6. Transition of the Environment

The studied area is situated in the central to western parts of the Kanto Tectonic Basin and the east of the Kanto Mountains. Judging from the distribution of the Yaoroshi, Hanno and Bushi Formations (Figs. 3-3, 3-4-1, 3-4-2, 3-5, 6-1, 6-2 and 6-3), the eastern ridges of the Kanto Mountains at the age were invaded by sea water of the Pre-Paleo-Tokyo Bay. Probably the Kanto Mountains were not so high as those of the present days.

The Yaoroshi, Hanno and Bushi Formations and Toyooka Gravel were deposited in the marginal area of the Pre-Paleo-Tokyo Bay (Asai, 1925; Fujimoto,1926) along the eastern margin of the Kanto Mountains, in the brackish and fresh water environments. The Pre-Paleo-Tokyo Bay had occupied the whole area of the Kanto Tectonic Basin. Many rivers had flowed from the mountains and highlands into the bay. The age of the Yaoroshi, Hanno and Bushi Formations were estimated as the late Pliocene to the early Pleistocene by the data of fossils and fission track age determination.

Above and the east of these depositions, the terrestrial gravels are widely distributed along the eastern margin of the Kanto Mountains to the Arakawa River Basin. The gravels of the middle Pleistocene to Holocene alluvial fan were deposited on the eastern margin of the Kanto Mountains. The areas of supply and deposition of gravels had been completed in the Kanto Mountains on the west and alluvial plain on the east. Following to eastward shifting of the bay shore, the progradation occurred and the fan had spread over beyond the outer fan to the east. The fan was gradually emerged and had formed many step-like terraces. The high terraces are usually located near the mountains. The middle terraces were spread over the Kanto Tectonic Basin widely, and the lower are near the present rivers. The Omiya Plateau is a fluvial or lacustrine terrace on the eastside of the Arakawa Lowland. The valley plains between the hills and plateaus are developed and the alluvial deposits were accumulated there.

I. The Plio-Pleistocene age preceding the terraces

a) **The geological age of the Yaoroshi Formation** (Fig. 6-1)

The Yaoroshi Formation (Figs. 3-1, 3-3, 3-4-1, 3-4-2, 3-5, Tables 1, 2, 4, Pls. 1 and 2) is distributed not only in the hills but also on ridges extending eastward from the Kanto Mountains. The Pre-Paleo-Tokyo Bay in that age was estimated to invade toward the eastern margins of the Kanto Mountains. No marine fossils from the Yaoroshi Formation were reported.

Stegodon bombifrons (Falconer and Cautley) was discovered from the Yaoroshi Formation in Akiruno City (Itsukaichi *Stegodon* Research Group, 1980). Taruno (1991) mentioned that *S. shinshuensis* is probably synonym with *S. bombifrons*.

Kurakawa and Majima (1982) distinguished the Tertiary and the Tertiary-Quaternary *Metasequoia* flora. They also distinguished the Quaternary plant of *Picea maximowiczii* and *Pterocarya rhoiforia* in the Kasumi Hills. The fossil plant indicates a slightly cool climate. Those remains were deposited in shallow water at the time. Marine fossil is not discovered until now in the Yaoroshi Formation. Alluvial plain of the time in the foot of Kanto Mountains was distributed at the western part of the Kanto Tectonic Basin spread toward the east.

b) **The geological age of the Hanno Formation** (Fig. 6-2)

The lithofacies of the Hanno Formation (Figs. 3-1, 3-2, 3-3, 3-4-1, 3-4-2, 3-5, Tables 1, 2, 4, Pls. 2 and 3) changes from the underlying Yaoroshi Formation as mentioned earier pages.

The Hanno Formation is distributed in the east of the Kanto Mountains and forms the alluvial fan. The gravel of the Hanno Formation transported by the Tama River, is particularly thick but became gradually thin in the north where it was carried by another river. The diameter of the boulder in the Hanno Formation is mostly over 70 cm at Morooka in Ome City but becomes smaller to eastward.

The distribution of the Hanno Formation is known on the ridge of the Kanto Mountains between the present Koma and Iruma Rivers. The apex of fan is estimated on the foothill of the Mt. Mitake which corresponds to the discordance of

topography at 300 to 500 m above the present sea level, to the west of Ome City (Fig. 2-1).

Suzuki and Yoshida (1969) imagined the conifer forest composed mainly of *Picea*, suggested a cold climate based on the result of pollen analysis of the samples taken from the upper part of the Hanno Formation.

The comparison of the depositional environment of the Hanno Formation and that of the present one is difficult, because so large supply of gravel and precipitation of the Hanno. The supply of gravel over 100 meters thick was so large in comparison with the terrace gravel of several to 20 meters thick.

Even if there were large amounts of gravel and precipitation after the "Tama Epoch", gravel of 20 meters thick in the studied area is rare, except for the terrace gravels in the inland basin such as Chichibu Basin where supplied a large amount of gravel. Thus, it is considered that the uplift of the Kanto Mountains (Fig. 3-5) was caused to supply a large amount of the Hanno Formation. Of course, there was s large amount of precipitation in comparison with that of the present.

The alluvial plain that was burried by the Hanno Formation is spread toward the central part of the Kanto Tectonic Basin from the foot of the present Kanto Mountains.

The Hirayama Sand (Tables 2, 4, Pl. 3, fig. 2 and Pl. 4, fig. 1) equivalent of the Hanno Formation, is considered to be deposited in the shallow sea with sandy seafloor by the molluscan shells and shallow marine deposits as the gravel and coarse grained sand.

The eastern and southern parts of the Kanto Region at the age of Hanno Formation were covered by the sea as same as the Kazusa Group or the upper part of the Miura Group.

c) The geological age of the Bushi Formation (Fig. 6-3)

The Bushi Formation (Figs. 3-1, 3-2, 3-3, 3-4-2, 3-5, Table 1, 2, 4, Pl. 4, fig. 2 and Pl. 5, fig. 1) consists of tuffaceous sand and clay, and distinguished from the underlying Hanno Formation in lithology. The tuffaceous sand and clay at the

base of the Bushi Formation are ten and several meters thick and change into the gravel bed upward. The overlying gravel bed changes also into the tuffaceous sand and clay upward. Such a cyclic alternation was occurred five times in the Bushi Formation.

Stegodon aurorae was reported from 7 horizon between the lower (A Member) and upper (D Member) parts of the Bushi Formation. The Bushi Formation was deposited in shore. The Ushizawa Shell Bed in the upper part (D) of the Bushi Formation was reported by Tokunaga and Iizuka (1926) to occur foraminifers. The molluscs and foraminifers from the Bushi Formation indicate the neritic environment.

The Bushi Formation is estimated to be deposited in marginal part of the Pre-Paleo-Tokyo Bay by some plant fossils. The Pre-Paleo-Tokyo Bay was estimated as 20 times as large as the present Tokyo Bay and wider than Paleo-Tokyo Bay. The fossil plants were discovered from A Member of the Bushi Formation and were of the mixed type of the broad-leaved trees and conifers.

The climate at the time was as cool and pluvial according to Suzuki and Yoshida (1969).

The Bushi Formation is correlated with the marine Umegase or Kakinokidai Formations in the Kazusa Group from the fission track ages and order of succession.

d) The geological age of the Komiya Sand

The Komiya Sand (Tables 2 and 4) overlying the Kasumi Gravels conformably distributes in the eastern part of the Kasumi Hills. The Komiya Sand is divided into the lower and upper parts. The lower part is consisted mainly of sand and the upper part is of mainly cobbles. The Komiya Sand is covered by the Mine Gravel with unconformity. Probably, the age of the Komiya Sand corresponds to the lower part of the Bushi Formation. Fossil cetacea, *Japonocetus akishimensis* Nishiwaki and Ozaki was discovered in the Komiya Sand. Many molluscan shells were discovered in the Komiya Sand. Some of them had inhabited under the

enfluence of a cold sea water.

e) The geological age of the Toyooka Gravel (Fig. 6-4)

The geological age of the Toyooka Gravel (Figs. 3-1, 3-3, 3-4-2, Tables 1, 2 and 4) is uncertained because no fossil were discovered up to date. The Toyooka Gravel overlies the Bushi Formation with unconformity. The distribution is only in the area of the Azuyama Hills being higher in altitude those of the other hills. It is inferred that the Toyooka Gravel was deposited by cyclic sedimentation of gravel and mud as like as the Bushi Formation. The depositional environment of the Toyooka Gravel is similar to that of the Bushi Formation.

II-1 The geological age of the high terrace (The age of the "Tama Terrace")

a) The geological age of the Kanekozaka, Kamikayama and Imokubo Gravels (Fig. 6-5)

These three gravels (Figs. 4-2, 4-3 and Table 4) were distributed in the Azuyama, Hanno and Sayama Hills at the middle Pleistocene. These are overlain by the Tama I Loams of Hatori and Juen (1958).

The equivalent gravels had not been discovered in other hills due to probably erosion. The gradient of the depositional surface of these gravels is continued to a steep foot slope on the west. The eastern margin of these distribution is not clear and dissected after the deposition of the gravel. The eastern margin of these gravels had been near the present Arakawa River Basin.

Almost no gravels and volcanic ashes were in the Hiki Hills and other hills having the same altitude of the summits dissected by small streams in high drainage density. These narrow ridges were resulted from the dissection of the hills between valleys formed by faults with NW-SE direction. There are many small faults in the direction of NW-SE in the hills of the north from the Iwadono Hills. The Konan Fault in the Konan Plateau and Imaichi-Sugaya Fault in the Hiki Hills are assumed as an active faults in the NW-SE direction.

The gravels building the high terraces are usually 10 to 20 m in thickness.

These are much thicker than the Recent gravels along the rivers. It is clear that there was a large supply of rock fragments more than that of the present. Probably, the reason for a large amount of supply is as stated in the chapter of the Hanno Gravel, due to the large amount of precipitation.

The altitude and gradient of the terrace gravels of the hills are higher than the present plateaus and rivers, though they are nearly parallel with those of the present. It is hardly believed that the uplift of the Kanto Mountains was especially large when the hills were the riverfloors. Probably, the uplift of the Kanto Mountains should be continued because the gradient of the hills (Figs. 3-5 and 7-2) are higher than that of the present plateaus and rivers. Of coarse, it is not considered that the gradient of the hills was large when the hills were the river floors. Probably, the much precipitation was more significant than the uplift of the Kanto Mountains during the age of the high terrace.

The same events are considered for the deposition of Kaneko-dai, Tokorozawa-dai, Narimasu and Musashino Gravel, but the depositions of the Naka-dai, Aoyagi and Haijima Gravel are similar to the present ones based on the width of the river and thickness of the gravel.

Otuka (1948) considered that the precipitation of the Musashino Gravel was not a pluvial age on the basis of the sizes of gravels that are the same with those of the present. But many researchers consider at present that there was a pluvial age from the thickness, volume and distribution of gravels.

b) The geological age of the Mine Gravel (Fig. 6-6)

The Mine Gravel (Table 4) is distributed on the eastern end of the Kasumi Hills. The Mine Gravel corresponds to the age between the Kanekozaka, Kamikayama and Imokubo, and the Maeganuki Gravels. The Mine Gravel is overlain by the middle part of the Tama I Volcanic Ash. The distribution of the Mine Gravel is narrow as well as the Maeganuki Gravel. The lower half of the Mine Gravel is composed mainly of gravels of sandstone, graywacke, chert and slate and the upper half is composed mainly of sand. The Mine Gravel is mainly

of the stream deposits with deltaic sediments because of some parts show a fairly good grading.

c) The geologic age of the Maeganuki Gravel (Fig. 6-7)

The Maeganuki Gravel (Fig. 4-2 and Table 4) is contemporaneous with the lower part of the Gotentoge Gravel (Table 4) in the Tama Hills. As the distribution of the Maeganuki Gravel is narrow and the most of the distribution area is under contruction for housing at the present, so the Maeganuki Gravel is hard to observe directly. The Maeganuki Gravel is distributed at about 135 m in altitude which is lower than that of the western part of the Tama Hills. The Maeganuki Hills is more inland in compared with the Tama Hills, and was formed almost at the same or little later than that of the Tama Hills. It is inferred that the uplift of the Tama Hills was larger than that of the Maeganuki Hills. The Tama Hills situate in the marginal area of the Kanto Tectonic and Sagami Sedimentary Basins (Fig. 7-6). The basining movements in the Kanto Region was occurred with the subsidence of the central parts of the basin and the uplift of the marginal part of the basin. Accordingly, the uplift of the Tama Hills was influenced by the development of the basin.

The environment at the age of the Maeganuki Gravel is not so clear because of narrow distribution.

II-2 The geologic ages of the middle and low terraces [after the age of the Shimosueyoshi Terrace (= Yodobashi Terrace) in broad sense]

a) The geologic age of the Kaneko-dai, Tokorozawa-dai Gravel (Fig. 6-8) **and Tokyo Formation** (Figs. 6-9 and 6-10).

The Kaneko-dai and Tokorozawa-dai Gravels (Fig. 4-4) are almost same with the Tokyo Formation (Figs. 4-4, 4-6, 4-7, 4-9, 4-10, 4-12, Table 4 and Pl. 10, fig. 2) in geologic age. The correlated formation in the Yokohama area are called the Shimosueyoshi Formation (Fig. 4-12) and the "Narita Formation" in the Shimosa Plateau. These Formations were consequent of the age to the Shimosueyoshi

Transgression. The sea in which the Tokyo Formation was deposited, is called Paleo-Tokyo Bay (Yabe, 1931 and 1951) which spread over the almost whole Kanto Tectonic Basin. As the sea level of the Paleo-Tokyo Bay was lowered, the distribution of the Kaneko-dai and Tokorozawa-dai Gravels were spread over to eastward. Most part of the Musashino Plateau in this age was recognized in the subsurface of the alluvial fan whose apex existed in Ome City. The Kaneko-dai and Tokorozawa-dai Gravels may be of the same components of this fan. Both gravels were remained from the stream and later formed the terraces in the Kaneko-dai and Tokorozawa-dai. The Yodobashi-dai and Ebara-dai along the fan margin were remained still beneath the sea level.

The eastern ends of Chiba and Ibaraki Prefectures were began to rise in those days and the emerged areas extended gradually westward. These areas took off from the water from the east. According to the sea level lowering, the central part of the Kanto Tectonic Basin was remained as the bay. While the Kanto Tectonic Basin had been changing to lake or river basins, the rivers of the northeastern part of the basin eroded the raised area on the eastern side and stream flowed into the Pacific Ocean. The Tone, Arakawa, Iruma, Tama and many other rivers flowed into the central parts of the Kanto Tectonic Basin and then eroded the southern part of the present Tokyo Bay and flowed through the Uraga Channel into the Pacific Ocean.

The Yodobashi-dai and Ebara-dai were emerged as well as the Shimosueyoshi Plateau. The Omiya Plateau remained subaqueous till air-borne volcanic ash deposited and accumlated into the Tachikawa and Musashino Volcanic Ashes.

The Tokyo Formation is overlain by the Kawaguchi Clay with conformity in the Omiya Plateau and contacts with the overlying Shimosueyoshi Volcanic Ash conformably at the Yodobashi-dai and Ebara-dai in the Musashino Plateau. It contacts with the terrace gravel unconformably in the Musashino Plateau. As the Tokyo Formation is distributed also under the Tokorozawa-dai Gravel, the sea invaded to the eastern margin of the Sayama Hills at the maximum phase of the Shimosueyoshi Transgression.

The Tokyo, Shimosueyoshi and "Narita" Formations are known as the products of the Shimosueyoshi Transgression in the Kanto Tectonic Basin. The Omiya Plateau had been emerged after the emergence of the Shimosueyoshi Plateau in Yokohama City.

The seafloor was flat and shallow shown under plant remains, sandpipes and shells, and was burried by sand and mud by the Shimosueyoshi Transgression in the Shimosueyoshi, Narita and Kawaguchi areas.

The molluscan shells of the Tokyo Formation shown in Table 5 were discovered from the shell bed at Tokumaru area, Itabashi-ku, Tokyo Metropolis (Kanto Loam Research Group, 1965). The molluscan shells indicate a cool climate and a shallow embayment.

The lower part of the Shimosueyoshi Formation yielded shallow marine species, *Anadara subcrenata, A. granosa* and *Batillaria zonalis* as mentioned by Regional Geology of Japan, Kanto (1986).

b) The geologic age of the Narimasu Gravel (Figs. 6-11 and 6-11-1)

The Narimasu Gravel (Fig. 4-7, Table 4 and Pl. 10, fig. 2) is distributed widely in the Musashino Plateau. The equivalents to the Narimasu Gravel are distributed on the north and south sides of the Shimosa Upper Terrace in the western part of the Shimosa Plateau. The Obara-dai Sand and Gravel in the Miura Peninsula is the equivalent to the Narimasu Gravel and was deposited on the bottom of the drowned valley.

The upper half of the Narimasu Gravel in the northeastern part of the Musashino Plateau consists of sand and clay. The upper half of the Narimasu Gravel was deposited on a floor with slow running water. No marine fossils are in the Narimasu Gravel. The Paleo-Tokyo Bay which spread over the almost whole Kanto Tectonic Basin was retreated and changed into the river basin. The present rivers flow across the Omiya Plateau into new (present) Tokyo Bay.

The Omiya Plateau was rized above the sea surface, but did not take off from the limnic area before the emergence of the Anegasaki Formation in Chiba

Prefecture along the Tokyo Bay. Probably the Omiya Plateau was under the environment of wide river or lake basins. The sea environment was static and is estimated at the time of fall of the Pm-I. There is no evidence that the Omiya Plateau was emerged by sea water. Judging from the distribution of fluvial and deltaic deposits (Arai *et al.*, 1977), the sea should be existed in the south of the present Tokyo Bay (Fig.6-11-1)

c) The geologic age of the Musashino Gravel (Figs. 6-12 and 6-12-1)

The Musashino Gravel (Fig. 4-9, Table 4 and Pl. 10, fig. 2) is distributed widely along the rivers and narrowly along the valley plains in the Shimosa Upper and Lower Terraces. The Musashino Gravel along the Miyako River in Chiba City is known as the Chiba Terrace Sand and Gravel (Nakagawa, 1960; Kanto Loam Research Group, 1965) (Table 4) which was formed by the First Chiba Terrace. The upper half of the Musashino Gravel is mostly of the sand and clay, and the lower half is mostly sand and granule at Hongo-dai. The depositional environment of the upper half of the Musashino Gravel was estimated to be the lakes and marshes with a little influence of running water.

The areas including the Omiya Plateau were emerged and formed in this age. The Omiya Plateau is overlain by the subaerial Tachikawa and Musashino Volcanic Ashes as like as the Musashino Terrace. The formation of terrace in the Omiya Plateau due to the Kawaguchi Clay (subaqueous deposit of the airborne Shimosueyoshi Volcanic Ash)(Figure 4-6) which was emerged and formed the surface of terrace. The Omiya Terrace is corresponding to the Shimosueyoshi Terrace is correlated with the Musashino Terrace (Fig. 5-3).

d) The geologic age of the Naka-dai Terrace Gravel (Fig. 6-13)

The Naka-dai Terrace Gravel (Table 4) is distributed along the stream on the north of the Tama River. The Naka-dai Terrace Gravel is distributed narrowly along the middle and lower streams of the Tama River and was formed in a short period. Then the stream course was shifted immediately. Therefore the

distribution of the Naka-dai Terrace Gravel is extremely small in the group of the Musashino Terrace as the M1, M2 and M3.

e) The geologic age of the Tachikawa Gravel (Fig. 6-14)

The Tachikawa Gravel is distributed underground along the down stream of the Tama River and in the Arakawa Lowland. The river floors of the past Tama and Arakawa Rivers are composed of the Tachikawa Gravel. With the lowering of sea level, the rivers extended and flowed into the bottom of emerged Tokyo Bay, joined the Paleo-Tokyo River (Chujo, 1961 and 1962; Kaizuka, 1964). The Tokyo Bay with joining the past Tama, Arakawa and other rivers were the land area. Those rivers flowed into the Pacific Ocean through the Uraga Channel.

The temperature in the age of the Tachikawa Gravel was felled considerably in the high latitude, particularly after the age of its top. From the analysis of the Ekoda Conifer Bed (Kanto Loam Research Group, 1965), the age of the Tachikawa Gravel is corresponded to the last glacial age. The age of the maximum development of the glacier and the ice sheets in the European alps and the high latitudes was said as 18,000 years ago or its immediately after (Penny *et al.*, 1969) or about 17,000 years ago (Harmon *et al.*, 1979). This age corresponds to the maximum glacial phase of the last glacial age. Sea level was 100 m or more lower than the present level at the maximum glacial phase. The down-cutting in the lower stream of the past Tama and Arakawa Rivers was steeper than the floors of the present Tama and Arakawa Rivers.

The appearance of the human race in the studied area had been known as the late Pleistocene; the chipped and polished stone toools were unearthed. Most of these stone tools of the Late Paleolithic Age were discovered from the Tachikawa Volcanic Ash Formation (30,000 years ago, Oda, 1985). Mr. Oda stated to the author that the old stone tools were unearthed from the just above the TP (about 50,000 years ago), in the lower part of the Musashino Volcanic Ash in the Tama Hills. The polished stone tools were also unearthed. Incidentally, the oldest stone tools were discovered about 600,000 years ago in Japan (Kamata, 1966).

The appearance of the human race in Japan corresponds to the age of the lower most part of the "Tama Volcanic Ash".

f) The geologic age of the Aoyagi Gravel (Fig. 6-15)

The Aoyagi Gravel (Fig. 4-11 and Table 4) is distributed narrowly along the Tama and Iruma Rivers and a little wide along the middle stream of the Arakawa River from Konan Town to the west of Kumagaya City. This distribution pattern is understood as down-cutting progressed rapidly along the Tama River and slowly along the Arakawa River. This is explained by many steps that the terraces were rapidly developed along the Tama River and slowly along the Arakawa River. This is explained that many steps of terrace were developed along the Tama River and few along the Arakawa River. The fan along the Tama River was near to the sea in comparison with that of the Arakawa River. As a result, the gradient of the Tama River was larger than that of the Arakawa River.

The gradient of the Aoyagi Gravel as well as that of the Tachikawa Gravel is steep. The Aoyagi Gravel is buried beneath the alluvial plain along the lower stream of the Tama and the Arakawa Rivers. Their longitudinal profiles are steeper than that of the present river floor.

The age of the Aoyagi Gravel was estimated as about 14,000 years ago (Yamazaki, 1978) and corresponded to several thousand years ago from the maximum phase of the regression and to a stagnant age of changing sea level in the climatic amelioration.

g) The geologic age of the Haijima Gravel (Fig. 6-16)

This age is corresponded to climatic amelioration. The Haijima Gravel (Table 4) is distributed narrowly along the upper stream of the Tama and Iruma Rivers. The Haijima Gravel is the Holocene deposit, because the Haijima Gravel is not overlain by the volcanic ash.

This age is called as the age of the Yurakucho or Jomon Transgression. The maximum phase of the transgression was about 6,000 yeas ago. The existences of

the buried volcanic ash formation and the Tachikawa Gravel are confirmed by the consequent deposit of the Yurakucho Transgression. The sea level had been risen and invaded the Arakawa and Nakagawa Lowlands.

The Jomon people had settled along the coastal line and probably eat marine shells and fishes. They dumped and mound the shells in the mound (Togi, 1926). As the shell mounds were distributed along the seashores, it was possible to presume a coast line in the Jomon Age by the distribution of the shell mounds (Togi, 1926). The sea in those days is called "Oku Tokyo Bay" (Ohyama *et al.*, 1933). Soon after, the marine regression had began and a coast line had been prograded toward the present position during the Yayoi Age. The human race had settled and started farming, and began the utilization of underground resources as copper and iron together with stone tools and earthenware.

h) The geologic age of the Alluvium (Fig. 6-17)

The alluvial deposits (Table 4) consist of deposits after the maximum phase of the regression about 18,000 years ago.

The valley plains between the plateaus were changed at the age of the maximum phase of the Yurakucho Transgression. Kawagoe City in the Arakawa Lowland and Fujioka Town in Tochigi Prefecture were invaded by the sea. Fossil shells in the alluvial deposits were discovered from many places during the river improvement works. The thickness of marine deposits was increased toward Tokyo Bay and exceeds 40 m thick (ex. the Yurakucho Formation, Yamakawa, 1909). The bay was retreated to the present position. The fluvial sand dunes were developed along the extended river of the Nakagawa Lowland. The muddy sediments were deposited in the Arakawa Lowland.