PART - V

COMPARATIVE STUDY OF THE THREE ISLAND ZONES

COMPARATIVE STUDY OF THE THREE ISLAND ZONES

The details regarding geomorphology, stratigraphy, sedimentology, ichnology and animal sediment relationships presented by the author in parts II, III and IV in this report reveal a wide variety of geological events and a spectrum of nearshore features including variety of shoreline types and oceanographic conditions on the Island zones of Piram, Diu and Bet Shankhodhar. The information so obtained is briefly compared in the following paragraphs and is also presented in Table 25.

33.1 GENERAL COMPARISION :

(i) In general, two characteristic coastal environments can be distinguished for the Islands of Piram, Diu and Bet Shankhodhar. These include : (a) The sheltered and tide dominated coasts of Piram and Bet Shankhodhar in the Gulf of Cambay and the Gulf of Kutch respectively, and (b) the open or the exposed high energy coast for the Island of Diu.

Within these two major types, there are great variations in the physical parameters (geology and geomorphology) and in the dynamic processes (oceanography), as observed in all these Islands.

(ii) The Island of Piram has relatively smallest configuration (1.5 sq.km exposed land mass and 7.5 sq.km including its intertidal zone), while the Diu Island has the largest (38.5 sq.km), and the Bet Shankhodhar Island intermittent (17.5 sq.km).

(iii) In almost all these Island zones the actual form of the coastline varies from straight - fault line coasts to complex crenulated low-land coast type.

(iv) Likewise, the shoreline types vary from the semiresistant vertical cliffs (maximum development observed in Diu followed by Bet Shankhodhar and Piram) where there are practically no beaches (Bet Shankhodhar and Piram) to large beach formations (as in Diu).

(v) This large scale beach formation has resulted in the formation of sand dunes and sand ridges especially at Diu and Bet Shankhodhar Islands.

(vi) Extensive salt marshes and mud flats are observed only in Diu with minor development of such features at Piram and Bet Shankhodhar Islands.

(vii) Tidal ranges vary from 6 to 12 meters in Piram, 2 to 3 meters in Diu and 3 to 4 meters in Bet Shankhodhar.

(viii) The wave energy levels although appear to be very high on the exposed coast of Diu, are rather low in its sheltered zones in the inland regions where beach, salt marshes and tidal flats are developed. In contrast, the wave energy levels are often fluctuating in the coastal zones of Piram and Bet Shankhodhar Islands.

(ix) It is this greater variability in the coastal shoreline processes mentioned above along with the coastal morphology (due to the semiresistant and unresistant rock bodies) aided by relatively smaller geographical area of each of these Island zone that appears to have shaped the present configuration of each of these Island's in saurashtra.

33.2 AGE :

The realtive geological ages for the Islands are :

(i) Piram : Upper Miocene to Pliocene and Recent

(ii) Diu : Pleistocene to Recent

(iii) Bet Shankhodhar : Pleistocene to Recent

33.3 COMMENCEMENT OF GEOLOGICAL INVESTIGATIONS

(i) Piram : 1836 by Lush

(ii) Diu : 1884 by Fedden

(iii) Bet Shankhodhar : 1884 by Fedden

Most of earlier efforts in Piram were toward identification of the vertebrate fossils and fixing their geological age.

The geology of Diu and Bet Shankhodhar is known only through some scattered studies and remarks, of the earlier workers.

33.4 STRATIGRAPHY :

The Island of Piram and Bet Shankhodhar are characterized by a "layered cake" stratigraphy. The Diu Island, on the other hand is typified by the stabilized Pleistocene sand dune terraces. In each of the three Island zones, there are many interesting lithological sequences which characterize the environments of deposition.

(a) Piram Island : The author has recognized three transgressive - regressive zones and six sedimentary facies including dark yellow to reddish sandstone; round pebble conglomerate and vertebrate bone bed; cherty pebble conglomerate; medium to fine grained sandstone; and siltyclay and claystone. Most of these facies had their deposition in intertidal to supratidal and tidal channel environments, in low, moderate and very high energy conditions. Deposition of the characteristic round pebble conglomerate and vertebrate bone bed is ascribed to the prevailing lagoonal basin and the flash flood conditions which supplied the phosphatic nodules and the vertebrate bone material to the depositional basin. The development of "tepee"

structure in the lower most lithological unit is possibly due to repeated thermal expansion and contraction in the intertidal environment when the rock containing these structures were alternately heated by insolation and cooled by the water. The "arcuate ridges" on the contrary would be resulting from the concentration of sands, previously bound by algal mats having been buckled locally into series of ridges which tend to be convex seawards. The younger sedimentary record is indicative of fixing upward pattern of deposition.

(b) Diu Island : In this Island the overall lithological sequence is dominated by the calcarenites or the carbonate sands continuously laid down during the Pleistocene time by the action of the prevailing winds. The whole sequence is thus characterized by various types by aeolian dunes and dune related sedimentary features, like various types of cross-beddings, grainfall strata, avalanche strata, etc.

The dune terraces have further been subjected to the post Pleistocene transgression of the sea and there by resulting into some spectacular mid-sea stacks, wave - cut platforms, Karren, Spitzkaren, solution basin, cockling, pothole formation etc.

(c) Bet Shankhodhar Island : The Island stratigraphy is once again characterized by a variety of facies (11 in number) and their vertical and lateral variations. In general, all these lithofacies together represent atleast two cycles of fining upward pattern in their deposition. These hetrolithic strata

further display unimodal and bimodal cross-stratifications and sedimentary structures which characterize the tidal dominated environments. Such structures include - tidal beddings, cross - beddings and herringbone structures, reactivation surfaces, clay drapes, rip up clasts, scoure and truncation surfaces, interferenc and flat - topped ripple laminations, flaser wavy and lenticular beddings, polygonal mud - crack surfaces etc. There are also some very prominant bio-sedimentary structures developed in most of the lithological units which imply important information on the relative rates of sedimentation, hydrodynamic conditions and animal substrate relationships besides giving useful clues on the palaeoecological conditions. Such biogenic structures are represented by dwelling and feeding burrows of decapods and polychaete worms, trails of gastropods and occasionally by the resting burrows of sea-anemones. In fact, no other Island locality is so rich as that of the Bet Shankhodhar Island to have an array of excellently preserved biosedimentary structures. the identified structures include the species of Ophiomorpha, Thalassinoides, Box-work net work burrows of crustacea, Phycodes, Skolithos, Monocraterion, Planolites, Palaeophycos, Conichnus, Bergaueria, Rosselia, Cylindricum, Zoophycus, and Scolicia.

33.5 TECTONICS :

Almost all the three Islands are variously subjected to the effects of tectonics. There are some major and minor faults afecting the Island zones directly or indirectly. In most cases

the fault movement appears to be basement controlled and has commenced from time to time and is perhaps continued even to-day.

33.6 NEARSHORE SEDIMENTARY FACIES:

(i) Beach and beach related features :

(a) Piram Island : In Piram there is comparatively a restricted development of beach. The beach, however, is characterized by the occurrence of high degree of black sand placers of magnetite, ilmenite, rutile, glauconite etc. The beach is further marked with usual current and wind ripples and the lebensspurens of some recent decapod crab burrows and polychaete worms and gastropod trails. The beach being narrow is seasonally subjected to storm conditions during which a great uprush of sediment takes place.

(b) Diu Island : Well developed beaches of Nagoa and Vanakbara chacterize this Island. Here, the beaches are developed as a result of marine water uprush through the unresistant miliolitic Pleistocene terraces surrounding the open sea region south of the Island zone. The beach sediments and the beach ridge sands along these coastal environments depict excellent sedimentary and biogenic sedimentary structures including crustacean and polychaete burrows, and gastropod and other animal trails, and also some well preserved wave and current ripples. Scattered development of black sand placers is also observed in Diu.

(c) Bet Shankhodhar Island : The beach and beach ridge system is a predominent shoreline feature of Bet Island. The major beach formation almost results in to a parallel coast along the north and northeast part of the Island. This beach as explained earlier is possibly a drowned low-land region. The possible formation of this structurally controlled (fault line) beach probably could be a result of differential erosion along the boundary between the partially submerged fault block of the unresistant Pliocene-Pleistocene sediments in the north and the uplifted block in the center. Any non-resistant sandstone-shale claystone of the normal sequence was subsequently eroded by the sea water in the long period of time and then covered by the beach sands.

The other small beaches (pocket beaches) are found developed in the sheltered areas of southwestern and eastern cliff sections.

(ii) Sand dunes :

Most spectacular development of sand dunes is found in the Island of Diu. In fact, the township of Diu and its old fort are built on the Pleistocene dune field. All varieties of dunes including parabolic, longitudinal, barkhan, blowouts etc. can be observed in the Pleistocene as well as recently formed dunes in Diu. All these dunes are characterized by the carbonate sands or calcarenites. They show typical aeolian features of their

deposition. In contrast minor development of dunes and dune related features are seen in Piram and Bet Shankhodhar Island.

(iii) Tidal flats and salt marshes :

In all the three Island zones tidal flats and salt marsh environments occur. The largest amongst there are, however located in the Island of Diu. At places (Piram - Bet Shankhodhar) these flats are vegetated with mangroves. Typical sedimentary and biogenic structures are very often developed on the sediments of these tidal flats.

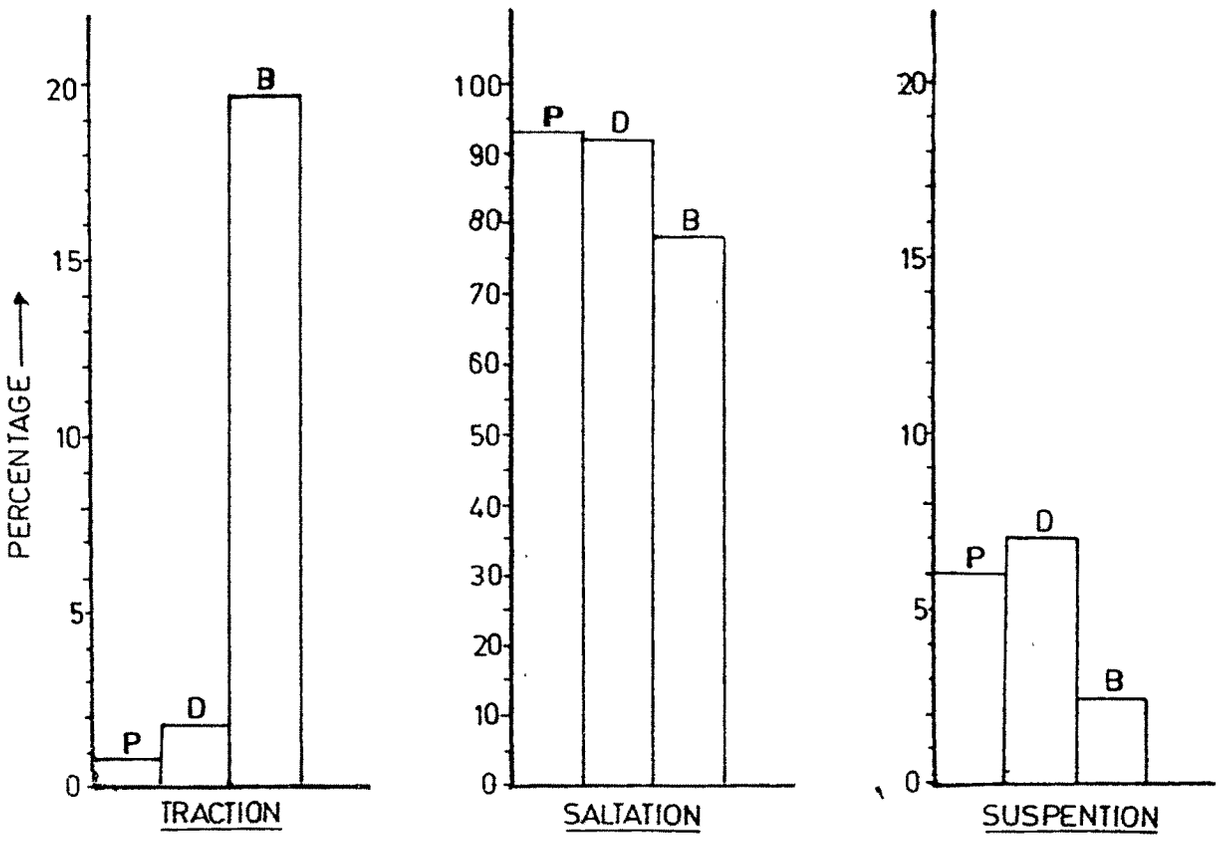
(iv) Sediment characteristics :

The sediments are invariably coarse to fine grained in almost all the Islands. In Diu the sediments are usually dominated by carbonate sands, while in Piram and Bet Shankhodhar they are of mixed origin. Sediment dispersion patterns in the three Island regions is given in Fig.35, and that of the heavy minerals in Fig.36.

(v) Foraminiferal morphotypes :

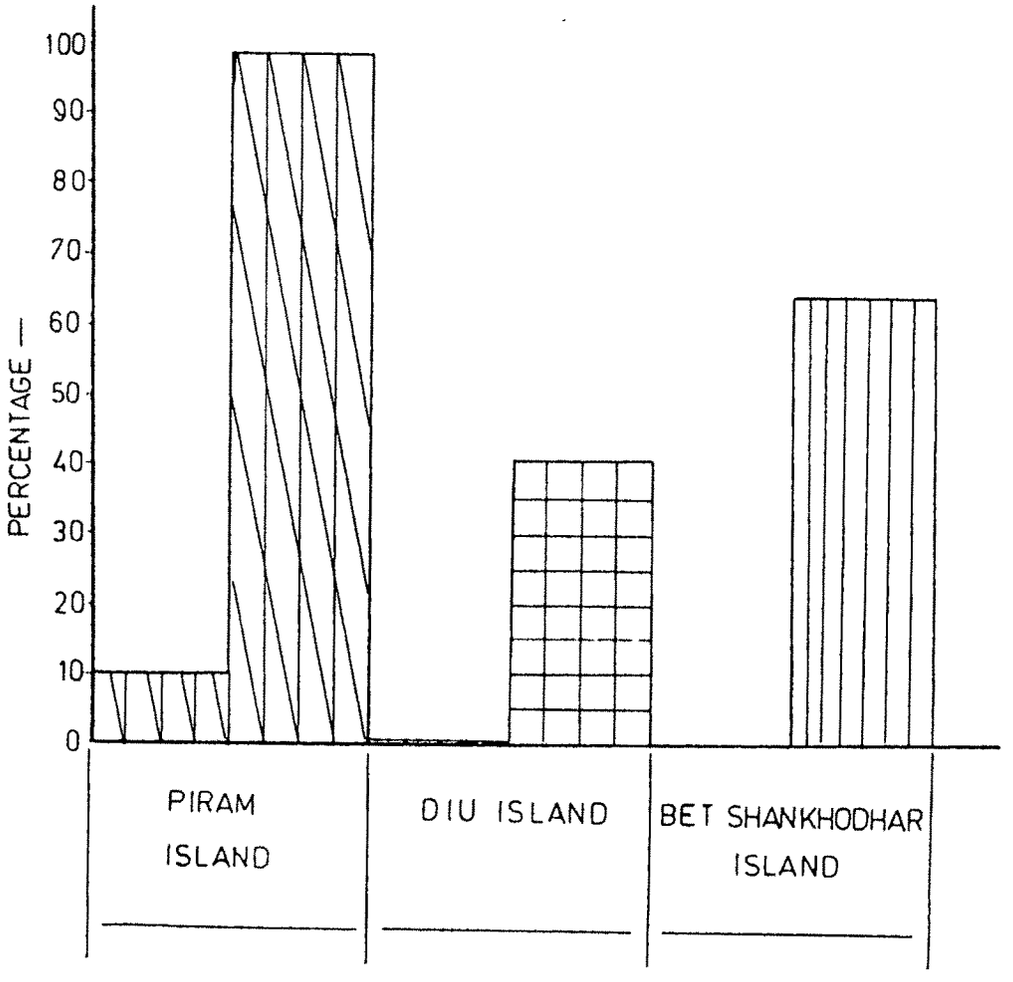
The common foraminiferal species in all the Island zone include species of : Ammonia, Eponides, Quinqueloculina, Spiroloculina Pararotalia, Discorbis, Cibicides, Nonion, Elphidium, Amphistegina, Bolivina and Textularia.

FIG. 35 A COMPARISION : TRACTION - SALTATION - SUSPENSION, SEDIMENT DISPERSION IN THREE ISLAND ZONES.



P - PIRAM ISLAND D - DIU ISLAND B - BET SHANKHODHAR ISLAND

FIG. 36. DISTRIBUTION OF HEAVY MINERALS IN THREE ISLANDS - COMPARATIVE HISTOGRAMS.



These foraminiferal species belong to five morphotypes including : Biconvex trochospiral, milioline, plano-covex trochospiral, rounded planispiral and conical tapered. The percentage variations of these forms in the beach foreshore, backshore and dune sections of the three Island zones are compared in Fig.37. Effect of natural processes on their sorting are discussed in the text.

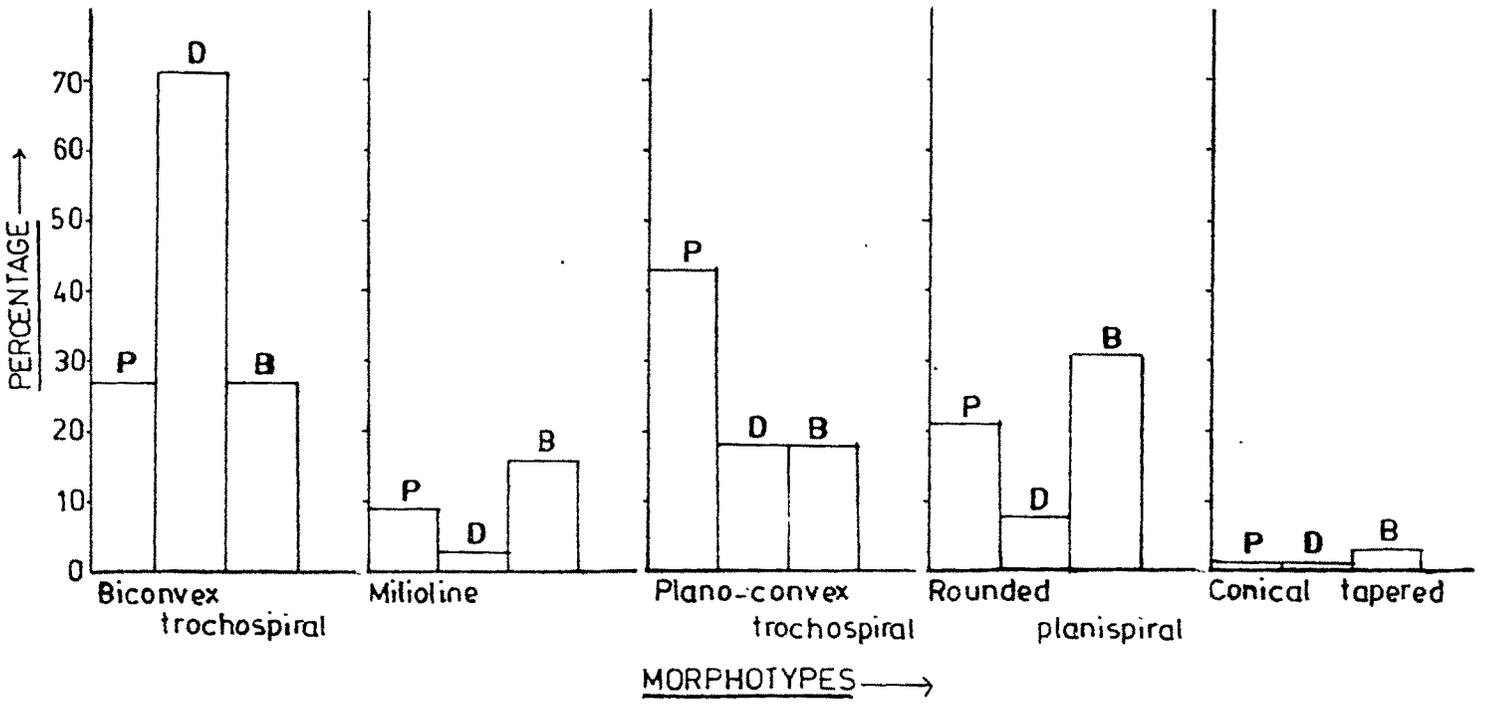
33.7 THE MAIN PROCESS LEADING TO THE FORMATION OF ISLANDS :

(i) PIRAM The overall sedimentary record in Piram is cyclic consisting of transgresive phases overlain by regressive sequence. Both parts of the cycles development during the upper Miocene to upper Pliocene rise in sea - level. These cycles accompanied episodes of high energy events followed with emergence of the platform and often nondeposition and subaerial exposures at short intervals. There were also periodic floods influencing heavy rains and debris flows because of extreme variation in climatic conditions. The present trend of the Island is clearly towards its continued development in land mass area.

(ii) Diu

The coastal sediments in the Island of Diu are primarily of shelf derived carbonate sands. These sand have been delivered to the coast of Diu since the post glacial marine transgression

FIG 37 PERCENTAGE VARIATION IN MORPHOTYPES - COMPARITIVE HISTOGRAM FOR THE ISLAND ZONES.



P - PIRAM ISLAND D - DIU ISLAND B - BET SHANKHODHAR ISLAND

(Pleistocene time). The sand laid down as coastal dunes (during lower sea-level) have been further modified as stablizied dune terraces. During the next sea-level rise these unresistant dune terraces were subjected to erosion. The combination of tidal currents, waves and wind processes are therefore the main agents that have influenced the formation of the Island during the past and the present.

(iii) Bet Shankhodhar

This Island is dominated by tidal depositional events. The entire Island zone is characterized by a distinct combination of sedimentary and biogenic structures, vertical and lateral facies changes reflecting tidal sediment transport in clastic to semi-clastic environments. In light of the criteria suggested by Klein (1971) two cycles of Paleotidal ranges are confirmed for the Island of Bet Shankhodhar. These ranges are 9.25 meter and 6.25 meter respectively.

TABLE 25 COMPARISION OF THREE ISLAND ZONES

	PIRAM (1)	DIU (2)	BET SHANKHODHAR (3)
	Miocene to Upper Pliocene and Recent	Pleistocene to Recent	Upper Pliocene to Pleistocene and Recent
ithology older sediments/ edimentary acies)	Dark yellow to reddish sandstone, round pebble conglomerate and vertebrate bone bed, cherty pebble conglomerate, medium to fine grain sandstone, siltyclay and claystone and gritty pebble conglomerate.	Pleistocene terraces of miliolitic limestone (calcarenite/carbonate sand deposits)	Flat pebble conglomerate, cross stratified calcareous sandstone, laminated sandstone-shale-clay-stone, round pebble conglomerate sandstone-mudstone rhythmites and gritty sandstones.
edimentary structures (i) Physical	Tepee structure, arcuate ridges desiccation cracks, current, wave and wind ripples rhythmites.	Small and large scale cross-stratification (tabular, planar and trough). Wave cut-plat forms stacks, karren, solution basins, cock-ling and potholes.	low angle cross-stratification, herringbone cross-stratification, falser, wavy and lenticular bedding mud cracks, ripples, rip-up-clasts, clay drapes etc.
(ii) Biogenic (Trace fossils)	Animal borings in round pebbles and vertebrate bones Skolithos and Monocraterion.	No distinguished biogenic structures are found	Ophiomorpha, Palaeophycus, Skolitho Planolites, zoophycos, Thalassinoic conichnus, Bargaueria, Rosselia, Cylindricum, Phycodes, Monocrateric scolicia, Teichichnus.
Mega and microfossils	Mammalian fossil bones and teeth (mostly transported).	Microfossils of foraminifera in the dune sands	
Depositional environments (older sediment)	Alternate periods of draining and emergence with periodic episodes of high energy events like flash flood etc. (heavy rains and debris flow in the basinal area).	Mostly wind borne at places marine	Tidal dominated

contd.

	(1)	(2)	(3)
Nearshore sedimentary environments			
(i) Beaches and beach related features	Restricted beach development.	Well developed beaches at Nagoa and Vanakbara	Developments related to the north a northeast fault plane.
(ii) Tidal flats and salt marshes	Tidal flats and salt marshes with mangrove vegetation in the southern part of the Island.	Well developed tidal flats and salt marshes in the northern part of the Island	Minor development of tidal flats an saltmarshes
(iii) Sand ridges and dunes	Minor dune formation along the coastal zone.	Dune field with foredunes, blowouts, parabolics and barkhan dunes	Main sand ridge development paralle to the northern coast.
Sediment characteristics	Mostly medium to fine grain sand.	Medium to fine grain sand	Coarse to fine grain sand
Heavy mineral suits	Predominant heavy mineral suits on the recent beaches and nearshore dunes.	Comparatively less prodominant	Proportion very low
Sediment type	Compound grain/pelletoidal/quartz sand, compound grain/black sand, compound grain /pelletoidal sand	Lamellibranch/foraminiferal sand, foraminiferal sand, compound grain sand, pelletoidal/foraminiferal sand.	foraminiferal/pelletoidal sand, gastropod/lamellibranch skeletal sand, compound grain/foraminiferal sand.
Morphotypes	Biconvex trochospiral (BT) - 27%; Milioline (M) - 8.5%; Plano-convex trochospiral (PT) 43%; Rounded planispiral (RP) 20-75%; conical tapared (CT) - 8.75%	BT - 71% M - 3% PT - 18% RP - 8% CT - 1%	BT - 27% M - 16% PT - 18% RP - 36% CT - 3%
Lebensspuren and animal sediment relation ships	Dwelling and suspension burrows, tracks and trails, borings	Uca Pugnax, Ocypoda Callianassa major Bivalve banding laminae gastropod trails polychaete tubes feeding holes by fishes	Decapod burrows, Callianassa major, Ocypode quadrata, Polychaete annelid burrows, gastropod trails
Main processes leading to Island formation	The overall record of sea level rise and fall has been responsible in depositing the sediments in Piram	sediments due to tidal currents, wind and wave processes modified by transgressive - regressive stages during Pleistocene to Recent	Tidally deposited sediments, transport in clastic to semi-clastic environments - two cycles of paleotidal ranges are confirmed.