CHAPTER - 6

BEACHROCKS STUDY

CHAPTER - SIX

BEACHROCKS STUDIES

SCOPE OF STUDIES

Beachrocks are consolidated deposits that result from lithification by calcium carbonate of sediment in the intertidal and spray zones of mainly tropical coasts. There are several articles that summarize the occurrences of beachrocks and review their probable origin. The most notable are Dana; (1851), Branner, (1905); Daly (1924); Kunen, (1950); Ginsburg, (1953); Illing, (1954); Emery et. al, (1956); Tanner, (1956); Russell (1959 1962, 1963,1965); Stoddart, (1965); Cooray, (1968); Alexanderssion, (1969); Scoffin, (1970); Schmatz, (1971); Siesser, (1971); Bathurst, (1971); Davies et.al, (1973); Moore, (1977); Hanor, (1978); Krumbein, (1979); Longman, (1980); and Beier, (1985). Similar occurences have been also reported along Bombay-Ratnagiri coast by several workers in the past (Theoblad, 1872; Blandford, (1872); Fedden, (1884); Foote, (1890); Ahmed, (1972); Power et al., (1978); Badve and Ghare, (1984); Sukkhtankar, (1986); Fakhri and Vashi, (1988) etc.

Beachrocks studies are important tools towards a proper understanding of the paleohydrodynamics condition, sealevel changes and neotectonism. Geomorphic studies of these rocks lies in tracing Holocene shoreline. These studies have enabled the author, to throw considerable light on many aspects related to ancient strandline (Flandrian sea). In this chapter, the author has analysed representive samples from all locations for the purpose of following studies :

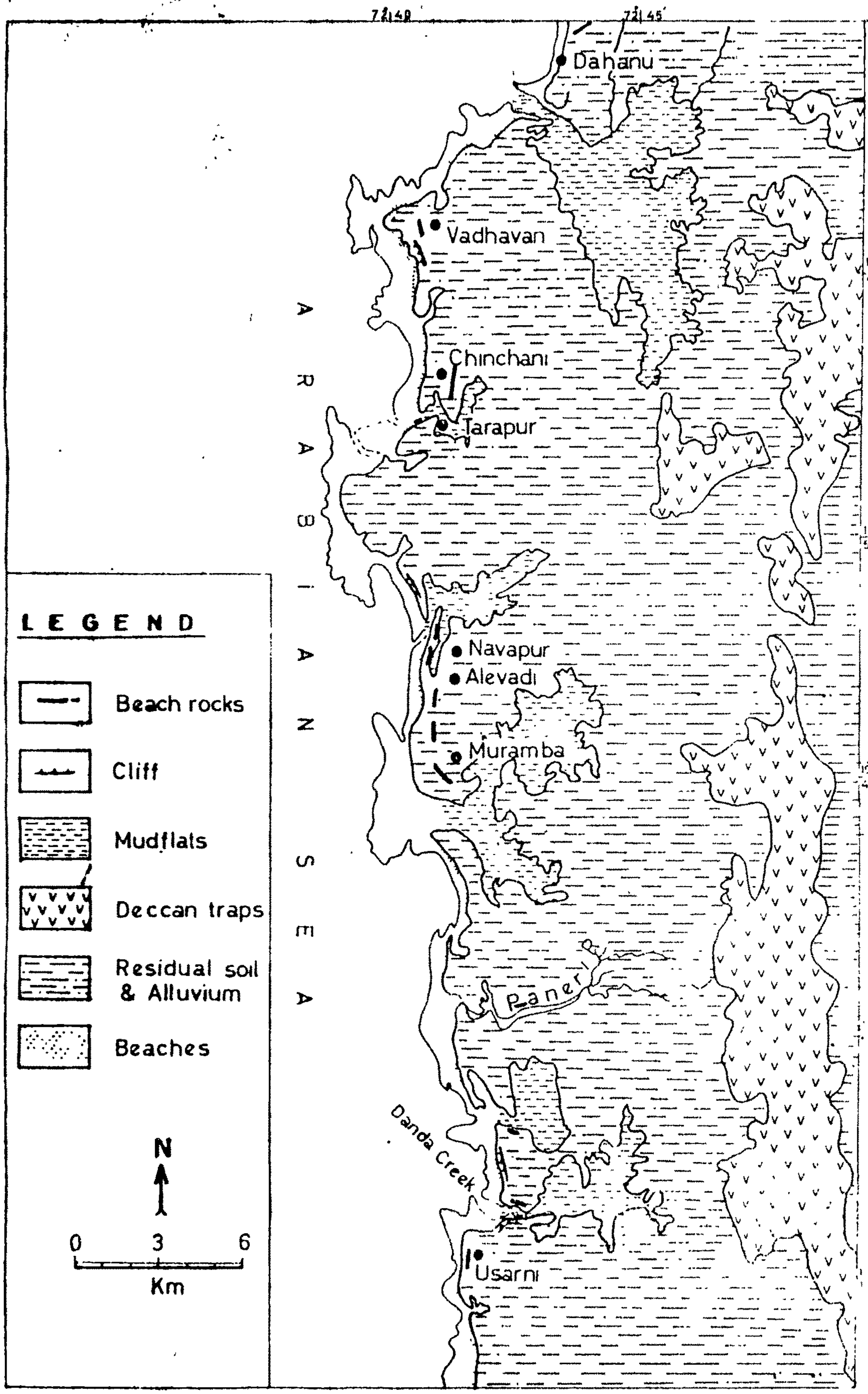
1. Petrographic studies : Routine studies of thin sections to determine the nature of various allochems, detrital particles clastic and the cement.
2. Textural studies : The sediment constituting beachrocks have been examined for their grain size characteristics which helped the authors to know the variation in hydrodynamics system prevailing at the time of deposition. The studies on the surface texture of quartz grains have also been done to know environment of deposition of these rocks.

FIELD OCCURRENCE

The occurrence of beachrocks in the area observed at Dahanu, Vadhavan, Chinchani, Navapur, Alevadi, Muramba, Mahim, Paneri, Danda and Usarni (Fig.VI.1). They occur as small patches and

FIG·VI·1

OCCURRENCE OF BEACHROCKS ON DAHNU-USARNI COAST



isolated thin beds dipping seaward (5° - 10°) and ranges in thickness from 0 to 4m. The beach rocks occurs in the intertidal zone as well as in landward as far as 200m to 700m from present coastline. This beachrocks deposits are found 2 to 8m high above mean sea level and comprise the well bedded rudaceous rocks with bioclastic intercalation of varying size. These layers contain the pebbles and cobbles of trappean rocks embeded in clastic material derived from the inland areas. These beachrocks exhibit well defined sedimentary structures like cross stratification and parallel lamination.

The author would like to give the detailed description of field occurrence of important outcrops of beachrocks in the different localities of the area.

1. **Dahanu Beachrocks**

These rocks are composed chiefly of quartz, skeletal fragments, heavies cemented by micrite, sparite and silica. The rocks are exposed in discontinous manner almost 2 metres above mean sea level. They show no signs of bedding and are having thickness of about 50 cm. They are moderately consolidated and located. 400-700 m away from Dahanu creek. Same material of beach rocks found in Semiconsolidated form exposed at low tide near creek mouth (Plate VI.1).

2. **Vadhvan Beachrocks**

These beachrocks are found in patches and are approximately 4m wide and 100m in length. They are exposed 2m above mean sea level and are composed chiefly of allochem, detrital and cement.

3. **Chinchani Beachrocks**

Chinchani beachrocks consist mainly of broken shells, rock fragments (mostly basaltic fragments) and quartz. The grain size varies from fine to coarse sands and occasionally congolmeratic (Plate VI.2). They are seen to rest over the Deccan trap platform near the mouth of Tarapur creek. They show a sea ward dip of about 7 and exposed to a height of 8 m above mean sea level. Normal sedimentary structures such as bedding and cross stratification have been recorded. The average thickness of outcrops is about 4m and have a width of 30 m and a length of 300 m. This rocks are moderately consolidated and have undergone considerable destruction and sand removal.

4. **Navapur Beachrocks**

The rocks here are found in the intertidal zone at Navapur creek mouth. Occurring slightly high-tide line they are composed chiefly of skeletal fragments and minor amount of quartz grains. These rocks are highly compact and show cross laminations with an average seaward dip of about 8° to 10°.

PLATE : VI.1 Semiconsolidated sediments exposed during low tide (locality : near Dahanu).

PLATE : VI.2 Congolmeratic beachrocks of Chinchani resting over the Deccan trap platform.

5. **Alevadi and Muramba Beachrocks**

These beachrocks are composed chiefly of skeletal fragments, quartz and calcreous cement. The rocks are found 300 - 500 m away from coast line. They are about 2 m thick and are found in patches (approximatly 7 metres wide, and 60 metres long). The rocks show normal bedding dipping 6 to 9 seaward and are moderately consolidated. They are seen to have undergone considerable destruction and sand removal.

6. **Paneri and Mahim Beachrocks**

The rocks here are found on the banks of Mahim creek and Paneri river and are exposed slightly above high tide line. They are composed almost of biogentic material and are cemented by sparite. They are 1-2 m thick and shows thin bedding within them (Plate VI.3). They occur almost in the form of ria deposit.

7. **Danda Beachrocks**

Danda beachrocks consist mainly of basaltic rockfragments, quartz grains and broken shells. The rocks occur as vertical cliff section running parallel to the coast as well as on the banks of Danda creek (Plate VI.4). The second category shows landward decrease in thickness from 3m to 1m. They are medium to coarse in size with Pebble fragments varies from 2mm to more than 3cm in diameter. Red soil is marking the top of these rocks while heavy concentration of black sand is seen at base. They show a seaward dip of about 5 and are exposed to a height of 4m

PLATE : VI.3 The beachrock exposed on the bank of Mahim creek.

PLATE : VI.4 The exposure of beachrock on the bank of Danda creek.

above mean sea level. Normal bedding with coarse shell fragment at the base have been recorded. They are moderately consolidated and have undergone intensive erosion especially rocks which are facing southwest wind direction.

8. **Usarni Beachrocks**

Usarni beachrocks consist mainly of biogentic material, few rock fragments, and quartz. They are exposed at a height of 5m above mean sealevel and having thickness varies from 1m to 3m. Normal sedimentary structures (bedding) have been recorded with slightly seaward dip. This rocks are moderately consolidated and have undergone considerable erosion, they are covered by thick layers of recent sand (Plate VI.5). At some places these rocks occur as vertical cliff (Plate VI.6) due to intensive wave action.

PETROGRAPHIC STUDIES

The Petrographic details of the beachrocks have been obtained on the basis of the routine thin section studies to know the constituents of beachrocks such as allochems, detrital particles and cement.

(A) **Allocheme**

Allochemical components or allochems are organized aggregates of carbonate sediment which have formed with in the

PLATE : VI.5 The moderately consolidated beachrocks covered by thick layers of recent sand (locality

PLATE : VI.6 The beachrocks showing a vertical cliff at Usarni.

basin of deposition (Folk, 1959, 1962). The allochems of the beachrocks are mostly bioclasts and peloids.

The bioclasts are the remains complete or fragmented of the hard parts of carbonate secreting organisms. The present author considered the following feautures to identify bioclasts.

(i) The overall shape and size of the particle.
(ii) The internal wall structure of the particle.

The bioclasts of the beachrocks of the area comprise mainly broken and abraded molluscan fragments, foraminifera, Echinoderm spines, bryozoa, corals and Algae, etc.

Molluscan bioclasts are common components of beachrocks, these bioclasts are rounded to well rounded and commonly exhibit grey to yellow colour in thin sections, and occur as circular, elliptical, crescentic or elongated grains, Foraminiferal tests show a variety of shapes and wall structures. The grains are of white, grey and brownish colour.

Echinoderm spines in thin section exhibit a wide variety of shape circular, elliptical or rod like. The spine fragments are of grey or brownish yellow colour and the various rings show optical continuity.

Corals are only sporadic and poorly preserved. Most of which have been recrystallised in to sparite.

Algae is characterised by grains of grey colour and reticulate appearance.

Peloids are grains composed partly or entirely of micrite, but having no concentric laminae in their outer most zones. In thin section some grains lack any recognizable internal structure and composed of micrite called peloids. They are circular or elliptical in shape and averaging about 0.1mm in diameter. Such peloids are generally interpreted as faecal in origin and are called pellets.

(B) **Detrital Particles**

The detrital particles of beachrocks consist mainly of quartz, trap fragments, and a few minerals like plagioclase, augite, hornblends, aragonite, calcite, zircon, magnatite and hematite etc... joined together by mirite and/or spariy micritic cement (Plate VI.7).

Quartz occurs in subordinate amount either as tiny micro-crystalline grains (Plate VI.8) or as ground mass. Plagioclase are found as scant grains with augite. Calcite and aragenite occur as interstitial grains forming the well developed crystals. They are mostly found to occur as cement. Aragonite occurs in abundance as compared to calcite and is characterised by fibrous

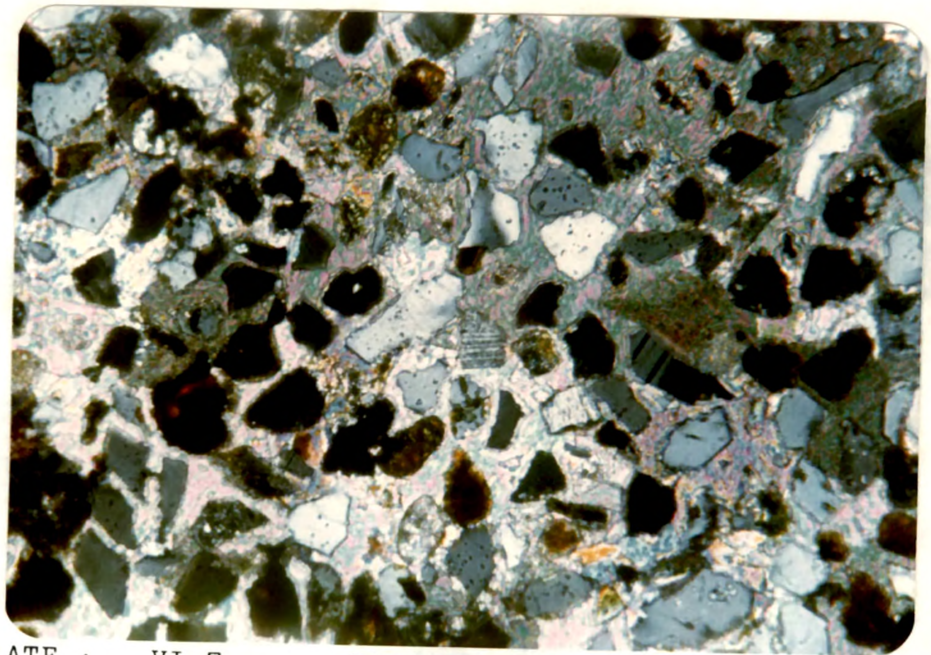


PLATE : VI.7 Photomicrograph showing detrital particles of beachrocks consisting mainly of quartz,trap fragments, plagioclase and heavies joined together by microspar cement (X 45).

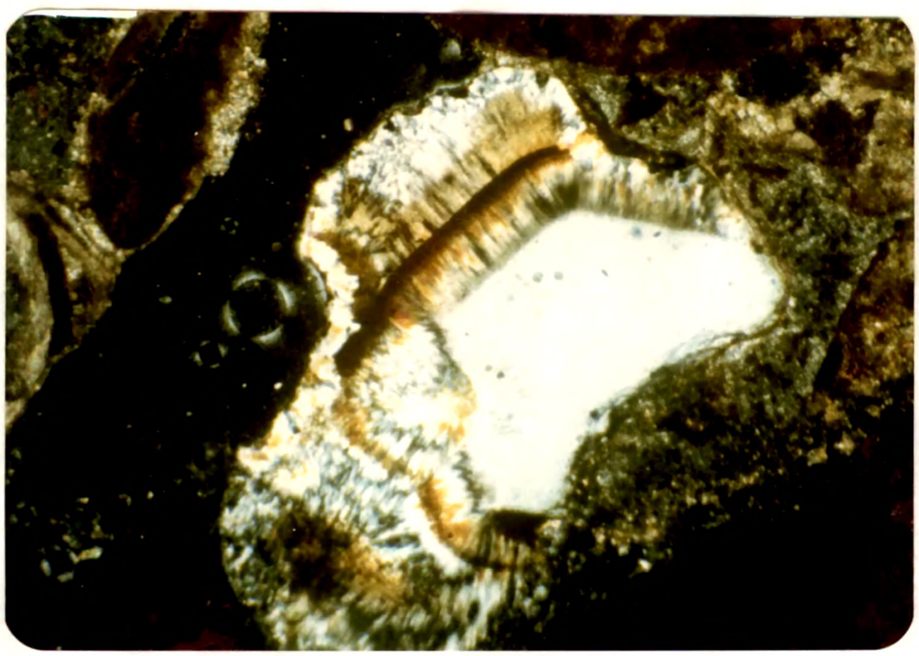


PLATE : VI.8 Photomicrograph showing microcrystalline grains (Chalcedony) occuring as a subordinate amount in the beachrocks (X 45) and accicular nature and also as microfossil replacement. The derivation of aragonite is perhaps from skeletons of bryozoans and benthic foraminifers. Magnetite and hematite also occur invariably as common heavy minerals. Magnetite is characterised by its opaque nature and steel blue and black colour while hamatite is recognised by its steel blue, red and black colour. Pebbles and cobbles of mostly trappean rocks embedded in clastic materials derived from inland areas seen in these rocks.

(C) Cement

The nature of the cement is divided into following two categories :

1 - Micrite : A microcrystalline of opague, generally formed within the environment of sedimentation of beachrocks. This material costitutes the matrix of mostly bioclast micrite It originates by abrasion of bioclast. disarticulacting of skeletal parts, and diagenetic recrystallizations.

2 - Sparite : In thin section sparite are seen as crystalline cement comprising crystals larger than 10-15m micron. It is formed after deposition of the surrounding sediments as a void-filling precipitation from super saturated interstitial waters. It is also formed by diagenetic recrystalization of micrite. Evidence for such origin is seen in thin section by the presence of microspar crystals that generally represent an intermediate stage of growth from micrite to sparry calcite.

Aragonite and Mg calcite (10-14 mol % $MgCo_3$) are the two important minerals occurring as cement in these rocks. The cement occurs in following three main morphological characters. The first morphological feature of the cement of these beachrocks is micritic coating (Folk, 1965). These have acrystal size 1-4 micron and usually appear like semi opaque mud. The second morphological feature is fibrous or bladed cement, these occurs as elongated crystals aligned perpendicular to the encrusted grain surface. The width of the fibrous cement is uniform in most beachrocks in the area. Aragonite is the more common mineral occurring as fibrous fabric in these beach rocks. The third morphological character of the cement is equant type (nearly equidimensional crystals).

Cement Fabric :

The authors have studied the following six important fabrics in the beachrocks of this area.

1-Isopachous fringes

The most common cement fabric in beachrocks of Navapur, Danda and Usarni are isopachous fringes of acculiar crystals fibrous in nature around the grains (Plate VI.9). Uniform coating of grains in this way suggests that the sand in this grains was continuous bathed in water. This fibrous cement is usually deposited in the form of aragonite under hypersaline conditions or in very shallow marine water in which Co_2 can be easily expelled (Friedman, 1964)

2. Meniscus cement

This type of cement fabric is observed in the beachrock of Dahanu, Tarapur, Alevadi, Muramba Mahim, Danda and Usarani (Plate VI.10). It is characterised by uneven cements precipatating at the contacts of the grains. This fabric suggests intertidal deposition with tidal regularity. Dunham (1971) described this fabric as a result of impermanent water saturation in the fresh water vadose zone in which lobes of air take the place of water as the rock drains.

3. Gravitational cement

This pendant cement consists microcrystalline equant crytals of calcite. This type of cement is found in the beachrocks of Vadhavan where the sands are impermanently saturated during drainage a thicker film of water persists at the under surface of grains. (Plate VI.11) Precipitation from such films will develop small scale stalactites beneath grains (Purser, 1969; Muller, 1971; Taylor and Illing, 1971).

4-Micritic cement

This type of cement fabric is observed in the beachrocks of Tarpur Muramba and Usarni. In thin section these micritic rims form first generation cement as cryptocrystalline mg-calcite micritization of grains is the most extensive at grain boundaries which has ultimately given rise to micritic rims (Plate VI.12).

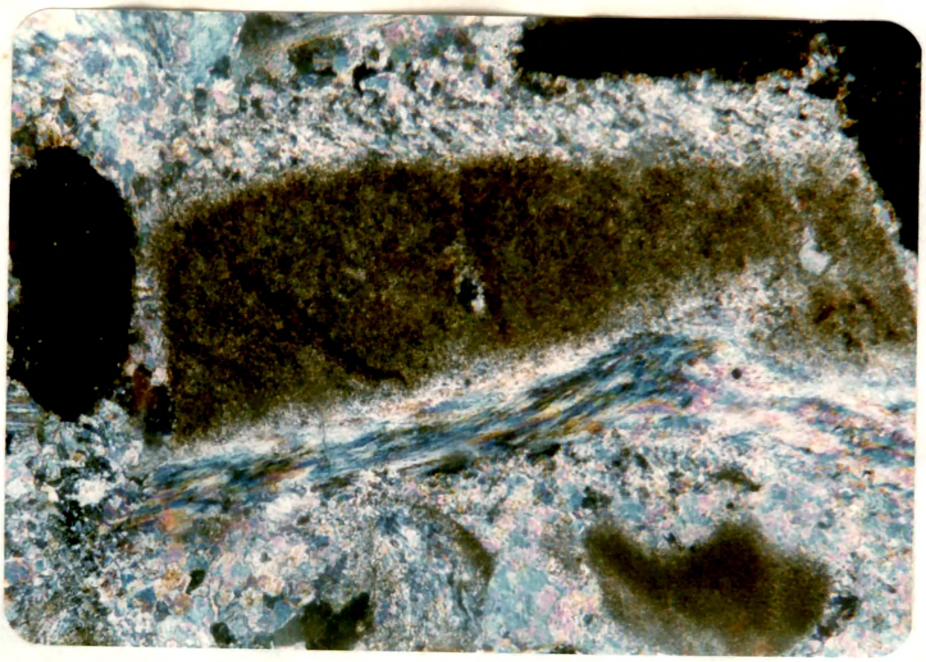


PLATE : VI.9 Photomicrograph of the cement of the Usarni beachrocks showing isopachous fringes of accicular crystals around the grains(X 45)

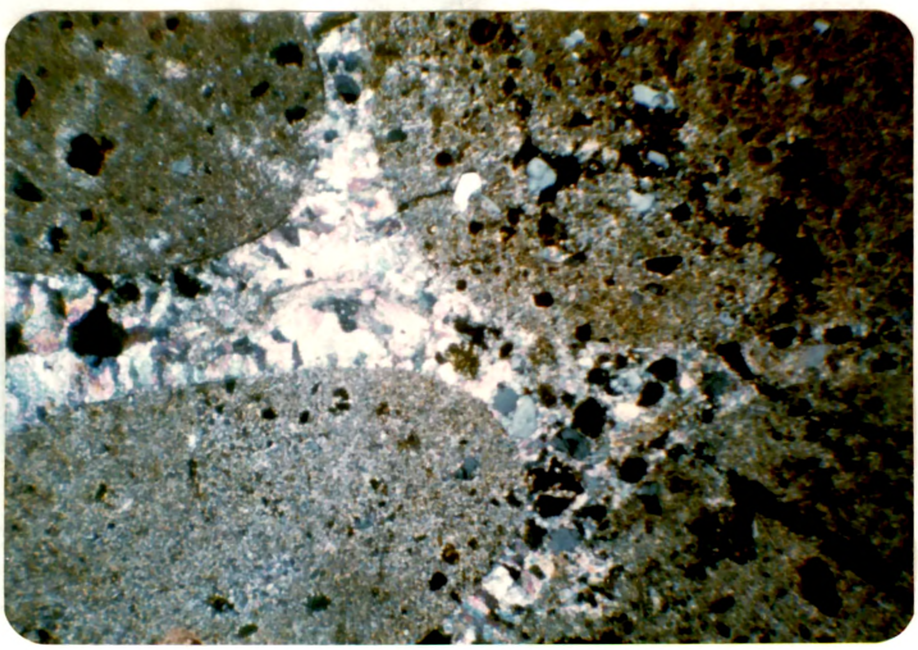


PLATE : VI.10 Photomicrograph of meniscus cement showing uneven precipatating at the contacts of the grains (X 45).

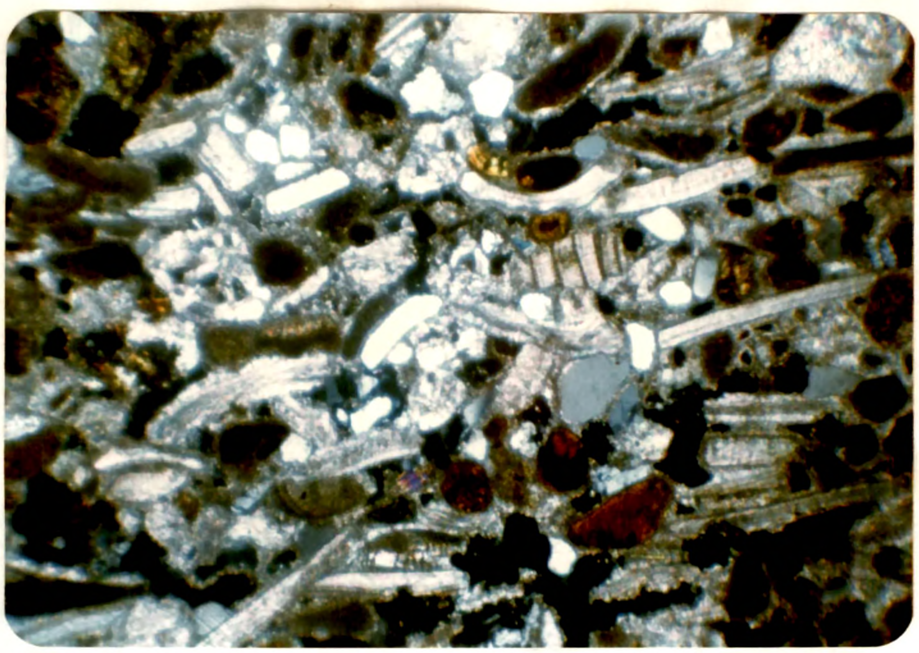


PLATE : VI.11 Photomicrograph of gravitational cement showing precipitation of cement beneath the grains (X 45)

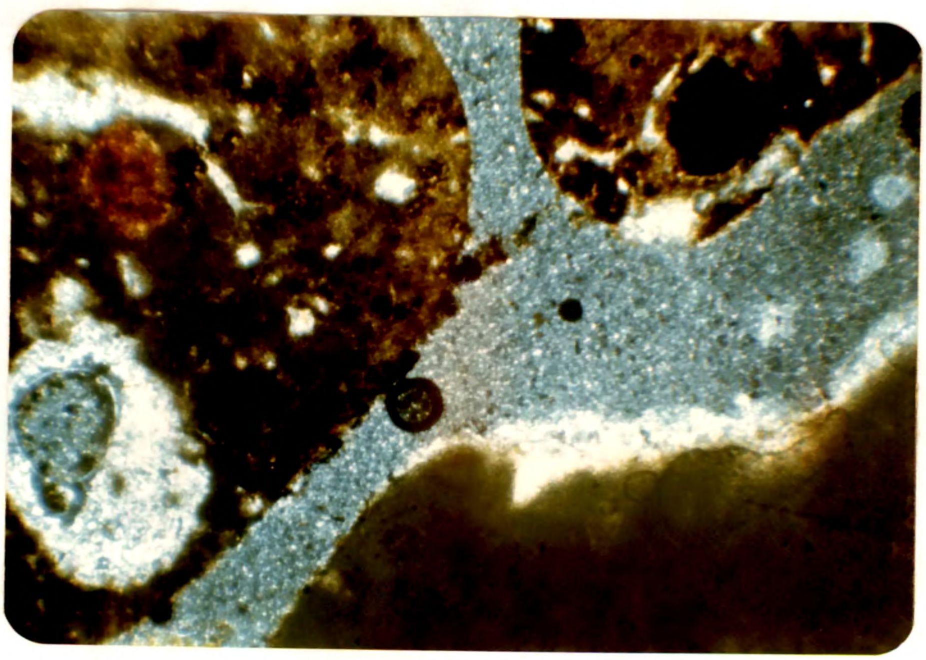


PLATE : VI.12 Photomicrograph of micritic cement showing micritization at grain boundaries (X 45).

5-Drusy cement

This type of fabric is found mostly in the beachrocks of Mahim and Paneri. The drusy rim crystals are smaller than those of the porefilling cements, and usually anhedral to subhedral in nature (Plate VI.13). Crystal size increases from pore walls to the center of cavities. It is formed as rims around the grains or lining the walls of the primary openings or secondary cavities produced by the dissolution of allochem as well as precipitation of equant calcite crystals by freshwater condition.

6-Dog tooth cement

This comprises small blocky (spar) cement lining the cavities between bioclast and lithoclast. It is characterized by Jagged dog-tooth corners (Plate VI.14).

ORIGIN OF CEMENT

The origin of cement in these beachrocks appear to fall in following three main categories :-

1. Physiochemical precipitation from evaporating seawater.
2. Physiochemical precipitation by mixing of meteoric water with sea water.
3. Endogentic cement.

The localization of Navapur beachrocks in the intertidal zone and the exclusive presence of aragonite cement in them suggest their cementation is due to the precipitation of calcium

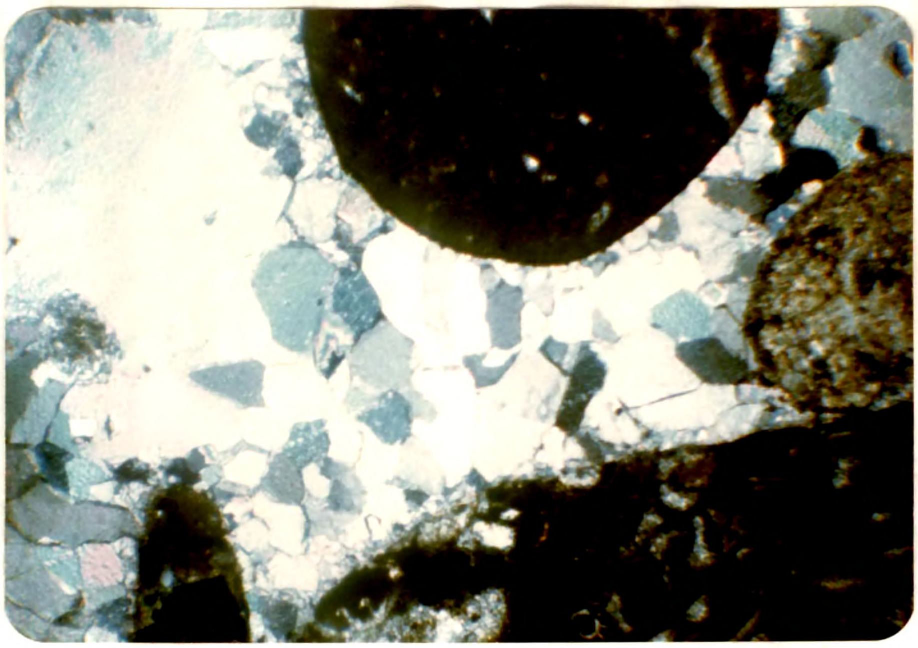


PLATE : VI.13 Photomicrograph of drusy cement showing Ist & IInd generation cement (X 45).

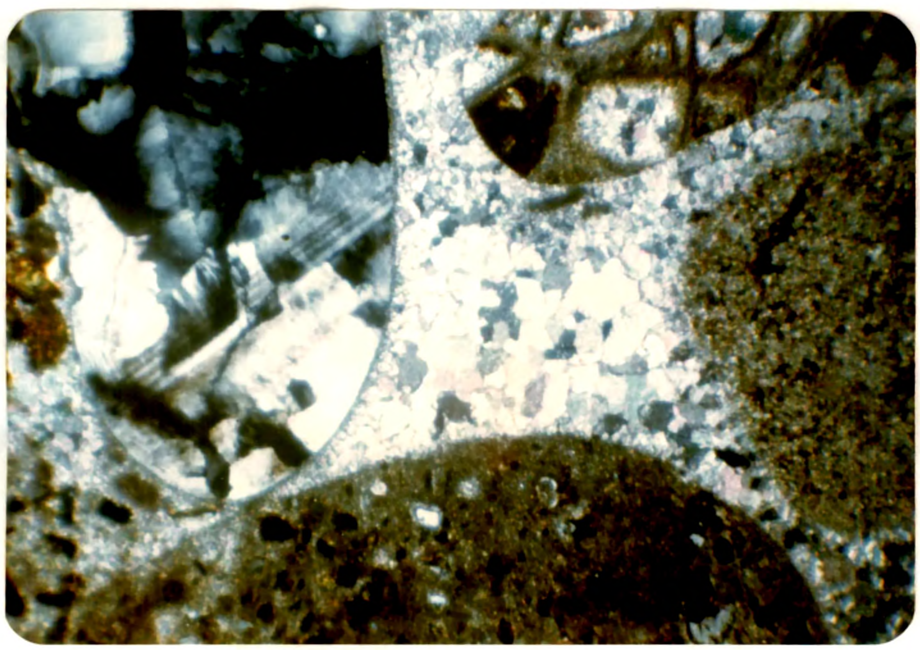


PLATE : VI.14 Photomicrograph of Dog tooth cement showing small blocky cement lining the cavities between the grains (X 45).

carbonate from sea water as result of heating and evaporation. (Dana, 1851. p.368; Daly, 1924; Kuenen, 1950). The meniscus and pendant type cements are easily recognized in the various outcrops of beachrocks in the area. This indicates the process of mixing sea water with meteoric in their formation. In the later stage of cementation the voids are filled with cement and the beach rocks are seen well bounded. At this stage the grins show considerable soulution and hence it is evident that the secondary cement is derived largly from the solution and redeposition of the constituent grain themselves.

The author has attempted to avaluate and analyse the petrogaphic characters to understand (i) the diagenetic alteranations (ii) diagenetic faces and (iii) Its nomenclature.

Diagenetic Alterations

Diagenetic alterations in beachrocks includes compaction, dissolution and replacement.

Compaction

A part from cementation, the major process leading to porosity reduction in sediments in compaction. Early stages of compaction in uncemented sediments involves the readjustment of loose grain fabrics to fit more tightly together. The author on the basis of a critical petrographic study, observed following features related to the compaction vis (i) deformation of early generation of cement; disorientation of the grains; (iii) interpretation of grains, (iv) breakage of grains (Plate VI.15), (v) elastic bending of grains (Plate VI.16), and (vi) the grain contacts such as point, tangential and suture contact (Plate VI.17).

Dissolution and Replacement

Dissolution of aragonitic bioclasts, mollusc fragments has occurred throughout the beachrocks of the study area. It is interesting to observe that often calcite replaces aragonite and also at times silica replaces calcite. Organic particles have varying degree of susceptibility to calcitisation and cryptocrystallisation. Schlanger (1964) and Bathurst (1971) have arranged the various skeletal minerals in order of decreasing susceptibility to calcitisation.

According to them the low magnesian calcite which is derived from the calcitisation of foraminifera (mg-calcite) could be younger than that derived from molluscs on account of the differences in their susceptibility the calcitisation.

There are two types of change from aragonnite to calcite which may be considered end members of the one process of dissolution/precipitation occurs in beachrocks. In the first variety the aragonite changes to calcite but traces of the micro-architecture of the original grain are preserved (Plate VI.18).

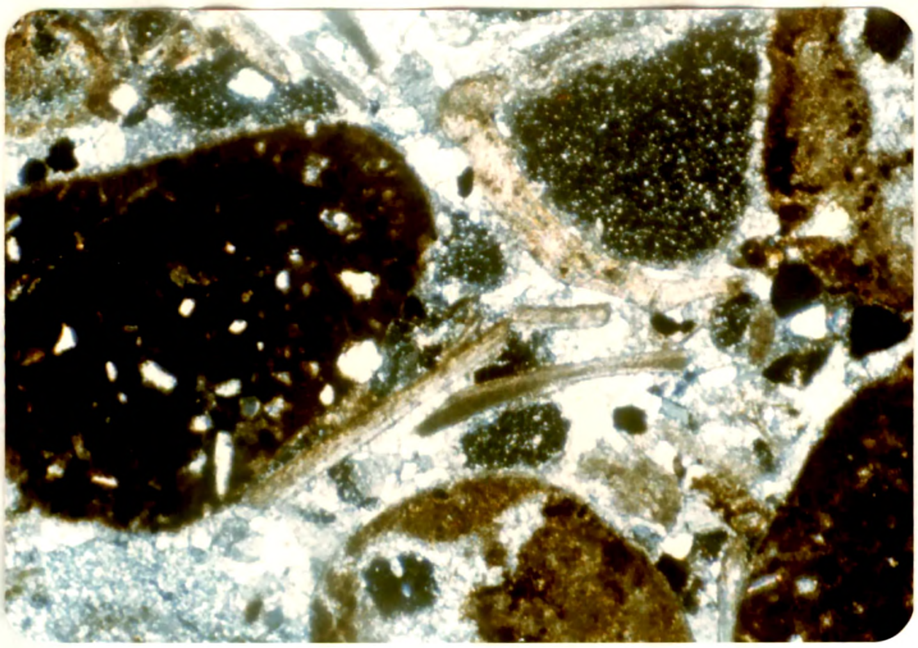


PLATE : VI.15 Photomicrograph showing breakage of grains due to compaction (X 45).

PLATE : VI.16 Photomicrograph showing elastic bending of grains due to compaction (X 45).

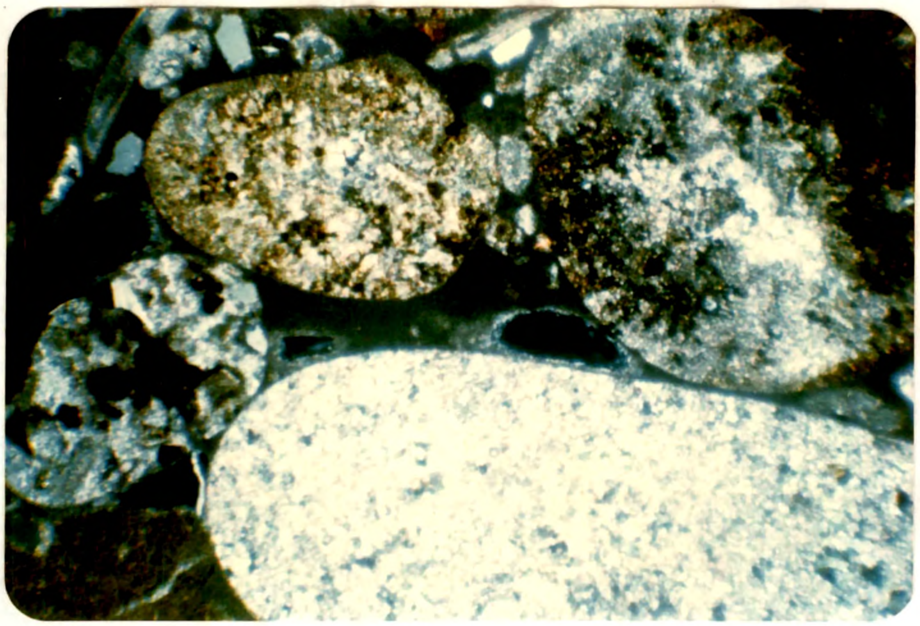


PLATE : VI.17 Photomicrograph showing tangential contact of grains due to compaction (X 45).

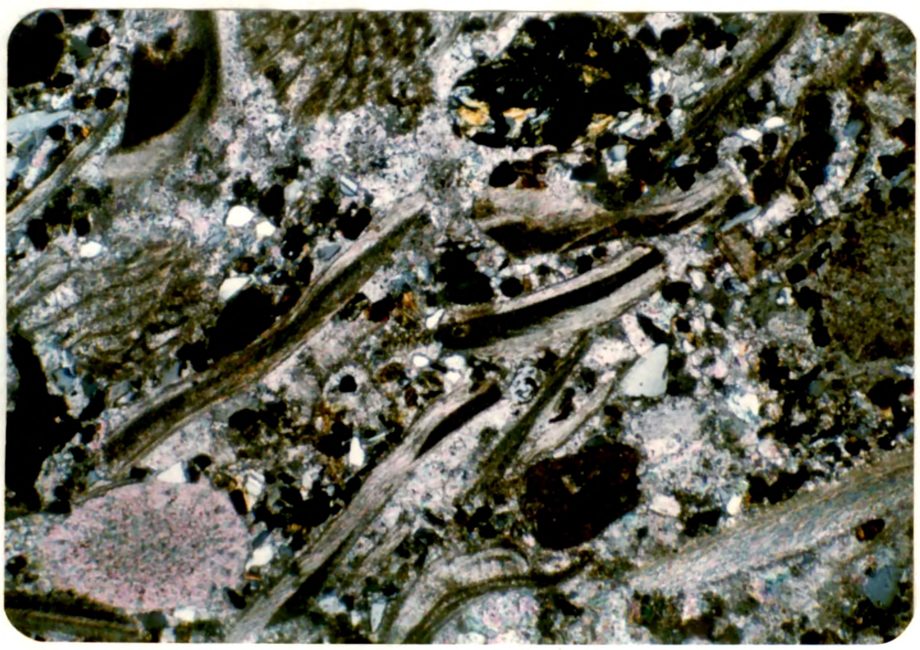


PLATE : VI.18 Photomicrograph showing dissolution of bioclasts with traces of the micro architecture of the original grain (X 45).

At the other extreme, the entire grain appears to have dissolved, leaving a mould which was later filled by pore-filling calcite cement. It is interesting to observe within the one beachrocks, some former aragonite skeletons undergo dissolution/ preciptitation on a microscale so that some microstructure is preserved, while neighbouring different species undergo total dissolution to a mould. The total dissolution of an aragonite grains will only leave recognizable void if there is a stable envelope around the grain that resisted solution and acted as a mould.

Calcite is seen replaced by microcrystalline silica (chalcedony) (Plate VI.19). This may be due different degree of precipitation/dissoultion of silica and calcite (Friedmen and Sanders, 1978).

DIAGENETIC FACIES

The study of the diagenetic cements of Quaternary beach rocks of Dahanu coast indicates sediment alteration in a variety of diagenetic environment. Fibrous aragonite cement and micritic rims indicate early marine diagenesis. Blocky spar cements are the characteristics of meteoric diagenesis. As calcite replaces fibrous aragonite this environment must have developed after early diagenesis.

The following three stages for a progressive diagenetic sequence is proposed by the authors for these beachrocks that passed through a cycle of glacio eustatic sea level changes.

In first stage aragonite fibrous cement indicates the marine processes were dominant in the intertidal zone and that lithification occurred in this zone. Subsequent micritization of the grains and cement altered the newly lithified beachrocks and resulted in the formation of well defined micritic rims around the grains (Plate VI-20.).

In second stage on account of the lowering of sea level, the shoreline moved sea ward, leaving beachrocks deposits in a more landward situation relative to that of their deposition. During this interval, the sediments were incontact with meteoric ground water. This meteoric water was probably contained in a microphreatic environment within the vadose zone, as evidenced by the discontinuous distribution of the spar cement. The most important process in this stage is neomorphic replacement of early aragonitic cement by larger cyrstals of low mg calcite.

In third and final stage a complete vadose superimposition, formation of vuggy porxsity and recrystallization of micrite took place in these beachrocks.

BEACHROCKS NOMENCLATURE

Beachrocks of the study area can be classified into two broad categories viz. (i) bioclastic dominant beachrocks and (ii) siliclastic dominant beachrocks. Based on MBS tringle

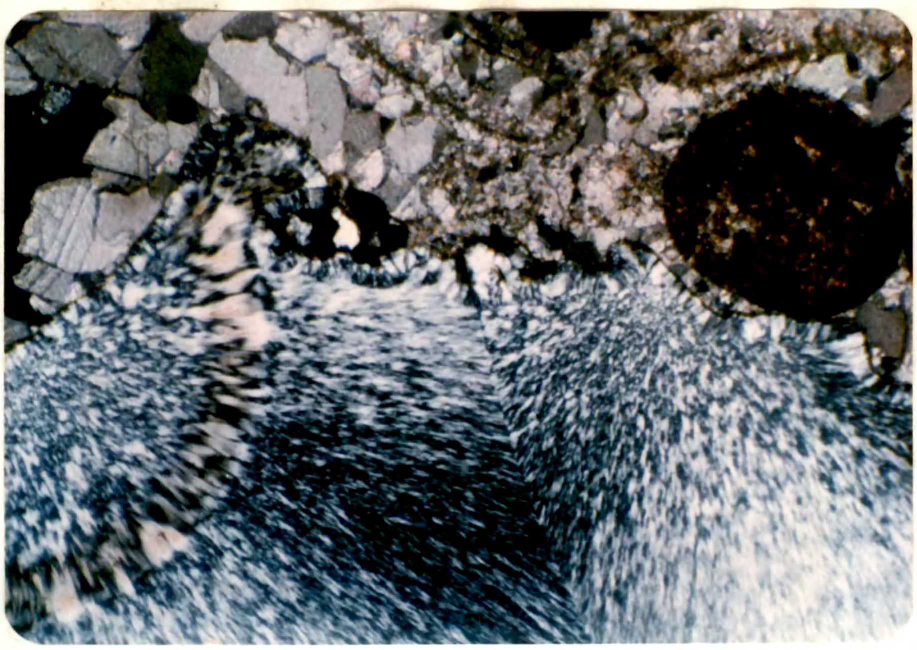


PLATE : VI.19 Photomicrograph showing replacement of calcite by microcrystalline silica i.e Chalcedony (X 45).

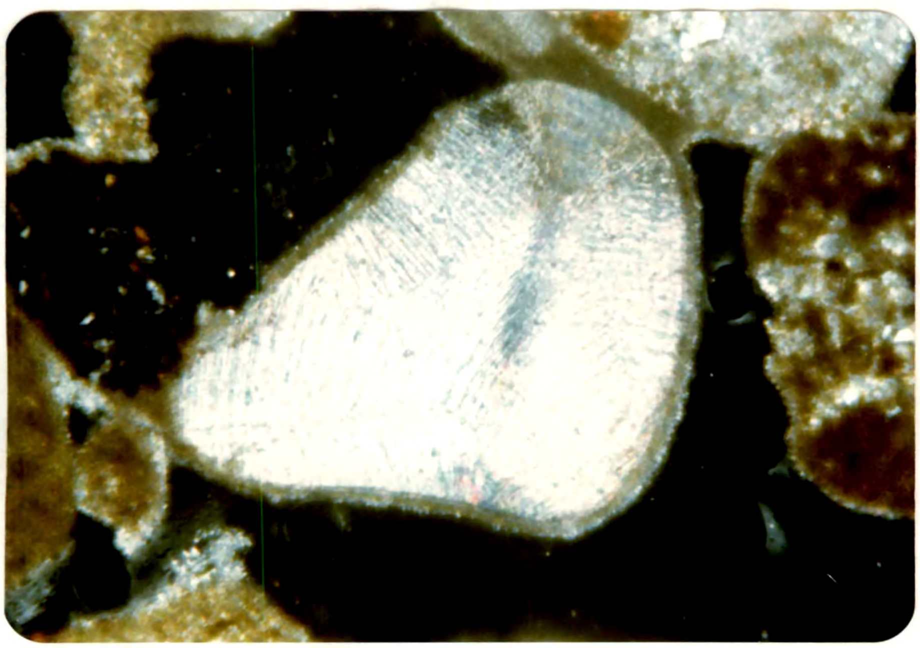


PLATE : VI.20 Photomicrograph showing well developed micritic rim around the grains (X 45).

(Nelson, 1978). These beach rocks fall in to two following zones (Fig.VI.2).

(1) Vadhavan, Navapur, Alevadi, Muramba, Mahim, Paneri and Usarni beachrocks fall in sandy biocalcarenite.

(2) Dahanu, Tarapur and Danda beachrocks fall in bioclastic arenite.

The first zone is mainly bioclastic dominant beachrocks having bioclasts range between (50-90%). Based on the texture, and also the percentages of allochem and oorthochem, this category of beachrocks are classified by following Folk (1959). This classification strictly describes the characteristics of rocks and not the genetic. In general these rocks are of biomicrites, vary upto intrabiomicrite. However in Paneri and Mahim beach rocks, these are represented by biosparite or intrabiosparite.

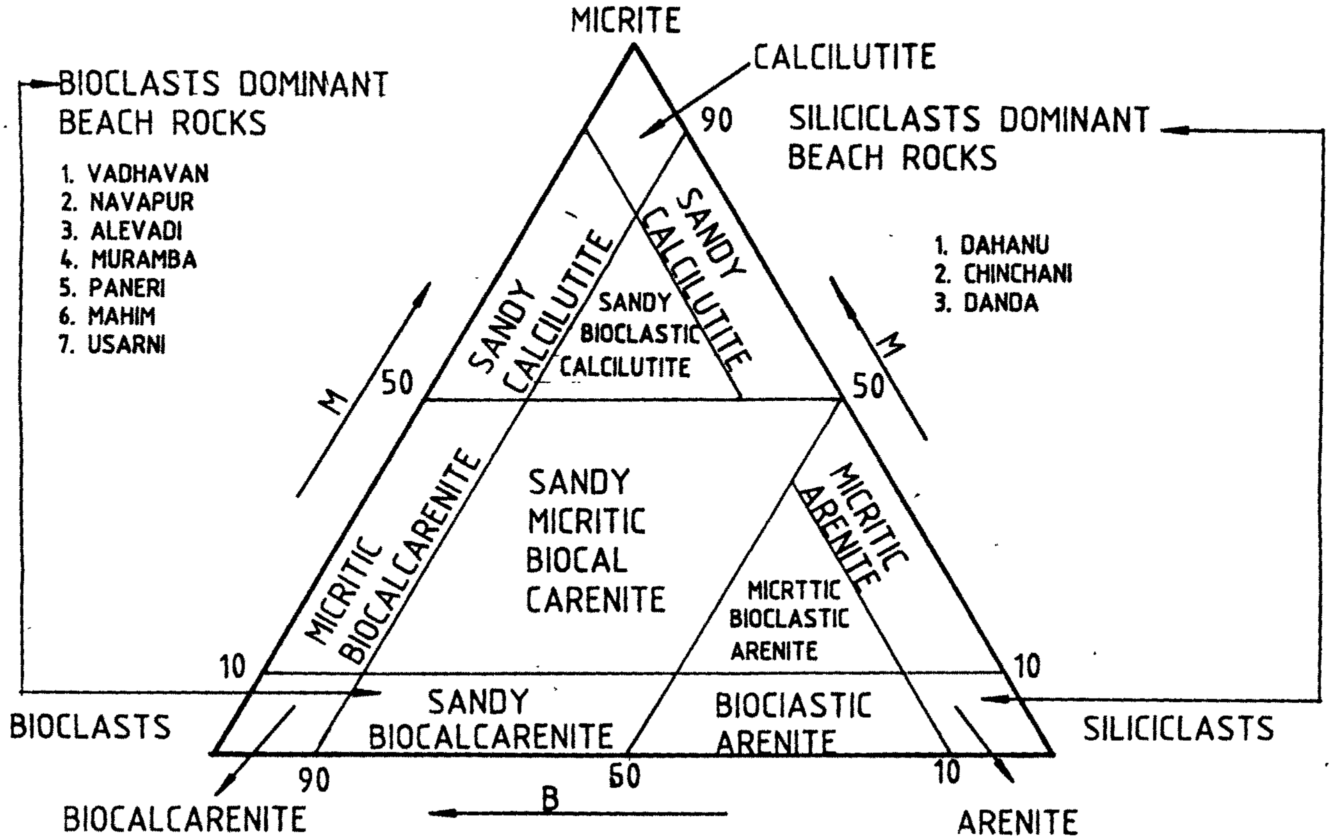
DEPOSITIONAL ENVIRONMENTS

The depositional environment of the beachrocks of the study area is based on the study of grain size, sorting, roundness, fossil contents, sedimentary structures and textures.

Grain Size

The sediments constituting beachrocks have been examined for their grain size characteristics which have helped the

FIG. VI·2



TENTATIVE CLASSIFICATION TRIANGLE FOR BEACH ROCKS WITH SILICICLATIC COMPONENTS.

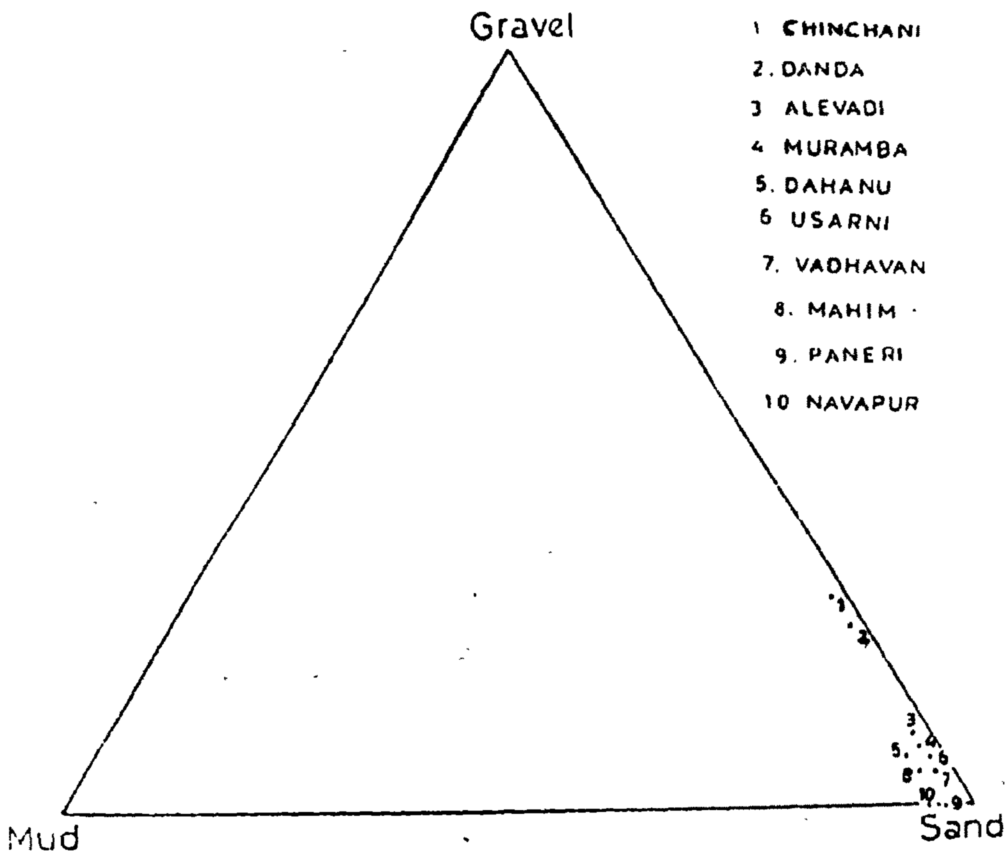
(MBS TRAINGLE AFTER NELSON')

authors to know the variation in hydrodynamic system prevailing at the time of deposition

The beachrock sediments of Dahanu-Kora coast contain the admixture of gravel, sand and mud (Fig. VI.3). The gravel : Sand : mud ratio from the different samples were determined after sieving the sediments on 1/2ϕ interval, each % constituent then plotted on a triangular diagram of Folk, Andrews and Lewis, 1970. The various plots clearly reveal that the most of the beach sediments of the study area occupy the domains of 'Slightly gravel muddy sand'. 'Slightly gravelly sand', 'Muddy sand' and 'Sand' in the above diagram. Maximum gravel percentage is found from Chinchani and Danda outcrops (20 to 30 % on an average), however the gravel % increases to a maximum of 50 in the near mouth exposures of Chinchani creek. The minimum percentage is found at Vadhavan, Mahim, Panari and Navapur where it varies between 0 to 20 (Table VI.1). This variation of gravel percentage is an imporant indicator of energy variation prevailing at the time of the deposition of the beachrocks pointing typically to a variations in current velocity, wave energy, slope, configuration of shoreline and amount of sediment supply.

The particle size analyses of mud sediments were sieved at 1/2ϕ interval. From this the particles having size less than 0.062 mm were taken for determining the percentage of silt and clay in the mud of beachrocks (Table VI.2). This silt clay determination was carried out in order to know the effect of tidal current at the time of deposition. The plot of size Vs.

FIG. VI·3



Triangular diagram showing Gravel, Sand and Mud in Beach Rocks of Dahanu-Usarni coast.

Table : VI.1

No.	Locality	Gravel	Sand	Mud
1.	Umargam	6	89.6	4.6
2.	Dhhanu	7	90	3
3.	Vadhavan	9	88.8	2.2
4.	Chinchani (Near Chinchani creek)	50.7	47.7	1.6
5.	Chinchani (Away from creek)	27	71.8	1.2
6.	Navapur	0	94.5	5.5
7.	Alevadi	10	89	1
8.	Muramba	8	90	2
9.	Panari	0	96	4
10.	Mahim	6	92.3	1.7
11.	Danda	24	74.5	1.5
12.	Usarani	8	91.	1

Gravel, Sand and Mud percentage in Beach Rocks of Dahanu-Usarni coast.

Table : VI.2

No.	LOCALITY	SILT	CLAY
1.	Umargam	13	87
2.	Dahanu	14.6	85.4
3.	Vadhavan	15	85
4.	Chinchani	16	84
5.	Navapur	56	44
6.	Alevadi	76.3	23.7
7.	Muramba	77.9	22.1
8.	Panavi	82	18
9.	Mahim	84.1	15.9
10.	Danda	84.3	15.7
11.	Usarani	85.2	14.8

Silt and Clay percentage in Beach Rocks of Dahanu-Usarni coast.

cummulative percentage of clay and silt in the mud of beachrocks were than ploted (Fig. VI.4) which shows a gradual decrease of clay and increase of silt contents in outcrops of the study area from north to south.

Degree of Sorting

The values of the inclusive graphic standard deviation ($\sigma\phi$) clearly reveal that most of the beachrock sediments are moderately sorted. Moreover this range in values (0.50 to 1) is perhaps on account of the variations in the hydrodynamic system and energy fluctuating conditions under which the depostion of these sediments took place.

Roundness

As per the terminology by Krumbein (1941), most of the constituents of the beachrocks are 'rounded' to 'well rounded'. Based on his Chart (1941), the roundness of the grains lie between 0.5 to 0.8. The above variation also indicates a combination of different processes operative on the Dahanu-Kora coast at the time of deposition. Rounding of particles of beachrocks results mainly by abrasion, which is one of the processes affecting the size reduction. Besides, the roundness could also be attributed to the prolonged transport of grains by fluvial agencies prior to their dumping into the coastal regime. Surface marking on individual grain has been examined in the field. Strong surface action accompanied by traction along the

PERCENTAGE OF CLAY-SILT IN MUD OF BEACH ROCKS OF THE STUDY AREA

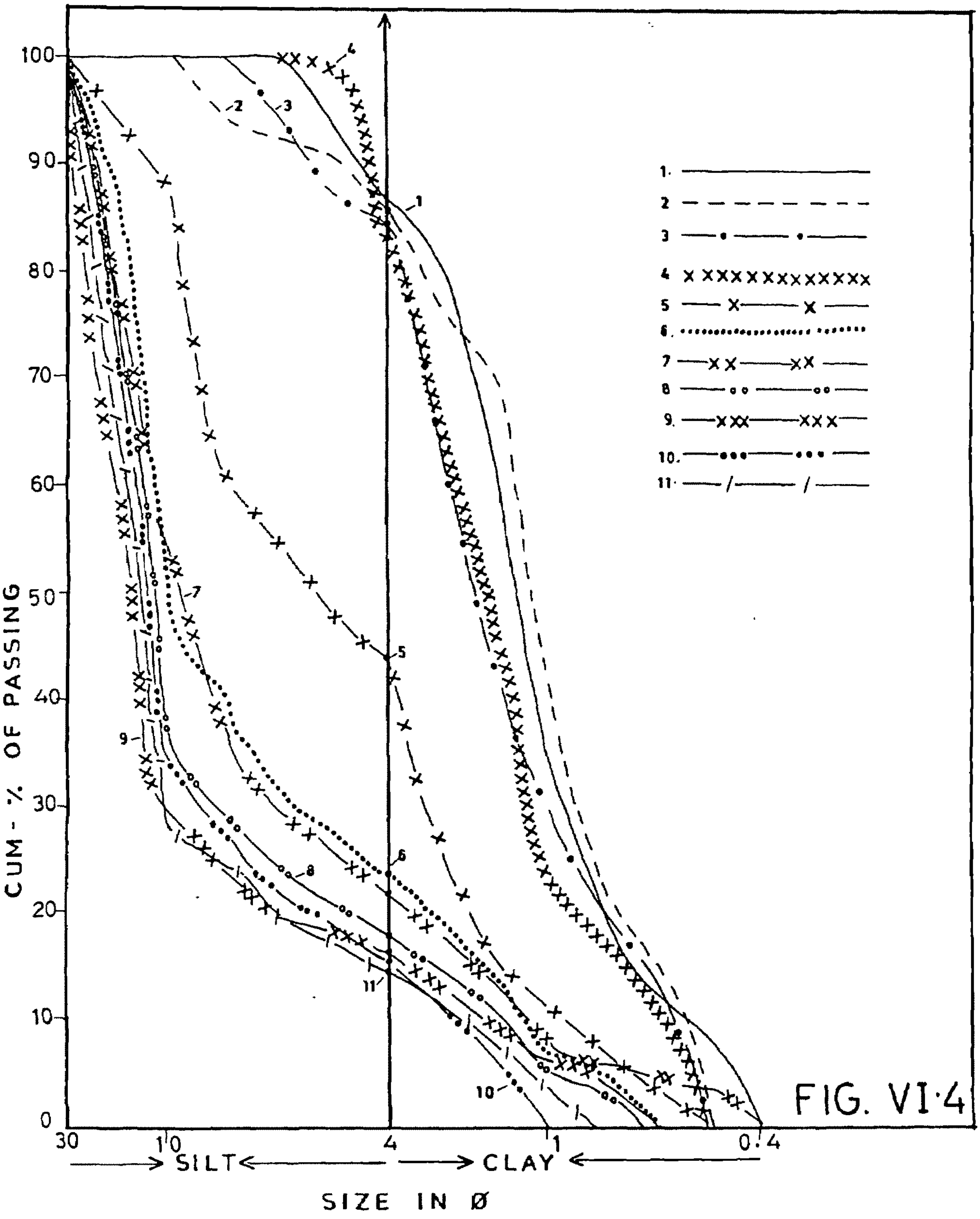


FIG. VI·4

Name of Localities :-

1. Umargam 2. Dahanu 3. Vadhavan 4. Chinchani 5. Navapur 6 Alevadi
7. Muramba 8. Paneri 9. Mahim 10. Danda 11. Usrani

rocky surface has quite often resulted into breaking of the pebbles.

Micropalaeontological Studies

The brief micropalaeontological studies from six samples of the study area have reveal the presence of following foramenifera

Ammonia beccaria, *Elphidium sp*, *Elphidium crispum*, *Elphidium craticulatum*, *Quinqueloculina Lam*, *Quinqueloculina oblong*, *Siphogeneria raphynus*, *Epoindes sp*. etc.

The above microfauna is suggestive of shallow marine condition of the sea at the time of deposition of beachrocks.

Sedimentary Structures

These beachrocks exhibit well defined sedimentary structures like bedding (Plate VI.21), lamination, cross-stratification, graded bedding etc; the dips (5^0 to 10^0) being seawards. These appear to have been deposited by a combination of wave action and longshore drift which brought about redistribution and redeposition of material generated along the shelf as well as added by the rivers from landward side or brought from the Gulf of Cambay by tidal currents. The low angle and convex cross-stratifications (Plate VI.22) indicate a slow drift of the sediments, suggesting that the sea was not rough during their depositions. Thin parallel lamination also point to a slow

PLATE : VI.21 Beachrock exhibiting well defined sedimentary structure (bedding) with mega fossils accumlated at the base at Danda.

PLATE : VI.22 Beachrock showing well developed cross-bedding at Chinchani.

reworking process of the sediments by the upthrow swash and back flow currents in a fairly quiet sea.

Textures

A brief studies of surface texture of quartz grains on a Scanning Electron Microscope (SEM). Shows development of primatic etch forms over flat surfaces. Flat surfaces obviously indicate a fluvial origin (Sychanthavong and Merh, 1988). The superimposition of etch forms is attributed to the grains involvement in coastal marine processes, the development of etch forms having been brought about by the chemical activity of sea water (Krinsley and Doornkamp, 1973; Friedman et al., 1976). Some grains Sporadically have developed triangular etch markings on plain surfaces (Plate VI.23). These features are diagnostic of a low energy coast, being absent from intermediate and high energy environments (Sychanthavong and Merh, 1988). Some quartz grain exhibit a good polishing on some parts of the surface, the remaining portions are marked by conchoidal breakage pattern (Plate VI.24). Such features develope on account of conterogenetic process (rubbing) by long distance transporation and breaking of grains by aqueous crushing between cobbles and pebbles (Krinsley and Donahue, 1968).

This superimposition effect is probably due to combine marine and fluvial action in the formation of these rocks.

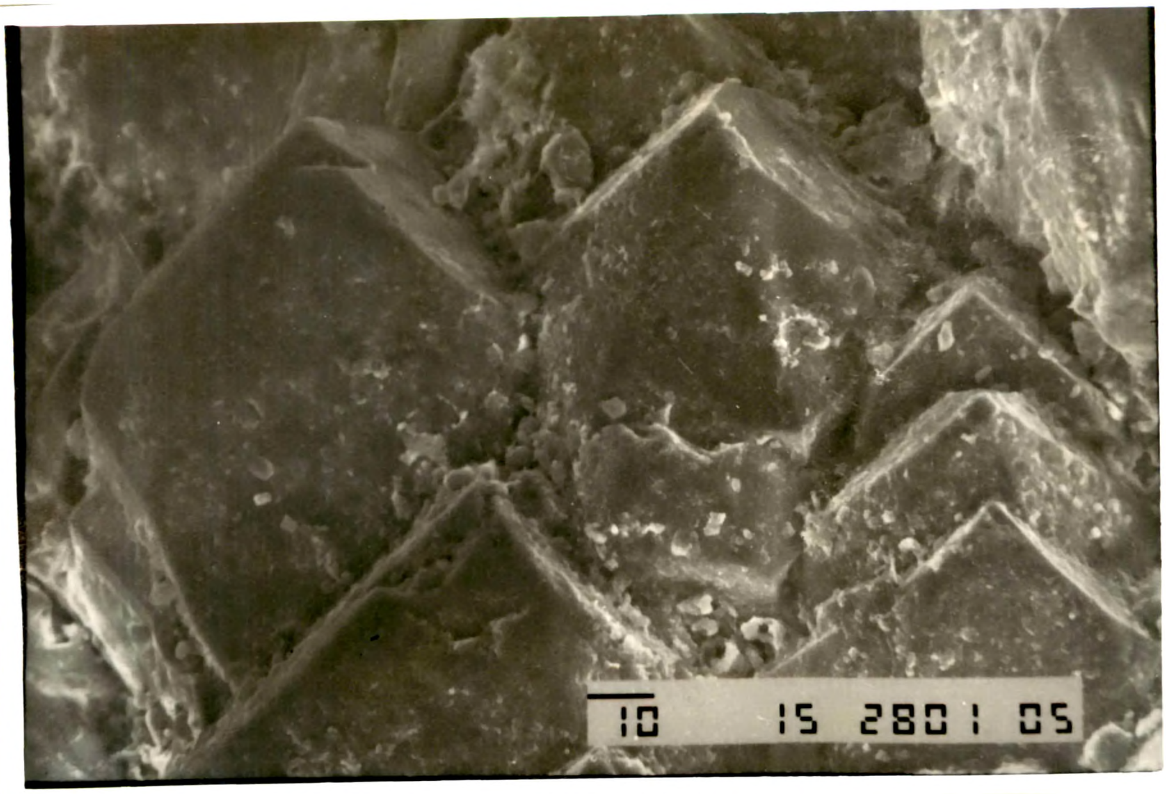


PLATE : VI.23 SEM Photomicrograph showing well developed triangular etch markings on plain surfaces.

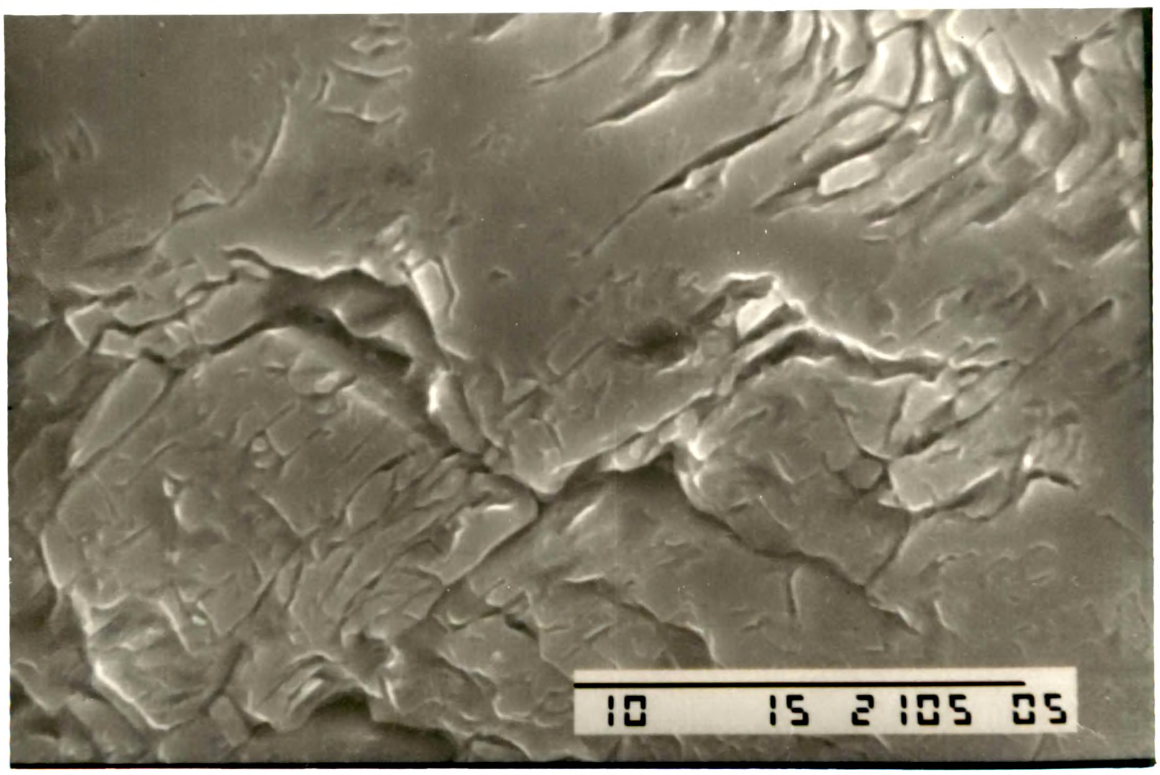


PLATE : VI.24 SEM Photomicrograph showing well developed conchoidal breakage pattern on grain surface.