Bryozoans, foraminifers, algae, and sedimentological characteristics of an exotic limestone block of the late Viséan Kirchbach Formation, Carnic Alps, Austria

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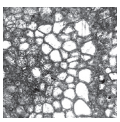

A late Viséan fossiliferous limestone block from the Kirchbach Formation (Mississippian) in the Carnic Alps (southern Austria) has been studied for its palaeontological and petrographic characteristics. The limestone block contains abundant fossils and is composed of different microfacies including bioclastic floatstone, coral bafflestone, bryozoan bindstone, bryozoan wacke- to grainstone, as well as bioclastic mud- to wackestone. The described fauna of bryozoans and foraminifers identify the age of the block as early Serpukhovian (Tarusian), and indicate deposition in a shallow shelf environment with high to moderate energy levels, moderate to high sedimentation rates and flexible to hard substrates. The limestone block, like the exotic limestone clasts of the carbonate conglomerates of the Kirchbach Formation, were transported into deeper marine environments by gravitational sedimentary processes from a shallow marine carbonate shelf that was developed along the northern margin of the Hochwipfel flysch basin. • Key words: Mississippian, Carnic Alps, Austria, microfacies, Bryozoa, foraminifers, ecology, taxonomy.

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The historical background of the Kirchbach Formation (Kirchbach Limestone/Kalk – Schönlaub 1985, Kirchbach Formation – Schönlaub *et al*. 2015) was summarized by Krainer & Vachard (2015) and Kabon & Schönlaub (2019). Schönlaub *et al*. (2015) defined the Kirchbach Formation as "grayish shale with layers of carbonate nodules and argillaceous nodular limestone and limestone clasts". The nodules are 30–40 cm large and partly composed of polymict breccia. Limestone clasts contain a diverse fossil assemblage. The thickness of the Kirchbach Formation is 4–8 m. The stratotype is located south of Kirchbacher Wipfel. The carbonate rocks of the Kirchbach Formation are interpreted to be derived from a shallow marine shelf area. The limestone clasts were reworked and transported into deeper marine settings by sediment gravity flows (Krainer &Vachard 2015, Rodríguez *et al.* 2018, Kabon & Schönlaub 2019). The Kirchbach Formation is intercalated in the Hochwipfel Formation and is exposed at several localities NW of the summit of Hochwipfel (2,195 m). In a tributary of Döbernitzgraben at an elevation between 1,500 and 1,580 m, polymict conglomerates within the Hochwipfel Formation are several tens of metres thick and contain carbonate clasts with diameters up to several decimetres.

Krainer & Vachard (2015) studied the Kirchbach Formation at an outcrop that is located along the forest road from Wipfelalm to Kirchbacher Wipfel at an elevation of approximately 1,720 m (Fig. 1). This location is considered as the type locality and type section of the Kirchbach Formation (see Flügel & Schönlaub 1990, Krainer & Vachard 2015). At this type locality, the Kirchbach Formation is under- and overlain by shale with intercalated sandstone beds of the Hochwipfel Formation. The Kirchbach Formation is approximately 8 m thick, starts with shale and intercalated mudstone, and is overlain by micritic limestone (80 cm) and carbonate conglomerate and breccia (Fig. 2).

The studied limestone block is probably derived from this carbonate conglomerate and breccia. According to Krainer & Vachard (2015), the micritic limestone bed is composed of bioclastic mudstone with few fossils. The conglomerate and breccia beds are composed of limestone

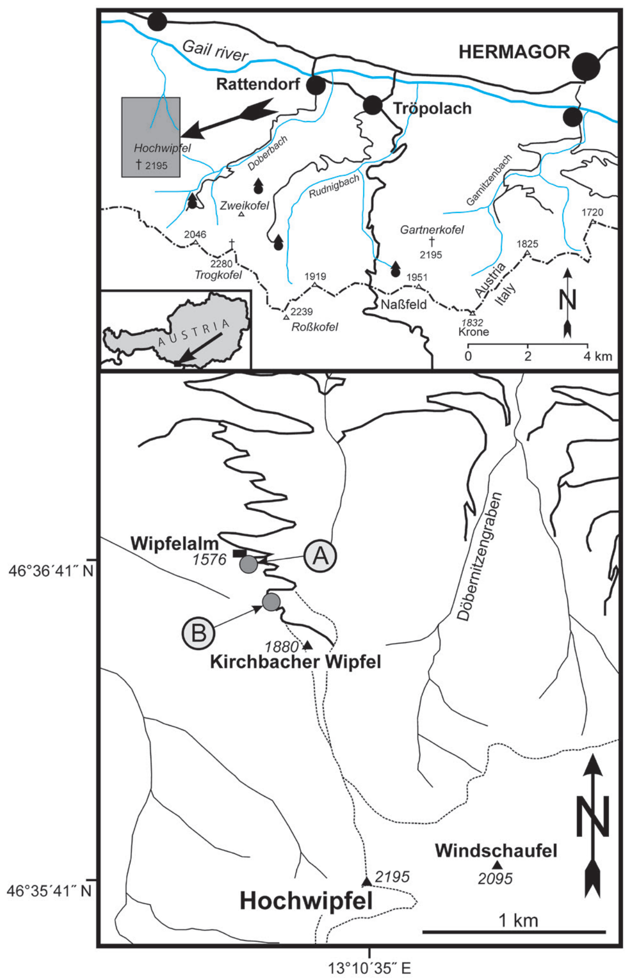


Figure 1. Map of the Hochwipfel area in the Carnic Alps (Austria) showing location of the studied outcrop. Legend: A – location where the studied limestone block was found; B – location of the type section of the Kirchbach Formation.

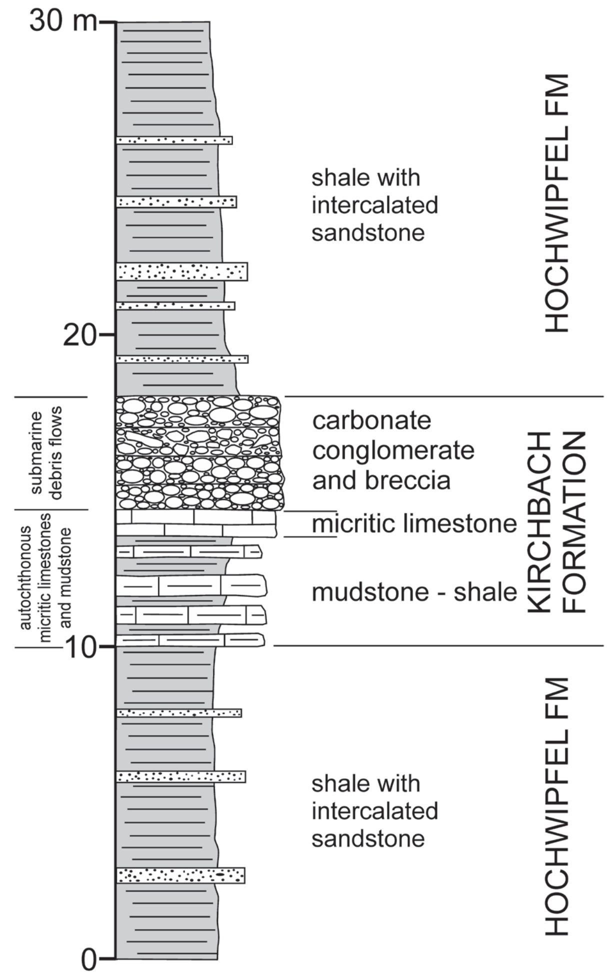


Figure 2. Lithological column of the type section of the Kirchbach Limestone (after Krainer & Vachard 2015).

clasts of different microfacies including bioclastic mudstone, wackestone, packstone, grainstone, rudstone and bindstone. Wackestone, packstone, grainstone and rudstone contain a diverse fossil assemblage. Similar microfacies types were described from these limestone clasts by Flügel & Schönlaub (1990) and Amler *et al*. (1991).

The limestone block of the Kirchbach Formation that was discovered by H. Kabon in 2017 (Rodríguez *et al.* 2018, Kabon & Schönlaub 2019) contains abundant corals of the genera *Lonsdaleia*, *Syringopora* and *Axophyllum*, crinoids (including several cm long crinoid stem fragments), bivalves, foraminifers, and calcareous algae (Kabon & Schönlaub 2019, figs 19, 20).

Rodríguez *et al*. (2018) reported different microfacies from the limestone block, ranging from bindstone to coral bafflestone and packstone. According to these authors the main building organism is the fasciculate rugose coral *Lonsdaleia carnica* Rodríguez *et al*. 2018. Other main building organisms are bryozoans, tabulate corals, and calcareous algae. Locally abundant cyanobacteria colonies (*Girvanella*) are present. Additionally, fragments of crinoids, bivalves, ostracods, brachiopods, trilobites, foraminifers and worm tubes are present. The limestone block is interpreted to be derived from a dominantly low-energy mound or reef complex which periodically was affected by high turbulence, and was transported into deeper marine environment by gravitational processes. The age of the limestone block is dated as late Viséan to Serpukhovian (Rodríguez *et al*. 2018).

The present paper aims microfacies analysis of the fossiliferous limestone block, description of bryozoans and foraminifers, discussion of the depositional environment and the age of the Kirchbach Formation as well as palaeogeographic significance of the described fauna.

Material and methods

The investigated limestone block was discovered by H. Kabon in 2017 (see above) at an outcrop exposed along a forest road (at "Plunger turn") from Wipfelalm (1,576 m) to Kirchbacher Wipfel (1,880 m), at an elevation of 1,650–1,670 m in the Carnic Alps, Carinthia (Southern Austria). During the road construction the slope was cut and the loose block was used to stabilize the face of the road. It probably is derived from the outcrops of the type locality which is located farther south at a distance of approximately 120 m at an elevation of approximately 1,720 m (Fig. 1).

From the discovered block, 31 thin sections were prepared for microfacies analysis and palaeontological studies (housed at the Institute of Geology, University of Innsbruck, abbreviations KK and KBK). Bryozoans were investigated in thin sections using a binocular microscope in transmitted light.

Lithology

The limestone block originally occurred either in shale/siltstone with intercalated sandstone of the Hochwipfel Formation (olistolith), or, more probably from the carbonate conglomerate/breccia of the type locality (section) of the Kirchbach Limestone (Kirchbach Formation).

The block is a medium grey to dark grey, fossiliferous limestone measuring approximately 65 × 40 × 20 cm (weight is approximately 60 kg). This block was split into a larger and a smaller block (see Rodríguez *et al*. 2018, fig. 2; Kabon & Schönlaub 2019, fig. 29).

Description of microfacies

Within the studied limestone block different microfacies types were recognized: bioclastic floatstone/rudstone, coral bafflestone, bryozoan bindstone, and bryozoan wackestone to grainstone. Smaller limestone clasts are composed of bioclastic mudstone to wackestone.

Bioclastic floatstone to rudstone. – This microfacies is composed of larger fossil fragments such as shells and shell fragments of brachiopods, bryozoans and echinoderms (crinoids, up to 1 cm in diameter) and smaller fossils including echinoderms (crinoids), ostracods, palechinid radioles, and rare foraminifers and calcareous algae (Fig. 3A). Locally, bryozoans are encrusting brachiopod shells. Rarely, *Eotuberitina* and *Tuberitina* encrust skeletal grains. Bioclastic floatstone locally contains pelmicritic matrix and rudstone is cemented by sparry calcite.

Coral bafflestone. – Locally, small colonies of the colonial rugose coral *Lonsdaleia carnica* are present that seem to have acted as sediment bafflers (Fig. 3B). The corals are embedded in micritic and pelmicritic matrix that contains few smaller fossils including echinoderm fragments, brachiopods, bryozoans, ostracods, smaller foraminifers and rare calcareous algae. The coral *Lonsdaleia carnica* is a new species that recently was described from the block by Rodríguez *et al*. (2018). Additionally, Rodríguez *et al*. (2018) observed tabulate corals, cyanobacteria (*Girvanella*), trilobites, and worm tubes.

Bryozoan bindstone. – Locally, up to several cm large bryozoan colonies of *Glyptopora michelinia* (Prout, 1860) are present that are attached on the sediment, locally encrusting fossil fragments, particularly echinoderm fragments and brachiopod shells (Figs 3C; 4E, F). The micritic matrix contains echinoderm fragments, brachiopods, ostracods and rare foraminifers.

Bryozoan wackestone to grainstone. – This microfacies contains abundant bryozoan fragments, subordinately echinoderm fragments, shell debris derived from brachiopods, foraminifers, ostracods and rare gastropods that are either embedded in micritic matrix or locally are cemented by sparry calcite (Fig. 3D, E).

Bioclastic mudstone to wackestone. – microfacies of a smaller limestone clast. This microfacies is bioturbated and displays a flasery texture. Small recrystallized skeletons, few ostracods, echinoderm fragments and thin bivalve shells are embedded in silty micrite. Locally, abundant small diagenetic pyrite grains are present (Fig. 3F).

Systematic palaeontology

Phylum Bryozoa Ehrenberg, 1831
Class Stenolaemata Borg, 1926
Superorder Palaeostomata Ma *et al*., 2014
Order Cystoporata Astrova, 1964
Suborder Fistuliporina Astrova, 1964
Family Fistuliporidae Ulrich, 1882

Genus *Fistulipora* M'Coy, 1849

Type species. – *Fistulipora minor* M'Coy, 1849. Carboniferous; England.

Diagnosis. – Massive, encrusting or ramose colonies. Cylindrical autozooecia with thin walls and complete diaphragms. Apertures rounded, possessing horse-shoe shaped lunaria. Autozooecia separated by the extrazooidal vesicular skeleton.

Remarks. – *Fistulipora* M'Coy, 1849 differs from *Eridopora* Ulrich, 1882 in having rounded, horseshoe-shaped lunaria instead of triangular ones. Furthermore, *Eridopora* develops persistently encrusting colonies, whereas *Fistulipora* may also develop massive and branched colonies. *Fistulipora* differs from *Dybowskiella* Waagen & Wentzel, 1886 in the shape of lunaria, whose ends do not inflect autozooecial chambers.

Occurrence. – Ordovician to Permian; worldwide.

***Fistulipora incrustans* (Phillips, 1836)**
Figure 4A, B; Table 1

See full synonymy of *Fistulipora incrustans* (Phillips, 1836) in Bancroft & Wyse Jackson (1995, p. 131–133). An additional record of this species was published by Ernst & Rodríguez (2013, p. 178, figs 3e, 3f, 4a, 4b).

Material. – Two colonies KBK-OC-1 and KBK-2A-3.

Description. – Encrusting colony, 0.66–1.83 mm thick. Autozooecia growing from thin epitheca, bending in the early exozone to the colony surface. Basal diaphragms rare. Autozooecial apertures circular to oval. Lunaria well-developed, rounded; ends of lunaria not indenting into autozooecia. Vesicles small to large, separating autozooecia in 1–2 rows, 10–14 surrounding each autozooecia aperture, with flat roofs, polygonal in tangential section. Autozooecial walls granular prismatic, 0.010–0.015 mm thick. Maculae not observed.

Remarks. – Two species from the Mississippian of Russia are similar to *Fistulipora incrustans* (Phillips, 1836): *F. parvilabrum* Schulga-Nesterenko, 1955 and *F. steshevensis* Schulga-Nesterenko, 1955. They have smaller and fewer vesicles surrounding autozooecial aperture (7–8 in *F. parvilabrum* and 8–9 in *F. steshevensis vs*. 10–14 in *F. incrustans*).

Occurrence. – Carboniferous, Mississippian, Viséan (Asbian-Brigantian); England, Scotland, Ireland. Carboniferous, Mississippian, Viséan (Asbian-Brigantian); El Collado, south-western Spain. Kirchbach Formation, Mississippian; Carnic Alps, Austria.

Genus *Eridopora* Ulrich, 1882

Type species. – *Eridopora macrostoma* Ulrich, 1882, by original designation. Lower Carboniferous; North America.

Diagnosis. – Thin encrusting colonies. Oval apertures with strongly developed lunaria of distinct triangular shape. Cylindrical autozooecia with thin walls and complete diaphragms.

Vesicular skeleton consists of angular vesicles.

Remarks. – *Eridopora* Ulrich, 1882 differs from *Fistulipora* M'Coy, 1849 in having large triangular lunaria instead of horse-shoe shaped ones, and predominantly encrusting colonies.

Occurrence. – Devonian to Permian; worldwide.

***Eridopora macrostoma* Ulrich, 1882**
Figure 4C, D; Table 2

1882 *Eridopora macrostoma* Ulrich; p. 137, pl. 6, figs 1, 2a.
1884 *Eridopora macrostoma* Ulrich, 1882. – Ulrich, pl. 3, fig. 8.
1895 *Eridopora macrostoma* Ulrich, 1882. – Simpson, p. 561, fig. 128.
1953 *Eridopora macrostoma* Ulrich, 1882. – Bassler, p. g85, figs 50, 3a–c.
1953 *Eridopora* aff. *macrostoma* Ulrich, 1882.– Nekhoroshev, p. 55, pl. 23, fig. 1a, b.
1963 *Eridopora macrostoma* Ulrich, 1882. – Perry & Horowitz, p. 24, pl. 4, figs 1, 2.

	N	X	SD	CV	MIN	MAX
Aperture width, mm	20	0.32	0.045	14.19	0.26	0.40
Aperture spacing, mm	20	0.48	0.075	15.69	0.30	0.60
Vesicle diameter, mm	20	0.10	0.034	33.63	0.06	0.20
Vesicles per aperture	8	11.8	1.581	13.46	10.0	14.0

Table 1. Descriptive statistics of *Fistulipora incrustans* (Phillips, 1836). Abbreviations: N – number of measurements; X – mean; SD – sample standard deviation; CV – coefficient of variation; MIN – minimal value; MAX – maximal value.

	N	X	SD	CV	MIN	MAX
Aperture width, mm	10	0.36	0.047	13.19	0.28	0.42
Aperture spacing, mm	10	0.46	0.052	11.40	0.38	0.55
Vesicle diameter, mm	10	0.12	0.021	17.19	0.10	0.16

Table 2. Descriptive statistics of *Eridopora macrostoma* Ulrich, 1882. Abbreviations as for Table 1.

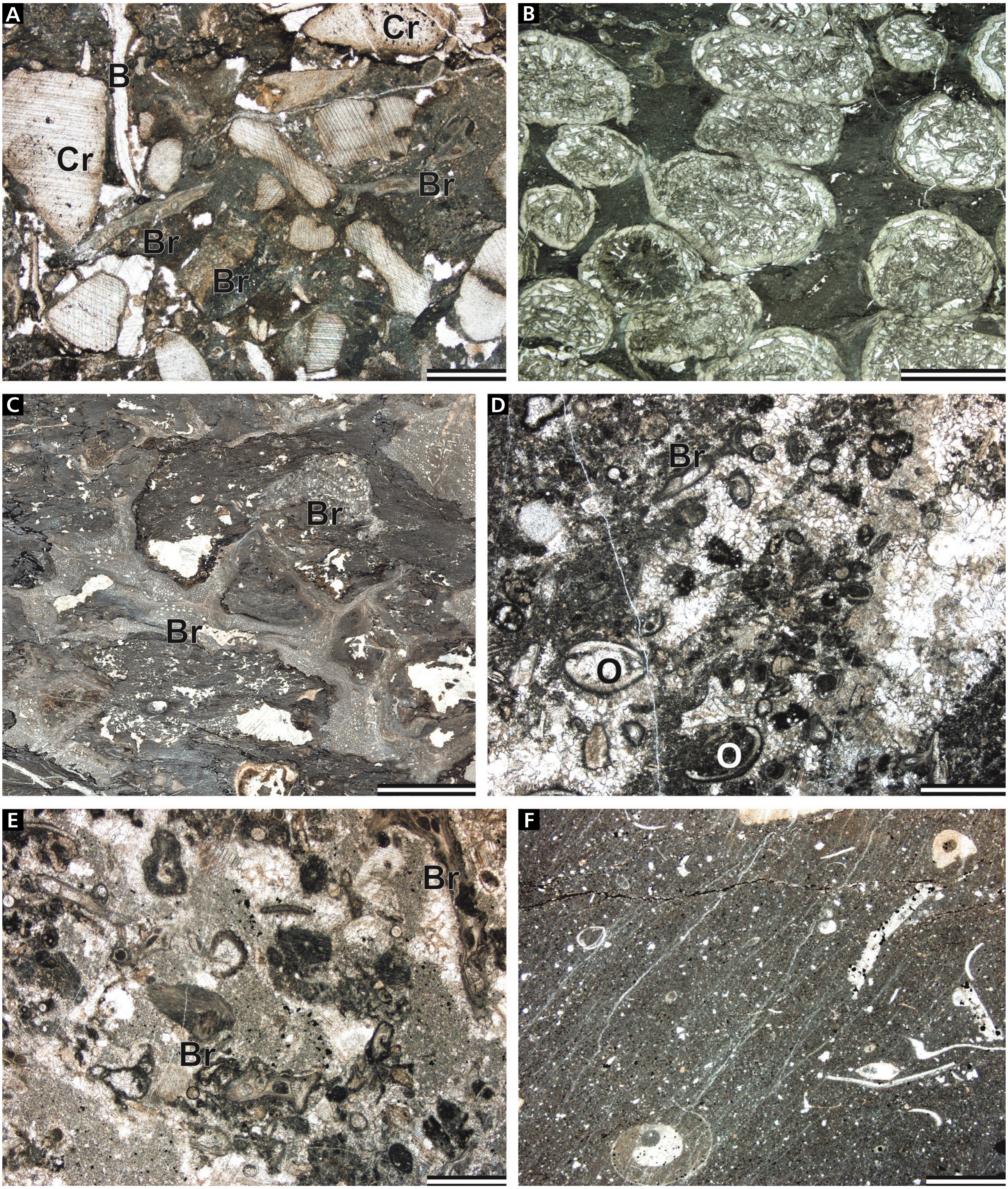


Figure 3. Microfacies types from the studied block. • A – KK-08-2, bioclastic rudstone. • B – KK-05-2, coral bafflestone. • C – KK-03b, bryozoan bindstone. • D – KK-04-20, bryozoan wackestone. • E – KK-04a-24, bryozoan grainstone. • F – KBK-c-1, bioclastic mudstone to wackestone. Scale bars: 5 mm (B, C), 1 mm (A, D–F). Abbreviations: B – brachiopod shell; Br – bryozoan; Cr – crinoid; O – ostracod shell.

1972 *Eridopora macrostoma* Ulrich, 1882. – McKinney, p. 29, pl. 5, figs 6, 7; pl. 6, figs 1, 2, 5.

1983 *Eridopora macrostoma* Ulrich, 1882. – Utgaard, p. 393, fig. l81, la–d.

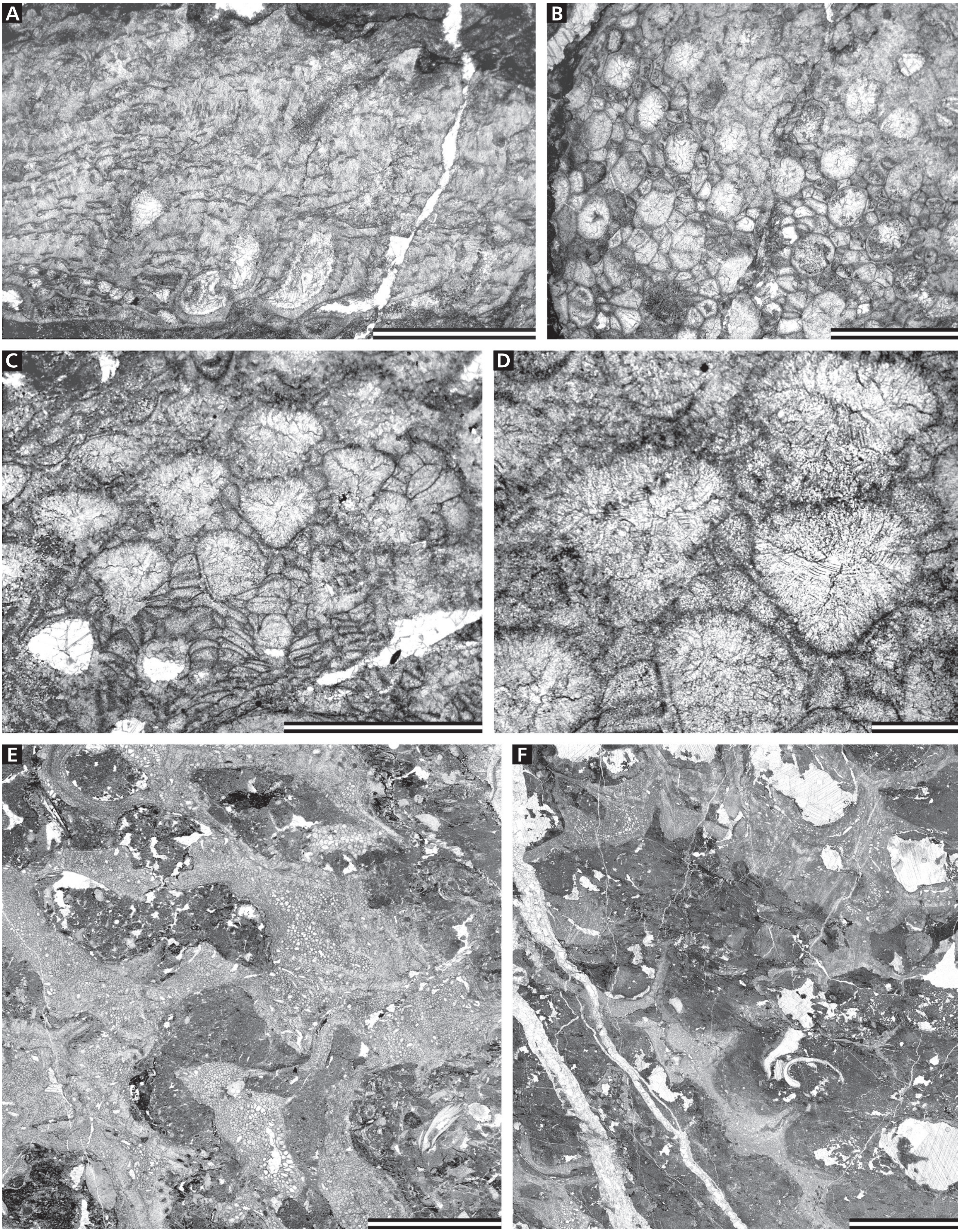


Figure 4. Bryozoans from the studied block. • A, B – *Fistulipora incrustans* (Phillips, 1836), KBK-OC-1, longitudinal (A), and tangential section (B). • C, D – *Eridopora macrostoma* Ulrich, 1882, KBK-2A-3, tangential section. • E, F – *Glyptopora michelinia* (Prout, 1860), KBK-2A-4 (E), KBK-03c (F), thin sections through honeycomb-shaped colonies. Scale bars: 5 mm (E, F), 1 mm (A–D), 0.2 mm (D).

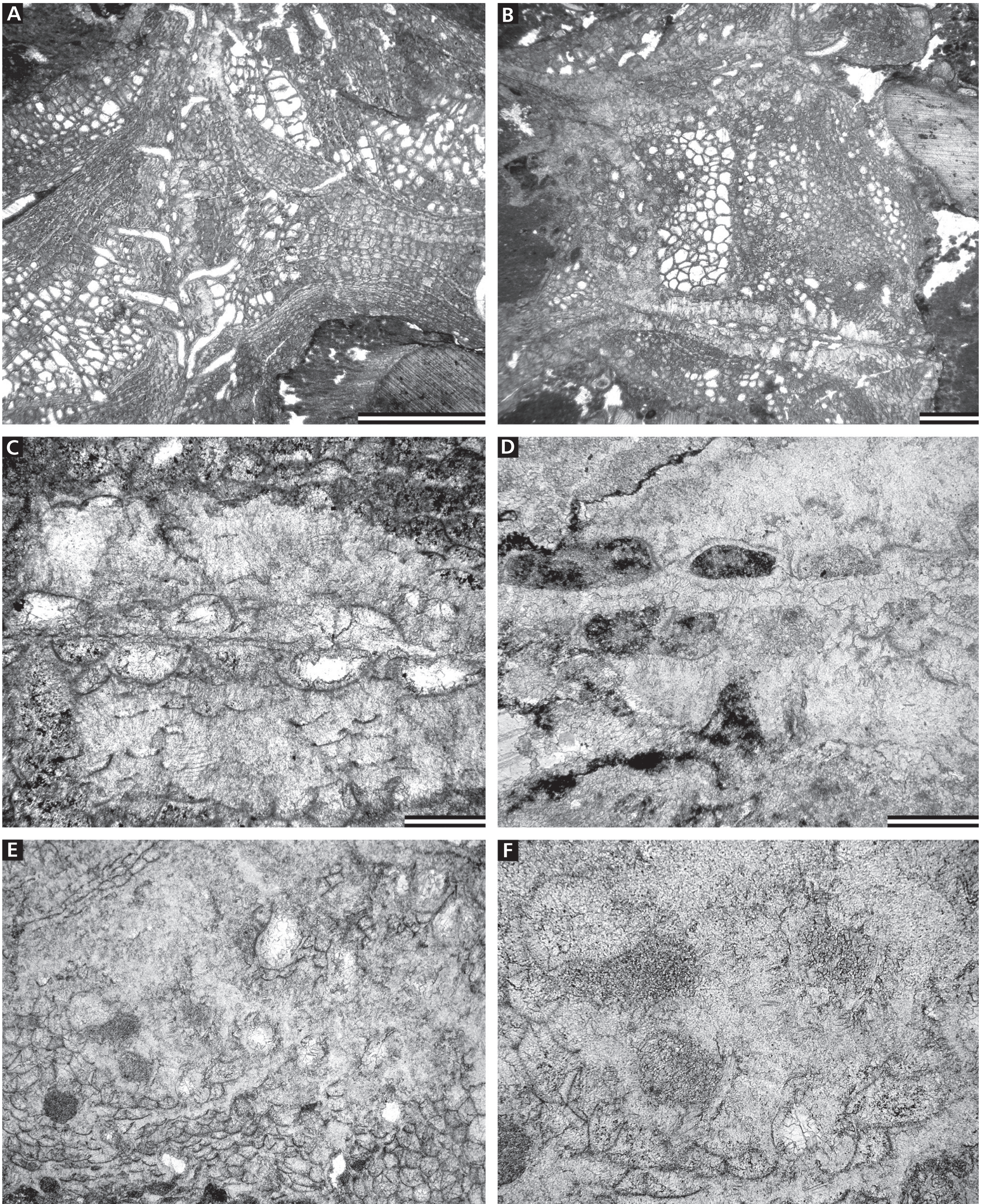


Figure 5. Bryozoans from the studied block. • A–F – *Glyptopora michelinia* (Prout, 1860); A, B – KBK-2A-4, longitudinal (A) and tangential (B) sections through honeycomb-shaped subcolony; C – KBK-0D-1, transverse section through lobe showing autozooecia, vesicles and mesotheca with rods; D – KBK-2A-4, transverse section through lobe showing autozooecia and mesotheca with rods; E, F – KBK-2A-4, tangential section showing autozooecial apertures and vesicles. Scale bars: 1 mm (A, B, E), 0.2 mm (C, D, F).

1986 *Eridopora macrostoma* Ulrich, 1882. – Bancroft, p. 24, figs 1.1–4, 2.1–8, 10–13.

Material. – Single colony KBK-2A-3.

Description. – Thin encrusting colony. Autozooecia growing from thin epitheca, bending in the early exozone to the colony surface. Basal diaphragms rare to absent. Autozooecial apertures circular to oval. Lunaria well-developed, triangular; ends of lunaria not indenting autozooecia. Vesicles small to large, separating autozooecia in 1 row, 12–14 surrounding each autozooecia aperture, with rounded roofs, polygonal in tangential section. Autozooecial walls granular prismatic, 0.010–0.015 mm thick. Maculae not observed.

Remarks. – *Eridopora macrostoma* Ulrich, 1882 differs from *E. definitiva* Gorjunova, 1988 from the Mississippian of Mongolia in larger autozooecial apertures (aperture width 0.28–0.42 mm *vs.* 0.18–0.26 mm in *E. definitiva*). *Eridopora macrostoma* differs from *E. singula* Morozova & Weis *in* Morozova *et al.*, 2006 from the Mississippian (Tournaisian) of Poland in larger autozooecial apertures (aperture width 0.28–0.42 mm *vs.* 0.22–0.25 mm in *E. singular*).

Occurrence. – Carboniferous, Mississippian (Viséan–Serpukhovian); USA, England, Austria, Kazakhstan.

Suborder Hexagonellina Morozova, 1970
Family Hexagonellidae Crockford, 1947

Genus *Glyptopora* Ulrich, 1884

Type species. – *Coscinium plumosum* Prout, 1860. Mississippian, Carboniferous; USA (Illinois).

Diagnosis. – Colony consisting of erect bifoliate lobes which may join to form inverted polygonal subcolonies in a honeycomb-shaped structure. Mesotheca with a dark and thin middle layer and two light and thick outer layers, containing median rods and longitudinal ridges parallel to growth direction. Autozooecia recumbent on the mesotheca or epitheca for a long distance, then bending upwards abruptly or gently, intersecting the surface almost perpendicularly. Hemisepta absent. Thin, complete diaphragms in autozooecia, common to abundant. Autozooecial apertures circular to oval. Lunaria often developed. Autozooecia separated by vesicular skeleton. Vesicular skeleton covered in outer parts by calcite material. Microacanthostyles in outer layer of the calcite material. Maculae depressed, long, narrow, consisting of stereom (modified after Utgaard 1983).

Remarks. – *Glyptopora* differs from *Evactinopora* Meek & Worthen, 1865 in absence of hemisepta, and from *Prismopora* Hall, 1883 in presence of median tubuli in mesotheca and absence of hemisepta.

Occurrence. – Carboniferous–Permian; North America, Europe, Australia.

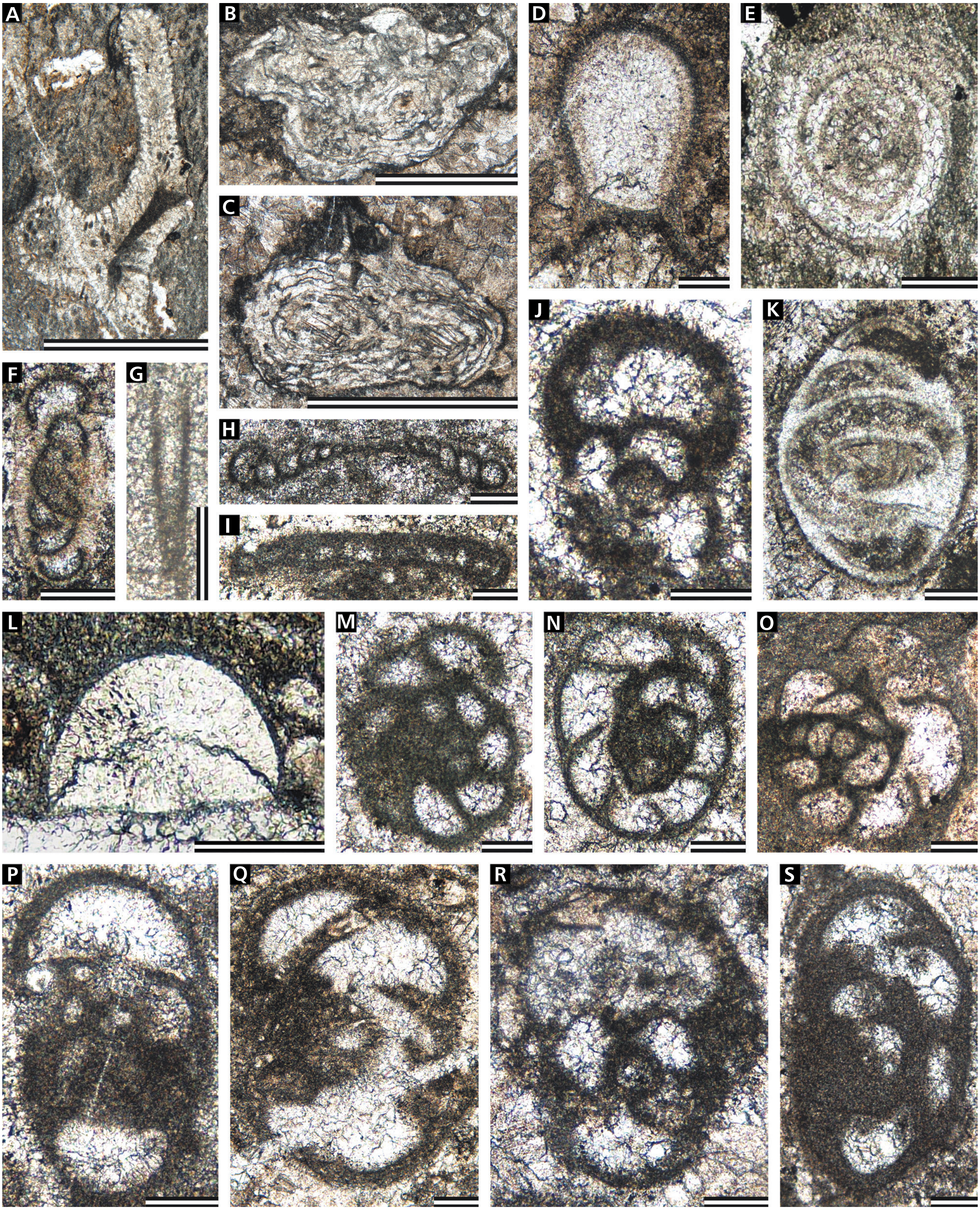
***Glyptopora michelinia* (Prout, 1860)**
Figures 3C; 4E, F; 5A–F; Table 3

1860 *Coscinium michelinia* Prout; p. 573.
1866 *Coscinium michelinia* Prout, 1860. – Prout, p. 414, pl. 22, figs 4, 4o.
1890 *Glyptopora michelinia* (Prout, 1860). – Ulrich, pp. 515, 516, pl. 78, figs 8–8b.
2013 *Glyptopora michelinia* (Prout, 1860). – Ernst & Rodríguez, p. 179, figs 4c–e, 5a–f, 6a–d.
2017 *Glyptopora michelinia* (Prout, 1860). – Ernst & Vachard, p. 21, figs 4a–f.

Material. – KBK-0C-1, KBK-0D-1, KBK-0E-1, KBK-0Fa, KBK-2A-(1–4), KK-03(a–c), KK-07b.

Description. – Colony initially encrusting, producing a series of erect bifoliate lobes. Lobes usually trifurcating radially and fused together forming a honeycomb-shaped structure. Lobes diverging radially from the central axis at angles of 100–145°. Bifoliate lobes 0.6–1.0 mm thick. Mesotheca with a dark and thin middle layer and two light and thick outer layers, 0.02–0.05 mm thick, containing abundant median tubuli. Median tubuli consisting of hyaline calcite, rounded in transverse section, 0.010–0.015 mm in diameter, developing short and densely spaced lateral projections. Autozooecia recumbent on the mesotheca or epitheca for a relatively long distance, then bending upwards abruptly, intersecting the surface almost perpendicularly. Thin, complete diaphragms in autozoo-

Figure 6. Foraminifers from the studied block. • A – *Anatolipora carbonica* Konishi, 1956, KK-06-2, typical longitudinal section. • B, C – *Fasciella kizilia* Ivanova, 1973; B – KK-04a-11, transverse section; C – KK-04a-11a, oblique transverse section. • D – *Tuberitina* sp., KK-04-7, axial section. • E – *Paraarchaediscus grandiculus* (Shlykova, 1951), KBK-0-1, transverse section. • F – *Paraarchaediscus stilus* (Grozdilova & Lebedeva *in* Grozdilova, 1953), KK-04a-22, subaxial section. • G – *Earlandia minor* (Rauzer-Chernousova, 1948a), KK-03-1, subaxial section. • H – *Monotaxinoides gracilis* (Dain *in* Reitlinger, 1956), KK-04a-1, axial section. • I – *Hemidiscopsis* cf. *muradymicus* (Kulagina *in* Kulagina *et al.*, 1992), KK-04a-3, subaxial section. • J, R – ?*Mstinia minima* Brazhnikova *in* Brazhnikova *et al.*, 1956; J – KK-04a-21, transverse section;



R – KK-04-17, transverse section. • K – *Archaediscus karreri* (Brady, 1873), KK-04-2, subaxial section. • L – *Eotuberitina* sp., KBK-0-3, axial section. • M – *Planoendothyra* sp. 1, KK-04a-17, subtransverse section. • N – *Endothyra bowmani* Phillips, 1846 *sensu* Brady, 1876 emend. China, 1965, KK-04a-18a, transverse section. • O – ?*Semiendothyra* cf. *penningtonensis* (Rich, 1980), KK-05-1, transverse section. • P – *Planoendothyra* sp. 2, KK-04a-18, subaxial section. • Q – *Planoendothyra* sp. 3, KK-04a-5a, subtransverse section. • S – *Planoendothyra* sp. 4, KK-04-18, subtransverse section. Scale bars: 1 mm (A–C), 0.1 mm (D–S).

	N	X	SD	CV	MIN	MAX
Aperture width, mm	10	0.14	0.015	10.91	0.11	0.16
Aperture spacing, mm	10	0.38	0.041	10.95	0.31	0.46
Vesicle diameter, mm	10	0.08	0.022	26.30	0.07	0.12
Vesicles per aperture	6	8.7	0.816	9.42	8.0	10.0

Table 3. Descriptive statistics of *Glyptopora michelinia* (Prout, 1860). Abbreviations as for Table 1.

ecia rare. Autozooecial apertures circular to oval. Lunaria developed, horseshoe-shaped to triangular. Vesicular skeleton well developed, covered in outer parts by calcite material. Vesicles moderately large, polygonal in tangential section, with rounded roofs, arranged in 1–3 rows between autozooecia, 7–10 surrounding each autozooecial aperture. Thin layer of extrazooecial material developed on the colony surface, containing tubules. Longitudinal depressed maculae lacking autozooecia apparently developed near bases of erect lobes along the axis of their fusion. Depressed maculae lacking autozooecia places between of fusion present, rounded, 0.55–0.88 mm in diameter.

Remarks. – *Glyptopora michelinia* (Prout, 1860) differs from *G. plumosa* (Prout, 1860) in the mode of lobe diverging. Whereas *Glyptopora michelinia* produced cups by lobes attached to a substrate, the lobes in *G. plumosa* arose from a common base and bifurcated and trifurcated to produce cups. Furthermore, maculae are less commonly developed in *Glyptopora michelinia* than in *G. plumosa*. *Glyptopora michelinia* possesses few diaphragms in contrast to *G. plumosa*, and has slightly smaller autozooecial apertures (0.11–0.16 mm *vs*. 0.15–0.20 mm in *G. plumosa*).

Occurrence. – Mississippian, Viséan; USA Illinois, Missouri, Virginia. Mississippian, uppermost Viséan (Brigantian); Caleras Bajas and Antolín sections, south-western Spain. Mississippian, uppermost Viséan (Venevian) to lowermost Serpukhovian (Tarusian) of Tourière and slope of Bataille, southern France. Kirchbach Formation, Mississippian; Carnic Alps, Austria.

Foraminifers and calcareous algae

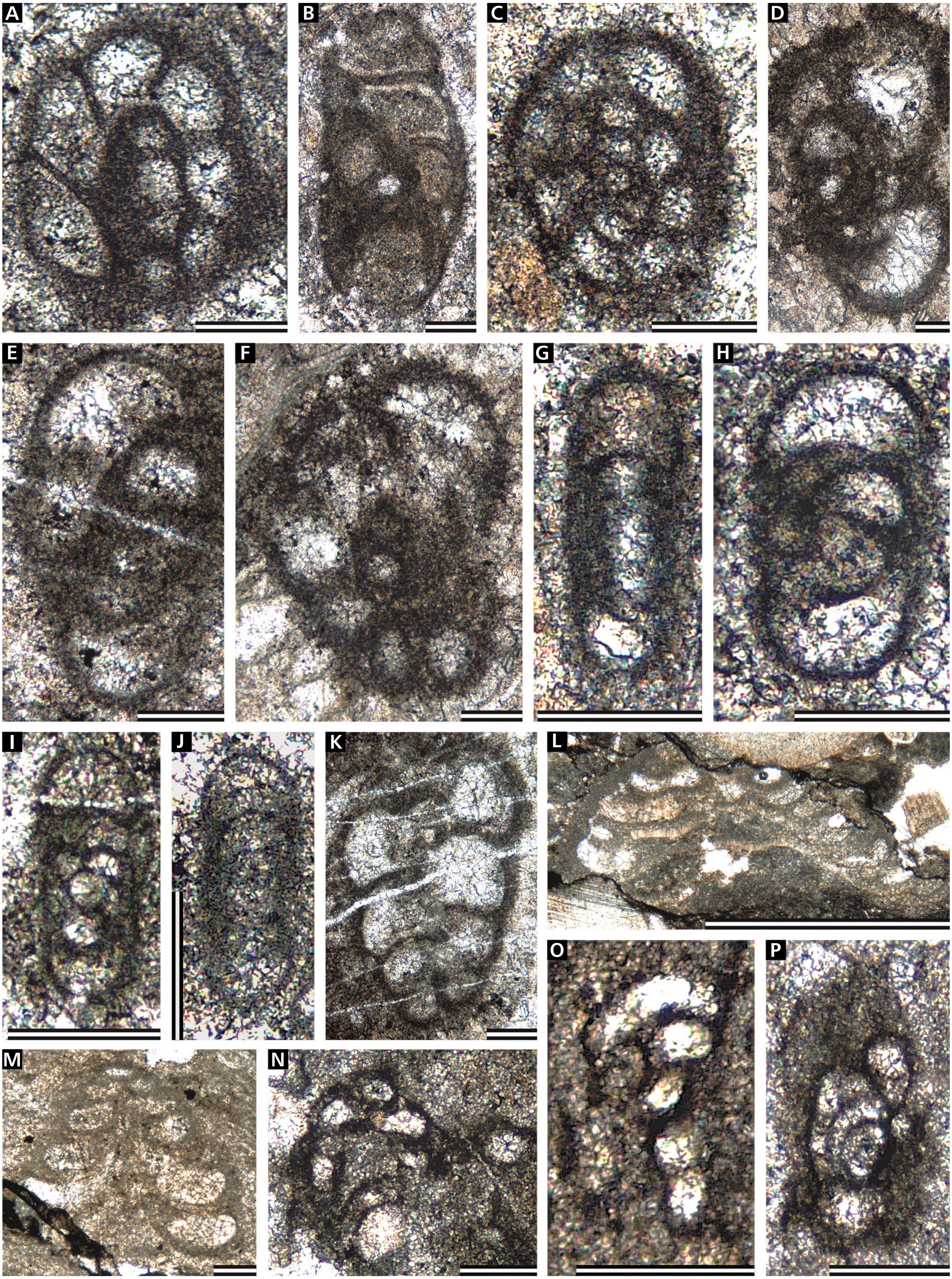
The studied block bears rich assemblage of foraminifers and calcareous algae which encompasses the following taxa: the green alga *Anatolipora carbonica* Konishi, 1956, the incertae sedis alga *Fasciella kizilia* Ivanova, 1973, the calcitarcha *Eotuberitina* and *Tuberitina*, and the foraminifers: *Paraarchaediscus grandiculus* (Shlykova, 1951), *P. stilus* (Grozdilova & Lebedeva *in* Grozdilova, 1953), *Archaediscus karreri* (Brady, 1873), *Monotaxinoides gracilis* (Dain *in* Reitlinger, 1956), *Hemidiscopsis* cf. *muradymicus* (Kulagina *in* Kulagina *et al.*, 1992), *Earlandia minor* (Rauzer-Chernousova, 1948a), ?*Mstinia minima* Brazhnikova *in* Brazhnikova *et al*., 1956, *Endothyra bowmani* Phillips, 1846 *sensu* Brady, 1876 emend. China, 1965, *Planoendothyra* spp., ?*Semiendothyra* cf. *penningtonensis* (Rich, 1980), ?*Eostaffella* ex gr. *prisca* Rauzer-Chernousova, 1948b, *Consobrinellopsis* sp., *Tetrataxis palaeotrochus* (Ehrenberg, 1854), *T. angusta* Vissarionova, 1948, *Quasilituotuba* sp., ?*Warnantella* sp. (Figs 6, 7).

All these taxa are present in the Viséan/Serpukhovian boundary interval, and, paradoxically they are more similar to the early Serpukhovian association recently found in the Nötsch Fm. (Vachard *et al*. 2018) instead of previous descriptions of the Kirchbach Formation, which were late Viséan in age (Amler *et al*. 1991, Krainer & Vachard 2015), and generally from the biozone MFZ14 of Poty *et al*. (2006). The Steshevian assemblage described in the Nötsch Formation by Vachard *et al*. (2018) shows more evolved taxa of Miliolata and Endothyroidea and, in consequence, the assemblage described in this paper could be Tarusian (*i.e.* earliest Serpukhovian) in age, and belong to the upper MFZ15 biozone.

Discussion

The Kirchbach Formation represents autochthonous mudstone (bioclastic mudstone to wackestone) and conglomerate/breccia of sediment gravity flows that contain limestone clasts derived from a shallow marine

Figure 7. Foraminifers from the studied block. • A – *Endothyra bowmani* Phillips, 1846 *sensu* Brady, 1876 emend. China, 1965, KK-04-19, transverse section. • B – *Planoendothyra* sp. 5 KK-04-16, oblique transverse section. • C?, G, I, J – ?*Eostaffella* ex. gr. *prisca* Rauzer-Chernousova, 1948b; C – KK-04-8, transverse section; G – KK-04a-6, axial section; I – KK-04a-4, axial section; J – KK-04a-13, axial section. • D–F – *Planoendothyra* sp.; D – KK-04-15, oblique axial section; E – KK-04a-12, oblique axial section; F – KK-04a-5a, oblique transverse section. • H – *Planoendothyra* sp. 2, KK-04a-7, axial section. • K – *Consobrinellopsis* sp., KK-04a-1, subaxial section. • L – *Tetrataxis palaeotrochus* (Ehrenberg, 1854), KBK-04-8, subaxial section. • M – *Tetrataxis angusta* Vissarionova, 1948, KBK-01-1, subaxial section. • N – *Quasilituotuba* sp., KBK-04-1, subtransverse section. • O, P – ?*Warnantella* sp.; O – KBK-04-3, subtransverse section; P – KBK-04-7, oblique section. Scale bars: 1 mm (L), 0.1 mm (A–K, N–P).


A
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shelf environment. This formation is intercalated in the early Viséan to Bashkirian Hochwipfel Formation that is composed of synorogenic deep marine siliciclastic sediments deposited in a flysch basin that formed during an extensional rifting phase in the foreland of the Noric terrane. The Hochwipfel flysch basin was closed during the Bashkirian (Variscan orogeny) (see discussion in Krainer & Vachard 2015).

Microfacies and fossils of the limestone clasts that are present in the conglomerates and breccias of the Kirchbach Formation indicate that they are derived from a shallow marine carbonate shelf with different shallow water environments. This carbonate shelf was developed along the northern margin of the Hochwipfel flysch basin. The limestone clasts were transported into deeper marine environments by sediment gravity flows (submarine debris flows) (Flügel & Schönlaub 1990, Krainer & Vachard 2015, Rodríguez *et al*. 2018, Kabon & Schönlaub 2019).

Foraminifers of these limestone clasts indicate a late Asbian age (MFZ 14; late Viséan) (Krainer & Vachard 2015). The bryozoan fauna that is described from these limestone clasts for the first time supports this age identification, displaying slightly wider distribution, which falls in the range of Asbian to Brigantian, reaching in the lowermost Serpukhovian.

The studied limestone block confirms the presence of a carbonate shelf and provides additional information on the depositional environments on the shelf. Coral bafflestone demonstrates that locally coral colonies formed small patch reefs (Rodríguez *et al*. 2018), and were associated with bryozoan bindstone.

The studied bryozoan association is represented by three encrusting species including one with complex honeycomb shaped colony consisting of numerous subcolonies (*Glyptopora*). All three species belong to the palaeostomate Order Cystoporata. Furthermore, fragments of unidentifiable trepostomes and fenestrates are present in the matrix pointing on moderate bryozoan diversity of the Kirchbach Formation. These species are represented by delicate branching colonies, with branch diameters less than 1 mm. The combination of encrusting, sheet-like colonies and fenestrate-delicate branching colonies indicates high to moderate energy levels, moderate to high sedimentation rates and flexible to hard substrates (*e.g.* Amini *et al.* 2004). According to bryozoan growth forms, this environment can be classified as shallow shelf.

The identified bryozoan species, *Fistulipora incrustans* (Phillips, 1836), *Eridopora macrostoma* Ulrich, 1882, and *Glyptopora michelinia* (Prout, 1860), are typical for the Mississippian deposits in Europe. *Fistulipora incrustans* (Phillips, 1836) is known from the upper Viséan of Great Britain and Spain, whereas *Eridopora macrostoma* Ulrich, 1882 and *Glyptopora michelinia* (Prout, 1860) were recorded from the interval of the upper Viséan and lower Serpukhovian of North America and Europe.

Conclusions

Microfacies and fossil assemblage of the studied limestone block supports the idea that a shallow shelf was present along the northern margin of the Hochwipfel flysch basin (Flügel & Schönlaub 1990, Amler *et al*. 1991, Krainer & Vachard 2015, Vachard *et al*. 2018, Kabon & Schönlaub 2019). Microfacies and fossil assemblages of the limestone block as well as the limestone clasts in the carbonate conglomerate of the Kirchbach Formation and the exotic limestone clasts of the Carboniferous of Nötsch are derived from this shallow shelf. The microfacies of the limestone block allow a more detailed characterization of the depositional environment of this shallow shelf. Coral bafflestone demonstrates that locally small patch reefs were present, associated with bryozoan bindstones. Patch reefs or skeletal mounds indicate formation during long periods of quiet water, periodically interrupted by short periods of higher water turbulence (Rodríguez *et al*. 2018). Microfacies of reworked limestone clasts are composed of wackestone, packstone, grainstone and rudstone containing a diverse fossil assemblage pointing deposition in a shallow, normal marine environment with moderate to high water energy (Flügel & Schönlaub 1990, Amler *et al*. 1991, Krainer & Vachard 2015). Limestone clasts composed of bindstone are derived from a very shallow, restricted shelf environment (Krainer & Vachard 2015). The presence of encrusting, sheet-like bryozoan colonies associated with fenestrate, delicate-branching colonies indicates moderate to high water turbulence, moderate to high sedimentation rates and flexible to hard substrate on an open, shallow shelf above the wave base.

The assemblage of foraminifers and algae is more similar to the association recently found in exotic limestone clasts of the Carboniferous of Nötsch (Vachard *et al*. 2018) than to the association described from the Kirchbach Formation, which was dated as late Viséan MFZ 14 (Amler *et al*. 1991, Krainer & Vachard 2015). Nevertheless, the Steshevian assemblage of the Carboniferous of Nötsch, reported by Vachard *et al*. (2018), shows more evolved taxa of foraminifers Miliolata and Endothyroidea. This indicates that the foraminiferal assemblage described in this paper is probably older, and Tarusian in age (*i.e.* earliest Serpukhovian and equivalent to the upper MFZ15 biozone).

Microfacies and fossil assemblage of the studied limestone block confirm that a shallow marine carbonate shelf was developed along the northern margin of the Hochwipfel flysch basin (see Vachard *et al*. 2018), from where clasts and larger blocks were transported into deeper marine environments by gravitational sedimentary processes.

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