can be made by calculating the shortening percentage across, local scale minor structural features like folds observed directly in the field and inferred folds constructed from the field data and/or geological profiles with that of the regional scale shortenings to figure out the tectonic processes in this region.

An attempt has been made to decipher about the original position of the ophiolite body by examining the traces of paleomagnetism in the associated rocks. Since the exact age is unknown, we cannot confirm anything about the true paleomagnetic pole of the samples but the variation in the paleo-pole direction may have some significance in determining the relative changes in the disposition of the ophiolite body from the time of its formation up to present position. The paleo-latitude derived from the paleomagnetic data may provide some explanation to the mode of emplacement of the IMR ophiolites.

1.1 The concept of Plate Tectonics

Crustal shortening across the IMR is due to subduction of the Indian lithosphere below the Eurasian continent, and the Myanmar micro continent. Along the convergent plate boundaries, most of the oceanic crust and lithosphere consumed in the mantle layers and lighter continental landmass and sedimentary layers are subjected to lateral compression, resulting in horizontal shortening with corresponding vertical thickening. As early as 1910 Alfred Wegener introduced ‘the concept of continental drift’ that continents had probably once drifted apart to the present configuration. In 1915 he wrote the first edition of his book ‘The origins of the continents and oceans’ in which he tried to re-establish connections between geophysics and geology and geography. The concept of Plate Tectonics was introduced with the idea of seafloor spreading by Harry Harmond Hess and Robert S. Deitz in the year 1960 and 1961 respectively (Hess, 1962 and Deitz, 1961). In 1965, Tuzo Wilson
added the concept of transform fault necessary to make the mobility of the tectonic plates (Wilson, 1963, 1965). In 1965 theory of Plate tectonics was officially accepted by the global scientific community (Blacket, Bullard & Runcorn, 1965). Edward Bullard and co-workers showed the best fit to close the Atlantic Ocean, with a computer calculation along both sides of the Atlantic. This was known as the famous "Bullard's Fit". In 1966 the concept of Wilson's cycle (fig. 1.2) was introduced (Wilson, 1966). W J Morgan proposed the actual idea of ‘plate tectonics’ with the existence of 12 rigid plates on earth that move relative to each other (Morgan, 1968). Xavier Le Pichon published a complete model of 6 major plates and their relative motions in the year 1968, and it was accepted by the scientific community of plate tectonics (Le Pichon, 1968). Mc Kenzie and Parker also presented a similar to that of Morgan's model using translations and rotations on a sphere to define the plate motions (Mc Kenzie et al, 1967).

The outer layers of the Earth are divided into lithosphere and asthenosphere based on differences in the mechanical properties and in the method for the transfer of heat and seismic waves. Mechanically, the lithosphere is cooler and more rigid compare to the asthenosphere which is hotter and flows like fluids (viscoelastic). In the lithosphere, heat is transferred by conduction whereas in the asthenosphere by convection and has a nearly adiabatic temperature gradient. The division between the crust and mantle is marked by the Mohorovivc discontinuity, a boundary defined by a contrast in seismic velocity and/or petrological character. Part of the lithosphere may be termed as mantle lithosphere as it extends below the Mohorovicic discontinuity. Tectonic lithosphere plates consist of lithospheric mantle overlain by either or both of the two types of crustal materials, the oceanic crust and the continental crust. The oceanic crust has higher density and generally lies below the sea level but the continental crust is exposed above the mean sea level.
The principle of plate tectonics assumed that the lithosphere exists as separate and distinct tectonic plates which ride on the viscoelastic solid layer of the asthenosphere. It is basically a kinematic phenomenon. Generally, accepted view is that tectonic plates are able to move because of the relative density of oceanic lithosphere and the relative weakness in the rigidity of the asthenosphere. Dissipation of heat from the mantle is also a main component to be the original source of energy driving the plate tectonics through convection or large scale upwelling and doming. New crusts are formed at the spreading centers of the mid-oceanic ridges and such old crusts are consumed at the subduction zones.
Continental crusts are derived from the oceanic crusts through the process of fractional differentiation over eons or formed during the process of volcanism along the island arc systems.

The regions where two plates meet are known as a plate boundary. The plate boundaries or plate margins are generally associated with tectonic or geological events like earthquakes and volcanism, the creation of topographic features like mountain ranges, volcanic arcs, mid oceanic ridges, oceanic trenches etc. Plate boundaries are of three types viz conservative, constructive and consuming (destructive) respectively. In the conservative boundaries or the transform boundaries, the crustal blocks slide each other horizontally. Constructive or the divergent boundaries are characterized by mid-oceanic ridges and rift-valleys. Destructive or convergent boundaries are characterized by subduction, continental collision and associated with marine trenches, formation of foreland basins and volcanisms. Indo-Myanmar Ranges was evolved in a destructive plate boundary in between Indian plate and the Myanmar micro plate, a part of the Eurasian plate. Subduction of the oceanic crust of the Bengal basin below the Myanmar plate occur in the part of the Manipur hills and Chin hills segments and collision of the Indian continental crust and Myanmar continent occur in the Naga hills segment (Kayal, 1995, 2010).

1.2 The Neo-Tethys

Shortening across the IMR has direct relationship with the closing and uplift phases of the IMR basin. Opening of such a basin is required for deposition of the sediments. As the Indian continental landmass approached Eurasia, the vast span of the Neo-Tethyan oceanic crust was consumed below in the mantle, closing the then oceanic gap in between. The geological time span preceding the arrival of the Indian plate towards the Eurasian continent is the time of the phases of the Tethyan Orogeny. G M Stampfli and G D Borel
CRUSTAL SHORTENING ACROSS THE INDO-MYANMAR RANGES OF THE NORTHEAST INDIA AND ITS TECTONIC IMPLICATIONS

(2002) laid down the plate tectonic model for Paleozoic and Mesozoic times by studying a number of terrenes and continents. Subduction of the oceanic crust of the Paleo-Tethys along the northern margin of the Gondwana starts by Carboniferous to Permian results in the detachment of the Cimmerian and Argo-Burman terrenes due to rifting along the continental margin. That event of rifting opened up the Neo-Tethys and Paleo-Tethys was closed by northward push of the Cimmerian terrenes with a collision on the Eurasian continent. Subduction of the Neo-Tethys oceanic crust under the Gondwana around Cretaceous detached the Indo-Australian plate by rifting, opened up the Indian Ocean with the onset of the closing phase of the Neo-Tethys. The Neo-Tethyan oceanic floors were totally closed consuming it in both sides below the Laurasian as well as the Gondwana Supercontinents. The Indian and Australian parts of tectonic plates detached from the mainland Gondwana, moved towards north and subducted under the Eurasian plate. Due to subduction of the part of the oceanic crust of the Neo-Tethys preceding the Indo-Australian plate, phases of rifting might have been taken place along the Eurasian margin with subsequent rapid closing of the opening seas (incipient subduction). Present opening in the Andaman Sea and closing of the Indo-Myanmar Ranges basin may be discussed as some of the events related to the part of the mega event of the Tethyan Orogeny.

1.3 Ophiolites Belt of IMR

Emplacement of the Ophiolite, on top of the younger sedimentary strata is the best evidence of the tectonic activity in this region. The Ophiolite belt of the Indo-Myanmar Ranges of northeastern India forms a belt extending about 200Km from Pokhpur (Nagaland state) in the north to Moreh (Manipur state) in the south, and further discontinuous blocks extending up to Arakan Yoma segment. This belt described as Ophiolite mélange zone occupies the eastern line of the ranges in the Northeast Indian states. This mélange
zone is thought to be the part of the ocean floor rocks, formed in the spreading center of the IMR basin, obducted during the closing phase of the same basin, while the Indian plate dipped below the Myanmar plate. It consist of different tectonic blocks of different units of the Ophiolite sequence, the ultramafic, basic dykes and sills, pillow lavas, pelagic sediments of shale, limestone, chert etc. and exotic sandstones floating on the surface. Exposures are seen as tectonic slices sandwiched with the Disang sediments with contact thrust planes align with the regional trend.

The Ophiolites of the IMR is mainly composed of peridotitic ultramafics. Peridotites are harzburgite and lherzolite (Khuman, 2009; Khuman & Soibam, 2010), and podiform chromites are observed in Manipur hills segment. Most of these ultramafics are highly serpentinised and relatively fresh blocks are found within. They have high magnetic susceptibility due to presence of spinel group of minerals. An attempt is made to extract the palaeomagnetic traces on these rocks to establish its tectonic relationship during the evolution of the IMR.

1.4 General accounts of the IMR States in India

Three Northeastern states of India share the political boundaries with the Myanmar territories along the Indo-Myanmar Ranges. The State of Nagaland occupies the northern Naga Hills segment of the IMR shared with the Somra tract of the Kachin State of Myanmar. Mizoram in India and Chin province of Myanmar share the Chin Hills segment of the IMR.

1.4.1 Nagaland

The land of Hornbill is the land of the ‘Nagas’ a group of ethnic tribes of the Tibeto-Burman Mongoloids. More than fifteen indigenous tribes inhabited the paradise land in bands along the hill ranges. Major tribal groups of the population includes Angami, Ao, Sema, Lotha,
Rengma, Chakhesang, Sangtam, Konyak, Phom, Chang, Yimchunger, Khiamungan, Zeliang, Pochury and Kuki. Christianity is the predominant religion of Nagaland. The state of Nagaland lies approximately in between 25°6' and 27°4' latitude, North of Equator and between the longitudinal lines 93°20'E and 95°15'E, extending an area of 16,527 sq. Km. The capital city is Kohima, at an altitude of 1444 m above mean sea level, and the highest peak in this state, Saramati, (3841 m) is in its eastern boundary. The state is connected with other part of the country by National highways (39, and 155), railways (NEFR) and airways. The state has a series of festivals throughout the year.

1.4.2 Manipur

The Jewel of India is the land of unity in ethnic diversities. More than thirty-three tribes and communities of different cultural heritage shared the hill ranges and flatland valleys in between. It has an area of 22,327 sq. Km extending within 23°50’N and 25°41’N latitudes and 93°00’ E and 94°45’ E meridians.

The state has many unique features in its geography, biodiversity, history and social set up of its people. Loktak is the largest fresh water lake in the Northeast India. Sangai the brow-antlered deer is the endangered species found only in Manipur, on a habitat of floating phooms on the national park of Keibul Lamjao, the only park of its kind in the world, floating on water. Phooms are floating mass on the lake water, composed of soils, decayed grasses and weeds, thickly overgrown with the same grasses and weeds. The column has an average thickness of two to three meters and supports the load above it just like a landmass. The Siroi Lily, a species found only in Siroi hills of Manipur state blossom in this land of jewels during May to July (discovered by Lord King Don Ward, a British officer). The ‘Imphal Valley’ occupying the central part of the state is the only flatland in the whole IMR. This valley had been the nucleus
of the ancient Manipur kingdom with a recorded history of about two thousand years (non-recorded was claimed for more than three thousand years). The world famous game of Polo, locally known as Sagol Kangjei originated from this land. Kang is also an old indigenous game played for more than eight hundred years in the history of the land. Another indigenous game is the Mukna-Kangjei which was very popular in the past. From the religious and artistic point of view, the Manipuri Classical form of dance is claimed to be one of the most chestiest, modest, softest and mildest but the most meaningful dances of the world. Khwairamband Keithel a market place more than three hundred and fifty years old is a market of women vendors only. Popularly known by the name Ima-Keithel, and is the only one of its kind in the world. The Moreh market on the border fencing of Indo-Myanmar International Boundary is the centre for cross border trades. It is about 109 Km far from the capital city, Imphal. The Imphal Valley is at an altitude of 780m from mean sea level. The highest peak in the state is Mt. Iso (2944 m) in its northern border.

The state of Manipur is inhabited by a number of ethnic groups belonging to various religious sects. Meetei-pangals are the Manipuris under the Islamic cults. Kabuis and Meeteis are two groups of people who still practice the indigenous religions. However, most of them adopted Hinduism or Christianity except with a few Buddhist among the Meetei community. Most of the hill people had adopted Christianity during the British regime (1891-1947). Tangkhul, Mao, Maram, Paomei, Maring, Anal, Aimol, Lamkang, Monsang, Moyon, Kom, Koirao, Koiireng, Chiru, Chothe, Kabui, Tarao, Thadou, Hmar, Paite, Gangte, Chin, Mizo, Vaiphei, Simte, Zou and Chakhesang are major tribes of Manipur having their own cultural history and customs.
1.4.3 Mizoram

The Songbird of the Northeast is the land of Mizo, a group of Kuki-Chin tribes belong to Tibeto-Burman mongoloids. The state is in a mountainous region covering an area of 21,087 sq. Km. located within latitude 21°58’N and 24°35’ N, and 92°15’E and 93°29’ E longitude. Myanmar in the east and south and Bangladesh in the west, Mizoram occupies a region of strategic importance in the northeastern corner of India. It has the most variegated hilly terrain in the eastern part of India. The hills are steep and are separated by rivers which flow either to the north or the south creating deep gorges between the hill ranges. The highest peak in Mizoram is the Phawngpui (Blue Mountain) with a height of 2210 metres. The capital city Aizawl lies at an average altitude of 1075 m above mean sea level. Mizoram has a pleasant climate. The entire area is under the direct influence of the monsoon. Winter in Mizoram is wonderfully decorated with the enchanting view of wide stretches of a vast lake of cloud. Mizoram has great natural beauty and endless variety of landscape and is very rich in flora and fauna. Almost all kinds of tropical trees and plants thrive in Mizoram. The hills are marvelously green.

The overall climatic condition in these states is sub-tropical to temperate depending on the altitudes and latitudes. Temperature varies between 0° to 35°C in the average. November to March is the usually dry period suitable for field studies.

1.5 Present Work

Although, a number of studies on the geological and tectonic setting about the IMR have been carried out as observed from general geological background above (e.g. Brunnschweiler, 1966, 1974; Acharyya, 1991; Acharyya et al., 1986; Mitchell, 1993; Mitchell & McKerrow, 1975; Nandy, 2001), till date no detailed work on the crustal shortening about the IMR and its tectonic implications has
been made by any worker. So, the main concentration of the present work is on the calculation of the shortening along different profile lines across the IMR of northeast India, and to compare the variation in the amount of shortening.

This result can be used to deduce the rotation vectors of the relative plate motion of the Indian plate and Myanmar plate. It will be useful to establish the possible direction of motion of the crustal blocks so as to reconstruct the evolutionary history of the region. Attempts are made to accumulate evidences from the angle of paleomagnetic studies, and supports from seismic and GPS data. Main objectives and methodologies involve in the study are as follows:

1.5.1 Objectives
1. To find out variation in the crustal shortening of the Indo-Myanmar Ranges (IMR) of the North-East India.
2. To establish the rotation vectors for Indian and Myanmar plates from different aspects including paleomagnetic studies.
3. To compute the shortening, using minor structure and their compatibility with that of the crustal rocks.
4. To examine the variation of the states of strain across the Indo-Myanmar Ranges of Northeast India.
5. To work out the stages of evolution of the Indo-Myanmar Ranges during the subduction process.

1.5.2 Methodology
1. Preparation of geological and topographic profiles along the selected sections of the IMR of Northeast India.
2. Calculation of shortening by using balanced cross-section techniques.
3. Evaluation of the pole of rotation by using the shortening data at various profile lines along the IMR.
4. Evaluation of the magnitude and direction of the relative plate movement at selected point.
5. Raw data collection of various minor structures, calculation of local shortening and comparison with that of regional shortening.

6. Preparation of charts, graphs and geometrical models using simple statistical methods, and analysis of the states of strain across the IMR.

More detail discussion on the methodologies adopted is made in the relevant sections and chapters.

1.6 Field work and Laboratory Studies

Field study related to this work covered parts of Nagaland Manipur and Mizoram. All the terrains are not suitable for field work in the monsoon season due to heavy precipitation. During summer also, little exposure of the outcrops are visible as covered by thick vegetations. February and March is most suitable for working in these areas. Besides, law and order situation in this region hampered the smooth progress of the research work. Sometimes, it made unable to reach the targeted spots for investigation due to many constraints related to insurgents as well as security point of view of the Army, paramilitary and police forces. However, structural data were collected from different parts of the region.

Samples of the ophiolite rocks are collected from three sections of Manipur hills segment only, Ukhrul, Kamjong and Moreh sections. Ukhrul and Kamjong sections fall within the widest part of the Ophiolite belt of the IMR, and assumed the samples as representative of the part of the belt exposed in the northern part of the IMR. Most likely this section coincides with the central region of the then IMR basin.

Due to law and order problem as mentioned above, it was decided not to take the risk of carrying the drilling instrument in the field. Some work of the core sampling had been done in the
laboratory, by collecting oriented samples from the field. Magnetic measurements are done in the Paleomagnetic laboratory of IIGM, Allahabad. Some part of the study area falls within security zone of the defense strategy of the country. Therefore, the toposheets of these areas of the required scale for the study was not available. But Digital Elevation Model (DEM) imageries downloaded from reliable sources are used in some cases.