Magyarhoni Földtani Társulat
Földtani Közlöny
Hungarian Geological Society

152/1, 17–30., Budapest, 2022

DOI: 10.23928/foldt.kozl.2022.152.1.17

Monospecific mass occurrence of a new species of the Early Jurassic genus Arzonellina (Brachiopoda) at Fenyveskút (Bakony Mountains, Hungary)

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A kora jura Arzonellina genus (Brachiopoda) új fajának tömeges, monospecifikus előfordulása Fenyveskúton (Bakony hegység)

Összefoglalás

A rendkívül gazdag jura brachiopoda faunáiról nevezetes Fenyveskút lelőhelyről egy különös, a lelőhelyről korábban nem ismert kifejlődésű brachiopoda lumasellát (kokvinát) tartalmazó mészkőtömb került elő. A vizsgálatok azt mutatták, hogy a mészkőtömb a korábban Svájcból leírt kingenoid *Arzonellina Sulser*, 2005 genus példányainak tömeges, monospecifikus felhalmozódását tartalmazza. A részletes külső és belső morfológiai (sorozatcsiszolásos) vizsgálatok alapján a példányok az *Arzonellina bogicae* n. sp. új fajhoz sorolhatóak. Az új faj részletes leírása és illusztrálása ebben a dolgozatban jelenik meg. A brachiopoda kokvina kora – közvetett bizonyítékok alapján – sinemurinak tekinthető. A tömeges brachiopodát tartalmazó mészkő pátitos jellege nagyon hasonlít a fenyveskúti lelőhelyen gyakori Hierlatzi Mészkőéhez. Az *Arzonellina* genus korábban dokumentált előfordulásai Svájcban és Montenegróban szintén sinemuri korúak. Annak érdekében, hogy az *Arzonellina* kokvinát tartalmazó tömb üledékes történetét megismerhessük, a fenyveskúti jura megabreccsa újraértékelését is indokolt volt elvégezni. A dolgozat ismerteti a megabreccsa tömbjeinek és mátrixának ősmaradvány-tartalmát és kőzetjellegeit, amit vékonycsiszolatos fényképfelvételek segítségével is illusztrál. A már a korai diagenezis során (a sinemuriban) cementált brachiopoda kokvinában egy több centiméteres kiterjedésű nyílt üreg maradt, amit később a jura során beszivárgó mikrites üledék töltött ki. A *Bositra* tartalmú mikrites kitöltő anyag azt bizonyítja, hogy az eredetileg bizonyára hasadékkitöltő brachiopoda kokvina egy tömbje a bajociban lett a megabreccsa egyik komponense. A brachiopodák monospecifikus, tömeges előfordulása sok esetben metántartalmú tenger alatti forrásokhoz kapcsolódik. A fenyveskúti anyagon végzett stabil izotópos vizsgálatok nem mutattak anomális szén-izotópos értékeket.

Tárgyszavak: Brachiopoda, új faj, kora jura, Bakony hegység

Abstract

A peculiar slab of brachiopod coquina was found at Fenyveskút locality (Lókút, Bakony Mountains, Hungary). The current investigation demonstrated that it was a mass occurrence of monospecific brachiopods which belong to the kingenoid genus *Arzonellina Sulser*, 2005, recently described from Switzerland. Detailed investigations of the external and internal morphology (the latter by serial sections) of the specimens proved that they represent a new species: *Arzonellina bogicae* n. sp. This new species is introduced, described and illustrated here in details. The age of the brachiopod coquina and the new species is considered Sinemurian on the basis of circumstantial evidence from the locality Fenyveskút, where the lithologically very similar, Sinemurian Hierlatz Limestone is frequent. The previously documented occurrences of *Arzonellina* in Switzerland and Montenegro are also Sinemurian in age. For better understanding the sedimentary history of the slab of brachiopod coquina with *Arzonellina*, the Jurassic megabreccia at the locality Fenyveskút is re-described here. The lithology and fossils of the major components (blocks) and the matrix are documented in detail, and illustrated with thin section photomicrograps. Detailed study of the sediments that accumulated in an internal open space (vug) of the formerly lithified (cemented) brachiopod coquina revealed that the piece of the *Arzonellina* coquina was incorporated into the megabreccia in the Bajocian. The monospecific mass accumulation of brachiopods gave a hint to an association with hydrocarbon seeps (“cold seeps”). However stable isotopic results from the Fenyveskút locality do not show any signatures that would indicate the influence of that special environment.

Keywords: Brachiopoda, new species, Early Jurassic, Bakony Mountains

Introduction

The Bakony Mountains are famous for their very abundant and diverse Jurassic brachiopods, from the Hettangian and Sinemurian (BÖCKH 1874; DULAI 1992, 1993, 2003), through the Pliensbachian and Bajocian (VÖRÖS 1983, 2001, 2009) to the Kimmeridgian and Tithonian (VÖRÖS & DULAI 2007). One of the best places to collect Jurassic brachiopods is the locality Fenyveskút, south of the village Lókút at the foot of the Papod Hill (*Figure 1*). A peculiar slab of brachiopod coquina was found just at the foot of the hillside by the daughter of the present author in the course of a family excursion in 1995. This loose, fallen block of a few decimetres size contained a crowded mass of apparently monospecific, centimetre-sized, smooth and flat brachiopods. At that time, the find was considered a mass occurrence of smooth *Rhynchonellina*-like specimens and was deposited in the palaeontological collections of the Hungarian Natural History Museum, Budapest.

In the last decades a very peculiar genus *Arzonellina* was described from the Sinemurian of the Southern Alps (Arzo: SULSER 2004) and was recorded from the same age from the Dinarides (Smokovac: SANDY et al. 2018, 2021). This new genus has strong external similarity to some of the smooth species of *Rhynchonellina*, e.g.: *R. suessi* (GEMMELLARO) and *bilobata* (GEMMELLARO), but its internal morphology is significantly different. Due to the unusual internal structures, SULSER (2004) did not place *Arzonellina* into any taxonomic order (used *incertae sedis*) and mentioned its "Paleozoic look". SANDY et al. (2018, 2021) produced further serial sections and attributed *Arzonellina* to a new family of the Kingenoidea (Terebratulida). These new results gave impetus for the detailed investigation of the "smooth rhynchonellinas" from Fenyveskút. At the same time this paper provides the opportunity to give an informative geological description of this famous but inadequately documented locality and its complex history of Jurassic sedimentation.

Locality

The Fenyveskút locality (coordinates: 47° 11´ 26´´ N / 17° 51´ 25´´ E) was the site to visit by the illustrious international participants of the „Regional field symposium on Alpine brachiopods" in 1992. A concise description of the outcrop and the Jurassic palaeogeographic interpretation of the surrounding area was given in a guidebook by VÖRÖS (1992, pp. 58–63) and is described in more detail here. A newly drawn, interpreted tentative profile of the Fenyveskút locality is shown in *Figure 2*.

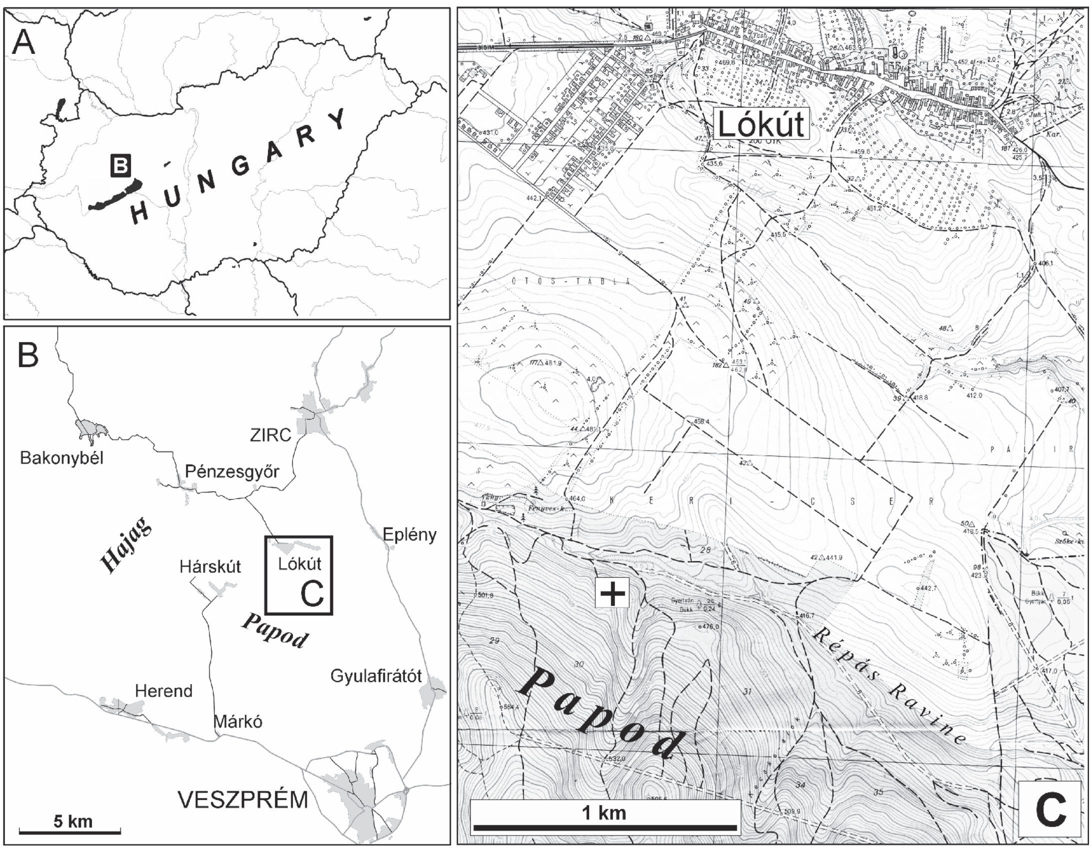


Figure 1. A) Map of Hungary showing the location of the Lókút area. B) Map showing the location of the Lókút area in the Bakony region. C) Detailed map of the Lókút area. The cross indicates the site of the Fenyveskút locality

1. ábra. *A) Lókút környékének helyzete Magyarországon belül. B) Lókút környékének helyzete a Bakonyon belül. C) Lókút környéke. A fenyveskúti lelőhelyet kereszt jelzi*

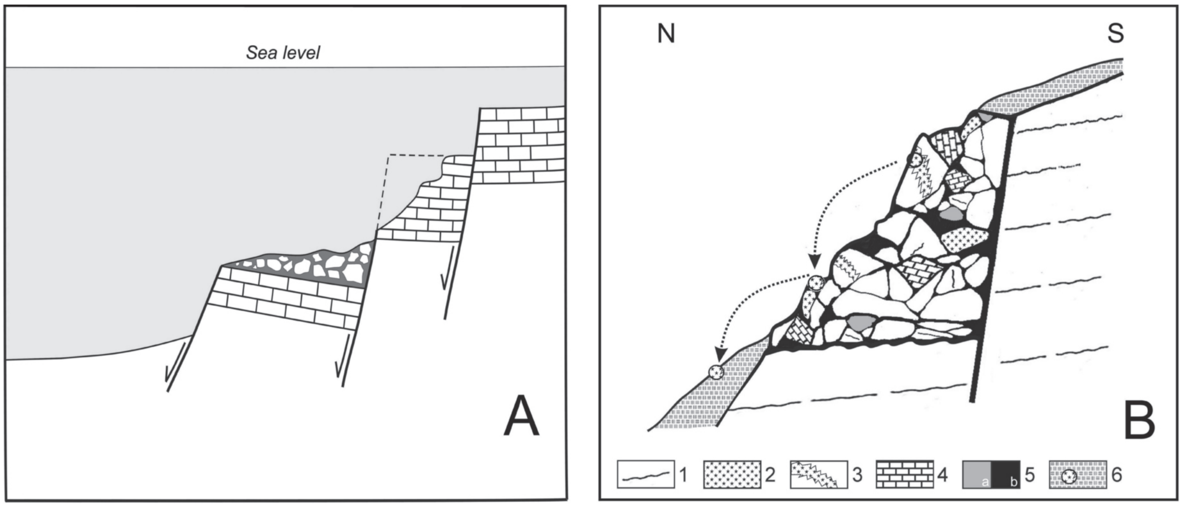


Figure 2. A) Conceptual model for the megabreccia accumulation triggered by normal faulting within a disintegrated carbonate platform (after Festa et al. 2010). B) Interpreted profile of the Fenyveskút hillside. Vertical scale is approximately 10 m

Legend: 1 – Kardosrét Limestone (Hettangian), 2 – Hierlatz Limestone in blocks (Sinemurian), 3 – Hierlatz Limestone in neptunian dykes (Sinemurian), 4 – Brachiopodal limestone (Hierlatz Formation, upper Pliensbachian), 5a – Red limestone (Tölgyhát Formation, Hárskút Member, middle Bajocian), 5b – Greyish-red limestone (Tölgyhát Formation, Hárskút Member, upper Bajocian), 6 – Soil, scree, with loose block. Dotted arrows indicate the inferred phases of transport of the block of brachiopod coquina

2. ábra. *A) Normál vetők által kiváltott megabreccsa-képződés elvi modellje szétdarabolódó karbonátplatformon belül (Festa et al. 2010 nyomán). B) A fenyveskúti hegyoldal értelmezett szelvénye. A függőleges méret kb. 10 m*

Jelmagyarázat: 1 – Kardosréti Mészkő (hettangi), 2 – Hierlatzi Mészkő blokkokban (sinemuri), 3 – Hierlatzi Mészkő neptuni telérekben (sinemuri), 4 – Brachiopodás mészkő (Hierlatzi Formáció, felső pliensbachi), 5a – Vörös mészkő (Tölgyháti Formáció, Hárskúti Tagozat, középső bajoci), 5b – Szürkés-vörös mészkő (Tölgyháti Formáció, Hárskúti Tagozat, felső bajoci), 6 – Talaj, lejtőtörmelék blokkokkal. Szaggatott nyilak jelzik a brachiopoda kokvina tömb áthalmozódásának feltételezett fázisait

This site, famous for its “big brachiopods”, was found by Noszky (1945) who collected here numerous, big, five centimetre-long specimens of “*Terebratula* (*Pygope*) *adnethensis* Suess 1852”. In the course of geological mapping by the Geological Institute of Hungary in the 1960’s a small trench was also excavated here which was named as “Section VIII” (Konda 1970). The occurrence was described as Sinemurian–Pliensbachian, brachiopodal Hierlatz-type limestone deposited on the uneven surface of the massive “Dachstein-type” limestone, partly capped by dark red Toarcian limestone. Similar settings were also reported along a tectonic belt bordering the northern foot of Papod Hill, exposed in the southern side of the Répás Ravine, in downfaulted tectonic contact with the Upper Triassic dolomite, forming the main mass of the Papod Hill (Konda 1970).

In the late 1970’s the present author started to make serial sections of some “big brachiopods” from Fenyveskút, supposed to be the Pliensbachian “*Terebratula*” *adnethensis*. Unexpectedly, the matrix of the sectioned specimen was full of *Bositra* shell fragments. Moreover, the internal morphology of the big brachiopod pointed to the Middle Jurassic genus *Karadagithyris*.

Motivated by the unpredicted appearance of Middle Jurassic rocks and fossils at Fenyveskút, A. Galácz and the author made a field survey along the foot of Papod Hill. Middle and late Bajocian brachiopods and ammonoids were found at several places, in dispersed blocks of dark red limestones between large blocks of the white “Dachstein-type” limestone. It was also recognized that “big brachiopods”, besides the Pliensbachian, occurred in the Bajocian limestones as well. The best occurrence was at Fenyveskút, a cliff-like shoulder between two side valleys on the south side of the Répás Ravine. The conditions of the exposures were rather poor; regular sequence of layers was not found, but it was easy to observe that limestone blocks of different size, lithology, colour and texture emerged from the soil.

In the course of several visits of the locality, with A. Galácz, the following different limestone types and fossils were found in this mélange:

Kardosrét Limestone (Hettangian)

It is a massive, yellowish-grey, micritic limestone with mudstone to grainstone or packstone texture. Its lithology and depositional environment is similar to that of the Upper Triassic Dachstein Limestone, but the Lofer cylicity is absent. Smaller oncoids or pellets commonly occur, cemented by sparry calcite. Mollusc fragments and foraminifers are found occasionally (*Figure 3A, B*). This rock (formerly called “Dachstein-type” limestone) formed the biggest and most frequently encountered blocks in the outcrop. The Hettangian age is circumstantial; direct biostratigraphical evidence is missing.

White and pink Hierlatz Limestone (Sinemurian)

It occurs in two types; in the form of separate blocks, and in fissure fillings (neptunian dykes) within Kardosrét Limestone blocks. The rock is composed mainly of skeletons and fragments of brachiopods and subordinately of bivalves, gastropods, crinoids and ammonoids, cemented by white, sparry calcite (*Figure 3C, D*). Geopetal structures are fre-

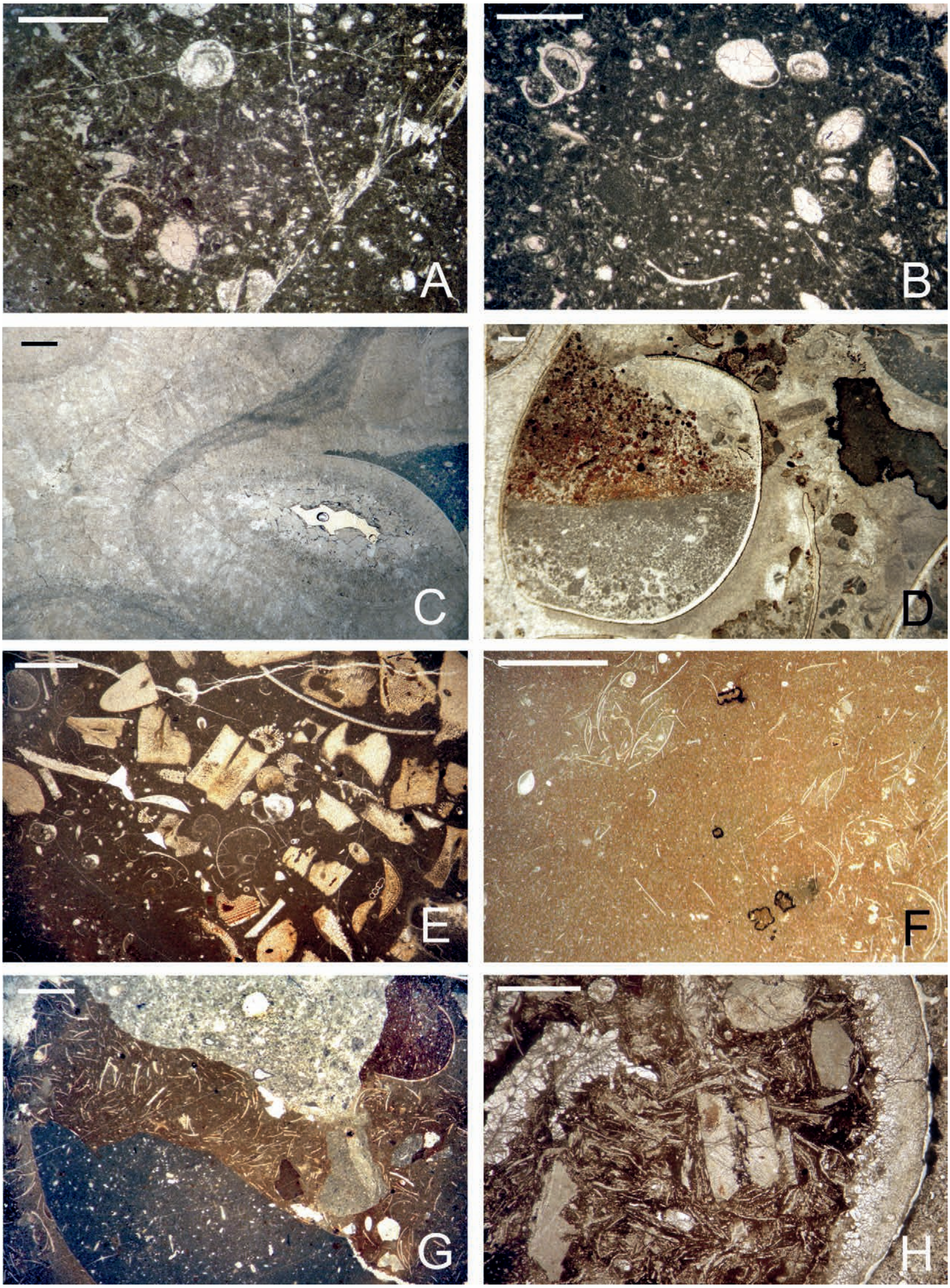


Figure 3. Thin section photomicrographs of the major limestone types of the blocks and matrix of the megabreccia ("mélange") at Lókút, Fenyveskút, Bakony Mountains, Hungary. A) Kardosrét Limestone with gastropod and foraminifers (*Triasina hantkeni*) (Hettangian). B) Kardosrét Limestone with gastropod and other foraminifers (Hettangian). C) Hierlatz Limestone with brachiopod shells in coarse crystalline sparry cement and subordinate micrite in geopetal structure (right center) (Sinemurian). D) Hierlatz Limestone with brachiopod shells and extraclasts in sparry calcite cement. Note the three phases of geopetal infilling in the brachiopod shell on the left (Sinemurian). E) Coarse crinoidal micritic limestone with brachiopod shell fragments. Note the frequent

quent. The dominant microfacies is biosparite of grainstone texture. In the earliest diagenetic stage, grains and the walls of inner or intergranular cavities were coated with radial-fibrous "isopachous" cement. This was usually followed by micrite infiltration. After the micritic phase the second, late diagenetic sparite was formed: coarse-grained, mosaic-like spar segregated in the remaining cavities. The age probably encompasses different parts of the Sinemurian; the early Sinemurian is evidenced by a piece of *Arnioceras* sp. The brachiopod fauna is rather diverse:

Prionorhynchia pseudopolyptycha (BÖCKH, 1874)
Calcirhynchia ? *hungarica* (BÖCKH, 1874)
Cuneirhynchia cartieri (OPPEL, 1861)
Pisirhynchia inversa (OPPEL, 1861)
Liospiriferina obtusa (OPPEL, 1861)
Cisnerospira angulata (OPPEL, 1861)
Papodina juvavica (GEYER, 1889)
Zeilleria stapia (OPPEL, 1861)
Zeilleria venusta (UHLIG, 1879)

Pink, red and ochre brachiopodal limestone (Upper Pliensbachian)

It is considered a special variant of the Hierlatz Limestone Formation where the micrite matrix prevails over the sparite cement. In the fine-grained carbonate matrix shells or skeletal fragments of brachiopods prevail; echinoderm skeletal elements are frequent; sponge spicules may abound locally in the micrite matrix (*Figure 3E*). Extraclasts and intraclasts occur. The rock is massive or thick-bedded biomicrite with packstone or wackestone texture. Red, pink or yellow micritic void-fillings and geopetal structures are frequent. Besides the dominant brachiopods, bivalves, gastropods, rarely solitary corals, worm tubes and ammonoids were collected. A few ammonoids indicate a late Pliensbachian (Margaritatus Zone ?) age (B. GÉCZY, pers. comm.). The brachiopod fauna is extremely diverse: VÖRÖS (2009) reported and described 46 species from the Fenyveskút locality, including the impressive *Securithyris adnethensis*. This is the rock type famous for "big brachiopods" (NOSZKY 1945, KONDA 1970). The most frequent brachiopod species are listed below:

Apringia piccininii (ZITTEL, 1869)
Apringia paolii (CANAVARI, 1880)
Apringia diptycha (BÖSE, 1898)
Megapringia stoppanii (PARONA, 1880)
Megapringia altesinuata (BÖSE, 1898)
Lokutella liasina (PRINCIPI, 1910)
Fenyveskutella vighi VÖRÖS, 2009
Paronarhynchia bulga (PARONA, 1893)
Koninckodonta fuggeri BITTNER, 1894
Liospiriferina sicula (GEMMELLARO, 1874)
Securithyris adnethensis (SUESS, 1855)
Linguithyris aspasia (ZITTEL, 1869)
Papodina bittneri (GEYER, 1889)
Aulacothyris ? *ballinensis* (HAAS, 1912)
Bakonyithyris ovimontana (BÖSE, 1898)

traces of bioerosion. Dark micrite (wackestone) with sponge spicules in the lower left corner (Pliensbachian). F) Mudstone to wackestone with manganese coated intraclasts, foraminifers and many *Bositra* shells (Toarcian). G) Breccia grains in Bajocian *Bositra* limestone matrix: a fragment of Hettangian Kardosrét limestone in upper centre and a clast of Pliensbachian micrite with sponge spicules in the lower part (Bajocian). H) Biomicrite infilling of a large brachiopod with coarse echinoderm and *Bositra* detritus (Bajocian). Scale bar = 1 mm

← ***3. ábra.*** *A fenyveskúti megabreccsa blokkjaiban és mátrixában felismert főbb mészkő típusok vékonycsiszolatainak mikroszkópi felvételei. A) Kardosréti Mészkő gastropoda és foraminifera (*Triasina hantkeni*) metszetekkel (hettangi). B) Kardosréti Mészkő gastropoda és foraminifera metszetekkel (hettangi). C) Hierlatzi Mészkő: durva kristályos pátittal cementált brachiopoda héjak, helyenként geopetális szerkezetet formáló mikrittel (jobb középen) (sinemuri). D) Hierlatzi Mészkő brachiopoda héjakkal és extraklasztokkal, pátit cementben. Baloldalon három fázisú geopetális kitöltés látható a brachiopoda teknőben. (sinemuri). E) Durva krinoideás mikrites mészkő brachiopoda héjtöredékekkel. Feltűnően gyakoriak a bioeróziós nyomok. A bal alsó sarokban sötét, szivacstűs mikrit (wackestone) válik uralkodóvá (pliensbachi). F) Vörös mudstone és wackestone szövetű mészkő mangánkérges intraklasztokkal, foraminiferákkal és gyakori* Bositra *héjakkal (toarci). G) Breccsa szemcsék bajoci Bositrás mészkő mátrixban: hettangi Kardosréti Mészkő töredék (fölül), és a pliensbachi szivacstűs mikrit litoklasztja (alul) (bajoci). H) Egy nagy brachiopoda biomikrites kitöltése durva echinodermata töredékekkel és tömeges* Bositra *héjakkal (bajoci). Mérce = 1 mm*

Dark red micritic limestone (Toarcian)

This rock, traditionally called "Indian red" limestone (Kisgerecse Formation), occurred very subordinately, as thin covers and eroded lenses mostly on top of Kardosrét Limestone blocks (for this reason this rock type is not represented in *Figure 2*). In the mudstone texture small foraminifers occur and thin *Bositra* shells abound locally (*Figure 3F*). Megafossils are almost absent, except the ammonoids which indicate an early Toarcian age (B. GÉCZY in KONDA 1970).

Red brachiopodal limestones (Bajocian)

Two types of Bajocian limestones were recognized, both may be classified as belonging to the Hárskút Member of the Tölgyhát Formation. One of them is a bright red micritic limestone crowded with thin *Bositra* shell pieces. This rock encloses fragments of various older limestone formations (*Figure 3G*). The abundant, medium-sized and small brachiopods and the occasional ammonoids partly bear ferro-manganese coatings. Many brachiopods are filled with sparry calcite. The ammonoids point to a middle Bajocian age (A. GALÁCZ, pers. comm.). The brachiopod fauna is rather diverse:

Apringia alontina (DI STEFANO, 1884)
Cardinirhynchia galatensis (DI STEFANO, 1884)
Septocrurella retrosinuata (VACEK, 1886)
Septocrurella micula (OPPEL, 1863)
Septocrurella ? *microcephala* (PARONA, 1896)
Striirhynchia subechinata (OPPEL, 1863)
Striirhynchia berchta (OPPEL, 1863)
Linguithyris nepos (CANAVARI, 1880)
Viallithyris ? *alamanni* (DI STEFANO, 1884)
Karadagithyris ? *fylgia* (OPPEL, 1863)
Papodina ? *recuperoi* (DI STEFANO, 1884)

The other type is a darker greyish-red limestone with very frequent, small, black manganese-oxide grains and coarse detritus of *Bositra* shells (*Figure 3H*). The brachiopods and echinoderm fragments usually have manganese-oxide coatings as well. This is the second rock type at Fenyveskút yielding "big brachiopods". The rare ammonoids indicate a late Bajocian age (A. GALÁCZ, pers. comm.). Despite the great abundance (around one hundred specimens collected), only two brachiopod species were identified from this rock type:

Apringia atla (OPPEL, 1863)
Karadagithyris gerda (OPPEL, 1863)

According to our field observations the size of the limestone blocks varied from a few centimetres to a few metres. Their orientation was chaotic (the tilting of the blocks were evidenced by certain primary sedimentary structures, e. g. bedding, or geopetal infill of brachiopod valves. Some of the blocks were composite. Blocks of formerly lithified breccia ("breccia in breccia") and blocks of Kardorét Limestone with dykes of Hierlatz Limestones frequently occurred.

We interpreted this unit as a megabreccia formed along the Jurassic submarine escarpment bordering the Papod submarine horst (see VÖRÖS & GALÁCZ 1998 for details). Repeated tectonic movements along the fault scarp occurred in the Sinemurian, late Pliensbachian, and twice in the Bajocian. The matrix of the mega-breccia cannot be directly observed but it is very probable that the youngest sediment (i. e. the upper Bajocian brachiopodal limestone) forms the matrix, which sets the age of the latest phase of breccia formation in the late Bajocian (GALÁCZ 1988, VÖRÖS & GALÁCZ 1998) (*Figure 2*).

Material and methods

The actual object of the present paper, the fallen block of coquina contained several hundred brachiopod specimens of various sizes, embedded in sparry calcite cement (*Figure 4*). The brachiopods were smooth and apparently represented a single species. Parts of the slab were cut, and polished surfaces were produced to reveal the internal sedimentary structures.

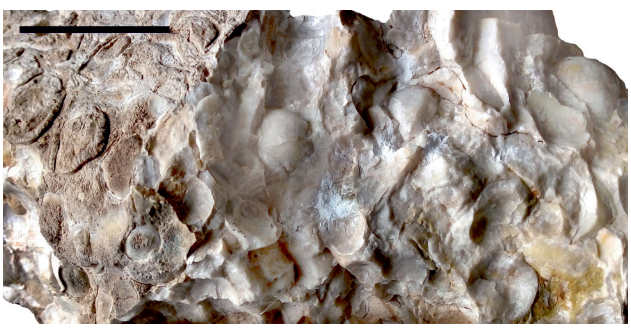


Figure 4. Weathered and broken surface of the slab of brachiopod coquina containing *Arzonellina bogicae* n. sp., Sinemurian (?), Lókút, Fenyveskút, Bakony Mountains, Hungary. Scale bar = 4 cm

4. ábra. *Az* Arzonellina bogicae *n. sp. példányait tömegesen tartalmazó brachiopoda kokvina tömb mállott és frissen tört felszíne. Sinemuri (?), Lókút, Fenyveskút, Bakony. Mérce = 4 cm*

Without destroying the whole slab, 88 brachiopods were removed from the host rock by hammer, chisels and pincers. Most of them (59 specimens) were fragmentary and/or disarticulated valves. 29 articulated specimens were further prepared by electric vibration tools. Four of them were selected for serial sectioning; 11 specimens for photographic illustration and were measured by callipers. The principal measurements (L = length, W = width, T = thickness, Ch = height of the commissural deflexion) are given in millimetres.

Before serial sectioning, casts for permanent documentation of the external features of the specimen were prepared. A silicon rubber mould was made by using Szilorka H-1 mass and H-10 catalyst. The elastic mould was filled with plaster to make the cast. Then the brachiopod was embedded, with a definite orientation, into plaster; the posterior part of the lateral commissure and the plane of symmetry of the specimen were kept vertical. The block of plaster was mounted on a steel plate of the Cutrock-Croft parallel grinding instrument. In practice, usually 0.2 mm grinding intervals were used or 0.1 intervals at more delicate parts. The specimens were sectioned (ground) from the tip of the beak to the distal end of the brachidium. At each interval (phase), the actual cross section was examined; if some significant change appeared, the cross section was documented by colour photograph. On the basis of the photographs, line drawings were prepared by using CorelDraw graphic software. In one case, projection drawing (a kind of artistic 3D reconstruction) was constructed in order to give a visual impression of the internal morphology of the specimen.

The photographs were made with a Canon EOS 700D camera. The specimens illustrated on the photographic plate/figure were whitened, i.e. coated with ammonium-chloride before making photographs.

Two samples, drilled from carbonate cements, were analyzed in the laboratory of the Institute for Geological and Geochemical Research, Budapest, in order to achieve ^{13}C (PDB) and ^{18}O (PDB) stable isotope values.

Results

Lithology and geochemistry

The cut and polished pieces of the fossiliferous coquina slab revealed a mass of disoriented brachiopod shells, mostly filled with sparry calcite but exhibiting geopetal structures as well (*Figure 5A*). A few smaller, angular micritic carbonate blocks were also recognized; these probably represent fragments of lower Hettangian Kardosrét Limestone and were encrusted by the same sparry calcite cement as the brachiopod shells (*Figure 5B*). The cementation consists of at least two main phases. In the first stage, the brachiopod shells and the walls of intergranular voids were coated by thick radial-fibrous cement. This was followed by micrite infiltration. Later the second, late diagenetic mosaic-like sparite cement precipitated in the remaining cavities; some

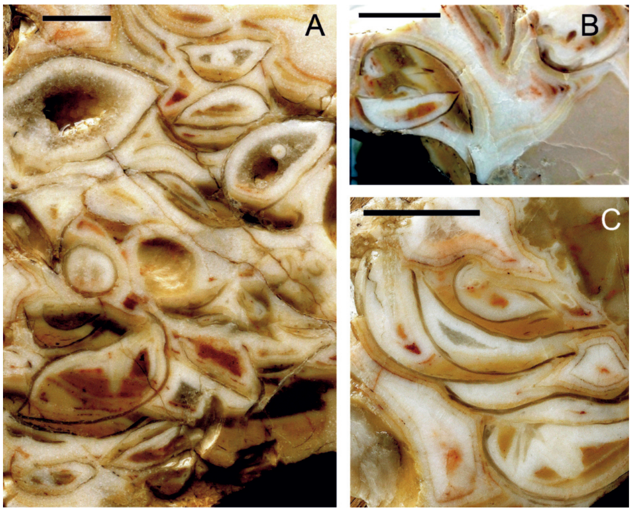


Figure 5. Polished surfaces of brachiopod coquina containing *Arzonellina* shells. A) The internal surfaces of double valves are lined by early radial-fibrous calcite, followed rarely by micrite and most frequently by coarse spar; some spaces remained open. B) Large intra-granular space between *Arzonellina* shells and a lithoclast of Kardosrét Limestone (lower right) is filled by several generations of early calcite. C) Open space (upper left), lined with early calcite, was filled with internal micrite. Note the small protuberances of the spar overlain by the micrite. Some longitudinal cross sections of *Arzonellina* show the typical internal features (lower right). Sinemurian (?), Lókút, Fenyveskút, Bakony Mountains, Hungary. Scale bar = 1 cm

5. ábra. *Az* Arzonellina *teknőket tartalmazó brachiopoda kokvina felületi csiszolatai. A) A kettősteknők belső felületein korai, sugaras-rostos kalcit vált ki; ezt ritkábban mikrit, gyakrabban durva pátit követte; néhány üreg máig üresen maradt. B) A nagy szemcseközti üreget az* Arzonellina *héjak és egy Kardosréti Mészkő litoklaszt (jobbra lent) között több generációs kalcit kiválás tölti ki. C) A bal felső sarokban az üreg falát korai pátit vonta be, majd a fennmaradó üreget mikrit töltötte ki. Egyes* Arzonellina *példányok hosszmetszete (jobbra lent) jól mutatja a taxonra jellemző belső szerkezetet. Sinemuri (?), Lókút, Fenyveskút, Bakony. Mérce = 1 cm*

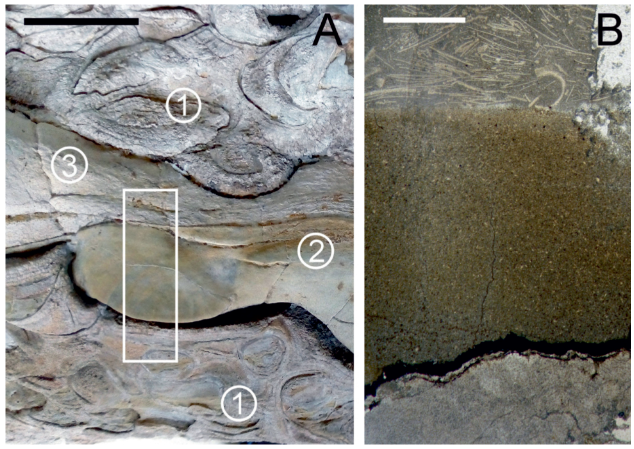


Figure 6. A) Weathered surface of the slab of brachiopod coquina showing the sedimentary structure of the infiltrated micritic sediments. 1 – Brachiopod coquina with sparry calcite cement, 2 – First generation of infiltrated micrite deposited on a ferromanganese crust, 3 – Second generation of infiltrated micrite, filling up the remaining open space. Rectangle indicates the approximate interval represented in the thin section photomicrograph (6B). Scale bar = 2 cm. B) Thin section displaying the succession of the infiltrated sediments: brachiopod coquina capped by ferromanganese crust, overlain by the first generation of infiltrated micrite, followed by the second generation full of *Bositra* shells. Sinemurian (+ Bajocian), Lókút, Fenyveskút, Bakony Mountains, Hungary. Scale bar = 1 mm

6. ábra. *A) A brachiopodás kokvina tömb mállott felszíne jól mutatja a később beszivárgott mikrites üledék szerkezetét. 1 – Brachiopoda kokvina pátit cementtel, 2 – a beszivárgott mikrit első generációja, ami vékony, vas-mangános kéregre települt, 3 – a beszivárgott mikrit második generációja, ami kitöltötte az üreg fennmaradó részét. A téglalap azt a részletet jelöli, ami megközelítőleg megfelel a 6B vékonycsiszolati képnek. Mérce = 2 cm. B) Vékonycsiszolati kép, ami a beszivárgott üledékek egymásra következését mutatja be. Alul: brachiopoda kokvina vas-mangános bevonattal, fölötte a beszivárgott mikrit első generációja, legfölül a második generáció,* Bositra *héjakkal teli. Sinemuri (+ bajoci), Lókút, Fenyveskút, Bakony. Mérce = 1 mm*

voids even then remained empty. The fine grained micritic matrix appeared in the geopetal structures of the brachiopod shells and in the remaining intergranular voids. The infiltration of this micrite apparently postdates the cementation of the coquina because the micrite overlies the protuberances of calcite cement along the walls of the voids (*Figure 5C*). This internal sediment does not contain any microfossils, yet it is believed to represent the Early Jurassic background sedimentation of pelagic mud.

Larger amounts of a very different micritic matrix form internal sediment infillings in greater voids of the brachiopod coquina and shows particular sedimentary structures (*Figure 6A, B*). This sediment was deposited in a several centimetre long and wide open space of the brachiopod coquina, previously cemented by spar in the Sinemurian. The walls of this large vug are lined by calcite crystals. The lower wall is coated with a thin black ferromanganese crust (*Figure 6A, B*). It is followed by a yellowish, unfossiliferous micrite; this is overlain, without a sharp break, by a micrite, full of *Bositra* shells. This *Bositra* micrite fills up the remaining space of the void.

Two samples drilled from carbonate cements revealed ^{13}C (–1.8‰ to +1.5‰) and ^{18}O (–5.5‰ to –1.0‰) values close to equilibrium with seawater carbonate and do not display signatures that indicate carbonate precipitation in the vicinity of hydrocarbon seeps. It should be mentioned that the stable isotope values obtained from this locality and from both sides of the Papod submarine horst (Vörös & Dulai 2007, table I) fell also within the same range.

Systematic palaeontology

The classification by Williams et al. (1996, 2006) is followed here with the addition of the Family Arzonellinidae by Sandy et al. (2021).

Phylum Brachiopoda Duméril, 1806
Subphylum Rhynchonelliformea Williams, Carlson, Brunton, Holmer & Popov, 1996
Class Rhynchonellata Williams, Carlson, Brunton, Holmer & Popov, 1996
Order Terebratulida Waagen, 1883
Suborder Terebratellidina Waagen, 1883
Superfamily Kingenoidea Elliot, 1948
Family Arzonellinidae Sandy, Radulović, Sulser, & Đaković, 2021

Genus *Arzonellina* Sulser in Sulser & Furrer, 2005

Type species: Arzonella exotica Sulser, 2004.
Species included: Arzonellina exotica (Sulser, 2004), *Arzonellina stachei* (Bittner, 1895) and *Arzonellina bogicae* n. sp.

Arzonellina bogicae n. sp.
Figures 7–13.

Holotype: Hungarian Natural History Museum (Budapest), inventory number: PAL 2021.35.1.

Locus typicus: Lókút, Fenyveskút, loose.

Stratum typicum: Brachiopodal Hierlatz Limestone, Sinemurian(?).

Paratypes: Hungarian Natural History Museum (Budapest), inventory numbers:

PAL 2021.36.1., PAL 2021.37.1., PAL 2021.38.1., PAL 2021.39.1., PAL 2021.40.1., PAL 2021.41.1., PAL 2021.42.1., PAL 2021.43.1., PAL 2021.44.1., PAL 2021.45.1., PAL 2021.46.1., PAL 2021.47.1., PAL 2021.48.1., PAL 2021.49.1.

Derivatio nominis: After the pet name of the author's daughter, who found the fossiliferous slab.

Diagnosis: Subcircular to subqadrate, strongly ventribiconvex shell. Beak low, indistinct. Lateral commissures straight, anterior commissure straight to unisulcate or paraplicate. Shell surface smooth. Divided septum passes into massive septal pillar. Hood is high and short. Crural bases develop from septal pillar near the base of the dorsal valve. Descending branches of brachidium long, curve ventrally; ascending branches reduced.

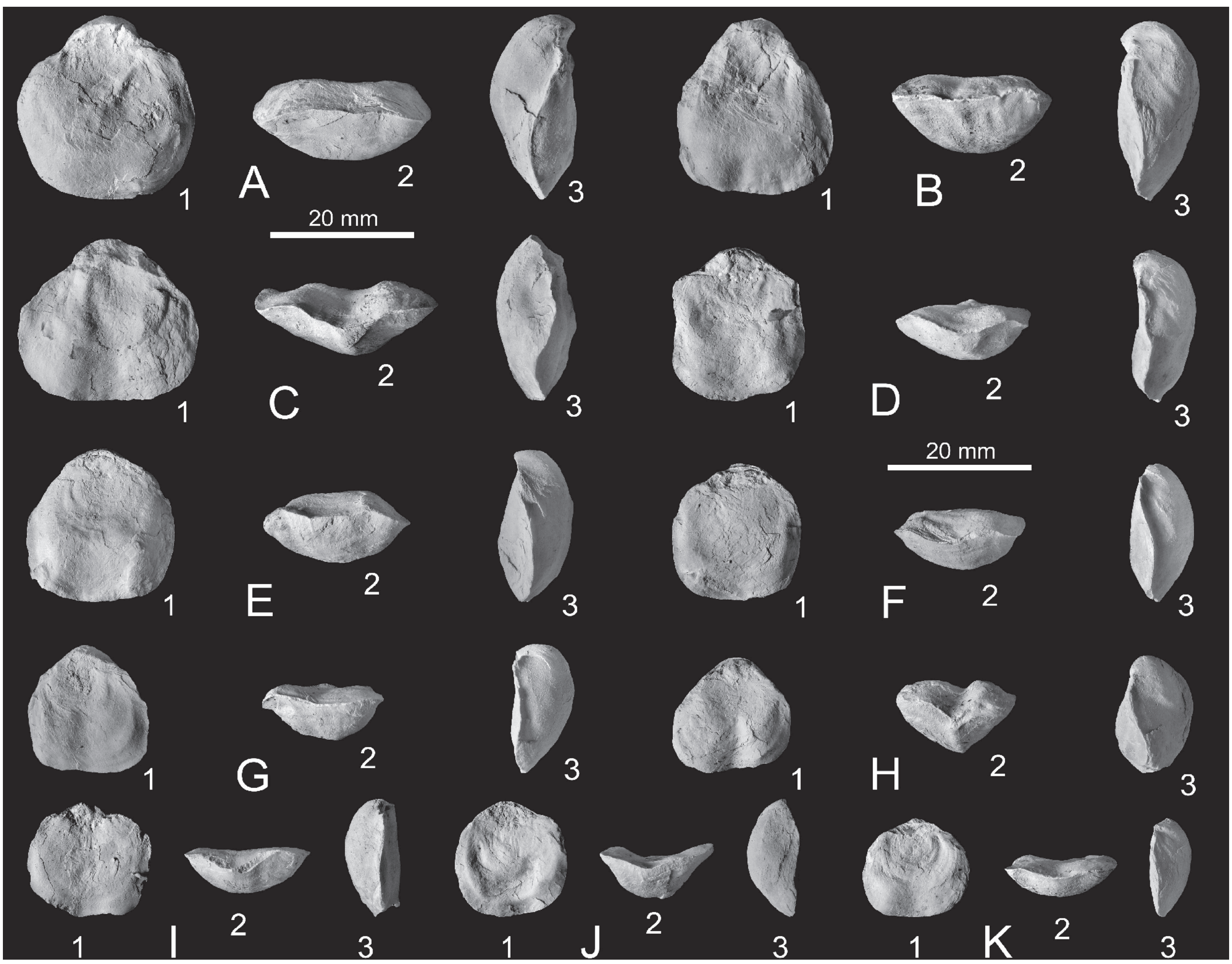
Material: 88 rather well-preserved double valves filled with sparry calcite where visible.

Measurement (*Table I*)

Inventory numbers	Measurements			
	L	W	T	Ch
PAL 2021.35.1.	26.7	25.2	11.7	1.8
PAL 2021.36.1.	25.1	21.5	10.4	1.8
PAL 2021.37.1.	21.9	23.2	9.7	3.8
PAL 2021.38.1.	21.9	18.5	7.9	2.8
PAL 2021.39.1.	21.6	20.5	9.6	2.1
PAL 2021.40.1.	19.8	18.1	8.7	2.6
PAL 2021.41.1.	18.4	17.3	7.7	2.4
PAL 2021.42.1.	16.8	16.9	10.1	3.1
PAL 2021.43.1.	16.8	17.1	6.6	3.1
PAL 2021.44.1.	16.5	15.7	7.5	2.8
PAL 2021.45.1.	14.1	15.1	5.5	1.6
Mean	**19.96**	**19.01**	**8.67**	**2.54**

Description

External characters: Medium-sized *Arzonellina* with subcircular to subquadrate outline; the shell is planoconvex to concavo-convex. The maximum width and the maximum convexity are reached near the middle of the length or shifted a little anteriorly. The nearly straight hinge margin is rather long; its length may reach the half of the width of the shell. The lateral margins are uniformly convex; in some cases (*Figure 7, F*) tend to be nearly straight. The lateral



commissures are nearly straight or gently sinuous. The anterior commissure is variable. Typically it is nearly rectimarginate or weakly and widely uniplicate (*Figure 7, A2, E2*); in many cases it is unisulcate (*Figure 7, H–K*) or tends to be paraplicate (*Figure 7 C2, D2*). The ventral valve is strongly and uniformly convex but in some specimens it has a long medial fold (*Figure 7, C2, H2*). The beak is rather high; erect to slightly incurved. The beak ridges are sharp; the features of the interarea and symphytium are not seen. The dorsal valve is nearly flat, or resupinate, i.e. it is deeply

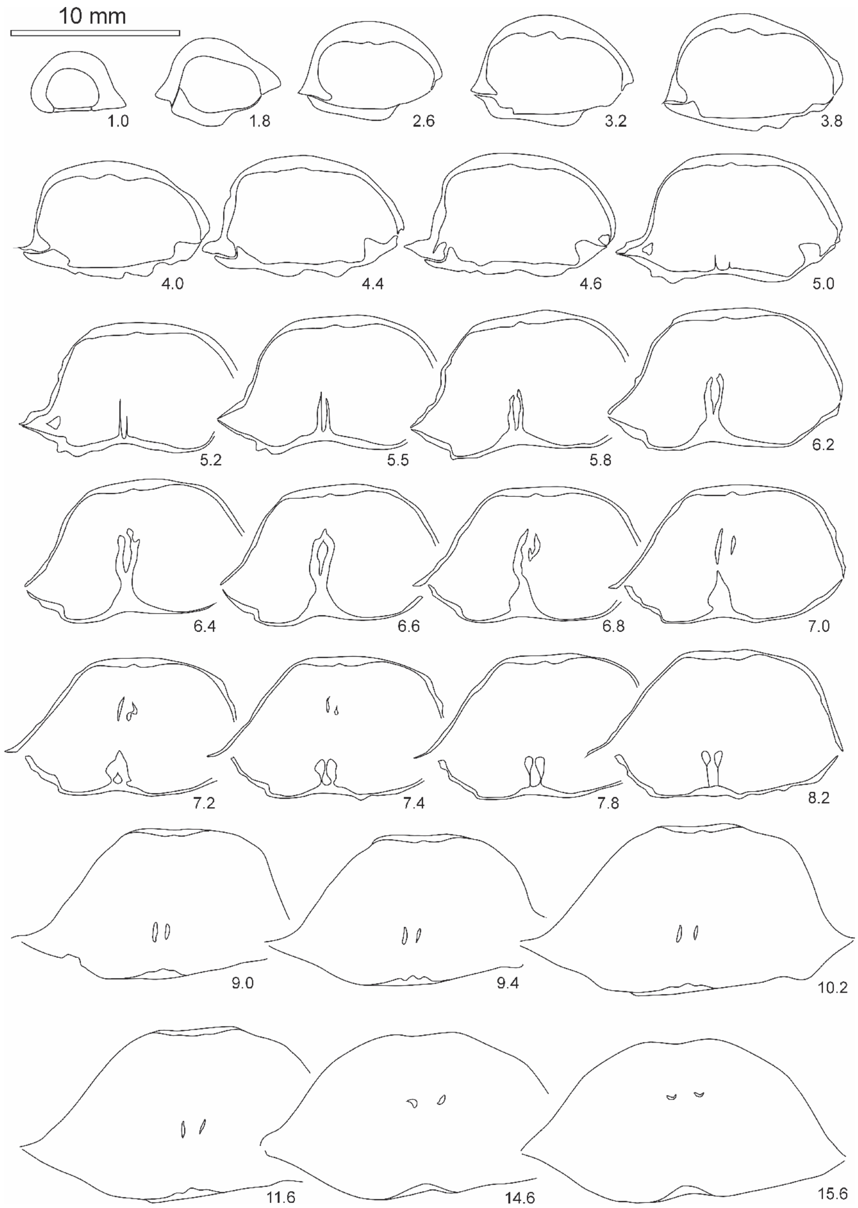


Figure 8. *Arzonellina bogicae* n. sp., Sinemurian (?), Lókút, Fenyveskút, Bakony Mountains, Hungary. Twenty-seven transverse serial sections through the posterior part of a paratype (PAL 2021.47.1.). Distances from the ventral umbo are given in mm. Original length of the specimen was 26.7 mm

8. ábra. Arzonellina bogicae *n. sp., sinemuri (?), Lókút, Fenyveskút, Bakony. Egy paratípus (PAL 2021.47.1.) huszonhét sorozatcsiszolati keresztmetszete. A búbtól mért távolságok mm-ben szerepelnek. A példány eredeti hossza 26,7 mm volt*

← **Figure 7.** *Arzonellina bogicae* n. sp., Sinemurian (?), Lókút, Fenyveskút, Bakony Mountains, Hungary. Each specimen is shown in dorsal (1), anterior (2) and lateral (3) views, respectively. Specimens have been coated with ammonium chloride before photography and are deposited in the collection of the Department of Palaeontology and Geology, Hungarian Natural History Museum. A) Holotype, PAL 2021.35.1.; B) Paratype, PAL 2021.36.1.; C) Paratype, PAL 2021.37.1.; D) Paratype, PAL 2021.38.1.; E) Paratype, PAL 2021.39.1.; F) Paratype, PAL 2021.40.1.; G) Paratype, PAL 2021.41.1.; H) Paratype, PAL 2021.42.1.; I) Paratype, PAL 2021.43.1.; J) Paratype, PAL 2021.44.1.; K) Paratype, PAL 2021.45.1.

← ***7. ábra.*** Arzonellina bogicae *n. sp., sinemuri (?), Lókút, Fenyveskút, Bakony. A példányok nézetei minden esetben: háti (1), mellső (2) és oldalsó (3). A fotózáshoz a példányokat ammonium-kloriddal vontuk be. A példányokat a Magyar Természettudományi Múzeum Őslénytani és Földtani Tára őrzi. A) Holotípus, PAL 2021.35.1.; B) paratípus, PAL 2021.36.1.; C) paratípus, PAL 2021.37.1.; D) paratípus, PAL 2021.38.1.; E) paratípus, PAL 2021.39.1.; F) paratípus, PAL 2021.40.1.; G) paratípus, PAL 2021.41.1.; H) paratípus, PAL 2021.42.1.; I) paratípus, PAL 2021.43.1.; J) paratípus, PAL 2021.44.1.; K) paratípus, PAL 2021.45.1.*

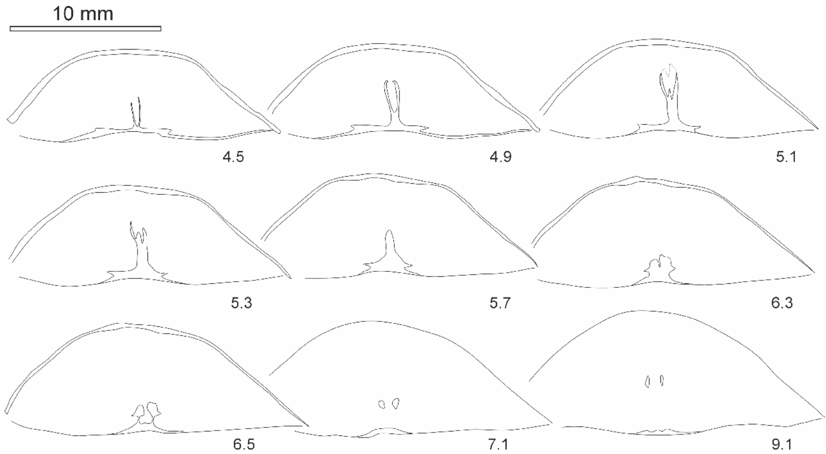


Figure 9. *Arzonellina bogicae* n. sp., Sinemurian (?), Lókút, Fenyveskút, Bakony Mountains, Hungary. Nine transverse serial sections through the posterior part of a paratype (PAL 2021.48.1.). Distances from the ventral umbo are given in mm. Original length of the specimen was 24.2 mm

9. ábra. Arzonellina bogicae *n. sp., sinemuri (?), Lókút, Fenyveskút, Bakony. Egy paratípus (PAL 2021.48.1.) kilenc sorozatcsiszolati keresztmetszete. A búbtól mért távolságok mm-ben szerepelnek. A példány eredeti hossza 24,2 mm volt*

concave posteriorly and becomes slightly convex anteriorly. Some specimens have a well developed dorsal sulcus. The surface of the shells is smooth except the growth rings of irregular spacing and strength. The outer shell layers are tending to be exfoliated.

Internal characters (*Figures 8–12*): *Ventral valve*: Pedicle collar was not observed. The delthyrial cavity is laterally elongated subcircular in cross section. Dental plates absent. Two parallel, very low ridges (probably myophragms beside an elongated muscle scar) were recorded in mature specimens (*Figures 8, 10*). The massive hinge teeth are oblique, laterally inserted; loosely fitting into sockets. *Dorsal valve*:

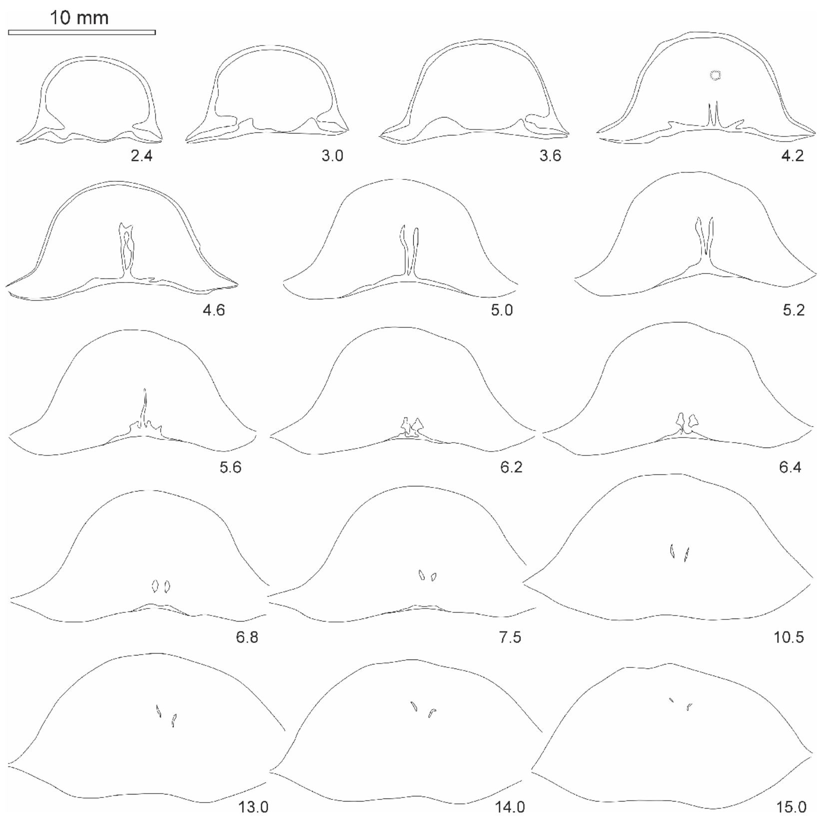


Figure 10. *Arzonellina bogicae* n. sp., Sinemurian (?), Lókút, Fenyveskút, Bakony Mountains, Hungary. Sixteen transverse serial sections through the posterior part of a paratype (PAL 2021.49.1.). Distances from the ventral umbo are given in mm. Original length of the specimen was 27.3 mm

10. ábra. Arzonellina bogicae *n. sp., sinemuri (?), Lókút, Fenyveskút, Bakony. Egy paratípus (PAL 2021.49.1.) tizenhat sorozatcsiszolati keresztmetszete. A búbtól mért távolságok mm-ben szerepelnek. A példány eredeti hossza 27,3 mm volt*

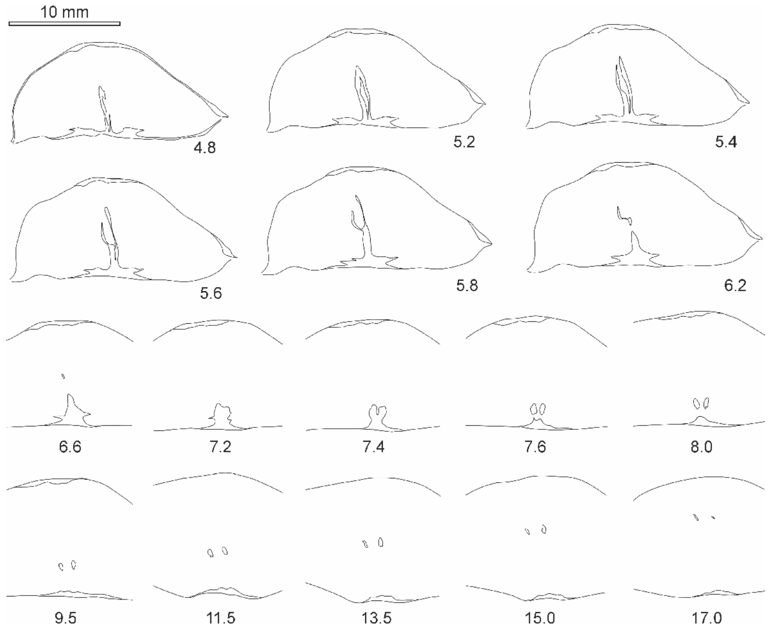


Figure 11. *Arzonellina bogicae* n. sp., Sinemurian (?), Lókút, Fenyveskút, Bakony Mountains, Hungary. Sixteen transverse serial sections through the posterior part of a paratype (PAL 2021.46.1.). Distances from the ventral umbo are given in mm. Original length of the specimen was 26.1 mm

11. ábra. Arzonellina bogicae *n. sp., sinemuri (?), Lókút, Fenyveskút, Bakony. Egy paratípus (PAL 2021.46.1.) tizenhat sorozatcsiszolati keresztmetszete. A búbtól mért távolságok mm-ben szerepelnek. A példány eredeti hossza 26,1 mm volt*

Cardinal process not developed. The denticulation is very simple. The outer socket ridges are very low and wide. The inner socket ridges are massive but do not lean over the teeth. Hinge plates are absent. Two, closely spaced, narrow, septum-like lamellae elevate from the strongly thickened medial part of the floor of the dorsal valve (*Figures 8, 9, 11*). They became gradually thickened, more elevated and fused into a very high but narrow hood. The ventral roof of the hood disappears, its ventral endings gradually vanish and two high, separate plates remain. The base of the hood is transformed into a massive septal pillar. This becomes lower and divides into two, closely set rods (crural bases) close to the valve floor. These give rise to narrow, subparallel and long descending lamellae, which curve ventrally and reach two-thirds of the length of the valve (*Figure 12*). The distal part of the ascending lamellae, which would be connected to the hood, are missing (resorbed ?).

Remarks: In size, *Arzonellina bogicae* n. sp. stands between the two, previously known species of *Arzonellina*. Its maximum length (26.7 mm) is less than that of *A. exotica* (Sulser, 2004) (37.5 mm) but slightly exceeds that of *A. stachei* (Bittner, 1895) (24.7 mm; according to Sandy et al. 2021). Externally, the almost plano-convex shape of *A. bogicae*, particularly the frequently concave area on the posterior part of the dorsal valve, is similar to *A. exotica*, but differs from *A. stachei* which is flat but constantly biconvex.

Serial sections were prepared from four specimens for studying internal morphology (*Figures 8–11*), which provided a coherent picture of the internal features of the new species and endorsed the attribution of the genus *Arzonellina* to the family Arzonellinidae Sandy, Radulović, Sulser, & Đaković, 2021 within the superfamily Kingenoidea Elliot, 1948.

The internal morphology of *A. bogicae* is markedly different from that of the previously described species of *Arzonellina*. The two long ridges in the apical part of the ventral valve, important enough to be included into the emended diagnosis of *Arzonellina* by Sandy et al. (2021), are very reduced or absent in *A. bogicae*. The posterior part of the brachidium of *A. bogicae* starts with two narrowly spaced, high septa, in contrast to *A. exotica*, where the first element is a massive septal pillar (Sulser 2004, fig. 5, at 3.4 mm), and to *A. stachei* where the brachidium starts with a small hood-like structure (Sandy et al. 2021, fig. 10, at 1.4 mm).

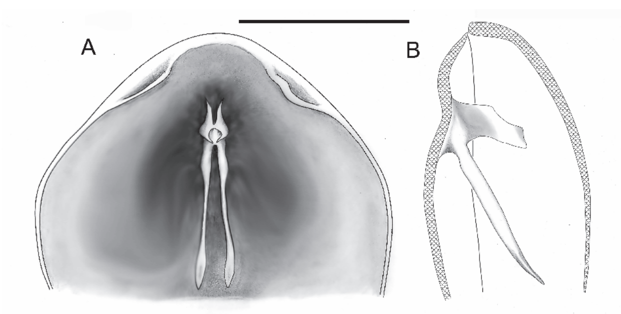


Figure 12. *Arzonellina bogicae* n. sp., Sinemurian (?), Lókút, Fenyveskút, Bakony Mountains, Hungary. Ventral (A) and lateral (B) views of the dorsal valve interior. Reconstruction based on serial sections from the paratype PAL 2021.47.1. Scale bar = 10 mm

12. ábra. Arzonellina bogicae *n. sp., sinemuri (?), Lókút, Fenyveskút, Bakony. A háti teknő belsejének hasi (A) és oldalsó (B) nézete. A rekonstrukció a PAL 2021.47.1. paratípus sorozatcsiszolata alapján készült. Mérce = 10 mm*

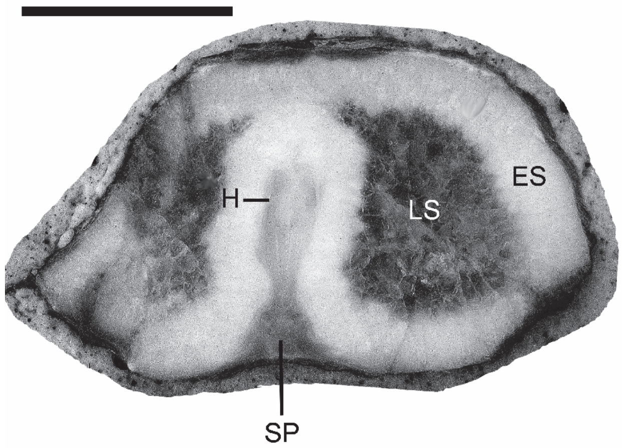


Figure 13. *Arzonellina bogicae* n. sp., Sinemurian (?), Lókút, Fenyveskút, Bakony Mountains, Hungary. Photomicrograph of a cross section of the paratype PAL 2021.47.1., at distance 6.6 mm from the ventral umbo, showing the early radial-fibrous spar (light grey, ES) outlining the inner wall of the shell and enveloping the brachidium, and the late spar (dark grey, LS) filling the remaining spaces. H – hood, SP – septal pillar. Scale bar = 10 mm

13. ábra. Arzonellina bogicae *n. sp., sinemuri (?), Lókút, Fenyveskút, Bakony. A PAL 2021.47.1. leltári számú paratípus egy (a búbtól 6,6 mm-re készült) keresztmetszetének fényképe. Jól látható a korai, sugaras-rostos pátit (világosszürke, ES), ami bevonta a teknők belsejét és a kartámasztó váz elemeit, valamint a késői, kristályos pátit (sötétszürke, LS), ami kitöltötte a fennmaradó üreget. H – hood (csuklya), SP – medián szeptum. Mérce = 10 mm*

The high and narrow hood of *A. bogicae* in the interval 4.6 to 6.6 mm can vaguely be recognized in *A. exotica* (SULSER 2004, fig. 5, at 6.0 mm), but seems to be absent in the 3.7 to 8.2 mm interval in *A. stachei* (SANDY et al. 2021, fig. 10). The most important difference is that the crural bases of *A. bogicae* (giving rise to the descending lamellae) are released close to the floor of the dorsal valve (around 6.5 to 8.0 mm interval), whereas the similar crural bases in *A. exotica* (SULSER 2004, fig. 5, at 9.2 mm), and in *A. stachei* (SANDY et al. 2021, fig. 10, at 3.7 mm) set off much more internally, i.e. closer to the centre of the shell cavity.

A feature common to all three presently known species of *Arzonellina* is that the anterior part of the ascending lamellae, which would connect the descending lamellae with the hood, is almost completely missing. The absence is clearly seen in the four sectioned specimens of *A. bogicae* (*Figures 8–11*) and in *A. stachei* (SANDY et al., 2021, fig. 10). In *A. exotica* (SULSER 2005, fig. 5, at 9.2 to 10.5 mm interval) only vague vestiges can be recognized.

Occurrence: Sinemurian (?), Fenyveskút, Bakony Mountains, Hungary; monospecific mass occurrence. The associated, lithologically similar, biosparitic Hierlatz Limestone yielded a diverse assemblage of quite different brachiopod taxa.

The present record of a new species of the genus *Arzonellina* (*A. bogicae*) endorses the previously published view (SANDY et al. 2021) that the genus has a "peri-Apulian", i.e. Mediterranean distribution. In fact, the occurrence in the Bakony (Transdanubian Range, Hungary), palaeogeographically lies between the Swiss (Arzo) and the Montenegro (Smokovac) records of *Arzonellina*.

Discussion

The loose, fallen, brachiopod-rich block of a few decimetres size, found in the scree at Fenyveskút in 1995, exhibited the major lithological characteristics of the Sinemurian Hierlatz Limestone. Yet, it was completely different from the previously known brachiopod-rich limestones of the Fenyveskút locality, because it contained a crowded monospecific accumulation of smooth and flat *Arzonellina bogicae* n. sp. In spite of its apparently unique character, this loose block could not have been derived from anywhere else but the Fenyveskút hillside above, and probably was derived from the megabreccia described above (*Figure 2*).

The sedimentary features (the close packing of shells, the rapid early cementation, infiltration of internal sediment), point to a rapid accumulation in the form of a neptunian dyke. In this respect the rock may represent a variant of the Hierlatz Limestone, i.e. a kind of a fissure filling in Kardosrét Limestone. In a palaeoenvironmental model, the hard, rocky submarine surface of the Kardosrét Limestone was colonized by benthic organisms, e.g. various brachiopod communities. Due to the extensional tectonic movements (see VÖRÖS & GALÁCZ 1998), fissures opened from time to time on the rocky bottom. The fissures received, or even sucked in, the shells available near the opening of the fissure. The brachiopod communities might be different from place to place and even from time to time; this may explain the differences in the composition of the fossil assemblages. Alternatively, certain brachiopod taxa might proliferate directly within the freshly opened fissures and produce monospecific communities. Similar brachiopod coquinas have been described in some places from Oxfordian neptunian dykes in Poland (WIECZOREK & KROBICKI 1994, KROBICKI et al. 2008, MATYSZKIEWICZ et al. 2016). Their features, both palaeoecologicaly and sedimentologicaly, indicate that these associations may reflect very dense life-communities within neptunian dykes. These analogies and this kind of speculation may help to understand the particular, monospecific character of the *Arzonellina*-rock.

On the basis of analogous sedimentary structures and colours shared with the Sinemurian Hierlatz Limestones at Fenyveskút, moreover by the character of the early internal sediment, the age of the rock of the fallen block is considered Sinemurian.

It is very probable that a decimetre-sized piece of the *Arzonellina*-rock first was removed from the neptunian dyke and then, as a result of secondary deposition, was incorporated into the megabreccia. This process is evidenced by the internal sediments accumulated in an open space of the formerly lithified (cemented) brachiopod coquina. *Figures 6A, B* illustrate three phases of internal sedimentation in the several centimetres long and wide, open space of the brachiopod coquina. The walls of this large void were lined by calcite crystals. First, the lower wall was coated with thin black ferromanganese crust, between the Sinemurian to Bajocian time interval. In the second phase, a yellowish micrite infiltrated to the void; the age of this unfossiliferous sediment is unknown. In a third phase a biomicrite, full of *Bositra* shells, filled up the remaining space of the void. This *Bositra* micrite corresponds to the Bajocian limestone (*Figure 3G*) considered the matrix of the megabreccia at Fenyveskút. This sediment records the tectono-sedimentary event when the piece of *Arzonellina* coquina entered the megabreccia. Finally, probably in the Quaternary, it was incorporated in the scree as a derived slab.

Remarkably, the other two, previously described occurrences of *Arzonellina* (Arzo and Smokovac) were also found in isolated blocks. In Arzo, in the Southern Alps of Switzerland, the genus was described from reworked clasts embedded in the Sinemurian Broccatello Formation (SULSER 2004, SULSER & FURRER 2005). In Smokovac (Montenegro) the block with *Arzonellina* was collected from Quaternary talus at the foot of Jurassic cliffs (SANDY et al. 2021).

Another common feature of the three, currently known assemblages of *Arzonellina* species is the partial or total absence of the ascending lamellae from their brachidia. The vanishing of the ascending lamellae might be caused by (1) resorption during the late ontogenetic development of the brachiopod; (2) tearing off by predators or scavengers during life or after the death of the brachiopod; or (3) very early dissolution by pore waters undersaturated for calcium-carbonate. It must be borne in mind that the ascending lamellae are the most delicate and friable part of the brachidium, thus most prone to damage. Anyhow, the disappearance of these delicate structures must have happened before the final accumulation of the dead shells. In the case of *A. bogicae* it definitely pre-dated the early phase of cementation of the host rock. During very early diagenesis, the inner walls of the shells and the whole brachidium were coated by thick radial-fibrous cement and by this the available internal structures were well preserved (*Figures 5C, 13*).

The monospecific mass accumulation of brachiopods may hint to an association with hydrocarbon seeps ("cold seeps"), as it has been proven in the case of some dimerelloid rhynchonellides (e.g. PECKMANN et al. 2013, SANDY & PECKMANN 2016, PÁLFY et al. 2017). The genus *Arzonellina*, though it has a degree of external homoeomorphy with the dimerelloid *Rhynchonellina*, does not seem to represent this special association. The stable isotopic results from the Fenyveskút locality and from Smokovac (SANDY et al. 2018, 2021) do not show any signatures that indicate a proximity to hydrocarbon seeps.

Conclusions

A peculiar slab of brachiopod coquina, found at Fenyveskút locality (Lókút, Bakony Mountains, Hungary), comprised a mass occurrence of monospecific brachiopods which turned out to belong to the genus *Arzonellina*.

Investigations of the external and internal morphology of the specimens proved that they represent a new species: *Arzonellina bogicae* n. sp., which is introduced, described and illustrated here in detail.

The age of the brachiopod coquina and the new species is considered Sinemurian on the basis of circumstantial evidence from the locality and from analogues in previously documented occurrences of *Arzonellina* in Switzerland and Montenegro.

The Jurassic megabreccia at Fenyveskút locality is redescribed, and the lithology and fossils of its major components and its matrix are described and documented with thin section photomicrographs.

The detailed study of the internal sediments accumulated in an open space (vug) of the *Arzonellina* coquina, revealed that this slab, lithified (cemented) in the Sinemurian, was incorporated into the megabreccia in the Bajocian.

Acknowledgements

Many thanks to A. DEMÉNY, Institute for Geological and Geochemical Research, Budapest, for stable isotope analysis of carbonate cements from the brachiopod coquina. The author is indebted to A. GALÁCZ for the help during joint field work at the locality. Thin sections were prepared by the courtesy of GY. LELKES and T. BUDAI what is deeply acknowledged. B. VÖRÖS helped in graphic visualization of internal features of one sectioned paratype. The thorough discussions on the genus *Arzonellina* with H. SULSER (Zürich), M. R. SANDY (Dayton) and B. RADULOVIĆ (Belgrade) greatly improved the views expressed in the present paper. The useful comments and corrections of the reviewers M. R. SANDY, A. DULAI and M. KROBICKI are deeply acknowledged. The author wishes to thank the leaders and staff of the Department of Palaeontology and Geology of the Hungarian Natural History Museum for their help and the possibility to use the facilities of the institution.

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Manuscript recieved: 04/10/2021