Geological Quarterly, 1999, 43 (4): 493–498

Sarmatian palynoflora from Jamnica near Tarnobrzeg (Carpathian Foredeep) — environmental and climatic implications

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Sadowska A. (1999) — Sarmatian palynoflora from Jamnica near Tarnobrzeg (Carpathian Foredeep) — environmental and climatic implications. Geol. Quart., 43 (4): 493–498. Warszawa.

The palynological profile of Middle Miocene marine deposits from the Jamnica S-119 borehole is described, and the Miocene plant communities, growing on the shores of the Paratethys sea and on the adjacent uplands, are reconstructed. The age of deposits is probably Early Sarmatian, though there are close similarities between Early Sarmatian and Late Badenian pollen spectra.

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Key words: Carpathian Foredeep, Sarmatian, marine deposits, palynostratigraphy.

INTRODUCTION

Marine Miocene samples from the Jamnica S-119 borehole donated by E. Król, Institute of Geophysics, the Polish Academy of Sciences in Warsaw in 1995, were analysed palynologically. The plant communities on the Paratethys shore are reconstructed and the age of the deposits are determined. The geological setting and lithostratigraphy of the deposits under examination have been determined by G. Czapowski (1994) and E. Gaździcka (1994). The lithology of the profile was described by G. Gorazd (1991).

MATERIALS AND METHODS

The Jamnica S-119 borehole is located in the Tarnobrzeg region, the northeastern part of the Carpathian Foredeep (Fig. 1). The profile studied consists of claystones and siltstones attributed the lower part of Krakowiec Clays within the Machów Formation. They are overlain by Quaternary deposits. In the lower part of profile the *Syndesmya* and *Pecten* Beds horizons occur, underlain by marly limestones and lithothamnium sandstones. The part of the profile analysed was dated with calcareous nannoplankton (E. Gaździcka, 1994) to the NN8–NN9 Zones of Sarmatian age.

25 samples were taken from the depth interval 36.0–255.0 m. They were macerated with hydrofluoric acid and treated by acetolysis (G. Erdtman, 1954). Because the frequency of sporomorphs in the whole profile was low, 3–10 slides were counted from each sample to obtain appropriate spectra, reaching sums from 114 to 303 pollen grains. Only in sample no. 11 (depth 136.0 m) was pollen material abundant, 560 sporomorphs being counted on two slides. In few samples single pollen grains only were found and percentage calculation of the pollen spectra was impossible. The pollen diagram is shown in Figure 2.

VEGETATION CHARACTERISTICS

Coniferous trees, especially *Pinus*, are dominant in the pollen spectra. There is a prevalence of *Pinus sylvestris* (composing 22.8–72.6% of spectra) over *Pinus haploxylon* (4.6–20.1%). There is also a high content of Taxodiaceae-Cupressaceae (max. 16.7%), Tsuga (11.2%), *Abies* (8.3%), *Picea* (8.0%), *Cedrus* (4.3%) and *Sciadopitys* (2.6%). Pollen of *Sequoia* was noted only in some samples. Among deciduous trees such

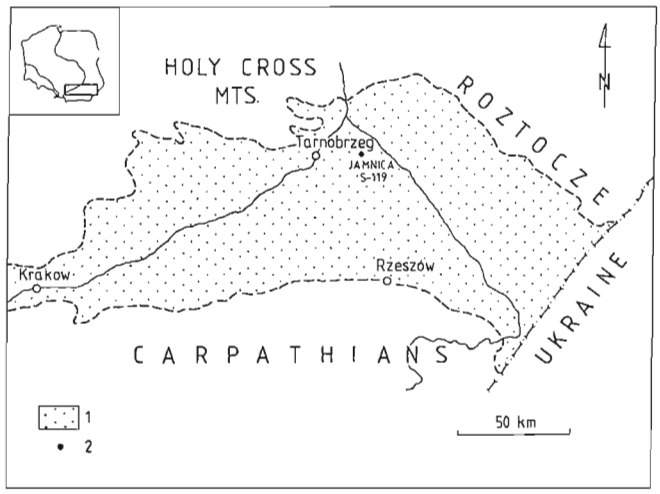


Fig. 1. Location of the borehole Jamnica-119 in the Carpathian Foredeep (after E. Gaździcka, 1994)

1 — recent extent of Miocene deposits of the Carpathian Foredeep; 2 — studied section

genera as *Ulmus* (max. 17.5%), *Quercus* (9.6%), *Alnus* (8.3%), *Carya* (3.5%), *Fagus* (3.3%), *Engelhardtia* (2.6%), *Pterocarya* (2.4%) and *Quercoidites henrici* (1.7%) prevail. Some samples contain usually small percentages of such tree taxa as *Betula, Carpinus, Liquidambar* and *Salix*. Sporadically pollen of *Acer, Castanea, Fraxinus, Juglans, Nyssa, Parrotia, Symplocos* and others (Fig. 2) were found. Shrub pollen are abundantly represented by Ericaceae (highest content 12.5%) and *Myrica* (2.1%). Such taxa as Araliaceae, *Buxus*, Caprifoliaceae, Cyrillaceae, *Ilex*, Myrtaceae, Oleaceae, Palmae, *Tricolporopollenites pseudocingulum* (*Rhus* and other Anacardiaceae) and Rosaceae occur less frequently. Herbaceous plants appear in very small quantities, the most numerous being ferns (Polypodiaceae, *Osmunda* and Cyatheaceae-Schizaeaceae), *Sphagnum* and sporadic Chenopodiaceae, Cyperaceae, Gramineae, Labiatae and *Nuphar* (NAP in pollen diagram).

In the whole Jamnica section Dinoflagellate cysts were numerous, being most frequent in the samples from the depth intervals 65.0–75.0 and 166.0 m (in this last one 32 cysts were noted). Some samples also contain foraminifera.

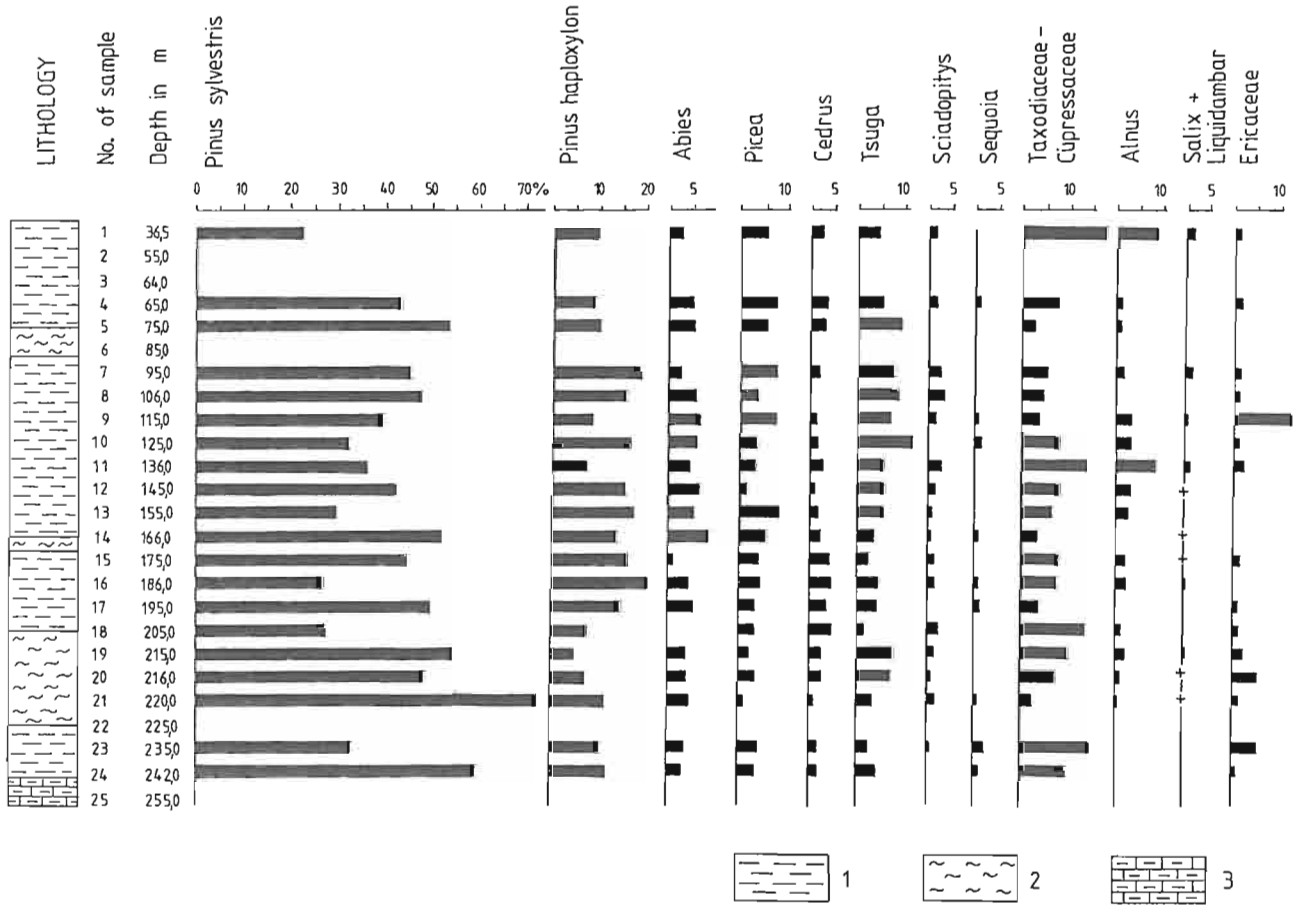
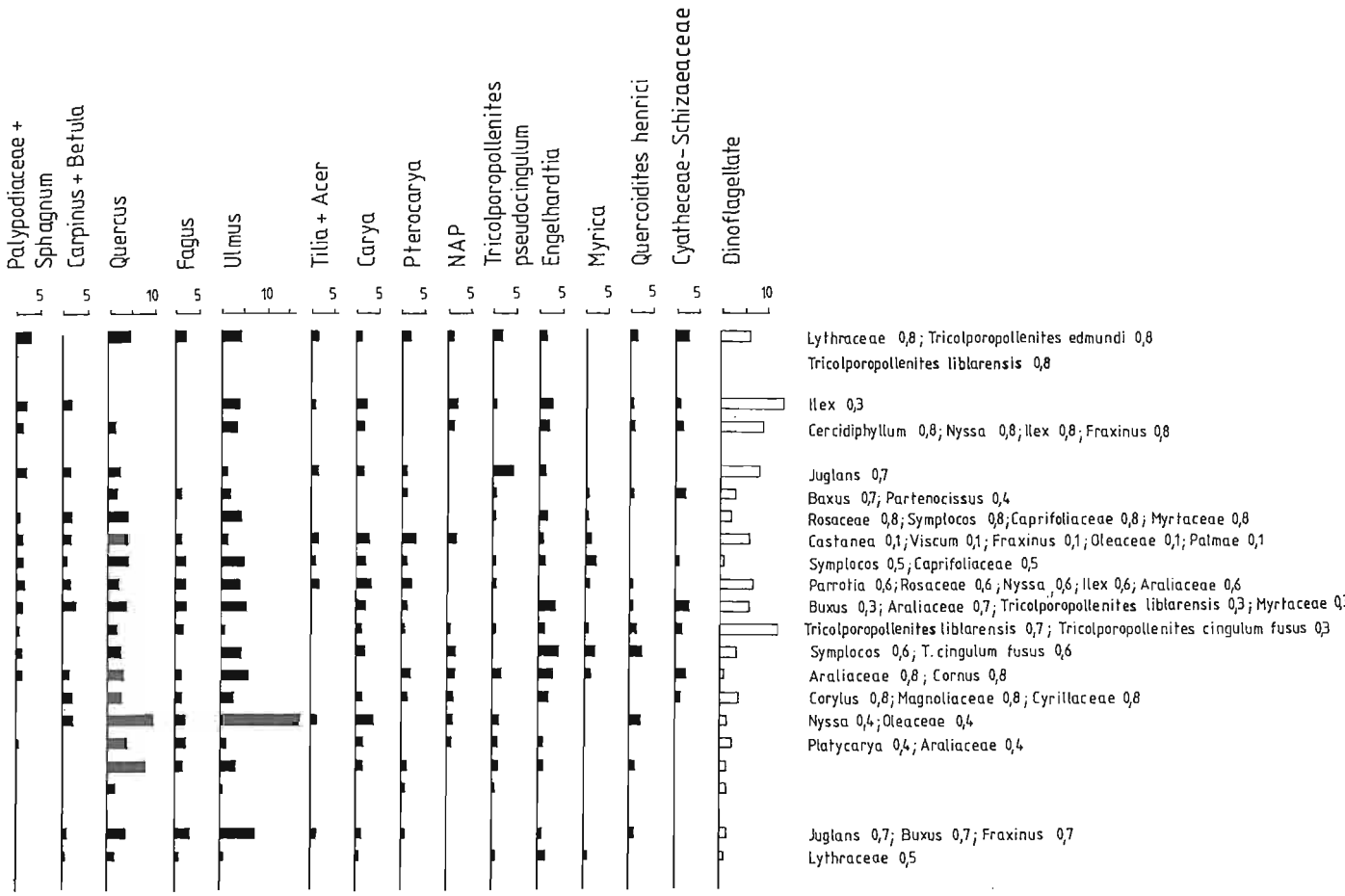


Fig. 2. Jamnica S-119 borehole section; pollen diagram

Reconstruction of the vegetation along the Paratethys sea shoreline over this stratigraphic interval was not easy. It was difficult to follow the changes in the plant communities caused by climatic fluctuations and edaphic conditions. Pollen spectra of marine sediments include not only pollen from the coast but also that from various floral zones, transported by wind and partially by rivers. In the Jamnica section, as in other marine sections, Coniferae saccate pollen prevaile, and these could easily have been transported for long distances, both from the northern sea shores as well as from the Carpathians. Conifers were probably important in the coastal forests but not so important in the plant communities of this region as suggested by the pollen spectra.

The habitats of the lowest areas, most probably sea-shores, bays and lagoons, as well as river valleys, were occupied by swamp forests including such genera as *Taxodium, Nyssa, Alnus, Liquidambar, Salix*, and occasionally also *Betula*. The occurrence of *Sphagnum* simultaneously with shrubs such as *Cyrilla, Myrica, Rhus,* Ericaceae, indicates local peat-bogs. Herbaceous plants, such as Chenopodiaceae and Gramineae, were growing along the shoreline whereas in the nearby forests ferns were numerous. Farther from the coastline forests dominated by *Ulmus, Carya, Pterocarya* and *Acer* existed; on the elevations and in the drier habitats, they were accompanied by such genera as *Carpinus, Engelhardtia, Fagus, Quercus, Tilia* and conifers. Most probably those forests occupied the slopes of Holy Cross Mountains. Shrubs from the families Araliaceae, Caprifoliaceae, Cornaceae, Oleaceae, Magnoliaceae and Rosaceae probably constitued the brushwood of those forests. The participation of Mediterranean components such as *Buxus* and Myrtaceae was characteristic for these communities.

Among the shrubs, Ericaceae pollen was most frequent, these plants being characteristic of many marine sections of Miocene age from the Carpathian foreland (M. Pautsch, 1957; Z. Kita, 1963; J. Oszast, 1967). The abundance of ericaceous plants may be partly connected with peat-bogs and forest undergrowth and partly with open areas adjacent to the coastline, within coastal peat-bogs or shrubby communities resembling Mediterranean macchia (J. Oszast, 1967). In pollen spectra of the Jamnica profile these plants co-occur with other shrubs such as Caprifoliaceae, Myrtaceae, Oleaceae, Rosaceae and others.



1 — claystones, 2 — silstones, 3 — marls

The composition of plant communities in the whole Jamnica section is quite homogenous and no temporal flora changes were observed. The highest content of pollen material in the middle part of the profile (depth 115–185 m), the more abundant pollen spectra, the higher frequency of wet habitat plants (*Alnus, Liquidambar, Myrica, Pterocarya*), as well as of deciduous trees and herbaceous plants, accompanied by a simultaneous decrease of *Pinus*, indicate a more landward position at this depth. It is a common opinion that the poorest pollen spectra in the marine deposits, dominated by Coniferae saccate pollen, indicate a distant, seaward location (E. Planderova, 1975). Such differences in the pollen spectra from Jamnica may then suggest a shoreline migration at this level.

AGE OF THE DEPOSITS

The Jamnica section is located in an Upper Badenian and Lower Sarmatian marine basin. Palynological studies of Badenian marine sediments from the Carpathian Foredeep are rare and mainly from its western part (A. Sadowska, 1996). Data include those from boreholes from the Bochnia region (Z. Kita, 1963; A. Sadowska, 1994; P. Krzywiec *et al.*, 1995), from the sulphur deposits at Piaseczno near Tarnobrzeg (J. Oszast, 1967), and from the western, Silesian part of the Carpathian Foredeep — from the Racibórz region (A. Sadowska *et al.*, 1977), the Głubczyce region (A. Sadowska *et al.*, 1978), the Kędzierzyn-Koźle vicinity: Stara Kuźnia (S. Dyjor, A. Sadowska, 1984), Biała and Twardawa (A. Sadowska, 1989) and from the borehole Gliwice-17 (A. Sadowska, 1997). The pollen spectra at these localities are characterized by high Coniferae, with a dominance of *Pinus sylvestris*. A prevalence of angiosperms were noticed only in the Piaseczno section (J. Oszast, 1967). The dominance of conifers with high levels of *Pinus sylvestris* is a characteristic feature of the Badenian in the whole Carpathian region (S. V. Syabryaj, L. Stuchlik, 1994). Apart from *Pinus*, conifers such as *Abies, Tsuga* and *Picea* are numerous. Among deciduous trees, the most significant role was played by *Quercus, Ulmus, Castanea, Engelhardtia, Fagus* and less important were *Carya, Pterocarya* and *Rhus*. The participation of shrubs and thermophilous ferns was also significant. The presence of swampy plants, so characteristic of continental sediments on the Polish Lowlands area, was — except for *Taxodium* — insignificant, and they included only such taxa as *Alnus, Liquidambar, Myrica* and *Ilex*.

Continental deposits of Late Badenian age from the Western Carpathians (the Czarny Dunajec and Koniówka sections in the Nowy Targ–Orawa Basin), correlating with Badenian sediments from the Polish Lowlands, contain a higher proportion of swampy forest elements, than the spectra from marine deposits. In the Carpathian sections a significant role was also played by *Engelhardtia* (J. Oszast, L. Stuchlik, 1977; L. Stuchlik, 1980).

So far, no pollen profiles of Sarmatian marine sediments have been published from the Polish part of the Carpathian Foredeep. The upper part of the Piaseczno section, represented by the Krakowiec Clays, is attributed to the Sarmatian although they were formerly dated as Tortonian (J. Oszast, 1967). Studies of continental deposits of Sarmatian age are more frequent, both in the Western Carpathian region (Tran Dinh Nghia, 1974; J. Oszast, L. Stuchlik, 1977) and in the Silesian part of Carpathian Foredeep (J. Oszast, 1960; A. Sadowska *et al.*, 1972, 1973, 1977, 1978; T. Kuszell *et al.*, 1974; A. Sadowska, 1977, 1989; S. Dyjor *et al.*, 1978; S. Dyjor, A. Sadowska, 1984).

Using palynological data L. Stuchlik (1980) divided the Sarmatian flora of southern Poland in the three geobotanical provinces: a mountain province — with a domination of coniferous trees, the North-European lowland province — with angiospermous plants prevailing, and the West-European one — with a high participation of coniferous trees but enriched in thermophilous elements. For the Sarmatian of the northern part of the Western Carpathians a coniferous pine-spruce forest was characteristic, with various species of *Tsuga*. In this part of the Carpathians the role of these forests decreased at the end of Sarmatian (S. V. Syabryaj, L. Stuchlik, 1994). In the same period the deciduous forests were dominated by such trees as *Acer, Alnus, Betula, Carpinus, Carya, Fagus, Liquidambar, Pterocarya* and *Ulmus*. Simultaneously in the western part of the Carpathian Foredeep swamp and wet habitat plants like *Taxodium, Alnus, Nyssa, Liquidambar* and Polypodiaceae were well developed, whereas *Celtis* became a significant component of the deciduous forests of moderately wet habitats (A. Sadowska, 1977; A. Dyjor, A. Sadowska, 1986).

The pollen profile from the Jamnica S-119 borehole shows crucial similarities to these Early Sarmatian spectra. As mentioned above, conifers predominate here; their average content in the whole profile equals 78.0%, with a prevalence of *Pinus sylvestris* (average content — 42,6%), accompanied by *Pinus haploxylon* (11.9%), *Abies* (4.0%), *Picea* (3.9%) and *Tsuga* (5.1%). Amounts of the Taxodiaceae-Cupressaceae are rather high (average value — 7.3%) but — like those of other swampy taxa — considerably lower than in the continental Miocene deposits of southern Poland. In some horizons the family Ericaceae is significant. J. Raniecka-Bobrowska (1970) connected is appearance with the Badenian stage, while J. Oszast (1967) considered it as a local phenomenon. Fossil flora from the Jamnica section thus reveals features of spectra known from marine Upper Badenian sediments as well as of those from continental Lower Sarmatian deposits from the Carpathian mountain province. More Coniferae saccate pollen were observed at Jamnica than in the latter reflecting the increased incidence of this pollen in marine sediments.

The age of the Jamnica S-119 section is constrained by the present palynological study to the Late Badenian–Early Sarmatian interval. So far the only feature differentiating the pollen spectra of these two stages is the number of such stratigraphically important thermophilous taxa as Araliaceae, *Arceuthobium, Castanea, Cyatheaceae-Schizaeaceae, Engelhardtia, Itea*, Lauraceae, Meliaceae, *Myrica*, Myrtaceae, Oleaceae, Palmae, *Platycarya, Quercoidites henrici, Reevesia*, Rutaceae, *Symplocos, Tricolporopollenites liblarensis, T.*

pseudocingulum and others. These plants often appear in the Badenian profiles, sometimes in significant amounts. *Engelhardtia* in particular is frequent here.

The role of these plants is minor in the Sarmatian profiles, due to the cooling and drying of climate caused by regression of the warm Paratethys sea from the western part of the Carpathian Foredeep at the Sarmatian onset as well as with the uplift of the Carpathians and Sudetes (R. Ney *et al.*, 1974; S. Dyjor, 1986; S. Dyjor, A. Sadowska, 1986; N. Oszczypko, 1996). From the general composition of the flora, it may be presumed that a warm-temperate climate prevailed during the Sarmatian in the region discussed, similar to the present-day climate of the Mediterranean area.

In the Jamnica section most of these thermophilous taxa were not found, and some of them appeared sporadically. Only *Engelhardtia, Quercoidites henrici* and *Tricolporopollenites pseudocingulum* are present in small quantities, as in other Sarmatian profiles. Therefore, on the basis of such features as a domination of conifers with a prevalence of *Pinus, Abies, Picea* and *Tsuga*, accompanied by deciduous trees of moderate climate such as *Ulmus, Quercus* and *Fagus*, and a low amount of thermophilous plants, it is deduced that the sediment studied were deposited in the Early Sarmatian. The pollen diagram from the lower part of section shows no features which could determine the boundary between the Badenian and Sarmatian stages.

FINAL REMARKS

The analysis of the Jamnica S-119 profile confirms former opinions that the Sarmatian flora of the northern shore of the Paratethys sea has the same taxonomic composition and plant community structure as flora of the Late Badenian (L. Stuchlik, 1980; S. V. Syabryay, L. Stuchlik, 1994). Therefore, it may be presumed that climate changes during these two stages were insignificant and also that the ecological conditions of the plant communities were similar. The Late Badenian plant communities survived into the Early Sarmatian in this area and the floristic transition from the earlier stage to the later one was gradual. Thus, determining the boundary between both stages from the pollen data alone is not possible.

The low content of pollen material in the sediments from the Jamnica section, its corrosion and the domination by easily transported saccate conifer pollen, indicates that the deposits studied were formed distant from a shore zone. However, local variations of coastline position are recorded in the pollen spectra.

Acknowledgements. The autor kindly thanks Dr. E. A. Król, Institute of Geophysics, of the Polish Academy of Sciences in Warsaw, for providing the samples from the Jamnica section.

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SARMACKA FLORA Z JAMNICY KOŁO TARNOBRZEGA W ŚWIETLE BADAŃ PALINOLOGICZNYCH — IMPLIKACJE ŚRODOWISKOWE I KLIMATYCZNE

Streszczenie

Badaniom palinologicznym poddano próbki z otworu wiertniczego Jamnica S-119, wykonanego w północno-wschodniej części zapadliska przedkarpackiego (fig. 1), w morskich utworach mioceńskich, które obejmowały głównie dolną część iłów krakowieckich oraz warstwy pektenowe w spągu profilu. Odtworzono obraz zbiorowisk roślinnych porastających brzegi morza Paratetydy i obszary położone w większej odległości, z których transportowany był głównie łatwo lotny pyłek drzew szpilkowych z workami powietrznymi. W sąsiedztwie morza występowały niezbyt rozległe bagienne lasy i torfowiska z takimi rodzajami roślin, jak *Taxodium, Alnus, Nyssa, Myrica, Rhus, Pterocarya*. Wyniesienia terenu, prawdopodobnie stoki Gór Świętokrzyskich, porastały lasy z dużym udziałem drzew szpilkowych z rodzajów *Pinus, Tsuga, Abies, Picea, Cedrus, Sciadopitys, Sequoia* i z drzewami liściastymi, wśród których dominowały *Ulmus, Quercus, Fagus, Engelhardtia, Carpinus, Carya* oraz z krzewami i paprociami w podszyciu (fig. 2). Charakterystyczny jest udział Ericaceae, które mogły wchodzić w skład lasów bądź nadmorskich krzewiastych zbiorowisk typu makchi. W profilu z Jamnicy brak jest zmian flory, które świadczyłyby o różnicach stratygraficznych. Bogatsze spektra pyłkowe w środkowej części profilu (głęb. 125–185 m) oraz wyższy udział roślin siedlisk bagiennych i drzew liściastych w tym poziomie, przy mniejszej roli drzew szpilkowych, wskazują na małą odległość badanych osadów od brzegu, a tym samym na spłycanie się morza i przybliżanie jego brzegów.

Diagram pyłkowy z Jamnicy wykazuje duże podobieństwa zarówno do nielicznych na terenie zapadliska przedkarpackiego profili pyłkowych z morskich osadów górnego badenu, jak też do profili z lądowych utworów dolnego sarmatu. Potwierdza to opinię L. Stuchlika (1980) oraz S. V. Syabryay i L. Stuchlika (1994), że flora późnego badenu i wczesnego sarmatu na obszarze północnego brzegu Paratetydy ma ten sam skład i przejście z jednego do drugiego piętra jest ciągłe. Brak jest natomiast dotychczas opracowanych palinologicznie osadów morskich sarmatu z tego obszaru, z którymi można by porównać uzyskane spektra. Nikły udział roślin ciepłolubnych w profilu z Jamnicy oraz panowanie drzew klimatu umiarkowanego przemawia za zaliczeniem analizowanych zespołów do wczesnego sarmatu.