Title	Relationships between Holocene geomorphic development of coastal ridges and human activities : a case study of the coastal lowlands along Suruga Bay, central Japan
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Relationships between Holocene Geomorphic Development of Coastal Ridges and Human Activities

—— A Case Study of the Coastal Lowlands along Suruga Bay, Central Japan ——

Akiko Matsubara

Abstract

Coastal ridges that represent former coastal barriers and beach ridges, are widely distributed among the lowlands of the Japanese Islands. The distribution of archaeological sites in the coastal lowlands indicates that these coastal ridges have been important landforms for human activities.

Relationships between Holocene geomorphological development and human activity in the regions are clarified from a study of three sites along Suruga Bay in central Japan where typical coastal ridge landforms are recognized and on which archaeological sites dating from ca.3,000 BP are also widely distributed.

The time lag between when enclosure of the lagoons behind the coastal ridges and human settlement is calibrated. It was often thousands of years after the final stages of their formation before humans began to advance and settle on the coastal ridges because it took several thousand years for the coastal ridges to become stabilized and to be free from the influence of seawater.

Key Words: Holocene; coastal lowlands; barriers and beach ridges; tectonic movements; volcanic events; archaeological sites

I. Introduction

Coastal ridges are widely distributed within the lowlands along the Japanese coastline. They represent former coastal barriers and beach ridges. The rise in sea level during the Holocene was a major factor in the development of these barriers, based on studies on barrier complexes around the world (Davis, 1994; Trenhaile, 1997). Generally, barriers were developing and transgressing landward when the sea level was rising rapidly. On the other hand, barriers began to grow seaward when the sedimentation rate became higher than the rate of rise in sea level. These geomorphological developments of coastal barriers have been recognized along the east coast of North America (Colquhoun *et al.*, 1968; Pierce and Colquhoun, 1970; Moslow and Colquhoun, 1981); on the Netherlands coast (Van Straaten, 1965; Hageman, 1969; Jelgersma and Van Regteren, 1969); around the Australian coast (Thom *et al.*, 1981; Thom, 1983); and along the Japanese coast (Matsubara, 2000).

A common pattern in relative sea-level change around Japan is that the sea rose above the present level (Bird, 2000). The Holocene transgression is called the Jomon transgression in Japan, as it is associated with the equivalent archaeological period. It is known that sea level generally reached its highest level (3 to 5 m higher than at present) at around 6,000 BP. After the culmination of the Jomon transgression, sea level stabilized, or even lowered slightly, and has since changed with only minor fluctuations (Ota *et al.*, 1981; Ota *et al.*, 1990; Umitsu, 1991). Beach ridges developed seaward of the coastal barriers along with these fluctuations in sea level. These indicate that geomorphic evolution of the coastal lowlands was deeply influenced by the Holocene sea-level changes.

Archaeological sites dating from the later Jomon period (ca. 3,000 BP) were widely distributed in the Japanese coastal lowlands. In particular, coastal ridges in the lowlands have been important landforms for human activity. Along Suruga Bay in central Japan, typical landforms of coastal lowlands with ridges can be recognized. Moreover, the archaeological sites since the later Jomon period are widely distributed on the coastal ridges.

The purpose of this paper is to make clear the relationships between the development of

coastal ridges and human activities both of the Ukishimagahara and Kano River lowlands in the innermost part along Suruga Bay, and of the Shimizu lowland in the western part of the bay.

II. Outline of Suruga Bay

1. Geomorphic, geologic and tectonic settings

Suruga Bay is located at the southern foot of Mt Fuji. It is 40 km wide and 55 km long, and faces the Pacific Ocean (Fig.1). The bay is situated at the boundary between two plates: the Philippine Sea Plate to the east and the Eurasian Plate to the west. The Philippine Sea Plate is subducting northwestward beneath the Eurasian Plate along the Suruga Trough. This tectonic depression runs from north to south in the middle of the bay with a maximum depth of over 2000 m. Neogene to Quaternary volcanoes such as Mt. Fuji, Hakone Volcano and the volcanic groups in the Izu Peninsula, front the east of the bay. In contrast, mountains and hills mainly composed of Tertiary to Quaternary sedimentary rocks face the west of the bay. The submarine topography in the west is rough and complex, whereas that in the east is simple and has a steep gradient toward the Suruga Trough. The continental shelf developed mainly in the west of the bay (Fig.1).

Concerning earthquake prediction, Suruga Bay and its vicinity in the eastern part of the Tokai district are regarded as the most likely area for earthquakes to occur in the near future in Japan. As the presence of a seismic gap in the eastern half of the Tokai district has been inferred from historical records about previous earthquakes, the occurrence of a "Tokai earthquake" is expected (e.g., Ishibashi, 1981). Coastal deformation along Suruga Bay has been studied on the basis of either geodetic surveys or the investigations of historical documents. Results from examinations of leveling along the coast during the period 1900-1973 indicate that the coasts along Suruga Bay are subsiding 0.14 to 0.55 cm per year (Geographical Survey Institute, 1978). The centre of subsidence is considered to be in the middle part of the west coast. On the other hand, according to historical documents, in the case of the Ansei-Tokai earthquake of 1854, the west coast was uplifted 1 to 3 m by the earthquake (Ishibashi, 1984). The inconsistency is explainable by the differ-

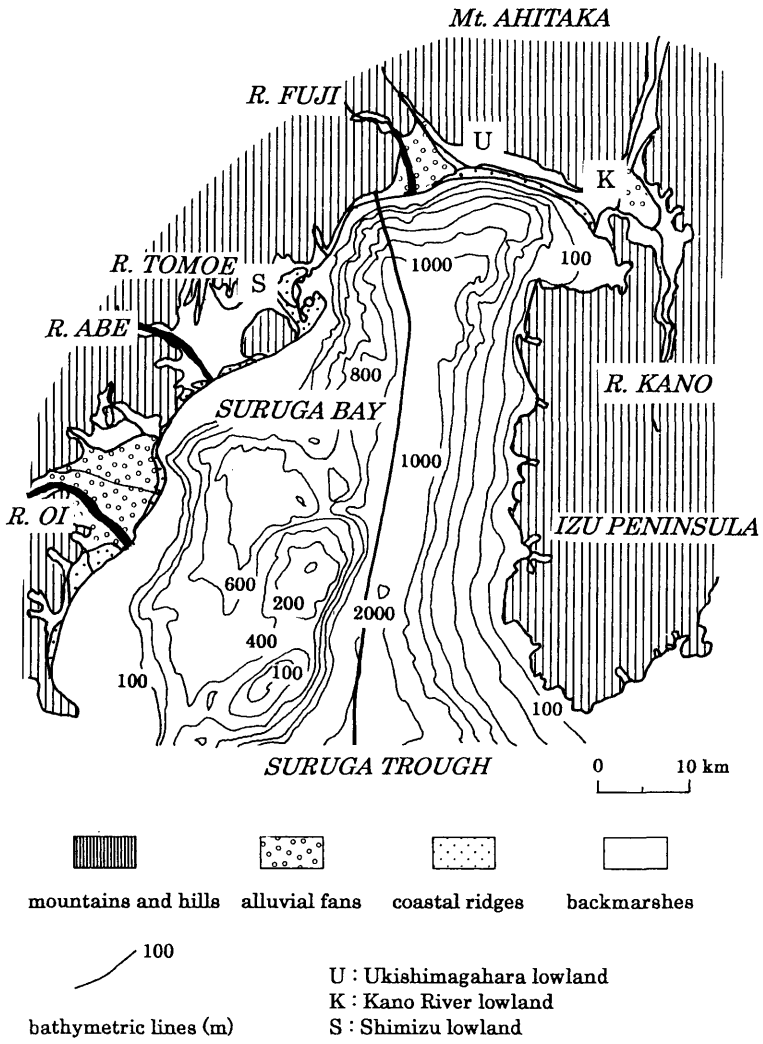

Fig.1 Geomorphological map of the coastal lowlands along Suruga Bay

ences between seismic and aseismic deformation. The upper plate, west of the Suruga Trough, subsides by the underthrusting of the lower plate between earthquakes, whereas the upper plate uplifts when earthquakes occur because of reverse faulting against the aseismic deformations.

2. Coastal lowlands along Suruga Bay

The Suruga Bay area has been recognized as an unusual region where coastal lowlands are not well developed because of the remarkable subsidence by comparison with sediment supply (e.g., Kaizuka *et al.*, 1985). However, various coastal lowlands have developed in this area. Moreover, they represent some of the best examples of coastal lowland with ridges in Japan. They comprise ridge-backmarsh complexes (barrier systems) such as the Ukishimagahara lowland; and delta-beach ridge complexes such as the Kano River lowland; beach ridge plains (strand plains) such as the Shimizu lowland. Consequently, it is possible to examine the overall characteristics of the evolution of coastal lowlands in Japan by clarifying the geomorphic development in those along Suruga Bay. Therefore, the preceding three coastal lowlands -the Ukishimagahara, Kano River and Shimizu lowland- were chosen as the study area as presented in this report (Fig.1).

III. Holocene geomorphic development of coastal ridges and human activities in the coastal lowlands along Suruga Bay

1. The Ukishimagahara and the Kano River lowlands

(1) Geomorphic development of coastal barriers and beach ridges during the Holocene

The Ukishimagahara lowland belongs to the sand or gravel ridge-backmarsh complex. The lowland is situated at the southern foot of Mt Ashitaka (a Pleistocene volcano) and faces the innermost part of Suruga Bay. One ridge-backmarsh system is recognized in the present lowland. In addition, a buried barrier and beach ridge system is confirmed under the backmarsh (Matsubara, 1984; 1988) (Fig.2).

Sampling of the Holocene deposits was carried out in the innermost part of the backmarsh by Yonekura *et al.* (1985) (Fig. 2). According to an analysis of fossil foraminiferal assemblages, the bay, which formed in the Ukishimagahara lowland began to change into a lagoon about 7,000 BP, with the lagoon turning into a marsh after ca. 5,800 BP. These environmental changes were caused by the enclosure of a coastal barrier (Coastal Ridge

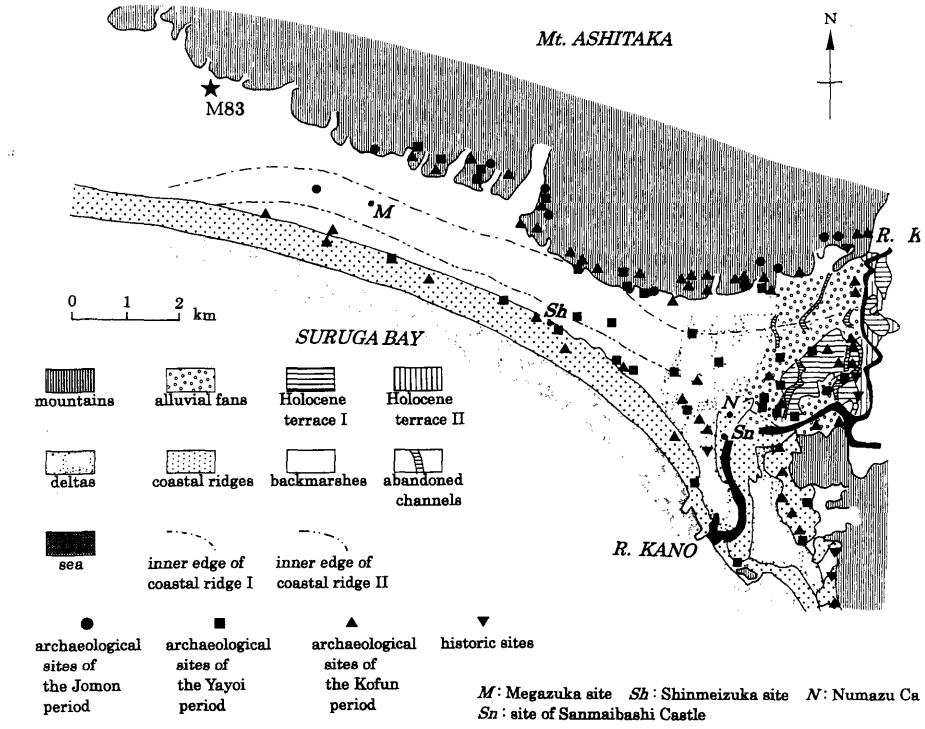

Fig.2 Geomorphological map of the Kano River and Ukishimagahara lowlands
M83 is boring site after Yonekura *et al.* (1985)

I). Consequently, it is inferred that the coastal barrier emerged and began to enclose the bay around 7,000 BP, and finished enclosing ca. 5,800 BP. This indicates that the coastal barrier was formed during a marine transgression. Then, beach ridges developed off the coastal barrier. The peat behind the inner beach ridge (Coastal Ridge II) began to accumulate during 5,000 to 4,000 BP, as deduced from ^{14}C dating. Consequently, the inner beach ridge enclosed the backmarsh over a 1,000-year period. In addition, the outer beach ridge (the present coastal ridge: Coastal Ridge III) is considered to have been constructed by 2,000 BP, because the age of the archaeological sites both on the beach ridge and in the backmarsh date from the Yayoi period (around 2,000 BP) (Matsubara, 2000a) (Fig.2).

The Kano River lowland is located in the east of the Ukishimagahara lowland, and has its source in the middle of the Izu Peninsula. The present costal ridge, running from the

Ukishimagahara lowland, develops around the mouth of the Kano River. In addition, the inner coastal ridge is recognized on the delta in the lowland. This ridge was constructed about 4,500 BP according to ^{14}C dates from backmarsh deposits. Consequently, this ridge corresponds to Coastal Ridge II in the Ukishimagahara lowland (Fig.2).

(2) Changes in human activities (Distribution of archaeological sites)

Although most of the archaeological sites in the Ukishimagahara lowland are distributed mainly on the foot of Mt Ashitaka and on the present coastal ridge (the outer beach ridge : Coastal Ridge III), the Megazuka archaeological site exists on Coastal Ridge I (the buried coastal barrier) (Matsubara, 1992) (Fig.2). This site is dated as being from between the middle Jomon and later Kofun periods (ca. 4,000 to 1,500 BP). Resulting from a series of excavations, the stratigraphic sequence and microlandforms at the Megazuka site as well as the periods of human activity have been determined (Figs. 3,4). During the initial stage of human activity during the middle to later Jomon period (4,000 to 3,000 BP), humans advanced onto the coastal barrier (Coastal Ridge I) as a campsite for fishing. Subsequently, humans began to settle on the coastal barrier in the latest Jomon period (3,000 to 2,500 BP). By the late Yayoi period (ca. 1,800 BP), they had maintained permanent settlement on the barrier for a long time (Fig.5). Excavation results confirm that humans were living on both fishing and farming. Following the early Kofun period (ca. 1,700 BP), human activity had reduced. Finally, human settlement at the Megazuka site was eventually abandoned in the later Kofun period (ca. 1,500 BP).

The initial stage of human activity coincided with the period when the area around the Megazuka site changed from a lagoon to a marsh with the construction of Coastal Ridge II (the inner beach ridge) at about 4,000 BP. Coastal Ridge I had not been affected by seawater since Coastal Ridge II had emerged by progradation. Only then could humans begin to advance onto Coastal Ridge I. Furthermore, the peak of human settlement was coincident with the period when Coastal Ridge III (the outer beach ridge) emerged and began to enclose the lagoon behind it ca. 2,000 BP. Human settlement at the Megazuka site was abandoned at the time of the Obuchi Scoria (ObS) fall from Mt Fuji (ca. 1,500 BP). Furthermore, tectonic movement in the Ukishimagahara lowland is characterized by sub-

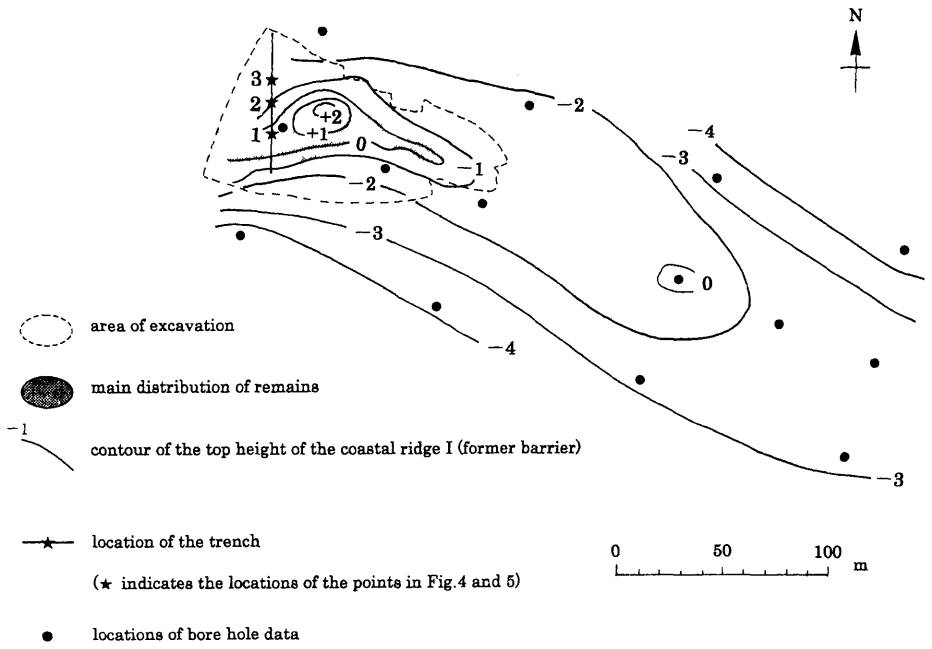

Fig.3 Microtopography at the Megazuka site

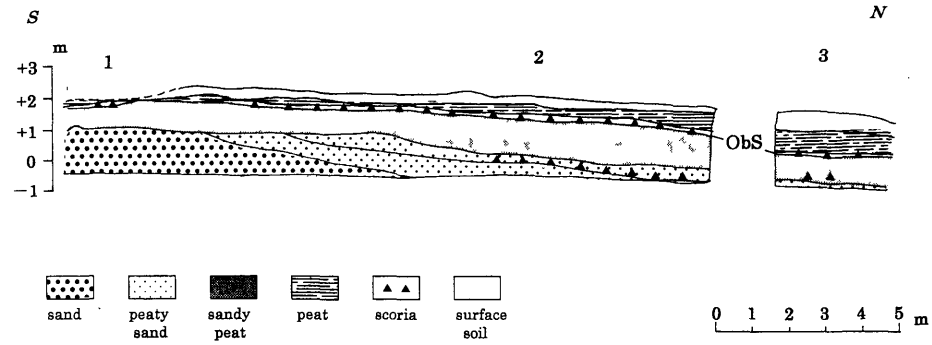

Fig.4 Geological section along the trench at the Megazuka site

sidence (westward and landward downtilting), which buried the former coastal barrier (Coastal Ridge I) beneath the marsh. Continued burial of the barrier made the environment of the Megazuka site unsuitable for human settlement. These findings indicate that both volcanic activity and tectonic movement influenced human settlement in the Ukishimagahara lowland.

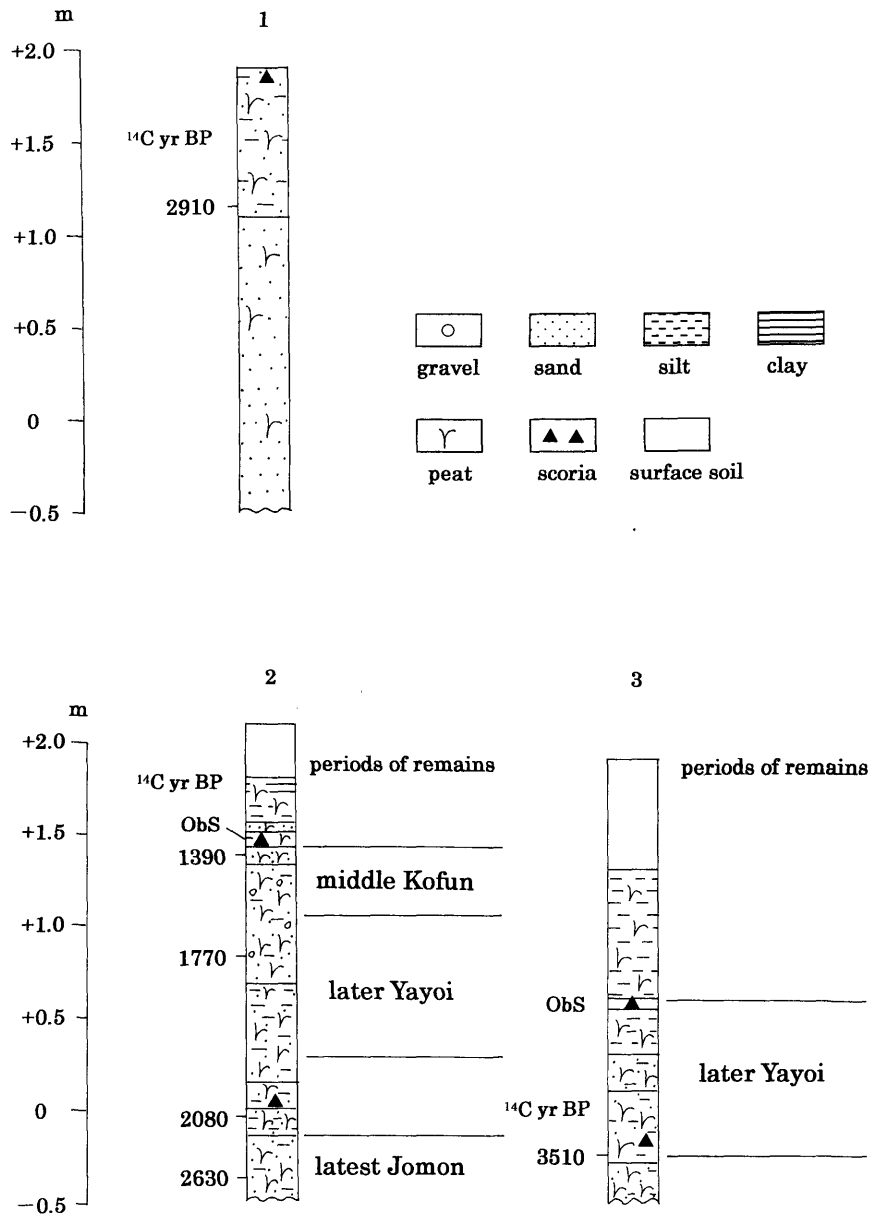

Fig.5 Geologic columns and periods of remains at the Megazuka site

On the other hand, many archaeological sites of the Kofun period are distributed both on Coastal Ridges II and III , for example, the Shinnmeizuka site, located on Coastal Ridge II (Fig.2) . Earlier excavations (Matsubara, 2000b) have clarified the fact that humans had advanced onto the coastal ridges and lived on fishing since the middle Yayoi period (ca. 2,000 BP) . This suggests that humans settled on Coastal Ridge I during the later Yayoi period (ca. 1,800 BP) , and also began to advance onto Coastal Ridges II and III. At that time, humans began to move from Coastal Ridge I to Ridges II and III, and finally settled there during the Kofun period (1,700 BP) .

In more recent times on the Kano River delta, Sanmaibasih and Numazu castles from the 16th and 18th centuries, respectively, were built on the coastal ridge corresponding to Coastal Ridge II in the Ukishimagahara lowland (Fig.2) . Archaeological excavations in the vestiges of the outer moat of Sanmaibashi Castle (Matsubara, 1998; 2000b) have revealed remains of the latest Jomon period (ca. 3,000 BP) that suggest that humans began to settle on the ridge at least by about 3,000 BP (Fig. 6) . However, the coastal ridge was covered with volcanic deposits from the Kawagodaira Pumice (KgP) fall as well as by pyroclastic flows supplied from the Amagi Volcano in the Izu Peninsula around 2,700 BP. In addition, the mudflows from the eastern side of Mt Fuji about 2,500 BP also affected the ridge. No archaeological remains have been found in these volcanic deposits (Matsubara, 1998) . Human activity such as the raising of Sanmaibashi and Numazu castles resumed about 500 BP in the mouth of the Kano River. Clearly, volcanic activity in this region strongly influenced human activity.

2. The Shimizu lowland

(1) Geomorphic development of coastal barriers and beach ridges during the Holocene

The Shimizu lowland belongs to the beach ridge plains, facing the western part of Suruga Bay. Mountains of Tertiary origin surround this lowland to the north with a hill (the Pleistocene Udo Hill) to the south (Fig. 7) . Natural levees have developed along the Tomoe River in the middle part of the lowland. At the northeast to the eastern foot of Udo

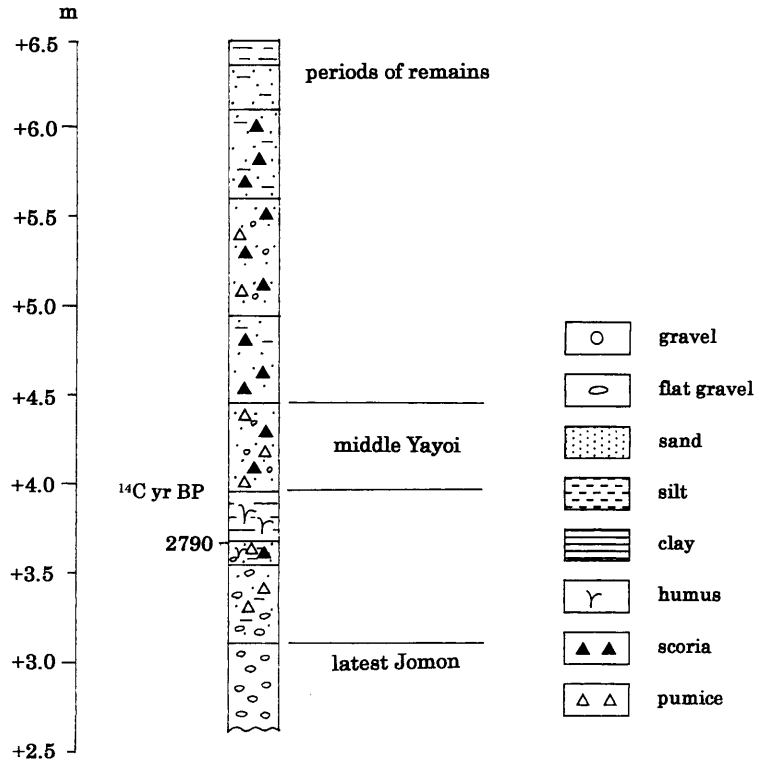

Fig.6 Geologic column and periods of remains at the Sanmaibashi Castle

Hill, Holocene there are coastal terraces (I~III). Alluvial fans, however, are mainly developed at the northwest to the western foot of the hill. Coastal ridges (I~III) have developed here in an atypical north-south direction. In addition, a sand and gravel spit (Miho Spit) runs from the southeastern part of the hill toward the northeast. The basal topography of Miho Spit suggests the existence of a strait at the root of the spit.

Coastal Terrace I had emerged around 6,000 BP, according to ^{14}C dates from marine deposits from the terrace. Afterwards, the Coastal Terraces II and III seaward of Terrace I emerged at the eastern foot of Udo Hill in turn until ca. 5,000 BP. Then, Coastal Ridge II developed seaward of the terraces between 5,000 and 4,000 BP (Matsubara, 2000a). Sampling of the Holocene deposits has been undertaken both in the backmarsh behind Miho Spit (Matsubara, 1988) and in the backmarsh between Coastal Ridges I and II (Matsubara, 2000a). From an analysis of fossil foraminiferal assemblages, a bay began to

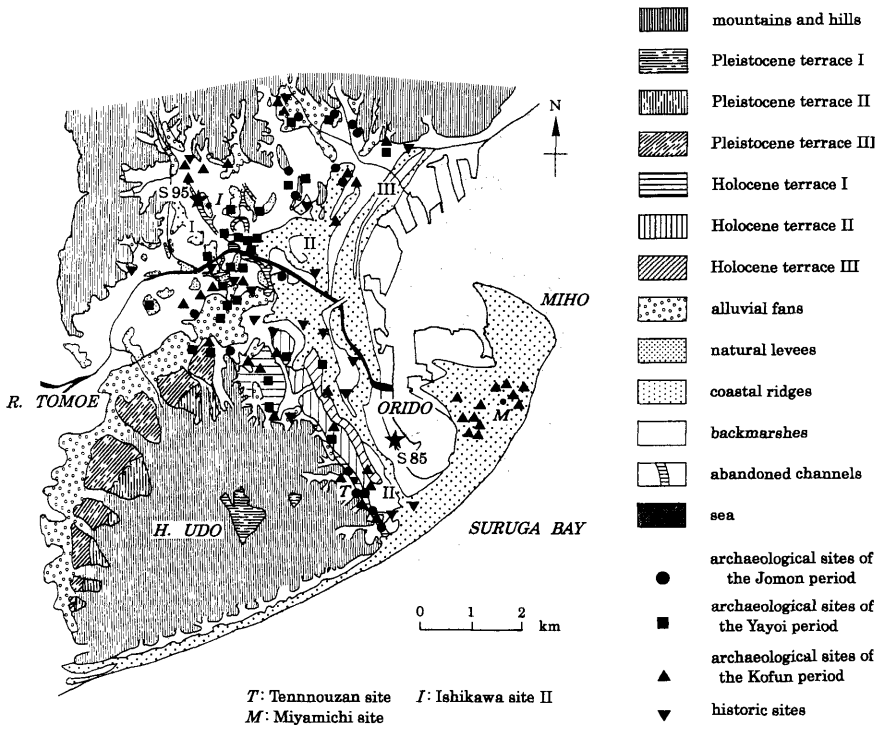

Fig.7 Geomorphological map of the Shimizu lowland
S85 and S95 are boring sites after Matsubara (1988) and Matsubara (2000a), respectively

form around 9,500 BP and Coastal Ridge I began to emerge as a coastal barrier around 6,000 to 5,000 BP. As the inner beach ridge (Coastal Ridge II) developed seaward of the barrier about 5,000 BP, a lagoon began to form behind it. The lagoon was then transformed into a marsh at ca. 4,300 BP by the enclosure of the ridge. While Coastal Ridge II developed, Miho Spit was formed after the connection of an island (Miho Island) with the eastern end of Udo Hill. The outer beach ridge (Coastal Ridge III) began to form around 2,000 BP, according to the ^{14}C dates from marine beds directly beneath the overlying ridge deposits.

(2) Changes of human activities (Distribution of archaeological sites)

The archaeological sites of both the Jomon and Yayoi periods in the Shimizu lowland are mainly distributed on Coastal Ridges I and II, and on the northeast to the eastern foot of

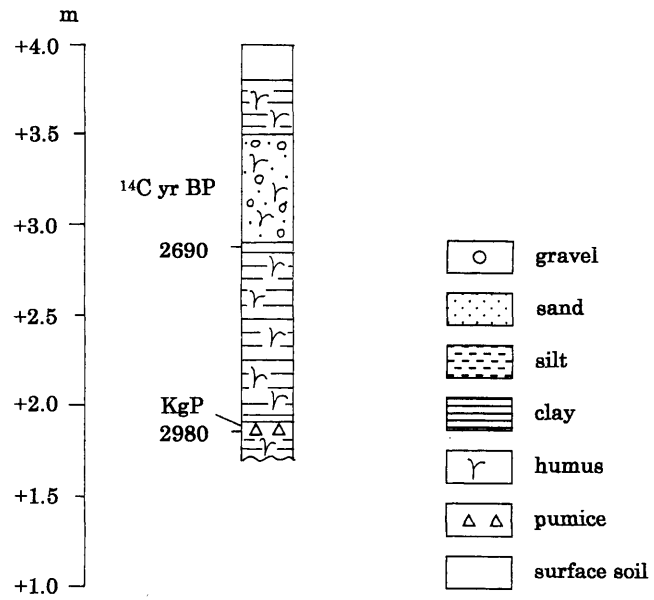

Fig.8 Geologic column at the Ishikawa II site

Udo Hill. In particular, archaeological sites of the Jomon period are recognized on Coastal Terrace I (Fig.7). Human settlement began at the Tennouzan site during the later to latest Jomon period (4,000 to 2,500 BP) on Terrace I. Many archaeological sites of the Yayoi period (ca. 2,000 BP) are distributed on both Coastal Ridges I and II, and also recognized on the natural levees. During the Yayoi period, humans settled in the Ishikawa II site situated on a natural levee (Matsubara, 2000a;b) (Fig. 8). On the other hand, archaeological sites of the Kofun period (ca. 1,500 BP) and historic sites are distributed also on Coastal Ridge III and Miho Spit. Most significantly, human settlement has been recognized at the Miyamichi site located in the middle part of Miho Spit (Fig. 7). Excavations have proved that humans were living there on fishing.

In the Shimizu lowland, humans began to settle on Coastal Terrace I which first developed ca. 6,000 BP, during the later Jomon period (4,000 to 3,000 BP). Since the Yayoi period (ca. 2,000 BP) humans have lived on Coastal Ridge I, constructed 6,000 to 5,000 BP, and on natural levees. Human activity has been verified on Coastal Ridge II and Miho Spit (developed ca. 4,000 BP) since the Kofun period (ca. 1,500 BP). As coastal ter-

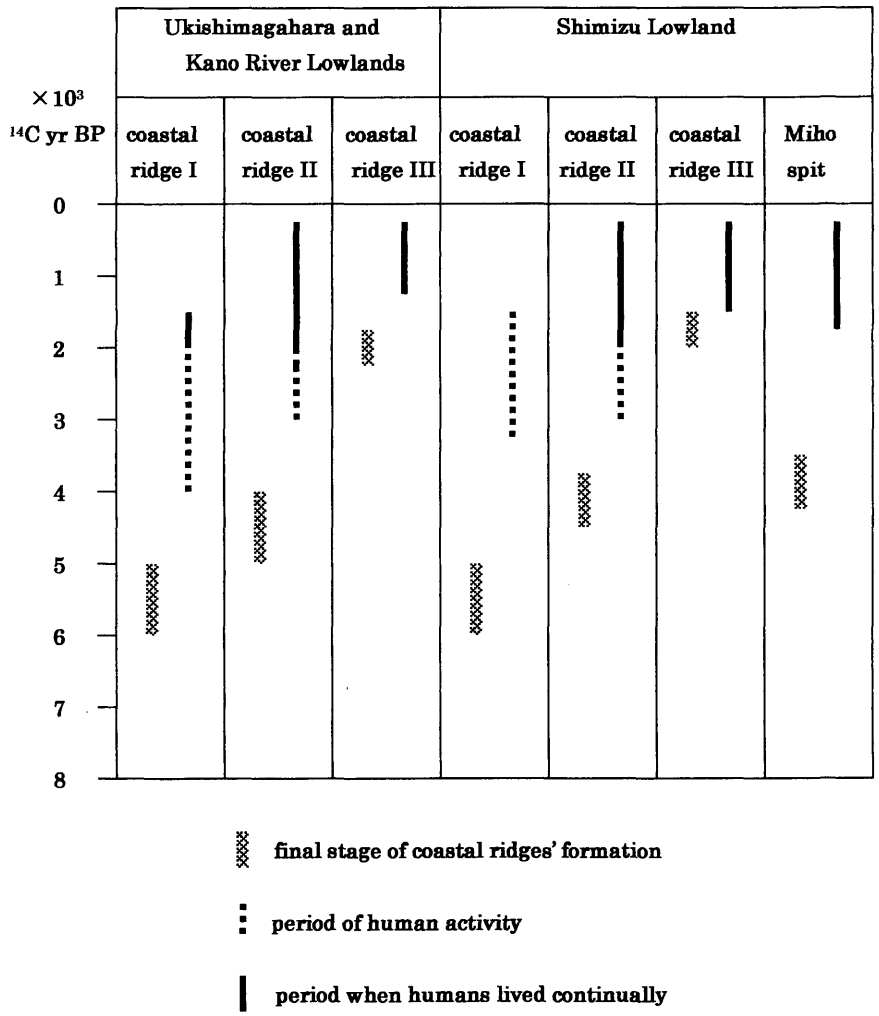

Fig.9 Relationships between the evolution of coastal ridges and human activity in the Kano River, Ukishimagahara and Shimizu lowlands

races at the eastern foot of Udo Hill were narrow, Coastal Terrace I on which the Tennouzan site exited was not sufficiently stable for human settlement until Coastal Ridge II had fully formed at ca. 4,000 BP. As Miho Island came to border on the eastern foot of Udo Hill, Miho Spit developed around 4,000 BP. The land at the root of Miho Spit (the former strait between Miho Island and Udo Hill) was narrow, and so it is inferred that humans could not advance easily onto the spit. It took thousands of years for them to set-

tle there.

IV. Holocene development of coastal lowlands and human settlement along Suruga Bay

The relationship between the development of coastal ridges and terrace, and the changes in human activities are here clarified for the Ukishimagahara, Kano River, and Shimizu lowlands (Fig.9) . In the Ukishimagahara lowland, humans began to advance on the coastal barrier around 4,000 BP. Subsequently, human settlement moved as the beach ridges developed seaward of the barrier. Moreover, tectonic movement (westward and landward downtilting) and volcanic activity (scoria falls) caused the abandonment of the settlement on the coastal barrier around ca. 1,500 BP. Although humans had settled on the coastal ridge in the Kano River lowland since 3,000 BP, volcanic activity disrupted their establishment on the ridge. In the Shimizu lowland, human settlement extended seaward along with the development of the coastal terraces and ridges.

Around 4,000 BP, in the Ukishimagahara lowland humans began to advance onto the coastal barrier, which finished enclosing the lagoon behind it about 6,000 BP. In the Shimizu lowland, humans began to settle in about 3,000 BP on the coastal terrace formed ca. 6,000 BP. In addition, around 2,000 BP, human activities were underway both on the coastal ridges, which finally enclosed the lagoon ca. 4,000 BP, and on the spit formed almost at the same period.

The chronology presented here indicates that humans began to advance and settle on the coastal terraces and ridges thousands of years after the final stages of their formation. The reason for the time lag is inferred from the fact that it took thousands of years for those landforms to become stablilized and free from the influence of seawater.

V. Conclusion

The coastal ridges in the lowlands were important landforms for human settlement during the Holocene. Human activity has been influenced by the development of the coastal

ridges and by devastating volcanic events. Time lags are recognized between the periods of the final stages of coastal ridges formation and when humans began to advance and settle on the ridges. It is inferred that the environment around the coastal ridges only became stable and suitable for human settlement thousands of years after coastal ridge enclosure.

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Notes : (J) : in Japanese, (J+E) : in Japanese with English abstract.