

## 16. NEOGENE PALYNOLOGY FROM THE SOUTHERN CALIFORNIA CONTINENTAL BORDERLAND, SITE 467, DEEP SEA DRILLING PROJECT LEG 63<sup>1</sup>

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### INTRODUCTION

Neogene palynofloras of southern California have been all too infrequently studied. Previous investigations of Pacific Coast sediments have been largely restricted to Pacific Northwest locales. Some important studies include those by Gray (1964), Wolfe, Hopkins, and Leopold (1966), Wolfe and Leopold (1967), Hopkins (1968), Piel (1969, 1977), Ballog, Sparks, and Waloweeck (1972), and Musich (1973). The only published study of southern California materials is that of Heusser (1978) on Holocene sediments of the Santa Barbara basin. Most of these studies are concerned with the microflora from a particular formation; thus they have limited stratigraphic value and in most cases involve nonmarine to marginal marine rocks where no planktonic zonation was available. Musich's (1973) study was the first attempt at tying pollen assemblages to a planktonic zonation over an extended stratigraphic interval (Miocene to Pleistocene).

Its location in the southern California Borderland (Fig. 1) and the sedimentary sections sampled make Leg 63 extremely valuable in deciphering the palynologic history of the Pacific Coast Neogene. Site 467 was chosen for our initial detailed study, because the relatively slow sedimentation rate provides an almost complete Neogene sequence of mainly terrigenous sediments and reliable planktonic age control is available.

The goals of this study were to: (1) establish a reference section of Neogene palynomorph assemblages; (2) develop biostratigraphic criteria for use in correlation with other localities; (3) correlate the palynologic assemblages with the planktonic zonations; and (4) study the paleoenvironmental history in the southern California Neogene.

### METHODS

A total of 134 samples were examined for this study. At least 20 cm<sup>3</sup> of material were taken to insure adequate palynomorph recovery. The samples were processed using standard palynologic techniques. After treatment with HCl to remove any carbonate, the samples were then treated in 70% HF for approximately 16 hours. They were then treated successively with concentrated HCl, HNO<sub>3</sub>, and NH<sub>4</sub>OH. These steps were followed by a heavy-liquid separation using zinc bromide and a short immersion in an ultrasonic generator. The Safranin-stained residue was then mounted on coverslips with polyvinyl alcohol and allowed to dry. The coverslip was secured to the microslide using an epoxy cement.

We attempted to identify palynomorphs to the generic level whenever possible. However, several groups were identified only to family level. These include Chenopodiaceae, Rhamnaceae, Gramineae, Anacardiaceae, Compositae, Elaeagnaceae, Polemoniaceae, Bombacaceae, Malvaceae, Onagraceae, and Caryophyllaceae. Also, Taxodiaceae, Cupressaceae, and Taxaceae were lumped into what we called the Taxo Group. We identified species of *Ambrosia* and members of the Compositae family separately and also grouped all Compositae except *Artemisia* into Asteraceae for use in our computer analyses. In addition, we lumped all spores and all dinoflagellates into two groups for purposes of interpretation.

We determined the abundance by counting all palynomorphs observed under the 20 × 40 mm coverslip; we attempted to count a minimum of 100 grains for each sample scrutinized. Table 1 lists the actual count of selected species encountered in Hole 467. Figure 2 is a sawblade diagram of 18 selected types. The abundance percentages plotted for the first 16 types on Figure 2 are calculated against the total number of all angiosperms and gymnosperms in each sample. Pteridophyte spores, dinoflagellates, acritarchs, microforaminifers, and algal bodies are excluded from this sum. The last two groups to the right on Figure 2 are total spores and total dinoflagellates, each plotted as a percentage of the total assemblage.

Statistical analysis of the data was undertaken using both Q-mode and R-mode cluster analysis programs. Q-mode, or normal analysis, involves the comparison of samples based upon their contained species; R-mode, or inverse analysis, involves the comparison of species based upon the samples in which they occur. Q-mode yields stratigraphic information, whereas R-mode is used primarily for paleoenvironmental determinations. The data was standardized using a species mean standardization and the Bray-Curtis coefficient for the Q-mode analysis, and a species maximum standardization with the Bray-Curtis coefficient for the R-mode analysis. These standardizations have been shown to be particularly useful when working with biological data (Smith, 1976). The matrix used for both analyses was initially transformed using a square-root transformation. The resultant analyses were plotted on a two-dimensional dendrogram.

### SITE 467

(33°50.97' N, 120°45.47' W; depth 2127.8 m)

Site 467 is located at San Miguel Gap in the outer California Continental Borderlands, near the eastern boundary of the California Current. A relatively complete section of Quaternary to middle Miocene is present and has been subdivided into four lithologic units.

Unit 1 consists of silty clay and diatomaceous nannofossil clay extending from the surface to 367 meters. Unit 2 extends from 367 to 699.5 meters and consists of claystone that becomes more lithified with depth. Unit 3, between 699.5 and 832.5 meters, is a pumiceous lapilli tuff interbedded with nannofossil-clayey chalk, limestone, and claystone. Unit 4, from 832.5 to 1041.5 meters, resembles Unit 2 in consisting of interbedded clayey chalk and calcareous claystone with minor thin beds of fine-grained quartzo-feldspathic sandstone.

Palynomorphs were recovered from all four units, although their abundances decrease somewhat with

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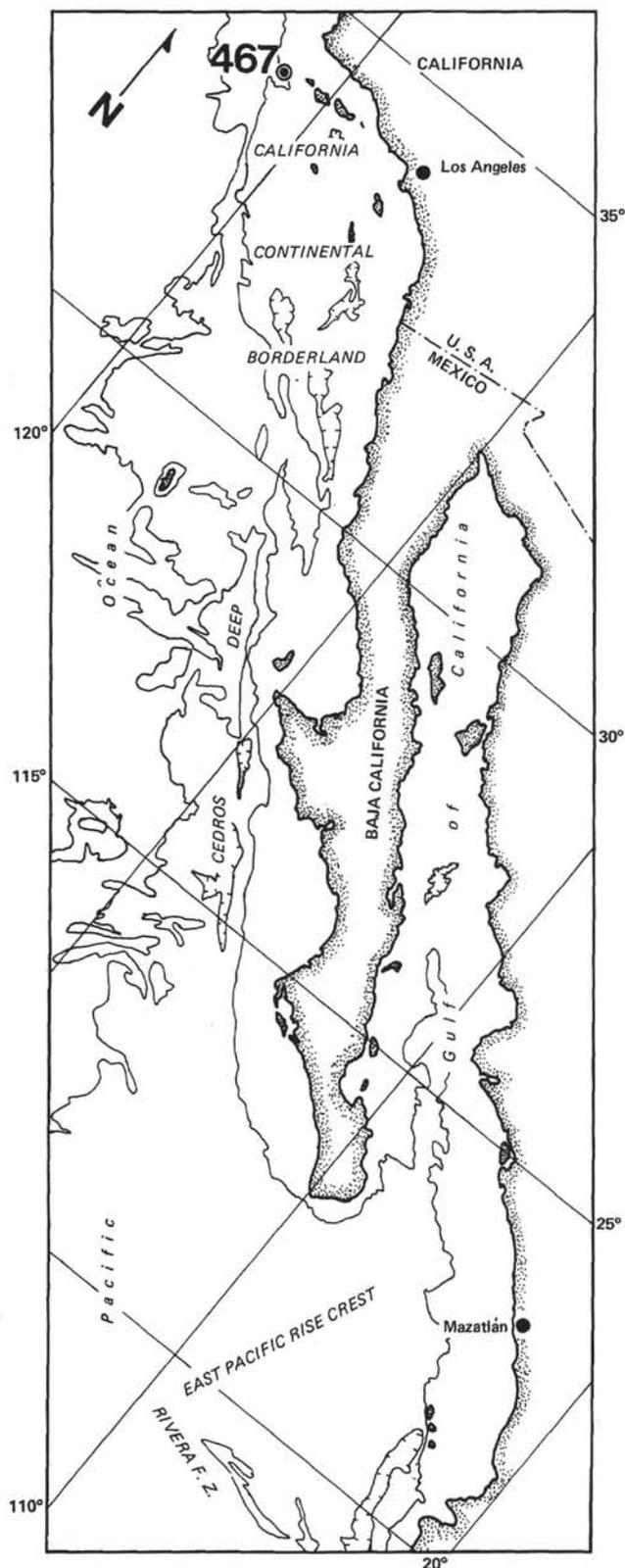


Figure 1. Location map, Site 467.

depth. The diagenetic break from clay to claystone at 367 meters has had no apparent effect, however, on the relative abundance of palynomorphs.

### STRATIGRAPHIC RESULTS

Because there are few stratigraphically restricted pollen species in the Neogene section of Hole 467, many of our biostratigraphic conclusions are based in large part on abundance data. With rare exceptions, most of the restricted ranges found in Hole 467 imply climatic variations and are not evolutionary extinctions. Thus, comparison of ranges of similar taxa from different areas is not a successful method of correlation for most Neogene pollen species. However, comparing abundance ranges using relative abundance curves or sawblades is a useful method of deciphering climatic conditions and comparing different stratigraphic sections within the same or adjacent basins. The most useful species of biostratigraphic correlation are the dinoflagellates, because they do provide some degree of interregional correlation within the Neogene.

In Hole 467, the genera that appear to have stratigraphically important ranges include: *Artemisia*, *Ambrosia*, *Eriogonum*, *Cannosphaeropsis* sp. A., and *Operculodinium* sp. 1. *Artemisia* evolved on a worldwide basis in the late Miocene to become a significant component of most temperate and/or xeric climates. In Hole 467 *Artemisia*'s earliest stratigraphic occurrence is within the upper Miocene *A. primus* Subzone of the *D. quinquerramus* Zone (Sample 52, CC), and it varies from 1% to 5% within the uppermost Miocene, Pliocene, and Quaternary. Another stratigraphically important member of the Compositae is *Ambrosia*. For this study we have separated *Ambrosia* into two species—sp. 1 and sp. 2. Both species range from the upper Miocene *D. variabilis* Zone through the Quaternary. The first appearances of both *Artemisia* and *Ambrosia* are significant points and can be used to date Neogene sediments throughout the Pacific Coast region. The third restricted pollen species *Eriogonum*, present only in Pliocene and younger sediments, has its first occurrence in Sample 43, CC. We do not know at this time if this earliest occurrence is of widespread regional significance, but it should prove useful within this area.

Two dinoflagellates have stratigraphically significant ranges within Hole 467. One, *Cannosphaeropsis* sp. A., of Williams and Brideaux (1975) is a zonal marker for the upper Miocene of the Grand Banks and Scotian Shelf (Williams and Bujak, 1977). This species has its last stratigraphic occurrence within the *A. primus* Subzone of the *A. tricorniculatus* Zone in Hole 467 (Sample 41, CC), and we propose that this species may be useful as a guide fossil for the uppermost Miocene on the Pacific Coast. The other dinoflagellate, *Operculodinium* sp. 1, is an undescribed variant of *Operculodinium centrocarpum* (see Harland, 1973, plate 2, figs. 13–15) that has its last stratigraphic occurrence in Sample 45, CC within the upper Miocene *A. primus* Subzone of

the *A. tricorniculatus* Zone. Additional studies are needed to document firmly the ranges of these two species, but it appears that they are important markers.

As stated above, abundance ranges provide much of the useful data for biostratigraphic control within the Neogene. As seen in Figure 2, *Pinus* constitutes about 50% of the total flora, with the Taxo Group and *Quercus* also dominant members of the flora. Within the upper Miocene, Pliocene, and Quaternary, both Chenopodiaceae and Asteraceae become important taxa. Chenopodiaceae become significant at 550 meters, in the upper Miocene, and remain abundant throughout the Pliocene and Quaternary. Asteraceae first become an important part of the flora at 625 meters and from there to 296 meters average 3% of the flora. From 276 meters to the top of the hole, Asteraceae increase to greater than 5% abundance. *Artemisia*, while never abundant, becomes statistically significant at 484 meters and averages between 1% and 5% through the Pliocene and Quaternary. Other important abundance trends include the increase in abundance downhole of *Juglans* and *Castanea* within the upper Miocene *D. variabilis* Zone and continuing down into the middle Miocene. *Carya* also is more abundant in the middle Miocene *C. miopelagicus* and *S. heteromorphus* Zones.

As stated previously, abundance peaks reflect climatic influences; we thus established biostratigraphic boundaries on the basis of climatic changes. Assuming that we correctly observed regional floral and climatic changes, the boundaries we established should correlate throughout the southern California Borderland.

One final abundance trend that is important is the decrease in abundance of total dinoflagellate percentage from 10% or greater within the late Miocene and older to less than 2% in the Pliocene and younger sediments. We will discuss this decrease later under paleoenvironment but should stress here that this important biostratigraphic event has been observed in other southern California Borderland sites.

It is important to note that both of the stratigraphically restricted dinoflagellate cyst species *Cannosphaeropsis* sp. A. and *Operculodinium* sp. 1 disappear from the section at points well above the sharp decrease in total dinoflagellate percentage (see Table 1 and Fig. 2). This suggests that if ecologic factors responsible for the decrease in dinoflagellate abundance did not restrict these two species, then their respective last-occurrence "tops" may well be evolutionary extinctions.

For stratigraphic purposes, a Q-mode cluster program is used to compare samples against each other. On the Q-mode dendrogram (Fig. 3) we can see four distinct groupings. These groups are divided as follows: Group I, Pliocene and Quaternary samples; Group II, a mixed group of upper Miocene and Pliocene samples; Group III, upper Miocene samples; and Groups IV, middle Miocene samples. It should be noted that the Pliocene and Quaternary samples group together. Based on this data as well as data from Table 1 and Figure 2, it can be seen that palynologically we cannot separate the Pliocene from the Quaternary in this area. The lumping

together, in Group II, of upper Miocene and Pliocene samples is probably the result of low diversity samples.

The R-mode cluster dendrogram, Figure 4, also contains four distinct groupings. Group A is composed of the three dominant long-ranging taxa observed in this study. Group B is a grouping of primarily xerophytic genera that predominate in the Pliocene through Quaternary samples. The taxa that compose Group C occur most abundantly within the Miocene, and Group D comprises less abundant and more cosmopolitan Pliocene and Miocene taxa.

Combining the data from both the Q-mode and R-mode analyses enables us to obtain an idea of which species are most important in forming the groupings shown in Figure 3. The species important in defining Group I include those from Group B. These are mainly xerophytic types either restricted to or most common within the Pliocene and Quaternary. The major break shown between Groups I and II and Groups III and IV is the result of the species from Group C becoming more important in the Miocene.

### PALEOENVIRONMENTAL RESULTS

From previous work (Heusser, 1978), we know that the late Quaternary is climatically very similar to the present. The data gathered in this study indicates that this climate persisted from at least early Pliocene. The presence of significant percentages of *Quercus*, Chenopodiaceae, and Asteraceae as well as the minor but consistent representation of *Eriogonum*, Rhamnaceae, and *Ephedra* shown in Figure 2 indicate that the coastal sage scrub, chaparral, and oak grassland communities were intact throughout the Pliocene. An absence of *Picea*, *Tsuga*, and *Sequoia* pollen indicates that not only has southern California been relatively climatically static since the Pliocene, but that elements from the Northwest Pacific Coast flora (Musich, 1973) have not been transported south by the California Current. The absence of *Picea* also possibly indicates a moderate elevation for the onshore highlands surrounding the drainage area of Site 467.

In the late Miocene we see a climatic change from the wetter, more humid climate to a more xeric climate of the Pliocene through Quaternary. This is shown by the increase in abundance of the Chenopodiaceae and Asteraceae and the presence of *Eriogonum*, as well as by the decrease in abundance of several warm temperate genera including *Juglans*, *Castanea*, and *Carya*. The increased abundance of these genera in the Miocene is probably indicative of the change from summer-wet conditions to the summer-dry conditions prevailing from Pliocene through Recent.

These conclusions relate to the onshore environment, but one important fact regarding the marine environment has been noted in Hole 467: the decrease in abundance and diversity of dinoflagellates within the late Miocene. This was mentioned earlier as an important stratigraphic datum because it has been observed in other offshore sites. It is also important environmentally as an indication of a change in surface waters. Al-





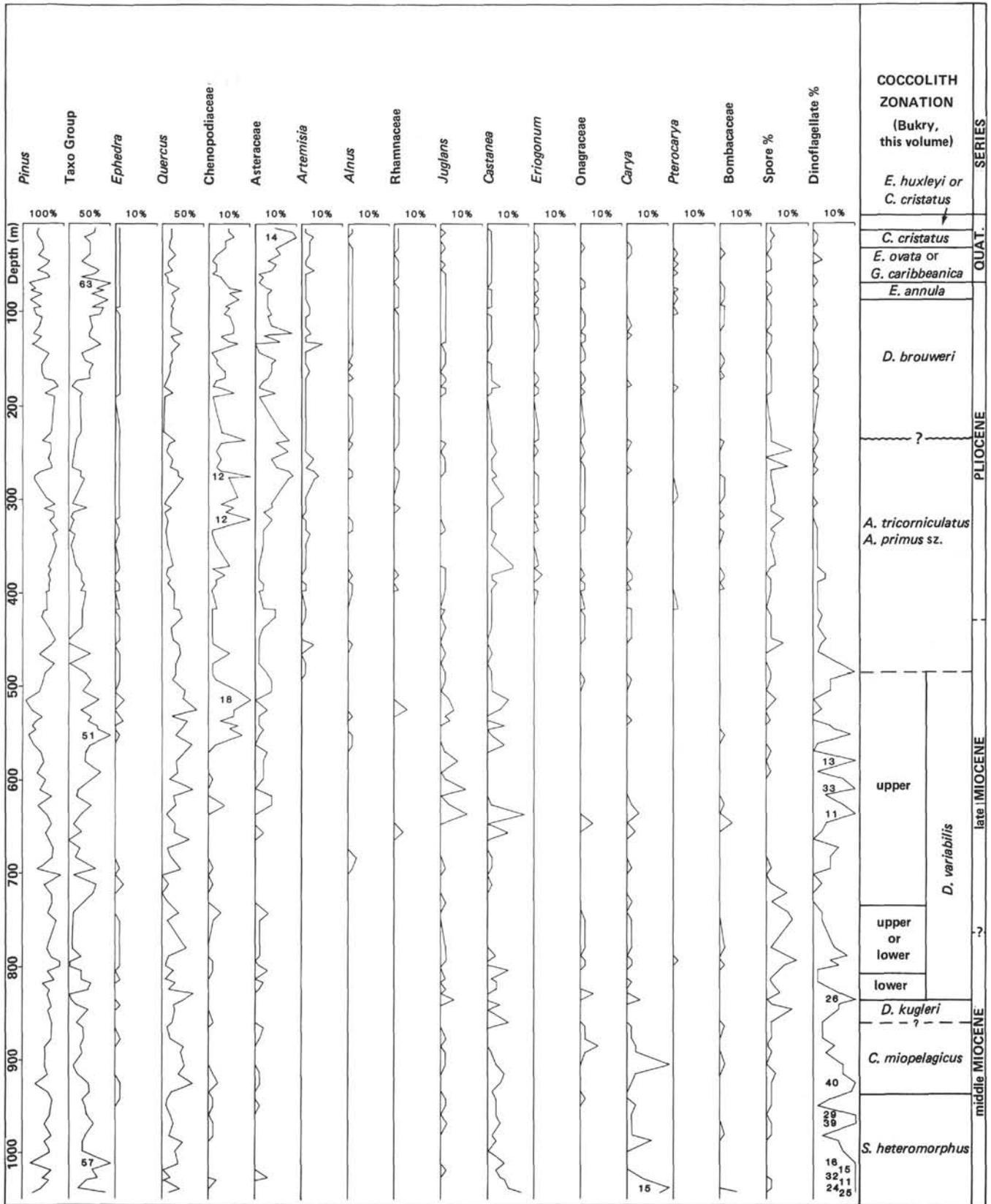


Figure 2. Sawblade diagram, Site 467.

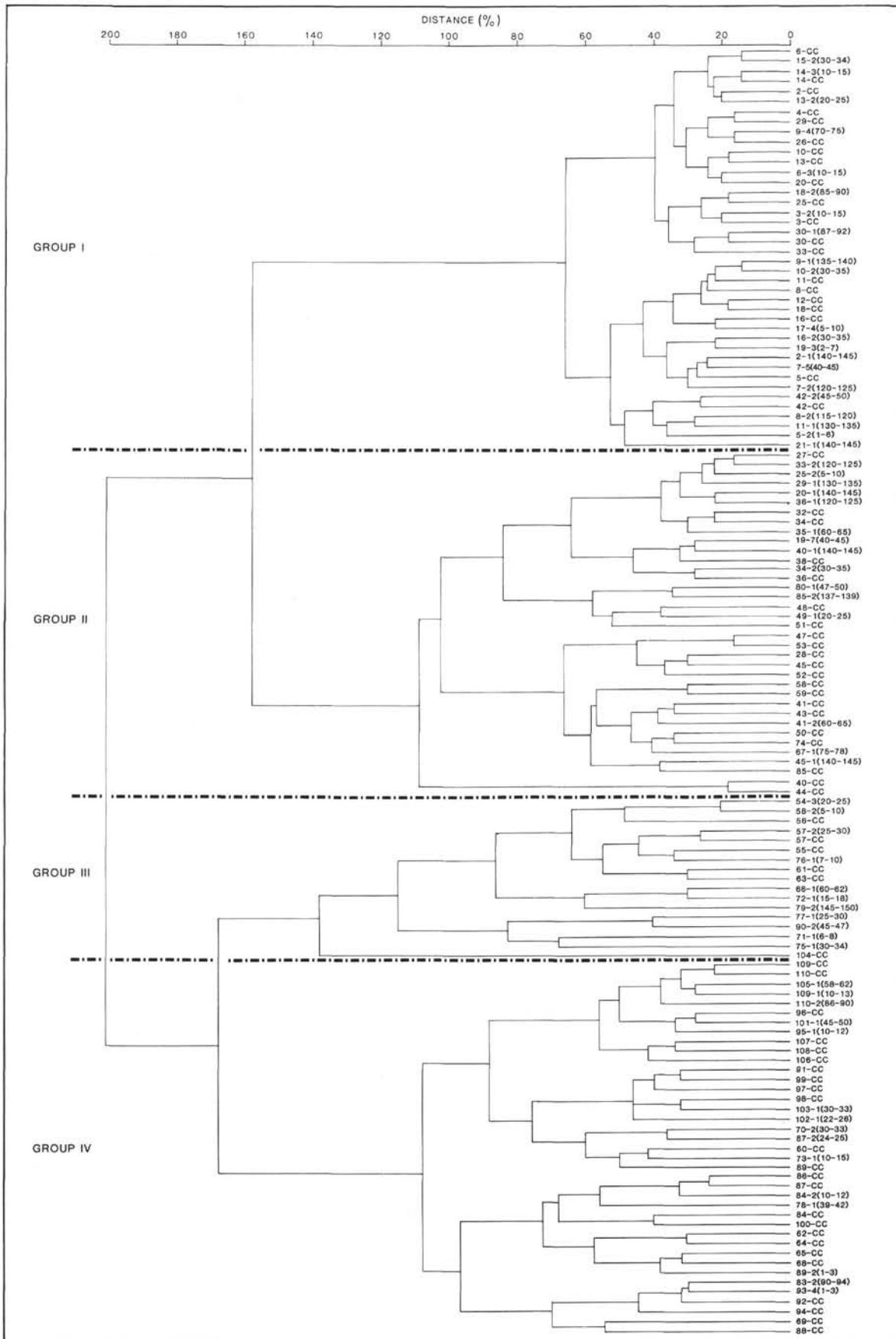


Figure 3. Q-mode cluster diagram, Site 467.

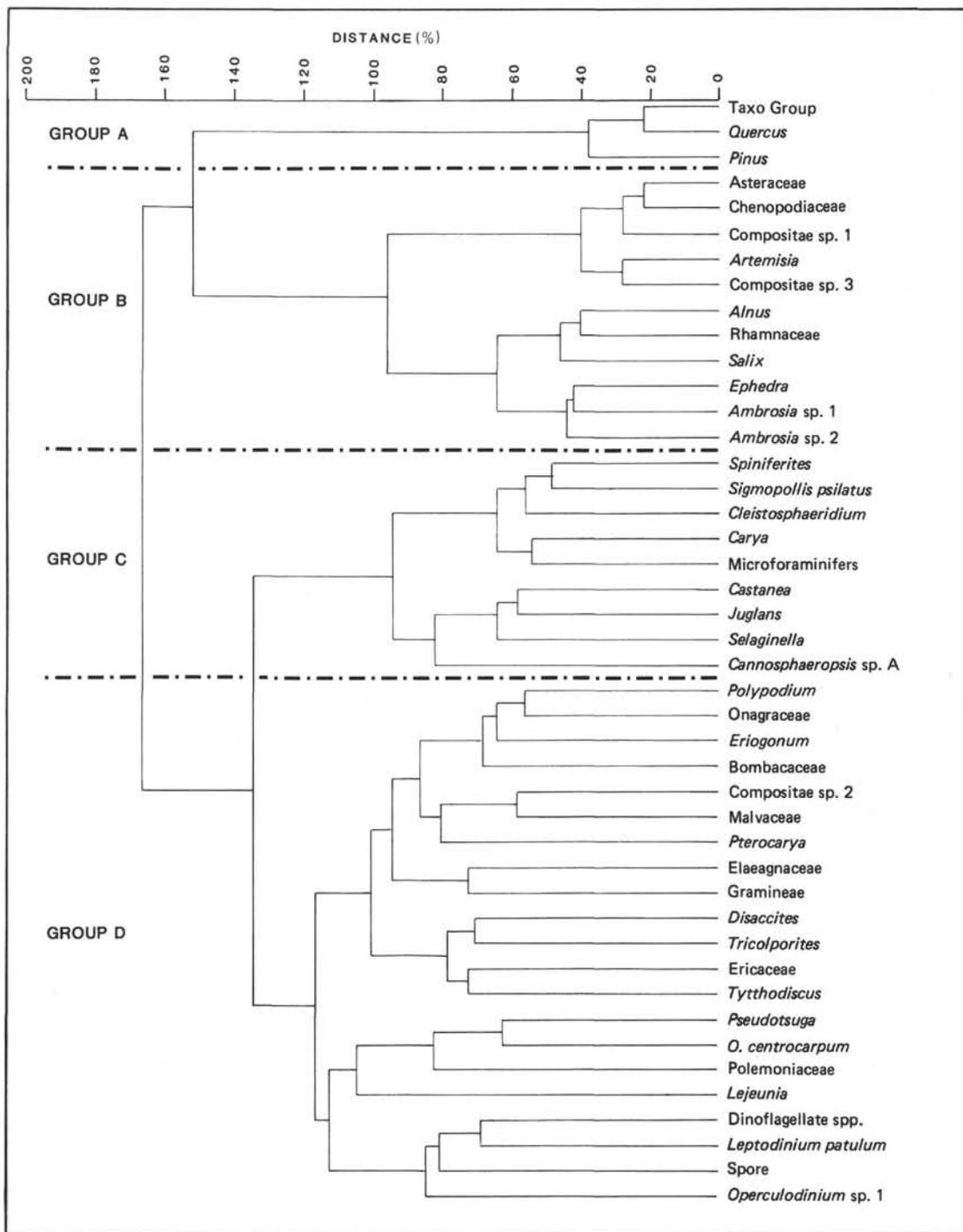


Figure 4. R-mode cluster diagram, Site 467.

though dinoflagellate cyst paleoecology is at this time inadequately understood, some recent ecologic data are available (Wall et al., 1977). Dinoflagellates live in the photic zone and their encystment is the result of either physical and/or biological stimuli. Whatever the exact cause, the abundance of dinoflagellate cysts in the sediments is assumed to be a reflection of dinoflagellate abundance in the overlying surface waters; Wall et al. (1977) have shown that this abundance is related to surface water composition. We interpret this change in

abundance and diversity within the late Miocene to reflect a major shift in the surface waters, possibly a change in location, composition, and/or temperature of the California Current. A relative change from warm to cool surface temperatures has been noted at approximately this same level in Hole 467 on coccolith evidence (Bukry, this volume). Other disciplines, including radiolarians, diatoms, and planktonic foraminifers, have noted this change in water mass composition in other studies of offshore California sites (Ingle, 1973).

## CONCLUSIONS

The data from Hole 467 provide us with our first in-depth study of palynologic assemblages from the southern California Neogene. Our preliminary biostratigraphic conclusions are: (1) *Artemisia* and *Ambrosia* are markers for late Miocene through Recent sediments; (2) *Eriogonum* appears to be a marker for the Pliocene through Recent; (3) *Carya* decreases significantly in abundance after the middle Miocene; (4) the extinction of *Cannosphaeropsis* sp. A., of Williams and Brideaux (1975) appears useful as a marker for the late Miocene; and (5) a decrease in abundance of the total dinoflagellate percentage within the late Miocene is an important biostratigraphic event. Figure 5 is a correlation of these events with the biostratigraphic zonations of coccoliths, radiolarians, and diatoms for Hole 467.

Conclusions regarding the environmental results include: (1) Pliocene climatic conditions persisted through the Quaternary; (2) during the Pliocene we see a change to summer-dry conditions from the previous summer-wet conditions of the Miocene; and (3) the decrease in dinoflagellate abundance during the late Miocene denotes a change in surface waters from warm within the Miocene to cool in the Pliocene through Quaternary.

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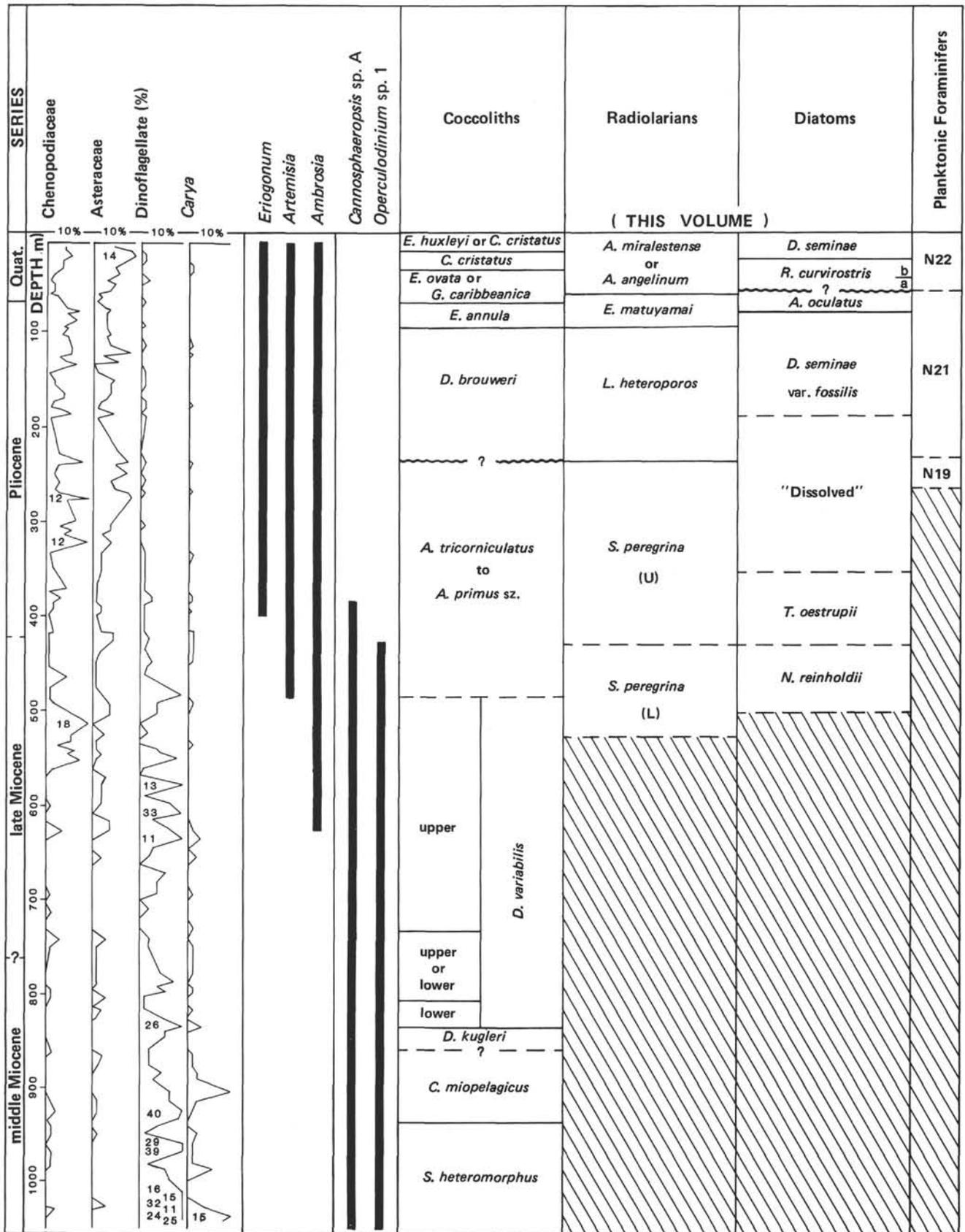


Figure 5. Correlation of palynologic markers and planktonic zonations, Site 467.

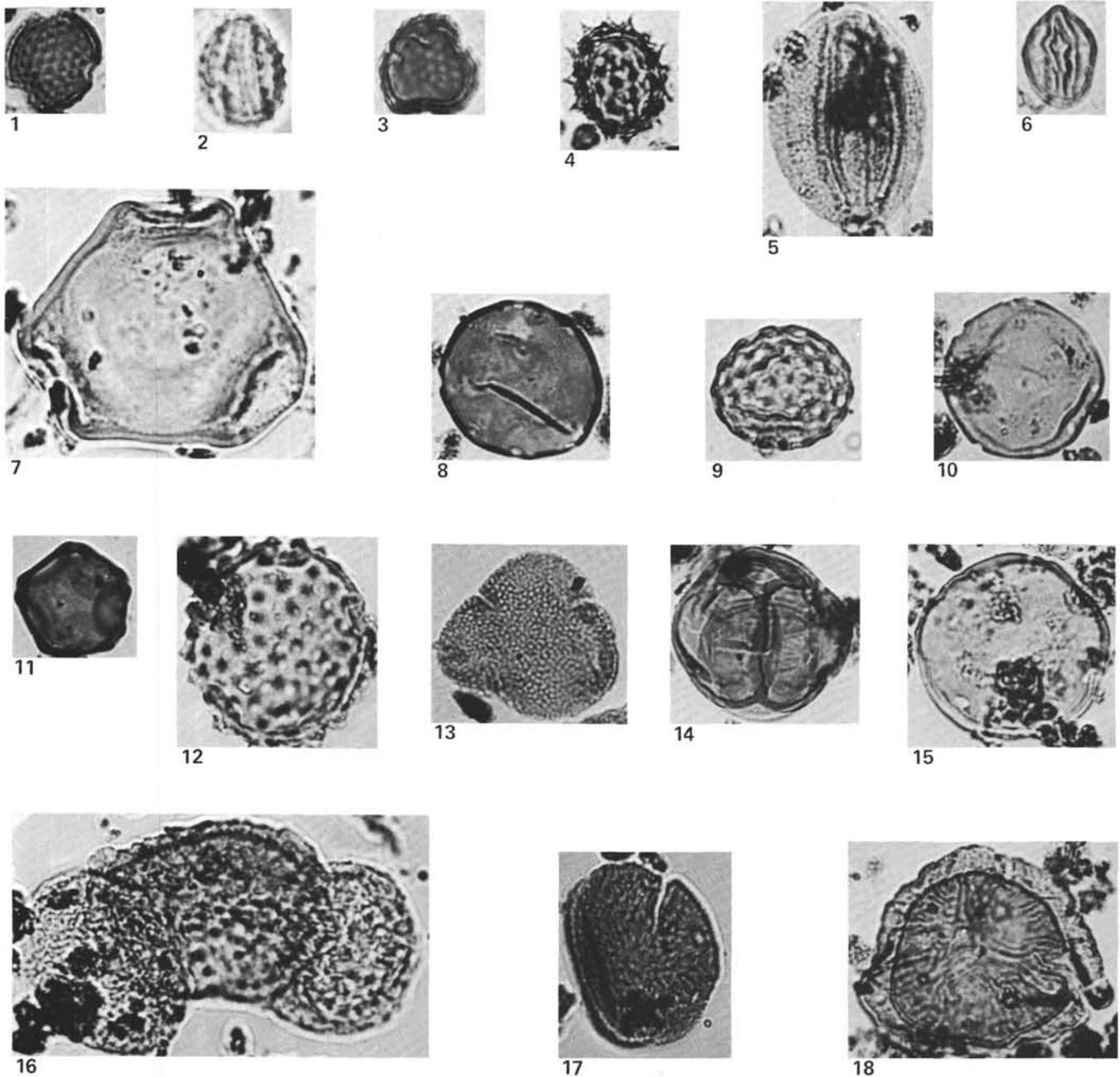


Plate 1. All figures are magnified  $\times 800$  except Figs. 2 and 3, which are  $\times 1000$ . 1. *Ambrosia* sp. 1 (Sample 467-13-2, 20-25 cm). 2. *Ambrosia* sp. 2 (Sample 467-9-1, 135-140 cm). 3. *Ambrosia* sp. 1 (Sample 467-6,CC). 4. Compositae sp. 1 (Sample 467-13-2, 20-25 cm). 5. *Eriogonum* (Sample 467-19-3, 2-7 cm). 6. *Castanea* (Sample 467-13-2, 20-25 cm). 7. Onagraceae (Sample 467-13-2, 20-25 cm). 8. *Pterocarya* (Sample 467-13-2, 20-25 cm). 9. Chenopodiaceae (Sample 467-6,CC). 10. *Juglans* (Sample 467-13-2, 20-25 cm). 11. *Alnus* (Sample 467-14-3, 10-15 cm). 12. Malvaceae (Sample 467-18,CC). 13. Bombacaceae (Sample 467-35-1, 60-65 cm). 14. Ericaceae (Sample 467-80-1, 47-50 cm). 15. *Carya* (Sample 467-95-1, 10-12 cm). 16. *Pinus* (Sample 467-51,CC). 17. Polemoniaceae (Sample 467-45,CC). 18. *Selaginella* (Sample 467-83-2, 90-94 cm).

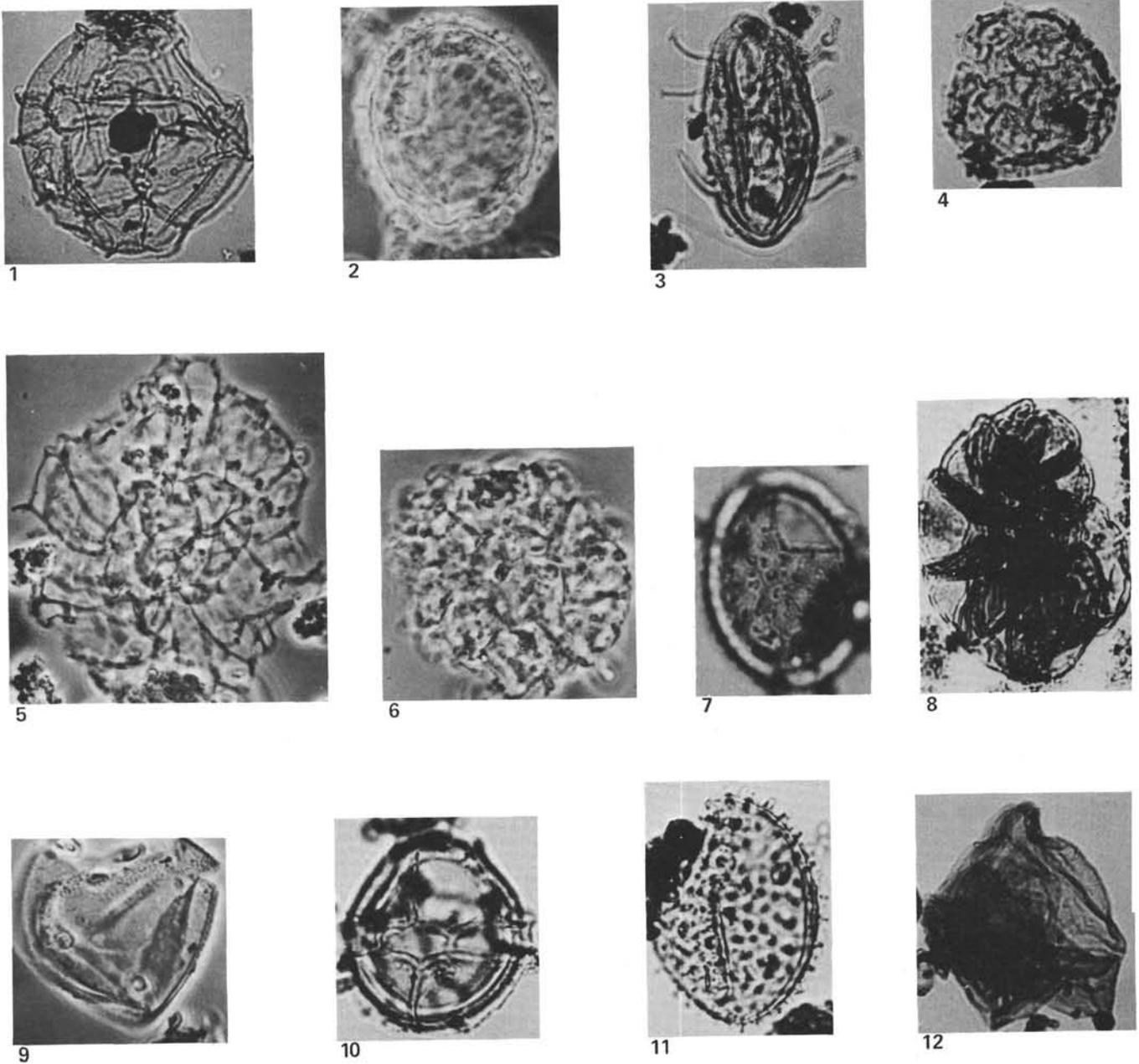


Plate 2. All figures are magnified  $\times 800$  except Figs. 5, 6, and 9, which are  $\times 1000$ . 1. *Leptodinium* sp. (Sample 467-85-2, 137-139 cm). 2. *Operculodinium* sp. 1 (Sample 467-85-2, 137-139 cm). 3. *Operculodinium centrocarpum* (Sample 467-25,CC). 4. cf. *Microdinium* sp. (Sample 467-85-2, 137-139 cm). 5. *Cannosphaeropsis* sp. A. of Williams and Brideaux (1975) (Sample 467-84-2, 10-12 cm). 6. *Cannosphaeropsis* sp. A. of Williams and Brideaux (1975) (Sample 467-42,CC). 7. *Operculodinium* sp. 1 (Sample 467-79-2, 145-150 cm). 8. Microforam (Sample 467-85-2, 137-139 cm). 9. *Tectatodinium*(?) sp. (Sample 467-35-1, 60-65 cm). 10. *Leptodinium* sp. (Sample 467-85-2, 137-139 cm). 11. *Operculodinium* sp. 1 (Sample 467-85-2, 137-139 cm). 12. *Lejeunia* sp. (Sample 467-74,CC).