SUMMARY AND CONCLUSIONS

1. Throughout the world, ophiolites are exposed typically along belts of intense tectonism (Fig. 2.1). They occur along major geosutures and are thought to mark the boundaries of ancient zones of interaction between oceanic and continental crusts (Coleman, 1977).

2. The contact between the Indian and the Asian Plates is delineated by a well-marked suture zone extending along the western, northern and eastern margins of the Indian Plate. The suture zone, wherever it has been identified, contains discontinuous linear outcrops of ophiolites, some of which are poorly characterised and in other places where the complete ophiolite suite of rocks is well established as in Ladakh and Kumaon regions of India and Muslimbagh region of Pakistan.

3. The Indo-Myanmar Range (IMR) links up to the northern and the eastern branches of the Alpine-Himalayas orogenic belt and extends to the south with the Andaman-Nicobar Islands and still further south with the Indonesian Island Arc. The latter in turn merges with the mobile belt around the Pacific Ocean.

4. The Nagaland-Manipur Hills form the northern part of the Indo-Myanmar Range. Along the eastern border between India and Myanmar, in the Nagaland-Manipur Hills region, the ophiolite suite of rocks and ophiolitic mélanges are exposed. The ophiolite suite of rocks overthrust the Disang shales from the east and the ophiolites are in turn, overthrust by the Naga Metamorphics also from the same direction. The flyschoid Disang Formation gradually grades into the molassic sediments of the Barail Group towards the west.
5. In the northern part of Manipur Ophiolite belt in Ukhrul district, linear zones of ophiolitic mélangé occur within the Disang shales, west of the main ophiolite belt. The ophiolitic mélangé is characterised by occurrence of exotic blocks of varying size (from few centimetres to tens of metres) composed of micritic limestone, marl, chert, sandstone, basic rocks, and conglomerate in a matrix of flyschoid sediments in the upper part of the Disang Formation.

6. The area under the present investigation falls in the Survey of India Topographical sheet (Restricted) No. 83 K/8 (District Ukhrul, Manipur) (Fig. 1.1). This area lies mid-way between the Nagaland-Manipur-Andaman-Nicobar Ophiolite belt. The present study is confined mainly in three localities, Hundung area, Kangkhui area and Lambui area, where the ophiolitic mélanges are well exposed. These three localities constitute parts of three synclinal ridges trending NE-SW which are demarcated as three linear mélangé zones (Fig. 3.4).

7. Four field trips were undertaken to Ukhrul area during March, 1990; January, 1992; January to February, 1993; and January, 1995. 120 samples were collected from three main localities namely, Hundung area, Kangkhui area and Lambui area. Five sections from five exotic limestone blocks were studied. During the first field trip reconnaissance survey of the whole area and a preliminary sampling from the exotic blocks was done. In many of the exotic limestone blocks the primary bedding plane is not recognisable. Thus any features such as colour bands, chert inclusions, cleavages, and joints planes which are likely to give clues to the primary bedding planes (time planes) were identified. Three to four samples were taken across each planar feature of a block for microfaunal studies. Few samples from the matrix shales and siltstones were also taken. The microfaunal assemblages (mostly foraminifers) of these samples were studied and the section along which there is maximum age range was identified for each blocks.
During subsequent field trips well planned sampling were done on exotic blocks and sections were measured.

8. The following olistoliths were studied in detail. The three limestone blocks, three sandstone blocks, occurring in Hundung area, one limestone block occurring in Kangkhui area, and a slice of banded chert and small blocks of sandstone in Lambui area (Fig. 3.4) are typically exotic blocks, incorporated within a matrix of flyschoid sediments.

In Hundung area, 4 km to the south of the Hundung lower village, four blocks of limestone are exposed over a strike length of 1.3 km along south-western slope (Fig. 3.4; pl.1, figs.a & b). The first block (northernmost) is reported as Hundung North Upper Band. The second block south-east of the first block is reported as Hundung North Lower Band. The third block, 500 m south-west of the first block along the down slope is reported as Hundung South Block. The fourth block occurs just at the Nungsangkhong Nala, 800 m south-west of the Hundung South Block and is reported as Mova Block. All these limestone blocks are within a sequence of shale, sandstone, and siltstone.

In Kangkhui area, 1 km south-east of Kangkhui Khullen (village), locally famous, the Kangkhui Limestone is exposed on the western slope of the Kangkhui ridge (Fig. 3.4). The limestone block comprises a 36 m thick sequence of layered limestones (Pl. 7, fig. a) and is reported as Kangkhui Block.

9. In general, the limestones are biomicritic in texture, and typically represent an organic ooze of a pelagic facies of a sedimentary basin of oceanic dimensions which has completely disappeared during the suturing of Indian and Shan Massif. The sandstones are matured quartzarenite, with pressure-solution features indicating that they have suffered intense compaction. The cherts are composed of small grains of siliceous radiolarian skeletons or small grains of quartz in a fine matrix of microcrystalline quartz.
10. The limestones are massive and hard, whitish-grey to brown in colour. They do not disaggregate under normal treatment of Hydrogen Peroxide. The limestones could be disaggregated with the help of a special method using concentrated acetic acid and copper sulphate crystals (a modified version of a maceration technique developed by Zolnaj., 1979).

11. All the limestone blocks are fossiliferous. In general, the recovered assemblages from all the limestone sections show the following characteristics. The assemblages are dominated by planktonic foraminifers associated with benthic foraminifers, nannoplanktons, radiolarians, a few shark placoid scales and ostracods. The foraminiferal assemblages that have been studied in detail comprise 60 species belonging to 20 genera and 5 families. This assemblage is a great significance because it has helped to constrain the age of the limestone blocks individually and close sampling attempted has yielded a number of intermediate forms which are important from the point of view of evolutionary history of the families: Heterohelicidae and Globotruncanidae. Though no new forms have been described, yet, the assemblages can be related and compared with assemblages described as low latitude assemblages from various part of the world such as Semsale region of Switzerland; Mendez shales of Tampico, Mexico; El Kef, Tunisia and Corsicana Formation of Texas, U.S. A.

12. Biostratigraphic zonation for each block of limestone could be established with the help of index foraminiferal taxa recovered. The zonal scheme attempted in this dissertation has been correlated with three global planktonic foraminiferal zonal schemes and a zonal scheme of east coast sedimentary basin of India (Fig. 5.6). In the east coast sedimentary basins of India the A. mayaroensis Zone does not mark the top of the Maastrichtian. This fact was demonstrated by various deep well (subsurface) sections along the east coast of India (Raju et al., 1991, 1995). They have also demonstrated that A. mayaroensis is not
the last Globotruncanidae to become extinct at Cretaceous -Tertiary boundary. An interval consisting of Globotruncanita stuarti and Globotruncanna rosseta in association with other smaller unkeeled forms overlies the A. mayaroensis Zone in Krishna- Godavari Basin (South India) (Raju et al., 1991, 1995). Thus, the A. mayaroensis Zone recognised in the Ukhrul area (present work) may not represents the top of the Maastrichtian.

The zonal scheme used in present work is exactly the same as that of Caron (1985) (Fig. 5.6). It is interesting to note that the zonal scheme of Caron (1985) was described as typical of tropical province (Caron in: Bolli et al., (1985), pp. 30, figs. 5 & 6). Accordingly, the assemblages described in this work are of a warm tropical province.

13. With the help of the planktonic foraminiferal zonal scheme attempted in this dissertation, the ages of the exotic limestone blocks have been constrained in the study are:

The Hundung North Upper Band (Fig. 5.2) ranges in age from Upper Campanian (Globotruncanina ventricosa Zone) to Lower Maastrichtian (G. aegyptiaca Zone).

The Hundung North Lower Band (Fig. 5.3) ranges in age from Upper Campanian (G. ventricosa Zone) to Lower Maastrichtian (G. aegyptiaca Zone).

The Hundung South Block (Fig. 5.4) ranges in age from Upper Campanian (Rudotruncanina calcara Zone) to Upper Maastrichtian (Gansserina gansseri Zone).

The Mova Block (Fig. 5.5) has an age of Upper Maastrichtian (G. gansseri to Abathomphalus mayaroensis Zones).

The Kangkhui Block (Fig. 5.1) ranges in age from Upper Santonian (Dicarinella asymetrica Zone) to Upper Maastrichtian (Abathomphalus mayaroensis Zone).

14. Stacking up of the four blocks of limestone in Hundung area reveals a striking stratigraphical reversal: that the structurally topmost, the Hundung North Upper Band and the Hundung North Lower Band are found to be the oldest (U. Campanian to L.
Maastrichtian). The Hundung South Block is found to be intermediate (Campanian/Maastrichtian Boundary) and the Mova Block which is the lowermost to be the youngest (U. Maastrichtian) (Fig. 3.5). One possible explanation is that the Mova Block represents part of the youngest pelagic sediments which were the first to slide down along the ensuing slope and get redeposited on the deepest part of the trench during the processes of formation of olistostrome (Fig. 6.5). The older, Hundung South Blocks and the Hundung North Bands were subsequently redeposited on shallower part of the trench as a result of the progressive obduction.

The Kangkhui Block which occur adjacent to the Main Ophiolite Belt has the thickest section and longest age range. Finally, the five exotic limestone representing pelagic sediments of a disappeared ocean has a total age range from Upper Santonian to Upper Maastrichtian (at least in study area) (Fig. 5.7).

15. Fine resolution biostratigraphic studies of the sediments associated with the ophiolite set constraints on the timing of various stages of basin evolution and the tectonic history of the region. For instance, the latest age of the pelagic sediments will give an estimate for the earliest limit for tectonic activity involving the disruption of the sea floor and suturing process. Based on the results from the present investigation and other existing data, a model for the tectonic evolution of the Indo-Myanmar Range has been attempted (Fig. 6.5). In brief the various stages are as follows:

a) The rifting and opening of the proto-Indo-Myanmar ocean was at least prior to Upper Santonian. By Upper Santonian times, pelagic sedimentation in this basin has commenced. There was uninterrupted pelagic sedimentation from Upper Santonian to Upper Maastrichtian. The ocean was deeper than the prevailing CCD in some part as indicated by the occurrence of exclusively radiolarian chert.

b) The Upper Maastrichtian times was marked by high productivity and maximum diversification of the foraminifers. By Latest Maastrichtian the pelagic sedimentation
stopped, the basin became much narrower and shallower, but flysch sedimentation continued as turbidites.

b) By the Mid-Eocene times a part of oceanic slab was obducted as ophiolite on to the Indian Plate margin as a result of progressive suturing between east margin of India and the west margin of Shan Massif. The fragments of ophiolite and pelagic sediments were redeposited along with the flysch in the ensuing trenches and troughs, a part of an olistostromal facies. Part of the obducted slab and associated sediments became positive areas along the northern rim, as evidenced from the conglomerates occurring in the olistostromal belt. The clasts of the conglomerates comprising of pebbles of basic rocks, chert, sandstone and micritic limestone point to a provenance of an ophiolitic mélange.

c) By the Oligocene the basin was completely closed, except for a remnant molassic basin. The major part of the Indo-Myanmar Range were uplifted, and molassic sedimentation phase of the orogeny commenced. The molasse basin progressively migrated westwards and the Barail, Surma, Tipam, and Dupi Tila Groups where deposited progressively. These sequences were later laterally compressed, folded and major east dipping thrusts were developed preferentially along differing lithological boundaries. Uplift and erosion has now produced the present day second-order-landform, at least in the Ukhrul area (Fig. 5.6 f and 3.4).