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SHORT COMMUNICATION

First Paleozoic *Zoophycos* trace fossils from the Sudetes (the Bardo Unit)

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The trace fossil *Zoophycos* has been first time recognized in the Sudetes within the lower Carboniferous (upper Visean, *crenistria* Zone) of the Paprotnia Beds in the Bardo Unit. A distinct concentration of *Zoophycos* occurs in the lower part of the Paprotnia profile, in mudstones interbedded with bentonites, which were most likely deposited between storm wave base and fair weather wave base, in oxygenated water.

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Key words: Poland, Sudetes, upper Visean, trace fossils, *Zoophycos*.

INTRODUCTION

The trace fossil *Zoophycos* is a complex burrow system consisting of a large number of three-dimensional helically coiled spreiten structures, which are very variable in morphology and are present in marine sediments ranging in age from Cambrian to recent (see Knaust, 2009). Uchman (1995) proposed the term "Zoophycos group" to include all the traces that share certain common morphological characteristics. Although *Zoophycos* structures are common and widespread in ancient and modern sediments, the producing animal has not yet been discovered and the behavioural explanation is still debated (e.g., Bromley, 1991). This ichnogenus was described from diverse sediments representing various palaeoenvironments from infralittoral to abyssal (Frey *et al*., 1990) and even in a glaciomarine environment (Gong *et al*., 2008). It is well-documented in the ichnological literature that the bathymetric range of this trace has increased with time (see Bottjer *et al*., 1988; Kotake, 1997).

This ichnogenus was known in Poland only from the Paleogene flysch deposits of the Polish Carpathians (Wetzel and Uchman, 1998; Uchman, 1998) Jurassic carbonates of Pieniny (Tyszka, 1994) and from the Tournaisian carbonate deposits of the Kraków Block (Hoffmann *et al*., 2009). This article reports the first certain discovery of *Zoophycos* in the Paleozoic rocks of the Polish Sudetes.

GEOLOGICAL SETTING

The Bardo Unit is a separate complex structure within the central Polish Sudetes (Fig. 1). The deposits containing *Zoophycos* occure within the Paprotnia Beds, which occur only in the western part of the unit and probably underlie flysch strata. The Paprotnia Beds are an informal unit belonging to an autochtonous/parautochtonous platform to foreland succession of the Bardo Unit (see Haydukiewicz and Muszer, 2002).

The exposed section, 13.7 m in thickness, is composed of claystones and mudstones with thin dark-grey micritic limestone beds and several bentonite layers, lenses and nodules of dark-grey organodetrital limestones and greywackes with intercalations of mudstones (Fig. 2). These deposits pass gradually into the polymictic Wilcza Conglomerates.

The Paprotnia Beds contain a very rich palaeontological record, that has been much studied (see Haydukiewicz and Muszer, 2002), which indicates that the beds belong to the ammonoid *G. crenistria* Zone, which corresponds with the Asbian regional substage of the upper Visean (V3b). Both the lithological and palaeontological features of the Paprotnia Beds reflect gradual environmental changes from offshore to onshore conditions (Haydukiewicz and Muszer, 2002).

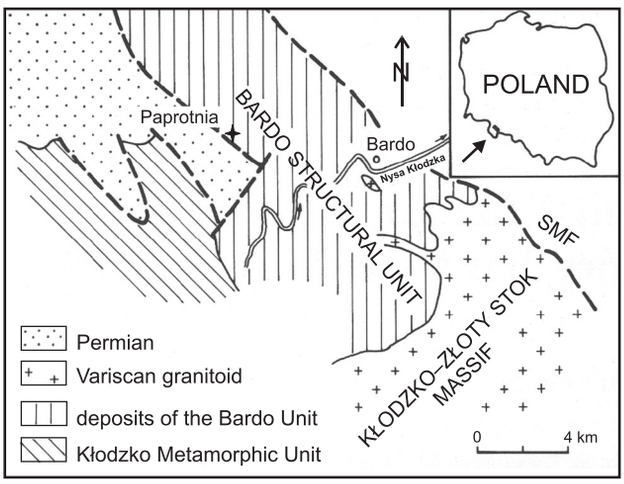

Fig. 1. Location of the Paprotnia site on the map of the Bardo Unit

SMF – Sudetic Marginal Fault

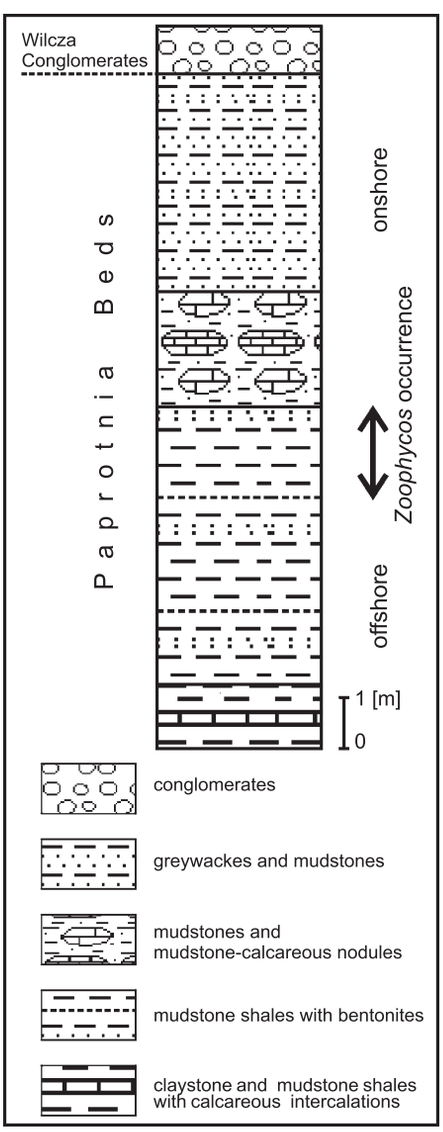

Fig. 2. Simplified lithological log of the Paprotnia section and *Zoophycos* occurrence

SYSTEMATIC ICHNOLOGY

Spreiten Burrows
Ichnogenus *Zoophycos* Massalongo, 1855
Zoophycos isp.
(Fig. 3)

M a t e r i a l a n d o c c u r r e n c e. – Several dozen incomplete specimens; the Paprotnia Beds (lower part of the section), the Bardo Unit (Sudetes).

D e s c r i p t i o n. – Large spreiten burrow structures showing either simple flat forms, or unilobate helicoidal forms parallel to bedding. Most collected specimens represent parts of larger structures whose architecture is unknown. Some helicoidal forms show downward growth. Measurement of many trace fossils is difficult because of cross-cutting. The interpreted total length of the forms ranges from 70 to 160 mm. Some slabs are encircled by cylindrical fragmentarily preserved marginal tubes 1–5 mm wide. The minimal height of the trace ranges approximately from 14 to 35 mm. The lobes are filled with prominent primary lamellae, the distance between two subsequent lamellae ranging from 1 to 7 mm. The secondary lamellae occur often only in the large forms; the distance of neighbouring ones is 0.7–1 mm. The angle between primary lamellae and secondary lamellae varies from 10 to nearly 30°. The lamina is spirally coiled around a vertical axis which is approximately perpendicular to bedding. The axial tunnel is oval in outline and its diameter reaches from 12 to 30 mm. The angle between the bedding plane and the upper part of the lamina varies between 20–55°.

D i s c u s s i o n. – The *Zoophycos* described above clearly corresponds to the constructional model of Gaillard and Olivero (1993) and is very similar to Tournaisian forms from Belgium (Gaillard *et al*., 1999), but in the Tournaisian material does not show secondary lamellae. The Paprotnia forms and the lower Carboniferous Japanese specimens (see Kotake, 1997) are similar in having an acute angle between major and minor lamella. Our forms have also a very similar distance between two subsequent primary lamellae and the axial tunnel to the forms from the middle Pennsylvanian of Nova Scotia (McIlroy and Falcon-Lang, 2006), but their length are much smaller.

CONCLUSIONS

The characteristic features and organization of *Zoophycos* from the Paprotnia Beds are very close to other Carboniferous forms (Kotake, 1997; Gaillard *et al*., 1999; McIlroy and Falcon-Lang, 2006). Concentrations of *Zoophycos* occur in mudstones, which are underlain by organodetrital limestones. These sediments indicate distinct shallowing. The environment was located between the storm wave and fair weather wave bases, in oxygenated water. The presence of *Zoophycos* in such deposits supports the previously published opinions that the trace-making animal preferred shallow-water environments during the early Carboniferous.

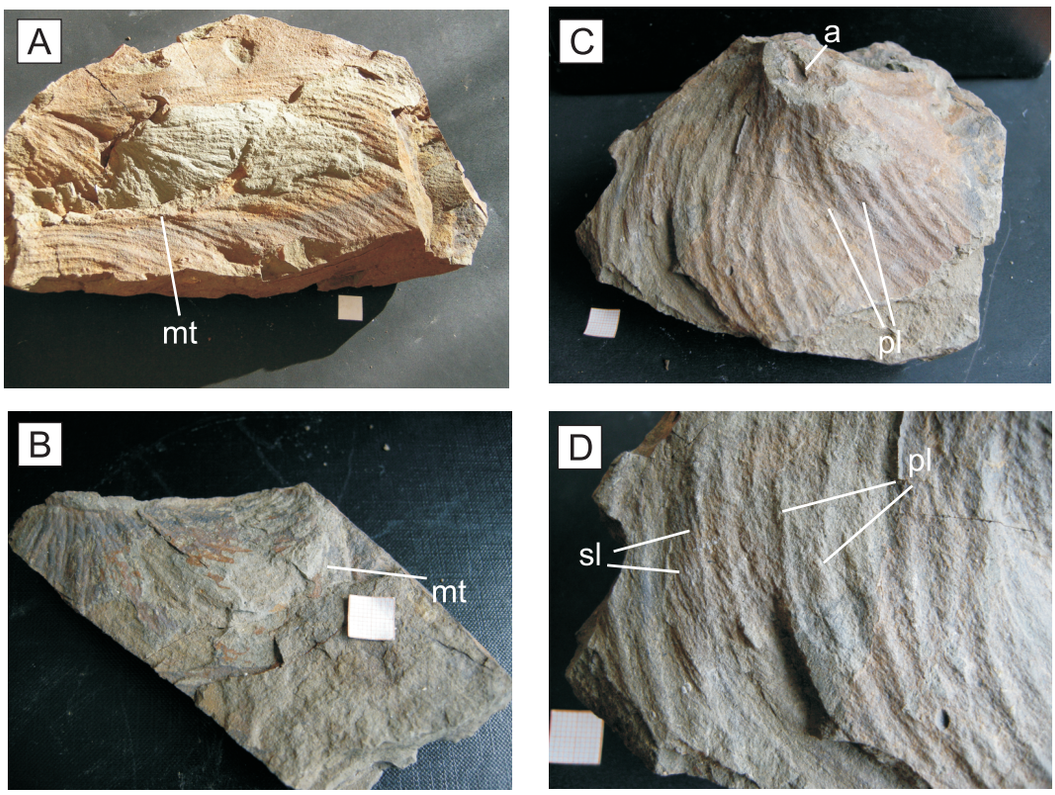

Fig. 3. Fragments of *Zoophycos* isp. from the Paprotnia Beds

A – sample ING/P-1, **B** – sample ING/P-25, **C**–**D** – sample ING/P-3; scale bar 1 × 1 cm; mt – marginal tube, a – axial tunnel, pl – primary lamellae, sl – secondary lamellae

We also note that ancient and recent Zoophycos-group ichnofossils, similar to *Zoophycos* from the Paprotnia Beds, often occurs in sediments containing pebble lags, tuffs or volcanic ash (e.g., Kotake, 1997; Gong *et al*., 2008; Hoffmann *et al*., 2009). Recognition of *Zoophycos* trace fossils in the Carboniferous of the Sudetes will encourage further ichnological study of these deposits.

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