Sedimentology of Marl and Marly Limestone Sequence of Upper Cretaceous Kawagarh Formation from Northern Kalachitta Range, Attock Hazara Fold and Thrust Belt, Pakistan

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ABSTRACT

Upper Cretaceous Kawagarh Formation is well exposed in the Attock Hazara Fold and Thrust Belt (AHFTB) and shows significant lateral and vertical variations in lithology. The present work deals with the sedimentological studies of marl and marly limestone sequence of Kawagarh Formation exposed at the Bagh Neelab, Ghariala north and Sojhanda villages in Northern Kalachitta Range. Detailed petrographic studies of marly limestone and hard marl substrate show that planktons and oysters are the main skeletal constituents of studied samples and clay and detrital quartz mainly composed the non skeletal fraction. X-Ray diffraction analyses of selected marl samples confirm the petrographic data. On the basis of skeletal and non skeletal content, two microfacies—marl microfacies and Planktonic microfacies are constructed. The faunal content, their paleoecology and detrital content of microfacies suggest that marl and marly limestone sequence of Kawagarh Formation was deposited over the mid and outer ramp settings.

Keywords:
Attok Hazara Fold & Thrust Belt, Fauna, Kalachitta Range, Microfacies, Ramp

1. Introduction

Marls represent sole variety of mixed siliciclastic-carbonate rock that contains variable amount of clays along with carbonate minerals. They frequently occur with limestone of diverse depositional environments. Marls are commonly interpreted as deposition of distal and deep marine settings including outer shelf and pelagic environments [1] [2] [3] [4] [5]. However, it has been developed under relatively shallow marine conditions like mid shelf environments [6] [7].

Upper Cretaceous Kawagarh Formation is well exposed throughout the Attock Hazara Fold and Thrust Belt (AHFTB) including the Hazara Basin and Kalachitta Range (Figure 1). It is very diverse in lithology and shows considerable lateral and vertical variations in different parts the AHFTB [6] [8] [9]. In Hazara Basin, the eastern par...
of AHFTB, Kawagarh Formation is represented by a sequence of limestone with subordinate dolomite and marl [6] [7] [10] [11] [12]. Marls are absent in the northern part of Hazara Basin [7] [11]. In Kalachitta Range, the western extremity of AHFTB, it is composed of limestone and marl with minor marly limestone and dolomite [6]. Limestone and marl constitute as major lithofacies in the southern part of Kalachitta Range whereas the northern part of Kalachitta Range is exclusively represented by the sequence of marl and marly limestone [6] [8] [13]. The southern sections of Kawagarh Formation are well studied in terms of Sedimentology and paleontology but no significant sedimentological record is available on the marl and marly limestone sequence of northern sections.

The present work mainly focuses on the sedimentological attributes including detrital and carbonate contents, faunal assemblage and sedimentary structures of marl and marly limestone sequence of Kawagarh Formation exposed in the northern Kalachitta Range to depict their depositional settings.

2. Regional Geology

Kalachitta Range, the part of AHFTB (Figure 1) is resulted by deformation and uplift of northern margin of India after the Late Eocene Indo-Asia continent-continent collision [16] [17] [18] [19] [20]. It constitutes the southernmost part of Lesser Himalaya in the west of Hazara Basin [17] [21]. Kalachitta Range is bounded by Main Boundary Thrust (MBT) and Nathia Gali Thrust (NGT) or Hissartang Fault (HF) in south and north respectively [15] [22]. It is truncated by Margalla Range in east and separated from Nizampur Basin in west by Indus River [15] [23]. Kalachitta Range is characterized by series of southward verging thrusts and wedge shaped structural geometry [23]. Kalachitta Range exhibits sequence of sedimentary rocks ranging in age from Triassic to Miocene-Pliocene (Figure 2) [8] [13] [24] [25]. MBT emplaced the sedimentary sequence of Kalachitta Range over the rocks of Northern Potwar Deformed Zone in south [23] [26]. This sedimentary sequence of Kalachitta Range is covered by the sediments of Cambellpur Basin in the north of Kalachitta Range [23].

3. Materials and Methods

After the thorough field excursion of northern and northwestern Kalachitta Range, three stratigraphically complete sections of Kawagarh Formation exposed at Bagh Neelab, Ghariala north and Sojhanda villages, Attock district were selected for the Sedimentological studies. All sections were exposed excellently with preserved bottoms and least deformation. All sections were measured by using Jacob Staff apparatus and measuring tape [27]. The outcrop data of studied sections including lithology, color, sedimentary structures, grain size, fauna, bedding contacts etc. were recorded on the Field data sheets. A total of 17, 19 and 21 samples were collected from Sojhanda, Ghariala and Bagh Neelab respectively. Collection of samples had been done at suitable intervals as per variations in lithology and thickness of different beds from all three sections. Each bed of marly limestone was sampled whereas only one sample was collected from the each marl horizon. Samples of limestone and marl were transported to laboratory for petrographic and mineralogical studies.

The limestone samples and selected hard chips of marls were thin sectioned. Thin sections were stained following the staining technique of given by Dickson, J. (1965) [28]. Thin sections were analyzed by using Polarizing microscope to determine the skeletal and non skeletal grains, matrix and depositional fabric of studied samples. The detrital content and mineral compositions of marls were also determined by the X-Ray diffraction analyses. The microscopic and X-Ray diffraction data of studied samples were used to construct the microfacies to deduce the depositional environments of studied sections. Deposition environments of microfacies were used to establish the depositional model of marl and marly limestone sequence of Kawagarh Formation exposed in the northern part of Kalachitta Range.
4.1. Outcrop Geology

In northern Kalachitta Range, Kawagarh Formation is mainly comprised of marl with subordinate marly limestone (Figure 3(a) & Figure 3(b)). Marl is generally light grey to medium grey and occasionally greenish grey on fresh surface and shows different weathering colors like yellowish brown and rusty brown (Figure 3(b) & Figure 3(c)). It contains silty and sandy concretions at places and also shows broken shell fragments at places. Marl is generally compacted and cleaved and also show some hard substrate at places. Marly limestone is generally light grey to medium grey and thin bedded to medium bedded with occasional thick beds. It is generally unfossiliferous and contains some burrows which are identified as Thalssinoids of Cruzania class (Figure 3(d)). The lower contact of Kawagarh Formation is slightly gradational which is marked by Lumshiwal Formation (Figure 3(e)) while the upper contact followed by the lateritic clays of KT Boundary (Figure 3(f)).

The skeletal content mainly includes the Planktonic foraminifera and benthic fragments of oysters, trigonia and brachiopods. Non skeletal grains mainly include detrital quartz and dolomite. Some sedimentary structures including horizontal and inclined burrows, abraded shells and graded bedding were also recorded in some samples. The petrographic data including type and abundance of skeletal grains and non skeletal grains, matrix and sedimentary structures were recorded and used to construct the microfacies.

4.2. Microfacies

Microfacies analyses are frequently used to deduce the depositional settings of ancient carbonate and mixed siliciclastic-carbonate rocks [3] [27]. In present study classification of [29] has been used with slight modifications suggested by [27] to construct the microfacies. The names of microfacies were assigned on basis of dominant biota type.

4.3. Marl Microfacies

Thin section studies of hard chips of marl samples show that marls contain minute content of biota. The skeletal content generally ranges from 4% to 6%. The preservation of biota is generally very poor. The skeletal content is mainly comprised of planktons and bioclasts of oysters with trace occurrence of brachiopod and trigonia (Figure 4(a) & Figure 4(b)). Planktons generally include the globotruncana with trace occurrence of heterohelix at places. The skeletal grains are widely distributed over the fine grained clayey and calcitic matrix. Planktons are generally 0.1 mm to 0.26 mm in size (Figure 4(a)). The plankton chambers are frequently replaced with sparite. The broken tests of planktons also occur at places. Oysters are generally broken and show the effect of abrasion marked by the sharp and modified margins (Figure 4(b)). The size of oysters generally ranges from 0.3 mm to 0.42 mm. Inclined burrows rarely occur in this microfacies. Clay and quartz represent the major detrital constituents of marl microfacies. Clays composed the fine grained matrix along with substantial amounts of calcite. Quartz grains are generally sub angular to sub rounded and very fine to silt sized (Figure 4(a) & Figure 4(b)). The quartz content ranges from 10% to 20%.

The XRD analyses of selected bulk samples of marl microfacies show that the marls are mainly composed of clays.
minerals including smectite and illite with subordinate calcite and quartz in sample (KBN-12) and (KSJ-04) samples (Figure 4(c) & Figure 4(d)). The total clay content is ranges from 50% to 65% and calcite content varies from 20% to 28%. The detrital quartz content is evaluated from 10% to 18%.

4.4. Planktonic Wackestone and Packstone Microfacies

Marly limestone generally represents Planktonic microfacies which are characterized by the dominancy of Planktonic foraminifera (Figure 5(a) & Figure 5(b)). Planktonic foraminifera are comprised of Globotruncanidae with rare occurrence of Globigerinoidae and Heterohelix (Figure 5(b) & Figure 5(c)). Planktonic content generally ranges from 25% to 32% with an average of 28% in wackestone microfacies and it varies from 52% to 60% in packstone microfacies with a mean of 55% (Figure 5(d)). The size of planktons generally varies from 0.25 mm to 0.6 mm.

Planktons are moderately to poorly preserved and their chambers are generally neomorphosed by the sparine whereas the peripheries are replaced by the microspar (Figure 5(c)). Chambers are also replaced by the dolomite at places. Planktons are broken at places and intact to broken ratio is about 3:1.

Detrital quartz and dolomite are major non skeletal grains of this microfacies (Figure 5(d)). Quartz grains are generally sub rounded and silt sized. The quartz content generally ranges from 3% to 5%. Dolomite generally occurs in form of small rhombic crystals and its content ranges from 1% to 2%. Inclined burrows are the only sedimentary structures of this microfacies and occur at places. The groundmass is generally fine grained and it dominantly composed of clay and calcite.

5. Depositional Environments

Unlike the clastic sedimentary rocks, the paleoecology of skeletal grains along with microfacies analyses is the only reliable criteria to decipher the depositional environments in carbonate rocks due to the lack of sedimentary structures [3] [7] [27] [30] [31] [32]. In present study, the paleoecology of skeletal grains has been used to deduce the depositional environments of studied sequence of marl and marly limestone. Petrographic studies show that planktons and oysters are the main skeletal constituents of both microfacies.

Planktonic foraminifera are significantly used to constraint the biochronology and paleo environments in ancient carbonate rocks [33] [34]. Planktons occur in diverse depositional environments ranging from shallow shelves to deep water systems like ocean basin in varying amounts [1] [3] [7] [27] [32] [35] [36]. The frequency of planktons is greatly affected by depth as very low over the shallow shelf up to 50 m depth and common to abundant at the deeper parts of shelves more than 50 m depth [37] [38] [39] [40]. Planktons generally coexist in minor amounts with high frequency of benthons over the shallow shelves [34] [41].

Oysters, the sub group of bivalves abundantly constitute the Mesozoic sedimentary rocks of diverse environments ranging from near shore settings to deeper shelves [42] [43] [44]. They generally occur in large amounts over shallow shelves and near shore environments [42] [43] [44] reported them from limestone and sandstone of shallow shelf environments. Furthermore, [44] marked a gradual decrease in frequency of oysters with increase of depth and placed them over the shallow shelf and shore face settings. The above mentioned paleoecological constraints of planktonic foraminifera and oysters clearly indicate that the studied microfacies of Kawagarh Formation exposed in the northern Kalachitta Range were deposited over open marine conditions under the moderately to deep water depths.

6. Depositional Model

Carbonate deposition generally occurs in five distinct settings including rimmed shelves, non rimmed shelf ramps, epeiric platforms and isolated platforms, characterized by the various depositional features and facies [27] [45] [46] [47] [48]. The absence of reefal facies, carbonate sand shoals, slump structures and pelagic sediments infer ramp settings for the deposition of Upper Cretaceous Kawagarh Formation (Figure 6). Similar ramp settings have inferred for Kawagarh Formation exposed in the Hazara Basin and Kalachitta Range [6] [7] [32] [49].
Ramp can be further divided into three sub settings including inner ramp, mid ramp and outer ramp on the basis of Fair Weather Wave Base (FWWB) and Storm Wave Base (SWB). The absence of oolitic facies, high frequency of benthic fauna and grainstone microfacies in the studied samples indicate that the studied microfacies were deposited below the FWWB. The occurrence of planktons along with broken pieces of oysters and low to common frequency of Planktonic foraminifera in marl microfacies suggest mid ramp settings, a transition between inner and outer ramp settings (Figure 6). [50] [51] characterized the mid ramp facies by the low frequency of planktonic and bioclasts, winnowed shells, hummocky cross stratification and fine grained detrital sediments transported by the storm action. The substantial amounts of very fine grained to silt sized detrital quartz (15% - 18%) also indicate a slightly land distal mid ramp settings for the deposition of marl microfacies. Fauna is generally poorly sorted within marl microfacies which are diagnostic feature of storm deposits. Furthermore, the abraded shells of oysters strongly indicate the transportation of oysters form the shallow settings caused by the storm action.

The marly limestones are represented by the Planktonic wackestone and packstone microfacies which are interpreted as outer ramp facies deposited below the SWB (Figure 6). Outer ramp facies are generally characterized by the high frequency of planktons, absence of benthic, lack of detrital material with abundant wackestone and packstone assemblage [3] [27] [36] [50]. The common to abundant occurrence of Planktonic foraminifera in Planktonic wackestone and packstone microfacies and their paleoecology suggested land distal low energy conditions like outer ramp settings for the deposition of these microfacies as discussed above [1] [3] [7] [27] [32] [35] [36]. The low content of detrital quartz also suggests distal deep water settings for Planktonic microfacies. Furthermore, the absence of slope structure, pelagic sediments and bedded cherts also confer a deep ramp conditions like outer ramp for the deposition of these microfacies.

7. Discussion

In vertical profiles of all three studied sections of Late Turonian to Early Maastrichtian Kawagarh Formation, the bases of all sections are marked by the marl microfacies (Figure 7) directly residing over the ferruginous and slightly calcareous sandstone of Lumshiwal Formation with sharp but slightly gradational contact (Figure 3(e)). Further, the marl microfacies are followed by Planktonic wackestone and packstone microfacies in all studied sections. This overlapping pattern of microfacies demarcates transgression at the bases all studied sections (Figure 7). The gradual increase in the frequency of planktons and decrease in detrital content from underlying marl microfacies to Planktonic microfacies also indicates gradual increase in the water depth [1] [5] [7] [36] [39]. This transgression corresponds to Late Turonian global sea level rise as marked on the global sea level curve of [52]. The transgressive cycles are further followed by the regressive cycles in all studied sections. Maximum sea level changes (including three transgressions and three regressions) have been recorded at easternmost section of Kawagarh Formation exposed at Bagh Neelab (Figure 7) while other two sections including Ghariala north and Sojhanda sections are characterized by four sea level changes. The tops of all studied sections are characterized by regressive cycles marked by the deposition of marl microfacies which are further followed by the lateritic clays of KT Boundary which marks the uplift and/or exposure of Kawagarh Formation.

8. Conclusion

The outcrop data, microfacies analyses and the absence of slope features, reefal facies and ocean basins clearly infer the ramp settings for the deposition of Upper Cretaceous Kawagarh Formation exposed in the northern Kalachitta Range. The marl microfacies were deposited under mid ramp settings while the marl limestone was deposited over the outer ramp settings. The inner ramp deposition is not recorded in the northern Kalachitta Range which indicates that the study area was located significantly distant from the land during the
deposition of Kawagarh Formation.

**Conflicts of Interest**

The authors declare no conflicts of interest regarding the publication of this paper.

**Cite this paper**

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succession of Middle–Late Campanian age has been investigated with respect to a Milankovitch-controlled origin of geochemical data. In general, the major element geochemistry of the marl–limestone rhythmites can be explained by a simple two-component mixing model with the end-members calcium carbonate and ‘average shale’-like material. Carbonate content varies from 55 to 90%. Source rock potential and depositional environment of Upper Cretaceous sedimentary rocks, Abu Gharadig Basin, Western Desert, Egypt: An integrated palynological, organic and inorganic geochemical study. International Journal of Coal Geology, Vol. 186, Issue, p. 14. CrossRef. Google Scholar. Rock formations. The high eustatic sea level and warm climate of the Cretaceous meant a large area of the continents was covered by warm shallow seas. In northwestern Europe chalk deposits from the Upper Cretaceous are characteristic for the Chalk Group, which forms the white cliffs of Dover on the south coast of England and similar cliffs on the French Normandian coast. The group is found in England, northern France, the low countries, northern Germany, Denmark and in the subsurface of the southern part of the North Sea. The group also has other limestones and arenites. Among the fossils it contains are sea urchins, belemnites, ammonites and sea reptiles such as Mosasaurus. Recommended For You Serpukhovian Epoch. Sedimentary Rocks. Marl. Chalk. Siltstone. The weathering, erosion and the eventual compaction of igneous, metamorphic or previously dependent sedimentary rocks amongst different biological sedimentations ends in the formation of sedimentary rocks. So, Those are constructed from previous rocks which might be relentlessly weathered or eroded and then deposited in which they go through compaction and cementation via a method called lithification- converting of sediments into a rock. This is how the name sedimentary rock changed into coined. Formation. All rocks, be it igneous, metamorphic, or the already existing sedimentary rocks are co