Chapter - III

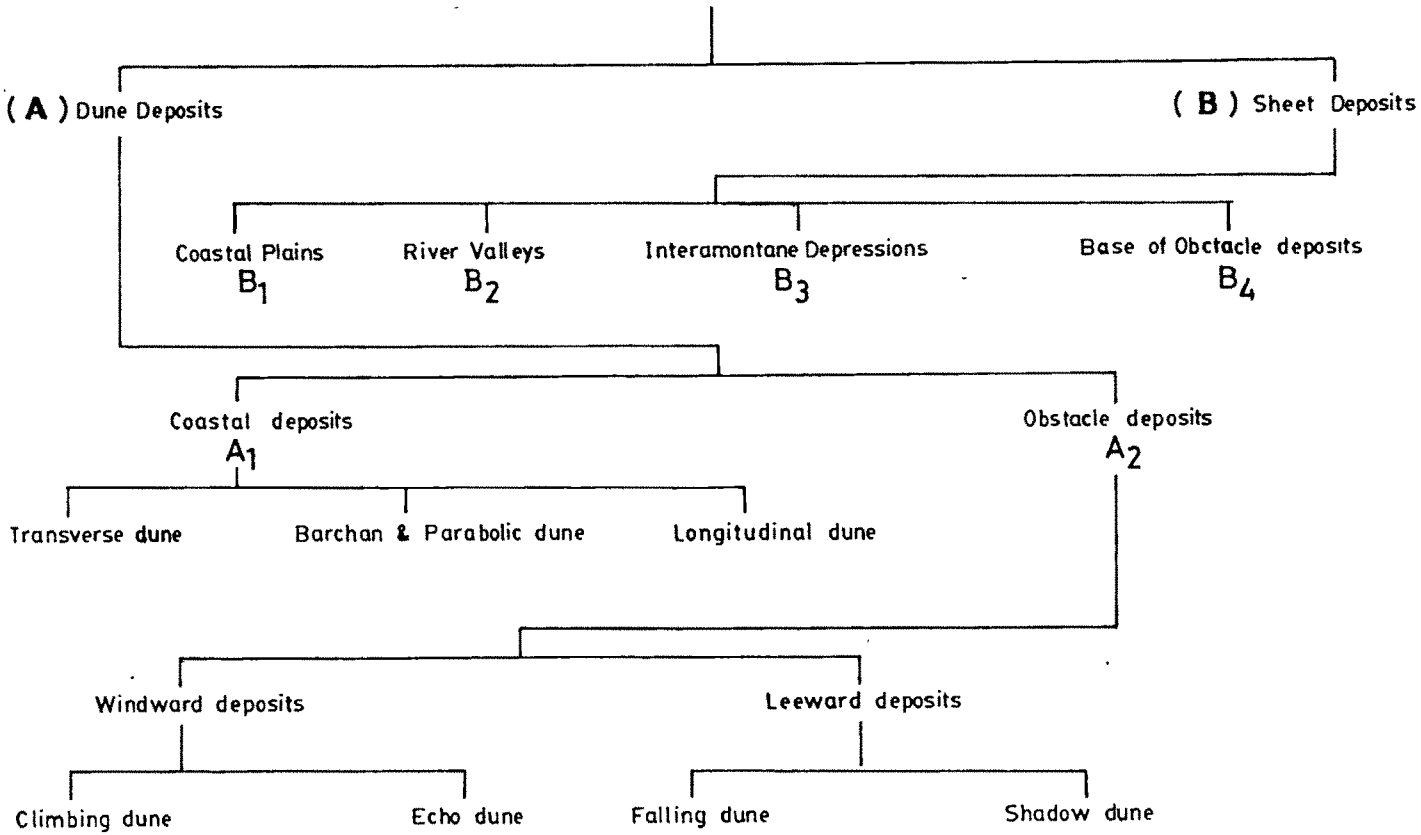
M O D E O F O C C U R R E N C E

GENERAL

Depending upon the palaeo-geomorphic expressions together with the influence of the depositional processes operated upon them and their preservation from the erosion, the three major types of Quaternary carbonate deposits viz. ancient beach rocks, miliolites and stabilised sand dunes can on a broad way be grouped into (A) Dune deposits and (B) Sheet deposits (Patel & Bhatt, 1992 a). Their formation depends upon the various factors like moisture, vegetation & nature of pavement in the area, amount of sand supply, wind velocity & directions etc. As these two types of deposits progressively grade from one to another, in the field it is rather difficult to demarcate the junction between the two. Table III.1 gives a broad picture of their modes of occurrences

Table III.1 MODE OF OCCURRENCE

(Quaternary Carbonate deposits of Saurashtra)



that have been discussed subsequently in the forthcoming paragraphs.

(A) DUNE DEPOSITS

As per Holmes (1978), dunes are mounds or ridges of sand having a crest or definite summit. They are formed due to primary aerodynamic instability (Wilson, 1973) with varying wavelengths (3 to 600 m) and heights (0.1 to 100 m). The carbonate deposits of Saurashtra, especially the miliolites and stabilised sand dunes, form coastal as well as obstacle type of dune deposits.

(1) Coastal Dune Deposits

The coastal plains of South Saurashtra are dotted with numerous exposures of miliolite limestones that show the morphology of transverse, parabolic, barchan and longitudinal dunes suggesting a desertic environment during their deposition (Fig. III.1).

(a) Transverse dunes

They form the coast parallel ridges with almost continuous crest lines, oriented more or less transverse to the prevailing unidirectional winds (Fryberger, 1980) and exhibit low to medium angled planar cross stratifications with considerable steep dips (20°-30°) on leeward side (Fig. III.1 a). Such dunes are encountered in the miliolites as well as in stabilised carbonate dunes, and are traceable on the coast between Harshad and Madhavpur suggesting southwesterly palaeowind direction. Atleast two to three such coast parallel transverse ridges have been

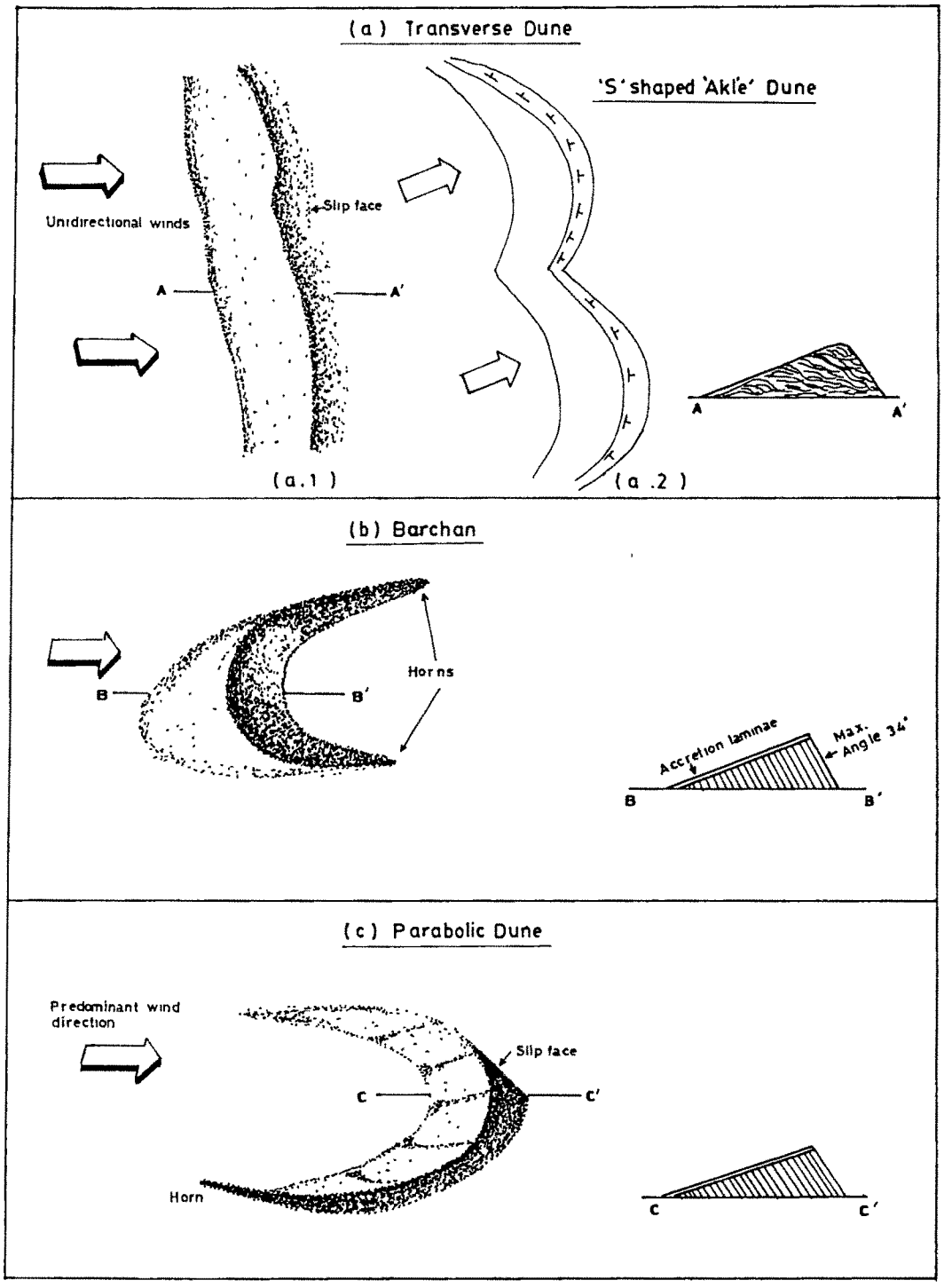


FIG III.1 GENERAL MORPHOLOGY OF VARIOUS DUNE DEPOSITS (a, b, c)

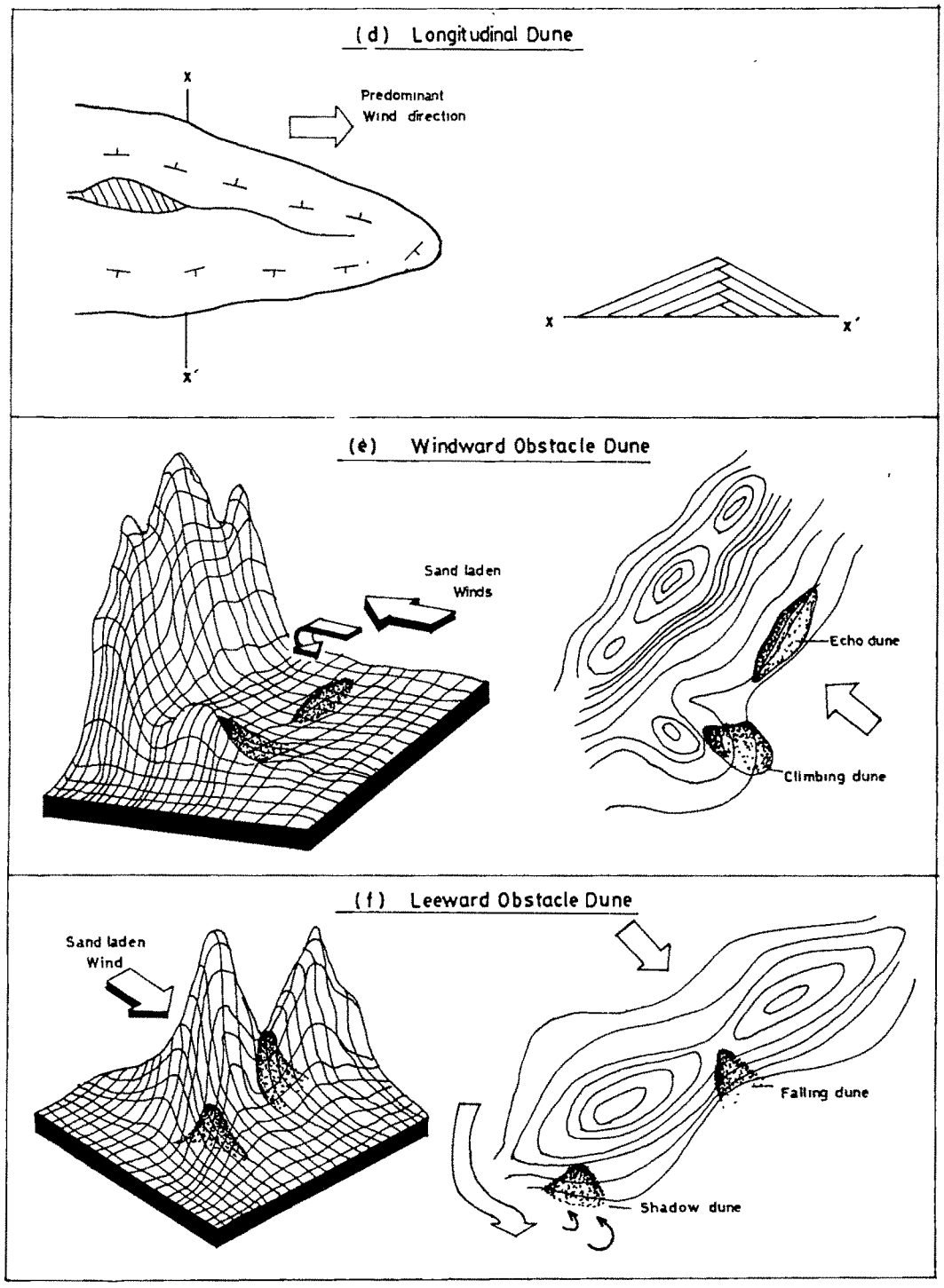


FIG. III.1 GENERAL MORPHOLOGY OF VARIOUS DUNE DEPOSITS (d, e, f)

noticed one behind another in this area. Around Madhavpur, Veraval and Kodinar, these dunes are seen modified to give rise to the typical 'S' shaped Akl'e(?) deposits which show arcuate geometry with alternating convex and concave downwind sectors (Fig. III.1 a'). These transverse dune deposits in the study area exhibit maximum thickness upto 8-10 m and width 50-100 m.

(b) Barchan and Parabolic dunes

The crescent shaped miliolite exposures occurring in the vicinity of Madhavpur, Veraval, Kodinar, Una and Jafrabad show varying dimensions, and on a closer look form either barchan or parabolic dunes. These dunes have been developed under the influence of single dominant southwesterly wind direction. The barchans possess concave slip faces with their horns extended in downwind direction (Fig. III.1 b). The parabolic dunes, on the contrary, are characterised by convex slip faces and horns extending in upwind direction (Fig. III.1 c). The individual fossil dune of such type in the study area hardly exceed 1 to 2 sq. km in lateral extent and 4 to 5 m in height. They show steep (20°-30°) leeward beddings following the shape of curved slip faces of the dunes.

(c) Longitudinal dunes

In the study area these are elongated in shape and form parallel to the dominant (or resultant) southwesterly winds; the crestline often tends to be some what sinuous with slip faces often nearer to the crest (Fig. III.1 d). These dunes are encountered in miliolites around Varwala, Arena, Veraval, Dolasa,

Desar and Una villages. Their beddings are inclined to either side of the dune alignment and show varying dips between 15^{o} and 30^{o}. Although in sand seas these dunes show length in several kilometers and are designated as 'seif dunes', but in the study area such dunes hardly reach upto 100 m in length.

On account of the porous - friable nature of rocks and constant wave actions, these deposits on the coastal areas form coastal cliffs & wave-cut platforms. The occurrences of submerged coastal dunes of miliolite rocks on South Saurashtra coasts also conspicuously reveal a lower strandline during their formation.

(2) Obstacle Dune Deposits

The topography, besides vegetation, plays a prime role in the deposition of aeolian sands by disturbing and deflecting the flow of the winds over and around the obstacles (Twidale, 1976). In the study area the trappean hills, Tertiary outcrops, river valleys etc. have formed the barriers to the organogenic carbonate sand bearing onshore winds to give rise to the various types of obstacle deposits. As in general the prevailing wind directions since Middle Pleistocene have remained southwesterly in Saurashtra (Mathur, 1987; Patel, 1991b; Patel & Bhatt, 1992), depending upon their occurrence on the southwestrn and northeastern side of the obstacles, these deposits are further classified as (a) Windward and (b) Leeward deposits respectively. The areas having the obstacles of low relief possess both, windward & leeward deposits whereas that of high relief are characterised by only windward deposits. These further merge into sheet deposits at their lower margins. The shape, thickness and extent of these deposits vary

from exposure to exposure and are controlled mainly by the site of deposition.

(a) Windward deposits

Based on their typical shapes and the processes responsible in featuring these windward deposits, two separate descripto-genetic terms as per Allen (1970) and Collinson (1986), have been applied as (i) climbing dune and (ii) echo dune.

The *climbing dunes* rest directly on the windward slopes of the hills occupying notches and depressions (Fig. III.1 e). They are triangular in shape, thickest in the middle part and gradually thinning out at their upper & lower margins. They exhibit wedge type planar cross stratifications with foreset dips ($5^{o}$to 35^{o}) due upwind directions. Such climbing dunes in Saurashtra miliolites are encountered at Harshad, Gop, Patan, Rakka, Chotila, Chobari, Chichod etc.

The *echo dunes* form a special type of windward deposits which are separated from the slope of the obstacle having their axis transverse to the wind direction and forming a gully or depression in between (Fig. III.1 e). They are formed due to the back flow of sand transporting wind currents after their striking to the obstacles, thus represent the echo of the sand laden winds. These are characterised by 'herringbone' (Shrock, 1948) type of cross stratifications showing their dips in upwind as well as in downwind directions. The miliolite rocks of Girnar (Dungarpur) and Barda (Adityana-Ranawao) hills form typical examples of echo dune deposits in Saurashtra.

(b) Leeward deposits

In the study area the leeward deposits are encountered where the southwesterly sand drifts have crossed the obstacles either due to their low relief or through the saddles of the hilly terrain where the wind borne material falls and accumulates on the leeward slopes and reaches upto the base of the obstacle, grading further to the sheet deposits (Fig. III.1 f). Allen (1970) and Collinson (1986) have described such dunes as *falling dunes*. The falling dune and the climbing dune may co-exist on opposite sides of the obstacle, however, depending upon the nature of slope & wind energy, the upwind side sometimes form wind deflated (winnowed) area. They are thinner at their upper and lower margins and show varying thickness (2 m to 20 m) in their median portion. The falling dunes are characterised by the tabular planar cross stratifications and their beddings generally show curved nature, following the shape of the depression (Plate III.1). At Bamanbor, Chobari, Rakka, Khatiya, Patan, Patanvav, Ambla, Piparla etc., the falling dune deposits constitute good miliolite quarries.

A special type of leeward deposit formed at the edge of relatively higher obstacle on account of the pressure difference created between wind shadow region and the sand drift is described as *shadow dunes* (Fig. III.1 f). In the study area, such miliolite deposits are encountered at Chobari, Sanosra, Rakka, Dhuniya, Alech hills etc. They show planar wedge type cross stratifications with low to moderate (5^{o}-20^{o}) downwindward dips (Plate III.2).

Plate III.1

The falling dune deposit occupying topographic depression (Loc. Harshad)

Plate III.2

Wedge type cross-stratifications in a shadow dune deposit of miliolites (Loc. Nava Dhuniya)

(B) SHEET DEPOSITS

The sub-horizontal to low angled thinly bedded rocks of varying thickness constitute the sheet deposits. In the study area, the beach rocks and miliolites at many localities exhibit this type of form. In miliolites, they are encountered at varying altitudes occupying the coastal plains, river valleys and depressions in the hilly terrain. Because of their nearness to the watertable, these deposits, in comparison to the obstacle deposits, are rather more compact and difficult to break. Depending upon their site of deposition they have been further categorised into :

(1) Sheets on the coastal plains,

(2) Sheets in the river valleys,

(3) Sheets in the intramontane depressions and

(4) Sheets at the base of obstacle deposits.

(1) Sheets on the Coastal Plains

The ancient beach rocks and miliolites form this type of deposits in the vicinity of the coast that rest either on older rocks (Traps, Gaj, Dwarkas) or on palaeosol. They show variable thickness (1 to 8 m) and gentle (5^{o} to 15^{o}) seaward dips (Plate III.3). At some localities (Baradia, Harshad, Ratadi, Porbandar, Madhavpur, Mangrol, Kadwar etc) they are even seen extended towards sea below the present shoreline, while their landward extension reaches upto 40-50 m contour on 10 to 15 km wide coastal plains where they form gently windward dipping miliolite sheets

Plate III.3

Gently seaward dipping coastal sheets of beach rocks
(Loc. Baradia)

(Plate III.4). On a closer view they show minor low angle aeolian cross laminations (Plate III.5). A few exposures of such miliolites are also encountered in the interdunal depressions around Porbandar, Mangrol, Chorwad, Veraval and Kodinar areas.

(2) Sheets in the River Valleys

The majority of the older river valleys in Saurashtra have provided appropriate sheltered sites for these isolated & patchy exposures of aeolian accumulations. In a general way they show sub-horizontal to gentle downstreamward dips depending upon their sites of deposition. The careful scrutiny of most of these valley fill sheets reveal the presence of aeolian cross stratifications. Such sheets are alternately bounded by thin horizontally bedded pedogenised layers comprising fluvial material (sandy silt/ kankar/ gravel etc). These alternate aeolian and fluvial cycles form a typical 'wadi' style of deposits (Glennie, 1970) indicating small periods of quiescence during the deposition of miliolite sands (Plate III.6). These deposits, in their present state, are not only found resting over the river terraces forming cliffy banks, but they are also encountered occupying the floors of the some river valleys (Singwada river near Pedhwada, Hiran river near Umrethi & Talala, Aji river near Rajkot etc.). The sheet deposits show varying thickness and extent from one outcrop to the another. In some of these rivers (Hiran, Saraswati, Machhundri, Bhadar etc) the sheets of miliolites are traceable for considerable distances and heights. Their occurrences at different levels misled some of the workers to invoke sea level changes and/or neotectonic

Plate III.4

Miliolite sheets on coastal plains showing gentle windward dips
(Loc. Moraj)

Plate III.5

Closer view of miliolite sheet showing cross-laminations
(Loc. Moraj)

Plate III.6

Intercalations of fluvial sediments in valley fill miliolites (Loc. Rakka)

activities in explaining their present disposition (Marathe et al, 1977; Verma & Mathur, 1978; Merh & Ganpathi, 1985 etc). However, Patel (1991 b) is of the firm opinion that they point to their deposition at different altitudes on pre-miliolite topography.

(3) Sheets in the Intramontane Depressions

The bioclastic carbonate sand accumulations in the intramontane depressions, form discontinuous and sporadic veneers over older rocks or palaeosol and consist of discrete patches of varying thickness, hardly exceeding 2 to 3 m. These deposits show planar wedge type current beddings with low to moderate leeward or windward dips. Some of the sheet deposits form thin veneers of sub-horizontal nature in the amphitheaters like low grounds and pedeplains. These types are found in the sheltered sites amidst the hilly terrain in the vicinity of Jam Jodhpur, Rakka, Khatiya, Patan (Alech), Ambla, Piparla, Bamanbor etc. (Plate III.7).

(4) Sheets at the Base of the Obstacle Deposits

Almost all obstacle deposits of miliolite limestones, windward and leeward, are progressively grading into the sheet deposits and taper out towards their lower margins till they reach the peneplained country rocks (Plate III.8). These deposits on the closer examination reveal low angle cross laminations and varying dips towards either upwind or downwind directions depending upon their association with windward or leeward deposits respectively.

Plate III.7

Miliolite deposits in the intramontane depressions
(Loc. Navagam near Bamanbor)

Plate III.8

Windward obstacle miliolite deposits merging into
sheet deposits at Patan (Alech hills)

These deposits are encountered in almost all localities associated with obstacle dune deposits especially at Dungarpur, Ranawao, Adityana, Alech hills, Osam hills, Gop hill, Ambla, Chamardi, Bamanbor etc.