Title	Landscape changes in the coastal plains of fringing reef island : Rarotonga in the Cook Islands
Sub Title	裾礁島における海岸平野の景観変化と人間居住
Author	近森, 正(Chikamori, Masashi)
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Abstract	海岸沖積平野の環境史は陸上生態系と海洋生態系の間の遷移的過程のなかにある.裾礁島の海岸平野は完新世後期,サンゴ礁の上方成長が海面に到達し,浜堤が形成されると急速に発達する.数年にわたるクック諸島ラロトンガ島の発掘調査によって,人間居住と海岸平野の地形発達との関係が明らかになった. (1)約6000年前の海岸線は,海岸平野の最奥,現海岸線から内陸500mの地点(平均海面上1.70m)に侵入しており,海岸平野の発達はその後の海退現象と関連している. (2)その後,間もなくオオハマボウ,パンダヌスが優占する海浜植生が成立した.この時期にさかのぼって,この島にはマングローブ植生が欠けており,その生態地位をオオハマボウの群落が占めていた. (3)4000年前から3000年前にかけて,サンゴの破砕礫からなる浜堤と州島が形成され,後背湿地や潟湖をもつ海岸平野が発達した.(4)初期的な人間居住の痕跡は,それら浜堤と州島の上で発見された.考古学的調査によって得られた最も早い居住は, 1030年前にさかのぼる. (5)内陸丘陵斜面における焼畑農耕によって森林破壊と土壌のラテライト化が急速に進んだ.豪雨などによって渓谷に滑落した土壌が,焼畑の炭化物とともに土石流となって海岸低地に運ばれ,堆積した.こうして渓谷の出口に小さな扇状地が複合的につくられ,現在の海岸平野が完成した. (6)おそくとも,300年前頃になると扇状地堆積が安定し,扇頂部にマラエ(祭祀神殿)が構築されて,谷筋を領有する社会単位(タペレ)が形成されたと考えられる. Coastal alluvial plains are transitional environments caught between terrestrial and aquatic ecosystems in the formation process. Our concern is to examine the environmental history of Rarotonga, the principal island in the Cook Islands of central Polynesia. In terms of human settlement, probably the most important change occurred after the Holocene high sea level when the slight drop in sea-level would have exposed shallow sea floor and increased near-shore sedimentation, creating coastal plains. Our excavation at the site located at the foot of hill terraces, inland side of coastal plains, revealed tidal marine deposits at 1.7 metres above mean sea level. On top of the layer we have found peat soil deposits containing waterlogged plant remains. This suggests that coastal woodland was formed and the land forming process was started around 6000BP. The beach-ridge, less than 2500 years old, provided enough protection from wave action and allowed for the rapid creation of coastal plains. These deposits laid down around 600 to 500 years BP were interpreted as having been derived from hillslope soils exposed by agricultural forest clearance. The occurrence of slips and transportation of soils in the valley system is closely related to periods of heavy rain such as cyclone season. After the sedimentation activity had slowed down until about 300 years ago, an apex of alluvial fan at valley debouch was selected as the site for building Marae or ceremonial court which is most important social focus by people.
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Landscape Changes in the Coastal Plains of Fringing Reef Island ; Rarotonga in The Cook Islands

Masashi CHIKAMORI(近森　正)

Introduction:

Geomorphology of the coastal alluvial plains has a history of transitional phases between oceanic and terrigenous sedimentations while in the process of formation and then proceeding on to an incorporation of the interactions and uses of these lands by the area's inhabitants.

This report attempts to define the potential resources of these coastal environments and how they have been affected by human influences.

(1) Geomorphological setting of Rarotonga:

Rarotonga is the principal island in the Cook Islands located in the central South Pacific and is considered to be one of the most beautiful island in Polynesia. It is an isolated volcanic island, highly dissected into steep

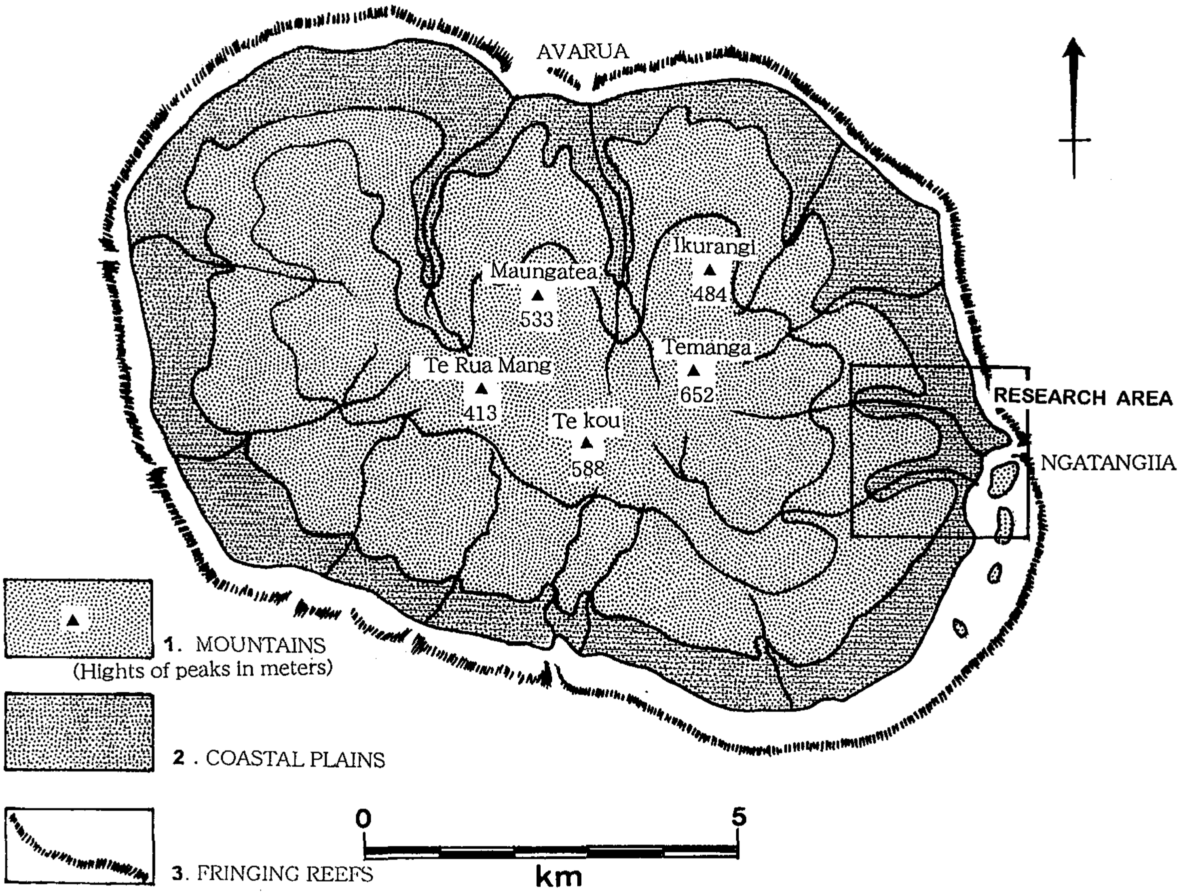

Figure 1. Landforms of Rarotonga Island

mountains which have created a rugged skyline with a maximum elevation of 640 meters above sea level. Rarotonga Island measures 8 x 11.5 km. and is surrounded by fringing coral reefs. (Figure 1)

Rarotonga rises from the ocean floor at a depth of 4,500 meters. Radiometric ages indicate a Pleistocene of 1.79 million years and 1.19 to 1.30 million years for the uppermost level of lava on the cone of phonolitic eruption. (Dalrymple, B. et al. 1975)

On the island, there is a wide variety of physical features such as forested mountain peaks, steep slopes dipping down into valleys, hills, alluvial-colluvial coastal plains, back marshes, beach ridges, lagoons and coral reef flats. On the east side of the island at Ngatangiia, the reef encloses a deep channel and there are three sand cays and one smallvolcanic islet.

The coastal geomorphology of Rarotonga is highly complex owing to its topography and drainages, and reef-lagoon system. Classification of the geomorphologial units may make it possible to advance a hypothesis for understanding the background of the island's formation.

Comparatively fertile soils spread across the coastal plain between the beach ridges and the foothills (from which the soil originated in mountainous areas) and have been cultivated by the inhabitants. Thus, at present, the bulk of the population resides in this region.

Beach ridges which encircle the island divide the coral reefs from the alluvium-colluvium plains and are composed of reef producing materials such as coral gravels, calcareous sand and shell fragments.

The coastline is surrounded by a continuous reef flat and these reef flat communities are composed of mainly *Porites, Favia and Favites.* Climatic conditions such as the southeast trade wind, a 2,110mm annual rainfall and tropical cyclones, which periodically strike this area, are constantly effecting the reef morphology.

(2) Field research:

We conducted several field works as part of archaeological research project in the Cook Islands since 1985 to present. (Chikamori, 1993, 1995, 1996, 1997, 1999) We have done intensive research study mainly in Ngatangiia district on the eastern side of the island. We chose this area because it possesses the most diverse geomorphological units for thorough observation. The two largest rivers, Avana and Turangi, discharge their waters into the Ngatangiia harbor and bay. Another reason we chose this area was because this district is the richest in the on-going historical events of the inhabitants as recorded through their oral traditions. Accordingly, it has been reported that the first tribe to arrive here was Takitumu who came ashore in Ngatangiia bay in large canoes. After establishing a community here, the Takitumu then branched out into the Avana valley and other areas.

Our excavation sites were selected along a transection line from shoreline to the foothills. Excavation locations are listed as follows: (Figure 2)

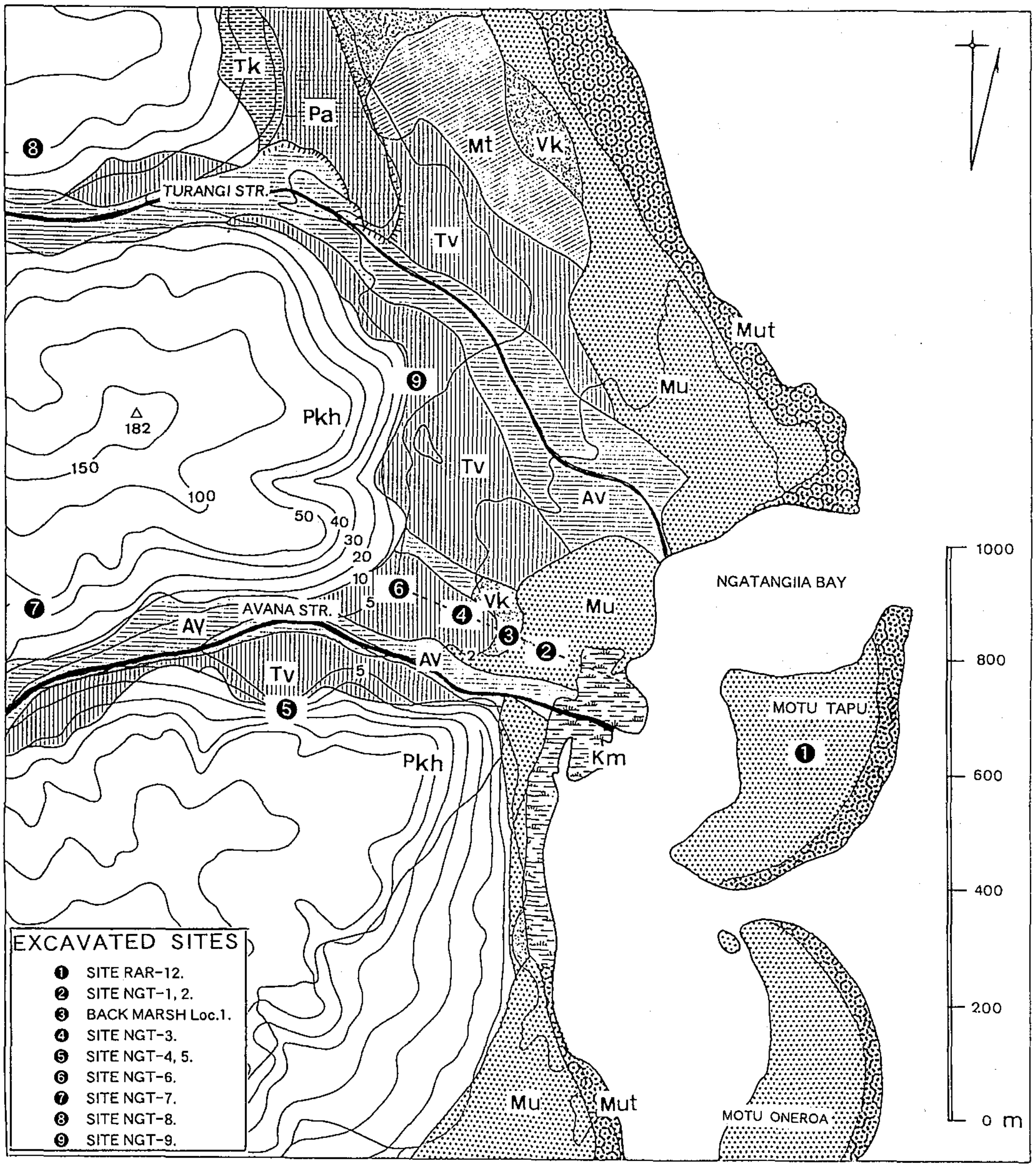

Figure 2. Excavated archaeological sites and geomorphological classifications of coastal plain, Ngatangiia area, eastern part of Rarotonga

Soil and Geomorphological types (after Leslie, 1980)

Km : Soil of estuarine margins. Developed on estuarine muds and sands derived from basaltic alluvium. Occurs at a level of slightly above mean sea level.

Mu : Soil of beach ridges. Sands and gravels derived from coral reefs. It form an almost continuous belt around the island.

Mut : Soil of storm ridges. Stony nature of the profile of the Mu. Occurs at outer side of the beach ridges.

Vk : Soil of backmarshes, depressions on the landward margin of the raised beach ridges.

Av : Soil of the younger flood plains. Basaltic alluvium occurs in valleys slopes toward coast.

Tv : Soil of the younger flood plains, occurs further from streams. Area tend to be less extensive than for Av.

Mt : Soil of the older flood plains, occurs on alluvium fans where streams debouch from interior of the island.

Pa : Soil of terraces developed in the Pleistocene time. Seaward margin of the terrace is marked by prominent escarpment.

Tk : Soil of fans extended away from hill margins, occurs mainly on apex of the fans.

Pkh : Soil of hilly land.

① Site RAR-12, a Marae on the cay of Motu Tapu.
② Site Ngt-1 and 2, habitation sites on a beach ridge.
③ Back marsh, between sites Ngt-1 and Ngt-3, for collecting samples of pollen and diatoms analysis.
④ Site Ngt-3, Marae of one of the Kainuku chiefs on the sea side edge of alluvium-colluvium plain.
⑤ Site Ngt-4 and 5, a rock shelter site at the debouch of the Avana valley.
⑥ Site Ngt-6, open site on the alluvium-colluvium plain.
⑦ Site Ngt-7, a conceivably dry agricultural garden on a hill slope in Avana valley.
⑧ Site Ngt-8, a conceivably dry agricultural garden on a hill slope in Turangi valley.
⑨ Site Ngt-9, a Marae situated on the side of Arametua, an ancient road, in Ngatangiia.
⑩ Site RAR-106, 107, 108, agricultural irrigation terraces on the up-stream side of Turangi valley.
⑪ Site RAR-105, a Marae on a ridge of hills on the upstream side of Turangi valley.

(3) Sea level changes during the late-Holocene time:

The geomorphological development of the coastal plains and coral reefs depended to a large extent on the history of the Quaternary period which particularly affected the sea level changes during the late-Holocene time.

Over the last few decades, the history of sea level changes in the Cook Islands has been subject to controversy. B. Wood (1970) found a raised reef at +1 meter above low sea level at Avarua, northern side of the island and dated it to 2,030 years BP. Wood has interpreted this as evidence of a high sea level coming from Eustatic movement.

However, N. Yonekura (1984, 1988), Department of Geography of Tokyo university, who has conducted extensive research works on the sea level changes and tectonics in the middle of Pacific Ocean, concluded there was no evidence to support the idea of a Holocene high stand of sea level in Rarotonga on the basis of the age-determination and analysis of coral sam ples taken from boring cores. At the same time, Yonekura noted that he could find no positive indications of an emerged feature from the Holocene time.

Our excavation in 1991 at Site Ngt-1 and 2, located on the surface of a beach ridge in the Ngatangiia area, revealed that an old reef flat underlies deposited coral gravels and sand. A lithified micro-atoll on the old reef flat which we found at the site was situated at the level of 0.9 meters above low sea level on average. (The tidal ranges showed a fairly small difference : 0.24 m at neap tide and 0.82 m at spring tide in Avarua Harbor in Rarotonga). These were dated between 4,000 and 3,000 years BP. (Chikamori, 1995) The vertical growth of the coral reef flat corresponded in general with the low sea level and, especially, the micro-atoll was strictly limited at the low level of the spring tide which provides further evidence for the Holocene high stand of sea level. (Figure 3)

Assuming that the relative sea level was much higher than the present level at the time of Holocene transgression, it is also possible to assume that the ancient beach had extended much farther inland below the alluvium-colluvium sediments. For this reason, we selected site Ngt-6 in the foothills on the inland side of Ngatangiia village which is about 500 meters from seashore.

Our excavation at site Ngt-6 proved that there is no coral reef : however, tidal marine deposits lie 4.5 meters below ground surface at the level of 1.7 meters above the preset mean sea level. This layer-VII is filled with silt and fine coral sand containing small pieces of marine shells which were identified as eight species of inter-tidal living forms. (Figure 4)

These evidences make clear that the Holocene transgression reached the most inner part of the coastal plain. Three samples of radio-carbon dating around 6000 years BP were assigned to layer-VI. (5,920±50yBP, 5,93070 ± yBP, and 6,260 ± 60yBP ; These were calibrated by the 13C adjusted ages.)

From the layer-VI, we have found fibrous peat soil deposits containing waterlogged plant remains such as Tree Hibiscus (*Hibiscus tiliaceus*), Coconut tree (*Cocos nucifera*), Pandanus (*Pandanus tectoris*), *Phyllanthus euphorbiacea* and four other species still not identified.

Among these species, the Tree Hibiscus takes up more than half of the total in dry weight from this layer. Plant species of mangrove are totally

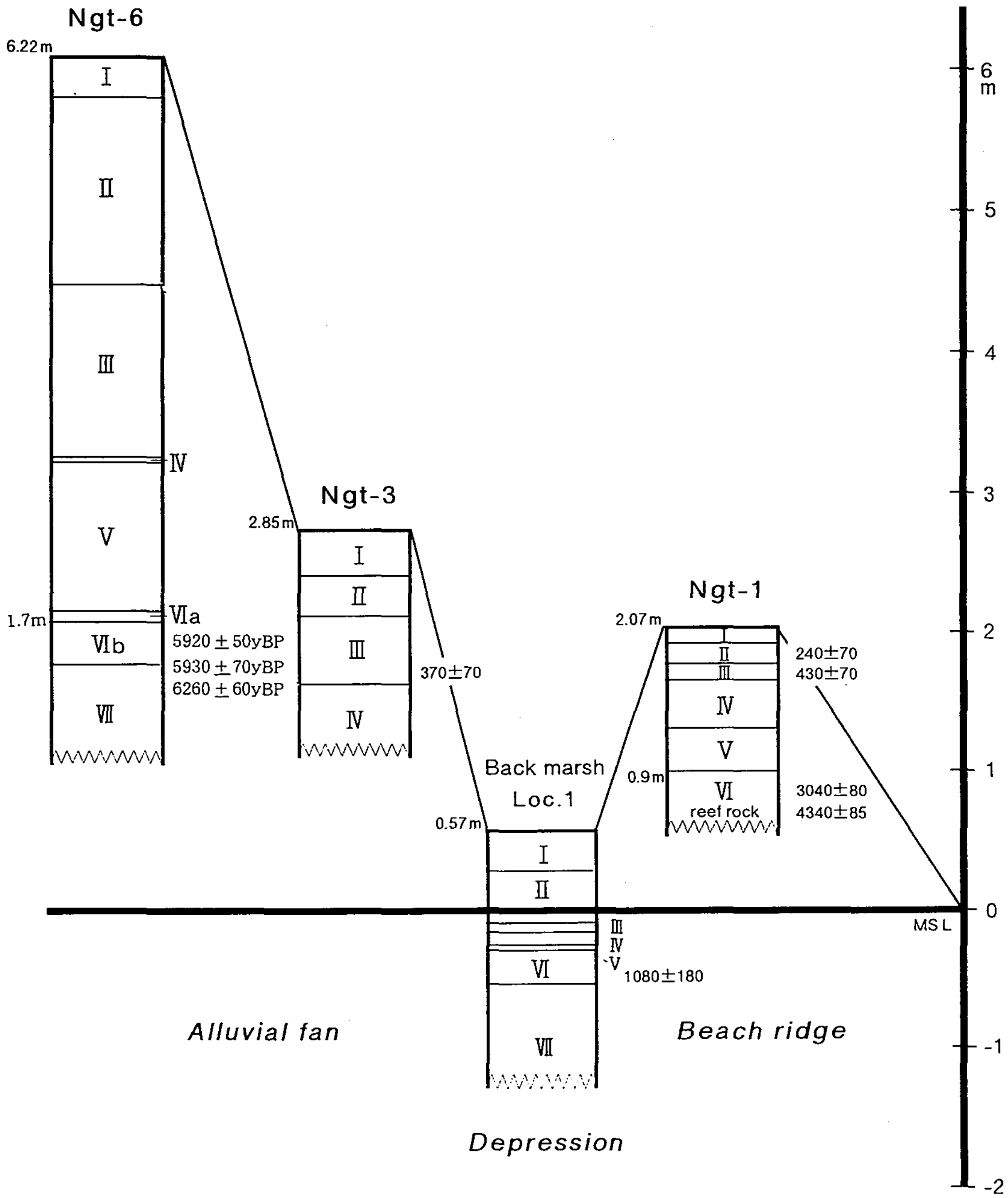

Figure 3. Stratigraphic correlation between the site Ngt-1 and Ngt-6 shown in relation to a schematic elevation profile of the transect

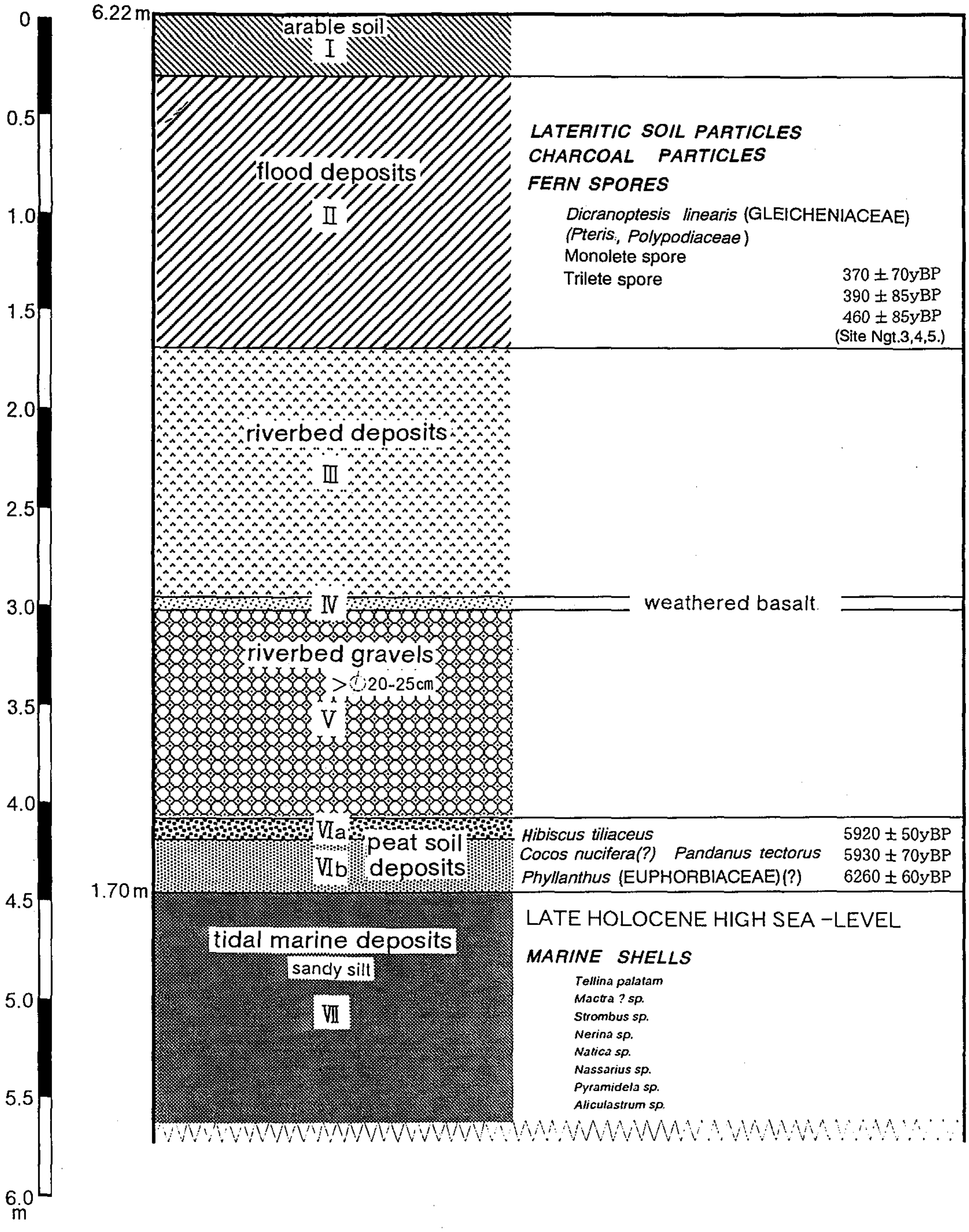

Figure 4. Schematic stratigraphic section of the excavation site Ngt-6

absent in this layer although several species are known today in Tonga and Samoa. (Setchell, 1924 : Yuncker, 1959) It is likely that the mangrove's ecological place in the flora system was taken over by the Tree Hibiscus which dynamically established its habitat at the time of sea level rise.

Some botanists have suggested that the Tree Hibiscus may have been introduced to Polynesia by man. (Whistler, 1991) However, there is a complete lack of archaeological evidence to support a human presence in this area at around 6,000 or 5,000 BP.

For the purpose of defining clearly the boundary between marine sediments and terrestrial sediments, we did X-ray fluorescence analysis for the sediment materials (crystallized educts) from layer-VI based on the fact that marine water contains much iron and sulfur in the form of pyrite (FeS_2) in comparison with fresh water. (Sea water :35% in one liter contained 2,700 mmg ; fresh water : only 50 mmg.) These figures indicate that layer-VI had a good likelihood for being of marine origin due to its high content of iron and sulfur.

Although a mid-and late-Holocene high stand of sea level throughout the central Pacific has been documented, further consideration is needed to determine whether the sea level rise may have been more than 1.7 meters.

Geological history in late-Holocene time is still not clear. The effects of the hydro-isostacy and tectonic are difficult to separate from contemporary Eustatic changes over short periods such as the late-Holocene. It can be seen the height level of layer-VI is slightly higher than that of other areas in the Northern Cooks (Chikamori, 1995), but we should notice that it measures 1.7 meters high which corresponds with the same height as for Mangaia Island in the Southern Cooks. (Yonekura et al., 1988) Outcrop of Pleistocene limestone can be seen at the headland of Ngatangiia bay directly overlooking the fringing reef in the form of bluffs. These bluffs have been notched by present day wave actions. However, we could not find any fossilized notches in the area.

Regardless of its height some 6,000 years before, seawater would have moved inland to cover the whole area of present day coastal plain. Sea waves may have thoroughly altered the shorelines which were not protected by coral reefs and beach ridges as is the case today. Cliffs of the Pleistocene terraces (Pa., Nikao terrace) continuing along the foothills may have been formed by lateral erosion of wave actions during that period.

We have no definite information on climatic shifts in the region over the past 6,000 years. But sea levels may have been followed by a drop after attaining a maximum high sea level. The upward growth of the coral reef may have reached the sea level during the period between 4,000 to 3,000 years BP as mentioned earlier. Time differences can be noted between the upward growth of the coral reef and the sea level changes.

(4) Formation of beach ridges and coral cay, and human settlements:

As the sea level approached its present level, beach ridges and coral cay or islet began to form. The powerful movements of waves during storms which periodically lashed the island broke off loosened corals from the reef edges and piled them up on the reef flats ; then, successive wave actions added more debris until a large accumulation formed these beach ridges at shoreline and encircled the whole island. Most recent beach ridges rise three to six meters above sea level and vary in width from 80 to 150 meters.

The beach-ridges are composed of coral debris and carbonated sands such as *Foraminifera*, calcareous algae and shell fragments. Sands from ancient formations have been uniformly weathered and differ sharply from fresh sediments. We can classify these into four separate beach ridges corresponding to different stages of progradation in the Ngatangiia area.

The oldest beach ridges have been covered with alluvium-colluvium soils. On the basis of results from our excavation we can estimate the oldest depositional features are dated to be less than 2,500 years ago.

Site Ngati Tiare

Beach ridge was selected by the first Polynesian inhabitants for their settlements. Because a beach ridge was located between land and sea, the inhabitants' two main economic activities--agriculture and fishing--could be conducted simultaneously and mutual advantage ; thus, these beach ridges became a desirable place to settle upon.

A settlement site (RAR-40) has been found on an old beach ridge covered by a widespread belt of alluvium soils in what is present day Ngati

Tiare in the Avarua district on the northern side of the island. (Bellwood, 1978) The site is located at a spot facing a deep, sheltered reef passage; there is also a very open, alluvial valley bottom on the back side. This site would have made a most suitable location for an initial Polynesian settlement on the island.

The earliest human settlement layer was clearly laid down on top of the surface of an old beach ridge. This layer consists of an intensive occupation phase which is suggested by earth ovens (umu) with much charcoal laying beneath a packing of volcanic stones. Some charcoal samples from this layer date to 720 years BP and 630 years BP. One-peace fish hooks, made of pearl shell and pig bones which were found in the layer, indicate that the people conducted fishing and agricultural activities. Pearl shell artifacts also suggest that trading voyages were made to other islands since these materials are completely absent on Rarotonga.

Marae at Motu Tapu (Site RAR-12)

In 1996 and 1997, we found much older human activities dating back 1,000 years at Motu Tapu (sacred island), a cay or coral islet in Ngatangiia bay. The cay itself has been formed by almost the same process as the beach ridges which experienced late-Holocene sea level falls. The cay measured 600 meters long and 360 meters wide and occupied an area of 11 ha. (Figure 5)

Prehistoric site on Motu Tapu is a Marae or ceremonial stone structures or shrine named Marae Mareva (RAR-12). It is situated in the middle of the islet about three meters above sea level. The Marae has a rectangular pattern, measuring 12.8 x 11.2 meters. Some 17 basaltic, upright stones are arranged on a fairly level area.

Our excavation revealed that another stone arrangement extended over 30 meters in a large area underneath the existing rectangular Marae. The pattern of old the stone arrangement is still not clear. Some earth ovens with charcoal were found beneath a packing of coral and volcanic stones and were excavated from the lowest layer. The earth ovens contain large quantities of pig bones, turtle bones, fish bones and fragments of human bones associated with stone adzes and shell blades.

There now exist enough evidences of these ceremonial activities on the site to suggest that Motu Tapu was an important religious center as its

Figure 5. Excavation of the site RAR-12, Motu Tapu, a coral cay in Ngatangiia bay. 1996

name implies since the beginning of human settlement there. Charcoal samples from the lowest layer have been dated to 1,030 years BP. As of this time, these artifacts provide us with the oldest evidences of human activities on Rarotonga.

(5) Formation of the alluvial-colluvial plain and expansion of human activities:

Since the beach ridges were first formed, the geomorphological phase of the coastal plain has changed dramatically. Beach ridges were instrumental in protecting the coastal plain from the destructive forces of sea waves. Alluviation and colluvium process has made rapidly progress. And the fall of sea level has formed fresh water tables, as another, under ground of new formed alluvial plain and led to drier conditions on it.

Results of analysis on the diatoms from the back-marsh which was a part of a former lagoon demonstrate that a sea water environment had begun to change into a fresh water environment around 1,080 years BP as large quantities of sediments poured down from the hillsides and covered the coastal plain. With the passing of this period, human activities became more significant.

Let us look once more at Site Ngt-6 : the upper layers from V to III are fluvial deposits. These materials are riverbed gravels and weathered basalt. In the upper part of the layer-III, fine-grained deposits have increased and the boundary between layer-III and II is not clearly defined.

Soil of layer-II can be identified to the Takuvaine soil (Tv.) on general textural properties. This soil has a loamy clay texture and contains heavily weathered gravels.

We should note an important feature here : these sediments contain particles of charcoal, lateritic soil or latosol fragments, and fern spores.

Results from an X-ray diffraction analysis for the lithified soil grains found some of them to be round in shape. Those collected from layer-II clearly indicate that they have gibbsite, goethite, and magnetite as constituent parts. Especially, gibbsite is a most characteristic product from the lateritization process.

We discovered through a pollen analysis of the soils in this layer a large quantity of fern spores. Classified species, Tangle fern (*Dicranoptesis lineraris*, or Tuanu'e, in local terminology), is a most significant vegetation for the composition of fern lands or fern covered inland areas. Tangle fern is never found on the coastal plain.

Fern land makes for a most conspicuous landscape for it is only one species of plant occupying an area. It can be seen on the hill slopes facing the valleys, lower spurs and sometimes, it extends up a mountain ridge of less than 200 meters. The area covers about 400 ha. or nearly 10% of the total area of the inland as of the present time. (Figure 6)

Regarding the excavated pits we worked in, the stratigraphical features on the Tangle fern coved hillsides were relatively simple. The darker topsoil had disappeared, the soils were compacted, and some were lithified with cobble and gravel down in depth. It was moderately acidic (pH 4.0-5.3) and showed typically in the form of laterite.

Figure 6. Excavation of the site RAR-8, a fern land in the valley of Turangi. 1997

It is probable that this fern-covered area was originally forest land and the process for turning it into fern land was triggered by clearing and slash burning of the primary forest to make the land serviceable for agricultural purposes. But over many years of repeated burnings, the soil was weakened and it became no longer profitable to use the land for agriculture.

It is known that fern land has existed for hundreds of years and this attested to by descriptions made by Captain Cook in 1777 and again later by missionaries in 1850's who arrived the Cook Islands.

The soil surface underneath the fern-covered land is fairly loose and is easily carried away. Erosion rates are very high when there is a heavy and intense rainfall in the area. Total soil loss spreads uniformly over the whole surface. Thus, garden work under humid, tropical conditions inevitably leads to higher erosion levels than what is normally expected.

Due to erosion and landslides, soil flowed toward the valley bottoms and was then transported farther downstream. On occasions of flash-floods, which occurred chiefly in conjunction with cyclonic depressions, large amount of sediments derived from uplands were pushed downward by powerful water flows accompanying heavy rains. The transported soil was then spread out over the coastal plains as alluvial fans at the debouch of a valley and rapidly altered the surrounding landscape.

As noted above, three important findings--particles of charcoal, lateritic soil grains, and fern spores from layer-II--all strongly support the assumption that these sediments originated in the uplands and flowed downward when the soil was strongly affected by natural forces. Thus, it can be asserted that human beings were the most likely agents for the geomorphic formation of the coastal plains.

None of the radio-carbon samples proved suitable for indicating a date directly related to the sediments in layer-II because the charcoal particles we collected were too small and their compositions proved unsuitable for dating at this stage. However, it is possible to estimate the dates on the basis of several radio carbon samples obtained from the same layer (Tv., Takuvaine soil) of Site Ngt-3, 4 and 5.

On this basis, we can surmise that layer-II was deposited until 500 to 300 years ago and has become more stabilized since then. In general, as the sedimentation rate increases rapidly during the first half of an early stage, it is thus likely that the beginning deposits for layer-II had probably been effected much earlier.

After the sedimentation activity had slowed about 300 years ago, a valley debouch, which was commonly shaped as the apex of alluvial fan, was selected as the site for building Marae or ceremonial court by the people. The Marae Ara-i-te-Tonga, one of the most sacred Marae, located at the debouchment of Tupapa valley which is a notable example of this formation. The apex of the alluvial fan points upstream in the valley and the fan itself spreads out from there to the coastal plain. This places it in the thickest and deepest sector of sediments. (Figure 7)

These sites may have provided the people with a symbolic meaning of sanctity for the land. The basic land division for each social unit was called "Tapere" and consisted of a single valley demarcated on both sides by ridges which extended down to the coastal plain. Land management and production in each Tapere has been closely controlled by traditional social

Figure 7. Marae Ara-i-te-Tonga, located at the debouchment of Tupapa valley, 1996

systems and the inhabitants have had sufficient knowledge of the land to pursue resource exploitation.

Summary:

Coastal alluvial plains are transitional environments caught between terrestrial and aquatic ecosystems in the formation process. Our concern is to examine the environmental history of Rarotonga, the principal island in the Cook Islands of central Polynesia. In terms of human settlement, probably the most important change occurred after the Holocene high sea level when the slight drop in sea-level would have exposed shallow sea floor and increased near-shore sedimentation, creating coastal plains. (Figure 8)

Our excavation at the site located at the foot of hill terraces, inland side

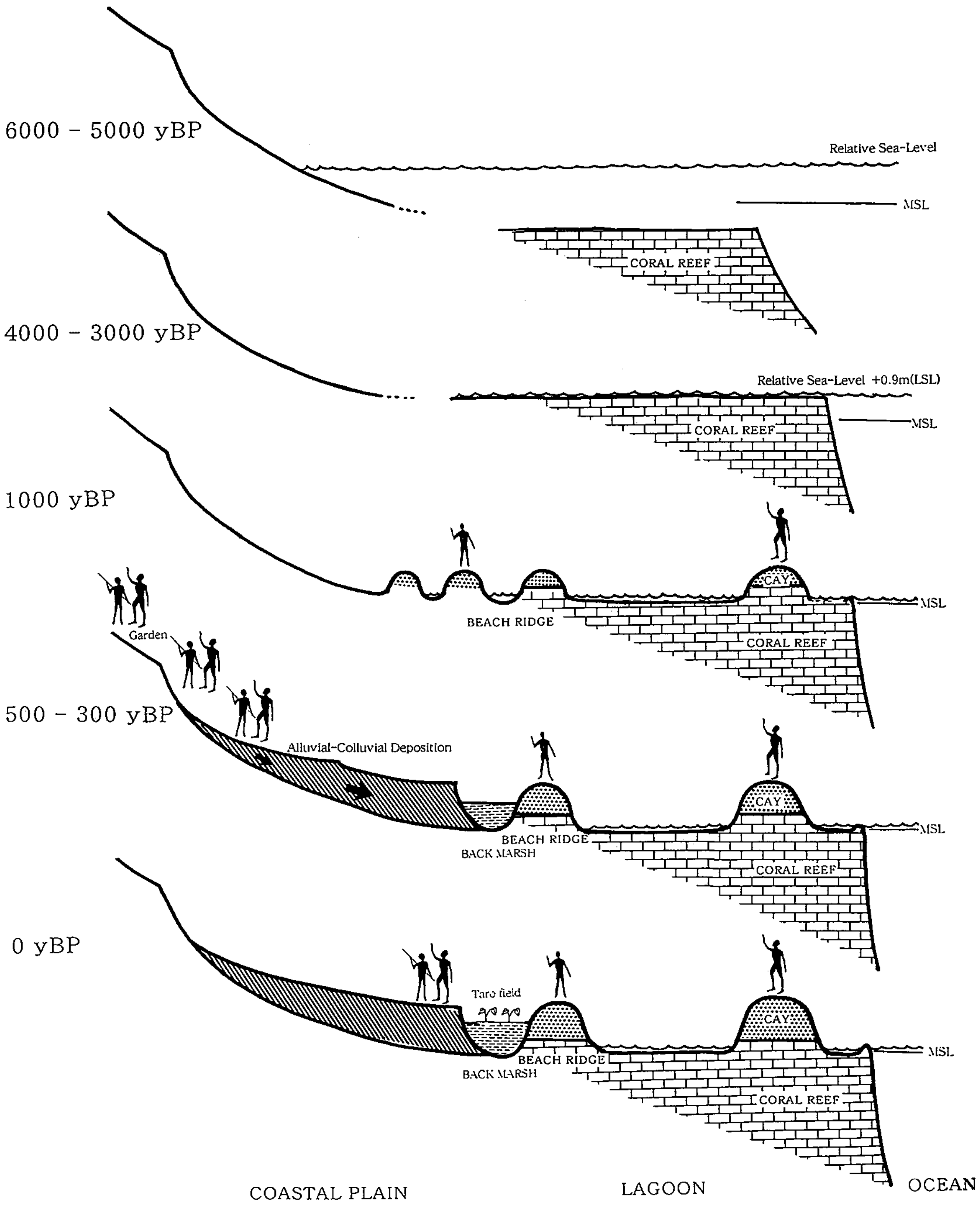

Figure 8. Sequence of landscape changes in Rarotonga, Late Holocene time

of coastal plains, revealed tidal marine deposits at 1.7 metres above mean sea level. On top of the layer we have found peat soil deposits containing waterlogged plant remains. This suggests that coastal woodland was formed and the land forming process was started around 6000BP. The beach-ridge, less than 2500 years old, provided enough protection from wave action and allowed for the rapid creation of coastal plains. These deposits laid down around 600 to 500 years BP were interpreted as having been derived from hillslope soils exposed by agricultural forest clearance. The occurrence of slips and transportation of soils in the valley system is closely related to periods of heavy rain such as cyclone season.

After the sedimentation activity had slowed down until about 300 years ago, an apex of alluvial fan at valley debouch was selected as the site for building Marae or ceremonial court which is most important social focus by people.

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(要旨)

裾礁島における海岸平野の景観変化と人間居住

近森　正

海岸沖積平野の環境史は陸上生態系と海洋生態系の間の遷移的過程のなかにある．裾礁島の海岸平野は完新世後期，サンゴ礁の上方成長が海面に到達し，浜堤が形成されると急速に発達する．数年にわたるクック諸島ラロトンガ島の発掘調査によって，人間居住と海岸平野の地形発達との関係が明らかになった．

(1)　約6000年前の海岸線は，海岸平野の最奥，現海岸線から内陸500mの地点(平均海面上1.70m)に侵入しており，海岸平野の発達はその後の海退現象と関連している．(2)　その後，間もなくオオハマボウ，パンダヌスが優占する海浜植生が成立した．この時期にさかのぼって，この島にはマングローブ植生が欠けており，その生態地位をオオハマボウの群落が占めていた．(3)　4000年前から3000年前にかけて，サンゴの破砕礫からなる浜堤と州島が形成され，後背湿地や潟湖をもつ海岸平野が発達した．(4)　初期的な人間居住の痕跡は，それら浜堤と州島の上で発見された．考古学的調査によって得られた最も早い居住は，1030年前にさかのぼる．(5)　内陸丘陵斜面における焼畑農耕によって森林破壊と土壌のラテライト化が急速に進んだ．豪雨などによって渓谷に滑落した土壌が，焼畑の炭化物とともに土石流となって海岸低地に運ばれ，堆積した．こうして渓谷の出口に小さな扇状地が複合的につくられ，現在の海岸平野が完成した．(6)　おそくとも，300年前頃になると扇状地堆積が安定し，扇頂部にマラエ(祭祀神殿)が構築されて，谷筋を領有する社会単位(タペレ)が形成されたと考えられる．