Formation and Evolution of Shore Platform around Southern Kii Peninsula

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Formation and Evolution of Shore Platforms around Southern Kii Peninsula

Tatsuo TAKAHASHI

1 Introduction

Along the southern coast of the Kii peninsula, there are numerous shore platforms of various features and levels. The purpose of this paper is to describe the features of platforms and discuss the following problems concerning their formation and evolution:

(1) The shore platforms are remarkably and innumerably distributed in this region, but the sea cliffs are not always bordered with platforms. What is the character of the coasts bordered with platforms, and why are those platforms not ubiquitous ?

(2) Their profiles are surveyed by leveling on the spot, and their evolution is examined from the profiles.

(3) The levels of shore platforms differ in localities in this region. What is the reason ? Their regional difference seems to correspond well to that of the heights of coastal terraces at the rear. Yonekura (1968) inferred that the mode of the late Quaternary crustal movement, revealed in the coastal terraces, is similar to that of the recent crustal movement which is associated with seismic activity in Southern Kii peninsula, because the vertical displacement of the monastirian shoreline restored by coastal terraces has the positive correlation to the vertical change of bench mark accompanied with recent earthquakes. Since the regional difference in the displacement of coastal terraces is brought about by crustal movement, the recent crustal movement must have displaced the shore platforms in like manner. It seems to be quite right to consider that the regional difference in the levels of shore platforms suggests the tendency of the recent crustal movement.

(4) The time range of formation and the level of planation of shore platforms are difficult problems as the opinions of investigators disagree (Cotton, 1963 and Fairbridge, 1961, 68). To explain the problems, it is necessary to study not only many cases but also to apply different methods. In this paper the time of formation and the level of planation are calculated by using the correlation between the present levels of shore platforms and the heights of upheaved monastirian shoreline restored by the coastal terraces.

2 Distribution of Shore Platforms

The geomorphological map (Fig. 2) shows the distribution of shores with platforms, shores with scattered reefs, coastal terraces, alluvial plains, beaches and so on.

As the "reefs" and "reefs exposed at low tide" on topographic maps on a scale of 1 to 25,000 (published by Geographical Survey Institute) are not always shore

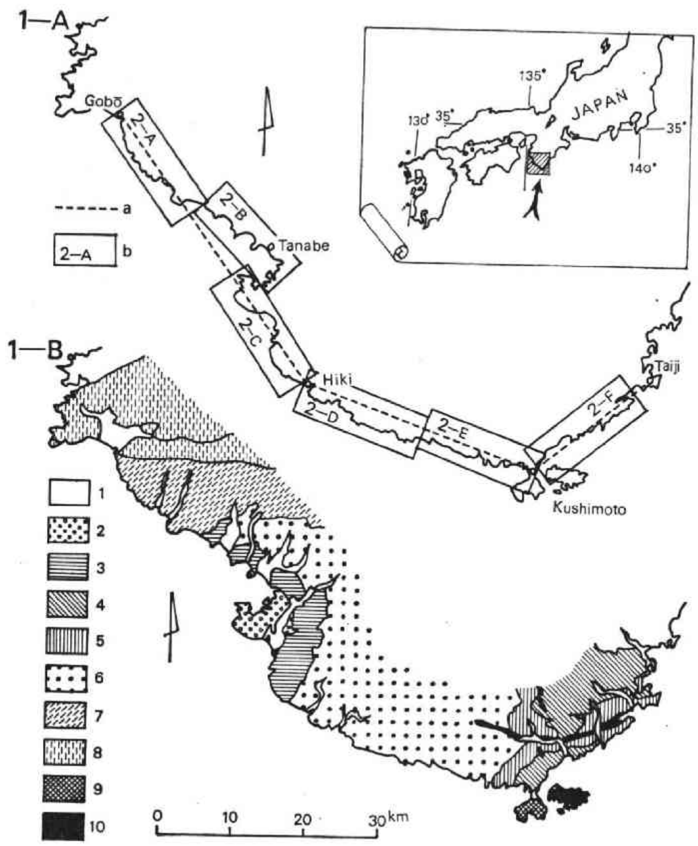

Fig. 1 Index map (1–A) and Geological map (1–B) of the investigated region
a: projection plane of levels of shore platforms and heights of raised beaches
b: index of Fig. 2
1: Quaternary 2: Kanayama formation (middle Miocene) 3: Tanabe formation (middle Miocene) 4: Shikiya siltstone member, Koguchi formation (middle Miocene) 5: Shimosato sandstone and siltstone member, Koguchi formation (middle Miocene) 6: Muro group (Paleogene-lower Miocene) 7: Inami formation (unknown Mesozoic) 8: Hidakagawa formation (unknown Mesozoic) 9: basic rock 10: Kumano acidic igneous rock

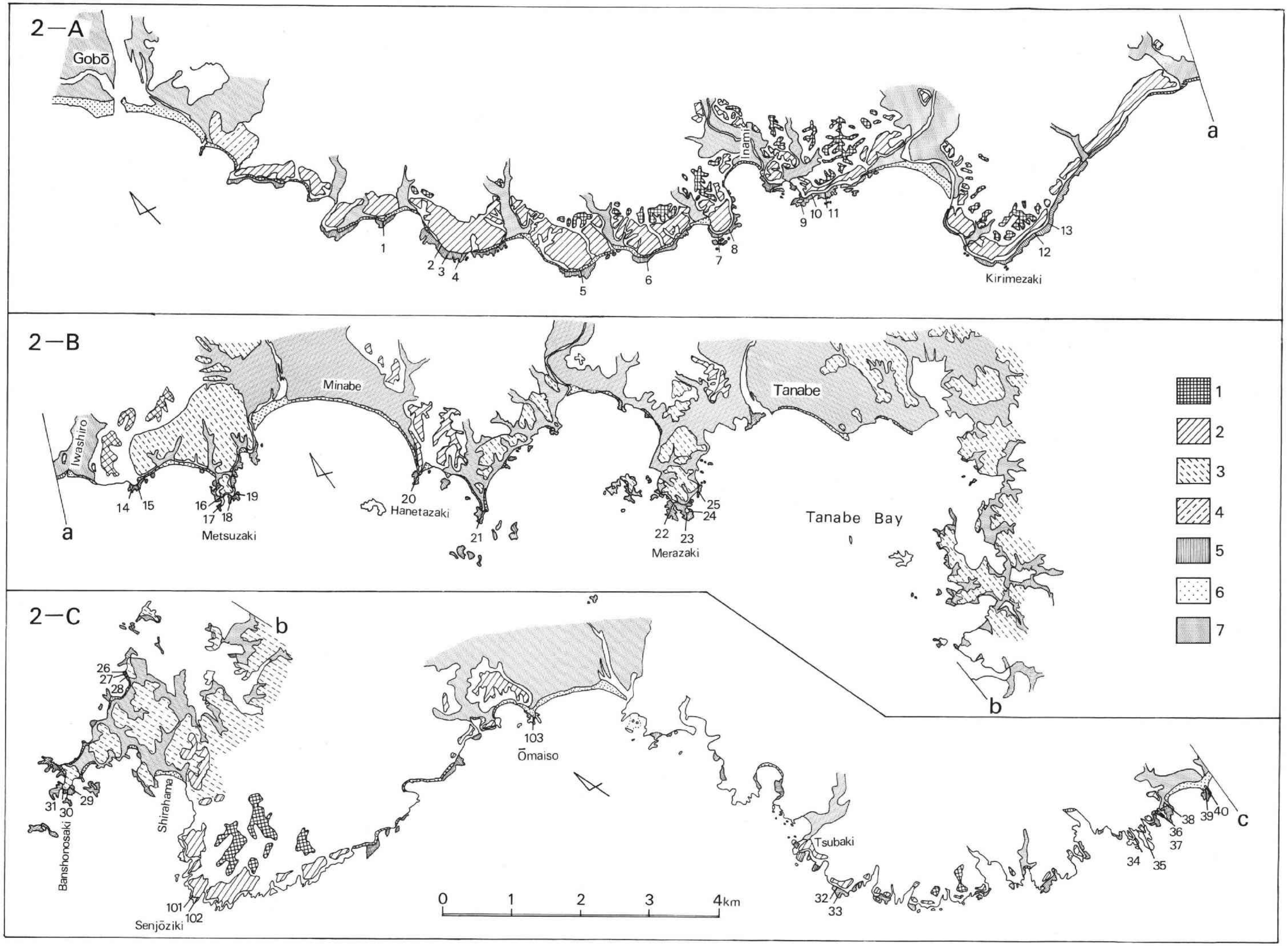

Fig. 2 Geomorphological map (1)
1: higher terrace 2: lower terrace 3: dissected terrace 4: other terrace 5: shore platform

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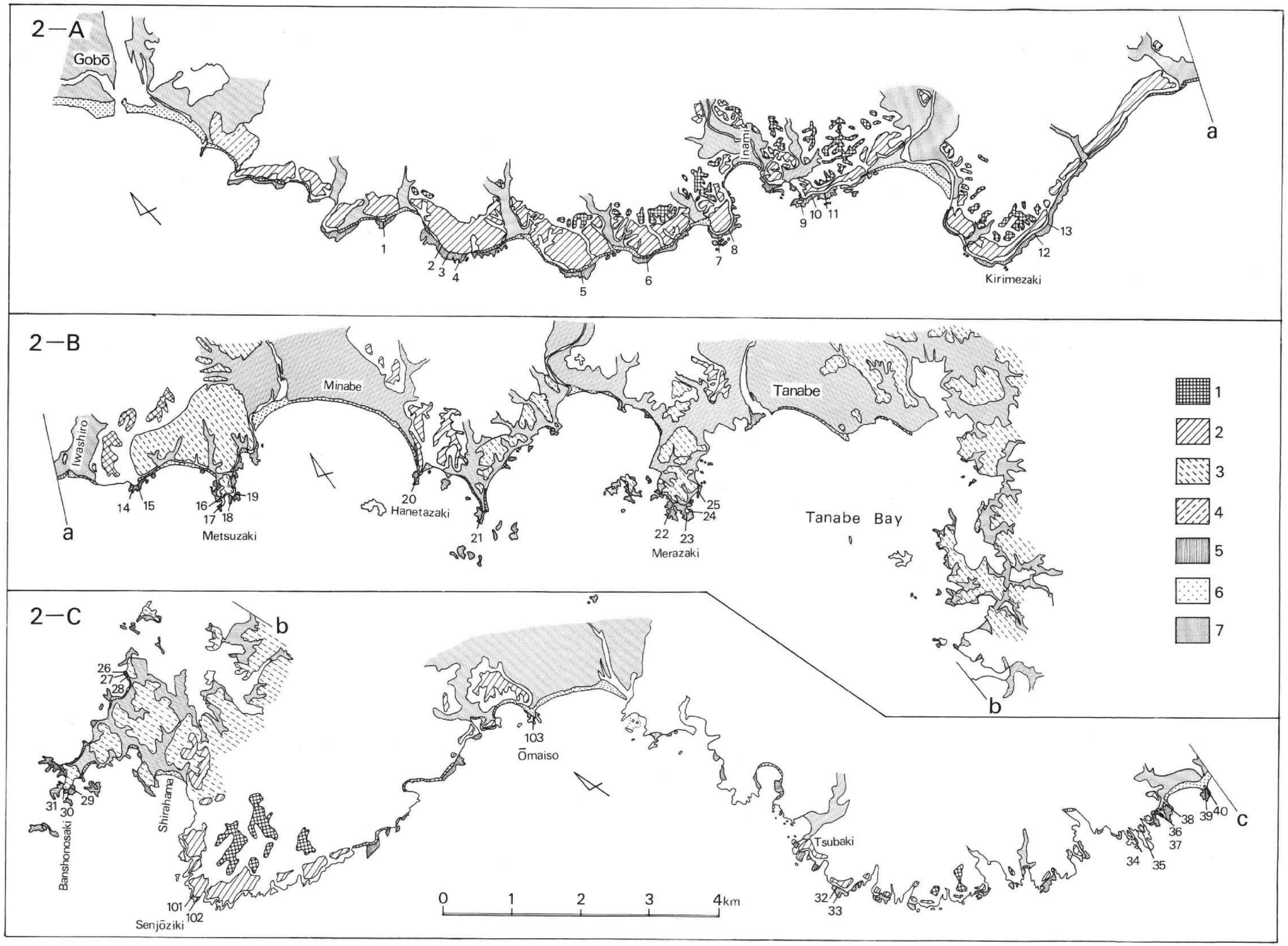

Fig. 2 Geomorphological map (1)
1: higher terrace 2: lower terrace 3: dissected terrace 4: other terrace 5: shore platform
6: beach 7: alluvial plain

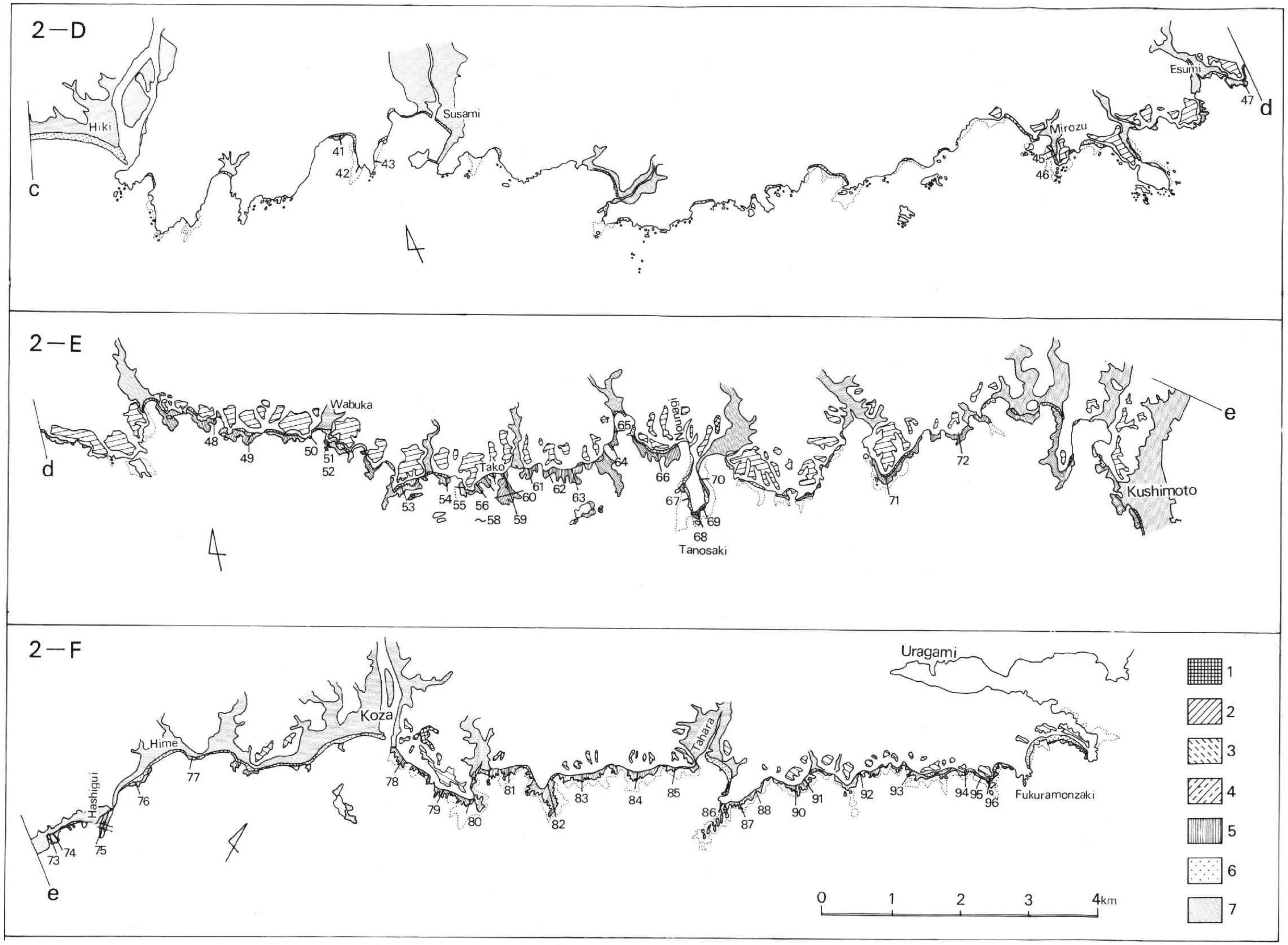

Fig. 2 Geomorphological map (2)
1: higher terrace 2: lower terrace 3: dissected terrace 4: other terrace 5: shore platform
6: beach 7: alluvial plain

platforms, the author classifies shores with reefs into two groups: shores with platform at the inter-tidal zone to slightly over the high tide level, and shores without platform but with scattered reefs. The coastal terraces are classified and correlated by the reading of air photographs and topographic maps, referring to the works by Mii (1962), Yonekura (1968) and Akojima and Suyari (1971).

The distribution of shore platforms has the following feature: at the terraced coasts, they border to the base of terrace scarp, and, on the contrary, at the non-terraced coasts, they have not developed off the sea cliff. Roughly speaking, the distribution of shore platforms seems to correspond to that of coastal terraces.

There are scarcely shore platforms and coastal terraces, on the cliffed coasts between Hiki and Mirozu, on the ria coasts in the north of Gobō and between Kinomoto and Owase. There are a few view points about the reason of scarcity of coastal terrace and shore platform on these coasts.

These coasts are in relatively subsiding areas as described later, and the coastal terraces may have submerged already; or they may have been destroyed by abrasion after their formation. Another explanation is the difficulty of formation of coastal terrace in terms of lithological control, such as the coasts between Hiki and Mirozu composed of resistant sandstone. Such reasons are significant respectively, but it can not be decided as yet which is the most essential.

Also, the reason of the scarcity of shore platforms seems to be similar with the abovementioned point of view. As the lacking of shore platforms is considered to be caused by the relative subsidence of the region, it is reasonable and convenient as an interpretation, to explain that the regional difference in the levels of shore platforms has been caused by the crustal movement as described later (see Chapter 5). However it is difficult to explain the reason of the partial existence of platforms in smaller scale along their coasts. In the nearshore zone in the front of headland which consists of relatively resistant sandstone between Hiki and Mirozu, there are no conspicuous shore platforms but fragmentary scattered reefs, however at a few spots composed of pelitic rock or alternation of sandstone and mudstone, there are some shore platforms of smaller scale. Although this fact suggests a role of lithology concerning the formation and evolution of the coast, it cannot be decided as yet, which of crustal movement or lithology is more effective for the formation and evolution.

In general, the distributional correspondence between shore platform and coastal terrace is not observed at every coast. Where the shore platforms develop at the base of the terrace scarp, as at Miura Peninsula in Kanagawa Pref., Omaezaki in Shizuoka Pref., Ōdose in Aomori Pref., there developed coastal terrace, too. But the cliffed coasts have no platforms though the coastal terraces developed, as at the coast of Shima Peninsula in Mie Pref.. On the contrary, there developed wide shore platforms, but no coastal terraces, as at Nichinan Coast in Miyazaki Pref. and around Hirado Island in Nagasaki Pref.. The meaning of the relation between both types of distribution has not been elucidated sufficiently as yet.

3 Descriptions of the Shore Platforms

The author drew the shore profiles (Fig. 3) in order to identify the features of shore platforms, and some characteristics of these platforms are picked up in Table 1. The profiles are levelled at intervals of 5 meters in about right angles to the shoreline, or at shorter intervals on rugged relief.

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

	at Shirahama	at Kushimoto
the highest tide level	126 cm	143 cm
mean high water springs (high water level of ordinary spring tide)	81 cm	77 cm
mean low water springs (low water level of ordinary spring tide)	−108 cm	−104 cm

Some profiles with noticeable features are shown in Fig. 3 as examples.

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 because they are of rugged relief. For the convenience of comparison simplified profiles were drawn as in Fig. 4, which represents the heights of 20 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 platform on this graph. The length of platforms is stated in Fig. 4 and their inclination on the main part of platform is shown in Table 1.

The features of shore platforms are described regionally as follows:

(1) On the Coast between Gobō and Iwashiro

On the coasts constructed of the alternation of sandstone and mudstone (the Hidaka group — unknown Mesozoic), non-structural platforms that have horizontally cut the formation with the dip of about 50° have slightly inclined with the angle of $0.2° \sim 0.5°$, and have serrated surface (or washboard-like relief) which is interpreted as a feature of lithological control, with crests in sandstone and troughs

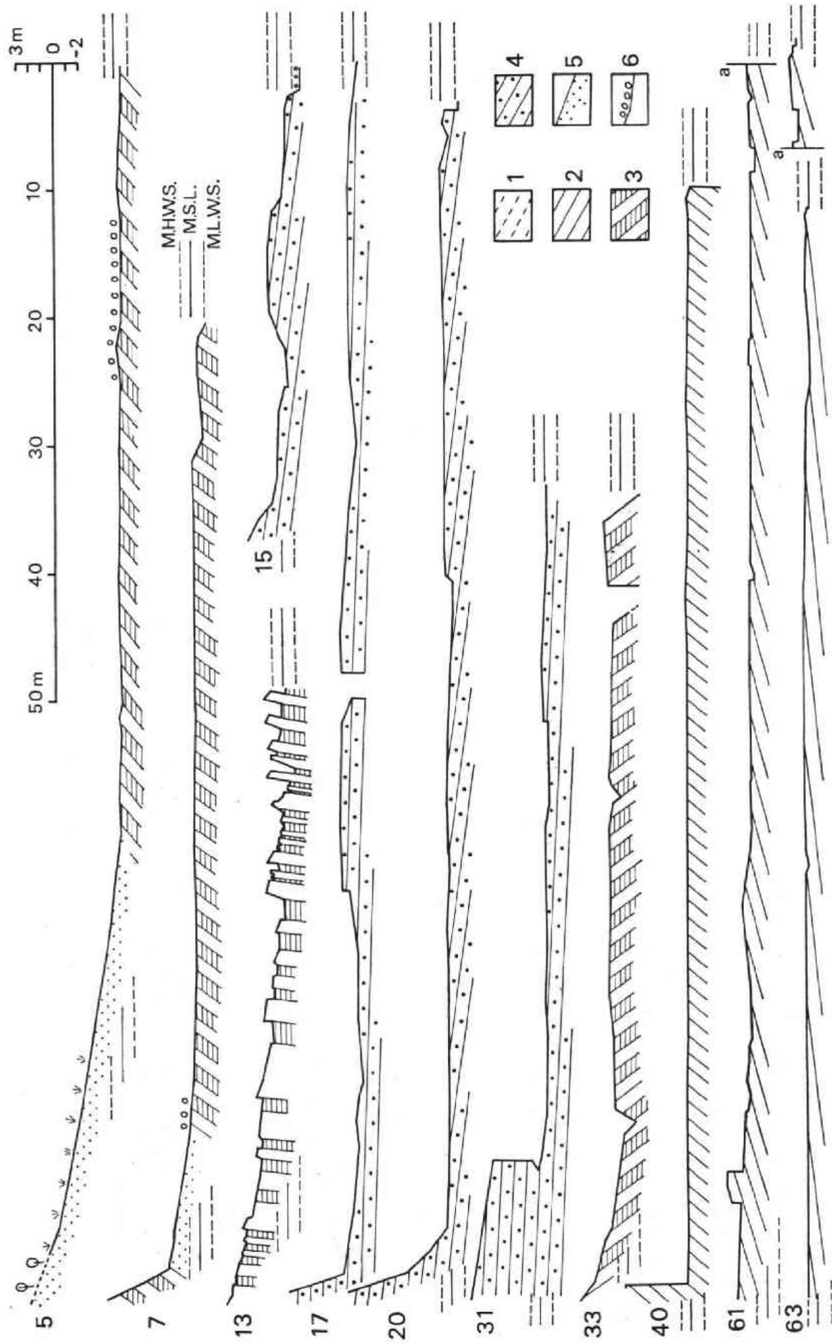

Fig. 3 Some examples of shore profiles (1)
1: standstone 2: siltstone and mudstone 3: alternation of sandstone and siltstone 4: conglomerate
5: beach (sand and gravel) 6: gravels on the surface

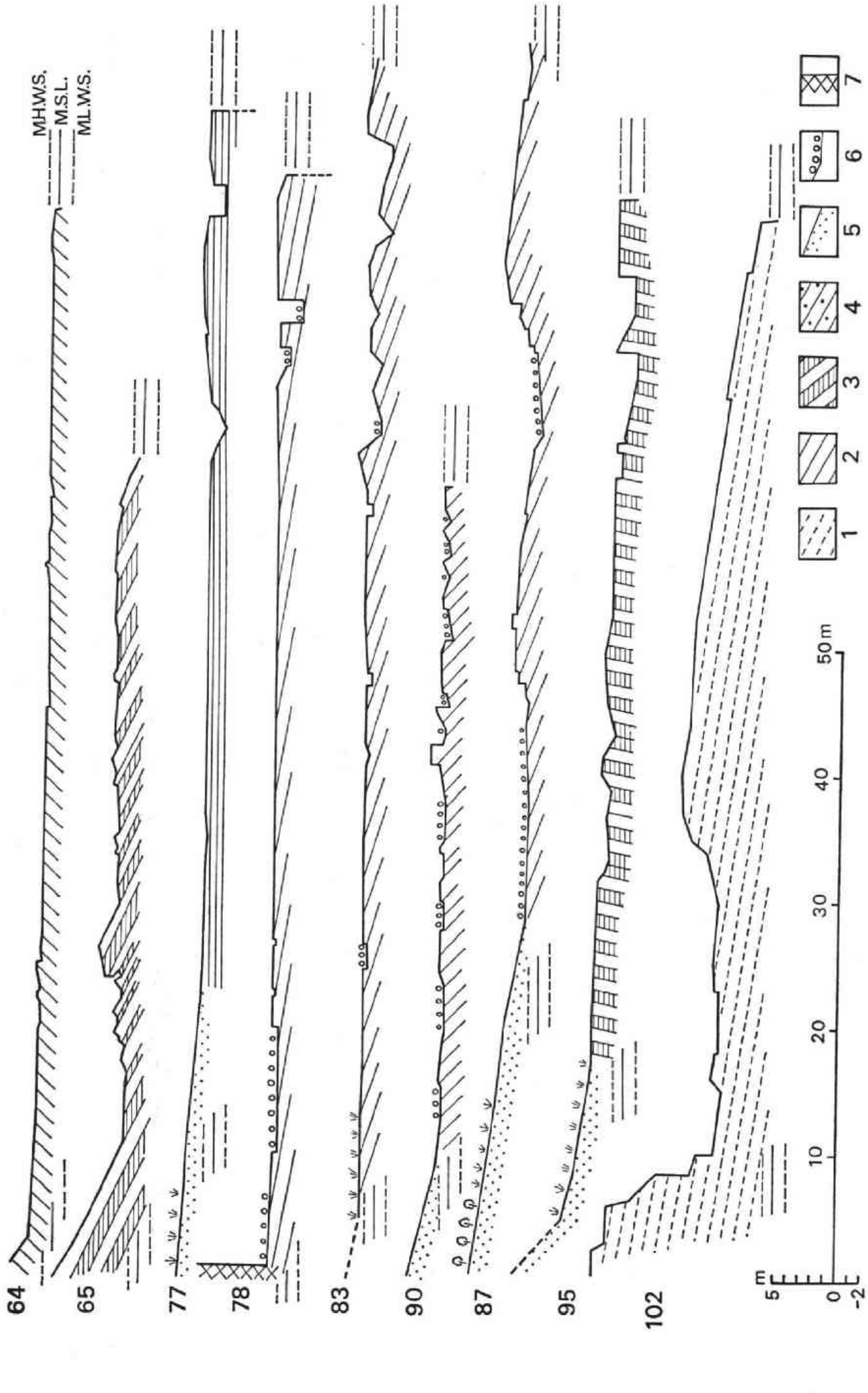

Fig. 3 Some examples of shore profiles (2)
1: sandstone 2: siltstone and mudstone 3: alternation of sandstone and siltstone 4:conglomerate
5: beach (sand and gravel) 6: gravels on the surface

in mudstone (Photo. 1). In some troughs, angular to subangular sandstone pebbles and cobbles remain (Loc. 1∼8, 12 and 13).

The shore platforms have developed near and below the mean sea level at the north of Inami, but southward slightly above the mean sea level. There is no conspicuous rampart at the seaward rim of the platform, and the nip on the front side of the platform is not too steep.

Broad coastal terraces developed at the rear, and there are gravel beaches between platforms and terrace scarp.

(2) On the Coast between Iwashiro and Tonda

These coasts consist of conglomerate or sandstone (the Kanayama formation of the Tanabe group, middle Miocene).

On the coasts at the southeast of Iwashiro (Loc. 14, 15) and at Metsuzaki (Loc. 16–19), two levels of shore platforms of conglomerate developed: near the mean sea level and high tide level (Photo. 2). As described later (see Chapter 6), it is thought that the higher platforms had been formed earlier, and after the later relative upheaval of these platforms, the lower platforms had been newly formed.

At Metsuzaki, there are many notches, caves and arches, such as the "Megane-iwa", a pair of arches with form like spectacle frame (Photo. 3). As the bottom of the west arch is at 3.6 m above the mean sea level and that of another is at 2.8 m above, they must have been formed at the higher sea level in the past. Under the west arch, a lower one is seen. As the ceiling of its opening is at 0.1 m above the mean sea level and the bottom is at 0.9 m below the level, it must be in formation at the present sea level.

At Banshonosaki, there are narrow ledge-like platforms which consist of conglomerate, behind the shore platforms in the inter-tidal zone, at 2∼4 m above the high tide level (Loc. 29∼31). Although it cannot be definitely concluded, the time of their formation may correspond to that of "Megane-iwa" sea arches from comparison of their heights.

In and out of the Tanabe bay, such shore platforms as were called "Old Hat type" benches by Bartrum (1926, 38) and Cotton (1963) are distributed near the high tide level or in the inter-tidal zone (Photo. 4).

At Senjōjiki (Loc. 101, 102) and Ōmaiso (Loc. 103), such structual coastal platforms as were classified as "Quarry type" by Mii (1962) have the steep surfaces adjusted with the seaward-inclined bedding of sandstone (Photo. 5).

(3) On the Coast between Tsubaki and Hiki

The coasts are constructed with the alternation of sandstone and mudstone (the Tsubaki formation of the Tanabe group, middle Miocene) or sandy siltstone and hard sandstone (the Hiki formation of the Tanabe group, middle Miocene).

Table 1 Features of the Shore Platforms

location	geology				profile				some features				
	lithology	epoch	strike	dip	direction	length (m)	inclination* (degree)	type**	rampart	pothole	gravels***	notch	topography at the rear
1	alter.	unknown Mesozoic (Hidaka group)	N65°W	75°W	N35°E	68	0.2	A	—	—	+	—	beach-const.
2	alter.		N75°E	50°～70°N	N65°E	80	0.2	A	—	—	+	—	beach-cliff
3	alter.		N75°E	40°～50°N	N75°E	131	0.7	A	—	—	+	—	beach-const.
4	alter.		N75°～80°E	40°～60°N	N80°E	107	0.2	A	+	—	+	—	beach-cliff
5	alter.		N85°E	40°～50°N	N40°E	60	0.3	A	—	—	+	—	beach-cliff
6	alter.		N70°E	15°～30°E	N35°E	48	0.3	A	—	—	+	—	cliff
7	alter.		N70°W	60°E	N40°E	61	0.1	A	—	—	+	—	beach-cliff
8	alter.		N65°W	65°～90°E	N25°E	59	0.4	A	—	—	+	—	beach-cliff
9	alter.		N70°W	80°W～80°E	N30°E	56		E	—	—	—	+	cliff
10	siltst.		N75°W	50°～60°E	N25°E	82	0.2	I	—	—	+	—	beach-cliff
11	alter.		N70°W	60°E	N40°E	102	0.0	I	+	—	+	—	beach-cliff
12	alter.		N75°W	75°N	N 7°E	45	3.6	I	—	—	+	—	cliff
13	alter.		N85°W	65°N	N15°W	49	1.4	I	—	—	+	—	cliff
14	conglo.	middle Miocene (Tanabe group)	N65°E	7°S	N55°E	73	0.3	A	—	+	—	+	cliff
15	conglo.		N65°E	7°S	N20°E	31	1.7	G	—	+	+	+	cliff
16	conglo.		N25°E	2°～5°W	N85°W	46	−0.8	F	—	+	—	+	cliff
17	conglo.		N25°E	2°～5°W	N80°E	95	0.2	F	—	+	—	+	cliff
18	conglo.		N25°E	2°～5°W	N50°E	60	0.1	B	—	+	—	—	beach-cliff
19	conglo.		N25°E	2°～5°W	N45°W	70	−0.7	F	—	+	—	+	cliff
20	conglo.		N10°E	10°W	N70°E	88	0.1	A	—	—	—	+	beach-cliff
21	conglo.		N55°W	10°S	N55°E	145	0.0	A	+	—	—	—	beach-const.
22	conglo.		N70°W	20°W	N60°E	213	0.0	B	+	—	—	—	const.
23	conglo.		N35°E	20°W	N47°E	97	0.0	BorD	+	—	—	—	cliff
24	conglo.		N35°E	20°W	N25°W	72	−0.5	F	+	—	—	—	cliff
25	conglo.		N35°E	20°W	N22°E	81	−0.2	C	—	—	—	—	const.
26	sandst.		N15°E	3°N	N45°W	40	3.0	B	—	—	—	—	cliff
27	sandst.		N15°E	3°N	N40°W	23	0.7	C	—	—	—	+	cliff
28	sandst.		N15°E	3°N	N70°W	33	1.9	F	+	—	—	+	cliff
29	conglo.		NS	5°W	N65°E	85	0.2	B	—	+	—	+	cliff
30	conglo.		NS	5°W	N55°E	32	0.5	B	—		—	+	cliff
31	conglo.		NS	5°W	N 2°E	62	0.1	B	—		—	+	cliff
101	sandst.		N 5°E	10°W	EW	61	11	J	—	—	—	—	terrace
102	sandst.		N 5°E	10°W	N87°E	75	9	J	—	—	—	—	terrace
103	sandst.		N35°W	10°W	N50°E	91	9	J	—	—	—	—	beach
32	alter.		N15°E	50°～60°W	N85°E	79	−0.1	F	—	—	—	—	cliff
33	alter.		N30°E	55°～60°W	EW	57	0.5	D	+	+	—	—	cliff
34	alter.		N65°W	5°W	N40°E	44	0.2	C	—	—	—	—	cliff
35	alter.		N35°W	4°W	N30°E	226	−1.3	F	—	—	—	—	cliff
36	alter.		N 5°W	5°～10°N	N10°E	135	−0.1	CorF	—	—	—	—	beach-cliff
37	alter.		N 5°W	5°～10°N	N10°E	132	−0.3	F	—	—	—	+	beach-cliff
38	alter.		N 5°E	15°N	NS	78	−0.2	C	—	—	—	+	cliff
39	siltst.		N30°E	30°N	N55°E	199	−0.2	F	+	—	—	—	cliff
40	siltst.		N30°E	30°N	N30°E	86	0.2	C	—	—	—	—	cliff
41	alter.	(Muro group)	N55°～75°E	40°～60°N	N20°E	53	−0.3	E	—	—	—	—	beach-const.
42	sandst.		N25°E	60°～70°W	N50°E	81	0.6	E	—	—	—	—	beach
43	alter.		N55°E	40°N	N50°W	57	1.2		+	—	—	—	beach-const.

Table 1 Features of the Shore Platforms

location	geology				profile				some features				topography at the rear
	lithology	epoch	strike	dip	direction	length (m)	inclination* (degree)	type**	rampart	pothole	gravels***	notch	
45	siltst.	Paleogene～lower Miocene (Muro group)	N28°W	80°E	N75°E	45	0.3	E	−	−	−	−	beach-const.
46	siltst.		N50°W	50°N	EW	57	0.4	E	−	−	−	−	const.
47	siltst.		N15°E	15°E	N 5°W	141	0.5	E	+	−	−	+	cliff
48	siltst.		N45°E	20°E	N15°E	62	0.0	C	−	−	−	−	beach-cliff
49	siltst.		N15°E	18°E	N15°E	136	−0.1	F	+	−	−	−	beach-const.
50	sandst.		N25°E	35°S	N30°W	56	1.4	E	+	−	−	−	cliff
51	sandst.		N85°E	30°N	N35°E	71	−0.2	F	+	−	−	−	beach-cliff
53	siltst.		N45°E	14°S	N 5°W	37	0.1	C	+	−	−	−	beach
54	siltst.		N55°E	60°S	N 5°E	75	−0.2	E	−	−	−	−	beach-const.
55	siltst.		N48°W	70°W	N70°W	41	0.0	C	−	−	+	−	beach
56	siltst.		N45°E	42°N	N25°W	95	0.2	D	+	−	−	+	cliff
57	siltst.		N65°E	40°N	N20°W	185	0.1	C	+	−	−	−	cliff
58	siltst.		N65°E	40°N	N 5°W	61	0.1	C	−	−	−	−	beach-const.
59	conglo.		N25°E	30°E	N 7°W	392	0.0	C	+	−	−	−	beach-const.
60	conglo.		N25°E	30°E	N88°E	168	−0.1	C	+	−	−	−	
61	conglo.		N45°E	30°N	N 2°E	102	0.1	D	−	−	−	−	const.
62	conglo.		N40°E	20°E	N15°W	79	0.1	D	+	−	−	−	cliff
63	conglo.		N55°E	70°N	N15°W	88	0.2	C	+	−	−	−	beach-const.
64	siltst.		N70°E	45°N	N35°W	64	0.3	C	−		−	−	beach-const.
65	siltst.		N65°E	40°N	N85°W	48	0.0	C	−		−	−	beach-const.
66	siltst.		N55°E		N 5°E	48	0.0	C	−		−	−	beach-cliff
67	siltst.		N45°E		EW	70	0.6	B	−		−	−	beach
68	alter.	middle Miocene (Kumano group)	N70°E	31°S	N15°W	56	−0.3	F	−		−	−	cliff
69	alter.		N65°E	40°S	N35°W	33	−0.3	F	−		−	−	cliff
70	siltst.		N35°E	50°E	N65°W	45	0.3	B	−		+	−	beach-const.
71	siltst.		N75°E	20°S	N85°W	97	0.1	C	+	−	+	−	beach
72	siltst.		N35°E	10°S	N 5°E	95	0.3	B	−	−	+	−	beach-const.
73	siltst.		N75°W	15°S	N55°W	85	0.5	H	−	−	−	−	beach-const.
74	siltst.		N60°E	12°S	N60°W	53	1.0	H	−	−	+	−	beach-const.
75	siltst.		N40°E	12°E	N 5°W	208	0.0	C	−	−	+	−	beach-const.
76	siltst.		NS	13°E	N45°W	48	0.1	D	−	−	−	−	beach-al.ter.
77	siltst.		N 5°W	19°E	N15°W	71	0.0	D	+	−	−	−	beach-al.ter.
78	siltst.		N35°W	20°W	NS	87	0.1	C	+	−	−	−	beach-al.ter.
79	siltst.		N35°W	10°W	N 2°E	125	0.1	D	+	−	−	−	beach-const.
80	siltst.		N15°W	18°W	N10°W	95	0.4	E	+	−	−	−	beach-const.
81	siltst.		N35°E	18°S	N15°W	75	0.1	C	+	−	−	−	beach-const.
82	siltst.		N75°E	10°S	N40°W	328	0.1	D	+	+	+	−	beach-cliff
83	siltst.		N25°E	22°S	N25°W	93	0.1	D	+	+	−	−	beach-const.
84	siltst.		N55°E	40°S	N20°W	206	0.4	E	+	+	+	−	beach-const.
85	siltst.		N60°E	35°S	N20°W	81	0.1	D	+	−	−	−	beach-const.
86	siltst.		N40°W	15°N	N15°W	36	−0.2	C or F	−	−	−	−	beach-cliff
87	alter.		N 5°W	32°S	N50°W	70		E	+	+	−	−	beach-const.
88	alter.		N55°E	25°S	N50°W	45	0.3	E	+	+	−	−	beach-const.
90	alter.		N45°E	45°S	N35°W	54	0.1	E	+	−	+	−	beach-const.
91	alter.		N57°E	62°S	N35°W	39	0.0	D	−	−	+	−	beach-const.

Table 1 Features of the Shore Platforms

location	geology				profile				some features				topography at the rear
	lithology	epoch	strike	dip	direction	length (m)	inclination* (degree)	type**	rampart	pothole	gravels***	notch	
92	alter.	(kumano group)	N63°E	55°S	N48°W	40	0.6	E	+	+	−	−	beach-const.
93	alter.		N75°E	70°S	N15°E	38	1.8	E	−	−	−	−	beach-cliff
94	alter.		N85°W	80°N	N50°W	38	0.5	E	−	+	−	−	beach-cliff
95	alter.		N85°W	80°N	N 8°W	74	2.4	E	−	+	−	−	beach-cliff
99	alter.		N85°W	80°N	N18°W	27	0.0	C	+	−	−	−	beach-cliff

* inclination of the main part of the shore platform
** type of the simplified profile (Fig. 5)
*** gravels on the surface of the platform
+: existence −: non-existence
alter: alternation of sandstone and siltstone (or mudstone)
conglo.: conglomerate sandst.: sandstone siltst.: siltstone and mudstone
const.: construction (such as wall, road, railroad and so on) al. ter.: alluvial terrace

There are shore platforms near the high tide level and coastal platforms at 1.5 m$\sim$3.5 m above the high tide level with the surfaces which inclined seaward or landward. Some surfaces have the serrated topography (or the so-called wash-board-like relief), and others have the surfaces that were partly regulated with the slightly inclined bedding of the sandstone. Judging from the correlation between the levels of shore platforms and the heights of raised beaches as described later (see Chapter 5), the levels of most platforms in this area seem to be too high. It is difficult as yet to explain the phenomena, but it is possible to regard the role of resistant rock as one of reasons.

(4) On the Coast between Hiki and Mirozu

The coasts which consist of sandstone (the Muro group, Paleogene or lower Miocene) have no coastal terraces, the slopes of mountains passing beneath the sea immediately. Although fragmentary reefs are scattered in the nearshore zone on some coast (Photo. 6), the platforms of small scale develop partly, being carved by furrows and grooves and presenting the rugged relief (Loc. 41, 42).

(5) On the Coast between Mirozu and Kushimoto

The coasts are constructed with siltstone, mudstone, pelitic conglomerate or the alternation of sandstone and siltstone (the Muro group) between Mirozu and Nounagi, and the alternation of sandstone and siltstone (the Koguchi formation of the Kumano group, middle Miocene) between Tanosaki and Kushimoto.

The high tide platforms without gravel on their surface developed almost

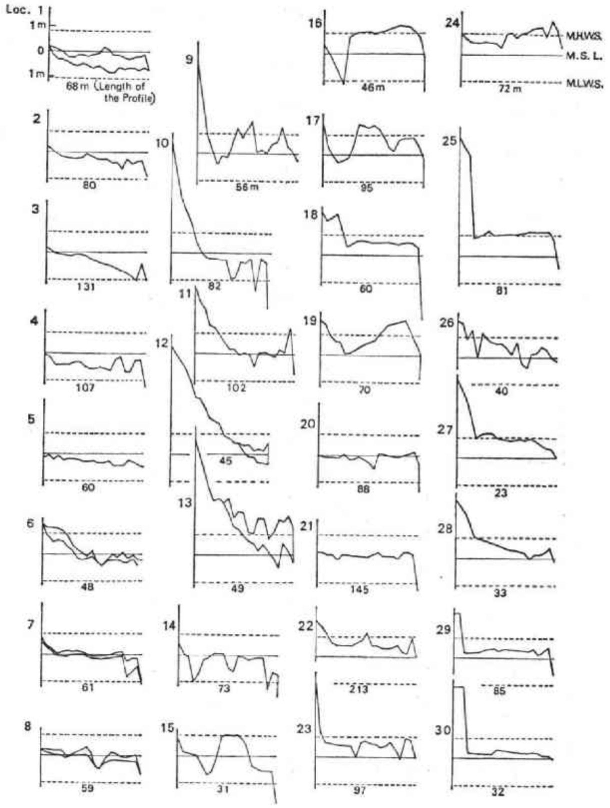

Fig. 4 Simplified profiles (1)

horizontally (0°～0.3°) and broadly, and at the area of more pelitic rock, they developed more broadly and smoothly (Photo. 7, Loc. 57, 59, 62, 63), but the seaward rims are slightly high. Coastal terraces developed broadly at the rear, and there are gravel beaches between platforms and terrace scarps. At Tanozaki (Loc. 68) the platform has the landward-inclined surface at 1.5 m above the high tide level.

The coast of Shionomisaki and Ōshima has not been investigated.

(6) On the Coast between Kushimoto and Uragami

The coasts are constructed with siltstone or mudstone (the Shikiya member of the Koguchi formation) between Kushimoto and Tahara, and the alternation of sandstone and siltstone (the Shimosato member of the Koguchi formation) between Tahara and Uragami.

At the west of Hashigui (Loc. 73, 74), there are the inter-tidal platforms with the slightly inclined surface of angle 0.5°～1.0° seaward. They have no conspicuous

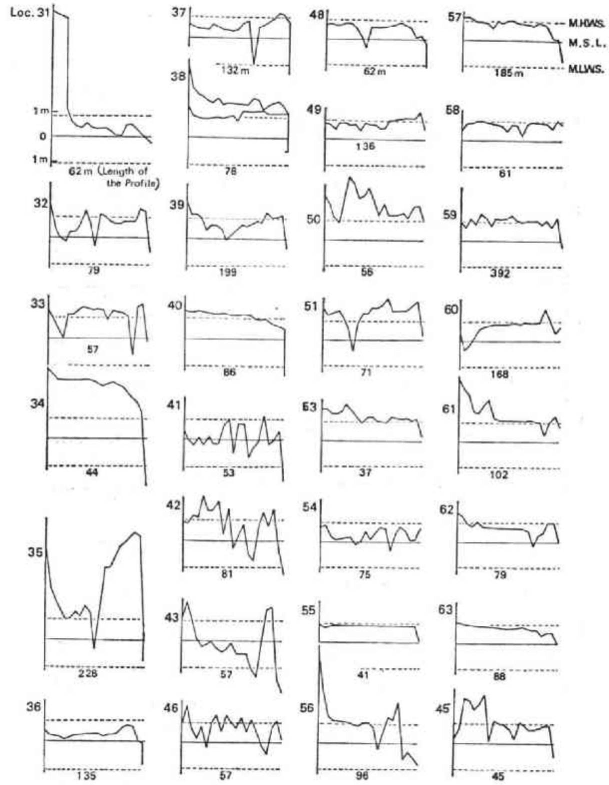

Fig. 4 Simplified profiles (2)

nip on the front side. The high tide platform at Hashigui (Loc. 75) has developed broadly and flatly at the lee side sheltered by the jutted stacks of dacite dykes, called "Hashigui-iwa" (Photo. 8). Adjacent to this platform, there is a higher platform, at about 2 m above the mean sea level, covered with silt and gravel. Toyoshima (1968) presumed from archaeological materials that the higher platform had been formed before the Middle Jomon age, and the high tide platform has been cut since 3,000 years ago.

The highest shore platforms are between Koza and Uragami in the investigated region, almost above the high tide level. Corresponding to that, the highest coastal terraces are also there.

On the coast between Koza and Tahara, although the shore platforms are horizontal (about 0.1°), their rims and fore parts are deeply carved by the wave furrow and cut to pieces in some places (Loc. 84, Photo. 9). On the contrary, on the coast between Tahara and Uragami, where the trenches have reached inward

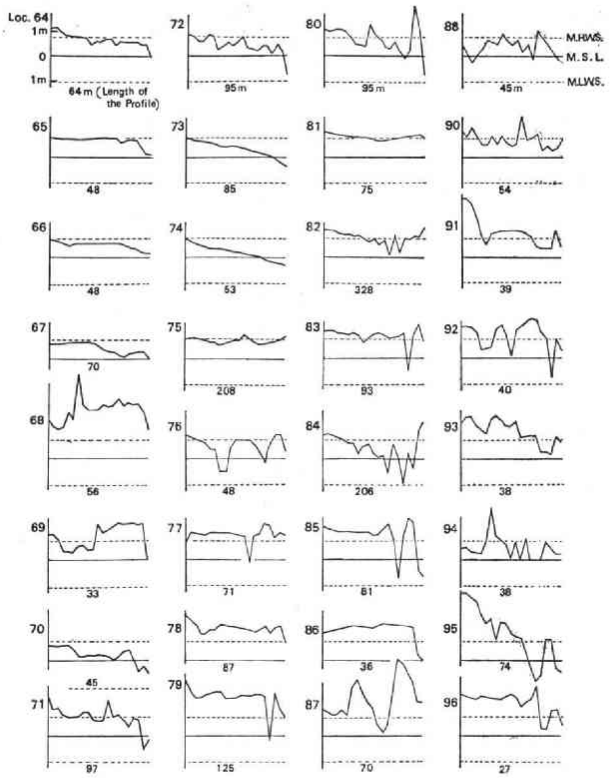

Fig. 4 Simplified profiles (3)

the platforms and the subaerial denudation progressed, the platforms are cut extremely to pieces and present more rugged relief without broad surfaces (Photo. 10). The phase difference in erosion between both areas above seems to be caused by lithology and geological structure. The former coast is relatively pelitic in lithology, and the latter coast has sandier rock, steeper dip of formation and more complicated geological structure.

4 Analysis of the Profiles

The simplified profiles can be classified into several types, as in Fig. 5, by comparison with one another.

The standard types (A, B and C types) are such profiles as incline slightly with the angle of $0°\sim0.4°$ and are edged with nip, which are subdivided into three as to the heights of platforms: A-type between the mean sea level and the low tide level, B-type between the mean sea level and the high tide level and C-type near and slightly above the high tide level. Although it is difficult to judge

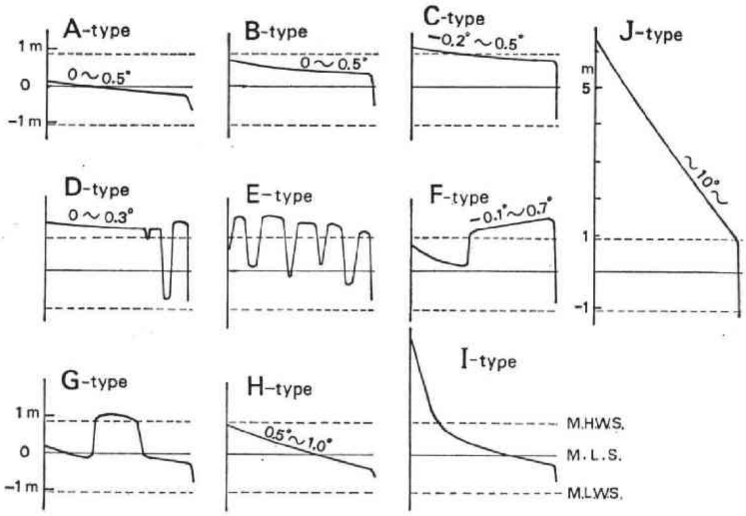

Fig. 5 Types of the simplified profiles of shore platforms

whether each type is formed coincidently to each level, or displaced after the formation at any level, at present it is mentioned that the latter is the case from the view point to reach later (see Chapter 5). The D, E, F and G types are added secondary erosion and deformation. Elevated shore platforms began to suffer secondary denudation, and have transformed gradually into D, E, F, or G types. The D-type is in the early stage, when the platform begins to be deeply carved from the seaward rim by wave furrow and cut to pieces in the frontal part. As erosion by wave furrow reached inward and subaerial denudation progressed on the surface, they have more rugged relief, that is the E-type. The platform with rim of resistant lithology is difficult to be carved from the front by wave furrow, it is denudated in the early stage, from the back by wave and washout through the side furrow, and the back surface lowers gradually. Splashed salt-spray and rain-water at the separated front flush landward onto the lowered back surface and result in the landward inclined frontal surface. The F-type is formed in this way. If erosion proceeds from both front and back, the original higher surface remains partially, then the profile is the G-type.

From the above mentioned point of view, the sequence of profile change is arranged as in Fig. 6.

On the sheltered coast the H-type platform extends with very gentle gradient ($0.5^\circ \sim 1.0^\circ$) from the high tide mark through the mean sea level beneath the sea. It equals to the "inter-tidal platform" by Bird (1969). The rear ramp is the characteristic of the I-type which is regulated by the bedding, but the front is

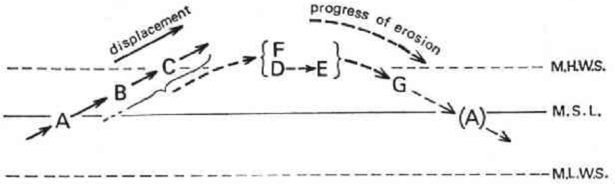

Fig. 6 Evolution of the types of the profiles

similar to that of A- or B-type. The J-type platform with the steep slope is the structual coastal platform that is controled by the bedding of sandstone, and was called "Quarry type" platform by Mii (1962).

5 Relation between the Levels of the Shore Platforms and the Deformation of the Raised Shoreline

The levels of the shore platforms differ in localities, and their regional differences correspond well to that of the heights of coastal terraces described as monastirian terraces by Yonekura (1968). The regional difference of the levels of shore platforms is compared with the deformation of the upheaved monastirian shoreline restored from the terraces (Fig. 7). The vertical range of platform in Fig. 7 is that of relatively broad surface, obtained from the shore profile or the simplified profile, and the level is presented with the height of platform in highest frequency.

As is evident in the figure, both correspond relatively well to each other, with some exceptions.

On the coasts between Iwashiro and Metsuzaki, there are two levels of shore platforms around the high tide level and around the mean sea level (Loc. 15～19). The former level suffered secondary denudation as stated above, and have been lowered to the latter level. It seems to correspond to the upheaved monastirian shoreline. Meanwhile, in view of this correspondence, the levels of platforms at Tsubaki and Hiki are too high (Loc. 33, 34, 38, 39, 40). It is difficult to explain, but it is possible to consider the role of resistant lithology. The inter-tidal platforms at the west of Hashigui are too low from the same point of view, but they must have been formed lower originally, as they are the sheltered coast.

The coefficient of correlation between the levels of shore platforms and upheaved monastirian shoreline restored by the coastal terraces, as shown in Fig. 8, is calculated as follows: $r=0.77$

Many authors discussed in Japan that the most of the late Quaternary crustal movement detected in coastal terraces is similar to that of the recent crustal movement associated with seismic activity and it continues till the present time

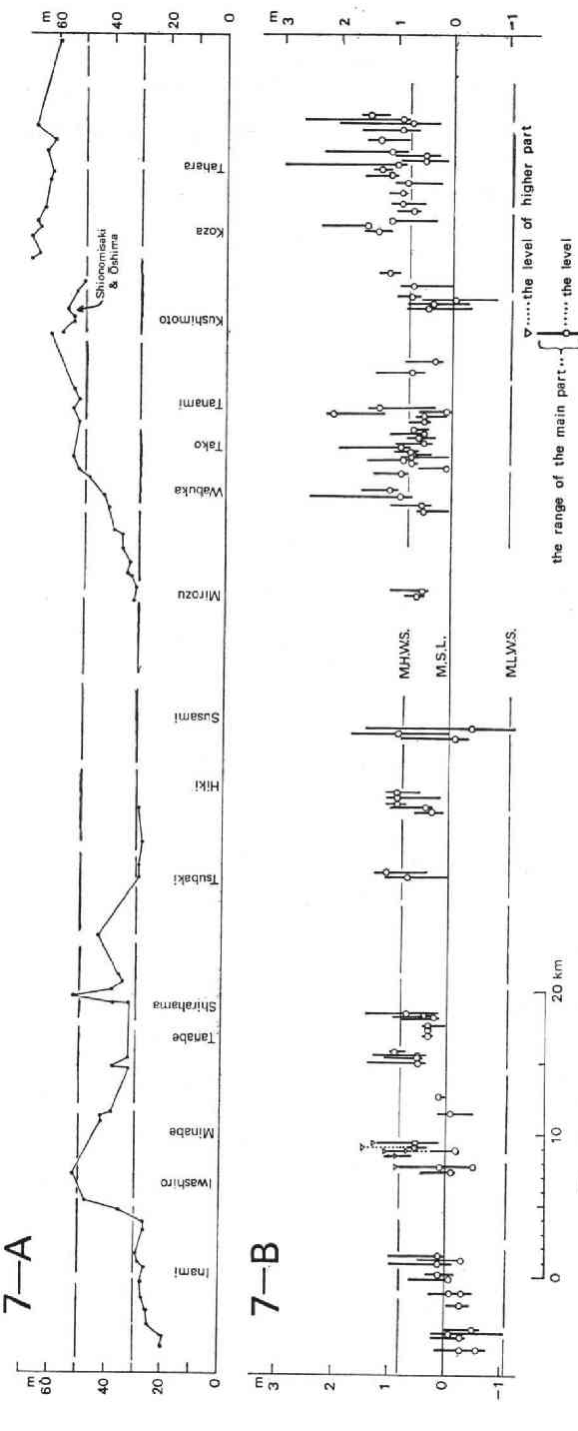

Fig. 7 Correspondence between height of raised beaches (7–A) and level of shore platforms (7–B)

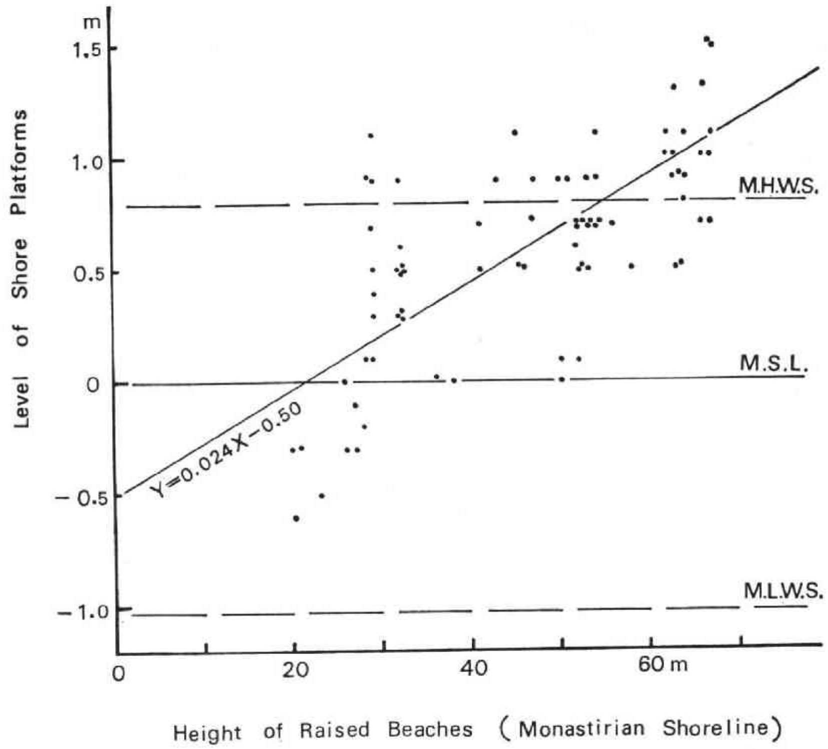

Fig. 8 Correlation between height of raised beaches and level of shore platforms

(such as Miyabe, 1955; Yoshikawa *et al.*, 1964; Kaizuka, 1967; Sugimura, 1967; Ota, 1968 and Yonekura, 1968). Based on this conclusion, the crustal movement has displaced similarly the shore platforms. Accordingly, the correlation between the levels of shore platforms and the heights of raised beaches is explained smoothly. The time and level of the formation of shore platforms, and their secondary modification are various in relation to a number of factors; lithology, structure, weathering processes, shore and nearshore topography, wave regime, tidal range, sea-level change and so on—which are different in localities. The dispersion of points in Fig. 8 expresses the influences of such intricate factors.

6 The Estimation of the Time of the Formation of the Shore Platforms and the Level of their Planation

From the relation between the level of shore platforms and the heights of upheaved monastirian shoreline restored by the coastal terraces as mentioned above, the time of the formation of shore platforms and the level of their planation was estimated.

The height of the monastirian shoreline and the level of shore platforms are respectively at about 63 m and 100 cm above the present mean sea level near Tahara, and at about 27 m and 0 cm near Inami.

Assumed that the monastirian shoreline was formed about 90,000 years ago (Emiliani, 1966 and Yonekura, 1968), the difference between both upheaval rates is as follows:

$$\frac{63\text{ m}-27\text{ m}}{90{,}000\text{ years}} = 0.4\text{ mm/years}$$

On the assumption that the difference of both upheaval rates has continued in the late Quaternary, the duration that has brought the existing difference of the levels of both shore platforms is calculated as follows:

$$\frac{100\text{ cm}-0\text{ cm}}{0.4\text{ mm/year}} = 2{,}500\text{ years}$$

If the monastirian sea level was at about 10 m above the present sea level at the age, the upheaval rates till the present are 0.6 mm/year $\left(\fallingdotseq \frac{63\text{ m}-10\text{ m}}{90{,}000\text{ years}}\right)$ at Tahara and 0.2 mm/year $\left(\fallingdotseq \frac{27\text{ m}-10\text{ m}}{90{,}000\text{ years}}\right)$ at Inami.

From these rates the upheaval amount of shore platforms is calculated tentatively, such as 150 cm (=0.6 mm×2,500 years) and 50 cm (=0.2 mm×2,500 years). Then, the levels at their formation about 2,500 years ago were both 50 cm below the present sea level.

By using the regression equation obtained from the correlation between the levels of shore platform (y meter) and the heights of uplifted monastirian shoreline (x meter), the age of the formation of shore platforms and the level of their planation are estimated.

The linear regression equation is:

$$y = 0.024\,x - 0.50 \qquad (1)$$

The height of the monastirian shoreline at present (x meter) can be obtained as the sum of the height of monastirian sea level at that age (M meter) and the upheaval amount [the rate (v m/year)×the duration (t_1 years)]

$$x = \mathrm{M} + vt_1 \qquad (2)$$

Assuming as M=10 (meter) and t_1=90,000 (years), the equation (2) is rewritten as follows:

$$x = 10 + 9 \times 10^4 v \tag{3}$$

Provided that the upheaval rate was constant in the late Quaternary, the present level of shore platform (y meter) is the total of the level at the age of formation (P meter), the upheaval amount [the rate (v m/year) × the duration (t_2 years)] since that age and the vertical secondary lowering ($-l$ meter):

$$y = \mathrm{P} + vt_2 - l \tag{4}$$

Substituting the equation (3) and (4) into the equation (1),

$$\mathrm{P} = (0.226 \times 10^4 - t_2)v - 0.26 + l \tag{5}$$

In the case of $v=0$ and $l=l_0$,

$$\mathrm{P} = -0.26 + l_0 \tag{6}$$

Then, if the secondary lowering is disregarded, the level of shore platform at the age of formation was 0.26 m below the present mean sea level.

Moreover, if it is rearranged by substituting the equation (6) into the equation (5), on the assumption that the amount of secondary lowering is uniform anywhere,

$$t_2 = 2{,}260 \text{ years}$$

From the above-mentioned calculation the shore platforms in this region are considered to be formed in the level several decimeters below the mean sea level between two thousand several hundred and two thousand years ago.

Such an estimation is approximately in accordance with the presumption of the archaeological materials by Toyoshima (1968). He presumed that the shore platform at Hashigui-iwa was formed since 3,000 years ago.

The thickness of secondary lowering was not yet confirmed. However, the altitudal difference of levels between the higher platform near high tide level and the lower platform near mean sea level at the Metsuzaki coast and at the south-east of Iwashiro as mentioned above is possible to indicate the amount, which is about a meter.

The age of the shore platform formation calculated above corresponds approximately to the Abrolhos submergence stage (about 2,600 to 2,100 years B. P.) called by Fairbridge (1961). He asserted that the sea level at that stage had risen, in brief period, to a level of 1.5 m above present datum.

Considering the sea level at the age and the amount of secondary lowering, their planation seems to have been working at the level below the mean sea level and near the low tide level at that age. However, it cannot be definitely concluded as yet, as the sea level change by Fairbridge does not always accord with that by others.

The problems on the planation level are difficult to solve as the opinions of investigators disagree. Fairbridge (1952, 68) referred that the "normal" platform had been formed at the low tide level. The authors estimation of the level supports the view of Fairbridge, but it cannot negate the possibility of the shore platform to be formed at the high tide level too. In other observations, the planation at two or more levels was pointed out (Takahashi, 1972).

As the time of the shore platform formation and their planation level are estimated under some assumptions, more studies are necessary in different approaches.

7 Summary

The features of shore platforms and the problems of their formation and evolution are summarized as follows:

(1) The distribution of shore platforms fairy well corresponds to that of the coastal terraces in this region.

The terraced coast has conspicuous and broad shore platforms, and the non-terraced coast has scarcely shore platforms. It means that the former is the upheaved coast and the latter is the submerged, but for the latter it is impossible to disregard the role of resistant lithology. The relation between the distributions of shore platforms and coastal terraces has not been sufficiently clarified at present.

(2) To compare the features of shore platforms, the simplified profiles were drawn from the actual profiles which are obtained by levelings, and these profiles were classified into several types (Fig. 4 and 5). Roughly speaking, these types are divided into two groups: types of platforms with horizontal or slightly seaward inclined broad continuous surface, and others eroded, denudated and cut to pieces since they had emerged. Arranging these types, the evolution of shore platforms was interpreted (Fig. 6).

(3) Between the levels of shore platforms and the heights of the upheaved monastirian shoreline restored by the coastal terraces, the positive correlation can be relatively well read (Fig. 7, 8).

(4) From the correlation, the regional difference of the levels of shore platforms seems to indicate the mode of crustal movement in the late Quaternary.

(5) From the correlation, it is estimated that the shore platforms have been formed in the level several decimeters below the present mean sea level since two thousand several hundred to two thousand years ago.

(6) The above age of formation corresponds approximately to the Abrolhos stage called by Faribirdge. The planation level of shore platform was perhaps near the low tide level below the mean sea level at the age. However, as the sea

level change by Fairbridge does not always accord with that by others, the authors estimation of the planation level of shore platforms is an interpretation.

(7) The estimated age is approximately concordant with the result, from archaeological materials by Toyoshima (1968), that the shore platform at Hashigui-iwa had been formed since 3,000 years ago.

(8) However, this estimation is under some assumptions, and more studies are necessary in different approaches.

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Photo 1 Serrated foreshore topography (or washboard-like relief) on the shore platform near Inami (Loc. 9)

Photo 2 Shore platform which has developed the two levels: near the mean sea level and high tide level, on the coast at the southeast of Iwashiro (Loc. 15).

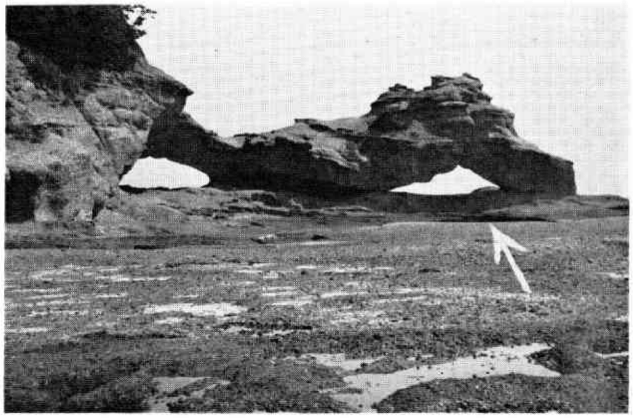

Photo 3 A pair of the sea arches named "Megane-iwa" at Matsuzaki (Loc. 17). Under the westside (right hand) arch, a lower arch is seen (follow the arrow).

Photo 4 Old hat type platform in and out the Tanabe bay

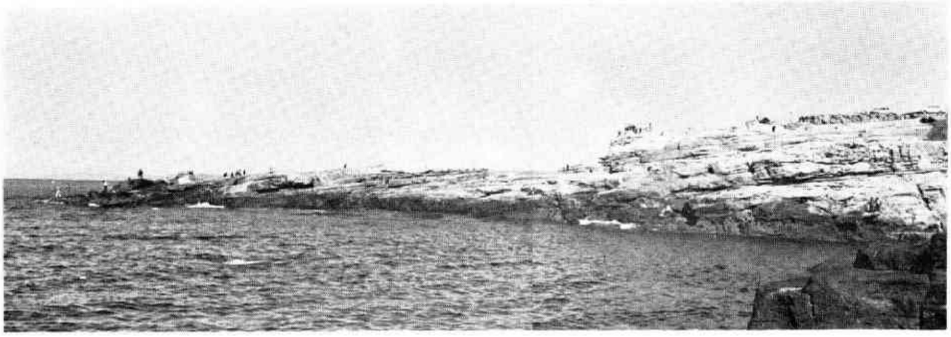

Photo 5 A structural coastal platform at Senjōjiki (Loc. 102). Its steep surface have been regulated by the seaward-inclined bedding of sandstone.

Photo 6 Scattered reefs at the west of Mirozu

Photo 7 Broad shore platforms which consist of pelitic rock, near Tako (Loc. 57, 58, 59)

Photo 8 A high tide platform at Hashigui has developed broadly and flatly at the lee side portion that is sheltered by the jutted stacks (Loc. 75).
Adjacent to this platform, there is the higher platform, at about 2 m above the mean sea level, covered with silt and gravel (follow the arrow).

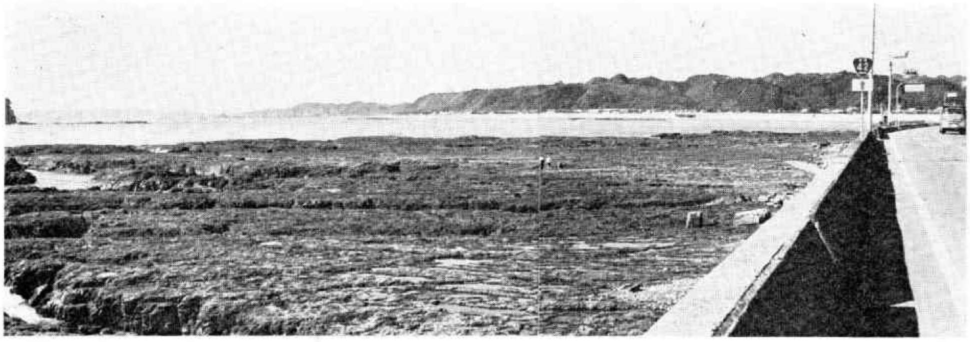

Photo 9 One of the highest shore platforms in the investigated region, at the east of Koza (Loc. 78).
The rim and the fore part are deeply carved by the wave furrow and cut to pieces in some places.

Photo 10 A shore platform with rugged relief at the east of Tahara (Loc. 87)