

Microfacies and depositional environments of upper cretaceous Kawagarh Formation from Chinali and Thoba sections Northeastern Hazara Basin, lesser Himalayas, Pakistan

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Abstract

The present study mainly focused on the microfacies based depositional environments of Upper Cretaceous Kawagarh Formation from Thoba and Chinali Sections exposed in northeastern Hazara Basin. A total of 325 samples of limestone were collected from above mentioned sections for petrographic studies. Calcspheres, planktons, inoceramids and filaments are recognised as dominant skeletal grains embedded in micritic matrix. Biota assemblages and their abundance are used to establish seven microfacies which include Calcsphere-Planktonic wackestone and packstone, Planktonic-Calcspher wackestone, Planktonic wackestone, Dolostone, Inoceramous-Planktonic wackestone, Planktonic-Filamentous wackestone and Filamentous-Planktonic wackestone microfacies. Absence of reef, extensive reworking and shallow deposition and carbonate sand shoal barriers suggest the deposition of Kawagarh Formation over the ramp setting. Paleoecology of main biota (calcspheres, planktons and filaments) and microscopic sedimentary structure recorded in microfacies reveal that Kawagarh Formation was deposited over mid and outer ramp settings as deepening upward sequence.

Keywords: Hazara Basin; Microfacies; Ramp setting; Planktons; Calcspheres; Filaments.

1. Introduction

Hazara Basin is confined between latitudes 33° 40' N to 34° 20' N and 72° 30' E to 73° 30' E and is located in the Hazara Division of Khyber Pakhtunkhwa Province of Pakistan (Fig. 1). Upper Cretaceous strata are well exposed throughout the Hazara Basin and represented by thick carbonate sequence of Kawagarh Formation. The Kawagarh Formation is mainly comprised of limestone with subordinate marl and dolomite (Latif, 1970; Ahsan, 2008; Ahsan and Chaudhry, 2008; Rehman, 2009; Ahsan et al., 2015). In the past many workers like Latif, (1970), Butt, (1986, 1989) and Butt et al., (1990) deduced the depositional environments of Kawagarh Formation using paleontological data without emphasizing microfacies analysis. Furthermore bathymetric and paleogeographic constraints were also established roughly on basis of limited paleontological information without focusing depositional fabric and energy conditions.

In present study, detailed petrographic studies of Kawagarh Formation exposed at Thoba and Chinali Sections in northeastern Hazara Basin have been conducted to determine the skeletal

and non skeletal grains and matrix type with their abundance. The skeletal grains data have been used to establish microfacies. The paleoecology of fauna and microscopic sedimentary structures are used to deduce the depositional environments.

2. Regional geology

Hazara basin is geologically confined between Panjal Fault (PF) in north and Main Boundary Thrust (MBT) in south, lies in the east and northeast of Kalachitta Block of Pogue et al., (1999). It geographically covers the area of Galiat-Abbottabad in north and Margalla hills in south (Fig. 1). Hazara basin is comprised of E-W trending sedimentary belt which converges into western limb of Hazara Kashmir Syntaxis (HKS) in east and northeast and truncated by Indus River and Kalachitta Range in west and southwest respectively. Hazara basin is represented by a thick sedimentary sequence (Fig. 2) of northern edge of Indian Plate ranging in age from Pre Cambrian to Eocene. Sedimentary sequence is highly folded and cut by numerous thrust and normal faults (Ahsan and Chaudhry, 2008).

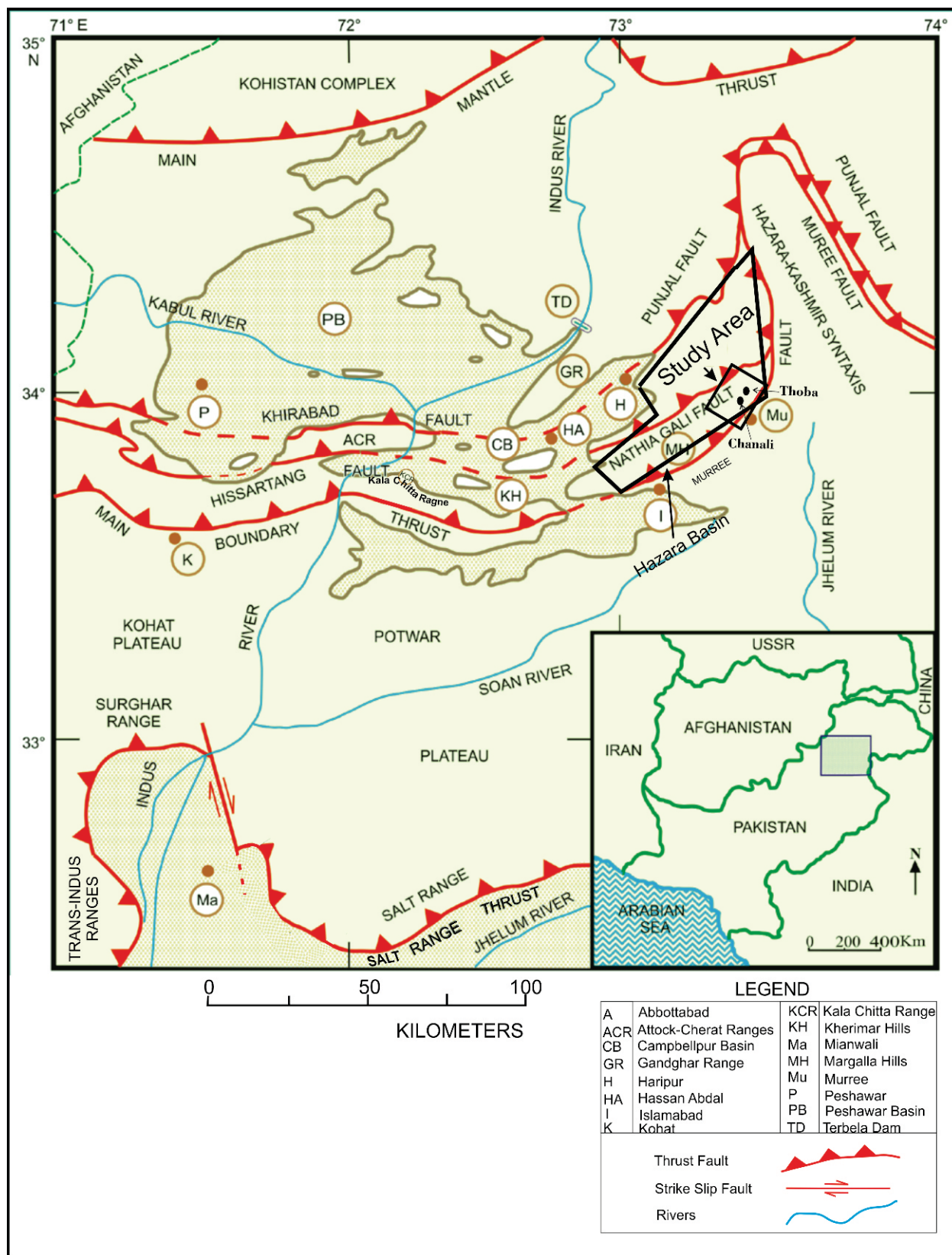


Fig. 1. Tectonic map of Northern Pakistan (modified after Hylland and Riaz, 1988).

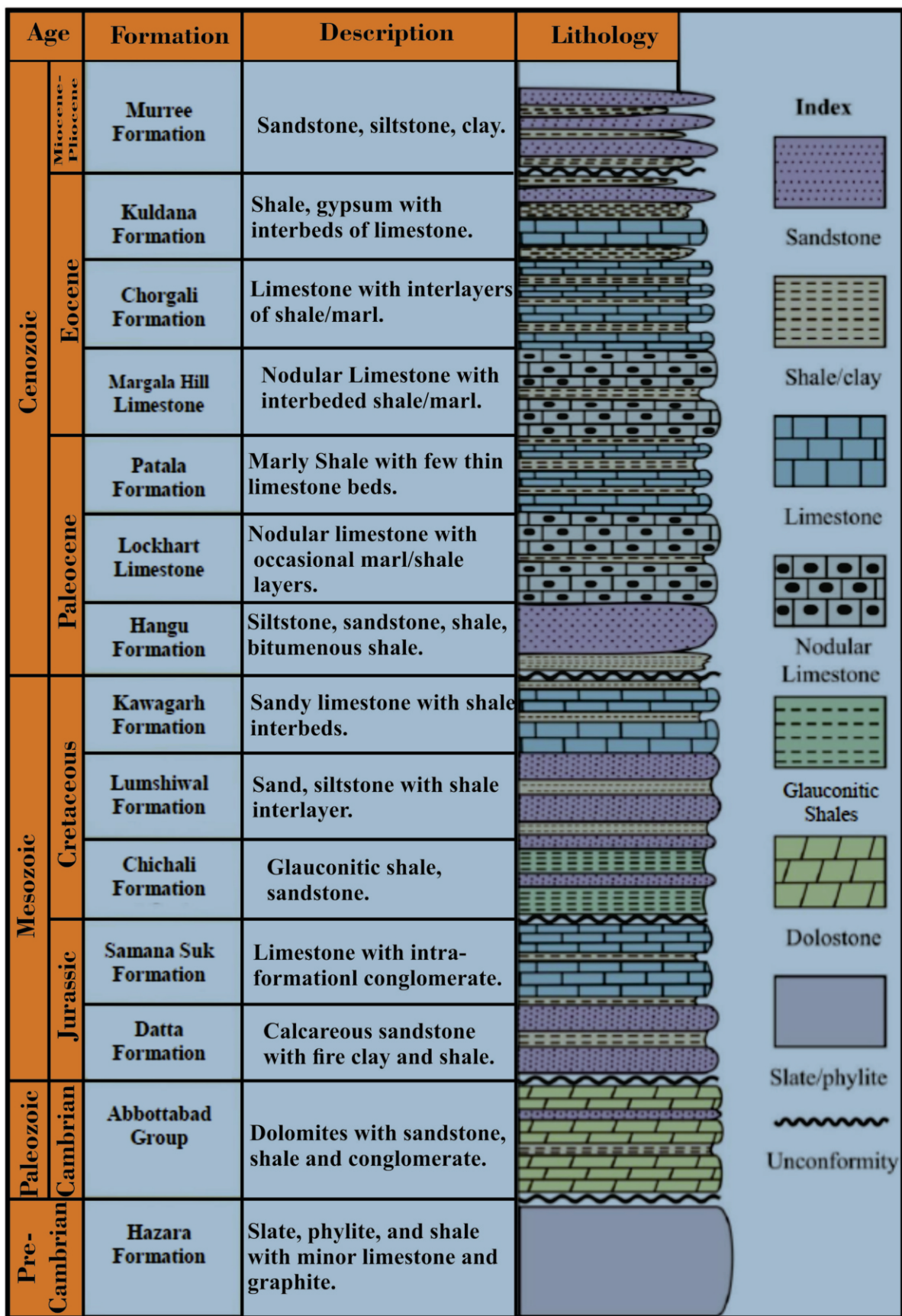


Fig. 2. Generalized stratigraphic column of Hazara Basin after Latif (1970).

3. Materials and methods

Two stratigraphic sections of Kawagarh Formation exposed at Chinali ($73^{\circ} 16' 45''$ E and $33^{\circ} 56' 20''$ N) and Thoba ($73^{\circ} 17' 33''$ E and $33^{\circ} 56' 50''$ N) villages Abbottabad District were selected for sampling (Fig. 1). Selected sections are stratigraphically normal with no structural complications and preserved top and bottom. Both the sections were measured with the help of Jaccob staff and measuring tape and sampling was carried out (Flügel, 2004). At Chinali (113 m thick) and Thoba (107 m) Kawagarh Formation is mainly composed of limestone and dolomite. All necessary information and field features like lithology, thickness, colour, grain size, fauna and sedimentary structures were recorded on field data sheets to construct the litho logs. A total of 325 samples were collected from two sections, 193 from Chinali and 132 from Thoba. Marls are absent in both sections. It is generally thin to thick bedded and medium to dark grey (Fig. 3). Limestone and dolomite are fine to medium grained. Dolomite generally exhibits yellowish brown to yellowish grey tones (Fig. 4) and is confirmed by very slow reaction with diluted HCl. Some alternate beds of fine grained limestone and medium grained dolomite (Fig. 5) occur in alternate pattern that are gradually replaced by fine grained limestone towards top. Dolomite shows sandy texture at places. Limestone, at places, contains dolomitic patches. Some burrows are also recorded at the base (Fig. 6). The lower contact with

Lumshiwal Formation is gradational whereas the upper contact with Hangu Formation is unconformable.

Thin sections were prepared and stained with staining solution of Dickson (1966) to differentiate the ferron and non ferron calcite. All thin sections were studied under the polarizing microscope to determine the skeletal, non skeletal grains, cement types and other petrographic features like microscopic sedimentary structures. The percentages of total skeletal grains and individual skeletal types were calculated by using grain counter. The percentages of individual skeletal types were calculated by dividing individual skeletal grains with total skeletal grains in each sample and multiplying with 100. The classification scheme of Dunham (1962) was used to construct the standard microfacies with slight modification after Flügel (2004) by determining the abundance of major skeletal grains within total skeletal content. Due to diagenetic alterations, abundance of skeletal grains has been used to assign the nomenclature to microfacies. Percentages of all microfacies have been calculated with respect to total number of samples and total thickness of each section. Facies abundance is calculated by dividing number of samples in individual microfacies by total number of samples in section and multiplying with 100. Similarly thickness percentage is calculated by dividing thickness of individual microfacies by total thickness of section and multiplying with 100.



Fig. 3. Thin to thick bedded limestone.



Fig. 4. Yellowish brown dolomite in Kawagarh Formation.



Fig. 5. Contact between medium grained and fine grained limestone.

4. Results and Discussion

1.1. Microfacies

Microfacies analysis is considered the most reliable technique in interpreting depositional environments of ancient limestones. (Reading, 1996a and b; Flügel, 2004). In the present study, microfacies have been established by using classification of Dunham (1962) with modified parameters developed by Flügel (2004). The worked out microfacies are tabulated and summarized in Table 1.

4.2. Calcspheric-planktonic wackestone and packstone microfacies (SMF1)

Calcspheric-Planktonic microfacies (Figs. 7 a, b) is the most abundant and represent the 31% of the total studied samples and about 34% of total thickness (34.2% at Thoba and 33.8% at Chinali). Calcspheres are dominant skeletal grains occurring in this microfacies that range in abundance from 15 to 90% with an average of 37% (17% in wackestone and 53% in packstones). Second major constituent is planktons generally globotruncanoidea and rarely globigerinidae, which range 3 to 20% with an average of 9% (5% in wackestone and 12% in packstone). Calcspheres generally range in size from 0.02 to 0.17 mm and planktons are 0.10 mm to 0.17 mm in size. Skeletal grains are randomly distributed in wackestones and exhibit close packing in packstones. Calcspheres are bedded in micritic



Fig. 6. Burrows in the basal part of Kawagarh Formation.

ground mass with strongly neomorphosed interiors. Sorting is overall poor. Oysters, Ostracods and Textularia (Fig. 7c) are the minor constituent of this microfacies. Dolomite and authigenic quartz are present in minor amount (1% to 2%) in some samples. Quartz occurs as sub angular to angular grains with sharp faces. Some skeletal grains especially planktons (globotruncana) show the effect of replacement generally by dolomite. Partial replacement and complete replacement are observed. Matrix is mainly comprised of fine grained micrite which is generally dark brown. Sparite is absent in this microfacies. Horizontal to slightly inclined burrows and graded bedding are found in some thin sections.

4.3. Planktonic-calcspheric wackestone microfacies (SMF2)

Planktonic-Calcspheric wackestone microfacies (Fig. 7d) is the second abundant microfacies and constitute the 25% of the total samples and about 28% of total thickness (30.3% at Thoba and 25.4% at Chinali). It is characterized by the abundance of planktons over calcspheres. Planktons are generally globotruncanoidea with some globigerinoidae, which range in abundance from 7% to 30% with average of about 17%. The mean content of planktons is higher in Chinali Section than Thoba Section. Calcspheres range 2 to 17% with an average of 8%. Planktons (globotruncana) are 0.11 mm to 0.19 mm in size and poorly preserved. Globotruncana are highly affected by neomorphism, mechanical

breakage and replacement. Chambers of some plankton are completely replaced by dolomitization at places. Dolomite occurs as rhombic crystals or patches which replace the chambers partially or completely. Chambers are generally neomorphosed and contain sparite. The estimated intact to broken ratio is 1:6. Skeletal grains are evenly distributed in micritic matrix of wackestones. Other subordinate grains are inoceramids, ostracods,

echinoids and textularia. Graded bedding (Fig. 7e) and burrows are the prominent features of this microfacies. Burrows are horizontal to inclined in orientation and show close packing. Burrows are completely filled with planktons and broken shells. Maximum size of burrow is 0.30×0.8 mm. The matrix is generally composed of fine grained, earthy to dark brown micrite.

Table 1. Microfacies and their abundance in studied sections.

Code	Microfacies	Facies Abundance (%)
SMF.1	Calcsispheric-Planktonic Wackestone and Packstone	31
SMF.2	Planktonic-calcsispheric Wackestone	25
SMF.3	Planktonic Wackestone	14
SMF.4	Dolostone	12
SMF.5	Inoceramous-Planktonic Wackestone	9
SMF.6	Filamentous-Planktonic Wackestone	5
SMF.7	Planktonic-Filamentous Wackestone	4

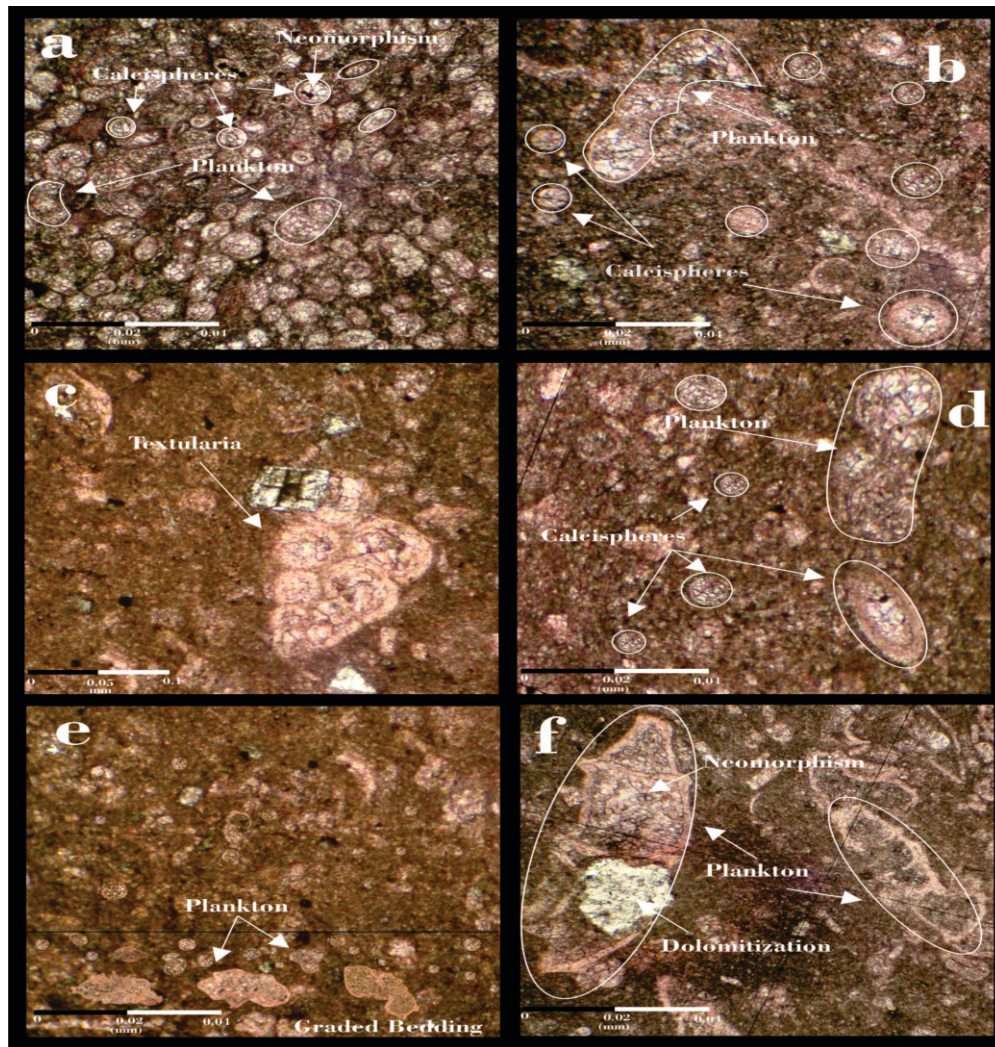


Fig. 7. (a) Calcsispheric-Planktonic Packstone, (b) Calcsispheric-Planktonic Wackestone, (c) Textularia in Calcsispheric-Planktonic Wackestone (d) Planktonic-Calcspheri Wackestone, (e) Graded bedding in Planktonic-Calcsispheric Wackestone, (f) Planktonic Wackestone.

4.4. Planktonic wackestone microfacies (SMF3)

Planktonic wackestones (Fig. 7f) microfacies constitutes 14% of total samples and about 14% of total thickness (9% at Thoba and 14.6% at Chinali). Planktons generally belong to globotruncanoida family with some globigerinoidae and range in abundance from 8 to 15% (mean = 11%). The planktons are generally widely distributed on fine grained, dark brown micritic matrix with no specific orientation and are generally 0.26 mm to 0.88 mm in size. Planktons show slight reduction of size in this microfacies as compared to SMF1 and SMF2. Subordinate grains are of dolomite that range from 40 to 43%. Dolomite generally occurs as individual rhombic crystals. The centers of crystals are black possibly due to iron content. The chambers of some plankton are affected by dolomitization (Fig. 7f). Test of planktons show the effect of neomorphism and exhibit sparry texture (Fig. 7f). The intact to broken ratio is 1 into 3. Some stylolites are also recorded which show bedding parallel orientation. The dolomitization is more intense along the stylolites. Rare oysters and ostracods have been observed along the planktons. Burrows are also found in this microfacies (Fig. 8a).

4.5. Dolostone microfacies (SMF4)

About 12% of total samples and 11% of total thickness (10.9% at Thoba and 12.2% at Chinali) are represented by Dolostone microfacies. Dolostone (Fig. 8b) generally composed of individual rhomb shaped crystals of dolomite or as mosaics of dolomite crystals (Fig. 8b). The average dolomite content is about 98% at Chinali Section and 95 % at Thoba Section. Dolomite crystals range in size from 0.02 to 0.36 mm. The individual rhomb shaped crystals are closely distributed and separated by some micritic matrix at places. The mosaics of dolomite crystals occur as interlocked crystal pattern without micritic matrix. This interlocking pattern shows the complete replacement. Dolostone is repeatedly interbedded in fine grained limestone at the lower part of Chinali and Thoba sections which exhibit the interlocking pattern of dolomite crystals. Centers of rhombic crystals are generally black.

4.6. Inoceramous-planktonic wackestone microfacies (SMF5)

Inoceramous-Planktonic wackestone microfacies (Fig. 8c) constitute about 9% of the total studied samples and about 9% of total thickness (7.1% at Thoba and 7.4% at Chinali). It is mainly comprised of inoceramids which generally occur in the form of broken pieces of blocky shape. The pieces of inoceramids are sparsely spaced. The inoceramids range from 15% to 35% with mean content of 23%. Planktons are distributed as disseminated grains and range from 10% to 15% with mean content of 8%. Planktons mainly include globotruncana and globigerina with some unidentified broken test. Other subordinate grains are filaments, echinoid (Fig. 8d), ostracod and oysters. Filaments very sparsely distributed and range from 1% to 3%. This microfacies show the poor sorting of fauna. Some abraded shells are also found. The bedding parallel stylolites are rarely encountered in some samples. Dolomite is totally absent. The matrix is comprised of micrite.

4.7. Filamentous-planktonic wackestone microfacies (SMF6)

Filamentous-Planktonic wackestone microfacies (Fig. 8e) constitute 5% of the studied samples and 5% of total thickness (6.3% at Thoba and 3.9% at Chinali). Filaments are randomly distributed and their mean content is 8% whereas planktons constitute 4%. Filaments are generally widely distributed over the micritic matrix. At places filaments exhibit bedding parallel orientation and graded bedding (Fig. 8e). Planktons are mainly represented by globotruncana and occur as disseminated grains along the filaments. Broken planktons are also observed showing the effect of compaction. Other subordinate grains are inoceramids and ostracods. The matrix is comprised of micrite. Dolomite ranges from 20 to 25%. Horizontal burrows are present in this microfacies. Stylolites are generally bedding parallel in orientation and some are inclined. Burrows are also encountered. Most of the burrows are horizontal and exceptionally inclined.

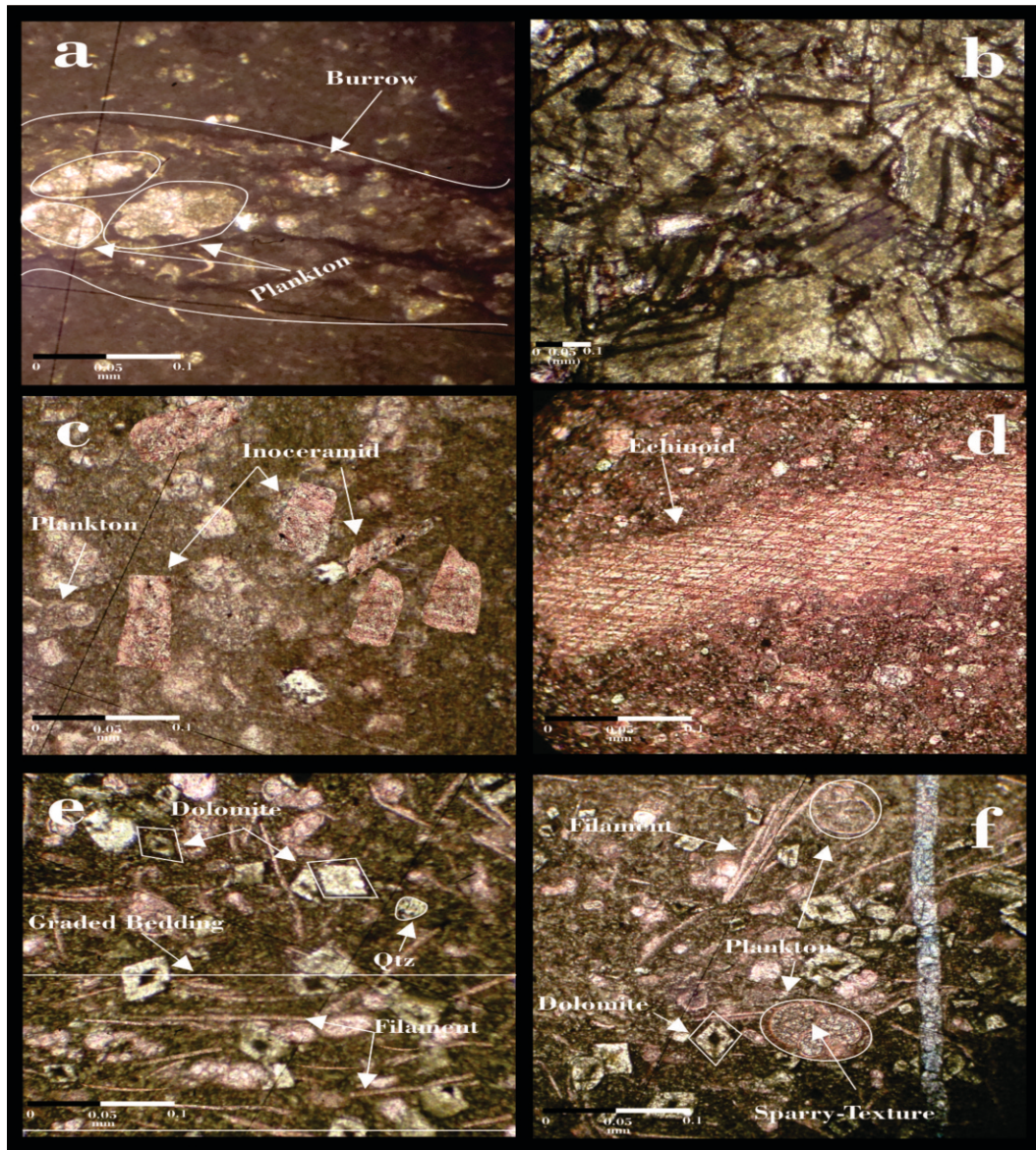


Fig. 8. (a) Burrow in Planktonic Wackestone, (b) Dolostone, (c) Inoceramus-Planktonic Wackestone, (d) Echinoid in Inoceramus-Planktonic Wackestone, (e) Filamentous-Planktonic Wackestone, (f) Planktonic-Filamentous Wackestone.

4.8. Planktonic-filamentous wackestone microfacies (SMF7)

Planktonic-Filamentous wackestone microfacies (Fig. 8f) is least occurring microfacies and represent 4% of the total samples and about 3% of total thickness (2.2% at Thoba and 2.8% at Chinali). SMF7 can be differentiated from SMF6 by abundance of planktons than filaments. Planktons range from 17 to 35% with mean content of 25%. Planktons generally include globotruncana with some unidentified planktons in trace amounts. Filaments range from 3 to 6% at Chinali and 2 to 5% at Thoba Section. The mean content of filaments is about 5%. Planktons are 0.23 mm to 0.91 mm in size. Chambers of Planktons are

strongly neomorphosed with sparite and at places replaced by dolomite. Intact to broken ratio estimated by visual calculation is 1:7. Filaments are very diverse in size, generally ranging from 0.02 mm to 1.45 mm. Filaments are sparsely distributed over the micritic matrix in wackestones and show some preferred and well defined orientation usually bedding parallel. Graded bedding is obvious in this preferred orientation. Horizontal to slightly inclined burrows occur in various samples that show close packing of biota. Other skeletal grains include echinoid and ostracod with very rare inoceramids. Dolomite occurs as scattered individual rhombic crystals and in some cases as minor cluster. The intensity of dolomitization is greater along the stylolites.

4.9. Depositional environments

In carbonate rocks, substantial amount of biota along with sedimentary structures is generally used for the interpretation of depositional environments. However, the interpretation becomes difficult if sedimentary structures lack in carbonate rocks (Tucker and Wright, 1990; Wright and Burchette, 1998). Due to rare sedimentary structures, diagenetic alterations and absence of mechanical grains, only reliable criteria have been used to interpret environment of deposition is paleoecology of fauna (Flügel, 2004). In the present account like many previous studies (Willems et al., 1996; Iqbal, 2000; Ahsan, 2008; Frank, 2010; Ahsan et al., 2015) the abundance of biota and their paleoecology have been employed to deduce the environments of deposition.

4.10. Paleoecology of fauna

Planktons (Fig. 7 b, d, e and f) belong to foraminifera and are the significant skeletal constituent of upper Cretaceous marine carbonates and represent a variety of depositional settings (Frank, 2010) with wide range of water depths from 25 to 200m (Butt, 1986). Generally planktons have been confined to 100m water depth in scarcity of clastic influx (Tucker and Wright, 1990). Hart et al., (2005) and Haynes (1981) reported the planktons from 10 to 50m of water depths. In addition to this planktons were also reported to occur at water depths exceeding 50m (Logan et al., 1969; Frank, 2010). Bertle and Suttner (2005) reported the occurrence of planktons along with calcispheres from deeper marine realm. Furthermore, the higher ratio of planktons is indicator of deep water conditions like middle and outer shelf and slope setting (Butt, 1986; Nichlos, 2009).

Calcispheres (Fig. 7 a and b) are very diverse in their habitat and occur in variety of environments ranging from shallow shelf to slope and ocean basin settings (Brasier, 1980; Hart, 1991; Willems et al., 1996). Calcispheres have been extensively reported from various shallow shelf and pelagic limestones of Cretaceous and Jurassic age (Flügel, 1982; Bralower, 1992; Jiang et al., 2010). Villan (1981) in a study recognizes them from outer shelf settings. Calcispheres are the indicative of

low energy conditions (Koch et al., 1989; Frank, 2010) and better water circulation (Willems, 1993). Frank (2010) also reported the occurrence of calcispheres with planktons from mid Cretaceous carbonates of the outer ramp settings. Similarly Ahsan (2008) reported calcispheres from distal middle and outer ramp deposits of NW Lesser Himalayas. Chaudhry et al. (1992) placed the calcispheres and planktons in same environments.

Filaments (Fig. 8 e and f) are considered as remnants of planktonic or epiplanktonic pelecypods and are abundantly found in Mesozoic limestones (Clapham et al., 2003). Filaments show a wide range of depositional setting that range from shallow shelf to deep basin (Flügel, 2004; Ahsan, 2008). Wilson (1975) recorded the filaments from pelagic and slope deposits. Filaments have also been interpreted as the constituent of deep water systems including shallow subtidal to bathyal settings (Zhicheng, 1997; Zhicheng et al., 1997). Azeredo et al., (1998) and Rao et al., (2007) recorded filaments from limestones, marls and phosphorites of mid to outer ramp settings. Ahsan (2008) and Ahsan and Chaudhry (2008) reported filaments from Kawagarh Formation from middle ramp settings.

Inoceramids (Fig. 8c) have been reported from shelf to deep water settings of Late Cretaceous (Gomez and Elorza, 2002). Nejbert and Gladysz (2009) reported the occurrence of echinoids and inoceramids along with the foraminifera/calcispherofacies from deeper shelves of Late Cretaceous.

Besides the earlier alluded dominant skeletal grains some other skeletal grains like crinoids, echinoids (Fig. 8d), oysters, ostracods and textularia (Fig. 7c) also occur in minor proportions. Echinoids are generally confined to normal oceanic waters. However, some echinoids are also reported from restricted setting (Crevello and Harris, 1985). Nejbert and Gladysz (2009) reported the occurrence of echinoids from outer shelf deposits of Late Cretaceous along with inoceramids. Ostracods are also similar to echinoids in their habitat and found in normal and well oxygenated marine water with some restricted lagoon species (Casier et al., 2002; Pipik et al., 2009).

4.11. Depositional model

Carbonate rocks generally deposit in five distinct settings which are rimmed shelves, non rimmed shelves, ramps, carbonate platform and isolated platforms differentiated by various features (Tucker, 1992). The absence of reef deposits, carbonate sand shoals, extensive reworking, bounding of shallow facies with deeper facies on all sides and extensive shallow deposition in Upper Cretaceous of north western Himalayas indicate deposition over the ramp setting (Shah, 2009). Ramp is further divided into inner, mid and outer settings. Inner ramp is characterized by the deposition over the fair weather wave base which can be identified by various features including oolitic limestone, bioclastic cross laminated sand shoals and organic buildups, bioclastic debris and high frequency of benthic foraminera (Flügel, 2004; Nichlos, 2009). Furthermore, the inner ramp facies are generally comprised of grainstone and packstone (Nichlos, 2009). These diagnostic features of inner ramp are completely absent in studied sections so it leads to interpret that the deposition of Kawagarh Formation was confined to the mid and outer ramp settings.

4.12. Middle ramp facies

The middle ramp represents storm controlled area lies between the Fair Weather Wave Base (FWWB) and Storm Wave Base (SWB) and characterized by wackestone and packstone facies (Wright, 1986; Tucker and Wright, 1990; Wright and Burchette, 1998; Nichlos, 2009). SWB is generally recognized by sharp erosional bases, graded bedding, hummocky cross bedding, bioturbation, intraclast lags, winnowed shell and suspension load deposits (Mohseni and Asim, 2006; Nichlos, 2009; Neumann et al., 2009). Some of these features like burrows, effects of transportation, graded bedding, abraded surfaces of grains, poorly sorted fauna and alignment of skeletal grains have been recorded in SMF5 (Inoceramous-Planktonic wackestone), SMF6 (Filamentous-Planktonic wackestone) and SMF7 (Planktonic-Filamentous wackestone). The presence of these features and relatively high frequency of deeper fauna in mud supported wackestone assemblage are the indicative of deposition in

relative low energy conditions on middle ramp setting (Fig. 9). However other features like hummocky cross bedding and sharp erosional bases lack in studied samples. Minor amount of detrital quartz along with poorly sorted shell lags also suggest the proximal origin of Filamentous-Planktonic Wackestone, Planktonic-Filamentous wackestone and Inoceramous-Planktonic wackestone microfacies.

4.13. Outer ramp facies

The outer ramp settings are characterized by deposition below the SWB, generally in low energy conditions (Tucker and Wright, 1990; Boggs, 2001; Nichlos, 2009). The influence of storm is minor on outer ramp due to the greater water depth (Boggs, 2001; Mohseni and Asim, 2006). SMF1 (Calcispheric-Planktonic wackestone and packstone), SMF2 (Planktonic-Calcispheric wackestone) and SMF3 (Planktonic wackestone) microfacies are regarded as outer ramp deposition (Fig. 9) because of deep water habitat of calcispheres and planktons and their high frequency in these microfacies (Scholle et al., 1983; Willems et al., 1996; Drzwiecki and Simo, 1997, 2000; Robaszynsky et al., 2010). The anomalous sedimentary structure of graded bedding in these microfacies is indicative of storm conditions (Mohseni and Asim, 2006). Graded bedding was formed by the storm surges blowing in seaward direction during the end phases of storm below the SWB (Tucker, 1992; Wright and Burchette, 1998; Ahsan, 2008). The paleoecological attributes of planktons and calcispheres, their abundance and presence in micrite and absence of terrigenous material are the indicatives of deposition in deeper environments like outer ramp (Fig. 9). Furthermore, absence of radiolarian chert, chert nodule, siliceous oozes, hemipelagic shales and slump structures also supports the deposition of these microfacies over the outer ramp setting rather than the ocean basin settings.

5. Discussion

The Kawagarh Formation overlies Lumshiwal Formation at both studied sections (Fig. 10 and 11). Lumshiwal Formation is

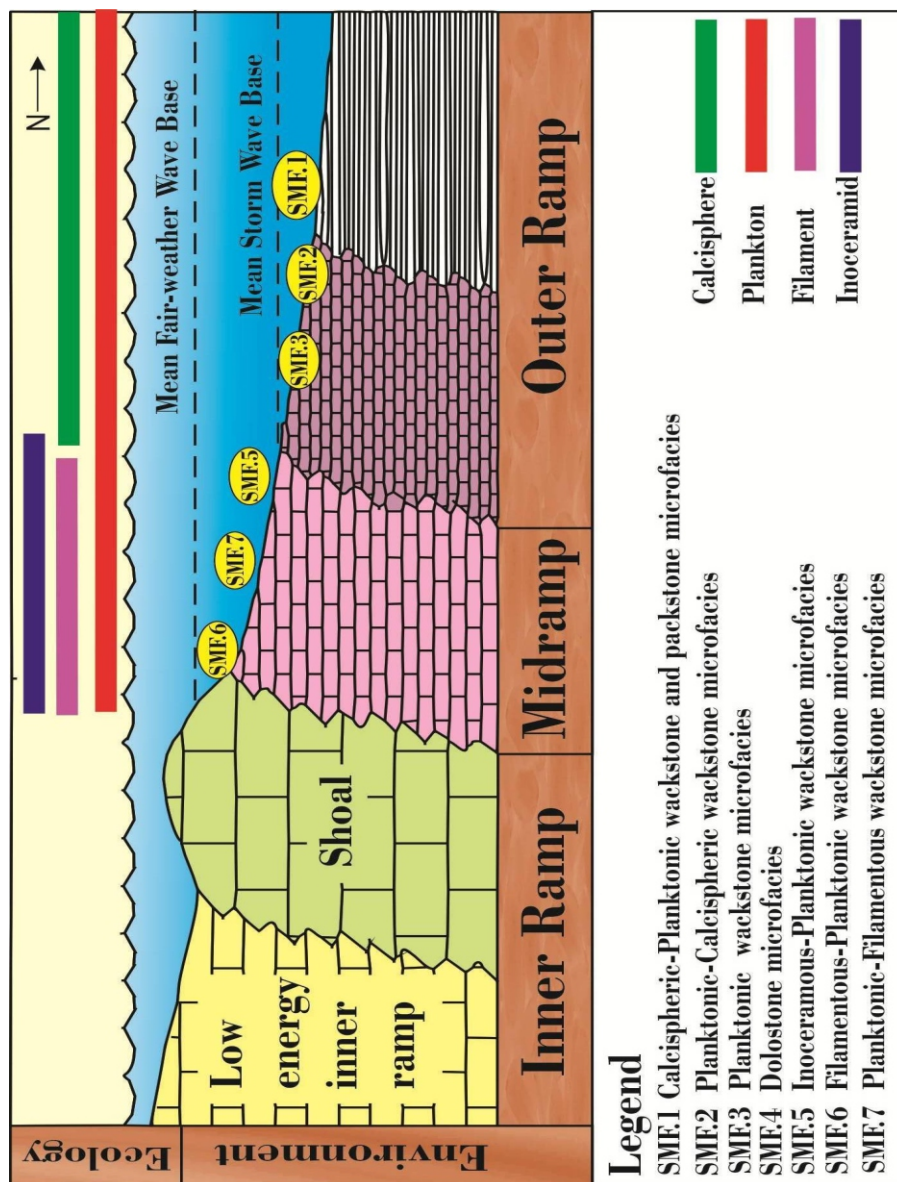


Fig. 9. Depositional model of Kawagarh Formation of Northeastern Hazara Basin showing the ecological ranges of fauna and the depositional sites of different microfacies.

dominantly composed of sandstone and shales which grades upward into glauconitic and ferruginaceous sandstone at Chinali and Thoba villages. Many workers like Ahsan et al. (1999), Chaudhry et al. (2000) and Ahsan and Chaudhry, (2008) regarded the Lumshiwal Formation as time transgressive unit and it was deposited at no more than 80 m depth. The age of Lumshiwal Formation is Thithonian to Lower Turonian (Ahsan and Chaudhry, 2008). Presence of ferruginous sandstone and slight lateritization in Lumshiwal Formation are indicative of sea level drop. After this drop, again marine settings were prevailed with the sedimentation of carbonates of the Kawagarh Formation in Turonian (Ahsan, 2008).

Paleoecological information of biota and their abundance indicate the subtidal depositional environments for Kawagarh Formation (Fig. 9). Sedimentary structures show that the deposition took place between FWWB and SWB (middle ramp) and below the SWB (outerramp and remaining 18% on mid ramp. Remaining 12% samples are represented by the dolostone microfacies which is the result of diagenetic processes. Due to change of original fabric in dolostone microfacies it is very difficult to depict their depositional settings. Inner ramp facies have not been recorded anywhere in study area. Foraminifera can be used as water depth indicator in depositional environments on their ecology (Wright and

Burchette, 1998). In this study, filaments are indicator of middle ramp settings and Planktons are characteristic fauna of middle and outer ramp while the calcispheres show outer ramp settings (Fig. 9). The abrupt increase of calcispheres in microfacies can be used to demarcate the transgression (Drzewiecki and Simo, 2000; Frank, 2010) and their gradual decrease as tentative sea level fall. The rapid northward flight of Indian plate in Cretaceous and subsequent formation of subduction related features (Bignold and Treloar, 2003; Petterson and Treloar, 2004; Khan et al., 2009) suggest that these changes are mainly caused by local tectonic events rather than global events and can be regarded as relative sea level changes. Vertical stacking of microfacies has been used

to demarcate the relative sea level changes with help of increase and decrease of calcispheres and microfacies association in vertical profile. The vertical facies profile shows that the middle ramp facies are superimposed two times by the outer ramp facies (Figs. 10 and 11). It suggests at least three relative sea level rise or transgressions were occurred in northern Hazara during the Upper Cretaceous. It also indicates an overall deepening upward sequence and represents a drowned ramp settings for the studied sections of Northern Hazara basin which are similar to the central Himalayas, the neighbouring parts of Hazara basin as in Zasker Range of Kashmir (Gaetani and Garzanti, 1991; Garzanti, 1991, 1993; Premoli et al., 1991; Corfield et al., 2005).

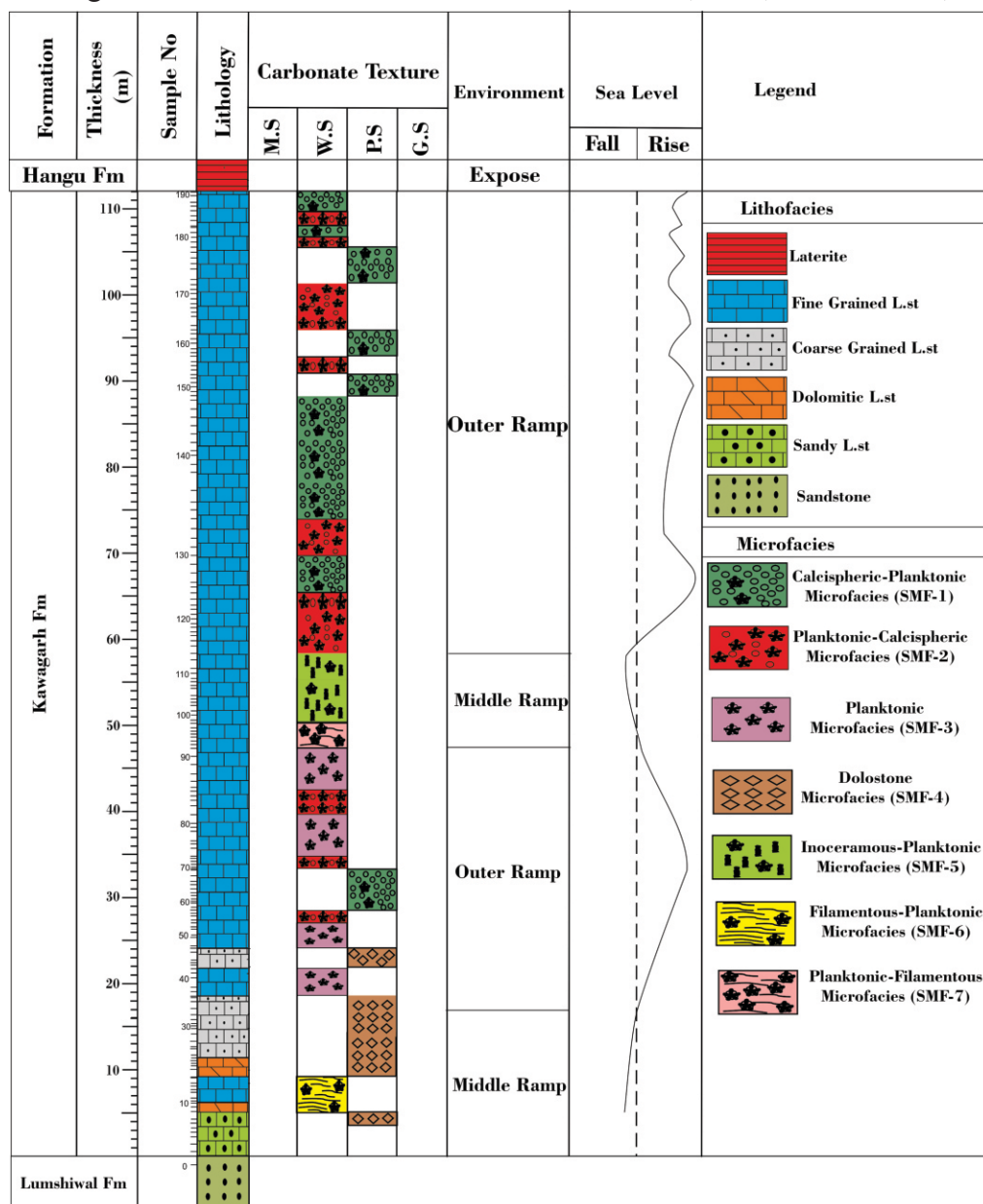


Fig. 10. Lithological and microfacies chart of Chinali Section.

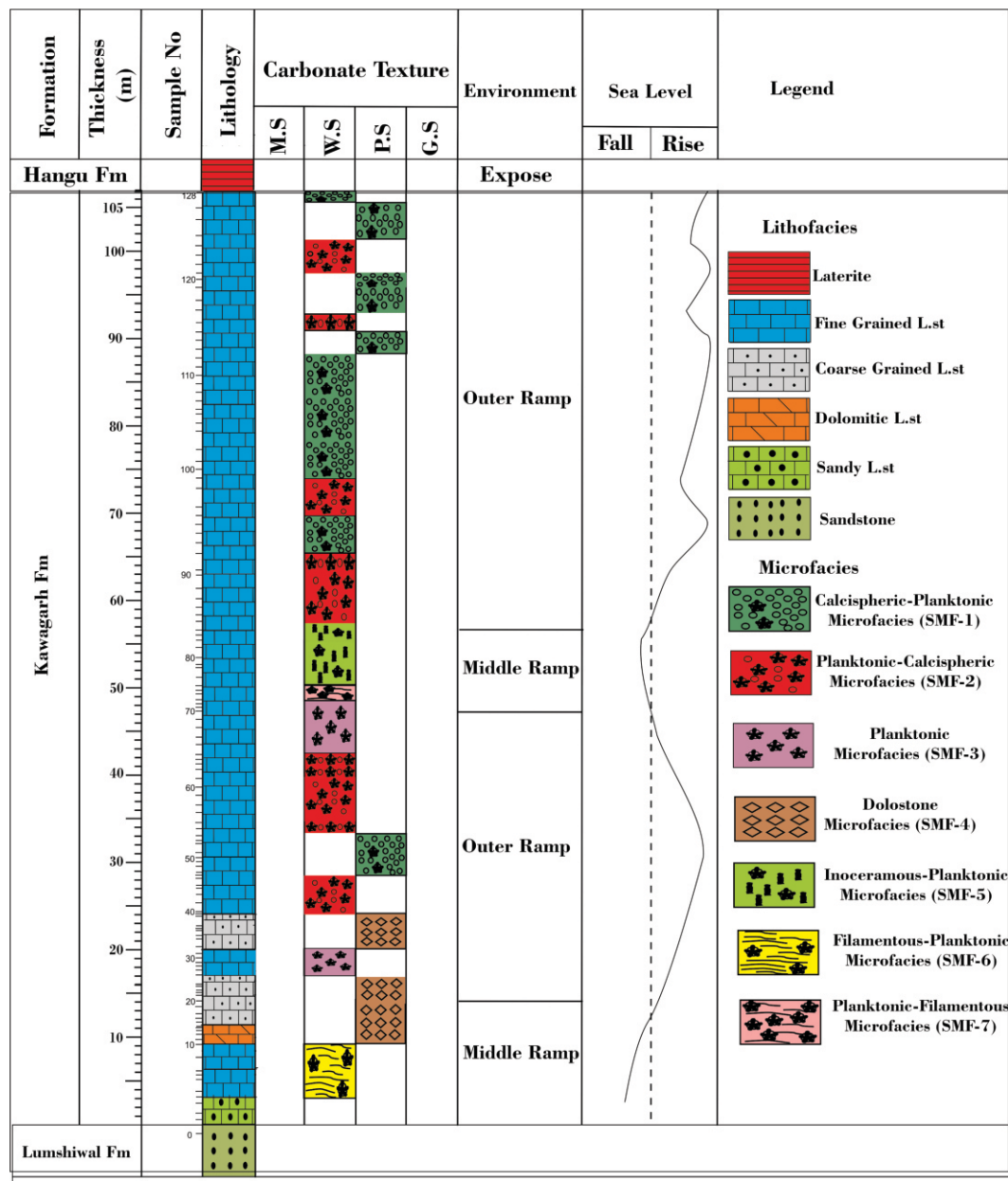


Fig. 11. Lithological and microfacies chart of Thoba Section.

6. Conclusions

In the absence of reef deposits, carbonate sand shoals, extensive reworking and hemiplegites in the Upper Cretaceous strata of NW Himalaya, a ramp setting along the northern margin of Indian Plate is envisaged in Hazara Basin. The deposition of Kawagarh Formation occurred on the ramp setting as a deepening upward sequence. Among the total 325 samples, 18% microfacies were deposited on the middle ramp and 70% microfacies on the outer ramp. The remaining 12% are represented by dolostone microfacies which are the result of diagenetic processes. The inner ramp facies are absent in the studied sections.

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