CHAPTER - VII

ORIGIN AND AGE

GENERAL

The phenomenon of miliolite formation of Kutch provides a complex yet fascinating picture that involves a variety of events and processes of Quaternary period. A critical evaluation of the available data clearly points out to the following facts.

(1) The constituents of the Kutch miliolites, especially the allochems, comprise sand-size carbonate beach material of marine origin.

(2) The present day miliolites represent aeolianites having been deposited by the strong action of wind.

(3) South-westerly winds lifted and transported sands inlandward and deposited them at appropriate sites.

(4) Subsequent fresh water diagenetic processes cemented these bioclastic sands into consolidated miliolites.

The above sequence of events essentially involves a combination of marine, aeolian and vadose environments, in that order, which appear to have been responsible for the origin of Kutch miliolites. Shallow coastal marine environment was responsible for the generation of beach sands with a dominance of biogenic carbonate sand particles. Strong aeolian action has to be invoked for lifting up the sands and dumping them at their present sites. Their subsequent consolidation and diagenesis in a vadose environment typically points to an effective role played by meteoric water. In this evolutionary model the factors of climatic variations and eustatic sea level changes during the Quaternary period have played an indirect but effective roles in the operation of the various processes responsible for miliolite formation. Obviously increasing exposure of beach sands to strong wind action would involve a receding/regressive strandline. Similarly, the aeolian phase points to a dry climate and the subsequent period of diagenesis is indicative of a wet phase. The sequence of events leading to the generation of carbonate beach sands and their subsequent transport, deposition and consolidation, is thus interwoven with successive wet and dry-transgressive and regressive strandlines of the Quaternary times. The author does not claim to have fully understood the problems of the origin and age of Kutch miliolites, there being still quite a few gaps in knowledge, yet the depositional model constructed by him does provide reasonably convincing answers explaining quite a few facts about miliolites, hitherto not understood by previous workers.

SOURCE MATERIAL

The author has already furnished adequate details pertaining to the modes of occurrence and petrographic characters of the Kutch miliolites. They are made up of sand size particles (bioclasts and terrigenous) cemented together by sparite cement. The faunal content of this rock is identical to the present day bioclastic beach sands of Southern Kutch coast. In order to fully understand the environmental conditions for the generation of ancient bioclastic sands that acted as source material for the miliolite, the author has followed the maxim, 'present is the key to the past'.

The middle segment of the coastline overlooking the Gulf of Kutch between Suthri and Mandvi was the source area that provided the bioclastics. Significantly, the sand deposits are restricted to this segment which occur as well-defined beaches and coastal dune ridges. Even the present day sands are quite rich in bioclastic s which considerably resemble their fossil counterparts (inland miliolites). This sandy stretch of the coastline appears to have been generating almost identical sand particles for the most part of the Quaternary period and it were such sands that were lifted up and carried landward in an northeasterly direction by strong winds to give rise to inland accumulations. The author has visualised following two factors primarily responsible for for the generation of adequate quantities of carbonate sands.

(1) A high energy carbonate sand generating shallow marine environment.

(2) An intermittent but progressive regression of strand-line increasingly exposing beach and littoral sands to wind action.

Samples from the present day beach and coastal dune accumulations along the coast between Suthri and Mandvi were analysed and it was observed that though the sands contain an appreciable amount of terrigenous material, they are significantly rich in abraded and unabraded molluscan shell fragments, foraminifera, echinoderm spines, ostracodes, bryozoa, algae, coral etc. along with peloids. The Kutch coast sands differ from those of west Saurashtra coast, the latter having a smaller percentage of terrigenous material. The reasons for the relative richness of present day Kutch sands in terrigenous grains is attributed to the transport of Indus river sediments into the gulf by tidal currents. Nair et al, (1982) have visualised " a high velocity tidal stream of the macrotidal gulf which acts as a dynamic barrier preventing the Indus borne sediments from being transported across the gulf mouth to the Saurashtra gulf". This explains the absence of terrigenous material along the Saurashtra coast today. Though it is difficult to know the precise composition of the ancient beach sands which provided the material for the inland miliolites, in all probability, the then Kutch beach sands were identical to their present day counterparts of Saurashtra, not only in their bioclastic content, but also in having a low percentage of terrigenous particles.

The next question that needed an answer is that relating to the precise shallow marine environmental conditions that were responsible for the coastal sands of the type now making up the miliolite material. Most workers (Schmidt, 1956; Hiltermann, 1966; Jordan, 1971; Milliman, 1974; Wilson, 1975; Davis, 1983) who have investigated marine biogenic carbonate rocks having invoked following environmental factors essential for generation of carbonate sands:

1. Salinity : Normal saline to hyposaline, 20‰ to 50‰.
2. Energy conditions: High energy (strong wave and surf action), and appropriate oxygen and food supply.
3. Depth and light: Shallow marine and photic zone; 10 to 200 m.
4. Temperature : Tropic and sub-tropic climate, between 30° N and 30° S latitudes.
5. Substrate : Hard and uneven
6. Terrigenous influx : Little

The clear waters of South Kutch coast overlooking the Arabian sea, ranging in normal saline to hyposaline conditions, provided opportunity for the growth of the invertebrate fauna in the offshore areas. Also the various sluggish rivers of Kutch Mainland meeting the Arabian sea did not carry any significant bed load because they must have been relatively small, flowing for short distances and draining a country which did not show much gradient. These rivers thus did not bring large quantities of water and detritus to the sea, and the coastal waters remained clear and less turbid. The rivers however, drained a Mesozoic trappean and Tertiary terrain and brought a relatively high content of dissolved $CaCO_3$ to the sea, which provided a favourable condition for the growth of organisms. Temperature is another important environmental condition for the growth of the carbonate organisms and the reconstruction of the paleoclimate. The areas of profound carbonate sedimentation are the shallow seas of tropic and sub-tropic between 30°N and 30° S latitudes (Wilson, 1975), characterised by warm waters. Therefore, the calcareous organisms flourishing in warm water show an abundance of number of species and their populations. The number of species is controlled by the depth of water upto which the light can penetrate i.e. with increasing depth and decreasing light intensity, the number of organisms would decrease. A majority of microfauna was generated in shallow marine environment below the tidal zone. Their subsequent beachward transport and abrasion is attributable to the strong wave and surf action. The swash and back-wash actions abrade the various shell fragments mostly by a process of attrition. Crashing waves also prevent silt accumulation which could inhibit the growth, and also provide more supply of food and oxygen for the growth of organisms. This action of high energy environment would result in the removal of fine sediments and accumulation of sand particles which show a better sorting and rounding on the beach. The production of carbonate sediment is also related to the terrigenous influx. The carbonate sediments develop in an area where little or no terrigenous influx persists (Wilson, 1975). The terrigenous sediments are the products of previously existing rocks that have been transported to the sea, whereas the carbonate sediments are formed in the sea. Therefore, the terrigenous sediments on the most continental margin, have the effect of stifling the luxuriant growth of carbonate producing organisms. As a result, carbonate building must occur on the shelves where little terrigenous sediment is introduced. The abundance of carbonate organic shell in miliolite indicates a high carbonate generating Quaternary sea. Today the Indus sediments are sucked into the gulf, but in those days, this sediment supply was perhaps not there.

The subsequent regression of the sea would synchronize with a glacial stage marked by a dry climatic phase. It could be quite a valid conjecture to visualise that during such a dry climatic phase, the Indus river run off was inhibited, thereby curtailing the terrigenous influx, and providing a suitable environment for the generation of carbonate dominant sediments.

In this context, the studies carried out by Pandya (1985) on the present day carbonate sands of Saurashtra coast, are most relevant. She has ideally described the processes responsible for the generation of biogenic sands comparable to the miliolite particles. The present author has reproduced her observations which are applicable to

Kutch miliolitic sands also. Pandya (1985, pp.281-283) has written as under:

" The different sand fractions have revealed several interesting facts in respect of the nature of peloids and the processes responsible for abrasion, rounding and micritisation. The study has also thrown light on the factors controlling the size and shape variations of the peloidal sand grains. It is observed that the peloids have originated by a process of abrasion followed by progressive micritization of abraded bioclasts, and in the earlier stages, the internal organic structure and original shapes are seen preserved. The abraded and micritized bioclasts point to a protracted evolutionary sequence. Initially, either entire tests or fragments of bigger shells were abraded, showing varying degrees of roundness. Subsequently, they were partly or fully micritized. The process of micritization appears to have been brought about by the action of blue-green algae in a shallow marine (tidal zone) environment (Bathrust 1966, 1971). The author has recorded conspicuous development of blue-green algae within the tidal zone and thin section of quite a few peloids and bioclasts reveal process of algal micritization and alteration of skeletal grains into aragonitic micrite. The varying degree of the algal alteration has been attributed to the factors of time span and of depth. A reduction of abundance of micritization with depth is to be expected, because algae photo-synthesis. Nadson (1927 a,b) has reported similar bored carbonate grains from many parts of the world. Margolis & Rex (1971) have ideally demonstrated this process of micritization. According to them when blue-green algae bore into carbonate substrate in the photic zone (holes about 6-10 um diameter) these boreholes when vacant following death and decay of the borer, provide sites for precipitation of fine cement of aragonite and Mg-calcite. The cement crystals are so small that, with the light microscope, the cement looks like micrite. Prolonged boring, drying and cement filling leads to centripetal replacements of grains. If this process stretched over a long period of time, finally all original structures are obliterated. Such micritised and abraded bioclasts have been designated as "bahamite" by Beales (1958), and fall under the category of "cortoids" of Flügel (1982). The sand grains showing different stages of abrasion and micritisation comprise not only foraminiferal tests but also those of lamellibranchs and gastropods. The sands derived from the lamellibranchs invariably represent fragments of bigger shells and form generally elongate, elliptical crescentic grains. On the other hand, grains of abraded gastropods show fairly wide variation in their shapes; a grain derived from the fragment of a bigger shell, representing only a part, is generally elongated. But a fairly large proportion of abraded and pelletised gastropods is seen to be made up of tiny entire shells; the turetted forms have given rise to elongated grains, while rounded shells have resulted into equidimensional grains. Peloidal foraminifers are equally abundant and these also show different shapes and sizes and varying degrees of abrasion and micritization. The original shapes are generally reflected in the shape of the peloidal grains ..... the biogenic constituents of the sands, as has already been stated, show varying degree of abrasion. Depending on the original shapes of the shells/shell fragments their abraded equivalents show diverse shapes. Equidimensional foraminiferal tests, gastropod shells and oyster fragments in advanced state of abrasion and micritization have given rise to peloids. The process of abrasion is obviously related to the high energy conditions prevailing along the coastline. The foreshore and the near offshore portions are marked by strong wave and surf actions, the unevenness of the miliolitic substrate is seen to generate wide zone of breakers. The net result is that aided by strong onshore winds, strong waves not only carry the various organisms beachward but they also bring about marked abrasion. The swash and backwash actions abrade the various shells and shell fragments mostly by a process of attrition. The abraded tests and shell fragments were subsequently micritized during which a progressive obliteration of internal organic structure is seen to have been brought about. Precise environmental conditions under which the bioclasts were micritized are not fully understood, but role of microorganisms (algae) in precipitating and infilling the tiny voids bored into the surface of the bioclasts, invoked by many workers (references already cited), has been attributed to the study area also. The sands of the foreshore when lifted up by strong winds have provided material for the coastal dunes, and it is obaserved that depending upon the wind velocities, the sand grains which are relatively smaller in size, lighter and flaky are dumped in instalments".

SEA LEVEL FLUCTUATIONS

As the lowest altitude at which the miliolite occurrences are recorded is about 28 to 30 m, the present author has presumed that the beach that provided these carbonate sands could be a few metres below this level. He has thus postulated a palaeo-strandline about + 25 m above the present sea level and the miliolitic sand is supposed to have been generated during this high sea stand. The sea subsequently regressed and went down to as much as - 20 m below the present level. Of course, it is not unlikely that the entire phenomenon of increasing regression punctuated by periodic rise and fall of sea level depending on the global climatic changes. On the basis of his observations, the present author has proposed the following four Quaternary sea levels for the Kutch Peninsula:

1.	Transgression	+ 25 m (Wet-Humid)
2.	Regression	- 20 m (Dry-Arid)
3.	Transgression (Flandrian)	+ 2 to 4 m (Wet-Humid)
4.	Regression	Present sea level (Dry-Semi-arid)

It is rather difficult to categorically state the precise factors responsible for the levels of high and low strandlines. Considerable confusion prevails in the literature pertaining to the question of Quaternary sea levels. Most of the workers on Quaternary have invoked fluctuations of sea level, correlatable with palaeo-climatic changes, glacial stages coinciding with regression and interglacial with transgression (Fairbridge, 1960, 1961; Donner, 1970; Pethick, 1984; Emiliani, 1970; Flint, 1971; King, 1974; Verma & Mathur, 1978; Pomerol, 1982). However, there does not seem to be unanimity in matters of the actual heights of the strandlines, because it has been pointed out by several workers that glacio-eustasy and tectono-eustasy should be appropriately understood and identified before absolute sea levels are fixed. According to Fairbridge (1961), the variations of seal-level were related to glacio-eustasy and the highest strandline position of +220 m was during Calabrian transgression, about 2.5 m.y.

ago, and that the successive high sea stands show a progressive decrease in heights, the last transgression being + 2 to + 3 m, 12000 years, B.P. (Flandrian). Such a picture of close relationship between glacial fluctuations and sea-level changes, has been controversial. Whereas regression and low sea levels have been generally accepted, the transgressive strandlines higher than the present sea level has not found favour with most subsequent workers (Curray, 1960, 1961; Shepard, 1963; Scholl & Stuiver, 1967; Shepard & Curray, 1967; Moore, 1982). Tricart (1974) has very aptly discussed the different aspects of high sea stands, and has unequivocally stated that the factors of tectonism and isostasy might have considerably affected the levels of marine terraces which have been considered to provide conclusive evidences of high sea levels, and according to this author even during the older Quaternary, the sea level might not have risen beyond a maximum of 40 m, and that levels higher than this must have been tectonically raised.

The strandline positions during transgression and regression along the Kutch coast, invoked by the author have therefore to be viewed in the light of the facts discussed above, and also keeping in mind the radiometric age data recently made available (Baskaran, 1986). However, it would be too rash for the present author to pinpoint the absolute heights and depths of the transgression and regression along the Kutch coast, in term of glacio-eustasy alone. The height of the transgressive strandline therefore has to be taken in a relative sense only.

PROBLEM OF AGE

Determining precise age of these miliolite rocks is a very difficult propostion and the author has kept his mind very open on this aspect. Of course, the miliolite of Kutch (or for that matter, even of Saurashtra) are of Quaternary age, and considering the various field and laboratory evidences, especially the microfaunal content, it can safely be stated that the process of carbonate sand generation was a characteristic phenomenon of the Quaternary period, essentially related to sea level changes and climatic variations. Faunal and stratigraphic evidences do not provide any precise information on the age of miliolites, because on account of repeated accumulations of identical material, the stratigraphic significance of layering has become ineffective. Moreover, even today, 'miliolitic' sand grains are being generated along Saurashtra coast and to some extent, even along the South Kutch coast. There are strong possibilities of accumulation of bioclastic sands in more than one instalments, the whole process spread over a large portion of the Pleistocene and Holocene epochs.

Radiometric dating of carbonates always posed numerous problems and in the case of miliolite and comparable deposits from elsewhere in the world, the ages on the basis of C^{14} dating have not provided any dependable and clear picture. Agrawal (1969, 1971) was the first worker to attempt to radiometrically date some of the Kutch miliolite occurrences by C^{14} method. He found following dates:

1)	Drubya Hill	12640 ± 170 years B.P.
2)	Jura Hill	$25480 \pm^{1025}_{915}$ - Years B.P.
3)	Katrol Hill	$33480 \pm^{2790}_{2085}$ - Years B.P.
4)	Katrol Hill	$29430 \pm^{1650}_{1380}$ - Years B.P.

On these ages, Merh (1980) has opined that "as miliolite comprise too complex a material to provide dependable dates, no great reliance can be placed on C^{14} dates". The C^{14} dating is not suitable for aeolianites represented by miliolite, because the contamination of aragonite shells by secondary calcite during cementation presents serious problems; shells are only suitable for dating if the degree of diagenesis is limited or where recrystallisation has occurred within a completely closed system (Chappel & Polach 1972; Thom, 1973). This is not so at least in the case of Kutch miliolites, where marine shells have been transported inlandward by action of wind and contaminated with the older rock material and later on diagenetically cemented under fluvial and vadose conditions.

Gardner (1983) has also identical opinion regarding the dependability of C^{14} dates for aeolianites. She studied the aeolian biogenic carbonate sands of S.E. India (which are identical to miliolite). She has also summarised the radiometric dates obtained from comparable aeolianites from different parts of the world, and according to her the "age range from the last interglacial to the Holocene probably reflects problems of sample contamination and dating methods as much as destruction of older deposits".

Very recently Baskaran et al (1986) have invoked the Th-230/U-234 methods for determining the age of Saurashtra miliolites, and following this technique, Baskaran (1986) has put forth a geochronological framework for Kutch miliolite also to which the author is considerably attracted. According to him, the Kutch miliolites show three age groups, viz. 60 $\pm$ 10, 95 $\pm$ 15 and 170 $\pm$ 30 kyrs, which fall into the three age groups obtained for the Saurashtra miliolites by Baskaran et al (1986). Baskaran (op.cit) has dated the allochems of miliolites from a number of localities and has obtained the above dates. These dates appear to be quite convincing to the present author because his depositional model also invokes fluctuating strandline with conditions favourable for aeolian transport for marine sands of more than one age . In this context, the findings of Moore (1982), have some relevance. The dates mentioned by him have to be considered in a broad sense, and not for pinpointing the precise ages of the Kutch miliolite material. His statements however, do provide a general picture prevailing during the Late Pleistocene period. According to him (Moore, 1982), the first major regression upto - 40 m took place around 160 kyr ago. Obviously, the transgressive phase prior to this event, could be taken to have generated the oldest miliolite material (170 ± 30 kyrs), the genesis of the two successively younger deposits (60 ± 10 and 95 ± 15 kyrs) are correlatable with Moore's high sea levels of -15 m and -28 m at 105 kyr and 60 kyr respectively. It is however, not the intention of the present author to fully follow or agree with Moore (1982), but his idea of referring to his work, which is the latest and generally accepted, is to highlight two points.

(i) The radiometric dates arrived at by Baskaran (1986) on the basis of Th-230/U-234 method which is at present thought to be a dependable method, provide some information on the dates of transgression and regression of sea during Late Quaternary, processes with which the miliolite deposits of Kutch are intimately related.

(ii) The miliolite sands were generated during a high sea stands and were transported by strong winds during the periods of regression and aridity that followed.

The radiometric dates have therefore been considered more by way of guiding factors rather than as precise ages. A lot more data is needed to fully understand the problem of age of Kutch miliolites and the present author is fully aware of this breach in the knowledge.