Title	完新世における日本の砂州・浜堤の発達過程
Sub Title	Processes in Holocene development of coastal ridges in Japan
Author	松原, 彰子(Akiko, Matsubara)
Publisher	慶應義塾大学日吉紀要刊行委員会
Publication year	2005
Jtitle	慶應義塾大学日吉紀要. 社会科学 No.15 (2005.) ,p.73- 90
JaLC DOI	
Abstract	
Notes	
Genre	Departmental Bulletin Paper
URL	https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=AN10425830-20050000-0073

Processes in the Holocene Development of Coastal Ridges in Japan

Akiko Matsubara

I. Introduction

The coastal lowlands of the Japanese Islands can be classified into alluvial fans, alluvial deltas, and sand or gravel ridges-backmarsh complexes. Alluvial fans develop at river mouths with high coarse sediment supply and face towards steep sea bottoms, such as the Fuji River fan along the Suruga Bay and the Kurobe River fan along the Toyama Bay. Alluvial deltas dominate in the coast of the inner part of bays and have been supplied with high level of fine sediment. The Nobi and Tsukushi lowlands are typical deltaic lowlands. Coastal ridges developed in sand or gravel ridges-backmarsh complexes are usually parallel to the shore and represent former coastal barriers and beach ridges. Among these three types of coastal lowlands, the ridge-backmarsh complexes are the most extensively distributed along the Japanese coast (Tab.1, Fig.1).

The purpose of this paper is to review the past studies on the development of coastal barriers and beach ridges in Japan, and clarify the characteristics of processes in the development.

Studies on the geomorphic development of the coastal lowlands in Japan have mainly dealt with the land-forming stage during the late Holocene. Regarding the studies on the coastal ridges, most have been on the development of beach ridges when the sea level stabilized or slightly lowered during the late Holocene. Some studies have dealt with the formation of barrier complexes when the sea level was rising before the culmination of the transgression in the early to mid Holocene (Moriwaki, 1979; Suzuki and Saito, 1987). However, they have

Tab.1 Studies on development of coastal ridges in Japan

No.	Lowlands or Lakes	Type	A	B	Literature
1	Sarobetsu lowland	b	○	○	Akamatsu *et al*.(1981), Sakaguchi *et al*.(1985), Ohira(1995)
2	Lake Saroma	a		○	Hirai(1987, 1994)
3	Tokoro lowland	b	○		Sakaguchi *et al*.(1985) Hamano *et al*.(1985), Matsubara(2000)
4	Notsuke spit	f-1			Takano(1978)
5	Lake Furen	a			Ohira *et al*.(1994)
6	Kushiro lowland	b			Okazaki(1960a,b)
7	Ishikari lowland	b	○		Uesugi · Endo(1973), Matsushita(1979)
8	Yufutsu lowland	c	△		Moriwaki(1982)
9	Lake Tsugaru-jusan	a		○	Onuki *et al*.(1963), Minoura · Nakaya(1990)
10	Aomori lowland	b			Matsumoto(1984)
11	Tanabu lowland	d-2			Matsumoto(1984)
12	Lake Ogawara	a		○	Hirai(1983, 1994), Ishizuka · Kashima(1986)
13	Noshiro lowland	a,b		○	Mii(1960), Shiraishi(1990)
14	Akita lowland	c		○	Mii(1960), Moriwaki(1982), Matsumoto(1984), Shiraishi(1990)
15	Shonai lowland	e	○		Ariga(1984)
16	Ishinomaki lowland	c			Matsumoto(1984)
17	Sendai lowland	b	○		Matsumoto(1981,1984), Ito(2003)
18	Niigata lowland	b	△		Niigata Ancient Dune Research Group(1974); Moriwaki(1982), Nakagawa(1987), Ohira(1992), Tanaka *et al*.(1996)
19	Lake Kamo	a	△		Kobayashi *et al*.(1993), Hirai(1995), Nguyen *et al*.(1998)
20	Iwaki lowland	c			Fujimoto(1988)
21	Lake Kasumigaura	a	○	○	Saito *et al*.(1990), Hirai(1994)
22	Kujukuri lowland	c	○		Moriwaki(1979)
23	Obitsu River lowland	e			Kaizuka *et al*.(1979)
24	Futtsu lowland	f-2	△	○	Kayane(1991)
25	Tateyama lowland	c			Matsubara(1995), Fujiwara *et al*.(1997)
26	Sagami River lowland	e	○	○	Ota · Seto(1968), Kaizuka · Moriyama(1969), Matsubara(2000)

No.	Lowlands or Lakes	Type	A	B	Literature
27	Matsuzaki lowland	d-1	△		Matsubara *et al*.(1986), Matsubara(1988, 2000)
28	Ukishimagahara lowland	b	○		Matsubara(1984, 1988, 2000)
29	Shimizu lowland Miho spit	c f-1	△	○	Matsubara(1988, 1999, 2000)
30	Haibara lowland	d-2	○	○	Matsubara(1988, 2000)
31	Lake Hamana	a	○		Saito(1988), Matsubara(2000, 2001, 2004)
32	Utsumi lowland	d-2	△	△	Maeda *et al*.(1983)
33	Toyama Bay lowland	b			Fuji(1975)
34	Lake Kahokugata	a	○	○	Fuji(1975), Kaseno *et al*.(1990)
35	Fukui lowland	b		○	Fuji(1975)
36	Osaka and Kawachi plains	b			Kajiyama · Itihara(1972)
37	Mihara lowland	e			Takahashi(1982)
38	Amanohashidate	a	△		Hirai(1995)
39	Tottori lowland	a		○	Akagi *et al*.(1993)
40	Lake Nakaumi	a		○	Mizuno *et al*.(1972), Tokuoka *et al*.(1990), Sadakata(1991), Hirai(1994)
41	Lake Shinji Izumo lowland	a e	○	○	Tokuoka *et al*.(1990), Hayashi(1991), Hirai(1994)
42	Suonada lowlands	b, d-1, e		○	Shiragami(1983)
43	Kochi lowland	b			Sadakata *et al*.(1988)
44	Tamana lowland	e			Nagaoka *et al*.(1997)
45	Miyazaki lowland	c	○		Nagaoka *et al*.(1991)
46	Kimotsuki lowland	d-2	○		Nagasako *et al*.(1999)

a. barrier-lagoon complexes b. barrier-backswamp complexes c. beach ridge plains d. valley plains(d-1. barrier-backswamp, d-2. beach ridges) e. delta-beach ridge complexes f. others(f-1. barrier spits, f-2. cuspate forelands)

A: Presence of barriers during the early to mid Holocene, B: Presence of basal landforms of barriers. ○ indicates the presence of barriers, or the presence of basal landforms of the barriers. △ indicates these presence without any definite evidences

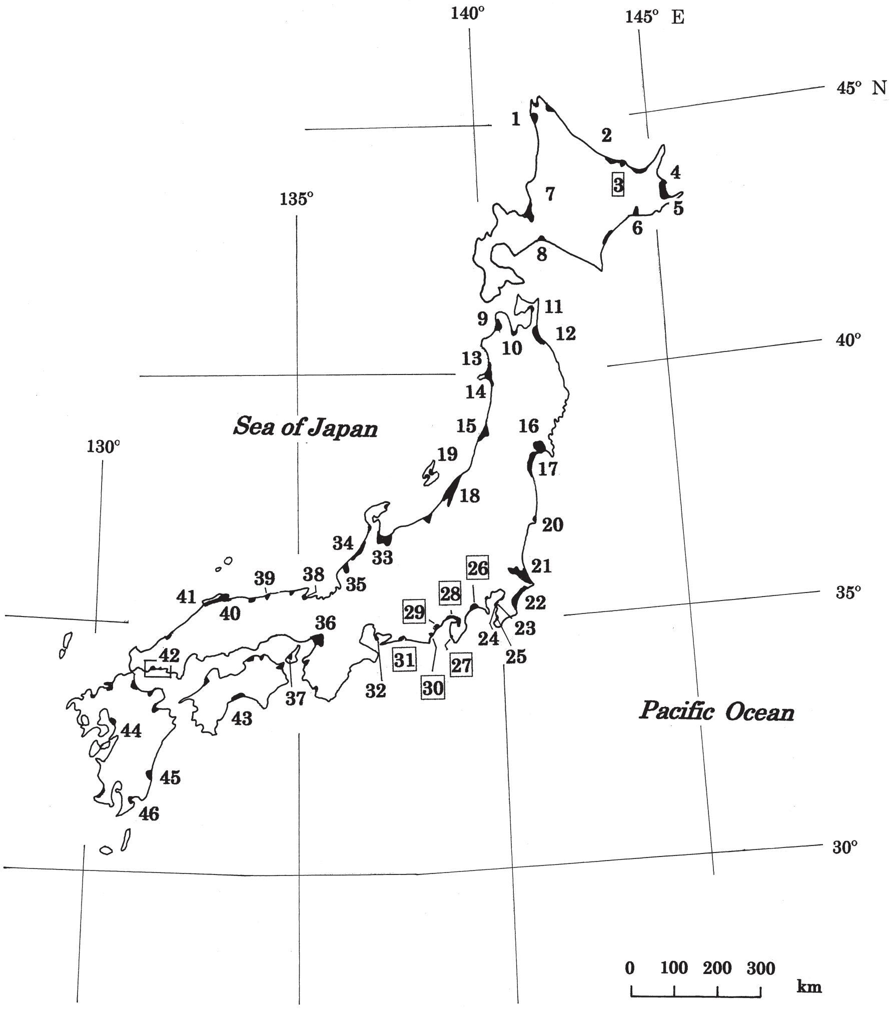

Fig.1 Distribution of coastal ridges in Japan

Each number corresponds to that in Table1.

not made clear enough the development of barriers and beach ridges through the Holocene. Matsubara (1988; 2000) reconstructed the palaeoenvironmental changes of the bays along the Suruga Bay on the basis of the analysis of fossil foraminiferal assemblages in the bore hole cores, and then clarified the geomorphic development of the coastal lowlands during the Holocene (Fig.2). These case studies indicated the processes in the development of barriers while the sea level was rising during the early to mid Holocene, and also in the development

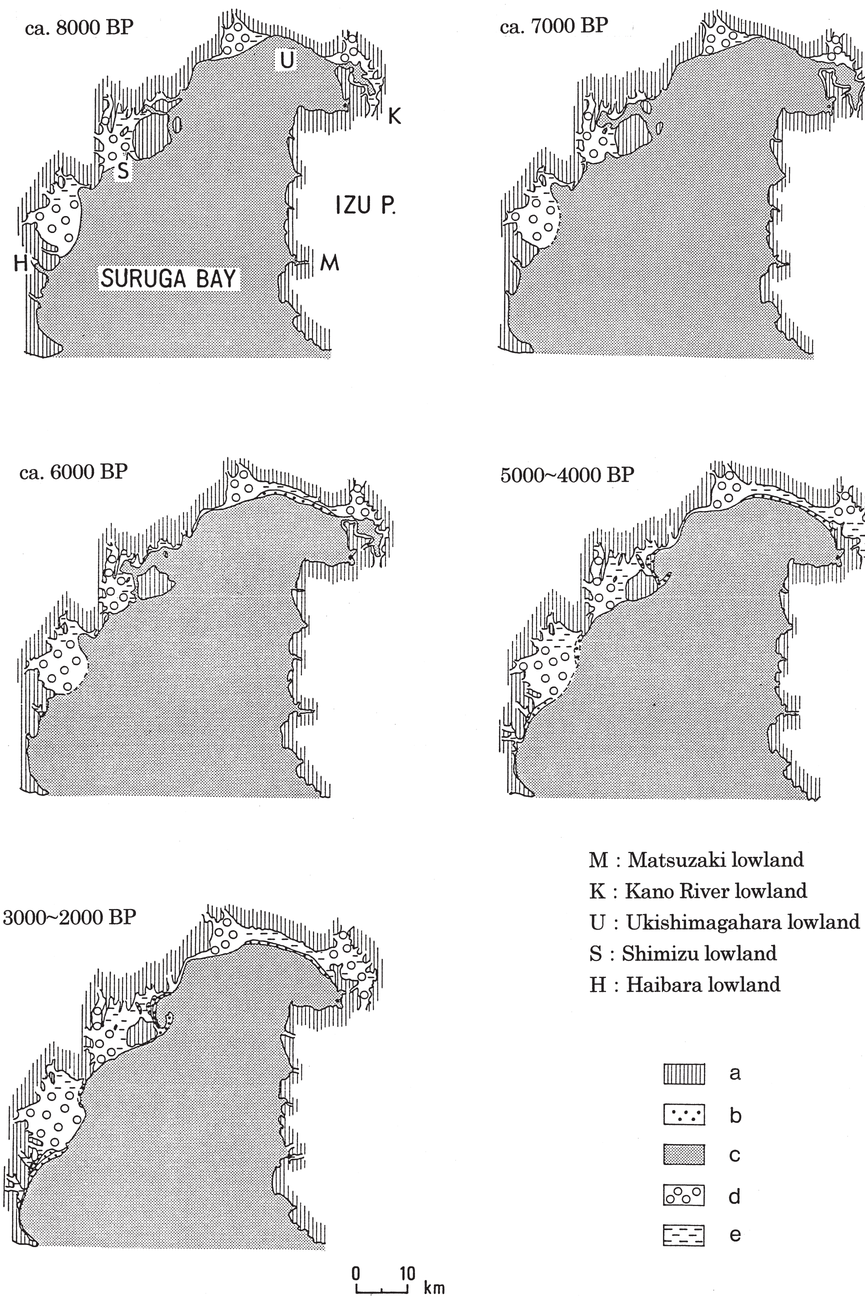

Fig.2 Palaeogeographical maps in the coastal lowlands along the Suruga Bay during the Holocene

a. mountains and hills; b. coastal ridges; c. sea; d. alluvial fans; e. backswamps.

of beach ridges when the sea level stabilized or slightly lowered during the late Holocene.

II. Classification and distribution of coastal ridges in Japan

The coastal lowlands composed of sand or gravel ridge-backmarsh complexes and the coastal lagoons can be classified into six types (a) to (f) as below, according to the present landform.

(**a**) **Barrier-lagoon complexes (barrier systems)**: Lagoons develop behind coastal barriers such as in Lake Saroma (No. 2 in Tab.1 and Fig.1), Lake Kasumigaura (No. 21), Lake Hamana (No. 31) and Lake Nakaumi (No. 40).

(**b**) **Sand or gravel ridge-backmarsh complexes**: Marshes or swamps develop behind the coastal ridges. Beach ridges' width are narrower. For instance, this type of lowlands develops in the Tokoro (No. 3), Ishikari (No. 7), Niigata (No. 18) and Ukishimagahara (No. 28) lowlands.

(**c**) **Beach ridge plains (strand plains)**: Beach ridges widely developed such as in the Kujukuri (No. 22), Shimizu (No. 29) and Miyazaki (No. 45) lowlands.

(**d**) **Valley plains**: Coastal ridges developed to enclose the past buried bays. The (d-1) type is valley plains with ridge-backmarsh complexes, such as in the Matsuzaki (No. 27) and Suonada (No. 42) lowlands. The (d-2) type is valley plains with beach ridges, such as in the Tanabu (No.11) and Haibara (No. 30) lowlands.

(**e**) **Delta-beach ridge complexes**: Both deltas and beach ridges well developed, such as in the Shonai (No. 15), Sagami River (No. 26) and Izumo (No. 41) lowlands.

(**f**) **Others**: The (f-1) type is barrier spits such as in the Notsuke (No. 4) and Miho (No. 29) spits. The (f-2) type is cuspate forelands such as in the Futtsu lowland (No. 24).

III. Geomorphic development of coastal ridges during the Holocene

1. Distribution and development of the coastal ridges in the world

Barrier islands widely distributed along wave-dominated and stable trailing edge coasts (Davis, 1994a; Koike and Ota, 1997). The primary requisites for formation of the barriers are sedimentary supply, processes of developing and maintaining the barriers, and geomorphic setting (Davis, 1994b).

The origin of barrier islands has been discussed for a long time. There were three main theories about the origin of barrier islands: (1) the drowning of coastal ridges (Hoyt, 1967); (2) the emergence of shallow sand bar (Otvos, 1970); (3) the growth of spit (Fisher, 1968). It is considered that there are various origins depending on region, period, and other setting. However, from the developmental point of view, the rise in sea level during the Holocene was common and major factor in the development of the coastal barriers (Davis, 1994b; Trenhaile, 1997). Before 7000 BP during the Holocene, the sea level rose rapidly. Therefore, there was no stable shoreline to exist long enough to develop barrier islands. On the other hand, around 7000 to 6500 BP, the rate of sea level rise slowed. Then, shoreline positions became more stable and molded the coasts (Davis, 1994a). Generally, barriers were developing and transgressing landward when the sea level was rising rapidly. On the other hand, the beach ridges began to develop seaward when the sediment rate became higher than the rate of the rise in sea level.

Beach ridge plains well develop along the north coast of Canada, the Gulf of Mexico, and the southeast coast of Australia. The development of beach ridges are considered to be related to the various conditions, such as waves, storms, sediment supply, the sea level changes, and isostatic crustal movements (Tanner, 1988; Mason, 1993; Mason and Jordan, 1993).

2. Geomorphic development of coastal barriers and beach ridges in relation to the sea level changes in Japan

A common pattern in the relative sea level changes around Japan is that the sea rose above the present level (Pirazolli, 1991; Bird, 2000). It is known that the sea level generally reached its highest level (3 to 5 m higher than at present) at around 6000 BP. After the culmination of the Holocene transgression, the sea level stabilized, or even lowered slightly, and has since changed with minor fluctuations (Ota *et al.*, 1982; Ota *et al.*, 1990; Umitsu, 1991). Geomorphic evolution of the coastal lowlands was deeply influenced by the Holocene sea level changes.

Common processes in the development of coastal barriers are recognized on the basis of the palaeoenvironmental changes in seven study areas (Matsubara, 2000; 2002). These areas are Lake Hamana (barrier-lagoon complexes), the Tokoro and Ukishimagahara lowlands (sand or gravel ridge-backmarsh complexes), the Shimizu lowland (beach ridge plains), the Matsuzaki lowland (valley plains with ridge-backmarsh complexes), the Haibara lowland (valley plains with beach ridges), and the Sagami River lowland (delta-beach ridge complexes). Three stages in the development of barriers are recognized in the following manner (Fig.3).

Ⅰ. **Initial period of formation of barrier:** Before 7000 BP, when the rate of the rise in sea level was higher than the sedimentation rate, the bays were formed by the Holocene transgression. At this stage, barriers had not yet emerged, though the basal deposits in the barriers began to accumulate. The bays were expanding by the transgression without regard to the differences of the antecedent topography and sediment supply.

Ⅱ. **Initial period of enclosure by barrier:** Around 7000 to 6000 BP, the sedimentation rate became higher than the rate of the rise in sea level. The facies of the marine deposits had no lithologic changes. Therefore, the cause of the relationships between the sedimentation rate and the rate of sea-level rise, is not the change in the rate of sedimentation, but the change in the rate of the rise in sea level. This suggests, then, that the rate of the rise in sea level was decreasing around 7000 to 6000 BP. Then, the sea level was stable or slightly lowered just after the culmination of the Holocene transgression about 6000 to 5000 BP (Ota *et al*., 1982, 1990; Pirazolli, 1991; Umitsu, 1991). At the period between 7000 and 5000 BP, barriers emerged and began to enclose the bays, and the bays changed into lagoons.

Previous studies implied that the coastal barriers began to form before 6000 BP in the Sarobetsu (Sakaguchi *et al*., 1985; Ohira, 1995), Ishikari (Matsushita, 1979), Niigata (Moriwaki, 1982), Sendai (Matsumoto, 1981; 1984; Ito, 2003), Yufutsu (Moriwaki, 1982), Kujukuri (Moriwaki, 1979), Miyazaki (Nagaoka *et al*., 1991), and Kimotsuki (Nagasako *et al*., 1999) lowlands.

Ⅲ. **Final period of enclosure by barrier:** Around 6000 to 5000 BP, when the sea level

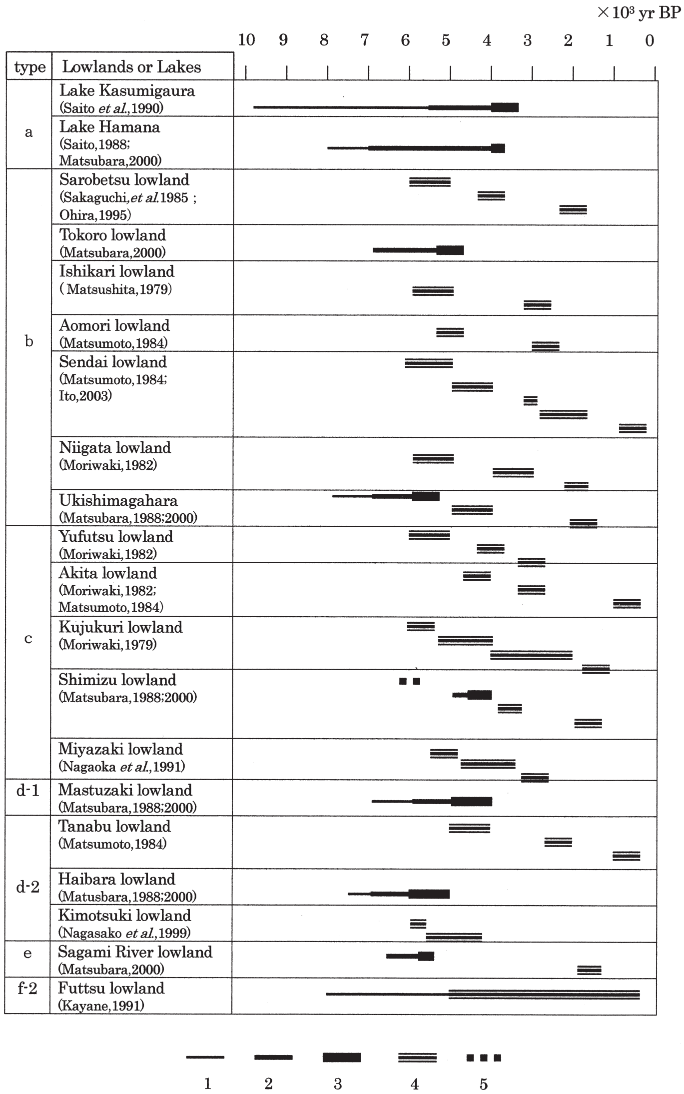

Fig.3 Holocene development of coastal barriers and beach ridges in Japan

1. the period when basal deposits in barriers accumulated
2. the initial stage of barrier enclosure inferred from analysis of fossil foraminiferal assemblages or sedimentary facies
3. the final stage of barrier enclosure
4. the final stage of barrier formation based on ^{14}C ages of bottom of peat or periods of archaeological sites on coastal barriers
5. the final stage of barrier formation (uncertain)

was stable or became lower, the barriers finished enclosure and changed the lagoons into marshes. Then, beach ridges began to develop seaward of the barriers.

The period of the development of the innermost beach ridges in the Ukishimagahara and Shimizu lowlands corresponds to the first phase on the regression after the culmination of the Holocene transgression around 5000 to 4000 BP (Ota *et al*., 1982; 1990). In the previous studies, similar results have obtained from the Sarobetsu, Yufutsu, Kujukuri, Miyazaki and Kimotsuki lowlands. The second beach ridges in the Ukishimagahara, Shimizu and Sagami River lowlands developed about 3000 to 2000 BP, when the second phase on the regression was recognized (Ota *et al*., 1982; 1990). Similar results have obtained from the Sarobetsu, Sendai, Kujukuri, and Miyazaki lowlands.

The differences in the development of coastal barriers can be recognized from the period of enclosure by the barriers. The controlling factors of both the barriers' development and the landforms of the coastal lowlands are tectonic movements, the basal topography of the coastal lowlands and the sediment supply. In the case study of the geomorphic development of the Ukishimagahara lowland, it can be recognized that the subsidence of a coastal barrier and an earlier enclosure of the bay by the barrier occurred from the tectonic movement of the downtilting landward. Furthermore, from the comparison of the Matsuzaki and Haibara lowlands, the presence of basal landforms in a coastal lowland, along with an abundant sediment supply, accelerated the development of a coastal barrier and beach ridges (Matsubara, 2002).

3. Relationships between development of coastal lowlands and human settlement

According to the results of the development of coastal lowlands and the changes in human activities in the Ukishimagahara, Kano River and Shimizu lowlands, the relationships between them were recognized in the followings (Matsubara, 2003).

In the Ukishimagahara lowland, humans began to advance on the coastal barrier around 4000 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 fall）caused the abandonment of the settlement on the coastal barrier around 1500 BP. Although humans had settled on the coastal ridge in the Kano River lowland since 3000 BP, volcanic activity disrupted their establishment in the ridge. In the Shimizu lowland, human settlement extended seaward along with the development of the coastal terraces and ridges.

Around 4000 BP, in the Ukishimagahara lowland, humans began to advance onto the coastal barrier, which finished enclosing the lagoon behind it about 6000 BP. In the Shimizu lowland, humans began to settle in about 3000 BP on the coastal terrace formed ca. 6000 BP. In addition, around 2000 BP, human activities were underway both on the coastal ridges, which finally enclosed the lagoon ca. 4000 BP, and on the Miho 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 stabilized and free from the influence of sea water.

IV. Conclusions

The processes of the geomorphic development of the barriers and beach ridges are clarified in relation to the relative sea level changes during the Holocene, in the following manner.

The basal deposits in the barriers began to accumulate before 7000 BP, at the time of the lower sea level during the Holocene transgression. However, the bays were expanding by the transgression without regard to the differences of the antecedent topography and sediment supply, and the barriers had not yet emerged.

The rate of the rise in sea level decreased around 7000 to 6000 BP, and the sea level was stable or slightly lowered about 6000 to 5000 BP. During these periods, the barriers emerged and began to enclose the bays.

When the sea level became lower about 6000 to 5000 BP, the barriers finished enclosing the bays and beach ridges began to develop seaward of the barriers. The periods of the development of the beach ridges correspond to the two phases on the regression after the culmination of the Holocene transgression around 5000 to 4000 BP and 3000 to 2000 BP, respectively.

References

Akagi, S., Toyoshima. Y., Hoshimi, K., and Tanimura, M. 1993: Geoenvironment and geologic history of Lake Koyamaike, Tottori Prefecture. *Mem. Geol. Soc. Japan*, 39, 103－116. （J+E）

Akamatsu, M., Kitagawa, Y., Matsushita, K., and Igarashi, Y. 1981: ^{14}C-age of the shell beds in Sarobetsu moor and Ishikari coastal plain, Hokkaido. *Chikyu Kagaku*（Earth Science）, **35**, 215－218. （J）

Ariga, T. 1984: Geomorphological development of Shonai coastal plain, northeastern Japan: The behavior of alluvial fan's front since latest Pleistocene. *Annals, Tohoku Geogr. Assoc*. **36**, 13－24. （J+E）

Bird, E. 2000: *Coastal Geomorphology An Introduction*. Wiley. 322p.

Davis, R. A. 1994a: *The Evolving Coast*. Scientific American Library. 231p.

Davis, R. A. 1994b: Barrier island systems － a geologic overview － . In *Geology of Holocene barrier island systems*. ed. R.A. Davis, 1－46. Berlin: Springer － Verlag.

Fisher, J. I. 1968: Barrier island formation: Discussion. *Geol. Soc. Amer. Bull*. **79**, 1421－1425.

Fuji, N. 1975: The coastal sand dunes of Hokuriku district, Central Japan. *The Quat. Res*., **14**, 195－220. （J+E）

Fujimoto, K. 1988: Beach-ridge ranges and their formative periods on three Holocene coastal plains in the southeastern part of Fukushima Prefecture, Northeastern Japan. *Annals, Tohoku Geogr. Assoc*. **40**, 139－149. （J+E）

Fujiwara, O., Masuda, F., Sakai, T., Fuse, T., and Saito, A. 1997: Tsunami deposits in Holocene bay-floor muds and the uplift history of the Boso and Miura Peninsulas. *The Quat. Res*., **36**, 73－86. （J+E）

Hamano, Y., Maeda, Y., Matsumoto, E., and Kumano, S. 1985: Holocene sedimentary history of some coastal plains in Hokkaido, Japan. III. Transition of diatom assemblages in Tokoro along the Okhotsk Sea. *Japan Jour. Ecol*., **35**, 307－316.

Hayashi, M. 1991: Geomorphic development of the Izumo plain, Western Japan. *Geogr. Rev. Japan*, **64**A, 26－46.（J+E）

Hirai, Y. 1983: Lacustrine and sublacustrine microforms of Lake Ogawara with relation to the lake-level changes after the maximum postglacial transgression. *Annals, Tohoku Geogr. Assoc*., **35**, 82－91.（J+E）

Hirai, Y. 1987: Lacustrine and sublacustrine microforms and deposits near the shoreline of Lake Saroma and the sea level changes in the Sea of Okhotsk in late Holocene. *Annals*, *Tohoku Geogr. Assoc*., **39**, 1－15.（J+E）

Hirai, Y. 1994: Geomorphological development of the lagoons in Japan. *Mem. Fac. Ehime Univ., Nat. Sci*., **14**, 1—71.（J+E）

Hirai, Y. 1995: *Lake Environment of the Coastal Lagoons in Japan*. Kokon-Shoin Ltd. 186p.（J）

Hoyt, J. H. 1967: Barrier island formation. *Geol. Soc. Amer. Bull*., **78**, 1125－1135.

Ishizuka, T. and Kashima, K. 1986: Holocene water level changes of Lake Ogawara presumed by diatom analysis, eastern part of Aomori Prefecture, North Japan. *Geogr. Rev. Japan*, **59**A, 205－212.（J+E）

Ito, A. 2003: Periods of beach ridge range formation on the Kitakami River lowlands and late Holocene sea-level changes around Sendai Bay, Northeastern Japan. *Geogr. Rev. Japan*, **76**, 537－550.（J+E）

Kaizuka, S. and Moriyama, A. 1969: Geomorphology and subsurface geology of the alluvial plain of the lower Sagami River, Central Japan. *Geogr. Rev. Japan*, **42**, 85－105.（J+E）

Kaizuka, S., Akutsu, J., Sugihara, S., and Moriwaki, H. 1979: Geomorphic development of alluvial plains and coasts during the Holocene in Chiba Prefecture, Central Japan, with a note on diatom assemblages in Holocene deposits near the junction of rivers Miyako and Furuyama. *The Quat. Res*., **17**, 189－205.（J+E）

Kajiyama, H. and Itihara, M. 1972: The development history of the Osaka plain with references to the radio-carbon dates. *Mem. Geol. Soc. Japan*, 7, 101－112.（J+E）

Kaseno, Y., Kojima, K., Nakagawa, K., and Miyata, T. 1990: Lagoon Kahoku-gata, Ishikawa Prefecture – Geologic history, geotechnics and the aqueous environment after reclamation works. *Mem. Geol. Soc. Japan*, 36, 35 – 45. (J+E)

Kayane, H. 1991: Change in molluscan assemblages in the Holocene accompanied by the foramation of Futtu Spit, Boso Peninsula. *The Quat. Res.*, **30**, 265 – 280. (J+E)

Kobayashi, I., Kanzo, K., Kamoi, Y., and Watanabe, Y. 1993: Natural environment and history of Lake Kamo, Sado Island. *Mem. Geol. Soc. Japan*, 39, 89 – 102. (J+E)

Koike, K. and Ota, Y. 1997: Coastal landforms in the world. In *Landforms in the World*. ed. S. Kaizuka, 229 – 247. Tokyo Univ. Press. (J)

Maeda, Y., Yamashita, K., Matsushima, Y., and Watanabe, M. 1983: Marine transgression over Mazukari shell mound on the Chita Peninsula, Aichi Prefecture, Central Japan. *The Quat. Res.*, **22**, 213 – 222. (J+E)

Mason, O. K. 1993: The geoarchaeology of beach ridges and cheniers: Studies of coastal evolution using archaeological data. *Jour. Coast. Res.*, **9**, 126 – 146.

Mason, O. K. and Jordan, J. W. 1993: Heightened North Pacific storminess during synchronous late Holocene erosion of Northwest Alaska beach ridges. *Quat. Res.*, **4**, 55 – 69.

Matsubara, A. 1984: Geomorphic development of the alluvial plain facing the inner Suruga Bay. *Geogr. Rev. Japan*, **57**, 37 – 56. (J+E)

Matsubara, A. 1988: Geomorphic development of barriers in the coastal lowlands during the Holocene – A case study of the coastal lowlands along the Suruga Bay, Central Japan – *Bull. Dep. Geogr. Univ. Tokyo*, 20, 57 – 77.

Matsubara, A. 1995: Palaeoenvironmental changes in Tateyama lowland. *Bull. Shonan Kokusai Women's Junior College*, 3, 25 – 39. (J)

Matsubara, A. 1999: Palaeogeographical changes in the Seishin lowland along the Suruga Bay. *Hiyoshi Rev. Soc. Sci., Keio Univ.*, 9, 1 – 19. (J)

Matsubara, A. 2000: Holocene geomorphic development of coastal barriers in Japan. *Geogr. Rev., Japan*, **73**A, 409 – 434. (J+E)

Matsubara, A. 2001: Coastal barriers in Hamana Lake and the Hamamatsu lowland. *Hiyoshi Rev. Soc. Sci., Keio Univ.*, 11, 20 – 32. (J)

Matsubara, A. 2002: Holocene geomorphic development of coastal barriers in Japan. *Hiyoshi Rev. Soc. Sci., Keio Univ.*, 12, 37 – 68.

Matsubara, A. 2003: Relationships between Holocene geomorphic development of coastal ridges and human activities – A case study of the coastal lowlands along Suruga Bay, Central Japan – . *Hiyoshi Rev. Soc. Sci. Keio Univ*., 13, 23 – 40.

Matsubara, A. 2004: Sedimentary environment around archaeological sites in the Hamamatsu lowland. *Hiyoshi Rev. Soc. Sci., Keio Univ*., 14, 35 – 52. (J)

Matsubara, A., Matsushima, Y., Ishibashi, K., Moriwaki, H., and Kashima, K. 1986: Environmental changes during the Holocene in the Matsuzaki Lowland, western part of the Izu Peninsula, Central Japan. *Jour. Geogr*., **95**, 339 – 356. (J+E)

Matsumoto, H. 1981: Sea-level changes during the Holocene and geomorphic development of the Sendai coastal plain, Northeast Japan. *Geogr. Rev. Japan*, **54**, 72 – 85. (J+E)

Matsumoto, H. 1984: Beach ridge ranges on Holocene coastal plains in northeast Japan – The formative factors and periods – . *Geogr. Rev. Japan*, **57**A, 720 – 738. (J+E)

Matsushita, K. 1979: Buried landforms and the upper Pleistocene～Holocene landforms deposits of the Ishikari coastal plain, Hokkaido, North Japan. *The Quat. Res*., **18**, 69 – 78. (J+E)

Mii, H. 1960: Holocene deposits of Hachiro-gata (Lagoon). *Sci. Rep., Tohoku Univ., 2nd Ser* (*Geol.*) *Spec. Vol*., **4**, 590 – 598. (J+E)

Minoura, K. and Nakaya, S. 1990: Origin of inter-tidal lake and marsh environments in and around Lake Jusan, Tsugaru. *Mem. Geol. Soc. Japan*, 36, 71 – 87. (J+E)

Mizuno, A., Ohshima, K., Nakano, S., Noguchi, Y., and Masaoka, E. 1972: Late Quaternary history of the brackish lakes Naka-umi and Shinji-ko on San'in coastal plain, and related some problems. *Mem. Geol. Soc. Japan*, 7, 113 – 124. (J+E)

Moriwaki, H. 1979: The landform evolution of the Kujukuri coastal plain, Central Japan. *The Quat. Res*., **18**, 1 – 16. (J+E)

Moriwaki, H. 1982: Geomorphic development of Holocene coastal plains in Japan. *Geogr. Rep. Tokyo Metropolitan Univ*. 17, 1 – 42.

Nagaoka, S., Maemoku, H., and Matsushima, Y. 1991: Evolution of Holocene coastal landforms in the Miyazaki plain, Southern Japan. *The Quat. Res*., **30**, 59 – 78. (J+E)

Nagaoka, S., Yokoyama, Y., Nakada, M., Maeda, Y., Okuno, J., and Shirai, K. 1997: Holocene geomorphic development and sea-level change in the Tamana plain, southeastern coast of

Ariake Bay, Western Japan. *Geogr. Rev. Japan*, **70**A, 287－306.（J+E）

Nagasako, T., Okuno, M., Moriwaki, H., Arai, F., and Nakamura, T. 1999: Paleogeography and tephras of the Kimotsuki lowland, southern Kyushu, Japan, in the middle to late Holocene. *The Quat. Res*., **38**, 163－173.（J+E）

Nakagawa, T. 1987: Late Pleistocene and Holocene developments of Niigata Plain, Central Japan. *Jour. Geol. Soc. Japan*, **93**, 575－586.（J+E）

Nguyen, V. L., Tateishi, M., and Kobayashi, I. 1998: Reconstruction of sedimentary environments for late Pleistocene to Holocene coastal deposits of Lake Kamo, Sado Island, Central Japan. *The Quat. Res*., **37**, 77－94.

Niigata Ancient Dune Research Group 1974: Niigata sand dunes and archaeological relics－The geohistory of the formation of Niigata sand dunes, PartI－. *The Quat. Res*., **13**, 57－65.（J+E）

Ohira, A. 1992: Geomorphic development of the northeastern part of the Niigata plain, Central Japan, during the Holocene. *Geogr. Rev. Japan*, **65**A, 876－888.（J+E）

Ohira, A. 1995: Holocene evolution of peatland and paleoenvironmental changes in the Sarobetsu lowland, Hokkaido, Northern Japan. *Geogr. Rev. Japan*, **68**A, 695－712.（J+E）

Ohira, A., Umitsu, M., and Hana, S. 1994: Late Holocene development of peatlands in small alluvial lowlands around Lake Furen, eastern Hokkaido, Japan. *The Quat. Res*., **33**, 45－50.（J）

Okazaki, Y. 1960a: Topographic development of the Kushiro moor and its surroundings, Hokkaido, Japan. *Geogr. Rev. Japan*, **33**, 462－473.（J+E）

Okazaki, Y. 1960b: Paleogeography of the Kushiro plain, Hokkaido in the alluvial age. *The Quat. Res*., **1**, 255－262.（J+E）

Onuki, Y., Mii, H., Shimada, I., Takeuti, S., Ishida, T., and Saito, T. 1963: Late Quaternary history of Tsugaru Jusanko（Jusan Lagoon）district, Aomori Prefecture, Japan. *Tohoku Univ., Sci. Rep.*（*Geol.* ）, **58**, 1－85.（J+E）

Ota, Y. and Seto, N. 1968: Note on the problems of sand dunes at the coastal area along the Sagami Bay, Kanagawa Prefecture, Central Japan. *Bull. Yokohama National Univ. Sci., Sec. II*., **14**, 35－60.（J+E）

Ota, Y., Matsushima, Y., and Moriwaki, H. 1982: Note on the Holocene sea-level study in

Japan − On the basis of "Atlas of Holocene Sea-level Records in Japan" − . *The Quat. Res.*, **21**, 133 − 143. (J+E)

Ota, Y., Umitsu, M., and Matsushima, Y. 1990: Recent Japanese research on relative sea level changes in the Holocene and related problems − Review of studies between 1980 and 1988 − . *The Quat. Res.*, **29**, 31 − 48. (J+E)

Otvos, E. G. Jr. 1970: Development and migration of barrier islands, northern Gulf of Mexico. *Geol. Soc. Amer. Bull.*, **81**, 241 − 246.

Pirazolli, P. A. 1991: *World atlas of Holocene sea-level changes*. Elsevier. 300p.

Sadakata, N. 1991: The influence of iron sand mining (Kanna-nagashi) on the formation of the Sotohama beach ridges in the Yumigahama Peninsula of South-western Japan. *Geogr. Rev. Japan*, **64**A, 759 − 778.

Sadakata, N., Shiragami, H., and Kashima, K. 1988: Sea level of the two stages in the late Holocene deduced from the deposits of the coastal low land in the subsided region of the southern Shikoku Island. *The Quat. Res.*, **27**, 125 − 129. (J)

Saito, Y. 1988: Barrier system as a recorder of Holocene sea-level changes and problems on reconstruction of their paleogeography in the early Holocene: Example from Lake Hamana, Central Japan. *Clastic Sediments* (*Jour. Res. Gr. Clas. Sed. Japan*), 5, 109 − 132. (J+E)

Saito, Y., Inouchi, Y., and Yokota, S. 1990: Coastal lagoon evolution influenced by Holocene sea-level changes, Lake Kasumigaura, Central Japan. *Mem. Geol. Soc. Japan*, 36, 103 − 118. (J+E)

Sakaguchi. Y., Kashima, K., and Matsubara, A. 1985: Holocene marine deposits in Hokkaido and their sedimentary environments. *Bull. Dept. Geogr. Univ. Tokyo*, 17, 1 − 17.

Shiragami, H. 1983: Beach ridges and their regional difference in the northern coast of the *Suo-Nada*, Seto Inland Sea. *Chiri-Kagaku* (Geogr. Sci.), **38**, 133 − 141. (J+E)

Shiraishi, T. 1990: Holocene geologic development of the Hachiro-gata lagoon, Akita Prefecture, northeast Honshu, Japan. *Mem. Geol. Soc. Japan*, 36, 47 − 69. (J+E)

Suzuki, T. and Saito, Y. 1987: Heavy mineral composition and provenance of Holocene marine sediments in Lake Kasumigaura, Ibaraki, Japan. *Bull. Geol. Surv. Japan*, **38**, 139 − 164. (J+E)

Takahashi, M. 1982: The geomorphological structure of the Mihara alluvial plain on Awaji Island, Hyogo Prefecture. *Annals Tohoku Geogr. Assoc*., **34**, 138－150.（J+E）

Takano, S. 1978: Development of the compound spit of Notsukezaki, Hokkaido. *Annals, Tohoku Geogr. Assoc*., **30**, 82－90.（J+E）

Tanaka, H., Hasegawa, T., Kimura, S., Okamoto, I., and Sakai, Y. 1996: The geohistory of the formation of the Niigata sand dunces. *The Quat. Res*., **35**, 207－218.（J+E）

Tanner, W. F. 1988: Beach ridge data and sea level history from the Americas. *Jour.. Coast. Res*., **4**, 81－91.

Tokuoka, T., Onishi, I., Takayasu, K., and Mitsunashi, T. 1990: Natural history and environmental changes of Lake Nakaumi and Shinji. *Mem. Geol. Soc. Japan*, 36, 15－34.（J+E）

Trenhaile, A. S. 1997: *Coastal Dynamics and Landforms*. Clarendon Press. Oxford. 366p.

Uesugi, Y. and Endo, K. 1973: On the topographies and soils of the Ishikari coastal plain. *The Quat. Res*., **12**, 115－124.（J+E）

Umitsu, M. 1991: Holocene sea-level changes and coastal evolution in Japan. *The Quat. Res*., **30**, 187－196.

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