ACTA GEOLOGICA HISPANICA, v. 37 (2002), nº 1, p. 21-27

Bioerosion and bioturbation of a weathered metavolcanic rock (Cretaceous, Czech Republic)

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ABSTRACT

The locality of Maršovický Hill (N Bohemia, Czech Republic) yielded an example of a Cretaceous sea-bottom composed of Na-metarhyolite. Two types of trace fossils penetrate the substrate, namely *Thalassinoides* isp. and ?*Gastrochaenolites* isp. *Thalassinoides* originated presumably in a firmground, i.e. the metavolcanite had to be "delithified" in some patches and subsequently re-hardened again. ?*Gastrochaenolites* isp. is interpreted as a boring trace of decapods.

Keywords: Bioerosion. Bioturbation. Metavolcanic substrate. Cretaceous. Decapoda. Czech Republic.

RESUMEN

La localidad de Maršovický Hill (Norte de Bohemia, República Checa) permite estudiar un ejemplo de un fondo marino cretácico compuesto de Na-metariolitas. Dos tipos de trazas fósiles penetran el substrato: *Thalassinoides* isp. y ?*Gastrochaenolites* isp. *Thalassinoides* se originó probablemente en un substrato firme, es decir que la metavolcanita se habría "deslitificado" en algunas zonas y posteriormente se habría vuelto a endurecer. ?*Gastrochaenolites* isp. se interpreta como un traza de bioerosión de decápodos.

Palabras clave: Bioerosión. Bioturbación. Substrato metavolcánico. Cretácico. Decapoda. República Checa.

INTRODUCTION

The Glossifungites Ichnofacies represents firm but unlithified substrates, typically dewatered chunky muds. Crystalline rocks typically represent substrates associated with the Trypanites Ichnofacies (e.g., Frey and Pemberton, 1984).

The locality of Maršovický Hill (northern Bohemia, Czech Republic) exposes transgressive Upper Cretaceous sediments overlying a body of the ?Early Palaeozoic metavolcanic rock (quartz keratophyre - e.g., Graber, 1907). The locality has been recently studied to find possible bioerosive traces in the Palaeozoic basement. However, traces suggesting both bioerosion and bioturbation have been found in the well-lithified metavolcanite rock immediately below the Upper Cretaceous sediments. The aim of the present contribution is to describe and interpret this unusual situation.

GEOLOGICAL SETTING

In the Bohemian Cretaceous Basin (Czech Republic), fossil rocky bottoms with cemented epibionts and bioerosive traces have been reported from numerous sites in the area N and NE of Praha, and from the vicinity of towns of Kolín and Čáslav (e.g., Žitt and Nekvasilová, 1996; Fig. 1). These fossil rockgrounds are composed mostly of Late Proterozoic silicites and greywackes (at Praha) and of various crystalline and metamorphic rocks, e.g., orthogneisses and metaquartzites (at Kolín and Čáslav). These hard and weathering-resistant rocks formed elevations after a long period of pre-Cretaceous denudation of the Bohemian Massif; therefore, most of them functioned as cliffs or islets in the initial phase of the transgression of the Late Cretaceous sea. In northern Bohemia, a transgression of the Cretaceous sediments over the crystalline basement is exposed only at the foot of Maršovický vrch Hill 5 km N of the town of Dubá (Fig. 1).

THE LOCALITY

The outcrop at the locality is a natural exposure in the narrow, steeply inclined gorge ca. 250 m SE of the lonely house of Podolec. The lower half of the outcrop is composed of Na-metarhyolite (Graber, 1907), reddish-grey to light grey in colour, showing a prominent schistosity; pencil structure is indicated in places. More detailed petrological and geochemical characteristics of the rock were provided by Zrustková (1982). The rock was subjected to extensive post-emplacement tectonism as indicated by zones of mylonitization. At surfaces exposed to present weathering, hardness of the Na-metarhyolite changes rapidly, from a well-lithified rock to a semi-consolidated substrate that enables, e.g., scratching by a fingernail.

The Upper Cretaceous sediments overlie a sharp erosional surface of the metavolcanite body. The erosional surface is subhorizontal, showing irregularities and small depressions of several centimetres to decimetres in size. Graber (1907) and Müller (1925) reported the presence of surf pockets filled with oyster shells; however, these phenomena were destroyed by fossil collectors. The basal Cretaceous layer, about 1 m thick, is composed of well-cemented, poorly sorted, polymictic conglomerate to sandstone. Pebbles (usually up to 50 mm long) form 10 to 50% of the rock volume, while the remaining clasts correspond to coarse-grained sandstone. The rock yielded rare finds of marine fauna (well preserved shells of oysters). Also, angular cobbles and blocks of the underlying metavolcanic rock are present. The basal Cretaceous layer is overlain by medium- to fine-grained sandstone with carbonate cement.

Biogenic (bioerosive and bioturbational) structures are preserved at and immediately below the erosional surface of the metavolcanic rock. Those visible directly on the outcrop all belong to the type described below as *Thalassinoides* isp. Several dozens of specimens of the same ichnotaxon and one possible ?*Gastrochaenolites* isp. were discovered, documented and collected on a huge (ca. 2 m) block of rock which crashed from the outcrop to the gorge bottom probably in 1997. Another, smaller fallen block found in debris ca. 20 m SW of the outcrop provided two specimens of ?*Gastrochaenolites* isp.

Seven thin sections of the metavolcanic rock were studied, both from the vicinity of the burrows/borings, and at some distance from the biogenic structures. Petrologically, the Na-metarhyolite is composed of groundmass (quartz and feldspar), phenocrysts (K-feldspar, plagioclase, quartz, weakly altered muscovite) and veinlets (mostly quartz). In the close neighbourhood of horizontal (presumably bioturbation) tunnels, the rock shows stronger alteration, ?mylonitisation, fracturing of phenocrysts, and clusters of clastic quartz grains corresponding to those of the overlying Cretaceous sediment (evidence of former plasticity of the substrate). Less frequently, a suite of other minerals and petrographical features is present (iron ore minerals, carbonates, pyrite aggregates). This points to a complex history of the rock, including metamorphism, mylonitisation of certain zones, pre-Cretaceous weathering, and incipient post-Cretaceous generation of minerals. However, it does not seem possible to recognise the history in greater detail.

SYSTEMATIC ICHNOLOGY

Thalassinoides EHRENBERG, 1944

Thalassinoides isp.

Plate I, figures 1, 3, 5

Material: Five collected samples from the block ca. 1.0 x 1.8 m. On the huge fallen block, about 20 tunnels or troughs (belonging probably to 2-3 burrow systems) were observed and documented in situ. At least five distinctive tunnels were observed on the outcrop.

Description: Cylindrical tunnels or troughs made in the metavolcanic rock at or immediately below its Cretaceous erosive surface. Width 1.5 - 3.0 cm, preserved length up to 30 cm. Tunnels are subhorizontal to oblique, rarely enlarged into initial forms of chambers, occasionally branching; most of the branches pointing downwards, showing finger-like, slightly enlarged terminations. Troughs are horizontal and they may pass into oblique tunnels. Walls of the trace fossils often show prominent xenoglyph, i.e. an ornament corresponding to a

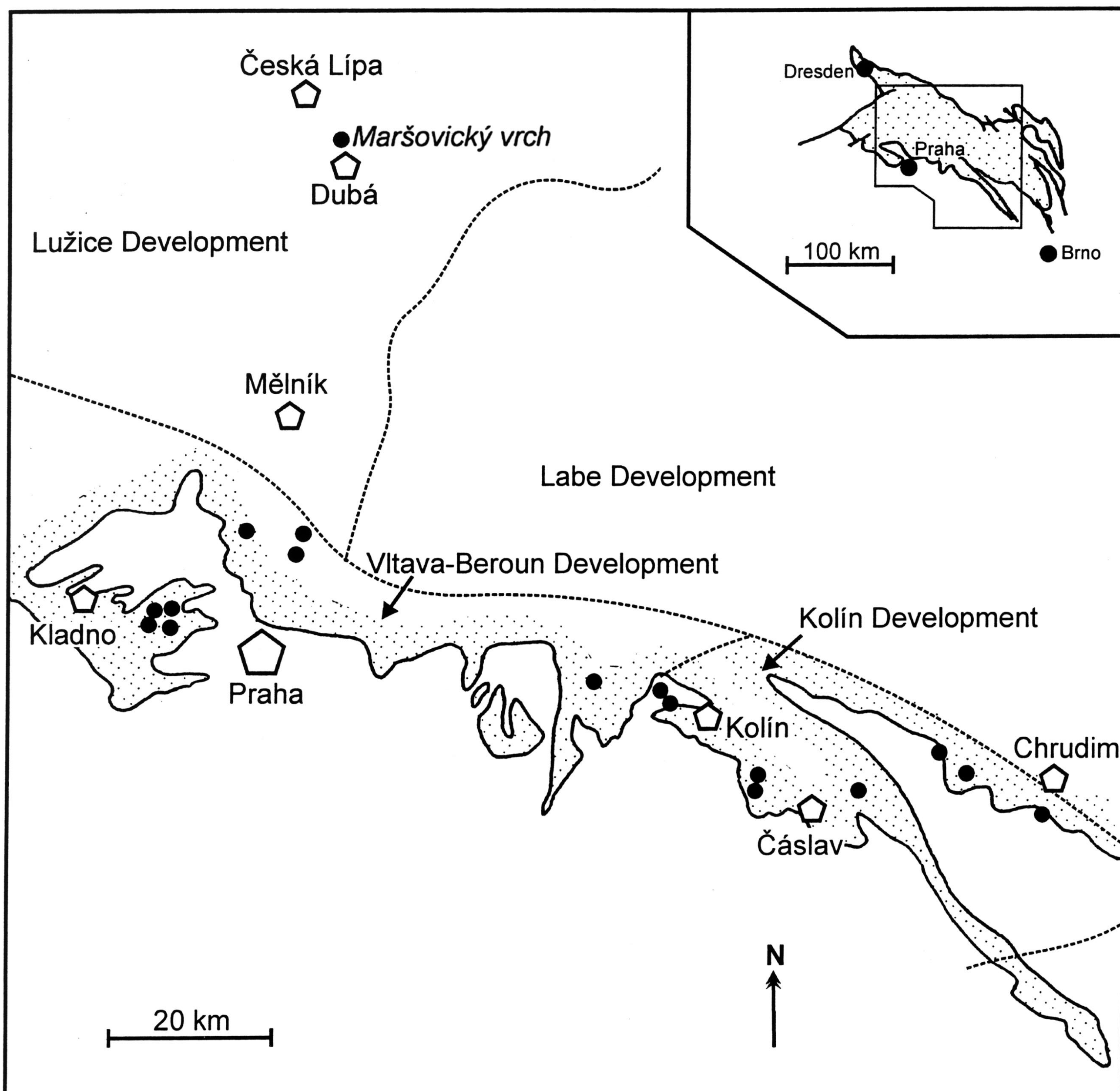

Figure 1. Geological sketch map of the Bohemian Cretaceous Basin. Large picture: Documented sites of Upper Cretaceous rocky seafloors (black points). Lower left: Overall extent of the preserved sedimentary fill of the basin (dotted).

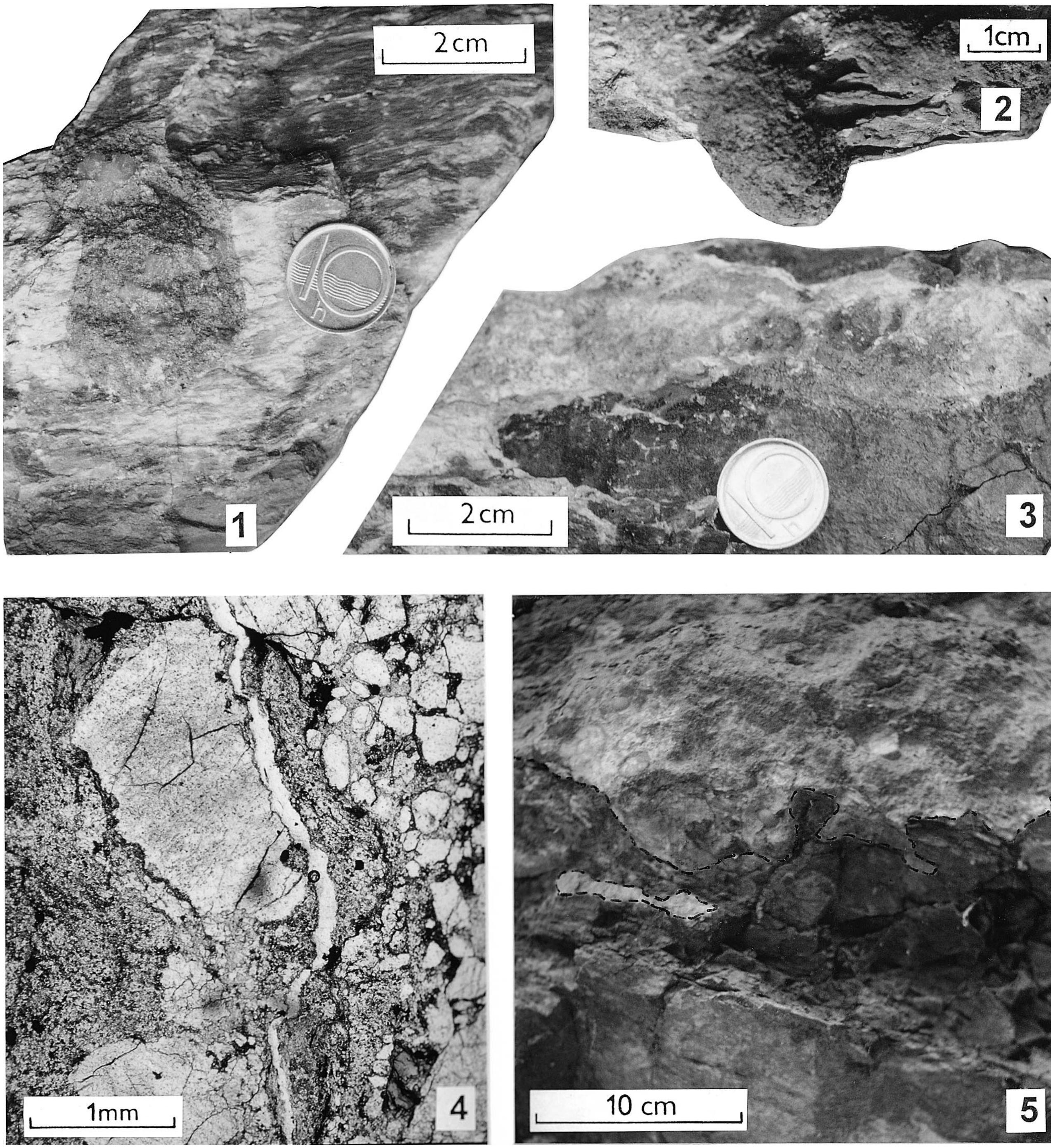

Plate I

1, **3**, **5**. *Thalassinoides* isp.; (1) transverse section of a subhorizontal tunnel; (3) longitudinal section of a subhorizontal tunnel; (5) part of the outcrop at Maršovický Hill showing basal Cretaceous layers and *Thalassinoides* isp. in the underlying crystalline rock.

2. ?*Gastrochaenolites* isp.; natural cast of the chamber.

4. Thin section of the Na-metarhyolite bordering the tunnel of *Thalassinoides* isp. The tunnel fill (mostly quartz grains) on the right; upper left, a clastic quartz grain corresponding to those of the overlying Cretaceous sediment occurs in the Na-metarhyolite.

structure (foliation or lineation) of the metavocanic rock. Fill of the trace fossils is passive, corresponding in its composition to the overlying basal bed of Cretaceous sediment.

Remarks: The "troughs" are probably collapsed or partially eroded tunnels. Overall morphology of the burrow systems is difficult to estimate but their dimensions in the horizontal direction must have exceeded 0.5 m. Vertical extent was probably less than 10 cm.

Appurtenance of trace fossils of the described morphology to the ichnogenus *Thalassinoides* follows the papers of Howard and Frey (1984), Bromley (1996), Uchman (1999) and many other recent publications.

Gastrochaenolites LEYMERIE, 1842
? *Gastrochaenolites* isp.
Plate I, figure 2

Material: One collected specimen and two additional specimens observed at the locality.

Description: Subvertical shafts slightly enlarged at their base to irregular, roughly drop-shaped chambers. Dimensions of the collected specimen: depth 28 mm, diameter at the presumed opening 13 mm, maximum diameter 15 mm. The shafts were made in the metavolcanite and filled passively with the Cretaceous sandstone to conglomerate.

Remarks: Overall shape of the trace fossils suggests their similarity to the ichnogenus *Gastrochaenolites* as defined, e.g., by Kelly and Bromley (1984). *Gastrochaenolites* usually represents dwelling chambers (borings) of molluscs; in such cases, the chambers show a precise regularity and symmetry. However, Ekdale et al. (2000) broadened the morphological range of *Gastrochaenolites* by including irregular, roughly drop-like trace fossils of the Ordovician age. Among the published examples of modern traces, ?*Gastrochaenolites* isp. resembles traces described by Fischer (1981), which were made by sea-urchins (*Diadema mexicana*) and decapods (*Alpheus saxidomus*) on basalts on the Pacific coast of Costa Rica.

DISCUSSION AND CONCLUSIONS

The present outcrop and the huge fallen block below the outcrop show a strong dominance of the ichnofossil *Thalassinoides* isp. The smaller block coming from another part of the fossil sea-floor (which is not exposed at present) bears specimens of ?*Gastrochaenolites* isp. This circumstance points to a patchiness of the ichnologic record at the locality. Unfortunately, the present state of the locality does not allow a more precise picture of the trace fossil distribution.

To explain the differences in the occurrence of the trace fossils, we find the substrate control to be the most probable cause. Present surfaces of the Na-metarhyolite (on fallen blocks and boulders, natural and artificial outcrops or in soil skeleton) retain in places a character of solid rock, but in other places they weather into a semi-consolidated substrate. We may presume that also during the period of the pre-transgression subaerial exposure the metavolcanite body had weathered in a similar way (though the climatic conditions were different). As we recognized no relevant differences in mineral composition between Na-metarhyolite tending to the "soft" weathering and the patches of hard, less weathered rock, we presume that a variation in degree of tectonic stress is responsible for the differences in weathering style.

Patches of the firm sea-floor could be colonised by the tracemakers of *Thalassinoides*. This trace fossil occurs frequently on semi-consolidated substrates (e.g., Frey and Pemberton, 1984). Decapods are the usual makers of *Thalassinoides*-like traces in modern settings and presumably also through the Mesozoic and Cenozoic (e.g., Bromley, 1996). However, decapods were recognised also as the agent of bioerosion of modern non-carbonate rocky bottoms (Fischer, 1981; Fischer and Meyer, 1985). The bioerosive traces of decapods do not resemble the *Thalassinoides*-like networks and boxworks, but they form irregular, finger-like, drop-like or bag-like chambers. These structures have not been described in the fossil record yet and therefore no ichnotaxon has been erected for them; anyway, it would be very complicated to demarcate boundaries between these irregular traces and *Gastrochaenolites*.

Traces of decapods described by Fischer (1981) from modern basalt coast of Costa Rica are similar to the traces described herein as ?*Gastrochaenolites* isp. We may presume that ?*Gastrochaenolites* isp. from the above-described locality represents bioerosive traces of decapods: they are less regular compared with *Gastrochaenolites* produced by boring bivalves. We may even suggest that *Thalassinoides* isp. and ?*Gastrochaenolites* isp. from Maršovický Hill were produced by the same decapod tracemaker: this possibility is supported by a similar diameter of both traces and, more significantly, by the similarity

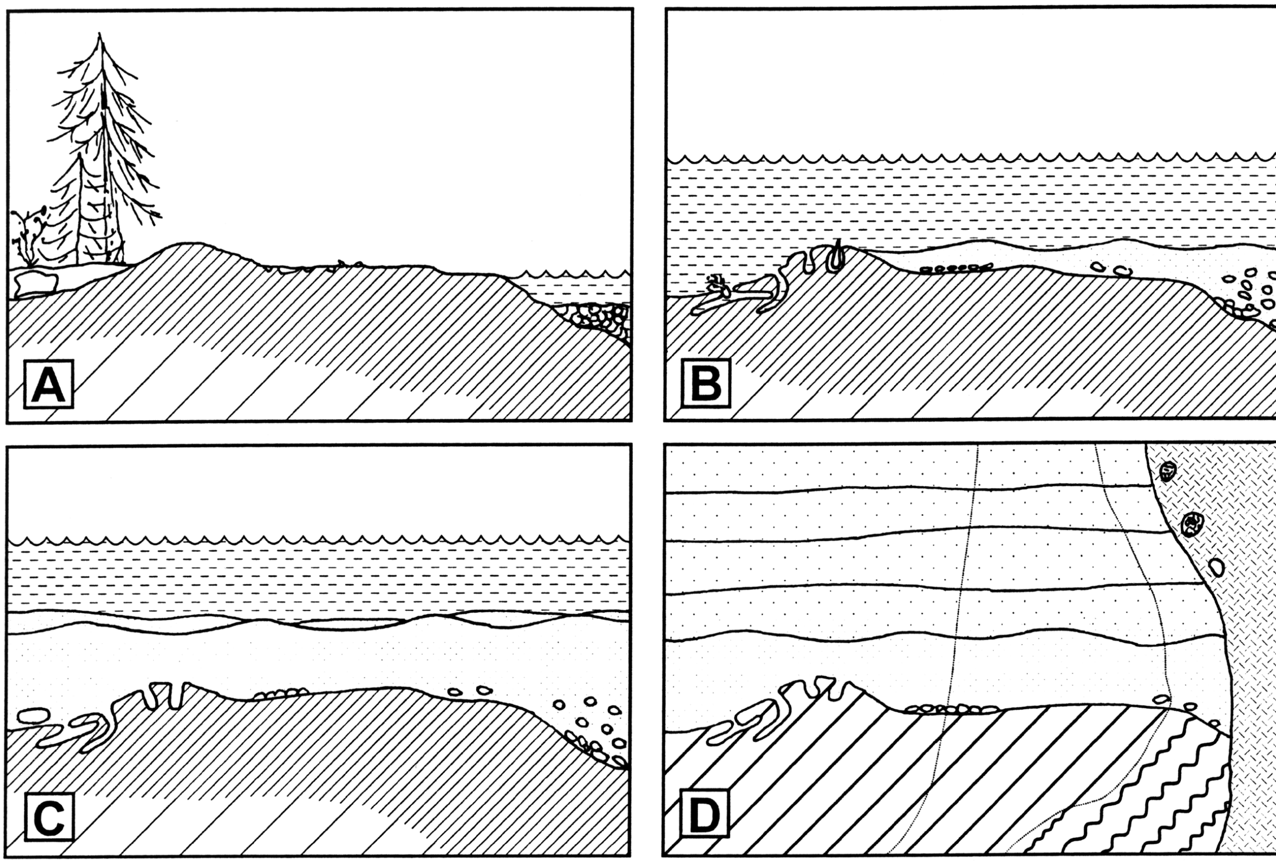

Figure 2. Possible scenario of development of the fossil sea-floor at Maršovický Hill. (A) the situation immediately before the Cretaceous transgression; (B) after the transgression; (C) after the obrution of the rocky bottom; (D) after the Tertiary magmatic activity. Not to scale. See the text for further explanation.

of terminations of tunnels of *Thalassinoides* and chambers of ?*Gastrochaenolites*. As the metavolcanite at the Maršovický Hill is a very fine-grained rock (in contrast to a coarse-grained fill of the trace fossils; Plate I, fig. 4), we cannot consider whether its individual grains were cut or by-passed.

Besides the substrate control, patchiness of the ichnological record could be influenced by some other factors, e.g., by exposure to wave action and currents. However, we find the following scenario for the development of the fossil record at the locality the most probable:

1) Pre-Cretaceous tectonic deformations and a long interval of pre-Cretaceous weathering (cf. Žitt and Nekvasilová, 1996) induced selective alterations of the Na-metarhyolite body at Maršovický Hill. As a result, some surfaces were firm while others retained the character of a hard rock (Fig. 2A).

2) The transgression at Maršovický Hill probably began with a non-sedimentation episode characterized by the appearance of the described burrowing/boring traces. We may presume high-energy settings, probably in a shallow sublittoral zone (Fig. 2B).

3) The coarse-grained, polymictic sediment buried the omission surface. The basal Cretaceous layer is remarkable for the presence of a well-preserved oyster fauna. Also the good preservation of xenoglyphs is notable on the trough-like parts of *Thalassinoides*. This points to the presumption of a sudden burial of the firmground by material accumulated nearby in the previous phase of transgression (Fig. 2C).

4) The present-day hardness of the metavolcanic rock was enhanced by the same processes as the diagenesis of the overlying Cretaceous sediments. Effects resulting from the considerable thickness of the Cretaceous sedi-

ments (several hundreds of metres – cf. Malkovský, 1974) were probably augmented by the Tertiary magmatic activity (Fig. 2D).

ACKNOWLEDGEMENTS

We thank Tony Ekdale, Markus Bertling and Jordi M. de Gibert for valuable comments to the topic during the 3rd International Bioerosion Workshop in Barcelona, and Richard Bromley for his reviewer's help. The study is a part of the Research Programme of the Institute of Geology, AS CR, Praha (No. CEZ: 23-013-912).

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