

A larger agglutinated foraminifer originally described as a marine plant: the case of *Arthrodendron* Ulrich, 1904 (Foraminifera), its synonyms and homonyms

MICHAEL A. KAMINSKI¹, ALFRED UCHMAN², THEODOR NEAGU³ & CLAUDIA G. CETEAN⁴

¹Department of Earth Sciences, University College London, Gower Street, London WC1E 6BT, UK and KLF3, 3 Boyne Avenue, Hendon, London NW4 2JL, UK (e-mail: m.kaminski@ucl.ac.uk)

²Institute of Geological Sciences, Jagiellonian University, ul. Oleandry 2a, 30-063 Kraków, Poland (e-mail: alfred.uchman@ing.uj.edu.pl)

³Department of Paleontology, University of Bucharest, b-dul N. Balcescu 1, 70111 Bucharest, Romania (e-mail: theodor.neagu@yahoo.com)

⁴Department of Geology, Babes-Bolyai University, str. Kogalniceanu 1, 400084 Cluj-Napoca, Romania (e-mail: ceteanc@yahoo.com)

ABSTRACT – The large, agglutinated foraminiferal genus *Aschemocella* Vialov, 1966 (type species *Aschemonella carpathica* Neagu, 1964) and the body fossil *Halysium* Świdziński, 1934 (type species *Halysium problematicum* Świdziński, 1934) are herein synonymized with the genus *Arthrodendron* Ulrich, 1904 (type species *A. diffusum* Ulrich, 1904), a form originally described as a marine alga from Upper Cretaceous (Maastrichtian) flysch sediments of the Kodiak Formation of the Yakutat Group (formerly Yakutat Formation) on Pogibshi Island, Alaska. The species *Aschemonella carpathica* Neagu is regarded as a subjective junior synonym of *Arthrodendron diffusum* Ulrich, which is herein lectotypified and transferred to the Foraminifera. *J. Micropalaeontol.* 27(2): 103–110, November 2008.

KEYWORDS: Foraminifera, algae, systematics, *Arthrodendron*, Upper Cretaceous

INTRODUCTION

During the 1899 Harriman Geological Expedition to the coast of Alaska, a curious segmented body fossil was distinguished as a new genus and species *Arthrodendron diffusum* (Ulrich, 1904). It was described from flysch sediments of the Kodiak Formation (formerly Yakutat Formation, now Yakutat Group), near the town of Kodiak and was originally regarded as a fossil alga of unknown affinity (Ulrich, 1904). Similar fossils have been found in the Alpine and Carpathian Cretaceous and Palaeogene flysch deposits, where they have been given different names. Since the 1960s, they have been considered to be large agglutinated foraminifera (Geroch, 1960; Neagu, 1964), commonly under the genus *Aschemonella* Brady, 1879 or *Aschemocella* Vialov, 1966. The genus *Arthrodendron* Ulrich, 1904 is now regarded as an agglutinated foraminifera and the senior objective synonym for these foraminifera described from Alpine–Carpathian flysch deposits.

Such fossils have been reported often in the palaeontological literature as algae. As late as 1990, specimens of *Arthrodendron*, tentatively identified as ‘fossil sea green alga’, were described from the Upper Cretaceous Lupkov Beds in eastern Slovakia (Plička & Thomka, 1990, pl. 49, figs 1–2).

The purpose of this paper is to clarify the generic affiliation of these large deep-sea agglutinated foraminifera based on restudy of the type specimens.

BACKGROUND

The genus *Arthrodendron*

The genus name *Arthrodendron* has had a troubled history and has been applied variously to a Carboniferous plant, marine algae and trace fossils. The first use of *Arthrodendron* was by Scott (*in* Seward, 1898) with reference to a specimen of calamitean plant stem from a North American coal field. Seward (1898) recognized three structural types of calamite stems that were regarded as subgenera belonging to the genus *Calamopitrus* Williamson, 1871 – *Calamodendron*, *Arthropytus* and

Arthrodendron. In his textbook *Studies in Fossil Botany*, Scott (1900) elevated *Arthrodendron* to generic rank. Henceforth, the name ‘*Arthrodendron*’ became entrenched in the botanical literature as a type of a Carboniferous plant, and the name can still be found in the *Encyclopaedia Britannica* used in this sense. Unfortunately, neither Seward (1898) nor Scott (1900) designated a type species for ‘*Arthrodendron*’ and, therefore, the name in its original sense must be regarded as *nomen nudum*.

One year after Seward applied this name to a fossil plant, an enigmatic fossil was discovered by G. K. Gilbert during the 1899 Harriman Geological Expedition to Alaska and described by Ulrich (1904) in the expedition reports, which were reprinted by the Smithsonian Institution in 1910 (hence the publication date is sometimes erroneously cited as 1910). Found in sedimentary rocks of ‘older than Cenozoic’ age on Pogibshi Island opposite the town of Kodiak Alaska (referred to as ‘Kadiak’ in the expedition reports), the fossil was originally regarded as a fossil alga of uncertain affinity. Apparently unaware of Steward’s description of Carboniferous calamite stems, Ulrich (1904) described and illustrated the fossil as ‘*Arthrodendron diffusum* n. gen. n. sp.’ (Fig. 1). The species was described as follows:

“Branches moniliform, springing from a central point and spreading outwardly and upwardly so as the form a loose bush-like mass as much as 15 cm in diameter; divisions dichotomous, at intervals varying from 6 mm to over 20 mm. Joints subelliptical, the lower half usually a little narrower than the upper half, 4 mm to 6 mm in length and from 2.2 mm to 2.28 mm in width; surface usually glossy and smooth, but where preservation is more favourable is covered by minute granules and punctae.”

Based on this specimen (Ulrich, 1904; pl. 14, fig. 1; reproduced herein in Fig. 1), the genus *Arthrodendron* was thus defined: ‘Plant ramose, bushy, the branches constricted at irregular intervals, and probably consisting each of a series of rounded or ovate, flattened (probably inflated) joints; surface of joints minutely granopunctate’.

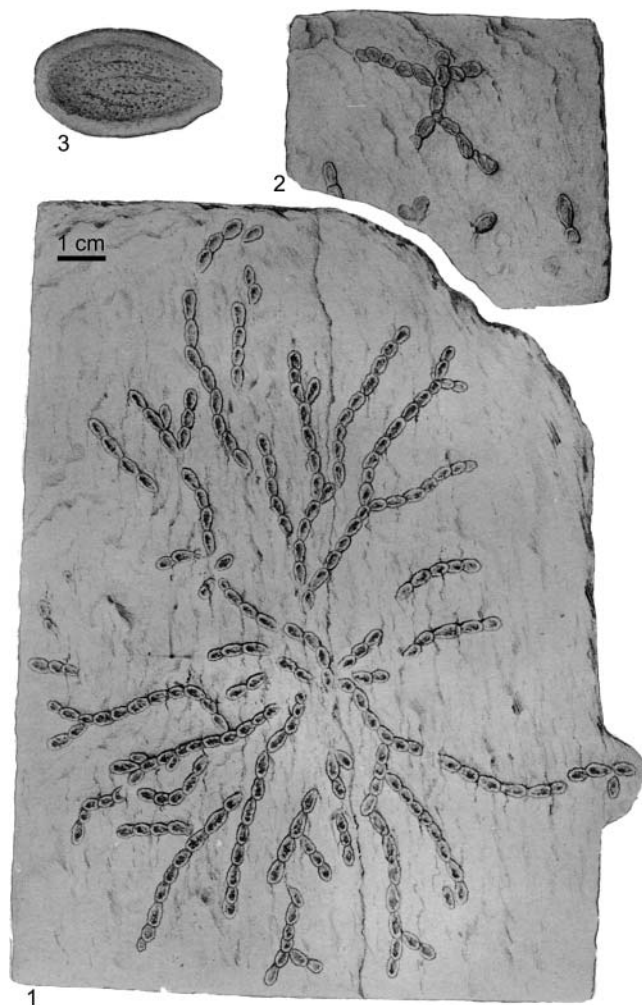


Fig. 1. Holotype of *Arthrodendron diffusum*, from Ulrich (1904): (1) 'a nearly complete specimen showing the mode of growth and the beaded or jointed character of the branches'; (2) 'several fragments on another piece of shale'; (3) 'one of the flattened elliptical joints of the preceding specimen ($\times 6.3$) showing surface markings'.

As pointed out by Reed (1952) this is undoubtedly the earliest valid use of the genus name *Arthrodendron*, and the name must be applied only with reference to Ulrich's Alaskan fossil. The calamite wood specimens from the Carboniferous were consequently renamed '*Arthroxyton*' by Reed (1952). Nevertheless, the name *Arthrodendron* still persists in the popular literature in its original sense.

The homonymy of the name *Arthrodendron* Seward with *Arthrodendron* Ulrich was also pointed out by Dayal (1964). Unaware that Seward's *Arthrodendron* was, in fact, a *nomen nudum*, Dayal regarded Ulrich's form to be the junior homonym and renamed it *Palaeoarthrodendron*, a rather unfortunate choice of a name because Ulrich's genus was described from much younger strata. Because Ulrich's description of *Arthrodendron* is valid, the replacement name *Palaeoarthrodendron* must be rejected as a superfluous name under the rules of the ICZN (1999). Consequently, *Arthrodendron* Ulrich, 1904 is available in the sense of ICZN rules. Because the first valid use of the genus name *Arthrodendron* Ulrich is from the twentieth

century and the name was used subsequently by Andrews (1955, 1970) and by Seilacher (1959), it is too young to be regarded as *nomen oblitum* under Paragraph 23.9.1 of the ICZN (1999).

Fortunately, many of the palaeontological specimens collected during the Harriman Alaskan Expedition have found their way to the Smithsonian Institution, where they are preserved in the collections of the Department of Paleobiology, including the specimens illustrated by Ulrich (1904; pl. 14, figs 1–3) (Fig. 1, Pl. 1). Without doubt, these specimens are not plants, but are large, agglutinated foraminifera, with a mineralized wall.

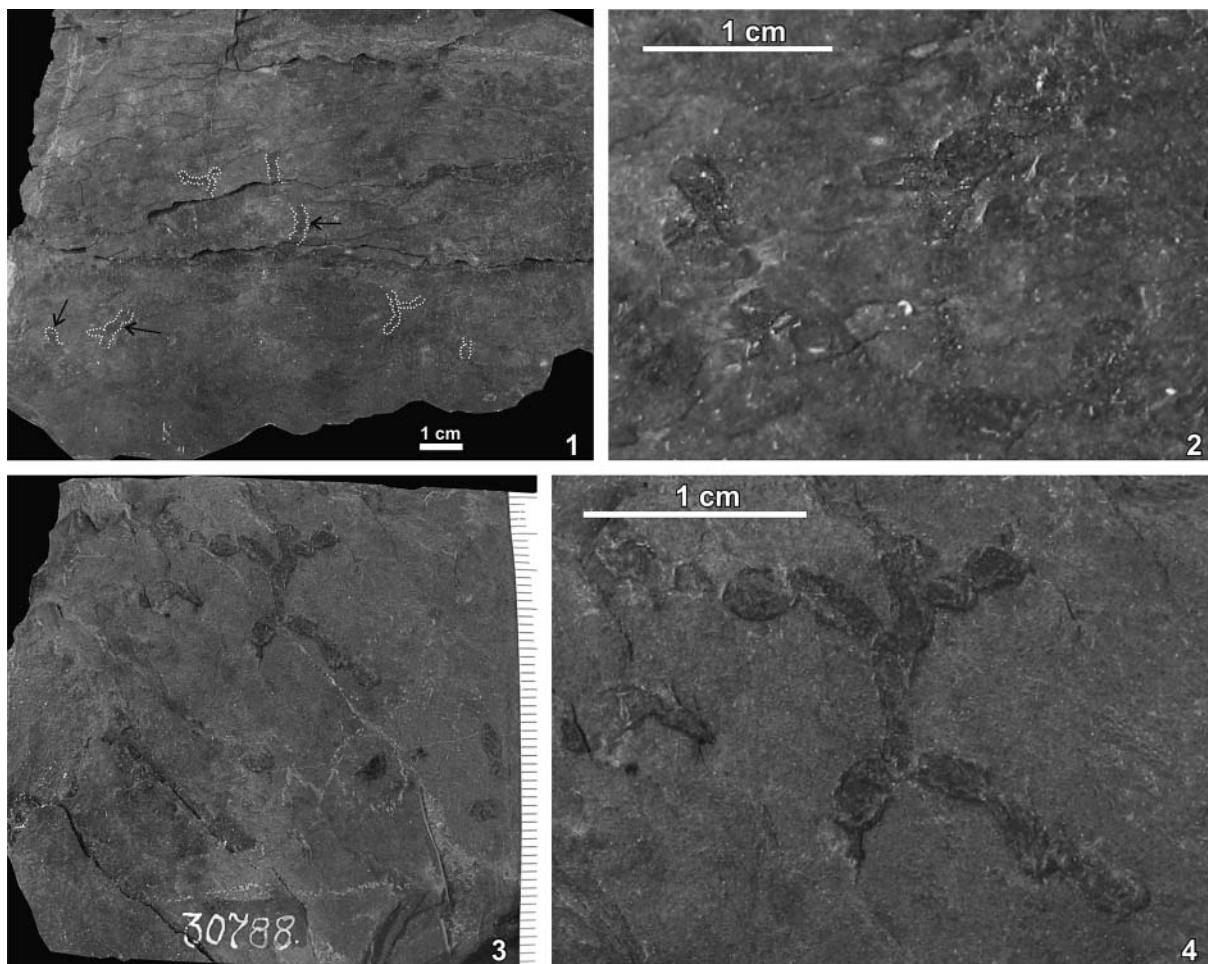
Nineteenth century descriptions

Arthrodendron or *Arthrodendron*-like fossils have been reported in the macrofossil literature as either algae, trace fossils, or as body fossils of uncertain affinity. There are several examples of presumed *Arthrodendron* in the nineteenth century literature, variously described as species of *Corallinites* Unger, 1841, *Hormosira* Endlicher, 1836 or *Halimeda* Lamouroux, 1812. The earliest report is that of Unger (1841), who described the species *Corallinites halimeda* from the 'Jurassic' of Austria. This specimen (Fig. 2a) shows strong similarity to *Arthrodendron diffusum* Ulrich. Massalongo (1856) described four additional species of *Corallinites* from the Tertiary marly limestones of the Vicenza Province of Italy; Heer (1877) described the species *Hormosira moniliformis* from flysch sediments of Freiberg Canton, Switzerland; and Fuchs (1894) described the species *Halimeda saportae* from the Eocene Greifenstein Sandstone of Kritzensdorf, Austria (Fig. 2b). All of these reports require further investigation to establish the possibility of synonymy with the type species of *Arthrodendron*. However, in each case the generic names applied were for green algae (*Corallinites*, *Hormosira*, *Halimeda*). Some of the species names described under these genera may be regarded as valid.

The genus *Halysium* Świdziński, 1934

A potential subjective junior synonym of *Arthrodendron* is the genus *Halysium* Świdziński, 1934 (Fig. 2c) [*non Halysium* Corda, 1837; type species *H. atrium* Corda, 1837] described from the Late Cretaceous Inoceramus Beds at Przegonina near Gorlice, Carpathian flysch in Poland. This genus was included under 'Body Fossils' in the *Treatise of Invertebrate Paleontology, Part W*, by Häntzschel (1975), who listed *Arthrodendron* Ulrich as a junior synonym on the grounds of its supposedly being *nomen nudum*. However, now that status of the type specimens of *Arthrodendron* housed in the collections of the Smithsonian Institution has been clarified, this can no longer be the case. *Halysium* was described in the *Treatise...* (p. W151) as follows: 'Ovate capsules, commonly flattened, smooth or minutely granulated, consistency differing from matrix; some specimens with carbonaceous lining; capsules forming branching rows [?Alga]'.

The only described species, *Halysium problematicum* Świdziński, 1934 displays chambers that vary in size and are elongated, as in *A. carpathica* Neagu, 1964. However, the individual figured by Seilacher (1962) as *H. problematicum* (and reproduced in the *Treatise...*) displays uniformly oval chambers



Explanation of Plate 1.

Type specimens of *Arthrodendron diffusum* Ulrich, 1904, from the Kodiak Formation of Pogibshi Island, Alaska, from the collections of the Department of Paleobiology, Smithsonian Institution. **fig. 1.** Lectotype (USNM 30787). Arrows point to most distinct chambers (outlined by dotted line). **fig. 2.** Detail of figure 1. **fig. 3.** Paralectotype (USNM 30788). **fig. 4.** Detail of figure 3. Photos by Bill DiMichele. Ruler for scale (in cm).

and more frequent branching than *A. moniliformis*, branching after only 2–5 chambers. The whereabouts of Świdziński's specimen is unknown.

The name *Halysium* Świdziński is a junior homonym of the fungal genus *Halysium* Corda, 1837 (Index Fungorum, 2004) and, as a result, it is unavailable. To the authors' knowledge there is no replacement name for *Halysium* Świdziński. If it were a valid name, *Halysium* Świdziński would be placed into the synonymy of *Arthrodendron* Ulrich, based on descriptions and the similarity of the published illustrations. Additionally, the genus *Halysium* Świdziński was reported by Kern (1977) from the Upper Cretaceous Sieveringer Schichten of the Wienerwald flysch in Austria.

Aschemonella carpathica Neagu, 1964

Neagu (1964) described large-sized agglutinated foraminifera *Aschemonella carpathica*, *A. moniliformis* and *Dendrophrya dichotomicus* from the upper part of the Cretaceous Valea Mare Beds in the Teleajen Nappe of the Eastern Carpathians. The type specimens were found in reddish sediments of late Campanian age that are overlain by lower Maastrichtian grey

marls in the Ulves Valley, near the Valea Mare, Romania (Neagu, 1968, 1970). The type description of *Aschemonella carpathica* Neagu, 1964 is as follows:

“Test free, moniliform, with an articulate aspect, dichotomically branched, consisting of numerous chambers with an oval-truncated-glandular contour. Parts connected with both the precedent and subsequent chamber nearly identical. Dimensions of chambers gradually but irregularly increasing. Test wall formed of quartz grains, mica flakes, sponge spicules, etc., of varying size, bound by an abundant siliceous cement. Wall thickness ca. 0.12 mm. Chambers filled with a dark greenish argillaceous material. Apertures circular, situated on small necks either at the end of terminal chambers or on the sides of the chambers. The size of the specimens varies between 2–7 cm, thickness 1–3 mm.”

The holotype specimen (Fig. 3) possesses chambers of varying length. Chambers on the central ‘stem’ are elongated, but chambers on lateral branches are smaller and more oval. Additional paratypes from the collection of the Laboratory of Palaeontology, University of Bucharest, are illustrated in

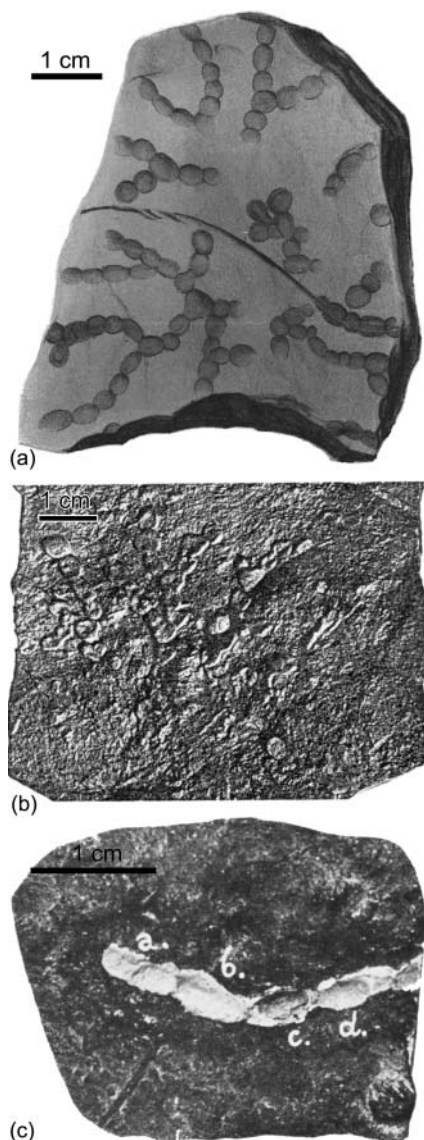


Fig. 2. Some synonyms of *Arthrodendron*: (a) type figure of *Corallinites halimeda* Unger, 1841, from 'Jurassic' limestone of Austria, from Unger (1841, pl. 39, fig. 7); (b) type specimen of *Halimeda saportae* Fuchs, 1894, from the Eocene Greifenstein sandstone of Austria, from Fuchs (1894, fig. 1); (c) holotype of *Halysium problematicum* Świdziński, 1934, from the Upper Cretaceous Inoceramian Beds at Przegonina, near Gorlice, Poland, from Świdziński (1934, fig. 2). The scale bars are approximate.

Plate 2. One of the specimens illustrated by Neagu (1964, pl. 26, fig. 5) was supplied by Stanisław Geroch. This specimen was collected from the Upper Cretaceous Inoceramian Beds of the Magura Nappe at Grybów, Poland. The Grybów locality is described in greater detail by Ślaczka & Kaminski (1998).

The genus *Aschemocella* Vialov, 1966 and the family Aschemocellidae Vialov, 1966

In the mid-1960s a series of papers was written by Soviet micropalaeontologists on the supposed Siliciniifera, a group of foraminifera that were purported to have primary siliceous tests. A number of new genera were proposed by researchers such as

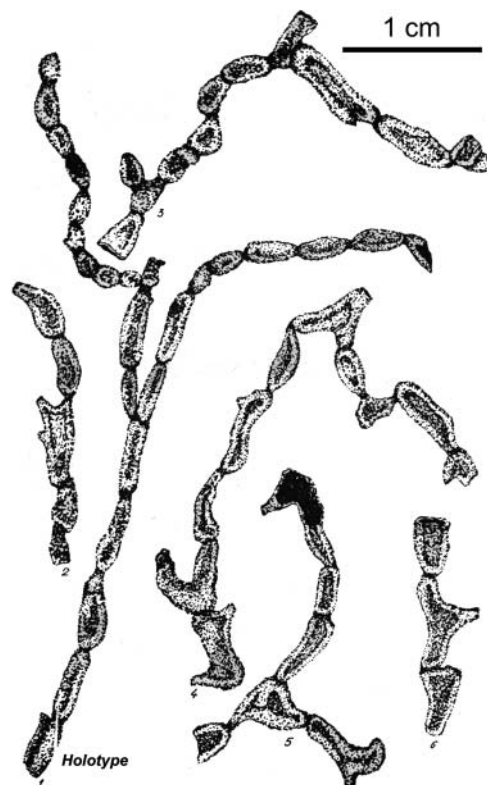
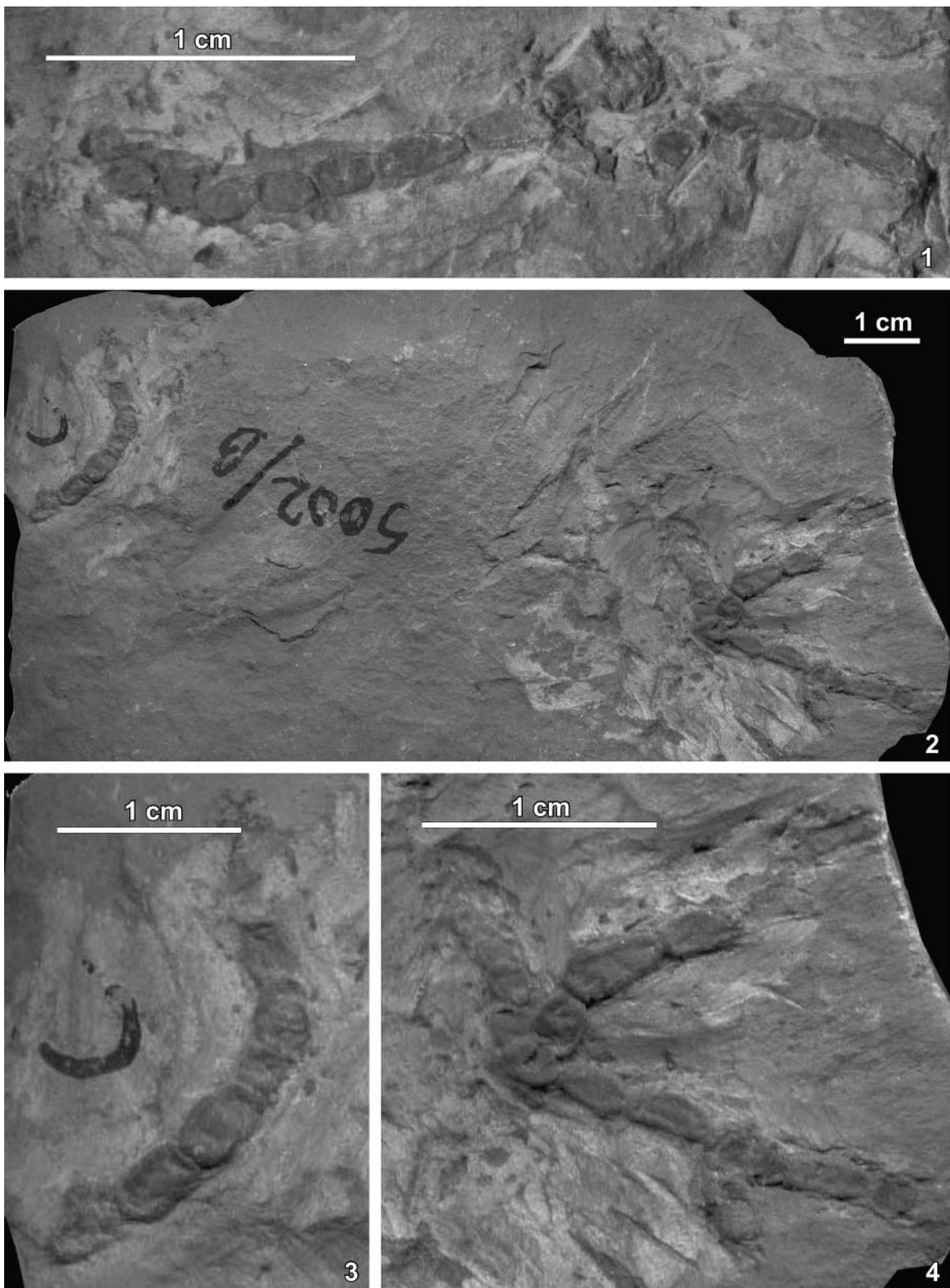


Fig. 3. Type specimens of *Aschemonella carpathica* Neagu, 1964, from the Valea Mare Beds, Braşov County, Romanian Carpathians, scale=1 cm (from Neagu, 1964).

E. V. Mjatluk (1966) and O. S. Vialov (1966) to separate the supposed 'siliceous' genera from their agglutinated homeomorphs. Unfortunately, for these authors, silicification of agglutinated foraminiferal tests turned out to be a purely diagenetic feature. As a result, whether or not an agglutinated test is silicified has no taxonomic significance, and most of the alleged 'siliceous' genera have been regarded subsequently as junior subjective synonyms.

One exception was the genus *Aschemocella* Vialov, 1966 (type species *Aschemonella carpathica* Neagu, 1964), which was considered by Loeblich & Tappan (1987) to be a valid name for fossil foraminifera formerly placed in the genus *Aschemonella*. Moreover, Vialov (1966) established the family Aschemocellidae for his new genus *Aschemocella*. The type species of *Aschemonella* (*A. scabra* Brady, 1879) was discovered by Gooday & Nott (1982) to synthesize barite crystals identical to those found in xenophyophoreans, and was transferred from the Foraminifera into the Xenophyophorea. A generic name was therefore required for the fossil foraminifera described as *Aschemonella* by Neagu (1964) from the Carpathian flysch. Vialov's genus *Aschemocella* served this purpose (see discussion by Berggren & Kaminski, 1990). Since 1990, the genus name *Aschemocella* has been applied consistently to large, mostly fragmentary chambers of multilocular foraminifera recovered from deep-water turbidites (Kaminski & Gradstein, 2005). However, the separation between the Xenophyophorea and the Foraminifera was brought into question by the discovery of Pawłowski *et al.*



Explanation of Plate 2.

Paratype specimens of *Aschemonella carpathica* Neagu, 1964, from the upper Campanian Valea Mare Beds, Braşov County, Eastern Carpathians, Romania, from the collections of the Laboratory of Paleontology, University of Bucharest, photographs by Cristian Focanu. **fig. 1.** Specimen LPB 5002/F. **fig. 2.** Specimen LPB 5002/B. **figs 3–4.** Details of figure 2.

(2003) that the xenophyophorean *Syringamina corbicula* is a foraminifer based on ribosomal DNA analysis. More molecular studies are needed to determine whether the taxonomic separation between Xenophyophorea and the Foraminifera should be maintained.

SYSTEMATIC PALAEOLOGY

Family **Aschemocellidae** Vialov, 1966

1966 Aschemocellidae Vialov: 31. Subsequent designation:
1987 Loeblich & Tappan: 55; 2004 Kaminski: 246; 2004 Mikhalevich: 339.
1974 Aschemocellinae Loeblich & Tappan: 43, nom. transl. ex family Aschemocellidae.

Type genus. *Arthrodendron* Ulrich, 1904.

Description. Test free, dichotomously branched, of ovoid to tubular or irregular uniserial chambers; wall imperforate, agglutinated, firmly cemented; apertures at ends of necks.

Remarks. The family name Achemocellidae is here maintained as valid according to recommendations of Article 40.1 of the ICZN. Irrespective of the validity of the generic name, the family name Aschemocellidae Vialov is conserved.

In the most recently published suprageneric classifications (Kaminski, 2004; Mikhalevich, 2004) the Aschemocellidae was placed within the Superfamily Hormosinoidea (or Hormosinoidea). Because of its large dimensions and catenate branching morphology, *Arthrodendron* bears superficial resemblance to the komokiacean genus *Catena* Schroeder, Medioli & Scott, 1989. This brings into question the systematic affiliation of the Family Aschemocellidae. The Superfamily Komokiacea encompass typically large, branching forms that are either unchambered or pseudochambered, and differ from other foraminifera in accumulating stercomata (faecal pellets) inside their tests. Because of their weakly cemented wall, the komokiaceans are not known to leave a fossil record. If it turned out that *Arthrodendron* accumulated stercomata, based on external morphology the Family Aschemocellidae would fit better within the Komokiacea. Until this matter is resolved, the Aschemocellidae are tentatively retained within the Hormosinoidea.

Genus *Arthrodendron* Ulrich, 1904

1904 *Arthrodendron* Ulrich: 138, pl. 14, figs 1–3 [type species: *Arthrodendron diffusum* Ulrich, 1904].
1934 *Halysium* Świdziński: 146 [type species: *Halysium problematicum* Świdziński, 1934; non *Halysium* Corda, 1837].
1964 *Palaeoarthrodendron* Dayal: 727 [nom. subst. pro *Arthrodendron* Ulrich, 1904].
1966 *Aschemocella* Vialov: 31 [type species: *Aschemonella carpathica* Neagu, 1964].

Type species. *Arthrodendron diffusum* Ulrich, 1904, p. 138, by original designation. [Subjective junior synonym: *Aschemonella carpathica* Neagu, 1964, p. 582].

Type specimens. The two specimens illustrated by Ulrich (1904, pl. 14, figs 1, 2) are housed in the Department of Paleobiology,

National Museum of Natural History, Smithsonian Institution, Washington D.C. The specimen illustrated by Ulrich in his fig. 1 (USNM 30787) is designated here as the lectotype (Pl. 1, figs 1–2). The paralectotype (Ulrich's fig. 2) is registered as USNM 30788 (Pl. 1, figs 3–4).

Type locality. The holotype of *A. diffusum* was collected by G. K. Gilbert during the 1899 Harriman Alaskan Expedition from the 'Yakutat Formation' (now the Kodiak Formation within the Yakutat Group) on Pogibshi Island separated by a narrow strait from the Kodiak Island opposite the town of 'Kodiak' [now Kodiak], Alaska. The accompanying trace fossil assemblage found at the locality included *Chondrites* and graphoglyptids, indicating a deep-sea environment. Sedimentological (Nielsen & Moore, 1979) and ichnological studies (McCann & Pickerill, 1988) indicate that the Kodiak Formation was deposited in a distal deep-sea fan turbidite setting.

Type level. The Kodiak Formation is now regarded to be of Late Cretaceous (Early Maastrichtian) age on the basis of inoceramid bivalves (Jones & Clark, 1973).

Diagnosis. Branched chains of large, often irregular chambers with a simple, imperforate, agglutinated wall.

Description. Test free, with large (commonly 1–3 mm wide) irregularly ovoid, flask-shaped, or tubular chambers in a linear or dichotomously branching series, increasing very slowly in size. Chambers are compressed with a raised outer rim and may have irregular shape at the point of branching. Wall imperforate, simple, of agglutinated quartz, mica, and sponge spicules in abundant cement, probably with an inner organic lining. May have more than one rounded aperture, which may be produced on a neck, terminal, or may be at the side of the chamber, probably just before a new branch arises.

Occurrence. Upper Cretaceous (Campanian–Maastrichtian) in Alaska, Austria, Italy, Poland, Romania, Slovakia, Switzerland, Ukraine; Palaeogene in Austria, Italy, Poland, Switzerland, Trinidad and the North Sea.

Remarks. The similarity between the type species *A. diffusum* Ulrich, 1904 and the species *Aschemonella carpathica* Neagu, 1964 is striking. Both species are reported from rocks of similar age and palaeoenvironment. Ulrich reported the thickened rims around the individual chambers of *A. diffusum*, a feature that is also typical of the type specimens of *A. carpathica*.

At least four valid species of *Arthrodendron* have been reported from Late Cretaceous to Palaeogene aged deep-sea sediments under various generic names. In addition to the type species *A. diffusum* (= *A. carpathica* Neagu, 1964), the species *A. moniliformis* (= *Aschemonella moniliformis* Neagu, 1964), *A. grandis* (= *Reophax grandis* Grzybowski, 1898) and *A. subnodosiformis* (= *Hyperammima subnodosiformis* Grzybowski, 1898) are commonly reported from deep-sea turbiditic deposits, mostly in the Carpathians. The latter two species were transferred to the genus *Aschemocella* by Kaminski & Geroch (1993). However, the validity of the nineteenth century species originally described as fossil algae needs to be evaluated. It is possible that some of

the species described by Unger (1847), Heer (1877) and by Fuchs (1894) may be senior synonyms of some of the species names in current usage.

The modern komokiacean genus *Catena* Schroeder, Medioli & Scott, 1989 is externally very similar to *Arthrodendron*, and the question of their synonymy requires further investigation. The type species, *Catena piriformis* Schroeder, Medioli & Scott, 1989 is a branching chain of elongated or pyriform chambers that may possess an additional aperture produced on a neck, as in *Arthrodendron*. Because of the presence of internal stercomata, Schroeder *et al.* (1989) placed their new genus in the Family Baculellidae Tendal & Hessler, 1977 within the Superfamily Komokiacea. Whether or not *Catena* is a junior synonym of *Arthrodendron* remains an open question.

CONCLUSIONS

Larger agglutinated foraminifera commonly occur in Upper Cretaceous and Palaeogene flysch deposits world-wide. Some of these specimens have been historically referred to numerous genera of marine plants, body fossils of unknown affinity, or trace fossils. The valid generic name for such fossils is *Arthrodendron* Ulrich, 1904 (with the genera *Halysium* Świdziński, 1934, *Palaeoarthrodendron* Dayal, 1964 and *Aschemocella* Vialov, 1966 included as junior synonyms), which is transferred to the Foraminifera. The type species of the genus *Aschemocella* (*Aschemonella carpathica* Neagu, 1964) is here regarded to be a subjective junior synonym of *Arthrodendron diffusum* Ulrich, 1904. At least three additional species known from the Alpine-Carpathian literature also belong in *Arthrodendron* Ulrich: *A. moniliformis* (Neagu, 1964), *A. grandis* (Grzybowski, 1898) and *A. subnodosiformis* (Grzybowski, 1898). The validity of the nineteenth century species originally described as fossil algae needs to be evaluated, as it is possible that some of the species described by Unger (1841), Heer (1877) and by Fuchs (1894) may be senior synonyms of some of the foraminiferal species names in current usage.

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