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28. MIOCENE POLLEN STRATIGRAPHY OF LEG 127 IN THE JAPAN SEA AND COMPARISON WITH THE STANDARD NEOGENE POLLEN FLORAS OF NORTHEAST JAPAN[1]

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ABSTRACT

Pollen floras were obtained from Miocene sediments recovered at four sites drilled during Ocean Drilling Program Leg 127. The local pollen floras of each site were correlated to the standard pollen zones of northeast Japan by using the concept of the essential members for each pollen zone. At Site 797, the complete floral range was obtained for recognition of the NP2 zone and the pollen components of the NP1 zone were also clarified continuously. The ages of the boundaries between pollen zones NP4/NP3, NP3/NP2, and NP2/NP1 are estimated to be about 7 Ma, 13 Ma, and 17–18.5 Ma, respectively. Even in the same pollen zone, the ratios of major pollen taxa vary with the location. This variation is expressed on maps representing two different times during the Miocene.

INTRODUCTION

The Neogene pollen flora of northeast Japan has been summarized by this author (Yamanoi, 1989). However, the pollen floras of the early Miocene are not well known due to the lack of outcrops of this age in northeast Japan. During Ocean Drilling Program (ODP) Leg 127, drilling reached the lower Miocene sediments at all sites (794 through 797, Fig. 1). Examination for marine microfossils revealed that they occurred only a little, or were barren, in the lower Miocene sediments at each site (Tamaki, Pisciotto, Allan, et al., 1990). Therefore, pollen fossils were expected to determine the age for the lower Miocene sediments. Then, pollen analyses were carried out, with priority given to the lower samples of each hole. Though the analyses are continuing, the results obtained thus far are summarized as Miocene pollen flora.

One purpose of this study is to show whether or not the local pollen floras of each site can be correlated with the standard pollen zones of northeast Japan. The components of the essential members of specific pollen floras, plotted on ternary diagrams, are used as an effective means for the correlation of the floras. Moreover, it can be estimated that the allochthonous character of pollen grains is emphasized for their marine sediments. Therefore, how the allochthonous pollen sedimentation is expressed in different marine sites is studied.

MATERIALS AND METHODS

Approximately 100 samples of Miocene sediment were selected for pollen analyses from the four sites of Leg 127 (Fig. 1). The samples were dried and sieved through a screen (60 mesh) after powdering. All the samples were treated with KOH (10%), HF (47%), and HCl + HNO_3 (1:1), then given acetolysis treatment, and finally treated with a solution of $ZnCl_2$ (specific gravity of 2) to concentrate pollen grains. Slides were prepared for light microscope (LM) study by mounting pollen grains in glycerine jelly. The total pollen grains per gram of dry sediment was obtained by using a method of Traverse and Ginsburg (1966).

During the course of microscopic examination of each sample, 100 pollen grains were classified in order to obtain a Pinaceae (vesiculate type) pollen vs. other pollen ratio, and 200 pollen grains were identified taxonomically, with the exception of vesiculate Pinaceae pollen.

RESULTS OF POLLEN ANALYSES

Pollen stratigraphic investigations for Leg 127 have been carried out in each hole in uphole sequence. The work is still continuing, but the results obtained so far are reported here. The pollen components and total pollen grains per gram of dry sediment of each sample are summarized in Table 1. Some occurrences of pollen fossils from each hole are briefly described here in north to south succession.

Site 795

This site is located in the northern Japan Sea, nearly equidistant from the coasts of Hokkaido and Sikhote-Aline, Siberia (Fig. 1). The results of pollen analyses for this site are summarized in a diagram showing major floral components (Fig. 2). The pollen flora of this site is characterized by a high percentage of *Larix,* Taxodiaceae, and *Fagus* in many samples. Especially, Taxodiaceae occurs very abundantly from Cores 127-795A-34X to 127-795B-1R. In this zone, *Alnus* and *Artemisia* also have relative dominance, but in contrast, *Larix* is not abundant. *Pterocarya, Alnus, Carpinus,* D. (deciduous type) *Quercus,* and *Ulmus* are fairly abundant in almost all samples.

Site 796

This site is located on the Okushiri Ridge and not far from Hokkaido (Fig. 1). Major floral components of Hole 796B are shown in Figure 3. As can be seen this diagram, Taxodiaceae is dominant in many samples except for a few lower horizons. The percentage of E. (evergreen type) *Quercus* becomes higher in lower horizons and reaches its maximum value (48%) at the lowermost Sample 127-796B-32R-5, 60–62 cm. *Alnus, Carpinus, Fagus,* D. *Quercus,* and *Artemisia* are fairly abundant in many samples.

Site 794

This site is located in the northernmost Yamato Basin, approximately 175 km from the Oga Peninsula of northern Honshu (Fig. 1).

The major floral components of this site are shown in Figure 4. These flora are characterized by a high percentage of E. *Quercus.* D. *Quercus* is also fairly abundant in many horizons. The occurrence of *Carya* is high from Core 127-794B-19R downhole and *Fagus* occurrence is high from this core uphole. *Larix* is abundant locally with its highest value of 19% occurring at Sample 127-794A-30X-1, 130–132 cm.

[1] Pisciotto, K. A., Ingle, J. C., Jr., von Breymann, M. T., Barron, J., et al., 1992. *Proc. ODP, Sci. Results,* 127/128, Pt. 1: College Station, TX (Ocean Drilling Program).

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Table 1. List of pollen occurrences for each site.

Hole:	127-795A-			127-795B-									
Core, section: Interval (cm):	34X-2 135–136	35X-4 135–137	37X-1 132–134	1R-1 134–136	8R-1 54–56	9R-2 133–135	10R-2 80–82	11R-2 83–84	12R-2 80–82	13R-2 79–81	14R-2 79–81	15R-2 82–84	16R-2 122–124
Arboreal pollen													
Larix	0.5	1.0	2.5	1.5	18.5	29.0	0.5	23.0	21.0	17.0	8.5	11.5	5.0
Dacrydium	—	—	—	—	—	—	—	—	—	—	—	—	—
Metasequoia	—	2.0	2.0	3.0	0.5	0.5	0.5	—	1.0	0.5	2.0	1.5	1.5
Taxodiaceae	42.5	32.0	43.0	31.5	15.5	14.5	38.5	13.5	20.0	2.5	11.0	12.0	11.5
Sciadopitys	—	—	—	—	—	—	—	—	—	—	—	—	—
Cunninghamia	—	—	—	—	—	—	—	—	—	—	—	—	—
Cupressaceae	—	—	—	—	1.0	1.5	—	—	0.5	1.0	1.5	—	—
Ephedra	—	0.5	—	—	1.0	1.0	0.5	—	—	0.5	0.5	—	—
Ginkgo	—	—	—	—	—	—	—	—	—	—	—	—	—
Sarix	0.5	—	—	—	—	—	—	—	—	—	—	—	—
Myrica	—	—	—	—	—	—	—	—	—	—	0.5	—	—
Juglans	0.5	0.5	0.5	—	1.0	—	—	0.5	—	—	—	—	1.5
Pterocarya	4.0	4.0	3.0	3.0	7.0	6.0	5.5	5.5	17.0	1.5	4.0	5.5	9.0
Carya	3.0	1.5	2.0	0.5	1.5	6.0	4.0	4.5	3.0	6.5	4.5	2.5	4.0
Engelhardia	—	0.5	—	2.5	1.5	1.5	1.0	0.5	—	1.0	1.0	2.0	3.0
Alnus	7.0	14.5	12.5	11.0	3.0	3.5	7.5	6.0	4.5	6.5	12.5	9.0	7.0
Betula	4.5	4.5	1.5	2.0	3.5	1.0	—	3.0	4.0	0.5	2.0	3.0	2.0
Carpinus	1.0	3.0	4.0	1.5	11.0	6.0	5.5	3.0	8.0	14.5	7.0	7.0	8.0
Corylus	3.0	3.0	1.0	1.0	2.0	—	1.5	3.5	3.5	1.5	1.0	2.0	1.5
Castanea	—	—	—	—	0.5	2.0	2.5	1.0	1.0	0.5	—	0.5	1.5
Fagus	15.5	21.0	9.0	18.0	11.5	8.5	12.5	14.5	4.0	22.0	21.5	21.5	21.0
Pasania	—	—	—	—	0.5	—	—	1.0	0.5	—	1.0	0.5	1.0
E. *Quercus*	—	1.0	—	—	1.5	2.0	4.5	1.0	1.0	2.0	0.5	4.0	4.5
D. *Quercus*	2.0	2.0	1.5	5.0	6.5	6.5	8.0	8.0	4.0	11.0	11.5	10.5	8.5
Ulmus	1.0	2.0	2.5	3.5	8.0	6.5	4.5	4.5	3.0	6.5	4.0	3.0	3.5
Zelkova	2.0	0.5	0.5	3.0	0.5	1.5	1.5	1.0	—	1.5	0.5	1.0	4.0
Celtys	—	—	—	—	—	—	—	—	—	—	—	—	—
Eurya	—	—	—	—	—	—	—	—	—	—	—	—	—
Liquidambar	—	—	0.5	0.5	0.5	0.5	1.0	—	—	—	—	—	0.5
Sapium	—	—	—	—	—	—	—	—	—	—	—	—	—
Rhus	—	—	0.5	—	—	—	—	—	—	—	—	—	—
Acer	0.5	0.5	1.0	—	1.0	0.5	0.5	—	—	—	—	1.0	—
Aesculus	0.5	—	—	—	—	—	—	—	—	—	—	—	0.5
Ilex	—	—	—	—	—	—	—	—	—	—	—	—	—
Tilia	1.5	0.5	—	2.0	1.5	1.5	—	2.0	1.0	1.0	1.0	0.5	—
Elaeagnus	—	—	—	—	—	—	—	—	—	—	—	—	—
Lagerstroemia	—	—	—	—	—	—	—	—	—	—	—	—	—
Alangium	—	—	—	—	—	—	—	—	—	—	—	—	—
Nyssa	—	—	—	—	—	—	—	—	—	—	—	—	—
Ericaceae	—	—	—	—	—	—	—	—	1.0	0.5	3.0	—	—
Symplocos	—	—	—	—	—	—	—	—	—	—	—	—	—
Ligustrum	—	—	—	—	—	—	—	—	—	—	—	—	—
Weigela	—	—	—	—	—	—	—	—	—	0.5	—	—	—
Non-arboreal pollen													
Persicaria	—	—	—	—	—	—	—	—	—	—	—	0.5	—
Chenopodiaceae	1.0	0.5	1.0	1.0	0.5	—	—	0.5	—	0.5	1.0	0.5	0.5
Caryophyllaceae	—	—	1.0	—	—	—	—	—	—	—	—	—	—
Ranunculaceae	—	—	—	—	—	—	—	—	—	—	—	—	—
Trapa	—	—	—	—	—	—	—	—	—	—	—	—	—
Patrinia	—	—	—	—	—	—	—	—	—	—	—	—	—
Artemisia	9.0	3.5	9.5	9.0	0.5	—	—	2.0	2.0	—	—	—	—
Carduoideae	0.5	—	0.5	0.5	—	—	—	0.5	—	0.5	—	—	—
Cichorioideae	—	—	0.5	—	—	—	—	—	—	—	—	—	0.5
Gramineae	—	1.0	—	—	—	—	—	1.0	—	—	—	0.5	—
Sparganium	—	0.5	—	—	—	—	—	—	—	—	—	—	—
Cyperaceae	—	—	—	—	—	—	—	—	—	—	—	—	—
Fupingopollenites	—	—	—	—	—	—	—	—	—	—	—	—	—
(Total = 100.0%)													
Assemblage of 100 grains													
Abies	3	2	1	4	—	4	3	2	3	3	—	—	—
Picea	35	51	45	30	50	61	16	54	50	38	42	27	29
Pinus	21	13	14	28	22	9	13	18	20	19	11	23	15
Tsuga	6	15	8	12	11	20	14	11	8	28	28	27	16
Others	35	19	32	26	17	6	54	15	19	12	19	23	40
Total pollen grains per gram of sediment	6240	3030	4150	15,040	5200	9160	2500	5710	11,390	5090	2550	4570	8600

Table 1 (continued).

127-795B-															
17R-1 138–140	18R-2 134–136	19R-2 134–135	20R-1 131–133	21R-2 132–134	22R-3 50–52	23R-3 49–51	24R-4 39–41	25R-5 41–43	26R-4 88–90	27R-2 109–111	28R-3 114–115	29R-3 135–137	30R-3 130–132	31R-3 126–128	32R-3 125–127
—	8.5	5.5	0.5	11.0	11.5	10.0	4.0	14.5	—	9.5	8.5	3.5	8.0	4.5	6.0
1.5	—	—	—	—	—	—	—	—	5.0	—	—	—	—	—	—
2.5	0.5	4.0	2.0	0.5	2.0	5.5	2.5	1.0	1.5	5.0	1.0	1.5	2.0	—	1.0
14.0	17.5	16.5	27.5	11.0	15.5	29.0	24.5	13.0	14.5	7.0	9.0	11.5	8.0	11.0	0.5
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	1.0	0.5	—	1.0	2.0	0.5	0.5	—	1.0	1.5	1.0	1.0	1.0	2.0	0.5
1.0	1.0	—	—	0.5	—	0.5	—	—	—	1.0	1.5	1.0	—	—	0.5
—	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	0.5	—	—	—	1.0	—	—	—	—	—	—	—	—	—	—
1.5	—	—	—	1.5	1.5	—	0.5	—	1.0	1.5	1.5	—	—	0.5	0.5
8.5	1.5	2.0	2.0	4.0	5.5	2.5	1.5	4.0	1.0	1.0	5.0	5.5	8.5	6.0	7.5
8.0	3.0	4.5	2.0	3.0	6.5	3.0	3.5	5.5	4.0	5.5	8.0	5.0	6.0	10.0	8.5
1.0	0.5	1.5	1.5	2.0	1.5	5.0	0.5	4.0	3.5	4.5	3.5	2.0	2.0	10.0	2.5
6.0	10.0	8.0	7.0	6.5	4.0	6.0	7.5	9.0	—	4.0	9.0	6.5	7.5	3.5	3.0
1.5	3.5	4.0	3.5	3.0	3.0	1.5	0.5	1.5	5.5	1.5	4.0	2.5	3.0	5.0	1.0
7.0	6.0	3.0	5.5	8.5	3.0	2.0	1.0	1.5	2.0	3.5	4.5	5.5	1.0	4.0	2.5
1.5	0.5	1.0	1.0	0.5	0.5	—	2.0	—	0.5	—	0.5	1.5	1.5	0.5	3.0
—	1.5	1.0	—	2.0	—	—	2.0	—	—	0.5	—	0.5	1.0	0.5	—
18.5	25.0	29.5	29.5	16.5	22.5	18.5	24.5	34.5	42.0	38.0	27.0	33.5	35.0	28.0	43.0
1.0	—	1.0	—	0.5	0.5	—	1.5	—	0.5	—	0.5	—	0.5	—	—
6.5	3.5	6.0	4.5	7.5	6.0	2.0	7.0	2.0	2.5	2.0	1.5	3.5	3.5	3.5	5.0
10.0	8.0	6.5	3.5	12.5	4.0	6.0	9.0	2.5	6.0	7.5	5.5	5.5	5.5	4.0	7.0
6.5	3.0	3.0	4.5	5.0	5.5	4.5	4.5	4.0	6.0	1.5	4.5	3.0	2.0	4.0	2.0
—	1.0	—	2.0	1.5	1.5	1.0	2.5	—	1.0	3.0	1.5	4.0	3.0	1.0	1.0
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	0.5	—	—	0.5	—	—	0.5	0.5	—	0.5	1.0	—	1.5
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0.5	1.0	0.5	0.5	0.5	0.5	0.5	—	1.0	—	0.5	2.0	0.5	—	—	0.5
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1.5	0.5	0.5	0.5	1.0	0.5	1.0	—	1.0	1.0	0.5	—	2.0	—	1.0	0.5
—	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1.0	0.5	1.0	1.0	—	1.0	—	0.5	0.5	—	—	0.5	—	—	1.0	1.5
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	0.5	—	1.0	—	—	0.5	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	0.5	—	—	—	—	—	—	1.0
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0.5	—	—	—	—	0.5	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	1.0	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	0.5	—	—	—	—	—	—	—	0.5	—	—	—	—	—
3	2	2	2	—	3	3	—	—	—	—	—	—	2	—	—
35	52	49	22	34	47	39	28	30	61	33	36	43	26	46	51
6	12	9	7	18	10	5	16	20	6	12	19	9	17	9	15
23	19	27	17	19	31	40	19	27	28	24	26	36	24	22	18
33	15	13	52	29	9	13	37	23	5	31	19	12	31	23	16
11,110	8640	5820	940	4220	6020	11,570	2310	1340	4400	4890	3880	7250	10,190	6483	3930

Table 1 (continued).

Hole:	125-795B-	127-796B-												
Core, section: Interval (cm):	33R-2 112–114	10R-1 68–70	11R-1 108–110	12R-2 95–97	14R-1 53–55	15R-2 42–44	17R-CC 6–8	18R-1 123–125	19R-1 133–135	20R-1 29–31	21R-1 81–83	22R-1 62–64	26R-1 72–74	27R-1 98–100
Arboreal pollen														
Larix	14.0	1.0	—	3.0	2.0	1.0	2.5	4.0	2.0	4.5	2.5	1.0	—	2.5
Dacrydium	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Metasequoia	1.5	4.5	2.0	2.0	5.5	6.0	8.0	2.5	0.5	3.0	1.5	6.0	1.5	1.5
Taxodiaceae	2.0	22.5	38.5	32.5	32.0	36.5	41.5	33.0	30.5	24.5	19.0	24.5	48.5	46.0
Sciadopitys	—	—	—	0.5	2.0	2.0	—	2.0	1.0	—	—	—	—	—
Cunninghamia	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—
Cupressaceae	—	—	—	—	1.0	0.5	—	—	—	—	—	—	—	—
Ephedra	0.5	1.0	0.5	—	—	1.5	1.0	—	1.5	—	—	1.0	0.5	1.0
Ginkgo	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sarix	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Myrica	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Juglans	—	—	—	—	—	—	—	—	—	0.5	1.5	—	—	—
Pterocarya	3.5	3.0	4.5	1.5	5.5	3.5	3.5	2.0	2.0	3.0	5.5	3.0	4.5	2.0
Carya	7.0	0.5	0.5	3.0	5.0	2.5	1.0	1.0	5.5	9.0	9.0	4.5	3.0	3.0
Engelhardia	1.5	—	0.5	1.0	1.0	—	1.5	0.5	0.5	1.0	0.5	2.0	—	1.5
Alnus	1.5	13.5	10.5	11.0	6.5	4.5	4.0	11.5	3.0	3.5	4.5	6.0	5.5	6.0
Betula	2.5	2.0	1.5	3.5	2.5	3.0	3.5	4.0	4.5	3.5	3.5	—	4.0	1.5
Carpinus	4.0	6.5	5.5	4.0	4.0	6.0	2.5	6.0	4.0	6.0	4.5	6.5	2.5	3.0
Corylus	0.5	1.5	1.5	2.5	1.5	1.0	1.0	2.5	1.5	1.5	2.0	3.5	2.0	0.5
Castanea	0.5	0.5	0.5	—	—	—	0.5	—	3.0	0.5	1.0	0.5	—	0.5
Fagus	32.0	19.5	16.5	16.0	7.0	6.5	9.0	14.0	10.5	9.0	10.0	11.5	9.5	4.5
Pasania	4.5	—	—	—	1.0	—	—	—	3.5	0.5	2.5	—	1.0	0.5
E. *Quercus*	9.0	4.0	1.5	0.5	3.5	3.0	3.5	4.0	7.5	9.5	6.0	7.5	4.0	6.0
D. *Quercus*	6.5	2.0	4.5	3.0	4.5	4.5	3.5	2.5	4.5	5.0	10.5	8.5	7.0	6.0
Ulmus	2.5	1.0	0.5	2.5	2.0	—	2.0	0.5	2.0	2.5	1.0	4.0	1.5	3.0
Zelkova	2.0	5.0	1.5	—	2.0	2.5	1.0	2.0	2.0	3.5	2.0	1.0	1.0	2.0
Celtys	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Eurya	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Liquidambar	2.0	—	—	2.5	0.5	—	0.5	0.5	0.5	2.0	0.5	—	—	—
Sapium	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rhus	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Acer	1.5	—	0.5	—	—	0.5	—	0.5	1.0	—	—	—	—	—
Aesculus	—	0.5	—	—	—	—	—	—	0.5	—	—	0.5	—	0.5
Ilex	—	—	—	—	—	—	—	0.5	—	—	—	—	—	—
Tilia	0.5	1.5	1.5	1.5	2.5	2.0	0.5	2.0	2.0	—	3.5	1.0	0.5	0.5
Elaeagnus	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lagerstroemia	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Alangium	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nyssa	—	—	0.5	—	1.0	—	0.5	—	—	—	—	—	—	0.5
Ericaceae	—	—	1.0	—	—	—	—	—	—	0.5	—	—	—	0.5
Symplocos	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ligustrum	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Weigela	—	0.5	—	0.5	—	—	—	—	—	—	—	—	—	—
Non-arboreal pollen														
Persicaria	—	0.5	0.5	—	—	—	—	—	1.0	—	—	—	—	—
Chenopodiaceae	—	1.0	0.5	1.0	1.5	2.5	1.0	0.5	1.5	1.0	3.0	4.0	1.0	1.5
Caryophyllaceae	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ranunculaceae	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Trapa	—	—	—	—	0.5	—	—	0.5	—	—	—	—	—	—
Patrinia	—	—	—	—	—	0.5	—	—	—	—	—	—	—	—
Artemisia	—	7.5	4.0	6.0	4.0	8.0	6.5	3.0	3.5	5.5	6.0	3.5	2.5	4.5
Carduoideae	—	—	—	1.5	—	2.0	1.0	0.5	0.5	0.5	—	—	—	—
Cichorioideae	—	—	—	—	1.5	—	—	—	—	—	—	—	—	—
Gramineae	—	0.5	1.0	—	—	—	0.5	—	—	—	—	—	—	1.0
Sparganium	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cyperaceae	—	—	—	0.5	—	—	—	—	—	—	—	—	—	—
Fupingopollenites	—	—	—	—	—	—	—	—	—	—	—	—	—	—
(Total = 100.0%)														
Assemblage of 100 grains														
Abies	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Picea	44	59	59	47	52	58	70	60	45	60	43	51	56	39
Pinus	12	9	8	27	23	17	8	19	17	12	19	8	14	8
Tsuga	29	12	15	10	11	6	9	9	11	15	18	18	5	12
Others	15	20	17	16	14	19	13	12	27	13	20	23	25	41
Total pollen grains per gram of sediment	8070	1450	3740	3070	3020	6740	7170	3310	8200	10,070	7780	2270	14,810	10,490

Table 1 (continued).

127-796B-					127-794A-										
28R-1 76–78	29R-1 80–81	30R-1 83–85	31R-2 60–62	32R-5 60–62	29X-1 130–132	30X-1 130–132	31X-2 130–132	32X-3 130–132	33X-3 130–132	35X-3 117–119	36X-2 39–41	37X-2 127–129	9R-1 74–76	12R-2 116–118	13R-2 73–75
0.5	3.5	2.0	2.0	2.5	1.5	19.0	7.0	7.0	2.0	2.0	3.0	—	—	0.5	1.5
—	—	—	—	—	—	—	—	—	0.5	—	—	—	—	0.5	—
5.0	4.5	4.0	4.5	1.5	1.0	3.5	2.0	—	5.0	0.5	1.5	7.5	4.0	1.5	—
37.5	12.0	10.5	6.0	4.5	5.0	4.0	7.0	2.5	9.5	2.0	—	7.5	10.5	7.0	3.0
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	0.5	—	—	—	1.0	1.0
—	1.0	1.0	3.5	—	0.5	—	0.5	—	0.5	—	0.5	2.0	1.5	—	0.5
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	0.5	—	—	0.5	—	—	—	—	—	—	—	—
—	—	3.0	—	—	—	—	0.5	—	—	1.0	—	—	—	0.5	—
2.0	7.5	9.0	5.5	2.0	7.0	15.0	4.5	9.0	0.5	5.5	4.5	4.5	5.5	5.5	5.0
3.5	7.0	12.0	13.5	11.0	7.5	15.5	9.0	6.5	6.0	18.0	5.0	6.0	10.5	2.5	6.0
1.0	0.5	4.0	1.0	1.0	—	—	—	0.5	0.5	0.5	0.5	2.0	—	—	1.0
7.0	5.0	6.0	1.5	0.5	2.5	3.0	2.0	1.5	3.0	0.5	—	1.5	3.5	1.0	1.5
2.0	2.0	1.0	3.0	1.5	2.5	1.0	5.0	2.5	1.0	3.0	1.5	2.0	4.0	3.0	1.0
4.0	7.5	6.5	3.0	3.5	2.5	1.0	0.5	7.5	9.0	9.5	6.0	3.0	3.5	3.5	2.0
1.5	1.5	0.5	—	—	0.5	4.0	1.5	—	—	1.5	—	—	0.5	0.5	—
0.5	2.0	—	0.5	—	1.5	—	2.5	2.0	2.5	0.5	3.0	4.0	0.5	4.0	3.0
8.0	9.5	9.5	3.5	8.5	10.5	6.5	11.0	19.5	13.0	19.5	15.0	8.0	12.5	20.5	24.5
2.0	3.5	0.5	2.0	3.5	11.0	—	3.5	0.5	1.5	0.5	4.5	4.0	3.5	9.5	5.5
9.5	9.5	5.0	20.5	48.0	5.5	2.0	9.5	11.0	22.5	14.5	38.0	30.0	24.5	18.5	28.0
6.0	8.0	5.0	6.5	7.0	22.5	10.0	16.5	14.0	11.5	8.5	9.5	11.5	5.0	9.0	7.0
1.0	4.5	9.0	2.0	0.5	3.0	2.5	3.5	5.5	4.5	6.0	3.5	1.5	3.0	4.5	2.0
0.5	4.0	6.0	0.5	2.5	3.0	5.5	4.0	2.0	2.0	2.0	1.0	2.5	3.0	2.5	1.5
—	—	—	—	—	—	—	—	—	—	—	—	—	1.0	—	—
—	—	—	0.5	—	—	—	—	—	—	—	—	—	—	—	—
—	0.5	—	0.5	—	2.0	1.5	1.0	1.0	—	2.5	—	—	0.5	2.0	3.0
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	0.5	—	—	—	0.5	—	—	—	—	—	—	—
—	0.5	—	—	—	—	—	1.0	2.5	—	—	—	—	1.0	1.5	0.5
—	—	0.5	—	—	—	—	—	0.5	—	0.5	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0.5	—	3.5	0.5	0.5	1.5	1.0	2.0	0.5	—	1.0	2.5	1.0	—	0.5	1.5
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	0.5	0.5	—	—	—	—	—	—	—	—	—	—	0.5
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	1.0	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	0.5	—	—	—
3.5	2.0	1.0	14.5	—	3.0	1.0	1.0	2.0	3.5	—	0.5	1.0	2.0	0.5	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4.0	4.0	—	1.5	—	4.0	2.5	1.0	0.5	—	—	—	—	—	—	—
0.5	—	—	2.0	—	1.0	—	—	0.5	0.5	—	—	—	—	—	—
—	—	—	—	—	0.5	1.0	—	0.5	—	—	—	—	—	—	—
—	—	—	—	—	0.5	—	1.0	—	1.0	—	—	—	—	—	0.5
—	—	—	—	—	—	—	1.0	—	—	—	—	—	—	—	—
—	—	0.5	—	—	—	0.5	1.5	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	2	3	4	9	5	2	3	2	—	—	—	—
30	57	44	56	57	42	54	48	28	40	20	24	46	46	20	10
15	22	38	28	15	9	8	10	12	24	17	23	18	15	26	24
9	11	9	3	9	16	20	14	10	17	13	19	18	9	5	3
46	10	9	13	17	30	14	19	45	17	47	32	18	30	49	63
8240	8394	2020	11,800	12,530	19,240	9340	8760	3970	9170	54,120	46,850	1350	2950	8080	4870

Table 1 (continued).

Hole:	127-794A-							127-797B-					
Core, section: Interval (cm):	14R-2 71–72	15R-2 30–31	19R-1 69–71	20R-1 115–117	21R-1 113–115	24R-1 21–23	25R-CC 13–15	33X-3 40–42	34X-5 40–42	35X-2 39–41	37X-2 40–42	38X-2 18–20	39X-1 17–19
Arboreal pollen													
Larix	1.0	0.5	1.5	6.0	9.0	2.0	2.0	—	—	—	—	—	—
Dacrydium	0.5	—	0.5	—	—	0.5	3.5	—	—	—	—	—	—
Metasequoia	2.0	—	3.0	5.0	5.5	0.5	2.5	—	—	—	—	—	—
Taxodiaceae	3.0	3.0	1.5	6.0	3.0	0.5	1.5	2.0	1.5	2.5	2.0	2.5	7.0
Sciadopitys	—	—	—	—	—	—	—	—	—	—	—	—	—
Cunninghamia	—	—	—	—	—	—	—	—	—	—	—	—	—
Cupressaceae	—	1.0	1.0	—	—	—	—	—	—	1.0	—	—	1.0
Ephedra	1.0	0.5	—	—	0.5	—	0.5	0.5	—	0.5	—	—	0.5
Ginkgo	—	—	—	—	—	—	—	—	—	—	—	—	—
Sarix	—	—	—	—	—	—	—	—	—	—	—	—	—
Myrica	—	—	—	—	—	—	—	0.5	—	—	—	—	1.0
Juglans	1.5	—	0.5	1.0	1.0	—	—	—	0.5	—	—	—	—
Pterocarya	4.0	0.5	5.0	8.5	13.5	16.5	5.0	6.5	3.5	4.0	4.0	5.0	6.5
Carya	8.0	2.5	11.5	18.0	20.5	25.5	27.0	9.0	19.0	20.5	17.5	10.0	11.5
Engelhardia	—	—	—	—	—	—	—	—	1.0	—	—	—	—
Alnus	1.0	1.5	0.5	—	1.0	—	1.0	1.5	0.5	—	0.5	2.0	1.5
Betula	2.0	2.5	0.5	1.0	2.0	—	—	1.5	2.5	1.0	0.5	1.5	4.5
Carpinus	4.5	3.0	2.0	6.0	4.0	4.5	4.0	4.0	4.5	2.0	5.5	3.5	2.0
Corylus	—	—	1.0	—	0.5	—	1.0	1.0	1.0	3.5	0.5	0.5	2.5
Castanea	1.0	1.5	2.5	1.5	4.0	1.0	2.0	1.0	0.5	2.5	0.5	—	0.5
Fagus	23.0	10.5	3.5	8.0	6.0	5.5	6.5	30.5	18.0	14.0	22.0	32.0	26.5
Pasania	4.5	18.0	7.0	1.5	3.0	3.5	5.0	1.5	3.0	6.5	0.5	1.5	1.0
E. *Quercus*	13.5	38.5	35.0	18.0	13.0	18.0	17.0	6.0	13.0	12.0	12.0	12.0	10.0
D. *Quercus*	16.0	6.0	12.0	10.0	6.5	9.0	5.5	20.0	15.5	14.0	14.5	16.5	9.0
Ulmus	3.0	1.5	5.5	5.0	2.5	1.0	4.0	5.0	7.5	3.0	6.5	1.5	5.5
Zelkova	0.5	2.0	2.0	2.0	2.0	4.0	6.0	5.5	4.5	5.5	5.0	4.5	3.5
Celtys	—	—	—	—	—	—	—	—	—	—	—	—	—
Eurya	—	—	—	—	—	—	—	—	—	—	—	—	—
Liquidambar	4.0	2.5	1.0	—	1.0	1.5	0.5	2.0	1.0	0.5	2.5	2.0	4.0
Sapium	—	—	—	—	—	—	—	—	—	—	—	—	0.5
Rhus	0.5	—	—	1.5	—	—	1.5	—	—	—	0.5	—	—
Acer	1.5	2.0	0.5	—	—	1.5	1.5	—	0.5	1.0	1.0	1.5	0.5
Aesculus	0.5	—	—	0.5	—	—	—	—	—	0.5	0.5	—	—
Ilex	—	—	—	—	—	—	—	—	—	—	—	—	—
Tilia	—	2.0	1.5	0.5	1.5	4.5	1.5	0.5	1.0	2.0	1.5	2.5	1.0
Elaeagnus	—	—	—	—	—	—	—	—	—	—	—	—	—
Lagerstroemia	—	—	—	—	—	—	—	—	—	—	—	—	—
Alangium	0.5	—	—	—	—	—	—	—	—	—	—	—	—
Nyssa	0.5	—	—	—	—	—	—	—	—	—	—	—	—
Ericaceae	—	—	1.0	—	—	0.5	0.5	1.0	—	1.0	—	—	—
Symplocos	—	—	—	—	—	—	—	0.5	—	—	0.5	—	—
Ligustrum	—	—	—	—	—	—	—	—	—	—	—	—	—
Weigela	—	—	—	—	—	—	—	—	—	—	—	—	—
Non-arboreal pollen													
Persicaria	—	—	—	—	—	—	—	—	—	—	—	—	—
Chenopodiaceae	0.5	0.5	—	—	—	—	—	—	1.0	1.5	0.5	1.0	—
Caryophyllaceae	—	—	—	—	—	—	—	—	—	—	—	—	—
Ranunculaceae	—	—	—	—	—	—	—	—	—	—	0.5	—	—
Trapa	—	—	—	—	—	—	—	—	—	0.5	—	—	—
Patrinia	0.5	—	—	—	—	—	—	—	—	—	—	—	—
Artemisia	—	—	—	—	—	—	—	—	—	—	—	—	—
Carduoideae	—	—	—	—	—	—	—	—	—	—	0.5	—	—
Cichorioideae	—	—	—	—	—	—	—	—	—	—	—	—	—
Gramineae	—	—	—	—	—	—	0.5	—	0.5	0.5	0.5	—	—
Sparganium	0.5	—	—	—	—	—	—	—	—	—	—	—	—
Cyperaceae	—	—	—	—	—	—	—	—	—	—	—	—	—
Fupingopollenites	1.0	—	—	—	—	—	—	—	—	—	—	—	—
(Total = 100.0%)													
Assemblage of 100 grains													
Abies	—	3	—	—	3	—	—	—	1	—	—	—	—
Picea	36	41	12	40	43	33	25	51	36	61	21	60	39
Pinus	12	24	46	6	33	47	49	7	12	3	4	20	9
Tsuga	5	6	6	8	10	4	4	11	10	4	18	5	6
Others	47	26	36	46	11	16	22	31	41	32	57	15	46
Total pollen grains per gram of sediment	3430	6220	7430	21,530	11,540	36,060	10,070	18,640	36,610	13,960	2840	18,080	26,620

Table 1 (continued).

127-797B-												127-797C-				
40X-2 41–43	41X-1 40–42	42X-1 40–42	43X-1 41–43	44X-1 10–12	46X-1 20–22	47X-1 35–37	48X-2 39–41	49X-1 35–37	50X-1 24–26	51X-1 34–36	52X-1 34–36	2R-1 96–98	3R-1 128–130	5R-2 44–46	6R-4 94–96	8R-1 39–41
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	1.0	—	—	—	0.5	0.5	—	—	—	—	—	—	—	—
—	1.0	—	1.5	1.5	1.5	0.5	3.5	3.0	1.5	—	—	0.5	—	5.5	3.5	3.0
1.5	4.5	3.0	—	1.0	1.0	2.5	1.5	4.0	3.0	0.5	—	3.5	0.5	7.5	9.0	7.0
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.0	0.5	—
1.5	—	—	0.5	1.5	1.0	0.5	0.5	1.0	—	1.0	0.5	2.0	—	2.0	3.0	1.0
0.5	1.0	0.5	1.0	3.0	—	—	—	—	—	0.5	—	0.5	—	—	—	0.5
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	0.5	0.5	—	0.5	—	—	—	—	—
0.5	—	0.5	1.0	0.5	—	0.5	—	—	0.5	1.5	—	0.5	—	—	1.5	0.5
3.0	7.0	7.5	7.0	10.5	2.5	1.5	1.5	5.5	8.0	14.0	15.5	5.5	7.0	10.0	5.5	8.0
9.5	23.5	7.5	9.0	8.0	10.5	4.5	2.5	9.0	13.0	18.0	15.5	21.0	7.0	10.5	9.0	23.0
—	—	—	0.5	—	0.5	0.5	0.5	1.0	—	0.5	0.5	—	0.5	0.5	1.0	2.0
1.0	2.0	1.0	1.0	2.0	0.5	0.5	—	1.5	1.0	—	1.5	0.5	—	1.0	2.5	2.0
1.5	5.0	2.0	1.5	1.5	1.0	—	0.5	—	—	—	0.5	—	1.5	—	0.5	0.5
5.0	2.5	5.0	4.5	2.0	2.5	2.5	0.5	4.5	5.5	4.5	1.5	2.5	3.0	3.5	3.5	3.5
0.5	2.0	1.0	—	—	1.0	0.5	—	0.5	0.5	0.5	1.0	—	—	1.5	0.5	1.0
0.5	0.5	13.5	1.5	1.0	4.5	2.0	5.5	7.5	0.5	1.0	3.0	2.0	4.0	3.0	2.5	—
27.0	15.5	13.5	29.5	12.5	10.0	4.0	3.5	7.5	12.5	3.5	5.0	6.0	3.5	3.0	8.5	6.5
2.5	2.0	14.0	6.0	3.0	10.5	13.5	25.0	10.5	0.5	2.5	3.0	1.5	1.5	1.5	1.0	0.5
17.0	9.0	12.5	14.5	22.5	30.0	37.0	39.0	24.0	24.0	21.5	26.5	27.0	42.0	31.0	16.0	8.0
10.5	8.0	7.5	7.0	11.0	8.0	7.0	10.0	10.5	17.0	10.5	10.0	16.0	16.5	10.0	17.0	18.5
6.0	4.5	4.5	3.5	5.5	6.0	9.5	3.0	4.0	5.0	9.0	5.0	3.5	3.5	3.5	6.5	7.0
2.5	5.0	1.5	2.5	2.0	2.5	3.0	—	0.5	2.0	4.0	1.5	2.0	4.5	1.0	—	1.0
0.5	—	—	—	—	—	0.5	—	—	—	—	—	—	0.5	0.5	—	1.0
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2.0	2.0	—	4.0	2.0	2.5	2.0	0.5	1.5	2.5	2.5	2.5	1.5	4.0	3.0	7.0	2.0
—	—	—	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	0.5	—	—	—	—	0.5	—	1.0	—	—	—	—
3.0	1.0	0.5	—	2.0	1.0	3.0	1.5	2.0	1.0	2.0	2.5	—	0.5	—	0.5	1.5
—	0.5	0.5	—	1.0	—	0.5	—	—	—	—	—	—	—	—	—	0.5
—	—	—	—	—	—	—	—	—	—	0.5	—	—	—	0.5	—	—
1.5	0.5	1.5	—	1.5	2.0	1.0	—	—	0.5	—	3.0	2.5	—	—	0.5	1.0
—	—	—	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	0.5	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	0.5	0.5	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—
1.0	—	0.5	—	—	—	—	—	—	—	—	—	0.5	—	—	—	0.5
—	—	—	—	—	—	0.5	—	0.5	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1.0	2.5	1.0	1.0	3.5	—	2.5	0.5	0.5	0.5	1.0	—	—	—	—	0.5	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
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—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	0.5	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	0.5	—	—	0.5	—	—	—	0.5	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	0.5	—	—	—	—	—
0.5	—	—	—	0.5	—	—	—	—	—	—	0.5	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
43	42	42	45	59	32	17	14	36	47	58	36	35	20	31	15	31
22	10	11	18	11	23	41	22	31	21	15	29	27	45	42	61	34
7	7	—	4	4	3	3	2	10	8	10	4	6	—	9	5	7
28	41	47	33	26	42	39	62	23	24	17	31	32	35	18	19	27
15,220	9680	20,990	13,860	8800	26,400	13,160	38,150	13,200	33,230	25,060	31,550	31,500	13,210	16,070	17,770	14,990

Table 1 (continued).

Hole:	127–797C–							
Core, section: Interval (cm):	11R-1 9–11	18R-1 64–66	19R-5 67–69	20R-1 92–94	22R-2 119–121	25R-1 131–133	31R-4 101–103	33R-1 103–105
Arboreal pollen								
Larix	—	—	—	—	—	—	—	—
Dacrydium	—	—	—	—	—	—	—	—
Metasequoia	1.0	1.5	2.0	—	—	—	1.0	3.0
Taxodiaceae	1.5	0.5	2.0	—	—	—	—	—
Sciadopitys	—	—	—	—	—	—	—	—
Cunninghamia	—	—	—	—	—	—	—	—
Cupressaceae	—	2.0	—	—	—	—	—	—
Ephedra	—	—	0.5	—	—	—	—	—
Ginkgo	—	—	—	—	—	—	—	—
Sarix	—	—	—	—	—	—	—	—
Myrica	—	—	—	—	—	—	—	—
Juglans	4.5	2.5	3.0	4.0	0.5	3.0	1.0	2.0
Pterocarya	6.5	12.5	11.0	7.0	11.5	11.0	12.0	7.0
Carya	13.5	23.5	16.0	16.5	21.5	20.5	20.0	16.0
Engelhardia	1.0	2.0	1.5	1.5	1.0	2.0	1.0	2.0
Alnus	1.0	4.5	3.0	3.0	3.5	6.0	1.0	2.0
Betula	—	0.5	—	2.5	0.5	—	1.0	—
Carpinus	6.5	2.0	8.0	4.0	2.5	3.0	2.0	8.0
Corylus	0.5	—	0.5	—	0.5	—	—	—
Castanea	1.0	—	—	—	—	—	—	—
Fagus	17.0	17.5	23.5	29.0	19.0	19.5	30.0	37.0
Pasania	—	—	—	—	—	—	—	—
E. *Quercus*	6.5	3.0	—	4.0	8.0	—	—	—
D. *Quercus*	16.5	5.0	7.0	4.0	10.5	12.0	18.0	3.0
Ulmus	11.0	13.5	12.0	11.5	11.5	17.0	7.0	10.0
Zelkova	2.5	—	0.5	4.0	3.5	1.0	1.0	—
Celtys	—	—	—	—	—	—	—	—
Eurya	—	—	—	—	—	—	—	—
Liquidambar	3.5	4.0	2.0	6.0	2.5	2.0	1.0	1.0
Sapium	—	—	—	—	—	—	—	—
Rhus	0.5	1.0	—	—	0.5	—	—	1.0
Acer	—	1.0	5.0	1.0	—	1.0	—	2.0
Aesculus	—	—	—	—	—	1.0	—	—
Ilex	—	—	—	—	—	—	—	—
Tilia	2.0	3.5	1.5	2.0	2.5	1.0	4.0	6.0
Elaeagnus	—	—	—	—	—	—	—	—
Lagerstroemia	—	—	—	—	—	—	—	—
Alangium	—	—	—	—	—	—	—	—
Nyssa	—	—	—	—	—	—	—	—
Ericaceae	0.5	—	—	—	—	—	—	—
Symplocos	—	—	—	—	—	—	—	—
Ligustrum	—	—	—	—	0.5	—	—	—
Weigela	—	—	0.5	—	—	—	—	—
Non-arboreal pollen								
Persicaria	—	—	—	—	—	—	—	—
Chenopodiaceae	—	—	—	—	—	—	—	—
Caryophyllaceae	—	—	—	—	—	—	—	—
Ranunculaceae	—	—	—	—	—	—	—	—
Trapa	—	—	—	—	—	—	—	—
Patrinia	—	—	—	—	—	—	—	—
Artemisia	—	—	—	—	—	—	—	—
Carduoideae	—	—	—	—	—	—	—	—
Cichorioideae	—	—	—	—	—	—	—	—
Gramineae	—	—	0.5	—	—	—	—	—
Sparganium	0.5	—	—	—	—	—	—	—
Cyperaceae	—	—	—	—	—	—	—	—
Fupingopollenites	2.5	—	—	—	—	—	—	—
(Total = 100.0%)								
Assemblage of 100 grains								
Abies	—	—	—	—	—	—	—	—
Picea	29	46	60	32	23	52	54	48
Pinus	36	14	14	6	8	11	15	11
Tsuga	4	5	10	8	6	1	12	15
Others	31	35	16	54	63	36	19	26
Total pollen grains per gram of sediment	8370	3550	2200	2400	4210	3390	550	440

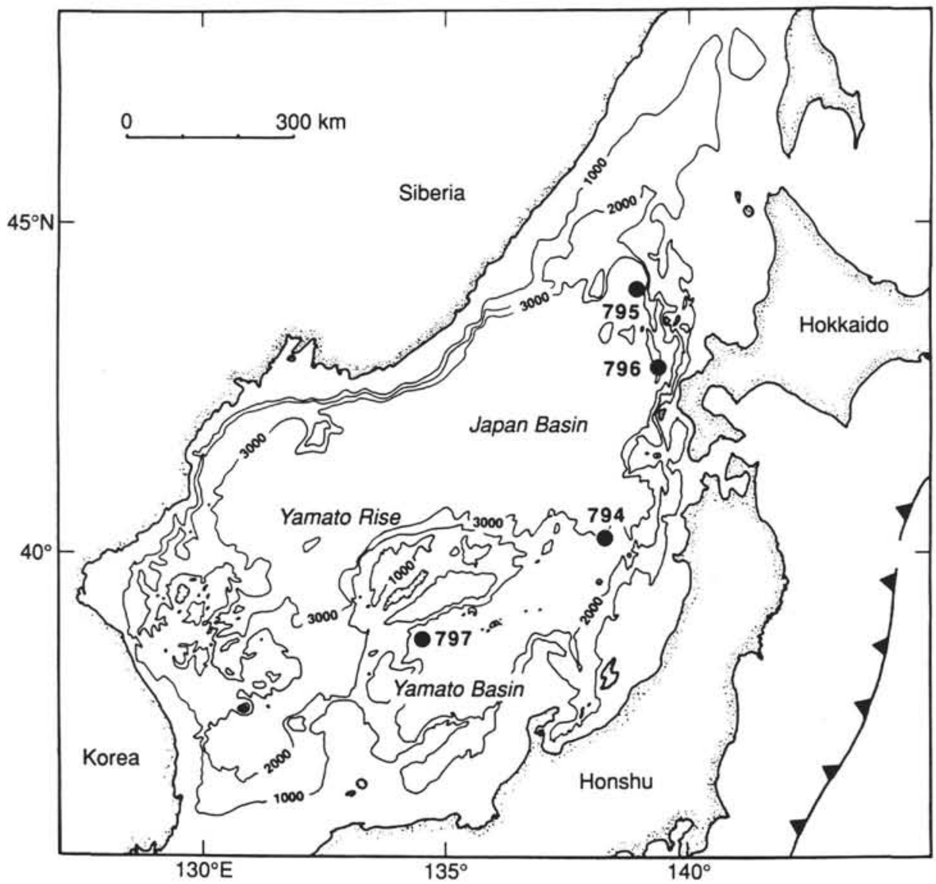

Figure 1. Map of the Japan Sea showing the locations of Leg 127 Sites 794–797.

Site 797

This site is located in the south-central Japan Sea within the Yamato Basin, about 300 km from the western coast of Honshu (Fig. 1). Drilling reached acoustic basement through thick marine sequence at 554 meters below seafloor (mbsf). The lower sediments in this sequence are composed of interlayered basaltic and sedimentary rocks. Drilling 350 m into this interlayered rock recovered not only igneous rocks but also some horizons of sedimentary rocks. Pollen fossils obtained from these lower, older sediments are different from those at the other three sites of Leg 127.

The results of pollen analyses of Site 797 are summarized in Figure 5, which shows the major floral components. *Pterocarya, Carya,* and D. *Quercus* are generally abundant at Site 797. However, *Carya* shows a rather high value from Section 127-797C-8R-1 downhole. *Fagus* occurs in every sample and especially shows a very high value above Section 127-797B-43X-1 and below Section 127-797C-11R-1. E. *Quercus* occurs abundantly at upper horizons and becomes especially high in abundance from Section 127-797B-44X-1 to Core 127-797C-5R. As can be seen in Figure 5, *Pasania* is abundant locally in upper horizons, with its highest value of 25% occurring in Sample 127-797B-48X-2, 39–41 cm.

The preservation of pollen grains is very good until above Section 127-797C-20R-1, but takes a sudden change for the worse from Section 127-797C-22R-1 to the lower end of this hole. Therefore, sufficient pollen grains for statistical treatment were not obtained in many samples. However, there are some samples in which fungi spores were very abundant. The analyses of these horizons are summarized in Table 2. In addition, a dinoflagellate cyst was found in Sample 127-797C-30R-2, 73–75 cm.

POLLEN FLORA OF MIOCENE SEDIMENTS

An Outline of Northeast Japan

Many Neogene sequences from the Japan Sea side of Honshu have been analyzed for palynological studies (Yamanoi, 1976, 1978a, 1978b, 1979, 1983, 1984; Yamanoi and Tsuda, 1986). These studies have revealed several principal trends on palynofloral changes during the Neogene. Moreover, five pollen zones are also recognized in these Neogene sequences on the basis of floral change. The five pollen zones are termed the NP1 to NP5 zones in upward sequence. Zones NP1 to NP4 are assigned a Miocene age, except for the upper part of Zone NP4, which is considered to be nearing Pliocene in age (Yamanoi, 1989). The characteristics of Miocene pollen zones recognized in northeast Japan are summarized below.

Zone NP1 consists mainly of deciduous broad-leaved trees and coniferous trees such as *Juglans, Pterocarya, Betula, Carpinus, Fagus,* D. *Quercus, Picea,* and *Pinus* (Yamanoi, 1989). Moreover, *Carya* is one of the most important elements of this zone (Yamanoi, in press). Therefore, the paleotemperature of this zone is estimated as temperate or rather cool-temperate. The lowermost limit of this zone is still unknown.

Zone NP2 is characterized by the abundance of *Carya,* E. *Quercus,* and *Liquidambar,* and also by some presence of *Dacrydium* (Yamanoi, 1989). Fossil pollen of mangrove plants are included in this zone in Southwest Japan (Yamanoi et al., 1980; Yamanoi, 1984; Yamanoi and Tsuda, 1986) and the mean winter temperature for these regions during the early middle Miocene is estimated to be nearly 16°C higher than today (Yamanoi, 1989). Such a warm event can be considered as a "tropical spike," which is named for the paleotemperature rising like

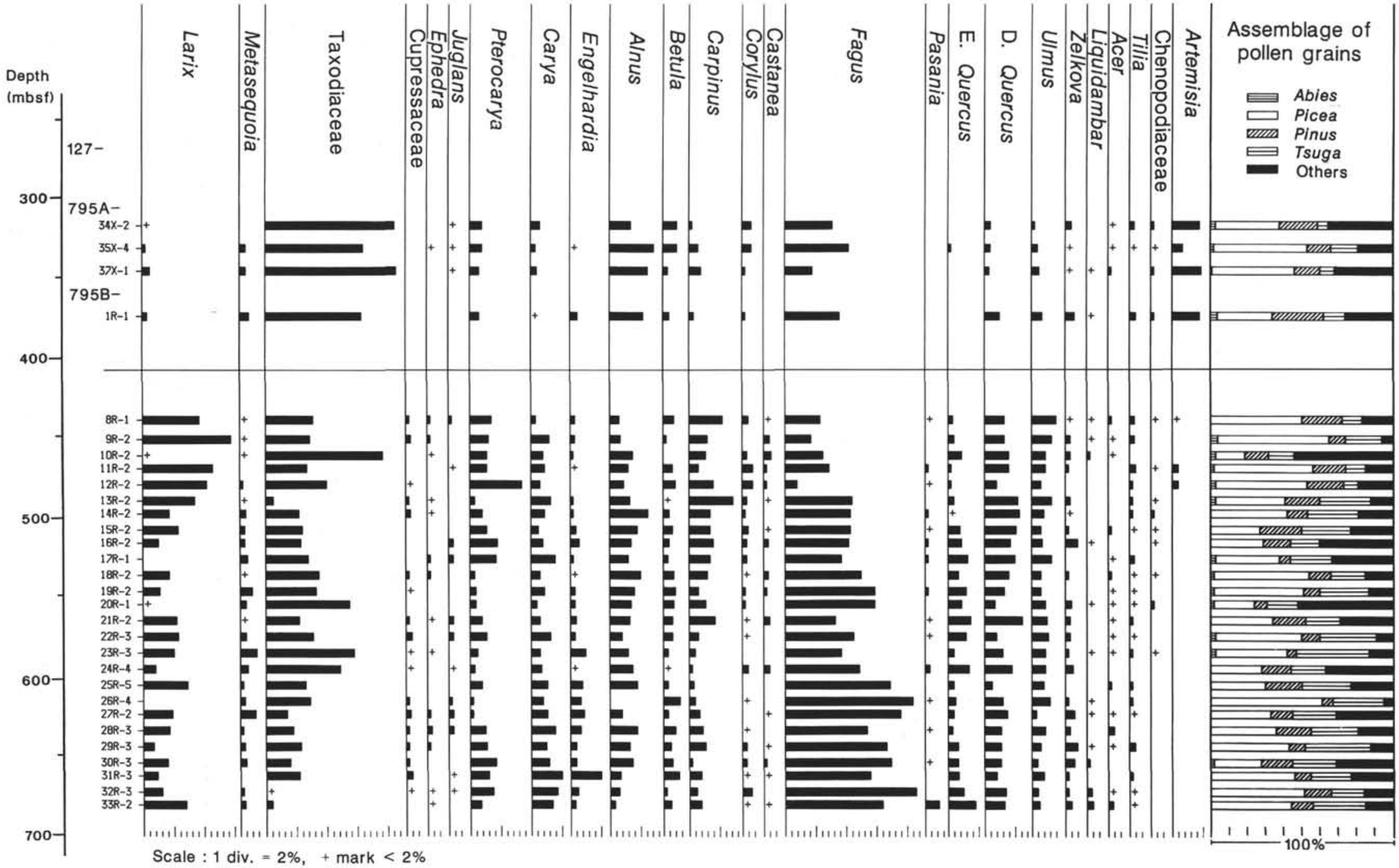

Figure 2. Pollen diagram showing major floral components of Site 795. Two fixed sums are represented: all pollen except for the vesiculate Pinaceae, $N = 200$; and all pollen for the "Pinaceae vs. other" diagram, $N = 100$ (shown on the right).

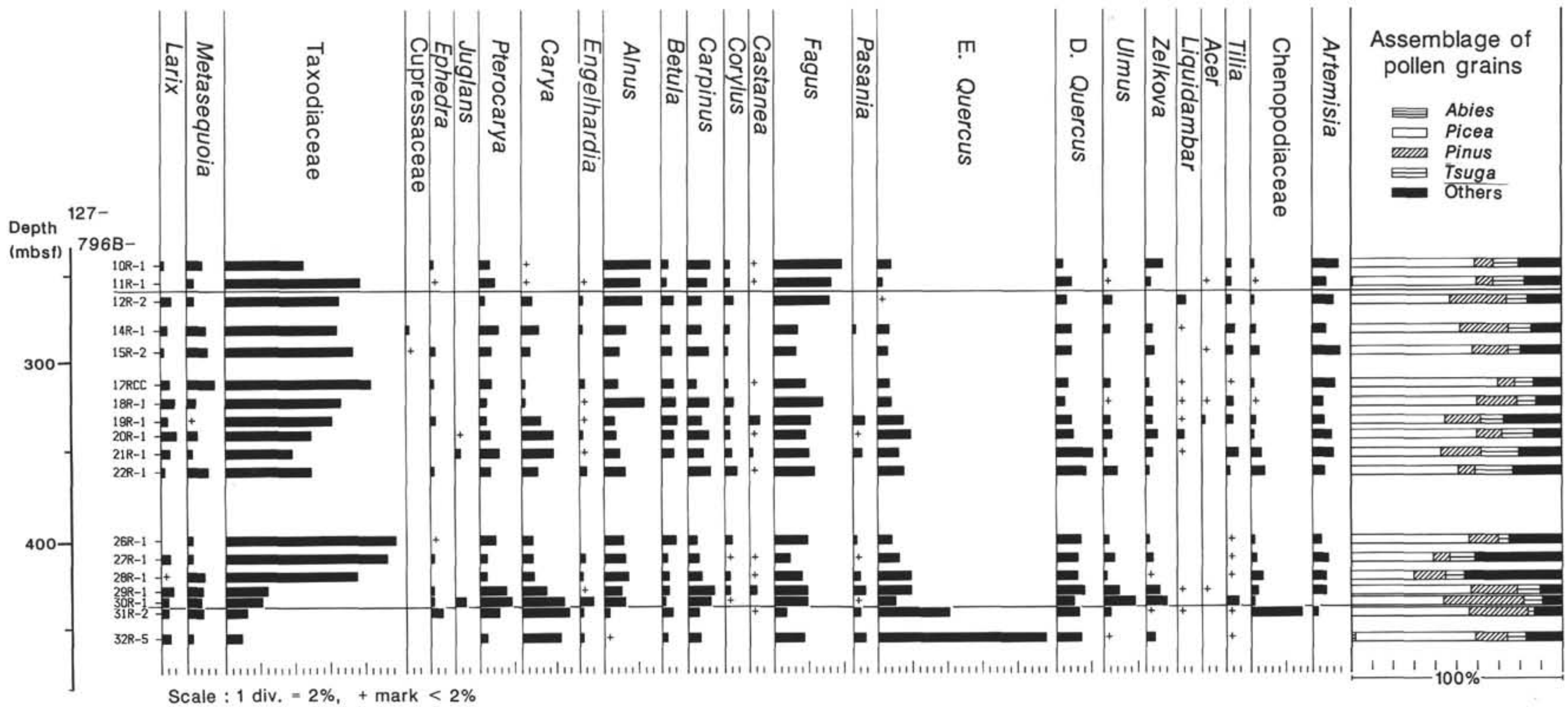

Figure 3. Pollen diagram showing major floral components of Site 796. See Figure 2 for further explanation.

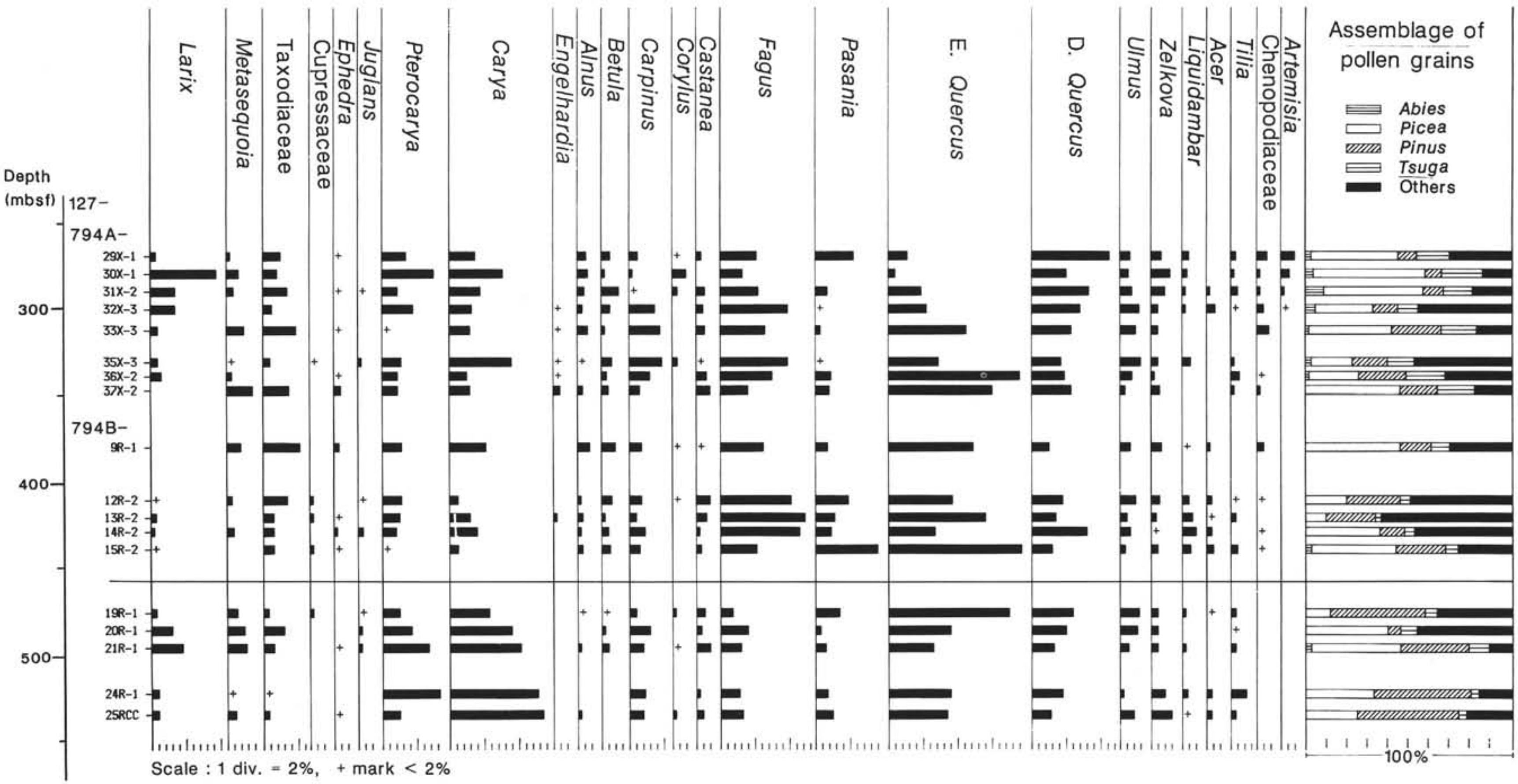

Figure 4. Pollen diagram showing major floral components of Site 794. See Figure 2 for further explanation.

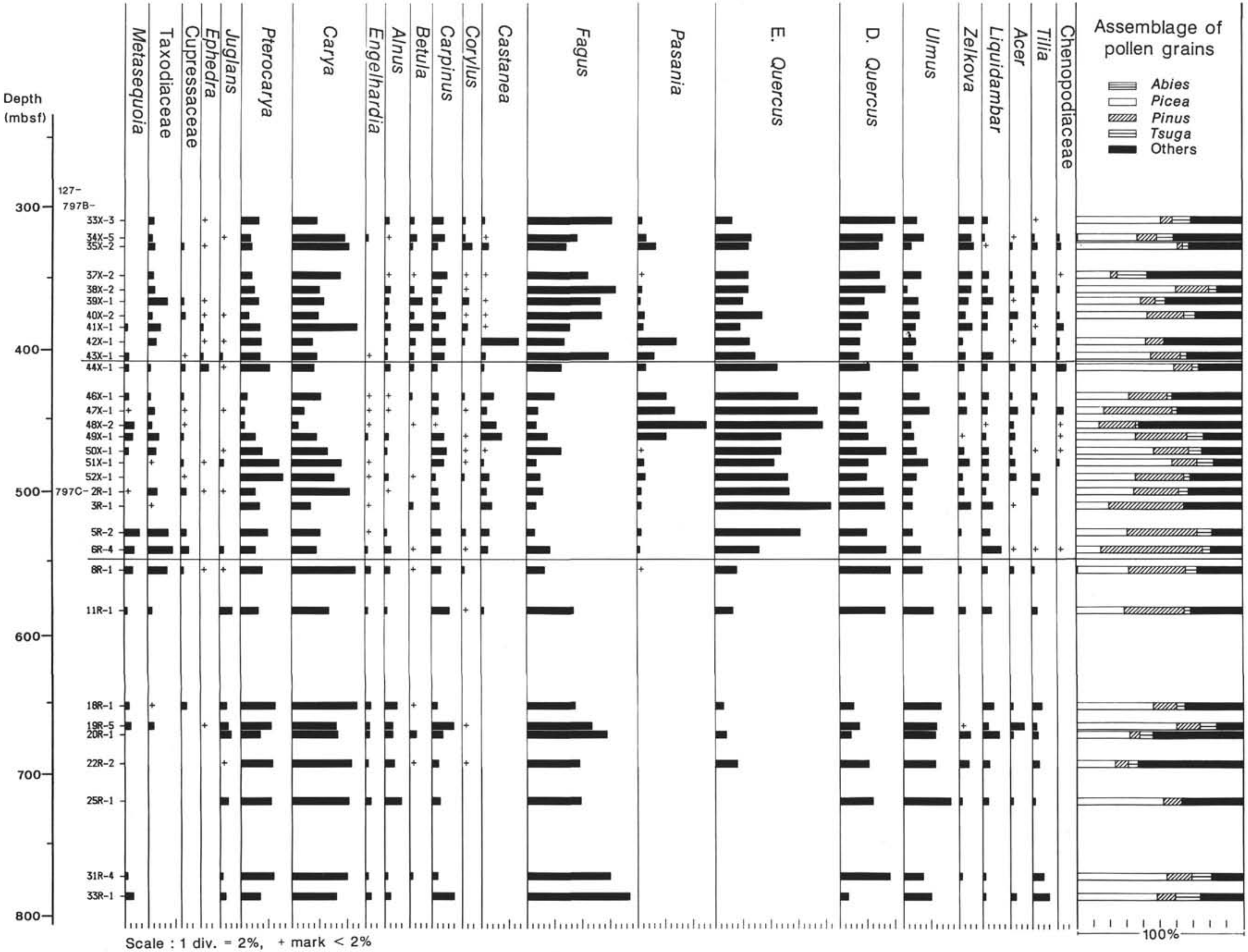

Figure 5. Pollen diagram showing major floral components of Site 797. See Figure 2 for further explanation.

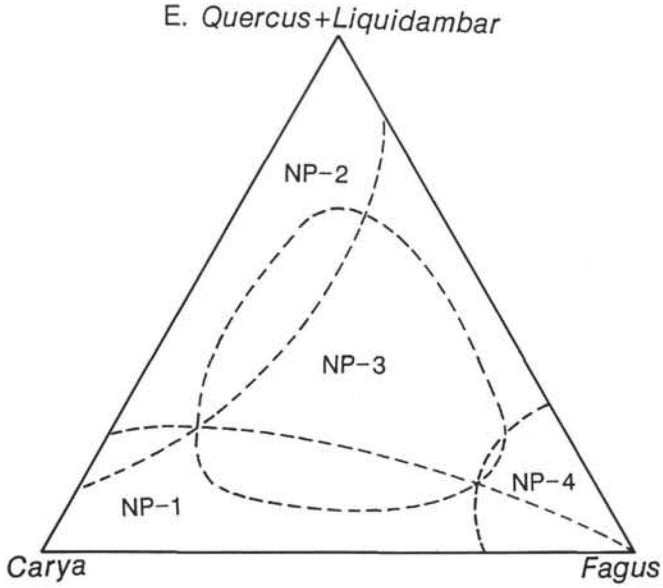

Figure 6. Ternary diagram showing the clusters of the components of the essential pollen members for Miocene pollen zones in northeast Japan.

a quick pulse (Itoigawa, 1989). Therefore, Zone NP2 contains the most abundant warm floral elements among all five pollen zones.

Zone NP3 is characterized by a high proportion of *Carya* and *Liquidambar.* The occurrence of E. *Quercus* becomes low, and in contrast, *Fagus* and Taxodiaceae are higher in percentages (Yamanoi, 1989). The paleotemperature indicated by this palynoflora is cooler than that of Zone NP2, but warmer than it is at present.

Zone NP4 is characterized by the abundance of Taxodiaceae and *Fagus.* The lower limit of this zone is defined by a very sharp decrease in *Carya* and *Liquidambar* (Yamanoi, 1978a). This boundary is clearly recognized in many localities of northeast Japan. Therefore, the writer named this horizon the "Funakawa floral change plane" (Yamanoi, 1978a).

As described above, there are several essential members that caused the palynofloral change in northeast Japan during the Miocene. Major floral changes are thus recognized by relative variations of such essential genera as *Carya, Fagus,* E. *Quercus,* and *Liquidambar.* These four pollen genera are divided first into three components, *Liquidambar* plus E. *Quercus* (warm element), *Carya* (moderate element), and *Fagus* (cool element) so that each pollen zone can be recognized through cluster plots on a ternary diagram such as the one shown in Figure 6.

Miocene Pollen Flora of Leg 127

Site 795

The pollen flora of this site is divided into two local pollen zones (Fig. 2). The boundary of these zones is expected to occur at any horizon between Sections 127-795B-1R and 127-795B-8R-1. However, this boundary cannot be determined with accuracy because of low recovery for this interval. The upper local pollen zone is characterized by an abundance of Taxodiaceae, *Alnus,* and *Artemisia.* In the lower local pollen zone, *Larix, Carya, Carpinus,* E. *Quercus,* and *Ulmus* are more dominant than in the upper local pollen zone.

The components of the essential member were plotted on a ternary diagram (Fig. 7). As shown in Figure 7, the upper and lower local pollen zones can be correlated with Zones NP4 and NP3 of northeast Japan, respectively. The points belonging to each zone do not separate sharply at their boundaries. The reason is considered to be that *Fagus* occurred dominantly in both zones, as this site is located farther north from northeast Japan.

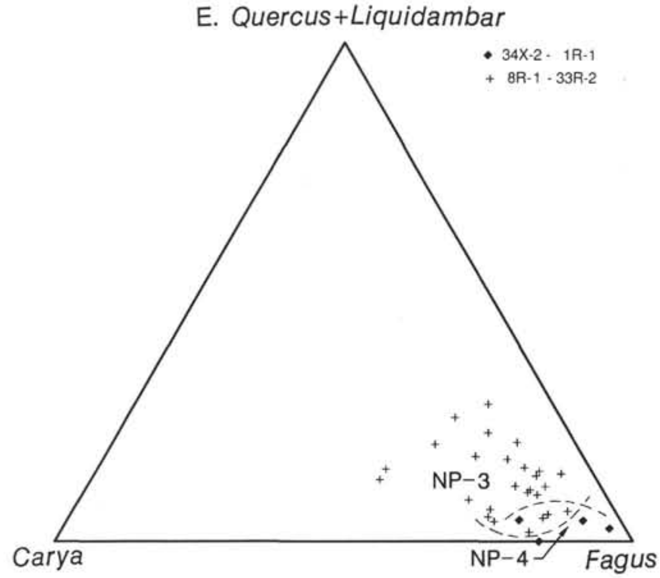

Figure 7. Ternary diagram showing the three-composition ratio of four essential pollen members for Site 795. Closely clustered plots regarded as representing entities of pollen floras, and their correspondence with the pollen zones of northeast Japan, are shown in Figure 6.

Site 796

A remarkable floral change can be seen in the older sediments at this site (Fig. 3). E. *Quercus* shows a high value and *Carya* is fairly abundant in Section 127-796B-31R-2 and its lower horizons. Therefore, this floral boundary is estimated to occur between Sections 127-796B-30R-1 and 127-796B-31R-2 (Fig. 3). The pollen floras marking this boundary are considered to correspond with Zones NP3 and NP2 of northeast Japan.

The components of the essential member were plotted on a ternary diagram (Fig. 8). From this we can see that there is a wide difference in the components between the horizons above Section 127-796B-30R-1 and below Section 127-796B-31R-2. Moreover, Figure 8

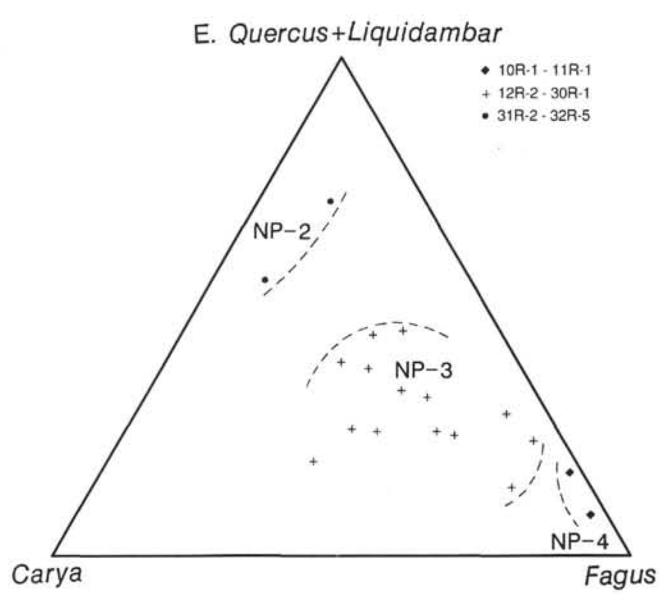

Figure 8. Ternary diagram showing the three-composition ratio of four essential pollen members for Site 796. See Figure 7 for explanation.

Table 2. Occurrences, color, and preservation of pollen grains and abundance of fungi spores in the lowermost cores of Hole 797C.

Core, section, interval (cm)	Total pollen grains per gram of sediment	Color of pollen grain	Preservation of pollen grain	Abundance of fungi spores
127-797C-				
18R-1, 64–66	3550	Light brown	Good	Few
19R-5, 67–69	2200	Light brown	Rare	
20R-1, 92–94	2400	Brown	Good	Few
22R-1, 53–55	10	Black	Poor	Rare
22R-2, 119–121	4210	Light brown	Moderate to poor	Few
22R-CC, 12–14	30	Black	Poor	Few
23R-3, 35–37	120	Dark brown	Moderate to poor	Few
23R-5, 83–85	10	Black	Very poor	Common
25R-1, 131–133	3390	Dark brown	Moderate to poor	Abundant
25R-6, 46–48	90	Dark brown	Poor	Abundant
30R-2, 73–75	130	Dark brown	Moderate to poor	Common
31R-4, 101–103	550	Brown	Moderete to poor	Few
33R-1, 103–105	440	Brown	Poor	Few
34R-3, 89–91	20	Brown	Moderate to poor	Few
34R-6, 104–106	0	—	—	—
37R-1, 38–40	340	Dark brown	Very poor	Few
37R-3, 148–150	30	Dark brown	Poor	Few
37R-4, 61–63	210	Dark brown	Very poor	Few
37R-6, 140–142	190	Dark brown	Very poor	Rare
41R-1, 145–147	30	Black	Very poor	Common
41R-3, 39–41	30	Black	Very poor	Common

shows that the components of Sections 127-796B-10R-1 and 127-796B-11R-1 belong to Zone NP4, as compared with the floral component of northeast Japan (Fig. 6).

Thus, the boundary between Zones NP3 and NP4 of this site can be drawn between Sections 127-796B-11R-1 and 127-796B-12R-2 (Fig. 3). The age of the NP4/NP3 boundary is estimated to be about 7 Ma on the basis of marine microfossil data for this site (Tamaki, Pisciotto, Allan, et al., 1990).

Site 794

The pollen flora of this site can be divided into the upper and lower local pollen zones (Fig. 4). The boundary must be between Sections 127-794B-15R-2 and 127-794B-1R-2. However, the boundary cannot be determined in detail because the samples of this horizon are not yet available. *Fagus* and E. *Quercus* are dominant in the upper local pollen zone (Fig. 4). In contrast, *Pterocarya, Carya,* and E. *Quercus* occur dominantly in the lower local pollen zone.

The essential member of the pollen flora of Site 794 was plotted for their components on a ternary diagram (Fig. 9). These components are classified into two clusters on the diagram. One cluster remarks the lower local pollen zone (Sections 127-794B-19R-1 to 127-794B-25R-CC) is correlated to the pollen flora of Zone NP2 of northeast Japan. Since the lower local pollen zone is correlated to Zone NP2, the upper local pollen zone (Sections 127-794A-29X-1 to 127-794B-15R-2) must correspond with Zone NP3 of northeast Japan. However, as can be seen in Figure 9, many points of the components for the upper local pollen zone shift upward on the diagram, considering that they belong to Zone NP3. This shift is caused by a high value of E. *Quercus* in this upper zone. Such a phenomenon probably reflects the sedimentational character of E. *Quercus* pollen grains in an offshore region at this time.

The age of the NP3/NP2 boundary is inaccurate as yet, but is estimated to be between 12.3 Ma and 14.5 Ma on the basis of marine microfossil data at Site 794 (Tamaki, Pisciotto, Allan, et al., 1990). In addition, the NP4/NP3 boundary is expected to come above the uppermost core shown in Figure 4.

Site 797

The pollen flora of this site is divided into the upper, middle, and lower local pollen zones. The boundaries of the three local pollen zones occur between Sections 127-797B-43X-1 and 127-797B-44X-1, and between Sections 127-797C-6R-4 and 127-797C-8R-1 (Fig. 5). In the upper local pollen zone, *Carya* and *Fagus* occur abundantly, with fairly abundant occurrences of E. *Quercus* and D. *Quercus*. The middle local pollen zone is characterized by the dominance of E. *Quercus* and the lower abundance of *Fagus*. Pollen of *Pterocarya, Carya,* and *Pasania* are abundant locally in this zone.

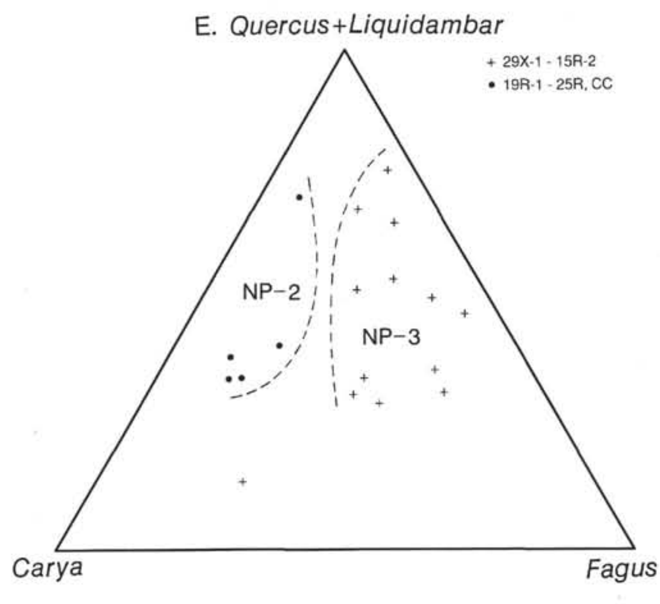

Figure 9. Ternary diagram showing the three-composition ratio of four essential pollen members for Site 794. See Figure 7 for explanation.

The components of the essential member were plotted on a ternary diagram (Fig. 10). The components are classified clearly into three clusters. These clusters, which are in accordance with the three local pollen zones, can be correlated with Zones NP1, NP2, and NP3 of northeast Japan (Fig. 10).

The age of the NP3/NP2 boundary of this site is about 13 Ma, based on associated marine microfossils (Tamaki, Pisciotto, Allan, et al., 1990). As discussed previously, the age of the boundary of the NP4/NP3 is estimated to be about 7 Ma at Site 796. Thus, the flora must be changed to the flora of Zone NP4 in the upper part of the upper local pollen zone. The components of the essential member occurring in Section 127-797B-33X-3 (Fig. 10) may belong to Zone NP4, but this is a subject for future study. The age of the NP2/NP1 boundary, which is not determined with accuracy because of the lack of other microfossil data (Tamaki, Pisciotto, Allan, et al., 1990), is assumed to fall between 17 Ma and 18.5 Ma. This is the first time a complete range of the pollen flora of early middle Miocene Zone NP2 has been obtained.

The horizon containing an abundance of E. *Quercus* and *Pasania* in Zone NP2 at Site 797 may be closely related to the early middle Miocene "tropical spike" (Itoigawa, 1989) at about 16 Ma.

In Zone NP1 of this site, the flora is characterized by the abundance of *Carya, Fagus,* and *Ulmus.* This is thought to reflect a cool or cool-temperate paleotemperature. Pollen grains are not only poor preserved but also occur in lower numbers in the lower part of Zone NP2 (Table 2). However, many kinds of fungal spores occur abundantly in these horizons (Sections 127-797C-25R-1 and 127-797C-25R-6). This fact indicates that much terrestrial matter was deposited at this site at that time, because many fungi live in well-ventilated, dried organic soil.

Pollen Stratigraphy

The pollen zones recognized at each site can be correlated as illustrated in Figure 11. Four pollen zones are recognized as a different type of flora. The ages obtained for the boundaries of these zones are about 7 Ma, 13 Ma, and 17–18.5 Ma (Fig. 11). Although the existence of Zone NP1 was confirmed at Site 797, this zone was not recognized in other Leg 127 sites because drilling did not penetrate sediments of the appropriate age. At Site 795, drilling did not reach sufficient depth even for Zone NP2.

Zone NP4 is correlated with the Mitoku-type flora (Tanai, 1961) and Zone NP2 can be correlated with the Daijima-type flora (Tanai, 1961). However, Zone NP3 may correspond to a barren zone of mega-plant fossils. The Aniai-type flora has been placed below the position of the Daijima-type flora (Tanai, 1961). Suzuki (1989) has

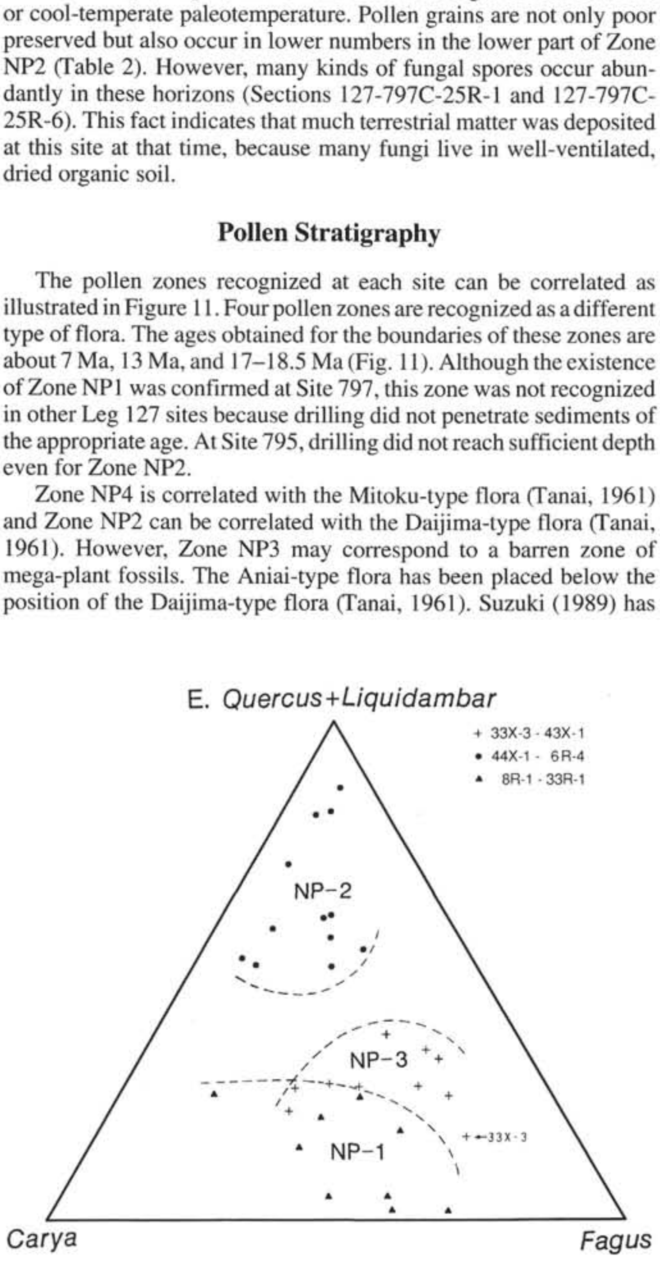

Figure 10. Ternary diagram showing the three-composition ratio of four essential pollen members for Site 797. See Figure 7 for explanation.

proposed the existence of the Aniai-Daijima mixed-type flora between the Daijima-type and Aniai-type floras. Moreover, the ages of the Daijimai-type and Aniai-type floras have been assigned to earliest Miocene to early middle Miocene (ca. 13–22 Ma) and latest Oligocene to earliest Miocene (ca. 22–26 Ma), respectively, by Kano and Yanagisawa (1989). However, as to the Aniai-type flora, the relations among the floral component, stratigraphic positions, and time range have not been clearly resolved. Therefore, the pollen flora of Zone NP1 may be useful in solving the problems associated with recognition of the "Aniai-type flora."

Certain differences are exhibited among the floral components of the pollen zones correlated in Figure 11. Concerning Zone NP3, *Fagus* and *Carya* have commonly abundant occurrences at individual sites. However, Taxodiaceae and *Larix* occur dominantly at Site 795, Taxodiaceae occurs very abundantly at Site 796, and E. *Quercus* is fairly abundant in Site 797. These floral differentiations of each site reflects the sedimentational character of pollen grains and the vegetational habitats on land areas of that time. The pollen data of Zone NP3 were obtained in this study, and those that have been obtained on land areas (Yamanoi, 1976, 1978a, 1978b, 1989) have been assembled. These data show the distribution of pollen that would be expected to be occur abundantly in Zone NP3 (Fig. 12). Figure 13 illustrates Zone NP2 in much the same way as Figure 12 does for Zone NP3. These maps will become more precise with increasing pollen data from the Japan Sea area.

SUMMARY

Approximately 100 samples of Miocene sediments were analyzed palynologically at four Leg 127 sites in the Japan Sea (Fig. 1). The pollen components and total pollen grains per gram of dry sediment of each sample are summarized in Table 1. The floral components of major pollen taxa of each site are illustrated in Figures 2 through 5.

Neogene pollen floras, which have been established as a standard pollen zones in northeast Japan, are briefly described. These standard pollen zones are represented by a cluster composition for essential members by using a ternary diagram (Fig. 6). The essential member of the local pollen floras of each site was plotted for components on ternary diagrams (Figs. 7–10). Closely clustered plots on these diagrams representing local floras at ODP sites can be correlated with the standard pollen zones of northeast Japan (Fig. 6).

The pollen zones of each ODP site are correlated as shown in Figure 11. The age of the boundaries of the pollen zones are about 7 Ma, 13 Ma, and 17–18.5 Ma (Fig. 11).

The pollen data of Zones NP3 and NP2, which were obtained in this study, and data obtained from land areas, were combined. These data are summarized in two maps showing distribution of the pollen which are expected to occur abundantly (Figs. 12 and 13).

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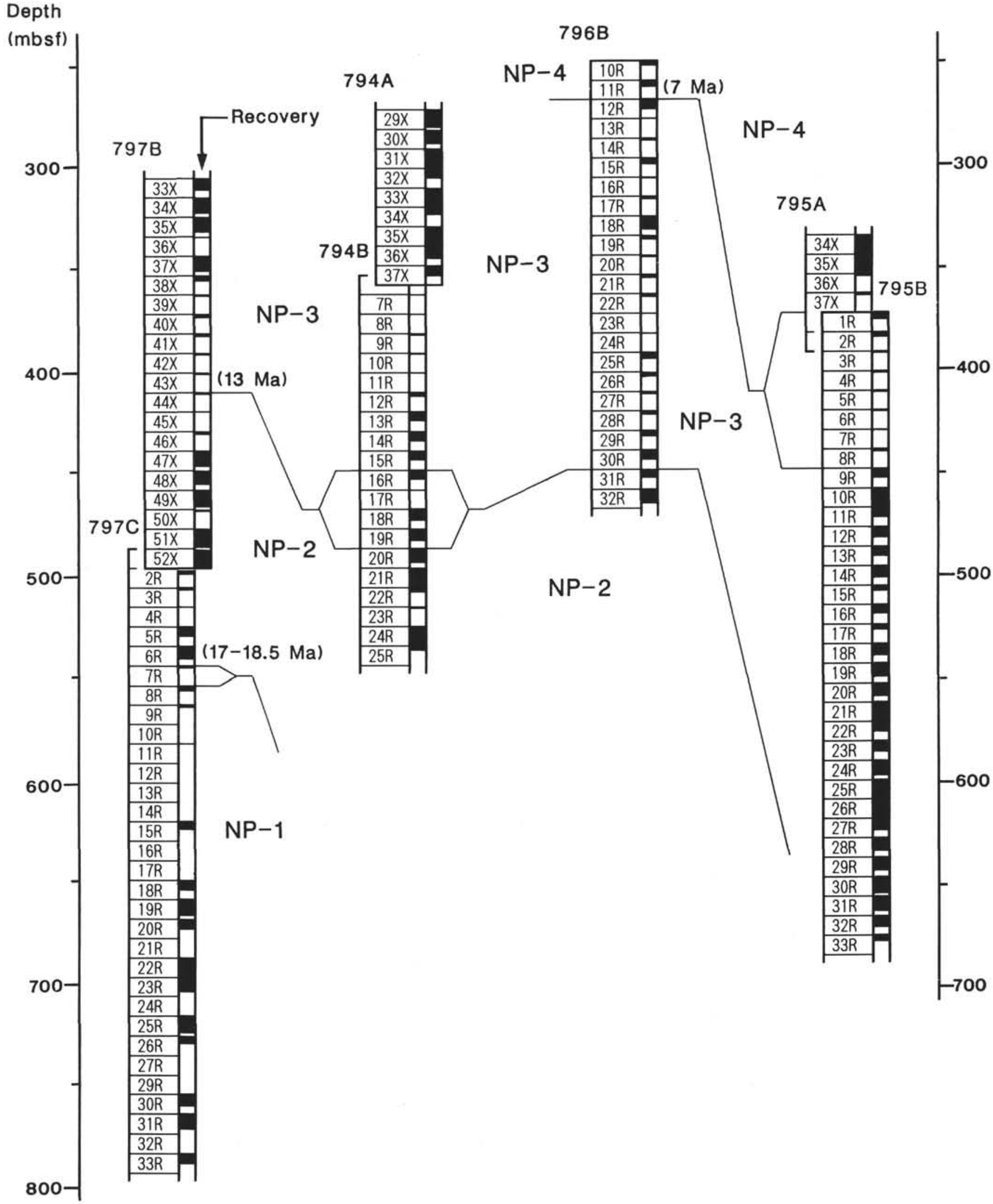

Figure 11. Correlation of Miocene pollen stratigraphies of four sites, Leg 127.

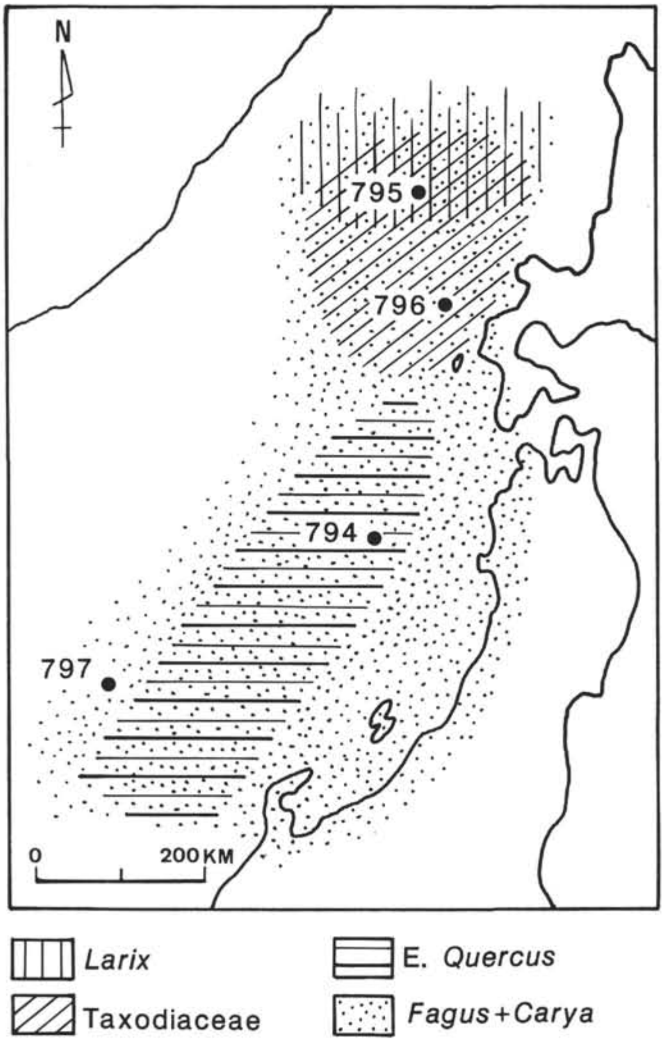

Figure 12. Map of the Japan Sea area showing the distribution of pollen fossils expected to occur abundantly in Zone NP3.

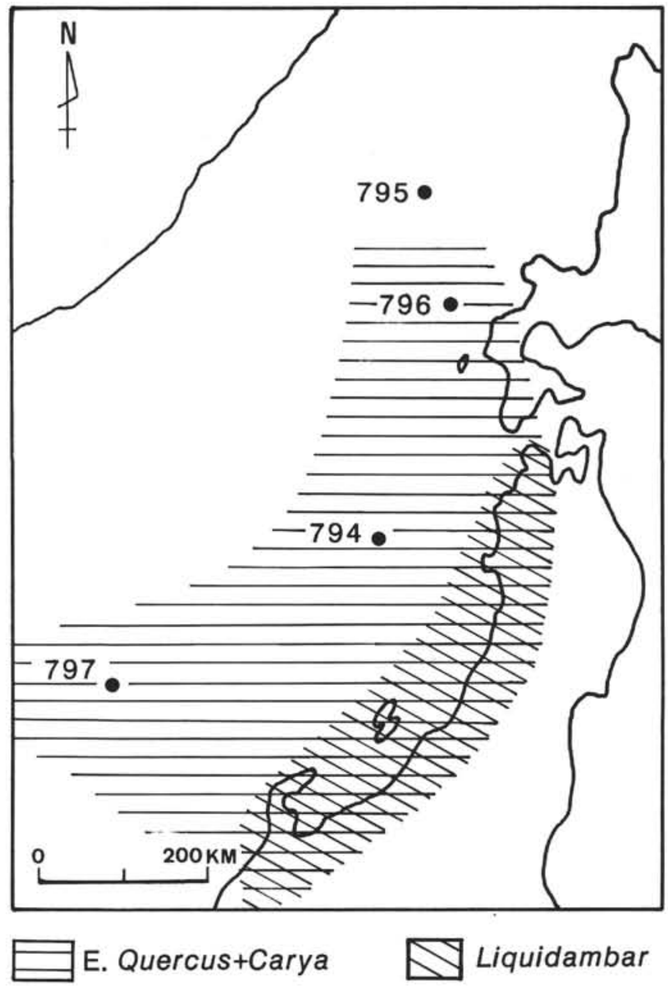

Figure 13. Map of the Japan Sea area showing the distribution of pollen fossils expected to occur abundantly in Zone NP2.

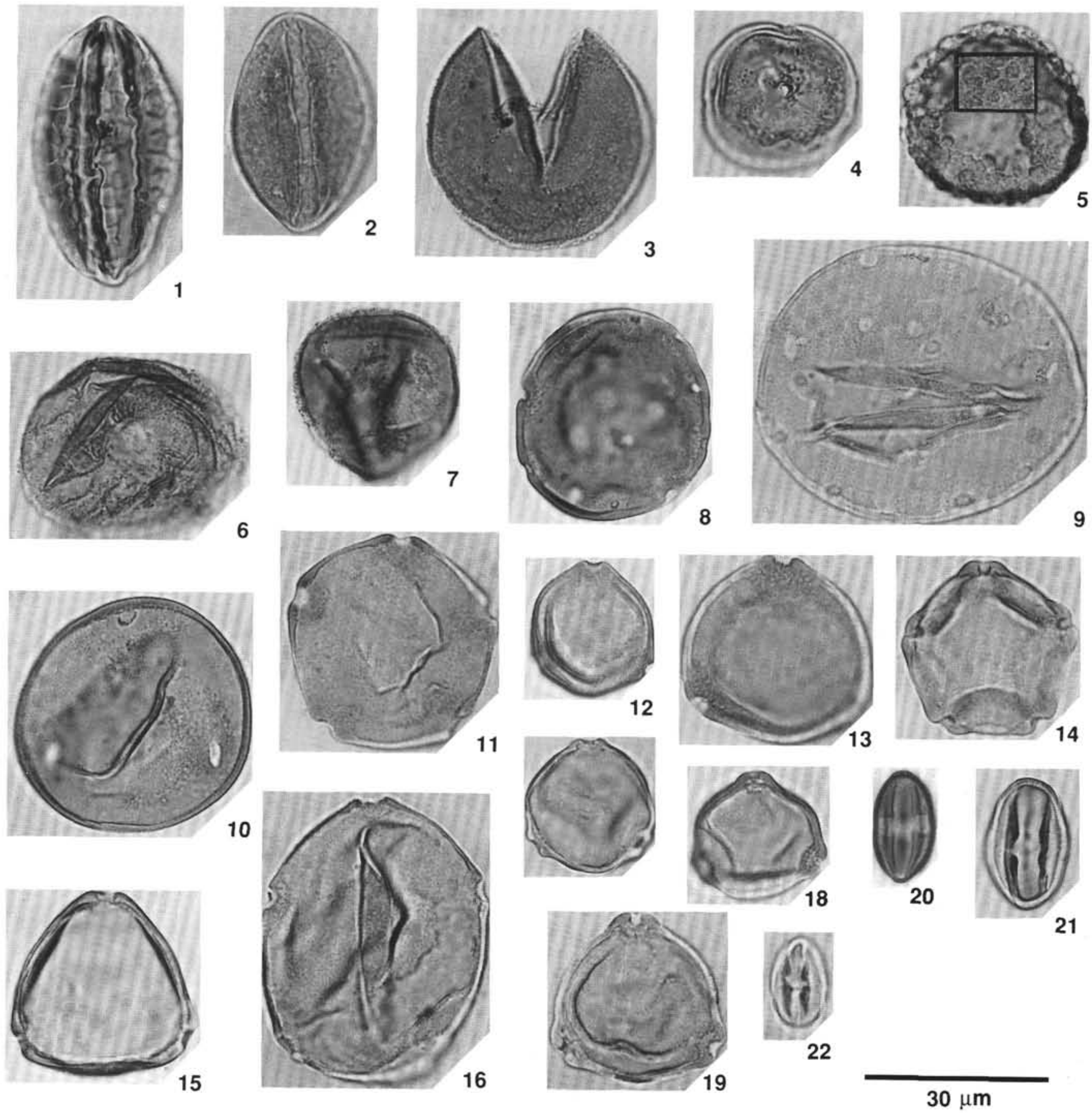

Plate 1. Pollen fossils of Leg 127 (LM). **1.** *Ephedra,* Sample 127-795B-15R-2, 82–84 cm. **2.** *Ginkgo,* Sample 127-795B-18R-2, 134–136 cm. **3.** Taxodiaceae, Sample 127-795B-19R-2, 134–135 cm. **4.** *Metasequoia,* Sample 127-796B-27R-1, 98–100 cm. **5.** *Sciadopitys,* Sample 127-795B-15R-2, 82–84 cm. **6.** *Cunninghamia,* Sample 127-797C-6R-4, 60–62 cm. **7.** Cupressaceae, Sample 127-797C-8R-1, 39–41 cm. **8.** *Juglans,* Sample 127-795B-32R-3, 125–127 cm. **9.** *Juglans,* Sample 127-794B-14R-2, 71–72 cm. **10.** *Carya,* Sample 127-795B-19R-2, 134–135 cm. **11.** *Pterocarya,* Sample 127-794B-24R-1, 21–23 cm. **12.** *Engelhardia,* Sample 127-796B-30R-1, 83–85 cm. **13.** *Engelhardia,* Sample 127-797B-43X-1, 41–43 cm. **14.** *Alnus,* Sample 127-795B-12R-2, 80–82 cm. **15.** *Corylus,* Sample 127-794A-32X-1, 130–132 cm. **16.** *Carpinus,* Sample 127-797B-43X-1, 41–43 cm. **17.** *Carpinus,* Sample 127-797B-34X-5, 40–42 cm. **18.** *Betula,* Sample 795B-15R-2, 82–84 cm. **19.** *Betula,* Sample 127-797B-34X-5, 40–42 cm. **20.** *Pasania,* Sample 127-794B-25R-CC, 13–15 cm. **21.** *Pasania,* Sample 127-796B-20R-1, 29–31 cm. **22.** *Castanea,* Sample 127-794B-12R-2, 116–118 cm.

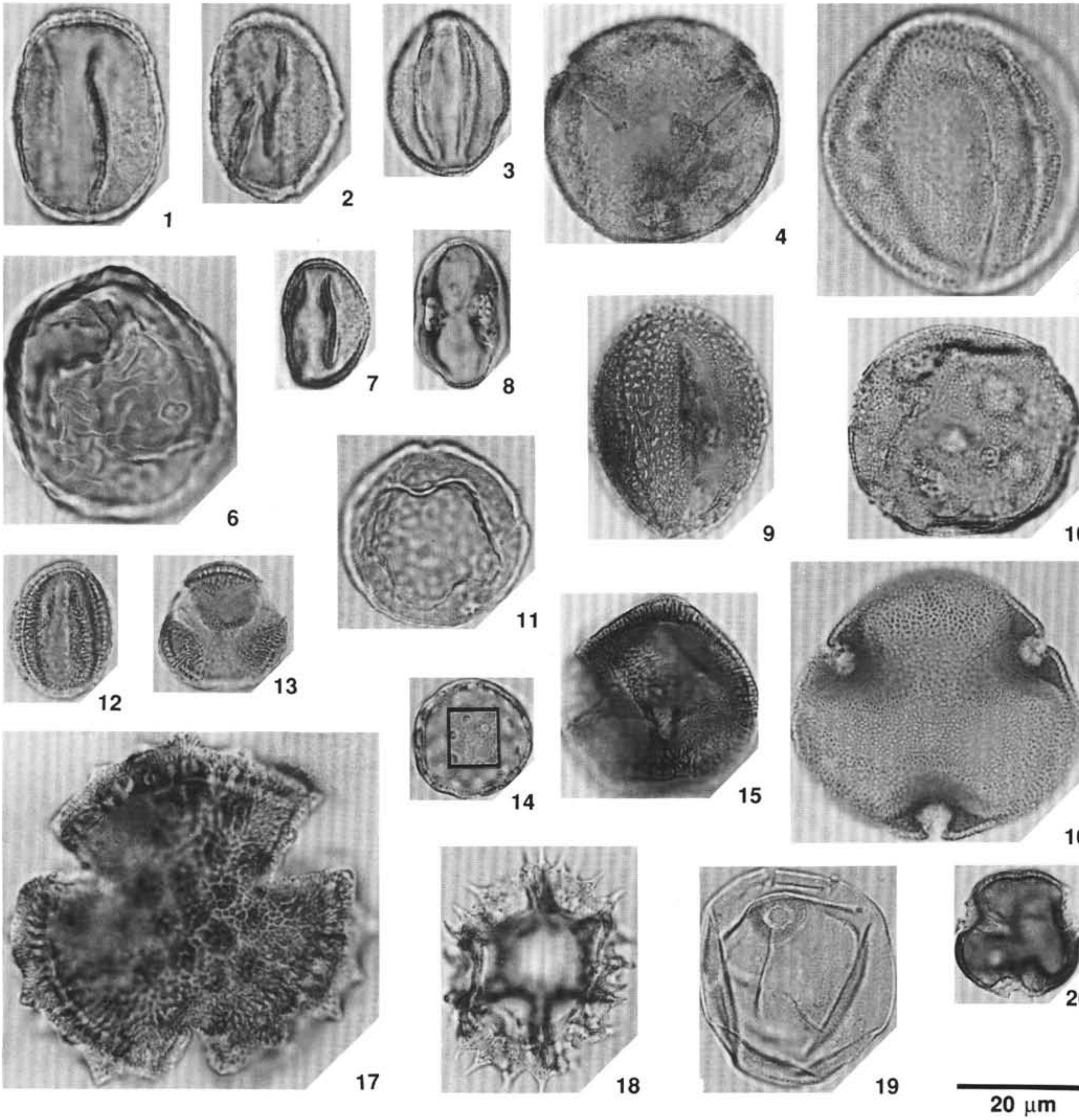

Plate 2. Pollen fossils of Leg 127 (LM) **1.** D. (deciduous) *Quercus,* Sample 127-794A-35X-3, 117–119 cm. **2.** D. *Quercus,* Sample 127-794A-35X-3, 117–119 cm. **3.** E. (evergreen) *Quercus,* Sample 127-794A-36X-2, 39–41 cm. **4.** *Fagus,* Sample 127-795B-21R-2, 132–134 cm. **5.** *Fagus,* Sample 127-797B-34X-5, 40–42 cm. **6.** *Zelkoova,* Sample 127-797B-43X-1, 41–43 cm. **7.** E. *Quercus,* Sample 127-796B-19R-1, 133–135 cm. **8.** *Aesculus,* Sample 127-796B-301R-1, 83–85 cm. **9.** *Rhus,* Sample 127-794B-25R-CC, 13–15 cm. **10.** *Liquidambar,* Sample 127-797C-8R-1 39–41 cm. **11.** *Ulmus,* Sample 127-795B-15R-2, 82–84 cm. **12.** *Artemisia,* Sample 127-795B-12R-2, 80–82 cm. **13.** *Artemisia,* Sample 127-795B-12R-2, 80–82 cm. **14.** Chenopodiaceae, Sample 127-794A-37X-2, 127–129 cm. **15.** *Fupingopollenites,* Sample 127-797C-8R-1, 39–41 cm. **16.** *Tilia,* Sample 127-797B-42X-1, 40–42 cm. **17.** Carduoideae, Sample 127-795A-32X-2, 135–136 cm. **18.** Cichorioideae, Sample 127-795B-14B-1, 87–89 cm. **19.** Gramineae, Sample 127-794A-33X-3, 130–132 cm. **20.** *Eurya,* Sample 127-796B-3R-2, 88–90 cm.