STOP 2: Pula, alginite mine

Pliocene Pula Alginite Formation, plant and vertebrate remains

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The young volcanism of the Pannonian Basin

Young (Pliocene-Pleistocene) basaltic volcanites are represented in different areas in the Pannonian Basin. Among these the most important volcanic units which cover larger areas are the following ones: 1. Graz Basin, 2. Kisalföld, 3. Balaton Highlands, 4. Nógrád-Gömör, 5. Persány Mountains. Besides these, several appearances in smaller areas are known in Burgenland, in the southern and middle part of the Alföld and in the vicinity of Temes and Bár villages. The individual areas were described in several works (Jugovics, 1969, 1972; Jámbor et al., 1981).

The age of the rocks is known through K/Ar radiometric age determinations (Balogh et al., 1982, 1986), morever, there is information about the occurrences beyond Hungary. According to these data the age of the rocks ranges between 11.5 – 0.71 Ma, the oldest are those in Burgenland, the youngest are the ones in the Persány Mountains, the occurence near Bár, the rocks in Temes and a few of the samples from Nógrád-Gömör.

The Transdanubian basalts and basaltic tuffs are present in two main areas, where almost a hundred eruption centra can be distinguished (Jugovics, 1969, 1972). The basaltic volcanoes are placed on a ground surface irregularly eroded in the Pannonian, with various basements which are usually Permian sandstones, Triassic carbonates or Pannonian pebbly, sandy, clayey beds (Jugovics, 1969). Among the volcanic structures there are mounts consisting of only lava flows, of only pyroclastics, and mixed ones built up of both. A frequent form of appearence of the volcanic edifices consisting of only dispersed material is the tuff ring (for example the areas between Gérce and Sitke, at Kemenesmagos, at Vásárosmiske, at Egyházaskesző and at Várkesző), and a similar structure is the tuff ring near Pula (figs. 1, 2).

The age of the basalts in the Balaton Highlands and in the Kisalföld is 2-5 and 3-6 Ma (Balogh et al., 1986) thus belonging to the middle phase of the basaltic volcanism of the Pannonian Basin. The age of the basalt building up the floor of the Pula Maar is 3.92-4.28 Ma (Balogh et al., 1986).

The formation of the alginite

Some part of these tuff rings is filled with alginite, which was discovered in 1973 in connection with the Pula occurence (Jámbor & Solti, 1976; Solti, 1987). Presently four maars are known which are filled with alginite together with the coincident basaltic bentonite (Pula, Gérce, Várkesző, Egyházaskesző).

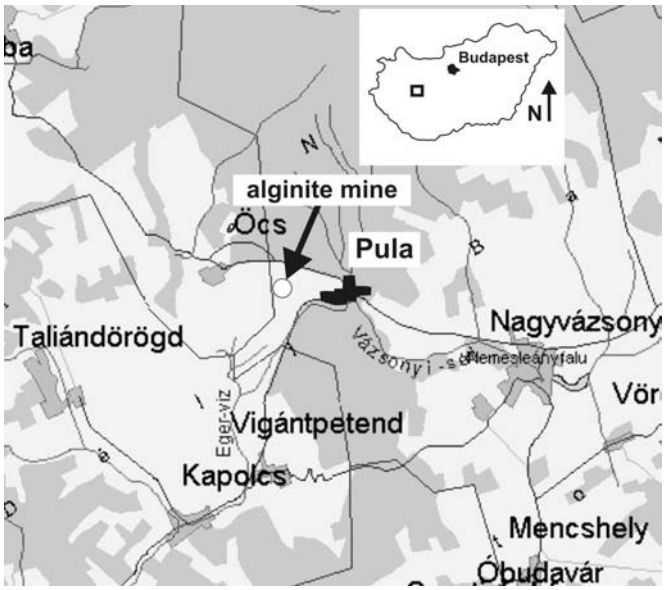

Fig. 1 — Location of the Pula alginite pit in western Hungary.

The alginite (and the basaltic bentonite) was deposited in the former crater lake enclosed by the tuff ring. In the 5-10 meters deep water rich in nutrients and trace elements special sedimentational circumstances were developed. Practically no material was transported into the lake from the outside thus the sediment was rapidly degrading pelitic (at Gérce sometimes sandy) grain-sized material eroded from the inner side of the crater. This was accompanied by the remains of algae (diatomes and *Botryococcus*) living in great profusion in the water of the crater lake, and by calci- and dolopelite formed by bacterial activity (Jámbor & Solti, 1976). As a result of still sedimentation and annual seasonal periodicity finely laminated sediment was formed. Considering the average 0.5 mm layer thickness and the 25-70 meters total thickness of the beds the existence time of the crater lakes

can be estimated at 50,000 (Pula) and 140,000 (Gérce) years (Jámbor & Solti, 1976). In contrast, Willis et al. (1999a, b) indicated 320,000 years for the duration of the Pula crater lake. In addition they demonstrated that „internally driven non-linear responses of the climate system at a period of 124000 years were at least as important as external forcing at the orbital frequencies of precession and obliquity in driving Late Pliocene large-scaled environmental change" (Willis et al., 1999b). The calm sedimentational circumstances were only interrupted by earthquakes related to the volcanic activity and by frequent mudslides as a consequence of the steep inner walls. The results of these can be observed in the Gérce alginite mine at many places.

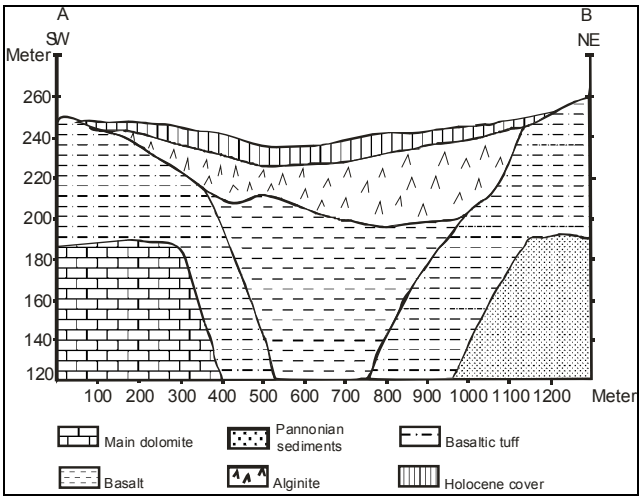

Fig. 2 — Geological schematic profile of the Pula alginite mine (after Solti, 1987).

The flora, vegetation, and climate of Pula

The exposed Gérce and Pula localities yield a rich leaf flora together with some winged carpoliths and very rarely compact carpoliths (Fischer & Hably, 1991; Kvacek et al., 1994; Hably et al., 1996, 1997a, b, 1998). The preservation of the leaves in the fine-grained alginite at Gérce is excellent while at Pula the better preserved imprints can be found in the calcareous, hard overburden of the alginite. Cryptogamous plants were not found and among gymnosperms only *Ginkgo adiantoides* (Unger) Heer is represented by remains with cuticule. From angiosperms the Fagaceae with *Quercus kubinyii* (Kováts et Ettinhausen) Czetzott, *Q. pseudorobur* Kováts and *Q.* div. sp., the Ulmaceae with *Zelkova zelkovifolia* (Unger) Bůžek & Kotlaba and Ulmaceae gen. et sp. are dominant. The Salicaceae has a great role in the flora, one of the two occurring species of *Salix* is dominant, and *Populus balsamoides* Göppert and *Populus* cf. *tremula* L. are also present. The Betulacea is known in the flora only through the genus *Carpinus*. As a rare accessory element leaf remains of *C. grandis* and besides the winged carpolith of *C. neilreichii* Kováts were also found. Further accessory elements are *Acer pseudomonspessulanum* Unger, *Buxus pliocenica* Saporta et Marion, *Crataegus* sp., *Dicotylophyllum* sp.1., *Dicotylophyllum* sp.2., *Dicotylophyllum* sp.4., Monocotyledonae gen. et sp. and cf. *Paliurus tiliifolius* (Unger) Bůžek.

On the basis of the composition of the flora a mesophyllic woodland vegetation composing of broadleaf deciduous trees can be visualized. The vegetation can be regarded as zonal vegetation living near the crater lakes but independent from the water of the lakes, while the traces of edaphic vegetation are also present. This is mainly due to the fact that most remains are from the overburden beds which represent the closing phase of the lakes.

The average annual mid-temperature calculated from the plant remains was 10-13°C and the average annual precipitaton was maximum 1,000 mm or less. Annual interim dry periods also can be also suggested, this is indicated by the small average size of the leaves, the presence of some xerophytic species and some morphological characters.

The vertebrate fauna of Pula

The mining started at Pula in 1973 but the first important vertebrate remains were discovered only in 1983.

Fish remains were discovered in large numbers from several levels of the mine. Their conservation is a great problem because the structure of the alginite changes as the rock dehydrates, it exfoliates along the layer surfaces similarly to newspaper and it moulds thus completely destroying the remains. For the preservation of the fish remains the resinous conservation method known from Germany can be used. According to this method one side of the fossil is completely prepared and cleaned, then a plasticine wall is erected around the fossiliferous piece of rock and it is filled with resin. After the resin hardened the other side is also prepared, cleaned and spilled with resin. This way the whole skeleton is completely embedded in resin in its original position and can be examined from both sides.

The composition of the fish fauna is monotonous, the most common and characteristic remains are species of the Percidae (fig. 3). From among these *Perca fluviatilis* L. and two other species, *Perca* sp.1. and *Perca* sp.2. can be determined. The family Cyprinidae

is represented by large specimens of *Leuciscus* sp. Cuvier (Pászti, 2003, 2004). The family Gobiidae is known through *Gobius* sp. from the locality. The fish remains can be found in several levels but in a few layers they are more accumulated. No signs of orientation can be evidenced. In addition to complete fish skeletons isolated vertebrae, scales and partial skeletons can be collected.

Fig. 3 — Fish remain from Pula.

Besides fishes several rhinoceratid remains (*Diceroрhinus megarhinus* (de Christol) Loose) were discovered. In 1983 an almost complete skeleton of this species was found. The find was transported to the Zirc Natural History Museum where it is housed up till present. The Cervidae, the Suidae and the Bovidae (Bovidae indet.1 and indet.2 cf. *Parabos*) families are also represented and fossilized feathers were found. The exact taxonomic determination still requires more material (Kordos, 1991, 1993). The large mammals presumably represent the strongly filled up swamp state in the development of the crater lake, where the animals entering far from the shore might have died in larger numbers (Kordos, 1991, 1993).

The fish remains support the hypothesis which suggests that the lake was fresh-water and the average annual temperature of the water was 10-12°C. Regarding the sedimentation, calm, undisturbed sedimentational cycle can be concluded since articulated, almost complete fish remains can be found and traces of bioturbation cannot be observed.

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