LATE PLEISTOCENE MARINE TERRACE CORRELATION AND CHRONOLOGY IN THE NORTHERN NORTHEAST JAPAN

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Abstract Late Pleistocene marine terraces in the northern Northeast Japan were correlated by tephro- and morpho- stratigraphic methods and were tephrochronologically dated. The used time-marker tephras are the Toya ash *ca.* 90 ka ago and the Aso-4 ash *ca.* 70 ka ago. Marine terraces correlated with the Takadate, Tagadai, Nejo and Shibayama surfaces of the Kamikita coastal plain are estimated to have been formed at the last interglacial culmination stage *ca.* 120-130 ka and the interstades *ca.* 100, 80 and 60 ka ago, respectively, when sea level stood at relatively high position.

Key words: late Pleistocene marine terrace, correlation, tephrochronology, Toya ash, Takadate surface

1. Introduction

Marine terraces occur along most of the present coastline of Japanese Island (Ota and Yoshikawa, 1978; Japan Association for Quaternary Research, 1987). The coastal region of the northern Northeast Japan is one of regions where marine terraces are well developed (Fig. 1). In this region, marine terraces are distributed up to about 200 m above present sea level, roughly parallel to the present coastline.

Ota (1975) first presented the synthesized correlation of the last interglacial culmination terrace (the S surface in the South Kanto, central Japan) *ca.* 120-130 ka ago for whole Japan, based on morphostratigrahic methods, and discussed its deformation pattern. Miyoshi (1985) estimated the age of younger marine terraces than the S surface in each area by comparison of simple regression coefficient representing the age ratio of two different former shorelines, accepting the S surface of Ota (1975) as a standard terrace. However, without direct data to determine the age of terrace formation, the extensive terrace correlation and chronology remained problematic in each area until quite recently.

Arai *et al.* (1986) clarified late Quaternary tephrostratigraphy in northern Japan. Machida *et al.* (1985) and Machida *et al.* (1987) discovered the two late Pleistocene vitric tephras (Aso-4 ash and Toya ash) extensively and showed the potential of tephro-

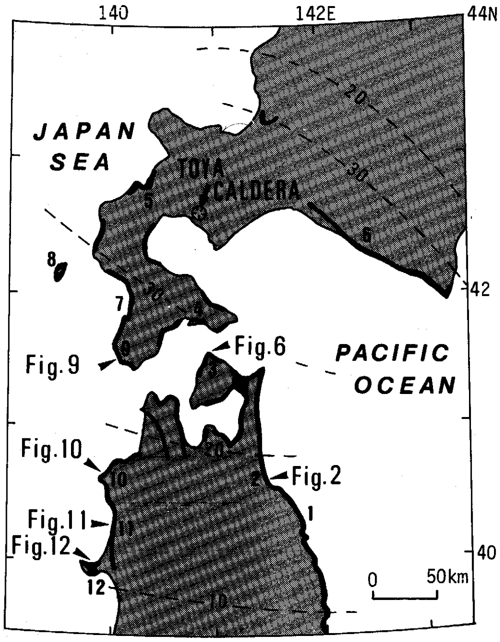

Fig. 1 Index map of the study region and the distribution of the Toya ash Thick line: coastal area where marine terraces are developed, Broken line: isopachs of the Toya ash in cm, 1-12: area numbers shown in Fig. 13

chronology in correlating terraces and evaluating terrace ages in the study region.

This study reexamines the previous terrace correlation on the basis of the terrace-tephra relation and terrace ages estimated from the dates of widespread tephras in the northern Northeast Japan.

2. Widespread Time-marker Tephras

Toya ash

This tephra erupted from the Toya caldera occurs extensively (Fig. 1, Machida *et al.*, 1987), and is recognized as a rhyolitic vitric ash, 10 to 40 cm thick, within the cover beds on marine terraces or within terrace deposits at many locations (Figs. 5 and 8). Near the source volcano, the Toya ash is accompanied by large-scale ignimbrite including zircon that is dated 130±30 ka by fission track method (Okumura and Sangawa, 1984). Machida *et al.* (1987), however, estimated the age of the Toya ash at ca. 90-100 ka on the basis of tephrostratigraphic relation between the Toya ash and other age-determined tephras. These dates indicate the posssibility that this tephra was formed during the last interglacial stage after *ca.* 130 ka ago. Detailed stratigraphic position and estimated age of the Toya ash will be mentioned later.

Aso-4 ash

This tephra is a widespread, rhyodacitic vitric ash occurring on whole land area and sea floor around Japan, which was derived from the Aso caldera, Southwest Japan, more than 1000 km southwest of northern Japan (Machida *et al.*, 1985). Detection of the Aso-4 ash in the study region was limited to a few locations where cover beds on the terraces are thick and are suitable for the preservation of the distal part of the Aso-4 ash (*eg*. at Loc. 3 in Fig. 5 and Locs. 6, 7 and 8 in Fig. 8).

Around the source volcano, the Aso-4 ash is accompanied by large-scale ignimbrite which is dated 840±25 ka by fission track method (Tamanyu, 1978) and 830±14 ka by electron spin resonance (ESR) method (Sawada *et al*., 1984). By contrast, Machida *et al*. (1985) estimated the age of the Aso-4 ash at *ca*. 70 ka, because it exists stratigraphically between the Obaradai pumice (66±6 ka ago) and the Ontake Pm-I (73±4 to 95±5 ka ago) dated by fission track method on obsidian and zircon from the tephra in South Kanto, central Japan.

3. Marine Terraces of Each Area

Field observation was carried out in most coastal areas where marine terraces are developed. This chapter provides the description of terrace features and deposits and the terrace-tephra relationship in six selected areas with many good exposures to demon-

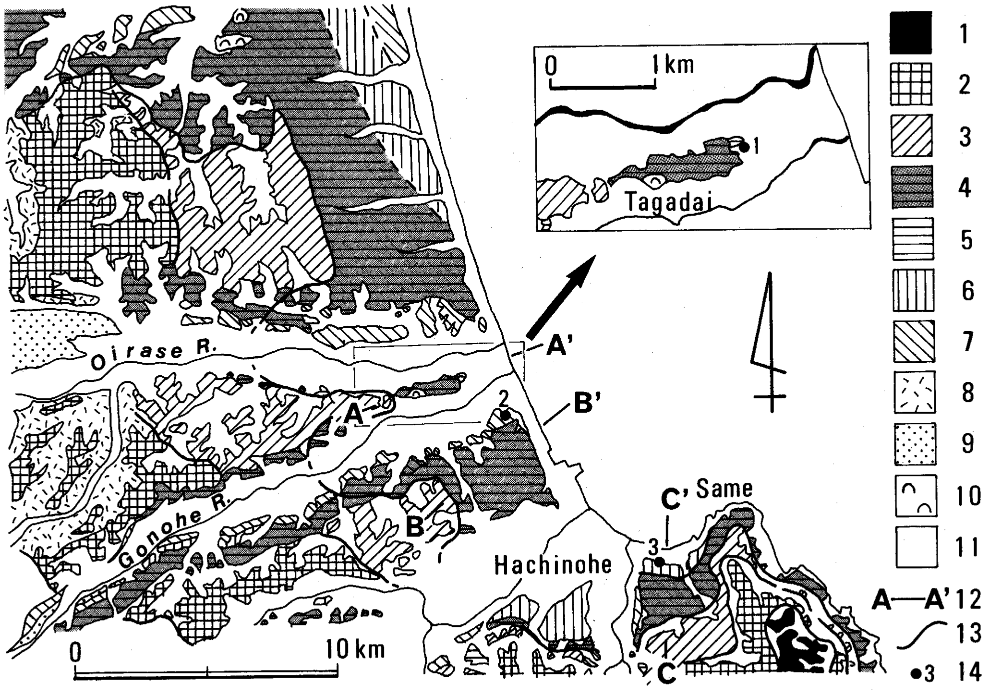

Fig. 2 Terraces in the Kamikita Coastal Plain (revised from Miyauchi, 1987)
1: Higher surface; 2: Shichihyaku surface; 3: Tengutai surface; 4: Takadate surface; 5: Tagadai surface; 6: Nejo surface; 7: Shibayama surface; 8: Shichinohe surface; 9: Sanbongi surface; 10: Dune; 11: Holocene lowland; 12: Locations of the sections shown in Fig. 4; 13: Former shoreline; 14: Locations of the sections shown in Fig. 5

strate the terrace correlation and chronology, that is the Kamikita coastal plain, western Shimokita Peninsula, Matsumae Peninsula, Nishi-tsugaru coast, northern Noshiro coastal plain and Oga Peninsula. The terrace correlation in the last five areas has not been confirmed. Height values of the terraces in the followings show altitudes of former shorelines.

Kamikita coastal plain

Six marine terraces — Higher, Shichihyaku, Tengutai, Takadate, Nejo and Shibayama — are found in this plain facing the Pacific Ocean, and are overlain by many marker-tephras (Fig. 2, Miyauchi, 1987). A narrow fluvial terrace, the Tagadai surface, was newly recognized between the Takadate and Nejo surfaces near Tagadai (Fig. 2, inset). According to the terrace chronology of the plain arranged in Fig. 3 (Miyauchi, 1987), the late Pleistocene terraces are taken up in the following description.

The Takadate surface is the best developed terrace with infilled valley features, at 20 to 50 m above sea level (asl). Relative height (*ca.* 10 m) of a cliff behind the former shoreline is the largest in this area (Fig. 4). The terrace is underlain by 5 to 20 m thick transgressive deposits composed of sand, mud and gravel with fossil shells. The cover bed on the terrace consists of 5 to 8 m thick airlaid tephra where the oldest marker-tephra is the Zarame pumice (ZP, Fig. 3).

The Tagadai surface at about 16 m asl is found only near Tagadai. The terrace deposits are composed of about 2 m thick, well-sorted sand and gravel formed near a

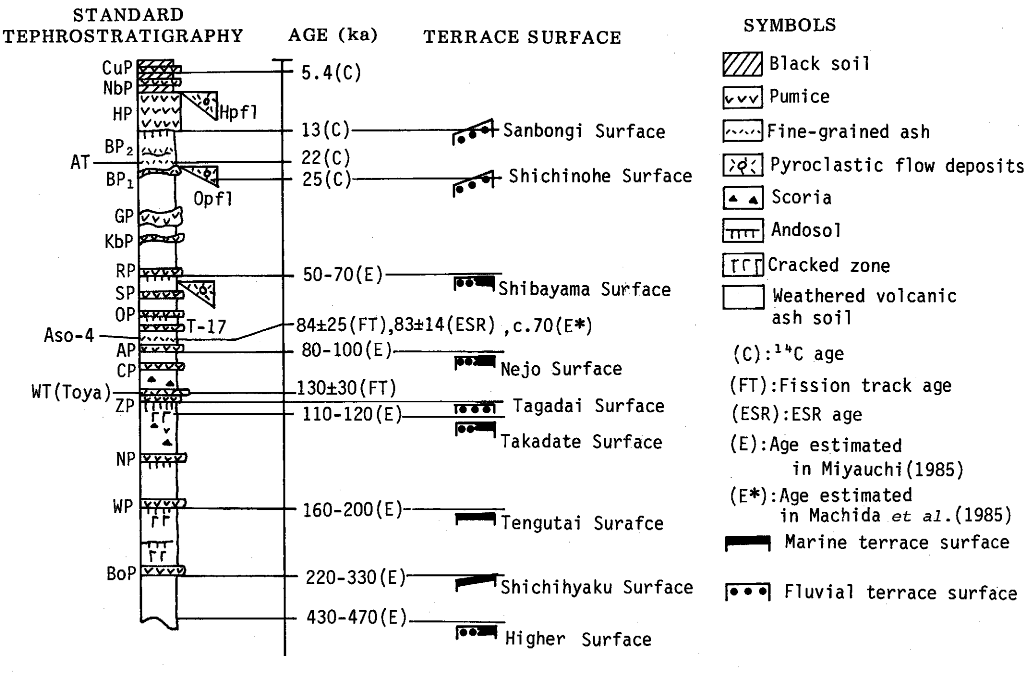

Fig. 3 Relationship between the terraces and the tephra in the Kamikita Coastal Plain (revised from Miyauchi, 1987)

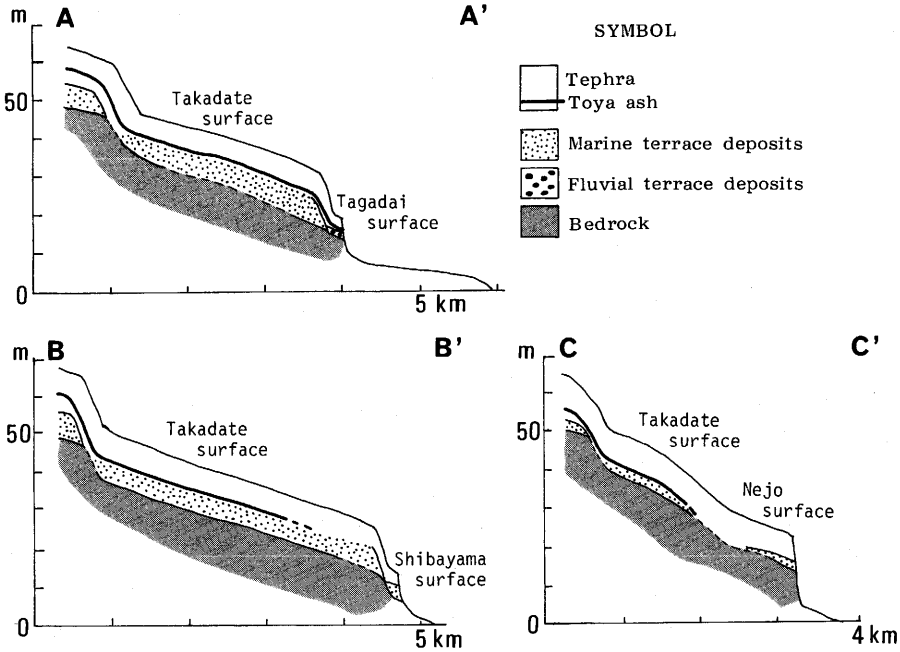

Fig. 4 Topographic and geologic sections in the Kamikita Coastal Plain
Locations of the sections are shown in Fig. 2.

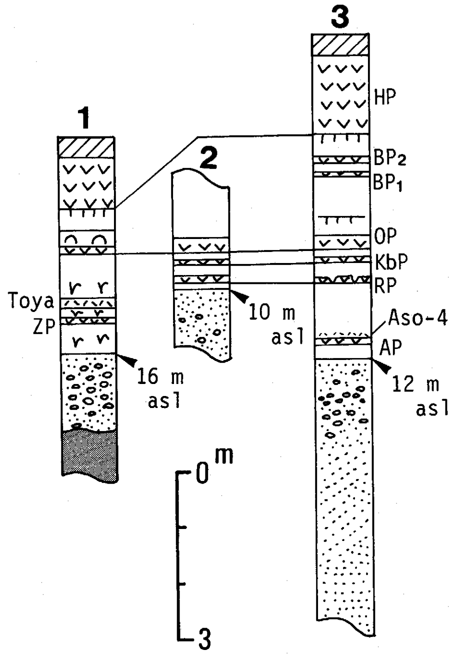

Fig. 5 Geologic columnar sections in the Kamikita Coastal Plain
Locations of the sections are shown in Fig. 2. Legend is the same as in Fig. 8.

river mouth, and are overlain by peat including the Toya ash (Fig. 5, Loc. 1).

The Nejo surface is of marine origin near the coast, at 15 to 12 m asl, and transfers to fluvial origin along rivers (Fig. 2). The terrace deposits are composed of more than 4 m thick, well-sorted and subrounded gravel and sand overlain by the cover bed where the Aosuji pumice (AP) is the lowest marker-tephra (Fig. 5, Loc. 3). The Aso-4 ash occurs as a 3 cm thick layer just above the AP.

The Shibayama surface at about 10 m asl is of marine origin only near the river mouth of the Gonohe River, fringing the Takadate surface (Fig. 2). The terrace deposits consist of more than 1 m thick, well-sorted sand and gravel overlain by the cover bed in which the Red pumice (RP) is the lowest marker-tephra (Fig. 5, Loc. 2).

Western Shimokita Peninsula

Five marine terraces are found in this area (Fig. 6). They have been named the Higher-A, Higher-B, Upper, Middle and Lower surfaces in descending order (Nitobe, 1969). Each marine terrace consists of wave cut surface overlain by less than 3 m thick

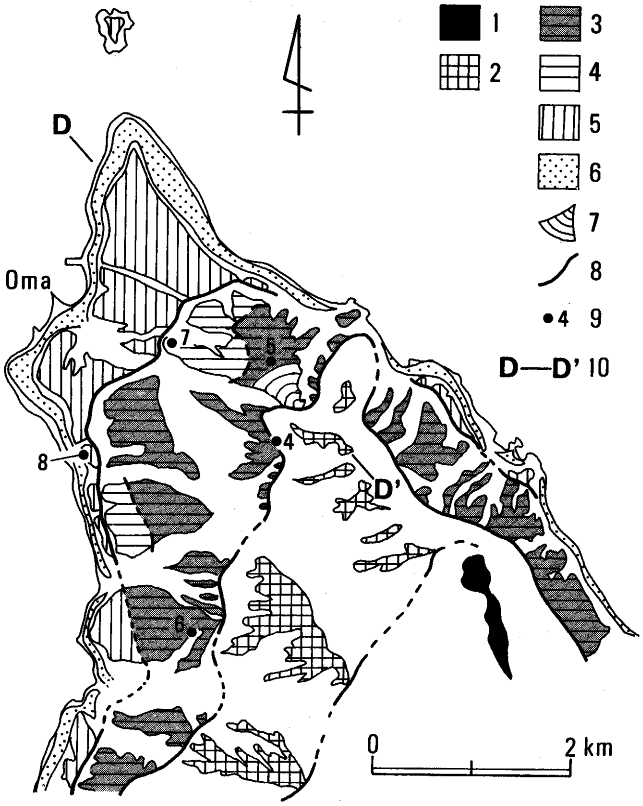

Fig. 6 Marine terraces in the western Shimokita Peninsula
1: Higher-A surface; 2: Higher-B surface; 3: Upper surface; 4: Middle surface; 5: Lower surface; 6: Holocene marine surface; 7: Alluvial cone; 8: Former shoreline; 9: Locations of the columnar sections in Fig. 8; 10: Location of the section in Fig. 7

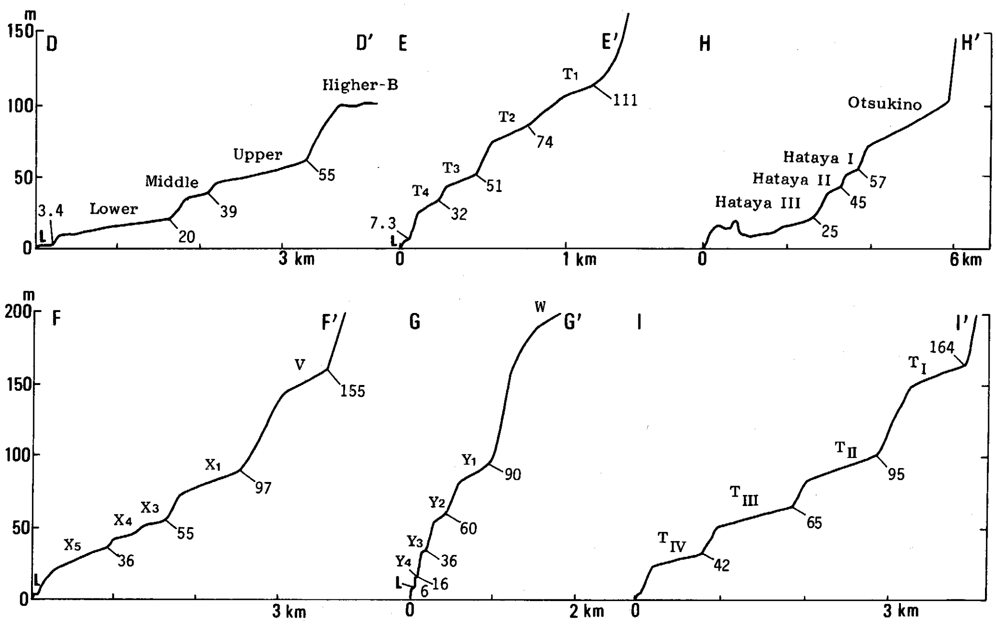

Fig. 7 Topographic sections in each areas
Locations of the sections are shown in Figs. 6, 9, 10, 11 and 12.

beach deposits, except for the Upper surface. A Holocene marine terrace (L surface) at 1 to 3 m asl is also shown in Fig. 6.

The Upper surface, at 50 to 30 m asl, is the best developed terrace with the highest fossil sea cliff behind the former shoreline in this area (Fig. 7, D—D' section). The terrace deposits are composed of 3 to 5 m thick sand and gravel overlain by the slope deposits and the tephra including the Toya ash (Fig. 8, Locs. 4, 5 and 6). The Middle surface is discontinuously distributed, at about 35 m asl. The Lower surface at about 10 m asl is overlain by the peat, tephra and dune sand (Fig. 8, Loc. 8). The Aso-4 ash occurs as a 6 cm thick whitish ash in the peat.

Matsumae Peninsula

Four marine terraces — T_1, T_2, T_3 and T_4 — continuously occur at 115 to 15 m asl (Fig. 9). A dissected marine terrace at more than 200 m asl is expressed as the H surface in Fig. 9, and a Holocene marine one at 3 to 7 m asl is expressed as the L surface. Each marine terrace consists of wave cut surface overlain by thin beach deposits, a few meter thick. The relationship between this classification and that of Segawa (1955) is shown in Table 1.

The T_1 surface is preserved at 60 to 115 m asl, with the highest fossil sea cliff at its inner margin (Fig. 7, E—E' section). Alluvial cones are developed on the inner part of the terrace. The terrace deposits are generally composed of about 5 m thick beach gravel and are thicker compared with lower terrace deposits in this area. The terrace is overlain by the tephra and alluvial cone deposits (Fig. 8, Loc. 9). The Toya ash occurs in the

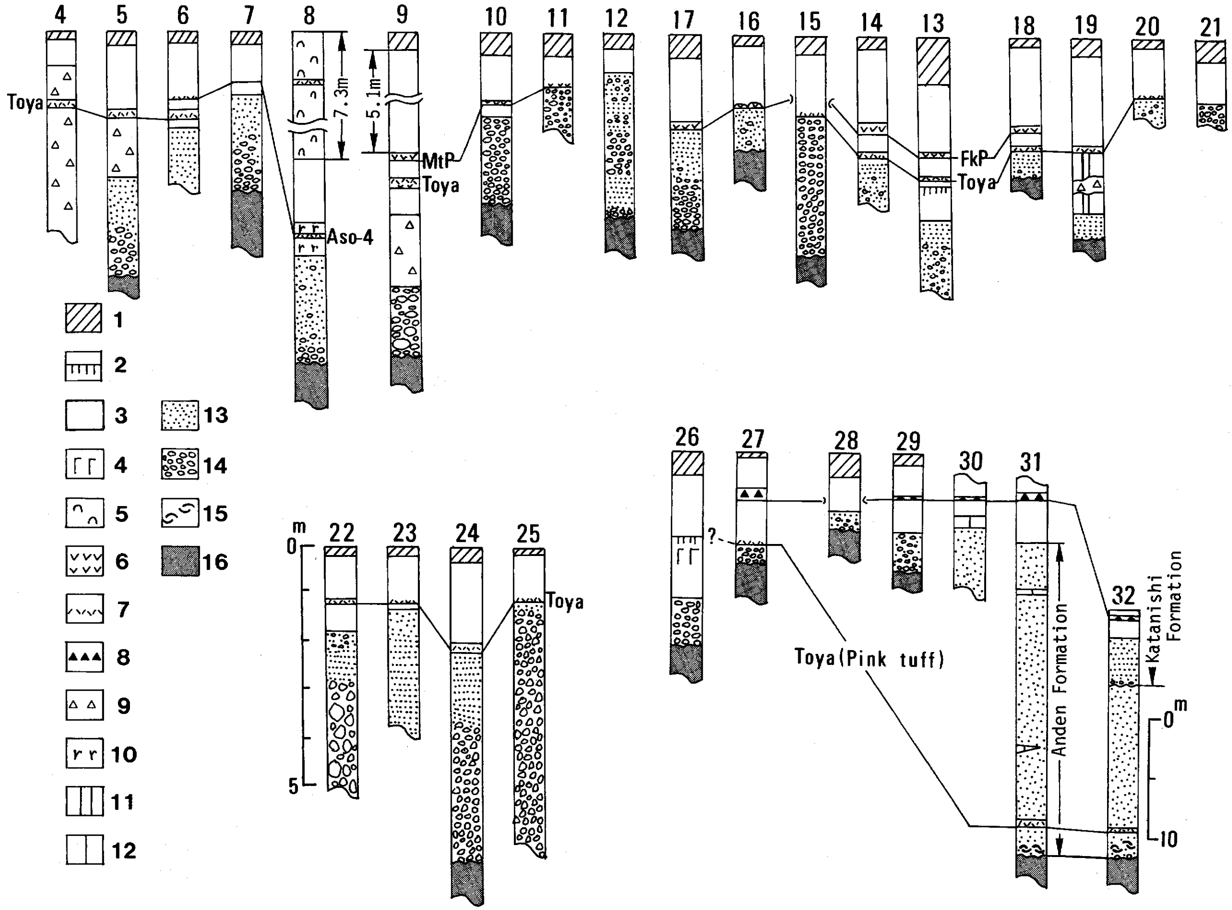

Fig. 8 Geologic columnar sections in each area
1: Humic soil; 2: Paleosol; 3: Brown weathered volcanic ash; 4: Cracked zone; 5: Dune sand; 6: Pumice; 7: Fine volcanic ash; 8: Scoria; 9: Angular gravel (slope deposits); 10: Peat; 11: Clay; 12: Silt; 13: Sand; 14: Gravel; 15: Shell bed; 16: Bedrock
Locations of the sections are shown in Figs. 6, 9, 10, 11 and 12.

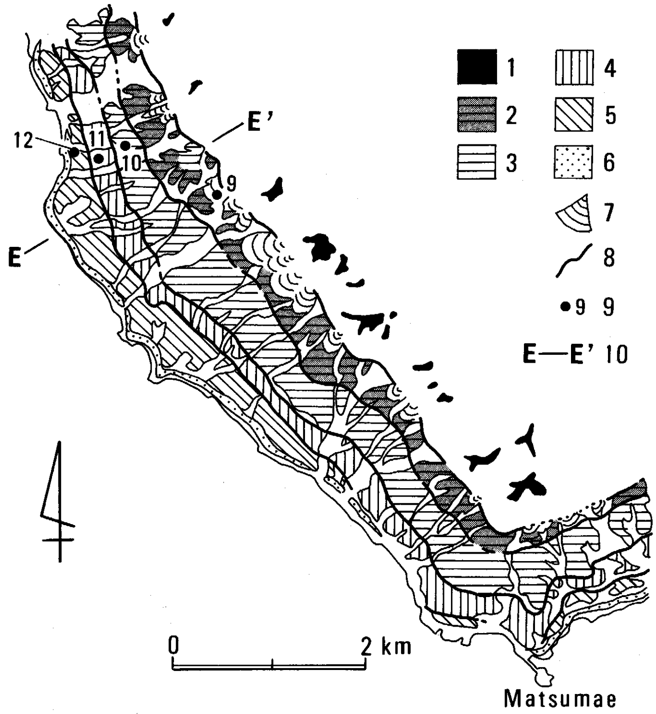

Fig. 9 Marine terraces in the Matsumae Peninsula
1: H surface; 2: T_1 surface; 3: T_2 surface; 4: T_3 surface; 5: T_4 surface; 6: L surface; 7: Alluvial cone; 8: Former shoreline; 9: Locations of the columnar sections in Fig. 8; 10: Location of the section in Fig. 7

Table 1 Classification and correlation of the marine terraces in the Matsumae Peninsula

	Segawa (1955)	This paper	Age (ka)
Middle Pleistocene		H surface	
Late Pleistocene	Upper surface	T_1 surface	c. 120
		T_2 surface	c. 100
	Middle surface	T_3 surface	c. 80 (?)
	Lower surface	T_4 surface	c. 60 (?)

(shaded) Marine terrace surface newly correlated with the last interglacial culmination stage

------- Last interglacial culmination marine terrace surface in previous work lowest part of the cover bed.

The T_2 surface ranges from 40 to 80 m asl in altitude. Its shoreline angle is generally unclear because the depositional gentle slope spreads on the foot of terrace scarp. The Toya ash is not detected within the cover bed on the terrace (Fig. 8, Loc. 10).

The T_3 surface, at 30 to 50 m asl, is overlain by the cover bed where the Matsumae pumice (MtP) is the lowest marker tephra (Fig. 8, Loc. 11). The T_4 surface is well preserved at 15 to 30 m asl, overlain by the cover bed which does not include marker tephra (Fig. 8, Loc. 12).

Nishi-tsugaru coast

Six marine terraces are recognized at 200 to 15 m asl (Fig. 10). Each terrace consists of wave cut surface overlain by a few meter thick beach deposits. It seems difficult to correlate the terraces with the same age terraces in different areas each other, because the former shorelines are very sinuous and their height greatly changes across the Yuno Stream near Fukaura. Such obscure features have resulted in the different subdivision and correlation of terraces between Ota (1969) and Nakata *et al.* (1976), although using the same morpho-stratigraphic method (Table 2). Thus, the following description on marine terraces is presented in the northern and southern areas separated by the Yuno Stream. Two or three Holocene marine terraces at 3 to 7 m asl are also shown as the L surface in Fig. 10.

Northern area

Six marine terraces are found at 160 to 20 m asl, and named the V, X_1, X_2, X_3, X_4 and X_5 surfaces in descending order.

The dissected V surface at 130 to 160 m asl is underlain by weathered beach deposits composed of 3 m thick, reddish sand and gravel. The cover bed on the terrace includes paleosol below the Toya ash (Fig. 8, Loc. 13).

The X_1 surface occurs at 80 to 100 m asl, accompanied by the continuous and highest fossil sea cliff behind the former shoreline (Fig. 7, F—F' section). The terrace deposits are generally composed of about 5 m thick, well-sorted beach sand and gravel, and is the largest in thickness. The Toya ash occurs at the lowest position in the cover bed on the terrace (Fig. 8, Loc. 14). The X_2 surface is discontinuously distributed and its height is about 70 m asl.

The X_3 surface is well preserved at 40 to 60 m asl, compared with higher surfaces. The X_4 surface is limitedly recognized west to Hiroto and its height is about 40 m asl. The Fukaura pumice (FkP) occurs at the lowest position of cover beds on these two terraces (Fig. 8, Locs. 16 and 17). The X_5 surface is discontinuously distributed, at 20 to 35 m asl.

Southern area

Five marine terraces are named the W, Y_1, Y_2, Y_3 and Y_4 surfaces in descending order. The lowest four marine terraces are very narrow in width.

The W surface at 170 to 200 m asl is severely dissected, forming the highest part of this area. The terrace deposits and the cover bed on them are not sufficiently exposed to describe their thickness and facies.

The Y_1 surface at 80 to 100 m asl is the widest terrace in this area. The fossil sea cliff behind the former shoreline is the highest in this area (Fig. 7, G—G' section). The Y_2

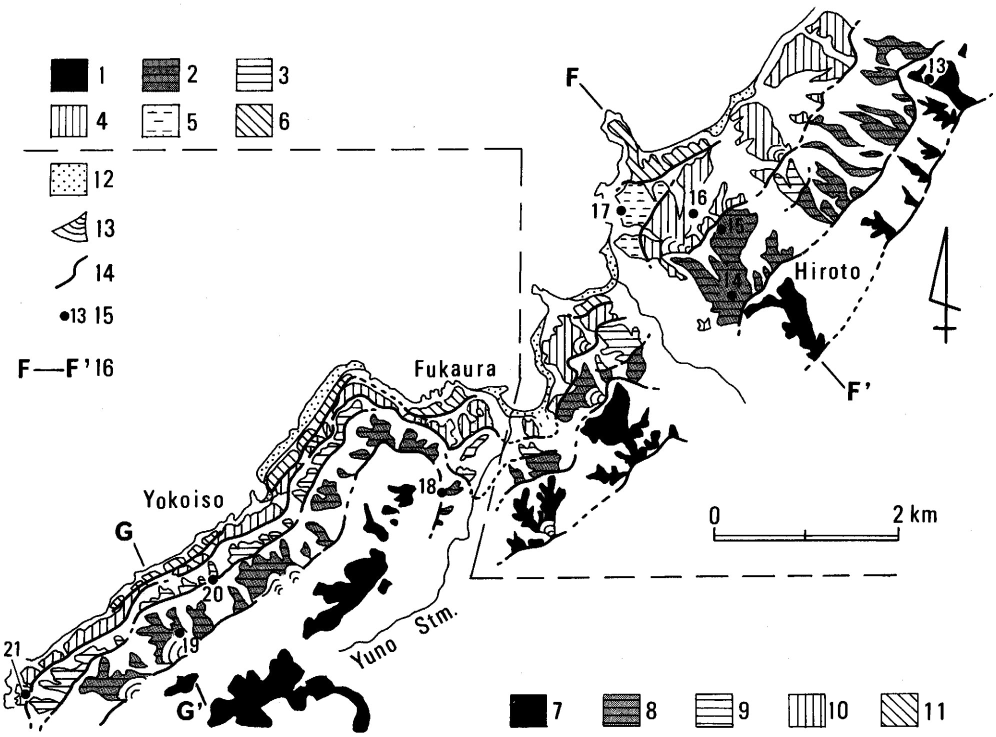

Fig. 10 Marine terraces in the Nishi-tsugaru Coast
1: V surface; 2: X_1 surface; 3: X_2 surface; 4: X_3 surface; 5: X_4 surface; 6: X_5 surface; 7: W surface; 8: Y_1 surface; 9: Y_2 surface; 10: Y_3 surface; 11: Y_4 surface; 12: L surface; 13: Alluvial cone; 14: Former shoreline; 15: Locations of the columnar sections in Fig. 8; 16: Location of the section in Fig. 7.

Table 2 Classification and correlation of the marine terraces in the Nishi-Tsugaru Coast

		NORTHERN PART			SOUTHERN PART			Age (ka) estimated in this paper
		Ota (1969)	Nakata *et al.* (1976)	This paper		Nakata *et al.* (1976)	Ota (1969)	
Pleistocene	Middle		H_1 terrace					
		First terrace	H_2 terrace	V surface	W surface	H_1 terrace		
	Late	Second terrace	M_1 surface	X_1 surface	Y_1 surface	H_2 terrace	Second terrace	c. 120
				X_2 surface	Y_2 surface	M_1 terrace	Third terrace	c. 100
		Third terrace	M_2 surface	X_3 surface	Y_3 surface	M_2 terrace	Forth terrace	c. 80 (?)
				X_4 surface				
		Forth terrace	M_3 surface	X_5 surface	Y_4 surface	M_3 terrace		c. 60 (?)

(shaded) Marine terrace surface newly correlated with the last interglacial culmination stage
------ Last interglacial culmination marine terrace surface in previous works

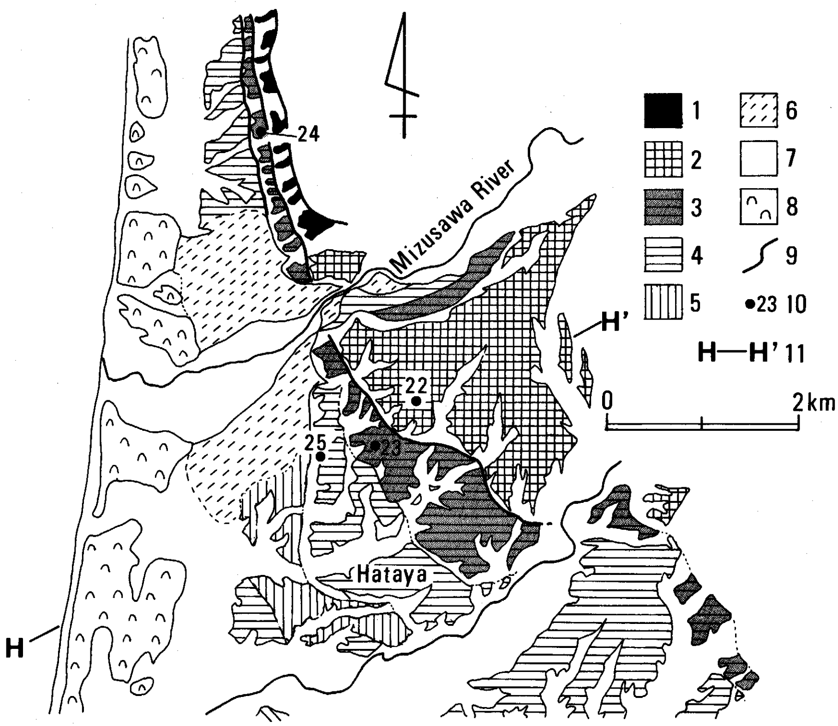

Fig. 11 Terraces in the northern Noshiro Coastal Plain
1: Moya surface; 2: Otsukino surface; 3: Hataya I surface; 4: Hataya II surface; 5: Hataya III surface; 6: Mizusawa surface; 7: Holocene lowland; 8: Dune; 9: Former shoreline; 10: Locations of the columnar sections in Fig. 8; 11: Location of the section in Fig. 7

surface is at 50 to 70 m asl and topographically continues to the Hataya II surface of the northern Noshiro coastal plain as mentioned later. The Toya ash directly covers these two terraces (Fig. 8, Locs. 18, 19 and 20). The Y_3 and Y_4 surfaces are stepped at 30 to 40 m and about 15 m asl, respectively. Marker tephras are not found in cover beds on these terraces (Fig. 8, Loc. 21).

The relation of terrace division between this study and previous works is shown in Table 2.

Northern Noshiro coastal plain

Six terraces are found (Fig. 11) and they have been named the Moya, Otsukino, Hataya I, Hataya II, Hataya III and Mizusawa surfaces (Naito, 1977). Three terraces, the Moya, Hataya I and Hataya II surfaces, are of marine origin.

The Hataya I surface at 50 to 60 m asl fringes the Otsukino surface underlain by thick fan deposits. The high fossil sea cliff is seen behind the former shoreline and forms the boundary between both terraces (Fig. 7, H—H' section). It turns to be of fluvial origin upstream. The terrace deposits are composed of 4 m thick stratified sand and gravel. The

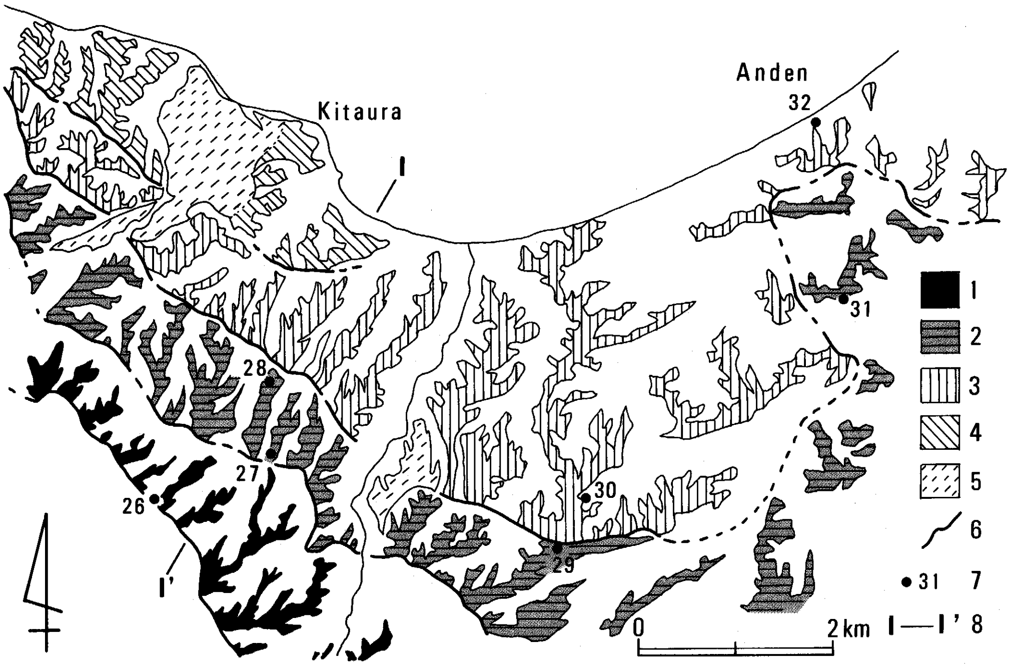

Fig. 12 Marine terraces in the Oga Peninsula
1: TI surface; 2: TII surface; 3: TIII surface; 4: TIV surface; 5: Fluvial surface; 6: Former shoreline; 7: Locations of the columnar sections in Fig. 8; 8: Location of the section in Fig. 7

Hataya II surface as a marine terrace is situated north to the Mizusawa River, with an altitude of 30 to 40 m asl. This terrace is underlain by thin beach deposits. The Toya ash occurs at the lowest position in cover beds on the the Hataya I and II surfaces (Fig. 8, Locs. 23, 24 and 25). The Hataya III and Mizusawa surfaces are of fluvial origin, underlain by thin beds of subangular gravel.

Oga Peninsula

At least six marine terraces have been recognized up to 290 m asl in this Peninsula (Ota, *et al.*, 1968; Imaizumi, 1977; Shiraishi *et al.*, 1981). The lowest four terraces have been named the T_{I}, T_{II}, T_{III} and T_{IV} surfaces in descending order (Imaizumi, 1977), and they are shown in Fig. 12.

The T_{I} surface at 150 to 190 m asl is dissected, showing ridge-like features. The terrace deposits consist of about 2 m thick beach gravel, and the cover bed on the terrace contains paleosol with cracked zone at the middle horizon (Fig. 8, Loc. 26).

The T_{II} surface is bounbed from the T_{I} surface by 40 m high fossil sea cliff (Fig. 7, I—I' section). The former shoreline height ranges from 80 to 130 m asl. In the western part of this peninsula, the terrace consists of wave cut surface overlain by thin beach deposits (Fig. 8, Locs. 27 and 28). In contrast, in the eastern part, it consists of depositional surface underlain by thick, sandy and muddy sediments with shell fossils (Fig. 8, Loc. 31). The thick marine bed have been named the Anden formation (Shiraishi *et al.*, 1981). The Toya ash occurs as the airlaid layer within the cover bed on the terrace near the shoreline angle, about 100 m asl (Fig. 8, Loc. 27) and occurs as the waterlaid one within the marine sediments (Anden formation), about 70 m asl (Fig. 8, Loc. 31).

The T_{III} surface is widely developed at 40 to 80 m asl. The terrace deposits are composed of 3 to 5 m thick beach sand and gravel. This bed has been named the Katanishi formation (Research Group of the Katanishi Formation, 1983). It unconformably overlies the Anden formation including the Toya ash near Anden (Fig. 8, Loc. 32). The T_{IV} surface, the best preserved one, is located at 30 to 55 m asl, underlain by thin beach deposits.

4. Marine Terrace Correlation

Criteria of correlation

The Kamikita coastal plain can be emplaced to the standard area of the terrace correlation for the reason that the tephra-terrace relation was well observed and the the evidences indicating relative sea level changes were obtained. In this plain, The Takadate surface is the lowest and widest terrace covered by the airlaid Toya ash. The presence of the thickest terrace deposits and the highest fossil sea cliff suggests that the Takadate surface was formed in relation to major sea level rise. Miyauchi (1987) assigned this terrace to the last interglacial culmination stage, comparing such characteristics with those of other terraces. Thus, the Takadate surface can be used as a typical marine terrace of this stage in the study region.

Consequently, in other areas, marine terraces with the tephra-terrace relation above are correlated with the Takadate surface. Narrow and discontinuous marine terraces below the Takadate surface, overlain by the airlaid Toya ash, can be correlated with the Tagadai surface of the Kamikita coastal plain (Machida *et al.*, 1987).

The Nejo surface is the lowest terrace covered with the airlaid Aso-4 ash in the Kamikita coastal plain. In other areas, marine terraces with such tephra-terrace relation are identified as the Nejo terrace.

Results of marine terrace correlation

According to the above-mentioned criteria, the marine terraces correlated with the Takadate surface are:

- the Upper surface of the western Shimokita Peninsula,
- the T_1 surface of the Matsumae Peninsula,
- the X_1 and Y_1 surfaces of the Nishi-tsugaru coast,
- the Hataya I surface of the northern Noshiro coastal plain,
- the T_{II} surface of the Oga Peninsula.

The marine terraces correlated with the Tagadai surface are:

- the Y_2 surface of the Nishi-tsugaru coast,
- the Hataya II surface of the northern Noshiro coastal plain.

The marine terrace recognized as the Nejo surface is only the Lower surface of the western Shimokita Peninsula, where the Middle surface is probably correlated with the

Tagadai surface, based on the terrace position between the Upper and Lower surfaces.

In result, previous terrace correlation was reconfirmed in the Shimokita and Tsugaru Peninsulas where the terrace number is few and the Takadate surface exists below about 50 m asl. By contrast, it was greatly corrected in the Matsumae Peninsula, Nishi-Tsugaru coast and Oga Peninsula where several marine terraces are vertically even-spaced and the Takadate surface exists over 100 m asl. This indicates that the marine terrace correlation by morphostratigraphic method must be checked by additional methods in areas with high uplift rate. Figure 13 shows the entire terrace correlation in the northern Northeast Japan, piled with those of the undemonstrated areas in chapter 3.

5. Chronology of Late Pleistocene Marine Terraces

Marine terrace chronology of the Kamikita coastal plain

This plain can be adopted as a standard area of the terrace chronology for the reason that many time-marker tephras occur and the tephra-terrace relation was established. Miyauchi (1987) estimated that the Takadate, Nejo and Shibayama surfaces were formed *ca.* 110-120, 80-100 and 50-70 ka ago, respectively (Fig. 3), based on the extrapolation from tephra accumulation rate calculated from the age-depth plots of three tephras (Fig. 3). He further correlated their formation stages with worldwide high sea level stages (oxygen isotope stage 5) *ca.* 120-130, 80 and 60 ka ago, respectively. The Tagadai surface is tephrochronologically emplaced between the Takadate and Nejo surfaces, and is also estimated to have been formed at a worldwide high sea level stage *ca.* 100 ka ago.

According to this chronology, the age of the Toya ash is limited around 90 ka younger than its fission track age (130 ± 30 ka). Many radiometric dating on tephra and other dating on terrace deposits are necessary to determine the terrace age.

Marine terrace chronology of each area

Applying the chronology of the Kamikita coastal plain to that of each area, marine terraces correlated with the Takadate surface are assigned to the last interglacial culmination stage *ca.* 120-130 ka ago (Fig. 13).

The Middle surface (western Shimokita Peninsula), the Y_2 surface (Nishi-tsugaru coast) and the Hataya II surface (northern Noshiro coastal plain) correlated with the Tagadai surface are estimated to have been formed *ca.* 100 ka ago. In these areas, the 120-130 ka marine terraces occur at the higher position than those of the Kamikita coastal plain (Fig. 7). This permits the interpretation that the occurrence of the *ca.* 100 ka marine terrace is limited in the areas with uplift rate greater than that of the plain (0.3 m/ka, Miyauchi, 1987).

The Lower surface (western Shimokita Peninsula) correlated with the Nejo surface is estimated to have been formed *ca.* 80 ka ago.

In most areas except for the western Shimokita Peninsula, the age of two terraces younger than the Toya ash has not been determined, because the Aso-4 ash has not been found out. The upper marine terrace is overlain by the thicker cover bed in every area.

This indicates that the upper terrace emerged at the older time as a result of the accumulation of uplift. Such a flight of marine terraces is generally recognized in uplifted coastal areas on the earth (Bloom, 1980; Lajoie, 1986). According to radiometric dates in such areas, terrace ages after *ca.* 100 ka ago are evaluated to be *ca.* 80, 60, 40 and 30 ka when sea levels stood at comparatively high levels in warm stages. As sea level should have similarly changed everywhere on the earth, it is expected that marine terraces with such ages also occur in the northern Northeast Japan.

By this view, the T_3 surface (Matsumae Peninsula), the X_3 and Y_3 surfaces (Nishi-tsugaru coast) and T_{III} surface (Oga Peninsula) are estimated to have been formed ca. 80 ka ago, judged by the terrace sequence. Likewise, the T_4 surface (Matsumae Peninsula), the X_5 and Y_4 surfaces (Nishi-tsugaru coast) and T_{IV} surface (Oga Peninsula) are estimated to have been formed *ca.* 60 ka ago. Figure 13 is constructed, adding this age estimation to the tephrochronology. The marine terrace chronology above suggests that at least four different stages at high sea levels occurred during late Pleistocene in the study region.

Figure 14 shows the height distribution of the Takadate shoreline. Their patterns are characterized by a small change (20-50 m) in the Pacific Ocean side and a great oscillating change (20-140 m) in the Japan Sea side as Ota (1975) already described a part of the deformation pattern. No occurrence of the Takadate surface beneath 20 m asl suggests that the northern Northeast Japan arc has uplifted extensively during late Quaternary. These new data from the corrected correlation and chronology will provide significant

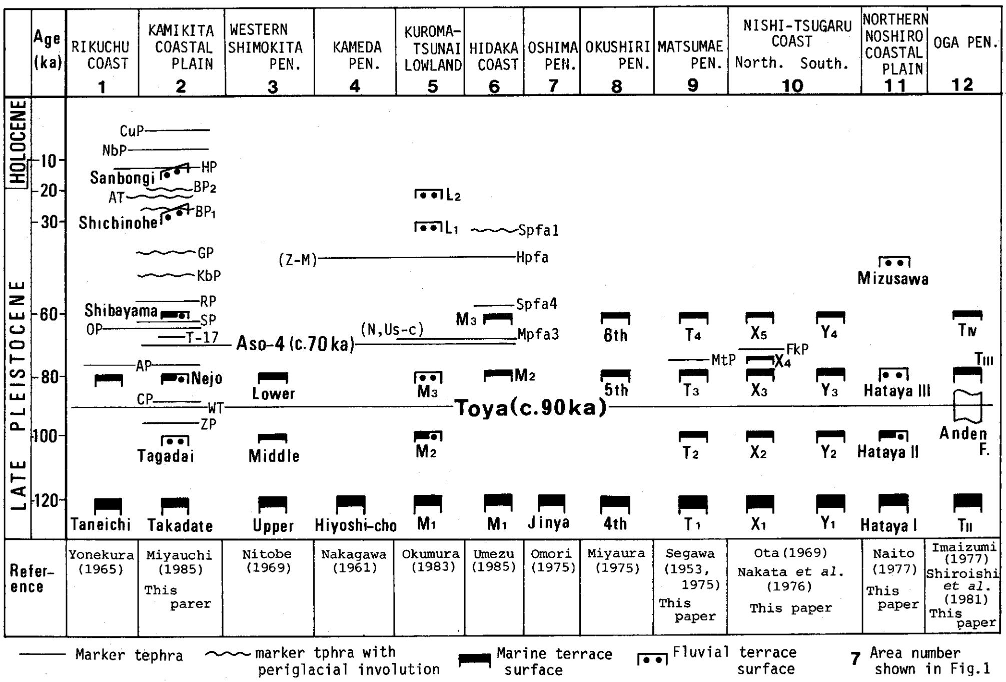

Fig. 13 Chronology of the marine terraces in the northern Northeast Japan

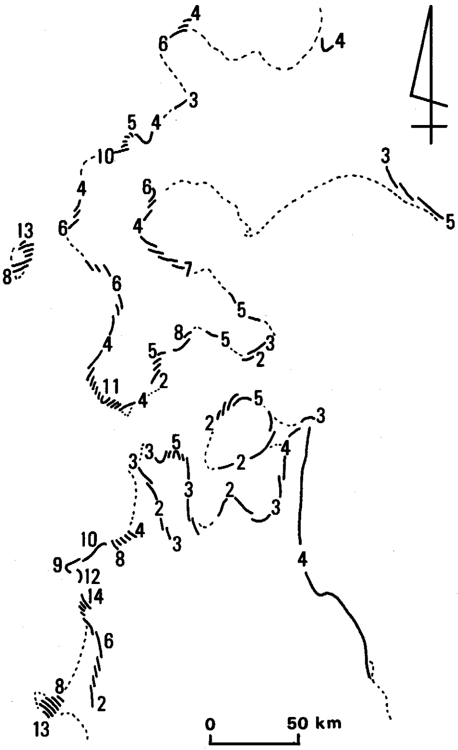

Fig. 14 Height distribution of the former shoreline on the Takadate surface (unit: 10 m)

informations to study late Quaternary vertical movements of the Northeast Japan arc.

6. Concluding Remarks

Extensive correlation and chronology were confirmed on late Pleistocene marine terraces in the northern Northeast Japan, using the widespread tephras and marked terrace features. The major results are as follows:

1) The *ca.* 120-130 ka marine terrace (Takadate surface) was widely identified, and its former shoreline height ranges from 20 to 140 m asl.

2) The *ca.* 100 ka marine terrace (Tagadai surface) was recognized in areas with larger uplift rate than 0.3 mm/yr. The *ca.* 80 ka marine terrace (Nejo surface) was recognized only in the western Shimokita Peninsula.

3) Two marine terraces after *ca.* 100 ka ago are probably correlated with the *ca.* 80 ka Nejo surface and the *ca.* 60 ka Shibayama surface in descending order in most areas, except for the western Shimokita Peninsula.

4) Occurrence of such marine terraces implies at least high sea level stillstands during late Pleistocene in the northern Northeast Japan.

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(* : in Japanese, * * : in Japanese with English abstract)