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CORRELATION OF MID-CRETACEOUS PLANT MICROFOSSILS FROM THE RARITAN FORMATION OF THE ATLANTIC COASTAL PLAIN WITH THE PERUC-KORYCANY FORMATION OF THE BLANSKO GRABEN

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ABSTRACT. Comparisons made between the palynological assemblage of the Raritan Formation of northern New Jersey (and partly Potomac Group of the Maryland and Delaware) and those reported from the Blansko Graben, Bohemian Cretaceous Basin, indicate that both contain many similar elements of angiosperm pollen. Organic-walled cysts of dinoflagellates and acritarchs are present in decreasing amounts in New Jersey surface outcrops, but increasing in the Blansko boreholes. These assemblages are valuable in that it occurs in a sequence of strata dated by macrofauna. Three Zones-II, III and IV of the Potomac and Raritan have been used for the correlation with the smaller lithological units A–H (the Peruc Member), I–J (the Korycany Member). The base of the Blansko boreholes V-127, 134 and 135 (unit A, B, palynozone "*Retitricolpites*" *georgensis-Dicotetradites* sp. A with Zone IIC, characterized by transition assemblage between zones IIB and III with many small reticulate tricolpates and oblate to prolate triangular tricolporoidates and rare tetrads of *Dicotetradites* sp. A, date as latest Albian to earliest Cenomanian.

Larger triangular psilate and reticulate tricolporates and new tricolpates appear in Zone III, lower Cenomanian, (IIC and III are found in the Potomac Formation of the Salisbury Embayment of Maryland and in subsurface of Delaware) which is comparable with the units C–H of the Blansko boreholes. The first primitive triporate Normapolles (*Complexiopollis*) appear at the top of the borehole V-134, unit J and it can be correlated with the lower part of the Zone IV of the Raritan Formation of New Jersey, dated by Doyle and Robbins, 1977 as middle Cenomanian-lower Turonian? (surface samples in Sayerville, New Brunswick and Perth Amboy). The Woodbridge Member of the Lower Raritan Formation has been dated as Late Cenomanian by occurence of the ammonites *Metoicoceras bergquisti* and *Metoicoceras mosbyense.* Unit J of the borehole V-127 been dated by *Inoceramus* (*Mytiloides*) *crippsi* (Čech, pers. comm.) as middle Cenomanian.

KEY WORDS. Correlation, middle Cretaceaous, palynomorphs, Atlantic Coastal Plain, Blansko 1 Graben

INTRODUCTION

The palynological comparison of the Raritan Formation and Peruc Member started last year as a topic of a common grant project. The purpose of this paper is to present palynological data concerned mainly on those angiosperm pollen which are common in our surface and subsurface samples or which have stratigraphic significance. Palynology of both the Atlantic Coastal Plain and Bohemian Cretaceous Basin confirms its value in using the sporomorphs in stratigraphy of fluvial-deltaic sequences of the continental Cretaceous deposits.

Slides are deposited both in the office of the Geological Institute of the Czech Academy of Sciences in Prague or in the Department of Geological Sciences of the University of New York at New Paltz.

PREVIOUS INVESTIGATIONS

Published palynological studies of the Cretaceous deposits of the Atlantic Coastal Plain are abundant. The palynological zones were proposed by Brenner (1963), who recognized two palynostratigraphic assemblage zones, Zone I and II, with Zone II divided into Subzones II-A and II-B. At Maryland outcrops, he found that Zone I corresponds to the Patuxent Formation and Arundel Clay, and Zone II corresponds to the Patapsco Formation. Brenner did not recognized any angiosperms in Zone I, but subsequent authors (Doyle 1969, 1973, Doyle & Hickey 1976, Doyle & Robbins 1977, Wolfe, Doyle & Page 1975, Christopher 1977, 1978, 1979) modified these zones and assigned the age more precisely. First four palynological zones in the Atlantic Coastal Plain correspond to the appearance and diversification of angiosperm pollen: Zone I characterizes monosulcates, Zone II tricolpates and tricolporoidates, Zone III triangular tricolporates and Zone IV triporate Normapolles.

Palynological assemblages of the Raritan Formation (Woodbridge member) at Raritan Bay, New Jersey were described by Groot, Penny and Groot (1961), Kimyai

(1966), Doyle 1969 and Wolfe and Pakiser (1971). The angiosperm pollen from the Delaware City wells were studied by Brenner (1967) and Doyle (1970), in which the upper boundary of Subzone II-B corresponds to the top of the Patapsco Formation, Subzone II-C and Zone III corresponds to the 'Maryland Raritan' and Zone IV to the lower part of the New Jersey Raritan Formation, Woodbridge member (Doyle 1973, Doyle & Hickey 1972, 1976). Stratigraphic correlation of the mid-Cretaceous sediments of the Atlantic Coastal Plain of eastern North America and Europe have been previously published. (Groot & Groot 1962, Pacltová 1971, Doyle & Robbins 1977).

Palynological results and palynostratigraphy of the boreholes from the Blansko Graben were published by Svobodová 1992, 1997.

SAMPLE LOCALITIES OF THE ATLANTIC COASTAL PLAIN

Fossiliferous surface samples were obtained at the following localities:

1. Old Sayerville abandoned clay pits, Raritan Formation, Upper Woodbridge Clay member, Sayerville, New Jersey, sample 2;
2. Raritan Centre Perth Amboy near Raritan Embayment, Sayerville, New Jersey, Lower Woodbridge Clay member of the Raritan Formation, sample 3;
3. Raritan Fire Clay behind warehouse, New Brunswick, New Jersey, sample 5A;
4. Raritan Fire Clay behind warehouse, New Brunswick, New Jersey, sample 5B.

Outcrops representing pollen Zones II-B, II-C and III are found in the Potomac Formation of the Salisbury Embayment of Maryland and in the subsurface of Delaware.

ATLANTIC COASTAL PLAIN (G.J.B.)

The rapid evolution of flowering plants that took place following their first appearance in the Lower Cretaceous of Northern Gondwana (Brenner pers. comm.) is mirrored in the fossil angiosperm pollen from the Middle Cretaceous terrestrial and marginal marine sediments of the Atlantic Coastal Plain. The rapid diversification of angiosperm pollen types in the late Albian and Cenomanian reflects the evolution of the angiosperm families taxonomically more complex than magnoliales. The sediments preserving this pollen diversification were formed during a global second cycle rise in eustatic sea level that began in the Aptian and culminated in a short-lived regression at the Cenomanian-Turonian boundary.

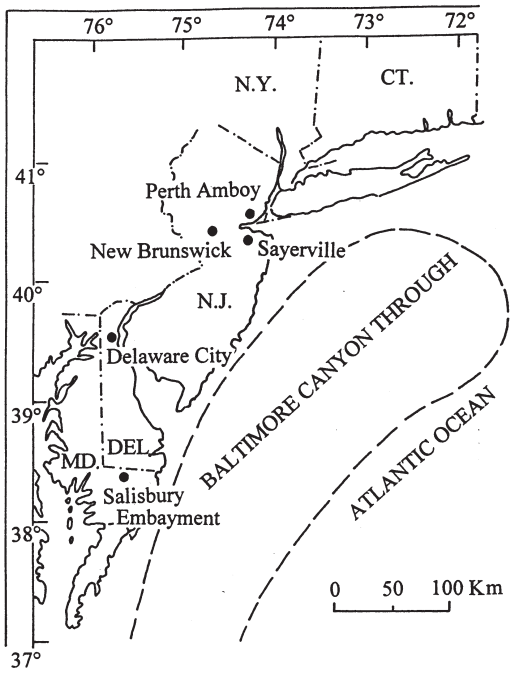

Fig. 1. Sample localities of the Atlantic Costal Plain

Outcrops representing pollen Zones II-B, II-C & III are found in the Potomac Formation of the Salisbury Embayment of Maryland and in the subsurface of Delaware. Outcrops of the Lower Raritan Formation of New Jersey are placed in pollen Zone IV of the Raritan Embayment. Sample localities of the Atlantic Coastal Plain are plotted in Fig. 1. Zone IV, the Woodbridge Member of the Lower Raritan Formation has been dated as late Cenomanian (*Metoicoceras bergquisti, Metoicoceras mosbyense*). The first triporate (Normapolles) and tricolporate pollen appear in this group as well as a marked diversification of triangular tricolporates of the *Nyssapollenites* types (Pl. 1, figs 29, 30).

Of the two samples studied in greater detail, the sample 2 and 3 from the upper and lower Woodbridge member (Old Sayerville clay pits in New Jersey) can be assigned to upper part of Zone IV on the basis of association of the angiosperms of *Complexiopollis-Atlantopollis*, larger triangular tricolporates "*Tricolporopollenites"* sp. C of Doyle and Robbins and very rare reticulate tricolpates. An association is dominated by gymnosperm bisaccate pollen of *Rugubivesiculites* (Pl. 3, fig. 4)*, Parvisaccites, Podocarpidites* and *Alisporites.* Dinoflagellates and foraminifers (10%) occur in both samples and confirm the marginal marine nature of this interval. The next samples 5A and 5B with datable flora, from the Raritan Fire Clay (New Brunswick, New Jersey) can be assigned to lower part of the Zone IV on the presence triporate Normapolles pollen of *Complexiopollis* (Pl. 1, figs 35, 36, Pl. 3, fig. 5), small triangular tricolporates of "*Tricolpopollenites*" *distinctus*, small and

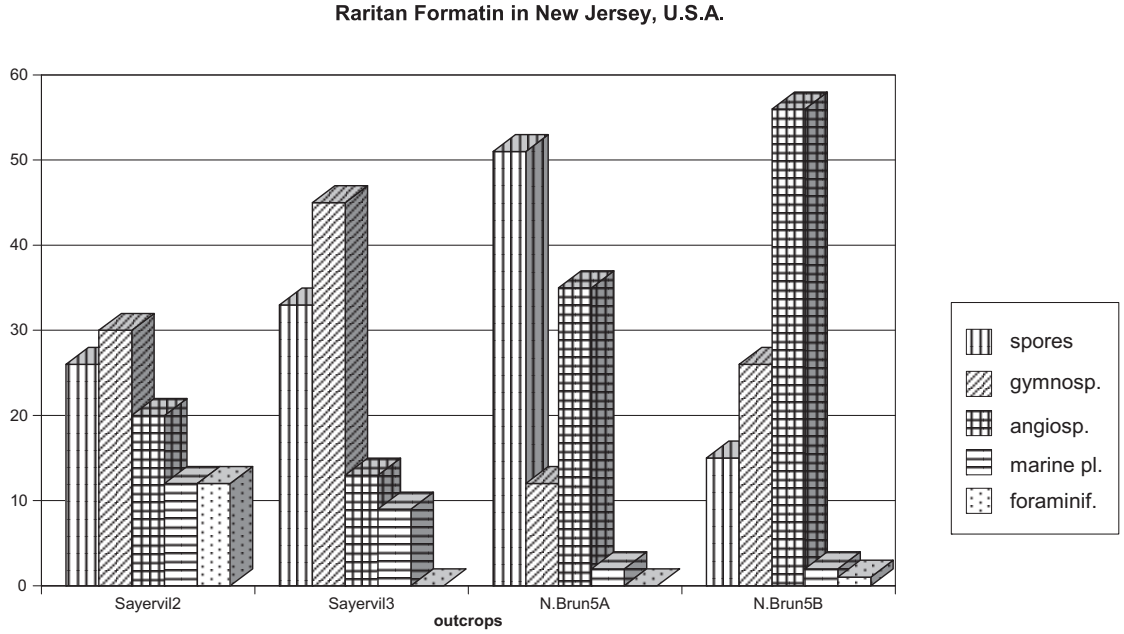

Fig. 2. Main plant microfossil groups in the Raritan Formation, New Jersey, USA

medium-sized tricolpates "*Tricolpopollenites*" *parvulus, Tricolpites nemejci, Rousea* sp. (Pl. 3, fig. 2), *Retitricolpites vermimurus, Tricolpites crassimurus.* Angiosperm pollen dominate in both samples (40 and 58% of the association). The samples yield a rich spore flora, dominated by gleichenioid types of *Gleicheniidites senonicus* and *Foveogleicheniidites confossus* (in sample 5A-more than 50%). *Ariadnaesporites spinocaperatus* (Pl. 3, fig. 6) spores occur in sample 5A. Only rare small spiny acritarchs *Micrhystridium* appear in both samples. Main plant microfossil groups are plotted in Fig. 2.

Zone III contains several species found in the Lower Clay Units of the Peruc Member (Pl. 2, figs. 3–7). Doyle & Robbins (1977) date this Zone as Early Cenomanian. This zone is recognised by its strong increase in the number of small prolate triangular tricolporates and many small tricolpates. I correlate (G.J.B.) Zone III with most of the Lower Clay Unit of the Peruc Member except for Unit A from southeastern part of the Blansko Graben.

Zone II-C contains a transition assemblage of angiosperm pollen between Zones II-B and III with some Potomac spores and rare amounts of prolate and oblate triangular tricolporates. Doyle and Robbins (1977) date this Zone as latest Albian to earliest Cenomanian.

Zone II-B contains for the most part only small prolate tricolpates with no tricolporates or oblate tricolporate pollen. Comparison of the tricolpate pollen from this zone (Brenner 1963, 1976) with published records places zone II-B in the middle Albian to late Albian. This appears (one of us – G.J.B.) to be equivalent to Unit A from the southeastern part of the Blansko Graben.

BLANSKO GRABEN (M.S.)

Zonation of the middle Cretaceous subsurface samples of seven boreholes from the Blansko Graben, southeastern part of the Bohemian Cretaceous Basin (early-middle Cenomanian) was made by Svobodová (1992, 1997). Svobodová (1997) recognized four palynozones; three in the Peruc Member, one in the Korycany Member.

Angiosperm pollen found in basal samples of the boreholes V-127, V-134 and V-135 (Unit A) differ strikingly from those found in the upper parts (see Tab. 1).

A distinct microfloral break occurs in spore-gymnosperm assemblage; *Vitreisporites pallidus* and *Eucommiidites minor* dominate in gymnosperm pollen and various forms of Schizeaceae (*Appendicisporites problematicus, A. insignis, A. auritus*), cicatricose form of *Costatoperforosporites* cf. *triangulatus*, or other spore forms restricted to Unit A as *Foveosporites canalis* Balme or *Psilatriletes radiatus* Brenner appear. Palynozone "*Retitricolpites*" (*Rousea*) *georgensis-Dicotetradites* sp. A (the oldiest angiosperms of Unit A) contains small reticulate tricolpates *Tricolpites micromunus, Tricolpites minutus,* tetrahedral tetrads of *Dicotetradites* sp. A (Pl. 1, fig. 2), monocotyledonous forms of *Liliacidites* (Pl. 1, fig. 4) and first tricolporoid forms of *Tricolporoidites subtilis* Pacltová (Pl. 1, figs 14, 15). Assemblage of the Unit A is similar to those found in Zone II-C and III occured in the so-called Raritan Formation (Doyle 1969) and which Wolfe and Pakiser (1971) considered the uppermost part of the Patapsco Formation of Maryland and Delaware or in the subsurface Potomac Group of New Jersey (Pl. 2).

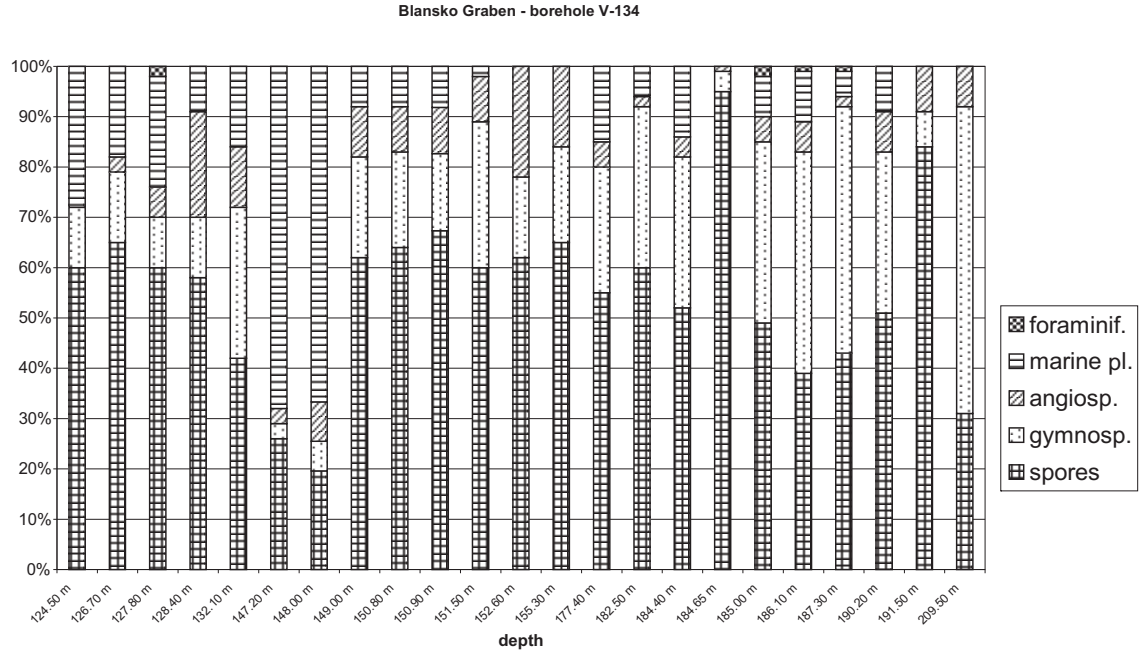

Fig. 3. Distribution of the main plant microfossil groups in the Blansko Graben borehole V-134

Table 1. Angiosperm pollen at the borehole V-134, 1–22 – depth in metres, 1–126.7, 2–127, 3–128, 4–132, 5–147, 6–148, 7–149, 8–150.8, 9–150.9, 10–151.5, 11–152, 12–155, 13–177, 14–182, 15–184, 16–184.6, 17–185, 18–186, 19–187, 20–190, 21–191, 22–209 m. Dicotetrad-*Dicotetradites*, Retitricolpi-*Retitricolpites*, Rousea geor-*Rousea georgensis*, Tricolpor-*Tricolporites*, Tricol. subtil-*Tricolporoidites subtilis*, Tri cf. Subtil-*Tricolpites subtilis,*Clavatipollen-*Clavatipollenites*, Liliacid.divid-*Liliacidites dividuus*, Psilcolpor.-*Psilatricolporites*, Psilacolpor-*Psilatricolporites*, Clavati hugh-*Clavatipollenites hughesii,* Retitr. exigui-*Retitricolpites exiguiexemplum*, Retitr. virgeu – *Retitricolpites virgeus*, Retitri. němej-*Retitricolpites němejci*, Tric. barrande-*Tricolpites barrandei*, Retitr. amplifi-*Retitricolpites amplifissus,* Psilatr. *parvul-Psilatricolpites parvulus*

V134	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Dicotetrad A																						*
Retitricolpi 1																					*	*
Retitricolpi 2																						*
Retitricolpi 3										*							*					
Retitricolpi 4																			*			
Rousea geor																					*	
Tricolpor. C							*															
Tricol. subtil.				*													*			*		*
Tri. cf. subtil					*				*		*	*			*							
Tric. subt. 1																		*				
Tri. cf. sub.1						*											*					
Tricolpites 5																						*
Tricolpor C																		*				*
Clavatipollen				*																		
Liliacid. divid																						*
Psilcolpor. C	*		*	*	*			*		*	*	*					*	*				
Psilacolpor D				*		*											*					
Clavati.hugh				*	*																	
Psilcolpor A				*																		
Psilcolpor C			*			*			*				*		*		*					
Tricolpites 6			*			*			*	*												
Retitr. exigui	*	*		*			*															
Retitr. virgeu			*	*	*		*		*				*									
Retitri. němej			*							*								*				
Tric. barrande				*						*					*			*				
Retitr. amplifi			*	*	*	*	*		*	*		*	*	*	*	*						
Ajatipollis A									*													
Striatopollis				*																		
Psilatr. parvul	*			*	*	*																
Asteropollis				*																		

The first occurrence of smooth triangular tricolporate pollen of *Perucipollis minutus* Pacltová (Pl. 1, fig. 12) (or also called "*Tricolporopollenites*" *triangulus* Groot et Penny or *Nyssapollenites*), together with thick-walled tricolpates of *Tricolpites barrandei* Pacltová (Pl. 1, fig. 7, Pl. 2, fig. 13), larger tricolpates – *Tricolpites němejci* Pacltová (Pl. 1, fig. 25, Pl. 2, fig. 28) a.o. characterize the middle and upper part of the Peruc Member (Units C-G). This pollen assemblage can be correlated with the Zone III of Doyle and Robbins (1977).

Rare triporate forms of the Normapolles-*Complexiopollis vulgaris*, striate tricolpates-*Striatopollis paraneus,* tetrads – *Dicotetradites* sp. B, larger and more diversified triangular tricolporates together with dinocysts characterize the upper part of the Blansko Graben boreholes (Units I-J), and which is assigned by Čech (pers. comm.) on the basis of the macrofauna to the middle Cenomanian. This section can be correlated with the lower part of the Zone IV of New Jersey, the Raritan Fire Clay.

CONCLUSIONS

1. Surface samples of the Raritan Fire Clay from New Brunswick, New Jersey, Zone IV can be correlated more or less with the Units I and J of the Korycany Member. The difference is in the assemblage of triporate pollen of the *Complexiopollis* type,which are more diversified in Zone IV than those found in Blansko Graben boreholes.

Doyle and Robbins (1977) did not excluded an early Turonian age for the top of Zone IV.

2. Angiosperm pollen from the base of the Blansko boreholes (Unit A) can be assigned to Subzone IIC, latest Albian-earliest Cenomanian.

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PLATES

Plate 1

All photomicrographs × 1000

1. *Tricolporoidites* cf. *T. minimus* Pacltová, V-127, Unit A
2. *Dicotetradites* sp. A of Doyle and Robbins 1977 (Zone IIC), V-127, Unit A
3. *Liliacidites* cf. *dividuus*, OK-3, Unit F
4. *Liliacidites* sp., V-134, Unit A
5. *Liliacidites textus* Norris, V-127, Unit B
6. *Retitricolpites minutus* Pierce, V-134, Unit A
7. *Tricolpites barrandei* Pacltová, V-134, Unit G
8, 9. *Liliacidites peroreticulatus* (Brenner) Singh, OK-3, Unit F
10. Aff.*Tricolporopollenites triangulus* Groot, Penny et Groot, V-134, Unit A
11. *Tricolporoidites* sp., V-134, Unit A
12. *Perucipollis minutus* Pacltová
13. *Retitricolpites* cf. *insolitimorus* Laing, OK-3, Unit F
14, 15. *Tricolporoidites subtilis* Pacltová, V-127, Unit A
16. *Tricolporopollenites distinctus* Groot, Penny et Groot, V-127, Unit C
17. *Tricolporoidites* sp., V-134, Unit B
18. *Tricolporoidites* cf. *bohemicus* Pacltová, V-127, Unit C
19. *Tricolporopollenites* sp. C of Doyle & Robbins, 1977, V-134, Unit J
20. *Tricolporopollenites* sp. B of Doyle & Robbins, 1977, OK-2, Unit I
21. *Tricolporopollenites* sp. B of Doyle & Robbins, 1977, V-134, Unit J
22. *Striatopollis paraneus* (Norris) Singh, V-134, Unit J
23. *Retitricolpites* sp., V-134, Unit G
24. *Complexiopollis* sp., corroded specimen, V-134, Unit J
25. *Tricolpites* cf. *němejci* Pacltová, V-134, Unit G
26. *Rousea* cf. *miculipollis* Srivastava, V-135, Unit G
27. Gen. et sp. n., V-134, Unit G
28. Gen. et sp. n., V-134, Unit G
29. *Tricolporopollenites* sp. (*Nyssapollenites* type), New Brunswick, sample 5A, Zone IV
30. *Tricolporopollenites* sp. (*Nyssapollenites* type), New Brunswick, sample 5A, Zone IV
31. *Tricolporopollenites* sp. B of Doyle & Robbins, 1977 New Brunswick, 5A, Zone IV
32. *Tricolporopollenites* cf. *distinctus* Groot, Penny et Groot, New Brunswick 5A, Zone IV
33. *Retitricolpites* (*Rousea* type), New Brunswick, 5A, Zone IV
34. *Tricolpites crassimurus* (Groot et Penny) Singh
35. *Complexiopollis* sp., New Brunswick, 5A, Zone IV
36. *Complexiopollis* sp., New Brunswick, 5A, Zone IV

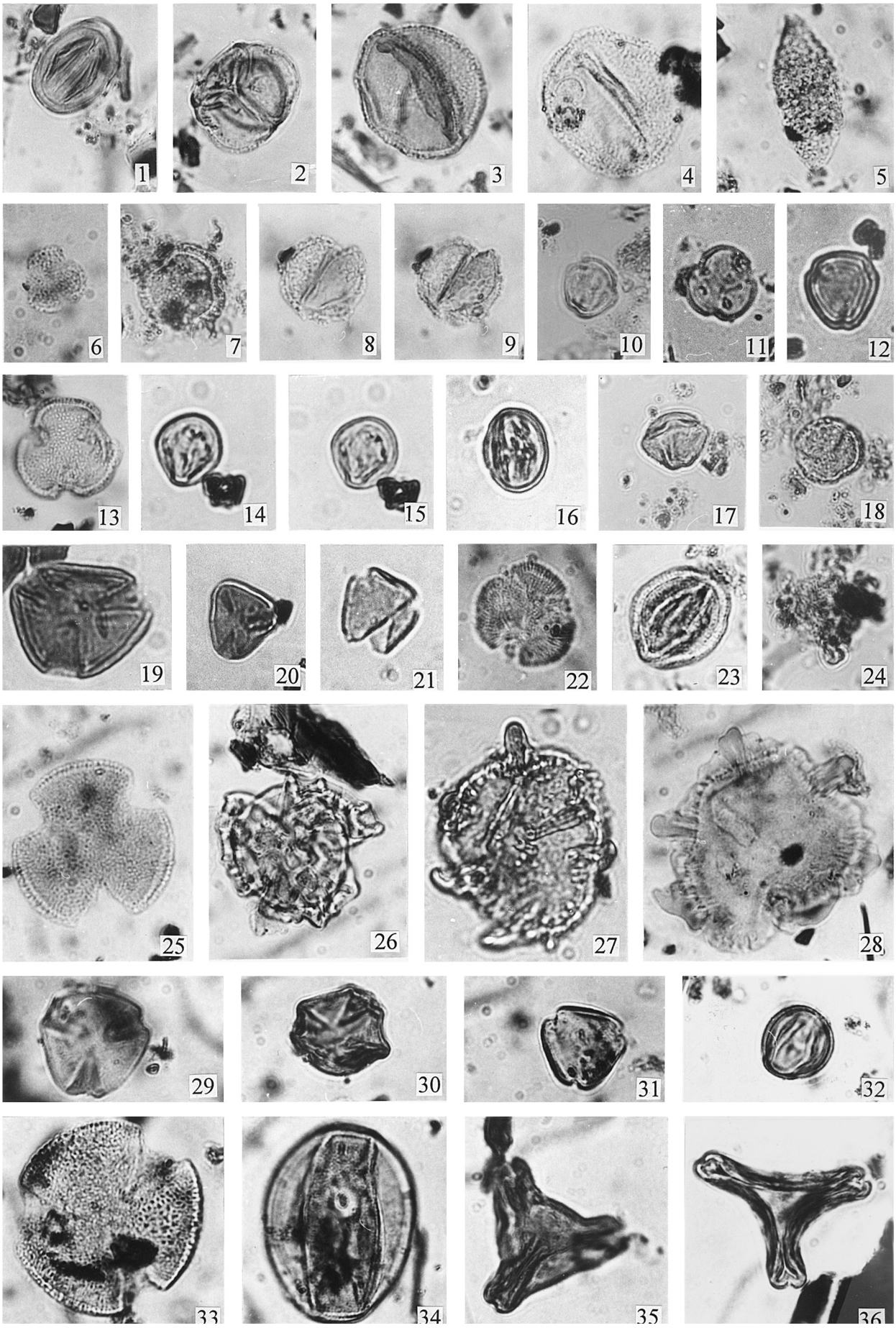
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Plate 2

Zones IIC and III are from Delaware 12, 13 well, Delaware City, Delaware, Brenner 1966, Doyle & Robbins, 1977; Zone IV from Lower Raritan, Sayerville, New Jersey

1, 2. *Tricolpites sagax*, Zones IIB-III
3. *Tricolporoidites* sp. A, IIB-III
4, 5. *Tricolporoidites subtilis* Pacltová, IIC-III
6, 7. *Tricolporopollenites triangulus* Groot, Penny et Groot, IIC-IV
8. *Tricolpites* sp. B of Doyle & Robbins, 1977, IIB-III
9. *Retitricolpites georgensis* Brenner, IIB-III
10, 11. *Tricolporoidites* sp. C of Doyle & Robbins, 1977, III
12. *Tricolpites vulgaris* (Pierce) Pacltová, III
13. *Tricolpites barrandei* Pacltová, III
14. *Retitricolpites paraneus* Brenner, III
15, 16. *Ajatipollis* sp. A of Doyle & Robbins, 1977, IIC-III
17, 18. *Striatopollis* sp. B of Doyle & Robbins, 1977, III
19. *Tricolporopollenites* sp., A III
20, 21. *Retitricolpites paraneus* Brenner, III
22. *Tricolporoidites bohemicus* Pacltová, III
23. *Asteropollis* sp., A III
24, 29. *Foveotricolporites rhombohedralis,* III
25. *Retimonocolpites* sp. A of Doyle & Robbins, 1977, III
26. *Tricolpites* sp. C of Doyle & Robbins, 1977, III
27. *Tricolpites crassimurus* (Groot et Penny) Singh, III
28. *Tricolpites němejci* Pacltová, III
30. *Tricolporopollenites* sp. B, III
31. *Tricolporopollenites* sp. C, III
32. *Tricolporopollenites* sp. E, III
33. *Tricolporopollenites* sp. D Woodbridge Member, III
34. *Atlantopollis* sp., IV
35. *Complexiopollis* sp., IV
36. *Stephanocolpites tentorius*, III

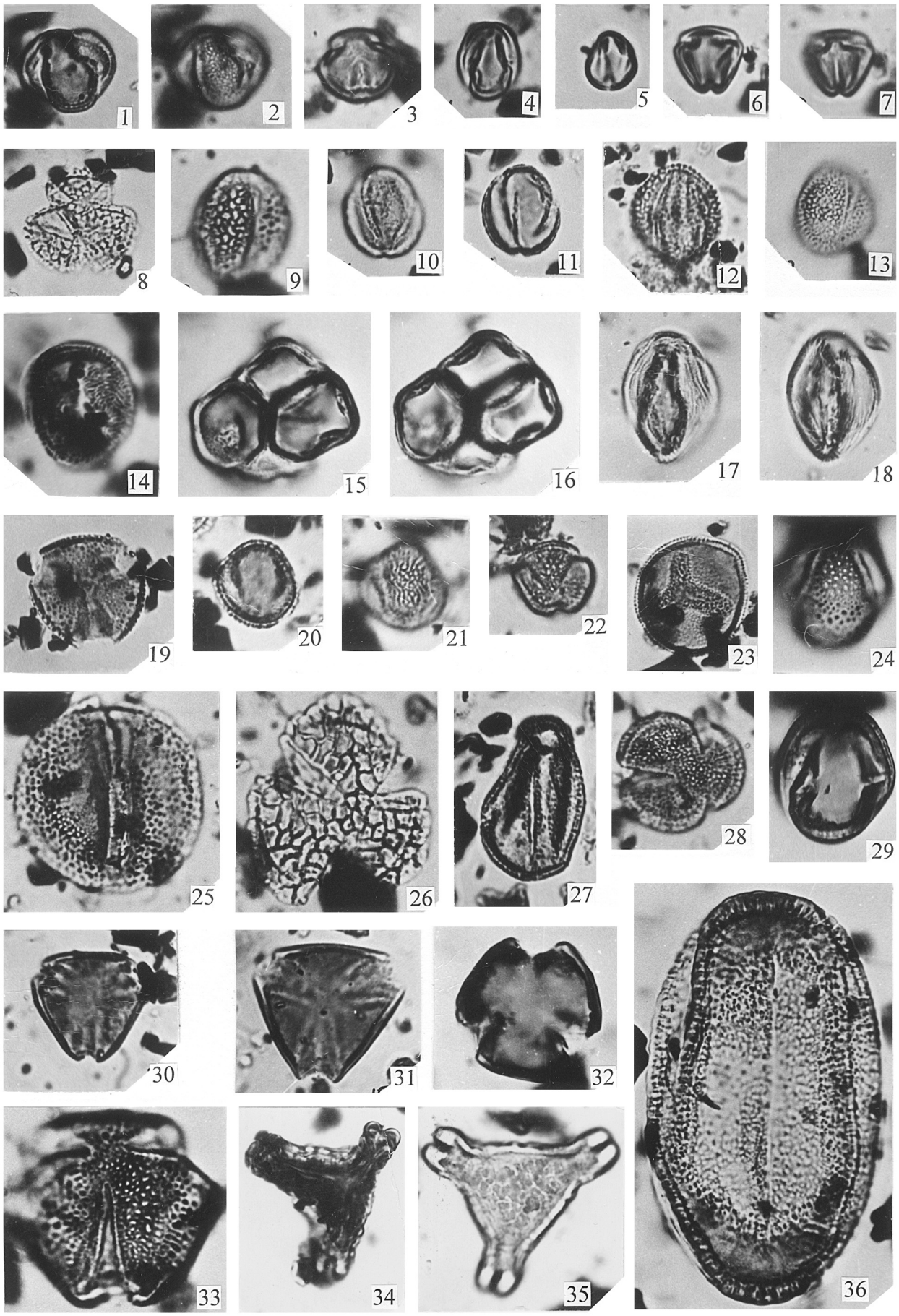
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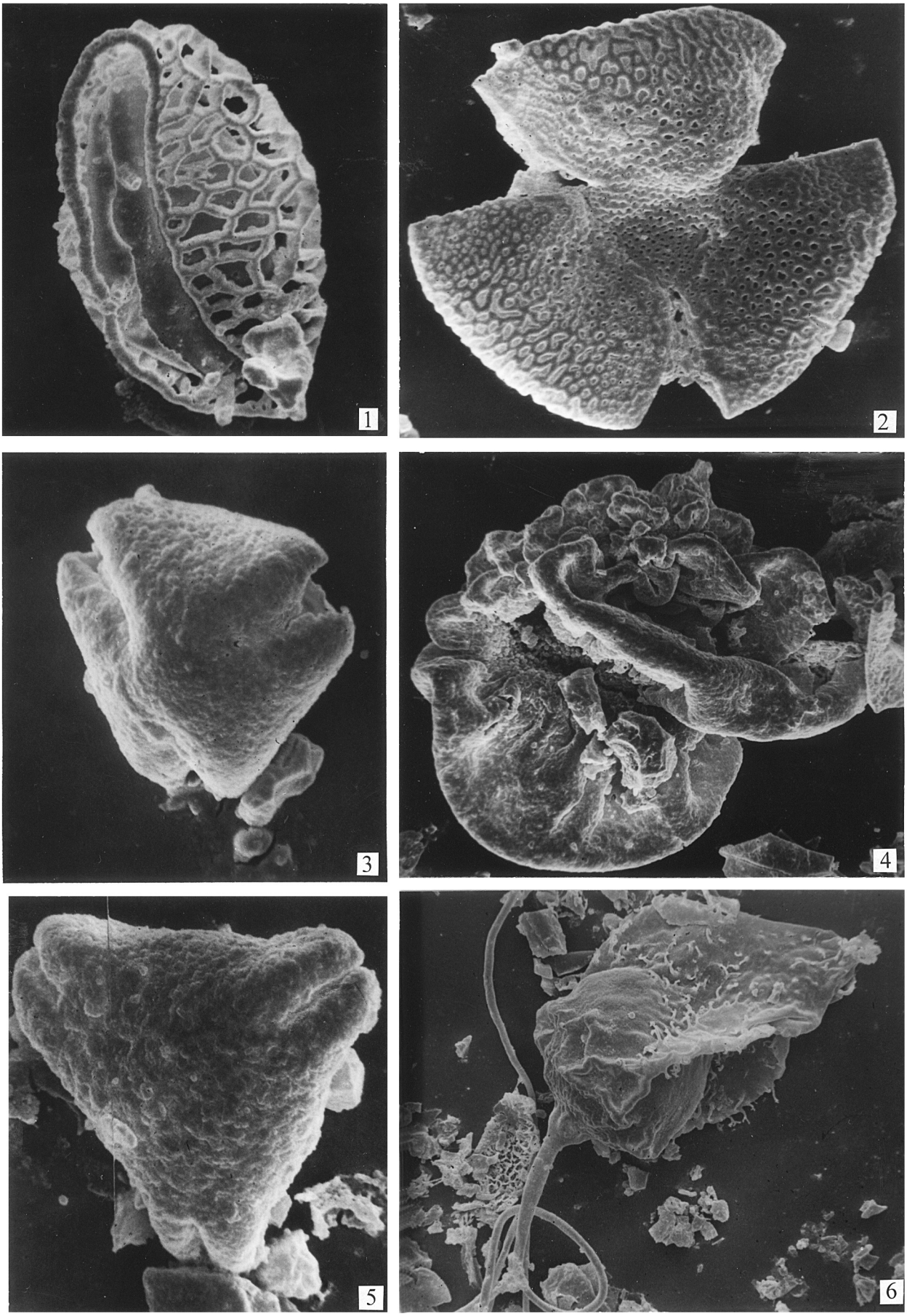
Plate 3

1. *Liliacidites* sp., Raritan Fire Clay, New Brunswick, New Jersey, Zone IV, SEM photomicrograph, × 4000
2. *Rousea* sp., Raritan Fire Clay, New Brunswick, New Jersey, Zone IV, SEM, × 3000
3. *Tricolporopollenites triangulus* (*Nyssapollenites* type), Raritan Fire Clay, New Brunswick, New Jersey, Zone IV, SEM, × 4500
4. *Rugubivesiculites* cf. *reductus* Pierce, Raritan Fire Clay, New Brunswick, New Jersey, Zone IV, SEM × 1500
5. *Atlantopollis* sp., Raritan Fire Clay, New Brunswick, New Jersey, Zone IV, SEM, × 4000
6. *Ariadnaesporites spinocaperatus* Phillips et Felix, Raritan Fire Clay, New Brunswick, New Jersey, Zone IV, SEM × 900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