

山梨県釜無川川岸の教来石礫層中から出土した中期更新世の埋没林

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**Middle Pleistocene Forests Buried in the Kyoraishi Gravel,
Yamanashi Prefecture, Central Japan.**

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Introduction

Studies of buried forests are important in paleobotany, in that past plant communities are preserved *in situ*. That is, in such a forest, the distribution of individuals can be reconstructed based upon the presence of stumps, and past plant communities can be recognized. But aside from some reports by geologists, few studies have been carried out from the standpoint of paleobotany. One example is the survey of buried forests under Fuji 1707 tephra by MIYAJI et al. (1985), in which they clarified the distribution of stands within a past forest, and drew a comprehensive picture of past vegetation.

In 1982, a buried forest in the Kyoraishi Gravel was excavated along the Kamanashi River, at the southwestern foot of Mts. Yatsugatake, by a flood that removed the sediments. This forest consisted of few coniferous stumps up to 6 m in circumference around the roots, some of which were identified as *Picea maximowiczii* (UEMATSU, 1984). As to the plant macrofossils from the same formation, SUZUKI (1967) had earlier reported *Picea maximowiczii* REGEL, *P. jezoensis* CARR., *P. cf. bicolor* (MAXIM.) MAYR., *Fagus crenata* BL., and *Magnolia obovata* THUNB., and stated that *P. maximowiczii* and *F. crenata* were dominant. But there has been no survey of this buried forest, and its character has been obscure.

Geological Setting and Occurrence of Fossils

The study site extends from 500 to 1000m below the Kokkai Bridge over the Kamanashi River, at about 680 m in altitude, which are now in Hakushu-cho, Kitakoma-gun, Yamanashi Pre-

fecture (Fig. 1). Four geological units can be recognized at this site, and they will be briefly described, starting with the bottom one (Figs. 2,3, 4). The lowermost unit is a hard silty layer, in which peaty beds with some stumps and gravel beds are intercalated. Its base cannot be observed at this site, and its top is attached to the main unit with an unconformity. The main unit is ca. 10 m in thickness, and is composed of unconsolidated granitic gravels and sands. Peaty beds, often with erect stumps, are intercalated among the gravels

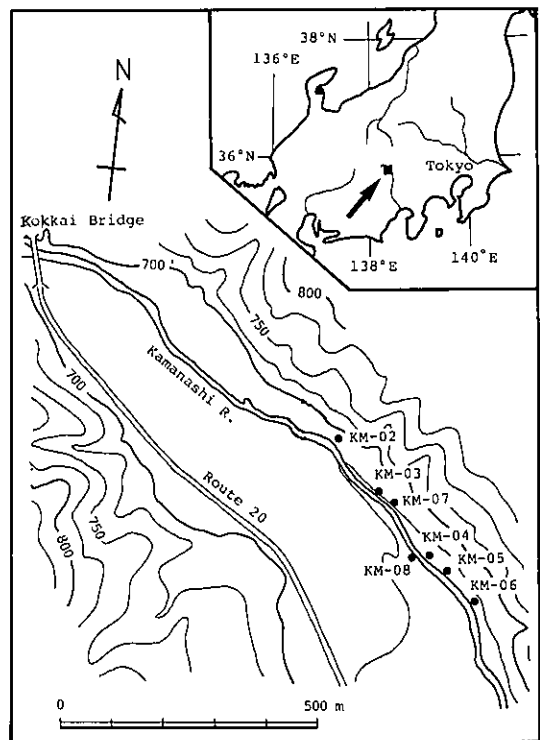


Fig. 1. Locality of the Study site.

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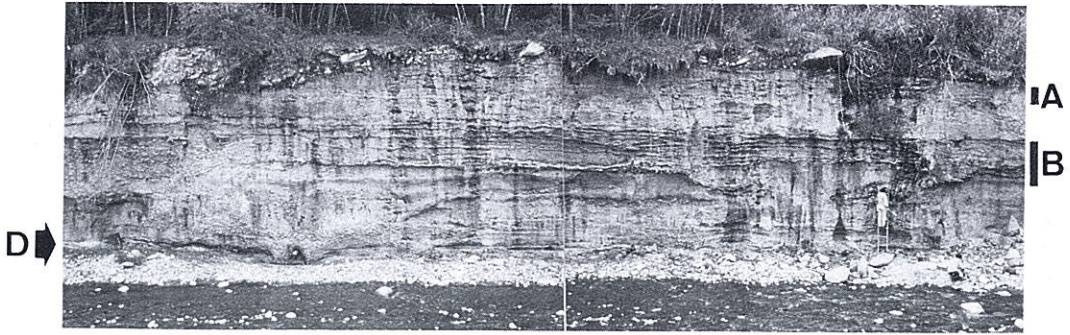


Fig. 2. Outcrop at point KM-04. A, B and D are horizons with erect stumps. Peaty beds in horizon C are not distributed here. (photographed by Dr. S. TSUJI)

and sands. The top of this unit is attached with an unconformity to another unit, a thick mudflow deposit, on the upstream side of point KM-03, and to still another, a terrace deposit of later period, on the downstream side (Fig. 4).

The Quaternary system around the study site has been surveyed by GOHARA (1967), the KOFU BASIN QUATERNARY RESEARCH GROUP (1969), the SHINSHU RESEARCH GROUP (1969), KAWACHI (1977), and the COLLABORATIVE RESEARCH GROUP FOR YATSUGATAKE (1982). According to GOHARA (1967), a gravel layer at this site is called the Kyoraishi Gravel, and is described as a gravel layer mainly composed of granitic gravels intercalated with some beds of peat or peaty sand. This facies agrees with that of the main unit of this site. The base of this gravel is attached with an unconformity to the Nigorigawa Pyroclastic Flow according to GOHARA (1967), and to the Ojirogawa Mudflow according to the KOFU BASIN QUATERNARY RESEARCH GROUP (1969), but it is not certain whether or not the lowermost unit corresponds to either of these. According to GOHARA (1967), the top of this gravel is covered with an unconformity by the Nirasaki Pyroclastic Flow, which is later called the Nirasaki Mudflow by KAWACHI (1977) and the COLLABORATIVE RESEARCH GROUP FOR YATSUGATAKE (1982). The mudflow deposit above the main unit corresponds to this Nirasaki Mudflow. The chronology of these units is not certain, but GOHARA (1967) correlated the Kyoraishi Gravel with the Tama Loam in the Kanto District, and the COLLABORATIVE RESEARCH GROUP FOR YATSUGATAKE (1982) also regarded this gravel as Middle Pleisto-

cene deposits. Therefore the main unit can be regarded as Middle Pleistocene deposits. UEMATSU (1986) earlier supposed this buried forest to be of the maximum of the Würm Glacial Stage, but judging from the sediments, it is of the Middle Pleistocene.

The peaty beds within the main unit are a few to 100 cm in thickness, layered almost horizontally, and composed of sandy to silty matrix with many plant fragments. They are not consistent in continuity, often diverging into several beds or abruptly disappearing among gravels, but can be

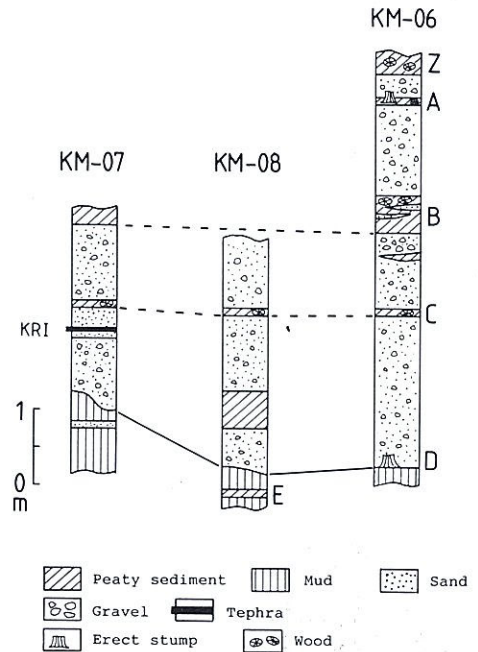


Fig. 3. Columnar sections at points KM-06, 07 and 08. A, B, C, D, E and Z are horizons with erect stumps.

traced as horizons within each level. Erect stumps are found in some of these peaty beds, and these horizons are named Z, A, B and C from the uppermost one (Fig. 3,4). Just above the unconformity between the main unit and the lowermost one, there are some peaty beds, and erect stumps in them have roots in the lowermost unit. This horizon is named D. The horizon of the peaty beds within the lowermost unit is named E. Therefore at least six buried forests have been recognized at this site.

A pink to purplish gray pumice bed has been discovered between horizons C and D, and is named Kyoraishi Pumice in this study (Fig. 3,4), the largest particles of which are ca. 5 mm in diameter. This tephra forms a distinct layer, ca. 3 cm in maximum thickness, on the upstream side of KM-08, but is scattered below this point.

Fossil woods other than stumps are scattered in these peaty beds, and rootwoods are usually found in the lower part of these beds. Sediments around stumps have not been studied critically so that the buried soil has not been recognized. Sedimental

facies of plant macrofossils are somewhat different between the horizons. In horizons Z, A and B, plant fragments are deposited in thin and dense laminas, a few centimeters or less in thickness, which are found in alternation with sandy or silty ones. Plant macrofossils such as coniferous leaves are found in clusters within these laminas. On the other hand, large plant macrofossils such as coniferous cones are scattered throughout the entire peaty sediments. In horizons C and E, peaty sediments are rather discontinuous, and laminas in them are not so conspicuous. The plant macrofossils are dispersed in these peaty sediments. In horizon D, peaty sediments are less developed and sporadic, usually in small lenses with thin laminas directly above the lowermost silty unit. Plant macrofossils are found within these peaty sediments.

Materials and Methods

Fossil woods were collected as block samples in the field, applying sample numbers that begin with 'KM.'. These samples were then hand-sectioned

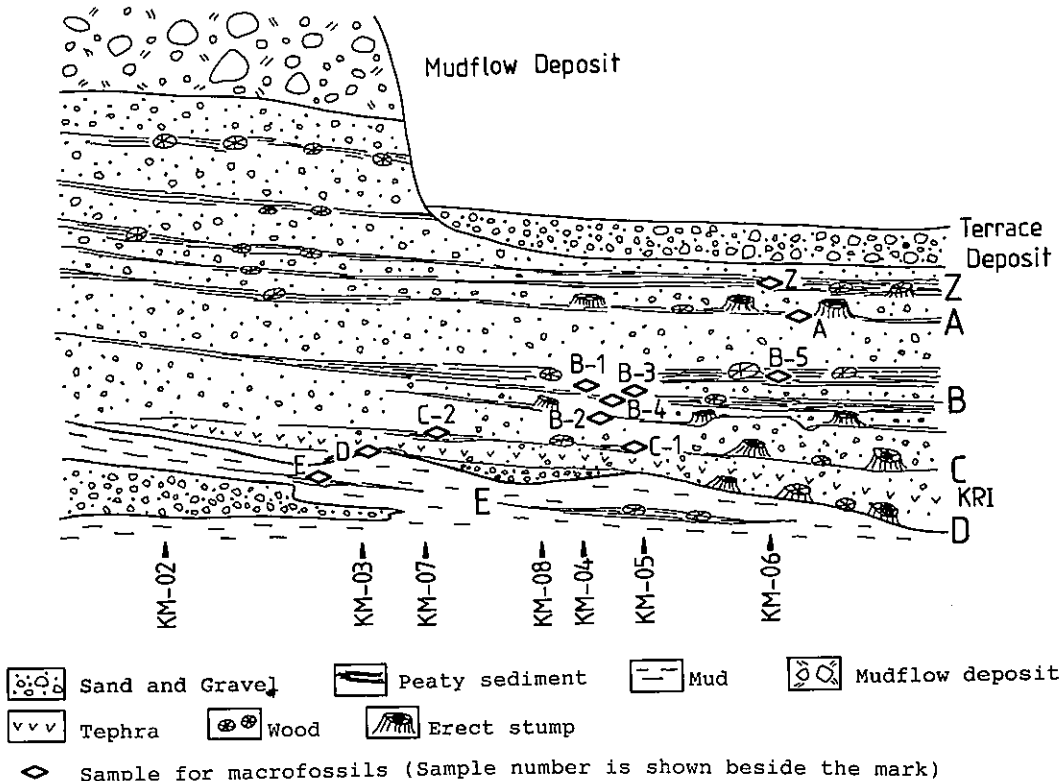


Fig. 4. Schematic diagram of the outcrop. KM-02 to 08 are points in Fig. 1. A, B, C, D, E and Z are horizons with erect stumps. KRI is the Kyoraishi Pumice.

with razor blades in the laboratory, and were mounted with Gum-chloral (a mixture of Chloral Hydrate 50 g, Arabic Gum 40 g, Glycerin 20 ml and Pure Water 50 ml). They were then observed and identified under an optical microscope. These specimens are deposited at Kanazawa University.

Plant macrofossils were collected with sediments at each stratum, and large ones were also collected from the outcrop. The sediments were loosened in water and sifted with a 0.25 mm mesh sieve in the laboratory. The specimens were then removed and identified under a binocular microscope. These specimens were preserved in 70 % alcohol after applying MINAKI's specimen numbers, and are deposited at Osaka City University.

Description of Fossils

To clarify the basis of identification, fossil woods and plants macrofossils of coniferous taxa will be briefly described.

Fossil Woods

Abies. Coniferous wood without vertical or horizontal resin canals; transition from the early- to the latewood gradual; resin cells not observed; rays composed only of parenchyma cells with conspicuous simple pits.

Tsuga. Coniferous wood usually without vertical or horizontal resin canals; occasionally traumatic resin canals observed; transition from the early- to the latewood gradual; resin cells not observed; rays composed of parenchyma cells and ray tracheids.

Picea maximowiczii REGEL (Fig. 5, a-c). Coniferous wood with vertical and horizontal resin canals; transition from the early- to the latewood rather gradual; spiral thickenings fairly distinct both in the early- and latewood tracheids; bordered pits of ray tracheids having big apertures with round margins, or small apertures with round or edged margins. Fossil woods of this type are identified with this species because of the presence of spiral thickenings both in the early- and latewood tracheids.

Picea (Fig. 5, d-f). Coniferous wood with vertical and horizontal resin canals; transition from the early- to the latewood fairly gradual; in some individuals, spiral thickenings observed in latewood tracheids (Fig. 5f); bordered pits of ray

tracheids having small apertures with edged margins. All the Japanese *Picea* species other than *P. maximowiczii* are included in this taxa. *Picea* fossil woods have been divided into two types, sp. A and sp. B, based on the presence of spiral thickenings in the latewood (TSUJI et al., 1984). However, this character has not been confirmed in rootwood or branch-wood, and thus further ontogenetical survey as well as the study of interspecific variation is required. Therefore, these types of samples are identified as *Picea* whether or not spiral thickenings are observed. In this taxa, some samples of *P. maximowiczii* might be included because of their poor preservation.

Larix (Fig. 5, g-i). Coniferous wood with vertical and horizontal resin canals; transition from the early- to the latewood abrupt; bordered pits on the radial walls of earlywood tracheids in single or double files; spiral thickenings not observed; bordered pits of ray tracheids having rather narrow apertures with thick margins. Though bordered pits of ray tracheids differ from those of the typical *Larix* wood, fossil woods of this type are identified with the genus mainly based on the transition from the early- to the latewood.

Pinus subgen. *Haploxyton*. Coniferous wood with vertical and horizontal resin canals; epithelial cells thin-walled and destroyed; transition from the early- to the latewood fairly gradual; cross-field pitting window-like; horizontal walls of ray tracheids smooth.

Chamaecyparis pisifera (SIEB. et ZUCC.) ENDL.

Coniferous wood without vertical or horizontal resin canals; transition from the early- to the latewood abrupt; latewood narrow; resin cells scattered near or in the latewood almost parallel to the growth ring boundaries; horizontal walls of resin cells nodular; cross-field pitting rather large, cupressoid tending to be taxodioid, 2 in one cross-field. Fossil woods of this type are identified with this species based on the cupressoid-taxodioid cross-field pitting, which is cupressoid-piceoid in *C. obtusa*.

Chamaecyparis (rootwood). Coniferous wood without vertical or horizontal resin canals; latewood very narrow, 1-2 cells wide; transition from the early- to the latewood abrupt; resin cells scattered near the latewood almost parallel to the growth ring boundaries; horizontal walls of resin

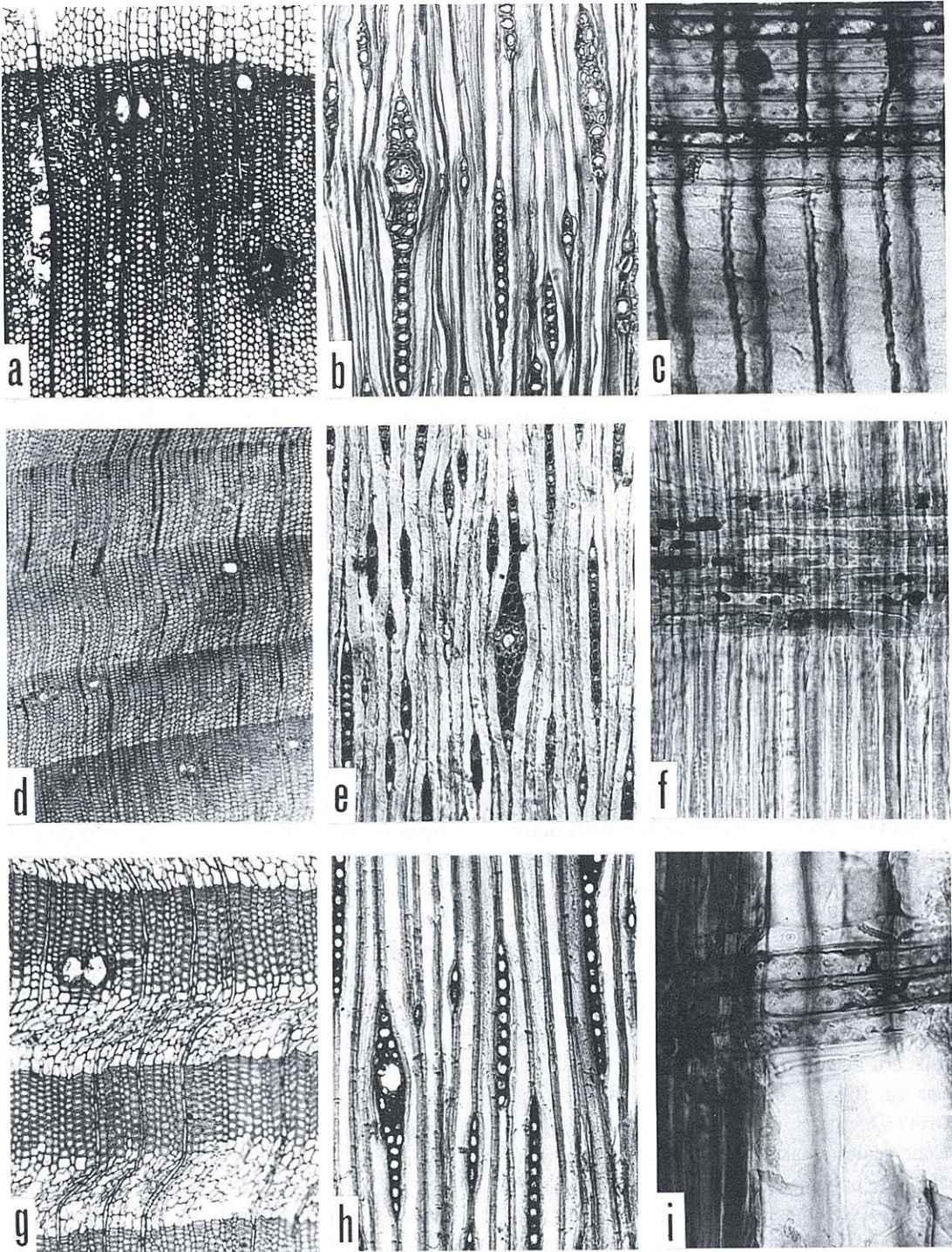


Fig. 5. Representative fossil woods obtained from the study site. a-c: *Picea maximowiczii* REGEL, KM-320. d-f: *Picea*, KM-252. g-i: *Larix*, KM-271. (a,d,g: cross section, $\times 40$; b,e,h: tangential section, $\times 100$; c,f,i: radial section, $\times 200$)

cells conspicuously nodular; bordered pits on the radial walls of earlywood tracheids in double files; cross-field pitting large cupressoid, 2-3 in one cross-field. Fossil woods of this type are judged to be *Chamaecyparis* rootwood because of the large thin-walled tracheids in the earlywood with double file bordered pits, and very narrow latewood, but the variation in rootwood among the extant species is not clear at present, so that identification at the species level is avoided.

Thuja standishii (GORD.) CARR. Coniferous wood without vertical or horizontal resin canals; transition from the early- to the latewood gradual; resin cells scattered near the latewood almost parallel to the growth ring boundaries; horizontal walls of resin cells nodular; cross-field pitting small taxodioid, 2 in one cross-field. Fossil woods of this type are identified with this species based on the rather small taxodioid pitting in cross-fields, which is smaller in *Thujopsis*.

Plant Macrofossils

Chamaecyparis pisifera (SIEB. et ZUCC.) ENDL. (Fig. 6, a-c). MM644-3, MM644-7.

Shoots flattened with scaly decussate leaves, 1.5-2.0 mm in diameter including leaves; leaf tips normally recurved to the axis, and seldom acute; seeds small, ca. 2 mm in length, trigonous or lenticular, with 1 to 4 small fusiform resin bodies on each face. Fossil seed morphology quite agree with that of *C. pisifera*, but this species tends to have more acute leaves on the shoots. Another extant species, *C. obtusa*, has recurved leaves, which are similar to these fossils. But the shoot characteristics are not so stable within these taxa, and cones or seeds of *C. obtusa* have not been obtained from this site. Therefore all the shoot fossils are identified with *C. pisifera*.

Abies sp. (Fig. 6, d). MM633-1-1, MM643-2-1,2, MM643-5,

Cone scales small in size, broad and short in shape; the only measurable cone scale, MM633-1-1 (Fig. 6,d), 13 mm in width, 8.1 mm in length. Bract scales are broken, so their specific identification is difficult. But judging from their small size and shape, they could probably be assigned to *Abies veitchii*.

Tsuga diversifolia (MAXIM.) MASTERS (Fig. 6, e, f). MM642-2-1,2.

Cones ovoid and small (Table 1). Among the

two extant *Tsuga* species in Japan, these fossils can be assigned to *T. diversifolia* because of their small size and concave margins of seminiferous scales. Cone scales of *T. sieboldiana* are generally bigger than 2 cm, with seminiferous scales having slightly convex or truncate margins.

Picea jezoensis (SIEB. et ZUCC.) CARR. (Fig. 6, g). MM631-1-1,1-14, MM636-1, MM637-2, MM641-1, MM642-4-1-4.

Cones cylindrical, ca. 40-50 mm in length, and ca. 13-17 mm in width (Table 1); seminiferous scales rhomboidal, acute with irregular teeth, arranged in 5:8 conjugated parastichy; bract scales narrow rhomboidal with minute teeth. All these well agree with the characteristics of the extant *P. jezoensis*.

Leaves dorsiventral, flattened and linear, ca. 10-15 mm in length, ca. 1-1.4 mm in width; double bands of stomata only on the upper side; two linear projections of resin canals on the lower side. *P. jezoensis* is the only *Picea* species in Japan that has such dorsiventral flattened leaves. *Picea* leaves of another type have also been obtained from this site, which are quadrangular linear, ca. 10-15 mm in length, ca. 0.7-1.5 mm in width, with bands of stomata on every side. Such leaves are assigned to *Picea* sect. *Picea*, in which all the *Picea* species in Japan are included, except *P. jezoensis*. *Picea* cf. *bicolor* (MAXIM.) MAYR A (Fig. 6, k). MM642-5-1,2.

Cones ellipsoidal and big (Table 1); seminiferous scales fan-shaped, obtuse and nearly entire with very minute teeth, arranged in 3:5 conjugated parastichy, many vertical linear ridges on the surface; bract scales narrow spatulate with minute teeth. Among the extant *Picea* species in Japan, *P. bicolor* sometimes bears cones of similar type, but they are normally bigger than these fossils, and their seminiferous scales have minute teeth. Therefore these fossils are treated as *P. cf. bicolor* A.

Picea cf. *bicolor* (MAXIM.) MAYR B (Fig. 6, j). MM635-2-1, MM638-2-1, MM640-1-1.

All the cones are broken and their full length could not be obtained. Cones ellipsoidal, ca. 20 mm in width (Table 1); seminiferous scales fan-shaped to rhomboidal, acute with irregular minute teeth, arranged in 3:5 conjugated parastichy; bract scales narrow spatulate, with

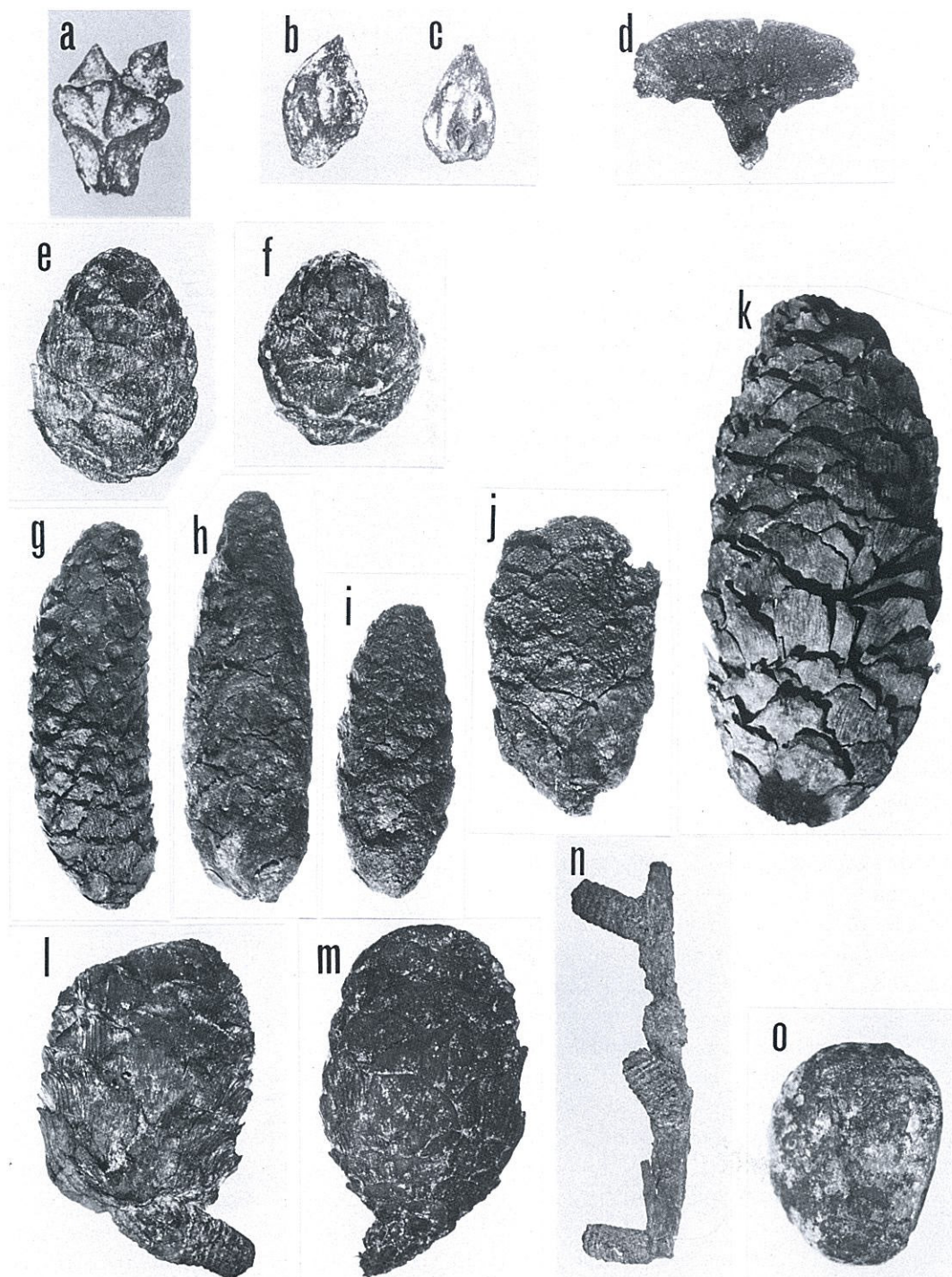


Fig. 6. Plant macrofossils obtained from the study site. a: *Chamaecyparis pisifera*, shoot, $\times 10$ (MM644-3-1). b, c: *Chamaecyparis pisifera*, seed, $\times 10$ (MM644-7-1, 2). d: *Abies*, cone scale, $\times 3$ (MM633-1-1). e, f: *Tsuga diversifolia*, cone, $\times 1.2$ (MM642-2-1, 2). g: *Picea jezoensis*, cone, $\times 1.2$ (MM631-1-1). h, i: *Picea maximowiczii*, cone, $\times 1.2$ (MM642-3-1, 3). j: *Picea* cf. *bicolor* B, cone, $\times 1.2$ (MM635-2-1). k: *Picea* cf. *bicolor* A, cone, $\times 1.2$ (MM642-5-1). l, m: *Larix* cf. *leptolepis*, cone, $\times 2$, (MM631-2-1, 634-1-1). n: *Larix*, shoot, $\times 2$ (MM631-2-4). o: *Pinus koraiensis*, seed, $\times 3$ (MM643-1-1).

minute teeth. These cones are quite similar to those of *P. bicolor*, except for their small size. They differ from the cones of *P. cf. bicolor* A in their small size and the shape of seminiferous scales. Variations within the modern species should be clarified before we can determine whether these fossil cones belong to *P. bicolor* or not.

Picea maximowiczii REGEL (Fig. 6, h,i). MM633-2-1, MM642-3-1,2,3,MM647-1-1.

Cones narrow ovoidal, 36.5-51.3 mm in length, 14.0-16.4 mm in width (Table 1); seminiferous scales fan-shaped, obtuse with entire margin, arranged in 3:5 conjugated parastichy; bract scales narrow spatulate, with minute teeth. These well agree with the characteristics of the extant *P. maximowiczii*.

Larix cf. leptolepis (SIEB. et ZUCC.) GORDON (Fig. 6, l,m). MM631-1-1,1-14, MM633-4-1,3, MM634-1-1,2-1, MM635-1-1-8, MM638-1-1-6, MM642-1-1-4.

Cones ovoidal to ellipsoidal, ca. 18-21 mm in length, 10-14 mm in width (Table 1); seminiferous scales orbicular, truncate with entire margins, tips slightly recurved (Fig. 6, l) or without recurvature (Fig. 6, m); bract scales seldom preserved completely; stalks of cones short, 2-8 mm in length, with many scaly leaf cushions. Fossil cones are smaller and have a lesser number of less recurved seminiferous scales than the normal cones of *L. leptolepis*, the only extant *Larix* in Japan. Fossil cones with such characteristics have also been reported from some other localities (SUZUKI, 1985). SUZUKI (1985) pointed out that such cones are also common among the young trees of extant *L. leptolepis*, and asserted that these fossils should be assigned to this species. However, to clearly state the distinctions from the extant one, they are treated as *L. cf. leptolepis* in this paper.

Pinus koraiensis SIEB. et ZUCC. (Fig. 6, o). MM643-1.

Seeds obovoidal; only two seeds well preserved, 11.3×8.1×4.6 and 13.7×11.3×2.8 mm respectively; other seeds probably similar in size; surface covered with thin soft seed coats with dark dots; wings or "elongations of wing tissue", i.e., the seminiferous tissue derivatives enclosing the seed surface (MINAKI, 1983), not preserved. In *Pinus* subgen. *Haploxylo*n of Japan, seeds are as

Table 1. Measurements of the fossil cones obtained from the study site.

Species	Sample Number	Specimen Number	Length (mm)	Width (mm)	Thickness (mm)
<i>Tsuga diversifolia</i> (Maxim.) Masters	C-1	642-2-1	17.3	12.2	6.7
	C-1	642-2-2	11.7	12.2	6.6
<i>Picea jezoensis</i> (Sieb. et Zucc.) Carr.	A	631-1-1	48.3	14.3	11.0
	A	631-1-2	49.5	15.4	5.9
	A	631-1-3	43.9	12.6	3.8
	A	631-1-4	40.9	13.3	7.1
	A	631-1-5	40.8	14.1	7.2
	A	631-1-6	36.8	12.2	3.8
	A	631-1-7	39.5+	13.7	9.3
	A	631-1-8	40.3	16.3	7.6
	C-1	642-4-1	45.0+	16.9	6.0
	C-1	642-4-2	45.3	17.3	10.3
	C-1	642-4-3	49.9	16.8	4.8
	C-1	642-4-4	38.9	14.8	7.4
max.			49.9	17.3	11.0
min.			36.8	12.2	3.8
mean			43.4	14.8	7.0
s.d.			4.6	1.7	2.3
<i>Picea cf. bicolor</i> (Maxim.) Mayr A	C-1	642-5-1	65.1	29.2	10.3
	C-1	642-5-2	58.6	27.6	8.6
<i>Picea cf. bicolor</i> (Maxim.) Mayr B	B-2	635-2-1	37.6+	21.0	8.9
	B-3,4	638-2-1	35.0+	20.0	5.1
	B-5	640-1-1	23.9+	19.4	6.7
<i>Picea maximowiczii</i> Regel	B-1	633-2-1	31.1+	15.8	10.6
	C-1	642-3-1	51.3	16.4	7.0
	C-1	642-3-2	38.1+	14.0	8.1
	C-1	642-3-3	36.5	15.0	8.0
<i>Larix cf. leptolepis</i> (Sieb. et Zucc.) Gordon	A	631-2-1	19.7	15.4	5.4
	A	631-2-2	19.3	12.7	4.4
	A	631-2-3	19.7	13.9	5.8
	B-1	633-4-1	21.0	11.2	8.2
	B-1	633-4-2	17.9	12.0	10.2
	B-1	633-4-3	20.7	11.9	8.3
	B-2	634-1-1	20.9	14.7	6.1
	B-2	634-1-2	20.4	13.7	6.2
	B-2	634-1-3	21.3	11.7	4.7
	B-2	634-1-4	18.6	12.3	5.0
	B-2	634-1-5	16.5	11.8	6.7
	B-2	634-1-6	15.6	10.7	6.7
	B-2	634-1-7	15.2	11.3	7.6
	B-2	634-1-8	19.7	12.7	5.5
	B-2	634-1-9	20.2	11.5	3.3
	B-2	634-1-10	18.1	12.5	4.1
	B-2	634-1-11	15.2	11.9	6.3
	B-2	634-1-12	17.5	11.7	5.2
	B-2	635-1-1	23.1	14.8	8.7
	B-2	635-1-2	18.1	15.1	7.7
	B-2	635-1-3	14.3	8.8	5.7
	B-2	635-1-4	14.2	9.7	8.7
	B-2	635-1-5	20.1	13.4	7.7
	B-2	635-1-6	20.0	12.4	8.4
	B-2	635-1-7	20.1	11.5	5.2
	B-3,4	638-1-1	21.0	12.0	9.2
	B-3,4	638-1-2	21.8	12.5	7.9
B-3,4	638-1-3	20.2	12.1	6.0	
B-3,4	638-1-4	20.1	12.1	6.9	
B-3,4	638-1-5	19.8	9.3	4.7	
B-3,4	638-1-6	20.7	16.2	6.4	
C-1	642-1-1	24.5	14.9	5.1	
C-1	642-1-2	19.0	13.5	6.4	
C-1	642-1-3	19.0	10.7	6.6	
C-1	642-1-4	20.4	12.5	4.1	
max.			21.5	16.2	10.2
min.			14.2	8.8	3.3
mean			19.2	12.4	6.5
s.d.			2.3	1.7	1.6

large as fossils in *P. koraiensis* and *P. armandii*, while they are smaller, usually less than 10 mm, in the others. Without wings or "elongations of wing tissue" it is somewhat difficult to make specific distinction between the two. But the assignment of these fossils to *P. koraiensis* has been possible based on their obovoidal shape, because seeds of *P. amamiana* are narrow obovoidal. Leaves and short shoots of *Pinus* subgen. *Haploxylo*n have also been obtained from this site. These leaves are trigonous and have bands of stomata on all sides. The anatomical characters of leaves are useful

Table 2. List of the fossil woods and number of stumps obtained from the study site.

Taxa	Horizon					
	Z	A	B	C	D	E
<i>Abies</i>		1	3	3(1)		2
<i>Tsuga</i>		1		1(1)		4(1)
<i>Picea maximowiczii</i> Regel	7(7)	1(1)	6(2)	1(1)	2(2)	
<i>Picea</i>	10(6)	69(34)	104(3)	16(2)	4(2)	12(1)
<i>Larix</i>	1(1)		3(1)	2		
<i>Pinus</i> subgen. <i>Haploxyylon</i>			1			
<i>Chamaecyparis pisifera</i> (Sieb. et Zucc.) Endl.					4(4)	
<i>Chamaecyparis</i> (rootwood)					1	2
<i>Thuja standishii</i> (Gord.) Carr.				2(1)	6(3)	2
<i>Salix</i>	1(1)					
<i>Alnus</i>				2(2)	2(1)	1(1)
<i>Prunus</i>				1		
Total	19(15)	72(35)	117(6)	28(8)	19(12)	23(3)

(): No. of stumps.

for the identification of *Pinus* species (IWATA and KUSAKA, 1952; MINAKI, 1983), but their preservation was too poor to make any cross sections.

Fossil Assemblage

Fossil Woods

Among 278 samples of fossil woods, 9 gymnospermous and 3 angiospermous taxa have been recognized (Table 2). *Picea* totals 215 of these and is dominant in every horizon except D. Then come 17 *P. maximowiczii*, found in 5 horizons except for the lowermost E. Among 79 stumps, 48 are *Picea* and 13 are *P. maximowiczii*, both of which occur rather evenly throughout the horizons. Among the other taxa, *Abies* and *Tsuga* are found from A to E, *Larix* from Z to C, and *Thuja standishii* and *Alnus* from C to E. *Chamaecyparis pisifera* is found only from horizon D.

Among 19 samples from horizon Z, 10 (including 6 stumps) are *Picea* and 7 (all stumps) are *P. maximowiczii*. Of 72 samples from horizon A, 69 (including 34 stumps) are *Picea*. The largest collection of 117 samples has been made from horizon B, of which 104 are *Picea* and 6 are *P. maximowiczii*, but there were only 6 stumps in this layer. Horizon C is richest in flora, and 8 taxa have been recognized among 28 samples, of which 16 are *Picea*, 3 are *Abies*, and 2 are *Larix*, *Thuja standishii* and *Alnus*. Of 19 samples from horizon D, 6 (including 3 stumps) are *Thuja standishii*, 4 (including 2 stumps) are *Picea*, and also 4 (all stumps) are *Chamaecyparis pisifera*. Among 23 samples from horizon E, 12 are *Picea* and 4 are *Tsuga*.

The diameters of fossil stumps range from 5 to 80 cm (Table 3). In horizon Z, diameters are large, with 9 stumps between 35 and 50 cm, and the maximum diameter is found in all the four taxa, i.e., *Picea*, *P. maximowiczii*, *Larix*, and *Salix*. In horizon A diameters are rather small, with 35 cm in *Picea* as the maximum and 31 samples are below 20 cm. In horizon B diameters are also small, with 30 cm in *P. maximowiczii* as the maximum. In horizon C diameters are large, with 50 cm as the maximum, the biggest two being *Picea*, and *Tsuga* the third. In horizon D diameters are fairly large, up to 80 and 60 cm in *Thuja standishii*, 50 cm in *Chamaecyparis pisifera*, 40 cm in *Picea*, and 30 cm in *P. maximowiczii*. In horizon E diameters are fairly small, with 12 cm as the maximum.

The characteristics of these assemblages can be summarized as follows:

- 1) *Picea* including *P. maximowiczii* predominates in almost every horizon, in which many are found as stumps.
- 2) The other Pinaceous taxa such as *Abies*, *Tsuga*, and *Larix* are found from several horizons from Z to E, but Cupressaceous taxa such as *Chamaecy-*

Table 3. Diameter of the fossil stumps.

Diameter (cm)	Horizon					
	Z	A	B	C	D	E
0-10	1	16	1	2		2
-20	3	15	4	1	2	1
-30	2	3	1	2	5	
-40	5	1		2	1	
-50	4			1	2	
-60					1	
-70						
-80					1	
Total	15	35	6	8	12	3

Table 4. List of the plant macrofossils obtained from the study site.

Taxa* ¹	Part of the fossils* ²	Occurrence in each horizon					Z		A	
		Z	A	B	C	D	E	sieve* ³	outcrop* ⁴	sieve
Conifer										
Abies	CS			+	+					
	L									
Tsuga diversifolia (Maxim.) Masters	CN									
Tsuga	L			+	+					
Picea jezoensis (Sieb. et Zucc.) Carr.	CN		+							14
	L			+	+					
P. cf. bicolor (Maxim.) Mayr A	CN			+						
P. cf. bicolor (Maxim.) Mayr B	CN			+						
P. maximowiczii Regel	CN			+	+					
Picea sect. Picea	CN	+		+					4	
	L		+	+	+	+	+			4
Picea	S			+	+	+	+			
	Sh			+	+					
Larix cf. leptolepis (Sieb. et Zucc.) Gordon	CN		+	+	+					3
Larix	L		+	+	+					1
	S			+						
	Sh		+							2
	SS			+	+	+				
Pinus koraiensis Sieb. et Zucc.	S				+					
Pinus subgen. Haploxyton	L				+					
	SS			+	+					
Chamaecyparis pisifera (Sieb. et Zucc.) Endl.	S									
	Sh									
Deciduous broadleaved tree										
Betula	F		+					+		1
Alnus	F							+		
	FB							+		
	I							+		
Rubus A	CR			+						
Rubus B	CR							+	+	
Sambucus racemosa L.	S			+						
Herb										
Selaginella remotifolia Spring	MS			+					+	
Carex sect. Vignea	F			+						
Carex A	F			+	+					
Carex B	F			+					+	
Carex C	F			+						
Carex D	F							+		
Carex E	F								+	
Cyperus A	F							+		
Cyperaceae A	F							+		
Eriocaulon A	S								+	
Duchesnea, Fragaria, or Potentilla A	CR		+	+		+	+		1	
Hypericum A	S			+					+	
Viola A	S		+	+	+				37	6
Viola B	S								+	
Lycopus	F			+						
Mosla	F								+	+
Labiatae A	F								+	+

*1. Suffixed letters to the genus or family names show morphological types. They do not always correspond to one. Rubus A : 1.7-2.2mm in length. Rubus B : 1.4-1.5mm in length. Carex A : brown to grayish brown, compressed, ca. 1.4mm in length. Carex D : brown to dark brown, convex-convex lenticular, 2.0-2.4mm in length, wet, flattened trigonous, ca. 1.0mm in length. Cyperaceae A : light brown, trigonous, cap like appendage on 0.8-1.1mm in length. Hypericum A : yellowish brown, 0.7-1.0mm in length. Viola A : 1.2-1.5mm in length.

*2. CN : cone. CR : core. CS : cone scale. F : fruit. FB : fruiting bract. I : infructescens. L : leaf.

*3. Numbers of fossils sieved from 100cm³ sediment.

*4. Numbers of fossils collected at the outcrop.

paris pisifera and *Thuja standishii* are found only from C to E, along with *Alnus*.

3) Diameters of stumps are often large, exceeding 40 cm in horizons Z, C, and D.

Plant Macrofossils

About 30 taxa are recognized from the plant

macrofossils obtained from the study site (Table 4). In horizon Z, *Picea* sect. *Picea*, *Viola* A, and '*Duchesnea* type,' which is *Duchesnea*, *Fragaria*, or *Potentilla* A in Table 4, are the only taxa identified. In horizon A, conifers such as *P. jezoensis* and *L. cf. leptolepis* are common, but broadleaved

and *P. maximowiczii*, and *Larix* including *L. cf. leptolepis*, while in C-2 occur *Abies*, *Larix*, and *Pinus* subgen. *Haploxyton* including *P. koraiensis* without any *Picea* species. But both are similar in character, in that conifers predominate with no broadleaved trees and few herbs.

The difference in assemblages between horizons A, B and C is within the deviation found in a single horizon such as B or C. The assemblage in horizon Z, though rare in fossils, is also similar.

The assemblage of horizon D is rather different from the above four. In this horizon *Chamaecyparis pisifera* is common, together with broadleaved trees such as *Alnus* and herbs such as *Mosla*, but Pinaceous conifers are rare. In horizon E, herbs predominate, and rare arboreal taxa include *Picea* sect. *Picea* including *P. maximowiczii*, and *Betula*.

The characteristics of these assemblages can be summarized as follows:

- 1) Pinaceous conifers predominate except for horizon D. *Picea jezoensis*, *P. sect. Picea*, and *Larix* including *L. cf. leptolepis* are common, being found in three or four horizons. *Abies*, *Tsuga* including *T. diversifolia*, *P. maximowiczii*, and *Pinus* subgen. *Haploxyton* are recorded from two horizons. *Picea cf. bicolor* A and B are recorded only from a single horizon.
- 2) Cupressaceous taxa such as *Chamaecyparis* including *C. pisifera* are found only from horizon D.
- 3) Broadleaved trees are quite rare except for horizon D.
- 4) Herbs are unusually rare, but common in horizons D and E and in some samples from horizon B. Truly aquatic plants are not recognized from this site.

Discussion

Establishment and Burial of Past Forests

The processes involved in the establishment and burial of these forests should be deduced not only from the fossil assemblages but also from the observation of sediments.

In horizon D, the surface on which plant communities existed can strictly be traced owing to the unconformity. The erect stumps of this horizon stand directly on the lowermost silty unit,

Table 5. Occurrence of the fossil woods and plant macrofossils in each horizon.

Taxa	Horizon					
	Z	A	B	C	D	E
<i>Abies</i>		W	WM	WM		W
<i>Tsuga diversifolia</i>				M		
<i>Tsuga</i>		W	M	WM		W
<i>Picea jezoensis</i>		M	M	M		
<i>P. cf. bicolor</i> A				M		
<i>P. cf. bicolor</i> B				M		
<i>P. maximowiczii</i>	W	W	WM	WM	W	M
<i>Picea</i> sect. <i>Picea</i>		M	M	M	M	M
<i>Picea</i>	W	W	WM	WM	WM	WM
<i>Larix cf. leptolepis</i>			M	M	M	
<i>Larix</i>	W	M	WM	WM	M	
<i>Pinus koraiensis</i>				M		
<i>Pinus</i> subgen. <i>Haploxyton</i>			WM	M		
<i>Chamaecyparis pisifera</i>						WM
<i>Chamaecyparis</i> (rootwood)					W	W
<i>Thuja standishii</i>				W	W	W
<i>Salix</i>	W					
<i>Betula</i>		M				M
<i>Alnus</i>				W	WM	W
<i>Prunus</i>				W		
<i>Rubus</i> A & B			M		M	M
<i>Sambucus racemosa</i>			M			

W: Wood fossil, M: Plant macrofossil.

extending roots into this layer. They are then directly covered with sands and gravels. At some other places in the same horizon, lens-like peaty beds with distinct laminas are intercalated directly above the silty unit. Therefore it is deduced that trees grew on the unconformity surface, and that peaty sediments are not the derivatives from the plant fragments which had deposited on the forest floor, but the deposits in a stream that had accumulated while the trees were alive, or in the beginning of the burying process. Afterwards both of these were covered with thick flood sediments.

Also in the other horizons, buried forests seem to have been formed in a similar process. Erect stumps stand on sandy or gravelly sediments, and are covered with a flood sediment together with peaty beds. These peaty sediments seem to have been deposited while these trees were alive, or at the early stage of the burying process. Thus it is possible that the establishment of stumps is a little different in time from the production of the other fossils.

In some horizons, trees attained 50 cm in diameter, up to 80 cm in D, and it must have taken much more than one hundred years for these trees

to grow to such size. From these facts, it is concluded that, in the Middle Pleistocene, there were recurrent floods carrying large gravels through this area with intervals of several hundred years or more in between. During these interval periods, coniferous forests composed mainly of *Picea* species established themselves, but as a rule they came to be buried *in situ* by these floods, together with peaty sediments deposited in a stream.

Past Flora and Vegetation

Occurrence of fossil woods and arboreal plant macrofossils in each horizon nearly correspond to each other (Table 5). This close correspondence seems to indicate that it is at this place that these arboreal taxa together formed a plant community several times in the past, which were then buried and subsequently became fossils. If there was any difference in time between the establishment of these stumps and the production of the plant macrofossils, it must not have been so large judging from the sediments, as stated above, and from the close correspondence between these two kinds of fossil assemblages.

Among fossil taxa recognized, *Picea* species seem to have been most prevalent, and *Picea maximowiczii*, *Picea* sect. *Picea*, and *Picea* occur throughout the horizons, while *P. jezoensis* and *P. cf. bicolor* A & B are found only between A and C. *Larix*, including *L. cf. leptolepis*, seems to have been next in prevalence, occurring from Z to D. *Abies*, and *Tsuga* including *T. diversifolia* are also frequent and are found from A to C, and in E. *Pinus* subgen. *Haploxyton*, including *P. koraiensis*, are found only in B and C. Cupressaceous taxa are unique in occurrence, *Chamaecyparis* including *C. pisifera* appearing only in D and E, and *Thuja standishii* only in C to E. Occurrence of broadleaved trees is rather sporadic, but *Alnus* is found from C to E, and *Rubus* A & B from B to E excluding C. Of the 17 herbaceous taxa recognized, all are marsh or terrestrial plants, among which '*Duchesnea* type' and *Viola* A are common, being obtained from 4 horizons.

From the above it is concluded that a coniferous forest had been established several times during the period when the main unit was being deposited. These forests were mainly composed of *Picea* species, such as *P. maximowiczii*, *P. jezoensis*

and *P. cf. bicolor* A & B, and *Larix* including *L. cf. leptolepis*. *Abies*, and *Tsuga* including *T. diversifolia* usually accompanied these trees. During the period when the lower part of the main unit below horizon C was deposited, Cupressaceous species, such as *Chamaecyparis pisifera* and *Thuja standishii*, and *Alnus* also existed, and were important elements of these forests. Trees in these forests usually exceeded 50 cm in diameter, and there should have been dark and dense forests around this area.

NASU (1972) plotted the distribution of plant macrofossils of *Picea maximowiczii* in Japan, and showed that this species appeared around the Plio-Pleistocene boundary and had a wide distribution during the Pleistocene until the Last Glacial Period. In this area, IIDA (1973) showed that *P. maximowiczii* existed together with *P. jezoensis*, *P. shirasawae* and *P. koyamai*? from Nakamura Peatbeds II and III dated at about 30,000 yBP. But there seem to have been no reports of *Picea* dominant, buried forests accompanied by *P. maximowiczii* during the Middle Pleistocene. It has been determined by this study that forests dominated by *Picea* species existed in the Middle Pleistocene period among foothills, which are now at about 700 m in altitude, and that *P. maximowiczii* was an important member of these forests. Explanation of the disappearance of these *Picea* dominated forests and the present state of the endemic distribution in *P. maximowiczii* should be sought in the change of vegetation through the Late Pleistocene period.

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摘 要

山梨県北巨摩郡白州町において、国界橋下流の釜無川川岸から埋没林が見いだされた。ここには中期更新世の教来石礫層があつく分布しており、数層の埋没林がこの砂礫層中の泥炭質層にともなって見いだされた。また下位の泥層中、および両者のあいだの不整合面にそつても、それぞれ泥炭質層をとまう埋没林が認められた。埋没林にとまう土壌層は確認できなかったが、埋没林と同層位の泥炭層は堆積状況から判断して、それぞれの立木が生育していた時点か、あるいは立木の埋没過程の初期に堆積したものと考えられた。それぞれの埋没林層位における立株とそれ以外の木材、および大型植物遺体の組成には大きな差はなく、これに基づいて当時の森林植生を復原した。それによると当時の森林にはヒメバラモミやエゾマツ、イラモミ近似種をはじめとするトウヒ属が優占しており、カラマツ近似種をふくむカラマツ属も伴っていた。またモミ属や、コメツガをふくむツガ属、チョウセンゴヨウをふくむマツ属単維管束亜属もしばしば存在した。下位の泥層中や不整合面、および礫層下部の埋没林には、サワラやネズコ、あるいはハンノキ属などが伴っており、森林の主要な構成要素であった。直径40 cmに達する根株がいくつかの埋没林において確認された。以上の事実より、中期更新世にはこの付近にトウヒ属が優占する森林が成立し、それが少なくとも数百年おきに洪水によって埋没するという過程が繰り返された。

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○ 岐阜県産シダ植物目録 岐阜県博物館編 (編集責任者安藤志郎), 昭和62年2月24日発行。B5判58頁。岐阜県博物館で開催された“岐阜県のシダ植物展”を機会に編集された県下のシダ(約250種)の目録である。(里見信生)