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# Pattern and nature of sedimentation on the continental shelves of the Indian Craton during Quaternary

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Inner shelf of the Indian continental margin is covered with sands, silts and clays, while the outer shelf with oolites/ooids, and relict sands, partly characterized by stained quartz grains. Algal and coralline ridges developed in the outer shelf area, run almost parallel to the coasts. The radio-carbon dates for oolites/ooids and algal limestone vary between 7,500 and 12,500 yr B.P., indicating late Pleistocene/Holocene period when the sea level had lowered down to 100 m or more.

## Introduction

THE Quaternary period witnessed organic evolution, extreme change in the climate, including glaciation and deglaciation on lands and relative changes in the land-sea interface, the high sea level stands coinciding with warm epochs. The sedimentation in the continental shelves was controlled by alternating glacial and inter-

glacial stages, resulting in low and high sea levels, respectively. The pattern and nature of sedimentation on the continental shelves of India provide excellent records of palaeoenvironments including imprints of past monsoonal conditions and of formation of seabed resources such as titanium, thorium, phosphates, lime, building material, refractory minerals, etc.

The continental shelf is, it may be recalled, the shallow platform that surrounds most of the continents, sloping 0–1° and is terminated seaward by a relatively sharp break in slope at an average depth of 550 m called the shelf edge or shelf break<sup>1</sup>. The shelf area is about 13.6% of the Indian landmass<sup>2</sup>.

## Geomorphology of continental shelves

The width of the western continental shelf is about 300 km off Bombay and narrows down to about 60 km

near 10° N latitude<sup>3</sup>. Off Saurashtra coast the width of the shelf is about 120 km and the shelf break is at a depth between<sup>4</sup> 130 m and 152 m. There are 1 to 2 m high underwater pinnacles and 1 to 2 m deep troughs (locally 10 m deep) in water depths between 65 and 100 m off Bombay<sup>5</sup>, where the shelf break is at the depth of 95 m. The terraces at -65, -75, -85 and -95 m depths off Ratnagiri and less-defined ones at depths of -62, -74, -85 and -90 m off Goa have developed on 70-93 km wide continental shelf off Vengurla. Parallel ridges have also been observed in the outer shelf in this region, which is rugged and marked by the presence of 5 m high pinnacles. The width of the continental shelf off Calicut decreases from 75 to 55 km in the south. The scientists of the GSI have identified two terraces at depths of 85 m and 105 m off Calicut and 50-60 m and 110-120 m depth off Trivandrum (Figure 1), the shelf break being between 110 m and 140 m. In general the topography of the inner shelf (0-60 m) of the western continental shelf of India is smooth. The outer shelf beyond 60 m to the shelf edge is uneven to rugged.

The eastern continental shelf diminishes from 105 km off Sandheads to about 6 km off Godavari Delta, and then gradually increases southward, the shelf break occurring at 100 m depth off Santapalli, 280 m off Pentakota and 100 m off Godavari Delta. The extensive work done by GSI showed presence of dome-shaped features of 3 to 5 m relief in water depths of 59 to 90 m. Similar domal features (Figure 2) at 50 to 70 m water depths off Visakhapatnam have been recorded<sup>6</sup>. While off Chhatrapur (Orissa)-Ekasingi (Andhra Pradesh) there are three topographic high/terrace at the depths of 28-30 m, 40-46 m and 53-56 m. Off

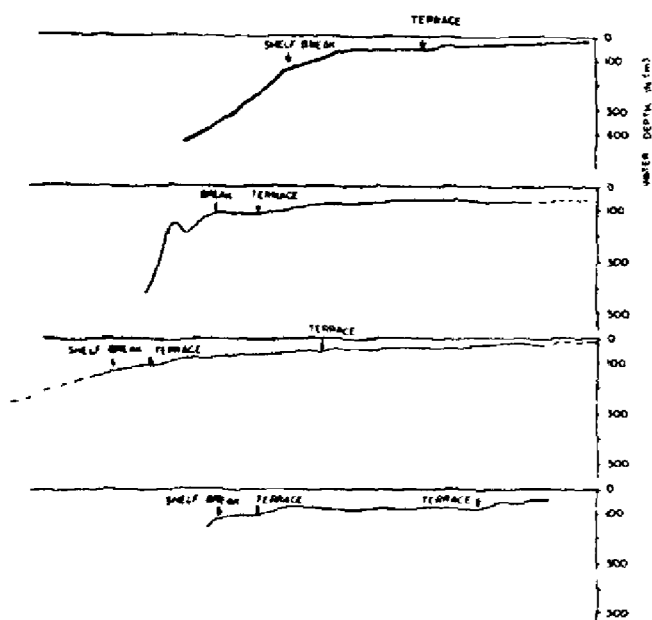


Figure 1. Bathymetric profiles off Trivandrum (after Dimri *et al.* of GSI 1985).

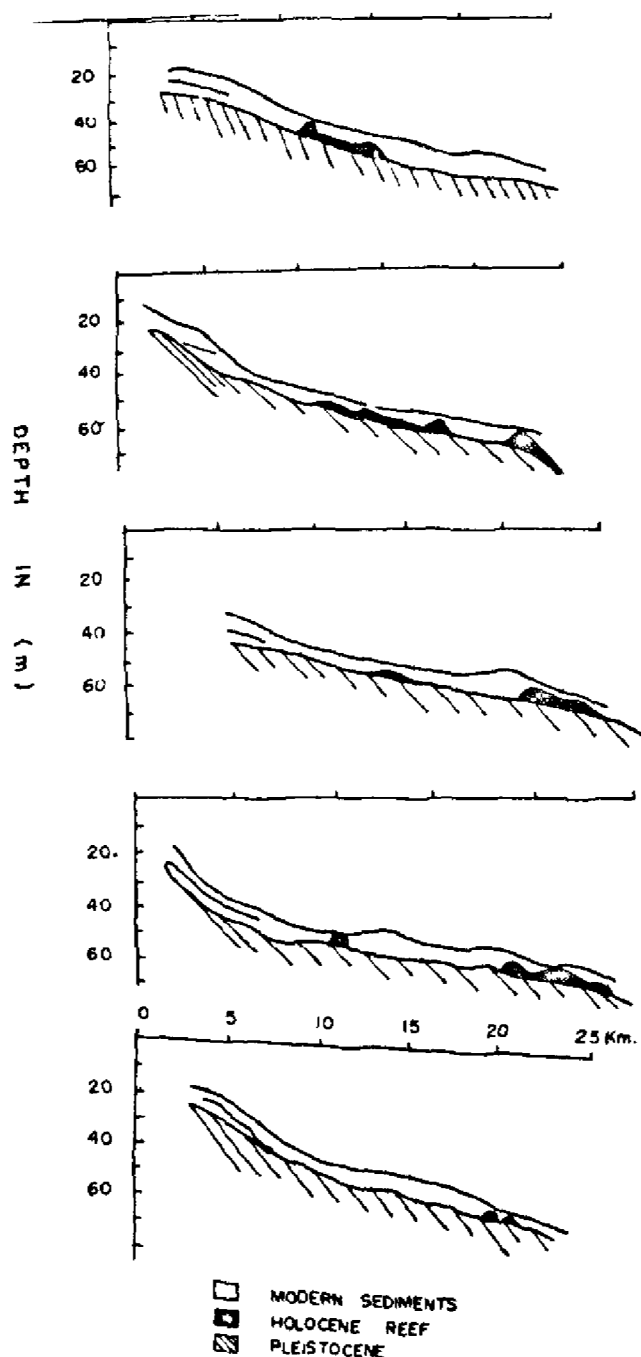


Figure 2. Uniboom/Sparker section over the shelf off Visakhapatnam (after Murthy *et al.* of GSI 1985).

Pondicherry to off Marakkanam, the 14 km wide shelf breaks at a depth of 78 m in the northern area. The width increases to 105 m southward. There are 4-6 m high pinnacles near the shelf break.

### Sea level changes

The sea level oscillated<sup>7</sup> between +200 m and -200 m in response to glaciations and deglaciations. In general, all over the world the sea level reached a maximum

stand at isotopic stage Se (last interglacial) and another high position in the Holocene about 5–6 ka B.P.<sup>8</sup>. Chatterjee<sup>9</sup> had earlier recognized terraces along the Indian coasts and correlated them with the classical Mediterranean Quaternary stratigraphy. On the basis of the presence of miliolites on top of a hill, the sea level had reached<sup>10</sup> up to 220 m. Patches of coarse sand beyond 10 m water depth off Gopalpur on the East Coast have been assigned an age of 7000 years B.P.<sup>11</sup>. The available radio-carbon dates of oolites, limestones, shells and wood found on the continental shelves of India are shown in Figure 3. The dates for oolites vary between 9,960 and 11,330 yr B.P. from different depths of water. The dates of limestones vary between 7,500 and 12,510 yr B.P. Shells have been dated at 3,410 and 9,135 yr B.P. The carbonized wood found at depths 4.20 m and 5.78 m below seabed in 25.0 m and 33.7 m deep water respectively has been dated at 9,630 and 8,620 yr<sup>12</sup>. A late Quaternary sea level curve (Figure 4) indicates that the sea level was around 138 m below the present sea level about 12,000 yr B.P.<sup>13</sup>. There must have been rapid rise of the sea level during early Holocene, while during the large part of the late Pleistocene period the sea level stood at lower levels.

### Sediment distribution

In the map showing distribution of bottom sediments of the seas bordering India<sup>19</sup> (Figure 5) the clays cover middle shelf all along the Western Coast from Gujarat to Kerala, except the southernmost part, and the outer shelf is covered with sands and clays over rocky floor in the middle and outer shelf region off Bombay. A narrow patch of sand and clay has been shown in the

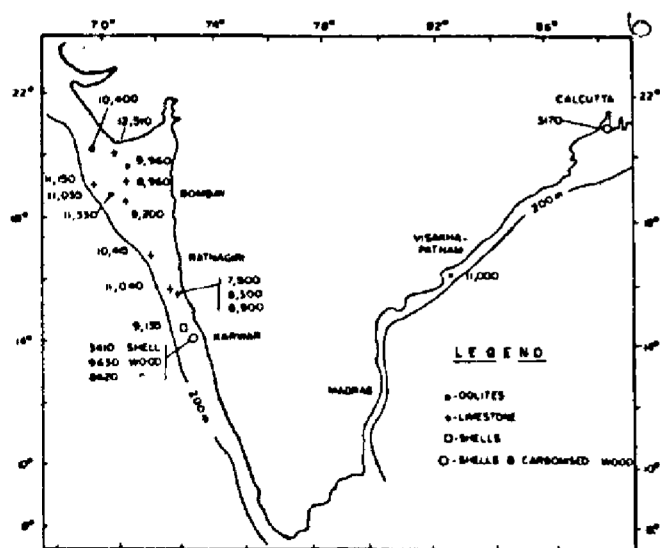


Figure 3. Radiocarbon dates (Siddique, *et al.*, 1975, Hashmi and Nair, 1985, Borole, *et al.*, 1987, Banerjee and Sen, 1988, Nambiar *et al.*, 1991).

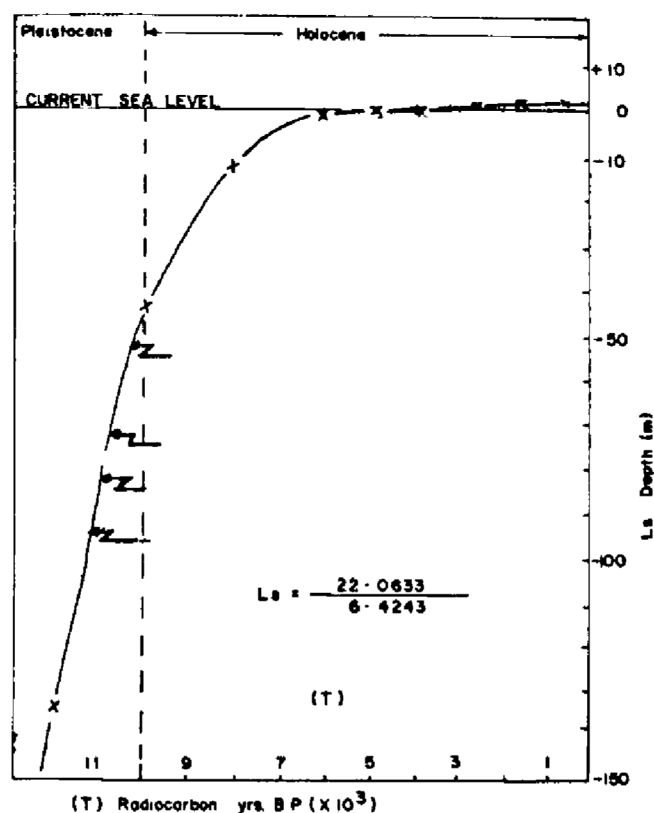


Figure 4. Late Quaternary sea level curve (Kale and Rajaguru 1985).

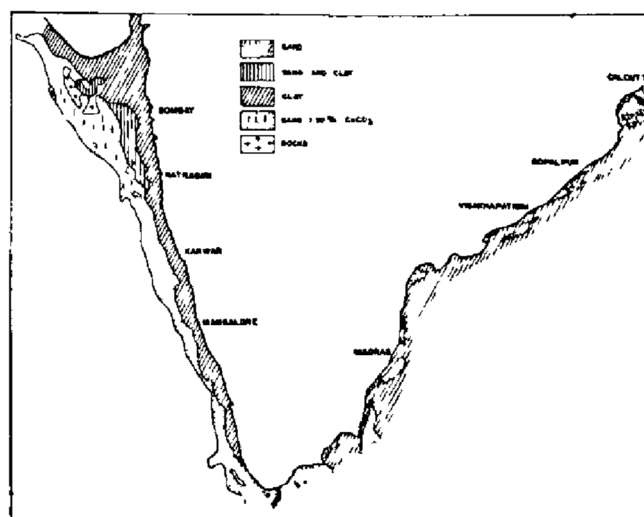


Figure 5. Sediment distribution on the continental shelf of India.

inner shelf-middle shelf region between Bombay and Ratnagiri. The thickness of clays varies from 10 to 23 m, gradually thinning out and terminating seaward around 35 km from the shore. This incidentally marks boundary of the recent sediments in the area. The outer shelf sediments contain abundant calcium carbonate due to the presence of oolites, and skeletal debris of molluscs, coralline algae, bryozoa and foraminifera<sup>4</sup> off Bombay. Off Ratnagiri four lithofacies, viz. mud aggre-

gate, pellets with mud aggregate, pellets and oolites are recognizable<sup>15</sup>, while the nearshore areas are covered with a thin band of sand, the outer shelf sands in the southern sector being quartzose whereas northern sands being rich in carbonates. Off Kerala coast fine-to-medium sands are rich in heavy minerals like ilmenite, rutile, zircon and monazite<sup>16</sup>, in water depths of 15 to 40 m. Along the Konkan coast heavy mineral sands are rich in ilmenites between the seabed in the bays to a water depth<sup>17</sup> of 9–12 m. The eastern continental shelf is covered mainly with clays. There are small patches of sands in the inner shelf and outer regions (Figure 5). An oolitic sand zone in the outershell off Visakhapatnam occurs at depths of about<sup>18</sup> 100–145 m. Calcareous concretions (*Kankar*) mixed with coarse sand are seen between depths of 19 m and 35 m off Orissa–Bengal coast<sup>19</sup>. There is a patch of coarse sands beyond 10 m water depth off Gopalpur<sup>11</sup>. Then there is an extensive area covered with pebbles and sands in the outer shelf region on the Pilot's Ridge. In the outer shelf region of Krishna-Nellore, there is a narrow zone of sands and another sand patch with shells and corals off Pulicat Lake. Patches of sand are observed south-east of Madras through Cuddalore-Nagapattinam and Calimere Point. Skeletal sands in the depth range of 35–45 m; detrital sands in the 18–31 m depths and pellet-rich skeletal detrital sands in the depth range of 40–50 m are discernible off Pondicherry.

## Sedimentation

The shelf sediments comprise nearshore sands, inner shelf silts and clays, and oolites or coarse sands in the outer shelf region. The oolites or coarse sands beyond the clayey sediments in the outer shelf region is relict in nature. The sea level had lowered down to about 138 m around 12,000 yr B.P.<sup>13</sup> with standstills at about –95 m, –85 m, –72 m and –50 m. The outer-shelf ooids forming below intertidal level less than 2 m might have formed during the lowered sea level in the Holocene period. The radio-carbon dates of the oolites vary between 9,960 and 11,330 yr B.P.

The ridges of algal limestone or coral reefs observed on the outer shelf between the depths 60–110 m must have developed when sea levels were lower. The radio-carbon dates for these limestones vary between 7,500 and 12,510 yr B.P. The corals generally occur in water depths of less than 15–20 m. So the present positions of these ridges are anomalous in terms of depth of water. Submerged terraces at –95 m, –85 m, –75 m and –65 m depths indicate former stillstands of the sea level. These ridges have been observed on both the eastern and western continental shelves, but are more conspicuous in the northern part of the western continental shelf and in parts of eastern shelf. The pellets

with mud aggregates occurring between 115 and 140 m water depths might have developed during initial stages of rise of sea level<sup>15</sup>, and by the next stage of transgression when the sea level stood around 90 m, the oolites were formed<sup>15</sup>. Presence of shallow-water benthic foraminifera bears further testimony to deposition at the time when the sea had come down. Brown stained quartz grains in the outer shelf area suggest sub-areal condition of deposition. It may be inferred from the above that various lithofacies of the outer shelf sediments were developed during different stages of the rising sea level. The presence of heavy mineral-bearing offshore sands over the weathered Quilon limestone and in another place over the oxidized clays indicate that these sands were deposited during the late Pleistocene and Holocene period<sup>16</sup>. The topographic high and terraces at depths of 28–30 m, 40–46 m and 53–56 m off Ekasingi and Chhatarpur may be interpreted as representing palaeosand ridges or bars which probably acted as barriers during transgression. On the basis of the distribution of insoluble residue it has been suggested<sup>20</sup> that the present-day sediments do not contribute beyond 60-m depth in the northern sector of the western continental shelf.

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