DEPOSITIONAL SETTINGS OF SAMANA SUK FORMATION TOWNSHIP SECTION, ABBOTTABAD, PAKISTAN

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A thesis submitted to Bahria University, Islamabad in partial fulfillment of the requirement of the degree of B.S in Geology

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ABSTRACT

Understanding the Samana Suk Formation will help in understanding the Pakistani Jurassic carbonates, which is the goal of this study. The Samana Suk Formation revealed in this region is mostly made up of hard, compact, fine- to coarse-grained dolomitic limestones, with dolomite developing as a secondary diagenetic characteristic in some areas. The limestone on the outcrop appears light grey on the new surface and light brown on the aged surface. The limestone is enormous in certain areas, planar, thin through medium to thick-bedded, and fossiliferous. We have investigated and noted several features in the field, including stylolite fractures, calcite veins, calcite patches, and dolomite beds and patches. A detailed depositional model of the microfacies has been established based on the photomicrographs which shows that these microfacies are deposited on the inner part of homoclinal ramp from lagoon to carbonate shoal setting.

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Above all else, it is of most extreme hugeness to bow our head before Allah Almighty who is the Mightiest and all Gracious. He made us ready to finish this thesis work effectively. Endless greetings are upon the Holy Prophet Muhammad (S.A.W.W), the establishment of knowledge who consistently guided His Ummah to seek information or knowledge.

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CHAPTER 1

INTRODUCTION

1.1 General Description

The Hazara Basin's Jurassic Samana Suk Formation was studied for its microfacies in this research. The stratigraphy of the basin is concerned with the link between the different sedimentary formations in terms of time and location. In a single basin or across many basins, geoscientists employ bio-stratigraphic data to link distinct rock units. In addition, it aids in separating the stratigraphic pinch-outs. Facies investigation is also important since only a few numbers of facies are found often in rocks of various ages all over the globe. Rather of treating each rock bed as a distinct entity, this allows us to examine sedimentary rocks in a way that would otherwise be impossible. Facies, however, are of little use when seen as a grouping. It is more typical for researchers to employ the nano and microfossils since they are more widespread and plentiful than macro- and microfossils, which are restricted in their distribution due to their biological niches. Studying fossils also aids in figuring out where different basin fill was deposited.

The paleoclimatic conditions that influenced geology are the primary reason for picking the Jurassic rock unit. During the Jurassic period, a variety of environmental conditions impacted the formation of carbonate grains in the rock. These ooids have been preserved quite well in Jurassic carbonate units.

1.2 Study Area

There is a large section of land in the study area that extends from west of the Kohat region and south of the Dera Ismail khan to the Hazara area. Near the township sector of Abbottabad's PMA Kakul, the study area is located (N34°11'0.1292", E73°17'24.4968"). The Samana Suk formation is situated in this region.

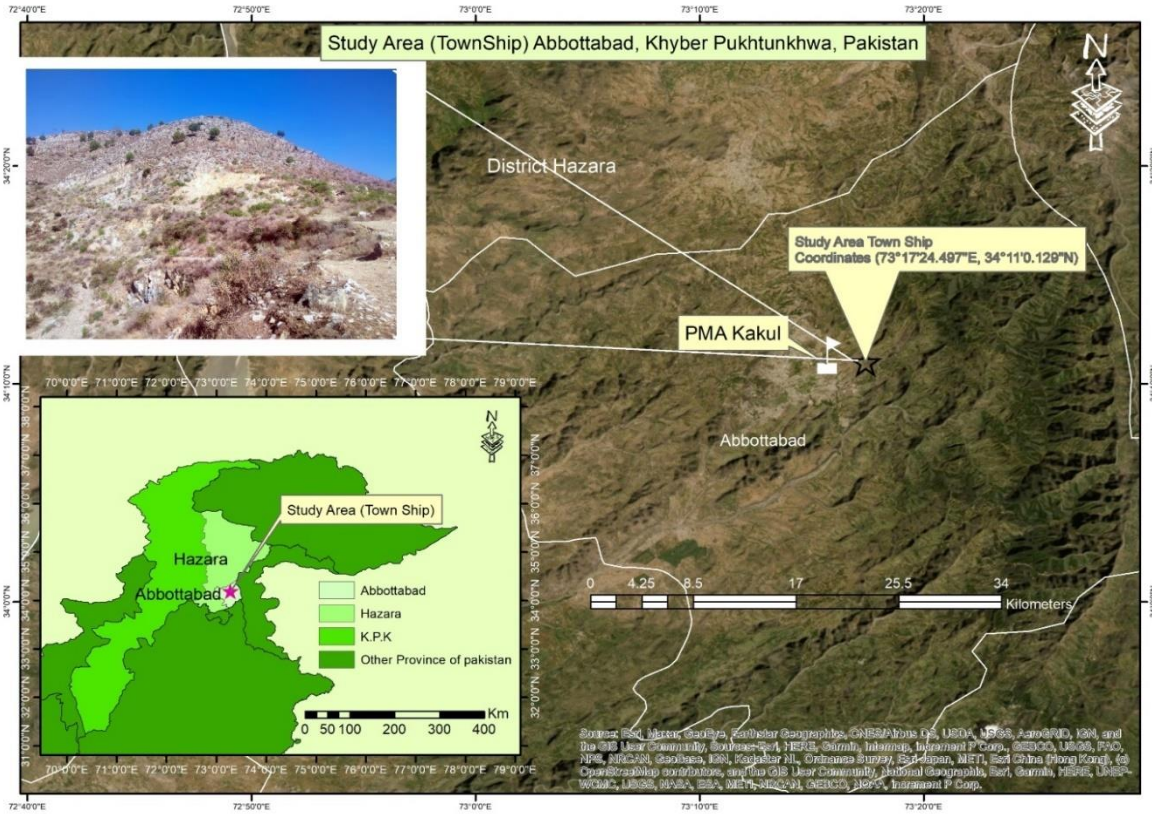


Figure 1.1. Map showing study area Samana Suk formation township section Abbottabad (ArcMap)

1.3 Objectives

This study's goals are as follows:

- Analysis of microfacies in Shah Allahditta area of Saman Suk Formation.
- To study the diagenetic changes in the Samana Suk Formation.
- To determine the conditions under which the Samana Suk Formation was deposited.

1.4 Methodology

The following paragraphs describe the methodology used to achieve the goals:

1.4.1 Field work

The research region was subjected to a geological field investigation. There were discovered Jurassic strata. The upper and lower boundaries of the Formation were visible. Samana Suk Formation total thickness has been measured. The lithological characteristics and sedimentary structures of the rock unit were investigated. The discrepancy in lithology led to the collection of a total of 12 additional samples. Field photographs were taken at various scales.

1.4.2 Laboratory Study

The thin section was prepared in the Laboratory of Hydrocarbon Development Institute of Pakistan (HDIP) created standard-sized thin sections for petrography in laboratory work. The petrographic lab of the National center of excellence in geology Peshawar (NCEGP) used a Leica DM750P polarizing microscope to identify fossils, establish microfacies, and other digenetic characteristics in thin sections. There are three metrics used to identify microfacies in the Samana Suk Formation: Wilson (1975), Dunham (1962), and Flugel (2004).

CHAPTER 2
GENERAL GEOLOGY

2.1 Tectonic setting of Pakistan

Due to continental rifting, the Indian plate was formerly a component of Gondwana during the early Jurassic period. India's Indian plate began to move toward Laurasia in the cretaceous period (at the North). This Indian plate was drifting in the Tethyan Ocean throughout the Jurassic-cretaceous and Eocene periods. Marine sedimentation may have occurred along the Indian Plate's shelf during these times. An intra-oceanic subduction event followed by the Indian plate's movement during the cretaceous period led to the development of the Kohistan Laddakh Arc (KLA). This research led KLA to divide the Tethys Ocean into two halves, the paleo- and neo-Tethys Oceans (south Tethys). The Main Karakorum Trust (MKT) was created in the late Cretaceous when the paleo-Tethys Ocean was emptied and the Ladakh arc clashed with the Eurasian plate. MMT emerged in the late Eocene when the Indian plate and second Tethys Ocean segment came into contact (Main mantle trust). Tethys Ocean served as a confined region for carbonate formation throughout the Eocene. (Kazmi and Jan 1997)

Over 2500 kilometers long, the tectonics of Pakistan, particularly in the north of the country, are well-defined geographically, extending from the west-northwest (Indus River) to the east (Brahmaputra River, Namche Barwa) convex toward the south. It's a product of the Himalayan orogeny, which began in the early Eocene, when two plates collided. Himalayan orogeny resulted in a closure of the Tethyan Ocean between the Eurasian and Indian plates due to their collision, which resulted in a subduction of India under Asia. Eurasian plates, the Kohistan Island Arc (KIA), and Indian plates may all be found in northern Pakistan. For example, the main Karakorum Thrust (MKT), which divides Eurasian and KIA plates, is the Shyoke suture zone (also known as the Indus suture). The Himalayan internal zone includes the Indian plate's foundation rocks of Precambrian age, as well as lower Paleozoic to Eocene sedimentary strata preserved in thrust slices to the south of this MMT. Between 70 and 100 Ma, when the Ceno-Tethys plate collided with the Eurasian plate, the KIA was begun, and it served as an Andean margin until the closing of the Ceno-Tethys and the Indian-Asian or Kohistan collision occurred between 65 and 50 Ma, according to Coward and colleagues (1986). Indian plates colliding with the Kohistan Island Arc created a suture, which has been dubbed the Main Mantle Thrust by earlier researchers. It corresponds to the central and eastern Himalayan region's Indus Tsangpo suture zone (ITSZ). Two collisions with the Eurasian and Indian plates have totally distorted and metamorphosed the lithology of the Kohistan Island Arc. In the Indian Plate footwall of the MMT, numerous rocks show a pre-Himalayan poly metamorphic and deformational history. Granolite facies and magnetization influenced Indian plate basement rocks (Gnessis) around 1850 Ma, reflecting the cooling age of various minerals, according to Treloar et al 2000. *(*Kazmi and Jan 1997).

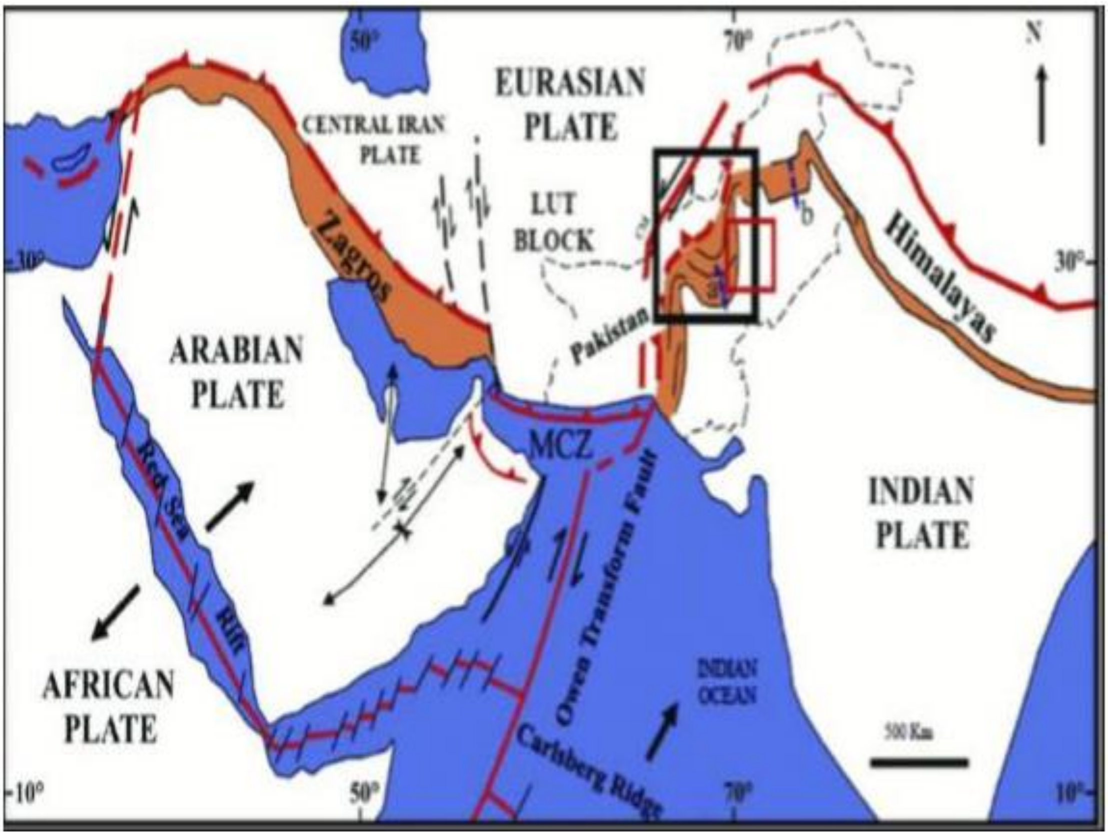


Figure.2.1. Tectonic setting of Pakistan (Jadoon, 2019)

2.2 Regional Geology

In the Carboniferous to early Permian, the supercontinent Pangaea began to split apart, resulting in the creation of a new ocean, the Neo Tethys. Across the Indian Ocean, the newly formed Indo-Pakistan continent began its journey towards the southern hemisphere's tropical regions. Neo-Tethys Ocean was squeezed in the Eocene (45-55 Ma) from the Pacific to the Mediterranean. Subduction of the Indian Oceanic Plate under the Asian Oceanic Plate in the Cretaceous era resulted in the KIA (Kohistan Island Arc). The Kohistan Island Arc was added to Eurasia in the Turonian era. At around 67 million years ago, the Indo-Pakistan Plate collided with the Kohistan Island Arc. Bio-stratigraphic analysis by Chaudhry et al. (1994b) provided further details on this finding. At 55 million years ago, the collision between India and Eurasia led to the formation of the Himalayan Orogeny.

Between the Eurasian and Indian plates, it is the world's youngest mountain range. Pakistan, which lies on the northwestern edge of the Indian plate, has preserved the Himalayan collisional orogenic imprints. The Himalayas and Tibetan Plateau rose as a result of the Indian and Eurasian plates clashing 55 million years ago. It is believed that thrusting in the Himalayas is a late-stage occurrence as a result of the adjustment of the Indian and Eurasian collision in the Neogene period. The Indian-Eurasian collision caused the Himalayas to rise dramatically and thrust faults to emerge.

In the Himalayas, a continent-continent collision has resulted in an orogenic system. It is bordered on the northwest by the Nanga Parbat syntaxes and on the northeastern side by the Namche Barwa syntaxes. Rocks and rocks and rocks make up the landscape. The divisions from north to south are the Trans-Himalayan batholiths, the Indus-Tsangpo Suture Zone, the Tethyan (Tibetan Himalaya), the Greater (Greater) Himalaya, the Lesser (Lower) Himalaya, and the Sub-Himalayan Himalaya. The lesser Himalayas are located south of the Greater Himalayas. The lower Himalayas are typically between 32 and 80 kilometers wide and between 3900 and 4500 meters high. Most of the lower Himalayas are composed of detrital sediments from the Indian edge of the late Proterozoic to early Cambrian era, with some granites and acid volcanics of the Early Proterozoic era intermingled. These strata are sometimes referred to as tectonic windows due to their forced movement along the Main Boundary Thrust.

The sub-Himalayas are bordered to the south by the foothills of the Himalayas, sometimes referred to as the lesser Himalayas. The sub-Himalayas have a width of 8 to 80 km with an average elevation of 900 m. Most of the sediments are composed of the Murree and Siwalik Formations, also referred to as the Eocene and Miocene molasse deposits. These layers are rich in fossilized vertebrate remains. Since the Eocene era, a series of thrusts in the Himalayas have been enlarging at a pace of 5 cm per year, resulting in 2500 km of crustal shortening. The collision in the Early Eocene appears to have caused a string of thrust faults stretching southward from the Indus-Tsangpo Suture Zone (ITSZ). The Main Karakoram Thrust (MKT), the most northern suture zone developed during the Cretaceous era, was caused by the collision between the Kohistan-Ladakh arc and the Karakoram block. Later, it was given the name North Suture. This thrust separates the Kohistan Island Arc from the rock units of the Karakorum Block. This zone is composed of red shale, slate, limestone, and volcanic greenstones. The Main Mantle Push, a local push that dips northward, separates the Kohistan Island Arc from the Indian plate. The Kohistan Island Arc was created because of the Indian plate subducting beneath it during the Eocene. On the western side, it stretches from the Khar area (Bajaur Agency) in the west to Naran in the east. Most of MMT's composition is made up of gneisses and Proterozoic schists. The Greater and Lesser Himalayas are separated by the Main Central Thrust, an intracontinental thrust fault that dips northward along the Himalayan Mountain range. It was initially illustrated by Heim and Gansser (1939).

The Main Boundary Thrust is unique among the Himalayan Belt's tectonic features. Metasedimentary rocks of the lower Himalayas have been forced on top of unmetamorphosed rocks of the Himalayan foredeep by a northward-dipping thrust. This syntaxis is known as the Hazara-Kashmir Syntaxis because the MBT drift east-west through the foreland basin and then travel north-west up to the Jhelum River. The Main Boundary Thrust (MBT) is projected to move about 40 kilometers, and a decrease is predicted along blind thrusts followed by shallow back thrusting (0–3 kilometers deep). Located at the southernmost point of the Salt Range, the Salt Range Thrust encircles the southern border of the range and bisects the Jhelum and Indus rivers. The Paleozoic/Precambrian strata of the Punjab platform have been pushed over the Quaternary/Neogene alluvium. Although much of this thrust is obscured by alluvium, the Paleozoic rocks that lie under the Neogene deposits of the Jhelum plain may be seen when it is exposed. At Kalabagh fault, it comes to an end in the west, whereas at Jhelum River's right bank, it disappears.

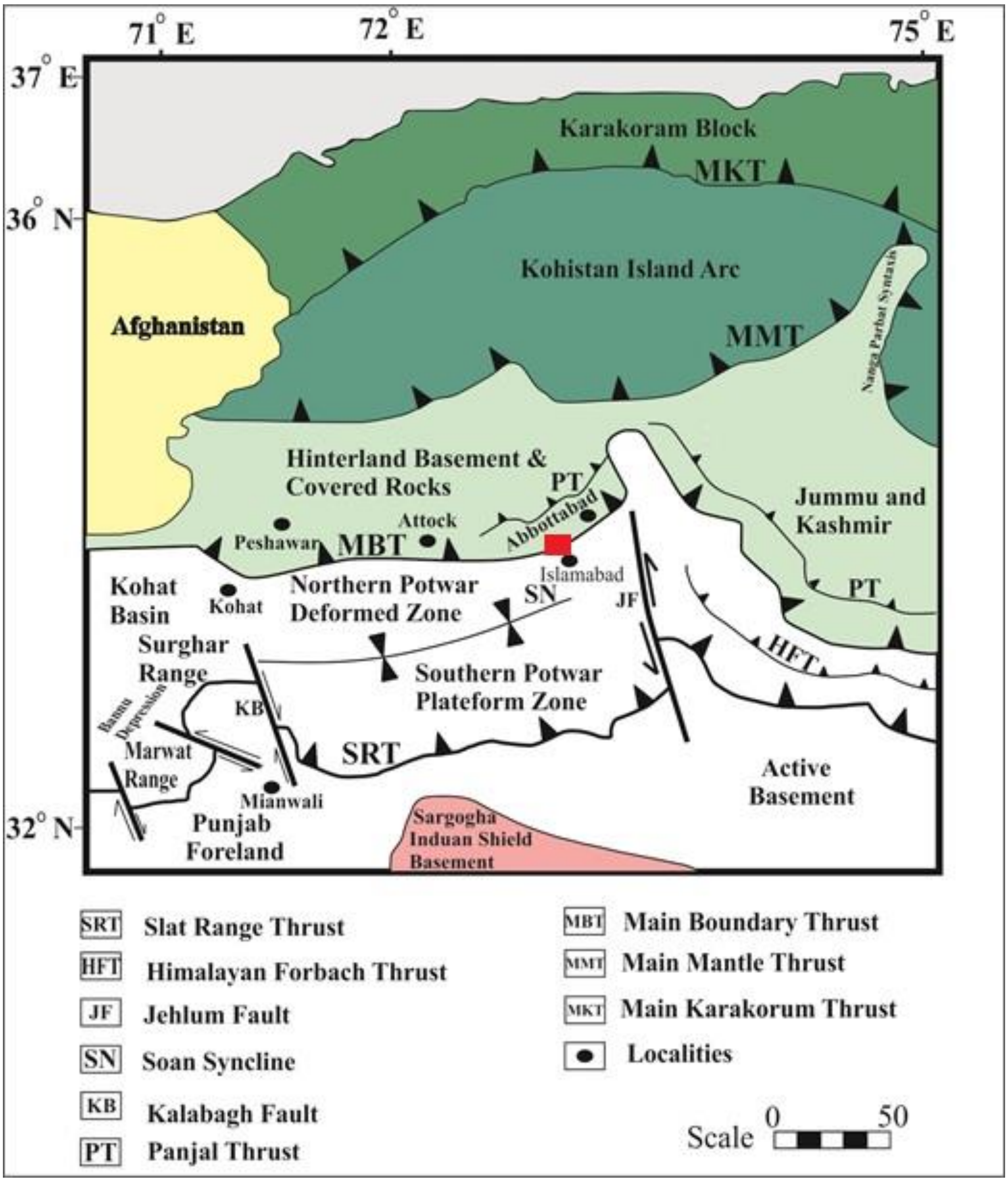


Figure 2.2 Tectonic map of northwest Himalayas of Pakistan, while the red square is showing the study area (after Kazmi and Rana, 1982).

2.3 Local Geology

The Hazara area, which lies on the NE-SW trending Lesser Himalayan terrane and forms the western limb of the Hazara-Kashmir Syntaxis, is situated on the Indo-Pakistani border. The Hazara area is defined by two significant thrust faults, the Panjal Thrust and the Main Boundary Thrust (MBT), as well as several lesser thrust faults that have a similar NE-SW trend (or "Hazara Arc").

The Hazara Fold and Thrust Belt contains the Main Boundary Thrust (MBT) in the south and the Panjal Thrust in the north (HFTB). Metamorphic, meta-sedimentary, and sedimentary rocks from the Precambrian to the Miocene have been encountered in the Hazara Basin. The structural characteristics of the Hazara Basin, which include many thrusts, folds of varying sizes, and a general north-east-south-west trend, clearly show compressional pressures from the northeast. The Pre-Cambrian Hazara Formation is the oldest geological formation in the area.

Sedimentary, igneous, and metamorphic rocks as well as unconsolidated material are found in the Hazara district's geological formations. More than a dozen stratigraphic units in the Hazara region have been linked to those in the Kala Chitta Hills, which are located 40 miles south of Abbottabad in the Kohat region, thanks to the work of A. N. Fatmi of Pakistan's Geological Survey and C. E. Meissner from the USGS among others. Some of the formations here are like those at Simla, India, some 300 kilometers to the southeast, as well as in the Kashmir region of Pakistan.

However, the clastic rock units of the Paleozoic period (Salkhala and Hazara Formations) and the Precambrian and potentially early Paleozoic eras (Tanawal Formation) are mostly carbonate. A largely complete succession of rock strata reaching 5,500 feet in thickness shows a protracted period of primarily carbonate deposition from the Carboniferous to the Eocene. Late in the middle and late Tertiary, the Himalayan orogeny began, resulting in the deformation of all rocks in the area.

There is a 180-degree bend in the geological features and mountain ranges in eastern half of this report's coverage region. "Hazara-Kashmir syntaxis" refers to the characteristic initially examined by Wadia (1931), who termed it the "Syntaxis of the Northwest Himalaya." The primary rock formations and faults then make a large arc westward toward the Indus River after going around this circle. Because of the Murree Formation (Oligocene to Miocene), the syntax's evolution continued until the post-

Miocene period. The Tertiary Himalayan orogeny seems to have undergone two distinct episodes of deformation.

Only the volcanic greenstone and "Agglomeratic Slates" of the Panjal Formation of Carboniferous to Permian age provide evidence of pre-Tertiary igneous activity. The Mansehra Granite was formed during the Late Cretaceous and early Tertiary periods of igneous activity and is the consequence of synorogenic intrusions. The vast granite intrusions in the Himalayan axial zone are assumed to have originated at the southern margins of these granite rocks. Mafic dikes and quartz veins are two examples of post-orogenic intrusive rocks. The latter are assumed to be linked to a period of mild hydrothermal activity that created soapstone and barite veins.

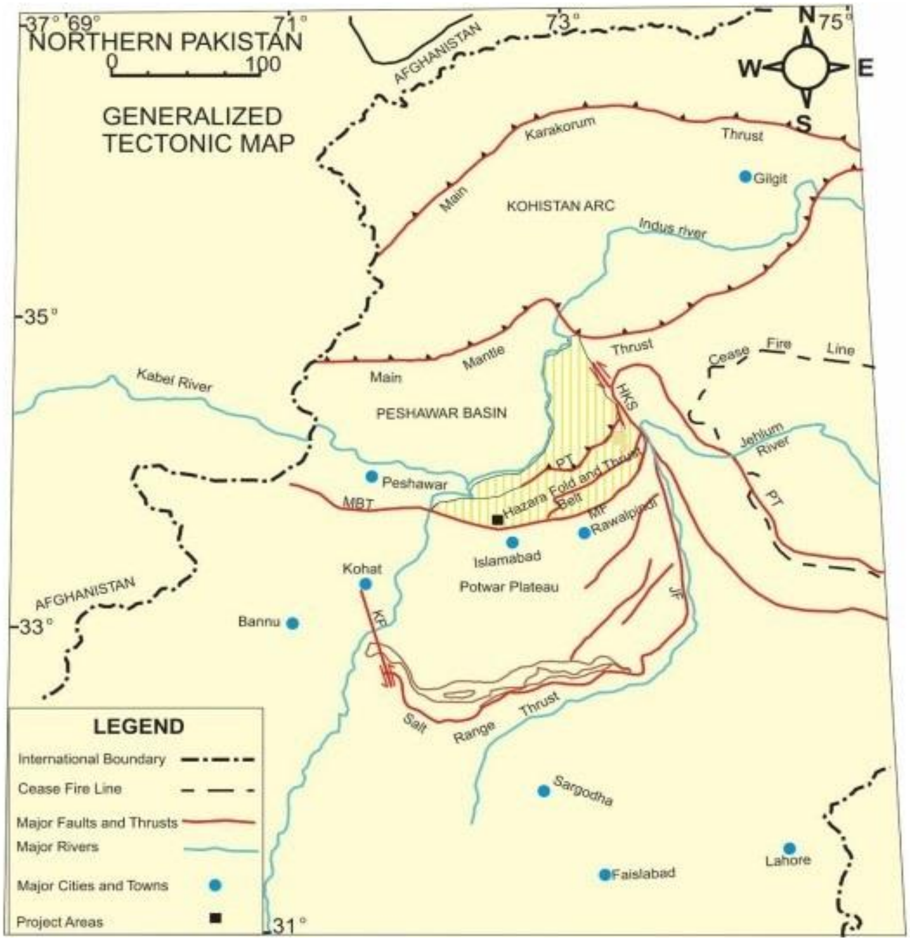


Figure 2.3. A generalized tectonic map showing major faults and tectonic regions along with the representation of project (Pakistan Journal of Geology (PJG), 2019, VOLUME 3, ISSUE 2)

2.4 Stratigraphy of study area

2.4.1 Samana Suk Formation

Samana Suk was proposed by Davis 1930 as the name for the Samana range. Salt Range and the Trans-Indus Range are referred to as 'broach limestone' by Gee 1945. It was dubbed "Upper section of Kioto Limestone" by Cotter in 1933 when it was discovered in the Kala Chitta Range. Known as "Kioto Limestone" by Middlemiss, Calkins & Matin 1968 dubbed it "Daulatmar Limestone," and Latif 1970 referred to it as "Sikhar Limestone" in SE Hazara by Latif. Type locality was not specified by Davis. Samana Suk (330 33' 50" N & 700 50' 13" E) is a mountain summit in the Samana Range. Fatmi 1968 defined a type of section in the western portion of the Samana Range northeast of Shinawari (lat. 330 31' 13' N and long. 700 48' 06' E).

There is a mixture of limestone, marl and shale in the lithology. There are intercalations of calcium-rich shale in the limestone at the type of site, which is grey to dark grey and moderately to thickly bedded. It is lighter in color, medium to thin bedded, and marly and shaly in the bottom half of the Salt Range and Trans Indus Ranges of limestone. Some dolomitic and ferruginous, sandy, oolitic deposits may be found in Hazara, Kala Chitta, and eastern Kohat. At Surghar Range, Hazara, Kohat, and Kala Chitta Range, the lower contact is conformable with the Shinawari Formation (Transitional) but not with the Datta Formation at Salt Range. In Surghar Range, the Upper Contact may be conformed to the Chichali Formation, however in Salt Range, it can be disconformed to the Hangu Formation. (Shah et al., 1977 and 1980)

The salt ranges, the Trans-Indus mountains, Kohat, Kalla Chitta, and Hazara all include the formation. This typical location is 186 meters thick. The thickness ranges from 190 meters (Chak Dalla portion) to 366 meters (Eastern Kohat, Nizampur, Kalla Chitta, and Hazara) eastward in Eastern Kohat, Nizampur, Kalla Chitta, and Hazara (Bagnoter section). In the eastern Surghur Range (66.5 m in the Chichali Pass region) and western Salt Range, it is missing, whereas in the eastern Salt Range, it is present but thin. It is 129 to 136 m thick in Broach Nala in the Surghur range, and 242 m thick in the Sheikh Budin Hills.

A middle Callovian fauna has been found in the Surghur Range's highest strata. Ammonoids and crinoids make up the rest of the fauna. Somalirhynchia nobelis is common among brachiopods. Homoya sp, Pecten sp, Arctostrea sp, and Tellurimya tellaries are among the bivalves found in the ocean. Belemnopsis grantana has been found in the top section of a formation in the Samana Ranges. Protocardia grandidieris, Eomiodon indicus, and Corbula Lyrata have been found in the topmost layers of Kalla Chitta (Jhallar and Chak Dalla region). In the northern Hazara region, there have been reports of gastropods (Cossmania species) (Calkins and Marin 1968). From various parts of Hazara, Latif (1970a) documented the following other fauna, as well: Protcardio sp., Stylina sp., Corbula S.P., Gervillia S.P. and Lima S.P. are some of the other species that make up the Stylina sp. taxonomic group. The fauna found here suggests that the region was mostly formed during the Middle Jurassic. Upper Battonian in Kalla Chitta is somewhat older than middle Callovian in the Salt Region and Trans-Indus range, and potentially younger in Hazara than middle Callovian. (Shah et al., 1977 and 1980).

In July 1987, the "Hydrocarbon News" in a Quarterly House Journal of the Hydrocarbon Development Institute of Pakistan said that "First Dinosaur Footprints Found in Pakistan" had been discovered in the Samana Suk Formation. In this area, the fine-grained Samana Suk Limestone is characterized by a mixture of clay and sand. It was found at an area of the shore that was just a few feet deep. The Saman Suk Formation dates from the Middle Jurassic, around 160-170 million years ago. The Sauischanian and Omithischian dinosaurs that formerly roamed this region are most likely to have lived here. The Takatu Limestone and Mazar Drik Member of the Takatu Formation of the Lower Indus Basin and Axial Belt are associated with this formation. Generalized stratigraphic column of Hazara area is shown in Fig 2.4.

Table 1 Generalized stratigraphic column of Hazara area (not to scale), Khyber Pakhtunkhwa, Pakistan (after Latif, 1970a).

AGE	FORMATIONS		LITHOLOGY	ENVIRONMENT
	STRATIGRAPHIC NOMENCLATURE AFTER LATIF (1970)	STRATIGRAPHIC NOMENCLATURE AFTER SHAH (1977)		
Mid-late Miocene	Kamlial formation	Kamlial formation	Massive red and brown sandstone, dark red clay	Fluvial environment
Early Miocene	Murree formation	Murree formation	Gray and reddish sandstone and shales	Fluvial environment
××××××××unconformity××××××××				
Eocene	Kuldana formation Lora formation Margala hill formation	Kuldana formation Chorgali formation Margala hill formation	Maroon colored shales and marl Thinly bedded limestone and marl Nodular foraminifera grey limestone	Transitional marine Inner shelf Carbonates shelf/reef
Paleocene	Kuza Gali shale Mari limestone Not mention	Patala formation Lockhart formation Hangu formation	Greenish grey shales with limestone Nodular foraminifera grey limestone Sandstone, claystone, laterite	Pelagic/hemi-pelagic shelf Carbonates platform Shallow marine-deltaic
××××××××unconformity××××××××				
Cretaceous	Chenali limestone Giumal sandstone group Spitti shale	Kawagarh formation Lumshiwal formation Chichali formation	Fine grained light grey limestone Grey to brownish coarse sandstone Dark grey shales with sandstone beds	Inner-outer ramp Inner-shelf-deltaic Mid-outer shelf
Jurassic	Sakhar limestone Maira limestone group Not reported	Samana Suk formation Shinawari formation Datta formation	Limestone with dolomite patches and oolites Sandstone, quartzite and micro conglomerates	Epi-continental and inter tidal Carbonates shelf Shallow marine, deltaic and alluvial plains
××××××××unconformity××××××××				
Cambrian	Hazira formation Galdanian formation Sirban formation Kakul formation	Hazira formation Abbottabad formation	Calcareous siltstone and slates Dolomites with sandstones, shale in lower part	Pelagic/hemi-pelagic shelf sub-tidal and fluvial
××××××××unconformity××××××××				
Pre-Cambrian	Tanol formation Hazara formation	Tanawal formation Hazara formation	Quartzite and quartz mica schists Slates, pelits sandstone and quartzite with horizon of gypsum and two limestone beds	Inner-outer shelf Deep marine

CHAPTER 3

METHODOLOGY

An area in the Hazara region was measured and sampled using normal procedures (township section Abbottabad). Surveyors took measurements and collected samples in township section Abbottabad Samana Suk (Type Section of the Samna Suk Formation). One meter sampling interval was used to gather 40 typical outcrop samples from the above-mentioned location, although closer spacing was also used when it was judged required. Each sample in the Samana Suk range is assigned a unique digit number. In the Samana Suk Section, samples numbers contain just one component: Second and third samples are designated as "A," "B," etc. when more than one sample is obtained from the same site.

Using samples from the Samana Range, the thin section laboratory at Pakistan's Hydrocarbon Development Institute cut polished slabs and thin sections from them' (4.5 cm, x 2.5 cm). Potassium ferricyanide and Alizarin Red S were used to identify dolomite, ferroan, and nonferroan calcite in thin slices as described by Dickson (1966).

The University of Peshawar's Institute of Earth Sciences conducted XRD analysis on three samples. From 22o to 32o 2, the samples were scanned. The carbonate bomb was used in conjunction with the Müller Technique to quantify the total carbonate content (TCC) of each sample.

A low-power binocular microscope was used to examine polished slabs. A petrographic microscope was used to examine thin sections (Laborlux Leitz). Visual charts were used to determine the proportion of each component, and the total grains were taken as 100%. Samples were tested for average and maximum grain size.

Following Flagel's methodology, the samples were categorised into distinct micro facies (1982, and 2004). Following Folk (1962), Flagel (1982), Dunham (1962), and Embry and Klovan (2000), the rock type and depositional settings have been categorised based on the texture and character of the organic remains (1972)

3.1 Sampling

The work for the thesis involves a combination of field and lab work. In the beginning of the field visit, sampling is regarded as a critical step. Before travelling into the field, a table study is done in which many aspects of the field, such as accessibility, location, lithology, fossils, and other characteristics, are reviewed.

3.2 Fieldwork

An intensive field investigation was conducted in the study region to identify the various formations that were exposed. Fieldwork was conducted in the township area of Abbottabad's Samana Suk formation in order to gather samples and investigate the many aspects that were revealed.

3.3 Laboratory Work

Before being cut into rectangular slabs using a tiny diamond saw, the field samples were trimmed with a big diamond saw. The rectangular slabs were marked on one side and then impregnated with epoxy on the opposite. Thin portions of the produced rocks were studied under a petrographic microscope to show their numerous allochemical components. With the help of these elements, we were able to create microfacies. The thin slices were examined in order to learn about the diverse diagenetic characteristics. Digital photomicrographs of well-preserved grains and other characteristics were taken using a microscope-mounted digital camera and a computer system.

3.4 Thin section study using polarizing microscope

The limestone was categorized using Dunham (1962) and Folk (1962) classification systems based on petrographic data such as percentages of allochems, matrix, and cements (1959). In order to identify the sub-environments of deposition, the allochems type had to be further determined. Following a photographic examination, microphotographs of the microfacies were obtained. Lab work was done in an orderly manner so that it could be properly interpreted. The varied allochemical components of the rocks were discovered by studying the produced thin slices under a petrographic microscope. With the help of these elements, we were able to create microfacies. The thin slices were examined in order to learn about the diverse diagenetic characteristics. A digital camera linked to a microscope and a computer system were used to take digital photomicrographs of well-preserved grains and structures like stylolite.

CHAPTER 4

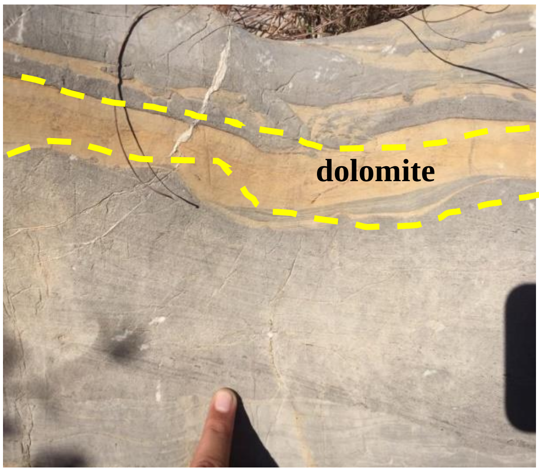
FIELD OBSERVATION

The Samana Suk Formation in Township section is 190 meters (m) thick, and it has greyish limestone interbedded with greyish brown dolomite having a sharp contact (Fig. 4.1 a-b). Fieldwork was carried out to observe field features, diagenetic alteration and to collect samples for further analysis. The sampling was done when a specific diagenetic feature was observed. Bioclasts were seen in mudstone and packstone facies. Highly fossiliferous thick bedded greyish limestone, brown dolomite and bioclastic grainstone is observed in the basal region of Samana Suk Formation in the Town ship section. Bioclastic limestone has a contact with brown dolomite (Fig 4.2. a-b). The bioclastic grainstone is bed is repeated at several intervals (Fig. 4.2 c-d). The major lithofacies is bioclastic grainstone unit in Township section (Fig. 4.3 a). These lithofacies are repeated at several intervals. Highly fossiliferous thick bedded grainstone, bioclastic packstone, intra-clastic and extra-clastic limestone, brown dolomite, massive parallel beds of limestone having dolomites patches are observed in the middle are of the section. Elephant skin weathering, veins filled with calcite, highly fracturing and calcite patches and veins were also observed. Thick, cyclic interval of bioclastic mudstone, peloidal bioclastic grainstone, ooidal grainstone, and ooidal peloidal grainstone were present in uppermost 25m part. Diagenetically the carbonate units are highly altered in the form of calcite veins and calcite patches (Fig. 4.3 b-c). Stylolites were clearly seen in the carbonate unit of Jurassic Samana Suk Formation at the township section Abbottabad (Fig. d).

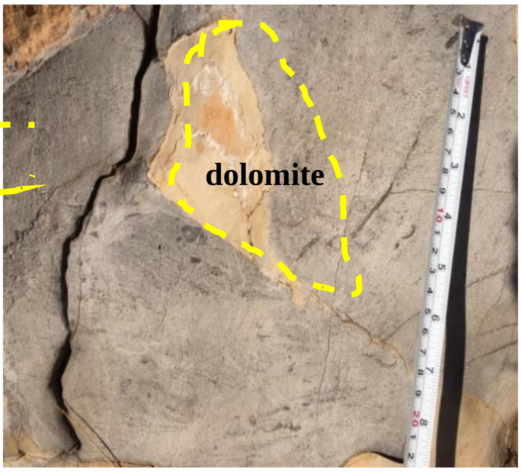
A

B

Fig. 4.1 Field Photographs (A) Paranomic view to Samana Suk Formation at township section. (B) closeup view of thick bedded limestone at the studied section



A



B

C

D

Fig 4.2 Field photographs (a) Brown dolomite in bioclastic grainstone bed. (b) Brown dolomite in the form of patches in grainstone unit. (c) grainstone bed along with stylolite. (d) Bioclastic grainstone unit,

A

B

C

D

Fig. 4.3 Field photographs (A) bioclastic grainstone bed (B) calcite in the form of patches (C) calcite in the form of veins. (D) stylolites shown with an arrow.

CHAPTER 5
MICROFACIES

Brown was the one who first proposed the word "microfacies" (1943). In a later definition by Flügel (1982), the phrase was described as "all paleontological and sedimentological criteria that may be separated into thin-section, peeling, and polished slabs."

The microscopic examination of 40 thin-sections and polished slabs serves as the foundation for the microfacies investigation of the Samana Suk Formation. In Flügel, Baccelle and Bosellini (1965) published comparison tables that were used to compute the percentages of the key components (1982). Biogenies are considered one group for percentage calculation, however their separate frequencies were also reported. The relative number and kind of elements, along with the texture of the rock, were used to describe the microfacies. The terms "rare" and "sparse" and "common" and "abundant" >40% are used interchangeably. The present study's microfacies were evaluated and associated with Wilson (1975) and Flügel's standard microfacies (SMF) kinds (1982, 2004). The Samana Suk Formation has a total of five microfacies; the descriptions, distributions, and hypothesized depositional settings of each are provided below.

5.1 Limestone Components

The components of the limestone, such as ooids, biogenies, bioclastic, peloids, pellets, oncoids, lumps/aggregates, and intraclasts, which characterize the different microfacies kinds, are explained in depth before moving on to the description of microfacies.

5.1.1 Ooids

A grain with a shape ranging from spherical to ellipsoidal with a diameter of 0.25 to 2.0 mm is called an ooid (Fig. 5.1 a). Its nucleus is coated by one or more precipitated coatings with radial or concentric crystal orientation. Flügel (2004). Detrital grains, skeletal pieces, pellets, and peloids make up most of the nucleus. The majority of ooids in the geological record are between 0.5 and 1.0 mm in size. According to Carozzi (1957), superficial ooids are those that have a cortex that is less than half the size of the complete ooid.

The broad word "ooid" is used to refer to coated carbonate grains that have one or more thin layers or coatings made of fine calcite or aragonite crystals surrounding a nucleus of some sort, such as a shell fragment, pellet, or quartz grain. The nucleus of some ooids could be too tiny to be clearly visible. Although the name "ooid" is favoured, these coated grains are sometimes occasionally referred to as "ooliths." Oolites are carbonate rocks that are mostly made of ooids Normal or mature ooids are spherical to subspherical ooids that have many interior concentric layers with a total thickness larger than the nucleus. Ooids develop in environments with strong bottom currents, agitated water, and high calcium bicarbonate saturation levels. Compared to ancient ooids, which are mostly made of calcite, modern ooids' coatings are mostly made of aragonite (Tucker and Write 1990).

Ooid mineralogy variations seem to be correlated with sea level changes. High stands of the sea appear to favour the production of calcite ooids because $C0_2$ levels are typically higher and Mg/Ca ratios are typically lower at these periods; low stands appear to favour the creation of aragonite ooids because $C0_2$ levels are dropped, and Mg/Ca ratios are up. Some ooids only have one or two extremely thin layers of covering, with a total thickness that is smaller than the nuclei. These ooids are sometimes referred to as pseudo-ooids or superficial ooids. Pisoids are coated grains that are bigger than 2 mm and have an interior structure that is like that of ooids (a rock composed of pisoids is a pisolite). Pisoids are often crenulated and less spherical than ooids. Like how stromatolites reformed, certain pisoids may be of algal origin and created by the binding and trapping activities of blue green algae (cyanobacteria). Oncoid stromatolites are spheroidal stromatolites larger than 1 to 2 cm (Tucker and Write 1990).

5.1.2 Peloids

Regardless of where they came from, peloids were first described as ovoid to ellipsoidal grains of micritic carbonate (McKee and Gutschick, 1969). A peloid is a grain of homogenous micrite that is rounded. Such grains were described as peloid in reference to ancient carbonate rocks with unknown origins.

Peloids are normally silt to fine-sand size (Fig. 5.1 b) (0.03-0.1 mm), however some may be bigger. They are smaller than ooids. Fecal pellets, which are formed by organisms that consume calcium carbonate muds and expel undigested mud as pellets, are the most prevalent type of peloid. Fecal pellets typically have a tiny, consistent size, an oval to rounded shape. By lacking a concentric or radial internal structure, pellets may be distinguished from ooids; spherical intra-clasts can be distinguished from pellets by their uniform shape, superior sorting, and small size. (Tucker and Write 1990).

Shallow marine carbonate deposits include peloids, which constitute a significant component. On the Great Bahamas Banks West of Andros Island, peloids make up about 30% of the sediment's total volume and 75% of the sand component (Tucker and Write 1990).

5.1.3 Intraclasts

According to Folk (1959; 1962), Intraclasts are described as erosional aggregates of recent muddy carbonate deposits, indicating that they are formed from the same sediments that they would eventually rest over. According to Flügel (1982), Intraclasts are reworked substrate products that have already undergone weak consolidation in the deposition basin (Fig. 5.1 c).

5.1.4 Lumps/Aggregates

Lumps are categorized as collections of carbonate grains with sand-like sizes that are penecontemporaneous in age and have intrabasinal origins (Fig. 5.1 d). When two or more initially distinct particles are micrite-cemented together, an aggregate grain is created. In the sediments of the Bahamas Banks, Illing (1954) identified three morphological forms of aggregate grains: (a) grapestone; (b) lumps; and (c) botryoidal lumps. Grapestones are aggregates of spherical grains (often microscopic ooids) connected by cements or organic encrustations and resembling tiny clusters of grapes. The aggregates known as lumps often have hollow interiors and a smoother outside.

According to Flügel (2004), botryoidal lumps are grapestones or lumps with a thin oolitic layer.

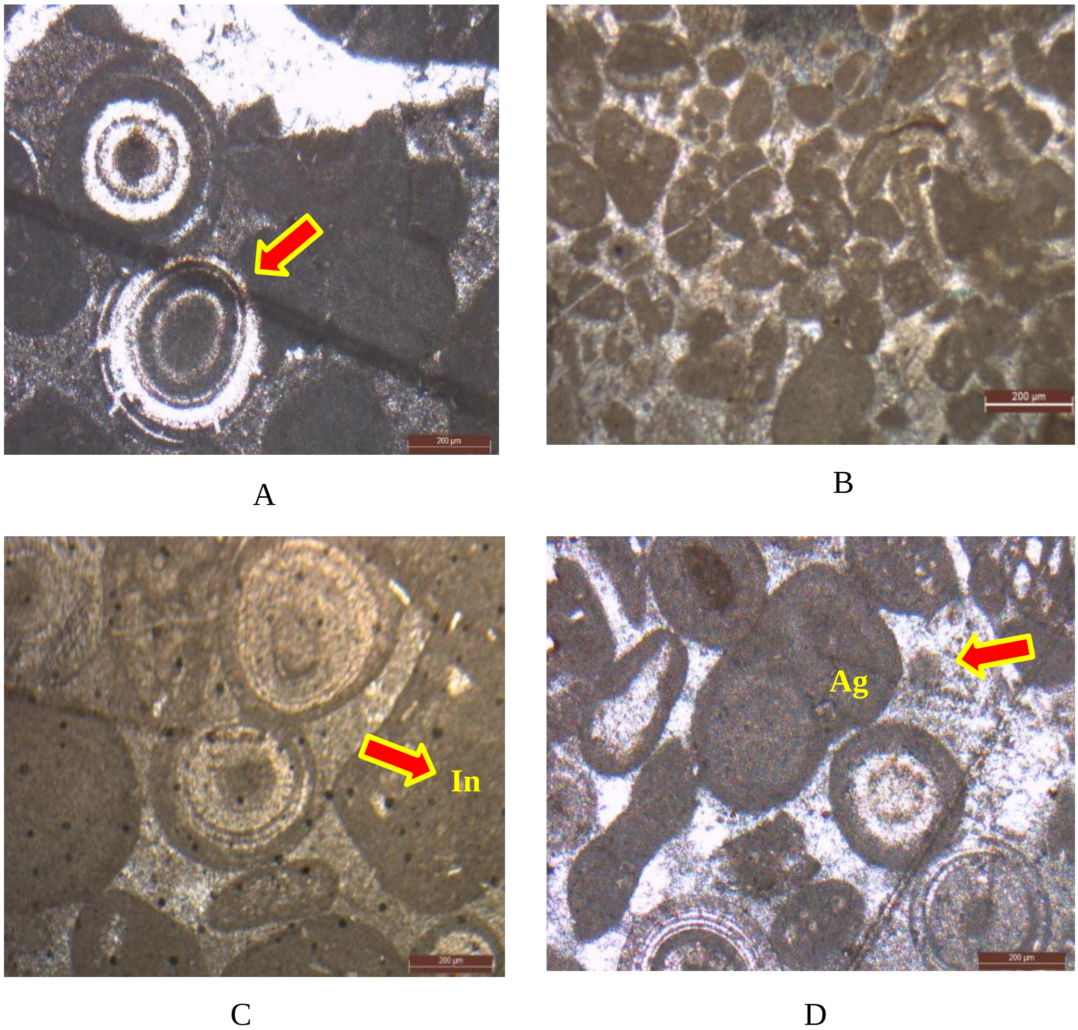


Fig. 5.1 Photomicrographs (A) Ooids shown with arrow (B) Peloids (C) Intraclast (In) (D) Aggregate grains (Ag)

5.2 Microfacies

There are several different kinds of microfacies in the Samana Suk Formation. There are now five separate microfacies. Below is a description of these microfacies and how to interpret them in terms of the depositional environment.

5.2.1 Mudstones (MF1)

Muddy carbonate rocks known as lime mudstones have grain-to-bulk ratios of less than 10%. (Dunham, 1962). The absence of grains and creatures that produce grains in these rocks may indicate poor environmental circumstances. The breakdown of microscopic, segmented blue green algae, such as penicillus, is known to cause the formation of lime mud in contemporary environments (Burchette and Wright 1992; Flugel 2010). The lime mud is cut by a lot of calcite veins. At several layers of the Samana Suk Formation exposed in this region, mudstones may be found. Where mudstones are visible, they are fragmented and filled with calcite (Fig. 5.2 a)

Interpretation

This microfacies is thought to reflect deposition in a low energy lagoonal context based on the allochem type, proportion of allochem vs matrix, absence of faunal contents, prevalence of lime mud as matrix, and papery lamination. This microfacies is comparable to Wilson (1975) and Flügel's RMF-19 (2004).

5.2.2 Bioclastic Mudstones (MF2)

Bioclastic mudstones are present in the measured portion on various levels. Micrite-colored lime mudstone that is fossiliferous, thin to thick bedded, extensively bioturbated, and only occasionally partially laminated with sporadic areas of pelletal grainstone, packstone, and wackestone These can be found in the formation under study at a variety of horizons. Fig. 5.2 b depicts the bioclastic mudstones in a representative manner.

Interpretation

This microfacies is dominated by lime mud, which denotes quiescent energy conditions under the fair-weather wave base. The presence of bioclastic and intraclastic material in mudstone facies demonstrates that the deposition took place in the peri-tidal zone (Emad et al.., 2020). SMF-20 of Flügel is quite prevalent in the intertidal zone, as well as in supratidal and shallow subtidal settings (1982; 2004).

5.2.3 Ooidal wackstone (MF3)

This microfacies comprise of 40-50 % of ooids, 10-20% of bioclasts and rare intraclasts (Fig. 5.2 c). The bioturbated rounded to sub-rounded shape ooids have a clear dark micritic rim. The sparry calcite and micro stylolites are documented along with patchy appearance due to bioturbation.

Interpretation

The presence of ooids in the micritic matrix that exhibit textural inversion, the high degree of bioturbation, and the sparse fauna suggest a low energy, partly constrained, shallow subtidal habitat that is likely on a back shoal or bar (Flügel, 2010).

5.2.4 Bioclastic peloidal grainstone (MF4)

The MF17 microfacies dominantly cover 65-80% of peloids and 10-15% of bioclasts. The peloids are fecal and well preserved (Fig. 5.2 d). The gastropods, bivalves, and other smaller benthic forams are the main bioclasts in this microfacie. The lithic pellets, pseudo ooids, sparse pelecypod fragments, and rare detrital quartz cover the remaining minor content.

Interpretation

In low energy, constrained, and shallow water habitats, endolithic algae that promote micritization of carbonate grains create the peloids (Hussain et al., 2013). The same applies to pellets, which cannot endure high energy levels that suggest low energy settings due to their fragility. Bivalves and gastropods advise the early cementation of shoal settings to prevent the wearing of delicate allochems based on the kinds of allochems and a lack of biota in combination with benthic foraminifera (Tucker & Wright, 2009)

5.2.5 Peloidal grainstone (MF5)

The MF14 microfacies incorporate majorly 80-95% of peloids (Fig. 5.2 e), with rare microbial crusts and ooidal grains as a minor component. The peloidal grains are well-sorted and cemented through blocky and granular calcite cement.

Interpretation

Micrite scarcity and peloidal grain sorting suggest a shallow depositional environment under high-energy circumstances. The shoal habitat has a limited relationship of mud low tidal and relative high wave energy, according to (Lasemi et al., 2012). Peloids are defined by the limited circulation of warm water at shallow depths in shoal depositional environments (Jank et al., 2006). Peloid grain that has not been damaged by a high energy environment is a good indicator of the quick cementation. The abundance of peloidal grains and the sparse number of ooids suggest a setting in high energy settings (Ham et al., 1962; Powell, 1979; Scholle & Ulmer-Scholle, 2003).

5.2.6 Ooidal grainstone (MF6)

This microfacies incorporate chiefly 80-90% of ooids in grainstone**.** The geometry of ooids is very well rounded and concentric exhibits dark and light color striped multi-laminae shown in (Fig. 5.2 f). The nuclei of ooidal grains are derived from pre-existing peloids, fragments of bioclasts, and ooids. The small benthic forams, peloids, and fragments of bioclasts cover the remaining minor components. The ooidal grains are held majorly by sparry and/or microspar calcite and the coarse blocky calcite cement.

Interpretation

The high-energy environment based on concentric and well-sortation of ooidal grains (Reolid et al., 2007). According to (Wilson, 1975; Burchette & Wright 1992; Buchem et al., 2002; Flügel, 2010) high energy deposits are chiefly related to shoals and bar environments either near or on the seaward edge of carbonate platforms. The profusion of ooids, scarcity of micrite, and the existence of well-sorted ooids signify a high-energy shoal environment above fair weather wave base (FWWB) (Harris, 1979; Insalaco et al., 2006; Hashmie et al., 2016)

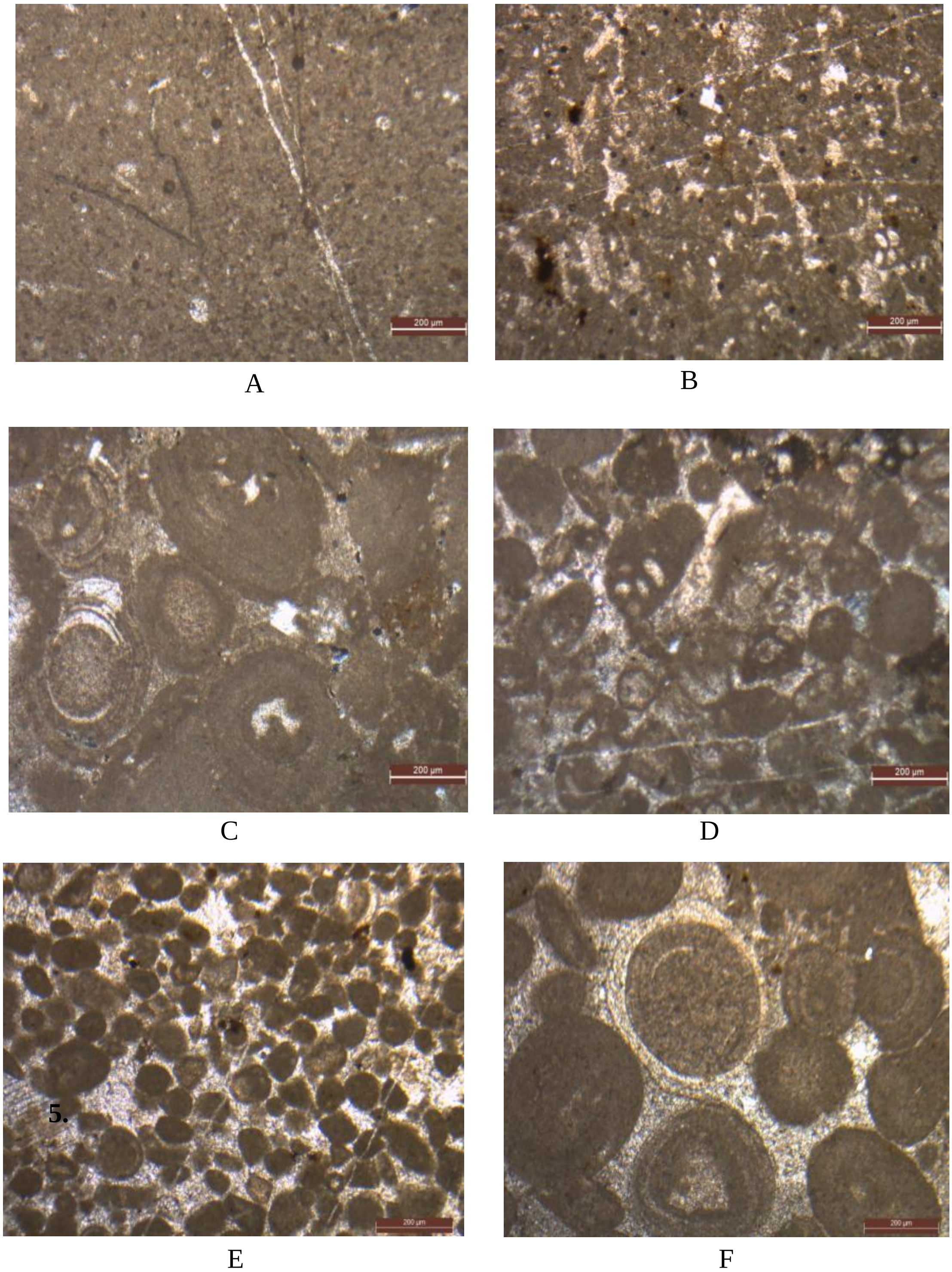


Fig.5.2 Photomicrograph (A) Mudstone (B) Bioclastic mudstone (C) Ooidal wackstone (D) Bioclastic peloidal grainstone (E) Peloidal grainstone (F) Ooidal grainstone

Petrographic studies revealed 6 different types of microfacies (MF1-MF6) characterized by skeletal and non-skeletal components, depositional textures, and other petrographic features. Based on the lithology and relative proportion of the non-skeletal and skeletal components, the microfacies are assigned to three facies association including peritidal flat, lagoons, and carbonate sands and shoals (Fig. 5.3). The studied microfacies are grouped into two facies assemblage on carbonate ramp based on standard Paleozoic and Mesozoic carbonates ramp facies by Flügel 2010. The inner ramp includes the lagoonal facies (MF1 to MF2) and shoals environment facies (MF4-MF-6). The lagoonal facies are characterized by low energy and restricted circulation while the facies of the shoal environment are represented as a moderate to high energy environment. The facies of lagoonal environment have low diversity of biota, mostly non-laminated, unfossiliferous, and has an abundance of non-skeletal fragments. The shoal environment facies are characterized by well-sortation, cross-bedding, and tight packing patterns of ooids, and the peloids are poorly sorted in sparry cement.

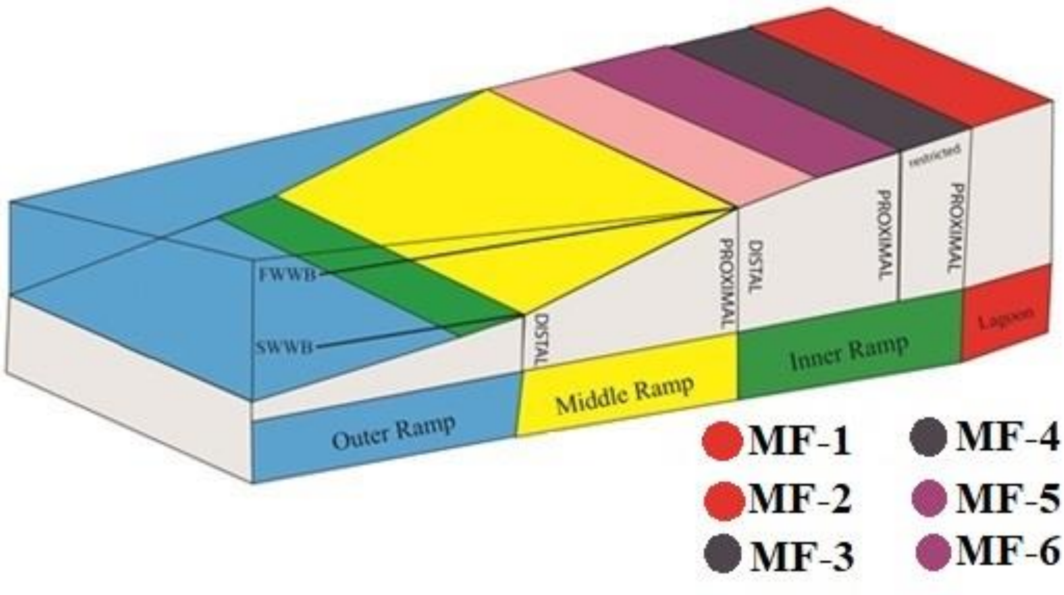


Figure 5.3 Depositional model of Jurassic Samana Suk formation town ship section, Abbottabad Hazara basin microfacies.

CONCLUSIONS

Understanding Pakistan's Jurassic carbonates will be aided by research into the Samana Suk Formation. The Samana Suk Formation revealed in this region is mostly made up of hard, compact, fine- to coarse-grained dolomitic limestones, with dolomite developing as a secondary diagenetic characteristic in some areas. The limestone on the outcrop appears light grey on the new surface and light brown on the aged surface. The limestone is enormous in certain areas, planar, thin through medium to thick-bedded, and fossiliferous. We have investigated and noted several features in the field, including stylolite fractures, calcite veins, calcite patches, and dolomite beds and patches. The Formation comprises of grainstone microfacies, mudstone microfacies and wackstone microfacies that are deposited on the inner part of homoclinal ramp setting. The microfacies MF1-MF6 are mudstone, bioclastic mudstone, ooidal wackstone, peloidal bioclastic grainstone, peloidal and ooidal grainstone microfacies respectively. The mudstone microfacies interpret deposition under low energy conditions particularly within calm and quiet waters of lagoons. The bioclastic mudstone sub microfacies shows the deposition occurred in the peritidal zone near lagoon. whereas grainstone microfacies is typical of high energy, shoal environment. A detailed depositional model of the microfacies has been established based on the photomicrographs which shows that these microfacies are deposited on the inner part of homoclinal ramp from lagoon to carbonate shoal setting.

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