JOURNAL OF THE PALAEONTOLOGICAL SOCIETY OF INDIA
VOL. 36, 1991, PP. 121-126

SIGNIFICANCE OF TRACE FOSSILS IN THE BHUJ SANDSTONE (LOWER CRETACEOUS), BHUJ AREA, KACHCHH

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ABSTRACT

A systematic record of trace fossils and bioturbated horizons in the Bhuj Sandstone of eastern Kachchh demonstrates that presence of trace fossils, e.g. *Rhizocorallium, Diplocraterion, Thalassinoides* and crab formed mound-crater topography of *Chomatichnus*, alongwith characteristic bioturbated sandstone horizons is indicative of a marine origin for these sandstones where marine body fossils are absent due to dissolution during diagenesis. The bioturbated sandstone horizons show complex superimposition of dense networks of various burrow systems. These bioturbated sandstone horizons represent submarine non-depositional events related to sea-level rise or short-term transgressions. The bioturbated sandstone horizons can be used in (making) event stratigraphy and correlation of various sections in the Bhuj Sandstone, where marine body fossils or other time or facies markers are absent.

INTRODUCTION

In last few decades study of trace fossils together with physical structures and lithological association has become a standard technique in facies analysis and interpretation of depositional environment. Study of trace fossils has been especially useful in sediments lacking body fossils, which have been invariably assigned a non-marine origin. Sometimes marine sandstones are found to be lacking in marine body fossils due to leaching of shell material during diagenesis; but diagenetic processes may enhance the trace fossil record and are found to be especially useful in facies interpretation (Howard, 1971; Singh, 1981; Howard and Scott, 1983). Identification of specific trace fossils, degree of bioturbation, and pattern of bioturbated horizons in a sedimentary sequence are especially helpful in facies interpretation, depth zonation in the marine realm, study of changing rates of sedimentation, identification of hiatus surfaces, and transgression — regression history of sequence. These parameters can be very significant in understanding the basin evolution.

The Bhuj Sandstone (Bhuj Formation) is the youngest lithostratigraphic unit of Kachchh Mesozoic. This sandy sequence is devoid of any marine body fossils and contains occasional plant fossils and fossil wood. This part of the sequence was traditionally referred to as *Coastal Gondwana* implying a fluvial origin. Later Biswas (1977, 1981, 1983) relying mainly on gross lithological characters and associations considered Bhuj Sandstone to be deltaic or fluvio-deltaic.

Casshyap *et al.* (1983) suggest a marine origin for the Bhuj Sandstone on the basis of trace fossils. Jaikrishna *et al.* (1982, 1983) proposed a marine origin for Bhuj sediments on the basis of sedimentary structures and trace fossils. Howard and Singh (1985) pointed out that absence of marine body fossils in the Bhuj Sandstone is due to leaching of shell material in these highly porous sandstones; and on the basis of trace fossil studies assigned a coastal marine origin for these rocks.

These preliminary studies of trace fossils in the Bhuj Sandstone opened up a possibility of using trace fossils for basin studies in the Mesozoic of Kachchh. In the present paper a preliminary attempt has been made to use trace fossil studies in Bhuj Sandstone for facies interpretation and recognition of depositional events.

STRATIGRAPHY

A summary of stratigraphic classifications of Mesozoic rocks of Kachchh is given in Table 1.

The Bhuj Formation of Biswas (1977) corresponds to the upper part of the Umia Formation. It is in western Kachchh that different Members of the Bhuj Umia Formation are developed. In eastern Kachchh about 350 m thick sequence of the Bhuj Formation is represented essentially by medium-to coarse-grained sandstone, devoid of any marine body fossils and commonly referred to as Bhuj Sandstone. In eastern Kachchh the Katrol - Umia Formation boundary is difficult to decipher. A useful field criteria is the presence of cyclic repetitive ferruginous coarse sand bands (densely bioturbated horizons) in the Umia Formation (Howard and Singh, 1985). Thus in eastern Kachchh, the Umia Formation corresponds to the

Table 1. Stratigraphic classification scheme of Mesozoic rocks in Kachchh. The members of Bhuj ~ Umia Formation are developed only in western part. In the study area (eastern Kachchh) the whole Bhuj Formation (sequence) is developed as sandy succession referred to as Bhuj Sandstone.

AFTER BISWAS (1977)		AFTER JAIKRISHNA, et. al. (1983). HOWARD & SINGH (1985), BASED ON OLDER CLASSIFICATIONS		AGES
BHUJ FORMATION	UPPER MEMBER	UMIA FORMATION	BHUJ MEMBER	UPPER TITHONIAN TO ALBIAN
	UKRA MEMBER		UKRA MEMBER	
	GHUNERI MEMBER		GHUNERI MEMBER	
JHURAN FORMATION	KATESAR MEMBER		KATESAR MEMBER	
	UPPER MEMBER		UMIA MEMBER	
	MIDDLE MEMBER	KATROL FORMATION		KIMMERIDGIAN TO MIDDLE TITHONIAN
	LOWER MEMBER			
JUMARA FORMATION	MEMBER IV	CHARI FORMATION	DHOSA OOLITE	UPPER BATHONIAN TO OXFORDIAN
	MEMBER III			
	MEMBER II			
	MEMBER I			
JHURIO FORMATION	MEMBER G	PATCHAM FORMATION		BAJOCIAN TO MIDDLE BATHONIAN
	MEMBER F			
	MEMBER E			
	MEMBER D			
	MEMBER C			
	MEMBER B			
	MEMBER A			

Bhuj Formation and is referred to as Bhuj Sandstone. The present study is limited to the Umia Formation (Bhuj Sandstone) of eastern Kachchh i.e. around Bhuj township and south of Bhuj (Fig. 1).

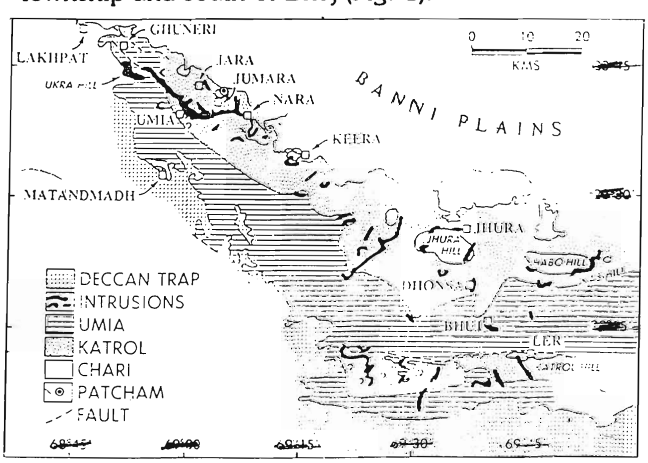

Fig. 1. Geological sketch map of Kachchh.

Shukla and Singh (1989) discuss facies and depositional environment of the Bhuj Sandstone. Distinctive trace fossils and bioturbated horizons are common.

TRACE FOSSILS

In the last few years some papers have appeared mentioning trace fossils from the Bhuj ~ Umia Formation. Kumar *et at.* (1982) list *Arenicolites, Lockeia, Planolites, Thalassinoides* and *Calianassa* burrows from the Bhuj Umia Formation near Bhuj township. Casshyap *et al.* (1983) describe *Planolites, Skolithos* and *Thalassinoides* from the Bhuj Formation. Howard and Singh (1985) describe *Rhizocorallium, Ophmorpha, Thalassinoides, Skolithos, Chondrites, Gyrochorte, Monocraterion, Teichichnus, Cylindrichnus* and *Medousichnus* from the Umia Formation; however, most of them are from shaly units of the Umia Formation in Western Kachchh.

Our experience in eastern Kachchh, where predominantly coarse-grained facies is developed, shows that preservation of trace fossils in the Bhuj Sandstone is poor because of coarse grain size, dense burrowing, and extreme weathering. It makes identification of individual trace fossil types somewhat difficult. Nevertheless, the following trace fossils and burrow patterns have so far been recognised in the Bhuj region.

1. *Vertical burrows* : Long, slender burrows with simple inactive filling are quite common in almost all the lithologies of the Bhuj Sandstone. Some well-developed horizons show vertical burrows 10-15 cm in length, 0.5-2 cm in diameter, that can be assigned to *Skolithos*.

2. *Rhizocorallium* (Plate I—1) : Horizontal to inclined U-shaped burrows with spreite are present in few horizons. They are 12-15 cm in length, 2-3 cm wide, with a tube diameter of 0.5 cm. Some larger ones are up to 30 cm in length. They are found in bioturbated sandstone lithofacies, and also in silty sandstone lithofacies.

3. *Diplocraterion* (Plate I—2) : Strictly vertical U-shaped burrows with spreite of highly variable dimensions are common and sometimes are densely crowded. Some of the larger examples are 50 cm in length, 10-15 cm in width. Smaller ones are 2-3 cm wide and 10-15 cm in length, and mostly densely packed.

4. *Thalassinoides* (Plate I—3) : Well-developed examples of *Thalassinoides* are mostly seen in coarse-grained cross-bedded lithofacies, where burrows are 2

cm across, diameter at swollen branching points being 5-6 cm. Their fill consists of finer-grained sediments than the adjacent sediments. Though poorly preserved, *Thalassinoides* are important in bioturbated sandstone lithofacies.

5. *Inclined sand-filled burrows* (Plate I—4) : In the interbedded sandstone-siltstone lithofacies horizons, sand filled, inclined burrows with circular or compressed outline and with a diameter varying from 0.2 to 2.0 cm are common.

6. *Sand-filled burrows in carbonaceous shales* : The carbonaceous siltstone and shale lithofacies contains prominent 2-5 cm long sand-filled burrows showing active filling. Most of them appear to be broader at base, narrowing upwards. Some of them appear to be related to *Teichichnus*.

Bioturbated sand horizons : A characteristic feature of the Bhuj Sandstone is bioturbated medium to coarse sand horizons (Howard and Singh, 1985) which represent a distinct lithofacies and have been referred to as *Bioturbated Sandstone Lithofacies* (Shukla and Singh, 1989). These horizons range in thickness from 60 cm to 10 m; most are 1-2 m in thickness. They are spongy, highly porous, ferruginous, reddish brown to dark brown in colour. The density of burrows is so high that it is very difficult to identify the complete geometry of individual burrows (Plate I-5).

Decimetre thick horizons appear to be individual units, while thicker horizons are made up of several vertically stacked 50 cm - 1 m thick units. The topmost 10-20 cm of individual units are very densely bioturbated, poor in matrix and show concentration of coarser particles. Mostly it is difficult to recognize specific trace fossils. But whenever the degree of burrowing is less, ***Skolithos, Thalassinoides, Diplocraterion***, and ***Rhizocorallium*** are identified. It is likely that there is a hierarchy of trace fossil types succeeding each other in time and reflecting changes in water depth and other ecological conditions. So far it has not been possible to establish such a sequence of events in this trace fossil assemblage.

Sometimes, within the bioturbated sand lithofacies, bedding plane surfaces are exposed showing a mound-crater topography (Plate I - 6) and surfaces showing funnel shaped vertical burrows. The mounds are conical in shape, 3-5 cm in height, 5-10 cm wide at the base, and 2-6 cm wide near the top. Central part of the mound mostly show a central burrow of 0.5 - 2.0 cm in diameter. Sometimes within a single mound two or more vertical burrows are seen. These mounds can be compared with the ichnogenus *Chomatichnus* that has been ascribed to the activity of the ghost shrimp *Callianassa* or related animals (Chamberlain, 1971; Warme, 1967).

Presence of these trace fossils, thick bioturbated horizons and the facies association (Shukla and Singh, 1989) point to shallow marine depositional environment for the Bhuj Sandstone, despite the lack of marine body fossils.

SIGNIFICANCE OF BIOTURBATED HORIZONS

As pointed out, the most characteristic feature of the Bhuj Sandstone is the presence of about 1 m thick horizons of bioturbated sand which seem to be very persistent laterally. These horizons are a result of one or more of the following events : periods of low sediment supply from land, slow rate of sedimentation, increased water depth below wave base so that physical reworking is rare, high population density of burrowing macrobenthos, long span to allow benthic communities to thoroughly bioturbate the sediments.

This situation in shallow marine settings is most easily explained by a rise in sea level, which results in flodding of river mouths by sea water causing siltation of river channels with little or no sediment supply in the marine system. Rise in sea level also results in increased water depth, bringing the reworked coastal sand below wave base, where sediment can be moved or added only during strong storms. The shoreline shifts according to the shoreface retreat model (Brunn, 1962, 1963). The area is densely populated by benthic organisms which given enough time can churn the sediment.

The cause of rise in sea level at a given place can be either due to subsidence of the depositional area as a result of tectonism or due to absolute rise in sea-level (eustatic sea level rise).

Each of the bioturbated sandstone horizons of the Bhuj Sandstone represents a disconformity or non-deposition surface corresponding to a short-lived transgressive event (Fig. 2) (Singh and Howard, 1986); while the sediment prisms between two successive bioturbated sandstone horizons represent progradational units. Throughout the Bhuj Sandstone there are no vertical trends of regional shoreline shifts of large dimensions.

The Lower Cretaceous broadly corresponding to

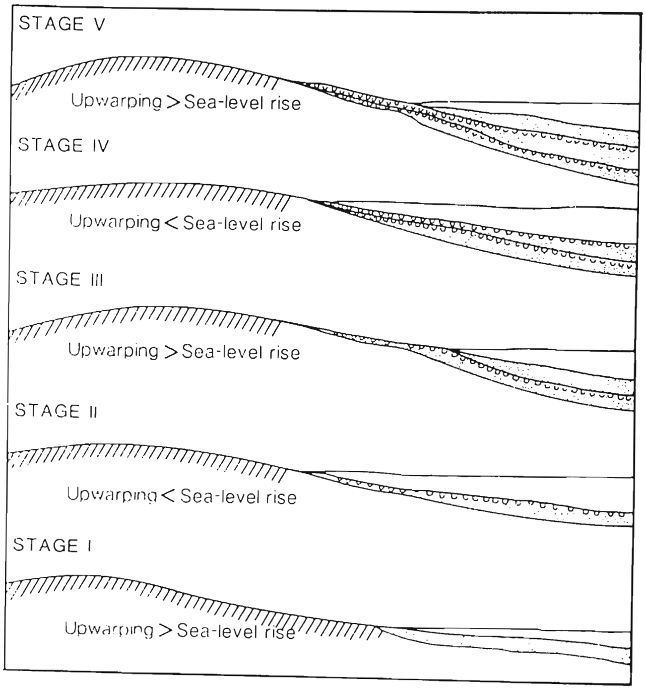

Fig. 2. Diagram showing genesis of bioturbated horizons in Bhuj Sandstone. Rise in sea-level increases water depth and cuts off the sediment supply; benthic organisms produce densely bioturbated horizon. With stillstand and increased sediment supply a sediment prism is deposited (after Singh and Howard, 1986).

the time of deposition of Bhuj Sandstone is a time of global sea level rise with intermittant stillstand phases (Vail *et al.* 1977). However, the Bhuj Sandstone from bottom to top shows evidence of deposition in the same environmental setting. This can be achieved only when the eustatic sea level rise is compensated by an increased sediment supply from the source area due to positive tectonism, coupled with subsidence in the depositional area to accommodate a thick sediment prism. In contrast, the bioturbated sandstone units must represent periods of (short-lived) tectonic quiescence in provenance and/or increased rate of sea level rise.

If the bioturbated sandstone horizons are short-lived transgressive events, then the number of such horizons can be expected to be similar in different sections and also correlatable. In addition, these horizons can serve as time markers and can be used to build an event stratigraphic framework of the Bhuj Sandstone. The two sections measured in detail sedimentologically, namely Rukmavati section and Sonari River section contain nine and ten horizons of bioturbated sandstone respectively.

If the hypothesis proposed in this paper is correct, the bioturbated sandstone horizons can be used as marker beds to help correlation in these unfossiliferous sandstones. These are interesting possibilities, which need to be tested with more data.

ACKNOWLEDGEMENTS

Thanks are expressed to Prof. S.K. Singh, Head, Department of Geology, Lucknow University, for providing the working facilities of the department and to Mr. P.P. Singh for the help during field work to one of us (UKS).

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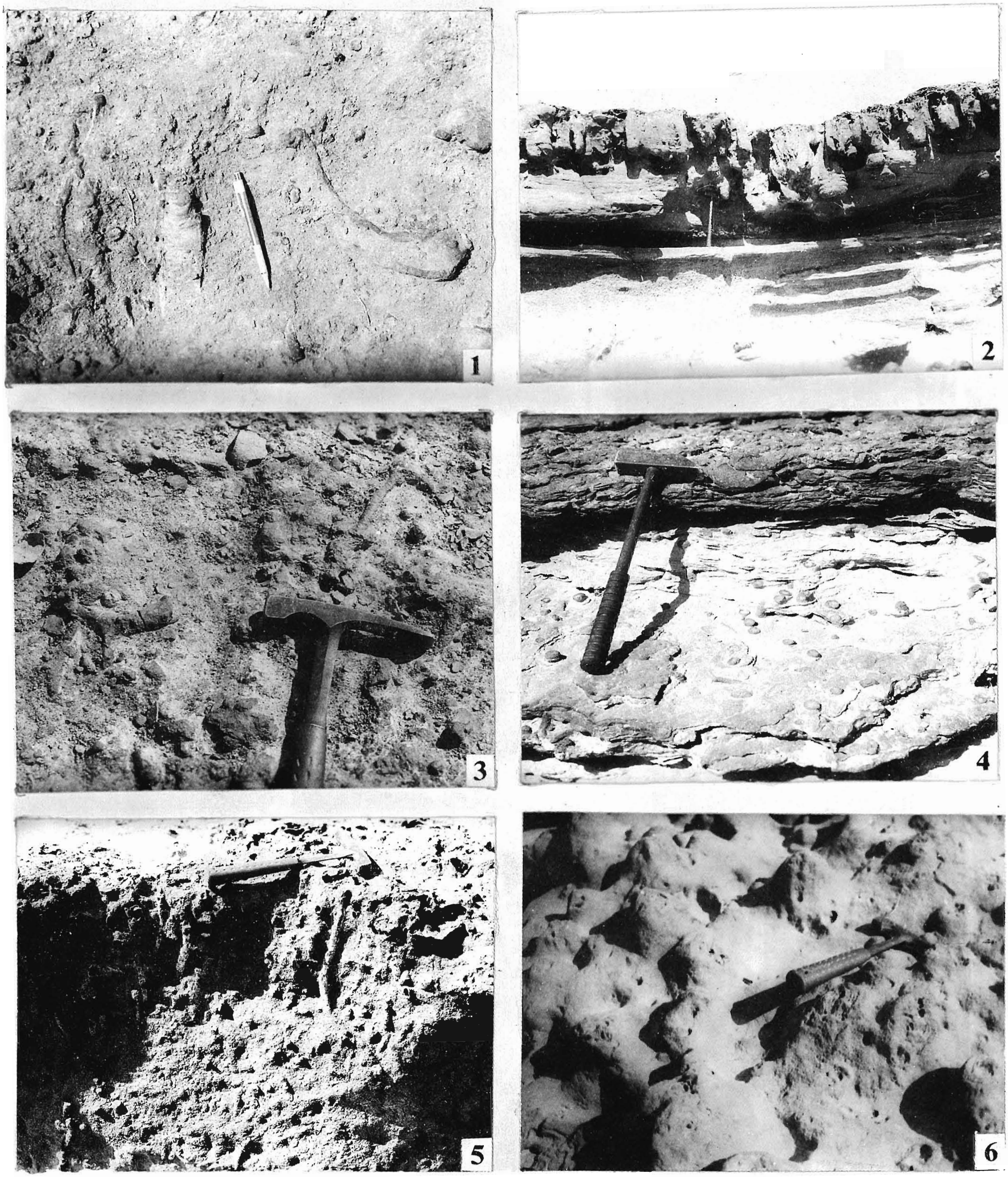
EXPLANATION OF PLATE

PLATE I

1. Photograph showing *Rhizocorallium* in bioturbated sand lithofacies. Rukmavati section.
2. A horizon of densely-packed *Diplocraterion* at the top of a bioturbated sand lithofacies. Rukmavati section.
3. A *Thalassinoides* burrow removed from a densely burrowed horizon. Rukmavati section.
4. Photograph of inclined sand-filled burrows with markings indicating active filling. Rukmavati section.
5. Field photograph of bioturbated sand horizon showing burrows in various orientations. It is difficult to determine the geometry of individual burrow systems. Length of the hammer = 27 cm. Rukmavati section.
6. Field photograph of bedding surface of a bioturbated sand horizon showing closely-packed small conical mound mostly with a vertical tube in the centre. Length of the hammer = 27 cm. Rukmavati section.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