PLATE I.1

A part of crescent shaped mound of miliolite limestone (Loc: Limestone Quarry, 4 km NNW of Delvada).
CHAPTER I

INTRODUCTION

PURPOSE OF STUDY

The southern Saurashtra coast between Una (Junagarh district) and Jafarabad (Amreli district) exposes within a short geographical span, great deposits of nearly pure carbonate sand and mud, consolidated and unconsolidated, in diverse geomorphological settings and of a variety of petrographical types. This area is exceptionally interesting and important as one of the most outstanding regions having deposits laid down in the warm, shallow, lime-depositing seas of a not very distant geological past, and which have
been in part heaped up into long fossil dunes which in their preservation have perhaps only few parallels in the world. Easy accessibility and general convenience of working conditions have rendered this area ideally suited for the studies of this unique phenomenon of carbonate deposition.

The nature and origin of the Quaternary carbonate deposits of the Saurashtra coast, have remained controversial for the last several decades. Comprising one of the most unique Quaternary deposits of the world, these have baffled the geologists in the past. The Saurashtra coastline typically marks an area of continued carbonate sedimentation since the Pleistocene times, and the processes then initiated are still continuing. Thus, this unique area affords an ideal site for the carbonate sedimentologists. Ever since Carter (1849) and Fedden (1884) mapped Saurashtra and described these coastal carbonate deposits and 'miliolite limestone', geologists have been arguing about the mode of origin of this 'fine oolitic freestone, almost free from sand and other particles, the nuclei of the oolitic grains being mostly organic'. A number of workers — geologists and archaeologists, have attempted to delve into the secrets of the
origin of these Quaternary deposits. But carbonates being a difficult material to study, the problem has still remained unsolved.

Carbonate deposits having somewhat identical mode of origin and other characters as those of Quaternary of Saurashtra are known from several tropical and subtropical shores in other parts of the world. They are mostly concentrated between the latitudes 30°N and 30°S. The Pleistocene limestones of Floda coast, Great Bahama Banks, Bermuda, Mediterranean coasts of Israel, shores of Sinatic peninsula near the northern end of the Gulf of Suez, Mauritius Island and Western Australia are some well known occurrences. Their modern analogues are being formed on these shores.

Within the last quarter century, the study of the Quaternary carbonate sedimentology of the above regions, especially that of Florida, Caribbean Islands and Western Australia, has advanced rapidly. These significant advancements particularly within the last decade, have been the result of both technological progress in refinement of equipments used in underwater observations and collection of samples, and the improved methods used in describing and analysing carbonate rocks and sediment samples. The
realisation, in recent years, that the Quaternary carbonate sediments of Western India offer excellent scope for the study not only of their genetic aspects, but also for the study of paleoclimates and such global phenomenon as the sea-level changes during Quaternary, has induced an interest in several workers. This is rather a welcome development, an overdue change in the attitude of Quaternary Scientists after a long apathy towards these sediments which are unique in more than one way.

The present study is a part of a much bigger programme aimed at unravelling the mysteries of the carbonate sedimentation in Saurashtra during Quaternary. The investigation, restricted to one of the crucial areas, was primarily undertaken to solve the problem of the origin of 'miliolite' - the most dominant and important constituent of the Quaternary carbonate deposits of Saurashtra. Previous workers have been debating on this issue. Some have laid emphasis on the marine origin, while others have suggested that these are dominantly aeolian. The truth however, appears to be that deposits of both marine and aeolian origin coexist. Obviously, these carbonates were laid down under shallow marine
conditions and were subsequently reworked by wind to form aeolian deposits. The real problem is then, to differentiate the ones of marine from those of aeolian origin and this is perhaps the most difficult problem in the environmental analysis of limestones. This is mainly because there are very few systematic and integrated studies of the sedimentary structures, textures, petrology and geometry of these coastal deposits.

In the past, geologists have argued for and against the marine or aeolian origin, mainly on the basis of their observations on the intriguing occurrences of 'miliolite' from the interior Saurashtra. The coastal 'miliolites' have been generally taken as marine, whereas the higher altitude occurrences of marine 'miliolites' have raised several doubts. A direct consequence of establishing the marine origin of some of the miliolite deposits of higher altitudes, is on the neotectonics of region which has ultimately brought the eustasy into fore-front. If the arguments in favour of marine theory of high level miliolite are accepted and tectonic stability of Saurashtra during Quaternary proved beyond doubt, the eustasy then must explain this higher strand line in
Saurashtra. This puts the advocates of eustasy in a bigger dilemma. Has the sea ever risen to heights beyond 100 m any time during early Quaternary? This moot question requires answer.

The carbonate deposits of Saurashtra are typically products of continuous geologic and the geomorphic processes that have been active along the coastal areas since early Pleistocene. The periodic rise and fall of sea level during the last 1.5 million years, have in turn given rise to a thick pile of carbonate deposits, both marine and aeolian, alternating or co-existing side by side. The process comprised formation of carbonate sediments in shallow water conditions, to be subsequently lifted up by strong winds to give rise to coastal dunes. The successive sea level changes might have repeated this process and intimately mixed up the two. In order to fully appreciate and understand the whole phenomenon, the author has conducted a detailed sedimentological study of the uncemented Recent carbonate sediments, because the textural characteristics of these Holocene deposits, not only throw light on their genesis, but also provide valuable clues to the older Pleistocene carbonate sediments,
which originated by the processes identical to those prevailing during Holocene and even to-day.

DESCRIPTION OF THE AREA

Location

Saurashtra is one of three geographic sub-divisions (viz., Saurashtra, Kutch, Gujarat mainland) of Gujarat - the westernmost state of India. Surrounded by blue waters of the Arabian Sea in the west and south, its north and east coasts are washed by the muddy waters of the Gulfs of Kutch and Cambay respectively. A narrow strip of land separates Saurashtra peninsula from the Gujarat mainland.

The area of investigation falls in the Una Taluka of Junagarh district and Jafarabad Taluka of Amreli district of Saurashtra (Fig. I.1). It is included in the Survey of India Topo Sheet Nos. 41P/1, 2 & 5 and is bounded by the latitudes 20°43'30"N and 21°00'00"N and longitudes 71°00'00"E and 71°25'00"E.

Accessibility

Una is the Taluka headquarter in Junagarh district and is approached by an all-weather metalled
road from Ahmedabad by the Coastal Highway via Bhavnagar and Mahuva. It is about 200 km from Bhavnagar (nearest Air-Port) and 400 km from Ahmedabad. Una is well connected by Metre Gauge railways from Ahmedabad via Veraval (Fig. I.1). Una is linked by Gujarat State Transport Buses with practically all the important towns of Saurashtra and Ahmedabad - the capital of Gujarat State.

Jafarabad also forms a Taluka headquarter in Amreli district which is well connected by all weather tar road with all the important towns of Saurashtra. Rajula is the nearest railway station situated 15 km NNE of Jafarabad (Fig. I.1). Jafarabad is an important fisheries centre that receives sea-vessels from all the important port-towns of the west coast of India.

**Physiography**

The Girnar Hill ranges, composed of Deccan Traps, constitute the most prominent physical feature of southern Saurashtra lie to the north and northwest of the area investigated. The highest peak in the study area is about 205 m above mean sea level. The trappean laterite forms detached ENE-WSW trending low hills near Umes, Timbi and
Balanivav villages. The Gaj and Dwarka sediments have almost been peneplained having a low gradient towards south.

Most striking physiographic features observed in Una area are the low crescentic shaped mounds of Quaternary limestones scattered over a large area in a roughly NW-SE disposition (Fig. 1.2). Rising about 5 m above the general level of the ground, these hillocks have steep slopes (about 20°) on the eastern flanks (Plate I.2a) and low angle slopes (about 5°) on the western flanks. The convexity of these ridges is invariably towards the east. At places the crescentic ridges are coalesced and form long oblique ridges. The study area is the only region in the world where the coastal dunes have been morphologically preserved. No unmistakable evidence of dune morphology has been reported in the literature so far (Martin 1968, p.811).

Near the coast two sets of sub-parallel coastal ridges, made up of semi-consolidated limestones, form a very prominent feature. They are aligned in the direction of the elongation of the active dunes (ENE-WSW elongation) which incidentally happens to be the direction
PLATE 1.2

a. A part of a fossil parabolic dune of miliolite limestone showing steep leeward slope. 5 km east of Una, southern Saurashtra

b. Coastal limestone cut into vertical cliff with wave-cut foreshore platform. Masania, Diu Island.
of prevailing winds in the area.

The coastline of the area is irregular with alternating deeply cut bays and rocky cliffs. The irregularity of the shoreline is due to the differences in the competency of the limestone and silty clay deposits of the coast. Wider bays have been scooped out in the latter deposits whereas the limestones have been cut into vertical cliffs by the strong coastal currents. The foreshore of the coastal cliffs is occupied by wave-cut terraces (Plate I.2b).

The newer tidal flats ('Rann') occupy the low ground between the coastal ridges and the creeks (Plate I.3a). Within a coastal span of 45 km between Goghala and Jafarabad, there are five creeks viz., Goghala, Baru, Buthrani and Rajparu creeks. They are hardly a couple of metres deep in their deepest channels. The coastal flats of Jafarabad and Goghala occupy the 40 sq km and 35 sq km areas respectively. Because of the periodic flooding of the muddy flats due to high-tides, helped by high aridity, dense subsurface brine forms.
PLATE 1.3

a. Tidal creek on newer tidal flat. 0.5 km NW of Hematpur Mandvi, southern Saurashtra.

b. Old tidal flat. 0.5 km NW of Hematpur Mandvi, southern Saurashtra.
The upper reaches of newer tidal flats are occupied by old tidal flats (Plate I.3b) having a very gentle southerly slope. The latter was identified on air-photos by the characteristic rill-marks (Fig. I.2) and a barren panorama.

The beaches of the area have low gradients of 3 to 5 degrees (Plate I.4a) with small berm. It is the direct reflection of the fineness of the grain-size of beach material. The coastal cliffs have steep vertical falls ranging from 10r to 70r facing with wave-cut platforms which are exposed during low-tide. Such parts of the coast are exposed to full action of currents which sweep along them and prevent the accumulation of sand (Plate I.4b).

The active dune fields of the coastal area are aligned in ENE direction from the coast. This direction happens to be the most effective direction of sand movement by the present-day wind. Occurring in the form of barchan, transverse and longitudinal dunes (Plate I.5a), the active dunes overlie the established sand/limestone of coastal region (Plate I.5b). The highest point in the coastal dune field area is 25 m above mean sea level.
PLATE I.4

a. Sandy beach profile. Hematpur Mandvi coast, southern Saurashtra.

b. Rocky coast profile with littoral dunes. Chaya coast, south-western Saurashtra.
a. Active dunes overlying the coastal limestones. 
0.8 km N80°E of Hematpur Mandvi, southern Saurashtra.

b. Active longitudinal dune. 1.5 km SW of Balana, 
southern Saurashtra.
Drainage

The area is drained by a number of small streams draining from north to south which rise from the Gir ranges and debouch into Arabian Sea. The three important streams of the area are Machhundri, Rawal and Dhanvantari rivers. The total length of these rivers does not exceed 50 km. There is no other perennial stream in the area (Fig. 1.3). None of the rivers of Saurashtra form delta. This is because of sluggish nature of the rivers with little carrying capacity resulting from the paucity of rainfall in the catchment areas. The strong coastal currents that sweep the coast also prevent the formation of delta. There is no continuous plain of river alluvial deposit on Saurashtra coast which can anywhere compare with that of East Coast of India. All the rivers are almost lost to the rann clay before entering the sea. They on the whole, deliver relatively small quantity of water and sediments to the coast at a very low level of dynamics and they tend to carry a relatively high load of dissolved salts.
Climate

The area enjoys a tropical climate with an annual rainfall of about 525 mm and mean temperature of about 25.5°C. The summer temperature ranges up to 25°C to 35°C during April to June. Most of the rainfall occurs between mid June to mid September. July receives the maximum rainfall. The temperature during winter months averages around 20°C.

The westerly and southwesterly wind blows for a maximum number of days in the year during summer and monsoon months at an average speed of about 23 km/hour. Northerly wind blows at an average speed of about 12 km/hour during winter months. The westerly direction forms the most predominant wind direction and the mean vector comes out to be 68°N.

Flora and Fauna

The sandy soils of the coast support xerophytic flora which are able to endure conditions of prolonged drought. A wide variety of cactus and creosote bush grow. Besides, dune stabilising halophytic and xerophytic plants which include long-rooted grasses and creepers (Plate I.6a) are grown by the Forest Department. One of the most
PLATE 1.6

a. The creeper *Ipomoea biloba* planted on active dunes to check inland sand migration. 3 km east of Hematpur Mandvi, southern Saurashtra.

b. Exotic branching palm *Hyphnea dichotoma*. Just NE of Hematpur Mandvi, southern Saurashtra.
interesting plant that catches the eyes of the visitor to the area is an exotic branching palm (*Hyphnea dichotoma*) which is growing wildly in a small span of about 100 sq km around Una-Delvada and also in the Diu Island (Plate 1.6b).

The following is the check list of flora of the area:

**Flora of Sandy Soil**

*Spinifex squarrosum* (Grass) *Borassus flabillifera* (Toddy), *Hyphnea dichotoma* (Branching Palm), *Opuntia* (Cactus), *Casuarina equisetifolia* (Saru), *Presopsis juliflora* (Bau-a), *Acacia arabica* (Babul), *Agave*, *Calotropis gigantea*, *Ipomoea biloba* (Creeper)

**Flora of Mangrove swamps**

*Rhizophora mucronata*, *R. candularia*, *R. conjugata*, *Acanthus elicitifolius*, *Sonneratia apetula*, *Aegiceras corniculata*, *Lumleza racemosa*, *Avicennia officinalis*, *A. marina*, *Ceriops roxburghiana*, *Brugaria indica*, *Salvadora persica*, *Dalbergia spinosa*, *Excoecaria agilacta*, *Clerodendron inerma*, *Sueda nudiflora*

The area under investigation is well known for marine fisheries products of commercial value. Among the major
fisheries of this zone are Bombay-duck (*Herpodon nehereus*, local name Bumla), Black Pomfret (*Parastromateus niger*, local name *Halwa/Adadio*), Silver Pomfret (*Pampus argenteus*, local name *Vichuda*), Chinese pomfret (*Pampus chinensis*, local name *Pathu*), Jumbo Prawns (*Penaeus indicus*, *P. canaliculatus*, local name Jimbo), Jinga (*Metapenaeus affinis*, *M. monoceros*, *M. brevicornis*; local name Samdi), Lobster (*Penulirus ornatus*; local name Titan).

The list of marine fishes (Elasmobranchs - sharks, skates, rays and Teleosts- Bony fishes), crustaceans (prawns, lobsters, crabs) and freshwater fishes forms an impressive list of more than 180 species.

Amongst the most prized possession of the wild life fauna of the southern Saurashtra coast are the black-bucks which are found in herds near Gupta Prayag. This species of antelope is fast nearing extinction and is found only in parts of Rajasthan deserts, Rann of Kutch and the study area.

**METHODS OF INVESTIGATION**

Before undertaking the investigation of the present area the reconnaissance of all the Quaternary carbonate
deposits of Saurashtra (Fig. 1.4) was carried out and one of the critical areas of south western Saurashtra was examined by mapping (Fig. I.5), measured traverses and petrographical studies.

An area of about 1450 sq km was geologically mapped on 1:253,440 scale between Una and Jafarabad (Fig. I.6) out of which the geomorphic units of the coastal belt were mapped on 1:30,000 scale by photointerpretation with ground checks (Fig. I.2).

The investigation of Saurashtra was commenced in 1971 as part of a larger programme of multidisciplinary studies of Quaternary carbonate sediments of Saurashtra. Detailed investigations were completed during the period 1971 to 1975 in Porbandar area (Junagarh district). The field investigations in the present area of Una-Jafarabad were carried out during 1974 and 1976.

Besides, making the systematic collection of samples from the investigated area, the cross bedding data of coastal and inland limestone deposits was collected from a number of localities which was statistically analysed. The petrographic and microfaunal analyses
of the rock samples were carried over in order to understand their nature. The unconsolidated carbonate beach and dune sands were subjected to mechanical analysis and their statistical parameters computed. Further details of the method of field collection, laboratory analysis, expression of measured data etc. are given in the chapter dealing with textural characteristic.