

BEACHROCK AND ASSOCIATED CARBONATE SEDIMENTS ON THE FIFTY FATHOM FLAT, A SUBMARINE TERRACE ON THE OUTER CONTINENTAL SHELF OFF BOMBAY

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ABSTRACT

Beachrock and associated carbonate sediments were obtained by dredging and coring on the Fifty Fathom Flat, a submarine terrace at a depth of fifty fathoms (91.5 meters) on the outer continental shelf off Bombay. The beachrocks are iron stained calcarenites composed of oolites and skeletal material cemented together in a fine-grained carbonate matrix. Thin sections show that the rocks are oobiomicrite with a high grain to micrite ratio. The allochems are superficial oolites, skeletal matter and grapestone and pellet intraclasts all of which either charged with iron oxide or glauconitised. Associated sediments on the Flat are glauconitic sand, oolites and coral debris. The karstic topography which is evident from the echograms and the occurrence of beachrock implies that the Fifty Fathom Flat stood at sea-level, probably during the Pleistocene and is now submerged due to eustatic and/or tectonic causes.

INTRODUCTION

A PRELIMINARY account of the surface sediment distribution on the Fifty Fathom Flat, a submarine terrace on the outer continental shelf off Bombay, is presented here. The hitherto unreported zone of carbonate sediment and rock was brought to light during the 4th, 5th and 6th cruise (Jan. 1969, Feb. 1969 and Jan. 1970) of the I.N.S. DARSHAK. The principal aim of the ship was to undertake hydrographic surveys in the Gulf of Cambay. However, a number of oceanographic stations were occupied along traverses across the continental shelf and slope. These traverses generally turned north-west at slope depths and terminated in the Gulf of Cambay. Samples were collected with gravity corer, LaFond-Dietz snapper and

dredge. Continuous echograms were obtained using a Kelvin Hughes MS 26-G echosounder.

RESULTS AND DISCUSSION

From the gross compositional characteristics of the samples obtained from the binocular microscope examination and using bottom notations from Admiralty Chart No. 2736 a surface sediment distribution map was prepared (Fig. 1). With the exception of nearshore sediment,

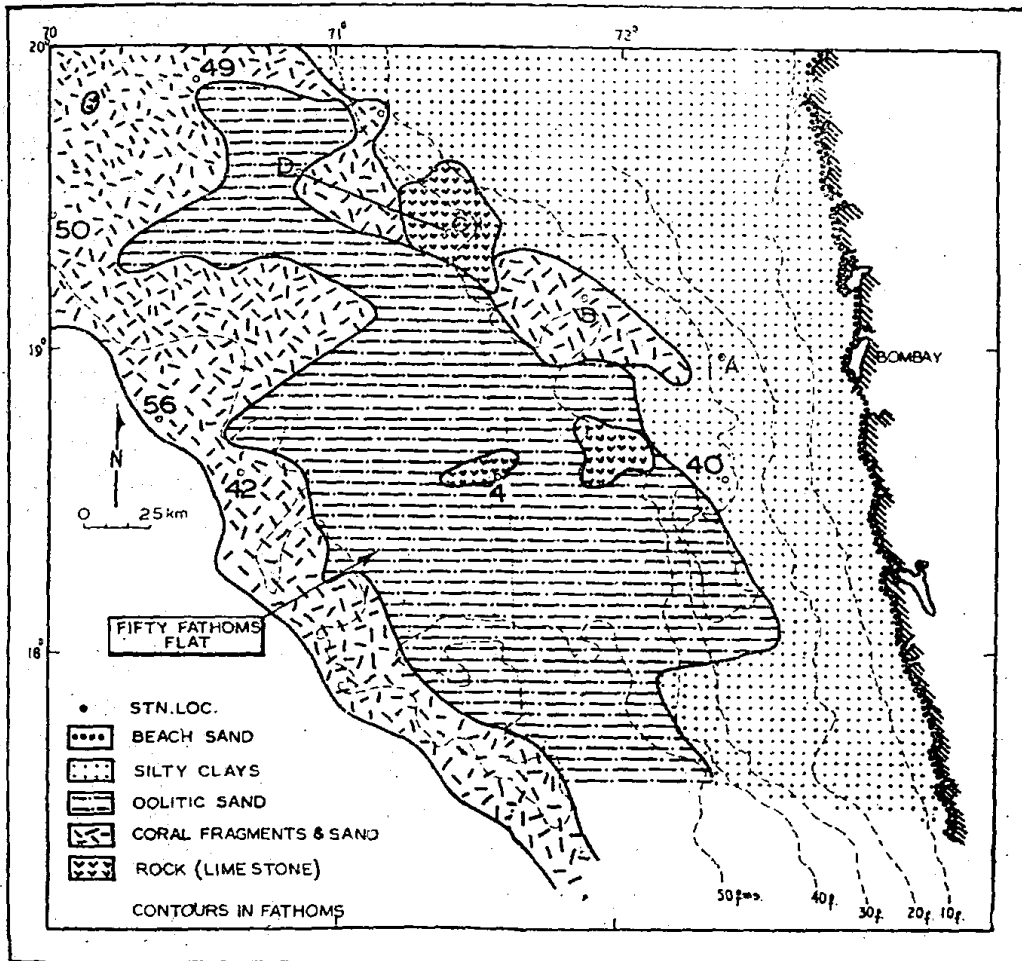


FIG. 1. Distribution of sediments on the Fifty Fathom Flat, showing predominance of carbonate sediments on the outer shelf. Line C-D shows location of profile shown in Fig. 2.

remainders were carbonates in the form of sand-sized material, rock and coral debris. From the nearshore region to a depth of 55 meters the shelf is covered with silty clays. Seaward from 55 meters to 99 meters

isobath which marks the seaward edge of the flat, the sediments are dominantly carbonate sand composed of oolites, coral fragments and limestone intermixed with non-carbonate mud and greenish glauconite sand. This carbonate band continues into the immediately adjacent slope, the grain size however becomes finer with depth while the carbonate content is largely due to foraminiferal tests. A dredge haul at station No. 42, depth 82 meters, yielded massive pieces of limestone. These limestones are calcarenites with abundant shell fragments and oolites cemented together in a fine-grained carbonate matrix. Preliminary examination of the shell material indicated the presence of bryzoa, gastropods, pelycypods and foraminifers such as *quinqueloculina*, *elphidium*, *triloculina*, *oolina*, *dentalia*. The bottom notation of 'rock' indicated in Fig. 1 probably represents similar limestone in other areas of the flat. A well-defined weathering crust of hematite and numerous solution cavities are found in all the dredged material (Fig. 2). Indicative of the extensive outcrop of rock on the sea bottom is the loss of a chain dredge by snagging on the bottom at one of the stations during the course of dredging.

Insoluble residues obtained after treating the rock samples with dilute hydrochloric acid were examined with a binocular microscope. Clear quartz of two different sizes is present, the small ones are angular while the large ones are rounded to subrounded. By far the most dominant component in the residue are (-63μ fraction is 95%) yellowish-brown grains of limonite (goethite?). Long interlocking filaments are also found and may be algal origin. Also present are small ovoids which may be coccoid forms of blue-green algae.

Polished sections were etched with dilute hydrochloric acid and stained with Fiegl's solution and Alizarin Red-S (Wolf, Easton and Warne, 1967). Results indicated that the cement may be aragonite. Positive identification is however rendered difficult by the heavy iron oxide impregnation. Thin sections were made of samples showing marked variation in colour. This was particularly well developed in certain samples which show one half of the specimen to be yellowish-white and the other half to be light to dark grey. The yellow half consisted of oolites in various shades of brown and the grey portion consisted of light grey to black oolites with light green glauconitic material in the matrix. Thin section shows the rock to be a oobiomicroite with a high grain to micrite ratio. Allochems are largely oolites, intraclasts, and skeletal matter. Most of the oolites are of the superficial type and only a few true oolites are present. The nucleus in most cases is cryptocrystalline calcite heavily charged with iron oxide.

Iron oxide concentrations at the periphery of the oolite is common but becomes more abundant in the grey and black glauconitised oolites. Intra-clasts are generally grapestone-like clusters of otherwise identical oolites and pellets (?). Skeletal matter is present in the form of whole and fragment shells of gastropods, pelicycypods and foraminifera, the cavities of the unfragmented shell being filled with oolites and/or glauconite. The particular half of the sample containing glauconite suggests that it may be the buried portion wherein the necessary locally reducing condition for the genesis of glauconite is available (Fairbridge, 1967). The cement between the grains is micrite which is also charged with iron oxide. Occasional sperulitic structure showing extinction crosses is also present. Under high power magnification (300×) fine acicular aragonite are found projecting into the interstices and also radially from the cavities of shells.

The Fifty Fathom Flat is a well-defined topographic feature on the outer continental shelf off Bombay (Shepard, 1963). The echogram shows the inner shelf to about 55 meters to be smooth and gently sloping. Seaward from 55 meters the bottom becomes progressively irregular. Topographic relief highly similar to karstic topography is evident (Fig. 3). An extensive zone composed of pinnacles with intervening depressions are found extending to the shelf edge (128 meters).

Most of the pinnacles are narrow and steep-sided and range in height from one to four meters. Such karstic structures may have come into existence in the limestone of the Flat during a Pleistocene low sea-level. This inference is supported by the localisation of the zone of carbonate sediments to the area of the Flat. The hematitic weathering crust, solution cavities, poorly sorted nature of the components of the limestone and the occurrence of shallow water foraminifera together with oolites suggests that these sediments were formed in waters shallow enough for them to be under the action of the wave base and that at times they were sub-serially exposed for periods long enough to generate a weathering crust. The high grain to micrite ratio provides further evidence that these rocks were formed in a high energy environment, analogous perhaps to the condition obtaining around the Great Bahama Bank. The above-mentioned characteristics of the limestone closely correspond to the description of beachrocks which are found to form at present in the inter-tidal zone such as at Laccadive and Maldiva Islands (Sewell, 1925), Marianna Islands (Cloud, 1965), Southern Florida (Ginsburg, Llyod, Stockman and McCallum, 1963), Hawaiian Islands (Emery and Cox, 1956). Instances of the occurrence of beachrock on the continental shelf are off the Great Barrier Reef (Veeh and Veevers,

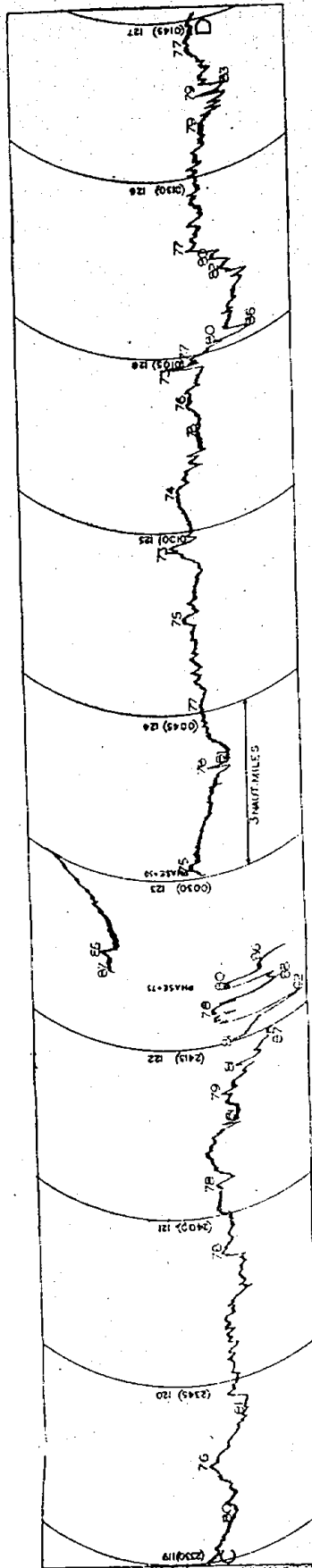


FIG. 3. Trace of echogram showing bottom profile on the Fifty Fathom Flat. Note pinnacles and intervening depressions. For location of profile, see Fig. 1. Depth in meters.

1970) and off Delaware Bay where an aragonite cemented sandstone resembling beachrock has been reported (Allen, Gavish, Friedman and Sanders, 1969). Regarding the origin of beachrock Cloud (1965, p. 147) states that the great bulk of the material called beachrock is primarily the product of cementation at the water-table beneath an overlying layer of unconsolidated sand rather than as a strictly marine phenomenon. This mode of origin is in substantial agreement with the findings of Stanley Gardiner on his studies of beachrock in the Laccadive and Maldivian Islands (Sewell, 1925). The exact process of lithification is, however, still a matter of dispute (Chillingar *et al.*, 1967; Wolf *et al.*, 1967). It may not therefore be unreasonable to conclude from the foregoing discussion that the Fifty Fathom Flat represents in all probability a submerged reef flat, the beachrock being formed during the period when the flat stood at or near the sea-level in the past.

With the available evidence it is difficult to assess at present which of the two possible causes, *viz.*, quaternary sea-level fluctuations or tectonic instability has been instrumental in bringing about the drowning. The results of seismic surveys in the area by Senguptha (Narain, Kaila, and Verma, 1968) have shown the presence of a number of faults in the underlying Deccan Traps (Basalts) which extend to the shelf edge and this evidence would favour the latter cause.

The existence of a parallel belt of coral atolls and coral banks on the continental slope, *e.g.*, Laccadive and Maldivian Islands, Angria Bank, Direction Bank is perhaps a striking feature. The relationship between these and the outer shelf high carbonate band that has been reported to exist throughout the western continental shelf (Nair, 1968) and in particular the Fifty Fathom Flat is, however, not quite clear.

ACKNOWLEDGEMENT

I am grateful to Dr. N. K. Panikkar for his interest and encouragement and particularly for drawing my attention to the report on the occurrence of beachrock on the Laccadive and Maldivian Islands. Shri M. V. S. N. Gupta identified the shell content of the beachrocks and I am indebted to him for the same. I thank Prof. K. O. Emery, Woods Hole Oceanographic Institution, for reading the paper and giving helpful comments. The co-operation of the officers and crew of the I.N.S. DARSHAK is gratefully acknowledged.

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Note added in proof

X-ray diffraction analysis of the beach rock confirms that the cement and grains are composed dominantly of aragonite. I thank Dr. J. D. Milliman, Woods Hole Oceanographic Institution for carrying out the analysis.

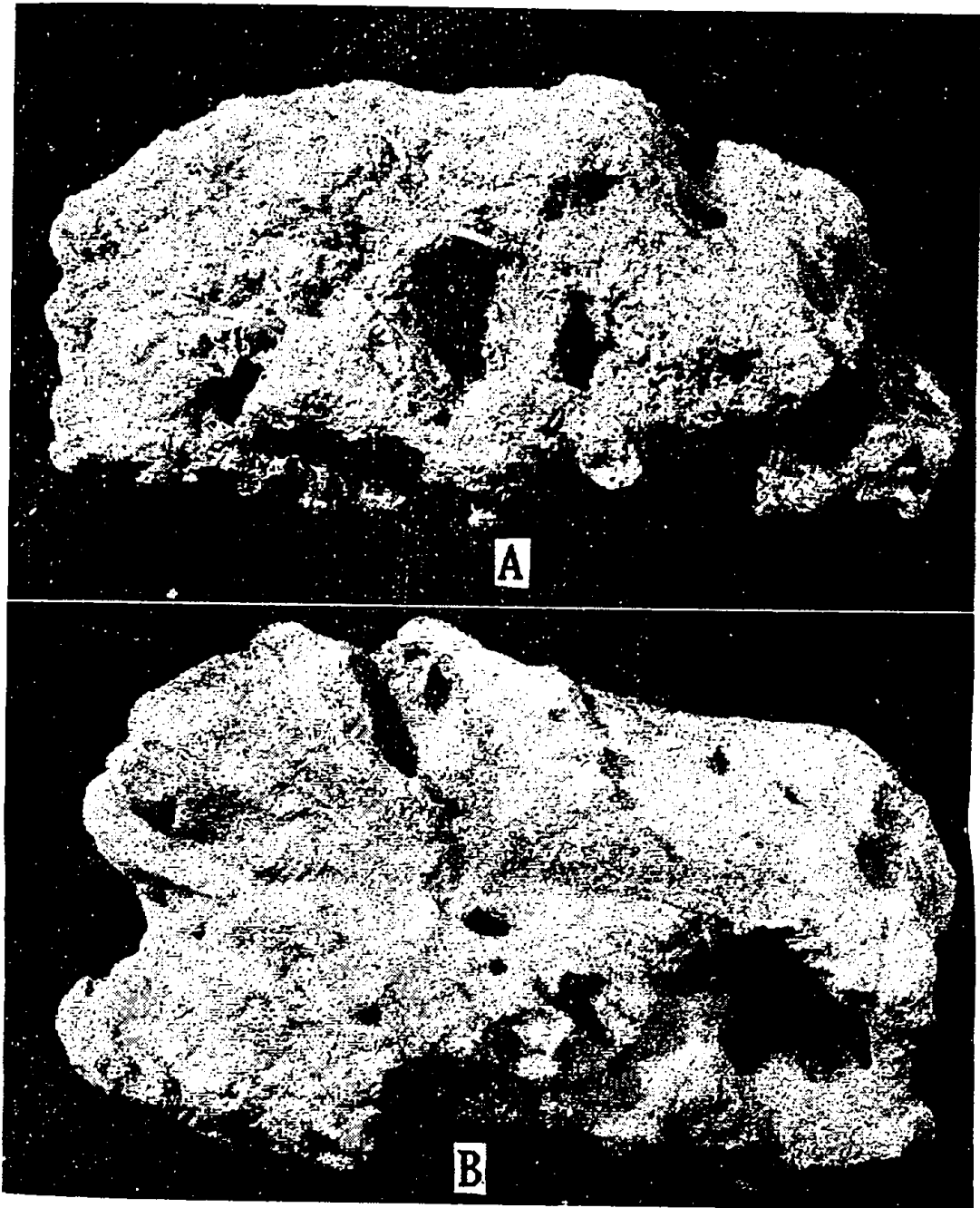


FIG. 2 A Beachrock from Station No. 42, showing large number of solution (?) cavities. Note annelid tubes at left and pelypod shell fragments on top respectively of large cavity at centre. Length of specimen 15 cm.

FIG 2 B. Finer grained and more compact specimen than A Station No. 42. Length of specimen 10 cm.