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The earliest Sabiaceae fruit remains of Hungary

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(with 2 figures, 1 table and 1 plate)

Numerous well-preserved plant-remains were discovered at the Upper Cretaceous Iharkút vertebrate fossil site (Csehbánya Formation, Bakony Mts., Hungary). A well determinable, but rare mesofossil form belongs to the Sabiaceae family. The internationally excellent Cenozoic fossil record makes the family of special phytogeographical and palaebotanical interest. Based on endocarp morphology we assigned the Iharkút specimens to *Sabia menispermoides*. These characters are also typical for the recent *Sabia* genus. KNOBLOCH and MAI described *Sabia menispermoides* from the Cretaceous of České Budějovice in 1986 as *Sabia* because of the high similarity to the recent forms. The now living Sabiaceae plants are trees, shrubs and lianas. The known representatives of the family are members of the subtropical and tropical vegetations in Asia and America. Their presence at Iharkút indicates subtropical climatic conditions of the vertebrate locality.

Introduction

The Hungarian Sabiaceae mesofossils are of interest because their widespread representation from the Upper Cretaceous of Central Europe. RÁKOSI mentioned Sabiaceae fossils from the Hungarian Upper Cretaceous (RÁKOSI pers. observation). He described presumably *Insitiocarpus* related fossils from the Ajka Coal Formation; from the 453,4-495,5 m depth of Gy-9 and 613,7-628,3 m depth of Kf-1 drillings. Both depths were determined as the Hungaropollis D pollen zone what was correlated to CC17 Nannoplanctonic Zone. From the Lower Eocene of Eurasia and North America fossilised Sabiaceae endocarps and leaf-imprints are common. Neither fossil flowers nor pollen data are known (GENTRY 1980, WANNTORP & DE CRENE 2007, BERTINI & MARTINETTO 2011).

Sabiaceae is a well-known angiosperm family of the tropical and neotropical flora.The recent Sabiaceae is a family of three genera (*Meliosoma, Sabia, Ophicaryon*) and about 80 species (GENTRY 1980). The family represents two developmental lineages; *Meliosoma* is related to Sapindaceae, Hippocastanaceae and Anacardiaceae, while *Sabia* is related to Menispermaceae, Icacinaceae and Schisandraceae (BEUSEKOM 1971). The recent representatives of Sabiaceae are trees, shrubs and lianas, these life forms are suggested for the fossil forms, too (CHANDLER 1964). The fruits of Sabiaceae are single seeded; drupaceous or consisted of two partially fused drupaceous carpels. The exocarp is fleshy, endocarp more or less woody, sometimes conspicuously sculptured. The seeds contain only a little or no endosperm (GENTRY 1980). This hard endocarp makes the fossilisation potential of the fruits high.

From the Upper Cretaceous of Central Europe three Sabiaceae fructification genera are known *Insitiocarpus* KNOBLOCH & MAI, *Meliosoma* BLUME and *Sabia* COLEBROOKE. The nine species of these genera are from in Walbeck, Eisleben (Germany), Březinka and České Budějovice (Czech Republic). The stratigraphic range of these fossils starts at the Cenomanian, but most of them are known from the Maastrichtian. Only one species was mentioned from the upper Turonian and Santonian (Table 1). From the Ha□eg Basin (Romania) three taxa (named as Taxon 6, 9 and 17) were published which shows similarities to the Sabiaceae family, but the determination needs

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more detailed studies (LINDFORS et al. 2010).

The studied well preserved specimens are providing additional information about the Upper Cretaceous spread area of the family and gives direct information about the vegetation of Iharkút vertebrate locality.

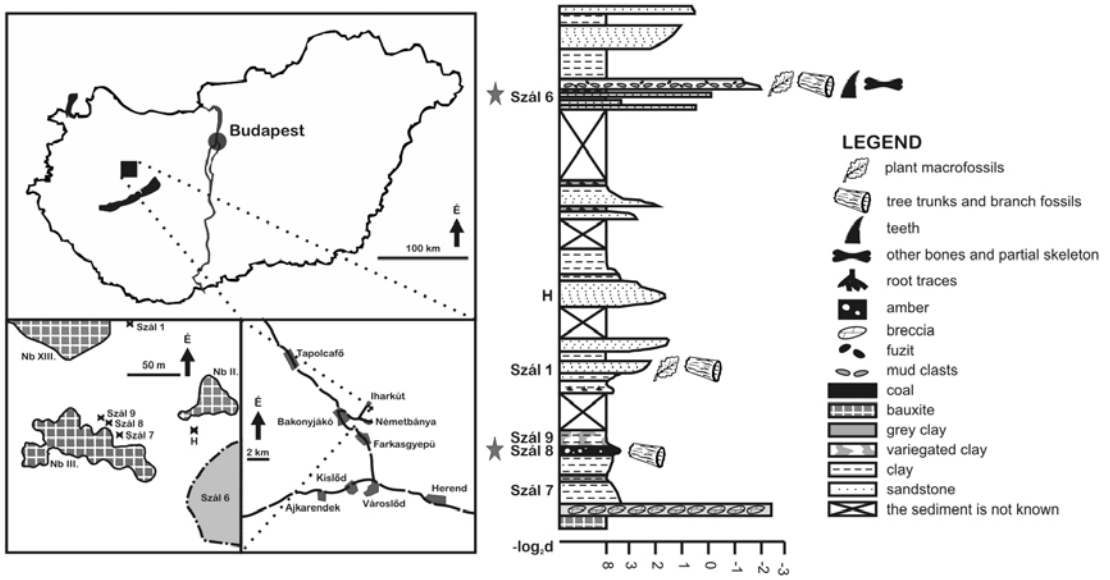

Fig. 1. The map of Iharkút locality and the stratigraphic column. The layers where *Sabia* endocarps were found are marked with grey star.

Geological background

The examined mesofossils were found in the washed material from the Iharkút locality of Upper Cretaceous (Santonian-Campanian) Csehbánya Formation in the Bakony Mts, Hungary. The locality is famous for its vertebrate remains. It is exposed in abandoned Iharkút open-pit bauxite mine near the villages of Bakonyjákó and Németbánya (Fig 1). The formation is formed by variegated clay, silt with interbedded grey and brown sand, and sandstone beds (JOCHA-EDELÉNYI 1988). At the locality several fluvial channel deposit were detected, and the sedimentology of the layers suggest also the presence of floodplain units (TUBA et al. 2006; ŐSI & MINDSZENTY 2009). Thousands of vertebrate remains were unearthed during the last 10 years, not only fish, amphibians, turtles, lepidosaurs, crocodiles, but also new dinosaur, pterosaur and bird species were described from the locality (ŐSI et al. 2005; MAKÁDI et al. 2006; ŐSI & RABI 2006; ŐSI et al. 2007; Gulyás 2008, ŐSI 2008; ŐSI et al. 2010; SZENTESI & VENCZEL 2010A, 2010B, 2012, RABI et al. 2011; DYKE & ŐSI in press, ŐSI et al. in press). Geochemical investigation on bones showed the freshwater habitat of the vertebrate fossils (KOCSIS et al. 2009).

The palynoflora of Iharkút is an angiosperm dominated assemblage, dominated by the *Normapolles* group. The palynological assemblage is referred to the *Oculopollis zaklinskaiae-Tetracolporopollenites* (*Brecolpites*) *globosus* Zone (or Zone "C") of the palynological zonation of GÓCZÁN (1964) indicating the upper Santonian age of the assemblage. That correlated to the CC16 nannoplankton zone (SIEGL-FARKAS & WAGREICH 1996). Not only palynomorphs appear, but also mesofossils and macroremains (DULEBA 2008; BODOR & BARANYI, 2012) The mesofossil association is dominated by a presumably Normapolles related form *Sphaeracostata barbackae* BODOR & BARANYI (represented by almost 1000 specimens), Magnoliaceae fossils are the second most common forms, *Discosemen*- and *Operculispermum*-like flat forms are also very common mesofossils of Iharkút.

Material and methods

The studied mesofossils were extracted from the sediments by sieving. The dry sediment was washed at the site using 2.00 mm, 1.00 mm and 0.32 mm mesh sizes. One layer was sampled since 2005 (szál 6; the bone bed type strata) another layer (szál 8) since 2006 and two more layers (szál 7 and szál 9) since 2008. From these only two sampling layers (szál 6 and szál 8) contained Sabiaceae mesofossils in two years (2005 and 2008). The now examined fossils were less than 1% of the fossils from those years. In Szál 8 2008 material 110 seeds and fruits were examined and only one *Sabia* was found, the percent of 2005 Szál 6 samples is almost the same: 780 mesofossils were studied and 7 *Sabia* were found. This 8 specimens are less than 0.3% of the total studied material, but representing a clearly determinable angiosperm group, new to the locality.

The endocarps are black and coalified. Sand grains often adhere to the surface of the seeds, these were removed by hydrofluoric acid (40 %). Scanning electronmicroscopical (SEM) studies were carried out with S-2660N microscope at the Department of Botany, Hungarian Natural Historical Museum. The endocarp was mounted on aluminium- stubs and sputter coated with gold-palladium using a Polaron SC7520 Mini Sputter Coater.

For the mesofossil determination the Knobloch Collection (National Museum Prague, Czech Republic) was studied. The preservation of the holotype made the SEM studies on that specimen impossible.

Systematics

Family Sabiaceae
Genus *Sabia* COLEBROOKE 1819
Sabia menispermoides KNOBLOCH et MAI 1986
Text fig.: 2.a. Pl. 1 Figs: 1; 2; 4.

1986 *Sabia menispermoides* – KNOBLOCH et MAI, Monographie der Früchte und Samen in der Kreide von Mitteleuropa, p. 105. Taf. XXIV, Fig 21-25.

Holotype: published by Knobloch et Mai 1986; pl. 24 fig. 21, stored in the National Museum Prague No. NMP F03674 (pate I. Fig. 3.)

Type horizon: Klikov Formation, Late Cretaceous (late Turonian– Santonian)

Type locality: borehole České Budějovice, Budvar 148,5m

Material: Eight well preserved, flattened coalified specimens. Iharkút SEM Tracer 1/1 and Szál8/2008 1; Szál6/2005 1-7. All material owned by the Hungarian Natural History Museum, Botanical Department, Palaeobotanical Collection.

Description: The fossils are obovoid, ellipsoidal to almost semicircle shaped. The size is circa 2,2 mm in diameter. The studied specimens are generally 2 mm long, 1.5 mm wide. The surface ornamented with shallow, crater-like pits. The pits are arranged regularly; forming two concentric semicircles (Plate 1, Figs 1-2). There are 13-17 holes in the outer circle and 7-9 in the inner circle. One bean-shaped crater is on every specimen in the centre of the two semicircles. The dimensions of the outer circle pits are 100-150 µm, in the inner circle 200-250 µm. The bean-like crater is 600 µm long and 100 µm wide. The entire surface is microgranulated. Microgranulae are in 5-10 µm in size. The craters are filled with sediment on the holotype, but in the case of the Iharkút specimens were cleaned, and the bigger microgranulae size was detected in the holes (Plate 1. fig. 3). There is a not well preserved funicle region presumed at the margin in the line of the bean like crater. Based on this endocarp morphology a drupaceous fruit is suggested.

Discussion: Almost every known recent *Meliosoma* species have endocarps larger than 1 cm (GENTRY 1980). The *Meliosoma idiopoda* is smaller (0.6-0.8 mm in diameter), but has a smooth surface. The Cenozoic *Bognoria* genus was also described as Sabiaceae, but the only known specimen has smooth surface (CHANDLER 1964). From the Pliocene the genus *Cicer* was described, which is similar to the examined form having a keel running in a rather pronounced break, but has no other surface ornamentation. Also, it is three times larger than the studied fossils (SZAFER 1946). Several *Meiosoma* species were described from the Paleogene and Neogene, most of them from the famous London Clay flora, but these usually have smooth surface. The *Meliosoma rigida* is an exception, described from the Pliocene of Japan; it has no sunken ventral pore and surface holes. But the number of the surface pits is only

six (GENTRY 1980). The *Sabia menispermoides* is most similar to the recent *Sabia parviflora* WALL & ROXB. (LAW & WU 1982). However, as in the case of all recent Sabiaceae, endocarp and size are quite different. The recent *S. parvifolia* is five times larger as the *S. menispermoides*. Both forms have excentrically ordered polygonal surface structures. This kind of size increase was detected at the Cretaceous-Paleogene boundary in several localities and plant groups (TIFFNEY 1984, ERIKSSON et al. 2000, ERIKSSON 2008, LINDFORS et al. 2010).

The Cretaceous Sabiaceae fossils are usually doubtful because the hylum, chalaza and funicle region are rarely preserved. The *Insitiocaprus* fossils are quite similar to each other and also to the not well preserved *Operculispermum* and *Discosemen* species. The examined specimens are similar to these fossils in size, shape and flatness, but the surface ornamentation and marginal situation of the funicle region makes clear its relation to *Sabia* genus. All Cretaceous Sabiaceae endocarps are smaller than the recent and Cenozoic forms, all are under 1 cm (Table 1). The holotype of *S. menispermoides* was re-examined; the same surface ornamentation was detected. The holotype is a bit larger (2.5 mm long and 2.1 mm broad), but that variability could be intraspecific variability (Fig. 2.).

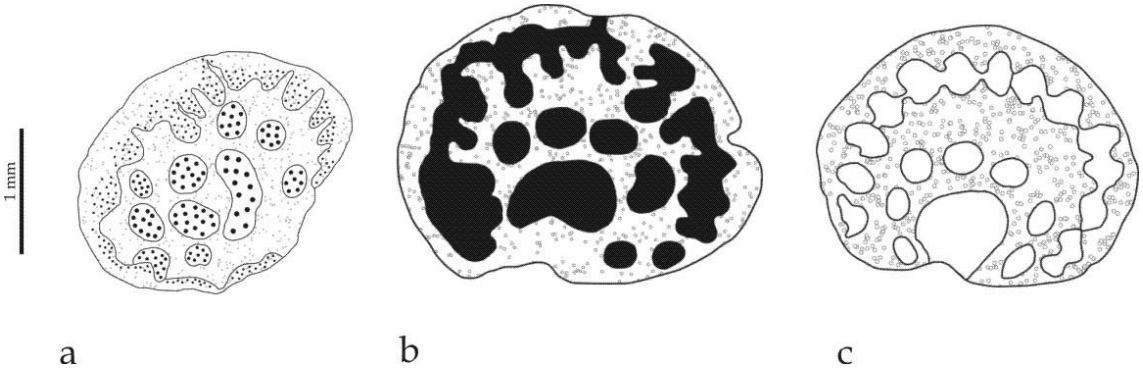

Fig. 2. Schematic drawings of the *Sabia menispermoides* specimen from Iharkút (a), the holotype (b) and the schematic drawing of the species (c). The dots symbolize the microgranulated surface, the black regions on the holotype are covered by sediment.

Table 1. Morphology of the Sabiaceae fruits of the Central Europeean Upper Cretaceous and their stratigraphic range.

NAME	AGE	SIZE	SHAPE	SURFACE
Insitiocarpus compressus Knobloch & Mai 1984	Maastricthian	3.3-3.4 mm in diameter	Obovoid, flat	1-2 ribs
Insitiocarpus microverrucosus Knobloch et Mai 1986	Maastrichtian	4.4 mm in diameter	Obovoid-rounded, flat	Around undulating
Insitiocarpus moravicus Knobloch et Mai 1986	Cenomanian	1.8-2 mm	Rounded, flat	A channel running round, small dotted surface
Insitiocarpus rugulatus Knobloch et Mai 1986	Maastrichtian	2.5 mm	Ovoid, spherical, thick	Irregular ribs and big pearls
Meliosoma praealba Knobloch et Mai 1986	Maastrichtian	2.2 mm	Spherical, almost rounded	With a concave ventral side and oval pore there
Sabia menispermoides Knobloch et Mai 1986	upper Turonian Santonian	2.5 mm	Ovoid, half-round shaped, flat	Intensively ornamented with eccentrically situated polygonal holes. In the middle part not ornamented.
Sabia microsperma Knobloch et Mai 1986	Maastrichtian	1.3-1.4 mm	Ovoid, flat	Eccentrically ordered shallow ridges, only one keel is well pronounced
Sabia praeovalis Knobloch et Mai 1986	Maastrichtian	4-7.5 mm	Ovoid, strong, thick walled	Irregular net like structure. The area of the funicle is often concave.

Palaeoecological interpretation

The recent Sabiaceae plants are living in the tropical and subtropical areas of Asia according to the Gentry Transect Dataset, BEUSEKOM 1971. LAW YUH-WU & WU YOUNG-FEN 1982, DENG YOU-FEI & GOU LI-XIU 2007, WANNTORP& DE CRAENE 2007and typical for the tropical areas of America (STEINMAN 2007). The family consists of trees shrubs and lianas, what confirms the assumed subtropical floodplain forest vegetation at Iharkút (HABLY pers. comm., BODOR & BARANYI, 2012.). The family is a member of the 154 ones, which were used in developing the paleoclimate model based on the Gentry Forest Transect Dataset of the Missouri Botanical Garden. This method could not be used at Iharkút to determine the palaeotemperature and precipitation because the taxonomical affinity of several mesofossil morphospecies not known. That makes impossible the use of the family climatic optima method, too (PUNYASENA 2008).

Conclusion

The palynological age determination of Iharkút locality makes doubtless that *Sabia menispermoides* is the earliest known Sabiaceae fossil of the country. The other possibly Sabiaceae-related fossils are from younger palyno-horizons (RÁKOSI and SIEGL-FARKAS pers. comm). During the recent investigations detailed morphological description of the species was given based on the first SEM studies of this species and the re-examination of the holotype at the Knobloch Collection.

About the endocarp morphology was also ascertainable that the *Sabia* genus shows almost no changes through the last almost 89 million years, except the size differentiation recognisable at the Cretaceous Paleogene boundary what is detectable in several localities and plant groups (ERIKSSON 2008, LINDFORS et al. 2010).

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Plate 1

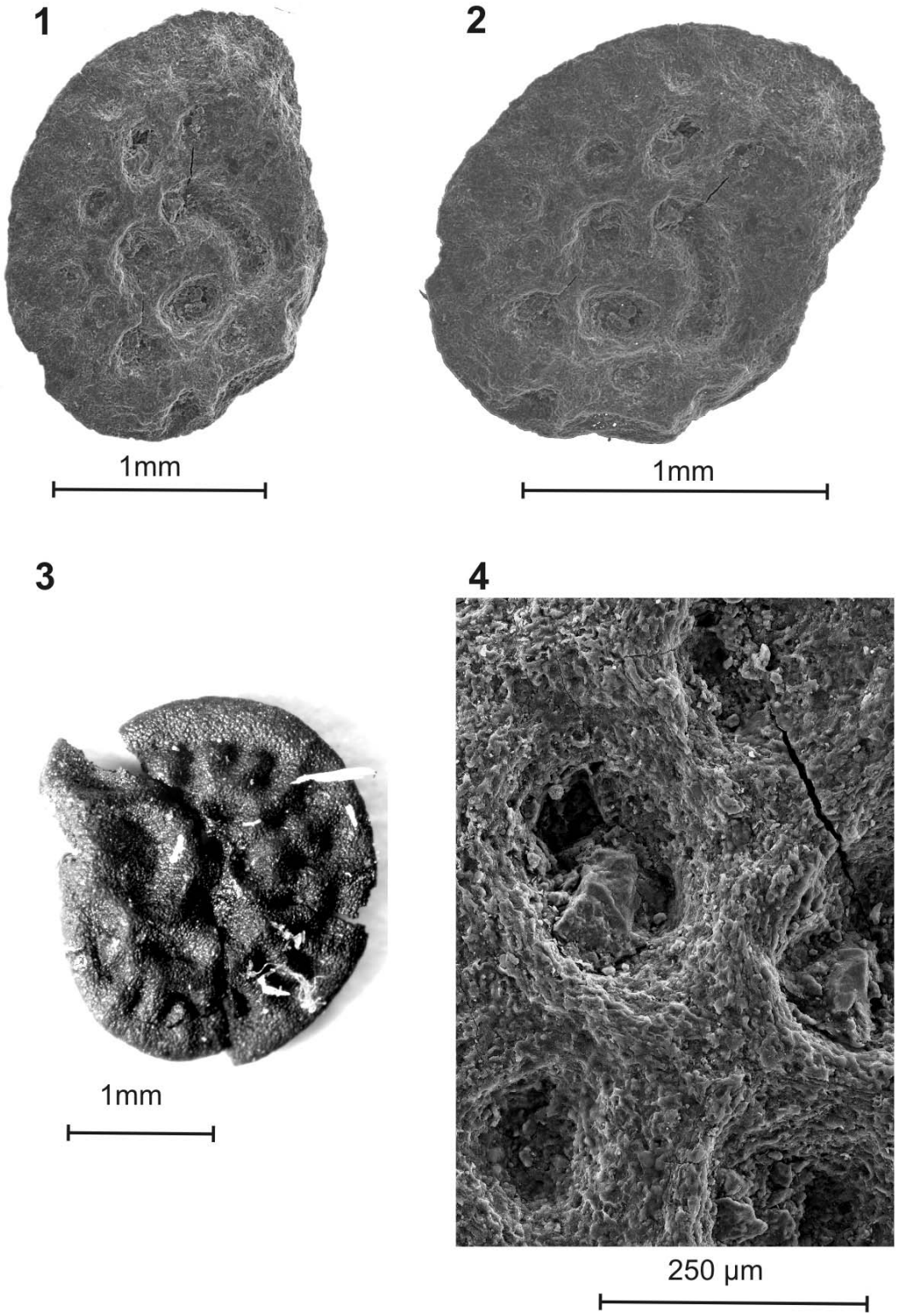

Fig. 1. *Sabia menispermoides* KNOBLOCH et MAI 1986 general SEM picture Iharkút SEM Tracer 1/1 2008/Szál8
Fig. 2. *Sabia menispermoides* KNOBLOCH et MAI 1986 general SEM picture Iharkút SEM Tracer 1/1 2008/Szál8
Fig. 3. *Sabia menispermoides* KNOBLOCH et MAI 1986 general light microscopic picture of the Holotype from Knobloch Collection *F0764*
Fig. 4. *Sabia menispermoides* KNOBLOCH et MAI 1986 SEM picture about the surface details. Iharkút SEM Tracer 1/1 2008/Szál8