

Buried Terraces in the Lower Sagami Plain,
Central Japan : Indicators of Sea Levels
and Landforms during
the Marine Isotope Stages 4 to 2 (Part II)

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3. METHOD AND STUDY FIELD

Data, method and study field will be shown in this chapter along with important terminology.

3.1 Data and method

To answer the questions shown above, and to get the paleo-data during the MISs 4 to 2, the author has given attention to evidence of buried landforms in south Kanto. Identification and correlation of buried terraces are important steps in finding answers to the questions.

1) Identification of buried terraces

The author obtained reports on test boreholes and core samples used for construction of buildings and public works, to examine the distribution and correlation of buried landforms. The borehole data have been obtained from various governmental and public offices. These 'primary' borehole logs contain columnar sections with depth, type of deposits, color, indications of shells, organic materials and tephtras, standard penetration test value (N-value), and other observed features.

Some compiled borehole data collections were also obtained. They contain only columnar sections with N-value. It was rather difficult to determine terrace deposits. Therefore, they were used as supplements for the identification of buried terraces.

On the other hand, the author intended to obtain core samples to verify the descriptions in test boring reports. Several core samples have been offered by courtesy of offices or individuals. Some samples were analyzed for the identification of marker tephtras.

The interpretation of borehole logs was carried out to distinguish buried terrace deposits from others. The author concerned that the deposits were of marine or fluvial origin, and investigated the depth and thickness of terrace deposits, as well as tephra covering the terrace deposits in each site.

2) Correlation of regional terrace sequence with marine isotope stages

The correlation of regional terrace and tephra sequence with isotope stages has been carried out on the basis of a chronological framework of tephra, landforms and deposits in south Kanto. Buried fluvial terraces were compared with subaerial terraces, in terms of longitudinal continuity of deposits and tephra sequence associated with terrace deposits.

In order to examine the correlation of buried terraces with subaerial terraces, the author prepared geological cross sections from extensive borehole data.

Buried fluvial terraces and deposits do not always show exact paleo sea level ; however, the deepest level of specific terrace deposits always shows the maximum height of the sea level in each stage. Moreover, distribution of buried terraces should contribute to reconstruct the paleo-geography of the plain in each stage.

3.2 Study Field

This study employs the lower Sagami River Plain for the main field, and the lower part of the Paleo-Tokyo River system for the complementary area (Fig. 3.1). The features favorable for this study are shown below.

The most important factor for obtaining paleo data from buried landforms in the lower Sagami Plain is the less developed continental shelf facing the river mouth. A deep tectonic submarine valley (a part of Sagami Trough) approaches only two kilometers from the river mouth. Then an extremely

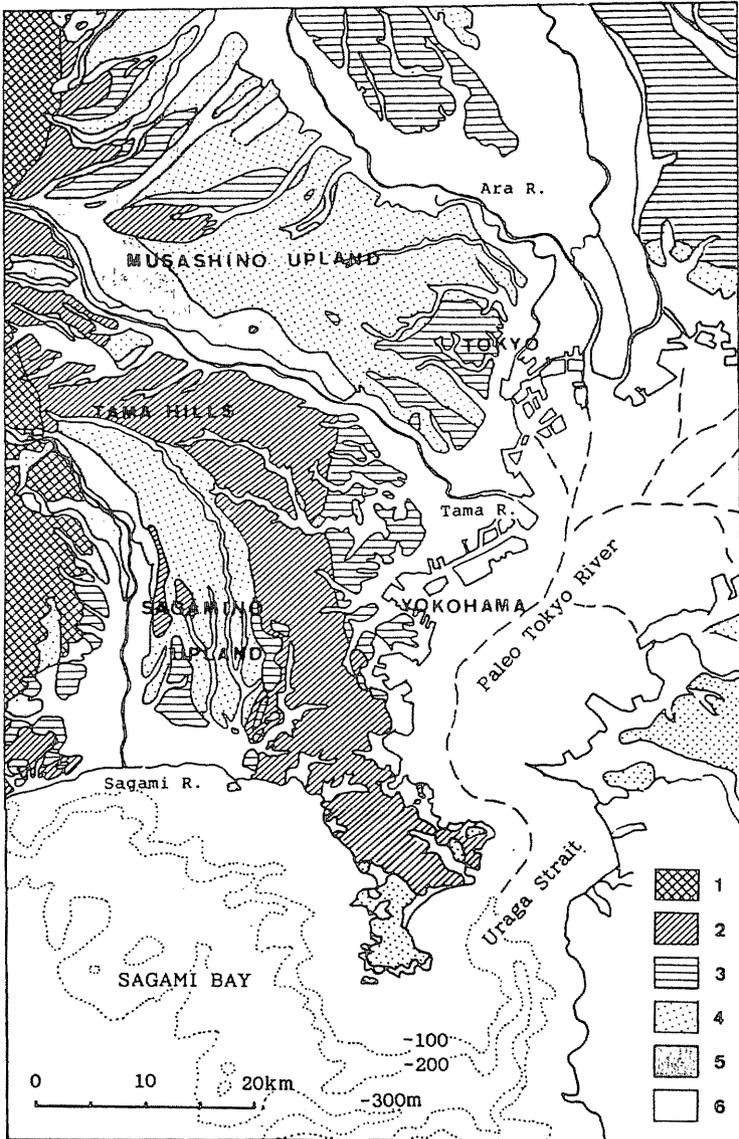


Fig. 3.1 Study area (Modified from Kaizuka and Matsuda, 1982)

1 : mountain, 2 : hill, 3 : Shimosueyoshi surface,

4 : Musashino surface, 5 : Tachikawa surface, 6 : lowland



Fig. 3.2 Landforms near the Sagami River mouth (Oya *et al.*, 1991)

steep slope occurs near the present river mouth extending to the valley (Fig. 3.2). Consequently, the Sagami River must have been sensitive to the Quaternary sea-level changes. This is supported by the occurrence of a flight of fluvial terraces, developed from the lower to upper reaches of the Sagami River. Their formation must have been associated with the sea-level drop and rise during the Last Glacial Cycle. In the city of Sagami-hara, more than twelve steps of terraces were formed during the Last Glacial Cycle (Machida *et al.*, 1984). The lower reaches of these terraces are buried with the Recent deposits (*Chusekiso*).

The other important feature of this area is the presence of thick tephra layers. They accumulated with time through the Late Quaternary. Mt. Fuji and Hakone volcanoes, located some 60 km and 30 km to the west, produced tephras on the lower Sagami Plain. The thickness of tephras on the Sagami-hara Terrace is about 20 m, which is twice as thick as the equivalent aged Musashino Terrace in Tokyo.

3.3 Terminology

The present study uses these terms with the following definition.

Age: approximate ages, including 'orbitally tuned' ages, are shown by the unit ka (1,000 years ago), except radiometric dated ages (see 'radiometric age').

Isotope stages: This study uses the marine isotope stages (Emiliani, 1955; Shackleton, 1987; Martinson *et al.*, 1987), instead of words like 'early last glacial', or 'pleniglacial'. Substages within the marine isotope stage (MIS). 5 are used as 'MIS 5e' and 'MIS 5c', instead of 'substage 5e' or 'substage 5.3'. it is because the MIS 5e is not a 'substage', but an independent period of the Last Interglacial.

'*Loam*': Relatively uniform brown-colored volcanic ash soil with many

scoria layers, which were derived by numerous and frequent small eruptions of the Fuji Volcano in this particular case. Formerly it was referred to as 'weathered ash', 'volcanic ash soil' and '*Kanto Loam*'.

Marker tephra : Single and remarkable tephra formation beds which consist of silisic pumice and widespread vitric ash, interposing between 'loam'. They are useful time-markers.

Paleo sea level : It means the height of the eustatic sea level in the past specific age, compared with the present sea level, without any tectonic movements. 'Observed (former) sea-level' includes eustatic plus tectonic factors. No hydro-isostatic correction is included in these values.

Radiometric age : The present study refers to radiometrically dated ages with the dating method used, such as fission-track, U-series, K-Ar and ^{14}C .

The Recent deposits : The so-called *Chusekiso* in Japanese. In the coastal area, it is a sequence of deposits associated by the Holocene transgression. It consists of the uppermost Pleistocene, and Holocene deposits, or deposits after the culmination of the MIS 2.

Tephra : this is a general term for air-fall and pyroclastic flow deposits produced by volcanism. It contains both marker tephtras and 'loam' (see 'marker tephra' and 'loam').

4. CHRONOLOGICAL FRAMEWORK FOR TEPHRA AND TERRACE SEQUENCE IN THE SAGAMI PLAIN AND ADJACENT AREAS

This study aims to establish the correlation of terraces in south Kanto with marine isotope stages. The standard tephrostratigraphy and terrace sequence in the Sagami Plain and adjacent areas are shown first, and they are arranged in order of the isotope stages.

4.1 Tephrostratigraphy

1) Stratigraphy

Fuji and Hakone Volcanoes are two major sources of tephras in south Kanto during the Last Glacial Cycle. Eruptions have occurred repeatedly providing many air-laid tephra layers to the east. These tephras, not only marker tephras but also volcanic ash soils, or 'loam', are available for tephrochronology. Each marker tephra indicates the simultaneous horizon between distant areas, while the thickness of 'loam' indicates the relative length of time between the marker tephras.

The tephrochronology is very useful in distinguishing the equivalent terraces and deposits. The same sequence of tephras are seen on the equivalent terraces, because after the emergence of the terrace surface, air-laid tephras accumulated on the surface. It is possible to correlate distant terraces, including marine and fluvial terraces.

A standard chronology of tephra in south Kanto has been established in Oiso Hills, located some 40 km east of Fuji Volcano and 20 km east of Hakone Volcano (*e.g.*, Machida and Moriyama, 1968 ; Machida, 1975 ; Uesugi *et al.*, 1983). the total thickness of tephras in Oiso Hills during the Last Glacial Cycle is about 60 m (Machida, 1971 ; Figure 4.1).

Figure 4.2 shows the standard tephra sequence with marker tephras in the Sagamino Upland.

2) Radiometric ages of marker tephras

The chronology of the Last Glacial Cycle has been established by applying fission-track dating of marker tephras in south Kanto (Machida and Suzuki, 1971). The fission-track ages of Hk-KIP-6 and 8, sitting on the Last Interglacial marine deposits (shown in Figs. 4.1 and 4.2) were shown

as 128 and 132 ka. The younger Hk-KIP-13, Hk-KmP-1 and KmP-7 were shown as 117, 98 and 89 ka respectively. The fission-track ages of On-Pm1, Hk-OP and Hk-TP were shown ca. 80, 66 and 49 ka. Machida and Arai (1992), however, reviewed and reestimated their ages as follows.

The age of Aso-4, interposed between On-Pm1 and Hk-OP, is estimated at about 85-90 ka (Machida and Arai, 1992), on the basis of dates by TL, ESR and K-Ar methods, as well as the marine isotope stratigraphy in the Pacific Ocean. Accordingly, ages for On-Pm1 and Hk-OP should be 95-100 ka and 80-85 ka respectively (Fig. 2.2), much older than the above-mentioned fission-track ages.

The age of Hk-TP has recently redated by radiocarbon methods. It is $50,100^{+2,700}_{-2,000}$ yBP by the liquid scintillation method (Togashi and Matsumoto, 1988), and $52,310 \pm 360$ yBP by AMS (Nakamura *et al.*, 1992). Machida and Arai (1992) however suggested the revised age for Hk-TP as 60 ka or more, on the basis of marine terraces and glacial deposits.

The age of AT has been measured by ^{14}C method. The age distribution of it is centered at 22,000 yBP (Machida, 1991). However, older ages have been shown by liquid scintillation and AMS ($24,720 \pm 290$ yBP; Matsumoto *et al.*, 1987). Machida and Arai (1992) suggested the age of AT as 22-25 ka.

3) Assumption of ages from accumulation rate of 'loam'

There are few radiometrically dated marker tephras for the periods of MISs 4 to 2, which is the target period of this study. Therefore, to estimate the ages of undated tephras and related terraces, the assumption of uniform accumulation rates of 'loam' has been used. Production of 'loam' is mainly due to frequent basaltic eruptions of Mt. Fuji in the Late Pleistocene. It appears that the thickness of 'loam' between time-marker tephras

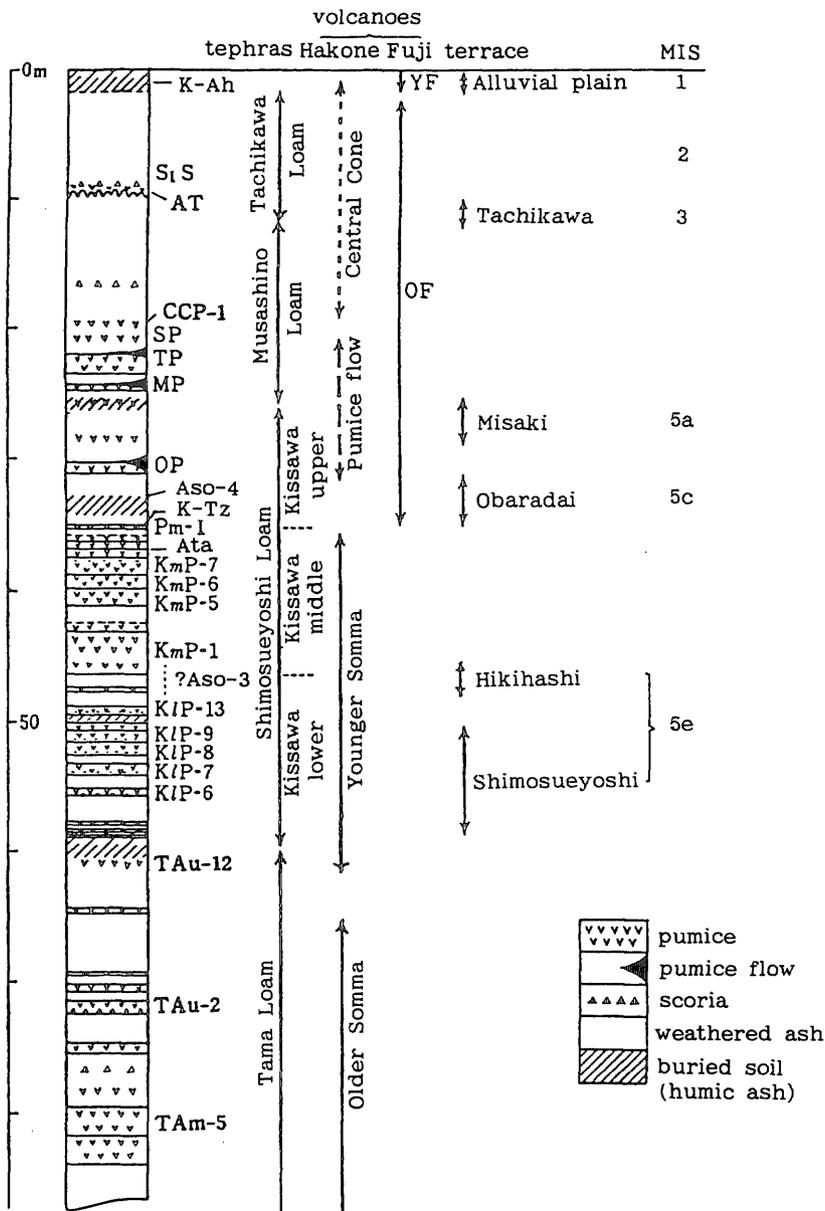


Fig. 4.1 Marker tephras in the Last Glacial Period in Oiso Hill (Arai *et al.*, 1977, revised)

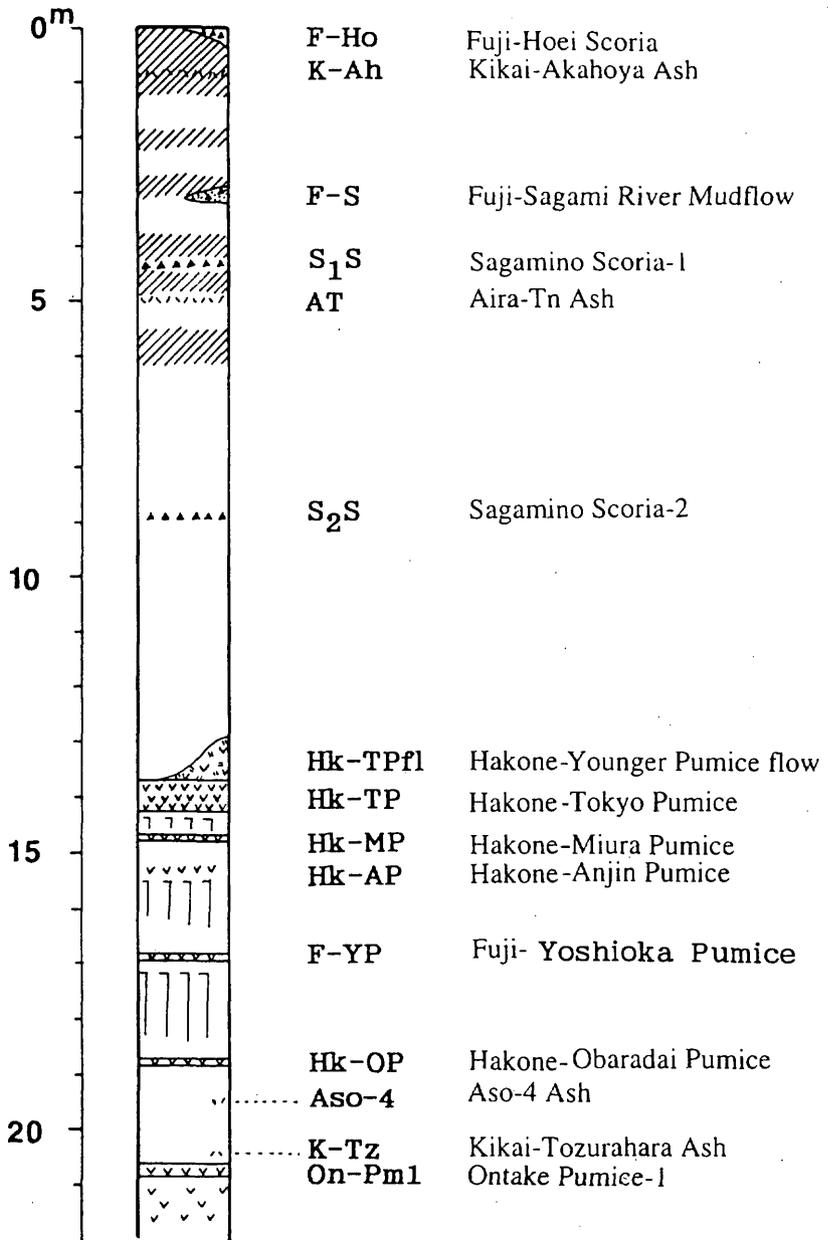


Fig. 4.2 Marker tephras in the Last Glacial Period in Sagami Upland

is roughly proportional to the time intervals.

Using important age controls in the tephra sequence in Sagamino Upland, the average accumulation rate of 'loam' is estimated (Fig. 4.3). Age controls are as follows: the base of Kuroboku and On-Pm1, while the thicknesses of Hk-TP, Hk-MP and Hk-OP were excluded. The rate, 0.23 m/ky between Hk-TP and AT is also used to estimate the ages within the MISs 4 and 3 (see 4.3).

4.2 Outline of subaerial terraces in the lower Sagami Plain and adjacent areas

An extensive Sagamino Upland occurs on the left bank (east) of the lower Sagami river, bordered by Tama Hills on its northeast. Sagamino Upland consists of marine and four groups of fluvial terraces, which have been formed during the Last Glacial Cycle: marine Koza Upland, Sagamihara Terrace group, Nakatsuhara Terrace, Tanahara Terrace group and Minahara Terrace group (Fig. 4.4).

The distribution of terraces and some characteristics of each terrace are described as follows (Machida *et al.*, 1984, 1985, 1986 and 1990).

1) Koza Upland

Koza Upland occurs in the southernmost part of the Sagamino Upland. Marine sandy terrace deposits are covered with about 30 m of thick tephra. It is recognized as the Last Interglacial marine terrace (Machida, 1971). The surface of the marine deposits tilts westward: lower than 15 m a.s.l. in the west, and higher than 30 m a.s.l. in the east (Machida, 1973). It is sometimes called "Koza Hills" because dissection caused the upland to show hilly land.

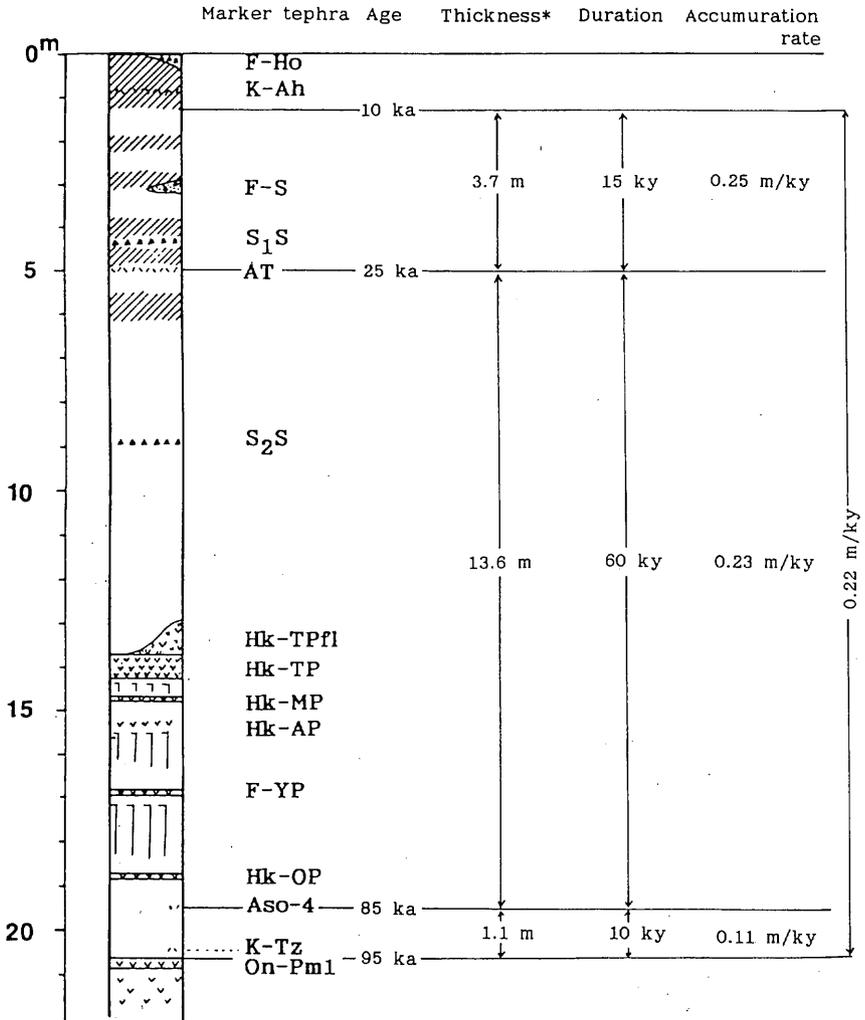


Fig. 4.3 Accumulation rates of 'loam' in Sagami Upland

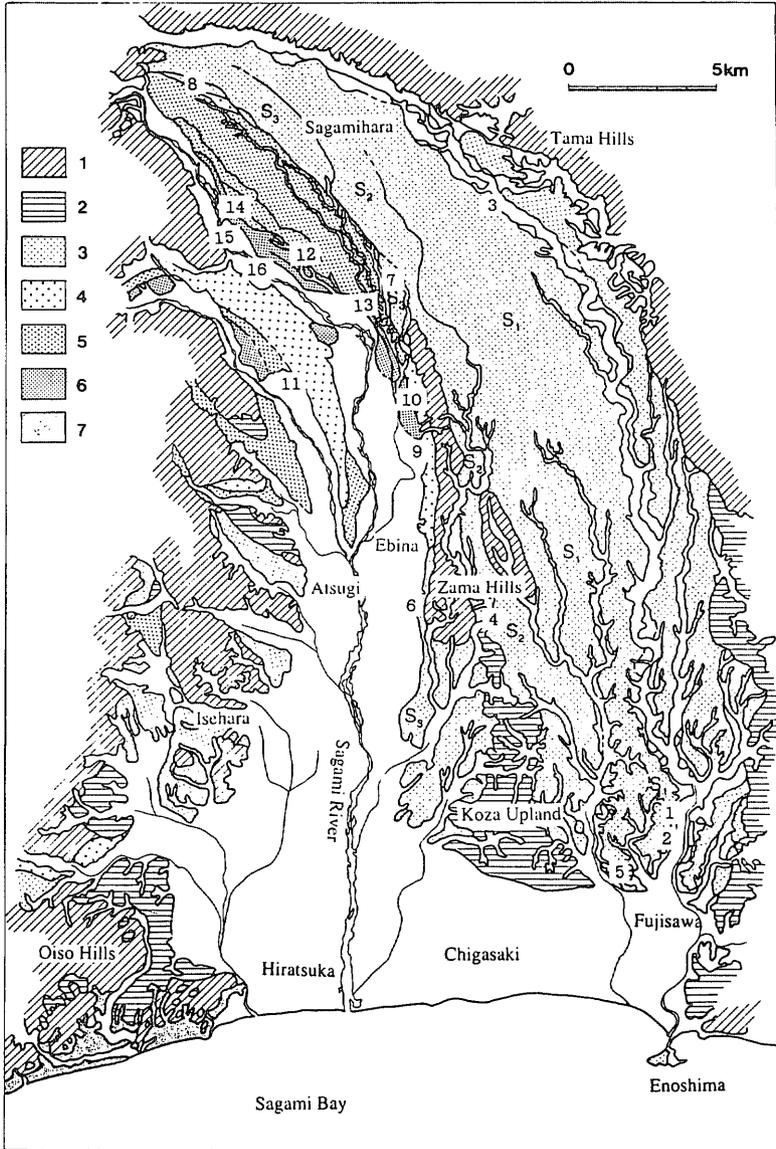


Fig. 4.4 Distribution of terraces in the lower Sagami Plain

1 : mountain and hill, 2 : Shimosueyoshi terrace, 3 : Sagamihara terrace, 4 : Nakatsuhara terrace, 5 : Tanahara terrace, 6 : Minahara terrace, 7 : Holocene marine terrace

2) Sagamihara Terrace Group

The present study subdivides Sagamihara Terraces into five surfaces (S1-S5) as Machida *et al.* (1984, 1985 and 1986) did.

S1 terrace : The S1 terrace occurs in the eastern part of Sagamino Upland. The higher terrace of Enoshima Island is identified as the only marine S1 terrace in the Sagami region, that corresponds to Obaradai Terrace in Miura Peninsula, south Kanto. Almost all of the other Sagamihara terraces are of fluvial origin.

The average thickness of tephra on the S1 terrace is about 20 m. The Obaradai Pumice (Hk-OP) is seen on the bottom of tephra covering this terrace. Hk-OP is coarse (10-20 mm in diameter) white pumice, forming a remarkable bed with the thickness about 50 cm in Fujisawa. On the other hand, it thins out to the north, and a layer with scattered coarse pumice of Hk-OP is seen in the northern Sagamino (Fig. 4.5).

The southern part of this surface is strongly deformed by tectonic uplift, showing northward-tilting.

This terrace consists of sand and gravel, showing that they formed a fan-delta. The thickness of the gravel bed is 10-20 m in Sagamihara City, while in the lower reaches, 5-10 m in Fujisawa. A 'buried valley' along JR Yokohama Line has more than a 30 m thick gravel bed (Machida *et al.*, 1986).

S2 terrace : The S2 terrace is identified in Fujisawa and Ayase, the southern part of the Sagamino Upland. It occurs from the north to south, in the central part of Sagamino Upland, between the Hikiji River and Zama Hills. However, the border between S1 and S2 is unclear in the northern part : they seem to converge in Sagamihara City. The gradient of this surface is greater than that of S1.

Yoshioka Pumice (F-YP) from Mt. Fuji forms a basal key bed on the S2

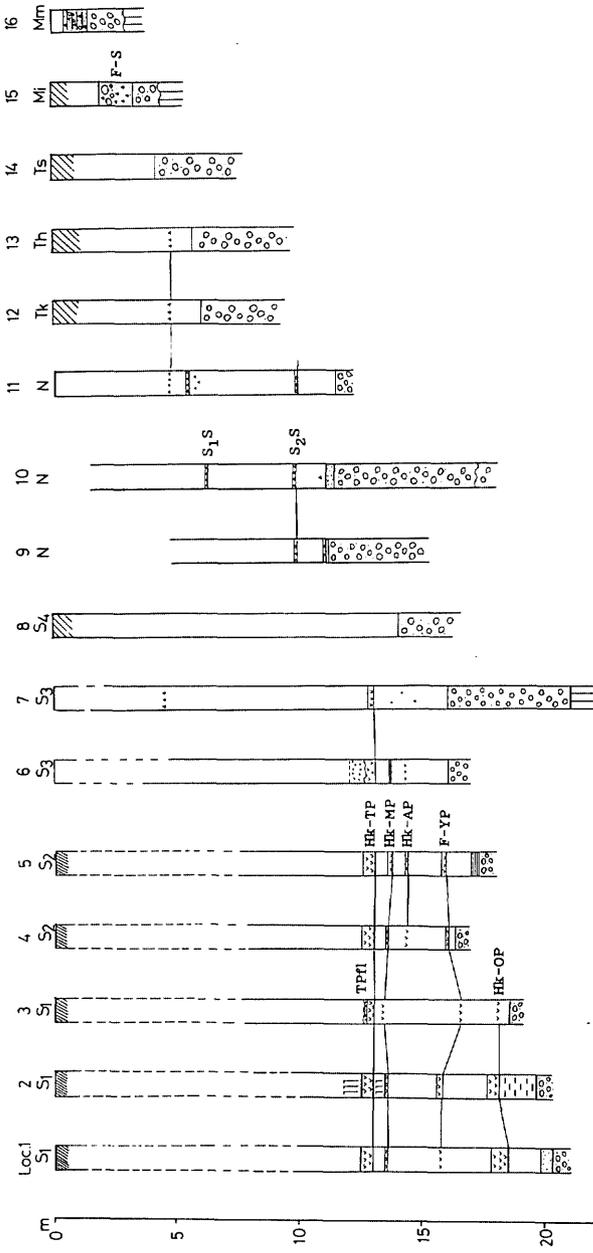


Fig. 4.5 Columnar sections of Sagamihara, Nakatsuohara, Tanahara and Minahara terraces. Localities are shown in Fig. 4.4

terrace. The S2 terrace was formed as a fill-strath terrace, which is cutting the S1 terrace.

S3 terrace : The S3 terrace exists in a limited extent in Sagami-hara City (in the upper reaches), and from Ebina City to Samukawa Town (along the lower reach of the Sagami Plain). The S3 terrace submerges into the alluvial plain near Samukawa. The gradient of the S3 surface is greater than that of S1 and S2. Anjin Pumice (Hk-AP), a thin, scattered fine white pumice layer, forms the basal marker in the overlying air-laid tephras. It becomes indistinct to the north. However, it is a marker tephra to identify the S3 terrace. Deposits of the S3 terrace also consist of sand and gravel.

S4 and S5 terraces : The S4 and S5 terraces are only seen in limited areas in Sagami-hara City. Test boring data showed that S4 is covered with Hk-TP and S5 is not (Machida *et al.*, 1986).

Both Miura Pumice (Hk-MP) and Tokyo Pumice (Hk-TP) are seen remarkably in the whole part of Sagami Upland. The thickness of the Hk-TP bed are about 50 cm in Fujisawa, and about 30 cm in Sagami-hara, while the thickness of Hk-MP varies from 10 to 5 cm. They consist of coarse (5-10 mm in diameter) yellow pumice. Pyroclastic flow deposits associated with Hk-TP (TPfl) are found in the central part of Sagami Upland. Dune-like pyroclastic surge deposits that is the basal part of the TPfl are observed in Ebina and Yamato.

These terraces seem to have steeper profiles than other Sagami-hara terraces.

3) Nakatsuhara Terrace

On the right bank (west) of the Sagami River, there occurs Nakatsuhara Upland, lying between the Nakatsu and the Sagami rivers. The main part of the upland is occupied by Nakatsuhara terrace, which is composed of flu-

vial sand and gravel covered with c. 10 m thick tephras (Fig. 4.5). It submerges into the alluvial plain near Atsugi City. The Nakatsuhara surface is also seen on the left bank of the Sagami River near Zama City in a small area.

This terrace has a thick gravel bed (>10 m), which is covered with Sagamino Scoria-2 (S2S), seen some 1 m above the terrace deposits. However, S2S is indistinct in other areas and no other marker tephras are available for this terrace. It was emerged during the interval between the deposition of Hk-TP and AT tephras. The thickness of 'loam' is 3-4 m between Hk-TP and the horizon from which the Nakatsuhara terrace emerged.

Yonezawa (1981) argued that Nakatsuhara terrace was formed accidentally, such as a burst of debris flow. Because its profile is steep, the overall part of it emerged within a very short time interval, and shows rather poorly sorted gravel. The author, however, does not support the above idea, because the Nakatsuhara Terrace is also seen along the main trunk of the Sagami River. The steep terrace profile seen in the right bank originated from the Nakatsu River (a tributary of the Sagami River), whose present profile is still steeper than the Sagami River.

4) Tanahara Terrace Group

The Tanahara terraces are well developed in Sagamihara City, the upper reach of the lower Sagami River Plain. Kaizuka and Moriyama (1969) subdivided it into four terraces: Kamimizo (Tk), Harataima (Th), Yotsuya (Ty) and Shimizu (Ts) terraces, respectively. They have steeper longitudinal profiles than that of the Sagamihara terraces. Among them, 'Th' terrace gravel is directly covered with AT tephra (Fig. 4.5). The AT ash is recognized just below a remarkable scoria of S1S. The 'Tk' and 'Th' terraces are covered with AT, while the other two terraces are not. The

thickness of tephra on this terrace is about 4-6 m.

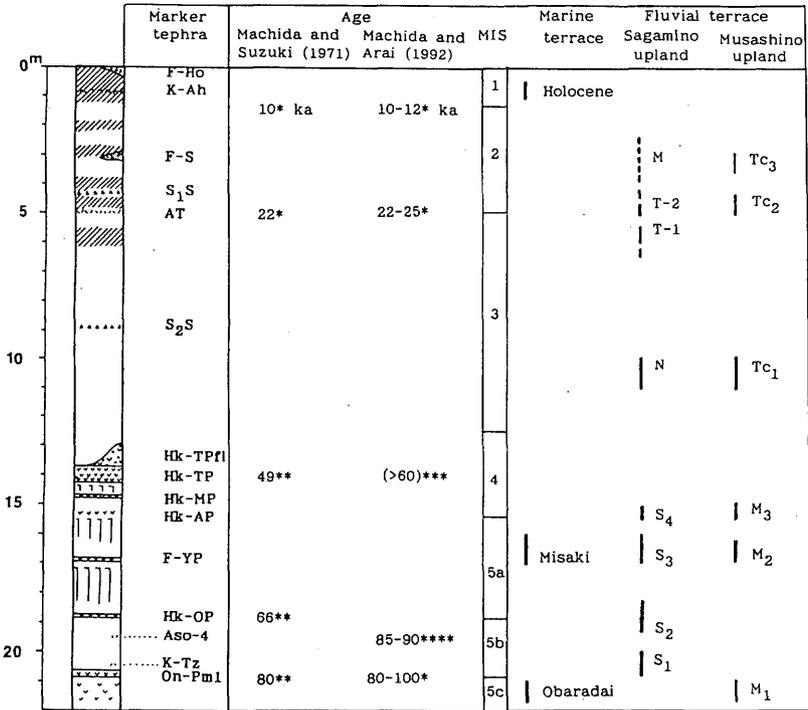
5) Minahara Terrace Group

Kaizuka and Moriyama (1969) divided this group of terraces into five : Yotsuji (My), Mochi (Mm), Tokiwa (Mt), Isobe (Mi) and Shoda (Ms) terraces. Minahara terraces have steeper profiles than other terraces along the Sagami River, and submerge into the alluvial plain in the upper reaches, Sagami-hara to Zama (Fig. 4.6). As the Mochi terrace has the steepest longitudinal profile, it was suggested that the terrace deposits of 'Mm' continue to the Basal Gravel of the Recent Deposits (BG) in the lower reaches (Kaizuka and Moriyama, 1969).

Fuji-Sagami River Mudflow deposits (F-S) form a remarkable key bed for identifying the Minahara Terraces (Fig. 4.5). Kaizuka and Moriyama (1969) referred to it as 'Old Fuji Mudflow deposits'. Machida *et al.* (1990) clarified that there are three units of F-S, and their ages were estimated to be in the period between 17 and 14 ka.

4.3 Correlation of regional stratigraphy with the isotope stages

Marine terraces and tephra sequences in south Kanto for the Last Glacial Cycle have been correlated with the MISs 5 and 1, *i. e.*, relatively high sea-level periods. On the other hand, the correlation of terraces with the MISs 4 to 2, *i. e.*, relatively low sea-level periods, has not been completed. The author attempts to correlate the regional stratigraphy with these stages by using various pieces of evidence. The correlation is summarized in Fig. 4.7.



*¹⁴C **FT ***stratigraphy/accumulation rate ****FT, U-series, ESR, TL, K-Ar

Fig. 4.7 Correlation of marine and fluvial terraces in south Kanto, with tephra and marine isotope stratigraphy

1) The MIS 5 : Correlation with marine terraces

Marine terraces are positive evidence of high sea-level stands, so they are comparable with peaks in the isotopic records.

According to previous works (Machida, 1971 ; Machida and Suzuki, 1971 ; Machida, 1975 ; Machida and Arai, 1992), chronology of marine terraces, which has established in south Kanto, is summarized as follows.

The MIS 5e and Shimosueyoshi terrace : Shimosueyoshi marine terrace and other equivalent terraces occurring in south Kanto provide abundant evi-

dence that they were formed during the interglacial period. The distribution of paleo shoreline of the Shimosueyoshi stage shows an distinct transgression, which widely covered south Kanto. The Koza Upland in Sagami-no, Kissawa and Senjojiki terraces in Oiso Hills (Fig. 4.8), and Yodobashi and Ebara uplands in Musashino correspond to this terrace.

The plant fossil assemblages for this stage were investigated by Tsuji (1980). He demonstrated the existence of warm temperate to sub-tropic elements, such as *Lagerstroemia*, *Sapium sebiferum*, *Melia azedarach*, *Aleurites cordata*, *Ehretia disksonii* and *Buxus*, obtained from the Kissawa formation in Oiso Hills. It was assumed that the climatic condition during the Shimosueyoshi transgression was similar to that of the present.

From a tephrochronological point of view, more than 1 m thick volcanic soil with no significant tephra layers was formed during the transgressive culmination of the Shimosueyoshi stage. This soil is considered to be an interglacial soil, called Shimosueyoshi Buried Soil (Machida, 1971). A marker tephra called Hk-TAu-12, with the fission-track age of c.140 ka, was recognized at the bottom of this soil.

Based on the above evidence, the Shimosueyoshi transgression has been correlated with the Last Interglacial period, or the MIS 5e. These well-developed Last Interglacial marine terraces are also widely seen in other coastal areas in Japan.

The transgression was followed by occurrence of Hk-KIPs and Hk-KmPs tephtras. The Hk-KIPs were emplaced in the regression and cool climate stage, which was suggested by plant fossil assemblages (Tsuji, 1980; Tsuji and Minaki, 1982). The latter cool climate stage can be correlated with the MIS 5d (Machida, 1995).

The MIS 5c and Obaradai Terrace : Machida and Arai (1992) correlated this terrace with the MIS 5c. The On-Pm1, with K-Ar age of 100-95 ka, is

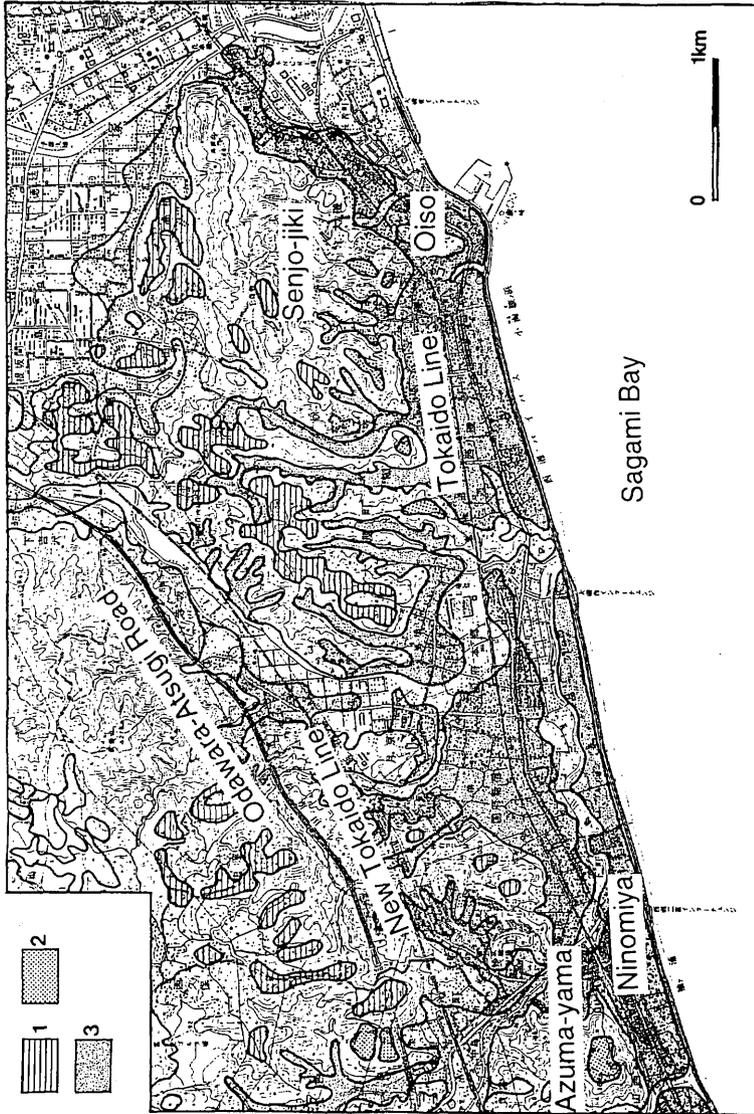


Fig. 4.8 Marine terraces in eastern Oiso Hills
1 : Shimosueyoshi terrace (MIS 5e), 2 : Azumayama terrace (MIS 5a), 3 : Nakamurahara terrace (MIS 1)
Base Map : GSI Topographic Map "Hiratsuka" (S=1/25,000)

a marker tephra that directly covers the marine Obaradai Terrace in Miura Peninsula (Fig. 4.9). The eruption of Aso-4 tephra with radiometric age of 90-85 ka, and the MISs 5b/5a transition occurred after the culmination of this stage. Hk-OP is another important tephra to identify the Obaradai Terrace. Machida and Arai (1992) suggested that the older Hikihashi Terrace in Miura peninsula belongs to the MIS 5e.

The fluvial S1 terrace in Sagamino Upland emerged before the eruption of Hk-OP, slightly later than the Obaradai marine terrace. This is because Hk-OP is found directly on the terrace deposits. The S2 terrace emerged prior to the MIS 5a, possibly in the transition stage of the MIS 5c/5b, because the altitude of this terrace is slightly lower than the S1 terrace.

The M1 fluvial terrace in Musashino Upland is said to be roughly equivalent to Obaradai Terrace.

The MIS 5a and Misaki Terrace : The marine Misaki Terrace in Miura Peninsula emerged before the eruption of Hk-MP (Arai *et al.*, 1977). In Oiso Hills, marine Azumayama terrace gravel is directly covered by Hk-AP. Both terraces are equivalent and assigned to the MIS 5a (Machida and Arai, 1992).

The fluvial S3 terrace in Sagamino Upland also emerged before Hk-AP fell. The present study supports that the S3 terrace is of fluvial origin in the MIS 5a stage. The M2 terrace in Musashino Upland is said to be equivalent with the Misaki terrace.

2) The MIS 4 : Indicated by pollen and tephra stratigraphy

Tsuji *et al.* (1984) showed that the abrupt change of fossil pollen assemblages into a highly cold climate occurred at the Hk-AP level, and such a cold climate continued at least until the Hk-TP level in Sagami and adjacent region, that is possibly correlated with the MIS 4.

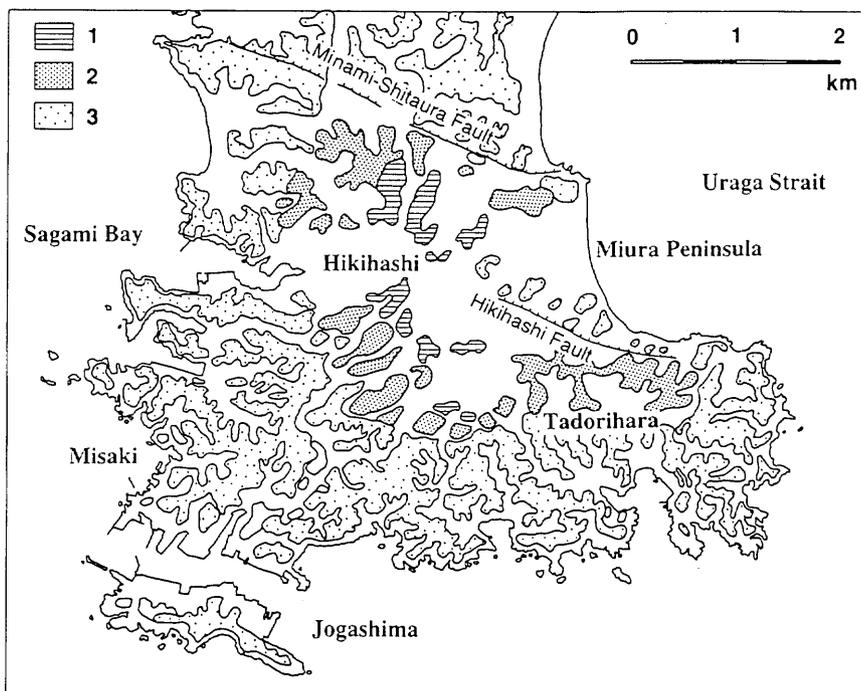


Fig. 4.9 Marine terraces in southern Miura peninsula

1 : Hikihashi terrace (MIS 5e), 2 : Obaradai (Tadorihara) terrace (MIS 5c), 3 : Misaki terrace (MIS 5a)

The pollen assemblage around the eruptio ages of On-Pml and F-YP (roughly the MISs 5b/5a) was characterized by *Cryptmeria japonica* and *Picea maximowiczii*, indicating a cool temperate coniferous forest. A cool temperate deciduous forest indicated by *Quercus* subgen. and *Lepidobalanus* is suggested for the age before the eruption of Hk-AP at Eda, Yokohama. This finding corresponds to the period of Misaki transgression (the MIS 5a).

Vegetation has abruptly changed from that of a cool temperate forest to a subarctic coniferous forest at the age of Hk-AP. Such cold pollen assemb-

lage can be found up to the age of Hk-TP. The deposits in Oiso Hills, Fujisawa and Yokohama areas that contain *Picea*, *Larix-Pseudotsuga* and *Alnus*, support the change.

They commented that it was the first cold climate forest of the Late Pleistocene, and corresponded to the Murodo glacial advance in Tateyama, Japan Alps.

The Murodo glacial advance was recognized between the eruptions of Omachi EPm (or, Tt-E) and Daisen Kurayoshi pumice (DKP) by Machida and Arai (1979). The age of glacial advance was estimated to be between 50-55 ka. It was based on the estimated ages of EPm (60 ka) and DKP (47-55 ka), both of which were extrapolated from the uniform accumulation rate of 'loam'. Moreover, DKP was found above the Yunokuchi Pumice, which directly covers Hk-TP in north Kanto. Therefore, this cold climate period between the eruption of Hk-AP and Hk-TP should be assigned to the MIS 4.

The age of this period, however, was disputed. Machida (1981) mentioned a problem concerning the age of the glacial advances. The age of the MIS 4 was assumed to be 75-70 ka by analyzing deep sea deposits, and glacial advances of the Laurentide Ice Sheet and New Zealand glaciers. These ages of the MIS 4 differ from the above-mentioned estimates in the Japan Alps.

Recently the age of Hk-TP is estimated c. 60 ka or older by Machida and Arai (1992). According to the interpolation of the accumulation rate of 'loam' in the Sagamino upland (0.23 m/ky, between Aso-4 and AT), the age of Hk-TP is estimated at 63 ka. These ages are in accordance with the age of the Misaki terrace (80 ka) and the continental glacial advance.

In this period no extensive terrace was formed; the only formation were those of the small S4 and S5 terraces in the Sagami Plain. They are not

well developed, and have steeper profiles than those of the MIS 5a, and they are covered with Hk-TP. They indicate a rapid base level drop in the transition of the MIS 5a/4. Consequently, the Sagami River may have followed the eruption of Hk-TP.

3) **The MIS 3 : Nakatsuhara terrace, whose age is estimated by the accumulation rate of 'loam'**

On the basis of tephrochronology, the MIS 3 must fall in the stratigraphic range between the marker tephra of Hk-TP and AT.

The AT was found in the deep sea cores drilled around Japan. According to the isotope stratigraphy in the Philippine Sea sediments shown in Machida and Arai (1992), AT occupies the transition between the MISs 3/2.

In this period, a well-developed Nakatsuhara Terrace emerged in the Sagami Plain. This terrace, however, has no dated marker tephra that directly covers the terrace gravel. Therefore, the author attempted an interpolation of a uniform accumulation rate of 'loam'. The thickness of the tephra between AT and terrace deposits is about 5 m. The thickness of 'loam' between the horizon of Aso-4 (85 ka) and AT (25 ka) is 13.6 m. On the assumption of a uniform rate of accumulation, the age of Nakatsuhara terrace is given as 47 ka.

The Tanahara terrace group in the Sagami Upland emerged around the age of AT. Within the group, only the Kamimizo and Haratama terraces ('Tk' and 'Th') are covered with AT. These terraces probably correspond to the latest part of the MIS 3. The present study tentatively calls these terraces Tanahara-1 (T-1).

The Tachikawa Terrace (Tc1) in Musashino Upland can be correlated with the Nakatsuhara terrace, for it is covered with tephra including AT in the middle section.

4) The MIS 2 : Minahara Terraces and the base of the Recent Deposits

The 'Ty' and 'Ts' of the Tanahara group (Tanahara-2), and the Minahara Terraces in Sagamino emerged after the AT emplacement, and they show many small steps of terraces with decreasing altitudes. It clearly indicates the influence of base level drop.

Kaizuka and Moriyama (1969) pointed out that Minahara Terrace have the steepest profiles of terrace surface in Sagamino. Consequently they submerge into the alluvial lowland in the uppermost reaches along the Sagami River. Kaizuka and Moriyama (1969) considered that the steepest 'Mm' terrace gravel continues to the Basal Gravel of the Recent Deposits. Accordingly, it is confident that Minahara terraces were formed during the lowest sea-level period of the MIS 2.

Machida *et al.* (1990) estimated the ages of the Fuji-Sagami River Mudflow deposits (F-S) as 17-14 ka, which also corresponds to the age of the Minahara terraces.

The Tc2 and Tc3 terraces in Musashino correspond to the Tanahara and Minahara terraces in Sagamino.

(to be continued)