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RESEARCH PAPER

Microfacies Analysis and its Implications for Depositional Environment of Margala Hill Limestone from Khaira Gali Road Section, North Eastern Hazara, Pakistan

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Abstract

Stratigraphic section of Margala Hill Limestone exposed in the Khaira Gali road section of the Hazara Basin has been measured, logged and sampled. The 96m thick section of Margala Hill limestone mainly consists of medium to thick bedded nodular limestone with intercalations of shale. The petrographic studies of formation show mainly wackstone to packstone carbonate texture with different assemblages of Larger Benthonic Foraminifera, e.g. (*Assilina spinosa, Nummulites globulus, Ranikothalia sindensis*, *Nummulites mamillatus, Assilina subspinosa, Nummulites atacicus, Assilina granulosa, Operculina patalensis, Assilina laminosa, Ranikothalia nuttalli, Lockhartia conditi, Ranikothalia sahni, Lockhartia tipperi, Discocyclina dispansa, Discocyclina ranikotensis* and *Quinqueloculina*), Bivalve and green algae. Five microfacies types have been interpreted on the basis of carbonate texture and skeletal grains present. These microfacies include Rotaliids-milliolids mud-wackstone, Algal- bioclastic packstone, Nummulitic wack-packstone, Assilinids wack-packstone and Discocyclina- Ranikothalia wack-packstone microfacies. On the basis of microfacies analysis, inner to mid shelf environment has been deduced. Occurrence of age diagnostic foraminiferal assemblage suggest the Early Eocene age for the Margala Hill Limestone.

Keywords: Hazara Basin, Nodular, Petrographic, Foraminifera, Microfacies, Eocene.

Introduction

The stratigraphic section of Margala Hill Limestone was measured at 73°23'51"E and 33°59'1"N from Khaira Gali road, NE Hazara Basin. Geographically, Hazara basin covers the area of Margala Hills, Abbottabad and Galliat. This basin is part of lesser Himalayas that comprises of NE to SW trending sedimentary belt (Fig. 1). It is extended between Panjal Thrust in the north and Main Boundary Thrust in the south. However, westward and southwestward, it is constrained by Indus river and Kala Chitta Range respectively (Chaudhry et al., 1998a; Latif et al., 1976). The Hazara Basin is characterized by Pre-Cambrian to Eocene thick sedimentary sequence of Tethys realm deposited on broad shelf area along northern margin of the Indian plate. The basin has been characterized by complex structural geometry, intensified by small scale fold and thrusts (Ahsan & Chaudhry, 2008; Afzal, 2009). The Paleogene strata of Hazara Basin remain a subject of great interest for researchers in paleontological and paleoenvironmental point of view. Previously, the detailed studies regarding the paleontological data and paleogeography of study area was not very well known. Therefore, the present study is aimed to interpret the detailed microfacies analysis based on the field as well

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as the petrographic studies and to determine the depositional environments along with 3D depositional model for the Margala Hill Limestone.

Geological Settings

Tectonostratigraphic division of NW Himalayas

The Himalayas has been divided into different tectonostratigraphic units (Fig. 1) cross the length of orogeny (Gansser, 1981; Hodges, 2000; DiPietro, 2004). These zones have been comprised of characteristic lithology and bounded by major thrust fault (Table 1).

Evolution of Hazara Basin

The evolution of Hazara Basin started with the deposition of Hazara and Tanawal Formation in marine environments (Kazmi & Jan, 1997). This deposition followed by Pan African orogeny related period of non-deposition, uplift, erosion, igneous plugs and metamorphism (Baig, 1989 and Duppret et al., 1990).

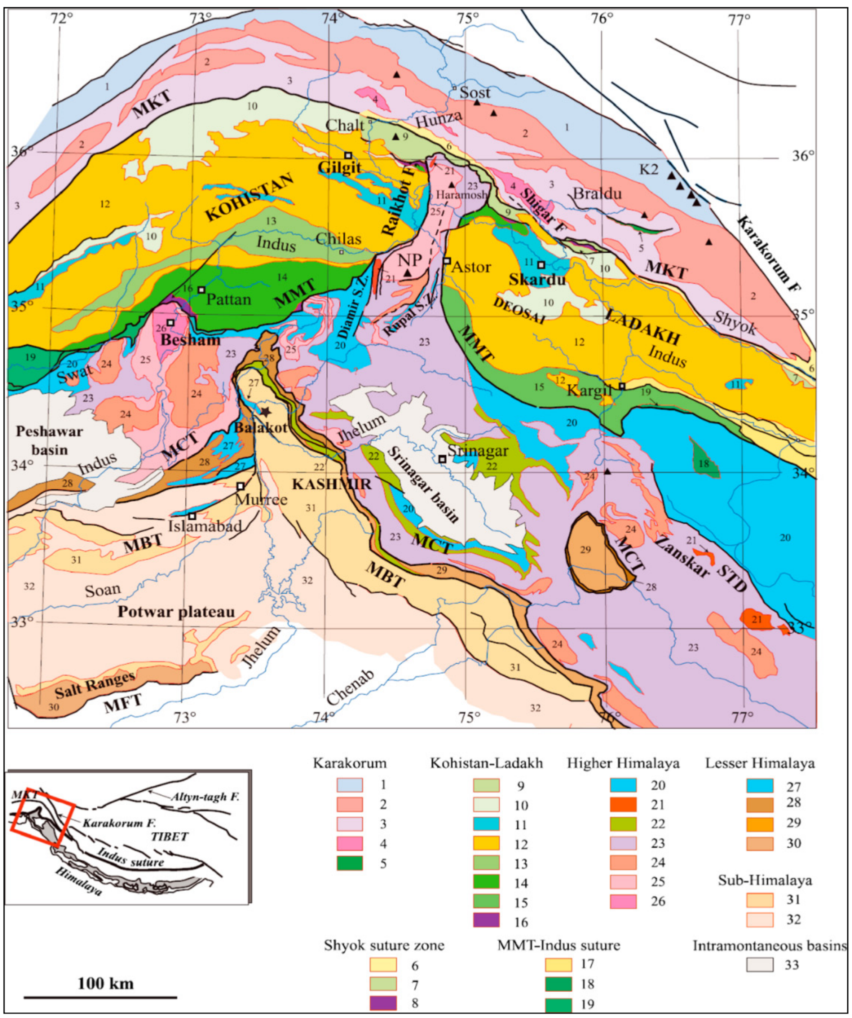

Figure 1. Geological map of the NW Himalaya (modified from Pêcher et al. 2008; Jouanne et al., 2013). Main tectonic boundaries: MKT, Main Karakorum Thrust; MMT, Main Mantle Thrust (Indus Suture Zone); STD, South Tibetan Detachment; MCT, Main Central Thrust; MBT, Main Boundary Thrust; MFT, Main Frontal Thrust; BBT, Balakot-Bagh Thrust

Table 1. Tectonostratigraphic division of Pakistan (after DiPietro et al., 2004; Searl et al., 2010 and Jagoutz, 2012)

Tectonostratigraphic division of Himalayas
e. Karakorum Block - northern sedimentary belt, southern metamorphic belt, axial batholith and other granitoids, greenstone complex, felsic gneiss, Paleozoic (Masherbrum complex)
- **MKT** -
d. Kohistan-Ladakh Island Arc - Chalt of Kohistan and Kardung of Ladakh volcanic, plutonic rocks (Kohistan and Ladakh batholith), Jaglot metasedimentary unites, gabbronorites and Ultramafic rock of Chilas complex, Kamila amphibolite (Kohistan), ultrabasites of Jijal complex, Dras volcano-sedimentary zones (Ladakh)
- **MMT** -
c. Higher Himalayas- Permian-Eocene Neo-Tethyan sedimentary unites, Nanga Parbat and Ladakh leucogranites, Panjal Traps of Permian age, High Himalaya Crystalline metasediments, Paleozoic granitic intrusions of Manserah and Swat, basement orthogneisses, Besham metaigneous unites and Zansker shelf sediments and shear zone
- **MCT** -
b. Lesser Himalaya- metamorphic rocks of Lesser Himalayas crystalline Nappe, panjal metavolcanics (Permian), Paleozoic-Eocene platform sedimentary cover, Early-Late Proterozoic metasediments of Hazara Formation (Abbottabad) and Dogra Slate (Kashmir)
- **MBT** -
a. sub Himalayas- Oligocene-Miocene molasses deposits of Rawalpindi Group, Neogene- Quaternary Siwalik sediments, Precambrian-Eocene sediments of salt range, Srinagar and Peshawar intra-mountainous basins

The sedimentary deposits along with metamorphic and magmatic products of orogenic events form the basement for rest of Alpine sequence (Baig, 1991). While Pre-Cambrian evaporates basin (Salt Range) evolved synchronously with these orogenic events (Sengor et al., 1988).

In Hazara area, whole Tanawal Formation was eroded before fluvial- fluvioglacial deposition of Tanaki conglomerates. During Early Middle Cambrian, the basin subsidized again and deposition of rest of Abbottabad Group and Hazira Formation was occurred in marine settings (Baig et al., 1988).

Up till Cambrian, deposition in Hazara basin occurred in Paleo-Tethys that exist between Laurasia and Gondwanaland. In Middle and Late Paleozoic the fragmentation of Gondwana land created Cimmerian micro-continent that were drifted northward and opened a new basin behind (Neo-Tethys). These Cimmerian micro continent eventually collided with the Eurasia and closed the Paleo-Tethys by late Triassic. Throughout that time Hazara Basin remain region of non-depositional. Thereafter, rifting in Gondwana land and consequently northward drift of Indian plate produced a broad carbonate platform on the western margin of the Indian plate (Kazmi & Abbasi, 2008 and Sengor et al., 1988). Firstly, Neo-Tethys mixed clastic carbonate facies of Datta Formation were deposited unconformably on Hazira Formation. Continuous subsidence ensued transgression which resulted in the deposition of Shinawari Formation and Samana Suk Formation of estuarine lagoonal to open marine settings respectively (Cheema, 2010). The sediments of Chichali Formation, Lumshiwal Formation and Kawagarh Formation were deposited in the fluctuating marine environments. By late Maastrichtian, Indian plate collide with the Kohistan Island arc caused the uplifting of the basin and subaerial exposure of Kawagarh Formation. During Early Paleocene the area was resubmerged again and Hangu Formation was deposited in transitional marine conditions (Kazmi & Abbasi, 2008). Thereafter, Paleocene–Eocene succession (Lockhart Limestone, Patala Formation, Margala Hill Limestone and Chorgali Formation) was deposited in various regressive and transgressive phases on carbonate platform. The Indian plate eventually collide with the Eurasian and close up the Neo-Tethys with the deposition of Kuldana Formation in transitional marine environments plate (Paracha, 2004). The Himalayas and Kohistan Ladakh uplifted as a result of that collision and narrow molasses basin was formed between these two ranges in which Oligocene-Miocene molasses sediments of Rawalpindi Group deposited unconformably on Eocene Succession (Kazmi & Abbasi, 2008).

Stratigraphy of the Area

The area under study shows a number of large or small scale folds and thrust faults. The rock succession exposed at Khaira Gali to Changala Gali road section range in age from Jurassic to Eocene. The oldest rock exposed in the study area is Samana Suk Formation.The stratigraphic sequence of these rock units (after Shah, 2009; Latif, 1970) are shown below in (Fig. 2).

Materials and Methods

The stratigraphic thickness of Ypresian Margala Hill Limestone from Khaira Gali section was measured, sampled and logged. Total 45 samples were collected using systematic methods with 1-1.5meter samples interval. The thin sections from collected samples were prepared and analyzed for petrographic features, which included carbonate texture, type of cementing material, %age of skeletal and non-skeletal grains and others sedimentary features present. Classification and terminology of Larger Benthonic Foraminifera those given by Davies, 1927, 1937; Hottinger, 1960, 2009; Nuttal, 1926; Pinfold & Davies, 1937; Nagappa, 1959; Gill, 1953 and Schaub, 1981 are used.

Results and Discussion

Outcrop studies

The Margala Hill Limestone, in the Khaira Gali road section, consists of medium to thick bedded and nodular limestone with minor intercalations of shale. The limestone is grey to dark grey, weathering pale grey and fine to medium grained while the shale is grey to greenish grey color. The Formation contains abundance of Larger Benthonic Foraminifer and oyster shells which can be observed in the field by hand lens. The total thickness of the formation encounter is 96.8m.

Petrographic Studies

The petrographic analysis of Margala Hill Limestone indicated mostly wackstone to packstone carbonate texture (Fig. 3). The cementing material is mainly micrite but iron oxide and Quartz are also present in some thin section. Both primarily and secondary microfractures which are unfilled or partially filled with sparite or insoluble black residue have been observed. These microfractures are cross cutting each other at various angles and suggest different episode of tectonic stresses. Several species of Larger Benthonic Foraminifera (LBF) along with bivalves' shells and green algae have been identified (Figs 4 a, b, c, d, e). LBF species include *Lockhartia tipperi* (Davies, 1937), *Lockhartia haimei* (Davies, 1927), *Nummulites atacicus (*Leymerie, 1846), *Nummulites mamillatus (*Fichtel & Moll, 1798), *Nummulites globules (*Leymerie, 1846), *Ranikothalia sahni (*Davies, 1952), *Ranikothalia sindensis (*Davies, 1927), *Assilina spinosa (*Davies & Pinfold, 1937), *Assilina laminosa (*Gill, 1953), *Assilina granulosa (*d"Archíac, 1848), *Assílina subspinosa, (*Davies & Pínfold 1937), *Discocyclina ranikotensis (*Davies, 1927), *Discocyclina dispansa (*Sowerby, 1840*) and Quinqueloculina (*d'Orbígny, 1826).

Microfacies Analysis

Petrographic analysis of the thin section included carbonate texture, grain fabric, fossils type and proportion of skeletal to non-skeletal grain, along with outcrop investigation led to interpret five microfacies. These microfacies compared with the standard microfacies of (Wilson, 2012).

MF-1 Rotaliids-milliolids mud-wackstone

Rotaliids milliolids mudstone to packstone microfacies is 10% of total microfacies observed. It is composed of 60% to 90% micritic cements and 10 to 40% biochems. These bioclasts are comprise of 7-12% milliolids 15-25% Rotaliidae, 5% algae and 10-25% broken shell fragments of LBF's. Vertical burrows have been observed. The textures vary from wackstone to mudstone. These microfacies are representative of thin section No # MG1, MG4, MG12, MG38 (Fig. 4a).

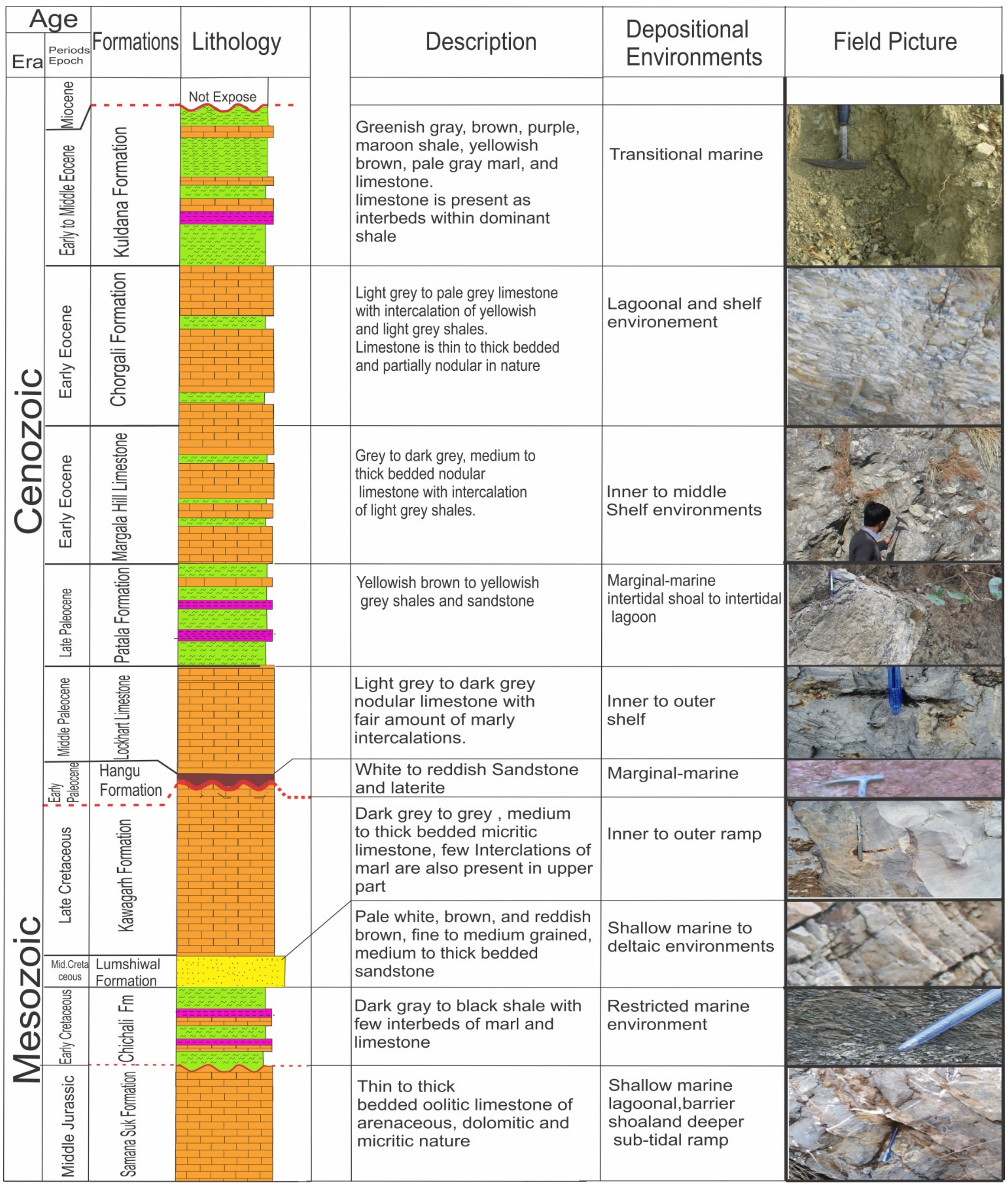

Figure 2. A generalized Lithostratigraphical column of Jurassic to Miocene Rocks exposed in Khaira Gali- Changla gali road North Eastern Hazara Basin. The oldest rock unit is Jurassic Samana Suk Formation and youngest unit is Eocene Kuldana Formation. The column also shows the depositional environment and field photograph of each rock unit

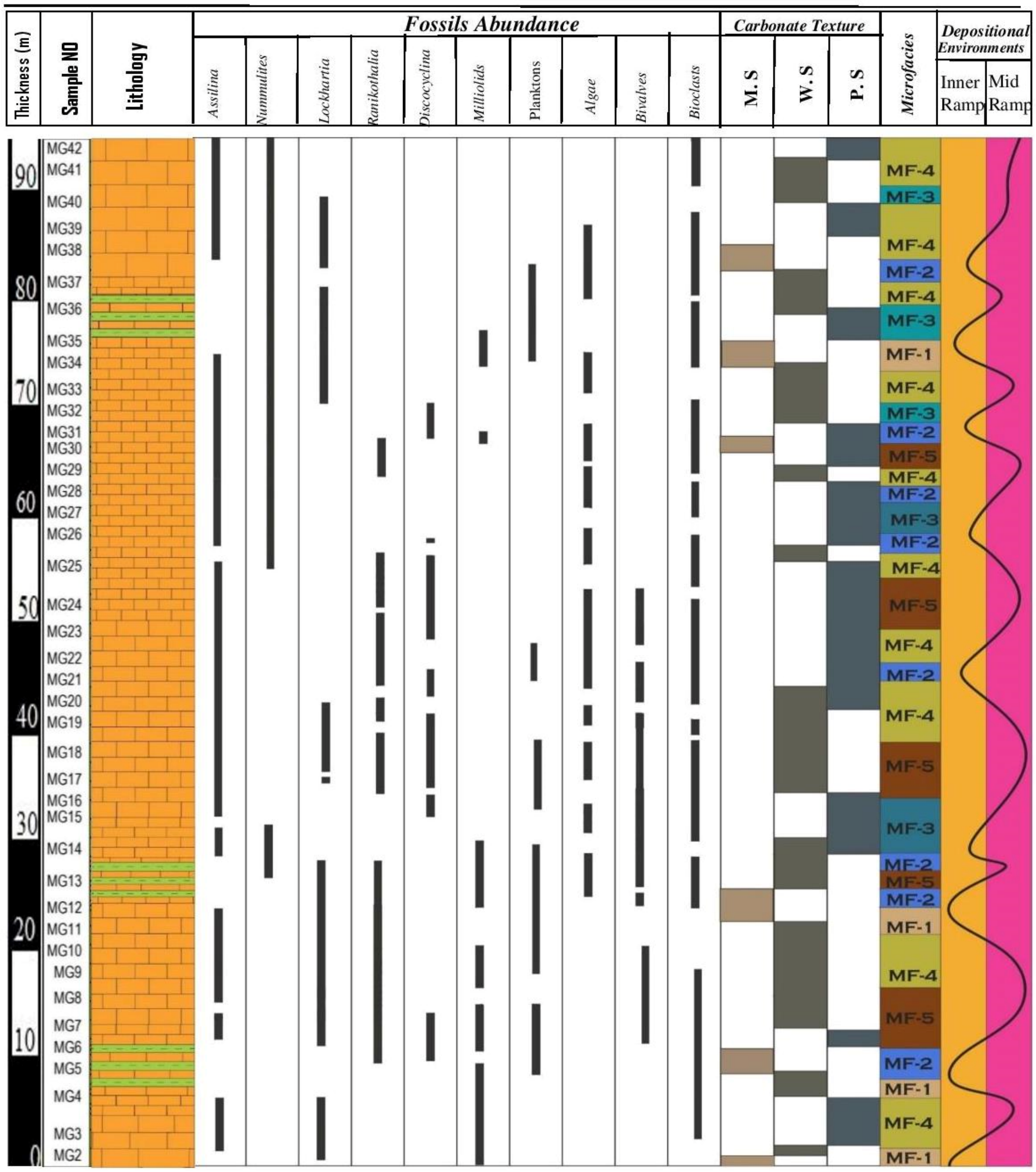

Figure 3. The lithological and microfacies distributional log of Early Eocene Margala Hill Limestone

Interpretation

The association of Lockhartia and Milliolids along with the mudstone and wackstone carbonate textures, show the deposition in low energy slightly restricted inner shelf environments (Racey, 2004; Pyros et al., 2006 and Zhang et al., 2013). The presence of sedimentary burrows and red algae further indicate the deposition took place with in water depth of 10-40m (Leckie, 1989; Fadel, 2012).

MF-2 Mixed-Bioclastic wack-packstone

Mixed Bioclastic microfacies is 20% of total microfacies observed in thin sections and characterized by the presence of different types of shell fragments. This microfacies constitutes 40% bivalves (oyster) shells, 10-30% green algae and 20-50% broken shell fragments of different species of planktons and larger benthonic foraminifera (Fig. 4b). Most of the skeletal grains are imbricated, disoriented and partially micritized. This microfacies is descriptive in thin section # MG6, MG15, MG27, MG29 and MG38.

Interpretation

The abundance of bivalves shell along with algae represent agitated, shallow high energy conditions above fair weather wave base (Fadel, 2004; Wanamaker et al., 2011).

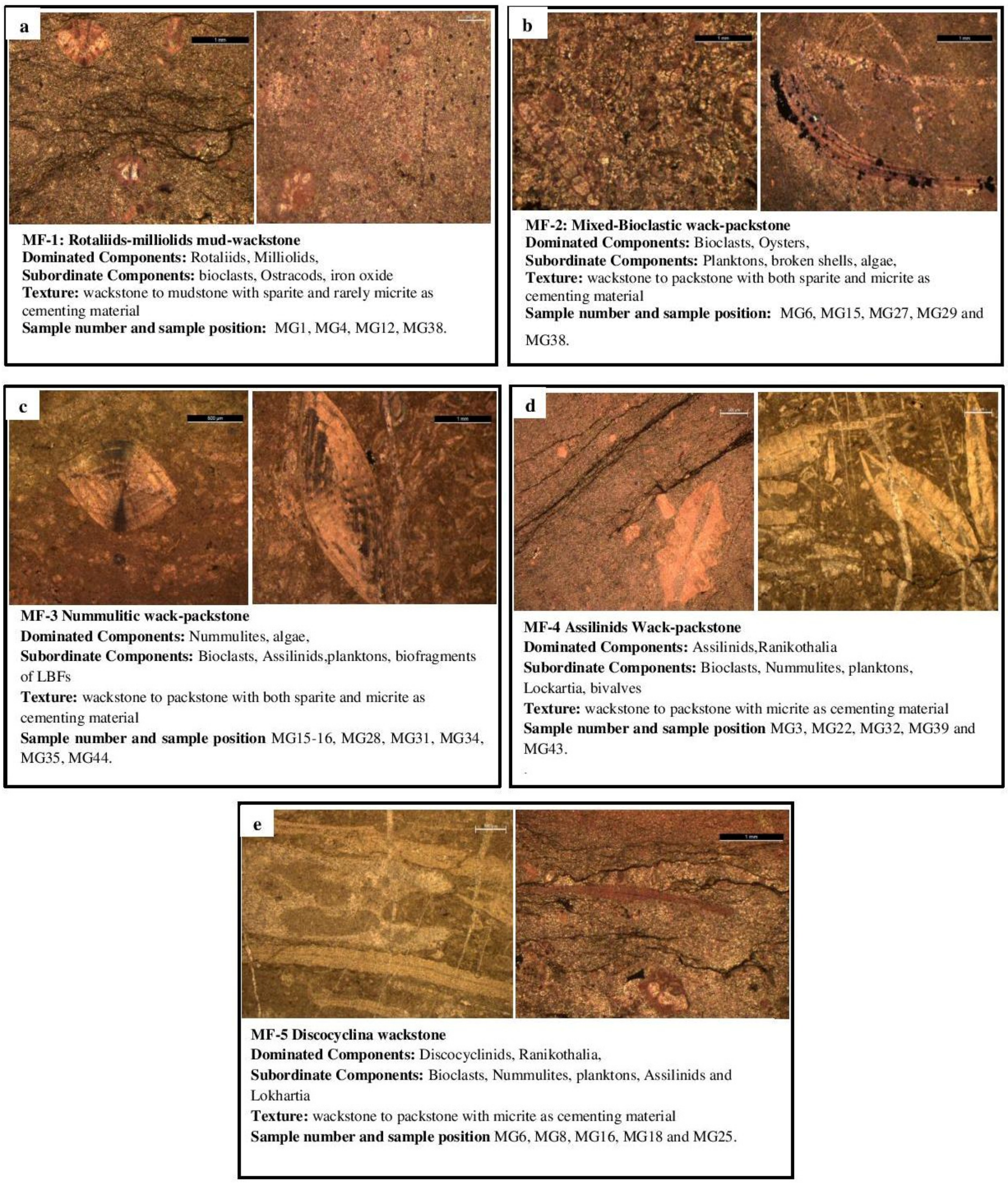

Figure 4. Shows microfacies of Margala Hill Limestone a) MF-1: Rotaliids-milliolids mud-wackstone b) MF-2: Mixed-Bioclastic wack-packstone c) MF-3 Nummulitic wack-packstone d) MF-4 Assilinids Wack-packstone e) MF-5 Discocyclina wackstone

Texture characteristic of this microfacies suggest the deposition in high energy environments in the distal part of the inner shelf.

MF-3 Nummulitic wack-packstone

Nummulitic wackstone microfacies comprises of 30% 0f total microfacies observed. It is characterized by 30-70% Nummulites, 30-50%bioclasts, 20-40% Calcispher, 10-35% Assilina, 15% algae, 10-40% bivalves and abraded shell fragments. The cementing material is micrite originally which has been recrystallized in to spary calcite. The shells and bioclasts show some degree of alignment. The microfacies is observed from sample # MG15-16, MG28, MG31, MG34, MG35 and MG44 (Fig. 4c).

Interpretation

Nummulites, bivalves and Assilina in this microfacies represent relatively more open marine environments in the proximal part of the middle shelf (Adabi et al., 2008). The packstone and wackstone texture implied moderate energy environments between Fair weather wave base and storm wave base, where water current was not strong enough to completely remove the micrite (Racey, 2004).

MF-4 Assilinids Wack-packstone

Assilina wacke-packstone microfacies contributes 40% of all microfacies observed in thin section. The microfacies is characterized by abundance of Assilina species e.g, A. spinosa, A. subspinosa, A. granulose and A. laminosa which constitute 30-80% of all skeletal grain. The others foraminiferal shells observed are 20% Discocyclina, 15-25% Nummulites and 10-60% bivalves and 20-50% broken pieces of LBF. The cementing material is mostly laminated lime mud with low content of sparite. Assilina wack-packstone microfacies is observed under thin section MG3, MG22, MG32, MG39 and MG43 (Fig. 4d).

Interpretation

The Assilina and Discocyclina represent the deposition in relatively deeper part of the shelf within water depth of 40-80m (Racey, 2001, 2004). The laminated texture of carbonate mud indicates low to moderate water circulation (Anketell, 2000).

MF-5 Discocyclina wack-packstone

Discocyclina Ranikothalia microfacies is 20% of all microfacies and comprises of 20-25% Discocyclina, 25-40% Ranikothalia, 20% Assilina, 10-15 Nummulites and 10-40% boclasts. The skeletal grains are mostly oriented parallel to the beddings. The cementing material is mainly micrite which is laminated and has undergone diagenetic alteration in some thin section (Fig. 4e).

Interpretation

The assemblage of Ranikothalia, Discocyclina, Assilina and bioclasts in this microfacies suggest the lower middle and proximal outer shelf environment (Jauhri et al., 2006 and Scheibner et al., 2008). The alignments of skeletal grain and packstone to wackstone texture suggest low to moderate energy environment with water circulation (Anketell, 2000 and Tlig et al., 2010).

Depositional Environment

The Paleocene-Eocene carbonate sequence of the Hazara basin was deposited on the broad shallow carbonate platform along the north western margin of the Indian plate and characterized by different episodes of Margala Hill Limestone is also part of this larger scale transgression and regression which started with the underlying Patala Formation (Late Paleocene-Early Eocene) and ended up with the overlying deposition of Chorgali Formation (Middle Eocene). A number of environmental changes occurred during this period, which bring significance impact on the bio-geosphere evolution and leading to extinction and flourishing of faunal communities (Serra Kiel et al., 1988). Microfacies analysis of the Margala Hill Limestone shows that much of the carbonate sediments are composed of diverse species of larger benthonic foraminifera and bivalves. The depositional environment of Margala Hill Limestone has been deduced on the basis of paleoecology of these larger benthonic foraminifer assemblages and carbonate texture.

The occurrence of these faunal association indicates the constancy of humid sub-tropical climatic condition throughout the deposition of the Formation (Racey, 2004). The interpretation of the five different microfacies associations of Margala Hill Limestone revealed the overall Inner shelf to middle shelf and proximal outer shelf environments. At the onset of deposition, presence of Milliolids and Rotaliids in association to mudstone-wackstone texture depict the inner-shelf settings under slightly higher seawater salinity, which transgress upward into algal bioclastic wackstone-packstone that reflected the high energy deeper inner shelf environments. These facies graded upward into Nummulites, bivalves, Ostracods, algae, bioclasts and quartz grain containing wackstone-packstone, indicating distal inner shelf to proximal middle shelf settings with the effects of current process. These Nummulites containing facies are laterally change into Assilinids wackstone-packstone and Discocyclina and Ranikothalia wackstone facies.

The abundance of elongated form of Assilina along with bioclasts, algae and Nummulites suggesting relatively deeper low energy middle shelf environments while Discocyclina Ranikothalia occurred in distal middle shelf to proximal outer shelf environments. Three cycle of these microfacies repetition has been identified in this section of the Margala Hill Limestone.

Depositional Model

The depositional model for the Margala Hill Limestone (Fig. 5) in studied area used herein refers to the model derived from (Racey, 2001 and Flugel, 2004).

This depositional model is characterized by five different microfacies types and involve the inner shelf to middle shelf settings. The distribution of these microfacies is plotted on this model based on the distinctive depositional environment deduced from the microfacies analysis.

Conclusion

A 96.8m thick outcrop of Margala Hill Limestone is exposed in the Changala Gali to Khaira Gali road section, which consist of medium to thick bedded nodular limestone with intercalations of shales. The formation yields abundance of larger Benthonic Foraminifera along with bivalves, green algae, planktonic foraminifer and Ostracods. Early Eocene (Ypresian) age has been assumed for the formation on the basis of reported fauna. Five microfacies which include Rotaliids-milliolids mud-wackstone, Algal- bioclastic wack-packstone, Nummulitic pack-wackstone, Assilinids wack-packstone and Discocyclina-Ranikothalia wack-packsotne has been identified.

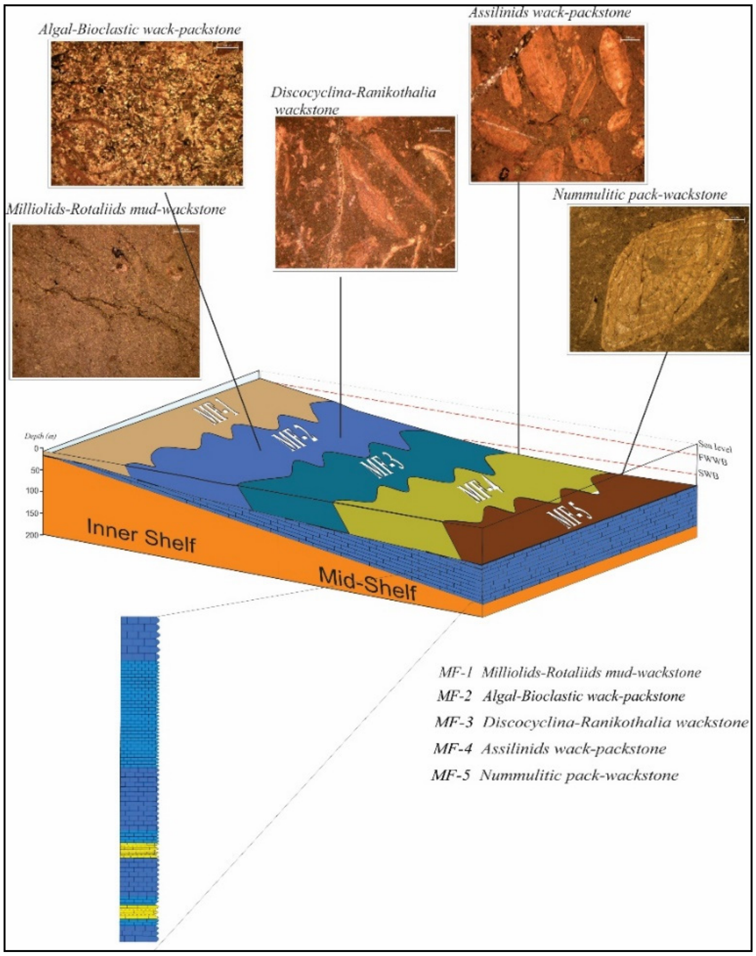

Figure 5. Microfacies despositional model of Margala Hill Limestone showing the types of different facies and their depositional settings

The interpretation of these microfacies infers inner to middle shelf environments for the deposition of Margala Hill Limestone.

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