

## 18. POLLEN OCCURRENCE IN EASTERN NORTH PACIFIC SEDIMENTS, DEEP SEA DRILLING PROJECT LEG 18

Lillian F. Musich, Deep Sea Drilling Project, Scripps Institution of Oceanography, La Jolla, California

### INTRODUCTION

Land floras are extremely sensitive to climatic changes and are distinctive indicators of continental temperature and moisture conditions. It is probable that plants living today occupied, in Neogene and Quaternary time (Leopold, 1969), the same type of habitat in which they are now found.

Pollen and spores show no sign of having evolved during the last 2 m.y., have extremely resistant outer coatings or exines which make them resistant to destruction, and are almost ubiquitous in continental and near-shore sediments. These factors make pollen important in deducing Pleistocene climates from ocean sediments as well as from land deposits.

Until now, no pollen criteria have been established for recognizing glacial-interglacial boundaries in oceanic sediments of the northeast Pacific region. With cores from the Deep Sea Drilling Project Sites 173, 174, and 175 (the Delgada and Astoria deep sea fans), the author will attempt to determine some of these criteria. The reasons for studying pollen of this particular area were: (a) a long and probably uninterrupted sequence of terrigenous Pleistocene sediments has been recovered from DSDP Sites 173, 174, 175; (b) the pollen sequence of the adjacent land section is known; (c) there is enough supportive evidence from marine microfossils in the sediments to establish relative geologic ages (Figures 1 and 2).

The goals of this study were to (a) determine climatologically significant pollen criteria for the Pleistocene of the North Pacific and use these criteria to determine Pleistocene climatic changes, and (b) correlate pollen stratigraphy with that of cooccurring marine microfossils.

### METHODS

#### Sample Preparation

The average sample size was 5 grams. Samples were treated with a 10 percent potassium hydroxide solution to remove organic colloids and 25 percent HCl to remove calcium carbonate. The pollen was then separated by heavy liquid flotation (zinc chloride solution, specific gravity 2.0) as described by Brown (unpublished manuscript, 1960). Although determination of absolute pollen frequencies is precluded by this method, it was possible to determine relative pollen abundances.

After processing, residues were stained with Safranin "O" and mounted in glycerine jelly. A minimum count of 200 grains per sample was attempted; however, this was not always possible owing to some extremely low pollen frequencies. Where fifty grains or less were counted, the data are noted in Tables 1 through 3, but not used in construction of the final pollen diagrams (Figures 3-5).

Specimens observed were identified to the genus level. Generic determinations were based on Erdtman (1943). Dinoflagellates are absent or very rare in samples observed. Their presence is noted on Tables 4 to 6, but no attempt was made to identify them.

The abundance of palynomorphs was determined by counting the number of grains appearing under a single, standard 22 × 30 mm glass cover slip. The following scale was used:

Abundant	150+ grains per slide
Common	75-150
Few	30-75
Rare	less than 30

This nomenclature is used in Tables 4 to 6 for comparison with other microfossils at the sites studied.

Only species which occur repeatedly in quantities greater than 2 percent were plotted on the pollen diagrams. Occasional occurrences of *Ulmus* and *Castanopsis*, as well as reworked *Ephedra* and *Ginkgo* (mostly from the Miocene of Site 173), were noted on Tables 1 through 3 but were not plotted.

#### Preservation

Three major categories of preservation were observed in the samples studied and are illustrated on Plate 1, Figure 1. The first category consists of grains that stain pale pink in Safranin "O", are intact, and have uncorroded emphytic and haptotypic structures (Plate 1, Figure 1A). The second category consists of grains that have been corroded; i.e., surface ornamentation appears abraded and grains may be fragmented (Plate 1, Figure 1B). The third category consists of grains that may or may not be mechanically abraded, but show definite signs of oxidation and carbonization (Plate 1, Figure 1C). The grains of the last category always stain deep yellow or brownish yellow in Safranin "O". It is possible that both the second and third categories are reworked; however, it is also possible that the third preservation category is a result of diagenetic alteration caused by increased temperature and pressure (Staplin, 1969). It is this type of poor preservation that becomes prevalent at the bottom of Holes 173, 174, and 174A, and at the Gulf of Alaska sites.

#### Paleoecological Criteria

In attempting to determine criteria applicable in establishing climatic boundaries, three parameters were used and compared.

1. Occurrence of climatically important species in the area.

The Pleistocene and post-Pleistocene palynology of the land section in southern Oregon is found in studies by Hansen (1938, 1941, 1945, 1947; Hansen and Allison, 1942 — see Figure 2 for location of Hansen's sites) of

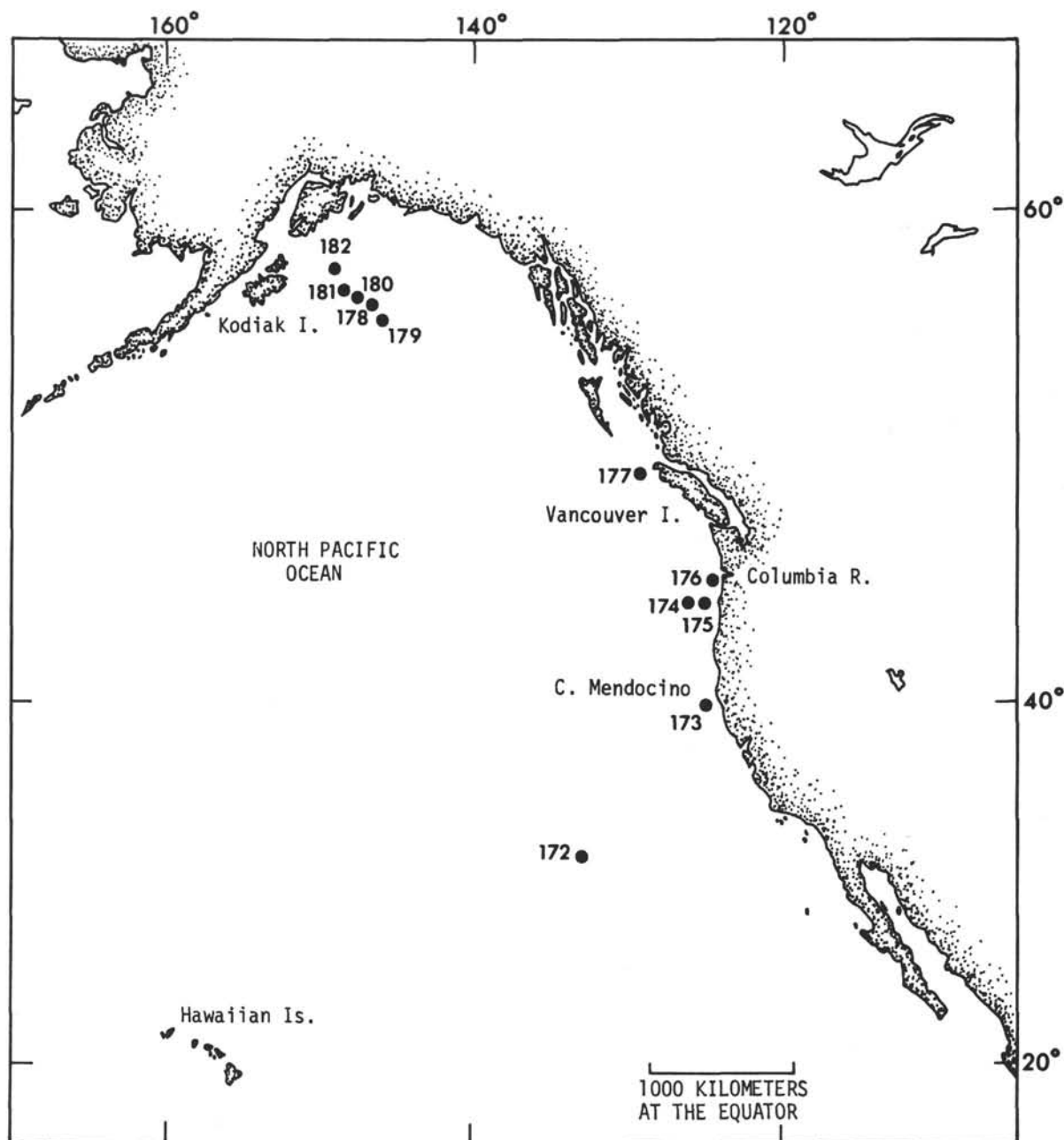


Figure 1. Location of sites, DSDP Leg 18.

coastal bogs of the region. He deals with the occurrence and cooccurrence of three dominating species: lodgepole pine, Sitka spruce, western hemlock. The primary pioneers and most tolerant species of the coastal north Pacific area is *Pinus contorta*. It is able to survive on the sandy, nonvegetated, unstable coastal soil and can tolerate direct sunlight. After pine has created a suitable environment, the next species to invade the area is *Picea*. Eventually *Picea*, in general, trees larger than the pine, will crowd out the pine. The proportion of *Pinus* to *Picea* is important in determining how stable the soil and how moderate the climate. When the climate is sufficiently ameliorated and the soil fairly stable, *Tsuga* will appear (Hansen, 1941; Hansen and Allison,

1942). These three conifers are dominant at all sites studied in detail. The fluctuations observed in coastal land sections compare well with those of the marine sections.

## 2. Biotic Diversity.

According to Fischer (1960), "The diversity of biotas on land and in the sea is greatest in climates of relatively high and constant temperatures, such as those found over much of the tropics, and decreases progressively into the fluctuating and the cold climates associated with higher latitudes."

As continental glaciers increase in size, the snow line is lowered and hence a shift in climatic zones occurs, with changes in temperature, rainfall frequency, and seasonabil-



TABLE 1  
Palynomorph Occurrence, Site 173

Sample	173-1 (CC)	173-2 (CC)	173-3 (CC)	173-4 (CC)	173-5 (CC)	173-6 (CC)	173-7 (CC)	173-8 (CC)	173-9 (CC)	173-10 (CC)	173-11 (CC)	173-12 (CC)	173-13 (CC)	173-15 (CC)	173-16 (CC)	173-17 (CC)	173-18 (CC)	173-19 (CC)	173-22 (CC)	173-23 (CC)	173-24 (CC)	173-25 (CC)	173-26 (CC)	173-27 (CC)	173-29 (CC)	173-30 (CC)
Pollen and Spores																										
<b>Trees</b>																										
<i>Pinus</i>	152	34	31	18	32	11	12	66	2	86	2	120	10		13	22	5			2	24	136	4	5	4	5
<i>Tsuga</i>	3	1	2	2	9	1	1	8	—	1	—	—	—		—	2	—			—	—	—	—	—	—	—
<i>Picea</i>	11	12	12	3	17	2	5	48	1	69	5	30	—		3	8	—			3	11	14	1	—	—	—
<i>Abies</i>	25	5	2	3	2	—	—	12	—	6	1	6	—		3	4	—			—	—	—	—	—	—	—
<i>Quercus</i>	11	3	1	—	1	—	—	7	—	9	3	10	—		1	3	1			—	1	3	—	—	—	—
<i>Alnus</i>	5	—	—	—	—	—	—	5	—	4	—	8	—		2	—	—			—	2	—	—	—	—	—
<i>Taxodium</i>	30	2	5	1	1	—	—	27	1	39	2	19	3		12	18	—			—	5	1	—	—	—	—
<i>Fagus</i>	1	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—			—	—	—	—	—	—	—
<i>Cedrus</i>	1	—	—	—	—	—	—	—	—	—	—	—	—		2	—	—			—	—	—	—	—	—	—
<i>Acer</i>	1	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—			—	—	—	—	—	—	—
<i>Fraxinus-type</i>	—	—	1	—	—	—	—	—	—	—	—	—	—		—	—	—			—	—	—	—	—	—	—
<i>Betula</i>	—	—	—	—	—	—	—	—	—	2	—	—	—		—	—	—			—	—	—	—	—	—	—
<i>Salix</i>	—	—	—	—	—	—	—	—	—	2	—	—	—		2	3	—			—	2	—	—	—	—	—
<i>Castanopsis</i>	—	—	—	—	—	—	—	—	—	4	—	—	—		—	1	—			—	—	1	—	—	—	—
<i>Ginkgo</i>	—	—	—	—	—	—	—	—	—	—	—	—	—		8	4	—			—	—	—	—	—	—	—
<i>Carya</i>	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—			—	—	3	—	—	—	—
<b>Grasses</b>																										
Graminae	4	1	1	—	2	—	1	17	—	14	—	10	—		—	1	—			—	—	—	—	—	—	—
Chenopodiaceae	2	1	1	—	—	—	—	2	—	2	1	1	—		1	—	—			—	—	—	—	—	—	—
Compositae	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—			—	—	—	—	—	—	—
<i>Ephedra</i>	2	1	1	—	—	—	—	3	—	7	—	3	—		1	—	—			1	—	—	—	—	—	—
<b>Pteridophytes</b>																										
Monolet spores	—	—	—	—	1	—	—	5	2	2	—	11	11		6	20	1			2	8	2	—	—	—	—
Trilete spores	—	1	1	—	—	—	—	1	—	14	2	—	—		4	—	—			—	—	—	—	—	—	—
Lycopodiaceae	3	—	1	—	—	—	—	—	—	—	—	6	—		—	—	—			—	—	—	—	—	—	—
Polypodiaceae	—	—	—	—	2	—	—	—	—	—	—	—	—		—	—	—			—	—	—	—	—	—	—

76 to 224 meters, becomes relatively constant from 224 to 288 meters, with a gradual increase below this point.

The tectonic activity and changes in geomorphology of the Oregon-northern California coast is also greater than that of the east coast of the U. S., and therefore exposure of shoreline may be due to other than eustatic causes. Hence, the occurrence of reworked palynomorphs to determine glacial boundaries is not reliable in this area.

#### SITE SUMMARIES

Fifteen holes at eleven sites were drilled during Leg 18 (Figure 1).

##### Site 172 (31°32'N, 133°22'W; water depth 4767 m)

Palynomorphs were not found in the brown zeolitic clays of Site 172. The absence of pollen and spores in this sequence is probably due to distance of this site from a major land mass but may also be the result of post-depositional oxidation.

##### Site 173 (39°57'N, 125°27'W; water depth 2927 m)

Site 173 is located approximately 50 miles off Cape Mendocino, California. The sediments down to 138 meters are predominantly terrigenous silty clays and fine sand (Core

16); diatomite with some nanno ooze to 285 meters (Cores 17-31); and mudstone, nannofossil ooze, and andesite basalt to 320 meters.

Palynomorphs are common to abundant in Cores 1 through 18 (0-167 m) and in Core 25 (224-233.5 m) but are virtually absent from all other samples examined. The absence of pollen in the majority of cores sampled is probably due to dilution of terrigenous material by marine microfossils, particularly diatoms (Korneva, 1964), and by the lack of preservation of pollen grains at the base of the hole. The latter phenomenon is reflected by the increasing percentage of poorly preserved pollen downhole, where in the case of Core 25 they form 90 percent of the sample. Corrosion and yellow staining of pollen may result from overburden pressure and high temperature (Staplin, 1969).

The composition of assemblages encountered indicates fluctuating cooler and warmer conditions on land, but most dramatic is the sharp break at the base of Core 8 (72 m) indicating a warm period which continues almost to the base of the section studied. Pine frequency decreases from a maximum of 85 percent at 55 meters to a minimum of 10 percent at 100 meters. Correspondingly, there is an increase in species diversity. This break corresponds to the Pliocene-Pleistocene boundary as determined by marine microfossils.



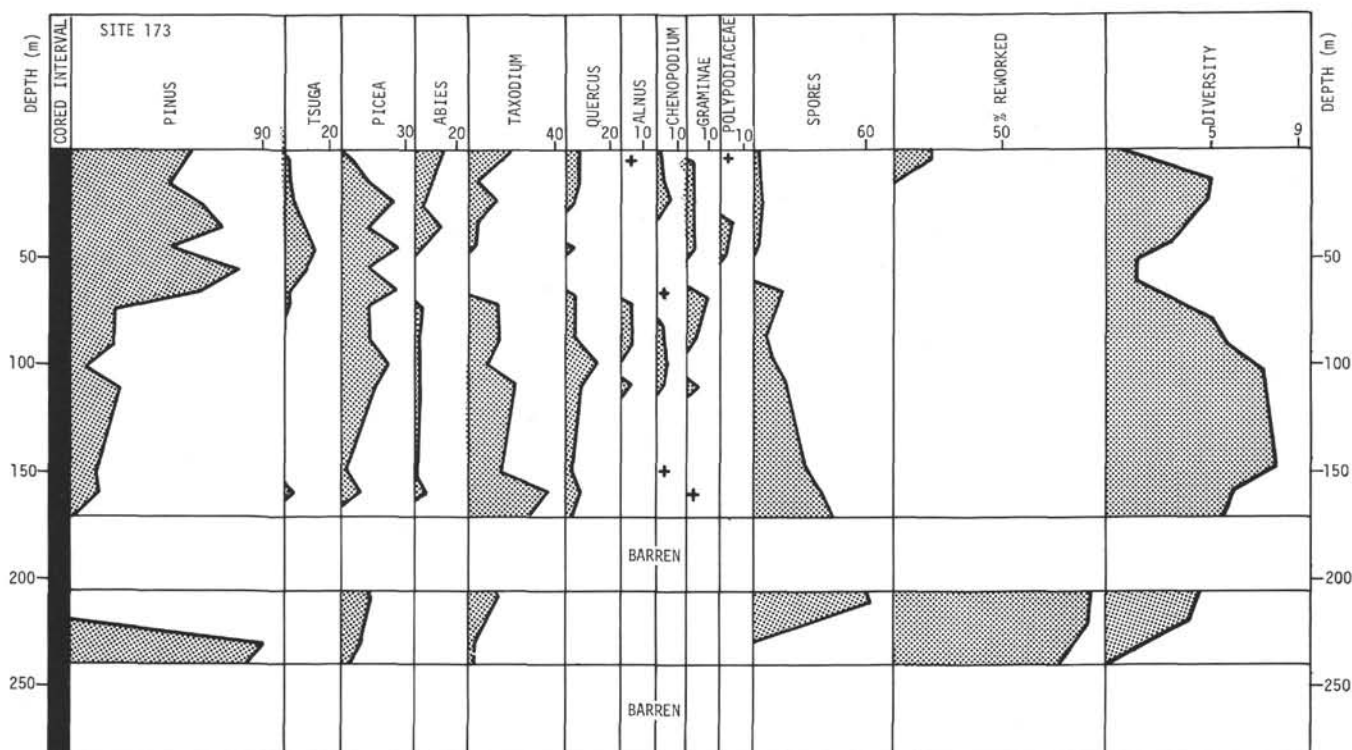


Figure 3. Pollen diagram, Site 173.

The lack of detail in climatic trends at Site 173 is probably the result of a relatively wide sample interval, precluding the detection of small-scale climatic events.

The appearance of *Ephedra* in Core 12 (110 m) marks the only occurrence at this site of a genus extinct in this area since Pliocene time.

**Site 174 (44°53'N, 126°21'W; water depth 2815 and 2799 m)**

Site 174, located approximately 300 miles northwest of Site 173 and about 75 miles from land, was drilled in the Astoria submarine fan, which is formed of sediment from the Columbia River. A late Pleistocene succession of medium to very fine turbidite sands grading into silt or silty clay was retrieved from the upper 284 meters of Hole 174A. From 284 to 879 meters the turbidite beds occur less frequently and finally grade to a gray fissile mud. The very thick and almost completely cored Pleistocene section of this site provided the most useful pollen data of the entire leg. The occurrence of palynomorphs varies from abundant to rare. Pollen frequency is highest in Cores 1 and 2 of Hole 174 and Cores 1, 5, 6, 7, 11 to 14, 17, 18, 22, 27, 28, 31, and 33 of Hole 174A. Pollen frequency below Core 35 (417 m) is so low that statistically reliable counts could not be made. The percentage of "reworked" grains increases dramatically below 280 meters, probably in conjunction with the lithologic change at 280 meters.

It is important to note that turbidite deposition may play an important role in masking and diluting palynomorphs at this site. Rapid deposition of sediments may explain the frequent and sudden disappearance of all palynomorphs and the common occurrence of reworked material.

Indications of warm conditions on the adjacent land mass, consisting of a mature conifer forest where *Tsuga* frequency and genetic diversity are high and pine frequency is low, were found at 31.1 meters (174-1-1, 138-140), 94.5 meters (174A-7, CC), and 132.5 meters (11, CC). The warming at 132.5 meters is the most striking, since at this point *Tsuga* constitutes almost 50 percent of the sample. Foraminifera and nannofossils at this level also indicate a warm condition.

**Site 175 (44°50'N, 125°14'W; water depth 1999 m)**

Site 175 is located about 25 miles east of site 174 in a small synclinal trough on the lower continental slope off central Oregon. Sediment types are predominantly dark greenish gray mud with occasional thin beds of fine sand and coarse silt. Medium gray mud rich in detrital carbonate occurs as intercalations in the lower portion of the hole.

Cores 3, 5, and 8 at Site 175 contain common to abundant spores and pollen. Cores 1 and 2 contain few palynomorphs and Cores 13 through 22 are barren. The dominance of conifers observed at other sites was also encountered here. *Pinus*, *Tsuga*, and *Picea* are most common, while deciduous trees and grasses are rare. Rare, reworked specimens of *Ginkgo*, *Carya*, and *Ephedra* occur in Core 2. Although data in this hole are sparse, a *Tsuga* peak occurs which directly corresponds to a rise in diversity and a drop in the pine count (Core 3, Section 4, 38-40 cm). Six meters below this (Core 3, CC) the opposite trend is observed: pine increases to 65 percent of the sample, *Tsuga* disappears entirely, and diversity drops sharply. It is possible that these extremes at 19.5 and 35 meters represent a warm period followed by a cool period.

TABLE 2  
Palynomorph Occurrence, Holes 174 and 174A

Pollen and Spores	Sample																																						
	174A-1 (CC)	174-2 (CC)	174A-1-1 (138-140)		174A-1-3 (70-72)	174A-2-1 (40-42)	174A-2 (CC)	174A-3 (CC)	174A-4-2 (123-125)		174A-4 (CC)	174A-5 (CC)	174A-6-2 (117-119)		174A-6 (CC)	174A-7-1 (85-87)		174A-7 (CC)	174A-8-4 (130-132)		174A-8-6 (96-98)	174A-9-5 (141-142)		174A-11-6 (40-42)		174A-11 (CC)	174A-12 (CC)	174A-13-2 (23-25)		174A-13-3 (114-116)		174A-13-4 (12-14)	174A-13-5 (47-49)		174A-13 (CC)	174A-14 (CC)			
Trees																																							
<i>Pinus</i>	162	96	30	33		3	2	4	12	101	10	66	30	110	2	25	3	14	53	27			49	12	9	3	51												
<i>Tsuga</i>	23	14	27	19						12		5		8		5		13	102	4	1	1		1		17													
<i>Picea</i>	52	59	22	23			1	7	9	68		31	12	38	1	26		5	44	12	1	38	7	16	4	54													
<i>Abies</i>	5	5		2					1	3		4	1			4		1	3	1				3	4														
<i>Quercus</i>	12	3	4	3		1	1		7	22		8	17	7		8		1	3	1		2		4	16														
<i>Alnus</i>	38	13	23	8						2	1	3	1	1		4			2	1		3		1	16														
<i>Taxodium</i>	3	1	7	2																																			
<i>Fagus</i>																																							
<i>Cedrus</i>																																							
<i>Acer</i>	1				1											1																							
<i>Fraxinus</i> -type	3	2																							1														
<i>Betula</i>																																							
<i>Salix</i>	2	1				2				4		2	5	4			1			2				2	1														
<i>Castanopsis</i>										3										1				1															
<i>Ginkgo</i>																									1														
<i>Carya</i>																																							
Grasses																																							
Graminae		1	1	2									1	1		4			1			1			4														
Chenopodiaceae	1	1		1				1					2			1			1			1			2														
Compositae		1			1				1		3	2	1		2	1		1	2	1	3				3														
<i>Ephedra</i>											1																												
Pteridophytes																																							
Monolete spores			2	7	1	1	2	1		5		3	7	3		5	1	1	3	2				6	9														
Trilete spores			3	9				1		3		2	6	3		8		1	4	4				3	14														
Lycopodiaceae	1	1			1					2			4	5																									
Polypodiaceae	1	4		1									5					1	2																				

#### Site 176 (45°56'N, 124°37'W; water depth 193 m)

Sediments from Site 176 consist of 41 meters of dark greenish gray clayey silt with a hard fissile shale layer of Pliocene age at the base of the hole. Because Site 176 is located close to the Oregon coast, and the sedimentation rate is low, it was thought that this site would provide a good pollen section. However, palynomorphs occur rarely in these sediments and all pollen found is coniferous. No conclusions concerning climate could be drawn because of low pollen frequencies and diversities.

#### Site 177 (50°28'N, 130°12'W; Water Depth 2006 m)

Lower Pleistocene sand and silt turbidites, with some nanofossil ooze, are the predominant sediments recovered

from Site 177, located at the northwestern end of Paul Revere Ridge. Most of the cores examined are barren of spores and pollen. Reasonably well preserved pollen grains (*Pinus*, *Tsuga*, *Picea*) and spores (*Lycopodium*), though very rare, occur at the base of Core 5 (54 m), whereas, Cores 1 to 4 and 6 to 10 have very fine-grained residues with no plant material.

Abundant, poorly preserved pollen grains occur at the base of Core 13 (184 m) along with coaly material (Y. Lancelot, personal communication). The assemblage has a very low diversity and is almost entirely coniferous in nature. Members of the family Polypodiaceae (*Polypodium* sp. aff. *P. vulgare* type) occur frequently. The occurrence of a badly preserved specimen of the genus *Ephedra* is the

--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

only palynological indicator of Pliocene material in this area; this specimen is possibly reworked.

#### Site 178 (56°57'N, 147°47'W; Water Depth 4218 m)

Sediments at Site 178 consist of gray silty clay with ice-rafted erratics, diatomaceous sediments, silt and sand turbidites, claystone, and shale.

Samples examined from this site generally contain few or no palynomorphs. Pollen of noteworthy abundance (Cores 24 and 42) is so badly preserved and oxidized that specific identification is impossible. Moreover, identifiable grains (*Tsuga*, *Alnus*, *Salix*, *Pinus*, psilate and trilete spores) are present in such small quantities that no paleoclimatological determinations could be made.

Coaly fragments are common throughout the cores. Where samples contain abundant diatomaceous material, no palynomorphs or coal fragments were observed. This is most likely the result of dilution by the rapid deposition of organic silica.

#### Site 179 (56°24'N, 145°59'W; Water Depth 3781 m)

Core catcher samples examined at Site 179 were nearly barren of pollen and spores. All specimens found (*Pinus* and Graminae) showed signs of oxidation. This is probably due, in part, to dilution of the sediment by marine microfossils.

TABLE 3  
Palynomorph Occurrence, Site 175

Sample	175-1 (CC)	175-2 (CC)	175-3 (CC)	175-3-4 (CC)	175-5-1 (18-20)	175-6-5 (22-24)	175-8 (CC)	175-12-1 (71-73)	175-13-4 (20-22)	175-14-6 (16-18)	175-15 (CC)
<b>Pollen and Spores</b>											
<b>Trees</b>											
<i>Pinus</i>	14	32	71	58	38	133	111	24			
<i>Tsuga</i>	4		66	1	16	42	26	1			
<i>Picea</i>	4	5	37	12	17	46	55	6			
<i>Abies</i>			3	1	1	8	4	1			
<i>Quercus</i>	1	2	1	1	1	1	3				
<i>Alnus</i>		1			1	9	1				
<i>Taxodium</i>	1		21		5	13	1				
<i>Betula</i>					1	1	2				
<i>Salix</i>				2	1		1				
<i>Castanopsis</i>						2					
<i>Ginkgo</i>		1									
<i>Carya</i>		1									
<b>Grasses</b>											
Graminae			1	1			1				
Chenopodiaceae			1		2						
Compositae	1	4	3	3	2	6	2				
<i>Ephedra</i>		1									
<b>Pteridophytes</b>											
Monolete spores		2	4	3	4						
Trilete spores		2	2	3	1						
Lycopodiaceae											
Polypodiaceae			7	2	5	1					

#### Site 180 (57°21'N, 147°51'W; Water Depth 4923 m)

Site 180 is located in the eastern Aleutian Trench. Except for occasional, badly oxidized palynomorphs, samples examined at Site 180 are barren of spores and pollen. The scarcity and poor preservation of grains is probably due to a dilution effect resulting from a high sedimentation rate and destruction of pollen grains in sediments of high porosity. Oxidized woody fragments are present throughout the cores. It is also possible that the poor preservation may be the result of increased temperature and pressure.

#### Site 181 (57°26'N, 148°27'W; Water Depth 3086 m)

Woody fragments, but no identifiable palynomorphs are present in samples examined at Site 181. Since conditions of deposition at Site 181 were similar to those at Site 180, lack of well-preserved and abundant spores and pollen was expected.

#### Site 182 (57°52'N, 148°42'W; Water Depth 1411 m and 1434 m)

Samples examined at Site 182 were found to be almost barren of spores and pollen. All woody fragments and palynomorphs found were oxidized beyond recognition.

It is interesting to note here that all pollen found at the Gulf of Alaska sites (Sites 178-182) showed signs of extreme oxidation. At Sites 181 and 182 this may be related to high temperatures and pressures which would occur in a zone of subduction. (See Gray and Laplante, this volume).

## PALEOCLIMATIC INTERPRETATIONS

### Modern Physiography and Climate of the Related Land Area

The three sites most relevant to this study are Sites 173, 174, and 175 (Figure 2). Because of their proximity to each other and to the north Pacific coast, they share a common pollen source area. The pollen found represent a broad spectrum of the northern California-southern Oregon flora but it is necessary to recognize and describe only two major climatic zones, although many microclimates can be found in this area.

The coastal Pacific Northwest has a maritime climate, typified by small year-round temperature variation, fog and cloudiness, a mild winter with abundant rainfall, a relatively cool, dry summer, and a frost-free season of 250 to 300 days (Hansen, 1945). The prevailing winds are southwesterly or northwesterly during most of the year. The coastal area is divided into two major zones: the coastal strip and the coastal range. The coastal strip lies between the coast range and the ocean. Although it is very narrow, it occupies approximately 500 miles of the northern California-southern Oregon coast. The average annual temperature along the strip is about 50° with an average daily maximum of 57° and a minimum of 44°. The area is shielded from strong continental influence by mountains of the coast range. These mountains tend to act as barriers and prevent moisture-saturated air from moving inland. Although the annual temperature range in these mountains varies little from the coastal strip, the daily temperature variation is greater. Due to their climatic similarities, both the coastal strip and the coast ranges support a very similar, mainly coniferous flora.

The present-day vegetation of the Oregon coast is dominated by lodgepole pine, Sitka spruce, and western hemlock. Dominant species have probably not changed in this area during the Pleistocene and, although specimens observed at the various sites are not referred to on the specific level, almost all specimens of pine, spruce, and hemlock (*Pinus*, *Picea*, and *Tsuga*) found in DSDP samples fit descriptions for lodgepole pine, Sitka spruce, and western hemlock. Occurring in low proportions are *Abies*, *Alnus*, *Acer*, Graminae, and Compositae (Hansen and Allison, 1942). This vegetation sequence is very similar to the general aspect of pollen diagrams from the sites studied, particularly Sites 173 and 174.

### Paleoclimatic Correlation With The Land Section

Tables 1, 2, and 3 show occurrence of pollen species and number of specimens counted in each sample. As can be seen from these tables and from Figures 3, 4, and 5, gymnosperms, particularly *Pinus*, *Tsuga*, and *Picea*, are dominant at Sites 173, 174, and 175. Deciduous trees, grasses, and Pteridophytes do not occur with great frequency and the most common deciduous trees are *Quercus* (oak) and *Alnus* (alder). These pollen profiles are compatible with Hansen's descriptions of late and post-Pleistocene pollen occurrences of continental coastal Oregon, where paleoclimatic change is based on the appearance and abundance of *Pinus*, *Tsuga*, and *Picea*. Climatic optima are characterized by the appearance of alder and grasses.



## POLLEN OCCURRENCE IN EASTERN NORTH PACIFIC SEDIMENTS

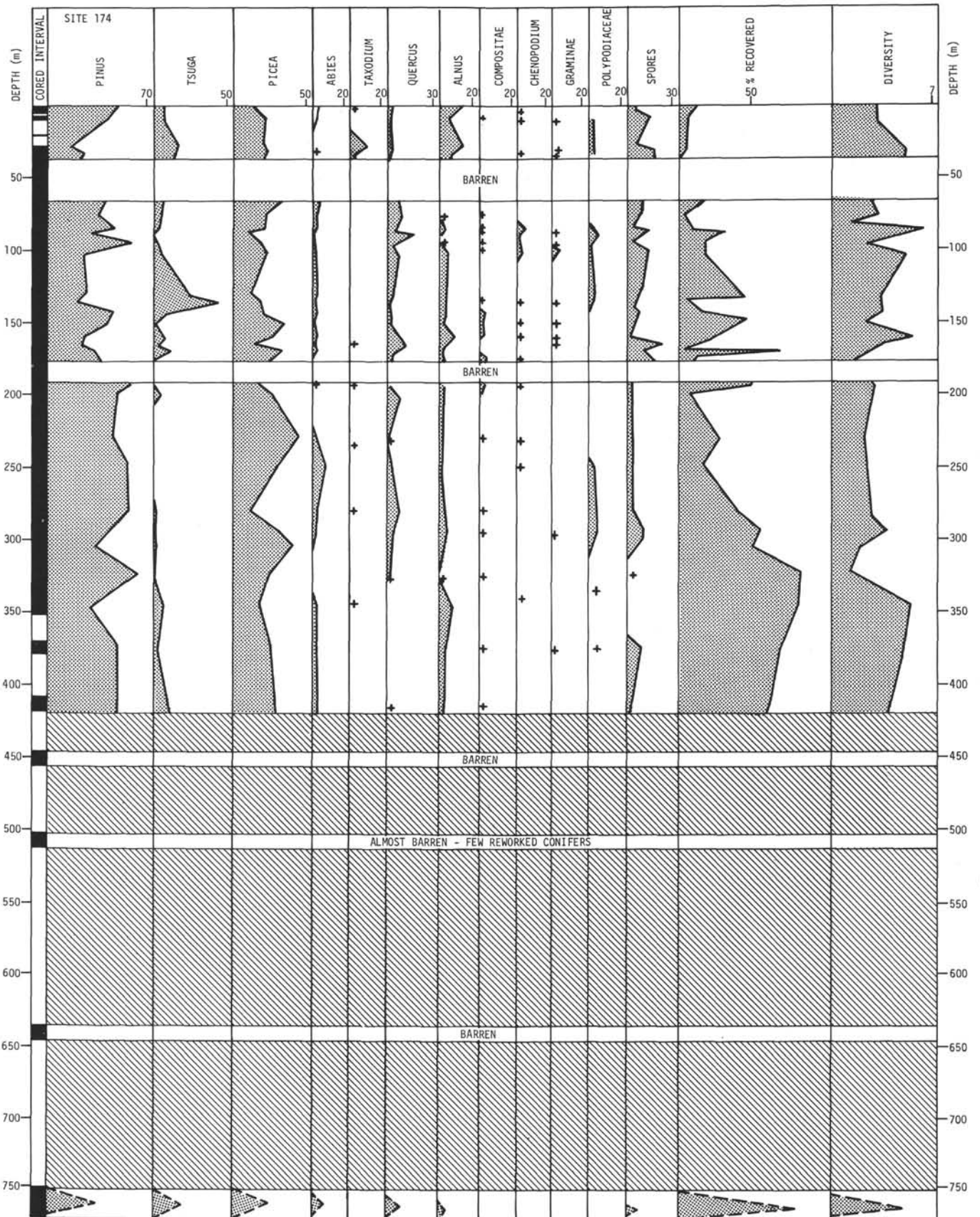


Figure 4. Pollen diagram, Site 174.

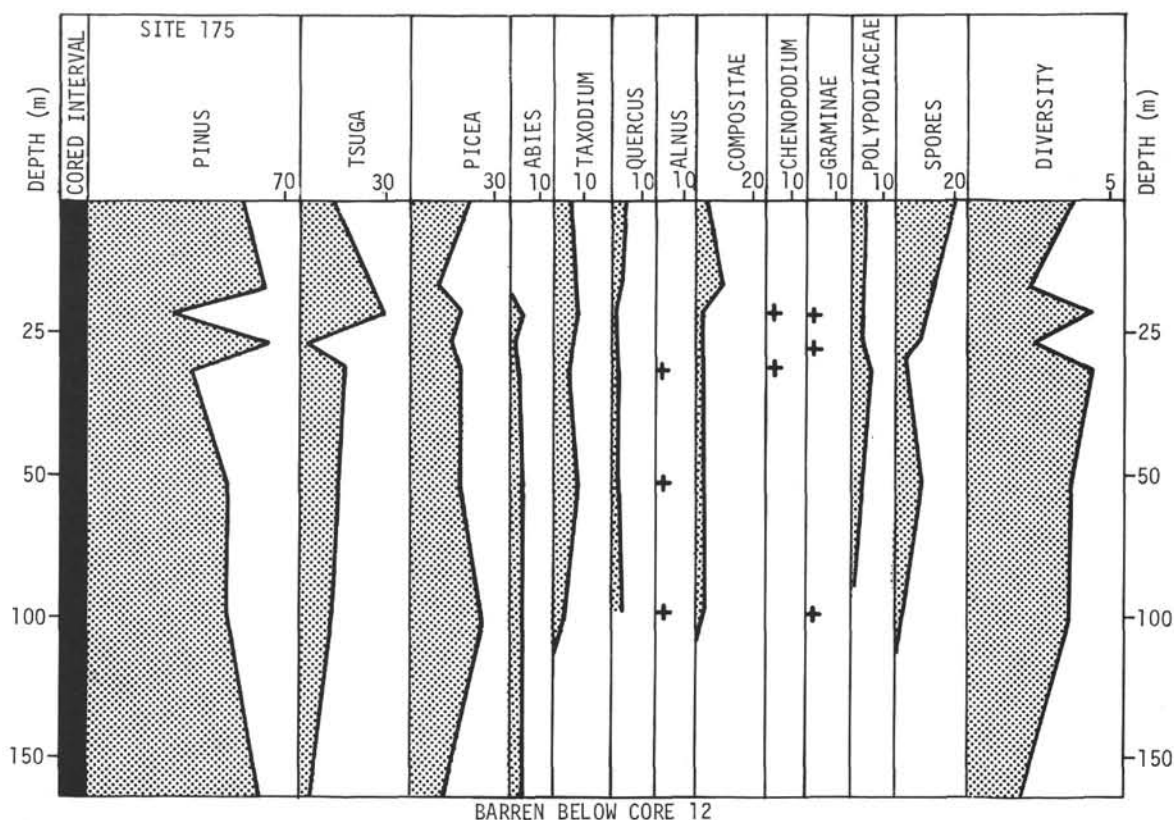


Figure 5. Pollen diagram, Site 175.

At Site 173 there is a marked warming trend at 62 meters, typified by a sudden drop in pine frequency and a sharp rise in diversity.

The fact that *Tsuga* almost disappears below this point may be the result of *Taxodium* occupying the ecologic niche in the Pliocene that *Tsuga* occupies in the mature Pleistocene conifer forest (see Figure 3).

Table 4 shows the location of general climatic trends established by calculating *Pinus-Picea-Tsuga* ratios and comparing them to diversity. At 224 meters (24, CC) there are two samples in an otherwise barren zone which contain genera indicative of a cool period. The age of the samples is middle Miocene.

In order to compare the three major genera at Site 174, a triangle diagram was constructed and normalized values of the three dominant conifers plotted. Samples containing 60 percent or more pine are considered to represent cool periods; samples containing 45 percent or more *Tsuga* are considered to represent optimal warm; samples dominated by *Picea/Pinus* are considered to be transitional cool; and those dominated by *Picea/Tsuga* are transitional warm. The triangular diagram was divided according to these parameters, and samples were plotted with reference to their general location on the diagram. The results are found on Figure 6. The terms cool, transitional cool, transitional warm, and warm are relative and have not been assigned absolute values.

According to these data, the warmest period at Site 174 occurs at 132 meters (11, CC). A transitional warm period occurs at 31 to 34 meters. This may correlate with Hansen's

climatic optimum, which occurs on land at 6000-8000 years B.P. These warm periods correlate with rises in diversity. In general, at Site 174, it should be noted that the diversity curve has excellent inverse correlation with the pine curve, implying that as pine frequency decreases (i.e., the forest matures), diversity increases.

Samples are sparse at Site 175 and therefore climatic interpretation here is quite speculative. One warm transitional period occurs at 24 meters with cool and warm intervals above and below 34 meters. No attempt was made to make paleoclimatic interpretations below this point.

#### Correlation With Marine Microfossils

It is possible to draw some climatic correlations between pollen and cooccurring marine microfossils.

Table 4 compares foraminifera and diatom data with that of palynomorphs at Site 173. One obvious correlation is that between diatoms and pollen which occurs at the Plio-Pleistocene boundary. As shown in the pollen diagram for Site 173 (Figure 2) dramatic reduction of pine frequency cooccurs with a sharp rise in diversity at 72 meters. This correlates with diatom data which show the same warm trend in the Pliocene. *Globigerina pachyderma* coiling data show an increase of maximum warmth from 12°C to 20°C below this point.

At 224 meters (24, CC) there appears to be a cool period.

Foram coiling data show a similar upper Miocene cooling period, but at 205 meters.

Table 5 compares pollen data of Site 174 with that of nannofossils and foraminifera. At 31 and 34 meters (where

TABLE 4  
Comparison of Pollen With Cooccurring Marine Microfossils, Site 173

Sample No.	Depth In Hole (m)	Forams.	Zone	Age	Climate	Siliceous Microfossils (Diatoms)	Zone	Age	Climate	Pollen Abund.	Age	Climate	Sediment Type
1(CC)	5.5	A/G	N 23			A/G	NPD I		Warm	A/G			Gray green silty clay
2(CC)	15.5	A/G			Cool	A/G			Warm	C/G			Gray green silty clay
3(CC)	24.5	A/G				A/G	NPD II		Warm	F/G	Pleistocene	Cool	Gray green silty clay
4(CC)	34.0	A/G		Late Pleistocene		A/G		Pleistocene		F/G			Gray green silty clay
5(CC)	43.5	A/G				A/G	NPD III		Warm	C/G			Gray green silty clay
6(CC)	53.0	A/G				A/G			Warm	R/G			Silty clay with some glass
7(CC)	62.5	A/G				A/G	NPD IV		Warm	R/G			Silty clay with ash <sup>a</sup>
8(CC)	72.0	A/G				A/G	NPD V		Warm	A/G			Gray green silty clay
9(CC)	81.5	A/G				A/G	NPD VI		Warm	R/G			Gray green silty clay
10(CC)	91.0	A/G				A/G		Pliocene		A/G	Pliocene		Gray green silty clay
11(CC)	100.5	A/G		Pliocene		A/G	NPD VII			R/G			Gray green silty clay
12(CC)	110.0	A/G				A/G				A/G			Gray green silty clay
13(CC)	119.5	A/G				A/G	NPD VIII			R/M			Diatom rich silty clay
16(CC)	148.0	A/G		Upper Miocene		A/G	NPD IX			F/G			Olive gray diatomite
17(CC)	157.5	A/G			Cold	A/G	NPD X			C/G			Olive gray diatomite
18(CC)	167.0	A/G				A/G	NPD XI						Nanno rich diatomite
22(CC)	205.0	A/G				A/G	NPD XII			B			Nanno rich diatomite
23(CC)	214.5	A/G				A/G	NPD XIII			B			Nanno rich diatomite
24(CC)	224.0	A/G		Middle Miocene		A/G		Miocene		F/G		Cold	Nanno rich diatomite
25(CC)	233.5	A/G				A/G				A/P			Nanno rich diatomite
26(CC)	243.0	A/G				A/G				R/P			Nanno rich diatomite
27(CC)	252.5	A/G				A/G				R/P			Nanno rich diatomite
29(CC)	271.5	A/G				A/G				R/P			Diatomite
30(CC)	281.0	A/G				A/G				R/P			Diatomite

<sup>a</sup>Pollen boundary based on the sudden increase in diversity and decrease in *Pinus*

pollen abundance and preservation are good) there is a climatic optimum. Pine frequency falls to 15 percent and percentages of *Tsuga* and *Alnus* rise to 20 and 15 percent respectively. There is also a sharp rise in diversity. Hansen (1945) found, in his study of post-glacial vegetation on land, a maximum warmth and dryness 8000 to 4000 years B.P., followed by a cooler moister climate which persists to the present day. An age of 8000 years is feasible for this part of the section, considering sedimentation rates for this interval (von Huene and Kulm, this volume).

The next major climatic event occurs at 132 meters, where *Tsuga* frequency reaches a high of 45 percent and pine drops to 25 percent. This warm period cooccurs precisely with warm-water foraminiferal and nannoplankton species. Also, according to von Huene and Kulm (Chapter 33, this volume, Figure 8) the occurrence of ice-rafted debris in the Gulf of Alaska suggests the beginning of an interglacial just prior to 0.3 m.y. The sedimentation rate of 132 meters at Site 174 implies a date of approximately 0.3 m.y. for this depth.

Another possible warm trend begins at approximately 270 meters, signified by the reappearance of *Tsuga* and *Alnus*. This also marks the beginning of a sharp increase of reworked specimens in this region and coincides with a

change in lithology from turbidite to non-turbidite sequences. It is possible that this indicates a change of sediment source (i.e., increased or decreased competency of the Columbia River) rather than climatic change.

Only one marked warm period is observed at Site 175. This occurs at 24 meters (175-4, CC) and is signified by a decrease in *Pinus*, an increase in *Tsuga*, and an increase in diversity. This is neither substantiated nor negated by cooccurring marine microfossils. Due to sparse sampling at Site 175 and lack of pollen below 34 meters, no attempts were made at correlation or interpretation.

## CONCLUSIONS

1. Criteria most meaningful in determining paleoclimates in oceanic sediments off northern California and southern Oregon in the Pleistocene are ratios of *Pinus-Picea-Tsuga* and the amount of genetic diversity.

2. At no time during the Pleistocene was the coastal area near Sites 172, 173, and 174 ever completely denuded of vegetation. Rather, when climates deteriorated as a result of growth of the glacial ice cap north of the area studied (see Figure 1), pine, the hardest of the conifers, able to

**TABLE 5A**  
Comparison of Pollen With Cooccurring Marine Microfossils, Holes 174 and 174A

Sample No.	Depth in Hole (m)	Nannos.	Zonation	Forams.	Zonation	Climate	Pollen Abund.	Climate	Sediment Type
<b>Hole 174</b>									
1(CC)	2.0	F/M	L. Pleist.	C/G			A/G		Fine sand with mud. Woody material – A
2(CC)	9.5		Barren	R/M			A/G		Fine sand. PICEA greater than 130μ, coaly frags C, Woody material – A
<b>Hole 174A</b>									
1-1(138-140)	31.14	C/G		C/G			A/G	Hansen's climatic optimum 4000 – 8000 B.P. Warm	Silty clay. Common woody and coaly frags.
1-3(70-72)	34.72	C/G		C/G			C/G		Very fine sand. Dinoflagellates C-A
2-1(40-42)		C/G		F/M			Almost barren		Fine sand. Coal material – R
2(CC)	47.0			F/M			Almost barren		Fine sand
3(CC)	56.5	R/M		F/G			Almost barren		Fine sand
4-2(123-125)		R/P		R/M			Almost barren		Fine sand
4(CC)	66.0	R/P		F/G			F/G		Silty clay. Coaly and woody frags – R
5(CC)	75.5	F/M		C/G			A/G		Silty clay. Coaly and woody frags – C
6-2(117-119)	78.5	R/M		C/G			Almost barren		Sand
6(CC)	85.0	R/M		C/G			A/G		Silty clay. Coaly and woody frags – C
7-1(85-87)	85.5	R/M		C/G <sup>a</sup>			C/G		Silty clay. Coaly and woody frags – A
7(CC)	94.5	R/M		C/G <sup>a</sup>			A/M		Silty clay. Coaly and woody frags – C

<sup>a</sup>Near shore.

**TABLE 5B**  
Comparison of Pollen With Cooccurring Marine Microfossils, Hole 174A

Sample No.	Depth In Hole (m)	Nannos.	Zonation	Forams.	Zonation	Climate	Pollen Abund.	Climate	Sediment Type
8-4(130-132)	98.5	R/M		R/P			Almost barren	?	Sand
8-6(96-98)	102.5	R/M		R/P		Cool	C/G		Sand
9-5(141-142)	111.5	R/M		F/M			Almost barren	Cool	Sand. Coaly frags – C
11-6(40-42)	132.0	F/M		C/G <sup>a</sup>			F/M		Silty clay
11(CC)	132.5	F/M		C/G <sup>a</sup>		Warm	A/G	Warm	Fissile mud. Abundant woody and coaly frags.
12(CC)	142.0	R/G		C/G			F/G		Fissile mud. Abundant woody material
13-2(23-25)	145.0	R/M		C/G			Almost barren		Silty clay. Woody material – R
13-3(114-116)	146.5	R/M		C/G			C/M		Silty clay. Much woody material
13-4(12-14)	148.0	R/M		C/G			Almost barren		Sand
13-5(47-79)	148.5	R/M		C/G			F/M		Silty clay. Much woody material
13(CC)	151.5	R/M		C/G		Cool	Almost barren	Cooler	Sand
14(CC)	161.0	R/M		R/M			A/G		Fine sand. Much woody and coaly material
15-4(67-69)	166.0	F/M		C/G			C/G		Silty clay. Woody material, coaly frags – C
15-6(85-87)	169.0	F/M		C/G			F/M		Silty clay. Woody material, coaly frags – C
15(CC)	170.5	F/M		C/G			F/G		Sand. Woody material, coaly frags – A
16-2(140-142)	173.5	B		R/M <sup>b</sup>			Barren		Fine sand
16-3(78-80)	175.0	B		R/M <sup>b</sup>			Barren		Silty clay
16-4(115-117)	176.5	R/M		F/M <sup>b</sup>			Almost barren		Silty clay. Woody material, coaly frags – C
16(CC)	180.0	B		F/M <sup>b</sup>			Almost barren		Sand
17(CC)	189.5	B		F/M			A/M		Silty clay
18(CC)	199.0	R/M		F/M			C/G		Silty clay

<sup>a</sup>Warm, near shore species<sup>b</sup>Near shore species



TABLE 5C  
Comparison of Pollen With Cooccurring Marine Microfossils, Hole 174A

Sample No.	Depth In Hole (m)	Nannos.	Zonation	Forams.	Zonation	Climate	Pollen Abund.	Climate	Sediment Type
19(CC)	208.5	B		F/M			Barren		Sand
21-2(120-122)	221.0	B		R/M			Almost barren		Sand
22-3(88-90)	230.0	B		R/P			C/M		Silty clay
23(CC)	246.5	B		R/P					Silty clay
27-2(104-106)	278.0	R/M		C/G			Barren	Cool	Silty clay
27(CC)	284.5	R/M		C/G		Cool	A/M		Silty clay. Dinoflagellates – C
28(CC)	294.0	R/M		B			A/P		Fissile mud. Coaly and woody frags – A
29(CC)	303.5	C/G		F/M			C/M		Silty clay
31(CC)	322.5	F/M	<i>Coccolithus doronicoides</i>	C/G <sup>a</sup>			A/P		Fissile mud. Coaly and woody frags – A
32(CC)	332.0	C/G		C/G			Almost barren		Silty clay. Coaly and woody frags – A
33-2(72-74)	345.0	F/M		R/M			A/P		Fissile mud. Coaly and woody frags – A
34(CC)	379.5	F/M		C/G <sup>b</sup>			F/P		Fissile mud. Coaly and woody frags – C
35(CC)	417.5	F/M	<i>E. annula</i>	C/G <sup>b</sup>			C/P		Fissile mud
36(CC)	455.0	R/M		C/G <sup>b</sup>			Barren	Warmer	Fissile mud. Coaly and woody frags – C
37(CC)	512.5	B		F/M <sup>b</sup>			Barren		Fissile mud
38(CC)	645.0	R/M		R/P <sup>b</sup>	Pliocene forms	Warm	Barren		Silty clay. Coaly and woody frags – C
39(CC)	759.5	R/M		C/M <sup>b</sup>			F/P		Limestone and sandstones. Coaly and woody frags – C
40-5(85-87)	778.5	B		F/M			Barren		Calcareous mudstone

<sup>a</sup>Near shore<sup>b</sup>Warm trend

TABLE 6  
Comparison of Pollen With Cooccurring Marine Microfossils, Site 175

Sample No.	Depth In Hole (m)	Nannos.	Zonation	Climate	Forams.	Zonation	Climate	Diatoms Zonation	Climate	Pollen Abund.	Climate	Sediment Type
1(CC)	5.0	F/P			C/M			A/G		F/G		Diatom bearing silty clay
2(CC)	14.5	F/P			C/G			A/G		F/G	Cool	Silty clay
3-4(38-40)	19.5	F/M			C/G			C/M		A/M	Trans.	Silty clay
3(CC)	24.0	B			C/G			C/M		C/G	Warm	Silty clay
5-1(18-20)	34.0	F/M			C/M			F/M		C/M	Cool	Silty clay
6-5(22-24)	49.2	B			F/M			C/M		A/M		Silty clay .26 m.y.
8(CC)	71.5	F/M			C/G			C/M		A/M	?	Silty clay .30 m.y.
12-1(71-73)	100.5	A/G			A/G			C/M		R/P		Silty clay

tolerate strong winds and unstable soil conditions, dominated. It is also probable that during glacial periods in this area, the change in climate was not only a cooling in temperature, but initiation of year-round precipitation rather than the seasonal precipitation now found.

3. It is possible to correlate changes in oceanic temperature with that of land, provided that the climatic change is a large-scale one.

4. The use of reworked pollen to determine glacial-interglacial boundaries does not seem indicative of climatic

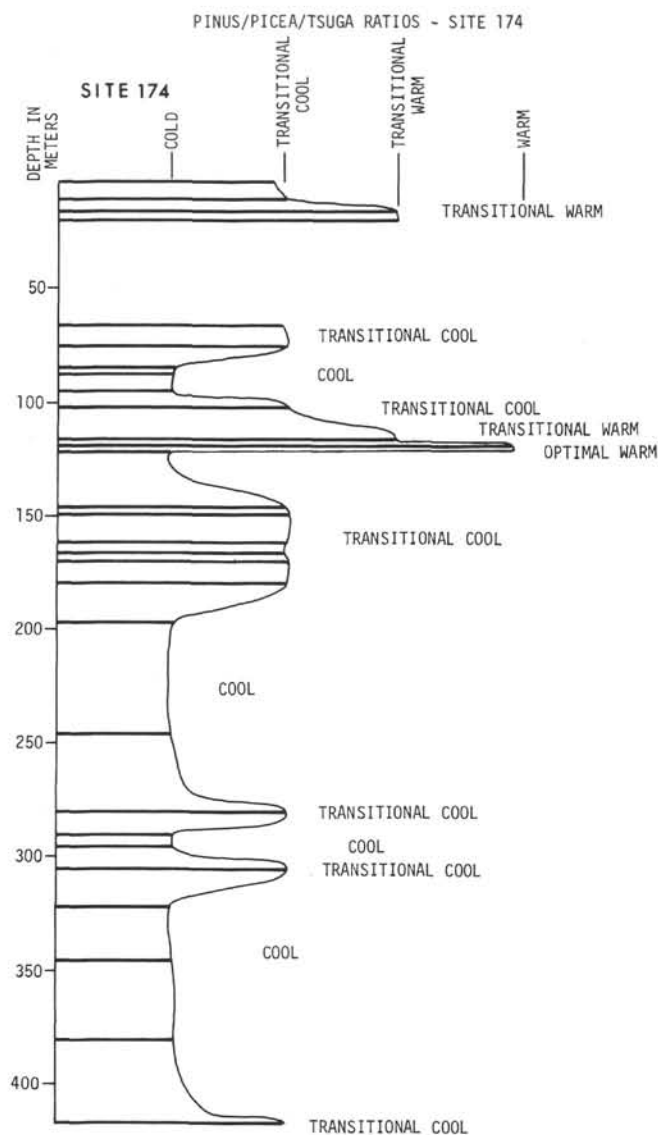


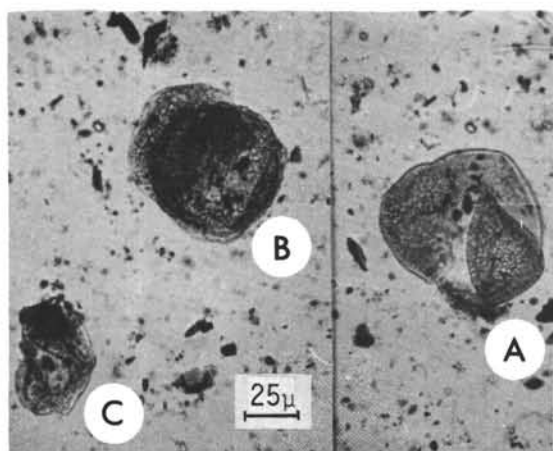
Figure 6. Pinus/Picea/Tsuga Ratio, Site 174.

changes in the coastal areas of northern California and southern Oregon.

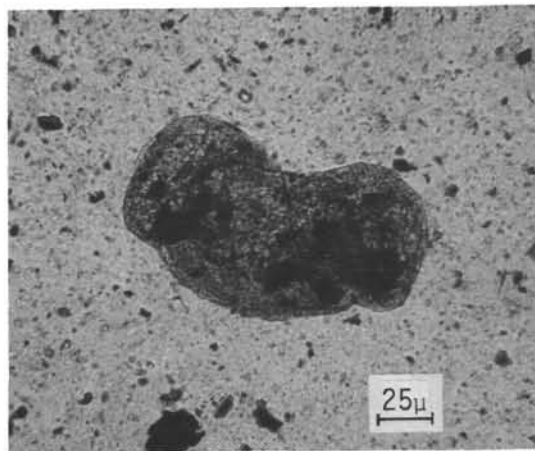
## REFERENCES

- Brown, C. A., 1960. Palynological Techniques. Unpublished manuscript, p. 28
- Erdtman, G., 1943. An Introduction to Pollen Analysis. The Ronald Press Company. 239 p.
- Fischer, A. G., 1960. Latitudinal variations in organic diversity. *Evolution*. 14 (1), 64.
- Hansen, H. P., 1938. Pollen analysis of three bogs on Vancouver Island, Canada. *Trans. Am. Phil. Soc.*
- \_\_\_\_\_, 1941. Paleocology of two peat deposits on the Oregon Coast. *Oregon State Univ. Monographs, Studies in Botany*, 3.
- \_\_\_\_\_, 1945. Post-glacial vegetation of Eastern Washington. *Northwest Science*. 18 (4), 79.
- \_\_\_\_\_, 1947. Post-glacial forest successions: Climate and chronology in the Pacific Northwest. *Monograph*.
- Hansen, H. P. and Allison, I. S., 1942. A pollen study of a fossil peat deposit on the Oregon Coast. *Northwest Science*. 16, 86.
- Koreneva, E. V., 1964. Distribution of spores and pollen of terrestrial plants in bottom sediments of the Pacific Ocean. *In Ancient Pacific Floras*. Univ. Hawaii Press. 31.
- Leopold, E. B., 1969. Late Cenozoic Palynology. *In Tschudy, R. H. and Scott, R. A. Aspects of Palynology*. New York. 377.
- Norem, W. L., 1956. Tertiary spores and pollen related to paleoclimates and stratigraphy of California. *Micro-paleontology*. 2 (4), 313.
- Stanley, C. A., 1965. Use of reworked pollen and spores for determining the Pleistocene-Recent and the intra-Pleistocene boundaries. *Nature*. 206 (4981), 289.
- Staplin, F., 1969. Sedimentary organic matter, organic metamorphism, and oil and gas occurrence. *Canadian Petrol Geol.* 17 (1), 47.

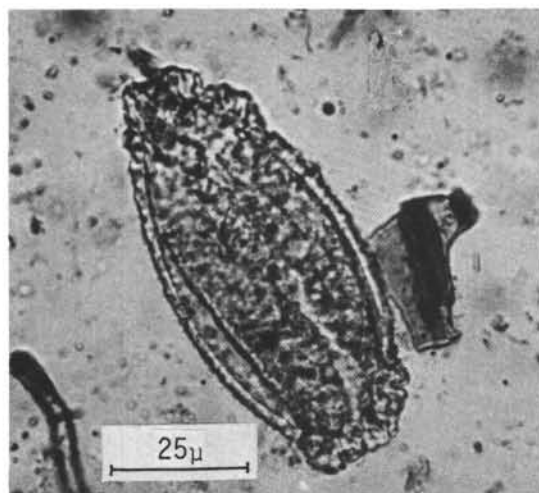
PLATE 1



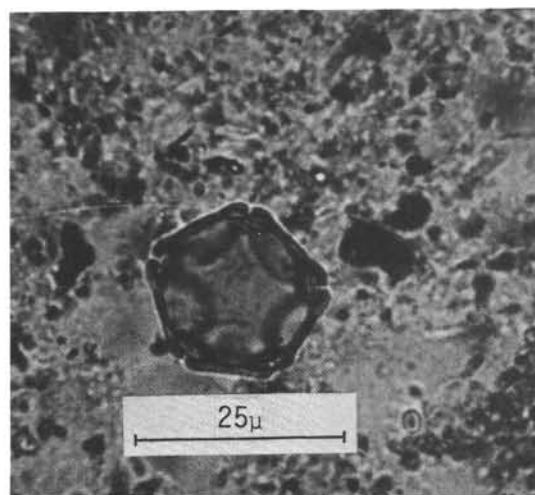
1



2



3



4

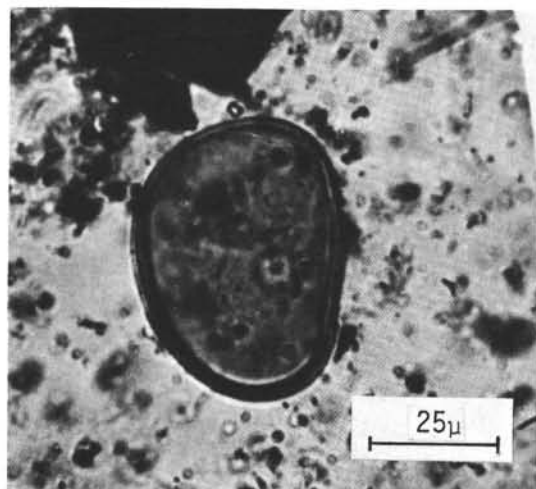
Figure 1. *Picea* and pine grains showing three states of preservation in the same core (173-8, CC).

Figure 2. Highly oxidized *Picea* grain from the bottom of Hole 174A.

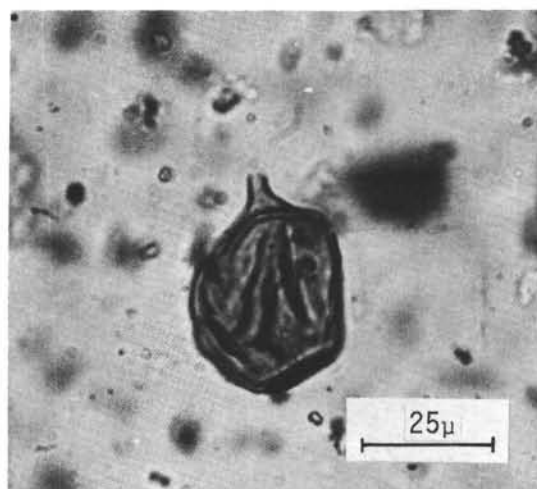
Figure 3. *Tsuga* (750 X).

Figure 4. *Alnus* (1250 X).

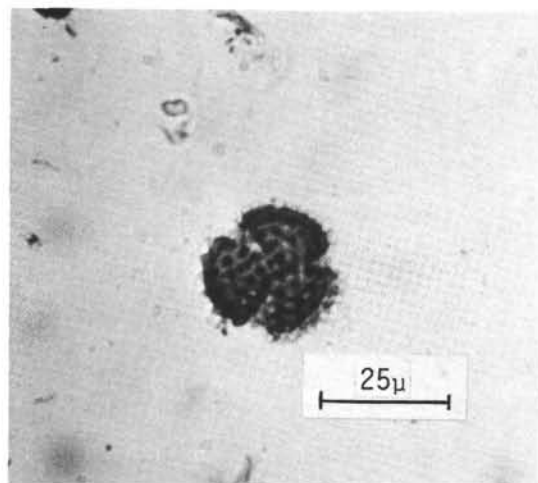
PLATE 2



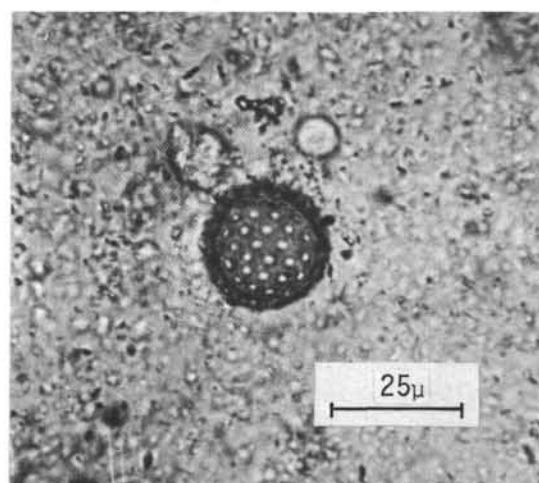
1



2



3

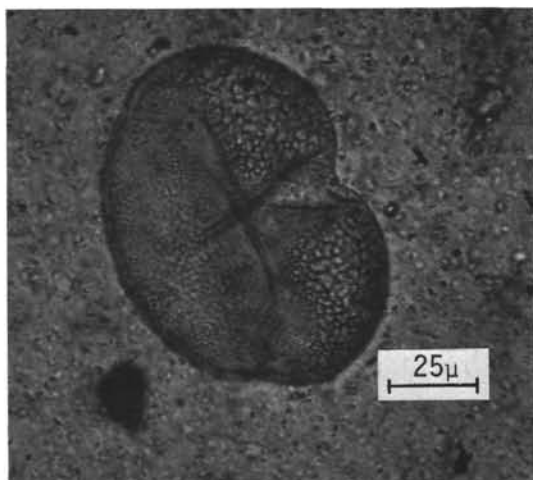


4

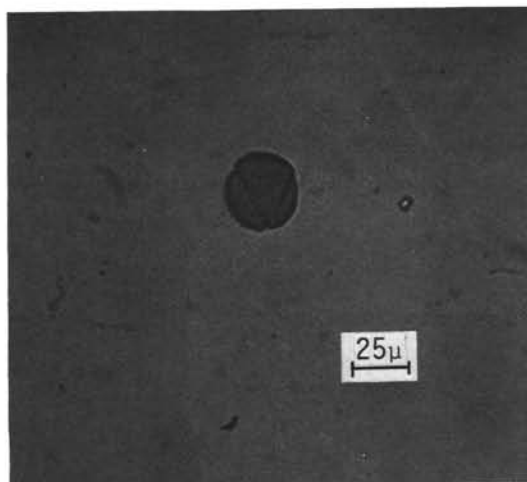
Figure 1. Graminae (750 X).  
Figure 2. Taxodium type (1250 X).  
Figure 3. *Artemesia* (750 X).  
Figure 4. *Chenopodium* (750 X).



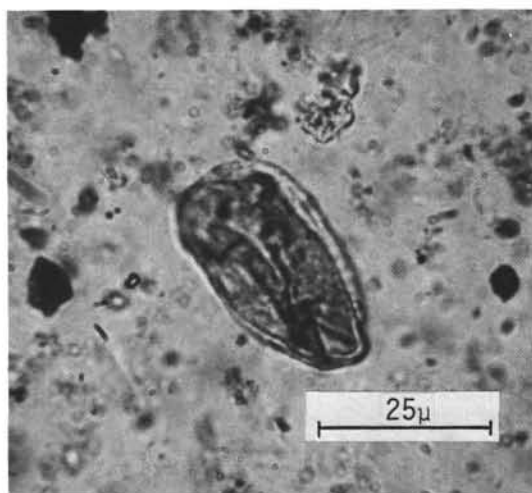
PLATE 3



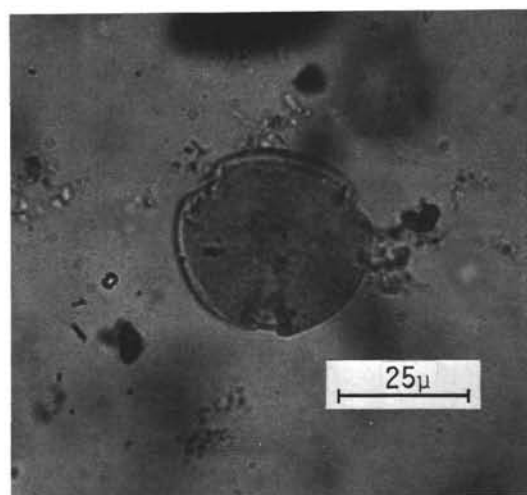
1



2



3



4

Figure 1. *Picea* (300 X).  
 Figure 2. *Quercus* (750 X).  
 Figure 3. *Ginkgo* (?) from 175-6-5 (22-24) (1250 X).  
 Figure 4. *Nyssa* from 174A-28 (CC) (750 X).