GEOMORPHOLOGICAL FEATURES OF VALLEYS DISSECTING THE UPLANDS OF THE KANTO PLAIN

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Abstract Valleys dissecting the Pleistocene terraces are well developed in the Kanto Plain. Some valleys dissecting the fluvial uplands, such as the Musashino and Sagamino uplands, have long, poor-branched and gutter-shaped forms. These valleys are estimated to have been formed by the reciprocal processes of tephra deposition and the remnant stream erosion. Valleys in marine-origin uplands show different features from those of fluvial-origin uplands. Asymmetrical valleys are also seen in valleys dissecting the Kanto Plain. In the Kanda River Valley of the Musashino Upland, valley-side slope asymmetry originated from slip-off slope of the meandering valley and a lower terrace.

Key words: Kanto Plain, Pleistocene upland, valley features, remnant stream, asymmetric valley

1. Introduction

The Kanto Plain has many Pleistocene terraces (diluvial uplands), which have been used as a standard of stratigraphy and chronology of the Quaternary system and land-form evolution in Japan. Some uplands are marine in origin and the others are fluvial. Thick tephra covers the upland surfaces and make the chronology of the uplands possible. Upland surfaces are dissected by small valleys whose heads are situated on the upland surfaces. Although there is a lot of studies of stratigraphy and landform evolution of the Kanto Plain, relatively little is known about valleys dissecting the Upland.

These valleys developed during the Last Glacial. There is no investigation as to how they developed during the Last Glacial.

Volcanic activities gave many influences by producing tephra layers, which accumulated successively on the upland surfaces and made uplands higher.

In some valleys dissecting the Musashino Upland, there are asymmetric valleys whose

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north-facing valley side slopes are gentle and south-facing slopes are steep. Kaizuka (1979) suggested that the frost action during the Last Glacial made the valley side slopes asymmetrical.

In this paper, the author will discuss the origin and characteristics of geomorphological features of valleys dissecting the uplands of the Kanto Plain, on the bases of their plan and cross-sectional forms.

2. Valleys Dissecting the Musashino and Sagamino Uplands

Distribution of Pleistocene uplands and valleys dissecting the Kanto Plain

Pleistocene uplands in the Kanto Plain consist of marine and fluvial terraces. They are classified into three major groups through their ages : the Shimosueyoshi (further refered as "S"), Musashino ("M") and Tachikawa ("Tc") stages (Fig. 1). M and Tc stages are subdivided into M_1, M_2, M_3, and Tc_1, Tc_2 and Tc_3, respectively.

S and M_1 (the oldest of the M group) Surfaces are widely distributed in the Kanto Plain. Most of them were sea bottoms during the Last Interglacial (approximately 130-80 ka). Fluvial terraces were mainly formed in the Last Glacial (*ca.* 80-13 ka, M_2, M_3 and Tc Surfaces), and are distributed along major rivers such as the Ara, Tama and Sagami rivers originating from the Kanto Mountains.

Dissecting started to develop after the upland surface was emerged. Previous workers said that the older surface is more dissected. The dissection ratio was therefore regarded to show the age of upland surface. This idea, however, is not suitable for the valley in the Kanto Plain because tephra continued to accumulate on the upland surface after the surface emerged. There are two geomorphological processes operating on the upland surface: stream erosion and tephra deposition. They reciprocally formed the valleys during the late Pleistocene.

Common features and origin of valleys in the Musashino and Sagamino Uplands

There are some common features in each valley in the Musashino and Sagamino Uplands.

The drainage patterns of valleys in the Musashino and Sagamino Uplands are very different from other uplands. They show parallel-pattern. Each valley is long, poor-branched and guttar-shaped. The longitudinal profile of valleys is characterized by three straight segments, in comparison with general concave profile.

Kubo (1988a) investigated the geomorphological features and evolution of these valleys by planforms, longitudinal and cross sectional forms of valleys.

Common features of the valleys

Valleys dissecting the Musashino and Sagamino Uplands have common features as follows: 1) The valleys dissect uplands which consist of gravel layers oberlain by thick air-laid tephras. 2) The planform shows that valleys are consequent to the upland slope direction and have few tributaries. The width of the gutter-shaped valleys is uniform throughout its entire reaches. 3) The longitudinal profile of valleys consists of three segments. 4) The wavelength of the valley meander is far larger than that of the stream

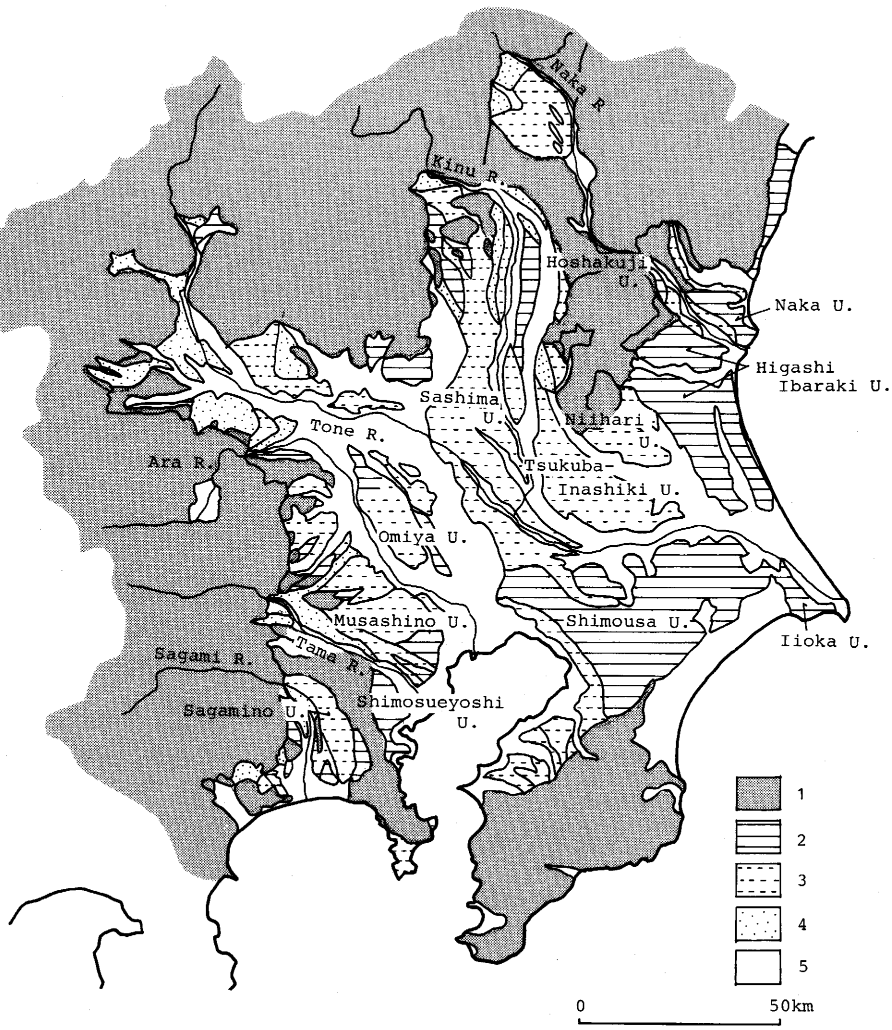

Fig. 1 Geomorphological map of the Kanto Plain (compiled from Machida, 1975 and Kaizuka, 1987)
1: mountain and hill; 2: Shimosueyoshi Surface;
3: Musashino Surface; 4: Tachikawa Surface; 5: lowland

channels in the valley.

The profile of valleys is divided into the upper, middle and lower segments. Middle segment is steeper than others. The upper segment has the same gradient with the surface of gravel layer. Lower segment is the surface of the Holocene deposit. The middle segment extends to submerge beneath the Holocene deposit. This suggests that the middle segment was formed in the stage of lower sea level before Holocene.

Origin of valleys

Major valleys in the Musashino and Sagamino Uplands are remnant of the former

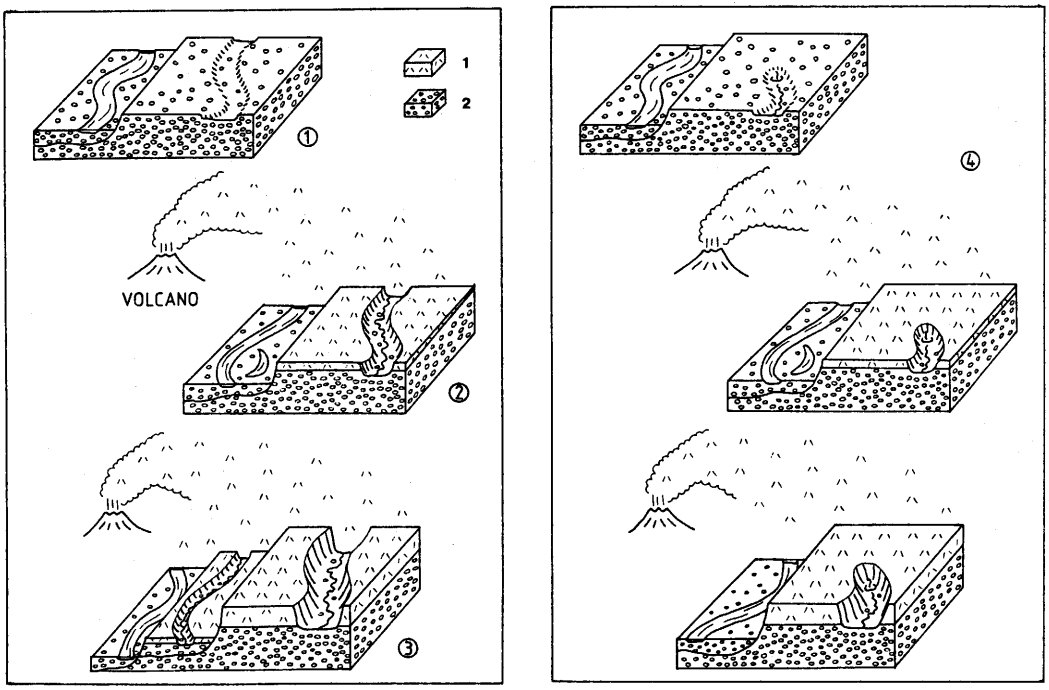

Fig. 2 Model showing the evolution of valleys (after Kubo, 1988a)
1: tephra; 2: gravel

river channels at the time when the upland surface emerged. Streams in the valleys have been maintained by springs. The erosional and transportational activities of the streams are very small, because peat and other fine materials are deposited in valley bottom. Streams can not cut down gravel bed which exposed on the valley bottom. Streams can only wash away small and light particles like tephras. Since a remnant stream continues to wash away tephras, a valley-shaped depression is formed on the upland surface.

Figure 2 is a model showing the evolution of these valleys: 1) A former river channel remains on a terrace surface when the terrace surface emerged. 2) A stream in the former river channel wash away tephras along the stream. 3) On the other hand, tephras accumulated on both side of the stream and consequently, the valley becomes deeper. 4) A water spring may create another valley head, where tephra cannot accumulate.

Cross-sectional form of valley and its asymmetry

In some valleys dissecting the Musashino Upland, there are asymmetric valleys with north-facing gentle slopes and south-facing steep slopes (*e.g.* Kaizuka, 1979).

Togi (1929-30) concluded that the northward subsidence caused asymmetric valleys.

Juen (1952) showed that the asymmetric level of ground water is a major cause of asymmetric valleys. In the uppermost part of the Kanda R., the ground water level is tilting towards the gravel bed. The valley side slope becomes steeper when the water level is higher than the top of the gravel bed, bacause tephras can be eroded more easily than gravels.

Kaizuka (1979) suggested that the frost action made the slopes of the Kanda and Meguro river valleys asymmetrical. In winter time, on the north-facing slope, needle ice arises during the night and melt in the daytime. This caused soil creep on the valley slope and resulted in gentler slope. On the south-facing slope, no frost action occurs due to drying.

There is no evidence of frost action in the deposits of the Musashino Upland. But the involution of the terrace deposits underlying the tephras was reported (Suzuki *et al.*, 1964).

Geomorphological features of the Kanda River Valley, Musashino Upland

General description

The Kanda River Valley is situated in the central part of the Musashino Upland (Fig. 3). Its valley head is the Inokashira Pond, which is fed by springs and the river flows through the Musashino upland and drains into the Tokyo Bay via the Sumida River. It has two major tributaries, the Zempukuji and the Myoshoji Rivers. The Kanda R. originally drained into the Hibiya Inlet of the Tokyo Bay before the 17th century. In the 17th century, the river course was artificially changed as it is now.

The Inokashira Pond, the stream head, is surrounded by steep slopes down from the M_1 Surface, with a height of about 8 m. The Zempukuji and the Myoshoji Rivers also have their valley heads on the M_1 Surface. The river channels in these valleys had small meandering before river control works were done. The wavelength of valley meanders of the upper Kanda, Zempukuji and Myoshoji Rivers, are much greater than those of stream channels.

Longitudinal form

Figure 4 shows the longitudinal profile of the Kanda River Valley. Three segments are distinguished. In the upper segment from the point *ca.* 13 km upstream from the river mouth, the projected upland surface and valley bottom run parallel. The relative height between the upland surface from the valley bottom is about 6-8 m. In the valley bottom, peat and fine materials are deposited. A gravel bed underlies these layers.

In the valley bottom of the Myoshoji River, a peat bed of the Last Glacial, the Egota Conifer Bed (Kanto Loam Research Group, 1961) is observed. The peaty layer in the Kanda River Valley bottom can be correlated with the Egota Bed. This deposit is distributed through the upper segment of the Kanda River Valley. Therefore, the outline of the valley form of Kanda River was determined at about 20ka ago in the Last Glacial.

In the middle segment, downstream from the point *ca.* 13km from river mouth, relative height between the valley bottom and projected upland surface becomes greater. Toward the downstream valley bottom therefore lowered to the gravel bed and it now reaches another underlying gravel bed, which is a member of the Tokyo Formation. The gradient of the middle segment continues to the base of the Holocene deposit in the lower segment. The steep lower segment was formed during the Last Glacial when the sea level was lower than the present.

The lower segment starts near Waseda at about 7 km from the river mouth. The Holocene deposit fills the deep valley and its surface gradient is very gentle. The

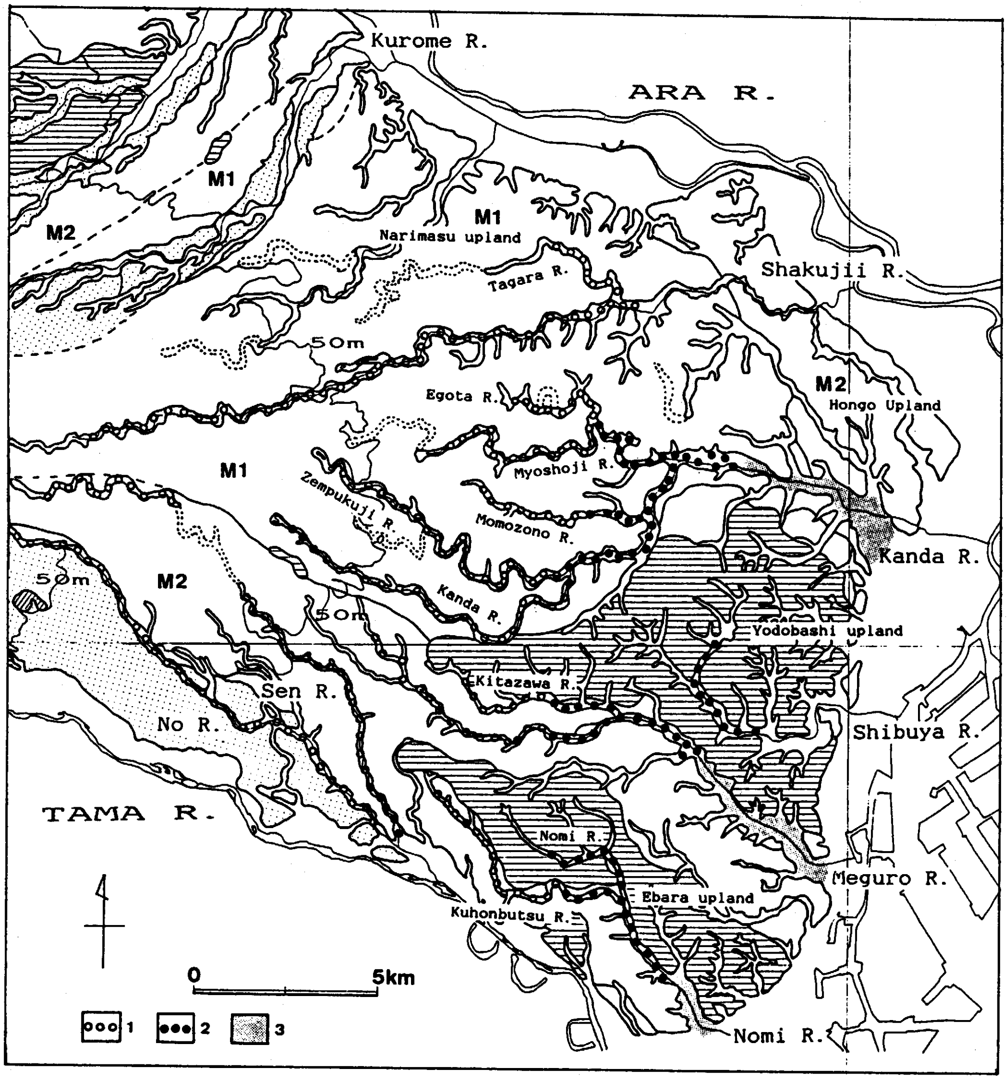

Fig. 3 Distribution of valleys in the Musashino Upland
1-3: upper, middle and lower segments of valley;
S: Shimosueyoshi Surface; M1, M2: Musashino Surface;
Tc: Tachikawa Surface

Holocene Transgression extended to the region of this segment.

cross-sectional form

Figure 5 shows the cross-sectional form of the Kanda River Valley. In the upper segment, the depth and width of the valley are very uniform. No distinct one-sided asymmetry is seen in this part, except the slip-off slopes of the valley meander.

In the middle and lower segments, the valley becomes deeper and has distinct asymmetric cross-sectional form. The north-facing slope is gentler there.

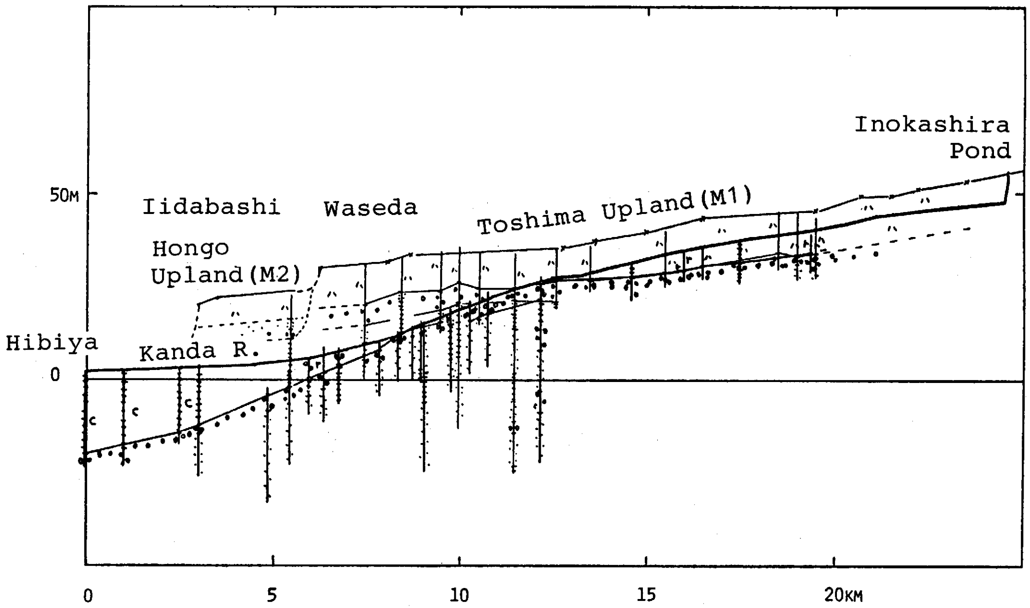

Fig. 4 Longitudinal section along the Kanda River Valley and projected upland surfaces
Symbols are same as Fig. 5.

Characteristics of landform along the asymmetric valley

The Waseda University is located on the gentle slope of the asymmetric valley of the Kanda River (Kaizuka, 1979), between the Yodobashi Upland (S Surface) and the Toshima Upland (M_1 Surface).

According to Kubo (1988b), the lower terrace is covered with a tephra layer of about 4 m thick, while the M_1 terrace with about 8 m thick. The lower terrace is composed of a thin gravel bed of poorly sorted and fine-grained fluvial gravels. There is a terrace cliff between this lower terrace and the M_1 terrace. Slope deposit on the foot of this cliff is coarse gravels forming a talus. The gravel fell down from the M_1 terrace gravel.

This lower terrace is distributed from Higashinakano to Iidabashi, about 4 km along the right bank of the Kanda River. This terrace submerges in the Holocene surface near Iidabashi, where the width of the Holocene lowland increases abruptly. Buried terrace deposits under the Holocene sediment are recognized in boring data in the lower reach from Iidabashi.

The age of the lower terrace is estimated to be 80 ka (M_1 terrace) to 20 ka (The AT ash from the Aira Caldera, Kyushu). During this period, the sea level was lower than the present and the terrace in the lower reaches is buried by Holocene deposit associated with the transgression.

This lower terrace on the right bank side produced asymmetry of the Kanda River Valley (Fig. 6).

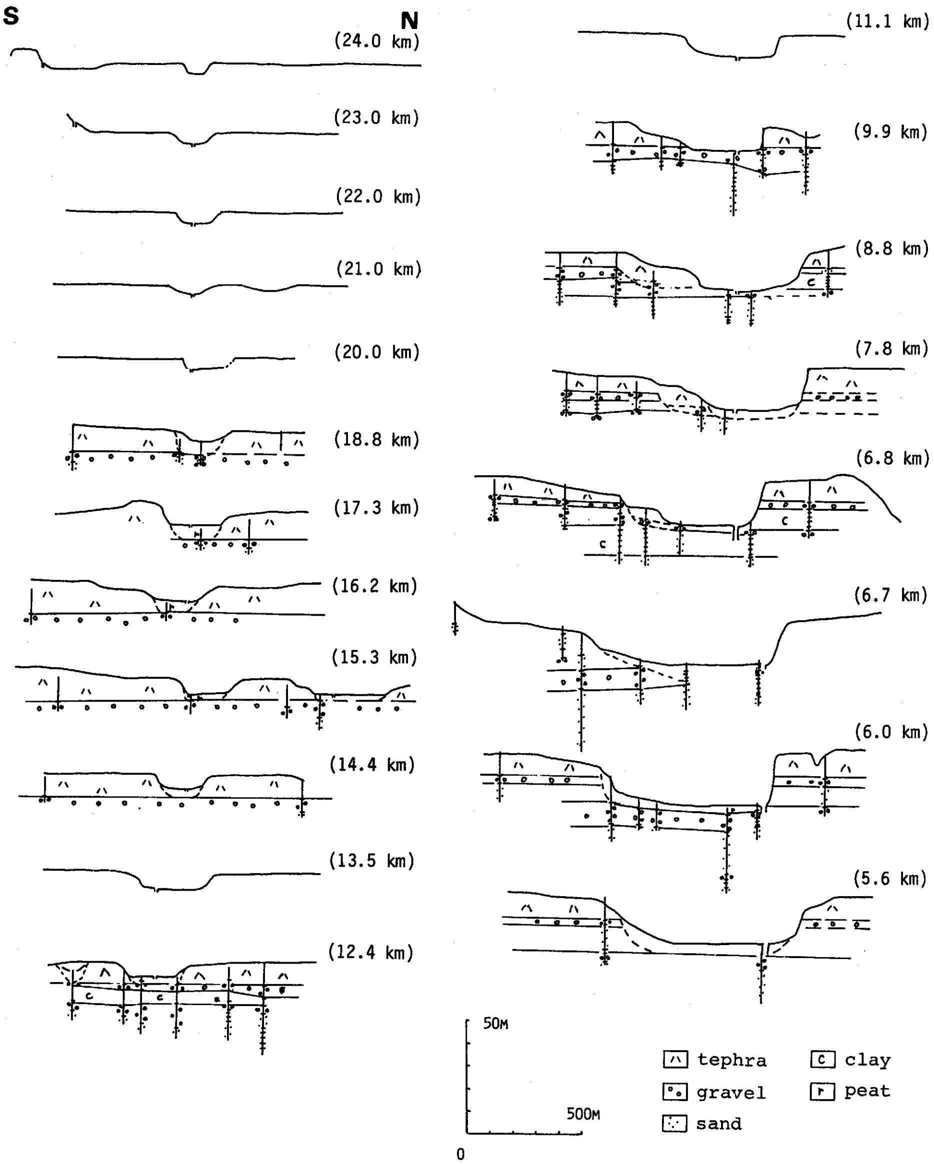

Fig. 5 Cross sections of the Kanda River Valley

3. Valleys Dissecting Other Uplands in the Kanto Plain

Musashino and Sagamino uplands are both fluvial terraces mantled with tephra layers. Valleys dissecting these uplands inherit former channels. In the Kanto Plain marine-origin terraces are also dissected by many valleys, some of which show asymmetry.

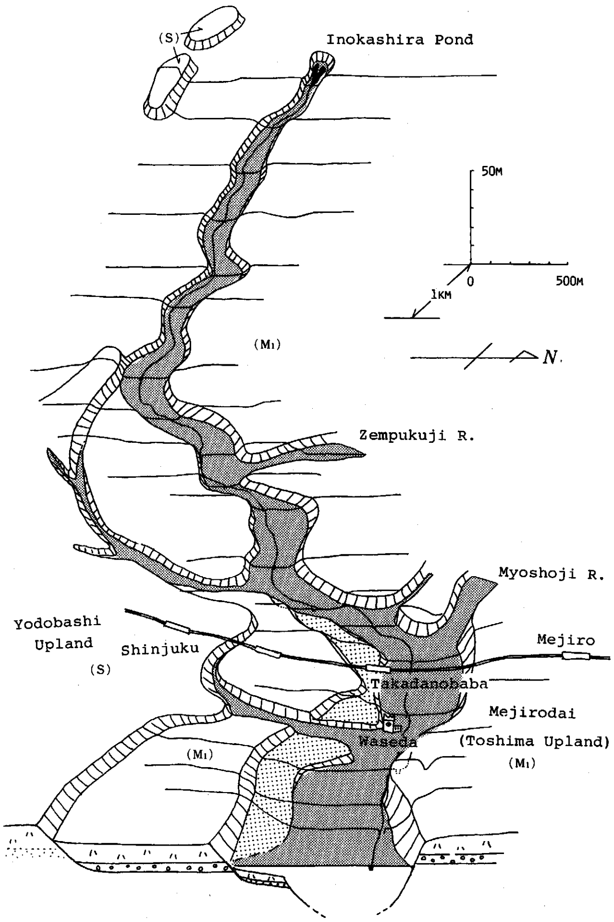

Fig. 6 A sketch of the Kanda River Valley

Drainage pattern of valleys

Upland surfaces of the Shimosueyoshi, Yodobashi, Omiya, Shimousa, Sashima, Tsukuba-Inashiki, Niihari and Higashi Ibaraki (see Fig. 1) are the emerged sea bottom of the Last Interglacial. The original surface gradient is very flat and the deposits underlain by the tephra layers consist of fine materials. But the distribution pattern of valleys of the Shimosueyoshi, Yodobashi and Shimousa Uplands are much different from that of the Musashino Upland. Valleys are distributed insequently. The planform is dendritic. The width of valleys becomes larger toward the downstream.

On the other hand, the Omiya Upland is dissected by parallel-shaped valleys, while the surface gradient is very flat. The direction of valleys runs parallel with the major rivers, the Ara and Naka (formerly Tone). The Omiya Upland was a previous fluvial plain because former river-side dunes were found by the Katazuna Research Group (1984).

As the Omiya Upland, the Kashima and Tsukuba-Inashiki Uplands have valleys running parallel with the Tone and Kinu rivers.

In the Naka Upland, Suzuki (1989) mentioned that the streams in valleys are remnant.

A gravel layer in the Miwa Formation lies under the tephra layer. This fluvial gravel caused to form valleys like in the Musashino Upland.

The fluvial Hoshakuji Upland is correlated with S. It has deep, long and gutter-shaped valleys. The depth of these valleys is about 20 m, which is correspond to the thickness of the tephra layer on this upland. Some groups of lower terraces, the Takaragi and Tawara uplands (Akutsu, 1957), also have valleys whose depth coincide with tephra thickness on the uplands. Their directions are parallel with the major river of Kinu.

There are some differences on dissecting valleys between fluvial and marine terraces. The distribution pattern of valleys in marine terraces are dendritic and insequent. Dissecting valleys on fluvial terraces are pararllel to major rivers, showing original channel directions and features.

Asymmetric valleys in other uplands

Other asymmetric valleys in the Musashino and Sagamino Uplands

There are some asymmetric valleys in the Musashino Upland besides that of the Kanda River. The Meguro River (see Fig. 3) flows through the southern part of the Musashino Upland between the Yodobashi Upland (S Surface) and the Meguro Upland (M Surface). The Yodobashi Upland is about 5 m higher than the M Uplands. The Meguro River Valley corresponds to the boundary between two uplands. the Nomi River Valley between the Ebara Upland (S) and the Kugahara Upland (M). These valleys indicate asymmetric cross-sectional forms because relative height of both sides of uplands are different.

The Sagamino Upland has some lower terraces or gentle slopes along the valleys of Sakai and Hikiji Rivers. These valleys have the same characteristics as the valleys in the Musashino Upland. The upper and middle segments of the Sakai River Valley show meandering (Fig. 7). Oka *et al.* (1979) recognized lower terraces along these valleys. These terraces are distributed on the slip-off slopes of valley meanderings. The S_1S scoria bed (about 20 ka old) from the Fuji Volcano was observed on the bottom of slip-off slope of the Sakai River Valley. In the lower segment of the Sakai and the Hikiji Rivers, the Matano Surface is distributed. The TPfl pumice (50 ka) flow bed from the Hakone Volcano covers this terrace.

These lower terraces in the Sagamino Upland arose in relation to the meander slip-off in the upper segment, and to the lower sea level in the lower segment. They produce valley asymmetry as in the Musashino Upland.

Asymmetric valleys in other uplands

Asymmetric valleys are also recognized in marine terraces of the Last Interglacial in the Kanto Plain.

In the Shimousa Upland, according to Sugihara (1970), lower terrace, named the Chiba Terraces, is distributed on the southern slope of valleys. The lower terrace has same age as the M and Tc surfaces.

In the Iioka Upland, eastern part of the Shimousa Upland, asymmetric valleys with gentle south-facing slopes were described by Hatta and Kawasaki (1983). They concluded that the tilting of the upland to the north formed the asymmetric valleys.

In the Tsukuba (Tsukuba-Inashiki) Upland, Ishii *et al.* (1987) investigated the gentle

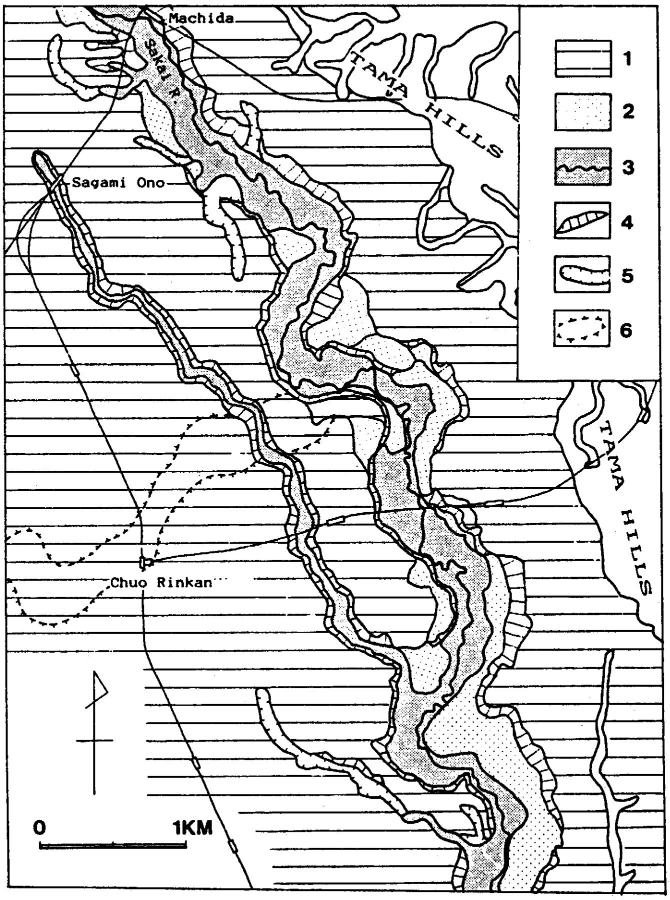

Fig. 7 Lower terrace along the Sakai River Valley, Sagamino Upland
1: Sagamihara Surface; 2: lower terrace; 3: lowland of valley bottom
4: steep slope; 5: shallow valley; 6: mound on the Sagamiha Surface

slope of the asymmetric valleys utilizing boring data. They recognized the slope deposit due to the freeze-thaw process in the Last Glacial.

Periglacial asymmetric valleys

Asymmetric valleys by periglacial processes are mainly observed in high latitude areas.

North-facing valley side slopes are steeper in the Konsen Plateau, Hokkaido (Iwata 1977). On the gentle south-facing slope, solifluction deposits were observed. The active layer of permafrost on the south-facing slope and tephra accumulation with snow should produce gentle slope in the Last Glacial.

French (1976) showed many periglacial asymmetric valleys. They are accompanied with permafrost in Canada, Siberia and western Europe. In western Europe, most asymmetric valleys were developed in the permafrost areas of the Last Glacial. The direction and the shapes of the gentle slope are not uniform.

Asymmetric valleys and the paleoenvironment in the Last Glacial

Valleys dissecting the Kanto Plain had been developed in the Last Glacial. There are few information on the climatic factors such as precipitation, temperature and insolation, frost action of the Kanto Plain in the Last Glacial.

Periglacial asymmetric valleys in the Konsen Plateau, Hokkaido and western Europe, were formed under the tundra environment with permafrost of the Last Glacial. On the other hand, there is no evidence of permafrost and tundra environment in the Kanto Plain. Ono (1983) observed recent soil erosion caused by frost action in the Tsukuba Upland. This observation, however, was made in an area without vegetation. The Musashino Upland in the Last Glacial was covered by the coniferous forest represented by the Egota Conifer Bed. This suggests that freeze-thaw process didn't form asymmetric valleys in the Kanto Plain.

The sea level change influenced the valleys. Because of the lower sea level in the Last Glacial, the valley bottoms of the coastal areas were lower. Deep valleys were formed and their longitudinal gradients were steep. Lower terraces were sometimes formed in the valleys.

A lot of tephras was supplied in the Kanto Plain mainly by the Fuji Volcano and the Hakone Caldera in the Last Glacial. The average rate of tephra deposition is several meters per year.

Volcanic activities as well as sea level changes are important factors for the evolution of uplands and valleys in the Kanto Plain.

4. Concluding Remarks

The geomorphological features of dissecting valleys in the Kanto Plain are summarized as follows.

1) Valleys dissecting the fluvial terraces are formed by the removal of tephras by remnant streams.

2) In the Kanda River Valley, distinct valley asymmetry due to the presence of lower terrace is seen in the lower segment. Valley side asymmetry in the upper segment depends on the slip-off slope of the meandering valley.

3) Most of asymmetric valleys in the uplands of the Kanto Plain were formed in relation to terraces and meandering. A few asymmetric valleys are attributed to crustal movements. The Tsukuba Upland has the gentle slope which resulted from freez-thaw process.

4) The insequent valleys dissecting marine-origin uplands have dendritic pattern were probably influenced by fine material and very flat surface of upland.

5) The sea level changes and volcanic activities are important factors for landform evolution.

Acknowledgements

The author expresses her thanks to Prof. Dr. Sohei Kaizuka for his supervision to this study, and pays her best regards for his works in the Tokyo Metropolitan University. Dr. Shinji Nagaoka, Hydrographic Department, Maritime Safety Agency has kindly taught and given many suggestions. Prof. Dr. Masahiko Oya, Waseda University also gives continuous support.

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