24. NEOGENE PALYNOLOGY OF DEEP SEA DRILLING PROJECT SITE 603 ON THE LOWER CONTINENTAL RISE, NORTHWESTERN ATLANTIC[1]

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ABSTRACT

The analysis of 104 core-catcher samples from Site 603 resulted in a continuous palynological record from the middle Miocene to early Pleistocene. Two palynological zones could be established (Zone 2, below 380 m: high *Pinus, Quercus,* and *Carya* values; Zone 1, above 380 m: high *Pinus,* and *Sphagnum* values). The marine pollen record was found to reflect the history of the vegetation of the eastern United States, the flora from Zone 2 indicating a warmer climate than that from Zone 1, which depicts a climatic cooling trend. The onset of Western Boundary Undercurrent deposition had no noticeable effect on the pollen distribution in the marine sediments.

INTRODUCTION

DSDP Site 603 is located on the lower continental rise 435 km east-southeast of Cape Hatteras (Fig. 1). Palynomorphs were examined from 54, 12, and 38 core-catcher samples from rotary-cored Holes 603 and 603B, and HPC Hole 603C, respectively. The purpose of this preliminary study was to determine the character (qualitative/quantitative) of the palynological contents of the sediments, its potential for biostratigraphy below the CCD, its relation with the onshore vegetation and climate, and the influence of the Western Boundary Undercurrent on the pollen distribution in the sediments.

METHODS

We prepared 10 cm^3 samples from the available core-catcher material using the following standard technique. HCl, Na-pyrophosphate, acetolysis treatment; bromoform separation (2×), and sieving over a 7 μm nylon mesh. Slides were mounted with glycerol jelly, and the cover-slips were sealed with paraffin.

Mesozoic and Paleogene forms (*Aquilapollenites, Classopollis, Trudopollis,* etc.) could be identified as reworked. No attempt was made to recognize reworked late Cenozoic pollen, because the use of autofluoresence as described by Gijzel (1967) would be too time-consuming, and staining techniques (Stanley, 1966) do not discriminate reworked from nonreworked Neogene pollen.

The standard pollen count is +200 angiosperm and gymnosperm pollen. Percentages of all the palynomorphs are calculated on that standard pollen sum. Most trilete spores, monolete spores, fungi spores, microforaminifers, dinoflagellates/acritarchs, and denticles were grouped and not further differentiated.

RELATED STUDIES

Modern Marine Palynology

Studies of marine sediments include work by Heusser (1983) on the pollen distribution in surficial sediments from the slope and rise of the western North Atlantic, and by Stanley (1966) on the palynology of Quaternary sediments from the continental shelf and ocean basin of the northwestern Atlantic. These sediments off the eastern coast of the United States contain high values of *Pinus* (pine) pollen (up to 90%), with less *Quercus* (oak) (10–20%) and other pollen types in very small numbers only. In general, the palynology of the marine sediments is a reflection of the vegetation of the adjacent land area, with a seaward increase in the relative frequency of *Pinus* pollen, and a seaward decrease in variety of pollen types.

Recent Onshore Pollen Distribution

According to Davis and Webb (1975), the southeastern North American forests are characterized by high percentages of *Pinus* (30–70%), *Quercus* (15–30%) and southeastern tree pollen: *Taxodium* (cypress), *Liquidambar* (sweet gum), *Nyssa* (black gum), and *Liriodendron* (tulip tree) (5–45%). Other common species are *Carya* (hickory), *Betula* (birch), and *Ulmus* (elm) (up to 5%). Locally important are, amongst others, *Acer* (maple), *Alnus* (alder), *Corylus* (hazel), and *Juglans* (walnut).

Late Tertiary Floras

Palynological studies by Traverse (1955) on the Brandon lignite, Vermont (upper Oligocene or lower Miocene), and by Rachele (1976) on the Legler lignite, New Jersey, give some information on the late Tertiary vegetation of the eastern United States. Apart from local swamp elements, one of the numerically important species is *Quercus* (mostly 30–70%); *Pinus* occurs in larger numbers only in the Legler lignite (up to 20%). The dominant vegetation of the Brandon lignite, excluding the swamp elements, contains *Quercus, Engelhardtia, Carya,* and *Ulmaceae,* that of the Legler lignite is *Quercus, Pinus,* and *Carya.*

RESULTS

From the 104 samples analyzed, three (603B-14,CC, 603B-15,CC, and 603B-16,CC) proved to be barren of palynomorphs. Two samples (603-10,CC, and 603-15,CC) contained less than the standard +200 pollen count, but

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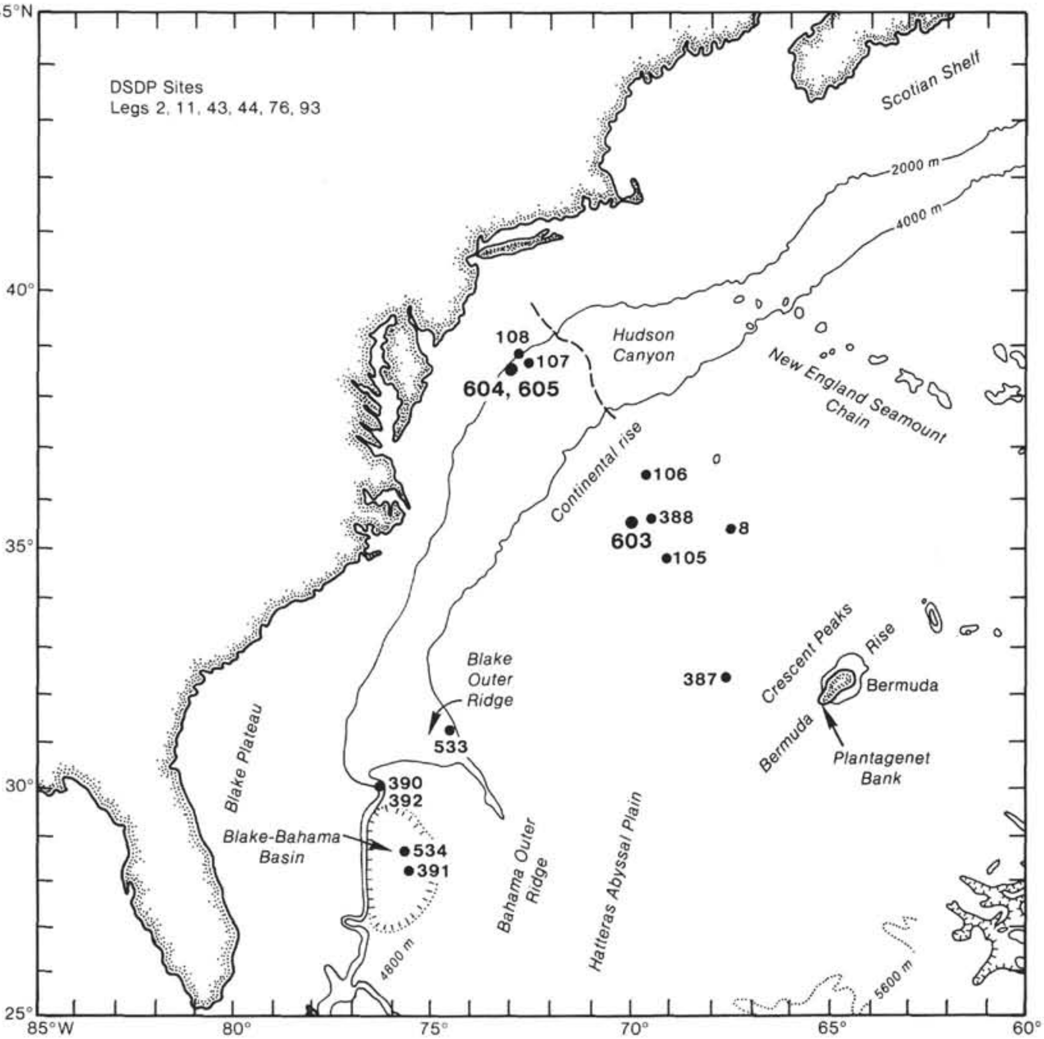

Figure 1. Location of Site 603.

more than 100 pollen; they were used in Figure 2A. In all other samples the standard pollen sum was reached. The relative percentage curves of 25 groups of palynomorphs are presented in Figure 2, in addition to these curves, infrequently occurring taxa are shown where they were encountered, with the percentage.

The numerically most important pollen taxa are *Pinus* (21–92%) and *Quercus* (4–58%), which together account for 70–96% of the pollen sum. The other pollen taxa generally each represent less than 2% of the pollen sum; only *Carya,* Gramineae, and Compositae reach 5–7%. The curves of the other palynomorphs (spores, dinoflagellates/acritarchs, etc.) do reach higher values.

Two zones could be established: Zone 1, above 380 m sub-bottom depth, is characterized by higher values of *Pinus* and *Sphagnum* (peat moss) and lower values of *Quercus* and *Carya* than is Zone 2, below 380 m sub-bottom depth.

Photographs of more frequently occurring unidentified palynomorphs are presented in Plate 1. All material is filed at the micropaleontological collection of the Institute of Earth Sciences, Free University of Amsterdam.

DISCUSSION

The rather small number of taxa and their often infrequent occurrence proved to be an obstacle in establishing a qualitative palynostratigraphy. We could establish the upper range of *Podocarpus* (middle–late Miocene, 600 m in Fig. 2B), *Engelhardtia* (middle Pliocene, 210 m in Fig. 2A and *Pterocarya* (middle Pliocene, 190 m in Fig. 2A). Above these limits, the taxa occur only sporadically and are probably reworked or transported over long distances. *Podocarpus, Engelhardtia,* and *Pterocarya* no longer exist in the eastern United States: *Podocarpus* and *Engelhardtia,*today, do not occur north of Mexico and the Caribbean islands, and *Pterocarya* is confined to Asia (Rachele, 1976).

The onset of contourite deposition from the Western Boundary Undercurrent at around 750 m in Figure 2B (see Site 603 chapter, this volume) is not reflected in the pollen distribution. There was no influx of marine-transported pollen from further north (pollen was still relatively locally derived), and no increase in the amount of reworked pollen.

In general the results in Figure 2 agree with the palynology of the modern marine sediments. The only marked difference is the *Pinus/Quercus* ratio below 380 m (Zone 2)—about 55/45 as compared with about 90/10 in Recent sediments, perhaps indicating a greater abundance of *Quercus* in the onshore vegetation than at present. The dominant vegetation below 380 m as reflected by Figure 2B, contained *Quercus, Pinus* and *Carya*, with *Ilex, Corylus, Juglans, Engelhardtia, Pterocarya, Liquidambar*, Gramineae, and Compositae as other important elements. This clearly resembles the Legler flora (Rachele, 1976), especially if the swamp elements from that flora are omitted. The similarity with the older Brandon flora (Traverse, 1955) is far less; *Pinus*, for example, is virtually absent from the flora.

We can therefore conclude that, in general, the history of the vegetation of the eastern United States is reflected by the marine pollen record in the sediments of the lower continental rise. The flora from Zone 2, below 380 m, suggest a warm temperate climate. In Zone 1, above 380 m, the *Pinus/Quercus* ratio reaches values found in modern marine sediments in this area (90/10) (Heusser, 1983). This change may represent a large-scale climatic cooling trend, as is further indicated by the larger numbers of *Spaghnum*, the lower number of *Carya* ,and the absence of *Juglans, Engelhardtia, Liquidambar*, and *Pterocarya* from most of the upper part of Zone 1 (Fig. 2A). Two possible Pleistocene glaciations may be reflected in Figure 2A at 80 m and from 50 to 60 m, which show very high *Pinus* and very low *Quercus* values, and where *Carya, Juglans, Engelhardtia, Pterocarya*, and *Liquidambar* are absent. The amount of reworked pollen remains the same through the section, and there is no noticeable difference between turbidites and turbidite-fed contourites.

CONCLUSIONS

1. The amount of palynomorphs in the studied sediments is adequate for future, detailed pollen analysis.
2. The onset of deposition from the Western Boundary Undercurrent is not recorded in the palynology of the sediments.
3. A detailed *qualitative* palynostratigraphy could not be established because of the stable vertical pollen distribution and the selectivity of marine pollen transport.
4. A more detailed *quantitative* palynostratigraphy, and consequently a more detailed investigation of the climatic changes is feasible, if larger samples are available, *Pinus* and *Quercus* are omitted from the standard pollen count (that is, if more pollen is counted), and a closer sample spacing is used. Our present results, based on widely spaced samples, suggest a large-scale climatic cooling trend.

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APPENDIX

Palynology of Some Samples Around the Cretaceous/Tertiary Boundary, Northwest Atlantic Sites 603 and 605

Eight core-catcher samples from DSDP Hole 605 and four from Hole 603B were processed for palynological analysis, using the following method: 10 cm^3 crushed sample was boiled in $\pm 20\%$ HCl (if required), followed by boiling in 10% Na-pyrophosphate, acetolysis, and bromoform separation.

The four samples from Hole 603B proved to be completely barren of palynomorphs (the heavy-liquid separation produced no organic residue at all). The eight samples from 605 contained "coal" fragments, plant debris, and some palynomorphs (see appendix Table 1). The number of palynomorphs was too small for meaningful pollen analysis, but additional sampling may yield age-diagnostic forms and sufficient numbers of dinoflagellates/acritarchs.

Table 1. Palynological results.

Core-catcher sample	Sub-bottom depth of core (m)	Pollen content
Hole 603B		
21,CC	1011.6–1020.6	Barren
22,CC	1020.6–1029.6	Barren
23,CC	1029.6–1038.6	Barren
24,CC	1038.6–1047.6	Barren
Hole 605		
57,CC	672.7–682.3	5 pollen grains[a]
60,CC	701.5–711.1	3 pollen grains[a]
66,CC	759.1–768.7	11 pollen grains[a]
68,CC	778.3–787.9	No palynomorphs
69,CC	787.9–797.5	2 pollen grains[a]
70,CC (top)	797.5–807.1	18 pollen grains[a]
70,CC (bottom)	797.5–807.1	4 pollen grains[a]
71,CC	807.1–816.7	Some dinoflagellates/acritarchs

[a] Sample also included some dinoflagellates/acritarchs.

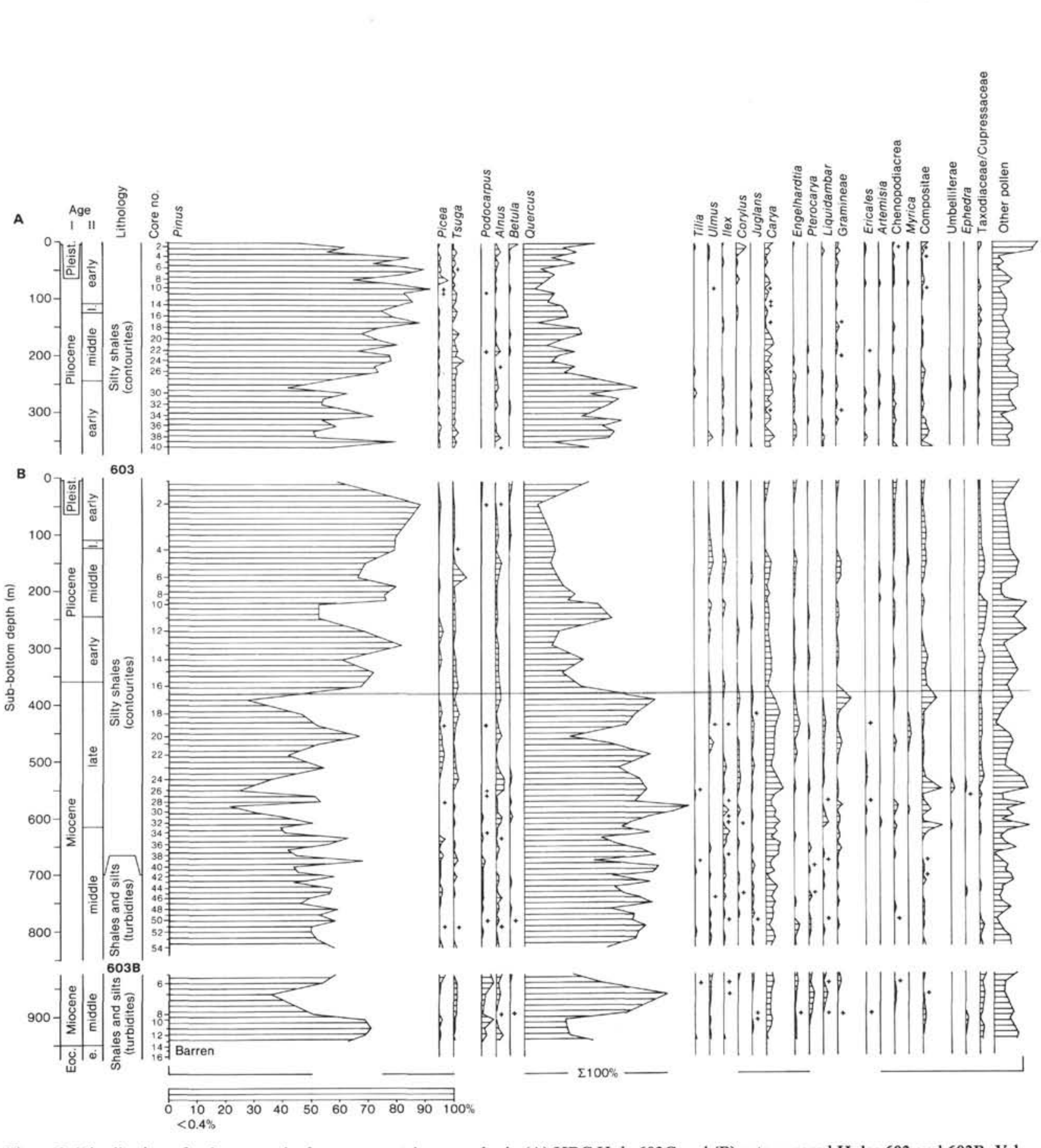

Figure 2. Distribution of palynomorphs from core-catcher samples in (A) HPC Hole 603C and (B) rotary-cored Holes 603 and 603B. Values for infrequently occurring pollen in percentages. Alternate time scales are based on dates for the Pliocene/Pleistocene boundary of (I) 1.6 Ma and (II) 2.6 Ma, respectively.

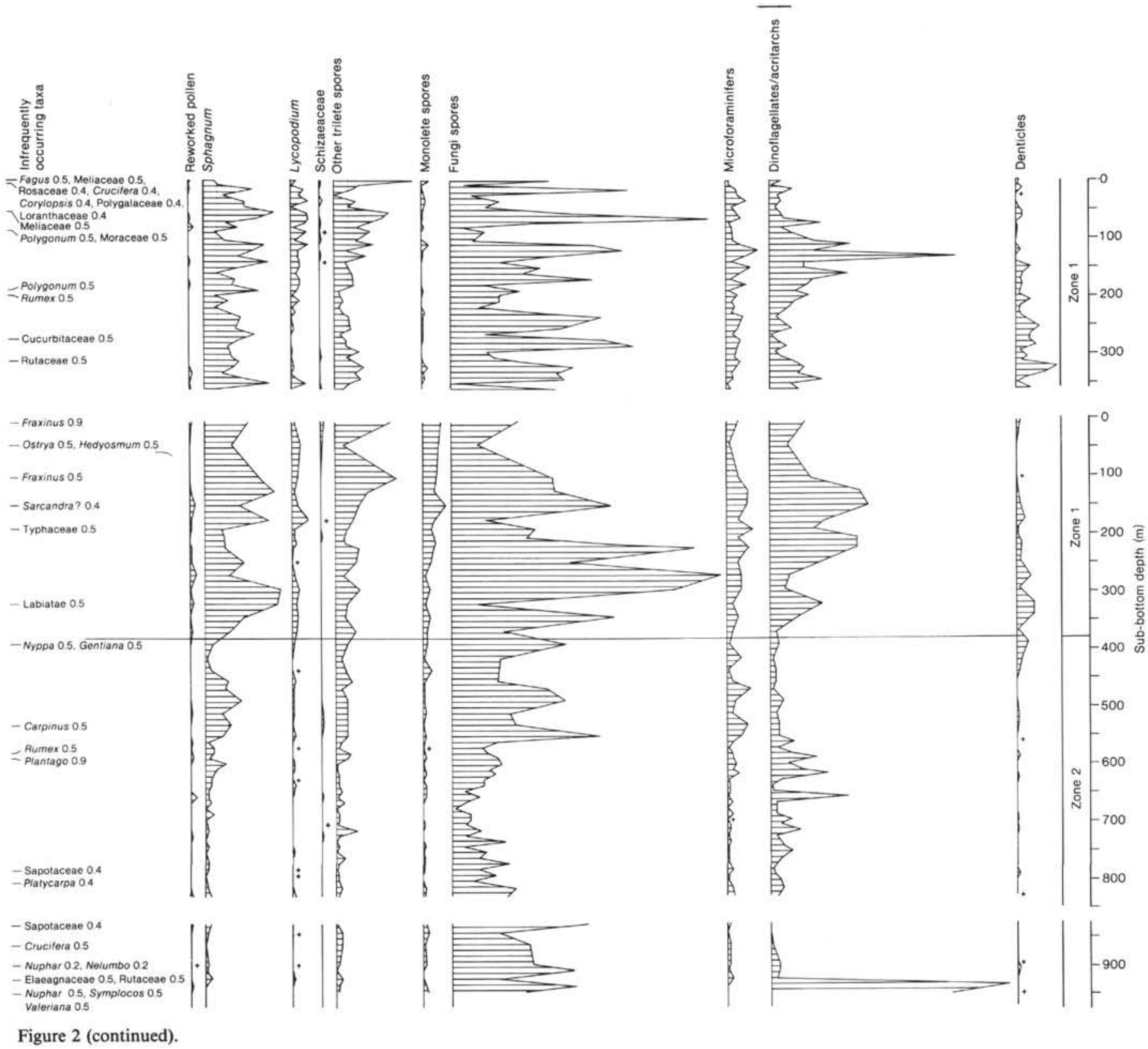

Figure 2 (continued).

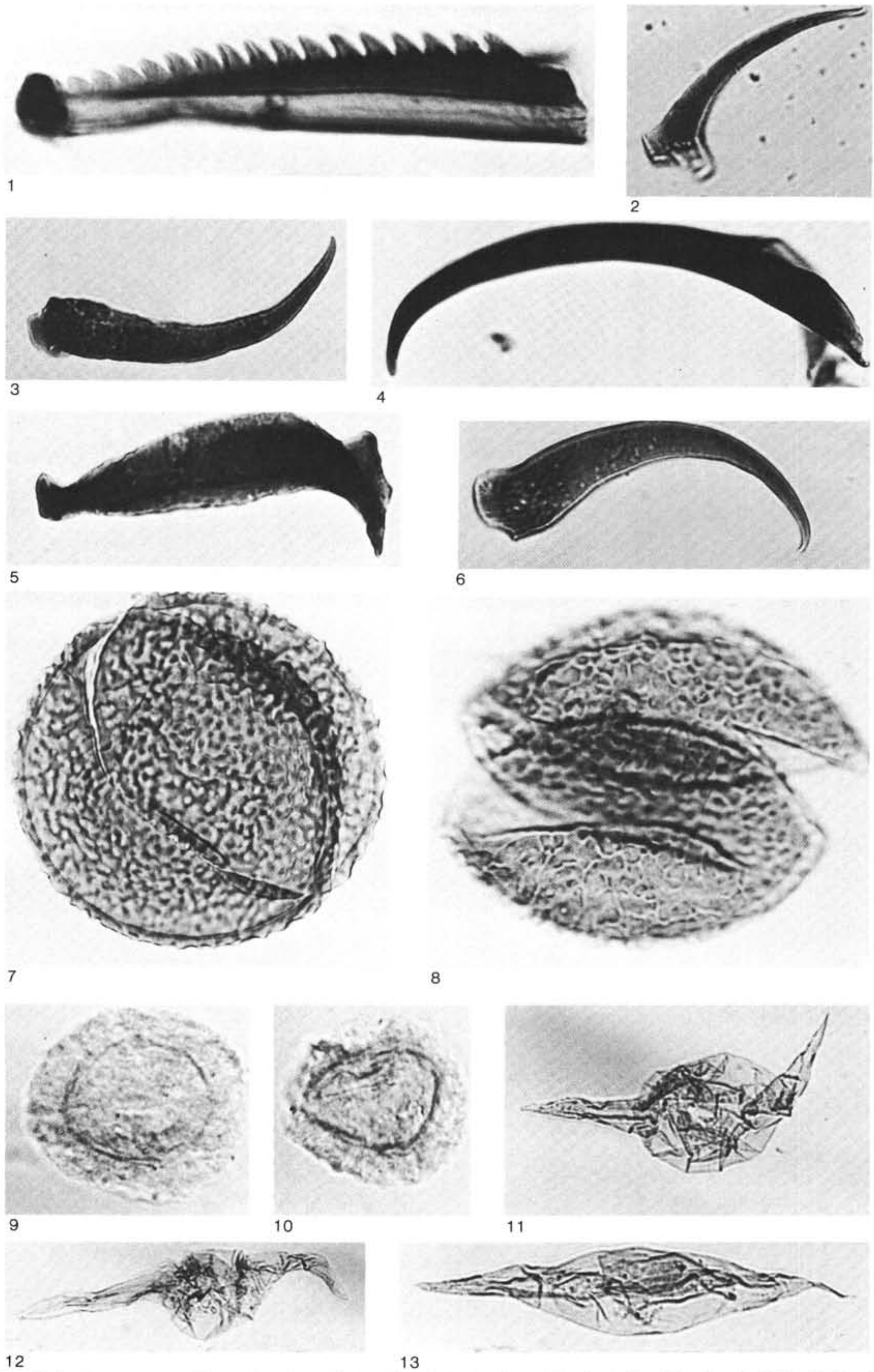

Plate 1. Unidentified palynomorphs. (Figs. 1, 9, 10, ≃1600×; Figs. 2–8, 11–13, ≃650×.) **1.** Denticle, Sample 603C-4,CC. **2, 3.** Denticles, Sample 603C-24,CC. **4.** Denticle, Sample 603C-4,CC. **5.** Denticle, Sample 603C-34,CC. **6.** Denticle, Sample 603C-24,CC. **7, 8.** Incertae sedis type B, Sample 603-37,CC. **9, 10.** Incertae sedis type E/F, Sample 603B-10,CC. **11-13.** cf. *Leiofusia*, Sample 603B-13,CC.