Acta Palaeobotanica 47(1): 261–273, 2007

The state of investigation of the Upper Pliocene Dvorets flora (SE Belarus)

FELIKS YU. VELICHKEVICH and EWA ZASTAWNIAK

Władysław Szafer Institute of Botany, Polish Academy of Sciences, Lubicz 46, 31-512 Kraków, Poland;
e-mail: Ewa.Zastawniak@ib-pan.krakow.pl

Received 3 July 2006; accepted for publication 12 January 2007

ABSTRACT. Lacustrine deposits with numerous plant macrofossils found near the village of Dvorets (south-eastern Belarus) in an exposure on the right bank of the Dnieper river, appeared to be very interesting material for studying the history of vegetation development in Europe in the younger Neogene. As a result of the palaeocarpological analyses made so far many fossil taxa of fruits and seeds have been determined. They belong to typical Pliocene species containing some currently extinct as well as modern species forming part of the present-day floras of Eastern Asia, Eastern Siberia and North America. On the basis of palaeocarpological and palynological analyses it has been found that the flora of Dvorets represents the Lower Dvorets Subhorizon within the Upper Pliocene. However, due to the domination of *Larix* and the important role of herbaceous plants it also has the touch of a Pleistocene flora. Further studies of materials collected in the locality should make it possible to determine more precisely and unequivocally the stratigraphic position of that fossil flora.

KEY WORDS: fruits, seeds, megaspores, fossil flora, pollen diagram, history of investigation, Upper Pliocene, Belarus

INTRODUCTION

The fossil flora found in the Dvorets locality in south-eastern Belarus (Fig. 1) has been the subject of many palaeobotanical studies, both palaeocarpological and palynological (Velichkevich 1970, 1975, 1990, Dorofeev & Velichkevich 1971a, b, Dorofeev 1986) as well as palynological only (Makhnach et al. 1970, Makhnach 1971, Zinova & Burlak 1982, Zinova et al. 1987). These studies have yielded controversial results as to the age of the flora. On the one hand, the results of the examination of fruit and seed remains indicated unequivocally from the very beginning that they were of Pliocene age. On the other, interpretations based on palynological studies suggested that the Dvorets deposits were of the oldest interglacial (Nalibokyan Interglacial) age (Makhnach et al. 1970). Only Burlak's (Zinova & Burlak 1982) and Rylova's later studies (in Zinova et al. 1987) confirmed the late Pliocene age of the Dvorets flora-bearing deposits.

Specimens representing the Dvorets fossil flora, illustrated on plates, are kept in the

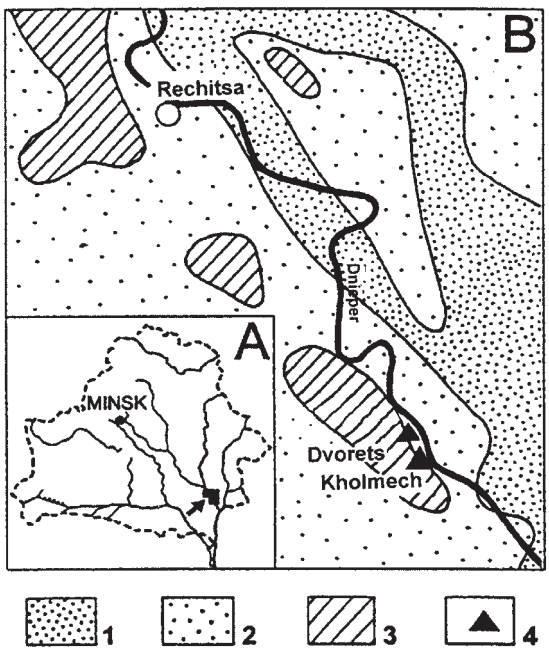

Fig. 1. Position of the fossil locality of Dvorets; **A** – in Belarus, **B** – in relation to the other sites; **1** – Upper Eocene maritime sediments, **2** – Lower Oligocene maritime sediments, **3** – Upper Oligocene to Pliocene continental sediments, **4** – localities with fossil floras (after Velichkevich & Zastawniak 2003, modified)

Palaeobotanical Museum of the Władysław Szafer Institute of Botany, Polish Academy of Sciences (KRAM-P). SEM images were made in the Aleksander Krupkowski Institute of Metallurgy and Material Sciences of the Polish Academy of Sciences in Cracow, Poland.

GEOLOGY AND STRATIGRAPHY

Lacustrine deposits with numerous plant macrofossils were discovered by Goretsky (1970) during a geological field survey, in an exposure on the right bank of the Dnieper river near the village of Dvorets. These are black, stratified clays and humic, fine-grained sands, up to 1.5 m thick, which occur in several lenticels along the bank of the Dnieper river, near open water, over a distance of about 700 m (Fig. 2). Lacustrine deposits with plant macrofossils are overlain by Quaternary deposits more than 21 m thick (Goretsky op. cit.).

According to the present stratigraphic division of the Neogene of Belarus, deposits containing the Dvorets fossil flora belong to the Lower Dvorets Subhorizon within the Upper Pliocene (Yakubovskaya et al. 2005).

PREVIOUS PALAEOBOTANICAL INVESTIGATIONS

One may distinguish two phases in the history of palaeofloristic studies of the Dvorets flora. In the first phase, during the 1970s, research efforts were focused on determining the taxonomic composition of the flora and identifying exotic species that could indicate its age. A list of typical Pliocene species found in the Dvorets flora was published in the first papers concerning that flora (Velichkevich 1970, Dorofeev & Velichkevich 1971a, b). It included *Salvinia tuberculata* P. Nikitin (Pl. 1, fig. 6), *Azolla pseudopinnata* P. Nikitin (Pl. 1, fig. 7), *Pilularia pliocenica* Dorof. (Pl. 1, fig. 3), *Hypericum tertiaerum* P. Nikitin and *Ranunculus gailensis* (E. M. Reid) (= *R. sceleratoides* P. Nikitin). Additionally, within it, some extinct species, new to science, such as *Selaginella borysthenica* Dorof. & Wieliczk., *S. reticulata* Dorof. & Wieliczk. (Pl. 1, figs 1, 2), *Elatine pseudoalsinastrum* Dorof. & Wieliczk. (Pl. 2, fig. 7) and *E. hydropiperoides* Dorof. & Wieliczk. (Pl. 2, fig. 8) were described. All the taxa identified enabled one to establish relations between the Dvorets flora and other Pliocene floras of the East-European Plain. The presence of numerous modern species, in

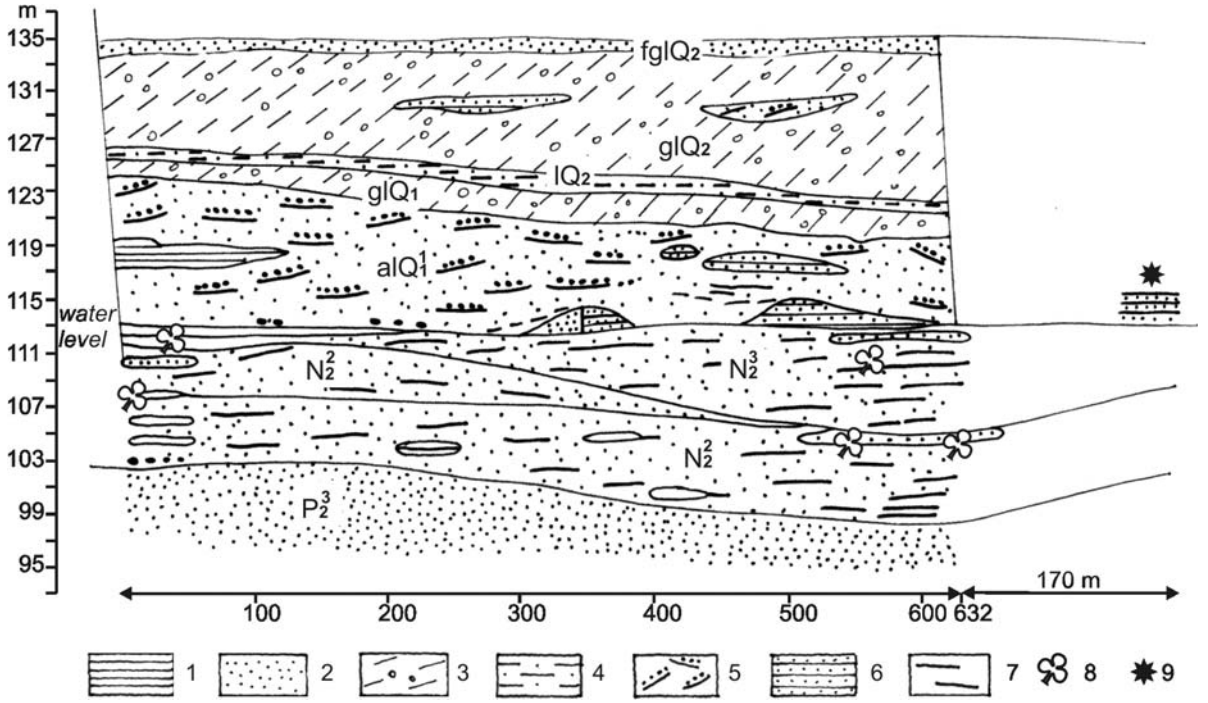

Fig. 2. Geological section of the right bank of the Dniepr river near the Dvorets village. **1** – loam, **2** – sand, **3** – morainic loamy sand, **4** – loamy sand, **5** – lens of gravel, pebble and clay, **6** – aleurite, **7** – small lens of clay, **8** – fossil plant remains, **9** – the main exposure, **P** – Palaeogene, **N** – Neogene, **Q** – Quaternary, **gl** – glacial, **fgl** – fluvioglacial (after Goretsky & Zinova 1981, modified).

addition to the occurrence of a whole group of extinct, exotic species, clearly indicated that the Dvorets flora was younger than the classic middle Pliocene floras of Central Russia, such as Krivobor'e and Uryv (Nikitin 1957). That stage of the history of studies on the Dvorets flora ended with the publishing of a comprehensive study by Velichkevich (1975), whose taxonomic list comprised more than 100 plant taxa, including such exotic, typical Pliocene species as *Lobelia pliocenica* (Dorof.) Mai (Pl. 1. fig. 8), *Sparganium crassum* P. Nikitin, *Potamogeton borysthenicus* Dorof., *Nymphaea pusilla* Dorof., *Aldrovanda eleanorae* P. Nikitin, *Myriophyllum borysthenicum* Dorof., *Sambucus pulchella* C. & E. M. Reid (Pl. 3, fig. 15), and the newly described extinct species *Potamogeton praemaackianus* Wieliczk. (Pl. 3, fig. 13) and *Carex paucifloroides* Wieliczk. (Pl. 3, fig. 17).

The results of studies on the Dvorets flora appeared to be so interesting that in the later part of the 1970s a longer expedition attended by a large group of researchers was organized, during which great amounts of flora-bearing deposits were collected and washed on the spot (Dorofeev 1986). These materials originated not only from the main exposure but also from some additional excavations situated around the neighbouring village of Kholmech (Dorofeev op. cit.). In these additional outcrops the floristic material was taken from the upper part of the Pliocene deposits, underlain by older Pliocene deposits containing a flora of the Kholmech type (Velichkevich & Zastawniak 2003).

Materials collected at that time were partly analysed by Dorofeev (1986) who described more new extinct species. This publication opened the second stage of studies on the Dvorets flora, which took place in the 1980s. The remaining materials collected during the expedition, deposited in the Palaeobotanical Museum of the Institute of Geochemistry and Geophysics of the Academy of Sciences of the Byelorussian SSR in Minsk, were later investigated by Yakubovskaya (1982), Rylova (in Zinova et al. 1987) and Velichkevich (1990).

THE PALYNOLOGICAL PROFILE OF DVORETS

The best illustration of plant succession in the fossil deposits of Dvorets is the diagram (Fig. 3) produced by Rylova (Zinova et al. 1987). It is based on the exposure which yielded the macroscopic remains for study. The general pattern of the pollen spectra is one dominated by the pollen grains of grasses and perennials whose proportions range from 9% to 59% and gymnospermous trees and shrubs amounting to 21–52%, with the exception of a bottom sample where the latter was as high as 82 %. The amounts of spores and angiospermous tree pollen were much smaller, 2–28% and merely 1–5%, respectively.

Pinus aff. s*ylvestris* pollen dominated that of coniferous trees. *Pinus* aff. *strobus* and some other species with pollen of the *Pinus haploxylon* type were represented by single grains. Taken together these made up 20–52%; in the sample from the bottom layer where the proportion was as great as 80%. *Larix* pollen grains occurred rather regularly but in small amounts (to 4%) as did those of *Picea* (to 2%). There were also single grains of *Sciadopitys* aff. v*erticillata*, *Tsuga* aff. *diversifolia* and Cupressaceae in the spectra.

Arboreous angiosperms were represented mainly by the pollen grains of *Betula* sect. *Alba* (< 24%); there were also small amounts of *Quercus*, *Salix* and *Myrica* pollen and single grains of *Ulmus*, *Alnus, Corylus, Tilia, Rhamnus, Fraxinus, Lonicera*, and Rosaceae. Herbaceous plants, including perennials, were represented mostly by the pollen grains of Poaceae (to 28%) and *Artemisia* (to 25%), also Chenopodiaceae (to 2 %), Asteraceae (to 6 %), Cichorioideae (to 1%), and Cyperaceae (to 4 %). The presence of some Ericaceae was found as well. In addition, pollen from the following families of herbaceous plants was found: Ranunculaceae, Caryophyllaceae, Polygonaceae (*Polygonum* aff. *bistorta*, *P*. aff. *persicaria*, *P*. aff. *amphibium*, and *Rumex*), Apiaceae, Violaceae, Brassicaceae, Euphorbiaceae, Lythraceae, Onagraceae, Valerianaceae, Dipsacaceae, Gentianaceae, Menyanthaceae, Scrophulariaceae, Plantaginaceae, Lamiaceae, and Campanulaceae. The total contribution of pollen from plants representing these families was 18%. The pollen of aquatic and waterside plants (Nymphaeaceae, *Myriophyllum*, *Alisma, Potamogeton*, *Sparganium*, and *Typha* aff. *latifol*ia)) made up a further 6%. Also seen were the spores of Polypodiaceae (< 3%), *Sphagnum* rarely, and just single spores of Bryales, *Selaginella selaginoides* and *Ophioglossum*.

An analysis of the spore-pollen complex of

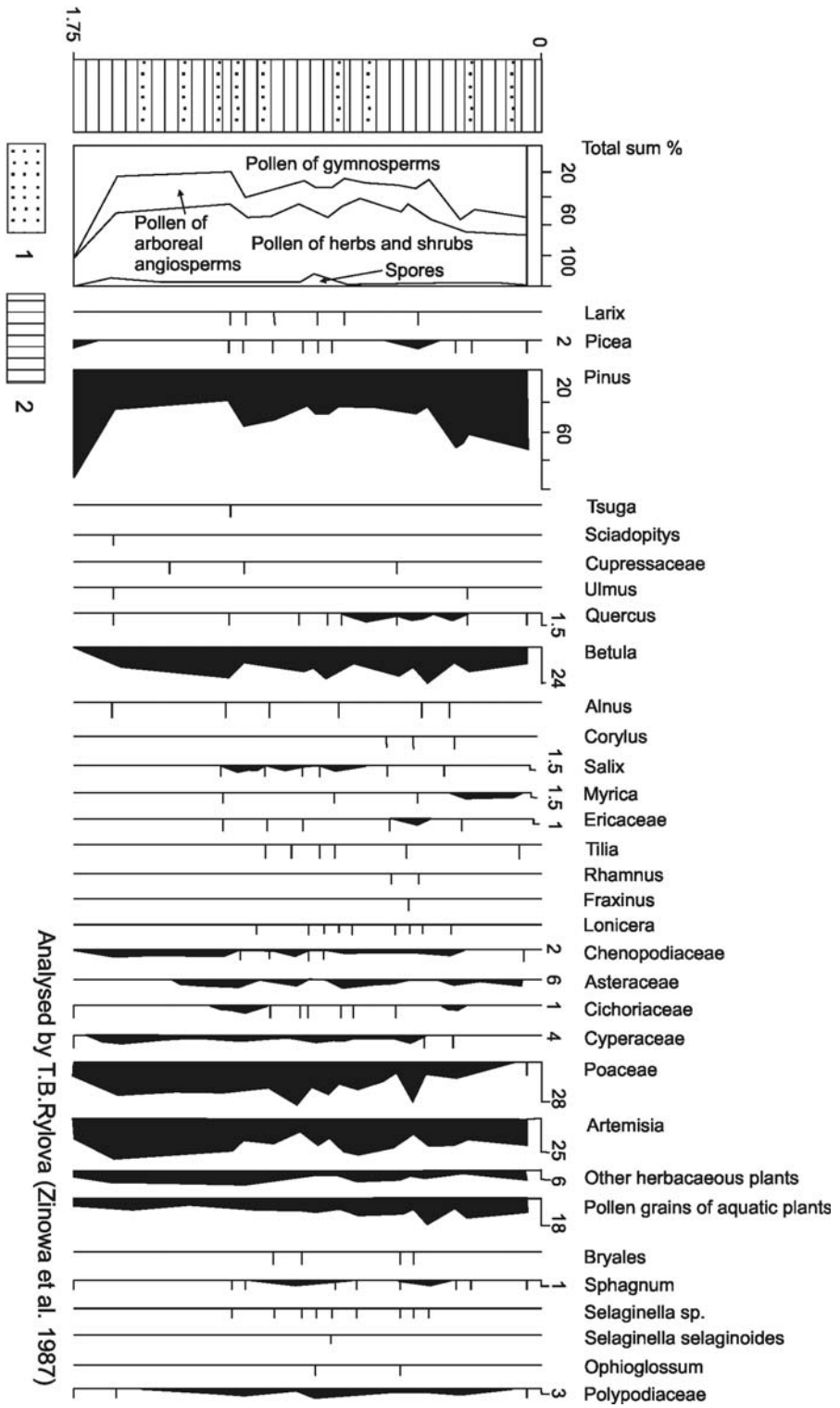

Fig. 3. Palynological spectra from the Lower Dvorets Subhorizon of the Dvorets site. **1** – sand, **2** – sandy loam (according to Rylova in Zinova et al. 1987, fig. 15, modified)

the Lower Dvorets Subhorizon which is similar to other late Pliocene complexes in Belarus, showed that during the formation of deposits of that age the Dvorets area was dominated by pure and mixed coniferous forest communities (small-leaved forest, mostly pine-birch). These contained some spruce and yew, and a small admixture of alder and such broad-leaved trees as *Quercus*, *Ulmus*, and *Fraxinus* together with *Corylus* and *Euonymus* shrubs. The area, however, was not covered by forest as a whole; open parts were overgrown with herbaceous vegetation. An increasing proportion of herbaceous plants showed that the

thermal conditions were gradually deteriorating at that stage of the late Pliocene and the vegetation was slowly becoming similar to that of the Quaternary period.

CURRENT KNOWLEDGE OF THE FOSSIL MACROFLORA OF DVORETS BASED ON THE MOST RECENT INVESTIGATION

The taxonomic composition of the flora was determined by Dorofeev (1986) for the main outcrop in Dvorets (Fig. 2). It comprised 128 taxa of trees, shrubs and herbaceous plants of which 40 % (52) were extinct. That percentage is very high in view of the floras relatively young age. It contained many new species, determined for the first time in the Dvorets flora where they were represented by large numbers of specimens. Closely related present-day species differ only slightly from the fossil ones, as is seen by comparison of the modern taxa and their numerous fossil counterparts.

According to Dorofeev (1986), these relatively young Pliocene species, which could be direct ancestors of one or several present-day species, are *Potamogeton ultimus* Dorof. (modern analogue *P. mandshuriensis* A. Benn.), *Myrica borysthenica* Dorof. & Wieliczk (Pl. 3, fig. 3; modern analoque *Myrica gale* L.), *Stachys pliocenica* Dorof. (*S. palustris* L.), *Mentha pliocenica* Dorof. (*M. aquatica* L., *M. arvensis* L.), *Nuphar adveniformis* Dorof. (*N. advena* Ait.), *Lysimachia nikitinii* Dorof. (*L. davurica* Ledeb.) and others. Many of these closely related modern species are found in the present-day floras of Eastern Asia, Eastern Siberia and North America. Such species as *Potamogeton praemaackianus* Wieliczk., *P. digynoides* Dorof., *P. ultimus* Dorof., *Eleocharis praemaximoviczii* Dorof. (Pl. 2, fig. 2), *Spiraea gomeliana* Dorof. (Pl. 3, fig. 7), and *Lysimachia nikitinii* Dorof. are analogues of modern East Asiatic species, while *Nuphar adveniformis* Dorof. and *Myriophyllum spinulosum* Dorof., are precursors of North American species. What is more, as often happens in Neogene floras, some fossil species are close to present-day species of two continents, e.g. Asia and North America. These are *Scirpus atroviroides* Dorof. (Pl. 2, fig. 1), *S. liratus* Dorof. (Pl. 3, fig. 6), *Hypericum foveolatum* Dorof. (Pl. 2, fig. 3), *Alisma minimum* (P. Nikitin) Dorof., and *Lycopus pliocenicus* Dorof. (Pl. 3, fig. 5). In addition to these species the Dvorets flora contains many extinct ones, partly described by Nikitin (1957) from fossil floras of Russia, whose affinity has not as yet been established. They are *Azolla pseudopinnata* P. Nikitin (Pl. 1, fig. 7), *A. interglacialis* P. Nikitin (Pl. 1, fig. 6), *Salvinia tuberculata* P. Nikitin (Pl. 1, fig. 5), *Selaginella reticulata* Dorof. & Wieliczk. (Pl. 1, fig. 2), *Sparganium crassum* P. Nikitin, *Potamogeton felixi* Dorof., *P. parvulus* Dorof. (Pl. 3, fig. 9), *P. mamillatus* Dorof., *Nymphaea pallida* Dorof. (Pl. 3, fig. 14), *Thalictrum pliocenicus* Dorof., and *Potentilla pliocenica* E. M. Reid.

The Dvorets flora is a forest flora, containing very numerous remains of both coniferous trees (*Pinus*, *Picea*, *Larix*) and deciduous trees and shrubs (*Salix*, *Myrica*, *Betula*, *Quercus*, *Acer*, *Tilia*, *Prunus*, *Sorbus*, *Crataegus*, *Rosa*, *Spiraea*, *Frangula*, and *Swida*), which testify to the mixed character of the forest communities. On the basis of this material Dorofeev (1986) determined the age of the flora as late Pliocene and stated that fossil floras of the same type occurred in many late Pliocene localities in the central part of the East-European Plain. Dorofeev (op. cit.) did not, however, relate the Dvorets flora to the youngest Pliocene.

The monograph of the Dvorets flora by Velichkevich (1990), based on a much greater amount fossil material, summarized all the earlier data on the Dvorets flora, discussed its age and affinities to other Pliocene floras in Russia, Belarus, Poland, Germany and the Czech Republic. In the Dvorets flora Vielichkievich (1990) distinguished, described and documented 177 plant taxa belonging to over 100 genera of sporophytes, gymnosperms and angiosperms, mostly determined to species. His studies (op. cit.) confirmed the forest character of the Dvorets flora, adding to it new taxa of trees and shrubs, such as *Alnus* sp. or *Betula cholmechensis* Dorof., *Fraxinus*, and *Sambucus pulchella* C. & E. M. Reid. Dominant elements in the flora were coniferous trees, above all European larch, *Larix decidua* Mill. In all layers of the flora-bearing deposits of Dvorets there occurred large quantities of different types of remains of that tree: seeds, needles, short-shoots, cones etc. These were accompanied by the less numerous remains of *Pinus sylvestris*-type, single remains of *Picea* and scarce remains of deciduous trees and

shrubs. The only birch was represented by rather numerous macrofossils.

The presence of larch in the Dvorets flora, so strongly marked in the macroscopic flora, is much less visible in the palynological diagram. However, as is well-known, the occurrence of even single pollen grains of *Larix* in diagrams may testify to its occurrence *in situ* or in the immediate surroundings of the place of deposition (Janssen 1966, Huntley & Birks 1983) and disproportions between the abundance of macroscopic remains and numbers of pollen grains are observed even in the forest-tundra zone (Wacnik et al. 2004).

No forest community of a similar composition is so far known from the Pliocene of Europe. Its presence testifies to the considerable transformation of forests in the East-European Plain during the final stage of Pliocene flora development. It is worthy of mention that in the older Kholmech flora, situated in the some neighbourhood, yew remains were completely lacking, and only scarce fragments of spruce needles or those of other coniferous trees were found (Velichkevich & Zastawniak 2003). Such a distinct change in the character of the vegetation as observed in the Dvorets flora in comparison with the other Pliocene floras of Belarus, particularly the dominance of yew and the important role of herbaceous plant communities documented also by palynological analyses, make it similar to Pleistocene floras. It should be added that it was *Taxus* that for some time dominated the floras of the older interglacials of Eastern Europe (Velichkevich 1982).

Velichkevich's studies (1990) completed the list of extinct species with such taxa as *Potamogeton perforatus* Wieliczk. (Pl. 3, fig. 11), *P. obtusus* Dorof., *Caulinia sukaczevii* Dorof. (Pl. 2, fig. 6), *Stratiotes goretskyi* Wieliczk., *Carex curvata* T.V. Jakub., *Betula cholmechensis* Dorof., *Nymphaea* cf. *cinerea* Wieliczk., *Aldrovanda eleanorae* P. Nikitin, *Hypericum tertiaerum* P. Nikitin (Pl. 2, fig. 4), *Ludwigia chandlerae* Knobloch = *Hypericum coriaceum* P. Nikitin) (Pl. 2, fig. 5), *Myriophyllum* cf. *subspicatum* Wieliczk., and *Sambucus pulchella* C. & E.M. Reid. Thanks to the augmented floristic list the proportion of the exotic element in the Dvorets flora has been verified at 30% which finally determines its stratigraphic position as the youngest Pliocene, close to the Pleistocene.

In the Palaeobotanical Museum of the Institute of Geochemistry and Geophisics, National Academy of Sciences of Byelarus in Minsk there are also additional new materials from the Dvorets flora, whose analysis will undoubtedly allow one to complete the list of exotic species and finally to recognize its importance as a transitional flora between the Pliocene and Pleistocene.

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to Mr Arthur Copping for linguistic verification of the English text. Many thanks also to Mr Antoni Pachoński for photography.

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PLATES

Plate 1

1. *Selaginella borysthenica* Dorof. & Wieliczk., megaspore, SEM
2. *Selaginella reticulata* Dorof. & Wieliczk., megaspore, SEM
3. *Pilularia pliocenica* Dorof., megaspore, SEM
4. *Salvinia aphtosa* Wieliczk., megaspore, SEM
5. *Salvinia tuberculata* P. Nikitin, megaspore, SEM
6. *Azolla interglacialis* P. Nikitin, megaspore, SEM
7. *Azolla pseudopinnata* P. Nikitin, megaspore, SEM
8. *Lobelia pliocenica* (Dorof.) Mai, seed, SEM

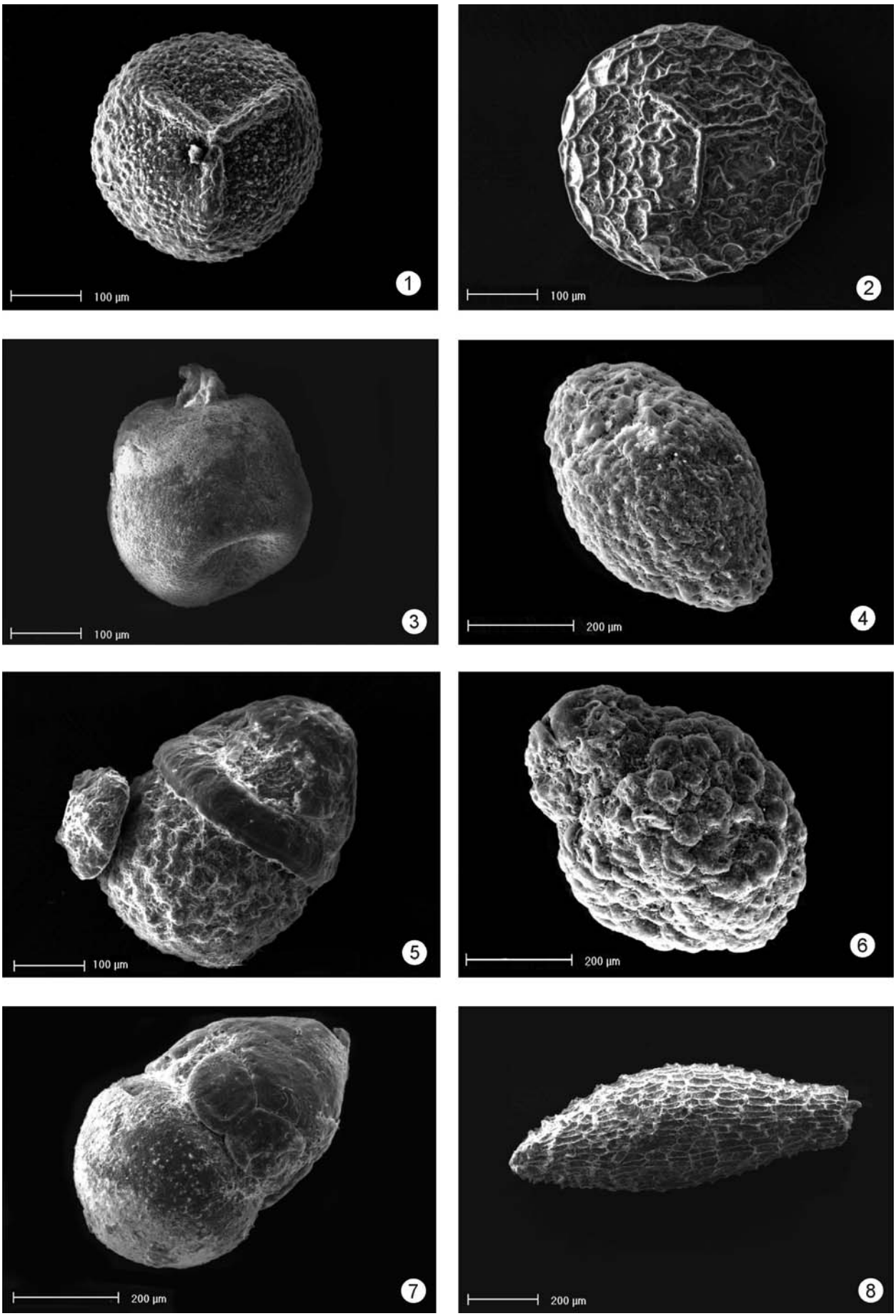
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Plate 2

1. *Scirpus atroviroides* Dorof., fruit, SEM
2. *Eleocharis praemaximowiczii* Dorof., fruit, SEM
3. *Hypericum foveolatum* Dorof., seed, SEM
4. *Hypericum tertiaerum* P. Nikitin, seed, SEM
5. *Ludwigia chandlerae* Knobloch, seed, SEM
6. *Caulinia sukaczevii* Dorof., seed, SEM
7. *Elatine pseudoalsinastrum* Dorof. & Wieliczk, seed, SEM
8. *Elatine hydropiperoides* Dorof. & Wieliczk, seed, SRM

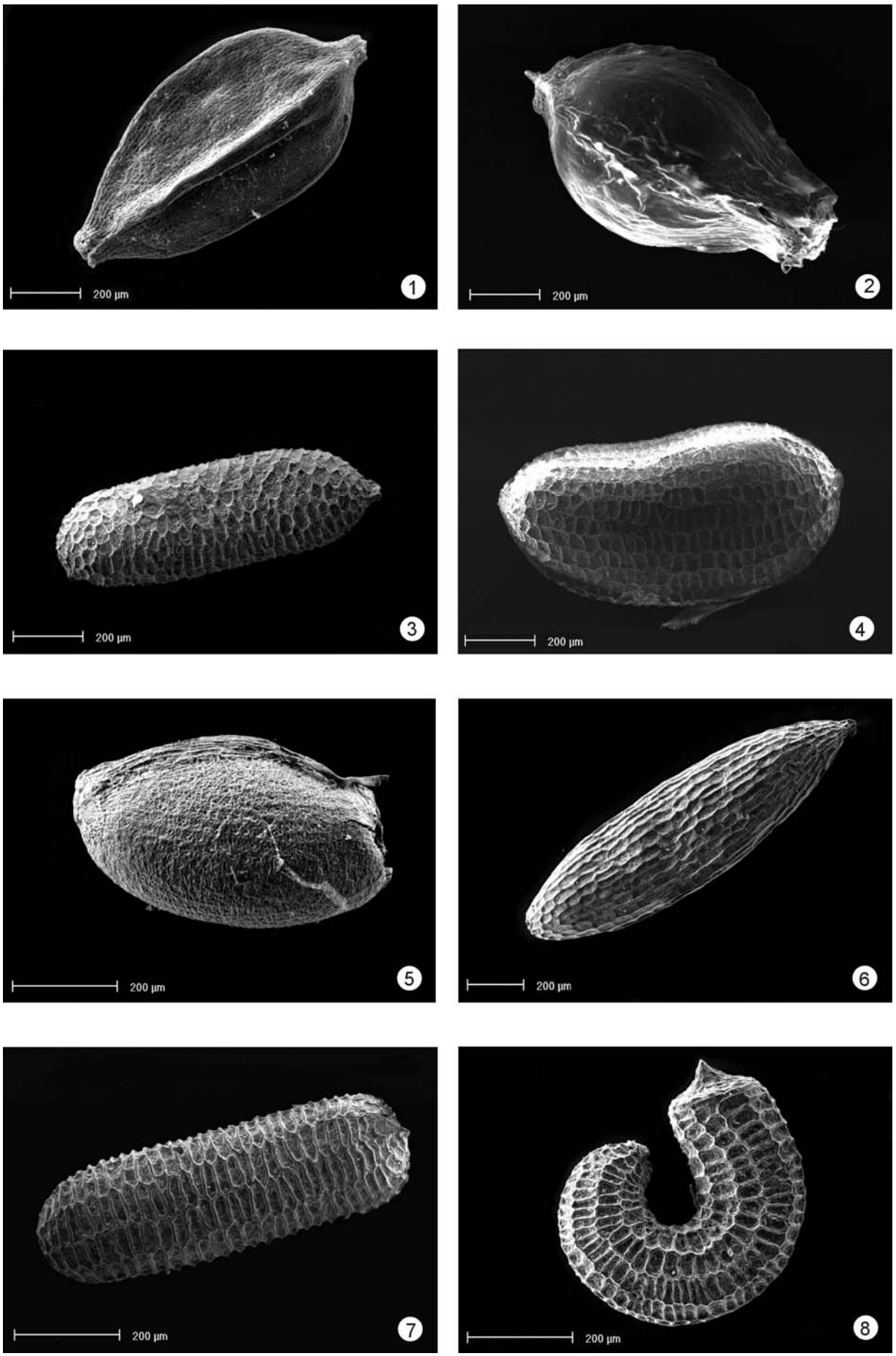
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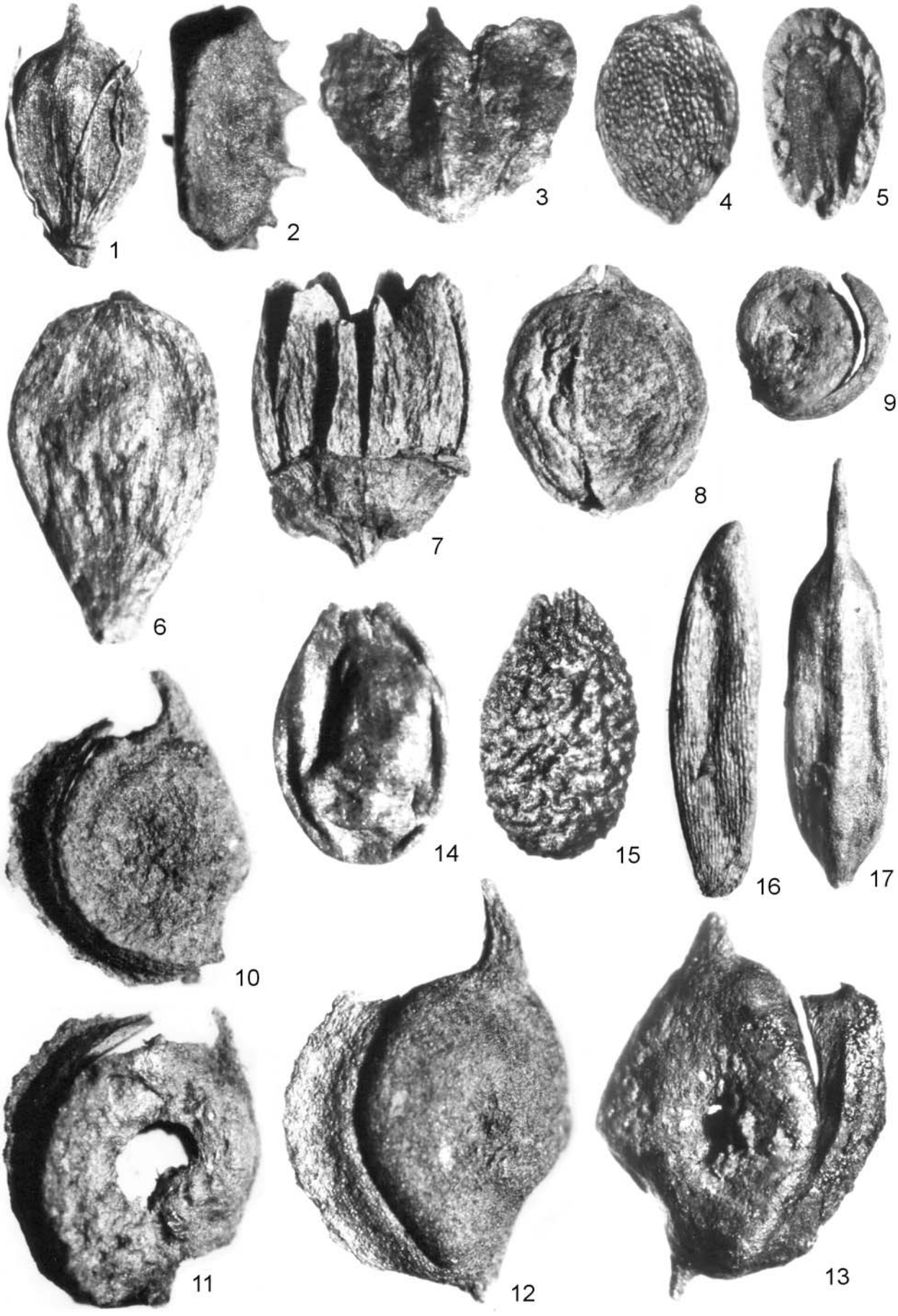
Plate 3

1. *Carex blysmoides* Dorof., fruit, × 25, KRAM-P 240/67b
2. *Myriophyllum subspicatum* Wieliczk., endocarp, × 25, KRAM-P 240/15
3. *Myrica borysthenica* Dorof. & Wieliczk., fruit, × 25, KRAM-P 240/83a
4. *Ranunculus pusillus* Dorof., fruit, × 25, KRAM-P 240/116b
5. *Lycopus pliocenicus* Dorof., fruit, × 25, KRAM-P 240/173a
6. *Scirpus liratus* Dorof., fruit, × 25, KRAM-P 240/60a
7. *Spiraea gomeliana* Dorof., fruit, × 10, KRAM-P 240/132a
8. *Tilia tenuicarpa* Dorof., fruit, × 10, KRAM-P 240/144a
9. *Potamogeton parvulus* Dorof., endocarp. × 20, KRAM-P 240/36c
10. *Potamogeton dyginoides* Dorof., endocarp, × 20, KRAM-P 240/29a
11. *Potamogeton perforatus* Wieliczk., endocarp, × 20, KRAM-P 240/37a
12. *Potamogeton felixii* Dorof., endocarp, × 20, KRAM-P 240/30a
13. *Potamogeton praemaackianus* Wieliczk., endocarp, × 20, KRAM-P 240/39a
14. *Nymphaea pallida* Dorof., seed, × 25, KRAM-P 240/109b
15. *Sambucus pulchella* C. & E. M. Reid, seed, × 25, KRAM-P 240/179a
16. *Caulinia palaeotenuissima* Dorof., seed, × 25, KRAM-P 240/49b
17. *Carex paucifloroides* Wieliczk., fruit, × 25, KRAM-P 240/65b

Phot. A. Pachoński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