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The gastropod fauna from the opalite of the late Miocene Lake Tschaterberg (Austria)

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Freshwater
Gastropoda
Miocene
Opalite

Contents

Abstract

The mollusk fauna of the opalite of the Tschaterberg region close to Kohfidisch in Burgenland (Austria) is re-evaluated. The assemblage is low diverse, comprising only lymnaeids, planorbids and four parautochthonous helicid gastropod species. The ecological requirements of the genera indicate a pure freshwater setting in a short-lived, shallow lake or pond with rich reed vegetation and peat formation. Stratigraphically, a correlation with the upper Pannonian (upper Miocene) is most likely, excluding any chemical influence on opalite formation by Dacian volcanism. Thus, the opalite-lake existed contemporaneously with the famous early Turolian mammal fauna from Kohfidisch, which is correlated with the European Mammal Zone MN 11.

Die Gastropoden Fauna des Opalits vom spätmiozänen Tschaterberg-See (Österreich)

Zusammenfassung

Die Molluskenfauna des Opalits der Tschaterberg Region nahe Kohfidisch im Burgenland (Österreich) wird neu evaluiert. Die Vergesellschaftung ist gering divers und umfasst lediglich lymnaeide und planorbide Gastropoden neben vier parautochthonen heliciden Schneckenarten. Die ökologischen Erfordernisse der Gastropoden verweisen auf ein reines Süßwasserhabitat eines kurzlebigen, seichten Sees oder Tümpels mit reicher Schilfvegetation und Torfbildung. Stratigrafisch ist eine Korrelation mit dem oberen Pannonium (spätes Miozän) sehr wahrscheinlich, was einen chemischen Einfluss auf die Opalitbildung durch dazischen Vulkanismus im Pliozän ausschließt. Der Opalit-See existierte daher zeitgleich mit der berühmten Turolium-Säugetierfauna von Kohfidisch, die mit der europäischen Säugetierzone MN 11 korreliert wird.

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Introduction

The locality Tschaterberg (Csaterberg, Csartherberg = Tschater Mountain) in the vicinity of Kohfidisch in Burgenland Province (SE-Austria), close to the Hungarian border, is famous for its opalite occurrences. Although the rock is largely unusable for jewellery production, the silicified wood found in the opalite is very well preserved, of high quality and has attracted collectors already in the Early Modern Period. First scientific descriptions date back even to the 16th century when Carolus Clusius (1526–1609) described fossil wood from Tschaterberg in his *Rariorum aliquot Stirpium per Pannoniam* (Clusius, 1583: 10). Eighteen years later, he repeated the description in his *Rariorum Plantarum Historia* (Clusius, 1601: 20), adding 1580 as year of collecting. His surprisingly modern descriptions represent the first explicit references to fossils from the territory of modern Austria. The geological setting was investigated much later by Hoffmann (1877). In his geological survey, Benda (1929) already tried to interpret the genesis of the opalite as result of geysers. First modern investigations of the silicified wood from the Tschaterberg region were published by Felix (1884) and Hofmann (1928, 1929). Additional paleobotanical data were provided by Kümel (1957), Müller-Stoll & Mädel (1957, 1959) and Pavlicek (2009). A comprehensive paper discussing the geological setting, mineralogy and genesis of the opalite and its fossils was published by Kümel (1957). Kümel (1957) rejected the “geysers-hypothesis” of Benda (1929) and suggested that the opalite formed as precipitation from an acidic spring, chemically fed by the underlying serpentinite. Thereafter, only small guidebook notes were published by Sauerzopf et al. (1990) and Pahr (2000), more or less repeating the results of Kümel (1957). The last synthesis summarizing also the recent (mainly collectors) literature dealing with the mineralogy of the Tschaterberg opalite was published by Götzinger & Pristacz (2009), who provided powder X-ray diffraction data on the chemical composition of the various opalite types. A detailed overview about the history of research of the Tschaterberg opalite was compiled by Horváth (1973).

Whilst the plant fossils have been repeatedly investigated, the associated mollusk fauna was only cursorily men-

Text-Fig. 1.
Geographic setting of the investigation area; map generated with Google Earth, Image © 2017; image taken in 6/9/2017).

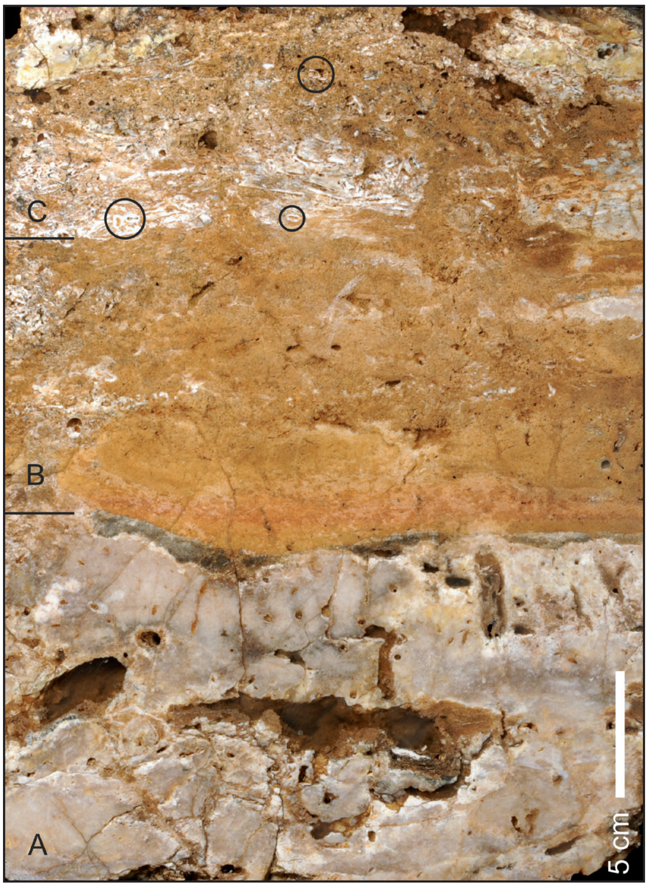
tioned by Benda (1929) and Kümel (1957). Benda (1929) mentioned *Helix, Pupa* and *Planorbis* and Kümel (1957) listed *Cepaea* (*Megalotachea*) sp., *Planorbis* (*Anisus*) cf. *confusus* Soós and *Limnaea* sp. Most probably, both authors referred to the same taxa: *Helix* sensu Benda (1929) = *Cepaea* (*Megalotachea*) sp., *Pupa* sensu Benda (1929) = *Stagnicola* sp. and *Planorbis* sensu Benda (1929) = *Anisus* cf. *confusus* Soós. The age of the opalite is difficult to assess. Benda (1929) assumed a Pleistocene age, whereas Kümel (1957) interpreted a Miocene age based on the mollusk fauna and the presence of taxodiacean wood. More recently, Sauerzopf et al. (1990) and Pahr (2000) speculated about a relation with Dacian volcanic activity during the Pliocene.

Herein, we try to re-evaluate the taxonomic composition and paleoecology of the mollusk fauna of the opalite and try to achieve more precise age constraints.

Geological setting and structure of the opalite

The Kohfidisch-Tschaterberg region is part of the Penninic Rechnitz Unit, which is represented here mainly by serpentinite and greenschist of the Eisenberg crystalline (Gratzer, 1985). These are surrounded and partly overlain by Neogene clay, silt and sand of late Miocene age (Kümel, 1957). The opalite forms three isolated occurrences, resting on the serpentinite, arranged along a c. 2 km long, roughly W–E trending line (see map in Kümel, 1957). The two main occurrences are found on the Klein Tschater (365 m a.s.l.) and the Hoch Tschater (341 m a.s.l.) (Text-Fig. 1). These two hills are the southwestern foothills of the Eisenberg (= Eisenberg Mountain).

Kümel (1957) identified four types of opalite within the Tschaterberg occurrence, which were mineralogically analysed by Götzinger & Pristacz (2009). The spatial relation of these opalite types, however, was unknown (Kümel, 1957; Götzinger & Pristacz, 2009). Similarly, the thickness of the opalite layer was unclear. To shed light on these problems, several large opalite blocks were excavated during a sampling campaign in 2018. The blocks were cut perpendicular to the bedding plane in the laboratory of the Natural History Museum Vienna (NHMW). The largest block is about 40 cm thick and displays a succession of opalite types (Text-Fig. 2), which was also found in other blocks from the Hoch Tschater (although the thickness of the layers is highly variable). The original orientation of the blocks was reconstructed based on internal erosive boundaries and on cavities of roots and stems crossing the observed layers. The basal layer of the illustrated block represents an about 15 cm thick, whitish, glossy and dense opalite composed of up to 70 % C-T-Opal and various amounts of quartz (Götzinger & Pristacz, 2009) (Text-Fig. 2A). Numerous tube-like cavities, which represent dissolved stalks of reed or comparable plants, characterize this layer. Kümel (1957) classified it as "silicified moss-peat". Locally, the layer passes into brownish, glossy and dense opalite with dissolved stalks. Mineralogically this opalite type is dominated by C-T-Opal (75–100 %) (Götzinger & Pristacz, 2009). This type was classified by Kümel (1957) as "silicified gyttja". A sharp erosive boundary with relief of up to 5 cm separated the lower opalite layer from an about 10 cm thick, granulose-porous, brownish, lustreless layer of goethite and quartz (Text-Fig. 2B). This type was classified by Kümel (1957) as "silica-iron gel". This layer passes without sharp boundary into another, about 10 cm thick layer of granulose-porous, brownish, lustreless opalite with lenses of porcelaneous opalite composed of about 40 % C-T-Opal and large amounts of quartz (Götzinger & Pristacz, 2009) (Text-Fig. 2C). These intercalations were classified as silicified leave-moss-peat by Kümel (1957) occurring within a gyttja matrix. Although mollusks are found in all layers, the basal part of the third layer is especially rich in lymnaeids and planorbids, which lie parallel to the bedding plane. The described thicknesses are variable and the described opalite succession may be a rather local phenomenon.



Text-Fig. 2.
Cross-section of the opalite, showing three different layers of opalite type (NHMW 2019/0031/0005). Note the cavities in the lower layer, which represent dissolved stalks preserved *in situ*. Circles indicate lymnaeid and planorbid gastropods.

Material

The herein analysed samples were collected in 2018 at the Tschaterberg in the forest area west of the small chapel around the position 47°10'31.30" N, 16°23'38.32" E. None of the samples occurred in-situ but as isolated blocks in the forest soil. In addition, the private collectors Peter Schebeczek (Pellendorf, NÖ) and Josef Kroiher (St. Florian, OÖ) provided samples from their private collections. Aragonite shells of the gastropods are completely dissolved and usually only partly replaced by silica. Typically, only the internal surface of the shells is preserved, which lack any sculptural details. Partial internal moulds are frequent as well. In rare cases, casts of the external shell surface are available. These cavities were filled by a two-component dental-silicone to allow identification. All material is stored in the paleontological collection of the Natural History Museum Vienna.

Systematics

Subclass Heterobranchia Burmeister, 1837

Superorder Hygrophila Férussac, 1822

Superfamily Lymnaeoidea Rafinesque, 1815

Family Planorbidae Rafinesque, 1815

Genus *Anisus* Studer, 1820

Type species: *Helix spirorbis* Linnaeus, 1758. Recent, Europe.

Anisus confusus Soós, 1934

Text-Fig. 3: Figs. 1–4, 9

1929 *Planorbis* sp. – Benda, p. 38.

*1934 *Anisus* (*Anisus*) *confusus* n. sp. – Soós, p. 194, Fig. 5.

1955 *Planorbis* (*Anisus*) *confusus* Soós – Bartha & Soós, p. 64, Pl. 5, Figs. 1–4.

1957 *Planorbis* (*Anisus*) cf. *confusus* Soós – Papp in Kümel, p. 8.

non 1953 *Planorbis* (*Anisus*) *confusus* Soós – Sauerzopf, p. 53, Pl. 2, Figs. 1a–c.

non 2004 *Anisus confusus* Soós 1934 – Harzhauser & Binder, p. 12, Pl. 4, Figs. 7–10.

Material: One opalite slab with numerous specimens (NHMW 2019/0054/0002).

Discussion: This is the most frequent gastropod in the opalite from Tschaterberg. *Anisus confusus* is characterized by its tightly coiled whorls, convex periphery and prominent growth lines. The largest specimen at Tschaterberg attains a diameter of about 8.5 mm, which is smaller than fully grown specimens from the type locality Öcs (12 mm) and from Balatonszentgyörgy in Hungary as described by Soós (1934) and Bartha & Soós (1955). A comparison of whorl diameter increase during ontogeny between *A. confusus* from Tschaterberg with a fully-grown specimen described by Bartha & Soós (1955) from Balatonszentgyörgy reveals a nearly identical mode of growth. Other alleged occurrences of *Anisus confusus*, mentioned by Sauerzopf (1953) and Harzhauser & Binder (2004) from Eichkogel (Vienna Basin, Austria) and Königsberg-Hannersdorf (Burgenland, Austria), differ in their distinctly smaller size and wider coiling. These differences were already discussed by Wenz & Edlauer (1942), who nevertheless identified the Eichkogel specimens as *A. confusus*. Especially the erroneous identification of specimens from Königsberg-Hannersdorf by Sauerzopf (1953) might have led Papp in Kümel (1957) to identify the Tschaterberg specimens as *A.* cf. *confusus*, because the upper Pannonian marl and limestone of Königsberg-Hannersdorf occurs only 5 km north of Tschaterberg. As the Königsberg-Hannerdorf and Eichkogel planorbids are most probably not conspecific with *Anisus confusus*, the correlation of the Tschaterberg opalite with the Eichkogel fauna by Papp in Kümel (1957) was based on a misidentification.

Only a small number of late Miocene to Recent *Anisus* species have been described so far. A morphologically similar species is the late Pannonian *Anisus krambergeri* (Halaváts, 1903), which differs in its distinctly angulated periphery (see Bartha, 1954, 1959; Schlickum, 1978; Fordinál, 1998; Harzhauser & Binder, 2004). The middle Pannonian *Anisus brunnensis* Sauerzopf, 1953 attains 9 mm in diameter and might be closely related to *A. confusus.* Based on the description in Sauerzopf (1953), it seems to differ only in its slightly tighter coiling and less convex whorl tops. The Tortonian *A. falsani* (Locard, 1883) from the Bresse-Valence Basin in France is smaller (max. diameter = 5 mm) and whorls widen faster. *Anisus komarovae* Prysjazhnjuk, 1974 and *A. bondartchuki* Prysjazhnjuk, 1974, from the Tortonian (Bessarabian–Khersonian) of Ukraine, are even smaller and differ in their relatively narrower whorls. The extant *A. vortex* (Linnaeus, 1758) and *A. leucostoma* (Millet, 1813) and the Pliocene *A. mariae* (Michaud, 1862) all differ in their flattened whorl tops on the apical side. The extant *A. spirorbis* (Linnaeus, 1758) is distinctly smaller (< 6 mm in diameter), and *A. septemgyratus* (Rossmässler, 1835) is much more narrowly coiled with hardly widening last whorl.

Ecology: *Anisus* species are obligate freshwater dwellers, which can build up a large population size within a year. The animals live in standing and slowly running waters of periodical and very small water bodies, in periodic swamps and even in moist meadows with rich vegetation; most species tolerate periods of drought (Glöer & Groh 2007; Welter-Schultes, 2012). The genus displays a wide range of pH-tolerance; e.g., *Anisus spirorbis* occurs in acidic ponds, whereas *A. vortex* appears also in alkaline waters (Spyra, 2017).

Stratigraphic and geographic distribution: *Anisus confusus* is restricted to the lower part of the upper Pannonian Transdanubian substage sensu Sacchi & Horváth (2002), roughly spanning an interval from 8.9–8.0 Ma. Geographically, it is recorded from the Balaton region in the Pannonian Basin (localities Öcs, Balatonszentgyörgy). The records from Orešany and Čel'adince in the Danube Basin (Slovakia) described by Fordinál (1998) might need verification.

Genus *Planorbarius* Duméril, 1805

Type species: *Helix cornea* Linnaeus, 1758. Recent, Europe,

Planorbarius cf. *halavatsi* Neubauer, Harzhauser, Kroh, Georgopoulou & Mandic, 2014

Text-Fig. 3: Fig. 5

cf. 1903 *Planorbis grandis* n. sp. – Halaváts, p. 57, Pl. 3, Fig. 5 [non *Planorbis grandis* Dunker in Küster et al., 1850].

cf. 1953 *Planorbarius grandis* (Halaváts) – Sauerzopf, p. 50, Pl. 1, Figs. 3–4.

cf. 1955 *Planorbarius grandis* (Halaváts) – Bartha & Soós, p. 63, Pl. 5, Figs. 15–17.

cf. 2004 *Planorbarius grandis* (Halavats) – Harzhauser & Tempfer, p. 60, Fig. 5/3.

cf. 2014 *Planorbarius halavatsi* nom. n. – Neubauer et al., p. 26.

Material: One natural cast (NHMW 2019/0054/0003).

Discussion: A single cast is available showing the umbilical side of a large planorbid of about 16 mm diameter and 4.8 mm height. The specimen has a deeply sunken umbilicus and consists of only three slightly flattened teleoconch whorls; the last whorl is missing. The fragmentary preservation does not allow a clear identification. Nevertheless, the available specimen fits well to sub-adult specimens of *Planorbarius halavatsi* from the upper Pannonian of Götzendorf (Austria). This species is characterised by its very large size and flattened whorls (Sauerzopf, 1953; Bartha & Soós, 1955). However, the type material shows a higher whorl expansion rate, which is why we only tentatively affiliate the present material with *P. halavatsi*. The flattened whorls allow a separation from the extant *Planorbarius corneus* (Linnaeus, 1758) and the superficially similar Miocene *P. mantelli* (Dunker, 1848). Specimens of *P. mantelli* (sensu Harzhauser & Binder, 2004) from the upper Pannonian Eichkogel section attain a much larger whorl height at the same growth stage. *Planorbarius margoi* (Lörenthey, 1894) from the late Pannonian of Kurd (Hungary), *P. philippei* (Locard, 1883) from the Tortonian of the Bresse-Valence Basin, *P. praecorneus* (Fischer & Tournouër, 1873) from the Tortonian of the Lower Rhône Basin, as well as the early Pliocene *P. thiollieri* (Michaud, 1855) from the same region all differ from the present species in exposing higher whorl expansion rates and relatively higher whorls. *Planorbarius margoi* moreover has a distinct angulation at the transition of whorl flank and umbilical side.

The present species was originally established by Halaváts (1903) as *Planorbis grandis*. That name is preoccupied by *Planorbis grandis* Dunker in Küster et al. (1850) and therefore, Neubauer et al. (2014) introduced *Planorbarius halavatsi* as replacement name.

Ecology: The extant *Planorbarius corneus* (Linnaeus, 1758) settles standing or slowly moving waters with rich vegetation in wetlands and floodplains and may tolerate periodical droughts. It prefers pH values around 6–9 (all data from Welter-Schultes, 2012). In the Vienna Basin, *Planorbarius halavatsi* was exclusively found in assemblages indicating freshwater wetland lakes (Harzhauser & Tempfer, 2004). The scarceness of *Planorbarius* cf. *halavatsi* in the opalite from Tschaterberg may indicate suboptimal ecological conditions.

Stratigraphic and geographic distribution: The oldest record of this species derives from the upper Pannonian of Götzendorf/Sandberg (southern Vienna Basin). The locality is correlated with the Mammal Zone MN 9 and the Pannonian Zone F sensu Papp (1951), roughly corresponding to an age of 10.0–9.5 Ma (Harzhauser & Tempfer, 2004). Younger occurrences in the Vienna Basin (Rauchenwarth, Schwadorf) are correlated with the Zone H of Papp (1951). Coeval occurrences from the Pannonian Basin in Hungary were described by Halaváts (1903), Strausz (1942) and Bartha & Soós (1955) from several localities in the Pannonian Basin (Balatonfőkajár, Balatonszentgyörgy, Borsosgyőr, Nyárád, Tihany, Tüskevár). These can be correlated with the lower part of the Transdanubian substage sensu Sacchi & Horváth (2002). Thus, the temporal range of *P. halavatsi* is c. from 10.9–8.0 Ma.

Family Lymnaeidae Rafinesque, 1815

Genus *Stagnicola* Jeffreys, 1830

Type species: *Buccinum palustre* Müller, 1774. Recent, Europe.

Stagnicola sp.

Text-Fig. 3: Figs. 6–7

1929 *Pupa* sp. – Benda, p. 38.

1957 *Limnaea* sp. – Papp in Kümel, p. 8.

Material: Six silicone casts (NHMW 2019/0054/0001).

Discussion: Lymnaeids are very abundant in the opalite deposits. Usually only fragments of the spire whorls are preserved, whereas the last whorls are rarely preserved. The species from the opalite is a small lymnaeid of about 14 mm height and 5.5 mm diameter. It is very slender, has a high spire and high whorls with oblique suture. Early spire whorls are relatively convex with distinct suture. These features are reminiscent of the extraordinarily slender *Stagnicola bouilleti* (Michaud, 1855) as reviewed by Schlickum (1970). Already Kümel (1957) discussed in a footnote the similarity of the Tschaterberg lymnaeids with *Stagnicola bouilleti* from the Eichkogel section in the Vienna Basin. *Stagnicola bouilleti*, however, is larger attaining more than 30 mm in height and has a straight columella and very wide basal margin, whereas the most complete Tschaterberg specimen displays a concave and twisted columella. Due to the convexity of early spire whorls, Benda (1929) seems to have misidentified spire fragments as “*Pupa*”, an outdated name often used in old literature for pupilloid terrestrial gastropods.

Ecology: Extant *Stagnicola* species prefer silent waters with rich vegetation and are found in ponds, swamps, temporary water bodies and periodically flooded areas. Some species may also stand periodical droughts (Welter-Schultes, 2012). *Stagnicola* species are found in alkaline and acidic waters but are most abundant under neutral pH-conditions (Spyra, 2017).

Stratigraphic and geographic distribution: The presence of *Stagnicola* has no stratigraphic significance.

Superorder Eupulmonata Haszprunar & Huber, 1990

Superfamily Helicoidea Rafinesque, 1815

Family Elonidae Gittenberger, 1979

Genus *Apula* Boettger, 1909

Type species: *Helix devexa* Reuss, 1861. Early Miocene, Czech Republic.

Apula sp.

Text-Fig. 4: Fig. 10

Material: One spire fragment in opalite, diameter: 9.1 mm (note that the last whorl is missing); collection Stefan Raimann (stored in the Steinmuseum Csaterberg).

Discussion: The single available spire fragment is an internal cast with impressions of the surface sculpture con-

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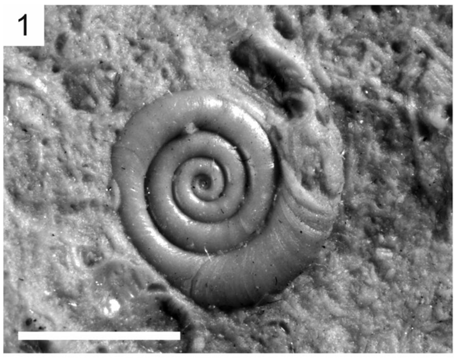

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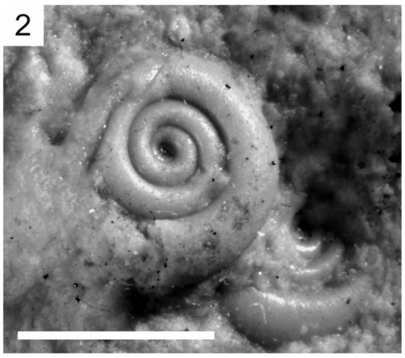

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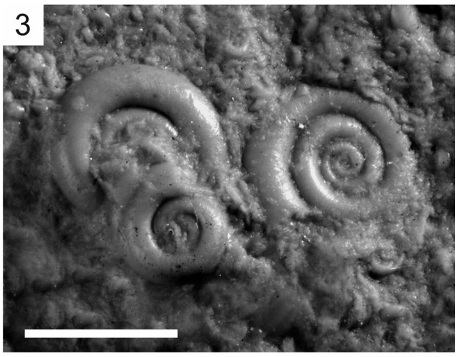

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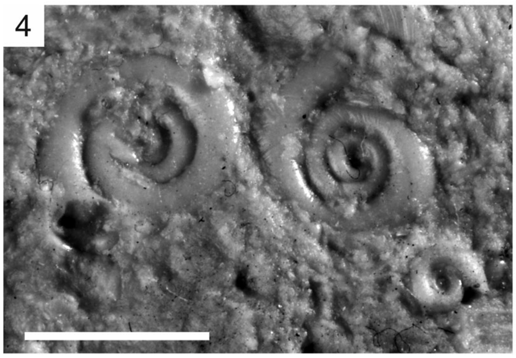

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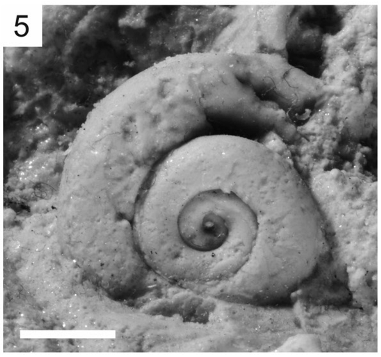

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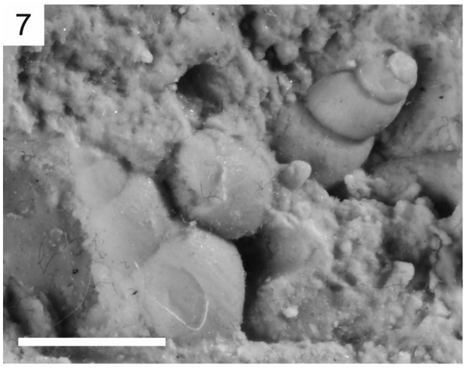

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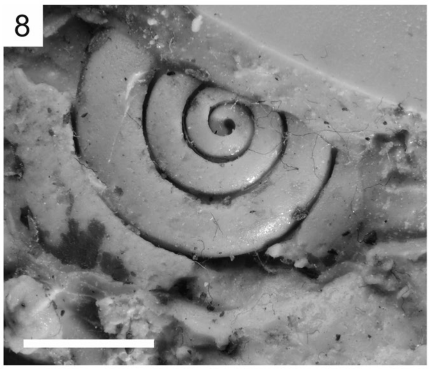

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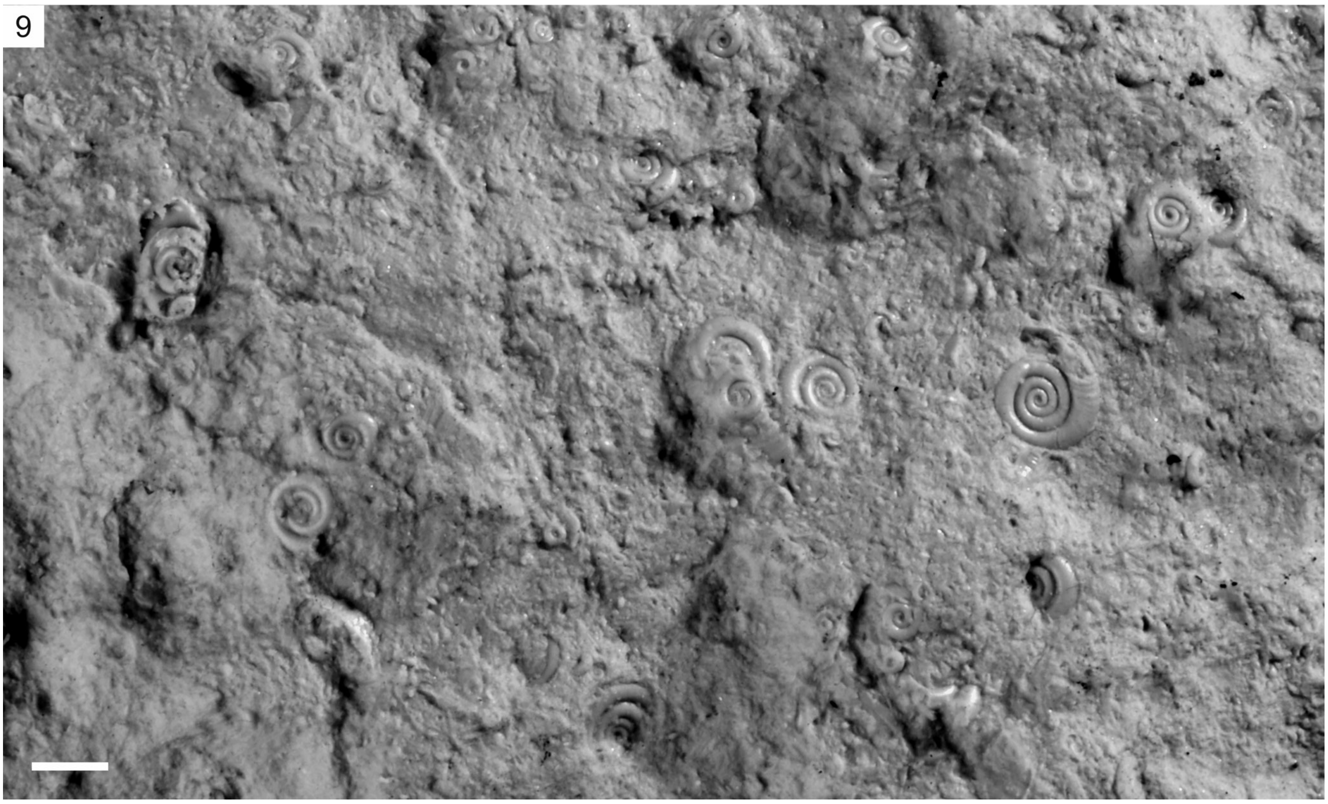

◀ Text-Fig. 3.
Silicone casts of gastropods from the Tschaterberg opalite. Figs. 1–4: *Anisus confusus* Soós, 1934 (NHMW 2019/0054/0002); Fig. 5: *Planorbarius* cf. *halavatsi* Neubauer, Harzhauser, Kroh, Georgopoulou & Mandic, 2014 (NHMW 2019/0054/0003); Figs. 6–7: *Stagnicola* sp. (NHMW 2019/0054/0001); Fig. 8: *Pseudochloritis* cf. *mollonensis* Truc, 1971 (NHMW 2019/0054/0004); Fig. 9: opalite surface showing several *Anisus* specimens parallel to the bedding plane (NHMW 2019/0054/0002); scale bars = 5 mm.

sisting of delicate papillae. This sculpture and the general shape of the narrowly coiled and low conical spire are reminiscent of *Apula goniostoma* (Sandberger, 1872) and *Apula vindobonensis* Harzhauser & Binder, 2004, which were both described from the late Pannonian of the Vienna Basin. These species are mainly distinguished by their peristome morphology and the width of the umbilicus. As both features are missing in the available specimen, an identification is impossible.

Ecology: *Apula* is an extinct genus. The Miocene species are generally associated with assemblages indicating forested wetlands (Harzhauser & Binder, 2004; Harzhauser et al., 2014a, b).

Stratigraphic and geographic distribution: *Apula* species occur throughout the Miocene. The specimen from the Tschaterberg is most probably conspecific with either *Apula goniostoma* (Sandberger, 1872) or *Apula vindobonensis* Harzhauser & Binder, 2004, which indicate a Pannonian age.

Genus *Pseudochloritis* Boettger, 1909

Type species: *Helix inflexa* Zieten, 1832. Miocene, Germany.

***Pseudochloritis* cf. *mollonensis* Truc, 1971**

Text-Fig. 3: Fig. 8; Text-Fig. 4: Figs. 1–3

cf. *1971 *Tropidomphalus* (*Pseudochloritis*) *mollonensis* n. sp. – Truc, p. 275, Pl. 17, Figs. 1–7, 11–14, Pl. 18, Fig. 1.
cf. 1981 *Tropidomphalus* (*Pseudochloritis*) *zelli depressus* Wenz – Lueger, p. 59, Pl. 11, Figs. 1a–b (non Wenz, 1927).
cf. 2017 *Pseudochloritis mollensis* [sic] (Truc, 1971) – Binder, p. 220, Pl. 6, Figs. 1–6.

Material: One natural cast of a spire fragment (NHMW 2019/0054/0004) and one more complete natural internal cast, diameter: 21.3 mm, height: 13.7 mm; collection Günter Baumann (stored in the Steinmuseum Csaterberg).

Discussion: Only internal casts are available showing a medium-sized helicoid of about 22 mm in diameter. One cast shows remnants of a strongly reflected inner lip and a moderately wide umbilicus. The low conical spire consists of five moderately convex whorls, slowly increasing in width, suggesting a relatively tight coiling. The coiling of the Tschaterberg species is reminiscent of *Pseudochloritis* species, such as the Sarmatian/Pannonian *P. gigas* (Pfeffer, 1930) and the Pannonian *P. mollonensis* Truc, 1971 sensu Binder (2017). *Pseudochloritis gigas* differs in its much larger size, whereas specimens of *Pseudochloritis mollonensis* from Götzendorf an der Leitha (Austria) agree in size, outline and umbilical features. Despite this similarity, a clear identification is impossible due to the poor preservation. Recently, Binder (2017) established *Papillotopsis* as new genus for some species formerly placed in *Pseudochloritis* based on their higher spire and typical papillae. Of these, the only Pannonian species, *Papillotopsis richarzi* (Schlosser, 1907), differs from the Tschaterberg species in its higher spire and its last two whorls are broader (see Harzhauser & Binder, 2004; Binder, 2017). *Mesodontopsis* Pilsbry, 1895 is much larger, has less convex whorls, an even flatter spire and the whorls increase rapidly in width (see also Binder, 2016). Some Miocene species of *Megalotachea* Pfeffer, 1930, such as *M. etelkae* (Halaváts, 1923) and *M. bulla* (Lueger, 1981), display a comparable type of coiling but differ in their higher spire.

Ecology: *Pseudochloritis* is an extinct genus. According to Binder (2017), all known species are bound to moist and warm woodland.

Stratigraphic and geographic distribution: *Pseudochloritis mollonensis* was described from the late Miocene (MN 9) of Mollon in France (Truc, 1971). *Pseudochloritis mollonensis* Truc, 1971 sensu Binder (2017) is documented from the late Pannonian of Götzendorf an der Leitha (MN 9), Stixneusiedl (MN 9) and Neusiedl (MN 10) (Binder, 2017).

Family Helicidae Rafinesque, 1815

Subfamily Ariantinae Mörch, 1864

Genus *Agalactochilus* Kadolsky, Binder & Neubauer, 2016

Type species: *Helix leobersdorfensis* Troll, 1907.
Late Miocene, Austria.

?*Agalactochilus* sp.

Text-Fig. 4: Figs. 7–9

Material: One natural internal cast, diameter: 27.6 mm, height: 17.7 mm; collection Günter Baumann (stored in the Steinmuseum Csaterberg).

Discussion: The largest gastropod cast represents a stocky species with wide spire whorls, a high last whorl, which increases in height distinctly towards the aperture, a reflected inner lip and a moderately wide and deep umbilicus. The resulting sub-globose outline is reminiscent of *Agalactochilus* as defined by Kadolsky et al. (2016). Especially the late Miocene *A. leobersdorfensis* (Troll, 1907) agrees in size and outline, but the poor preservation does not allow a clear identification.

Ecology: *Agalactochilus* is an extinct genus. Most species seem to have preferred humid habitats along lakeshores and flood plains (Kadolsky et al., 2016).

Stratigraphic and geographic distribution: The genus is restricted to the Miocene of Europe and becomes extinct during the late Miocene (Kadolsky et al., 2016). Reliable records of *Agalactochilus leobersdorfensis* (Troll, 1907) are described from the middle and late Pannonian of the Vienna Basin (MN 9) (Kadolsky et al., 2016).

Text-Fig. 4.
Internal casts of casts of gastropods from the Tschaterberg opalite. Figs. 1–3: *Pseudochloritis* cf. *mollonensis* Truc, 1971; Figs. 4–6: *Megalotachea* cf. *etelkae* (Halaváts, 1923); Figs. 7–9: ?*Agalactochilus* sp.; Fig. 10: *Apula* sp.; all specimens stored in the Steinmuseum Csaterberg); scale bars = 5 mm.

Subfamily Helicinae Rafinesque, 1815

Genus *Megalotachea* Pfeffer, 1930

Type species: *Helix turonensis* Deshayes, 1832. Miocene, France.

***Megalotachea* cf. *etelkae* (Halaváts, 1923)**

Text-Fig. 4: Figs. 4–6

cf. *1923 *Helix* (*Tachaea*) *Etelkae* Halaváts, p. 403, Pl. 14, Figs. 7a–b.
1957 *Cepaea* (*Megalotachea*) sp. – Papp in Kümel, p. 8.
cf. 1981 *Cepaea* (*Cepaea*) *etelkae* (Halavats) – Lueger, p. 72, Pl. 13, Figs. 1–2, Pl. 14, Figs. 1–7.
cf. 2004 *Cepaea etelkae* (Halaváts 1923) – Harzhauser & Binder, p. 27, Pl. 11, Figs. 20–21 (cum syn.).

Material: One natural internal cast, diameter: 18.5 mm, height; 12.8 mm; collection Günter Baumann (stored in the Steinmuseum Csaterberg). A second internal cast is stored in the Steinmuseum Csaterberg.

Discussion: The two available specimens are characterized by their relatively high, conical spire and a faint angulation of the last whorl. A narrow but deep impression behind the peristome indicates a prominent inner lip. Size and shape agree well with high-spired specimens of *M. etelkae* from the Vienna Basin and from Öcs (Hungary) stored in the NHMW collections (see also Lueger, 1981: Pl. 14, Figs. 4, 6, 7). Nevertheless, a reliable identification is impossible due to the poor preservation.

Ecology: *Megalotachea* is an extinct genus. According to Lueger (1981), *M. etelkae* was a euryoecious species, which preferred moist habitats.

Stratigraphic and geographic distribution: *Megalotachea etelkae* appeared during the early Pannonian and was a common species in the Vienna and Pannonian basins. Its last records in the Vienna Basin derive from "Pannonian H" localities (e.g., Eichkogel, Velm, Schwechat) and from the Transdanubian substage in the Pannonian Basin (Lueger, 1981; Harzhauser & Binder, 2004).

Discussion

The formation of the opalite was interpreted by Kümel (1957) as precipitation from acidic spring water, which attained its silica by dissolution from the underlying serpentinite. Extant *Anisus* and *Stagnicola* both tolerate a wide range of pH-values, ranging from acidic to alkaline lake waters (Spyra, 2017), whereas *Planorbarius* prefers neutral to slightly alkaline waters (Welter-Schultes, 2012). Thus, the rare occurrence of *Planorbarius* would fit to slightly acidic conditions. All taxa are bound to freshwater conditions and avoid brackish waters. Therefore, we reject the interpretation of Kümel (1957), who assumed that the region was a marginal part of brackish Lake Pannon. Instead, the Tschaterberg opalite likely formed in a small pond or lake. Moreover, the western margin of Lake Pannon has already shifted to the Danube Basin at that time (Magyar et al., 2013). Similarly, the mollusk faunas mentioned by Kümel (1957) from the close-by upper Pannonian outcrops at Hannersdorf, lack any Lake Pannon species. The terrestrial mollusks of Tschaterberg are represented by few species of genera, which are all indicative for moist woodland, which is supported by the paleobotanical record comprising Taxodiaceae, Ulmaceae, Betulaceae, Oleaceae, Tilioideae and *Quercus* (Kümel, 1957).

The internal structure of a herein studied block of Tschaterberg opalite suggests at least three different phases with slightly differing ecological conditions. The first phase is represented by a peat bog with moss and reed vegetation. Numerous *in situ* stalks indicate that the silicification took place rapidly, preserving a geological snapshot. Locally, the moss-peat passes into areas in which gyttja accumulated. Planorbids and lymnaeids are found especially in samples with reed vegetation, indicating an autochthonous assemblage with minor time averaging. An interruption of the sedimentation is reflected by an erosional relief separating this first peat bog phase from the overlying layer. This "silica-iron gel" layer is poor in plant fossils and gastropods. Thus, this layer may represent a slightly deeper part of the peat bog at some distance of the reed belt. The increasing amount of leaves and other plant debris in the uppermost layer might indicate a shallowing trend. Especially, the leaf litter is rich in planorbids and lymnaeids. The erosional phase between layer 1 and 2 may either represent a short drying up phase or a change in water chemistry during a water level rise. As no indications for weathering can be found, the latter hypothesis seems to be more realistic. Due to the restricted data availability, however, it remains unclear if this succession is representative for the entire opalite occurrence or a local phenomenon at the Hoch Tschater.

The preservation and low diversity of the mollusk fauna make a reliable dating of the opalite difficult. In the Pannonian Basin, *Anisus confusus* is restricted to the lower part of the Transdanubian substage of the Pannonian, spanning an interval of ~8.9 to ~8.0 Ma (Sacchi & Horváth, 2002). *Planorbarius halavatsi* has a slightly longer range from ~10.0 to ~8.0 Ma. The *Pseudochloritis* group became extinct around the Miocene/Pliocene boundary. Therefore, a late Miocene age of the Tschaterberg opalite is most likely. The opalite lake would thus have been contemporaneous with the famous vertebrate fauna from the close-by Kohfidisch/Kirchfidisch locality, situated about 4 km southwest of the Tschaterberg. That locality represents fossiliferous marly clay in a karstic cave and fissure fillings in Paleozoic limestones and is correlated with the lower Turolian European Mammal Zone MN 11 (Daxner-Höck & Höck, 2015). The late Miocene age clearly excludes any influence of the much younger Dacian volcanism, as hypothesized by Sauerzopf et al. (1990) and Pahr (2000).

Conclusions

The opalite from the Tschaterberg region close to Kohfidisch formed in a small freshwater lake or pond, which was settled by a low-diversity mollusk fauna of planorbids and lymnaeids. Likely, all taxa were adapted to periodic droughts and preferred the vegetated zone of the lake. The opalite displays a threefold internal succession, which might indicate a sequence of establishment of reed vegetation in a very shallow peat bog, a slight increase of the water level coinciding with a decrease in plant fossils and gastropods and a subsequent shallowing with gyttja and peat formation and the development of large populations of lymnaeids and planorbids. The rare terrestrial gastropods indicate a moist and warm forest surrounding the lake.

The fauna suggests a late Miocene age corresponding to the Pannonian Zone H of Papp (1951) and the Transdanubian substage of Sacchi & Horváth (2002). During that time, the western coast of Lake Pannon had already shifted towards the Danube Basin and, therefore, the freshwater lakes that formed in the Tschaterberg, Kohfidisch and Hannersdorf area were hydrologically disconnected from Lake Pannon.

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