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Lithofacies properties, biostratigraphy, cyclicity and depositional environment of the Margala Hill Limestone, Hazara Basin, Northern Pakistan

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1. Introduction

The Margala Hill Limestone is composed of bioclastic limestone, and marls. It lies over the Patala Formation and is overlain by the Chorgali Formation. Both upper and lower contacts are conformable. The formation is well exposed and well developed in Hazara area, lesser Himalayas (Figure 1) (Latif, 1970; Shah, 1977). The bioclasts of the formation are dominated by foraminifera, mollusks, algae and echinoids (Raza, 1967; Cheema, 1968; Latif, 1970). The larger benthic foraminifera dominate the allochemical content of the formation. Cheema (1968) and Latif (1970) have recorded various species *of Nummulites, Alveolina, Lockhartia, Discocyclina,* and *Ranikothalia* from the formation. The occurrence of the larger benthic foraminifera in the Margala Hill Limestone indicated a shallow marine depositional environment in a carbonate ramp platform (Akhter and Butt, 1999). Swati et al. (2013) have performed the biostratigraphy of the formation and have recognized three microfacies from the formation in Kohala Bala section, Southeastern Hazara. The formation is correlated to the Eocene Sakesar Formation of Potwar basin by Abir et al. (2013). The previously studied section of the Margala Hill Limestone by Swati et al., 2013 has a missing upper contact, and 40 Meters of the middle portion of the formation is covered. The previous study on the formation was also very general and lacking a detail investigation for the depositional modeling, biostratigraphy and cyclicity. No one has attempted to perform sequence stratigraphic analysis of the formation. Therefore, the present study is aimed to investigate the formation lithological and biostratigraphically in order to interpret its depositional setting and cyclostrtigraphic properties.

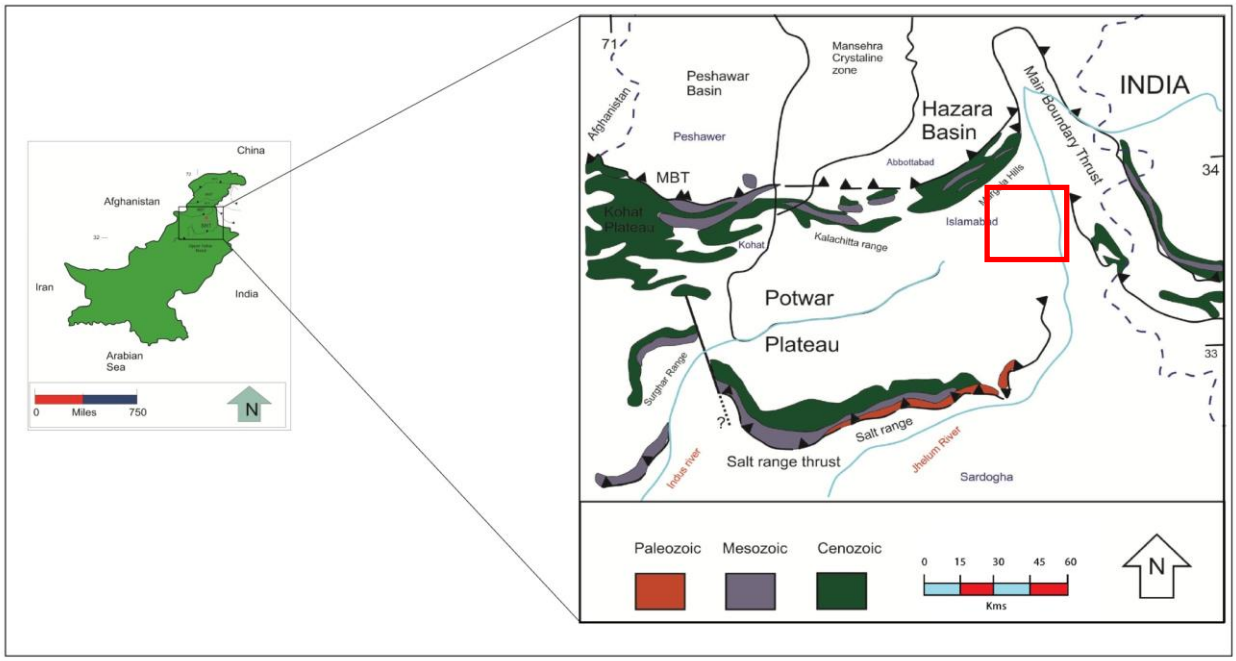

Figure1: Map showing the distribution of various sedimentary strata in the Lesser Himalayas. The red square shows the study area and is located along the Margala Hills, near Islamabad.

2. Methodology and results:

The methodology of this project includes fieldwork, petrographic analysis, and literature review.

2.1 Lithofacies analysis

The outcrop investigation incorporated with the petrographic analysis allows the recognition of nine lithofacies units (Mf1-Mf9). These lithofacies units are: i) Miliolid bearing mudstone (Mf1), ii) Algal-Miliolid wackestone/packstone (Mf2), iii) Bioclastic packstone (Mf3), iv) *Nummulites-Assilina* wackestone/packstone (Mf4), v) *Nummulites-Discocyclina* wackestone/ packstone (Mf5), vi) Elongated benthic foraminifera wackestone (Mf6), vii) Planktonic foraminiferal mudstone (Mf7), viii) Bioclastic Marl (Mf8), and unfossiliferous marl (Mf9). The sedimentary structures, sedimentary textures, the fossil associations of these lithofacies suggest deposition in a homoclinal carbonate ramp setting. The inner part of the ramp was comprised of three sub depositional environments: 1) Lagoon, 2) Transitional and 3) a bioclastic barrier. The MF1 lithofacies represents deposition in a semi restricted-restricted lagoonal environment. The Mf2 lithofacies represents the transitional zone while the Mf3 lithofacies represents a bioclastic barrier depositional environment. The mid ramp (Below FWWB) is represented by Mf4, Mf5 and Mf8 lithofacies. These facies are characterized by tempestite beds which underscore the deposition below the FWWB. The deepest part of the ramp (outer ramp) is represented by the elongated benthic foraminifera wackestone (Mf6), Planktonic rich mudstone (Mf7) and unfossiliferous marl (Mf9) lithofacies units. The vertical stacking nature of these lithofacies suggests cyclic deposition. Three types of cycles (A, B, and C) have been identified from the formation. A) Mudstone-Packstone Cycle: This type of cycles have a planktonic foraminiferal mudstone in the base and grades upwards into *Nummulitic-Assilina* rich wackestone and culminates into bioclastic packstone lithofacies. These types of cycles are present in the lower 20m-25m of the formation. B) Wackestone-Packstone Cycle: elongated benthic foraminiferal lithofacies (Mf5) marks

the base of this cycle and grades upward into Mf4, Mf3 and ends up into Mf2 lithofacies. These kinds of cycles are present in the middle 40m-45m of the formation. C) Packstone-Mudstone Cycle: These types of cycles have *Nummulites* rich packstone in the base (Mf4), grading upward into the bioclastic and algal packstone lithofacies (Mf3/Mf2). The miliolid rich mudstone (Mf1) marks the top of this cycle in some locations. These types of cycles are mostly present in the upper 20m-25m of the formation. The absence of supratidal signature and exposure surfaces suggests a subtidal depositional setting of these cycles. The vertical stacking of the cycle A, B and-C suggests an overall shallowing-upward nature of the formation.

2.2 Biostratigraphy of the Margala Hill Limestone

The larger benthic foraminifera (LBF) dominates the allochemical content of the formation. These fossils have been thoroughly analyzed in this study. The identified index species are *Nummulites globulus, N.atacicus, N.mamillatus, N.sp, Assilina granulosa, A.spinosa, A. supspinosa, A.laminosa, A.sp.* Other associated LBF are *Lockhartia conditi, L.Sp, Discocyclina dispansa, D. ranikotensis, Operculina sp.* and *Ranikothalia.* In this study, these fossils have been grouped into a biozone (MHF1). The comparison of the MHF1 biozone with the standard biozonation schemes of the tertiary rocks suggests the Middle Ilerdian 2/SBZ8 age of the Formation. The lower boundary of the Middle Ilerdian 2/ SBZ8 is (54 Ma) while the upper boundary of SBZ 8 is (52.8) in age. So it is concluded that the formation is deposited in a time span of 1.2 Ma.

2.3 Cyclicity of the Margala Hill Limestone

The Margala Hill Limestone (SBZ8) along with the upper part of the Patala Formation (SBZ6-7) and Chorgali Formation (SBZ9) suggests deposition in one Super Cycle, named here as PMC supercycle. The lower boundary of the SBZ 6 is (55.5Ma) while the upper limit of the SBZ 9 is (52.5). Thus, the biostratigraphy suggests 3 Ma for the PMC cycle. The PMC cycle is further comprised of two 3rd-order Transgressive cycles. These cycles are named here as TR-1 and TR-2. The upper part of the Patala Formation and the lower-middle part of the Margala Hill Limestone is represented by TR-1. Whereas, the upper part of the Margala Hill Limestone and the overlying Chorgali Formation are represented by TR-2 cycle. The Margala Hill Limestone makes the middle part of the PMC supercycle. The formation is internally comprised of 7 parasequences. These cycles are 4th -5th order in nature.

3. Conslusions

In the study area, the formation has an average thickness of 80 m; it conformably lies over the Paleocene-Eocene Patala Formation and conformably overlain by the Early Eocene Chorgali Formation. The Margala Hill Limestone consists of different bioclastic limestone lithofacies with subordinate gray to brownish gray, thin marl interbeds. The limestone lithofacies are commonly grey, weathering pale grey, fine-to medium-grained, nodular, thinly to thickly bedded and rarely massive in nature. . Field data integrated with petrographic analysis allows recognition of nine lithofacies (Mf1-Mf9) from the studied sections. These lithofacies includes miliolid Mudstone (Mf1), Algal-miliolid wackestone-packstone (Mf2), Bioclastic Packstone (Mf3), *Nummulites-Assilina* packstone-wackestone (Mf4), *Nummulites-Discocyclina* wackestone-packstone (Mf5), elongated Benthic Foraminifera wackestone (Mf6), Planktonic Foraminifera mudstone (Mf7), Bioclastic Marl Lithofacies (Mf8) and unfossiliferous Marl Lithofacies (Mf9). The overall depositional setting of the formation is

envisaged to be a quiet to moderately agitated ramp setting where lithofacies Mf1, Mf2 & Mf3 represents inner ramp, lithofacies Mf4, Mf5 & Mf8 represents middle ramp and lithofacies Mf6, Mf7 & Mf9 are outer ramp deposits. The index fossils *Nummulites atacicus, Nummulites globulus* and *Assilina laminosa* suggests the Middle Ilerdian 2/SBZ8 (54Ma-52.8Ma) age for the formation. The Margala Hill Limestone along with the upper part of the Patala Formation and Chorgali Formation suggests deposition in one super-cycle, named here as PMC super cycle. The Supercycle is comprised of two 3rd-order Transgressive-Regressive depositional sequences (TR-1 & TR-2). The Margala Hill Limestone makes the middle part of the PMC super cycle and is comprised of seven, 4th-5th-order shallowing upward cycles.

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