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SEDIMEMTOLOGY OF THE MIDDLE JURASSIC SAMANA SUK FORMATION, MAKARWAL SECTION, SURGHAR RANGE, TRANS INDUS RANGES, PAKISTAN

BY

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Abstract: *The sedimentology of the Middle Jurassic Samana Suk Formation, Makarwal Section, Surghar Range, Trans Indus Ranges, was investigated to elaborate its microfacies and diagenetic settings. The Samana Suk Formation is mainly composed of limestones and dolomitic limestones with some dolomite and intercalations of marl and shale at different levels. A detailed study was conducted after collecting systematically a total of 98 rock samples and studying selected 72 thin sections. To investigate its sedimentology, microfacies package and diagenetic settings the petrographic study of unstained and stained thin sections has been executed. Detailed field observations and laboratory investigations revealed that it contains microfacies forming SMF zones and is comprised of oolitic, peloidal, cortoidal and skeletal grainstones, bioclastic, ooidal and peloidal packstones, bioclastic wackstones, bioclastic mudstomes and mudstones microfacies along with presence of dolomite at certain stratigraphic levels. This research work also demonstrates the presence of various cement types and their morphologies and diagenetic overprinting. The dolomitization has developed at different horizons as cement as well as replacement and as stylocumulate along stylolites. The dedolomitizatioin has, also, been recorded along with incorporation of iron into calcite and dolomite at some later diagenetic stage. The Samana Suk Formation is widely exposed in the Upper Indus Basin of Pakistan. The microfacies analysis and diagenetic settings lead towards the conclusion that the formation was deposited in shallow shelf environment with open and restricted marine conditions.*

INTRODUCTION

The Samana Suk Formation is a recognized as the most prominent stratigraphic unit in the Upper Indus Basin of Pakistan. It is integral part of the Mesozoic strata of Trans Indus Ranges, Cis-Indus Salt Ranges, Hazara Mountains, Kohat Tribal Range, Samana Range and Kala Chitta Range as the most important lithological package of carbonates. Further towards the west the Chiltan Formation and Mazar Drick Formation, exposed at a number of sections in the Sulaiman Fold and Thrust Belt and Murree Brewery Gorge near Quetta, Balochistan, Pakistan, are correlated with it. The Makarwal Section is located near Makarwal, District Mianwali, at a distance of 5km (Fig. 1). This section is located approximately at Latitude 32º 55′35″ N and Longitude 71º 08′50″ E on Toposheet No. 38 P/1 (Survey of Pakistan, Rawalpindi). It lies in the north trending southern part of the Surghar Range and is striking in the NS direction near Makarwal. The Makarwal, a coal miners' small town, is accessible from the Kalabagh, Kamar Mashani and Isakhel through Mianwali-Bannu Road. A detailed study was conducted after collecting systematically a total of 98 rock samples and studying selected 72 thin sections to investigate sedimentology of the Samana Suk Formation exposed at this section. Here the formation is 37.98m thick. The present paper concentrates on sedimentology of the Samana Suk Formation. This contribution forms part of the doctoral thesis of the principal author.

PREVIOUS INVETIGATIONS

Earlier workers named this formation as Kioto Limestone (Cotter, 1933), Samana Suk Limestone (Davies,

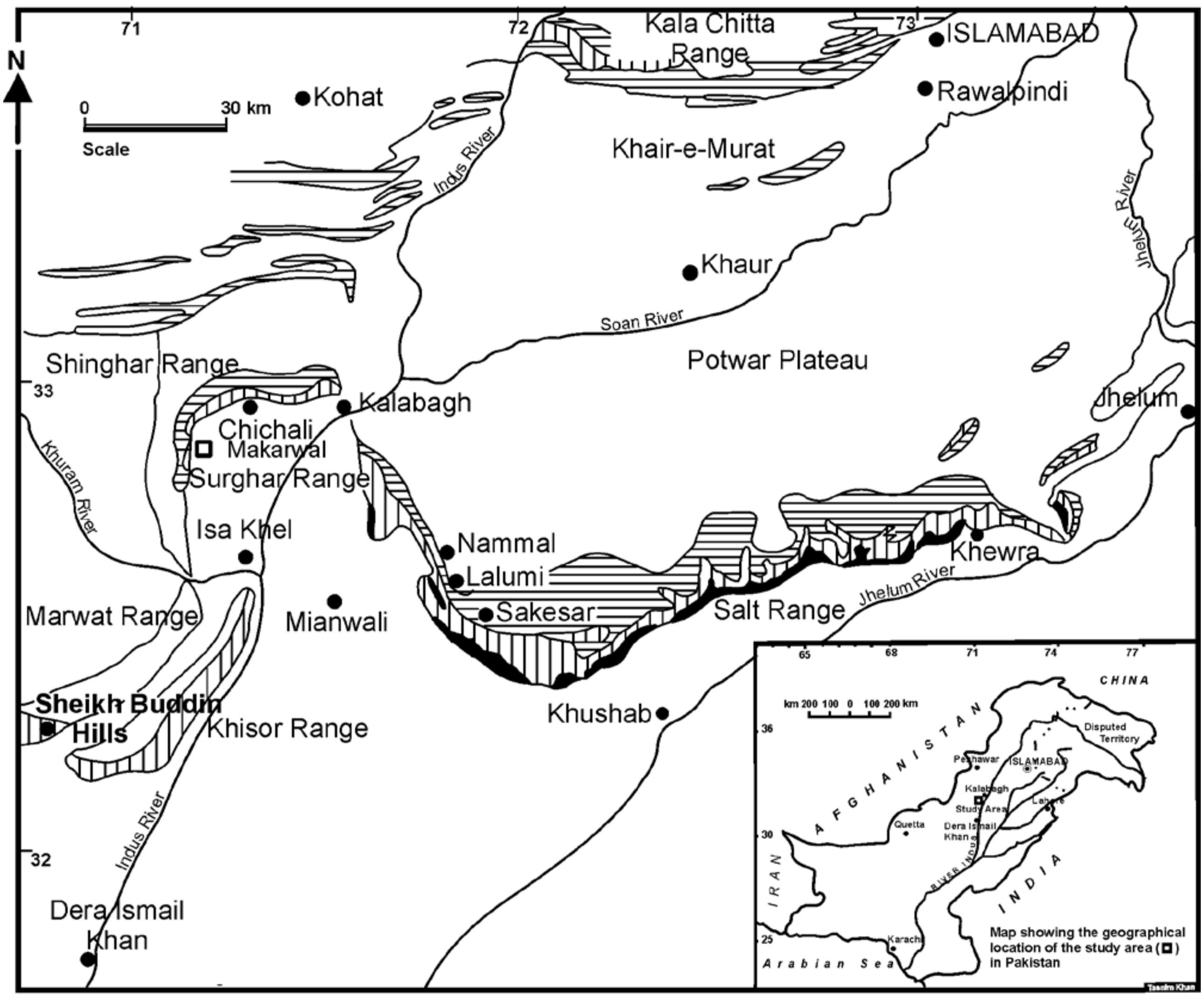


Fig.1 Map showing the location of Sheikh Buddin Hills Section (□) in the Trans Indus Ranges (Modified after Gee,1989)

1930) and Broach Limestone (Gee, 1947). The name, Samana Suk Formation, was formalized in 1974 by Fatmi, et al., 1990. In the Upper Indus Basin, where the Trans Indus Ranges are situated (Anwar, et al., 1992 and Gee, 1989), the Jurassic strata is composed of Datta Formation, Shinawari Formation and Samana Suk Formation (Shah, 1977). According to Bender and Raza (1995) the lower part (relatively much thinner) of Chichali Formation is part of this Jurassic sequence. The upper part of Jurassic column is occupied by the Samana Suk Formation, which is a shallow water marine carbonate rock (Fatmi, et al., 1990). Mensink, et al. (1988), Fatmi, et al. (1990) and Mertmann and Ahmad (1994) reported that the Jurassic rock formations are exposed at a number of localities in the Trans Indus Ranges, particularly in the Surghar and Marwat Ranges. A number of previous workers executed commendable investigations on the Samana Suk Formation of middle Jurassic age, Trans Indus Ranges with different angles. Mensink, et al. (1988), Fatmi, et al. (1990) and Mertmann and Ahmad (1994) worked on its microfacies and depositional environments in a broad spectrum covering these ranges on regional scale. Danilchick and Shah (1987) investigated the stratigraphy and coal reserves of the Makarwal area, Surghar Range. The facies development during Jurassic of Trans Indus Ranges was investigated by Mensink, et al. (1988) based on the study of geological sections of Gulakhel, Broach Nala and Chichali Pass. Fatmi, et al. (1990) executed investigations on the occurrence of lower Jurassic Ammonoids from the Surghar Range and revised the nomenclature of the Measozoic rocks of the Salt Range and Trans Indus Ranges on the basis of their research findings. The Jurassic shelf sedimentation and sequence stratigraphy of the Surghar Range was discussed by Ahmed, et al. (1997). Akhtar (1983) gave a brief account of stratigraphy of Surghar Range. The literature survey shows that no detailed work on sedimentology of the Samana Suk Formation was carried out in the host area of Makarwal Section, Surghar Range. Therefore a detailed investigation on microfacies analysis and diagenetic settings of the Samana Suk Formation was carried out by the present authors.

The parameters, like, field observations, section measurement, sampling, field photography, laboratory investigations (thin sections studies using petrographic microscope, chemical staining with Alizarin Red S and Potassium Ferricyanide) and digital photomicrography have been applied in the present research work.

SAMANA SUK FORMATION

In Makarwal Section the Samana Suk Formation is comprised of thin, medium to thick and massive limestones/dolomites beds, which are uneven to wavy at places in the stratigraphic stacking. It is mainly composed of limestone and dolomitic limestone with intercalated calcareous shales/marls, present at a number of stratigraphic horizons. These argillaceous contents are deposited due to the periodic influxes of clay in response to small scale and distant tectonic uplift and erosion or climatic change on an area acting as provenance. The shale/marl breaks and intercalations present at different levels are irregular and do not show any cyclic deposition. The limestones are light grey and yellowish grey and at places dark grey and are mostly dense, hard and compact. Micritic and oolitic limestones are very fine to coarse grained. The general topographic impression of these limestones is that of a ridge former. These limestones also form steep slopes and impassable cliffs in the studied area. The Samana Suk Formation is stratigraphically sandwiched between the Shinawari Formation and Chichali Formation (Table 1). The lower contact with the Shinawari Formation is conformable and transitional one. The top most sandstone bed of the Shinawari Formation is marked here as the lower stratigraphic contact (Akhtar, 1983 and Mertmann and Ahmed, 1994). The upper contact with the Chichali Formation is disconformable and sharp and is marked by hard ground with lateritic encrustation (Mertmann and Ahmed, 1994 and Sheikh, 1991). Two hard ground surfaces have been recorded in this section, which mark the presence of regressive cycles and periods of non erosion-non deposition. According to Spath (1939) the age of this formation in the Trans Indus Ranges is Late Jurassic (Late Callovian) on the basis of cephelopod fauna present, however, its age is considered Early to Middle Callovian (Middle Jurassic) based on the occurrence of Middle Callovian Ammonites in highly fossiliferous sections of the Datta Nala, Punnu Nala, Landa Nala, Mallakhel and Makarwal areas in Surghar Range (Fatmi, 1972).

MICROFACIES

The microfacies analysis of this section revealed that the developed microfacies here include: bioclastic, peloidal, ooidal and cortoidal grainstones, bioclastic, ooidal and peloidal packstones, bioclastic wackestones, bioclastic mudstones and mudstones.

Grainstones

The following types of grainstones have been elaborated on the bases of petrographic analysis:

Bioclastic grainstones: This microfacies is composed of skeletal shells and fragments of organisms, sometimes in association with other carbonate grains (Plates 5a and d).

Table 1

Stratigraphic sequence of the Makarwal Section, Surghar Range, Trans Indus Ranges, Pakistan, showing the position (**bold**) of Samana Suk Formatiom (Hemphil and Kidwai, 1973, Akhtar, 1983, Danilchik and Shah, 1987 and Warwick, et al., 1995).

ERA	AGE	GROUP	FORMATION
CENOZOIC	EOCENE	CHHARAT GROUP	Sakesar Formation
			Nammal Formation
	PALEOCENE	MAKARWAL GROUP	Patala Formation
			Lockhart Formation
			Hangu Formation
UNCONFORMITY			
MESOZOIC	CRETACEOUS	SURGHAR GROUP	Lumshiwal Formation
			Chichali Formation
	UNCONFORMITY		
	JURASSIC	BROACH GROUP	**Samana Suk Formation**
			Shinawari Formation
			Datta Formation
	UNCONFORMITY		
	TRIASSIC	MUSAKHEL GROUP	Kingrialli Formation

Peloidal grainstones: The peloidal grainstones have been recorded at a number of stratigraphic levels in the measured section and are predominantly represented. This sub microfacies consists of faecal pellets and peloidal grains which are micritized and have no internal micro architecture (Plates 1a and 6a). The other carbonate grains are also found in associations with peloids (e.g., foraminifera) in these grainstones (Plate 1a).

Ooidal grainstones: The ooids present in these grainstones have concentric laminar microfabrics (Plate 4c). Various skeletal grains act as nuclii in these ooids. Peloid and skeletal grains have also been recorded in association with ooids (Plate 4c).

Cortoidal grainstones: The cortoids are coated grains covered by micritic envelope and constitute a type of non-laminated coated grains (Tucker and Wright, 1990). This sub microfacies of grainstones has been found only at one horizon in this section (Plate 3a and 7b). The frequency of appearance of cortoids in other microfacies is relatively low.

Packstones

The packstone microfacies, commonly, display various types of grains as their components. These grains include skeletal grains, ooids and peloids. The following microfacies of packstone have been documented in this section.

Bioclastic packstones: This microfacies is composed of skeletal grains of different sorts. The frequency of occurrence of various bioclasts, shells, tests, and biodebris shows a variety of component skeletal grains (Plates 3b and d). This microfacies mainly exhibits skeletal shells and grains of mollusks, forams and brachiopods.

Ooidal packstones: It has been recorded only at two horizons in the investigated section (Plate 1c). The recorded ooids generally have concentric laminae.

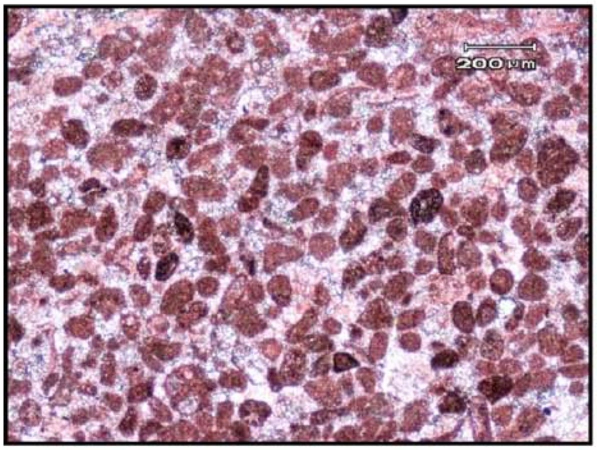
Peloidal packstones: The peloidal packstones are present at few levels in the investigated section (Plates 4a and 5c). However, the frequency of appearance of peloids in association with other grains in other microfacies is low.

Wackestones

A microfacies with more than 10% carbonate grains set in micrite is categorized as wackestone according to Dunham classification (1962) of the carbonate microfacies. Only the bioclastic wackestones have been found here.

Bioclastic wackestones: The bioclastic wackestones have been documented at various levels in the studied section. The faunal diversity has also been noted in these wackestones (Plate 4d). The skeletal shells and fragments of mollusks are commonly found in this microfacies.

Plate 1



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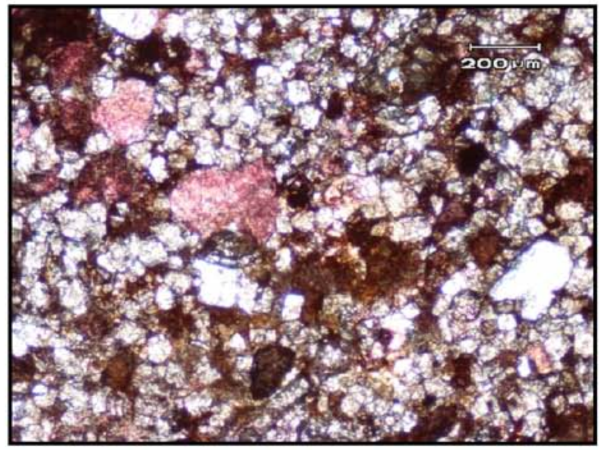

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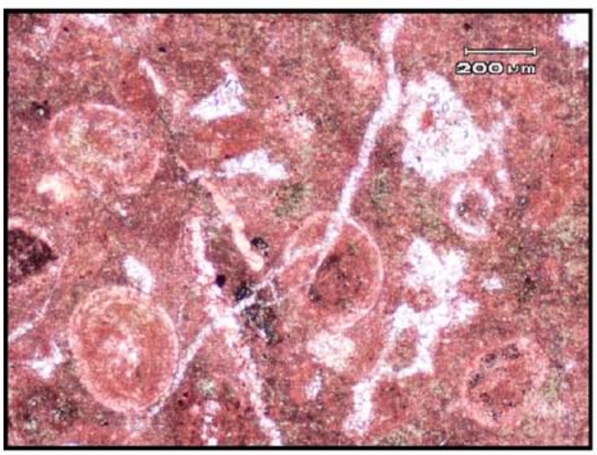
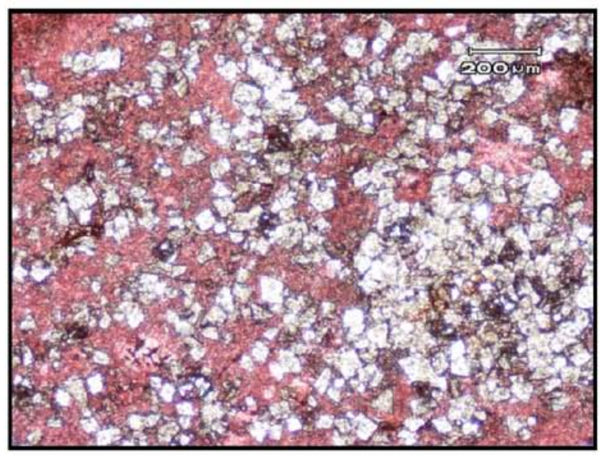


c.



d.

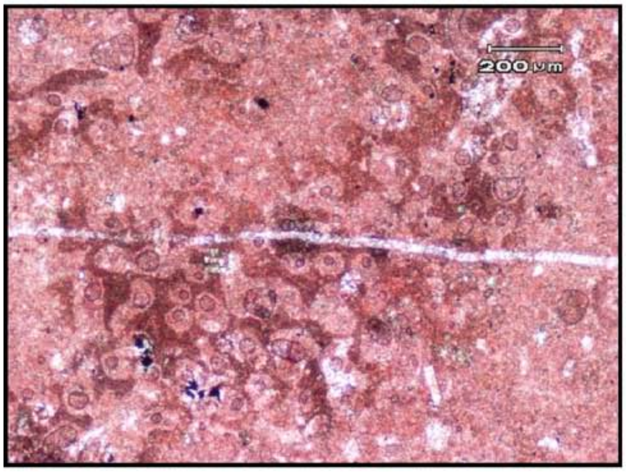
a. Photomicrograph showing peloidal grainstone cemented by intergranular cement **(C)** with drusy mosaic of crystals. A few associated foraminifers' shells **(F)** are present as well. (PPL, stained) **Sample No. MKW-11T**

b. Photomicrograph showing dedolomitization/calcitization in a dolomitized horizon. The neomorphosed calcite **(NC)** is a non-ferroan calcite with pink stain colour. The dolomite crystals display a hypidiomorphic mosaic of crystals. (PPL, stained) **Sample No. MKW-19**

c. Photomicrograph displaying fractures **(FR)** bearing ooidal packstone with associated indeterminate skeletal grains **(SK)**. The ooids **(O)** have concentric microfabrics. (PPL, stained) **Sample No. MKW-12T**

d. Photomicrograph showing dedolomitization/calcitization **(NC)** with pink stain colour. The dolomite crystals display well developed crystal faces. (PPL, stained) **Sample No. MKW-21M**

Plate 2



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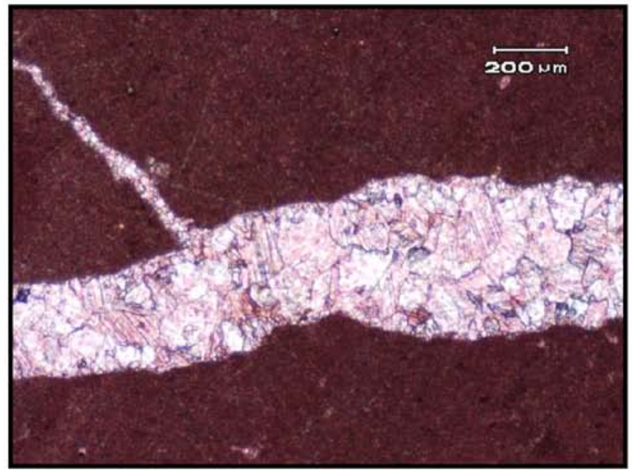

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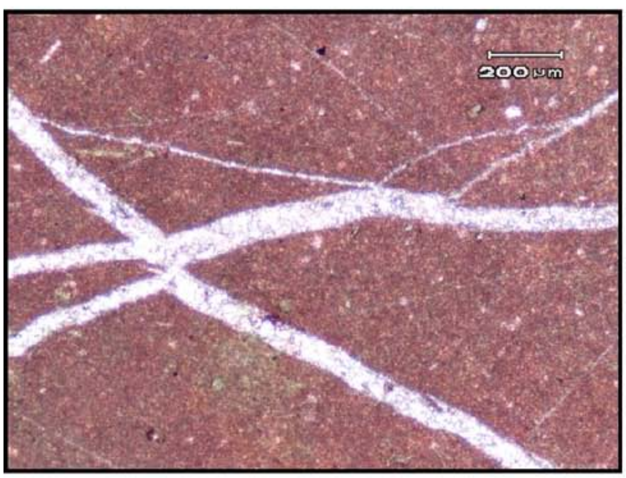


c.

d.

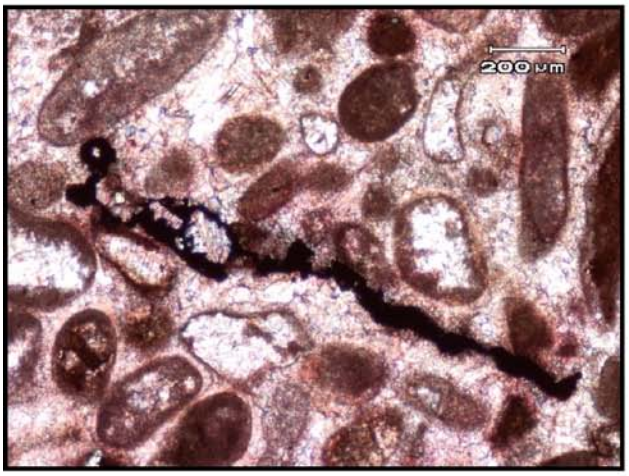
a. Photomicrograph showing bryozoan **(BZ)** bioclastic packstone. A small fracture **(FR)** is cutting across the slide. (PPL, stained) **Sample No. MKW-22**

B. Photomicrograph showing a large fracture **(FR)** and its splay occluded by calcite in mudstone. (PPL, stained) **Sample No. MKW-35**

c. Photomicrograph dispaying a highly fractured mudstone. The fractures **(FR)** are now filled with calcite and belong to multi phase fracturing. (PPL, stained) **Sample No. MKW-36**

d. Photomicrograph showing bioclastic mudstone. The skeletal grains belong to pelecypod **(P)** and gastropod **(G).** (PPL, stained) **Sample No. MKW-48M**

Plate 3



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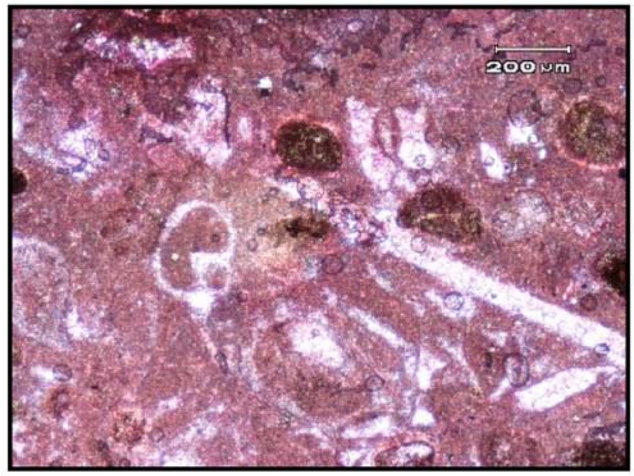

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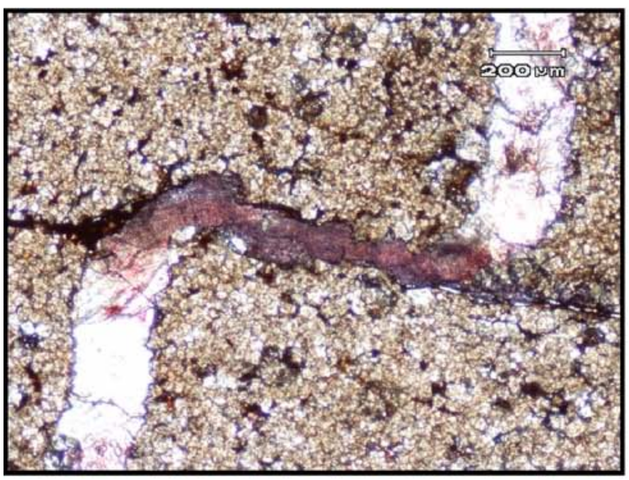

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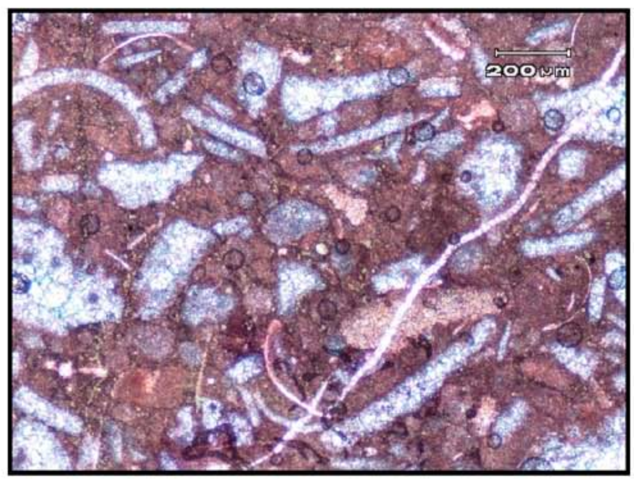


d.

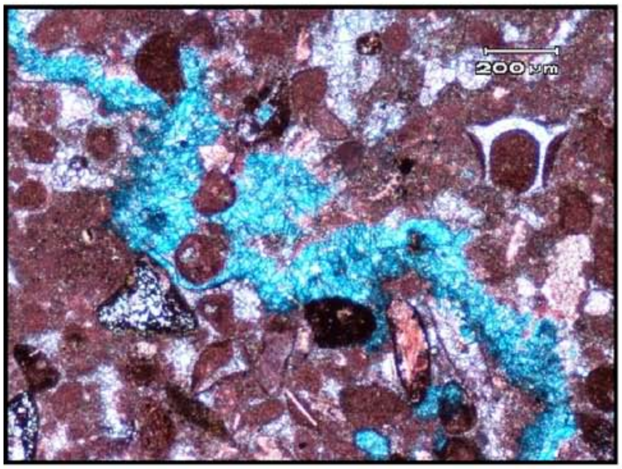
a. Photomicrograph displaying cortoidal grainstone. The dog tooth cement has nucleated cortoids. The coated grains **(CT)** have micritic envelopes **(E)**, which serve to protect morphology of these grains. (PPL, stained) **Sample No. MKW-49**

b. Photomicrograph showing bioclastic packstone. Gastropod **(G)** shells and brachiopod **(BR)** grains are present. (PPL, stained) **Sample No. MKW-75U**

c. Photomicrograph showing dolomite, in which a stylolite **(ST)** is cutting a fracture **(FR)**, thus is postdating this fracture. (PPL, stained) **Sample No. MKW-76**

d. Photomicrograph showing bioclastic packstone. Shells of pelecypod **(P)**, gastropod **(G)** and algae **(A)** are present. A small fracture **(FR)** is cross cutting all the grains. (PPL, stained) **Sample No. MKW-79**

Plate 4



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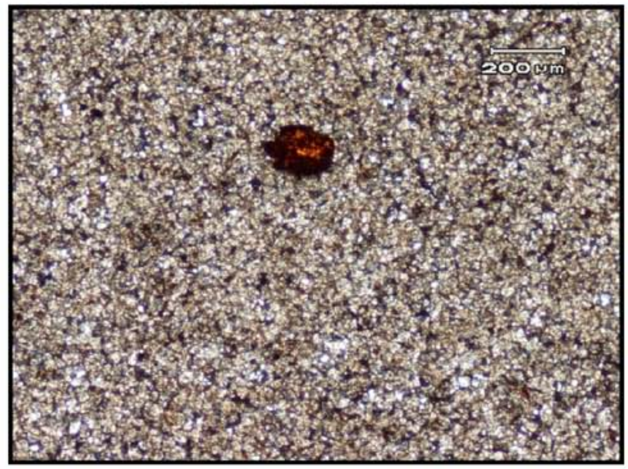

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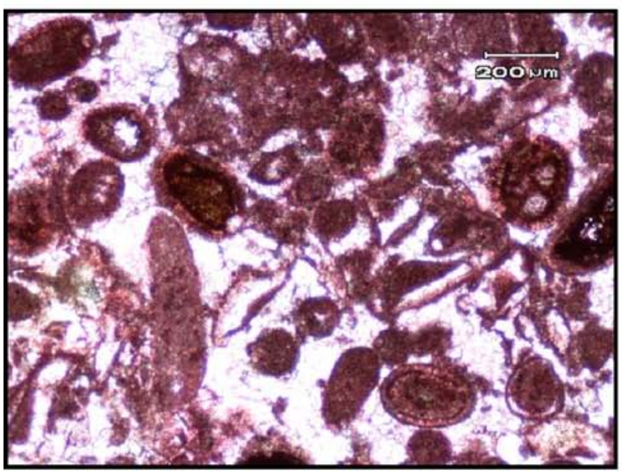


c.

d.

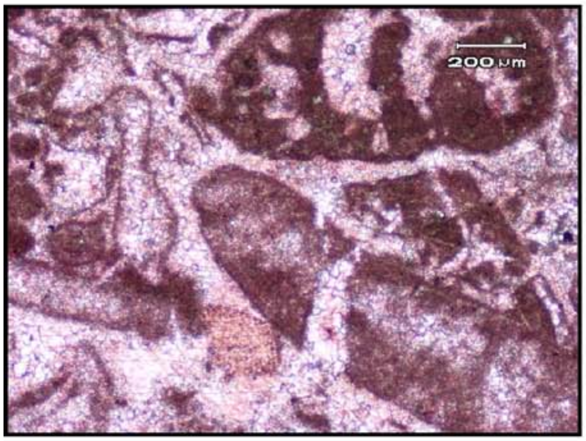
a. Photomicrograph showing peloidal packstone bearing a fracture **(FR)** occluded by ferroan dolomite **(FD)** with turquoise stain colour. (PPL, stained) **Sample No. MKW-87U**

b. Photomicrograph showing dedolomitization/calcitization **(NC)** with pink stain colour in microdolomite. (PPL, stained) **Sample No. MKW-18**

c. Photomicrograph displaying ooidal grainstone in association with algae **(A)** and other bioclasts. The ooids **(O)** have concentric laminae. An indeterminate calcitized grain, having aragonitic composition originally, converted to sparry calcite **(SP)** for aragonite is metastable and dissolves first of all. The grain has lost internal structure due to dissolution/precipitation phenomenon and now possesses micritic envelope **(E)**, which serve to preserve its outline. (PPL, stained) **Sample No. MKW-28**

d. Photomicrograph showing fabric/grain selective dolomitization in a bioclastic wackestone. The present shells belong to gastropods **(G)**. (PPL, stained) **Sample No. MKW-20L**

Plate 5



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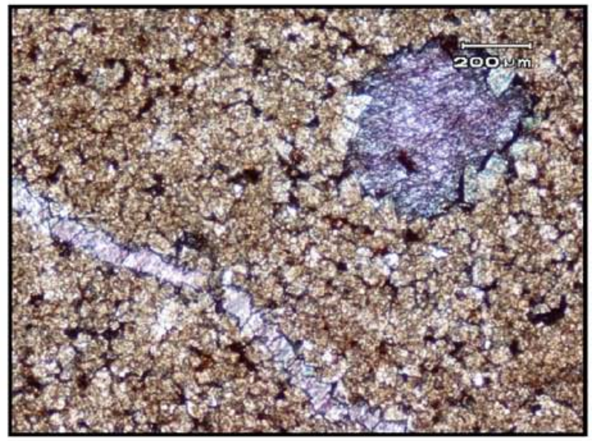

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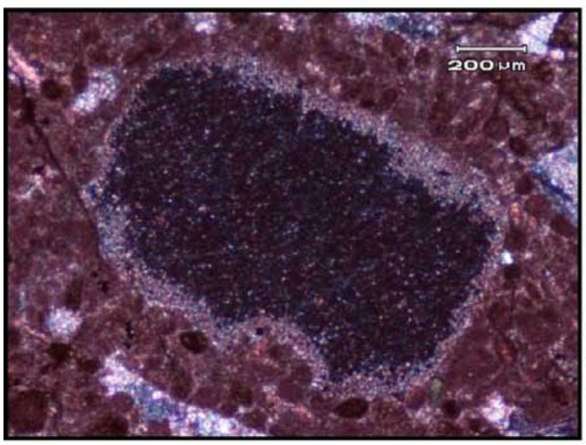

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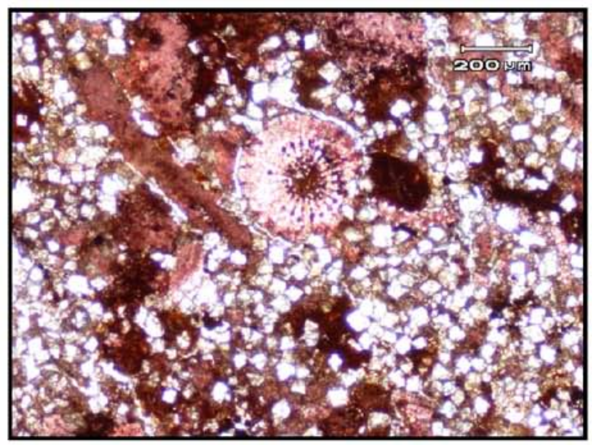


d.

a. Photomicrograph showing bioclastic grainstone in association with grapestones **(GR)**. Broken clasts exhibit signs of mechanical compaction **(MC)**. (PPL, stained) **Sample No. MKW-56**

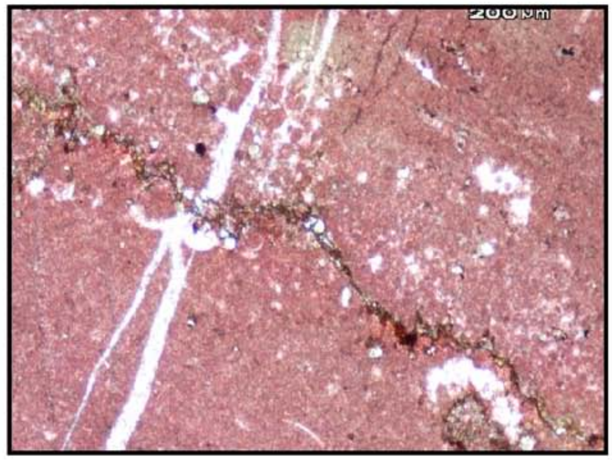
b. Photomicrograph showing a ferroan calcite **(FC)** with mauve stain colour and a fracture **(FR)** in dolomite. (PPL, stained) **Sample No. MKW-76**

c. Photomicrograph showing peloidal packstone. Syntaxial rim cement **(SR)** developed in optical continuity on an echinoderm **(EC)** grain is shown as well. The grain is exhibiting characteristic single crystal extinction and uniform coarse porous structure. (XN, stained) **Sample No. MKW-8L**

d. Photomicrograph displays pervasive dolomitization of bioclastic grainstone. The dolomite crystals display well developed crystal faces. The cross section of echinoderm spine **(ES)** shows very characteristic lacy pattern. A test of algae **(A)** is present too. (PPL, stained) **Sample No. MKW-27**

Plate 6

a.



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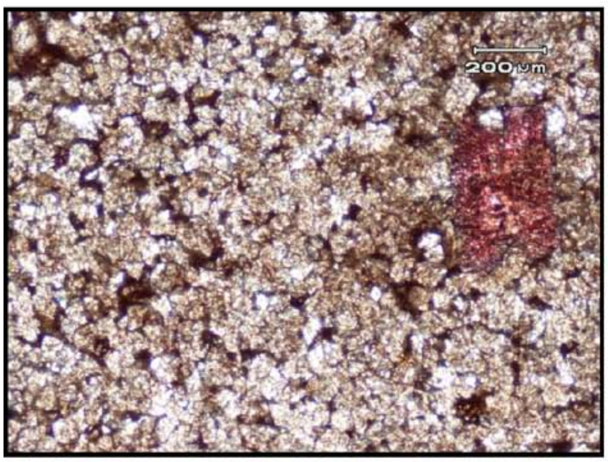

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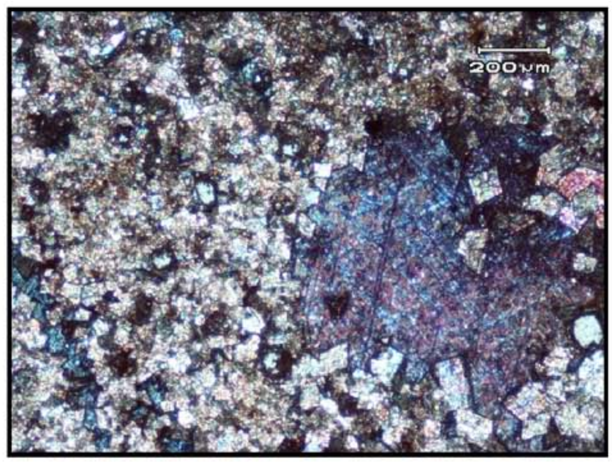


d.

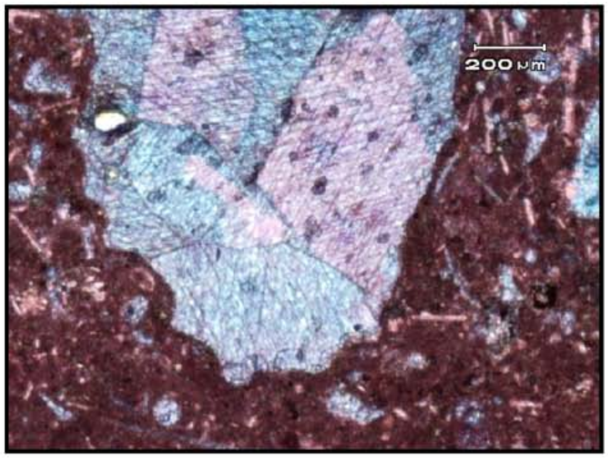
a. Photomicrograph showing younger poikilotopic cement **(PC)** and older circumgranular columnar **(arrowed)** cement in peloidal grainstone. A very small fracture **(FR)** is cutting grains and cement and is postdating the cement and grains. (PPL, stained) **Sample No. MKW-26**

b. Photomicrograph showing mudstone. A fracture **(FR)** is being cross cut by stylolite **(ST)**, thus predating it. (PPL, stained) **Sample No. MKW-36**

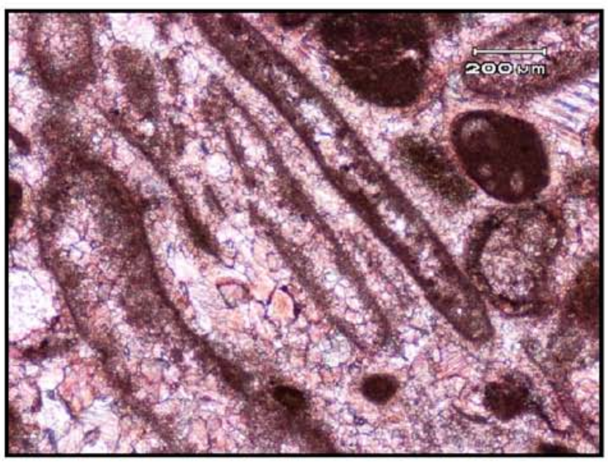
c. Photomicrograph displaying dedolomitization/calcitization in a dolomitized horizon. The pink stain color displays the neomorphosed non-ferroan calcite **(NC)**. The dolomite crystals exhibit a xenotopic mosaic of crystals. (PPL, stained) **Sample No. MKW-20M**

d. Photomicrograph showing dolomite and dedolomitization. The calcite is now ferroan calcite **(FC)** due to incorporation of iron afterwards. (XN, stained) **Sample No. MKW-74**

Plate 7



a.



b.

a. Photomicrograph showing late stage ferroan calcite **(FC)** with purple stain colour and ferroan dolomite **(FD)** with turquoise stain colour in peloidal packstone. (PPL, stained) **Sample No. MKW-87L**

b. Photomicrograph showing cortoidal grainstone. The tests of algae **(A)** are present. The broken algal grains exhibit signatures of mechanical compaction **(MC)**. Younger circumgranular dogtooth **(arrowed)** cement **(IG)** has developed over a grain and older intergranular cement has occluded the interstices. (PPL, stained) **Sample No. MKW-49**

Mudstones

This microfacies is also found at different levels in the measured section. These mudstones are sometimes highly fractured and fractures are filled with calcite. Mudstones devoid of any skeletal grain have been recorded in Plates 2b and c. A fractured mudstone with a medium amplitude stylolite, postdating these fractures, is shown in Plate 6b. Mudstones with skeletal grains are described in the following lines.

Bioclastic mudstones: The bioclastic mudstones found in this section are composed predominantly of bioclasts of molluskan shells and their fragments (Plate 2d). These are found at a number of horizons in the studied formation.

STANDARD MICROFACIES (SMFs)

The microfacies found in this section have been compared with the Standard Microfacies (SMFs) of Wilson (1975) and Flugel (1982), which include: SMF Nos. 8, 9, 11, 15, 16 and 23.

DIAGENESIS

The petrographic analysis of diagenetic settings of the studied formation exposed at this section revealed the following diagenetic features:

Micritic envelopes

These envelopes develop on carbonate grains with original aragonitic mineral composition. Aragonite, being metastable among carbonate minerals, is dissolved in the first phase of diagenesis of carbonate sediments and replaced by calcite (Plate 4c). Micritic envelopes serve to preserve the outline and morphology of the grains.

Cements

Cementation of the carbonate sediments is an important diagenetic process, which endows strength and stability to the concerned microfacies. The well developed cement, always, resists physical, as well as, chemical compaction and fracturing episodes. Early diagenetic cement precipitates as fibrous aragonite. While dog tooth cement (circumgranular equent cement), dolomite cement, drusy mosaic cement, poikilotopic cement and radiaxial cements precipitate as later diagenetic cements. Various stages of cement formation and stratigraphy are shown in Plates 6a and 7b. The following cement types have been found at different levels and in different microfacies of the Samana Suk Formation from the studied section:

Circumgranular cement: The following two types of this cement have been found.

i. ***Dog tooth cement:*** The dog tooth cement is circumgranular equant cement which precipitates as later diagenetic cements, such as dolomite cement, drusy mosaic cement, poikilotopic cement, etc. Its examples are given in Plates 3a and 7b.

ii. ***Syntaxial rim cement:*** The syntaxial rim cement grows over the host grain in optical continuity. It is common in many carbonate rocks. It usually develops on echinoderm (crinoids and echinoids) \`shells/grains in optical continuity and is recognized by simultaneous extinction. It has been observed in Plate 5c.

Intergranular cement*:* The intergranular cement is found at a number of horizons of Samana Suk Formation (Plate 1a and 7b). According to Sheikh (1992) it is the next phase of carbonate diagenesis regarding cement stratigraphy.

Poikilotopic cement: This cement develops after the pervasive dolomitization and development of intergranular cements. In this type of cement coarse crystals enclose fine grains, which look like speks. It develops in phreatic environment commonly in burial regime and is shown in Plate 6a.

Fractures

Different phases of fracturing, open or filled with calcite/dolomite and belonging to one or more episodes were recorded in this section (Plates 1c, 2b and c and 5b). Fracturing along with stylolites observed in this section show that stylolites developed in the carbonate mudstone and other microfacies disrupted the fractures/veins (Plates 3c and 6b). Mudstones particularly bear fractures, which at places are highly fractured with several phases of fracturing sometimes (Plates 2c and 6b). Fractures are also found in other microfacies, for example in Plates 1c, 2a and 3c. Imprints of mechanical compaction (broken grains) are shown in Plate 5a and 7b.

Stylolites

The stylolites have been observed at various levels of the formation. Examples are shown in Plates 6b and 3c). The stylolites are found mostly in mudstones. Some of the stylolites are found cutting across the filled fractures and thus postdate the fracturing of that microfacies (Plates 6b and 3c). The recorded stylolites indicate the signatures of chemical compaction, which might be result of one or both tectonic stresses and overburden pressure.

Dolomitization

It is developed at various levels in this section. The following three types of dolomitization have been observed here:

Pervasive dolomitization: It is formed as a result of extensive process of dolomitization in limestones. In this type the dolomitization is not texture selective and attacks fabric of the rock and the whole of the rock gets dolomitized (Plate 5d).

Microdolomitization: Very small and fine crystals of dolomite are produced in this diagenetic process and sometimes larger magnification is required to observe these crystals (Plate 4b).The Plates 3c and 4b exhibit good examples of microdolomites.

Dedolomitization

It is a reverse process in which during diagenesis the dolomite is calcitized. It is a common phenomenon in carbonate rocks. The dedolomitization/calcitization has been observed in the Samana Suk Formation of investigated section in Plates 1b and d, 4b and 6c).

Incorporation of iron in calcite and dolomite

Incorporation of iron in calcite and dolomite is a late stage diagenetic phenomenon. Ferroan calcite (Plates 5b, 6d and 7a) and ferroan dolomite (Plates 4a and 7a) have been recorded from this section.

DIAGENETIC EVENTS' SUCCESSION

The diagenetic event's succession of different diagenetic processes and their products depending on time hierarchy of presently discussed section is described here.

Micritic envelopes

It is the first diagenetic phase, which takes place in the marine diagenesis of limestones. Micritic envelopes develop around fauna which have original aragonitic mineralogical composition. These envelopes serve to define and preserve the outline and morphology of the carbonate grains over which these envelops develop.

Dissolution of aragonite

In the second phase the aragonite dissolves in the faunal grains having aragonitic mineralogy and is precipitated as sparite. Sometimes the internal structure of the skeletal grains is totally destroyed and no relict structure is observed at all. However, the outline and morphology of these grains is preserved.

Fabric selective dolomite

The fabric selective dolomitization is the next phase of the diagenetic history of lomestones, in which only the dolomitization of matrix takes place and component grains/allochems takes place.

Fracturing and physical compaction

The physical compaction of the carbonate sediments is the next diagenetic event. Under this diagenetic process the inter-grain space reduces, which results in the overall reduction of porosity of the rock. In case of poorly cemented sediments the component grains may break due to physical compaction process. This and other factors produce fractures and ultimately enhance the porosity and permeability of the rock.

Chemical compaction

In this phase as a result of increasing compaction first the grain to grain contacts take place and then simple grain contacts developed into sutured grain contacts. Later on dissolution of grains starts at these contacts. Sometimes the embayment of one grain into the other is, also, observed.

Stylolitization

It is the last diagenetic event. The stylolites are actually manifestation of a diagenetic phenomenon, named as pressure-dissolution or chemical compaction.

Dedolomitization

It is also a late stage diagenetic process, in which dolomite is converted into calcite. It is also known as calcitization.

Incorporation of iron into calcite and dolomite

It is the last event in the course of diagenesis of carbonate sediments and is related with the late stage uplifting and/or unconformity surface. The leached out iron in this environment gets incorporated into calcite (rendering it into ferroan calcite) and dolomite (rendering it into ferroan dolomite) as per demand of the prevailing environmental conditions.

DISCUSSION

The Samana Suk Formation in Makarwal Section is comprised of limestones, dolomitic limestones and dolomites with calcareous shales/marls breaks appearing at a number of levels. These shale/marl breaks and intercalations are irregular and do not show any cyclic deposition. The limestones are light grey and yellowish grey and at places dark grey and are mostly dense, hard and compact and contains faunal and floral tests, shells and grains. Two hard ground surfaces, recorded in this section, mark the presence of regressive cycles and periods of non erosion/non deposition. The microfacies developed here include bioclastic, peloidal, ooidal and cortoidal grainstones, bioclastic, ooidal and peloidal packstones, bioclastic wackestones, bioclastic mudstones and mudstones. The bioclastic microfacies form the predominant component of limestones of this section. These bioclastic microfacies host from small to very large skeletal shells and fragments of foraminifera, brachiopoda, gastropoda, pelecypoda, sponges, corals, echinoderma and algae. The cement types found at different levels and in different microfacies are dog tooth cement, intergranular cement, poikilotopic cement and syntaxial rim cements. Important diagenetic phases noted include dissolution, replacement, alteration, dolomitization, dedolomitization and incorporation of iron into calcite and dolomite as late stage diagenetic events.

CONCLUSIONS

The following conclusions have been drawn:

The Samana Suk Formation exposed at this section is predominantly composed of fine to coarse grained hard and compact limestones, dolomitic limestones and dolomites with thin intercalations of calcareous shales and marls.

Hard ground surfaces are present at two different levels showing the regressive cycles during deposition of this formation and mark the periods of non erosion/non deposition.

The microfacies types found here include bioclastic, peloidal, ooidal and cortoidal grainstones, bioclastic, ooidal and peloidal packstones, bioclastic wackestone, bioclastic mudstones and lime mudstones devoid of any fossils. The faunal and floral assemblage present in the bioclastic microfacies consists of shells and grains of foraminifera, brachiopoda, gastropoda, pelecypoda, sponges, corals, echinoderma and algae.

Through a number of diagenetic episodes the development of different cement types (dog tooth cement, intergranular cement, poikilotopic cement and syntaxial rim cements), dissolution and replacement minerals, alteration products, fracturing, mechanical and chemical compactional features (broken component grains, dissolution seams and stylolites), dolomitization and dedolomitization and incorporation of iron into calcite and dolomite were produced at different levels and in different microfacies of this section.

It is inferred by the analytical studies of depositional fabric, microfacies and diagenetic settings of the Samana Suk Formation found at this section that it was deposited in the open marine environments of shallow (outer and inner) shelf with open and restricted marine conditions.

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