OUTCROP GEOLOGY, MICROFACIES ANALYSIS AND DEPOSITIONAL ENVIRONMENTS OF CHORGALI FORMATION FROM BHATTIAN AND GHARAGA, SOUTHERN HAZARA BASIN PAKISTAN

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ABSTRACT: In Hazara Basin, Early Eocene is represented by carbonate succession of Chorgali Formation which is mainly composed of limestone with marls and calcareous shale. Limestone is predominantly marly and argillaceous in nature. Two Stratigraphic sections of Chorgali Formation exposed at Gharaga and Bhattian villages have been completely examined and sampled for outcrop characteristics, petrography, microfacies and depositional settings. These sections have both well preserved lower and upper contacts with Early Eocene Margalla Hill limestone and Middle Eocene Kuldana Formation, respectively. The petrographic analyses reveal that Chorgali Formation exposed at Gharaga and Bhattian sections yields abundant Eocene foraminifers along with other fauna and their broken shells. On basis of outcrop data and detailed petrographic analyses, five microfacies are recognized including Nummulites-Lockhartia wackestone to packstone (MF-1), Nummulites- Assilina wackestone to packstone (MF-2), Ostracods-Miliolids packstone (MF-3), Marls Microfacies (MF-4) and Calcareous shale Microfacies (MF-5). Comprehensive microfacies, palaeoecological and outcrop data reveal that deposition of Chorgali Formation was occurred on mid ramp settings with some deposition in attached to partially restricted lagoonal area of inner ramp and proximal part of outer ramp.

Keywords: Chorgali Formation, Hazara Basin, Foraminifera, Microfacies, Ramp settings

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INTRODUCTION

Discovery of carbonates as petroleum reservoirs significantly diverted the focus of geologists over the carbonate rocks in mid 50’s which resulted extensive research on microfacies, depositional settings and diagenetic alteration through outcrop data, petrographic and geochemical analyses for better understanding of reservoir characteristics. The microfacies provide comprehensive information about the carbonate grains, their distribution and fabric which are used to decipher the depositional settings which having pivotal significance in assessing reservoir potential of carbonate rocks (Flügel, 1982, 2004). Eocene carbonates had been successfully drilled as reservoirs of Hydrocarbons in Upper Indus Basin and Sulaiman Fold & Thrust Belt of Pakistan (Kadri, 1995). However, the Eocene carbonates of Hazara are not still well understood in context of precise depositional modelling.

During Late Paleocene to Early Eocene transgressive cycles occurred due to ongoing north ward subduction of Neo Tethys shelf under the Kohistan Island Arc (KIA) which deposited shallow shelf limestone, marl, and shale sequence in Hazara and Kashmir basins (Ahsan and Chaudhry 2008, Munir et al 2005). The Early Eocene of Hazara Basin is represented by thick marine sequence of carbonates and mixed siliciclastics as limestone and shale with subordinate marl (Latif, 1970a, 1970, 1976; Ahsan, 2007; Ahsan and Chaudhry 2008). These depositional sequences are named Margalla Hill Limestone and Chorgali Formation. This depositional episode was continued along with subduction until the Late Eocene continent-continent collision between Indian Plate and KIA which closed the Neo Tethys by depositing last marine record in form of Middle Eocene Kuldana Formation in northern Pakistan. The Kuldana Formation typically consists of argillaceous facies with some calcareous, sandy and evaporitic facies which overly the Early Eocene strata (Ahsan and Chaudhry, 2008). The post collisional convergence resulted in deformation and uplift which developed the Himalayas and consequently, denudation of Himalayas laid down thick pile of molasse sediments over the Eocene strata (Powell, 1979).

Eocene Chorgali Formation is mainly comprised of limestone and calcareous shales, and it is widely distributed in the Potwar Plateau, central and eastern Salt Range, Kala Chitta Range, Hazara and Kashmir basins

(Sameeni et al., 2013; Ahsan & Chaudhary 2008; Munir et al., 2005). In Khair-e-Murat Range, Chorgali pass is designated as type locality of Chorgali Formation which is composed of thick sequence of dolomitic limestone at the base and alternate beds of limestone and shale (Jurgan and Abbas, 1991; Pascoe, 1920; Fatmi, 1973). In Salt Range it appears at the top of Sakesar Limestone having alternate beds of flaggy limestone and shale with abundant foraminifers (Pascoe, 1920; Gill, 1959; Yasin et al., 2015; Munawar et al., 2022). In Hazara and Kalachitta, Chorgali Formation formerly Lora Formation of (Latif, 1970) composed of very thin to medium bedded limestone with intercalation of shale and some marls, gypsum at places. Limestone has dark gray, greenish gray to light gray in color, the upper part of formation consists of flaggy limestone. Chorgali Formation mainly reflects the shallow marine environments of deposition during regression of Neo Tethys shoreline as the shallowing upward succession of flaggy limestone on the top of Chorgali Formation (Ahsan and Chaudhry 2008; Sameeni et al., 2013).

This work reveals the detailed and comparable analysis of Chorgali Formation exposed at Gharaga Village, Haripur District and Bhattian Village, Abbottabad District (Fig.1), Southern Hazara Basin which has included field data from bottom to top, microfacies identification and the nature of skeletal components.

Regional Geological Settings: The Hazara Basin (Chaudhry et al., 1998), the eastern part of Attock Hazara Fold & Thrust Belt is tectonically falls in the Lesser Himalayan terrain (Fig.1) and it occupies the southern part of the Lesser Himalayas in the west of Hazara

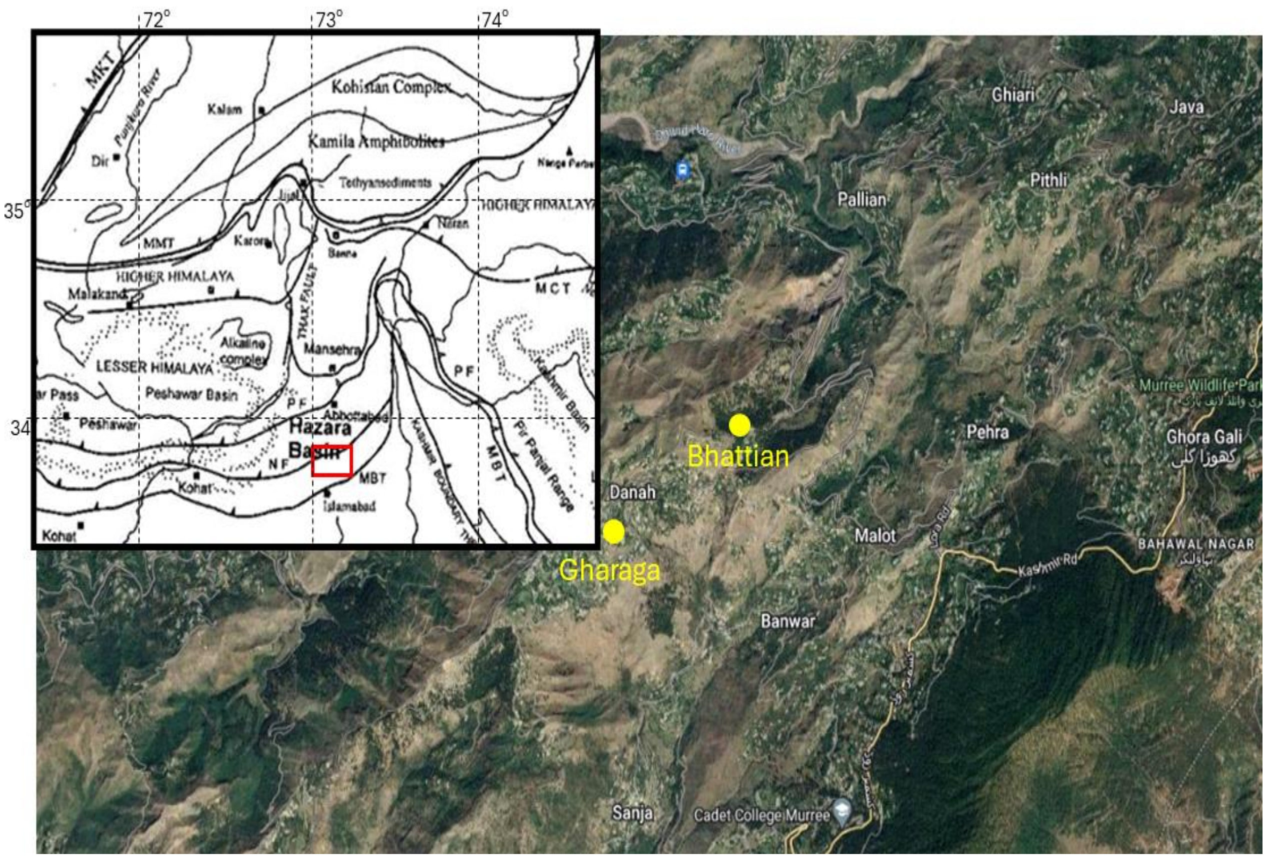

Figure1. Satellite and Tectonic map of Hazara Basin after Ghazanfar (1993).

Kashmir Syntaxis (HKS) which separates it from the Kashmir Basin. To north it is delimited by Panjal Fault (PF) and restricted by Main Boundary Thrust (MBT) in the south whereas the Indus River separates it from the Peshawar Basin in the west (Baig and Lawrence, 1987). The Hazara Basin crops out a thick NE-SW trending sedimentary succession (Fig. 2) with low grade metamorphosed base ranging in age from Pre-Cambrian to Eocene-Miocene (Latif, 1970, 1976; Shah, 2009; Ahsan and Chaudhry, 2008). The metamorphosed base is represented by slates with greywacke of Precambrian Hazara Formation which is unconformably followed by clastic package with some carbonates of Abbottabad Formation which overlain by Jurassic carbonates with a major gap in deposition (Latif, 1970; Ahsan and Chaudhry, 2008; Mahmood et al., 2023). Jurassic is conformably followed by clastic-carbonate sequence of Cretaceous with minor mixed carbonate-siliciclastic rocks which further overlain by Paleogene strata with Cretaceous-Tertiary Boundary in between them (Shah, 2009; Ahsan and Chaudhry, 2008; Rehman, 2017; Rehman et al., 2016, 2023). The Paleogene sequence mainly consists of carbonates with some siliciclastic and mixed carbonate-siliciclastic rocks which are unconformably overlain by Miocene molasse sediments (Shah, 1977; Ali et al., 2024). Structurally, Hazara Basin is very complex and suffered multiple phases of deformation. The strata is extensively folded and faulted, characterized tight asymmetrical anticlines with numerous reverse faults (Yeats and Lawrence, 1984; Baig, 1990; Baloch et al., 2002). The studied sections are located in eastern part of the Hazara Basin.

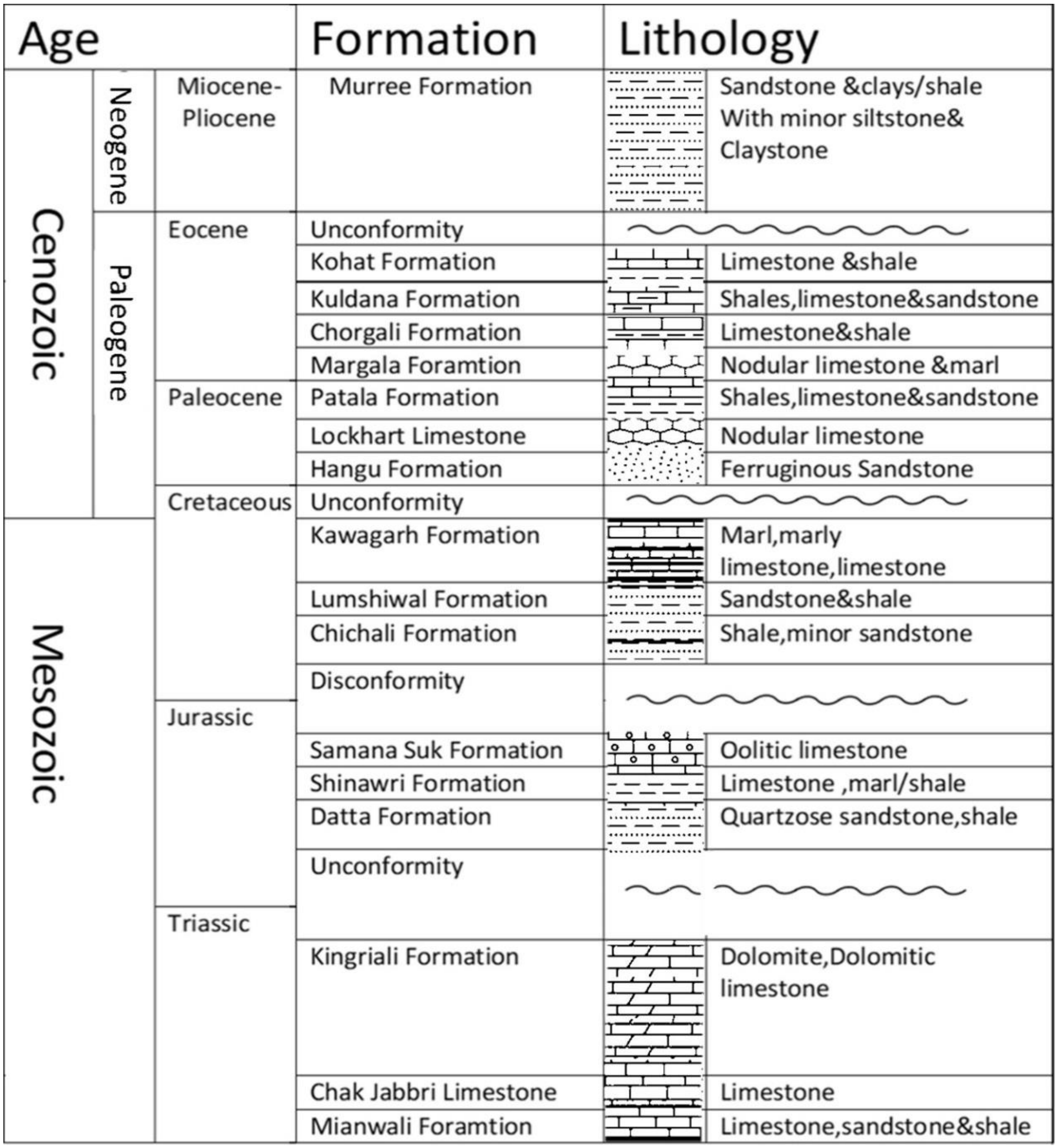

Figure 2. A generalized stratigraphic sequence in South Hazara after Latif (1970).

METHODOLOGY

After detailed overview of the study area, two sections with preserved tops and bottoms had been selected for section measurement and sampling with appropriate tools like Geological hammer, Camera measuring taps, scale, notebook, hand lens, Burton compass, handheld GPS, diluted HCL dropper, Geological map. Stratigraphic notes and complete field logs were prepared that contains all the information and noticeable features including bedding, color, texture, primary and secondary structures with emphasis on faunal distribution conferring to standards of various investigators (e.g. Compton, 1962; Tucker 1992; Flügel, 2004 and Ahsan 2007). All samples were transported to laboratory and thin sections and polished surfaces of harder marls and limestone were prepared for comprehensive petrographic analyses by using Polarizing microscope. Whereas softer marls and shale samples were treated and washed for fossil separation. The separated fossils were studied under stereo-zoom binocular microscope. All of the obtained data including texture, mineralogy, bedding, digenetic fabric, microstructures, skeletal and non-skeletal grains in rock sample was used to establish different microfacies by following the parameters of Tucker (2003) and Flügel (2004). The classification of carbonate rocks was made by following Duhnam (1962). Moreover, field logs were compiled with great accuracy using graphic software package to mark thickness of different beds and their characteristics in details.

RESULTS AND DATA

Field Data: Chorgali Formation in the study area largely variable in lithology, faunal content and depositional textures. It is generally fossiliferous and yields different assemblages of larger benthic foraminifera and smaller planktons with some suspension feeders. Lithologically, Chorgali Formation is composed of limestone, marls, and calcareous shale. Limestone is found in two compositions including marly and argillaceous which occur at lower and upper part of the formation, respectively. Limestone is generally light grey to yellowish grey and buff at surface. It is frequently argillaceous and fossiliferous. It contains Eocene large benthonic forams mainly including Nummulites, Assilina and Lockhartia which are easily identifiable in hand specimens. Marls are light grey to buff grey and laminated. Shale appears light grey to yellowish grey at surface and is frequently fissile, partly laminated and silty. It has lower gradational contact with underlying Margalla Hill limestone and overlain by Kuldana Formation with gradational intercalated contact at both studied sections. Both sections of Chorgali Formation show various preserved characteristics like rock type, texture, color, faunal diversity, grain size, cement, fabric, post and syn-depositional sedimentary structures. (Fig.3A, B). On the basis of these characteristics three main distinctive Lithofacies of the Chorgali Formation has been interpreted the study area.

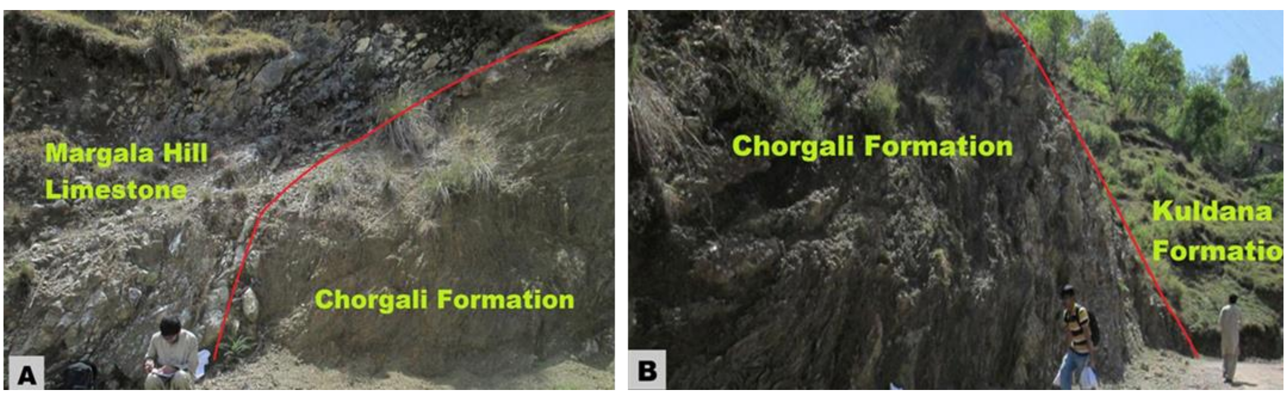

Fig. 3 Contact relationship of Chorgali formation at Gharaga section (A) lower contact of Chorgali formation with Margalla Hill Limestone. (B) Upper contact of Chorgali formation with Kuldana formation.

Marly Limestone Lithofacies: The basal part of the formation is comprised of massive marl, thin bedded limestone, and intermixed parallel bedded marly limestone. It exhibits flaggy nature due to increment of marly intercalations in limestone (Fig. 4B, C). The marly limestone is laminated and light yellowish to light grey in color which is thick toward top. These facies are generally fossiliferous, well-preserved genera of larger benthic foraminifera can be observed with naked eyes. (Fig. 5A, B).

Primary texture commonly destroyed due to addition of thick clustered calcite veins and stylolites visible at both outcrop and microscopic level. Marls are less compacted due to incompetent lithologies and growth of various secondary processes on it. Thin bedded limestone is jointed, fractured and brecciated with fractured filling solutions.

Calcareous Shale Lithofacies: Calcareous shale facies encountered in both studied sections of the Chorgali Formation and commonly intercalated with argillaceous limestone (Fig. 4C). Most of the shale is greenish grey, fissile to laminated and occurs as thin to thick layering between limestones. Shale lamination varies 1 mm to 3 mm in thickness. Shale frequently consists of clay minerals with appreciable amounts of calcite (more than 10%) and fine-grained silts. Reworked quartz grains also occur in minor amounts. Thin bedded flaggy limestone also occurs within the shale horizons. This lithofacies occupies the middle to upper parts of the formation. Towards top of the formation, it also appears in between the limestone and laminated calcareous mudstone (Fig. 6A). Rare to very less broken shells and small number of benthonic foraminifera were observed in this lithofacies. Gypsum patches and calcite veins are also found at outcrop and in polished softer slabs.

Argillaceous Limestone Lithofacies: This lithofacies is predominantly composed of impure limestone which is comparatively softer than the basal limestone of the Chorgali Formation (Fig. 6B). At outcrop, uppermost 20m thick unit constitutes the argillaceous limestone facies and it also show minor occurrence in middle and lower part of the formation. Argillaceous limestone is mainly light grey to light brown in color and very thin to thin bedded with thickness ranging from 3cm to more than 15cm (Fig. 7A, B). Post depositional processes are commonly present with calcite veins growth parallel and across to the bedding planes and minute breakage of fauna. Limestone exhibit flaggy appearance and smaller nodules are also encountered at places.

Fig. 4 Lithofacies of Chorgali Formation, Gharaga Section. (A) Marls (B) Marly Limestone (C) very thick bedded Argillaceous Limestone.

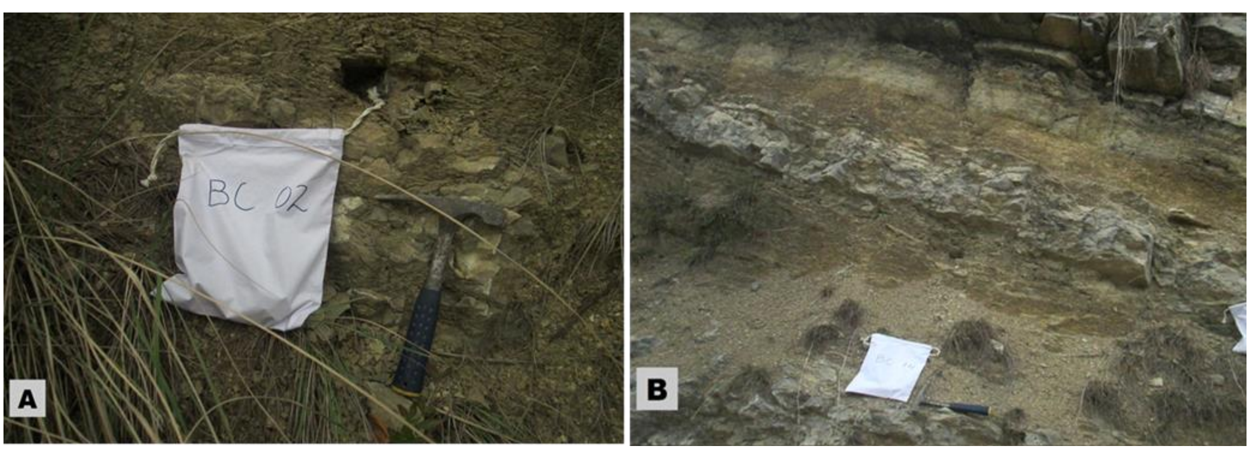

Fig. 5 Lithofacies of Chorgali Formation, Bhattian Section. (A, B) Marls and Marly Limestone beds from base of the Chorgali Formation.

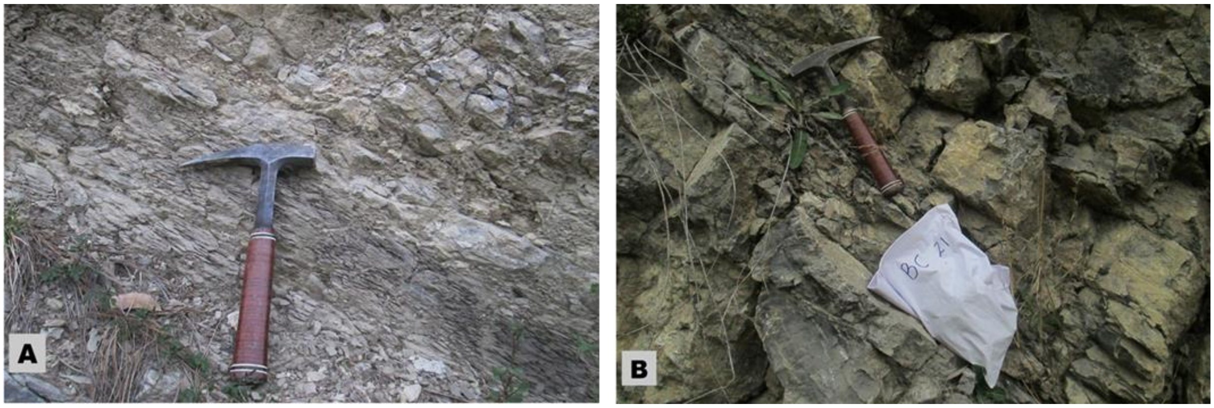

Fig. 6 Lithofacies of Chorgali Formation, Bhattian Section. (A) Calcareous shale from middle part of formation (B) Very thick bedded argillaceous limestone from upper beds.

Fig. 7 (A) Parallel beds of argillaceous limestone at Gharaga Section. (B) Flaggy limestone beds at upper part of the formation at Gharaga Seection.

Microfacies Data: After detailed petrographic analyses, on basis of faunal content, faunal distribution and detrital constituents in both sections of Chorgali Formation five distinct microfacies were established by following Flügel, (1982, 2004), Dunham (1962) and Wilson (1975). The detailed description of each microfacies is discussed in the following.

Nummulites-Lockhartia wackestone to packstone (MF-1): This microfacies is most frequently occurring microfacies of both studied sections and constitutes 26% of the total samples of Chorgali Formation. The petrographic examinations of this microfacies show that the skeletal component of this microfacies varies from more than 10 % to 65 % whereas the groundmass/matrix dominantly appears as micrite. In this wackestone to packstone microfacies Nummulites are more abundant than any other skeletal grains and constitute less than the half of the total skeletal portion. They are followed by Lockhartia in abundance which are 21% of the total skeletal component. Major species of genus nummulites recognized in this microfacies are N. atacicus, N. globulus, N. mammillatus whereas genus Lockhartia mainly include Lockhartia tippri and Lockhartia conditi, with less common grains of Assilina laminose (Fig. 8A). The skeletal granular portion of this microfacies also contains patches of green algae with minor skeletal grains of pelecypods, bivalves echinoids, orbitolites, ostracods, smaller plainispiral planktonic foraminifera and rarely Miliolids. Broken bioclasts present 25-35 % of the skeletal grains which mainly belongs to Nummulites and Lockhartia with some aforementioned grains. In both wacke and pack facies binding material is micrite and it contains fine sand, silt and clay sized grains of clastic sediments as well as fine carbonate grains.

Nummulites- Assilina wackestone to packstone (MF-2): This microfacies is identifiable at outcrop by thin to thick bedded limestone encountered between marlstone at the basal part of formation and by identifiable fauna including Nummulites and Assilinids. Limestone is dark grey in color and contain abundant bioclasts of larger benthic foraminifera. This microfacies forms 24% of the total samples of the Chorgali Formation by volume and skeletal component varies from 17% to 70%. Detailed analyses of this microfacies reveal that among the skeletal grains Nummulites and Assilinid are the abundantly occurring constituents. The content of Nummulites is higher than the Assilina which forms the 40% of the total skeletal grains. Assilina are subordinate to Nummulites and constitutes more than half of the Nummulites. The fauna is well preserved and various species of Nummulites including Nummulites atacicus, Nummulites mammillatus, and Nummulites globules, and two species of Assilinoids namely Assilina subspinosa, Assilina laminose are found (Fig. 8B). The less common skeletal grains of this microfacies are bivalve, Pelecypods, green algae patches Ostracods and very rare Miliolids. These grains present in ratio of 3 % to 5 % in this microfacies in scattered patterns. Abundant broken bioclasts of all these fossils and other minor and smaller biodebris are found and they contribute 10% to 17% in this microfacies. Various cycles of wackestone to packstone are emerged, mainly due to accumulation of broken skeletal grains. The matrix is micrite largely rich in calcite with muddy components containing silt and sand sized clastic and carbonate grains.

Ostracods-Miliolids Packstone (MF-3): This microfacies occurs in the upper part of the formation and consists of thick to very thick bedded limestone. Ostracods and Miliolids are comparatively found in equal ratio and in different thin sections its ratio varies from 40% to more than 55%. All the skeletal grains of Miliolids are commonly preserved with unaltered internal structure (Fig. 8C). There is very less infillings of micrite observed in the inner portion of Miliolids. While internal structure and test surfaces of Ostracods are completely or partially destroyed due to micritic fillings and microspar growth. Other fauna recovered as deficient values include remains of green algae, Pelecypods, gastropods, bivalves, Echinoids, Globorotalia, and Textularia. Broken bioclasts mainly consists of Ostracods remains with lesser counterpart of Miliolids. Matrix composed of micrite and calcite cement with measurable proportion of muddy material. In which clastic influx is higher in topmost sample and its thin sections.

Marls Microfacies (MF-4): Marl microfacies mainly lie at the bottom of the formation and is also encountered in the middle part. Highly laminated marls are present as repeated horizons and laminations within limestone beds. Lamination in marls microfacies also observed at micro level during thin section studies. This microfacies is mainly composed of calcareous and argillaceous contents with reworked intraclasts of limestone ranging from 20% to 25% and by parts in many samples of marlstone. In marls, bioclasts and smaller planktons are common while this microfacies mainly comprised of planktons along with larger flat Nummulites and Assilinid (Fig. 8D). These benthos are generally flat and retain thin-walled tests with closely spaced chambers. Various veins and pressure solution seems randomly distributed, seen under thin section.

Calcareous Shale Microfacies (MF-5): This microfacies constitute the rock unit as a minor portion as compared to other microfacies. It occurs in the middle to upper part of the formation and constitutes the 9% of the total microfacies. Calcareous Shale microfacies is associated with thick bedded dark grey limestone of the middle part, where the shale is highly laminated and appear as very thin bands. Largely, it contains very minute amounts of skeletal grains which mainly include larger thin walled flat benthonic foraminifera and planktonic foraminifera. Finer particles of clay minerals and fine silty grains are more common in this microfacies (Fig.8E).

Depositional model: Carbonates are generally result of deposition over fine distinct settings namely rimmed shelves, non-rimmed shelves, platform, isolated platform, and ramps characterized by different architectures of settings and facies (Nichlos, 2009; Flügel, 2004; Ahr, 1973). Among the diagnostic features of these settings, the absence of reef facies, sand shoal, slope structures like slumps and overlapping of shallow facies belt abruptly by deeper facies in present study indicate the deposition of Chorgali Formation over the ramp settings. Work of Ahsan and Chaudhary (2008) and Rehman et al., (2016, 2019, 2021) infer the ramp settings for Hazara basin from Upper Cretaceous to onward Paleogene strata. Similarly, Sameeni et al., (2013), Ahsan (2008), Ghazi et al., (2014) and Mujtaba (1999) suggested ramp deposition for Eocene strata of NW Himalayas.

In present study, the depositional environments were deduced by using skeletal grains and their paleoecology and ratio of benthon to plankton along with detrital constituents (Latif, 1976; Flügel, 2004; Rehman, 2017; Rehman et al., 2016, 2017, 2019, 2021). The Chorgali Formation abundantly yields variety of benthonic foraminifers and other fauna mainly including Nummulites, Assilinid, Lockhartia, Miliolids and Ostracods with minor amounts Algae, Pelecypods, Gastropods and planktonic foraminifera. Nummulites are bottom dweller organisms which live on soft bottom mud frequently in non-turbid marine waters under normal salinity conditions (Lehmann, 1970). These are reported from variety of shallow marine settings ranging from inner to outer shelf maximum up to 130m depth (Reiss and Hottinger, 1984). Cosovic et al., (2004) describe the development of nummulite shoals or bars in a proximal middle ramp setting deposited near the fair-weather wave base (FWWB). Similarly, Assilinids are also carbonate dwelling organisms which live in open marine conditions ranging from offshore to shoal (Sinclair et al., 1998). Srivastava and Singh (2017) reported Assilina along with Nummulitidae, from inner to middle ramp setting. Like Assilinids, Lockhartia also have been observed in variety of depositional settings ranging from low and high energy

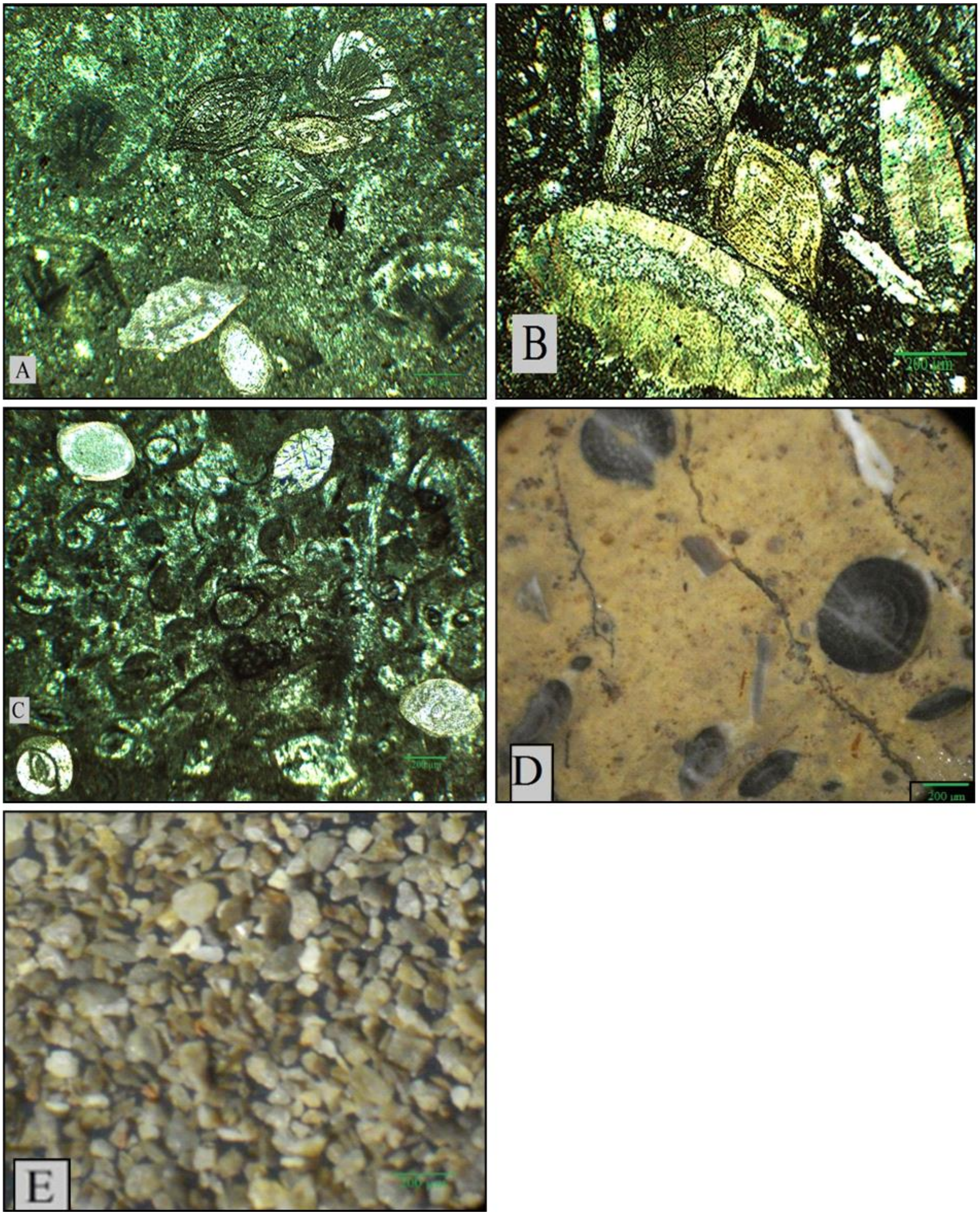

Fig. 8 Microfacies of Chorgali Formation. (A) Nummulites-Lockhartia wackestone to packstone MF-1. (B) Nummulites- Assilina wackestone to packstone MF-2. (C) Ostracods-Miliolids packstone MF-3. (D) Marls Microfacies MF-4 (E) Calcareous shale Microfacies MF-5.

and brackish to open marine conditions (Abbott, 1997). Furthermore, Hottinger (1997) reported Lockhartia from depth of 40 to 80m along with Assilinids and Nummulites. Contrary to this, Miliolids are frequently reported from restricted shallow marine conditions like lagoonal settings (Luterbacher, 1970; Hottinger, 1982). Ostracods occur in a variety of settings ranging from fresh water to restricted lagoons and open marine conditions including shallow and deep settings (Park et al., 2000; Martens et al., 2008). Yamaguchi and Goedert (2009) reported ostracods along with benthic foraminifera including Miliolids, Nummulites, Assilina and Lockhartia from the Crescent Formation in the Black Hills, suggesting water depths shallower than 50 m. on the other hand, Planktons have been reported from a variety of settings ranging from shallow shelves to slope, and abyssal environments. However, the frequency of planktons varies from setting to setting as rare to less at shallow shelves and common to abundant at deep shelves (Flügel, 2004; Ahsan, 2008; Rehman et al., 2016, 2019).

On basis of palaeoecological attributes of major fauna, distribution of fauna and its coexistence were used to interpret the depositional environments of recognized microfacies. The Nummulite bearing microfacies are the most abundantly microfacies at both Gharaga and Bhattian sections which are characterized by Nummulites with subordinate Assilinid and Lockhartia. The aforementioned paleoecology suggests mid ramp setting for Nummulites-Assilinid-Lockhartia assemblage. Further, Nummulites-Lockhartia Wackestone to Packstone microfacies are placed over the distal part of the mid ramp due occurrence of planktonic foraminifera whereas the Nummulite-Assilind Wackestone to Packstone microfacies are interpreted as deposition over the proximal part of the mid ramp. The abundance of miliolids in Miliolid-Ostracod microfacies depict that it was deposited in restricted conditions like the attached lagoonal part of the inner ramp. Due occurrence of abundant planktons in shale and marl, these microfacies were interpreted as outer ramp deposition. However, the occurrence of thin walled flat Nummulites, and Assilina with rare Lockhartia and their broken shells in shales/marls infer proximal outer ramp settings for shale and marls.

DISCUSSION

The presence of large and smaller benthonic foraminifera including Nummulites, Assilina, Ostracods, Milliolids and Lockhartia along with some planktons and trace pelecypods, bivalves, algae and echinoids suggest shallow open to slightly restricted marine deposition for Early Eocene Chorgali Formation. Further, many workers (e.g. Sameeni et al., 2013; Ahsan 2008; Ghazi et al., 2014; Mujtaba, 1999) reported ramp settings for deposition of Eocene strata in NW Himalayas which confer that Chorgali Formation was deposited under partially restricted to open marine ramp settings. The fields data reveal that Chorgali Formation conformably overlies the Early Eocene Margalla Hill limestone. The upper part of Margalla Hill limestone is represented by thick bedded large benthonic foraminifera including Nummulites and Alveolinid bearing nodular limestone. The available data of larger benthonic foraminifera recovered from the top of Margalla Hill limestone indicate that deposition took place on a shallow inner ramp. It was followed by mixing of clastic influx over the carbonate ramp which gradually change in facies to deposit the marl/shale and limestone sequence of Chorgali Formation. This Early Eocene clastic influx is also obvious to west of Hazara Basin particularly in Kalachitta, Kohat and Sulaiman Fold & Thrust Belt (Shah, 2009).

The inner ramp thick bedded nodular limestone of Margalla Hill limestone is gradually replaced by the medium to thin bedded argillaceous limestone at the basal part of Chorgali Formation. The basal argillaceous limestone yields abundant Nummulites and Lockhartia with some planktons and is classified Nummulites-Lockhartia microfacies of distal mid ramp settings. These mid ramp facies are overlain by Marl microfacies of proximal outer ramp settings. The vertical stacking of deeper microfacies over shallow microfacies is indicative of transgressive cycle at the base of the Chorgali Formation. Marl microfacies are again capped by Nummulitic microfacies of mid ramp settings which marked the regressive cycle. Numerous small scale transgressive and regressive cycles can be marked in the lower part of the Chorgali Formation which preserved as rhythmites of argillaceous limestone and marl. In the middle part of the Chorgali Formation marl microfacies are overlain by Nummulitic microfacies mid ramp followed by Miliolid-Ostracod microfacies of inner ramp setting inferring a major regressive cycle. The upper part of the formation is characterized by repetition of inner and mid ramp microfacies with inner ramp microfacies at the top which suggesting a regressive cycle at the top of formation which is consistent with many previous works like Mujtaba (1999) and Sameeni et al., (2013).

According to the microfacies data from base to top deposition of Chorgali Formation indicate a shallowing upward sequence. Minor deepening and shallowing upward sequences also occurred due to gradually induced cycles of transgression and regression of the shoreline. These changes clearly occurred in the basal sequence of marl and limestone which indicate that deposition was occurred on middle and outer ramp in minor episodes with an overall shallowing upward sequence.

Conclusions: The detailed lab and field studies of both section of Chorgali formation led to the following conclusions:

- Lower contact of the Chorgali Formation with underlying Margalla Hill limestone is marked as gradational conformable contact while upper contact with kuldana formation is gradational intercalated.

- Early Eocene Chorgali Formation in the study area comprised on limestone, marls, and calcareous shale. Marls and limestone mostly in the lower part and shale and limestone present in the upper part.
- Three main lithofacies have been established as marly limestone, calcareous shale, and argillaceous limestone facies.
- Thin section analyses show well preserved benthic foraminifera including Nummulites atacicus, Nummulites mammillatus, Nummulites globulus Lockhartia conditi, Lockhartia tipper, Assilina laminose and Assilina subspinosa which are commonly abundant throughout the formation. On the base of recovered larger benthic foraminifera early Eocene age assigned to the Chorgali Formation at studied sections.
- The paleoecology of fauna, their distribution and microfacies analyses suggest that the Chorgali Formation exposed at Gharaga and Bhattian was deposited over ramp settings with an overall shallowing upward sequence.

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