

Relic carbonate deposits along the western margin of India: sea level and environmental changes during the Late Quaternary

V. Purnachandra Rao

National Institute of Oceanography, Dona Paula, Goa-403 004

vprao@nio.org

It is well known that during the Last Glacial Maximum (18,000 ¹⁴C yrs BP) the Glacio-eustatic sea level was at about 120-130 m below the present position (Fairbanks, 1989). Thereafter the sea level started rising largely due to the melting of glacial ice. The sea level rise occurred at different steps and reached its present position at about 6000 years BP. The sea level rise is not uniform, and the rate of sea level rise at times varied from 23 m/ka to 1 m/ka. The maximum rise was observed during the melt-water pulse (MWP) 1A and 1B respectively at 12,000-11,000 years and 10,000-9,000 ¹⁴C years BP. The impact of sea level rise is many-fold. Some continental margins could not keep pace with the rapid rise of sea level rise and as a consequence sediment material was lost from the marginal areas. Abundant carbonate buildups were developed on some continental margins during times of slow or moderate sea level rise and these buildups now occur as relic carbonate sandy sediments on the outer continental shelves of the World Oceans. They are largely of shallow water origin formed during late Pleistocene and early Holocene low stands of sea level. Some carbonate deposits such as *Porites* corals can precisely be used as proxy indicators of sea level. Other shallow water deposits if not useful as a proxy indicators for sea level may otherwise indicate environmental conditions at the time of their formation. Using age and depth of occurrence of the proxy indicator, one can able to decipher factors influencing local and regional variations in sea level during the late Quaternary. In this lecture detailed investigations made on the relic carbonate deposits along the western margin of India are presented.

Relic shallow water sediments are exposed on the outer continental shelf of the western margin of India, between the Gulf of Kachchh and Cape Comorin at depths between 18 m and 110 m. The relic sediments occur as dolomite crusts, aragonite sands (pelletal/oolitic sediments) and aragonite-cemented limestones, oyster shells, corals, coralline-algal and foraminiferal-dominated nodules. The petrology and mineralogy of the deposits indicate that except for aragonite sands and foraminiferal nodules, the others were formed in shallow marine conditions and serve as sea level indicators (Vander Plache., 1986). Radiocarbon dates were measured for 62 relic deposits covering the entire margin (Fig. 1). The age versus depth plot of the samples on the glacio-

eustatic sea level curve of Fairbanks (1989) indicates that many samples fall farther from the curve (Fig. 2). It appears that different segments of the continental margins responded differently for the sea level rise. It may be due to the combined influence of sea level and neo-tectonic changes. Area-wise interpretations are necessary to better understand the sea level changes.

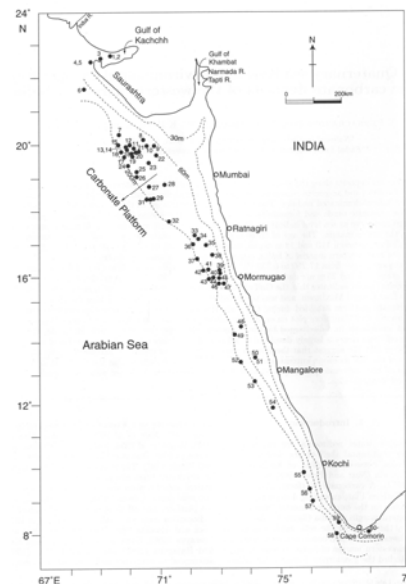


Fig. 1 Location of samples along the western margin of India

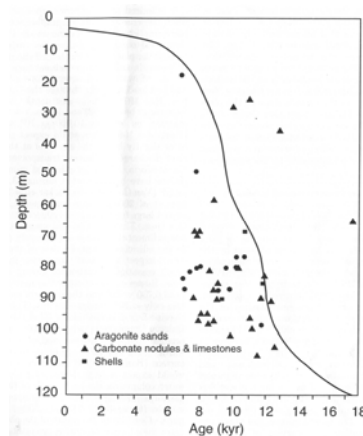


Fig. 2. A plot of radiocarbon ages and depth of the samples on a glacio-eustatic sea level curve of Fairbanks (1989)

Deposits of the Gulf of Kachchh

Dolomite crusts, corals belonging to the Favidae family (*Leptastrea transversa*) and micritic limestones were recovered from the Gulf. Petrographic studies indicate that the laminations in the dolomite crusts are caused by encrustation of microbial filaments at intertidal depths. Corals of Favidae family are characteristic of turbid water and occur at shallow depths <6 m. The ages of Favia corals (10.8 cal.kaBP) and dolomite crusts (12.5 ka) at 28 m and 25 m, respectively at the mouth of the Gulf do not correspond with that of glacio-eustatic sea level. Furthermore aragonite crusts dated at 13.7 ka occur in a core (at 100-105 cm interval) collected at 55 m depth on the shelf off the Gulf of Kachchh. These ages suggest that after the Last Glacial Maxima, the Gulf must have inundated much early, at least by 15 ka. This indicates the role of regional tectonic activity and subsidence and uplift of the Gulf at different times in the Holocene. Several evidences exist that the Kachchh region is seismically active at different times in the Holocene and in recent times including that of 2001 Bhuj earth quake.

Deposits on the Carbonate Platform

The carbonate platform measuring about 28000 sq km, extending 4 degrees of latitude lies between 60 m and 110 on the outer continental shelf of the northwestern margin of India. Despite the platform lies off major rivers such as Narmada and Tapi, it contains <10% terrigenous material. The relic deposits on the carbonate platform are largely carbonate sands. Thin section studies indicate that some of these sands are Crustacean faecal pellets while others are oolite-dominated. The age of the sands ranges between 14.3 ka to 7.6 cal kaBP. The limestones associated with the platform exhibit acicular aragonite cements and their ages lie between 11 ka and 13.3 kaBP. Large oyster shells (Fig. 3) dated 13.81 kaBP were also recovered at 85 m depth. The dolomite crusts at 64 m depth on the platform were dated at 20.3 kaBP. The samples dated 14.3 and 7.6 kaBP from the platform spread at depths between 105 m and 65 m. This suggests that carbonate sedimentation continued on the platform despite the glacio-eustatic sea level rise by about 80 m (between 14 and 7.6 kaBP), or the platform was subjected to intermittent neotectonic activity. It appears that platform may have been at a different elevation during LGM and subsequently subsided during the Holocene. The exact time/times and rate/rates of subsidence are unknown and it is difficult to quantify the phases of subsidence with the existing data. Evidences such as deeper water terraces, pristine dolomite crusts of 20.3 kaBP, vadose diagenetic limestones of Holocene age and age range of aragonite sands can not be explained by any other single mechanism without invoking neo-tectonic activity. It is amazing how carbonates developed when one considers the geographic setting (off major rivers), age of the sediments of the platform, and environmental conditions

(intense monsoon) during the early Holocene. The absence of terrigenous flux on the platform and continued carbonate growth until 7.6 kaBP implies that the riverine flux delivered either filled the innershelf or diverted towards south under the influence of southwest monsoon current.



Fig. 3. Pelecypod shells on the platform

Deposits off Vengurla-Mangalore

Carbonate nodules are abundant in this region. They are dominated by foraminiferal (*Gypsina*) encrustations with intermittent thin coralline algal laminations. *Mesophyllum*, *Lithothamnium*, *Archaeolithothamnium*, *Sporolithon*, *Lithoporella* and *Porolithon* are the different genera of the coralline algae. These associations represent moderate to deeper depths and low energy environments at the time of their formation. In certain nodules repeated successions of alternate laminations of foraminifers, coralline algae and corals can be seen. The age of the nodules ranges between 10 ka and 8 ka while that of Goa-Mangalore is slightly higher 12.9 ka. Although these nodules show lack of usefulness as sea level indicators, successional alternations of corallines, foraminifera and corals may have some climatic significance (Fig. 4).

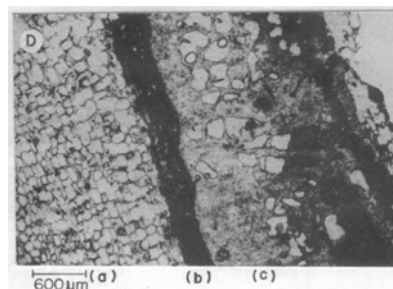


Fig. 4. Thin section of a nodule showing alternate laminations of foraminifera (a), coralline algae (b) and encrusted corals (c).

Climatic conditions in terms of monsoonal variations are well known for the growth period of nodules. It appears that seasonal variation in water transparency and nutrient flux controlled by monsoonal climatic conditions, can account for the successional characteristics of the nodules. During monsoonal season foraminiferal encrustations are favoured due to excessive turbidity. The growth of coralline algae is favoured as

microlaminations when waters were more transparent under non-monsoonal seasons. Therefore, the cyclic bands of foraminifers, coralline algae and corals forming in the nodules may indicate an improvement in environmental conditions in the water column from turbid and eutrophic to clearer and oligotrophic at the time of their formation.

Deposits off Mangalore –Cape Comorin

The ages of *Porites* corals off Mangalore at 105 and 110 m water depths range between 14.77 to 13.42 cal kaBP. *Porites* corals are used as proxy indicator for sea level. The age and depth of the corals plot on the glacio-eustatic sea level curve. Relic *Porites* reefs were reported at depths of around 90-100 m off the Camoro Islands and in the Red Sea. Thin sections of the spherical nodules (Fig. 5) indicate dense coralline algae belonging to *Lithothamnium* and *Lithophyllum* with thin veneers of encrusting foraminifera. Solution features, alteration of skeletal material and micritization of algal material are common in the nodules. These nodules can also be used as proxy indicators for sea level. The nodules at 90 m water depth are dated 13.5 kaBP. Foraminiferal sands at 49 m depth are dated at 8.4 kaBP. These plot very close to the sea level curve of Fairbanks (1989). Our results suggest that significant reef development occurred along the margin during 14.77 to 13.42 kaBP. Subsequently they have been affected by rapid changes in sea level that accompanied the main phase of deglaciation.

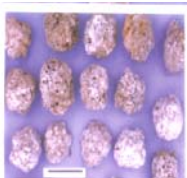


Fig. 5. Spherical algal nodules

Existing data is not sufficient enough to bring out precision of past sea level changes in different areas and a systematic work needs to be carried out in different segments of the western margin of India. Relic deposits on the eastern margin of India are buried under recent marine sediments and little work was carried out on past sea level changes. Moreover, the sediment load brought by the rivers acts as a load and several areas are affected by neo-tectonic activity. In other words, more complex processes are involved in understanding past sea level changes along the eastern margin of India.

Suggested reading

- Fairbanks, R. G., 1989. A 17,000 year glacio-eustatic sea level record: influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation. *Nature*, 342, 637-642.
- Rao, VP., Rajagopalan, G., Vora, KH., Almeida, F. 2003. Late Quaternary sea level and environmental changes from relic carbonate deposits of the western margin of India. *Proc. Indian Acad. Sciences*, 112, 1-25.
- Rao, VP., Montaggioni, L., Vora, KH., Almeida, F., Rajagopalan, G. 2003. Significance of relic carbonate deposits along the central and southwestern margin of India for late Quaternary environmental and sea level changes. *Sedimentary geology*, 159, 95-111.
- Vander Plache, O. 1986. *Sea level Research: A manual for the collection and evaluation of data*, Geobooks, Norwich.