

23. FIRST RESULTS OF LATE TRIASSIC PALYNOLOGY OF THE WOMBAT PLATEAU, NORTHWESTERN AUSTRALIA¹

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ABSTRACT

Cores from Leg 122, Sites 759, 760, 761, and 764, were sampled at intervals of one sample per 1.5-m section in the Upper Triassic sequences. Spores, pollen, acritarchs, freshwater algae, and dinoflagellate cysts were studied to establish a palynostratigraphic framework for the Late Triassic.

The palynological sequence is interpreted in terms of Australian spore-pollen zones: the Carnian *Samaropollenites speciosus* Zone, the Norian *Minutosaccus crenulatus* Zone, and the Rhaetian *Ashmoripollis reducta* Zone. The *Samaropollenites speciosus* Zone–*Minutosaccus crenulatus* Zone boundary is marked by the change of pollen abundance and has a gradual character. Therefore, a transitional uppermost Carnian to Norian *Samaropollenites speciosus*/*Minutosaccus crenulatus* Zone is used. Age-determining dinoflagellate cysts are present in the Norian and Rhaetian sediments.

INTRODUCTION

During Leg 122 of the Ocean Drilling Program (ODP), nine holes were drilled at four sites (Site 759, 760, 761, and 764) in a north-south transect on the Wombat Plateau, a small sub-plateau of the northern Exmouth Plateau (Fig. 1). The oldest sediments drilled on the Wombat Plateau are late Carnian in age. They are also the oldest marine sediments drilled during the 20-year history of Deep Sea Drilling Project (DSDP) and ODP drilling. The sediment succession begins with late Carnian prodelta claystone and siltstone followed by deltaic, marginal-marine, and fluvial nonmarine sediments in the uppermost Carnian and in the Norian (Sites 759 and 760). Uppermost Norian sediments were recovered at Site 761 and Rhaetian sediments at Sites 761 and 764. The uppermost Norian consists of a carbonaceous claystone with coal seams. The overlying Rhaetian sequence at Site 761 is comprised of crinoid limestone and laminated claystone facies. Site 764, which is located farther basinward, near the shelf edge, consists of a reef complex overlain by a shelf limestone. Jurassic sediments are completely missing on the Wombat Plateau.

The Upper Triassic sequence is unconformably overlain by Lower Cretaceous sediments in the central part of the plateau (Site 761), which pinch out toward the south (Site 760). Toward the north (Site 764), the Cretaceous is further thinned, and only a condensed Upper Cretaceous section is present.

The purposes of this paper is to provide a palynostratigraphic zonation and a palynofacies framework of the Upper Triassic sediments. Except for a short comment on undescribed species, taxonomic discussion and description of the dinoflagellate cyst, acritarch, freshwater algae, and spore/pollen assemblages will be given elsewhere.

METHODS

During Leg 122, shipboard palynological studies were made from about 120 samples of the Triassic sediments. Onboard laboratory processing facilities precluded routine use of hydrofluoric acid (HF). The preparation technique used on the ship (Haq, von Rad, O'Connell, et al., 1990) yields only a

partial assemblage of the entire palynomorph content of the sediment and is not usable for quantitative stratigraphic and palynofacies examinations. Therefore, the shipboard samples were not used for shore-based studies.

About 250 samples were taken from the Upper Triassic sediments of the Wombat Plateau. All the samples were given the following standard palynological processing treatment: after cleaning and drying, 20 g of the sample were boiled with 35% hydrochloric acid (HCl) and then washed over a 10- μ m sieve. The residue was processed with HF and washed again over a 10- μ m sieve. A small quantity of residue was removed for fluorescence and SEM studies. The remainder was treated with 60% nitric acid (HNO₃) to remove pyrite and amorphous organic debris. Slides were mounted with Entellan.

PALYNOFACIES

Palynofacies definition can be based primarily on total kerogen component or on palynomorph assemblages (Batten, 1982; Bint and Helby, 1988; Hart, 1986). The latter definition is used in this study.

The different components of a organic microfossil assemblage have different origin, either aquatic or terrestrial. Aquatic elements are freshwater algae, marine algae (dinoflagellate cysts and acritarchs), animal parts, such as scolecodonts (teeth of annelids), or the inner organic layer of foraminifers, also called foram-liners. Terrestrial elements are wood fragments, cuticle, spores, and pollen.

The terminology used here for palynofacies nomenclature refers more to the composition of palynomorph assemblages than to an absolute environment interpretation. For example, a high terrestrial palynomorph input can overprint the marine assemblages; therefore, environments within the shallow-marine realm (e.g., estuarine or lagoonal) could be interpreted as restricted marine or even nonmarine. A detailed study of the palynofacies, incorporated with well-log data and sedimentological interpretations, will be the subject of future work.

PALYNOSTRATIGRAPHY

Zonation Used For Leg 122

The spore-pollen zonation of the western Australian Triassic is based on the biostratigraphic units of Dolby and Balme (1976), modified by Helby et al. (1987) (Fig. 2). These zones

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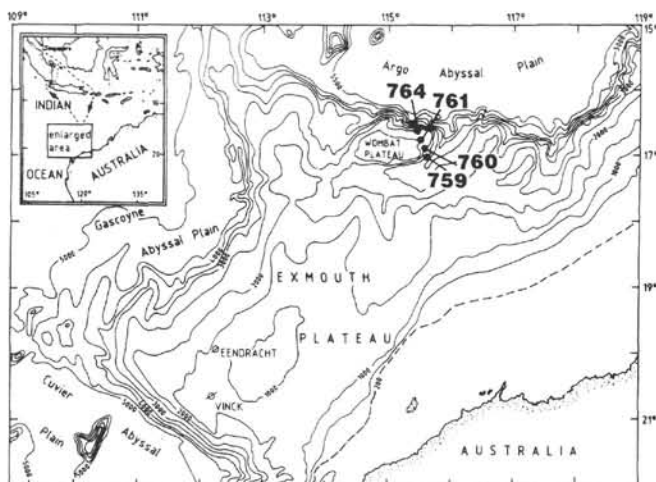


Figure 1. Bathymetric map (in meters) of the Australian Northwest Shelf region showing location of ODP sites on the Wombat Plateau.

are defined in the sense of the International Guide to Stratigraphic Classification (Hedberg, 1976) as assemblage zones by Dolby and Balme (1976) and as Opper zones by Helby et al. (1987). The only published dinoflagellate zonation of the western Australian Triassic is by Helby et al. (1987). The shorter ranges of the dinoflagellate cysts in contrast to the spores and pollen make it possible to define the zones as interval zones in the sense of Hedberg (1976).

The boundary between the *Samaropollenites speciosus* Zone and the *Minutosaccus crenulatus* Zone is defined by a marked decline in prominence of *Enzonalasporites vigens*, *Samaropollenites speciosus*, and an uphole increase in *Falcisporites australis* (Helby et al., 1987). Therefore, this boundary has a more gradual character. In addition, the uppermost Carnian and Norian sediments of the Wombat Plateau were deposited in various shallow-marine, paralic, and coastal plain environments, and the ranges and abundance of the organic microfossils can be overprinted by ecological factors. This, and the possibility of secondary redistribution of palynomorphs in the marginal-marine palynofacies (Bint and Helby, 1988), together with the absence of age-significant marine palynomorphs, make it necessary to place the boundary between the *Samaropollenites speciosus* Zone and the *Minutosaccus crenulatus* Zone within a transitional interval.

Palynomorphs At Site 759

Sample 122-759B-6R-1, 58–63 cm, is in the *Heibergella balmei* dinoflagellate Zone (*Minutosaccus crenulatus* spore-pollen Zone) (middle to late Norian).

This sample differs from all other samples analyzed from the Triassic of the Wombat Plateau in containing the dinoflagellate cyst *Heibergella balmei*, which occurs only in the middle to late Norian. The abundance and diversity of marine palynomorphs suggest a marine environment of deposition (Fig. 3).

The interval from Sample 122-759B-7R-1, 72–77 cm, to Sample 122-759B-20R-1, 74–76 cm, is in the transitional *Samaropollenites speciosus*/*Minutosaccus crenulatus* Zone (latest Carnian to early Norian).

This interval consists of sediments from a shallow-marine to a nonmarine environment. Many of the palynomorphs show evidence of mechanical abrasion, resulting in relatively poor preservation. In addition, poor recovery in this interval results in sparse sample points. Therefore, the resulting stratigraphic

resolution is low, and the palynofacies interpretation is more fragmentary.

Relatively few dinoflagellates could be found in Sample 122-759B-16R-1, 18–20 cm. Sample 122-759B-7R-1, 72–77 cm, contains no marine palynomorphs. The absence of dinoflagellates and the low abundance of trilete spores point to a restricted or marginal-marine environment. The spore-pollen association gives a transitional assemblage between the *Samaropollenites speciosus* Zone and the *Minutosaccus crenulatus* Zone. Whereas the presence of the spores *Camerosporites secatus* and *Camerosporites pseudoverrucatus* suggests a Carnian age, the permanent low abundance of *Samaropollenites speciosus* points to a Norian age. The differentiation between the *Samaropollenites speciosus* Zone and the *Minutosaccus crenulatus* Zone is based mainly on the change in abundance of the eponymous species. However, this sequence was deposited in a marginal-marine environment and we cannot exclude the possibility that the spore-pollen assemblage is overprinted by ecological factors. This, and the absence of age-determining dinoflagellate marker species, leads to suggest a latest Carnian to early Norian transitional *Samaropollenites speciosus*/*Minutosaccus crenulatus* Zone for this sequence.

The interval from Sample 122-759B-20R-2, 60–64 cm, to Sample 122-759B-39R-5, 71–74 cm, is in the *Samaropollenites speciosus* Zone (late Carnian).

This interval can be subdivided into five units:

Unit I. Samples 122-759B-20R-02, 60–64 cm, and 122-759B-20R-3, 60–64 cm. The uphole increase in acritarchs and the absence of dinoflagellate cysts suggest a marginal-marine environment for this unit.

Unit II. Samples 122-759B-20R-4, 22–26 cm, to 122-759B-22R-2, 72–74 cm. The uphole decrease of marine palynomorphs and the simultaneous increase of trilete spores suggest a regressive character for this interval. The presence of megaspores and large cuticle fragments, and the absence of marine palynomorphs in Samples 122-759B-20R-4, 22–26 cm, to 122-759B-21R-2, 74–76 cm, suggest that this part of unit II is predominantly nonmarine.

The interval from Sample 122-759B-22R-3, 72–74 cm, to Sample 122-759B-23R-2, 58–61 cm, contains only a few poorly preserved palynomorphs without a clear assignment to unit II or unit III.

Unit III. Samples 122-759B-23R-3, 21–23 cm, to 122-759B-27R-1, 74–77 cm. Low abundance of trilete spores and abundance of acritarchs in the upper part of this unit (Samples 122-759B-23R-3, 21–23 cm, to 122-759B-25R-2, 71–74) suggest a marine to open-marine environment.

Unit IV. Samples 122-759B-27R-2, 59–61 cm, to 122-759B-32R-3, 74–76 cm. Acritarchs are present and trilete spores are abundant, pointing to a restricted marine environment. On the other hand, the absence or very rare occurrence of freshwater algae suggests more of a marine environment with a high terrigenous influx.

Unit V. Samples 122-759B-27R-2, 59–61 cm, to 122-759B-39R-5, 71–74 cm. The low abundance of trilete spores, the absence of freshwater algae, and the presence of acritarchs suggest that this interval belongs to a marine environment.

Palynomorphs At Site 760

The interval from Sample 122-760A-11X-1, 32–33 cm, to Sample 122-760B-13R-1, 77–79 cm, is in the *Minutosaccus crenulatus* Zone (Norian).

The base of this zone is marked by the first occurrence of *Suessia listeri* and *Suessia swabiana*. This corresponds with

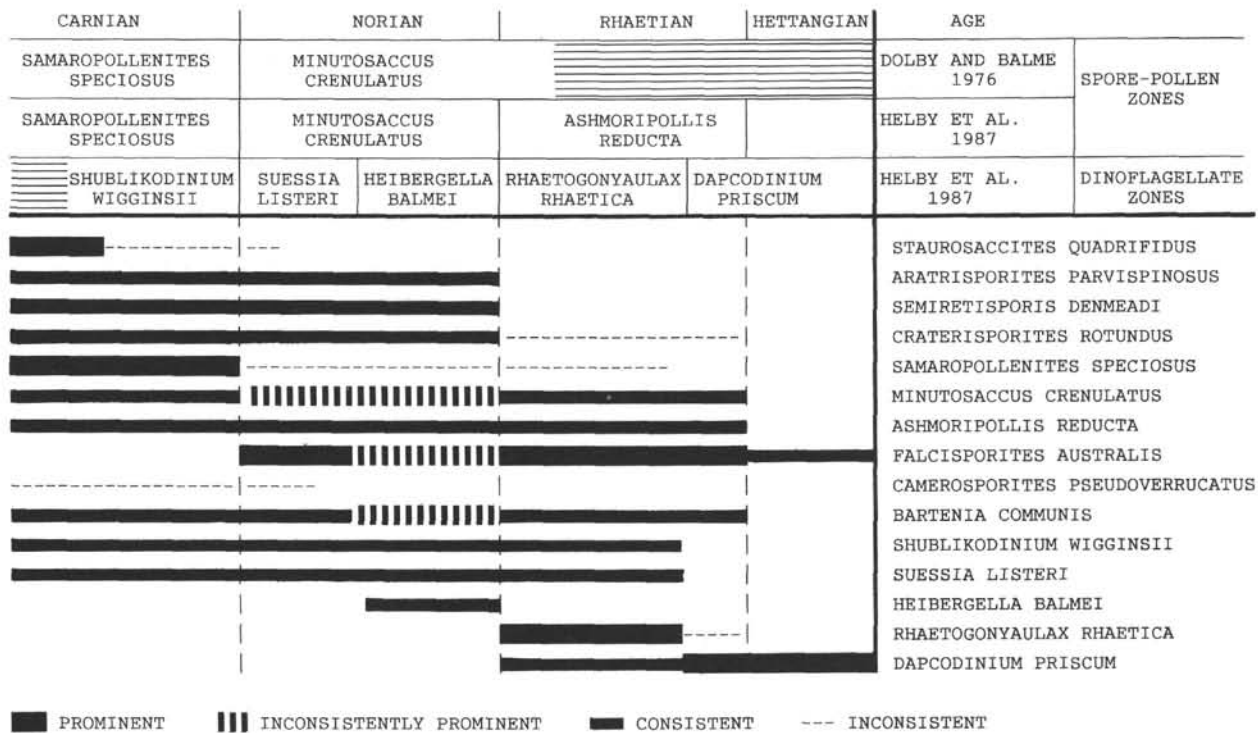


Figure 2. Spore-pollen zones, dinoflagellate zones, and stratigraphic ranges of selected palynomorphs. Adapted and simplified from Dolby and Balme (1976) and Helby et al. (1987).

the definition of the Norian *Suessia listeri* Zone (Helby et al., 1987). The sporadic prominence of *Bartenia communis* suggests that this interval belongs more to the middle to late Norian (Helby et al., 1987), whereas the absence of *Heibergella balmei* can be facies-controlled as well as age significant.

The palynofacies varies several times from marine to nonmarine environments. Also the preservation and abundance of the palynomorphs change from barren intervals to intervals with abundant palynomorphs and good preservation, as outlined on Figures 4 (Hole 760A) and 5 (Hole 760B).

The interval from Sample 122-760B-13R-2, 94–97 cm, to Sample 122-759B-29R-4, 74–76 cm, is in the transitional *Samaropollenites speciosus/Minutosaccus crenulatus* Zone (latest Carnian to early Norian).

The absence of *Suessia listeri* and the presence of *Shublikodinium* spp. in this interval point to the *Shublikodinium wigginsii* dinoflagellate Zone, which is Carnian in age. However, the absence of *Suessia swabiana*, which should also be present in the upper part of this zone, and the rare occurrence of *Shublikodinium* spp. suggest that the occurrence of dinoflagellates in this interval is environmentally controlled and cannot be used for stratigraphic dating. A prominent presence of *Enzonalasporites vigens*, which suggests a Carnian age (*Samaropollenites speciosus* Zone), could be found only in the interval from Sample 122-760B-18R-1, 78–80 cm, to Sample 122-760B-19R-2, 76–78 cm (Fig. 5). All samples, from Sample 122-760B-26R-1, 30–33 cm, down to the bottom of the hole, yield few, poorly preserved palynomorphs.

Palynomorphs At Site 761

Few organic microfossils could be found in two small intervals (Fig. 6). Most of the palynomorphs are poorly preserved and fragmented, suggesting that the assemblages

reflect a selective preservation of the palynomorphs rather than a primary composition. Therefore, the zonation is based only on the range of *Rhaetogonyaulax rhaetica*, and no range chart, is provided for Site 761.

The intervals from Sample 122-761C-23R-1, 128–130 cm, to 122-761C-26R-6, 50–53 cm, and from Sample 122-761C-30R-1, 87–88 cm, to 122-761C-31R-4, 122–125 cm, are in the *Rhaetogonyaulax rhaetica* dinoflagellate Zone/*Ashmoriipollis reducta* spore-pollen Zone (Rhaetian).

In all samples palynomorphs could be found in a very low abundance and predominantly poor preservation. Only foraminifers are relatively common and show moderate to good preservation. Warrington (1978) reported a similar situation from Upper Triassic limestones (White Lias) of England. He interpreted the depositional environment as shallow-marine, with an increase in turbulence. Also possible for higher concentration of linings is an increasing salinity (Stancliffe, 1989).

Nevertheless, few specimens of the dinoflagellate cysts *Rhaetogonyaulax rhaetica* and *Suessia listeri* are present in all samples. In addition, the absence of pollen of the *Corollina/Classopollis* type (although it may be environmentally controlled) points to an early to middle Rhaetian age for this interval.

In the basal interval (Sample 122-761C-30R-1, 87–88 cm, to Sample 122-761C-31R-4, 122–125 cm) the absolute abundance and the preservation are better than in the interval above. The palynomorph assemblages are essentially similar and there is a downhole increase in plant debris.

The interval from Sample 122-761C-32R-3, 78–82 cm, to Sample 122-761C-33R-CC is in the *Minutosaccus crenulatus* Zone (Norian).

The palynomorph assemblage in this interval is dominated by bisaccate pollen but dinoflagellate cysts (e.g. *Suessia listeri*

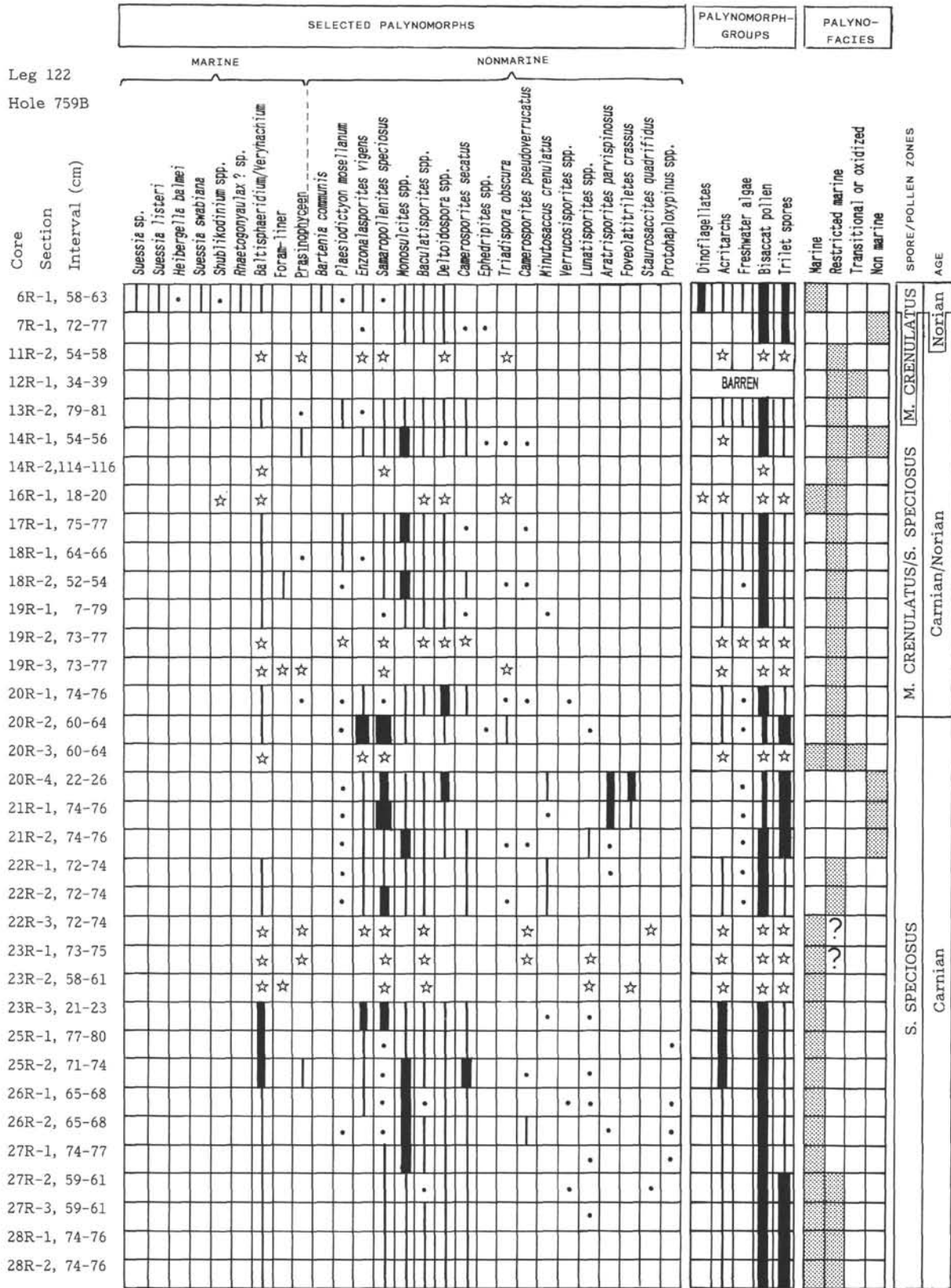


Figure 3. Range charts of selected spores, pollen, dinoflagellate cysts, and abundance of the different palynomorph groups with a palynofacies interpretation at Hole 759B. Stars indicate that species are present, but bad preservation and/or a small number of palynomorphs reflect only a selective assemblage. Dots = rare; narrow lines = few; medium lines = common; and wide lines = abundant.

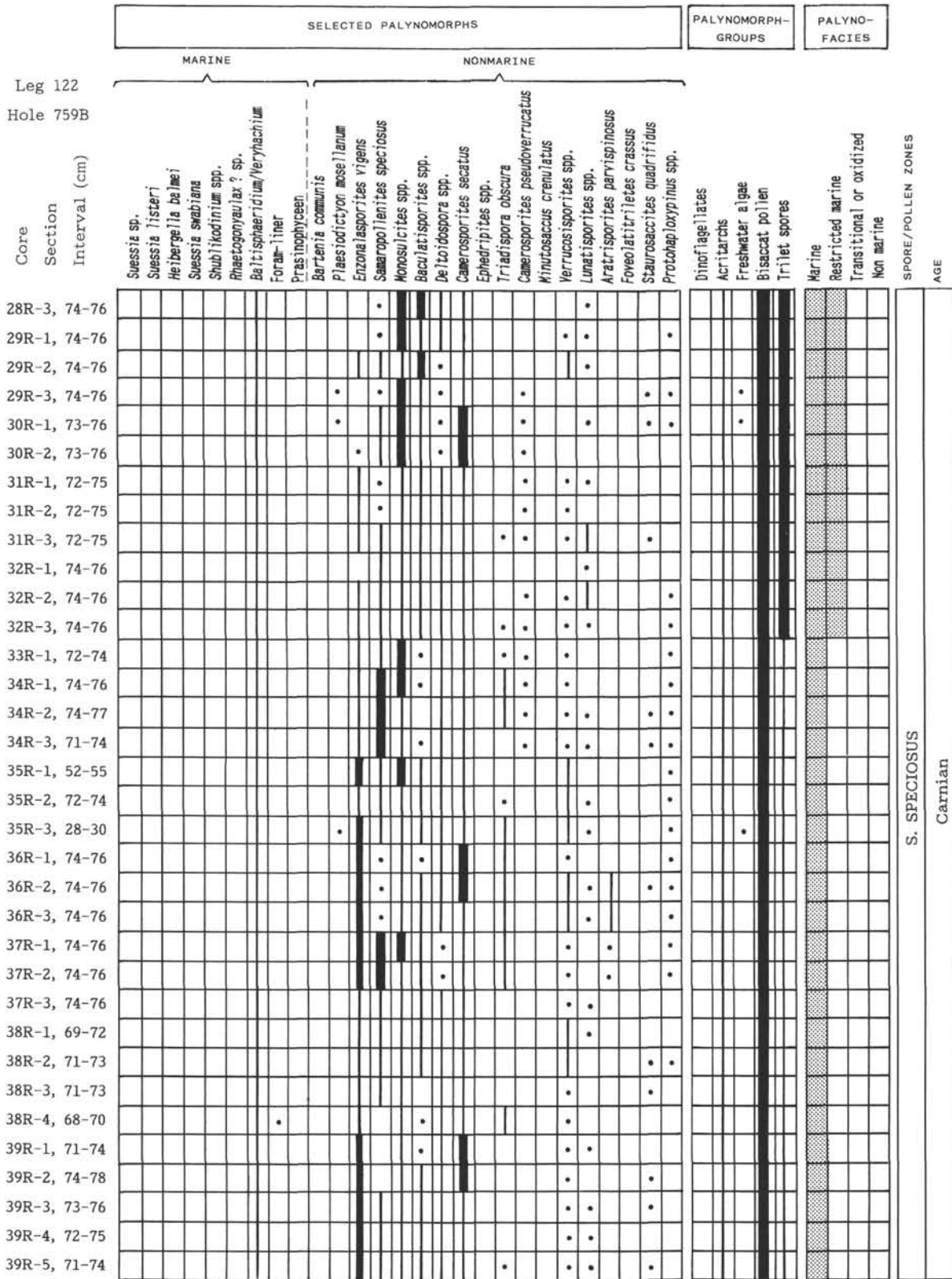


Figure 3 (continued).

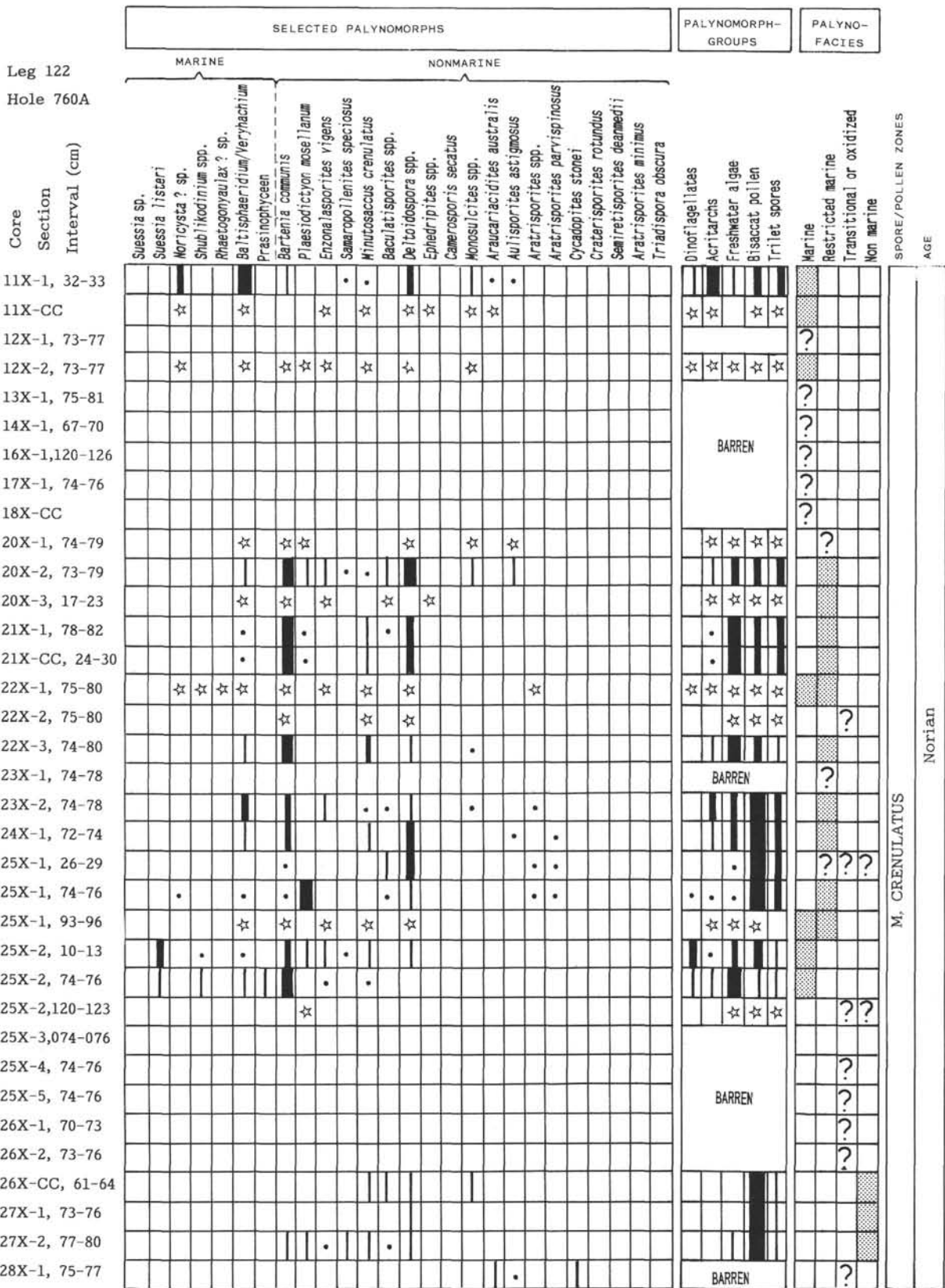


Figure 4. Range charts of selected spores, pollen, dinoflagellate cysts, and abundance of the different palynomorph groups with a palynofacies interpretation at Hole 760A. Stars indicate that species are present, but bad preservation and/or a small number of palynomorphs reflect only a selective assemblage. Dots = rare; narrow lines = few; medium lines = common; and wide lines = abundant.

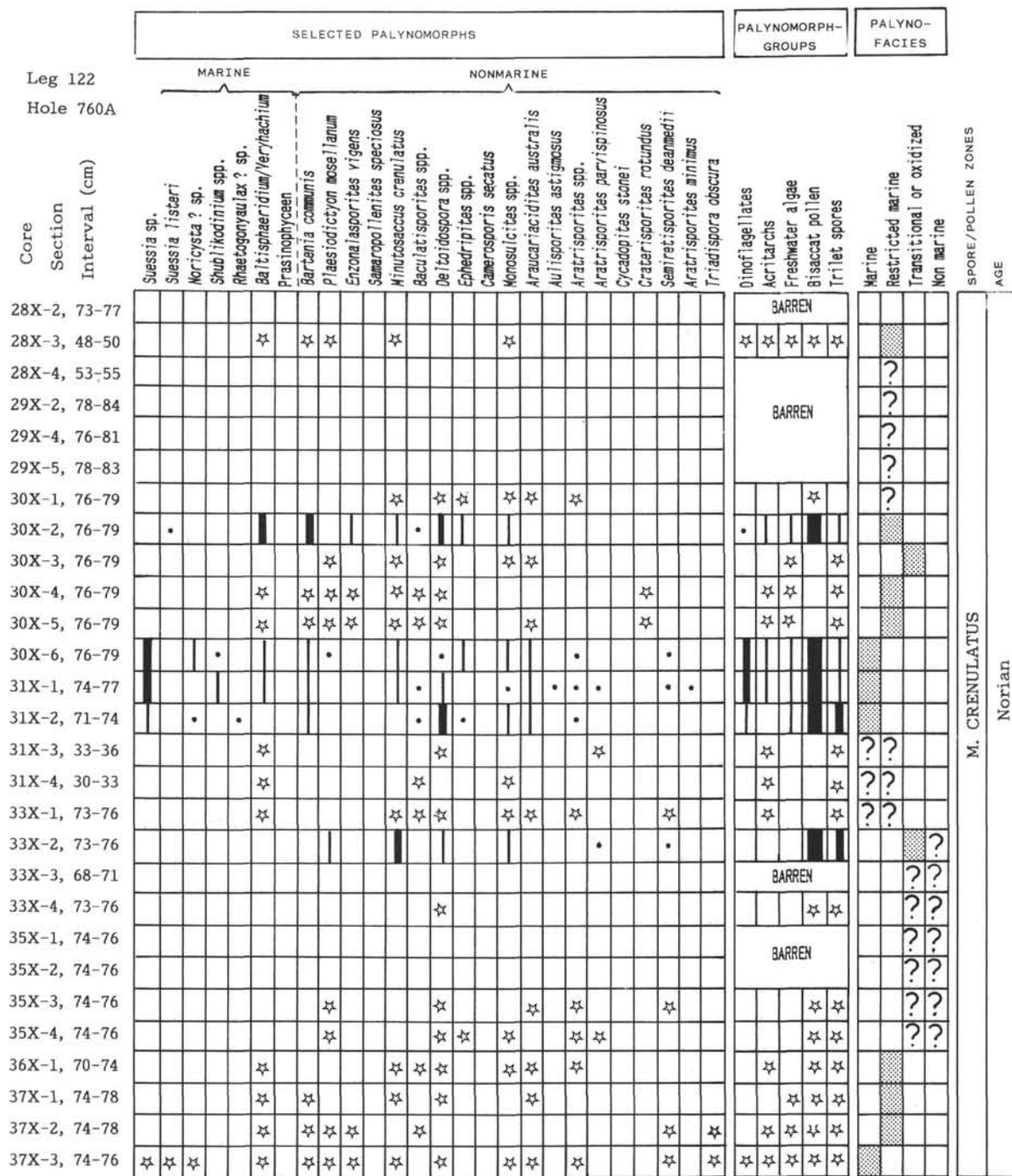


Figure 4 (continued).

and *Shublikodinium* spp.) and acritarchs are also present. These, together with abundant cuticle and wood fragments, point to a marine but nearshore environment. The apparent absence of *Rhaetogonyaulax rhaetica* suggests that the assemblage is older than Rhaetian.

Palynomorphs At Site 764

At this site only two small intervals contain few, poorly to moderately preserved palynomorphs: Sample 122-764B-4R-CC to 122-764B-8R-1, 55-58 cm, and Sample 122-764B-

31-1, 142-144 cm, to 122-764B-31R-CC (Fig. 6). All assemblages yield *Rhaetogonyaulax rhaetica*. This gives a clear Rhaetian age from Sample 122-764B-4R-CC to the bottom of the hole.

Samples 122-764B-4R-CC and 122-764B-5R-1, 120-125 cm, yield foram-liners and very few fragments of *Rhaetogonyaulax rhaetica* and bisaccate pollen. The palynomorphs in Samples 122-764B-6R-1, 83-86 cm, 122-764B-7R-1, 70-73 cm, and 122-764B-8R-1, 55-58 cm, are moderately to well preserved. Spores and pollen are rare, foram-liners and acritarchs are common, and *Rhaetogonyaulax rhaetica* dominates all assemblages.

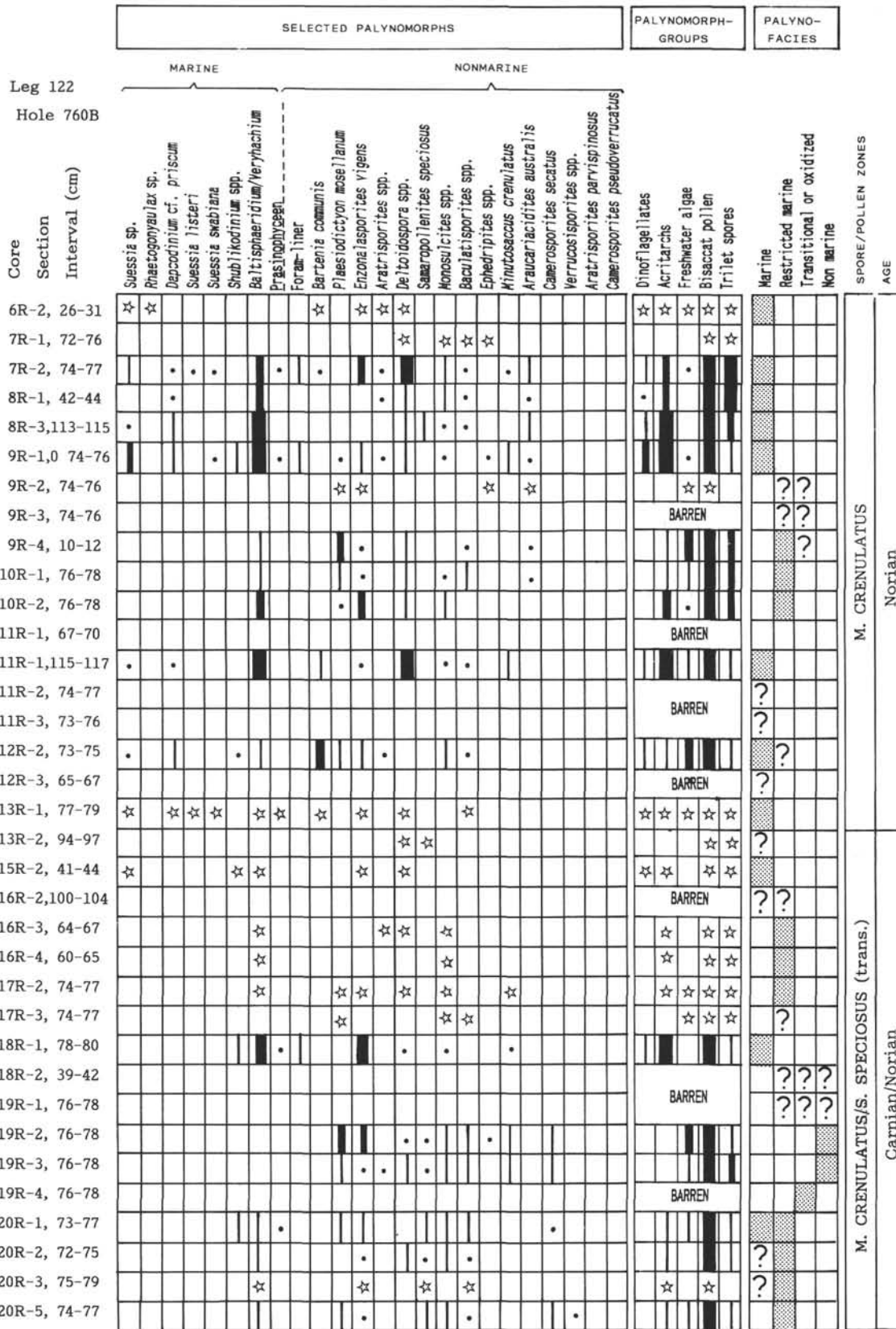


Figure 5. Range charts of selected spores, pollen, dinoflagellate cysts, and abundance of the different palynomorph groups with a palynofacies interpretation at Hole 760B. Stars indicate that species are present, but bad preservation and/or a small number of palynomorphs reflect only a selective assemblage. Dots = rare; narrow lines = few; medium lines = common; and wide lines = abundant.

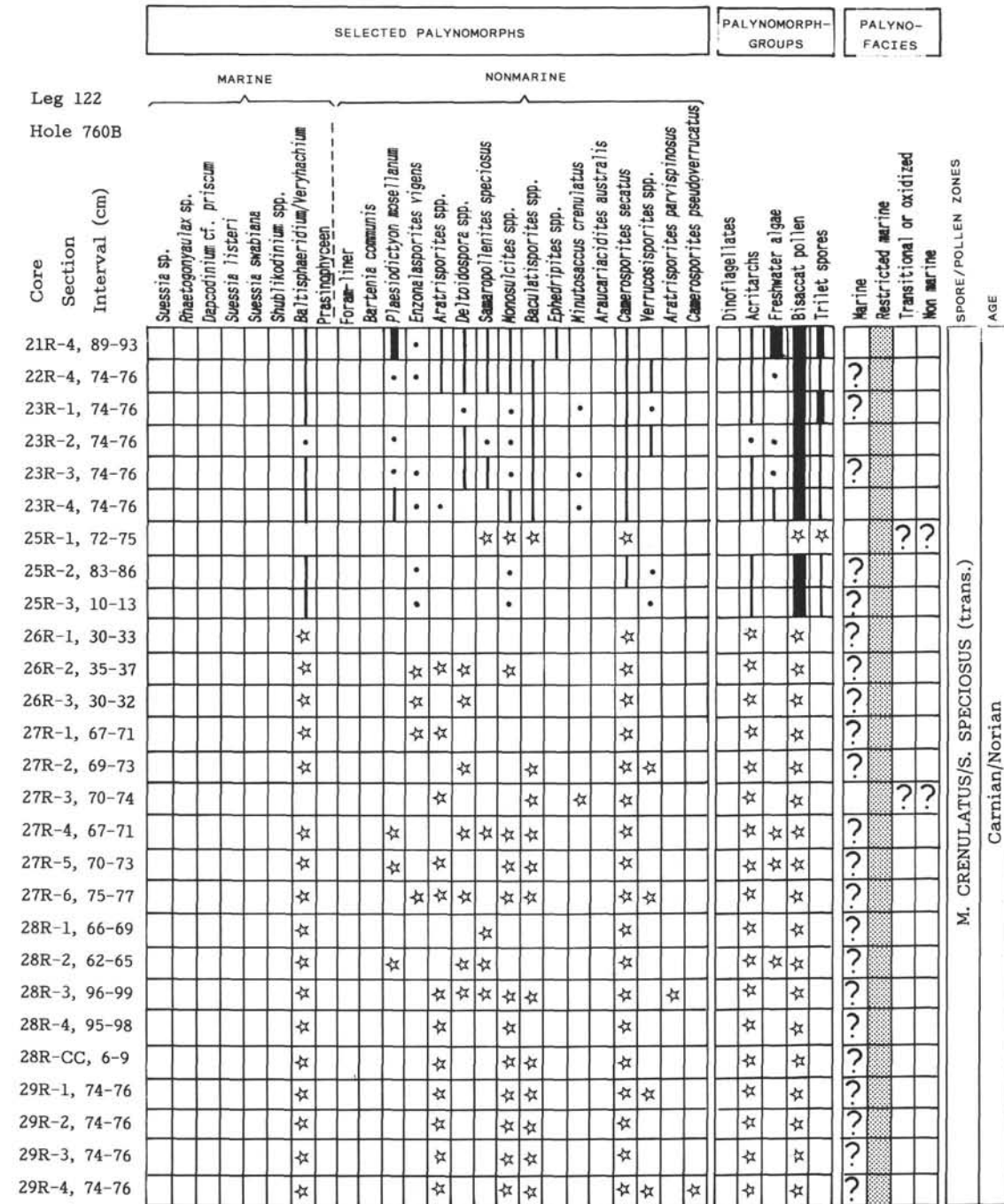


Figure 5 (continued).

The interval from Sample 122-764B-31R-1, 142-144 cm, to 122-764B-31R-CC yields only few *Rhaetogonyaulax rhaetica*, whereas *Suessia listeri* is the prominent form.

CONCLUSION

The Rhaetian sequence at Sites 761 and 764 consists of shelfal to shallow-marine, reefal, and non-reefal limestone (Haq, von Rad, O'Connell, et al., 1990; Sarti, this volume; Williamson, this volume). The sediments of this environment have undergone oxidation and the potential for fossilization of organic material is very low (Röhl et al., this volume). Nevertheless, a few specimens of the index species *Rhaetogonyaulax rhaetica* give a clear

age. This species is recorded worldwide with a range restricted to the Rhaetian stage (Achilles, 1980; Brenner, 1986; Fisher and van Helden, 1979; Helby et al., 1987; Lund, 1977; Morbey, 1975; Sharma and Sarjeant, 1987, and others).

The Norian sequence at Site 760 consists of shallow-marine to marginal-marine or nonmarine sediments (i.e., tidal flat with channels to distributary bay to estuarine). The palynomorph assemblages show a (cyclic?) alteration between marine and nonmarine elements (dinoflagellate cysts and acritarchs vs. freshwater algae, spores, and pollen). The age determination is based primarily on the occurrence of dinoflagellate cysts with well known absolute ranges.

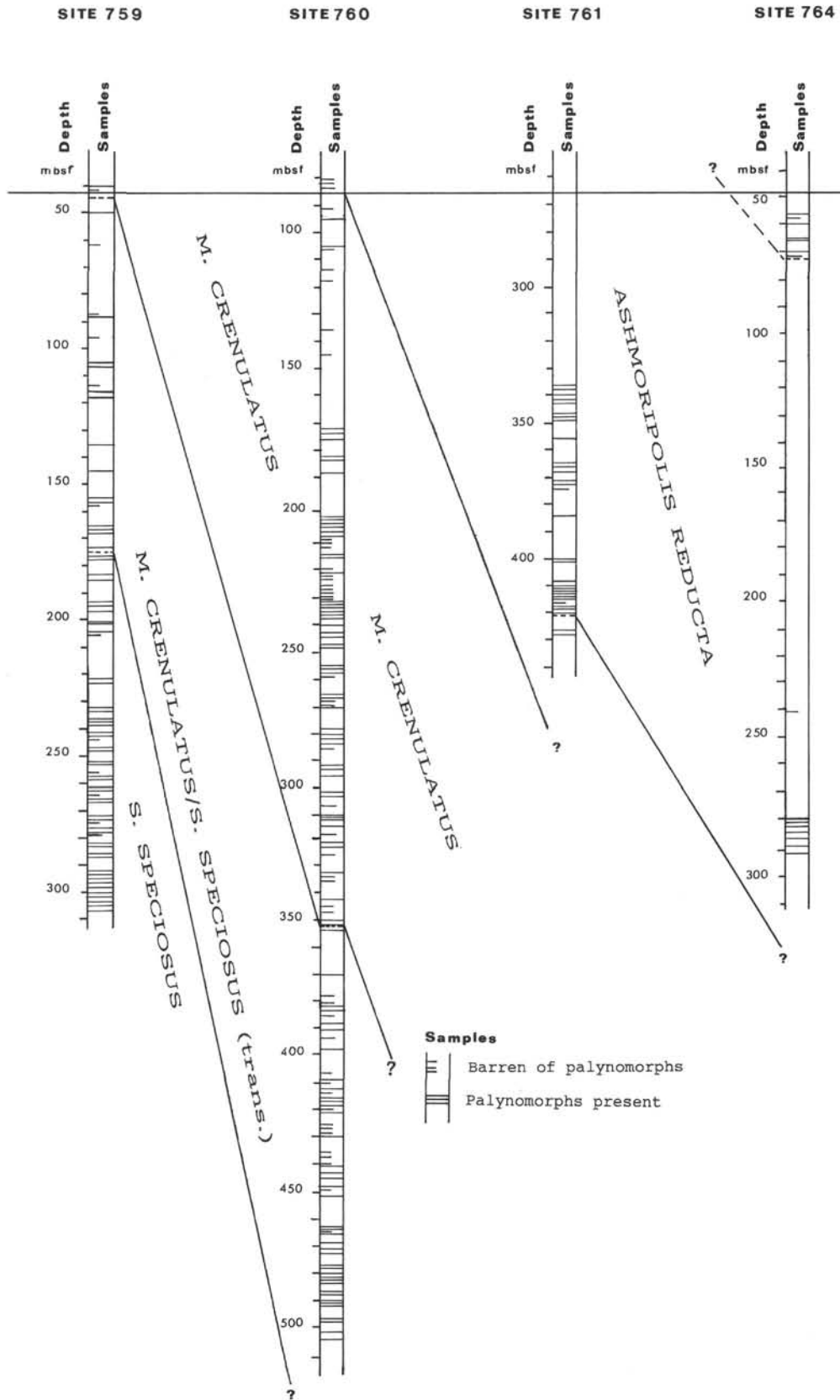


Figure 6. Sample distribution and palynostratigraphic correlation of Sites 759, 760, 761, and 764.

The transitional interval between the Norian and the Carnian of Sites 759 and 760 consists of shallow-marine claystone, siltstone interbedded with sandstone, coal seams, and carbonates. Dinoflagellate cysts and foram-liners are absent or very rare and freshwater algae occur throughout. This may indicate a lower salinity or a constant freshwater influence over this interval. Age determinations here could be based only on spores and pollen; however, their abundance and ranges have a more transitional character between the Carnian *Samaropollenites speciosus* Zone and the Norian *Minutosaccus crenulatus* Zone as also described by Dolby and Balme (1976). Therefore, an exact Carnian-Norian boundary cannot be given for this transitional interval.

The Carnian sequence at Site 759 consist of a shallowing-upward interval from prodeltaic to deltaic overlain by shallow-marine to nonmarine sediments. The spore/pollen assemblage can be clearly correlated with the *Samaropollenites speciosus* Zone of Dolby and Balme (1976) and Helby et al. (1987).

RANGE CHART SPECIES LIST

Spores and Pollen

Aratrisporites minimus Schulz, 1967
Aratrisporites parvispinosus Leschik, 1955
Araucariacites australis Cookson, 1947
Aulisporites astigosus (Leschik, 1956) Klaus, 1960
Camerosporites secatus Leschik, 1955
Camerosporites pseudoverrucatus Scheuring, 1970
Craterisporites rotundus de Jersey, 1970
Cycadopites stonoi Helby, 1987
Enzonalsporites vigens Leschik, 1955
Foveolatitriletes crassus Orlowska-Zwolinska, 1983
Minutosaccus crenulatus Dolby in Dolby and Balme, 1976
Samaropollenites speciosus Goubin, 1965
Semiretisporites denmeadi (de Jersey 1962) de Jersey, 1970
Staurosaccites quadrifidus Dolby in Dolby and Balme, 1976
Triadisporea obscura Scheuring, 1970

Freshwater Algae

Bartenia communis Helby, 1987
Plaesiodyctyon mosellanum Wille, 1970 (Pl. 2, Figs. 1–10)

Dinoflagellate Cysts

Heibergella balmei Stover and Helby, 1987
Noricysta Bujak and Fisher, 1976
Noricysta? sp. (Pl. 1, Figs. 1–4)
Suessia listeri Stover and Helby, 1987
Suessia sp. (Pl. 1, Figs. 5–7)
Suessia swabiana Morbey, 1975
Rhaetogonyaulax rhaetica (Sarjeant, 1963) Loeblich and Loeblich, 1968
Rhaetogonyaulax? sp., (Pl. 1, Figs. 8–10)

TAXONOMIC REMARKS

Noricysta? sp.
 (Plate 1, Figs. 1–4)

Remarks. Cavate, nontabulate cyst with a uncertain archeopyle type (could be apical or combination apical and intercalary). The paracingulum is expressed by a distinguished folding of the periphragm. The endophragm of the epicyst is normally thinner than the endophragm of the hypocyst. A similar phenomenon is observed with *Dapcodinium priscum* Evitt (1961). *Noricysta?* sp. differs from *Dapcodinium* in being cavate and from *Hebecysta* Bujak and Fisher (1976) in having an apical archeopyle rather than an intercalary.

Rhaetogonyaulax? sp.
 (Plate 1, Figs. 8–10)

Remarks. This form is intermediate between *Shublikodinium* Wiggins (1973), with two antapical horns or an antapical lobation, and *Rhaetogonyaulax*, with only one antapical horn. The horns are differentiated into a "primary horn" at paraplate 1^{'''}, the some

location as the single horn of *Rhaetogonyaulax* (see Below, 1987), and a "secondary horn" at paraplate 3^{'''}, which could be reduced to a small bulge.

Suessia sp.
 (Plate 1, Figs. 5–7)

Remarks. Proximate cyst with subspherical outline, nontabulated hypocyst, and a smooth, thin (less than 1 μm) autophragm. Paratabulation is partly indicated on the epicyst by low parasutural ridges and by the shape of the archeopyle margin. The number, shape, and arrangement of the visible paraplates points to a suessoid paratabulation.

ACKNOWLEDGMENTS

Thanks are due to the Deutsche Forschungsgemeinschaft, Bonn, for supporting the present study, to H. P. Luterbacher, who made it possible to begin this study at the Institut für Geologie und Paläontologie Tübingen, and to J. Thiede, who facilitated the continuation of this study at GEOMAR, Kiel. I also thank R. Boyd (GEOMAR) for discussion of the geological and stratigraphical problems, G. Dürr (Institut für Geologie und Paläontologie, Tübingen) for processing a part of the samples, and R. Helby and A. N. Bint for reviewing this paper.

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Date of initial receipt: 1 June 1990

Date of acceptance: 4 March 1991

Ms 122B-157

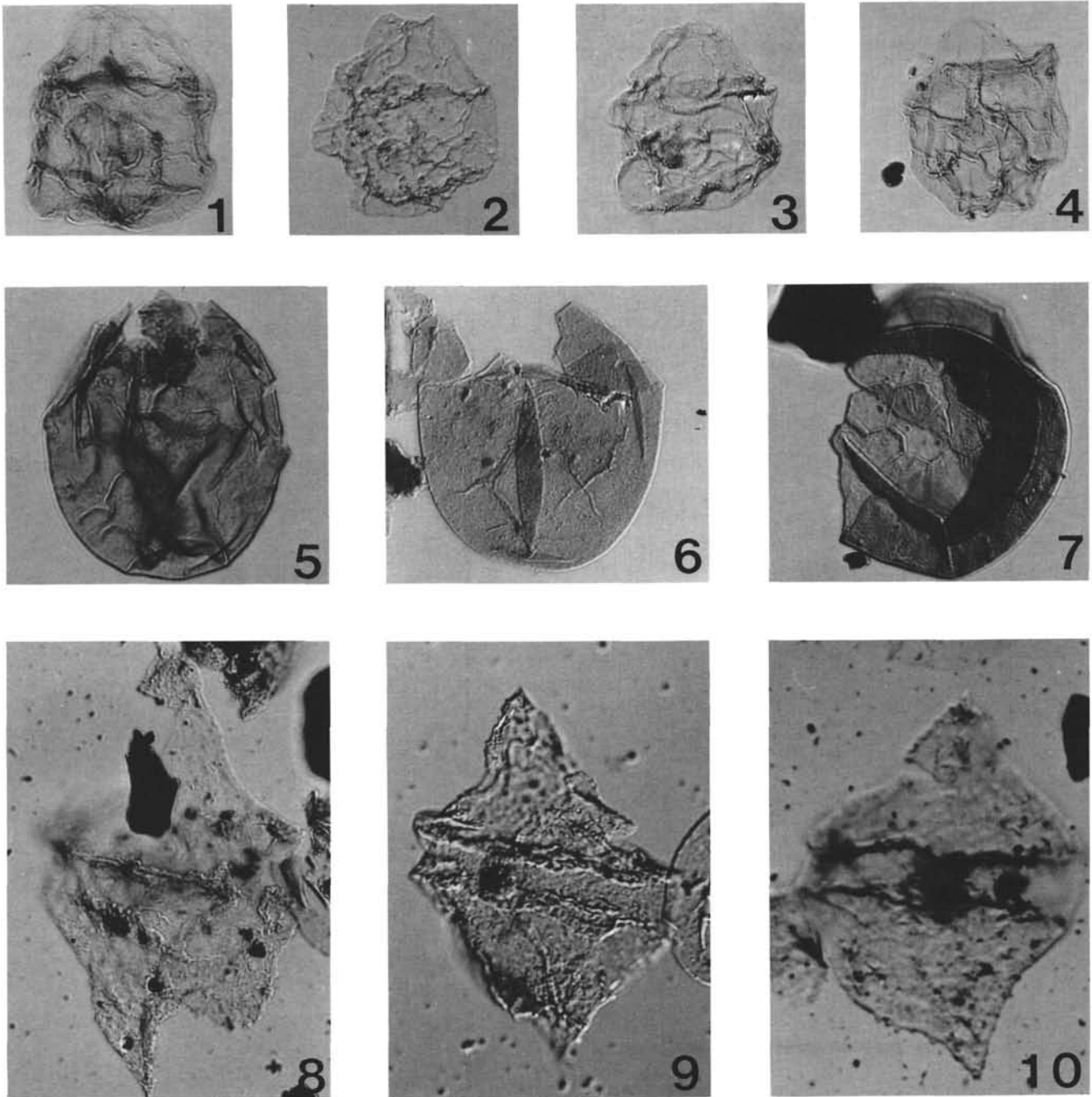


Plate 1. Magnification $\times 1000$. 1. *Noricysta?* sp., Sample 122-760A-30X-6, 76–79 cm. 2. *Noricysta?* sp., Sample 122-760A-30X-6, 76–79 cm. 3. *Noricysta?* sp., Sample 122-760A-30X-6, 76–79 cm. 4. *Noricysta?* sp., Sample 122-760A-30X-6, 76–79 cm. 5. *Suessia* sp., Sample 122-760A-30X-6, 76–79 cm. 6. *Suessia* sp., Sample 122-760A-30X-6, 76–79 cm. 7. *Suessia* sp., Sample 122-760A-30X-6, 76–79 cm. 8. *Rhaetogonyaulax?* sp., Sample 122-759B-6R-1, 58–63 cm. 9. *Rhaetogonyaulax?* sp., Sample 122-759B-6R-1, 58–63 cm. 10. *Rhaetogonyaulax?* sp., Sample 122-759B-6R-1, 58–63 cm.

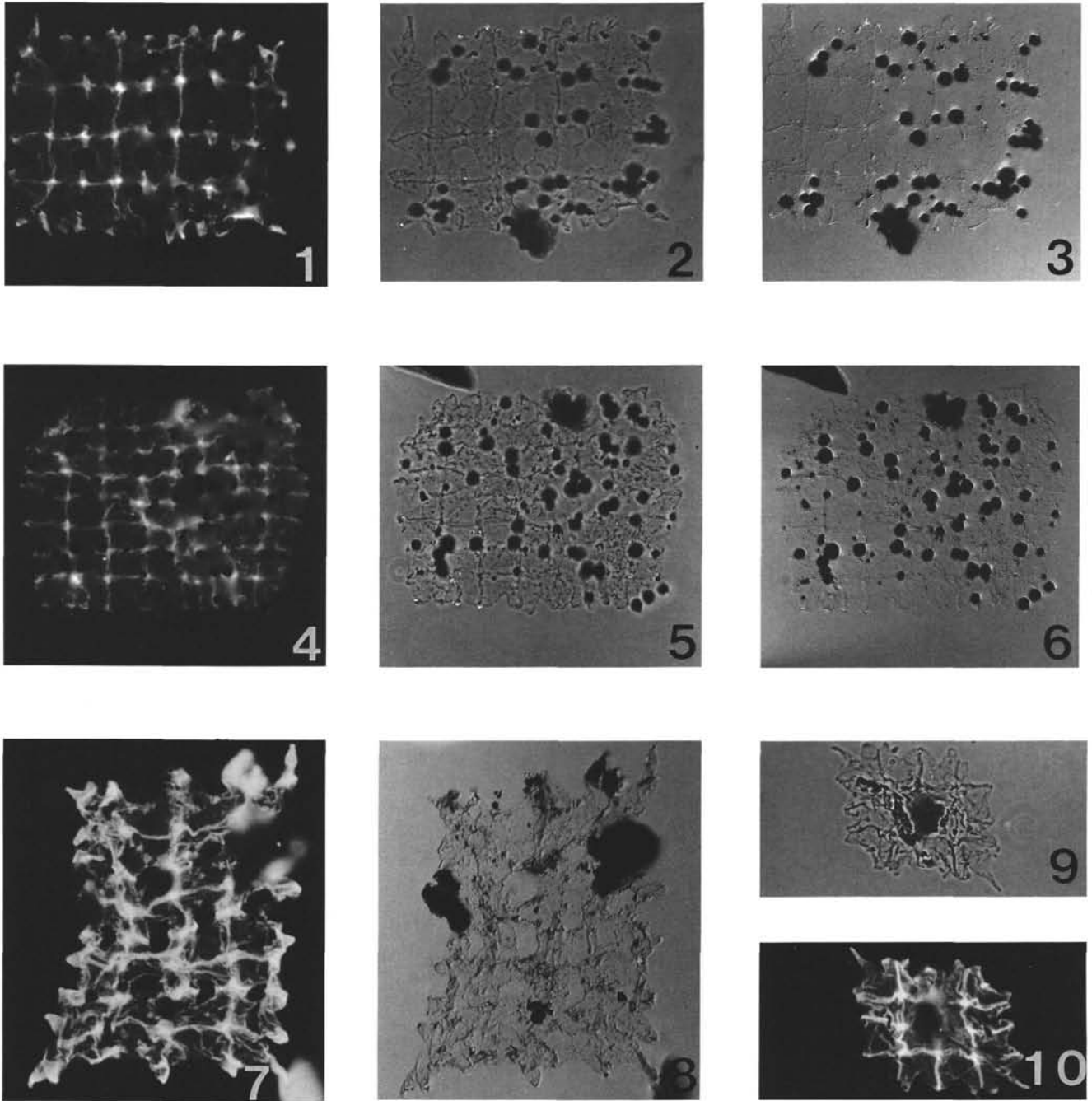


Plate 2. Magnification $\times 500$. 1-3. *Plaesiodictyon mosellanum* ssp. *sinuosum*, Sample 122-759B-18R-2, 52-54 cm; fluorescence (1), phase contrast (2), and interference contrast (3). 4-6. *Plaesiodictyon mosellanum* ssp. *perforatum*, Sample 122-759B-18R-2, 52-54 cm; fluorescence (4), phase contrast (5), and interference contrast (6). 7, 8. *Plaesiodictyon mosellanum* ssp. *sinuosum*, Sample 122-760B-19R-2, 76-78 cm; fluorescence (7) and interference contrast (8). 9, 10. *Plaesiodictyon mosellanum* cf. ssp. *sinuosum*, Sample 122-760B-19R-2, 76-78 cm; fluorescence (10) and phase contrast (9).