Chapter - II

L I T E R A T U R E R E V I E W

GENERAL

A vast array of literature is available on the Quaternary carbonate deposits of western India, especially on the miliolite limestones, as this topic pertains to a highly controversial problem with regards to their deposition by marine or aeolian processes. Even to archaeologists this subject is of great importance as it advocates wealth of informations supporting the presence of Stone Age culture in Gujarat. These deposits have been studied in Kutch as well as in Saurashtra by different geo-scientists taking in to account one or other aspects, following two separate waves in time. In 19th century pioneer work started since their first report by Carter (1849) but after Adye (1914)

the study of these deposits was ignored till 1958 when R. W. Fairbridge revived the interest of workers in the miliolite rocks by throwing light on its significance in the study of Quaternary sea level changes. Although most of these works were emphasising on miliolites, the other carbonate deposits like ancient beach rocks and stabilised organogenic carbonate sands were not studied separately in detail. In the following paragraphs a brief review of various workers has been given which may help the readers in providing the background informations to understand the present study. The concerned literature regarding Kutch, a counterpart of Saurashtra miliolites, has also been incorporated to avoid any reference 'hole' in reviewing these deposits.

ANCIENT BEACH ROCKS

The shelly fragmental rocks occurring all along the Saurashtra coast were described by various workers as coast fringing rocks, littoral concrete, dead coral reefs & oyster beds, Chaya Formation etc. assigning their age either younger than miliolites or considering them upper most part of Dwarka beds. The present author, following Patel (1991 a), has considered them as of early Middle Pleistocene age as they occur below the miliolites and for the same reason they have been described as 'ancient' beach rocks.

While working in Saurashtra, Fedden (1884) described these rocks as "porous, open or inpart compact limestones of pale-yellowish colour, gritty with quartz grains, and finely crystalline" rocks designating them as 'coast fringing rocks',

which according to him mark the upper limit of the Dwarka beds. Regarding the age of these rocks he writes, "a set of rocks, seldom met with at any great distance from the coast, and which I have tentatively included within the upper limit of the present group, - in the absence of distinct evidence to the contrary, - may, as already intimated, be eventually regarded as of Post-Pliocene age". Again for the similar rocks occurring in the neighbourhood of Patan (Somnath), Veraval and Mangrol, he further writes, "...The sub-recent sandy beds are stronger, and represent a littoral accumulation or raised beaches; for, at one place, I obtained many well-fossilized shells, such as *Conous, Cypraea* and several Pelecypoda. The harder portions of this rocks, not always on the same horizon, have been largely quarried for an inferior building stone, while other portions of it are still incoherent. The upper part, which contains the shells, is coarse-grained and softish".

Sastri & Pant (1959), during the course of their mapping of Quaternary carbonate deposits of Mangrol area, concluded that during the Upper Pleistocene the sea stood nearly 4.5 m above the present level that deposited the raised beaches alongwith the miliolites.

Shrivastava (1968 a & b) described these beach rocks as lithified coquina formed on an old beach and composed of broken shell fragments; forming slabs of crumbly & porous deposits, some of which show a large scale, low angle, simple or planar cross-stratification which generally slopes towards sea, but sometimes also in the opposite direction. According to him, these beach

rocks are the younger most deposits formed following the regressive shoreline.

Agrawal et al. (1970) dated a shell collected from raised beach near Porbandar (3.5 m AMSL), likewise coral from Baradia village and many others by C^{14} method which comes to be of 36070 (+5550; -3290) years.

Gupta (1972) dated some raised beach deposits of Saurashtra, occurring in several patches and extended as much as 4 to 6 km inlandward by C^{14} radiometric dating technique; their age range from 5000 to 35000 yrs BP.

Gupta & Amin (1974) dated corals and shells from dead coral reefs and raised beaches of western & northern Saurashtra coasts by Th^{230}/U^{234} and U^{234}/U^{238} methods, and postulated that the sea during 6000, 30000 and 120000 years BP was 2 to 6 m higher than the present. Gupta (1977) continuing their study in the same area proposed three age groups for the corals and beach rocks he dated, (i) between 4500 & 6700 yrs BP, (ii) between 23000 & 35100 yrs BP and (iii) between 105000 & 125000 yrs BP, and supported Gupta & Amin (op.cit.) by concluding that "...the absence of field evidences to support tectonic instability of Saurashtra coast, suggests that the fossil coral and beach deposits are remnants of a higher sea level".

Govindan et al. (1975) reported dead oyster bed near Badalpur village in Saurashtra along the bank of a stream of Saraswati river at a height of 8.39 m AMSL. The C^{14} age of a shell collected from this bed is about 21,430 years B.P.

The GSI workers Mathur & Mehra (1975) studied the semi/unfossilised shells containing calcirudites from western and southern Saurashtra coasts and separated them out from the miliolites as 'Chaya Formation' suggesting their age Upper Pleistocene to Holocene. Mathur (1978) and Verma (1979) investigated such shelly rocks all along the coast and placed them at higher position over miliolites in the Quaternary stratigraphy. According to them the Chaya Formation consists mostly of calcirudites - containing complete and/or broken semi to unfossilised remains of invertebrates and are devoid of any oolitic and pelletic calcareous grain. Mathur (op.cit.) differentiated Chaya rocks from the Dwarkas on the basis of highly fossilised & recrystallised nature and the presence of fossil *balanus* in the latter.

According to Patel (1991 a) these rocks are restricted to southern fringe of the Saurashtra coast between Dwarka and Kodinar and lie below the miliolites representing littoral and beach accumulations along the foreshore of an early Middle Pleistocene high sea.

MILIOLITE LIMESTONES

The term 'miliolite' was introduced for the first time by Carter in 1849 to the "granular deposits composed of oolitic particles of calcareous sand united together into a firm compact rock on the Arabian sea coast having predominance of the foram belonging to the genus Miliolina".

Fedden (1884) mapped the coastal areas of Porbandar, Veraval, Jafrabad and Gopnath-point and described the miliolite rocks as "finely oolitic freestone, almost free from sand and other foreign particles; the nucleii of the oolitic grains are mostly organic". For the inland miliolites, especially those occurring at the lower fringes of Chotila hill near Rajkot, he suggested marine origin invoking the submergence of a greater part of Saurashtra peninsula in comparatively recent time.

Blake (1897) examined some of the Kutch miliolite deposits in detail and stated that they "consist of fine particles, very slightly agglutinated so that a blow of the hammer shatters them to dust". He considered these white calcareous rocks as products of aeolian accumulation.

In the vicinity of Kodinar in Saurashtra, Foote (1898) described these rocks as fine oolitic freestone composed of greater part of foraminifera whose tests formed the nucleii of the oolitic grains of which the limestone is composed.

Evans and Chapman were first to consider the inland miliolites of Saurashtra to be of aeolian origin. Evans (1900) compared the Junagarh limestone with identical rocks of Kutch, Arabian coast, islands of Persian Gulf and those of other tropical and subtropical coasts of the world. For the miliolites occurring in the vicinity of Junagarh he writes, "There seems to be every reason to believe that Junagadh limestone was formed by aeolian action.... but it is impossible to believe that this calcareous material could have been blown 30 miles over barren plains.... We

must assume that at the time when it was formed, the present site of the city of Junagadh was close to the margin of the sea". The interior deposits of miliolite were considered by him to be "the products of transportation by wind action on the ancient coastal sediments".

Chapman (1900), who examined the miliolite rocks from Junagadh and Porbandar areas, thought that the worn and polished nature of the foraminifera present in miliolite limestone is suggestive of their abrasion by wind transportation. He thus believed that the miliolite rocks represent the aeolian accumulations of material derived from littoral calcareous sediments. He, however suggested that some of the coastal miliolites of Saurashtra were deposited in the shallow marine waters assigning their age not older than Late Pleistocene.

Pilgrim (1908) compared the miliolite rocks of Saurashtra and Kutch with those of Persian Gulf and adjoining areas of Persia and Arabia, and invoked them to be of aeolian origin.

Adye (1914) gave a detailed account on the geological settings and the occurrences of miliolites of Navanagar (Jamnagar) state and considered that most of these deposits are littoral but he does not rule out the possibility of different origin for the other similar deposits.

Sastri & Pant (1959) studied the miliolites with other calcareous deposits of Saurashtra, giving special emphasis on the eustatic changes during the Quaternary period. In the subsequent

paper, based on their faunal content, they (Sastri & Pant, 1960) assigned a Pleistocene to sub-Recent age for the miliolites.

For the first time the petrography of miliolite rocks from Diu island was presented by Ubaldo Maria de Lourde (1961) and according to her they are clayey detrital calcarenites of uniform composition and mostly composed of oolites, organic remains and cement.

Shrivastava (1968 a & b) studied the petrography of miliolite rocks of western Saurashtra coast in detail and considered that most of them including the inland ones, are of marine origin. According to him, these rocks comprise the calcareous beach deposits, formed in agitated warm and shallow waters which have been cemented by secondary $CaCO_3$ precipitated from sea water, consisting of mostly high energy calcarenites, calcirudites, coquinoid bands and minor carbonate mud. For the occurrence of these rocks over Tertiary coastal plains and interior trappean country he writes, "Miliolite beds rest unconformably over the Pliocene strata north of Porbandar, indicating that the advance of the sea commenced in the Post-Pliocene. The sea has since receded to its present stand, and successive younger beach and allied deposits were formed following the regressive shoreline". It is also suggested that the aeolian sands interstratified with the limestones are probably deposits formed on the old shoreline (comparable to the modern shore dunes), which were submerged under the advancing Pleistocene sea and are now elevated above high water mark, consolidated during submergence and overlain by the younger beach deposits.

Shrivastava (1968 b) attributed this sea level rise to the Quaternary tectonism, postulating down-faulting of the entire Saurashtra in Pleistocene causing widespread marine transgression during which the formation of miliolite rocks took place. Following this, the process of uplifting commenced during the Post-Pleistocene time which, according to him, is still continuing.

Hardas & Merh (1968) encountered few occurrences of such rocks around the city of Bhuj in Kutch and described them as miliolite like arenaceous limestone that could be named as "sandy fossiliferous oomicrites" deposited under shallow east-west creek or lagoonal condition.

Glennie (1970), supporting Evans (1900), stated that the calcareous sands (miliolites) of western India are of aeolian origin. In his book on 'Desert sedimentary environments' he writes, "...the only evidence to connect the sands with the marine environment of their origin is their rich faunal content of miliolids and other skeletal fragments. There is no necessity for invoking a 300 m rise in Pleistocene sea level to account for their presence; a slight lowering of sea level, to expose a broad area of the present continental shelf to wind during a polar glacial period, seems a much more reasonable hypothesis to account for their presence".

Biswas (1971) believed in aeolian to fluvio-aeolian origin of the inland miliolites of Saurashtra and Kutch, and invoked strong northwestward winds for transporting the calcareous sands

from South Saurashtra coast to as far north as Kutch and various islands in the Great Rann. According to him, the coastal rocks of Saurashtra might have been formed under marine conditions earlier than the inland miliolites of Kutch and Kathiawar; the sediments being derived from the disintegration of these coastal rocks. He proposed Early Pleistocene time for the deposition of the miliolite rocks of the Saurashtra coast and Late Pleistocene to Early Holocene for the inland miliolites.

Lele (1973) studied the miliolite rocks from Bhadar valley and suggested submarine/littoral environment for their deposition. According to him the sea has entered from the southern and western side of the Saurashtra Peninsula during Early Quaternary, having two cycles of transgression and regressions evidenced by the presence of "thick, red brown coloured clay with calcareous matter" of varying thickness between two layers of miliolites. On the basis of occurrence of Middle Palaeolithic tools associated with miliolites, Lele (op. cit.) suggested Early Quaternary age for the miliolites in Saurashtra.

Goudie et al. (1973) gave an account on fossil dune morphology of miliolite deposits of Una-Veraval area and postulated that their occurrences beneath the Microlithic and above the Middle Palaeolithic artifacts indicate a Late Pleistocene age comparable to the quartzitic sand dunes of Rajasthan.

Sperling & Goudie (1975), categorically differed from the work of Lele (1973) and stated that, "We believe some of Lele's

points are unfounded and that there are sound arguments in favour of the aeolian hypothesis in explaining the origin of a substantial part of the miliolite deposits of Kutch and Saurashtra, though we recognise that there may be more than one type of foraminiferal limestone of Pleistocene age in the area as was suggested by Adye (1914)".

Govindan et al. (1975) studied the lower reaches of Hiran & Saraswati rivers and invoked marine origin for the miliolites. They however, consider that the some of the miliolites could be the aeolian coastal dune deposits, not very far above the zone of coastal environment. About the Stone Age culture in Hiran & Saraswati valley they write, "... the Stone Age man arrived in this area only during the Late Quaternary, but certainly not later than 30,000 - 40,000 yrs BP and witnessed marginal changes in the relationship between land and the sea".

Rajaguru and Marathe (1977) investigated the miliolite deposits of Hiran valley in detail and concluded that the miliolites of the Hiran valley, upto 40 km inland and about 100 m AMSL seem to have formed in fluctuating high energy littoral and coastal dune environment to low energy tidal-flat environment.

Marathe et al. (1977) and Marathe (1981), on the basis of their work in the Hiran valley, postulated that the miliolites occurring in Saurashtra upto 75 m AMSL are certainly of marine origin and those occurring above that are of aeolian and/or fluvio-marine origin. According to them there were atleast two major transgressive phases during which the bulk of the miliolites

was formed. They designated the older one as M-I of Middle Pleistocene age and the younger one as M-II belonging to the Late Pleistocene time.

On the basis of bimodal nature of lithoclasts, rolled and polished microfossils, thin iron oxide coatings on the grains and surface texture studies of quartz grains of miliolite rocks from Junagarh, Dungarpur and Chotila areas, Agrawal & Roy (1977) and Agrawal et al. (1978) revealed the aeolian origin for these inland miliolite deposits.

Bhatt & Patel (1977) studied the miliolite limestones between Veraval and Kodinar and on the basis of the presence of pseudoolitic grains in these rocks, they concluded that these rocks were deposited under shallow, warm, agitated waters supersaturated with $CaCO_3$.

Verma & Mathur (1977) examined the Miliolite Formation along the southern coast and interior parts of Saurashtra and included all the calcareous deposits ranging in composition from micrite to calcirudite under a single term 'Miliolite'. Based on their field and laboratory observations they suggested that the miliolites of Saurashtra consist both, marine as well as aeolian deposits.

The occurrence of miliolite limestones at varying height above the present sea level, according to Verma & Mathur (1978) could be due to the Quaternary glacio-eustatic changes. In their doctoral theses, Mathur (1978) and Verma (1979) described in detail the field and laboratory characters of southern Saurashtra

miliolites. Mathur (op. cit.) studied the miliolite beds & shelly rocks (calcirudites) alongwith the miliolites and suggested that the inland miliolites are of aeolian origin and the sheet/ coastal miliolites are of shallow, muddy tidal flat environment. He further classified the Miliolite Formation of Porbandar Group (Verma et al. 1973; Mathur & Mehra, 1975) into lower-Dhobaliya Talav Member and upper- Adatiana Member based on their lithic characteristics.

Verma (1979) established the field criteria for distinguishing the marine and aeolian miliolites and presented a rich work on microbiota of these Quaternary limestones. According to him, the miliolites of both, marine as well as aeolian origin co-exist at all the localities at different altitudes in Saurashtra; their occurrences being related to the glacio-eustatsy and not to the neotectonism.

Reviewing the entire miliolite problem of Kutch and Saurashtra, Merh (1980) writes, "A salient feature of these rocks is that at most places, the miliolite occurrences comprise both marine and aeolian. Even the inland miliolites of Saurashtra and Kutch are the products of marine accumulation near higher strandlines. ...the socalled 'ooliths' of the miliolite rocks are mostly 'peloids', and these have originated by a process quite different from that which would give rise to ooliths. .... Relatively low oolith content and dominance of peloids derived from shells, point to a shallow marine environment which was not conducive to the oolitisation of carbonate precipitates. Perhaps the agitation was not that high, or the waters were not

supersaturated. ... The fact that miliolites, marine and aeolian must have accumulated in several instalments, related with the sea-level fluctuations, takes us to another problem, that of precise time-stratigraphy. ...the various higher strandlines that are indicated by miliolites in Saurashtra and Kutch, point to a combination of eustasy and tectonism".

On the basis of field & laboratory studies and microfaunal assemblages of Kutch miliolite rocks, Desai et al. (1982) invoked marine origin for the low lying valley fill sheet miliolites, and aeolian origin for those abutting against the hills and ridges comprising obstacle dunes. According to them the occurrences of marine deposits at different levels, could be due to the isostatic uplift and differential neotectonism.

Deshpande & Sharma (1984) studied the miliolite rocks from Porbandar, Veraval and Mahuva areas and suggested shallow marine intertidal and nearshore supratidal environment for the deposition of coastal miliolites and aeolian processes for the accumulation and upward capillary action of saline groundwater rich in $CaCO_3$ for the consolidation of inland miliolites of Junagarh. For the first time they made boron estimation in miliolites to understand palaeosalinity.

Ganpathi et al. (1984) stated that the sheet miliolite deposits of southern Saurashtra are mostly ria deposits along E-W strandline, their height differences being related to the differential uplift/ subsidence on account of vertical neotectonic movements along the transverse faults and also the extension of

Narmada fault. They wrote, "Till Upper Pleistocene, this part (Mahuva-Gopnath block) of Saurashtra coast remained a positive area, a site of accumulation of coastal carbonate sand dunes. It is observed that the renewed activity along these fractures in Upper Pleistocene down faulted this block and this neotectonic movement is amply substantiated by the submergence of the coastal dunes".

According to Deshpande & Biswas (1986) the miliolite occurrences of coastal region of Saurashtra were deposited in shallow marine intertidal and lagoonal environments, whereas the inland deposits of Saurashtra as well as Kutch were the recycled coastal marine deposits by aeolian and fluvial processes during Holocene time.

Ganpathi & Merh (1986) found that the coastal dune accumulations between Gopnath and Mahuva coast were of more than one generation, related to the successive transgression and regression of the sea during Late Pleistocene to Holocene.

Pandya & Bastani (1986) described the various allochems of miliolite rocks from Kutch and Saurashtra and stated that the benthonic foraminifera though indicate warm, shallow, agitating and near shore marine origin, their abraded tests support a combination of various processes like wind, wave and surf actions.

Baskaran & Somayajulu (1986) described a detailed mineralogy of Saurashtra miliolites by XRD studies and inferred that the miliolites are rich in calcite and aragonite only; the calcite

being predominant (50.2 to 100%, mean 86.8%) over aragonite. The other minerals occurring in small amount are quartz and clay minerals like smectite & illite.

Allahabadi (1986) mapped and described almost all the miliolite occurrences from Kutch during the course of his doctoral research and threw considerable light on their petrography, diagenesis and depositional environments. According to him, the Kutch miliolites are product of a combination of marine, aeolian and vadose environments. In this regard he writes, "Shallow high energy 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".

Mathur (1987) made palaeowind direction analysis from the dip-azimuthal data of the cross stratifications in the aeolian deposits of Miliolite and Chaya limestones and inferred that throughout the period of miliolite deposition, the prevailing wind direction on the South Saurashtra coast were westerly and southwesterly.

Baskaran et al. (1987) detected four strandlines above the present coast of western Saurashtra using remote sensing techniques and measured Th^{230}/U^{234} dates for the representative miliolite samples from each of the strandline which range between

52 & 235 kyr. Considering the Peninsula tectonically instable, they calculated the average uplift rates of strandlines 0.12 to 0.58 mm/year.

Bruckner et al. (1987) provided some new aspects on miliolites of Saurashtra and concluded that the inland miliolites and some coastal miliolite dunes were deposited by aeolian processes and cemented under meteoric water condition. According to them the profiles of the coastal miliolites along the coast around Porbandar show a marine base which grades continuously to an aeolian top. The occurrence of marine macrofossils and well rounded pebbles embedded in miliolite upto 4 m AMSL in these areas, as per them, are indicative of marine transgression maximum upto 4 m during the Quaternary period. They have also reported Th^{230}/U^{234}, Io/U and ESR ages for some samples from Saurashtra miliolites and inferred that, the bulk samples of miliolites show minimum ages only and hence cannot be used either as indicators for the time of deposition or for the calculation of uplift rates. They further suggested that the ESR dates (94.9 to 115 kyr) of the macrofossils from the miliolite profiles of Porbandar and Chorwad areas are more reliable.

Patel & Allahabadi (1988) discussed a detailed petrography with special mention of the diagenesis and cementation in these rocks from Kutch. The discovery of coated grains like vadoids & cortoids and typical dog-toothspar cement in these carbonates rocks led them to invoke aeolian origin for the Kutch miliolites.

Based on the radiometric (Th^{230}/U^{234}) dates, Baskaran et al. (1989) stated that, "Miliolite formation in Saurashtra took place mainly during 50-120 ka BP. There are two distinct groups M-I (age=50-70 ka) and M-II (age=75-115 ka) and older ones (M-III) show a spread of ages 140-210 ka. Whereas M-I and M-II occur even in most inland areas, M-III is confined to <15 km from the present-day coast as a small area". According to them neotectonism rather than sea level changes appear to be responsible for the occurrence of many inland miliolites with respect to their upliftment at the rate ranging from 0.23 to 2.2 mm/year.

Bruckner (1989) discussed the Late Quaternary sea level changes along the Indian coastline wherein with the evidences from Konkan, Kerala and Tamilnadu coasts, he described the miliolite limestones of Saurashtra and invoked the transgression of the sea upto +4 m during the last interglacial phase (125 ka). According to him the Holocene transgression reached its maximum around 5000 to 6000 yrs BP when sea level rose higher by 1 m. He suggested the marine origin of miliolites only upto 4 m AMSL which contain macrofossils of the genera *Tellina, Cerithium, Ostrea* and *Arca* alongwith coral pebbles; all the other organogenic grainstones being of aeolian origin.

Chakrabarti & Baskaran (1989) reported biogenic faecal pellet mounds associated with ichnofossil lebensspuren (burrow) and *Striatichnium natalis* (tetrapod swimming tracks) on the bedding plane of miliolites at nearly 150 m contour and considered

them as nearshore or intertidal deposits. The radiometric age (U/Th) of these rocks is 54.2 ±6.2 kyr BP. To explain the occurrence of these marine deposits at considerable heights, Chakrabarti & Baskaran (op. cit.) invoked neotectonism, as according to Chappel & Shackleton (1986) during last 200 kyr there has been no marked rise in the eustatic sea level.

Baskaran & Somayajulu (1990) analysed clay minerals - smectite, illite, kaolinite and chlorite of dated miliolite samples from Saurashtra and Kutch. The proportion of smectite and illite ranges from 0.0 to 88.2% and from traces upto 72.4% respectively; the former being a product of weathering of basalt, thought to be contributed by Saurashtra and Mainland Gujarat sources whereas the latter one by Indus river from a weathered product of granite. In Kutch miliolites Smectite & Illite vary from 6.3 to 55.1% and 23.3 to 69.5% respectively.

Subramanyan et al. (1990) correlated the coastline of Saurashtra Peninsula with that of Tamilnadu and demarcated 3 to 4 bands representative of higher shorelines during Quaternary period in this part of terrain using satellite imageries.

Patel (1991 b) gave a detailed account on the inland miliolite occurrences of Kutch and Saurashtra and very firmly suggested their aeolian origin. Considering the region as a whole tectonically stable, he invoked a combination of glacio-eustatic changes, strong wind actions and pre-miliolite topography in explaining the present disposition of the miliolite rocks. He writes, "Progressive regression of a high sea (Middle Pleistocene)

that synchronised with glacial stage marked by dry climate, exposed enormous amount of beach and littoral sands on southern coasts of Kutch and Saurashtra. The southwesterly strong winds lifted these sands in instalments and carried them landward by combined processes of surface creep, saltation and suspension to give rise to inland accumulations. ... The topography and drainage of Kutch and Saurashtra Peninsula has been responsible for the deposition of miliolite rocks by providing appropriate obstacles and sheltered sites for the wind-borne material to give rise to the present day isolated and patchy occurrences of miliolites in Kutch as well as in Saurashtra".

Commenting on the work of Baskaran et al. (1989), Gupta (1991) stated that "...the Quaternary miliolite deposits of Saurashtra are not an ideal material for radiometric dating". He critically analysed the reliability of radiometric datings of miliolite rocks and raised a question against its use in drawing the conclusions towards the eustatic changes & neotectonic movements.

STABILISED SAND DUNES

Only a few references are available on the stabilised carbonate sand dunes that occur in the coastal areas of Saurashtra, southern fringes of Kutch and semi-arid North Gujarat plains that lie NE of the depressed area joining the Gulfs of Kutch and Cambay. These deposits represent the reworked aeolian beach material of Holocene high sea.

Patel & Desai (1988), during the course of their study on fossil sand dunes of North Gujarat, suggested that a +8 to 10 m high Flandrian sea provided the sites for carbonate generating sandy beaches. Accordingly, during the subsequent regression that synchronised with an arid phase, strong southwesterly winds transported the enormous amount of exposed beach sands to landward areas. The advent of the humid phase, according to them, was marked by their stabilisation concomitant with the formation of calareous nodules in these dunes. Some of the miliolite occurrences of Biswas (1971), especially of Wagad high land, and those of Patcham, Khadir and Bela islands have been considered by Patel & Desai (op. cit.) as part of these aeolianites. Later on Patel (1991 a) considered the occurrence of similar stabilised, loosely consolidated, coast parallel sandy ridges of SW Saurashtra as the coastal sand dunes related to the Holocene shoreline when the sea was ~+6 to 10 m high.

The recent biogenic carbonate sands of southern coasts of Saurashtra are in many ways identical with those of stabilised sand dunes and miliolite rocks of Kutch and Saurashtra, especially in their faunal contents. Although they differ in degree of diagenesis and the amount of the various constituents from one coastal segment to the other one. The author, in the following paragraphs, felt it imperative to give a brief review of these deposits as these coastal segments only have provided the material for miliolites and stabilised carbonate dunes.

Mathur (1978) studied these unconsolidated beach sediments from South Saurashtra coast that comprise dominantly of the fragments of mollusca and the pellets. As per him, the pellets in these sands are derived from the disintegration of miliolite rocks, by micritisation of skeletal grains and also by the excreta of burrowing molluscs and crabs.

Hardas & Patel (1984) studied the beach & dune sands of South Saurashtra coast that comprise bioclastic material mostly foraminiferal tests and molluscan shell fragments in different stages of abrasion, representing the present day unconsolidated equivalents of miliolite rocks occurring all along this coastline. They concluded that the shelly beach sands have derived their material by the shoreward transport of the thriving masses of invertebrate organisms living directly offshore, and the associated dunes with consistant presence of quartz grains, being derived both from offshore as well as onshore winds. According to them, the extensive and continued accumulation of biogenic carbonate sands all throughout the Quaternary period, has been made possible because of (i) the very low supply of terrigenous detritus by the Saurashtra rivers and (ii) high Ca^{2+} content of the river water and warm shallow nearshore marine environment, whereas the beach and dune sands east of Diu and further inward to the Gulf of Cambay, which show high amount of the non-carbonate detritus is due to the supply of high amount of sediments from Mainland by different major rivers like Sabarmati, Mahi, Narmada etc. which has inhibited the growth of foraminifera.

Verma (1979), Desai & Pandya (1982), Desai & Shringarpure (1982) and Pandya (1984, 1985) have thrown considerable light on the microfaunal contents and ecology of these carbonate sands from Saurashtra and Mainland Gujarat coasts.

The above cited literature regarding the Quaternary carbonate deposits poses number of problems which remained still unresolved and require a detailed study. The present author, jointly with Dr. M. P. Patel, has presnted his observations and views regarding these deposits at national and international levels which are referred to the relevant places in the account that follows.