Microfacies Analysis of Samana Suk Formation, Shah Alla Ditta, Islamabad

A thesis submitted to Bahria University, Islamabad in partial fulfillment of the requirement for the degree of BS in Geology

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CERTIFICATE

DEDICATION

We truly dedicate our dissertation to the most valued personalities; our parents and teachers. Parents have instilled the precious virtues in us due to which it has been possible to reach this culminating objective. We owe this success to our prestigious mentors. You have been the constant source of extrinsic motivation. The efforts which such auspicious personalities have put to make us successful will remain sacred.

ABSTRACT

Fossils give information that unveil the geologic past including paleoenvironment, paleogeographic conditions and depositional settings. Samana Suk Formation is well exposed near Shah Alla Ditta in Islamabad. It is section of Margalla Hill ranges which is the part of lesser Himalayas. It is located in western margin of Main Boundary Thrust. The Samana Suk Formation consists of medium to thick bedded limestone with intercalations of calcareous shale. The limestone contains fragments of Brachiopods, Bivalves, Ammonoids, Gastropods and Crinoids fauna. The petrographic study revealed different microfacies including bioclastic facies, dolomitic facies and quartz rich dolomitic facies. These microfacies were identified on the basis of faunal content e.g., bivalve fragments, ooids, peloids, intraclasts, algae and other sedimentological characteristics. The identified microfacies are consistent with the lagoonal to middle ramp depositional setting.

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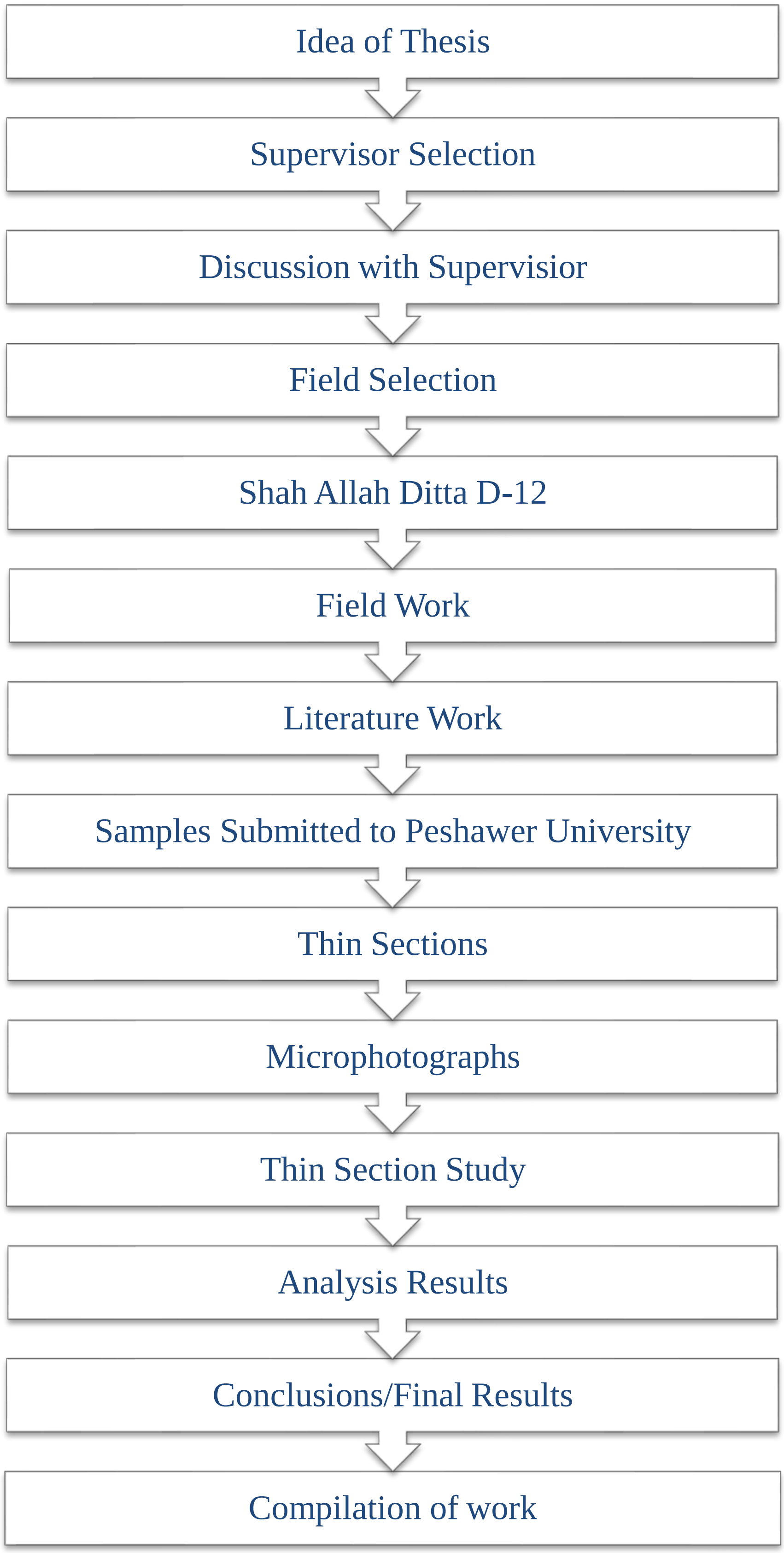

CHAPTER 1
INTRODUCTION

1. Introduction

Margalla mountain ranges are the smallest part of the Himalayas present in north of Islamabad, Pakistan. These are located at west of Pakistan's main fault systems, Main Boundary Thrust Fault (MBT). It creates a mountainous separation between the Potwar basin to the south and the Hazara basin to the north (Munir, 2005).

The stratigraphic sequence of the Margalla mountain ranges in Shah Alla Ditta section, Islamabad includes the Paleocene Hangu Formation, Patala Formation and Lockhart Limestone, while the Eocene succession consists of the limestone of the Margalla hill, Chorgalli Formation and Kuldana Formation. The present study is carried out on the carbonate sequence of hanging wall of Main Boundary Thrust . The sequence involves Samana Suk Formation, Lockhart Limestone and Margalla Hill Limestone of Jurassic, Paleocene and Late Paleocene to Early Eocene age respectively.

In the study area the Samana Suk Formation contains brachiopods, bivalves, gastropods, ammonoids, crinoids and shelly remains. The Lockhart Limestone abundant in foraminifers, corals, molluscs and echinoids. Eocene limestone indicates the biogenic deposition. Its accumulation can exceed 70 to 80 percent of the amount of rock. Index fossils play an important role in the geological timescale because of their limited age.

1.1 Location and accessibility

The study area which is located at the north of the Shah Alla Ditta Village having latitude and longitude (33^{o} 43’ 7.2” to 33^{o} 43’ 8.3”N and 72^{o} 54’ 59” to 72^{o} 54’ 55.4”E) and it is easily accessible through Islamabad at a distance of 20km by Shah Alla Ditta. Figure 1.1 show location & accessibility map.

Figure 1.1. Accessibility Map.

1.2 Climate

According to the Pakistan Meteorological Department (PMDC) the region has a tropical climate, with the monsoon season as well as a mild winter with summer. The warmest months are May to July, when the average high temperature reaches 38^{o}C. The monsoon season begins with heavy rains and several storms from July to September.

1.3 Topography

The Margalla Hill Ranges has several valleys and steep slopes. Its height varies from west side to the eastern part with an average height of 1000m (Anwar, 2001).

1.4 Previous work

Margalla Hills lie on the hanging wall of Main Boundary Thrust (MBT) which is important province of the Lesser Himalayas, North Pakistan. It consists Paleocene-Eocene carbonates, which are exploration targets for oil and gas production. Many geologists have researched regional geology and stratigraphy in detail for many years. A brief report on the work done by some researchers in what is explained below.

In 1930 Davies introduced the name “Samana Suk” for Jurassic Limestone in Samana Ranges and is derived from the mountain peak of same Samana range. In 1968 Fatmi designated its type locality in North East of Shinawari (Lat 33^{o}31’13’’; Long 70^{o} 48’ 06’’) Samana Ranges in western part. Fatmi, 1977 designated the type section of Samana Suk Formation consists of grey to dark grey oolitic , medium to thick bedded limestone with subordinate marl and calcareous shale intercalation. The fauna consisting of gastropods, ammonoids, crinoids reported by the Fatmi (1968, 1972). The ichno-fossils of the Middle Jurassic Dinoasaur were discovered for the first time in the Central Salt Ranges of Pakistan in the form of dinosaurs' footprints, which were imprinted in the limestone with mud cracks in the upper most part of the Middle Jurassic Samana Suk Formation near Mahorian, district Khoshab, Punjab Pakistan (Abdur Rauf and Fahim, 2015). In different part of Hazara additional fauna was reported by Latif (1970a), and this suggest the middle Jurassic age of this Formation.

The Paleocene Limestone unit in the Kohat area was named as Lockhart Limestone by Davies (1930a). The other similar units were also named as Lockhart Limestone by the Stratigraphic Committee of Pakistan in the Kohat- Potwar and Hazara areas. The type locality in designated near Fort Lockhart (Lat.33^{o}26'N: Long 70^{o}30'E) in the Samana Ranges. Many fossils have been reported there which includes foraminifers, mollusk, corals, echinoids, and algae. Algae and Foraminifers have been reported by Eames, Bhola, and Nagappa (1951). In the Hazara areas, foraminifers were reported by Cheema (1966) and Latif (1970c) and all details analysis and paleontological studies indicates a Paleocene age.

1.5 Objectives

The present research aims to attain the following objectives:

1. To analyze the faunal content of Samana Suk Formation.
2. To assign the microfacies based on sedimentological characteristics.
3. To evaluate the depositional settings.

1.6 Methodology

The present study work is composed of field work and laboratory work, which are discuss below.

1.6.1 Fieldwork

Field work was carried out in order to collect the samples and then these samples transformed and made into thin sections. Lithological and paleontological characters, contact relationship, bedding plane, structural features and sedimentary structures were also observed during the field work.

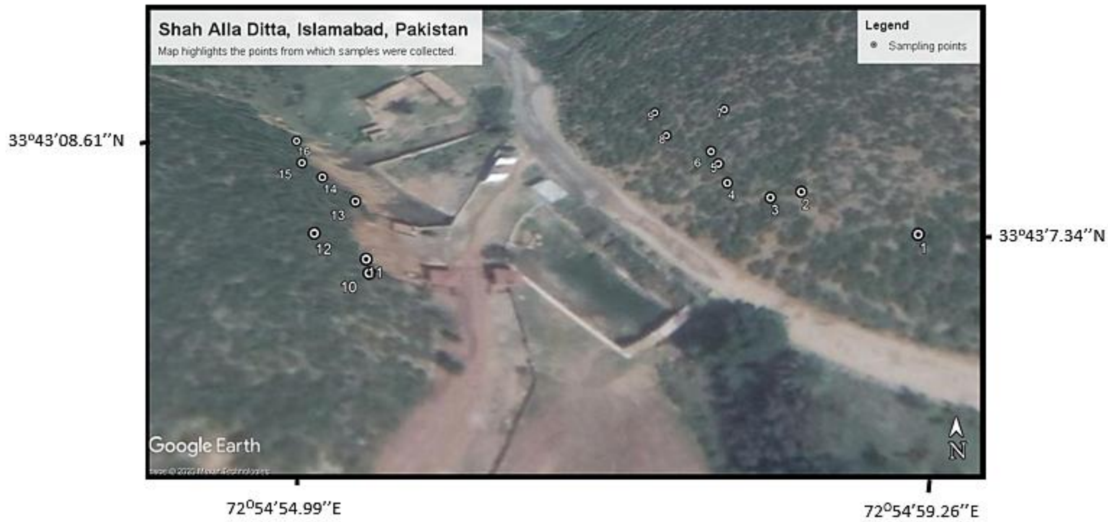

Figure 1.2. Map of Shah Alla Ditta along sampling locations.

1.6.2 Laboratory work

Samples from the site area were safely delivered to the Department of Geology at University of Peshawar for the preparation of thin sections for microscopic studies. The thin sections were made with the necessary precautions, such as the right orientation to obtain the maximum level of details of microfossils. After the preparation, thin sections were studied and microphotographs were taken in sedimentology lab in National Centre of Excellence in Geology, University of Peshawar. The thin sections were studied under polarized microscope for identification and assigning of the microfacies.

CHAPTER 2
TECTONICS

2. Introduction

Pakistan contains a unique part of the important history of tectonic framework which lies on three main lithospheric plates such as Arabian, Indian- Australian and the Eurasian plate. The related geological features that can be recorded in Pakistan including the subduction zones related features (the Indus and Shyok sutures), transform fault boundary related features (the Chamman Fault), volcanic arcs related features (Chagai, Kohistan- Ladakh arc region), and the trench arc system that was active and deformed margins of the plate margins(Makran). The mountain ranges have been seen by the result of these activities named as the Himalayas, Hindukush and Karakoram. Precambrian to recent rocks sequence are present due to the tectonic activity of the region (Kazmi and Jan 1997).

2.1 Regional geologic setting

In Carboniferous to early Permian (300-250Ma) super continent Pangea started to break, and the formation of new plates resulted, microplates and the formation of neo Tethys (Scotese et al.,1979; Condie, 1984). Indian plate, which is the newly formed plate moves towards north, and in the southern hemisphere the Indian ocean start drifting resulting in the closure of Neo-Tethys that stretches from Pacific to Mediterranean (Frarah and Dejong,1979; Tapponier et al.,1986).

In the Eocene age the Indian and Eurasian plate started collision and resulted in the closure of Neo-Tethys ocean (Tahirkheli et al., 1979). The major tectonic features in the northern part of Pakistan formed due to the under thrusting of Indian plate beneath the Eurasian plate that are still active and including the major thrusts, Main Karakoram Thrust (MKT) (Gansser, 1981; Coward and Buttler, 1985; Coward et al., 1986), Main Mantle Thrust (MMT) (Tahirkheli and Jan, 1979; Kazmi et al., 1986), Main Central Thrust (MCT) (Heim and Gansser , 1939; Le Fort , 1975; Tahirkheli, 1991), Main Boundary Thrust (MBT) (Yeats and Lawrence , 1984; Treloar et al., 1989), Salt Range Thrust (SRT) (Gee, 1945, 1989; Yeats et al., 1984; Lillie et al., 1987) and the Karakoram, Hindukush, Himalayas ranges are associated with these faults.

2.2 Northern division of Himalayas in Pakistan

The mountain ranges of Himalayas of about 2500 km long and 160-400 km wide. The tectonic division of mountain ranges by Gansser (1964) including Tethyan, Higher, Lesser, Sub-Himalayas that extends from SRT to MMT and each unit is separated by the major boundary thrust (Fig.2.1). The rock sequences of Indian plate include the Phanerozoic sediments and Proterozoic basement. The sedimentary cover which is thickly deposited is deformed by Indian-Eurasian collision and also intruded by igneous rocks and also affected by the metamorphic events (Kazmi and Jan,1997). Due to this complex Himalayan nature is formed. By the help of geophysical tools the continental crustal thickness between 50-80 km identified which is double than the normal thickness (Molnar,1984,1988). These variations resulted in the continuous under-thrusting and under plating of Indian plate under the Eurasia. According to Le Fort (1975) the tectonostratigraphic zones of Himalayas are as follow in following table 2.1

Ladakh / Tibet Block
--------------- Tethyan Himalayas ---------------
Indus-Tsangpu Suture Zone (MMT)
--------------- Higher Himalayas ---------------
Main Central Thrust (MCT)
--------------- Lesser Himalayas ---------------
Main Boundary Thrust (MBT)
--------------- Sub Himalayas ----------------
Main Frontal Thrust (MFT)
Himalayan Foredeep

Table 2.1 Tectonostratigraphic zones of Himalayas

The study area is present in the Lesser Himalayas and located near the Main Boundary Thrust (MBT).

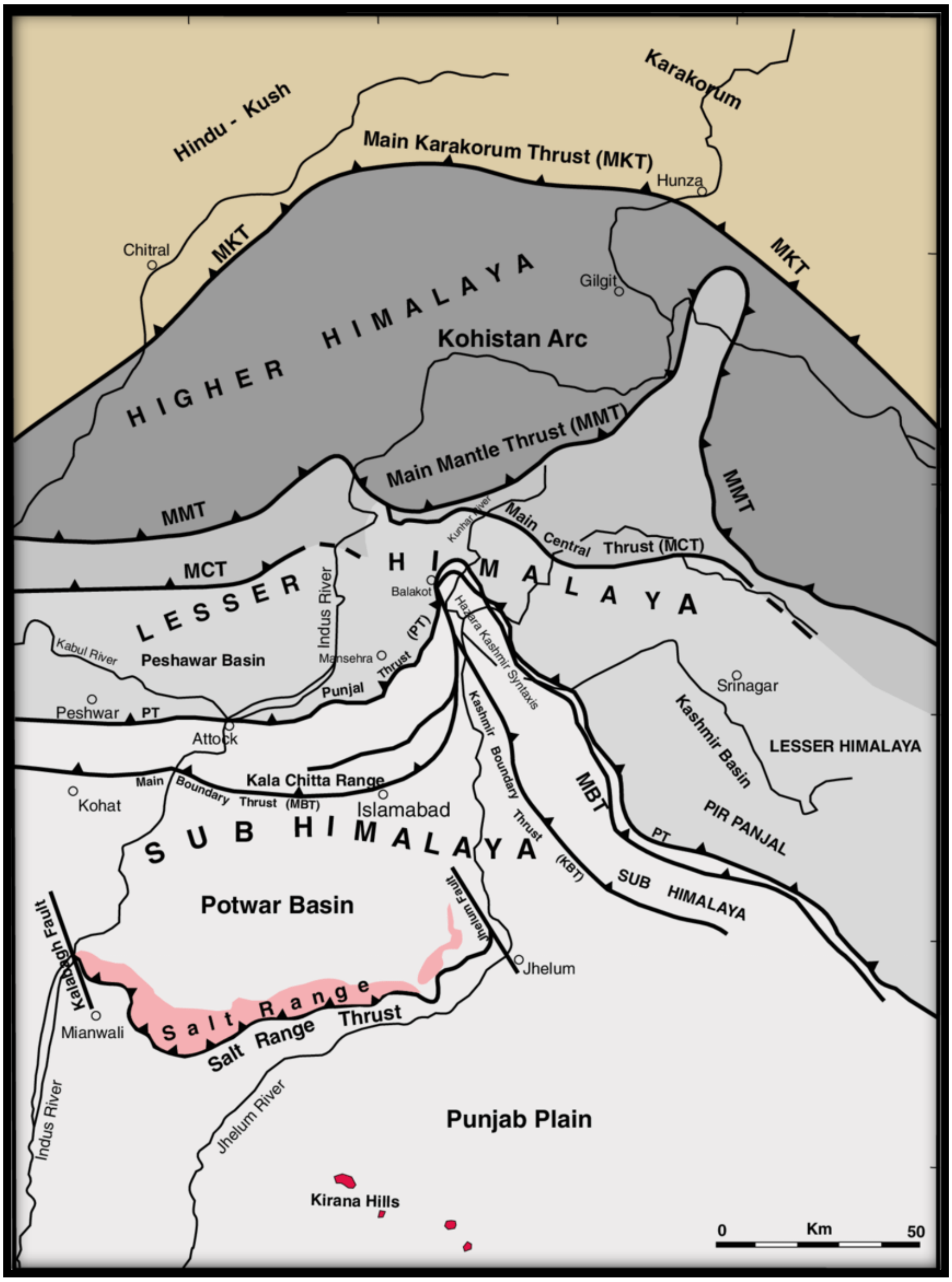

Figure 2.1. Generalized Tectonic map of northern Pakistan, showing sub-divisions of Himalayan Mountains (after Gansser 1981; Kazmi and Rana 1982).

2.2.1 Lesser Himalayas

In north Main Central Thrust and in south Main Boundary Thrust, Lesser Himalayan zone is present. Pre Cambrian to late Paleozoic meta-sediments and Paleozoic sedimentary and volcanic rocks of several thrust sheets are present in this zone. Various scientists give different explanations due to difficulties in stratigraphic correlation and highly complicated structure of Lesser Himalayas.

This region shows the various system of ranges that bear sharp curves and changes in orographic axes, various feature referred as NW Himalayan Syntaxis (Wadia,1931), Punjab Orocline (Carey,1958), Western Himalayan Syntaxis (Gansser,1964), Kashmir Syntaxis (Calkins et al.,1975), Hazara Syntaxis (Desio,1978), Punjab Re-entrant (Johnson and Vondra,1972) and Jhelum Re-entrant (Visser and Johnson,1978). The study area is present at the Margalla Hills of Islamabad. Mesozoic to lower Tertiary carbonates with over lapping of foreland basin sediments of upper Eocene to Miocene age rocks of Murree Formation are present in the study area near the thrust.

2.2.2 Main Boundary Thrust

The thrust stretches in the east-west direction and initiating from Afghanistan in the west and across Pakistan while enter into India in the east and it is the major south verging thrust. The structural setting of study area is controlled by MBT whose strike is NE to SW at the front of this deformed fold and thrust belt in the northward direction where it joints the Hazara Kashmir Syntaxis (HKS) around Hazara Kashmir region Figure 2.1. The high degree of deformation is produced from intensive stresses in the area of HKS. The amount of shortening of rocks is due to the Panjal fault and Nathiagali fault which runs parallel to the Main Boundary Thrust.

Frontal portion of southern ranges of Lesser Himalayas is occupied by Main Boundary Thrust, and the Jurassic to Paleocene age formations are equally lies with the Miocene sediments of Sub-Himalayas that are derived mainly from the erosion of Higher Himalayas. Due to the different episodes of ongoing collision shows the increase in shortening that are resulted in the tight folding in the hanging wall of Main Boundary Thrust, that can be the main reason of folds in the Margalla Hills.

Samana Suk Formation of Jurassic age is unconformably overlain by Paleocene Lockhart Formation, which is also overlain by Margalla Hill Limestone, Chorgali and Kuldana Formations of Eocene age that is present in the hanging wall stratigraphy of MBT. Chorgali, Kuldana and Murree Formations of Eocene and Miocene ages respectively are present at the footwall stratigraphy of Main Boundary Thrust.

CHAPTER 3
STRATIGRAPHIC SEQUENCE

3. Introduction

Lesser Himalayan region lies in the Hazara basin, and part of one of the largest sedimentary basins of Pakistan. The trend of Indus basin is NE-SW and length is 1600 km and width is 300 km (Shah, 1977). Rock formations from Pre Cambrian to recent age are present in that area which shows complex depositional and complicated tectonic episodes. Sedimentary environments ranging from deep marine to carbonate and clastic shallow marine and fluvial system and evolved in Hettangian (Early Jurassic Stage). Carbonates interspersed by diastems, hiatus and unconformities that are mostly dominated by Mesozoic to Eocene.

In the study area the stratigraphic column in the Hazara basin consists of Jurassic Samana Suk Formation, Lockhart Formation and Patala Formation of Paleocene age, Eocene Margalla Hill Limestone and Miocene Murree Formation Figure.3.1.

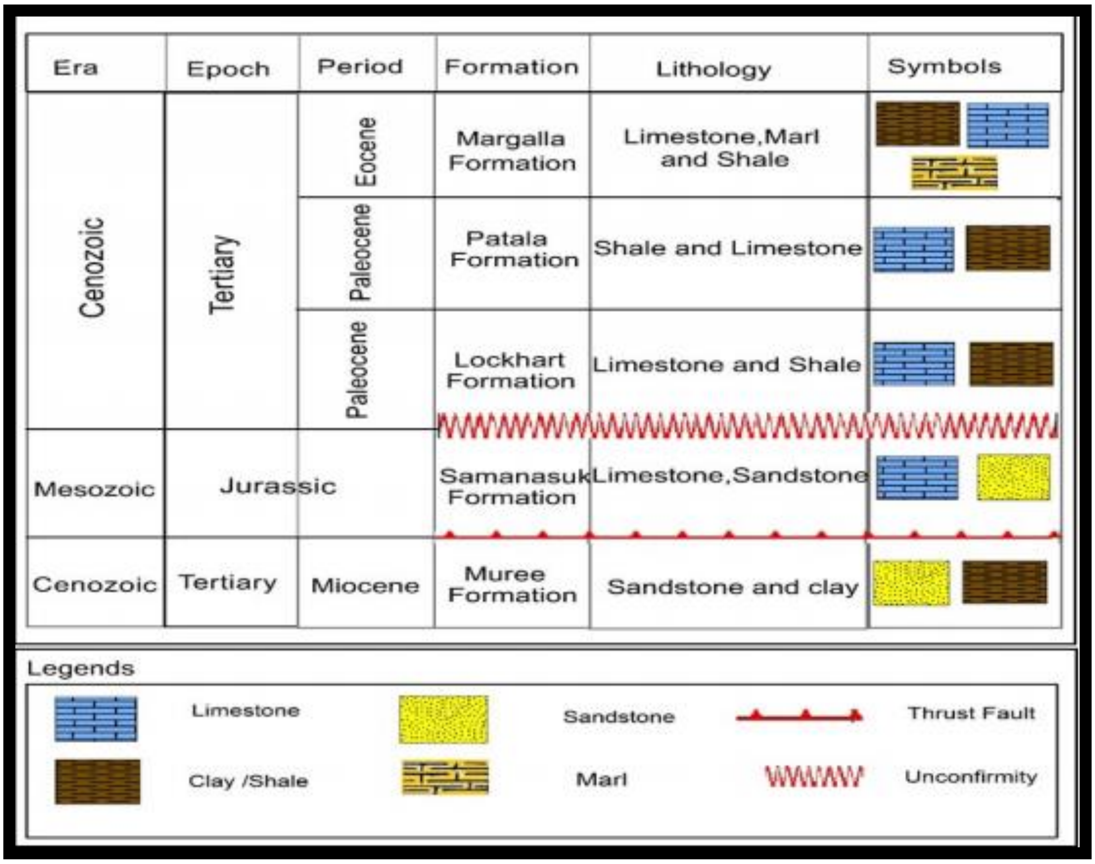

Figure 3.1. Stratigraphic column of study area (Khattak et al.,2017).

3.1 Jurassic sequence

3.1.1 Samana Suk Formation

It is derived from a mountain peak in the Samana ranges and the name derived for Jurassic Limestone is Samana Suk that is introduced by Davies (1930). It is in the western part of Samana range in the NE of Shinawri (Lat. 33°31'13" N; Long. 70°48'06" E) and its type locality is assigned by Fatmi (1968). It is grey to dark grey, medium to thick bedded limestone with calcareous shale intercalations (Fatmi, 1977). Brachiopods, Bivalves, Ammonoids, Gastropods and Crinoids fauna are reported by (Fatmi,1968,1972). In different parts of the Hazara area further studies reported the additional fauna are present there that will assign the Middle Jurassic age of this formation (Latif, 1970a).

In the study area the Samana Suk Formation is thin to medium bedded (Fig.3.3), and its fresh color is grey. Weathered color is yellowish brown. Limestone is oolitic and contain broken fragments of Bivalves at the top and base of this formation shown in Figure 3.3. Its lower contact with Murree Formation is faulted and upper contact with Lockhart Formation is unconformable shown in Figure 3.3.

Figure 3.2. Broken fragments of Bivalves in Samana Suk Formation (Lens for scale).

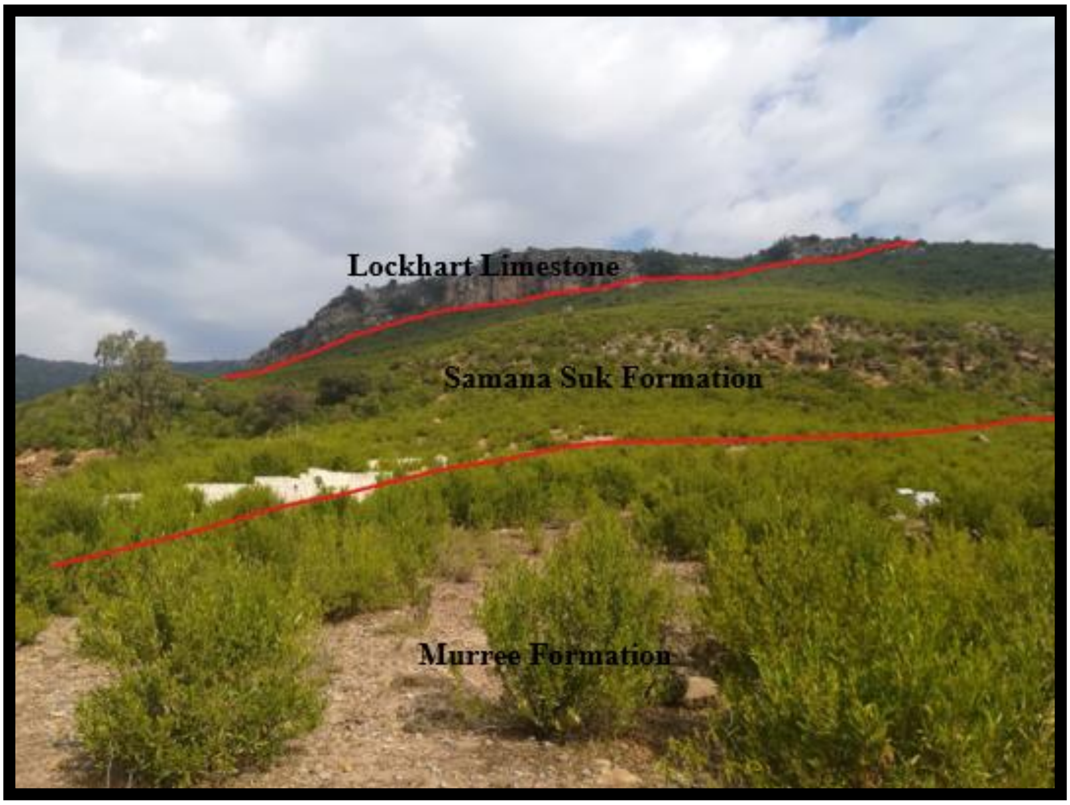

Figure 3.3. Field Illustration of the upper and lower contact between the Samana Suk Formation and the Lockhart Formation and Murree Formation in Shah Alla Ditta village, Islamabad.

3.2 Paleocene sequence

3.2.1 Lockhart Limestone

Paleocene Limestone unit in the Kohat area, the name used by Davies (1930) was Lockhart limestone, and the name has been approved by Stratigraphic Committee of Pakistan for same units in Kohat-Potowar and Hazara areas. The type locality is near Fort Lockhart (Lat. 33^{o}26’ N; Long. 70^{o}30; E) in Samana range.

Many fossils are reported which includes Corals, Echinoids, molluscs, Algae and abundant foraminifera. Algae along with foraminifers have been reported by Eames, Bhola and Naggapa (1951). Paleontological study in the Hazara area indicates the number of foraminifers have been reported by Raza (1967); Cheema (1968) and Latif (1970c).

Lockhart Limestone is medium to thick bedded in the study area and its color is light to dark grey. It gives pungent smell when hits by hammer. Nodules are present that are poorly developed but not as same that of Margalla Hill Limestone. The lower contact with Samana Suk Formation is unconformable and upper contact is with Margalla Hill Limestone as shown in figure 3.1.

3.2.2 Patala Formation

The Patala Shale was formally introduced by Stratigraphic Committee of Pakistan and Davies and pinfold in (1937) and it extended in Kohat potwar and Hazara areas. Eames in (1952) give the name of this formation "Tarkhobi Shales" part of the limestone of Wynne in (1873), Cotter in (1933) gives this formation named as "Nummulitic formation" of Waagen and wynnes in (1872) introduce the part of "Nummuletic series" of middle Miss(1896) the Latif in (1970a) named it "Kuzagali Shale"

Patala Nala is the location where this section exposed (Lat 32^{o}40'N: Long 71^{o}49'E) in the Salt Range has designated in this section. Shale and Marl with subordinate limestone and sandstone in salt range. The shale is greenish grey selenite bearing in place carbonaceous and calcareous also contain marcasite nodules.

Patala Formation and Lockhart Limestone have conformably contact with each other abundant in foraminifers, mollusk and ostracods are present.

3.3 Eocene sequence

3.3.1 Margalla Hill Limestone

The name Margalla Hill Limestone is introduced by Latif (1970), that is derived from the Margalla Hills in the Hazara area and accepted by the Stratigraphic Committee of Pakistan. Orderly it was known as Nummulitic Formation Waagen and Wynne (1872), upper part is called Hill Limestone by Wynne (1873) and Cotter (1933), and by Middlemiss (1896) was called by Nummulitic series. The Limestone is nodular with interbedded shale or marl. Fresh color is dark grey and weathered color is grey to pale grey.

Foraminifers, Echinoids, Molluscs fossils are present in this formation. Foraminifers in the formation are recorded by Raza (1967); Cheema (1968) and Latif (1970). Early Eocene age is assigned to this formation by these studies.

Margalla Hill Limestone is consists of nodular Limestone with interbedded shale or marl in the study area. Interbedded shale or marl thickness increases in upper part and nodularity varies in diameter. Fracture and joints are present frequently with calcite veins. Fossils are abundantly present in Margalla Hill Limestone that are easily visible with naked eye.

3.4 Miocene sequence

3.4.1 Murree Formation

The formation of Miocene age named as Murree Formation which is derived from Murree Hills located in district Rawalpindi. Wynne (1874) named this group Mari group, Lydekkar (1876) named this group Murree beds and Pilgim (1910) named this group Murree Series. Stratigraphic Committee of Pakistan (Shah, 1977) formally named this formation as Murree Formation. Repetition sequence and dull lithology consists of purple grey and greenish grey sandstone with intraformational conglomerates. Gritty Sandstone are minor and medium to fine and coarse-grained sandstone are predominantly present in this formation. The most common lithologies of Murree Formation are shale and claystone.

The fossil content is poor with only few plants remains in Murree Formation, fish remain frogs, silicified wood and mammal bones have been observed and recorded there. The age of Murree Formation is indicated by fauna.

The region of Murree Formation contains tight folding because of thickness of Murree Formation is uncertain. Estimated thickness of 6000 feet measured or observed by Wadia (1928). Greenish to brownish is the weathered color of Murree Formation. It extended upto Nepal and represent the base of Mollasse sequence.

CHAPTER 4
MICROFACIES ANALYSIS

4. Introduction

Facies may be defined as the mass of a rock unit which can be identified by its composition, structures and fossil contents. It reflects back the depositional environment of rock unit. It can allow us to distinguish rock unit from adjacent one which has different origin. Different experts compile different criteria combination to explain the term facies which are given below in table 4.1

Middleton (1978)	a. Lithological characteristics b. Structural characteristics c. Organic characteristics
Flugel (2004)	a. Sedimentological characteristics b. Paleontological characteristics
Tucker & Wright (1990), Flugel (2004)	a. Fossil distribution b. Rock composition c. Depositional textures

Table 4.1. Different criteria explained by experts to explain facies.

Based on fauna, trace fossils and lithology, lateral subdivisions of the stratigraphic unit are known as ichnofacies, lithofacies, biofacies.

Genetically related facies with a having certain significance are grouped into facies associations while facies are characterized by a variation in one or more parameters in the vertical series (e.g. grain size, abundance of sand, sedimentary structures) are called a facies succession.

A special deposition system with many examples of recent sediments and ancient rocks called the facies model. A facies model must be static when interpreted under a fixed outline of processes while dynamic facies model is used or known for lateral and vertical facies distribution under different environments.

4.1 Field observations

Field observation consists of the criteria which can help in better understanding of out crop or core cutting in facies analysis. Following criteria are given below:

a) Lithology
b) Texture
c) Rock Type
d) Bedding
e) Sedimentary structures
f) Fossils & Biogenic structures.

4.1.1 Lithology

Actually, sedimentary rocks have wide varieties and combination to study or examine which are given below:

a) Siliclastic rocks (Clay/ Mudstone; Siltstone; Sandstone).
b) Conglumerate/ Breccias.
c) Carbonate rocks (Limestone; Dolomite).
d) Mixed siliclastic carbonates (Marl; Argillaceous; Sandy Limestone).
e) Evaporites (Gypsum; Anhydrite; Salts).
f) Silicious sedimentary rocks (Cherts).
g) Organic rich rocks.

Our main focus on the carbonates which make up 20% – 25% of sedimentary rocks present in geologic records and categorized as limestones and dolomites. In figure 4.1 limestones consist of greater than 50% $CaCO_3$. They comprise limestone and dolomitic limestones. Dolomite consists of more than 50% of $CaMg(CO_3)_2$ and subdivided into calcareous dolomite (50% - 90% dolomite) or dolomites. Detailed differenced examine in the laboratories. On filed location 10% diluted HCL use for the difference purpose because limestone show reaction while dolomite does not. Figure 4.1. shows different lithologies with combinations.

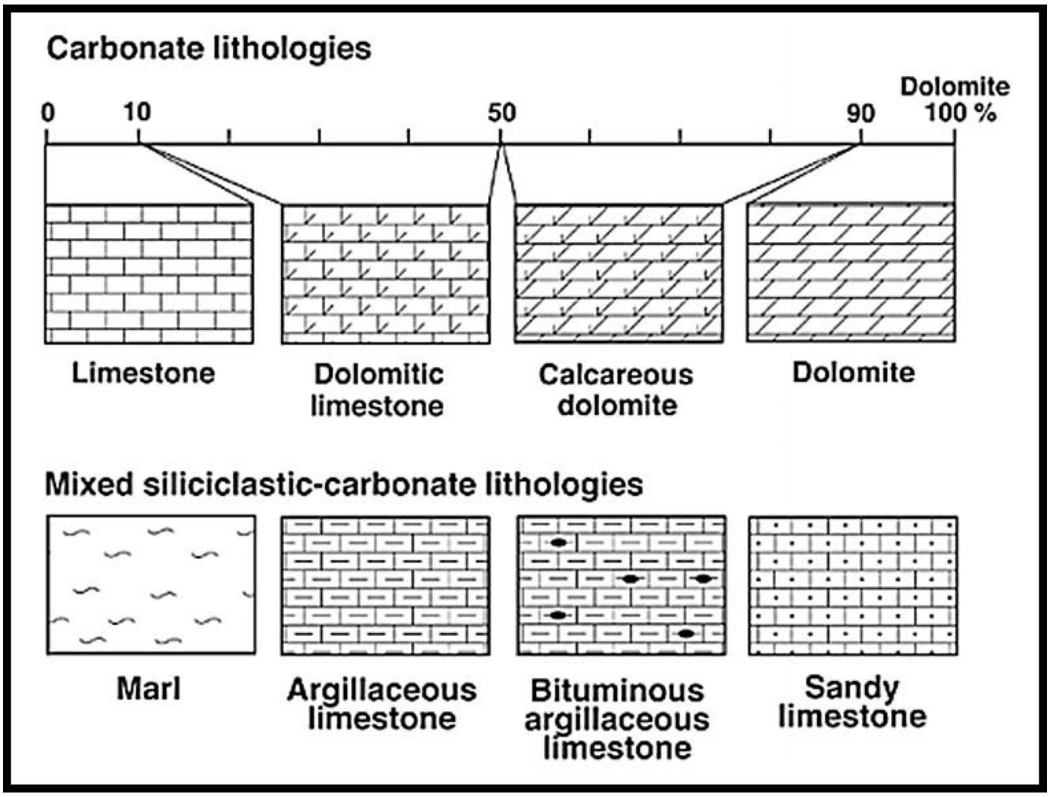

Figure 4.1. Common lithologies of carbonate rocks and mixed carbonate-siliciclastic rocks. The symbols used are those from the standard Shell Legend.

4.1.2 Textures

The limestone classified on the fields with the help of classification scheme which was purposed by Dunham in 1962. Much more information is provided by the size, shape and sorting of grains, the ratio of the matrix to grain and fabrics. The textual composition in beds and laminas can be characterized by the vertical gradation of the grain. If the order of the grains at the top is finer and lower coarser, then the sequence is in the normal sorting, while in reverse sorting coarser at the top, while finer at the bottom. Gradation is important in determining depositional processes.

4.1.3 Rock colors

In 1968 Folk explained that limestone shows distinct rock colors which require more specific terminology for explanation. In general limestone shows grey coloration scheme while dolomite shows creamy yellow tint or brown color. Verbal description like the (US National Research Council rock color chart based on the Munsell color system Goddard) use for the characterization of rock color. Rock color also examine by the comparison of fresh color from fracture with the standard colors scheme. Coloration of the carbonates highly depend upon the input of detrital material and the diagenetic processes of sediments.

4.1.4 Bedding

Carbonates are stratified and non-stratified. Non-stratified is result of

a) Lack of primary bedding (reef).
b) Bed destruction process (burrowing).
c) Diagenetic processes (Dolomitization; Recrystallization of limestone).

Field studies of bedding and stratification contains following terms

a) Boundary plains & bedding surfaces.
b) Bed thickness.
c) Composition & internal structures.
d) Vertical bed sequence.

4.1.5 Sedimentary structures & fossil contents

There are the markers of paleoenvironment, and variety come up with pre; syn; post depositional features. They are allowing us to interpret past activities. Many sedimentary structures are identical with siliclastic rock (ripple marks; crossbedding) but due to strong impact of biogenesis and diagenetic factors on carbonates. Fossils, biogenic sediments are the keys to paleoenvironments, sedimentary patterns and diagenesis.

4.2 Sampling

Sampling techniques depends upon the kind of project or research (Griffith 1967). It is most important step in field because all things depend on samples so it can be do neatly and nicely. Following are the points should remember while sample examination:

a) Depositional texture which aids in classifying rocks.
b) Types; textures; size of grains of carbonates help in finding depositional environment.
c) Paleontological aspects.

Sample size does matter because it holds all information about formation under study. Size ranges from 5x5 to 20 x 15 cm larger in size.

4.3 Microfacies analysis (Method)

For analysis of microfacies 16 samples collected from the field location of Shah Alla Ditta. Microfacies analysis done by examination of rock thin section by using Digital Camera aided by Nikon Petrographic Microscope. Rock outcrop gives lithology description while microfacies analysis based on the microscopic investigation of thin section. The size, abundance, type of foraminiferal test with invertebrates (echinoids, gastropods, mussels, brachiopods, bryozoans) provides important information for deposition environments. The petrographic classification is supported by Dunham's 1962 classification of carbonate rocks.

CHAPTER 5
MICROFACIES ANALYSIS OF THE SAMANA SUK FORMATION

5. Introduction

The word “Facies” used in association of geology for the sedimentological studies. It shows reflection of specific environment in which sedimentary processes occurred. In sedimentology, facies refer as the sum of distinct characteristics of sedimentary unit (Middleton and Hampton, 1973). Most common characteristics list contains dimensions, grain size and type, color, structure formed during & after sedimentation, biogenic content of rock unit (Boggs, 2009).

Facies which are classify on the basis of lithological characteristics know as lithofacies. It contains physical and chemical aspects of rock. Facies having biogenic content known as biofacies. An accumulation of trace fossils which indicate conditions for formative organism inhabitant known as ichnofacies (Boggs, 2009). Carbonate rocks contain microfacies which refers all aspect of paleontological & sedimentological studies with the help of thin sections, peels, polished slabs (Flugel, 2004).

Every environment of deposition have its own parameters (chemical, biological, physical) which preserves in form of carbonate rocks facies. Identification of above parameters is key of interpretation of paleoenvironment and history of deposition. Different parameters which was provided by Wilson (1975) and Flugel (2004) helps in microfacies analysis. Size and shape of carbonate grains, lithology and abundance of microfacies are main parameters for paleoenvironment interpretation.

For microfacies analysis, the scheme which was suggested by Dunham (1962) has been followed. According to Dunham’s scheme of classification limestone divided into two major groups:

1. Limestone in which components bounded together organically in time of deposition known as boundstones.
2. Limestone in which components bounded together with help of matrix and grain while organic content is absent totally.

   Further this group classified into following categories given below:

   a) Limestone which contains matrix above 90% known as lime mudstone.
   b) Limestone with mud support contain grains above 10% called wackstone.
   c) Limestone with grain support having lime mud known as pack grainstone.

Prefixes used before rock name show presence of specific content like bioclastic; wackstone; mudstone; peloidal mudstone; peloidal intracastic grainstone etc. below figure 5.1 explains classification.

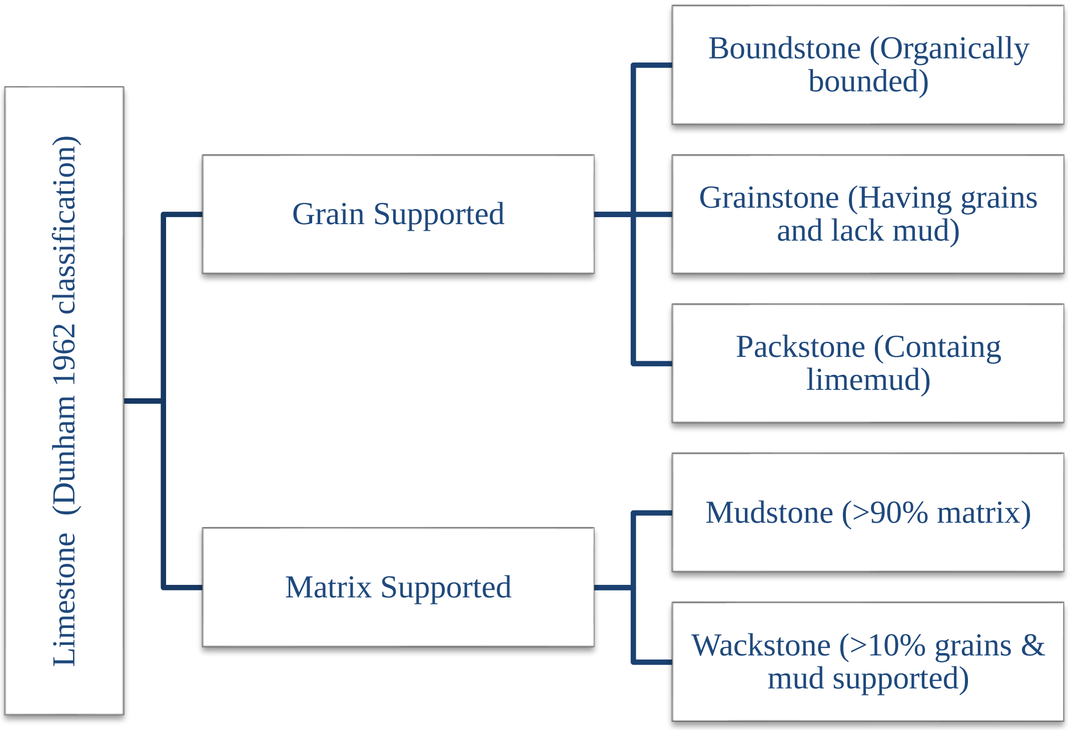

Figure 5.1. Dunham classification scheme 1962 for limestone.

5.1 Methodology

Extensive literature was reviewed to gain knowledge on different aspects of microfacies and its depositional setup. A lot of published papers from national & international journals regarding microfacies analysis studied for best understanding and gain views about interpretation.

Nikon DS-Fi2 microscope was used for studying thin sections. OLYMPUS DP 12 camera attached from microscope for obtain micrographs. Visual methodology applied for calculating ratios of different contents or allochems which is present in thin sections. By using 2x, 5x, 10x magnification power lens, 10 – 12 views took from each thin section to cover each portion of thin section. During work grain to matrix & grain to cement ratios obtained. If grain to matrix ratio is 2:98 it means 2% grains and 98% matrix. Same procedure adopted from grain to cement ratio.

In later portion of compilation extensive points explain regarding thin section study to unveil their paleoenvironments and paleontological descriptions.

5.2 Peloidal mudstone microfacies

5.2.1 Field observations

On outcrop section sample exhibited light grey color on fresh side of sample while on weathered portion brownish color was present. Bedding was medium to thick. Calcite filled veins was also observed.

Figure 5.2. Field observation of mudstone

5.2.2 Petrographic description

Thin sections SKTS–13; SKTS–14 interpretations show that they are dominant in matrix while grains are present in the form of peloids. The peloids are rounded or subrounded, spherical, ellipsoidal to irregular, micro and cryptocrystalline carbonate grains generally smaller than other carbonate particles (Tucker and Wright, 1990; Flügel, 2004). Dolomitization is observed in facies. Bioclasts show neomorphism. Hair line fractures, veins filled with calcite and quarts observed in these thin sections. Plate (5.1, 5.2, 5.3) shows different features observe during petrographic analysis.

5.2.3 Paleoenvironment

Presence of lime mud in large amount; abundance of peloids content while fauna content is missing. It shows that the depositional environment is lagoonal to tidal flat. The usual interpretation of mudstones is that they represent deposition of fine-grained sediment under low-energy conditions allowing carbonate mud to settle in calm and quiet waters (Flügel, 2004).

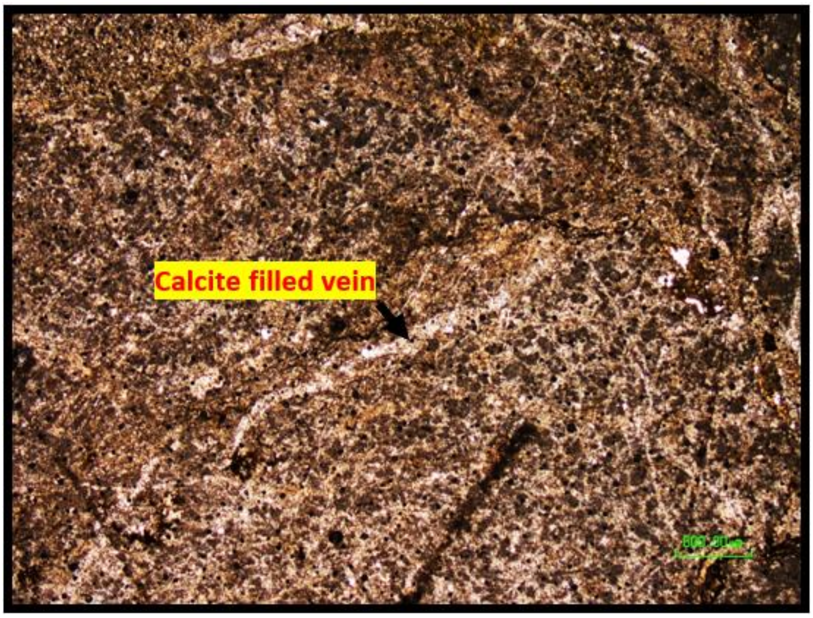

Plate 5.1 Petrographic description of Peloidal mudstone facies. Prominent features are Peloids, Calcite filled veins, bioclasts and dolomitization. Used lens magnifying power 2x.

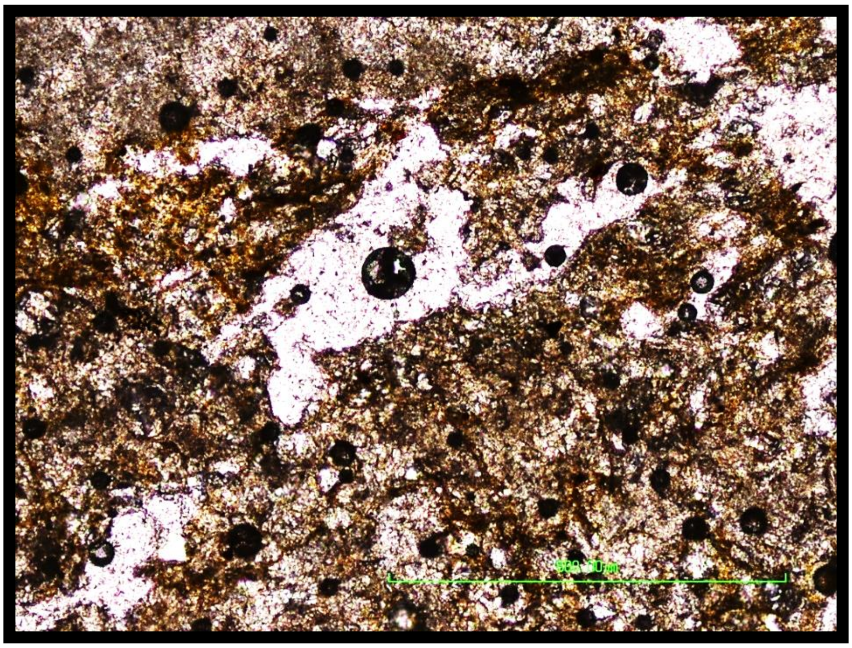

Plate 5.2 Petrographic description of Peloidal mudstone microfacies exhibit dolomite crystals and quarts in white color having pink tint. Used lens magnifying power 10x.

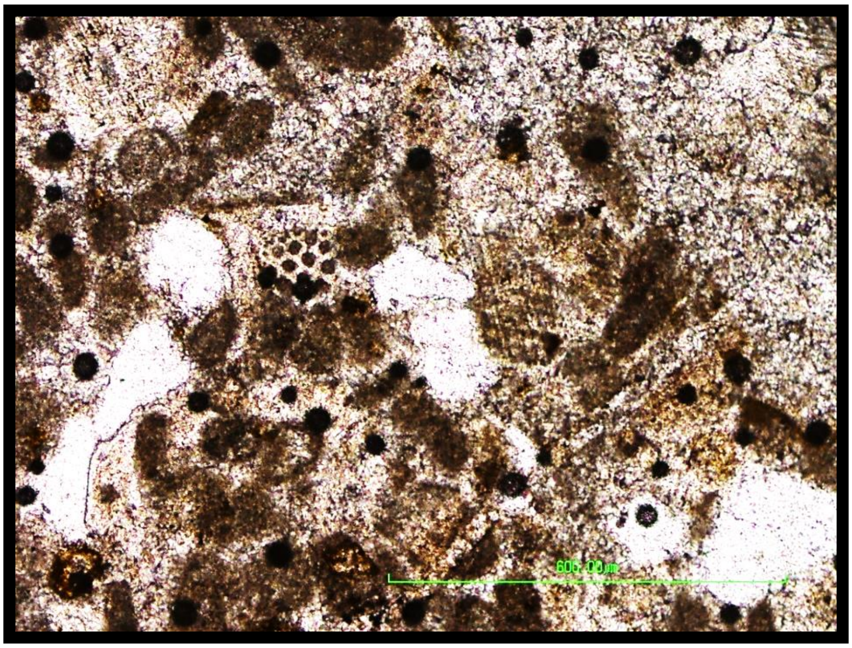

Plate 5.3 Petrographic description of Peloidal mudstone microfacies unveil quarts content & Algae.

5.3 Peloidal intra-clastic grain-stone microfacies

5.3.1 Field description

On field area these facies exhibit light to dark grey color which is fresh color while brown color show weathering. Outcrop was medium to thick bedded containing calcite filled veins. Megascopic bioclast was also observable feature.

Figure 5.3. Field observation of grain-stone

5.3.2 Petrographic description

SKTS–1 and SKTS–3 samples represent peloidal intraclastic grainstone microfacies. During petrographic studies thin sections show that peloids are in large amount; ooids are in small amount while bivalves intraclasts presents in considerable amount. Line fractures observed filled with calcite while some bioclast show micritization. Aggregates of grains observed. Selective dolomitization exist in thin sections. Plate 5.4 shows peloids, ooids & bivalve fragments while Plate 5.5 shows selective dolomitization, hair line fractures & process of micritization.

5.3.3 Paleoenvironment

Combination of considerable amount of cement; peloids dominant and intraclasts which shows high energy condition. Algal remains presence is evidence of sunny shallow marine environment. Existence of peloids with bioclasts (bivalves) give evidence of landward portion having ramp setting. Shallow-marine environments in which intra-clasts are formed are characterized by wave-dominated regimes and tides that continuously rework carbonate (Flügel, 2004). Peloids are abundant in tropical and subtropical shallow-marine environments (platforms, ramps, reefs)(Flügel, 2004).

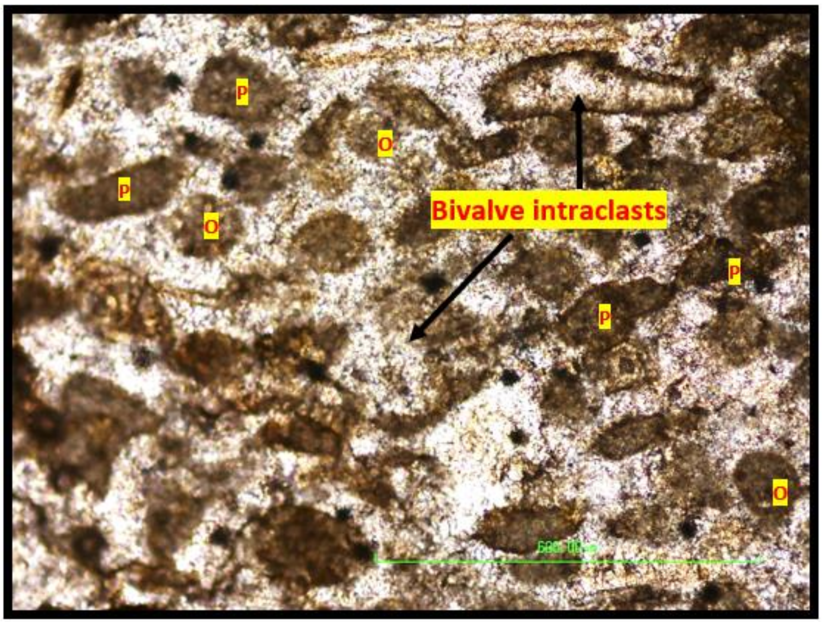

Plate 5.4 Petrographic description Peloidal intraclastic grainstone microfacies shows ooids (O); Peloids (P); Bivalves intraclasts.

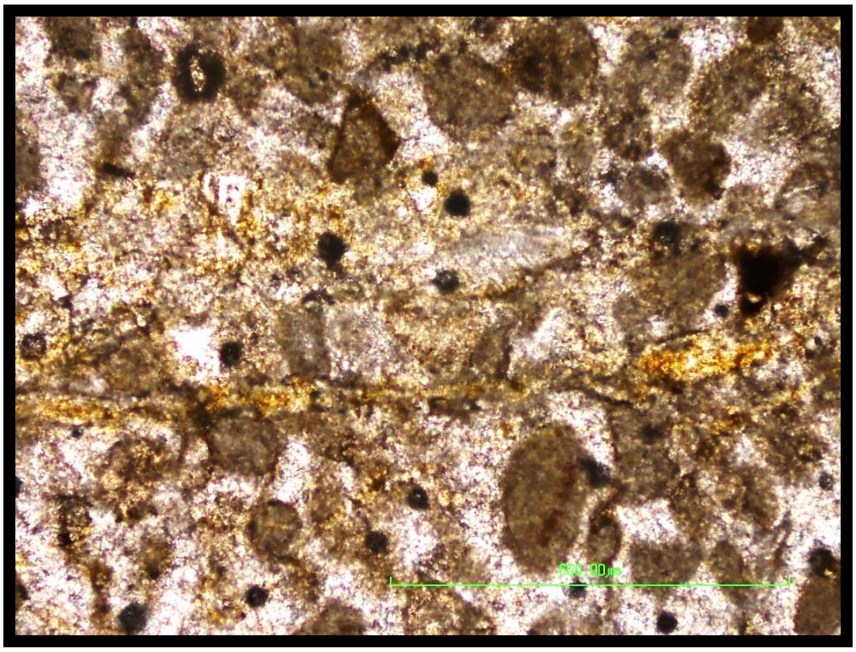

Plate 5.5 Petrographic description Peloidal intraclastic grainstone microfacies exhibit selective dolomitization; micritization & hairline fractures.

5.4 Intra-clastic bioclastic grain-stone microfacies

5.4.1 Petrographic description

SKTS–10 sample represent abundance of bivalve fragments and considerable amount of ooids and peloids. It also contains algae content. Ooids and peloids have small to medium size while algae have medium size. Bivalves intraclasts fragments observed. Calcite filled veins surely present while cement present in form of rim and prismatic cement. Intraclastic fragments widely present in this sample. Plates (5.6, 5.7, 5.8, 5.9) shows above explain features.

5.4.2 Paleoenvironment

Abundance of bivalve fragments and considerable amount of ooids and peloids. It also contains algae content. Intraclasts is evidence of high energy environment. Algal remains presence is evidence of sunny shallow marine environment. Middle ramp is present between fair-weather wave base and storm-wave base. The bottom is frequently reworked by storm waves (Burchette and Wright 1992) (Flügel, 2004). Grainstone produced in high-energy, grain-productive environments where mud cannot accumulate (Dunham, 1962). Intra-clastic bioclastic grain-stone microfacies shows depositional evidence in middle ramp depositional settings.

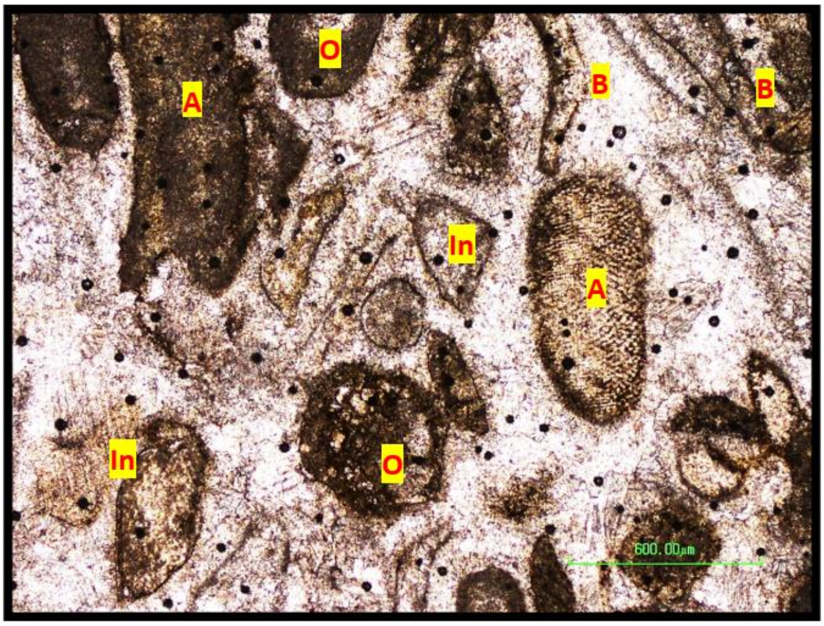

Plate 5.6. Petrographic description of intraclastic bioclastic grainstone microfacies contains Algae (A); Bivalve fragments (B); Intraclasts fragments (In); Ooids (O).

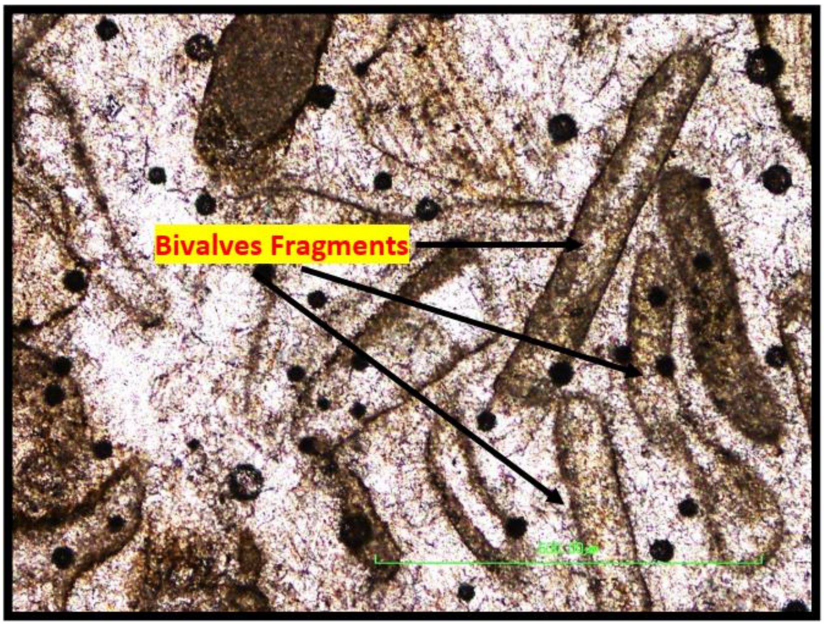

Plate 5.7. Petrographic description of intraclastic bioclastic grainstone microfacies shows bivalves intraclasts fragments.

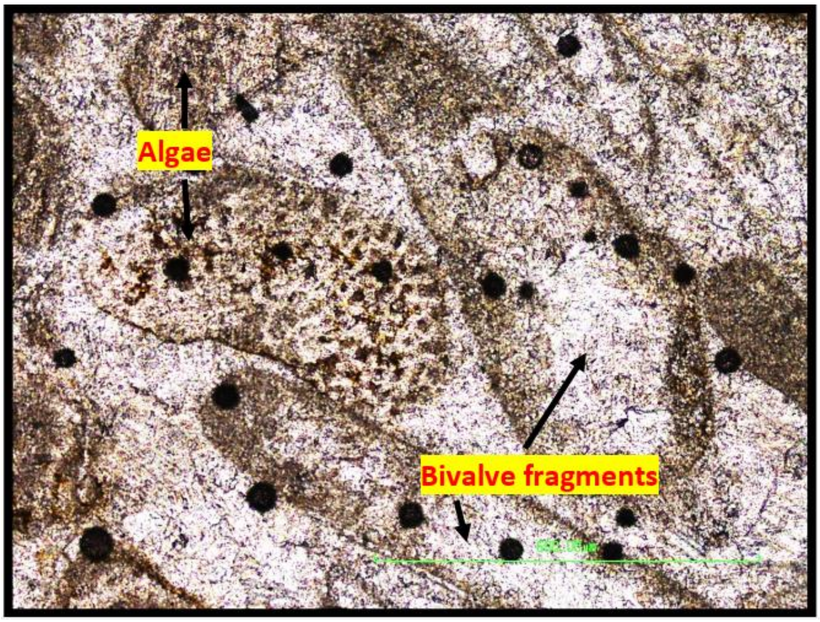

Plate 5.8. Petrographic description of intraclastic bioclastic grainstone microfacies shows algae in 10x resolution.

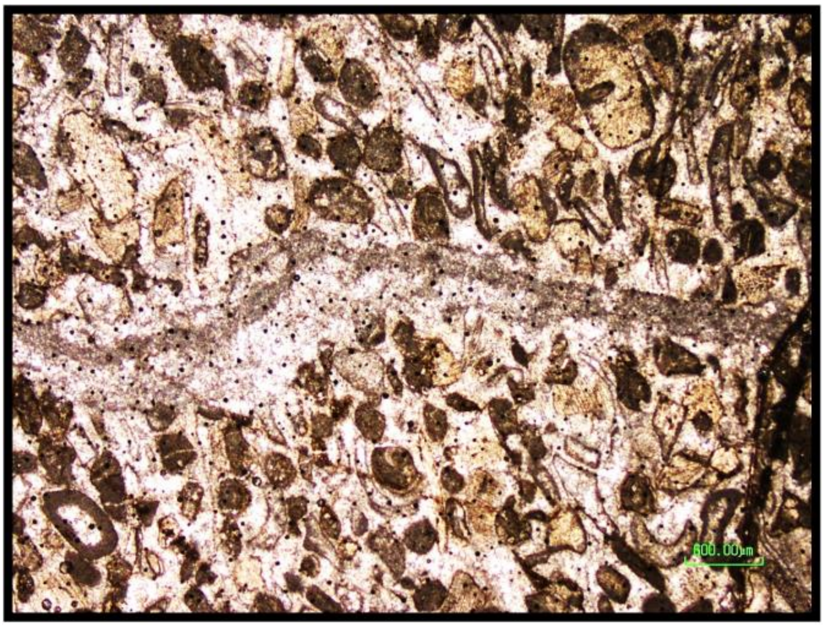

Plate 5.9. Petrographic description of intraclastic bioclastic grainstone microfacies shows Bioclastic intraclasts in 2x resolution.

5.5 Petrographic analysis results

On basis of petrographic interpretations three microfacies are recognized from Samana Suk Formation in Shah Alla Ditta section of Islamabad.

a) Peloidal mudstone microfacies
b) Peloidal intraclastic grainstone microfacies

c) Intra-clastic bioclastic grain-stone microfacies

Mudstone microfacies are deposit in tidal and lagoonal depositional settings while grainstone microfacies deposit in inner to middle ramp depositional settings. Grainstone produced in high-energy, grain-productive environments where mud cannot accumulate (Dunham, 1962). Allochemical composition which contains ooids; peloids; algae and bivalve intraclasts. They are evidence that deposition occurred in shallow water in which sunlight reach while intraclasts show high energy environments. Figure 5.2 shows depositional model of microfacies.

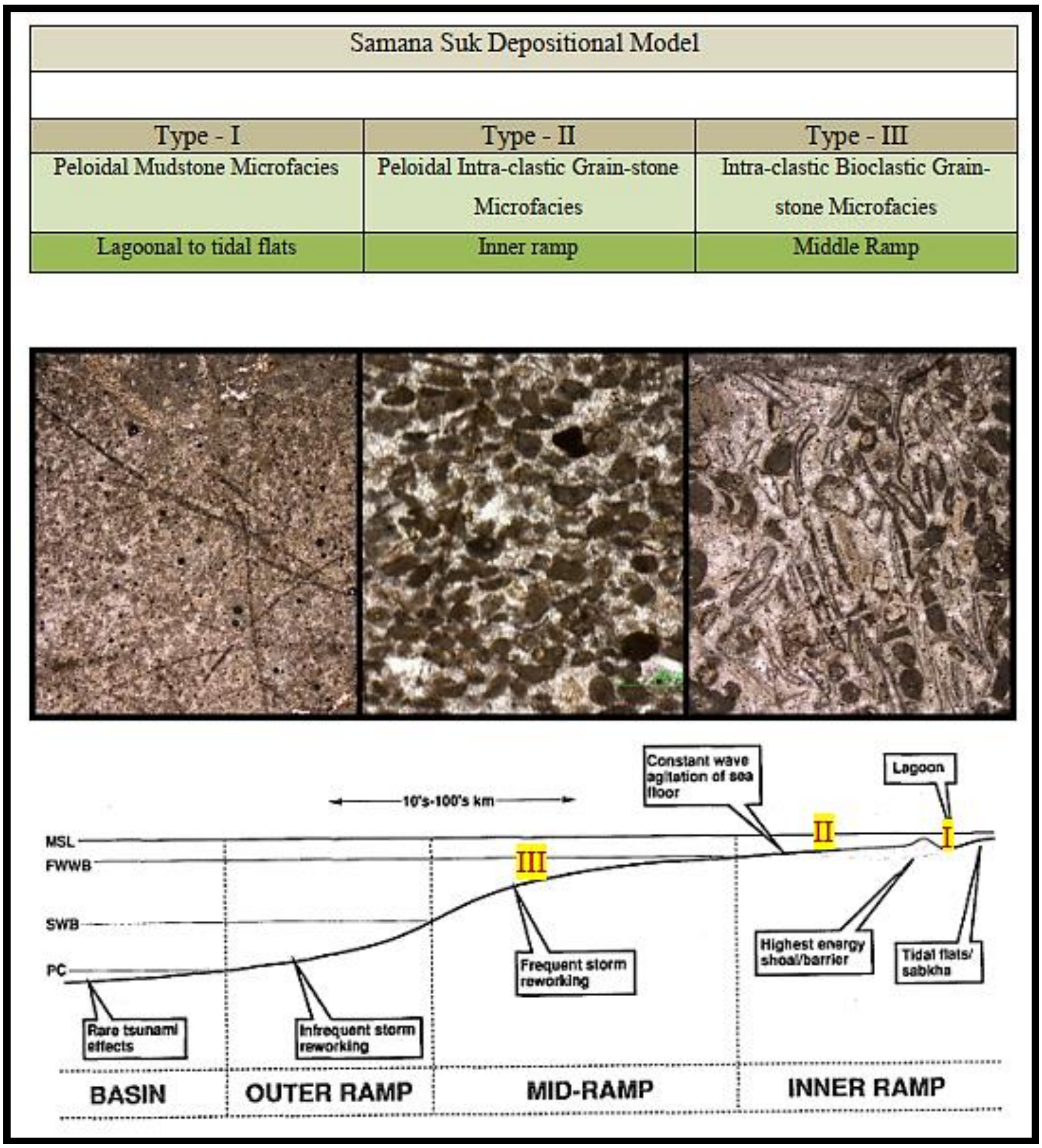

Figure 5.4. Depositional model of Samana Suk Formation, Shah Alla Ditta Section. Carbonate ramp depositional settings (Burchette and Wright, 1992). MSL (Mean Sea Level), FWWB (Fair Weather Wave Base), SWB (Strom Wave Base), PC (Pycnocline).

CHAPTER 6
DIAGENETIC PROPERTIES OF SAMANA SUK FORMATION

6. Introduction

Process of diagenesis is a combination of processes which associates with the physical, chemical & biological activities. These processes totally or partially altered the sedimentary structure of the rock unit; before the stresses of metamorphism (Tucker & Wright, 1990).

Processes which transform the sediments of Samana Suk Formation comprises of microbial micritization, dissolution & reprecipitation, cementation, physical & chemical compaction, bioclast recrystallization. Samples which was studied explain these processes.

6.1 Diagenetic processes

6.1.1 Cementation

Filling of pre-existing pore spaces or secondary origin pores with the new precipitated mineral is known as cementation. It can also be defined as the process of combining or joining fragments with the minerals either it is from precipitation or from conversion of minerals. In this research compilation, petrographic studies interpret two types of cementation one is rim cementation and other is blocky cementation. (Plate 6.1) and (Plate 6.2) shows type of cementations.

6.1.1.1 Rim cementation

The cementation around the grains in form of rims which contains equidimensional crystals. It forms cement lining in or around pores. Represents meteoric phreatic environment (Flugel, 2004). This type of cementation can be observed in intraclastic ooidal grainstone microfacies & intraclastic bivalve fragments grainstone microfacies. (Plate 6.1) intraclastic bivalve fragments grainstone microfacies show rim cementation.

6.1.1.2 Blocky cementation

Blocky cementation is the combination of medium grained to coarse grained crystals without having any orientation. Crystals in blocky cement have different sizes and shape which have identifiable boundaries (Flugel, 2004). Peloidal mudstone microfacies may have contains blocky cement content in petrographic analysis. (Plate 6.2) shows peloidal mudstone facies shows blocky cementation.

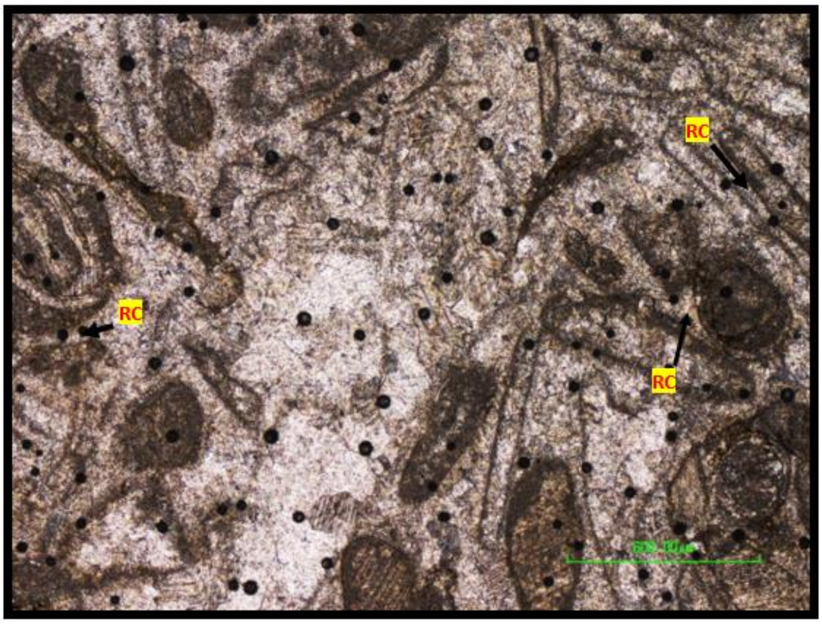

Plate 6.1 Petrographic interpretation of intraclastic bioclastic grainstone microfacies show rim cementation.

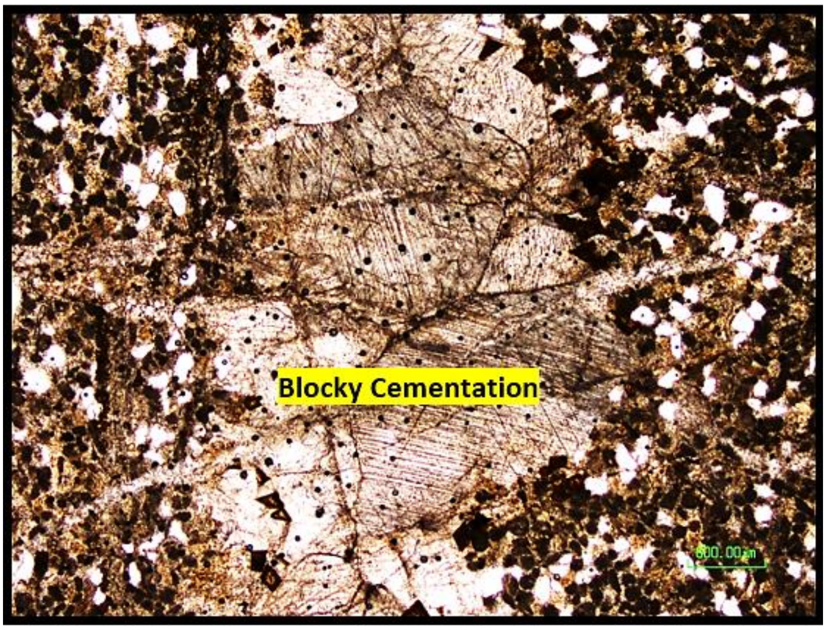

Plate 6.2 Petrographic interpretation of peloidal mudstone facies shows blocky cementation.

6.2 Dissolution

Many grains altered by the dissolution & reprecipitation in pore spaces. Dissolution occurs as a result of fluids which is undersaturated in pore spaces and leading cause of dissolution of grains and cement. It occurs right after when deposition completed. Identifiable in peloidal intraclastic grainstone, bioclastic peloidal wackstone, peloidal mudstone, peloidal packstone. (Plate 6.3) shows bivalve intraclasts grainstone microfacies exhibit dissolution (D) phenomena.

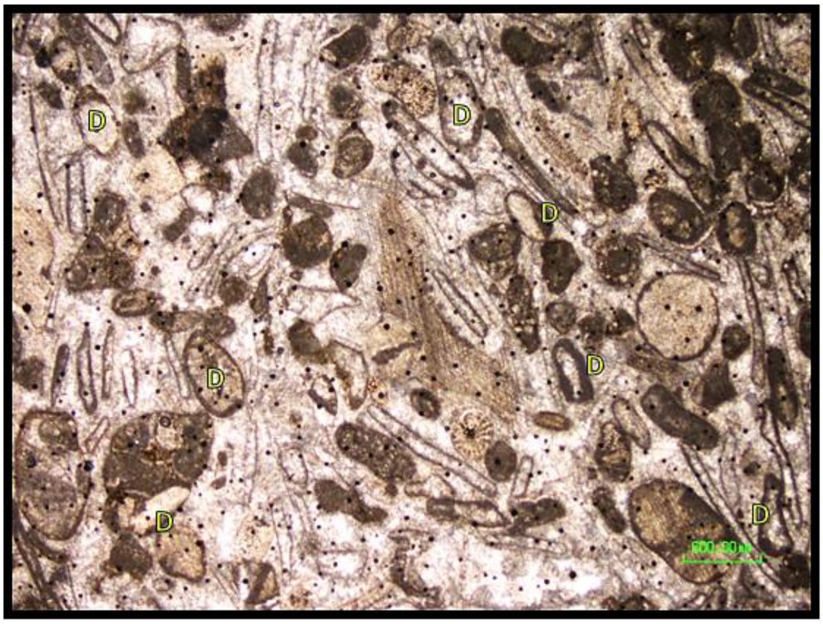

Plate 6.3 Petrographic interpretation of intraclasts bioclastic grainstone microfacies exhibit dissolution (D) phenomena.

6.3 Micritization

It occurs due to the endolithic algae which is present in shallow marine environment under the photic zone (Tucker and Wright, 1990). Micritization not too common but it can be found in peloidal intraclasts grain-stone, intraclastic ooidal grain-stone, bioclastic peloidal wackstone and bioclastic wackstone microfacies. (Plate 6.4) exhibit calcite filled fracture along micritic peloids while (Plate 6.5) shows micritic envelop around bioclasts and micritize bioclasts

6.4 Dolomitization

Rock which contain varying amount of dolomite mineral called dolomitization (Flugel, 2004). On other hand, Folk (1959) explained dolomitization in which rock contains >10% replaced dolomite. Under study formation petrographic description shows two type of dolomitization.

6.4.1 Selective dolomitization

Microfacies which cannot completely dolomitize but their constituents or small portion is dolomitized known as selective dolomitization. Original allochems texture preserved in dolomite grains. Peloidal intraclastic grainstoone, peloidal mudstone, bioclastic peloidal wackstone, peloidal packstone these facies contain selective dolomitization. (Plate 6.8) shows selective dolomitization.

6.4.2 Pervasive dolomitization

Complete microfacies convert into dolomite and it is not texture oriented. Facie which converted into dolomite has rhombohedral crystals. In petrographic interpretation of Samana Suk Formation mudstone facies is completely dolomitized. (Plate 6.6) shows pervasive dolomitization.

6.5 Calcite filled veins

Fractures are known as secondary features which is formed as the result of mechanical & tectonically induced stresses (regional level) (Tucker and Wright, 1990; Flugel, 2004). It has variety in size (hairline to several centimeters), orientation (straight to intersecting) and may be multiples in numbers. When fractures filled with calcite then it is known as calcite vein. In studied Samana Suk Formation section. A lot of calcite fractures and veins are visible in studied section. Most of them present in peloidal intraclastic grainstone, peloidal mudstone, peloidal packstone microfacies. (Plate 6.4) show calcite filled fracture while (Plate 6.6) shows calcite veins.

Plate 6.4. Petrographic interpretation exhibit calcite filled fracture along micritic peloids.

Plate 6.5. Petrographic interpretation shows micritic envelop around bioclasts and micritize bioclasts.

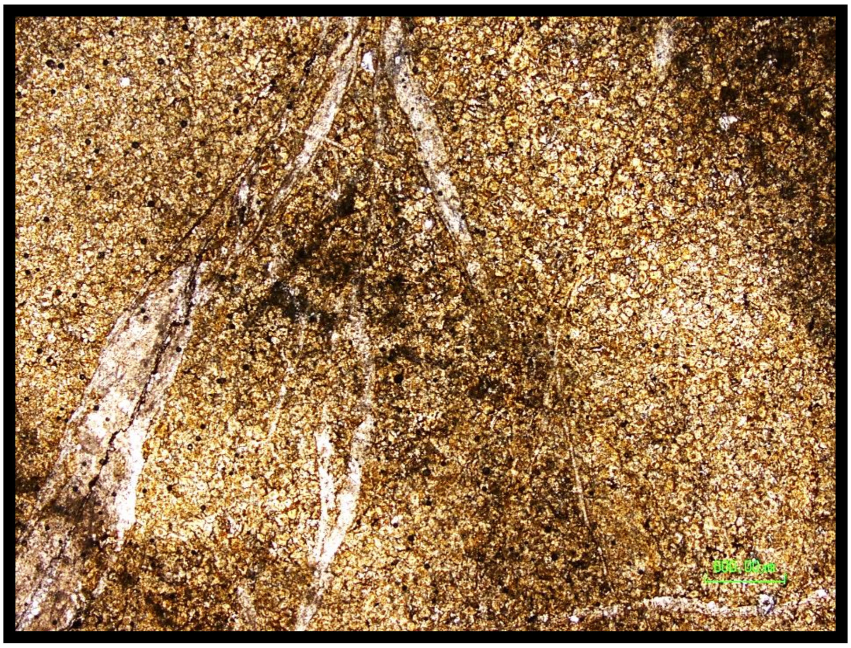

Plate 6.6. Petrographic interpretation of samples SKTS–6, SKTS–8, SKTS–11, SKTS–12, SKTS–16 shows pervasive dolomitization.

Plate 6.7. Petrographic interpretation exhibit rhombic crystals of dolomite in 10x view.

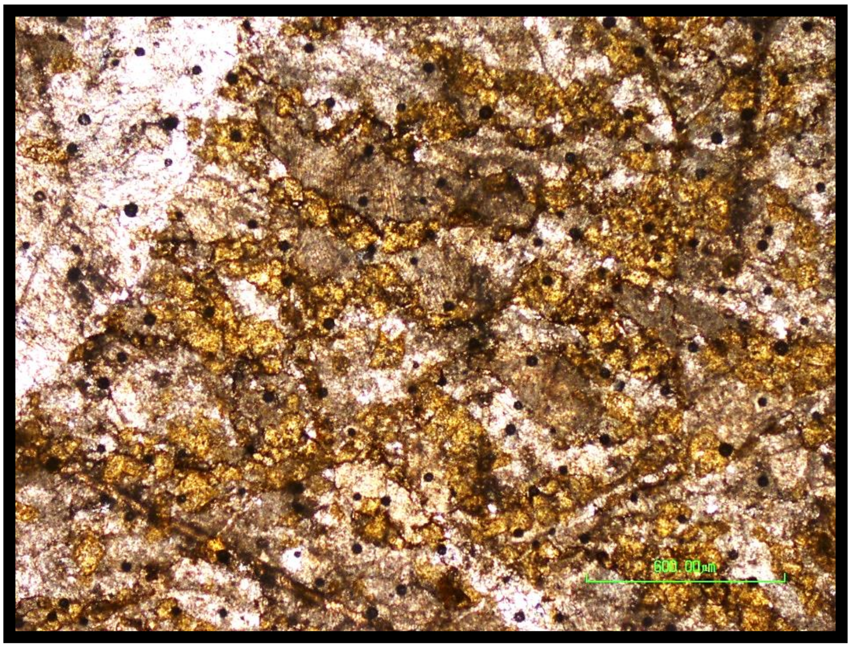

Plate 6.8. Petrographic analysis of SKTS–7, SKTS–9, SKTS–13, SKTS–15 samples shows selective dolomitization.

Samples	Lithology	Environment	Peloids	Ooids	Bioclasts	Algae	Quarts	Dolomite	Micritization	Veins / Fractures
SKTS - 16	Grainstone	High energy						Y		Y
SKTS - 15	Mudstone	Lagoonal to Tidal flats					Y		Y	
SKTS - 14	Mudstone	Lagoonal to Tidal flats	Y				Y		Y	
SKTS - 13	Mudstone	Lagoonal to Tidal flats					Y	Y		Y
SKTS - 12	Mudstone	Lagoonal to Tidal flats					Y	Y		Y
SKTS - 11	Mudstone	Lagoonal to Tidal flats					Y	Y		Y
SKTS - 10	Grainstone	High energy	Y	Y	Y	Y			Y	
SKTS - 9	Mudstone	Lagoonal to Tidal flats						Y		Y
SKTS - 8	Mudstone	Lagoonal to Tidal flats						Y		Y
SKTS - 7	Mudstone	Lagoonal to Tidal flats					Y	Y		Y
SKTS - 6	Mudstone	Lagoonal to Tidal flats						Y		Y
SKTS - 5	Mudstone	Lagoonal to Tidal flats	Y	Y	Y			Y		
SKTS - 4	Mudstone	Lagoonal to Tidal flats						Y		Y
SKTS - 3	Grainstone	High energy	Y	Y						Y
SKTS - 2	Mudstone	Lagoonal to Tidal flats	Y	Y			Y	Y	Y	Y
SKTS - 1	Grainstone	High energy	Y	Y					Y	Y

Table 6.1 Petrographic analysis summary of Samana Suk Formation (Y) shows existence of different components .

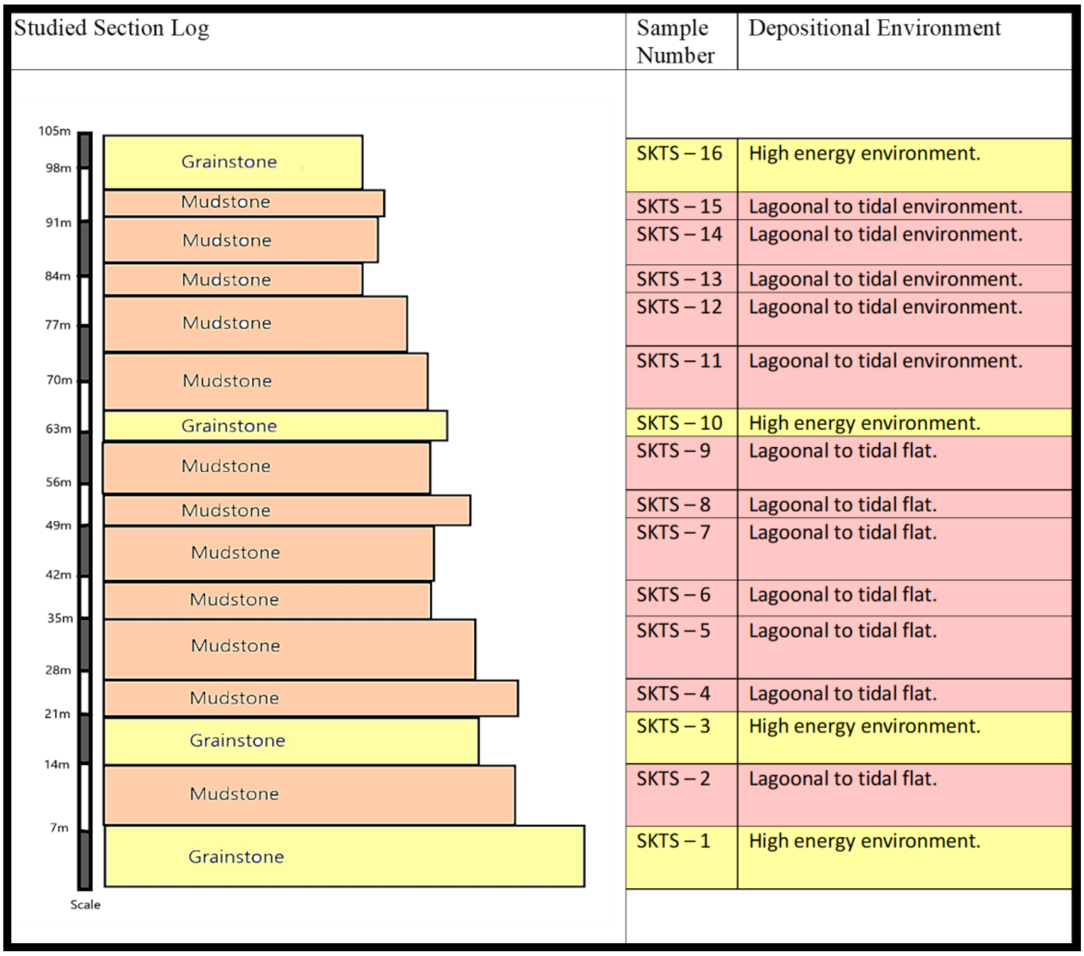

Figure 6.1. Stratigraphic log of studied section Shah Alla Ditta (Samana Suk Formation)

CONCLUSIONS

i. Petrographic interpretation of Samana Suk Formation unveils the different microfacies which are Peloidal mudstone microfacies, peloidal intra-clastic grain-stone microfacies and Intra-clastic bioclastic grain-stone microfacies.

ii. Major constituents faunal content present in Formation are peloids, bivalve fragments intraclasts while minor constituents are ooids, algal remains.

iii. Pervasive and selective dolomitization, Blocky and rim cementation, micritization, dissolution observed diagenetic features. Persuasive dolomitized microfacies contain well developed rhombic crystals. Samana Suk Formation have fractures ranges from hairline to several meter thickness which is filled with calcite.

iv. Depositional environment of microfacies is shallow marine environment, lagoonal to middle ramp settings.

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