

SUBMERGED INTERTIDAL CALCAREOUS SANDSTONE¹ IN THE GULF OF KUTCH

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ABSTRACT

An area of about 950 sq km of the rocky bottom was demarcated near the southern side of the mouth of Gulf of Kutch. The mineralogical and petrographical studies indicate that the rocks are calcareous sandstone which are medium to fine grained and have the micritic matrix and framework of quartz and feldspars with rock fragments. The petrology of the rocks, study of foraminifera and the nature of insoluble residue suggest that these were formed in an intertidal region of deposition during the period of lowered sea level.

INTRODUCTION

In January 1975 bottom samples from the Gulf of Kutch region (Okha) were collected approximately between 22° 15' : 22° 40' and 68° 40' : 69° 30' by operating a La Fond Dietz snapper at 157 stations. Only from 52 stations, mostly outside the Gulf's entrance, sediment samples could be obtained. Inside the Gulf generally the sampler could not collect any sediment except some coral/rock pieces at a few stations. The corals were collected from 18 stations and rocks from 11 stations (Fig. 1).

The tidal variation and the tidal current of the Gulf of Kutch are very large and reach upto 4 m and 5 knots respectively (West Coast of India Pilot, 1961).

In the adjoining land area, *i. e.*, the north western side of the Saurashtra peninsula the coastal Teritaries ranging

from Oligocene to Pliocene age known as Dwaraka beds and the Pleistocene deposits are exposed (Wadia, 1975).

The present paper deals with the distribution of the rocks in the region.

EXTENT OF THE ROCKY BOTTOM

A map showing the rocky area was prepared by plotting the data obtained from all the stations. Bottom notations of the hydrographic chart L (D7) 203 on a base map of 1:150,000 with different symbols have also included in the map (Fig. 1). The stations with no recovery have been inferred as hard bottom and these have been shown by different symbols. Towards the west off Okha two elongated rocky patches running north-south get clearly marked. Of the two the eastern patch at about 22°35' : 65°00' turning eastward and follows approximately the axis of the Gulf upto the longitude 69°30'.

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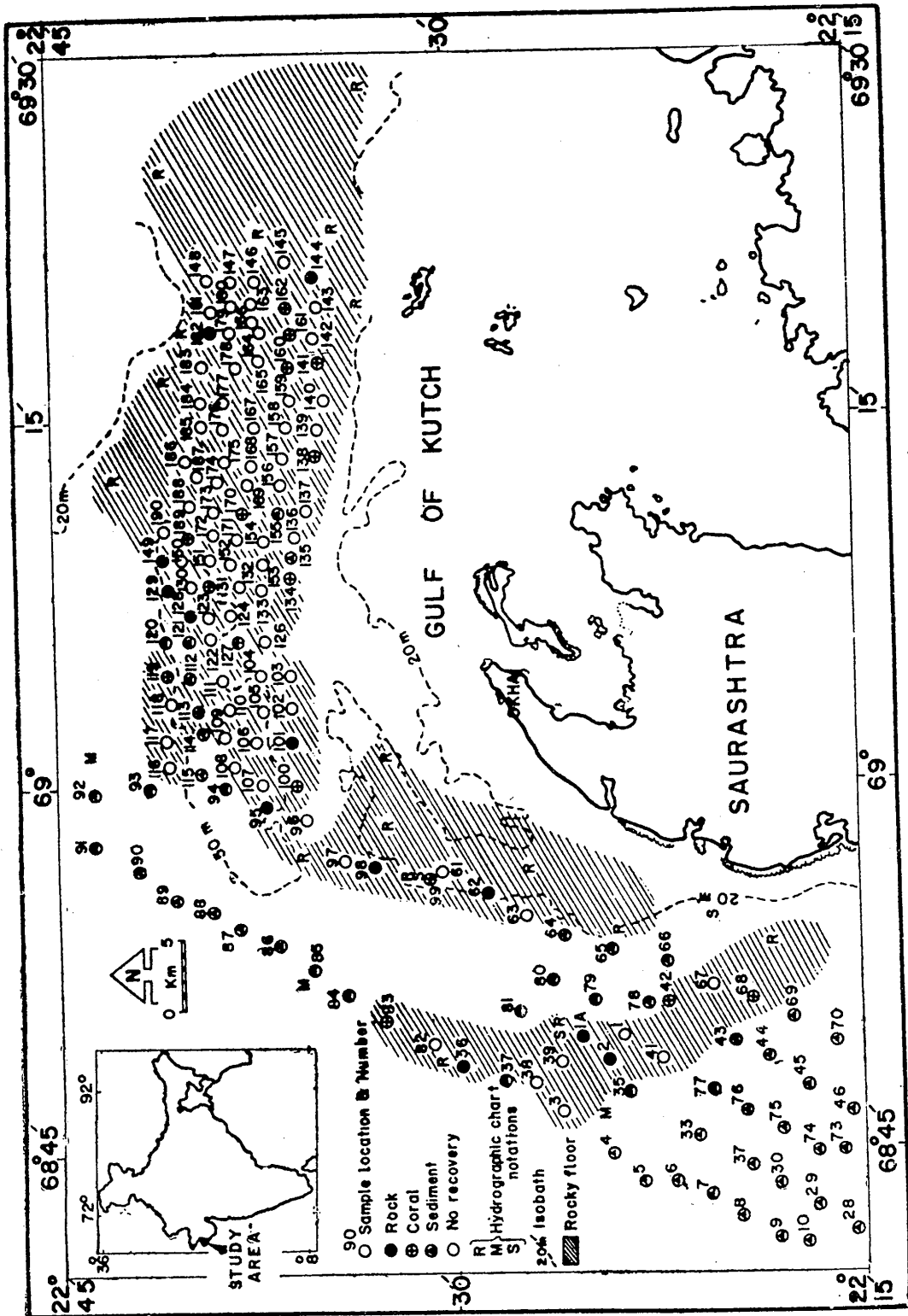


Fig. 1. Sample location and extent of the rocky bottom.

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LABORATORY METHODS

The recovery of the rocks was so poor that only six samples could be taken up for the mineralogical and petrographical studies and four samples for foraminiferal studies. These studies were divided into the following three main aspects:

- (i) Megascopic and thin sections studies,
- (ii) Study of the insoluble residue,
- (iii) Foraminiferal study.

Megascopic examinations include the colour of the rock samples, study of the polished sections, stain tests etc. The polished sections were etched with dilute hydrochloric acid and stained with Feigl's solution and Alizarine Red S (Friedman *In* Carver, 1971) to differentiate between Aragonite and Calcite. For the study of the insoluble residue the samples were treated with 10% hydrochloric acid and washed over 62 micron sieve for obtaining the sand fraction which was further sieved on a half phi interval scale. Only three samples 1A, 101 and 144 could be subjected to this type of analyses. Each fraction or the entire sample was examined under the stereo binocular microscope for counting the different constituents, *i. e.*, quartz, mica, feldspar, rock fragment and others. The roundness of the quartz grains was estimated visually following the method of Shepard and Young (1961). The quartz grains were classified under two types (i) fresh looking transparent quartz and (ii) frosted quartz.

The other part of the samples were disintegrated and washed according to the method given by Pokorny (1962) for the study of foraminifera. Ten grams

of the washed and dried material was examined and from each sample all the foraminifers were identified and counted. To assess the probable paleoenvironment of the deposit, the techniques discussed by Murray (1973) were applied. These are: (i) Fisher α index (ii) triangular plot of suborders Rotaliina, Miliolina and Textulariina (RMT Ratio).

The Fisher α index was obtained by plotting the number of total specimens against the number of the species on the base graph given by Murray (1973).

RESULTS AND DISCUSSIONS

Megascopic character: In hand all the samples looked similar and were hard and compact, except sample 101. The colour varies from olive grey (5Y 6/2) to dusky brown (5YR 2/2) and the texture from medium to fine grained. Encrustations of corals, lamellibranchs, ostracoda, worm tube, bryozoans were common. The surface of the sample showed burrowing cavities with shells of burrowing lamellibranchs. The stain tests revealed that the sample 1A contains a few traces of aragonite in the matrix. In the sample 144 few patches of magnesium rich calcite in the groundmass were present along with thin veins of aragonite criss crossing the sample. The matrix of sample 2 and 128 was magnesium rich.

Thin section study: In thin sections, the rocks were medium to fine grained and mainly composed of quartz and feldspars along with a few grains of muscovite, clinopyroxene, hornblende opaques, rock fragment and biogenic material set in a matrix of cryptocrystalline calcite.

Quartz was the most abundant mineral; angular to sub-angular with the inclusions of sillimanite, rutile etc. (samples 128 and 144). The grains were polycrystalline with a few monocrystalline with a size range from 0.1 to 0.3 mm. Most of the grains showed straight extinction but some showed undulatory extinction also. In some samples (144), a large number of grains were fractured and filled with brownish ferruginous material. Some of the quartz crystals were replaced by the groundmass material (micrite). Next in abundance to quartz was feldspar which includes both plagioclase and alkali feldspars. Some of the grains of feldspars showed the effect of corrosion, fracture and replacement by groundmass (1A and 144) with a size range from 0.1 to 0.3 mm. Other secondary minerals were muscovite, hornblende and augite. Rock fragments were mostly quartzite and phyllite which were sub-rounded.

The limited range of grain size (0.1 to 0.3 mm) of feldspar and quartz and their angularity in the thin sections suggest that they were not carried far from the source.

Study of the insoluble residue: The study of the insoluble residue was undertaken on the rock samples with emphasis on the nature of quartz grains. Quartz provides one of the most useful criteria for delineating the environmental conditions of the sediments and the sedimentary rocks. In the samples under study the insoluble residue ranged from 22 to 52% (Table I).

Table I. Weight percentage of different constituents.

Sample No.	Depth m	Carbonate %	Insoluble Residue	
			Sand Fraction %	Silt & Clay Fraction %
1A	51	57.1	35.8	7.1
2	55	76.3	5.1	17.6
101	40	74.4	11.8	13.8
128	70	76.7	3.2	20.1
144	62	46.3	37.2	15.5
148	30	74.4	6.4	19.2

The mineralogical composition of the insoluble residue in the sand fraction (2000 to 62 μ) has been shown in Fig. 2.

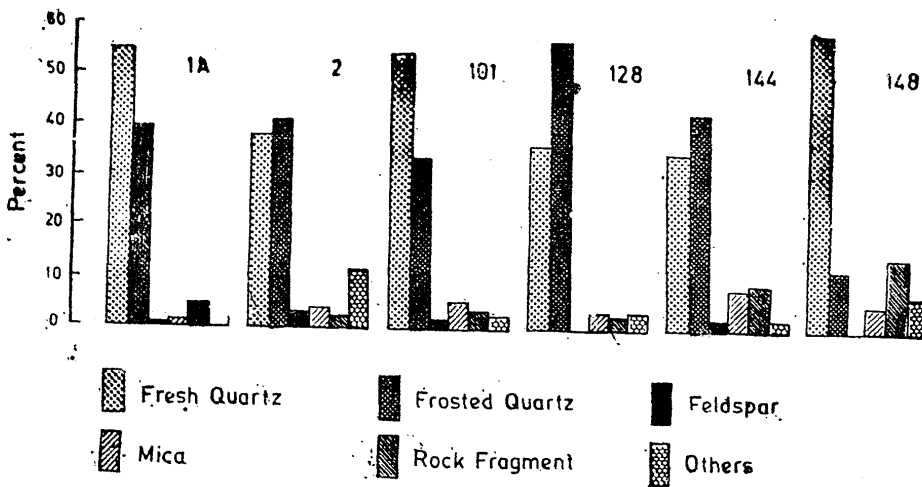


Fig. 2. Mineralogical composition of the insoluble residue.

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The dominating constituent was quartz which showed two forms (i) clear and (ii) frosted quartz. The clear quartz had its usual vitreous lustre and conchoidal fracture. The clear quartz was angular while the frosted quartz was dull in lustre, either smooth or pitted surface and was sub-angular to rounded. The pitting on the frosted grains was common only in the samples 1A, 2 and 101 collected near the mouth of the Gulf or outside, while in the samples 128, 144 and 148 obtained from inside the Gulf the pitting was either less or absent. The clear quartz was more abundant in the samples 1A, 101 and 148 than that of frosted quartz and former ranged from 54 to 59% while the latter was between 12 to 39%. In the other samples (2, 128 and 144), the frosted grains dominated (41 to 57%) over the clear grains (35 to 38%). This surface texture of the quartz grains such as the dull, opaque and pitted surfaces indicate that the grains are partially eolian origin (Kuenen and Perdok, 1962).

The percentage of feldspar varied from zero (128 and 148) to 3% (2) and mica ranged from 0.5 (1A) to 8% (144). The percentage of the rock fragments

ranged between 3 (101) to 15% (148). Generally the rock fragments were metamorphic (Quartzite and Phyllite). The minerals not included in above list were grouped as others and ranged between 0.25 (1A) to 11% (2).

Roundness was estimated on the entire sample as well as on different size fractions. The very angular grains dominated the samples 1A and 2 while angular to sub-angular grains were in the samples 101, 144 and 148. The highest percentage (16%) of the sub-rounded grains was found in the sample 128 while rounded grains were 5% (2 and 128). Very well rounded grains were generally absent and if they were at all present the percentage was 0.2 to 2% (Fig. 3). The percentages of very angular and angular increased towards the finer sizes (Fig. 4).

Table II. Size parameters.

Sample No.	Mode Md	Mean Size Mz	Standard Deviation σ_1	Skewness Sk _r	Kurtosis K _G
1A	2.25	2.18	0.72	0.38	1.30
101	2.95	2.83	1.04	-0.32	1.56
114	2.72	2.76	0.32	0.61	0.78

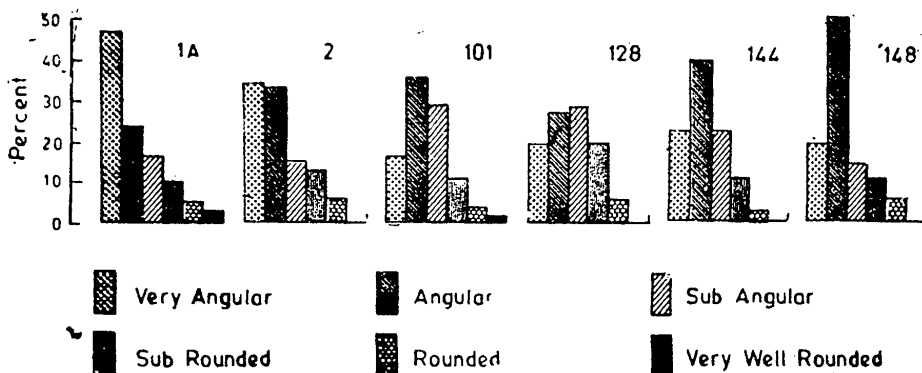


Fig. 3. Roundness of quartz in entire sample.

Size analyses were carried out on three samples in which the quantity of insoluble residue was found to be sufficient. The size parameters thus calculated have been shown in Table II. For the determination of environment, the CM pattern (Passega, 1957) was plotted and thus suggests a beach deposit. The truncation points in saltation, suspension and surface creep populations were compared with Visser's proposed environment (1969) and it was concluded that the samples 101 and 144 were

deposited in a tidal channel environment whereas the sample 1A in the beach environment.

Foraminiferal study: A total of 45 benthonic foraminifera species belonging to 28 genera were identified from the guidelines given by Loeblich and Tappan (1964) in the four samples (1A, 101, 128 and 144). A check list of the foraminiferal genera together with the range of their percentage occurrence are given in Table III. The values of

Table III. Checklist of foraminiferal genera.

Genera	Percentage
Ammonia	16-30 _e
Poroepionides	9-22
Pararotalia	4-17
Quinqueloculina	8-16
Anomalinoidea	8-12
Elphidium	6-12
Calcarina	4-6
Pateoris	4-6
Scutularis	3-6
Cibicides	3-6
Spiroloculina	2-6
Parrina	3-5
Borelis	2-4
Triloculina	2-4
Miliolinella	2-4
Florilus	2-4
Brizalina	2-3
Textularia	1-2
Nonion	1-2
Amphistegina	1-2
Biloculinella	1-2
Bolivina	1-2
Gyroidinoides	1-2
Loxostomum	1-2
Operculina	1-2
Planorbulinella	1-2
Cancris	1
Neonorbina	1

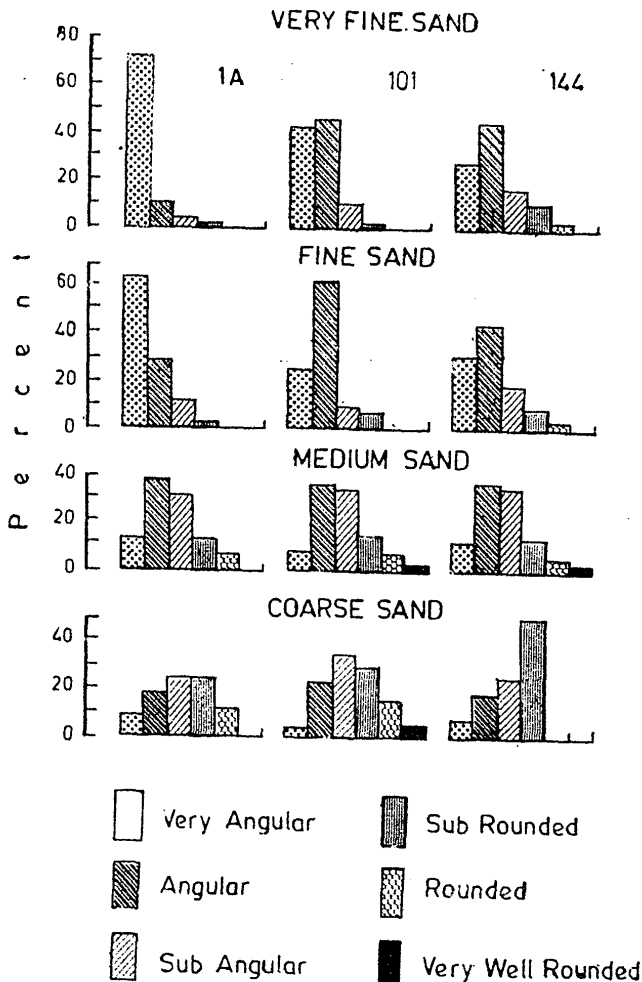


Fig. 4. Roundness of quartz in different sand-size fractions.

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Fisher α index and the percentage of Rotaliina, Miliolina and Textulariina have been compiled in the Table IV.

Table IV. Fisher α index and RMT ratios

Sample No.	Fisher α Index	RMT ratios		
		Rotaliina	Miliolina	Textulariina
1A	6	58	42	0
101	9	82	16	2
128	11	74	26	0
144	6	78	22	2

A striking feature of the foraminiferal fauna of these rocks was the absence of planktonic foraminifera. This indicates a relatively shallow water marine environment. Relative sparseness of Textulariina and the high abundance of Miliolina further indicate hypersaline condition. The fauna was dominated by *Anmonia*, *Pararotalia*, *Poroponides*, *Elphidium* (keeled) and *Quinqueloculina* which are normally found in the shallow inner shelf and the intertidal zones of the modern ocean. The very shallow environment is further indicated by the occurrence, albeit rare, of *Borelis*, *Amphistegina*, *Calcarina* and *Operculina*. A large number of specimens showed signs of abrasion which suggest that these have either undergone transportation prior to their deposition or they were deposited in a very high energy environment. A comparison of Fisher α index plot and the RMT triangular plot with the standard figures (Murray, 1973) reveal the following paleoenvironmental possibilities: (i) normal marine lagoon, (ii) hypersaline lagoon and (iii) nearshore shelf sea. However, the absence of typical lagoonal genera *Ammotium*,

Miliammina, *Eggerella*, *Peneroplis* and unkeeled *Elphidium* rules out the possibility of lagoonal environment. The composition of the foraminiferal assemblage, together with Fisher α index values and the RMT ratios, agrees well with the data for high energy coasts. Here the two possibilities are (i) beach environment and (ii) tide pool environment. The diversity values of the present samples ($\alpha = 6$ to 11) are rather high to suggest a beach environment and similarly the Miliolina percentage are also high to suggest a similar feature.

With these characteristics and evidences, it can be concluded that the rocks were deposited in an intertidal zone.

The present study has helped in demarcating the extent of rocky bottom of the Gulf of Kutch. At present with the limited number of rock samples and the absence of the other details from the Gulf the question of the lithification remains open. Whether the cementation had taken place in the submarine conditions or whether any tectonic activity had lowered these to the present position or whether the cementation had taken place during the period of lowered sea level, are the questions at present difficult to answer. However, the possibility of cementation does exist during the period of lowered sea level which is a well known fact on the western continental shelf of India (Nair, 1974, Nair *et al.* In press).

ACKNOWLEDGEMENT

The authors are grateful to Dr. S. Z. Qasim, Shri H. N. Siddiquie and Shri R. R. Nair for critically reading the manuscript and suggesting the improvements.

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