PART - II

PIRAM ISLAND

Plate:1 EXPEDITION TO PIRAM

PIRAM ISLAND

GENERAL REVIEW :

The Landmass around Piram forms part of a regional embayment or reentrant at the southeastern Saurashtra coast of Gujarat, called the gulf of Cambay. The embayment is influential in the development of sedimentary facies around the Island because tidal effects are magnified by it. The embayment is further subjected to the heighest tides (about 12 meters) on the entire western coast of India. The tidal excursion is discernible as much as 40 km inland from the coast. Tides are semidiuranal having an average range of 9.0 meters. This tidal range in combination with low relief of a broad area landward thus results in twice-daily exchanges of tremendous volume of water and sediment between the Island region and the nearshore shelf. The nearshore water is usually charged with suspended sediment load of finely divided organic detritus and clays. Their concentrations, are often variable in space and time. Water visibility generally ranges from zero to few decimeters. Wind velocities are usually low, except during the storms. This part of the Saurashtra coast is, therefore recoginized as a mesotidal, high energy zone.

The fundamental aim of the author in investigating the geology of Piram Island will be therefore, to provide first approximations to all the above natural processes that are responsible in shaping the present and the past configuration of the Island coastal zones.

BACK GROND INFORMANTION

2.1 INTRODUCTION

Piram Island (elongated in NNE-SSE direction, having 7.5 sq.km of intertidal zone and 1.5 sq.km. of total land area) is situated within the Gulf of Cambay, close to the eastern fringe of Saurashtra peninsula near Ghogha in Bhavnagar District (21° 34' 00" to 21° 38' 00" north latitudes, and 72° 20' 00" to 72° 23' 00" east longitudes), (Fig. 1).

A complex and sequential Pliocene-Pleistocene-Holocene depositional environment marks the geology of this Island. The Island is surrounded by intertidal rocky platforms which run 5 to 6 km toward the north and the southeast of the Island. Beach is well developed in the eastern part, where it is more than 100 meter wide and is made up of medium to fine grained sand. Recent mudflats, salt marshes and mangrove-swamps are welldeveloped on the south and southeastern side. The inland portion of the Island is covered by dunal sands and alluvium. Maximum thickness of which is 10 meter. The beach sediments are invariably found covered with black sand placers. The Island as a whole exhibits an interesting "layered cake" stratigraphy that suggest an extremely gentle depositional relief and the basin fill represents a sensitive record of environmental changes. The over all sequence shows a fining and shallowing upward pattern of deposition.

2.2 WORK AND STUDY PLAN

Exposures in the Island were located by reference to the Survey of India Toposheet No. 46 C/6. The locations of a few exposures were acquired orally from persons familier with the area. Sections were measured with stadia rod, and with a steel tape. Most measurements were made to the nearest tenth of a meter. Each measured section is divided into sedimentation units of uniform lithology, limited vertically by changes that were detected readily in the field. Units, thus distinguished were described separately, and lithology, thickness, fresh and weathered colour, fossils, secondary minerals and sedimentary structures were recorded.

For nearshore facies their subfacies were ascertained as the beach, dune, tidal flats, mangroves etc. and their limits were plotted. Sediment samples on grid pattern were collected for sedimentological and micropalaeontological studies. Biogenic structures were recorded and photographed in the field.

Based on the laboratory studies various illustrations and diagrams were prepared which have been used in the final modelling of the environments of deposition.

2.3 ACCESSIBILITY

Approach to Piram Island is only through the sea. This very often becomes difficult because of the high velocity of the tidal currents and the rocky exposures that surround the Island especially to its north and southeast fringes. These intertidal rocky inland platform attain greater depths between the northwest end of the Island and Ghogha, where at low water level the passage although is little more than half a mile wide, there is a depth of nearly 60 fathoms. Moreover, there are strong eddies in the channel which very often turn the vessels and make control unmanagable. Only local pilot known anything about these water channels and one has to fully rely on them.

2.4 PIRAM ISLAND AND ITS EARLIER INHABITANTS

The Island has been known since fourteenth centuary and was then held by Bariya Kolis of Gujarat. It then passed into the hands of Mokhdaji Gohil of Umrala in 1325. Gohil's power was shortlived. About 1347, complains of his piraticals were laid before the Emperior Muhammad Tughlug, then in Gujarat quelling a revolt. Advancing in person he attacked Piram, slew Mokhdaji and took his fort. On Mokhdaji's defeat, the Island was deserted. After this failure no attempt was made to fortify Piram, till, on the decay of Moghul power about the middle of the eighteenth century, a merchant from Surat named Mulla Muhammad Ali, built a fort on Piram with an intention to establish himself as an independent chief. The light house tower built from the ruins of Mullla's fortress, is being renovated at present. The whole Island at the present has no drinking water resources and is almost barren of human population.

2.5 CLIMATE

The climate of Piram is equable throughout the year. Winters are usually mild and of short duration. Coldest months are December and January. Weather is quite pleasant in February and March, whereafter the temperature rises. The period from March to May is one of continuous rise in temperature. May is generally the hottest month, the mean daily maximum temperature at Piram being 35.9^{o}C. Thunder showers which occur on some days during the premonsoon period in the afternoon bring welcome relief. With the onset of the south-west monsoon by about the middle of June and sometimes much later, the day temperature decrease a little. With the progress of the season, howerver, the day become cooler. After mid September, day temperature increase and a secondary maximum in day temperature is reached in October.

2.6 FLORA AND FAUNA

Acacia arabica (Babul) and _Prosopis juliflora_ (gando baval) has been successfully introduced in these areas especially in the salty waste lands and a good plantation of _Prosopis juliflora_ are being raised throughout the Island. Along the coast mangroves have been found to be thriving and steps are being taken to bring them under scientific management. In the eastern part of the Island some bajri and till are grown. An attempt has recently been made to grow coconut on the Island. Cows and goats (very few in number) were found, as there is trouble of fodder which has to be brought from mainland Saurashtra.

PREVIOUS WORK

The geological work on this Island began as early as 1836 (Lush), it was subsequently carried out by Falconer (1845-1868), G. Buist (1855), Fedden (1884), Lydekker (1874-1887), Osborn (1936-1942), Pilgrim (1926-1932), Colbert (1938), Babu (1957), Rao and Jain (1959) and Datta (1959). Recently, Prasad (1974), Published a memoir on vertebrate fauna of Piram. Most of these studies pertain to the identification and description of vertebrate fauna. Significant details on litho-and bio-stratigraphy of Piram rocks, however, are not available in any of these studies.

STRATIGRAPHY AND SEDIMENTARY FACIES

4.1 STRATIGRAPHY

As mentioned earlier, the Piram Island exposes an interesting sedimentary sequence formed during an upper Miocene, Pliocene and Holocene to Recent time. Most of the rock record is preserved in the form of a "Layered cake" stratigraphy where the individual units are rather thin (Plate - 2). Very often, many of these units are found concealed beneath the hill sands or are draped over by the recent beach deposits. The basal units, comprising sandstones and hard compact conglomeratic beds, on the other hand, can only be observed clearly during the receding tides especially during the months of March, April and May (prior to the setting of Monsoon). A complete stratigraphic sequence confirmed by the author can be given as under (Table. 6).

4.2 SEDIMENTARY FACIES

For an objective interpretation of the sedimentary environments, it is necessary to recognise the lateral and vertical facies variation in a stratigraphic section. In most of

Table : 6 Sedimentary facies and its depositional environments - Piram Island

Age	Unit	Lithology (lithofacies)	Thickness in m.	Sedimentary structure	Fossils	Environment of deposition
Uppermost Pliocene to (?) Lower Pleistocene	Upper Transgressive Facies	Coarse pebble gritty conglomerate	1			High energy nearshore
(?) Upper Pliocene	Middle Transgressive Regressive Facies	Silty clay and claystone subfacies	2	claynodules dish structure Thin lamination ripple marks	plant strand pollen	Stream influence
		Medium to fine grained sandstone subfacies	0.5-1	Thin cross-lamination	Textularia sp. cibicides sp. Elphidium sp.	Tidal channel with moderate to low energy
Middle Pliocene		Cherty pebble conglomerate subfacies	0.5-1		Vertebrate bones and teeth	-----
Upper Miocene to Lower Pliocene	Basal Transgressive Facies	Vertebrate bonebed and round pebble conglomerate subfacies	1-15		Mammalian bones bones Fossil	Estuarine proximal delta
		Dark yellow to reddish coloured sandstone subfacies	--	Tepee structure Arcuate ridges Polygonal disiccation cracks (algal mats)		intertidal to supratidal

PLATE : 2

"Layered Cake" Stratigraphic sequence
(cliff section SSE of Piram)
(A) Cherty Pebble conglomerate;
(B) Medium of fine grained sandstone;
(C) Siltyclay and claystone and
(D) Coarse pebble gritty conglomerate

such cases (according to Reading, 1978); after this stage has been recorded that depositional environments can be relatively inferred. Middletone (1978) and Walker (1979) have stipulated that any particular facies will be representative of a single environment. Although, Middleton (1978) and Walker (1979) have stressed the importance of objectivity on facies deposition direct one-to-one correlation of a single facies with a particular environment, can bypass the important step of process inference emphasised by Reading (1978). It would be, thus, reasonable to name an objectivity defined facies that would reflect the characteristic of the rocks assigned to that particular facies.

In the present studies of Piram Island each sedimentary facies is first defined by the author on purely objective grounds, and is then used as a basis for its inferred depositional environment discussed later. The limited occurrences and poor areal distribution of the exposures, however, limited the establishment of detail regional facies trends. As a result, this study is focused mainly on vertical facies relationship exhibited at a few outcrops, in Piram.

In order to get the required facies information, the stratigraphic sections in Piram were measured at southeast, south and southwest localities around the Island (Plate 2 & 11). Lithologic correlation was accompained by "walking out" the strata and by referring the individual beds to their stratigraphic positions below or above the time planes viz the vertebrate bone bed, the cherty pebble conglomerate etc.

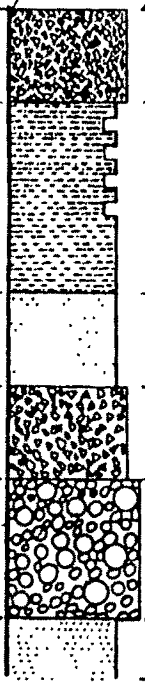
In general, two main categories of the sedimentary facies were recognised in Piram. These include (1) the sedimentary facies in vertical sequence, and (2) the nearshore (younger) sedimentary facies.

The vertical (older sequence) facies comprise three lithostratigraphic units : (A) A basal transgressive unit - consisting of the dark yellow to reddish coloured sandstone and overlying vertebrate bone bed, (B) the middle transgressive-regressive unit-comprising the cherty pebble conglomerate subfacies, the medium to fine grained sandstone subfacies, and silty, clay and claystone subfacies; and (C) the upper most transgressive unit - consisting of coarse pebble gritty conglomerate, subfacies.

The nearshore sedimentary facies, on the other hand, include the beach, dune, tidal flat, salt marshes and mangrove swamp facies.

The determination of all these sedimentary facies is further based on the area of occurrence, lithofacies geometry, and stratigraphic position, lithology and texture, physical and biological sedimentary structures and on the general patterns of deposition (Fig. 5).

FIGURE 5 SEDIMENTARY FACIES IN VERTICAL SEQUENCE - PIRAM ISLAND



THICKNESS IN M.	LITHOLOGY (SUBFACIES)	SEDIMENTARY STRUCTURES	FOSSILS	SEDIMENTARY ENVIRONMENTS	FACIES / UNITS
1.0	Coarse pebble grity conglomerate			High energy coastal	Transgressive
2.0	Silt clay and claystone	Scour marks Ripple marks Dish structure	Plant strands Pollens	High enegry Stream deposits	Transgressive-Regressive
0.5 -1.0	Medium to fine grained sandstone	Desiccation cracks Parallel laminae Cross beddings	Textularia Cibicides Elphidium	Tidal channel	
0.5 - 1.0	Cherty pebble conglomerate		Drifted Mammalian bones	High energy coastal	
1.0 -1.5	Round pebble conglomerate and Vertebrate bone bed		Drifted Mammalian bones & Fossil Wood	Estuarine proximal delta	Transgressive
---	Dark yellow to reddish coloured sandstone	Tepee structure Arcuate ridges		Intertidal to Supratidal	

Description and interpretation of each of these lithofacies is now attempted in the following text.

4.3 SEDIMENTARY FACIES IN VERTICAL SEQUENCE

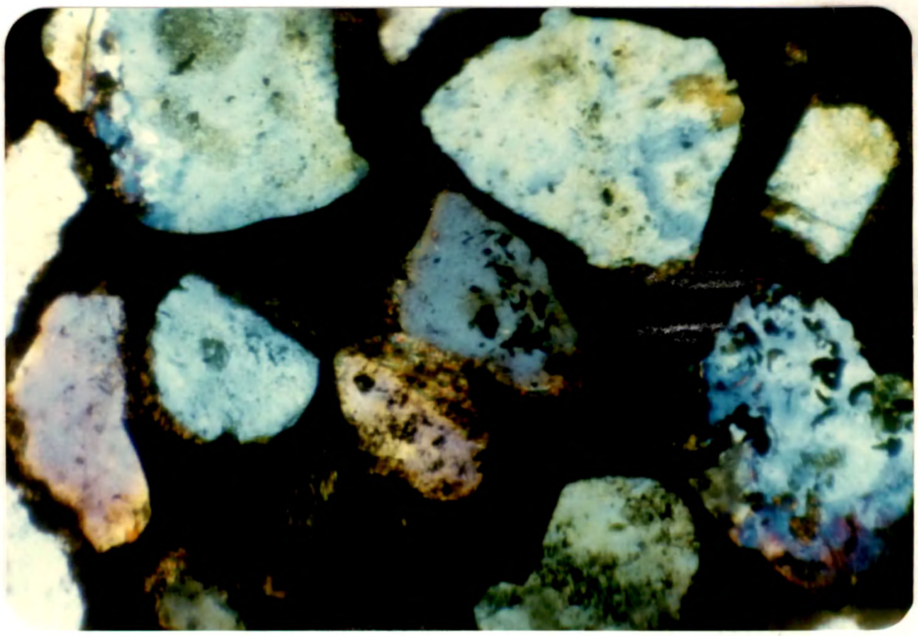
4.3.1 BASAL TRANSGRESSIVE FACIES

(I) The dark yellow to reddish coloured sandstone subfacies

This sandstone unit which forms the basal portion of the stratigraphic sequence in Piram (Fig. 5) probably represents the distal expression of the thicker sandstone body of the Lower Gaj rocks exposed in the inland area of Kuda in Bhavnagar district. Exposures of such sandstone subfacies can be ideally located below the conspicuous bone bed in south and southeastern part of the Island, during the low water tidal conditions (Plate 5a). The rocks at places are dark red in colour and exhibit wave ripple laminations and vertical burrows of *Skolithos* and *Monocraterion* (Plate 3a). As far the colours of the sediments are concerned, in the first place (red sandstones), the dark red colour appears to be the more predominant factor because of weathering of hematite, while in the second (dark yellow), limonite, is found to be more prevalent in imparting the dark yellow colour. The dark yellowish coloured areas very often display polygonal "tepee" and "arcuate ridge" structures (Plate 4a,b). Explanation regarding formation of polygonal structures, "tepees" and "arcuate ridges" is delt with in the interpretation part of the discussion.

PLATE:3

(a) The dark yellow to reddish coloured sandstone with wave ripple laminations and vertical burrows of Skolithos and Monocraterion.



(b) Photomicrograph of the dark yellow to reddish coloured sandstone. x 25

In thin section the rock shows fine to medium grained sand size particles of quartz, cryptocrystalline silica, and minor proportions of magnetite. The sandstone as a whole displays quartz grains scattered in groundmass of hematite and limonite. The sorting is poor, grains are subangular to angular, not well compacted and bounded by ferrugineous cement. Under the microscope, the interstitial void fillings appear dark brown in transmitted light and entirely amorphous under crossed nicols (Plate 3b). Occasionally, these sandstones which are without closely packed quartz grains are cemented by an undetermined combination of organic matter and iron oxides. Similar sandstones have been called "alios" in French by Carozzi, (1960).

In the first place it will now be important to determine the nature of the ferruineous cement in which the quartz grains appear to be floating, as to be of primary or secondary origin. Precipitation of the iron oxides penecontemporaneous with the deposition of the detrital particles can be assumed. In such cases according to Carozzi, (1960, P.46) precipitates appear like small dots which under very high magnification can only be resolved because of their small size (clay size particles). Secondary iron oxides are deposited later during diagenesis, either by circulating solutions or through the oxidation of iron-bearing minerals. It is, however difficult to visualize conditions under which sand grains could be so distributed during the deposition of an original ferrugineous precipitate (unless extensive wind action as suggested by Carozzi - 1960 is considered).

Yet another possibility will be to assume the original cement to be calcium carbonate, which itself was replaced by iron oxides during a later diagenetic phase. For the Bet samples it will be logical to assume the deposition of an arenaceous calcarenite in which the quartz grains are uniformly distributed by mechanical mixing. There are two additional clues that tend to emphasize the petrographic picture of quartz grains floating in a calcite cement. The first is the tendency of calcite to force particles apart during crystallization (Carrozzi, 1960). This is also observed in our thin section where quartz grains are separated from one another and also by grains that have been forced apart and their fragments are rotated and no longer in optical continuity with one another. The second case is the corrosion of the quartz grains by calcite and this process of replacement might have continued till the demise of the original calcitic material in the matrix. Both these possibilities are observed in the Piram sandstones and the more significant evidences in this respect also be confirmed when the sandstones are subjected to mild acid test. They respond well with typical effervescences as in any carbonate rock. May be the relict carbonates atleast in parts are still not completely replaced by iron oxides.

<u>Tepee Structures (Plate 4a)</u> : This type of structure was so named by Admans and Frenzel (1950) because of its resemblance to the American Indian tent. It is suggested that the Piram Island "tepee structures" could have been initiated by the cracking of the intertidal sandstone beds into large-scale polygones, illustrated in (Plate 4b). Similar structures have also been observed in the Trucial coast of the Persian Gulf. The work of Artjshkoo (1963) offers an explanation of the origin of such conspicuous polygonal structures. According to him, any loading on light medium (underlying loose sediment by a heavier medium intertidal rocks), in case of Piram the vertebrate bone beds and the round pebble conglomerates) induces gravitational instability, which leads to the development of polygonal structures. In the case in question, the upper medium is rigid, so the polygonal structures have to appear as cracks (this feature is very well noticed in Piram). As further claimed by Artjshkoo (1963), the cracking also can be caused or at least aided by repeated thermal expansion and concentration, which generally takes place as the intertidal rock is alternately heated by insolation and cooled by water. Once formed, the cracks would tend to become filled by loose sediments, either from above the normal sedimentation or from below due to upward movement of the underlying loose sediment in response to the gravitational instability already discussed. The effect of renewed thermal expansion coupled possibly with the force of crystallizing calcite cement during further cementation of the cracked rocks is likely to first buckle the polygonal slabs into

"tepees" and later thrust them one over another, giving rise to more mature structures of this type. Most of such criteria resulting in "tepee" structures in Piram can be marked in the field (Plate 4a). The undulatory polygonal markings in the sandstone beds are thus very significant.

Arcuate Ridges : Another interesting feature observed in the Piram Island associated with the sandstones is the occurrence of arcuate ridges, which tends to be convex seawards (Plate 4b). These possibly originated through the concentration of sand, previously bound by algal mats, the latter having been buckled locally into series of ridges such as those shown in (Plate 4b). The convexity of the ridges towards the sea gives them the appearance of cave dams. Modification of buckled algal mats to intertidal cave-dam structures would be yet another indication of the rapid carbonate precipitation which seems to be the characteristics of the initial Piram environment.

In summary, the dark yellow to raddish coloured sandstone facies seem to represent deposition in an intertidal to supratidal environment with intermediate periods of subaerial exposure. It is further postulated that this marine deposit which was later subjected to frequent tidal conditions existed at the most landward edge of the shallow sea.

(II) Round Pebble Conglomerate and Vertebrate Bone Bed Subfacies.

The round pebble conglomerate and the vertebrate bone bed which in fact appears to make a single depositional unit, is the

PLATE:4

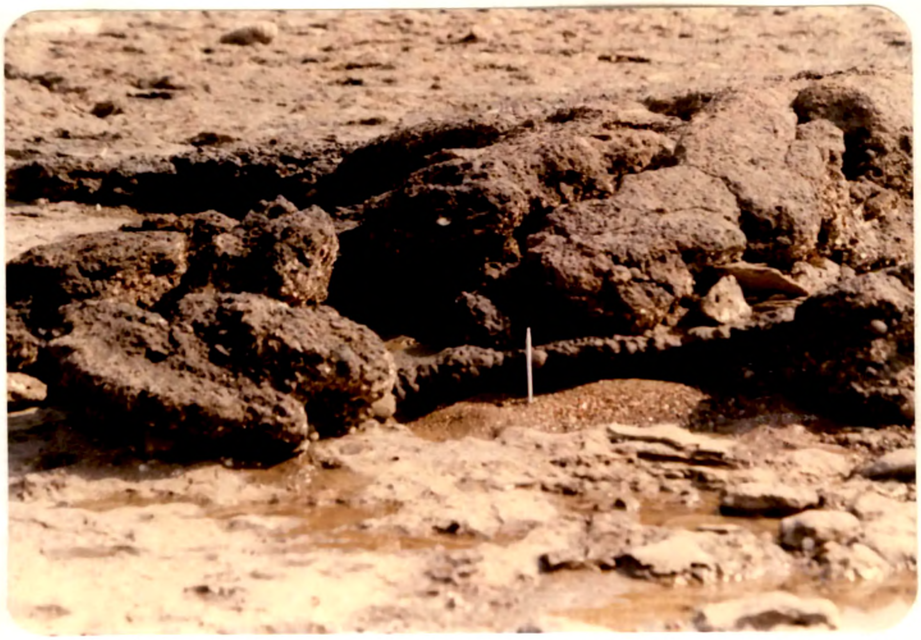
(a) Southeast view Piram Island showing teepee structures. Mangrove vegetation in the background.

(b) Arcuate ridges and polygonal desiccation cracks in the dark yellow to reddish coloured sandstone.

most conspicuous and interesting lithofacies amongst the vertical stratigraphic sequence in Piram. It constitutes a motif of various lithologic associations and records different types of intermittently working processes during its formation. The author has made a detailed probe into all these aspects that resulted in the formation of this lithofacies. These observations are presented below.

The Round Pebble conglomerate :- This Lithofacies in the form of thin sheet of clastic conglomerate is located overlying the upper Miocene dark yellow and red coloured sandstone facies in the intertidal zone south and southwest of the Piram Island. The beds are 20 to 30 cm thick, sheet like in appearence and are laterally continuous in the intertidal and subtidal regions (Plate 5a). Their lower contact with the underlying sandstone is sharp. These conglomerates are clast supported, the larger clasts being supported by a mixture of pebbly, coarse to fine sand and silt. At places these are very tightly packed with pebbles of very resistant lithologies (Plate 5b). Some of the pebbles, however have been removed from the conglomerated bed and are spread over on the beach by waves. The clasts are usually subrounded to rounded and possess a low to moderate and high sphericity and do not show any preferred orientation. Exposed clasts of the conglomerates are very often found blackened in contrast to the internal clasts, which are embedded in the matrix and exhibit original colours (Plate 5b). The darkness of the pebbles could be due to the periodic influence of

PLATE : 5



(a) Contact between the dark yellow to reddish coloured sandstone and round pebble conglomerate (intertidal zone SSE of Piram).

(b) Tightly packed round pebble conglomerate in pebbly, coarse to fine sand, and silty matrix.

the sea water, influence of algae and decaying organic matter during their subareial exposure. Many of the rounded pebbles display rhythmically spaced rind surfaces. These are observed on the pebbles that are spalled off in places (Plate 5a).

There is a wide range in grain size composition of the conglomerate where pebble size varies from 1 to 7 cm. Mineralogical composition of the conglomerate studied in thin section indicates assorted grains of grey, pink, red, yellow quartz, chert, bone fragments and hematite in ferrugineous cement. Most of these grains are angular to subangular in nature.

The clast composition of the conglomerate shows that the sediments excluding the rounded pebbles are petrographically immature. In most of the grains the angular and subangular quartz fragments make more than 30 to 40 percent of the grain. The local or nearer source is reflected in the petrographic immaturity of the matrix. Thus, even though the conglomerates occur in the intertidal zone, their textural characters are not consistent with either normal beach or near shore deposits.

The high degree of roundness of the conglomerate pebbles seems to have been attained from previous cycles and appears to be as characteristic of the pebbles in the alluvial deposits or those in the coastal plain (Cliffton, 1967). This similarity suggests that the clasts are not derived from the same rock, but are from the reworking of the unconsolidated debris on the unstable slopes or from the extensive gravel sheets covering the coastal plain which has been dissected by a river or streams. Chemical composition of the pebbles (Table : 7) however, supports the first assumption.

Furthermore in case of the Typical wave-worked beach pebbles as suggested by Cliffton (1973), the pebbles are better segregated into discrete beds of great lateral extent than those deposited by alluvial processes. He, further states that in the nearshore environment, continuous reworking and winnowing away of the sand leave behind a concentration of lag gravel. None of these processes seem to have influenced the Piram conglomerate as their textural characters show polymodal grain size, considerable sand content, poor sorting and limited lateral extent. Such features according to Cliffton (1973) are indicative of sediments deposited rapidly during flash floods and lack of subsequent reworking in the depositional environment. It could be suggested, therefore that the conglomerate clasts were transported to the emergent shelf by some flooding that might have existed for a short period.

The fineness and the nature of the matrix material, however is not significant with high energy flood sedimentation and indicate that the matrix had not been deposited simultaneously with the rounded pebbles and gravels. It is possible that the sand - silt matrix and the carbonate mud have accumulated by subsequent infiltration at a lower energy flow stage into what was originally an open gravel. Beschta and Jackson (1979) have experimentally demonstrated such an intrusion of sand into a pebble gravel bed. The exact time for such happenings, is rather difficult to confirm.

The nature of the rounded pebble conglomerates further became significant when the occurrence of phosphate was detected in the same (Table : 7). Chemical analysis shows the

Table : 7 Phosphate content in different samples

Material/Sample	Moisture in %	Residue in %	Organic matter in %	Phosphate % in 1 gm.
Black pebble	1.2	93.0	7.0	11.0 mg.
Bone bed conglomerate	1.8	89.5	10.5	0.5 mg.
Fossil wood	0.8	92.5	7.5	8.5 mg.
Gritty conglomerate	2.5	78.9	21.1	12.0 mg.
Dark yellow to reddish coloured sandstone	0.7	92.5	7.5	14.0 mg.

material to be mainly hydrous tricalcium phosphate with varying amounts of calcium carbonate and fluoride. Because of admixture of nonphosphatic materials such as calcite, dolomite, chalcedony and iron as cement and also detrital contaminates such as quartz and clay, analysis are highly variable in different samples.

As it is quite well known the phosphorite beds occur in rocks of all ages from Precambrian to Holocene, and on all continents (Blatt, 1982). The conditions in which they were formed therefore have not been uncommon throughout the geologic time. Furthermore, phosphorite are chemical or biochemical rocks rather than terrigenous detrital rocks. Therefore, it is informative to determine the character of the water in which phosphate can be concentrated. The first person to consider this question was a Russian A.V. Kazakoo, 1937. From the oceanographic data, he determined that $P_2 O_5$ content of marine water is at a maximum depth about 30 - 500 m. At less than 30m, the phosphate is consumed by photoplankton during photosynthesis. At depth greater than 500m, the content of CO_2 in water is so great that the water cannot became saturated with apatite, because apatite like calcite is soluble in acid. So usually, the depth greater than 100m or so are not of much interest to any event of phosphate concentration. Apparently, as suggested by Blatt, (1982) the phosphate material has a tendency to crystallize interstitially among particles at and immediately below the water-sediment interface, and in its process of formation it commonly replaces existing materials.

As claimed by many writers (Pettijohn, 1984); (Blatt, 1982) etc.) the phosphatic pebbles are found not only in limestones but are even distributed in other sediments including chalk (Adams, Grooh and Tiller, 1961). They also occur on present sea floor (Diatz- Emery and Shephard, 1942). Such objects vary from small granules to pebble size material several centimeter in diameter. They are typically black and have a hard shiny surface. Larger nodules contain much foreign matter including sand grains, mica flakes, shell debris etc. Most of this description is analogous to the rounded pebbles found in the Piram conglomerate. One more variety of pebble usually found scattered on the rock surfaces in Piram appears to have been formed by the replacement in the limestone pebbles (Plate 6b). In this case the relict textures in the original rock, are replaced by the phosphate bearing solution. It could be the metasomatic phosphate variety described by Pettijohn (1984).

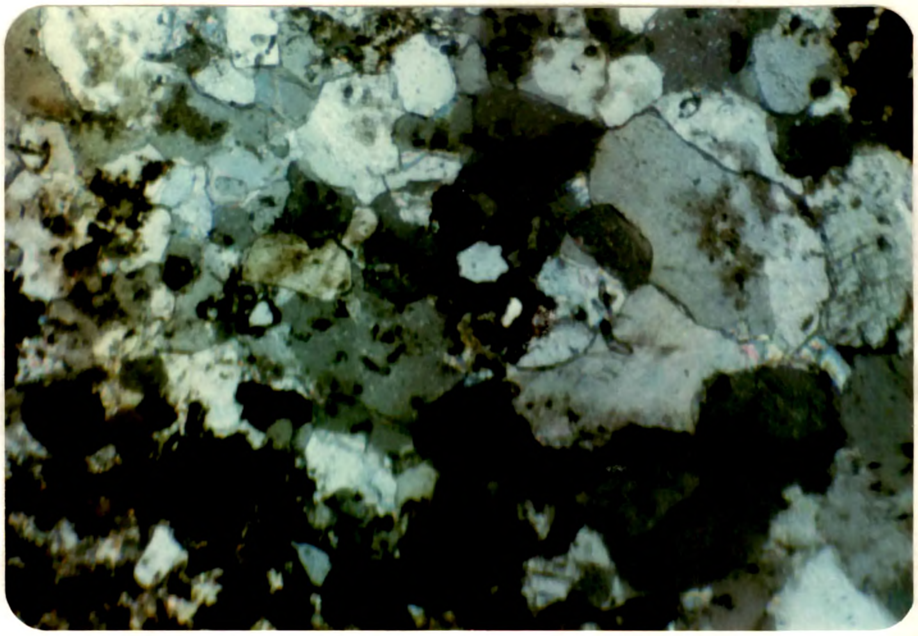
With the above information it will now be appropriate to probe into the vertebrate bone bed which forms a sizable portion of the conglomerate. The vertebrate bones also display phosphatic material in the form of characteristic globular masses, as is usually the case with the microbially influenced formation of phosphate. Therefore the question regarding the primary or secondary origin of the phosphate sedimentation the author feels,the answer has to be resolved in a broader perspective of all such evidences, available in the entire sedimentary facies.

The Vertebrate Bone Bed

The vertebrate bone bed consists of distinct surfaces with mammalian and other bones disbursed over the round pebble conglomerate (Plate 7). It comprises an assemblage of Crocodiles, Chelonids, Elasmobranchs, Bovides, Tragulids, Giraffids, Suicls, Equuids, Rhinocerotids and Proboscidean scattered bones (Prasad-1974). The mammalian fossil bones

PLATE:6

(a) (i) Close up of poished surfaces of round pebbles, displaying rhythmatically spaced rind surfaces.
(ii) Close up of typical round pebble conglomerate with some associated flat pebbles.



(b) Photomicrograph of round pebble x 25

PLATE : 7

Associated fossil vertebrate bone with round pebble conglomerate.

indicate a mix assemblage with Rhinocerotids and Suids living in the vicinity of swamps and forms such as Equuids, Giraffids and Proboscidans preferring forest to open Savannah type of land conditions.

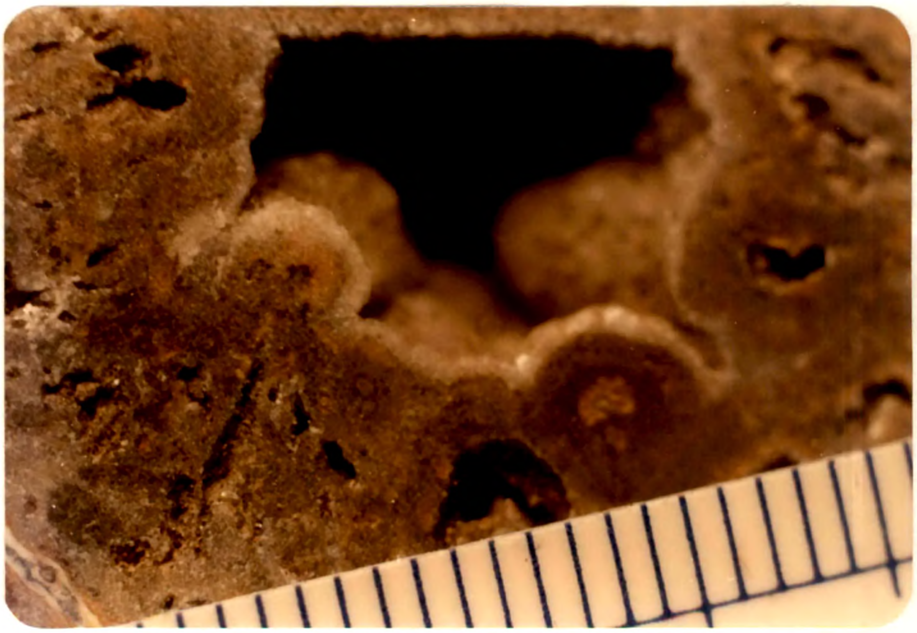
Most of these fossils have at places a peculiar black stain and are generally yellowish to dark brown in colour, probably due to the iron content in the conglomerates in which they are found embedded. Very often these bones are found to be eroded by the sea waves and then subjected to diagensis whereby framboidal (Globular) phosphatic materials are released into the cavities of the bones (Plate 8a,b). Likewise many of the bones are subjected to borings by different borers (Plate 9a). Large masses of fossilized drift-wood many of them bored are very common along with the vertebrate remains (Plate 9b). Table 8 tabulates the mammalian and other vertebrate fossils found in Piram.

Although, the conglomerate containing abundant bone fossils have been investigated from Fedden's (1884) time, there has been no particular effort to interpret the provenance of the material and to fix the geological age of the formation. Fedden (1884), preferred to assign these beds to the Gaj formation, while Lydekker (1885) suggested these beds as equivalent to upper Siwaliks. Pilgrim (1926, 1932), on the other hand, claimed them to be of Nagri (Sarmatian) and Dhok Pathan age (Pontian age) while Colbert (1938) calls it Post-Pontian, Osborn (1942) agrees with Pilgrim. However, Rao and Jain, (1959) as reported by Shrivastava (1982) identified Dicoryphocherus cf. Titan, Table : 8 Distribution of vertebrate fossils in round pebble conglomerate (Information based on Fedden, 1884; and Prasad, 1974)

	Genus : Scoliodon Muller and Hanley Scoliodon sp.	Tertiary
PISCES	Genus : Prionodon Muller and Hanley Prionodon sp.	Tertiary
	Genus : Aprionodon Gill Aprionodon sp.	Tertiary
	Genus : Myliobatus Cuvier Myliobatus sp.	Tertiary
CHELONIA	Piramys auffenbrgi	Pliocene
	Genus : Lyssemys Gray Lyssemys Piramensis sp. nov.	Plicene
	Genus : Colossochelys Falc & Caut Colossochelys atlas	Tertiary
	Genus : Gharialis Geoffroy Gharialis curvirostris Lyd.	Cenozoic
EQUIDAE	Genus : Hipparian Christol Hipparian protylum Gerviis Hipparian antiopinum Falc. and Caut.	Nagri (Sarmatian)
	Genus : Hippariantheobaldi	Dhok Pathan (Pontian)
	Genus : Aceratherium Kaup. Aceratherium Perimense Falc. and Caut.	Mio-Pliocene
	Genus : Antilope Pallas Antilope planicornis pilgrim	Tatrot (Astian)
BOVIDAE	Genus : Tragocerus Gaudry Tragocerus perimensis Capra perimensis	Pliocene- Pleistocene
	Genus : Tragoporiax Pilgrim Tragoporiax sp.	
	Genus : Ruticenos Pilgrim Ruticenos compressa sp. nov.	Dhok Pathan (Pontian)
	Genus : Pachyportax Pilgrim Pachyportax nagri Pilgrim	Nagri (Sarmatian)
PROBOSCIDEA	Genus : Stegolophodon Schlesinger Stegolophodon cautlegi Lyd.	M. Pliocene
	Genus : Anancus Aymard Anancus Perimensis Falc. & Caut.	M. Pliocene
	Genus : Seienoportax Pilgrim Seienoportax vexillaris Pilgrim	Dhok Pathan (Pontian)
	Genus : Dorcatherium Kaup. Dorcatherium minus Lyd. Dorcatherium nagri	Chinji to Dhok Pathan (Tortoni to Pontian)

PLATE:8

(a) Close-up of polished surface-fossil vertebrate.



(b) Enlarged view showing the concentration of phosphatic globules in the core part of the above fossil.

PLATE:9

(a) Bored vertebrate bone embedded in round peble conglomerate.

(b) Close-up of fossil wood with animal borings.

Gazella Cf. _Lydekkeri_ _Trilophodon_ sp. (teeth) from the conglomerates and suggested age of the conglomerates as Lower Pliocene. The _Trilophodon_ sp., found later by them signified an upper Miocene age. These beds according to Rao and Jain (1959) are therefore, not older than the upper Miocene. Based on the evidence of progressive Bovid and Proboscidean fauna, Prasad (1974) suggests the Piram assemblage in all possibility belonging to the Dhok Pathan stage of Middle Siwaliks and therefore, of Pontian in age. As further claimed by Prasad (1974) the overall lithology of Piram Island indicates a shore facies deposition, whereas the embedded fossils are suggestive of proximal land conditions. He further states that the ecological, lithological and depositional conditions of the whole unit appear somewhat different from the freshwater geosynclinal deposits of the Siwalik Formation.

There remains now the question of actual processes that led the landliving vertebrate fossil bones to be associated with the round pebble conglomerate, the timings for such an event and the overall phosphatization of the pebbles, bones and sediments, whether primary or secondary and the chronology of these events.

The problem about the rounded pebbles and their immature matrix is already discussed in the earlier paragraphs. The questions to be answered now are, whether the phosphatic materials were directly precipitated from the sea water ? or whether the deposits that were originally calcareous were subsequently replaced by phosphate ? And if so, was the replacement synsedimentary, taking place on the sea floor or was it epigenetic and took place after lithification of the vertebrate bones ?

In general, the field observations indicate both the primary precipitation of the phosphate and its metasomatic replacement in majority of the nodules (Plate 8a,b). There is also the possibility that the phosphate was extracted from sea water by a biological agent (may be algae) and released to be later precipitates abiotically as granules and pebbles. Later the diagenetically released phosphate, from the vertebrate bones also might have significantly contributed to the whole system of phosphate deposition.

We may now follow the sequence of events. First, it will be logical to consider the drawning of the older sandstone beds under a very shallow transgressive sea. This could have happened sometime during the Late Miocene period. Later establishment of the tidal and subtidal conditions in the system perhaps favoured the formation of algal mats and their arcuate ridge system. Development of the polygonal structures, tepee and arcuate ridges reveal alternate periods of drawing and emergence and these episodes may have commenced for quite a long period of time. Next was the episode of flash flood deposition when the rounded pebbles possibly derived from the unconsolidated debris on the unstable ocean slopes were transported and spread over like sheets on the growing calcareous algal mats and the arcuate ridges. These in turn were then mixed with the coarse to medium and fine grained detritus sands drawn from their source not far away from the site of their deposition. It is possible that the two episodes took place without much of the time lapse. This event was then followed by the mixing of the vertebrate bones this too perhaps instantly. The vertebrate material being supplied through fast moving source. As mentioned earlier, most of these vertebrate fossils were landliving animals, living either in swamps or grassy lands. The oldest of these being upper Miocene in age. It is therefore possible to fix an upper most Miocene to lower Pliocene age to the round pebble conglomerate and their associated bone bed. It could further be suggested that the deposition of the conglomerate may have been comparitively a very slow process that witnessed periodic episodes of high energy events followed with emergence of the platform and nondeposition and subaerial exposures at short intervals. There were also periodic flash floods may be because of extreme climatic variations (heavy rains and debris flow) resulting in freshwater runoffs and area of deposition was perhaps situated on the edge of the continental land surface most likely as an estuarine proximal delta.

4.3.2 MIDDLE TRANSGRESSIVE - REGRESSIVE FACIES

(I) Cherty Pebble Conglomerate Subfacies

Another conglomerate which almost disconformably overlie the round pebble conglomerate is the cherty pebble conglomerate. It shows a sharp contrast with the former in its colour as well as the clastic material. The rounded pebbles are absent in it and its place appears to have been taken by subrounded to subangular clasts, which are grey, pink, red, blue, and yellow in colour. These conglomerates are also clast supported but the clast are very often found to have been fragmented and angular (Plate 10a). The clasts are 2 to 7 cm in length and embedded in the calcareous matrix with coarse to fine grained material, which is similar to the large sized clast. These conglomerates also incorporate a few vertebrate bones and teeth in them (Plate 10 b,c). Like the previous conglomerate this type also displays a sheet like appearance. It's occurrence is further restricted to the southern part of Piram Island.

The cherty pebble conglomerate, although not very spectacular as compared with the round pebble conglomerate is still very conspicuous. Actually, Blanford as early as (1863) was the first to note the occurrence of this variety in Piram. According to him the matrix of the pebble of this variety of conglomerate which forms the bulk of the rock, is coarse sandstone, containing fragments of agate and quartz pebbles without much of their rounding. He however, makes no comment on its depositional setting. As, is rather apparent, the formation of the conglomerate appears to have taken place after a sizable time gap since the earlier episode of the round pebble conglomerate deposition. The material of the clast is rather unimodal, with very coarse grained quartz, angular chert and fine grained angular to subangular sand in calcareous and ferruginous

PLATE:10

(a) Close-up of cherty pebble conglomerate.

(b) Fossil vertebrate bone embedded in cherty pebble conglomerate.

PLATE : 10

(c) Close-up of vertebrate teeth in cherty pebble conglomerate.

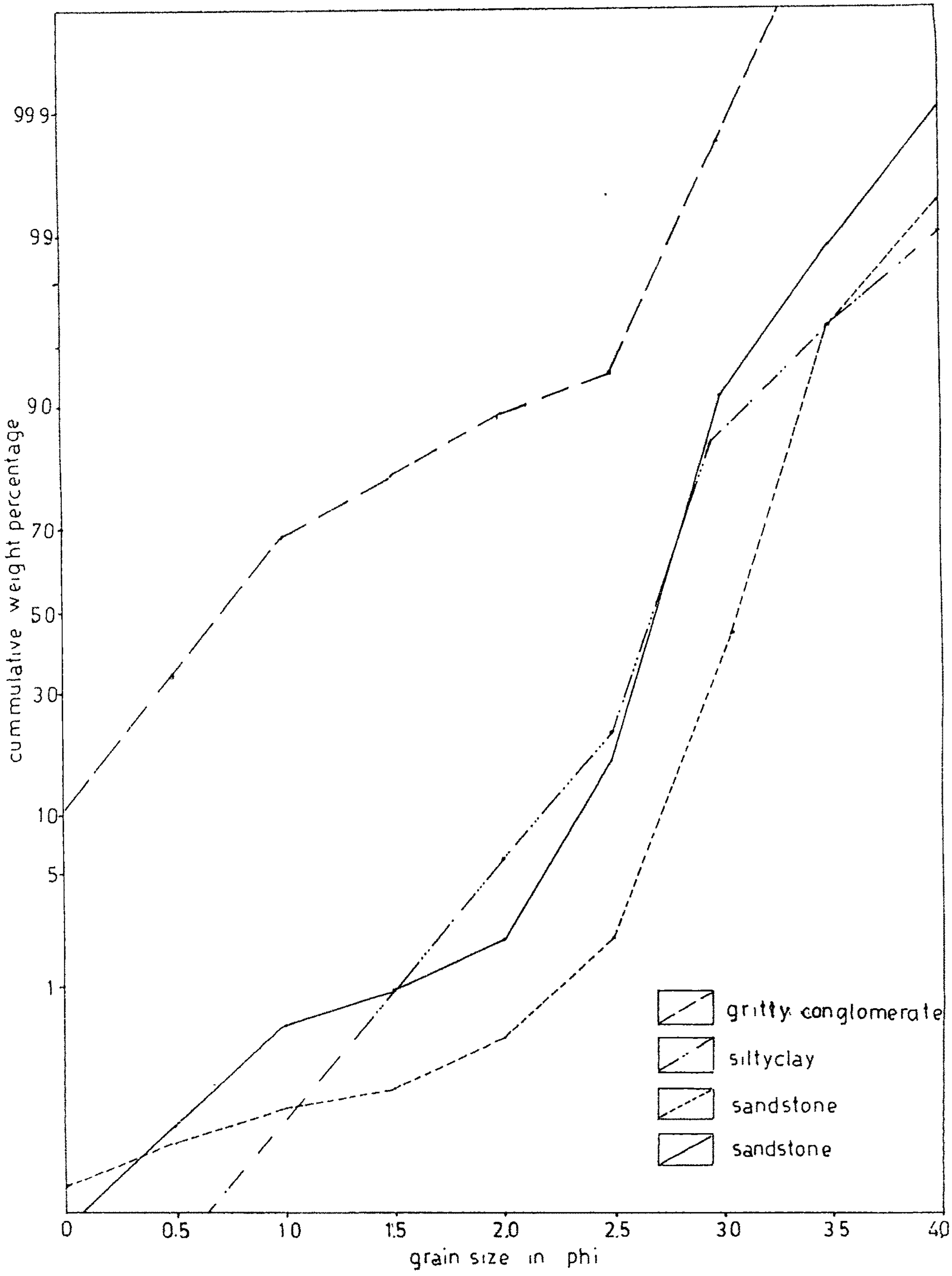
matrix. The source of this material thus must not have been very far. Poor sorting of its material and wide sediment range indicates its sudden deposition. It could be guessed that the patterns of deposition of the vertebrate bone bed and this conglomerate, perhaps, remained the same. Evidences on these matters at present, however are inconclusive.

(II) Medium to Fine-Grained Sandstone Subfacies

The rocks of this subfacies are horizontally stratified and disconformably overlie the cherty conglomerates. Its contact at the base with the cherty conglomerate is very sharp and the bed is clearly distinguishable in the field (Plate 2 & 11). Exposures of this rock type can be observed along the cliff section in the south and southwest of the Island. Lateral trace of the rocks is not possible for a longer distance as very often they pinch out in the northern side or get concealed beneath the recent sand deposits. Maximum thickness of the unit varies between 1 to 1.5 metres. Desiccation cracks on the upper bedding plane are common. Except faint parallel laminations and minor cross-bedding no other sedimentary structures are observed. These rocks do not contain any megafossils or biogenic sedimentary structures.

In thin section the sandstone shows fine to medium grained sand size particles of quartz, agate, chalcedony, hematite, magnetite, muscovite flakes, hornblende and felspars. The grains are mostly sub-angular to sub-rounded, moderately sorted and

FIG. 6 CMMULATIVE CURVES FOR TEXTURAL INTERPRETATION OF OLDER SEDIMENTS - PIRAM ISLAND.



cemented by calcareous and ferrugineous cements. The microfossils include reworked foraminiferal species of <u>Textularia</u>, <u>Cibicides</u>, and <u>Elphidium</u>.

The textural characteristics of the sediments are represent in figure 6 and the interpretation from the cummulative frequency curve are shown in Table : 9.

The textural, mineralogical and microfaunal studies indicate deposition of this subfacies in a tidal channel with moderate to low energy conditions.

Table 9 Verbal Interpretation of the Textural Parameters

Sample No.	Graphic Mean Mz	Inclusive Graphic Deviation δI	Inclusive Graphic Skewness SK_I	Graphic Kurtosis K_G
Basal Sandstone (A)	2.7 (fine sand)	0.24 (very well sorted)	-0.08 (negatively skewed)	1.56 (very lepto kurtic)
Middle Silty clay (B)	2.68 (fine sand)	0.39 (well sorted)	-0.226 (negatively skewed	1.7 (lepto kurtic)
Upper Clay stone (C)	3.05 (very fine sand)	0.24 (very well sorted)	0.43 (very positively skewed)	1.39 (very leptokurtic)

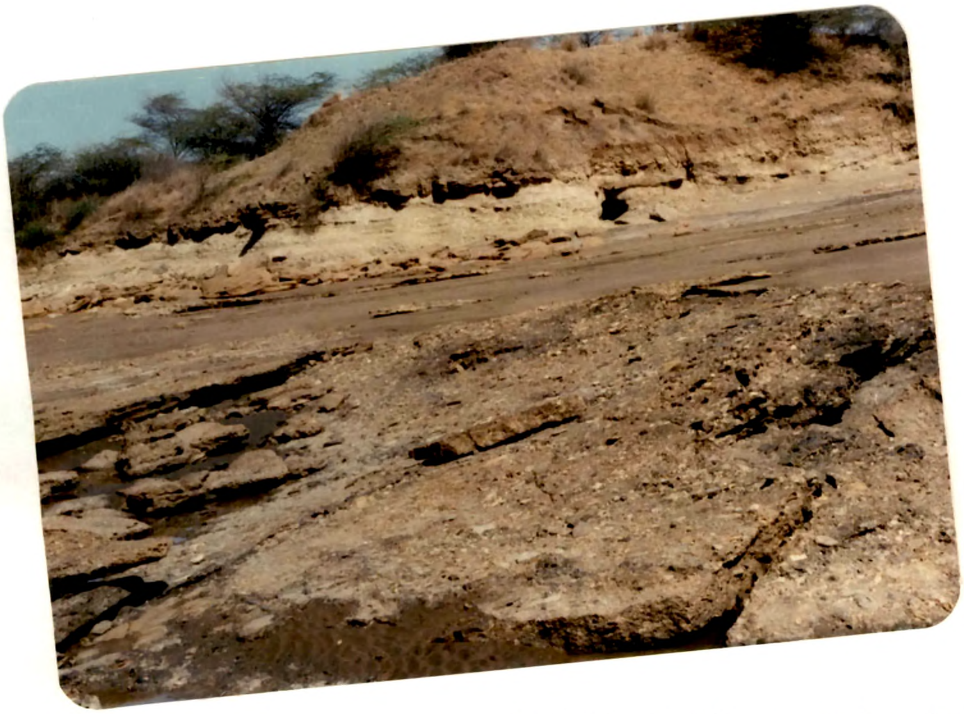
(III) <u>The Silty Clay and Claystone Subfacies</u>

This subfacies is characterized by thin bedded alternations of cm to mm thick laminations of silty clay and claystone deposits. Its predominant colour is grey to white, but locally the rock is light to dark olive grey and at places even greenish or reddish. The clayey layers are very often found to be weathered into small brittle flakes. The contact of this subfacies with the underlying sandstone and overlying gritty conglomerate bed can easily be determined in the field (Plate 11). Many of these laminated clay beds are structureless. However, a few show sharp erosional bases with, minor scours and ripple laminations. Faint "dish" structures can also be marked in the upper horizons of this unit. Concretionary clay nodules aligned along the bedding planes are the common features in many exposures. The nodules are generally 10 to 20 mm in diameters, that are distributed in nearly five horizons in the vertical section exposed at the southern extremity of the Island (Plate 2). The large number of such concretionary nodules along the strata make useful marker beds. No microfossils or trace fossils have been found in these rocks.

Thin section studies indicate that the silty clays as a whole are made up of fine to very fine grained silt size particles of quartz, Chert, magnetite, limonite embedded in the fine grained silt and clay matrix. Some unidentified plant strands and pollens are seen in the thin section.

The deposition of the silty clay and claystone subfacies as evidenced from its well bedded and laminated structures appears to be considerably slower as compared to the previous units. Furthermore, this subfacies, conformably overlies the sandstone

PLATE : 11



Stratigraphic section (cliff section south of Piram showing beds : A - Cherty pebble conglomerate; B-medium to fine grained sandstone; c-silty clay and claystone; and D-coarse pebble gritty conglomerate. Tepee structures in the foreground.

below and may represent a continuous event in the depositional phase. However, the sharp lithological and textural changes from the sandstone facies to the very fine grained silty clay and claystone, together with considerable intraclasts (oriented nodules) represent episodes to indicate change in the sedimentary fabric without much time lapse. Such events could have resulted from the mechanical transport of clay during the time of heavy rains.

The greenish claystone suggests slightly reducing environment, and the red claystone probably represents longer exposed periods.

4.3.3 UPPER TRANSGRESSIVE FACIES

(I) Coarse Pebble Gritty Conglomerate Subfacies

This youngest conglomerate unit rest unconformably over the silty clay, claystone subfacies. It shows its maximum thickness of 1 metre in the south, southwest, and southeast parts of the Island along the exposed cliff section. This facies incorporates coarser grains of quartz, chert, agate, sandstone and claystone in the ferrugineous matrix which also contains medium to fine grained fragments of quartz, chert, chalcedony and agate. The sorting is very poor and the grains are angular to subangular in nature. In the upper levels of the unit this facies becomes more gritty. No physical or biosedimentary structures are observed in this facies. It further shows no bedding structures or laminations of any sort.

The textural analysis of the rock gives the following results; graphic mean size (Mz) 0.88 phi, (coarse sand); standard deviation (σI) 0.78 phi, (moderatively well sorted); skeweness (SKi) 0.3 phi, (fine skewed); and Kurtosis (Kg) 1.17 phi, (Leptokurtic).

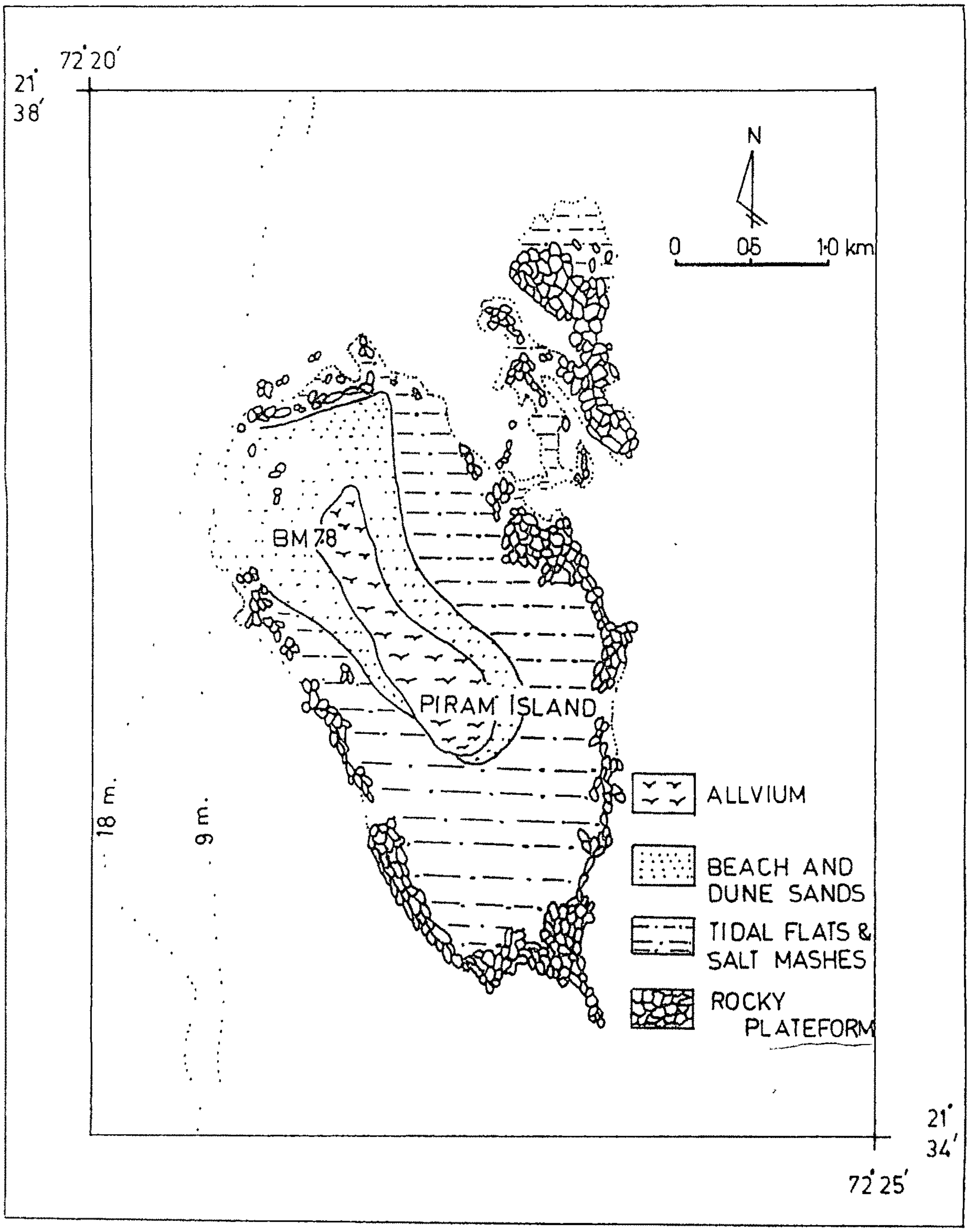
The younger conglomerate once again reveals episodes of high energy conditions for their deposition after a possible long nondepositional interval. The textural analysis of the sediments and their overall immaturity indicate nearness of the source. Absence of sedimentary and biogenic structure probably suggest its deposition by debris flow through some flash floods which continued for very short durations along side the coastal plain.

NEARSHORE SEDIMENTARY FACIES

Nearshore is defined here as the zone of shoaling waves (including the surfzone), where the wave generated rip and longshore currents prevail (Shephard, 1963; Cliffton, Hunter and Phillips, 1971). Under this defination the width of the nearshore zone varies, expanding under larger waves and contracting under small waves. For the most part nearshore lies in water depths of less than 10 m.

The Island of Piram being twice everyday subjected to extreme tidal variations the nearshore morphology as expected displays a complex depositional pattern. As a result numerous present day depositional and erosional features are typically displayed around the Island of Piram. The observed surface morphology of nearshore sedimentary facies in Piram is illustrated in Figure 7. Though, small in extent, the depicted areas are reasonably representative of the developed land forms in Piram. These include not only the beaches and dunes, but also the tidal flats and salt marsh deposits. Because of the intertidal and supratidal exposure of the beaches and dunes and

FIG. 7 GEOMORPHOLOGICAL MAP OF PIRAM ISLAND.



the regorous physical processes, the overall abundance and diversity of organisms generally is very poor. Very often the beaches are covered with extremely fine grained black sand placers in the form of irregular patches and layers. All these geological features are described in detail in the following text.

5.1 BEACHES AND BEACH RELATED FEATURES

Beaches :

Typical beach development can be observed on the northern and northeastern part of the Island. Beach slopes commonly are less than 10 towards the sea and the seasonal changes show some variation. Pronounced effects of neap and ebb tides can be observed at the northern and northwestern extremity of the Island where the associated material of very large sized (Pebble and Cobbles) flat discs is presently being accumulated, very close to the beach shoreface zone (Plate 12a). This material in turn gradually decrease in size and finally ends in the fine grained dune sands (Plate 12b). The berm along the beach is poorly developed or is totally absent. Sediment consist predominently of fine-grains, well sorted quartz sands, and mixed pelletoidal sands. Heavy minerals are concentrated in the upper foreshore, backshore and in dunes in decreasing proportions. Typical beach laminations can be observed in the freshly opened cuts (Plate 12a) Rill and Swash marks and oscillation, current and

PLATE:12

(a) View of foreshore, backshore and dune field from NNE of Piram.

(b) Beach laminations on freshly cut section.

rhomboid ripples are found on beach surfaces. Ripples in the backshore and dunes are commonly of aeolian origin (Plate 13a).

<u>Foreshore</u> : The foreshore commonly is about 25 to 30 m. wide and has a seaward dip of 2. The usual features of the foreshore include (a) occasional mud layers, (b) fragmented shell layers, (c) ripple laminae, and (d) biogenic sedimentary structures (abundance very low). The other observable changes in the foreshore are the migration of ridges and runnels.

<u>Backshore</u> : The backshore has a very negligible seaward dip as compared to the foreshore. It is about 30 to 35 m. wide. In contrast to the smooth, wave and swash planed surface of the foreshore, the backshore has a variety of irregular structures. In Piram heavy mineral concentrations are commonly left on the backshore beach surfaces and the lighter fractions are generally carried to dunes by the prevailing winds. The backshore sediments are thus less homogenious in appearance than are the foreshore sediments.

Diverse sedimentary structure are observed in this zone. These include various types of wave and current formed ripples. Wind ripples are prominent on surfaces which are left exposed to wind conditions for several days.

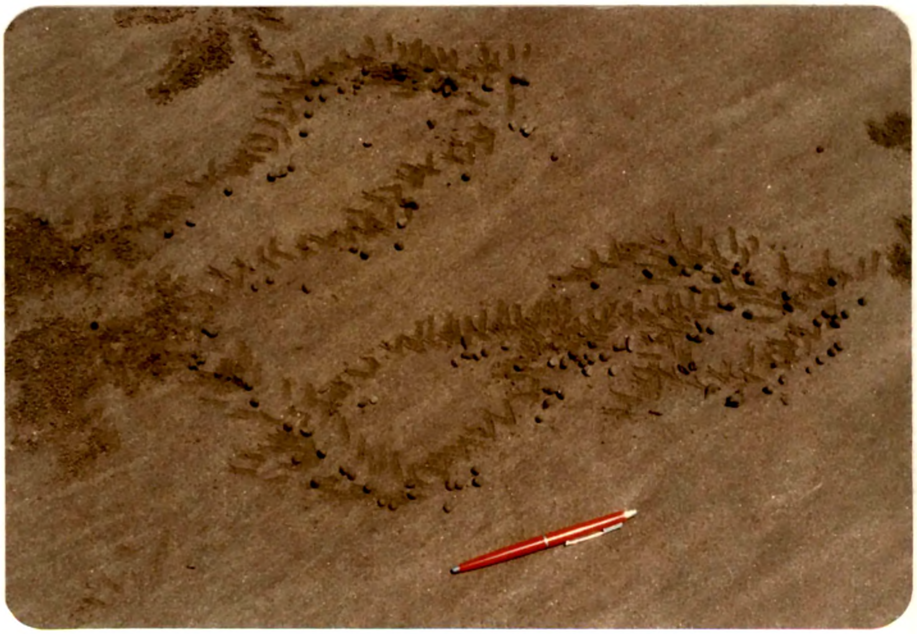
Burrows of <u>Callianassa</u> <u>major</u> are comparatively less abundant in the backshore because this area is so seldom covered by water for longer duration of time. In their place, there are unlined burrows of the ghost crab Ocypode, a beach scavenger. During burrow excavation the crab deposits large incohesive pellets of sand on the beach surface (Plate 13b). Abundant tracks and trails to their mobility can also be located along side with the fecal pellets in this zone.

Dunes :

Rows of dunes typically 2 to 4 m. high mark the landward edge of the beaches in Piram (Plate 13c). Invariably the depositional agent here is wind. Saltation of sand across the dunes occurs continuously, although the dune position at the present appears to have been stabilized. Typical wind ripples less than 5 cm high, with coarser sediments on crest are very often found associated with these dunes. Occasionally the dune profile appears to have been subjected to storm (Plate 13d). Evidences to such an event could be found in the sands accumulated arond the light house region in Piram. These sands approximately 10 m. thick have textural characters almost similar to those of the foreshore and backshore sands, with the growing vegetations on it. These deposits further display an appearance like a stabilized dune. With the termination of this major episode and except for the seasonal storm recurrences (Plate 13d), the normal processes appear to be constantly restoring the beach dune equilibrim profile.

PLATE : 13

(a) Structure developed on the dune.



(b) Grazing marks with feeding pellets of crab on upper foreshore zone.

PLATE:13

(c) Stabilized dune with vegetation cover.

(d) Effect of recent storm. Sand deposit compeletely covering drifted bullock

5.2 TIDAL FLATS, SALT MARSHES AND MANGROVE SWAMPS

Tidal flats, salt marshes and mangrove swamps in Piram are forming in its southeastern part, espcially in areas where the wave and current energy is markedly reduced during the receeding tides. Much of this zone is occupied by the growing mangroves. This zones also provides abundant nutrition for the development of organic communities which inturn produce large amount of fecal pellets and pseudofaces that become incorporated within the sediments. The sediments of the tidal flats and salt marshes are predominently fine-to medium grained sands possibly derived from the adjacent beach.

Surfacial features on the tidal flats, salt-marsh and mangrove swamps typically include ripple marks, having amplitudes of 2.0 to 3.5 cm and wave length of 4 to 6 cm (Plate 14). Ripples are oriented with respect to dominent wave energy. Most of the troughs are filled with fecal material and organic detritus, the later mostly derived from salt marsh plants. Internal structures of ripple lamination reveal both onshore and offshore dip directions, onshore directions, however predominate. Rising tides and onshore currents help to generate ripples, and falling tides truncate or modify them.

In the tidal flat and salt marsh, zone of the biogenic processes predominates over the physical ones. Distinctive burrows of small and large animals are invariably found in these

PLATE : 14

View looking SE of Piram : development of tidal flat and salt marsh. Also visible are the mangroves and black sand placers.

zones. There are often some common structres like the holes made by some fishes while foraging on polychaetes and other animals.

TEXTURAL CHARACTERISTICS OF THE COASTAL SAND

For the purpose of textural analysis, samples were collected from a wide range of beach and dune micro-environments, like low tide level, high tide level, first line of dunes and interior dunes. In every instance, efforts were made to collect comprehensive samples representative of the condition at the time of sampling and also of the considerable variation in grain size with in the same environment.

In the laboratory the textural analysis of the sediments were made using dry sieving techniques for the representative samples. About 50 gms of the material was obtained by coning and quatering of the washed oven dried samples which were then put into cleaned standard ASTM sieves (10,14,18,35,45,60,80,120,170, and 230 mesh). The fraction of sand remained in each sieve were weighed individually upto a fraction 0.001 in electrical balance. Once the sediments were analysed and the frequency of the distribution in selected size-intervals obtained, the next step followed was : (1) to represent the frequency distribution on graphs, and (II) to calculate statistical parameters by graphical method.

6.1 GRAPHIC REPRESENTATION

The graphic methods were adopted following Krumbein and Pettijohn (1939). The representation of the size-analysis data was done by preparing (a) histogram, (Figure : 8) and (b) cummulative curves (Figure : 9) using probability ordinate graph.

(a) Histogram : Histograms are the simplest form of expression of grain size data. Though histograms are of little value for determination of any statistical parameters, they were found to be useful to interprete general features of sediments - eg. unimodel/bimodel.

(b) Cummulative Frequency Curves : Cummulative frequency curves were made plotting the added weight percentage of the succeeding classes on the probability ordinate paper. When the ordinate scale is a probability percentage in a cummulative frequency curve, the shape of the curve is a straight line for a log-normal distribution values of parameters which are of great interest in environmental interpretations. Skewness and Kurtosis were read of to nearest 0.01 phi from the probability paper.

The various statistical parameters so obtained were computed by using the formula proposed by Folk and Ward (1957). The results are tabulated in the following Table 10.

FIGURE: 8 HISTOGRAMS:GRAIN SIZE DISTRIBUTION - PIRAM SEDIMENTS

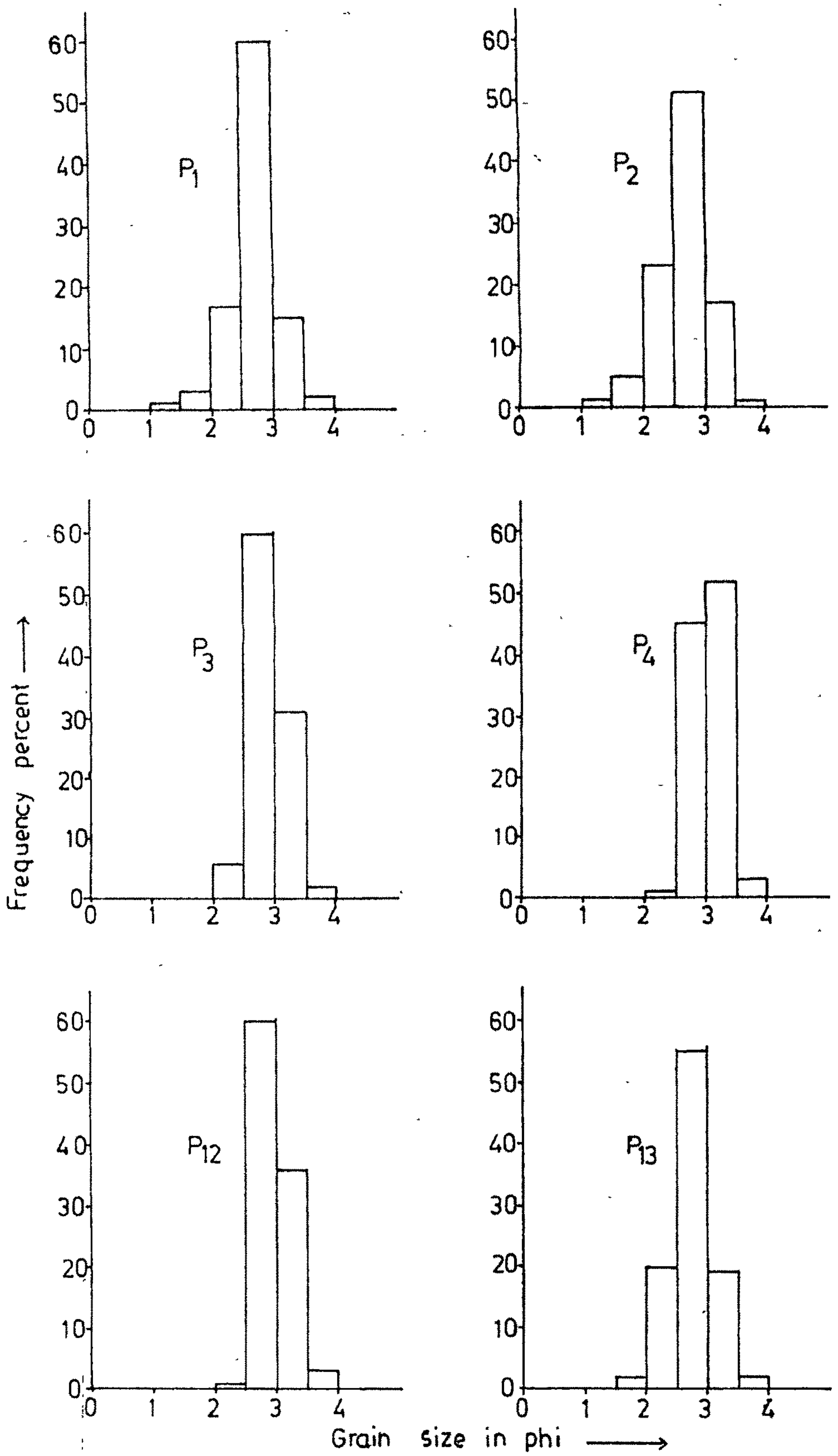


Fig. 9 Cummulative curves for textural interpretation of Piram sediments

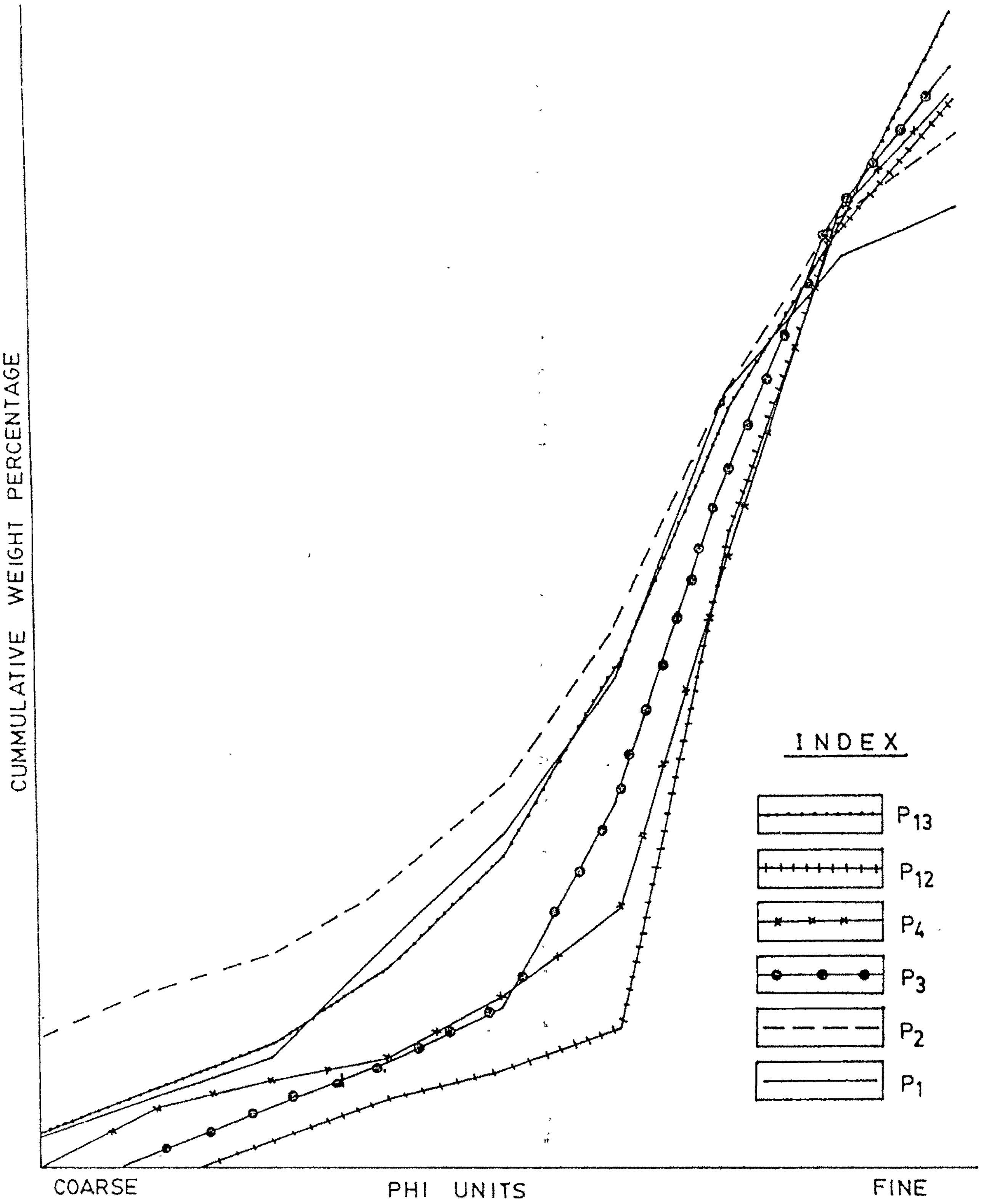


Table : 10 Sediment Characteristics of Piram Island

Sample No.	Mean Size (Mz)	Standard Deviation (σ_I)	Skewness (SK_I)	Kurtosis (K_G)
P_1	2.75	0.39	0.036	1.43
P_2	2.6	0.43	-0.030	1.23
P_3	2.92	0.28	0.070	0.97
P_4	3.02	0.25	0.100	1.05
P_{12}	2.98	0.25	0.188	0.99
P_{13}	3.25	0.37	0.000	1.33

6.2 SEDIMENT CHARACTERISTICS

From the table, it is seen that the graphic mean size value in general ranges from very fine sand (3:25 phi) to fine sand (2.65 phi), the inclusive graphic standard deviation value suggests well sorted (0.43 phi) to very well sorted (0.25 phi) sediments. The graphic inclusive skewness value ranges from fine skewed (0.188 phi) to nearly symmetrical (-0.03 phi). The graphic kurtosis value of the sand varies from leptokurtic (1.43 phi) to mesokurtic (0.97 phi). From the histograms (Figure 8) the sediments are unimodal in character and from the cummulative frequency curves (Figure 9) the average percentage of grain transport by traction is 0.83, by saltation 92.9 and by suspension 6.05. These values could be very significant. There is a little variation of sediment characteristic from beach to dune.

HEAVY MINERAL STUDIES

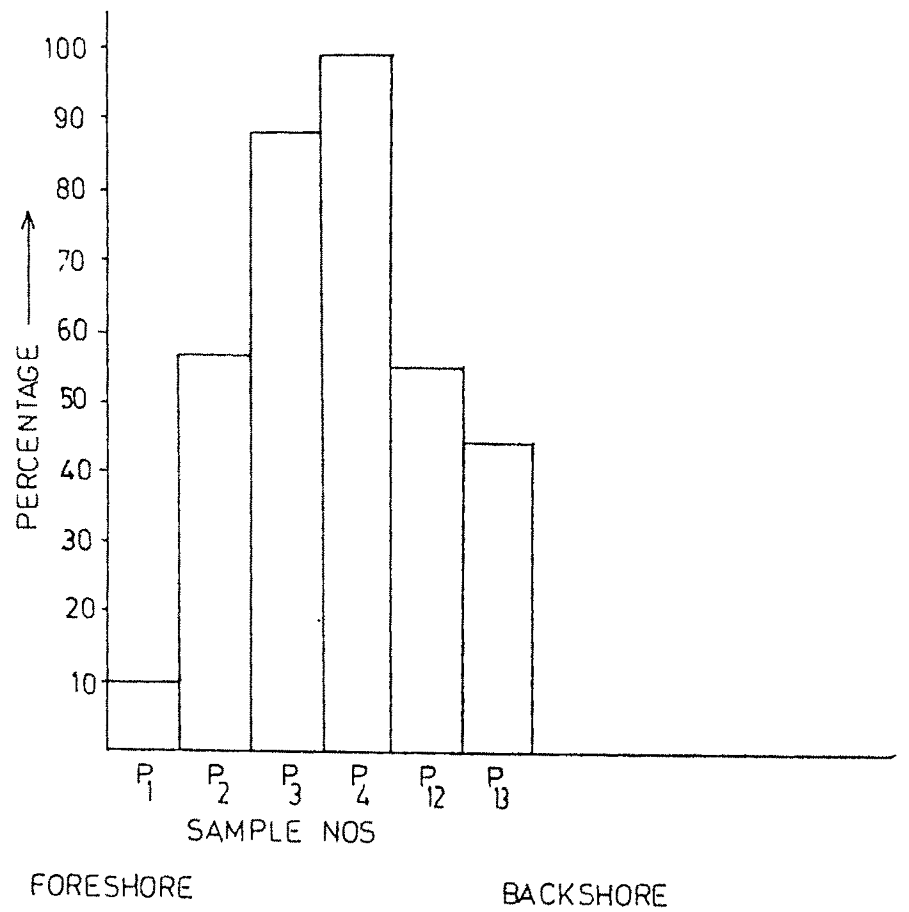
As mentioned earlier the black sand placers occur on the beaches just below the high water mark. Thickness of such sand layers varies from a few mm to maximum observed thickness of 10 cm. The size of the heavies range from silt (more than 0.01 mm) to coarse sand (less than 2 mm). Layers containing heavy minerals exceeding 2 mm thickness are seldom found. Laterally these heavy mineral streaks persist for a few meters upto several ten of meters. Discontinous concentrations of the heavies can be seen in the depressed portions of ripples and cross beddings of the recent dunes. As such, samples were collected from different patches and layers of the foreshore and backshore regions of the eastern and northeastern parts of the Island.

Heavy Minerals were separated by centrifugal method by using bromoform (Sp.Gr. 2.89) and the weight percentage of heavies from the bulk samples were calculated (Table - 11).

Table : 11 Showing Weight Percentage of Light and Heavy Crops

Sample No.	Light Mineral Wt. %	Heavy Minerals Wt. %	Total Wt.%
P_1	89.323	10.676	99.99
P_2	42.944	57.055	99.99
P_3	11.857	88.143	99.99
P_4	0.681	99.318	99.99
P_{12}	44.923	55.076	99.99
P_{13}	55.135	44.864	99.99

FIG 10 a DISTRIBUTION OF HEAVY MINERALS IN COASTAL ZONES - PIRAM ISLAND.



From the above table it is seen that the weight percentage of heavies range between 10 and 99% in different patches and layers and from nearshore upto the dunal areas (Figure 10a).

Separation of heavy minerals was also made using Frantz Isodynamic Magnetic Separator using + 120 mess grains with 30° side slope and 25° forward slope at 0.2 amps current interval. The magnetic susceptibilities of minerals determined are shown in Figure 10b.

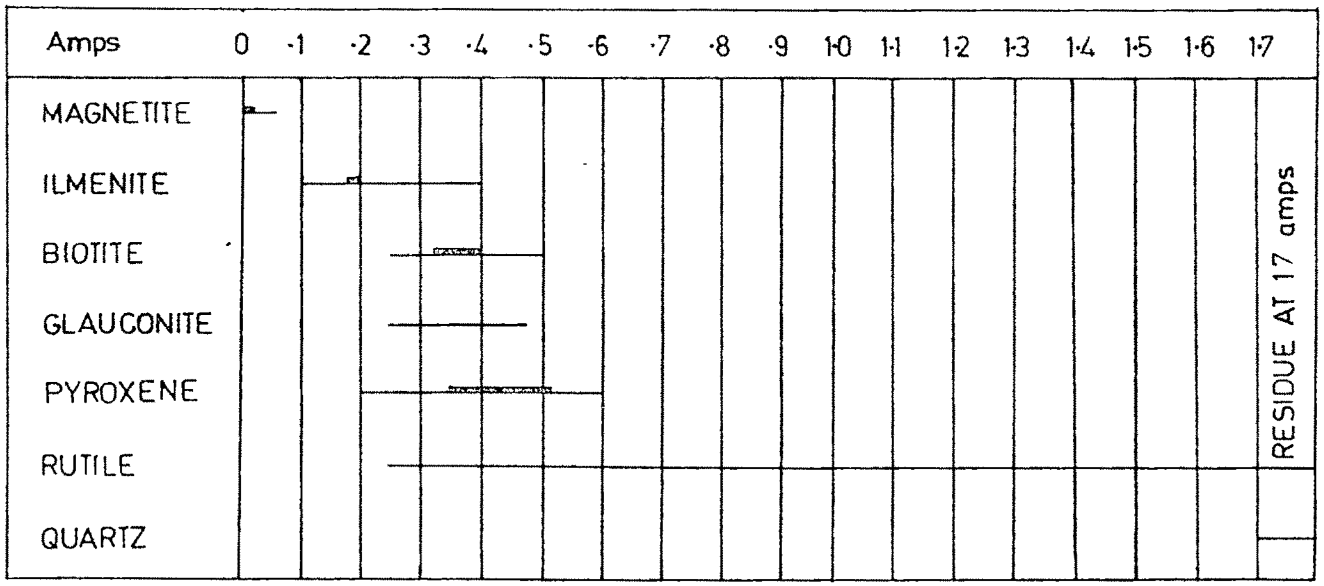
The values of the minerals of Piram black sands containing magnetite, ilmenite, rutile, pyroxene (augite), and glauconite ranges from 0, 0.1 to 0.6, 0.3 to 1.2, 0.2 to 0.8, and 0.2 to 0.5 respectively, were plotted on the diagram of Rosenblum (1958) in D.W. Lewis (1983), where in 100-150 u sized grains with side tilt 15, forward tilt 25 were used. The quartz and rutile remained as residue after 1.2 amps.

7.1 PROVENANCE AND CONDITIONS OF BLACK SAND FORMATION

Two principle factors contributing the black sand placers to the Piram beaches could be visualized - material availability at the source, progressive sorting of this material during transport.

As mentioned earlier the opaques, or black sand minerals in the present study include abundance of magnetite, ilmenite, rutile, augite etc. These are typical minerals found in the

FIG.10b. MAGNETIC SUSCEPTIBILITIES OF MINERALS IN FRANTZ ISODYNAMIC MAGNETIC SEPARATOR.



(AFTER ROSENBLUM, 1958)

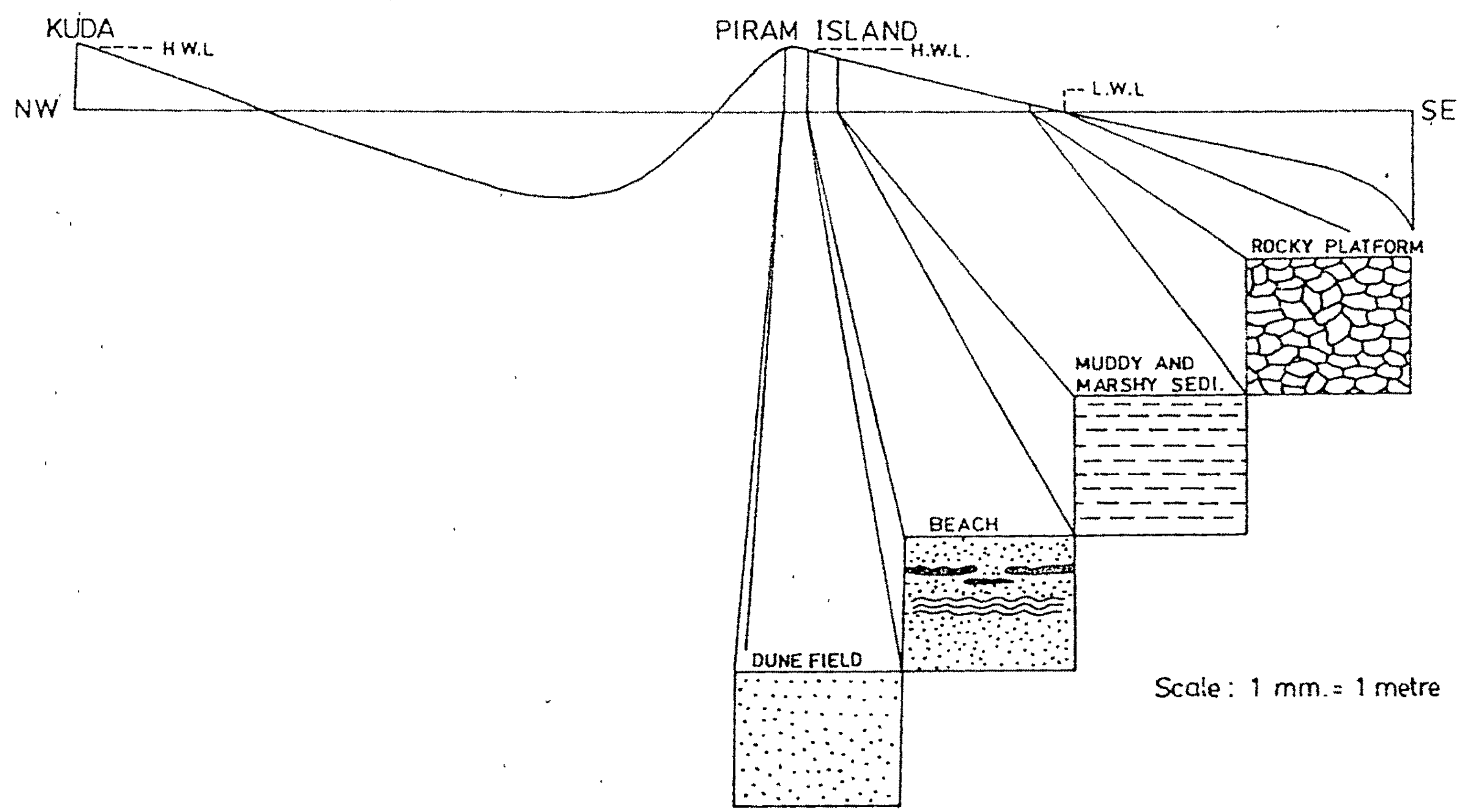
basic igneous rocks including some dolerite dykes. The primary source of the black sands in Piram therefore seems to be from the extensive deposits of basaltic rocks surrounding the inland region of Piram. Perhaps some major rivers like Shetrunji, Malesari, Mahi, Narmada and Tapi while flowing through their basaltic terrains might have brought this load. The progressive sorting of this load further contributed the deposition of these placers.

According to Luepek (1980) the concentration, thickness and lateral extent of heavy sands depend on five main factors such as, (a) type, size, grain density of the heavy mineral supplies; (b) bottom configuration of the basin; (c) areal topography of the Island; (d) the hydrodynamic conditions of the sedimentation medium and (e) the geotectonic activity, if any.

The grain size parameters as worked out by the present author show a dominance of saltation by grains which is about 92.9 % of the total. This otherwise indicates influence of some dominant physical factors. The most likely agencies responsible for the sorting of the grains in such situations according to Twenhofel (1943) are the areas of confluence of longshore currents. Such an understanding is strengthened, since the Gulf of Cambay is characterized as a very high tidal energy zone. Another important hydrodynamic factor in case of the Piram Coastal region is the fact that, the bottom currents are ebb dominated and have net bed load transport towards the sea. It is therefore possible that the topographic configuration of the Island of Piram with its general slope on eastern and northeastern sides, the prevailing longshore currents, the diurnal tides, and the powerful ebb currents all have been active in setting up swells of water with piles of sediments along the Island (Fig. 11). The greatest concentration of black sands observed on ripple marks, channel marks, cut and fill structures could be the result of their deposition during the high water conditions when the waves are able to reach the backshore and concentrate its load in the depressions. Very fine fractions of this load when subjected to wind action spread the black minerals on the adjacent coastal dunes.

Absence of black minerals in the older intercalated layers is rather conspicious. It indicates that the placer desposition has taken place in recent time only. As claimed by Zimmierle (1973) the accumulation of heavy mineral suit is more abundant during orogenic cycles and less frequent in epirogenic time. If this was so, the presence of heavy minerals in Piram Island may indicate possibilities of some orogenic (neotectonic) activities in the source area.

Fig·11 Profile along the PIRAM ISLAND showing distribution of sediments



SEDIMENT TYPES

A simplified classification of the Holocene sediments in Piram based on textures and grain types further results in three main units. These include, (1) compound grains/pelletoidal/ quartz sand, (2) compound grains black sand, and (3) compound grains/pelletoidal sand. A brief description and photographic illustration of these units together with their likely sedimentary processes is presented in this section to give a broad but valid impression of the Piram sedimenatary pattern. The distribution of the these units throghout the Piram (although complicated by numerous physical processes) is relatively simple, because the Piram mean sea level grades progressively from a tidally dominated shoreline into a short distanced coastal dune field. As a result, sediments grade from the compound grains/pelletoidal/quartz sand through compound grain black sands, and the compound grain/pelletoidal sands, these sands often overlapping each other at different places. All these sediment types and their These simple relationships vary laterally around the periphery of the Island. Lateral variation is also dependent upon the regional seaward slope and with respect to the intensity of the neap and ebb tidal currents.

A number of samples were collected on grid basis to understand these sediment types in general. All of these samples were examined under the binocular microscope to ensure that a reasonable measure of the true texture were obtained. The distribution of the three types in illustrated in Figure 12.

8.1 DESCRIPTION OF SEDIMENT TYPES

Type - I Compound grains/pelletoidal/quartz sand (Plate 15a).

Grains size : Mostly fine grained sand

Sorting : Well sorted

Total foraminifera in measured sample : 126

Sedimentology : The sediments are extremely variable in their characters. The larger being those of quartz grain (43.0%). The rest include pellets (13.0%), heavy minerals (mostly magnetite 34.0%), and skeletal elements (10.0%) The skeletal elements consist of broken pieces of larger invertebrates and microfossils of foraminifera. The dominant foraminifera include *Discorbis* and *Ammonia*. The test of these foraminifera are mch more delicate, fragile and glassy. The individual species are relatively small in their size.

Relation to environment : The sands are not limited or restricted to environments. They nearly always occur in areas of moderate to high energy settings, especially around foreshore parts of beaches and around the tidal flats and salt marshes.

Type - II Compound grains/black sand (Plate 15b)

Grain Size : Fine grained sand

Sorting : Well sorted

Total foraminifera in measured sample : 70

Sedimentology : Concentrates of black sands in the form of irregular patches and layers can be well seen on the beaches just below the high water mark. The opaque minerals dominating the black sands are magnetite, ilmenite, rutile, glauconite and augite; the magnetite and ilmentie being in larger proportions. These major portion in the sands include Ammonia, Discorbis sp. Tests of foraminifera are very small in size are glassy, fragile and delicate.

Relation to environment : The concentrate of black sand close to the high tide mark could be the results of confluence of longshore currents, the diurnal tides, and the powerful ebb currents - all of which may have been active in setting up swells of water with piles of sediments along the coast of the Island.

Type - III Compound grains/pelletoidal sand

Grain Size : Very fine grained sand

Sorting : Well sorted

Total foraminifera in measured sample : 87

Sedimentology : This sediment is extremely variable in character. It's most constant components are grains of black sands though the pellets are dominating over quartz particles. Pellets are ellipsoidal varying in length from 0.5 - 1.0 mm. These sand consist of tiny form of foraminiferal tests like Discorbis, and Nonion species.

Relation to environment : As observed in the field the sands are being transported from the beachshore region, which when subjected to wind action spread their finer material to form the coastal dunes.

FIGURE 12 DISTRIBUTION OF SEDIMENT TYPES IN PIRAM ISLAND

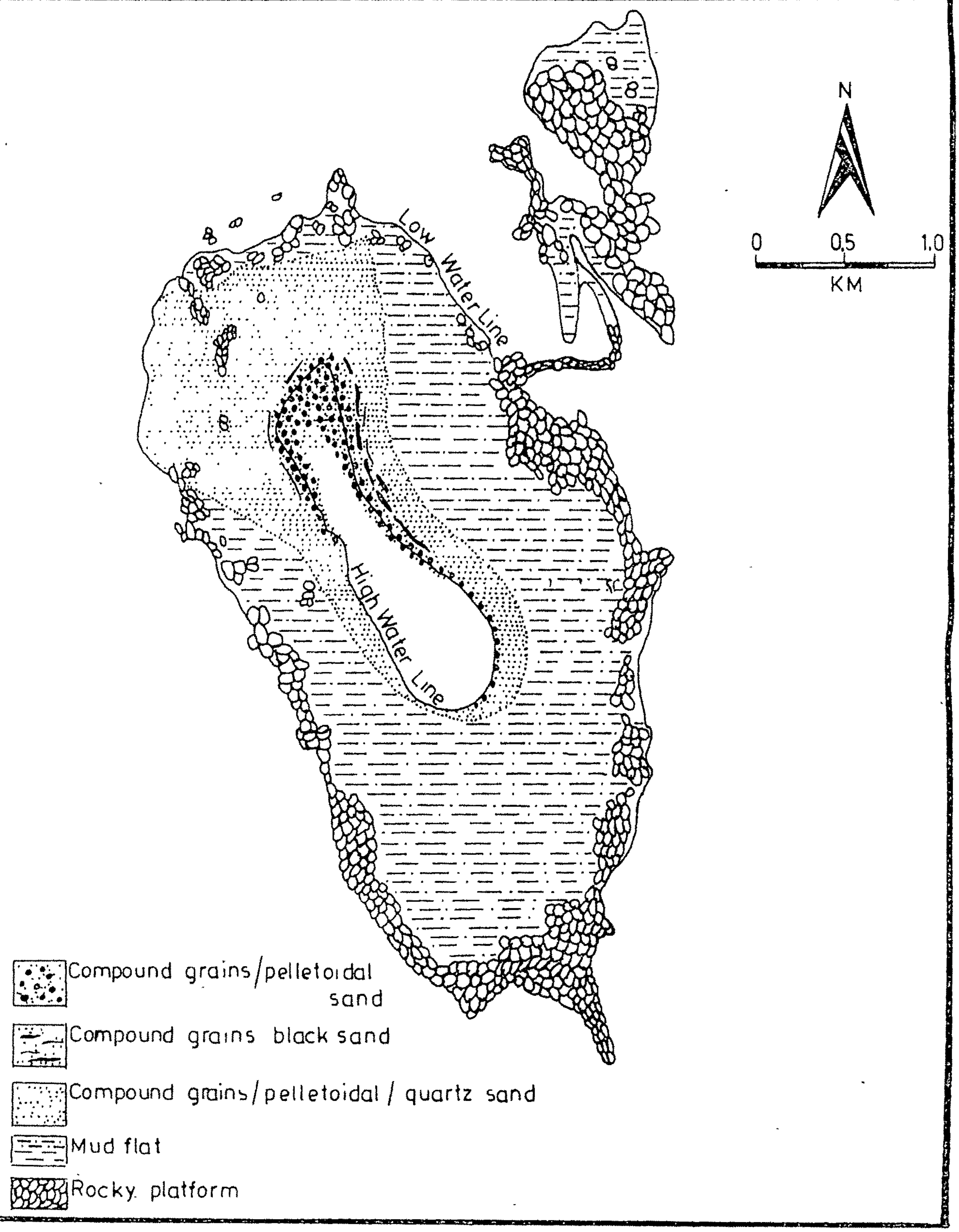
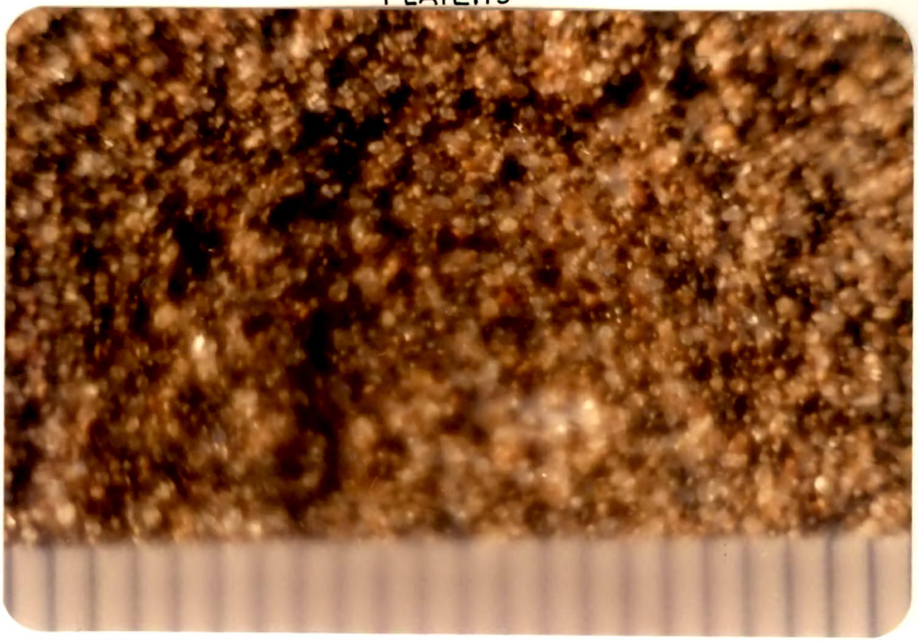
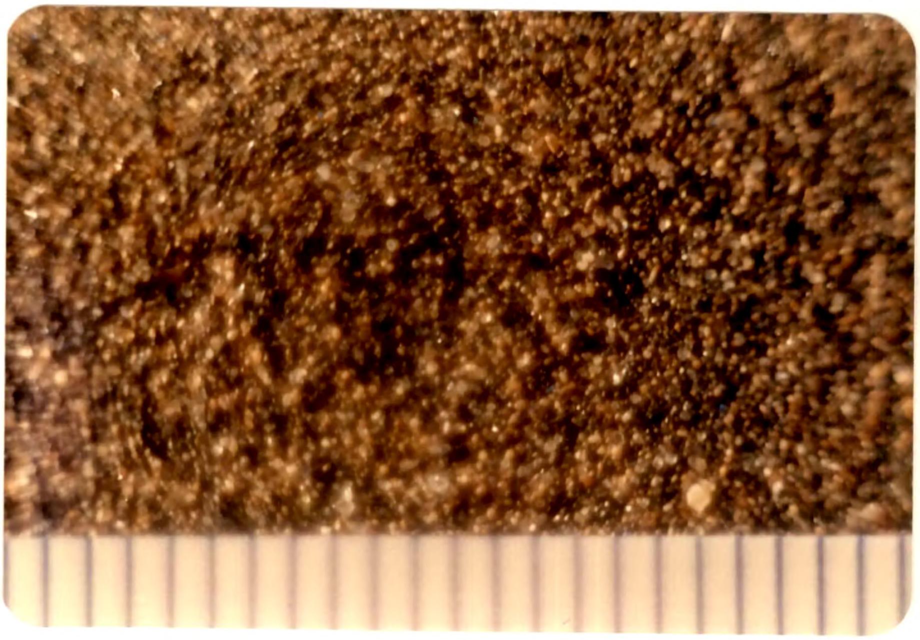


PLATE:15



(a) Compound grains/pelletoidal/quartz sand x 6



(b) Compound grains/black sand x 6.

ANIMAL SEDIMENT RELATIONSHIPS

The main emphasis of the author in this discussion will be on the foraminiferal morphotypes and on the biogenic sedimentary structures or lebensspurens observed in the field. It is expected that this data will hopeflly impart a clear picture of the animals, their habitats, and especially of the animal-substrate relationships.

For convenience the author has subdivided this topic into two subdivisions reflecting the most fundamental attributes of the categories of the type of animal present in the depositional system. These include the foraminiferal tests which are supplied to the system by the transporting agencies and the biogenic sedimentary structures which are almost invariably the part of the basin and the substratum.

9.1 MORPHOTYPE PATTERNS IN FORAMINIFERA

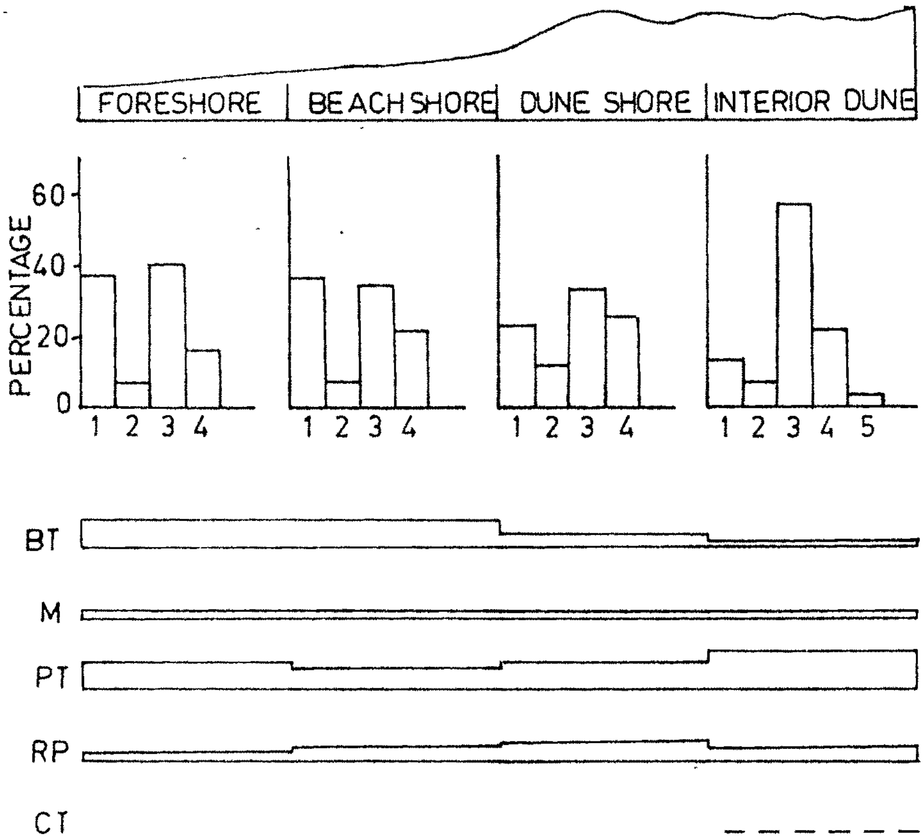
The sediment samples collected from the various nearshore facies were further examined for their foraminiferal contents. The samples in the form of loose sand were firstly cleaned by boiling with NaOH solution, secondly by washing them in water, and finally drying in oven at the temperature of about 60Rs C. The dry samples were then sieved by ASTM sieve of 60, cleaning the sieve by brush after every sample had been sieved. This precaution was taken in order to avoid contamination of samples. The fraction of sample thus obtained was sorted with the help of binocular microscope and the sorted fossils were identified and arranged according to their morphotypes. The distribution and abundance of different foraminiferal types is presented in Figure 13a. The percentage frequency of foraminiferal groups are illustrted in (Fig 13b).

Foraminiferal test which form the dominant microfaunal elements in the Island's coastal zones exhibit a variety of test shapes. In all five morphotypes are observed. These are based on the shape of the test and the nature of coiling. Most species can be easily placed into these five categories, although a few species were difficult to classify. Some categories are associated with epifaunal taxa; and some of them with infaunal taxa. The five morphotypes and their percentage are listed in the following Table 12 and illustrated in (Fig. 14).

Table : 12 Foraminifera and their Morphotype Percentage

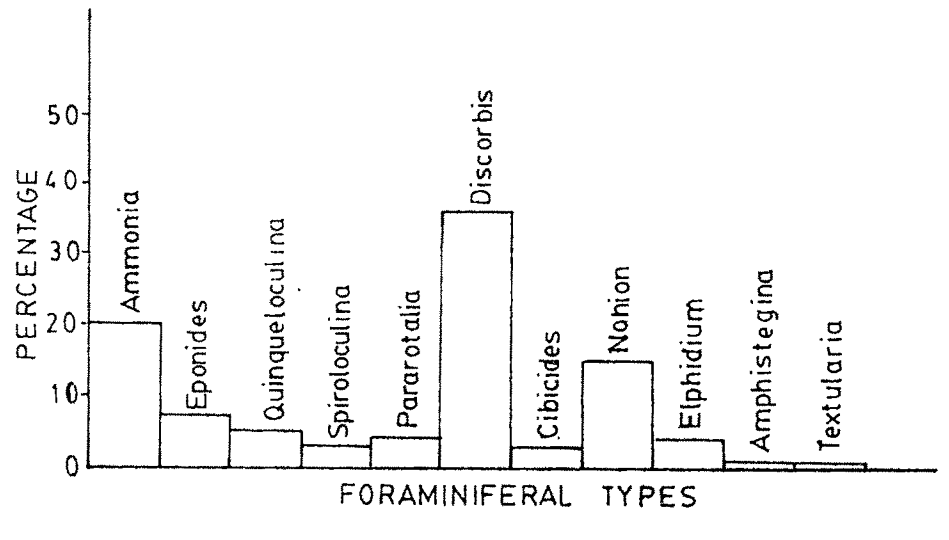
Microfossils	Morphotype	%age
Ammonia Eponides	Biconvex trochospiral	27.0
Quinqueloculina Spiroloculina	Miliolina	8.5
Pararotalia Discorbis Cibicides	Plano-convex trochospiral	43.0
Nonion Elphidium Amphistegina	Rounded Planispiral	20.75
Textularia Bolivina	Conical tapened	0.75

FIG. 13 a. DISTRIBUTION AND RELATIVE ABUNDANCE OF FORAMINIFERAL TYPES - PIRAM ISLAND



1 - BT - BICONVEX TROCHOSPIRAL
2 - M - MILIOLINE
3 - PT - PLANOCONVEX TROCHOSPIRAL
4 - RP - ROUNDED PLANISPIRAL
5 - CT - CONICAL TAPERED

FIG. 13b HISTOGRAM SHOWING VARIATION IN PERCENTAGE OF FORAMINIFERAL TYPES IN PIRAM SEDIMENTS



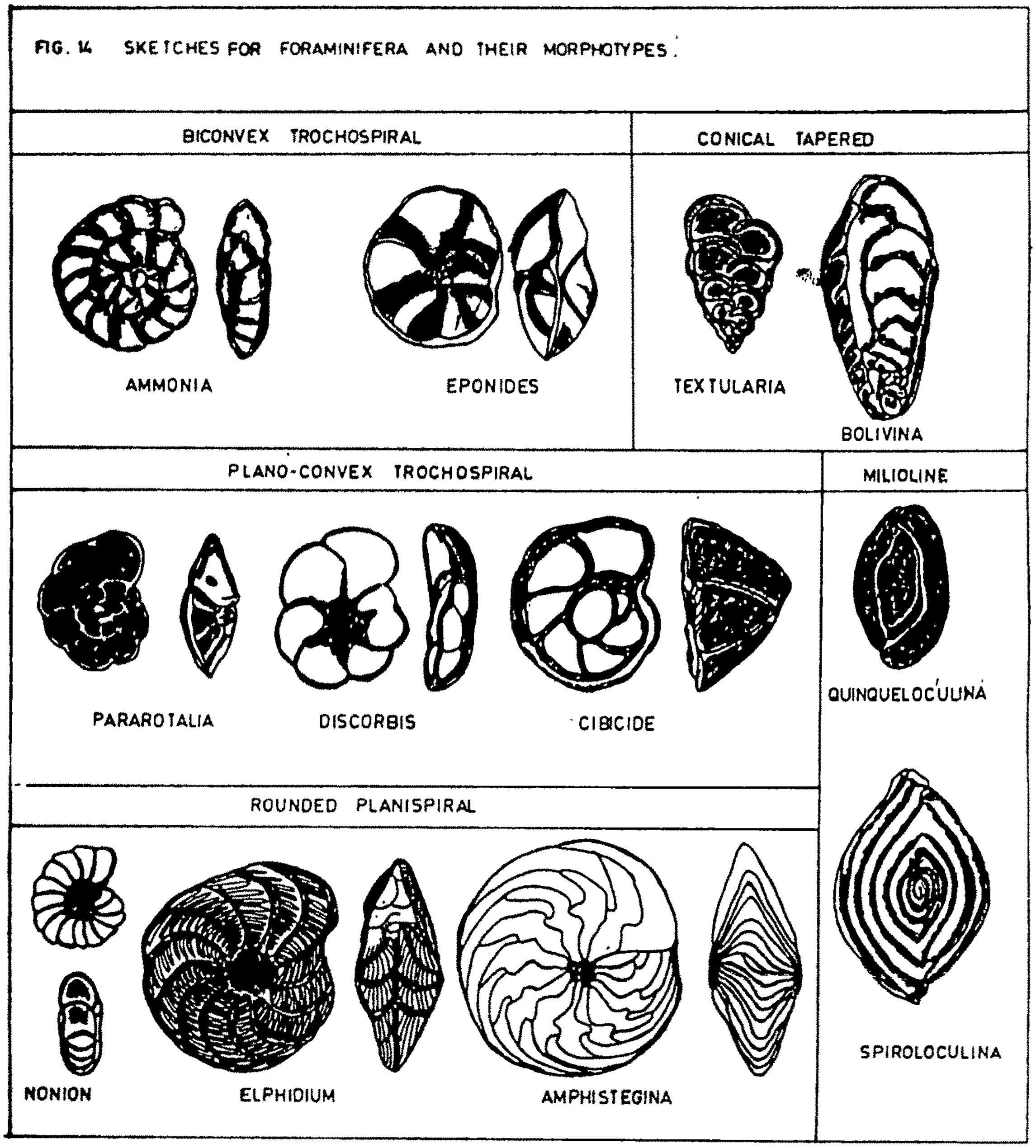


FIG. 14 SKETCHES FOR FORAMINIFERA AND THEIR MORPHOTYPES.
BICONVEX TROCHOSPIRAL
CONICAL TAPERED
AMMONIA
EPONIDES
TEXTULARIA
BOLIVINA
PLANO-CONVEX TROCHOSPIRAL
MILIOLINE
PARAROTALIA
DISCORBIS
CIBICIDE
QUINQUELOCULINA
ROUNDED PLANISPIRAL
NONION
ELPHIDIUM
AMPHISTEGINA
SPIROLOCULINA

Interpretation : An important contribution to the test morphology of formanifera and their microhabitat preferences is made by Corliss (1985).

According to him,epifaunal species, which are defined as those living in the upper 1 cm of sediment, have plano-convex or biconvex shapes and trochospiral coiling; wall pores are found on only one side of the test or are not present. Infaunal species on the other hand include taxa generally found below 1 cm, having planispiral coiling with a rounded periphery, or cylindrical and ovate tests with biserial or triserial coiling; pores are evenly distribted over the entire test.

The correlations according to Corliss (1985, p. 437) between test shape, pore distribution and sediment depth suggest that these morphological variables are related to the microhabitat preference of the individual species. The plano-convex or biconvex shapes of the foraminiferal species may be advantageous for attachment at the bottom during times of bottom turbulence and for stability in travelling on or near the surface. For example, in shallow water turbulent environments, Cibicides sp., which have plano-convex shapes, are attached to the substrate to resist transport or destruction in these high energy regions. The plano-convex or biconvex shapes that would be advantageous for stability and mobility at or near the surface would be unnecessary within the sediment and these shapes are indeed absent.

The higher surface-area/volume shapes of the infaunal species and the greater pore density are interpreted to be adaptations to low-oxygen conditions within the sediment (Corliss, 1985).

As is very well known, because of their small size, empty tests of foraminifers are sorted, reworked and transported by currents or gravity in the same way as are mineral grains of similar size and configuration. They are carried into areas where they were not living and similarly may live in areas where their tests, are not carried away are deposited. Currents aid in dispersal of species especially of planktonic forms.

F.D. Smith (1955) made a study of the ratio of planktonic specimens to the total assemblages in the Gulf of Mexico and Mississippi sound, for the purpose of testing its value as an indication of nearness to shoreline, depth of water and topographic anomalies such as offshore islands. In an unobstructed area of Gulf a correlation between depth and percentage of planktonic specimens to total foraminiferal number was found. As suggested by Smith (1955), use of similar methods in fossil sediments would indicate the direction of the shoreline. A sharp decrease in percentage of planktonic species in adjoining areas in fossil material might according to him indicate the presence of former reefs or barrier islands.

In all these context the foraminiferal tests in Piram appear to be very significant. Most of the forms belong to the benthic varities and only a small amount constitutes the planktons.

It will now be interesting to know about the original water depths to which all these tests were subjected during their living state. Phleger (1960), regard depth as the most important environmental factor, stating that benthonic foraminiferal faunas are zoned offshore according to depth of water. Distinct faunas occur in each of the minor environments. Those of coastal lagoons can be distinguished from adjacent near-shore open ocean assemblages. Deltaic marshes with rapid sedimentation have a chracteristic fauna which is surprisingly similar throughout a wide geographic range, whether brackish or hypersaline in character. Sand lagoon barriers may have a mixture of species representing open ocean, lagoon, and marsh benthonic environments, those from the open ocean.

According to Krasheninnikor (1960) different faunal facies occur at the same depths, depending on rate of sedimentation and bottom characters. Thus with mobile water and rapid sedimentation at shallow depths the Elphidiidae predominate, whereas with quiet water and slower sedimentation at the same depth, porcelaneos forms are most abundant, as well as attached forms. In clastic deposits composed of sandy clays, dominant families are Textulariidae, Discorbidae, Rotaliidae, Elphidiidae and Nonioniidae. In shallow water of algal facies Cibicides are abundant along with Discorbidae, Textulariidae.

From the forgoing discussion it now becomes clear that most of the foraminiferal tests found in Piram were being displaced and later dispersed from their original habitat and were further accumulated in a manner as would be the case on any of the barrier island systems at the present. Most of the identified forminiferal species have their average depth ranges between 50 to 120 meters.

9.2 LEBENSSPUREN AND BIOTURBATION

Animal sediment relationship in Piram also involve several aspects of sedimentology that are important to determine facies patterns. Among these are the sediment sorting, biogenic graded bedding, deformation of laminae, and general bioturbation. Discussion on these aspects will follow after a brief mention of the actual lebensspuren observed on the nearshore facies zones.

(I) Dwelling tubes : Dwelling tubes which are more or less permanent domiciles built and maintained by nonmigratoary animals are found in the muddy intertidal sands of Piram. Their number is rather limited. In fossil record such structures would be referred to the genus Skolithos.

(II) Burrows : Burrows are open, well-defined biogenic sedimentary structures having the potential for reuse by the animal.

Burrows of two major groups of animals are well represented in Piram : decapods and polychaetes. The decapod burrows are very distinct, well constructed, smooth walled systems used by the shrimps for both feeding and dwelling. Most of the burrow systems are not very large. In fossil form such burrow system would be called Thalassinoides, and Skolithos respectively.

The foreshore and backshore regions in Piram are significantly inhabitated by such decapods where they produce vertical or inclined burrows. The life functions of these animals in addition to their dwelling burrows is also found in their tracks and trails around the excavated surfaces and in the form of fecal pellets. These pellets do not posses any particular shape and are very friable (Plate 13b). The receding water tides very often sporadically distribute the pellets all over the beach.

(III) Trails (Plate 16) : Recent marine gastropods produce distinct grazing trails on marshy or muddy sediments. Such activities can be observed on the eastern part of Piram, especially during the low tide. The populations of the trails increases just after the receeding of water. The traces do not show greater variability in morphology as well as dimensions, and are represented by simple, smooth, straight to gently curved, winding meandering, looping, and ribbon like flat surface trails.

(IV) Borings : Borings are excavations made by organisms into firm or consolidated substrates, such as rock, shell wood and

PLATE : 16

Grazing trails of gastropod.

bone. Such substrates are not very abundant in Piram and neither are the boring organisms. However, a few significant examples found on the bones and some pebbles are reported in the following paragraphs.

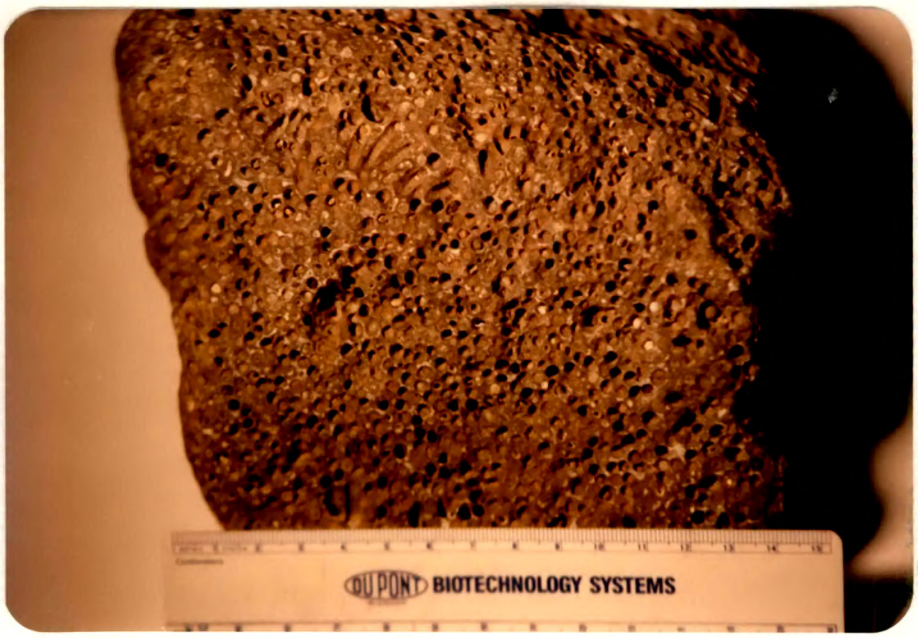
(a) Bored bones : Many, if not most of the larger specimens of fossil mammalian bones in Piram show evidence of boring by marine organisms (Plate 17a). Some bones contained a hundred or more boreholes, others only a few. In some specimens the borings are concentrated only on one side, where as in other all surfaces are ridelled with borings indicating that the bones were probably shifted by currents several times. The borings range from approximately 1 mm to 5 mm in length and average about 3 mm in length and 1.5 to 2 mm transversely. They are remarkably uniform in size, being circular in cross-section, and ovoid in longitdinal profile. The walls of the borings are smoothly polished.

Choices for the identity of the borers in vertebrate fossils are severely limited by the hardness and the chemical nature of the bones. Many kinds of borers successfully penetrate wood, or limestones but only a few notably the pholadids can penetrate harder substrates, (Warme, 1975). Such borings can be easily identified by their distinctive shapes. Further description to such an aspect is given along with the description on the bored pebbles found associated with these vertebrate bones.

(b) Bored pebbles : These borings on pebbles (Plate 17b) are dense 100-125/25 cm^2 and occur as circular pits. Individual boreholes range from less than 1 mm to 4.0 mm in diameter with depths of 10 to 30 mm. These holes are usually club - shaped having straight axis to the cylindrical holes. Boring preserved in full relief has smooth walls and a broad rounded and smooth bottom. The pebbles are thoroughly bored in such a way that the surface sculpture produces honey-combed structure. Incomplete boreholes are very common.

It is suspected that the borings are made by the pholodidal bivalves. The pholadids are clearly adapted for endolithic life, possessing a shell and foot modified for boring activities. They are usually primarily mechanical borers excavating in sandstones, mudstones and wood, as well as schists and other apparently very hard substrates (Turner, 1954). According to Turner (1954), few species of pholadid such as Diplothyra smithi also have the capability to bore Oysters as well as limestones, using chemical means. The smooth surface of the boreholes and the presence .of large number of unfinished boreholes indicates that the animal has rotated repeatedly in the hard calcareous substrates while making the holes in downward direction. The borehole morphology in Piram, thus resembles the description by Warme (1975) and indicates, obviously made by pholadid bivalves.

PLATE : 17



(a) Flask shaped pholadidae bivalve borings on vertebrate bone.

(b) Pholadiadae bivalve borings on round pebble.

9.2.1 SEDIEMNTOLOGICAL IMPLICATION

(a) Sediment sorting : Detritus incorporated into dwelling tubes of some organisms are examples of one kind of sediment sorting which then is left in transport across the depositional surface. Such an activity is almost negligible in Piram.

(b) Biogenic graded bedding : This includes the role of deposit feeders who also are responsible in sediment sorting and reworking. Large ingesting animals which make such activities are found around the salt marshes which in Piram are very quickly covered by the tides and their ingested material is mixed with the sediments.

(c) Deformation of laminae : The most sensitive indication of such scour and fill are the decapod burrows. These burrowing shrimps occupy areas of relatively high wave and current energy. Thus upper part of this burrow excavations and faecal pellets are continuously subjected to erosion and burial.

In short, in Piram physical aspects dominate over the biologic and hence the degree of bioturbation comparatively is very low.

SEDIMENTATION MODEL

In this section an evolutionary model is presented by the author on the basis of the data he has analysed in detail. It is apparent from all the foregoing discussions that the sedimentary history of the Piram Island is rather varied. The overall record also shows great variations in the duration of the Island sedimentation as a whole.

It was during the late Miocene time that the area which today comprises the Island of Piram was covered by a shallow sea. It is possible that during this time circulation in the basin was restricted. The area was then subjected to minor sea-level fluctuations and some tectonic adjustments that had considerable influence on the ecological conditions especially on its margins. Three environemntal zones along the margins of the sea are likely to have prevailed during such a time : (1) the more or less open sea regime towards the mouth of the embayment (Gulf of Cambay), where the water mass was normal marine, (2) shallow, flattened lagoon at the sea-margin, and (3) a supartidal environment along the coastal land surface. It is possible that during the initial low sea-level stand the microbial algal mats developed extensively under low-energy conditions in the lagoon like depressed portion, their filaments and organic mucus forming a sticky-plastic layer over the sediment and later developing into the tepee and arcuate ridges. In between an open sea broke through the shallow lagoon and spread the rounded pebbles over the sticky mats. The formation of the rounded pebble conglomerate thus may indicate a regional and basin wide significance. This episode was perhaps more intensive causing the dispersal of the rounded nodules (phosphatic in nature as explained earlier) througout the earlier sediments into a 1-1.5m thick bed. If this was an episodic event because of an hurricane or storm it also may had pronounced effects on the terrestrial climates resulting into heavy rains and flash floods to bring the land living vertebrate fossil bones to be associated with the pebbly conglomerates. Following Pettijohn (1984, p.430) it may be argued that the pebble-vertebrate bone conglomerate bed which forms a prominent marker horizone was in all probabilities a submarine disconformity or an unconformity. Such surfaces according to Pettijohn (1984) are surfaces of nondeposition rather than eriosion or exposure, and show extreme slowness of sedimentation. As could be very well further noted the sedimentary sequence in which the pebble-vertebrate bone conglomerate is formed in Piram exhibit a collection of sedimentary features such as hard ground profiles, mineralized crusts, and borings by encrusting faunas indicative of a distinctly reduced net deposition. Furthermore, this drop in sea-level and reduction in energy level could have resulted in the diagensis of the vertebrate bones. Many of these bones (Plate 7,8a,b) must have then contributed their phosphetic contents to the surrounding sediments imparting a peculiar reddish tint (phosphate + sulfate + ferrus minerals).

During the next sea-level rise and fall (probably middle to upper Pliocene) the environmental zones in Piram once again shifted back and forth as a result of cyclic changes in the bathymetry, climate and tectonism, leading to alternating deposition of normal and abnormal marine low and high energy, moderately deep and shallow marine sediments. This include the shallowing upward sequence from the cherty pebble conglomerate, medium to fine grained sandstone, and the silty clay and claystone beds. The younger conglomerate once again reveal an episode of high energy deposition afrter a brief interval of nondeposition.

The overall sedimentary record in Piram is thus cyclic, consisting of transgressive phases overlain by regressive sequences. Both parts of the cycle probably developed during the Upper Miocene to Upper Pliocene rise in sea-level. The cycles are asymmetric in the sense that the two parts are not mirror images and that the regressive sequence is rather much thicker. The shallowing or regressive sequence reflect Island sedimentation rates in excess of the rates of sea-level rise.

As depicted in Figure 4 the Saurashtra region in its Southern part is susceptible to the earlier faults. In this regard the question to be resolved is whether the deposition in Piram was on an uplifting region or a non uplifting one and what where the corresponding effects.

In the uplifting regions as suggested by Dupre, et.al (1980), rising sea-level results in erosional transgression recorded largely as a wave cut platform and a few patches of sediments. Thus, the sedimentary record as preserved in coastal terrace deposits in uplifting regions is largely restricted to marine sediments deposited during periods of falling sea-level. In non uplifting regions (i.e. stable or subsiding), the rise in sea-level is recorded by a thick sequence of fluvial and estuarine sediments deposited in the coastal valleys (Dupre, et al, 1980). Extensive flood plain surfaces form during the highstand of sea-level.

It could now be emphasised in case of Piram, that both the nonuplifting and uplifting phases perhaps were simultaneously taking place during different geological times. Initially it must have been the non uplifting phase with the high stand of sea-level that deposited the extensive flood plane deposits and later the uplifting phase with regression of sea-level which built up the thick pile of the shallowing upward sedimentary column. The younger conglomerate (? Lower Pleistocene) marks the level and the time at which the whole system was once again transfered to the non-uplifting type. This level also marks the transgressive - high stand sea-level phase which is even confirmed at the present.

Considering the over all evidences it may finally be concluded that, the present day Island stratigraphy and the nearshore environments bordering the Island of Piram provide an insight into its recent evolutionary trends and future development of the Island. The trend is clearly towards development of the Island, primarily through colonization by mangroves, and stabilization of the beaches and the inland dunes. The sedimentation model so discussed is depicted in Figure 15.

FIG 15 SEDIMENTATION MODEL FOR PIRAM – SCHEMATIC DIAGRAM