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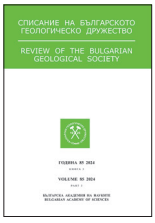

First finding of a fossil leaf imprint from the sedimentary rocks hosted the Underwater Petrified Forest natural phenomenon (Sozopol Bay, East Bulgaria)

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Първа находка на фосилен листен отпечатък в седиментните скали на природния феномен Подводна вкаменена гора (Созополски залив, Източна България)

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Abstract. Here we report the first fossil leaf imprint part of a leaflet of *Gleditsia* cf. *lyelliana* (*Fabaceae*). The studied leaf fragment was obtained from the sedimentary successions at the bottom of the Sozopol Bay hosted the Underwater Petrified Forest natural phenomenon. This is the first fossil record of *Gleditsia* cf. *lyelliana* collected from the territorial waters of Bulgaria. The recent species *Gleditsia aquatica*, which is a nearest living relative of the fossil species, inhabits swamps, sloughs, bottomland forests in the Southeastern United States, suggesting close to subtropical climatic conditions at the time of deposition of the fossil material.

Keywords: fossil flora, *Gleditsia aquatica*, *Gleditsia lyelliana*, Miocene, Sozopol Bay.

Introduction

The natural phenomenon Underwater Petrified Forest is located at a depth of about 20 meters at the bottom of the Sozopol Bay (Black Sea) in the water area between the Stolets Peninsula (Sozopol) and the islands of St. Ivan and St. Peter. The natural phenomenon represents fossilized logs, trunks and remains of trees formed during early to middle Miocene as a result of various geological processes (Siskov et al., 1988).

Material and methods

The sample was collected using the SCUBA technique using the CMAS Scientific Diver Operation and Safety Standards. The studied material is a leaf imprint with charred cuticle, obtained from the claystone beds exposed at the bottom of the underwater section (Fig. 1a). It is stored under No. Sz-1 at Sofia University “St. Kliment Ohridski” (Fig. 1b). Description of the leaf type follows the scheme for leaf morphology of the angiosperm plants of Dilch-

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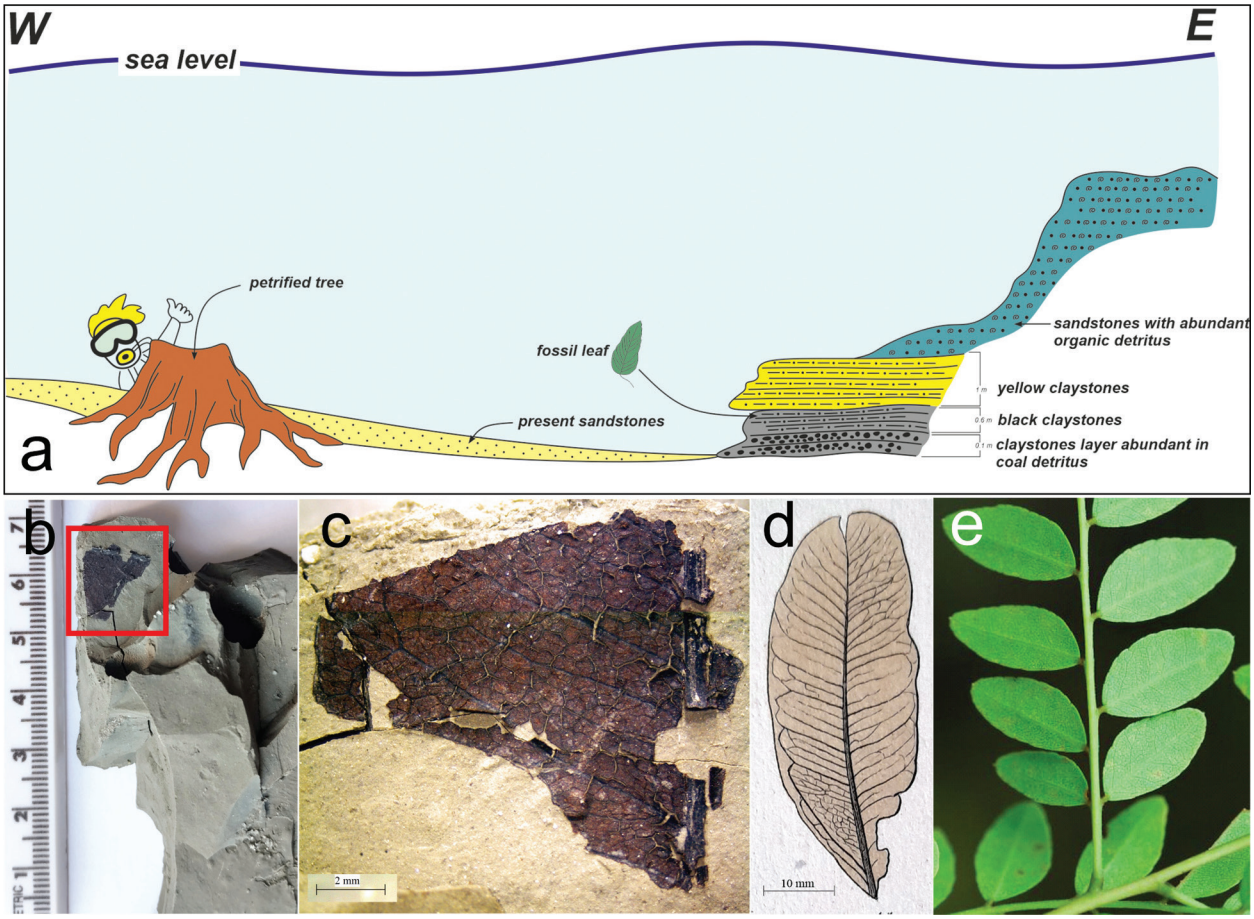

Fig. 1. *a*, Simplified geological scheme of the underwater sedimentary section, with the position of the fossil leaf; *b*, sample Sz-1, stored at the Sofia University "St. Kliment Ohridski"; *c*, imprint of leaflet part of *Gleditsia* cf. *lyelliana* with charred cuticle; *d*, *G. lyelliana* (*sub nom. Podogonium latifolium* after Heer, 1859); *e*, *G. aquatica* leaflets (after https://www.missouriplants.com/Gleditsia_aquatica_page.html).

er (1974). The photos were taken with an optical lens Leica EZ4D and photo software LAS EZ.

Geological background

The coastal area between the Burgas Bay and the town of Primorsko is characterized by the presence of an Upper Cretaceous volcano-intrusive structure known as the Rosen Paleovolcano as a synonym for the Sozopol volcano, according to Petrova and Simeonov (1989). The development of the Sozopol Caldera, a key feature of this volcanic structure, is closely associated with the formation of the underwater natural phenomenon known as the Petrified Forest, located along the coastline between Sozopol and Cape St. Agalina (Siskov et al., 1988).

In the eastern part of the studied phenomenon, a subhorizontal sedimentary succession composed of claystones and sandstones is exposed (Velev et al., 2023). At the bottom of the succession, a bed of gray-black to black claystones, abundant in charred plant detritus and rare fossil leaves are observed. This lower clay-rich bed of the section probably overlies the petrified trees. The fossil leaf was obtained from the second black claystone bed (Fig. 1a).

Results and discussion

The small size of the fossil material suggests that it represents part of a leaflet of a compound leaf. The other preserved morphological features, such as the type of leaf margin and venation, point us to representatives of the Family *Fabaceae*. An analogous leaf morphology is possessed by the fossil species *Gleditsia lyelliana* (Heer) Hankte (Fig. 1d), but due to the fragmentary nature of the imprint we prefer to use the combination *Gleditsia* cf. *lyelliana* in determining the fossil material.

Family *Fabaceae* Lindl.
Genus *Gleditsia* L.
Gleditsia cf. *lyelliana* (Heer) Hnatke

1859. *Podogonium lyellianum* Heer, p. 117, Pl. 136, Figs 22-48.
1859. *P. latifolium* Heer, p. 116, Pl. 136, Figs 11-13, 15, 18-19.
1964. *P. knorrii* Heer; Palamarev, p. 24, Pl. 134, Fig. 2; Fig.-text 24.
1980. *Gleditsia lyelliana* (Heer) Hantke in Gregor & Hantke, p. 167, Pl. 9, Fig. 5.
1987. Palamarev & Petkova, p. 114, Pl. 30, Figs 9-12.
1999. Bozukov, p. 54, Pl. 7, Fig. 4.
2004. Palamarev & Bozukov, p. 135, Pl. 5, Fig. 4.

Material: Imprint of leaflet part with charred cuticle No. Sz-1 (Fig. 1c).
Description: Shape of the leaflet lamina – probably elliptical; entire leaf margin; the midvein is straight, much thicker than the secondary veins; brochidodromous type venation; the intersecondary veins are of composite type; the secondary and intersecondary veins form an angle of 60° to the midvein; tertiary veins form a random reticulate pattern; the restored width of the leaflet is 2.2 cm.
Geographic and statigraphic range: The fossil species *G. lyelliana* is distinguished by an extensive range, which includes Central, Eastern and Southeastern Europe. Its stratigraphic range spans late Eocene–early Pliocene interval (Palamarev, Petkova, 1987). It was recorded in 12 Bulgarian localities from late Eocene–late Miocene interval (Palamarev, Bozukov, 2004; Palamarev et al., 2005). *G. lyelliana* has been recorded in the Miocene sediments from NW, SW and SE Bulgaria (Palamarev, 1964; Palamarev, Petkova, 1987; Bozukov, 1999; Palamarev, Bozukov, 2004).
Notes: Based on the well-preserved fossil spores and pollen Siskov et al. (1988) assume early–middle Miocene age of the Underwater Petrified Forest. This stratigraphic interval and the aforementioned widespread distribution of *G. lyelliana* in Bulgaria during the Miocene are another argument for the determination of our fossil material as related to the fossil species indicated.

Gregor and Handke (1980) accepted as nearest living relatives of the fossil species the Chinese *G. heterophylla* Bunge and the North American *G. aquatica* Mars. We accept only the last one, because of the following differences with the fossil material: secondary veins of *G. heterophylla* are more widely spaced and at an angle of 45° to the midvein.

G. aquatica is a tree native to SE states of U.S. (from Florida west to eastern Texas), which is most at home in swampy areas. Leaves are alternate, 1–2 times pinnately compound, compound leaves 12–15 cm long, with 7–10 pairs of leaflets (Fig. 1e), these 1–5 cm long, 0.5–1.5 cm wide (https://www.missouriplants.com/Gleditsia_aquatica_page.html).

The attachment of this species to swampy habitats fully corresponds to the hypothesis of the existence of a swamp in the area of the Underwater Petrified Forest. This fact is in sync with the genus *Taxodioxylon* (*Cupressaceae*) established there as fossil wood by Iamandei (unpub. data), which has as a nearest living relative *Taxodium distichum* Rich. – again, a swamp-dwelling species native to the SE U.S. The existence of nearest living relatives from the Atlantic coast of North America during the Miocene is not an isolated case in Bulgarian paleoflora. According to Bozukov (2001), this type of plants reaches 17,6% in the middle Miocene flora from Satovcha (SW Bulgaria).

Conclusions

The first fossil leaf imprint defined as *Gleditsia* cf. *lyelliana* obtained from the sedimentary strata hosted the Underwater Petrified Forest here is announced. The mode of life of the nearest living relative of the fossil taxon i. e. *G. aquatica* in the swamp conditions confirms the presence of the march environments and subtropical climate during the formation of the natural phenomenon.

The finding of this type of fossil in the investigated sediments suggests the presence of more similar ones. It is necessary to continue these studies and by new phytofossil findings to contribute to the reconstruction of the ecological conditions during the deposition of the fossil material.

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