TEPHROCHRONOLOGY, CORRELATION, AND DEFORMATION OF MARINE TERRACES IN EASTERN HOKKAIDO, JAPAN

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Abstract Tephrochronology of Akan, Kutcharo and intercalating exotic marker tephras innovated the chronology and correlation of Middle to Late Pleistocene marine terraces in eastern Hokkaido. The vertical displacement of M1 and older paleoshorelines along the Okhotsk Sea indicates two distinctive uplift zones of Abashiri and Shiretoko. On the Pacific coast, respective gentle eastward tilting and westward bending in the east and in the west of Abashiri tectonic line evidence active thrusting beneath. The westward shift of the Kurile forearc sliver accounts for the thrusting at the Abashiri tectonic line in the outer Kurile arc and the growth of dextral *en échelon* ridges in the inner arc.

Key words: eastern Hokkaido, tephrochronology, coastal tectonics, forearc sliver

1. Introduction

Several levels of marine terraces fringe Hokkaido, the northernmost main island of Japan, along almost entire length of the coastlines. These marine terraces have long attracted attention of geologists and geomorphologists. Among them, Sakaguchi (1959) was the first to accomplish geomorphological correlation of the marine terraces in central and eastern Hokkaido east of the Ishikari lowland to discuss the coastal tectonics. Correlation of the Quaternary system in Hokkaido using marker tephras began in the 1960s and advanced in the 1970s. At the same time intensive geological researches on individual volcanoes brought much information on local tephrostratigraphy (*e.g.*, Katsui and Sato, 1963). However, until the middle 1980s none has attempted to establish extensive correlation and absolute chronology of the Quaternary system throughout Hokkaido.

Okumura *et al.* (1985) and Machida *et al.* (1987) first introduced such widespread marker tephras as Spfa-1, KSr, Aso-4, Toya, and KHb that cover nearly entire Hokkaido (Figs. 1 and 2) with chronological framework for the Late Pleistocene. The results are summarized by Okumura (1991) and Machida and Arai (1992).

As to the active tectonics in eastern Hokkaido, Kaizuka (1975) hypothesized the

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westward shift of the Kurile forearc sliver driven by the oblique subduction along the Kurile-Kamchatka trench based on major topographic relief of southern Kurile and eastern Hokkaido. Kimura (1978) presented geological evidences of the shift and collision along the Abashiri tectonic line in the Late Miocene. However, there was little quantitative information on the Quaternary activity of the forearc sliver. This paper aims to reveal the Quaternary regional crustal movement of eastern Hokkaido using the altitude of paleoshorelines as an indicator of coastal tectonics.

2. Tephrochronology and Correlation of Marine Terraces

Figures 1 and 2 show the chronostratigraphy of the Middle to Late Pleistocene marker tephras. Toya ash, KPIV, and KHb are the key beds to correlate the Last Interglacial marine deposits. They cover the Pacific coast between Nemuro and Erimo as well as almost entire Okhotsk coastal area except north of Esashi. The marine terrace emerged shortly before the deposition of Toya or KPIV-KHb is named M1 terrace and its paleoshoreline assumedly represents the highest sea stand during the substage 5e (Okumura, 1991).

KPV, AUP, and AWT erupted during the Stage 6 (Fig. 2). South of Lake Notoro (Fig. 3C) KPIV covers thick M1 terrace deposits consist of reworked KPV and AUP. In Kushiro, the M1 terrace deposits overlie fluvial gravel incising dark-colored pyroclastic

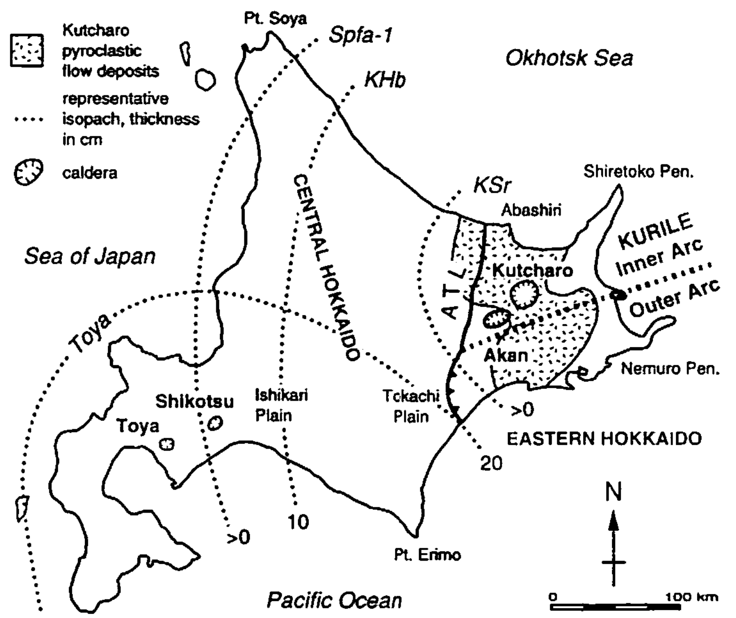

Fig. 1 Late Pleistocene widespread marker tephras and neotectonic framework of eastern Hokkaido

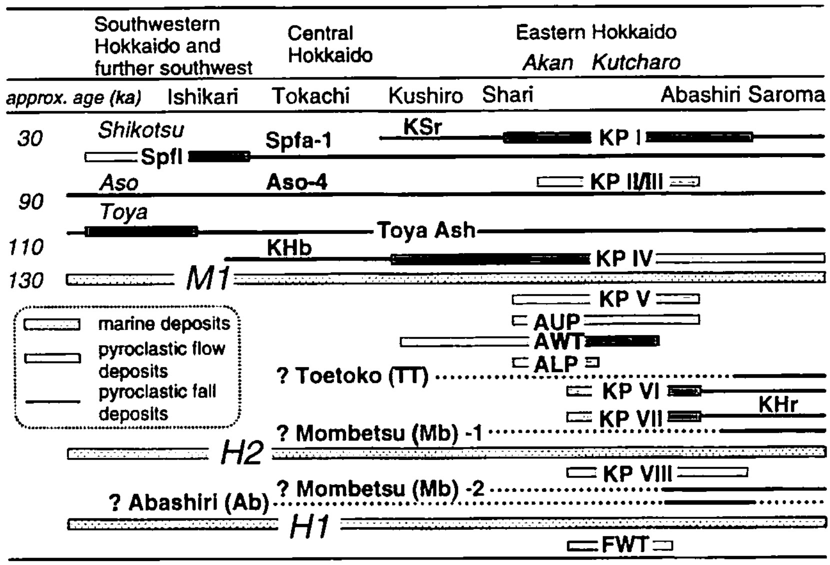

Fig. 2 Space-time diagram of marker tephras in Hokkaido
After Katsui and Sato (1963), Okumura (1991) and Machida and Arai (1992).
Vertical line for the age is not in scale. KP: Kutcharo pyroclastic flow, AUP: Akan upper pyroclastic flow, AWT: Akan welded tuff, ALP: Akan lower pyroclastic flow, FWT: Furume welded tuff.

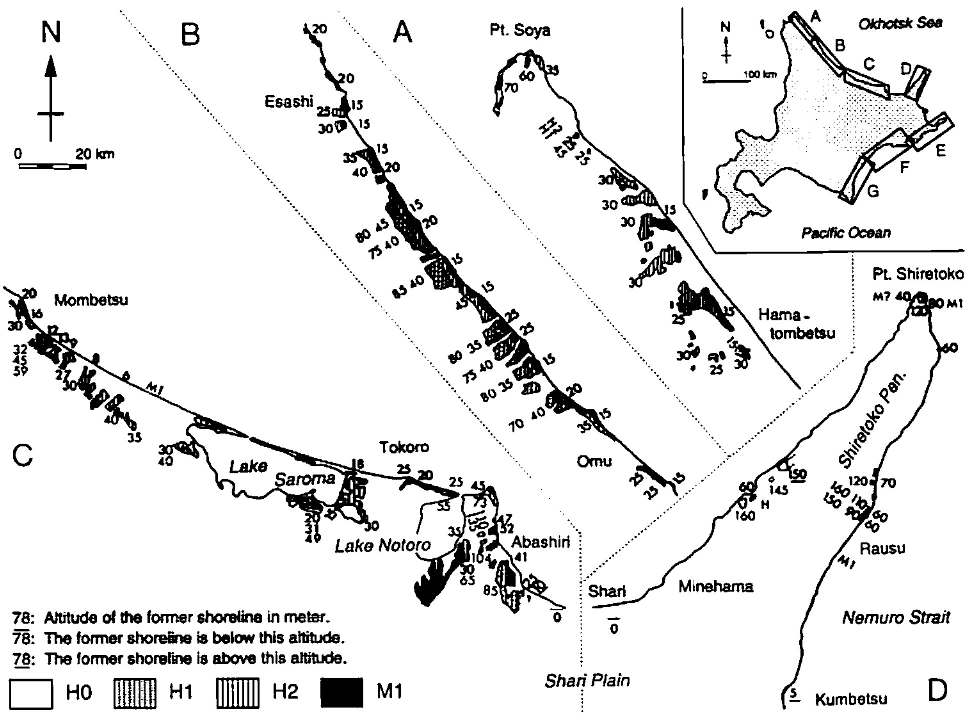

Fig. 3 Distribution of marine terraces along the Okhotsk Sea

flow deposits (Matsui *et al.*, 1987) identical with AWT, which covers M2 terrace near Otanoshike (Fig. 4F).

Tephrochronology of Middle Pleistocene marine terraces are established only in the area between Mombetsu and Abashiri (Fig. 3C). The sequence of marine sediments and overlying tephras prior to KPIV is preserved in the east of Lake Saroma (Sakaguchi and Okumura, 1986; Okumura, 1991). Mb-1 ash and KHr ash (co-ignimbrite of KPVII; Fig. 2) marks a high sea stand that formed the H2 terrace.

KPVIII, Mb-2 ash, and Ab ash cover the H1 marine terrace with its paleoshoreline at around 100 m a.s.l. near Abashiri. The ages of H2 and H1 transgression might be correlated with the Stages 5 and 7 but this should be tested with reliable absolute ages, which are insufficient for further chronological discussion.

Tephrochronology is not applicable for M1 terrace in Shiretoko Peninsula and north of Esashi, where topographic characteristics were taken as the bases for the correlation. The M1 terrace is usually the lowest and the narrowest marine terrace in Eastern Hokkaido. The lowest terrace at Pt. Shiretoko looks younger for its uneroded surface without tephra cover. This is the only possible level of marine terrace later than the M1 terrace.

For H2 and H1 terraces to the northwest of Mombetsu on the Okhotsk Sea, their correlation is constrained by the M1 terrace below and the geomorphic continuity from the southeast. In Shiretoko Peninsula and the Pacific coast chronology and correlation of H group marine terraces are not as reliable as that along the Okhotsk Sea because of the total lack of marker tephras.

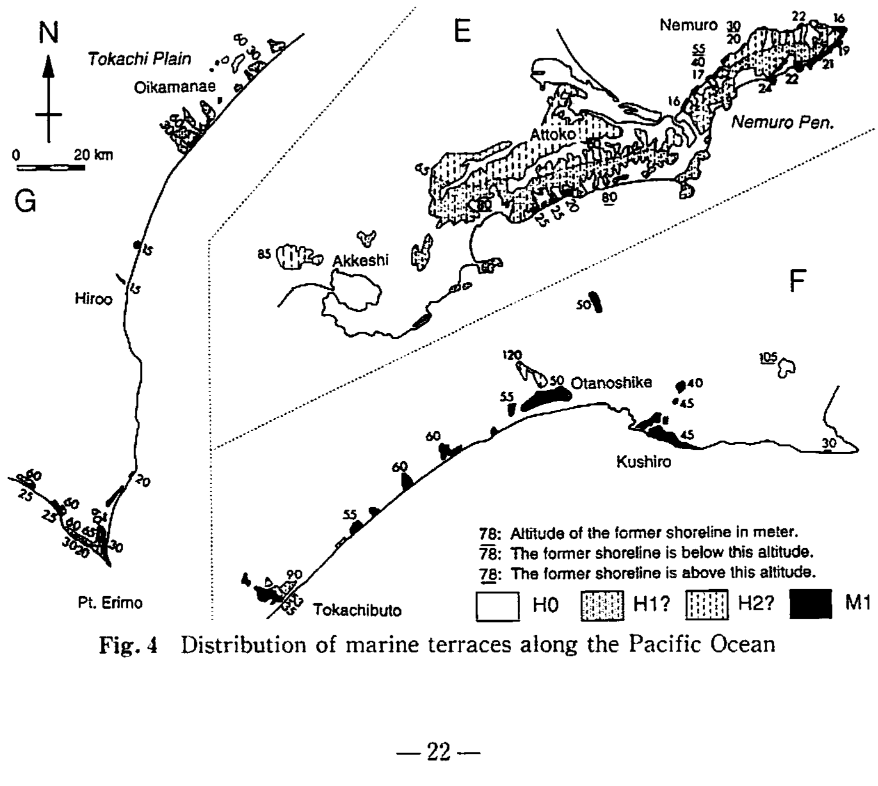

Fig. 4 Distribution of marine terraces along the Pacific Ocean

3. Deformation of Paleoshorelines

The correlation of M1 paleoshoreline made it possible to estimate vertical crustal movement since the Last Interglacial period. Though the correlation of the H group terraces is not so decisive, their paleoshorelines are useful indicator of local deformation and supplement the data from the M1 paleoshoreline. The paleoshoreline altitude of Tokachibuto, Nemuro Peninsula, and Abashiri-Mombetsu area was measured with barometric altimeter of 1 meter resolution. For the other areas, paleoshoreline altitude was measured on 1/25,000 topographic maps. Accuracy for barometric altimetry and topographic contour lines is respective ±2 and ±5 meters. This error does not affect the essence of crustal deformation shown in the Figs. 5 and 6. Distinctive features in the profiles are two narrow (30—40 km) uplift zones along the Okhotsk Sea and the wide gentle upwarping along the Pacific Ocean.

The Shari plain between Abashiri and Shiretoko Peninsula has been subsiding in the late Quaternary. There is no marine sediment intercalated in the Kutcharo pyroclastic flow and fall deposits above present alluvial surface in and around the plain. The constructional surface of the M1 marine sediments lowers abruptly in the east of Abashiri to be buried under alluvial sediments. The Koshimizu plateau in the eastern Shari Plain does not consist of uplifted and inclined marine terraces (Sakaguchi, 1959; Sato, 1968) but is a composite alluvial fan that postdates the age of Aso-4.

The uplift of Shiretoko Peninsula is also pronounced. In the western side of the peninsula the subsidence of Shari Plain is clear. On the other side at Kumbetsu, KHb ash covers M1 silt layer at 5 m a.s.l. The M1 paleoshoreline must be higher but cannot reach

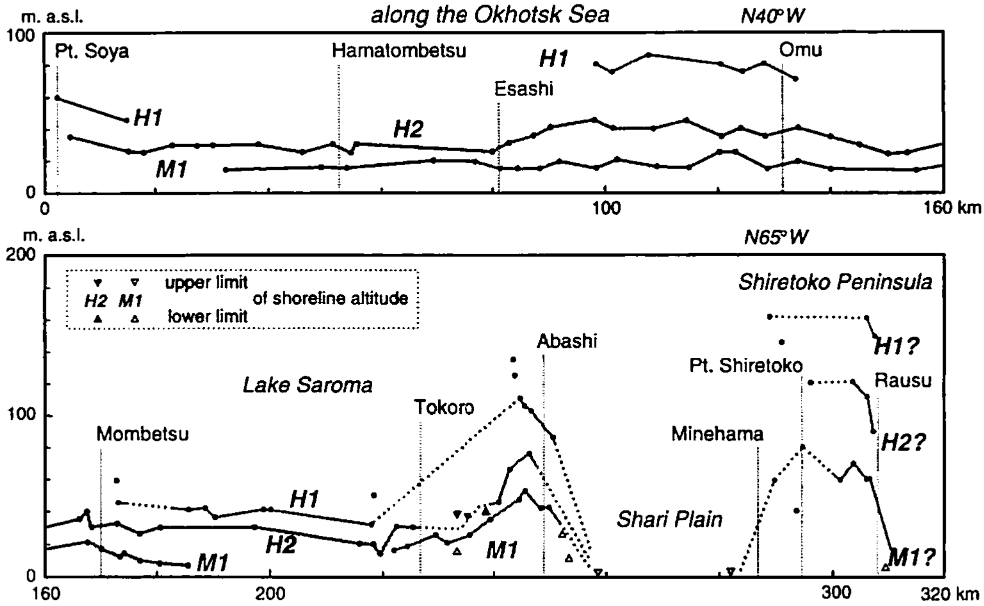

Fig. 5 Profiles of former shoreline altitude along the Okhotsk Sea

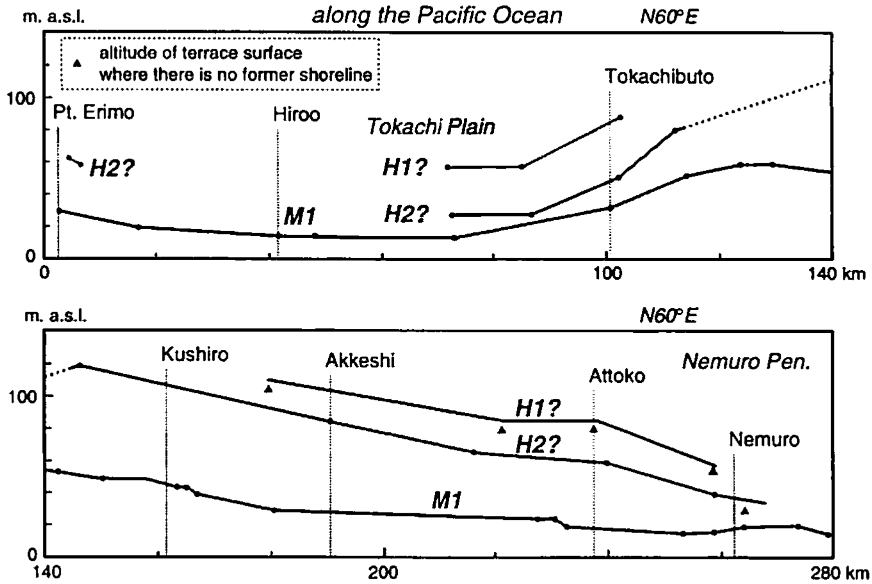

Fig. 6 Profiles of former shoreline altitude along the Pacific Ocean

so high as 60 m a.s.l. or above at Raus (Fig. 3D).

Along the Pacific Ocean, the paleoshoreline altitude gradually increases from Nemuro Peninsula to the eastern margin of the Tokachi plain in over 150 km distance. Then the altitude decreases less gradually towards Tokachi Plain in 50 km interval. This profile indicates gentle eastward tilt and rather steep westward bending respectively.

Pleistocene shoreline angle is not recognized in eastern Konsen plain between Nemuro Peninsula and Shiretoko Peninsula. M1 constructional surface outcropping along the Nemuro strait is not higher than 5 m a.s.l. and the fluvial deposits underlain immediately below KPIV are not higher than 10 m a.s.l. in the coastal area. These indicate that the eastern part of the Konsen plain is a rather stable area.

4. Discussion

The deformation in Abashiri seems to represent an uplifted zone with N-S axis though it does not accompany any particular tectonic line. It is because of the general N-S trend of the topographic features in the area and of possible southern extension of the Kitami-Yamato bank, an N-S trending tectonic ridge with active faults on both sides (Research Group for Active Faults of Japan, 1992). Ridge uplift is obvious for Shiretoko Peninsula where active reverse faulting push up the mountain range on both sides. These two uplifting zones consist the southwestern part of active *en échelon* ridges in the Kurile inner arc region.

The eastward tilting of the Kurile forearc sliver in the east of the Abashiri tectonic line is gentle but consistent. And the bending between the Abashiri tectonic line and the

Tokachi plain is also distinctive. This asymmetric large-scale deformation requires a deep-seated low angle east-dipping thrust. The characteristics of the thrust well agree with the model of continental collision in the southern part of the Abashiri tectonic line (Kimura, 1978).

The coastal tectonics of the eastern Hokkaido revealed the active uplift of the inner arc *en échelon* ridges in Abashiri and Shiretoko, and the active thrusting along the southern part of the Abashiri tectonic line. The late Quaternary regional crustal movement evidenced the westward shift and collision of the Kurile forearc sliver.

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