CHAPTER - II

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

GENERAL

Except for some limited and sporadic references to the miliolites of Kutch, no systematic account of these rock occurrences is available in literature. However, looking to the fact that they are in many ways identical and comparable to the inland occurrence of Saurashtra, the author has considerably benefitted by perusing through the relevant literature on Saurashtra miliolites, which have received wide attention of geologists for the last hundred years and much information is now available on the nature of these rocks.

These foraminiferal calcarenites have been a subject matter of interesting debate whether the vast piles of carbonate sands are marine or aeolian. During the last two decades, the researches on these rocks have become multidisciplinary; and the scientists have attempted to delve deep into the characteristics of these carbonate accumulations, looking for the evidences of the various events of the physical environments under which these rocks had originated.

EARLY STUDIES (1849-1900)

Carter (1849) made an exclusive study on the coastal carbonate deposits of Quaternary age of Saurashtra and gave the name 'Miliolite', or 'Miliolite Limestone', for a group of granular calcareous deposits, being rich in foraminifers belonging to the family 'Miliolidae' and composed of oolitic particles of calcareous sand and united together into a firm compact rock on the Arabian sea coast.

Wynne (1872) was the first to report the miliolite occurrences of Kutch and described them under the name of 'Concrete' and considered them to be a Sub-Recent calcareous sandstone.

Fedden (1884) described in detail the miliolite limestones and four other biogenically rich Quaternary rocks of Saurashtra. He defined these rocks as finely oolitic freestone, almost free from sand and other particles, the nucleii of the oolitic grains being mostly organic. He gave details of the field characters of the rock from the coastal as well as inland miliolite deposits. Amongst the inland miliolite deposits, he made a special mention of Chotila hill near Rajkot, where according to him, miliolite formed " a fringe around the truncated top at a height of 1173 ft above sea level". According to him, these limestones were the products of littoral marine accumulation.

Blake (1897) subsequently examined some of the Kutch deposits in greater detail and stated that they " consist of fine particles, very slightly agglutinated so that a blow of the hammer shatters them to dust ..... they are for the most part obliquely laminated, and in this case the slope of the laminae in the part of the deposits nearest the solid rock is in the direction of that rock". Regarding the composition, he further wrote "the majority of these rocks in composition are white and cemented with calcareous matter. In the more southerly exposures there are calcareous particles also, which are completely rounded, and on examination appear to be organic fragments. All the

localities may be described as spots where a wind coming from the west or south would be stopped by an obstacle, or where a shelter spot exists on a long scarp". He urges that these rocks cannot be marine, as the only large organic remains are land shells (Buliminus), and that rocks laid down under water never have this loose porous structure.

Foote (1898) described the miliolite rock from Kodinar 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 (1900), not only described the Quaternary limestone deposits of Junagadh (Saurashtra) with special reference to their mode of origin, but also compared them with identical rocks of Kutch, Arabian coast, Islands of Persian Gulf and other tropical and sub-tropical coasts of the world. He for the first time put forth an aeolian origin for some of the carbonate sand deposits, but invoked a higher strandline. He wrote, "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". Evans (1900) believed that the miliolites were formed in shallow waters between tidal limits and were littoral accumulations, the inland deposits thus being "the product of transportation by wind action on the ancient coastal sediments".

Chapman (1900) examined in detail the miliolite rocks from different parts of Saurashtra. He thought that the worn and polished nature of the foraminifers (which originally inhabited moderately shallow to littoral marine areas) present in the miliolite limestone was suggestive of their abrasion by the transporting action of wind. He has therefore concluded that the miliolite rock represents accumulations of aeolian material derived from "littoral calcareous mud". He, however, suggested that some of the miliolitic rocks of Saurashtra coast comprised deposits in the shallow marine waters and stated that these rocks cannot be older than Late Pliocene.

RECENT STUDIES (1958-1986)

Miliolite received little or no attention for a period of about six decades after 1900. It was in 1958 when R.W. Fairbridge during his visit to India, revived the interest of geologists in these Quaternary carbonate rocks. He provided a new direction to the study of miliolite problem.

as he recognised in these rocks the potentiality of furnishing the critical data on the sea level changes during the Pleistocene and Holocene periods.

Sastri & Pant (1959) studied the miliolites, associated raised beaches and other calcareous Quaternary deposits of Saurashtra giving special emphasis on the eustatic changes in the sea levels during Quaternary period. They mapped Quaternary carbonates of Mangrol area, and concluded that the presence of raised beaches occurring at a height of 4.5 m above M.S.L. indicated an eustatic rise of the sea level during Pleistocene, and suggested that these limestones were products of Pleistocene marine transgression. On the basis of their foraminiferal content, they assigned a Pleistocene to Sub-Recent age to these rocks.

Shrivastava (1968a,b) made a detailed petrographic study of the miliolite rocks of southern Saurashtra, and considered most of them including the inland ones, to be of marine origin. According to him, these rocks comprised "a succession of mostly high energy calcarenite, calcirudites coquinoid bands, and minor carbonate mud", formed under warm, agitated and shallow waters only a few feet deep. Shrivastava (1968 b) postulated that during Pleistocene period the sea-level stood much higher than the present; the sea has since receded to its present stand and

successive younger beach and allied deposits were formed following the regressive shoreline. He further suggested that the aeolian sands interstratified with the limestone probably represent the deposits formed on the old shorelines which were submerged under the advancing Pleistocene sea. These are, now elevated above present day high-water mark, consolidated during submergence and overlain by younger beach deposits. Shrivastava (op.cit) further considered the occurrence of these rocks along the coastal plains and in the inland areas of Saurashtra as indications of " a higher stand of the sea during Pleistocene time than at present". He attributed this sea level rise to the Quaternary tectonism, postulating down-faulting of 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 times, which according to Shrivastava (op.cit) is still continuing.

Hardas & Merh (1968) encountered a few occurrences of miliolite around the city of Bhuj in Kutch and considered them to be a product of marine deposition in an inland shallow east-west creek, or lagoon during Pleistocene or Sub-Recent times, either due to a rise in sea-level during the post-glacial period of due to subsidence of

Kutch region. They have considered the rock to comprise a chemically formed marine limestone that could be named as "sandy fossiliferous oomicrites". These workers have referred to the pelletised and micritised shells as oolites. For the cross bedding so characteristic of aeolian dunes, these authors have suggested that the fluctuations in the stream which brought the material from the nearby hills could very well have caused the cross bedding.

Agrawal (1969, 1971) dated some of the aeolianites of Kutch by C^{14} method and assigned Late Pleistocene age to them. The C^{14} dates of dead corals and shells from the raised beaches of Saurashtra carried out by Gupta (1972, 1977) indicate higher sea-level during the Late Quaternary, and not uplift of the coast during Recent times.

In his book on 'desert sedimentary environments' Glennie (1970, p.130) has described miliolites of Kutch and Saurashtra. He has supported Evans (1900) and stated that these calcareous sands (miliolite) of Western India are of aeolian origin. He has very aptly commented that " 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 the wind during a polar glacial period, seems a much more reasonable hypotehsis to account for their presence".

The first ever systematic and somewhat detailed study of Kutch miliolites was made by Biswas (1971) of O.N.G.C. He visited several occurrencesof miliolite rocks scattered over the highland areas of Kutch. According to him, the miliolites comprise "peletoidal calcareous sandstone" consisting essentially of quartz, calcareous pellets and cement. He found the pellets to be rounded foraminiferal tests, and according to him all the Kutch occurrences were aeolian or fluvio-aeolian deposits; the source of sediments for these deposits was the beach sands of Saurashtra coast. Biswas (op.cit) invoked strong north-westerly winds for transporting these calcareous sands from Saurashtra coast to as far north as Kutch and to the various islands in the Great Rann. According to him, the coastal rocks of Kathiawar might have been formed earlier than the inland miliolites of Kutch and Kathiawar; sediments for the inland miliolites being derived from the disintegration of coastal limestones. On the basis of stratigraphic

relationship, palaeontological and geomorphological studies, he assigned a Late Pleistocene to Early Holocene age for these miliolite rocks. According to him, the miliolite rocks of Kathiawar coast might have been deposited in a beach environment but the inland occurrence of Kathiawar and Kutch are of different origin, and the evidences tend to show aeolian to fluvio-aeolian environment for their deposition.

Lele (1973), studied the miliolite rocks of Bhadar valley and Chotila hill in Saurashtra and believed that these rocks were the product of sub-marine (shallow marine) / littoral environment sedimentation, by the transgression of the sea from southern and western side of the Saurashtra peninsula and consequent submergence of its different parts during Early Quaternary. He assigned the Pre-middle Palaeolithic age to miliolite rocks of Saurashtra on the basis of his archeological findings. To explain the miliolite occurrences situated 300 m above M.S.L. at Chotila, he invoked tectonism. Goudie et al. (1973), have described an interesting Fossil dune morphology of miliolite deposits in Una-Veraval area.

Sperling & Goudie (1975), while commenting on the work of Lele (1973), categorically differed from the

latter, and postulated aeolian deposition of all high-level miliolite occurrences. They have stated that "there are sound arguments in favour of an 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), on the basis of their study of the Quaternary formations of the Lower Hiran Valley in Saurashtra, have invoked a marine origin for the miliolite. These authors, however, do not rule out the possibility of a part of the miliolite being " an aeolian coastal dune deposit, but not for above the zone of coastal environment".

Verma et al. (1976) have described limestones of the southwestern part of Saurashtra, and invoked a marine origin for these rocks.

Rajaguru & Marathe (1977) and Marathe et al.(1977) investigated the miliolite of Hiran river valley of Saurashtra. On the basis of field and laboratory (geomorphological, petrographical and archaeological) characters of the miliolite, they concluded that " the miliolite from the Hiran valley upto 40 km inland and about 100 m above M.S.L. seem to have formed in fluctuating

high energy littoral and coastal dune environment to low energy tidal flat environment". On the basis of the discovery of lower palaeolithic tools (Middle Pleistocene) in rocks below the miliolite limestone, they have suggested that miliolite limestones of higher reaches were of Middle Pleistocene age, while coastal miliolites are of Late Pleistocene age. They have also come to the conclusion that an early man saw the relationship between land and sea changing at least twice in the coastal parts of southern Saurashtra.

Agrawal & Roy (1977) carried out the SEM studies of quartz grains of coastal as well as inland miliolites of Junagadh, Dungarpur and Chotila areas and concluded that the inland miliolites are definitely deposited by aeolian processes.

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

According to Verma & Mathur (1978), the occurrence of miliolite limestone at varying height above the present sea level is on account of eustatic changes of sea level

during the Quaternary and believe that epierogenic movements might have raised the heights of marine miliolite deposits to some extent.

Mathur (1978) and Verma (1979) in their doctoral theses, have described in great details the field and laboratory characters of south Saurashtra miliolites, and believe that these rocks are deposited by both marine as well as aeolian processes. The former has also described the present day beach sands which are quite identical to miliolite material.

Merh (1980) has ideally reviewed the entire miliolite problem of Kutch and Saurashtra in his presidential address to the Geology and Geography section of the 67th Indian Science Congress. He has summarised that "the miliolite occurrences comprise both marine and aeolian. Even the inland miliolites of Saurashtra and Kutch, are the product of marine accumulation near higher strandlines.....the so called oolites of the miliolite rocks are mostly 'peloids' and these have originated by a process quite different from that which would give rise to ooliths. The peloids have been derived from the foraminifera shells by a process of abrasion, rounding and recrystallisation. This has got considerable environmental significance. Relatively low oolith content and dominance of peloids derived from shells,

point to a shallow marine environment which was not conducive to the colitisation of carbonate precipitates.. .....the fact that miliolites, marine and aeolian must have accumulated in several instalments related with the sea-level fluctuations". He (Merh, 1980) recognised five likely levels of marine miliolite occurrences in Kutch and Saurashtra as under:-

1.	150 to 200 m	(Kutch; Chotila; Bamanbore)
2.	55 to 60 m	(Barda hills; Junagadh)
3.	35 to 45 m	(Hiran Valley)
4.	5 to 6 m	(SW coast of Saurashtra; Kutch)
5.	2 to 3 m	(" " " ")

He has stated that "it is most probable that the various higher strandlines that are indicated by miliolites in Saurashtra and Kutch, point to a combination of eustasy and tectonism".

Ganapathi (1981) and Ganapathi & 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.

The work of Desai et al. (1982) on some of the Kutch miliolite occurrences is of significance. On the basis of field and laboratory studies and microfaunal assemblages of

miliolite rocks, these authors suggested that the low lying valley fill sheet miliolite deposits were of marine origin, whereas those abutting against the hills and ridges comprised obstacle dunes. According to them the occurrence of marine deposits at different levels, could be on account of the isostatic uplift and differential neotectonism.

More recent works on miliolites are those of Deshpande & Sharma (1984), Ganapathi et al. (1984), Mathur et al. (1986), Deshpande & Biswas (1986), Baskaran (1986), Somayajulu (1986), Bhattacharya (1986), Baskaran et al. (1986), Pandya & Bastani (1986) and Allahabadi & Patel (1986).

Deshpande & Sharma (1984), have attempted to describe the stratigraphy of the Quaternary carbonate (miliolite) strata of western, southern and south-western coastal region of Saurashtra. They believe that these rocks are of Mio-Pliocene and Pleistocene age, and have undergone both high energy intertidal and supratidal deposition.

Ganapathi et al.(1984) have stated that the sheet miliolite deposits of Saurashtra both along the coast and river valleys were deposited in a marine environment, their height difference being related to the differential uplifts/ subsidences on account of the vertical neotectonic movements along numerous faults that have cut the Saurashtra peninsula

into several segments.

Mathur et al.(1986) who worked on the Quaternary stratigraphy of southern Saurashtra, have stated that the miliolite and Chaya Formations were deposited in or at near the strandline of a shallow Quaternary sea which fluctuated due to eustatic changes.

Deshpande & Biswas (1986) have thrown more light on the origin of the miliolite rocks of Kutch as well as Saurashtra. They believe that the miliolite occurrences of coastal region of Saurashtra were deposited in shallow marine intertidal and lagoonal environments, whereas the inland deposits were the recycled coastal marine deposits by aeolian and fluvial processes during Holocene.

As the miliolite comprise too complex a material to provide dependable radiometric dates, not much reliance can be placed on C^{14} method. Baskaran (1986), Somayajulu (1986), Bhattacharya (1986) and Baskaran et al. (1986) have arrived at reasonably dependable ages for miliolites on the basis of Th-230/U-234 and C^{14} both for Saurashtra and Kutch. Baskaran's (1986) studies seem to be most pertinent to the age problem of miliolite. According to him the miliolite deposits show following three ages.

1. 60 ± 10 K yr.
2. 95 ± 15 K yr.
3. 170 ± 30 Kyr.

The present author along with his associates (Allahabadi & Patel, 1986; Pandya & Bastani, 1986) has recently published his findings pertaining to the (i) aeolian origin and (ii) allochem content of miliolites, details of which are given in this thesis.

PROBLEMS AND CONTROVERSIES

The review of available literature on miliolites of Saurashtra and Kutch highlights the following problems.

1) Are all the miliolites marine or aeolian or some of them are marine and some are aeolian?
2) Do inland miliolites occurring at various heights comprise marine accumulations related to higher strandlines or they comprise aeolian deposits having been transported for long distances by strong winds?
3) Do indication of high strandlines establish that the sea had risen to those heights in the past or the present day high strandline positions are on account of isostatic and/or neotectonic uplifts?

4) How far the granulometric and petrographic characters provide clues towards establishing marine or aeolian deposition?
5) What are the factors responsible for the abrasion of bioclasts and their subsequent micritisation?
6) Do miliolites contain oolites and pellets?

Most of the previous workers, though having contributed significantly to the knowledge on miliolites have somehow carried out generalized studies. The present author being considerably benefited by the contribution of all the previous workers has in this thesis made an attempt to describe in extenso intrinsic sedimentological and diagenetic aspects, thereby trying to unravel some of the problems portrayed above.