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FACIES ANALYSIS OF BHUJ SANDSTONE (LOWER CRETACEOUS) BHUJ AREA, KACHCHH

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ABSTRACT

Facies analysis of Bhuj Sandstone (Bhuj Formation ≃ Umia Formation) using bedding structures, trace fossils, and geometry of lithounits is attempted and five major lithofacies are identified with specific depositional environments: Lithofacies 1 - Carbonaceous Siltstone and Shale (coastal lagoon deposit), Lithofacies 2 - Coarse-grained Cross-bedded Sandstone Lithofacies (estuarine channel deposit), Lithofacies 3 - Inter-bedded Sandstone - Siltstone Lithofacies (tidal flat - tidal chanel deposit), Lithofacies 4 - Silty Sandstone Lithofacies (sandflat - shoal deposit), Lithofacies 5 - Bioturbated Sandstone Lithofacies (transgressive shelf sheet sand deposit).

The idealized complete sequence is Lithofacies 1 → Lithofacies 2 → Lithofacies 3 → Lithofacies 4 → Lithofacies 5. In incomplete sequences, some of the Lithofacies can be missing. The total thickness of about 350 m of Bhuj Sandstone is madeup of many complete and incomplete facies sequences. The Lithofacies 1 to 4 represent deposition during still stand or coastal progradation in tide-dominated estuarine coast line. The Lithofacies 5 represents sheet sand of shallow shelf formed in response to events of sea level rise (Transgression).

Primary sedimentary structures, trace fossils, lithofacies, and facies sequences all conform to a shallow marine coastline deposition model for Bhuj Sandstone.

INTRODUCTION

Bhuj Sandstone is the youngest lithostratigraphic Unit (Formation) of the Kachchh Mezozoic Basin of probably upper Tithonian - Lower Albian age. It outcrops extensively on the Kachchh Mainland and is made up of predominently medium to coarse sand. Depositional environment of Bhuj Sandstone was traditionally considered fluvial or deltaic; though recently it has been argued that Bhuj Sandstone represents coastal marine sand (Jaikrishna *et al.*, 1983; Howard and Singh 1985).

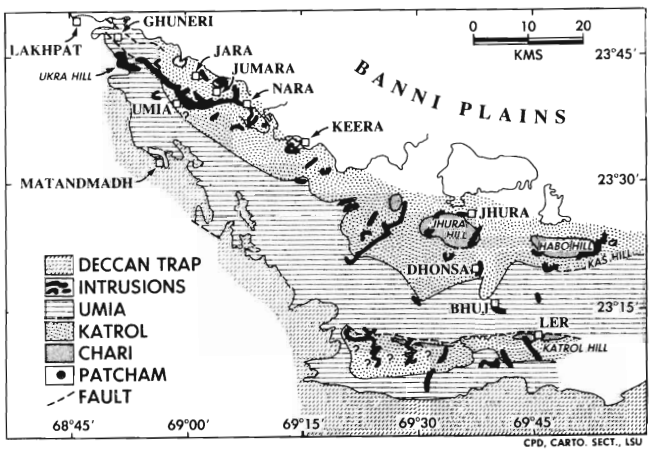

Fig. 1. Geological map of Kachchh mainland showing distribution of Umia Formation.

In the present paper a systematic facies analysis of Bhuj Sandstone in Bhuj area is carried out to understand the depositional environment of these rocks.

GEOLOGICAL SET UP

The Kachchh basin is pericratonic basin on the western margin of the Indian Plate formed due to reactivation of Precambrian lineaments during Gondwanaland break up. The basin occupies the Kachchh district and western part of Banaskantha district in Gujarat State. Mesozoic sequence is 2 - 3 km thick exposed in several domes and in peripheral plain (Fig. 1).

Wynne (1872) provided the first detailed description of the geology of Kachchh. Important contributions are made by Rajnath (1932), Agrawal (1957), Mitra and Ghosh (1964). Biswas (1971, 1977) proposed a new lithostratigraphic classification of Kachchh Mesozoic and provided for the first time a lithological description of the rock units. Biswas (1981) proposed a depositional model of Kachchh Mesozoic, relying mainly on the lithological characteristics.

Bhuj Formation of Biswas (1977) corresponds only to the upper part of Umia Formation of older literature (see Jaikrishna et al., 1983; Howard and Singh,

1985) (table 1). Umia (≃ Bhuj) Formation in the Western Kachchh can be distinguished into a number of Members; while in Eastern Kachchh Umia (≃ Bhuj) Formation is represented by only sandstone facies, i.e. Bhuj Member or Upper Member. This sandy sequence is mostly referred to as Bhuj Sandstone and represents complete Umia (≃ Bhuj) Formation.

Bhuj Sandstone is very well developed around Bhuj township. Rukmavati section, south of Bhuj is one of the main reference section of Bhuj Formation proposed by Biswas (1977). Biswas (1977, 1981) considers Bhuj Formation to be fluvio-deltaic deposits, showing marine incursions in the western part (Ukra beds); while eastern part is mostly fluvial.

Jaikrishna *et al.* (1983), Howard and Singh (1985), Singh and Howard (1986) infer deposition of Umia Formation in marine setting based on study of trace fossils and broad facies associations. Their study was based mainly on the observations in Western Kachchh.

In the present study Bhuj Sandstone (representing Bhuj ≃ Umia Formation) of Bhuj area has been investigated. Bhuj-Mandvi road section, Rukmavati section, and sections around Bhuj township are studied. Detailed facies analysis has been attempted using sedimentary structures, sequence of sedimentary structures, trace fossils, grain size, palaeocurrent, geometry of lithounits.

FACIES ANALYSIS

The term facies is widely used with different connotations. In the present paper the term facies or lithofacies is used in sedimentological sense (de Raaf et al., 1965; Walker, 1984) where a facies is identified in the field based on grain size, bioturbation, and bedding structures, which has a specific motif, geometry and can be assigned to specific depositional processes and subenvironment.

LITHOFACIES OF BHUJ SANDSTONE

The Bhuj Sandstone in the study area is made up of medium to coarse-grained sandstone, with fine-grained sandstone, siltstone, silty clay, silty carbonaceous clay as subordinate lithologies. Five major lithofacies are identified in the Bhuj Sandstone, each with a specific grain size, sedimentary structure association and geometry. Each of these five lithofacies can be further identified into a number of subfacies; however, in the present discussion only the major lithofacies are considered.

LITHOFACIES 1 — CARBONACEOUS SILTSTONE AND SHALE LITHOFACIES

(Plate I — 1)

This lithofacies is characterised by alternation of carbonaceous silty clay and silty to fine sand layers; characteristic bedding structures are lenticular bedding, wavy bedding, small ripple bedding mostly of wave origin, laminated silt and clay. The shale-rich horizons show characteristic sand-filled burrows.

The burrows are common in specific horizons, and range in diameter from 0.2 to 3.0 cm. Silt and fine sand in this lithofacies occurs in two forms, a - lenses, b - definite layers of few mm to 25 cm thickness. Thicker sand layers show ripple bedding, low angle planar cross bedding, climbing ripple lamination. Plant debris, wood pieces are commonly found.

This lithofacies occurs more commonly in the lower part of the Bhuj Sandstone, and ranges in thickness from a few meters to 10 meters. Generally, lower and top part of a given unit are siltier than the middle part which is more carbonaceous and shaly.

LITHOFACIES 2 — COARSE-GRAINED CROSS-BEDDED SANDSTONE LITHOFACIES

(Plate I — 2, 3)

This lithofacies is characterized by medium to coarse-grained channelized sandbodies with invariably lower erosional contact. Characteristic bedding structures are large-scale polymodal cross-bedding, water-escape deformation structures, and thin layers of small ripple bedding. Often herringbone cross-bedding, backflow ripples in planar cross-beds are also seen.

Gravels are mostly present, occurring either as lenses, or concentrated with bottomset of cross-bedding. Bioturbation structures are scarce; sometimes thin horizons of sandstone showing branched and unbranched burrows are interlayered.

Mostly within a single unit, grain size and dimensions of various sedimentary structures decrease upwards. In stratigraphically lower part of Bhuj Sandstone this lithofacies is rather finer-grained with many fine sand intercalations; while in the stratigraphically upper part this lithofacies is coarser-grained, dominantly medium to coarse-grained sandstone with gravel horizons.

LITHOFACIES 3 — INTERBEDDED SANDSTONE - SILTSTONE LITHOFACIES

(Plate I — 4)

This lithofacies is made up of dcm thick fine to medium grained sandstone layers, alternating with

Table 1. Stratigraphic classification scheme for Kachchh Mesozoic. The subdivisions of Bhuj ≃ Umia Formation are developed only in western part. In eastern Kachchh (study area) the sequence is developed as sand-stone facies and whole sequence can be designated as Bhuj Sandstone (Bhuj Formation ≃ Umia Formation).

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 MiddleTithonian
	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			

siltstone-shale bands, showing rippled layers. The sandstone layers are sometimes completely bioturbated. The siltstone - shale horizons are generally ferrugenous.

The siltstone - shale layers characteristically contain wave and current rippled horizons, surface tracks of organisms, and occasional burrows. Rarely thin bioturbated horizons are present.

The medium-grained sandstone layers show planar and trough cross-bedding.

Mostly, within a single unit of this lithofacies, the lower portion is rich in siltstone and shale layers, and there is a gradual increase in the number and thickness of sand layers. Some of the sand layers may be upto 1 m thick, pinching out laterally in tens of meters.

LITHOFACIES 4 - SILTY SANDSTONE LITHOFACIES

(Plate I — 5)

This lithofacies is characterized by well-bedded fine to medium-grained, matrix rich, cross-bedded sandstone. Occasionally, few cm thick ripple-bedded silt layers are intercalated.

The matrix-rich sandstone layers mostly show 20 -50 cm thick cross-bedded units. Some of the cross-bedded units show distinctive tidal bundles, and rare spring neap tide cycles.

The siltstone horizons contain both wave and current ripples and occasional burrows, rarely climbing ripple lamination is also observed.

LITHOFACIES 5 - BIOTURBATED SANDSTONE LITHOFACIES

(Plate I — 6)

This lithofacies is represented by ferrugenous, coarse-grained sandstone with gravel layers and showing extensive bioturbation. The degree of bioturbation is mostly 80 - 100%, and primary physical structures are completely destroyed.

Individual units are mostly less than 1 m thick, sometimes thickness upto 10 m has been observed.

The sandstone is highly ferrugenous, reddish to dark brown in colour, rather clean, devoid of any matrix. Generally topmost part of a single unit is enriched in coarser particles, and devoid of matrix

Degree of bioturbation is very high, mostly it is difficult to identify individual burrows. Whenever degree of bioturbation is low, individual burrows can be identified. They are mostly few mm to 1 cm in diameter, horizontal, inclined or vertical. Sometimes moundlike features are observed on bedding surfaces. Some surfaces also show characteristic funnel shaped burrows. Most of the burrows can be assigned to *Skolithos*, *Thalassinoides*, and *Diplocraterion*.

Rare finer-grained layers are intercalated, showing ripple-bedding. Wherever degree of bioturbation is low, faint cross-bedding is seen in the sandstone.

PALAEOCURRENT ANALYSIS

In two sand bodies on Bhuj - Mandvi road section, and in one sand body of Rukmavati section, paleocurrent measurements were carried out using only large-scale cross-bedding. Statistical parameters and

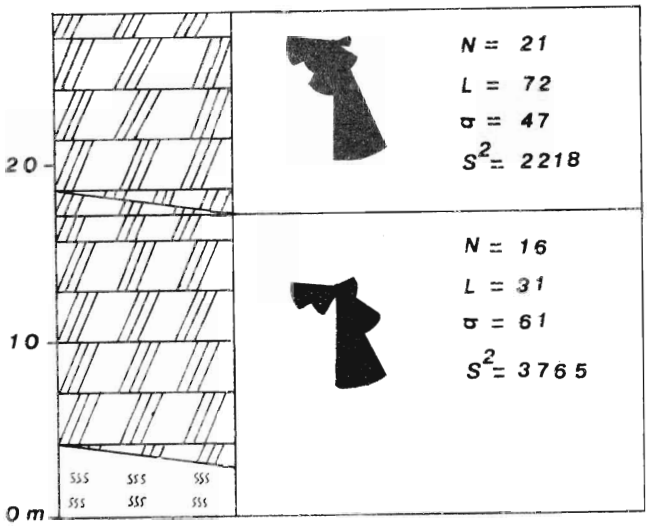

Fig. 2. Litholog and palaeocurrent data of two superimposed sandbodies in Bhuj Mandvi road.

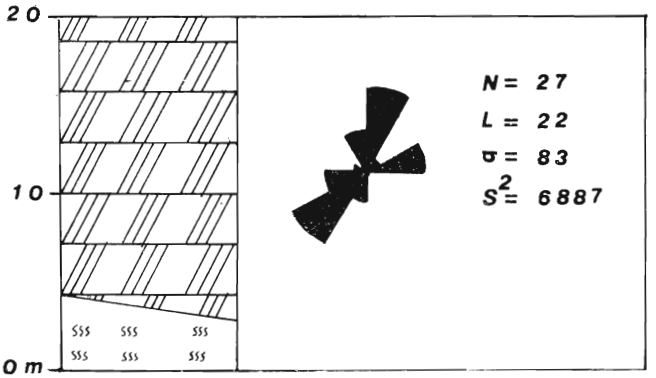

Fig. 3. Litholog and palaeocurrent data of a sandbody in Rukmawati section.

rose diagrams are given in figures 2, 3. The palaeocurrents are distinctly bimodal to ploymodal.

DEPOSITIONAL ENVIRONMENT AND FACIES SEQUENCE

Interpretation of depositional environment is done by identifying various facies and their processes of formation, and by recognizing the facies sequences, i.e. the order of superimposition of individual facies. The facies sequences help not only in the identification of depositional environment, but also in understanding of the transgression-regression events following the Walther's law of facies.

The *lithofacies 1 - Carbonaceous Siltstone and Shale Lithofacies* represents deposition in a coastal lagoon, where wave energy was prominent. Poor circulation and low reworking led to the preservation of organic matter. Horizons of extensive borrowing indicates dense benthonic population and slow rate of sedimentation. Sand deposits are related to storm events and overwash across barriers.

The *lithofacies 2 - Coarse-grained Cross-bedded Sandstone Lithofacies* represents channelized sand deposits. Polymodal palaeocurrent suggest it to be estuarine or tidal channels cutting across the lagoonal fill, as evidenced by the erosional basal surface. High rates of sedimentation caused liquefaction leading to penecontemporaneous deformation. Due to high rate of reworking, burrow structurers are mostly not preserved; though in protected setting sometimes bioturbated horizons developed.

The *lithofacies 3 - Interbedded Sandstone - Siltstone Lithofacies* is deposit of tidal flat-tidal channel areas with both wave and current energy available, and low-energy areas occupied by shaly sediments with intense burrowing.

The lithofacies 4 - Silty Sandstone Lithofacies is deposit of sand flats-shoals under strong tidal influ-

ence as evidenced by large-scale cross-bedding showing tidal bundles. Energy of deposition of this lithofacies is higher than that of lithofacies 3.

The *lithofacies* 5 - *Bioturbated Sandstone Lithofacies* is shallow marine deposit below wave base, under conditions of little or no supply of new sediments, dense benthonic population, relatively long time available for churning and winnowing of the sediments by benthonic organisms.

Wherever sequences are continuous and well-developed following facies sequence is recognized (Fig. 4): Lithofacies 1 → Lithofacies 2 → Lithofacies 3 → Lithofacies 4 → Lithofacies 5.

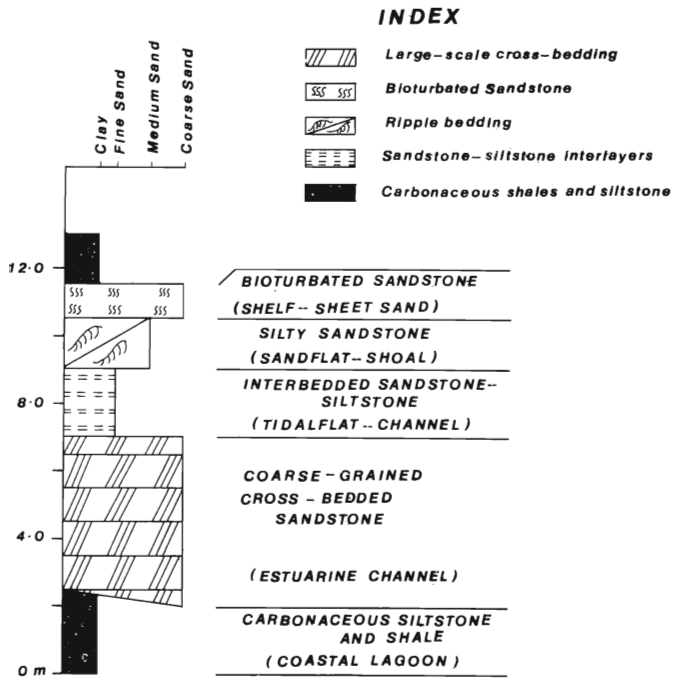

Fig. 4 Schematic complete facies sequence in Bhuj Sandstone.

The basal contact of lilthofacies 2 is almost always erosional. Contacts between lithofacies 2-3-4-5 are all non-erosional, mostly gradational sometimes sharp. The lithofacies 1 sits on lithofacies 5 with a sharp contact though non-erosional.

Lithofacies 3 and Lithofacies 4 may be absent in certain sequences and the facies sequence is Lithofacies 1 → Lithofacies 2 → Lithofacies 5. Rarely, Lithofacies 2 may be absent and the sequence is Lithofacies 1 → Lithofacies 3 → Lithofacies 4 → Lithofacies 5. The Lithofacies 5 always follows sandy sequence Lithofacies 2, 3, or 4, and never occurs directly on Lithofacies 1.

These facies sequences and facies association can be interpreted in following manner. A well developed coastal lagoon is gradually filled producing lithofacies 1. Estuarine channels enter the coast cutting the lagoonal fill, and carry large amounts of coarse sand. Polymodal cross-bedding indicates activity of strong tidal currents within these channels (Lithofacies 2). Marginally to estuaries tidal flats and channels developed (Lithofacies 3), or sometimes shoals and sand flats (Lithofacies 4). Depending upon the position of section and shifting activity of the estuarine channels either Lithofacies 2, 3 or 4 or all of them may be present in a sequence.

The sequence of Lithofacies 1 to Lithofacies 4 can be considered a sequence developing on a progradational coastline or during still stand due to lateral shifting of the lagoon, estuary, and tidal flat areas in a subsiding basin.

However, the lithofacies 5 is rather distinctive. This lithofacies makes about 1 m or more thick horizon which caps the facies sequence and extends laterally over long distances. This lithofacies is probably formed during events of sea-level rise or transgression. During events of sea-level rise estuaries were drowned, shutting off the sediment supply. The sediment of the newly formed shallow shelf was dispersed to produce a sheet sand, covering the underlying progradational sequence. The sheet sand was densely populated and winnowed to produce a highly porous, bioturbated coarse sand.

In the next cycle of coastal progradation, a tidal flat or lagoon developed on top of the bioturbated sheet sand deposit.

The whole of Bhuj Sandstone is made up of repeated complete or incomplete facies sequences of the type described above, where Bioturbated Sandstone Lithofacies makes the marker horizons. Thus deposition of Bhuj Sandstone of Bhuj area took place in a tide-dominated coastline in estuaries, tidal flats, shoals, lagoons punctuated by short-lived transgressive events.

Jai Krishna *et al.* (1983), Howard and Singh (1985), Singh and Howard (1986) have assigned a coastal environment with tidal influence to the Bhuj ≃ Umia Formation in western Kachchh. Bose *et al.* (1988) consider part of the Bhuj Formation (Umia Member) also to be shallow marine deposits. We propose here, that Bhuj ≃ Umia Formation of Kachchh basin represent deposits of a tide-dominated coastline with important roles of estuarine channels. It is in contrast to the fluvio-deltaic model proposed by Biswas (1981) for Bhuj Formation.

CONCLUSIONS

1. Bhuj Formation in Bhuj area is represented predominantly by sandstone (Bhuj Sandstone) and cannot be distinguished into Members as is the case in western Kachchh area.
2. Five distinct Lithofacies are identified in Bhuj Sandstone, namely Lithofacies 1 - Carbonaceous Siltstone and Shale Lithofacies (coastal lagoon deposit), Lithofacies 2 - Coarse-grained Cross-bedded Sandstone Lithofacies (estuarine channel deposit), Lithofacies 3 - Interbedded Sandstone - Siltstone Lithofacies (tidal flat-tidal channel deposit), Lithofacies 4 -Silty Sandstone Lithofacies (Sandflat-shoal deposit), Lithofacies 5 - Bioturbated Sandstone Lithofacies (transgressive shelf sheet sand deposit).
3. The idealized complete facies sequence is lithofacies -1→ lithofacies 2 → lithofacies 3 → lithofacies 4 → lithofacies - 5. The basal contact of lithofacies 2 is always erosional.
4. Lithofacies 1 to 4 represent deposition in a prograding estuarine, tide-dominated coastline; while lithofacies 5 represents deposition on shallow shelf below wave base during events of sea-level rise (transgression).
5. The Bhuj Sandstone is made up of repeated complete or incomplete facies cycles punctuated by short-lived transgressive events in a tide-dominated estuarine coast line.

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REFERENCES

AGRAWAL, S.K. 1957. Kutch Mesozoic: A study of the Jurassic of Kutch with special reference to the Jhura dome. - *Jour. Pal. Soc. Ind.* **2**: 119-130.

BISWAS, S.K. 1971. Note on the Geology of Kutch. *Quart. Jour. Geol. M.M. Soc. Ind.* **43**(4): 220-235.

BISWAS, S.K. 1977. Mesozoic rock stratigraphy of Kutch. -*Quart. Jour. Geol. M.M. Soc. Ind.* **49**(3-4): 1-52.

BISWAS, S.K. 1981. Basin framework, paleoenvironment and depositional history of the Mesozoic sedimentary rocks of Kutch Basin, Western India. - *Quart. Jour. Geol. M.M. Soc. Ind.* **53**(1-2): 56-85.

BOSE, P.K., GHOSH, G., SHOME, S & BARDHAN, S. 1988. Evidence of superimposition of storm waves on tidal current in rocks from the Tithonian - Neocomian Umia member, Kutch, India. *Sedimentary Geology*, **54**: 321-329.

de RAAF, J.F.M., READING, G.G. & WALKER, R.G. 1965. Cyclic sedimentation in the Lower Westphalian of North Devon, England; *Sedimentology*, **4**: 1-52.

HOWARD, J.D. & SINGH, I.B. 1985. Tracefossils in Mesozoic sediments of Kachchh, Western India. - *Paleogeography, Paleoclimatology, Paleoecology.* **52**: 99-122.

JAIKRISHNA, SINGH, I.B., HOWARD, J.D. & JAFAR, S.A. 1983. Implication of new data on mesozoic rocks on Kachchh, Western India - *Nature.* **305**: 790-792.

MITRA, K.K. & GHOSH, D.N. 1964. A note on the Chari series around Jhura dome, Western Kutch. *Sci. & Cult., India* **30**(4): 192-194.

RAJNATH. 1932. A contribution to the stratigraphy of Kutch. -*Quart. Journ. Geol. M.M. Soc. Ind.* **4**: 161-164.

SINGH, I.B. & HOWARD, J.D. 1986. Depositional framework of Mesozoic kachchh basin, Western India (Manuscript).

WALKER, R.G. 1984. General Introduction: Facies, facies sequences and facies models. In: R.G. Walker (Editor). - Facies Models, Geoscience, Canada. Reprint Ser. **1**, 141-170.

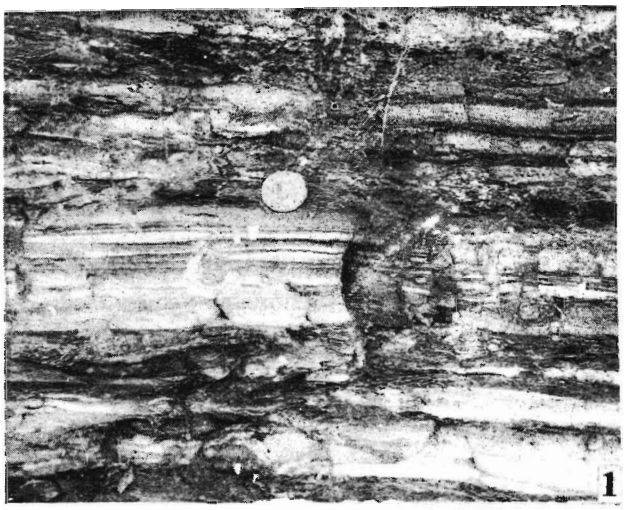
WYNNE, A.B. 1872. Memoir on the Geology of Kutch etc. -*Mem. Geol. Surv. Ind.* **9**(2): 289.

EXPLANATION OF PLATES

PLATE I

1. Lithofacies 1 - Carbonaceous Siltstone and Shale Lithofacies. Within silty carbonaceous shale cm thick rippled fine sand layers are present. Few vertical burrows are visible. Rukmavati section. Scale - diameter of coin = 2.3 cm
2. Lithofacies 2 - Coarse-grained Cross-bedded Sandstone Lithofacies. Large-scale penecontemporaneous deformation is seen. Rukmavati section. Scale-length of hammer = 2.7 cm.
3. Lithofacies 2 - Coarse-grained Cross-bedded Sandstone Lithofacies. Several sets of large scale cross-beds are seen. Rukmavati section. Scale-length of hammer = 2.7 cm.
4. Lithofacies 3 - Interbedded Sandstone - Siltstone Lithofacies. Cm thick sand and silt layers are alternating. A zone of convolute bedding is visible. Rukmavati section. Scale-length of hammer = 2.7 cm.

5. Lithofacies 4 - Silty Sandstone Lithofacies. Cross-bedded silty sandstone and ripple bedded sandstone are seen. One cross bedded unit shows distinct tidal bundles (arrow). Sonari River section along Bhuj - Mandvi Road. Scale-length of hammer = 3 4 cm.
6. Lithofacies 5 - Bioturbated Sandstone Lithofacies. Note dense network of superimposed burrows. Rukmavati section. Scale -length of hammer = 27 cm.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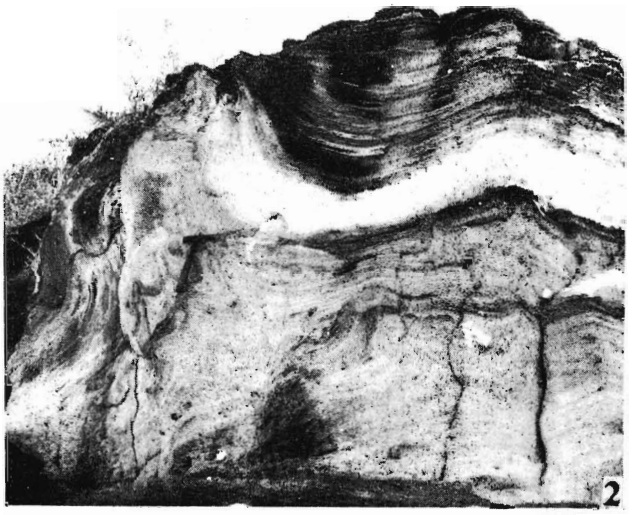
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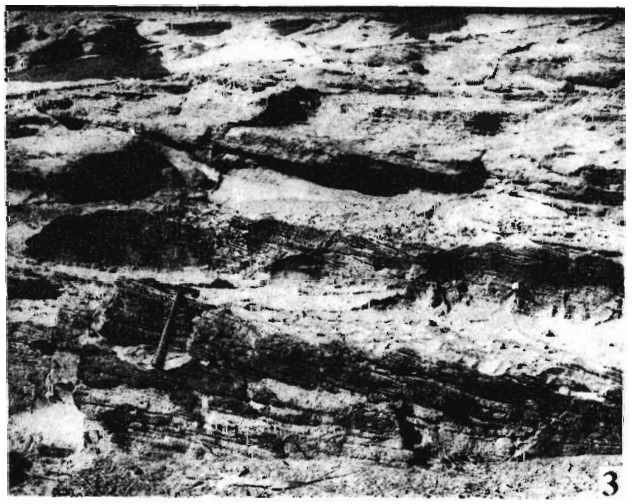
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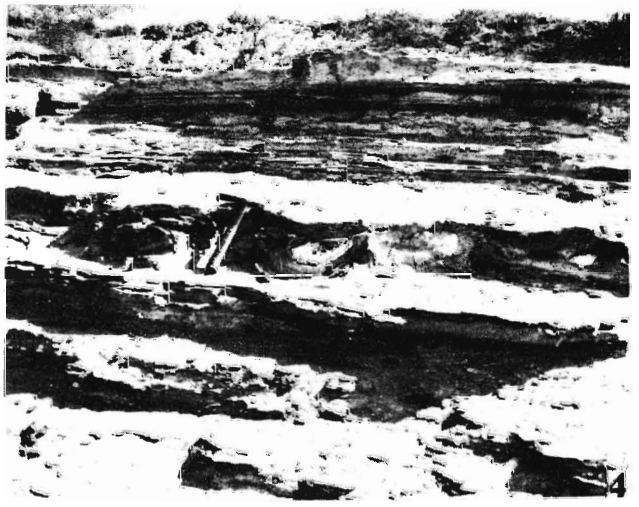
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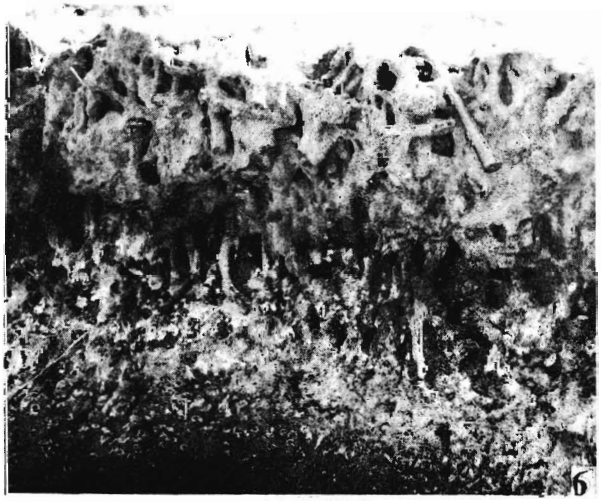
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