4. Division of Volcanic Ashes

Historical reviews of the Kanto Volcanic Ash

Since the 19th century in Japan, the term "loam" has been commonly used for brown air-borne clay on the subaerial land (Brown, 1881). It is recognized as a term of soil science and refered for soil of certain grain size and composition with a fine grained pyroclastic material. This term of "loam" is defined by soil composed of a mixture of equal proportion of sand, silt and clay. Consequently, at present, this interpretation for "loam" in the Kanto region has been generalized by the name of Kanto Loam. In this paper, the author adopted it as the term of "volcanic ash" which indicates its origin.

Many papers mentioned the existence of volcanic ash as the Kanto Loam or Kanto Volcanic Ash since the 1800's. Aoki and Tayama (1930), Makiyama (1930), Tada (1946) and Juen (1951) reported the thickness and distribution of the volcanic ash (=Kanto Loam). However, there are almost no papers stated on the stratigraphy of the volcanic ashes. Nakao (1940) reported the difference between the lower and upper volcanic ashes. Harada (1943) reported the stratigraphical key-beds of the pumice beds in the volcanic ashes. Afterward, Kaizuka and Toya (1953) divided the Kanto Volcanic Ash into the upper (Tachikawa and Musashino Volcanic Ashes) and lower (Shimosueyoshi Volcanic Ash) parts. At present, four volcanic ashes, as "Tama", Shimosueyoshi, Musashino and Tachikawa in ascending order are recognized in the southern part of the Kanto Region. These volcanic ashes overlying the terrace deposits, are mainly known in the area of Hanno, Azuyama, Sayama, Kasumi, Tama Hills, Musashino, Shimosueyoshi and Shimosa Plateaus. The names of the volcanic ashes were originated from the areas of their geographical distribution.

The volcanic ash formation is generally thick in the southwestern and northwestern parts of the Kanto Region. The thickness is closely connected with geomorphic evolution of the areas. The volcanic ash overlies the older terrace more thickly than the younger terrace, and usually eroded in the areas of the jagged mountains (Kaizuka, 1954).

The Kanto Loam Research Group (1954, 1956, 1958 and 1960) established stratigraphic division of the volcanic ashes, on the basis of the relation between terrace deposits and volcanic ashes. This result was published in a book entitled "Kanto Loam" by the Kanto Loam Research Group (1965). To this publication, Arai (1962), Akutsu (1957a, b) and Suzuki (1959) contributed in the division and distribution of volcanic ashes and terraces in the field investigations of the northwestern part, the north and northeastern parts of the Kanto Region respectively.

The volcanic ashes were ejected from the Mt. Fuji, Mt. Hakone, Mt. Yatsugatake, Mt. Asama, Mt. Haruna, Mt. Akagi and Mt. Nantai Volcanoes, and carried by air, into the southern and northern parts of the Kanto Region. The units of the volcanic ashes were recognized on the basis of the relation between the terrace formation and overlying volcanic ash along the down stream of the Tama River and in the Yokohama area.

The unit was latey considered by the volcanic activities, especially in subdivision of the "Tama Volcanic Ash". Clinounconformity and black coloured zone are often recognized at the boundary of the volcanic ashes. The boundary is expected to represent the interruption of volcanic activities.

For example, the "Tachikawa Volcanic Ash Formation" which was first named as the volcanic ash of about 2 m thick overlying the Tachikawa Gravel. The volcanic ash under the "Tachikawa Volcanic Ash" is continuous to the additional part of the "Tachikawa Volcanic Ash". The total thickness of the Tachikawa Volcanic Ash is about 4 m. The additional volcanic ash is inclusively called as the Tachikawa Volcanic Ash (Fig. 4-1). The volcanic ash of 4 m thick contacts with the underlying volcanic ash obliquely and is regarded as one unit of volcanic ash.

The Musashino Volcanic Ash (Fig. 4-1) 3 to 4 m overlies the Shimosueyoshi Volcanic Ash and is covered by underlies the Tachikawa Volcanic Ash Formation or the Musashino Gravel. At 0.5 to 1 m above the base of the Musashino Volcanic Ash, an orange colored pumice bed is intercalated. It is called the Tokyo Pumice named by Harada (1943; abbreviation; TP), which is a markable key-bed in the

southern part of the Kanto Region. The volcanic ash of 4 to 5 m thick underlying the Musashino Volcanic Ash and overlying conformably by the Shimosueyoshi Formation (right columnar section in Fig. 4-12) is named the Shimosueyoshi Volcanic Ash (Fig. 4-1 and Table 4).

On the younger terraces of the "Tama Terrace Group", ten to several ten meters thick volcanic ash is underlying the Shimosueyoshi Volcanic Ash. This is the "Tama Volcanic Ash".

After the latter half of the 1960's, the "Tama Volcanic Ash" was subdivided into minor units (Machida, H., 1973; Machida *et al.*, 1974; Uesugi *et al*, 1970; Oka, 1991) in Yokohama City, and Oiso Hills in the south of the Hanno and Sayama Hills. All the volcanic ashes underlying the Shimosueyoshi Volcanic Ash Formation were called as the "Tama Volcanic Ash". The subdivision of the "Tama Volcanic Ash" become possible by the identification and tracing of the volcanic ash between each hills by a key of pumice and scoria beds as well as the unit of the Shimosueyoshi, Musashino and Tachikawa Volcanic Ashes.

This subdivision is based on the relation between the terrace deposits and volcanic ash formations.

The clinounconformity and eroded surface in the volcanic ash that was classified conveniently to the "Tama Volcanic Ash" in the studied area is not recognized. However, there are several pumice beds that cover the studied area, Tama Hills, Yokohama and Oiso areas. It is possible to utilize them as key-beds for time marker. So it is possible to divide the "Tama Volcanic Ash" into the lower Tama I and upper Tama II Volcanic Ashes in the studied area (Fig. 4-1, Tables 4 and 7).

In the northwestern part of the Kanto Region, the volcanic ash was divided into three units: the Lower, Middle, and Upper Loams.

The Lower, Middle and Upper Loams are correlated with the Shimosueyoshi, Musashino and Tachikawa Volcanic Ashes, respectively. The boundaries of the loams are resulted from interruption of the volcanic ash fall which are represented by black coloured zone or a crack zone in the clayey surface of the unit. Besides,

there is a characteristic relation between the volcanic ash and terrace formations.

Arai (1962) pointed out the possibility of the lower part of the Lower Loam is correlated with the upper part of the "Tama Volcanic Ash".

The volcanic ash is divided into four units: the Tomatsuri, Hoshakuji, Takaragi and Tahara Loams in the north and northeastern part of the Kanto Region (Kanto Loam Research Group, 1965). There is a chocolate-colored crack zone between the Hoshakuji and Takaragi Loams and is a black zone between the Takaragi and Tahara Loams. The Hoshakuji, Takaragi and Tahara Loams are correlated with the Shimosueyoshi, Musashino and Tachikawa Volcanic Ashes, respectively. The Tomatsuri Loam of the lowest part is possibly correlated with the upper part of the "Tama Volcanic Ash".

After the publication of the book of "Kanto Loam", the studies of stratigraphy of the Kanto Volcanic Ash and classification of terraces by tephrochronology have been developed.

The most upper part of the "Tama Volcanic Ash", covering the Tsuchihashi Terrace (Tsurumi and Ohmura, 1966) in the Tama Hills is lacking in the studied area. The volcanic ash covering exclusively the Tsuchihashi Terrace is called the Tsuchihashi Loam (Tsurumi and Ohmura, 1966) corresponds to the upper half of the Tama II Volcanic Ash in this paper. Machida *et al.* (1974) subdivided the "Tama Volcanic Ash" into five formations as the Kamosawa (abbreviation; TE), Zoshiki (TD), Fujisawa (TC), Soda (TB) and Tsuchiya (TA), in ascending order (Table 7) on the basis of the relation between the volcanic ash and underlying terraces. The upper part of the TC, TB and TA and the upper part of the TC are lacking in the studied area and the volcanic ash older than TE is added under the bottom in the studied area.

Uesugi *et al.* (1978) subdivided the "Tama Volcanic Ash" into ten units on the basis of the relation to the eustatic sea level changes and volcanic activities. He insisted that the duration from the minimum to the next minimum changing sea level was corresponded to the volcanic activities represented by the Nl, Nm, Nu, Karasawa, Zoshiki, Shimoniwa, Fujisawa, Soda, Shichikunitoge and Tsuchiya

Loams (Table 7).

The whole or partial successions of the Musashino and Tachikawa Volcanic Ashes cover the terraces older than Aoyagi Terrace.

The pumice, scoria and felsic pyroclasts come from a distant volcanoes are intercalated in the volcanic ash layers. The correlation of the volcanic ash layers between the distant places is possible by these beds. In this paper, the volcanic ash is the fine-grained pyroclasts. Pumice is the pyroclasts of white, gray or yellow coloured felsic magma origin which is vesicular and has small apparent specific gravity. Scoria is the pyroclasts of black, brown or dark red coloured mafic magma origin which is vesicular and has small apparent specific gravity. This is the same usage with that of Kanto Loam Research Group (1954, 1956, 1958, 1960 and 1965).

Detailed exposition of the volcanic ashes

a) Tama Volcanic Ash (Fig. 4-1, 4-2, 4-3, Tables 4, 7 and Plate 6)[Tama Loam of the Kanto Loam Research Group (1956)]

Type locality: The type locality was designated at Noborito 1-chome, Higashi-Ikuta, Tama-ku, Kawasaki City in the eastern part of the Tama Hills. The Tama Hills were thereafter divided into the higher area of the western part (area of the T_1 Terrace) and the lower area of the eastern part (area of the T_2 Terrace). There is a difference in the succession of the "Tama Volcanic Ash" between the western and eastern parts. The volcanic ash in the western part covering the T_1 Terrace (Fig. 7-3) is named as the Tama I and II Volcanic Ashes (Fig. 4-1, Tables 4 and 7) and that in the eastern part covering the T_2 Terrace (Fig. 7-3) is named as the Tama II Volcanic Ash. The Tama I Volcanic Ash is continuous with the overlying Tama II Volcanic Ash.

The above mentioned type locality was designated herein because the whole succession of the Tama I Loam Formation can not be confirmed at the single outcrop. The type locality of the lower part of the Tama I Loam is at Hakonegasaki,

Mizuho Town, Nishitama-gun, Tokyo Metropolis (Oka, 1991). The middle part of the Tama I Loam is at Minamiyahagi, Iruma City of the northern part of Sayama Hills (Oka, 1991). The uppr part of the Tama I Loam is near Butsuzoin Temple at Horinouchi in Tokorozawa City in the eastern part of the Sayama Hills (Oka, 1991).

The type locality of the Tama II Loam was established at the cutting along a road of Oshinuma at 1-chome, Higashi-Ikuta, Tama-ku, Kawasaki City. The Tama II Loam overlies the Tama I Loam with conformity. The Gomashio Pumice Beds 1 and 2 (abbreviation; Gop-1 and Gop-2: Figs. 4-1, 4-2, 4-3 and Table 4) are intercalated in the lower part of the Tama II Loam which is a valuable key-beds in the studied area and the Tama Hills.

The "Tama Volcanic Ash" in the studied area is distributed in the Hanno, Azuyama, Sayama and Kasumi Hills.

Ten and several meters thick of the upper part of volcanic ash above the Noborito Daiichi Pumice Bed that is intercalated in the "Tama Volcanic Ash" in the Tama Hills, is lacking in the studied area, probably owing to denudation.

The "Tama Volcanic Ash" (Figs. 4-1, 4-2, 4-3, Tables 4, 7 and Pl. 6) in the studied area was supplied from the Mt. Yatsugatake Volcanoes. There are great differences in chemical and mineral compositions of pumice in the volcanic ash compared with those of the Tama Hills supplied from the volcanoes of Izu and Mt. Hakone. The "Tama Volcanic Ash" in the studied area is felsic and the "Tama Volcanic Ash" in the south from the Tama Hills is mafic. The deposition of the volcanic ash in the studied area preceded in the area of the south from the Tama Hills (Table 7). Hatori and Juen (1958) suggested the southern limit of the volcanic ash from the Mt. Yatsugatake Volcanoes and the northern limit of that from the volcanoes of Izu and Mt. Hakone are between the Tama and Sayama Hills.

The felsic minerals of hornblende, biotite, zircon and apatite are originated from the felsic volcanoes in all horizons in the "Tama Volcanic Ash" of the studied area. The felsic minerals mentioned above are few in the "Tama Volcanic Ash" of

the Tama Hills in comparison to the studied area. The "Tama Volcanic Ash" of the Tama Hills includes many pyroxene originated from the mafic volcanoes. There are few felsic minerals in the "Tama Volcanic Ash" of the Tama Hills and so it was understood that the pyroclasts from the Mt. Yatsugatake Volcanoes were rarely brought into the south from the studied area.

The "Tama Volcanic Ash" was weathered and was changed into the brown to yellowish brown in color. Many pumice beds are intercalated in the volcanic ash. As the pumice beds was intercalated in the lower half, the lower half is more felsic than that in the upper half of the "Tama Volcanic Ash". The pumice beds of the lower half are yellowish white to white in color. The features of the particular pumice and particular volcanic ash beds in the "Tama Volcanic Ash" in the Hanno Hills are described as in the followings from the base to upward. The most of the pumice beds are named after the local name of the best exposure, a tone of color and visible contents of the minerals.

Main key beds in the "Tama Volcanic Ash"

Kamikayama Pumice Bed 1 (abbreviation; Kap-1; Figs. 4-1, 4-2 and Table 4)

The Kap-1 is yellowish white in color and observable only in the Hanno Hills at present. The Kap-1 is 20 to 25 cm thick and consists of pumice grains of 1 to 3 mm in diameter. There are few heavy minerals and many kaolinites in the pumice.

Biotite bearing Ash Zone (abbreviation; Bi: Figs. 4-1, 4-2, 4-3, Table 4 and Pl. 6, fig. 2)

The Bi is volcanic ash of about 10 cm thick and distributed in the Hanno and Sayama Hills. Shimizu and Horiguchi (1993) recognized the Bi in the Azuyama Hills recently.

The Bi contains many grains of biotite which were changed into white colored kaolinite and is not so sticky as clayey volcanic ash of the other horizons. The biotite grains in the Bi are larger than that of the Hachioji Biotite Pumice Bed.

The Bi consists of very fine-grained ash. The Bi is bright and brown in comparison with the volcanic ash layers above and below the Bi. The Bi contains the light pink colored zircon grains that can be seen by the naked eye. The light pink colored zircon grains can not be found from the Kanto Volcanic Ashes. The grains size (muximum size is over 3 mm) is the biggest in the Kanto Volcanic Ashes. The fission track age measurement by zircon collected from the Bi at Yamaguchi in Tokorozawa City (Pl. 6, fig. 2) was $55 \pm 7 \times 10^4$ years B.P. (Table 8). These zircon grains contain high content of uranium and have a measurable area in a short time. The error of area due to big crystals is not appeared on the data, except for the measurement error, so the error of the age is minimized. This age measurement is safely said to be precised. The result of this fission track age measurement shows near the lower limit of the "Tama Volcanic Ash" and is older than the lower limit of the "Tama Volcanic Ash" in the Tama and Oiso Hills. The lower limit of the "Tama Volcanic Ash" in the studied area is said to be the oldest in the Kanto Region. The fission track age determination will correspond with the results of Tokuhashi *et al.* (1983), and Watanabe and Danhara (1996). The horizon of the lower limit of "Tama Volcanic Ash" is contemporaneous with the upper part of the marine Kasamori Formation (Kawai, 1952). There are several white tuff layers including light pink colored zircon grains. The tuffs are intercalated in mudstone of the upper part of the Kasamori Formation. One of the white tuff layers will be correlated with the Bi.

Kamikayama Pumice Bed 2 (abbreviation; Kap-2: Figs. 4-1, 4-2, 4-3, Table 4 and Pl. 6).

The Kap-2 is yellowish white in color and well sorted and mainly distributed in the area of Sayama and Hanno Hills. The Kap-2 is 20 to 40 cm thick. The Kap-2 consists of "foamy" pumice grains of 0.5 to 1 mm in diameter. The Kap-2 was recognized by Shimizu and Horiguchi (1993) who investigated in the Azuyama Hills and named it as the WPS2. The heavy minerals included in the pumice grain of the Kap-2 are too small to see by naked eyes. The boundary of Kap-2 and

volcanic ash is uncleared.

Kamikayama Pumice Bed 3 (abbreviation; Kap-3: Figs. 4-1, 4-2 and Table 4)

The Kap-3 is brilliant yellowish white to white colored pumice bed in the "Tama Volcanic Ash". The Kap-3 is 25 to 40 cm in thickness. The pumice in the Kap-3 is 1 to 2 mm in grain size and the best sorted in the "Tama Volcanic Ash". The upper part of the Kap-3 contains bluish gray-colored speckles of about 2 to 5 cm in diameter and 1 cm dark volcanic ash stained with manganese or almina at the bottom of the Kap-3. The heavy minerals can barely be seen by the naked eyes. The upper part of the Kap-3 grades into the volcanic ash and the base of the Kap-3 is indistinct from the underlying bed. The Kap-3 is distributed in the Sayama Hills.

Kamikayama Pumice Bed 4 (abbreviation; Kap-4: Fig. 4-1)

The Kap-4 is yellowish bitter orange in color and differs from those of the Kap-1, Kap-2, and Kap-3, in color and mafic content. The pumice beds of the Kap-5 to Kap-11 resemble with the Kap-4 in colour tone. The Kap-4 includes bluish gray lithic fragments of the same amount of pumice grains. The Kap-4 is 10 cm thick and is lenticular in the volcanic ash formation. The pumice grains in the Kap-4 are poorly foamed and the average grain size is 5 mm and maximum size is 10 mm.

Kamikayama Pumice Bed 5 (abbreviation; Kap-5: Fig. 4-1 and 4-13)

The Kap-5 is yellowish bitter orange to yellowish white in color, and is 15 to 20 cm thick. The pumice in the Kap-5 is poorly foamed and the grain size is 5 mm and the maximum 10 mm.

The Kap-5 is correlated petrographically with the upper part of the "Tama Volcanic Ash" by order of the consecutive pumice beds in the Odamaki Hills of Chichibu near the Mt. Yatsugatake Volcanoes.

Kamikayama Pumice Bed 6 (abbreviation; Kap-6: Figs. 4-1, 4-3 and 4-13):

The Kap-6 is yellowish white to yellowish orange in color and is 20 cm thick. The grain size of pumice is 1 to 2 mm in diameter. The pumice grains of the lower part of the Kap-6 is smaller than those of the upper part. There is bluish gray coarse grained volcanic ash, which is well known as a "mustache" in field that is 2 cm thick at the base of the Kap-6. The Kap-6 resembles to the Kap-5 in lithofacies as if both are same origin and the interval of them is a little less than 1 m. The Kap-6 is distributed in the Odamaki Hills.

Kamikayama Pumice Bed 9 (abbreviation; Kap-9: Figs. 4-1, 4-2, 4-3 and 4-13)

The Kap-9 comprises two layers of yellowish orange or yellowish white pumice beds. The upper layer is generally 20 cm thick and the lower is 15 cm with an interval of 10 cm between them. In places, the lower layer becomes thicker than the upper layer. In places where no interval is between both layers, both are composed of only one pumice bed. The grain size of pumice in the upper layer is 1 to 3 mm and that in the lower layer is 1 mm. The upper and lower limits of the Kap-9 are the most indistinct pumice bed in the "Tama Volcanic Ash". In the Kap-9, there are many almina balls 2 to 4 cm in diameter which are made from black colored manganese core. The Kap-9 is distributed in the Odamaki Hills.

Kamikayama Pumice Bed 10 (abbreviation; Kap-10: Figs. 4-1, 4-2, 4-3 and 4-13)

The Kap-10 is yellowish orange or yellowish white in color and is 40 to 50 cm in thickness. The grain size of pumice in the Kap-10 is about 2 to 3 cm. The basal horizon of the almina balls is the lowest horizon of the Kap-10. Colour tone of the Kap-10 is deeper than that of the Kap-1 to Kap-9.

Kamikayama Pumice Bed 11 (abbreviation; Kap-11: Figs. 4-1, 4-2, 4-3 and 4-13)

The Kap-11 is yellowish orange to yellowish white in color and is 40 to 50 cm in

thickness. The grain size of the pumice is about 1 mm in the lower part, 3 mm in the middle part, and 2 mm in the upper part. There is a zone of fresh volcanic ash deposited in reductive condition and the ash is bluish gray in color. The upper half of the Kap-11 intermingles with many bluish to brown lithic fragments. The Kap-11 is of 5 cm above the upper most of the Kap-10 and resembles the Kap-10 in lithofacies. The Kap-10 contact with the pumice beds of the Kap-11 and appears as one bed in the Odamaki Hills.

Hachioji Biotite Pumice Bed (abbreviation; HBP: Figs. 4-1, 4-2, 4-3, 4-13 and Table 4)

The HBP is yellowish gray in color. The HBP includes many biotites alternated into white kaolinite. The HBP was thought to be an accumulation bed of pumice depressed by a load of the overlying layers but was proved a felsic volcanic ash.

The HBP is about 20 cm in thickness, and is distributed throughout the Tama Hills in the south and the Odamaki Hills on the west. Machida *et al.* (1974) identified the HBP as the Hy-3 [third key bed from the lower part of the Higashiyatsu Formation (=Jizodo Formation) that is intercalated in the lower part of the marine Jizodo Formation in Chiba Prefecture. They called the Hy-3 as the TE-5 (fifth key bed from the lower part of the TE Loam). The TE-5 is 15 to 45 cm thick bluish gray to pinky gray coloured silt bed. The fission track ages are reported as TE-5 is $39\pm8\times10^4$ years B.P. and HBP is $46\pm7\times10^4$ years B.P. (Suzuki and Sugihara, 1983). There was a contradiction between correlation and fission track age measurement: the age of the TE-5 and HBP should be the same value. The data of $46\pm7\times10^4$ years B.P. is older than the data by other pumice in the present area. Fission track age of the HBP (TE-5 of Suzuki and Hayakawa, 1990) from the Odamaki Hills (Fig. 4-13), Chichibu area was $38\pm7\times10^4$ years B.P. (Table 8). This is near the age of the TE-5 of Suzuki and Sugihara (1983).

Gomashio Pumice Bed 1 (abbreviation; Gop-1: Figs. 4-1, 4-2, 4-3 and Table 4)

The Gop-1 is yellowish white in color and is 20 cm in thickness or a little less. The Gop-1 is distributed in the Tama Hills and exceeds 30 cm thick at the cutting along a road of Oshinuma. The Gop-1 and Gop-2 appear in pair with an interspace of 1 m. Both pumice beds resemble in lithofacies and heavy mineral composition. The Gop-1 includes dominantly biotite which altered into white kaolinite. Hara and Nirei (1988) measured the fission track age for the type locality of Gop-1 correlated with the marine Semata Formation (equivalent to the Yabu Formation) in Chiba Prefecture and obtained the data of $35\pm7\times10^4$ years B.P.

Gomashio Pumice Bed 2 (abbreviation; Gop-2: Figs. 4-1, 4-2, 4-3 and Table 4)

The Gop-2 is yellowish white in color and is about 10 cm thick. In the "Tama Volcanic Ash", the Gop-2 is the uppermost pumice bed in the studied area. Suzuki and Sugihara (1983) measured the fission track age of the Gop-2 taken from the type locality of the Semata Formation and obtained $31.0\pm5.0\times10^4$ years B.P. The Gop-2 includes white kaolinite altered from biotite. The Gop-2 exists together with the Gop-1 in the Tama Hills.

b) Shimosueyoshi Volcanic Ash (Fig. 4-1and Table 4) [Shimosueyoshi Loam of the Kanto Loam Research Group (1956)].

Type locality: Cliff at Shimosueyoshi, Tsurumi-ku, Yokohama City (right column of Figure 4-12)

The Shimosueyoshi Volcanic Ash is defined by the lower limit of the buried soil (Machida and Kawachi, 1969) on the underlying "Tama Volcanic Ash". The lower limit of the Shimosueyoshi Volcanic Ash is usually defined by the horizon of the Sanshokuaisu Pumice Bed (abbreviation; SIP: Figs. 4-1, 4-4, 4-5, 4-6, 4-12, Table 4, Pls 7, 8, and Pl. 9, fig. 2). There is the volcanic ash of 70 to 100 cm below the SIP at the Kaneko-dai (Fig. 4-4, and Pl. 7, fig. 1) and the Tokorozawa-dai (Fig. 4-4, Pl. 7, fig. 2 and Pl. 8, fig. 1). As the buried soil at the base of the Shimosueyoshi

Volcanic Ash was not exposed in the both areas, the Shimosueyoshi Volcanic Ash in both areas is older than that in the type locality of the Shimosueyoshi Plateau (Pl. 9, fig. 2). The emergence in Kaneko-dai and Tokorozawa-dai was estimated to be earlier than that in the Shimosueyoshi Plateau where emergence was at the horizon of the SIP (Pl. 9, fig. 2).

The volcanic ash was altered into clay by the weathering but its degree is not same with that of the "Tama Volcanic Ash". The Shimosueyoshi Volcanic Ash is dark brown or purplish brown in fresh surface, and weathered into brown in colour owing to aridity. The vertical cracks are developed perpendicular to intercalated pumice beds. Due to saturation of waters and dehydration in alternation of arid and humid conditions, the cracks below the pumice beds had developed.

In the distribution area of the Narimasu Gravel, the upper or the upper and middle parts of the air-borne Shimosueyoshi Volcanic Ash were deposited (Fig. 4-7). In the Omiya, Shimosa and Hitachi Plateaus, the Shimosueyoshi Volcanic Ash was deposited subaqueously and altered into the greenish brown clay. The color is called "bush warbler" in Japanese. The clay is called the Kawaguchi Clay (Machida, M., 1973) in the Omiya Plateau, the Onakage Clay (Kanto Loam Research Group, 1965) in the Iruma Plateau and the greenish brown clay in the Konan Plateau and the Joso Clay (Nakamura and Fukuta, 1953) in the Shimosa and Hitachi Plateaus. The lower part of the Kawaguchi Clay includes the SIP (Fig. 4-6 and Plate 8, fig. 2). The Pm-I is intercalated in the middle part of the Kawaguchi Clay. The Obara-dai Pumice Bed (abbreviation; OP) is the upper part of the Kawaguchi Clay. The OP can not be recognized there because of a discontineous lenticular distribution. Suzuki and Kitazaki (1953) reported the subaqueous deposition of the Shimosueyoshi Volcanic Ash in the Yodobashi-dai and called it the Shibuya Clay. The outcrop at the Yodobashi Water Works (present Tokyo Metropolitan Government Office) in the Yodobashi-dai, includes volcanic ash as shown in No.40 of Fig. 4-12.

Main key beds in the Shimosueyoshi Volcanic Ash

Sanshokuaisu Pumice Bed (Kobayashi et al., 1968: abbreviation; SIP: Fig. 4-1, 4-4, 4-6, 4-12, Table 4, Pls 7, 8 and Pl. 9, fig. 2)

The SIP is easily recognized by colour. The thickness of the SIP changes from 25 cm in Kawaguchi City (Fig. 4-6 and Pl. 8, fig. 2), and 5 cm in Tokorozawa City (Fig. 4-4 and Pl. 7, fig. 2) to 0 to 3 cm in Iruma City (Fig. 4-4 and Pl. 7, fig. 1).

The SIP at Akai, Kawaguchi City, is intercalated in the Kawaguchi Clay deposited in the water and comprises 5 layers of colour in brown, yellow, purple, brown and yellow. The SIP at Hongo in Tokorozawa City and Omori in Iruma City differs in their mineral composition from that of Akai, Kawaguchi City (No.15 in Fig. 4-6 and Pl. 8, fig. 2). It is understood that the difference of the mineral composition in the same pumice bed is resulted from a degree of the weathering in the depositional condition.

Machida (1971) correlated the SIP in Tokorozawa City with the 7th or 13th pumice beds of the Kissawa Loam Formation (=Shimosueyoshi Volcanic Ash) in the Oiso Hills. The author mentioned that the thermal demagnetization curve and currypoint of a pumice collected from Hongo in Tokorozawa City indicates to the pumice bed and correlative with the SIP (Fig. 4-5).

As the fission track age of the SIP ranges from $11.7\pm1\times10^4$ to $13.2\pm1\times10^4$ years B.P. (Machida and Suzuki, 1971), the SIP is not a single pumice bed but comprises several pumice beds erupted intermittently.

Pumice Bed I of the Kiso Ontake Volcano (Kobayashi and Shimizu, 1962, abbreviation; Pm-I: Figs. 4-1, 4-4, 4-6, 4-7, 4-8, 4-12, Pl. 7, Pl. 8, fig. 1 an Pl. 9, fig. 1)

The Pm-I is aeolian deposit and distributed in Kaneko-dai (Fig. 4-4 and Pl. 7, fig. 1), Tokorozawa-dai (Fig. 4-4, Fig. 2 of Pl. 7 and Pl. 8, fig. 1), Narimasu-dai (Fig. 4-7) and Hino Plateau (Fig. 4-8). The Pm-I is intercalated in the middle part of the Shimosueyoshi Volcanic Ash (Figs. 4-1, 4-4 and 4-12). The Pm-I is situated at the base of the Shimosueyoshi Volcanic Ash in the Narimasu-dai and Hino Plateau (Figs. 4-7 and 4-8). In many outcrops, the Pm-I was washed away by running

water on the underlying Narimasu Gravel. The Pm-I is intercalated in the middle part of the Kawaguchi Clay (Fig. 4-6) in the Omiya Plateau. The Pm-I was discovered in underground at Minamiurawa Elementary School (No.12 on Fig. 4-6) in the Omiya Plateau. From the fresh exposure of the Pm-I, the apatite was recognized under a microscope as same with the fresh Pm-I in the Kiso Region of Nagano Prefecture. As no elongated grains of columnar zircon were found in any other pumice, the Pm-I can be identified by its unique shape of zircon. The Pm-I is yellowish white in colour and distinguished clearly from the other pumice beds in the Shimosueyoshi Volcanic Ash. The Pm-I is characterized also by the existence of biotite altered into white kaolinite and manganese or alminous black specks. The Pm-I is 25 to 30 cm in Ome and Hino Cities, 10 to 15 cm in Tokorozawa City, and 5 to 10 cm at Narimasu-cho, Itabashi-ku in Tokyo Metropolis. The subaqueously deposited Pm-I is composed of white clay bed and is 5 to 10 cm in Urawa and Kawaguchi Cities. Fission track age of the Pm-I ranges from $7.3\pm 0.4\times10^4$ to $9.5\pm0.5\times10^4$ years B.P. (Machida and Suzuki, 1971).

Obara-dai Pumice Bed (Hashirimizu Research Group, 1965: abbreviation; OP: Figs. 4-1, 4-4, 4-7, 4-8, 4-12, Table 4, Pl. 7, fig. 2, Pl. 9, fig. 2 and Pl. 10, fig. 1)

The OP includes scattered pumice grains ranges from 0.5 to 2 cm in diameter at the upper part of the Shimosueyoshi Volcanic Ash. The OP is distributed in the Narimasu-dai (Fig. 4-7), Tokorozawa-dai (Fig. 4-4 and Pl. 7, fig. 2) and Kaneko-dai (No.7 of Fig. 4-4).

The OP gradually changes from the lenticular to continuous bed consisting by only pumice grains toward the southern Yokohama, Miura and Kisarazu. In pumice bed, the ratio of small sized grains to large one increases toward the south area. The OP was deposited thickly and massive in the area of the Miura and the central part of Boso Peninsula, and is 30 to 40 cm in thickness. The Kaneko-dai is the northern limit of the distribution of the OP. Fission track age of the OP is 6.6 $\pm0.6\times10^4$ years B.P. (Machida and Suzuki,1971).

Boundary between the Shimosueyoshi and Musashino Volcanic Ashes

The dencely concentrated horizon of reddish brown "iddingsite" (Machida,et al 1983) altered from the weathered olivine of opaque was recognized at near the boundary between the Shimosueyoshi and Musashino Volcanic Ashes. The "iddingsite" was concentrated and exceeded half of the heavy mineral contents (No.17 of Fig. 4-7) in the boundary of both volcanic ashes. According to the results of further investigation at some places, many grains of "iddingsites" are existed in the interspace between the Pm-I and TP in the Tama Hills, Musashino and Omiya Plateaus.

In the sections and core sections in which the Pm-I, OP and TP can not be seen owing to the lenticular distributions, the boundary between the Shimosueyoshi and Musashino Volcanic Ashes is estimatable by heavy mineral analysis as "iddingsites".

This is an example of the weathering products for the key-bed. Tagami (1954) mentioned the reddish brown olivine is fayalite originated from the antibasic magma. This reddish brown olivine, "iddingsite" and reddish brown parts in olivine are mainly of goethite, lepidochrocite, ilmenite and others.

c) Musashino and Tachikawa Volcanic Ashes (Fig. 4-1)[Musashino and Tachikawa Loams of the Kanto Loam Research Group (1956)]

Type locality: Type locality of the Tachikawa Loam was proposed as the cutting along a road of 200 m ENE of Seikado-bunko Museum of Fine Art, Futagotamagawa, Okamoto-cho Setagaya-ku, Tokyo Metropolis by Kanto Loam Research Group (1958), but that of the Musashino Loam is not decided by the Kanto Loam Research Group (1958) at that time. In general, the typical outcrop of the Musashino Loam is considered at the area along the Kokubunji cliff line of the Musashino Plateau.

The Musashino and Tachikawa Volcanic Ashes were deposited continuously. The author describes both formations since it is hard to divide them from the feature of lithofacies. The whole or partial succession of the Musashino and

Tachikawa Volcanic Ash cover the terraces which are older than the Aoyagi Terrace.

The base of the Musashino Volcanic Ash exists between the OP and TP. [Uesugi *et al.* (1978) and Oka (1991) designated that the lower limit of the Musashino Loam is between the Pm-I and OP in correspondence to the volcanic activity]. At the boundary, many cracks are developed and Musashino Volcanic Ash is changed into a chocolate color. In the case of chocolate colored ash, there are gravel or clay beds substituted for the Shimosueyoshi Volcanic Ash.

It was thought the color was originated by permeation of the water into the air-borne volcanic ash from the subaqueous deposits.

The Musashino and Tachikawa Volcanic Ashes are reddish in color from the base to upward and contain conspicuous reddish scoria grains in the upper part. Above the TP intercalated near the base of the Musashino Volcanic Ash, many cracks are developed owing to desiccation of the volcanic ash. There are two black colored zones of 30 to 50 cm thick at 1 to 1.5 m below the top of the Tachikawa Volcanic Ash. There is often no interspace between both black colored zones, and the bed becomes thick. The Aira-Tn Volcanic Ash (abbreviation; AT: Table 4 and Pl. 12, fig. 2) ejected from the Aira Caldera in the southern part of Kyushu, situates between these two black zones. The Tachikawa Upper Glassy Volcanic Ash (Yamazaki, 1978, abbreviation; UG) exists just below the humus of the surface soil. The AT and UG are hard to recognize by the naked eyes, but distinctly by microscope.

The Musashinio and Tachikawa Volcanic Ashes are brown to reddish brown in color. When volcanic ash is dried, weathered surface becomes bright. The Tachikawa Volcanic Ash [equivalent to the Upper Loam of Arai (1962)] ejected from the northern part of the Kanto Region is seen in the Honjo and Kushibiki Plateaus. The brightness of the Upper Loam is larger than that of the Tachikawa Volcanic Ash in the southern part of Kanto Region. It is easy to distinguish the origin of volcanic ash by the brightness in color. The Itahana Brown Pumice Bed intercalated in the lower part of the Upper Loam and the Itahana Yellow Pumice

Bed is intercalated in the middle part of the Upper Loam of north western part of the Kanto Region (Arai, 1962). Both pumice beds are intercalated lenticularly in the Upper Loam and lithofacies are similar to the TP.

Main key beds in the Musashino and Tachikawa Volcanic Ashes

Tokyo Pumice Bed (Harada, 1943, abbreviation; TP. Figs. 4-1, 4-4, 4-6, 4-7, 4-8, 4-9, 4-12, Table 4, Pl. 7, fig. 2, Pl. 9, fig. 2, Pl. 10, fig. 1 and Pl. 11, fig. 1)

The TP is composed of pumiceous scoria and pyroxene. The TP includes many pumiceous scoriae and should be called the scoria bed rather than the pumice bed. The TP is composed of yellowish brown to reddish brown scoria, yellow pumices and black pyroxene crystals. By these colors and minerals, the TP is said to be a crystal bearing scoria bed. The author treats the TP as the pumice bed as usual. The average size of scoria grains is of 1 to 2 mm in diameter and 1 cm in the maximum size in the studied area. The scoria, pumices and pyroxenes are dotted in the volcanic ash (Pl. 11, fig. 1). The distribution of the TP gradually becomes unclear from south to northward and its distribution of northern limit is a line linked Hanno and Higashimatsuyama Cities.

The fission track age of the TP is $4.9\pm0.5\times10^4$ years B.P. (Machida and Suzuki, 1971).

Aira-Tn Volcanic Ash Bed (abbreviation; AT. Fig. 4-1, Table 4 and Pl. 12, fig. 2)

The interspace between two black colored zones in the Tachikawa Volcanic Ash is 10 to 20 cm and 1 to 1.5 m below the top of the Tachikawa Volcanic Ash. The volcanic ash between two black zones is massive and monotonous, and does not change as far as observed in the field. Many flakes of volcanic glass are recognized in AT. It is an excellent key bed in the Tachikawa Volcanic Ash. The volcanic ash containing many flakes of volcanic glass were discovered by Machida and Arai (1976) and are called as the Aira-Tn Volcanic Ash (AT) that was ejected from the Aira Caldera of Kagoshima Bay.

When the AT can be confirmed in the field, the AT was weathered to white to

yellowish white clay. The AT includes grains of zircon. The ^{14}C age of the AT was given as 2.1 to 2.2×10^{14} years B.P. by many geologists. The AT is composed of a very fine and well sorted volcanic ash, and 99 % of the minerals are volcanic glasses. The sizes of the volcanic glasses are from several hundreds to several ten microns. The glasses of flat board have sharp edges and include bubbles as so-called bubble wall type.