GEOMORPHIC DEVELOPMENT OF THE MIDDLE PLEISTOCENE FLUVIAL SURFACES IN THE KANTO PLAIN, CENTRAL JAPAN: A KEY GEOMORPHIC SURFACE OF MARINE ISOTOPE STAGE 17 TO 16

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Abstract Two middle Pleistocene tephras HBP and KMT derived from the volcanoes in the Hida Mountains are favorable marker tephras for the chronological study of this time in the Kanto Plain. On the basis of many radiometric ages and stratigraphic positions in the marine sediments of the Boso peninsula, the ages of HBP and KMT are estimated at 0.38-0.41 Ma (MIS 11) and 0.58-0.69 Ma (MIS 17.3-15.3), respectively. Judging from the stratigraphic relation with KMT, dissected fluvial surfaces, that is, the Azuyama and Sayama surfaces in South Kanto and the Kitsuregawa upper surface in North Kanto are correlative, and it is assumed that they were formed a few tens of thousands of years preceding the deposition of KMT. Preservations of these surfaces are well, and initial alluvial fans of them seem to be broad. Referring to the geomorphic development of late Pleistocene, alluvial fan deposits constituting these surfaces are most likely formed during the period from MIS 17.3 to 16.2 of a transition from interglacial to glacial. This term is specific for the geomorphic development of middle Pleistocene, characterized by the long duration keeping the stable conditions for the formation of broad fans.

Key words: middle Pleistocene, Geomorphic development, tephrochronology, Kanto Plain, central Japan

1. Introduction

The Kanto Plain, the widest in the Japanese Islands, is regarded as one of the typical area for the chronological standard of Japanese Quaternary study (Yoshikawa *et al.* 1981). This is resulted from the presence of many tephra layers useful for classifying the terraces and marine to fluvial formations. Intensive studies of the tephra and Quaternary sediments and the geomorphic surfaces in this area have revealed the detailed geomorphic development in the late Quaternary (Kaizuka *et al.* 1977; Kaizuka 1979). However, until the 1980s the middle Pleistocene chronological framework of the Kanto Plain had not been established in detail, contrast to that of the late Pleistocene. Therefore, the chronological studies had not yet confirmed the correlation of geomorphic surfaces and marine to fluvial formations with oxygen marine isotope stages with the exception of the Oiso hills and the

Boso peninsula standards of the Japanese Quaternary study. Recently. tephrochronological studies focusing the middle Pleistocene widespread tephra layers have advanced in 1990s (Machida 1999), providing several precise datum planes of this period covering the Kanto Plain. The recognition of two known marker tephra layers, the Hachioji Biotite Pumice tephra (HBP) (Minagawa and Machida 1971) and the Kasamori 22 tephra (Ks 22) (Tokuhashi and Endo 1984), widespread tephras derived from the source vents located in the southern part of the Hida Mountains in central Japan, played a significant role in the reconstruction of the geomorphic development in coastal to inland areas of the Kanto Plain. This paper shows a tephrochronologically reconstructed geomorphic history of the middle Pleistocene in the Kanto Plain, with special reference to sea level changes as well as climatic changes, controlled by Milankovitch cycle.

2. Marker Tephras for Chronology

HBP Tephra correlated to TE-5 and Omachi-A$_1$Pm Tephras

HBP tephra, its type locality is the Tama hills in the west part of the Kanto Plain, is one of the most well-known marker tephras since the early of 1970s in and around the Tama hills (Minagawa and Machida 1971) . because this tephra has specific properties characterized by presence of abundant biotite. In middle of 1970s, Machida *et al.* (1974) identified this tephra in several localities in and around South Kanto. that is, the Oiso hills in the most southern part of the Kanto district and the Boso peninsula of a standard Quaternary sequence in Japan. Recently. HBP is correlated to the Odamaki ash (ODA) (Suzuki and Hayakawa 1990) in the Chichibu basin, the Kanto Mountains, and to the Omachi-A$_1$Pm tephra (Suzuki and Hayakawa 1990) derived from the Suien-dani source vent (Harayama 1990) in the Hida Mountains (Suzuki 2000a).

Kaisho-Kamitakara Tephra

The Kaisho-Kamitakara tephra (KMT) erupted from the Kaisho source vent (Harayama 1990) in the southwest part of the Hida Mountains in central Japan is composed of a pyroclastic flow deposit and a fallout tephra (>40 km^3) distributing in the Chubu to south Tohoku areas (Fig. 1). Suzuki (2000b) described the characteristic properties available for identification of KMT and stratigraphic positions in several areas. Many radiometric ages on KMT by previous studies and its stratigraphic position in the Boso peninsula indicate that the deposition of KMT occurred between the marine isotope stage (MIS) 17.3 and 15.2 (0.58 - 0.69 Ma) as shown in Fig. 2 (Suzuki 2000b). Former names by previous studies and stratigraphic positions of tephra layers identified as KMT by Suzuki (2000b) are as follows: Biotite Zone (Minagawa and Machida 1971) above the Imokubo gravel forming the Sayama surface in the Sayama hills, a biotite zone correlated to the Biotite Zone of Minagawa and Machida (1971) by Shimizu and Horiguchi (1994) above the Toyooka gravel forming the Azuyama surface in the Azuyama hills. the Hoshitoge Biotite tephra (HtB: Koike *et al.* 1985) above the Sakaibayashi gravel forming the Kitsuregawa upper surface in the Kitsuregawa hills, and Ks 22 in the Kasamori formation of the Kazusa Group in the Boso peninsula.

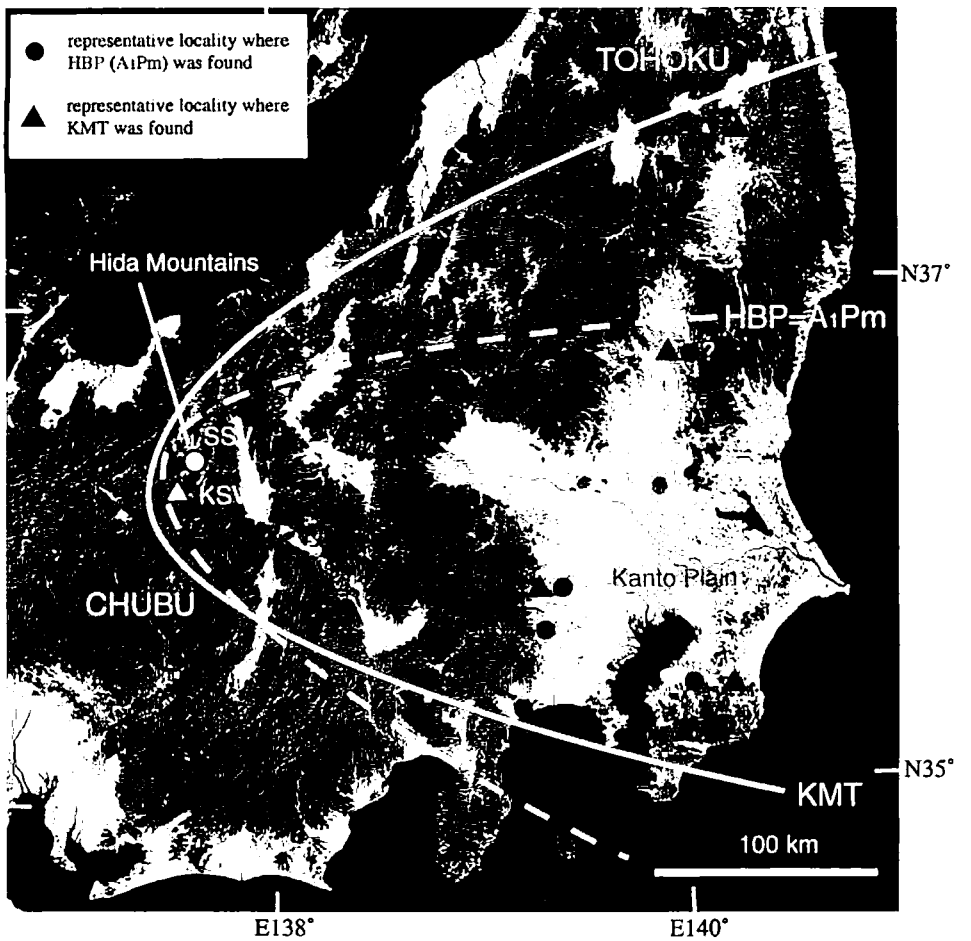

Fig. 1 Satellite image of the Kanto Plain and the adjacent area showing the distributions of KMT and HBP (A_1Pm) tephra.
SSV: Suien-dani source vent, KSV: Kaisho source vent

3. Correlation of Geomorphic Surfaces

Owing to the stratigraphic positions of KMT, dissected fluvial surfaces, Azuyama, Sayama, and Kitsuregawa upper surfaces, were correlated, and it is suggested that they were formed a few tens of thousands of years preceding the deposition of the KMT (Fig. 2). The distributions of the Azuyama and Sayama surfaces, originally had been continuous, suggest that a broad alluvial fan, which is the origin of these surfaces, had developed in the area at least from the Azuyama hills to the Sayama hills (Fig. 3). Both width and angle of this restored fan are larger than those of several late Pleistocene fans (Kaizuka 2000) formed the following periods: MIS 6-5e (S surface); MIS 5a-4 (M_2, M_3 surfaces); MIS 3-2 (Tachikawa surface group); and are comparable to those of the M_1 surface (MIS 5c) the broadest fan surface of late Pleistocene. Also, in the north part of the Kanto Plain, a prominent fan surface

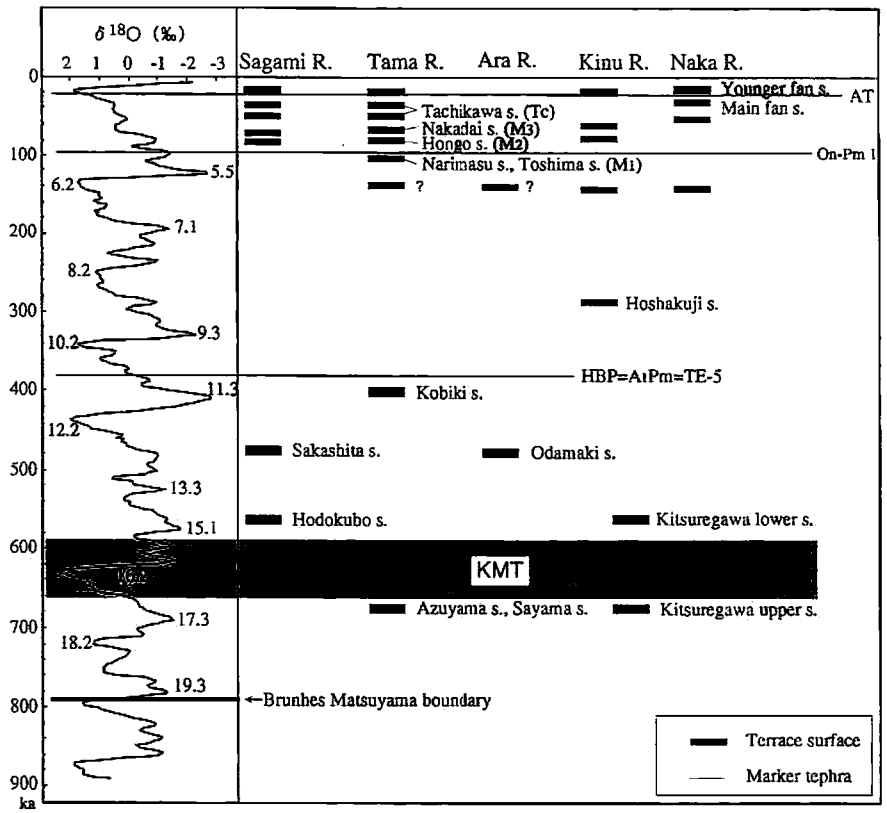

Fig. 2 Chronology of geomorphic surfaces in and around the Kanto Plain during the late Quaternary.
After Suzuki (2000b).
Compiled by Minagawa and Machida (1971), Machida and Arai (1992), Akagi and Koike (1978), Kaizuka *et al.* (2000) and Suzuki (2000c). The δ O^{18} curve is after Bassinot *et al.* (1994).

of the Kitsuregawa upper surface had emerged a few tens of thousands of years preceding the deposition of KMT. Although the depositional surface of the Kitsuregawa upper surface was fairly dissected, it is well preserved as a broad hill, and the area of this surface is the largest among those of other younger alluvial fan surfaces in this area. As shown this, broad fan surfaces formed a few tens of thousands of years preceding the deposition of KMT develop in some areas of the Kanto Plain. The presence of these well developed alluvial fans seems to indicate that there was a fairly long and stable duration of favorable conditions for the formation of broad fans.

4. Age and Condition of the Azuyama Surfaces and its Correlative

The estimated age of KMT, 0.58-0.69 Ma, and stratigraphic relation of this tephra with the Azuyama, Sayama and Kitsuregawa upper surfaces shows that these surfaces emerged at a time between MIS 17.3 and 15.3 (0.7-0.6 Ma). If the Azuyama and Sayama surfaces were

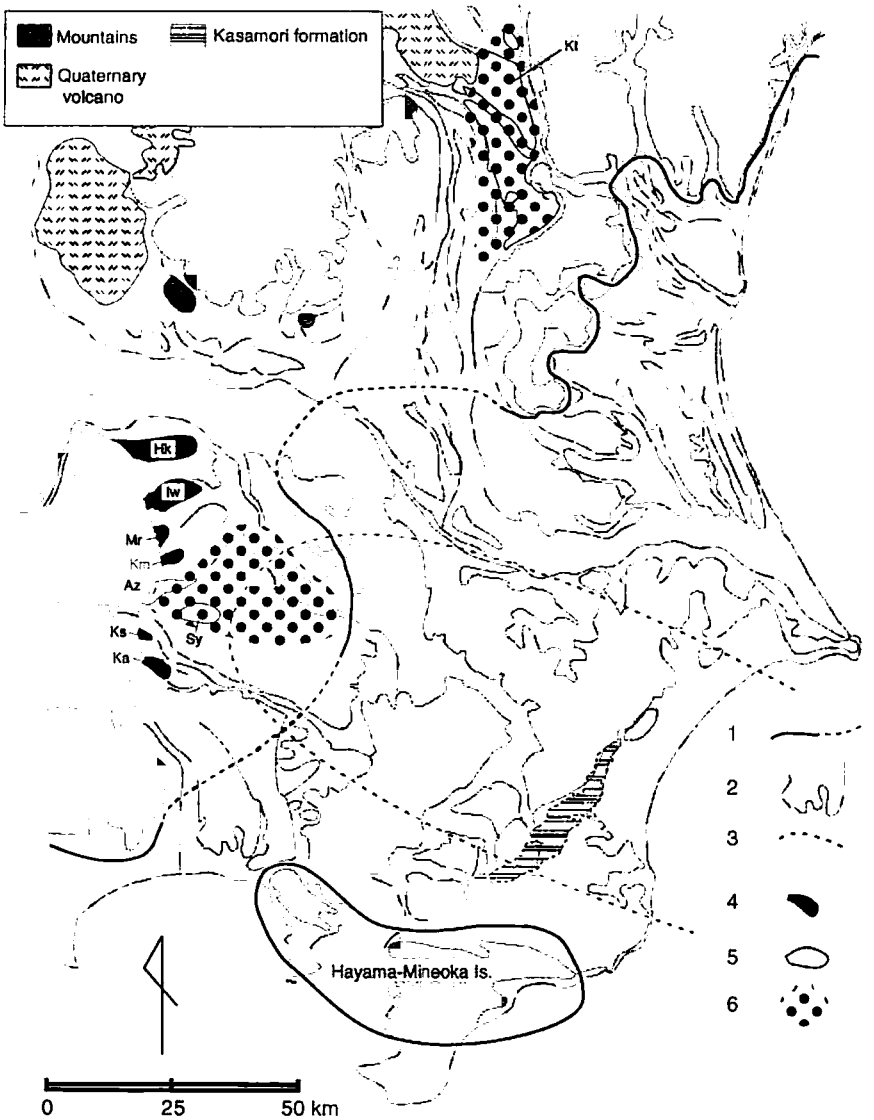

Fig. 3 Paleogeography in and around the Kanto Plain before and after the deposition of KMT. Modified of Suzuki (2000b).
1: shoreline, 2: boundary of present landform, 3: Kazusa Trough, 4: hills formed preceding Marine Isotope Stage 17, 5: Sayama surface and geomorphic surfaces correlated to the Sayama surface, 6: estimation of original distribution of Imokubo gravel and gravel bed correlated to Imokubo gravel Kt: Kitsuregawa hills, Hk: Hiki hills, Iw: Iwadono hills. Mr: Moroyama hills, Km: Koma hills. Az: Azuyama hills. Sy: Sayama hills. Ks: Kusabana hills. Ka: Kasumi hills

formed under the same geomorphic condition of the terracing during late Pleistocene in South Kanto, it is assumed that they were emerged during the period from 17.3 to 16.2, a transition from interglacial stage to glacial stage by the following reason. Generally, in the west part of the Kanto Plain, where flights of emerged fan surfaces of different altitudes and ages were seen, the present river bed in deeply excavated narrow valley shows deep incision, and so is the river bed of the last interglacial period (MIS 5e) (Kaizuka *et al.* 2000). In contrast to this, several alluvial fans, formed in the transitional stage from the interglacial stage of MIS 5e to the culmination of the last glacial stage of MIS 2, broadly develop with the longitudinal profiles characterized by steeper gradient and curvature. Typical terrace surfaces of them along the Tama River are Narimasu and Toshima terraces (MIS 5c), Hongo terrace (MIS 5a) and Tachikawa terrace group (MIS 3-2) (Kaizuka 1979). These alluvial fan deposits are originated from the sediments transported by extended river of paleo Tama River flowing on emerged delta and coastal plain accompanied with a highstand of sea level of MIS 5e. As shown in Fig.3 of a paleogeographical map illustrating the locality of the former shoreline, plains and mountainous area, geomorphic setting of the early half of middle Pleistocene, before and after the deposition of KMT, is similar to that of late Pleistocene. Thus, alluvial fan, origin of the Azuyama and Sayama surfaces, is most likely formed under the similar geomorphic condition at the formation of M_1 to M_3 surfaces and Tachikawa terrace group, and the timing of the formation of the latter is correspond to a long transitional period from interglacial stage to glacial stage. Noticing the term from MIS 17.3 to 15.3, it is easy to recognize the period of MIS 17.3 to 16.2 as a remarkable transitional period of interglacial to glacial. Therefore, it is concluded that an original alluvial fan of the Azuyama and Sayama surface was formed in a regressive stage just after MIS 17.3.

On the other hand, along the middle reach of the Naka River, prominent terraces originated from alluvial fans formed in MIS 3 to 2 (Main fan surface) and MIS 2 (Younger fan surface) (Akagi and Koike 1978) are well developed, and the present river bed shows deep incision in the excavated narrow valley cutting these terraces. This landform development, similar to that of the southern part of the Kanto Plain, indicates that the formation of broad alluvial fan synchronizes a transitional stage from interglacial to glacial. Therefore, it is concluded that alluvial fan deposits constituting the Kitsuregawa upper surface had formed under the similar geomorphic condition of the period of MIS 17.3 to 16.2.

5. Younger Geomorphic Surfaces and the Condition of their Formation

As discussed previously, we can recognize two periods with the formations of broad alluvial fans, which correspond to transitional stages from interglacial stage to glacial stage, that is MIS 17.3 to 16.2 and MIS 5 to 2. In middle Pleistocene, other transitional stages from interglacial to glacial have repeatly occurred (Fig. 2). Are there any alluvial fans formed during these transitional stages? The Hoshakuji surface, an emerged alluvial fan surface in the north part of the Kanto Plain is considered to be formed in a transitional stage of MIS 9.3 to 8.2 (Suzuki 2000c). In the west part of the Kanto district, owing to the relative stratigraphic position of the constitute materials in the tephra sequence, that is between HBP and KMT, it appears that the Sakashita surface (Sagami River) and Odamaki surface

(Ara River) (Minagawa and Machida 1971) are correlative ones and were formed under the geomorphic condition associated with the transition from interglacial to glacial of MIS 13 to 12.

Although the Sakashita, Odamaki and Hoshakuji surfaces are younger than the Azuyama, Sayama and Kitsuregawa upper surfaces, the preserved areas of the former are limited, showing separated distribution. Thus, despite of the older age of the Azuyama surface and its correlative, they are well preserved. This paradox is most likely caused by the development of original fan surface with wide area, and this is more acceptable than an explanation that by chance the surface has been prevented from the lateral erosion since the emergence of 0.6-0.7 Ma. This interpretation suggests that there was a long duration with geomorphically stable condition favorable for keeping graded river, associating with strong lateral erosion and minor changes of river bed in altitude.

Here, we can show a problem left in the study of geomorphic development in middle Pleistocene. This is the confirmation that a transitional stage of MIS 17.3 to 16.2 is a specific term for the formation of middle Pleistocene landform, thus the judgement that formation of the prominent alluvial fans in this age is general or not in the whole area of the Japanese Islands and its adjacent areas.

Acknowledgments

Part of this study was financially supported by Grants-in-Aid for Science and Culture of Ministry of Ed. Sci. Cul., Japanese Government: Shorei kenkyu (A) No. 09780137: Chemical analysis of major elements on titano-magnetite by EPMA and its applicative study for identification of tephra.

I wish to dedicate this paper to Professor Takao Kikuchi in commemoration of his retirement from Tokyo Metropolitan University, who led the author have much interests in landform of middle Pleistocene and their origin. I am grateful to him for his hearty advice, encouragement and constructive criticism.

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