SUMMARY AND CONCLUSIONS

The continental margins of India fall into the category of mid plate continental margin. The north-western continental shelf has been the focus of the present studies. It is a well defined morphological feature with a maximum width of about 300 km off the Gulf of Khambhat which narrows progressively towards north and south. The shelf break occurs between 120-150 m. The shelf can be divided, based on topographic features, into even, uneven and rugged regions. The even topography has originated due to the deposition of recent sediments in the inner shelf region (upto 60 m) while the uneven and rugged topography on the outer shelf is relict. The study of the sediments revealed that in general the shelf is floored with three different type of sediments. The boundaries among these are gradational to each other. The first of these is modern sands of the shore zone occurring within few kilometres of the coast and extend to about 5-10 m water depth. These sands are composed of quartz with varying proportion of heavy minerals. They are derived as a result of wave erosion of cliffs and promontories of the west coast. Beyond this zone modern muds are encountered. These are
terrigenous clastics, texturally clays and silts having low carbonate (< 10%) and high organic matter (3%). They extend offshore up to a distance of 160 km off Bombay to a depth of about 60 m. The source of these muds are the rivers which drain the Western Ghats and the coastal plain at their root. To the north-west, off the Kathiawar coast, the shelf is bordered by the semi-arid land which is a poor source of sediments but fine grained sediments do occur with the limited distance of the coast. Succeeding these are the coarse and medium grained calcareous sands consisting of a variety of skeletal and non-skeletal assemblages of the outer shelf which are of late Pleistocene/Holocene origin when the sea level stood 60-90 m below the present level. Evidences of the lowered sea levels are the presence of ooids and the shallow water foraminifera. The radio-carbon ages of the calcareous sediments are between 9,000-10,000 years before present, and they are termed as relict sediments.

The sharp difference across the shelf in the texture of the sediments, their content of coarse fraction and terrigenous component alongwith the clay/(clay + silt) ratio; the index of accumulation process of fine grained sediments can be taken as being representative and demonstrating the contrast between the sediments of the inner and outer continental shelf of north-western continental shelf of India (Fig. 69). The
Fig. 69  Distribution of clay/(clay+silt)
boundary between recent fine sediments and relict sediments which occurs at about 60 m bears a causal relationship with the depth at which the boundary occurs, long period waves and the depth of effective sediment movement of these waves. The boundary is, therefore, attributed to the action of long period waves.

The size parameters were computed for each samples and it is found that the range of these on the inner shelf are: mean size 1.7 to 8.7 phi (average 6.94 phi), sorting 0.56 to 4.5 phi (average 1.96 phi), skewness -0.7 to 0.8 (average -0.14) and kurtosis 0.5 to 1.72 (average 1.19). The corresponding values for the outer shelf sediments are 0.8 to 8.6 phi (average 3.8 phi), 0.7 to 3.3 phi (average 2.02 phi), -0.6 to 0.5 (average 0.16) and 0.5 to 1.96 (average 1.19) respectively.

These studies helped in discussing the size distribution pattern of the sediments.

The basic CM-pattern revealed that the inner shelf sediments of the study area are confined to the values corresponding to the largest grain size transported as uniform suspension and graded suspension, while outer shelf sediments to transported action by rolling. Further the comparative study of the graphic and moment measures revealed that (i) mean size and standard deviation have comparable values, (ii) the skewness is also comparable, but to a lesser extent than the mean size.
and standard deviation, (iii) the skewness calculated by Folk and Ward's method shows better comparability with the moment skewness than the phi skewness and (iv) the kurtosis does not show any comparability.

The distribution pattern of the terrigenous component of the sediments indicate that the bulk of the terrigenous material is confined to the inner shelf (>75%) leaving the outer shelf free from terrigenous sediment accumulation (<10%). The important heavy minerals in the assemblage are opaques, clinopyroxene, epidote, monazite, zircon, muscovite, biotite and chlorite. The assemblage indicates a mixed igneous and metamorphic source with major contribution from the igneous rocks.

Clay mineral determination were made on the inner shelf sediment samples and it was found that smectite is the most dominant clay mineral followed by kaolinite, illite and chlorite. These clay minerals were used to retrace the signatures of the environment/lithological zones occurring on the north-western coast. The Gulf of Kachchh and the area north of it shows relatively higher abundance of chlorite and illite which are due to the influence of Indus River. Further two zones were demarcated based on this study viz; (i) the smectite-kaolinite-illite-chlorite zone off the Gulf of Kachchh
and (ii) the smectite rich zone off Gulf of Khambhat.

The outer shelf carbonate sediments are coarse grained (1 to 3 phi) and having carbonate content ranging between 30 to more than 75%. The higher values of carbonate was found on the outer shelf off Bombay (> 90%). The carbonate content is mostly in the coarse fraction and assemblage consists of skeletal bivalves, gastropods, foraminifera and calcareous algae. Of the non-skeletal components ooids and pelletoids constitute the majority. They present to the extent of 50 to 90 % off Bombay and decreases to 30 % to the south.

The carbonate assemblages of the north-western shelf of India on comparison with the carbonate assemblage of the typical carbonate dominated open continental shelves of the world (Ginsburg and James, 1974) shows that the assemblage is in general similar to those found on the other shelves (Fig. 70). Difference in the number and variety of the assemblages are minor and may be attributed to climate, variation in physiography of the coastal rock formation, bathymetry, hydrography and water chemistry.

Carbonate is also present on the outer shelf in the form of precipitated carbonate cement which has lithified loose grains of various types into hard rocks resulting in the development of hard ground. Rock samples obtained by dredging
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- **Molluscs**: \(\odot\)
- **Ooids**: \(\odot\)
- **Bryozoa**: \(Y\)
- **Benthic foraminifera**: \(\odot\)
- **Planktonic foraminifera**: \(\odot\)
- **Coralline algae**: \(\Delta\)
- **Barnacles**: \(B\)
- **Peloids**: \(P\)
- **Lithoclasts**: \(L\)

**Fig. 70** Zonation of predominant grain types in carbonate sediments on open shelves [Carbonate assemblages on western continental shelf of India shown for comparison]
on the shelf indicate the presence of a variety of limestones such as calcareous sandstones, oolitic limestones, algal limestones.

Sedimentary processes operating on the north-western shelf are the accumulation process acting most commonly in the nearshore areas and the inner shelf because production of sediments are higher in relation to either destruction or dilution.

The evidence for onshore transport of outer shelf sediments is present in the form of grapestone occurrence in the nearshore region at a depth of 10 m. The process of onshore transport, however, needs corroboration from some more data. The presence of bottom current is inferred from the lack of sediment fill in the V-shaped depressions on the outer shelf. Resuspension of the sediments is probably active and resuspended sediments apparently accumulate on the upper slope as fine laminated sediments.

Using the ooids as an environment indicator it would appear that these superficial ooids had formed in the environment of low agitation though not necessarily accompanied by low turbulence. Such an environment that immediately comes in mind is lagoon or a coastal embayment which results from the development of barrier beaches and bars. It has been suggested here that these ridges are ancient beaches and bars that formed during the Holocene transgression.