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Microfacies Analysis of Kuldhar Limestone, Jaisalmer Formation (Callovian-Oxfordian), Western Rajasthan, India

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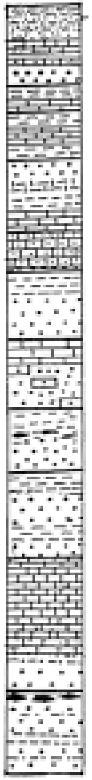
Abstract. The Jaisalmer basin experienced sedimentation since late Proterozoic-Early Cambrian with intervening hiatuses. During Mesozoic, sedimentation started with the deposition of Lathi Formation (Lias to Bathonian) and were followed by deposition of Jaisalmer Formation (Callovian to Oxfordian). Jaisalmer Formation, a carbonate sequence with basal siliciclastics is subdivided into five members. The studied Kuldhar member consists of fossiliferous limestones, pelletal limestones and claystones.

The depositional environments were recognised on the basis of microfacies identification and interpretation. The presence of wackestone-Packstones rich in micrite represents deposition in lagoon to restricted warm shelf. The interbedded grainstones and ooidal bioclastic packstones were deposited in a shallow agitated water above wave base. Presence of homogenous microbioclastics and iron rich argillaceous micrite suggest open shelf deposits below wave base to slightly deeper conditions.

Introduction

The Jaisalmer baisn, 30,000 km^2 in area, is the largest of several sedimentary basins, which comprise the vast and well differentiated west Rajasthan shelf (Fig. 1). The shelf forms the northwestern slope of the western Indian shield and extending westward from the Aravalli range, across the Thar desert upto the mobile belt of Indus Basin in Pakistan. The Jaisalmer Formation forms a major part of the Jurassic sequence. Rocks of Kuldhar Member are exposed around Jaisalmer town of western Rajasthan and extends in northeast-southwest direction between latitude 26º45′ and 27º10′N and longitude 70º45′ and 71º10′E.

TABLE 1. Mesozoic and cenozoic stratigraphy of the Jaisalmer Basin, Western Rajasthan, India (After, Misra *et al.*, 1993).



Litho - log	Formation	Lithology	Thickness	Age
	Shumar	Sand, Sandstone, Limestone	730	Quaternary
	Bandah	Shale, Limestone	200	Middle to Upper Eocene
	Khuiala	Shale, Limestone	400	Palaeocene to Lower Eocene
	Sanu	Sandstone, Marl, Limestone, Shale	670	Palaeocene
	Parh	Argillaceous Limestone	350	Turonian to Coniacian
	Goru	Sandstone and Shale	565	Aptian to Cenomanian
	Habur	Arenaceous Limestones and Calcareous Sandstones	200	Aptian
	Pariwar	Sandstone, Shale, Lignite	670	Neocomian
	Baisakhi / Bhadasar	Sandstone, Shale	730	Kimmeridgian to Hathonian
	Jaisalmer	Sandstone, Limestone	1130	Callovian to Oxfordian
	Lathi	Sandstone, Shale, Lignite	600	Lias to Bathonian

------------------UNCONFORMITY------------------

PRE MESOZOIC

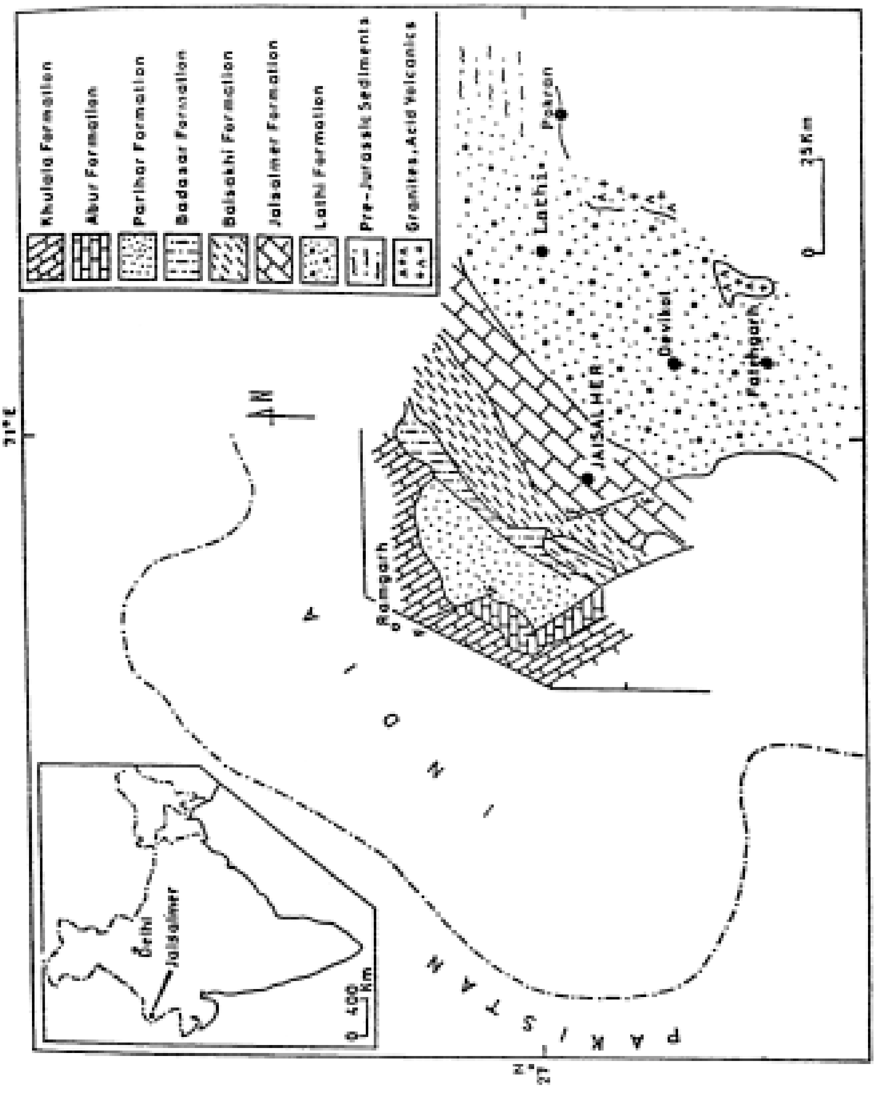


FIG. 1. Geological map of the study area.

The tectonic evolution of western Rajasthan can be divided into four distinct phases. The first phase encompasses the interval from Precambrian to Triassic and corresponds to Pre-Indian plate movement. The second phase commenced in Triassic onward when the precursor activities such as doming and incipient rifting, which led to the incipient breaking of the Indian plate form the southern continent started taking place. The third phase relates to the final rifting and drifting and the fourth phase to the collision of Indian plate with Asian plate from Eocene onwards (Ghosh, 1952 and Veevers, 1989).

The Jaisalmer basin experienced sedimentation since Late Proterozoic-Early Cambrian to Quaternary with intervening hiatuses (Misra *et al.,* 1993). During the middle Jurassic, after considerable clastic influx, carbonate deposition was widespread on an extensive stable shelf comprising several cycles of carbonate sedimentation. The Jaisalmer Formation is sub-divided into five members, *viz.* the Basal, the Joyan, the Fort, the Badabagh and the Kuldhar members, in the ascending order (Mahender and Banerji, 1989).

The Jaisalmer basin has been studied by various workers, specially for regional geology and basin configuration (Pareek, 1984), basin evolution (Datta, 1983 and Biswas *et al.,* 1993), stratigraphy (Mishra *et al.,* 1993) (Table 1), biostratigraphy (Chidambaram, 1991), sedimentological aspects (Mahender and Banerji, 1989 & 1990) and hydrocarbon potential (Dhannawat and Mukherjee, 1996 and Tripathi *et al.,* 1998).

This study was carried out for interpreting the depositional conditions of the carbonates of the Kuldhar Member.

Methods and Materials

The study is based on the measurement of lithostratigraphic sections and examination of thirty thin sections for microfacies analysis. Thin sections were stained with Alazarin Red S. The percentages of allochems, micrite and spar were estimated by counting 300-400 point counts from each thin section. On the basis of percentages of various constituents, seven types of microfacies were identified.

The lithostratigraphic section of the Kuldhar Member (Fig. 2 & 3) was measured in a river cutting near Kuldhar village. Sedimentary structures present include wavy bedding, cross-bedding and ripple marks (Fig. 4).

The studied Kuldhar sequence (Kuldhar Member) consists of poorly fossiliferous limestones, fossiliferous limestones, pelletal limestones and claystones. The limestones mainly comprise coarse, whole and broken shells, peloids, common to superficial ooids and intraclasts, set mostly in micrite.

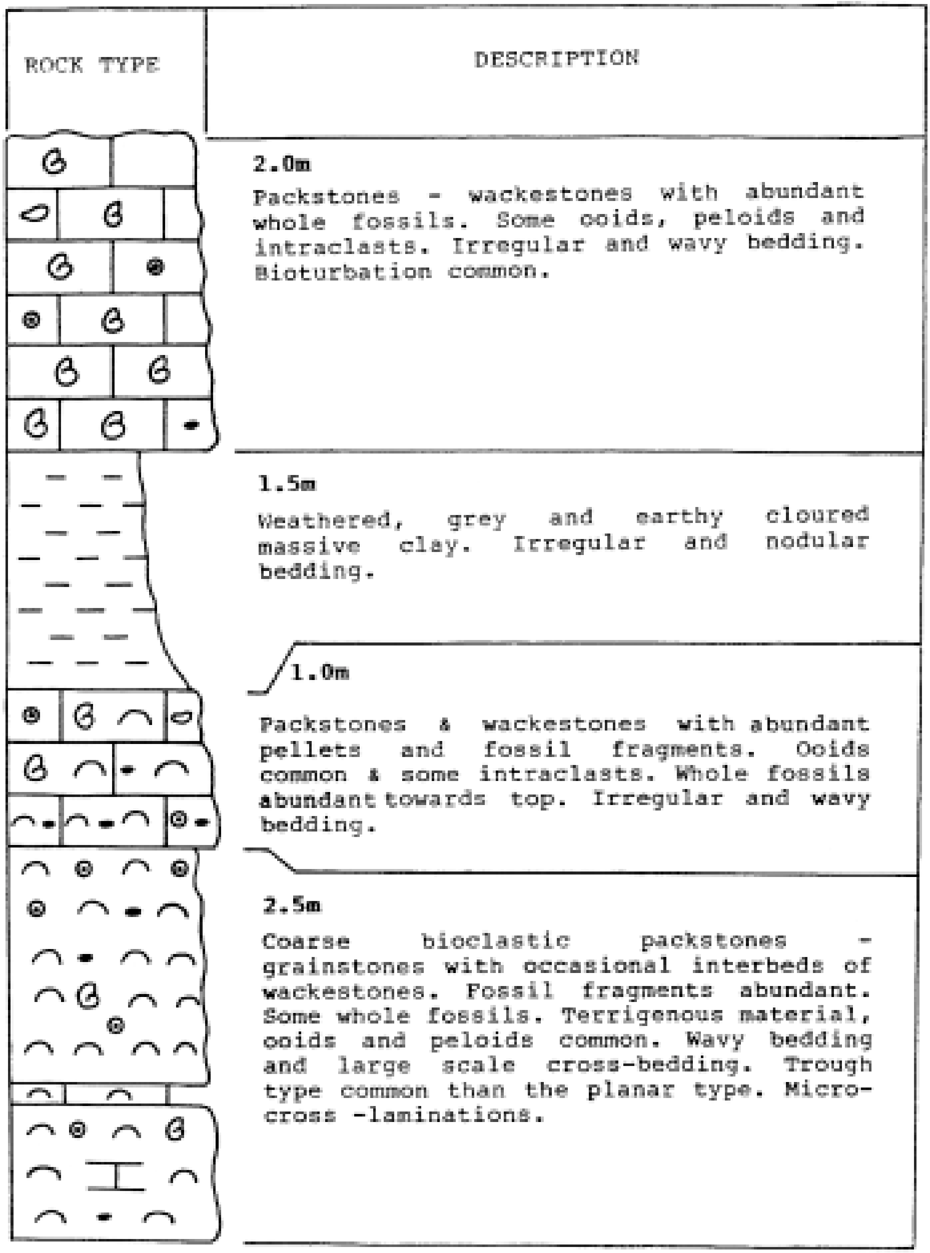


FIG. 2. Measured stratigraphic section of the Kuldhar Member.

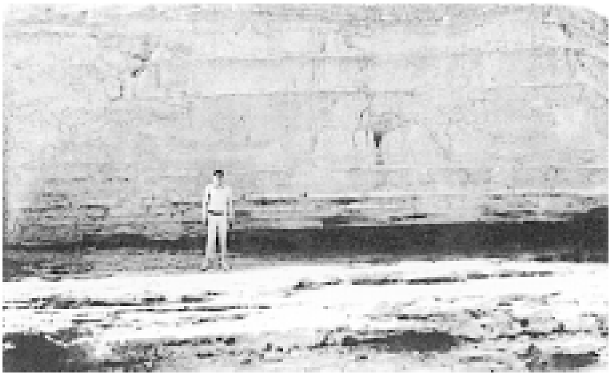


FIG. 3. A general vertical measured section of the Kuldhar Member.

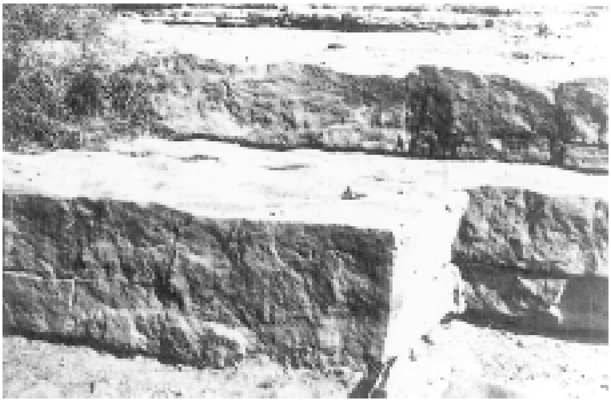


FIG. 4. Wavy bedding due to rippling in grainstone-packstone of the Kuldhar Member.

Bioclasts include mainly shell with some whole remains of brachiopods, echinoderms, molluscs (belemnites, ammonites and pelecypods), foraminifers and occasional bryozoans. 'Oolicasts' and 'pellcasts' cavities left behind after removal of ooids and peloids are observed. Shell cavities have been filled with pelmicrite. Branched and horizontal burrows have been filled with micrite.

Description of Microfacies

Dunham (1962) and Folk (1962) schemes were followed for the classification of the studied limestones. Flugul (1982) method was used for identification, nomenclature and description of carbonate microfacies.

Bioclastic Wackestone

This microfacies occurs in thin, wavy bedded fossiliferous limestones interbedded with cross-bedded poorly fossiliferous arenaceous limestones in the lower part of Kuldhar Member.

The microfacies mainly consist of micrite (45%) and bioclasts (43%). The other textural constituents include ooids (6%), dolomites (3%), terrigenous admixture (2%), intraclasts and peloids (1%) (Fig. 5).

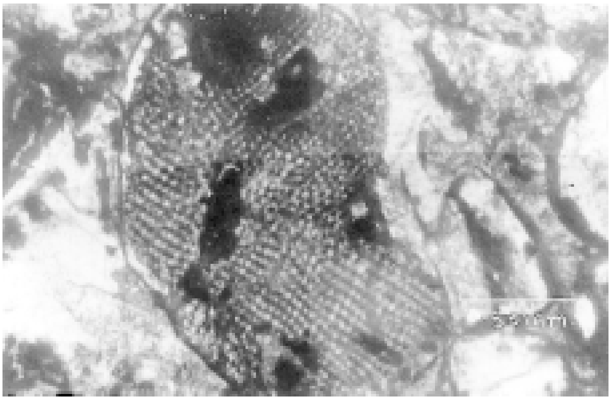


FIG. 5. Photomicrograph showing Bioclastic Packstone in the Kuldhar Member.

Micrite matrix is ferruginous and argillaceous. Bioclasts include molluscs, mostly gastropods, brachiopods, echinoderms, bryozoans, ostracods and foraminifers and traces of algal encrustations. The bioclasts are poorly sorted, show sharp to ragged boundaries and are moderately compacted. Shell cavities in gastropods are filled with dark coloured, ferruginous micrite.

Ooids include superficial and true ooids and occasionally composite ooids. Dolomite occurs as small isolated patches, terrigenous admixture includes quartz, feldspars, iron and clay minerals.

Ooidal Bioclastic Packstone

This microfacies occurs in irregular and nodular bedded limestones in Kuldhar Member. It consists of mainly micrite (35%), ooids (34%) and bioclasts (21%). The other components include peloids (6%), intraclasts, grapestone lumps, and terrigenous (4%) admixture (Fig. 6).

The micrite matrix appears ferruginous and has recrystallized to pseudospar at some places. Superficial ooids are abundant but true ooids and composite ooids are also present.

The bioclasts are predominantly fragmented, but whole fossils occasionally occur. They include molluscs (pelecypods, gastropods, and belemnites) (Fig. 7), echinoderms, brachiopods, foraminifers, serpulid worms, calcispheres, and traces of ostracods, and few unidentified bioclasts. This microfacies show moderate to poor sorting.

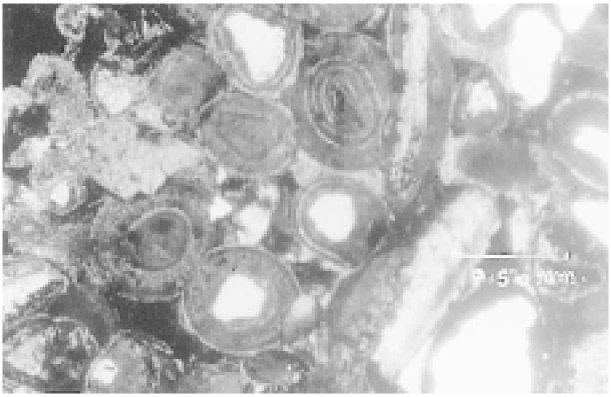


FIG. 6. Photomicrograph showing ooidal bioclastic packstone in the Kuldhar Member.

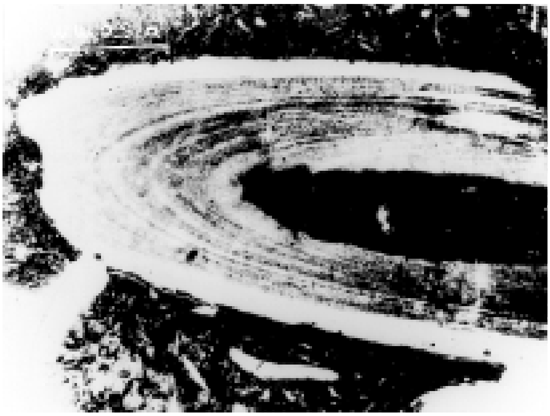


FIG. 7. Photomicrograph showing belemnite whole fossil packstone in the Kuldhar Member.

Ooids present are mainly normal ooids with more than three laminae and have high sphericity. These ooids normally show tangential microstructure. Few superficial ooids are also present and seems to be micritic ooids. Compaction diagenesis is evidence in this microfacies by high packing density and inter-penetrative contacts.

Peloids are well rounded and well sorted. They show the typical bioclastic shape and 'ghost' of original wall microstructure suggesting their derivation by micritization of bioclasts.

The intraclasts are made up of pelletal grainstone, ooidal bioclastic pack-stone, ooidal wackestone and bioclastic wackestone. Terreginous admixture includes quartz grains.

Pelletal Packstone

This microfacies occurs in nodular-bedded limestones in the middle part of Kuldhar Member. It contains mainly bioclasts (40%) faecal pellets (34%) and micrite spar (25%). Other constituents are superficial ooids, intraclasts, and terreginous material (1%). The rock shows nodular structure in thin section in form of bedding parallel discontinuity microstructure resulted due to fissure fillings (Fig. 8).

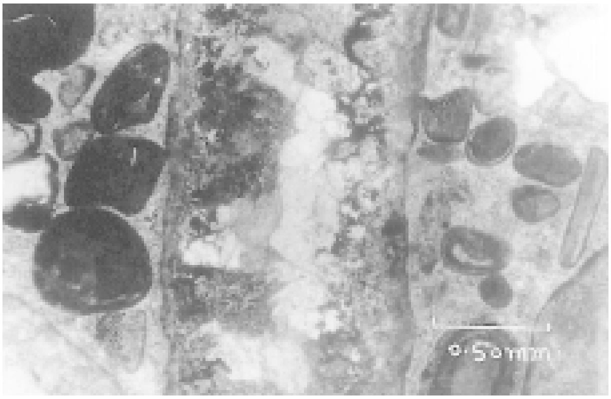


FIG. 8. Photomicrograph showing pelletal packstone in the Kuldhar Member.

Bioclasts are poorly sorted and include molluscs, bryozoans, echinoderms, brachiopods, foraminifers, ostracods, minor amounts of calcispheres and tintinnines and some unidentified bioclasts. Whole fossils mostly belong to gastropods. Ooids are mostly superficial possessing nuclei of faecal pellets, and altered unidentifiable bioclasts also occur. Stylolites of black colour are common.

Crinoidal Packstone

This microfacies occurs in irregularly bedded fossiliferous limestones of the middle part of the Kuldhar Member.Its major constituents are crinoids (48%), other bioclasts (14%), peloids (14%), recrystallized micrite (22%), terrigenous admixture and traces of ooids and intraclasts (2%). The other bioclasts include brachiopods, molluscs, bryozoans, ostracods & foraminifers, calcispheres and tintinnines.

Peloids are ovoid and superficial. Intraclasts of ferruginous silty lime mudstone and ferruginous bioclastic wackestone. Micrite matrix is generally recrystallized. Terrigenous admixture includes silt size quartz and feldspar grains.

Molluscan Packstone

This microfacies is confined to bioturbated, irregular bedded limestones of the upper part of the Kuldhar Member. It consists of dominant bioclasts (45%) and micrite (38%), other minor constituents include ooids and intraclasts (6%), peloids and terrigenous admixture (5%) (Fig. 9).

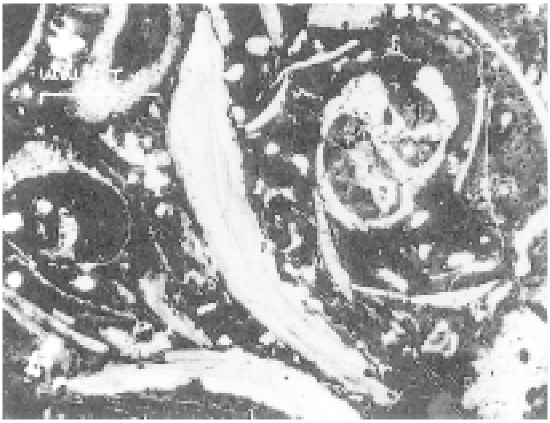


FIG. 9. Photomicrogh showing molluscan packstone in the Kuldhar Member.

Bioclasts include whole fossils of belemnites (Fig. 7), fragments of brachiopods, echinoderms, corals, algae and foraminifers. Most bioclasts have well preserved wall microstructure. The shell cavities in belemnites have been filled with ferruginous bioclastic wackestone. Abundant elongated borings and some elliptical borings are also present in the belemnite shells. The borings have been filled with the same micrite as present outside. Algae occur as dark coloured encrustations on bioclasts.

Micrite matrix is dark brown, ferruginous and appears homogenous. Both superficial and true ooids are present along with intraclasts of ooidal wackestone, bioclastic wackestone/packstone and pelletal wackestone. Terriginous admixtures are largely quartz grains.

Sandy Packstone-Grainstone

This microfacies occurs in cross-bedded arenaceous limestones of the lower part of the Kuldhar Member. The dominant constituent is terrigenous admixture (34%). Other constituents include sparry calcite (17%), micrite, bioclasts, peloids, ooids, dolomite and intraclasts (49%) (Fig. 10).

Bioclasts include fragments of brachiopods, mollucs, (gastropods, pelecypods), echinoderms, foraminifers and traces of ostracods and bryozoans. The bioclasts are moderately sorted and well rounded with sharp boundaries, whilst peloids are well rounded and well sorted. Dolomite occurs in small patches of finely crystalline to mostly medium crystalline rhombs. Sparsely distributed intraclasts of pelletal bioclastic packstone and ferruginous silty wakestone.

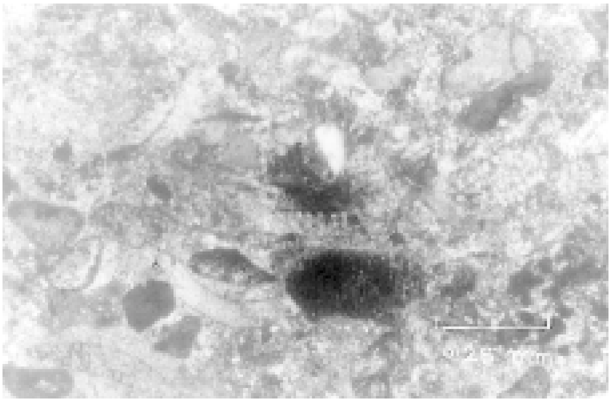


FIG. 10. Photomicrograph showing sandy packstone/grainstone in the Kuldhar Member.

Micrite matrix and sparry calcite cement are present in almost equal amounts. Terrigenous admixture includes mainly quartz grains with minor amount of chert, tourmaline, biotite and muscovite.

Bioclastic Grainstone

This microfacies occurs in cross-bedded limestones of the lower part of the Kuldhar Member. The microfacies comprises bioclasts (37%), sparry calcite (28%), ooids (12%), peloids (7%), intraclasts and terrigenous admixture (8%) (Fig. 11).

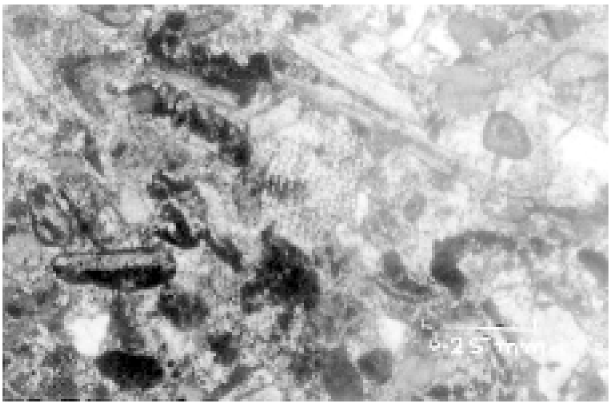


FIG. 11. Photomicrograph showing bioclastic grainstone in the Kuldhar Member.

Bioclasts consist of mostly fragments of mollusc (pelecypods and gastropods), other bioclasts include fragments of brachiopods, echinoderms and very small amount of bryozoans and foraminifers. The shell cavities have been filled with dark coloured micrite. Sparry calcite cement occurs as thin isopachous rims.

Ooids include both superficial and true types but the former are common. Composite ooids are occasionally present. Terrigenous admixture is high and includes sand and silt size quartz and feldspars.

Depositional Environments

1. The basal part of the Kuldhar Member consists of interbedded terrigenous bioclastic packstone-grainstone, coarse coated bioclastic grainstone and bioclastic wackestone. The interbedding of terrigenous grainstones, poorly washed biosparite and bioclast-rich wackestones suggests that these sediments were deposited under variable energy conditions ranging from shelf and lagoon to platform with open circulation. Presence of homogenous iron-rich argillaceous micrite suggests intermixing of microfacies elements in shallow water and their redeposition below wave base or in back waters.
2. The overlying lithology is rich in ooids, sand and bioclast admixture. The ooids are well sorted, spherical and are well formed with mainly tangential microtexture. This microfacies indicates high energy environment found in beach/ coastal zone wherein siliciclastics and abraded bioclasts were incorporated during reworking and winnowing.
3. The ooidal packstone is followed by bioclastic pelletal packstone and recrystallized crinoidal packstone, thus suggesting deposition in shallow warm water with moderate water circulation normally found in shelf-lagoon complex or sometimes in open marine conditions below wave base.
4. The bioturbated packstones-wackestones, with abundant whole fossils and bioclasts including ammonites and belemnites, represents deposition in open shallow marine conditions.
5. Similarity, repetition and overlapping of microfacies in the Kuldhar sequence suggest gradual deepening during transgression followed by shallowing in regression resulted into local changes in environmental condition. The overall change in wave base level has resulted into mixing of faunal bioclasts, terrigenous material and other microfacies elements, which may have formed in a shelf lagoon.

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References

Biswas, S.K., Bhasin, L. and **Ram, J.** (1993) Classification of sedimentary basins in the framework of plate tectonics, In: *Proceedings of Second Seminar on Petroliferous Basins of India,* **S.K. Biswas et al.** (Eds), Indian Petroleum Publishers, **1:** 169-214.

Chidambaram, L. (1991) Mesozoic biostratigraphy, paleo-bathymetry and paleobiogeography of subsurface sediments in western Rajasthan, In: *Proc. Conf. on Integrated Exploration Research : Achievements and Perspectives,* **J. Pandey** and **V. Banerjee** (Eds.), pp. 179-187.

Datta, A.K. (1983) Geological evolution and hydrocarbon prospects of Rajasthan Basins, In: **L.L. Bhandari et al.** (Eds.) *Petroliferous Basins of India. Petrol Asia. J.,* **4:** 93-100.

Dhannawat, B.S. and **Mukherjee, M.K.** (1996) Source rocks studies in Jaisalmer Basin, India, *Ind. J. Petrol. Geol.,* **6:** 25-42.

Dunham, R.J. (1962) Classification of carbonate rocks according to depositional texture, In: **W.E. Ham** (ed). *Classification of Carbonate Rocks,* Am. Assoc. Petroleum Geologists Mem. **1:** 108-121.

Flugel, E. (1982) *Microfacies Analysis of Limestones,* Springer-Verlag Berlin, Heidenberg, New York, 633 p.

Folk, R.L. (1962) Spectral subdivision of Limestone types, In: **M.E. Hm** (Ed.), *Classification of Carbonate Rocks,* Am. Assoc. Petroleum Geologists. Mem. **1:** 62-84.

Ghosh, P.K. (1952) Western Rajputana – Its tectonics and minerals including evaporites, *Proc. of Symp. on Rajputana Desert. Bull. Nat. Inst. Sci. Ind.,* **1:** 101-130.

Mahender and Banerji (1989) Textural study and depositional environment of sand grains from Rocks of Jaisalmer Formation, Jaisalmer District, Rajasthan, *India. J. Geol. Soc. India,* **33:** pp. 228-242.

Mahender and Banerji (1990) Petrography, diagenesis and depositional environment of Middle Jurassic Jaisalmer carbonates, *Ind. J. Earthsciences,* **17:** 194-207.

Misra, P.C., Singh, N.P., Sharma, D.C., Upadhya H., Koroo, A.K. and **Saini, V.L.** (1993) *Western Rajasthan Basins: Lithostratigraphy of Indian Petroliferous Basins,* Document 11, KDMIPE, ONGC, DEHRADUN, pp. 1-16.

Pareek, H.S. (1984) Pre-Quaternary geology and mineral resources of Rajasthan, *J. Geol. Soc. India*, **22: 5**17-527.

Tripathi, R.P., Sharma, S.K., Patel, K.R., Srivastava, K.L. and **Ram, S.** (1998) A Mosbaur approach to hydrocarbon, prospecting in Jaisalmer basin of Rajasthan, *India. J. Petrol. Geology,* **7:** 47-58.

Veevers, J.J. (1989) Middle/Late Triassic (230±5) singularity in the stratigraphic and magmatic history of the Pangea's heat anomaly, *Geology,* **18:** 784-787.

تحليل السحنة الدقيقة لحجر جيركولدار ، متكون جايسلمار (كوللوفي-أكسفوردي) راجستان الغربية ، الهند

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عليجـــر - الهنــــــد

المستخلص. استمر الترسيب بحوض جايسلمار منذ البروتيروزوي-الكامبري المبكر مع بعض فترات التوقف . ثم بدأ الترسيب أثناء حقب الحيـاة الأوسط بمتكون لافي (ليـاس- باثوني) الـذي يتـبـعـه مـتكون جايسلمار (كوللوفي-أكسفوردي) حيث يبنى من تتابع من صخور الحجر الجيري تعلو صخوراً فتاتية سيليكاتية قسم إلى خمسة أعضاء . ويتكون أحد أعضائه (كولدار) المعني بالدراسة الحالية من حجر جيري حفري وحجر جيري عقدي بالإضافة إلى حجر الصلصال .

هذا وقد تم تحديد بيئة ترسيب عضو كولدار استناداً إلى تعريف خصائص السحنات الدقيقة المكونة لوحداته الصخرية . حيث دل وجود نسيج الواكي ستون والباكستون في وفرة من الوحل الجيري على ترسيب في بيئة متدرجة بين لاغونية إلى رفية دافئة ، بينما دل وجود النسيج الحبيبي المحتوى على سرئيات وحتات صخري على ترسيب في بيئة ضحلة ومياه مضطربة تعلو مستوى قاع الموجة . كما دل وجود الحتات الهيكلي المتجانس مع فرشة أرضية طينية غنية بالحديد على ترسيب في بيئة تتراوح بين رفية مفتوحة ومياه هادئة أسفل قاع الموجة إلى أعمق من ذلك .