Paleobotany and Paleoenvironment of the Late Pleistocene in the Sagami Region, Central Japan¹⁾

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Macroscopic plant fossils and pollen assemblages from the Late Pleistocene in the Sagami region are described, and the vegetation and paleoenvironment are discussed. The taxonomy and phytogeography of *Selaginella*, *Larix* and *Picea*, are described. *Picea* is classified into two species and three types, i.e., *P. jezoensis*, *P. maximowiczii*, *P. sp. A*, *P. sp. B* and *P. sp. C*. Cool-temperate coniferous forests composed of mainly *Cryptomeria japonica* and *Picea maximowiczii* were dominant between 90,000 and 60,000 y.B.P., and indicate the wet cool-temperate climate with a high annual precipitation. Vegetation during the Misaki Transgression, ca. 60,000—55,000 y.B.P., was distinguished by an expansion of cool-temperate oak forests; therefore the climate was relatively warm with low annual precipitation. The subarctic to cool-temperate coniferous forests composed of mainly *Picea maximowiczii* and *Larix* in ca. 55,000—50,000 y.B.P. were the first cold climate forests in the Late Pleistocene. This cold age corresponds to the Murodo Glacier Stage on Mt. Tateyama in Toyama Prefecture. Transitional mixed forests between subarctic coniferous and cool-temperate broad-leaved forests were dominant between ca. 16,000—13,000 y.B.P. These forests spread out in the southern Kanto region in the latest Pleistocene. The descent of subarctic coniferous forests is more than 1,000 meters on the eastern slope of Mt. Fuji.

Introduction

The Kanto region is ideal to elucidate the vegetational history and the relation between vegetational and geological developments during the Late Pleistocene. The Upper Pleistocene deposits contain many interbedded tephrae useful as time markers from huge volcanoes, including Hakone, Fuji, and Asama. Furthermore, several major tephrae were dated by fission track and radiocarbon methods. Therefore, Late Pleistocene stratigraphy and chronology in this region has been recognized as a standard for the Japanese Archipelago (KOBAYASHI, 1965).

There have been several systematic investigations of the Late Pleistocene flora and vegetation in Japan, i.g., Shinshu (SAKAI, 1981; PALYNOLOGICAL RES. GROUP FOR

NOJIRI-KO EXCAVATION AND THE FOSSIL PLANT RES. GROUP FOR NOJIRI-KO EXCAVATION 1980), Abukuma (YOSHIDA *et al.*, 1981), Hokkaido (IGARASHI and KUMANO, 1981) etc. However, only fragmentary investigations have been made for the Kanto region. MIKI (1938) and NAORA (1958) studied macroscopic plant fossils obtained from "The Conifer Bed of Ekoda". In addition, pollen assemblages from several sites in Tokyo and Kanagawa Prefectures were reported by SHIMAKURA (1961), TOKUNAGA (1979) and NISHIMURA (1980).

The authors studied plant fossil assemblages from Pleistocene deposits since approximately 150,000 y.B.P. in the Kanto region, and have already reported on the plant fossil assemblages from the Lowermost and the Lower Members of the Kissawa Loam, from approximately

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150,000 to 120,000 y.B.P., in southern Kanto (TSUJI, 1980; TSUJI and MINAKI, 1982; TSUJI *et al.*, 1982).

In this paper, Plant fossil assemblages from the Middle and the Upper Members of the Kissawa Loam and the Younger Loam, from approximately 90,000 y.B.P., in the Sagami region, southern Kanto, are described, and the vegetational history and paleoenvironment are discussed.

Localities and Stratigraphy

A. Review of tephrostratigraphy

Late Pleistocene tephrostratigraphy in the southern Kanto region was systematically studied by the KANTO LOAM RES. GROUP (1965), MACHIDA and MORIYAMA (1968), MACHIDA (1971) and UESUGI *et al.* (1978). The KANTO LOAM RES. GROUP (1965) divided the aeolian tephtras, distributed in the Tama and Musashino Hills, into three tephra formations: in ascending order, the Shimosueyoshi Loam, the Musashino Loam, and the Tachikawa Loam. MACHIDA and MORIYAMA (1968) described aeolian tephtras in the Sagami region, situated close to the Hakone and Fuji volcanoes, as sources of the tephtras, and divided them into two formations, the Kissawa Loam and Younger Loam. They correlated the former with the Shimosueyoshi Loam and further subdivided it into, the Lower, Middle and Upper Members, and correlated the latter with the Musashino Loam and the Tachikawa Loam. Later, UESUGI *et al.* (1978) additionally established the Lowermost Member of the Kissawa Loam and defined the boundary between the Kissawa Loam and the Younger Loam to be the Obaradai Buried Soil (OB in abbreviation; MACHIDA, 1971).

In order to clarify the history of the Fuji volcano, several volcanostratigraphical studies were carried out. Late Pleistocene tephtras on the eastern slope of the Fuji volcano were designated as the Older Fuji Tephra Formation by MACHIDA (1977). UESUGI *et al.* (1980) restudied and divided it into two new formations, namely the Early and Late Older Fuji Tephra Formations. They were both correlated with the Upper Member of the Kissawa Loam and the Younger Loam.

Each unit composing the tephra formation was labelled by MACHIDA (1971), UESUGI *et al.* (1980) etc. MACHIDA (1971) described almost all of the key tephtras of the Kissawa Loam and the important ones of the Younger Loam. UESUGI *et al.* (1980) described about 170 units from the Older Fuji Tephra Formations in detail.

Fission track ages of the major tephtras were reported by MACHIDA and SUZUKI (1971). According to them, KmP-1 and 7 in the Middle Member of the Kissawa Loam are $98,000 \pm 12,000$ and $89,000 \pm 13,000$ y.B.P., and Ontake-I Pumice (Pm-I) in the Upper Member of the Kissawa Loam is from $73,000 \pm 4,000$ to $95,000 \pm 5,000$ y.B.P.. Furthermore, Obaradai Pumice (OP) and Tokyo Pumice (TP) in the Younger Loam are $66,000 \pm 6,000$ and $49,000 \pm 5,000$ y.B.P.. MACHIDA (1976) assumed the age of the Yoshioka Pumice (YP) to be approximately 60,000 y.B.P.. Based upon his stratigraphical investigations in the Shinshu region, SAKAI (1981) proposed that the previous fission track ages of Pm-I are not acceptable and that it is younger, approximately 60,000 y. B. P. However, the evidence is insufficient to decide which age is correct; thus, in this paper we have used the ages determined by the fission track method.

B. Localities and horizons of fossils

Our descriptions are based upon the stratigraphical sequence proposed by UESUGI *et al.* (1978). Each name of the tephtras corresponds with those in MACHIDA (1971) and UESUGI *et al.* (1980). In the figures, the expedient names by UESUGI *et al.* (1980) are given in parentheses after the formal names by MACHIDA (1971).

Fig. 1 and Table 1 show the study sites. Columnar sections and fossil horizons are shown in Figs. 2 and 3. Fossil horizons at SK-4 correspond to the Middle to Upper Members of the Kissawa Loam and others correspond to the Younger Loam. The upper part of the deposits at 9 sites except SK-4 could be correlated to one another because of the presence of tephra TP. In the southwestern region, MP is also an effective time marker. On the contrary, the lower part of

Fig. 1 Locality map.

Table 1 List of study sites.

Site no.	Location	Latitude (N)	Longitude (E)	Altitude (m)
SK-1	Takenouchi, Hadano, Kanagawa Pref.	35°22'	139°10'	140
SK-2	Iseyamabe, Fujisawa, Kanagawa Pref.	35°21'22"	139°29'	20
SK-3	Ohba, Fujisawa, Kanagawa Pref.	35°21'30"	139°27'	20
SK-4	Oyama, Sunto, Shizuoka Pref.	35°22'30"	139°0'10"	450
SK-5	Kyuden, Totsuka-ku, Yokohama, Kanagawa Pref.	35°25'40"	139°30'47"	30
SK-6	Nippa, Kohoku-ku, Yokohama, Kanagawa Pref.	35°31'20"	139°36'30"	20
SK-7	Eda, Midori-ku, Yokohama, Kanagawa Pref.	35°32'30"	139°34'	50
SK-8	Motoishikawa, Midori-ku, Kanagawa Pref.	35°34'17"	139°33'43"	55
SK-9	Okazu, Totsuka-ku, Yokohama, Kanagawa Pref.	35°26'10"	139°31'27"	40
SK-10	Motoishikawa, Midori-ku, Kanagawa Pref.	35°34'17"	139°33'40"	60
SK-18	Nishiodake, Hadano, Kanagawa Pref.	35°21'35"	139°14'10"	90
SK-31	Rengeji, Gotenba, Shizuoka Pref.	35°19'12"	138°57'56"	410

the deposits at SK-6, 7 and 9 could not be directly correlated because of absence of important tephra. Blue-colored tephra situated in the lowermost part of aeolian loam at SK-5 is probably correlated with Yoshioka Pumice (YP), based upon lithological features and stratigraphy in a field investigation. Therefore, the lower peat intercalating tephra, Y-66 and YP, at SK-1 are somewhat younger than at SK-5.

The outcrops at four sites, SK-7, 8, 9 and

10 were destroyed after this work and turned into housing lots.

The outline of the deposits examined and their stratigraphy is described below.

a. SK-1

Plant fossils were obtained from the lacustrine sediments exposed facing a tributary of the Shijuhasse River. They are mainly composed of pumiceous sand or mud, and peaty mud, intercalating marked tephra, namely Y-66, YP and the Miura Pumice (MP).

Fig. 2 Columnar sections at sites SK-1 to 10.

Fig. 3 Columnar sections at sites SK-18 and 31.

They unconformably overlie Middle Pleistocene aeolian tephra formation and the Tertiary Misaka Group, and are unconformably overlain by TP and the Younger Hakone Pyroclastic-flow (TPH).

b. SK-2 and 3

Both sites are situated in the southern part of the Sagami Hills. Plant fossils were obtained from the upper part of the terrace deposits. OKA *et al.* (1979) named them Dai Gravel and correlated them with the Musashino-III Surface (YOSHIKAWA *et al.*, 1973). Dai Gravel unconformably overlies the Tsuchiya Formation at SK-2, and the Soda Formation at SK-3 (OKA *et al.*, 1979). The lower part of the Dai Gravel is composed of gravel, while the upper part consists of peat or peaty mud, containing remarkable intercalated tephtras such as MP and TP. At site SK-2, furthermore, Anjin Pumice (AP) is also interstratified. The age of the base of peat is younger than approximately 60,000 y.B.P., because the Dai Gravel was deposited after the eruption of YP (OKA *et al.*, 1979).

c. SK-4

Site SK-4 is located in an upper stream of the Nishizawa River. Plant fossils were obtained from the lacustrine sediments cor-

responding to the middle part of the Suruga Gravels (MACHIDA *et al.*, 1975). At this site, they are mainly composed of pumiceous tephtras, peaty mud, sand and gravel.

The lower part contains a yellow-white pumice bed, approximately 50 cm in thickness. MACHIDA *et al.* (1975) correlated it with KmP-2, one of the lower tephtras in the Middle Member of the Kissawa Loam, based upon the hyperthene index. However, based on stratigraphy, it very possibly could be correlated with one of the upper ones (Y. UESUGI and H. MACHIDA, pers. comm., 1981).

The peaty mud in the upper part contains marked tephra Pm-I and yields fossil fragments of wood. MACHIDA *et al.* (1975) reported that the fossil wood obtained from the same horizon was identified as *Picea maximowiczii* by Dr. A. YAMANOUCHI.

d. SK-5

Plant fossils were obtained from the lower peaty mud of the fan deposits. They unconformably overlie the Shimosueyoshi Formation and Shimosueyoshi Loam.

Sand and peaty mud constitute the lower part and contain many wood and pumice fragments. On the contrary, the upper part is composed of aeolian sandy loam interbedded with marked tephtras of MP and TP.

e. SK-6, 7, 8, 9 and 10

Plant fossils were obtained from the peaty mud of the fan deposits. They unconformably overlie the Shimosueyoshi Formation at SK-6, the Oshinuma Formation at SK-7, 8 and 10, and the Miura Group at SK-9. The uppermost part of these fan deposits contains tephra TP.

IDA (1955) reported the occurrences of macroscopic fossils, including *Fagus japonica*, *Carpinus erosa*, *Corylus heterophylla* var. *thunbergii* and *Quercus serrata*, obtained from peaty sediments at SK-6.

f. SK-18

Plant fossils were obtained from lacustrine sediments exposed at two sites (A and B), facing a tributary of the Muro River. These sediments consist of mainly silt, sand and peat, intercalating four major tephtras, namely NO-1, 2, 3 and 4. The middle two tephtras,

Table 2 List of the macroscopic plant fossils obtained from sites SK-1, 3 to 7, and 10.

Localities and horizons Species		SK-1			SK-3			SK-4			SK-5			SK-6			SK-7			SK-10		
		M-1	M-2	M-3	M-4	M-5	M-6	M-7	M-8	M-9	M-10	M-11	M-12	M-13	M-14	M-15	M-16	M-17	M-18			
<i>Selaginella</i> sp.	MS				2						5	13										
<i>Larix</i> sp.	C				1																	
<i>Picea maximowiczii</i> Regel	C		1				7				23	1	2	2				2	10			
<i>P. sp. A</i>	C						3				1							1	1			
<i>P. sect. Eupicea</i>	C	1	1	3			12	8			7	11			1	3		4	8			
	CS						14				2	4			2	1						
	L						28				15	193	46		11	6		24				
<i>P. sp.</i>	Sh											1						1				
<i>Cf. Picea</i>	S						4				2	6	14	8	23	7		18				
<i>Alisma canaliculatum</i> A.Br. et Bouche	F		1										6	4	11	6	17					
	S												2		2							
<i>Cf. Eleocharis</i>	F										1	15						7				
<i>Cyperus</i> sp.	F										1		1		1			1				
<i>Scirpus</i> sp.	F										1				3	37						
<i>Carex</i> sect. <i>Vignea</i>	F												1									
<i>C. sect. Carex</i>	F														1			1				
<i>C. cf. sect. Paludosae</i>	F		3	2							2				7	4	4					
<i>C. cf. sect. Extensae</i>	F										33				1		1					
<i>C. cf. sect. Graciles</i>	F												2	257	208	17	12	5				
<i>C. sp.</i>	F														1	2		1				
<i>Juglans sieboldiana</i> Maxim.	E							2	5													
<i>Carpinus cordata</i> Blume	F												1									
<i>C. cf. tschonoskii</i> Maxim.	F										6											
<i>Corylus heterophylla</i> Fischer	F												1									
<i>Betula</i> sp. A	F												1									
<i>B. sp. B</i>	F												1									
<i>Alnus japonica</i> (Thunb.) Steud.	I				4																	
<i>A. subgen. Alnus</i>	F																					
<i>Fagus crenata</i> Blume	Cu										2								4			
	N										5								1			
<i>Quercus cf. aliena</i> Blume	Cu												3	1					3			
<i>Q. sp.</i>	N														1							
<i>Morus bombycis</i> Koidz.	S										1											
<i>Polygonum thunbergii</i> S. et Z.	F											2	4						1			
<i>P. hydropiper</i> Linn.	F										30		2						2			
<i>P. cf. conspicuum</i> (Nakai) Nakai	F																					
<i>P. sp.</i>	F																					
<i>Prunus salicina</i> Lindl.	E										2				1				1			
<i>Rubus</i> sp.	E										5								1			
<i>Potentilla</i> , <i>Fragaria</i> and/or <i>Duchesnea</i>	E										8	2							3			
<i>Cf. Rosaceae</i>	Sp														1							
<i>Oxalis</i> sp.	S						1						2									
<i>Zanthoxylum schinifolium</i> S. et Z.	E												1									
<i>Phellodendron amurense</i> Rupr.	E													4	1	1						
<i>Acer mono</i> Maxim.	F																1					
	S																	1				
<i>Aesculus turbinata</i> Blume	YF									1												
<i>Impatiens cf. textori</i> Miq.	S													1								
<i>Actinidia arguta</i> (S. et Z) Planch., ex Miq.	S										1											
<i>Viola</i> sp.	S				5						1	3	4	1		2	1	1				
<i>Labiatae</i>	F				1						8							1				
<i>Lycopus</i> sp.	F												1									
<i>Cf. Moss</i>	F										2											
<i>Isodon</i> sp.	F													1								
<i>Cf. Compositae</i>	F												5	3		1						

C : cone CS : cone scale Cu : cupule E : endocarp F : fruit I : infructescence
L : leaf MS : macrospore N : nut S : seed Sh : shoot Sp : spore YF : young fruit

composed of scoria and lithic fragments, were correlated with Y-138 and 139 by UESUGI *et al.* (1980). They are considered to be approximately 13,000 y.B.P. in age based upon the tephrostratigraphic sequence by UESUGI *et al.* (1980).

g. SK-31

Plant fossils were obtained from the swampy peaty sediments that conformably overlie the Old Fuji Mudflow-3 (Mf-3; MACHIDA *et al.*, 1975). They contain some intercalated scoriaceous tephros. The ^{14}C age of a wood

fragment obtained from the peaty sediments is $16,500 \pm 400$ y.B.P. (GaK-318; KANTO LOAM RES. GROUP, 1964). MACHIDA (1977) also reported the ^{14}C age of a wood fragment obtained from Mf-3 to be $16,450 \pm 370$ y.B.P. (GaK-3676).

Plant Fossil Assemblages

A. Macroscopic plant fossils

Macroscopic fossils obtained from the four horizons in the Middle and the Upper Members of the Kissawa Loam and seventeen

Table 3 List of the macroscopic plant fossils obtained from sites SK-18 and 31.

Localities and horizons		SK-31		SK-18
Species		M-11	M-20	M-21
<i>Larix</i> sp.	L	84		2
	SS	6		
Cf. <i>Larix</i>	S	1		10
<i>Abies veitchii</i> Lindl.	CS	20	30	
<i>A.</i> sp.	L	72	6	3
<i>Picea</i> sp. A	C	1	1	
<i>P.</i> sp. B	C	1		
<i>P.</i> sp. C	C	1		
<i>P.</i> sect. <i>Eupicea</i>	L	87		5
<i>P. jezoensis</i> (Sieb. et Zucc.) Carr.	L	35		
<i>P.</i> sp.	G		1	
Cf. <i>Picea</i>	S	12		5
<i>Potamogeton</i> sp.	E	4		
<i>Carex</i> sect. <i>Vignea</i>	F	7		
<i>C.</i> cf. sect. <i>Extensae</i>	F	2		80
<i>C.</i> cf. sect. <i>Graciles</i>	F	1		
<i>Betula</i> cf. <i>platyphylla</i> Sukatchev	L	2		
<i>B.</i> sp. A	F	2		
<i>B.</i> sp. B	F			4
<i>Alnus</i> subgen. <i>Alnus</i>	F	4		13
<i>A.</i> subgen. <i>Alnaster</i>	F	4		1
<i>Polygonum thunbergii</i> Sieb. et Zucc.	F			3
<i>P.</i> cf. <i>pubescens</i> Blume	F	3		4
<i>P.</i> sp.	F	3		
<i>Prunus</i> sect. <i>Pseudocerasus</i>	E	1		
<i>Potentilla</i> , <i>Fragaria</i> and/or <i>Duchesnea</i>	E	19		
<i>Impatiens textori</i> Miq.				1
<i>Viola</i> sp.	S	2		
<i>Myriophyllum</i> sp.	F	18		
<i>Lycopus</i> sp.	F	19		1

C: cone CS: cone scale E: endocarp F: fruit
L: leaf S: seed SS: short shoot G: insect gall

horizons in the Younger Loam are shown in Tables 2 and 3. All specimens examined are preserved at the Osaka City University. Peat or peaty sediments of the following horizons yielded abundant well-preserved fossils; M-6 at SK-4, M-10 at SK-5, M-12 to 17 at SK-7, M-18 at SK-10, and M-19 and 20 at SK-31.

Coniferous fossils, especially genus *Picea*, were well represented in each horizon, while broad-leaved tree fossils were scarce. Cones of *Picea maximowiczii* were frequently obtained from the peaty sediments correlated with the Middle and the Upper Members of the Kissawa Loam and the lower part of the Younger Loam below tephra TP. Peaty mud sediments of M-10 and 17 yielded fossils of both *Picea maximowiczii* and *Fagus crenata*. However, fossils of *Picea maximowiczii* were not found in silty peat corresponding to the upper part of the Younger Loam at both sites, SK-18 and 31. From the sediments at SK-31, abundant *Picea jezoensis*, *P.* sect. *Eupicea*, *Larix* and *Abies* leaves and many *Abies veitchii* cone scales were obtained. Silty

peat at SK-18 also yielded some *Larix*, *Abies* and *Picea* sect. *Eupicea* leaves.

Many herbaceous fossils were obtained from peat or peaty sediments at SK-5, 7, 18 and 31. They included mostly fruits of Cyperaceae and *Polygonum*. At SK-7, fossils assemblages in the upper horizons (M-12 and 13) were characterized by a dominance of *Carex* cf. sect. *Glaciles*, while those in the lower part (M-14 to 17) were marked by occurrences of *Scirpus* and other sections of *Carex*.

The following morphological descriptions report the taxonomy and phytogeography of important macroscopic fossils, *Selaginella*, *Larix* and *Picea*.

a. *Selaginella* (Plate I, 1)

The macrospore is spherical, and 0.75—0.86 mm in diameter. It is a trilete type with three ridges (commisural ridge or margo), 0.21—0.24 mm in length. It is reticulated with narrow muri and wide lumina. The lumina surface verrucates.

Among the extant heterosporous ferns in Japan, *Isoetes japonica* and a few species of *Selaginella* have reticulated macrospores. But the former is easily distinguished by its distinct equatorial ridge, while present fossil lacks it. NASU and SETO (1980) made preliminary study of the spore morphology of *Selaginella* in Japan and Formosa. According to them, this fossil resembles *S. remotifolia* Spring; but the knowledge of the extant species is too sparse to determine its fossil affinity.

b. *Larix* (Plate I, 2)

The cone is ovate, and it is 14 mm in length and 10 mm in width. The stalk is curved, 3 mm in length, with protuberant leaf cushion. Conjugated parastichy is 3:5. The apical half of the seminiferous scale and bract scale are not preserved, so their morphological details are unknown.

Two species of this genus are extant in Japan and northeastern Asia, i.e., *L. leptolepis* (S. et Z.) GORD. in Honshu and *L. gmelinii* (RUPR.) KUZENEVA var. *japonica* (MAXIM.) PILGER in the Kuriles and Sakhalin. KITAMURA and MURATA (1979) and MIKI (1957) indicated that the two species have different cone parastichies, i.e., the former is 3:5 or 5:8 and the latter is 2:3. According to them,

Table 4 Size measurements of *Picea* fossil cones

LH	S	Lmm	Wmm	Tmm	LH	S	Lmm	Wmm	Tmm
SK-1	-	38.2	12.3	10.3	SK-6	m	32.2	11.3	10.2
M-3	-				M-11	-	44.3	17.9	7.8
SK-4	A	53.6	15.4	10.5		-	43.2	17.2	11.4
M-6	A	53.1	14.6	11.7		-	41.2	15.3	10.2
	A	53.9	18.1	11.1		-	40.2	19.6	9.2
	m	46.3	17.7	13.5		-	36.2	12.5	7.4
	m	46.9	19.8	8.7		-	34.0	11.5	9.0
	m	38.7	14.6	12.8	SK-7	m	30.2	12.6	12.0
	m	39.7	15.3	9.9	M-12	m	27.2	10.7	8.9
	m	38.2	15.1	9.9	SK-7	m	35.9	14.7	10.3
	m	37.1	15.2	9.6	M-14	m	29.2	12.3	11.3
	m	38.2	14.5	10.0	SK-7	A	56.1	20.1	14.7
	-	34.4	11.8	8.4	M-17	m	45.3	16.0	13.4
	-	35.7	13.9	11.0	M	m	32.3	10.7	8.1
	-	33.2	11.9	9.6	SK-10	A	50.2	16.7	13.5
SK-5	A	58.0	17.9	11.4	M-18	m	40.8	16.2	12.2
M-10	m	48.7	20.2	11.3		m	43.7	15.5	12.3
	m	44.6	17.7	14.2		m	41.4	16.2	12.2
	m	44.2	17.7	13.4		m	39.1	14.9	12.2
	m	43.6	16.3	14.0		m	41.2	15.2	14.2
	m	43.2	19.6	17.2		m	42.2	13.3	13.2
	m	42.8	17.5	12.5		m	34.8	14.7	13.0
	m	41.7	17.6	15.8		m	35.2	16.0	13.4
	m	41.0	17.1	10.7		m	38.0	14.2	12.5
	m	40.2	15.8	9.8		m	38.0	15.1	14.1
	m	39.8	15.0	13.9	SK-31	A	46.2	15.5	13.3
	m	19.5	18.0	11.1	M-19	B	-	22.4	21.3
	m	38.3	15.2	14.5	C	78.6	24.8	20.3	
	m	37.3	16.9	12.5	SK-31	A	52.3	18.9	17.0
	m	37.2	13.8	12.2	M-20				
	m	35.2	15.4	13.5					
	m	35.2	14.0	11.7					
	m	35.1	15.3	12.4					
	m	34.0	15.9	14.5					
	m	33.2	12.5	11.6					
	m	32.2	16.3	13.3					
	m	32.2	12.9	9.6					
	m	31.4	9.7	8.9					
	m	30.2	11.8	10.5					

LH : localities and horizons.

S : species. A, *Picea* sp. A. B, *Picea* sp. B.C, *Picea* sp. C. m, *Picea maximowiczii*.

-, sp. unknown.

L : length.

W : width.

T : thickness.

this fossil has close affinity to *L. leptolepis*. But the present authors observed that *L. gmelinii* sometimes bears cones with 3:5 parastichies rows; thus the specific identification of poorly preserved fossils should be reserved.

c. *Pices* (Plate I, 3—14)

Classification of the genus *Picea* by individual organs is very difficult even for extant species. In this paper based on leaf and cone morphology, 2 species and 3 types, *P. jezoensis* (S. et Z.) CARRIERE, *P. maximowiczii* REGEL, *P. sp. A*, *P. sp. B*, and *P. sp. C*, were identified.

P. jezoensis is identified by its dorsally flattened needles with two stomatal bands on its upper side only. The other four species and types have four angled needle with stomatal bands on all sides. Classification of the four species and types is based upon their

cone morphology described below. Measurements of the cones are listed in Table 4.

P. maximowiczii REGEL (Plate I, 8—14): The cone is ovate to oblong-ovate, 27.2—48.7 mm in length, 9.7—20.2 mm in width and 7.9—14.2 mm in thickness. The apex and base are obtuse and the parastichy is 3:5. The seminiferous scale is obovate, and the entire margin becomes thinner at the apex. The bract scale spatulate's apex is obtuse to the base of the cone, and has minute teeth in the middle and top of the cone. The characteristics of this fossil are identical with *P. maximowiczii* extant in Japan.

P. sp. A (Plate I, 5—7): The cone is oblong, 46.2—58.0 mm in length, 14.6—20.1 mm in width and 10.5—17.0 mm in thickness. The apex is obtuse to somewhat acuminate, whereas the base is obtuse to acute. The parastichy is 3:5. The seminiferous scale and bract scale have almost the same characteristics as *P. maximowiczii* var. *senanensis* HAYASHI, but small cones of *P. shirasawae* HAYASHI and *P. koyamae* SHIRASAWA sometimes have similar features. On the other hand, *P. sp. A* is accompanied by *P. maximowiczii* at 4 out of 6 sites where *P. sp. A* was found. The morphology of these two species seems to shift gradiently. Thus, these specimens may be a large form of *P. maximowiczii*, which might have been more wide spread in the Pleistocene than now.

P. sp. B (Plate I, 3): The cone found at M-19 of SK-31 is oblong with the upper half broken off. It is more than 38.5 mm in length, 22.4 mm in width and 21.3 mm in thickness. The base is obtuse and the parastichy is 5:8. The seminiferous scale is obovate to narrow rhombate and the margin is unevenly eroded exhibiting minute teeth, which may have been produced from an originally wavy margin scraped off its convex parts from it. This cone is similar to extant *P. bicolor* Carr. excepting it is smaller.

P. sp. C (Plate I, 4): The cone found at M-19 of SK-31 is oblong and is 78.6 mm in length, 24.8 mm in width and 20.3 mm in thickness; the largest in the present study. The parastichy is 3:5. The seminiferous scale and bract scale have almost same characteristics

as *P. maximowiczii* and *P. sp. A.* This cone is probably identical to extant *P. shirasawae*, though *P. koyamae* sometimes bear similar cones.

B. Pollen assemblages

All of the samples used in this study were boiled in a 10 % KOH solution, followed by treatment with HF to remove siliceous matter, and subsequently by the acetolysis method. All specimens examined are preserved at the Osaka City University.

The pollen diagrams are shown in Figs. 4—8, based upon counts of approximately 400 arboreal pollen grains per sample. The percentages of arboreal pollen are calculated from the total arboreal pollen grain counts, and percentages of nonarboreal pollen and fern spores are calculated from the total pollen and spore counts. The characteristics of the pollen assemblages of each site are summarized in Fig. 9.

a. SK-1 (Fig. 4)

In the lower part of the lacustrine deposits (sp. no. 25—34), *Cryptomeria* was the most abundant arboreal pollen, and *Picea* was also always present in high frequencies. Only a few pollen grains of cf. *Theligonum* were found.

The samples of the upper part (sp. nos. 1—3, 5—10, 12, 17) yielded abundant *Picea* and *Larix-Pseudotsuga* pollen grains. *Pinus* was also found in relatively high frequencies.

b. SK-2, 3 and 9 (Figs. 5 and 6)

The sediments at these three sites contained a lot of *Picea* and *Alnus*. Generally, *Picea* tended to dominate in the lower part, and *Alnus* in the upper part.

c. SK-4 (Fig. 5)

The peat sediments corresponding to the Middle and the Upper Members of the Kissawa Loam were generally characterized by a lot of *Cryptomeria* pollen, and contained pollen grains comparable with *Theligonum*. The samples below tephra Pm-I always contained *Sciadopitys* pollen with high frequencies (10 % or more). Other coniferous pollen grains, including *Tsuga*, *Picea*, and *Pinus*, occasionally occurred with high frequencies. The entomophilous pollen grains of *Acer* and *Elaeagnus* were also present, although they

were scarce. On the contrary, in the upper peat corresponding to the Upper Member of the Kissawa Loam, *Picea* always occurred with high frequencies (15 % or more), and *Sciadopitys* was scarce.

d. SK-5 (Fig. 6)

Cryptomeria, *Picea* and *Alnus* were the most abundant arboreal pollen. Two samples of the upper part (sp. no. 2 and 3) contained many *Picea* pollen grains.

e. SK-7 (Fig. 6)

There were distinct differences in the pollen assemblages between the lower peaty mud (sp. no. 5—7) and upper peat (sp. no. 1—4). The peaty mud below the intercalated gravel bed was characterized by a dominance of *Quercus* subgen. *Lepidobalanus* and concomitant *Carpinus-Ostrya* and *Fagus* pollen, and the presence of entomophilous pollen grains of *Orixa*, *Buxus*, *Acer*, and *Tilia*. On the contrary, in the upper peat, *Picea* was the most abundant arboreal pollen, and *Pinus*, *Alnus*, and *Betula* were present with high frequencies.

f. SK-8 and 10 (Fig. 6)

There was a difference in the pollen assemblages between the two sites in spite of the same horizon just below the tephra TP and the neighborhood. *Quercus* subgen. *Lepidobalanus*, *Alnus*, *Picea* and *Pinus* were the major arboreal pollens at SK-8. On the contrary, *Picea* greatly outnumbered all the rest (approximately 75 %) at SK-10.

g. SK-18 (Fig. 7)

The coniferous and broad-leaved trees, including *Abies*, *Tsuga*, *Picea*, *Pinus* subgen. *Haploxylon*, *Betula*, and *Alnus* were always present with high frequencies. There was a difference in the occurrence of *Fagus* and *Larix-Pseudotsuga* between the lower part and the upper part below the tephra NO-2. *Fagus* was present with relatively high frequencies (approximately 5 %) in the former, and *Larix-Pseudotsuga* was present with relatively high frequencies in the latter.

h. SK-31 (Fig. 8)

The coniferous and broad-leaved trees, including *Abies*, *Tsuga*, *Picea*, *Pinus* subgen. *Haploxylon*, *Cryptomeria*, *Fagus* and *Alnus* were responsible for most arboreal pollen. However,

Fig. 5 Pollen diagram of site SK-4.

Fig. 6 Pollen diagrams of sites SK-5, and 7 to 10.

their presence was variable throughout the peat bed. *Cryptomeria* was always present (10 % or more). The lowermost sample contained abundant pollen grains of *Fagus*. *Pinus* subgen. *Haploxylon* was more abundant in the middle to upper part of the peat bed than in the lower part.

Discussion

A. Cool-temperate coniferous forests before 60,000 y.B.P.

Pollen assemblages from the Middle and the Upper Members of the Kissawa Loam and the lower part of the Younger Loam below

Fig. 9 Changes in pollen assemblages, vegetation and annual precipitation in Late Pleistocene time in the Sagami region.

- 2) Dominant or characteristic taxa: A. *Cryptomeria* > *Sciadopitys*.
 B. *Cryptomeria* and *Picea*.
 C. *Quercus* subgen. *Lepidobalanus*.
 D. *Picea*.
 E. *Picea*, *Tsuga*, *Abies*, *Pinus*, *Betula*, *Fagus*.
- 3) a. cool-temperate coniferous forests dominated by *Cryptomeria japonica* and *Picea maximowiczii*.
 b. cool-temperate deciduous broad-leaved forests composed mainly of *Quercus* subgen. *Lepidobalanus*.
 c. cool-temperate to subarctic coniferous forests.
 d. mixed forests of cool-temperate to subarctic conifers and broad-leaved deciduous trees.

Cryptomeria japonica and *Sciadopitys verticillata* now grows mainly in cool-temperate regions with limited distributions, while *Picea bicolor* which had the same habitat as *P. maximowiczii* is now common in the upper cool-temperate to subarctic (or subalpine) regions (KIRA and YOSHINO, 1967). Furthermore, *Cryptomeria japonica* now grows in wet regions with high annual precipitation over 1,500 mm (TSUKADA, 1967).

These pollen assemblages are similar to those of the Kissawa-II plant fossil assemblage zone described by TSUJI and MINAKI (1982) because large quantities of *Cryptomeria* pollen were found, but they are distinguishable from them because there are abundant pollen grains of *Picea*. These facts show that *Picea maximowiczii* dispersed during the time of the Middle Member of the Kissawa Loam. The expansion of *Picea maximowiczii* was possibly caused by the climate becoming colder. On

the other hand, the infrequency of broad-leaved trees in Kissawa-II can be ascribed to the active eruptions during the time of the Lower Member of the Kissawa Loam, as discussed by TSUJI (1980) and TSUJI and MINAKI (1982). In the Shinshu region, SAKAI (1981) reported that the first evidence of a cold climate since the Last Interglacial, shown by pollen assemblages dominated by *Picea* pollen, is found at the basal part of the Fujimi Peat Bed intercalating the tephra Pm-I in the upper part of it. This is supported by the present study.

YONEZAWA (1981) called the period from Pm-I to OP, approximately from 80,000 to 65,000 y.B.P., the "Mud Stage" based upon geomorphological developments in the Sagami River and the Doshi River Basins in the Sagami region. He inferred that this period was characterized by a sedimentation of debris composed of mainly fine particles supplied

from a broad slope on which vegetation and humus soil were well-developed. It is a very possible that such erosion and sedimentation are associated with cool-temperate coniferous forests with high annual precipitation dominated by *Cryptomeria japonica*.

No fossils of extinct taxa in Japan, including *Sapium sebiferum*, *Aleurites cordata*, *Hemiptelea davidiana* and *Vitex* cf. *cannabifolia*, characterizing the Kissawa-I Plant Fossil Assemblage Zone (TSUJI *et al.*, 1982), were found in the Middle and Upper Members of the Kissawa Loam and the lower part of the Younger Loam. These facts show that they finally disappeared in Kissawa-II. On the other hand, only one pollen grain of *Lagerstroemia* extinct in Japan proper was found at SK-5 (Kyuden). NISHIMURA (1980) also found several pollen grains of this taxon in the same sediments. *Lagerstroemia* was also one of the characteristic species in Kissawa-I (TSUJI and MINAKI, 1982) and its fossil pollen grains were found in the early Holocene Shimobara Formation (ENDO *et al.*, 1979). If the fossil pollen grains found at SK-5 are not derived one, their records are the latest from the Pleistocene in the Kanto region.

NISHIMURA (1980) established the *Picea-Pinus-Cryptomeria* zone, corresponding to the upper part of the Shimosueyoshi (Kissawa) Loam and the lower part of the Younger Loam, based upon the pollen assemblages obtained from peaty sediments at SK-5. However, *Picea* and *Pinus* are not generally predominant, as mentioned above.

B. Vegetational changes around 50,000 y.B.P.

Large quantities of pollen grains of *Quercus* subgen. *Lepidobalanus* in the lower peaty mud sediments at SK-7 indicate cool-temperate deciduous oak forests. These forests included *Orixa* and *Buxus*, distributed mainly in the warm-temperate regions of Japan. These facts show a relatively warm climate with a low annual precipitation. According to UESUGI *et al.* (1980), during the time from YP to Y-69-7 just below AP, approximately 60,000-55,000 y.B.P., the basal level of erosion was relatively high and the warm or wet climate

was dominant. At the same time, the Misaki Surface was formed by transgression (MACHIDA, 1973). All data consistently indicate a relatively warm climate, however there is insufficient evidence to make a statement on the amount of precipitation.

The pollen assemblages from the upper part sediments at SK-7 are similar to those from the peat or peaty sediments at SK-1, 2, 3, 8, 9, and 10 in that they contain a lot of *Picea* pollen. They are sometimes characterized by high frequencies of *Larix-Pseudotsuga* and *Alnus*. These sediments are correlated with the upper ones at SK-7 because of the presence of the tephra TP and MP. It can be inferred that the cool-temperate to subarctic (or subalpine) climate with low annual precipitation predominated, considering the high frequencies of *Picea* pollen assumed to be *P. maximowiczii* and *Larix* at SK-1 and 9. Therefore, these floral data indicate the first cold climate of the Late Pleistocene Younger Loam in the Kanto region. This cold age corresponds to the Murodo Glacier Stage on Mt. Tateyama, Toyama Prefecture, as defined by FUKAI (1974), because MACHIDA and ARAI (1979) elucidated the ages of the Murodo Glacier to be approximately 50,000-55,000 y.B.P. based upon tephrostratigraphy and chronology.

The high frequency of *Alnus* pollen, assumed to be *A. japonica* by the presence of fossil infructescences, in this cold age is also important and comparable with the Kissawa-II Plant Fossil Assemblage Zone after the maximum Shimosueyoshi Transgression (TSUJI and MINAKI, 1982). These phenomena may frequently appear at the beginning of regression.

C. Coniferous and broad-leaved mixed forests in the latest Pleistocene

The pollen assemblages in the latest Pleistocene Tachikawa stage at SK-18 and 31 characteristically contained pollen grains of conifers and broad-leaved trees and shrubs, including *Picea*, *Tsuga*, *Abies*, *Pinus* subgen. *Haploxylon*, *Cryptomeria*, *Larix-Pseudotsuga*, *Betula* and *Alnus* with relatively high frequencies. *Fagus*, the major species of the cool-temperate, was not scarce. *Larix-*

Pseudotsuga pollen is assumed to be *Larix* because of coexistent leaf fossils. These pollen grains and the macroscopic fossils of the subarctic (or subalpine) species, *Abies veitchii* and *Picea jezoensis*, at SK-31 show the development of the transitional mixed forests between subarctic coniferous and cool-temperate broad-leaved deciduous forests, in the low mountains and hills in the Kanto region. Abundant and well-preserved macroscopic fossils and the coexistence of variable parts of plants of the subarctic conifers at SK-31 situated on the eastern slope of Mt. Fuji show that neighboring plant community is the source of almost all of the macroscopic fossils. The descent of subarctic coniferous forests is more than 1,000 meters compared with their present distribution on Mt. Fuji.

MIKI (1938) and NAORA (1958) described plant fossil assemblages, composed of cool-temperate to subarctic conifers and cool-temperate beech forest elements, obtained from a peat bed, namely "The Conifer Bed of Ekoda" or "Egota Fossil Plant Bed". These assemblages are very similar to those at SK-18 and 31. KANTO LOAM RES. GROUP (1957; 1965) restudied the stratigraphy of this bed, and confirmed that it was correlated with the upper part of the Younger Loam, namely the Tachikawa Loam. According to them, there is a large possibility that the plant fossils studied by MIKI (1938) obtained from the clay sediments were dated back to $28,770 \pm 2,600$ y.B.P. for the lower part and to $11,840 \pm 300$ and $11,300 \pm 260$ y.B.P. for the upper one by the radiocarbon method. Therefore, the transitional mixed forests mentioned above were widely dispersed in the southern Kanto region in the latest Pleistocene.

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相模地域における後期更新世の植物相と古環境¹⁾辻 誠一郎²⁾・南木 睦彦²⁾・大沢 進³⁾

(要 旨)

相模地域の後期更新世の大型植物化石・花粉化石群集を記載し、植物群と植生、および古環境を論じた。

植物分類・地理学上注目すべきイワヒバ・カラマツ・トウヒ各属の大型植物化石の形態を記載した。このうちトウヒ属は、トウヒ、ヒメバラモミの 2 種とトウヒ属 A・B・C の 3 型に分けられた。

主に、スギおよびヒメバラモミからなる冷温帯針葉樹林が約 9 万—6 万年前に優勢であった。これは上部冷温帯の年降水量の多い湿潤な気候を示す。約 6 万—5.5 万年前の三崎海進を通じての植生は、冷温帯のナラ類林の拡大によって区別される。これは年降水量の少ない比較的温暖な気候を示す。約 5.5 万—5 万年前の主にヒメバラモミとカラマツ属からなる亜寒帯ないし冷温帯針葉樹林は、関東地方で従来知るかぎり後期更新世における最初の寒冷気候を示す。この時代は立山で確認された室堂氷期にあたる。亜寒帯針葉樹林と冷温帯落葉広葉樹林

の間の移行的な混交林が約 1.6 万—1.3 万年前に優勢であった。このような森林は更新世末期の南関東に分布拡大していたと思われる。この時代の富士山東麓における亜寒帯針葉樹林の下降は 1,000m 以上であった。

(地 名)

Eda 荏田
Ekoda, Egota 江古田
Iseyamabe 伊勢山辺
Kyuden 給田
Nippa 新羽
Rengeji 蓮花寺
Shijuhasse River 四十八瀬川

(地層名)

Kissawa L. 吉沢ローム層
Younger L. 新期ローム層
Anjin Pumice 安針軽石

Explanation of the Plate

Plate I Macroscopic plant fossils obtained from the Late Pleistocene deposits in the Sagami region.

1. *Selaginella*: macrospore, M-11; a. polar view, $\times 47$; b. equatorial view, $\times 47$; c. surface of the macrospore, $\times 200$.
2. *Larix*: cone, M-5, $\times 2$.
3. *Picea* sp. B: cone, M-19, $\times 0.75$.
4. *Picea* sp. C: cone, M-19, $\times 0.75$.
- 5—7. *Picea* sp. A: cone, $\times 0.75$; 5, 6. M-6; 7. M-18.
- 8—14. *Picea maximowiczii* REGEL: cone, $\times 0.75$; 8. M-17; 9, 10. M-18; 11—13. M-6; 14. M-10.
- 15—17. *Abies veitchii* LINDL.: cone scale, M-20, $\times 2$.
18. *Juglans sieboldiana* MAXIM.: endocarp, M-9, $\times 0.75$.
- 19—21. *Fagus crenata* BLUME: 19, 20. cupule, M-10, $\times 1$; 21. nut, M-17, $\times 1$.
22. *Quercus* cf. *aliena* BLUME: cupule, M-13, $\times 2$.
23. *Aesculus turbinata* BLUME: young fruit, M-9, $\times 1$.