Additions to the Pliocene flora of Gérce
(Western Hungary)

A gércei pliocén flóra

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(3 figures, 1 table, and 4 plates)

Abstract

Oil shale deposits at Gérce contain well preserved macroflora of Pliocene age. Recent excavations yielded diversified assemblage of mostly broad-leaved deciduous mesophytic vegetation dominated by oaks and elms. Newly recovered plants include also Ginkgo, Torreya, Sassafras, Celtis, Engelhardia, Pterocarya, Rosa, Crataegus beside others. Megafossil assemblage is well comparable with the pollen flora except for the overrepresentation of the Pinaceae in the latter.

Összefoglalás

A gércei pliocén korú olajpala gazdag makroflórát tartalmaz. A legutóbbi gyűjtések során egy többnyire széles levelű, lombhullató fajokból álló, viszonylag nagy diverzitású növényegyüttes került elő. Ebben a mezofita jellegű vegetációban a tölgy és a szil uralkodó. A hazai pliocénre számos új taxon került elő: Ginkgo, Torreya, Sassafras, Celtis, Engelhardia, Pterocarya, Rosa, Crataegus, valamint több más csoport. A makroflóra adatok jól egyeznek a pollenflórával, kivéve a Pinaceae jelenlétét illetően, mely a pollenspektrumban uralkodó mennyiségben van jelen.

Key words: Pliocene, flora, maar, basaltic volcanism, Hungary

Introduction

In the summer 1993 a short-term intensive field work in the clay pit of alginate (Alginit Co. Ltd.) between the villages Gérce and Sitke (Fig. 1.) was undertaken to continue collections of the late E. HORVÁTH. He first recovered this site and deposited...
the material in the Savaria Museum in Szombathely. *Fischer & Hably (1991)* based the first account on this collection and described geological setting of the site as well as the leaf fossils belonging to 21 angiosperms. In the following paper we add more than 20 other species identified so far (see Table 1).

![Fig. 1. Location of the paleobotanical site.](image)

**The Plio-Pleistocene basaltic volcanism in the Pannonian Basin and the formation of alginite**

Plio-Pleistocene alkaline basaltic volcanic products occur in several parts of the Pannonian Basin (Fig. 2):

1. Graz Basin
2. Little Hungarian Plain (LHP)
3. Balaton Highland
4. Nógrád-Gömör
5. Perșani Mountains

An isolated occurrence of alkaline basalts can be found near Timiș. In addition to these areas Late Miocene alkaline basalts are known in Burgenland (Austria) and in the southwestern part of the Great Hungarian Plain. A small occurrence of ultrapotassic rock has been described near the village of Bár (southern part of the Pannonian Basin; *VicziaN, 1965; Szederkényi, 1980; Harangi et al., in prep.*). Detailed studies of the

Formation of the alkaline basalts has close relationship with the tectonical evolution of the Pannonian Basin. The Miocene to Quaternary subduction at the northern to eastern margin of the Pannonian Basin initiated a back-arc type extension behind the subduction zone. This resulted in the thinning of the lithosphere and the upwelling of the hot asthenospheric mantle (EMBEY-ISZTIN 1976, 1981). SZABÓ et al. (1992) suggested that the alkaline basaltic volcanism occurred during the cooling phase of the mantle diapir and was associated with the uplifts and the tectonic rejuvenation of the area. The basaltic products originated by small degree of partial melting of the mantle and show predominantly less differentiated character. They consist of ol-tholeiites (Late Miocene volcanics in Burgenland), alkaline olivine basalts, basanites, and nephelinites (EMBEY-ISZTIN et al. 1985; 1993; SZABÓ et al., 1992). A weak correlation between the age of the basalts and their chemistry appears as an alkali enrichment and an increasing silica-undersaturation in the younger volcanic products (SZABÓ et al., 1992). Basanites with higher normative nepheline content can be found mainly in the peripheral parts of the Pannonian Basin (Graz Basin, Nógrád-Gömör and Perșani Mts.; SZABÓ et al.,
Detailed geochemical descriptions of the Plio-Pleistocene basalts can be found in MAURITZ (1948), JUGOVICS (1976) and EMBEY-ISZTIN et al. (1985, 1993). The basalts appear mainly as lava flows, while pyroclastic deposits are characteristic of the Little Hungarian Plain. In the latter area basaltic magmas penetrated into the wet Pannonian clastic sedimentary sequence yielding frequent explosive eruptions. The mantle and lower crustal xenoliths are often enclosed in the basalts (EMBEY-ISZTIN 1976; KUBOVICS et al., 1985, 1989; EMBEY-ISZTIN et al., 1989; SZABÓ & VASELLI, 1989; DOWNES et al., 1992).

The Plio-Pleistocene alkaline basalts of the Pannonian Basin show porphyritic texture with predominantly olivine and less clinopyroxene phenocrysts. The Nógrád-Gömör basanite contains clinopyroxene phenocrysts with aegirine-augitic cores implying magma-mixing process (DOBOSI, 1989). The groundmass consists of basic plagioclase, clinopyroxene, olivine, magnetite and glass in variable amount. In the more silica-undersaturated volcanic rocks nepheline, analcime and leucite also occur. Olivine, clinopyroxene and spinel megacrysts can be frequently found in the basalts.

The volcanic formations are well dated by detailed K/Ar radiometric dating studies (BALOGH et al., 1982, 1986) from 11.5 to 0.71 Ma.

Fig. 3. Basalt and basaltic tuff regions in the central part of the Pannonian Basin. (Transdanubian Region, Little Hungarian Plain and Balaton Highland). (After BALOGH K. et al., 1982.)

The oldest volcanic products are the ol-tholeiites of Burgenland, while the youngest ones can be found in the Persani Mts. (Mihailă & Kreuzer, 1981; Pécskay et al. 1992) and in the Nógrád-Gömör area (Mihaliková & Simová, 1989).

The volcanic activity in Transdanubia

In the central part of the Pannonian Basin (Little Hungarian Plain and Balaton Highland) more than 100 individual volcanic centres have been recognized (Jugovics, 1969, 1972), (Fig. 3). In the Little Hungarian Plain the basaltic volcanoes are underlain by Pannonian clastic sedimentary series. The volcanic activities started with explosive eruptions that resulted in generally fine-grained phreatomagmatic deposits at 6 Ma. They were followed by rhythmic Strombolian-type and phreatomagmatic pyroclastic products in several parts of the Little Hungarian Plain (Gérce-Sitke, Kemenesmagos, Vásárosniskó, Egyházaszkésző, Várkesző, Pula). The basal pyroclastic layers are covered by thick lava flows only at four localities (Somló, Kissomlyó, Hercseghegy, Sághegy). The volcanism in the LHP terminated at 3 Ma (Balogh et al., 1986). The basalts differ geochemically from each other. The Sitke-Hercseghegy basanites show the most primitive composition with stronger silica-undersaturation and higher incompatible trace element content than the alkali olivine basalts of Sághegy and Somló.

Genesis of the alginite

Inner parts of the tuff-rings of the Little Hungarian Plain and Balaton Highland are filled by alginite, first described at Pula by Jambor & Solti (1976) and Solti (1987). So far, four volcanic craters, i.e. (Pula, Gérce, Várkesző, and Egyházaszkésző) have been recognized, which contain alginite and are associated with basalt-bentonite (Fig. 3). Water of the 5 to 10 m deep lakes in the tuff-rings, where the alginite and basalt-bentonite were deposited, was rich in nutrients and had high trace element content due to special circumstances of sedimentary deposition. The lacustrine, dominantly fine-grained sediments accumulated exclusively from the weathered material of inner walls of the tuff-rings. In these pelitic deposits huge amount of remains of planktonic algae (diatoms, Botryococcus accumulated (Nagy, 1976). Calcipelite and dolopelite were deposited due to bacterial activity (Jambor & Solti, 1976). Quiet sedimentation and seasonal rhythmicity resulted in finely bedded, laminar deposits. However, earthquakes often associated with volcanic activities and mud-slidings from steep crater walls caused disturbances in the otherwise quiet basins (e.g. at Gérce). Such development has been corroborated also by petrological studies (Ravasz, 1976). The sedimentary infill is usually laminated. Average thickness of a lamina is 0.5 mm, while the thickness of the whole sequences ranges from 25 to 70 m. Considering these values, Jambor & Solti (1976) estimated 50,000 (Pula) and 140,000 (Gérce) years for the crater lakes to be filled. The radiometric age of the basalts from the Hercseghegy Hill at Gérce is 4.55 Ma, while the basalts underlying the alginites of Pula are 3.92 to 4.28 Ma old (Balogh et al., 1986). These ages can be accepted also for the formation of the alginites, where a rich macroflora was found. The stratigraphic position and radiometric age of the volcanic rocks prove the age of the flora. It is the first Pliocene macroflora in Hungary.
Depositional conditions, preservation of fossils

A few days of collecting at Gérce yielded more than 400 plant fossils including leaves, fruits and seeds. All the specimens are kept in the palaeobotanical collection of the Hungarian Natural History Museum in Budapest. In the clay pit the oil shale, called alginite for high content of algae (Botryococcus), is excavated for agricultural purposes. The section is well accessible in the thickness of about 3 to 5 m. The fossiliferous layers are interbedded within the complex irregularly. The composition of plant assemblages varies from one layer to another.

Leaf fossils are widely scattered, mostly not damaged, preserved as coaly compressions, exceptionally as small foliage shoots (Zelkova, Carpinus, Quercus). Winged fruits occur less frequently. More compact fruits or seeds have been recovered very rarely. Some leaf compressions bear cuticular membrane that may curl up in more coriaceous fossils after drying (Ginkgo, Buxus) or become completely destroyed (Quercus) if not preserved in wet state. Two procedures have been employed for preparations of cuticles. Before maceration samples have been cleaned in hydrofluoric acid. The routine treatment in Schulze solution has been good for coriaceous fossils only. Hydrogene peroxide with small additions of kalium-hydroxide has been used in other cases, but only with limited success.

Flora

Although pollen spectra (NAGY, 1992) include pteridophyte spores, no megafossils have been recovered so far. Except for Laevigatosporites hardtii, other form genera of fern spores have been recorded in very low amounts.

Gymnosperms have been recovered as rare accessories in megafossil assemblage Ginkgo (Pl. 1, Figs. 1–2.), Cupressaceae (Pl. 1, Fig. 3.), Tsuga and Pinus. The pollen spectra include much abundant record of conifers with dominant Pinuspollenites labdacus and some other form taxa referred to Abies, Picea, Keteleeria or Sciadopitys, and also Tsuga, Taxodiaceae-Cupressaceae as well as Ginkgo. Dicotyledons are most abundant and belong to several families. Fagaceae (Quercus kubinyi, Q. roburoides, Quercus sp. div. (Pl. 1, Figs. 4–5) and Ulmaceae (Ulmus ruszovensis, Ulmus sp. div., Zelkova zelkovifolia (Pl. 1, Fig. 6.), rare Celtis, (Pl. 1, Fig. 7) are well represented. Frequent accessories of the flora are representatives of Buxaceae (Buxus plicenica), Salicaceae (Populus populina (Pl. 1, Fig. 8.), Populus sp., Salix sp.), Betulaceae (Carpinus grandis, fruits of the C. betulus (Pl. 2, Fig. 1) and C. orientalis types (Pl. 2. Figs. 2–3.), Betula). Quite rare are Juglandaceae (Pterocarya (Pl. 2, Figs. 4–6.), cf. Caryia (Pl. 2, Fig. 7.), Engelhardia orsbergenisis, (Pl. 3, Fig. 1.), Juglandaceae sp. (Pl. 3, Fig. 2.), Rosaceae (Rosa (Pl. 3, Fig. 3.), Crataegus (Pl. 3, Fig. 4.)), Hamamelidaceae (Parrotia pristina (Pl. 3, Fig. 5.)), Aceraceae (Acer pseudomonspessulanum (Pl. 4, Figs. 2–3), A. cf. palaeosaccharinum (Pl. 4, Fig. 4.), Acer sp. (Pl. 3, Fig. 8.)) and Lauraceae (Sassafras ferretianum (Pl. 4, Fig. 1.)). Several other leaf fossils may represent Leguminosae, Ericaceae (Pl. 3, Fig. 6.), Vitaceae and other so far not specified dicotyledonous groups as well as monocotyledonous (Cyperaceae (Pl. 3, Fig. 7)). Pollen spectra correspond well with the above listed taxa of arboreal flora.
However, pollen of some more genera have been recorded: *Alnus*, *Corylus*, *Ostrya*, *Fagus*, *Liquidambar*, *Magnolia*, *Tiliaceae* (*Intratriporopollenites instructus*), *Juglans*, *Nyssa* and *Myrica*. Non-arboreal element is much less diversified (e.g. *Chenopodipollis*, *Nympheaeapollenites*, *Tubulifloridites*, *Droseridites teste* NAGY 1992) and not recorded as megafossils.

Monocotyledons are preserved as leaf fragments, which cannot be identified to genera. Rare fruits belong to Cyperaceae (Table 1). According to NAGY (1992) pollen of monocots (*Sparganiaceaepollenites*, *Graminidites*) is present in low quantities throughout the section.

**Comparison with Neogene European floras**

In Hungary there are no other more completely studied floras of Pliocene age (MAGYAR & HABLY, 1994). The Late Miocene (Pannonian) sites, e.g. Rudabánya (KRETZOI et al., 1974), Iharosberény, Tiszapalkonya (HABLY, 1992a), Tihany (HABLY, 1992b), and other localities from W Hungary (HORVÁTH, 1961, 1963, 1964, 1971—72, 1987) show little similarities in floristic composition, although physiognomically the assemblages are mostly broad-leaved deciduous, like the flora of Gérce. The above mentioned floras, except that from Tihany, reflect swampy environment of the Pannonian. The typical association of this time was *Byttneriophyllum tiliaefolium–Alnus cecropiaeifolia–Glyptostrobus europaeus*. The Lower Pannonian localities (e.g. Rudabánya) show more diversified assemblages with additional *Osmunda*, *Ginkgo*, *Cercidiphyllum*, cf. *Sassafras*, *Liquidambar*, *Banisteriaecarpum*, *Acer* div. sp., *Nyssa*, *Byttneriophyllum*, *Ulmus*, *Zelkova*, *Celtis*, *Carpinus*, *Betula*, *Alnus*, *Quercus* div. sp., *Daphnogene*, *Engelhardia*, *Pterocarya*, *Salix* div. sp. The Tihany locality is of Late Pannonian age. The composition suggests rather the riparian forest dominated by *Platanus leucophylla*, *Liquidambar europaea*, *Cedrela sarmatica*, *Smilax weberti*, *Alnus ducalis*, *Populus* div. sp., *Juglans acuminata*. In contrast to all these localities the Gérce flora includes mostly mesophytic elements (*Ginkgo*, cf. *Juniperus*, *Quercus kubinyii*, *Zelkova*, *Acer* div. sp., *Rosa* etc.). Some of them appear in the Hungarian Tertiary for the first time (*Torreya, Buxus pliocenaica*). It is note worthy that some floras of the Hungarian Sarmatian e.g. Erdőbénye (ANDREÁNSZKY, 1959) are much alike. These similarities are to large extent due to analogous environment. The zonal vegetation in both periods are comparable with warm temperate, hardwood forests with very low percentage of subtropical elements. While the Sarmatian floras include still *Tetraclinis*, *Podogonium*, *Daphnogene* and other evergreen Lauraceae, the only more therophilous element in Gérce appears *Engelhardia*.

The paleogeographical changes during the Miocene–Early Pliocene could largely influence the development of the flora. The Sarmatian time was characteristic of large regressions and extensive volcanic activity. Such a situation gave rise to numerous localities where mesophytic vegetation widely spread. The Pannonian lake favored the expansion of swampy conditions, which caused ecological changes in plant cover. The Early Pliocene volcanoes in Western Hungary were again suitable sites for preservation of mesophytic vegetation. This may explain the analogy between the Sarmatian and Early Pliocene floras in Hungary. The typical association of *Quercus kubinyii–Zel-
kova–Ulmus–Parrotia–Carpinus–Populus persisted from the Sarmatian to Early Pliocene, but impoverished by extinction of the above listed thermophilic elements.

In contrast to most Late Neogene floras, Fagus is not represented (except for rare pollen record) in Gérce. This feature connects this flora with Late Pliocene of Hajnácká South Slovakia (SITÁR et al., 1989). Both localities have much in common (Ginkgo, Torreya, Quercus roburoides etc.). The younger age of the Hajnácká flora may be seen in additional woody plants (e. g. Tilia platyphyllos L.) and lack of thermophilous elements.

In West Europe we find comparable but much more diversified floras of Pliocene age at Willershausen or Frankfurt am Main, which are dominated by other hardwood genera, e.g. Fagus, but not by oaks and elms as it is the case of Gérce. We can also notice a great similarity with the locality Domansky Wierch (ZASTAWNIK, 1972) as already suggested by FISCHER and HABLY (1991).

It is very difficult to find floristic discrimination in the Late Miocene–Early Pliocene time interval, which would not be influenced by edaphic conditions. Also the comparison between the floras, which are characterized either by leaves or fruits and seeds respectively, is difficult or even misleading. The climatic changes must have been negligible at that time to influence large-scale migrations of floristic elements.

Acknowledgements

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Plate I

1. Ginkgo adiantoides (UNG.) HEER, 93.131.1.
2. Ginkgo adiantoides (UNG.) HEER, 93.236.2.
3. Cupressaceae, 93.244.2.
4. Quercus sp., 93.16.2.
5. Quercus sp., 93.5.2.
7. Celtis sp., 93.157.2.
8. Populus populina (BRONGN.) KNOBL., 93.60.2.
Plate I
Plate II

1. *Carpinus betulus* L. type, 93.4.1.
2. *Carpinus orientalis* MILL. type, 93.126.1.
3. *Carpinus orientalis* MILL. type, 93.18.1.
4. *Pterocarya paradisiaca* (UNG.) ILJ., 93.23.1.
5. *Pterocarya paradisiaca* (UNG.) ILJ., 93.249.1.
Plate II
Plate III

1. Engelhardia orsbergensis (WESS. et WEB.) JÁHNICHEN et al., 93.282.1.
2. Juglandaceae, 93.98.1.
3. Rosa sp., 93.257.2.
4. Crataegus sp., 93.9.2.
5. Parrotia pristina (ETT.) ŠTÚR, 93.71.1.
7. Cyperaceae, 93.281.2.
8. Acer sp., 93.29.2.
Plate IV

1. *Sassafras ferretianum* MASSALONGO, 93.267.2.