DIFFERENTIATION OF KAWAGARH AND LOCKHART FORMATION AND DEMARCATION OF CRETACEOUS – TERTIARY (K-T) BOUNDARY AT NIZAMPUR, KHYBER PAKHTUNKHWA, PAKISTAN

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

ALI ABID

HAMID FAIZ

ARSLAN ZAHEER

Department of Earth and Environmental Sciences

Bahria University Islamabad

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ABSTRACT

Khawre Khwar Nizampur is located in the north-west of deformed Kala-Chitta Range. The study area is highly deformed and has undergone different phases of deformations. The rocks exposed in the area have age range from Jurassic to Paleocene. Kawagarh Formation (Cretaceous) and Lockhart Formation (Paleocene) are emphasized regarding thin section study of the collected samples from both the formations show mostly the biostratigraphic assemblage. These formations have faulted contact in the area. Kawagarh Formation is overlying the Lockhart Formation. By this deformation different types of folds can be easily observed. Main focus of the study is Demarcation of Cretaceous-Tertiary (K-T) boundary, studying the diagenetic features and their depositional environments, planktonic foraminifera are observed which includes Heterohelix reussi, Uniserial and Biserial Foraminifera in Kawagarh Formation and in Lockhart Formation, larger benthic foraminifera are observed which includes Lockhartia, Operculina, Miscellanea and Actinosiphon. These microfossil assemblages help to identify depositional environments of outer neritic for Kawagarh Formation and inner neritic for Lockhart Formation. Diagenetic features of both formations are more or less similar but dolomitization in Kawagarh Formation and nodulartity in Lockhart Formation separated them from each other.

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INTRODUCTION

1.1. Introduction

The Nizampur district of Khyber Pakhtunkhwa which is bounded by Attock-Cherat and Indus River on the North and South respectively. The Indus basin is divided into Potwar sub basin and Kohat sub basin and these are located on eastern and western flank of Indus River and Nizampur basin is present in Kohat sub basin. Kala-Chitta Ranges are separated from the Attock-Cherat Ranges by distinct Hissartang Fault. Study area is consisting of sedimentary rocks and extremely tectonically active which consist of complex folds and faults in it.

1.2. Location and Accessibility

The study area is bounded between longitudes and latitudes (72°05'63.0"E, 33°81'51.6"N) and (72°05'98.6"E, 33°81'30.6"N). It is situated on Nizampur road and easily accessible from Bahria University Islamabad Campus (Fig. 1.1.).

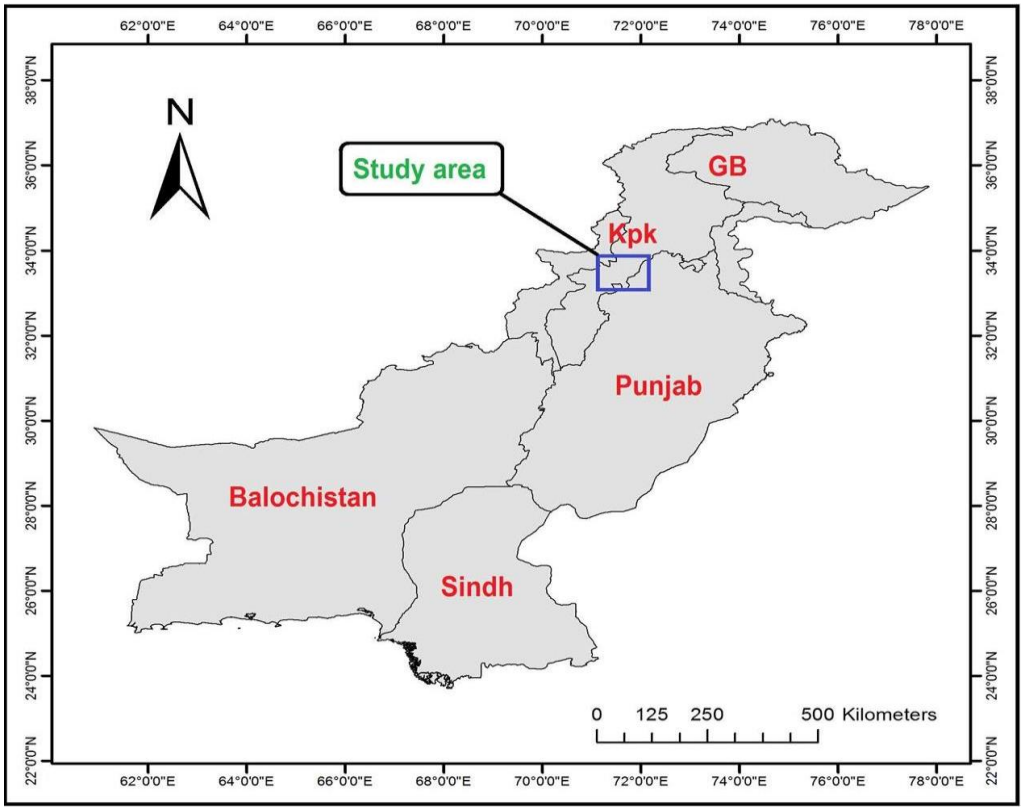

Figure 1.1. Location and study area on map.

1.3. Geography of Nizampur

Nizampur has a diverse climate. Winter season is in November, December and January and the summer season is in June, July and August. The study area lies in the semi-arid region of Pakistan. Rainfalls occur mostly in monsoon and in addition to that winter rainfalls also contribute it to some extent. Annually rainfall in this area is around 87-90mm. The language spoken in this area is Pushto and source of income is mainly agriculture. People employed in Askari cement factory for earning. Several rivulets and tributaries are also present in an area which flow toward the Indus River.

1.4. Field instruments

Instruments used in this field are shown in (Fig.1.2.) are following:

a. Geological hammer.

b. Measuring tape.

c. GPS (Global Positioning System).

Figure 1.2. Field instruments, (A): Geological hammer (B): Measuring tape (C): GPS

1.5. Objectives

The goals of research are as follows.

a) To find the biostratigraphic assemblage of Kawagarh Formation (Cretaceous) and Lockhart Formation (Paleocene).

b) To demarcate of Cretaceous-Tertiary (K-T) boundary at Nizampur area.

c) To study the diagenetic features.

d) To evaluate the depositional environments.

1.6. Methodology

The methodology followed to achieve the objectives includes extensive field work and laboratory work.

1.6.1. Fieldwork

An extensive field work was carried out in the study area to identify different Formations exposed over there. After distinguishing Kawagarh and Lockhart Formations on their identification criteria, samples were taken at a regular interval from both the Formation at the study section. The Formations were measured and photographs were taken for the record. Marl was present on the base of Kawagarh Formation and nodularity was seen in Lockhart Formation which separated it from Kawagarh Formation and as well as lower and upper contacts of Formations was identified. Geological hammer was used to break hard and compacted rocks to collect fresh samples. More than 50 samples were collected from both Kawagarh Formation and Lockhart Formation with 5 meter interval between samples. Global positioning system was used to identify the coordinates i.e. Longitude and Latitude. Photographs of important features were also taken at field. At the end samples were sent to laboratory.

1.6.2. Laboratory work

1.6.2.1.Thin section preparation

The collected samples were cut and made into thin sections at the rock cutting laboratory of Department of Geology, University of Peshawar. Total 36 thin sections were prepared, 18 thin sections from each Formation. Thin section laboratory is shown in (Fig 1.3.).

Figure 1.3. Thin section laboratory, University of Peshawar.

1.6.2.2.Microscopic study

The prepared thin sections were further studied under polarizing microscope at the Sedimentology laboratory of National Centre of Excellence in Geology, University of Peshawar (Fig. 1.4). Microfossils and other features like cleavage, fractures, matrix, cementing and stylolites were identified and photomicrographs were taken for analysis and explanation.

Figure 1.4. Polarizing Microscope at Sedimentology laboratory NCEG, University of Peshawar.

CHAPTER 2

REGIONAL TECTONICS AND STRATIGRAPHY OF STUDY AREA

2.1. Regional tectonics

There are several major thrust faults present from north to south in Pakistan. The Main Karakoram thrust is the northernmost member of the thrust system separating the deformed metasedimentary and igneous rocks of the Asian Land mass in the north from Kohistan Island Arc (KIA) complex in the south. The Main Mantle Thrust bounds the Kohistan Island Arc to the south and the Indian Plate to the north. It formed as a result of collision and subduction of Indian Plate underneath the KIA during Eocene time (Tahirkheli, 1979, 1982). The Main Boundary Thrust juxtaposes stratigraphic assemblages ranging in age from Pre-Cambrian to Cenozoic in north over younger strata to south (Seeber et.al, 1981). The Main Boundary Thrust trends east west along most of the foreland basin and turns northward, west of Jhelum River forming a major bend called Hazara Kashmir Syntaxis (DiPietro et al., 1996). The Main Boundary Thrust is thought to be connected to the Hazara and Murree Faults that bound the northern margins of the Kala-Chitta and Hazara Ranges (Seebar et al., 1979; Yeats and Lawrence, 1984). The southernmost thrusts of North Pakistan include the Salt Range Thrust and the Trans- Indus Range thrust that brings Precambrian to Pleistocene continental shelf and foreland basin sequence of the Salt Range and Trans-Indus Range over the Indo Gangetic Plain (Blisnick, 1966).

Kala-Chitta Range is bounded between Attock-Cherat Range in the north and Margalla hills in the south (Fig. 2.1). Both of these Ranges linked with Hazara Kashmir syntaxis. Nizampur basin is located in a north western edge of Kala-Chitta Range above the Main boundary Thrust. Attock-Cherat and Kala-Chitta Ranges are associated with late Cenozoic arrangements of thrust faults. Attock-Cherat Range is older than Kala-Chitta Range. Age of uplifting of Attock-Cherat is approximately 3 million years while Kala-Chitta Range is uplifted about 2 million years ago (Burbank and Tahirkheli, 1985; Burbank, 1982). Kala-Chitta Range is distinguished by its thrusting that is well preserved in Nizampur basin. Alluvium is present in the northern side of Kala-Chitta Range but some Jurassic rocks are exposed there. In the North eastern side of Nizampur, Jurassic rocks are isoclinally folded and thrusted on Cretaceous Lumshiwal Formation and in the south the Triassic Mianwali Formation

to Paleocene Patala Formation form the Kala-Chitta Foreland sequence and outcropped in a fold thrust belt. Moreover, small scale disharmonic folds are also present in fold thrust belt (Hussain, 1984).

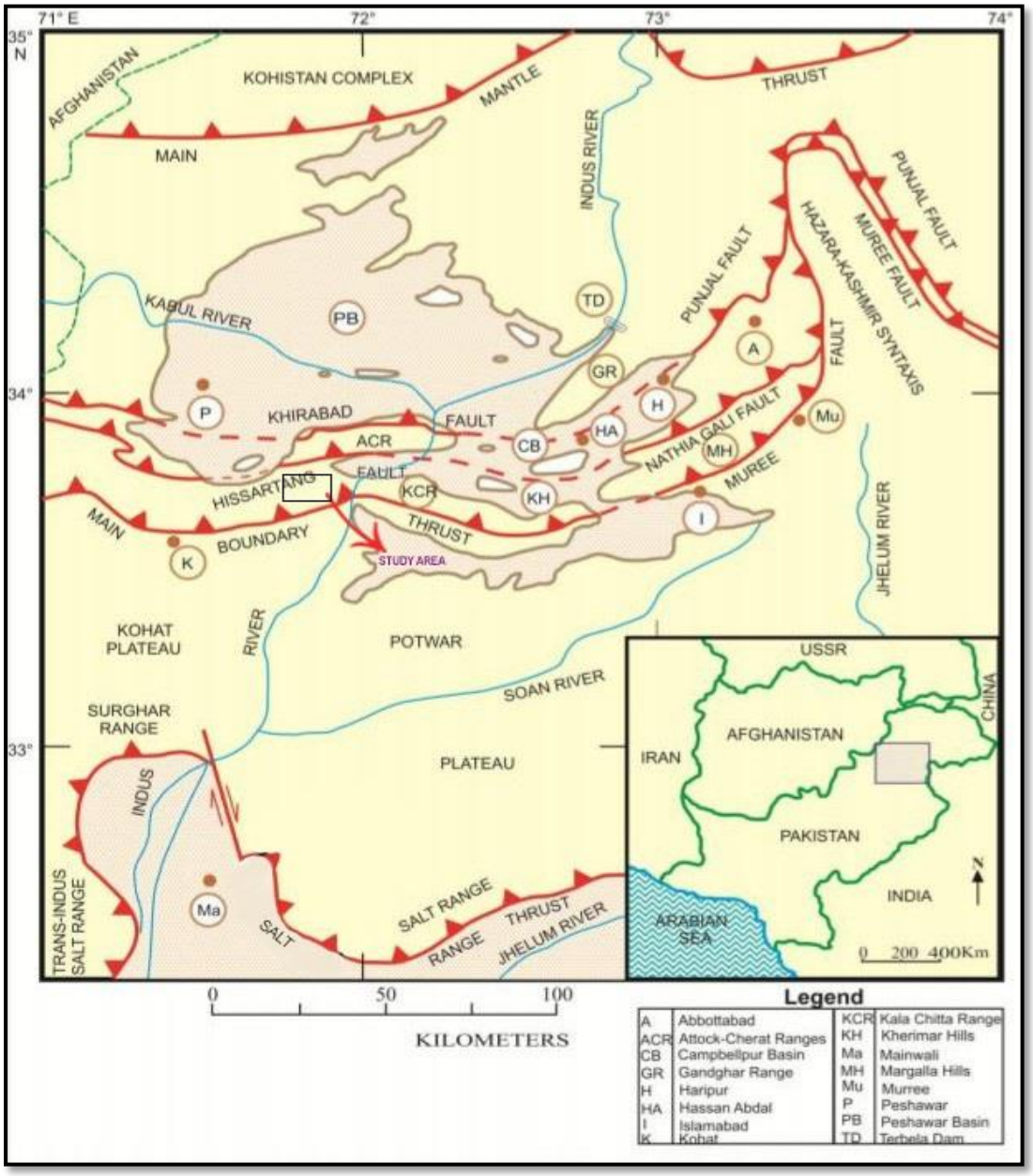

Figure 2.1. Tectonic map of northern Pakistan, showing major structural boundaries. Rectangle shows study area, Halland et al. (1988).

2.2. General stratigraphy

Several lithostratigraphic units are reported from Triassic to Quaternary in age and these units are of marine and non-marine origin. (Akhtar and Khan, 1983). Hussain et al. (1990) modified and amended the stratigraphy of the area. He used the word “Undivided Formation” for Jurassic Rocks exposed. The Jurassic rocks are undivided because of extreme structural deformation in an area that makes it impossible to differentiate between these units. The northern part of the Kala-Chitta Range is covered by alluvium except for limited exposure of Jurassic Limestone (Tab .2.1). Five kilometers north-east of Nizampur, Jurassic strata are thrust over Cretaceous Lumshiwal Formation (Hussain, 1984). The Baroach Group (oldest) of Jurassic age is overlain by Surghar Group of Cretaceous age which is overlain by Makarwal Group (youngest) of Paleocene age. Among all of these Geological contacts are unconformable.

Table 2.1. General Lithostratigraphical table of Kala-Chitta Range by (Akhtar and Khan, 1983).

AGE			FORMATIONS
CENOZOIC	TERTIARY	Miocene	Kamlial Formation Murree Formation
		Eocene	Kohat Limestone Kuldana Formation Chorgali Formation Margalla hill Limestone
		Paleocene	Patala Formation Lockhart Formation
MESOZOIC		Cretaceous	Kawagarh Formation Lumshiwal Formation Chichali Formation
		Jurassic	Samana Suk Formation Shinawari Formation Datta Formation
			Kingriali Formation

2.3. Stratigraphy of study area

The following Groups are exposed in a study area:

a) Baroach Group (Oldest)
b) Surghar Group
c) Makarwal Group (Youngest)

2.3.1. Baroach Group

It includes three Formations:

a) Datta Formation (Oldest)
b) Shinawari Formation.
c) Samana Suk Formation (youngest)

2.3.1.1. Datta Formation

a) Terminology

Its name was initially introduced Gee as "Variegated Stage" in (1945) and then Danilchik and Shah (1961, 1967) named it as Datta Formation. Its Type Section is Located near Datta Nala.

b) Lithology and Distribution

Datta Formation comprised of sandstone, siltstone and shales. It is characterized by variegated colors red, maroon, grey, green and white etc. and in addition to that Datta Formation also contains the economic minerals like silica sand, fire clay, sulphur, coal etc. Formation is well developed and exposed in Trans Indus Ranges that are Khisor, Surghar and Shinghar and as well as in Salt Range. Datta Formation is also reported from Samana and Kala-Chitta Ranges. There is a different thickness of Formation in different localities. In Kala-Chitta Range it is up to 10m and in Samana Range its thickness is approximately 270m. According to Shah (2009) no fossils are present in it but some carbonaceous remains are reported in Formation.

2.3.1.2.Shinawari Formation

a) Terminology

This Formation is named by Fatmi and Khan (1966) after a village name "Shinawari" located in west of Samana Range.

b) Lithology and Distribution

There is thin and thick interbedded Limestone with calcareous shale and quartz. Formation has also Ferruginous and calcareous Sandstone. The color of Limestone is grey. Shale is of grey color that is calcareous and non-calcareous in nature. At some places sandy, oolitic and ferruginous beds are also present. The sandstone is of white to light grey in color and stratified in thin and thick bedding. A division is identifiable in Eastern Kohat, Kala-Chitta Range and some parts of Hazara. The upper part is consisting of red shale (12m) in Chak Dalla of Kala-Chitta Range and 25m in Bagnotar section of Hazara. Fossils that are present in Shinawari Formation are brachiopods, gastropods and corals that give the Formation Early to Middle Jurassic age. (Fatmi and Cheema, 1972).

2.3.1.3.Samana Suk Formation

a) Terminology

Middlemiss named it as "Kioto Limestone" for the very first time in (1896). Later on Latif (1970) renamed the Formation is named as "Sikhar Limestone" in south eastern Hazara. Davies (1930) introduced the name "Samana Suk" in Samana Range and this name was approved by Stratigraphic Committee of Pakistan. The name for this Formation is derived from the mountain peak "Samana Suk" in Samana Range.

b) Lithology and Distribution

Its lithology comprises of subordinate marl, shale and limestone. At type locality Limestone is also oolitic with intercalation of calcareous shale. Limestone is lighter in color and medium to thin bedded and marl is present in its lower part in salt Range and Trans Indus Ranges. Kala-Chitta, Hazara and Eastern Kohat have also some dolomitic, ferruginous and oolitic beds exposed. Thickness of the Formation in type locality is approximately 185m. In Kala-Chitta Range its thickness varies from

170 to 365m (Shah, 2009). Brachiopods, gastropods, ammoniods and crinoids are reported from the Formation. Middle Jurassic age is given to Samana Suk Formation on the basis of its fossil content.

2.3.2. Surghar Group

Surghar Group is characterized by the three Formations of Cretaceous age. Those are following below:

a) Chichali Formation (oldest).
b) Lumshiwal Formation
c) Kawagarh Formation (youngest).

2.3.2.1.Chichali Formation

a) Terminology

The Formation Firstly named as "Spiti Shale" by Middlemiss in (1896) in Kala-Chitta Range. Danilchik and Shah in (1967) used the term Chichali Formation after the Chichali pass in Mianwali District.

b) Lithology and Distribution

The Lithology contains interbedded Sandstone and shale. Overall Formation color is greenish grey. Sandstone and shale have phosphatic nodules and shale is carbonaceous at some places. The Formation is well distributed in Trans Indus Ranges, Kala-Chitta Range and in Kohat area. At type locality its thickness varies from 50 to 70m and in Kala-Chitta Range it is approximately of 25m. Beleminites are abundant in Chichali Formation with small amount of bivalves and ammonites. Early Cretaceous age is given to the Formation on the basis of fossil content.

2.3.2.2.Lumshiwal Formation

a) Terminology

The name "Giumal Sanstone" was given for the first time by Middlemiss in (1896). Davies gave a name "Mari sandstone series" in (1930) at Kala-Chitta, Hazara and Kohat area. Later on Gee proposed the name Lumshiwal Formation in (1945) that is approved by the Stratigraphic Committee of Pakistan.

b) Lithology and Distribution

The overall lithology comprises of massive sandstone, limestone and shale. At type locality glauconitic shale is present at the base and feldspathic sandstone is present in upper part (Fatmi, 1973). Thickness of the Formation at type locality varies from 80 to 120m and in Samana Range it is about 190m. In Kala-Chitta, Samana and Hazara Ranges the sandstone have intercalation of limestone with abundant fossils of forams and echinoderms (Spath, 1930). The age of Lumshiwal Formation is Middle Cretaceous.

2.3.2.3.Kawagarh Formation

a) Terminology

The Kawagarh Shale is initially proposed by Cotter (1933) and formalized as Kawagarh Formation, after the Kawagarh Hills, present at north of the main Kala-Chitta Range, in the Attock. Both lower and upper contacts are conformable with Chichali and Kawagarh Formations respectively.

b) Lithology and distribution

It consists of Marl at the base and massive limestone in the upper parts. In Eastern Kohat dolomitic limestone is present in the lower part of the Formation. In Eastern Kohat its thickness Ranges from 70 to 90m and in Nizampur area its thickness is 110m. As Hungu Formation is not exposed in the study area while laterite bedding present between Kawagarh Formation and Lockhart Formation. Small forams, and corals are preserved in it. Beds are inclined in Kawagarh Formation exposed in study area because of tectonism (Fig. 2.2). The age is given to the Formation is Late Cretaceous.

Figure 2.2. Kawagarh Formation outcrop in study area.

2.3.3. Makarwal Group

This Group is also comprised of three Formations but in study area there are only two Formations are exposed:

a) Lockhart Limestone (Oldest)

b) Patala Formation (Youngest)

2.3.3.1.Lockhart Formation

a) Terminology

Davies introduced the term "Lockhart Limestone" in (1930). The name "Lockhart Formation" is approved by Stratigraphic Committee of Pakistan.

b) Lithology and Distribution

Lithology is mainly Limestone with small amount of shale. Nodularity can be seen in Lockhart Limestone. It is grey to medium grey in color. Formation is well distributed throughout the upper Indus basin. Its thickness in Nammal gorge is about 70m and in Kala-Chitta Ranges (Nizampur area) it is approximately 260m (Shah, 2009). The Formation is well exposed in study area. The age of Formation is Late Paleocene.

2.3.3.2.Patala Formation

a) Terminology

Davies and Pinfold proposed a term “Patala Shales” in (1937) and after that the name “Kuzagali Shale” was given by Latif in (1970).The term was formalized by Stratigraphic Committee of Pakistan.

b) Lithology and Distribution

In Salt Range, Formation is comprised of shale, limestone and sandstone. Its color is Dark greenish grey. Limestone is white to light grey and shale is present in its lower part. Calcareous sandstone is also present in the upper part. In Kala-Chitta Ranges it comprised of brown marks with thin interbeds of limestone (Shah, 2009). Its thickness in Patala Nala and Kala-Chitta are about 90m and 20m. The assigned age is Late Paleocene (Shah, 2009).

As study area is highly deformed structurally so Cretaceous and Paleocene strata is also in faulted contact. Cretaceous (Kawagarh Formation) is overlying Paleocene (Lockhart Formation. In (Fig. 2.3) Satellite image is showing sampling locations and excavated Laterite bed. And K-T boundary is shown in (Fig. 2.4).

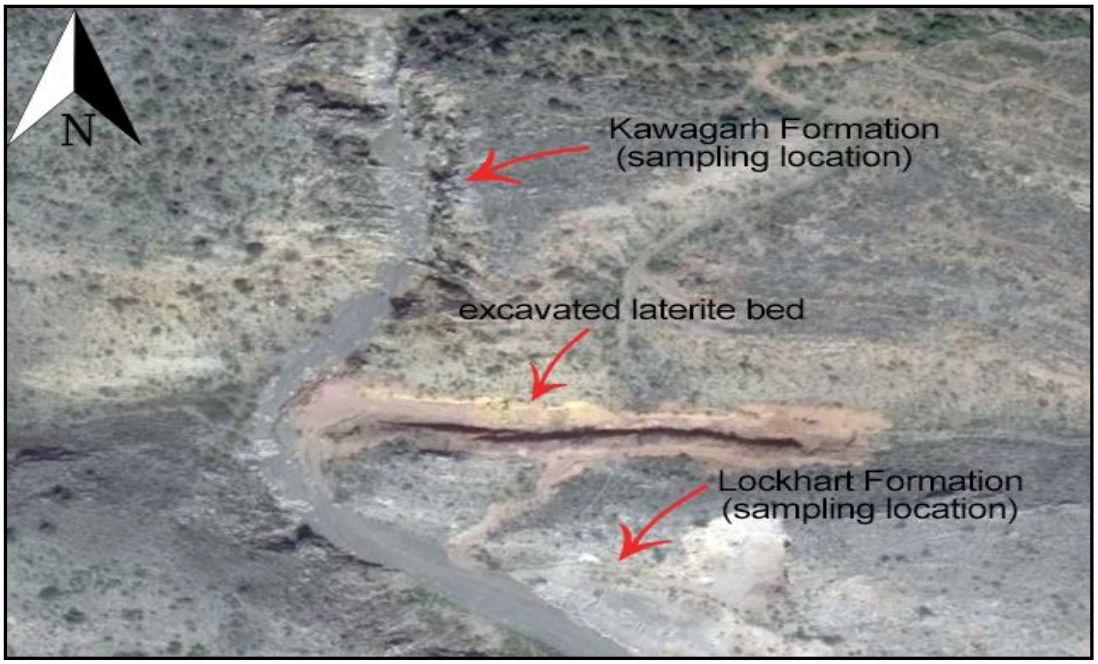

Figure 2.3. Satellite image showing Formations (sampling locations) and excavated Laterite bed (Google Earth).

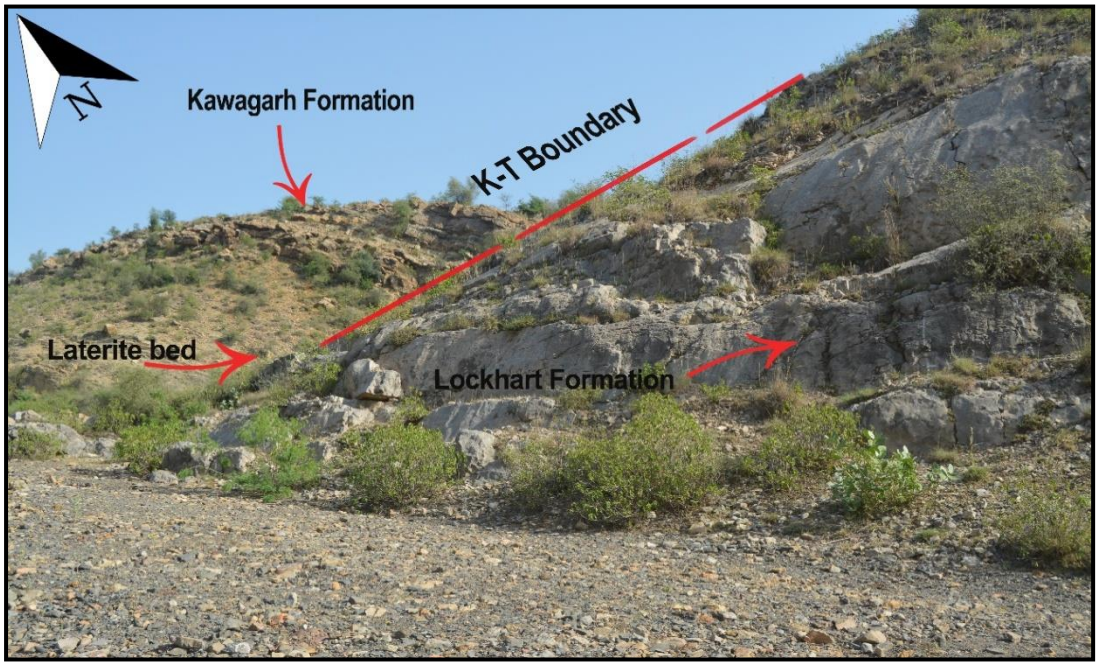

Figure 2.4. Faulted contact between Kawagarh Formation and Lockhart Formation.

CHAPTER 3

FIELD OBSERVATIONS

3.1. Laterite bed

An excavated laterite bed is observed between Kawagarh Formation and Lockhart Formation (Fig. 3.1). It was excavated by people because of its economic value. Its width is about 7.7 meter and length is 140 meter approximately.

Figure 3.1. Excavated laterite bed between Kawagarh Formation and Lockhart Formation.

3.2. Intraformational folds

Study area is highly deformed structurally so several intraformational folds are developed. **"Z"** and **"S"** shape folds are observed (Fig. 3.2, 3.3). These folds are developed in east-west orientation which shows that the tectonic forces are in north-south direction. One partially eroded synform is also seen in study area (Fig. 3.4).

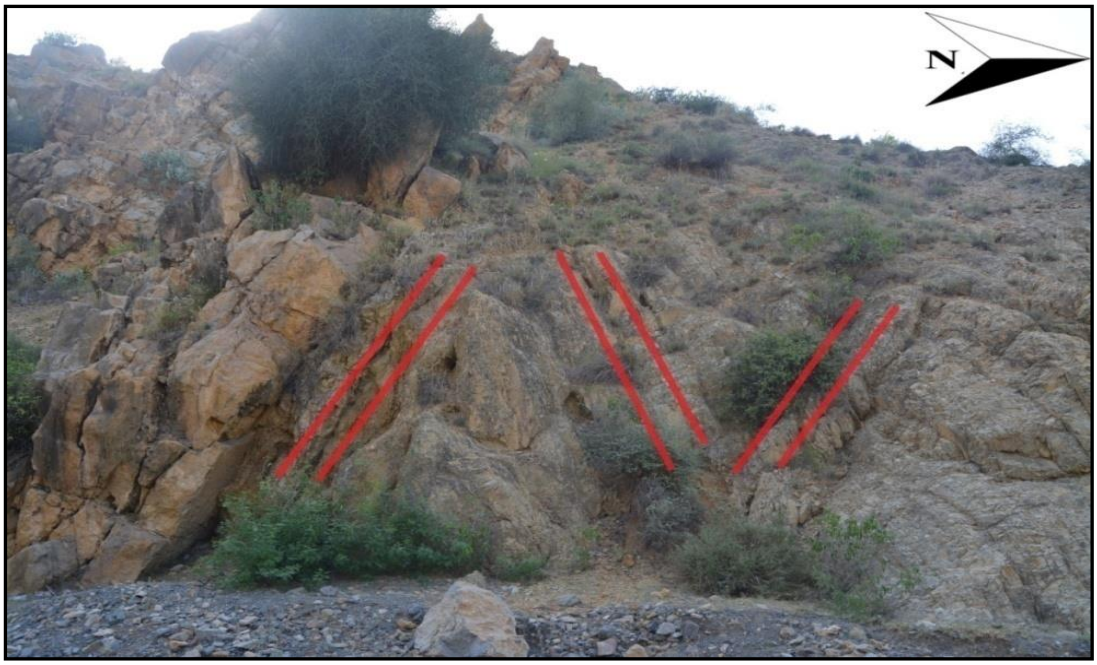

Figure 3.2. "Z" type fold in Kawagarh Formation.

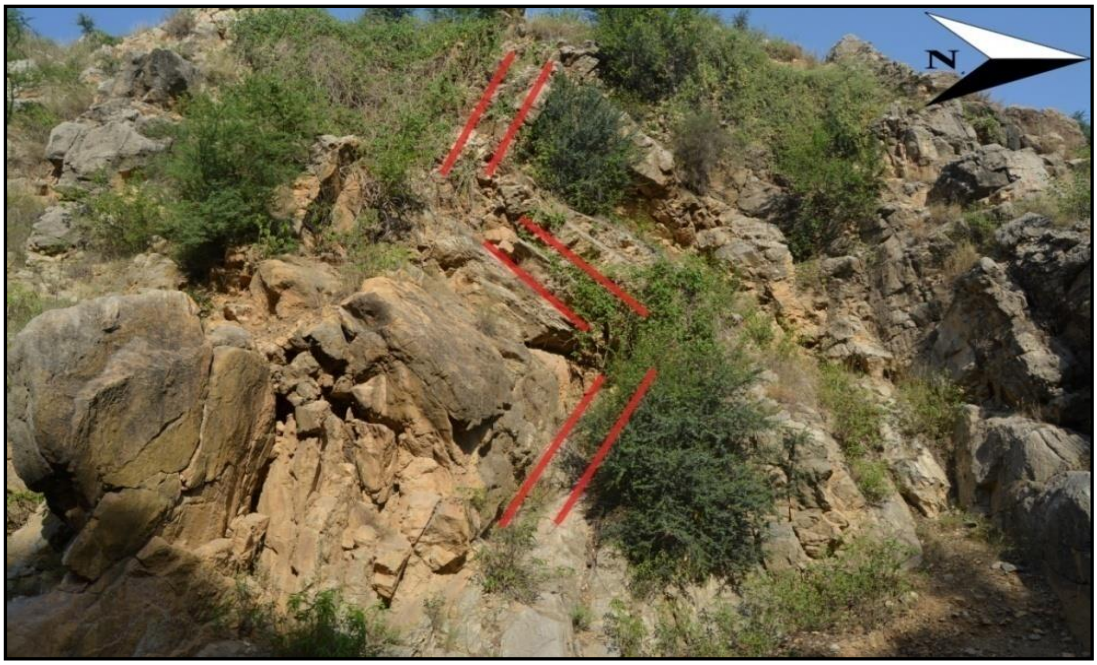

Figure 3.3. "S" type fold in Kawagarh Formation.

Figure 3.4. Partially eroded synform in study area.

3.3. Visible Faunal assemblage

Besides microfossils other faunal assemblage is also preserved in the study area. There is an abundance of Bivalves and their broken fragments in Lumshiwal Formation and it is present on the north of Kawagarh Formation (Fig. 3.5).

Figure 3.5. Bivalves in Lumshiwal Formation.

3.4. Industrial importance of area

Massive limestone gives a high industrial importance to Nizampur because of its considerable economic value. By the British standard specifications of cement manufacturing limestone should have composition of CaO (lime), MgO (magnesia), R_2O_3 (alumina and iron oxide), SiO_2 and small amount of Alkalies with percentages of 54.84%, 0.20%, 0.41%, 1.14%and respectively and Nizampur limestone meets up this criteria and is most suitable for cement manufacturing (Nazir jan et al., 2009). This limestone is also used in glass industry, pottery, paper mills etc (Hussain, 1995). In the study area limestone is brought by quarrying and send to Askari cement factory (Fig. 3.6).

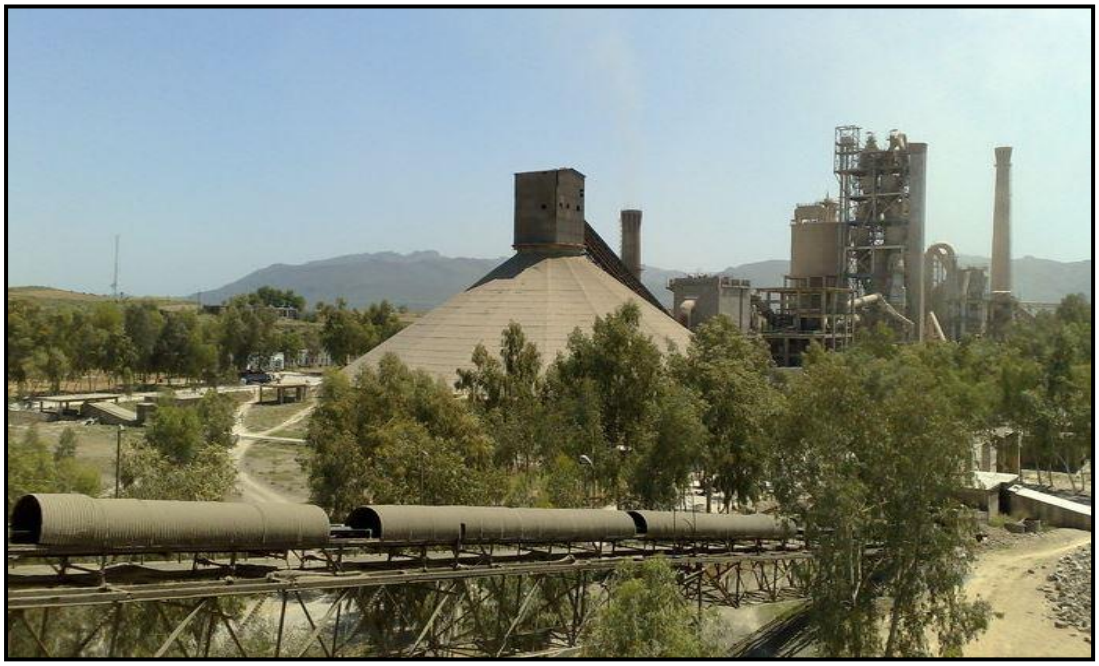

Figure 3.6. Askari cement factory Nizampur.

CHAPTER 4

BIOSTRATIGRAPHY, DIAGENETIC FEATURES AND DEPOSITIONAL ENVIRONMENTS

Biostratigraphy focuses on correlating and assigning ages of rock strata by using fossil assemblages contained within them. Microfossils are often extremely abundant, widespread and quick to appear and disappear from stratigraphic record (Gluyas and Swarbrick, 2004).

Diagenesis is the process by which sediments are lithified into sedimentary rocks and represents the sum of physical and chemical changes that occur during burial. Several diagenetic features are developed in the studied Formations (Marshak and Stephen, 2009).

This study was undertaken to identify the Kawagarh Formation and Lockhart Formation to mark the Cretaceous-Tertiary (K-T) boundary and further on to investigate the microfossil assemblage, demarcate the diagenetic features and evaluate the depositional environment of the Cretaceous Kawagarh Formation and Paleocene Lockhart Formation in the Khawre Khwar section Nizampur.

4.1. Lockhart Formation

4.1.1. Biostratigraphy

Total of 18 thin sections were prepared from Lockhart Formation and studied under the polarizing microscope. A wide Range of microfossils found and identified. Lockhart Formation is full of Foraminifera. Reported species are as follows.

- Actinosiphon semmesi
- Assilina subspinosa
- Biloculina contraria
- Bigenerina sp.
- Cibicides multifarious
- Daviesina langhami
- Decastroporella tergestina
- Eoannularia eocenica
- Lockhartia conditi
- Lockhartia tipperi `
- Lockhartia haimei

- Miscellanea miscella
- Miscellanea juliettae
- Milliolid
- Operculina salsa
- Operculina subsalsa
- Pseudohatigerina sp.
- Planorotalites chapmani
- Ranikothalia sahnii
- Rotalia trochidiformis
- Textularia sp.
- Coral

The foraminiferal genus Ranikothalia is characterized by its presence in Late Paleocene rocks of Pakistan but in some areas of the world it also lies in Early Eocene. Species like Miscellanea miscella, Lockhartia haimei, Operculina subsalsa and Daviesina langhami are strictly reported from Late Paleocene succession. It indicates that Lockhart Limestone is of Late Paleocene (Akhtar and Butt, 2000). Lockhart limestone is also devoid of any specie of Nummulites. According to Cavelier and Pomerol (1983) Nummulites began to appear in Eocene. It also confirms the age of Lockhart Limestone to be Paleocene.

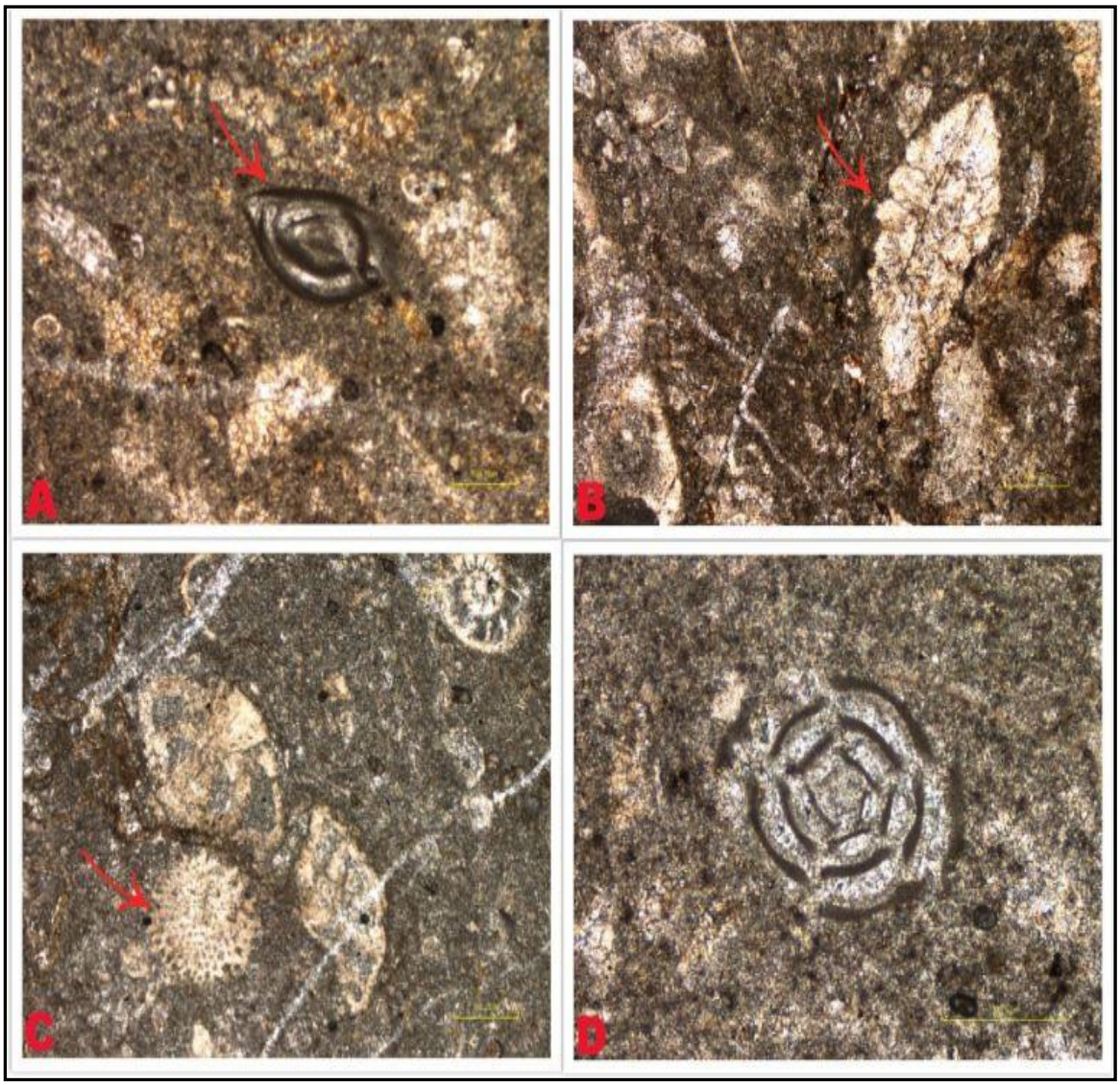

Figure 4.1. **(A)** Milliolid **(B)** Assilina subspinosa (DAVIES & PINFOLD) **(C)** Coral **(D)** Biloculina contraria (D'ORBIGNY)

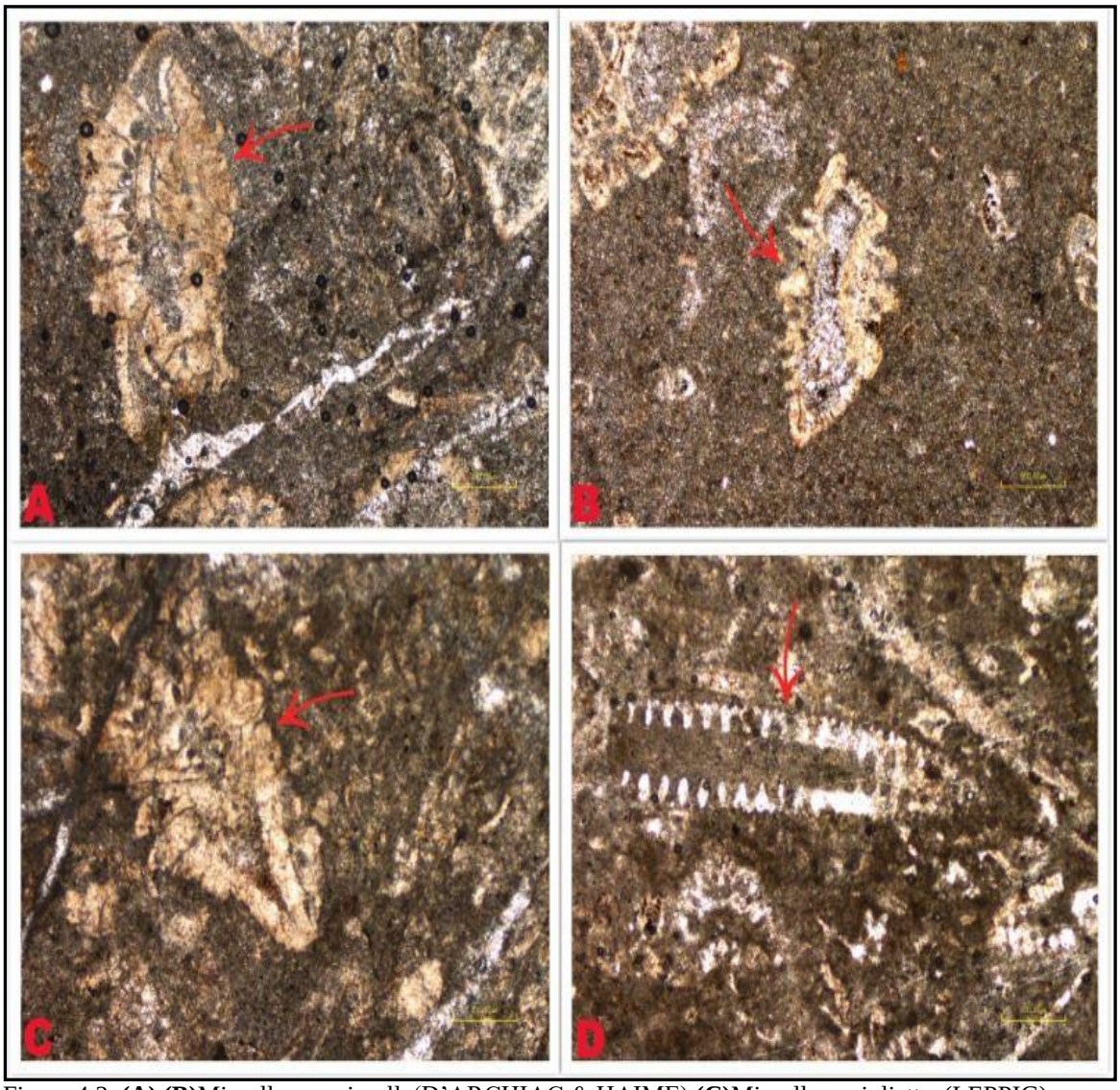

Figure 4.2. **(A),(B)**Miscellanea miscella(D'ARCHIAC & HAIME) **(C)**Miscellanea juliettae(LEPPIG) **(D)** Decastroporella tergestina

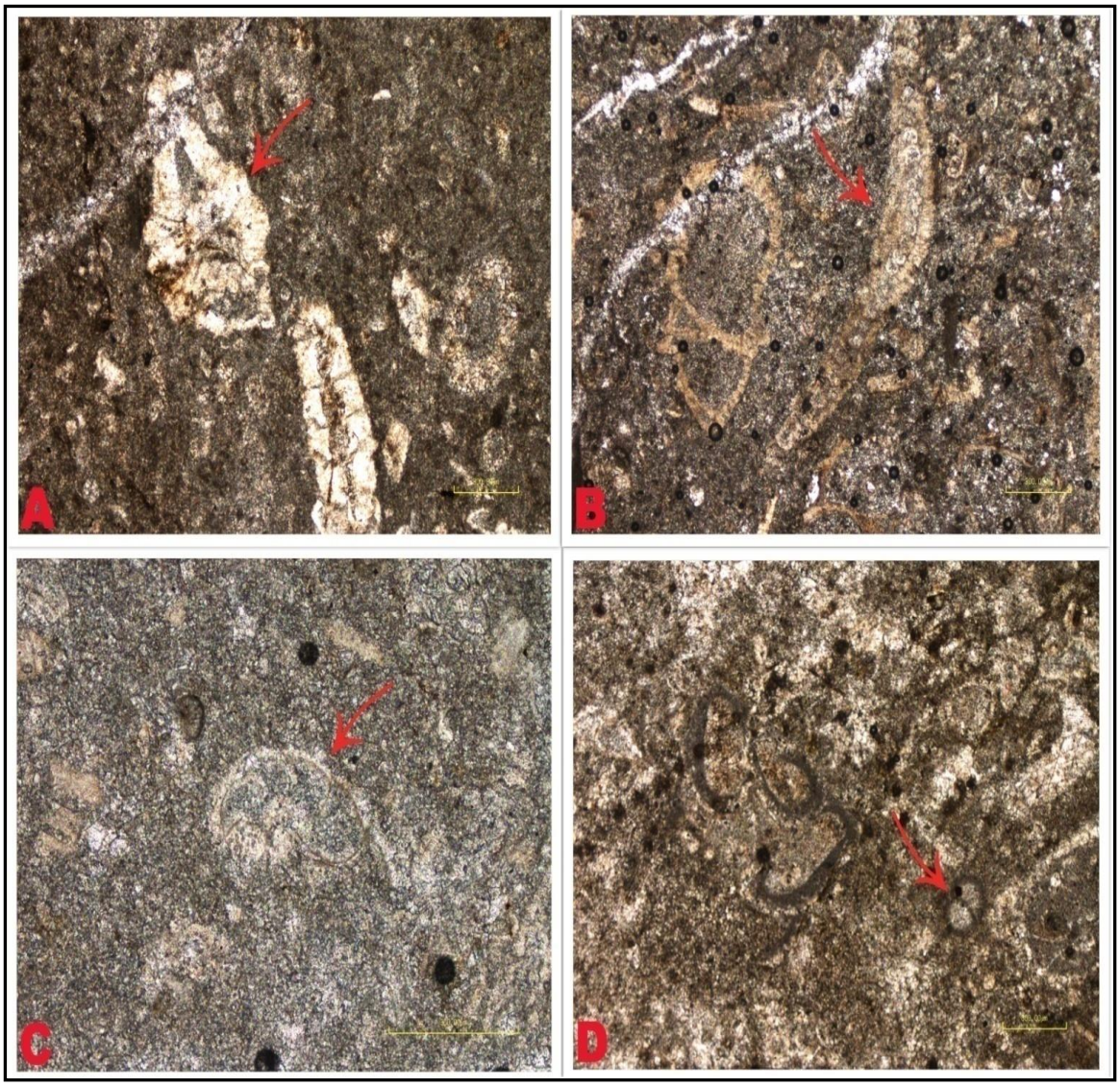

Figure 4.3. **(A)**Daviesina langhami(SMOUT)**(B)**Eoannularia eocenica(COLE & BERMUDEZ) **(C)**Cibicides multifarious **(D)**Actinosiphon semmesi(VAUGHAN).

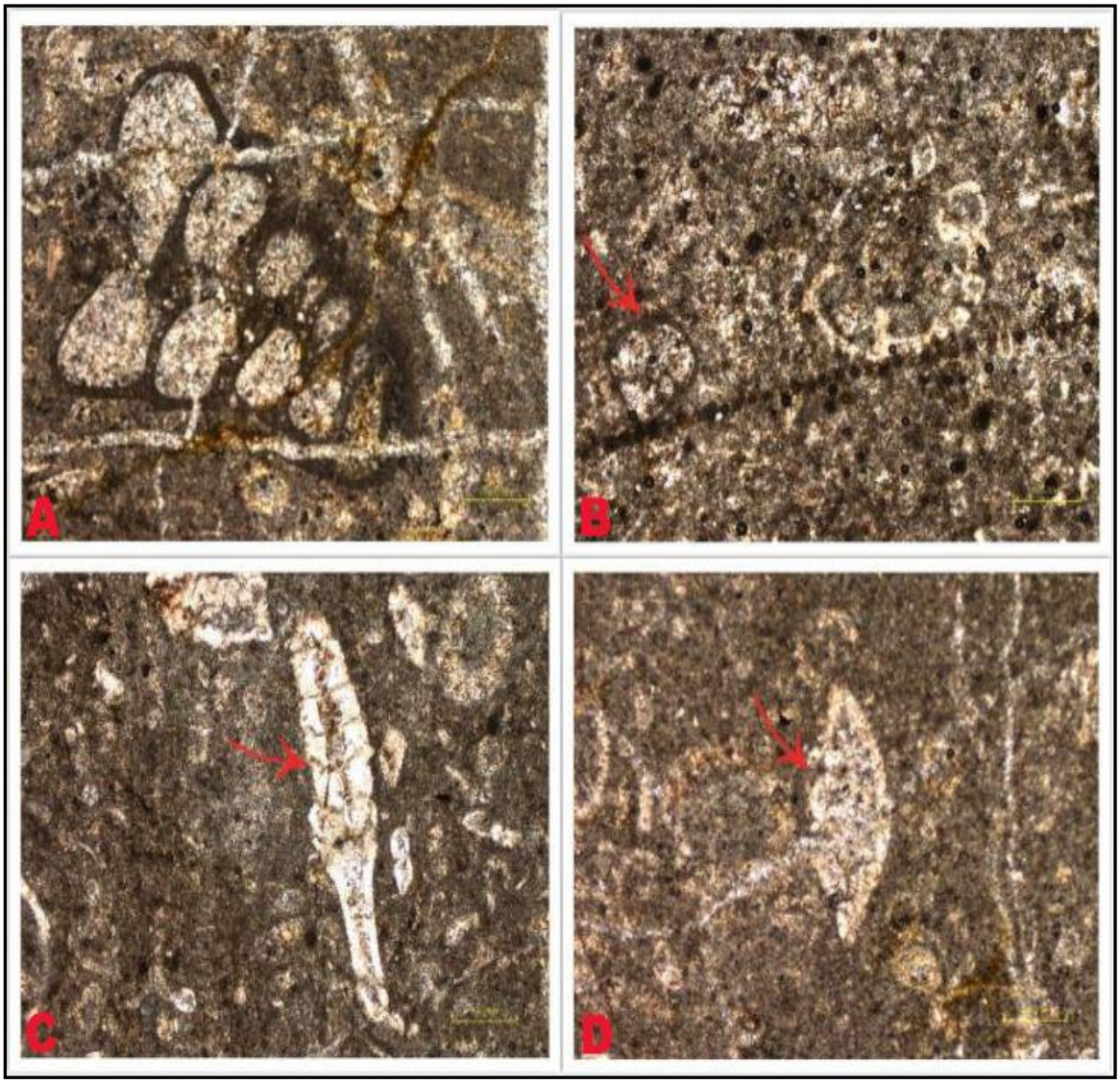

Figure 4.4. **(A)**Textularia sp. (DEFRANCE) **(B)**Subbotina sp. **(C)**Ranikothalia sahnii(DAVIES) **(D)**Rotalia trochidiformis (LAMARK)

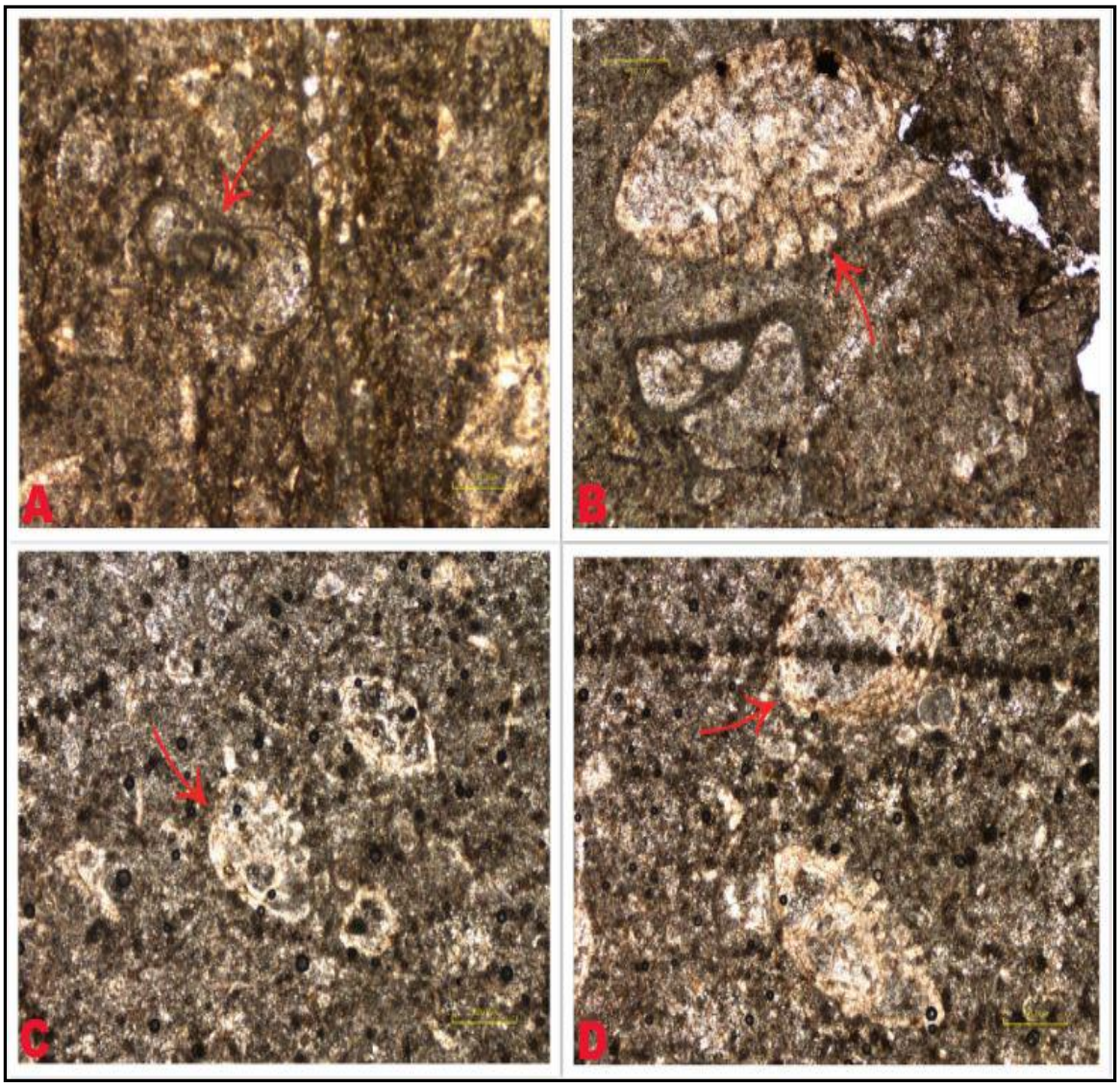

Figure 4.5. **(A)**Pseudohatigerina sp. **(B)**Lockhartia tipperi (DAVIES) **(C)**Lockhartia conditi (NUTTALL) **(D)**Lockhartia haimei (DAVIES)

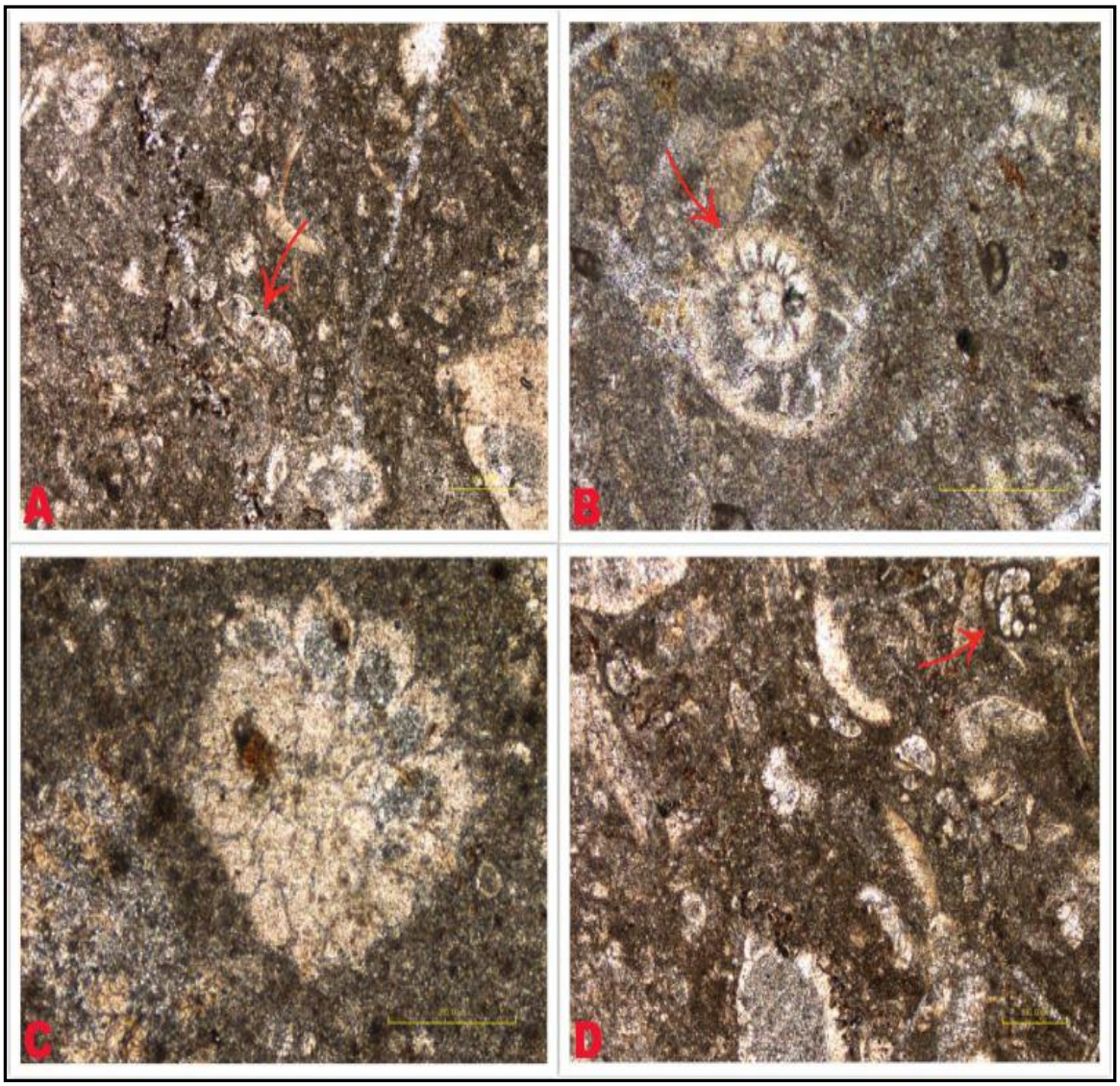

Figure 4.6. **(A)**Planorotalites chapmani(PARR)**(B)**Operculina subsalsa(DAVIES & PINFOLD) **(C)**Operculina salsa(DAVIES & PINFOLD)(**D)**Bigenerina sp. (D'ORBIGNY).

4.1.2. Diagenetic features

Mineralogical, textural changes, cementation and dissolution have a significant effect on carbonate rocks. These alterations can occur at any time from initial deposition to deep burial. Porosity is affected by these changes. Numerous diagenetic features have been identified in Lockhart Formation and during petrographical analysis. All these features are follows.

4.1.2.1.Low amplitude microstylolites

Most of observed stylolites are of low amplitude (Fig. 4.7).The stylolites present are formed as a result of pressure dissolution during the compaction of carbonate rocks.

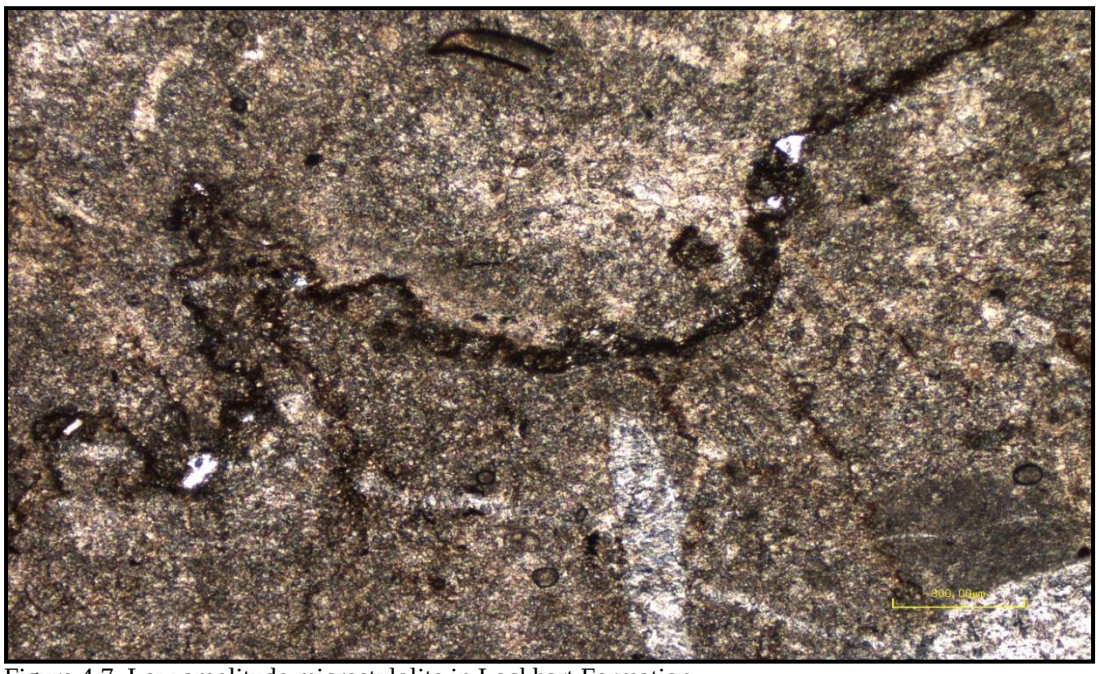

Figure 4.7. Low amplitude microstylolite in Lockhart Formation.

4.1.2.2.Spar filled fractures

The Lockhart Limestone contains abundant spar filled veins intersecting each other. It is interpreted that these were originally fractures developed during deformation and later filled with sparry cement (Fig. 4.8). These fractures occur as single or multiple sets with cross cutting relations. Some of these fractures are also unfilled which makes the Lockhart Formation good permeability prospect.

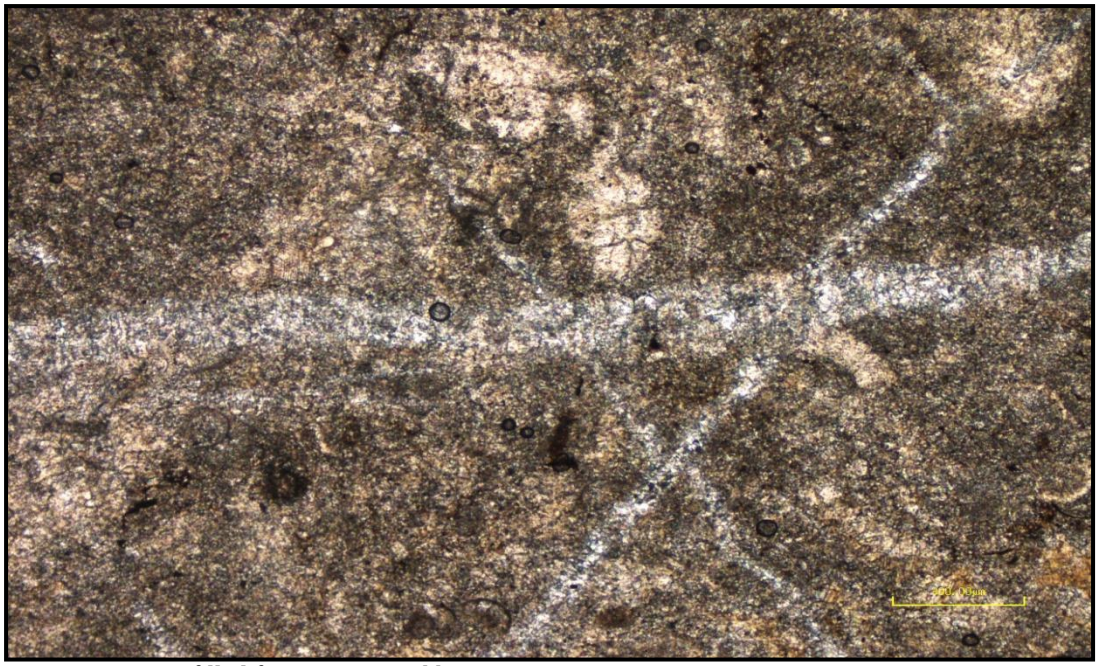

Figure 4.8. Spar-filled fractures in Lockhart Formation.

4.1.2.3.Nodularity

In case of Lockhart Limestone which is dominated by shallow water benthic fauna and flora with low input of planktons, restricted to some facies, the development of nodularity is mostly attributed to pressure dissolution related to deep burial. Nodularity is most commonly associated with deeper water pelagic limestones which are bounded by hard grounds and omission surfaces (Fischer and Garrison, 1967).

4.1.2.4.Micritic envelopes

Micritic envelope owe their origin to accretion of fine grained calcite (micrite) to the exterior of a grain (Fig. 4.9.). Micrite envelopes on bioclasts may help to preserve its shape when removed by dissolution during diagenesis.

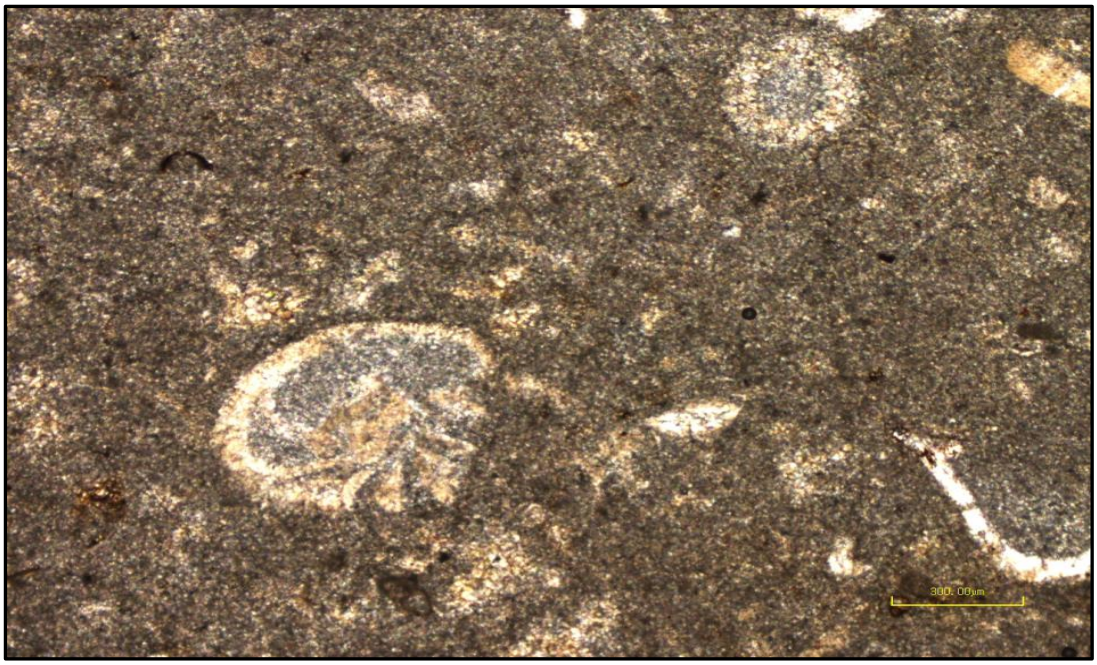

Figure 4.9. Micritic envelop around fauna.

4.1.3. Depositional environment

The diagnostic benthic larger foraminifera of different generas i.e Lockhartia, Assilina, Actinosiphon, Miscellanea, Operculina and Discocyclina are observed. This foraminiferal assemblage designates shallow shelf (inner neritic) marine environment of Lockhart Formation. Similar observations have been made by Munir et al (2005).

4.2. Kawagarh Formation

4.2.1. Biostratigraphy

Kawagarh Formation has been previously investigated thoroughly by different researchers in different parts of the country. Ahsan et al (1993) and Latif et al (1970) reported species which are Globorotalia multisepta, Globotruncana sp., Haplophrogmoides eggeri, Lenticulina sp., Planularia liebusi, Rugoglobigerina rugose, Textularia sp., Trochamina diagonis, Heterohelix globulosa and Pseudotextularia sp. Latif (1970) also reported the same species from Hazara area. Ahsan et al. (1993) also worked on Kawagarh Formation of Barian area on the microfacies of the Formation. Butt (1969) published a note on Cretaceous-Tertiary boundary of Hazara area and reported foraminiferal species from Kawagarh Formation.

The planktonic foraminiferal assemblage of the Kawagarh Formation includes

-Heterohelix reussi

-Planoglobulina sp.

-Textularia boudouiniana

-Globotruncana fornicate

-Globotruncana linneiana

-Globotruncana carinata

-Globotruncana arca

Total 18 thin sections were prepared from Kawagarh Formation and then studied under polarizing microscope. These samples were observed for the microfossils content but no significant fossils were identified to report apart from few Uniserial, Biserial Forams and Heterohelix reussi.

The absence of fossils in the study area can be attributed to the intense deformation activities in the area that has undergone several phases of deformation through geological time. The structural geometry with an east-west strike indicates that the area has passed through successive phases of north-south compressional deformation.

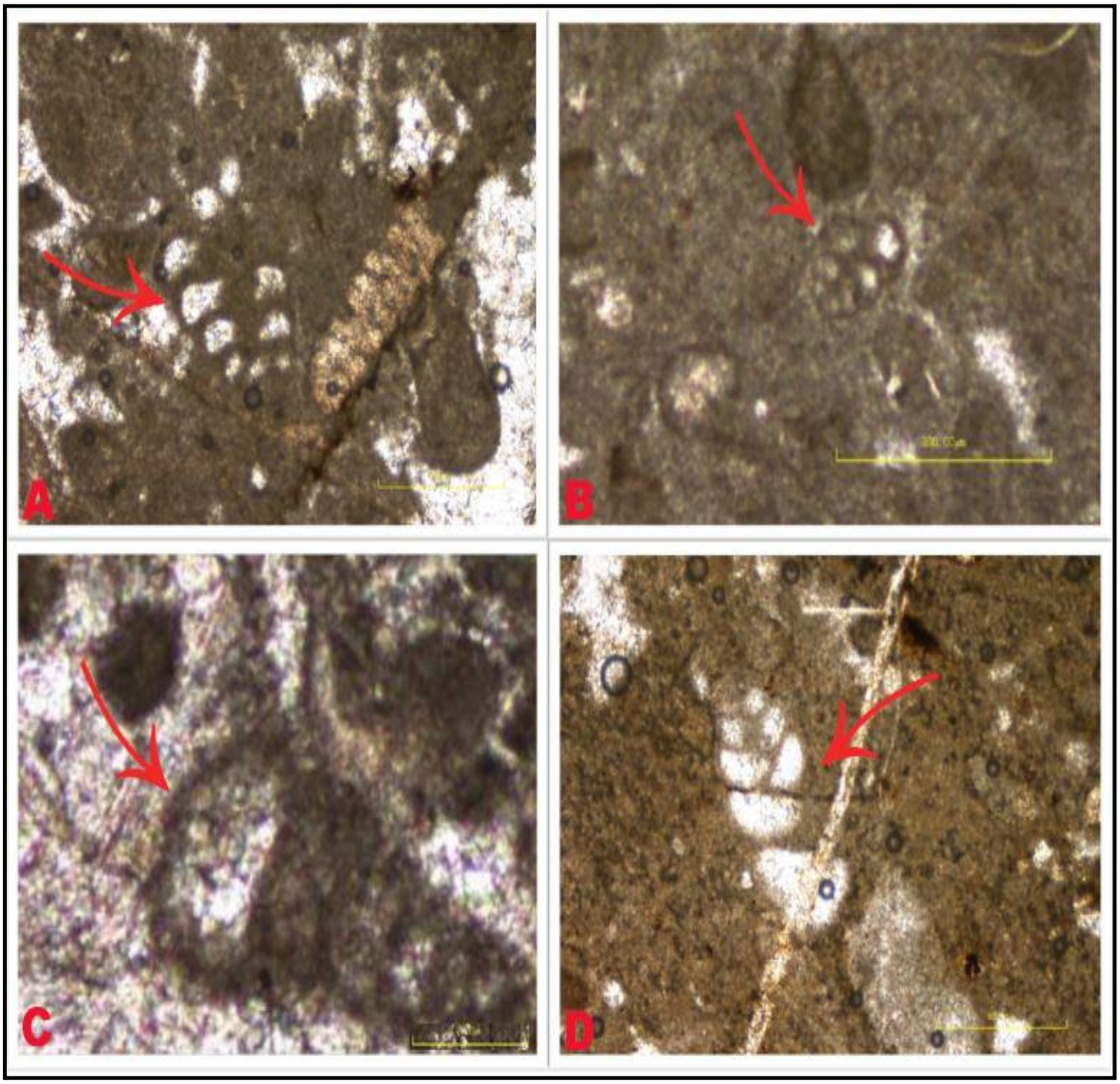

Figure 4.10. **(A),(B)** Heterohelix reussi(CUSHMAN) **(C)** Uniserial Foram **(D)** Biserial Foram.

4.2.2. Diagenetic features

4.2.2.1.Dolomitization

Dolomitization is the process in which limestone is altered into dolomite; when limestone comes into contact with magnesium-rich water, the mineral dolomite, calcium and magnesium carbonate, $CaMg(CO_3)_2$, replaces the calcite (calcium carbonate, $CaCO_3$) in the rock, volume for volume. In some samples there is an extensive dolomitization (Fig. 4.11.). This feature occurred when magnesium (Mg) replaced calcium (Ca) in limestones. It is a post-depositional alteration of limestone by magnesium-rich groundwater. Euhedral to sub-hedral rhomboid crystals of dolomite can be seen in below figure.

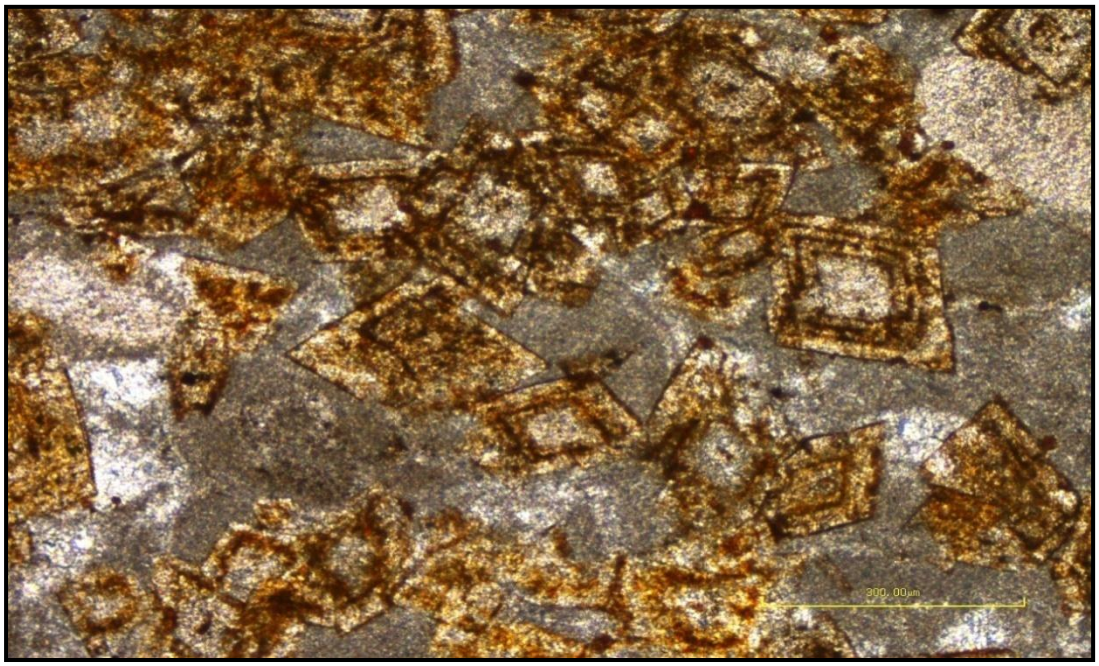

Figure 4.11. Rhomboid crystals of Dolomite in Kawagarh Formation.

4.2.2.2.Spar filled fractures

Same feature was also observed in Lockhart Formation. Firstly fractures are produced then they are filled by sparite to form veins (Fig. 4.12). Veins that are filled with calcite choke permeability in rocks.

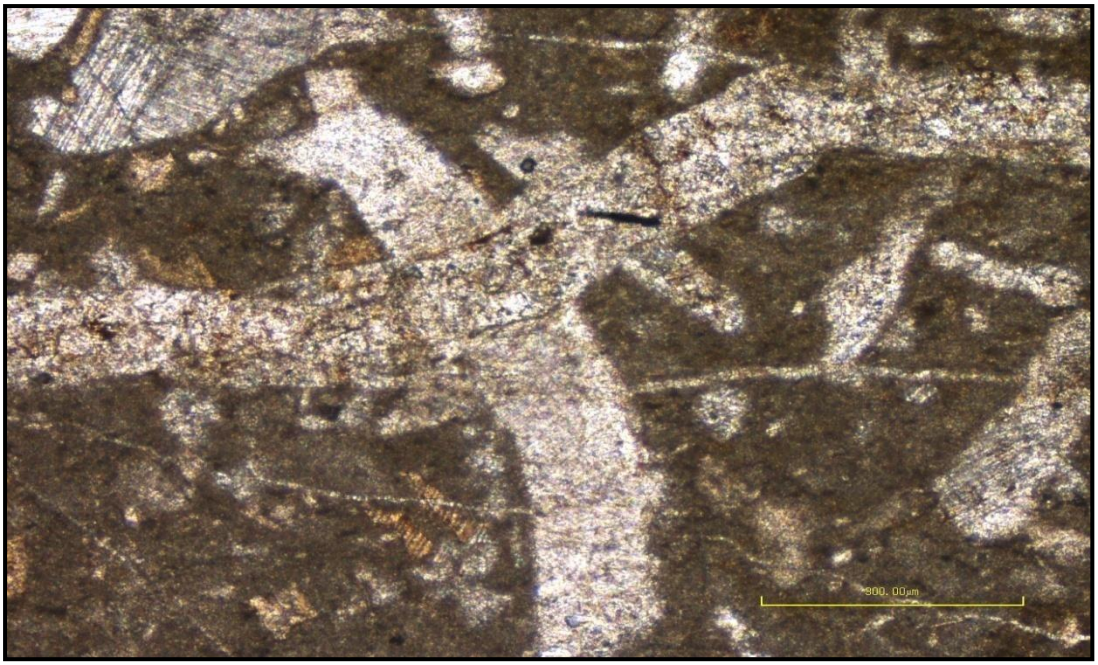

Figure 4.12. Spar filled intersecting fractures in Kawagarh Formation.

4.2.2.3.High amplitude microstylolites

Stylolites that are observed in this Formtion are of high amplitudes but stylolites having low amplitudes are also commonly found (Fig. 4.13.).

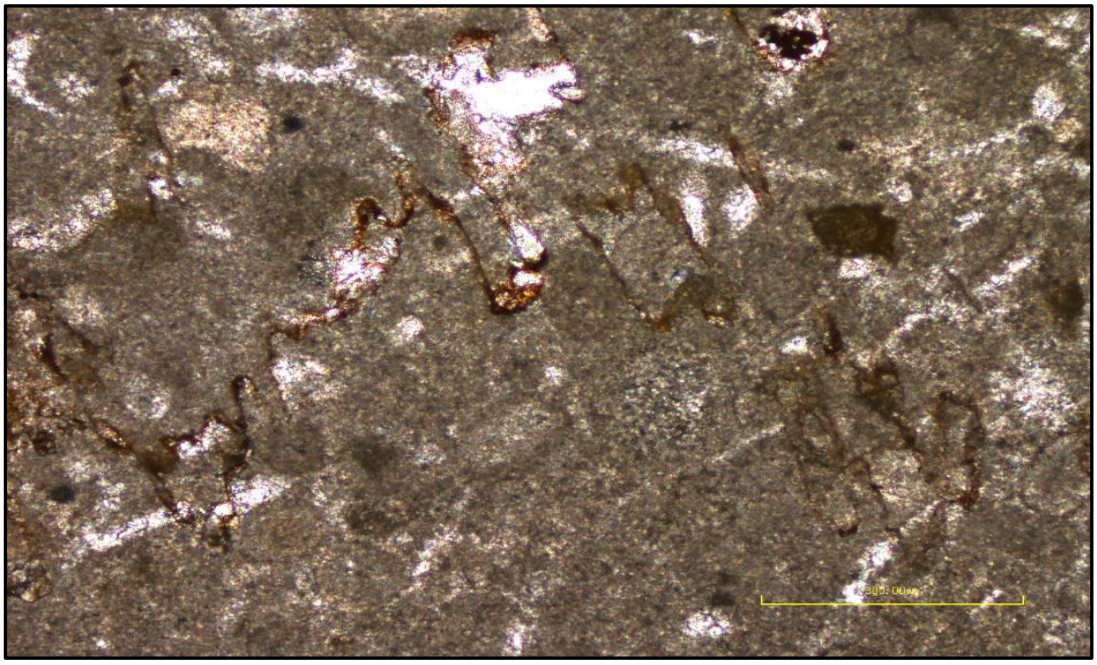
Figure 4.13. High amplitude microstylolite in Kawagarh Formation.

4.2.3. Depositional environment

Sameeni (1989) and Munir et al. (2005) stated that, on the basis of Planktonic foraminiferal genera Globotruncana, Rugoglobigerina and Heterohelix, it is determined that the Formation was deposited in outer neritic, open marine environment.

CONCLUSION AND RECOMMENDATION

Kawagarh Formation mostly have planktonic foraminifera including, Heterohelix reussi, Uniserial and Biserial Foram and in case of Lockhart Formation, larger benthic Foraminifera are common including Lockhartia, Operculina, Miscellanea and Actinosiphon. These microfossil assemblages help to identify that Kawagarh formation is deposited in outer neritic environment and Lockhart Formation is deposited in inner neritic environment. Diagenetic studies showed that both Formations are full of fractures that are developed due to extensive deformation. Hence significant secondary porosity is developed and both Formations can act as good reservoirs. The entire study confirmed that Cretaceous-Tertiary (K-T) boundary is present in Nizampur area.

Nizampur area is less explored as with respect to micropaleontology. Therefore it is recommended that more micropaleontological and petrographical works should be carried out, so that more details will be revealed.

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