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DEVELOPMENT OF SEDIMENTATION, MOLLUSCS AND PALYNOSPECTRA IN THE LOWER MIOCENE OF THE SOUTH-WESTERN PART OF THE CARPATHIAN FOREDEEP IN MORAVIA (CZECH REPUBLIC)

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ABSTRACT. The environment in the south-western part of the Carpathian Foredeep in Moravia (surroundings of Znojmo and Miroslav) in the Lower Miocene (Eggenburgian, Ottnangian) was extraordinarily variable. Marine facies interchanged with those of lagoons and deltas. Sedimentation took place in a subtropical climate and in the inshore zone. Changes of the marine environment in this area were connected primarily with sea level changes (fluctuations in water depth and dynamics, light, aeration, salinity) and with variable rates and intensities of sediment accumulation. The flora and fauna reflect all these environmental changes with great occuracy.

KEY WORDS: sedimentology, palaeontology – molluscs, palynology, Lower Tertiary, Carpathian Foredeep, Czech Republic

INTRODUCTION

The boundary between marine and terrestial environments can be studied in the Lower Miocene sediments (Eggenburgian, Ottnangian) in the south-western part of the Carpathian Foredeep in Moravia, in the neighbourhoods of Znojmo and Miroslav. Information about the character of the marine environment was gained largely from sedimentological (Nehyba) and palaeontological investigations (the molluscan fauna – Hladilová), and that about the terrestrial environment from studies of the palynospectra (Doláková) – Nehyba, Hladilová, Doláková (1997). The most important pollen taxa are shown on Pls 1–3.

RESULTS

The environment in this part of the Carpathian Foredeep at that time was extraordinarily variable and marine facies interchanged with those of lagoons and deltas.

a) The neighbourhood of Znojmo

Around Znojmo, where the Eggenburgian marine transgression first penetrated the seacoast was formed of heavily weathered crystalline rocks, predominantly with highly differentiated relief configurations (ridges, depressions). This is reflected in the raised amounts of Pinaceae pollen in the palynospectra (over 40% in the Unanov borehole), while *Cedrus* pollen was also more abundant (Zdražílková 1992, Nehyba, Hladilová & Zdražílková 1995).

During the Eggenburgian marine transgression, a complex basin system developed in this area. The basins were set in an area of diverse relief and were variably interconnected, as well as being linked to the open sea. With the exception of temperature, practically all the features of the marine environment (water depth and dynamics, light, aeration, salinity) were highly variable and ascillatory in each basin, indicating highly unstable sedimentary conditions in general. The sea was predominantly shallow (up to about 40 m) and warm (subtropical temperatures). The molluscan fauna responded to these changes with a great variability in the number of genera, species diversity and dominance, assemblages of marine and (almost) freshwater environments alternating with those of brackish ones. The two basic mollusc communities, *Congeria* sp. / *Nematurella* sp. (+ *Hydrobia* sp., *Staliopsis* sp. and *Clithon* aff. *pictus*) and *Pirenella moravica* / *Cerastoderma* sp. (+ *Ostrea* sp.) were found. They were generally relatively very species poor and occurred alternately vertically as well as laterally dependending on environmental conditions. In general, evidence of extreme conditions in the marine environment is provided by the fact that only relatively species poor mollusc assemblages occur in this area (Čtyroký 1991, 1993, Hladilová 1988, Hladilová & Hladíková 1993).

The terrestrial flora confirmed the relative proximity of the shoreline. Due to the oscillations in salinity as well as the inluence of occasional higher evaporation rates, the shores of individual gulfs and lagoons were repeatedly salted, facilitating the growth in places of a relatively rich halophilous vegetation. High numbers of members of the family Chenopodiaceae, which contains many halophytes, sometimes accompanied by increased numbers of *Ephedra* and Buxaceae (e.g. *Monocirculipollis zahnaensis*), were observed in the studied boreholes (Únanov, Čejkovice, Šafov 12, 13). In borehole HV-301 at Čejkovice, which was described in the greatest detail, it was even possible in part to correlate changes in the molluscan assemblages, connected with the salinity fluctuations, with similar changes in some elements of the palynospectra -Chenopodiaceae, Ericaceae (Hladilová 1988, Zdražílková 1992).

Saltmarsh vegetation developed in time and space through to the various growth stages of coal swamp (the sea lagoons gradually became overgrown), and in places, even flora growing directly in fresh water appeared. Higher percentages of Taxodiaceae, Myricaceae, Polypodiaceae, *Osmunda* and *Lygodium* were observed in the boreholes. Even taxa growing in shallow fresh water such as *Sparganium*, *Nelumbo* and Cyperaceae were found (principally in boreholes 12, 13 at Šafov). Šafov borehole 12 (17.5 m) contained a great amount of *Platanus* pollen. Furthermore, frequent pollen of the Poaceae, Ericaceae and *Corsinipollenites* were characteristic for this facies (Doláková-Zdražílková 1996).

Abrupt spatial and temporal changes of the palynospectra reflect the great variability of environmental conditions on the land. The flora generally confirms a warm climate with all the studied palynospectra rich in thermophilous – tropical – subtropical elements. Frequently and abundantly represented were the families Sapotaceae, Palmae, Cyrillaceae, Myricaceae the genera *Engelhardtia*, *Lygodium* and the species *Quercoidites microhenrici*, *Castaneoideapollis pusillus*, *Tricolporopollenites fallax* and *Tricolporopollenites liblarensis*. *Quercoidites henrici*, *Symplocos*, *Reevesia*, *Cornaceaepollis satzveyensis*, *Castaneoideapollis oviformis*, *Tricolporopollenites marcodurensis*, *Tricolporopollenites pseudocingulum* and the families Araliaceae and Rutaceae occurred regularly but in lower quantities and in several samples the genus *Nelumbo* was found. Arctotertiary elements occurred less frequently with the genera *Betula*, *Alnus*, *Fagus*, *Liquidambar*, *Sciadopitys* and *Pterocarya* being found sporadically. *Carya*, *Juglans* and *Celtis* occurred regularly but not in great quantities. Elements depending on the facies (Ulmaceae, Chenopodiaceae, Ericaceae, Poaceae and *Tricolporopollenites retiformis*) were, however observed more frequently. Spores of the lower plants occurred, depending on the facies. Polypodiaceae (*Laevigatosporites haardti*, *Verrucatosporites* div. fsp., *Cingulisporis* div. fsp.), *Selaginella* (*Echinatisporis* div. fsp.), *Lygodium*, *Osmunda*, *Leiotriletes wolffi* and *Toroisporis (Toroisporis) teupitzensis*, were all observed, together with smaller quantities of *Lycopodium* and *Zlivisporis.* Explicit climate changes did not show upin the palynospectra.

b) Miroslav neighbourhood

The marine transgression reached the Miroslav district later than the Znojmo area, because the progradation of the sea basin was generally accompanied by a nothern displacement of the shoreline. In the wider neighbourhood of Miroslav, the coastal strip behind the seashore was flatter than in the Znojmo area. Around Miroslav the marine sedimentation penetrated that of the deltas. Furthermore great accumulations of sediment took place, and the coastline became even less undulating. Consequently, the effects of any sea level changes in this area extended much further inland than they had done around Znojmo. Near Miroslav, the sea was warm and shallow, originally with relatively high dynamics and salinity, although, later on, there was a general decrease in the dynamics and salinity due to the deltaic sedimentation which took place (several pollen grains were found in the pollinia of the Chenopodiaceae, Myricaceae, *Platanus* and *Corsinipollenites* – suggesting low water dynamics in some parts of the profiles – Nehyba, Hladilová, Zdražílková 1994, 1995). The effects of these changes on the mollusc assemblages were similar to those in the Znojmo area. The comparable mollusc assemblages at Miroslav and the shallow-water zones of Znojmo suggest that similar sedimentary conditions occurred in both areas (Čtyroký & Čtyroká 1989, Nehyba, Hladilová & Zdražílková 1994, 1995). The flora evidences a warm climate, oscillations in water salinity and the proximity of a shoreline whose characteristics were undergoing continual change. Different forms of brackish and freshwater plant microplankton are abundant in all the palynospectra (for example much *Botryococcus*, *Ovoidites*, *Sigmopollis* and less *Circulisporites*, *Sculptizygodites* and Tasmanaceae). The relative abundance of particular types varies in the individual samples. Some forms can be regarded as being present en masse – e.g. *Botryococcus* (Trboušany borehole PMK-5A) and *Sigmopollis* (Únanov borehole). Dinoflagellates with branched projections, typical for waters with a good connection to the open sea, were found sporadically. They could have been swept in to the sedimentation areas during storms.

In places, the coastal substrate was – like that of the Znojmo area – considerably saline, promoting the growth of halophilous vegetation (about 37% of the palynospectrum in Miroslav borehole PMK-1, at a depth of 73.65 m – consists of Chenopodiaceae pollen). Later on, the coast changed its character, and moorland and marginal swamp appeared. Water there was essentially stagnant. This is evident, for example, from the palynofacies of the higher parts of the Miroslav and Trboušany boreholes, where, in the latter, there was a great amount of *Lygodium*. Most exstraordinary was the situation observed in the Trboušany borehole at a depth of 49.7 m where a monotonous palynospectrum with dominant triporate pollen of myricoid type occurred, constituting over 40% of the total, together with that of other members of the swamp vegetation such as Taxodiaceae, *Lygodium* and *Osmunda.* The origin of these swamps was of course – unlike the Znojmo area – connected with the delta environment (Nehyba, Hladilová & Zdražílková 1994, 1995).

The changes in the marine environment in this area were primarily connected with changes in the sea (fluctuations in water depth and dynamics, light, aeration and salinity) and with the varying rates and intensities of sediment accumulation. In particular, repeated and appreciable salinity changes must be considered a very important factor.

In the final stage (Ottnangian), deltaic deposition was no longer taking place in the study area, and a reduced supply of sedimentary material as well as completion of the delta progradation process occured. The delta platform was inundated and in the following transgression stage, the sea probably penetrated further north into the area.

ACKNOWLEDGEMENTS

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P L A T E S

Plate 1

× 1000

1. *Sigmopollis laevigatoides* W. Kr. et Paclt. 1990, Únanov, 6.8 m
2. *Sigmopollis laevigatoides* W. Kr. et Paclt. 1990, Únanov, 6.8 m
3. *Botryococcus braunii* Kützing 1959 – Trboušany, 65.8 m
4. *Leiotriletes maxoides maxoides* W. Kr. 1962 –Trboušany, 17.1 m
5. *Sapotaceoidaepollenites sapotoides* (Th. et Pf. 1953) R. Pot. 1960 – Trboušany, 17.1 m
6. *Sabalpollenites areolatus* (R.Pot. 1934) R. Pot. 1958 – Šafov 13, 20.5 m
7. *Symplocoipollenites latiporis* (Thomson et Pflug 1953) Słodkowska 1994 – Únanov, 6.8 m
8. *Sapotaceoidaepollenites obscurus* (Th. et Pf.1953) Nagy 1969 – Čejkovice, 200.7 m
9. *Reevesiapollis triangulus* (Mamczar 1960) Krutzsch 1970 – Miroslav, 78.4 m
10. *Tricolporopollenites liblarensis* (Potonié 1934) Grabowska 1994 – Šafov 13, 20.5 m
11. *Platycaryapollenites miocaenicus* Nagy 1969 – Trboušany 65.8 m
12. *Engelhardtioidites punctatus* (R. Pot. 1931) Potonié 1951 ex Potonié 1960 – Únanov, 6.8 m
13. *Quercoidites henrici* (Pot.1931) R. Pot., Thoms. et Thierg. 1950 – Miroslav, 78.4 m
14. *Quercoidites microhenrici* (R. Pot. 1931) R. Pot., Thoms. et Thierg. 1950 – Únanov, 6.8 m
15. *Tricolporopollenites pseudocingulum* (R. Pot. 1931) Th et Pf – Čejkovice, 181 m
16. *Tricolporopollenites marcodurensis* Thomson et Pflug 1953 – Trboušany, 69 m
17. *Tricolporopollenites megaexactus* (R. Pot.1931) Th. et Pf. 1953 – Únanov, 6.8 m
18. *Castaneoideaepollis pusillus* (R. Pot. 1934) Grabowska 1994 – Únanov, 6.8 m
19. *Platanus* sp. Pacltová 1966 – Šafov 12, 17.5 m
20. *Platanus* sp. Pacltová 1966 – Šafov 12, 17.5 m
21. *Platanus* sp. Pacltová 1966 – Šafov 12, 17.5 m

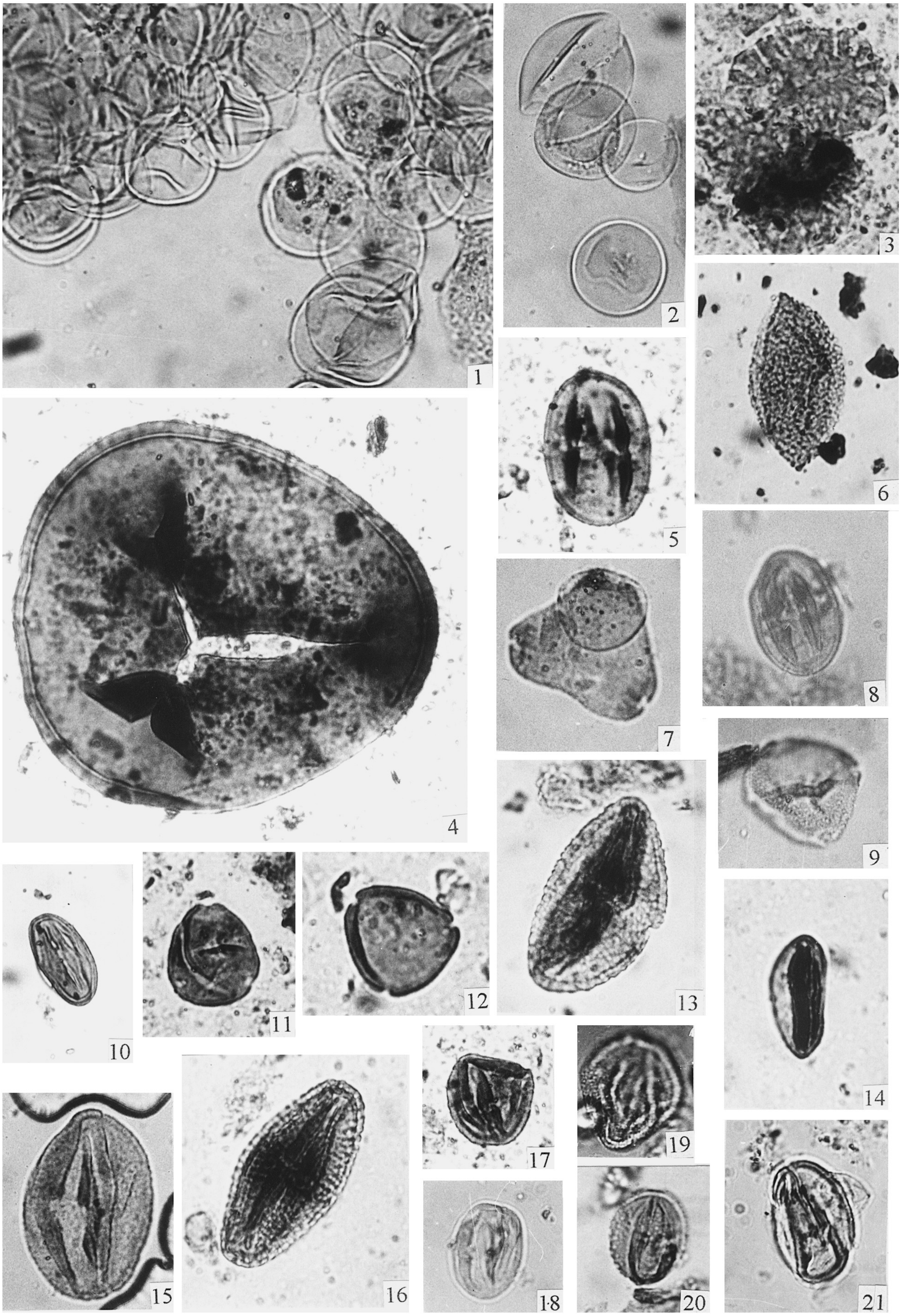
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Plate 2

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1. *Cedripites miocaenicus* W. Kr. 1971 – Únanov, 6.8 m
2. *Cedripites miocaenicus* W. Kr. 1971 – Únanov, 6.8 m
3. *Corsinipollenites oculusnoctis* (Thierg. 1940) Nakoman 1965 subsp. *oculusnoctis* W. Kr. 1968 – Šafov 12, 17.5 m
4. *Inaperturopollenites hiatus* (R. Pot. 1931b) Th et Pf. 1953 – Trboušany
5. *Pinuspollenites alatus* (R. Pot. 1931) Planderová 1990 – Šafov 13, 6.5 m
6. *Myricaceaepollenites* indet. – pollinium – Trboušany 49.7 m
7. *Myricaceaepollenites* indet. – Trboušany 49.7 m
8. *Myricaceaepollenites* indet. – Trboušany 49.7 m
9. *Sparganiaceaepollenites polygonalis* Th. 1937 – Šafov 12, 17.5 m
10. *Ericipites callidus* (R. Pot. 1931) W. Kr. 1970b – Únanov 6.8 m
11. *Nelumbopollenites europaeus* (Tarasevich 1983) Skawińska 1994 – Šafov 13, 10.5 m
12. *Cyperaceaepollis piriformis* Thiele-Pfeifer 1980 – Šafov 12, 17.5 m

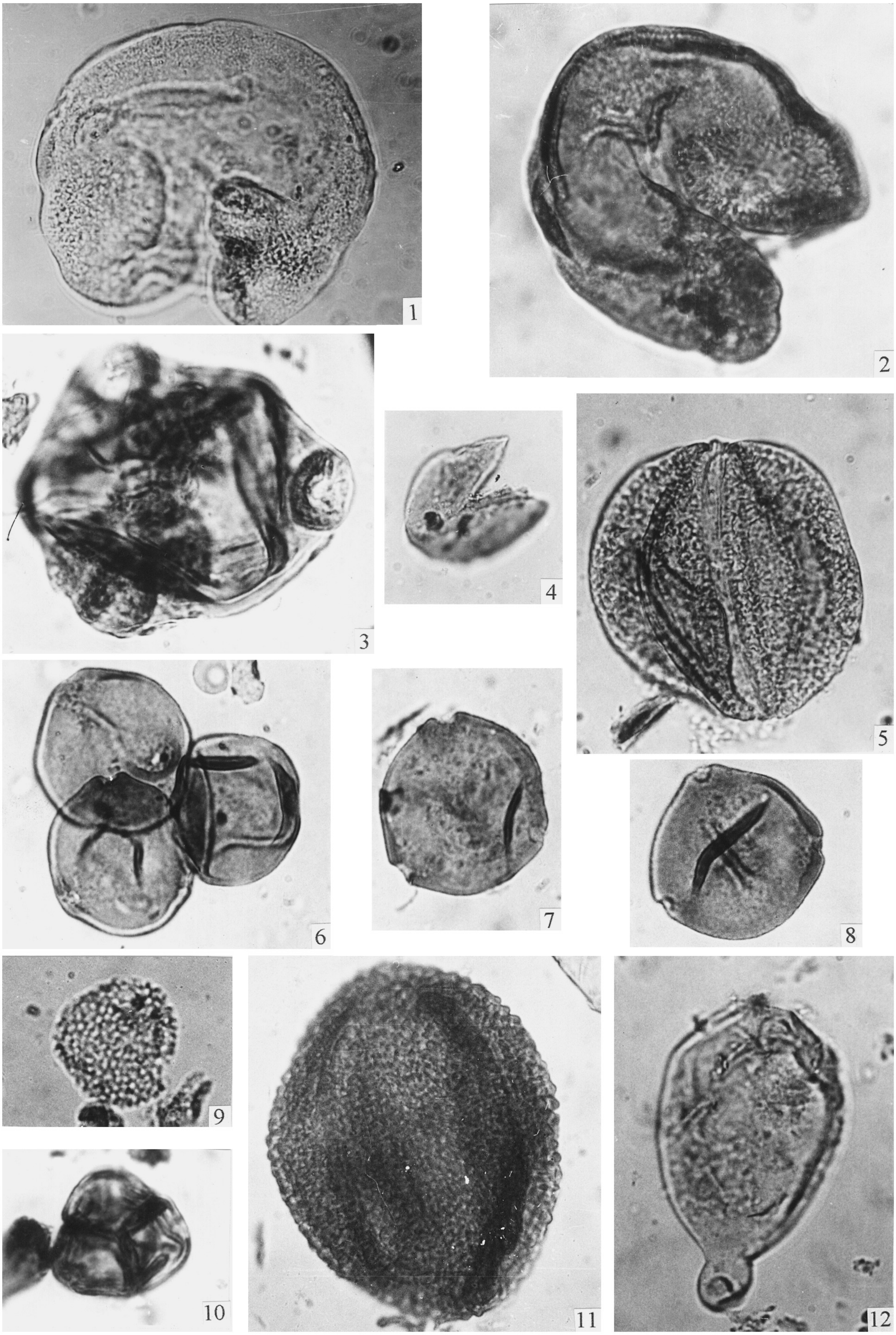
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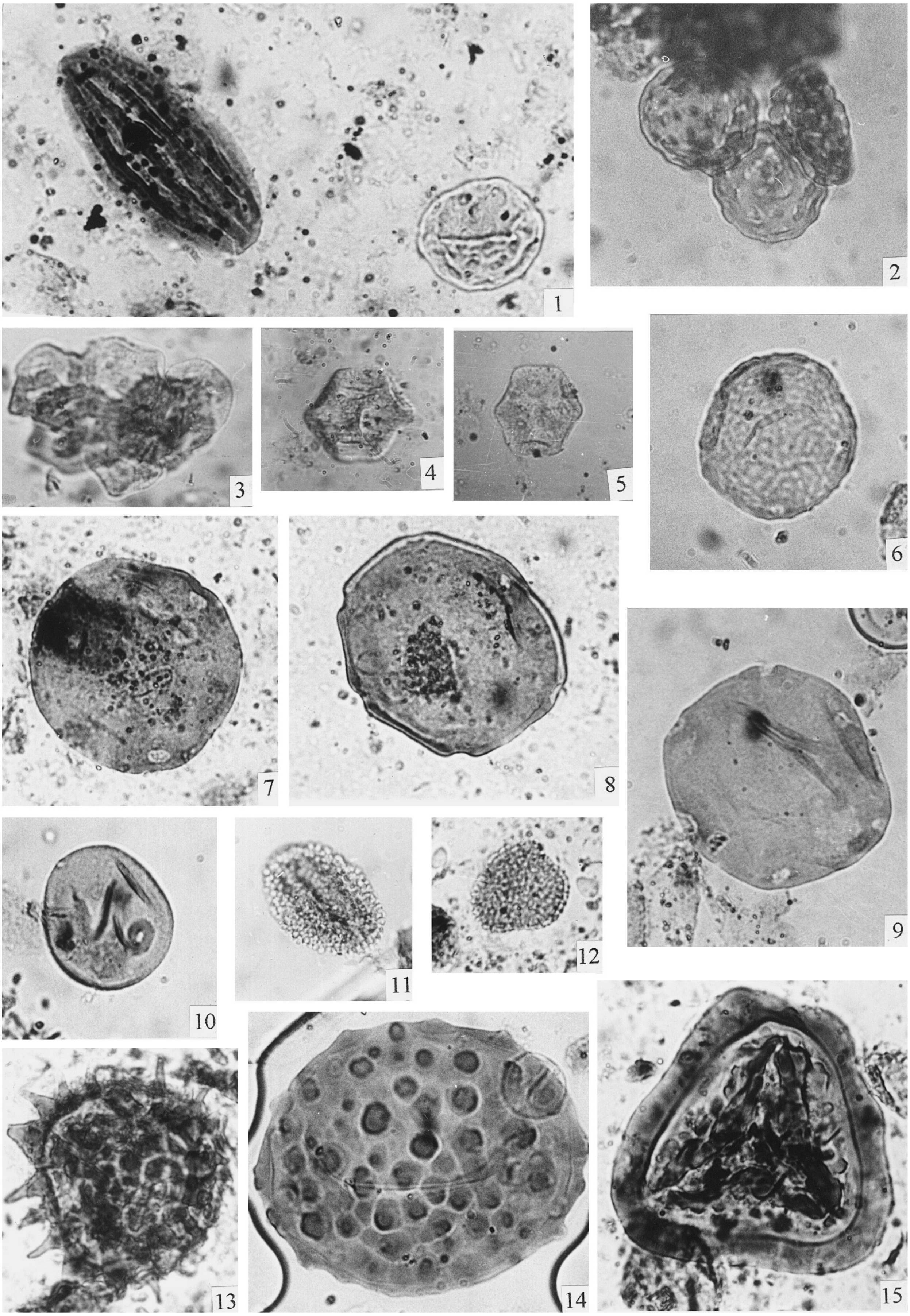
Plate 3

× 1000

1. *Ephedripites (Ephedripites) treplinensis* W. Kr. 1961 and *Chenopodipollis multiplex* (Weyl. et Pf. 1957) W. Kr. 1966 – Miroslav, 73.65 m
2. *Chenopodipollis multiplex* (Weyl. et Pf. 1957) W. Kr. 1966 – pollinium – Miroslav, 78.4 m
3. *Monocirculipollis zahnaensis* W. Kr. 1967 – pollinium – Čejkovice, 176.8 m
4. *Monocirculipollis zahnaensis* W. Kr. 1967 – Únanov, 6.8 m
5. *Monocirculipollis zahnaensis* W. Kr. 1967 – Čejkovice, 176.8 m
6. *Ulmipollenites* div. fsp. – Únanov, 6.8 m
7. *Caryapollenites simplex* (R. Pot. 1931) R. Pot. 1960 – Trboušany, 65.8 m
8. *Pterocaryapollenites stellatus* (R. Pot. 1931) Thiergart 1937 – Trboušany, 69 m
9. *Juglanspollenites verus* Raatz 1937 – Únanov, 6.8 m
10. *Graminidites laevigatus* W. Kr. 1970 – Šafov 12, 17.5 m
11. *Ilexpollenites margaritatus* (R. Pot. 1931) Thierg. 1937 ex R. Pot. 1960 – Trboušany, 49.7 m
12. *Oleaoidearumpollenites* sp. (Th. et Pf 1953) Ziembińska-Tworzydło 1994 – Miroslav, 73.65 m
13. *Selaginellisporis* (*Echinatisporis* W. Kr. 1963) *miocenicus* (Krutzsch et Sontag 1963) Ważyńska 1994 – Trboušany, 65.8 m
14. *Verrucatosporites alienus* (R. Pot. 1931c) Th. et Pf. 1953 – Únanov, 6.8 m
15. *Cingulisporis semiverrucatus* (W. Kr. 1967) – Nagy 1985 – Miroslav, 75.1 m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