Distribution of the Recent Deposits and Buried Landforms in the Kanto Lowland, Central Japan

Iware MATSUDA

PREFACE

Since the time of their commence of agriculture, human beings have been more closely related with the Alluvial lowlands, lowlands consisting of the Recent deposits, than uplands or hills, and their relations have varied the import as the time elapsed. Human beings used the Alluvial lowland first as the fields for agricultural production and then they used there as the fields for the secondary and tertiary industries and the settlement areas. Almost all of the great cities of Japan are located on the Alluvial lowland now, where population and estates are being concentrated with remarkable rapidity. It is a distinctive feature of Japan that the Alluvial lowlands have utmost importance as a sphere for human activities.

There are only micro-reliefs in the Alluvial lowland. Especially the deltaic lowland is nearly flat. When divided on the basis of geomorphological characteristics, almost all sections of the Alluvial lowland will be classified into some units with similar characteristics. The ground conditions of the Alluvial lowland are on the contrary, not homogenious but vary complicatedly both in the vertical and horizontal directions. If we wish to make best use of the Alluvial lowlands as urban foundations, it is indispensable to understand correctly the regional conditions of the ground which are the most important for construction of many sorts of urban facilities.

If the regional characteristics of the ground can be known, it will be possible to establish a city planning which takes account of the countermeasures against disasters, or to predict which area or areas have great potentialities of being attacked by disasters such as earthquakes, land subsidence and so on.

The ground of the Alluvial lowland is mainly composed of the Recent deposits, whose distribution determines the "ground types". Such a "ground type" can be defined as a classification unit of a constitution of the layers from the surface down to the bed layer on which a heavy structure can be borne. The lowest layer of the Recent deposits defined in this paper consists of sand and gravel distributed in a valley floor which was formed by the maximum stage of the Würm Ice Age. The Recent deposits include, therefore, a part of the late Pleistocene deposits as well as the Holocene deposits.

On the basis of the view points above mentioned, the author will discuss the Recent deposits and their basal landforms of the Kanto Lowland where is one of the most representative Alluvial lowlands and one of the most densely populated areas in Japan. The purpose of this study is to clarify the ground condition of the Kanto Lowland.

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THE RECENT DEPOSITS OF THE ALLUVIAL PLAINS IN JAPAN

The Recent deposits distributed in a number of the Alluvial plains have many traits of their basal landforms and lithofacies in common, for evolution of the Recent deposits have been influenced by a global phenomenon of glacial eustasy. The author intends to review the studies on the Recent deposits in order to clarify the common features in their lithostratigraphy, basal landforms and so on (Tab. 1).

Table 1. Correlation of the Recent deposits distributed in the Alluvial lowlands of Japan

		Iwakigawa Lowland (Onuki et al. 1963)	Ishinomaki Lowland (Hase 1967)	Sagamigawa Lowland (Kaizuka and Moriyama 1969)	Tokaido Region (Ikeda 1964)	Niigata Plain (Wada 1972)	Nobi Plain (Furukawa 1972)	Osaka Plain (Amagasaki District) (Hujita and Maeda 1966)	Ariake and Shiranui bay (Ariake Bay Research Group 1965)
Years B. P.		Upper sand m.	Upper clay and sand Upper sand	Top sand and gravel/Top mud Upper sand	Upper layer (clay, sand, gravel)	I (clay, silt, sand, peat)	Nanyo formation: Upper m. (sand, silt peat)	Upper layer: Upper sand and gravel Middle clay	Ariake clay formation
	5,000	Middle silt m.	Middle clay	Upper mud Middle sand and gravel	Middle layer (clay, silt)	II (clay, sand)	Lower m. (clay, silt)	Lower sand and gravel	
	10,000	Lower alternation m.	Lower sand and clay	Lower mud		III (clay, silt)			Shimabara Kaiwan formation (clay, silt)
	15,000	Goshogawara gravel		Lower sand and gravel	Lower layer (clay, silt, sand)	IV (clay, silt, sand)	Nobi formation (sand, mud)	Lower layer (clay, sand, gravel)	
	20,000		Lower sand and gravel	Basal gravel	Basal gravel	V (clay, silt, sand)	First gravel		
Depth of the buried landforms under the delta region	Buried abrasion platform	Coastal terrace is located at the height of +10m	-10 to -20m	-5 to -15m	about +3m* about -5m about -15m about -28m		0 to -10m*	higher than --10m about -20m	
	Buried river terrace	about -20m	-30 to 40m -50 to 60m	-25 to -30m lower than -40m		-70 to -100m	-20 to -30m*	about -30m	
	Buried valley floor	lower than -70m	lower than -90 to -100m	about -90m	about -100m		lower than -70m	about -35m*	-130 to -150m
Depth of the base of the Upper layer		-15 to -27m (base of Middle silt member)	-40 to -50m (base of Middle clay)	-20 to -30m (base of Middle sand and gravel)	-25 to -30m (base of Middle layer)	-70 to -80m (base of III)	about -40m (surface of unconformity)	-40 to -50m (surface of B layer in the Osaka Bay)	about -40m* (surface of unconformity in the Ariake Bay)
Reference					* in the Tsurumigawa lowland		* after Iseki and Kojima (1959)	* -70m in the Osaka Bay	* in the Ariake Bay

m.: member

The Iwakigawa Lowland

Onuki et al. (1963) reported the results of a synthetic study of the Recent dposits distributed in the Iwakigawa Lowland, northern part of North-eastern Japan. The Recent deposits consist of Goshogawara gravel and the Jusanko formation. The Goshogawara gravel is developed in the valley bottom of the paleo Iwaki River. The Jusanko formation can be divided into three members of the lower alternation member, the middle silt member and the upper sand member.

The lower alternation member consists of an alternation of sand and silt beds being intercalated by peat layer. The member is the deltaic deposits with the thickness of more than 20 meters. The middle silt member consists of thick soft silt, whose thickness is 10 to 20 meters in the central part of the lowland and for which almost all of N-values of standard penetration test are zero. The upper sand member is 1 to 10 meters thick consisting of silty fine sand, sandy silt and sand intercalated by peat layer.

There is a buried river terrace named Takane terrace of which the surface is at the height of 20 meters below sea level near the strand line of the lagoon of Jusanko.

The Ishinomaki Lowland

Some Alluvial lowlands develop around the Sendai Bay, southeastern part of Northeastern Japan. The Recent deposits of these lowlands are investigated by Hase (1967). He subdivided the Recent deposits into lower gravel, lower sand and clay, middle clay, upper sand and upper sand and clay. The lower gravel, or river bed deposits of 0 to 10 meters thick, is developed in the valley bottom of the paleo Kitakami River. The lower sand and clay shows an alternation of sand and clay beds with three cycles. The thickness of the alternation is 40 to 50 meters and the upper limit of the distribution is 30 to 40 meters below sea level in height. The middle clay is marine deposits of 20 to 35 meters in thickness. The upper sand is neritic or littoral deposits with the thickness of about 20 meters. The upper sand and clay consists of natural levee deposits, back swamp deposits and so on which give rise to the micro-reliefs of the Alluvial lowland.

Four fossil landforms are buried by the Recent deposits. Two of them are the buried river terraces recognized at the depth of 30 to 40 meters and 50 to 60 meters. The buried valley bottom of the paleo Kitakami River is deeper than 90 to 100 meters below sea level in height. The shallowest platform is a buried abrasion platform distributed at the depth of 10 to 20 meters.

The Sagamigawa Lowland

Kaizuka and Moriyama (1969) classify the Recent deposits of the Sagamigawa Lowland, southern part of Central Japan, into eight lithostratigraphic units: basal gravel, lower sand and gravel, lower mud, middle sand and gravel, upper mud, upper sand, top mud and top sand and gravel in ascending order. The basal gravel is river bed deposits in regression prior to the maximum stage of the Würm Ice Age. From then, the lower sand and gravel of river bed deposits and the lower mud of bottom-set bed of delta were formed as the sea level rose. When a minor regression occurred at about 10,000 years B.P., the middle sand and gravel were deposited in the valley bottom dissecting the lower mud. The upper mud and the upper sand are marine deposits which were composed during the transgression of post glacial age. The top mud and the top sand and gravel are alluvial deposits composing micro-reliefs of the Sagamigawa Lowland.

Buried valley bottom which continues to the continental shelf of the Sagami Bay is the base of the Recent deposits. Three buried river terraces can be seen in a geologic section of the area located about 12 kilometers inland from the coast. Two of them are traced to the coastal part of the lowland. They indicate two platforms, one at 20 to 30 meters and the other at 40 meters or more below sea level. Besides these buried landforms, a buried abrasion platform can be found 5 to 6 meters in depth.

The Tokaido region

Ikeda (1964) described the Recent deposits of the Alluvial lowlands in the Tokaido region, the Pacific coast of Central Japan. The Recent deposits are classified into upper member, middle member, lower member and basal gravel in connection with the change of sea level over past 20,000 years. The basal gravel is river bed deposits developed in the buried valley bottom. The lower member consists of alternation of sand and clay beds. The middle member consists of marine soft clay and silt and the upper member is the alluvial deposits. He discussed the genesis of various lithofacies seemed in the Recent deposits and pointed out that the most important element determining the lithofacies is the relation of velocity between the rise of sea level and the aggradation in the drowned valley. The general rules which he found are as follows:

Case (A): the rising velocity of sea level $>$ the aggradation velocity $\rightarrow$ transgression
Case (B): the rising velocity of sea level $=$ the aggradation velocity $\rightarrow$ equilibrium
Case (C): the rising velocity of sea level $<$ the aggradation velocity $\rightarrow$ regression.

Marine deposits are accumulated in case (A), littoral or deltaic deposits in case (B) and fluvial deposits in case (C), respectively.

The Niigata Plain

According to Wada (1972), the Recent deposits of the Niigata Plain, northern part of Central Japan, are divided into five members of I, II, III, IV and V in descending order. The member V consists of lucustrine deposits distributed from 100 to 150 meters below sea level in height. Lagoon or lacustrine deposits of the member IV are distributed between the height of 80 and 100 meters below sea level. Silty and clayey deposits of the member III are developed 40 to 80 meters below sea level in height. The result of pollen analysis of the member shows much the same climatic environment as the present. The member II are developed between 20 and 50 meters below sea level in height, consisting of lagoon or bay deposits with fossil shells composed under a little colder climate than that of the present. The member I overlaying these members is swampy land deposits with a thickness of about 20 meters.

Two platforms can be recognized in the basal landform of the Recent deposits. The depth of the upper one is 70 to 100 meters and the lower one 130 to 160 meters below sea level in height.

The Nobi Plain

Furukawa (1972) divided the Recent deposits of the Nobi Plain, western part of Central Japan, into the first gravel bed, the Nobi formation and the Nanyo formation. The first gravel bed of 10 to 20 meters in thickness were deposited during the maximum stage of the Würm Ice Age. The Nobi formation covers the first gravel bed unconformably, which consists of an alternation of sand and mud beds of the maximum thickness of about 40 meters. Radio-carbon dates of the peats intervened in the lower part of the formation are between 18,000 and 16,000 years B.P. The Nanyo formation overlays the Nobi formation unconformably and a surface of unconformity shows a platform spreading at the height of about 40 meters below sea level. Radiocarbon dates obtained from the lowest part of the Nanyo formation are between 11,400 and 10,500 years B.P. The Nanyo formation can be subdivided into the upper sand member and the lower mud member. The lower member consists of sediments deposited in the bay opened to the ocean under a warm climatic condition. The upper sand member are composed of medium or coarse sand bed and an alternation of silt and sand beds. Peats are often formed in the sandy parts of the upper member.

Two sorts of buried landforms, a buried river terrace and a buried abrasion platform, are pointed out by Iseki and Kojima (1959), which surfaces show the platforms at the depth of 20 to 30 meters and 0 to 10 meters respectively.

The Osaka Plain (Amagasaki district)

The Recent deposits of the Osaka Plain and the Osaka Bay were investigated by using many bore hole records and the continuous seismic profiler (Hujita and Maeda 1966 and 1969). Hujita and Maeda divide the Recent deposits into the upper and lower layers. The lower layer consists of gravel and humic clay which may be correlated with the B layer in the Osaka Bay. The upper layer can be further subdivided into lower sandy gravel, middle clay and upper sand. The middle clay of marine deposits continues to the A layer in the Osaka Bay.

A buried valley floor is at about 35 meters in depth under the coastal region, which continues to a platform of 70 meters in depth in the Osaka Bay. The height of buried river terrace is 35 meters below sea level and those of buried abrasion platforms are about 20 meters and less than 10 meters below sea level.

The Ariake Shiranui Bay

The Recent deposits of the Bays of Ariake and Shiranui, northwestern part of Kyushu, were reported by the Ariake Bay Research Group (1965 and 1969). The Recent deposits are divided into the Shimabarakaiwan formation and the Ariake clay formation by a surface of unconformity of 40 meters in depth. The base of the Shimabarakaiwan formation has not been made clear.

Lithostratigraphy and the basal landform of the Recent deposits deduced from literatures

It is a common result of studies conducted in such lowlands as mentioned above that the Recent deposits can be divided into four layers of basal gravel, lower layer, upper layer and top layer. The basal gravel is river bed deposits which is developed in buried valley bottoms formed prior to the maximum stage of the Würm Ice Age. The lower layer consists of an alternation of sand and clay beds which were formed during the transgression prior to the Alleröd oscillation at about 10,000 years B.P. This transgression is named the early Yurakucho transgression by the author. The depth of the surface of the lower layer is 20 to 40 meters below sea level. The upper layer is the deposits composed during the Holocene transgression which is called the late Yurakucho transgression by the author. The upper layer is subdivided into marine soft clay of bottom-set bed of delta and sand of foreset bed of delta. The height of the surface of the upper layer is near the present sea level. In some lowlands, the middle layer is recognized between the lower and upper layers. The top layer consists of aqueous deposits accumulated after about 6,000 years B.P. in the deltaic region, which are composed of gravel, sand, clay and silt, humus and peat.

The basal landform of the Recent deposits consists of three sorts of landforms of a buried valley bottom, a buried river terrace and a buried abrasion platform. The bottom of the buried valley has a depth of 70 to 100 meters. The buried river terrace is distributed at the depth of 20 to 40 meters under the coastal area. Lower buried river terraces are recognized in some of the Alluvial lowlands. There are two stages of buried abrasion platforms. The upper one is distributed at the depth of 0 to 20 meters and the lower one 20 to 30 meters.

STUDIES ON THE RECENT DEPOSITS AND THE BURIED LANDFORMS IN THE KANTO LOWLAND

The Kanto Plain is bordered on the west by the Kanto Mountains and on the north by the

Ashio and the Yamizo Mountains which are composed of Mesozoic and Paleozoic. The hills of the Miura Peninsula and the Boso Peninsula consisting of Tertiary and lower Pleistocene limit the southern end of the lowland. The Kanto Plain surrounded by these mountains and hills is composed of uplands and the Alluvial lowlands.

An Alluvial lowland in the central part of the Kanto Plain is called the Kanto Lowland. The Kanto Lowland is divided into four parts; the Tokyo Lowland facing the Tokyo Bay is located in the southern part of the plain, the northward extension and the northwestward extension of the Tokyo Lowland are called the Nakagawa Lowland and the Arakawa Lowland respectively, and in the northern part of the plain the Tonegawa Lowland occupies the upper course region of the Nakagawa Lowland (Fig. 1).

The uplands surrounding the above mentioned lowlands are divided into several parts, too; the Musashino Upland borders on the western frontier of the Tokyo Lowland and on the southern frontier of the Arakawa Lowland, the Shimousa Upland borders on the eastern frontier of Tokyo Lowland and the Nakagawa Lowland, the Omiya Upland is surrounded by the lowlands of Nakagawa, Arakawa and Tonegawa (Fig. 1).

The Reconstruction Bureau surveyed the ground condition of the lowlands around the cities of Tokyo and Yokohama three times in 1924, 1926 and 1929 in order to examine a relation between the ground condition and the damages occurred by the Great Kanto Earthquake in 1923. The result made clear that the Recent deposits were classified into three parts: the lower, middle and upper layers, and that their basal landforms were composed of two platforms of 0 to 10 meters and about 30 meters in depth and of a buried valley floor. Some workers discussed the Recent deposits and their basal landforms on the basis of the data obtained by the Reconstruction Bureau, but a study on the evolution of the Recent deposits was scarecely developed because of deficiency in the knowledge of glacial eustasy.

In the nineteen-fifties, the relations between the eustatic change of sea level and the formation of the continental shelf off the coast of southern Kanto and of the buried valleys in and around the Tokyo Bay were discussed (Sugimura 1950 and 1956, Kaizuka 1955). A structure of peatbogs found in the small valley bottoms dissecting the uplands was investigated about that time (Sakaguchi 1954, Sakaguchi et al. 1954, Nakano 1956). The "Tokyo Jiban Zu (the Ground Condition of the Tokyo Lowland)" was published in 1955 by the Research Group of the Ground Condition of the Tokyo Lowland. They made clear an existence of a deeper fossil valley than that pointed out by the Reconstruction Bureau and a platform of 0 to −10 meters in height in the eastern part of the Tokyo Lowland. They classify the Recent deposits into the lower and the upper Shitamachi formations. The lower Shitamachi formation is subdivided into the Marunouchi gravel member and the lower Yurakucho member in the western part of the lowland. The lower Yurakucho member is called the Sumida mud in the central part of the lowland which is composed of soft clayey deposits of more than 50 meters in thickness.

The submarine topography and geology in the Tokyo Bay were being studied by using a continuous seismic profiler since 1961 (Kagami et al. 1962, Chujo 1962, Nasu et al. 1962). As a result, submarine topography was detected; the paleo Tokyo River and its lower course of erosional surface at the depth of 110 meters, erosional surfaces of 70 to 80 meters, 30 to 50 meters and about 20 meters in depth, depositional surfaces of 50 to 60 meters, about 20 meters and about 10 meters in depth. It did not, however, made clear when they had been formed.

Hatori et al. (1962) examined the Recent deposits and their basal landforms around the

Table 2. Stratigraphic division of the Recent deposits of the Tokyo Lowland

		Reconstruction Bureau (1929)	Research Group of the Ground Condition of the Tokyo Lowland (1959)	Hatori et al. (1962)	Shibasaki (1969)	Tokyo Institute of Civil Engineering (1970)	This paper	Tamagawa Lowland (Matsuda 1973)
Years B. P.	5,000	Upper layer (peat, clay, sand, gravel, clayey sand)	Alluvial deposits Sumida sand (Upper Y. f.*)	Upper layer: Upper sand Mud	Ia (silty sand) Ib (silt)	Yurakucho formation: Upper (sand, gravel) Lower (clay)	Uppermost Alluvium (UA) (mud, sand, gravel, peat) Upper Sand (US) Upper mud (UC)	Uppermost Alluvium Upper Sand Upper Mud
	10,000	Middle layer (clay, sandy clay)	Sumida mud (Lower Y. f.)	Lower sand	Ib' (silt)		Middle Sand (MS)	Middle Sand
	15,000	Lower layer (sand, gravel)	Marunouchi gravel	Lower layer (sand, sandy silt)	IIb (silty sand, silty clay)	Nanagochi formation (sand, clay)	Lower Clay (LC)	Lower Clay
	20,000				IIb' (clayey sand, clay, humic clay)		Basal Gravel (T_4G)	Basal Gravel
Buried landform	Buried abrasion platform	0 to −10m	0 to −10m	−10m −20 to −30m		0 to −10m	0 to −5m −5 to −10m −20 to −30m −30 to −40m	0 to −5m −5 to −15m about −25m about −35m about −50m
	Buried river terrace	−30m	−30m	−20 to −40m		−20 to −30m −30 to −40m	−30 to −35m −40 to −50m −55 to −60m	about −10m about −25m about −35m about −45m
	Buried valley floor	lower than −50m	lower than −50m	−50m		−60m	lower than −70m	about −60m

* Y. f.: Yurakucho formation

Tokyo Bay. They divided the recent deposits into the upper and the lower members which showed cyclic sedimentary facies respectively. Their basal landforms were analysed to be composed of buried abrasion platforms of about −10 meters and −20 meters in height, a buried river terrace of −20 to −40 meters in height and a buried valley floor at the height of about −60 meters. In addition, a relation between the buried river terrace in the Tamagawa Lowland and the river terraces along the upper course of the Tamagawa River was speculated and it was clarified that the buried river terrace continues to the Tachikawa terrace and the buried valley floor continues to a base of the Haijima gravel.

The studies on the Recent deposits of the Tokyo Lowland were progressed as many bore hole records became available due to the construction of expressways and subways. Aoki and Shibasaki (1966) classify the Recent deposits of the Tokyo Lowland into three layers of I, II and III. The layer III is the Kanto Loam called "Akanendo (red clay)" which is distributed on the buried river terraces as well as on the uplands. The layer II consisting of the sandy clay and an alternation of sand and mud beds shows various lithofacies. The layer I unconformably overlaying the layer II is subdivided into the upper sand and the lower clay. After Aoki (1969) reexamined the Recent deposits and their basal landforms of the Tokyo Lowland, he gave the layers I and II the names of the Yurakucho formation and the Nanagochi formation respectively, and he found two buried river terraces; the upper one overlaid with the buried Kanto Loam is distributed at the height of −20 to −30 meters and the lower one is distributed at the height of −30 to −40 meters. Shibasaki (1969) subdivided the layer II and the lower clay of the layer I into two parts respectively. He noted that the lower part of the layer II had been deposited in fresh water under the colder climate than that of the present, and the upper part had been deposited in brackish water under the almost same climate as that of the present. He also mentioned that a sedimentary environment of the lower part of the lower clay of the layer I was about the same as that of the lower part of the layer II, and the upper part of the lower clay of layer I was marine deposits.

The ground condition of the coastal region of Chiba Prefecture was surveyed by the Katsunan Development Office (1967) and the Development Bureau of Chiba Prefectural Office (1969). In these surveys, three platforms at the depth of 0 to 10 meters, about 20 meters and 25 to 40 meters were recognized as buried abrasion platforms and a distribution of the buried valleys was disclosed. It was also made clear that the Recent deposits showed two cyclic sedimentary facies whose boundary was found at the depth of about 30 meters.

Scrutinizing many bore hole records in the Arakawa and the Nakagawa Lowlands, the Planning Department of Saitama Prefectural Office (1963) uncovered an existence of buried terraces and buried valleys.

The Recent deposits developed in and around the Tokyo Lowland are classified into upper and the lower layers as in other Alluvial lowlands in Japan (Tab. 2). The lower layer consists of an alternation of sand and clay beds and is deposited in brackish to fresh water under the climate colder than that of the present (Mori 1965, Akutsu 1968 and 1972, Utashiro et al. 1972, Niigata Quaternary Research Group 1972). On the other hand, such a basal gravel as is found in almost all of the Alluvial lowlands in Japan has not been found in the Tokyo Lowland. The upper layer consists of soft marine clay and sand. The results of micro-fossil analysis indicated that they were deposited in a bay under the warmer climate than that of the present (Akutsu 1968 and 1972, Utashiro et al. 1972, Niigata Quaternary Research Group 1972).

The basal landform is composed of three sorts of fossil landforms; a buried valley floor, a buried river terrace and a buried abrasion platform (Tab. 2). The buried valley floor is at the depth of 60 meters in the Tokyo Lowland and is able to be traced into the Tokyo Bay as the paleo Tokyo River. It continues to the continental shelf in the ocean through a submarine canyon in the Uraga Strait. There are two buried river terraces; the upper one overlaid with the Kanto Loam is at the depth of 20 to 30 meters and the lower one is at the depth of 30 to 40 meters. The buried abrasion platforms show two different stages; the lower one of 20 to 30 meters in depth was formed at about 10,000 years ago when the minor lowering of sea level occurred, and the upper one of 0 to 10 meters in depth was formed at around the highest stage of sea level of the late Yurakucho transgression. In addition, some platforms were found out in the Tokyo Bay but they have not been correlated with the buried landforms under the Tokyo Lowland except the buried valley of the paleo Tokyo River.

As reviewed above, many studies on the Recent deposits of the Kanto Lowland have been published, but the followings are not fully discussed:

(1) The evolution of the Recent deposits in the whole Kanto Lowland has not been speculated.

(2) A reason why basal gravel was not developed in the Tokyo Lowland has not been given.

(3) It has not been made clear whether the upper layer of the Recent deposits covers the lower one unconformably or not.

(4) The basal landform of the Recent deposits has not been well reconstructed, for the base of the Recent deposits has not been difined rationally.

RECENT DEPOSITS AND THEIR BASAL LANDFORMS IN THE KANTO LOWLAND

Micro-reliefs in the Kanto Lowland

The Kanto Lowland is divided into an alluvial fan region, a natural levee region, a delta region and a small valley flat according to the distribution of various micro-reliefs (Fig. 1).

The gradient of land surface changes at around the 25 meter contour line between Menuma and Kumagaya in the lowlands of Tonegawa and Arakawa. This line forms the boundary between the alluvial fan region and the natural levee region. The gradient of land surface of the alluvial fan region is greater than 1/1,000. The materials composing the alluvial fan region are mostly sand and gravel, but they are overlaid with sandy silt of some tens of centimeters in thickness.

The gradient of land surface of the natural levee region is about 0.4/1,000. Almost all of the Arakawa Lowland and the Nakagawa Lowland are included in the natural levee region. In this region, many series of natural levees are developed and back swamps are distributed between them. While the natural levees are composed of sand or sandy silt, the back swamp deposits consist of silt, clay and peat.

The gradient of land surface becomes less than 0.2/1,000 in the delta region where sand bars and sand spits replace natural levees. The boundary between the natural levee region and the delta region is not clear in general. The boundary between these regions in the Kanto Lowland nearly coincides with the northern limit of the Tokyo Lowland at the height of about 2 meters. The coastal part of the delta region is an artificial lowland that has been reclaimed and mounded since the sixteenth century.

Small valley flats which invade into the upland are one of the landform elements of the Kanto Lowland. The main streams of rivers responsible for construction of the Kanto Lowland flowed once in some of the small valley flats dissecting the Omiya Upland, such as the Motoarakawa Lowland and the Ayasegawa Lowland. In these cases, coarse materials are deposited in the valley flats. But almost all of the streams in the small valley flats are only the branches whose stream-heads are located in the upland, and coarse materials are not supplied into the valleys. Accordingly, the small valley flats are generally covered with peat or fine deposits containing much organic materials. The representative cases are the valley flats of the Shibakawa River and of the Mamagawa River.

Analysis of geologic sections

Method of analysis of geologic sections

It is indispensable for the stratigraphic classification of the Recent deposits on the basis of bore hole records to analyse the datum geologic sections. The bore hole records, which were put into operation in order to investigate the ground conditions for construction of railways, highways and power transmission lines, were chosen to make the datum geologic sections. The locations of the section lines are shown in Fig. 1. Though fourteen datum geologic sections were analysed, six of them are not given in this paper. It must be mentioned that a buried slope separating the buried platforms is delineated by a mostly vertical line in the geologic sections, for a ratio between a vertical height and a horizontal distance is 1 to 61.5.

It is said that lithofacies, soil mechanic properties, colors and contained materials such as fossil shells, volcanic ashes and organic materials are useful indicators for the stratigraphic classification. Based on the difference in these indicators, longitudinal and transversal continuities of deposits were examined. In doing this, the remarks written on the bore hole

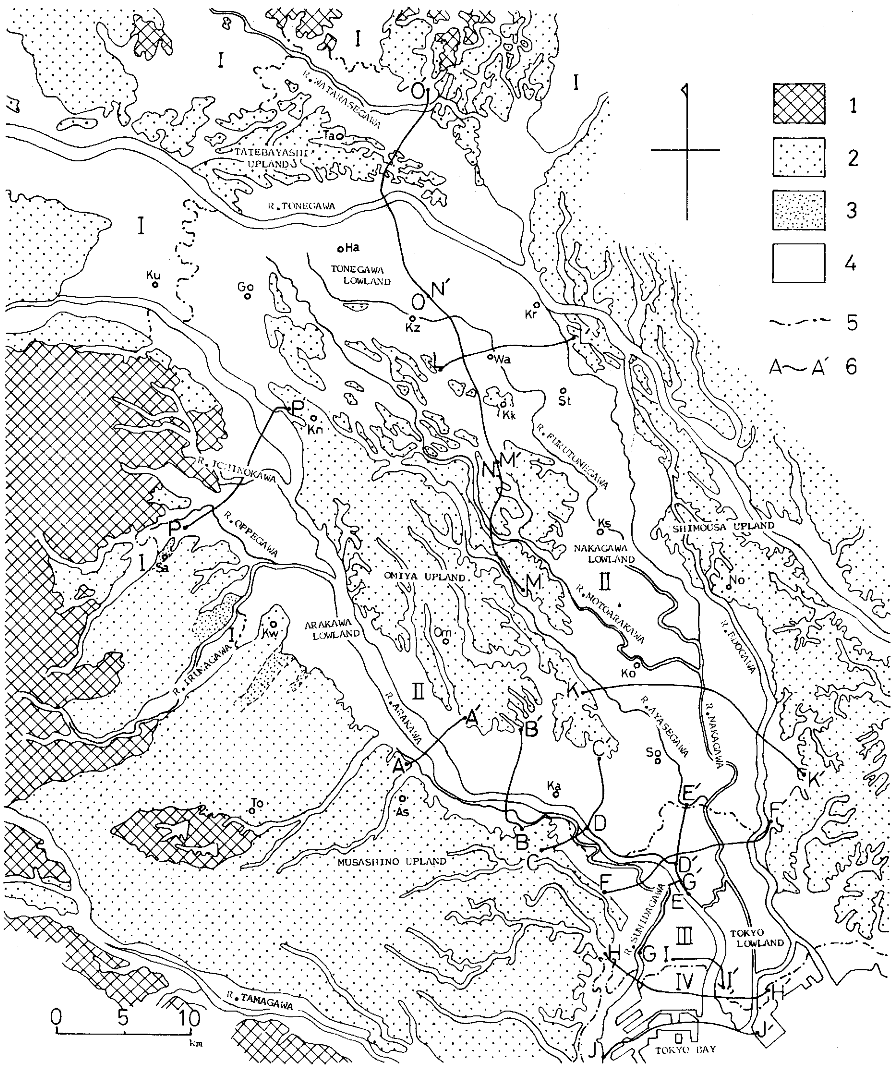


Fig. 1 Investigated area and location of section lines
1: Hill, 2: Upland, 3: Upland which goes to be buried with the Recent deposits, 4: Alluvial Lowland, 5: Boundary of Landform Region in the Alluvial Lowland, I: Alluvial Fan Region, II: Natural Levee Region, III: Delta Region, IV: Reclaimed Land, 6: Location of Section Lines of Figs. 4A–4P. Cities: As: Asaka, Go: Gyota, Ha: Hanyu, Ka: Kawaguchi, Kk: Kuki, Kn: Konosu, Ko: Koshigaya, Kr: Kurihashi, Ks: Kasukabe, Ku: Kumagaya, Kw: Kawagoe, Kz: Kazo, No: Noda, Om: Omiya, Sa: Sakado, St: Satte, So: Sooka, To: Tatebayashi, To: Tokorozawa, Wa: Washimiya.

records and the general characteristics mentioned in the previous chapters were recalled to correlate each layer composing the Recent deposits.

Analysis of the geologic section A-A'

The geologic section of the central part of the Arakawa Lowland is shown in Fig. 2A. The Musashino Upland consists of well consolidated sandy gravel, sand and clayey sand overlaid with the Kanto Loam. On the other hand, there exist relatively soft mud and sand under the Kanto Loam to the height of –20 meters beneath the Omiya upland. Their N-values of standard penetration test are 3 to 25. If Upper Mud (UC) of the Recent deposits covers this Pleistocene muddy deposits directly, a boundary between them are defined by the difference of N-value and preconsolidation load.

Gravelly deposits of 8 to 9 meters in thickness are developed at the height of –30 to –40 meters between Nos. A6 and 25, where No. A6 refers to a bore hole number 6 in the geologic section A-A'. These gravelly deposits may be regarded as the basal gravel of the Recent deposits, because they do not continue into the Pleistocene deposits of fine sand under a buried river terrace covered with the buried Kanto Loam between Nos. A2 and 4, and also because their base shapes a deep valley. The gravelly deposits are named the Basal Gravel and shown in the geologic sections by a symbol of T_4G. Also, the buried valley which is recognized as the basal landform of the Basal Gravel (T_4G) is named the paleo Arakawa River.

Muddy deposits containing organic materials are found over T_4G, whose N-values are 5 to 12 in the lower part and 2 to 5 in the upper part. Lenticular sandy deposits which are partly composed of gravel intervene in the muddy deposits. The N-values of the sandy deposits are 20 to 50, and even more than 50 is not rare. These deposits are named the Lower Mud and Sand, for which a symbol of LC stands in the geologic sections.

The Lower Mud and Sand (LC) are overlaid by homogenious muddy deposits with the N-value of 0 to 1, which contain fossil shells and are more than 10 meters in thickness. The author gives these marine deposits the name of Upper Mud to be denoted by UC in the geologic sections.

The boundary between UC and LC is defined from the facts as follows: the N-value is less for UC than for LC, UC contains fossil shells but LC does not, organic materials contained are in great quantity in LC but only little in UC, and LC is intercalated with sandy deposits but UC is not.

Sandy deposits containing fossil shells are often found between UC and LC. Generally speaking, their N-values are smaller than that of sandy deposits composing LC. These sandy deposits are given the name of Middle Sand and a symbol of MS in the geologic sections.

Five meter thick sandy deposits are accumulated over UC. The sandy deposits consist of a fore-set bed and a top-set bed of a delta which has been formed since the time of the highest stand of sea level of the late Yurakucho transgression. The fore-set bed containing fossil shells is dark grey to dark bluish grey in color. Its N-value is less than 15, about 5 being the most frequent. This sand originated in the fore-set bed of the delta is named the Upper Sand with a symbol of US in the geologic sections. The top-set bed containing organic materials appears dark bluish grey to dark brown, its N-value being generally larger than US. The author includes the former in the Upper Alluvium, which is denoted by a symbol of UA in the geologic sections. UA is aqueous deposits which form an alluvial fan, a natural levee, a back swamp and other micro-reliefs composing an Alluvial plain. The boundary between UA and US is not clear in Fig. 2A.

Gravel of more than 10 meters in thickness is developed between Nos. A2 and 4 in Fig. 2A, of which the top is at about −16 meters in height. Tufaceous clayey deposits are accumulated on the gravel. Since the clayey deposits are dark brown and their upper parts consist of humus, it may be possible to correlate them to the buried Kanto Loam, the existence of which has been confirmed on a buried river terrace in the Tokyo Lowland (Aoki and Shibasaki 1966). The gravel and the buried Kanto Loam are cut by the paleo Arakawa River as mentioned previously. Accordingly, the gravel is regarded as the buried river terrace gravel. The gravel and the buried river terrace are termed T_1 G and T_1 respectively.

The base of the Recent deposits between Nos. A26 and 27, and Nos. A29 and 30 is located at about −3 meters in height. This basal landform of the Recent deposits is considered as a buried abrasion platform which has been formed during the stage of the highest stand of sea level of the late Yurakucho transgression, because it is directly covered with US and is distributed in the Alluvial lowland along the periphery of the uplands.

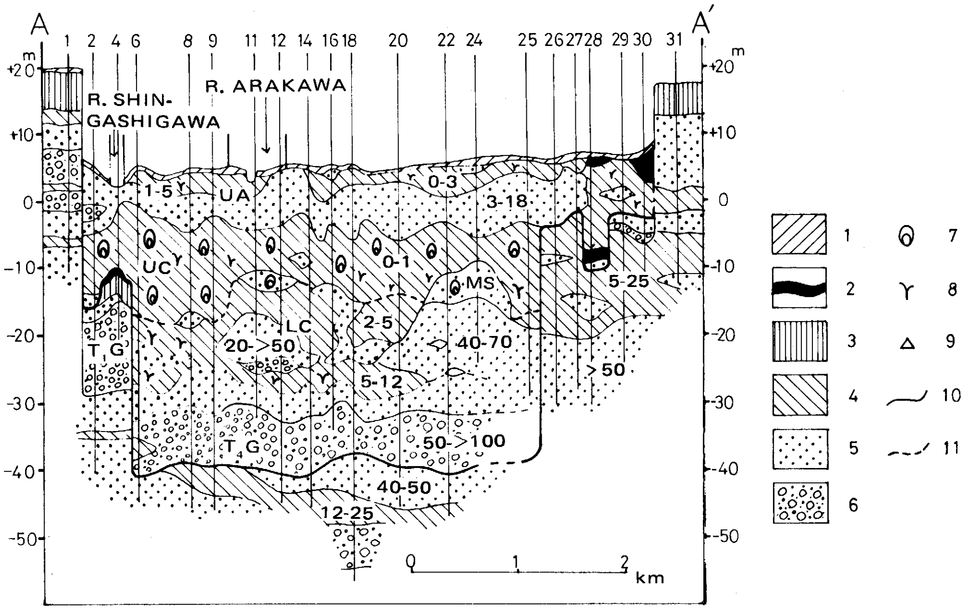


Fig. 2A Geologic section
The central part of the Arakawa Lowland
1: Filled up soils, 2: Humus or Peat, 3: Kanto Loam, 4: Clay and Silt, 5: Sand, 6: Sand and Gravel, 7: Shell, 8: Organic Materials, 9: Volcanic Ash or Pumice, 10: Base of the Recent Deposits, 11: Boundary between Upper Part and Lower Part of the Recent Deposits; Recent Deposits: UA; Uppermost Alluvium, US: Upper Sand, UC: Upper Mud, MS: Middle Sand, LC: Lower Sand and Mud, T_4G: Basal Gravel, T_0G – T_3G: Buried River Terrace Gravels. Figures in geologic profile show the N-value of standard penetration test. Legend is common in all geologic sections.

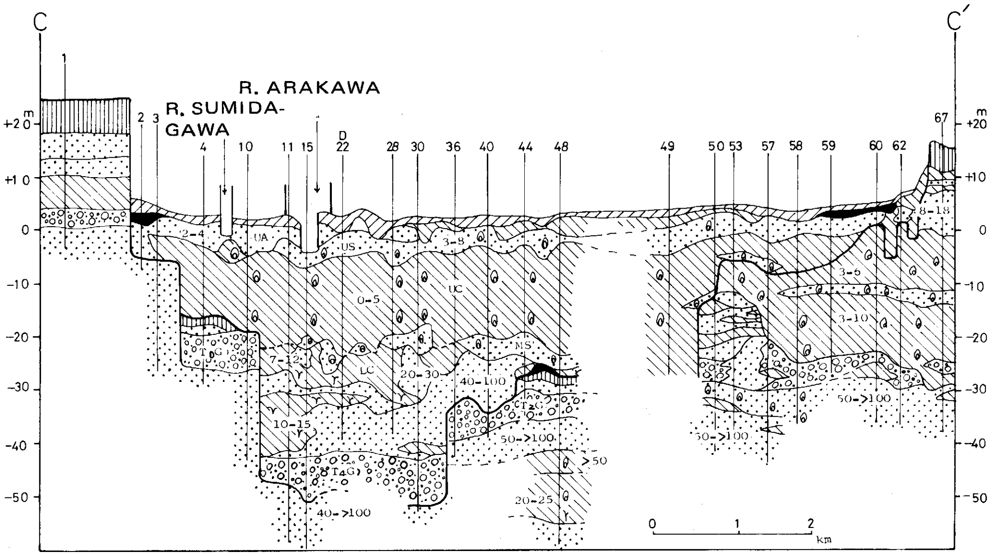


Fig. 2C Geologic section
The eastern part of the Arakawa Lowland

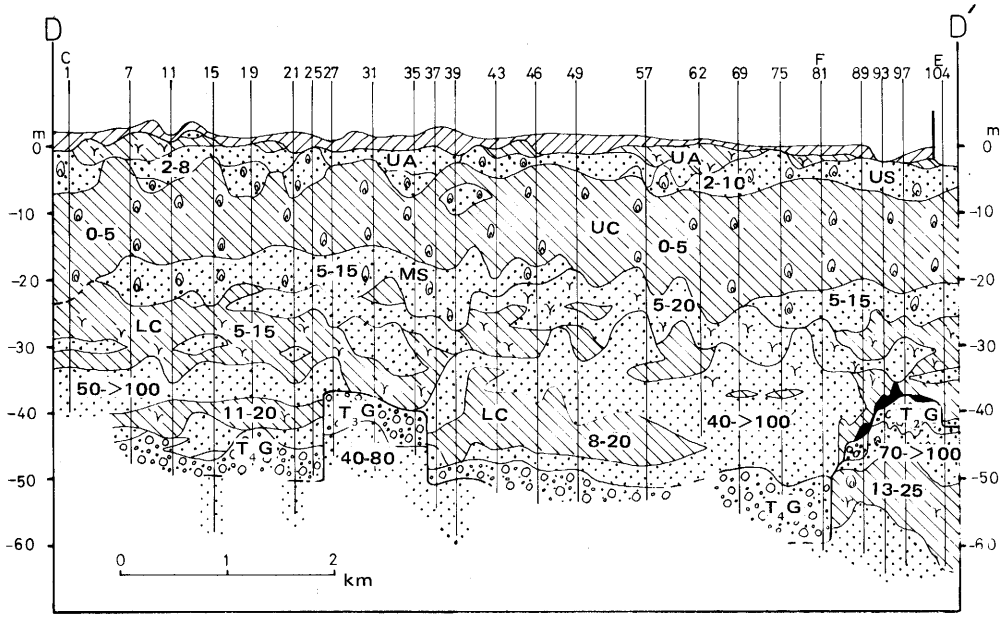


Fig. 2D Geologic section
The northern part of the Tokyo Lowland (I)

Analysis of the geologic section C-C′

Fig. 2C shows a geologic section of the eastern part of the Arakawa Lowland, which is located 13 kilometers downstream from the section line A – A′ (Fig. 1).

Three continuous gravel layers at distinctly different heights are seen between Nos. C4 and 10, Nos. C11 and 30, and Nos. C36 and 48. Since the base of T_4G is at the height of about –40 meters in Fig. 2A, the height of the base of T_4G must be lower than –40 meters in Fig. 2C. The gravel of 5 to 8 meters in thickness whose base is at the height of about –51 meters is necessarily regarded as T_4G.

The gradient of T_4G is 0.85 to 0.91/1,000 between the location of section lines A–A′ and C–C′. If the gradient of T_1G is the same as that of T_4G, the top of T_1G may be higher than –27 or –28 meters in Fig. 2C. The top of T_1G may be higher than –27 or –28 meters in height, for the gradient of T_1G is smaller than that of T_4G. The height of –19 meters is, however, too shallow for the top of T_1G in Fig. 2C. Then the gravel higher than T_1G whose top is at the height of about –19 meters between Nos. C4 and 10 must be regarded as T_0G. The gravel which top is at –30 to –31 meters in height between Nos. C36 and 48 is considered as T_2G, for its top is located lower than that of the supposed height of T_1G. The buried river terraces composed of T_0G and T_2G is named T_0 and T_2 respectively.

LC consists of mud and sand. The N-value of mud varies from 7 – 12 in the upper part to 10 – 15 in the lower part. The upper part of sand has the N-value of 20 to 30, while the lower part has 40 to 100.

MS is distributed more continuously than that in Fig. 2A and its base is observed at the height of –22 to –24 meters. UA and US can be distinguished from each other on the basis of contained materials and colors. US is loose deposits with the N-value of 3 to 8.

A buried abrasion platform is seen at the height of –6 to –8 meters. US overlays the Pleistocene clay between Nos. C53 and 61. US has fossil shells and the N-value of 0 to 5. The Pleistocene clay contains fossil shells, too, but its N-value is 3 to 6. It is often difficult to discriminate them even by observing the core samples of bore holes. But a great difference between the two lies in preconsolidation loads. The preconsolidation load is 3.5 to 5.5 kilograms per square centimeter for the Pleistocene clay, while it is less than 1.0 kilogram per square centimeter for UC. In addition, continuous development of sand of 2 meters in thickness at the height of –10 to –14 meters characterises the Pleistocene clay.

Analysis of the geologic section D-D′

Fig. 2D shows a relation between the Recent deposits in the Arakawa Lowland and those in the Tokyo Lowland.

The same datum is used for No. D1 and No. C22. T_4G is necessarily identified as the gravel which has its base at about –50 meters in height between Nos. D7 and 25 and at the height of –50 to –60 meters between Nos. D37 and 81.

Gravel of 4 to 6 meters in thickness is observed between Nos. D27 and 35. The gravel is defined as T_3G, for its top is higher than T_4G and lower than T_2G. T_3G is not covered with the buried Kanto Loam nor humus, but LC is deposited over it. This section illustrates that T_2G with humus at its top is at about –38 meters in height between Nos. D93 and 104, and its thickness is about 4 meters.

The top of LC is at –20 to –25 meters in height. Muddy deposits composing LC may be divided into the upper and the lower parts. The upper part is 5 to 15 in the N-value, and the lower part 8 to 20 or 11 to 20. Consolidated sandy deposits of the N-value of 50 to more than 100 are developed between them.

Continuous MS is discerned, which contains fossil shells and whose N-value is 5 to 15.

Analysis of the geologic section F-F'

The geologic profile of the northern part of the Tokyo Lowland is exhibited in Fig. 2F. Buried abrasion platforms appear between Nos. F4 and 6 and between Nos. F67 and 74. T_1G is seen to be covered with thick humus between Nos. F8 and 12. The great part of the thick humus can be considered as the buried Kanto Loam. T_2G is shown between Nos. F16 and 33.

It is difficult to determine the base of the Recent deposits owing to lack of deep bore hole records. Futhermore, sandy deposits constituting the lower part of LC is often taken for the Pleistocene deposits, for they are well consolidated and their N-value are 50 to more than 100. The sandy deposits are classified as the Pleistocene deposits in the "Tokyo Jiban Zu (the Ground Condition of the Tokyo Lowland)" and in the "Jiban Chishitzu Zu (the Soil Mechanic Properties of Ground of the Tokyo City)". Accordingly, the basal landforms of the Recent deposits are not rationally reconstructed in these publications. The failure may have been arisen from the fact that the buried valley has not been traced from the upper course.

Considering that the base of T_4G is exhibited at the height of about –60 meters in Figs. 2D and 2E, the author can regard the gravel as T_4G, which lies at about –60 meters in height between Nos. F61 and 65. No. F39 corresponds to No. D81 in Fig. 2D. If the geologic profile of Fig. 2F is considered from the relation to that of Fig. 2D, sandy deposits are identified as the Recent deposits, whose N-value ranges from 50 to more than 100 and whose top lies at the height of about –26 meters between Nos. F39 and 43 and at –40 to –42 meters between Nos. F48 and 53.

MS is well developed, reaching greater than 15 meters in thickness. The base of MS is at –25 to –29 meters in height in the western part, while the lowest height is about 39 meters below sea level in the eastern part. Therefore, it is suggested that a boundary between MS and LC forms a surface of unconformity.

Between Nos. F19 and 21 and around No. F26, US is thicker than elsewhere. These two parts of US are not, however, two separated deposits, but they are constituted by one continuous buried bar deposits composed of sand and gravel.

Analysis of the geologic section H-H'

Three buried abrasion platforms are seen in the geologic profile of the southern part of the Tokyo Lowland (Fig. 2H). Two of them are located in the western part and bordered by a buried valley. The upper one is formed at about the same height as the present sea level, and the lower one at the height of 5 to 6 meters below sea level. The buried abrasion platform is distributed at 20 to 25 meters below sea level in the eastern part, which is dissected by the small buried valleys.

T_1G appears between Nos. H10 and 20, with its top at the height of 30 to 33 meters below sea level. It is covered with the buried Kanto Loam of 2 to 5 meters in thickness, which is correlated to the Tachikawa Loam (Aoki and Shibasaki 1966). The gravel, whose top is at the height of 46 to 48 meters below sea level, is present between Nos. H21 and 22. It may possibly correlated to T_2G, reasoning from their distribution height. But its horizontal distribution is unknown. Limited distribution of T_2G is recognized between Nos. H33 and 34.

A gently sloping plain is buried between Nos. H39 and 55. It is possible to be conjectured

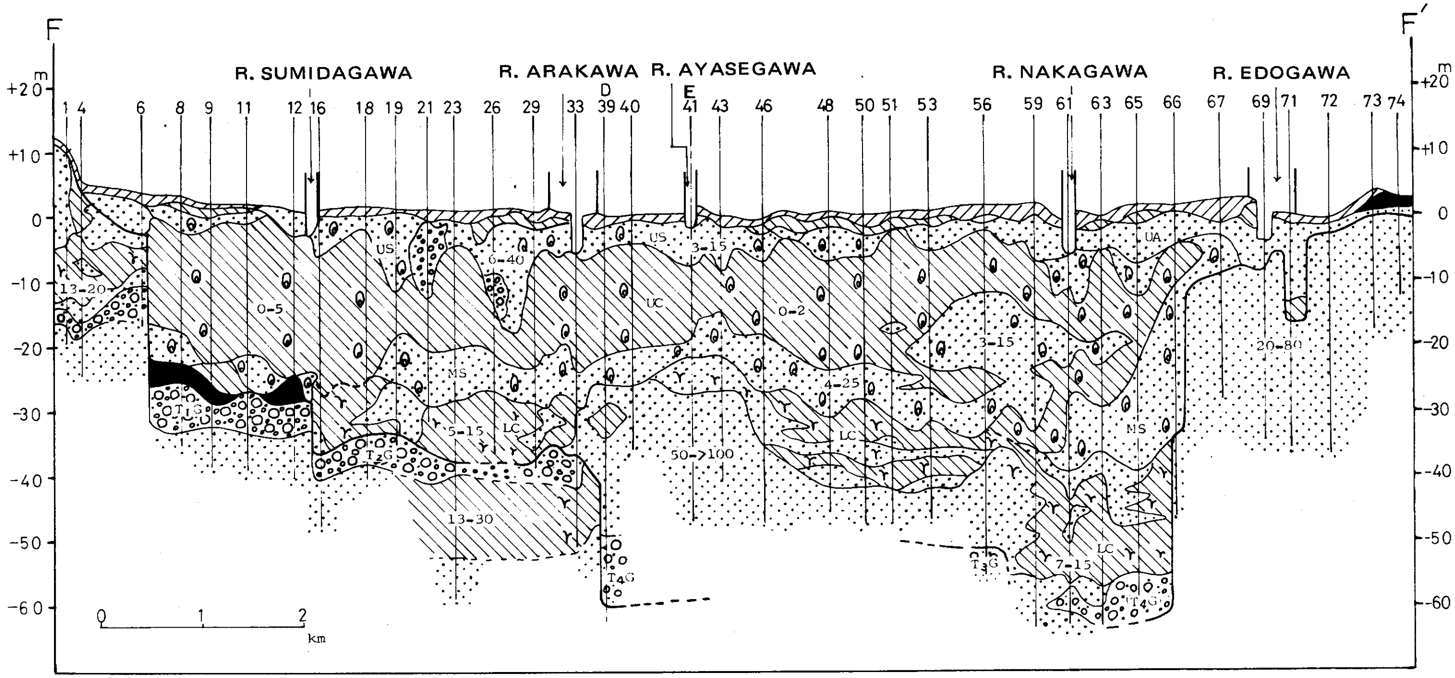


Fig. 2F Geologic section
The northern part of the Tokyo Lowland (II)

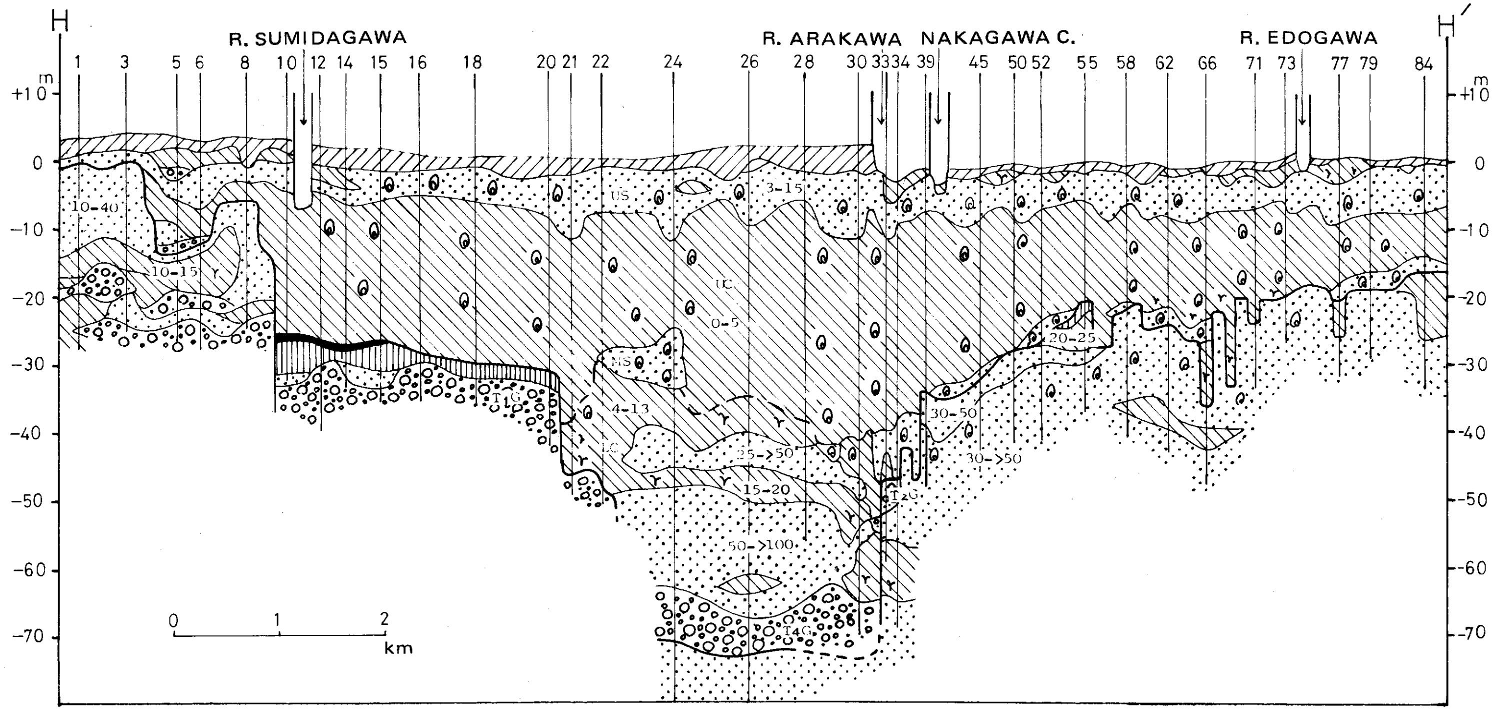


Fig. 2H Geologic section
The southern part of the Tokyo Lowland (I)

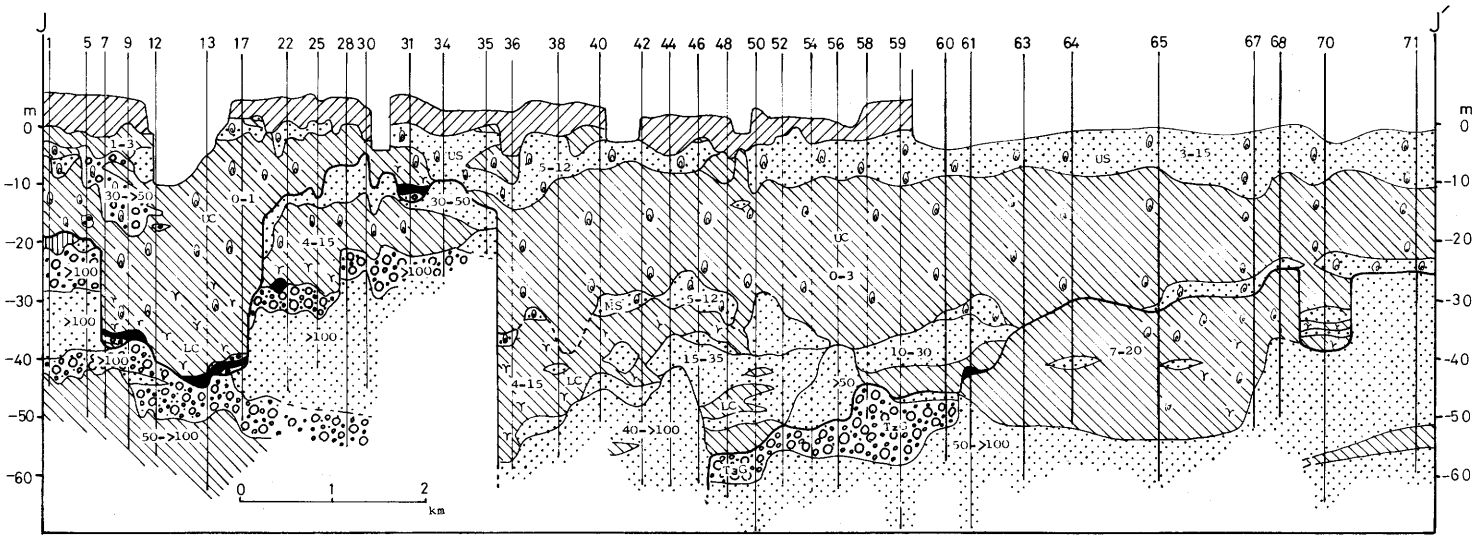


Fig. 2J Geologic section
The southern part of the Tokyo Lowland (II)

that the buried plain was formed before the lowest stage of sea level during the Würm Ice Age, for it is partly covered with the buried Kanto Loam. It is not made clear when the buried plain was formed. For convenience's sake the author correlates it to T_1 in Fig. 7 on the basis of their height.

Gravel is shown to be about 6 meters thick between Nos. H24 and 30, its base being at the height of -70 to -72 meters. The gravel does not continue into the Pleistocene deposits under T_2G in the eastern part, but such a fact can not be confirmed in the western part. The base of T_4G is at the height of lower than 60 meters below sea level in Fig. 2F, where the section line runs at the distance of 11 kilometers upstream from that of Fig. 2H. If the gravel whose base is at the height of 70 to 72 meters below sea level in Fig. 2H is identified as T_4G, a gradient of the base of T_4G in the Tokyo Lowland is 0.73 to 0.91/1,000. It is almost the same gradient as that in the Arakawa Lowland. Therefore, the author has no difficulty to say that the basal gravel of the Recent deposits is developed in the Tokyo Lowland as in many Alluvial lowlands of Japan. A two kilometers wide fossil valley in which T_4G is deposited is necessarily defined as the paleo Tokyo River.

Thick deposits composed of well consolidated sand cover T_4G to the height of 48 to 50 meters below sea level. However, insufficient deep bore hole records may reduce a profile of the sandy deposits to a simpler appearance than it would be.

The development of MS is much worse in Fig. 2H than in Fig. 2F. This fact means that the fore-set bed of the delta composed of MS did not reach the southern part of the Tokyo Lowland. That is to say, the lowest part of UC in the southern part of the Tokyo Lowland is composed of the bottom-set bed of the delta consisting of MS.

Analysis of the geologic section J-J'

A deep buried valley appears between Nos. J7 and 17 in Fig. 2J, that is, the geologic section of the southernmost part of the Tokyo Lowland. The maximum depth of the buried valley is at the height of about 45 meters below sea level. The author wishes to give the name of the paleo Kandagawa River for the buried valley. Gravel forming the valley floor of the paleo Kandagawa River is rather regarded as the Pleistocene deposits. Namely, a downward erosion by the paleo Kandagawa River ceased in the gravelly deposits. The paleo Kandagawa River is filled up by soft clayey deposits with the N-value of 0 to 1. They must be classified into UC and LC, but their boundary is not clear.

Gravelly deposits are seen between Nos. 1 and 5, whose top is at the height of about 21 meters below sea level and is covered with the buried Kanto Loam. They are considered to be the Pleistocene deposits and to continue to the gravel developed between Nos. J22 and 25 rather than they are regarded as the terrace gravel formed by the paleo Kandagawa River.

A buried abrasion platform appears between Nos. J22 and 35. Ruggedness of its surface is originated in the erosion by the branches of the paleo Kandagawa River and the paleo Tokyo River.

Thick muddy deposits of more than 20 meters in thickness is developed between Nos. J63 and 68, whose top is at the height of about 30 meters below sea level. They are often taken for the Recent deposits, for they contain fossil shells and have the N-value of 10 to 15. If they were UC, their N-value should be less than about 5. If they were LC, they should be composed of an alternation of mud and sand beds and should scarecely contain fossil shells. Therefore, it is not difficult to regard them as the Pleistocene deposits. In addition, their surface may be considered as a buried abrasion platform, for it is covered with thin sandy deposits containing fossil shells.

Gravel is exhibited at the height of about 50 meters below sea level between Nos. J48 and 60. Because the gravel does not continue into the Pleistocene deposits distributed under the previously mentioned muddy deposits, and because a height of its base is too high to regard it as T_4G, it is considered as a buried terrace gravel. It is possible to divide the gravel into two parts on account of the height of their bases.

The paleo Tokyo River may exist between Nos. J36 and 46. The base of valley floor is not, however, confirmed because of lack of deep bore hole records.

The top of LC is at the height of 30 to 38 meters below sea level. The lower part of LC consists of well consolidated sandy deposits with the N-value of 40 to more than 100. They are not included in the Nanagochi formation as defined after Aoki (1969).

Correlation of gravels

The heights of the tops and bases of gravels, which have been analysed in the geologic sections, are projected on a plane having an axis along the paleo Arakawa River and the paleo Tokyo River (Fig. 3). The latter is the lower course of the former. The continuity of each gravel can be read in the figure.

The average gradient of T_4G is 0.9/1,000 in the paleo Arakawa River and 0.8/1,000 in the paleo Tokyo River. T_1G characteristically covered with the buried Kanto Loam and humus shows the gradient of 0.6 to 0.7/1,000 in the Arakawa Lowland and 0.4/1,000 in the Tokyo Lowland. The gradient of T_2G is steeper than that of T_1G. The relative height between them increases downstream. It may be impossible to identify T_3G on the basis of its continuity, for its distribution is restricted. Therefore, T_3G refers to the gravel, which lies lower than T_2G but higher than T_4G.

The top of T_0G is higher than that of T_1G. T_0G is not always composed of buried terrace deposits, but a part of T_0G consists of the Pleistocene gravel which has been exposed by the erosion of the paleo Arakawa River.

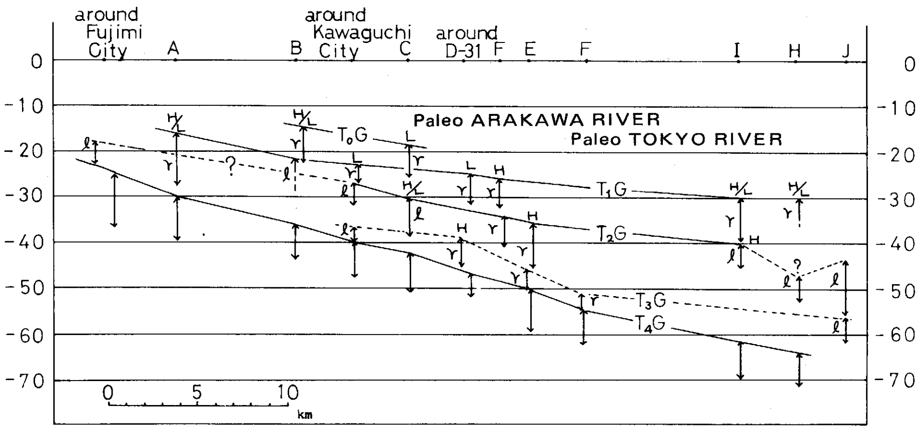


Fig. 3 Correlation of Gravels
A, B, —— J: Location of section lines, H: Humus, L: Buried Kanto Loam, r: Right coast, l: Left coast.

Analysis of the geologic section K-K'

The geologic profile of the southern part of the Nakagawa Lowland is shown in Fig. 4.

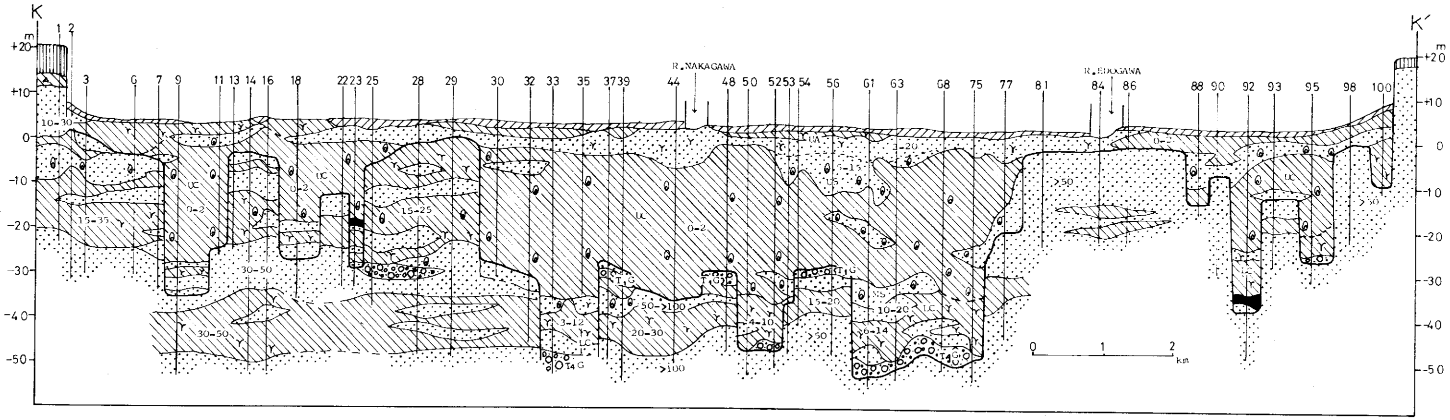


Fig. 4 Geologic section of the southern part of the Nakagawa Lowland

The buried valley floor must appear at the height of about 50 meters below sea level in Fig. 4, for its section line runs still upstream 13.5 kilometers apart from that of Fig. 2F. There are three buried valleys which have their floors at around that height. The buried valley floors have the height of lower than 50 meters below sea level between Nos. K33 and 35, about 48 meters below sea level between Nos. K50 and 52, and 50 to 52 meters below sea level between Nos. K61 and 75. The last buried valley seems to be the broadest, but an actual width is about 1 kilometer, for a section line of Fig. 4 crosses obliquely over the buried valley.

It is impossible to determine a main buried valley only from Fig. 4. Therefore, a main buried valley is reconstructed by using bore hole records in the vicinity of the section line. In doing this, the fact is taken into consideration that an axis of the maximum value of land subsidence is generally located along a buried valley in the Alluvial lowland. The results thus obtained are: the buried valley appearing between Nos. K61 and 75 may continue to the valley which is located in the northwest of Noda City and dissects the Shimousa Upland; the deeper buried valley exhibited between Nos. K33 and 35 has captured the shallower one, for only one buried valley is found in the region between the rivers of Motoarakawa and Furutonegawa. Accordingly, the burried valley found between Nos. K33 and 35 is regarded as the main buried valley, which is named the paleo Nakagawa River by the author. The paleo rivers of Nakagawa and Arakawa join to form the paleo Tokyo River in the northern part of the Tokyo Lowland.

The paleo Ayasegawa River is illustrated around No. K9, and its tributaries are shown around Nos. K18 and 23.

Buried river terraces are seen around Nos. K32, 39, 48 and 56. These buried terraces are composed of gravel or gravelly sand whose tops are at the height of about 30 meters below sea level. They are not covered with the buried Kanto Loam. The relation between the buried river terraces distributed in the Arakawa Lowland and those in the Nakagawa Lowland can not be directly understood. But because the above mentioned buried river terraces are the highest and the broadest in the Nakagawa Lowland, it is appropriate to correlate them to T_1 in the Arakawa Lowland, and to consider that the buried Kanto Loam was washed during the Yurakucho transgression.

Buried abrasion platforms are distributed at 0 to –5 meters in height around Nos. K6, 14, 29, 84 and 98. Although the origin of the platforms at the height of about 10 meters below sea level around Nos. K22 and 93 is unknown, they are classified as the abrasion platforms because they show fairly constant height.

The Recent deposits in the Nakagawa Lowland are able to be classified stratigraphically into the same units as those in the Arakawa and the Tokyo Lowlands, but lithofacies are much different. The thickness of T_4G of basal gravel is thinner in the Nakagawa Lowland. LC is composed of muddy deposits with the N-value of smaller than about 10, and sandy deposits intervene lenticularly in them. Such thick and well consolidated sandy deposits as constitute the lower part of LC in the Tokyo Lowland are not conspicuous in the Nakagawa Lowland.

In the Nakagawa Lowland MS and US are only poorly developed, whereas UC and UA are well developed. UC reaches about 30 meters in thickness in the southern part of the Nakagawa Lowland and is composed of soft marine mud of the N-value of 0 to 2. US is only partly distributed except the region adjacent to the upland where a sand bar is formed.

Summary of the evolution of the Recent deposits

The Kanto Lowland region was eroded by the paleo Tokyo River and its branches as sea level lowered to the lowest stand at the maximum stage of the Würm Ice Age. As the oscillations of sea level intervened several times during this regression stage of sea level, some buried river terraces were formed. These buried terraces were classified into T_0, T_1, T_2 and T_3. Radiocarbon dates of humuses, which were obtained in the buried Kanto Loam on T_1G, are 22,950±1,100 years B.P. (GaK-1933), 23,200±800 years B.P. (GaK-1935) (Shibasaki 1971) and 33,200±2,600 years B.P. (GaK-143) (Kigoshi and Miyazaki 1966). Hence, T_1 is correlated to the Tachikawa terrace distributed along the Tamagawa Lowland.

During the maximum stage of the Würm Ice Age, the paleo Arakawa River and the paleo Nakagawa River joined in the northern part of the Tokyo Lowland to form the paleo Tokyo River. The paleo Tokyo River ran across the Tokyo Bay, which had been dried up at that time and flowed into the Pacific Ocean. The uplands were dissected by the branches of these paleo rivers until that time.

The Recent deposits were classified into 6 lithostratigraphic units of T_4G, LC, MS, UC, US and UA. The evolution of the Recent deposits is able to be explained as follows:

T_4G was deposited in the buried valley bottom at about the maximum stage of the Würm Ice Age. LC was formed during the early Yurakucho transgression. LC may be divided into the upper and the lower parts whose boundary is at the height of about 25 to 40 meters below sea level. The lower part is composed of well consolidated sand with the N-value of 50 to more than 100 and consolidated mud with the N-value of 10 to 20. The upper part consists of somewhat loose sand and soft mud. It seems that the upper part dissects more than 10 meters deep into the lower. Accordingly, the existence of oscillation of sea level may be expected during the early Yurakucho transgression. LC is also divided into two parts in the Arakawa Lowland, but not in the Nakagawa Lowland. The deposits composing the lower part of LC in the Tokyo Lowland were supplied by the paleo Arakawa River. On the other hand, the sediment yield to the Nakagawa Lowland was much less at that time, for the fossil river of the Tonegawa River was taking the course to the Arakawa Lowland. This fact is able to be detected from the result of analysis of the geologic section M-O′, in which the fossil valley compared with the paleo Arakawa River or the paleo Nakagawa River can not be recognized. Accordingly, LC was not deposited so thick that it could be divided into two parts in the geologic sections made from the bore hole records.

After the deposition of LC reached to the height of −25 to −30 meters in the Tokyo Lowland, the sea level lowered a little. LC was eroded more than 10 meters deep and a surface of unconformity was formed. It is speculated that the abrasion platform of A_4 was formed during the oscillation, for it is distributed at 30 to 40 meters in depth and is covered with the upper part of the Recent deposits. The surface of unconformity can be pointed out easily as the boundary between LC and MS or between LC and UC. The Recent deposits of the Kanto Lowland can be divided into the upper and the lower parts by the surface of unconformity as in many other Alluvial lowlands of Japan.

After that, the sea level began to rise again, namely the late Yurakucho transgression. The rate of sea level rise was retarded after the sea level had reached the height of about −30 meters. MS of the fore-set bed of a delta was deposited and the abrasion platform of A_3 was formed in this stage. When MS was being formed, aquous deposits must being deposited in the upper course region and UC of the bottom-set bed of the delta in the Tokyo Bay. The aquous deposits should be classified into the upper part of the Recent deposits because they were formed during the late Yurakucho transgression. Accordingly, the author gives the name of LC′ for these aquous deposits. But it was not possible to divide them from LC in the geologic sections located in the upper course region than the region in where MS is distributed.

Humuses are formed in T_2G which is distributed in the adjacent region to a river mouth of the Arakawa River. The humuses are covered with LC and MS. Radiocarbon dates of the humuses were 12,300±230 (GaK-144), 11,500±230 (GaK-145), 11,750±150 (GaK-146) and 15,570±740 (GaK-147) years B.P. (Kigoshi and Miyazaki 1966). The radiocarbon date of a fossil shell contained in the lowest part of MS in the same region is 9,900±600 years B.P. (GaK-223) (Kigoshi and Miyazaki 1966). In addition to these dates, two other radiocarbon dates are obtained from the humuses in the paleo Tokyo River in the southern part of the Tokyo Lowland. Their dates are 9,880±290 years B.P. (GaK-138) at the height of –40 meters and 9,310±200 years B.P. (GaK-139) at the height of –48 meters (Kigoshi and Miyazaki 1966). The author is suspicious that the latter date is too young, for these samples are obtained from the same bore hole.

From the consideration of these radiocarbon dates and a stratigraphical relation between LC and MS, it is resulted that a minor fall of sea level happened to occur between 11,000

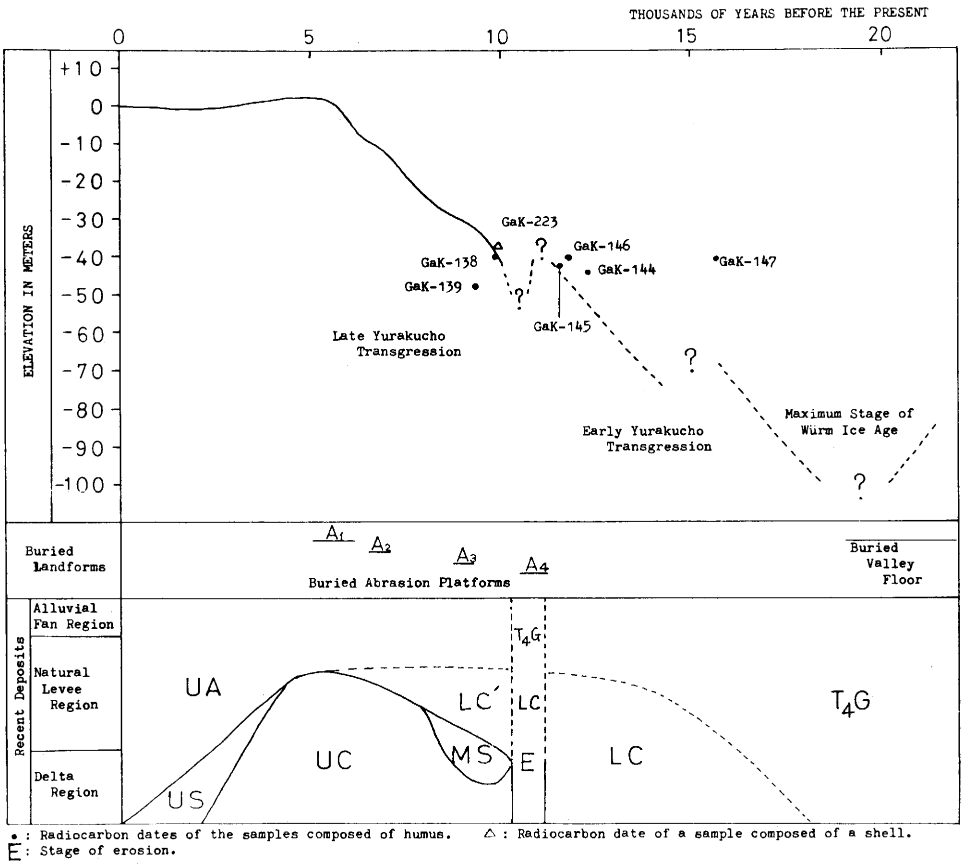


Fig. 5 Sea Level Change, Buried Landforms and Evolution of the Recent Deposits.

and 10,000 years B.P. and that the rate of sea level rise in the late Yurakucho transgression began to retard at about 10,000 years B.P. (Fig. 5).

The coastline of the Kanto Lowland was retreated as the sea level rised during the late Yurakucho transgression and the fossil valleys were drowned. The paleo rivers of Tokyo, Arakawa and Nakagawa were drowned to form Oku Tokyo Wan (the Interior Tokyo Bay) in the Kanto Lowland region. The Interior Tokyo Bay invaded into more inland region in the Nakagawa Lowland than in the Arakawa Lowland, for the sediment yield is much more in the Arakawa Lowland than in the Nakagawa Lowland, and for the former is less influenced by the Kanto basin making movement than the latter. UC was deposited in the Interior Tokyo Bay, and abrasion platforms of A_1 and A_2 were formed (Fig. 5). The sea level reached the height of several meters above the present sea level at the maximum stage of the late Yurakucho transgression (Sakaguchi 1963 and 1968, Wajima et al. 1968).

Rivers flowing down to the Interior Tokyo Bay began to bury the bay, as the sea level fell gradually to the present sea level after the maximum stage of the late Yurakucho transgression. US is a fore-set bed of the delta formed in the Interior Tokyo Bay during this stage.

On the other hand, as small valley bottom dissecting the northeastern half of the Omiya Upland were buried to about the same height as the surface of the upland, the relative height between the upland and the valley flats decreased. Since that time, the rivers of Arakawa and Tonegawa changed their channels from the Arakawa Lowland to the valley flats or the Tonegawa Lowland. It may be said that the times when these rivers changed their channels were after around the maximum stage of the late Yurakucho transgression, for humuses or peats are distributed at the height of several meters above sea level and sands of river bed deposits are developed higher than the humuses or peats.

If the Recent deposits are subdivided into some lithostratigraphic units on the basis of their lithofacies as mentioned above, it is speculated that the beginning and the ending of their depositions are not necessarily synchronized at one area with another in the Kanto Lowland. In addition, each unit is not developed equally over the lowland, especially the distributions of the units composed of marine sediments are restricted. Also, the surface of unconformity is formed between LC and UC or MS in the delta region, but it is formed between LC and LC′ in most of the natural levee region where UC or UA overlies LC′ conformably. These facts are schematically shown in Fig. 5.

Distribution of the buried landforms

Reconstruction of the basal land form of the Recent deposits

Reconstruction of the basal landform of the Recent deposits, namely, reconstruction of the buried landforms is necessary to obtain the basic data for a regional division of the Kanto Lowland. But the extent where the buried landforms were reconstructed is limited in the southern part of the lowland, for the bore hole records were not available enough to reconstruct the buried landforms in the whole lowland.

When the author discriminated the Recent deposits from the older ones, as many geologic sections as possible were made, which were analysed with reference to the geologic sections above mentioned.

The base of the Recent deposits is easily found in the region where the buried river terrace deposits and Basal Gravel (T_4G) are distributed, for the top of the buried river terrace gravel and the base of the Basal Gravel are able to be regarded as the base of the Recent deposits. When the basal landforms are not composed of gravel, e.g. the buried abrasion platforms, the indicators to identify the Recent deposits are different from one another. The Pleistocene deposits under the Alluvial lowland around the uplands of Musashino and Shimousa are composed of dark brown or brown sand and gravel which are well consolidated. The Recent deposits overlie the Pleistocene mud in the Alluvial lowland

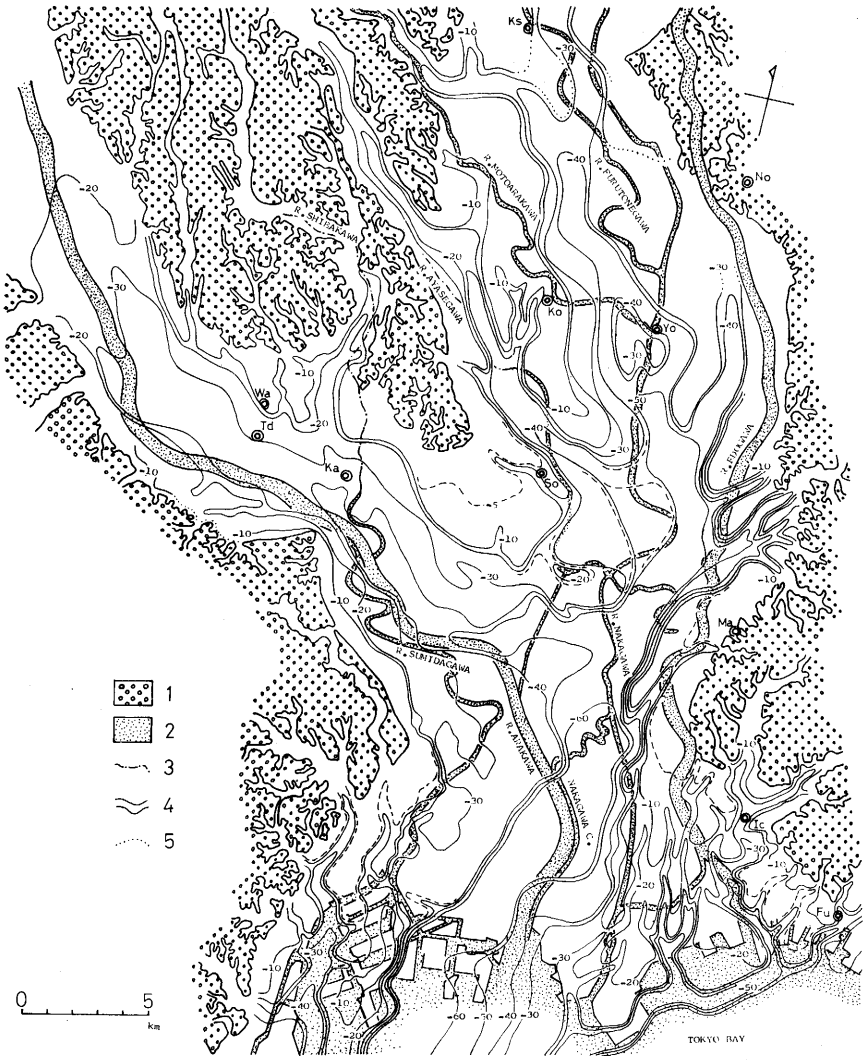


Fig. 6 Basal landform of the Recent deposits
1: Upland, 2: River Channel, 3: Stream Channel, 4: Contour line of the base of the Recent deposits, 5: Estimated contour line of the base of the Recent deposits; Cities: Fu: Funabashi, Ic: Ichikawa, Ka: Kawaguchi, Ko: Koshigaya, Ks: Kasukabe, Ma: Matsudo, No: Noda, So: Sooka, Td: Toda, Wa: Warabi, Yo: Yoshikawa.

around the Omiya Upland. In this case, it is possible to make a distinction between them on the basis of difference of N-values and preconsolidation loads.

Based on the method as mentioned above, the height of the base of the Recent deposits was determined on each bore hole record and was plotted on a map on the scale of 1:25,000 to obtain Fig. 6. Strictly speaking, contour lines in Fig. 6 do not show the basal landform of the Recent deposits because of the reasons as follows:

(1) The contour lines in the buried valleys show the height of the top of T_4G in stead of the base, for almost all of the bore hole records do not reach the base of T_4G, and for T_4G has the N-value and the thickness enough to bear heavy structures.

(2) All of the buried Kanto Loam is not the Recent deposits, but the contour lines on the buried river terraces show the heights of the tops of the gravels overlaid with it.

(3) All of the valley floors of small valley flats dissecting the uplands must continue to the buried valleys. But all of them were not able to be reconstructed because of lack of bore hole records.

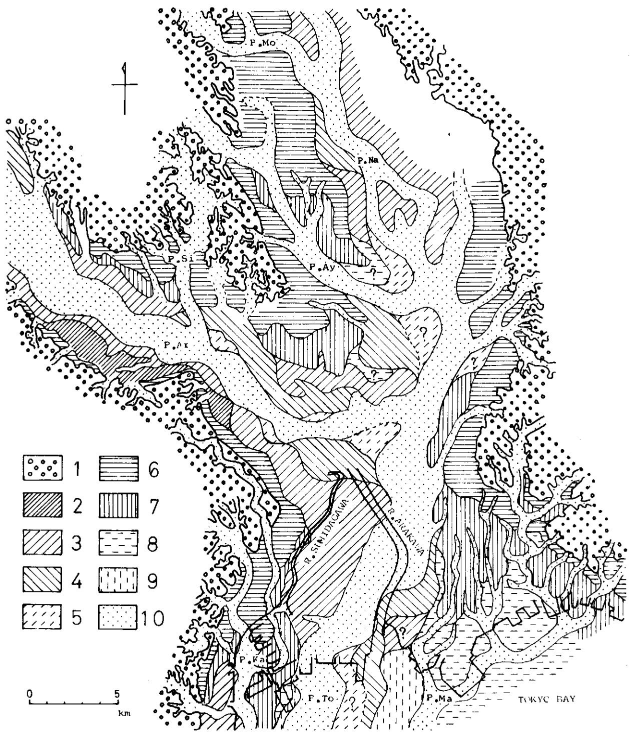


Fig. 7 Distribution of the buried landforms
1: Upland; Buried terraces: 2: T_0, 3: T_1, 4: T_2 5: T_3; Buried abrasion platforms: 6: A_1, 7: A_2, 8: A_3, 9: A_4; Buried valley floor: 10: Buried valley floor; Buried valleys: P. To: Paleo Tokyo River, P. Ar: Paleo Arakawa River, P. Na: Paleo Nakagawa River, P. Ay: Paleo Ayasegawa River, P. Mo: Paleo Motoarakawa River, P. Ka: Paleo Kandagawa River, P. Ma: Paleo Mamagawa River.

Distribution of the buried landforms

Based on Fig. 6, the author made clear the distribution of the buried landforms which were revealed in the geologic sections (Fig. 7).

There are four buried river terraces of T_0, T_1, T_2 and T_3. T_0 is several meters higher than T_1 and its distribution is restricted in the southern part of the Arakawa Lowland. T_1 is distributed most extensively, which forms the platforms at the height of about 30 meters below sea level in the Tokyo Lowland and 20 to 30 meters below sea level in the Nakagawa Lowland. Its distribution can be traced in the Arakawa Lowland, too. The deltaic deposits correlated to T_1G should be formed in the Tokyo Bay, but they have not been found out.

T_2 is distributed in the southern part of the Tokyo Lowland at the height of 40 to 50 meters below sea level, along the both coasts of the paleo Arakawa River at the height of about 35 meters below sea level and so on. The buried river terraces which are lower than T_2 were classified together as T_3. But the distribution of T_3 is restricted. As a relative height between T_3G and T_4G decreases upstream in the valley bottom of the paleo Arakawa River, it is hard to discern between them in the Arakawa Lowland. Therefore, the paleo Arakawa River extended over T_3 is shown more extensively in the Arakawa Lowland.

Four steps of the buried abrasion platforms of A_1, A_2, A_3 and A_4 were formed in the Interior Tokyo Bay. A_1 forms a platform of higher than 5 meters below sea level in height and is covered with UA and US. A_1 is developed in the lowland adjacent to the uplands where the ground height is above the present sea level in general. Taking account of that A_1 was formed in the drowned valley of the Interior Tokyo Bay, its distribution in the Nakagawa Lowland is too extensive. A_1 may be dissected more complicatedly by many branches of the buried valleys in fact.

A_2 forms a platform of 5 to 15 meters below sea level in height and is covered with thin layer of UC as well as UA and US. The broad distribution of A_2 is seen in the southeastern part of the Tokyo Lowland. A_3 distributed at the height of 20 to 30 meters below sea level was formed simultaneously with MS. A_4 is distributed at 30 to 40 meters in depth. The distribution of A_3 and A_4 is rather extensive in the Tokyo Bay.

The paleo Tokyo River runs in the central part of the Tokyo Lowland and bifurcates into the paleo rivers of Nakagawa and Arakawa in the northern part of the Tokyo Lowland. The paleo rivers of Ayasegawa and Motoarakawa join the former and the paleo Shibakawa River the latter. Two other fairly large buried valleys are seen in the Tokyo Lowland. The paleo Kandagawa River which has an origin in the Musashino Upland is located in the eastern part, and the paleo Mamagawa River whose origin is in the Shimousa Upland is located in the western part.

REGIONAL DIVISION OF THE SOUTHERN PART OF THE KANTO LOWLAND ON THE BASIS OF THE GROUND TYPES

Classification of the ground types

Ground conditions in the Alluvial lowland are determined by the characteristics and thickness of the Recent deposits and the characteristics of the layers under them.

As for the characteristics of the Recent deposits, the followings were made clear in the last Chapter:

(1) Among the six lithostratigraphic units into which the Recent deposits can be divided, T_4G and sand composing the lower part of LC have the N-value and the thickness enough

to bear a heavy structure on it. Very dense sand of more than 50 in N-value and hard clay of more than 30 in N-value can be used for a bed layer to bear a heavy structure, if they are at least several meters in thickness.

(2) Consistency of the clayey deposits of UA having the N-value of 0 to 1 is very soft, and that of UC of 0 to 5 in N-value is soft or very soft. Relative density of MS, US and sandy deposits of UA are loose or medium according to their N-values. Consistency of the clayey deposits of LC is stiff, and relative density of its sandy part except the lower part is medium.

The thickness of the Recent deposits is restricted by their basal landforms and also by their relative locations in the Alluvial lowland. The relation between each lithostratigraphic unit and its horizontal distribution in the Alluvial lowland is shown in Fig. 5. The relations between each lithostratigraphic unit and the buried landforms are also exhibited in Fig. 8 by means of a model geologic section of each lowland.

When the Pleistocene deposits which can not bear a heavy structure is directly overlaid with the Recent deposits, a bed layer must be sought in the deeper deposits.

Based on the above mentioned facts, it is possible to classify the ground conditions in the Alluvial lowland into a number of types. They are entered on the top of Fig. 8 by using marks. The thicknesses of the deposits composing each ground type are shown in Tab. 3.

A. Tokyo Lowland

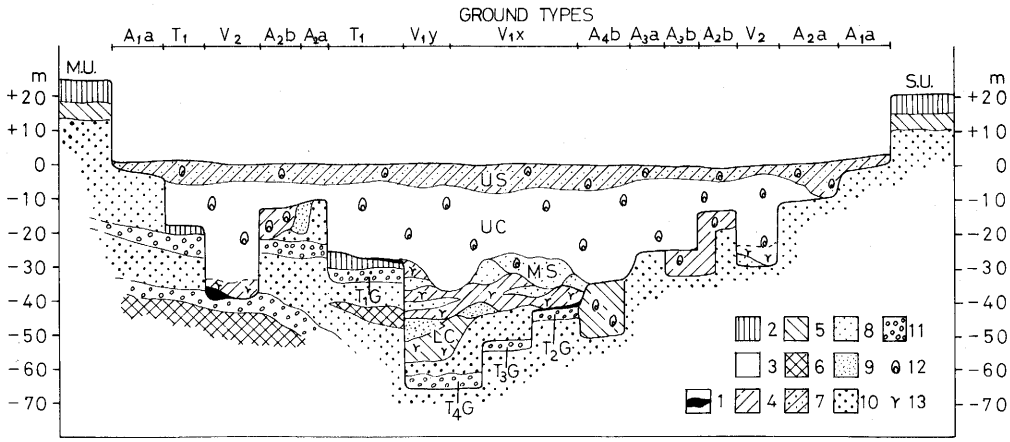
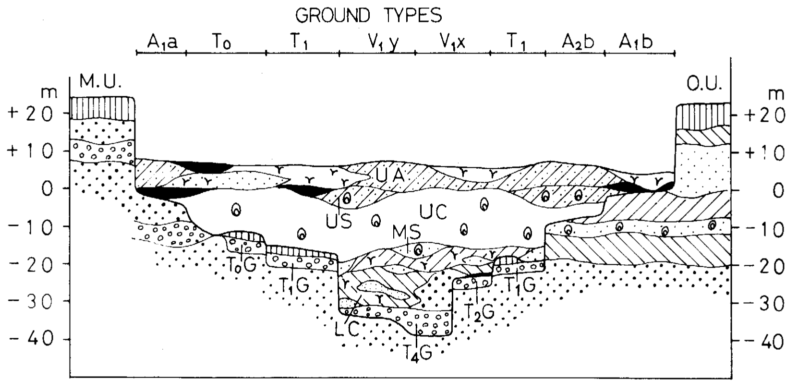


Fig. 8 Schematic profile of geology

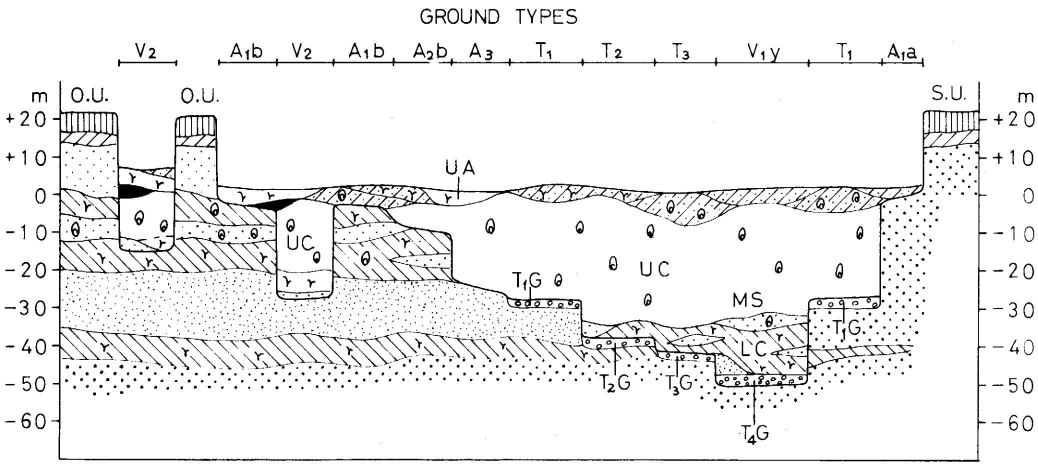
1: Humus or Peat, 2: Kanto Loam, 3: Very soft or soft clay, 4: Medium clay, 5: Stiff or very stiff clay, 6: Hard clay, 7: Loose sand, 8: Medium sand, 9: Dense sand, 10: Very dense sand, 11: Sand and gravel, 12: Shell, 13: Organic materials; Recent deposits : UA: Uppermost Alluvium, US: Upper Sand, UC: Upper Mud, MS: Middle Sand, LC: Lower Sand and Mud, T_4G: Basal Gravel; Buried river terrace gravels: T_0G, T_1G, T_2G, and T_3G

Uplands: M.U.: Musashino Upland, S.U.: Shimousa Upland, O.M.: Omiya Upland.

B. Arakawa Lowland



C. Nakagawa Lowland



The types of A_1, A_2, A_3 and A_4 are located over abrasion platforms. "a" means that an abrasion platform is formed on the well consolidated Pleistocene deposits, but "b" means that it is necessary to revise a depth of bed layer to the surface of the well consolidated Pleistocene deposits. The types of T_0, T_1, T_2 and T_3 correspond to the buried river terraces. T_0G, T_1G, T_2G and T_3G compose the uppermost part of the bed layer. But T_2G, T_3G and T_4G are often covered with very dense and thick sandy deposits composing the lower part of LC in the lowlands of Arakawa and Tokyo. V_1x is such a type that a bed layer is composed of T_2G, T_3G and the above mentioned sand. When the very dense sand is thin, namely, the thickness of sand is less than about 10 meters, the ground type is classified as V_1y. But the boundary between V_1x and V_1y is not very clear. The V_1x type is not distributed in the Nakagawa Lowland, for thick and very dense sandy deposits of the lower part of LC are not developed. The V_2 type is seen in the branches of the paleo rivers of Tokyo, Nakagawa and Arakawa. These branches are filled with fine deposits, for the sediment yields are very little. Especially, peat or humus is formed in the upper reaches of these branches dissecting the uplands.

Table 3. Ground types and layers composing them

Lowland	Buried landform		Revision of bed layer	Thickness of the Upper layer of the Recent deposits (m)	Thickness of soft layer of the Lower layer of the Recent seposits (m)	Thickness of soft layer of the Pleistocene (m)	Depth to bed layer (m)
Arakawa Lowland and Tokyo Lowland	Buried abrasion platform	A_1	a	3– 5	0	0	3– 5
			b	3– 5	0	10–25	10–30
		A_2	a	5–10	0	0	5–10
			b	5–10	0	5–20	10–30
		A_3	a	20–30	0	0	20–30
			b	20–30	0	about 5	25–35
		A_4	b	30–40	0	10–25	40–55
	Buried river terrace	T_0		10–20	0	0– 5*	10–20
		T_1		15–25	0– 5	0– 5*	15–35
	Buried valley floor	V_1	x	15–40	0–15	0	20–45
			y	15–40	15–20	0	30–60
		V_2		5–40	about 5	$+\alpha$	5–45
Nakagawa Lowland	Buried abrasion platform	A_1	a	3– 5	0	0	3– 5
			b	3– 5	0	10–25	10–30
		A_2	b	5–10	0	5–20	10–30
		A_3	a	15–25	0	0	15–25
	Buried river terrace	T_1		20–30	0	0	20–30
		T_2		35–40	0– 5	0	35–40
		T_3		35–40	5–10	0	40–45
	Buried valley floor	V_1	y	20–40	5–15	0	25–55
		V_2		5–15	about 5	$+\alpha$	5–20

a: Revision is not necessary. b: Revision is necessary. x: Revision is necessary.
y: Revision is not necessary. *: Buried Kanto Loam.

Distribution of each ground type

The distribution of each ground type can be known by interpreting the buried landforms into the ground types and by revising a depth of bed layer (Fig. 9).

A boundary between different ground types is formed by a buried slope. The larger a

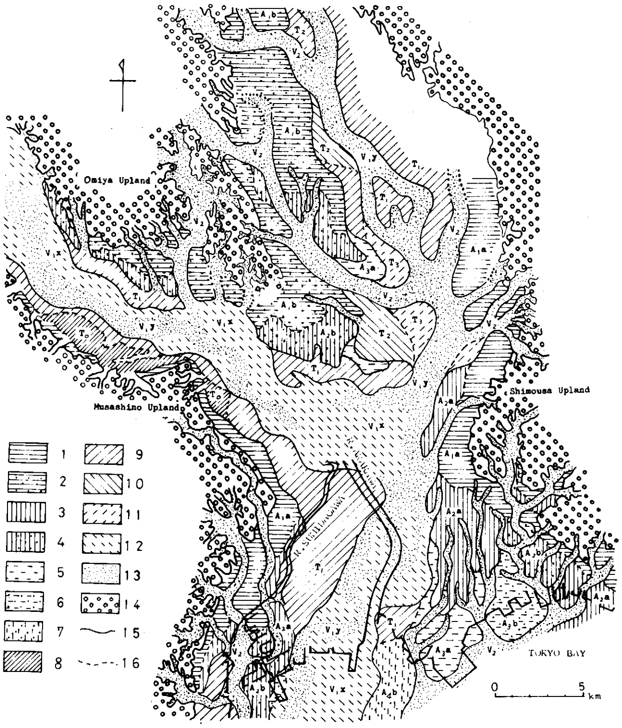


Fig. 9 Regional division based on the ground types
Ground types : 1: A_1a, 2: A_1b, 3: A_2a, 4: A_2b, 5: A_3a, 6: A_3b, 7: A_4b, 8: T_0, 9: T_1, 10: T_2, 11: T_3, 12: V_1x, 13: V_1y or V_2; Upland : 14: Upland; Boundaries : 15: Conspicuous boundary, 16: Not so conspicuous boundary.

relative height of a buried slope is, the more conspicuous a difference of characteristics of the ground is. When the A_1 or A_2 type adjoins with the V_1y or V_2 type, the ground conditions differ from each other most conspicuously. For example, the depth of bed layer differs by as great as about 50 meters between the types of A_1 or A_2 and the V_1y in the northeastern part of the Tokyo Lowland (Fig. 2F). Such a difference as mentioned above exists between the types of A_1 or A_2 and the V_2 which are formed in the valley bottoms of the paleo rivers of Ayasegawa, Kandagawa and Mamagawa. The difference of ground conditions between the types of A_1 or A_2 and the T_1 is remarkable especially in the lowlands of Tokyo and Nakagawa, in where the depths of bed layers differ by more than about 20 meters between them and the difference is equivalent to the thickness of very soft clay of UC.

Other parts of the Kanto Lowland

There are a great number of buried valleys dissecting the buried uplands to the depth of 10 to 20 meters in the Tonegawa Lowland. The ground conditions on the buried valley bottom differ remarkably from those on the buried uplands, for the Recent deposits are composed of very soft clay intercalated by humuses or peats.

On the other hand, there is a buried river terrace in the upper course region of the Arakawa Lowland (Fig. 10), which makes the ground conditions different from the area over the buried valley bottom.

Though such differences of ground conditions as mentioned above are discernible in the geologic sections, it is impossible to practise a regional division on the basis of the ground types because of lack of bore hole records.

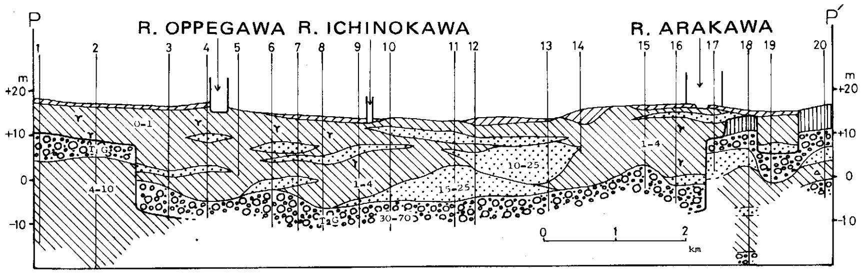


Fig. 10 Geologic section of the northern part of the Arakawa Lowland

SOME SIGNIFICANCES OF REGIONAL DIVISION BASED ON THE GROUND TYPES

For construction of structures

The important characteristics of ground for constructing many sorts of structures are the depth of the bed layer and the soil mechanic properties of the deposits composing the ground.

Though the depth of the bed layer decreases upstream except the ground types over the buried abrasion platforms, the ground types exhibited in Fig. 9 show that the depth of the bed layer differs from one ground type to other even in an adjacent region. In addition, different ground types have different lithostratigraphic units of the Recent deposits and different thicknesses as shown in Fig. 8 and Tab. 3. It has been made clear in many reports of ground survey in many coastal lowlands in Japan, such as "Toshijiban Chosa Hokokusho (the Serial Reports of Ground Survey for Urban Land Use)" by the Planning Bureau, Ministry of Construction and many collaborating offices, that each lithostratigraphic unit is characterized by different soil mechanic properties. Accordingly, Fig. 9 shows the regional division of ground condition for the purpose of construction of many sorts of structures.

For disasters

For land subsidence

Because land subsidence is mainly caused by compaction of soft clayey deposits due to over-pumping of ground water, its amount is a function of the thickness of soft clayey deposits, such as UC and the clayey part of LC and UA, as well as of the water quantity that is pumped up. There are some examples. The thickness of the Ariake clay and the amount of subsidence show an apparent possitive correlation (Ariake Bay Research Group 1965). The core areas of land subsidence in the Tokyo Lowland, where subsidence occurs at the rate of more than 100 milimeters per year, coincide with the area over the buried valleys (Nakano, Kadamura and Matsuda 1969). Discontinuity in the amount of land subsidence lies over the buried terrace slopes and the buried valley walls in the Tsurumigawa Lowland (Matsuda 1970).

Such facts as mentioned above mean that the regional division based on the ground types is useful to show where land subsidence is likely to occur and where its amount varies discontinuously.

For earthquake disaster

Many studies on the distribution of earthquake damages have made clear that earthquake damages are greater in the area where soft ground is developed (for example, Omote 1946, Omote and Miyabe 1951, Ooba 1957, Kadomura 1966 and so on). Based upon the studies on the dynamic properties of the ground, the same result was obtained, too (for example, Kanai and Tanaka 1961 and 1966, Shima 1969 and so on). If the ground is treated as a medium of seismic waves, the relation between the degree of earthquake damages and the ground conditions can be explained rationally. Seismic waves are transformed during propagation in the grounds. In addition, the degree of transformation of seismic waves differs in accordance with the difference of density and shear modulus of the grounds. When seismic waves enter into a soft layer from a well consolidated layer, they are amplified. Accordingly, if the distribution of soft ground can be understood, the area where an input of seismic energy to a structure is large may be detected.

Very long facilities, such as a dike, a railway and an expressway crossing over the area where the thickness of soft layer changes suddenly, are likely to suffer from earthquake damages, for the characteristics of seismic waves differ conspicuously between the both sides of the area. It is important to know the location of buried valley walls and buried terrace slopes. Therefore, the regional division based on the ground types may as well serve as the regional division showing the causative factors of earthquake damages.

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