

## INFERENCE OF COASTAL SUBMERGENCE FROM THE STUDY OF BEACH ROCK OFF VISAKHAPATNAM

G. Victor Rajamanickam, K. Mohana Rao and  
T.C.S. Rao.

### Abstract

The beach rock samples obtained during the dredging operation in the littoral waters off Visakhapatnam for establishing the fishing harbour show characteristic beach deposits with high roundness factor and low magnesium calcite as the main cementation material. Their heavy mineral assemblage suggests the khondalite -- charnockite as the source rocks. They contain rare agglutinated foraminifera. In view of the existence of low-magnesium calcite as the cementing material in the surroundings of the static fresh water table just below the dunes, the beach rock formation has been ascribed to the inorganic precipitation induced by the fresh water table. The occurrence of such beach rocks in the littoral waters has been assigned to the probable coastal submergence during the Holocene transgression.

### Introduction

Beach rock, also known as beach sandstone or beach conglomerate is a friable to well cemented rock, made up of quartz sand, coral rubble, basalt boulders, bottle caps or something else, but bonded exclusively by calcium carbonate that too, of calcite and originated

along the water table. Russel, (1971). Friedman and Sanders, (1978) have described the beach rocks as those formed by the cementation of the sediments in the inter-tidal parts of beaches. A low insular bank, well cemented wave worked sand and shell debris mainly made up of oolites, foraminifera, etc., coined as 'Calcarenite' have also been grouped under beach rock.

Beach rocks have been considered as either the cause of the evaporation of the percolated marine water during the alternate drying period in the recurring tidal cycles (Dana, 1890); or wave action induced aerated warm sea water (Branner, 1904) with either at the fresh water table or rain water (Yonge, 1930; Gardinar, 1931) or biogenic processes through bacteria, algae etc. (Murray and Irvine, 1889; Drew, 1914; Tuyl, 1916; Lipman, 1924; Vaughan, 1924; Mawson, 1929) or the contact of fresh water table level having the constant temperature of 21°C for eight months in a year and inorganic precipitation (Russel, and McIntire, 1965; Russel, 1971).

These beach rocks have been commonly reported in a number of Pleistocene-Holocene sequences, spanning a climatic range from tropical/subtropical to arid and sublittoral humid regions of the world right from England in the North to New Zealand in the South. Along the Indian coasts, beach rocks have been noticed in the forms of miliolitic-oyster-beds, marine conglomerate and raised beach terraces. Along the East coast of India beach rocks/sandstones are well marked along Mandapam - Kilakarai - Tuticorin section (Foote; 1889). Occurrence of beach sandstones along Visakhapatnam coast is so far recorded by Blanford (1872) but the extension of such beach rocks is too light. The authors had an opportunity to obtain some beachrock samples from Visakhapatnam port authorities that were collected during dredging operations in the littoral waters for the construction of fishing harbour at Visakhapatnam (Fig. 1A).

## Methods of Study

About 50 gms of these beach rocks were treated in 1:10 HCl and allowed to remain in effervescence. Acid was added till there was no more effervescence and then the loose and disintegrated sediments were washed, dried and weighed. These were sieved at half phi interval and the respective weight percentages were used to calculate the size parameters following Folk (1974). The composition of the cementing material was examined by directly staining with alizarin red-S on a well polished and HCl etched rock surface and by X-ray diffraction technique by utilising the rock powders (Katz and Friedman, 1965). Thin sections were prepared to study the proportions of shell remains and mineralogy of the cementing material. The grain mounts were separately prepared for both light and heavy minerals to study the shape, angularity and their assemblage.

## Results and Discussion

These rocks are light coloured and are so well cemented in such a way to use dynamites to break them. Big blocks exhibit the typical cracks and channels developed through elongate joints, solution basins and pot holes which are considered to be of the characteristics of the beach rock (Emery and Cox, 1956). They contain 72% of quartz primarily of poly-crystalline and wavy extinction type. They are dominantly sub-rounded while few grains are highly angular and well rounded (Table IA). Among the heavy minerals, hypersthene, mica, hornblende, epidote, garnet and zircon are found in the order of prevalence. They are mainly angular to subangular in shape. When the disintegrated grains are usually estimated after Krumbein and Sloss (1963), more than 50% of them display 0.7-0.9 sphericity while the roundness varies from 0.7-0.1 (Table IB). Standard deviation for the roundness values, obtained from the arithmetic probability sheet is found to be

0.21 which indicates very good roundness sorting factor.

Staining test shows the presence of low-magnesium calcite by displaying light red colour. X-ray diffraction also confirms the occurrence of low-magnesium calcite in the cementing material (Fig. 1B). The cementing material made up of calcite, under high magnification of the polarised microscope shows rims of fibrous crystals that radiate from the boundaries of sand grains in fan-like arrays with wavy extinction. In plane-polarised light, the rims are colourless to pale yellowish-brown. The contact boundary between inner margin of the rims and sand grains suggests a peripheral replacement due to their sharp and straight to irregular and corroded edges while their outer margins of the rims are found to be smooth, resembling closely to low-magnesium calcite, reported in Fraser river delta, British Columbia (Garrison, et.al., 1969).

The average values of grain size textural parameters of mean, standard deviation, skewness and kurtosis are  $2.21\phi$ ,  $0.62\phi$ ,  $-0.30$  and  $1.94$ , respectively. The mean grain size values indicate the presence of fine grained sand while the standard deviation values bring them to a class of moderate sorting. Negative skewness (value ranging from  $-0.25$  to  $-0.35$ ) supports the domination of beach characters. The relatively higher values of kurtosis suggest the paucity of fines in the sand and also, in turn, lead to an inference of high energy environment of deposition. The heavy mineral assemblage indicates to the nearby source rocks of acidic composition, made up of khondalite and charnockite in the hinterland. The occurrence of very good roundness factor (sorting) for the sands that are so closely placed to the source rocks having high relief confirms their stay for longer duration in the foreshore zone where to and fro wave motion is predominant. Subsequently, when these sands were brought to the zone of water table contact, they got themselves well cemented in the form of beach rocks.

The lack of shells and foraminifera but for a few agglutinated benthic fauna supports the prevalence of terrigenous conditions and supply during their deposition. Though they are found presently in the littoral waters, they do not show either any evidence for the later introduction of shells, etc. or any diagenetic transformation of calcite by way of partial recrystallisation or the replacement character of having the left out aragonite etc. It indicates that these rocks should have been well cemented so as to avoid any further percolation and precipitation even before reaching the littoral water conditions.

The occurrence of beach rocks are very good indicators of the previous sea level stand, as they are formed within the tidal range or spray zone. The beach rocks seen in the raised terraces and the littoral waters indicate the vertical movement of the sea level. These beach rocks are also considered as the previous still water stand of sea level like that of 6 m stand known in Bahaman coast (Broecker and Thurber, 1965; Veeh, 1966) and 9 m stand evidenced from north boundary beach (Russel, 1971). Setty and Wagie (1972) have attributed the occurrence of beach rock in high elevation to the coastal uplift or eustatic movements of the sea level. From the beach rock (calcarenite) collected at 50 fathom flat off Bombay, Nair (1970) adjudged the region to the earlier Pleistocene sea level stand caused by the eustatic and/or tectonic cause. In similar lines, the beach rocks in the study area too, indicate the sealevel variations by way of submergence introduced during the Holocene times. The study of grain size along the Orissa coast indicated the existence of the earlier beach ridges in the littoral waters, and the same has been attributed to the Holocene marine transgression (Mohana Rao et. al., 1989). The identification of low-magnesium calcite as the only cementing material in these rocks may be attributed to the earlier formation during the Pleistocene times as indicated by Stehli and Hower (1961), Friedman

(1964) and Bathurst (1975) who have found a characteristic change from Recent to Pleistocene which consists of only low-magnesium calcite, formed by the fresh water influence in the tidal and sub-tidal zones.

The occurrence of low-magnesium calcite as the cementing material in the present case clearly aids the inference of the influence of fresh water and the calcite present in the inland sands as the aragonite and high magnesium calcite are found in the typical forms of  $\text{CaCO}_3$  under marine influence. Setty and Wagle (1974) have also supported the inorganic cementation along the zone of water table migration instead of bacterial, algal or other organic activities.

During the seaward migration and upward squeezing, water might have saturated  $\text{CaCO}_3$  by dissolving the shells and calcite sands and precipitated the  $\text{CaCO}_3$  at the sea water contact. These possibilities are supplemented by the presence of semi-artesian conditions developing hydraulic gradient in this area and prevalence of fresh water bearing sand dunes all along the coast and lack of shell remains in the rock. The water table passes below the sand dunes and intercepts in the sea as shown in Fig. 1. Sarma (1965) and Prasad (1980) have reported a relatively high percentage of bicarbonate and low magnesium in these waters and also added that the effective warding off of the sea water intrusion in the beach due to heavy rain fall and lack of permeability in the weathered disintegrated rock is taking place. Marine water surge into the water table is very much inhibited due to the high relief and heavy inflow of fresh water leading to the still water zones (Fig. 1C). So, this study also indicates a close similarity in the mode of origin of these beach rocks to the once proposed by Russel and McIntire (1965), Garrison et. al., (1969) and Russel (1971).

The beach rocks are commonly seen overlain

by unconsolidated sands/beach materials. Russel (1971) has asserted that the formation of beach rocks needs an overburden of about 76 cm where the required temperature of about 21°C for the precipitation of carbonates is expected to be found. In the present case, these rocks are noticed in the seabed well exposed without any unconsolidated sediment cover which would have been associated with the formation of these beach rocks. It is possible that these beach rocks would have been submerged along with the overburden and subsequently the unconsolidated sediments' cap might have been removed by the strong bottom currents (2.5 knots/hr) prevailing at this place and got deposited elsewhere.

### ACKNOWLEDGEMENTS

The authors wish to express their gratitude to Director, National Institute of Oceanography, Dona-Paula, Goa, for having given the permission to publish this paper; Shri. N.H.Hashimi, Scientist, NIO, for providing X-ray data; to our colleagues Shri S.Kannan for having provided the figures and map; Mrs. A.Syamala for typing assistance and to the authorities of Visakhapatnam Port Trust for supplying the samples.

### REFERENCES

- Bathurst, R.G.C., (1975) Carbonate sediments and their diagenesis. Elsevier Scientific Publishing Co., Amsterdam.
- Blanford, W.J., (1872) Geology of Orissa, V. 2 pp. 61.
- Brauner, J.C., (1904) The Stone Reef of Brazil, Their Geological and Geographical relation with a chapter on the Coral Reefs. Bull. Mus. Com. Zool, Harvard, Coll, 44.

- Broecker, W.S. and Thurber, D.L., (1965) Uranium series dating of Corals and Colites from Bahaman and Florida Key Limestones, *Science*, V. 149, pp. 58-60.
- Dana, J.D., (1890) Coral Island, 3rd Edi. (Dodd Mead & Cgi) New York, p. 440.
- Drew, G.H., (1914) On the precipitation of calcium in the sea by Marine Bacteria and on the action of denitrifying bacteria in tropical and temperate seas, pap. Totuga Lab Carnegie Inst., Wash Publ., p. 182.
- Emery, K.O. and Cox, D.C., (1956) Beach rock in the Jawaliah Islands, *Pacific Science*, V. 10, pp. 383.
- Folk, R.L., (1974) Petrology of Sedimentary Rocks, Hemphill, Texas.
- Friedman, G.M., (1964) Early diagenesis and lithification in carbonate sediments, *Jour. Sedi. Petr.* V. 34, pp. 777-813.
- Foote, R.G., (1989) The Coral Reef of Rameshwaram Island, Extract, *Scotts Geogr. Mag.*, V.6, pp. 257.
- Gardiner, J.S., (1931) Studies on Coral Reefs and Atolls, McMillan & Co., New York, p. 181.
- Garrison, R.R., Luternauer, J.L. Grill, E.V., Mcdonald, R.D. and Murray, J.W., (1969) Early diagenetic cementation of recent sands, Fraser, river delta, British Columbia, *Sedimentology*, v. 12, pp. 27-46.
- Illing, L.V., (1954) Bahamian Calcareous sands, *Bull. Assoc. Petr. Geol.* V. 38, pp. 1-95.
- Katz, A. & Friedman, G.M., (1965) The preparation of stained acetate peels for the study of carbonate rocks., *Jour. Sed. Petr.*, V. 35, pp. 248-249.



- Krumbein, W.C. and Sloss, L.L., (1963) *Stratigraphy and Sedimentation*, 2nd Edi. Freeman, San Francisco.
- Lipman, C.B., (1924) A critical and Experimental Study of Drew's bacterial hypothesis on  $\text{CaCO}_3$  precipitation in the sea. *Pap. Dep. Mar. Sci. Carnegie, Inst. Wash. Publ. V. 240*, pp. 179.
- Mawson, D., (1929) Some South Australian Algal Limestones in process of formation, *Quart. Jour. Geol. Soc., London*, 85.
- Murray, J. and Irvine, R., (1989) On Coral reefs and other carbonate lime formations in modern seas, *proc. Royal Soc. Edinburgh.*, V. 17, pp. 79-109.
- Mohana Rao, K. Rajamanickam, G.V. and Rao, T.C.S., (1989) Holocene transgression as interpreted from bathymetry and sand grain size parameters off Gopalapur, *Proc. Indian Acad. Sci.*, V.90, pp. 173-181.
- Nair, R.R., (1970) Beach rock and associated carbonate sediments of the fifty fathom flat, a submarine terrace on the outer continental shelf off Bombay, *Proc. Indian Acad. Sci.*, V. 72, pp. 148-154.
- Pettijohn, F.J., (1949) *Sedimentary rocks*, 1st Edi. (Harper Bros., New York).
- Powers, M.C., (1953) A new roundness scale for sedimentary particles, *Jour. Sedi. Petr.*, V. 23, pp. 117-119.
- Prasad, N.V.B.S.S., (1980) Geohydrological and Geophysical investigations along Visakhapatnam-Bhimuniapatnam Coast, Ph.D., Thesis, Andhra University, Waltair.
- Russel, R.J., and McIntire, W.G., (1965) Southern Hemisphere beach rock, *Tech. Rep. No. 15, Part G. Geogl. Rev.*, V. 55, pp. 17-45.

- Russel, R.J., (1971) Water Table effects on Sea coasts, *Geol. Soc. Amer. Bull.*, V. 82, pp. 2343-2348.
- Russel, R.D. and Taylor, R.E., (1937) Roundness and shape of Mississippi river sands, *Jour. Geol.*, V. 45, pp. 225-267.
- Sarmay, V.V.J., (1965) Preliminary investigations on the occurrence of fresh water in wells along Visakhapatnam Beach, Andhra Pradesh, India, *Jour. Indi. Geophys. Union*, V. 2, pp. 197.
- Setty, M.G.A.P. and Wagie, B.C., (1972) Beach rock from Goa Coast, *Proc. Indi. Natl. Sci. Acad.*, V. 38, 1 & 2, pp. 9-20.
- Stehli, F.G., and Hower, J., (1961) Mineralogy and early diagenesis of carbonate sediments, *Jour. Sed. Petr.* V.31, pp. 358-371.
- Taylor, J.C.M. and Illing, LV., (1969) Holocene intertidal calcium carbonate cementation, Qatar, Persian Gulf, *Sedimentology*, V. 12, pp. 69-107.
- Van Tuyl, F.M., (1916) A contribution to the Oolite problem, *Jour. Geol.*, V. 24, pp. 792-797.
- Vaughan, T.W., (1924) Present status of studies on the cause of the precipitation of finely divided calcium carbonate, *Natl. Res. Dept., Commo Sidim.*, pp. 53-58.
- Veeh, H.H., (1966)  $T^{230}/U^{238}$  and  $U^{234}/U^{238}$  ages of Pleistocene high sea level stands, *Jour. Geophys. Research*, V. 70, pp. 1834-1848.
- Yonge, C.M., (1930) A year on the great Barrier Reef, Putnam, London.

TABLE - 1A

Degree of Roundness in the Detrital Grains of the Investigated Beach Rock

Class	Average Roundness factor percentages after		
	Russel & Taylor <sup>36</sup>	Pettijohn <sup>34</sup>	Powers <sup>35</sup>
Very Angular	--	--	03.50
Angular	00.61	05.40	08.00
Sub-Angular	25.00	21.59	22.00
Sub-Rounded	65.74	59.90	56.20
Rounded	06.17	08.60	07.80
Well Rounded	02.47	04.50	02.49

TABLE - I B

Chart of Average Percentages for Roundness and  
Sphericity Calculated from the Visual Estimation  
of the Detrital Grains in the Beach Rock  
(after Krumbein and Sloss<sup>20</sup>)

Sphericity class	Roundness				Class
	0.1	0.3	0.5	0.7	0.9
0.9	--	07.90	10.70	12.09	--
0.7	10.70	12.09	13.49	12.09	00.46
0.5	03.26	06.51	06.51	00.93	--
0.3	00.46	00.46	01.86	00.46	--

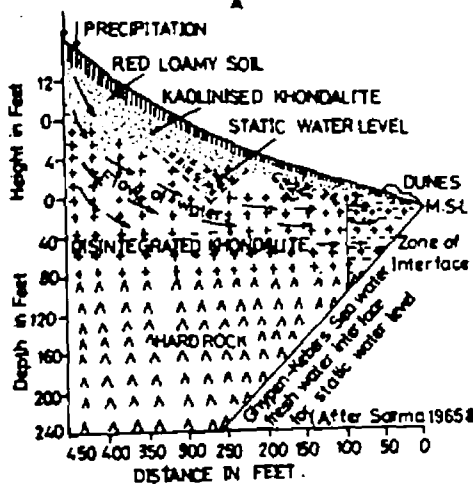
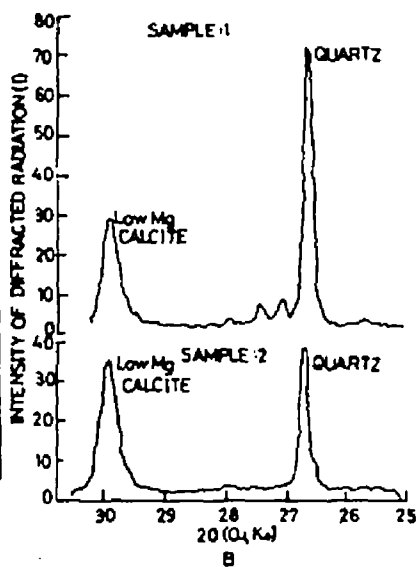
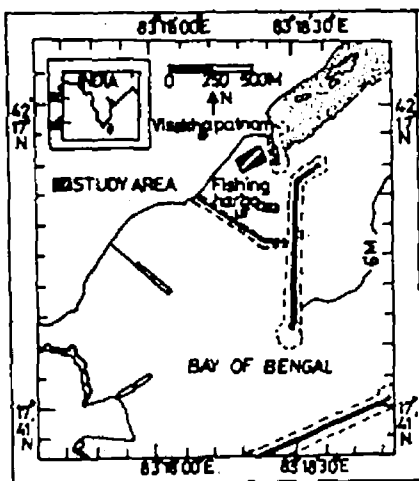


FIG. 1  
 A LOCATION OF THE STUDY AREA.  
 B TRACE OF DIFFRACTOGRAMS OF THE BEACH ROCK  
 C STATUS OF WATERTABLE IN THE STUDY AREA