CHAPTER I

INTRODUCTION

The Manipur - Nagaland Hills, the sentinel of the Northeast India, have enlivened and sustained the life and culture of our people from time immemorial. Nestling in the shadows of these hills, at the easternmost corner of the country, Manipur State of India seems much like an exquisite work of an art executed by the superb hands of Nature. The exotic landscapes of Manipur with undulating hills, green valleys, blue lakes, sparkling rivers and emerald forests justify it to be called the "Little paradise on the Earth". This young mountain system of the world has instilled and inspired thinkers, philosophers and adventurists throughout our history. This has been a source of perennial knowledge right from the vedic period and enshrined in the folk tradition of the country.

Right from the year 1883 or so, modern scientific and geological investigations have been directed towards understanding this range of mountain system. The
detailed geology of the Manipur - Nagaland Hills has been on the anvil during the recent years. Not much has been written about it. More investigations are needed to fill in the gap and to present a detailed appraisal of geological data in the light of modern geodynamic concept. The stratigraphic and structural setting of Manipur - Nagaland Hills have remained debatable even now, mainly because of the paucity of adequate stratigraphic controls, rarity and good preservations of fossils as well as tectonic complexities.

The Manipur - Nagaland Hills comprise the central part of the Indo Burmese Range. It has an arcuate trend, the convex side pointing towards India. It is about 400 km in length and 50 to 70 km in width in different sections. The Manipur - Nagaland Hills in their southern part is known as the Manipur Hills. Manipur is the easternmost state of India bounded by latitudes 23°50'N and 25°41'N and longitudes 93°2' E and 94°47'E.

The State has an area of 22,356 sq. km. Manipur has been known for its fabulous beauty, wonderous fertility and extreme climates. The State has been subdivided into eight districts viz. Imphal, Thoubal, Senapati, Bishnupur, Chandel, Tamenglong, Churachandpur, and Ukhrul.

The Manipur Hills consist of a series of parallel
ranges trending N-S, extending from Nagaland Hills in the north and joining Mizo and Chin Hills in the south. In the eastern side of Manipur State, the average height of hills is about 1,500 m, while further northeast it rises above 1,800 m.

On the western side of the State, the hills rise above 2,500 m. Some of the important peaks are Khayangbung (2,833 m), Siroi (2,568 m), Kachoobung (2,498 m), Tenipu (2,994 m), Koubru (2,652 m), and Tamphaba (2,664 m). The State is principally drained by Barak River System, Manipur River System and the Chindwin System. The Barak and its tributaries namely, Irang, Makru, Tuivai, and Jiri flow in the northwestern hills of the State and form a part of the Brahmaputra System. The tributaries of Manipur and Chindwin river systems constitute part of Irrawady drainage system.

The Manipur - Nagaland Hills comprise the most important segment of the Tertiary mountain chains because they display a cross-section of litho-units of Sumatra coast (Mitchell and McKerrow, 1975). The ophiolites are tectonically exposed in a part of the main frontal zone of the Alpine - Himalayan tectogene, lying along and within the easternmost ranges of the Indo-Burma system (Brunnschweiler, 1966) and form a part of the Peri Indian Suture Zone (Gansser, 1980).
The lensoid bodies of limestone occur throughout a linear belt from Nagaland in the north to Manipur in the south. These carbonate deposits were first described by Pascoe (1912). Similar, bodies are also reported from Jampui hills, Tripura and Senai river section, Mizoram (Nandy and Gupta, 1990) and from the Chin hills and Arakan Yoma (Brunnschweiler, 1966). Their geological setting and nature of occurrences have been controversial for a long time now. They are considered as allochthonous bodies occurring as exotic floats within the flysch country. Recently, they have been considered as of olistostromal deposits (Mitra et al., 1986).

1:1 THE STUDY AREA:

The study area extends from Sokpao to Paoyi and then upto Phungyar via Kangkhui and Changa towards the south. The area lies in Ukhrul District of Manipur State Fig.1. It lies between latitudes 24°59′N and 25°16′N and longitudes 94°22′E and 95°25′E, covering a linear tract of nearly 50 sq. km with varying width probably on account of their exotic nature. The study area is covered by the Survey of India topographical

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Sheet nos. 83---, 83---, and 83---. The area is located at about 83 km from Imphal in eastern part of the State.
FIG.1: LOCATION MAP OF THE STUDY AREA
The above mentioned sections provide an opportunity for studying the various types of carbonates. In this area, carbonates occur at Hundung (23°03'N: 94°20'E), Ukhrul (25°06'N: 94°22'E), Kangkhui (25°30'N: 94°24'E), Paoyi (25°16'N: 94°25'E), Changa (25°03'39"N: 94°25'E), Sokpao (24°59'N: 95°16'E) and Phungyar (24°49'20"N: 94°25'E).

Near Hundung village, there are three carbonate deposits. The largest of the three carbonate deposits, is exposed by the side of the Imphal - Ukhrul Road and is known as Hundung North deposit. The southernmost occurrence is on the bank of Nungsangkhong nala and is known as the Mova deposit. The third deposit lies between the two deposits and is known as the Hundung south deposit. The deposits at Hundung south and Mova are fully exposed as pyramidal or conical bodies.

In Ukhrul area, the carbonate rocks are located at about 400 metres east of View Land Bazar, Ukhrul town. The second deposit is observed near the head quarters of the 6th Bn., Manipur rifle. The other minor deposits occur as lenses associated with the Disang Formation.

The Kangkhui carbonate deposits are located near Kangkhui village, about 13 km from Ukhrul town, facing the Choithar village.
The Paoyi carbonate deposits are located at about 37 km off Ukhrul towards the north. The Phungyar carbonates are located near Phungyar village, about 83 km south of Ukhrul town. The other minor deposits are located near Sokpao and Changa villages.

The area under investigation, being close to the border between India and Myanmar (Burma), is of immense strategic importance. On account of this and other factors like inaccessible heights, climatic hazards, restrictions on photography and use of topographical maps in the field, the extent of field work was only limited to detailed geological mapping and sampling along some permissible traverses, tracks, paths and road sections. The geological map appended with this work is based on extrapolation of data collected during various criss-cross traverses, in the study area, and some published regional geological maps.

1 : 2 AIM AND SCOPE OF INVESTIGATION:

A perusal of published literature on the geology of Manipur brings out the necessity of, localised and sectorwise intensive investigations of the belt. Much of the published data are based on reconnaissance survey of the belt with regional bias and, therefore, many gaps are apparent when one considers the relationship accruing
between carbonate and flyschoid deposits in which they occur as exotic bodies.

Regional appraisals have their own value though much of it is lost in the myriad of confusion on account of various shades of opinion. Invariably the data of significance are so scanty that any attempt to decipher the genetic systematics and occurrence of the carbonates in the broader frame work of geodynamic evolution of the Manipur - Nagaland Orogenic Belt, becomes rather difficult. This is primarily because of the fact that very few attempts have been made to study these carbonates in detail.

The aim and scope of the present investigation has been to identify signatures of values in the carbonates vis-a-vis their types, relationship, stratigraphic position and age as well as their genetic significance. The problems are complicated and often in such orogenic belts one has to make sincere efforts to tie up the traits to carve out a picture of some value. Such endeavours, beset with numerous limitations, are multifaceted and, therefore, diverse types of study encompassing geological, stratigraphical, petrological and geochemical investigations are needed to be carried out in some very typical sections in order to obtain some the basic data for their authenticated and modern appraisal.
Ukhrul and its adjoining area is one such ideal section to undertake the proposed type of study and hence this area was selected for the work.

The writer has made sincere efforts to obtain some data of significance accruing from investigations using diverse methodology so that they could be helpful in understanding various aspects of carbonate geology in keeping with the astounding changes in geotectonic concept that have taken place during the last two decades or so. No attempt has been made in the present work to test the hypothesis. Nevertheless, the endeavour has been to obtain some basic data on a very critical sector, the study area, comprising a part of the orogenic belt. It is imperative from the observations made by various workers that the solid geological, geochemical, petrological, and age-data on the study area are scanty. The nature of carbonates, environment of deposition and genetic-tectonic models proposed so far have been rather speculative. Nevertheless, the carbonates occurring in the Manipur - Nagaland Orogenic Belt and their evolutionary history have often been discussed by some researchers. These have been reviewed in the proceeding section of the work. In tackling such fascinating and complex problems, systematics have to be worked out and the present work is a modest attempt in this direction.
METHODS OF INVESTIGATION:

Geological investigation, particularly of the present type, which demands diversification of the techniques in order to obtain some correlatable data, very much depend upon field and laboratory sampling procedures backed by a reasonably good fieldwork and geological mapping. This is again conditioned by the nature and theme of the project under investigation as well as the study area. Geochemical data are significant only when they are precise, reproducible and have been determined in samples which have been precisely identified petrominerallogically. The data is reliable only when the samples analysed are controlled, representative, free from contamination and have been properly located. The diverse types of investigations conducted in a very arduous and inaccessible terrain, like Ukhrul area of Ukhrul District of Manipur State, essentially calls for enormous facilities to complete the work. Since much stress, in the present study, has been laid on efforts to obtain some valuable geochemical data, the author had to utilise all available resources for a controlled sampling of the area and for analytical works.

For detailed investigations of these carbonate rocks, the author used a flow chart of Erik Flugel (1982) with the addition of some modern techniques. The chart is reproduced below:
Table 1:1  Carbonate investigation flow chart.
(after Flugel, 1982)

| Field Work | Lithology--- |
| Sampling | Rock colour-- |
| Hand Specimen | Sedimentary structures--- |
| | Sedimentary textures--- |
| | Fossils------ |
| | Geometry of the rock---- |
| Cutting Fracturing Powder Preparation | |
| Thin section Acid Etching Peels | |
| Covered Slides Uncovered Slides------Staining | SEM (Scanning Electron Microscope) | |
| | Chemical Analysis DTA XRD | |
| | Major Elements Trace Elements Stable Isotopic Analysis | |
The investigation was carried out in linear tract of about 50 km lying between Sokpao, Paoyi and Phungyar, with varying width, which was permissible by the authorities and feasible to negotiate during the field work. Geological mapping in the entire study area was carried on 1: 50,000 scale while the carbonate deposits were mapped on 1: 9,000 scale, preceded by a reconnaissance survey. The mapping was done by taking close traverses though restrained at many places because of being the country’s frontier area. Brunton-tape/pace method of mapping was followed. The data were plotted on the base maps. The geological maps produced based on the present investigation and on considerations of the published data are presented in Figs. 4 - 5. Field and petrographic observations have been used in delineating various lithologic contacts.

Since the present study has been aimed at obtaining some quantitative geochemical data, the author undertook a very detailed sampling of outcrops occurring on all possible close traverses in the study area. Attempts were made to collect fresh and homogeneous carbonate samples besides a score of random samples of all the rocks even though some of them were not mappable on
the scale. In some cases, chips and a large number of bulk samples were collected to obtain one representative sample. The location of sample points has been shown on the geological map prepared by the author (Fig. 1).

1: 6 **PETROGRAPHIC INVESTIGATION** :

A routine petrographic investigation of about 200 representative thin sections of the carbonates was carried out. The thin sections were prepared of different lithologic units were prepared, various beds. For petrographic analysis, thickness of thin sections is 30 micron. For detailed fabric investigations, 30 to 70 micron thick sections are usually preferred. Such "thick sections" often allow the textures and structures of carbonates to be identified more easily. In case of very fine grained micritic carbonate rocks, ultra-sections (0.5 to 5.0 microns) are necessary (Honjo, Fischer, Lingholn and Dean, 1973). These sections facilitate to scan the rocks under high magnification between X 150 and X 1000. Use of cover slips is not always recommended for determination of carbonate minerals like calcite, dolomite, aragonite, etc., on stain test, etching (indication of distribution of non-carbonate components) and scanning Electron Microscopic (SEM) examinations. The author used all such slides during the present work. SEM has been used to determine the shape, size and other
topological features of carbonate minerals in the rock. Moussa (1976) has suggested plastic spray as a cover some thin the sections of carbonates. The modal composition of allochems and micritic materials, in thin sections of the rocks, were determined by using point counter.

The ideal chemical composition of the carbonates has been estimated by calculating the Niggli values from the chemical analyses of some of these rocks.

Other methods used by the author for petrographic investigation of the carbonate rocks are staining test, Differential Thermal Analysis (DTA), X-Ray Diffraction (XRD) analysis and Scanning Electron Microscopy (SEM).

1. STAINING TEST:

Much importance has been assigned to the identification of different carbonate minerals by staining techniques. A number of schemes have been proposed for these tests (Freidman, 1959; Warne, 1962; Evamy, 1963 and Dickson, 1965). The present author followed the procedure of Dickson (1965).

Dickson's (1966) technique for staining of carbonate thin sections was carried out in three stages as follows:
Stage I : Etching of uncovered slides with 1.5 per cent HCl (10 seconds).

Stage II : Staining with standard mixture of Alizarine red-s and potassium ferricyanide solution in 1.5 per cent HCl (45 seconds).

Stage III : Staining with Alizarine red-s in 1.5 per cent HCl (8 seconds)

The time limit of various stages can be increased or decreased depending upon the types of carbonate rock. The identification of carbonate minerals was easily done on the basis of the following colours shown by them in stained slides.

- Calcite : Pink to red
- Ferroan calcite : Purple
- Dolomite : Colourless
- Ferroan dolomite : Light to deep turquoise

1 :6.2. DIFFERENTIAL THERMAL ANALYSIS (DTA) :

The DTA method, unlike X-ray powder diffractometry, ordinarily cannot be used on a completely unknown rock to identify its mineralogy from the thermogram because the curves of different constituents overlap with one another. There is also a chance of reaction between components. Any reaction in the sample will give a peak.
DTA, however, can quickly identify the presence of small quantities, for example, of carbonate minerals, or kaolinite and other clays minerals in the rocks. However, it cannot be considered as a similar "finger printing" method as the X-ray diffraction analysis.

If any peak can, with certainty, be assigned to a single mineral constituent, the volume of that component in the specimen is related to peak area, measured by a planimeter from the extrapolated baseline, up or down. Ten representative samples of carbonate were subjected to Differential Thermal Analysis at the Department of Chemistry, Manipur University, Canchipur using the Shimadzu DT-30 instrument.

The powdered samples (-200 mesh) were analysed by DT-30 system consisting of record controller and furnace plateform. The parameters like chart speed (C.S.) = 5 mm/min and heating rate (H.R) = 50°C/min were kept constant during the analysis.

The characteristic peaks (endothermic and exothermic) recorded on the thermogram were utilised for the identification of minerals.

1:6.3 X-RAY DIFFRACTION (XRD) ANALYSIS:

On account of the limited facilities, it was possible to get the X-ray diffraction analysis of 13 (thirteen) representative samples of carbonates done at
the University Instrumentation Centre, Gauhati University, Guwahati. The powdered materials (-200 mesh) were analysed by Philips X-ray diffraction apparatus model PW 1130/00 using CuKα radiation and Ni filter. The samples were run between 10° and 70° (2θ - values) with 1°/minute rotation. The characteristic d-value (Å), calculated from the diffractogram, and hkl values obtained from ASTM cards were used for the precise mineral identification.

1.6.4. **SCANNING ELECTRON MICROSCOPY**

The identification of surface textures in these carbonates have been done by using Scanning Electron Microscope (SEM). The thin sections of carbonate were cut into 5 x 5 mm size and etched with dilute HCl acid. The sample was fixed on the aluminium rod, of 9 mm diameter and 1 cm length, with the help of adhesive and coated with gold. The samples were kept in horizontal position and the photographs were taken by the Scanning Electron Microscope (Model Jeol - 25A).

The sample preparation of the rocks was done by the present author while the gold coating of the samples was performed and the photographs were taken at the Centre of Advanced Study in Geology, Panjab University, Chandigarh.
1 : 7. **SAMPLE PREPARATION** :

The whole rock bulk samples (+ chips, if any) were crushed to 1 to 2 cm sizes on steel plates and grinding was done in percussion mortar and pestle to approximately +40 to +60 mesh (ASTM) size. No sieving was done at this stage and care was taken to ward-off contamination from the use of hammer and pestle. Iron powders were separated from the samples by using a horse-shoe magnet wrapped in paper. The above mentioned samples were reduced in bulk by coning and quartering. Out of the 1000 gm of such samples, one half was further crushed and grinding was done in carborundum steel mortar to above +120 mesh size. The samples were again purified by removing the iron-filings as mentioned above. Further powdering and pulverisation of samples were done in an electrically operated (Fischer type) agate mortar and pestle. These samples were then used for chemical analysis, DTA and XRD investigations.

1 : 7.1 **GEOCHEMICAL INVESTIGATION** :

The whole rock samples for chemical analysis were selected on the basis of precise petrographic identification so that almost all types of carbonate rock could be selected. The same set of percussion mortar-pestle, agate mortar-pestle and glass as well as other vessels were used during the chemical analysis.
The prepared and purified samples, of about five grams of each rock powder, were used for the major and trace element analyses. Such samples were dried overnight at 80°C and stored in glass vials in a desiccator.

1.7.2 **MAJOR ELEMENTS:**

The chemical analysis of rocks for the determination of major elements in weight per cent oxides was carried out following the methods of "Rapid analyses of silicate, carbonate and phosphate rocks" (Shapiro and Brannock, 1962). Solution 'A' was prepared for the determination of Al₂O₃, SiO₂ and the determination of TiO₂, FeO, Fe₂O₃, MnO, P₂O₅, MgO, CaO, Na₂O and K₂O was done by using solution "B". The contents of SiO₂, Al₂O₃, MnO, P₂O₅, TiO₂ and Fe (total iron) were determined by comparing the optical densities of colour complexes, developed by these elements in solutions, against the standard ones using Hilger and Watts Spectrophotometer (UVISPEC) and Perkin-Elmer Hitachi 200 UVISPEC spectrophotometers.

The alkali elements as Na₂O and K₂O were determined by using the EEL Flame photometer and CaO as well as MgO were estimated volumetrically by EDTA titration method with indicators like, screened calcein, Nephthol green and 0-cresophthalein. Ferrous iron was estimated by standard titration method using potassium dichromate as the titrant and diphenylamine sulphonate as
indicator.

1:7.3 Standards Used:

Two international rock standards, BCR-1 and GSP-1 supplied by the U.S.G.S., were used during the major and trace element analyses. Other standards used for various oxide are as follows:

Table. 1:2

<table>
<thead>
<tr>
<th>Oxides</th>
<th>Standards (ANALAR Grade)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TiO₂</td>
<td>Potassium titanyloxalate</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>Ferrous ammonium sulphate</td>
</tr>
<tr>
<td>FeO</td>
<td>Ferrous ammonium sulphate</td>
</tr>
<tr>
<td>MnO</td>
<td>Manganese sulphite</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>Calcium phosphate</td>
</tr>
<tr>
<td>CaO</td>
<td>Calcium carbonate</td>
</tr>
<tr>
<td>Na₂O</td>
<td>Sodium chloride</td>
</tr>
<tr>
<td>K₂O</td>
<td>Potassium chloride</td>
</tr>
</tbody>
</table>

The USGS, standard were used for determination of major and trace elements in carbonate rocks by the use of XRF at geochemistry laboratory of KDMIPE (ONGC) at Dehra Dun.
1 : 7.4 **TRACE ELEMENTS** :

The trace elements Rb, Zn, Sr, Ni, Co, Cr and Ba were determined in whole rock powder samples, using the Atomic Absorption Spectrophotometer (AAS) in solution "B" and by HF - H₂SO₄ solution method (after Angino and Billings, 1967) at the Centre of Advanced Study in Geology, Panjab University, Chandigarh. The X-ray Fluorescence (XRF) analysis of these samples for their major and trace elements was carried out at the KDMIPE (ONGC) at Dehradun.

1 : 8 **INSOLUBLE RESIDUES INVESTIGATION, STUDIED CARBONATES** :

The insoluble residue study of a sizable number of representative samples of the analysed carbonates has been carried out with a view to identify mineral assemblage. Separation of insoluble residues from the carbonates involve the use of acids. The author has followed the recommendation of Ireland (1971). Commercial hydrochloric acid was used for the separation of insoluble residues from the studies carbonates. After careful examination, the samples were selected from different microfacies of different localities.

About 4000 mg of crushed samples were digested in 20% commercial hydrochloric acid. Samples, which could not be completely digested at room temperature, were subjected to slow heating on sandbath. The digested
samples were filtered by Whatman filter paper No.4. The insoluble residues retained on the filter paper were dried. The residue were weighed and expressed in weight percentage. The insoluble residues were examined under binocular and petrological microscopes.

1 : 9  **ISOTOPIC (STABLE) INVESTIGATION** :

\[ \frac{13}{12} \quad \frac{18}{16} \]

The gamma (C/ C) and gamma (O/ O) determinations in the studied carbonate samples (seven) were carried out in the Isotope Laboratory of the KDMIPE (ONGC) at Dehradun using the standard practices and VG-MS Ratio Mass Spectrometer against the world standards PDB and SMOW, respectively.

1 : 10  **COMPUTERIZATION** :

The HCL PC - AT 386 sanctioned to the supervisor, under the DST project, was used for computerization of the data accruing from the present investigations and word processing. The major element data have been computerized using standard FORTRAN programmes in order to estimate the variance, co-variance, other statistical discriminants, functions, and parameters. They have been discussed in a section of the present work dealing with the data.
1:11 Previous Work:

Geological studies in the Manipur-Nagaland Orogenic Belt (MNOB) commenced with the reconnaissance fieldwork by Theobald (1873), Mallet (1876), Oldham (1883), Hayden (1910), Pascoe (1912) and Chibber (1934). Theobald (1873), Cotter (1938) and Clegg (1941) carried out geological studies of Burma, which also has some reference of the geological setting of this area. Oldham (1883) was the first to report the occurrences of Cretaceous flysch containing limestone and serpentinite at Ukhrul, in the northeastern part of Manipur. He correlated the limestone bearing bed around Ukhrul with 'Axial Formation of Arakan Yoma', the southern tectonic equivalent of Manipur Hill ranges. Later, Pascoe (1912) gave an account of the rocks occurring on the eastern and western part of Imphal Valley. He grouped much of the sediments of eastern Manipur into Disangs consisting of shales, sandstones and slaty sandstones pierced by serpentinites. He assigned a lower Tertiary age to the Disangs with a comment that it might perhaps transgress downward into the topmost Cretaceous sequence. Evans (1932) gave geological description of the section through the Upper Assam to Naga Hills. He opined that stratigraphic succession of Upper Assam is continuous in Nagaland and Manipur States. Mathur and Evans (1964) gave an account of the tectonics of NE India. They considered that the inner belt of the
Naga - Lushai - Patkai hill ranges have been occupied by two synclinoria viz. the Kohima and Patkai. They identified a 'Belt of Schuppen' (consisting of eight or possibly more overthrusts) present all along the northeastern border of Nagaland, adjoining the Assam plains. A valuable description of the section through the Indo-Burma ranges was given by Brunschweiler (1966, 1974). He reported that in the eastern Naga Hills, the metamorphites were overlain by molassic facies and ophiolites. An account of the geology and mineral resources of Manipur State has been compiled (Anon, 1974).

During the last three decades many officers of the Geological Survey of India have carried out systematic mapping in different parts of the area. The observations, interpretations and conclusions made by these workers are included in their respective unpublished reports of the Geological Survey of India, which are not listed in the references of the work viz. Biswas (1962); Dayal (1962); Dayal and Daura (1963); Sriram and Mukhopadhaya (1971); Sriram et al. (1972); Prasad and Sharma (1979) (cf. Ghose, 1980; Sinha et al. 1982).

Recently, the main emphasis has been laid on the dismembered ophiolites occurring along the Indo-Burmese range. Within the political limits of India, these rocks
have been studied by Agarwal and Rao (1971); Agrawal (1977); Sen and Chattopadhyay (1978); Srivastava et al. (1978); Anon (1978); Agrawal and Kacker (1979); Ghose, 1979; Ghose and Singh (1980, 1981, 1982); Agrawal and Kacker (1980); Acharyya et al. (1984, 1986, 1989); Chattopadhyay et al. (1983); Nandy (1984); Venkataraman et al. (1984a, b); Sengupta et al. (1985); Prasad et al. (1986); Acharyya (1986); Acharyya and Ghose (1986); Agrawal and Ghose (1986); Ghose et al. (1987); Vidyadharan et al. (1989); Sen (1990), Singh et al. (1990); Joshi and Vidyadharan (1980), Ranjit (1990), Agrawal et al. (1990); Singh and Anand (1990). Acharyya (1991) and others.

The minimum age of ophiolites is estimated with reference to associated fossiliferous sediments. Studies of such sediments indicate varying ages of these rocks, from Albian to Palaeocene, in Nagaland and Manipur Hills. Mitchell (1981, 1986) gave K/Ar age of 158/148 + 20 Ma to a hornblende-pegmatite dyke within the serpentinite sheet, suggestive of a Pre-Jurassic age for the generation of ophiolite crust. Sarkar (cf. Nandy and Sengupta, 1990) recorded K/Ar age of 145 Ma for the four volcanics of Nagaland.

Recently, some works have been done in the area under investigation. Sriram and Mukhopadhyay (1971) carried out systematic mapping in the Ukhrul district and
they subdivided Disang Group into Litan Formation and Siroi Formation (cf. Anon, 1974). Later Chattopadhyay et al. (1975) classified the rock succession of eastern Manipur into Chingai Formation (Eocene age) and Kongai Formation (Palaeocene age). They included small pockets of limestone into lower part of the Chingai Formation. A broad based regional geology of the Manipur – Nagaland Orogenic belt given by Biswas (1962) incorporates the suggestion that basinal marl facies developed near Toupokpi in Manipur may correspond to the Langpar Formation of Meghalaya. Bhandari et al. (1977); Das Gupta (1977); Anon (1978); and Sinha et al. (1982) recorded the presence of radiolarians of Maestrichtian age in the chert beds at Gamnom in Ukhrul district of Maestrichtian age. Duarah et al. (1983 a,b) suggested that limestone bodies, in this region, are in faulted contact with the Disang shales. They considered them exotics of late Cretaceous age on the basis of their fossil content. Rangarao (1983) gave an excellent account of the geology and hydrocarbon potential of this region. Mishra (1984) assigned Middle Eocene to Palaeocene age to the olistostrome bodies occurring at Paowi and Yarshoka in Ukhrul district respectively. Mitra et al. (1986) identified NE - SW trending olistostromal belt from Kiphire in Nagaland to Lambui area in Manipur. These olistostromes are allochthonous bodies of varying age
from lower Eocene to Palaeocene. Ghosal (1986) for the first time, studied the limestone bodies around Ukhrul. He suggested that they occur as exotic bodies within the Disang sediments as revealed by of geological mapping in this area. These limestones have been assigned Upper Cretaceous age. Sporadic occurrences of several small rodingite have been reported from the ophiolite belt of Manipur by Shukla (1989). Vidyadharan et al. (1989) discussed the regional geology and tectonics of Manipur Ophiolites. They also identified a zone of olistostromal limestone located in the upper part of Disang Formation. Das and Nandy (1990) carried out preliminary investigation of limestone occurring in the dark shale and siltstone in Phungyar area of Manipur. They assigned it Cretaceous - Palaeocene age on the basis of pelagic fauna.

In parts of Ukhrul and Chandel districts of Manipur, a few melange zone and intrusive ultramafics within the Disang Group of sediments have been identified by Joshi (1990) during the photogeological mapping of the region. Khan (1990) carried out systematic geological mapping and found two major zones of melange and bodies of limestone. The intervening region between melange zones is occupied by the rocks of Disang and Barail Groups.

Singh and Anand (1990) discussed the petrography
of the carbonates occurring in Ukhrul area. They identified three microfacies viz. fossiliferous micrite, sparse biomicrite and packed biomicrite. Singh et al. (1990) identified the cement grade limestone, covering an area of 0.270 sq.km. in New Paoyi area, Ukhrul district, Manipur State. Singh and Anand, (1991) carried out major element characterization of the carbonates from the Ukhrul area. They observed that the carbonates could be classified into limestone, slightly dolomitic limestone and dolomitic limestone on the basis of their chemical composition. Anand et al. (1992) introduced a new term the Hundung Formation, for the first time, in the geology of Manipur and they compiled a geological map. The Hundung Formation comprises carbonate - sandstone - conglomerate sequences localised in the Disang Formation. The type section is exposed in Hundung village of Ukhrul district in Manipur State. On the basis of faunal assemblages, it is assigned Lower Cretaceous age. The rock of similar facies are exposed at different places in Ukhrul district. On the basis of their own observations and published works, these authors compiled a geological map of the area.

Vanbemmelen (1949) first gave the tectonic picture of the region. He suggested that the development of Burmese arc controlled orogenic pulsation directed towards stable continental margin. The Arakan - Yoma
Fold belt, western Sumatra and the Tertiary fold belt of Assam have been considered to be an extension of the southeast Asian belt (Klompe, 1957). The geometry, structural style and tectonic setting of these ophiolites contradict the prevailing views according to which these are considered as steep dipping bodies marking the Suture Zone along the eastern margin of the Indian plate (Rodolfo, 1969). Mathur and Evans (1964) and Raju (1964) compared their regional observations with the geosynclinal model. They thought that sedimentation took place in two troughs i.e. miogeosyncline and eugeosyncline, which were separated by two ridges, miogeanticline and eugeanticline. Balasundaram and Ray (1973) favoured a geosynclinal concept for the Assam - Naga hills. According to them the Naga - Lushai geosynclinal development was more complete than that of proper Himalaya. In recent times with the identification of ophiolites in the eastern part of the Assam - Arakan Basin, the basinal evolution is being explained by plate tectonics. Mitchell and Mckerrow (1975) and Mitchell (1981, 1985, 1986) classified the Burma orogenic belt into three major structural and morphological belts. They considered that India - Burma ranges are made of the Arakan - Yoma, Chin and Naga hills, which pass northward into a belt of NW - trending structure linking with Himalaya and in the southwest with Andaman and Nicobar Island. They thought that the development of the
orogenic belt was due to collision of Indian plate with the Burmese plate. The ophiolites present in the Indian continental block represent obducted oceanic lithosphere. They reached their position by means of gravitational gliding as suggested by Stoneley (1974). The common model for the region envisages under thrusting of the Indian plate below the Chinese plate. Evidences of this underthrusting come from seismic records, metamorphism, Tertiary and sub-Recent volcanism in Burma as well as from the regional tectonic setting of the south-eastern region (Dutta and Saikia, 1976; Kaila et al. 1976). Warsi and Molnar (1977) synthesised Cenozoic-Quaternary tectonic setting of the region, based on landsat and earthquake data. Saikia et al. (1987), based on earthquake studies, identified progressive geodynamic development of an arc in the region. Banerjee et al. (1980) proposed that the Indo-Burmese and Andaman-Nicobar ophiolites represent tectonically transported allochthonous bodies within the older metamorphics. Mukherjee (1981) opined that the ophiolites of Arakan-Yoma are mantle-derived material related to the deep crustal disturbances associated with still poorly understood processes of mountain building, probably of intracontinental nature. Gansser (1980) suggested that the ophiolite belt of the Indo-Burmese range continues into Andaman islands, and represents
the suture along which eastern plate collided with the Burmese plate. Roy and Kacker (1980) are of the view that the late Mesozoic - Cenozoic orogenic belt of Naga hills has resulted from continental collision following palaeogene subduction of the Indian plate along its eastern margin below the Burmese plate. Nanday (1976a,b, 1981, 1982, 1983, 1984) evaluated the structural seismic and gravity data/anomaly of Indo - Burma range. He considered that the Naga - Chin - Arakan - Yoma thrusts, ophiolites, and melange zone, showing an arcuate trace from Tirap district of Arunachal Pradesh to north Burma and extending to Andaman islands, represent a subduction line. The Indian plate drifted east and northeast towards the Shan - Teuasserim block in Burma during the Cenozoic time in an oceanic crust/ island arc/ continental crust setting. Bender (1983) recognised a parallel ophiolite belt farther in the east passing through Central Burma, Sumatra and Java and which is of late Mesozoic - Palaeocene age. Le Dain et al. (1984) considered that the Indo - Burmese range is formed due to subduction of Indian lithosphere below Arakan Yoma fold belt as revealed by landsat imageries interpretation, earthquake focal mechanism solution and fold axes study. Armijo (1986) compiled a schematic structural map of the collision boundary between India and Asia around Assam syntaxis, including the areas of Arakan Yoma fold belt. Gupta and Bhatia (1986) have delineated almost a
vertical zone of intermediate focus earthquakes extending to a depth of about 200 km. An arc-trench evolutionary model for the Indo - Burmese Orogen has been suggested by Roy (1989). Sengupta et al. (1989) and Vohra et al. (1989) considered that the Indo - Burmese and Andaman ophiolites broadly represent marginal ocean basin crust. The Arakan - Yoma fold belt is presently in an early stage of mountain building (Gupta et al., 1990).

The ophiolite of the Naga - Andaman belt are imputed to the ongoing Andaman - Java - subduction activity which began since Cretaceous time and extends northward in space (Karig et al., 1979; Curray et al., 1982; Mukhopadhyay and Dasgupta, 1988) and these ophiolites are located within the accretionary prism (Morres et al., 1984).

Acharyya et al., (1986a, 1989, 1990); Acharyya and Roy (1986) and Acharyya (1989, 1990, 1991) have given a good account of the geology and tectonics of the Nagaland ophiolites. It has been suggested that the late Cretaceous and Eocene olistostromal flysch belt tectonically floors the ophiolite melange of the Naga - Chin - Andaman belt, which marks the eastern continental margin of the Indian plate. Further, they proposed that the Indian and Eurasian plates were broadly moving northward and the Indian plate and Sino - Burmese
microplate converged obliquely and ultimately collided during late Oligocene. The ophiolites of the Naga hills - Andaman islands occur as nappe over the Palaeogene distal shelf to flyschoid sediments. The ophiolites containing remnants from seamount were accreted at the subduction zone. They are of the view that Burmese, Himalaya and Tibetan continental fragments are part of the Gondwanic Pan - Indian continent followed by subsequent collision and reamalgamation of the fragments. The ophiolites of this region represent a residual fore-arc basin crust. Dasgupta et al., (1990) and Dasgupta and Nandy (1990) suggested that the Burmese - Andaman magmatic arc evolved at the Asian continental margin as a result of eastward subduction of the Indian lithosphere. Bhattacharjee (1991) opined that the ophiolites of this region are rootless. He identified three stages in the tectonic evolution of the belt, viz., the Indo - Burma was formed due to the collision of the Indian plate, welded island arc and collision of the Indian plate with the island arc and then with the Burmese plate, which was initiated during the Cretaceous.

A detailed analysis of palaeontological data, magnetic anomalies, basement ages and fracture zone lineation led Chatterjee (1992) to postulate a new model for the tectonic evolution of the Indian plate since the early Jurassic to the Present. A consideration of the regional geologic-tectonic setting is an essential element
in understanding the evolution of the Himalaya. The major strike-slip belts, the Ornach-Chaman Fault in the west and Shan Boundary Fault in the east bound the Himalayan fold thrust belt (Abdel-Gawad, 1971). The Himalayan and Baluchistan Arc and the Himalayan and Burmese Arc are characterised by divergent tectonic style. These two arcs served as sites of major shearing deformation, associated with foldings, thrusting and transcurrent faults. Chatterjee (1992) has proposed as model for "oblique convergence to explain the origin of the Ninety east Ridge during the north-northeast movement of India". He is of the view that the oblique convergence between India and Australian plates along this ridge is responsible for volcanic chains along the Ninety.