THE PRIABONIAN BRYOZOAN-DECAPOD ASSOCIATION FROM THE BOROVÉ FORMATION (THE ĎURKOVEC QUARRY, NE SLOVAKIA) AND ITS PALAEOECOLOGICAL IMPLICATIONS

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Abstract. Co-occurrence of decapod crustaceans with bryozoans is relatively uncommon and poorly recorded in the literature. An assemblage consisting of two decapod species, Coeloma vigil A. Milne-Edwards, 1865 and Ranina sp., associated with a small bryozoan association is reported from the Priabonian (Upper Eocene) of the Borové Formation (the Hornád Basin, NE Slovakia). The most common bryozoan taxon from the studied section is Reteporella sp. The rest of the association is composed of free living (probably belonging to the genera Lunulites sp. and/or Smittipora sp. and/or Cupuladria sp. and/or Reusirella sp.), rigid erect (Metrarabdotos, Myriapora sp. and/or Smittina sp.), and cyclostomatous forms (Hornera sp.). Based on the presence of the studied taxa and their mode of preservation it can be concluded that during the sedimentation of layers with large bryozoans within the Tomášovce Member of the Borové Formation, the environment was very shallow, marine, with permanent water currents.

Introduction
Bryozoans in general have ecological importance and influence the feeding and protection of other groups (e.g. Echinodermata and Polyplacophora), while competing for space with other organisms, mainly other Bryozoa, Porifera, and Polychaeta (Gordon 1972). Decapod crustaceans are known to associate with a variety of sessile invertebrates (e.g. corals). Bryozoans are also one of the possibilities. In extant environments, colonial taxa (e.g. Schizoporella) often shelter a large and diversified invertebrate fauna including decapods (Lindberg and Stanton 1988; Mantelatto and Souza-Carey 1998; Morgado and Tanaka 2001, and references therein). A similar ecological role for bryozoans could also be assumed in the fossil record.

The Eocene was a good time for bryozoans. The family-level global diversity reached its peak during that time (Taylor and Larwood 1990). New areas in which moss animals had never been seen before, became available for population and billions of colonies grew, eventually forming rocks after their death.

To understand the position of the Bryozoa during the Eocene and Oligocene and the response of this group to various challenges, we initiated a systematic study of faunas and environments of the Upper Eocene. Eocene bryozoans have been extensively studied from the Liptov Basin (Borové Formation) and from the Rajec Basin (Zuberec Formation) in Slovakia by Zágoršek (1992, 1994, 1996a,b, 1997). New occurrences of a rich bryozoan fauna associated with decapod crustaceans at the Žurkovec quarry (the Hornád Basin) provide additional information for reconstruction of palaeoecological settings of the sedimentary area and also document the evolution of the Tomášovce Member within the Borové Formation.

Geological settings

Geology and stratigraphy of the Borové Formation

The Borové Formation is part of the Podtatranská (Subtatric) Group, which is composed of sedimentary rocks of Paleogene age. The Borové Formation is a typical transgressive formation with occurrences of marine fauna, mostly bivalves and gastropods. Lithologically it consists of breccias, conglomerates, sandstones, limestones, and occasionally, also claystones (Gross et al. 1984). There are a few regional lithostratigraphic units of the Borové Formation in the Hornád Basin: the Hornád Member, the Chrášť Member and the Tomášovce Member (Gross et al. 1999). The latter represents the uppermost member of the Borové Formation occurring in the Hornádska and Šarišská vrchovina uplands and dates to the Priabonian – lower Oligocene (predominantly the youngest Priabonian) time (Filo and Siráňová 1996). The Tomášovce Member represents an up to 150 m
thick complex, composed of alternating fine-grained sandstones and siltstones with pyrite concretions and rare intercalations of medium-grained carbonate arenites and fine-grained petromict conglomerates.

**Previous palaeontological studies of the Tomášovce Member**

Since the 19th century, the Tomášovce Member has been reported as “the sandstones with plants imprints and macrofauna” (Hazslinszky 1852; Miczynski 1891; Staub 1891). More recent investigation (Filo and Siráňová 1996) showed that the Tomášovce Member is a sedimentary sequence containing a rich neritic macrofauna (mainly bivalves), benthic foraminifers, and a tropical flora dominated by a hydrophyllous association of angiosperms.

The rich macrofloral association is composed of *Pinus*, *Araucarites*, *Magnolia*, *Dryophyllum*, *Castanopsis*, *Pasania*, *Quercus*, *Ficus*, *Cinnamomum*, *Laurus*, *Andromeda*, *Apocynophyllum*, *Banksia* and *Dryandroides* (Sitár in Filo and Siráňová 1996).


**Studied section at the Ŏurkovec quarry**

The stratotype of the Tomášovce Member established by Filo and Siráňová (1996) is situated in the Ŏurkovec quarry (Tex-fig. 1), 1 km south from the village of Spišské Tomášovce in the Spišská Nová Ves district (GPS location: N 48°57'0.21" E 20°28'21.74"

In the 19th century the Ŏurkovec quarry was opened for sandstone extraction and its two levels are still active. As a consequence of the rapid progress of quarrying, the stratotype section (ca. 10 m sequence) as defined by Filo and Siráňová (1996) is no longer present. A reference section which is the subject of this study was established by the senior author in 2009. This new section can be correlated with the topmost three meters of the original stratotype section (Filo and Siráňová 1996, fig. 5). Unfortunately due to continuous quarrying in 2011 the new correlation section was completely destroyed.

The studied section (text-fig. 2) consists of a ca. 4.5 m sequence of alternating fine-grained calcareous sandstones and siltstones. The sequence starts with thick layered sandstones (up to 50 cm thick). The upper part of the sequence is composed of distinctly thinner layers (ca. 20 cm thick) with more siltstone intercalations. In the section, several bioturbated horizons occur; these are usually bound to the upper parts of the layers. The trace fossil association consists mostly of the ichnogenera *Planolites*, *Scolicia*, and *Thalassinoides*. Perpendicular burrows of unknown affinities have also been identified.

The quarry has been thoroughly studied since the 1960s. Since 1988, staff from the Civic Museum in Spišská Nová Ves have performed continuous research there which yielded a rich bivalve association containing *Pholadomya*, *Cyp-
rina, Panopea, Tellina, Pecten, Cardium, and Thracia (Krempaská 1998). A shark tooth from Xiphodolania has also been found (Holec et al. 2005). Recently, the senior author found a rich association of bryozoans, the description of which is one of the goals of this paper.

**Material and methods**

The studied section was sampled bed-by-bed. All macrofauna were collected. The rate of bioturbation was estimated in relation to the entire section.

The bryozoan material was obtained from rock samples, and was usually preserved as impressions of dissolved skeletons or as remains of the skeleton. The selected specimens were sorted under a binocular microscope and documented by an online camera DP70 (Olympus). The best preserved examples of each species were cleaned ultrasonically and studied using a low-vacuum Hitachi S-3700N SEM at the National Museum, Prague, the Czech Republic. This instrument allowed backscattered electron images to be obtained of uncoated specimens temporarily mounted on stubs using adhesive carbon tabs, or affixed to stage mounts with carbon plastic.

The decapod crustacean material was preserved either as isolated dorsal carapaces or intact with all appendages, including preserved chelipeds and eye stalks (Text-fig. 3). The specimens were prepared using a fine pneumatic needle. To enhance greater contrast the specimens were coated with ammonium chloride prior to photography.

**Text-fig. 2.** Studied section at the Ďurkovec quarry. Note the co-occurrence of bryozoans and decapod crustaceans.

**Text-fig. 3.** Coeloma vigil A. Milne-Edwards. Nearly complete specimens from several different layers. A – layer 15; B – layer 11; C – layer 16. All specimens are deposited at KGP MH. Key: ch=chelipeds; es=eye stalks; p=pereiopods. Scale bar 10 mm. Specimens were covered with ammonium chloride prior to photography.

**Results**

**Bryozoans from the Ďurkovec quarry**

Altogether about 100 fragmentary specimens of different sizes and modes of preservation were found in the studied section. Generally, the preservation of the material is very poor; no surface features on the colonies are visible, only the impressions partly retain the original skeleton. However, the shape and size of the colonies can be easily estimated.

The most common taxon is *Reteporella*, which is easily determinable due to the fan shape of its colonies. The colonies are usually very large (the largest specimen is 62 mm in diameter), forming extensive fans, without broken branches (Text-fig. 4).

The second group of bryozoans belongs to the free living forms, perhaps belonging to the genus *Lunulites* and/or *Smittipora* and/or *Cupuladria* and/or *Reusirella*. Due to the poor state of preservation, more detailed determination is impossible (Text-fig. 5). However, the size and remaining structures resemble free living genera from Východná (Pribonian, Gross and Köhler 1980). Larger colonies are similar to *Smittipora* as described by Zágoršek (1996b), the smaller one (Text-fig. 6) showing the characteristic arrangement of autozooecia, resembles *Lunulites* as reported by

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**Text-fig. 4. Reteporella sp., deposited in NM Prague under number T 3318. A – Large colony suggesting very short transport. Scale bar 10 mm. Optic photography. B – the detail of branch showing the mode of preservation (no original skeleton preserved). Scale bar 1 mm. SEM photography (BSE detector).**

**Text-fig. 5. Free living colonies, showing a mode of preservation which does not allow for precise determination but clearly exhibiting features characteristic for *Smittipora* and/or *Cupuladria* and/or *Reusirella*. (note the clear intrazooecial buds). Specimen deposited in NM Prague under number T 3319. A – imprint, B – counterpart to fig A. C – Specimen deposited in SNM under number Z 37724. Optic photography. Scale bar 1 mm.**
One colony shows characteristic reproduction from the fragment, similar to those from the Lan- 
gian section Korytnica, Poland (Zágoršek et al. 2012). The third group of bryozoans are rigid erect forms, per-
haps belonging to Metrarabdotos and/or Smittina (Text-
fig. 7A). A more precise determination is impossible due to 
the preservation. The size of the fragment is much smaller 
than those of Reteporella and the free living taxa, indicating 
much longer transport to the depositional area. The last group are erect rigid cyclostomatous bry-
zoans, from which the genus Hornera is clearly identified 
(Text-fig. 7B).

Decapod crustaceans from the Ďurkovec quarry

Decapod crustaceans represent some 5% of all macro-
fossils, and some 10% of all macrofaunal remains found at 
the Ďurkovec quarry. Their distribution, however, seems to 
be restricted to several horizons. A preliminary report on the 
crab fauna from the Ďurkovec quarry was published by 
Hyžný (2007); an updated list of taxa occurring there was 
given in Hyžný (2011). In the studied section two crab 
species were recorded, Coeloma vigil A. MILNE-EDWARDS, 
1865 and Ranina sp.; the latter is represented by a single 
fragmentary specimen from the topmost part of the section 
(cf. Hyžný 2007).

Text-fig. 6. Lunulites(?) , deposited in NM Prague under num-
ber T 3320. A – optic (scale bar 1 mm) and B – SEM (BSE 
detector) photography (scale bar 100 µm) showing characters 
suggesting determination as Lunulites (square shape and lin-
ear arrangement of autozoecia, short cryptocyst and pres-
ence of vibracularia).

The most common crab in the section, C. vigil, is a well 
known taxon reported from the Upper Eocene to ?Middle 
Oligocene of Europe (Jagt et al. 2010, table 1). The speci-
cmens from the Ďurkovec quarry correspond to all the previ-
ously published descriptions (Milne-Edwards 1865; Allasi-
naz 1987; De Angeli and Beschin 2001; Ilyin 2005). Although bryozoans often foul decapods when alive, no 
fouled specimen has been found in the studied section. This 
can be attributed to taphonomic processes as the epicuticle 
upon which epibionts such as bryozoans attach to living 
crabs is lightly calcified and tends to be readily lost during 
fossilization (Waugh et al. 2004).

Palaeoecology

The occurrence of large fragments of colonies and even 

near-complete colonies of free living bryozoans indicate the 
absence of, or only very short, post mortem transport. 

Lunulites produce fragile colonies which can easily be bro-
ken (O’Dea 2006). Therefore, the preservation of large frag-
ments of this taxon indicates relatively rapid burial by sed-
mament without long transportation. Therefore, it is highly probable that large reteporiforms and free living colonies may be regarded as autochthonous and document the palaeoenvironment of the Tomášovce Member.

When alive, Lunulites preferred tropical to subtropical waters with sandy bottoms, with slow but continuous water flow, and a very low sedimentation rate. This statement may be also supported by the presence of Reteporella, which grows in higher energy water, usually close to underwater currents (Hayward and Ryland 1996), at a very shallow depth (up to 50–100 m).

The presence of cyclostomatous genera, especially Hornera, also indicates a shallow water environment, while large colonies of Metrarabdotos and/or Smittipora and/or Myriapora may indicate a deeper setting (ca. 100 m), and a slight decrease of oxygen. However, large erect colonies which are usually preserved as very small fragments, which may indicate longer transport. Thus, such colonies might originally have lived in a different environment and subsequently were transported to the shallow water where reteporiforms and Smittipora/Lunulites lived. Metrarabdotos, Smittina and Myriapora fragments were deposited during transgressive, highstand times when water depth was greater. Later, during lowstand times, the fragments were reworked and redeposited in shallower water together with Smittipora/Lunulites bryozoans. A similar mechanism has been described by Derman and Gürbüz (2007) from the Miocene of the Adana Basin (Turkey). The second possibility is that the transport from a deeper to a shallower part of the basin may be explained by currents, as in the Miocene of the Adana Basin (Turkey). The second possibility may be regarded as autochthonous and document the palaeoenvironment of the Tomášovce Member.

The autochthonous association of large bryozoans, Reteporella, and free living forms, Smittipora/Lunulites with Coeloma vigil crabs is reported for the first time from the Upper Eocene strata of the Tomášovce Member (the Borové Formation). A normal marine, shallow warm (tropical to subtropical) environment with sandy bottom is suggested for the studied horizons. Continuous underwater current brought food for the bryozoans, which was also beneficial for the crab fauna. A continual decrease of the sedimentation rate in the upper parts of the section is predicted.

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