CHAPTER – 1

INTRODUCTION

The N-S to NNE-SSW trending arcuate ophiolite belt of Nagaland-Manipur forms the northern part of the Indo-Burman Range (IBR). Within the Indian Territory it extends nearly for about 200km from northeast of Chokla in Nagaland to south of Moreh in Manipur. On the western contact of the ophiolite belt occurs a chaotic assemblages of limestones, conglomerates, gritstones, sandstones, radiolarian cherts, ophiolitic derivatives and turbidites. Such chaotic assemblages, characterised by the blocks of competent rocks of variable dimensions surrounded by incompetent rock matrix, are referred as melange (Greenly 1919; Baily and McCallien 1950 and Hsu 1968) or ophiolitic melange (Ganser 1974).

The NE-SW trending olistostromal exotics have been traced for about 40km from Kiphire in Nagaland to Lambui in Manipur (Mitra et al. 1986). These exotic bodies occur within the matrix of flysch sediments represented by shale-siltstone–graywacke–rhythmites of Upper Disang Formation and are highly variable in shape, size, composition and age.

A perusal of available literature reveals that till date the melange units associated with Nagaland-Manipur Ophiolite Belt has not been well defined and studied. However Singh (1984); Gaur and Khan (1984); and Vidyadharan et al. (1985) have reported a zone of olistostromal deposits within the turbidites of Disang from southern part of the Nagaland–Manipur Ophiolite belt. Mitra et al. (1986) gave a brief account on the olistostromal deposits of Ukhrul area. Singh (1993) has worked out the petrology and geochemistry of the exotic calcareous rocks around Ukhrul. Singh (1994) has studied Thermoluminescence of some sedimentary rocks of Ukhrul area. In order to understand the origin and tectonic setting of the melange unit a multidisciplinary approach is needed. The present work, “Sedimentological
FIG. 11  THE STUDY AREA - SAMPLE LOCATION MAP
Investigation of Arenaceous Rocks in and Around Ukhrul”, is one such effort by the present author.

1.1 THE STUDY AREA

The study area is confined in and around Ukhrul. Ukhrul, a hill district of Manipur has unique identity, where Siroi lilly blooms. The location, physiography, climate and vegetation of the study area are discussed below.

a) LOCATION

The present study area, in and around Ukhrul forms an integral part of the ophiolitic melange. It is located at about 81km towards northeast of Imphal, the capital town of Manipur states. It can be approached by road from Imphal as well as Nagaland. The area under present investigation lies between 24°25'N and 25°10' N Latitudes and 94°10'E and 94°30' E Longitudes (fig.1.1) and covers about 50 sq km area. It falls under the Survey of India Topographic Sheet Nos. 83K/8, 83L/1 and 83L/5 on 1:50,000 scale.

b) PHYSIOGRAPHY

The entire area represents rugged hilly terrain, occupied by steep, thickly forested N-S to NNE-SSW trending structural ridges. Elevations of these ridges are highly variable. They ranges from 1200 to 2570m from Mean Sea Level. Sirohi is the highest peak in the area. The entire area is drained by the Thoubal River and its tributaries such as Nungsangkhong, Yanglui, Ri, Rishila, Teinguiro etc. While traversing through diverse types of litho-units, river Thoubal and its tributaries display various types of drainage patterns. The structure, lithology and physiography of the area dominantly control these drainage patterns.

c) CLIMATE

Ukhrul district enjoys sub-tropical climate with heavy rainfall. The average annual rainfall is about 1700mm. Maximum rainfall occurs from April to September.
Due to high altitude and thick vegetation the area experiences very cold climate during winter. In the months of December and January, sometime temperature drops down to 0°C.

d) **FLORA AND FAUNA**

The vegetation in and around Ukhrul includes sub-tropical thick forest of shrubs, bushes, bamboos, pines etc. These forests are rich in wild life, which includes wild buffaloes, dears, leopards, bores, and different kinds of reptiles. The patches of terrace cultivation and horticulture can be seen in the areas where slope is moderate. However, people of the area dominantly practiced shifting cultivation. Recently on experimental basis the State Govt. has started Sericulture by developing Tasar plantation.

1.2 **AIMS AND OBJECTIVES**

The systematic geological mapping of Nagaland-Manipur Ophiolite Belt was taken up by the Geological Survey of India during the early seventies but till now very little work has been completed. Unfortunately some of the works done by GSI are yet to be published. However notable workers are Sriram and Mukhopadhyay (1971), Bhandari et al. (1973), Chattopadhyay et al. (1975), Dasgupta (1977), Anon (1978), Agrawal et al. (1978), Sen and Chattopadhyay (1978), Agrawal and Kacker (1980), Ghosh (1980 and 1986), Ghosal (1983), Venkataramana et al. (1983), Ghosh et al. (1984), Acharyya et al. (1984), Acharyya (1990), Prasad et al. (1986), Mitra et al. (1986), Shukla (1989), Vidyadharan et al. (1989), Joshi (1990), Singh (1993), Singh (1994) and others. Available published and unpublished geological literature on Nagaland-Manipur Ophiolite Belt reveals that much of the work is confined in the Nagaland region. Keeping above facts in mind the author has selected the present problem that aims to-

1) do the systematic survey of the arenaceous rocks.
2) prepare a lithotectonic map of the area.
3) do petrographic and granulometric analysis,
4) geochemistry and clay mineral analysis, and
5) find out interrelationship among variables generated in the laboratory.
The data generated from the field and laboratory studies shall be utilized to work out the sedimentological and tectonic history of these sandstone bodies.

1.3 METHODOLOGY

Main aim of the sedimentological studies is to reconstruct the palaeogeography and palaeotectonic condition of the depositional basin, direction of sediment transport and the provenance. To arrive at the goal, diversified field and laboratory techniques are needed. These techniques are discussed below.

a) FIELD SURVEY AND SAMPLING

During the course of field survey systematic studies are conducted along Shokpao-Singcha; Ukhrul-Khangkhui, Ukhrul-Imphal old road sections, Ukhrul-Sirohi section, and around Hungdung and detail information are recorded from different locations within sedimentary horizons. Due to thick vegetation, steep slope and inaccessibility problems, vertical lithologs could not be prepared. Due to erratic distribution and their occurrence in pocket forms the techniques of random sampling is used for the collection of samples. Number of samples collected from each section varies according to the availability of good exposures and lithological variation. A total number of 98 samples have been collected from different locations.

b) LABORATORY TECHNIQUES

Samples collected from various localities are subjected to different kinds of laboratory test. It includes preparation of thin section, petrography, grain size analysis, clay mineral analysis, geochemical analysis, etc.

i) THIN SECTION PREPARATION:Thin section is the basis of much relative description and interpretation. In order to get good result samples from present study area requires impregnation before the preparation of thin sections. For impregnation the samples are heated for about 2 hours at 90°C in the mixture of Araldite and Hardner which is dissolved in three parts of Toluene.
ii) GRAIN SIZE ANALYSIS: Depending upon the nature of the samples and suitability, different techniques i.e. thin section, sieving, and settling velocity methods are used for grain size analysis. From each thin section, the long axes of about 500 quartz grains are measured using micrometer scale on ocular of the petrological microscope. While measuring the size in thin section, every care is taken to avoid broken grain, overgrowth and etching. Some of the samples are friable enough to be disaggregated without breaking the original grains. In such cases, the sieving technique has been used for the estimation of grain size. The sieves used for the analysis ranges from 7 to 230mesh that are arranged at one-phi equivalent class intervals. From each disaggregated sample 100gm is taken for sieving. For the measurement of fine grains-silt and clay size particles, settling velocity method has been used.

iii) PETROGRAPHY: Petrographic studies are carried out using Leitz Laborlux 11 Pol and Carl Ziess Pol Jenalab petrological microscopes in the Department of Earth Sciences, Manipur University. It includes mineral identification and modal analysis. Modal analysis is carried out using ELCO made Automatic Shift Point Counter fitted with petrological microscope.

iv) X-RAY DIFFRACTION ANALYSIS: X-ray diffraction analysis has been performed for twenty representative samples at USIC Gauhati University, Guwahati. For this purpose, part of the sample is crushed to the size less than 2μm in diameter. The slide mounted powdered sample is run on the diffractometer, PW1710 using CuKα radiation with a wavelength of 1.54056Å and nickel filter. The instrument is operated at 40kV and 20mA at a speed of 0.2 sec. per step, with continuous scanning. Throughout the analysis, 0.02 step size is maintained. In order to identify the minerals, d-spacing of the standard minerals as recorded by American Society for Testing Materials (ASTM) have been used.

v) GEOCHEMICAL ANALYSIS: Geochemical analysis is carried out for 20 representative samples collected from different locations. Si, Al, Fe, Mn,
Mg, Ca, Cu, Pb, Zn, Na, K, Co, Sn, Ni, Cr and Ti are analysed using AAS, ICP-AES, Spectrophotometer and Flame Photometer. These analyses are carried out at RSIC, Shillong and Geochemical Laboratory, Atomic Mineral Division, Shillong. Except Si and Al, for the analysis of other elements, 0.1gm sample is digested in 2.5ml solution of HF and HClO₄ in the ratio of 2:3.5. After complete digestion 3ml conc. HCl and 15ml distilled water is added and boiled. After the solution becomes cold it is filtered and made to 50ml volume by adding distilled water. Prepared solution is run on AAS for the detection of Fe, Mg, Ca, Pb, Zn, Cu, K, Ni, Cr and Co. ICP-AES is used for the detection of Sn and Ti. Na is detected with the help of Flame photometer.

For the detection of Si and Al, 0.05gm of sample is mixed in 10ml of NaOH solution (15%). The mixture is transferred in nickel crucible and heated to dryness with the help of infrared lamp, which gives slow heat. Since the infrared lamp is very costly, the sand-bath can serve the purpose of slow heating. There after, crucible along with sample is heated on the gas burner till it becomes red-hot. Then the crucible is allowed to cool down and after adding 50ml distilled water it is kept overnight. After that the sample is transferred in 250ml flask that already contain 20ml of 1:1 HCl and made upto the volume by adding more distilled water. For the detection of Si and Al with spectrophotometer colour development is necessary. SiO₂ concentration is measured at 650nm in the spectrophotometer after 30minutes of developing blue colour. For the colour development 1ml of ammonium molybdate is added to 10ml of solution. After 10minutes 4ml of tartaric acid (10%) and 1ml of reducing agent are added and made up to the volume of 100ml. The reducing agent can be prepared by dissolving 0.7gm of Na-solute in 10ml of water and by adding 0.15gm of 1amino-2 napthol-4 sulfonic acid. This mixture is stirred until it completely dissolved. 9gm of NaHSO₃ are dissolved in 90ml distilled water and are added to the previous solution.

Concentration of Al₂O₃ is measured at 475nm after 2hours of colour development. The colour development is done by adding 1ml CaCl₂ to 20ml
aliquot and 1ml HAH (10%), 1ml potassium-ferricyanide (1%) and allowed to stand for 5 minutes. Thereafter 10ml buffer solution is added and kept for 10 minutes. Then 5ml of alizarin red (0.1%) is added. This mixture is diluted to 100ml with distilled water and allowed to stand for 2 hours. Buffer solution is prepared by adding 70gm of sodium-acetate in 30ml of glacial acetic acid and diluted to 500ml with distilled water.

c) PRESENTATION OF DATA

Data generated in the laboratory are tabulated in various ways. Data presented in tabular form can not be readily used for visual comparison, thus it needs to be presented graphically and statistically.

i) GRAPHICAL PRESENTATION: A large number of procedures are available for the graphical presentation of data. For some purposes, one method is best suited; for other purpose other method is suitable. Grain size data generated from thin sections, sieving and pipette analysis are graphically presented as histograms, frequency curves and cumulative curves. All these graph uses grain size as the abscissa (horizontal scale) and frequency as the ordinate (vertical scale). Grain size data may either be plotted directly in mm, using a logarithmic-base paper or they may be plotted in phi-unit using arithmetic base paper. It is necessary to follow a standard procedure in preparing these graphs, as variation in scale will alter the appearance of graphs, thus comparison of different grain size distribution becomes difficult.

The data from sieving and pipette sedimentation are expressed in terms of weight frequency percentage while those from the thin sections as number frequency percentage and are plotted along ordinate. Diameters of the grains in phi unit are plotted along the abscissa. In the present analysis histograms and frequency polygons are prepared on the computer using EXCEL Software package. The frequency polygons are obtained by joining the midpoint of the histogram column. Cumulative curves are plotted manually on the probability log paper using probability scale. The cumulative curves are used for pictorial interpretation as well as for the computation of percentile values.
Scatter plots as suggested by Moiola and Weiser (1968), Freidman (1961) and C-M diagram after Passega (1957, 1964 and 1977) are plotted in order to interpret depositional environment and mechanism of transport. Framework constituents (quartz, feldspar and rock fragments) are plotted in triangular diagrams as suggested by Dott (1964), modified by Pettijohn (1984). Geochemical data generated through various techniques are presented in the form of different bivariate plots and triangular diagrams. These plots have been used for the discrimination of tectonic setting of the depositional basin.

ii) **STATISTICAL PRESENTATION:** Numerous attempts have been made to introduce a number of statistical parameters for the presentation, comparison and interpretation of geological data. Quantitative methods used in the present analysis include descriptive statistics, correlation coefficient, discriminant function and principal component analysis. Correlation Coefficient and Principal Component analyses have been worked out on computer using MINI-TAB software package while rest of the parameters is calculated manually with the help of scientific calculator.

**Descriptive Statistics:** Descriptive statistical parameters used in the present analysis include median, graphic mean, inclusive graphic standard deviation, inclusive graphic skewness and graphic kurtosis. For the calculation of these parameters, formulae that suggested by Folk and Ward (1957) have been used.

**Correlation Coefficient:** Identification of the casual relationship among different parameters is a prime concern of any scientific study. A casual relationship between two parameters exists when one of them is logically considered as cause of the other. The parameter, which is considered to be the cause, is known as the *independent variable* and the one, which is supposed to be the effect, is known as the *dependent variable*. So, the variations in dependent variable may be explained in terms of the variations in the independent variables. If the casual relationship exist among the parameters, values of both independent and dependent variables vary together. This property of co-variation is known as correlation and is the
ratio of the covariance of two parameters to the product of their standard deviation. The degree of interrelationship between variables can be worked out with the help of correlation coefficient.

\[
\text{Correlation Coefficient } (r_{jk}) = \frac{\text{Cov}_{jk}}{S_j S_k}
\]

Correlation coefficient is a unitless number and cannot exceed the product of the standard deviations of its variables. It ranges between +1 to -1. A correlation value of +1 indicates perfect direct relationship among the variables and -1 indicates a perfect inverse correlation. The correlation coefficient value, zero indicates that no linear relationship exists among the variables.

In the present analysis, to estimate the degree of interrelation between parameters the Correlation Coefficient suggested by Karl Pearson has been used.

\[
\Sigma xy = \frac{\Sigma xy}{n} = \frac{\Sigma x \Sigma y}{N}
\]

\[
1 = \frac{[\Sigma x^2 - (\Sigma x^2/N)]^{\frac{1}{2}} [\Sigma y^2 - (\Sigma y^2/N)]^{\frac{1}{2}}}{\Sigma x^2 - (\Sigma x^2/N)^{\frac{1}{2}} [\Sigma y^2 - (\Sigma y^2/N)]^{\frac{1}{2}}}
\]

**Discriminant Function Analysis:** Discriminant function analysis is a powerful method of multivariate analysis. It is considered to be an appropriate statistical tool when single dependent variable happens to be non-matrix and requires to be classified into two or more groups on the basis of its relationship with other independent variables that happen to be matrix. Discriminant function analysis is one of the most widely used multivariate procedures in geological sciences. In the present analysis to discriminate the different mechanisms and environments of deposition, discriminant function analysis as suggested by Sahu (1964) has been used.

**Principal component analysis:** Principal component analysis is a branch of factor analysis. It is a technique designed to synthesize a large number of variables into a smaller number that retains maximum amount of
descriptive ability. Morrison (1967) has described the principal component analysis as a method to discover those hidden factors, which might have generated the dependence or covariance among the variables. It essentially requires an orthogonal transformation of a set of interrelated variables into a new set of independent variables. Hotelling (1933) gave mathematical formulation of the principal component analysis as below:

Let \( X = (X_1, X_2, \ldots, X_p) \) be a set of \( p \)-vectors of standardized random variables having good correlation with each other. The principal components of these \( p \)-variables are such linear combinations that give maximum variance. Thus, the required linear function is

\[
Y = a_1X_1 + a_2X_2 + \ldots + a_pX_p
\]

The coefficient vector \( a' = (a_1, a_2, \ldots, a_p) \) must be such that:

i) \( S^2 Y = a'Sa \), (i.e. the variance of \( Y \) ) is maximum for all the variables of ‘a’ and

ii) \( a'a = 1 \) (a normalization condition, only for the sake of mathematical convenience).

Where \( S \) is the variance-covariance matrix of \( X \) and \( S^2 Y \) is the variance of \( Y \).

Main objective of the principal component analysis is to find out the values of the coefficient vector \( a' = a_1, a_2, \ldots, a_p \) which satisfies both the above conditions (i and ii). Mathematical solution of this problem indicates that ‘a’ is one of the \( P \)-eigen vectors of the matrix of inter-correlation ‘R’ among the original variables \( (X_1, X_2, \ldots, X_p) \). So there are \( p \)-eigen vectors and the number of components derived in this way are equal to the number of original variables, \( P \) which is associated with \( (x_1, x_2, \ldots, x_p) \). The solution indicates that the variance of a component is equal to the eigen value \( (\lambda_i) \) of eigen vector used. The descriptive power of each component is expressed as the ratio \( \sqrt{\lambda_i}/p \). The component that has highest eigen value is known as the first principal component. The components correspond to 2nd 3rd 4th and so on upto \( p \)-th eigen values are known as second, third, fourth and the \( p \)-th principal components. It is generally found that only few principal components having higher variances explains major portion of the total variance \( p \).