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Journal of Geosciences, Osaka City University
Vol. 20, Art. 4, p. 59-92
December, 1976

Palynological Study of the Forest History in the Coastal Area of Osaka Bay since 14,000 BP

Environmental Changes in the Osaka Bay Area during the Holocene. Part-II.

Yasuo MAEDA*

(with 5 Tables, 5 Plates and 17 Figures)

Introduction

The Holocene is a short but nevertheless the most significant geologic age. This is because it is the one in which the present natural environments were formed. About 20,000 BP, in the maximum stage of the last glaciation, the coastal area of Osaka Bay was covered extensively by sub-arctic coniferous forest or cool-temperate broad-leaved deciduous forest.

The transmigration of such archaic forests to the present warm temperate broad-leaved evergreen forests during the Holocene has hardly been investigated based upon reliable materials. The results given in this paper, however, are obtained from samples collected directly from the outcrops of the undisturbed Holocene deposits in the bottom of Osaka Bay. They will hopefully contribute to the advancement of the study of the Holocene.

Geologic Setting and Sampling Method

The Osaka Bay area is a tectonic depression surrounded by uplifted mountain blocks reaching an elevation of several hundreds meters, among which the Rokko Mountains are the highest being more than 900 meters in elevation. Large rivers are flowing into the bay and forming the wide alluvial plain of Osaka along the northeastern coast. Four sampling sites were chosen for this study at the mouth of River Yodo (this volum p. 44. Fig. 1).

The caisson used to build the foundations of a huge bridge connecting the new reclaimed land and the Osaka Port were used effectively to collect reliable samples of the Holocene sequences. Many materials for radiocarbon dating were also collected from various horizons. As a result, a new stratigraphy for the Osaka Bay Formation was established (MAEDA 1976, this volume) ranging from about, 14,000 BP to the present.

Obtained samples of 10–50 cc were processed by the KOH-acetolysis-HF method. All pollen grains and spores on a slide were counted up to a sum of 200–400 grains per slide. Pollen percentages for all levels were based on the total number of pollen grains and spores. More than 100 slides from the following four sites were treated.

* Kobe City Institute for Educational Research. 4–18 Kitanagasa-dori, Ikuta-ku, Kobe, 650

site	name	depth (m)	samples	age (Y.B.P.)
1	Minato-Bridge pier No. 3	−17.5∼−33.9	35	4,500∼14,000
2	Minato-Bridge pier No. 2	−24.7∼−33.7	25	7,500∼14,000
3	Hankyu Umeda Station	− 5.3∼−25.5	41	1,800∼ 6,000
4	Nakajima Bridge	− 7.3∼−23.9	29	1,700∼ 9,000

The sedimentary columns from the four sites are shown in the pollen diagrams (Figs. 3–6).

Pollen Assemblage Zones

The pollen assemblage zones in sites 1,2,3 and 4 are summarized in Table 2,3,4 and 5, Figs. 3,4,5 and 6. All sections are divisible into two major zones I and II, with subzones designated a,b,c and d as shown in Table 1.

Table 1 Pollen assemblage zones of the Osaka Bay Formation.

^{14}C age 10^3 B.P.	Pollen assemblage zone			
	Zone		Subzone	
2	II	*Quercus* (*Cyclobalanopsis*)	d	*Pinus* *Cyclobalanopsis* *Cryptomeria*
4			c	*Cyclobalanopsis* *Abies*
			b	*Cyclobalanopsis*
6			a	*Cyclo. Ab. Tsu.*
8	I	*Quercus* (*Lepidobalanus*)	d	*Lepido.-Cyclo.*
10			c	*Lepidobalanus* *Celtis*
			b	*Lepido. Cyclo.*
12, 14			a	*Lepidobalanus* *Fagus* *Aesculus* *Tilia*

Zone I. *Quercus* (*Lepidobalanus*) Zone

This zone is characterrized by dominancy of *Quercus* (*Lepidobalanus*) and various broad-leaved deciduous trees, but conifer trees are rare. Zone I can be divided into four subzones.

Subzone Ia; *Quercus*. (*L.*) occurs in large quantity throughout this subzone, with broad-leaved deciduous trees, such as *Alnus, Fagus, Carpinus, Corylus, Celtis, Ulmus-Zelkova, Acer, Aesculus, Tilia, Fraxinus* and also *Quercus* (*Cyclobalanopsis*), although it is very rare.

As conifer trees, *Pinus, Abies, Picea, Tsuga, Cryptomeria* and *Sciadopitys* were obtained, but they are rare except for *Pinus.*

Subzone Ib; this zone is dominated by *Quercus* (*L.*), but a number of *Quercus* (*C.*) also appears.

Subzone Ic; *Quercus* (*L.*) is dominant in this subzone, *Celtis, Carpinus, Corylus, Ulmus-Zelkova* have a tendency to increase, while *Quercus* (*C.*) is stable. Such broad-leaved deciduous trees dominated by *Quercus* (*L.*) occur unstably.

Subzone Id; *Quercus* (*L.*) is still dominant, but it is remarkable that *Quercus* (*C.*) increase rapidly. Not only *Quercus* (*L.*) but also *Fagus, Acer, Aesculus* and *Tilia* are decreasing as are *Celtis, Ulmus-Zelkova, Carpinus, Corylus*. Although this subzone represents a short period, it is very significant in the sequence of the forest transition. In this paper, the border line of the zones between *Quercus* (*L.*) and *Quercus* (*C.*) is drawn when the ratio of them reachs 1:1. However, from the view-point of the transition of forests, it may be suitable to put this subzone into Zone II.

Zone II *Quercus* (*Cyclobalanopsis*) Zone

In this zone, *Quercus* (*C.*) takes the place of *Quercus* (*L.*), and conifer trees, such as *Abies, Pinus, Tsuga, Cryptomeria, Sciadopitys* and *Podocarpus* obtain stable occurrence. Zone II can be devided into four subzones.

Subzone IIa; Reaching the highest ratio of abundance, pollen grains of *Quercus* (*C.*) exceed those of *Quercus* (*L.*). They are associated with *Abies, Pinus, Tsuga, Cryptomeria, Sciadopitys, Podocarpus, Castanopsis, Myrica* and *Aphananthe*. Among them, as will be explained later, *Abies, Tsuga* and *Sciadopitys* are considered to behave as a group. As for the decreasing trees, the following broad-leaved deciduous trees can be cited: *Quercus* (*L.*), *Alnus, Carpinus, Corylus, Fagus, Celtis*.

Subzone IIb; *Quercus* (*C.*) reched a stable condition with the highest ratio of abundance.

Subzone IIc; while *Quercus* (*C.*) dominantes the period, *Abies, Pinus, Tsuga, Cryptomeria* and *Sciadopitys* are also stable.

Subzone IId; *Abies, Tsuga, Sciadopitys, Quercus* (*C.*) decrease slightly, while *Pinus* and *Cryptomeria* increase.

Mutual Relations among Arboreal Trees

To examine the mutual relations among eight representative arboreal trees, the following two new methods have been tried to analyze the compositions and their changes of fossil pollen assemblages.

Fig. 1 is drawn by the first method. The absolute numbers of pollen grains of two genera contained in the slides representing each horizon are plotted on these graphs. The numbers on the graph show 10^3 years BP. During the period of 14,000–7,000 BP, *Quercus* (*L.*) was dominant, while in 6,000–1,000 BP, *Quercus* (*C.*) became dominant. This change really occurred during a period of only 1,000 years, about 6,000 BP. Both subgenus are considered to be the trees living in different environments (mainly climatic conditions). The graph showing positive of *Quercus* (*L.*) and *Fagus* (Fig. 14) indicates that *Quercus* (*L.*) and *Fagus* belong to the same forest zone, but *Quercus* (*C.*) and *Fagus* (Fig. 15) belong to the different zones.

This graph also shows clearly the relationship between them even in the case of low frequency as in the example of that between *Sciadopitys* and *Abies* (Fig. 8).

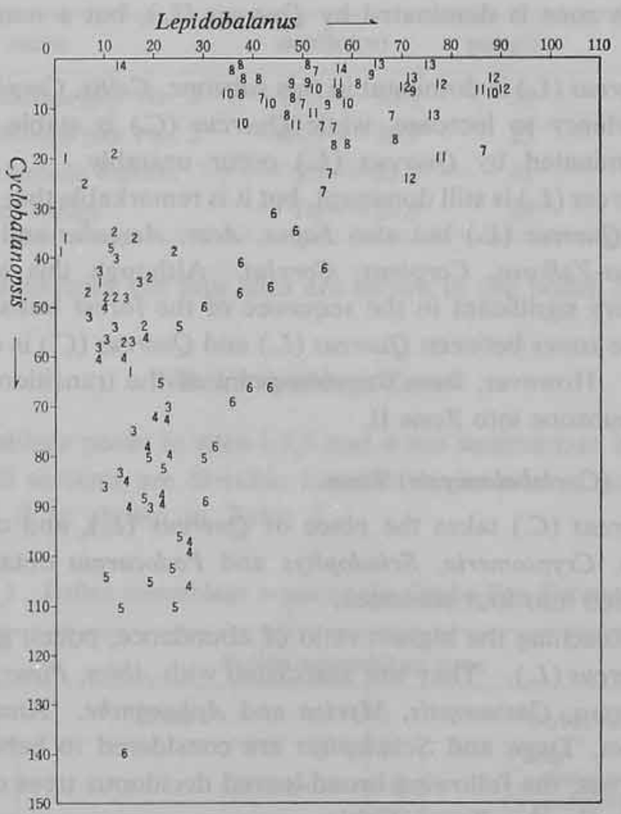


Fig. 1. The mutual relationship between *Quercus* (*Lepidobalanus*) and *Q.* (*Cyclobalanopsis*).

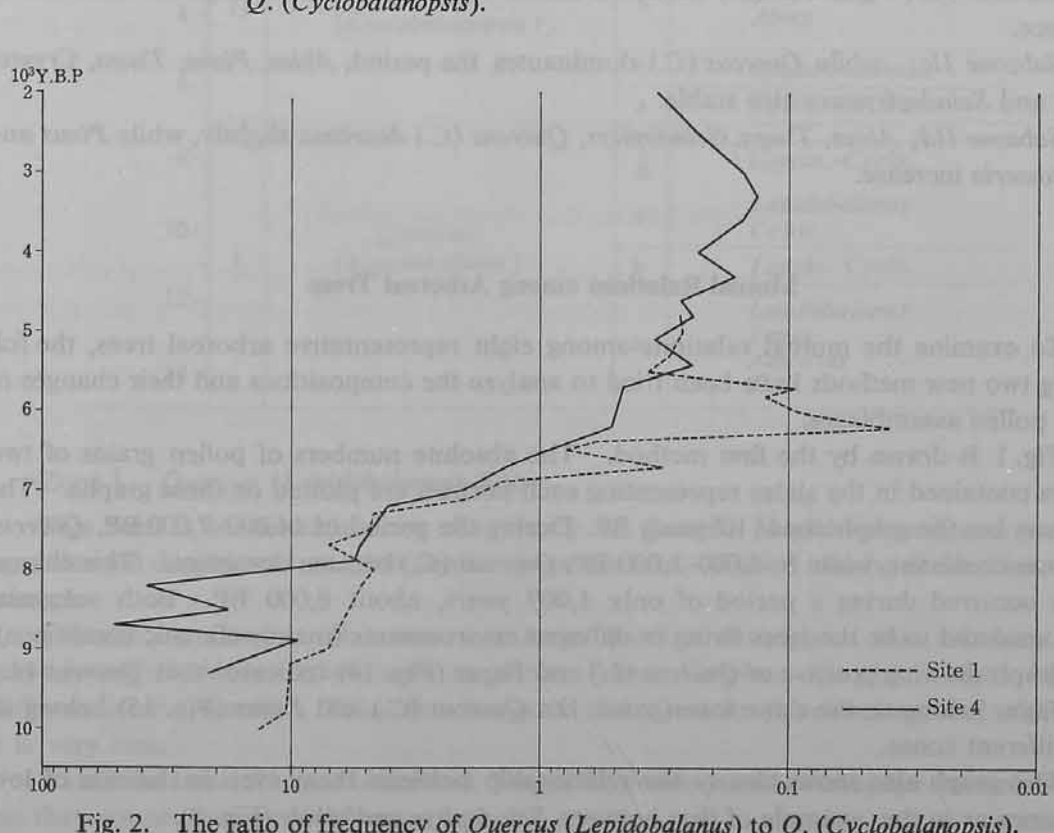


Fig. 2. The ratio of frequency of *Quercus* (*Lepidobalanus*) to *Q.* (*Cyclobalanopsis*).

The second is a method to plot the ratio of *Quercus* (*L.*) to *Quercus* (*C.*) on the abscissa and the age on the ordinate. The curve, thus obtained, clearly suggests the transitional period or the period of climatic climax forest as shown in Fig. 2.

The above two new methods are superior to the ordinary percentage method, but they can be used only when detailed stratigraphic and chronological data are obtained. The following pollen assemblage zones are established based on the mutual relationships among the main genera of trees, *Abies, Pinus, Tsuga, Cryptomeria, Sciadopitys, Quercus* (*Lepidobalanus, Cyclobalanopsis*) and *Fagus*. The relationship between eight genera is positive, negative or unknown as follows:

Abies ....*Tsuga, Pinus* to *Sciadopitys* is positive. *Fagus, Q.* (*Lepidobalanus, Cyclobalanopsis*) to *Cryptomeria* is negative.

Pinus ....*Abies, Tsuga* to *Sciadopitys* is positive. *Fagus* to *Q.* (*Lepidobalanus*) is negative. *Cryptomeria* to *Q.* (*Cyclobalanopsis*) is unknown.

Tsuga ....*Abies, Pinus* to *Sciadopitys* is positive. *Q.* (*Lepidobalanus, Cyclobalanopsis*) to *Fagus* is negative.
Cryptomeria is unknown.

Cryptomeria ....*Q.* (*Lepidobalanus, Cyclobalanopsis*) to *Fagus* is negative.
Abies, Pinus, Tsuga to *Sciadopitys* is unknown.

Sciadopitys ....*Abies, Tsuga* to *Pinus* is positive. *Q.* (*Lepidobalanus, Cyclobalanopsis*) to *Fagus* is negative.

Fagus ....*Q.* (*Lepidobalanus*) is positive. *Abies, pinus, Tsuga, Cryptomeria, Sciadopitys* to *Q.* (*Cyclobalanopsis*) is negative.

Q. (*Lepidobalanus*)......*Fagus* is positive.
Abies, Pinus, Tsuga, Cryptomeria, sciadopitys to *Q.* (*Cyclobalanopsis*) is negative.

Q. (*Cyclobalanopsis*)...*Abies, Tsuga, Cryptomeria, Sciadopitys, Fagus* to *Q.* (*Lepidobalanus*) is negative. *Cryptomeria* is unknown.

Above eight genera can be inferred as the following species according the thier relationships of co-existence or the observations of the apparent features.

Abies....A. firma,. Pinus....P. densiflora and *P. thunbergii,. Tsuga....T. sieboldii,. Cryptomeria ....C. japonica,. Sciadopitys....S. verticillata, Fagus....F. crenata* and *F. japonica, Quercus* (*Lepidobalanus*)....*Q.*(*L.*) *mongolica* var. *grosseserrata, dentata, serrata, variabilis, aliena* and *acutissima, Quercus* (*Cyclobalanopsis*)....*Q.* (*C.*) *acuta, gilva, glauca, myrsinaeforia, salicina, sessilifolia* and *Q.* (*Lepidobalanus*) *phillyraeoides*.

Thus, there have existed three types of forest groups in the coastal area of Osaka Bay since 14,000 BP.

1 *Quercus* (*Lepidobalanus*) group
2 *Quercus* (*Cyclobalanopsis*) group
3 *Abies* group

Changes of Forest Vegetation

Three periods of forest changes during the last 14,000 years can be distinguished.

1) *Quercus* (*L.*) forest: Broad-leaved deciduous forest period ...from 14,000 to 7,500 BP

2) Transitional Period from *Quercus* (*L.*) to *Quercus* (*C.*) forest...from 7,500 to 6,000 BP
3) *Quercus* (*C.*) forest: Broad-leaved evergreen forest period ...from 6,000 to present

1) *Quercus* (*Lepidobalanus*) forest period

The Osaka Bay coast was widely covered with broad-leaved deciduous forests between 14,000 and 12,000 BP. The dominant trees were *Quercus* (*L.*) admixed with such genera as *Alnus, Betula, Pterocarya, Carpinus, Corylus, Fagus, Ulmus-Zelkova, Acer, Aesculus, Fraxinus* and *Tilia,* and such conifers as *Abies, Pinus, Tsuga, Cryptomeria* and *Sciadopitys.* The composition of this forest is similar to that of the present cool-temperate broad-leaved deciduous forest, but it is characterized by the rare occurrens of *Fagus.* According to YOSHIOKA (1974), the present broad-leaved deciduous forest on the Japan Sea side is somewhat different from that of the Pacific side, because *Fagus crenata* and *Quercus* (*L.*) *mongolica* var. *grosseserrata* are dominant in the former, but *Quercus* (*L.*) *mongolica* var. *grosseserrata* and *Abies homolepis* are dominant in the latter. The composition of the forest of the Osaka Bay area characterized by dominant *Quercus* and sparse *Fagus* and *Abeis* suggests that the climate of that period was dryer than that at present.

Starting from about 11,000 BP, a small change had occurred in this deciduous broad-leaved forest. It was the appearance of *Cyclobalanopsis* (evergreen oaks). Although it is only about 5 percent of the total amount of pollen grain and spores, the signigficance of this is by no means small considering the future potential of *Quercus* (*C.*) in the broad-leaved forest.

Between 10,000 and 7,500 BP, the forest was dominated by *Quercus* (*L.*), but a somewhat conspicuous change had appeared in its composition as shown by the increase of *Celtis, Zelkova, Carpinus, Abies,* and *Tsuga. Quercus* (*C.*) occurres continuously although it is sparse. This forest is similar to the warm-temperate broad-leaved deciduous forest distributed in the transitional zone from cool-temperate forest to warm-temperate forest. It is a further problem to try to separate this period as an independent forest stage.

2) Transitional period from *Quercus* (*Lepidobalanus*) to *Quercus* (*Cyclobalanopsis*) forests

Although the period from 7,500 to 6,000 BP was short, it is significant that deciduous trees such as *Fagus, Acer, Aesculus, Tilia* etc. admixed with *Quercus* (*L.*) decrease, while *Quercus* (*C.*), *Abies, Tsuga* and *Sciadopitys* tend to increase. From the geographical point of view, it means that cool-temperate broad-leaved deciduous forest migrated to the north, and warm-temperate broad-leaved evergreen forest advanced from the south. Moreover, it is very interesting that such a change of forest has been followed by the rise of sea-level showing the climatic optimum (Umeda transgression) with an interval of 500 to 1,000 years (MAEDA 1976).

From physiognomical view-point, the period from 7,500 to 6,000 BP is the age when evergreen forest dominated by *Quercus* (*C.*) was replaced by broad-leaved deciduous forest was a climatic climax forest. The genera associated with *Quercus* (*C.*) are *Podocarpus, Myrica, Castanopsis, Aphananthe, Mallotus, Sapium, Fagara, Ilex, Lagerstroemia, Ligstrom* and *Symplocos* etc.. Coniferous trees, *Abies, Pinus, Tsuga,* and *Sciadopitys* also increased. This is a most important period, for it is the one in which large-scale migration of the forest zone in the Osaka area had conspicuously proceeded. The relationship between *Quercus* (*L.*) and *Quercus* (*C.*) is clear in Figs. 1 and 2.

3) *Quercus* (*Cyclobalanopsis*) forest period

During the period from 6,000 to 5,000 BP, warm-temperate broad-leaved evergreen forest reached climatic climax. From about the middle of this period, the relations between *Qurcus* (*C.*) and coniferous trees, such as *Abies, Tsuga, Sciadopitys* and *Pinus* show negative correlation and the forest zone has been differentiated, as shown in Figs. 10, 13, 16 and 17. Fig. 10 shows the fact that *Quercus* (*C.*) decreased while of *Abies* increased about 5,000 BP. It is considered that it was due to the lowering of temperature.

During the period from 5,000 to 2,000 BP, it is considered that warm-temperate broad-leaved evergreen forest dominated by *Quercus* (*C.*) occupied the lowlands, and warm-temperate coniferous forest dominated by *Abies, Tsuga, Sciadopitys* covered the mountain areas.

During the period from 2,000 to the present, *Pinus* and *Cryptomeria* have increased, but the predominant species has been *Quercus* (*C.*). The marine sediments of this period are so unconsolidated that it is difficult to collect samples to know how the forest change.

Studies of Other Areas

NAKAMURA (1965, 1972) first reported the change of Japanese Holocene forest from cooltemperate to warm-temperate at the RII, according to the data collected from the Kochi plain in Shikoku Island. Later findings supporting his study were published by HATANAKA (1973) in Kyushu, YASUDA (1974) in the Osaka area, Mizoroga-ike Research Group (1975) in the Kyoto area of Kinki. According to NAKAMURA,'s results (1972) obtained in the Ise Bay area of Chubu it is the late stage of R II that *Quercus* (*C.*) replaced *Quercus* (*L.*) in the area of Ise Bay. The writer, however, is considering that the change of the forest has occurred in the early middle stage of R II, according to the pollon diagram of Loc.k. MORI (1965) and Niigata Group (1972) reported on Tokyo Bay areas, but both did not separate *Quercus* from *Lepidobalanus* and *Cyclobalanopsis* in the latter stage of Holocene.

The Sendai area is important because it is the northern limit of *Quercus* (*C.*). According to YOSHIOKA's studies (1953) of the living forests, *Quercus* (*C.*) is distributed as far as north Kakuda and Sohma (38° latitude) near. TAKEUCHI (1974) studied succession of the pollon assemblage of this forest. According to her report, *Quercus* is dominant, but the relationship between *Lepidobalanus* and *Cyclobalanopsis* is not clear.

Studied of changes in the Holocene forest of Japanese Islands are still in progress. In this regard, detailed studied with chronological data such as that in the Osaka area should be undertaken in furture.

Summary

1) About 14,000 BP, the Osaka Bay coastal area had been covered with cool-temperate broad-leaved deciduous forest, which continued up to about 7.500 BP.
2) Since 7,500 BP, warm-temperate broad-leaved evergreen forest has stabilized and has continued up to the present.
3) About 6,000 BP, warm-temperate broad-leaved evergreen forest reached climax

Acknowledgements

I would like to acknowledge the continuing guidance and encouragement of Prof. K. HUZITA of Osaka City University. I also appreciate the critical discussions of Prof. M. SHIMAKURA of Kansai Foreign Language College, Prof. T. KIRA, Prof. T. KASAMA, Emeritus Prof. N. IKEBE and Mr. K. MATSUOKA of Osaka City University.

Reference

HATANAKA, K. (1973): Pollen analytical study of the Holocene sediments in Suho-nada area, Kyushu (in Japanese). *Rep. a development project on the Western Setouti area.* Ministry of the Construction. p. 25–35.

MAEDA, Y. (1976): The Sea level changes Osaka Bay from 12,000 BP to 6,000 BP. *Jour. Geos., Osaka City Univ.* **20**, p. 43–58.

MATSUOKA, K. & Y. MAEDA (1975): Microfossils with organic wall and Scanning electronmicroscope with reference to living and fossil *Quercus* pollen (in Japanese). *NOM.* 3, p. 19–31.

MIZORO-GA-IKE Research Group (1975): Study on Mizoro-ga-ike (Pond). (in Japanese with English abstract). *Earth. Sci.* **30**, p. 15–38, 122–140.

MORI, Y. (1965): Pollen analysis of the cores obtained from the bottom of Tokyo Bay (in Japanese with English abstract). *Quaternary Research* (*Daiyonki-kenkyu*), **4**, p. 191–199.

NAKAMURA, J. (1965): Palynological study of the vegetation history since the late- glacial. period of the lowland in Kochi Prefecture (in Japanese with English abstract). *Quaternary Research* (*Daiyonki-kenkyu*). **4**, p. 200–207.

do. (1972): Pollen analysis of the Quaternary sediments from the Nohbi plain and vicinities, Central Japan (in Japanese with English abstract). *Research Rep. Kochi Univ.* **21**, p. 1–46.

NAKAMURA, J., H. MITSUSHIO, T., KURODA & O. YOSHIKAWA (1972): Palynological study. part I. -The Quaternary system in Kochi Prefecture-(in Japanese with English abstract). *Op. cite.* **21**, p. 87–113.

NIIGATA Quaternary Research Group (1972): Studies on the Biostratigraphic division and the sedimentary enveironments of the Alluvium in the Tokyo lowland and Niigata plain, Central Japan (in Japanese with English abstract). *Coastal plain of Japan. Mem. Geol. Soc. Japan.* no. **7**.

YOSHIOKA, K. (1956): Forest communities in the northern limits of the forests of the evergreen oaks. *Sci. Rep. Fukushima Univ.* **5**, p. 11–23.

do. The flora and vegetation of Japan. Elsevier, Amesterdam. p. 87–124.

TAKEUCHI, S. (1974): The vegetation history during the Holocene in the Kakuda area, Miyagi prefecture, Japan. *Saito Ho-onkai Museum Research Bull.* **43**, p. 27–33.

YAMAZASAKI, T. & M. TAKEOKA (1959): Electronmicroscope investigations on the surface structure of the pollen membrane, based on the replica method. V Especially, on the pollen of genus *Quercus* (in Japanese with English abstract). *Jour. Japanese Forestry Soc.* **41**, p. 125–129.

YASUDA, Y. (1974): Palynology and Archaeology since the Late glacial age in Japan (in Japanese with English abstract). *Quaternary Research* (*Daiyonki-kenkyu*), **13**, p. 106–134.

Table 2 Percentages of pollen grains and spores at Site 1 (Minato-Bridge main pire No. 3)

Genus \ depth (−m)	17.50	18.10	18.70	19.10	19.30	19.50	19.90	20.30	21.10	21.50	21.90	22.30	22.70	23.10	23.50	23.90	24.30	24.90	25.30	26.90	27.30	28.30	28.70	29.10	29.50	29.90	30.30	30.70	31.10	31.50	31.90	32.30	32.90	33.50	33.90
Abies	4.1	3.8	8.3	7.0	6.0	6.8	8.4	6.7	5.8	8.7	2.3	2.2	5.4	3.7	2.3	1.6	0.9	0.9	1.6	1.1	0.6	1.5	0.8	2.0	2.0	1.4	1.6	1.9		0.6	0.3	0.7	0.9	1.3	1.2
Picea		0.9			0.3		0.3		0.3	0.3							0.6				0.3	0.3		0.3		0.3			0.3		0.3	0.2	0.3		
Pinus	8.0	9.8	10.9	10.2	10.0	7.4	10.5	7.5	6.7	12.6	4.9	4.4	4.6	12.4	10.4	10.5	4.6	5.8	2.7	5.8	4.2	4.5	8.7	6.0	5.2	3.3	3.3	2.5	3.4	5.8	2.5	3.2	3.6	2.3	0.9
Tsuga	1.6	2.7	3.4	2.1	2.3	1.4	1.4			1.4	0.6		0.3	3.1	1.3	0.3	0.3	0.9		0.6	0.6	1.8	0.8	0.3	0.3		0.8	0.3	0.3	0.3		0.2	0.3	0.7	
Cryptomeria	1.9	3.6	3.0	3.9	2.0	1.4	3.8	1.1	0.7	0.3	1.0	2.2	1.7	0.6	1.3	0.3	0.3	0.9	1.6	0.3	3.8	0.3	2.3		2.9		0.8	0.3	2.7		0.3	0.7	0.9	1.7	0.3
Sciadopitys	1.9	6.8	7.9	3.5	7.7	2.0	6.5	0.7	1.7	4.9	0.3	0.6	2.3	0.3	0.6	1.0	0.3	1.2	0.3		0.6	0.6		0.3			0.3	0.6		1.0	0.3		0.6		
Other Coniferous trees	0.3		0.8	1.4				0.7	1.0	0.7	0.6								0.3																
Podocarpus	6.4	2.4	1.5	2.2	0.6	2.4	0.6	0.7	1.7	0.3	0.3		0.3	0.6	1.0	2.8	0.9	0.6	1.3	2.5	1.0	0.6		0.6	0.6		0.3	0.3			0.3	0.2		1.7	0.6
Myrica					0.3					0.3					0.3	0.3																			
Juglans		0.6	1.1			0.3	0.5		1.7	1.4		1.2	0.6		1.0					0.3			0.3	0.8	0.3		0.8	0.6			0.3	0.5		1.0	1.2
Pterocarya		0.3		0.4		0.3				0.3		0.3	0.3		0.6	0.6	0.6	0.6	0.3	1.1	1.3	0.3	0.8		1.6	0.8		0.3	0.7	0.3	1.7	0.7	0.6	0.3	0.9
Salix									0.3		0.6		0.3		0.3		0.3	0.3	0.5	0.6	1.0			1.4	0.3	1.1	0.3					0.2	0.3	0.7	0.9
Alnus	1.6	0.9	1.5	1.1	1.7	1.1	1.1		0.7	2.1	1.0	3.1	2.9	3.4	1.6	4.5	6.1	1.7	4.7	4.2	2.2	3.6	4.9	2.6	2.3	4.7	2.2	4.6	3.4	5.5	3.3	3.7	6.5	4.7	2.7
Betula	0.3								0.3					0.3				0.3	0.5	0.6	0.3	0.6			0.7	0.3	0.3	0.9				0.5	0.3	0.3	
Carpinus	0.6	0.3	1.1	0.7	0.3	1.1	1.1	1.1	1.3	2.8	3.2	3.1	2.3	5.3	1.9	1.9	3.3	0.9	3.0	1.7	1.9	4.5	2.3	3.4	4.0	2.2	2.7	3.7	2.7	3.9	0.6	2.5	3.6	2.7	4.6
Corylus	0.3	0.3		0.4	0.3	0.3		0.4	1.0	1.0	1.9	1.6	1.7	0.6	0.6	0.6	0.6	0.6	1.1	0.8	0.3	0.9	1.5	1.4	1.3	1.1	0.8	2.2	1.0	1.3	4.4	1.5	0.9	0.7	0.6
"*Castanopsis*"	0.6		0.4	0.4	0.3	1.7	0.5	4.5	1.3	0.7	1.6	2.2	0.3																		1.9				
Fagus	1.6	1.2	0.8	1.1	0.7	0.9	0.5	0.7	0.3	2.1	2.3	1.9	2.3	1.2	3.2	1.9	1.8	3.2	2.2	4.2	2.9	3.9	1.1	3.7	4.0	4.4	3.0	2.2	2.7	1.3	2.5	3.0	1.8	6.3	3.4
Lepidobalanus	8.6	6.5	6.0	10.5	3.3	4.6	3.5	11.6	13.0	12.9	9.7	11.5	10.6	18.3	27.8	20.1	23.4	23.3	18.6	17.5	25.6	22.2	34.8	22.2	18.9	18.7	26.4	27.2	27.9	31.4	28.9	21.2	26.0	34.3	35.4
Cyclobalanopsis	31.5	24.3	19.9	28.1	34.7	37.3	37.8	29.2	22.1	16.4	28.9	17.8	8.9	9.3	5.8	4.1	3.3	4.9	3.6	2.5	2.6	2.1	2.7	2.6	2.0	3.3	1.6	6.5	8.7	2.3	1.4	0.5	0.6	2.0	0.6
Aphananthe		0.3		0.4		1.1		0.7	0.3		1.0	0.3	0.9	0.6	0.3																				
Celtis	0.3	0.9	0.8	0.7	0.7	0.6		1.9	3.0	1.7	3.6	3.7	4.6	5.3	3.2	5.4	7.0	2.6	1.6	2.5	2.6		1.1	1.7	0.7	0.5		0.3		1.0		1.5	0.3	0.3	0.6
Ulmus-Zelkova	0.6	1.5	1.9	2.1	2.0	1.1	1.3	4.5	3.3	4.5	5.1	3.4	6.3	2.1	2.3	2.2	1.8	2.4	1.9	1.1	2.5	3.9	2.7	2.3	2.9	1.9	2.7	2.1	2.0	3.3	2.5	2.5	1.2	4.4	2.4
Sapium	1.0	1.2	1.5	0.7	0.7	0.3				0.3		0.3		0.3		0.3		0.3	0.3			0.3		0.6			0.3								0.3
Acer		0.6	2.3	0.7		0.6	0.3	0.4	0.7	1.0	0.3	0.6	0.6		1.0	1.0	1.5	2.0	1.9	1.7	2.6	1.5	1.1	1.4	2.3	0.5	0.8	0.6	2.0	1.0	1.7	0.2	2.4	1.0	0.6
Aesculus			0.4						0.7		0.3	0.6	0.6			1.3	1.2	2.0	3.0	1.9	1.0	1.5	2.3	2.0	1.3	4.1	1.6	1.2	1.3	2.9	0.6	2.0	3.6	3.0	0.9
Ilex		0.6		0.4											0.3		0.3		0.3	0.6			0.4	0.6					0.7				0.6		0.3
Fraxinus type	0.3			0.4	1.0	0.9	0.3	0.4	0.7	0.7	1.0	0.6	1.1	0.6	0.3	1.6	0.9	2.0	1.4	2.5	5.8	3.3	1.9	1.1	6.2	5.2	2.2	2.5	6.4	1.6	0.8	2.2	3.3	2.0	3.4
Other broadleaf trees	1.9	4.2	3.0	2.7	1.3	2.6	0.8	0.7	2.9	3.5	2.5	2.4	2.7	1.5	3.7	3.0	2.1	3.6	6.2	4.7	2.9	1.2	2.8	4.8	3.9	3.7	3.6	2.4	2.3	0.9	3.2	3.2	3.0	3.3	6.6
Grass	11.3	9.3	3.1	8.3	8.5	5.8	5.5	9.4	11.9	6.0	13.3	4.9	19.1	12.6	16.2	18.1	19.1	20.4	18.6	23.6	16.0	24.9	10.7	12.1	9.1	15.3	17.2	20.3	13.4	17.8	26.8	26.9	11.6	12.4	13.6
Indeterminable	12.5	11.7	12.5	8.7	10.2	17.9	9.9	18.3	14.7	13.2	12.8	30.5	17.9	10.8	8.8	10.0	13.5	8.3	15.7	13.1	12.4	11.1	16.4	20.8	23.5	18.5	18.6	11.0	16.3	14.6	12.7	14.7	21.5	7.2	15.0
PTERIDOPHYTA	3.4	8.3	10.7	5.5	5.4	2.3	5.7	1.1	3.0	1.7	1.9	2.5	2.6	8.0	6.8	7.0	6.0	11.9	7.4	8.4	7.3	5.7	4.5	8.6	6.0	11.0	9.3	6.4	1.8	3.9	4.7	8.0	7.7	7.9	6.1
Total number of pollen grains & spores	314	338	266	285	300	351	370	267	299	286	308	254	350	323	309	314	329	344	365	361	312	333	264	351	307	364	364	288	298	309	360	406	338	300	328

Table 3 Percentages of pollen grains and spores at Site 2 (Minato-Bridge main pire No. 2)

Genus \ depth (−m)	24.70	24.90	25.60	25.70	25.90	26.20	26.50	26.80	27.10	27.40	27.70	28.00	28.30	29.65	29.95	30.25	30.70	31.00	31.45	31.75	32.05	32.35	32.80	33.40	33.70
Abies	2.2	3.6	2.8	1.8	1.3	1.7	0.4	1.1	1.4	1.3	1.8	1.8	0.9	0.4	1.1	1.9	2.0	1.9	1.3	0.8	1.8	1.4	2.2	2.3	0.8
Picea	0.4		0.3		0.4			0.4		0.4	0.4						1.0		0.3		1.5		0.4	1.6	0.8
Pinus	4.0	11.2	11.4	5.9	8.8	7.5	5.2	9.5	6.8	6.8	9.4	5.1	3.9	4.8	4.5	6.4	5.4	4.6	6.0	3.8	14.4	6.3	4.7	14.0	7.2
Tsuga	1.3	1.1	1.7		0.8	0.8				1.3	0.7	0.4	0.9	0.4		1.6	1.4	0.8		0.8	1.5	0.4	0.4	2.0	0.8
Cryptomeria	0.9	2.9	2.8	2.3	1.7	2.1	0.4	1.5		1.3	3.6		1.3	2.4	0.8	1.6	0.3	2.7	0.3	1.2	1.2	1.4	2.5	1.3	4.4
Sciadopitys	0.4		2.4	1.4	0.8	0.4	0.8				0.4					0.3	1.0	0.4		0.8	2.4	1.4	0.7	4.9	
Podocarpus	0.4															0.3									
Other Coniferous trees	1.3	0.4	1.0	0.9	0.4	0.8	0.4	0.4	0.5	2.5	0.4	3.2		1.2	1.5	0.3	1.0	0.8	1.6	2.8	0.3	0.7		0.3	
Myrica																									
Juglans	0.9	1.4	0.7		0.4		0.9				0.7						1.4	0.4		0.8	0.3	0.4			
Pterocarya		0.4			0.8		0.9	0.4	0.9		0.4			1.2	0.4	0.3	0.3	0.8			1.8	0.7	1.1	0.7	0.4
Salix			0.7	0.5		0.4		0.4	1.4	0.4		0.7	0.9	0.8	0.4	0.6	0.3		0.3	0.8	0.6	0.4	0.7	0.3	0.4
Alnus	4.8	4.0	1.7	2.3	4.2	4.2	4.3	3.8	3.2	2.5	2.9	4.0	4.8	6.7	7.2	4.2	3.7	3.8	4.3	6.5	0.6	4.6	2.5	2.9	2.0
Betula			0.3		0.4	0.4		0.4	0.5						0.4				0.3			0.7			
Carpinus	3.5	4.7	4.5	5.4	1.7	1.7	3.4	1.5	1.8	4.6	2.5	2.5	3.1	4.4	3.0	1.6	6.1	1.9	6.6	3.1	2.9	3.5	2.2	1.6	2.8
Corylus	1.3	0.7	1.4	1.4	1.3		1.3	0.4	0.9	1.3	1.4	0.7	1.3	0.4	0.4		1.0	0.4	1.3	1.5		1.4	2.9	0.7	0.4
"*Castanopsis*"																									
Fagus	2.2	2.9	1.7	0.9	1.3	0.4	0.9	1.5	4.5	3.8	2.5	1.4	2.2	3.6	1.9	0.3	2.0	2.3	1.7	3.1	2.1	2.5	1.1	0.3	1.6
Lepidobalanus	24.2	20.1	20.3	17.1	17.2	20.0	16.4	23.2	23.1	20.3	18.8	12.7	18.8	14.7	18.6	18.0	29.2	27.0	23.6	30.0	22.4	25.4	38.0	18.9	30.1
Cyclobalanopsis	10.1	6.1	5.9	1.8	1.7	3.3	3.0	1.9	2.3	2.1	3.6	2.5	3.9	5.2	4.9	5.5	2.0	2.3	1.7	1.9	3.5	1.4	0.4	0.7	1.2
Aphananthe	0.4	0.4	0.3				0.4						0.9												
Celtis	9.3	4.0	2.8	8.1	5.0	3.8	4.7	3.8	6.3	5.5	2.2	2.2	5.7	0.8	0.4		0.3	0.8				1.1	1.8	0.7	
Ulmus-Zelkova	4.8	3.2	3.5	1.8	1.2	2.5	2.1	1.2	2.8	2.1	1.4	1.4	3.0	4.0	2.7	1.3	2.7	1.1	3.0	2.4	1.5	2.5	2.9	1.6	
Sapium			0.3			0.4									0.4			0.4			0.3				
Acer	2.2	0.7		1.8	1.3	1.3		1.9	2.3	1.7	1.4	1.1	2.2	1.6		3.2	1.0	0.8	0.3	0.8	0.3	0.4	0.4	0.3	1.6
Aesculus	0.9	1.1	0.7	6.3	0.8	0.8	2.2	2.3	4.5	2.1	1.8	3.3	1.7	2.0	1.9	1.0	1.0	1.1	3.7	1.5		0.7	0.4		1.2
Ilex				0.5			0.4								0.4	0.3							0.4		
Fraxinus type	2.6	2.5	1.7	2.7	5.4	2.5	3.4	2.7	3.2	2.1	1.8	1.4	2.6	0.8	1.1	2.6	0.3	1.9		1.9	0.9	1.4	1.4	1.3	4.4
Other broadleaf trees	1.3	2.2	2.9	2.9	2.4	1.6	3.5	1.6	3.3	0.4	3.3	2.9	1.8	2.8	3.2	3.2	2.9	3.2	0.9	2.4	3.0	2.6	3.0	1.0	0.8
Grass	2.5	7.6	5.0	13.4	13.3	9.1	16.3	15.7	11.1	11.4	10.3	5.6	5.2	11.0	15.2	19.8	13.4	15.6	16.5	18.5	5.7	12.3	13.6	8.4	9.2
Indeterminable	16.2	15.7	20.2	19.7	17.4	25.1	23.1	16.5	14.1	20.7	21.1	29.9	26.6	20.7	19.7	12.8	11.4	15.3	18.1	14.8	8.3	15.7	10.0	14.2	20.8
PTERIDOPHYTA	3.0	6.1	4.8	3.2	11.3	10.0	8.6	9.5	8.6	5.5	10.2	8.0	8.3	12.7	11.7	13.2	10.1	11.9	7.6	2.3	26.0	13.8	8.7	20.6	9.6
Total number of pollen grains & spores	227	278	290	222	239	240	232	263	221	237	276	276	229	252	264	311	295	263	301	260	340	284	276	307	249

Table 4-a Percentages of pollen grains and spores at the Site 3 (Hankyu Umeda Station)

Genus \ depth (−m)	5.30	5.80	6.30	6.90	7.80	8.30	8.80	9.30	9.80	10.30	10.80	11.30	11.80	12.30	12.80	13.20	13.80	14.20	14.85	15.30	15.80
Abies	1.4	2.3	3.6	4.2	12.7	12.9	10.3	11.4	9.9	10.7	6.2	15.8	9.1	6.3	8.1	8.8	11.7	4.1	7.7	5.0	11.7
Picea								0.3	0.6					0.6		0.9		0.3			
Pinus	5.4	3.9	5.7	3.4	7.0	9.2	9.3	9.1	8.0	5.8	6.5	12.3	9.8	7.2	12.0	10.7	13.6	11.9	6.5	5.3	8.7
Tsuga	0.8	0.9	1.8	1.1	3.8	3.4	2.8	3.5	3.1	3.1	0.6	2.5	3.5	2.1	2.1	1.3	4.5	1.3	1.3	1.5	1.9
Cryptomeria	5.4	4.5	4.7	3.7	6.3	4.6	2.6	3.5	2.8	8.0	2.9	2.8	1.9	4.5	5.3	3.2	2.6	3.4	3.5	5.3	2.6
Sciadopitys	2.0	0.7	1.3	1.1	2.2	4.6	6.7	5.3	4.0	5.8	2.9	5.3	8.2	5.1	6.7	7.3	7.8	5.9	7.1	4.3	7.4
Podocarpus	0.3	0.5	0.8		1.6	0.9	0.5	0.6	1.2	1.5	0.6	0.7	1.6	0.9	0.4	0.6		0.3	0.6		
Other Coniferous trees	1.8	2.6	3.9	2.2	1.8	1.7	1.8	0.3	0.9	1.2	0.9	1.1	0.3	0.9	1.5	0.6	1.6	1.2	1.6	0.6	
Myrica	0.6	0.2	0.5	0.3					0.6		0.6		0.3			0.3	0.3		0.3	0.3	
Juglans	0.8		0.5		0.9	1.4			0.6	1.2	0.6	0.8	0.3	0.3	0.7			0.3	1.0		
Pterocarya		0.5			0.3	0.3			0.6			0.4								0.3	
Salix	0.3		0.5	0.3		0.3					0.3					0.3			0.3		0.3
Alnus	1.1	1.4	0.8	0.8	0.6	1.1	3.9	1.5	0.3	0.9	0.3	1.8	0.6	0.9	0.7	0.3	0.6	0.9	1.9	0.6	1.3
Betula	0.3	0.7			0.3		0.5						0.3	0.3	0.4				0.3		0.3
Carpinus	0.6	0.5	0.8	0.3	0.3	0.3	0.3	0.3	2.2	1.2	0.9	0.4	1.3	0.6	0.4	0.3	1.3		0.3	2.2	0.6
Corylus		0.5	0.8	0.5	0.3	0.6	0.3		0.6	0.3	0.9		0.3		1.1		0.3	0.3	0.3	0.6	
"*Castanopsis*"	2.8	1.6	0.8	1.3	0.3	0.6	0.8	0.3	1.5	0.9	0.6	0.4	2.5	2.1	0.7	1.3	0.6	2.2	1.9	1.5	0.3
Fagus	1.7		0.5	0.5	0.9	0.6	0.5	0.9	0.9	0.9	0.9	2.5	1.6	0.6	0.4		1.0	0.6	1.3	0.6	1.6
Lepidobalanus	4.2	2.7	2.6	5.8	3.8	4.6	4.9	5.3	8.4	3.7	6.2	4.2	3.2	3.0	4.9	5.0	3.9	7.5	6.1	5.6	7.4
Cyclobalanopsis	19.8	15.4	17.4	18.0	15.2	10.3	11.4	15.8	13.9	14.7	22.0	19.0	18.0	25.8	20.1	16.1	12.9	15.6	18.7	24.1	22.7
Aphananthe	0.6	0.5	0.3					0.3	0.3	0.6	0.3			0.3			0.3				0.3
Celtis	0.6		0.5	0.3	0.6	0.3	0.5	0.9	0.9	0.9	0.9	0.4	0.6		0.4	0.9	0.6		0.3		
Ulmus-Zelkova	1.4	0.7	0.8	1.1	1.3	1.4	0.5	3.8	1.5	1.8	0.6	1.4	2.8	3.6	2.9	3.2	1.9	3.4	1.9	1.9	0.6
Sapium	0.3	0.2	0.5	0.3	0.9				1.2		0.6		0.6	0.6	0.7	0.9		0.9			0.3
Acer	2.0	0.9	0.5	0.8		0.6	0.3	0.3	0.6		1.2			0.6		0.6	1.3	0.6	0.3	0.9	0.6
Aesculus	0.8	0.5	0.5	0.5			1.6			0.3	0.3									0.3	
Ilex		0.2	0.3	0.3			0.5				0.6		0.3	1.3			0.3	0.6	0.3	0.3	
Fraxinus type	1.4	0.9	0.3	1.9		0.6	0.3		0.6	0.3	0.3	0.7	0.3		0.4	0.3	1.0	0.6	0.3		
Other broadleaf trees	5.3	3.8	2.9	2.6	3.3	2.9	1.0	0.3	4.2	4.5	4.2	2.0	1.8	3.4	4.4	1.5	0.9	2.1	3.1	2.1	2.4
Grass	11.9	14.5	14.1	18.8	8.5	8.6	10.3	6.8	5.3	7.3	7.1	3.3	1.8	2.1	3.1	3.1	2.8	2.8	3.4	3.4	1.9
Indeterminable	28.7	32.6	27.1	24.5	22.2	23.1	22.5	22.5	20.6	21.7	27.3	14.2	21.1	24.9	19.3	26.2	20.5	25.9	25.3	30.0	22.5
PTERIDOPHYTA	1.2	8.8	7.0	6.4	6.2	7.3	7.5	6.7	7.4	6.4	6.5	9.1	9.0	5.7	7.1	7.2	8.0	8.7	6.1	4.3	5.2
Total number of pollen grains & spores	354	441	384	378	310	348	387	342	323	327	341	284	317	333	284	317	309	320	310	323	309

Table 4–b Percentages of pollen grains and spores at the Site 3 (Hankyu Umeda Station)

Genus / depth (−m)	16.30	16.80	17.30	17.90	18.30	19.30	19.90	20.30	20.70	21.50	21.90	22.30	22.70	23.10	23.50	23.90	24.30	24.70	25.10	25.30	25.50
Abies	8.1	8.8	5.4	12.3	16.9	6.9	10.2	8.5	6.8	9.9	12.3	5.8	8.3	5.9	6.6	5.9	6.4	5.0	3.3	8.1	7.2
Picea			0.5		0.7			0.3			0.3	0.6				0.6		0.6		0.6	0.2
Pinus	7.1	10.8	7.5	13.8	14.0	6.3	10.2	14.3	7.1	8.6	7.1	11.9	7.4	5.6	5.9	6.8	5.2	9.4	4.6	8.4	8.6
Tsuga	1.6	1.7	3.0	3.1	5.9	2.3	1.9	2.9	1.4	2.9	2.3	1.9	1.8	1.6	1.7	0.8	0.9	1.2	1.0	3.0	2.0
Cryptomeria	2.9	3.4	3.5	3.1	2.0	3.3	2.2	2.9	2.4	1.3	1.6	1.9	0.6	1.6	1.4	2.0	3.5	2.4	2.3	2.4	3.7
Sciadopitys	2.6	6.4	2.7	6.0	8.1	1.7	5.2	2.3	4.7	5.1	4.8	3.2	2.2	3.1	4.2	2.8	2.0	3.8	3.6	11.1	5.3
Podocarpus	0.3			6.0	0.3		0.3	0.3							0.3	0.3			0.3	0.3	0.4
Other Coniferous trees	1.6	1.0	0.5	1.2		1.4	0.6	0.3	1.7		0.3	0.3			1.3	0.3		0.3	0.3	1.2	1.0
Myrica												0.3	0.3		0.3	0.6	0.3	0.3	0.3		0.2
Juglans	1.3			0.3	0.3	0.3			0.7	0.3		0.3	0.9		0.3		0.6	0.6		0.3	0.2
Pterocarya		0.3	0.3	0.3		0.3	0.3	0.3	0.7			0.6	0.3	0.3			1.2	0.3	1.0	1.8	0.2
Salix					0.3												0.3		0.3		
Alnus	0.6	2.4	1.1	0.6	0.7	2.0	0.6	1.0	1.4	0.3			0.6	0.9	1.0	1.1	1.2	0.6	0.7	0.3	0.8
Betula		0.3															0.6	0.3			
Carpinus	0.6	0.3	0.8		0.3	0.3	0.9	1.0	0.3	1.3	1.0	0.6	0.6	0.3	1.0	1.1	1.2	0.3	1.0	4.2	2.3
Corylus	2.3	0.3	0.8	1.3	1.3		0.9	0.7			0.6	0.6	1.2	0.3		0.3	0.6	0.3	0.7	0.3	0.4
"*Castanopsis*"	1.9	0.3	1.6	1.6	0.7	1.7		0.7	0.7	0.3	1.6	1.3	1.2	1.9	0.7	2.8		0.9	0.3		0.6
Fagus	1.9	1.7	1.9	1.3	1.6	1.0	2.8	1.6	1.7	2.6	0.6	1.0	1.2	1.6	1.4	0.8	2.0	1.2	3.3	0.3	1.0
Lepidobalanus	6.1	6.1	5.6	2.8	3.3	4.6	7.1	6.5	9.1	6.7	7.1	7.1	4.0	7.5	8.4	5.4	7.2	7.4	14.0	16.3	14.3
Cyclobalanopsis	29.0	18.9	23.9	18.9	16.0	28.1	24.7	23.5	35.8	28.1	24.2	23.2	33.8	34.2	35.7	29.7	27.7	28.3	16.0	12.7	17.6
Aphananthe	0.3	0.3	0.3				0.3	0.3			0.3	0.3	0.3		1.0	0.3	0.6		0.3		
Celtis	0.6		0.3		1.0		0.6		0.7	0.3	1.0	0.6	0.3		0.7	0.3	1.4	0.9	0.7	1.2	1.2
Ulmus-Zelkova	2.9	3.4	1.4	3.1	2.9	3.7	1.8	4.9	1.4	2.2	2.3	2.3	2.2	2.2	1.0	2.0	2.0	4.4	1.3	5.1	2.5
Sapium	0.6					2.0	0.3			0.3		1.3	1.5		0.3	0.6	0.6	0.3			
Acer		0.3	0.8		0.3	0.7	0.3			0.6			0.6	0.3		0.6		0.3	0.7	0.3	1.0
Aesculus		0.3			0.3						0.3							0.6	1.3		0.4
Ilex				0.3		0.7					0.6			0.3		1.1	0.6				
Fraxinus type	0.3		0.5	0.3		0.3	0.3				0.3	0.3		0.9	0.3			0.3		0.6	0.4
Other broadleaf trees	3.1	1.8	2.0	1.8	1.5	3.6	1.2	1.2	1.7	1.2	1.5	4.4	4.2	3.4	2.9	5.0	6.7	3.3	3.9	3.0	2.2
Grass	1.9	2.0	2.2	2.1	1.5	2.4	0.9	2.2	2.2	2.7	5.3	1.2	1.5	3.3	2.6	4.1	2.4	2.1	5.8	3.3	5.5
Indeterminahle	20.1	25.0	26.1	17.2	14.0	26.7	19.9	16.9	12.8	16.9	16.1	25.8	24.0	21.8	13.8	25.2	28.3	23.1	30.6	11.4	16.2
PTERIDOPHYTA	4.3	4.4	8.0	4.9	6.2	3.2	7.7	7.9	3.0	8.3	9.0	5.5	3.3	3.6	7.9	2.4	2.1	3.6	3.3	6.0	5.8
Total number of pollen grains & spores	310	296	372	318	307	303	324	307	296	313	310	310	325	322	286	353	346	339	307	332	511

Table 5 Percentages of pollen grains and spores at the Site 4 (Nakajima-Bridge)

Genus \ depth (−m)	7.30	7.70	8.30	9.30	9.81	11.30	11.80	12.30	13.30	13.90	14.40	14.90	15.50	15.90	16.60
Abies	6.9	3.6	2.5	3.0	4.1	3.0	2.2	2.4	3.2	2.0	3.7	11.1	9.5	7.8	11.4
Picea			0.4												0.3
Pinus	8.9	1.8	12.6	4.7	7.3	3.4	6.2	6.0	7.2	3.2	3.3	7.0	8.4	5.0	9.5
Tsuga		0.5	1.4	0.3	1.8	1.0	0.7		0.8	0.4	0.4	1.5	1.0	0.4	0.7
Cryptomeria	6.9	5.4	6.1	5.7	6.4	2.0	4.8	1.6	2.8	1.2	1.5	1.9	2.7	1.8	1.6
Sciadopitys	1.0	1.4	1.8	2.0	0.5	1.0	1.1	0.8		0.4	1.9	1.9	3.4	4.6	3.6
Podocarpus		0.9	0.4	0.3		0.5	1.1	2.0		0.4				1.1	
Myrica	4.0	2.9	1.5	2.6	3.7	2.5	4.8	3.2	4.8	6.4	2.6	0.7	0.7	0.4	
Other Coniferous trees	1.0	1.4	0.4	0.3	0.5	2.0					0.4				1.0
Juglans		0.5	0.4	1.0	0.5	0.5	0.7		0.4		0.4	0.4	0.3		0.3
Pterocarya				0.3			0.4				1.1			0.4	
Salix		0.9				0.5	0.7	1.2	1.6		0.4	0.4	0.3		
Alnus		0.9	0.7	1.0	0.5	1.0	1.8	1.2	1.2	1.2	1.9	0.7	0.3	0.7	1.6
Betula								0.8							
Carpinus	2.0	0.9	1.1	0.7	0.9	1.5	0.4	1.2	0.4	0.8	1.1	0.7	1.4	1.4	2.0
Corylus				0.7	1.8	0.5	0.4	0.4	0.4		0·7	1.1	0.7	0.4	0.7
"*Castanopsis*"			2.2	1.3	0.9	3.4	0.4	1.2	1.6	0.4	0.7	1.5	1.0	2.8	1.3
Fagus			0.4	0.3	0.9	0.5	0.4	1.2			0.4	3.7	1.0	2.5	3.3
Lepidobalanus	2.0	0.5	0.7	4.0	2.3	4.4	2.6	5.2	5.6	6.0	10.0	7.0	7.1	6.7	8.2
Cyclobalanopsis	19.8	17.8	12.9	11.8	11.5	28.6	19.0	32.9	24.1	36.3	36.7	28.9	22.0	28.0	17.6
Aphananthe		0.5	0.4	1.0		0.5	0.7	0.8	0.8	0.8	0.7	0.4		0.4	1.3
Celtis	1.0	0.5	1.4	0.4	0.5	1.5	0.7	1.6		0.4	0.7	1.1	1.4	3.2	1.3
Ulmus-Zelkova	1.0		0.7	2.0	0.5	0.5	1.1			1.6		5.2	3.4	3.5	2.6
Sapium				0.3		1.0	0.4	0.4	0.8		1.1				
Acer		2.3	0.7	2.4	0.5	2.5	0.7	0.8	1.6	0.8	0.4	0.7	0.7	0.4	
Aesculus	2.0	0.9	1.4	0.7		0.5	0.7	0.4	0.4	0.8	0.7	0.7	1.0		0.3
Ilex		0.5	0.4	0.3		0.5	0.4	0.4				0.4		1.1	
Fraxinus type		2.3		0.3	1.8			1.6	0.8	0.8	1.1	0.4			
Other broadleaf trees	1.0	6.7	2.8	6.4	4.3	6.0	6.2	5.2	4.4	1.6	5.6	2.0	1.2	1.9	2.9
Grass	19.4	11.4	14.1	9.9	14.0	6.5	7.3	3.6	6.4	2.8	4.6	3.4	8.4	6.4	10.4
Indeterminable	17.0	32.6	26.7	33.1	30.0	27.4	31.2	24.6	27.2	2.99	20.2	17.5	21.4	19.2	17.7
PTERIDOPHYTA	7.0	8.1	7.6	6.7	5.6	2.5	6.6	4.4	6.8	2.8	2.7	1.5	3.0	2.1	2.9
Total number of pollen grains & spores	101	227	278	297	218	203	273	252	249	248	270	270	296	282	306

Genus \ depth (−m)	17.30	17.80	18.30	18.80	19.30	19.80	20.30	20.80	21.30	21.80	22.30	22.80	23.10	23.90
Abies	4.1	3.7	2.1	3.1	1.5	0.9	2.3	1.5	2.2	2.5	0.5	2.7	3.1	0.9
Picea									0.4			0.4	0.4	
Pinus	14.4	6.3	6.0	7.1	7.5	6.0	7.0	5.4	15.4	10.0	6.3	7.1	7.0	5.2
Tsuga	1.4	0.4	0.9	1.4	0.4		1.4	0.5	0.4		0.5		0.4	0.9
Cryptomeria	0.7	3.0	0.9	1.7	1.5	2.8	1.4	2.0	3.1	2.1	4.1	2.2	3.5	0 9
Sciadopitys	2.4	3.0	1.7	1.7	1.9	3.2	0.9		0.4		1.4			
Podocarpus	0.7													
Myrica	0.9	1.5	0.8	1.0	1.2	2.3	1.9	1.5	1.3	0.4	0.5	1.8	1.2	0.9
Other Coniferous trees			0.9											
Juglans	0.3	0.4	0.9	0.7	0.7	0.5		0.5				0.9	0.4	
Pterocarya			0.9	1.4	0.4		1.4		1.3	0.4		1.3	1.3	
Salix			0.4	0.3		0.5	0.5	1.0						
Alnus	2.7	3.0	4.3	4.1	2.2	8.3	6.1	7.4	4.4	1.7	2.7	4.9	3.5	2.6
Betula				0.3	1.1	0.5		1.5	0.9			0.4		
Carpinus	3.4	3.3	7.3	2.7	2.6	3.4	3.1	3.9	1.8	0.8	2.7	1.3	1.8	6.0
Corylus	0.7	0.7	1.3	3.1	1.5	6.0	0.5	2.9	1.3		0.9	2.2	0.9	1.7
"*Castanopsis*"		0.7	0.4											
Fagus	1.7	1.5	2.6	3.7	1.9	0.9	2.3	1.5	2.2	2.5	0.5	0.9		
Lepidobalanus	12.4	16.0	20.5	18.3	20.1	19.4	23.5	18.6	15.8	21.3	25.7	28.3	21.5	24.1
Cyclobalanopsis	23.7	17.1	15.0	8.8	4.9	3.7	4.2	0.5	0.9	0.4	2.7	1.3		
Aphananthe		0.4	2.1		0.4									
Celtis	0.7	2.6	3.4	1.7	4.9	6.0	3.3	4.4	6.6	3.8	4.5	4.4	7.0	
Ulmus-Zelkova	4.2	3.7	6.0	3.4	5.3	1.4	2.8	3.0	1.3	1.6	3.6	1.7	3.9	2.6
Sapium	0.3	1.1				0.9	0.5			0.8				
Acer	0.7	0.7		1.7	1.9		1.4	1.0	0.9	0.8	1.8	0.4		1.7
Aesculus		1.1		0.7	0.4	0.9	1.9		0.9	0.8	1.8	1.3	0.9	
Ilex	0.7		0.9				0.5						0.4	
Fraxinus type	1.0	1.1	0.9	0.7	2.6	0.9	0.9	2.0	2.6	4.6	3.2	1.8	1.3	7.8
Other broadleaf trees	1.6	3.1	8.2	3.3	3.7	2.4	4.3	3.9	2.2	1.6	0.9	2.6	2.1	
Grass	2.2	3.4	4.6	9.7	5.3	5.6	9.0	13.3	8.1	17.1	14.1	11.4	20.0	19.2
Indeterminable	18.5	20.2	10.6	19.6	22.9	22.2	16.9	22.3	18.3	18.3	22.5	18.2	12.2	6.1
PTERIDOPHYTA	2.7	4.1	2.6	3.4	6.3	4.2	4.7	4.9	7.4	10.2	1.8	4.9	5.2	11.2
Total number of pollen grains & spores	291	269	234	295	268	217	213	204	228	239	222	226	228	116

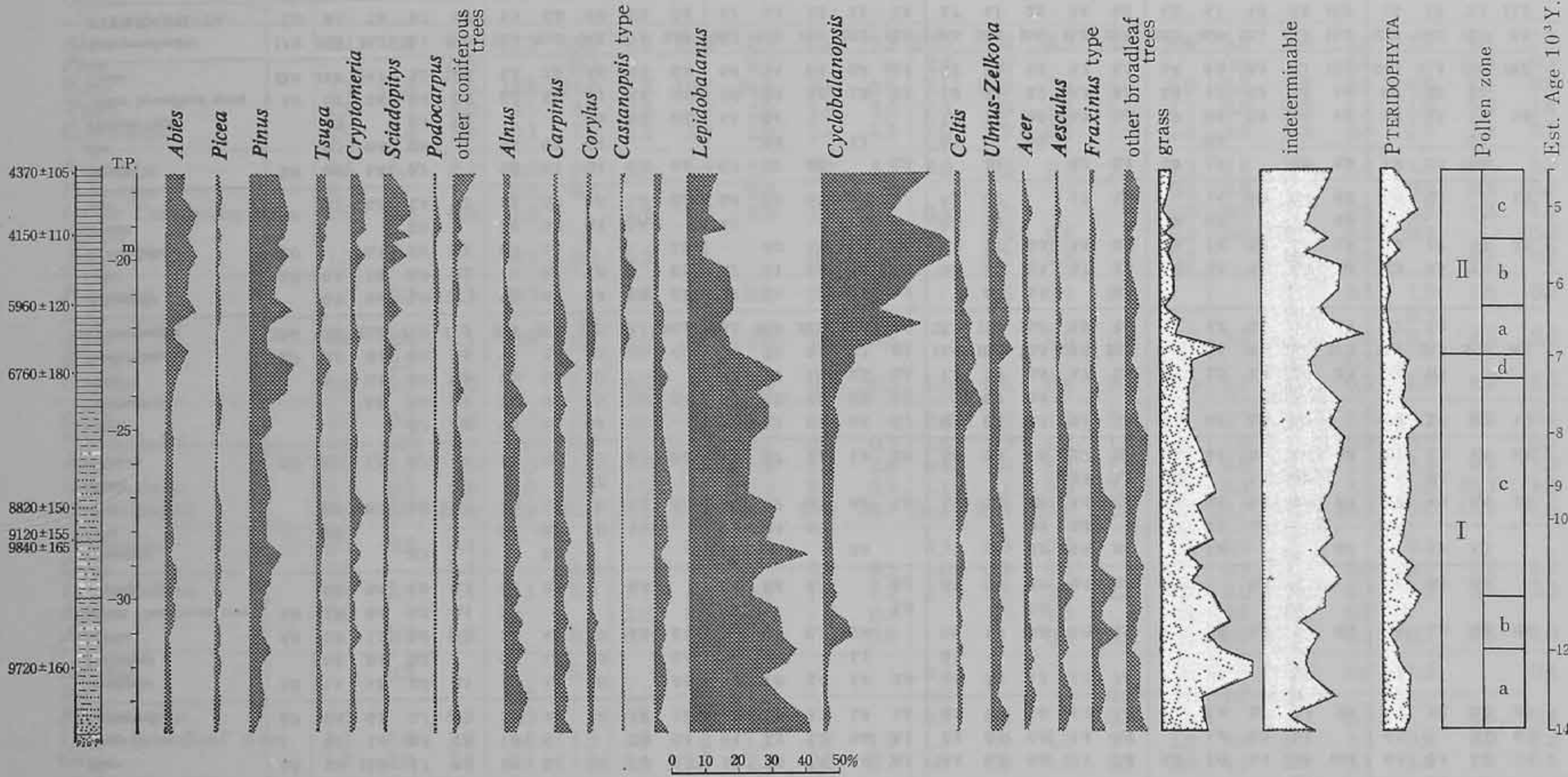


Fig. 3. Pollen-percentage diagram for Site 1 (Minato Bridge main pier No. 3).

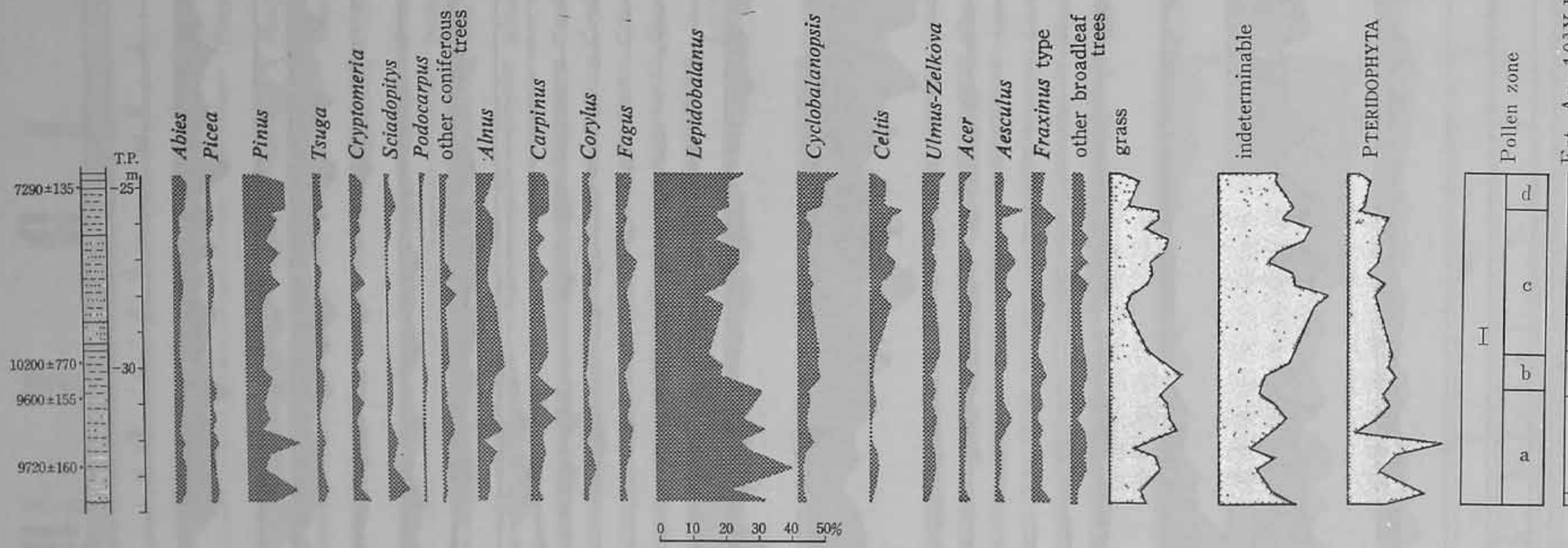


Fig. 4. Pollen-percentage diagram for Site 2 (Minato Bridge main pier No. 2).

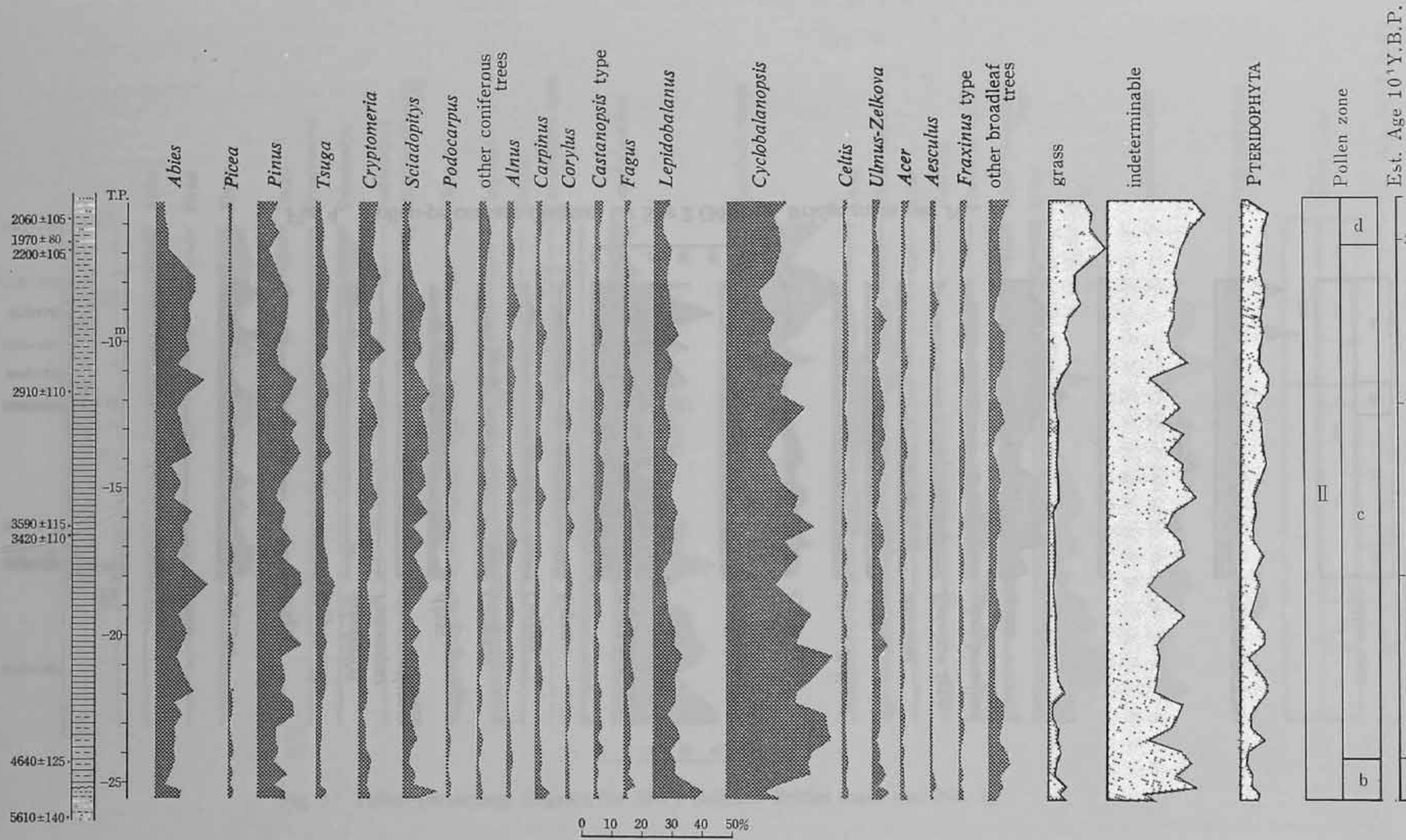


Fig. 5. Pollen-percentage diagram for Site 3 (Hankyu Umeda Station).

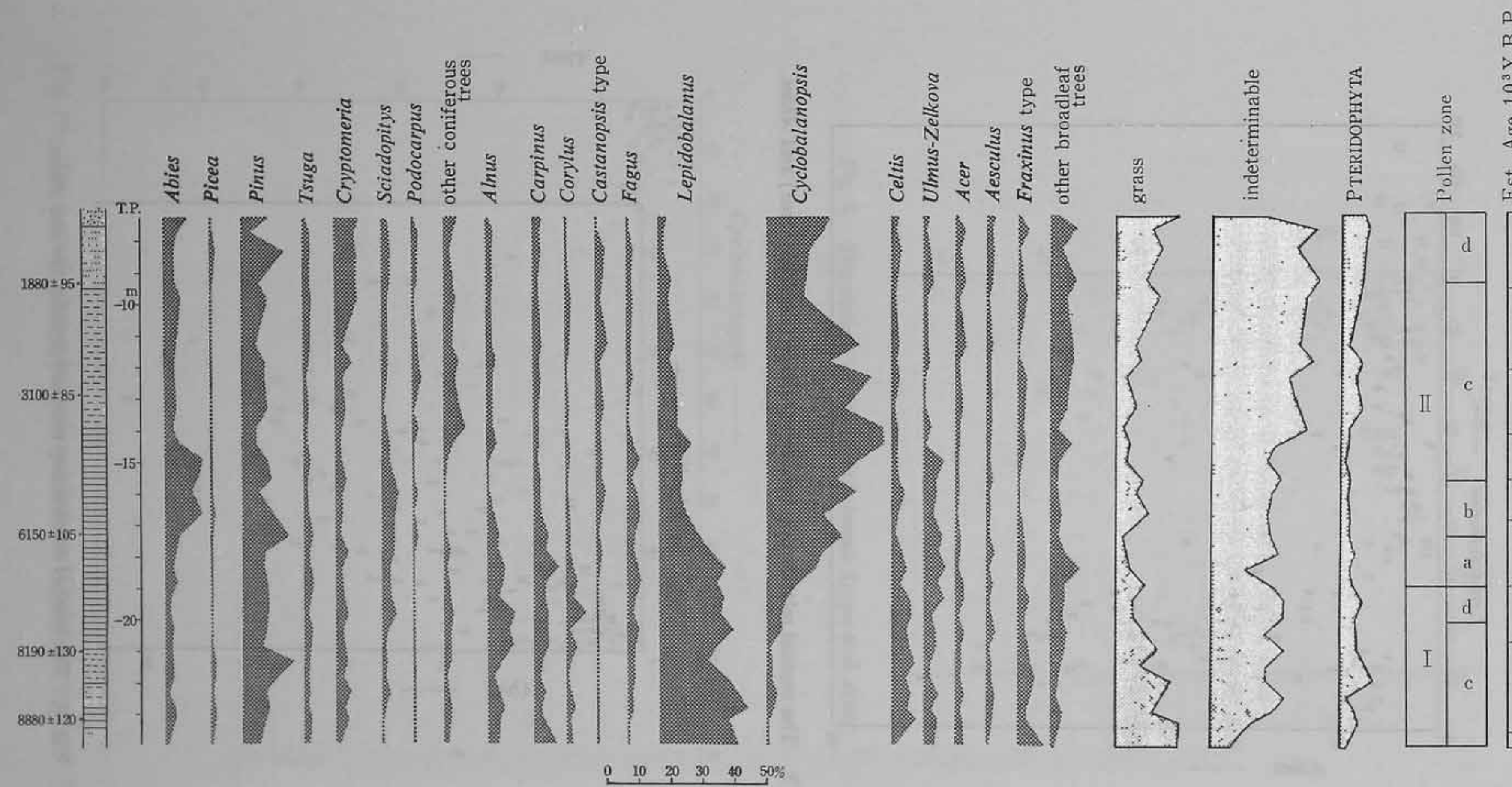


Fig. 6. Pollen-percentage diagram for Site 4 (Nakajima Bridge).

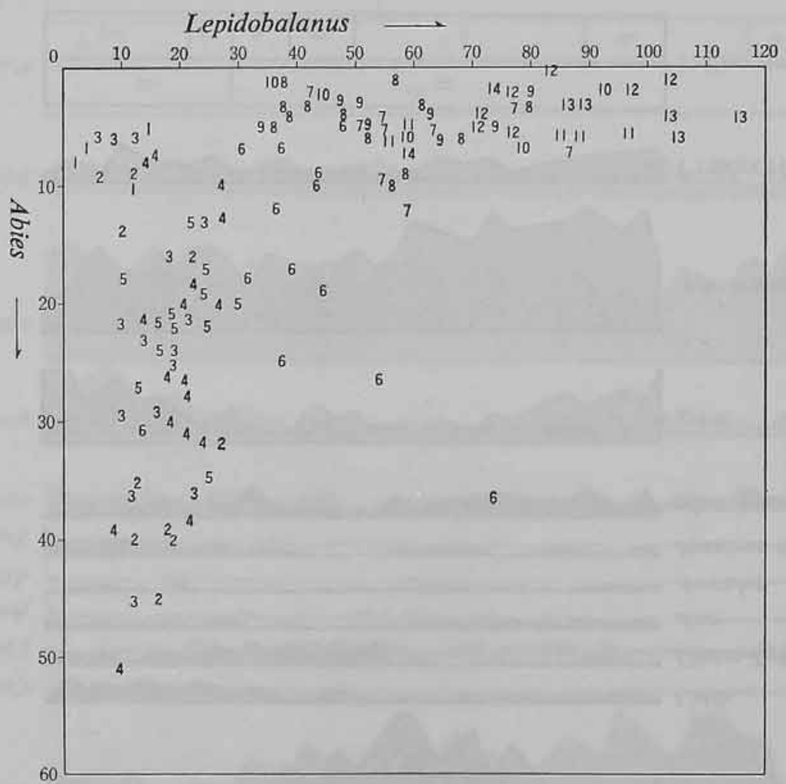


Fig. 7. The mutual relationship between *Quercus* (*Lepidobalanus*) and *Abies*.

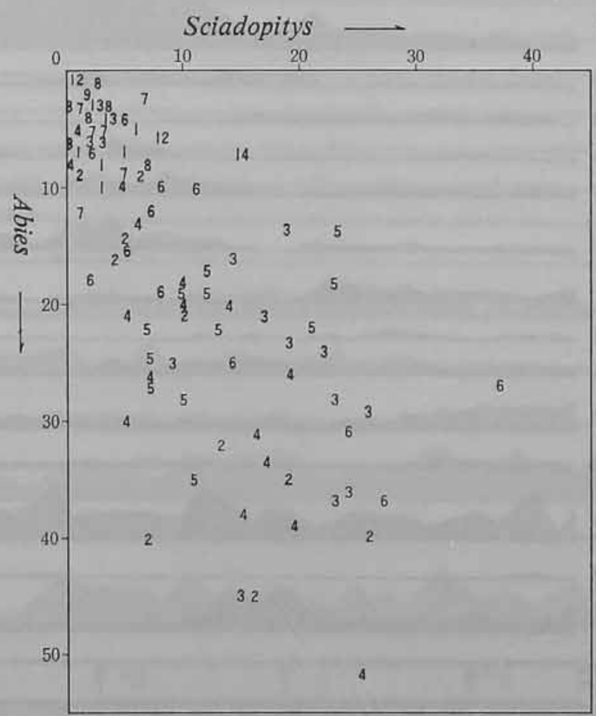


Fig. 8. The mutual relationship between *Sciadopitys* and *Abies*.

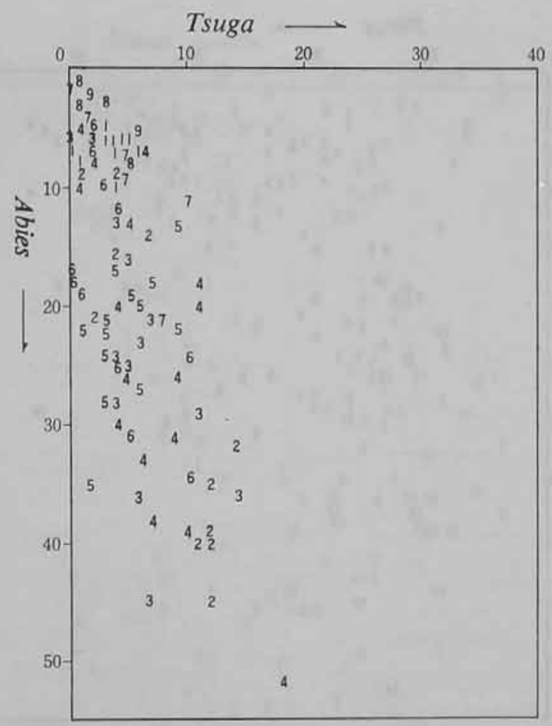


Fig. 9. The mutual relationship between *Tsuga* and *Abies*.

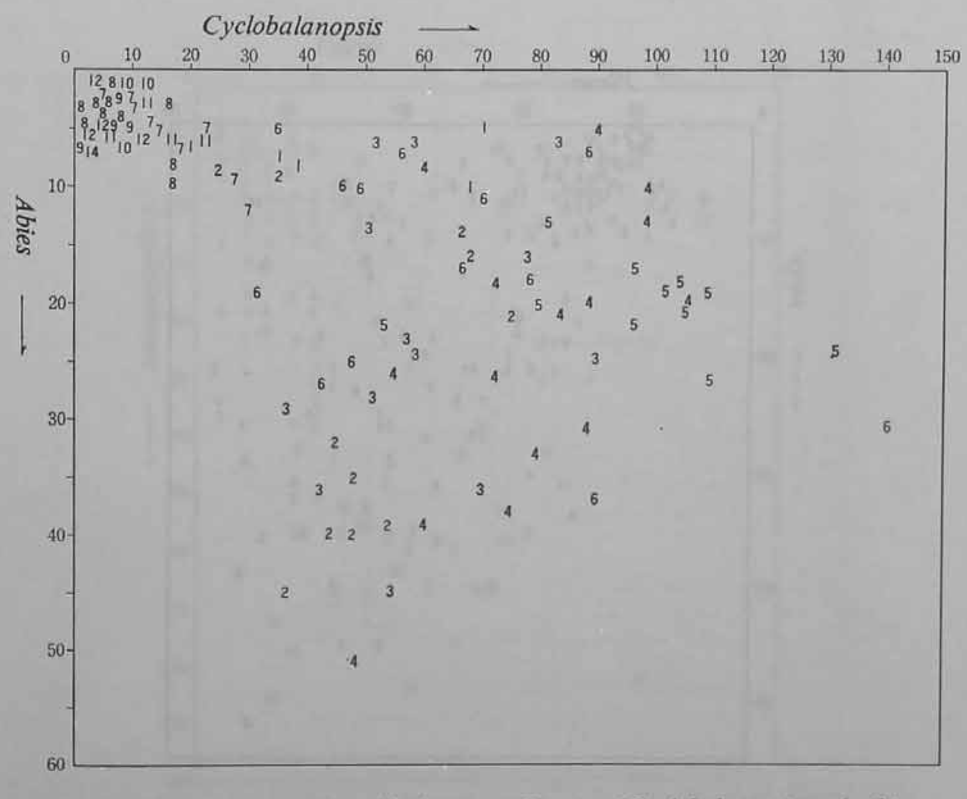


Fig. 10. The mutual relationship between *Quercus* (*Cyclobalanopsis* and *Abies*.

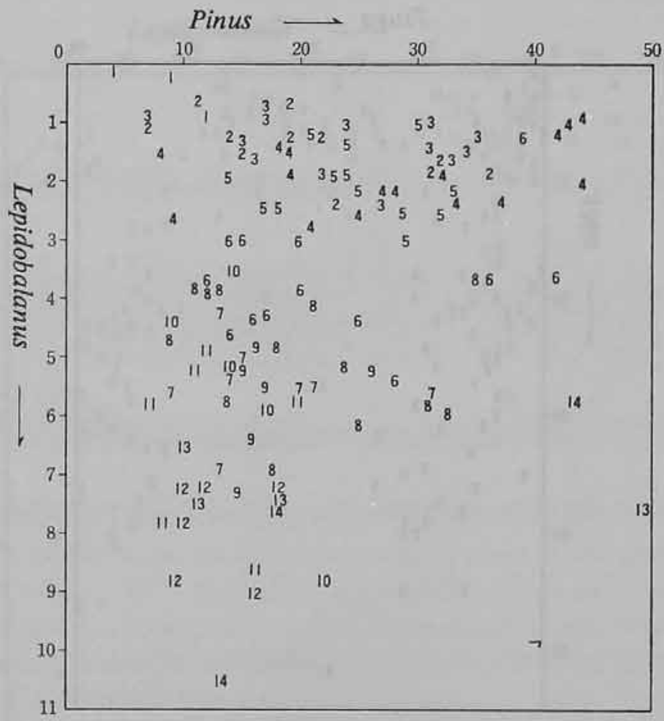


Fig. 11. The mutual relationship between *Pinus* and *Quercus* (*Lepidobalanus*).

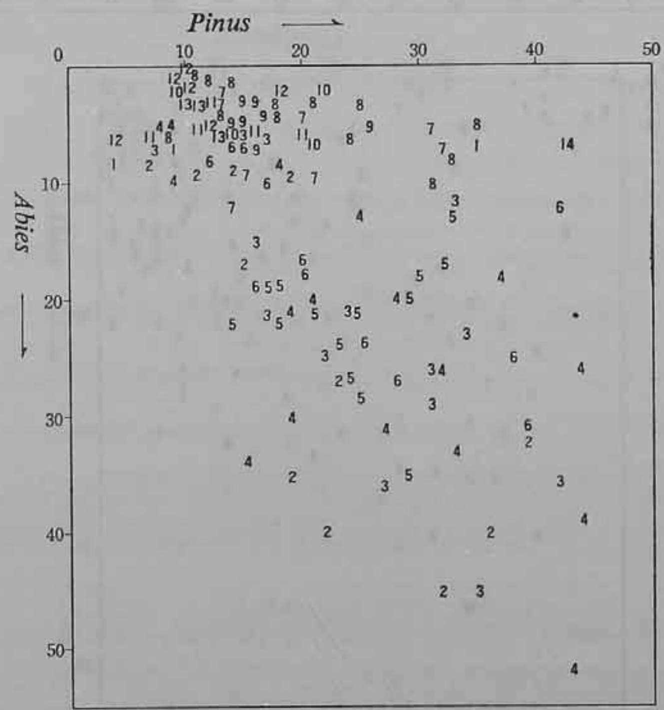


Fig. 12. The mutual relationship between *Pinus* anp *Abies*.

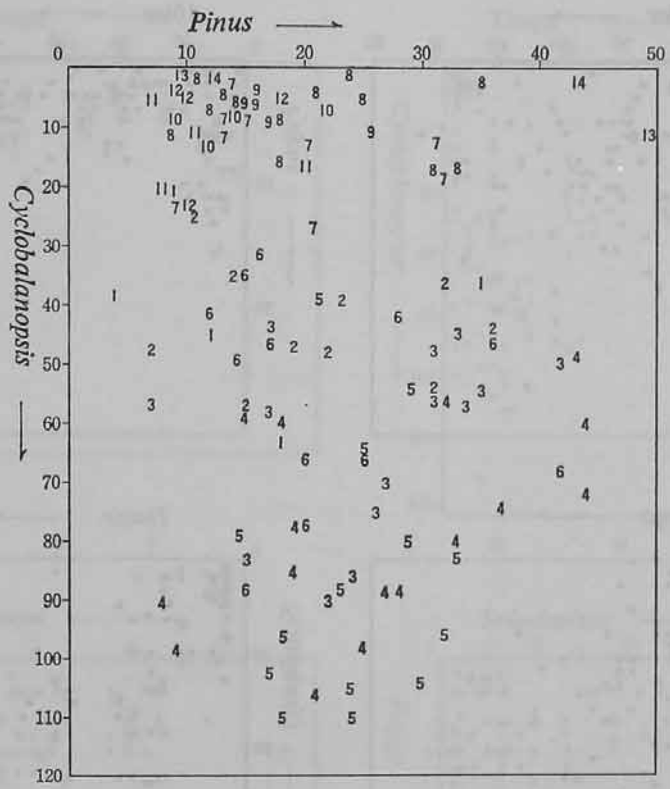


Fig. 13. The mutual relationship between *Pinus* and *Quercus* (*Cyclobalanopsis*).

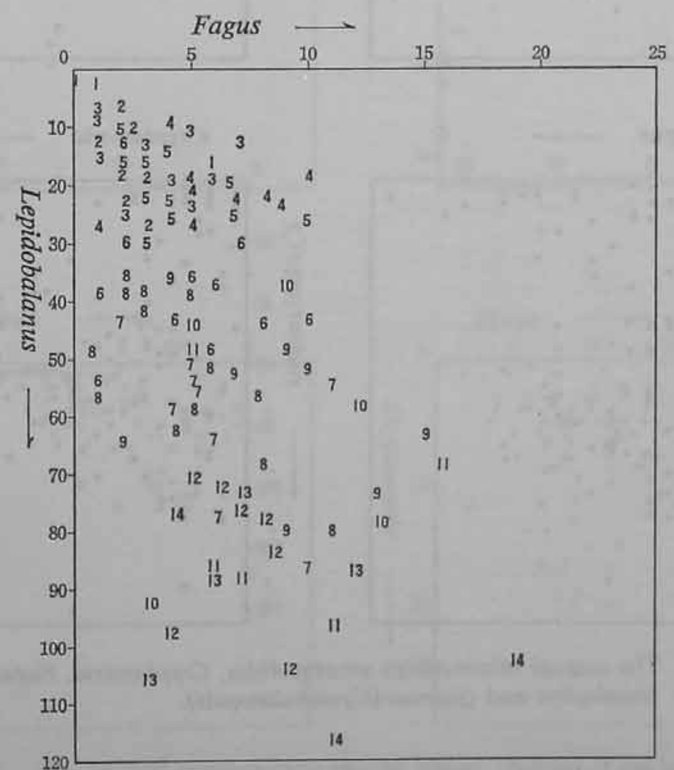


Fig. 14. The mutual relationship between *Fagus* and *Quercus* (*Lepidobalanus*).

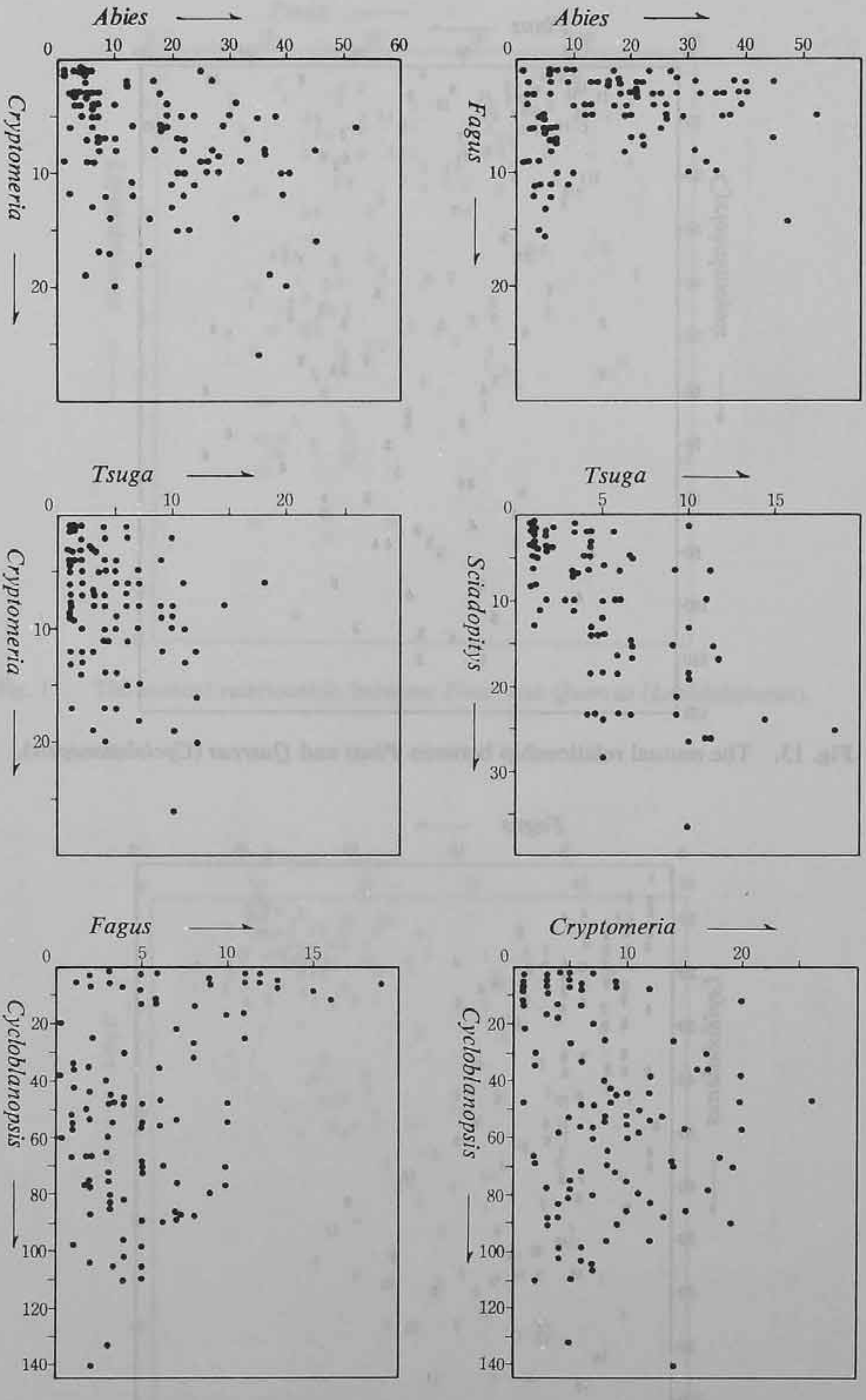


Fig. 15. The mutual relationships among *Abies*, *Cryptomeria*, *Fagus*, *Tsuga*, *Sciadopitys* and *Quercus* (*Cyclobalanopsis*).

Fig. 16. The mutual relationships among *Tsuga*, *Quercus* (*Lepidobalanus*), *Q.* (*Cyclobalanopsis*), *Fagus*, *Sciadopitys*, *Pinus* and *Cryptomeria*.

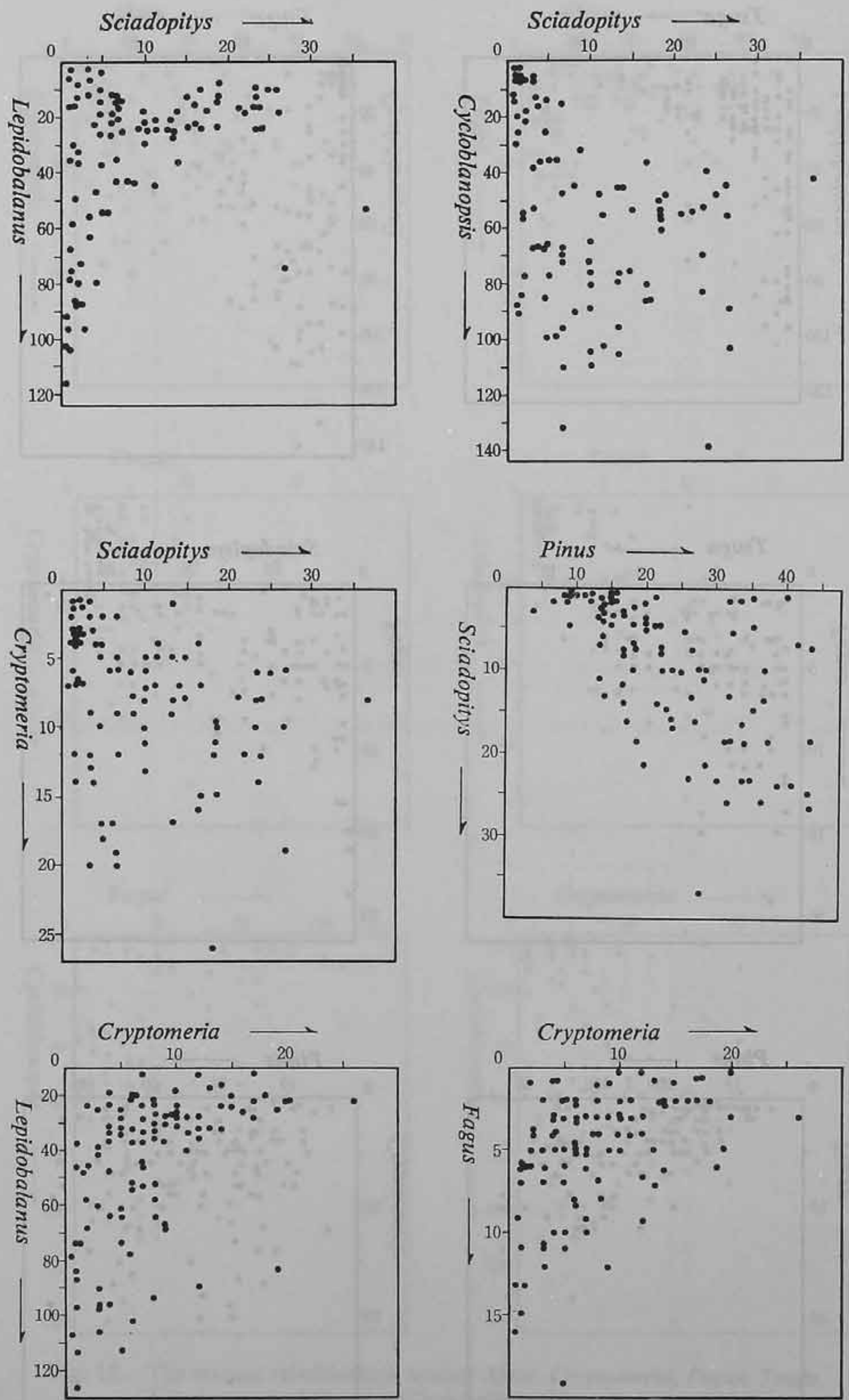
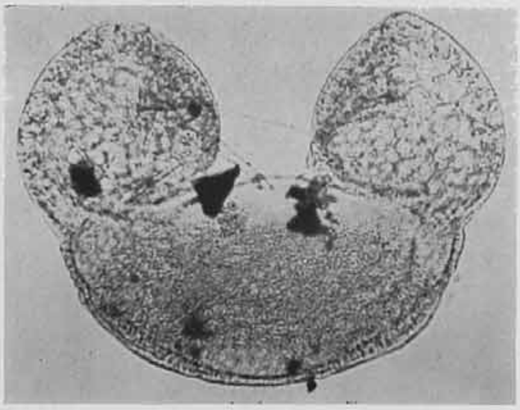


Fig. 17. The mutual relationships among *Sciadopitys*, *Quercus* (*Lepidobalanus*), *Q*. (*Cyclobalanopsis*), *Cryptomeria*, *Pinus* and *Fagus*,

Plate 1

Explanation of Plate 1

Fig. 1 *Abies* ....ca ×400
Fig. 2 *Picea* ....ca ×400
Fig. 3 *Pinus* ....ca ×600
Fig. 4 *Podocarpus* ....ca ×600
Fig. 5a, 5b *Tsuga* ....ca ×400
Fig. 6a, 6b, 6c *Sciadopitys*..........................ca ×700
Fig. 7, 8 *Cryptomeria* ....ca ×600



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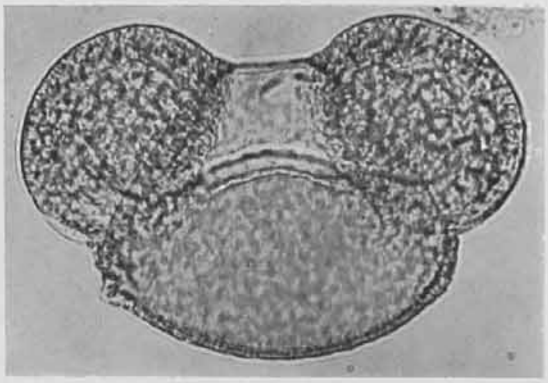

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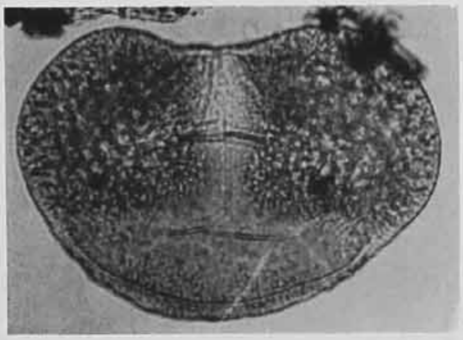

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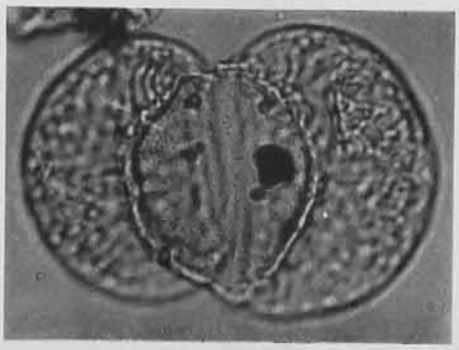

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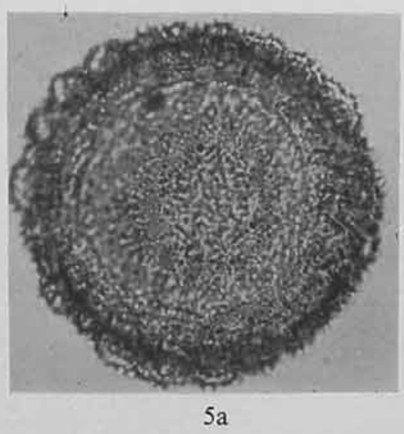
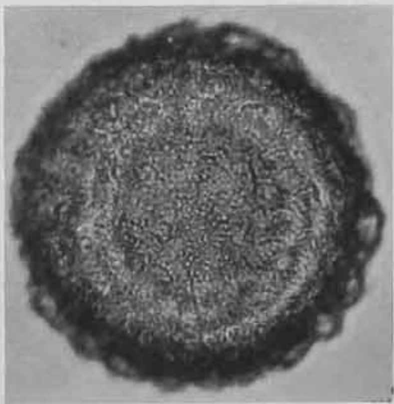
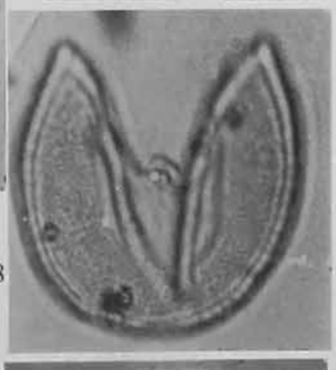


5a



5b



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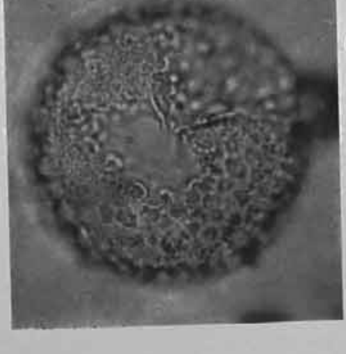
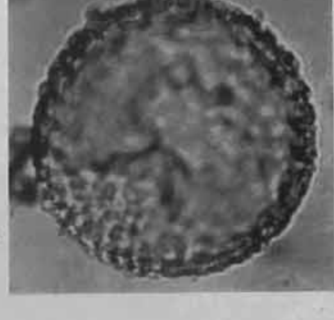


6a

6b



6c

Plate 2

Explanation of Plate 2

Fig. 1–6 *Quercus* (*Cyclobalanopsis*), "evergreen oak" type

Fig. 7–11 *Quercus* (*Lepidobalanus*), "deciduous oak" type

All specimens, ca $\times 1{,}000$


1a


1b


2a


2b

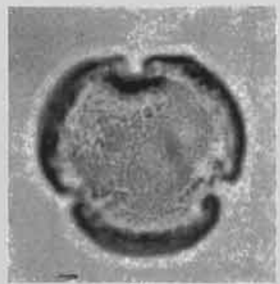

3a


3b


4a


4b


5a


5b


6a


6b


7


8


9


10


11


12

Plate 3

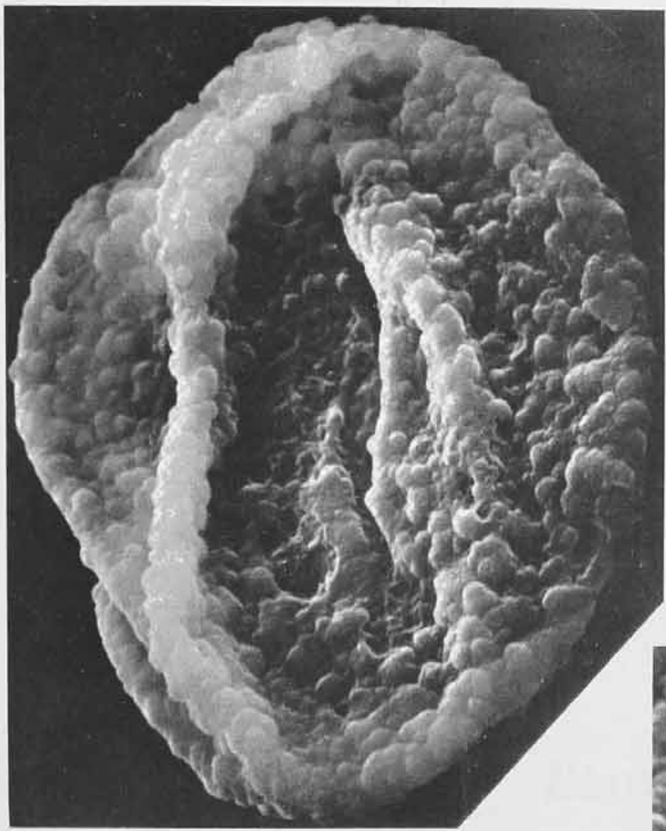
Explanation of Plate 3

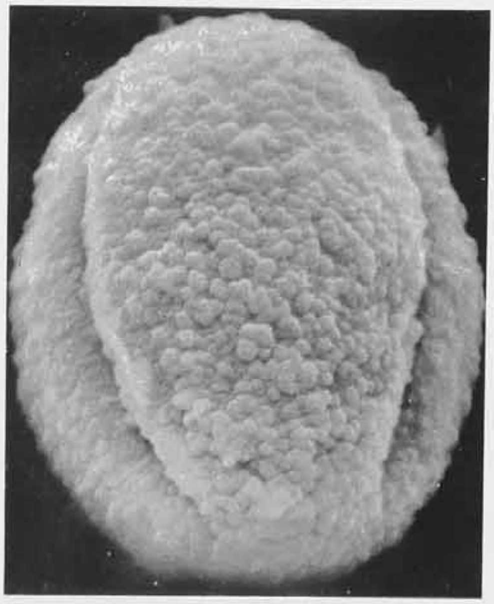
Fig. 1a, 1b *Quercus* (*Lepidobalanus*)
The fossil pollen grain; from the Osaka Bay Formation.
1a......ca ×3,000 1b......ca ×15,000

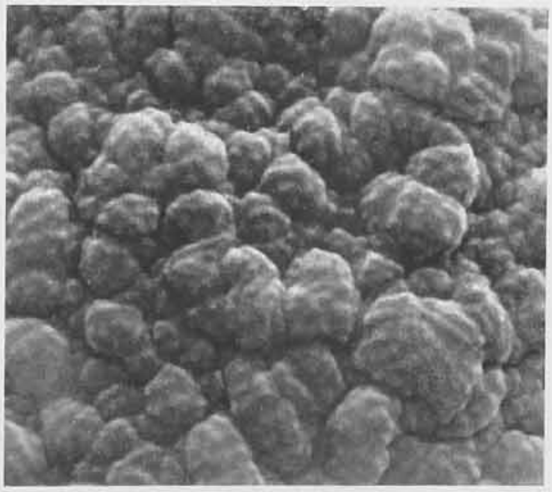
Fig. 2a, 2b *Quercus* (*Lepidobalanus*) *serrata* THUMB.
The living pollen grain
2a......ca ×2,000 2b......ca ×15,000

Photo. by K. MATSUOKA

According to YAMASAKI and TAKEOKA (1959), the surface of pollen membrane is covered all over with irregularly arranged granules, on the snrface of which are recognized fine spinules. And it was clarified that small openings are dotted here and there. The length of varrucae (varty granules) is about 0.2～0.1μ, and that of spinules about 0.1～0.2μ.


1a


2a


2b

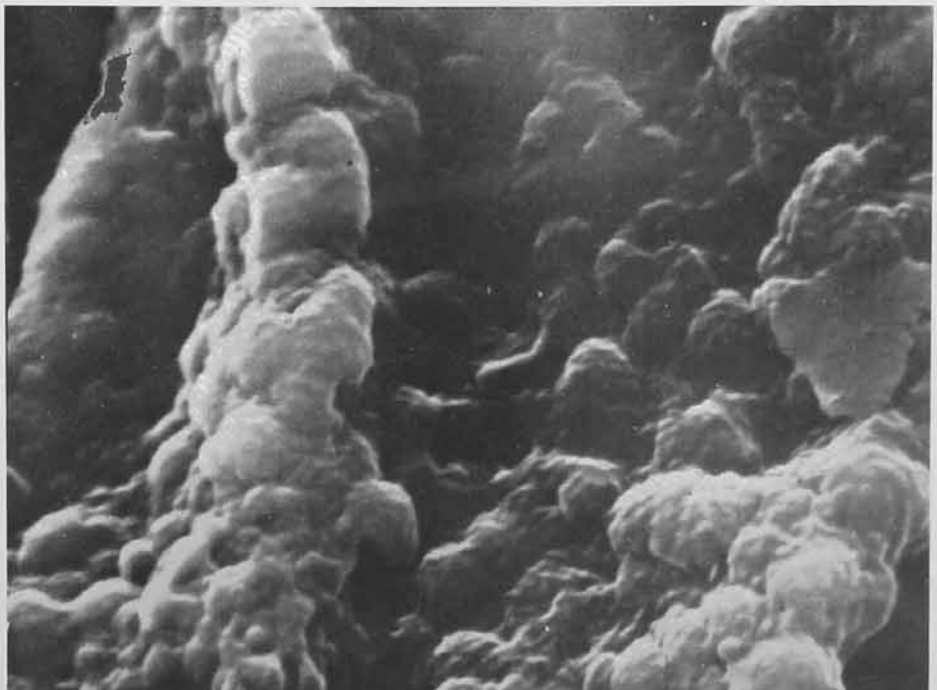

1b

Plate 4

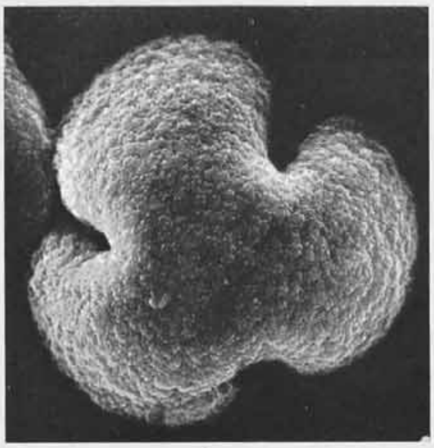
Explanation of Plate 4

Fig. 1a, 1b *Quercus* (*Cyclobalanopsis*) *glauca* THUNB.
The living pollen grain
1a……ca ×2,000, 1b……ca ×15,000

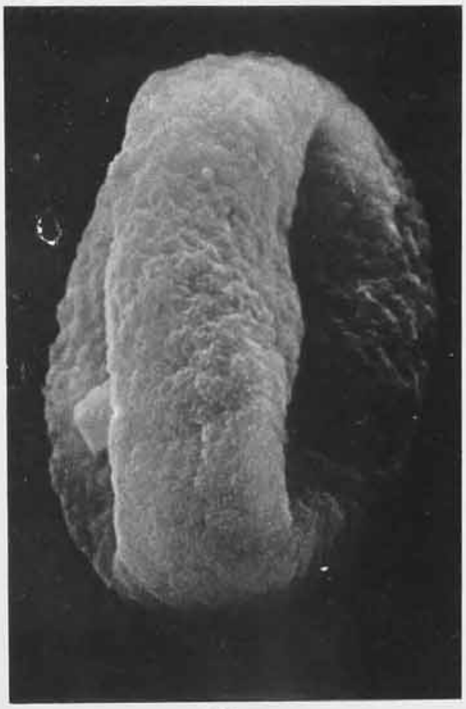
Fig. 2a, 2b *Quercus* (*Cyclobalanopsis*)
The fossil pollen grain; from the Osaka Bay Formation
2a……ca ×3,000, 2b……ca ×15,000

Photo by K. MATSUOKA

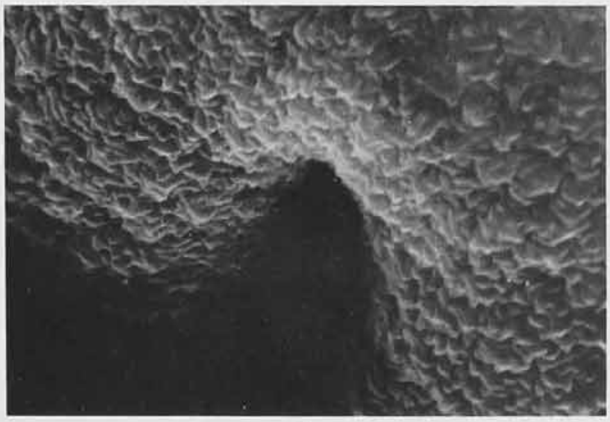
According to YAMAZAKI and TAKEOKA (1959); the surface of pollen membrane has a structure resembling the cauliflower-shape, and from the surface of its protrusions are projected fine spinules. The length of the spinules is about $0.1\sim0.3\mu$.



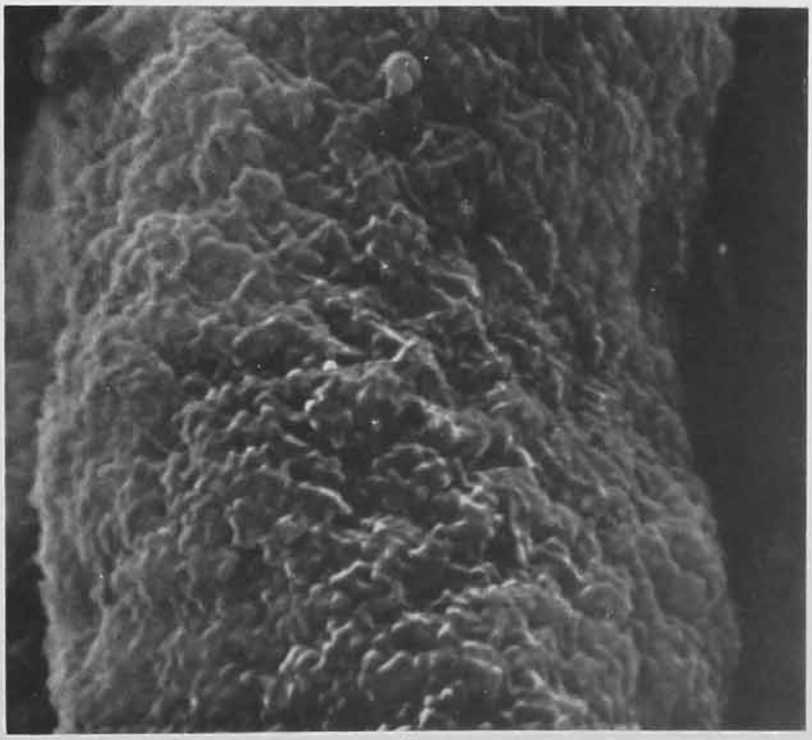
1a



2a



1b



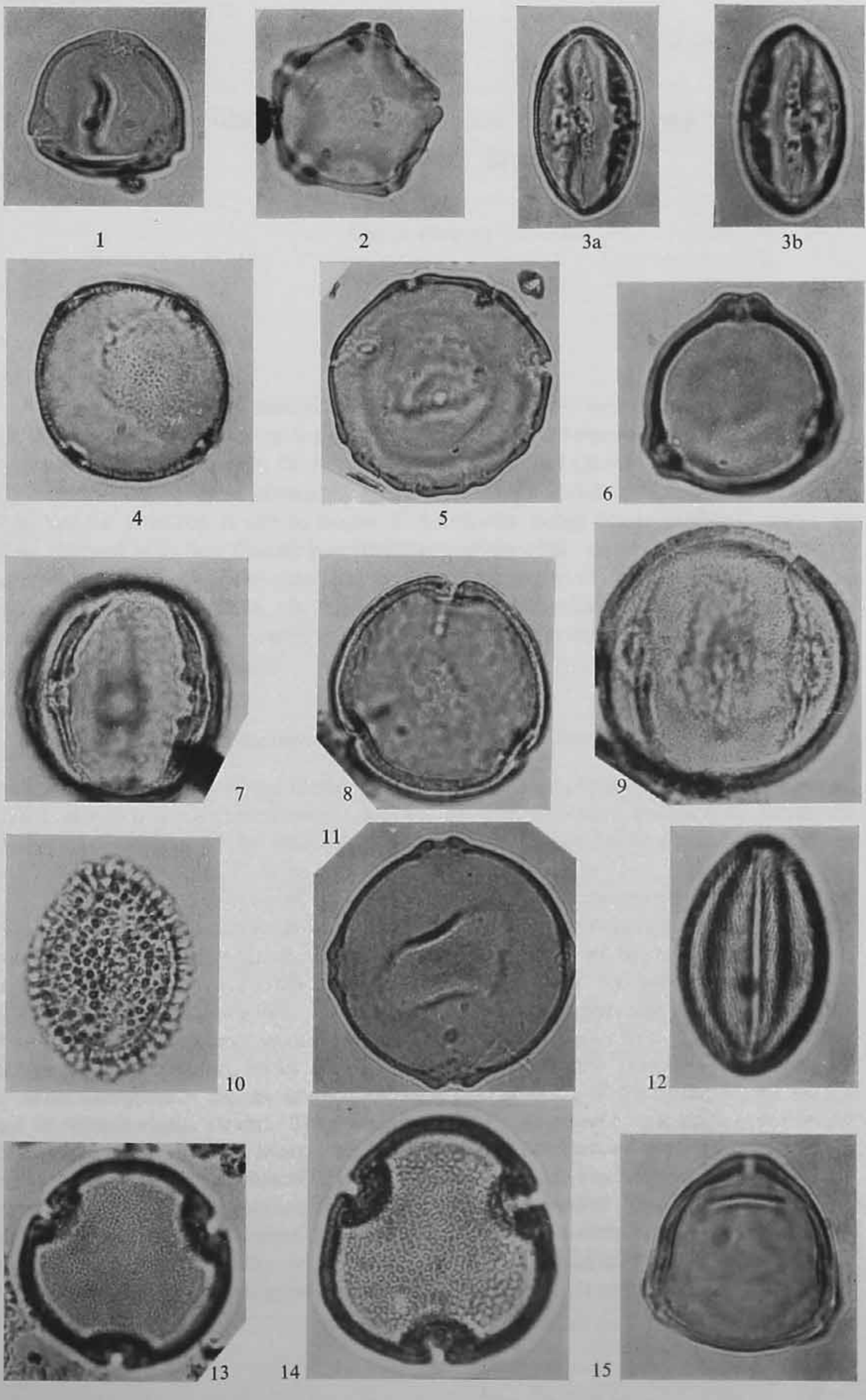
2b

Plate 5

Explanation of Plate 5

Fig. 1	*Myrica?*
Fig. 2	*Alnus*
Fig. 3a, 3b	*Aesculus*
Fig. 4	*Celtis*
Fig. 5	*Pterocarya*
Fig. 6	*Betula*
Fig. 7-9	*Fagus*
Fig. 10	*Ilex*
Fig. 11	*Carpinus*
Fig. 12	*Acer*
Fig. 13, 14	*Tilia*
Fig. 15	*Corylus*

All specimens, ca $\times 1{,}000$


1
2
3a
3b
4
5
6
7
8
9
10
11
12
13
14
15