Cercidiphyllum crenatum (UNGER) R. BROWN 1935 FROM THE BOZOVICI BASIN, SOUTH CARPATHIANS, ROMANIA

CĂLIN Alexandru Gabriel, POPA Mihai Emilian, PIRNEA Roxana, PARASCHIV Valentin

Abstract. *Cercidiphyllum crenatum* (Unger 1850) R. Brown 1935 (Magnoliophyta, Cercidiphyllaceae Engl.) is reported from the Badenian coal-bearing deposits of the Bozovici Basin, South Carpathians. Although it is a common species in the European Mio-Pliocene deposits, *Cercidiphyllum crenatum* is a rare species in the Romanian fossil flora, as it was previously collected and described from only two Pontian localities in Transylvania (GIVULESCU, 1964; GIVULESCU & GHIURCĂ, 1969; GIVULESCU, 1984). This is the first record of *Cercidiphyllum crenatum* in the Miocene continental formations of Romania. From a palaeoecological point of view, *Cercidiphyllum crenatum* lived in a warm-temperate climate, associated with gymnosperms belonging to the genera *Abies*, *Sequoia* and to angiosperm genera such as *Acer*, *Salix*, *Betula*, *Juglans*, *Fagus*, *Carya* and *Quercus* (PREDA et al., 1994; PETRESCU, 2003).

Keywords: Cercidiphyllaceae, *Cercidiphyllum crenatum*, Miocene, Bozovici Basin, Romania.

Rezumat. *Cercidiphyllum crenatum* (Unger) R. Brown 1935 din Bazinul Bozovici, Carpații Meridionali, România. *Cercidiphyllum crenatum* (Unger 1850) R. Brown 1935 (Magnoliophyta, Cercidiphyllaceae ENGL.) a fost găsită în depozitele badeniene din Bazinul Bozovici din Carpații Meridionali. Deși este o specie des întalnită în depozitele mio-pliocene din Europa, *Cercidiphyllum crenatum* este o specie rară în flora fosilă a României, fiind colectată și descrisă doar din două localități ponțiene din Transilvania (GIVULESCU, 1964; GIVULESCU & GHIURCĂ, 1969; GIVULESCU, 1984). *Cercidiphyllum crenatum* este semnalată pentru prima dată în formațiunile continentale miocene din România. Din punct de vedere paleoecologic această specie trăia într-un climat temperat-cald, în asociație cu gimnosperme precum *Abies*, *Sequoia* și cu angiosperme precum *Acer*, *Salix*, *Betula*, *Carya*, *Juglans*, *Fagus*, *Carya* și *Quercus* (PREDA et al., 1994; PETRESCU, 2003).

Cuvinte cheie: Cercidiphyllaceae, *Cercidiphyllum crenatum*, Miocen, Bazinul Bozovici, România.

INTRODUCTION

The family Cercidiphyllaceae, Order Saxifragales, with a single extant genus *Cercidiphyllum* Siebold et Zuccarini 1846, is considered to be a member of the core eudicots (SOLTIS et al., 2007; JIAN et al., 2008; APG III, 2009). *Cercidiphyllum* is an archaic Cretaceous genus with peculiar morphology, considered illustrative for the evolution and development of plants (KRASSILOV, 2010). The genus *Cercidiphyllum* includes two extant species: *Cercidiphyllum japonicum* Siebold et Zuccarini 1846 and *Cercidiphyllum magnificum* (Nakai) Nakai 1920.

Cercidiphyllum japonicum is living in the following Chinese provinces: Henan, Zhejiang, Hebei, Shanxi, Shaanxi, Gansu, Jiangsi and Sichuan, as well as in the following Japanese prefectures: Shikoku, Kyushu, Hokkaido and Honshu, while *Cercidiphyllum magnificum* is living in Nikko and Honshu prefectures of Japan (SPONGBERG, 1979). *Cercidiphyllum japonicum* is a large canopy tree, reaching 25-30 m in height and 2-2.5 m in diameter, living in warm-temperate, deciduous forests of China and Japan. *Cercidiphyllum magnificum* is a small sized tree living in cool-temperate, subalpine forests of Japan (QI et al., 2012). Nonetheless, both species are dioecious and have very similar leaves, making it difficult to separate them morphologically.

The Cenozoic reprezentatives of genus *Cercidiphyllum*, mainly *Cercidiphyllum crenatum* (Unger) Brown 1935, are recorded from western North America, Europe and eastern Asia, occuring in Oligocene-Pleistocene continental formations (GIVULESCU, 1964; GIVULESCU & GHIURCĂ, 1969; GIVULESCU, 1984; MEYER & MANCHESTER, 1997; KOVAR-EDER et al., 1998; KVAČEK, 2008; MANCHESTER et al., 2008; DENK et al., 2017; KVAČEK et al., 2018). In Romania, *Cercidiphyllum crenatum* was reported from Transylvania, from two Pontian localities (GIVULESCU, 1964; GIVULESCU & GHIURCĂ, 1969; GIVULESCU, 1984). In this paper, we discuss a new record of *Cercidiphyllum crenatum* in Romania, from the Bozovici Basin, South Carpathians, Badenian in age.

GEOLOGICAL SETTING

The Bozovici Basin is a typical Alpine molassic, intramountainous basin of the South Carpathians (Fig. 1), formed during the post-Laramian Alpine phases. This Tertiary basin is sealing two significant tectonic units of the South Carpathians, the Getic Nappe and the Danubian Units (BALINTONI, 1997; IANCU et al., 2005). It occurs in the Caraș-Severin County, bordered by the Semenic Mountains to the North, the Almăj Mountains to the South and the Locva Mountains to the South-West. The Bozovici Basin has an irregular shape, having approximatively a NE-SW orientation. It is 40 km long and its maximum width is 7-8 km in the area of Bozovici and Eftimie Murgu towns. The Bozovici Basin was studied primarily mainly because of its coal seams (POP, 1959; RĂILEANU et al., 1963; PETRESCU et al., 1987; PREDA et al., 1994; POPA & PREDEANU, 2018; POPA & ANASTASIU, 2019), while its fossil plants were under-rated by stratigraphical and coal geology studies.

The sedimentary sequences of the Bozovici Basin are formally separated in two formations (Fig. 2): the Lăpușnicul Mare Formation and the Dalbosețț Formation (CODREA, 2001). The Lăpușnicu Mare Formation includes two members: the Pârâul Lighidia Member, Eggenburgian in age, and the Valea Slătinicului Member, Badenian in age. The age of the two members belonging to the Lăpușnicu Mare Formation was debated for a long time. The Eggenburgian age of the Pârâul Lighidia Member was established by GRIGORESCU (1985), based on the occurrence of the vertebrate remains assigned to *Brachyodus onoideus* Gervais. Also, the same age was confirmed by PETRESCU & NICORICI (1989) based on the results of the palynomorph study. The Badenian age of the Valea Slătinicului Member was suggested by CODREA (2001), based on micro-mammal remains.

The sedimentary sequences of the Bozovici Basin can reach up to 750 m and they consist mainly of sandstones, clays, marls and conglomerates, including up to nine interbedded coal seams with highly fossiliferous roof shales and tuff intercalations. An essential peculiarity of this flora is the occurrence of well-preserved permineralized trunks, both silicified and carbonatic (PREDA et al., 1994).

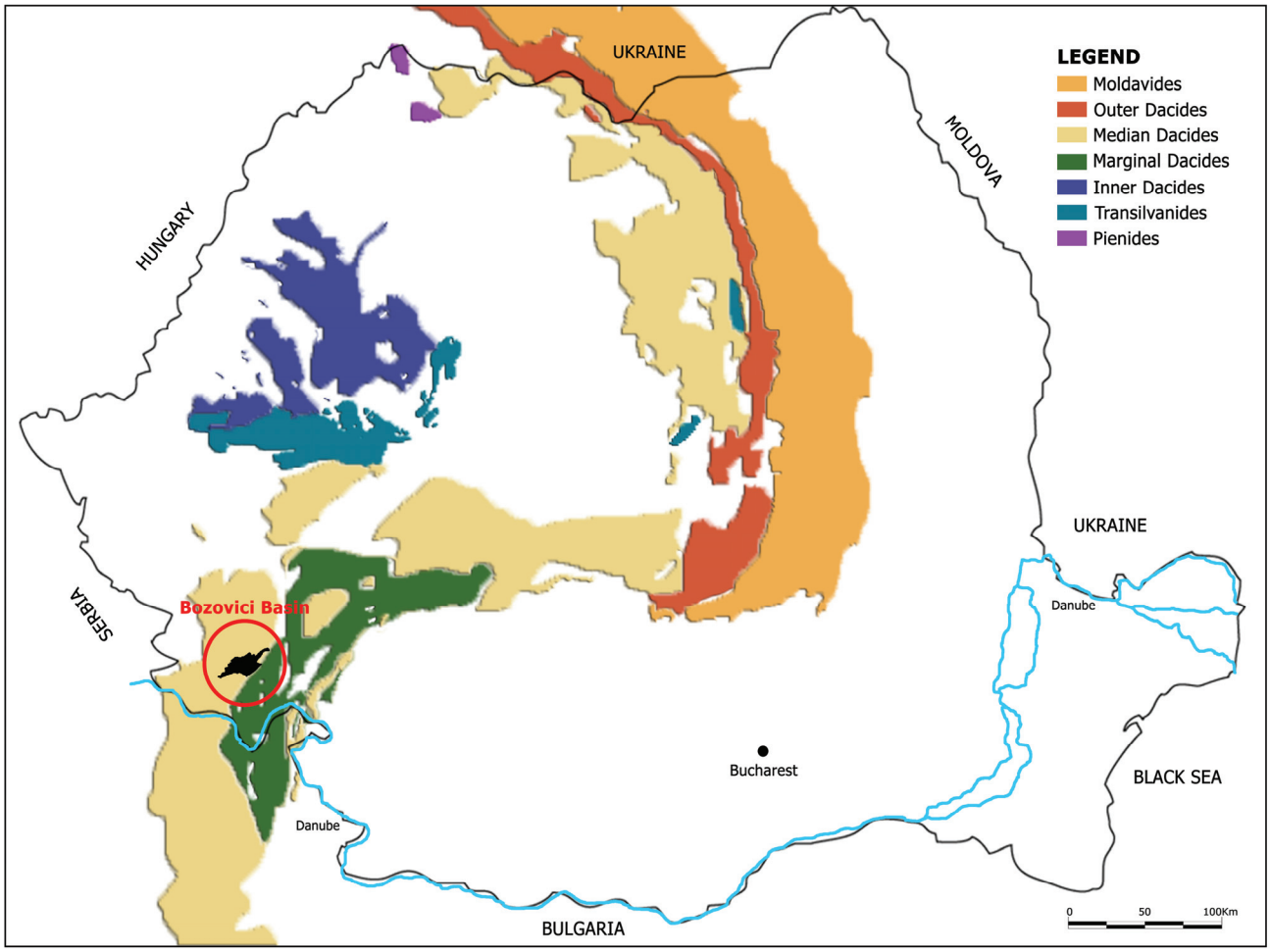

Figure 1. The simplified geological map of Romania and the occurrence of the Bozovici Basin in the South Carpathians (modified after SĂNDULESCU, 1984; POPA et al., 2017).

MATERIAL AND METHODS

The sample was collected from the Lighidia quarry by one of the authors (C.A.G.), an open cast mine located near the Bozovici town, during one of the several field work campaigns of 2015-2017. The stratigraphic position of the material is from the upper sequence of the Valea Slătinicului Member of the Lăpușnicu Mare Formation. The sample, recorded in the field as Boz1, is preserved as an impression on red porcelanite. The sample is curated as 27626 at the National Geological Museum of the Geological Institute of Romania, in Bucharest. The macrophotographs were taken using a Canon EOS 60D digital camera with a Canon EF-S 18-55mm lens. More detailed photographs were taken using a Carl Zeiss Stemi 508 Stereo Microscope (Fig. 2).

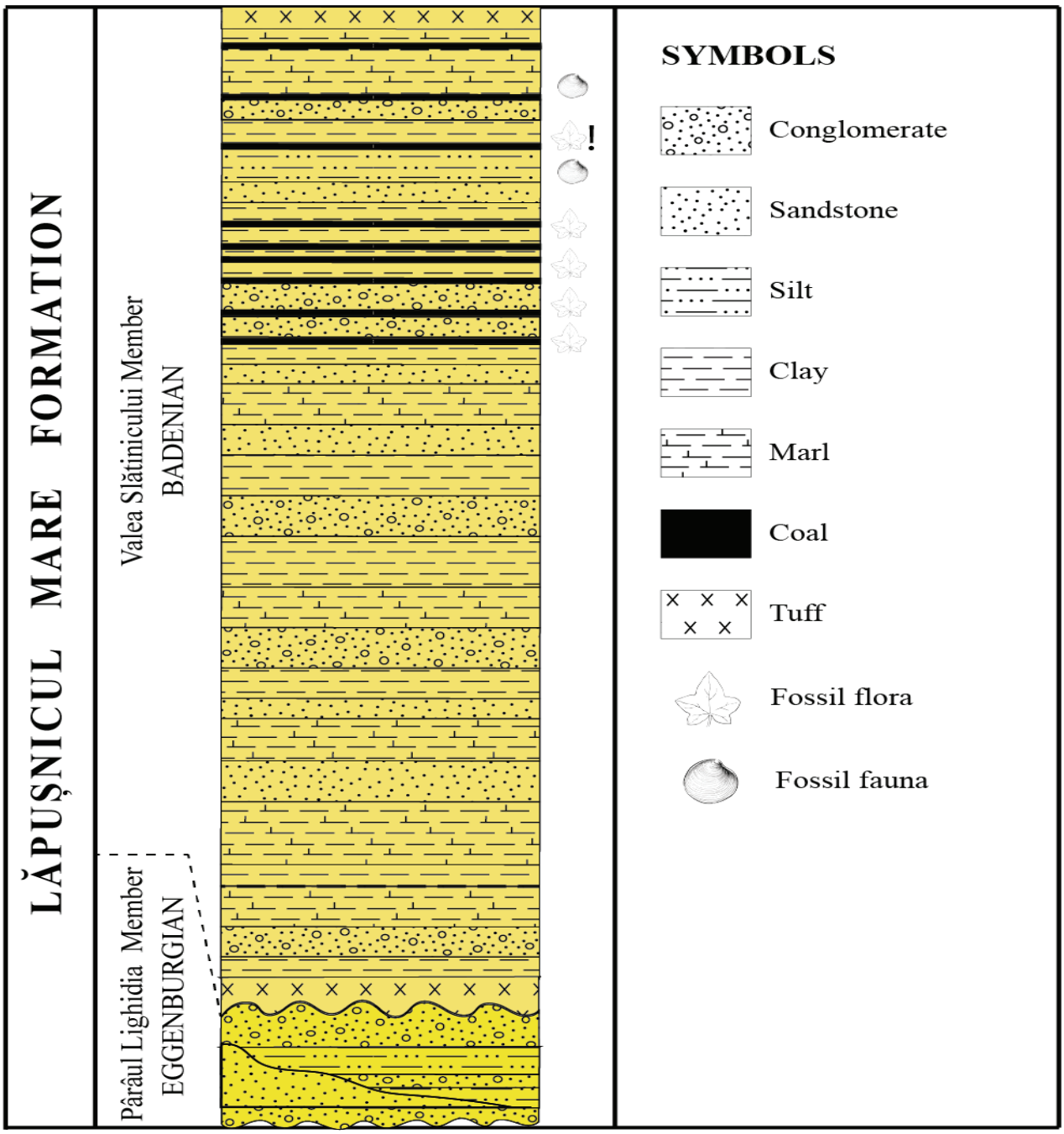

Figure 2. Stratigraphic synthetic column of the Miocene formations of the Bozovici Basin, with the stratigraphic position of *Cercidiphyllum crenatum* marked by a fossil leaf symbol (with the exclamation mark) (modified after CODREA, 2001; PIRNEA & POPA, 2018).

SYSTEMATICS
Phylum Magnoliophyta
Class Magnoliopsida
Order Saxifragales
Family Cercidiphyllaceae Engler 1907
Genus *Cercidiphyllum* Siebold et Zuccarini 1846
Cercidiphyllum crenatum (Unger) Brown 1935

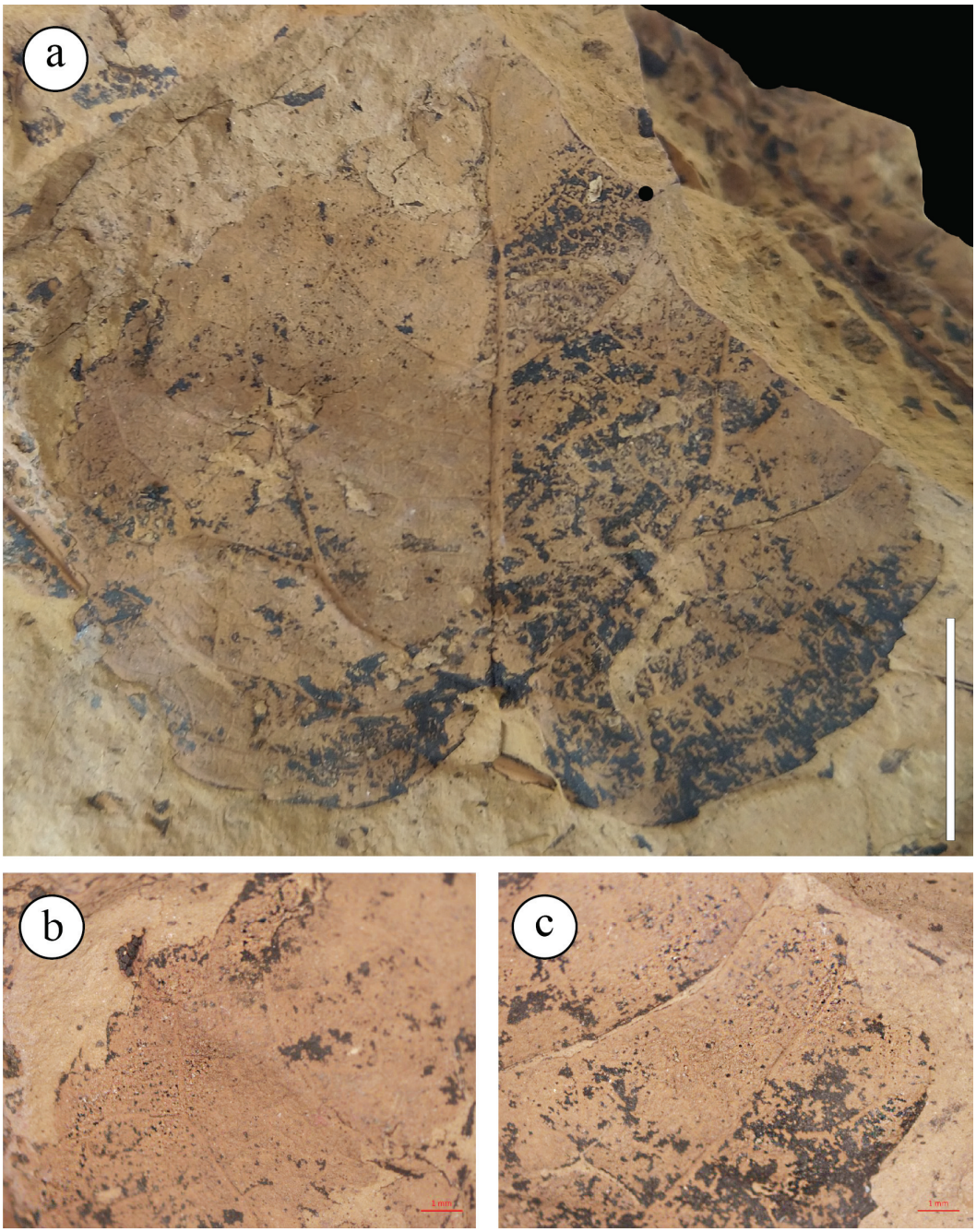

Figure 3. *Cercidiphyllum crenatum*, from Bozovici, Valea Slătinicului Member, Lăpușnicul Mare Formation, Bozovici Basin, Lighidia quarry. Sample 27626. a: general view; b-c: details of the leaf fragment showing the 2nd and 3rd vein category and the crenate-serrate leaf margins. Scale bar: 10 mm.

1935 *Cercidiphyllum crenatum* (Unger) R. W. Brown – Brown: p. 575, Pl. 68, Figs. 1, 9, 10
1964 *Cercidiphyllum crenatum* (Unger) R. W. Brown – Givulescu: p. 569, Fig. 1
1969 *Cercidiphyllum crenatum* (Unger) R. W. Brown – Givulescu & Ghiurcă: p. 21, Pl. 3, Fig.2
1977 *Cercidiphyllum crenatum* (Unger) R. W. Brown – Kasaphgil: Fig. 27
1984 *Cercidiphyllum crenatum* (Unger) R. W. Brown – Givulescu: 4 (72), Pl. 7, Fig. 17
1987 *Cercidiphyllum crenatum* (Unger) R. W. Brown – Manchester & Meyer: p. 116, Fig. 3G
1989 *Cercidiphyllum crenatum* (Unger) R. W. Brown – Zhilin: Fig. 1
1995 *Cercidiphyllum helveticum* (Heer 1855) Jähnichen, Mai et Walther – Meller: p. 46, Pl. 7, Figs. 1 – 4
1996 *Cercidiphyllum helveticum* (Heer 1855) Jähnichen, Mai et Walther – Meller: Table 1 – 2
1996 *Cercidiphyllum helveticum* (Heer 1855) Jähnichen, Mai et Walther – Kovar-Eder: Table1
1997 Cercidiphyllum crenatum (Unger) R. W. Brown – Meyer & Manchester: p. 73, Pl. 7, Figs. 2-8; Pl. 8, Fig. 1
1998 *Cercidiphyllum helveticum* (Heer 1855) Jähnichen, Mai et Walther – Kovar-Eder et al.: Table 5
1998a *Cercidiphyllum helveticum* (Heer 1855) Jähnichen, Mai et Walther – Meller: Tab. 7, Figs. 1 – 4

1998b *Cercidiphyllum helveticum* (Heer 1855) Jähnichen, Mai et Walther – Meller: Table 1, Figs. 3 – 5
1998 *Cercidiphyllum crenatum* (Unger) R. W. Brown – Kovar-Eder: Pl. 1, Figs. 23 – 24
2000 *Cercidiphyllum crenatum* (Unger) R. W. Brown – Kvaček & Hurnik: Pl. 3, Fig. 1, pl. 4, Fig. 10
2004 *Cercidiphyllum crenatum* (Unger) R. W. Brown – Kovar-Eder et al.: Pl. 2, Fig. 7
2017 *Cercidiphyllum crenatum* (Unger) R. W. Brown – Denk et al.: Pl. 12, Figs. 6 – 8
2018 *Cercidiphyllum crenatum* (Unger) R. W. Brown – Kvaček et al.: Pl. 5, Fig. 1

Description. The sample includes a single leaf fragment (Fig. 3a), a microphyll (933 mm^2) with 35 mm in length and 40 mm in width. The lamina is symmetrical, with a marginal position of the petiole's attachment. The leaf has an oblate shape and a length/width ratio of 0.9/1. The base of the leaf is cordate, with a reflex angle, and the apex is convex and obtuse. The leaf margin is crenate-serrate. The tooth spacing is regular with a single order of teeth and five teeth per centimetre. Each tooth apex is simple with convex basal and apical teeth and the sinus between teeth is angular (Fig. 3b). The first vein category is basal actinodromous, the major secondary vein category is semicraspedodromous with excurrent attachment. The interior secondary veins are present and the intercostal tertiary vein fabric is irregular reticulate (Fig. 3c). The major secondary vein spacing is irregular with an uniform vein angle.

DISCUSSION

Cercidiphyllum crenatum (Unger) R. W. Brown 1935 (Fig. 3) from the Bozovici Basin is characterized by a series of typical characters: crenate-serrate margin, basal actinodromous first vein and tertiary random reticulate vein. No fruit and flower fragments have been found.

Cercidiphyllum crenatum has been recorded from continental formations from all around the world, within the Oligocene-Pleistocene timespan. Its very first citation was given by BROWN (1935), from the Early Oligocene Bridge Creek flora of the John Day Formation, in north-central Oregon, U.S.A. *Cercidiphyllum crenatum* was also collected and described from Miocene continental formations of western North America, from Latah and Clarkia areas (CHANEY & AXELROD, 1959; SMILEY & REMBER, 1985; MEYER & MANCHESTER, 1997). Other reported occurrences of *Cercidiphyllum crenatum* come from Early Oligocene (Rupelian) continental formations of western Kazakhstan, in the Ashcheayrykian flora (ZHILIN, 1989), northern Ustyurt and Chagravan Plateau, in the Myneskesuekian flora (TOKAR & KORNILOVA, 1975) and in the Shintuzsay flora (KORNILOVA, 1950; KORNILOVA & TOKAR, 1973). From the Late Oligocene (Chattian), *Cercidiphyllum crenatum* was recorded in the Kumsuat flora (ZHILIN, 1989) from western Kazakhstan. In Russia, *Cercidiphyllum crenatum* was collected and described from the Dembi flora (Middle-Late Oligocene), Velikaya Kema flora (Middle – Late Oligocene), and Rettikhovsk flora (Early Miocene) (AKHMETYEV & BRATZEVA, 1973). Also, *Cercidiphyllum crenatum* was recorded in the Early Miocene (Aquitanian) from the following occurrences: a. northern Ustyurt, from the Baygubekian flora (ZHILIN, 1974, 1989); b. from the Orzhilansay flora (KORNILOVA, 1955, 1956, 1966; ZHILIN, 1974, 1989) and the Nausha flora. From the Guvem area, in northwestern Central Anatolia, *Cercidiphyllum crenatum* was found in lacustrine sediments of the Derekoy pyroclastics, early Miocene (Burdigalian) in age, associated with a humid temperate climate (DENK et al., 2017).

In Europe, the oldest occurrence of *Cercidiphyllum crenatum* is recorded in Early Oligocene of Usti Formation (Ceske Stredohori Mountains, Czechia) in Bechlejovice, Kundratice, Suletice, Holy Kluk, Markvartice, Zichov and Hrazeny areas (KVAČEK & WALTHER, 2001, 2003; KVAČEK & TEODORIDIS, 2007). It was also cited from the Decin Formation of Matry Hill around Sebuzin area, in the Ceske Strednohori Mountains pointing to a humid climate (KVAČEK et al., 2018). In the same region (North Bohemia), *Cercidiphyllum crenatum* was reported from the Most Basin from several occurrences: a. the Main Coal Seam (Middle Most Formation) in a few layers of the Vrsovice area; b. from the Upper Sandy-Clayey Beds (Upper Most Formation) in the pelitic layers of the Zelenky area and c. in the Overlying Beds (Upper Most Formation) from the Dolany area. All these occurrences are Early Miocene in age (KVAČEK & HURNIK, 2000). Another occurrence of *Cercidiphyllum crenatum* comes from the Early Miocene continental formations of Zug County, Switzerland (KOVAR-EDER et al., 1994). KOVAR-EDER et al. (2004) described a single specimen of *Cercidiphyllum crenatum* with subtropical climate affinities, from Karpatian/Early Badenian (late Early/early Middle Miocene) continental formations of Parschlug (Styria, Austria). In Poland, *Cercidiphyllum crenatum* was described from the Ruja lignite deposit, Middle Miocene in age, where it lived in a warm temperate climate (WOROBIEC et al., 2008). In Hungary, *Cercidiphyllum crenatum* was collected and described from Pannonian (Late Miocene) formations of Rudabanya, where it lived in a subtropical-warm-temperate climate (NAGY & PÁLFALVY, 1961; ERDEI et al., 2011). It was also collected from the Badenian continental formations of Nógrádszakál (KORDOS-SZAKÁLY, 1984).

In Romania, GIVULESCU (1964, 1984) and GIVULESCU & GHIURCĂ (1969) described *Cercidiphyllum crenatum* from Odești and Chiuzbaia sites in Transylvania, both Pontian in age. There, this species is associated with gymnosperms such as *Sequoia abietina*, *Glyptostrobus europaeus* and angiosperms such as *Liriodendron procaccini*, *Ceratophyllum* sp., *Platanus platanifolia*, *Alnus pseudojaponica*, *Betula pseudoluminifera*, *Carpinus cobălcescui*, *Fagus attenuata*, *Castanea cf. crenata*, *Quercus drymeja*, *Quercus praeprinus*, *Ulmus pyramidalis*, *Acer tricuspidatum*, *Populus populina* and *Populus gigantea*. The Chiuzbaia flora is one of the richest Pontian floras from Europe, while its fossil plants association indicates a mixed-mesophytic forest (GIVULESCU, 1990), in which *Cercidiphyllum crenatum* thrived.

The Bozovici flora was briefly studied and cited by the previous authors (POP, 1959; ILIESCU et al., 1967; PIRNEA & POPA, 2018). PETRESCU (2003) studied the palynology of the Bozovici Bazin and identified a series of gymnosperms such as *Abies*, *Picea*, *Pinus*, *Sciadopithys*, *Sequoia* and angiosperms such as *Magnolia*, *Juglans*, *Celtis*, *Engelhardia*, *Carya, Platicarya*, *Alnus*, *Betula*, *Carpinus*, *Ulmus*, *Nyssa* and *Quercus*. PIRNEA & POPA (2018) collected and described *Pronephrium stiriacum* from Valea Slătinicului Member, from the same sedimentary sequence where *Cercidiphyllum crenatum* occurred. *Cercidiphyllum crenatum* and *Pronephrium stiriacum* are associated in many sites of the European flora, especially in the Oligocene-Miocene continental formations (KVAČEK & HURNIK, 2000; KVAČEK & TEODORIDIS, 2007; KOVAR-EDER et al., 2004), with *Pronephrium stiriacum* indicating a warm-temperate climate. JÄHNICHEN et al. (1980) in KOVAR-EDER et al. (1994) pointed out the ecological shift of *Cercidiphyllum crenatum*, from a mixed-mesophytic forest during the Oligocene-Early Miocene interval to a mainly deciduous forest in a warm temperate climate during the Late Miocene-Pliocene timespan. The youngest fossil record of *Cercidiphyllum* comes from Pleistocene continental formations of eastern Asia (ONOE, 1989), where it found a refuge and therefore surviving during the Quaternary glaciations.

CONCLUSIONS

Cercidiphyllum crenatum (Saxifragales, Cercidiphyllaceae) is reported from the Lighidia Quarry, Bozovici Basin, within the Lăpușnicul Mare Formation, Valea Slătinicului Member, Badenian in age. Here, the collected fossil material has typical morphological characters which enabled its systematic identification. Although *Cercidiphyllum crenatum* is frequently reported from Miocene European floras, this is its first Miocene record in Romania.

ACKNOWLEDGEMENTS

We thank Eduard C. Ghinescu (Geological Institute of Romania) for his help with photographing the fossil material. Helpful suggestions for improving the manuscript were provided by Lilla Hably and an anonymous reviewer. This paper was financially supported by "The Program for Financing Installations and Special Objectives of National Interest – IIN2019" to two of the authors (C.A.G. and P.V.).

REFERENCES

AKHMETYEV M. A. & BRATZEVA G. M. 1973. Fossil remains of the genus *Engelhardita* from Cenozoic deposits of Sikhote-Alin and Southern Primorye. *Review of Palaeobotany and Palynology*. Elsevier. Amsterdam. **16**: 123-132.

APG III. 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. *Botanical Journal of the Linnean Society***.** Oxford University Press. **161**: 105–121.

BALINTONI I. 1997. *Geotectonics of the metamorphic terranes from Romania*. Edit. Carpatica. Cluj Napoca. 176 pp.

BROWN R. W. 1935. Miocene leaves, fruits, and seeds from Idaho, Oregon, and Washington. *Journal of Paleontology*. Society for Sedimentary Geology. Boulder, Colorado. **9**: 572-587.

CHANEY R. W. & AXELROD D. I. 1959. *Miocene floras of the Columbia Plateau*. Carnegie Institution of Washington Publication. **617**: 1- 237.

CODREA V. A. 2001. Badenian insectivores from Bozovici Basin. *Acta Palaeontologica Romaniae*. Edit. Universității din București. **3**: 67-75.

DENK T., GÜNER T. H., KVAČEK Z., BOUCHAL M. J. 2017. The early Miocene flora of Güvem (Central Anatolia, Turkey): a window into early Neogene vegetation and environments in the Eastern Mediterranean. *Acta Palaeobotanica*. Polish Academy of Sciences. Kraków. **57**: 237-338.

ERDEI B., HABLY L., SELMECZI I., KORDOS L. 2011. Paleogene and Neogene localities in the North Hungarian Mountain Range. *Studia Botanica Hung*arica. Hungarian Natural History Museum**.** Budapest. **42**: 153-188.

GIVULESCU R. 1964. *Cercidiphyllum crenatum* (Ung) Brown im Pliozan Rumaniens. *Neues Jahrbuch für Geologie und Paläontologie Abhandlungen*. Schweizerbart science publishers. Stuttgart. **9**: 569-571.

GIVULESCU R. 1984. Die fossile flora des Fundortes Chiuzbaia „H" (Kreis Maramureş, Rumänien). *Dări de Seamă ale Şedinţelor*. Institutul de Geologie şi Geofizică. București. **69**: 69-93.

GIVULESCU R. 1990. *Flora fosilă a Miocenului superior de la Chiuzbaia (județul Maramureș)*. Edit. Academiei Române. București. 235 pp.

GIVULESCU R. & GHIURCĂ V. 1969. Flora pliocenă de la Chiuzbaia (Maramureș). *Memorii.* Institutul Geologic. București. **10**: 1-81

GRIGORESCU D. 1985. Asupra prezenței lui *Brachiodus onoideus* Gervais în depozitele neogene din Bazinul Bozovici și semnificația lui biostratigrafică. *Studii și cercetări de geologie, geofizică, geografie. Geologie*. Edit. Academiei Române. București. **30**: 122-128.

IANCU V., BERZA T., SEGHEDI A., MĂRUNȚIU M. 2005. Palaeozoic rock assemblages incorporated in the South Carpathian Alpine thrust belt (Romania and Serbia): a review. *Geologica Belgica*. University of Liege. Liege. **8**: 48-68.

ILIESCU O., RADU A., LICA M. 1967. Geologia Bazinului Bozovici. *Dări de Seamă ale Institutului Geologic*. Institutul Geologic. București. **53**: 341-366.

JÄHNICHEN H., MAI D. H., WALTHER H. 1980. Blätter und Früchte von *Cercidiphyllum* Siehold and Zuccarini im mitteleuropäischen Tertiär. *Schriftenreihe für geologische Wissenschaften*. Akademie Verlag. Berlin. **16**: 357-400.

JIAN S., SOLTIS P. S., GITZENDANNER M. A., MOORE M. J., LI R. Q., HENDRY T. A., QIU Y. L., DHINGRA A., BELL C. D., SOLTIS D. E. 2008. Resolving an ancient, rapid radiation in Saxifragales. *Systematic Biology*. University Press. Oxford. **57**: 38–57.

KASAPLIGIL B. 1977. A late Tertiary conifer-hard-wood forest from the vicinity of Güvem village, near Kizilcahaman, Ankara. *Bulletin of the Mineral Research and Exploration*. Mineral Research & Exploration General Directorate. Ankara. **88**: 25-33.

KORDOS-SZAKÁLY M. 1984. New data to the Miocene flora of Nógrádszakál (Hungary). *Annales Historico-Naturales Musei Nationalis Hungarici.* Budapest. **76**: 43-63

KORNILOVA V. S. 1950. Novye materialy k tretichnoy flore Turgaya. *Vestnik Akademii nauk Kazakhskoĭ SSR*. Izd-vo Akademii nauk Kazakhskoĭ SSR. Alma-Ata. **12**: 61-67.

KORNILOVA V. S. 1955. K kharakteristike flory bolattamskikh sloev Turgaya. *Isvestiya Akademii Kazakhskoi SSR, Biological Series.* Izvestiya of the Academy of Sciences of the U.S.S.R. **9**: 3-19.

KORNILOVA V. S. 1956. Itogi izucheniya oligotsenovoy flory Turgaya. *Trudy Instituta Botaniki, Akademiya Nauk Kazakhskoi SSR*. Alma-Ata. **3**: 59-101.

KORNILOVA V. S. 1966. Ocherk istorii flory i rastitel'nosti Kazakhstana. *Rastitelnyy pokrov Kazakhstana*. Izd-vo Akademii nauk Kazakhskoĭ SSR. Alma-Ata. **1**: 37-190.

KORNILOVA V. S. & TOKAR L. B. 1973. Lavrovye iz oligotsenovykh otlozheniy Shintuzsaya (Tsentral'nyy Kazakhstan). *Biologiya i geografiya.* Izd-vo Akademii nauk Kazakhskoĭ SSR. Alma-Ata. **7**: 5-11.

KOVAR-EDER J. 1996. Eine bemerkenswerte Blätter-Vergesellschaftung aus dem Tagebau Oberdorf bei Köflach, Steiermark (Unter-Miozän). *Mitteilungen der Abteilung für Geologie, Paläontologie und Bergbau am Landesmuseum Joanneum*. Steiermärkisches Landesmuseum Joanneum. Graz. **54**: 147-171.

KOVAR-EDER J. 1998. Leaf Assemblages from the Early Miocene Lignite Opencast Mine Oberdorf (N Voitsberg, Styria, Austria) in Steininger F. F. (Ed.). *The Early Miocene Lignite Deposit of Oberdorf, N Voitsberg (Styria, Austria)*. *Jahrbuch der Geologischen Bundesanstalt*. Geologische Bundesanstalt Wien. Wien. **140**(4): 447-452.

KOVAR-EDER J., MELLER B., ZETTER R. 1998. *Cercidiphyllum crenatum* (Unger) R.W. Brown in der kohleführenden Abfolge von Oberdorf N Voitsberg, Steiermark. *Mitteilungen des Referats für Geologie und Palaontologie Landesmuseum Joanneum*. Steiermärkisches Landesmuseum Joanneum. Graz **2**: 239-263.

KOVAR-EDER J., KVAČEK Z., STRÖBITZER M. 2004. The Miocene Flora of Parschlug (Styria, Austria) -Revision and Synthesis. *Annalen des Naturhistorischen Museums in Wien*. *Serie A*. Wien. **105**: 45-159.

KOVAR-EDER J., GIVULESCU R., HABLY L., KVAČEK Z., MIHAJLOVIC D., TESLENKO J., WALTHER H., ZASTAWNIAK E. 1994. Floristic changes in the areas surrounding the Paratethys during Neogene time. *Cenozoic Plants and Climates of the Arctic*. Springer. Berlin. Heidelberg. 347-369.

KRASSILOV V. 2010. *Cercidiphyllum and Fossil Allies: Morphological Interpretation and General Problems of Plant Evolution and Development*. Pensoft. Sofia-Moscow. 150 pp.

KVAČEK Z. 2008. Whole-plant reconstructions in fossil angiosperm research. *International Journal of Plant Sciences*. The University of Chicago Press. Chicago. **169**: 918–927.

KVAČEK Z. & HURNIK S. 2000. Revision of Early Miocene plants preserved in baked rocks in the North Bohemian Tertiary. *Acta Musei Nationalis Pragae*. Series B. Historia Naturalis. Praga. **56**(1-2): 1–48.

KVAČEK Z. & WALTHER H. 2001. The Oligocene of Central Europe and the development of forest vegetation in space and time based on megafossils. *Palaeontographica. Abteilung B*. Schweizerbart science publishers. Stuttgart. **159**: 125–148.

KVAČEK Z. & WALTHER H. 2003. Reconstruction of vegetationand landscape development during the volcanic activity in the České tředohoří Mountains. *Geolines*. Hibsch Special Volume. Institute of Geology of the Czech Academy of Sciences. Prague. **15**: 60–64.

KVAČEK Z. & TEODORIDIS V. 2007. Tertiary macrofloras of the Bohemian Massif: a review with correlations within Boreal and Central Europe. *Bulletin of Geosciences*. Czech Geological Survey. Plzeň. **82(4)**: 409–418.

KVAČEK Z., TEODORIDIS V., RADOŇ M. 2018. Review of The Late Oligocene Flora of Matrý Near Sebuzín (České Středohoří Mts., The Czech Republic). *Fossil Imprint*. Narodni Muzeum. Prague. **74:** 292-316.

MANCHESTER S. R., CHEN Z. D., LU A. M., UEMURA K. 2008. Eastern Asian endemic seed plant genera and their paleogeographic history throughout the Northern Hemisphere. *Journal of Systematics and Evolution*. Blackwell Publishing Asia Pty Ltd. Beijing. **47**: 1–42.

MELLER B. 1995. Früchte und Samen aus dem Köflach-Voitsberger Braunkohlenrevier (Miozän; Steiermark, Österreich). *Diss. Formal - Naturwiss*. Fakultät Univ. Wien. D 28789/**1, 2**: 1-191.

MELLER B. 1996. Charakteristische Karpo-Taphocoenosen aus den untermiozänen Sedimenten des Köflach-Voitsberger Braunkohlenreviers (Steiermark, Österreich) im Vergleich. *Mitteilungen der Abteilung für Geologie, Paläontologie und Bergbau am Landesmuseum Joanneum*. Steiermärkisches Landesmuseum Joanneum. Graz. **54**: 215-229.

MELLER B. 1998a. Systematisch-taxonomische Untersuchungen von Karpo-Taphocoenosen des Köflach-Voitsberger Braunkohlenrevieres (Steiermark, Österreich; Untermiozän) und ihre paläoökologische Bedeutung. *Jahrbuch der Geologischen Bundesanstalt*. Geologische Bundesanstalt Wien. **140 (4)**: 497-655.

MELLER B. 1998b. Diaspore Assemblages from the Early Miocene Lignite Opencast Mine Oberdorf, N Voitsberg, Styria, Austria. In: Steininger F. F. (Ed.). *The Early Miocene Lignite Deposit of Oberdorf, N Voitsberg (Styria, Austria)*. *Jahrbuch der Geologischen Bundesanstalt*. Geologische Bundesanstalt Wien. **140 (4)**: 453-460.

MEYER H. W. & MANCHESTER S. R. 1997. The Oligocene Bridge Creek flora of the John Day Formation, Oregon. *Geological Sciences.* University of California Publications. **141**: 1-195.

NAGY L. & PÁLFALVY I. 1961. Felső-pannóniai növények Rudabányáról. (Upper Pannonian fossil plants from Rudabánya). *MÁFI Évi Jel.* Annu. Rep. Geol. Inst. Hungary. **58**: 417-426.

NAKAI T. 1919. A new variety of Cercidiphyllum japonicum*. Botanical Magazine*. Tokyo Botanical Society. Tokyo. **33**: 198.

ONOE T. 1989. Palaeoenvironmental analysis based on the Pleistocene Shiobara flora in the Shiobara volcanic basin, central Japan. *Report of Geological Survey of Japan*. Tokio. **269**: 1-207.

PETRESCU I. 2003. *Palinologia Terţiarului*. Edit. Carpatica. Cluj-Napoca. 249 pp.

PETRESCU I. & NICORICI E. 1989. Palynological studies of the Lower Miocene deposits in the Bozovici Basin. *Studia Universitatis Babeş-Bolyai, Geologia-Geographia*. Babeş-Bolyai University. Cluj-Napoca. **34 (2)**: 43-45.

PETRESCU I., NICORICI E., BIŢOIANU C., ŢICLEANU N., TODROS M., IONESCU M., MĂRGĂRIT G., NICORICI M., DUŞA A., PĂTRUŢOIU I., MUNTEANU A., BUDA A. 1987. *Geologia zăcămintelor de cărbuni, vol. II. Zăcăminte din România.* Edit. Tehnică. Bucureşti. 386 pp.

PIRNEA R. & POPA M. E. 2018. Genus *Pronephrium* Presl 1851 (Thelypteridaceae) in Romania. *Journal of Palaeogeography*. Elsevier. Amsterdam. **7**: 1-13.

POP E. I. 1959. Studiul geologic al Bazinului Bozovici. *Buletinul Institutului de Mine Petroşani*. Institutul de Mine Petroşani. **6**: 79-94.

POPA M. E. & PREDEANU G. 2018. Coals of Romania: Geology, petrology and use. *International Journal of Coal Geology*. Elsevier. Amsterdam. **200**: 103-122.

POPA M. E. & ANASTASIU N. 2019. *Resurse de cărbuni*. In: Constantinescu E., Anastasiu N. (Eds.) *Resursele minerale ale României*. Vol. III. *Resurse energetice*. Editura Academiei Române. Bucureşti. 435-504. 647 pp.

POPA M. E., PREDEANU G., GHIRAN M. D., MARIŞ I., PIRNEA R. 2017. *Pliocene coals and Neogene formations of the Prahova County: field trip guide*. Editura Universităţii din Bucureşti. 66 pp.

PREDA I., TURCULEŢ I., BARUS T., ANDROHOVICI A., BĂDĂLUŢĂ A. 1994. *Geologia zăcămintelor de cărbuni. Partea a II-a. Răspândirea zăcămintelor de cărbuni*. Editura Universităţii Bucureşti. Bucureşti. 392 pp.

QI X. S., CHEN C., COMES H.P., SAKAGUCHI S., LIU Y. H., TANAKA N., SAKIO H., QIU Y. X. 2012. Molecular data and ecological niche modelling reveal a highly dynamic evolutionary history of the East Asian Tertiary relict *Cercidiphyllum* (Cercidiphyllaceae). *New Phytologist*. Blackwell Publishing Inc. London. **196**(2): 617-630.

RĂILEANU G., GRIGORAŞ N., ONCESCU N., PLIŞCĂ T. 1963. *Geologia zăcămintelor de cărbuni, cu privire specială asupra RPR*. Edit. Tehnică Bucureşti. 344 pp.

SĂNDULESCU M. 1984. *Geotectonica României*. Edit. Tehnică Bucureşti. 336 pp.

SIEBOLD P. F., ZUCCARINI J. G. 1846. Florae Japonicae familiae naturales: adjectis generum et specierum exemplis selectis. Sectio altera. Plantae dicotyledoneae (gamopetalae, monochlamydeae) et monocotyledoneae. *Abhandelungen der mathematischphysikalischen Classe der Königlich Bayerischen Akademie der Wissenschaften*. Akademie der Wissenschaften. Berlin. 125 pp.

SMILEY C. J. & REMBER W. C. 1985. Composition of the Miocene Clarkia flora. In: SMILEY C.J. (Ed.) - *Late Cenozoic history of the Pacific Northwest*. *Pacific Division of the American Association for the Advancement of Science*.
American Association for the Advancement of Science. San Francisco: 95-112.

SOLTIS D. E., CLAYTON J. W., DAVIS C. C., GITZENDANNER M. A., CHEEK M., SAVOLAINEN V., AMORIM A. M., SOLTIS P. S., CHASE M. W. 2007. Monophyly and relationships of the enigmatic family Peridiscaceae. *Taxon*. Botanisches Institut der Universitaet Wien. **56**: 65-73.

SPONGBERG S. A. 1979. Cercidiphyllaceae hardy in temperate North America. *Journal of the Arnold Arboretum*. Arnold Arboretum of Harvard University. **60**: 367-376.

TOKAR L. B. & KORNILOVA V. S. 1975. Novyy vid Parthenocissus iz oligotsenovykh otlozheniy Turgayskoy vpadiny. V kn. *Novosti paleobotaniki Kazakhstana*. Izd-vo Akademii nauk Kazakhskoĭ SSR. Alma-Ata: 105-112.

UNGER F. 1850. *Genera et species plantarum fossilium*. XL. Wien (W. Braumüller). 627 pp.

WOROBIEC G., WOROBIEC E., KASIŃSKI J. 2008. Plant assemblages of the drill cores from the Neogene Ruja lignite deposit near Legnica (Lower Silesia, Poland). *Acta Palaeobotanica*. Polish Academy of Sciences. Kraków. **48**(2): 191-275.

ZHILIN S. G. 1974. *The Tertiary floras of the Plateau Ustjurt (Transcaspia)*. Komarov Botanical Institute of the Academy of Sciences of the USSR. Leningrad. 122 pp. (in Russian).

ZHILIN S. G. 1989. History of the development of the temperate forest flora in Kazakhstan, USSR from the Oligocene to the early Miocene. *The Botanical Review*. Springer. New York. **55**(4): 205-330.

Călin Alexandru Gabriel
Geological Institute of Romania, National Museum of Geology,
Kiseleff Ave, No. 2, Sect. 1, 011345, Bucharest, Romania.
E-mail: calin_alexandru94@yahoo.com

Mihai Emilian Popa
University of Bucharest, Faculty of Geology and Geophysics,
Department of Geology, Laboratory of Paleontology, 1 N. Bălcescu Ave, 010041, Bucharest, Romania.
E-mail: mihai@mepopa.com

Pirnea Roxana
University of Bucharest, Faculty of Geology and Geophysics,
Department of Geology, Laboratory of Paleontology, 1 N. Bălcescu Ave, 010041, Bucharest, Romania.
E-mail: roxana.pirnea@gmail.com

Valentin Paraschiv
Geological Institute of Romania, National Museum of Geology,
Kiseleff Ave, No. 2, Sect. 1, 011345, Bucharest, Romania.
E-mail: paleovaly@yahoo.com

Received: March 21, 2019
Accepted August 16, 2019