Journal of Mountain Area Research
Vol. 7, 2022
https://doi.org/10.53874/jmar.v7i0.112

Full length article

MICROFACIES STUDIES OF THE JURASSIC TAKATU FORMATION, WESTERN SULAIMAN FOLD-THRUST BELT, PAKISTAN

*Abdul Saboor Kakar[1, *], Razzaq Abdul Manan[1], Aimal Khan Kasi[1], Muhammad Ahmed Farooqui [2]*

1. Centre of Excellence in Mineralogy, University of Balochistan, Quetta, Pakistan
2. COMSAT Institute of Information Technology, Defense Road off Rawalpindi Road, Lahore

ABSTRACT

Takatu Formation is well exposed in the western Sulaiman Fold- Thrust Belt, Pakistan. It has an unconformable upper contact with Sembar Formation which is marked by oxidized surface and lower contact with Triassic Wulgai Formation. The Takatu Formation contains a wide variety of limestones, which are fine to coarse grained, palatal, lumpy, skeletal, micritic, nodular, oolitic, and intraclastic. The Takatu Formation is mainly carbonate-litho package with minor siliciclastic content interbedded as shale and marls. The petrography of limestone allowed the differentiation and demonstrated of four major and sub microfacies types. These includes, Mudstone, Wackestone, Packstone and Grainstone microfacies, which are further sub-divided into five microfacies such as, Bioclastic wackstone, Calcispheric packstone, Peloidal packstone, Ooidal grainstone, and Lithoclastic grainstone. These microfacies were compared with standard microfacies and standard zones for their possible depositional environments. On the bases of our studies, it is interpreted that Takatu Formation was deposited in diverse environment ranging from the marginal shallow shelf, upper slope and in deeper parts of the shelf.

KEYWORDS: Takatu Formation; Petrography; Microfacies; Kirthar Sulaiman Fold-Thrust Belt; Indian Shield

*Corresponding author: (Email: Saboor.kakar100@gmail.com)

1. INTRODUCTION

The study area mostly contains sedimentary succession of Triassic-Pleistocene age, however some partly volcanic and volcaniclastic rocks are also exposed (Table 1). Takatu limestone was named [1], for the Jurassic Formation in the Takatu range near Quetta city. Stratigraphic Committee [2,3], named the Takatu Formation after the [1], and the Mazar Drik member in upper part. Initially it was mentioned as Chiltan Limestone of Hunting Survey Corporation [4], and the name was adapted [5] and [1]. The Chiltan Limestone is still in practice in Central Balochistan [5] and massive limestone [6]. This limestone is considered as biohermal and reefal [3, 4]. The Takatu Formation contains a wide variety of limestones, fine to coarse grained, palatal, lumpy, skeletal, micritic-, nodular-, oolitic-, arenaceous-, chert nodules and intraclastic-limestones have been found in the Takatu range and vicinity of Morghi nala. Limestone is dark- to very light-grey and brown to brownish grey. Shale is also present in minor proportion. Takatu Formation might be better described as a reef complex [4]. The Takatu Formation type section (Dara Manda), is located South of Bostan, Pishin District, Quetta (Figure 1). This paper focuses on the petrographic descriptions, interpretations, and depositional environments of the carbonate microfacies studies of a Jurassic succession of the Sulaiman Fold-Thrust Belt, that had been deposited on the northwestern margin of the Indian Plate.

Table 1: Stratigraphic Successions of the Sulaiman Fold-Thrust Belt, Pakistan (after 4, 7, 26)

Age	Group	Formation	Lithology
Pleistocene		Lie Conglomerate, Spin Karez group	Conglomerate, sandstone
Miocene-Pleistocene	Urak Group	Uzda Pasha Formation, Shin Matai Formation and Urak Formation	Sandstone, claystone and conglomerate
***Disconformity* (Angular unconformity in some areas)**			
Middle-Late Eocene		Spintangi Limestone	Limestone, shale and sandstone
Early Eocene		Ghazij Formation	Claystone, siltstone, conglomerate, limestone and coal seams
Paleocene		Dungan limestone	Limestone and shale
***Disconformity* (in some areas)**			
Late Cretaceous		Pab Formation, Mughal Kot Formation, Fort Munro Formation and Bibai Formation	Sandstone, siltstone, shale, limestone in-situ basic volcanic rocks, volcanic conglomerate, breccia and mudstone
Early-Late Cretaceous	Parh Group	Sember Formation, Goru Formation and Parh Limestone	Limestone (bio-micritic), marl and shale
Disconformity			
Early-Middle Jurassic		Loralai Formation	Medium to thin bedded limestone with shale and marl
Middle Jurassic		Chiltan Limestone	Thick to massive bedded limestone
Late Jurassic		Takatu Formation	Medium to thick bedded limestone (micritic, reefal and nodular limestone)

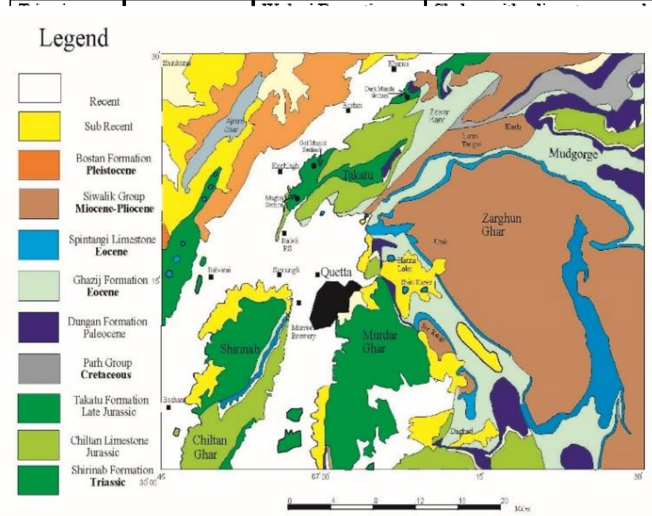

Figure 1. Geological map of the Sulaiman Fold-Thrust Belt showing location of the measured sections (Modified after,10).

2. GEOLOGICAL SETTING OF THE AREA

The study area lies in Quetta Syntaxes, which is an arcuate structure on the boundary of Kirthar and Sulaiman Fold-Thrust Belt (KSFTB) [8,9] near the north-western boundary of the Indian Plate[10,11,12]. The Sulaiman Fold-Thrust Belt (SFTB) is bounded in the north and northwest by the Eurasian Plate and in the south and southeast by the Indian Plate (Figure 2).

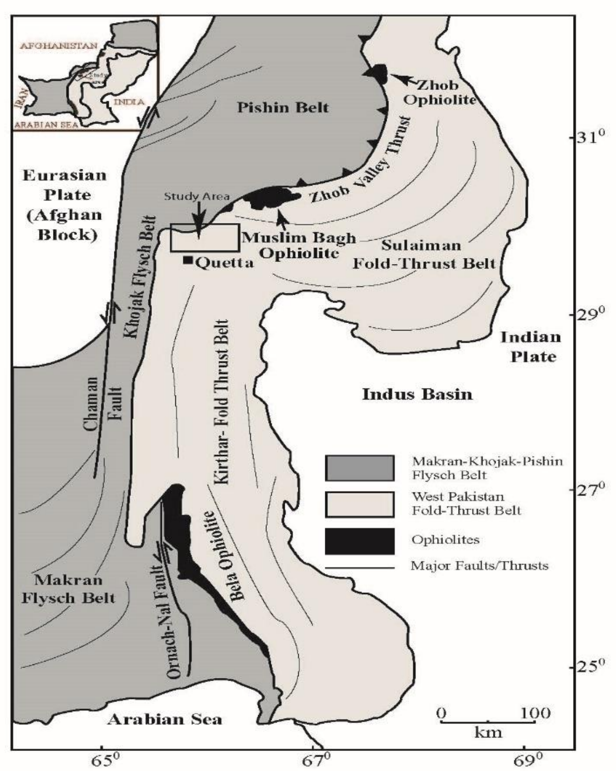

Figure 2. Geological map of the Kirthar-Sulaiman Fold- Thrust Belt showing location of the study area (Modified after, 10].

Broadly the Sulaiman Fold-Thrust Belt is bounded to the west and north by the left lateral strike-slip Chaman fault. The active Sulaiman lobe to the south and east of foredeep is formed mainly as a result of tectonic compression between the Indian plate and the Afghan block. The major east-west trending structural elements (arcuate folds and faults) in the SFTB are rotate rapidly to a north-south direction along the active fold belt margins. At the surface imbricated faults are present, whereas the frontal part of the fold belt gradually disappear northward in the subsurface [12,13]. The initial collision event took place between Late Cretaceous-Early Eocene times, which is demonstrated by the obduction of the Muslim Bagh ophiolites [14].

3. MATERIALS AND METHODS

The present work involves field data and laboratory examination of forty-two (42) samples, which were collected from three stratigraphic sections (Dara Manda, Mughai, Gol Masjid) of Late Jurassic Takatu Formation of Sulaiman Fold-Thrust Belt, Pakistan (Figures 3a, 3b). Thin section was prepared and examined under the polarizing microscope to determine the (skeletal, non-skeletal) grains, cement types and other features The total percentage of allochemical and orthochemical constituents have been calculated by visual estimation [15,16], and [17]. [18] have been used to classify the carbonate rocks further modified by [19]. Microfacies have been prepared by comparing with the Standard Microfacies (SMF) [37] and Standard Zones [15, 16].

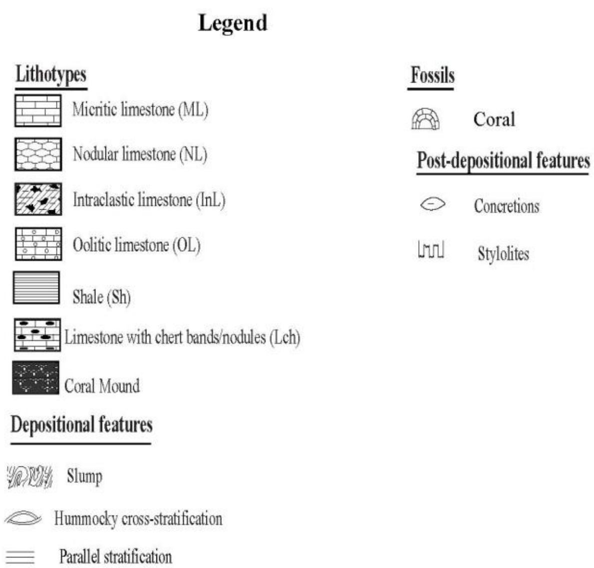

Figure 3a. Legend showing various geological features observed and shown in the following figure

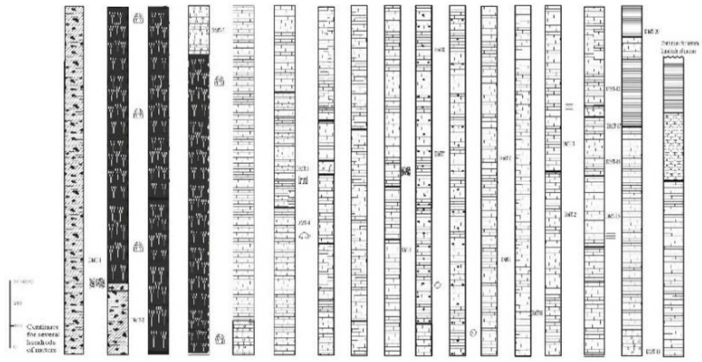

Figure 3b. Columnar profile of Takatu Formation showing lithofacies of Dara Manda type section near South of Bostan, Pishin District.

4. PETROGRAPHY OF TAKATU CARBONATES

Microfacies of carbonate rocks have been defined [18] and [19]. The word Microfacies described petrographic and paleontological criteria studied in thin sections [20, 21]. Microfacies analysis is most important technique in interpreting the depositional environments of carbonate rocks, [22, 23]. Classification model of [18] has been used, which was further classified [15, 16, 19], the microfacies analysis of Late Jurassic Takatu Formation. These Microfacies of the measured sections of Takatu Formation have been compared with the standard microfacies (SMFs) and Standard Zones (SZ) [23]. and [15, 16].Details of various microfacies found are given below:

4.1. Mudstone

Microfacies work is based on the forty-two samples, which were carefully studied under an optical (Leica DM 500) binocular polarized microscope. The petrographic study of the limestones of Takatu Formation allowed the differentiation and demonstration of four major microfacies types; 1) Mudstone 2) Wackestone 3) Packstone and 4) Grainstone microfacies, which are further sub-divided into five (5) microfacies such as, Bioclastic wackestone, Calcispheric packstone, Peloidal packstone, Ooidal grainstone, and Lithoclastic grainstone. The following microfacies description are as follows:

4.1.1 Mudstone

This mudstone microfacies of the studied thin sections have no allochemical constituents. The dominant orthochemical constituents is micro-crystalline calcite cement. It displays micro hair line fracture (Figure 4a), which have been filled with calcite. This mudstone is comparable to the SMF-23 [23] and [15, 16] i.e. *non-laminated uniform, non-fossiliferous lime mudstone*, representing deposition of fine-grained (carbonate mud) sediment under low-energy and calm conditions. This microfacies was deposited in deeper parts of the shelf below the fair-weather wave base [15, 16].

4.2 Wackestone

Microfacies having more than 10% carbonate grains set in micrite is termed as Wackestone [18]. The following microfacies of Wackestone was identified.

4.2.1 Bioclastic wackestone

The bioclastic wackestone microfacies contains high percentage (30-40%) of bioclast (Figure 4b). Bioclast are mainly bivalve and gastropods, which ranges from 1-100 µm. These bioclasts are partly or fully replaced by sparry calcite cement. 100-1000 µm (Figure 4b).

The Bioclastic wackestone microfacies is similar to SMF-9 [23] and [15, 16] , which shows faunal diversity. The abundant mud matrix indicate deposition within calm and low-energy conditions. However, presence of bioclast (bivalve, gastropods) is interpreted in open shallow marine environment.

4.3. Grainstone

The carbonate dominated rock having no lime or less than 1% mud as grain supported classified grainstone [18]. Following two types of grainstone are identified.

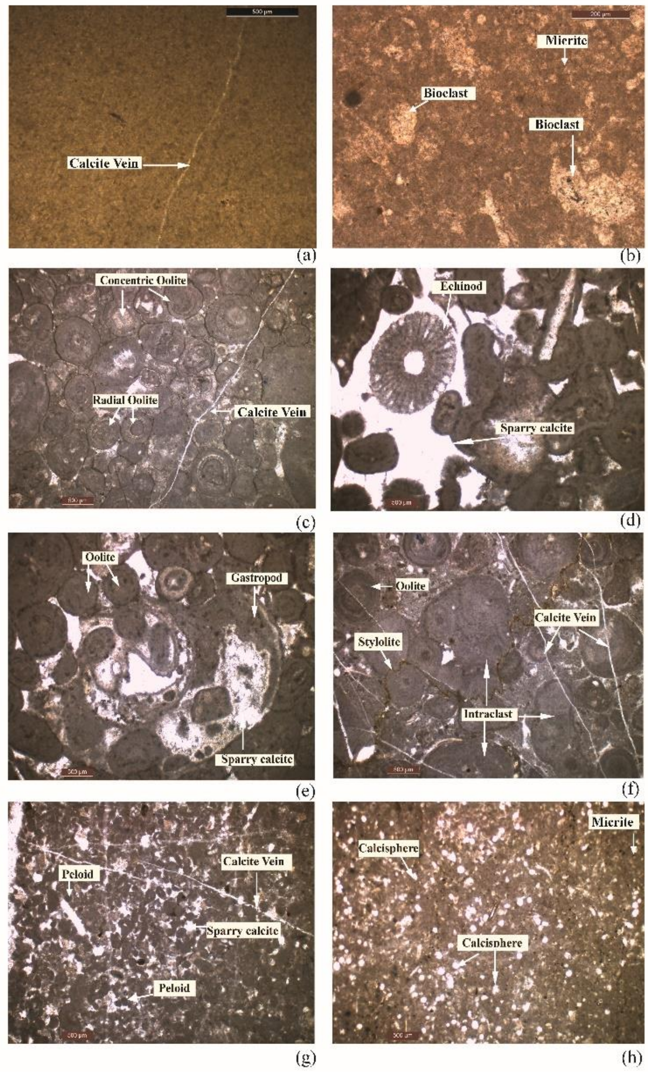

Figure 4. Photomicrographs of studied thin sections of the limestone displaying various microfacies: **(a)** Mudstone with micro hair line fracture, PPL; Dara Manda section, Bostan; **(b)** fossil fragments in bioclastic wackestone, PPL; Dara Manda section, Bostan; **(c)** grain to grain contacts are suture, PPL; Gol Masjid section, Bostan; (**d**) *Echinoids* partly replaced by sparry calcite cement in ooidal grainstone, PPL; Gol Masjid section, Bostan; (**e**) ooidal grainstone containing brachiopod, PPL; Gol Masjid section, Bostan; (**f**) a small amplitude stylolite (arrow), in lithoclastic grainstone, PPL; Dara Manda and Gol Masjid sections, Bostan; **(g)** allochems composed of micrite in peloidal packstone, PPL; Gol Masjid section,

Bostan; **(h)** rounded and oval shape calcispheres in calcispheric packstone, PPL; Gol Masjid section, Bostan.

4.3. Grainstone

The carbonate dominated rock having no lime or less than 1% mud as grain supported classified grainstone [18]. Following two types of grainstone are identified.

4.3.1 Ooidal grainstone

The microfacies is largely constitutes of ooides, which are set in sparry calcite cement. Microcrystalline cement is also present but less than 1%. Majority of ooides size ranges from 0.50 – 1mm, however some are over 1mm. Ooides are mostly sub-rounded to rounded having a concave and sutured contact (Figure 4c), which makes up to 98%. The growth of ooids is mostly concentric and rarely radial. Allochems are mainly micritic, which indicates intense micritization. The allochems displays chemical compaction, which has reduced the porosity. Calcite veins are present which has cut the ooides and partly replaced. Some of the nuclei of ooids are fossil fragments. Fossils are mainly echinodes, (Figure 4d) corals, algae, sponges, brachiopod, gastropod (Figure 4e) and some broken shell fragments. Cortoids have been observed and its size is 3mm. This microfacies is similar to Standard Microfacies SMF-15 and sub-microfacies SMF-15C, which are deposited in shallow-marine (high- to low-energy) conditions, water depths of few meters to tens of meters in regularly agitated environments. The ooidal grainstone is present at the Gol Masjid section.

4.3.2. Lithoclastic grainstone

This microfacies major constituents are lithoclasts with some oolites, bioclasts and peloids. Lithoclasts are represented by micritized grains irregular, elongated, poorly sorted (Figure 4f) set in a sparry calcite cement. The size of the lithoclasts range in size from 1mm to 4mm. Bioclasts are also present which makes <2 %. This microfacies show moderate compaction which is indicated by stylolites (Figure 4f). This microfacies is similar to the SMF-4 [23] and [15, 16]. This type of lithoclast from in shoal water environments, where grains are weakly cemented to marine and intertidal crust or sea floor, where it is broken into aggregate fragments transported to deeper marine environment by storms. It is proposed that this microfacies of Dara Manda and Gol masjid sections were deposited in the outer shelf to upper slope environments by slides, slumps or turbidity currents.

4.4 Packstone Microfacies

The carbonate microfacies containing lime mud and grain supported defined as Packstone [18]. The following two types of Peloidal packstone microfacies has been identified.

4.4.1 Peloidal packstone

The allochemical constituent of this microfacies shows abundant of peloids and bioclasts. Peloids size range from 0.06 to 0.10 mm. These peloids are allochems composed of micrite (Figure 4g). Peloids are mostly elliptical, rod-like, sub-rounded to rounded in shape, which are set in micrite matrix. Patches of irregularly dispersed calcite cement are also observed. Micro veins are present which has introduced secondary sparry calcite cement, that cuts through peloids and bioclasts (Fig. 4g).

This microfacies is comparable with the sub-microfacies *none-laminated, fine grained peloid packstone* of SMF-16 of [23] and [16], which is common in shallow marine shelves with moderate water circulation [15, 23, 24]. Based on above-mentioned features, it is interpreted that this microfacies was deposited in the marginal to shallow shelf (agitated) and shelf-interior environments.

4.4.2 Calcispheric packstone

Calcispheres are spherical to ellipsoidal, single chambered, calcite hallow bodies. The diameter of these micro calcareous fossils ranges from 30 to 400 µm (Figure 4h).

This microfacies corresponds to sub-microfacies SMF-3-Calp (*Calpionellid packstone* of [23] and [15, 16]. The presence of pelagics, such as calpionellids, and radiolarians, it is interpreted to deposit in distal part of the deep marine, lower slope-basin plain environments. Calcisphere microfacies is present in the Gol Musjid section.

5. DISCUSSION

Though in Triassic period, breakup of the supercontinent Pangea was initiated but still the continents were very close together at the beginning of Jurassic time [25]. About 180 million years ago, the supercontinent of Gondwana began to break. Jurassic was the time of very important global change in continental configurations, biological systems and oceanographic patterns. In Jurassic time, supercontinent Pangea split apart allowing for the final development of mountain-building events, and attachment of islands onto continents. Many continents were covered by shallow seaways, and marine sediments were deposited, preserving a wide range of fossils and thriving reef ecosystems [25]. This break-up of Gondwana was manifested in the development of extensive carbonate platform sedimentation, where Jurassic Formations of Sulaiman Fold-Thrust Belt (Chiltan, Loralai and Takatu Limestones) were deposited as massive, thick and medium shallow to deep water carbonates [26, 27].

The Takatu Formation was deposited as significant carbonate litho-package comprised of palatal, lumpy, skeletal, micritic-, nodular-, oolitic-,arenaceous-,chert nodules and intraclastic-limestones with minor shale/marl. Reefs of Dara Manda section indicates reefal limestone, which is very well exposed containing algae, corals, and sponges. The presence of reefs in Late Takatu Formation is very important feature for targeting as potential reservoir, however it has not been tested yet by anyone. This conformation can be achieved by petrological, laboratory analysis (TOC) and with good geophysical data.

This is a first attempt to describe in detail the microfacies of the Takatu Formation. So far there is no published literature available on Takatu Formation. The equivalent carbonate formation of comparable age in the Sulaiman Fold Thrust Belt are Chiltan and Loralai Formations. We have compared our work with Chiltan and Loralai Formations [26, 27], which shows some lithological, depositional and microfacies resemblances. Our work indicates four major and five sub microfacies, which is comparable, however calcisiltite (Graded-, Parallel laminated-, Cross laminated-calcisiltite) and lithoclastic rudstone microfacies in Loralai Formation were not observed in Takatu Formation. Since these microfacies are related slope to deep marine turbidites, the Takatu Formation does not show any turbidite characters. The Loralai Formation is distinct from the Takatu and Chiltan Formations in terms of depositional environment and microfacies as it represents carbonate turbidites and there is no evidence of reefal growth [26, 27].

Microfacies studies of Takatu Formation in Dara Manda, Gol Masjid, and Mughai section suggests low to high energy shelf facies, whereas the presence of oolites and reefs (ooidal grainstone, peloidal packstone) are indicative of high energy environment of shelf edge. Bioclastic Wackestone and Ooidal grainstone shows diverse faunal assemblage that include gastropod, bivalves, brachiopods, echinoderm, which are indicative of diverse shallow marine fauna.

Based on the presence of pelagics, such as calpionellids, and radiolarians (Calcisphere microfacies, mudstone) in the Gol Musjid section, it is interpreted to deposit in lower slope to basin plain environments.

Lithological logs of the measured sections clearly indicate several small to large scale shallowing and thickening upward sequences indicative of the sea level changes. The formation experienced several episodes of fracturing during its geologic history, in which fractures of different nature and size were produced, which were later filled by secondary calcite. These phenomena are also confirmed in thin sections on a small scale as hair like veins/fractures which were filled with calcite. Westward progradation of these reefal facies is also considered possible fluctuation in sea level across the shelf in the Sulaiman Fold Thrust Belt. The prograding sequence of the reef might have resulted in the development of multiple reefs parallel to each other along the shelf edge and plate margin. Reef production usually can keep pace with sea level rise, except when the changes in the sea level is very rapid or where the environment of carbonate production deteriorates due to changes in light penetration, salinity, oxygenation, nutrient level, and siliciclastic input [28, 29, 30].

CONCLUSIONS

The succeeding conclusions have been drawn from the thin section studies of the carbonate rocks of Late Jurassic Takatu formation as follows:

1) The carbonate samples of Takatu formation show diversity, which include mud-supported and grain-supported microfacies.
2) Study of various grains and microfossils (grainstone) show that components are mostly derived within the basin.
3) Different faunal assemblage was recognized, which indicates diverse fauna shallow (gastropod, bivalves, brachiopods, echinoderm) to deep (pelagic, Radiolaria, Calcisphere) marine environment.
4) Mudstone and wackestone microfacies reflect deposition in shallow water (inner shelf) with open circulation close to wave base.
5) Packstone and grainstone microfacies indicate shallow marine, high-energy settings on oolitic shoals and tidal bars, while some areas of the of the successions were deposited below the wave base.
6) It is proposed that lithoclastic grainstone microfacies of the study area was deposited in the outer shelf to upper slope environments by slides, slumps or turbidity currents.
7) The field- and microscope-studies revealed fractured and stylolitized indicating compression/over burden after deposition.

DECLARATIONS

The present research work is a part of M.Phil. thesis of Mr. Abdul Saboor Kakar. The authors are thankful to the Director CEM, for his cooperation and providing financial support for field work and accesses to the petrography laboratory.

The manuscript has been approved by all authors and has not been published or under the conside-ration for publication elsewhere. The authors cont-ribution in this research paper have been explicitly indicated below;

Razzaq Abdul Manan & Aimal Khan Kasi: Supervision, Conceptualization, Methodology, Writing- Original draft preparation. **Saboor Kakar**: Data collection, Laboratory work, Initial draft preparation. **Muhammad Ahmad Farooqui**: Reviewing and Editing.

REFERENCES

[1] Williams, M. D. Stratigraphy of the Lower Indus Basin, West Pakistan. *5th World petroleum Congress*. World Petroleum Congress, New York, (1959). 19, 337-391.

[2] Shah, S. M. I. Lithostratigraphic units of the Sulaiman and Kirthar Provinces, lower Indus basin, Pakistan. *Geological Survey of Pakistan,* (1977). *Record,* 107, p 138.

[3] Shah, S. M. I. Stratigraphy of Pakistan. *Geological Survey of Pakistan,* (2009). *Memoir* 22, p 381.

[4] Jones, A. G. Reconnaissance Geology of part of West Pakistan. a Colombo Plan Cooperative Project. A report published for the government of Pakistan by the government of Canada: Oshawa, Ontario, (1961). Maracle Press, p 550.

[5] Anwar, M. Fatmi, A.N. and Hyderi I.H., Revised nomenclature and stratigraphy of Ferozabad, Alozai and Mona Jhal Groups of Balochistan (Axial Belt), Pakistan. Acta Mineralogica Pakistanica, (1991). 46-61.

[6] Vredenburg, E. W. *Report on the Geology of Sarawan, Jhalawan, Mekran and the State of LasBela, Considered Principally from the Point of View of Economic Development*... Geological survey of India, (1909). 38. 3. 189-215.

[7] Kassi, A. M., Kelling, G., Kasi, A. K., Umar, M., and Khan, A. S. Contrasting Late Cretaceous–Palaeocene lithostratigraphic successions across the Bibai Thrust, western Sulaiman Fold–Thrust Belt, Pakistan: Their significance in deciphering the early-collisional history of the NW Indian Plate margin. Journal of Asian Earth Sciences, (2009). 35.5. 435-444.

[8] Powell, C. McA. A speculative tectonic history of Pakistan and surroundings: some constraints from the Indian Ocean. *In:* Farah, A., Dejong, K. A., (Eds.), Geodynamics of Pakistan. Geological Survey of Pakistan, Quetta, (1979). 5-24.

[9] Sarwar, G. and DeJong, K. A. Arcs, Oroclines and Syntaxe: the curvatures of mountain belts in Pakistan. *In:* Farah, A. and DeJong, K. A., (Eds.), Geodynamics of Pakistan. Geological Survey of Pakistan, Quetta, (1979). 341-349.

[10] Bannert, D., Cheema, A. and Schaffer, U. The structural development of the Western Fold Belt, Pakistan. Journal of Geology, (1992). 80, 3-66.

[11] Bender, F., and Raza, H. A. Geology of Pakistan. Gebruder Borntreager, Germany, (1995). p 414.

[12] Kazmi, A. H., and Jan M. Q. *Geology and tectonics of Pakistan*. Graphic publishers, (1997). P 554.

[13] Kazmi, A. H., and Rana, R. A. "*Tectonic map of Pakistan 1:2000000: Map showing structural features and tectonic stages in Pakistan*. Geological survey of Pakistan, (1982).

[14] Allemann, F. Time of emplacement of the Zhob Valley ophiolites and Bela ophiolites, Baluchistan(preliminary report). *Geodynamics of Pakistan. Geological Survey of Pakistan, Quetta,* (1979). 215-242.

[15] Flügel, E. *Microfacies of carbonate rocks: analysis, interpretation and application*. Springer Berlin Heidelberg New York, (2004). P 976.

[16] Flügel, E. *Microfacies of carbonate rocks: analysis, interpretation and application*. Springer Heidelberg Dordrecht London New York, (2010). p 984.

[17] Baccelle, L., and Bosellini, A. Charts for visual estimation of the percentage composition in sedimentary rocks.

Geological Society of Paleontology, (1965). 1, 59-62.

[18] Dunham, R.J. Classification of carbonate rocks according to depositional textures. American Association of Petroleum Geologist, (1962). Memoire, 1, 108-121.

[19] Embry, A.F., and Klovan J. E. A late Devonian reef tract on northeastern Banks Island Nordwest Territories. Bulletin of Canada Petroleum Geologist, (1971). 19, 730-781.

[20] Wright, V. P. A revised classification of limestones. *Sedimentary geology,* (1992). 76. 177-185.

[21] Alling, H.L. Use of microlithologies as illustrated by some New York sedimentary rocks. *Geological Society of America Bulletin,* (1945). 56.7. 737-756.

[22] Tucker, M. E. "Geological background to carbonate sedimentation". *In*: Tucker, M. E., and Wright,V.P., (Eds.), Carbonate Sedimentology, (1990). Blackwell Scientific Publications, Oxford. 28-69.

[23] Wilson, J. L. The lower carboniferous Waulsortian facies. *Carbonate facies in geologic history*. Springer, New York, (1975). 148-168.

[24] Wanless, H. R., Burton, E. A. and Dravis, J., Hydrodynamics of carbonate fecal pellets. Journal of Sedimentary Petrology, (1981).51, 27-36.

[25] Ali, J. R. and Aitchison, J. C. Gondwana to Asia: Plate tectonics, paleogeography and the biological connectivity of the Indian sub-continent from the Middle Jurassic through latest Eocene (166–35 Ma). Earth Science Review, (2008). 88, 145-166.

[26] Manan, R. A. Sedimentology and Petrology of the Triassic-Jurassic succession, western Sulaiman Fold-Thrust Belt, Pakistan. Unpublished Ph.D. thesis, Centre of Excellence in Mineralogy, University of Balochistan, Quetta, Pakistan, (2014).

[27] Kassi, A. M. and Khan, A. S. The Loralai Limestone Facies around Qila Saifullah and Rud Malazai Areas, Northeast Balochistan. Geological Bulletin, University of Punjab, 28 (1993) 81-91.

[28] Schmid, DU, Leinfelder, R.R and Nose, M. Growth dynamics and ecology of Upper Jurassic mounds, with comparisons to Mid-Palaeozoic mounds. Sedimentary Geology, (2001). 145, 3-4, 343-376.

[29] Leinfelder, R.R., Nose, M., Schmid, D.U. and Werner, W. Microbial crusts of the Late Jurassic: composition, palaeoecological significance and importance in reef construction. Facies, (1993b). Special volume "Microbial Carbonates" Erlangen 29, 195-230.

[30] Van Soest, R.W.M. Shallow-water reef sponges of Eastern Indonesia. *In:* Rutzler (ed.): New Perspective in Sponge Biology. Proceedings. 3rd International Conference Biology, (1990). Sponges, Woods Hole, 302-308, Washington (Smithsonian).

Received: 27 Aug. 2021. Revised/Accepted: 14 Dec. 2021.