LEPIDOPHLOIOS ACEROSUS LINDLEY AND HUTTON 1831 IN THE CARBONIFEROUS CUCUIOVA FORMATION, “IRON GATES” NATURAL PARK (BANAT, ROMANIA)

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ABSTRACT

The Carboniferous Cucuiova Formation of the Sirinia Basin, Danubian Units, in Almăj Mountains, South Carpathians, yields a highly diverse yet rare compressive flora representing significant heritage values of the “Iron Gates” Natural Park. This flora includes pteridophytes (lycopsids, sphenopsids, filicopsids) and gymnosperms (pteridosperms and conifers), some of these representatives being important coal generators during the Late Carboniferous times. The facies features, distribution and paleofloral features of the Cucuiova Formation are discussed in the framework of the Sirinia Basin. The lycopsid *Lepidophloios acerosus* Lindley and Hutton 1831 is reported for the first time in Romania from the Cucuiova Formation in Dragosela Valley, in the central part of the “Iron Gates” Natural Park.

RÉSUMÉ: *Lepidophloios acerosus* Lindley et Hutton 1831 dans la Formation Carbonifère de Cucuiova, Parc Naturel des “Portes de Fer”.

La Formation Carbonifère de Cucuiova, bassin de Sirinia, Unités Danubiennes, Monts des Almăj, dans les Carpathes de Sud, inclue une flore compressive rare et diverse à forte valeur patrimoniale pour le Parc Naturel des Portes de Fer. Cette flore inclue des ptéridophytes (lycopsides, sphénopsides, filicopsides) et des gymnospermes (ptéridospermes et conifères), quelques unes d’entre elles ont été des carbogénératrices importantes durant le Carbonifère tardif. Les caractéristiques de facies, la distribution et les caractéristiques paléofloristiques de la Formation de Cucuiova sont discutées dans le cadre du bassin de Sirinia. Le lycopside *Lepidophloios acerosus* Lindley et Hutton 1831 est rapporté pour la première fois en Roumanie, dans la Formation de Cucuiova, Valle de Dragosela, dans la partie moyenne du Parc Naturel des Portes de Fer.

REZUMAT: *Lepidophloios acerosus* Lindley și Hutton 1831 în Formațiunea carboniferă de Cucuiova, Parcul Natural „Porțile de Fier”.

Formațiunea de Cucuiova, de vârstă carboniferă, din cadrul Bazinului Sirinia, Unitățile Danubiene, Munții Almăj, Carpații de Sud, cuprinde o floră compresivă diversă și rară, reprezentând valori patrimoniale semnificative ale Parcului Natural „Poțile de Fier”. Această floră include pteridofite (lycopside, sfenopside, filicopside) și gimnosperme (pteridosperme și conifere), unele dintre acestea fiind carbogeneratori importanți în timpul Carboniferului târziu. Caracteristicile faciale, distribuția și caracteristicile paleofloristice ale Formațiunii de Cucuiova sunt discutate în cadrul Bazinului Sirinia. Lycopsidul *Lepidophloios acerosus* Lindley și Hutton 1831 este raportat pentru prima dată în România, din cadrul Formațiunii de Cucuiova, pe Valea Dragosela, în partea centrală a Parcului Natural „Poțile de Fier”.

INTRODUCTION

The Sirinia Basin, also known as the Svinița-Svinecea Mare sedimentary zone, represents a part of the sedimentary cover of the Upper (Internal) Danubian Units, developed mainly within the structures of the Almăj Mountains, South Carpathians, in Romania. This basin includes Palaeozoic and Mesozoic sedimentary cycles, the Palaeozoic cycle yielding Carboniferous and Permian Formations. The central and southern parts of the Almăj Mountains, where Carboniferous deposits mainly outcrop, occur in the middle area of the “Iron Gates” Natural Park, the second largest natural park in Romania. These deposits yield rare yet diversified plant fossils, their rarity being related to the scarcity of Carboniferous outcrops in the area, as well as to the low potential of fossilisation in the area.

The Carboniferous deposits of the Sirinia Basin (Svinița-Svinecea Mare sedimentary zone) were known since the XIXth Century, when the first studies were published by Hauer (1870), Schafarzic (1894, 1912), Stur (1870) and Tietze (1872); while a contribution dealing with these deposits in a wider geological synthesis was provided by Codarcea (1940). Detailed research was later published by Răileanu (1953), including an inventory of Carboniferous outcropping areas in the Sirinia Basin, and a detailed geological map (Răileanu et al., 1963). Năstăseanu et al. (1973) attempted a general correlation of Carboniferous and Permian deposits, followed by the work of Stănoiu and Stan (1986) dealing with the formal definition of the Cucuiova Formation. The subject was detailed also in various textbooks, such as in Petrescu et al. (1987), Preda et al. (1994) and Răileanu et al. (1963).

Later paleobotany works dealing with the Carboniferous coal flora of the Sirinia Basin were published by Bițoiianu (1972a, b, 1973, 1974, 1987), Dragastan et al. (1997), Maxim (1967, 1969), Popa and Cleal (2012), and Semaka (1962, 1970). Bițoiianu (1966), Ilie and Bițoiianu (1967), and Bițoiianu and Ilie (1968) described fungal remains in coal petrography studies. A general revision of this flora, based on previous works and also of the early paleobotanical contributions of Hantken (1878) and Schafarzic (1894), was published by Popa (2005), who also stressed the main difficulties when undertaking paleobotanical studies in the area: the disappearance of the previous paleobotany type collections, the low quality of outcrops, and the scarcity of illustrated or described taxa in previous papers. The type collections are missing almost entirely, excepting several hand specimens partly figured in Maxim (1969), curated at the “Babeș-Bolyai” University, and an unpublished hand specimen from Cucuiova found in the Silvia Cotuțiu collection, curated at the Bucharest Geological Museum. Another difficulty is the unclear recorded geographical, local names in the region, where valleys and hills were not formally recorded, and they differ from author to author. Popa (2005) detailed the systematic lists of the Cucuiova Formation, together with updates on the lithological logs of the same formation; therefore this type of information will not be reiterated.

The Cucuiova Formation

Recent fieldwork undertaken by the author and his collaborators using GPS gear and GIS methods in the Sirinia Basin showed again the evidence of covered outcrops, as well as the emergence of new, although smaller outcrops, such as those along the Dragosela Valley.

The Carboniferous System in the Sirinia Basin is represented by the Cucuiova Formation (Stănoiu and Stan, 1986). Its stratotype was defined by Stănoiu and Stan (1986) in the Cucuiova Hill – Povalina Valley with its tributaries Coșarnița, Zelenii (Ielenii), Zlana, Pepelaria and Drena creeks, where the sequence was considered Westphalian – Stephanian in age, based on previous paleobotanical information (Fig. 1). The local structure is represented

by the Cucuiova syncline, where the Carboniferous deposits reach about 300 m in thickness, including conglomerates, sandstones, mudstones and thin coal seams. The syncline includes also the Permian terrigenous and volcanoclastic sequences, formerly defined by Stănoiu and Stan (1986) as the Povalina (terrigenous) and Trescovăț (volcanoclastic) formations. The outcrops are scarce, as the Cucuiova Formation was recorded mainly to the east and north-east of the Cucuiova Hill. Fossil material was recently collected by the author's team in 2012-2014 through digging along the Drena Creek slopes, in an attempt to rediscover Maxim's outcrops.

The Dragosela Valley is another significant area in the Sirinia Basin, where the Cucuiova Formation outcrops (Răileanu, 1953; Bițoiianu, 1972b), between the confluence of Dragosela and Tulinecea and Berzasca (Valea Mare) rivers, in the Debelilug area to the west, and towards the confluence of the Dragosela and Dragosela Mică rivers, to the east, north of the Tulinibreg Hill (Fig. 1). Here, the Cucuiova Formation has a syncline structure, as a part of the larger Sirinia Syncline, outcropping along the valley in 14 outcrops of various sizes. A former exploration gallery was found, probably the former G3 gallery of Bițoiianu (1972b), as well as one supplementary sterile dump. The newly collected flora is badly preserved, including a *Lepidophloios acerosus* Lindley and Hutton 1831 fragment curated in the University of Bucharest, described here. Here, quartzite conglomerates, quartzite, micaceous, coarse grained sandstones were found overlaying the Ielova metamorphic series, together with finer sediments such as mudstones and fine, black or brownish sandstones and centimetric coals. Bițoiianu (1972b) cited a floral assemblage marking the Westphalian D – lower Cantabrian interval, but the illustrations are difficult to interpret, as well as the taxonomic composition. Popa (2005) reinterpreted the age of the Cucuiova Formation in Dragosela as Bolsovian – Westphalian D – Cantabrian (Westphalian C – Stephanian).

Baia Nouă is another important area where the Cucuiova Formation was intensively mined (Fig. 1). The local structure is represented by a funnel shaped syncline, the former mine having two main horizons for the extraction of a high quality bituminous coal seam. The age of the Cucuiova Formation in Baia Nouă, based on the fossil flora, was considered by Bițoiianu (1972a, 1974) as Bolsovian (Westphalian C) – lower Westphalian D. Here, the outcrops were cited by Răileanu (1953) along the Tișovița Valley, and by Bițoiianu (1973, 1974) along the Tișovița Valley, Popesc Creek and the Cărbunari Creek, but today these outcrops are missing. The sterile dump permitted collecting fresh material including *Neuralethopteris rectinervis* (Kidston) Laveine 1967 and *Neuralethopteris schlehanii* (Stur) Cremer 1893, described and illustrated by Popa and Cleal (2012). This assemblage indicates the basal sequences of the Cucuiova Formation in Baia Nouă as Langsettian (Westphalian A) in age, the oldest Pennsylvanian age in the Sirinia Basin and in the South Carpathians.

According to Răileanu (1953), the Cozile Valley records the flank of the reversed Sirinia Syncline with Carboniferous and Permian sediments, caught under basement rocks (Fig. 1). Recent field work showed the occurrence of small Permian outcrops represented by red beds and lacustrine limestone lenses, but no outcrops yielding Carboniferous sediments. A former exploration gallery was found in Cozilele Valley, where under red beds sequences occur black, coaly clays which may indicate the Carboniferous age.

The Cucuiova Formation was recorded also in the eastern part of the Sirinia Basin, upstream of the Mraconia River, where the Carboniferous sediments outcrop along a north-south oriented stripe, unconformably overlying the basement (Fig. 1). Also, an outcrop with possible Carboniferous conglomerates was recorded by Răileanu (1953) upstream of the Stariștea (Staricica) Valley.

Figure 1 a: Occurrence of the studied area in the South Carpathians, Romania;
 b: Outcrops of the Carboniferous Cucuiova Formation, in grey, with fossil plant occurrences (underlined); modified from Popa (2005), and Popa and Cleal (2012).

MATERIAL AND METHODS

The studied material consists of rather poorly preserved compressions, stored within the collections of the Laboratory of Palaeontology, Faculty of Geology and Geophysics, University of Bucharest. In the field, paleobotanical material was collected from small sized outcrops or from sterile dumps of the former coal mines (Popa, 2011). A Garmin GPSmap 62s unit was used in order to record accurately the occurrences. In the laboratory, the material was studied using a Carl Zeiss Stemi 2000-C dissecting microscope with a Canon Powershot A640 digital camera attached. Close-up images were taken using a Panasonic DMC-L10 digital camera with an Olympus Zuiko 35 mm macro lens and a Kaiser copy-stand with two Ikea lateral lights (Popa, 2011). Garmin Basecamp software was used for interpretation of geographical data and Corel Draw was used to prepare illustrations.

Systematics

The Carboniferous flora of the Cucuiova Formation is represented by pteridophytes and gymnosperms. This paleoflora is compressive and coal generating, as it generated the bituminous coals extracted from Baia Nouă and explored from Dragosela, Cozilele, Stânei, Cucuiova and Povalina valleys. Popa (2005) and Popa and Cleal (2012) updated the general list of taxa and described the paleoflora of the Baia Nouă mine. Regarding the Carboniferous paleobotanical heritage of the Sirinia Basin, Popa (2003) advanced the idea that the sterile dumps of former coal mines such as Baia Nouă deserve SSSI (Site of Special Scientific Interest) status. The Carboniferous list of the Sirinia Basin counts 116 taxa, but this list is under constant revision due to difficulties related to type collections and previous publications.

Pteridophytes include sphenopsids such as *Calamites carinatus* Sternberg, 1825, *Sphenophyllum cuneifolium* (Sternberg) Zeiller, lycopsids such as *Sigillaria tessellata* Brongniart, 1837, *Stigmaria ficoides* (Sternberg) Brongniart, 1822, and ferns such as *Pecopteris arborescens* Brongniart, and *P. cyathea* Brongniart, among many other species. Gymnosperms are represented by pteridosperms such as *Neuralethopteris rectinervis* (Kidston) Laveine, 1967 and *N. schlehanii* (Stur) Cremer, 1893 and conifers such as *Cordaites principalis* (Germar) Geinitz, 1855.

Pteridophyta

Lycopsida

Lepidodendrales

Lepidodendraceae

Genus *Lepidophloios* Sternberg, 1825

Genus *Lepidophloios* is rarer and less diverse than genus *Lepidodendron* Sternberg, and it is defined mainly by its broader than long leaf cushions (Crookal, 1929; Josten, 1991; Cleal and Thomas, 1994; Thomas et al., 2013). *Sublepidophloios* Sterzel, 1907 is also similar, with an intermediary position between *Lepidodendron* and *Lepidophloios* (Thomas et al., 2013). In Romania, the genus *Lepidophloios* was never cited, described or illustrated (Popa, 2005).

Lepidophloios acerosus Lindley and Hutton, 1831 (Fig. 2a-c)

1831 *Lepidophloios acerosum* Lindley and Hutton, (Fig. 1); 1910 *Lepidophloios acerosus* Renier, Pl. 8; 1929 *Lepidophloios acerosus* Crookal, p. 25-26, Pl. III, 1; pl. XXII, k; 1994 *Lepidophloios acerosus* Cleal and Thomas, p. 71, text-fig. 24A, B, Pl. 4, figure 3; 2011 *Lepidophloios acerosus* Psenicka and Oplustil, p. 65, pl. II, figures 1-2; 2014 *Lepidophloios acerosus* Oplustil et al., p. 784, figure 7; figure 9A, B.

Figures 2a, b, c: *Lepidophloios acerosus* Lindley and Hutton, Dragosela Valley, Sirinia Basin, South Carpathians, stored in the Laboratory of Palaeontology, University of Bucharest as sample P377/C6/1. a. General view of the plant fragment, scale bar: 10 mm; b. Detail, showing leaf cushions, scale bar: 10 mm; Detail, showing enlarged leaf cushions.

LS: leaf scar, K: keel, LPA: ligule pit aperture, scale bar: 5 mm.

Description

An external cast of a trunk shows rhomboidal leaf cushions which are little broader than long, arranged spirally (Figs. 2a, b and c). The lower end or bulge of the leaf cushions is rather rounded, while their upper end is acute. The leaf scar occurs towards the base of the leaf cushion (Fig. 2c) and it is connected to the upper end of the leaf cushion through a prominent keel. The two other lateral keels are difficult to observe. The ligule pit aperture occurs just above the leaf scar (Fig. 2c). The leaf cushions are 6-7 mm wide and 5-6 mm long, and the leaf scars are 3-4 mm wide and 2-3 mm long (Fig. 2c).

Remarks

The shape of the leaf cushions, the lower position of the leaf scar and the prominent keel point to *Lepidophloios acerosus* Lindley and Hutton 1831. A similar species to *Lepidophloios acerosus* is *L. laricinus* Sternberg 1825, but the latter has much broader than long leaf cushions, a central position of the leaf scar and a less prominent keel.

Oplustil et al. (2014) consider *Lepidophloios acerosus* a canopy taxon, recording it within the lower part of the Radnice Member of the Kladno Formation, in Ovcin, Czech Republic. There, *Lepidophloios acerosus* is recorded as Bolsovian (Westphalian C) in age. The species was reported also from Ovcin and Svinna, by Oplustil et al. (2009), and from the Ujezd u Svateho Krize Coalfield in the Radnice Basin, where it is Bolsovian in age (Psenicka and Oplustil, 2011). In West Yorkshire, *Lepidophloios acerosus* is Langsettian (basal Westphalian or Westphalian A) in age (Cleal and Thomas, 1994). Cleal (2008) reported this species from the Etruria Formation, South Staffordshire Coalfield, where it may reach Bolsovian age, and also from northern Devon, within the upper Bideford Formation (Cleal and Thomas, 2004). In South Wales, within the Millstone Grit sequences, *Lepidophloios acerosus* may reach even Namurian age (Cleal et al., 2009). Another occurrence of *Lepidophloios acerosus* is reported from Dobrogea Coalfield (Tenchov, 1987; Cleal et al., 2009), Westphalian in age.

Lepidophloios acerosus may indicate any age in Sirinia Basin, including Langsettian, which is consistent with the ages marked by the assemblage with *Neuraethopteris schlehanii* and *N. rectinervis* in Baia Nouă, in the eastern part of the basin (Popa and Cleal, 2012). This could prove a wider development of Langsettian deposits in the Sirinia Basin, also in the western part, in Dragosela Valley. However, as *Lepidophloios acerosus* was reported elsewhere as Bolsovian in age, its occurrence in Dragosela Valley may be relevant for this age too. A Bolsovian age of *Lepidophloios acerosus* in the area is consistent with the Bolsovian – Cantabrian age of the Cucuiova Formation in Dragosela Valley, as this age was previously considered by Popa (2005). *Lepidophloios acerosus* may have no stratigraphic significance, as it could be recorded from Langsettian to Asturian (Barry T., pers. comm.).

Nevertheless, *Lepidophloios acerosus* is a coal generator, occurring in wet habitats such as the edges of coal producing mires. Libertin et al. (2009) reported *Lepidophloios acerosus* from distal floodplain paleosoils, above coal seams, from the Intra-Sudetic Basin, Czech Republic. *Lepidophloios* species marked various Late Carboniferous wet intervals, such as *L. harcourtii* (Witham) Seward and Hill for the Langsettian substage and *L. hallii* (Evers) DiMichele 1979 for the Westphalian D substage (Cleal, 1991).

Material and occurrence

Only a single fragment, rather badly preserved, recorded on hand specimen P37/C6/1 (Figs. 2a-c) was collected by Săvescu B. on the sterile dump of a former coal gallery in Dragosela Valley, in the northern-central area of the “Iron Gates” Natural Park. The fragment is curated in the collections of the Laboratory of Palaeontology, University of Bucharest.

CONCLUSIONS

The Carboniferous Cucuiova Formation of the Sirinia Basin outcrops scarcely within the Almăj Mountains, therefore its fossil plants are difficult to collect. Although they are usually poorly preserved, these fossils represent significant geological heritage values of the “Iron Gates” Natural Park, occurring especially in Baia Nouă, Cucuiova-Povalina and Dragosela localities, all of them being collected from the sterile dumps of former coal mines or rarely from small sized outcrops. In the Dragosela Valley, a former coal mine’s sterile dump permitted to record a rare *Lepidophloios acerosus* fragment, the first report of this genus and species in Romania.

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