MEMOIRS OF THE FACULTY OF SCIENCE, KYOTO UNIVERSITY, SERIES OF GEOL. & MINEAL.,
Vol. XXXIX, No. 1, p.1-64, 1 App-fig., Aug. 31, 1972

Late Pleistocene Glaciation and Terrace Topography in the Ina Valley, Central Japan

By

Hideki SHIMIZU*

Abstract

The Ina valley has been well-known as one of the typical areas of the river terrace topography in Japan. In this paper, the classification of the geomorphic surfaces and the history of terrace formation in the area are examined from the view point of volcano-stratigraphy. The stratigraphical relation between the tephra units (Shinshû Loam) and the glacial morphology of the Kiso mountains affords a good explanation for the glaciation and the terrace formation during Late Pleistocene in the Ina valley. Moreover, by tracing some tephra units from this intermontane region to the coastal area of the South Kantô plain, it is ascertained that the maximal extension of the glaciers in the Kiso mountains was contemporaneous with the lowest sea-level. In connection with this, the peculiar feature of the river terrace crossing topography is explained as the product of the maximal glaciation of c. a. 30,000 yrs. B.P.

Introduction

A study of the alluviation and denudation by river streams involves more than a complex of interacting physical and chemical elements. So, many geologists have paid much attention to clarify the laws which controls those processes (TROLL, 1957).

Throughout middle latitudes and at high elevations, stream basins were repeatedly subjected to the processes of the periglacial zone in the course of the Pleistocene. As W. SOERGEL (1924) and J. BÜDEL (1944) discussed, periglacial stream gravels are as important as glaciofluvial deposits, and alluviation should continue for the duration of cold climate, ie., the time span of the glacial advance.

The relation between alluviation and climatic changes, which is the cause of the advance and retreat of glaciers in the proglacial area, was discussed in detail by C. TROLL (1957). According to him, the glaciofluvial deposition started at the maximum of Würm, and vast deposition had continued outside of the moranic gate until the late-glacial phase. In such proglacial area, significant development of clastic deposits of glacial epoch had been witnessed, but it has never been clarified whether the same phenomena had occurred in non-glaciated area or not (KOBAYASHI, 1962). Moreover, JAHN (1956) pointed out another interpretation of proglacial deposition in Europe.

The Ina valley, where the Tenryû river runs through is situated in an in-

* The present adress; Ina Kita High School, Ina City, Nagano Pref.

termontane basin surround by the Kiso mountains in the west and the Akaishi mountains in the east, both of which were once glaciated at the time of the Würm. Besides, there are many well-developed river terraces in this valley. Therefore, it is problable to say that this valley is one of the best place to study the above-stated fluvial process of the glacial time in non-glaciated area at the intermontane basin. So, the present investigation was undertaken to examine the main factors which controlled the terrace building in this area from the view point of stratigraphical, chronological and paleoclimatological studies.

Since 1954, the author has studied the "Shinshû Loam" which were distributed in vast area including the southern part of Central Japan, and he made it possible to take this older volcanic ash series as the key bed to correlate the Pleistocene deposits distributed separately with each other in the Southern Shinshû district and in the South Kantô plain. Consequently, he made it clear that stratigraphic correlation was possible between the Shinshû Loam and the Kantô Loam, the latter is the generic name of older volcanic ash deposits which are widely distributed in the Kantô district of Central Japan. Thus, the investigated area was subjected mainly to the Ina valley of the southern part of Shinshû district as well as to South Kantô plain, namely Kôfu, Hachiôji, the basin of the river Katsura, Tokorozawa, Kiyose, Urawa, Hino and Shimosueyoshi of Yokohama.

As a result, based on volcano-stratigraphical study, some glacial episodes which had held in the intermontane basins of the inland region and some events in the coastal plain have been correlated with each other. In this paper, the author described the volcano-stratigraphy in the Ina valley and considered the course of the terrace building in this area with reference to the Late Pleistocene events such as glaciation and sea-level changes.

Before taking up the main subject, the author sincerely expresses his deep gratitude to Prof. T. KAMEI of Kyoto University and to Prof. K. KOBAYASHI of Shinshû University for their unfailing guidance throughout the course of this work. The author's collaboration with numerous friends, colleagues and students in the field and laboratory stimulated his enthusiasm for the Quaternary research. To all these and particularly to Assist. Prof. Y. GÔHARA, Dr. K. MOMOSE, Dr. T. YAMADA, Mr. J. SAKAI of Shinshû University and Mr. T. NASU of Kyoto University, he is indebted beyond measure. Grateful acknowledgement is made to Dr. K. SUZUKI of Fukushima University for identification of fossil plants, and to Dr. S. KURABAYASHI of Tôkyo Educational University who kindly helped in identification of clay mineral.

Previous Studies

The well-developed river terraces in the Ina valley has been attractive to many geomorphologists for a long time. After the first study by T. TSUJIMURA (1919), M. ICHINOSE (1926) recognized that there were nine groups of river terraces in the southern part of this area (Iida basin), and he discussed that almost of all those terraces belonged to the erosion terraces, with exception of some accumulation terraces. Further, based upon the presence of agglomerate (author's tuff breccia bed), he proposed the name of "Ryûto volcano" to an assumed extinct volcano at the east side of the river Tenryû. Similar consideration was held by S. USHIMARU (1927) in the west of Takato town, northern part of this area. He assumed "Tenjinyama thoroide" by the presence of andesitic breccia bed distributed there. Such consideration for the assumed extinct volcanoes in this area was supported by T. YAGI (1928).

Those early works were mainly done from the geomorphological wiew point, but there were some geological works, particularly of the Pleistocene geology. T. YAGI (1928) gave the name "Tenryû formation" to the gravel bed of this area which attains 300 m in thickness at most, and he considered this deposits to be Lower Pleistocene in age. T. SHIKAMA and K. KOBAYASHI (1949) revised YAGI's work, and they divided that gravel bed into two stratigraphical units such as "the Tenryû gravel formation" of the upper and "the Ina formation" of the lower. Although they recognized nine groups of terraces in the Ina valley as same as ICHINOSE's classification and also they admitted the presence of "Ryûto volcano", their work involved the new concept that depositional process of the Tenryû gravel formation was the product of Late Pleistocene glaciation. This noticeable opinion is the fundamental concept of the present paper.

As for the Ina formation, Y. MINO (1951) used the name "the Tsukueyama formation", and he classified river terraces in this area into four groups. Furthermore, T. SAKAMOTO (1956) and T. ARII (1960) carried out the study of the Ina formation precisely, and the former author reported the first discovery of biological evidence of the occurrence of *Metasequoia*.

Most of those studies above mentioned were devoted to the southern part of the Ina valley, while concerning to the northern part of this valley, some works were taken up from the view point of volcano-stratigraphy (KOBAYASHI, YAMADA and SHIMIZU, 1961; YAMADA and SHIMIZU, 1961; SHMIZU, 1962). As a result of those studies in the northern part of the Ina Valley, new evidences which denied the idea of assumed extinct volcanoes of ICHINOSE and others have emerged. That is, those pyroclastic materials were tuff breccia bed derived from the Enrei formation, Late Pliocene to Early Pleistocene sediments distributed near the Enrei Pass, north of Ina City. This pyroclastic bed is consituted with a mud flow which once flown down along the Ina valley, and it makes an useful key bed to correlate older sediments separately distributed in this area.

In this occassion, the author intended to divide the sediments which form the river terraces of this area and to pursue the succession of the terrace building in the Ina valley (SHIMIZU, 1962; KOBAYASHI and SHIMIZU, 1962, 1965).

Apart from the problem of terraces, the glacial topography in the Kiso mountain range had been studied for the first time in detail by G. IMAMURA (1935). Later, SHIKAMA and KOBAYASHI (1949) discussed the date of the glaciation in the Hida and the Kiso mountains, but precise examination about the relation between the glaciation and the terrace building was not yet determined. Afterwards, many workers challenged that subject and found some evidences which indicated the mutual relationships between the Pleistocene volcanic ash and the morainic deposits at Mt. Kisokomagatake and Mt. Minamikomagatake. Then, they recognized some glacial cycles in the Kiso mountains (KOBAYASHI et al.; SHIMIZU, 1960; KOBAYASHI and SHIMIZU, 1962; SHIMIZU and KOBAYASHI, 1965).

As shown above, numerous data concerning to Pleistocene episodes such as glaciation, terrace buildings, climatic changes and so on in the Ina valley have been accumulated, but none of synthetized work has been taken up until now. Then, the present author has tried to compile those accumulated data from the view point of the stratigraphy, and the result is sumarized and shown in Appendix Fig.

Stratigraphy of Quaternary Deposits

The Quaternary deposits in the Ina valley consist mostly of gravel and loam (the Shinshû loam originated from volcanic materials). Among them, the loam is characteristic and is classified according to some characters such as color, degree of weathering, state of plant remains contained, nature of cracks, state of buried soil (dark band), heavy mineral composition and clay mineral association. On the other hand, gravel beds are classified stratigraphically according to such characters as petrographic composition of gravels, morphometry of gravels, degree of decay and stratigraphical relation with overlying or intercalating loam beds. Correlation and stratigraphy of those loam and associated gravel beds are shown in Table 1 and 2.

The gravel beds in the Ina valley were formerly summarized as one unit as "the Tenryû formation" and were assigned simply to Lower Pleistocene deposits (YAGI 1928). But SHIKAMA and KOBAYASHI (1949) divided that gravel formation into two, the Ina formation of the lower and the Tenryû gravel formation of the upper, of which the latter was regarded as the deposits formed by the terrace building during Upper Pleistocene. MINO (1951) and ARII (1960) used the name "Tsukueyama formation" for the same as the Ina formation. SAKAMOTO (1956) presumed the date of the Ina formation to be Latest Pliocene by reason of

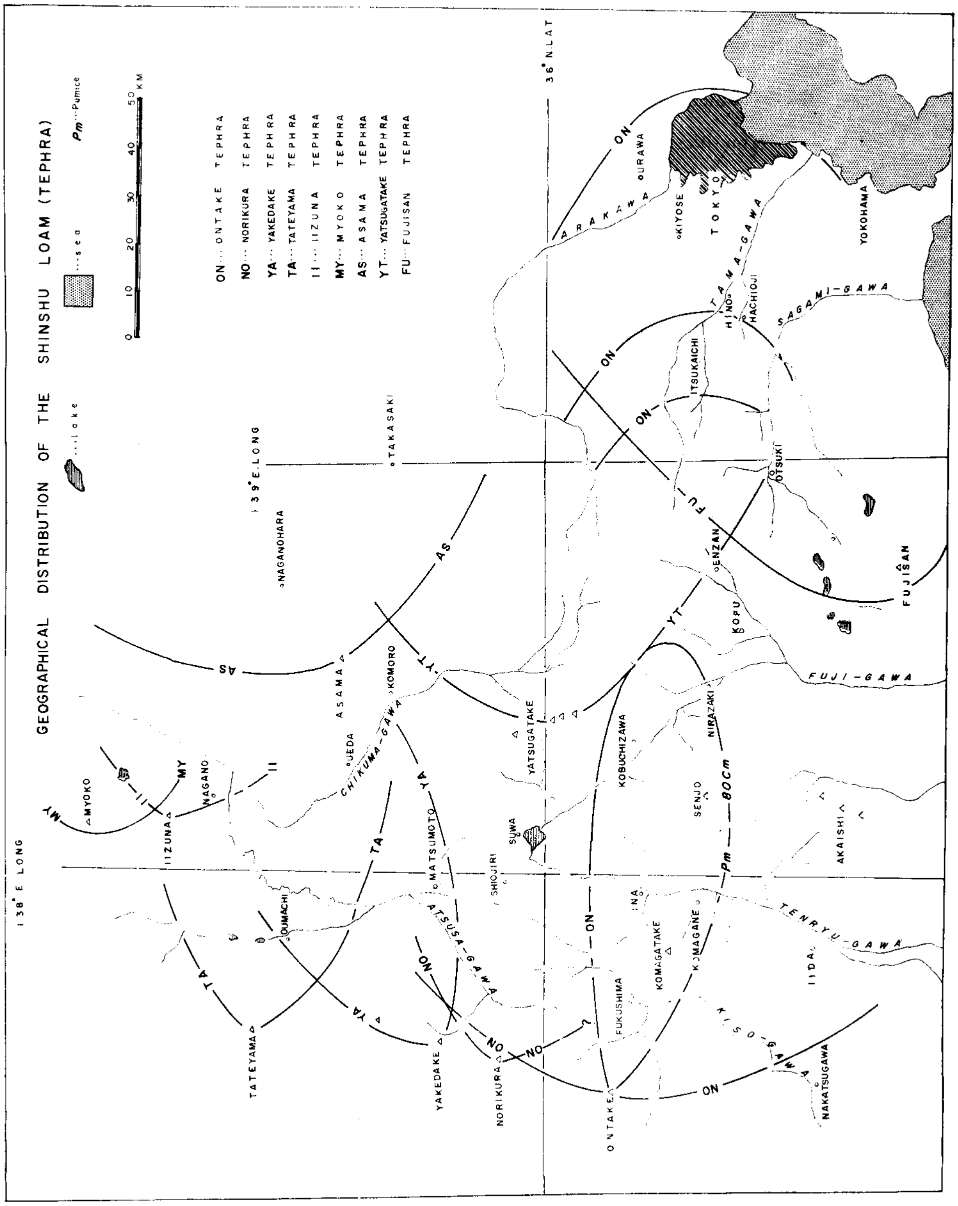

Fig. 1. Geographical distribution of the Shinshū Loam.

Table 1. Classification and correlation of the river terraces in the Ina valley.

Tephra	Northern Ina valley	Middle Ina valley	Southern Ina valley
	Flood plain	Flood plain	Flood plain
	Kinoshita terrace (KS)	Miyada terrace (MY)	Furumachi terrace (FR)
Pm - V	Minamidono terrace (MD)	Komagane terrace - 3 (KO - 3)	Nago terrace (NA)
	Mikoshiba terrace - 2 (MK - 2)	Komagane terrace - 2 (KO - 2)	?
Pm - IV			
	Mikoshiba terrace - 1 (MK - 1)	Komagane terrace - 1 (KO - 1)	Iida terrace (ID)
Pm - III			
	Transitional terrace (OM)	?	?
Pm - II			
Pm - II			
Pm - I	?	?	Yokomaya terrace (YK)
Pm - I'			
	Ôizumi terrace (OZ)	Akaho terrace (AK)	Ôzima terrace (OZ)
	Takao terrace (TK)	?	Takao terrace (TK)
Pm - O			

Pm; pumice fall deposit.

the occurrence of *Metasequia japonica* and *Juglans megacinerea* from the lignite bed at Horikoshi of Toyooka-mura. As a result of the recent studies, however, it is quite possible that a part of this formation may belong to Lowest Pleistocene because of the coexisting of the cold climate plant remains with *Metasequoia* in the upper part of the Ina formation at Ozono etc.

The distribution pattern of the Ina formation suggests that the Paleo-Tenryû river once provided very wide flood plains. In the northern part of this valley, that formation is distributed mainly on the west of the Tenryû river, while in the southern part of the valley the distribution area is biased only on the east of the

Table 2. Classification of the river terraces and associated gravel beds in the Ina valley.

Tephra	Northern Ina valley	Middle Ina valley	Southern Ina valley
	Flood plain	Flood plain	Flood plain
	KS	MY	FR
	Kinoshita gravel	Miyada gravel	Furumachi gravel
Pm - V	MD	KO - 3	NA
	Minamidono gravel	Komagane gravel - 3	Nagao gravel
	MK - 2	KO - 2	?
	Mikoshiba gravel - 2	Komagane gravel - 2	
Pm - IV			
	MK - 1	KO - 1	ID
	Mikoshiba gravel - 1	Komagane gravel - 1	Iida gravel
Pm - III			
	OM	?	?
Pm - II'	Mikoshiba gravel		
Pm - II			
Pm - I	?	?	?
Pm - I'			
	OZ	AK	OZ
	Ôizumi gravel	Akaho gravel	Ôzima gravel
	TK	?	TK
Pm - O	Takao gravel		Takao gravel

Pm; pumice fall deposit

Tenryû river on the contrary. Such peculiar distribution pattern means the insertion of the crustal movements after the deposition. The terrace building of later stage might have been controled by such peculiar distribution pattern of the pre-existed Ina formation.

The Ina formation is subdivided as follows.

Ina formation { Ina member / Tuff breccia bed / Horikoshi member

Although the Ina member and the Horikoshi member are separated by the intervening tuff breccia bed, it is difficult to deiscriminate both members only by lithological features at the place where the key bed is absent.

Distribution: This formation has the wide distribution both in the northern and the southern parts of the Ina valley, and it is well developed on the eastern side of the Tenryû river in the southern Ina valley. Well dissected fill-top surfaces of the Ina formation hold the height ranging from 600 to 700m above the sea-level. Prior to the following discussion, the characteristics of this formation is stated briefly.

Horikoshi member

Type locality: Cliff at Loc. S-200,* northwest of Horikoshi elementary school, Toyooka-mura (Fig. 23b–33).

Distribution: Horikoshi and Nagasawa, Toyooka-mura; Kamihira and Ôwachi, Takagi-mura; Kerokubo, Tatsue-mura; and Ozono, Iida city in the southern part of the Ina valley. This member is absent both in the northern and the middle regions of the Ina valley.

Thickness: 15m + at the type locality.

Stratigraphy and lithology: This member overlies unconformably on the basement rock of granite, and is composed mainly of clay and silt beds deposited in standing water environment. In the lower part, there are some gravel beds which consists of non decayed gravels of sandstone, chert, granite and slate, and in the upper part, some layers of clay, pumiceous tuff and peat are intercalated. Sometimes, there is also fine sand beds which are composed of angular quartz grains derived from weathered granite. The presence of abundant gravels of granite, chert, sandstone and slate is characteristic of this member. *Metasequoia distica, Alnus, Carex* and *Juglans megacinerea* were reported from the peat beds in this member (MIKI, 1955)

Tuff breccia bed

This bed has been formerly called "agglomerate", but now, it is regarded as a very useful key bed of the Ina formation. This bed was known as "Misobeta", "Ibo-iwa", or "Obi-iwa" as local names.

Type locality: Locality N-81 at Kojin-yama, southeast of Tatsuno-machi in the northern part of Ina valley (Fig. 21a–3).

Distribution: Localities N-39, 68, 230 and 357 in the northern region of the Ina valley. In the middle of the Ina valley, the presence of this bed is also known by the well holes and the boring holes at Ôtagiri, northeast of Komagane city. In the southern region, however, this bed is widely distributed, in the length of about 11 km and in the width of about 1 km, from the junction of the Koshibu river and the Tenryû river to the catchment area of the Kagasu river in Takagi-mura. The

* Locality numbers are shown in Appendix Fig. and so forth

distribution of this bed ranges from 450 m to 600 m above the sea level in heights. But it is conspicuous that the relative height to the present flood plain of the Tenryû river decreases gradually towards the downstream, and furthermore, in the left side of the Tenryû river the tuff breccia bed inclines generally from east to west toward the main stream.

Thickness: more than 20 m at Tatsuno.

In the southern region of the Ina valley, thickness of the bed becomes thinner, viz. 3 m+ at the cliffs near the river bed of the Tenryû river, and 7 m at Ozono.

Lithology: Gravels are mainly composed of angular to subangular andesites blocks, but sometimes, rounded to subrounded gravels of sandstone, clayslate, chert, hornfels, and granite are contained in tuffaceous matrix cement. Therefore, such lithological feature means that those sediments was a sort of volcanic mudflow.

From the distribution and the lithology above stated, it is clear that the tuff-breccia bed is the sediments which had once distributed along the Paleo-Tenryû river in the Ina valley. Therefore, the grounds for formerly assumed "extinct volcanoes" in the Ina valley, like as "Tenjinyama thoroide" (USHIMARU, 1927) and "Ryûtô volcano" (ICHINOSE, 1926), were abandoned. To trace the distribution of this sediment, it is possible to conclude that the tuff-breccia bed had derived from the Enrei formation, alternation of pyroclastic sediments and lava, exposed at the northern extremity of the Ina valley. Moreover, the geological age of this bed can be dated to be 1,300,000 K-Ar. yrs. B.P. (MOMOSE et al; 1966). According to the date and the occurrence of above stated plants remains from underlying Horikoshi member, it is possible to presume that the tuff-breccia bed is Early Pleistocene in age.

Ina member

Type locality: Loc. S-147, cliff of east of Ozono, Iida City in the southern part of the Ina valley (Fig. 23a–29).

Distribution: Loc. N-97 and 279 in the northern part of the valley. In the southern part of the Ina valley, this member is exposed continuously along the eastern bank of the Tenryû river from the Koshibu river region at Yanagisawa to Kerokubo at Tatsue-mura. In the western side, the tuff-breccia bed was observed from place to place at the river side of the Matsukawa river at Kamiarai, near Yawatahara in Kanae-machi and at southwest hilly district of Araihara at Shimotonooka in Iida City.

Thickness: More than 10m in the northern area, but 3m+ at the west bank of the Tenryû river in the southern area. It attains even more than 100 m at Horikoshi, Tsukueyama and Ozono in the eastern region of the Tenryû river. On the whole, it is estimated that the thickness ranges from 100 m to 150 m, but usually it becomes to decrease the thickness towards the north.

Lithology: The Ina member consists mostly of well-sorted and massive gravel beds and intercalates a few sand beds. It is composed of rounded or subrounded gravel of chert, sandstone, clayslate, granite, hornfels, andesite and epidiabase. Diameter of gravels generally ranges from 8 to 10 cm, but some of them attains to 20 cm. Both matrix and gravels are well weathered and are distinct brown color, especially in the upper part of the member. From the sedimentary structures, it may be possible to consider that the Ina member was a kind of collovial deposits.

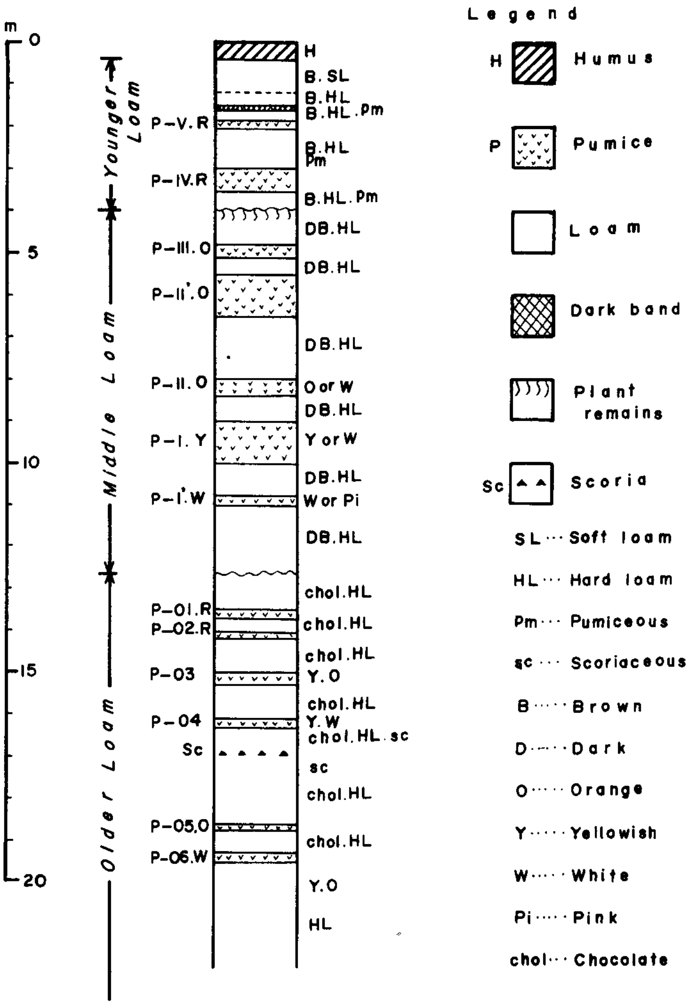

Fig. 2. Standard column of the Shinshû Loam in the Ina valley.

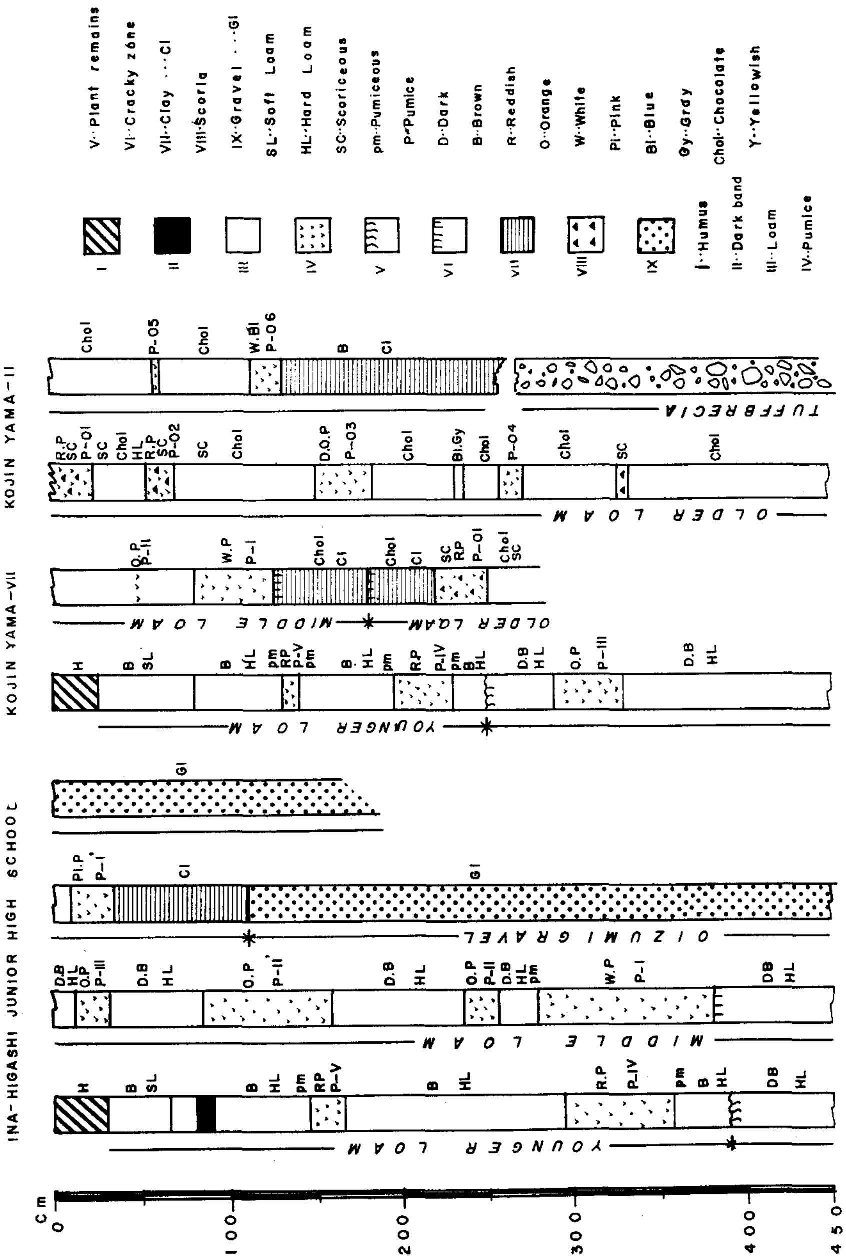

Fig. 3. Columnar sections of the Shinshû Loam at type localities.

Shinshû Loam

The aeolian volcanic ash formations which deposited widely in the Pleistocene land sections of the Shinshû district (central part of Central Japan) are called generally "Shinshû Loam" (Figs. I and 2). The lithology and the mode of occurrence of the Shinshû Loam are much resemble to those of the Kantô Loam which is widely distributed in the Kantô plain. Besides them, it is noticeable that some parts of the Shinshû loam distributed up to the Kantô plain and they deposited intercalating in the Kantô loam. Therefore, the Shinshû loam bears important roll as a common time indicator to correlate the phenomena in the Shinshû district with the Kantô plain. Concerning to their distribution, it is clear that the Shinshû Loam in the Ina valley (Shinshû loam of "South Shinshû type") was mainly originated from volcanic ash fall of the Ontake volcano. As to the source materials, J. SAKAI (1963) has the same opinion to be based upon the volcano-stratigraphical correlation between the Ina valley and the Kiso valley.

The Shinshû Loam of South Shinshû type outcrops typically in following localities: Loc. N-338 at Ina-Higashi Junior High School, east of Ina city, and Loc. N-74 at Kôjinyama Hill, southeast of Tatsuno (Figs. 3, and 5). All successin of three tephra units such as the Older-, the Middle- and the Younger Loam units are observable at those localities. Thickness of the Shinshû Loam in the Ina

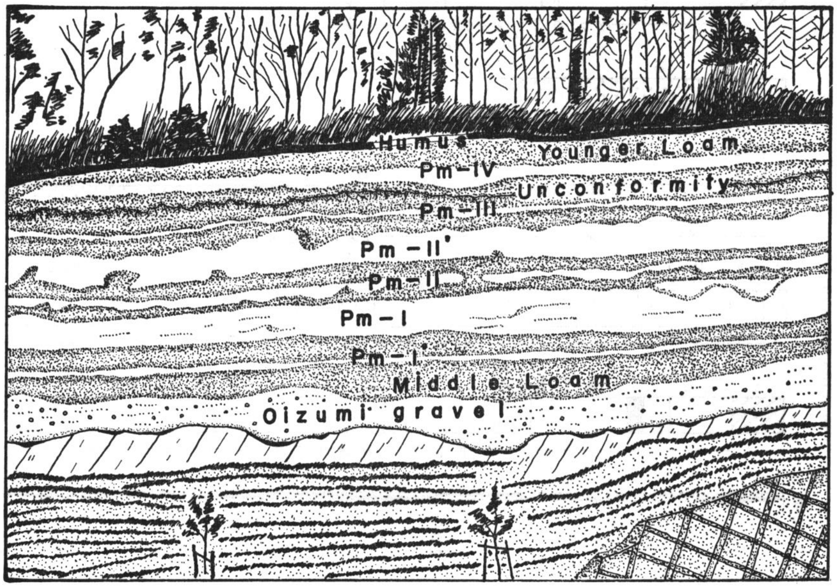

Fig. 4. A sketch of the exposure at Ina-Higashi Junior High School, east of Ina city.

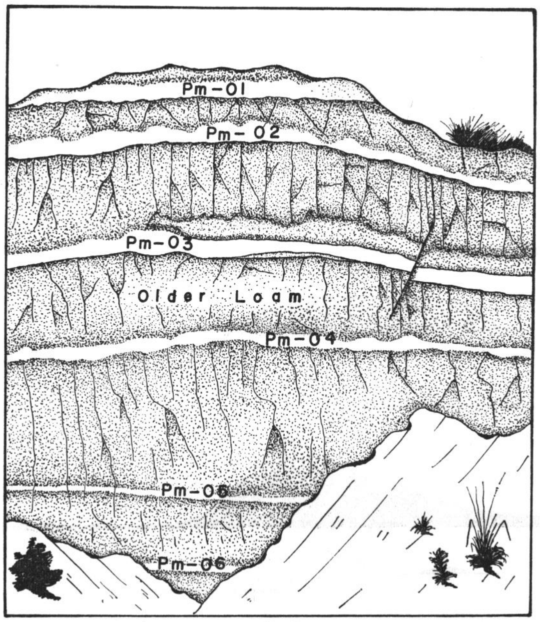

Fig. 5. A sketch of the exposure at Kôjinyama hill, south east of Tatsuno.

valley is ca. 16 m in the northern area, ca. 10 m in the middle area and ca. 4 m in the southern area. Thickness and distribution of the important pumice beds in the Shinshû Loam are shown in Figs. 6 and 7.

(a) *Older Loam*

Type locality: Loc. N-74 at Kôjinyama hill, southeast of Tatsuno in the northern part of the Ina valley (Figs. 3 and 5).

Modes of occurrence: The Older Loam, the lowest stratigraphical unit of the Shinshû Loam, can be observed only at high elevation such as some hill-tops. This unit is characterized by the occurrence of aqueous tephra intercalated in gravel beds (i.e. Takao gravel) with exception of air-laid tephra at Kôjinyama hill.

In the aeolian Older Loam, some six beds of pumice can be discriminated and these pumice beds are designated as 01, 02, 03, 04, 05 and 06 in descending order (Kobayashi and Shimizu, 1965).

Lithology: Chocolate-colored loam is very sticky owing to its much clay mineral contents, and is rich in pumice and scoria. Cracky structure is typical when exposures are in dry condition. 01 and 02 pumice beds are scoriaceous rather than pumiceous, and are characteirzed by dark red color. 03 pumice bed is characterized by bricky color and is rather thick in bed. (30 cm in general). 04 and 05

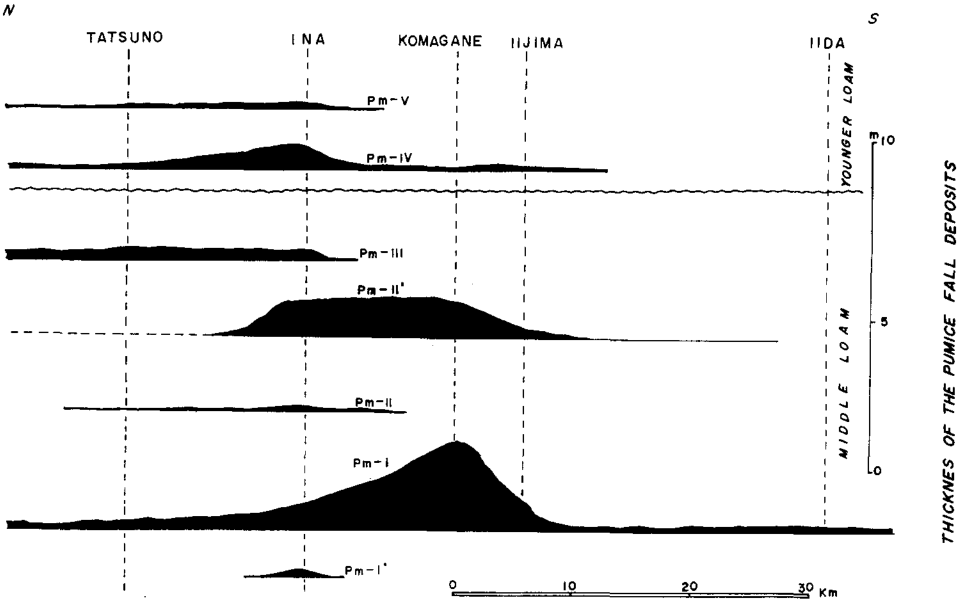

Fig. 6. Thickness distribution of pumice-fall deposits in the Ina veally.

pumice beds are orange-color, while 06 pumice bed is white in color and is characterized by the presence of distinct biotite flakes.

Heavy mineral composition: As mineral grains in the Older Loam are commonly decayed, the specific identification is generally very hard, with exception of magnetite, under the microscope. Dominance of magnetite in the Older Loam may owe to the nature of the stability of that mineral. Limonite is also characteristic and hyperthene and hornblende are contained in small quantity.

Clay minerals consist of illite and 14 Å mineral (montmorillonite or the mineral of intermedate state between montmorillonite and vermiculite), together with halloysite (KURABAYASHI and TSUCHIYA, 1963).

As to the Older Loam in the Ina valley, it is very difficult to determine its source volcano from distribution pattern. Because almost of all the Older Loam are sediments which deposited under subaqueous condition and aeolian tephra of this is mostly absent. In the Kiso valley neiboruing to the Ina valley, various mode of occurrence of "Older Loam" have been reported, and it has been confirmed that some of them in the Kiso valley had been originated from the Ontake volcano. (KISODANI RESEARCH GROUP, 1967). It is difficult to say that all of the Older Loam of both areas are correlative definitely with each other, but it is probable to say that a part of the Older Loam in the Ina valley had been derived from the Ontake volcano.

(b) *Middle Loam*

Type locality: Loc. N-338 at Ina Higashi Junior High School, east of Ina City in the northern part of the Ina valley (Figs. 3 and 4). And following exposures are available to supplement that of type area: Loc. N-131, 163 and 215 in the northern area of the Ina valley, Loc. M-152, 158, 172 and 192 in the middle area, Loc. S-22, 27 and 28 in the southern area.

Modes of occurrences: The distribution of the Middle Loam is very wide in the Ina valley, and usually full succession of it can be observed in loamy sediments which overlie on the depositional surfaces of the Ôizumi and the Takao gravel

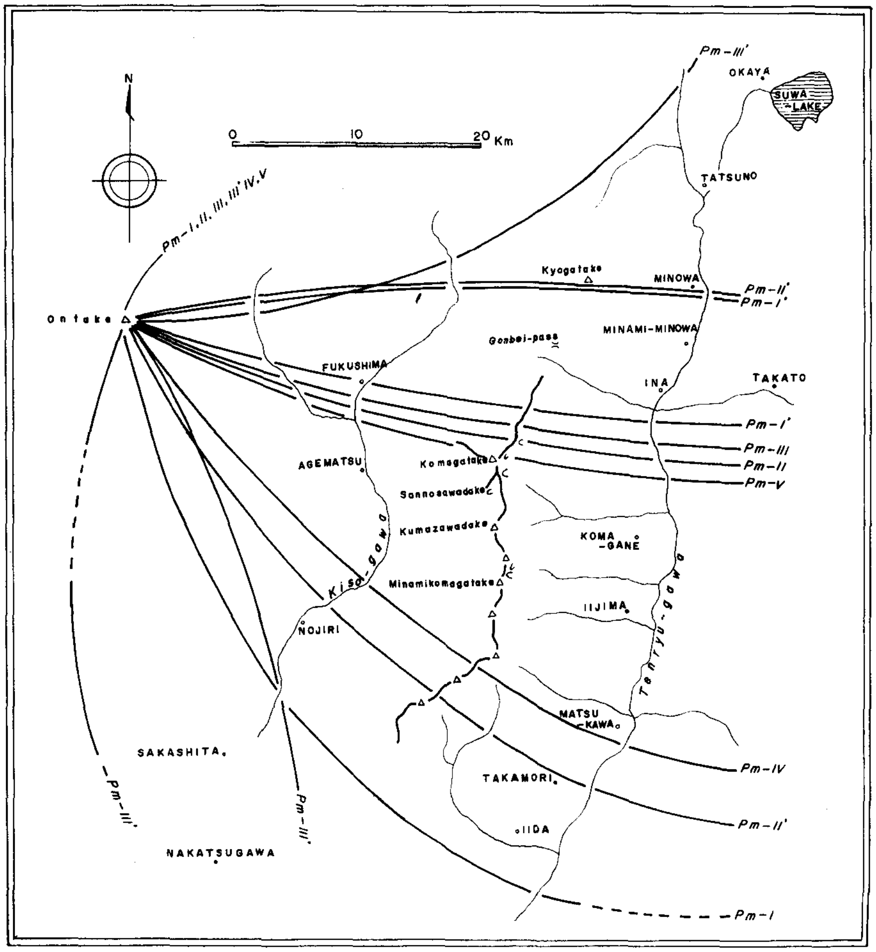

Fig. 7. Geographical distribution of Pm-I, I', -II, II', -III, -IV and V.

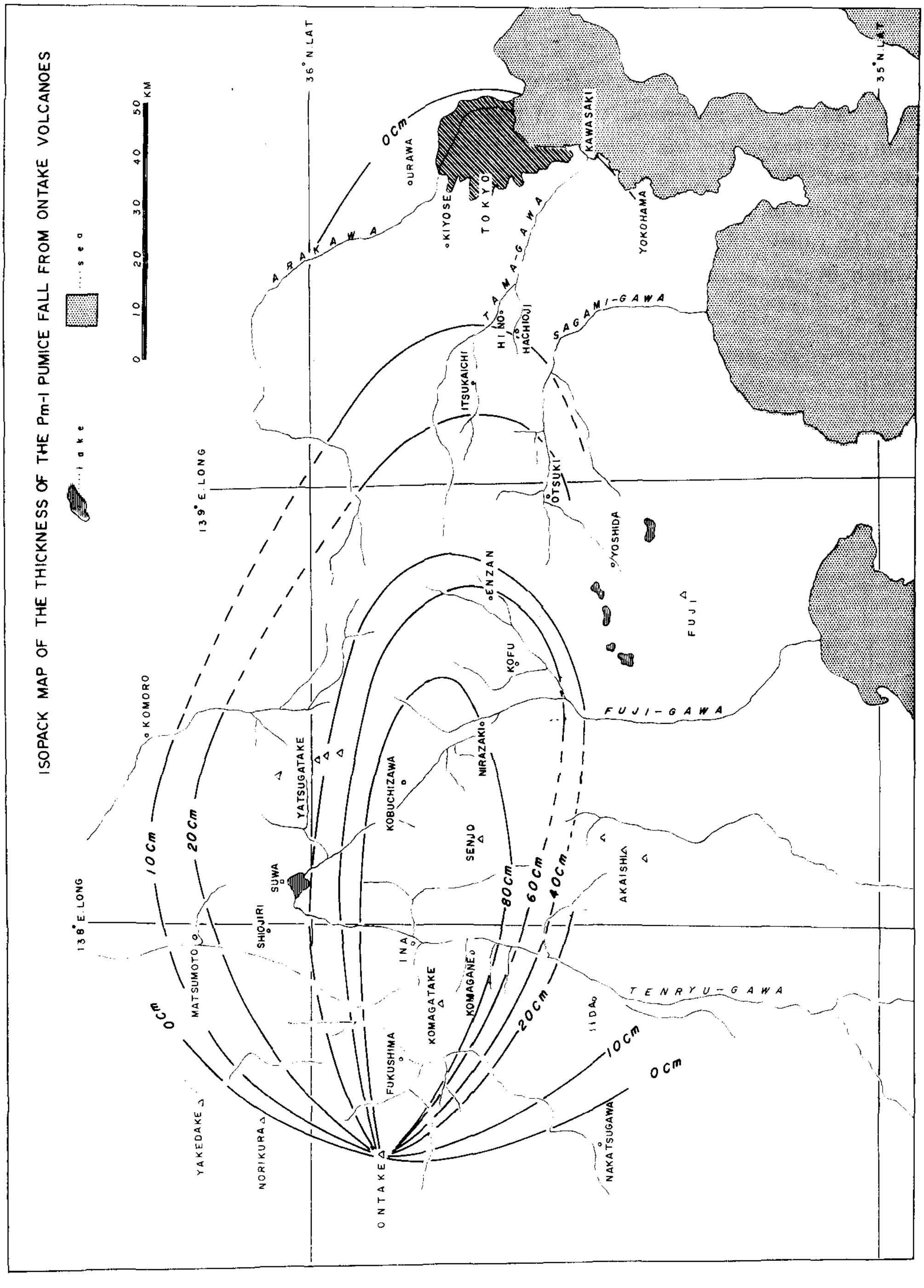

Fig. 8. Maximum grain size distribution of Pm-I.

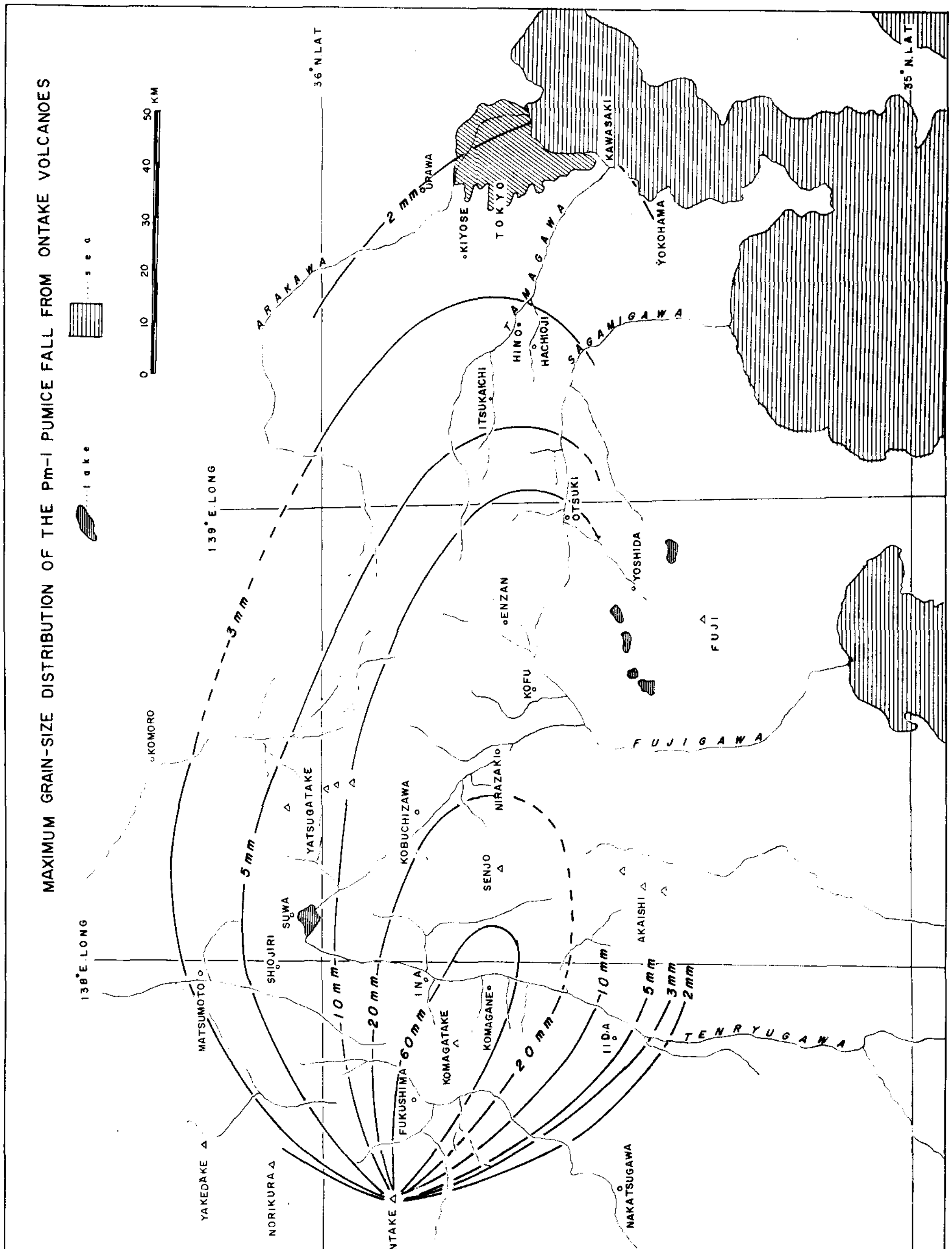

Fig. 9. Isopack map of Pm-I.

beds. In another case, water-laid deposits of this Middle Loam are sometimes intercalated in the Mikoshiba gravel-I (Loc. N-289 and 313, M-155)

Five pumice beds have been recognized in aeolian tephra and they are designated as Pm-I', Pm-I, Pm-II, Pm-II' and Pm-III in ascending order (KOBAYASHI and SHIMIZU, 1965). But as the distribution patterns of those pumice beds are different with each other, it is not always possible to observe all of them in one single locality. Although a full set of them is generally found in the northern area, there can be seen three in the middle area and only two in the southern area.

Thickness: Generally, the thickness of the Middle Loam is more or less about 6 m in the northern area, but occasionally it attains to more than 12 m. (Loc. N-132 of Yatsudo). The Middle Loam has a tendency to decrease its thickness toward the south, i.e. 4 m thick in the middle area and 2~4 m in the southern area. Among pumice beds of the Middle Loam, Pm-I is the thickest and has the widest distribution. The distribution of it can be pursued from the piedmont area of the Mt. Ontake and Kiso valley, through Ina valley and the Kôfu basin (the Sone hill), Uenohara of the Katsura river basin to the Kantô plain, i.e. Hachiôji, Urawa, Hino, Tokorozawa (in the Kantô district), and Shimosueyoshi terrace in Yokohama city. The distribution and the granularity variation of the Pm-I were shown in Figs. 8 and 9.

Lithology: The upper limit of this unit is always represented by the dark band (buried soil), and then, the Middle Loam is separable from the Younger Loam with unconformity. As the Pm-I' of the base is usually less developed, it is convenient to take the Pm-I above Pm-I' as the horizon marker of the lower limit. The Middle Loam is greyish brown in color and is rather hard. Compared with the Younger Loam, it is characteirzed by the presence of abundant pumice patches, the degree of clay mineralization and the state of cracking. Colors of

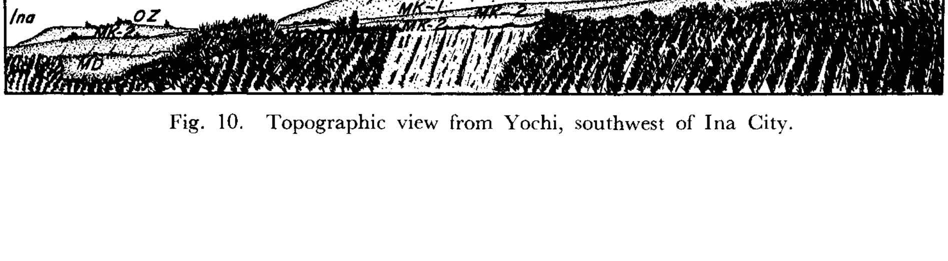

Fig. 10. Topographic view from Yochi, southwest of Ina City.

each pumice beds are as follows; the Pm-I' is pink, the Pm-I and -II are white or yellow, and the Pm-II' and -III are orange. By the differences in color, it is easy to distinguish pumice beds with each orther, but it must be added to say that the Pm-I has local variation in color i.e. white to yellow in the northern area and yellow in the southern area.

In the Middle Loam, plant remains of *Menyanthes* etc. were found from the peat bed of Pm-III horizon (KOBAYASHI and SHIMIZU, 1965) and fossil teeth of *Bison* were unearthed from the horizon just below the Pm-III (SHIMIZU, KAMEI and KOBAYASHI, 1965).

Heavy mineral composition: Magnetite, augite, hypersthene and hornblende, accompanying with biotite and zircon in some pumices in the lower part. Hornblends are rather common in the lower part (Figs. 21, 22 and 23).

The weight ratio of heavy to total minerals and glass fraction in Pm-I does not attains to the amount of 10%, but the magnetite is dominant and hornblende, hypersthene, augite are in descending order. Zircon occupies nearly to 10% of the total heavy minerals (Table 3). Pm-II is quite different in mineral composition from that of Pm-I, and then, it is characterized by dominance of hypersthene accompanied by less amount of magnetite and hornblende. Pm-II' is rich in "magnetite" (including ilmenite). In Pm-III, the amount of hypersthene, sometimes with augite, is larger than that of magnetite. It is fairly known that Pm-III' is present both in the Kiso valley and the Matsumoto basin and is absent in the Ina valley as shown in figure 7. A characteirstic of this pumice is represented by the presence of magnetite with less amount of hornblende and hypersthene.

Table 3. Heavy mineral composition of some pumice fall beds in the Shishû Loam of the South Shinshû type (in grain-size fraction 1/8-1/16 mm). H/T: percentage of heavy minerals in the total weight.

Sample	H/T	Hornb.	Aug.	Hyp.	Mag.	others	%
Yochi-II (Pm-V)	61.0	3.0	13.5	65.2	18.2	—	99.9
IHJS (Pm-IV)	28.7	—	14.7	53.1	32.2	—	100.0
OS-X-1 (Pm-III')	32.0	29.9	—	25.4	44.7	—	100.0
IHJS (Pm-III)	14.0	3.2	56.2	37.3	—	—	99.9
IHJS (Pm-II')	16.5	2.1	—	22.2	75.7	—	100.0
IHJS (Pm-II)	21.0	6.4	—	77.5	15.6	(Z)0.5	100.0
IHJS (Pm-I)	5.9	38.2	5.6	9.7	37.4	2.5+ (Z)6.7	100.1
IHJS (Pm-I')	9.0	21.4	4.3	5.6	59.0	8.5+ (Z)1.3	100.1

OS; Osakada, Shiojiri. IHJS; Ina Higashi Junior High School.
(Z); Zircon. Pm; pumice fall deposit of the Ontake volcanoes.

Clay minerals: In fine grained part of this loam, hydrated halloysite is usually identified. Pumice beds consist of allophane and 14 Å mineral (probably Al-vermiculite), and also allophane and hydrated halloysite are often found in the horizon of pumice beds (KURABAYASHI and TSUCHIYA, 1963).

(c) *Younger Loam*

Type localities: Loc. N-338 at Ina-Higashi Junior High School, east of Ina City in the northern part of the Ina valley (Figs. 3 and 4), and also Loc. N-339 near the former locality.

Mode of occurrence: The whole section of this upper part of Loam can be recognized in the sediments which covers the Mikoshiba-1 surface or higher terraces. On the terraces lower than the Mikoshiba-1 surface, on the other hand, only a part of the Younger Loam can be found as aeolian or water-laid deposits intercalated in the Mikoshiba gravel and in the Minamidono gravel. The Younger Loam unit has been also known in the glacial moraines in Mt. Kisokoma and Mt. Kumazawa of the Kiso mountains. Especially, it is signicant that a pumice bed of Pm-IV was found as the cover of the lowest moraine of Mt. Kumazawa cirque.

As shown in Fig. 3, 4 and 6, two beds of pumice and scoria called Pm-IV and Pm-V in ascending order are generally intercalated in the Younger Loam at northern and the middle area of the Ina valley. In the southern area, however, only one pumice bed (Pm-IV) can be recognized.

Practically, Pm-IV is scoria with labradorite but without hornblende, while Pm-V is andesitic in mineral composition, consisting of a few hornblende and other various coarse fragments.

Thickness: Ca. 4 m in the northern area, 1.8 m in the middle area, and less than 1.2 m in the southern area. It becomes thinner toward the south. Distribution and thickness of pumice beds are shown in Fig. 6 and 7. Pm-IV indicates a bedded structure in the northern and the middle areas, however in the southern area, it exhibits scattering occurence within a zone of 40~50 cm in thickness. Pm-V is present in bedded structure in the northern area, but it is sporadic in the middle area and is absent in the southern area.

Lithology: The Younger Loam shows bright yellowish brown in color, and its upper part changes gradually into black humus. Below the lower limit of humus, porous soft loam makes a zone of about 20 to 50 cm thick without any cracking structure. As to underlying hard loam, it is easy to discriminate from overlying soft loam by hardness, development of columnar joints and large amount of clay minerals.

In general, color of pumice beds in the Younger Loam is reddish brown, and Pm-V is characterized by the presence of slightly orange-colour and the by presence of white patches of pumice grains. Some of dark bands which may indicate rather long duration of vegetation growth are developed in the Younger Loam.

Heavy mineral composition: The Younger Loam as a whole is characterized by the dominance of hyperthene and by less amount of magnetite and augite. And further, a quantities of associated hornblende is extremely small. As the result of high stability for weathering of magnetite, percentage of magnetite increases downwardly. (Figs. 21, 22, and 23).

Although both pumice beds, i.e. Pm-IV and Pm-V contains augite, hypersthene and magnetite, and especially Pm-V is characterized by the presence of hornblende and by a little amount of apatite to compare with Pm-IV (Table 3).

Clay minerals: Loam and pumice consist mostly of allophane, but there exist the clay minerals of mixed layer of allophane and hydrated halloysite in the lower part of the Younger Loam (KURABAYASHI and TSUCHIYA, 1963).

Gravels

The classification of the gravel beds is a fundamental frame work to establish the Quaternary geochistory of the Ina valley, and a synoposis is as shown in Table 2. Description of each gravel bed will be given as follows.

(a) *Takao Gravel*

Type locality: A river side cliff on the right bank of the Yotagiri river at Senninzuka, Nanakubo, Iijima-machi in the middle area of the Ina valley (Loc. M-158; Figs. 26b–20).

Distribution: The Takao gravel bed which forms the Takao terrace (Table 1) is distributed in Mukaibukuro (southwest of Tatsuno), Tera (east of Ina city), Hirasawa (west of Ina City), Senninzuka (Iijima-machi in the middle area), and at the eastern piedmont of the South Kiso mountains (Table I and 2).

Lithology: Although the lithofacies of the Takao gravel bed in the middle and the southern areas is rather constant, it is variable in other areas from place to place owing to the difference of the source areas. The Takao gravel bed of the west of the Tenryû river in the northern area are mainly composed of gravels derived from Palaeozoic basements. On the other hand, those of other areas are mainly composed of gravels of granitic rocks. The Takao gravel bed is assumed to be fan deposit which consists of gravels carried from the mountains just behind. Concerning to the gravel composition, kinds of pebbles differ slightly from those of the present river bed, and such composition of the Takao gravel indicates long distance transportation far from the upper stream. The Takao gravel bed is also characterized by the intercalation of the Older Loam and Pm-0 pumice bed. It is another distinctive nature that matrix of the gravel consists of granitic sand. As a whole, it is brown in color, but when overlying thick loam bed is absent, red earths produced by severe weathering is developed (Loc. S-166).

Thickness: 20 m at the northern area, 30 m at the middle area, and 50 m at the southern area of the Ina valley.

Size and roundness of gravels: Size variation is very wide in each locality, but as a whole, mean size is about 30 cm. Maximum diameter is about 50 cm, but occassionally it attains over 100 cm. Roundness of gravel ranges from sub-

Table 4. Heights of terraces above the sea-level and relative heights from the present river floor.

a) Takao terraces.

Ina valley	Terraces	Heights above the sea-level		Relative heights
		East	West	
Northern part	TK - 1	800 m	840 m	200 m
	TK - 2	—	—	—
Middle part	TK - 1	—	800 m	300 m
	TK - 2	—	700 m	200 m
Southern part	TK - 1	—	800 m	300 m
	TK - 2	—	600 m	200 m

b) the Ôizumi terrace.

Ina valley	Tenryû river			
	West		East	
	Heights above sea-level	Relative heights	Heights above sea-level	Relative heights
Northern part	720 m	70 m	730 m	75 m
Middle part	630 m	150 m	650 m	160 m
Southern part	562 m	160 m	582 m	200 m

c) Yokomaya terrace.

Ina valley	Heights above sea-level	Relative heights
Northern part	700 m	55 m
Middle part	640 m	150 m
Southern part	635 m	135 m

d) Mikoshiba terrace-1.

Ina valley	Heights above sea-level		Relative heights
	West of the Tenryû river	West piedmont	
Northern part	720 m	850 m	50 m
Middle part	700 m	760 m	200 m
Southern part	670 m	800 m	185 m

e) Mikoshiba terrace-2.

Ina valley	Heights above sea-level		Relative heights
	West of the Tenryû river	West piedmont	
Northern part	700 m	1,000 m	40 m
Middle part	600 m	900 m	65 m
Southern part	500 m	780 m	120 m

f) Minamidono terrace.

Ina valley	Heights above sea-level	Relative heights
Northern part	680 m	30 m
Middle part	580 m	60 m
Southern part	528 m	80 m

g) Kinoshita terraces.

Ina valley	terraces	Heights above sea-level	Relative heights
Northern part	KS-1	670 m	20 m
	KS-2	658 m	12 m
	KS-3	650 m	6 m
Middle part	KS-1	560 m	30 m
	KS-2	540 m	20 m
	KS-3	530 m	10 m
Southern part	KS-1	500 m	40 m
	KS-2	440 m	20 m
	KS-3	430 m	15 m

angular to subrounded in the northern area, and from subrounded to rounded in the middle and the southern areas.

(b) *Ôizumi Gravel*

Type locality: Loc. N-225, southeast of Ôizumi, Minamiminowa-mura in the northern area of the Ina valley (Fig. 21b–9).

Distribution: The Ôizumi gravel bed which made a fill top called "Ôizumi terrace" (Table 2) overlies unconformably on the Takao gravel bed, and it is distributed to form monadnock-like topography along the Tenryû river. The unconformity above stated can be seen at a river-side cliff along the Nakatagiri river (Loc. M-120; Fig. 22a–17), and the Seisenji temple, Katagiri, Matsukawa-machi (Loc. S-53; Fig. 23a–29) (Table 1 and 2)

Lithology: The Ôizumi gravel bed is similar to the Takao gravel bed in the gravel composition and the appearence of sedimentation. Therefore, it may be explained that the Ôizumi gravel bed is also fan deposits which was brought by the transportation of some tributaries at the piedmont areas. Matrix is repressented by sandy matrials, especially of granitic. Weathering degree is less than that of the Takao gravel bed.

The Ôizumi gravel bed is distinguishable from other gravel beds in having the aeolian Middle and the Younger Loam units just above the depositional surface without any intercalation of waterlaid loam units. Furthermore, the followings are characteristic; i) the thickness of the bed is comparatively thin, but the filltop height is rather high, ii) the gradient of the bed is smaller than those of other gravel beds, iii) the bed is usually overlain by some younger gravel beds near the top of fan.

Thickness: Thickness of the Ôizumi gravel bed is about 10 to 15 m in the northern area, about 20 m in the middle area, and it attains over 50 m in the southern area; i.e. the thickness increases toward the south.

Size and Roundness: Gravel are rounded to subrounded and about 30 cm in medium size. The maximum size of gravel is about 90 cm, but occassionally it attains about 130 cm.

(c) *Yokomaya Gravel*

Type locality: Loc. S-21 at Yokomaya, Nakagawa-mura, Kamiina-gun, in the southern area of the Ina valley (Figs. 23a–24).

Distribution: The Yokomaya gravel bed is distributed at Rokudohara on the east side of the Tenryû river, in the northern area (the north bank of the Mibu river). Yokomaya village, and Ôkusa and Kutsurashima in the Nakagawa-mura. (Tables I and 2)

Lithology: As a whole, the lithological feature of the Yokomaya gravel is quite similar to that of the Ôizumi gravel, but it is distinguishable from the latter by the presence of loamy matrix in the upper part and also by the presence of overlying the aeolian Middle Loam which occupies the upper portion above Pm-I.

Thickness: More than 5 m in the northern area, and more than 8 m in the southern area.

Size and Roundness: Such characters as size, color, and roundness are nearly same to those of the Ôizumi gravel, but there is a slight difference that the upper part of the Yokomaya gravel bed has rather larger gravels than those of the Ôizumi gravel bed.

(d) *Mikoshiba gravel*

Type locality: An river-side cliff on the left side of the Ozawa river at Yochi, west of Ina City in northern part of the Ina valley (Loc. N-289).

Distribution: The Mikoshiba gravel bed which forms the Mikoshiba terrace of fill-top type is widely distributed entirely throughout the Ina valley. (Tables 1 and 2).

Lithology: Pumice beds of the Middle Loam unit, and the lower part of the Younger Loam unit are intercalated in gravels as subaqueous deposits. In the northern part, the Mikoshiba gravel bed is composed mostly of Palaeozoic rock materials, whereas in the middle and the southern parts it is only composed of granite boulders. The Mikoshiba gravel bed is considered as fan-like deposits, because the gravel composition excludes the materials which were carried along main course of the Tenryû river. Matrix is mainly occupied by sandy materials, and loamy sand is dominant in the upper part. Gravels are less decayed to compare with those of the underlying Ôizumi gravel bed.

As to the Mikoshiba gravel bed, it is possible to classify two gravel units. The lower part is represented by the pumice intercalation ranging from Pm-I to Pm-III, while the upper part is identified by the intercalation of Pm-IV. Those both gravel beds are conformable with each other near the top of fan.

Thickness: It attains more than 25 m in the northern area, and more than 40 m in the middle area. Then, it is estimated that the thickness attains more than 50 m in the southern area.

Size and Roundness: Gravel are subrounded to subangular and about 25 cm in medium size. The maximum size is up to 80 cm.

(e) *Minamidono Gravel*

Type locality: Cliff on the west side of the Tenryû river at Minamiminowa-mura, in the northern area (Loc. N-230: Fig. 21b–11).

Distribution: The Minamidono gravel bed which makes forming the Minami-dono terrace of fill-top type is distributed in narrow belt along the Tenryû river and its tributaries. (Tables 1 and 2)

Lithology: Gravels on the west side of the Tenryû river in the northern area consist mostly of sandstone, chert and slate, but it is noticeable that there are small quantity of granite (Takatô Granite) and hornfels transported by the main course of the Tenryû river. In other areas, on the contrary, gravels carried by the main river course are less in quantity, but a large number of granitic gravels are comprised. Especially, granitic materials are rich in the gravels which is distributed along tributaries, and so, the evidences suggest that those gravels were derived directly from the mountain area just behind. Therefore, it seems to be likely that the deposits form strath terrace. Matrix is mainly composed of sand or sandy loam in the uppermost part. In addition to weak weathering, the Minamidono gravel bed is distinguishable from the underlying Mikoshiba gravel bed as follows; i) Pm-IV is intercalated in gravels as subaqueous deposits and aeolian Pm-IV has been also know at many places, ii) the presence of exotic gravels transported along the main river course.

Thickness: It is about 2 to 4 m in the northern area, but it attains more than 10 m at the Kitanosawa river, southeast of Tatsuno-machi. About 5 m in the middle area, and 15 m in the southern area. Along the upper course of the Maezawa river, northwest of Matsukawa-machi, it attains up to 20 m.

Size and roundness: The size of gravels is variable in different localities, but generally it becomes larger from north to south, 45 cm in average at Ôjima in Matsukawa-machi. The Minamidono gravel bed is generally composed of subangular to subrounded gravels. In general, boulders derived immediately from the mountains area just behind are large enough to attain more than 100 cm.

(f) *Kinoshita Gravel*

Type locality: A river-side cliff on the west of the Tenryû river at Kinoshita, Minowa-machi in the northern area of the Ina valley (Loc. N-136; Fig. 25b–6).

Distribution: The Kinoshita gravel bed makes the Kinoshita terrace of fill top type, and it is distributed slightly discontinuously along the Tenryû river and its tributaries. It is developed in the middle and the southern areas. (Tables 1 and 2).

Lithology: The bed is mainly composed of gravels of slate, sandstone, hornfels, chert and granite, accompanying with sandy matrix. Thus, this bed is characterized by containing non-decayed gravels carried by the main course of the Tenryû river, such as Takatô-Granite and andesite in the northern area and such as chert and slate in the southern area. The Kinoshita gravel bed can be divided into three parts named respectively Kinoshita gravel −1, −2 and −3 in ascending order, and they are distinguishable by each mode of occurrence of loam units overlying on each gravel bed.

Thickness: Thickness of the bed becomes larger toward the south, e.g. 4~8 m in the northern area, 10~15 m in the middle area, 15~20 m in the southern area.

Size and roundness: Gravel size of the bed is 15 cm in average and 25 cm in maximum, so that it is smaller than that of the Minamidono gravel bed.

Terrace Topography

The former studies on the terraces in the Ina valley have been based mainly on the geomorphic features of them in the southern part of this valley. Nine terrace groups were identified by ICHINOSE (1929) and SHIKAMA and KOBAYASHI (1949), but otherwise, MINO (1951) classified them into four terrace groups. Moreover, there have been some various opinions about the geological age of each terrace, so the synthetic consideration on the terrace classification has been left untill now.

Here, the author wishes to propose his idea on the classification of terraces in the Ina valley from the stratigraphical view point as shown in Appendix Fig. and Tables 1 and 2. The names of terraces are represented in abbreviation as IE, TK, OZ, YK, OM, MK-1, MK-2, MD, KS-1, KS-2 and KS-3.

Ina surface (Enrei surface; Tsukueyama surface) = IE

The surface on which generally complete set of air-laid tephra from the Older Loam to the Younger Loam is observed.

Takao terrace = TK

On the terrace plane, both units of the Younger Loam and the Middle Loam are seen as aeolian deposits. Fill-top terrace.

Oizumi terrace = OZ

On the terrace plane, both units of the Younger Loam and the Middle Loam are seen as aeolian deposits. Fill-strath terrace.

Yokomaya terrace = YK

The terrace surface is covered by air-laid tephra of the Younger Loam unit and of a part of the Middle Loam unit (upper than Pm-I horizon). Loamy sediments below Pm-I horizon is absent.

Transitional terrace = OM

The terraces surface on which air-laid tephra of the Younger Loam unit and of a part of the Middle Loam unit (upper than Pm-III horizon) are found.

Mikoshiba terrace—1 = MK-1

On the surface, the Younger Loam unit excluding lower part of lower than Pm-IV horizon are found as aeolian deposits.

Mikoshiba terrace-2 = MK-2

The Younger Loam of upper horizon than Pm-V and its associated tephra are completely found as aeolian deposits on the surface of the terrace. An intercalation of water-laid Pm-IV is often found in the gravel bed which forms the MK-2 terrace.

Minamidono terrace = MD

On the surface, air-laid tephra of the Younger Loam unit upper than Pm-V horizon is found, but sometimes, Pm-V pumice is observed in either subqueous or aeolian.

Kinoshita terrace-1 = KS-1

On the surface, aeolian tephra of 50～80 cm thick which correspond to the upper part of the Younger Loam is found.

Kinoshita terrace-2 = KS-2

On the surface, aeolian the Younger Loam Unit which is represented by its upper part of 10～40 cm in thickness lies on the surface of the terrace.

Kinoshita terrace-3 = KS-3

The terrace is covered by black humus and/or loamy material or sandy loam.

Topographical characters of each terraces will be described in the next.

(a) *Ina surface (Enrei surface, Tsukueyama surface)*

Enrei surface: There is rather flat geomorphic surface of about 1,000 m high above the sea level around Lake Suwa. (MOMOSE, KOBAYASHI and YAMADA, 1959). This surface is built by volcanic ejecta of the Enrei formation, and it inclines gently toward the Tenryû river with average about 20 degrees in gradient. In general, the surface is intensely eroded to form the low-relief erosion surface. On that surface, the Older Loam unit is usually observed, but it is not so clear whether the Older Loam unit covers the Enrei formation conformably or not. The Enrei formation consisting of tuff-breccia and less amount of andesite lava is the sediments which had once flown down along the Ina valley, and a part of them had been intercalated in the Ina formation. And a continuous flat plain with an altitude of 800 m which is developed southwardly from Hiraide, northeast of Tatsuno may be thought to be the surface equivalent to the depositional plane of the Enrei formation.

Tsukue-yama surface: A plain which ranges from 500 to 600 m in height is seen discontinuously on the east side of the Tenryû river in the southern part and is called Tsukue-yama surface. This surface seems to be as same as the Enrei surface. Therefore, in this paper, those surfaces above stated are treated together as "Ina surface" in the lump.

(b) *Takao terrace* (TK)

The Takao terrace is assigned to the fill top terrace consisting of the Takao gravel, but the terrace plain is fairly dissected. This terrace is developed in many places at piedment area in southeast of Tatsuno, at the east of Ina City and also at the middle area. Especially, the distribution of this terrace is well known from following places; the piedmont region on the west side of the Tenryû river in the southern area, upper stream areas of some tributaries such as Matsukawa-(Katagiri), Maezawa-, Tazawa-, Ôjima-, Miyazaki-, Nozoko- and Matsukawa (Iida) rivers. Moreover, in the southern area, this terrace can be classified into two terraces such as TK-1 and TK-2 from the view point of volcano-stratigraphy. The surfaces of both terraces incline commonly with high gradient toward the main course of the Tenryû river. The heights above the sea level and the relative heights from the present river bed are shown in Table 4a.

(c) *Ôizumi terrace* (OZ)

The Ôizumi terrace had been made by the deposition of the Ôizumi gravel which had followed after the partial erosion of the Takao terrace. The terrace is typically developed at the "Rokudohara tableland", west of Ina City, but in many cases, the pattern of the terrace distribution shows some conspicuous feature such as monadnock-like form standing slightly high above the surfaces of younger terraces developed along the Tenryû river (see Appendix Fig.).

The Ôizumi terrace has generally the following characteristics; (1) Surface gradient in E-W profile is less than those of younger terraces, so it may suggest that the stream gradient at the time of Ôizumi gravel deposition might attain to high equilibrium; (2) after the terrace surface were formed, severe undercutting followed succeedingly. The heights above the sea level and the relative heights from the river bed are shown in Table 4b.

(d) *Yokomaya terrace* (YK)

The Yokomaya terrace is composed of the Yokomaya gravel, but generally it indicates the characters of the fill-strath type terrace, namely by the denudation to the Ôizumi terrace pre-existed. The construction of the terrace was completed just before the fall of the Pm-I. The surface gradient is very small in E-W profile, but it is rather larger in N-S profile to compare with that of the present main course of the Tenryû river. Therefore, it is larger than that of the Ôizumi terrace. The distribution of the terrace is limitted as follows; Rokudohara at Ina City in the northern area; Akasu, southeast of Komagane City, and Iijima-machi in the middle area, and Yokomaya, southeast of Nanakubo, Iijima-machi, Ôkusa and Katsura-shima on the west of the Tenryû river in the southern area. The terrace is also found but in small scale at Debara, Takamori-machi in the southern area. The heights above the sea level and the relative heights of the terrace are shown in

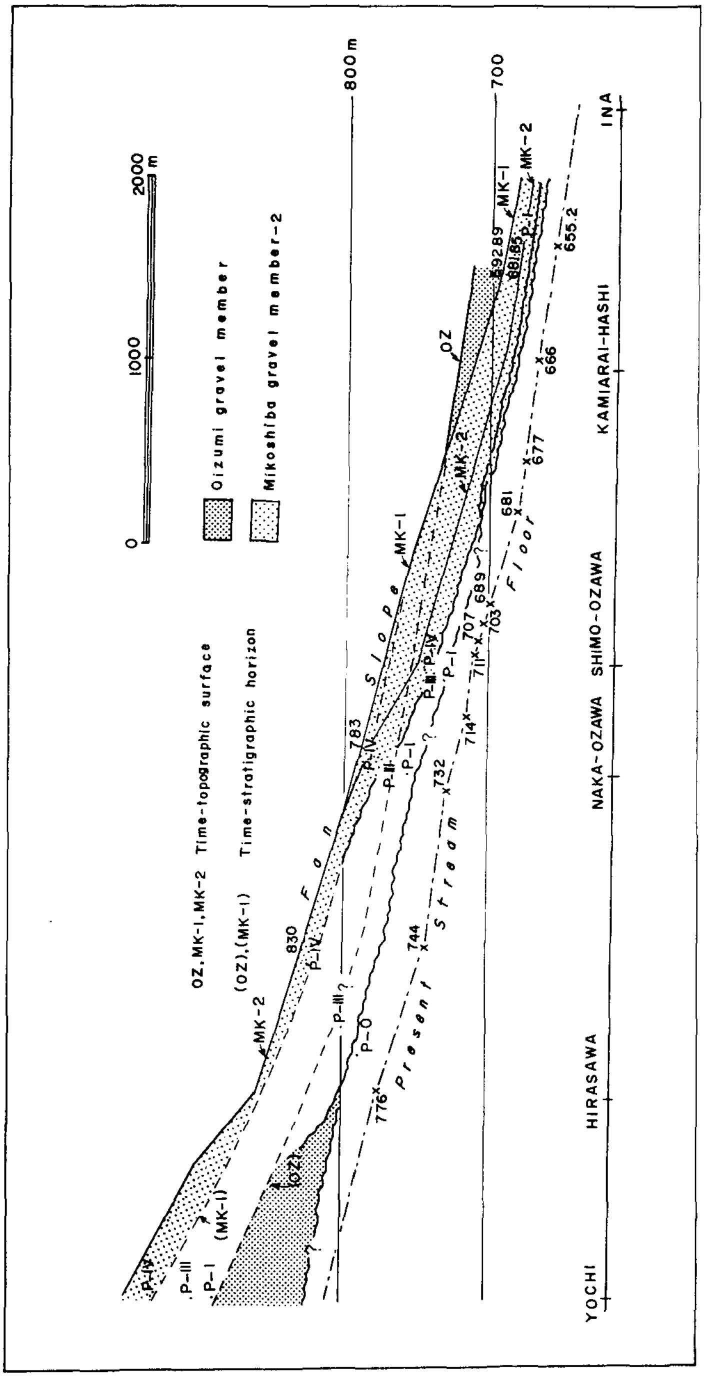

Fig. 11. Profile of the terraces along the Ozawa river.

Table 4c.

(e) *Transitional terrace* (OM)

The transitional terrace between the Ôizumi terrace and the Mikoshiba terrace is clearly distinguishable from those two terraces by the presence of a loam unit ranging from Pm-III to the top of the Younger Loam unit. The distribution of this terrace is strictly limited only at Misono, northwest of Ina City in the northern part. Height of 700 m above the sea level and the relative height of 55 m from the river bed of the Tenryû river are much resemble to those of the Yokomaya terrace.

(f) *Mikoshiba terrace*-1 (MK-1)

The Mikoshiba terrace-1 is composed of the Mikoshiba gravel-1 which followed after the deposition and the denudation of the Ôizumi gravel. The terrace surface highly inclines toward the main course of the Tenryû river, because that formation of the terrace was mainly due to the process of transportation by some tributaries, especially on the west of the Tenryû river. Therefore, the terrace level is higher than those of the Ôizumi and the Yokomaya terraces at piedmont area where the process of deposition was very active, while it is lower than the Ôizumi terrace owing to rapid downcutting in the area near the junction of the main stream course and tributaries. The terrace shows the monadnock-like distribution similar to that of the Ôizumi terrace, and it developed widely throughout whole area in the Ina valley.

The heights above the sea level and the relative heights from river bed are shown in Table 4d.

(g) *Mikoshiba terrace*-2 (MK-2)

The Mikoshiba terrace-2 is composed of the Mikoshiba gravel-2 that succeeded to the Mikoshiba gravel-1. As the terrace was formed mainly by the transportation of tributaries which flow down with right angles to the Tenryû river, the surface profile in E-W direction tends to show high inclination to the main river course. Along the main river course, heights of the terrace is generally lower than those of the Mikoshiba-1- and the Ôizumi terraces, while *vice versa* at the upper stream area of tributeries (viz. piedmont area). Thus, the distribution pattern of this terrace shows typical "terrace crossing topography" (Figs. 10 and 11).

The distribution area of this terrace is the widest among those of others throughout the Ina valley. The heights above the sea level and the relative heights are shown in Table 4e.

(h) *Minamidono terrace* (MD)

The Minamidono terrace is a fill-strath type terrace built by the deposition of the Minamidono gravel which overlie on the Mikoshiba gravel. Surface gradient in E-W profile is smaller than that of the Mikoshiba terrace-2, and also in N-S profile. Generally, the height of this terrace is lower than those of all of above mentioned terraces. The distribution of the terrace is limited only in narrow area along tributaries of the Tenryû river. The heights above the sea level and the relative heights are shown in Table 4f.

(i) *Kinoshita terrace*-1 (KS-1)

The terrace which is covered by the upper part of the Younger Loam is composed of Kinoshita gravel-1. Its surface has been highly flat and so the gradients in both longitudinal and transverse profiles are commonly very small. The terrace is distributed along the main course of the Tenryû river and its tributary streams. The heights above the sea level and the relative heights are shown in Table 4g.

(j) *Kinoshita terrace*-2 (KS-2)

The terrace is a fill-top type terrace of the Kinoshita gravel-2, and its surface is covered by the uppermost part of the Younger Loam. The surface has been highly flattened as same as the KS-1, and this terrace is the lowest among those terraces above mentioned. It is distributed along the Tenryû river and its tributary streams. The heights above the sea level and the relative heights are also shown in Table 4g.

(k) *Kinoshita terrace*-3 (KS-3)

It is a fill-top type terrace of the Kinoshita gravel-3, and is covered only a layer of humus of which the lower part consists of loamy material or sandy loam. Its surface is also highly flattened as same as KS-1 and KS-2. It develops along the Tenryû river and its tributaries, but it shows some various developmental stages from place to place. It develops rather widely at Kinoshita, Minowa-machi in northern area; Miyata-mura in the middle area, Iinuma, Kamisato-mura in the southern area. The heights above the sea level and the relative heights are also shown in Table 4g.

Late Pleistocene Glaciation in the Kiso Mountains (Central Japan Alps)

Regarding to the glaciation in the Kiso mountains, it must be mentioned that the first study was the recognition of some cirques near the summit of that mountains (IMAMURA; 1937, 1940). Later, topographical and tephrochronological studies were done by KOBAYASHI (1957, 1958), SHIMIZU (1962), KOBAYASHI and SHIMIZU (1962, 1966) and SHIMIZU and KOBAYASHI (1966). Distribution of the glaciated areas in the Kiso mountains are shown in Fig. 13, and on the other hand, the

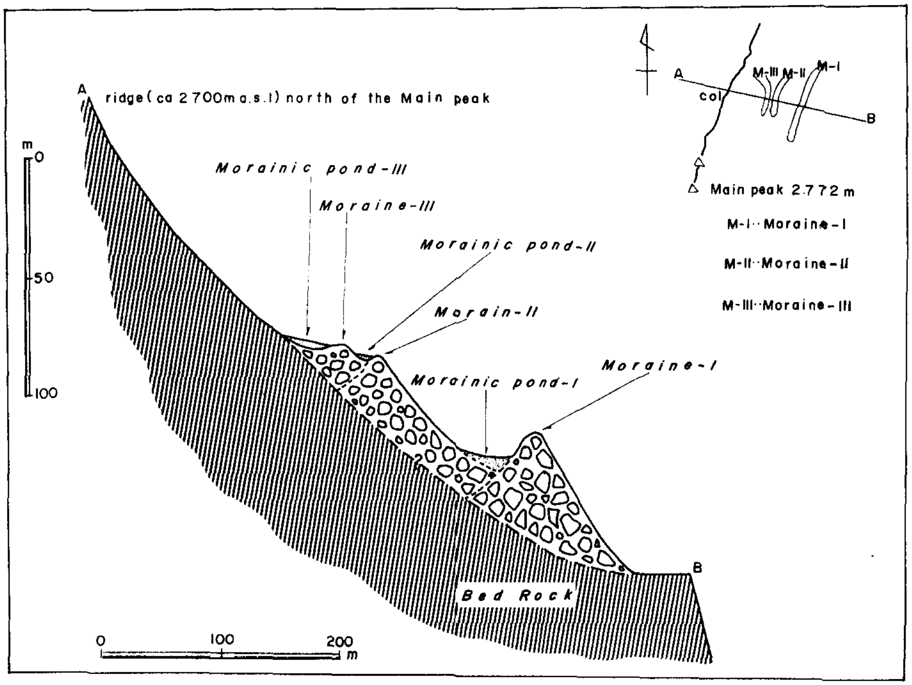

Fig. 12. Profile of the Kumazawa cirque.

numbers of the moraines, and the heights above sea level of the cirques floor and the moraines are listed in Table 5. It has been reported that the "Hata Loam" (equivalent to the Younger Loam in the Ina valley) covers on the moraines and the cirque floors at Nôgaike and Senjôjiki (1 and 3 in Fig. 13). And also aeolian pumice Pm-I of the Middle Loam unit has been known at 8 m west of the Miyata Hut near the ridge of Mt. Komagatake.

According to KOBAYASHI (1958), the maximal phase of the glaciation (Koma gracial-I) was immediately followed by the recession (Koma glacial-II). His conclusion was mainly based upon the analysis of moraines and the relation to the stratigraphy of the loam unit in the cirques of Nôgaike and Senjôjiki. Similar result has been known from the cirque on Mt. Arakawa Higashi in the Akaishi mountains, as shown in Table 6 (KOBAYASHI, YAMADA and SHIMIZU, 1964).

In consideration of those results, the author tried to define the maximal phase of the glaciation at the Kumazawa cirque (Fig. 12) which locates on the northeast of the peak of Mt. Kumazawa-dake (SHIMIZU, KOBAYASHI and SHIBUYA 1965). For this cirque, IMAMURA (1937) has already given the name "Ikenotaira cirque", but his recognition was slightly differ from the author's definition.

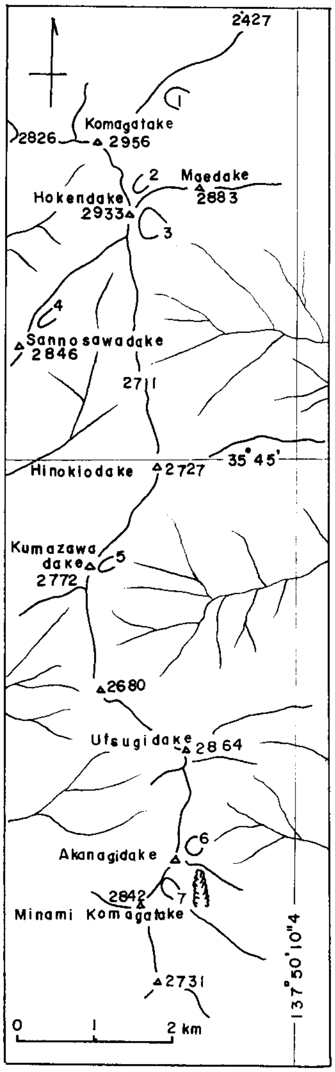

Fig. 13. Glacial remains in the Kiso mountains.

1; Nôgaike cirque.
2; Komakai cirque.
3; Senjôjiki cirque.
4; Sannosawa cirque.
5; Kumazawa cirque.
6; Akanagi cirque.
7; Suribachikubo cirque.

There are three moraines in the Kumazawa cirque as shown in Fig. 14, named as the Moraine-I, -II and -III from lower to upper. All of those moraines are covered by a part of the Younger Loam. The Moraine-I is situated at about 2,500 m above the sea level, and at present, it is within the range of the *Betula ermanii* zone of the alpine vegetation.

Both the moraine-I of the maximal glacier extension and the moraine-II are comparatively large in scale. There are morainic ponds between each moraines,

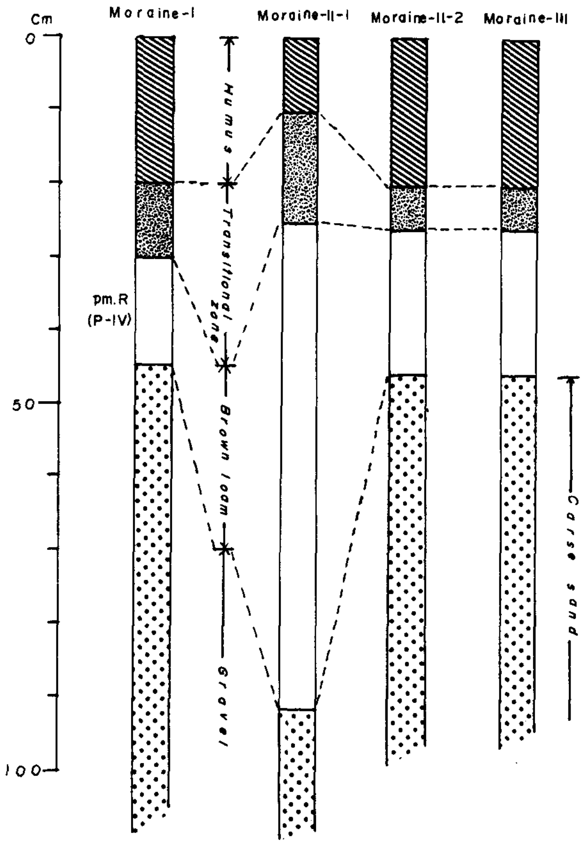

Fig. 14. Sections of the Shinshû Loam on the moraines in the Kumazawa cirque. Pm; pumice. R; red loam. P-IV; pumice fall of the Ontake.

but usually a little water except a temporary stagnation. The relative heights of the Moraine-I is 58 m from the floor, and that of the Moraine-II is 40 m. The horizontal distance between them is 117.7 m, while the distance between the Moraine-II and the Moraine-III is 31.2 m. Such a distance between the Moraine-I and the Moraine-II suggests that there was a long interval between the formation of both moraines. The Moraine-III would be formed during the short time after the recession above mentioned and it is located about 100 m apart from the lowest "col" of cirque-wall.

At present, the moraines in the Kiso mountains situate in the upper part of the forest zone, but the thickness of covering tephra on them seems to be rather large, e.g. that of the Moraine-II attains as thick as 60 cm. (Fig. 14). As for the mineral

Table 5. Heights of cirque floors and moraines in the Kiso mountain range above the sea-level.

Cirque	Altitude of floor	Moraine-I	Moraine-II	Moraine-III
Nôga-ike	2,700 m	2,540 m	2,670 m	—
Komakai-no-ike	2,750 m	—	—	—
Senjôjiki	2,650 m	2,657 m	—	—
Sanno-sawa-dake	2,600 m	2,612 m	—	—
Kumazawa-dake	2,490 m	2,500 m	2,530 m	2,555 m
Suribachi-kubo	2,600 m	2,610 m	—	—

Table 6. Heights of glaciated scoured surface and the moraines in the Akaishi mountains above the sea-level.

Moraine and scoured surface	Height above the sea-level
Scoured surface	2,590 m
I moraine	2,670 m
II moraine	2,845 m
III moraine of central cirque	2,830 m

Table 7. Heavy mineral composition of tephra on the moraines of the Kumazawa cirque.

Sample	Hornb.	Aug.	Hyp.	Oliv.	Mag.	Others	%
Pumice fall on the Moraine-I	10.7	17.7	28.8	0.5	40.0	2.3	100.0
Loam on the Morain-I	16.1	5.5	18.6	—	56.2	3.8	100.2
Loam on the Morain-II		Aug.	<Hyp.	>Mag.			

composition of the tephra layer, the Moraine-III is characterized by the mixing of considerable quantities of exotic materials. Loam and pumice layer on the Moraine-I is 15 cm in thickness and it contains unquetionable Pm-IV. The heavy mineral compositions of those tephra are shown in Table 7 for comparison.

Tephra deposits on high mountains such as those in the cirques of Senjôjiki and Nôgaike are generally impure owing to wind and frost actions of mixing up with exotic materials. In spite of such impure state, the tephra covering on the Moraine-II is characterized by the presence of abundant hypersthene crystals. This suggests the possibility that the tephra in question belongs to the upper part of the Younger Loam or the upper part of the Middle Loam. At the same time, the presence of fresh glass grains in this tephra indicates also one of the characteristics of the Younger Loam. Therefore, the tephra unit on the Moraine-II can be correlative to the upper part of the Younger Loam without any doubt.

It is also known that there is a loam layer containing some pumice grains on

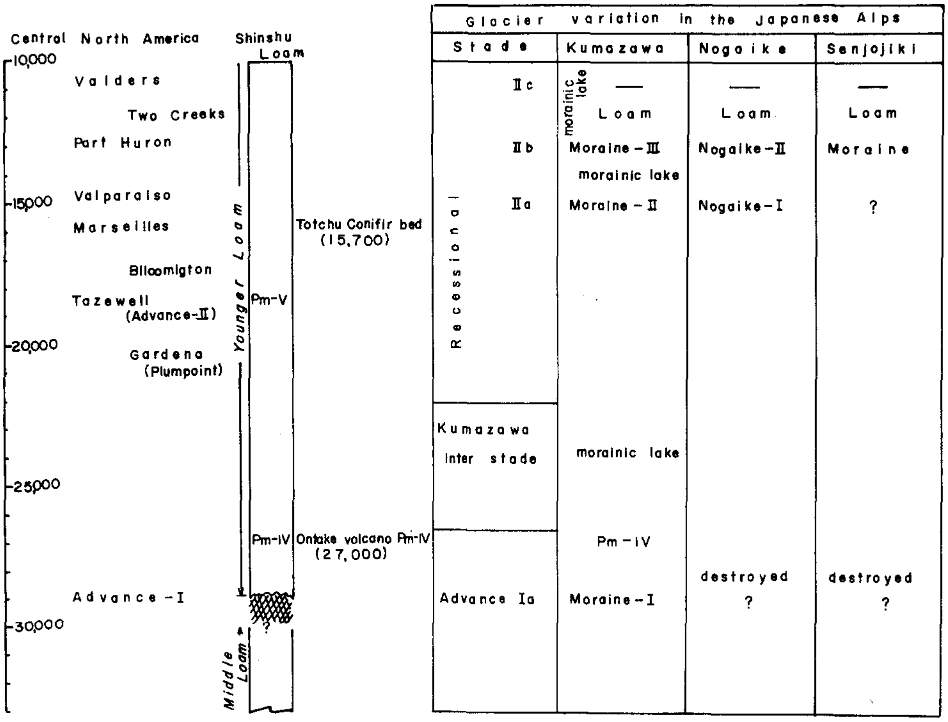

Fig. 15. Correlation with Central North America.

the Moraine-I. As these pumice grains are reddish brown in color and as large as the finger tip, it is evident that they are easily identified with Pm-IV. Moreover, the distribution pattern of each pumice bed cited before (Fig. 7) and their heavy mineral composition may assist this conclusion (Table 7).

The distribution of Pm-IV covers the area within the distance of more than 100 km toward the east from the source area. Its maximal thickness attains to 60 cm in the Ina valley, and it is evident that this pumice fall is the product which had common genesis of the Kisogawa volcanic mudflow in the Kiso valley. Besides them, it may be possible to say that the lowest horizon of tephra on the Moraine-I is equivalent to the lower part of the Younger Loam unit and that on the Moraine-II is the upper part of the Younger Loam unit.

A wood remains taken from the Kisogawa volcanic mudflow has been dated to be 26,600±1,600 ^{14}C yrs. B. P. (Gak-240 a) and 27,800±2,000 ^{14}C yrs. B.P. (Gak-204 b) respectively (Q. R. G. K. V. & KIGOSHI 1964). This Carbon-isotope ages indicates that the date of the Kisogawa mudflow is roughly coincide with the interstadial stage of the Latest Pleistocene glaciation in Europe and America, that is, the "Farmdalian" interstadial in fluctuation of Michigan glacial lobe in North American (FRYE and WILMAN 1960, 1965) and "Paudorfer interstadial" in northern Europe (GROSS 1964).

Meanwhile, a wood from the Totchû conifer bed which corespond to the upper part of the Younger Loam unit overlying on the Moraine-II was dated as 15,750 ± 390 ^{14}C yrs. B.P. (KOBAYASHI 1965). Furthermore, SAKAI (1963) pointed out that the Pm-V horizon may be correlative to the glaciation in the Kiso mountains, because a marked involution referable to cryoturbation was found at the horizon of Pm-V in the Kiso valley.

In addition to them, the occurrence of cold climate plant remains, such as *Menyanthes* etc. was reported from the Pm-III horizon (KOBAYASHI and SHIMIZU, 1965). And also fossil teeth of *Bison* were found from pale brownish loam layer just bellow Pm-III (SHIMIZU, KAMEI and KOBAYASHI, 1966). Based on the evidences mentioned above, it is possible to say that the date of the Moraine-I of the maximal glaciation was c.a. 30,000 yrs. B.P., and that of the Moraine-II was c.a. 15,000 yrs. B.P. Consequently, the name of the Kiso glacial stage is given to the time duration of the glacial advance and retreat represented by the Moraine-I, -II and -III, and furthermore, this glacial stage is divided into three substages such as I, II and III by means of the position of those morains. Accordingly, in this paper, the Koma glacial I and II of KOBAYASHI (1957) seems to correspond respectively to the Kiso glacial II and III of the author.

It has been known that one of the maximal advance of glacier during the Würm glacial was dated as ca. 18,000 yrs. B. P. (GROSS, 1964). In North America, the Tazewell stage is c.a. 19,000 yrs. B.P., and "the advance of glacier I" that was dated as c.a. 29,000 yrs. B.P. has been known from Central North America (LEMKE et al., 1965). Therefore, it is possible to say that the Kiso glacial I represented by the Moraine-I is correlative with "the advance of glacier I" in Central North America. Furthermore, it is also able to correlate the age of the moraine-II with the "Marseilles" in Central North America and slightly younger than the age of the Totchû conifer bed. Considering from the thickness of covering tephra, the Moraine-III of Mt. Kumazawa and the moraines in the cirques of Senjôjiki and Nôgaike would be formed during the latest stage of the glaciation. Those considerations are summed up and illustrated in Fig. 12 and 15.

As already mentioned, the Moraine-I which is overlain by the pumice bed of Pm-IV is considered to be the product of the maximal phase of the glaciation in the Kiso mountains. On the other hand, it is important to note that the same pumice bed overlie on the Mikoshiba terrace-I as water- and or air-laid deposits, while that is known as waterlaid deposits in gravels in the case of the Mikoshiba terrace-2. In addition to them, it must be recalled that these two terraces have the widest distribution in the Ina valley. Anyhow, it will be assumed that such abnormal event as the deposition of vast materials was contemporaneous with the maximal advance of the glacier in the Kiso mountains. Moreover, as stated precedingly, it is important to remember that both of those two Mikoshiba terraces reveal together a peculiar crossing topography with the Ôizumi terrace in longitudinal profile along tributary streams (Fig. 11). Therefore, it is reasonable to assumed that such peculiar feature of terrace crossing was the product under physical condition during the Kiso glacial stage.

Formation of terraces in the Ina valley

The Takao terrace group

The Takao gravel filled the pre-existed valley in which the Ina formation of the basement had been partly carved. Therefore, the Takao terrace was originally a fill-terrace. Generally, gravel beds of that terrace inclines toward the main river course of the Tenryû river and the marginal cliffs of those terraces show alignment nearly in a straight line. So, it may be evident that those terraces were influenced by some crustal movements after the formation. The height difference between the Takao terrace plane and the Ôizumi terrace plain of the younger is 100 m in the northern area, 150 m in the middle area, and 218 m in the southern area. Such variation of the value may reveal the results of differential movement after the formation of the Takao terrace.

The Tsukueyama surface developing 650 m to 700 m above the sea level on the east of the Tenryû river in the southern area is considered to be a part of the fill-top surface of the Ina formation. Although this surface is heavily dissected, it inclines with high gradients towards the main stream to the west. The Ina formation is the fresh-water sediments which deposited evenly on flat basement floor during Latest Tertiary to Early Quaternary. But now, the Ina formation has the dip of 10° to 20° to west or northwest, and in the southern area, there are some structural disturbances and some minor faults thrusting up to the west. These structures show westward tilting accompanied with faults after the deposition. It has been known that the crustal movement of this kind had continued to the time of the Takao gravel deposition.

As precedingly mentioned, the Takao terrace is the oldest terrace, and it is characteristic that this terrace is overlain by red soil layer and the gravels which are highly decayed. But it is still obscure how the climatic condition during the deposition of the Takao gravel was. In the southern area, there is the evidence of denudation after the depositional phase of the Ina formation and before that of the Takao gravel. Furthermore, the height of the fill-top surface of the Ina formation increases southwardly. Therefore, it may be assumed that

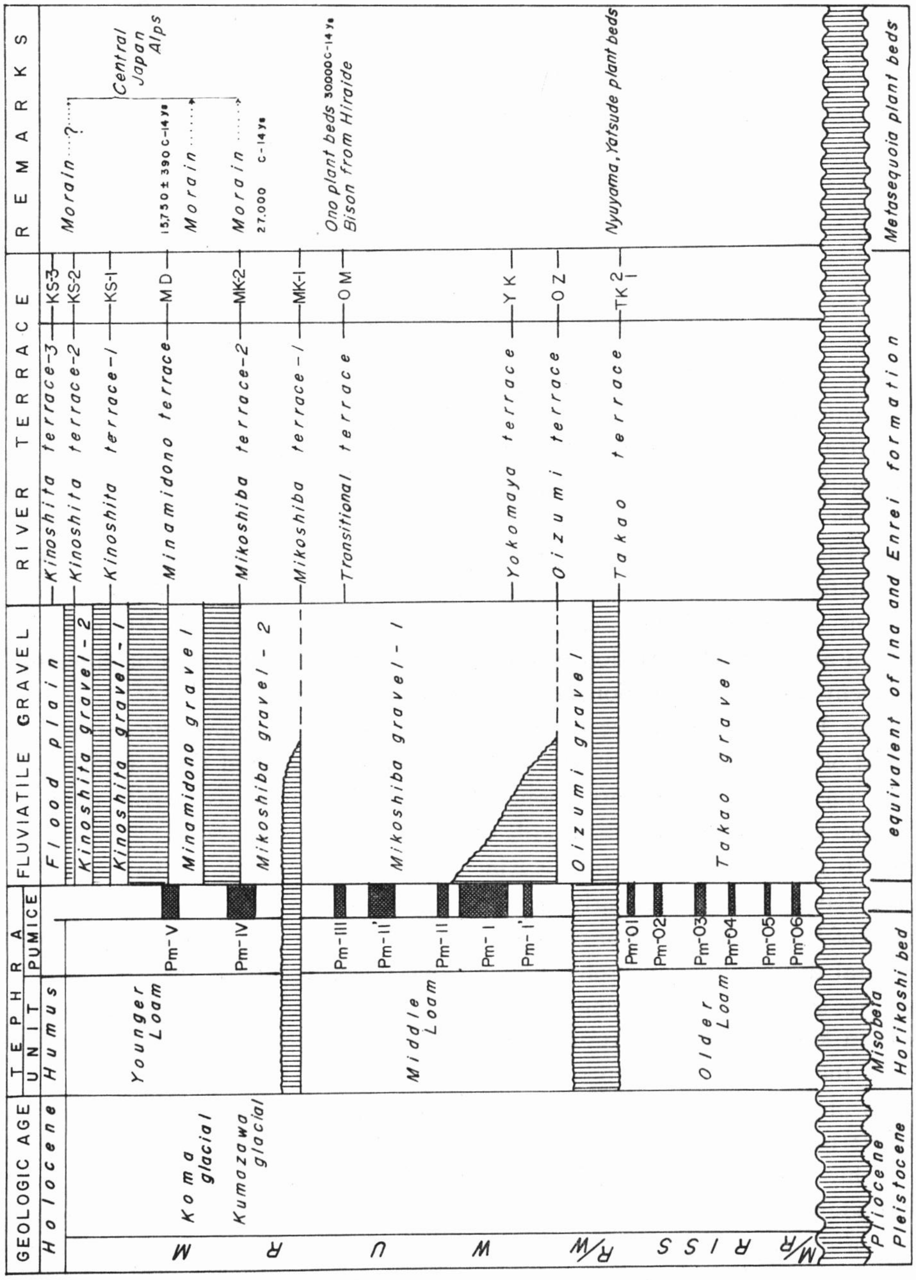

Fig. 16. Pleistocene geohistory in the Ina valley.

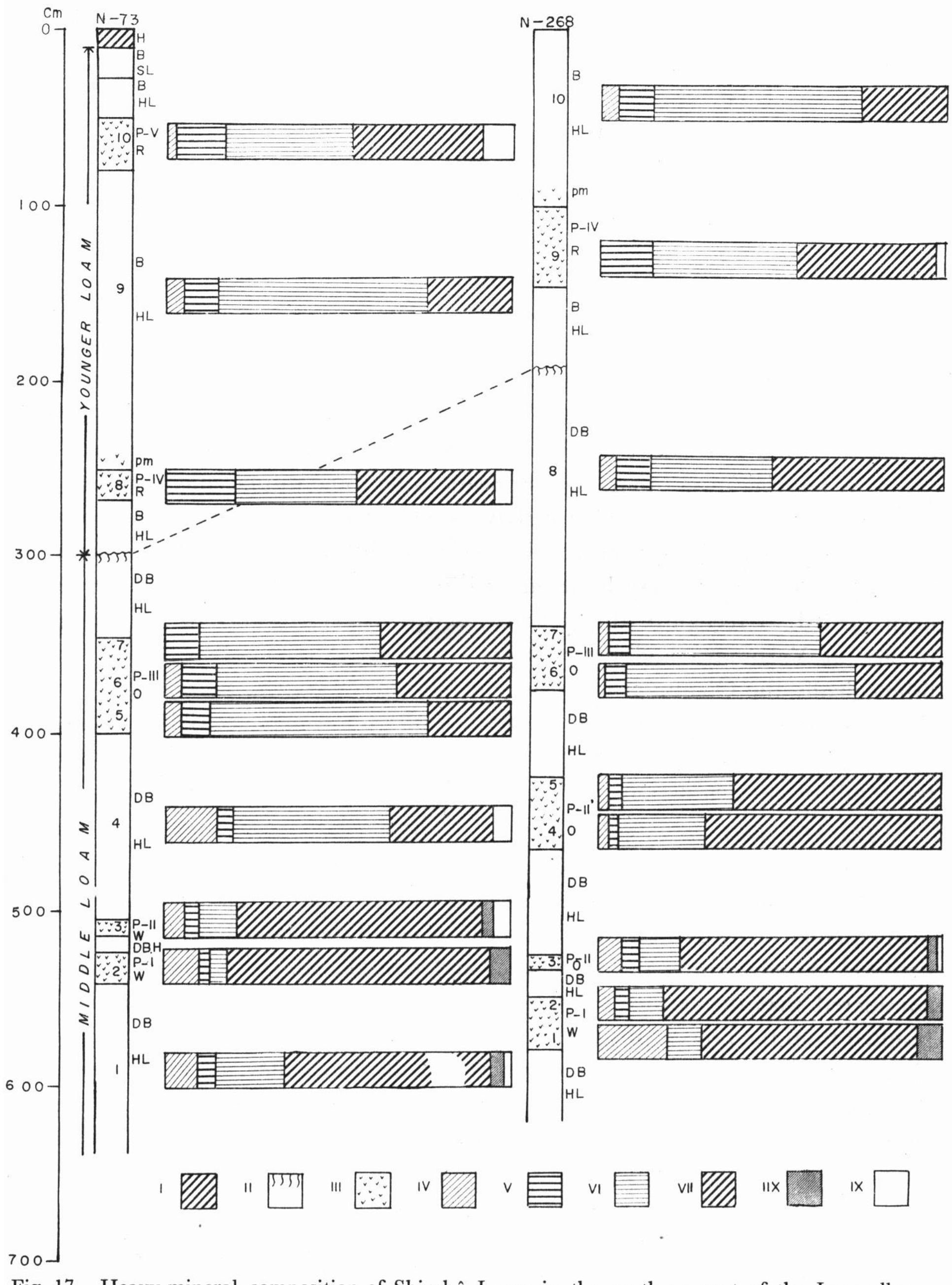

Fig. 17. Heavy mineral composition of Shinshû Loam in the northern part of the Ina valley. I; humus. II; plant remains. III; pumice. IV; hornblend. V; augite. VI; hyperthene. VII; magnetite. VIII; zircon. IX; other minerals.

there was subsiding in the upper-stream area of Iida City. Nevertheless, the height from the base of the Takao gravel to the Tsukueyama surface is very large and the Takao gravel indicates the stage of a vast accumulation throughout the Ina valley. Consequently, it is evident that such process had proceeded mainly under the influence of tectonic control, but it is very difficult to estimate the relation between the sedimentation and the climatic condition of those days.

The Ôizumi terrace group

The Ôizumi gravel overlies unconformably on the Takao gravel and has made the Ôizumi terrace of fill-strath type. The surface of this terrace has rather gentle gradient to compare with that of the present river floor of the Tenryû. In the southern part of the Ina valley, the Ôizumi gravel has a considerable thickness, and it may be assumed that the accumulation of this gravel had been influenced by some crustal movement continued from the time of the Takao gravel.

It is possible to say that there appears to be some displacement causing fault movement, as there is no evidence that the height difference between the Ôizumi terrace and the Yokomaya terrace situated in slightly lower than the former seems to indicate a long time gap between both terrace formation. For instance, it has been denied to recognize the presence of the Ôizumi gravel in the Yokomaya terrace at Yokomaya and its environs. Namely, it is very hard to distinguish lithologically the Ôizumi gravel from the Yokomaya gravel, but also there is only slight difference in the mode of occurrence of tephra layer overlying both gravel beds. This indicates that the height difference between both terraces may due to the result of faulting action.

The Mikoshiba terrace group

It is peculiar that the longitudinal profile of the Mikoshiba terrace-1 along tributary system in the Ina valley intersects with that of the Ôizumi terrace. Such phenomenon of terrace crossing has been generally explained in connection with sea-level change during the pre-glacial and post-glacial. NAKAGAWA (1961) also considered that the terrace crossing in some coastal districts of Japan had been resulted from the process of accumulation and denudation controlled by the eustatic changes. But, as for the case recognized in the Ina valley, one may need some different explanation, because those terraces have been escaped far from the process in the coastal region. Nevertheless, it must be recognized that there is an analogy with which BAULIG (1935) called his attention. At first, the accumulation starts to set the debris at the apex of the fan, but as down-cut erosion proceeds, the down stream side of the tributary attains to have steep gradient to make corssing terrace. Regarding to the Mikoshiba terrace in fact, the followings are enumerated.

(1) Supply of debris from high mountains might always surpassed the abrasion at the upper stream of tributaries.

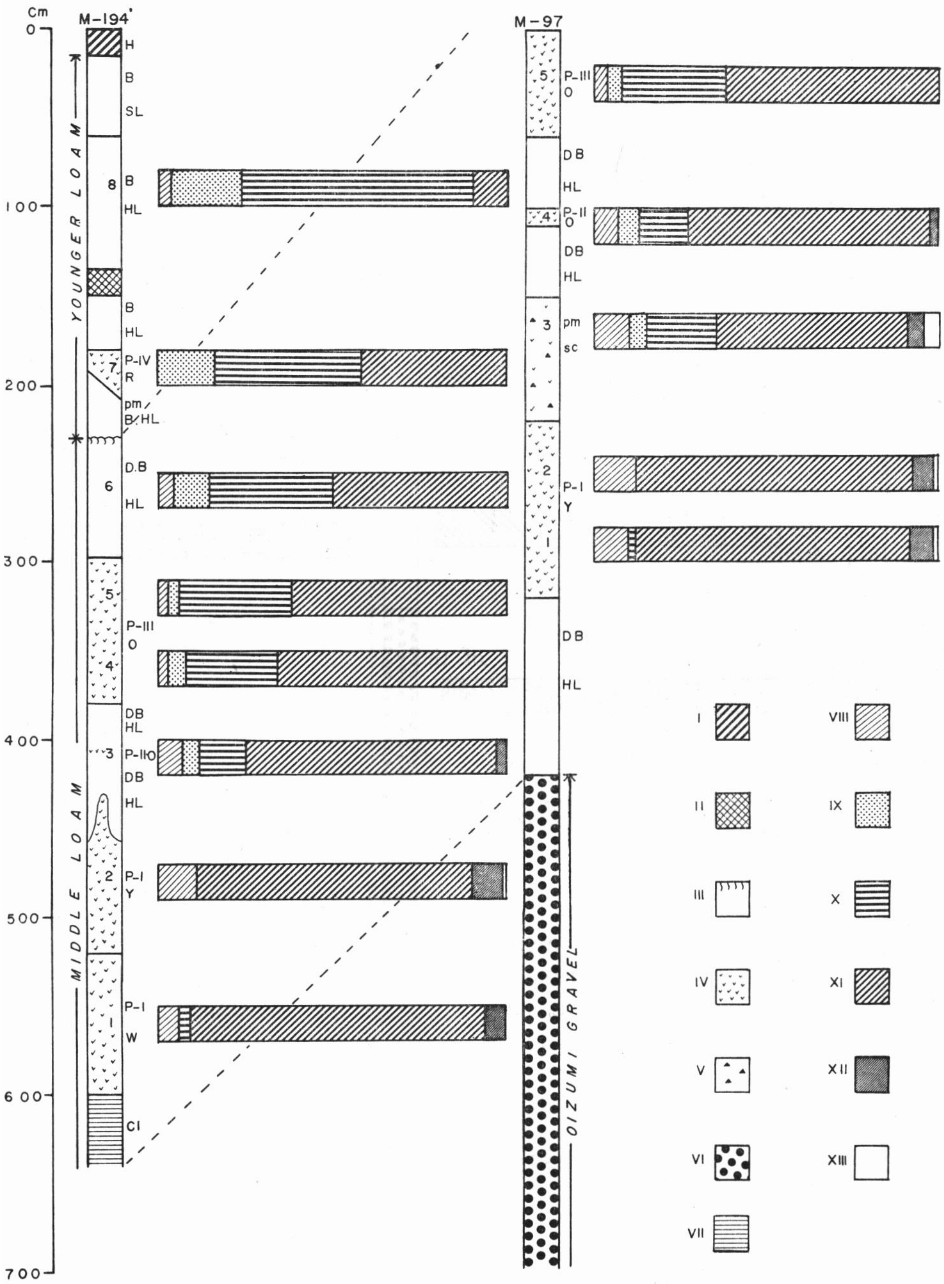

Fig. 18. Heavy mineral composition of Shinshû Loam in the middle part of the Ina valley. I; humus. II; dark band. III; plant remains. IV; pumice. V; scoria. VI; gravel. VII; clay. VIII; hornblend. IX; augite. X; hypersthene. XI; magnetite. XII; zircon. XIII; other minerals.

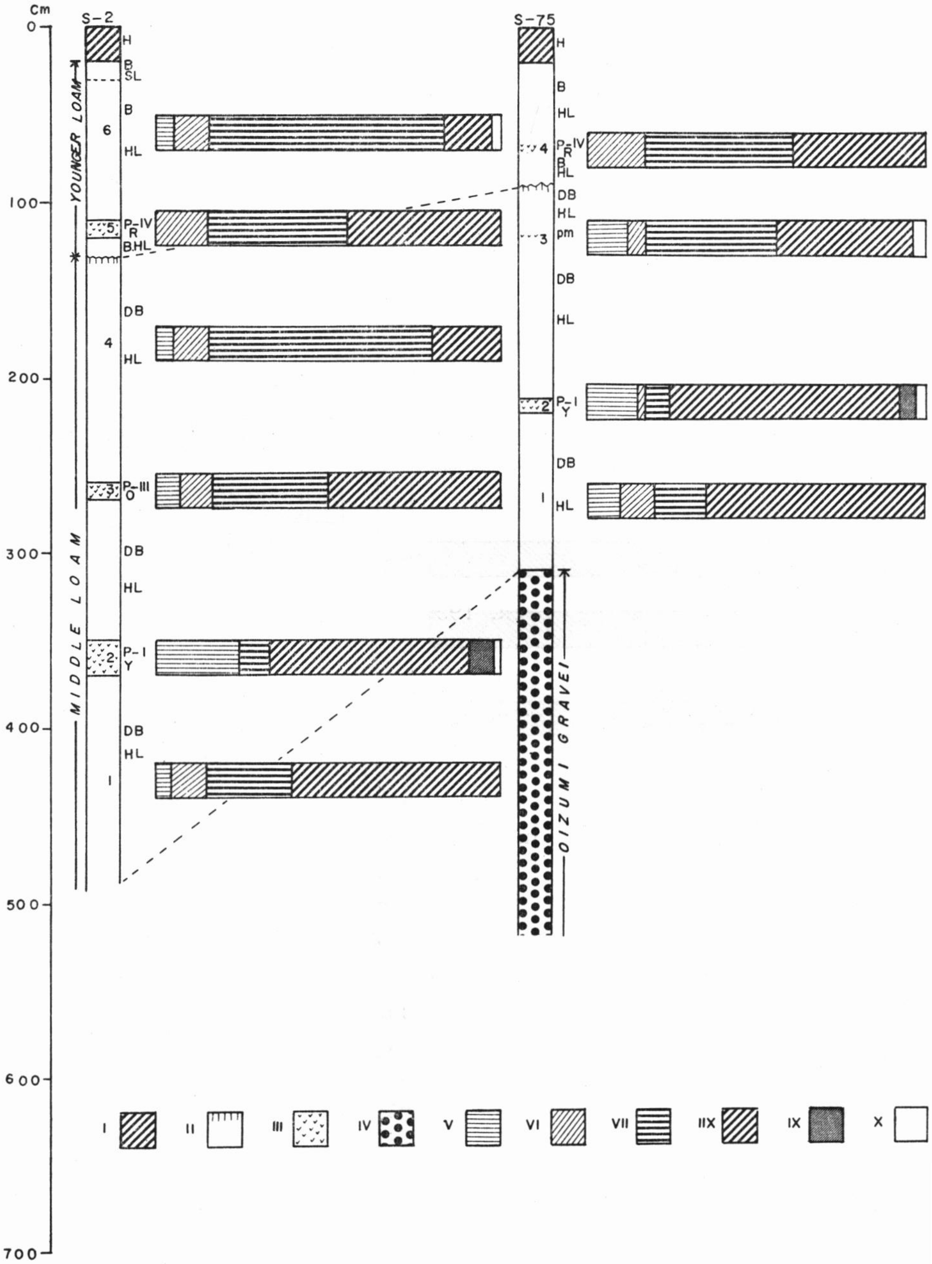

Fig. 19. Heavy mineral composition of Shinshû Loam in the southern part of the Ina valley. I;humus. II; cracky zone. III; pumice. IV; gravels. V; hornblend. VI; augite. VII; hypersthene. VIII; magnetite. IX; zircon. X; other minerals.

(2) In the area neighbouring to the vomitory from source area in high mountains, the supply of debris might continue without interruption from the depositional stage of the Ôizumi gravel to the Mikoshiba gravel-2. On the other hand, in the down stream side of tributaries, the floor level might fall down from time to time intermittently.

(3) The age of the Ôizumi gravel deposition is confirmed to be the time ranging from the beginning of Riss-Würm interglacial to the middle of Würm gracial, before Würm II. Namely, it corresponds to the time before the middle moraine in the Kiso mountain range. Succeedingly, the down-cut erosion of the Mikoshiba-I terrace in down stream of the tributary system might be followed by the time of the lower moraine. Therefore, it is possible to take into account that the deposition of the Mikoshiba gravel-2 and the advance of the glacier represented by the lower moraine coincide with each other. As a conclusion deduced, it is probable to say that the date of the lowest moraine and that of the Mikoshiba gravel-1 are correlative.

(4) Some workers, have considered that usually in the periglacial are, the supply of debris became to increase to be associated with the descent of the forest zone during the glacial age (ZEUNER, 1959). Similar phenomenon in the non-glaciated area was also reported by BÜDEL (1944). Therefore, it may be natural to define that the Mikoshiba gravel-1 and -2 which had incorporation with the formation of crossing terrace might be the products of the glacier advance.

The Minamodono terrace group

There is no superposition of the Minamidono terrace surface to other older surfaces even at apical portion of fan. So, it seems that there was a interval of the supply of debris. Namely, following to the formation of the Mikoshiba gravel, severe down-cut erosion might proceed throughout the Ina valley. During that process, however, there were some construction of terraces, like as the Minamidono terrace with covering gravel veneer. On the other hand, in the northern area, the pre-existed Takao and Ôizumi gravels had been mostly eroded out, and instead of them, thick (about 10 m) deposits had formed the fan, of which relative height above the Kinoshita terrace of the younger is 5–18 m in the northern area, 30–50 m in the middle area and 40–65 m in the southern area.

The process of down-cut erosion after the formation of the Minamidono terrace might advance toward the south according to such factors as follows (1) regional differences of tectonic movement; (2) degree of down-cut erosion relating to the amount of running water (LEOPOLD, 1953). The longitudinal profile of terrace in the Ina valley generally shows a divergent appearence, like as crossing of terraces as already mentioned. This seems to be resulted from the characters of the main course of the Tenryû river which had variable amounts of running water (generally

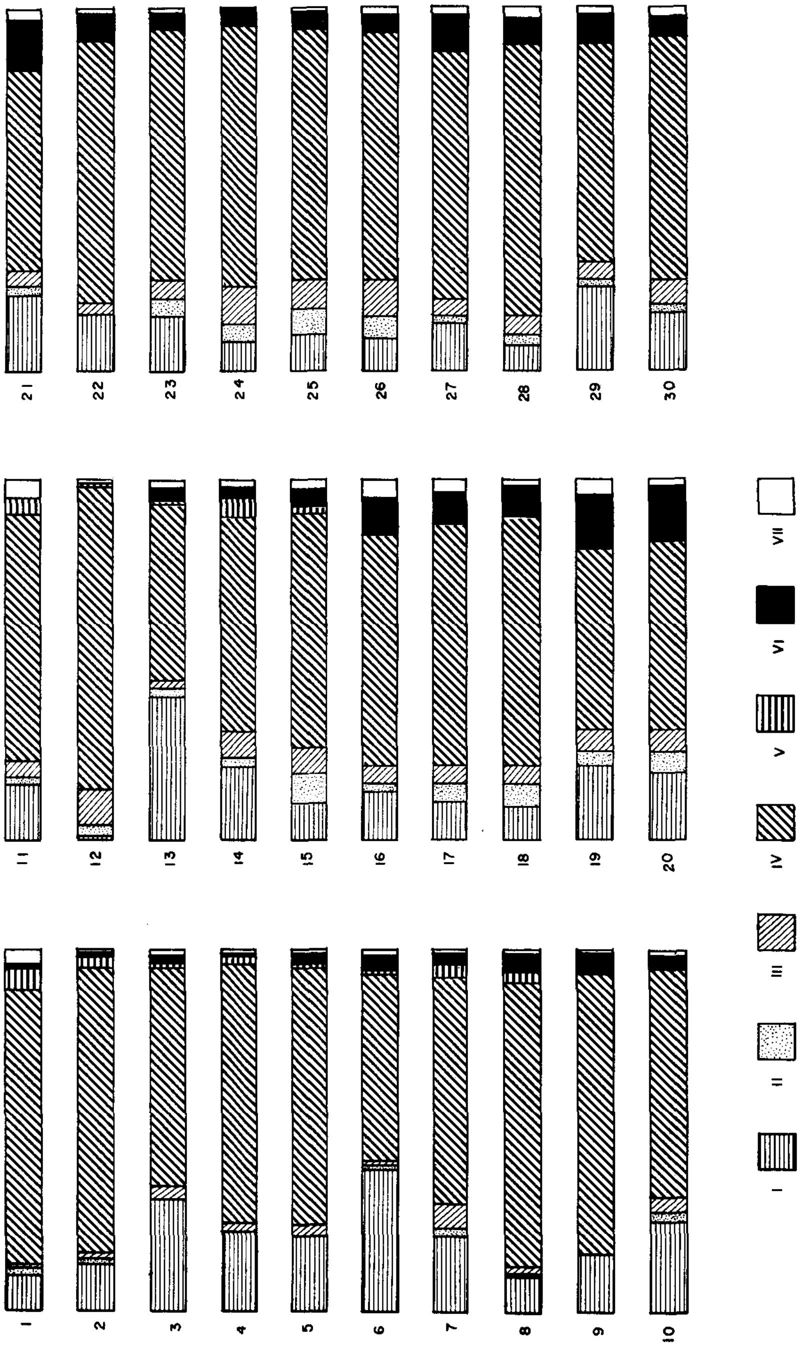

Fig. 20. Heavy mineral composition of Pm-I in the South Kanto plain and in the Ina valley. I; hornblend. II; augite. III; hypersthene. IV; magnetite. VI; zircon. VII; other minerals. 1,2,10,11; Shimosueyoshi. 3; Tsurumi. 4; Terao. 5; Takao. 6, 7, 8, 9; Uenohara. 10; Sagamigawa. 13; Hino. 14; Kiyosato. 15; Kofu. 16,30; Ina valley.

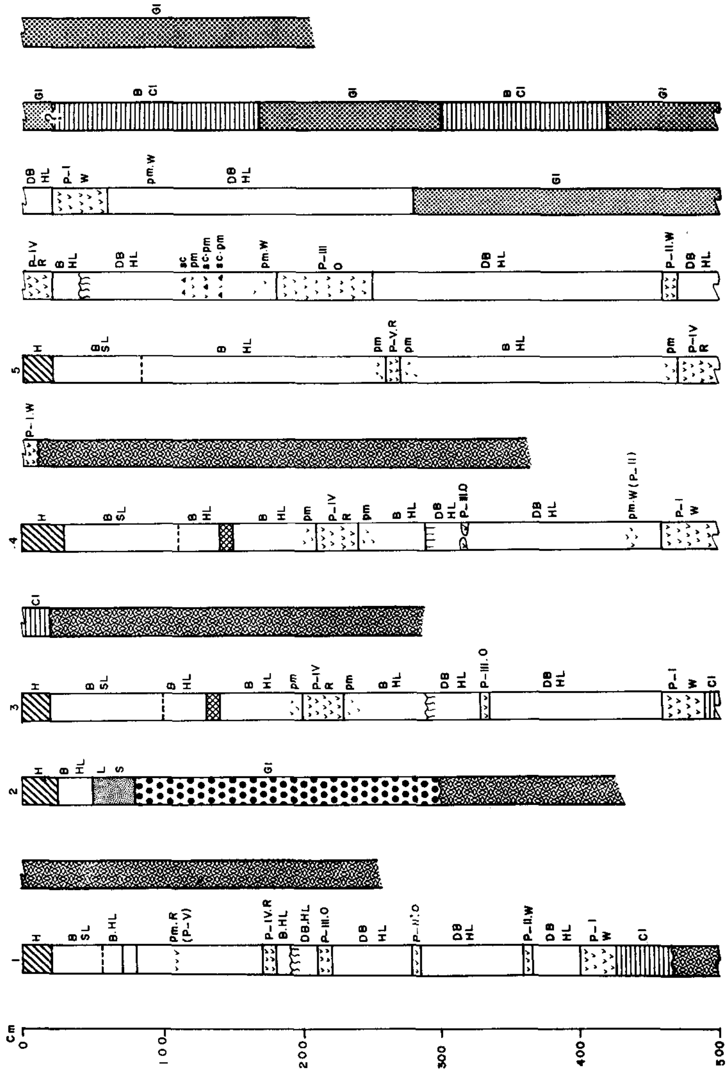

Fig. 21a. Columnar sections of the Quaternary deposits in the northern part of the Ina valley. 1; Locality N-39. 2; Locality N-73. 4; Locality N-81. Abbreviations and symbols are explained in p. 53.

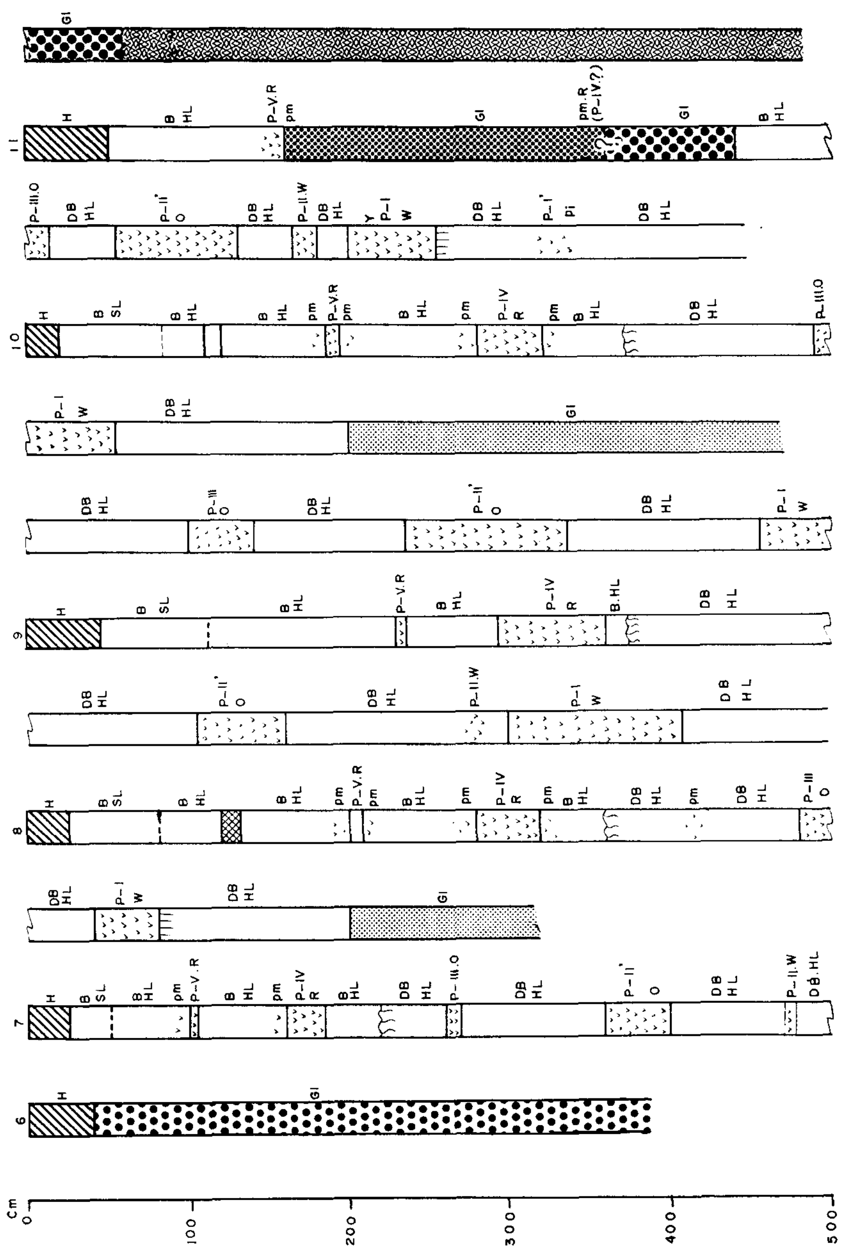

Fig. 21b. Columnar sections of the Quaternary deposits in the northern part of the Ina valley. 6; Locality N-136. 7; Locality N-163. 8; Locality N-215. 9; Locality N-225. 10; Locality N-228. 11; Locality N-230. Abbreviations and symbols are explained in p. 53.

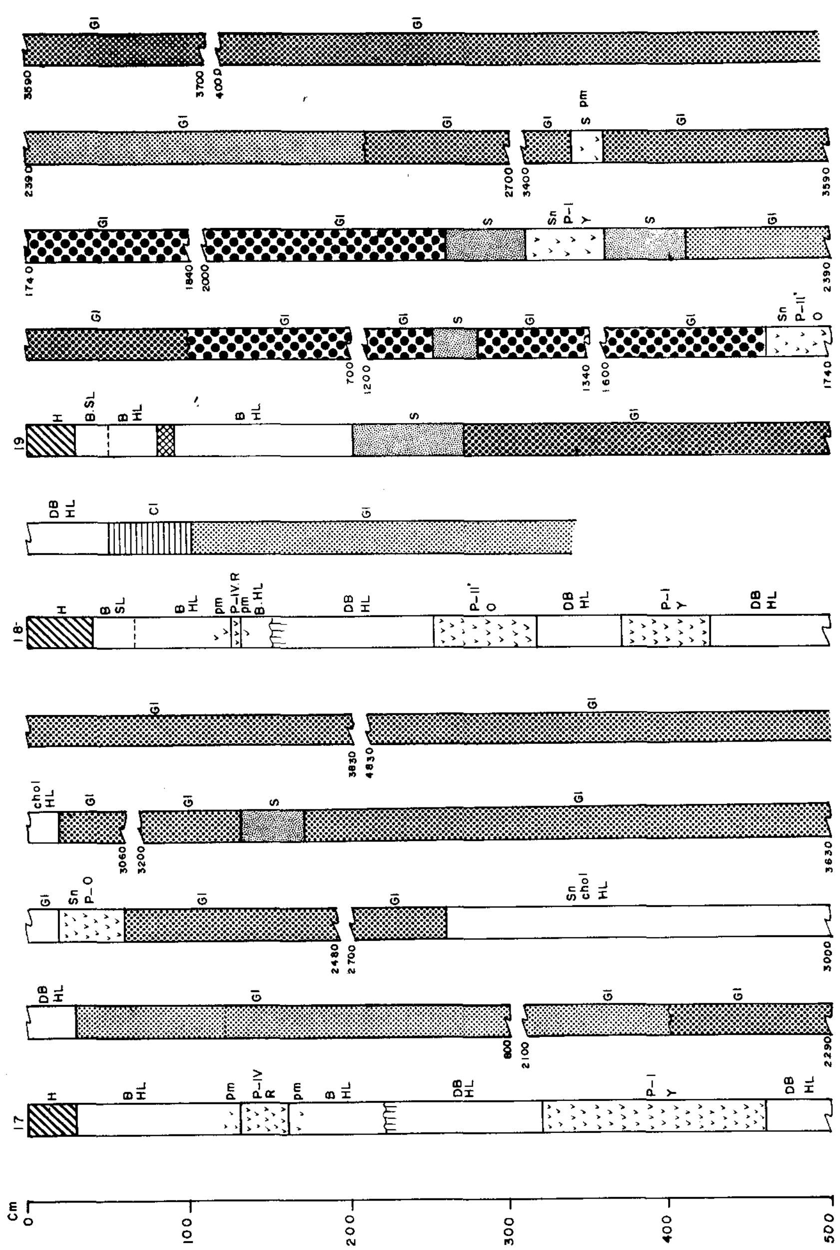

Fig. 22a. Columnar sections of the Quaternary deposits in the middle part of the Ina valley. 17; Locality M-120 (south of Komagane). 18; Locality M-152 (south of Iijima). 19; Locality M-155 (ditto). Abbreviations and symbols are explained in p. 53.

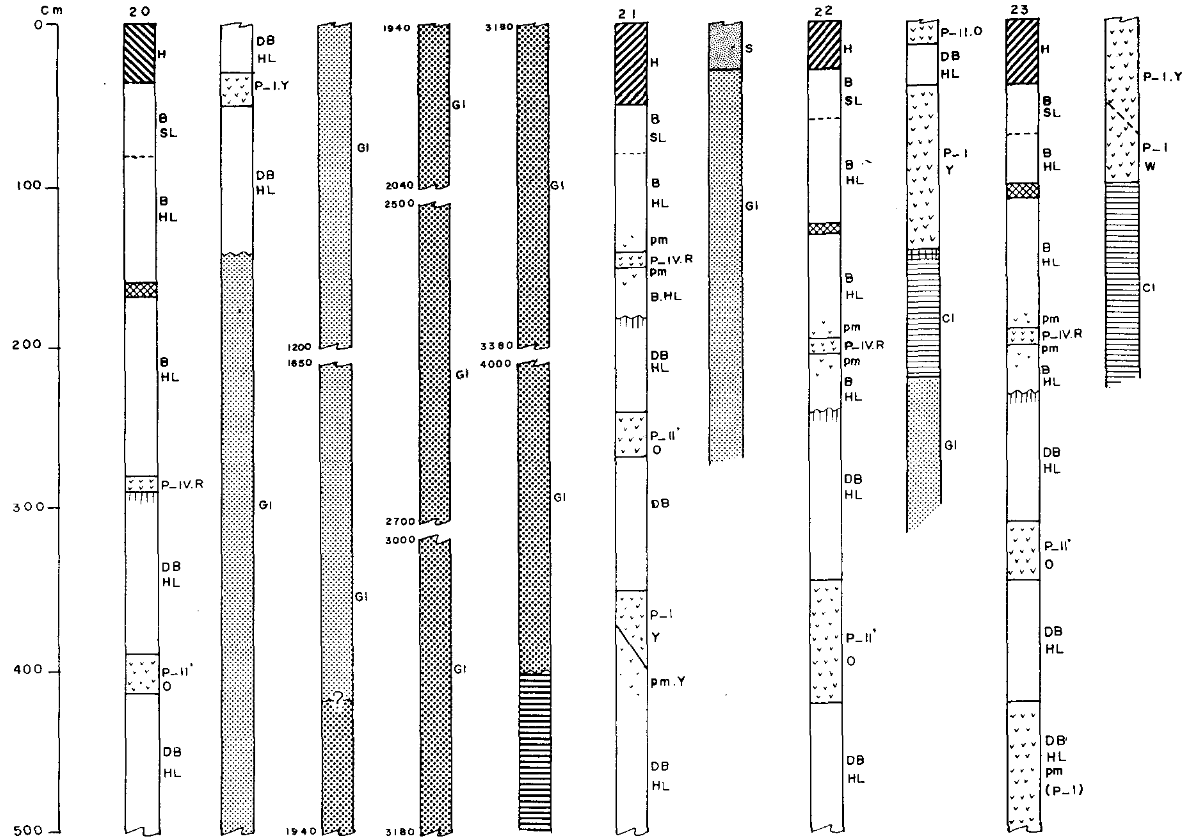

Fig. 22b. Columnar sections of the Quaternary deposits in the middle part of the Ina valley. 20; Locality M-158. 21; Locality M-172. 22; Locality M-192. 23; Locality M-194. Abbreviations ansd Ssymbols are explained in p. 53.

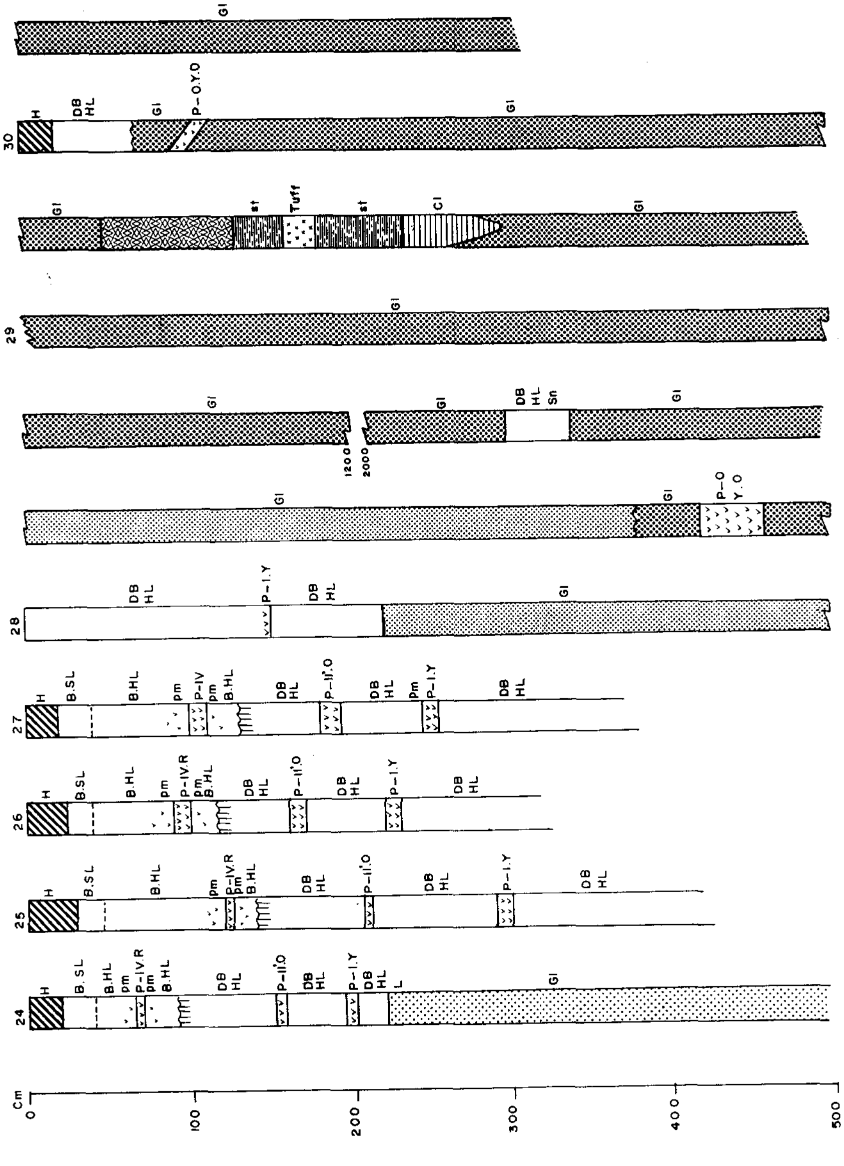

Fig. 23a. Columnar sections of the Quaternary deposits in the southern part of the Ina valley. 24; Locality S-21. 25; Locality S-22. 26; Locality S-27. 27; Locality S-28. 28; Locality S-53. 29; Locality S-147. 30; Locality S-166. Abbreviations and symbols are explained in p. 53.

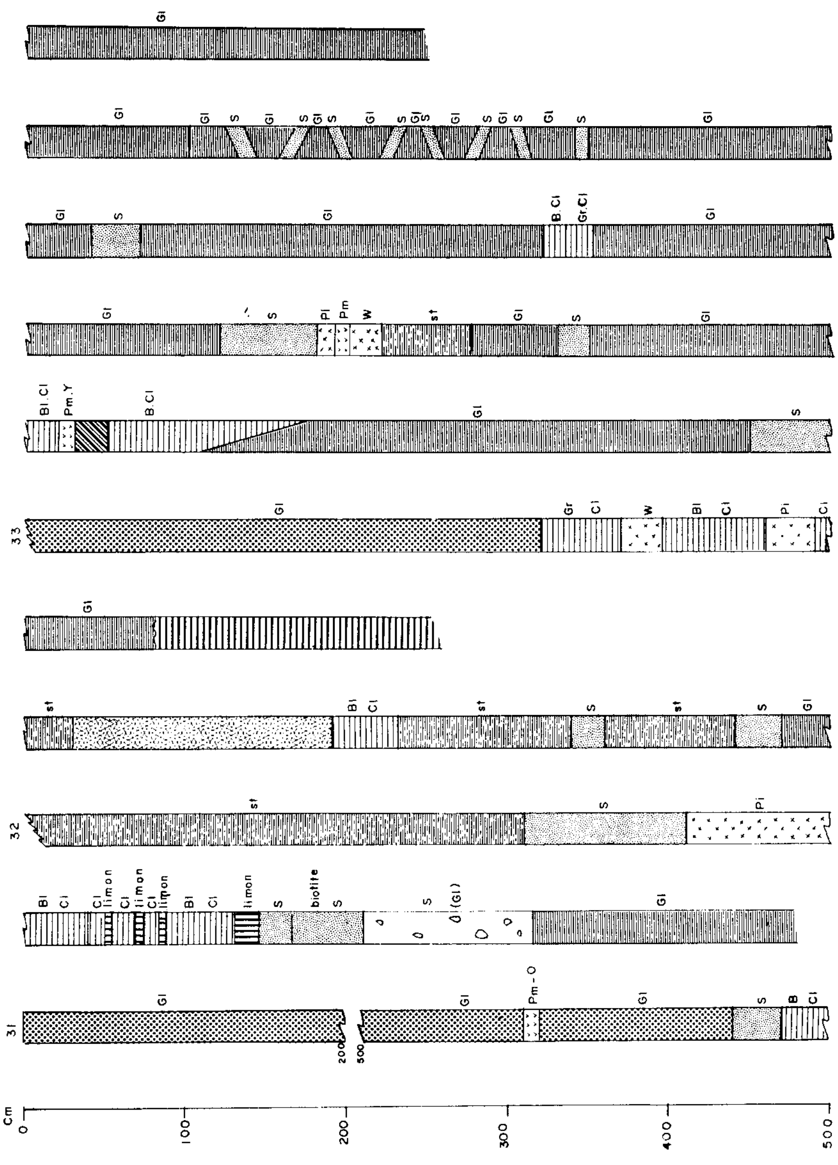

Fig. 23b. Columnar sections of the Quaternary deposits in the southern part of the Ina valley. 31; Locality S-182. 33; Locality S-11. 33; Locality S-200. Abbreviations and symbols are explained in p. 53.

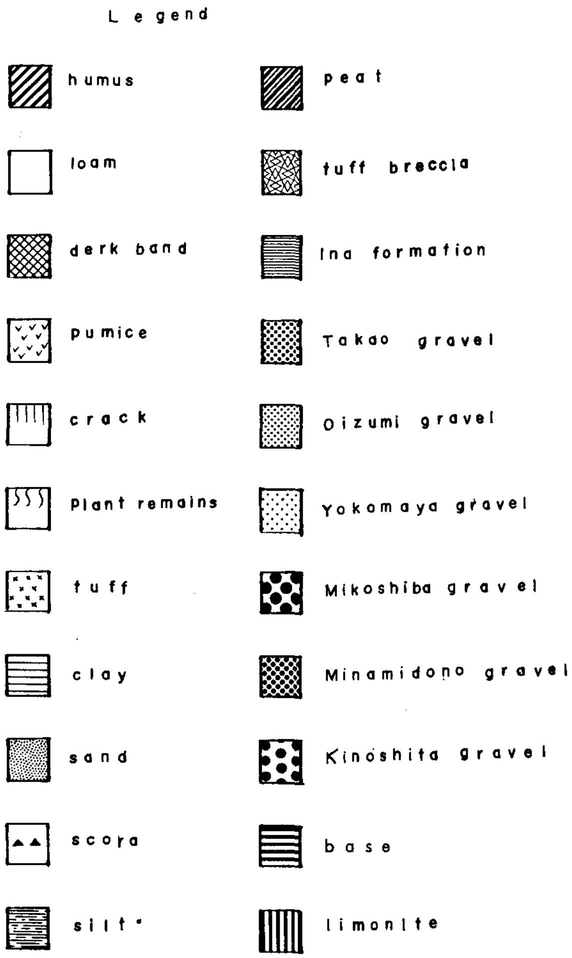

Fig. 24. Lithofacies symbols in columnar sections of Fig. 21–23.

Abbreviations in Fig. 21–30 are as follaws: SL; soft loam. HL; hard loam. GL; gravel. S; sand. P; pumice. St; silt. pm; pumiceous sediment. Sn; sandy sediments. L; loamy sediment. limon; limonite. B; brown. D; dark. R; reddish. O; orange. Y; yellow. W; white. Pi; pink. Gr; grey. Bl; blue. chol; chocolate color. H; humus.

larger in the southern area and different down-cut processes of each tributaries.

The Kinoshita terrace group

The Kinoshita terrace has no superposition to other older surfaces also. Although the surface gradient from north to south is similar to that of the present river floor of the Tenryû river, the thickness of gravel bed forming the terrace increases toward the south. This fact seems to indicate that down-cutting was more predominant in the southern area as same as in the case of the Minamidono terrace. It might be brought about by the regional difference of tectonic movement and of amounts of running water.

Correlation with South Kantô Plain

In order to correlate the stratigraphy of the Shinshû Loam in the Ina valley with that of the Kantô Loam in coastal region of South Kantô plain, Pm-I bed in the Middle Loam is used as a useful key bed owing to its remarkable thickness and continuity.

Lithological feature of Pm-I pumice grains is white or yellow in color, porous and fibrous, and is characterized by the presence of biotite. Heavy mineral composition is represented by abundant hornblende accompanied by biotite and zircon. Basing upon lithological feature and heavy mineral composition just mentioned, it is possible to make tracing Pm-I from the Ina valley to the Pacific coast. However, two different pumice beds have been found from nearly the same horizon as the Pm-I in the Tozurahara formation of the Katsura river. Those are discriminable by abundance of hypersthene and by richness in hornblende respectively, but both of them contain none of zircon crystals.

To trace to east from Ina City and Komagane City, the undoubted Pm-I is recognized at Kobuchizawa, Nirasaki and Kôfu (Sone-hill, Ichinose, Enzan and so on) (Fig. 29–1, 2, 3). The Pm-I bed observed at Sone-hill is 80 cm in thickness and overlies unconformably on the Sone gravel. Further to east, the water-laid Pm-I bed has been known at the depth of 7.4 m from the top of the Todohara formation in Itsukaichi City (Fig. 30a–7). The loamy sediments at Todohara has been considered to be correlative to the Tama Loam unit of the Kantô Loam (SUZUKI, 1962). But it has been clarified that the air-laid tephra covering terraces of this area is assignable to the Musashino and Tachikawa Loam units and so this terrace may belong to the Musashino terrace group in the Kantô plain. Therefore, the water-laid tephra layer in which the pumice bed of Pm-I is intercalated is probable to assign to the Shimosueyoshi Loam unit. And also, Pm-I bed of 18 cm in thickness is intercalated in the air-laid Shimosueyoshi Loam at Okunugi, south of Uenohara, along the Katsura river (Fig. 29–5).

Also at Yasudo and Sanda, a white pumice layer of Pm-I has been recognized.

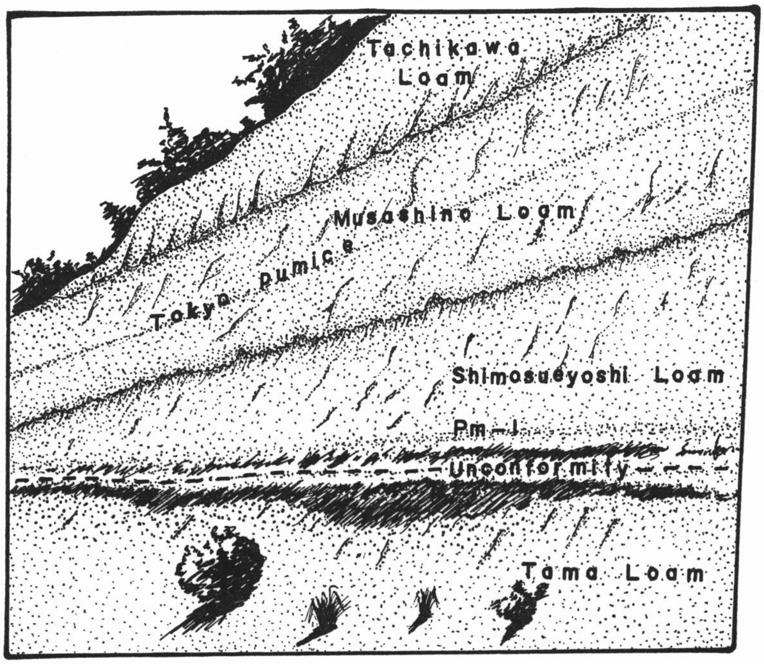

Fig. 25. A sketch of the exposure at Yasudo.

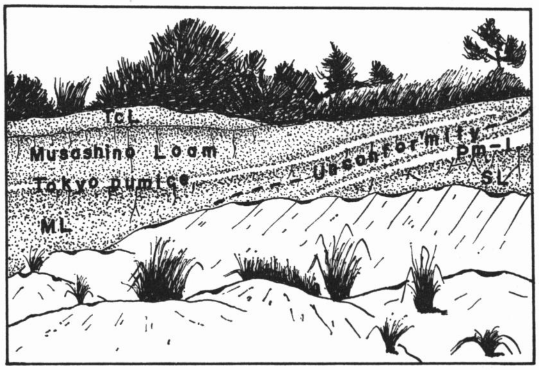

Fig. 26. A sketch of the exposure at Sanda. TcL; Tachikawa Loam, ML; Musashino Loam. SL; Shimosueyoshi Loam. Pm-I; pumice fall from the Ontake.

At Yasudo, Pm-I bed can be observed at the horizon of 3.2 m lower than a cracky zone which is 2.5 m lower than the Tôkyô pumice of the Musashino Loam unit (Figs. 25, 30a–6), then, it is positive to say that Pm-I bed is intercalated in the air-laid Shimosueyoshi Loam. At Sanda, Pm-I is also contained in the air-laid Shimosueyoshi Loam unit (SHIMIZU, YANO and KOBAYASHI, 1964. KOBAYASHI, 1965) (Fig. 26). At Hino in Tôkyô, the white pumice bed of Pm-I, 20 cm in thickness, is known at the horizon of 2.5 m lower than a cracky zone which is 1.9 m lower than the Tokyo pumice (Figs. 28, 30a–8). It has been also known that there is the Yellow pumice bed at the horizon of 7.5 m lower than that of Pm-I at Uenohara, Hino, Yose, Shimosueyoshi and other places. In such way, that pumice bed seems to be available "key bed" for the field survey both in Shinshû and Kantô districts.

At Kiyosato in Kiyose, east of Hino, Pm-I of yellow in color is recognized at the horizon of 1.6 m to 3.8 m lower than a cracky zone which is 80 cm lower than the Tôkyô pumice bed as shown in Fig. 30a–9. Further to east, water-laid layer of white sticky pumice of Pm-I can be observed to be overlain by a layer of blue clay which is 1.2 m below a cracky zone, 90 cm lower than the Tôkyô pumice bed, at Minami-Urawa (Fig. 30b–10). The water-laid deposits of the Omiya tableland at Minami-Urawa, has been considered to be the Tama Loam unit (KANTO LOAM RESEARCH GROUP, 1965), however, the evidences above stated may indicate that the Omiya tableland does not belong to the Shimosueyoshi terrace group but to the Musashino terrace group. Therefore, it may be correct to say that the water-laid blue clay and Pm-I is not the member of the Tama Loam unit but of the Shimosueyoshi Loam unit. It is possible to trace the Pm-I bed intercalated in the Shimosueyoshi Loam as far as Tsurumi and Shimosueyoshi, the type locality of

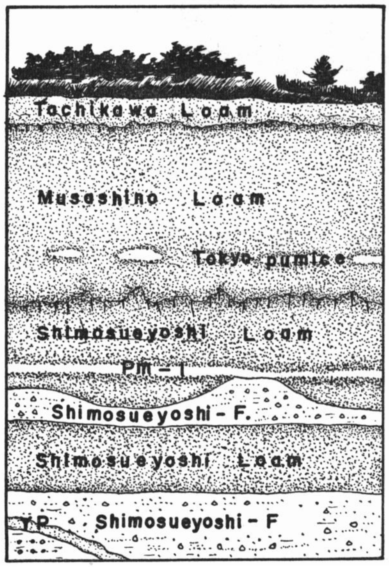

Fig. 27. A sketch of the exposure at Hino. Pm-I; pumice fall from the Ontake.

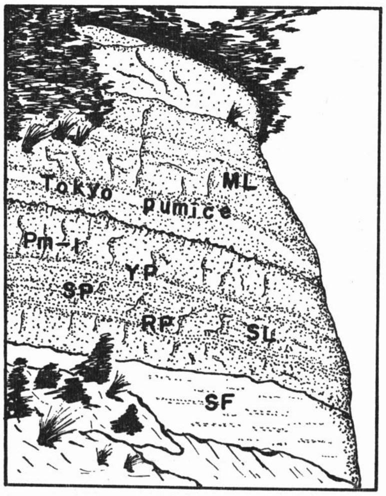

Fig. 19. A sketch of the exposure at Shimosueyoshi, the type locality of the Shimosueyoshi Loam unit. ML; Musashino Loam. Pm-I; pumice fall of the Ontake. YP; upper Yellow pumice bed of Shimosueyoshi Loam. SP; upper pumice bed of Shimosueyoshi Loam. SL; Shimosueyoshi Loam. RP; lower pumice bed of Shimosueyoshi Loam. SF; the Shimosueyoshi formation.

the Shimosueyoshi Loam (Fig. 28).

From those facts enumerated above, it is obvious that Pm-I bears the stratigraphic position in the Shimosueyoshi Loam unit. Besides them, those of "Pm-I" in the South Kantô Plain and in the Ina valley are consistent with each other in heavy mineral composition (Fig. 20). In considering of radiocarbon date of the middle part of the Tachikawa Loam (16,500 ^{14}C yrs. B.P.) and of the Totchû fossil bed (15.750$\pm$390 ^{14}C yrs. B.P.), The Tachikawa Loam unit is roughly contemporaneous with the Younger Loam unit of the Shinshû Loam. Therefore, the date of the Tachikawa terrace formation may correspond to the maximal stage of the Kiso glacial.

In this way, as for the sediments, tephra deposits and terraces, it is possible to correlate between the Ina valley and the South Kantô plain. Mutual relations among tephra deposits supplied by volcanoes such as the Ontake, Mt. Fuji, Mt. Asama and others are possible to research, basing upon the distribution of Pm-I.

Quaternary geohistory of the Ina valley

As for the geohistory in the Ina valley, one may start to discuss on the Ina and the Enrei formations which are considered to be contemporaneous with each other. Those sediments deposited at first under standing water conditions in the valley with wide and flat floor situated between the Kiso and the Akaishi mountain ranges

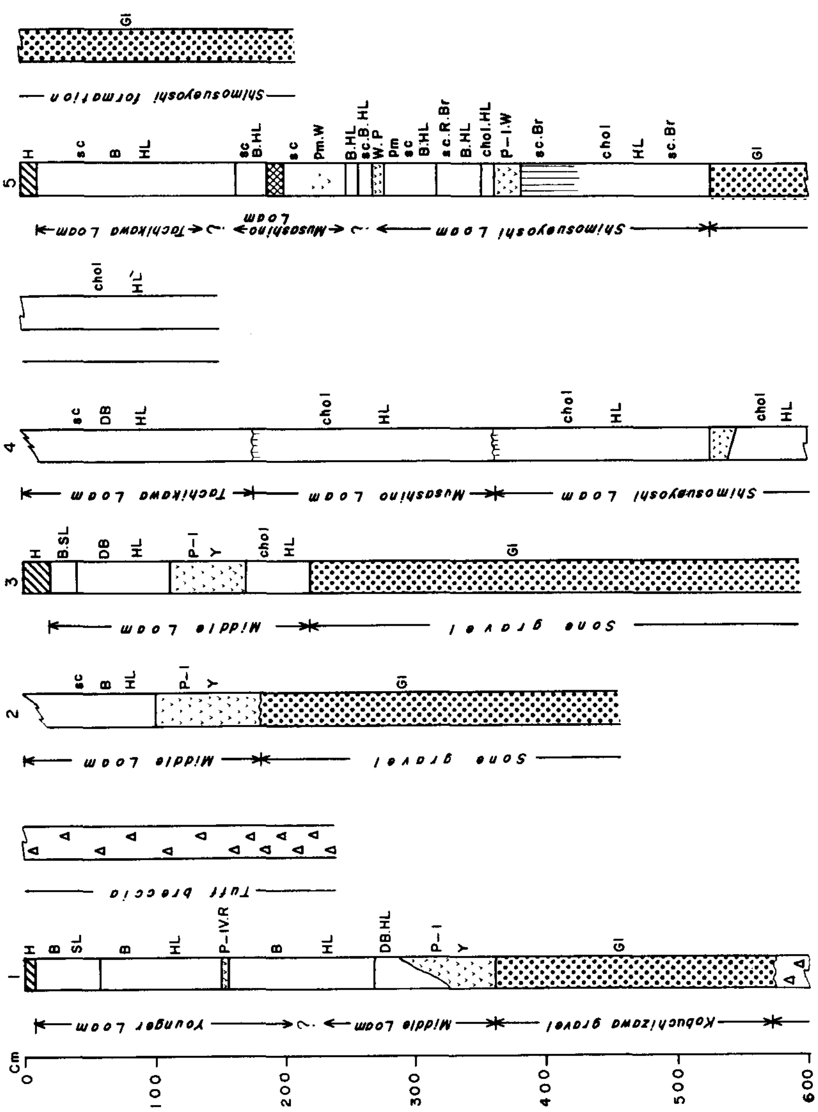

Fig. 29. Columnar sections of the Quaternary deposits near Kobuchizawa and in the Kôfu basin. L; Kobuchizawa. 2; Kofu. 3; Enzan. 4; Okunugi (Uenohara). 5; Uenohara. See p. 53 and Fig. 30b. in p. 60.

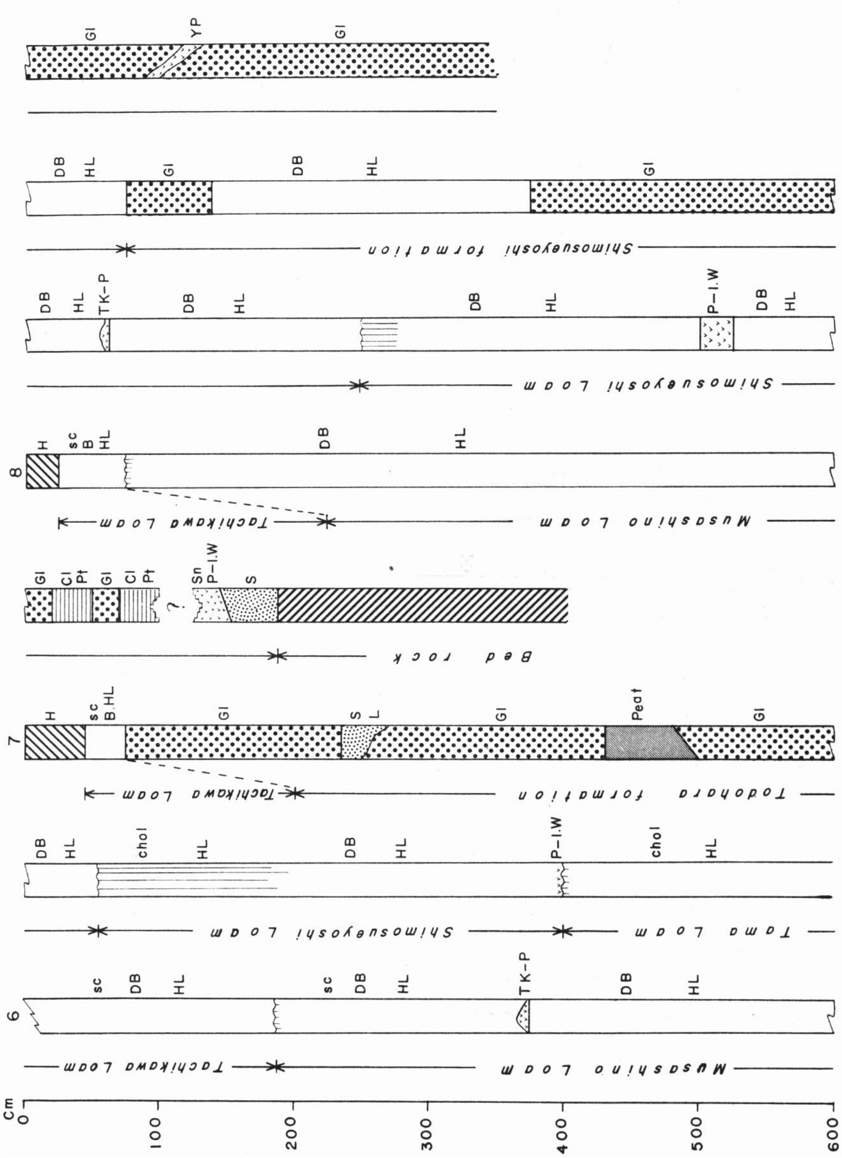

Fig. 30a. Columnar sections of the Quaternary deposits in the South Kanto plain. 6; Yasudo (Hachioji). 7; Todohara (Itsukaichi). 8; Hino (Tokyo). See p. 53 and Fig. 30b in the next page.

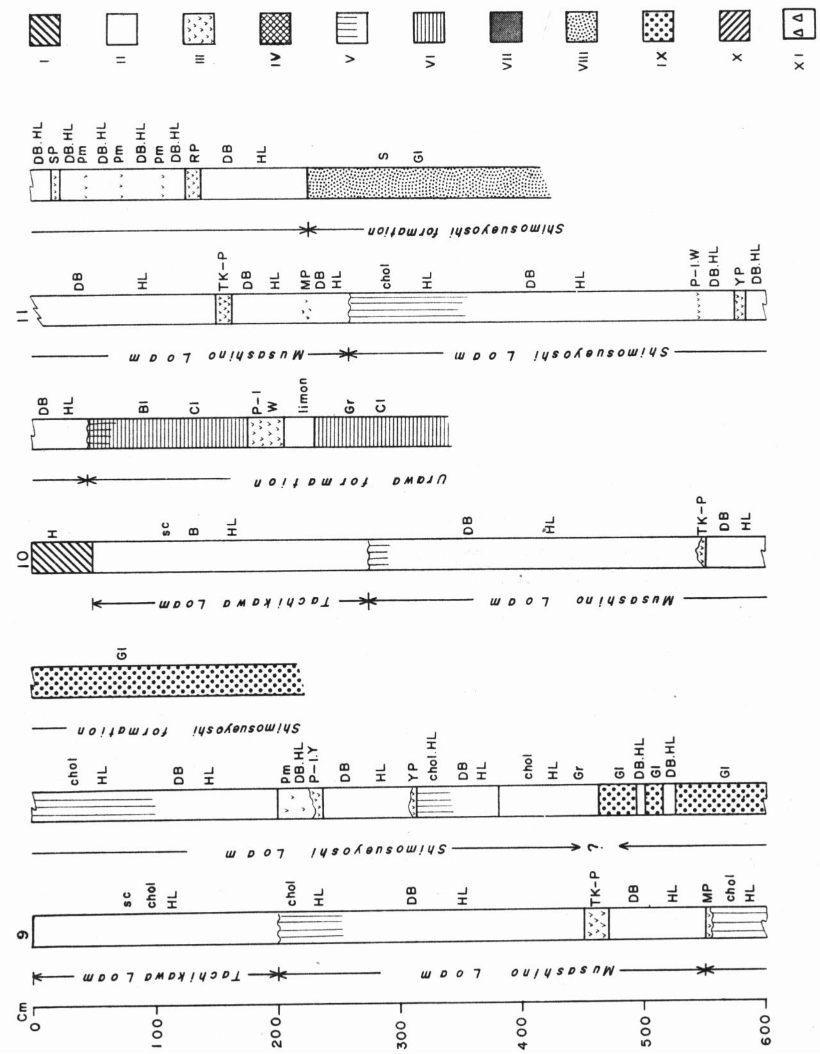

Fig. 30b Columnar sections of the Quaternary depostits in the South Kanto plain. 9; Nakasato (Kiyose). 10; Urawa. 11; Shimosueyoshi. I; humus. II; loam. III; pumice. IV; dark band. V; cracky zone. VI; clay, VII; peat. VIII; sand. IX; gravel. X; basement rock. XI; tuff breccia. Abbreviations are explained in p. 53.

of basement rocks. From the view point of facies change, the sedimentary circumstances of their deposits shiffed gradually to fan-like environments upwardly. For the geological age, it is possible to say that they belong to Early Pleistocene, i.e. "the extinction age of Metasequoia flora" of ITIHARA (1961), because of the coexistence of *Metasequoia* and *Menyantes*. Those sediments built the fill-top of the Ina surface, and that surface is known at present as the highest terrace plain which is highly undulated.

After that, remarkable down-cut erosion was followed under the influence of tectonic movement, and at the same time, the channel of the main stream was filled with coarse sediments derived from mountain region which were undertaking upheaval movement. It was the stage of the formation of the Takao terrace group. During this stage, the Ontake volcano began to be active and suplied a part of the Older Loam widely which is nearly contemporaneous with the Tama Loam in the South Kantô plain.

The Takao terrace was eroded partially in the latest stage of the deposition of the Older Loam, and the Ôizumi gravel overlay on that eroded surface. As the result of volcanic activity of the Ontake volcano, the Ôizumi terrace was covered by the air-laid tephra of the Middle Loam.

It is noteworthy that Pm-I in the lower part of the Middle Loam can be also recognized in the middle part of the Shimosueyoshi Loam in the South Kantô plain, and so, it is possible to say that the Middle Loam unit in the Ina valley may correlative partly with the Musashino Loam and the Shimosueyoshi Loam.

During the stage of the Younger Loam, the glaciers on the Kiso mountains advanced down to the position of the lowest moraines, and lowlands were densely covered with the vegetation of cold climate. On the other hand, a large quantity of rock fragments which were derived from the mountain region formed the Mikoshiba terrace which has wide distribution in the Ina valley. This terrace is contemporaneous with the Tachikawa terrace formed in the time of maximum depression of the sea-level during Last glaciation.

After then, all of those terraces were subjected to denudation and consequently the lower terraces of small extent such as the Minamidono terrace group and the Kinoshita terrace group were formed mainly along the tributary streams.

Summary

In Central Japan, there is a peculiar alignment of low-land strips, "Ina valley" extended from north to south along the Tenryû river from the Lake Suwa. It is well known that many terraces are developed in this valley. On the other hand, there are many glacial remains on the Kiso and the Akaishi mountains which stand

in parallel on both sides of the Ina valley. All of those characteristic geomorphic features in the Ina valley was brought about mainly during the Quaternary.

The tephra so-called "Shinshû Loam" are widely distributed in the Ina valley, and parts of them are known from the South Kantô plain of the east. Therefore, mainly by the tephrochronological method, the author tried to synthesize the mutual relationship among terrace building, glaciation and geomorphic history held of the inland basins of the Ina valley.

1) The Shinshû Loam in the Ina valley is divided into three stratigraphic units and named as the Younger, the Middle and the Older Loam units in descendant order. They are distinguishable with each other by their lithological features, heavy mineral compositions, and the nature of pumice bed intercalated.

2) Especially, it has been definitely shown that Pm-I in the Shinshû Loam is intercalated in the middle part of the Shimosueyoshi Loam. Therefore, the Shinshû Loam in the Ina valley is able to be correlated with the Kantô Loam in the South Kantô plain.

3) Concerning to those tephra deposits, the correlation is probable between the terrace deposits in the Ina valley and the Quanternary deposits in the South Kantô plain.

4) From the relation to overlying tephra unit, the terrace deposits in the Ina valley can be classified stratigraphically, viz. Ina formation, Takao gravel, Ôizumi gravel, Yokomaya gravel, Mikoshiba gravel, Minamidono gravel and Kinoshita gravel in ascending order.

5) Basing upon the tephra units and underlying terrace deposits, the terraces are classified as the Ina surface (EI), Takao terrace-1, -2 (TK-1, -2), Ôizumi terrace (OZ), Yokomaya terrace (YK), Transitional terrace (OM), Mikoshiba terrace-1, -2 (MK-1, -2), Minamidono terrace (MD), and Kinoshita terrace-1, -2, -3 (KS-1, -2, -3).

6) Based upon the relation between moraines and overlying tephra falls of the Kumazawa cirques in the Kiso mountains, author proposed the name of the "Kiso glacial" stage, divided into three substages such as substage I of maximal phase, substages II and III which include recessional phase of the Last glaciation. As a results, it is ascertained that the maximal extension of the glacier was about 30,000 ^{14}C yrs. B.P., which is contemporaneous with the Tachikawa stage in the South Kantô plain, i.e. the stage of the maximal depression of the sea level.

7) It is proved that topographical feature of the terrace crossing that is shown in the case of the Mikoshiba terrace has been formed during the time of the Kiso glacial I substage owing to excessive supply of rock fragments in the upper stream side, and increasing erosion in the lower stream side. Namely, the Mikoshiba terrace which occupies a large scope in this area seems to be the climatic terrace.

References

ARII, T. (1956): Geomorphological studies on the western area of Tenryûkyô, Nagano Prefecture. *Tokyo Gakugeidai Kenkyu-hokoku.* **8**, p. 357–362.

BAULIG, H. (1935): The changing Sea-Level. G. Philips. London.

BÜDEL, J. (1944): Die morphologischen Wirkungen des Eiszeiklimas imgletscherfreien Gebiet, *Geol. Runds.* **34**, p. 482–519.

FRYE, J. C. & H. B. WILLMAN (1960): Classification of the Wisconsian stage in the Lake Michigan glacial lobe. *Illinois State Geol. Surv. Circular.*, **285**, p. 16

FRYE, J. C., H. B. WILLMAN & R. F. BLACK (1965): Outline of glacial geology of Illinois and Wisconsin, in "Quaternary geology of United States". p. 43–61.

GROSS, H. (1964): Das Mittelwürm in Mitteleuropa und angrenzenden Gebieten, *Eisz. u. Gegenw.* **15**. p. 23–28.

ICHINOSE, Y. (1926): Iida Basin and its Terraces. *Geogr. Rev. Journ*, **2**, p. 219–2C1, 323–336, 418–429. (in Japanese)

IMAMURA, G. (1937): Past glaciers and the present topography of the Japanese Alps. *Sci. Rep. Tokyo Bunrika Daigaku.*, **2**, 7. p. 1–71.

IMAMURA, G. (1940): The Japanese Alps and the Past Glaciers. Iwanami, Tokyo. (in Japananese)

ITIHARA, M. (1961): Some Problems of the Quaternary Sedimentaries in the Osaka and Akasi Areas, Japan. *Jour. Inst. Polytech. Osaka City Univ.* G. **5**, p. 13–29.

KANTO LOAM RESEARCH GROUP (1965): Kantô Loam, its genesis and nature, Tsukiji Shokan, Tokyo. (in Japanese)

KOBAYASHI, K. (1958): Quaternary glaciation of the Japan Alps. *Journ. Fac. Lib. Arts and Sci. Shinshu Univ.*, **8**, p. 13–67.

KOBAYASHI, K. (1961): The so-called "Shinshu Loam", *Journ. Geol. Soc. Japan*, **67**, p. 32–47.

KOBAYASHI, K, Y. MORI, T. HARADA & S. KAWACHI (1957): Glacial and postglacial deposits in some cirques of the Central Japan Alps. *Jour. Geol. Soc. Japan*, **63**, p. 9–25. (in Japanese)

KOBAYASHI, K, T. YAMADA & H. SHIMIZU (1961): Late Cenozoic History of the northern Part of Ina valley. (Resumé) *Jour. Geol. Soc. Japan.*, **67**, p. 394. (in Japanese)

KOBAYASHI, K. & H. SHIMIZU (1962): Pleistocene Tephras in the Northern Part of Ina valley, Central Japan. *Jour. Fac. Liber. Arts & Sci. Shinshu Univ.*, **12**, 2, p. 20–45.

KOBAYASHI, K. & H. SHIMIZU (1965): Classification and Corrlation of Shinshu Loam in the South Shinshu tephrogenetic region, Central Japan. *Jour. Fac. Lib. Arts & Sci. Shinshu Univ.*, **15**, p. 37–59

KOBAYASHI, K. (1965): Problems of Late Pleistocene history of Central Japan. *Spec. Paper, Geol. Soc. Amer.*, **84**, p. 367–391.

KOBAYASHI, K. & H. SHIMIZU (1966): Significance of the Ikenotaira Interstadial Indicated by Moraines on Mt. Kumazawa...... *Jour. Fac Sci. Shinshu Univ.*, **1**, p. 97–113.

KOBAYASHI, K., K. MINAGAWA, M. MACHIDA, H. SHIMIZU & K. KITAZAWA (1968): The Ontake Pumice-Fall Deposit Pm-I as a Late Pleistocene Time-Marker in Central Japan. *Jour. Fac. Sci. Shinshu Univ.*, **3**, p. 171–198.

KURABAYASHI, S. & T. TSUCHIYA (1963): Consideration of the weathering process of volcanic ash on the basis of clay mineralogy. *Quat. Res*, **3**, 1–2, p. 31–39.

LEMKE, R. W., W. M. LAIRD, M. J. TIPTON & R. M. RINDVALL (1965): Quaternary Geology of northern Great Plains. Quaternary Geology of United States. p. 15–27.

LEOPOLD, L. B. (1951): Pleistocene climate in New Mexico. *Amer. Jour. Sci.*, **249**, p. 152–168.

MIKI, S. (1955): Nut Remains of Juglandaceae in Japan. *Jour. Inst. Polytechn. Osaka City Univ.*, D. **6**, p. 131–144.

MINO, Y. (1951): Geomorphology of the Ina valley. *Geogr. Rev. Jour.*, **24**, p. 1–16. (in Japanese)
MOMOSE, K., K. MOBAYASHI & T. YAMADA (1959): Palaeomagnetic and geologic researches for the Pliocene volcanic rocks around Lake Suwa. *Bull. Earthq. Res. Inst.*, **37**, p. 432–481.
NAKAGAWA, H. (1961): Pleistocene eustasy and glacial chronology along the Pacific coastal region of Japan. *Rep. Tohoku Univ., Inst. Geol. Pal.*, **54**, p. 1–61. (in Japanese)
QUATERNARY RESEARCH GROUP OF KISO VALLEY (1967): Quaternary Geology of the Upper stream of Kiso Valley. *Earth-Sci.*, **21**–1, p. 1–10. (in Japanese)
QUATERNARY RESEARCH GROUP OF KISO VALLEY & K. KIGOSHI (1964): Radiocarbon Data of the Kisogawa volcanic Mudflows. *Earth-Sci.*, **71**, p. 1–7.
SAKAI, J. (1963): The Shinshu Loam in Kiso valley, Central Japan. *Earth-Sci.*, **67**, p. 13–20; **68**, p. 19–21. (in Japanese)
SAKAMOTO, T. (1956): Problem on the Ina formation. *Ina.*, **338**, p. 6–11. (in Japanese)
SHIKAMA, T. & T. KOBAYASHI (1949): On the Ice age of the Central mountainland of Japan. *Jour. Geol. Soc. Japan.*, **55**, p. 65–71. (in Japanese)
SHIMIZU, H. (1960): Periglacial Geomorphology - On the patterned Ground on the Nishi-Komagatake Mts. Inaji. **4**, p. 12. (in Japanese)
SHIMIZU, H. (1961): The Birth of Kojin-Yama. *Kamiinakyoiku.*, **25**, p. 29–36. (in Japanese)
SHIMIZU, H. (1962): Geomorphology and Geology of Ina Basin. Kamiina-gunshi, **I**, 1, p. 196–242. (in Japanese)
SHIMIZU, H. (1962): Glacial and periglacial Geomorphology. Kamiina-gunshi, I, 1, p. 170–195.
SHIMIZU, H., K. YANO & K. KOBAYASHI (1964): Shinshu Loam recognized in Kanto Loam section. *Daiyonki.*, **5**, p. 57–60. (in Japanese)
SHIMIZU, H., K. KOBAYASHI, Y. GOHARA, K. KITAZAWA, S. KAWACHI & T. KOBAYASHI (1965): The pumice bed Pm-I from Ontake volcanoes excellent tephra horizon. (Resumé). *Jour. Geol. Soc. Japan.* **71**, p. 360. (in Japanese)
SHIMIZU, H., T. KAMEI & K. KOBAYASHI (1966): Fossil Bison excavated from Tatsuno-mach, Ina valley. (Resumé). *Quat. Res.*, **5**, 2, p. 74. (in Japanese)
SHIMIZU, H., K. KOBAYASHI & Y. SHIBUYA (1966): Kumazawa-dake cirques of the Central Japan Alps. (Resumé). *Quat. Res.*, **5**, 2, p. 74–75. (in Japanese)
SOERGEL, E. (1924): Die Diluvialen Terrassen der Ilm. G. Fischer, Jena. p. 1–79.
TROLL, C. (1957): Tiefenerosion, Seitenerosion und Akkumulation der Flusse im fluvioglazialen und periglazialen Berich. *Det. Mitt. Erg. H.*, **262**, p. 213–226.
TSUJIMURA, T. (1919): Intramontane Basisins in Ina Valley and Terraces and Gorge of Tenryukyo. *Jour. Geol. Soc. Japan.*, **26**, p. 214–220; 249–266; 346–359; 383–393; 433–446. (in Japanese)
USHIMARU, S. (1927): Geology of the Takato District, Prov. Shinano. Shinano-Kyoikukai. (in Japanese)
YAGI, T. (1928): Distribution and Geological Age of Pleistocene Deposits in Shinshu Prov. *Jour. Geol. Soc. Japan.*, **35**, p. 371–372. (in Japanese)
YAMADA, T. & H. SHIMIZU (1961): Volcanic rock at Tenjin-yama, Takatomachi. *Inaji.*, **3**, p. 1–6. (in Japanese)
ZEUNER, F.E. (1959): The Pleistocene Period. 2nd ed. Hutchinson, London.