Shore Platforms and Coastal Platforms along Nichinan Coast, Southern Kyūshū

Tatsuo TAKAHASHI

1 Introduction

Along the Nichinan Coast between Aoshima and north Aburatsu there are very broad shore platforms, which are among the most spacious in southwest Japan, with serrated relief (or so-called washingboard-like relief) in the inter-tidal zone. On the other hand, far above high tide level are partially seen the ledge-like platforms that are clearly distinguished in feature, level, scale and lithology from the former platforms. Two types of platforms are in striking contrast to each other.

The purpose of this paper is to describe each platform, and discuss the problems on their formation and the level of their planation.

Shore platforms at relatively high levels have been interpreted in various way (Cotton, 1963). Most authors are convinced that these platforms are actively developing under the attack of storm waves at present (Bartrum, Edwards, Johnson, Jutson, King, Stearns or Wentworth). The shore platform of the storm-wave type that is often found on surf-beaten coasts, are not necessarily at high tide level but are commonly several feet above it — one foot or two to 8 feet on the west coast at Auckland, New Zealand (Bartrum, 1924 & 1952). Wentworth (1938) observed in Hawaii that the benches up to the height of 3 m are occasionally washed over by heavy breaking waves, which may reach 4 m or 5 m above sea level. On the contrary, Fairbridge (1952, 1961), an outspoken opponent against this theory, regards all the platforms in question as developed at the level of low tide at a time when sea level was considerably higher than it is now. Mii (1963) recognized in Japan 2 m-bench and 6 m-bench, and inferred from their continuity with raised beaches that each bench had possibly been formed at each previous high sea level. Bird (1969), classifying the shore platforms, grouped those which developed at or slightly above mean high tide level as 'high tide shore platform'. But the platforms above high tide level are not uniform in height, feature and formation process. For instance, on high wave energy coasts near Port Campbell, Australia, storm waves may develop 'structural' benches as high as 60 m above present sea level on horizontal or gently-dipping stratified formation (Baker, 1958 and Bird, 1969). The platforms which are described in this paper are 'non-structural' benches, which cut across the local structure of coastal rock formation at the height of 2–13 m above mean sea level. Reports of research on such a platform have scarcelly been published in Japan to date. As the platforms at relatively high levels have not always been made clear, more studies on various cases are needed. The platform far above high tide level is often termed 'storm wave platform' (Bartrum, 1924 and Edwards, 1941), otherwise 'emerged platform' but it is not always appropriate to use such terms without clear elucidation of their formation. The purely descriptive term 'coastal platform' or 'coastal rock platform' is preferred here.

2 The General Feature of Nichinan Coast and the Platforms

The Udo mountain range is a cuesta with gentle slope seaward, which regulated by the geological structure with roughly N-S in strike and 15°E or thereabout in dip of the homoclinal strata that consist of alternation of sandstone and mudstone, with thick beds, 5–10 m in thickness, of sandstone (Miyazaki group, upper Miocene).

The shoreline is rather indented with embayments where consequent rivers flow into sea. Concerning the feature of the indented shoreline, Endo (1954) indicated that the coast had submerged, while Nishimura (1957) put a significant emphasis on the effect of differential erosion. As Nishimura pointed out, this coast is not so indented as typical ria coast and the shape of embayment is rather discordant with that of drowned valley. Then it is relevant to consider that such an indented shoreline has been shaped as the result that the drowned valley was buried with shoreline regression and on the other hand the embayment was enlarged with differential erosion. The distribution of shore platforms at intertidal zone and ledge-like coastal platforms far above the high tide level is shown in Fig. 1.

The former is the broadest one in southwest Japan. For instance, the shore platforms of 100 m or more in width extend along nearly straight shoreline with distance of 4 km from Tozakibana to Uchiumi harbor (photo 1), and other platforms near Yōkōen have width of nearly 500 m.

Development of shore platform requires a delicate balance between rock resistance and intensity of wave attack. For the development of spacious platforms at this coast, the less resistant lithology, rather than the high energy wave, plays more important role by the following reasons: whatever high energy the wave may bring at the shore, it must lose the energy expeditiously when it traverses over the broad platform. Moreover, as there is a breakwater-like rampart with the height of about 2 m (see profiles of Loc. 21, 31 & 32 in Fig. 2 and Photo 2 & 3) along the platform rim, the wave crossing over the rampart must loss the energy distinguishably. Under the lee side of the island (e.g. west side of Aoshima island),

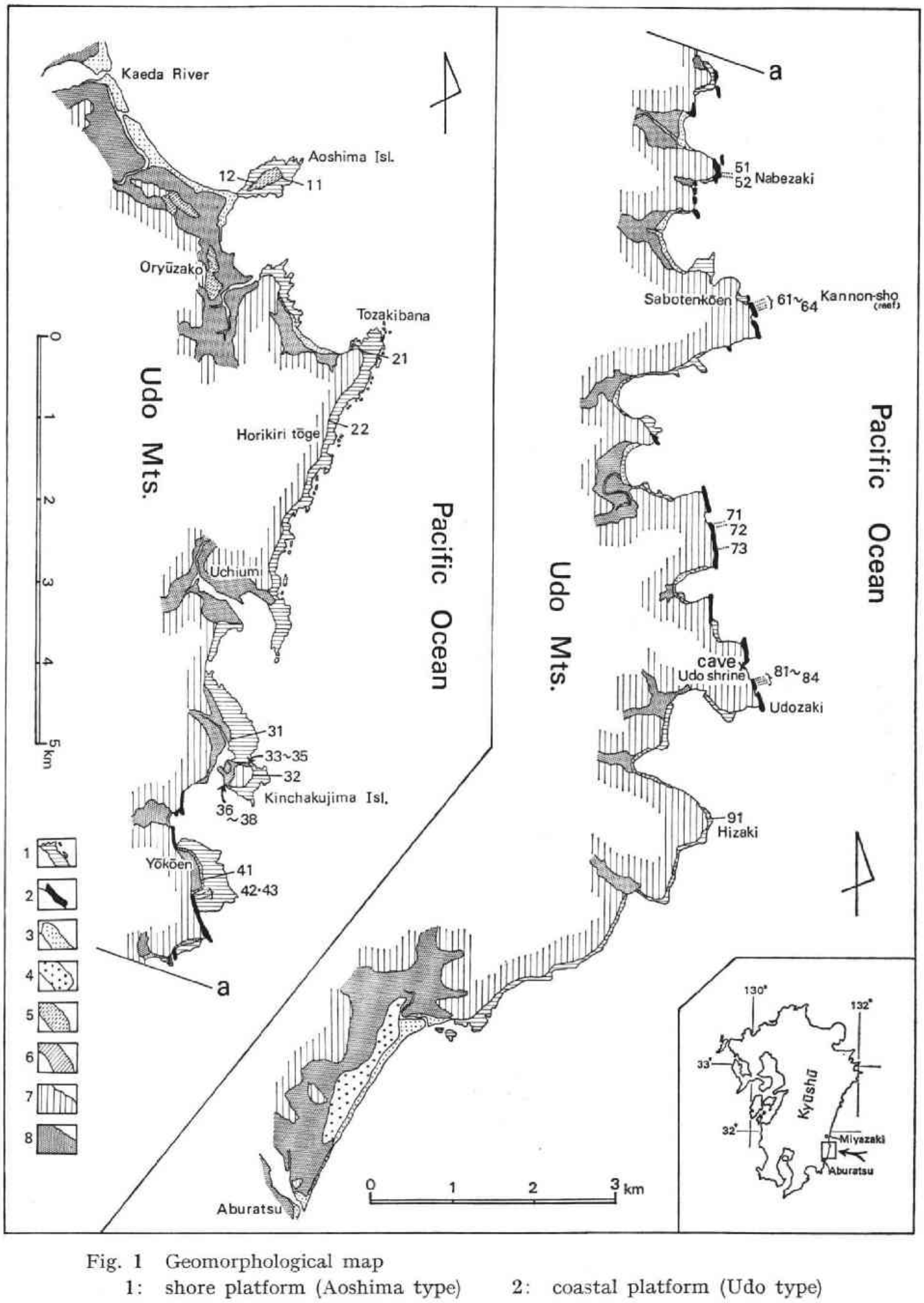

Fig. 1 Geomorphological map

1: shore platform (Aoshima type)
2: coastal platform (Udo type)
3: beach (including small sand dune)
4: sand dune
5: emerged sand deposits
6: coastal terrace
7: mountain
8: alluvial plain

number: location number of profile

the shore platform is not so narrow although the high energy wave never reach there. The feature of the shore platform is evidently different in its form and origin with that of the abrasion platform below sea level (Toyoshima, 1967). The principal agency for the planation of the shore platform is not so much the abrasion as the weathering (water-level weathering of Wentworth, 1938, or water-layer weathering of Hills, 1949) and the wave action keeps merely the transportation of loosed materials. Therefore, as at Yōkōen (Loc. 41), the shore platform of mudstone-rich alternation that is less resistant against weathering caused by alternate wetting and drying, is comparatively broad. At some coast with shore platforms there are coastal terraces (e.g. at the southern coast of Kii peninsula: Takahashi, 1973), but at this coast, notwithstanding the broad shore platform, the coastal terrace is not seen except extremely small one at Kinchaku Island. A clear explanation about the reason can not be made as yet.

3 The Types of Platform

The shore profiles in order to indentify the features of shore platform and coast platform are levelled at intervals of 5 m in about right angles to the shoreline, or at shorter intervals on rugged relief (Fig. 2)

The mean sea level in the profiles is estimated from the data of the tidal observation at Aburatsu tide gauge station and the tide table (edited by Japan Meteorological Agency). The tide at Aburatsu can be seen in the tide table (1972) as follows:

highest tide level	104 cm
mean high water spring (high water level of ordinary spring tide)	85.3 cm
mean low water spring (low water level of ordinary spring tide)	−115.4 cm
lowest tide level	−138 cm

The profiles are so various in length that it is difficult to compare with one another, and it is not convenient to read the features and the levels because they are of rugged relief. For convenience of comparison the simplified profile and the height frequency were drawn in Fig. 3. The simplified profile represents the height of 20 or 40 points at equal intervals on the part of platform in shore profile on the vertical axis and the width of profile in uniform size in spite of the actual length of platform on the horizontal axis. Consequently, it is difficult to compare mutually the inclination of the platforms on this graph. The length of the platforms and their inclination on the main part are stated in Fig. 3. The graph of the height frequency shows the frequency and additional frequency in height of 20 or 40 points mentioned above.

From the survey of figures the platforms are classified into two types with distinct difference in the feature, level, scale and lithology. One is broad shore platform which is constructed by homoclinal alternation of sandstone and mudstone with serrated surface at the inter-tidal zone (Loc. 11, 12, 21, 22, 31, 32, 41 and 91). The other is the coast platform which carved a homoclinal bed of sandstone with relatively steep slope far above high tide level (Loc. 42, 43, 51, 52, 61, 62, 63, 64, 71, 72, 73, 81, 82, 83 and 84). Provisionally, in this paper the former is named 'Aoshima type' and the latter is called 'Udo type' from the place names of type localities. Judging from the level and the range of the surface, Udo type platform is proper to be termed as the coastal platform rather than the shore platform.

The features of Aoshima type platforms can be summarized as follows: (1) They overspread broadly 100–500 m in width; (2) The surface of those platforms is levelled in intertidal zone and especially between the mean sea level and the mean high tide level, except seaward rampart, but at Yōkōen (Loc. 41) a platform is seen below mean sea level; (3) They are constructed of homoclinal alternation of sandstone and mudstone with strike of N10°W–N25°E nearly parallel to the general direction of the shoreline and dip of 15°–22°E toward sea; (4) Their surface, which has cut the formation horizontally, has the serrated relief (or washingboard-like relief — Photo 3 & 4) with alternation of sandstone crest and mudstone trough; (5) The surface inclines slightly toward sea 0.1°–0.5° in inclination at the main part; (6) Along the rim of them there are tall breakwater-like ramparts which are a kind of cuesta regulated with comparatively thick beds of sandstone (Photo 3); (7) On the surface there are few rounded gravels, although brick-like sandstone fragments, into which the prominent crest of serrated relief breaks along joint-surface of sandstone, are seen sporadically; (8) Those platforms have not been carved with deep wave furrows; (9) The cliffs at the rear of them are not so fresh.

Because the wave that goes over the breakwater-like rampart about 2 m high and traverses across the broad platform must lose the energy expeditiously, it is difficult to explain that so broad and almost horizontal platform is built up merely by abrasion. The wave armed with rock fragments are powerful agents of abrasion, and the wave without such fragments is capable of only limited abrasion. But on the surface of shore platform at this coast there are few clear evidences of the potency of waves armed with abrasive debris, which are such as smoothed and rounded gravels, excavated potholes and wave furrows with the direction that coincides with the wave course. Accordingly, it may be right to consider that the principal agency for planation of such platforms is not so much abrasion as water-level weathering. The platform surface, that are levelled approximately horizontal-

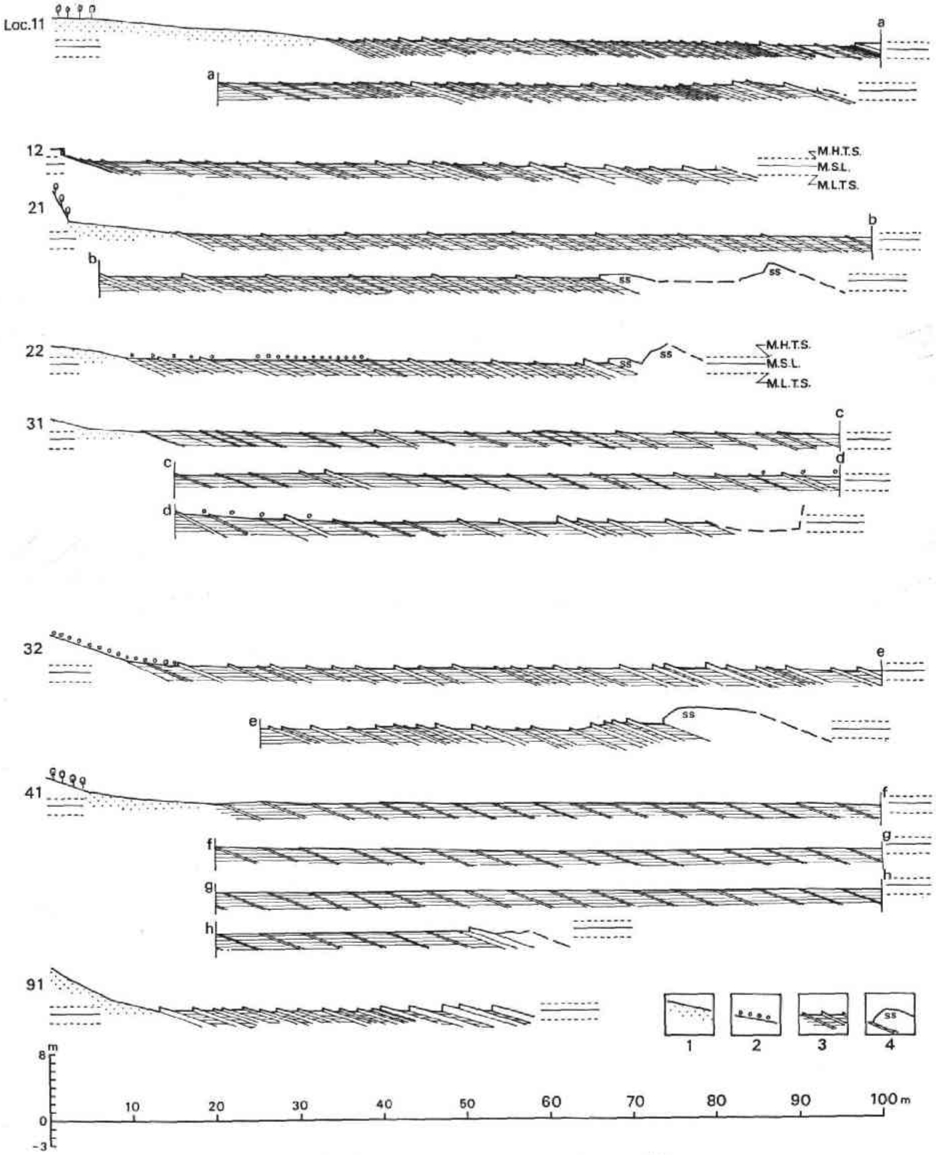

Fig. 2–(1) Profiles of shore platforms and coastal platforms (1)
1: beach 2: gravel on the surface 3: alternation of sandstone and mudstone
4: thick bed of sandstone

ly in inter-tidal zone, may correspond with the lower limit of sea-level weathering. The mudstone is easily loosened as it has the less resistant lithology for weathering caused by alternate wetting and drying in inter-tidal zone. And chips of mud-

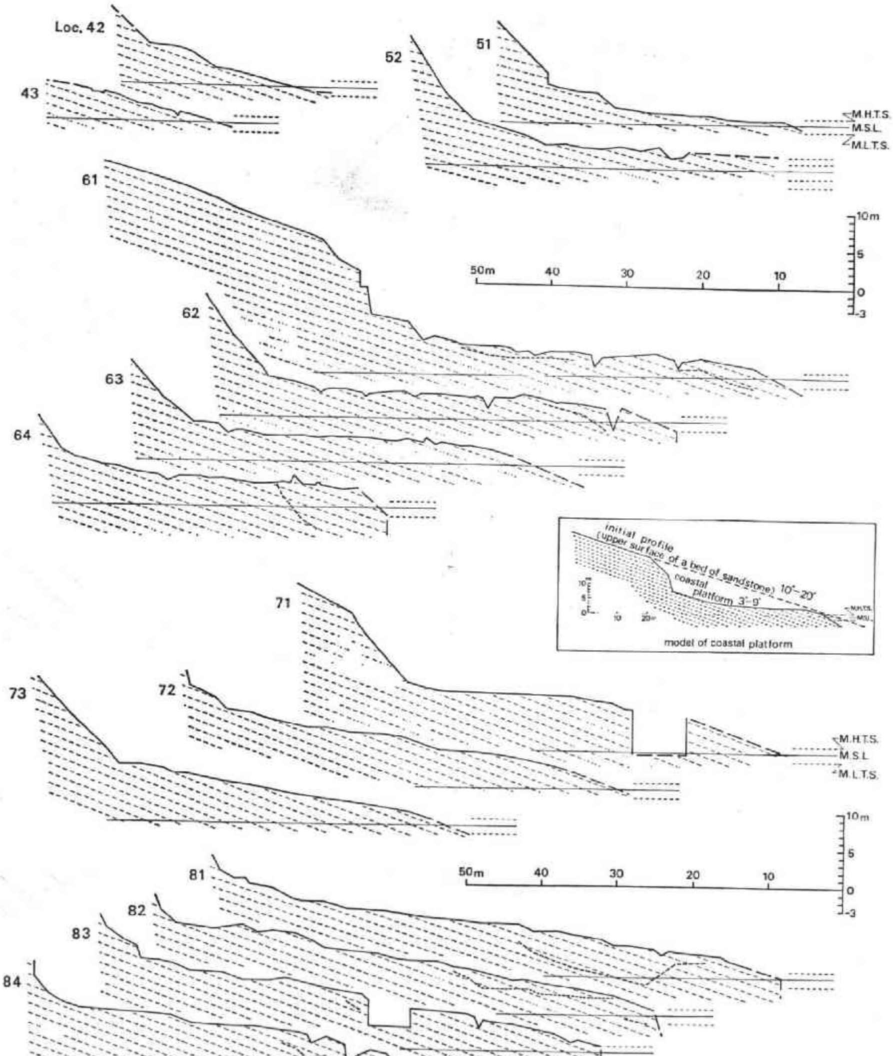

Fig. 2–(2) Profiles of shore platforms and coastal platforms (2)
The stratum is an inclined sandstone bed.

stone are quickly transferred away even by calm waves at usual high tide. The prominent crest of sandstone, which sticks out as the result of the loss of mudstone, breaks easily into the brick-like fragments along the joint-surface caused by wave attack. Thus the platforms are flattened nearly horizontally in inter-tidal zone.

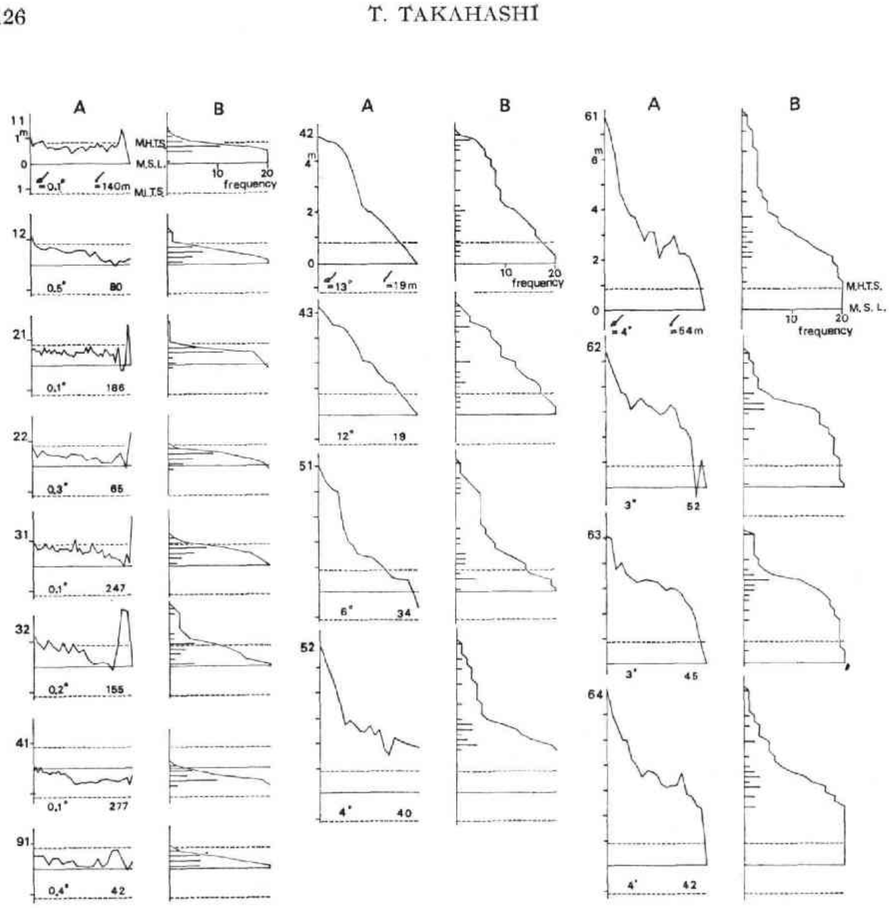

Fig. 3–(1)

Fig. 3 Simplified profiles (A) and Height frequencies (B) of shore platforms and coastal platforms

d: inclination at the main part of the shore platform (in degree)

l: length of the profile (in meter)

The features of Udo type platforms are arranged as follows: (1) They are 'non-structural' platforms, which have carved into a homoclinal bed of sandstone 5–10 m in thickness, N10°–20°W in strike that coincides almost with general direction of the shoreline and 10°–20°E in dip inclining toward sea (see the model of coastal platform in Fig. 2 and Photo 5 & 6); (2) Their surface extends far above high tide level and is in the range of 2–13 m above mean sea level, although its range is somewhat various at places; (3) Their surface inclines relatively steep seaward 3°–9° in dip at the main part; (4) The width of the surface is 30–70 m at the most; (5) On the surface, develop honeycomb structures, solution pools, potholes and mushroom rocks which consists of nodule, but no gravel, soil and vegetation (Photo

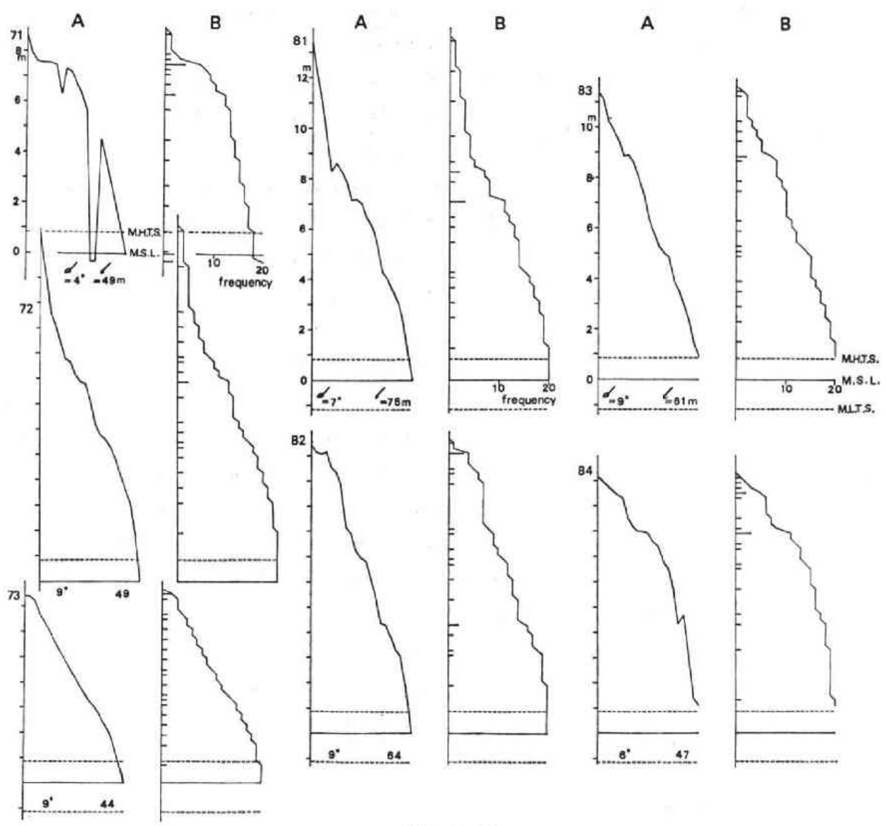

Fig. 3–(2)

7); (6) The rampart can not be seen; (7) The platforms are carved by wave furrows which are regulated with joint and fault, deeply at the frontal part; (8) The sea cliffs are rather fresh without disintegrated rock materials on their base, but no notches are carved there.

Those platforms, merely splashed with break waves and salt-spray at the frontal part, are not ordinarily covered by sea water, but have been kept fresh externally by surf that occasionally washes over them during storm. Fresh cliffs, honeycomb structures, potholes and mushroom rocks on the surface may be the clear evidences. Accordingly, it seems right to consider that those are the storm wave platforms. In general, on the outcrops of relatively resistant sandstone, platforms have developed far above high tide level: As mentioned above, on the high wave energy coasts near Port Campbell, Australia, the huge waves that break against the coast during storms may develop platforms as high as 60 m above present sea level (Baker, 1958); In Japan, there are inclined platforms whose strata are dipping, at ten and several meters high above sea level on their surf-beaten coast near Tanabe bay (Mii, 1962; Takahashi, 1973) and near Makurazaki in southern Kyūshū (Takahashi, 1972) and so on. Such platforms far above high tide level are 'structural' in the sense that their surface coincides with the upper surfaces of resistant strata: they are horizontal at flat bedding, and inclined at dipping rocks. Against such platforms, the platforms on this coast are 'non-structural' as they cut obviously across relatively resistant massive sandstone. It is doubtful to consider, merely because they are occasionally washed with storm-waves, that they, especially non-structural platforms at relatively high level, are initially made by present storms. On the other hand, it is not impossible to regard them as emerged features which developed during higher relative sea level, although they are secondarily modified and externally kept fresh by storm-waves of the present time.

As will be described later, the former sea levels about 2.5 m high and several meters high above the present sea level can be inferred at this coast. Consequently the possibility of the existence of the platform that corresponds to the former sea level is undeniable. Moreover at Udo shrine, there is an emerged sea cave at the approximate level as adjacent coast platform. Mii (1963) recognized 2m-benches and 6m-benches in Japan, and regarded, from the existence of emerged beaches correlated with them, that each bench had been formed to each former sea level. And also the writer (1972) described the emerged platforms several meters above sea level, which are accompanied with other emerged landforms along southern coast of Satsuma Peninsula, Kyūshū.

4 Correspondence between Some Coastal Landforms and Former Sea Levels

Around the lee side of Kinchaku Island which is tied to the land with shore platform, there are small-scale coastal terraces (Photo 8). The height of those terraces is 9–5 m above sea level at the north side of the Island and lowers gradually westward. The terrace surface at the southwest side can be divided into two, 10–7 m and 6–4 m surfaces. The terrace scarps shown in Fig. 4 are present sea cliffs, below which the shore platforms overspread. The terrace deposits covering an erosion surface which had cut across the homoclinal alternation 2.5 m above mean sea level (3.5 m above the sandstone crest), are composed of silt, sand, brick-like sandstone gravel with small holes by boring shell, coral gravel and shell fragments probably accumulated at the then shore (Photo 9 & 10).

From their features are properly inferred the two higher relative sea levels corresponding to the terrace surface and the erosion surface underlying the terrace deposits: they are about 10 m and about 2.5 m above present mean sea level.

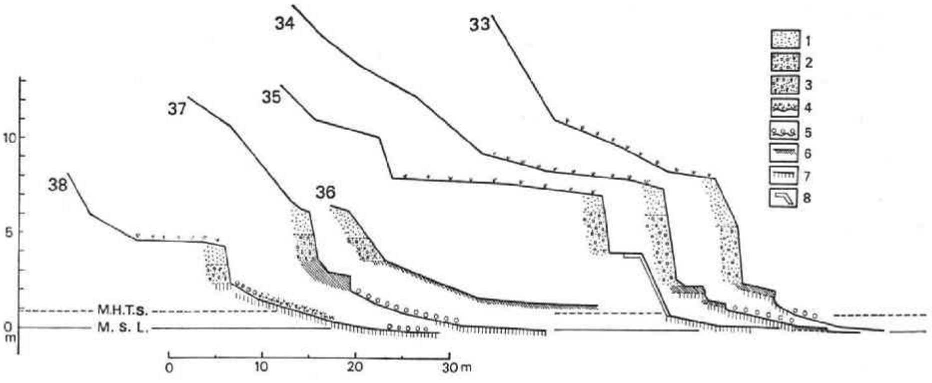

Fig. 4 The structure of coastal terraces at Kinchaku Island
1: silt and sand 2: silt, sand and gravel 3: silt, sand and gravel including coral gravel and shell fragment 4: sand and shell on shore platform 5: gravel on the shore platform 6: mudstone 7: sandstone 8: concrete wall

During the period of 2.5 m higher sea level the erosion surface with serrated relief as seen on the present shore platform had been formed as the then shore platform. Subsequently, as the sea level rose up relatively several meters high, the terrace deposits accumulated on the former shore platform. Lastly, the sea level dropped to the present level and new shore platforms have been cut spaciously. The absolute time of each previous sea level is unknown as yet.

It is possible to find out some landforms which correspond with the former sea levels as mentioned above. Aoshima Island is constructed with sand deposits covering previous platform, whose surface is several meters high above sea level. Near Oryūzako there are sand deposits which are regarded as emerged sand bars or retreated beach ridges at the height of several meters to 10 m. It is difficult to correlate immediately both levels of formation of these sand deposits and the terraces, but each of them must be the product of previous sea level and all have the similar height.

In such sense, it is not impossible to consider that the initial form of the platform of Udo type may have been formed at the sea level of several meters. An emerged cave at Udo shrine is just an evidence. Most of the platform which corresponded with the former 2.5 m sea level had lost the initial form by secondary erosion at the later sea levels of several meters or storm waves. Therefore, it is difficult to distinguish the platform clearly from the profile.

As it is not sufficient to infer the correspondence of landforms merely by the height, even with somewhat local difference in the height, more confirmatory evidence is desirable for further discussion.

5 Summary

The features of the shore platforms and the coastal platforms along Nichinan coast are summarized as follows:

(1) The shore platforms (Aoshima type) overspread broadly in the inter-tidal zone and especially between mean sea level and mean high tide level. Their surface cutting horizontally across the homoclinal alternation of sandstone and mudstone has been formed as serrated relief by weathering caused by alternate wetting and drying in the inter-tidal zone.

(2) For the development of the broad platform, the less resistant lithology rather than the intensity of wave attack played more important role.

(3) Coastal platforms (Udo type) with relatively steep slope in the range of 2–13 m above mean sea level are non-structural platforms carved onto a bed of relatively resistant massive sandstone, secondarily modified and kept fresh externally by storm-wave at present.

(4) It is not impossible to presume that the latter is the emerged platform.

(5) The higher relative sea levels about 2.5 m and about 10 m above the present mean sea level are inferred from coastal terraces at Kinchaku Island and emerged landforms by sand deposits near Oryūzako, but the absolute times of the sea levels are unknown as yet.

(6) From their correspondence in height, it is possible to regard that the coastal platforms (Udo type) are the product of the former sea levels.

The writer would like to thank Professor Kasuke Nishimura of Tōhoku University and Professor Ken-ichi Tanabe of Miyagi University of Education for their continuing guidance and encouragement. Sincere thanks are also present to Miss Kazuko Fujita and Mrs. Yoshiko Murakami for their helps in the field work and the drawing of figures.

References (*in Japanese)

Baker, G. (1958): Stripped zones at cliff edges along a high wave energy coast, Port Campbell, Victoria. Proc. Roy. Soc. Vict., **71** 175–179

Bartrum, J.A. (1924): The shore platform of the west coast near Auckland: its storm wave origin. Rep. Aust. Ass. Adv. Sci., **16** 493–495

——— (1952): Comment on 'Marine erosion' by R.W. Fairbridge. Proc. 7th Pacific Sci. Cong., **3** 358–359

Bird, E.C.F. (1968): Coasts. Aus. Nat. Univ. Press, Canberra

Cotton, C.A. (1963): Level of planation of marine benches. Zeitsch. Geomorph., N.F. 7, Heft 2, 97–110

Edward, A.B. (1941): Storm-wave platforms. J. Goemorph., **4** 223–236

Endo, T. (1954): Geology of Aoshima.* Reports of investigation on Aoshima, 12–27

Fairbridge, R.W. (1952): Marine erosion. Proc. 7th Pacific Sci. Cong., **3** 347–359

——— (1961): Eustatic changes in sea level. Physics and Chemistry of Earth, **4** 99–185

——— (1968): Wave-cut platforms. Encyclopedia Geomorph. 859–865

Hills, E.S. (1949): Shore platforms. Geol. Mag., **87** 137–152

Mii, H. (1962): Coastal geology of Tanabe Bay. Sci. Reps. Tōhoku Univ. 2nd Ser. (Geol.), **34** 1–93

——— (1963): Relation of shore erosion to sea level.* J. Mar. Geol., **2** 8–17

Nishimura, K. (1957): Structural engulfment: Differential erosion in coastal landform.* Hiroshima Univ. Studies (Liter. Dept.) **12** 388–393

Takahashi, T. (1972): Coastal geomorphology of the southern coast of the Satsuma peninsula, Kyūshū, Japan.* Geogr. Rev. Japan, **45** 267–282

——— (1973): Formation and evolution of shore platforms around southern Kii peninsula. Sci. Reps. Tōhoku Univ. 7th Ser. (Geogr.) **23** 63–89

Toyoshima, Y. (1967): A study on marine erosive features along San-in coast.* Jour. Fac. Edu. Tottori Univ. (Natural Sci.) **18** 1–35

Wentworth, C.K. (1938): Marine bench-forming processes: water-level weathering. J. Geomorph., **1** 6–32

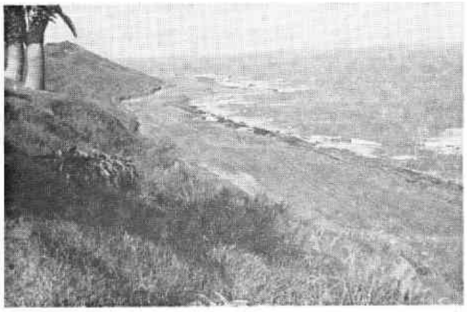

Photo 1 Spacious shore platform along nearly straight shoreline near Horikiri Pass

Photo 2 A tall breakwater-like rampart which is a kind of cuesta regulated with comparatively thick beds of sandstone (Loc. 22)

Photo 3 Shore platform (Aoshima type) and breakwater-like rampart about 2 m in height along the platform rim near Horikiri Pass (Loc. 22)

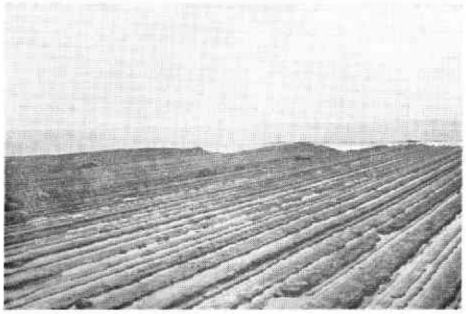

Photo 4 Shore platform (Aoshima type) with serrated relief (washingboard-like relief). Alternation of sandstone crest and mudstone trough

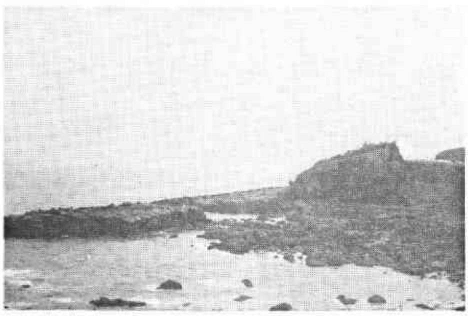

Photo 5 Coastal platform (Udo type) near Sabotenkōen (Loc. 61) carved onto dipping beds of sandstone

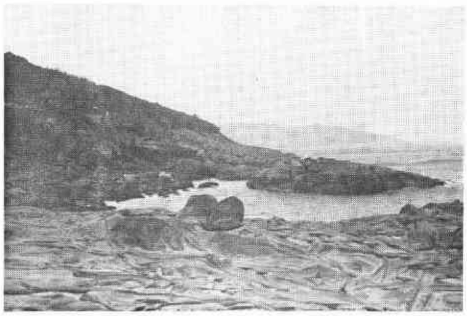

Photo 6 Coastal platform (Udo type) near Udozaki and a cave at Udo shrine

Photo 7 Relatively steep surface of coastal platform (Udo type) with mushroom rocks near Udozaki (Loc. 81)

Photo 8 Coastal terrace at the north side of Kinchaku Island

Photo 9 Coastal terrace scarp at north side of Kinchaku Island

Photo 10 Terrace deposits, composed of silt, sandstone, brick-like sandstone gravel, coral gravel and shell fragment at Kinchaku Island