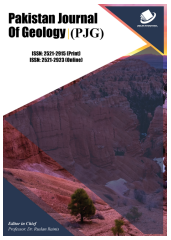
ZIBELINE INTERNATIONAL PUBLISHING

Pakistan Journal of Geology (PJG)

DOI : http://doi.org/10.26480/pjg.01.2018.21.29

Print ISSN : 2521-2915
Online ISSN : 2521-2923

CODEN: PJGABN



BENTHIC FORAMINIFERAL BIOSTRATIGRAPHY, MICROFACIES ANALYSIS AND DEPOSITIONAL ENVIRONMENT OF CHORGALI FORMATION YAADGAR SECTION, MUZAFFARABAD, PAKISTAN

Muhammad Shahid Khawaj [1*], Muhammad Faisal[2] , Qasim Ur Rehman [1], Tofeeq Ahmad[1], Salman Ahmad Khattak[1], Ahsaan Saeed[1], Muhammad Toseef Adnan[1], Irfan[1], Saif Ur Rehman[1], Iqtidar Ahmed[2], Muhammad Ishfaque[2]

[1]Department of Geology, University of Haripur, KPK, Pakistan
[2]Insitute of Geology, The university of Azad Jammu and Kashmir, Muzaffarabad, Pakistan
****Corresponding author email: shahid_wah123@yahoo.com***

ARTICLE DETAILS

Article History:

Received 12 November 2017
Accepted 12 December 2017
Available online 1 January 2018

ABSTRACT

Present study deals with microfacies analysis, interpretation of depositional environment and foraminiferal biostratigraphy of Early Eocene Chorgali Formation in Yadgar section, Muzaffarabad, Azad Jammu and Kashmir, Pakistan. Study area lies on apex of western limb of the Hazara-Kashmir Syntaxis, which is the part of North-West Himalayan Fold and Thrust Belt. The stratigraphic succession of the area is consisted of sedimentary sequences, ranging in age from Precambrian to Miocene excluding Ordovician to Cretaceous and Oligocene successions, those are marked by unconformity. Early Eocene Chorgali formation in this area is consisted of dark to reddish grey limestone, light grey dolomite, greenish grey shale intercalations, marl and argillaceous limestone. Nodulations is also present in few limestone beds. Formation was measured and described in the field. Thickness in this area is 52 meters. Detailed petrographic analysis of 15 thin sections was carried out. On the basis of fauna and lithology, four microfacies are identified, they are as followed:
1. Dolomitic Grainstone Microfacies,
2. Benthic Foraminiferal Packstone Microfacies,
3. Mixed Bioclastic Wackstone Microfacies,
4. Planktonic Mud-Wackstone Microfacies.

Allochemical constituents present in the formation include pelloids, intraclasts, extraclasts and bioclasts (Gastropods, Bivalves, Ostracods and brachiopods). Orthochemical material is mostly micrite. Spar is also present but in less amount. Foraminifera are the major fossil contents present in the Chorgali Formation and have good age diagnostic fossils. Faunal assemblages include following Genera: Assilina, Nummulites, Lockhartia, Miscellanea, Discocyclina, Operculina, Brachiopoda and Mollusks. Early Eocene age is assigned to Chorgali formation on the basis of these Larger Benthic Foraminifera i.e. Assilina, Nummulites and Lockhartia. Planktonic foraminifera are also present including Milliolids, Nodosaria and Echinoderms. But these are not studied in detail as they are not index fossil. Depositional environment is interpreted on the basis of microfacies and foraminiferal assemblages. Most part of the formation is deposited in inner shelf, while some part is deposited in middle to outer shelf. Lagoonal to tidal flat deposition is also found. Overall the formation represents the deposition in inner shelf, more specifically middle shelf to inner shelf environment.

KEYWORDS

Microfacies and Diagenetic Analysis of Lockhart Limestone.

1. INTRODUCTION

Eocene is an important Epoch for carbonate depositions in Pakistan. It was the time of marine transgression that is why it represents the period of sedimentation throughout the Indus basin. In this region, limestone and shale facies were dominated. Yadgar section lies on top most part of western limb of Hazara Kashmir syntaxes. Rocks exposed here are sedimentary, ranging in age from Cambrian to Miocene. Chorgali formation contains interbedded limestone and shale sequence. These sedimentary sequences contain many age diagnostic foraminifera. Analysis of larger benthic foraminifers (Lockhartia, Assilina, Ranikothalia, and Nummulites) indicate the sequence deposited in a Neotethys, an open sea, upper slope to outer shelf shallow marine environments [1]. Area is part of the eastern Tethyan region and was excellent for the tropical to sub-tropical marine sedimentary deposition. On the basis of the fossil assemblages Middle Eocene age of the formation is confirmed [1]. Eocene is an important Epoch for carbonate depositions in Pakistan and Chorgali formation is one of those carbonate sequences. Age of the formation on the basis of fossil assemblages is dated to be early to Middle Eocene.

Chorgali Formation lies in Cherat group, which includes Margalla Hill limestone and Chorgali formation. In the Yadgar section of Muzaffarabad, Chorgali formation is 52 meters thick. Lithologically it is composed of shale, limestone, dolomite, argillaceous limestone and marl. Microfacies analysis and field observations indicate the deposition of formation in inner shelf conditions. Present work is about identification of Microfacies of Chorgali formation, interpretation of depositional environment and its foraminiferal biostratigraphy.

2. GEOLOGICAL SETTING

Pakistan lies on the boundaries between Indo-Pakistan, Arabian and Eurasian plates. Afghan Block covers a considerable part of Pakistan's northwestern edge. Its structure is predominantly affected by interrelationships of these tectonic plates. Pakistan's tectonic is controlled by two active convergent boundaries i.e. Eurasian plate-Kohistan island

arc, Indian plate and Arabian plate subducting beneath Afghan micro palate.

Tectonically Pakistan is divided into following 5 segments;

- Northern collisional zone,
- Subduction complex association of Baluchistan
- Chaman Transform zone
- Ophiolites and ophiolitic mélanges
- Platform areas

Northern collisional zone is the part of Himalayan orogeny and Hazara-Kashmir Syntaxis lies in this zone. Pakistan is encompassed by Himalayas towards North-East, Peninsular Shield of India on the East, Arabian Sea on the South, Makran subduction zone on southwest part of Pakistan and Hindukush Mountains to the North and Northwest. The continental drift, Sea-floor spreading, and collisional tectonics are responsible for the formation of Himalayas and accretion of Indo-Pakistan sub-continent with Eurasia [2,3]. Northwestern part of Indo-Pakistan Plate is characterized by active fold and thrust belt, which can be divided into two parts i.e. Sulaiman belt and Northwest Himalayan fold and thrust belt [4].

The splitting of Super continent Pangea was started about 300-200 Ma and subsequent rifting produced major new ocean called "Tethys" which separated the Eurasia continent in the north from the Gondwana continent in the south [5]. Eurasia continent was comprised of northern Europe and Asia, while Gondwana continent was comprised of Arabia, Africa, Antarctica and Australia. Numerous small continental fragments were present between these two continents; therefore, Tethys Ocean was subdivided in to northern ocean called "Neo-Tethys" and Southern Ocean known by "Paleo-Tethys [5]. The collision between Indian plate and Kohistan-Ladakh Island Arc occurred in the Eocene as the Neo-Tethys Ocean closed [6]. This was the time of Himalayan orogeny.

Northward under thrusting of Indian plate beneath Eurasian palate is still in progress, this under thrusting forms the major tectonic fabric of northern Pakistan that includes the Main Karakoram Thrust (MKT) or Shyok suture zone which separates rocks of Eurasian plate from the rocks of Kohistan Island Arc, Main Mantle Thrust (MMT) or Indus suture zone which brings the rocks of Kohistan Island Arc on top of Higher Himalayan rocks belonging to the Indian Plate, Main Central Thrust (MCT) Separating rocks of Higher Himalayas from Lesser Himalayas and Main Boundary Thrust (MBT) is present between rocks of Lesser Himalayas and Sub Himalayas and Salt Ranges Thrust (SRT) [7].

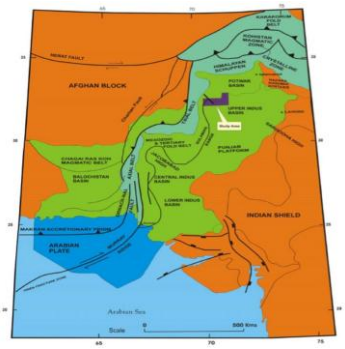


Figure 1: Geological map of northern Pakistan showing major structure boundaries, the study area is indicated by diagonal ruling.

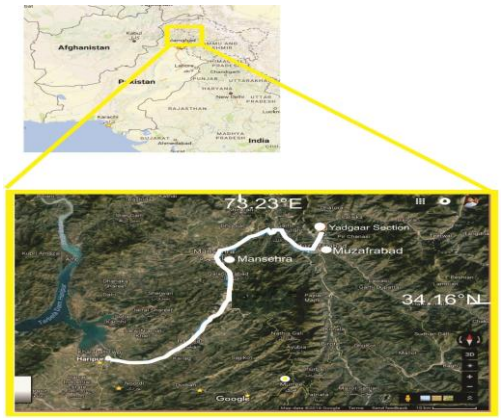


Figure 2: Accessibility map of study area, black box shows the study area.

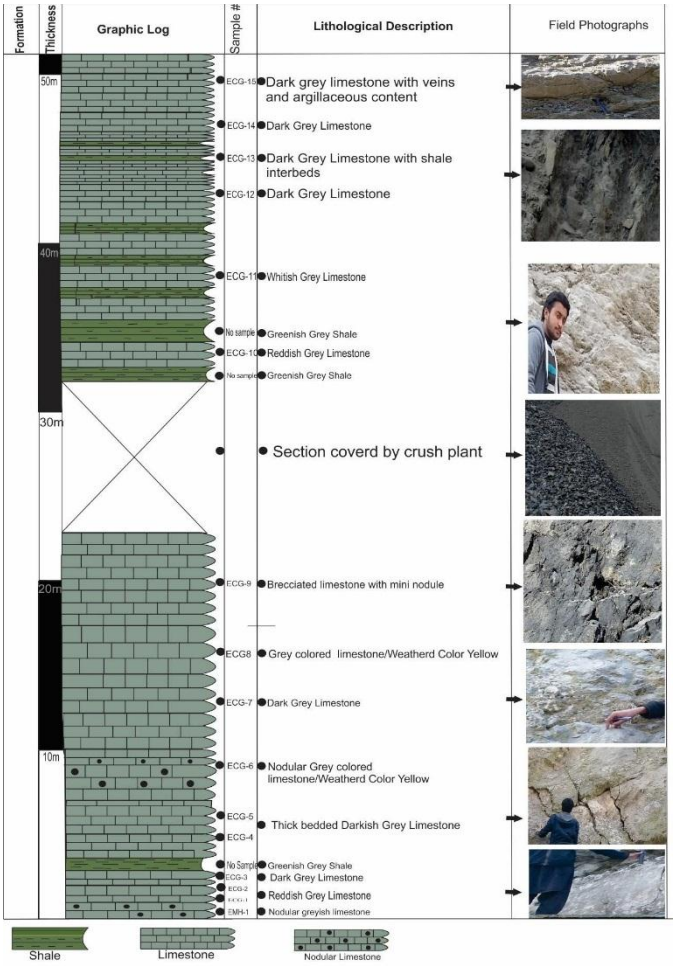


Figure 3: A brief description of the stratigraphy involved in Yadgar Section, Muzaffarabad.

3. METHODOLOGY AND DATA

3.1 Methodology that was applied is as follows:

- Instruments used for field work were G.P.S, geological hammer, 10 % dilute HCL, Measuring tape, Jacob Staff, Brunton Compass and hand lens.
- Section was inclined, so older to younger sequence was from left to right.
- Vegetated and under debris part of the Chorgali formation is considered as cover and included in stated thickness.
- Systematic sampling was done, at least one sample was taken from each bed irrespective of the thickness of beds.
- 30 samples were taken, 1 sample from Margalla hill limestone and 1 from Kuldana formation.

3.2 Lithological log was prepared

- 15 Polished Thin sections were prepared.
- Prepared thin sections were then studied under polarizing microscope for microfacies analysis and biostratigraphy.

3.3 Microfacies Analysis and Depositional Environment

The term facies were first used by Swiss geologist, Gressly in 1838, as part of his contribution to the foundations to modern stratigraphy. The same approach is used for environmental interpretation of carbonate rocks as for Siliciclastic rocks. The characteristics of a rock or sediment unit that reflect its environment of deposition and allow it to be distinguished from rock or sediment deposited in an adjacent environment [8].

The term facies are defined as "The sum of the characteristics of sedimentary units resulting from some particular set of physical, chemical and biological parameters that work to produce a unit with specific textural, structural and compositional properties. According to a study, facies are defined as "Any lithological, structural and organic aspect of rock which can be noticeable on field" [9]. Other researcher defines that "The nature of material deposited anywhere will be determined by the physical,

chemical, biological processes which have occurred during the formation, transport and deposition of sediment, these processes also define environment of deposition" [8]. As originally defined by a researcher and again independently by the other, the term 'micro- facies' referred only to petrographic and paleontological criteria studied in thin-sections [10]. Today, however, Microfacies is regarded as the total of all sedimentological and paleontological data which can be described and classified from thin sections, peels, polished slabs or rock samples. The Microfacies of carbonate rocks are identified by studying thin sections. Like lithofacies, microfacies are defined by a set of particular characteristics, but in this case the data is obtained from thin sections, peels and polished slabs. Microfacies mainly involves determination of composition and texture of limestone.

3.4 Outcrop Characteristics

Three lithofacies were identified of Chorgali formation at Yaadgar formation:

1. Greenish Grey Shale
2. Bedded Limestone
3. Nodular Limestone

At outcrop, the Chorgalli formation at Yadgaar section comprises of medium bedded reddish grey limestone at the base overlying nodular dark greyish Margalla Hill limestone, then medium to thick bedded limestone dark grey limestone overling the reddish grey limestone, and then a patch of shale is encountered that is greenish grey in colour. Above the Patch of shale is thick bedded darkish grey limestone whose weathered color is light brown. After that medium to thick bedded dark grey nodular limestone is present whose weathered colour is yellow and then thick bedded dark grey limestone above which nodular grey limestone with mini nodules is encountered and is brecciated a bit. After that brecciated limestone with mini nodules is greenish grey shale above which reddish grey limestone with shale interbeds is present and is overlain by dark grey limestone with shale interbeds is present and at top dark grey limestone with argillite is presents.

3.4.1 Microfacies Analysis

For studying Microfacies, 30 samples were collected from study area (Yaadgar Section) and thin section were prepared from 15 samples. Description of Microfacies is based upon the petrographic study of thin sections. The Microfacies study includes allochems, cementing material, matrix and textural features. The abundance, type and size foraminifera, skeletal grains and non-skeletal grains percentages that provide useful information for interpretation of environment of deposition.

3.5 Microfacies of Chorgali Formation

Based upon field data and petrographic studies, four Microfacies were recognized in Chorgali formation Yaadgar Section, Muzaffarabad, Azad Jammu and Kashmir (UAJK). These facies are compared with some other study and each facie represent specific environment of deposition [11].
Following are the four facies that were identified while studying Chorgali formation at Yaadgar section petrographically:

1. Benthic Foraminiferal Packstone Facie (ECF-1)
2. Bioclastic Wackestone Facie(ECF-2)
3. Planktonic Mudstone-Wackestone facie (ECF-3)
4. Dolomitic Grainstone Facie (ECF4)

The ECF stands for Eocene Chorgalli Facie. The description of the microfacies is as follows:

3.5.1 Benthic Foraminiferal Packstone Facie (ECF-1)

At outcrop Benthic Foraminiferal Packstone Facie is represented by thick to medium bedded dark grey limestone with visible foraminifera The Microfacie has a total thickness of 8.5m and is repeated one time in the section. The Microfacies ECF-1 is recorded in thin section ECG3, ECG-4, ECG-5 and ECG-7. Petrographically the Microfacie comprise 70% of allochems and contain benthonic forams (Assilina, Nummilites, Lokhartia, Operculina), and skeletal material is present in less amount. In Thin Section skeletal material is destroyed due to diagentic activity. The facie is dominated by benthonic foraminifera, among which Assilina is most abundant and then Nummilites and Lokhartia. Cementing material is micrite. Microfacies is shown in Plate 1.

Interpretation: The facie indicates deposition in medium to high energy and shallow water as it contains variety of benthic foraminiferal fossils. The facie represent deposition in middle to high energy and in inner shelf. It is similar to SMF-18 Microfacie of a scientist [11].

3.5.2 Bioclastic Wackestone Facie (ECF-2)

At outcrop Bioclastic Wackestone Facie is represented by medium to thick bedded nodular grey coloured limestone whose weathered coloured is yellow. The Microfacie has a total thickness of 13m and is repeated one time in the section. The Microfacie ECF-2 is recorded in thin section ECG-6, ECG-8 and ECG-9. Petrographically the Microfacie is composed of 30% of allochems that includes 10% benthonic forams (Lokhartia, Nummilites and Assilina), 10% Planktonic forams and 10% of other bio-clasts i.e. Gastropods shells, Echinoderms and Bivalves. Cementing material is micrite, which is converted to spar in some amount. Microfacies are represented in plate 2.

Interpretation: The facie represent deposition in moderate energy condition and in middle shelf as it contains planktons, benthic, bivalve and echinoderms. The facie resembles SMF-9 of a study [11].

3.5.3 Planktonic Mudstone-Wackestone facie (ECF-3)

The facie on outcrop is represented by interbedded shale and limestone. The Microfacie was recorded in thin section ECG-12, ECG-13 and ECG-14. The facie has a total thickness of 7m and is not repeated in the section. Petrographically the facie is composed of 8-20 percent of allochems with an average 14% of allochems. Cementing material is micrite, and is converted to spar in some amount. Allochemical material is planktonic forams and some skeletal fragments are present. Cementing material is micrite. Veins are also present in it. Microfacies are shown in plate 3.

Interpretation: Abundance of Micritic matrix suggests deposition in low energy. Facies resembles SMF-3 of Flugel, 2004 and appears to be deposited in outer shelf.

3.5.4 Dolomitic Grainstone Facie (ECF-4)

At outcrop ECF-4 is represented by thin bedding and has reddish grey color in lower and middle part and dark grey in the upper part. The Microfacie ECF-4 is recorded from thin section ECG-1, ECG-2, ECG-10, ECG-11 and ECG-15. Petrographically the facie is comprised of 73% grains that are dolomitized mostly, very rare destroyed fossils are present. Microfacies is represented in plate 4.

Interpretation: The facies seems to be deposited in high energy conditions of middle-outer shelf.

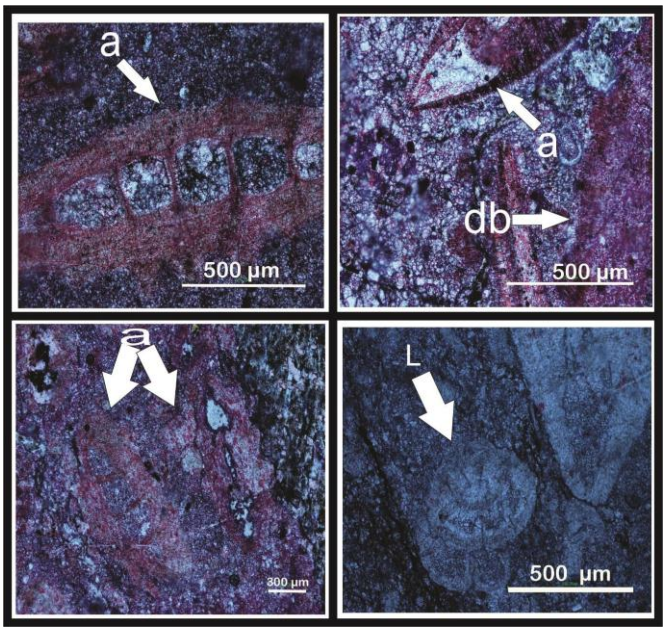


Plate 1: Microphotographs of Benthic Foraminiferal Packstone Facie (ECF-1) (a) Assilina, (L) Lokhartia, (db) micritized bioclast

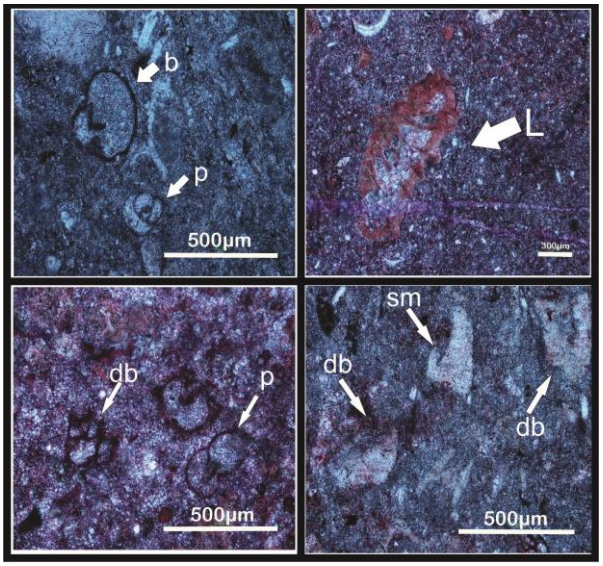


Plate 2: Microphotographs of Mixed Bioclastic Wackestone Facie (ECF-2) (b) Bivalve, (p) Plankton, (L) Lokhartia, (bioclast with internal structure destroyed), (sm) Skeletal Material

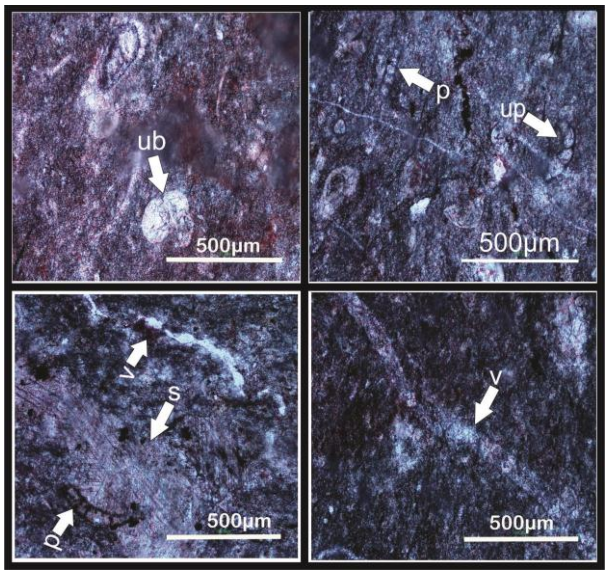


Plate 3: Photomicrograph of Planktonic Mudstone-Wackstone Facie (ECF-3) p (plankton), (ub) unidenfiable bioclast, s (micrite converted to spar), v (vein), up (uniserial planktonic foraminifera).

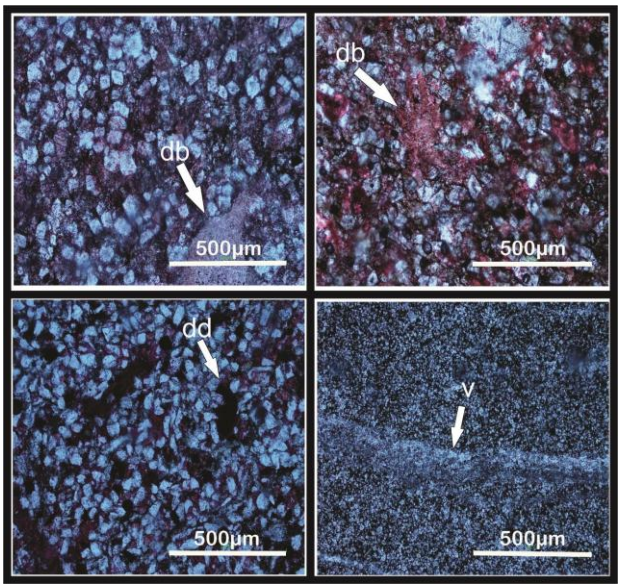


Plate 4: Photomicrograph of Dolomitic Grainstone Facie (ECF-4) db (bioclast with internal features destroyed), dd (de-dolomitization), v (vein)

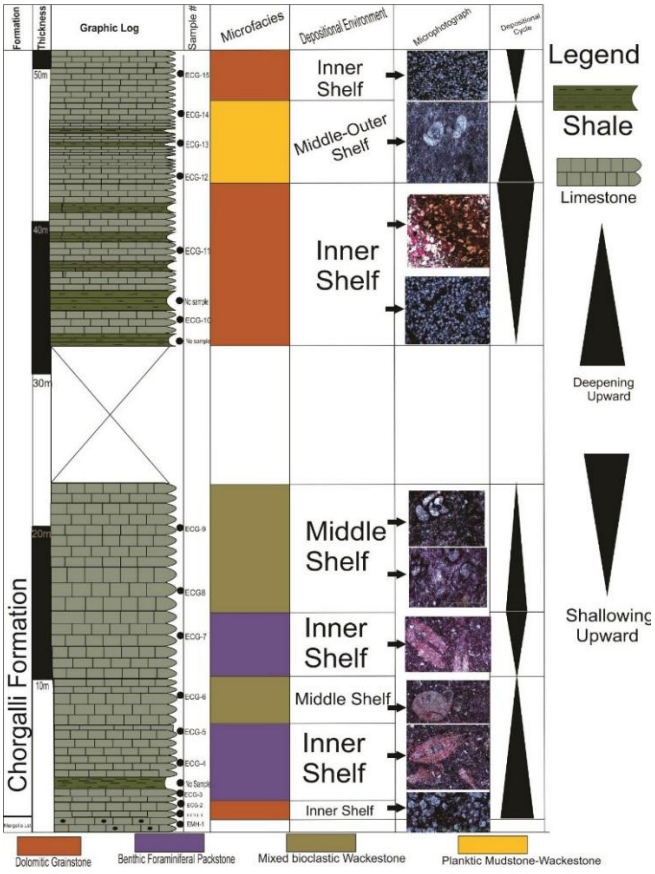


Figure 4: Litholog showing Microfacies and their Cyclicity.

4. DEPOSITIONAL ENVIRONMENT

4.2 Introduction

Every environmental setting has certain chemical, physical and biological characteristics, which control sedimentation and are diagnostic of those particular conditions. The major physical and chemical controls are water depth, salinity, temperature, light penetration, nutrient supply, amount of clastic sedimentation and degree of calcium and magnesium [12]. As every depositional environment has specific controlling factors of sedimentation and faunal diversity, so identification of microfacies and fossils is criteria to interpret the depositional environment of given depositional environment [13].

4.3 Depositional Environment of Chorgali formation

The constituent elements, Vertical distribution of microfacies and interpreted depositional environment of individual microfacies of chorgali formation indicate deposition in Shallow marine [14-20]. Mostly sediments are deposited in tidal flat to middle shelf, while to some extent in outer shelf. The source of carbonate deposition of the Chorgali Formation was depending upon the organically derived particles (larger benthic foraminifera, algae and gastropods).

Deposition of chorgali formation initiated with dolomitic grainstone in tidal flat to inner shelf. Followed by prolonged marine transgression, during which packstone accumulated in inner shelf as it contains extraclasts and skeletal grains showing agitated condition; this packstone exhibit high diversity of benthic foraminiferas [21-23]. During this time, sea level continued to rise and wackstone deposited on middle shelf in stormy condition as indicated by aggregate of benthic foraminiferas, few plankton species and extra-clasts. Later on, sea level fall for short period of time during which benthic foraminiferal packstone formed on inner shelf.

Sea level started to rise again, during which mixed bio-clastic wackstone deposited on middle to outer shelf because in some parts planktons to benthons ratio is greater than other parts. After that, marine regression happened for longer time, during which dolomitic grainstone accumulated in tidal flat to lagoonal environment as it contains stylolite and lacks fossils. It was 1st complete cycle of sea level [24].

2nd cycle started, and Marine Transgression resulted in deposition of Planktonic mud-wackstone on middle to outer shelf [25-28]. Followed by marine regression, in which dolomitic grainstone formed in tidal flat, which is unfossiliferous.

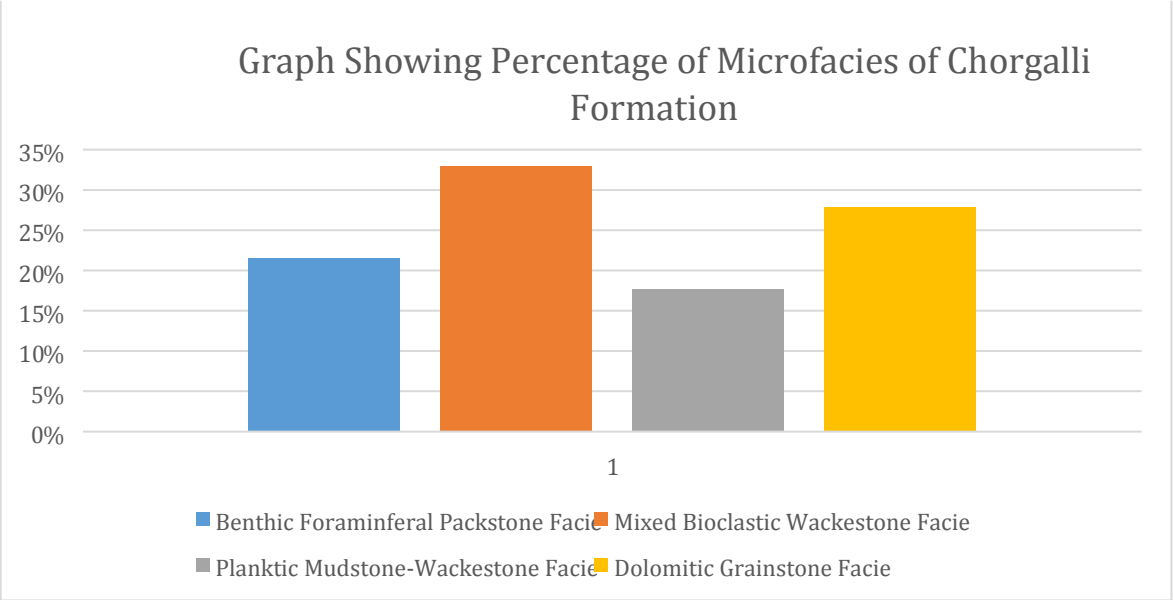


Figure 5: Graph showing percentages of Microfacies of Chorgali formation at Yaadgar Section, AJK

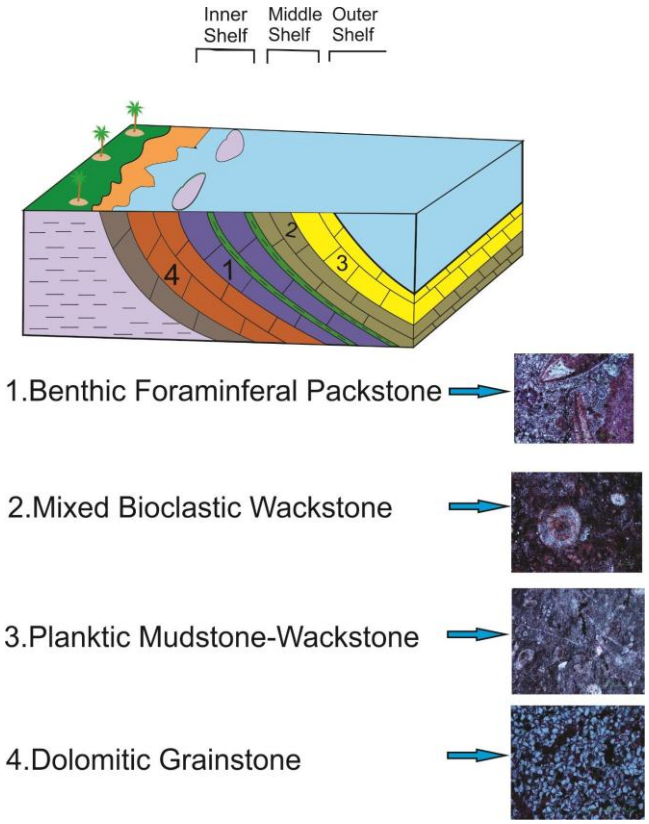


Figure 6: Depositional Model of Chorgali formation at Study Area.

5. BIOSTRATIGRAPHY

5.1 Introduction

The characterization and correlation of rock units on the basis of their fossil content is called biostratigraphy. Fossil organisms have important role in stratigraphy. Sedimentary rocks are subdivided into identifiable stratigraphic (biostratigraphic) units on the bases of information provided by fossils [29,30]. In addition, they make possible the ordering and relative age dating of strata and their correlation on both a continental and (in some cases) a global scale. Stratigraphy based on the paleontologic characteristics of sedimentary rocks is also referred to as stratigraphic paleontology, the study of fossils and their distributions in various geologic formations.

Organisms have undergone successive changes throughout the geologic time, this principal provides the base for concept of biostratigraphy [31]. Thus, dating and characterization of any unit of strata can be done by its fossil content, as well as this stratigraphic unit can be differentiated from stratigraphically younger and older units.

Separation of rock units on the basis of fossil content may or may not yield stratigraphic units whose boundaries coincide with the boundaries of lithic stratigraphic units. Biostratigraphic units and lithostratigraphic units such as formations commonly can be subdivided by distinctive fossil assemblages into several smaller biostratigraphic units [32-36]. Indeed, one of the primary objectives of biostratigraphy is to make possible differentiation of strata into small-scale subunits or zones that can be dated and correlated throughout wide geographic areas, allowing interpretation of Earth history within a precise framework of geologic time [37-46]. We identified following major genera:

1. Assilina
2. Lockhartia
3. Nummulites
4. Operculina
5. Ranikothalia
6. Mollusks
7. Brachiopoda

5.2 Systematic paleontology

The larger benthic foraminifers are the dominant biota in the Chorgali Formation. Foraminifera are small, predominantly marine heterotrophic protists that construct chambered shells (tests). The group belongs to the phylum Sarcodina and the class Rhizopoda [33]. Similar to calcareous algae, foraminifera are of prime importance in microfacies analyses. Foraminifera provide time markers for biozonations of shallow and deep marine carbonates [47].

Genus: Nummulites Lamarck, 1801

Kingdome: Animalia
Phylum: Protozoa
Class: Sarcodina
Order: Foraminifera
Superfamily: Nummulitoidea
Family: Nummulitidae

Species of Genus Nummulites

Nummulites mamillatus (Fichtel and Moll)

(Plate 5.1 a)
1798. Nautilus mamilla Fichtel & Moll, Testacea Microscopica", p. 53-54; pl. 6, Figs. a-d
Age: Eocene
Remarks: It is characterized by strongly biconvex shell and thick wall, chambers are narrowly spaced. Nummulites mamillatus (Fichtel and Moll)

and Nummulites globulus Leymerie appears as same species. However, the topotype material of both species should be examined to determine the actual taxonomy. It is found lower to middle part of formation. Present in abundance.

Nummulites atacicus Leymerie

(Plate 5.1 c)
1846. Nummulites atacicus Leymerie, Memoirs of the Geological Society of France, Vol.
I (2), p. 358359; pl. 13, Figs. 13a-13e
Age: Eocene
Remarks: its test is lens like. Having 3 to 5 chambers, greater distance between successive chambers. It is present in lower and middle part.

Nummulites djodjokartae MARTIN, 1881

(Plate 5.4 c)
Nummulites djodjokartae Martin,K, 1881. Tertiaer Versteinerungen von OstlichenJave.
Sammlungen des Geologischen Reichsmuseums in Leiden
1: 105-130.
Age: Eocene
Remarks: have very thick thick chamber walls, and lesser chambers than all nummulites.
It is found in lower part of formation, Rarely found.

Genus: Assilina d'Orbigny, 1826

Species of Genus: Assilina

Assilina Dandotica (Davies, 1937) [13]

(Plate 5.3 a)
Assilina dandotica Davies, L. M. and Pinfold (1937), The Eocene beds of the Punjab Salt Range. Geol. Surv. Mem., Paleont. Indica, New series, V. 24 (1), p. 79.
Age: Late Paleocene to Early Eocene
Remarks: Test is lenticular to discoid, central portion is thick, having sharp periphery. Shell contains few granules unlike other forms of Assilina. It is present in abundance, from lower to middle part of formation.

Assilina granulosa (d'Archiac)

(Plate 5.2 a)
1848. Nummulites granulosa d"Archiac (pars); d"Archiac, Geological Society of France
Memoir (2), Vol. 3, p. 415-416; pl. 9, Fig. 21
Age: Late Paleocene to Early Eocene
Remarks: Assilina granulosa (d"Archiac) is characterized by heavily granulated surface with distinct septal ridges. And spines are absent. And it is pinched in middle part. It is present in lower part of formation.

Assilina laminosa Gill

(Plate 5.3 b)
1953. Assilina laminosa Gill; Gill, Contributions of Cushman Foundation, Foraminiferal
Research, Vol. 4, Pt. 2, p. 83, pl. 13, Fig. 15
Age: Early Eocene
Remarks: Assilina laminosa Gill is characterized by internally laminated shell wall. It lacks spines and granules. It is found in lower to middle part of formation.

Assilina subspinosa Davies and Pinfold

(Plate 5.2 c)
1937. Assilina subspinosa Davies and Pinfold, Geological Survey of India, Paleontologica
Indica, New Series, Vol. 24, Memoir 1. p. 33-34, pl. 4, Figs.
19-20, 23-26
Stratigraphic range: Upper Palaeocene to Early Eocene.
Remarks: Assilina subspinosa and Assilina spinosa of Davies and Pinfold (1937) are ornamented with granules which give spinose appearance. Assilina subspinosa don't have central depression, this feature differentiates it from Assilina spinosa. It is present in lower to middle part of formation.

Assilina spinosa Davies and Pinfold

(Plate 5.2 b)
1937. Assilina spinosa Davies and Pinfold, Geological Survey of India Memoir, Paleontogica Indica, New Series, Vol. 24, Memoir 1, p. 31-33, pl. 4, Figs. 11-12, 16-17
Age: Early Eocene
Remarks: Assilina spinosa Davies and Pinfold is distinguished from Assilina subspinosa
Davies and Pinfold by its central depression in addition to having their different stratigraphic ranges. It has sharp spines than sunspinosa. It is spread from lower to middle part of formation.

Genus: Operculina

(Plate 5.1 d)
Age: Paleocene to Recent.
Remarks: It has planispiral evaluate shell. Every succeeding chamber is bigger than previous chamber. It is present in middle part.
Genus: Discocyclina Gumbil, 1868
Super family: Orbitoidacea
Family: Discocyclinidae

Species of Genus Discocyclina:

Discocyclina Ranikotensis
(Plate 5.1 b)
Age: Late Paleocene to Early Eocene
Remarks: Test is discoidal to lenticular, having less granules on shell surface. It is very rare, present only in middle part.

Genus Miscellanea Pfender, 1935, emend. Smout, 1954.

Superfamily: Nummulitoidea
Family: Miscellaneidae

Species of Genus Miscellanea:

Miscellanea Miscella (d' Archiae and Haime, 1853)
(Plate 5.4 d)
Age: Paleocene to Lower Eocene
Remarks: its test is lenticular having broadened and thickened margin. Chambers are involute. It is found in lower middle part of formation.

Genus: Lockhartia Davies, 1932

Kingdom: Animalia
Phylum: Protozoa
Class: Sarcodina
Order: Foraminifera
Superfamily: Rotaliacea
Family: Rotaliidae

Species of Genus Lockhartia

Lockhartia conditi (Nuttall)

(Plate 5.3 c)
1926. Dictyoconoides conditi Nuttall, Geological Magazine, London, Vol. 63, p. 119, 498; pl. 11, Figs. 7-8
Stratigraphic range: Late Paleocene to Early Eocene. It is in abundance, as it is found in lower to middle part of formation.
Remarks: Lockhartia conditi (Nuttall) is characterized by high trochospiral shell with few thick pillars on the umbilical side. Ornamentation is absent. Base is faintly convex while magin sub acute. Lockhartia conditi (Nuttall) is distinguished from Lockhartia tipperi (Davies) by its high trochospiral shell.

Lockhartia haimei (Davies)

(Plate 5.3 d)
Lockhartia haimei (Davies) Davies & Pinfold 1937. Mem. Geoi. Surv. India, Pal. Indica, New Series, vol.24 (1), pl.7, figs.9-13, 15.
Age: Upper Paleocene
Remarks: In dorsal view it is conical having apical angle of 120^0. Indistinct ornamentations of the apical angle. In axial section chambers are evolutes. Rarely found, in lower and middle part.

Lockhartia tipperi (Davies)

(Plate 5.4 a)
1926. Conulites tipperi Davies, Geological Survey of India, Records, 59, p. 247-248; pl.

18, Fig. 8
Stratigraphic range: Late Palaeocene to Early Eocene.
Remarks: Lockhartia tipperi (Davies) is characterized by low trochospiral shell with rounded peripheral margin and umbilical pillars. Apical angle is 180^0. Dorsal surface is ornamented. It is present in lower part of formation.

Lockhartia Conica (Smout 1954)

(Plate 5.4 b)
Age: Paleocene to early Eocene
Remarks: Test is conical, the diagnostic of this specie. Sutures are visible while perforation and dorsal ornamentation is absent in the shell. Radial sutures are straight. Very rare, present only in one bed in lower part.

Fauna other than Benthic Foraminifera:

Other than foraminifera, there are many other faunal assemblages present in chorgali formation. They're not age diagnostic fossils, as their stratigraphic range is very large.
They are as follow:

Echinoderms: Their age range from Cambrian to recent. Fossil have radial symmetry, lack body segmentation and have spiny skin.

Gastropods: Their age varies from Cambrian to recent. They have uni-valved coiled shell, either planispiral or trochospiral.

Bivalve: stratigraphic range is from Cambrian to recent. They have oval shape shell, comprised of two valves. Both valves are equal in shape and size.

Brachipods: Their age ranges from Cambrian to recent. They have two valved shell that are unequal in shape and size.

Nodosaria: Age varies from Triassic to Recent. It is multi-chambered trochospiraly / serialy arranged.

Miliolid: Their age varies from Triassic to Recent. They are multi-chambered, spirally or cyclically arranged.

Larger benthic foraminifera distributed throughout the Chorgali Formation indicate Early Eocene age. As in the base we have only Assilina and Nummulites, which indicates that deposition of Chorgali formation iniated in Early Eocene time.

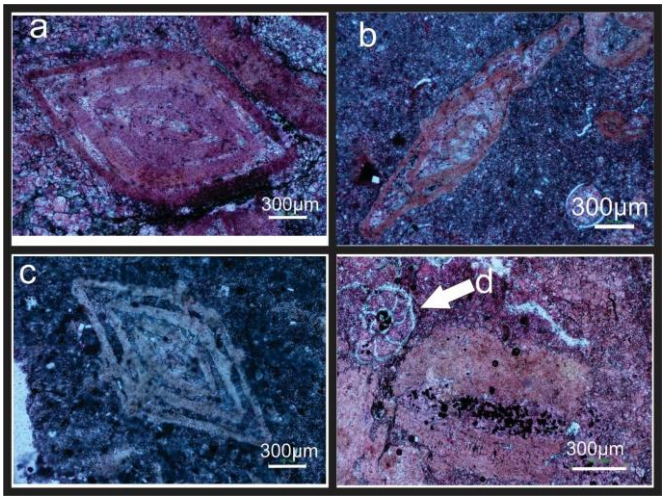


Plate 5: a) Nummulites Mammilatus, b) Discocyclina ranikotensis, c) Nummulites Atacius, d) Operculina

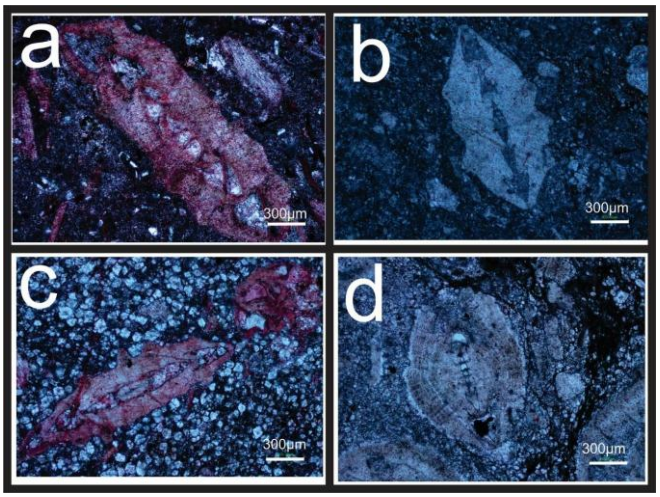


Plate 6: a) Assilina Granulosa, b) Assilina Spinosa, c) Assinilna Subspinosa, d) Genus Assilina

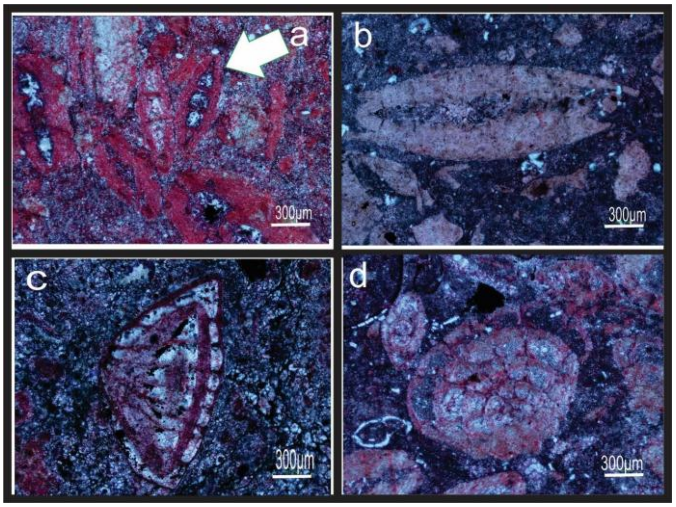


Plate 7: a) Assilina Dandotika, b) Assilina Laminosa, c) Lockhartia Conditi, d) Lockhartia Haimei

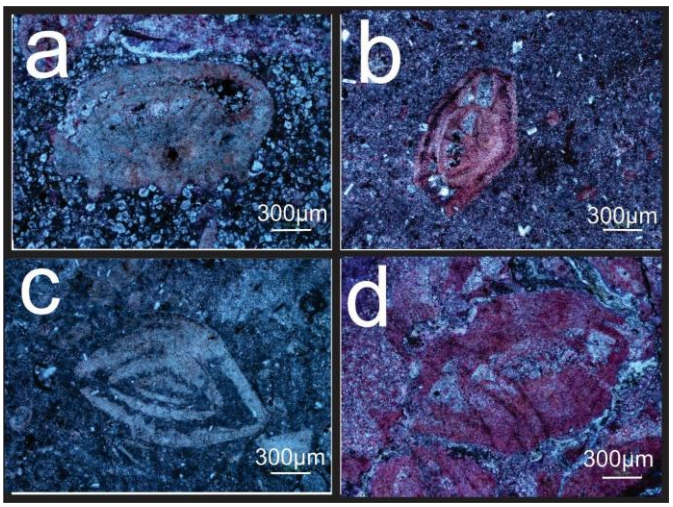


Plate 8: a) Lockhartia Tipperi, b) Lockhartia Conica. c) Nummulites djodjokartae, d) Miscellanea Miscella

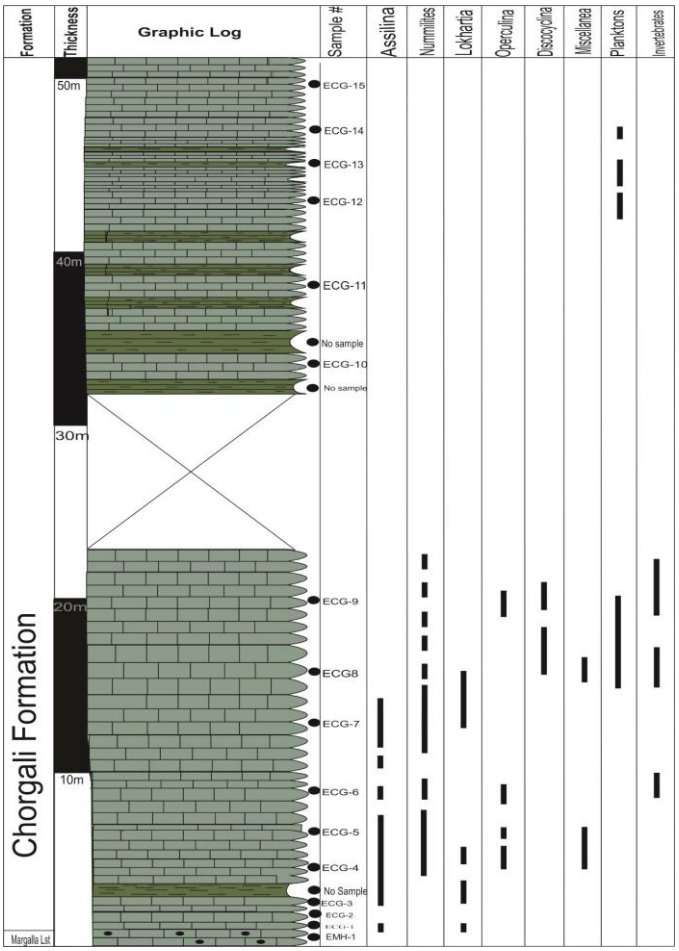


Figure 7: Litholog showing distribution of fossils

6. DISCUSSION

The microfacies identification and interpretation shows that the Lockhart Limestone represents deposition in near-shore, inner to middle shelf environments, (Figure 5). Sea level changes control the distribution of microfacies, which reveal the onset of shallow marine conditions. During sea level still-stand the Foraminiferal Wackestone/Biomicrite Microfacies was deposited. Times of gradual sea level rise are associated with the deposition of Mixed Bioclastic Mudstone Microfacies. The Algal Foram Wackestone in the middle of the Lockhart Limestone indicates sea level fall and inner shelf subtidal settings.

ACKNOWLEDGEMENT

I am special thankful to my all friends and family member which help me during my research work. I am special thanks to faculty and Department of Geology, University of Haripur, Pakistan.

Funding Information: The funding for this research is provided by the Department of Geology, University of Haripur, Pakistan.

Ethics: This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved in this manuscript.

REFERENCES

[1] Baig, M.S., Munir, M.H. 2007. Foraminiferal biostratigraphy of Yadgar area, Muzaffarabad Azad Kashmir, Pakistan. Journal of Himalayan Earth Sciences, 40, 33-43.

[2] Kazmi, A.H., Abbas, S.G. 2001. Metallogeny and mineral deposits of Pakistan. Graphic publishers, Karachi, 47-58.

[3] Coward, M.P., Windely, B.F., Broughton, R., Luff, I.W., Peterson, M., Pudsey. Rex, D., Asif, M.A. 1986. Collision tectonics in the NW Himalayas. In: Coward, M. P. and Ries, A.D. (eds). Collision tectonics. Geological Society special publication, London, 19, 201.

[4] Kazmi, A.H., Jan, M. Q. 1997. Geology and tectonics of Pakistan. Graphics Publishers, Karachi, Pakistan., 1-545.

[5] Smith, A.G., Hurley, A., Briden, J.C. 1981. Phanerozoic Paleo continental world maps. Cambridge Unvi. Press, 102.

[6] Tahir, R.A.K., Jan, M.Q. 1979. Geology of Kohistan, Karakoram, Himalaya, northern Pakistan. Geological Bulletin University of Peshawar, 11, 1-30.

[7] Seeber, L., Armbruster, J. and Quitmeyer, R. C. 1981. Seismotectonics of Pakistan. A review of results from network data and implications for central Himalaya. Geological Bulletin University of Peshawar, 13, 151-168.

[8] Nicholes, G.J., Fisher, J.A. 2007. Process, facies and architecture of fluvial distributary system deposits. Sedimentary Geology, 195, 75-90.

[9] Middleton, G.V. 1973. Johannes Walther's law of correlation of facies. Bulletin of the Geological Society of America, 84, 979-988

[10] Brown, S.1943. Suggested use of the word microfacies. Economic Geology, 38, 325, New Haven.

[11] Benchilla, L., Swennen, R., Akhtar, K., Roure, F., 2002. Sedimentology and diagenesis of the Chorgali Formation in the Potwar Plateau and Salt Range, Himalayan foothills (NPakistan). AAPG Hedberg Conference, Palermo- Mondello, Sicily, Italy.

[12] Flügel, E. 2004. Microfacies of Carbonate Rocks: Analysis, Interpretation and Application. Springer-Berlin, Heidelberg, New York.

[13] Flügel, E. 1982. Microfacies Analysis of Limestone, Springer-Verlag, Berlin, 633.

[14] Bossart, P., Ottiger, R. 1990. Rock magnetic properties and structural development in the core of the HazaraKashmir Syntaxis, NE Pakistan. Tectonics, 9 (1), 103-121.

[15] Bossart, P., Dietrich, D., Greco, A., Ottiger, R., Ramsay, J.G. 1988. The tectonic structure of the Hazara-Kashmir Syntaxis southern Himalayas, Pakistan. Tectonics, 7, 273-297.

[16] Bossart, P., Dietrich, D., Greco, A., Ottinger, R., Ramsay, J.G. 1984. A new structural interpretation of the Hazara Kashmir Syntaxis, Southern Himalayas, Pakistan. Kashmir journal of geology, 2, 19-36.

[17] Calkins, J.A., Offield, T.W., Abdullah, S.K.M., Ali, S.T. 1975. The Geology of the Southern Himalayas in Hazara Pakistan and adjacent areas. United States Geological Survey Professional Paper, 716-c, 29.

[18] Coward, M.P., Butler, R.W.H., Cambers, A.F., Graham, R.H., Izatt, C.N., Khan, M.A., Knipe, R.J., Prior, D.J., Treloar, P.J., Williams, M.P. 1988. Folding and imbrication of Indian crust during Himalyan collision. Philosophical Transaction of Royal Society of London, 144, 377-391.

[19] Davies, L.M., Pinfold, E.S. 1937. The Eocene beds of the Punjab Salt Range. Geological Survey of India, Mem, Palaeont. Indica, New series, 24 (1), 79.

[20] Durrani, M.M. 1999. Microfacies and environment of deposition of Chorgali formation, Chorgali pass, Khair-e-Murat range, Punjab, Pakistan. Department of geology, university of Peshawar.

[21] Eames, F.E. 1952a. A contribution to the study of Eocene in western Pakistan and western India, Part A., The geology of standard sections in western Punjab and in the Kohat district. The Quarterly journal of the Geological Society of London, 107 (2), 159-172.

[22] Eames, F.E. 1952b. A contribution to the study of Eocene in western Pakistan and western India, Part B., Description of the faunas of certain standard section and their bearing on the classification and correlation of the Eocene in Western Pakistan and Western India. Ibid., 107 (2), 173-200.

[23] Ghazanfar, M., Chaudhary, M. N., Zaka, K. J., Baig, M. S. 1986. The geology and structure of Balakot area, District Mansehra, Pakistan. Geological Bulletin, Punjab University, 21, 30-49.

[24] Ghazi, S., Ali, A., Hanif, T., Sharif, S., Arif, S. J. 2010. Larger benthic foraminiferal assemblage from the early Eocene Chorgali formation, salt range, Pakistan. Geological Bulletin of the Punjab University, 45, 83-91

[25] Gill, W.D. 1953. Facies and Fauna in the Bhadrar Beds of the Punjab Salt Range, Pakistan. Journal of Paleontology, 27 (6), 824-844.

[26] Greco, A. 1991. Stratigraphy, metamorphism and tectonics of the Hazara Kashmir Syntaxis area. Kashmir Journal of Geology, 8 (9), 39-66.

[27] Hussain, A., Mughal, N., Haq, I., Latif, A. 2004. Geological Map of the Garhi Habibullah Area, District Mansehra and Parts of Muzaffarabad District, AJK. Geological Survey of Pakistan, Islamabad, Geological Map Series, VI (13).

[28] Iqbal, N., Yaseen, A., Lashari, R., Usmani, P., Ahsan, N. 2011. Some Palycepod Fossils from Chorgali Formation, Nurpur Area, Central Salt Range, Pakistan. Sindh University Research Journal - SURJ (Science Series), 43 (2), 181-184.

[29] Jamal, T., Azhar, R., Haneef, M., Saboor, A., Ali, N., Swati, M.A.F., Uddin, Z. 2015. Microfacies and diagenetic fabric of the Chorgali Formation in Bhuchal Kalan, Kalar Kahar, Salt Range, Pakistan. Journal of Himalayan Earth Sciences, 48 (1),14-25.

[30] Johnson, B.D., Powell, C.M.A., Weavers, J.J.1976. Spreading history of eastern Indian Ocean and greater India's northward flight from Antarctica and Australia. Bulletin of Geological society of America, 87, 1560-1566.

[31] Kazmi, A.H., Rana, R.A. 1982. Tectonic Map of Pakistan. Geological Survey of Pakistan, Quetta, Scale 1: 2000000.

[32] Khatoon, S., Baqri, S.R.H., Iqbal, N., Roohi, G., Hasan, A., Chaudhry, B., Sarwar, A. 2001. The study of some gastropod fossils from Bradrar beds (Chorgali formation), Nurpur area, Salt range, Punjab, Pakistan. Geological Bulletin of University Peshawar, 34, 105-111.

[33] Latif, M.A. 1970a. Explanatory notes on the geology of southeast Hazara to accompany the revised geological Map. Wein Jb. Geol. B.A., Sonderb. 15, 5-20.

[34] Latif, M.A. 1970c. Micropalaeontology of the Galis group, Hazara, West Pakistan. Ibid., Sonderb, 15, 63-66.

[35] Marks, P., Ali, C.M. 1962. The Abbottabad Formation: a new name for Middlemiss' InfraTrias. The Geological Bulletin of the Panjab University, 2, 56.

[36] Mujtaba, M. 2001. Depositional and diagenetic environments of carbonates of Chorgali formation (Early Eocene) Salt range-Potwar plateau, Pakistan., University of the Punjab, Quaid-e-Azam campus, Lahore.

[37] Nagappa, Y. 1959. Foraminiferal biostratigraphy of the Cretaceous-Eocene succession in the India Pakistan-Burma region. Micropaleontology, 5 (2), 145-192.

[38] Ottiger, R. 1986. Einige Aspekte der Geologic der Hazara-Kashmir Syntaxis (Pakistan). Diss. ETH Nr.8083, Zurich.

[39] Pascoe, E.H. 1920. Petroleum in the Punjab and N.W.F.P. Memoirs of the Geological Survey of India, 40 (3), 330-489.

[40] Pinfold, E.S. 1918. Notes on structure and stratigraphy in the N. W. Punjab. Geological Survey of India, 48 (3), 137-160.

[41] Sameeni, S.J., Ahmad, A., Ahmad, N., Ahsan, N. 2013. Biostratigraphy of Chorgali formation, Jhalar area, Kala Chitta range, Northern Pakistan. Science International (Lahore), 25 (3), 567-577.

[42] Shah, S.M.I. 2009. Stratigraphy of Pakistan. Geological Survey of Pakistan, 22, 1-381.

[43] Sam Boggs, Jr. 2006. Principles of Sedimentology and Stratigraphy, 4th Edition., Pearson Prentice Hall., Upper Saddle River, New Jersey 07458.

[44] Treloar, P.J., Coward, M.P., Chambers, A.F., Izatt, C.N., Jackson, K.C. 1992. Thrust geometries, interferences and rotations in the Northwest Himalaya. In: McClay, K.R. (ed.), Thrust Tectonics. Chapman and Hall, London, UK, 325–342.

[45] Vercher, A. 1867. On the Geology of Kashmir Himalaya and the Afghan Mountains. Journal of Asian Society of Bengal, 89-133,159-203, 36, 9-50, 83-115, 201-229.

[46] Wadia, D.N. 1957. Geology of India, 3rd Edition (Revised). McMillan and Company Limited, New York, 536.

[47] Wadia, D.N. 1930. Hazara-Kashmir Syntaxis. India Geological Survey Records, 129-138.