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Late Pleistocene Climatic Changes in Central Japan

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Contents

Abstract

The purpose of this work is to make clear the Late Pleistocene climatic changes in Central Japan. For this purpose the author tried to correlate nearshore sediments in the Nobi coastal plain with fluviatile sediments in the inland area by means of tephrochronology and rock magnetism. In the studied area, pumice and scoria beds erupted from Ontake Volcano are widely distributed being intercalated with peat beds and other sediments. These volcanic products were precisely examined with the features of field occurrence, mafic mineral composition and thermomagnetic

property (J–T curve), and were classified into twelve pumice and two scoria beds. Then the stratigraphical relations among the Late Pleistocene sediments in Central Japan were made clear by these pumice and scoria beds, good marker beds (Fig. 4).

Samples which have been stratigraphically confirmed were analysed palynologically and paleobotanically. Pollen diagram of each locality was classified into pollen zones based on characteristic and dominant taxa.

The Late Pleistocene climatic changes in Central Japan were considered based on the vegetational feature of pollen zones. Plant remains were also very usefel in considering the vegetational features represented by the pollen zones. Lastly the Late Pleistocene time in Japan was subdivided into the following four periods based on climatic changes and carbon–14 dates.

(1) Latest interglacial : R/W Interglacial (before than 65000 to 70000 yr B. P.)

This period is characterized by the dominance of *Cryptomeria* and deciduous broad–leaved trees, including *Fagus*. The climate is estimated to have been warmer and wetter than that of the present.

(2) Early Würm Glacial (from 65000 to 55000 yr B. P.)

Two interstadials are inferred by the dominance of *Cryptomeria*, *Sciadopitys*, *Ulmus–Zelkova* and *Corylus* during early half of this period. The later half of this period is characterized by the subarctic forest which is estimated to have been 5°C to 6°C lower than the present in average annual temperature.

(3) Middle Würm Glacial (from 55000 to 25000 yr B, P.)

Cool climate prevailed throughout this period, intervening a remarkable warm climate which reached a maximum at about 37000 years ago. In the Nobi coastal plain, the Atusta Surface was formed by the transgression during the warm climate.

(4) Late Würm glacial (from 25000 to 10000 yr B. P.)

This period is dominated by subarctic forest. Periglacial agency acted at the place higher than 1000 m above sea–level in the Kiso Valley during the early half of this period.

I. Introduction

Since the evidences of glaciation was first reported by N. YAMASAKI (1902), the glacial geomorphology in the alpine region of Central Japan has been discussed by many researchers. In fact, effects of Quaternary glaciations are recorded there, and some of them, cirques of the past on the top of the Japan Alps are ascribed to the glaciation of the Würm Glacial (KOBAYASHI, K., 1958). Neverthless, it is also true that no attempt has resulted in success so far to make clear the stratigraphic relationship between glacial deposits on high mountains and the Late Pleistocene fluvial deposits in low–land areas of Japan. On the other hand, world–wide glacial eustacy resulted certainly in sea level changes along coastal plains of the Japanese islands.

In the cirumstances, the author considered that it is necessary to clarify precisely the Late Pleistocene stratigraphic relations among sediments of those three areas, high mountains glacial, low land fluvial and coastal marine sediments. For this purpose he tried to correlate nearshore sediments of coastal areas with fluviatile sediments of inland areas by means of tephrochronology and rock magnetism.

Until now the Late Pleistocene climate has been studied by some workers (NAKAMURA, J., 1973; Quaternary Flora Research Group, 1974; YASUDA, Y., 1978), but they have only relied on radiocarbon chronology without any consideration based upon comprehensive stratigraphical examinations.

In Central Japan, the Late Pleistocene sediments of inland areas are generally composed mainly of gravels, volcanic breccias and mudflows with intercalations of peat beds, but they are always separately distributed with complicated and variable sedimentary facies from one valley to another. Therefore, it is not easy to confirm chronological succession accurately in deposits of different valleys. Furthermore, it is very hard to obtain peat samples from continuous sequence of long time interval in one outcrop for pollen analysis.

In spite of those difficulities, the author could find some methods applicable in his study. Pumice and scoria erupted from Ontake Volcano are widely distributed in the areas studied, and those volcanic materials are available for good marker beds. For example, it is possible to classify them stratigraphically into twelve pumice and two scoria beds (Fig. 2), and each of them can be identified by its characteristic assemblage of mafic minerals. In addition, by thermomagnetic curve analysis (J-T curve) of their ferromagnetic minerals each bed also can be identified (Fig. 5, 6 and 7)*. Furthermore the contemporaneity of sediments through Kiso Valley to Nobi Plain can be recognized by tracing special sedimentary facies such as the Kisogawa Volcanic Mudflow and the Kisodani Formation, both of which are made up mainly of characteristic volcanic materials. Radiocarbon dates are also helpful to establish a chronological sequence of various stratigraphic units.

Consequently, such comprehensive work could clearly picture the environmental scheme of the past which is displayed from the Shinshu inland area to the Nobi coastal plain. Basing upon the results provided, the author intended to reconstruct the Late Pleistocene climatic succession of those areas and to discuss the correlation with that of other regions.

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* MOMOSE, K. *et al.* (1968, 1972) show Curie temperature (Tc) and thermomagnetic curve (J-T curve) of ferromagnetics of pumice grains indicate similarity in the pumice layer of same fall, independently of sampling site and grain size of minerals. For this reason, the author applied Tc and J-T curve of pumice grains for identification of specific pumice beds.

II. General geology

The area treated here covers a part of the Innerbelt and the Ryoke zone of Southwest Japan, and a part of northern Fossa Magma ("a great fissure") zone stretching for about 140 km (Fig. 1 and 2).

The south–western part of the area comprises chiefly the Upper Paleozoic rocks, granitic rocks and Nohi Rhyolites as basement rocks. On the other hand, northern and northeastern part of the area is covered by thick Neogene sediments intruded by a few diorite masses. The gravels and volcanics of the Lower and Middle Pleistocene widely overlie on the Neogene sediments with marked unconformity. In the area investigated, main distribution of the Upper Pleistocene deposits is known in

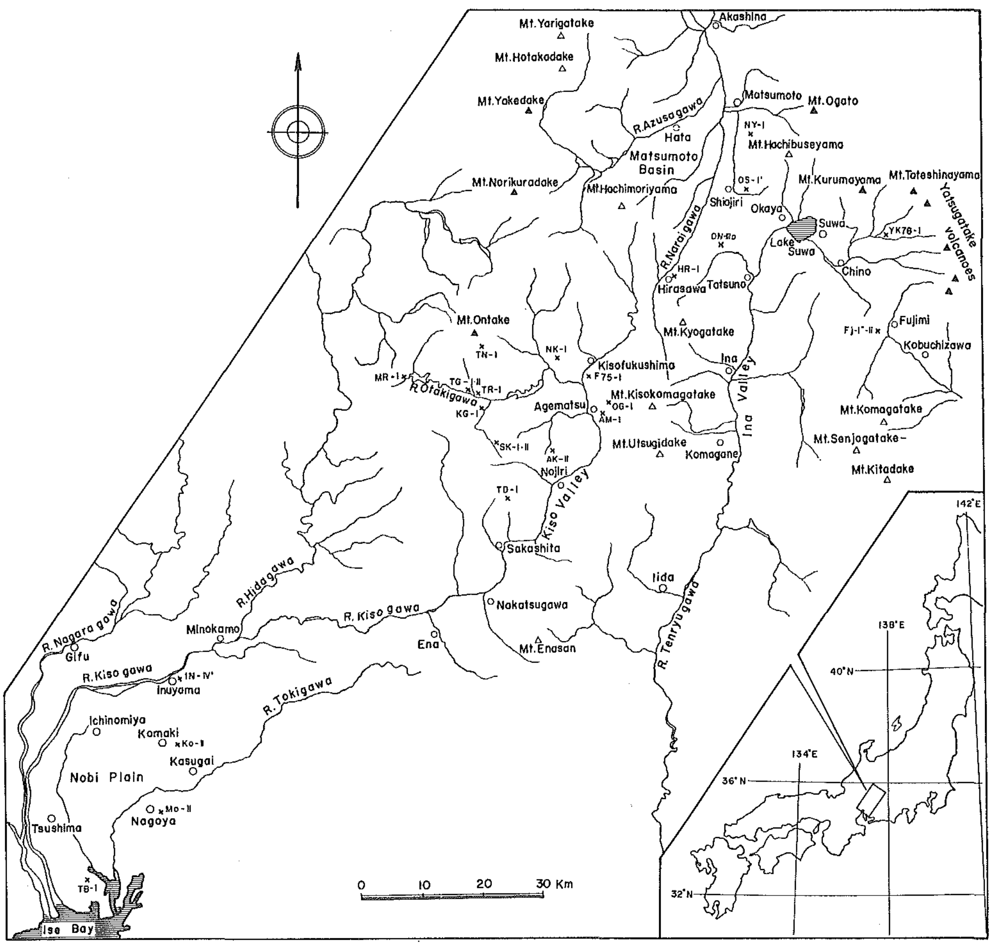


Fig. 1 Location of studied area

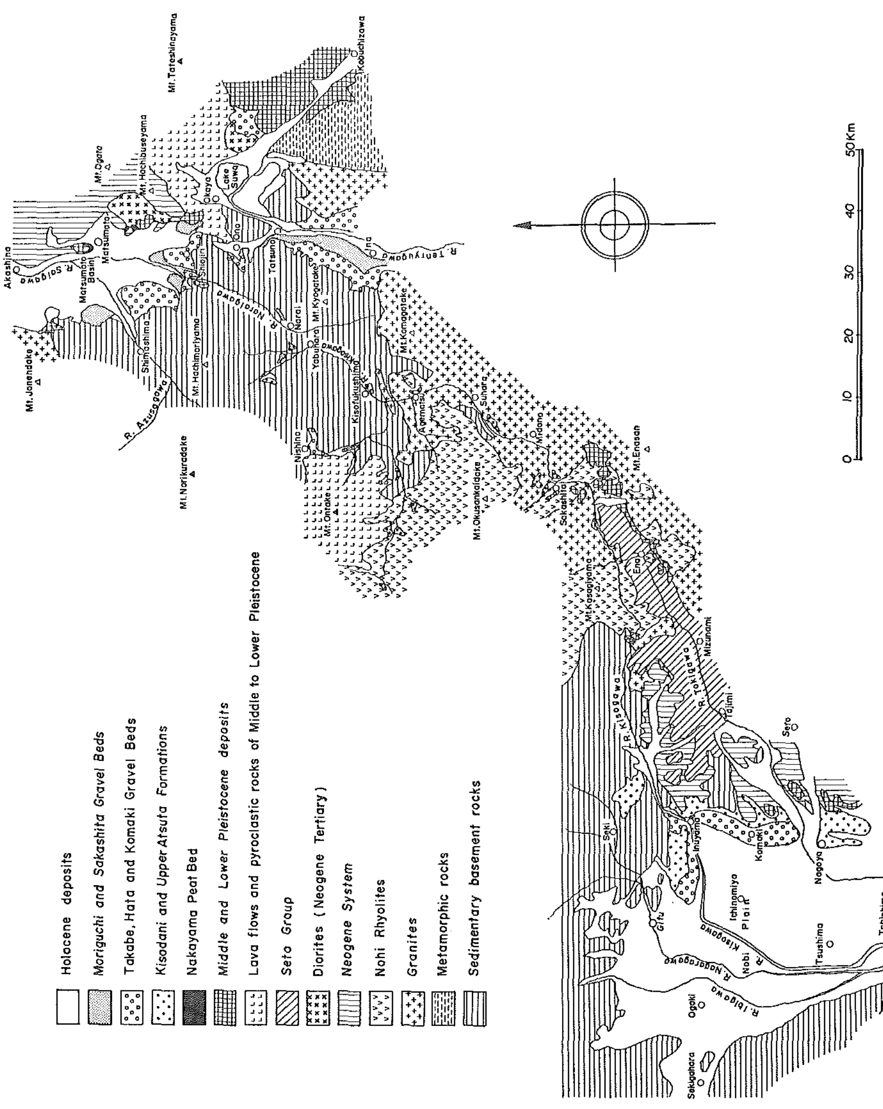


Fig. 2 Geological map of studied area in Central Japan

the Matsumoto Basin, western foot of Yatsugatake Volcanoes, Kiso Valley, southern foot of Ontake Volcano and Nobi Plain.

In the Matsumoto Basin the Upper Pleistocene deposits consist of the Nakayama Peat, Hata Gravel and Moriguchi Gravel Beds in ascending order (Fig. 3). The Nakayama Peat Bed which contains plant remains is exposed at the eastern border of the basin, with intercalations of two distinct pumice beds originated from Ontake Volcano. The Hata Gravel Bed, more than 100m thick, conformably overlies the

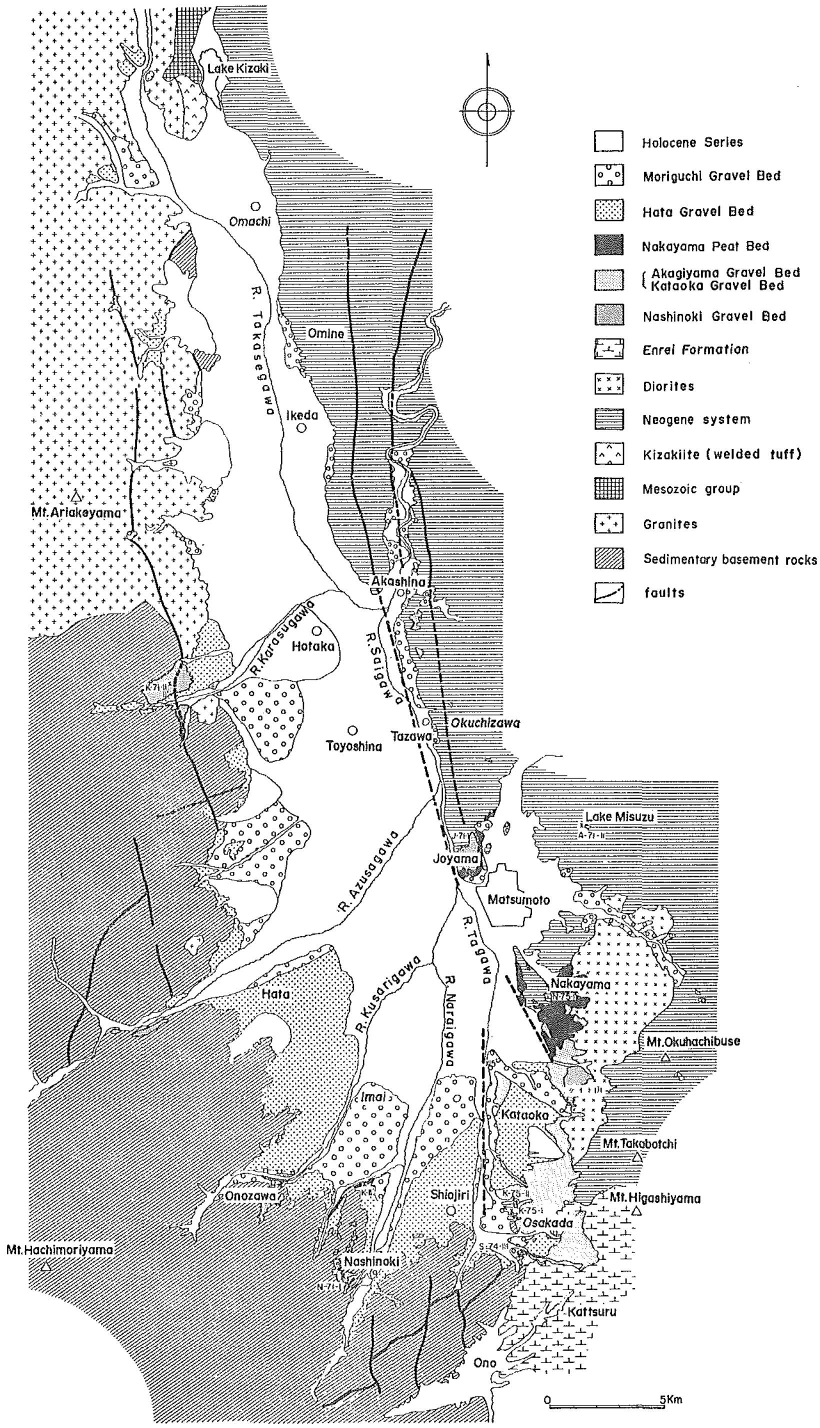


Fig. 3 Geological map of Matsumoto Basin (affer Matsumoto Basin Collaborative Reseach Group, 1977)

Nakayama Peat Bed, and consists mainly of rounded pebbles. In the western border of the basin, a remarkable topographic surface is developed and is called as Hata Surface. Here, a thin gravel veneer of the Moriguchi Gravel Bed covers unconformably on the Hata Gravel Bed.

The western foot of Yatsugatake Volcanoes is formed by the Upper Pleistocene volcanic materials which are composed mainly of lava flows, pyroclastic rocks, volcanic mudflows and gravels, and many peat beds are intercalated within those deposits. Volcanic ashes and pumices originated from Ontake Volcano are also present in and on those deposits, and they are good marker beds useful for correlation with the deposits of other districts.

Along the Kiso Valley three river terraces are developed throughout, and all of those terrace deposits are made up chiefly of gravel and sand intercalated with abundant pumice and scoria beds. Lacustrine deposits exposed along the River Otakigawa contains numerous plant remains, and are correlated with the Kisodani Formation which forms the highest terrace along the River Kisogawa.

In the Nobi Plain which subsided continuously since Pliocene are accumulated thick Pliocene, Pleistocene and Holocene sediments, and the Upper Pleistocene sediments are buried deep under the surface. The Upper Pleistocene deposits, however, have some pumice beds and a mudflow same as those in the Kiso Valley, which enable the accurate correlation between inland and coastal plain.

III. Volcanic ash formation

Among the Japanese geologists, "loam" is used as usual term for Quaternary aeolian volcanic ash, but the usage of this "loam" is not so clearly defined. In this paper the term "loam" is used in stratigraphical meaning as the formation name, such as the Hata Loam Formation and Osakada Loam Formation. As the stratigraphic unit volcanic ash plays an important role in this work, the description of each volcanic ash bed will be given at first. For the "Shinshu Loam Formation" distributed in the Matsumoto Basin and Ina Valley, many researcher has worked until now (KOBAYASHI, K., 1960, 1961; KOBAYASHI, K. *et al.*, 1967, 1971; SHINSHU GROUP, 1969; SAKAI, J. and SHIMONO, M., 1972). On the other hand, the details of volcanic ash bed in the Kiso Valley are reported by SAKAI, J. (1963) and KISODANI QUATERNARY RESEARCH GROUP (1967). The results of these studies are summarized in Fig. 4.

(1) Osakada Loam Formation

The Osakada Loam Formation is composed of volcanic ash and pumice erupted from Ontake Volcano. The formation is measured 3.5 m thick at Osakada Park, to the south of Matsumoto City and more than 7 m thick in the Kiso Valley of west and the Ina Valley of south. At the top of this formation, a black band of paleosol

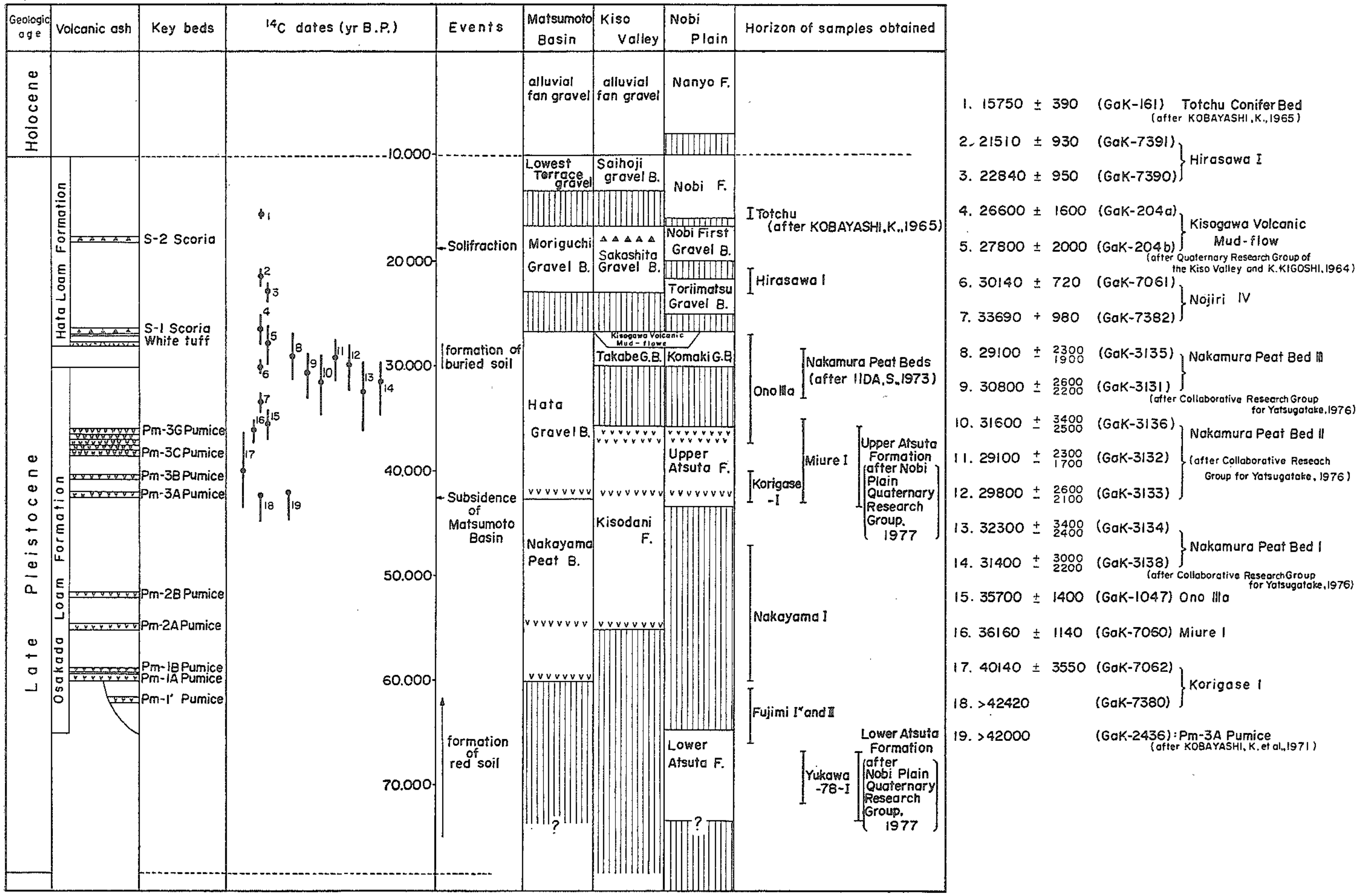
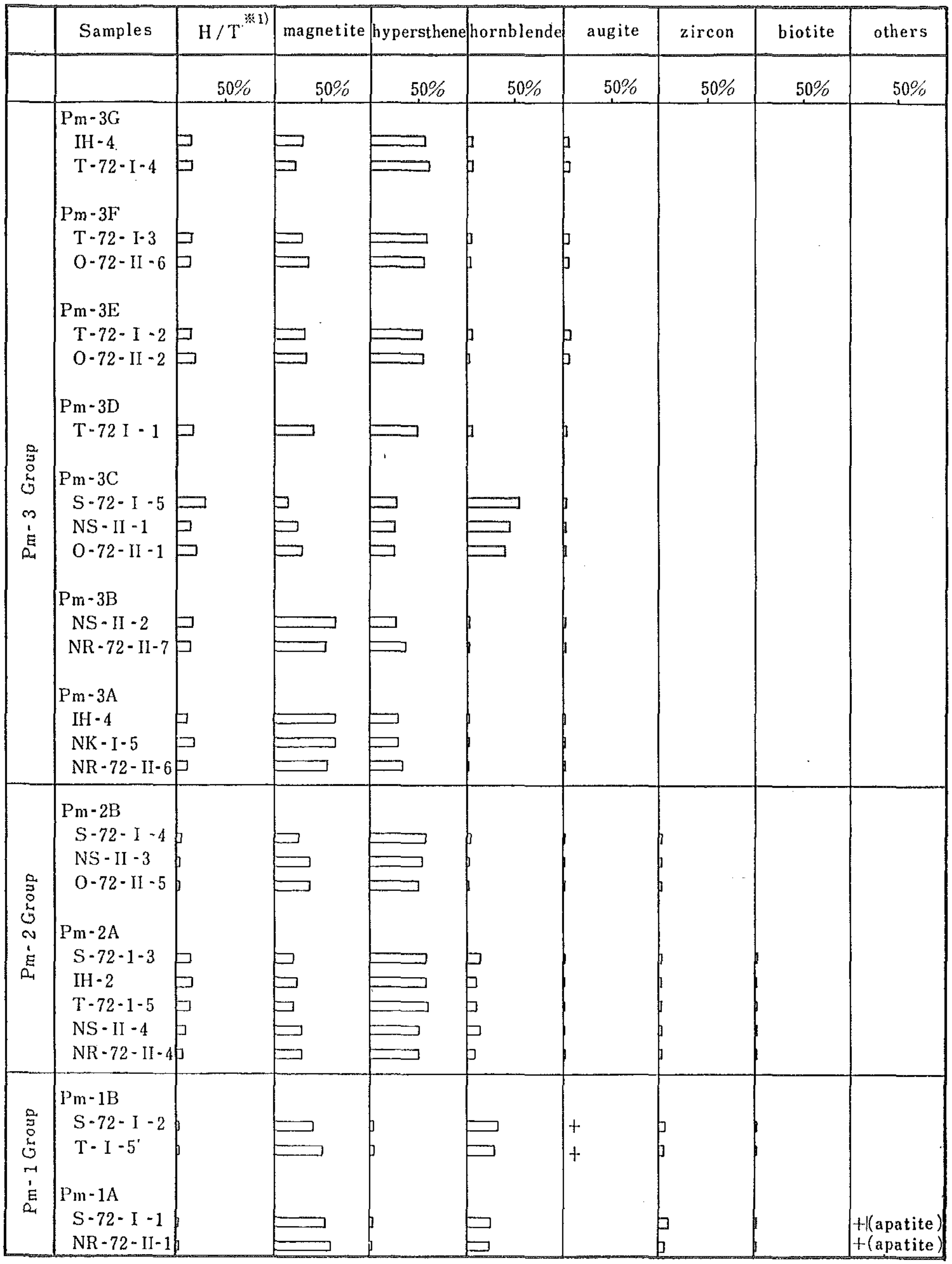


Fig. 4 Stratigraphic classification of the Late Pleistocene in the Matsumoto Basin, Kiso Valley and Nobi Plain



※1) H: mafic minerals
T: mafic minerals + light minerals + glass

Fig. 5 Mafic mineral assemblages of the pumice grains in the Osakada Loam Formation (affer SAKAI, J. and SHIMONO, M., 1972)

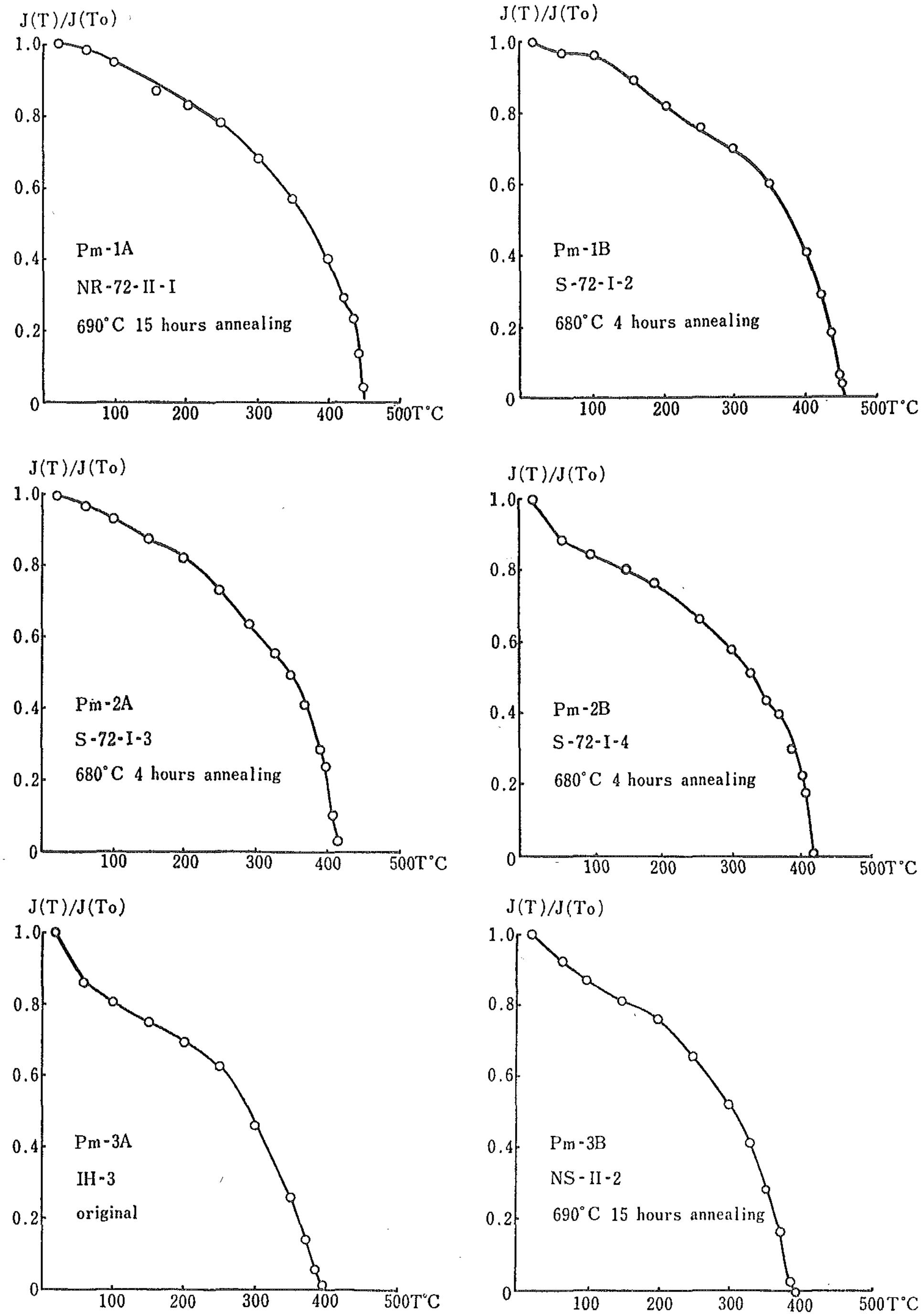


Fig. 6-A J-T curve of ferromagnetic mineral contained in pumice grains of the Osakada Loam Formation, Hex=2400 Oe (in vaccum), $1/8<\phi<1/4$mm(after SAKAI, J. and SHIMONO, M., 1972)

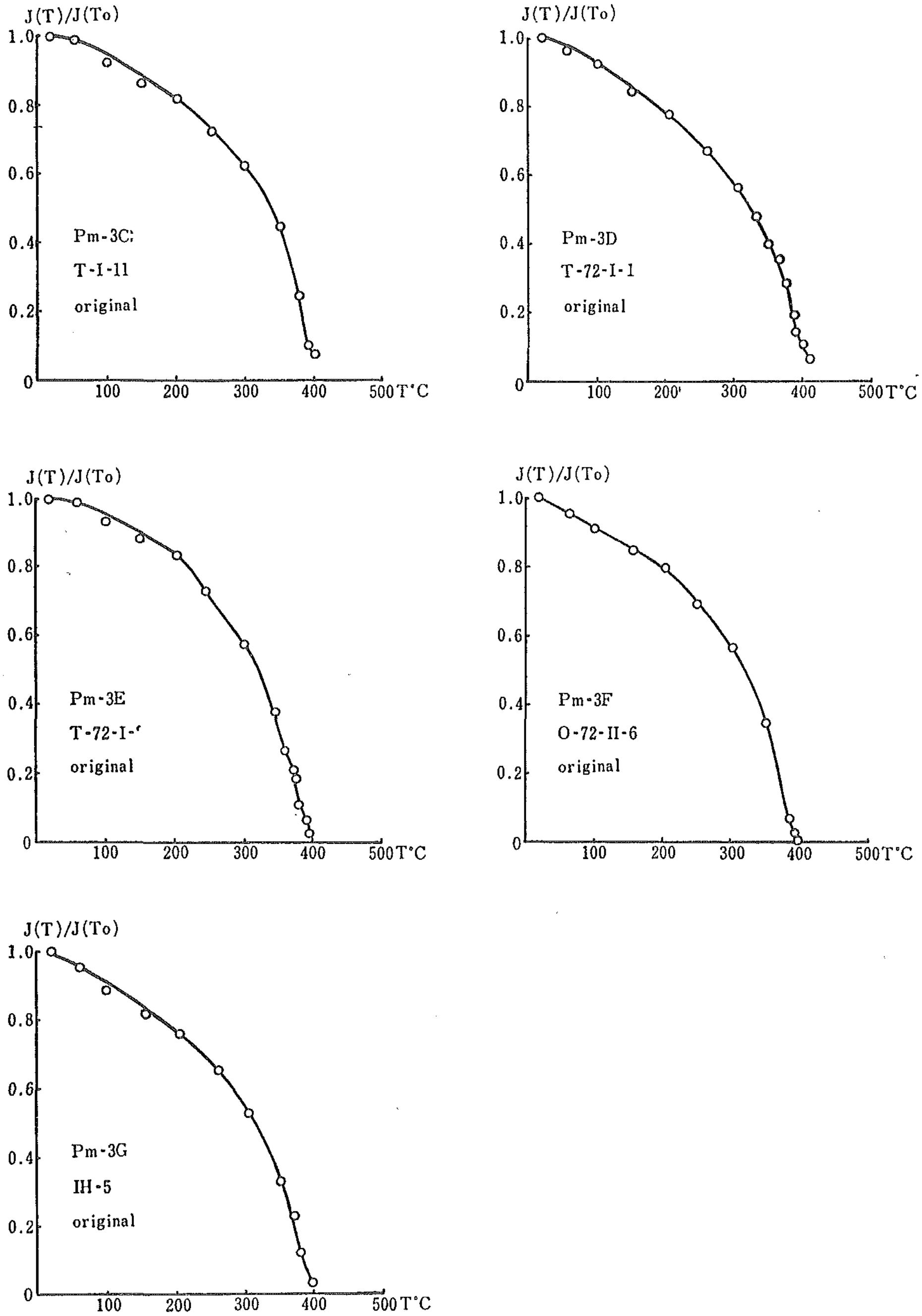
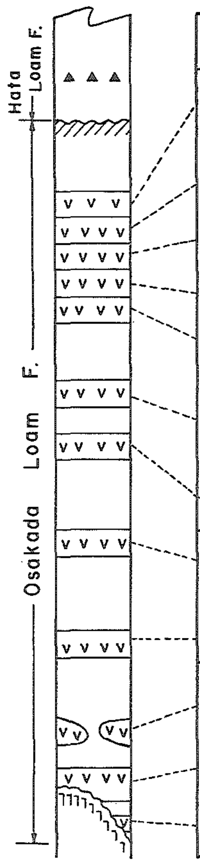


Fig. 6-B J-T curve of ferromagnetic mineral contained in pumice grains of the Osakada Loam Formation, Hex=2400 Oe (in vaccum), $1/8<\phi<1/4$mm (after SAKAI, J. and SHIMONO, M., 1972)



Pumice Beds			H / T	Mafic Mineral Assemblages	Tc (C°)	Distribution in Matsumoto Basin and Ina Valley	Other Remarks
Pm - 3 Group	Pm - 3 G		10 to 20 %	hy > ma ≫ au + ho	400°	From central to northern Ina Valley	
	Pm - 3 F	Pm-3 (Kobayashi, K. and Shimizu, H., 1962)	10 to 20%	hy > ma ≫ au + ho	400°	Northern Ina Valley	
	Pm - 3 E	Hy Type Pm-3 (Sakai, J., 1963)	10 to 20%	hy > ma ≫ au + ho	400°	Northern Ina Valley	
	Pm - 3 D		10 to 20%	hy > ma ≫ ho + au	400°	Northern Ina Valley	fine grains (0.5 to 1 milimeter)
	Pm - 3 C	Pm-3 (Kobayashi, K., 1961), Ho Type Pm-3 (Sakai, J., 1963), Pm-3' (Kobayashi, K. and Shimizu, H., 1966)	20 to 30%	ho > hy ≒ ma > au	400°	From southern part of Matsumoto Basin to northern Ina Valley	Porous texture
	Pm - 3 B	No discription	15 to 20%	ma > hy > ho + au	400°	Southern part of Matsumoto Basin	fine grains (0.5 to 1 milimeter)
	Pm - 3 A	Ma Type Pm-3 (Sakai, J., 1963) Pm-2' (Kobayashi, K. and Shimizu, H., 1962)	15 to 25 %	ma > hy > ho + au	60°, 400°	From southern to central Ina Valley	
Pm-2 Group	Pm - 2 B	No discription	2 to 5 %	hy > ma > ho + au accompanied by Zircon	60°, 415°	From southern part of Matsumoto Basin to northen Ina Valley	Mixed by bluish grey Volcanic sand
	Pm - 2 A	Pm-2 (Kobayashi, K. and Shimizu, H., 1962)	10 to 20 %	hy > ma > ho ≫ au accompanied by Zircon and biotite	425°	From southern part of Matsumoto Basin to central Ina Valley	
Pm-1 Group	Pm - 1 B	Pm-2 (Kobayashi, K. 1961) Pm-1 (Kobayashi, K. et. al. in Shinshu Research Group, 1969)	1 to 5 %	ma > ho ≫ hy > au accompanied by Zircon and biotite	60°, 450°	From southern part of Matsumoto Basin to central Ina Valley	coarse grains
	Pm - 1 A	Pm-1 (Kobayashi, K. 1961)	less than 1 %	ma > ho > hy accompnied by Zircon, biotite and apatite	450°	From central part of Matsumoto Basin to southern Ina Valley	very coarse grains fibrous texture
	Pm - 1'	Pm-1' (Kobayashi, K. and Shimizu, H. 1965)					

Fig. 7 Characteristics of pumice beds of the Osakada Loam Formation
hy : hypersthene, ma : magetite, au : augite, ho : hornblende
(after Sakai, J. and Shimono, M., 1972)

is observed. A typical pumice fall of Pm–1A in the basal part, is peculiar to the formation, and the presence of a thick and well developed cracky reddish soil layer beneath Pm–1A Pumice Bed suggests the heavy weathering under warm climate before the pumice fall of Pm–1A. In some cases, about 1 m thick volcanic ash member is recognized below Pm–1A in the Osakada Loam Formation in Kiso and Ina Valley. In this member a thin pumice bed (Pm–1′) is intercalated in the middle part.

On the characteristics of the pumice beds of the Osakada Loam Formation, SAKAI, J. and SHIMONO, M. (1972) made a precise study (Fig. 5, 6–A, 6–B and 7), and, as a result, a stratigraphical value of those pumice is remarkably increased. The pumice beds of the Osakada Loam Formation are classified into twelve beds, that is, Pm–1′, Pm–1A, Pm–1B, Pm–2A, Pm–2B, Pm–3A, Pm–3B, Pm–3C, Pm–3D, Pm–3E, Pm–3F and Pm–3G in ascending order.

Pm–1′ Pumice Bed : It consists of fine–grained white pumices which contain mafic minerals scarcely. The grain size of pumice is 0.5–1 mm at Fujimi and 1–3 mm in the Kiso Valley. From mafic mineral composition, pumice of Pm–1′ is similar to Pm–1A (Fig. 8), but the former is distinguishable from the latter in having more abundant magnetite and less amount of hornblende. J–T curve (Fig. 9) shows a single phase with Tc which is close to 460°C.

Pm–1A and Pm–1B Pumice Bed: The distribution of Pm–1A is widest among the pumice beds of the Osakada Loam Formation, extending to the Kofu Basin. The thickness of the pumice bed ranges from 3 to 5 m in the Kiso Valley to about 1 m in the Ina Valley and 0.3 m in the Matsumoto Basin. The size of pumice is 4–6 cm in the Kiso Valley, 2–3 cm in the Ina Valley and 1–2 cm in the Matsumoto Basin. Pumice of Pm–1A is characterized by fibrous texture and by presence of biotite crystal. The color of pumice is generally white when it is fresh, but is yellow when it is weathered.

In the type section, Pm–1B Pumice Bed lies about 10 cm above Pm–1A Pumice Bed. It is characteristics of Pm–1B that it is thin in general and is sometimes represented by sporadic pumice grains in sediments. In mafic mineral composition, Pm–1A and Pm–1B are quite similar to each other in having abundant magnetite and hornblende, with a small amount of biotite and zircon.

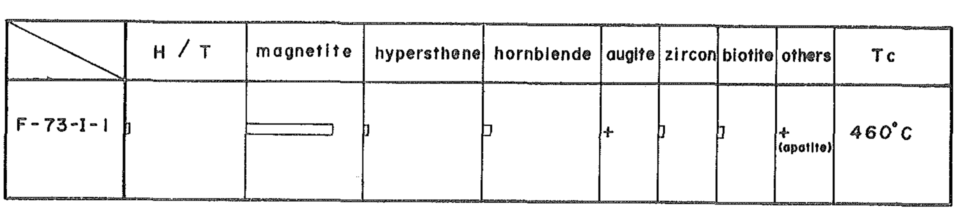


Fig. 8 Mafic mineral assmblage Pm–1′ Pumice

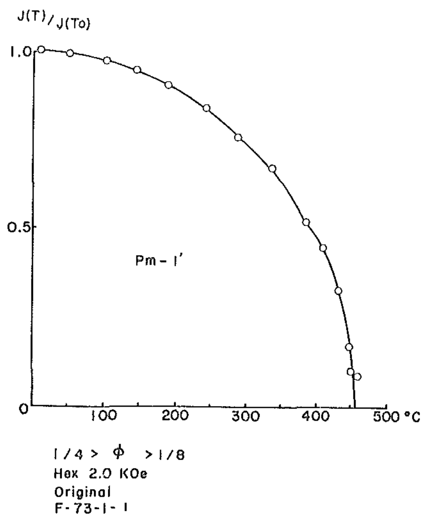


Fig. 9 J–T. curve of ferromagnetic minerals in Pm–1′ Pumice

Pm–1A and Pm–1B Pumice reveal commonly Tc of 450°C, but the former has a single phase J–T curve and is distinguishable from the latter which shows double phase J–T curve with Tc of 60°C and 450°C (Fig. 6–A).

Pm–2A and Pm–2B Pumice Beds : Pm–2A Pumice Bed is distributed in the northern part of the Kiso Valley, the northern part of the Ina Valley and the southern part of the Matsumoto Basin. The pumice bed is from 10 to 15 cm thick at Shiojiri and about 50 cm thick at Ina City. The size of pumice is 2–3 mm at Shiojiri and 2–4 mm at Ina City. The mafic mineral composition of pumice is characterized by abundant hypersthene accompanied by a less amount of magnetite and hornblende. J–T curve shows a single phase with Tc of 425°C.

The distribution of Pm–2B Pumice Bed is restricted to the southern part of the Matsumoto Basin and the upper reaches of the River Naraigawa. The pumice bed is characterized by mixture of very fine–grained yellow pumice and abundant bluish volcanic sand. Mafic mineral composition of Pm–2B closely resembles that of Pm–2A, but is marked by lack of biotite. J–T curve shows a double phase with Tc of 60°C and 415°C.

Pm–3 Pumice group : It is characteristic that biotite and zircon are generally absent in the pumices of Pm–3 group. The Pm–3A Pumice Bed has a wide distribution next to Pm–1A. The thickness of the pumice bed is about 2 m at Kisofukushima and 1.5 m at Ina. Grain size of the pumice is 10 to 20 mm at Kisofukushima and 2 to 5 mm in diameter at Ina. Mafic minerals are dominated by magnetite and hypersthene. J–T curve shows a double phase with Tc of 60°C and 400°C.

Extention of Pm–3B Pumice Bed reaches to the southern part of the Matsumoto Basin and the upper reaches of River Naraigawa which is south to the basin. The pumice bed is thin, and its grain size is very small. The mafic mineral composition is rather similar to that of Pm–3A Pumice, and its J–T curve shows single phase with Tc of 400°C.

Pm–3C Pumice Bed is rather widely distributed covering the area of the Matsumoto Basin, the northern part of the Ina Valley and Kiso Valley. Pumice of the bed is characterized by porous texture and in having over 50 percent hornblende.

Pm–3D, Pm–3E, Pm–3F and Pm–3G Pumice Beds show a continuous deposition at the type section of Tatsuno, and they seem to compose a single stratigraphical unit. Accordingly, they can be classified only by grain size; 0.5–1 mm in Pm–3D, 1–3 mm in Pm–3E, 2–5 mm in Pm–3F and 1–3 mm in Pm–3G, Thickness of each bed is 5 cm (Pm–3D), 30 cm (Pm–3E), 60 cm (Pm–3F) and 30 cm (Pm–3G) respectively. Among them Pm–3G has the widest distribution. These four pumice beds resemble each other in having similar mafic mineral composition and commonly single phase J–T curve with Tc of 400°C.

(2) Hata Loam Formation

The Hata Loam Formation is composed of weathered volcanic ashes erupted from Ontake and Norikura Volcanoes (KOBAYASHI, K., 1960, 1961; SAKAI, J., 1963). The thickness of the formation is 2.8 m at the type section of Osakada Park in Shiojiri, but it reaches more than 10 m on the eastern foot of Ontake Volcano. The formation is intercalated with two scoria beds, S–1 and S–2. S–1 Scoria Bed is correlated with the Kisogawa Volcanic Mudflow of the Kiso Valley. Radiocarbon dates of the latter are 26600±1600 yr B. P. (Gak–204a) and 27800±2000 yr B. P. (Gak–204b) (Quaternary Research Group of Kiso Valley and K. KIGOSHI, 1964). S–2 Scoria Bed is interbedded in the middle part of the formation. It is noteworthy that periglacial phenomena has been recognized in the horizon just below S–2, at the level of about 1000 m above sea–level or more than it in the Kiso Valley. It suggests the advent of cold climate which brought about solifraction (SAKAI, J., 1963).

Scoria of S–1 and S–2 closely resemble each other in mafic mineral composition,

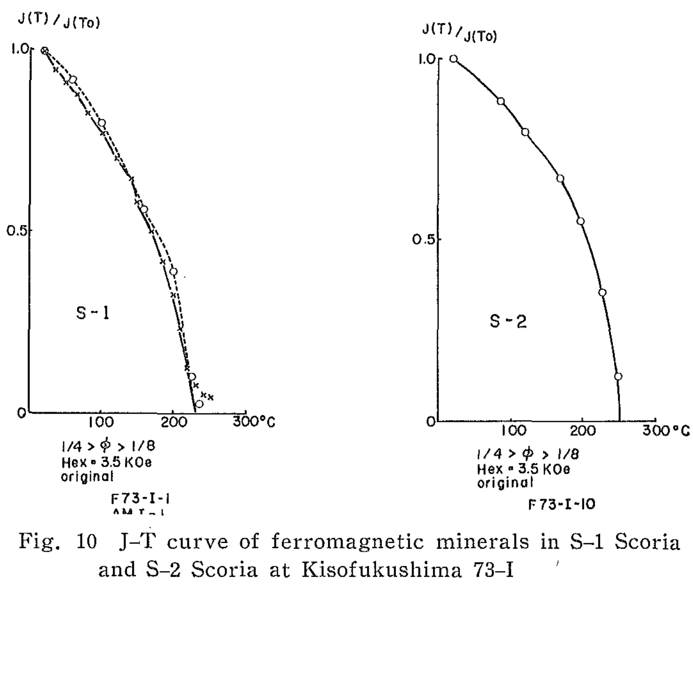


Fig. 10 J–T curve of ferromagnetic minerals in S–1 Scoria and S–2 Scoria at Kisofukushima 73–I

but S–2 is distinguishable from S–1 by the existence of hornblende. As shown in Fig. 10, J–T curves of S–1 and S–2 are both represented by single phase, but Tc is different from each other.

IV. Upper Pleistocene stratigraphy of the area

A. Kiso Valley and Nobi Plain

(1) Kisodani Formation and its correlatives

It is commonly agreed that the Kisodani Formation consists mainly of volcanic sand derived from Ontake Volcano (SAKAI, J., 1963; Kisodani Quaternary Research Group, 1967; KOBAYASHI, K. *et al.*, 1971), and it has been accepted that the Kisodani Formation has Pm–1A Pumice intercalation at the base and Pm–3 Pumice group in the uppermost. As stated before, SAKAI, J. and SHIMONO, M. (1972) made systematic study on pumice beds of the Osakada Loam Formation (Fig. 5, 6 and 7). On the basis of that study, the author correlated the pumice beds of the formation with those of the Kisodani and Atsuta Formation. As a result, he came to have a different conclusion from previous workers.

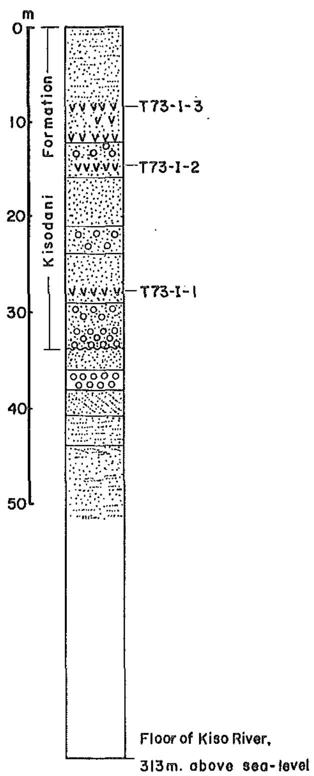


Fig. 11 Columnar section at Tadachi 73–I

The pumice grains contained at the base of the Kisodani Formation is not Pm–1A Pumice (Pm–1 in KOBAYASHI, K. *et al.*, 1971), but Pm–2A Pumice (Pm–2 in KOBAYASHI, K. *et* al., 1971). Therefore, deposition of the Kisodani Formation started just before the pumice fall of Pm–2A.

A geologic section can be observed on the left side of River Kisogawa at Aso of Yamaguchi–mura, Nagano Prefecture, and is shown in Fig. 11, schematically. In this place the lower part of the section is composed mainly of cross–laminated arkose sand without any volcanic products like pumice, scoria and ash. Such a sedimentary facies has never been known in the Kisodani Formation. The deposits of the upper part covers unconformably the lower part, and they show a typical sedimentary facies of the Kisodani Formation. In these upper deposits three pumice intercalations are observed. These pumice grains have no fibrous texture and are small, 1 to 5 mm in diameter. In other words these pumice grains have nothing of characteristics of Pm–1A Pumice. Mafic minerals of a sample (T73–I–1) are hypersthene (46.9% in weight), magnetite (33.0%, do), hornblende (15.6% do), augite (2.2%, do), zirocn (1.8%, do) and biotite (0.4%, do). Weight ratio of mafic minerals to total sum of minerals and glass is 8.6, much larger than 0.1 of Pm–1A Pumice, J–T curve is single phase with Tc of 425°C (Fig. 12). Taking all of the information into consideration, those pumice grains are assignable to Pm–2A Pumice. Pumice grains of other samples of higher horizons (T73–I–2 and T73–I–3) are also clarified to belong to Pm–3B to Pm–3G of Pm–3 Pumice group, from the view point of field occurrence, mafic mineral assemblage and J–T curve (Fig. 12).

Consequently, there is no evidence that Pm–1A is present in the Kisodani Formation. This conclusion may be applied to the Kisodani Formation in other areas.

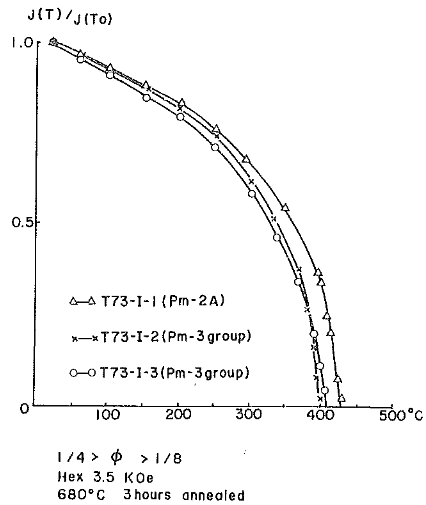


Fig. 12 J–T curve of ferromagnetic minerals in pumice grains at Tadachi 73–I

Lacustrine sediments are distributed in some places at Miure, Takigoshi and Korigase on the southern foot of Ontake Volcano, and an unnamed pumice bed is newly discovered in those sediments. Similar pumice is contained in large quantities in a mudflow–like deposits along River Otakigawa, which are correlated with the Kisodani Formation. The pumice grains are characterized by the presence of rich mafic minerals and unique feature of J–T curve (Fig. 13). But, after thermomagnetic treatment of the sample it becomes clear that J–T curve (TR–I–1) is consistent with normal J–T curve of Pm–3B to Pm3G Pumice group. Moreover, mafic mineral assemblage of TR–I–1 is same to that of Pm–3B to Pm–3 Pumice group, that is, 49.6% of magnetite, 46.5% of hypersthene, 1.9% of hornblende and 1.9% of augite (weightpercent). Accordingly, it may be concluded that unnamed pumice belongs to Pm–3 Pumice group, and that lacustrine deposits on the southern foot of Ontake Volcano is synchronous with the Kisodani Formation.

1a) Korigase I (KG–I)

The peat bed KG–I is included in the lacustrine deposits near Korigase (980 m high above sea–level) along River Uguigawa, a tributary of River Otakigawa. The lacustrine deposits overlie unconformably the Nohi Rhyolites, and is composed mainly of alternation of peaty silt and fine sand. Gravel beds are contained in the lower, middle and uppermost parts of this deposits. Carbon–14 dates of plant remains contained are 40140±3500 yr B. P. (Gak–7062) and older than 42400 yr B. P. (Gak–7380).

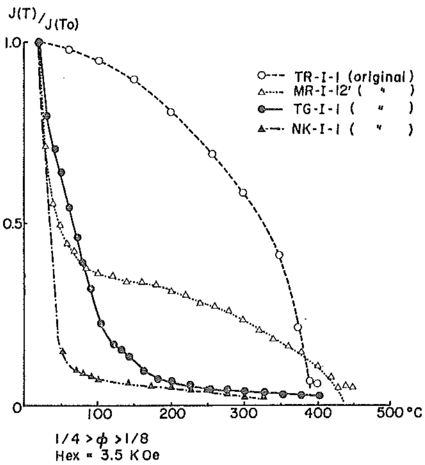


Fig. 13 J–T curve of ferromagnetic minerals in pumice grains obtained from lacustrine deposits on the foot of Ontake Volcano

1b) Takigoshi I. II (TG–I. II) and Terasawa I (TR–I)

The peat beds of TG–I. II and TR–I are located at Takigoshi (about 1100 m high above sea–level). Alternation of peaty silt and sand are of lacustrine origin and contain a large number of plant remains. Pumice sample TR–I–1 is obtained from the lower part of the laustrine deposit which is more than 50 m in thickness.

1c) Miure I (MR–I)

The peat bed MR–I is exposed at a locality west to Lake Miure, which is about 1300 m high above sea–level. Peaty silts are intercalated in the middle of gravel bed which overlies unconformably the older lava–flows of Ontake Volcano. The peaty silts contain many palnt remains and white pumice grains are distributed sporadically in it. Carbon–14 date of plant remains of the upper part is 36160±1140 yr B. P. (Gak–7060). J–T curve of the pumice grains is shown in Fig. 13.

1d) Nakagiri I (NK–I)

The location NK–I is 14 km south–east to Ontake Volcano. The bed makes a river terrace in small scale, and is composed of mudflow–like deposits. In these sediments many pumice grains are contained and tree remains are found. J–T curve of the pumice grains is shown in Fig. 13.

(2) Lower Atsuta Formation and Upper Atsuta Formation

In Nobi Plain, the stratigraphy of the Lower Atsuta and Upper Atsuta Formations is subjected to the present sutdy. The lower limit of the upper Atsuta Formation has been controversial. In the reports based on the drilling data, SAKAI, J. (1963) and Kisodani Quaternary Research Group (1967) are all of the opinion that in the Upper Atsuta Formation the pumice grains of Pm–1A and Pm–3 are contained in its lower part and upper part respectively, and, KOBAYASHI, K. *et al.* (1968, 1971) also reported the presence of Pm–1A Pumice in the same formation. Concerning this complicated problem, the author made critical reexamination and obtained following results.

All of the pumice grains sampled from the Upper Atsuta Formation are characterized by abundance of mafic minerals and absence of fibrous texture. As these features suggest that the pumice grains of the Upper Atsuta Formation are different

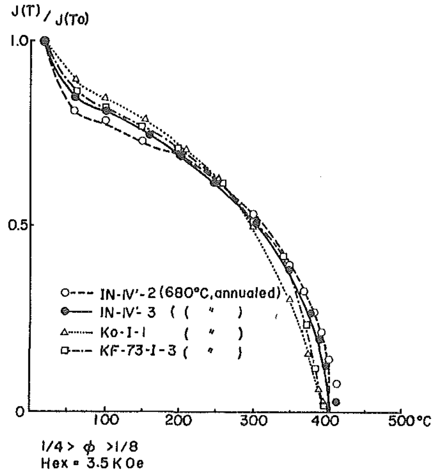


Fig. 14 J–T curve of ferromagnetic mineals in Pm–3 Pumice

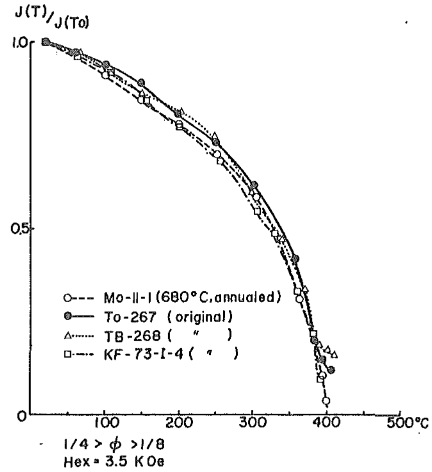


Fig. 15 J–T curve of ferromagnetic minerals in Pm–3 Pumice (Pm–3B to Pm–3G)

from those of Pm–1A, it is possible to say that there is no Pm–1A in that formation. Moreover, mafic mineral assemblage lacks biotite and zircon indicating also that these pumice grains are not of Pm–2A or Pm–2B Pumice.

Two types of J–T curve are shown in the pumice grains of the Upper Atsuta Formation (Fig. 14 and 15). One is double phase J–T curve with Tc of 60°C and 400°C, which is typical in the samples obtained from the northern part of Nobi Plain, including Inuyama and Komaki. The other is single J–T curve with Tc of 400°C, shown in the pumice grains collected from the southern part of Nobi Plain, including Tobishima and Atsuta Surface area, east to the Nagoya station. Consequently the former may be assignable to the Pm–3A type, and the latter may belong to the Pm–3D to Pm–3G type.

There is only one confirmable sample of Pm–1A Pumice. It was reported from the borehole at West II of the Nagoya port (KOBAYASHI, *et al.*, 1968), and was considered to be contained in the Upper Atsuta Formation (Fig. 16). In connection with it, the author tried to examine accurate stratigraphical position of this Pm–1A. At Tobishima about 2 km west to the locality of the Nagoya Port, the Upper Atsuta Formation contains Pm–3C to Pm–3G Pumice (Fig. 17 and 18). In the geologic profile of Nobi Plain, a continuity of these deposits is confirmed by drilling data from Tobishima to Nagoya Port (Fig. 19). In this profile, the Upper Atsuta Formation overlies unconformably the deposits which contain Pm–IA. Therefore, it is concluded that the pumice grains at West II of the Nagoya Port may be not of the Upper Atsuta Formation, but of the Lower Atsuta Formation, and that the lowest pumice bed of the Upper Atsuta Formation is Pm–3A. But some discussions on the

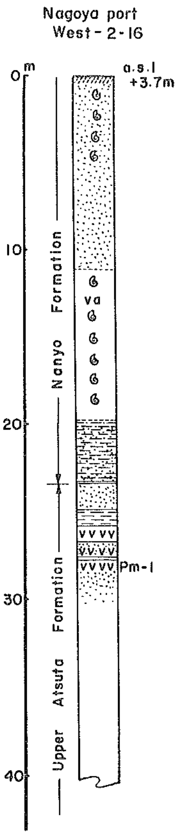


Fig. 16 Columnar section in Nagoya Port West-2-16 (after KOBAYASHI, K. et al., 1968)

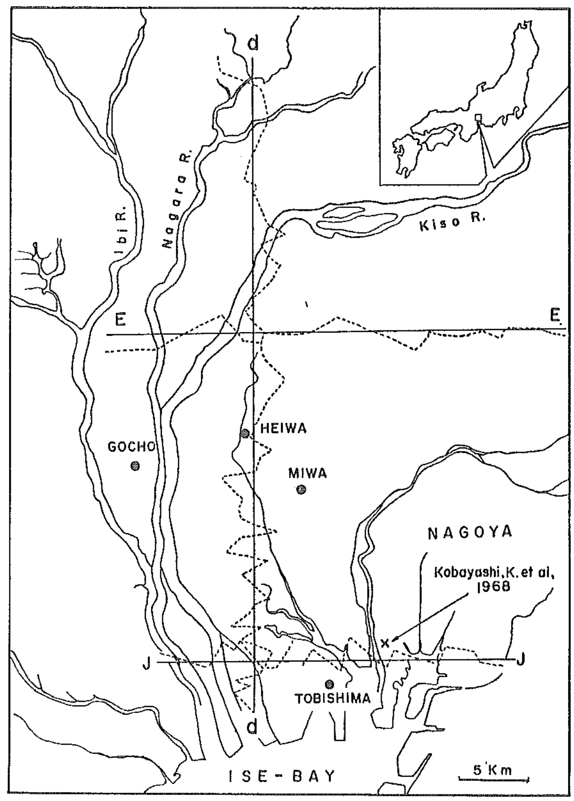


Fig. 17 Geologic section and location of drilling in the Nobi Plain (after Nobi Plain Quaternary Research Group, 1977)

stratigraphic position of Pm-1A should be taken into consideration. There will be given alternative assumption.

1) If Pm-1A is contained in the uppermost part of the Lower Atsuta Formation, it would be mostly worn out by erosion in other areas.
2) If Pm-1A deposited after the time of the Lower Atsuta Formation, it would distribute far to offshore area from the present Nagoya Port area except for some samll areas under particular condition.

(3) Takabe Gravel, Komaki Gravel and Kisogawa Volcanic Mudflow

The Takabe Gravel of the Kiso Valley and Komaki Gravel Beds of the Nobi Plain overlies unconfomably the Kisodani Formation and the Upper Atsuta Formation respectively. On the other hand, both gravel beds are overlain conformably by the Kisogawa Volcanic Mudflow, which is exposed on the surface from Inuyama to

Komaki and is buried under alluvial deposits in the southern part of the Nobi Plain. The Takabe Gravel Bed and Kisogawa Volcanic Mudflow form the Takabe Surface, and the Komaki Gravel Bed makes up the Komaki Surface.

(4) Sakashita Gravel Bed

The Sakashita Gravel Bed is distributed only in the Kiso Valley, and overies unconformably the Takabe Gravel Bed and Kisogawa Volcanic Mudflow. This gravel bed is composed mainly of rounded pebbles and small amount of sandy matrix. In this bed S–2 Scoria is contained at Hosojima in the uppermost reaches of River Kisogawa. The plant bed, Hirasawa I (HR–I) is situated at Hirasawa, upper reaches of River Naraigawa. In this place, the gravel formation which is correlated with the Sakashita Gravel Bed mentioned above intercalates alternation of peat and peaty silt yielding abundant plant remains (SAKAI, J. *et al.*, 1979). The carbon-14 dates are 21510±930 yr B. P. (Gak–7391) in upper part of the plant bed and 22840±950 yr B. P. (Gak–7390) in lower part of its.

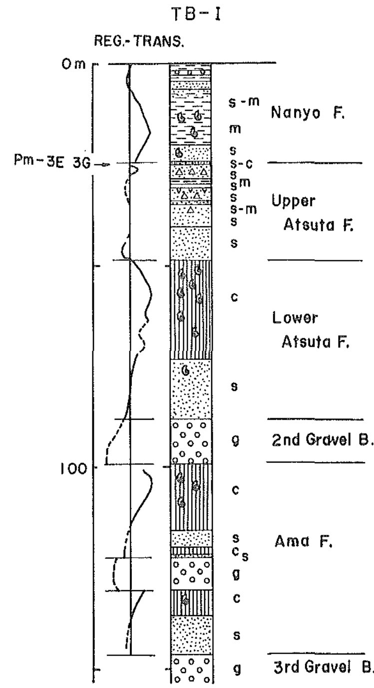


Fig. 18 Columnar section in TB–I (after Nobi Plain Quaternary Reseach Group, 1977)

(5) Toriimatsu Gravel Bed, Nobi First Gravel Bed and Nobi Formation

Chronological order of the Toriimatsu Gravel Bed, Nobi First Gravel Bed and Nobi Formation have been discussed by many workers. It was one of the problems whether the Nobi First Gravel Bed was before or after the Maxmum Würm stage. In this paper the author treats the Nobi First Gravel Bed as the deposits after the Maximum Würm following to KUWABARA, T. *et al.* (1972) and Nobi Plain Quaternary Research Group (1977) (Fig. 4).

B. Matsumoto Basin and its environs

(1) Nakayama Peat Bed

The Nakayama Peat Bed exposed at the eastern and south–eastern edge of Matsumoto Basin intercalates Pm–1A at the base and Pm–2B in the upper part (Matsumoto Basin Research Group, 1977). Moreover, it has been known that this bed contains Pm–2A in the middle part (SAKAI, J., 1973a). The Nakayama Peat Bed is overlain conformably by the Hata Gravel Bed which contains Pm–3A Pumice at the base. Therefore, the Nakayama Peat Bed is represented by a continuous

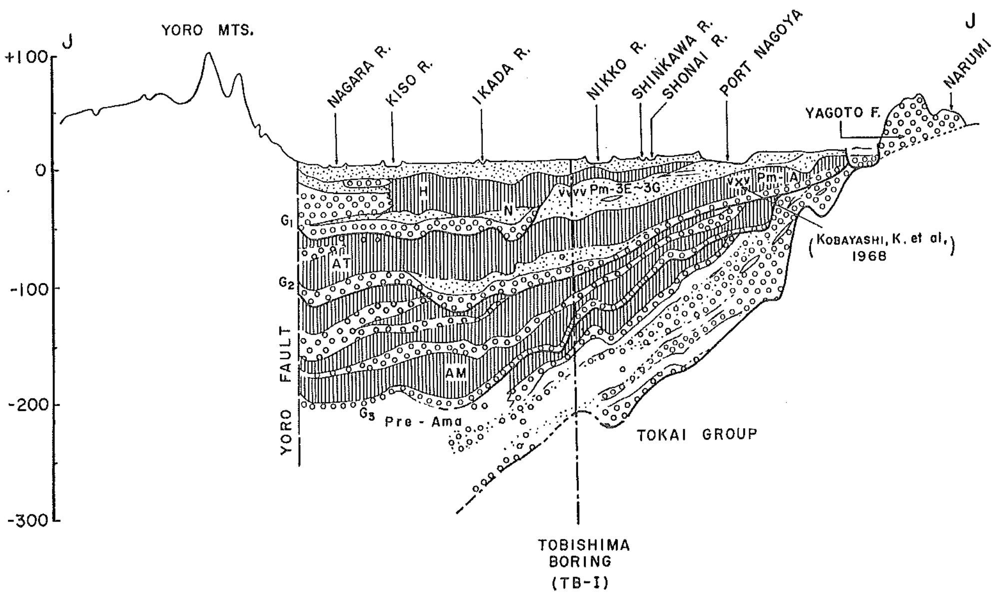


Fig. 19 Geologic section of Nobi Plain (after Nobi Plain Quaternary Research Group, 1977)

depositional sequence from the time of Pm–1A to that of Pm–3A.

(2) Hata Gravel Bed

The Hata Gravel Bed, about 100 m thick, is composed mainly of rounded pebble. This bed forms the widest topographic surface in the Matsumoto Basin, named as the Hata Surface. This gravel formation contains Pm–3A at the base. On the Hata Surface, most of the Hata Loam Formation are observed as aeolian covering, but its lowermost part which contains S–1 Scoria is not present.

The locality of the Ono Peat Bed is situated in a small basin about 3 km south from the southern edge of Matsumoto Basin. The Ono Peat Bed exposed in this basin has been known to yield abundant plant remains. It contains Pm–3E and Pm–3G in the lowermost part, and is conformably overlain by the Hata Loam Formation. Carbon–14 date at the middle part of the peat bed is 35700±1400 yr B. P. (Gak–1047) (KOBAYASHI, K. and SHIMIZU, H., 1966).

(3) Moriguchi Gravel Bed

The Moriguchi Gravel Bed unconformably overlies the Hata Gravel Bed. It forms the Moriguchi Surface which is developed as river terraces in Matsumoto Basin. This gravel bed is 5 to 10 m in thickness, but it has no distinctive marker bed. On the Moriguchi Surface, the upper part of the Hata Loam Formation covers.

The Totchu Conifer Bed (KOBAYASHI, K., 1965) is known at Totchu about 1 km east of Akashina, north to Matsumoto, and is about 600 m in altitude. This bed is about 6 m thick, and is composed mainly of mudstone breccias derived from the Tertiary rocks nearby. In this bed, two peat layers are intercalated, which contain abundant plant remains. Fossil antler of a giant deer *Megaloceros* was also unearthed (KAMEI, T., 1958). The carbon-14 date of lower part of the peat bed is 15750 ±390 yr B. P. (Gak-161).

C. Western foot of Yatsugatake Volcanoes

The piedmont district of Yatsugatake Volcanoes occupies a vast area of central part of Central Japan, and provieded one of the best fields for Pleistocene stratigraphy. In the present paper, the author would like to refer some of important sections in relation to this study.

(1) Yukawa Peat Bed (Y-78-I)

The Yukawa Peat Bed, 4.5 m thick, is exposed along River Takinoyukawa and is situated 1050 m high above sea-level. This bed is composed of alternations of peat and peaty silt with intercalations of two white tuff layers in the lowermost part. The Yukawa Peat Bed is almost conformably overlain by Tateshinakogen Lava Flow which is correlated with the Otometaki Lava Flow in the east of Chino City (Fig. 20). Further the latter lava flow is also overlain unconformably by the Furuta Gravel Bed. It is noteworthy that the constitutents of this bed grade into pumices of Pm-1A upwardly. Although the Furuta Gravel Bed, Fujimi Peat Bed and Kobuchizawa Peat Bed are separately distributed in this district, those three beds have Pm-1A in common and referred to be contemporaneous with each other. Pollen fossils and plant remains of the Yukawa Peat Bed were reported by SAKAI, J. *et al.* (1979).

(2) Fujimi Peat Bed (F-I″. II)

The Fujimi Peat Bed, about 10 m thick, is situated at Fujimi, about 960 m above sea-level. It consists mostly of peat and peaty silt, and is conformably overlain by thick Pm-1A. In the upper part of this bed a thin pumice layer of Pm-1′ is intercalated. Pollen fossils and plant remains were reported by SAKAI, J. (1973 b).

(3) Nakamura Peat Beds

The Kitayama Pumice Flows covers the area of Minamioshio on the western foot of Yatsugatake Volcanoes. These pumice flows can be divided into four sheet units by the intervention of three peat beds' namely Nakamura Peat Bed I, II and III in ascending order. These peat beds are stratigraphically upper than Pm-3 horizon, and lower than S-1 Scoria horizon. Pollen floras of the peat beds were studied by IIDA, S. (1973). Carbon-14 dates of the peat beds are as follows (Yatsugatake Collaborative Research Group, 1976).

Nakamura Peat Bed III : $29100\pm^{2300}_{1900}$ yr B. P. (Gak-3135) ; $30800\pm^{2600}_{2200}$ yr B. P.

Age \ Area		Western foot: Environs of River Takinoyukawa	Western foot: Environs of River Shibukawa	Southern foot	Key beds
Holocene		Alluvium	Alluvium	Alluvium	
Pleistocene	Late	Younger Volcanic Ash F.; Kitayama Pumice Flows	Younger Volcanic Ash F.; Kitayama Pumice Flows and Nakamura Peat B.; Izumino Gravel F.	Younger Volcanic Ash F.	▲▲▲ S-1 Scoria Bed; v v v Pm-3 Pumice Beds; v v v Pm-1A Pumice Bed
			Furuta Gravel B.	Fujimi Peat B. · Kobuchizawa Peat B.	v v v Orange Pumice Bed
		Tateshinakogen Lava	Otometaki Lava		
		Yukawa Peat B.	Shibukawa Loam F.; "Shirasu" Volcanic Sand F.		White Tuff Bed
			Shibukawa Tuffbreccia		
			Nagakura Gravel B.	Omugawa Gravel B.	
	?		Serigasawa Tuffbreccia		
	Middle	Takinoyukawa Tuffbreccia	Itogaya Pyroclastic Flows	Hinoharu Sand and Mud F.	
			Yanagawa Pyroclastic Flows	Nirasaki Pyroclastic Flows	

Fig. 20 Stratigraphy on the western and southern foot of Yatsugatake Volcanoes (modified from SAKAI, J. et al., 1979)

(Gak–3131)

Nakamura Peat Bed II : $31600\pm^{3400}_{2500}$ yr B. P. (Gak–3136); $29100\pm^{2300}_{1700}$ yr B. P. (Gak–3132); $29800\pm^{2600}_{2100}$ yr B. P. (Gak–3133)

Nakamura Peat Bed I: $31400\pm^{3000}_{2200}$ yr B. P. (Gak–3138); $32300\pm^{3400}_{2400}$ yr B. P. (Gak–3134)

Carbon–14 date of the Kitayama Pumice Flow IV (the uppermost sheet) is also 24600±100 yr B. P. (Gak–616) (KAWACHI, S. and KITAZAWA, K., 1967).

V. Palynology and Paleobotany

A. Method of pollen analysis

The technique, which is employed by the author, is briefly described to illustrate the stages of cleaning.

1) After 10 percent KOH treatment without boiling, field sample is washed repeatedly with water

2) Sieve it with 60 mesh screen

3) Heat it with 10 percent KOH for 5 minutes in a boiling water–bath

4) Wash it with water (10 times)

5) Packed it in a tube with 70 percent $ZnCl_2$, and heat it in centrifuge tube. Repeat this procedure once more

6) Make HF treatment in a plastic centrifuge tube

7) Wash it with water and dehydrate it with glacial acetic acid. Treat it centrifugally.

8) Treat with a fresh mixture of Ca. 9 parts anhydric acetic acid and one part H_2SO_4 conc.. Heat 30 seconds in a boiling water–bath. Centrifuge

9) Wash it with glacial acetic acid and water

10) Preparation of permanent mount by the use of glyceraljelly and manicure.

About 200 to 500 pollen grains are counted in each sample. The percentage of each AP (arboreal and shrub pollen) is expressed in the total AP, and that of each NAP (nonarboreal pollen) is expressed in the total pollen grains summing up Ap and NAP.

B. Pollen analysis of recent sediments

In order to interpret contemporary pollen assemblage from neighbouring site, the pollen analysis was carried out for recent sediments in forested area. A result of this work is shown in Fig. 21, and the explanation of sampling sites are as follows.

Akasawa–II–17 is located at the site west to Agematsu in Kiso Valley, and the forest trees of this site (1140 m above sea–level) are of *Chamaecyparis obtusa* (Japa-

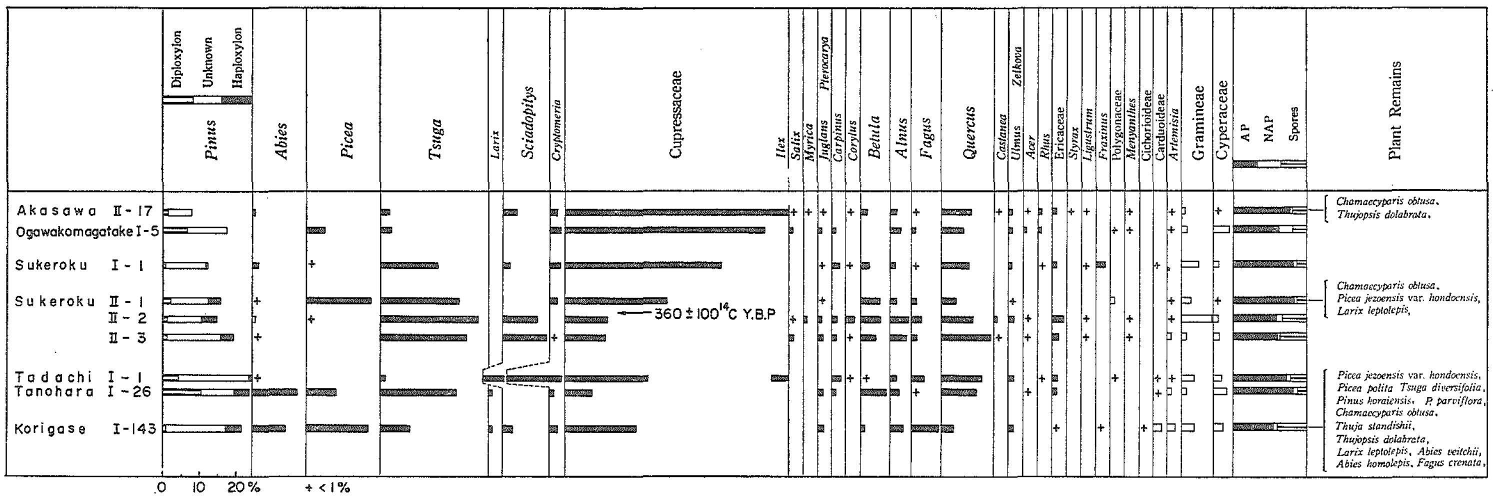


Fig. 21 Pollen diagram for recent sediments in Kiso Vally

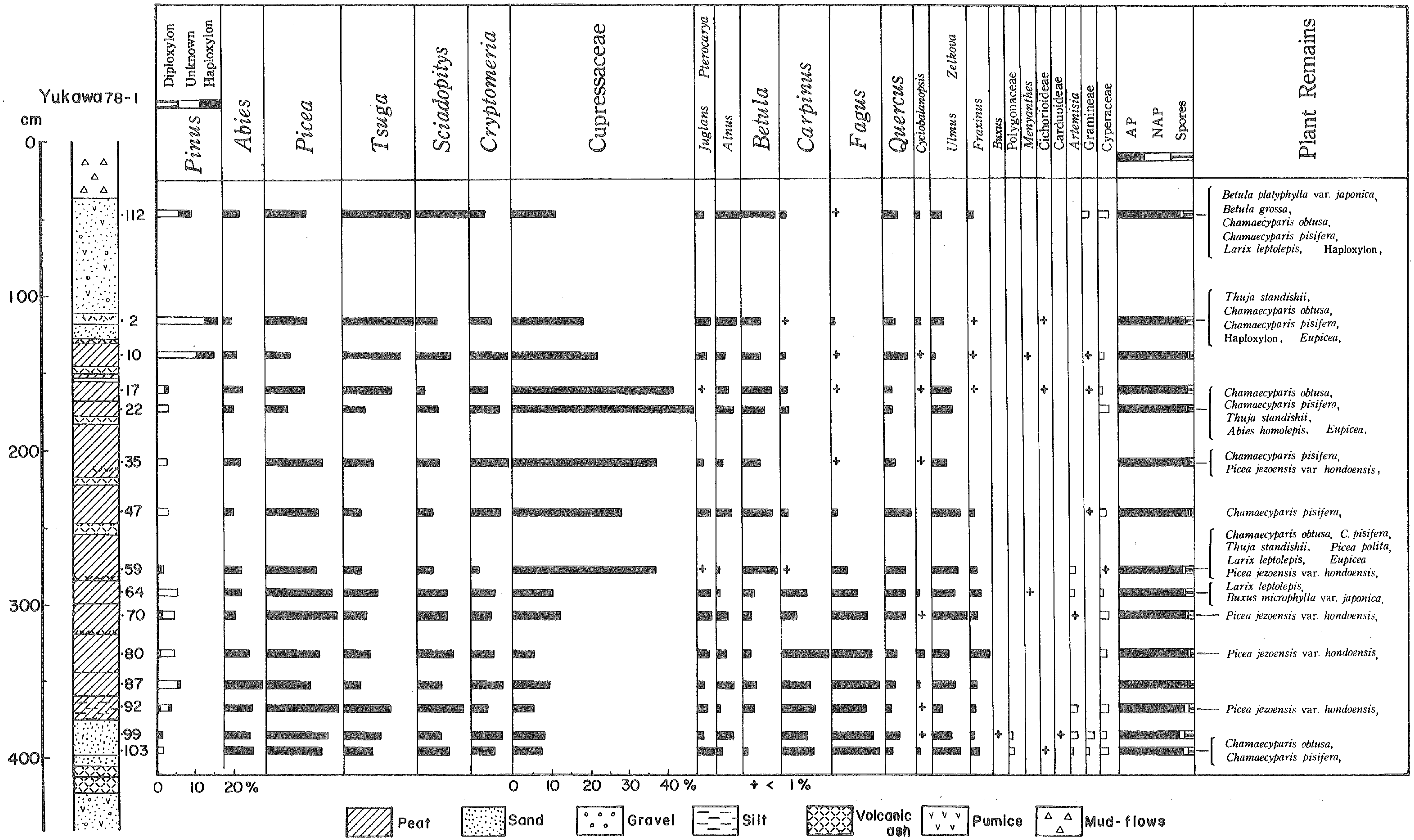


Fig. 22 Pollen diagram for Yukawa 78-I

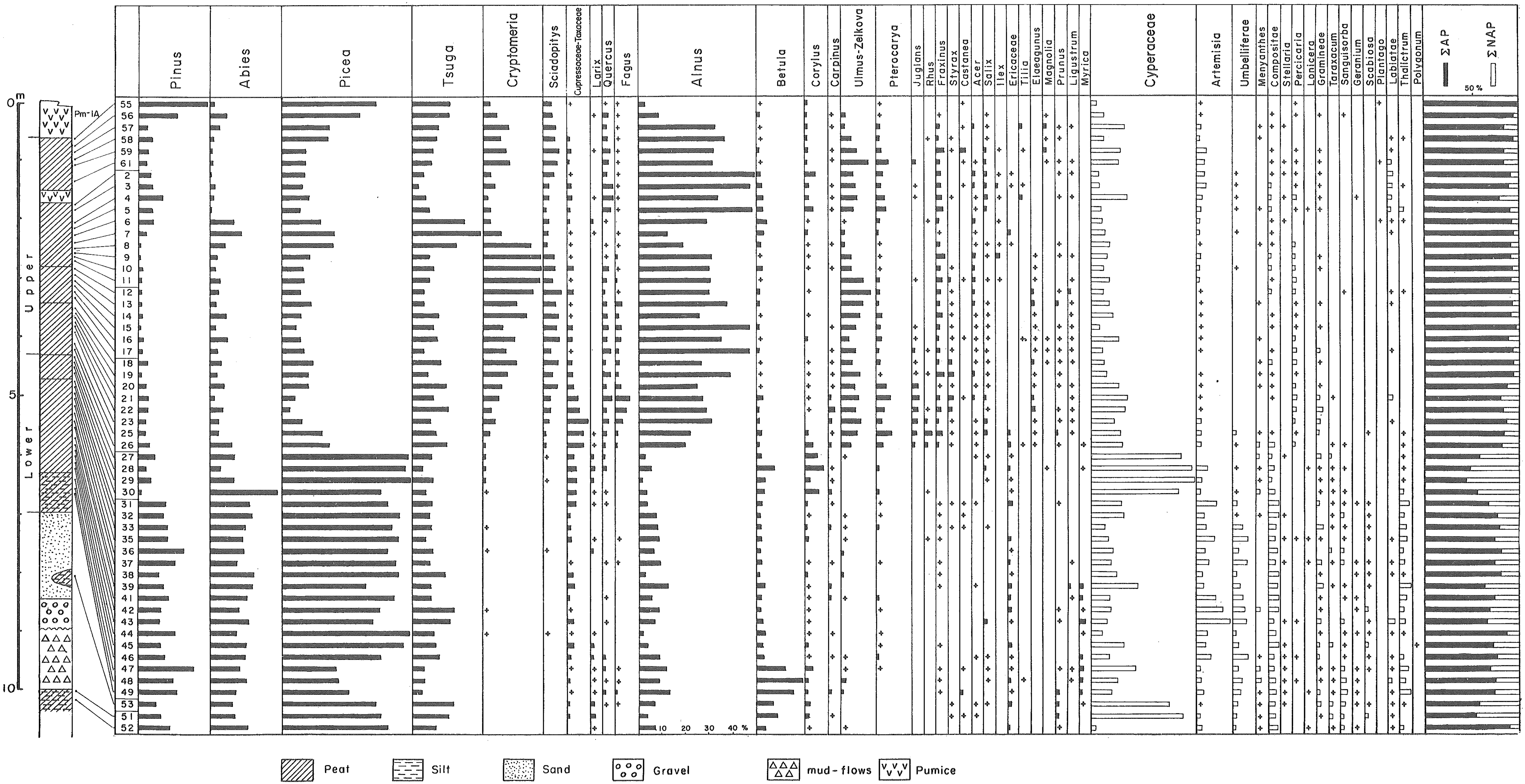


Fig. 23 Pollen diagram for Fujimi I"·II (after SAKAI, J., 1973·b)

nese cypress) (65%), *C. pisifera* (Japanese cypress) (32%) and *Thujopsis dolabrata* (hatchet–leaved arbor–vitae) (3%). Ogawakomagatake–I–5 is also located at the site about 4 km north–east of Agematsu (1290 m above sea–level) and is forested by abundant *Chamaecyparis pisifera* and less number of *C. obtusa*. Both Sukeroku–I and Sukeroku–II are located at the site about 7 km to the south of Korigase (1330 m above sea–level). The present forest of this site is composed mainly of *Chamaecyparis obtusa*. Carbon–14 date of plant remains directly above Sukeroku–II–2 horizon is indicated as 360±100 yr B. P. (Gak–7070). Tadachi–I–1 about 8 km north of Sakashita is in the forest dominated by *Chamaecyparis obtusa*, *Pinus parviflora* (Japanese five–leaved pine) and *Quercus serrata* (Japanese oak) (1530 m above sea–level). The site of Tanohara–I–26 is in Tanohara moor of Ontake Volcano, 2180 m above sea–level. The forest surrounding the moor is formed mostly by *Abies veitchii* (Japanese subalpine fir), *A. mariesii* (Japanese subalpine fir), *Picea jezoensis* var. *hondoensis* (Japanese spruce) and *Tsuga diversifolia* (Japanese subalpine hemlock–spruce). In addition, *Pinus pumila* (alpine creeping pine) and *Betula ermanii* (Japanese subalpine white brich) grow densely on the slope around the moor. The sample of Korigase–I–143 was collected from the Upper Pleistocene lacustrine deposits, which was indicated by carbon–14 age of 40140±3500 yr B. P. (Gak–7062). From the same horizon abundant plant remains were obtained; they are *Picea jezoensis* var. *hondoensis*, *P. polita* (Japanese montane spruce), *Tsuga diversifolia*, *Pinus koraiensis* (Korean pine), *P. parviflora*, *Chamaecyparis obtusa*, *Thuja standishii* (Japanese arbor vitae), *Thujopsis dolabrata*, *Larix leptolepis* (larch), *Abies veitchii*, *A. homolepis* (Japanese montane fir) and *Fagus crenata* (beach). These data mentioned above show that the pollen assemblages of the deposits are indicated by the dominance of main tree taxa of the forest, and the amount of those taxa attains up to 45 to 50 percent or more. It agrees with the results of SOHMA, K. (1957).

Next, some species which are systematically overestimated on account of excessive production, like *Pinus*, may be represented by less than 10 percent of the pollen assemblages, even if the species are absent in the neighbourhood.

C. Flora of the deposits older than Pm–1A Pumice

Characteristics of pollen flora and plant remains of each locality will be stated as follows

(1) Flora of Yukawa Peat Bed

YK–78–1 represents the Yukawa Peat Bed and its pollen assemblages are shown in Fig. 22.

Samples 103 to 64 are characterized by the dominance of *Fagus*, *Carpinus* and *Ulmus–Zelkova*, with *Cyclobalanopsis* and *Buxus*. Associating plant remains are identified as follows; *Chamaecyparis obtusa*, *C. pisifera*, *Picea jezoensis* var. *hondo-*

ensis, *Larix leptolepis* and *Buxus microphylla* var *japonica* (box-tree).

Samples 59 to 17 are marked by the considerable increase of Cupressaceae and the decrease of *Fagus* and *Carpinus*. Associating plant remains are identified as follows : *Chamaecyparis obtusa*, *C. pisifera*, *Thuja standishii*, *Abies homolepis*, *Picea polita* and *P. jezoensis* var. *hondoensis*.

Samples 10, 2 and 112 characterized by the increase of *Pinus* (*Haploxylon*) and *Tsuga*, and the decrease of Cupressaceae. Plant remains are *Chamaecyparis obtusa*, *C. pisifera*, *Thuja standishii*, *Larix leptolepis*, *Betula platyphylla* (white birch), *B. grossa* (birch), *Picea* sp. (*Eupicea*) and *Pinus* sp. (*Haploxylon*).

Throughout all samples, *Cryptomeria* and *Sciadopitys* are present in large amount. As to the plant remains, it is noticeable that leaves of *Eupicea* are preserved well, but those of *Omorica* are mostly broken.

(2) Fujimi Peat Bed

Fig. 23 shows the pollen diagram of the Fujimi Peat Bed.

Samples 53 to 31 are characterized by the dominance of *Picea*, with subordinate amount of *Abies*, *Pinus* and *Tsuga*. Ericaceae and *Myrica* occur steadily, though they are less in the pollen diagram.

Samples 30 to 27 are predominated by *Picea*, while amount of *Pinus* and *Abies* tend to decrease in general. *Corylus* increases remarkably in this unit. Plant remains are represented by *Menyanthes trifoliata*.

Samples 26 to 8 are characterized by the increase of *Cryptomeria*, *Sciadopitys*, *Fagus*, *Quercus*, *Ulmus-Zelkova*, *Pterocarya*, *Juglans* and *Alnus*, and the decrease of *Picea*, *Abies* and *Pinus*. Plant remains are *Juglans sieboldiana* (walnut) and *Styrax* sp.

Samples 7 to 2 are marked by the increase of *Tsuga*, *Picea*, *Abies* and *Pinus* and the decrease of *Cryptomeria*, *Sciadopitys*, *Faqus*, *Ulmus-Zelkova* and *Pterocarya*.

Samples 61 to 57 are characterized by the dominace of *Picea*, *Tsuga*, *Cryptomeria*, *Ulmus-Zelkova* and *Alnus*.

Samples 56 to 57 are characterized by the dominance of *Picea*, *Pinus* and *Tsuga*, with subordinate amount of *Cryptomeria* and *Sciadopitys*. Rapid disappearance of broad-leaved forest trees is suggested here. Plant remains are represented only by *Pinus koraiensis*.

(3) Lower Atsuta Formation

Fig. 24 shows the pollen diagram of the Lower Atsuta Formation.

Samples 787 to 648 are dominated by *Quercus* and *Alnus*. Among them, sample 787 is characteristic in having rich *Ulmus-Zelkova*. The unit which includes samples 787 to 648 is also marked by only a little amount or absence of *Lagerstroemia*.

Pollen assemblages of samples 598 to 559 are composed mainly of *Pinus*, *Fagus*, *Quercus* and *Alnus*, and are characterized by a considerable increase of *Fagus* and

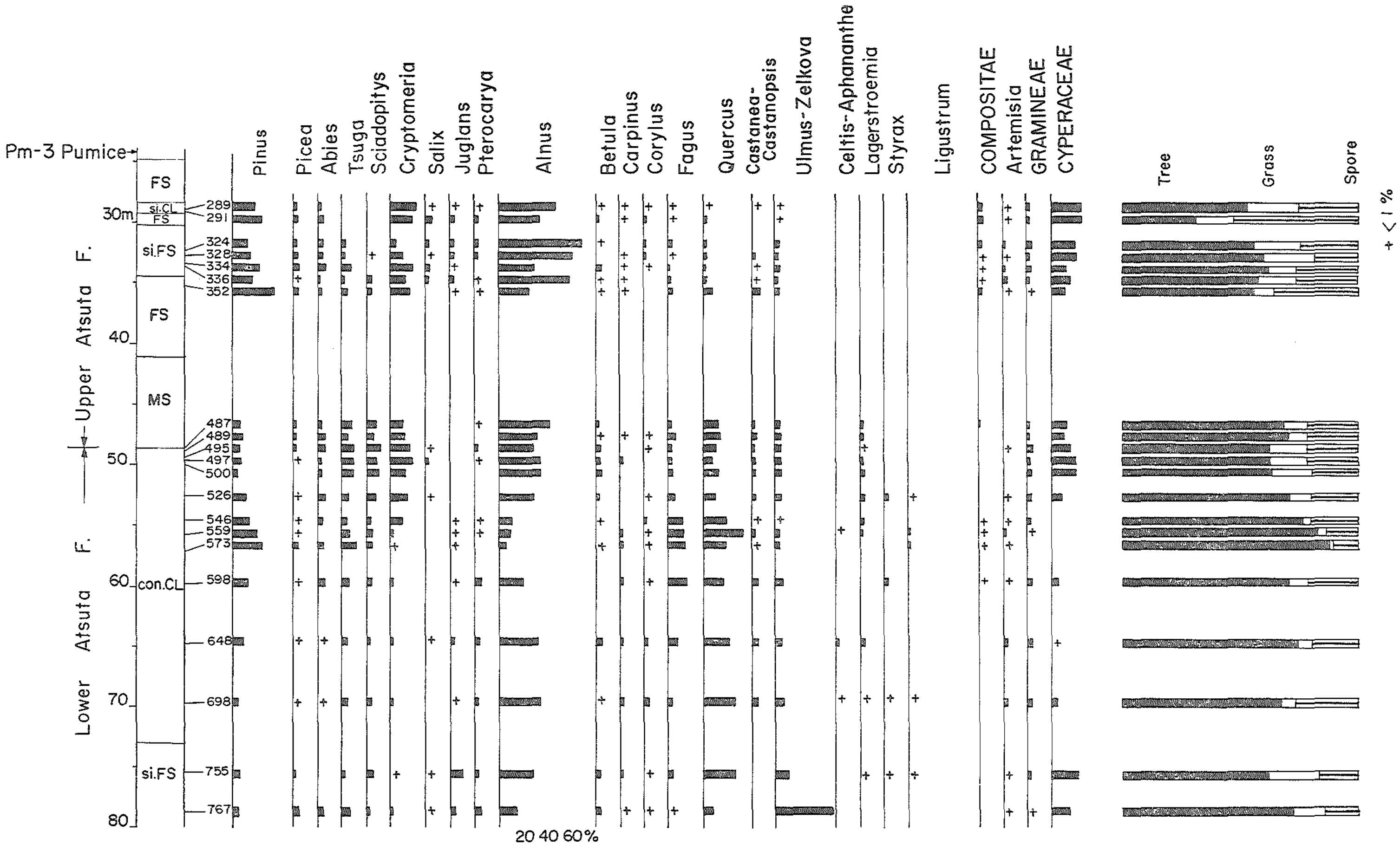


Fig. 24 Pollen diagram for Lower and Upper Atsuta Formation (after Nobi Plain Quaternary Research Group, 1977)

Pinus.

Samples 546 to 487 are dominated by *Cryptomeria*, *Sciadopitys*, *Tsuga*, *Pinus*, *Quercus*, *Alnus* and Cyperaceae. In addition, the unit is marked by the increase of *Cryptomeria*, *Lagerstroemia* and Cyperaceae, and the decrease of *Pinus*, *Fagus* and *Quercus.*

In connection with the floral change, the depositional environmental turnover in the Lower Atsuta Formation is interesting. At the horizon beneath sample 597, an open sea condition is clearly indicated by the presence of foraminiferas. On the other hand, the results of diatom study reveal the enviromental change from fresh water of the lowermost to brackish of the lower, salty waser of the middle and again to brackish water of the uppermost. Based on those informations, the Atsuta transgression is proposed for the Lower Atsuta Formation, and its maximal stage is assigned at the level of −60 to −55 m below the surface in the section at Tobishima (Nobi Plain Quaternary Research Group, 1977).

D. Flora of the deposits younger than Pm–1A Pumice

(1) Nakayama Peat Bed

Fig. 25 shows the pollen diagram of the Nakayama Peat Bed (NK–I). Samples 22 to 8 are as a whole characterized by the predominance of *Picea*, with small amount of *Pinus*, *Abies*, *Tsuga*, Cupressaceae–Taxaceae, *Cryptomeria* and *Sciadopitys.* Between the horizons of samples 13 and 12 were obtained abundant plant remains of *Picea maximowiczii.* Samples 7 to 1 are dominated by *Picea.* The unit is, however, marked by the increase of *Cryptomeria*, Cupressaceae–Taxaceae and *Alnus* and the decrease of *Picea.*

(2) Korigase I (KG–I)

Fig. 21 shows a pollen spectrum of KG–I–143 alone. The pollen assemblage of the sample is composed mainly of *Pinus*, *Picea*, Cupressaceae, *Abies*, *Tsuga*, *Fagus*, *Quercus* and *Alnus.* Plant remains of KG–I are as follows : *Picea polita*, *P. jezoensis* var. *hondoensis*, *Tsuga diversifolia*, *Pinus koraiensis*, *P. parviflora*, *Chamaecyparis obtusa*, *Thuja standishii*, *Thujopsis dolabrata*, *Larix leptolepis*, *Abies veitchii*, *A. homolepis and Fagus crenata.*

(3) Miure I (MR–I)

Fig. 26 shows the pollen diagram of MR–I. The pollen assemblages MR–I are represented by *Sciadopitys*, *Cryptomeria*, Cupressaceae, *Picea*, *Abies*, *Tsuga*, *Pinus* and *Alnus.* The associations can be grouped into two, *Picea*, *Abies* and *Tsuga* group and *Sciadopitys*, *Cryptomeria* and Cupressaceae group. These two groups are contradistinctive in the increase and decrease.

Samples 1 to 6 are characteristic in abundant *Sciadopitys* and Cupressaceae, and this unit yields plant remains of *Picea jezoensis* var. *hondoensis*, *Abies veitchii* and

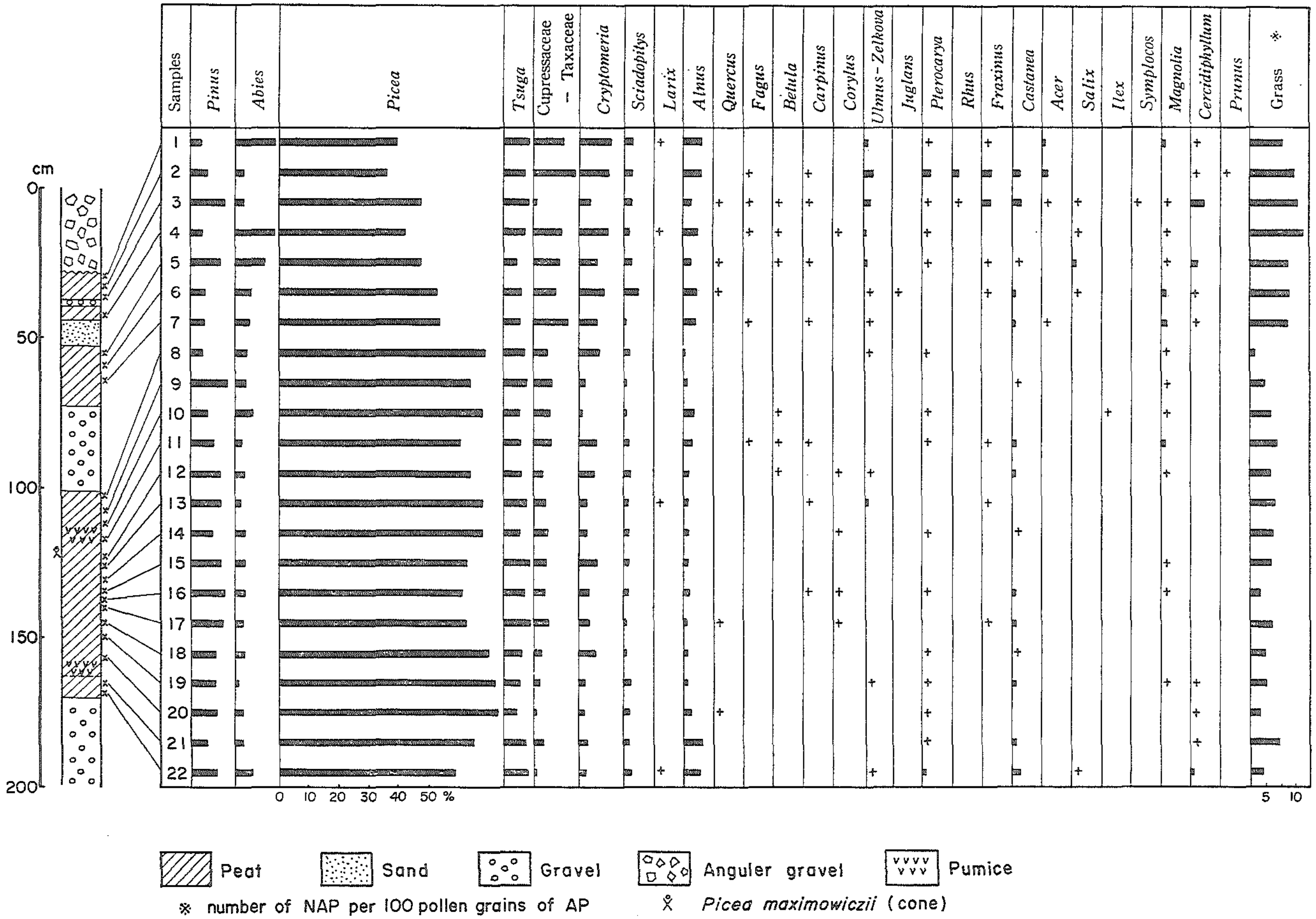


Fig. 25 Pollen diagram for Nakayama-I
(after Matsumoto Basin Research Group, 1972)

Sciadopitys verticillata (umbrella pine).

Samples 7 to 13 are characterized by the increase of *Picea* and the decrease of *Sciadopitys* and Cupressaceae. The unit contains plant remains of *Picea jezoensis* var. *hondoensis*, *Abies veitchii* and *Pinus koraiensis*.

Samples 14 to 24 are represented again by the dominance of *Sciadopitys* and Cupressaceae, and the decrease of *Picea* is found in this unit. The plant remains of *Picea jezoensis* var. *hondoensis*, *Abies veitchii*, *Pinus koraiensis* and *Tsuga diversifolia* were obtained from the unit.

Samples 25 to 29 are characterized by the increase of *Abies*, *Tsuga*, *Picea* and *Pinus*.

(4) Upper Atsuta Formation

The pollen diagram of the Upper Atsuta Formation is presented in Fig. 24. The samples investigated were obtained from a drilling core at Tobishima. Those of the lower half of the formation was barren in pollen fossils. But the upper half are rich in *Pinus*, *Cryptomeria*, *Alnus* and Cyperaceae, accompanied with samll amout of *Picea*, *Abies*, *Tsuga*, *Sciadopitys*, *Fagus* and *Quercus*, but *Lagerstroemia* is absent in this unit.

Although the Upper Atsuta Formation is generally characterized by the presence of fresh water diatoms, its Pm-3 Pumie group horizon is represented by marine to brackish environment, as deduced from foraminiferas. In Tobishima this horizon was detected at 26.1 m below the surface (Nobi Plain Quaternary Research Group, 1977).

(5) Ono Peat Bed (Ono-IIIa)

Fig. 27 illustrates the pollen diagram of Ono-IIIa. Among the pollen assemblages of Ono-IIIa *Picea*, *Tsuga*, *Pinus* and *Abies* are representatives and the elements of deciduous broad-leaved forest are almosrt absent in the horizon dominated by those four taxa. As *Tsuga* and *Cryptomeria* show a strong parallelism in the diagram, it may be certain that the *Tsuga* pollen may be combined with *Tsuga sieboldii* of montane zone, not of *T. diversifolia* of alpine zone.

Samples 84 to 70 consists mostly of *Picea*, *Tsuga*, *Pinus*, *Abies* and *Alnus*, accompanied by small amount of *Cryptomeria*, *Sciadopitys*, *Quercus*, *Betula*, *Corylus* and *Ulmus-Zelkova*.

Samples 69 to 52 present upward gradual increasing of *Tsuga* and *Cryptomeria*, and decreasing of *Picea*. Maximum *Tsuga* and *Cryptomeria*, and synchronously minimum *Picea*, are presented in the horizon of samples 54 to 53.

Samples 1 to 4 are characterized by the abundance of *Picea* and *Abies*, and by decreasing of *Tsuga*. Deciduous broad-leaved pollen are almost absent in this unit. The seeds of *Menyanthes trifoliata* were obtained here.

In samples 6 to 14 *Tsuga* pollen are recovered again, while *Picea* and *Abies*

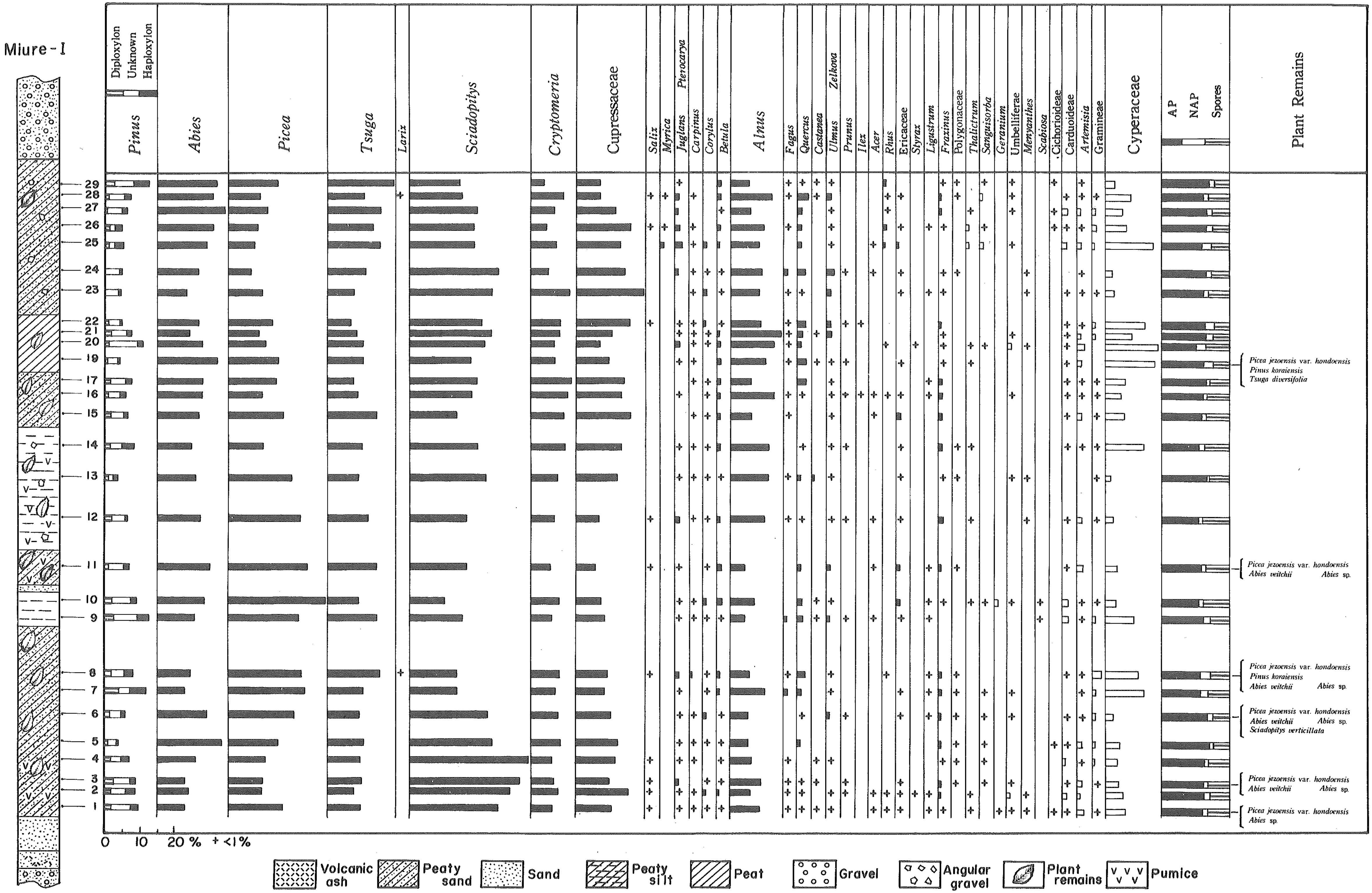


Fig. 26 Pollen diagram for Miure－I

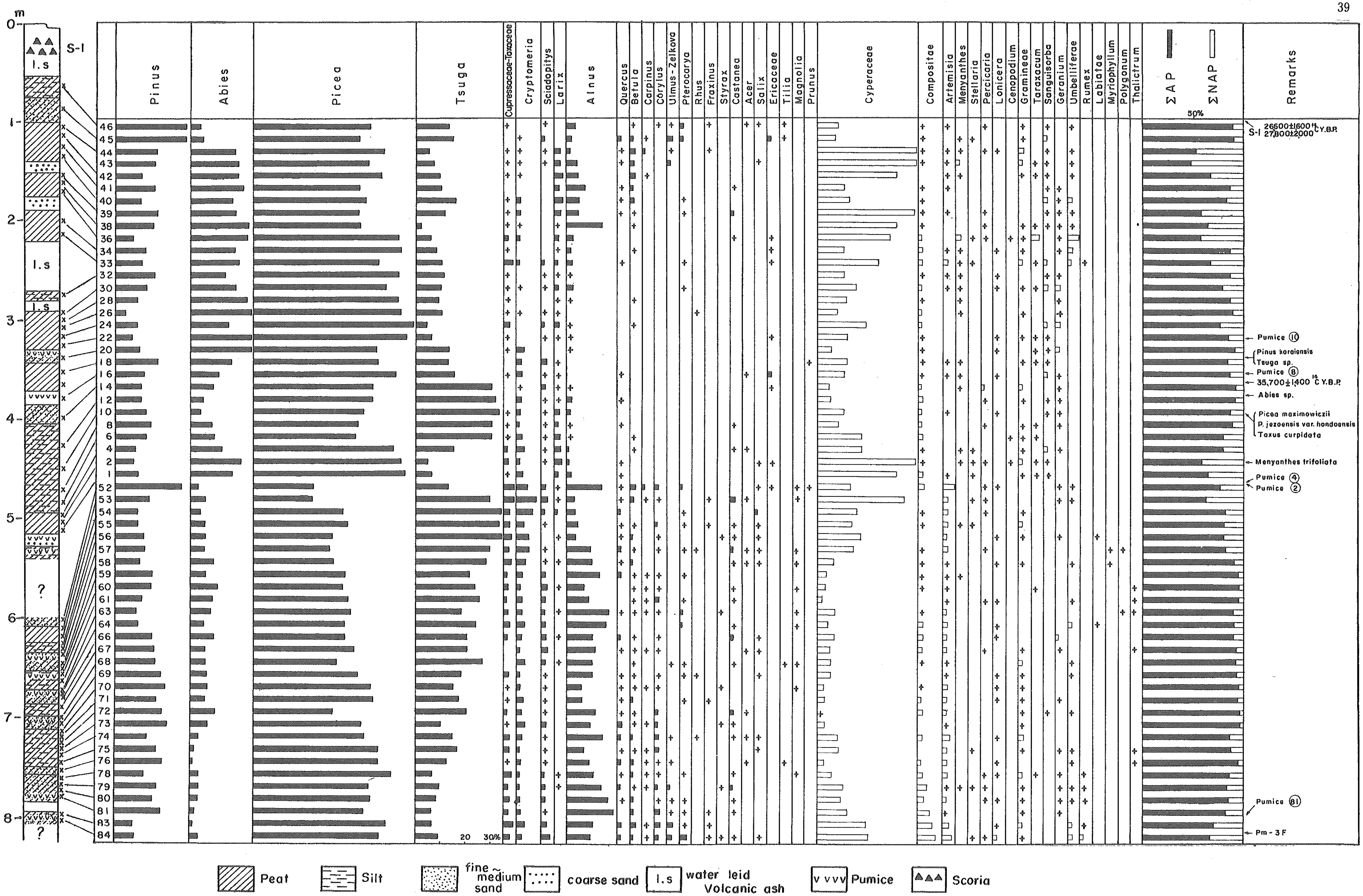


Fig. 27 Pollen diagram for Ono-IIIa (after SAKAI, J., 1973-a)

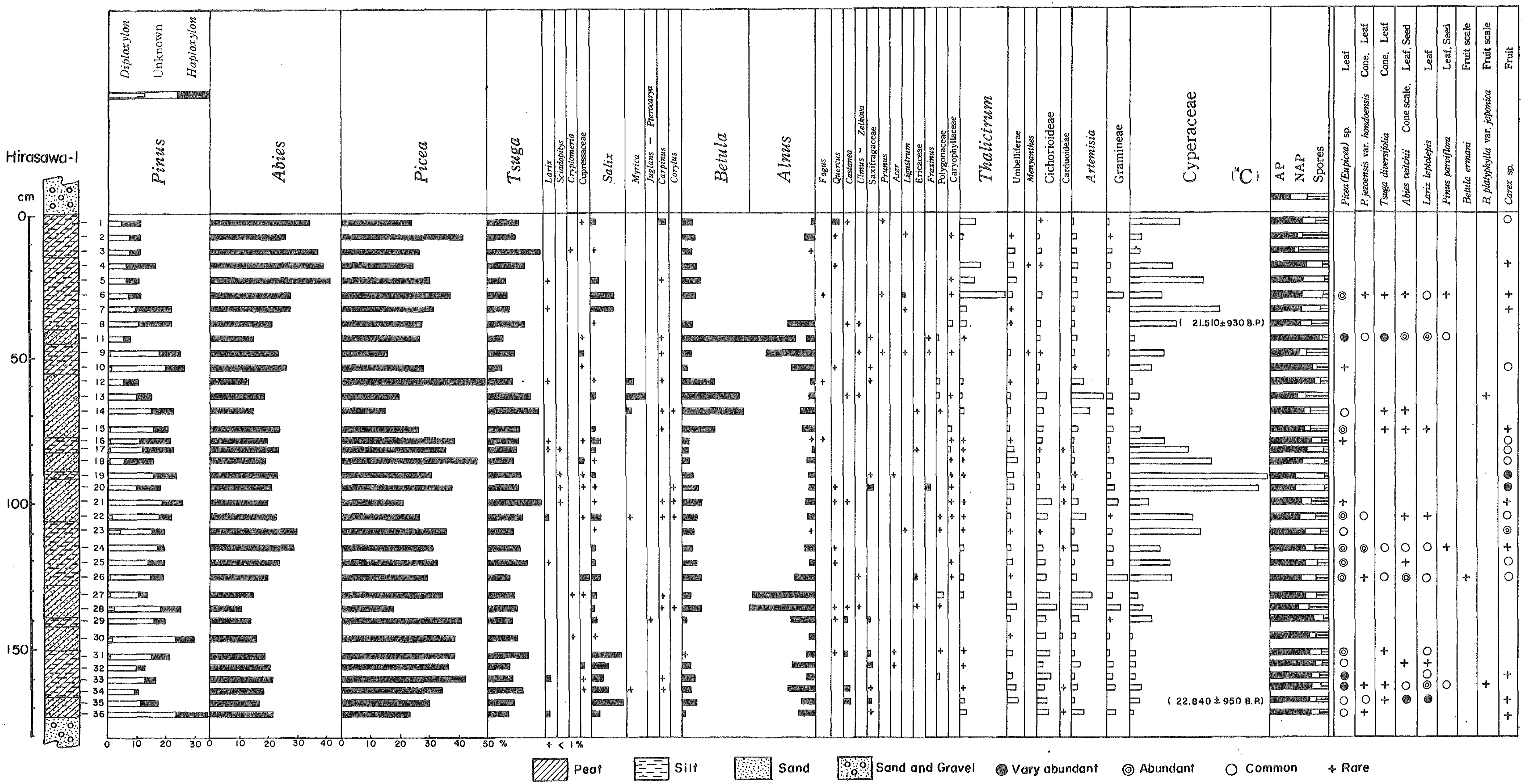


Fig. 28 Pollen diagram for Hirasawa I (after SAKAI, J. et al., 1979)

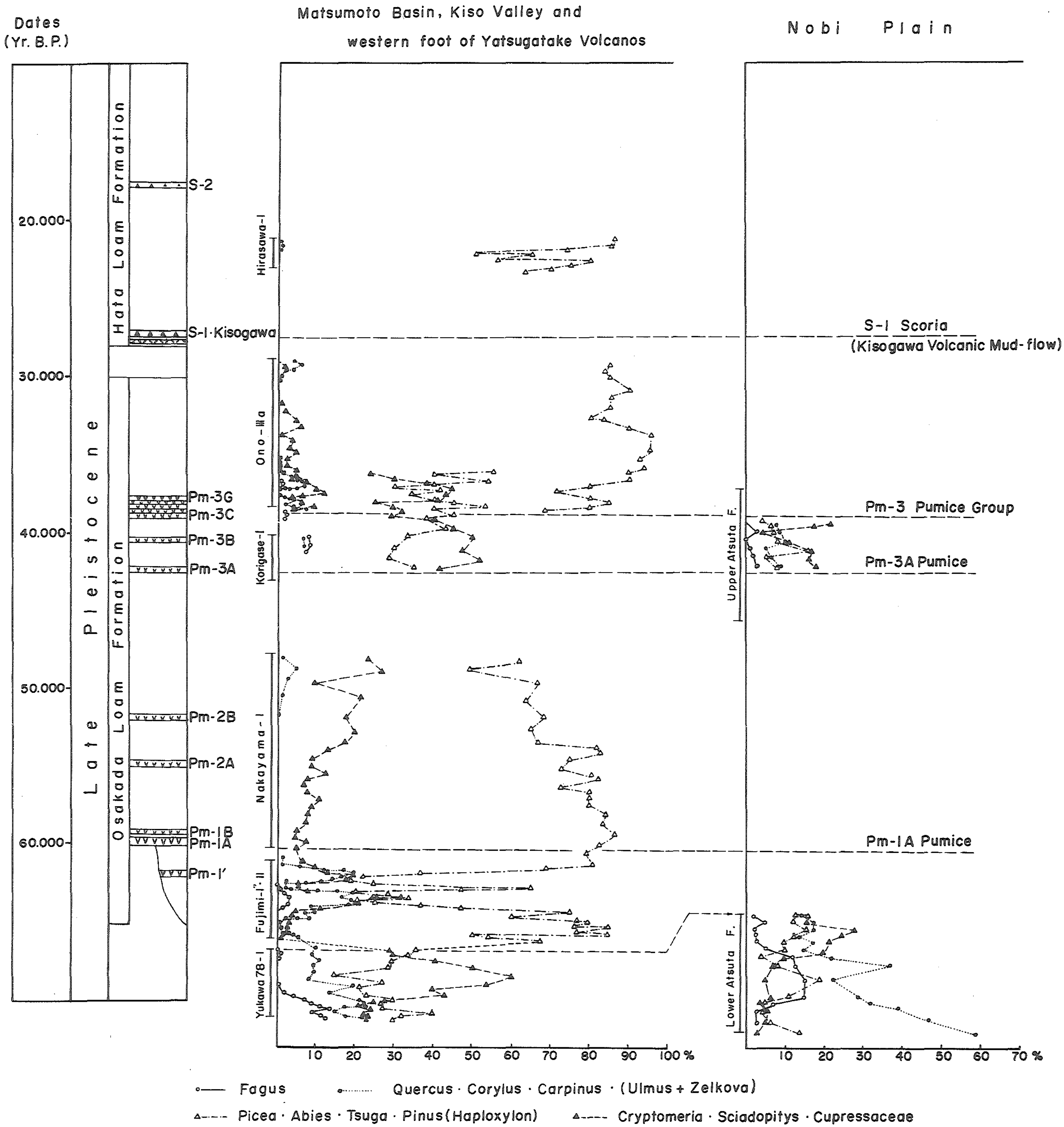


Fig. 29 Changes in the occurrences of main pollen taxa

are decreasing. Plant remains associated with pollen are *Picea maximowiczii*, *P. jezoensis* var. *hondoensis* and *Taxus curpidata.*

Samples 16 to 44 are marked by predominance of *Picea*, accompanied by subordinate amount of *Abies*, *Pinus* and *Tsuga*. Pollen grains of deciduous broad-leaved forests seem to be revived again at the upper part of the unit. The seeds of *Pinus koraiensis* were obtained from the lower part of the unit.

Samples 45 and 46 are characterized by the increase of *Pinus* and *Tsuga*, and the decrease or absence of *Abies* and *Larix*.

(6) Hirasawa Peat Bed (HR-I)

The pollen diagram of HR-I is shown in Fig. 28. As a whole the pollen assemblages of HR-I are represented by the dominance of coniferous tree pollen, such as *Picea*, *Abies*, *Pinus* and *Tsuga*. Except for *Salix*, *Betula* and *Alnus*, deciduous broad-leaved pollen are mostly absent.

Samples 36 to 16 represent the pollen assemblages of *Picea*, *Abies*, *Tsuga* and *Pinus* (chiefly *Haploxylon*), and are also rich in *Salix* in the lower part of the unit. Cyperaceae appears largely in the samples from the upper part of the unit.

The pollen assemblages of samples 15 to 11 are similar to those below this unit in the occurrence of coniferous tree pollen. But it is different from the latter in the fact that *Betula* and *Alnus* are increasing in general in this unit.

Samples 8 to 1 are remarkable by the increase of *Abies*, *Thalictrum* and Cyperaceae, and by the decrease of *Pinus* (*Haploxylon*). In considering plant remains, *Pinus* (*Haploxylon*) pollen is assignable to *Pinus parviflora* which grows in montane to lower alpine zone in Central Japan.

The Hirasawa Peat Bed yields the following plant remains, *Picea maximowiczii*, *P. jezoensis* var. *hondoensis*, *Abies veitchii*, *Tsuga diversifolia*, *Larix leptolepis*, *Pinus parviflora*, *Betula ermanii* and *B. platyphylla* var. *japonica.*

(7) Totchu Conifer Bed

The Totchu Conifer Bed yields the following plant remains; *Pinus koraiensis*, *Picea maximowiczii* (?), *P. jezoensis* var. *hondoensis* (?), *Tsuga diversifolia* and *Abies veitchii* (KOBAYASHI, K., 1965)

E. Pollen taxa as climatic indicators

In this place some considerations will be given to the characteristics in the occurrence of main pollen taxa in the studied area (Fig. 29). The vegetation zones are here used as shown in Table 1.

Fagus

Fagus is the most typical genus of the cool-temperate zone in Japan, and is a good indicator of wet climate. A considerable amount of *Fagus* pollen is described from the lower part of the Yukawa Peat Bed, while only a small amount of *Fagus*

Table 1. Relation between climatic zone and horizontal vegetation zone in Japan

Climatic zone	Subarctic zone	Temperate zone		Subtropical zone
Vegetation zone	Subarctic forest zone	Cool-temperate forest zone	Warm-temperate forest zone	Subtropical forest zone

pollen is reported from the middle part of the Fujimi Peat Bed and upper part of the Korigase lacustrine deposits. It is usual that *Fagus* pollen are absent in other inland sediments of Central Japan. On the other hand, in coastal region of the Nobi Plain, the Lower Atsuta Formation contains a large amount of *Fagus* pollen, on the contrary, the Upper Atsuta Formation yields only 2 to 3 percent of *Fagus* pollen.

In this way, *Fagus* appears in general in the deposits lower than Pm-1A and disppears or decreases in the deposits upper than Pm-1A.

Quercus+*Corylus*+*Carpinus*+*Ulmus*+*Zelkova*+*Juglans*+*Pterocarya*

As in the case of *Fagus*, those of deciduous broad-leaved forests are typical elements of cool-temperate zone in Japan.

Pollen of this association are comparatively rich in the Yukawa and Fujimi Peat Beds. This pollen association, however, is absent or presented in only a small amount in the inland deposits upper than the Pm-1A. In the Nobi Plain this pollen association is dominated in the Lower Atsuta Formation and also continues to the Upper Atsuta Formation.

Picea+*Abies*+*Tsuga*+*Haploxylon*

This pollen association may indicate subarctic forest environment in this area, particularly in the inland area. This pollen association is comparatively small in amount in the Yukawa Peat Bed, and is abundant in general in the Fujimi Peat Bed. In the latter case, however, the mode of pollen occurrence is not constant but very variable. On the other hand, in the deposits stratigraphically upper than the Pm-1A this pollen association is dominant through.

In the Lower and Upper Atsuta Formations of the Nobi Plain a small amount of the association are known.

Cryptomeria+*Sciadopitys*+Cupressaceae

This pollen association is represented by coniferous trees which range from warm-temperate to cool-temperate zone of the present. In Central Japan this pollen association is generally known to be oppositional to the above-mentioned *Picea*+*Abies*+*Tsuga*+*Haploxylon* association in the occurrence. This mixed cool-to warm-temperate coniferous association is abundantly known in the middle part of the Yukawa Peat Bed and in the middle part of the Fujimi Peat Bed. This pollen association also abundantly occurrs at the uppermost part of the Nakayama Peat Bed.

From the results stated above, some conclusions will be summarized below.

1) The deposits younger than Pm–1A in the inland area are generally characterized by the dominance of subarctic elements.

2) Mixed cool–to warm–temperate coniferous elements are increasing at least in two stratigraphical horizons younger than Pm–1A in the inland area.

3) A large amount of *Fagus* pollen can be detected only in the deposits older than Pm–1A.

4) Amount of subarctic elements is very few in the coastal region in comparison with the inland area.

VI. Pollen zones and paleoenvironments

Except for the recent deposits only few works have been done to establish pollen zones in Japan. In the present paper the author wishes to establish the palynological sequences as stated before and to arrange them by means of pollen zones (Fig. 30).

(1) Yukawa 78–I

In the Yukawa Peat Bed can be distinguished four zones as follows.

Fagus zone (samples 103 to 64)

This zone is characterized by the dominance of *Fagus*, *Picea* and *Carpinus*, and the existence of *Buxus*. The zone corresponds to the cool–temperate forest vegetation with rainfall thoughout the year.

Cupressaceae zone (samples 59 to 17)

This zone is marked by the remarkable increase of Cupressaceae and the disappearance of *Fagus* and *Carpinus*. It seems to indicate the mixed forest vegetation of cool– to warm–temperate which was prevailed in warmer climate than the present.

Tsuga · *Pinus* zone (Samples 10 to 112)

The characteristic of this zone is the increase of *Tsuga* and *Pinus*, and the existence of a large amount of Cupressaceae. It is inferred that cool–temperate forest had existed in the inland area during the period.

(2) Lower Atsuta Formation

The pollen of Lower Atsuta Formation can be divided into three zones.

Alnus · *Quercus* zone (samples 787 to 648)

This zone is generally characterized by abundant *Alnus* and *Quercus*, and *Ulmus–Zelkova* is associated only at the lowermost part alone. Cool–temperate forest is presumed from this zone because of absence or a very small amount of *Lagerstroemia* and *Quercus*. A comparatively large amount of *Picea* and *Abies* is found at the base.

Pinus · *Fagus* zone (samples 598 to 559)

This zone is characterized by the increase of *Pinus* and *Fagus*, and by the existence of a comparatively large amount of *Quercus*. This zone corresponds to a cool–temperate forest with some warm–temperate elements.

Cryptomeria zone (samples 546 to 487)

This zone is marked by the appearance of a large quantity of *Cryptomeria* and the increase of *Lagerstroemia*, *Sciadopitys* and *Alnus*. This zone shows that the warm–temperate forest was dominant in the inland area.

(3) Fujimi I″ · II

Following six pollen zones are recognized in the Fujimi Peat Bed.

Picea zones (samples 53 to 31)

This zone abounds on the whole in *Picea*, *Abies*, *Pinus* and *Tsuga*. It corresponds to cool–temperate forest with subarctic elements, and was distributed in the inland area of Central Japan.

Picea · *Corylus* zone (samples 30 to 27)

The characteristics of the zone are the predominance of *Picea* accompanied by the increase of *Corylus* and *Betula*, the appearance of *Cryptomeria*, and the decrease of *Abies*. This zone corresponds to cool–temperate forest.

Cryptomeria · *Ulmus–Zelkova* zone (samples 26 to 8)

This zone is characterized by the increase of *Cryptomeria* and *Ulmus–Zelkova*, and the remarkable decrease of *Picea*. It suggests that deciduous broad–leaved forests begin to appear. The zone indicates that cool–temperate forest with warm–temperate elements was distributed in the inland area of Central Japan.

Tsuga · *Picea* · *Quercus* zone (samples 7 to 2)

This zone is marked by the increase of *Tsuga*, *Picea* and *Quercus*, and by the decrease of *Cryptomeria* and *Ulmus–Zelkova*. This zone is assignable to that of cool–temperate and subarctic mixed forest with less precipitation.

Ulmus–Zelkova · *Cryptomeria* zone (samples 61 to 57)

This zone means recovering of *Ulmus–Zelkova*, *Cryptomeria* and *Sciadopitys*. Amount of *Picea* and *Tsuga* decreases in the zone. This zone suggests that cool–temperate forest grew widely in the inland area. The climate might be warmer than the present.

Picea · *Pinus* · *Tsuga* zone (samples 56 to 55)

This zone is composed mainly of *Picea*, *Pinus* and *Tsuga*, and shows that deciduous broad–leaved forest almost disappeared in it. The climate might become gradually colder onwards.

(4) Nakayama I

In the Nakayama Peat Bed two pollen zones can be recongized

Picea zone (samples 22 to 8)

This zone predominates in *Picea*, and suggests the presence of subarctic forest.

Picea · *Cryptomeria* zone (sample 7 to 1)

This zone is characterized by the dominance of *Picea* and by the increase of *Cryptomeria* and *Sciadopitys* which are cool-temperate forest elements. It suggests that deciduous broad-leaved forest developed gradually. The zone is assigned to mixed forest of cool-temperate and subarctic elements.

(5) Ono IIIa

The Ono Peat Bed has following five pollen zone.

Picea · *Pinus* zone (samples 84 to 70)

In this zone *Picea* · *Pinus*, *Tsuga* and *Alnus* are abundant. Among these, *Picea* pollen can be assigned to *Picea maximowiczii.* Judging from the appearance of *Cryptomeria*, *Quercus*, *Corylus*, *Carpinus* and *Ulmus-Zelkova*, the zone is inferred to belong to that of mixed forest of cool-temperate and subarctic elements.

Tsuga · *Picea* · *Cryptomeria* zone (samples 69 to 52)

This zone is dominated by *Tsuga* and *Picea.* Gradual increase of *Cryptomeria* and Cupressaceae-Taxaceae is presumed in the zone. Accordingly, this zone is assigned to a cool-temperate forest.

Picea · *Abies* zone (samples 1 to 4)

This zone is marked by the dominance of *Picea*, *Abies* and Cyperaceae, and by the decrease of *Tsuga.* It suggests that deciduous broad-leaved forest almost disappeared in the zone. Therefore, this zone shows that subarctic forest was dominant in the inland area of Central Japan.

Picea · *Tsuga* zone (samples 6 to 14)

This zone is characterized by abundant *Picea* and *Tsuga*, but the latter tends to increase in expense of the former. *Abies* decreases also in the zone. *Picea* pollen of this zone is assignable to *Picea maximowiczii.* The zone also yields *Taxvs curpidata.* Accordingly, it may be concluded that mixed forest of cool-temperate and subaractic elements is predominated in that time.

Picea · *Abies* zone (samples 16 to 44)

This zone shows the increase of *Picea*, *Abies* and *Larix*, and the decrease of *Tsuga* which is assigned to *Tsuga sieboldii.* This zone indicates the presence of subaractic forest.

Picea · *Pinus* zone (samples 45 and 46)

This zone is marked by the dominace of *Picea*, the increase of *Pinus* and *Tsuga*, and the decrease of *Abies.* This corresponds to mixed forest of cool-temperate and subarctic elements.

(6) Miure I

The Miure Peat Bed comprises four pollen zones

Sciadopitys zone (samples 1 to 6)

This zone is dominated by *Sciadopitys*, *Picea*, *Abies*, *Tsuga* and Cupressaceae, and suggests the presence of mixed forest of cool-temperate and subarctic elements.

Picea · *Abies* · *Tsuga* zone (samples 7 to 13)

This zone is characterized by the dominance of *Picea*, *Abies*, *Tsuga* and *Sciadopitys*. The zone is also assigned to the mixed forest of cool–temperate and subarctic elements.

Sciadopitys · Cupressaceae zone (samples 14 to 24)

This zone is marked by the dominacne of *Sciadopitys* and Cupressaceae, and the decrease of *Picea* and *Tsuga*. *Quercus* and *Ulmus–Zelkova* increase in small amount. This zone corresponds to cool–temperate forest.

Tsuga · *Abies* zone (samples 25 to 29)

This zone abounds in *Tsuga*, *Abies* and *Sciadopitys* and shows a cool–temperate forest with subarctic elements.

(7) Korigase I

Pinus · *Picea* · *Fagus* zone is recognized in the Korigase Peat Bed.

Pollen and remains of *Fagus* occur in a comparatively large amount in this zone. It is assigned to the cool–temperate forest with subarctic elements.

(8) Upper Atsuta Formation (TB–I)

Cryptomeria · *Pinus* zone (samples 352 to 289) is recognized in the Upper Atsuta Formation. This zone is marked by the dominance of *Pinus*, *Cryptomeria* and *Alnus*, and is assigned to a cool–temperate forest.

(9) Hirasawa I

In the Hirasawa Peat Bed, three pollen zones are recognized.

Picea · *Abies* zone (samples 36 to 16)

This zone is characterized by the dominance of *Picea*, *Abies* and *Tsuga*, and by the existence of *Salix*, *Betula* and *Alnus*. The zone is assigned to a subarctic forest.

Betula · *Picea* · *Abies* zone (samples 15 to 11)

This zone is composed mostly of *Picea*, *Abies*, *Pinus*, *Tsuga* and *Betula*. The characteristic of the zone is represented by the increase of *Betula* and the decrease of *Picea* and *Abies*. This zone indicates also a subarctic forest.

Abies · *Picea* zone (samples 8 to 1)

This zone is marked by the increase of *Abies* and *Picea*, and the decrease of *Betula*. As a quantity of *Pinus* decreases in this zone, the *Pinus* pollen may be assigned to *Pinus parviflora*. The zone corresponds to subarctic forest.

VII. Late Pleistocene climate in Central Japan

(1) Warm climate before Pm–1A

It has been known that the zone of weathered red soil was developed well below Pm–1A distributed widely in Central Japan. As such thick buried soil may have developed during the period of heavy weathering under a warm climate, a

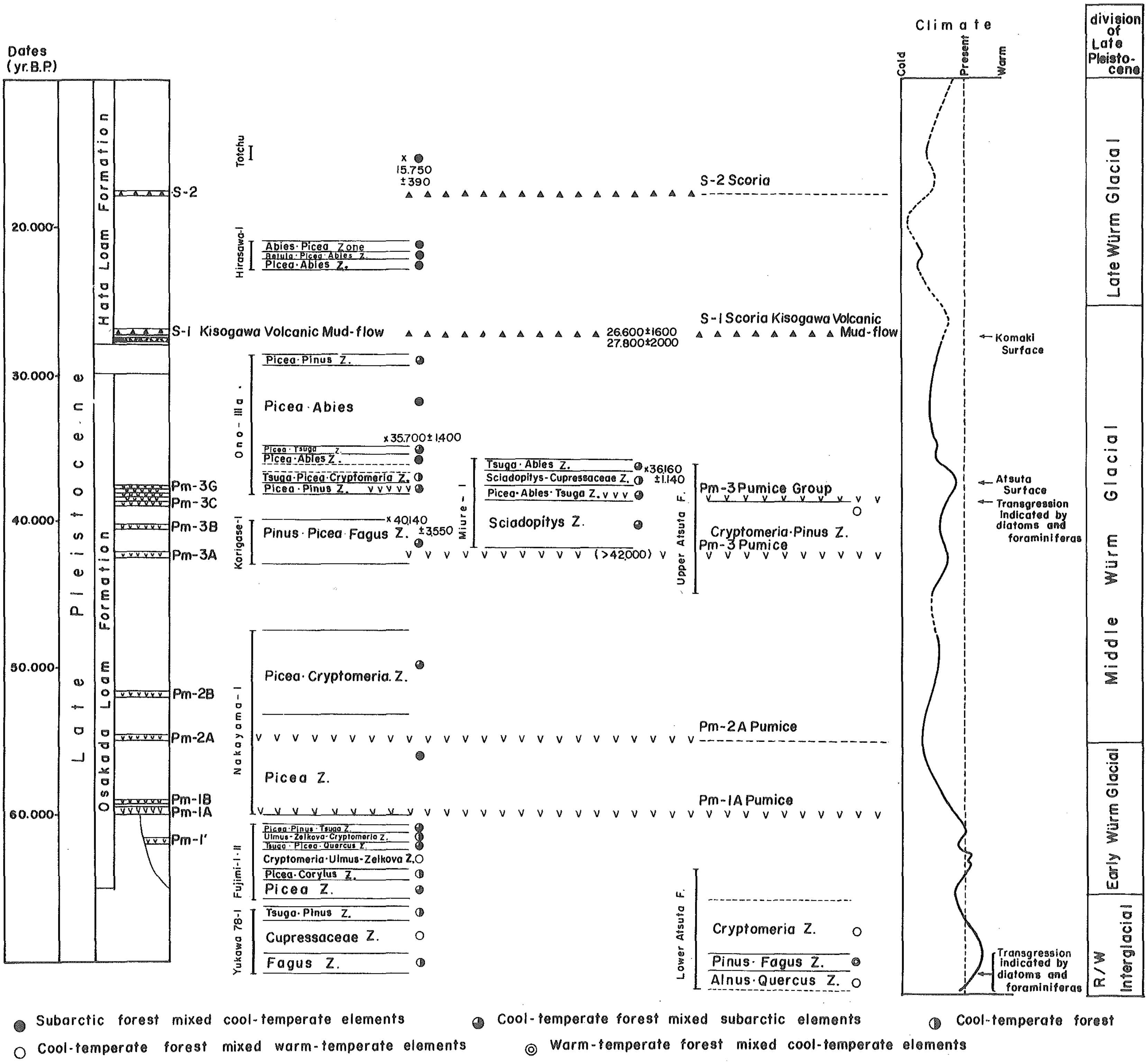


Fig. 30 Pollen assemblages and climatic changes during the Late Pleistocene in Central Japan

long period of warm climate before the pumice fall of Pm-1A is estimated.

The deposits below Pm-1A are represented by the Yukawa Peat Bed and the Fujimi Peat Bed in the inland area, and by the Lower Atsuta Formation in the coastal area. Palynological investigations verify that three horizons of warm climate are recognized in the former two inland deposits, but that of the Yukawa Peat Bed is more distinctive in comparing with other two of the Fujimi Peat Bed, which is stratigraphycally younger than the former bed. The deposition of the Fujimi Peat Bed was immediately before the pumice fall of Pm-1A.

It is probable that the time of Pm-1A corresponds to the early stage of regression. As mentioned before, the pollen flora indicates cold climate. On the other hand, Pm-1A in the Lower Atsuta Formation has been known only from one locality at Nagoya harbour in the Nobi Plain. It suggests that most of Pm-1A Pumice fall on terrestrial region had been eroded away at the regression time.

The marine Lower Atsuta Formation is the product of transgression, and it is reasonable to correlate it with the Yukawa Peat Bed of inland area which is far below Pm-1A. The Cupressaceae zone of the Yukawa 78-I is thus correlated with *Cryptomeria* zone of the Lower Atsuta Formation (Fig. 30).

The warm climate represented by the Yukawa Peat Bed and the Lower Atsuta Formation may be assigned to later stage of the latest interglacial, Riss/Würmian, on palaeobotanical grounds. The maximal stage of transgression, however, seems to had antedated to vegetational climax of warm climate.

(0) Early cold climate

Palynological study shows the presence of cold climate at the basal part of the Fujimi Peat Bed. Assuming that the underlying Yukawa Peat Bed belongs to the sediments of the latest interglacial, this cold phase will represent early stage of the last glacial, Würm Glacial. In this horizon, *Picea*, *Abies*, *Tsuga* and *Haploxylon* pollen become to dominant remarkably, and it is reasonable to say that the last glacial period started at the Fujimi Peat Bed.

In north-western Europe, three interstadials of Early Würm Glacial, Odderade, Brörup and Amersfoort, are recognized (DANSGAARD, W. *et al.*, 1971; VAN DER HAMMEN, T. *et al.*, 1971) (Fig. 31 and 32). Two warm climatic episodes of the Fujimi Peat Bed may correspond to some of those interstadials of the Early Würm. The age of Pm-1A in the Fujimi Peat Bed is not certain, and, on the other hand, the fission track ages of "Pm-1A" in the Kanto Loam Formation are reported as 73000±4000 yr B. P., 77000±8000 yr B. P., 78000±10000 yr B. P., 82000±10000 yr B. P., and 95000±5000 yr B. P. (MACHIDA, H. and SUZUKI, M., 1971). But it seems that those fission track ages are rather older than actual from the stratigraphical view points. Moreover thier fission track ages have some methodological problem. In Matsumoto basin, the Osakada Loam Formation is represented by conti-

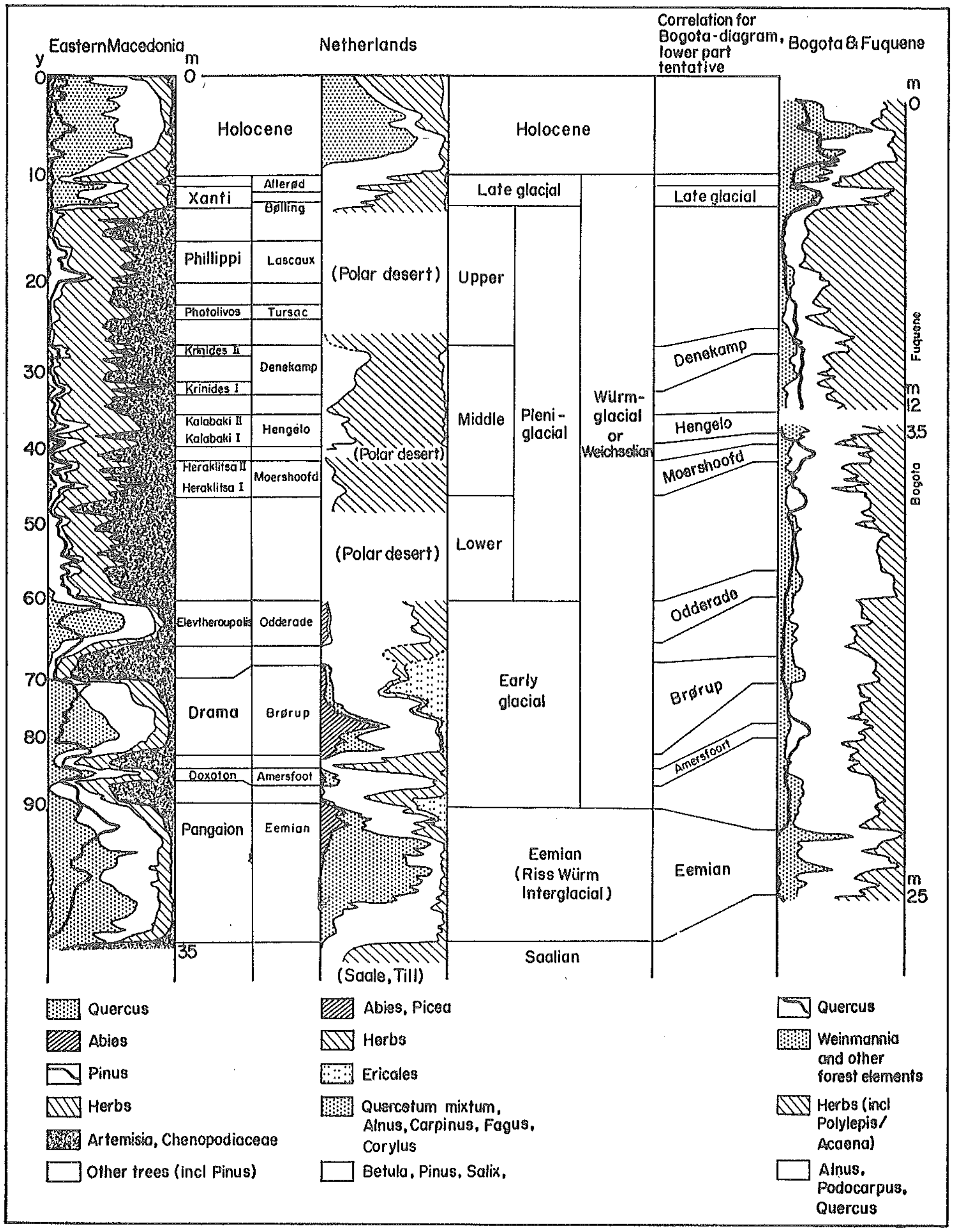


Fig. 31 Pollen diagrams for the last interglacial (Eemian), last glacial (Weichselian), Holocene from Philippi (northeastern Macedonia), the Netherlands, and Bogotá, Colombia (redrawn after Wijmstra 1969; Zagwijn, parts unpublished; and Van der Hammen et al., parts unpublished). (after HAMMEN, T. van der, et al., 1971)

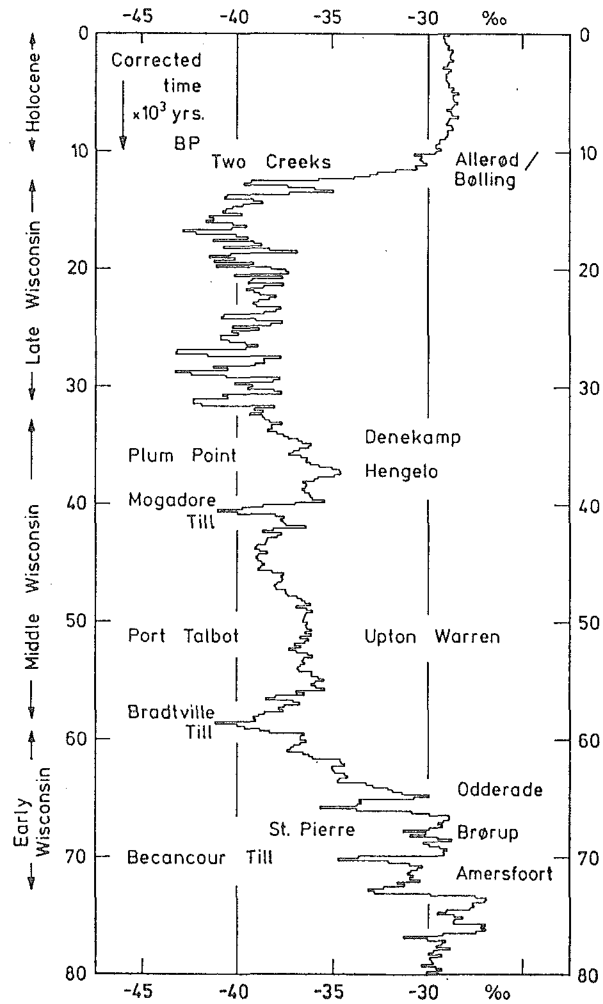


Fig. 32 Curve representing a large part of the Camp Century, Greenland, ice core, in which $\delta(O^{18})$ is plotted against time, calibrated as explained in text. The curve compares well with the curves shown in fig 16–11; hence its authors have suggested, by means of labels, possible correlations with stratigraphic units elsewhere. (Dansgaard et al. in Turekian, ed., 1971).
(after DANSGAARD, W. et al., 1971)

nuous succession from Pm–1A to S–I (Fig. 4). When Carbon–14 dates and sedimentation ratio are taken into consideration, it is probable to estimate the age of Pm–1A at about 60000 yr B. P.. As to the Osakada Loam Formation, carbon–14 dates of 36100±1140 yr B. P. and 35700±1400 yr B. P. of the horizon imediately above Pm–3G, and of older than 42000 yr B. P. of Pm–3A horizon are referable. Anyhow, it is possible to say that the early cold climate, or Early Würm Glacial, might begin at the time of about 65000 to 70000 years before present.

(3) Cool climate for Pm–2A to Pm–3A

After the early cold phase, cool climate continused steady during periods from Pm–2A to Pm–3A.

(4) Warm climate of Pm–3

From the pollen diagram a short period of warm climate can be recognized during the time after Pm–3G Pumice fall. On the other hand, the maximum transgression of the Upper Atsuta Formation is indicated by the studies on foraminiferas and diatoms at the horizon of Pm–3 group. The Atsuta Surface is the product which was brought about by the transgression corresponding to Pm–3 warm climate.

(5) Ono cold phase

A relatively cold climate is recorded during the period continuing from the middle to upper part of the Ono Peat Bed. Contemporaneous cold climate is also known from the palynological study of the Nakamura Peat Beds on the western foot of Yatsugatake Volcanoes (IIDA, S., 1973)

(6) Warm climate of S–I Scoria time

Although there are no evidences from palynology, it is assumed that the horizon of S–I Scoria indicates warm climate. The Komaki Surface is developed commonly in the Nobi Plain, and is considered to be formed during high sea–level time of warm climate. The Kisogawa Volcanic Mudflow which is synchronous to S–1 Scoria conformably covers this surface.

(7) Cold climate below S–2 Scoria

Periglacial phenomena of the past have been reported in Kiso Valley, and the lowest level of them is situated at about 1000 m above sea–level. This periglacial horizon is limited below S–2 Scoria, and is contemporary with the Nobi First Gravel Bed in Nobi Plain, which is considered to be the deposits of low sea–level time under the cold climate. Until now none of palynological data has been obtained in those deposits, because they are composed chiefly of gravels and other coarse sediments.

VIII. Classification of the Late Pleistocene in Japan based on paleobotany

The vegetational classification of the Late Pleistocene in Japan is illustrated in Fig. 33 which is mainly based on palynological evidences. In order to illustrate the

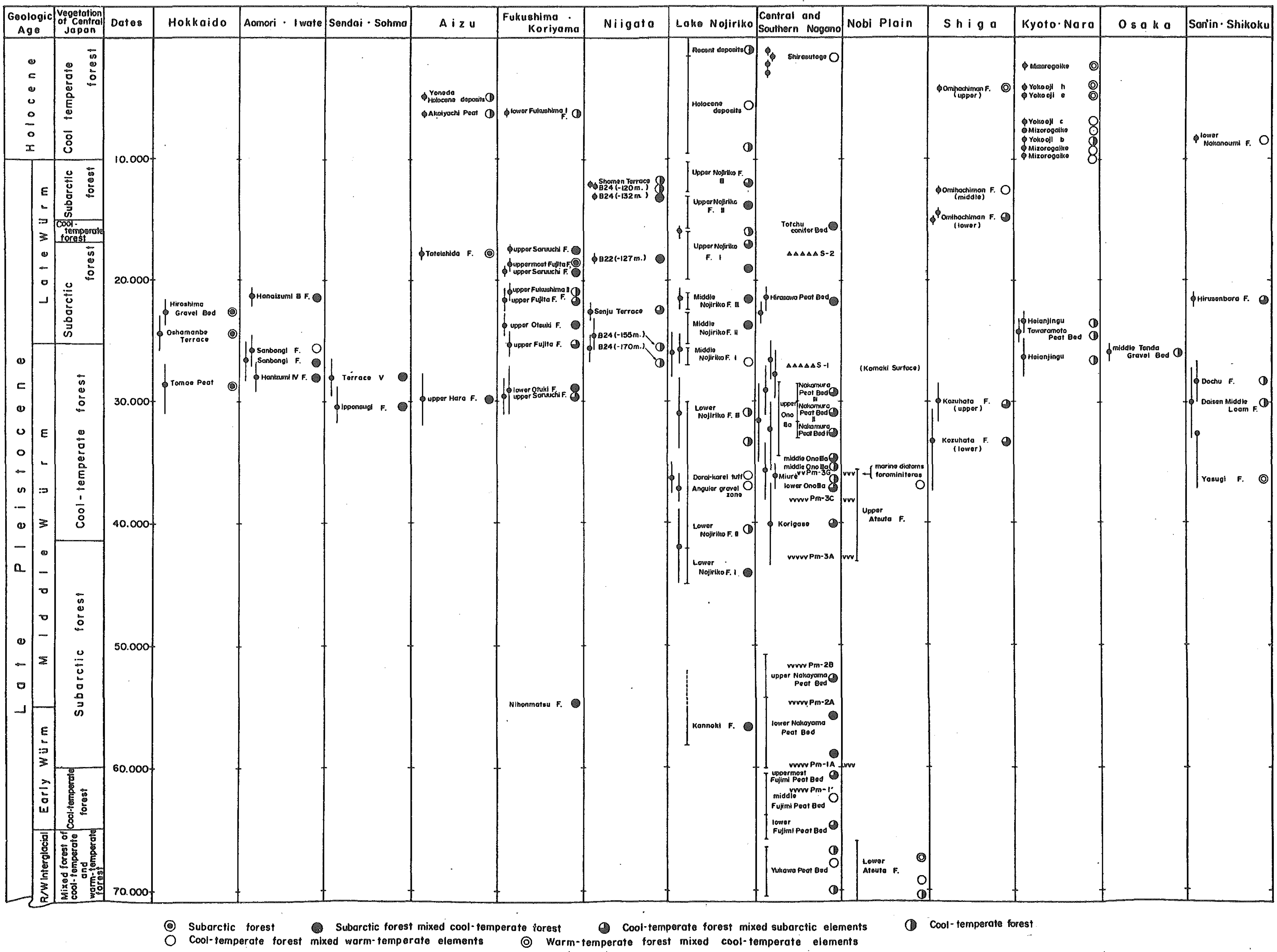


Fig. 33 Characteristics of the floras of the Upper Pleistocene and Holocene in Japan (after Quaternary Flora Research Group. 1974; Nobi Plain Quaternary Research Group. 1977;)

figure, the author paid attention to use only reliable data. It is desirable that those data are prepared by pollen fossils together with plant remains. But when the data depend upon pollen fossils only, they were employed when the vegetational features can be interpreted clearly by those data. Consequently, the results obtained is almost not incosistent with the climatic fluctiation curve in Central Japan (Fig. 30 and 33).

It is paticularly important that the warm climate deduced from the data of the Upper Atsuta Formation coincides with that of the Lower Nojiriko Formation III of northern part of Central Japan and the Yasugi Formation of San'in District of West Japan. The lower part of the Lower Nojiriko Formation III is dominated by pollen grains of such deciduous broad-leaved cool-temperate forest as *Fagus*, *Corylus*, *Carpinus* and *Ulmus–Zelkova*, accompanied by a small amount of *Buxus* and *Cyclobalanopsis*, which are typical warm-temperate elements in Japan. The carbon-14 age of this horizon is 37220±1240 yr B. P. (Gak-7793). On the other hand, the Yasugi Formation is marked by the pollen grains of *Abies*, *Tsuga* and *Cyclobalanopsis*. In this case *Tsuga* and *Abies* are assigned respectively to *Tsuga sieboldii* and *Abies firma*. Accordingly, the pollen flora of the Yasugi Formation belongs a typical warm-temperate forest (ONISHI, I., 1977). In addition, this corresponds to Hengelo Interstadial at about 37000 to 38000 yr B. P. in Greenland and Netherland as shown in Fig. 31 and 32.

It is the first time in Japan that an episode of warm climate is confirmed in the middle part of Latest Glacial by stratigraphy and paleobotany. This warm phase may correspond to the Hengelo Interstadial of north-west Europe, which is estimated as 37000 to 38000 yr B. P. (Fig. 32).

As a result, the Late Pleistocene of Japan is classified into the following four periods. For convenience the names of Alpine glacial epoch of Europe like Riss and Würm are used here in a wide sense. They are Riss/Würm Interglacial (before 65000 to 7000 yr B. P.), Early Würm (from 65000 to 55000 yr B. P.), Middle Würm (from 55000 to 25000 yr B. P.) and Late Würm (from 25000 to 10000 yr B. P.).

(1) R/W Interglacial

The mixed forest of cool- and warm-temperate flourished in Central Japan during this period. The climate is estimated to have been warmer and wetter than that of the present.

(2) Early Würm Glacial

In early half of this period, the presence of two interstadials is detected in the Fujimi Peat Bed. This period is marked by the dominance of cool-temperate elements, such as *Cryptomeria*, *Sciadopitys*, *Ulmus–Zelkova* and *Corylus*. During later half of this period, subarctic forest dominated in inland area of Central Japan. In average annual temperature, it might be about 5°C to 6°C lower than that of present.

The base of this stage is coincident to the base of the *Picea* zone in the Fujimi Peat Bed.

(3) Middle Würm Glacial

In this period, except for the earliest time, the inland area was covered by mixed forest of cool–temperate and subarctic forest, accompanied by a small amount of warm–temperate elements, such as *Cyclobalanopsis* and *Buxus*. In spite of cool climate throughout this period a remarkable warm climate was intervened with a maximum of about 37000 years ago. The transgression owing to the warm climate also resulted in the formation of the Atsuta Surface in the Nobi Plain.

The marine deposits of "lower or middle terraces" in the coastal plains of Japan have often been corelated with the Shimosueyoshi Formation of the Kanto Plain. In connection with this, the problem on the Atsuta Surface should be further studied in detail whether it is widely recognized in Japan. The relation between "the Shimosueyoshi Surface" and the Atsuta Surface is also important. The author has the opinion that a part of the so–called "Shimosueyoshi Surface" is correlated with the Atsuta Surface.

(4) Late Würm Glacial

In this period the inland area was covered again by the forest which were dominated by subarctic elements.

The relationship between the glaciation in the Japan Alps and the climatic evidences of the low land area is still obsure from the stratigraphical view point. According to KOBAYASHI, K. and SHIMIZU, H. (1966), in the Ikenotaira Cirque on Mt. Kumazawa of Central Japan Alps, the S–1 Scoria rests on the outermost moraine, but it does not on the inner two moraines which are postdated to the former. If it is justified, the outermost moraine must have been formed during Middle Würm Glacial and the inner two belongs to Late Würm Glacial. This must be examined in future.

IX. Conclusive remarks

In this paper, the author has mede clear the Late Pleistocene stratigraphy in Central Japan by means of tephrochronology and rock magnetism, and has revealed the Late Pleistocene climatic changes in this area based on pollen analysis and paleobotany.

Comparing the results thus obtained with other regions in Japan, the Late Pleistocene of Japan is classified into the following four periods.

(1) Latest interglacial : R/W Interglacial (before than 65000 to 70000 yr B. P.)

This period is characterized by the dominance of cool–temperate forest accompanied with warm–temperate elements in the inland area and warm–temperate forest with cool–temperate elements in the Nobi coastal plain of Central Japan. The climate is estimated to have been warmer and wetter than that of the persent.

(2) Early Würm Glacial (from 65000 to 55000 yr B. P.)

The presence of two interstadials is inferred by the dominance of cool- and warm-temperate elements such as *Cryptomeria*, *Sciadopitys*, *Ulmus-Zelkova* and *Corylus* in early half of this period.

During later half of this period, subarctic forest was flourished in the inland area of Central Japan. The average annual temperature may have been about 5°C to 6°C lower than the present.

(3) Middle Würm Glacial (from 55000 to 25000 yr B. P.)

In this period, except for the earliest time, the inland area was covered by cool-temperate forest accompanied with subarctic elements, and also with a small amout of warm-temperate elements, including *Cyclobalanopsis* and *Buxus*. Cool climate prevailed throughout this period, intervening a remarkable warm climate which reached a maximum at about 37000 years ago, immediately before the Pm-3 Pumice. The transgression caused by the warm climate resulted in the formation of the Atsuta Surface in the Nobi coastal plain.

(4) Late Würm Glacial (from 25000 to 10000 yr B. P.)

In this period, the iland area was covered again by the forest which was dominated by subarctic elements.

Periglacial phenomena are observed at the horizon beneath the S-2 Scoria Bed which falled in this period in the inland of Central Japan.

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