2. Outlines of geomorphology and geology

The following topographies of mountains, hills, plateaus and lowlands (Fig. 1-2) are well recognized in descending order from the Kanto Mountains on the west to the central part of the Kanto Region on the east.

In the present thesis, the author gives a definition for the following four wards as they are sometimes confused;

Mountain: Any parts higher than a hill, sufficiently elevated above the surrounding land surface. It is a part to be considered worthy of a distinctive name, and characterized by a restricted summit area, and with steep sides. It can occur as a single, and/or a group forming a high range. It may be formed by earth movements or erosion. Generally, a mountain is considered at least 150 meters above the sea level and has a name.

Hill: A natural elevation of the land surface with rising rather than prominently above the surrounding land, and usually in limited extention. This has a well-defined outline, and height from 50 to 300 meters above sea level. Generally, a flat surface of the summit area is narrower than that of a plateau and has the same origin of formation with that of a plateau. A hill is commonly higher than a plateau.

Plateau: Comparatively flat area of the great extention and elevation. Extensive land region considerably elevated (more than 10-200 meters in height) above the alluvial plain or above sea level. It is commonly limited at least one side by an abrupt descent, has a flat or nearly smooth surface but is often dissected by small rivers and is bounded by hill or mountain. A plateau is higher than an alluvial plain. A plateau is a kind of a place name.

Terrace: Long, narrow, relatively level or gently inclined surface, generally less broad than the alluvial plain, bounded along one edge by a steeper descending slope and the other by steeper ascending slope. A large bench or step-like ledge breakes the continuity of a slope. A terrace is above water surface, marking a former water level. A terrace is formed from the deposits of gravel, sand and clay. The flat plane of the upper limit of gravel, sand and clay corresponds to the terrace plain.

An altitude of the mountain ranges from 200 to 2,000 m, the hills from 50 to 300 m, the plateaus from 10 to 200 m and the lowlands from 5 to 50 m. Every hills, plateaus and lowlands have flat surface, but the mountain has no flat surface. Figure 2-1 is the summit level map in the areas including the eastern half of the Kanto Mountains and the western part of the Kanto Tectonic Basin on the eastside of contour line of 300 m. The topography of the studied area contrasts strikingly with that of the Kanto Mountains on the westside of 300 m contour line. There are remarkable steep slopes in the northwestern part (Fig. 2-1). The slopes extend west and incline north at the south side of the Chichibu Basin. The strike of this slope is almost equal with that of the Hakutai Tectonic Line extending further west from the area of the summit level map. The extension of the Hakutai Tectonic Line is not clear, but the interspace of contour lines becomes narrower nearby Mt. Monomiyama (Fig. 2-1).

The Chichibu Basin has a remarkable depressional topography. Otsuki City and its adjacent area in the southern part of the Kanto Mountains are situated in a depressional basin extending to the east and west. The wide river valleys were developed there in the age of "Tama" or more earlier. On the eastside of Mt. Daibosatsu, the gentle slopes are recognized at altitudes between 700 and 900 m, and 1,100 and 1,500 m. The latter is extended over the north flank of Mt. Daibosatsu. These gentle slopes were formed before the hills and the surfaces have been preserved as gentle slopes, after severe dissection.

The lowland area between the southern part of the Yoshimi Hills and the northern part of Kawagoe City was recognized (Figs. 2-2, 2-3.and 7-1). The altitude of the hills and plateaus becomes high toward north and south from the area mentioned above. The hills and plateaus became lower toward the central part of the Kanto Tectonic Basin.

The term Kanto Tectonic (= Structural) Basin was used in the Japanese paper entitled "Geological age of the terraces along the mountain foots surrounding the Kwanto Structural Basin," published by Yabe and Aoki (1927). Two years before, Yabe (1925) also used the term "Kwanto Structural Basin" in the paper of "The Great Kwanto Earthquake of September 1, 1923, geologically considered — the Second Preliminary Report". The present time, the term "Kwato Structural Basin" has been used for "Kanto Tectonic Basin" in English. Yabe and Aoki (1927) and Yabe (1925) used the term "Kwanto Structural Basin" because the high and low terraces in the Kanto area, are inclined toward the central part of the Kanto Region, by tectonics in the surrounding mountains.

Aoki and Tayama (1929, 1930) had an idea that the Kwanto Structural Basin had been represented by the sedimentary basin and the depositional surface of the "Narita Group", as Aoki (1930) mentioned that the basining movement was continued since the age of the deposition of the "Narita Group". The transitions of movement of the basement complexes occurred under the sea of the Kanto Tectonic Basin as expressed by the Kurotaki Unconformity (Koike, 1957). The main scarp of slump (the normal fault falling southward) corresponds to a tectonic line called the Tonegawa or Kanto Tectonic Line (Nakagawa, 1962 and 1988 a, b). Along the normal fault taken place in Cretaceous along the Tone River, a huge slumping as the Kurotaki Unconformity occurred in the Pliocene. The movement of the block was continued intermittently since the deposition of the Kazusa and Shimosa Groups. The history of the geomorphic development of the Kanto Tectonic Basin is considered as follows:

There was collision of the Tanzawa Massif, and the Izu micro-continent followed against the Eurasian Plate at about 5 Ma B.P. It was the age of a violent uplift in the Kanto region, as known by the early Pleistocene Ashigara Group that is distributed in the southwestern part of the Kanto Region. Amano *et al.*, (1986) stated that the Ashigara Group is deposited to filled in the trough between the

Eurasian Plate and the Izu micro-continent. The trough was northwestward extension of the Sagami trough at that time. The Ashigara Group was correlated with the Kazusa Group in the Boso Peninsula.

The Paleogene Mineoka Group was deposited in the Tanzawa-Mineoka Zone of the Boso Peninsula, and then, the Hota and Sakuma Groups are deposited in the Miocene Period. The Kiyosumi Formation covered the Amatsu Formation. The Kiyosumi Formation was formed by sediments supplied from the northsouthward (Tokuhashi, 1976). The lower parts of the Cenozoic deposits in the Boso Peninsula were deposited on the submarine slopes dipping south.

The Kurotaki phase (Koike, 1952) is Geomagnetic Gauss Normal Polarity Chron in the late Pliocene. The Kurotaki Unconformity was probably occurred on the seafloor (Nakagawa, 1988a). The Kurotaki Unconformity represents the movement of basement beneath the seafloor and the Kazusa Group was deposited on the surface of the unconformity inclined northward. The center of the subsidence had shifted northward. This is the incipient phase of the geomorphic development of the Kanto Tectonic Basin. Depression at the north of the Tanzawa-Mineoka Zone in the direction of WNW-ESE (parallel to the trend of Sagami Trough) was combined later with a synclinal structure of NNE-SSW trend (parallel to the trend of Tokyo Bay). This direction was parallel to the Japan Trench and related to form of the Kanto Tectonic Basin (Nakagawa, 1962, 1988a).

The center of the subsidence had been shifted northwestward and the deposition had been occurred between the Tama Hills and the central part of the Boso Peninsula.

The northern part of the Kanto Region had been uplifted above sea level in the early Pleistocene and the southern part was a part of the Pre-Paleo-Tokyo Bay with the mouth opened to the Pacific in the direction to Kujyukuri (Koike, 1957) in middle Pleistocene. The Shimosa Group was deposited in the basin since middle Pleistocene. The Japanese Islands were generally uplifting in the Pleistocene, but thick marine sediments in the Kanto Region had been deposited. The Paleo-Tokyo Bay had widely opened eastward by this time.

The Paleo-Tokyo Bay succeeded to the Pre-Paleo-Tokyo Bay from middle to late Pleistocene was during the latest transgression of late middle Pleistocene.

The northern part of the Kanto Region was a limnic land (Suzuki, 1959) as well as the western part as shown in Figs. 6-4, 6-5 and 6-6.

The rivers of Tone, Arakawa, and other streams that flowed across the existed terrace in the Kanto Region, were extended to the southeast with the progress of regression after the formation of the Shimosueyoshi Terrace. The extended river courses of the Tone, Arakawa and others were completed in the age of Narimasu Gravel.

In the studied area, the hills and plateaus are well developed. The hills developed along the eastern foot of the Kanto Mountains. Some hills are distributed as an island, like the Sayama Hills surrounded by plateau. The plateaus are distributed as alluvial fans extended toward the central part of the Kanto Tectonic Basin from the eastern margin of the Kanto Mountains. The Omiya Plateau is surrounded by alluvial plain in the central part of the basin. The surfaces of the hills and plateaus descend toward the Koga City, Ibaraki Prefecture and Kurihashi Town, Saitama Prefecture.

The flat surfaces on the hills are formed as a depositional surface of gravel, sand and other deposits of river floors. The floors were left after the lowering of the base level. The gravels formed the flat surface of terraces, are covered with aeolian volcanic ash. Original flat surfaces of the hills were preserved only in the small parts. However, the original flat surface of the hills can be seen only in distant views. The altitudes of the hills are as follows from north to south: 140 to 80 m on the Kodama Hills, 120 to 70 m on the Matsuhisa Hills, 140 to 60 m on the Hiki Hills, 80 to 50 m on the Yoshimi Hills, 140 to 60 m on the Iwadono Hills, 105 to 50 m on the Moroyama Hills, 190 to 70 m on the Hanno (= Koma) Hills, 220 to 120 m on the Azuyama (= Kaji) Hills, 190 to 80 m on the Sayama Hills, 330 to 150 m on the Kusabana Hills, 260 to 100 m on the Kasumi Hills and 230 to 120 m on the western part of Tama Hills (Fig. 2-2 2-3 and 7-1).

The plateaus as well as the hills were formed by the changes in the base level of erosion that is controlled by sea level changes and the vertical movements of the ground. The surfaces of plateaus are not so eroded as those of hills, because the plateau is younger than the hill. The altitudes of the plateaus are as follows from the north to south: 110 to 50 m on the Honjo Plateau along a tributary of the Kanna River, 100 to 35 m on the Kushibiki Plateau, 125 to 40 m on the Konan Plateau along the Arakawa River Basin, 70 to 20 m on the Higashimatsuyama Plateau, 110 to 20 m on the Hanno Plateau, 190 to 20 m on the Musashino Plateau of which apex is at Ome City, 180 to 120 m on the Akiru Plateau and 13 m on the northeastern margin, a little lower than 20 m on the southeastern margin and a little higher than 30 m on the northwestern margin of the Omiya Plateaus existed in the central part of the Kanto Tectonic Basin.

In the hills, there are many ravines that have inclined east to northeastward. Besides them, there are ravines descended to the southeast in the Hiki Hills and those in the ESE trend in the Kasumi Hills. In the Iwadono Hills, like an independent peak, there are many ravines diverging from the center of the hills but those in the SSE trend and those in the north and south trend are predominant. These ravines in the SSE trend and north to south trend are influenced by the fault like the Hachioji Tectonic Line and the boundary between the crystalline schist and Tertiary System. The Hachioji Tectonic Line divided the Kanto Tectonic Basin on the east and the Kanto Mountains on the west. The summit planes of all the hills, except the Iwadono Hills, are uniform and are descending eastward or northeastward.

The drainage divide of the Azuyama and Kusabana Hills is deviated to their southern parts. These hills exist along the southwestern margin of the Kanto Tectonic Basin. The northern half of these hills have been inclined with development of the Kanto Tectonic Basin. As a result of lowering of the central part, the drainage divide of these hills was deviated to the southern part.

The Hanno, Bushi Formations and Toyooka Gravel are overlain by the terrace gravels, which are covered by the "Tama Volcanic Ash" of the middle Pleistocene. The late Pleistocene terrace gravels are also covered by the Shimosueyoshi, Musashino and Tachikawa Volcanic Ashes. The Holocene terrace gravels are distributed narrowly along the almost all rivers. The Yaoroshi, Hanno and Bushi Formations and their equivalents consisted of marine, deltaic and terrestrial deposits yielded the fossils of shells, whales, elephants, foot prints of animals and plants.

The hills and plateaus formed the terrace, had obviously caused the displacement because the topography and layers descended toward the central part of the Kanto Region from the original altitude.

The Yaoroshi Formation and its equivalents are distributed only in the south of the Oppe River flowing along the southern margin of the Yoshimi Hills.

In the Hanno, Azuyama, Kasumi and Sayama Hills, the terrace gravels are covered with the volcanic ashes. Above the Onita, Moroyama, Monomiyama and Yoshimi Gravels being equivalent to the Hanno Formation in the Kusabana, Moroyama, Iwadono and Yoshimi Hills, the terrace gravels and the volcanic ashes had been eroded away. The Azamiyama Gravel in the Kodama and Matsuhisa Hills, is probably a terrace formation.

The terrace gravels covered by the volcanic ash are distributed widely on the plateaus, but the plateaus were formed in Holocene consisted only by the terrace gravels without volcanic ash cover.

The alluvial deposits are distributed on the valley floor between the plateaus. The thickness of alluvial deposits is mostly several meters; on the Arakawa Lowland in Urawa and Kawaguchi Cities is over 20 m and the Arakawa Lowland of Tokyo Metropolis is more than 40 m.

History of definition of the Quaternary

In 1948, the 18th International Geological Congress was held in London. The special temporary commission recommended the definition of the Pliocene-Pleistocene boundary. The recommendation of the commission as follows:

(1) The commission considers that it is necessary to select a type-area where the Pliocene-Pleistocene (Tertiary-Quaternary) boundary can be drawn in accordance with stratigraphical principles.

(2) The commission considers that the Pliocene-Pleistocene boundary should be based on changes in marine faunas, since this is the classic method of grouping fossiliferous strata. The classic area of marine sedimentation in Italy is regarded as the area where this principle can be implemented best. It is here too that terrestrial (continental) equivalents of the marine faunas under consideration can be determined.

(3) The commission recommends that, in order to eliminate existing ambiguities, the lower Pleistocene should include as its basal member in the type-area the Calabrian formation (marine) together with its terrestrial (continental) equivalent the Villafrancian.

The commission notes that according to evidence given this usage would place the boundary at the horizon of the first indication of climatic deterioration in the Italian Neogene succession (King and Oakley, 1949; International Geological Congress, 1950).

Marine faunas of the lower limit of the Calabrian had been represented by the appearance of the northern immigrants *Arctica islandica* and *Hyalinea baltica* in the Mediterranean Sea for the first time. Those immigrants had impressed the climatic deterioration and had been considered to correspond with the growth of glacier in the European Alps. The beginning of the Ice Age would have been considered since 700,000 years ago. This age corresponds with the early stages of Brunhes normal porality (Nakagawa, 1970).

The Calabrian of the south Italy had been regarded as the lowest member of the Pleistocene together with the Villafranchian that had clarified to belong the Pliocene deposit later (Selli, 1967).

In 1952, during the 19th International Geological Congress held in Algiers, the Geological Society of Italy introduced four places as the type locality of the Pliocene-Pleistocene boundary but the Calabria was not included at the time. However the decision of the boundary had been put on the shelf.

Only the reports about paleotemperature in le Castella by Emiliani *et al.* (1961) and magnetostratigraphy in le Castella by Nakagawa *et al.* (1971) were existed for a long time.

Research on Project 41, "Neogene/Quaternary Boundary", was initiated in 1974 under the auspices of the International Geological Correlation Program held in Vienna.

Nakagawa (1971, 1977), Nakagawa and Niitsuma (1970) and others reported about the progress since then, but the type locality has not been selected. During this period, many informations about the Pliocene-Pleistocene boundary were accumulated and many researchers were eagerly waiting for the selection of the boundary and the type locality.

It has recently came to decision about the Pliocene-Pleistocene boundary and the type locality. The boundary was decided at the just above the *e* horizon of the Vrica Section as the type locality, and the southern suburb of Crotone, Calabria, Italy (Aguirre and Pasini, 1985).

The age determination of the volcanic ash *e* of the type locality cannot be measured because the suitable sample for analyses was not find. The age of the Pliocene-Pleistocene boundary is a little younger than 1.8 Ma in Chapter 2 of the book edited by Van Couvering. (1997). In this publication (Van Couvering, 1997), the other chapters reported the ages of the beginning of the Pleistocene from 1.63 Ma to 1.88 Ma. The age (ca. 1.80 Ma) for the top of the Olduvai Normal Polarity Subchron shows just below the *e* horizon. At the Pliocene-Pleistocene boundary, there are no differences between the biostratigraphic and climatologic bases to mark the boundary.

The Quaternary Period is divided into the Pleistocene and the Holocene Epochs, and the Pleistocene-Holocene boundary is dated to about 12,000 y. B.P. (some 10,000 y. B.P. in Japan). Forbes (1846) recommended that the Pleistocene is used as a name for the deposits of the "Ice Age" and the Holocene is of the "Post-glacial strata". The both terms had been used in general by most stratigraphers (Foreward edited by Van Couvering, 1997).

There are many reports about the Quaternary age measurement. Main reports are on the ^{14}C and fission track methods. ^{14}C method is applied to the age for younger deposits about 30,000 y. B.P. and fission track method is applied to all the age of the Quaternary. Fission track method is mainly applied to the Osaka Group, Kanto Volcanic Ash and others. The method was used for the tuffs intercalated in the Kazusa Group recently as stated in Chapter 3 and was used to the Uonuma Group in Niigata Prefecture. Fission track method is a most popular age measurement method at present.

Chronology based on the magnetic polarity is also available to the stratigraphic succession.