

ICHTNOLOGICAL RECORD OF PALAEOENVIRONMENTAL CHANGES IN THE LOWER CRETACEOUS OF THE SILESIAN UNIT, POLISH FLYSCH CARPATHIANS

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Abstract. Diversity, composition, tiering pattern of trace fossil associations, depth of penetration in sediments, and degree of bioturbation indicate oxygenation changes in the uppermost Jurassic - Lower Cretaceous deep-sea (flysch and pre-flysch) deposits of the Silesian Unit. There were short and longer anoxic events during sedimentation the Upper Cieszyn Shale, Grodziszczce Beds, Verovice Shale and the Logta Beds. They are partly coeval to the oceanic anoxic events.

Key words: Trace fossils, ichnofacies, Lower Cretaceous, Carpathians, Poland

Introduction

Traditionally, deep-sea environment is regarded as a very stable habitat with long, gradual colonization (e.g. Seilacher, 1974, 1978). In light of this view trace fossil associations should change only in small degree in long-term spans. In flysch deposits of the Silesian Nappe, which occupies the largest part of the Polish Carpathians, and displays the most full section from the Kimmeridgian to the Oligocene/Miocene, ichnoassociations are characterized by distinct changes from lithostratigraphic unit to unit. In this paper, the Kimmeridgian – Lower Cretaceous units of the Silesian Nappe are considered, where the changes are very clear.

Geological setting

The Silesian unit, occurring in the Ukrainian, Polish and Czech Flysch Carpathians, contains diverse Upper Kimmeridgian-Miocene deep-sea, mainly flysch deposits. The Lower Cretaceous deposits are represented by: (1) Cieszyn Limestone (Upper Tithonian-Berriasian), 100-250 m thick, dominated by turbiditic, commonly sandy calcarenitic and calcilutitic limestones interbedded with marly shales (e.g., Malik, 1986; Słomka, 1986); (2) Upper

Cieszyn Shale (Valanginian-Hauterivian), about 300 m thick, dominated by dark-grey marly mudstones intercalated regularly with thin-bedded calcareous sandstones (e.g., Geroch & Nowak, 1963); (3) Grodziszczce Beds (Upper Hauterivian-Barremian), 95-140 m thick, represented by grey marly shales intercalated with rare thin calcareous sandstone beds and marlstones. Locally, the sandstone beds are more frequent. In some areas, these facies are replaced by thick-bedded calcareous sandstones with exotic pebbles and blocks (Geroch & Nowak, 1963; Kamiński et al., 1963; Malik & Olszewska, 1984); (4) Verovice Shale (Barremian-lowermost Albian), about 200 m thick, composed of non-calcareous black mudstones interbedded with rare cross-laminated thin sandstone beds. Sideritic concretions are also present; (5) Lgota Beds (Albian-Cenomanian), 300-350 m thick, dominated by thin- and medium-bedded turbiditic sandstones and greenish grey spotty mudstones. Locally, thick-bedded sandstones occur in the lower part, and spongiolitic cherts in the upper part of this unit. (Unrug, 1959, 1977).

Trace fossils and oxygenation

Trace fossils and ichnofabrics show significant vertical changes from the unit 1 to the unit 5. The Cieszyn Limestone displays a moderate diverse trace fossil assemblage dominated by *Chondrites targionii*, *Thalassinoides*, and *Helminthopsis*. Other trace fossils (e.g., *Lorenzina*, *Glockerichnus*, *Paleodictyon*) are rare. Upper part of turbidites is bioturbated up to 6.5 cm from the top. All these features, together with overall relatively light colour of shales, indicate well-oxygenated environment

Trace fossils of the Upper Cieszyn Shale are relatively abundant and diverse. *Chondrites intricatus*, *Helminthopsis*, and *Planolites* are the commonest ichnotaxa. Extent of bioturbation from the top of turbidites is very limited, and commonly does not exceed 1 cm (Fig. 1). This proves decrease of oxygenation of sediments in comparison to the Cieszyn Limestone. In some beds or packages of beds, the bioturbated horizons do not occur. This is related to temporary anoxia.

The shaly facies Grodziszczce Beds in the western part of the Silesian unit display relatively diverse trace fossil assemblage. *Chondrites*, *Phycosiphon*, *Helminthopsis*, *Taenidium* are common. Other trace fossils (e.g., *Belorhaphe*, *Urohelminthoidea*, *Paleodictyon*) are rare. It is worthy to note the occurrence of *Diplocraterion*, which is a very rare trace fossil in deep-sea deposits. The bioturbated layers are thicker (up to 6 cm) than in the underlying Upper Cieszyn Shale (Fig. 1). This suggests improved oxygenation of

sediments. The shaly-sandstone facies in the eastern part of the unit display much less diverse ichnoassemblages dominated by simple opportunistic forms. Only the uppermost thin layer of hemipelagites is bioturbated. There are beds which are not bioturbated. They represent short anoxic events.

The black deposits of the Verovice Shale would be easily considered as an example of Lower Cretaceous anoxic deposits. However, such a view can be only partially confirmed according to ichnological evidences. Sections of the Verovice Shale are dominated by laminated mudstones and siltstones barren of trace fossils. However, less than 1 cm-thick bioturbated horizons locally occur. The horizons are slightly lighter in colour and occur at the top of some sedimentary events. *Phycosiphon incertum*, *Chondrites intricatus*, and *Planolites* are the dominant ichnotaxa. Below some bioturbated horizons, *Protovirgularia pennatus* and *Protovirgularia obliterated* occur in a few centimetres thick zone. These trace fossils have been produced by probably chemosymbiotic bivalves in anoxic sediment. The occurrence of trace fossils in anoxic zone below *Chondrites*, which commonly occupies the deepest tier in fine-grained deposits, is a unique situation among trace fossil communities. Such a trace fossil tiering expresses adaptation of macroinfauna to the poorly oxygenated environments during the Early Cretaceous. Generally, an anoxic environment is proposed for the Verovice Shale, with short dysaerobic events indicated by the mentioned bioturbated horizons.

At the few top meters of the section of the Verovice Shale, a few centimetre-thick layers of greenish, bioturbated, spotty shales occur. They contain *Planolites*, *Chondrites* and *Thalassinoides*, and are typical of the overlying Lgota Beds. Their occurrence indicates general improvement of oxygenation.

The Lgota Beds contain low diverse trace fossil assemblage dominated by *Planolites*, *Chondrites* and *Thalassinoides*. *Arthropycus tenuis* is common on sole of some turbiditic beds. The oldest occurrence of *Scolicia* in the Flysch Carpathians, which is the trace fossil produced by irregular echinoids, is noted here. Below some turbidites, shales are dark and barren trace fossils. There are not evidences of significant erosion. This indicates short anoxic events, however oxygenation of the sediments was generally better than in the underlying Verovice Shale.

The decrease of sediment oxygenation during sedimentation of the Upper Cieszyn Shale and the Verovice Shale can be related to the widely known Lower Cretaceous anoxic events. Ichnological analyses help very much in determination of short- and long-term

oxygenation changes. The black deposits are not necessarily anoxic through all the section as in the case of the Verovice Shale.

The changes of oxygenation in the Lower Cretaceous of the Silesian Nappe have been already noticed by Książkiewicz (1977), but without detailed discussion. The first anoxic event from Barremian to Albian is coeval with sedimentation of the Verovice Shale and Lgota Beds.

The problem of ichnofacies

The classical ichnofacies (Seilacher, 1967; Frey & Seilacher, 1980) can be applied to the investigated deposits only to a certain limit. The Cieszyn Limestone, Upper Cieszyn Shale, and partly the Grodziszczce Beds contain the typical *Nereites* ichnofacies with contribution of graphoglyptids, typical of the *Paleodictyon* ichnosubfacies (Seilacher, 1978).

There is a basic difficulty in application of the ichnofacies to the Verovice Beds and Lgota Beds. The Verovice Beds, obviously deposited in deep-sea, do not contain any graphoglyptid or meandering trace fossils, which are the index forms of the *Nereites* ichnofacies. *Protovirgularia obliterated*, *Chondrites intricatus*, *Planolites*, and *Phycosiphon incertum* are the commonest forms. Particularly, the presence of *Protovirgularia* is intriguing. It was produced by bivalves, which were able to burrow in anoxic mud. Probably they used chemosymbiotic microorganisms for feeding, similarly to the bivalve *Solemya* (Seilacher, 1990). Occurrence of *Protovirgularia* is also very characteristic of the Upper Cieszyn Shale, locally of the Grodziszczce Beds. The trace fossil association is very unique and specific of the Lower Cretaceous of the Silesian unit. *Protovirgularia* occurs also in younger deposits of the Carpathian Flysch, but is very rare, and is never a significant component of ichnoassociations. The recurrence of the Lower Cretaceous association with *Protovirgularia* remains unknown, because the Lower Cretaceous flysch deposits are poorly known.

The ichnoassociation of the Lgota Beds is dominated by *Chondrites*, *Planolites* and *Thalassinoides*. The meandering forms (*Scolicia*, *Helminthopsis*) and occurrence of graphoglyptids (*?Acanthorhaphe*, *?Spirorhaphe*, *?Lorenzina*) is problematic. This ichnoassociation can be ascribed to the very impoverished *Nereites* ichnofacies.

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