Palynological Investigation of the Uozu Submerged Forest in the Hokuriku District, Central Japan[1)]

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Abstract

Remnants of the Holocene Uozu Submerged Forest were found in the southwestern marginal area of the Kurobe-gawa alluvial fan in the coastal area of Toyama Bay, the Hokuriku district, Central Japan. The remains of standing tree stumps and roots are distributed between the present sea-level and about 2m below the present sea-level, and the ages of from 1300 to 1700 years prior to the present have been determined by the ^{14}C-method of tree remains and peats. Pollen grains of *Cryptomeria, Alnus japonica*-type and *Salix* spp. are the most commonly preserved genera, and the result of the palynological study is in agreement with the results obtained from the abundant tree stumps. The pollen analysis permits an assessment of the palaeoenvironment as the present climate or slightly cooler and backmarshes with *Cryptomeria japonica* forest near the coast. It may be concluded that the submerged forest which is composed mainly of *Cryptomeria japonica* and other swampy plants growing at the coastal area (about −2m to +1m in the present altitude) during the Yayoian Regression of from the late Jomonian period to the early Yayoian period was formed by an overlap of flash flood sediments in the Yayoian Transgression which ranges chronologically from the late Yayoian period to the early old Tomb period (about 1500 to 1300 years ago).

Introduction

The Uozu Submerged Forest is Located in the southwestern marginal area of the Kurobe-gawa alluvial fan, Toyama Prefecture, Central Japan. This fan is situated near the northern end of the Itoigawa-Shizuoka Tectonic Line named Fossa Magna, which is tectonically one of the largest active faults of Japan (Fuji *et al.*, 1982, 1986; Fujii *et al.*, 1986).

When Uozu Harbor was reconstructed in 1930, this submerged forest was discovered, and attended frist, by Yamaya and Ishii (1940) from the viewpoint of topography and Quaternary geology. It has provided good evidence of subsidence of land in this district. In 1987 and 1988, the Educational Board of Uozu City excavated the area surrounding the Uozu Submerged Forest, which was found in 1930 (Uozu City Education Board, 1990).

In this paper, from the viewpoint of palaeoenvironment, and on the basis of palynological and Quaternary geological investigations the present writer discusses the cause of the formation, and the plant community of the submerged forest found by the present excavation.

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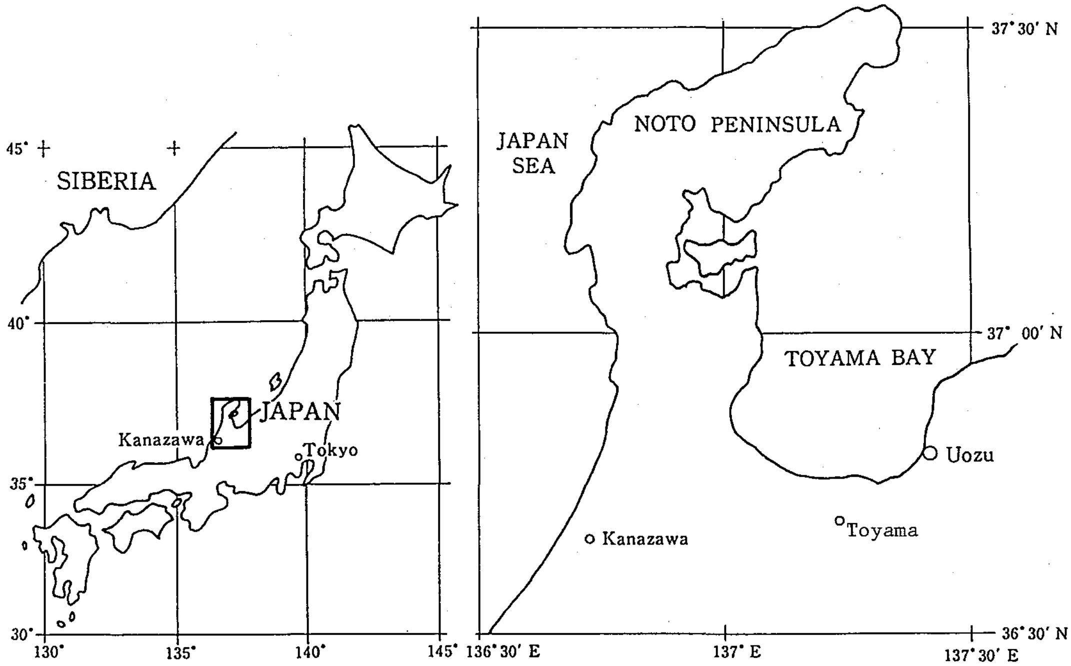

Fig. 1 : Map showing the studied locality.

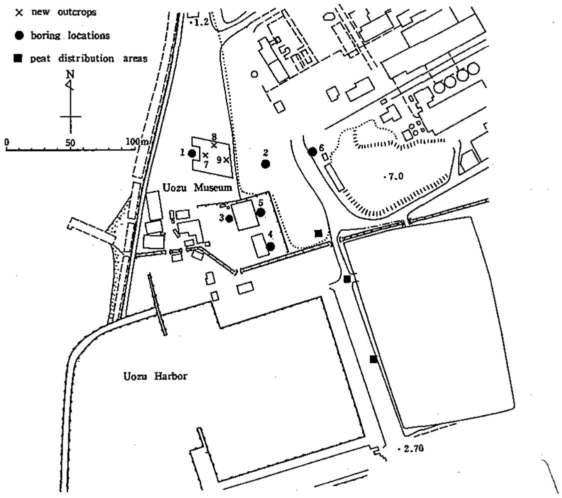

Fig. 2 : Map showing boring locations, outcrops and areas of peat distribution.
x7, x8 and x9 show outcrop at the excavated area.

Sediments and Stratigraphy

Sediments distributed in and around the submerged forest have been divided roughly into three parts, that is, the upper, middle and lower parts, on the basis of survey at the excavated outcrops in 1989 (Uozu City Education Board, 1990).

The upper part is composed of artificial sediments heaped up or buried under hollows by soil (about 2 m thick). The middle part is about 1.5 to 2 m thick and composed of fine-grained sand and pebble layers, and the lower part blue silty mud, peat and fine-grained sand layers including some submerged tree stumps and grass fragments which are distributed +2 to −2m in the present altitude (Fig. 5).

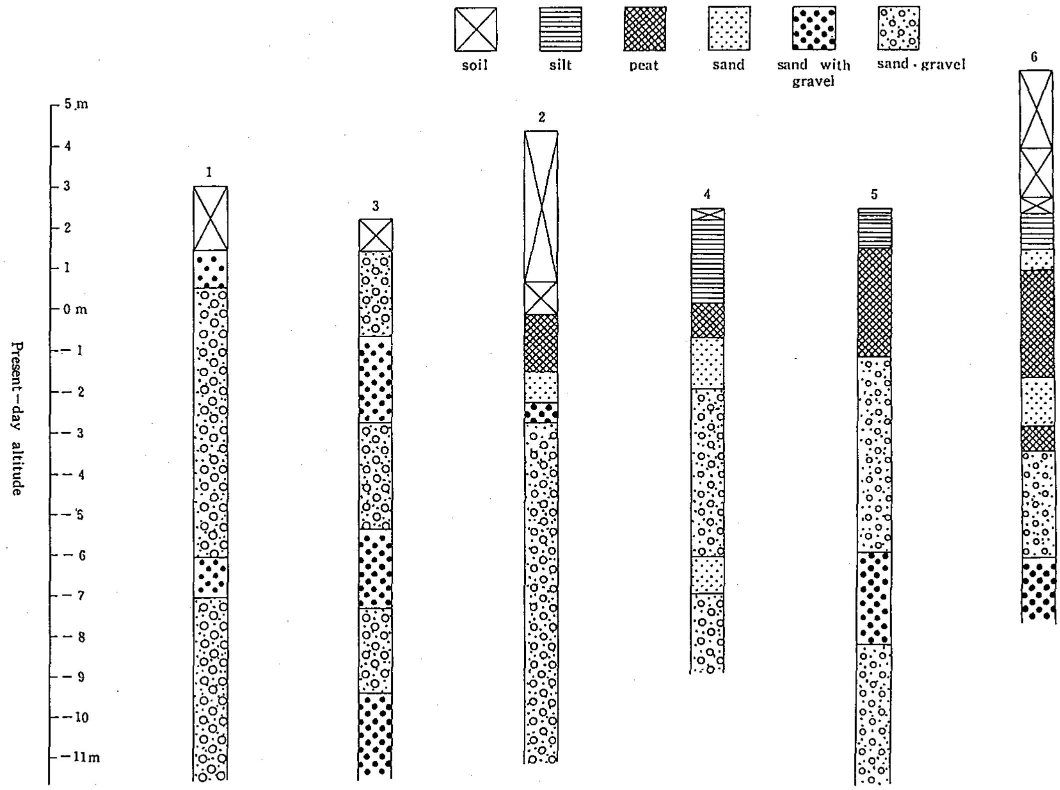

Fig. 3 : Columnar sections at the boring localities.

Judging from the sedimentological observation, it is estimated that the above-mentioned middle part was deposited by the flood in the marginal area of the Kurobe-gawa alluvial fan, and that the lower part was deposited little by little in a swampy area as lagoons, bogs and backmarshes formed between the sea coast and the marginal areas of the fan.

Palynological Investigation

(1) Samples

About thirty samples were collected from four sections of the present excavated area near the Uozu Submerged Forest Museum as shown in Fig. 2 (Uozu City Education Board, 1990).

Namely, twelve hand-specimens from six peat, two clay and three silt horizons of Section I, eleven hand-specimens from five peat and six silt horizons of Section II, three hand-specimens from three peat horizons of Section III, and one hand-specimen from the peat horizon of Section IV as shown in Figs. 4 and 5 were collected for pollen analyses. The samples obtained for pollen analyses have been analyzed also for grain-size and diatom analyses (Uozu City Education Board, 1990).

(2) Preparation for Pollen Analyses

Pollen grains in the sediments were concentrated in the laboratory by the slight modification of the process described by Faegri and Iversen (1964). Sediments containing coarse organic materials as moss, small leaves and small plant fragments were strained through a fine acreen. As most sediments were predominantly silt and clay, they were left for two hours in hydrofluoric acid to remove the silicate minerals. They were treated by a standard acetolyses. Pollen grains and spores were stained with safranin, and mounted in glycerine jelly (Fuji, 1965, 1966a).

(3) Microscopic Examination

The materials concentrated by chemical and physical treatments were mounted on slides, and the pollen grains and spores were identified and counted by use of a mechanical stage of a microscope (Ernst Leitz GmbH Wetzlar triocular microscope). The identification of fossil pollen grains and spores was continued until more than one thousand arboreal pollen grains. Alternate traverses were counted with a periplan 6.3 time or 10 times and a 40 times/0.85 objective. In case of the critical identification, the present writer identified by an oil immersion method (90 times / 1.32 oil immersion objective).

Identification was made with the aid of the key of Faegri and Iversen (1964), other references

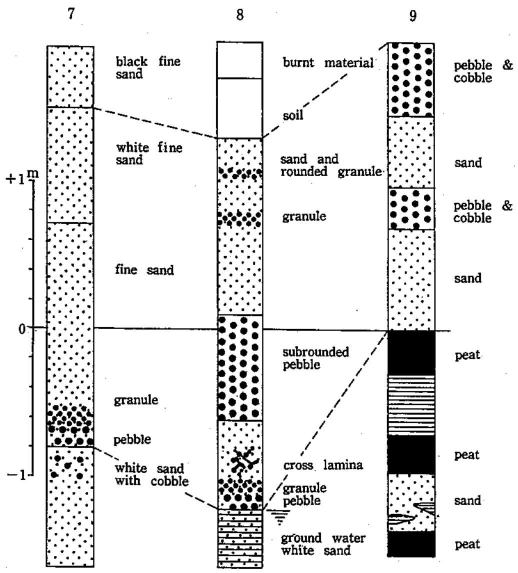

Fig. 4 : Three columnar sections at the present excavated area.

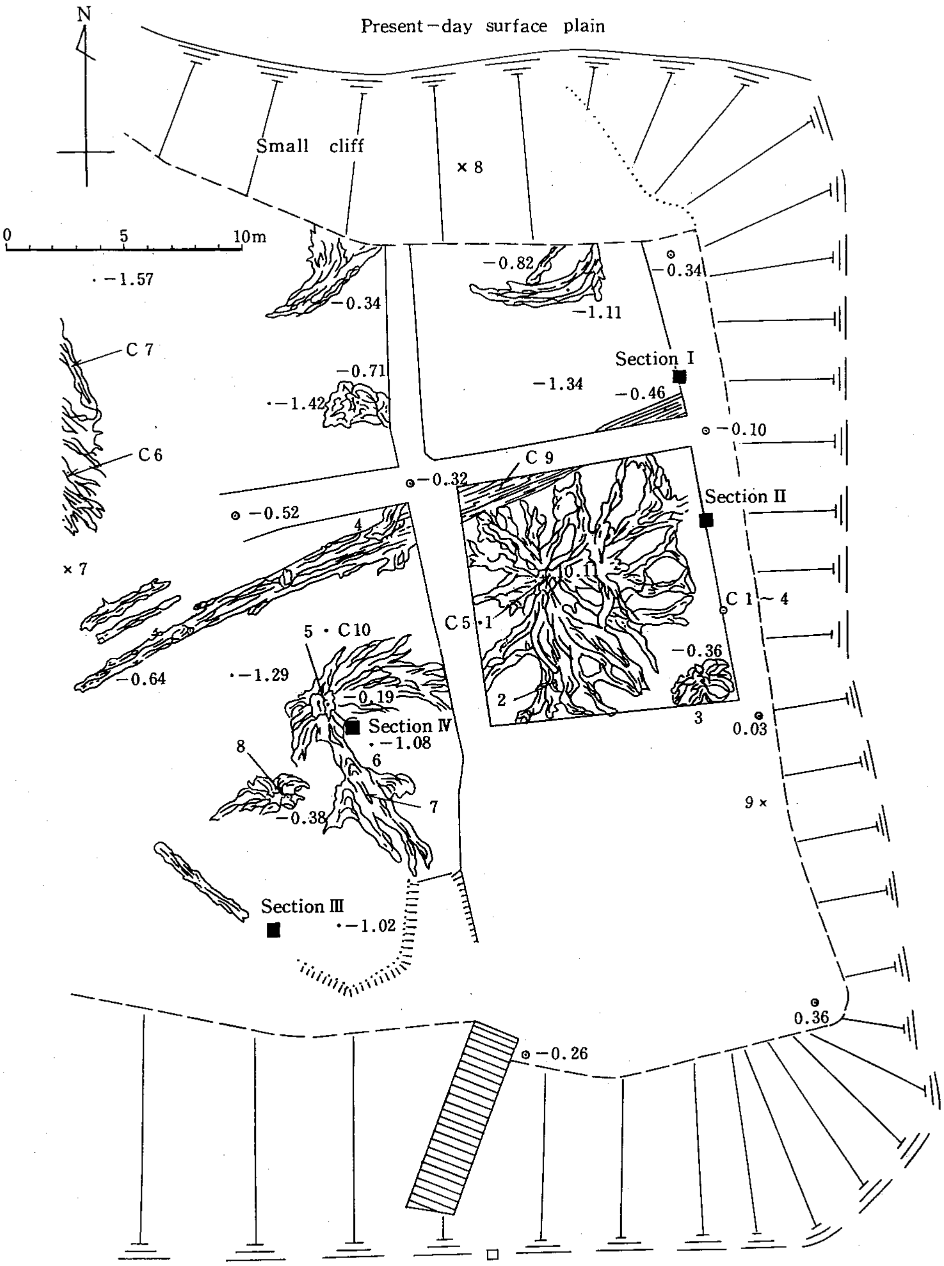

Fig. 5 : Sampling locations for pollen analyses (Sections I. II, III and IV) and ^{14}C-dating (C1. C2, C3, C4, C5, C6, C7, C9, C10), and distribution of submerged tree stumps (1, 2, 3, 5, 6, 7, 8) at the excavated area are shown. X7, X8, X9 : Location of the outcrop Nos. 7,8 and 9.
Section III, IV : peat layer only (30 cm thick).

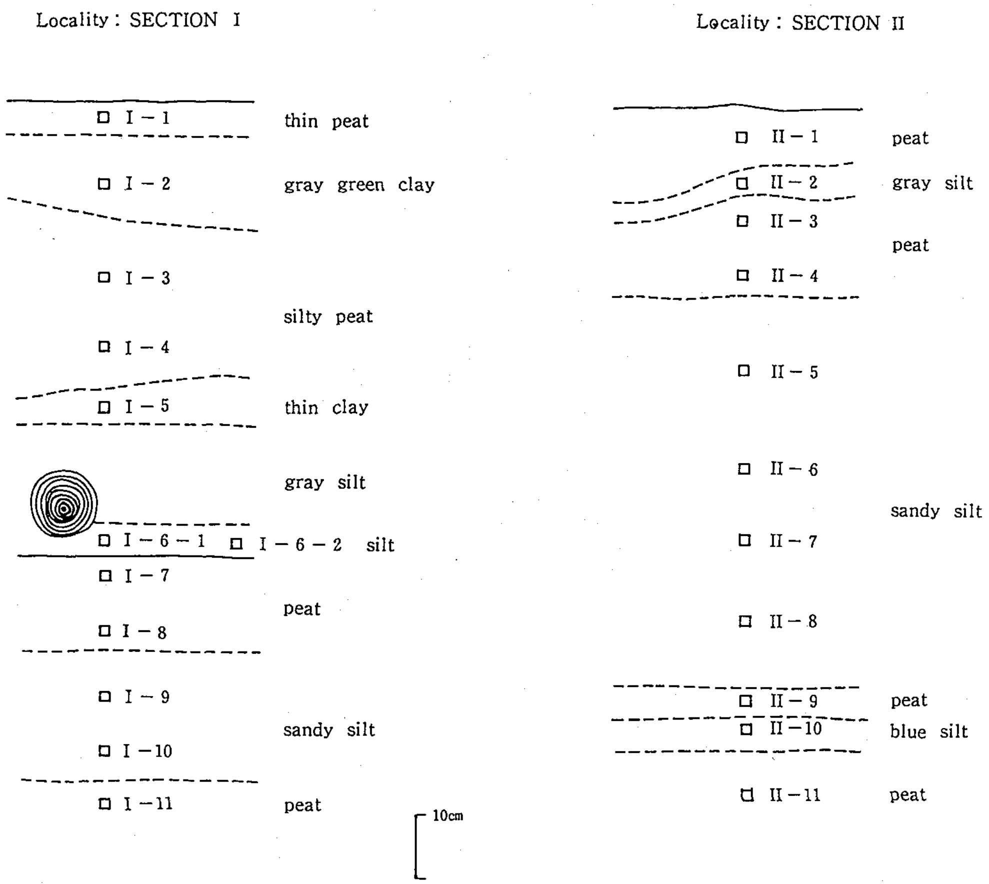

Fig. 6 : Stratigraphy at the excavated area and sampling horizons for pollen analyses. Locality of Sections I and II is shown in Fig. 5.

(Fuji, 1996a; Fuji *et al.*, 1979) and the modern pollen grains from the Japanese Islands. Difficult determination for pollen grains were identified with the aid of a reference collection of about 500 species for identification of important trees, shrubs, and acquatic herbs of the Japanese Islands in the collections of the Dapartment of Earth Sciences, Kanazawa University, and also with the aid of a reference collection of about 9,000 species in the Limnological Research Centre, the University of Minnesota, Mineapolis, the United States of America.

(4) Remarks on the Identification of Pollen Grains and Spores

Most of the pollen grains and spores from the samples are also found in the present Japanese Islands, and their descriptions can be found in the published references (Fuji, 1966b; 1972).

(5) Pollen Assemblages

Pollen assemblages identified are illustrated as in the pollen diagrams of Figs. 7 and 8.

Sample No. I-1 is characterized by dominance of *Cryptomeria* and *Alnus*, common *Salix*, and by the low frequency of *Pinus Diploxylon*—type, *Abies*, *Castanopsis*, *Lepidobalanus*, *Cyclobalanopsis*, and *Juglans*, Cf. *Berchemia*, *Machilus*, Nymphaeaceae and Cf. *Potamogeton*. The frequency of *Cryptomeria* is 23%, and that of *Alnus* is 18%.

Sample No. I-2 is characterized by the predominance of *Pinus Diploxylon*—type (27%), the dominance (about 15%) of *Cryptomeria* and *Alnus*, and by the low frequency of *Carpinus*, *Lepidobalanus*, *Juglans*, *Pterocarya*, *Salix* and Nymphaeaceae.

Sample No. I-3 is shown by the predominance of *Cryptomeria (29%) and Alnus* (23%), and by the low frequency of *Pinus Diploxylon*—type, *Fagus*, *Castanea*, *Lepidobalanus*, *Juglans*, *Salix*, Cf. *Berchemia*, *Phragmites* and *Nuphar*. This assemblage is almost similar to that of Sample No. I-1. In contrast to these assemblages, the pollen-spore spectrum of Sample No. I-2 is not similar to that of Sample No. I-3.

Sample No. I-4 is written by the predominance of *Cryptomeria* (24%) and *Alnus* (21%), common *Lepidobalanus* (7%), and by the low frequency of *Pinus Diploxylon*—type, *Fagus*, *Juglans*, *Salix*, Cf. *Berchemia*, *Phragmites* and Cf. *Potamogeton*.

Sample Nos. I-5, I-6-1 and I-6-2 are shown by the predominance of *Pinus Diploxylon-type* (26-22%), the dominance of *Cryptomeria* (about 16%), common *Alnus* (13%), and by the low frequency of *Abies*, *Fagus*, *Castanea*, *Lepidobalanus*, *Juglans*, *Mallotus*, *Salix*, *Machilus*, Ericaceae, Chenopodiaceae, Gramineae, *Phragmites*, Nymphaeaceae, *Nuphar*, and *Persicaria*. In this sample, the plants which grow in the wet or swampy areas show a frequency lower than that of the plants such as *Pinus* which thrives in the arid area. The pollen-spore assemblage of these samples are, roughly speaking, similar to that of Sample No. I-2.

Sample No. I-7 is characterized by the predominance (27%) of *Cryptomeria*, the dominance (18%) of *Alnus*, and by the low frequency (2-4%) of *Pinus*, *Abies*, *Carpinus*, *Fagus*, *Castanea*, *Salix*, *Machilus*, Cf. Elaeagnaceae, *Phragmites* and *Nuphar*.

The pollen-spore assemblage of Sample No. I-8 is shown by the predominate *Cryptomeria* (27%) and *Alnus* (19%), common *Lepidobalanus* (13%) and *Salix* (10%), and by the small percentage of *Pinus*, Cf. *Berchemia* and *Phragmites*. Pattern of pollen-spore assemblages of Sampe Nos. I-7 and I-8 is similar to pattern of Sample Nos. I-1, I-3 and I-4.

The pollen-spore spectrum of Sample No. I-9 is characterized by dominant *Pinus* Diploxylon—type (18%), and by common Cryptomeria (11%).

The pollen-spore spectrum of Sample No. 10 is characterized by predominant *Pinus Diploxylon*—type (26%), dominant *Cryptomeria* (16%), and by common *Alnus* (9%).

Sample No. I-11 is represented palynologically by the predominance of *Cryptomeria* (26%) and *Alnus* (20%).

Sample Nos. III-1, III-2, III-3 and III-4 obtained from Section III show almost the same palynological spectra; that is, their spactra are characterized by predominant *Cryptomeria* (23-30%), dominant or common *Alnus* (15-20%), and by the low percentage of *Pinus*, *Carpinus*, *Fagus*, *Castanea*, *Lepidobalanus*, *Juglans*, *Pterocarya*, *Salix*, Chenopodiaceae, *Phragmites*, *Persicaria* and Cf. *Potamogeton*.

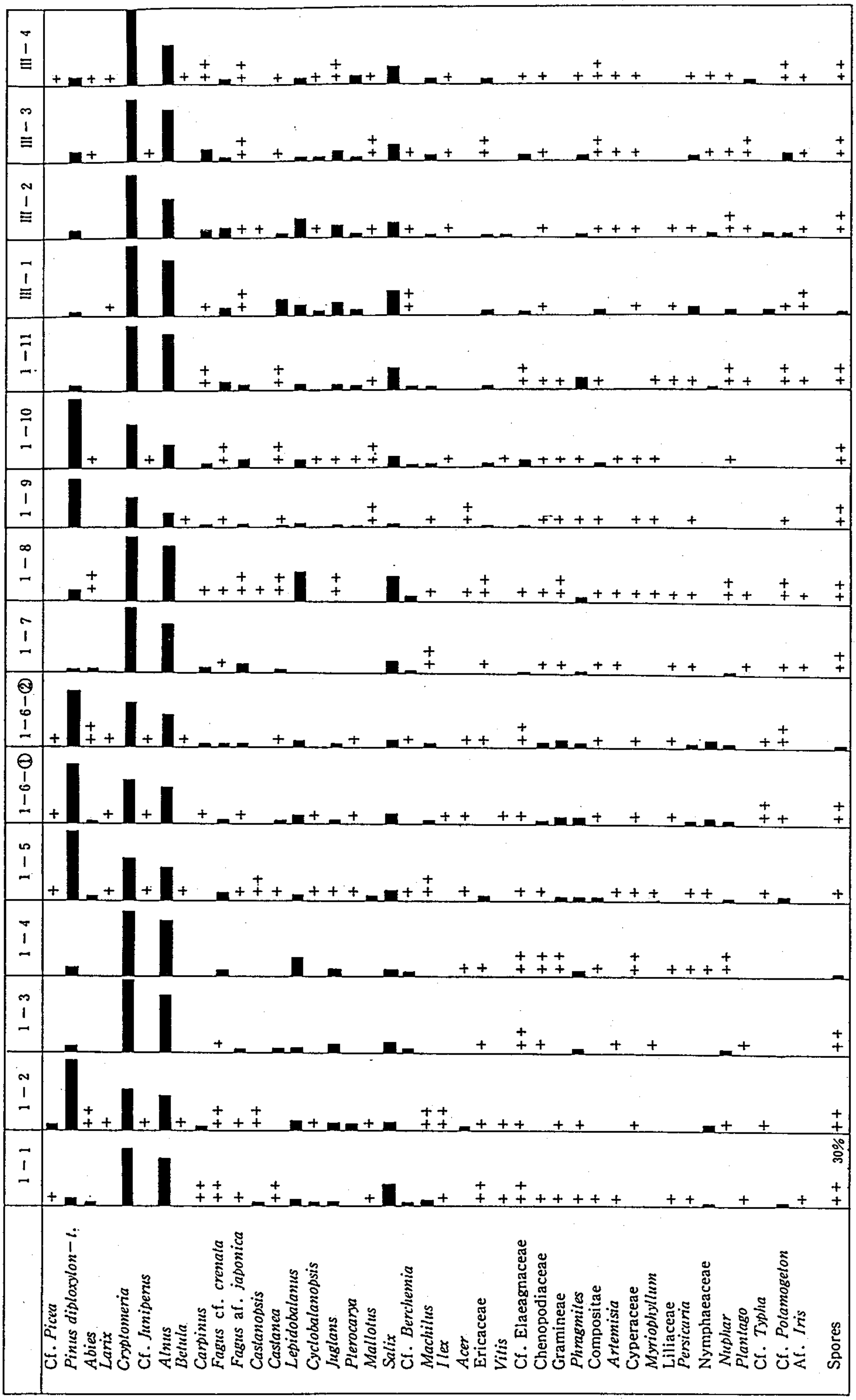

Fig. 7 : Pollen diagram for Sectiors I and III shown in Fig. 5.

Sample No. II-1 is shown by the predominance of *Cryptomeria* (22%), *Alnus* (11%), and by the low frequency of *Pinus, Abies, Fagus, Castanopsis, Castanea, Lepidobalanus, Cyclobalanopsis, Juglans, Pterocarya, Machilus* and Ericaceae.

Samples No. II-2 is characterized palynologically by the dominance of *Pinus Diploxylon*-type (22%), *Cryptomeria* (20%), common *Alnus* (15%), and by the low frequency of *Fagus, Castanopsis, Pterocarya, Salix, Machilus* and *Nuphar.*

Sample Nos. II-3, II-4, II-9 and II-10 show palynologically the same pattern of pollen-spore assemblage. That is, *Cryptomeria* is predominant or dominant, and *Alnus* is dominant or common.

In contrast to the diagrams of Sample Nos. II-1, II-3, II-4, II-9 and II-10, pollen-spore assemblages of Sample Nos. II-5, II-6, II-7, II-8 and II-11 are characterized by the predominance of *Pinus Diploxylon*—type and common *Cryptomeria* and *Alnus.*

The pollen-spore spectrum of Sample No. IV-1 obtained from Section IV is characterized by predominant *Pinus Diploxylon*—type (24%), common *Cryptomeria* (17%) and *Alnus* (9%), and by a few percentage of *Salix, Fagus, Lepidobalanus, Cyclobalanopsis, Juglans, Pterocarya, Machilus* and Gramineae.

On the basis of the pollen analyses, the swampy plants such as *Cryptomeria japonica, Alnus japonica*-type, *Salix,* Nymphaeaceae including *Nuphar,* and *Potamogeton* together with *Juglans, Pterocarya, Phragmites* and *Myriophyllum* were dominant in the peat and peaty mud layers, whilst plants thriving in the dry area such as *Pinus, Carpinus, Castanopsis, Castanea, Lepidobalanus, Cyclobalanopsis,* etc. were rare or lacking. Broadly speaking. from the pollen above-mentioned, a number of genera and/or species of tree remains is rare, and the frequency of grasses and spores is dominant in the peat layers.

In contrast to the phenomenon above-mentioned, although plants growing in the arid land such as *Pinus* were dominant in clastic sediments such as mud and silt, the swampy plants are rare in the sediments. Roughly speaking, although kind of tree is dominant, that of grass and spore is rare in the clastic sediments.

Tree Stumps, Seeds and other Plant Fragments

All the woods found from the new excavated area of the submerged forest have been softened by subterranean water, and appear to have swollen slightly. Most of the stumps stand 30 to 50 cm high, the tallest discovered so far being 90 cm high. The tops are now rounded by underground water weathering and general decay, and sometimes a flat top is observed. Tree stumps are 20 to 50 cm in diameter, the widest so far recorded being 60 cm.

The species of tree stumps has been identified by microscopic studies of thin sections of samples from ten tree stumps (Hasegawa, 1990). According to the microscopic identification, six *Cryptomeria japonica,* three *Alnus japonica* and one *Quercus* (perhaps *Cyclobalanopsis)* were recognized. Determination of 90 erect stumps in the previous survey (Shimakura, 1936) of the Uozu Submerged Forest is shown as follows :

Cryptomeria japonica (79 specimens), *Pinus* sp. (1 specimen), *Castanea* sp. (1 specimen),

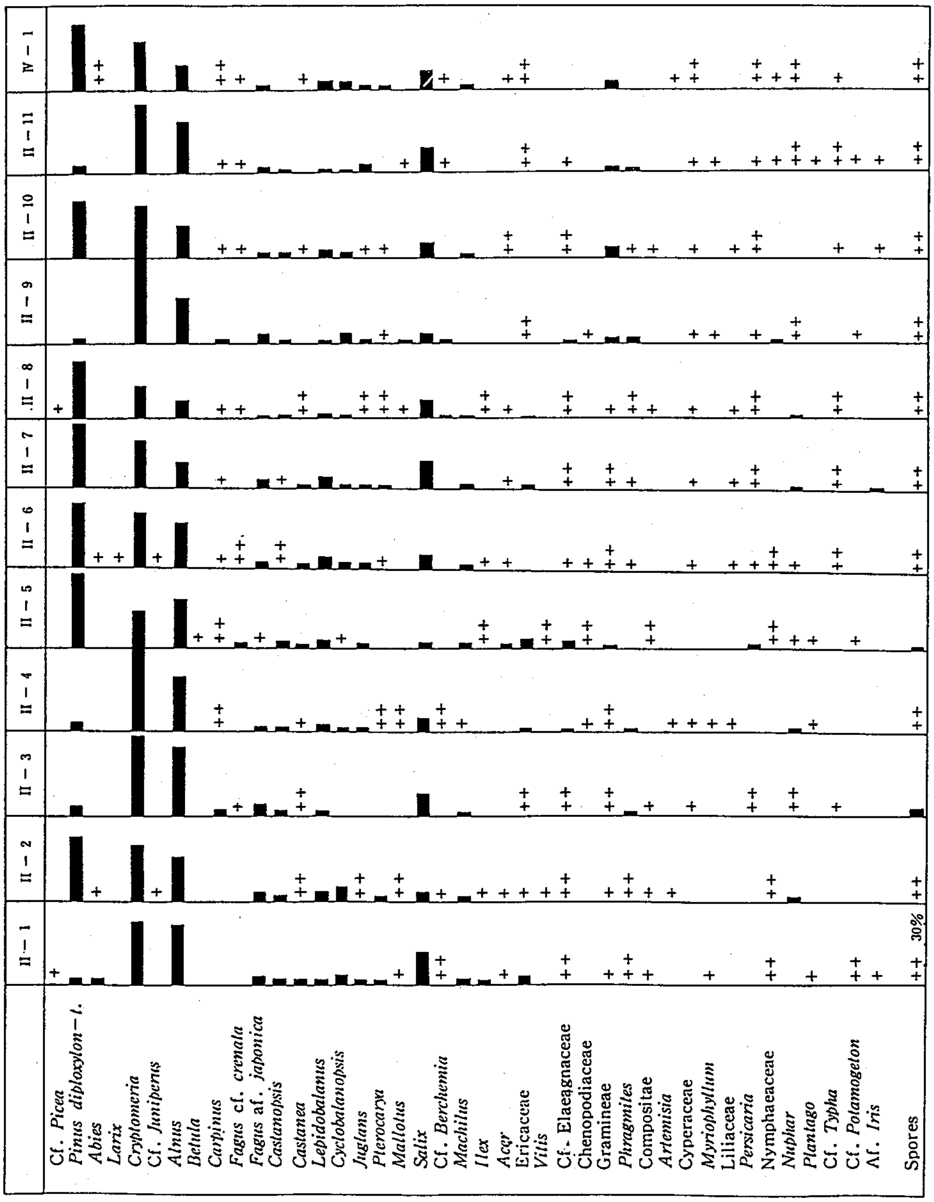

Fig. 8 : Pollen diagram for Sections II and IV shown in Fig. 5.

Table 1 ^{14}C dating for remnants of tree stumps and peat fragments from the Uozu Submerged Forest excavated and its Museum in Uozu, Central Japan.

Sample No.	Sample Cord No.	Material for dating	^{14}C dating (Y.B.P.)
C1	NUTA-1,002	uppermost of peat layer	1,170±80
C2	NUTA- 999	uppermost of peat layer	1,130±80
C3	NUTA-1,000	middle part of peat layer	1,410±70
C4	NUTA-1,001	lower part of peat layer	1,700±100
C5	NUTA-1,003	stump remain of *Cryptomeria*	1,380±100
C6	NUTA-1,076	stump remain of *Cryptomeria*	1,470±220
C7	NUTA-1,004	stump rerain of *Cryptomeria*	1,640±80
C8	NUTA-1,014	stump remain of *Cryptomeria*	1,350±100
C9	NUTA-1,020	stump remain of fallen *Cryptomeria*	1,760±80
C10	NUTA-1,021	stump remain of *Cryptomeria*	1,480±80
C11	NUTA-1,022	stump remain from Uozu Museum	1,620±100
C12	NUTA-1,061	stump remain from Uozu Museum	1,360±130
Fukai's sample	Gak-246	stump remain of *Cryptomeia* from Uozu Museum	1,960±70
Fujii's sample	Gak-563	stump remain of *Cryptomeria* from Uozu Museum	1,750±90

Zelkova sp. (1 specimen, perhaps *Zelkova serrata), Celtis* sp. (3 specimens), *Cercidiphyllum* sp. (2 specimens), *Alnus* sp. (1 specimen), *Fraxinus* sp. (1 specimen), and an indeterminable stump (1 specimen).

In this forest, the wood of *Cryptomeria japonica* was dominant (about 80%), and other coniferous and dicotyledonous woods were only 13% of the total.

According to Yoshii's identification (1990) of seeds, nuts and other plant fragments, *Cryptomeria japonica, Alnus japonica, Actinidia* sp., *Mallotus japonicus, Phellodendron amurense, Fagara ailanthoides, Fagara mantchurica, Zanthoxylum* sp., *Aesculus turbinata, Berchemia* sp., *Ampelopsis brevigedunculata, Cornus controversa, Cornus brachypoda, Styrax japonica, Menyanthes trifoliata, Callicarpa* sp., *Clerodendron trichotomum, Sparganium* sp.,*Phytolacca* sp., *Diospyros* sp., and Cyperaceae have been reported.

Radiocarbon Dating

The radiocarbon ages of eight tree stumps and plant fragments of four peat layers have been measured in Nagoya University. The half-life of ^{14}C used is 5570 years. The ages range between 1960 and 1130 years B. P. (B. P. : before 1950 year A.D.) in Tab. 1 (Uozu City Education Board, 1990).

Discussion for Reconstruction of Palaeoenvironment

On the basis of the palynological investigation, the results of identification for tree stumps and other macroplants such as seeds, cone scales and nuts, etc., and diatom analyses, it may be estimated that large trees such as *Cryptomeria japonica, Machilus* and *Quercus* were abundant, and that many swampy plants such as *Alnus japonica, Juglans, Pterocarya* were growing together with *Salix,* Ericaceae and numerous swampy grasses such as Nymphaeaceae, *Potamogeton, Menyanthes trifoliata* and *Sparganium,* etc. It may be inferred that these swampy areas such as backmashes and lagoons were formed between the marginal areas of the Kurobe-gawa alluvial fan and the coastal areas of Toyama Bay (Fuji, 1972, 1975, 1982; Fuji *et al.*, 1981, 1986).

Judging from the palynological evidence, boreal plants such as *Picea* and *Abies,* and plants such as *Betula* and *Fagus crenata* thriving in the cool temperate and subalpine zones are very rare (about 0.2 to 0.3%) or lack. Plants such as *Castanopsis, Cyclobalanopsis* and *Cinnamomum* growing in the warm temperate zone are rare. It is conceivable that the palaeoclimate at the time when the plants of the submerged forest were growing from about 1700 to 1300 years ago (Fuji, 1966b), had been slightly cooler than the climate of the present day or like that of the present day.

On the basis of geological and topographical investigations (Fuji, 1965; 1983), the early half (about 1700 to 1500 years ago) of that time is correlated with the Yayoian Regression which occurred from the late Jomonian period to the early Yayoian period, and the late half (about 1500 to 1300 years ago) to the Yayoian Transgression which occurred from the latest Yayoian period to the earliest Old Tomb period (Bloom, 1977; Clark *et al.,* 1978: Fairbridge, 1961; Fuji, 1984; Fuji *et al.*, 1982).

It may be estimated that the strand-line was about 1 km off the recent strand-line during the Yayoian Regression, and that the sea level was about -1 to -2 m lower than the present sea level (Fuji, 1966a, 1984; Separd *et al.*, 1986).

It may be concluded that the plant-assemblage composed of *Cryptomeria japonica, Alnus japonica, Salix* spp. and other swampy plants around the present Uozu Submerged Forest Museum thrived under the palaeoenvironmental conditions above-mentioned, and that the direct cause of the formation of the submerged forest may be both a small rise of sea level in the Yayoian Transgression after the Holocene Optimum and an overlap of sediments during the transgression age (Fuji, 1975 ; 1982 ; 1983 ; 1984 ; 1993).

Conclusion

New remnants of the late Holocene Uozu Submerged Forest were found in the fan deposits of the marginal area of the Kurobe-gawa alluvial fan in Toyama Prefecture, Central Japan in 1987 and 1988.

The remnants of standing tree stumps are distributed between about 1 m above the present sea level and about 2 m below the present sea level, and the age of from 1300 to about 1700 years prior to the present have been determined by the ^{14}C-method of tree remains and peats distributing around the remnants.

On the basis of palynological investigation and the results of the identification of tree stumps and macroplant remains such as seeds, cone scales and nuts, etc., it may be estimated that large trees such as *Cryptomeria japonica, Machilus thunbergii* and *Quercus* were abundant, and that many swampy plants such as *Alnus japonica, Juglans, Pterocarya* were growing together with Ericaceae and numerous swampy grasses such as Nymphaeaceae, *Potamogeton, Menyanthes trifoliata, Sparganium,* etc.. All these were found in swampy areas such as back-mashes or small lagoons which had been formed between the marginal areas of the Kurobe-gawa alluvial fan and the coastal areas of Toyama Bay. It is conceivable that the palaeoclimate at the time when the plants of the submerbed forest were growing from 1300 to 1700 years ago, was more or less cooler than the climate of the present day or like that of the present day.

It may be concluded that the direct cause of the formation of the submerged forest may be both a small rise of the sea level and overlap of flash flood sediments on the remnants during the Yayoian Transgression.

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Hokuriku district 北陸地方, Uozu 魚津, Kanazawa 金沢, Kurobe-gawa 黒部川, Toyama Bay 富山湾, Jomonian 縄文時代の, Yayoian 弥生時代の, Toyama Prefecture 富山県, Itoigawa-Shizuoka 糸魚川一静岡, Nagoya 名古屋, Tateyama Museum 立山博物館

北陸魚津埋没林の花粉学的研究：富山県魚津市の國指定天然記念物「魚津埋没林」近辺における1989年の発掘調査の結果，新たにスギ*Cryptomeria japonica*の大樹幹等が検出された。埋没樹周辺の堆積物の花粉学的研究によって，埋没樹が繁茂していた1300年～1700年前頃の，埋没林一帯の古環境を，樹幹・葉体・種子等大型遺体と共々総合的に解析した。

Key words : Uozu Submerged Forest, pollen analysis, palynology, palaeovegetation, Toyama Bay, Yayoian Transgression.

Figure 9.

1, 6, 12：*Cryptomeria*；1：32μ；6：30μ；12：37μ

2,3,4：*Pteridium*；2, 3：28μ；4：20μ

5, 11：*Lycopodium*；5：38μ；11：18μ

7：*Monoletesporites*, 26μ

8：*Pleuricellaesporites*, 36μ

9：*Polyadosporites*, 28μ

10：brown spore *(Inapertisporites)*, 10μ

13：Gramineae (small type), lateral view, 26 x 28μ

14：Gramineae (large type) (perhaps *Phragmites)*, lateral view, 36 x 38μ

15, 16：Gramineae (large type), Lateral view, view of pollen aperture, 26 x 32μ

17, 18, 19, 20：*Betula*；17：polar view, 26 x 34μ；18 &19：view of pollen aperture；20：view of pollen aperture and surface sculpture

21, 22, 23, 24, 25：*Alnus*：21：polar view, 24 x 26μ；22, 23, 24, 25：view of pollen aperture, 20 x 26μ

26：*Juniperus*, focus on surface sculpture, 28μ

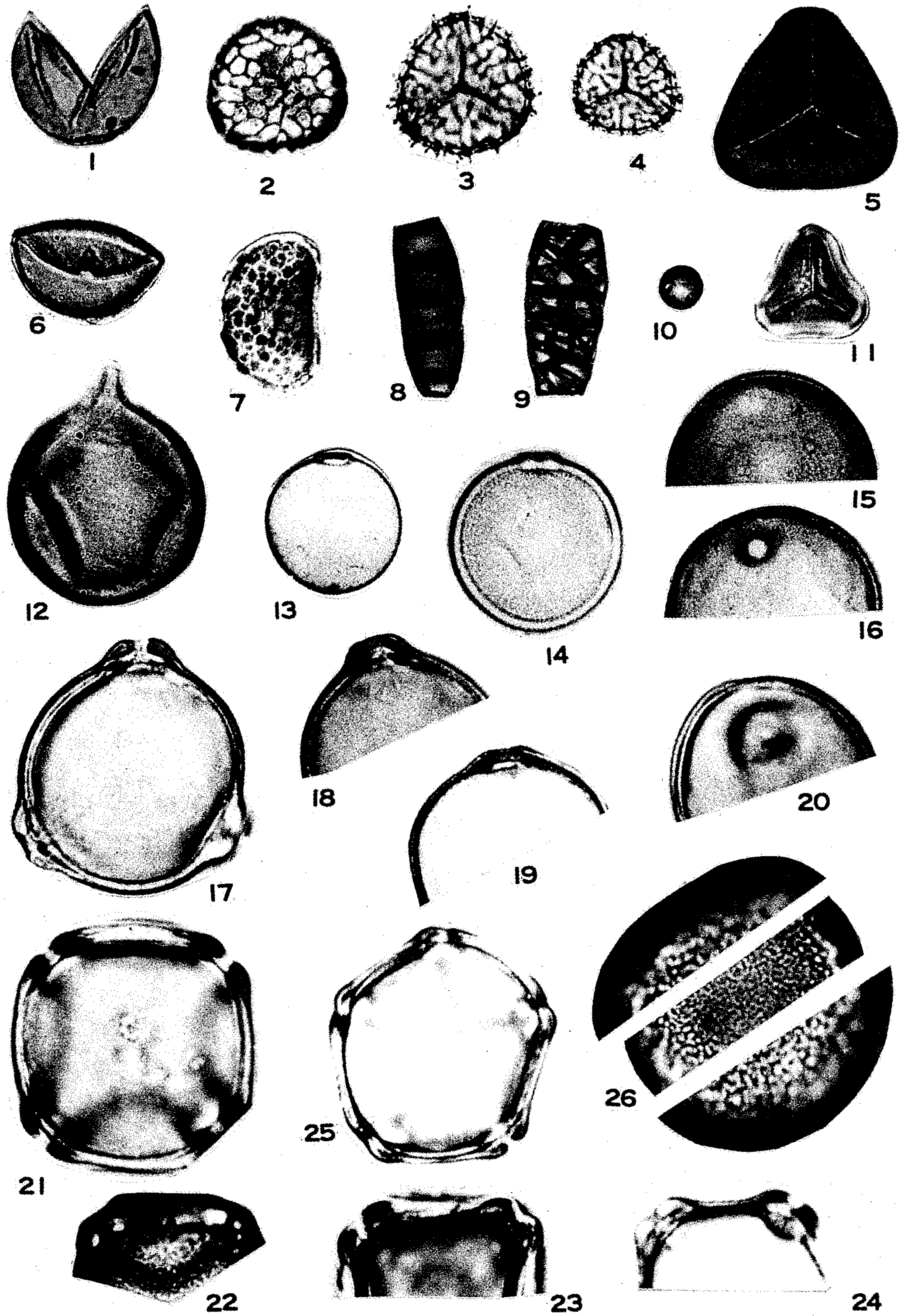
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Figure 10

1, 5 : *Carpinus* ; 1 : polar view, 34 x 38μ ; 5 : equatorial view, focus on pollen aperture sculpture, 42 x 46μ

2, 3 : *Juglans*, polar view ; 2 : 42 x 46μ ; 3 : 40 x 42μ.

4 : *Pterocarya*, polar view, 36 x 40μ

6, 7 : *Tilia*, polar view ; 6 : focus on pollen aperture, 34 x 40μ ; 7 : focus on surface sculpture, 32 x 36μ

8, 9, 10 : *Salix* ; 8 : equatorial view, focus on pollen colpus, 24 x 26μ ; 9 : equatorial view, focus on surface sculpture, 20 x 24μ ; 10: polar view, 20 x24μ

11 : Ericaceae

12, 13, 14 : *Carduoideae*, polar view, 46 x 46μ ; 12 & 13 : focus on surface sculpture ; 14 : focus on equatorial zone

15 : *Chenopodium*, polar view, 25μ

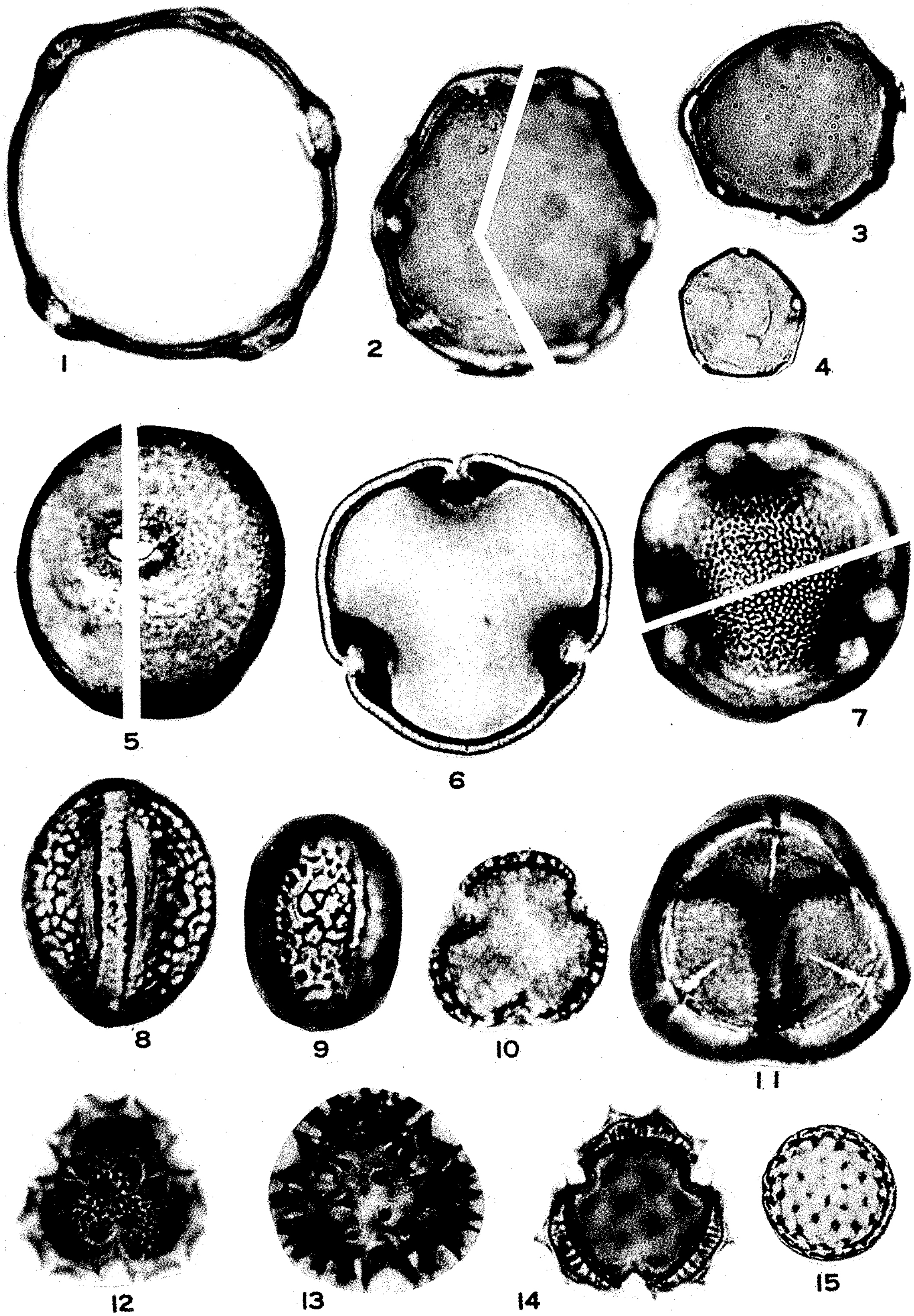
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Figure 11

1：Cfr. Saxifragaceae, equatorial view, focus on surface sculpture and pollen colpus, 18 x 22μ

2, 3：*Cyclobalanopsis*；polar view, 24μ；3：equatorial view, 24 x 27μ

4：Cfr. *Machilus,* polar view, 40 x 42μ

5：*Castanopsis,* equatorial view, 12 x 18μ

6, 12：*Ilex*；6：polar view, 28 x 32μ；12：equatorial view, 32 x 36μ；left：focus on clavates, right：focus on pollen ornamentation

7, 8, 9：*Artemisia,* equatorial view, 24 x 28μ；7：focus on pollen colpusen, 8：focus on surface sculpture；9：focus on pollen aperture and colpuses

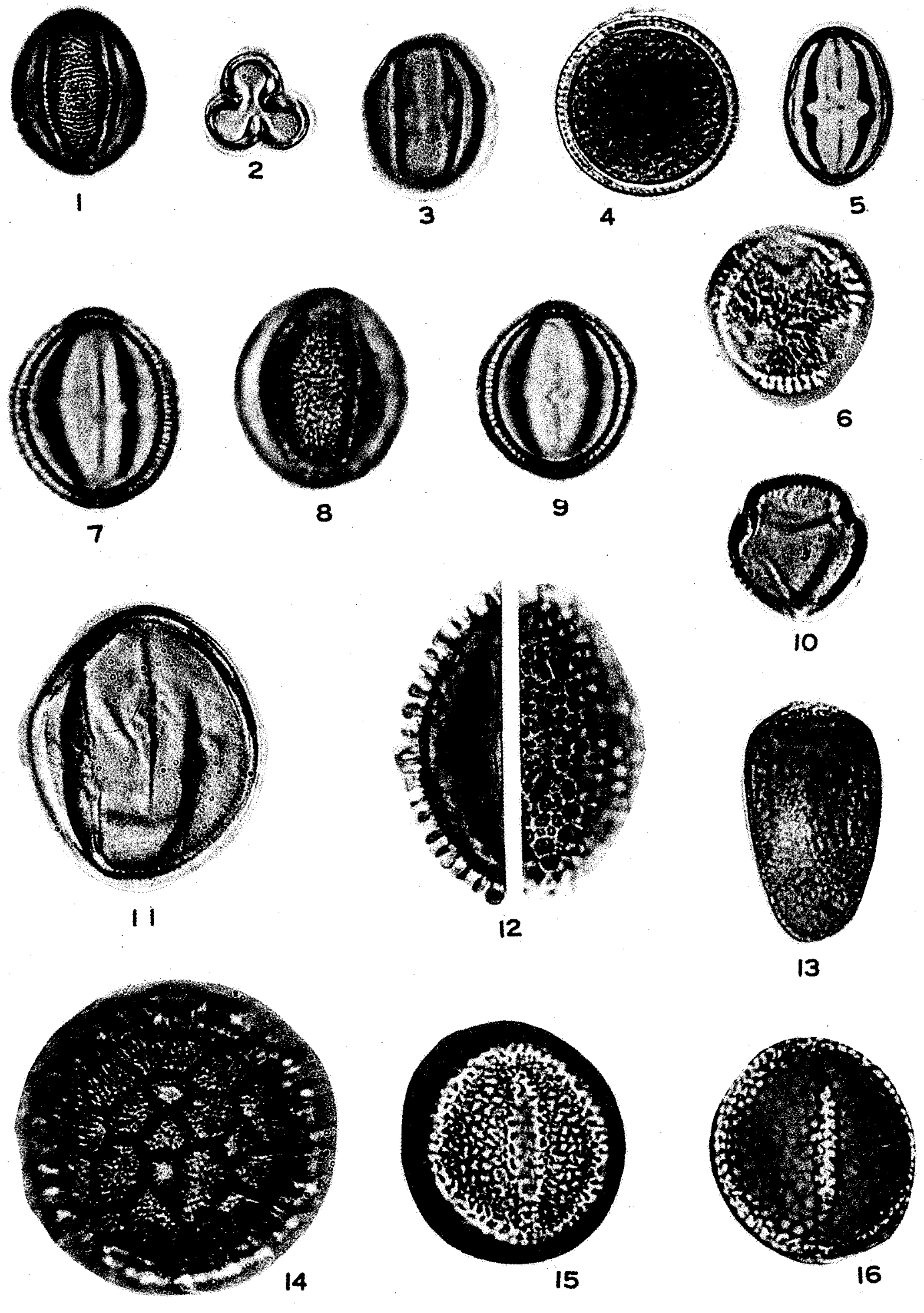
10：Cfr. *Rhus,* polar view, 30 x 32μ

11：*Fagus*, equatorial view, 42 x 46μ

13：Cyperaceae, 28 x 50μ

14：*Persicaria*, polar view, 56 x 78μ

15, 16：*Fraxinus*, equatorial view, 28 x 32μ, focus on pollen colpus and ornamentation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