Level and Age of the Planation of Emerged Platforms near Cape Muroto, Shikoku

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1 Problem Setting

Cape Muroto, the southeastern tip of Shikoku, is bordered with conspicuously rugged coastal platforms at several to ten meters above sea level. They are judged to be emerged features, as there are emerged potholes in places on the surface and emerged notches at the stacks adjacent to the platforms.

The purpose of this paper is to discuss the following problems concerning the level and age of the planation of platforms, and the process of their emergence.

(1) It is difficult to restore the original platform surface from the present rugged platforms, because the emerged platforms are deeply carved and cut in pieces with rainwash and occasional storm waves. But the small flat tops of most of the pieces of platform have the similar height or several meters above sea level. Moreover, near Gyōzuinoike some emerged potholes are recognized on the surface within the range to several meters above sea level, and some emerged notches at the stack side are seen at several meters above sea level. Accordingly, it is not impossible to infer the level of their formation by arranging such heights.

In order to restore the former shoreline from the present coastal terraces, the height of knickpoint between the terrace surface and the former sea cliff behind is measured on map or by barometer in the ordinary geomorphological method. But this method cannot be applied to restoring the level of platforms of several meters in height, because the displacement of those platforms is too small to void the observational and personal errors at the measurement. As to infer the planation level of platforms, is necessary more accurate measurement such as precise levelling.

To discern the planation level of those platforms is a difficult problem as there have not always been agreed opinions among the investigators (Cotton, 1963). Moreover, some emerged platforms may have been secondarily lowered by denudation. Therefore, the writer tried to infer the planation level of the platforms not only from the height of surfaces but from the location of emerged potholes and notches.

(2) The writer tried to infer the planation age of platforms. As platforms, potholes, or notches have not been covered with deposits containing the available

materials indicating the age, the age will have to be inferred by other method.

Yoshikawa, Kaizuka and Ōta (1964) discussed the relation between the development of coastal terraces and the composite process of crustal movement and eustatic sea level change in Quaternary on the southwest coast of Muroto Promontory, as follows:

The crustal movement in late Quaternary has continued as a uniform composite process of the reiteration of minor acute upheavals accompanied by earthquakes and the chronic subsidence throughout ages. And the upheaval rate at Cape Muroto is calculated 2 mm/year. According to this rate the Monastirian terrace of Cape Muroto, assumed that it was formed about 90,000 years ago, is to be at about 180–190 m above sea level at present. This calculation coincides with the actual fact. Still more, they concluded that the differentiation of coastal terraces was caused not by the intermittent upheaval but by the eustatic change of sea level.

If extending the above inference, it may be said the shore platforms must have emerged also in the same crustal movement, and their heights also resulted from the accumulation of crustal movements. Then, the writer tried to infer the planation age of platforms from the relation between the upheaval of coastal landforms and the sea level change, and he considered the role of the eustatic sea level change in the process of emergence of shore platforms.

About the geology of this district the report of Kattō (1960) is referred to in this paper.

2 Distribution of Some Coastal Features

Coastal terraces in the study area are grouped into three levels: Higher Terraces (260–200 m), Middle Terraces (M_1: 190–150 m and M_2: 140 m) and Lower Terraces (lower than ten several meters).

The Middle Terraces with steep scarps at east and west sides have been carved deeply with valleys mainly from west side, but still have comparatively wide terrace surfaces. Yoshikawa *et al.* (1964) inferred by the correlation of terrace heights that the Middle Terraces correlated to Monastirian age had tilted up southward along the west coast of Muroto Peninsula, but Suyari *et al.* (1971), correlating those terraces with the red weathering crust in terrace gravels as a key, did not approve such tilting.

It is possible to subdivide the Lower Terraces into two levels, but this division is not clearly seen everywhere for they are covered with taluses. The terrace base covered by the veneer of gravels seems to extend to the emerged platforms.

The coastal reef zone bordering the Lower Terraces is divided into two parts: lower and higher (Fig. 1). The lower parts of the coastal reef zone, which are distri-

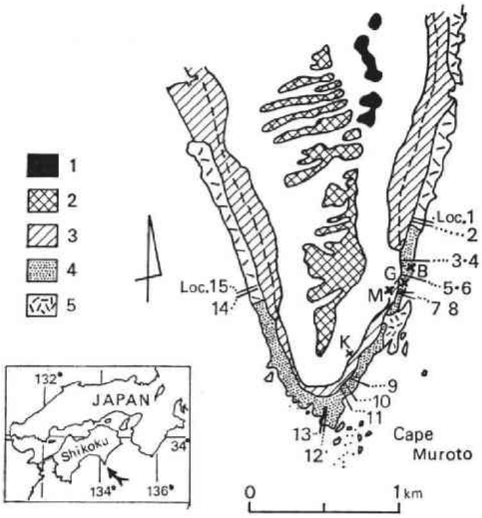

Fig. 1 Distribution of coastal features near Cape Muroto
1: higher terrace 2: middle terrace 3: lower terrace 4: higher part of coastal reef zone
5: lower part of coastal reef zone
B: Bishagoiwa G: Gyōzuinoike M: Mikurodo K: Kannonkutsu

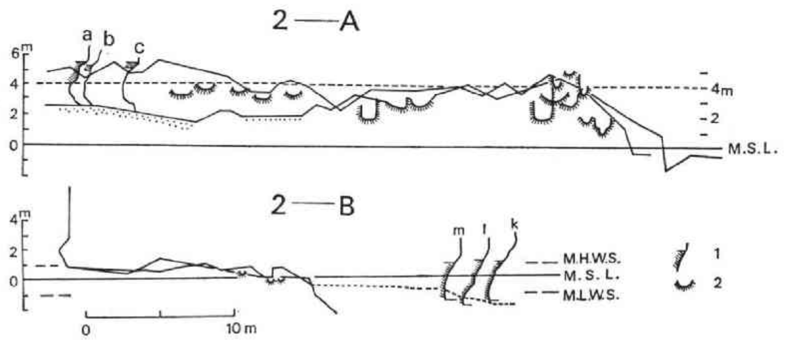

Fig. 2 Profiles of platforms, potholes and notches near Gyōzuinoike (2-A) and near Bishagoiwa (2-B)
a, b, c, k, l, m: notch 1: calcareous remains on the notch 2: pothole

buted on both sides of Muroto promontory, have coastal platforms, shore platforms and boulder gravels 2 m or more in diameter on the platforms, and they consist of shale, sandstone, alternation of sandstone and mudstone, or conglomerate (Muroto Formation, Palaeogene) (Photo 1 and 2).

The higher parts of the coastal reef zone, which occupy the front of Cape Muroto, have rugged coastal platforms and stacks, and they are constructed with sandstone, shale, alternation of sandstone and mudstone (Muroto Formation), and gabbro which intruded into the strata (Photo 3).

3 Formation Level of Platforms, Potholes and Notches

Near Gyōzuinoike, coastal platforms (Loc. 5 and 6) which consist of sandstone have the emerged potholes on the surface, and there are notches at the stack side adjacent to the platforms (Photo 4 and 5). Their profiles are shown in Fig. 2-A.

The levelling profiles of platform are at about right angle to the shoreline with moderate intervals so that the relief of platform may be represented. The profiles of pothole and notch are projected onto the platform profiles. The mean sea level in the profiles is calculated from the tide table (edited by Japan Meteorological Agency, 1972) on the basis of the sea level at the measurement. The tide at Kōchi and Cape Muroto is read in the tide table as follows:

	at Kōchi	at Cape Muroto
highest tide level	90 cm	104 cm
mean high water springs	81	
mean low water springs	−110	
lowest tide level	−115	−129

In general, it is difficult to restore the sea level by notch, because it is formed in various heights regulated with geological structure (Mii, 1962; Toyoshima, 1965; Takenaga, 1968 or Akagi, 1970). For example, at Shirahama in Wakayama Prefecture, a series of notches within the distance of ten several meters has disparity of 3 m in height (Mii 1962). Nevertheless, the reasons for using emerged notches as an index for restoring the sea level in this paper are as follows: (1) No structural regulation is recognized on these notches. (2) At a stack called 'Bishagoiwa' near Gyōzuinoike, which consists of gabbro, there is a series of notches which probably has a relation to the present sea level (Fig. 3 and Photo 6). Moreover, the shore platform of sandstone near Bishagoiwa is located between the mean sea level and the mean high water springs and a few small potholes are seen on the surface near the mean sea level (Fig. 2-B). The relation between these land features and the present sea level may correspond to the relation between the emerged land features near Gyōzuinoike and the former sea level which was related to their formation. (3) Moreover, the upper limit of the calcareous remains of *Polychaeta* or *Cirripedia* on notches is useful as an index for the correspondence of both, though on notches near Gyōzuinoike the calcareous remains in the lower part was stripped off.

On the distribution of potholes, Mii (1963) observed that their distribution ranged at and under the lower intertidal zone, and they hardly developed above the mean sea level. At the open coast of the southern part of Satsuma Peninsula

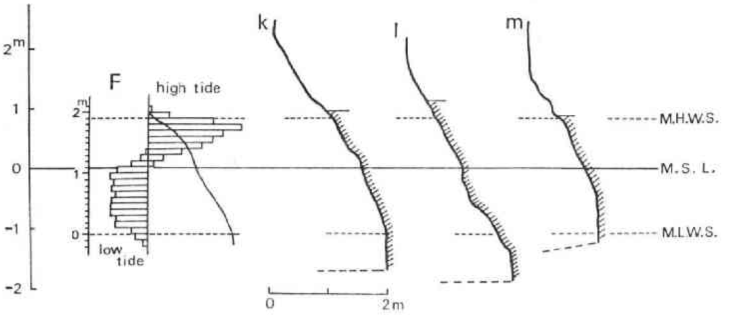

Fig. 3 Profiles of notches at Bishagoiwa
k, l, m: notches
part of oblique lines: calcareous remains
F: tide-height frequencies (1972) at Cape Muroto

many potholes were seen near the mean high water springs (Takahashi, 1972). On the arrangement of those observations, the upper limit of the distribution of potholes on the shore platform is judged to be near the mean sea level, and it must be higher on the seaward rim suffering much effective wave-abrasion.

From the above relations between the sea level and the profiles of platforms, potholes and notches near Gyōzuinoike the former sea level which related to their formation is inferred to have been at the range of 4–4.5 m above the present mean sea level (Fig. 2-A). Such an inference leads to the claim that the surface of platforms was located at the level corresponding to the inter-tidal zone at that time, most of potholes below the mean sea level, and potholes on the platform rim between the mean sea level and the mean high water springs.

There are some platforms corresponding to each other in the height. Platform profiles in the study area are shown in Fig. 4. Simplified profiles and height frequencies in Fig. 5 represent the heights of 20 points, in which the width of profile is equalized for convenience of comparison. A platform near Mikurodo has two levels of small flats at 3–5 m and 7–9 m above the mean sea level (Loc. 7 and 8). The lower flat corresponds to the platform near Gyōzuinoike. However, near front of Cape Muroto (Loc. 9–11) the height range of the fragmental platform surfaces, 4–7 m above the mean sea level, is about 1–2 m higher than that of the coastal platform near Gyōzuinoike. Accordingly, it is difficult to correlate them. At the front of the Cape (Loc. 12 and 13), there are some rugged platforms at 6–10 m above the mean sea level, which seem to correspond to the upper flat of the platform near Mikurodo. Their planation level is roughly estimated at 8–10 m above the present mean sea level.

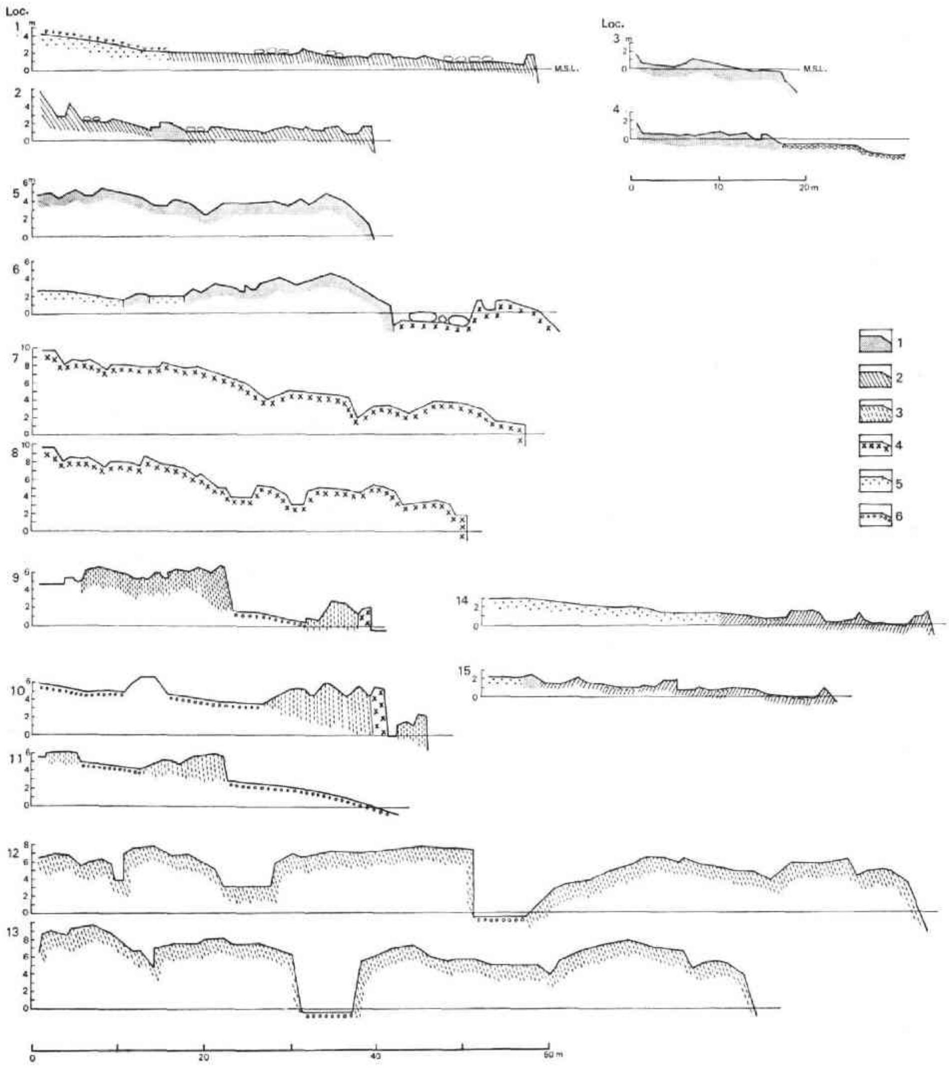

Fig. 4 Profiles of shore platforms and coastal platforms near Cape Muroto
1: sandstone 2: mudstone (shale) 3: alternation of sandstone and mudstone
4: gabbro 5: sand 6: gravel

4 Planation Age of Coastal Platform

On the assumption that the upheaval with the rate of 2 mm/year at Cape Muroto has continued in late Quaternary as described above, the height-time relation of a landform with the present height of 4 or 4.5 m is written as follows:

$$y = -2\times 10^{-3}x + 4 \text{ (or 4.5)}$$

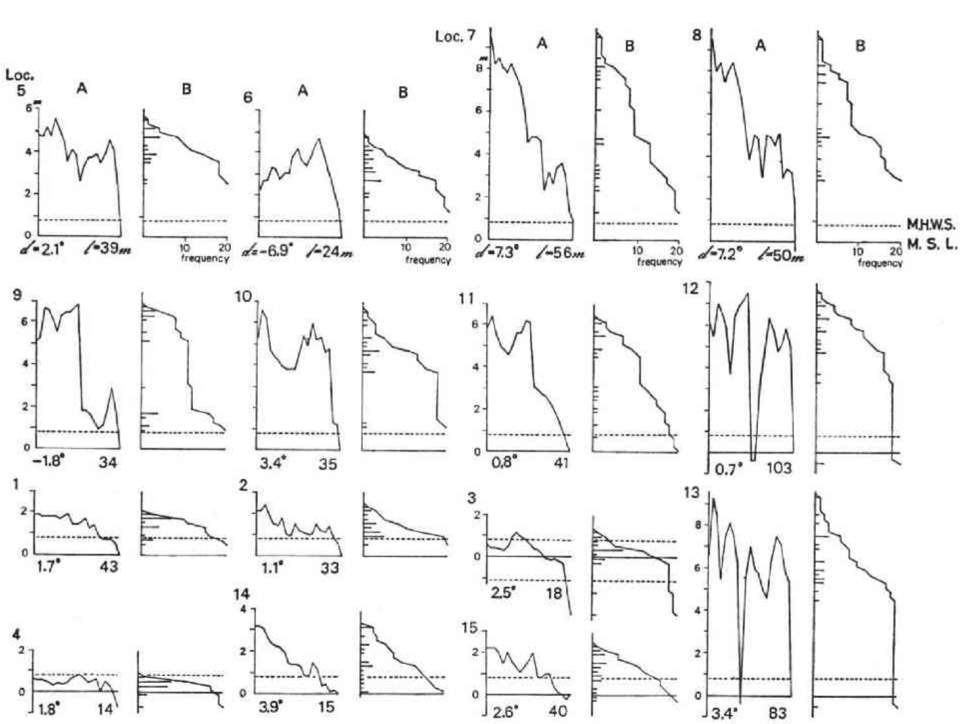

Fig. 5 Simplified profiles (A) and height frequencies (B) of shore platforms and coastal platforms

where y is height in meters and x is time in B.P. years.

The uplift curve represented by this equation can be superposed on the curve of the eustatic change of sea level presented by R.W. Fairbridge (1961) as in Fig. 6.

In Fig. 6 the latest intersection of the two curves is read at about 2,100 years B.P., and in 2,000–3,000 years B.P., including the stage of Abrolhos Submergence, the landform above-mentioned was located near the sea level at that time. This age is judged to have been the main or the last planation age of coastal platform which is the landform corresponding to the sea level. From such superposition, it is inferred that the planation age of coastal platform is from 3,000 to 2,000 years B.P. in a rough estimation.

In Japan we have only a few data on the planation age of platform. Toyoshima (1968) presumed, from archaeological materials, that the shore platform at Hashigui-iwa near Kushimoto, Wakayama Prefecture, was formed since 3,000 years B.P. The writer (1973) inferred, from the regional differences of the levels of platforms, that the shore platforms around southern Kii Peninsula were formed two thousand several hundred to two thousand years ago. These opinions of

Toyoshima or the writer are approximately concordant with the age inferred in this paper.

If the platforms are uplifting with the rate less than the secondary lowering rate, they never emerge above the sea level, being always lowered by denudation acting near the sea level. On the other hand, the emergence of platforms must have been fairly rapid in order that their initial surface may be kept. According to Fairbridge, in his Florida Emergence of 2,000–1,500 years B.P., the sea level dropped several meters lower than that of Abrolhos Submergence, when platforms, potholes and notches must have appeared above the sea with the coastal emergence.

Thus, a 'Submergence' and the succeeding 'Emergence' are necessary for the planation and emergence of platforms, and such sequence are thought to be potential origins of platforms, which are as follows:

Table 1

Age (years B.P.)	Submergence — Emergence Sequences (Potential origins of platform)
I 6,000–3,500	
Ia 6,000–4,500	Older Peron Submergence — Bahama Emergence
Ib 4,000–3,500	Younger Peron Submergence — Crane Key Emergence
II 3,000–2,000	Abrolhos Submergence — Florida Emergence
III 1,500– 0	Rottnest Submergence Mediaeval Submergence

From the aforementioned point of view, it is possible to expect the two levels of emerged coastal features corresponding to I and II in the study area. The rugged platform at the front of the Cape at 6–10 m in height and the upper part of the platform near Mikurodo at 7–9 m above the sea level corresponds probably to I. And also, the higher part of the Lower Terrace may be correlated with I.

On the middle terrace scarp at east of Gyōzuinoike, there are two caves called 'Mikurodo' at 11 m–16 m in height of the entrances. They are judged to be emerged sea caves by the reason that honeycomb structures, calcareous remains or notches have been remained on their wall and a few coral fragments are found in them. The age of their formation may be correlated with I from the height. Mii (1963) pointed out presumptively that 2m- and 6m-benches in Japan were planed at the former higher levels respectively, which may correspond to I and II.

However, the writer's inference above is under some assumptions, and moreover the curve of sea level change (Fairbridge) is not always in accord with the curve obtained by others. Therefore, further investigations with different approaches is necessary.

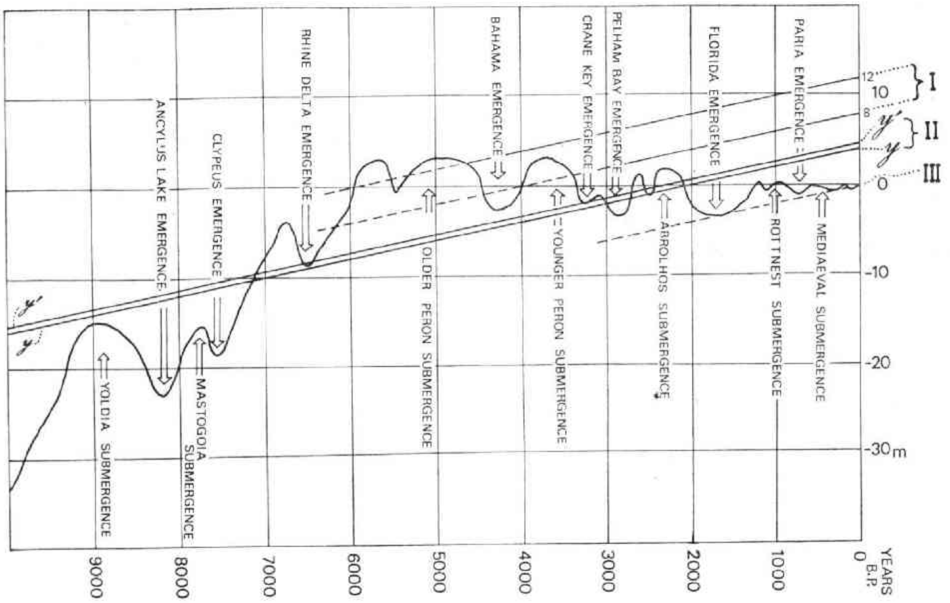

Fig. 6 Superposed uplift curve on Fairbridge's curve of sea level change
$y=-2\times10^{-3}x+4 \quad (y'=-2\times10^{-3}x+4.5)$
I, II, III: uplift curve connecting with age I, II or III in Table 1.

5 Summary

Level and age of the planation of coastal platforms in the study area are summarized as follows:

(1) As for the planation level of platform with conspicuous rugged relief, it is useful to treat not only the heights of platform surface but also of notch or pothole. In this method the planation level of platforms near Gyōzuinoike is inferred 4–4.5 m above the present sea level (Fig. 2).

(2) From the superposition of the uplift curve with the rate of 2 mm/year on the curve of eustatic sea level change (Fairbridge) (Fig. 6), the planation age of platforms is estimated 3,000–2,000 years B.P.

(3) From such superposition it is inferred that a 'Submergence' and the succeeding 'Emergence' are necessary for the planation and emergence of shore platform. On this inference some ages of the planation of platform are considered as follows: [I] 6,000–3,500 years B.P., [II] 3,000–2,000 years B.P. and [III] 1,500–0 years B.P. There are two levels of emerged coastal features correspoding possibly to I and II in the study area. The planation level of the rugged platform at the front of Cape Muroto and the upper flat of the platform near Mikurodo, which

may correspond to I, is roughly estimated at 8–10 m above the present sea level. Moreover, the age of two caves called 'Mikurodo' at 11–16 m in height may be correlated with I.

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Photo 1 Lower part of coastal reef zone, which is distributed on both sides of Muroto Promontory, has coastal platforms, shore platforms and boulder graveles 2 m or more in diameter on the platform

Photo 2 Lower Terrace and lower part of coastal reef zone on west side of Muroto Promontory

Photo 3 Higher part of coastal reef zone, which occupies the front of Cape Muroto, has rugged coastal platforms and stacks

Photo 4 A coastal platform near Gyōzuinoike

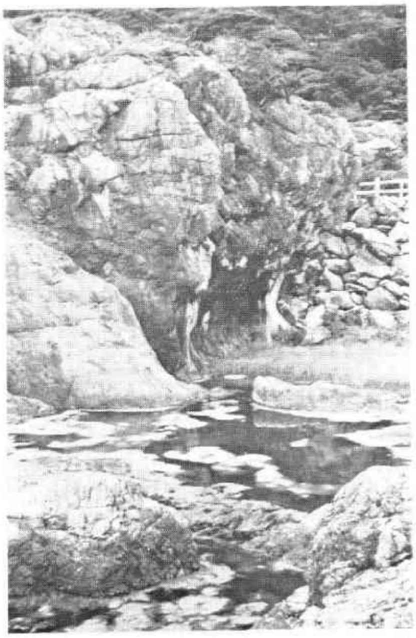

Photo 5 An emerged notch on a stack side near Gyōzuinoike

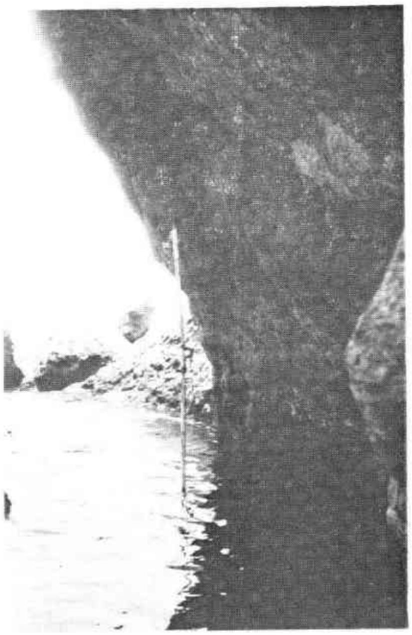

Photo 6 A notch on a stack side at Bishagoiwa