FOSSILS IN LATE CRETACEOUS TO EARLY PALAEOCENE FLINT NODULES EMBEDDED IN PLEISTOCENE GLACIOFLUVIAL SEDIMENTS NEAR FUKOV (DĚČÍN DISTRICT, NORTHERN BOHEMIA)

RICHARD POKORNÝ, JAROSLAV KAŠE
Faculty of the Environment, Jan Evangelista Purkyně University in Ústí nad Labem, Králova Výšina 7, 400 96 Ústí nad Labem, the Czech Republic; e-mail: richard.pokorny@ujep.cz

JIŘÍ KVAČEK, KAMIL ZÁGORŠEK
National Museum, Department of Palaeontology, Václavské nám. 68, 115 79 Praha 1, the Czech Republic; e-mails: jiri.kvacek@nm.cz, kamil_zagorsek@nm.cz

TOMÁŠ KOČÍ
Ivančická 581, Praha 9 – Letňany 199 00, the Czech Republic; e-mail: protula@seznam.cz

JIŘÍ ŽÍTT
Institute of Geology of the Academy of Sciences of the Czech Republic, v.v.i., Rozvojová 269, 160 00 Praha 6; e-mail: zitt@gli.cas.cz

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Abstract. Faunal and floral fossil remains of Late Cretaceous – Early Palaeocene age were recovered from flint pebbles from glaciofluvial gravel sediments in the Fukov area, northern Bohemia, the Czech Republic. Sedimentology of these sediments is discussed. Suggestions are made regarding the origin of the flints and their possible sources. The recovered taphocoenosis consists of one fossil plant taxon, nineteen bryozoans, three molluscs, one sabellid, and seven echinoderms. This type of flint and fossil fauna may indicate a pioneer character of the association found in glaciofluvial sediments near Fukov, perhaps an unconsolidated environment on a continental shelf margin which is characteristic for North-western European chalk. The occurrence of plant fossil in this type of deep shelf sediment is unique and suggests the existence of some land mass at a relatively close distance to the place of deposition.

■ Late Cretaceous, Palaeocene, glaciofluvial sediments, flint, erratic boulders, taphocoenosis, Northern Bohemia, Pleistocene glaciation

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Introduction

Continental glaciation sediments in the northern part of the Czech Republic have been known for more than a century (e.g. Magerstein 1888, Cammerlander 1890, 1891). Field documentation and thorough description of these remains however is still not complete (cf. Nývlt et al. 2011).

Pleistocene glaciofluvial sediments deposited during the last million years occur in Fukov near Šluknov in Northern Bohemia. In this contribution we report on Late Cretaceous and Palaeocene fossils originating from these glaciofluvial sediments.

The northern part of the Czech Republic was affected at least three times by the North European ice sheet during the Middle Pleistocene, i.e. during the Elsterian and Saalian glacial stages.

Two separate glaciation events took place during the Elsterian, both of them influenced a part of the territory of the Czech Republic. The chronologically older stage, correlated by Aitken and Stokes (1997) with the Marine Isotope Stage (MIS) 16 (ca. 620–635 ka BP sensu Jouzel et al. 2007), represents the maximum glaciation in the westernmost part of the Czech territory (Nývlt 2008). A large part of Šluknov and Frýdlant Spurs plus the Zittau Basin was covered by an ice sheet. The ice sheet extended to the Jítrava Saddle and Ralsko Hilly land. The second glaciation occurred during MIS 12, ca. 430 ka BP and extended over a generally slightly smaller area in northern Bohemia (Nývlt et al. 2011).

The continental glacier extended to the foothills of Zlaté hory Mts., Hrubý Jeseník Mts. and the Zlatohorská Highlands in northern Moravia and Silesia during the Elsterian glaciation and it also covered the area of the Ostrava Basin. The ice sheet presence in the Moravian Gate territory was questioned by Tyráček (2011). He considers most of the sediments there as glaciofluvial.

The Saalian stage glaciation arrived in the Czech territory during its first maximum in MIS 6 (approx. 160 ka BP, Nývlt et al. 2007). However, its extent in northern Bohemia was more restricted than during the Elsterian glacial stages. It is possible to find evidence of its presence only in the northern part of the Frýdlant Spur in northern Bohemia. It covered the Ostrava Basin territory and the Opava Hilly land in the northern Moravia and Czech Silesia and advanced further to the south to the Moravian Gate (Nývlt et al. 2011).

Due to contact of the ice sheet with markedly heterogeneous geological units during its journey to the south, erratic boulders contained in the material transported by the ice sheet are represented by a wide range of rock types with an admixture of Nordic elements which had been transported more than 1000 km. Individual petrotypes of these sediments are quite well documented (see e.g. Gába and Pek 1997, 1999; Nývlt and Opletal 2002 and Nývlt et al. 2007).

Flints, which are our main focus, represent relatively abundant elements in the Nordic erratic in the studied area. Based on clast analysis, Gába and Pek (1999) state an average percentage of 8.4% in the northern Moravian glacial sediments. The flint originated in Baltic area and is latest Cretaceous to early Palaeocene in age. On the surface of the flint nodules and inside it is possible to find a number of fossils, which mostly correspond to the fossil record of the Baltic sedimentation area.

Palaeontology of flint erratics in northern Moravia was studied in detail by Gába and Pek (1999), who described abundant fossil invertebrates, especially sponges, bryozoans, echinoderms, pelecypods, brachiopods and also trace fossils.

Although flint also represents an important part of Nordic erratics in glaciofluvial sediments of northern Bohemia (Nývlt et al. 2007), they represent an average of ~3.5% from the Šluknov Spur (Nývlt 2008). The palaeontological content of these flints has not yet been studied in detail. Only Mikuláš and Šimo (2006) commented in a short paper on an isolated find of the trace fossil *Thalassinoides* sp. from a sand pit in Doubice (Česká Lípa district) and Kaše et al. (2010) described a bryozoan fauna from an abandoned sand pit in the Fukov Spur.

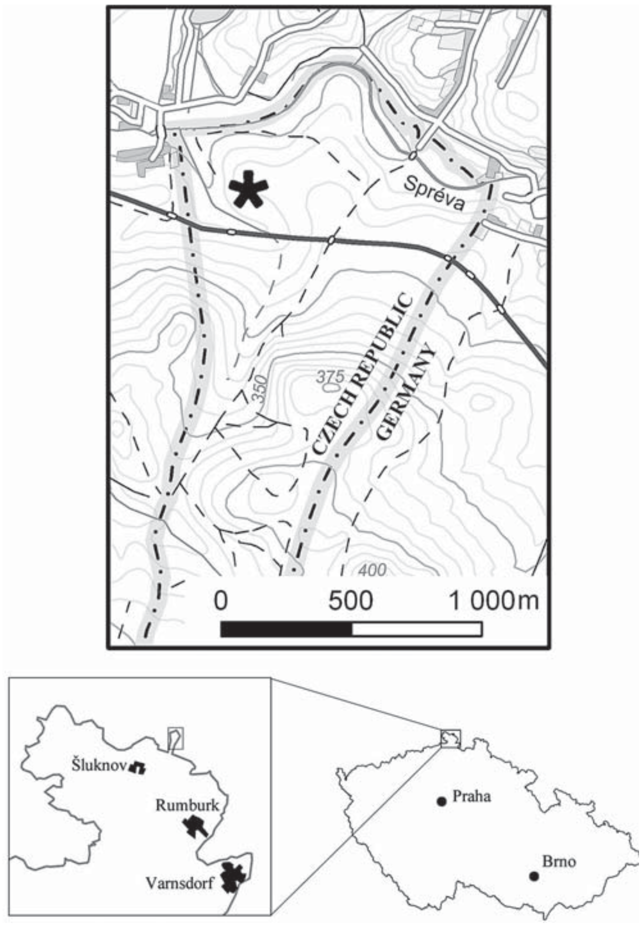
Newly recovered material shows that the range of fossils from the above mentioned locality near the abandoned village of Fukov is much more variable. Therefore, the present study gives a more complete list of fossils found there and includes also preliminary palaeoecological implications.

Material and methods

The study site is located in the northwestern part of the Fukov Spur, ca. 170 m from the German border on the left bank of the Spréva River (N 51°2'31.292"; E 14°29'39.306"), see Text-fig. 1. It is an abandoned sand pit, although occasionally still used for limited local needs. The thickness of the proglacial sands and gravels here reaches at least 15 m.

There are three excavation benches 3–5m high and 90 m long as remnants of former mining in the Fukov sand pit. Fossils contained in flints were collected from all three benches. The largest amount of fossils was collected from the upper bench, 1–2 m below the soil cover. A total of about 550 flint nodules were collected. Flints without visible fossils on their surface were mechanically disintegrated and all fragments also checked.

The lithology of this locality was studied in detail by Nývlt et al. (2007), who described the planar, ripple and trough cross-bedded, usually medium-grained sands and gravels. In addition, thin beds of laminated coarse-grained silts to fine-grained sands occur locally. Sub-horizontally layered sand units occur only sporadically. The sediments present here are of glaciofluvial origin. Several individual river channels flowing along the glacier front deposited the whole sequence during MIS 16, i.e. the first Elsterian glacial stage (Nývlt et al. 2007, 2011). The channels gradually filled up and moved by lateral migration on the proglacial braidplain. The interchannel bars were deposited during high discharge.



Text-fig. 1: Topographical location of the Fukov gravel pit.

Melting water flowed along the front of the "Odra ice lobe". This ice lobe was main pronounced advancing part of Northern European ice sheet in Poland, eastern Germany and also in northern Bohemia (Eissmann 2002, Marks 2002, Nývlt 2008, Nývlt et al. 2011). The lobe locally divided into several partial branches in the Šluknov hilly area – the Spréva and Mandava ice lobes. These lobes again joined together in the area of today's Rumburk (Nývlt et al. 2007, Nývlt 2008).

Latex casting was used for the study of echinoderms. Latex was applied to the cavities remaining after dissolution of fossil skeletal remains. The latex casts were coated with ammonium chloride, before photographing.

Fossils were observed under binocular microscope, Olympus SZX12, and documented with an Olympus DP 72 camera. For higher magnification and observation of particular details, a Hitachi S-3700N SEM was employed. All bryozoans were ultrasonically cleaned prior to observation and documentation was by SEM, using low vacuum mode to document uncoated specimens. Images of fossils were prepared using CorelDRAW X4 software.

Fossils described here are deposited in collections of the National Museum Praha (NMP) and the Jan Evangelista Purkyně University in Ústí nad Labem, Faculty of Environment (FZP).

Systematic Palaeontology

Plantae

Fossil plants are a very rare element in the studied material. Only one angiosperm fossil leaf fragment was found. Its systematic affinity is defined as an angiosperm – Magnoliopsida.

Magnoliopsida

Pl. 1, fig. 1

M a t e r i a l : Collection number NMP G 9402.

Only a single plant fossil was recovered in the locality. This specimen is unique in terms of preservation and occurrence. Deep shelf sediments usually do not contain any remains of terrestrial flora. According to our knowledge, this is the first leaf recovered from these Maastrichtian – Palaeocene flints, although earlier rare finds of conifers and marine plants from Maastrichtian area (the Netherlands) were already reported (van der Ham et al. 2001, 2003, van der Ham and van Konijnenburg-van Cittert 2003, van der Ham and Dortangs 2005, van der Ham et al. 2007).

The leaf fragment is small, 14 × 10 mm in size. It is most probably a fragment of a larger leaf. The fragment is palmately veined without preserved margins. The medially placed midvein is more pronounced than the other six primaries which are arranged in threes on both sides of the mid vein. Even using SEM, we were unable to observe any detail of the leaf surface epidermis.

This specimen could represent a basal part of a *Trochodendroides* sp. leaf (compare Kvaček et al. 1994, Kvaček and Manum 1997, Golovneva 1994). *Trochodendroides* leaves have, however, particularly distal veins arranged at wide angles.

Its shape also resembles a bract, however this type of bract does not have any modern relative. A fossil bract with a similar arrangement of veins was described by Heer (1876, pl. 21, fig. 6) as *Macclintockia tenera* Heer, 1876 and refigured by Budantsev and Golovneva (2009, pl. 77, fig. 5). The fossil at hand shows a rather different arrangement of veins, with less densely placed veins in the central part of the bract. However, interpretation of the fossil as a bract cannot be ruled out.

Evertebrata

Bryozoa

Pl. 2, figs 5 - 9

M a t e r i a l : Collection numbers FZP/P/12/2-3/024 –FZP/P/12/2-3/050.

The state of preservation is critical for precise determination of the Fukov bryozoans. Volumetrically bryozoans dominate in the studied association, but only a few fragments show features enabling their determination to species or generic level. Most of the fragments are visible only as oblique sections and neither chemical, nor mechanical methods (Kedrová and Zágoršek 2011) enabled the outer surface of the colonies to be viewed as required for precise determination.

Only the colonies naturally weathered on the surface of the flint were suitable for study. In addition in a previously published paper (Kaše et al. 2010) we examined an additional 27 samples in which bryozoans were on the weathered surface of flint fragments. Among them, we found 3 additional taxa, including *Idmidronea* Canu and Bassler, 1920, *Porella* Gray, 1848 and a celleporid colony. Therefore, recently, altogether, 19 taxa may be formally identified from the Fukov section. Erect rigid colonies from cyclostomatous genera such as *Mecynoecia* Canu, 1918, *Crissisina* d'Orbigny, 1853, and *Filisparsa* d'Orbigny, 1853 dominate the association but the cheilostomes were more diverse (11 taxa from the total). The dominant cheilostomatous taxon was *Coscinopleura angusta* (Berthelsen, 1962), of which altogether 25 fragments were identified. Encrusting colonies were not found.

The abundance of the species *Coscinopleura angusta* indicate a Danian – lowermost Palaeocene age for the studied association (Berthelsen 1962).

Mollusca

Class: **Bivalvia Linnaeus, 1758**

Ordo: **Ostreida Férussac, 1822**

Family: **Gryphaeidae Vyalov**, 1936

M a t e r i a l : One poorly preserved valve, collection number: FZP/P/12/2-3/001.

D e s c r i p t i o n : Right valve, considerably inequivalve, oval in outline, slightly inequilateral. Length 8 mm, height 10 mm. Flat, lid-shaped, moderately convex. Muscle scar broadly oval, located approximately in the middle of the shell, near the top.

R e m a r k s a n d r e l a t i o n s h i p s : Due to the poor preservation and the absence of important features exact determination is not possible. According to the general shape, it is a solitary, semi-infaunal pycnodonteine oyster, probably with some relationship to the genus *Pycnodonte* Fischer de Waldheim, 1835, which is described from the Upper Maastrichtian and Lower Danian (e.g. Müller 1970, Machalski 1988, Abdel Aal and El-Hedeny 1998, Casadío 1998). No fossil oysters have yet been confirmed from glacial sediments in the Czech Republic. Quite common findings are however known from Germany (Hucke 1967, Lienau 2003). In sedimentary strata in situ, the presence of pycnodonteine oyster on a flint nodule surface is very frequent – for more information see Jagt et al. (2007) or Jolkičev (2007).

Ordo: **Limida Moore, 1952**

Family: **?Limidae Rafinesque, 1815**

Pl. 1, figs 2, 3

M a t e r i a l : One incomplete right valve of a small specimen, collection number: FZP/P/12/2-3/002.

D e s c r i p t i o n : A moderately convex, inequilateral valve. The pronounced ornamentation consists of 19 tall, straight, regularly spaced ribs, oval in cross-section, with flat interspaces. Auricles are not visible.

R e m a r k s a n d r e l a t i o n s h i p s : Exact determination is impossible. On the base of overall appearance it is possible to consider limid bivalves from the group *Limaria* Link, 1807 or *Lima* Bruguière, 1797. The genus *Lima* was found by Gába and Pek (1999) in north Moravia, limids are also often found in glacial sediments from Germany (Hucke 1967, Lienau 2003).

Ordo: **Pectinida Gray, 1854**

Family: **?Pectinidae Rafinesque, 1815**

Pl. 1, figs 4, 5

M a t e r i a l : One fragment of a very small specimen, collection number: FZP/P/12/2-3/003.

D e s c r i p t i o n : Slightly convex valve. The surface is covered by 10 well developed, sharp, straight ribs, in the lower part bifurcated, triangular in cross-section. Interspaces between ribs are significantly concave. Thin symmetrical concentric growth lines are visible perpendicular to the ribs. The general shape and auricles are not visible. Size of fragment is 2 mm.

R e m a r k s a n d r e l a t i o n s h i p s : The reticulate character of the ribbing and growth lines is comparable with small pectinids, e.g. *Dhondtichlamys* Waller, 2001 or *Camptochlamys* Arkell, 1930, described from the Danian of Alaska by Waller and Marincovich (1992). In particular the left valve of a propeamussiid of the genus *Parvamussium* Sacco, 1897, also common in the Danian, is also similar (del Río et al. 2008). Gába and Pek (1999) mentioned the genus *Lyropecten* (now *Dhondtichlamys*, see Dhondt 1972, Waller 2001) from Upper Cretaceous flint nodules from glacial sediments in north Moravia and pectinids are also described from flints from Germany (Hucke 1967).

Annelida

Class: **Polychaeta Grube, 1850**

Ordo: **Sabellida Fauchald, 1977**

Family: **Sabellidae Latreille, 1825**

***Glomerula* Nielsen, 1931**

***Glomerula* sp. ex gr. *lombrica* (Defrance, 1827) / *serpentina* (Goldfuss, 1831)**

Pl. 2, figs 1 – 4

M a t e r i a l : Five specimens preserved either as longitudinal sections of the tubes or as sections through the “glomerulate knot”, collection numbers FZP/P/12/2-3/004, FZP/P/12/2-3/005, FZP/P/12/2-3/006, FZP/P/12/2-3/007, FZP/P/12/2-3/008.

D e s c r i p t i o n : Tube and lumen circular in cross-section, strongly and irregularly curved to form a knot. Outer surface of the tube bears no ornamentation. The tube diameter is 0.5 to 1.2 mm.

R e m a r k s a n d r e l a t i o n s h i p s : Gába and Pek (1999) mentioned the occurrence of sporadic remains of sabellid worm tubes belonging to *Glomerula gordialis* (von Schlotheim, 1820) in facetted flint pebbles of Late Cretaceous age in the Moravian-Silesian area.

Systematics of species within the genus *Glomerula* is extremely problematic. Jäger (personal communication to Tomáš Kočí) believes that the genus *Glomerula* consists of a large number of species, but states that it is nearly impossible to distinguish between them, because the construction of the tube is so simple and the morphological variation between specimens, even within one sample, is exceptionally wide.

According to the partly artificial scheme published by Jäger (2005) and later somewhat modified in Jäger (2012), due to their relatively young age, the either latest Cretaceous or early Palaeocene tubes, must belong to the phylogenetically advanced set of species including *G. lombrica* (Defrance, 1827) and *G. serpentina* (Goldfuss, 1831). These are characterized by the occasional occurrence, present in only a small percentage of specimens, of trilobate narrowing of the tube lumen, a construction presumably enabling the animal to fix itself inside its tube as a protection against being drawn out of it by a predator. Unfortunately, the cross-section visible in the specimens examined in the present study do not show any distinct trilobate narrowing. A third species of this phylogenetically advanced set, *G. plexa* (J. C. Sowerby, 1829), can be ignored here because it represented by clusters formed by various numbers of tubes, whereas the specimens dealt with in the present paper each consist of a single tube (or, perhaps, a limited number of tubes).

The most important difference between *G. lombrica* and *G. serpentina* is simply that the former is smaller and the latter is larger in tube diameter, with 0.7 to 1.0 mm being the approximate boundary. Due to this criterion, some specimens found in the flint nodules could belong to *G. lombrica*, some are intermediate between the two species, and only the largest specimen could belong to *G. serpentina*.

Moreover, practical experience has shown that only in fine-grained offshore sediments and only in the Cretaceous period, it is logical to differentiate between the small *G. lombrica* and the larger *G. serpentina*. In contrast, in all coarse-grained nearshore sediments, from the Cretaceous as well as from the Palaeocene and Eocene, and also in Palaeocene and Eocene fine-grained offshore sediments, all *Glomerula* tubes, independent of their size, should belong to a single species, *G. serpentina*. While there is no doubt that the flints dealt with in the present study are derived from fine-grained offshore sediments, without closer investigation of the co-occurring fauna it can not be stated with certainty if the flint is derived from Late Cretaceous or Palaeogene sediments as the genus *Glomerula* occurs in both. It is this unanswered question regarding the definite age of the flint nodules which prevents taxonomic determination of the *Glomerula* tubes down to species level.

Echinodermata Klein, 1734

Class: **Crinoidea Miller, 1821**

Ordo: **Isocrinida Sieverts-Doreck, 1953**

***Nielsenicrinus* (?) sp**.

Pl. 3, fig. 7

Material: 1 pluricolumnal, collection number FZP/P/12/2-3/009.

Description: The pluricolumnal contains at least 16 columnals (the neighbouring ones may be covered by rock), which all are internodals. The columnals are slightly pentalobate with smooth latera.

Remarks: If the specimen belongs to *Nielsenicrinus* Rasmussen, 1961, the species *N. fionicus* (Nielsen, 1913) from the Upper Danian of Denmark and Sweden (Rasmussen 1961) may be considered. Some affinity to *Isselicrinus* Roveretto, 1914 [most probably to *I. buchii* (Roemer, 1840), from the Maastrichtian of Denmark, Sweden, Germany, England and France] can not be excluded.

Class: **Echinoidea Leske, 1778**

Ordo: **Cidaroida Claus, 1880**

***Tylocidaris* (*Tylocidaris*) sp.**

Pl. 3, fig. 5

Material: 5 fragmentary spines, collection numbers FZP/P/12/2-3/010, FZP/P/12/2-3/011, FZP/P/12/2-3/012, FZP/P/12/2-3/013, FZP/P/12/2-3/014.

Description: The spines are stout, the shaft ornamented with coarse granules, adapically organized in rows. The neck not sharply demarcated from the shaft.

Remarks: The spines resemble the species *Tylocidaris* (*T.*) *sorigneti* (Desor, 1856) from the Lower Turonian (e.g., Bohemian Cretaceous Basin, see Žítt et al. 2006) or *T.* (*T.*) *velifera* (Agassiz et Desor, 1846) from the Lower Cenomanian of England (Smith and Wright 1989) and *T.* (*T.*) *bruennichi* Ravn, 1928 and *T.* (*T.*) *abildgaardi* Ravn, 1928 from the Danian of Denmark and the Netherlands (Ravn 1928; Jagt 1999, 2000) (the last two species have been used as zonal markers in the Danian type area by Brotzen (1959)). Another similar species, *T.* (*T.*) *vexillifera* Schlüter, 1892, is also known from the Danian of the NW Europe and its spines were found even in flints of glacial deposits from northern Germany (Schlüter, 1892). However, the spines of this species have small wings or depressions distally which are absent in the recently studied material. A reliable con-specification of our material with any of the above mentioned species is not possible due to its unfavourable preservation.

***Cidaris* (?) sp. A**

Pl. 3, fig. 3

Material: 5 spine fragments, collection numbers FZP/P/12/2-3/015, FZP/P/12/2-3/016, FZP/P/12/2-3/017, FZP/P/12/2-3/018, FZP/P/12/2-3/019.

Description: The spine is long and slender with longitudinal striation and coarser unpreserved structure (minute tubercles?) in rows. The base of the spine is not preserved.

***Cidaris* (?) sp. B**

Pl. 3, fig. 6

Material: 1 incomplete interambulacral plate, collection number FZP/P/12/2-3/020.

Description: The plate has a large and only slightly sunken areole, mamelon perforated, incompletely preserved but probably with a diameter only slightly smaller than the diameter of the platform. The platform with very soft dense ridges, resembling crenellae. They are not developed on the platform margin. Extrascrobicular surface with many small tubercles (badly preserved). Scrobicular tubercles and adradial margin of the plate unpreserved.

Remarks: Affinity of this species to the above described *Tylocidaris* (*Tylocidaris*) sp. may be almost excluded (*Tylocidaris* has no platform crenulation in interambulacral plates). Considering the overall morphology and many small and dense extrascrobicular miliary tubercles, the affinity of our plate to *Temnocidaris* Cotteau, 1863 is possible (Smith and Wright 1989).

Ordo: **Phymosomatoida Mortensen, 1904**

***Phymosoma* (?) sp.**

Pl. 3, fig. 1

Material: 1 spine, collection number FZP/P/12/2-3/021.

Description: The spine is cylindrical with smooth shaft and well-defined milled ring.

Remarks: Similar spines were found in situ e.g. in *Phymosoma koenigii* (Mantell, 1822) from the Santonian of England (Smith and Wright 1996). The stratigraphic range of the genus is Upper Jurassic-Palaeocene.

Ordo: **Spatangoida L. Agassiz, 1840**

Family: **Hemiasteridae (?) H. L. Clark, 1917**

***Hemiaster* (?) sp.**

Pl. 3, fig. 2

Material: Dorsal part of 1 test, collection number FZP/P/12/2-3/022.

Description: Apical system unpreserved, ambulacra differentiated as for their function. The posterior paired petals shorter than the anterior ones, the anterior petals distally closing. Pores in pore-pairs rather elliptical than circular. Anterior ambulacrum non-petaloid, very shallow, plates short and wide, pore-pairs uniserially arranged. Interambulacral plates large, tubercles unpreserved. Fasciola unpreserved.

Remarks: The specimen most probably represents an internal cast of the test in which no external structures are preserved. Because of this unfavourable type of preservation, the most taxonomically important features are missing (number of gonopores, fasciolae). The overall character of the single test indicates a relationship to some species of *Hemiaster* Agassiz et Desor, 1847. The affinity to some other echinoid taxa, e.g. hemiasterids *Bolbaster* Pomel, 1869 or *Proraster* Lambert, 1895 is not probable (cf. Kahlke, Neumann and Taake 2009). *Bolbaster* is dorsally more convex and *Proraster* has dorsally very deep anterior sulcus (Smith and Kroh 2011).

Family: **Micrasteridae Lambert, 1920**

Micrasterid sp.

Pl. 3, fig. 4

Material: 1 test fragment, collection number FZP/P/12/2-3/023.

Description: The fragment of echinoid test is flat and bears rows of small crenulated secondary tubercles and a short section of fasciola.

Remarks: The above mentioned characters, together with shape of the test fragment, indicate possibly a plastron fragment of a micrasterid. Both the genera *Micraster* (L. Agassiz, 1836) and *Diplodetus* Schlüter, 1900 which cross the Cretaceous/Palaeocene boundary may be considered.

Discussion

Fossils occurring in the Fukov sand pit belong to the secondary taphocenose re-sedimented by proglacial glaciofluvial processes. Nývlt et al. (2007) term it as an "open locality", i.e. without any influence of the surroundings landscape to the glaciofluvial deposition.

The erratics were transported from their primary source areas incorporated in an ice sheet. The Elsterian Northern European ice sheet advanced to the Czech territory from a north to north-east direction. Nývlt (2001) and Nývlt et al. (2007) confirmed this based on spatial analysis of till fabrics and the study of glacial linear landforms. The main direction of the ice sheet across northern Europe was described by Eissmann (2002) in his study of the erosional glacial landforms and the micro relief shapes. Kjaer et al. (2003) reconstructed in detail the general movement of the Northern European ice sheet in Europe.

It is not possible to determine the exact area of the flint erratic's origin because of the wide front of the ice sheet extended across northern Europe. We can use only the correlation with similar flint occurrence, based on the *in situ* localities, to determine the approximate area of its origin. Large amounts of the erratics originate from currently inaccessible areas of the Baltic Sea floor and thus this method is not very reliable. The same situation applies to the stratigraphic position which can be estimated only on the base of the flint fossil content.

Gába and Pek (1999) analysed in detail fossiliferous flints from northern Moravia and they distinguish two main types based on the dominant fossils. First the dark coloured flint of the Upper Senonian (Maastrichtian) with dominant sponges and also abundant trace fossils, echinoderms and pelecypods. Second is the grey to brown-grey flint of the Lower Palaeocene (Danian), which contains colonies of typical widely found bryozoans, echinoids and crinoids. Maastrichtian flints originated from the south-western part

Text-fig. 2 Section in proglacial sands and gravels in the abandoned sand pit near Fukov.

of the Baltic Sea between Denmark and Rügen Island. Lower Palaeocene flints come from the area between the Skåne Peninsula (Sweden) and adjacent part of the Baltic Sea.

Víšek and Nývlt (2006) published an analysis of source areas of the main Nordic indicators in glacial sediments from the northern Bohemian area. They used the Theoretic Indicator Centre (Theoretische Geschiebezentrum; TGZ) method developed by Lüttig (1958) in their study. They stated that the Fukov locality shows a different composition of Nordic indicators, than the other sites in northern Bohemia. Petrotypes coming from central Sweden (Dalarna region) dominate at this site by the amount of 63.3% of all the Nordic indicators, in contrast an average percentage of 44.6% is found in the northern Bohemian glaciated area. The Åland archipelago source area is represented by 16.7% in the Fukov locality (average value for northern Bohemia is 33.1%). The remainder of the Nordic indicators are represented by Småland rocks (10.0%), Baltic seafloor rocks (6.7%) and other less common petrotypes (Nývlt 2008).

It is impossible to connect flints from Fukov with any specific area, defined by exact coordinates, because of the wide occurrence in the source area. For this reason it is not possible to use the flints as indicators sensu Lüttig (1958) and therefore they are not mentioned in the analysis by Víšek and Nývlt (2006).

Kaše et al. (2010) tried to locate the stratigraphic and geographic position of northern Bohemian flints. Based on the determined bryozoan taxa they proposed a Lower Palaeocene age and a source area as southern Sweden. However, probably not all the flints are of Palaeocene age and part of them may belong to the Upper Cretaceous. These are nodules without the presence of Bryozoan colonies. In the present study fragments of pectinid limid bivalves, typical of the Maastrichtian stage were found.

Palaeoecological implications

The abundance of bryozoan colonies indicates very suitable ecological settings for them in a fully marine environment. A similar massive occurrence has been described from the Eocene and/or Miocene of the central Paratethys and is known as the "bryozoan event" (Zágoršek 2003, 2010). The environmental setting leading to the bryozoan event is still not fully understood, but the dominance of erect rigid forms indicate cooler and/or deeper water (McKinney and Jackson 1989). A majority of cyclostomes may indicate a pioneer character of the association from Fukov site, perhaps an unconsolidated environment on the shelf margin with an upwelling of cool water as reconstructed by Holcová and Zágoršek (2008) and Zágoršek (2010).

The rare occurrence of mollusc fossils does provide sufficient information with which to comment on the palaeoenvironment. On the basis of a single occurrence of a pycnodonteine oyster we can expect deep marine environment with a soft substrate on the seafloor (Odin and Lamaurelle 2001, Bennington et al. 2010).

The sabellid genus *Glomerula* could live in a soft bottom environment where it formed small coiled balls – glomerulate knots (Seilacher et al. 2008). The small larvae settled on a small rock particle or a foraminifer test or a fragment of an oyster valve, and the tube grew to form a glomerulate reeflet. This mode of adaptation is known in several *Glomerula* species. If larger solid objects (e.g. hardground, pebbles, large oyster valves, ammonite and nautiloid shells, echinoid tests, sponges, corals, etc.) are available, the *Glomerula* tubes may spread over a larger part of the available surface to form a wider but relatively lower morphology of the total tubes. This mode of life is known and described in *Glomerula solitaria* Regenhardt, 1961, *Glomerula gordialis* (Schlotheim, 1820), *Glomerula flaccida* Goldfuss, 1831, *Glomerula serpentina* (Goldfuss, 1831) (Ippolitov 2007; Jäger 1983, 1993, 2005, 2011; Radwańska 2004; Seilacher et al. 2008; Sklenář et al. (in prep.)).

Echinoderms were both epibenthic species (crinoids, regular echinoids) and infaunal burrowers living in sufficiently fine-grained, thick bottom sediments (spatangoids).

Conclusions

A relatively low diversity taphocoenosis of Late Cretaceous – Early Palaeocene age was recovered from pebbles of glaciofluvial sediments in the Fukov area, northern Bohemia, the Czech Republic. One fossil plant taxon, nineteen bryozoans, three molluscs, one sabellid, and seven echinoderms were identified. This type of marine fauna is characteristic of deep shelf marine soft-bottomed conditions. Chalk in NW Europe was deposited on the continental shelf during the earliest stages of the opening of the Atlantic Ocean (Zijlstra 1995). Chalk in this part of Europe was typically deposited within a depth range of 100–300 m, which correspond to the outer continental shelf. However, sea level varied throughout its deposition. The occurrence of a plant fossil in this type of sediment is unique and suggests the existence of some land mass at a relatively close distance (50–100 km) to the place of sedimentation.

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Explanation to the plates

PLATE 1

1. Leaf or bract fragment showing actinodromous venation, No. NMP G 9402.
2. Fragment of the right valve belonging to the family Limidae, No. FZP/P/12/2-3/002
3. Detail of smooth ribbing on limid from Fig. 2, No. FZP/P/12/2-3/002
4. Small fragment of pectinid bivalve, No. FZP/ /P/12/2-3/003
5. Detail of reticulate ornamentation on pectinid from Fig. 4, No. FZP/P/12/2-3/003

PLATE 2

***Glomerula* sp. ex gr. *lombrica* (Defrance, 1827) / *serpentina* (Goldfuss, 1831)**

1. Cross section showing the wall and lumen, which is preserved as a glomerulate knot, No. FZP/P/12/2-3/004
2. Cross section of the sabellid tube with undeterminable bryozoans, No. FZP/P/12/2-3/005
3. Cross section of knot, No. FZP/P/12/2-3/006
4. Inner part of knot, No. FZP/P/12/2-3/007

Cheilostomata indet.

5. Cross section of small erect colony and two colonies with hollow in the centre probably indicating encrusting on soft material (algal stem), No. FZP/P12/2-3/004.

***Idmidronea* sp. (left), *Mecynoecia* sp. (right)**

6. Colonies showing characteristic preservation (on the naturally weathered surface of the flint fragment), No. FZP/P12/2-3/0024.

***Mecynoecia* sp. (middle stem), *Celleporidea* indet. (upper left) and Malacostega indet. (lower right)**

7. Characteristic example of preservation with mixture of different species, No. FZP/P12/2-3/0025.

***Porella* (?) sp.**

8. Part of a weathered bryozoan colony from a flint, No. FZP/P12/2-3/0026.

Bryozoa indet.

9. Cross section through characteristic association of the studied flint fragments showing a number of indeterminable bryozoans, mostly cyclostomatous, but a few cheilostomatous forms may also be recognized, together with sabellid and mollusc fragments, No. FZP/P12/2-3/004.

PLATE 3

(Scale bars represent 1 mm except for fig. 2 where it is 5 mm)

***Phymosoma* (?) sp.**

1. Spine (on the right). The foraminiferal test *Nodosaria* sp. on the left, No. FZP/P/12/2-3/021.

***Hemiaster* (?) sp.**

2. Cast of inner surface of dorsal part of test, with anterior part of test directed down, No. FZP/P/12/2-3/022.

***Cidaris* (?) sp. A**

3. Spine, No. FZP/P/12/2-3/015.

Micrasterid sp.

4. Test fragment of a micrasterid. Plastronal part with subanal fasciole (arrow), No. FZP/P/12/2-3/023.

***Tylocidaris* (*Tylocidaris*) sp.**

5. Spines, No. FZP/P/12/2-3/010.

***Cidaris* (?) sp. B.**

6. Interambulacral plate, No. FZP/P/12/2-3/020.

***Nielsenicrinus* (?) sp.**

7. A pluricolumnal, No. FZP/P/12/2-3/009.

PLATE 1

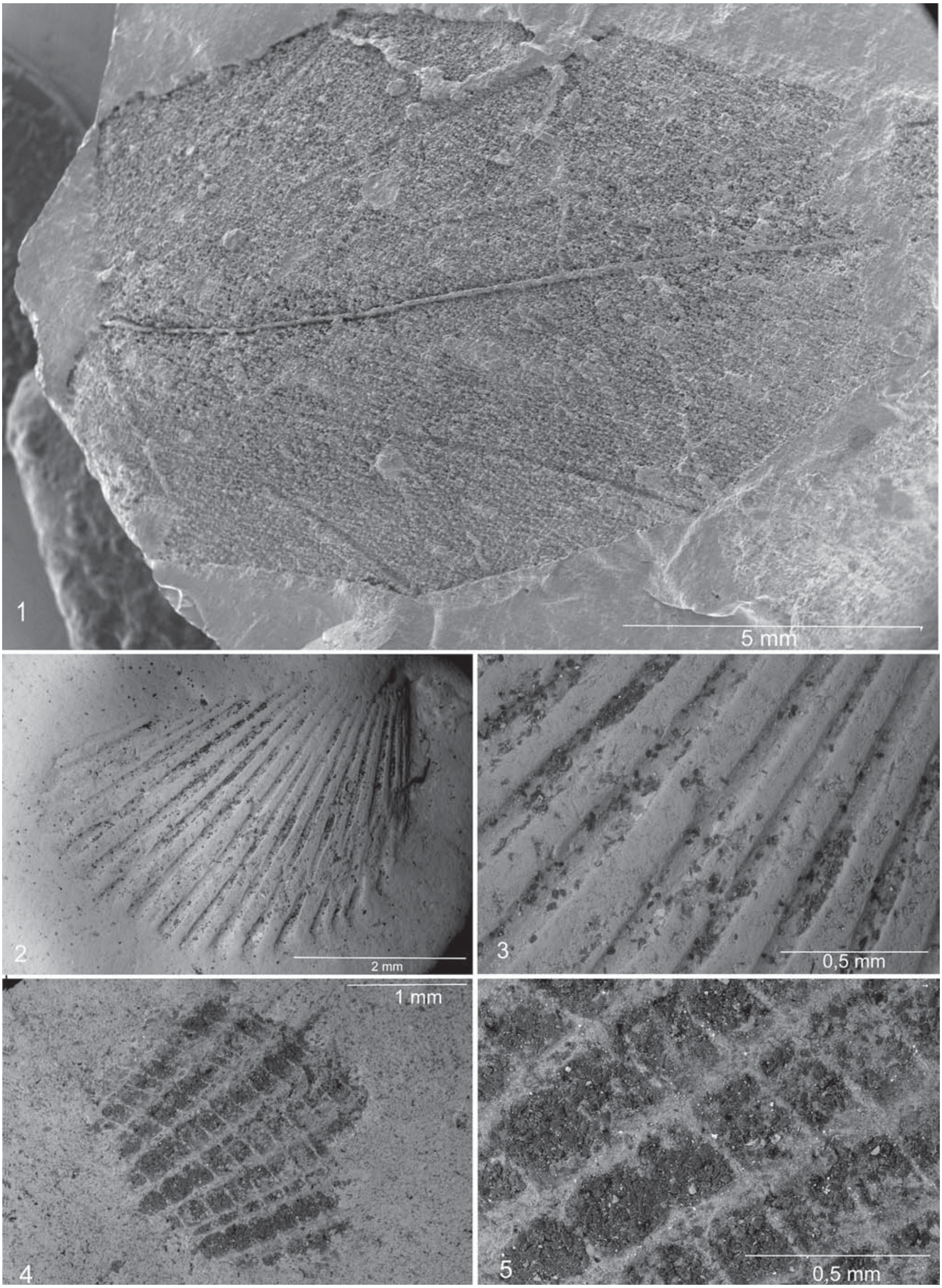

PLATE 2

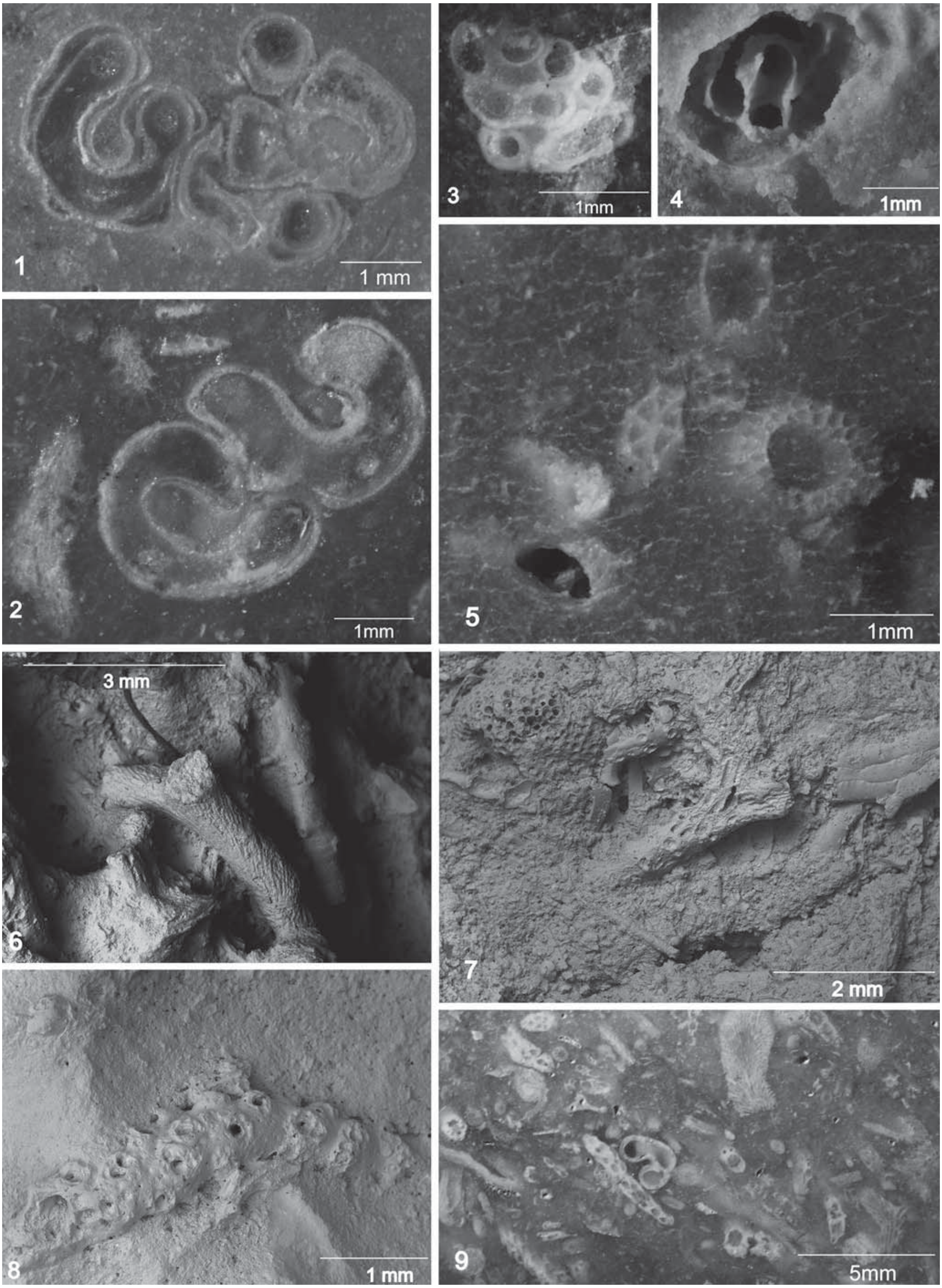

PLATE 3