Chapter 1

Introduction

The present is the key to the past

James Hutton (1785)
1 INTRODUCTION

Structural Geology and Tectonics is one of the most fast developing branches of geological sciences since the introduction of the concept of plate tectonics by Morgan (1968) in the field of Earth Sciences. The entire gamut of geological sciences has been reviewed in the context of this great unifying theory - plate tectonics. The large regional to global structural features such as the mountain belts, mid-oceanic ridges, island arcs and trenches, seismic activity in the peripheral zones of plates are all drawn together by this theory. Even sedimentary basin formation and evolution, morphotectonics, petrogeochemical studies, etc. all seem to be redefined in the perspective of plate tectonics. For instance, what type of basins can be formed in various plate boundaries, what will be the characteristics of their basin-fills and what type of igneous rocks will form in different plate boundaries, can be correlated based on their petrogeochemistry. Indeed, it is one of the most thought-provoking theory ever introduced in the field of Earth System Sciences.

The present work, "Structural and Tectonic Analysis of Manipur with Special Reference to Evolution of the Imphal Valley" tries to provide a comprehensive but brief accounts on the structural and tectonic framework of Manipur state. The principal objective of this work is to decipher the evolution mechanism of the Imphal Valley and so, all other objectives - structural and tectonic lineaments analysis, plate kinematics, analysis of minor structures, etc. revolve around this principal theme providing necessary data to envisage the evolutionary model of the valley. How these objectives have been corroborated with field and laboratory data analyses, and how they can be amalgamated in order to envisage the evolutionary model, in conjunction with the evolution of the Indo-Myanmar Range (IMR) as an accretionary prism, will be clearly observed in the subsequent chapters. However, before going into the
details of the structural and tectonic analysis, let us have some general accounts about the state of Manipur.

1.1 GENERAL ACCOUNT OF MANIPUR STATE

Manipur is a small state situated in the north-eastern corner of India bordering with the Union Socialist Republic of Myanmar (Burma) on the eastern side. The state is practically a hilly terrain endowed with excellent natural beauty and rich cultural heritage. In the central part of this hilly terrain, there is a small valley known as the Imphal/Manipur Valley. The valley, which is also surrounded by hill ranges in all sides, has a fresh water lake called the Loktak Lake which further beautifies the state. Because of its natural beauty and rich cultural heritage, the state has been described as “A Little Paradise On Earth” and “The Jewel Of India” by a number of great personalities of the country including the late, first and foremost prime minister of India, Pandit Jawaharlal Nehru.

The state is inhabited by three major ethnic groups of people. The Meiteis (Meeteis), forming the largest group of people mainly inhabit the valley while the Naga and Kuki tribes mainly settle in the surrounding hill areas. There are also a number of small sub-tribes belonging to these two, Naga and Kuki tribes. Anal, Kabui, Mao, Maram, Maring, Tangkhul, etc. are some of the tribes that belong to the Nagas while Aimol, Gangte, Hmar, Paite, Ralte, Simte, Thadou, etc. belong to the Kukis (Kabui, 1990; Deva Singh, 1993). Besides, there are also a number of small minority communities in the state. Among them Manipuri Muslims (Meitei Pangals) is an important community having a long association in the historical background of the state. Nowadays, a number of other communities, from different parts of the country, have also settled in different parts of the state. People in the state are predominantly Mongoloid, and speak Tibeto-Burman languages. Although, there are a number of dialects of these tribes, the Meitei language (Meitei Lon) which is also the mother-tongue of the Meiteis, is the lingua franca of the state.
According to the Census of India (1991), Manipur has a population of about 1.84 million with a decadal growth rate of 29.29%. So, by 1998, the state may have a population of about 2.20 million. Population density of the state is 82 persons per Km\(^2\) which is relatively low in comparison with that of the nation i.e. 274 persons per Km.\(^2\) However, the valley which represents only 10% of state’s total area has a population concentration of 65% giving rise to a population density of about 530 persons per Km.\(^2\) The literacy rate of the state is about 60% which is comparatively higher than the national average rate of about 52%.

Almost all the religious faiths are practised in the state by different groups of people. The Kuki and Naga tribes are mainly followers of the Christianity while the Meiteis mainly embrace Hinduism (Vaishnavism). There is also another group of Meiteis following an ancient religious practice known as the Sanamahi (Sanamahism). The Meitei Pangals are basically followers of the Islam.

The Meiteis, and each and every tribes in the state have their own characteristic and artistic handlooms and handicrafts as well as cultural heritage. Rich handlooms and handicrafts of the state are quite famous and popular throughout the country. Among the cultural heritage of the Manipuris, Manipuri Dance (Ras Lila), Mridanga Dance (Pung Cholom), as well as other Folklores/Folk dances are highly praised and famous all over the world. In the recent years, younger generations of the state also have come up in the limelight through the arena of games and sports both in the national and international levels.

1.2 LOCATION AND ACCESSIBILITY

Manipur state lies in the north-eastern part of India (Fig.1.1). It is the easternmost state of the country extending approximately between 23°50’ N to 25°41’ N latitudes and 93°00’ E to 94°45’ E longitudes. On the east and south-east it borders with the Union Socialist Republic of Myanmar (Burma). Nagaland, Assam and Mizoram states of India lie on the northern, western and southern sides of the state respectively.
Fig. 1.1. Location map of Manipur. Inset is the map of India where the blackened part is Manipur.
The state has an area of about 22,327Km². Presently the state is divided into nine districts viz. Bishnupur, Chandel, Churachandpur, Imphal East, Imphal West, Senapati, Tamenglong, Thoubal and Ukhrul. The four districts - Bishnupur, Imphal East, Imphal West and Thoubal virtually constitute the Manipur (Imphal) Valley at present representing nearly 10% of the total area of the state. The remaining five districts - Chandel, Churachandpur, Senapati, Tamenglong and Ukhrul, comprising nearly 90% of the state's total area, are principally hilly and rugged terrain.

Imphal, the capital city of Manipur, is well connected by air as well as surface transport systems with the rest of the country. It is connected with Calcutta, Delhi, Guwahati and Silchar by daily and/or weekdays flight services of the Indian Airlines. The state is also well connected by roadways to the nearest railway stations at Dimapur in Nagaland state by N.H. 39 and at Jiribam by N.H. 53. It is also linked with important towns/cities and commercial centres of the sister states of Northeast India such as Guwahati, Shillong, Silchar, Dimapur, etc. by daily coach services through the two national highways. Moreh, a small town at the border with Myanmar and Tamu, a border town of Myanmar are linked with Imphal by N.H. 39. In the recent years, these two border towns have become important commercial centres as soon as the border trade between India and Myanmar opened, providing good avenues for self employment of the educated youths of the state.

District headquarters and other important towns of the state are also properly connected with the capital city through the national as well as state highways. According to Statistical Handbook of Manipur (1992), Manipur has a road density of only 4.2 Km road length per Km². Therefore, a number of villages/localities, specially in the hill areas, are basically accessible on foot only. Similarly, geological field works are mainly conducted on foot trekking. Although, almost all of the roads (Fig.1.1) are motorable throughout the year, some of the routes mainly in the hilly terrain are better accessible in dry seasons only. So, geological field works are usually conducted during dry seasons.
1.3 CLIMATE

Manipur has a subtropical to temperate climate. Although, latitudes are generally low (i.e. 23.50° N to 25.41° N), temperature varies considerably since altitudes are widely variable in different parts of the state. The usual range of temperature is 0°C to 35°C. But, at some places, the maximum temperature rises to 40°C depending on the elevation. For instance, Jiribam area (western side) and Moreh area (eastern side), the elevations being nearly 40m and 180m respectively above the mean sea-level, are relatively warm. Imphal/Manipur Valley has an average maximum temperature of about 33°C and minimum temperature of about 2°C though, sometimes mercury touches 0°C. In the higher places, such as Tamenglong, Ukhrul, Churachandpur, etc. the average maximum temperature is about 30°C and minimum temperature is commonly 0°C which sometimes drops below zero mainly during the months of December and January. Snowfall is usually not observed but, light frost is common specially in the higher reaches during these months.

The state has an average annual rainfall of about 2000-2300mm (Statistical Handbook, 1992). However, the annual rainfall is highly variable from place to place depending upon the location and altitude of the stations. Generally western half of the state as well as places of high elevations have relatively higher rainfall ranging between 2600 to 3200mm. This is probably due to the SW monsoon that comes from the Bay of Bengal and Indian Ocean which, in turn, is helped by the highest range of the state comprising of Mt. Iso, Koupru and Thangjing acting as the rain barrier. For the state, the maximum rainfall is experienced by Tamenglong and its adjoining areas, recording an average value of about 3400mm. Rainfall in this area sometimes far exceeds 4000mm also.

Eastern half of the state including Manipur Valley, except a few stations of high altitude, has relatively low rainfall ranging between 1400 to 1800mm per annum. Possibly this part of the state becomes slightly rain shadow area due to the high range mentioned above that occurs immediately on the western side of the valley. Imphal Valley although, records an average rainfall of about 1400mm, it varies quite
frequently from year to year. In rainy years it exceeds 2000mm and in drought years it goes down much below 1000mm. However, the valley quite often experiences floods during rainy seasons specially in the last few years. Silting and shallowing of the river/stream beds resulted from excessive soil erosion in the upper reaches of the adjoining hills may be the prime factors of these floods. Humidity in the state is also relatively high, where the maximum relative humidity in the air generally ranges from 90 to 100% throughout the year. But, the minimum relative humidity is widely variable which is sometimes as low as 12%.

Seasonal variation of climatic condition is very common in Manipur. Rainy season is quite long extending from the middle of April to the middle of October though, June to August is the usual period of heavy monsoon rains. Hailstorms and thunderstorms are common during the months of May and June. November to March is the usual dry season even if, there is occasional winter rains. So, this period is the ideal time for geological field trips.

1.4 FLORA AND FAUNA

Manipur, due to its wide variations in the topographic landforms as well as the climatic conditions and elevations, has rich both plant and animal habitats. The state has a number of rare plant and animal species making an important spot in the biological map of the country and even in that of the world. The hill ranges, due to its elevation and rainfall, have certain typical plant and animal lives while the central valley, which is low-lying area having a number of freshwater lakes (paats), has its own characteristic floral and faunal habitats.

Manipur has rich Tropical (Monsoon) and Tropical Rain (Equatorial) forests with lesser amount of Deciduous to Semideciduous and Subtropical Coniferal forests. Such a wide ranging types of forests of the state have been resulted mainly from its location and climatic conditions. The vegetation consists of a large variety of plants ranging from short and tall grasses, reeds and bamboos to trees of various species. Among the trees, Teak, Pine, Oak, Uningthou, Leihao, Tan, Tolhao, Tairen and
Khanggra are some of the important varieties widely used for furniture and other construction purposes. Bamboo is another, one of the most important plant, found mainly in the hill districts of the state. In the state, this plant is found not only in different varieties but also in large quantity on which some industry specially the paper-mill can bank. Bamboo shoots in the form of chips and slices are consumed as a popular dish by the local people, like the other people in Southeast Asian countries. Processed bamboo shoots could be a source of income for the state provided they are exported to other countries as done by some Southeast Asian countries (e.g. Thailand). Detailed accounts on the flora of Manipur state can also be had from Deb (1961, 1961a), Bikramjit Singh (1987), Sharma (1987), Kumar Singh (1990), etc. Besides, Manipur also has a number of orchids (Fig. 1.2A), horticultural as well as medicinal plants having economic potentials. It has been claimed that there are about 500 taxa of orchids belonging to 80 genera in the state. 50% of these orchids has commercial economic viability and many of them are exclusively found only in the state of Manipur (Jojita Devi, 1986; Dhanapati Devi, 1998). Among the important horticultural plants that have good economic implications are pine-apple, orange, lemon, tea, coffee, banana, pears, peaches, lichi (lychee), cardamom, etc. These are providing, not only livelihood and employment specially to a large section of the hill population, but also could be good resources for generating income of the state in the long run. There are about 1200 medicinal plants in the state, of which nearly 430 varieties have been used as medicinal herbs since historical times by the local people (Sinha, 1996). In the central valley of the state, food and cash crops such as paddy, sugarcane, potato, mustard, tobacco, pulses, cabbage, etc. are mainly grown.

Although, there is marked decrease in the faunal characteristics of the state in comparison with historical background, Manipur still has good number of animal-lives specially in the hill districts. A number of rare species of animals, fishes and birds of typical characters are found in the state, besides commonly available animals such as bears, wild boars, foxes, various types of fishes and amphibians, etc. Beside these, animals and birds that are commonly found in different parts of the state, specially in the hill districts, are Himalayan black bear, Malayan sun bear, Leopard cat and Clouded leopard, Sambar, Barking deer and Hog deer, Tragopan, Capped
Fig. 1.2. Typical flora and fauna of Manipur. A. Khongumellei (*Dendrobium chrysotoxum*), a commonly found orchid of Manipur which blooms during April-May. B. Sangai, brow-antlered deer (*Cervus eldi eldi*), an endangered faunal species found in Keibul Lamjao National Park, the only floating park of the country (courtesy, Tourism Directorate, Govt. of Manipur).
langur, Hoolock gibbon, Python, Peacock pheasant, Indian horn bill (Uchek Langmeidon) and other horn bill birds.

Considering the marked decrease, as well as in order to protect the rare and endangered floral and faunal species of the state, Government of Manipur has framed legislations (see Manipur Gazettes, 1974; Shamungou Singh, 1992) and declared a number of places of the state as National Parks and Wild Life Sanctuaries. Among them, some of the important ones are Keibul Lamjao National Park, Siroi Hill National Park, Yangoupokpi Lokchao Wild Life Sanctuary, etc. Keibul Lamjao National Park is located on the southern side of Manipur Valley (SE side of Loktak Lake) nearly 46Km away from Imphal city. It is claimed to be the only floating park in India. The floating mass, locally known as Phumdi, is composed of decayed plants and humus having a variable thickness of about 1-3m. This mass floats rising and lowering, as the water level in the lake varies. A rare, rather endangered faunal species, Brow-antlered deer (Cervus eldii eldi) which is locally called, Sangai (Fig. 1.2B) is exclusively found in this park as its natural habitat. In Siroi Hill National Park the rare, state flower - “Siroi Lily” (Lilium mackliniae) is grown and it is believed that the rare state bird - “Nongyin” is also found in this park.

In addition to the above faunal and floral species, Manipur has rich fresh water fish fauna, some of which are rare and exclusively found in the state of Manipur. As many as 137 species of fishes are known in the state and 7 of them are thought to be purely endemic and found only in Manipur. A detail account about the fishes of the state can be had from Vishwanath (1997), Tombi Singh (1998). Vishwanath (op.cit.) has discussed even the possible role of plate tectonics in the distribution and migration of these endemic fishes of Manipur.

1.5 GEOMORPHOLOGY

Manipur is a small state having geographically distinct entity. The hills in the state form an integral part of the Indo-Myanmar (Burma) Range (IMR). Naga-Patkoi Hills lie on the northern and north-eastern sides while Chin-Arakan-Yoma Hills lie on
the southern side of the state. More than 90% of the total area of the state is made up of hilly and rugged terrain. The remaining 10% constitutes the Manipur Valley and Plains of Jiribam situated in the central and western parts of the state respectively. Almost all the geomorphic expressions and drainages in the state have a close and compatible relationship which is probably due to structural and tectonic control of these landform features. A brief discussion on the relationship between structural and tectonic lineaments, and drainage system of the state is, therefore, attempted in chapter 5. All the hills in the state run in a more or less N-S to NNE-SSW trend with intervening valleys occupied by major streams and rivers.

1.5.1 Topography

Although 90% of the geographical area of the state is hilly, it can be divided into a number of topographic or physiographic subdivisions (Fig. 1.3). They are given below -

(i) Manipur Western Hills
(ii) Manipur Eastern Hills
(iii) Manipur Central Valley
(iv) Manipur Western Plains.

(i) Manipur Western Hills

This topographic subdivision lies between the Manipur Central Valley on the east and the Manipur Western Plains on the west. It is principally made up of Barail and Surma sediments of Tertiary Age. The Barail Range lying in this topographic unit is the continuation of the range in Assam and Nagaland states on the north-western side of Manipur. Manipur Western Hills consist of the highest peak of the state known as Mt. Iso (Tenipu) lying on the border with Nagaland state near Mao. This peak is 2994m high above the mean sea-level and continues southward forming a range consisting of a number of high and important peaks, such as the Koupuru (2561m), Loiching (2015m), Thangjing (2109m), etc. immediately on the western
Fig. 13: Landsat TM (FEO) imagery showing major landform and topographic features of Manipur. In the overlay, the abbreviations stand as:

- MEH - Manipur Eastern Hills
- MWH - Manipur Western Hills
- TV - Imphal Valley
- MWP - Manipur Western Plains
side of the Manipur Valley. This highest range of the state, also sometimes known as Koupuru-Laimaton-Thangiing Range, forms the main water divide between the drainage systems of Manipur east (Chindwin system) and Manipur west (Barak system). The elevation of this topographic unit then gradually decreases towards the Western Plains. Almost all the hill ranges, in this topographic unit, trend N-S to NNE-SSW with intervening valleys of low altitudes. The valleys are mainly occupied by streams and rivers. The elevation of these stream/river channels are generally low sometimes only a few meters above the sea-level. Even the Barak river, in its source area, has an altitude of about 1000m only near Senapati which becomes as low as 60m or less at the confluence between Tuivai river and Barak itself. This probably reflects high base-level erosion of these rivers. The hill ranges are also frequently cut across transversely by the rivers revealing their possible structural control.

(ii) Manipur Eastern Hills

This topographic unit constitutes the entire hill ranges of the eastern half of Manipur including the hills on the northern and southern sides of the Central Valley. It is principally composed of Disangs and the Ophiolite Belt of Manipur and Nagaland with isolated blocks of Barails. It has a major range running in a NNE-SSW direction from Jessami on the north towards Ukhrul (Siroi) and Tengnoupal on the south and farther beyond. This range also serves as the main water divide between the Imphal river system and the Yu-Khampat river system. The highest peak, in this range of the Manipur Eastern Hills, is the Siroi (Siroi Furar) peak having an altitude of about 2568m. The lowest elevation is represented by the eastern foothill regions around Moreh having an altitude of about 180m above the mean sea-level.

Unlike the Manipur Western Hills, this unit lacks parallel to sub-parallel ridges with intervening valleys except for the Imphal river and some of its tributaries such as Thoubal and Irl rivers. In the northern part around Ukhrul, the streams/ricers have a nearly N-S courses while in the southern part around Chandel they have a nearly E-W courses. Major tributaries of the Yu-Khampat river system, coming off
this range, however, have oblique to transverse relationship with the regional strike reflecting another type of structural control of these streams and rivers.

(iii) Manipur Central Valley

This topographic unit represents the Manipur or Imphal Valley. It is an elongated, irregular square or rhomb shaped valley tapering on both northern and southern sides (see Fig. 1.3). The valley is nearly 60-65 Km (N-S) long and 30-35 Km (E-W) wide having an area of about 2000 Km². Although, there is a small gradient towards south, it is nearly a flat valley having an average elevation of about 780m above the mean sea-level. The valley is mainly composed of sediments of fluvial-lacustrine origin in the central part while near the foothills, pebbly deposits are common. There are a number of isolated hillocks within the valley rising above the flat alluviums. Some of them reach a considerably high altitude of about 1583m (Nongmai Ching) while others mainly have an average elevation of about 900m above the mean sea-level. These hillocks are principally made up of Disang sediments with some of them having Barail cappings in the form of outliers.

Manipur Valley has also a fresh water lake known as the Loktak Lake on the southern side. It is the largest fresh water lake in the entire Northeast India. Although, the lake is a major depression having average altitude of about 765m above the mean sea-level, surprisingly none of the major river such as Imphal, Iril, Thoubal, Khuga fall into the lake. These rivers follow nearly NNE-SSW courses parallel to the regional strike reflecting possible structural control. These features indirectly indicate possible evolution of the lake as well as the valley through tectonic mechanism rather than the usual erosional processes.

(iv) Manipur Western Plains

It represents the plains of western foothills around Jiribam and so, sometimes it is also known as the Jiribam Plains. The areal extent is relatively small and in fact, it is the eastward extension of the Cachar Plains of Assam. It is mainly made up of
alluviums of the Barak river and its tributary system (e.g. Jiri river) and the low-lying hills of Tipams and Surmas. In the central portion of the plain as well as near the river/stream channels, the alluviums are mainly composed of sand, silt and clay while near the foothills cobbly to pebbly deposits are common.

The average elevation of Manipur Western Plains may be about 100m. In Jiribam and Bara Bekra areas the elevation is approximately 40m above the sea-level while some of the hill peaks have an altitude of about 181m above the sea-level. Some typical drainage pattern (Trellis) is also observed near Jiribam area (see Fig.5.11) reflecting intimate relation between structure and topography.

1.5.2 Drainage

Manipur has drainage systems belonging to two distinct and major drainage systems of Southeast Asia, viz. Brahmaputra System and Irrawaddy System. This is due to the fact that the main water-divide of the two systems, the Indo-Myanmar Range, passes through the central part of the state. The general trend of the drainage in the state is NNE-SSW although, there are oblique to transverse exceptions (Fig. 1.4 & 5.1). All the streams and rivers have a high degree of base-level erosion, some of which is below 50m above the sea-level as in the case of Barak river. Such base-levels of many major rivers of the state are much lower than the average elevation of the Imphal Valley. The rivers of Manipur can be broadly grouped into two drainage systems on a regional scale. They are -

(i) Barak Drainage System and (ii) Chindwin Drainage System.

(i) Barak Drainage System

This system lies on the western side of the state and occupies nearly 40 percent of the total catchment area of the state. The watershed of this system is divided from that of the Chindwin by the Koupru-Thangjing Range situated immediately on the western side of the Imphal Valley. Major tributaries of the Barak
Fig. 1.4. Drainage map of Manipur showing major river systems of the state. A more detailed drainage map is also represented by figure 5.1.
river are Irang, Tuivai, Makru, Jiri and Leimatak rivers (Fig. 1.4 & 5.1). Beside Barak, both the Irang and Tuivai rivers have good perennial flow and so, have good economic potentials specially for generation of hydroelectricity. Barak river water is also used for navigation such as transportation of timber, bamboo, etc.

Almost all the rivers and major streams of the Barak Drainage System follow the regional strike (NNE-SSW) occupying antiformal and synformal axes, and faults and fractures. Rivers, transverse as well as oblique to the regional strike, also normally follow some other fault and fracture zones. Rivers usually have high-level old terraces which in majority of the cases display unpaired nature, revealing possible structural or lithological control of these rivers/streams.

(ii) Chindwin Drainage System

Chindwin river flows in the Myanmar territory but all the streams and rivers in the eastern half of the state fall into this river. So, it is discussed under the head, Chindwin Drainage System. For the state, it can be divided into two smaller systems as given below.

(a) Imphal River System and (b) Yu-Khampat River System.

(a) Imphal River System

Imphal river forms the main drainage system of Manipur central part and the Imphal Valley. It originates from the northern side of Imphal near Kangpokpi and flows southerly through the valley and Sugunu hump, thereafter, it is known as Manipur river. Manipur river then usually follows a more or less straight course for miles and joins with Myittha river following a broad and large NW-SE to E-W turn before falling into the Chindwin river. Important tributaries of the Imphal river are Iril, Thoubal, Khuga, Chakpi, etc. (Fig. 1.4 & 5.1). Tributaries such as Iril, Thoubal rivers, etc. have more or less parallel courses to the Imphal river and flow in the same southerly direction while others such as Khuga and Chakpi rivers flow in opposite
direction to that of the Imphal river displaying barbed pattern. While other smaller rivers/streams such as Sekmai, Wangjing, etc. do have oblique to transverse relationship to the Imphal river. Imphal river, even if flows through the Manipur Central Valley, does not fall into the Loktak Lake. It is, however, connected with the lake by an artificial channel for constant water supply to the Loktak Hydro Electric Project.

Loktak Lake, located in Bishnupur district, has a separate, although small, drainage system. Its important rivers are Nambul, Nambol and a number of streams (e.g. Thongjaoorok, Ningthoukhong, etc.) coming off the Western Hills. The sediments of these streams are directly dumped into the lake and so, it is likely to be dried up very quickly if proper preventive measures are not taken up in time. The size of the lake is highly variable. During rainy season, its areal extent is very large, majority of which remains as swampy and marshy lands during dry season. Within the lake there are a few hillocks known as Thanga, Ithing and Karang isles. These are good spots for tourists attraction.

(b) **Yu-Khampat River System**

Yu and Khampat rivers also flow in the Myanmar territory, along the Kabaw/Tamu Valley on the eastern side of the state. But, almost all the main tributaries of Yu and Khampat arise from the Eastern Hills of Manipur (Fig. 1.4 & 5.1) and hence, it is discussed as a separate drainage system. Tuyunghi, Maklang, Taret, Lokchao rivers are some of the important tributaries of the system originating from the Eastern Hill Ranges of Manipur. The two rivers, Yu and Khampat follow a NNE-SSW course and flow in opposite directions to one another. However, all the tributaries follow NW-SE to nearly E-W directions and none of them have courses parallel to the two rivers. These features indicate another typical pattern revealing possible delicate relationship with the subsurface structural elements. Kabaw/Tamu Valley, through which Yu-Khampat river flows, is nearly 150-200m high from the sea-level and has one of the richest forest resources in the world. Teak is one of the most important produces of this valley.
Beside Imphal river and Yu-Khampat river systems, Manipur has two more small systems on the north-eastern part of the state belonging to Chindwin Drainage System. They are Laniye-Chammu Rivers System and Sana River System. Laniye and Chammu rivers flow towards north following nearly straight courses and meet the Tizu river of Nagaland before falling into the Chindwin river. Sana river, on the other hand, flows in a southerly direction and then have a nearly 90° anticlockwise turn before meeting with the Chindwin river. All these rivers also seem to follow some structural and tectonic lineaments of regional scale.

1.6 PREVIOUS WORKS

Geological accounts of Manipur date back to the last century although, the state still remains to be one of the least explored part of the country. Oldham (1883) was the pioneering worker who gave a geological picture of the state. Prior to him, Godwin-Austen (1874) gave some geological information about the state having scientific values. In his, “Report on the Geology of Parts of Manipur and Naga Hills”, Oldham (op.cit.) wrote: but it was not till Major (now Lieutenant Colonel) Godwin-Austen visited this tract in charge of a survey party during 1872-73 that any information of scientific value was obtained. Godwin-Austen (1875) was also the pioneering worker who ventured to give a possible idea of glaciation in parts of Naga Hills and Manipur. He even thought that Imphal Valley might be a glaciated valley. After Oldham, geological studies of the state remained almost negligible till the beginning of sixth decade of this century although, brief regional geological descriptions were provided by Pascoe (1912) and Evans (1932). Evans (op.cit.) was the first worker who gave a more or less complete sequence of the Tertiary rocks of Assam. He described the rocks on the western side of the Imphal Valley as Barails and that on the eastern side as Disangs. His accounts are much similar to those of the later workers though, minor changes and/or modifications are made here and there.

After independence of the country, Dayal and Daura (1966), and Daura and Debadhikari (1968) carried out systematic geological mapping in various parts of the state. They also adopted similar type of geologic succession as outlined by Evans.
They further noted the possible structural complicity of the region based on the presence of narrow bands of Barails on the eastern side of the Imphal Valley. Dayal and Daura (op.cit.) correlated the conglomerates in the northern part of Ukhrul with the Chimi conglomerates of Nagaland described by Pascoe (op.cit.), as the base of Disangs. Sriram and Mukhopadhyay (1975) and Sriram et al (1976) conducted systematic mapping in Ukhrul district and divided the Disangs into three formations viz. Litan Formation, Ukhrul Formation and Sirohi (Siroi) Formation.

Manipur-Nagaland Circle Office of the Geological Survey of India (GSI), with its headquarters at Dimapur, Nagaland was established in 1971-72 with an objective to expedite geological explorations of the two states. Since then regular geological investigations and mappings have been conducting in the state. But, majority of the works remain directed towards mineral and project site investigations. So, there was no much improvement in the geological knowledge of the state, at least in academic sense. Moreover, almost all the geological information remained as unpublished as well as restricted reports. Geological accounts of the state describing mainly its economic potentials was provided in Anonymous (1974) since inception of the circle office at Dimapur. In 1977, the Geology and Mining Cell of Manipur state was opened in the Directorate of Industries, Government of Manipur. The chief objectives were to carry out geological investigations in order to evaluate mineral resources of the state with a view to establish certain mineral based industries. A mini cement plant was thus, commissioned at Hundung near Ukhrul town. However, the geological explorations of state is yet to carry out to its fullest extent. For instance, detailed subdivision and classification of various lithounits (Groups/Formations), their age determination and correlation as well as structural and tectonic framework studies are still far from satisfaction. A changing trend in the classification and subdivision specially of the Disangs and Barails has, however, been provided by Bohra and Raju (1991), Setty and Kisku (1991). Laisong Formation of Barails proposed by Evans (1932) has been treated as Upper Disangs by them. They have not given any concrete reason for inclusion of this Formation as part of the Disangs, but seems to have adopted considering the original concept provided by Mallet (1876). Kisku and Muraleedharan (1993) have even included the alluviums and underlaining ferruginous
sandstone and clay of Jiribam area in Dupitila Group. This is quite confusing because, the descriptions of Tipam Sandstone and Girujan Clay of Tipam Group seem to have similar lithocharacters to that of Dupitilas described by them.

In 1984, Department of Earth Sciences was opened in Manipur University. Since then regular geological studies of the state have been carried out by the faculty members, scholars as well as students of the department, particularly in the fields of geomorphology, sedimentology, structural geology and tectonics, geochemistry, geohydrology, etc. A number of students have been awarded Ph.D. degrees by the Manipur University in recognition of their contributions made in the fields of geomorphology, sedimentology, geohydrology and geochemistry. Among them, Debojit Singh (1995) worked on the sedimentological aspects of Disang-Barail transition zone while Ibotombi Singh (1992) worked on the petrochemical aspects of carbonate rocks of Ophiolite Melange Zone of Ukhrul area. Studies on geomorphic and basin analyses of various river basins of Manipur were carried out by Ibyaima Devi (1992), Dinachandra Singh (1994), Girija Devi (1994). Hydrogeomorphological studies, specially of the Imphal Valley were conducted by Rajen Singh (1993), Minaketa Singh (1996).

A number of papers concerning with the general geology and structure of the region have been presented and published in seminars and symposia proceedings and journals mainly in the last one and half decade specially by the workers of the GSI, Oil and Natural Gas Corporation Limited and other academic as well as professional organisations. Majority of these papers, however, deals with the regional geology and tectonics of north-eastern India. Some of them that deals with the geology of Manipur are Chattapadhyay et al (1983), Ghosal (1983), Mitra et al (1986), Saxena (1987), etc.

1.7 SCOPE OF THE PRESENT WORK

It is clearly seen that very few works have been done on the structural and tectonic framework studies of Manipur though, there are a number of papers dealing with the general structural and tectonic framework of Northeast India in general and
that of Indo-Myanmar Range in particular. So, the present study, "Structural and Tectonic Analysis of Manipur With Special Reference to Evolution of the Imphal Valley", is attempted here in this work. The purpose is to make a brief analysis of the structural and tectonic framework of the state in order to know about the deformation mechanism of the region in conjunction with the evolution of the Indo-Myanmar Range of Northeast India. Because, this will provide an insight about the deformation and evolutionary model of the Imphal Valley which is also the principal objective of the present work. The main objectives of the present work are given below.

1.7.1 Objectives

(i) To analyse the structural and tectonic lineaments of Manipur and its implied kinematics.

Analysis of structural and tectonic lineaments is carried out in order to evaluate the stress field as well as the resultant strain ellipse of the rocks of Manipur. Because such an analysis enables us not only to establish the compression and extension motion vectors but also the deformation mechanism of the region.

(ii) To study the plate kinematics of the region and its role in evolving the tectonic framework of the state.

By studying plate kinematics of the region we will be able to decipher under which interactions of Indian, Eurasian, and Burma (Myanmar) plates, the structural and tectonic framework of the state was evolved, and such an interaction has the compatibility with the deformation/evolution mechanism of the region.

(iii) To analyse the spatial relationship between the physiographic patterns (drainage) and the structural and tectonic lineaments of the state.
Drainage systems of Manipur have a systematic change in pattern from east to west. Analysis of their spatial relationship provide us an understanding that how they are controlled by the lineaments of the region and their mechanics of deformation.

(iv) To analyse the minor structures (e.g. folds, faults, fractures, joints, etc.) of the Imphal Valley and examine their kinematic and tectonic significance.

Analyses of minor structures will enable us to compare whether such structures were formed under a uniform stress field, are they compatible with the large scale structures of the region, and how these analyses can be used to envisage the evolution mechanism of the Imphal Valley.

(v) To calculate the regional crustal shortening (WNW-ESE) and stretching/extension (NNE-SSW) of the state.

Estimation of regional crustal shortening parallel to tectonic transport direction will provide us a better insight about loss or gain of area, degree/intensity of deformation, geometric aspect of structures present in the region. Similarly estimation of crustal stretching/extension can provide information on the area gained or lost, subsidence of the crust and their role in basin evolution.

(vi) To evaluate the deformation as well as evolutionary mechanism/model of the Imphal Valley.

Taking into consideration of all the studies made in the above five objectives, an appropriate deformation and evolutionary model of the Imphal Valley may be worked out.

1.7.2 Methodology

The approach of study adopted in the present work is the geophysical way of study. That is, in geophysical studies, one starts with the regional to global scale study
followed by small, local scale studies. For instance, geophysicists start with the study of gravity and/or magnetic field of the earth, then the knowledge is applied in order to know about the subsurface configuration of a small area based on the magnetic and/or gravity anomaly of that area. On the other hand, geological approach of study is just the opposite. Geologists first start with the study of a thin section or hand specimen, and then the finding is applied to the whole region to explain their formation, deformation, etc.

Plate tectonics although, studied by almost all geoscientists, its manner of study is also similar to the geophysical approach. Because, the concept of plate tectonics was first developed, in the field of earth sciences, in the global scale, then geoscientists now try to apply the concept to explain regional to local microtectonics of a region. Here, in this study also, this approach is employed where structural and tectonic analysis of the state is first attempted. Because, once the deformation mechanism of the region is known, then the evolutionary model of the Imphal Valley can be easily worked out since they are interrelated to one another. The following methods have been used for the present study.

- Structural and geologic mapping of the Imphal Valley with collection of as many as raw data on dip-strike, fractures, folds, joints, etc. Also geologic mapping on selected traverses across the state.

- Preparation of structural and tectonic lineaments map of Manipur using visual interpretation of satellite imagery (LANDSAT, IRS IC, SPOT, etc.), field checks, mapping data and published literature.

- Computation of plate motion vectors of the region using Euler Vectors calculated by various workers employing spherical trigonometry and/or vector algebra.

- Use of simple statistical analysis as well as stereographic/equal area projections to study and examine various geometric and kinematic aspects of the structures.
- Calculation of regional crustal shortening using balanced sections of geological profiles as well as individual structures (e.g. folds, thrust faults) and crustal stretching using normal faults.

Brief practical procedures are provided in the chapters concerned with the particular methodology adopted in the investigation along with references wherever possible.