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THE FIRST OCCURRENCE OF THE DEVONIAN RUGOSE CORAL *CALCEOLA SANDALINA* (LINNÉ, 1771) IN THE BARRANDIAN AREA, CZECH REPUBLIC

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Abstract: *The calceolide coral Calceola sandalina (Linné, 1771) has been observed in the Acanthopyge Limestone (Choteč Formation, Eifelian) in the Koněprusy area, Czech Republic. Its presence in the Barrandian area indicates absence of significant palaeogeographic barriers restricting the distribution of this tetracoral in the Middle Devonian. Association of Calceola with a taxonomically diverse ribbed brachiopod faunas attests for two different types of environment on the Koněprusy submarine elevation during deposition of the Acanthopyge Limestone. Calceola-bearing beds represent a high-energy reefal environment different from somewhat deeper and calmer environment characterized by smooth-shelled, small to medium sized spire-bearing brachiopods.*

Key words: Calceola, Calceolitidae, Eifelian, Koněprusy reef, Barrandian, Czech Republic

INTRODUCTION

The distinctive rugose coral *Calceola* Lamarck, 1799 is an easily recognizable Devonian fossil. Its worldwide distribution includes France, Germany, Belgium, Poland, Moravia, North Africa, southern China and eastern Australia. As noted by Wright et al. 2010, that genus was largely a Gondwanan fauna element. *Calceola sandalina* (Linné, 1771) is widespread during the Emsian, Eifelian, and

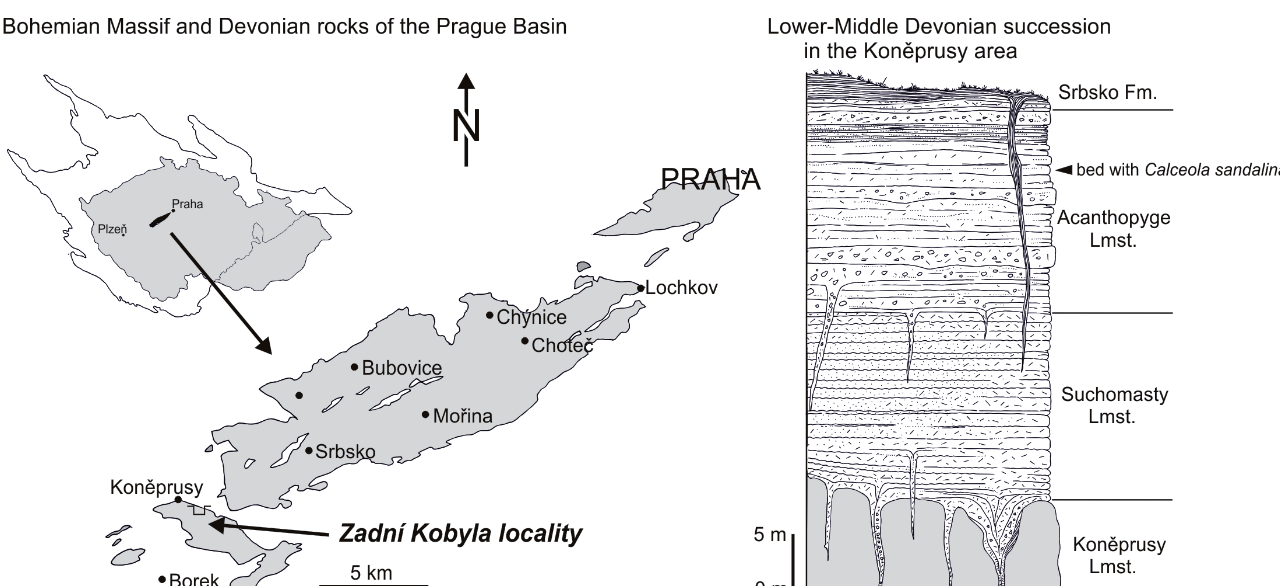

Figure 1. *Sketch map of the Devonian of the Prague Basin, and generalised stratigraphy of the Koněprusy Limestone (Pragian), Suchomasty Limestone (Upper Emsian), Acanthopyge Limestone (Eifelian), and the top of the Acanthopyge Limestone and the Srbsko Formation (transition Eifelian-Givetian) in the Koněprusy area with marked neptunian dykes and approximate positions of Calceola-bearing limestone bed. Modified after Chlupáč et al. (1986) and Hladil et al. (1992).*

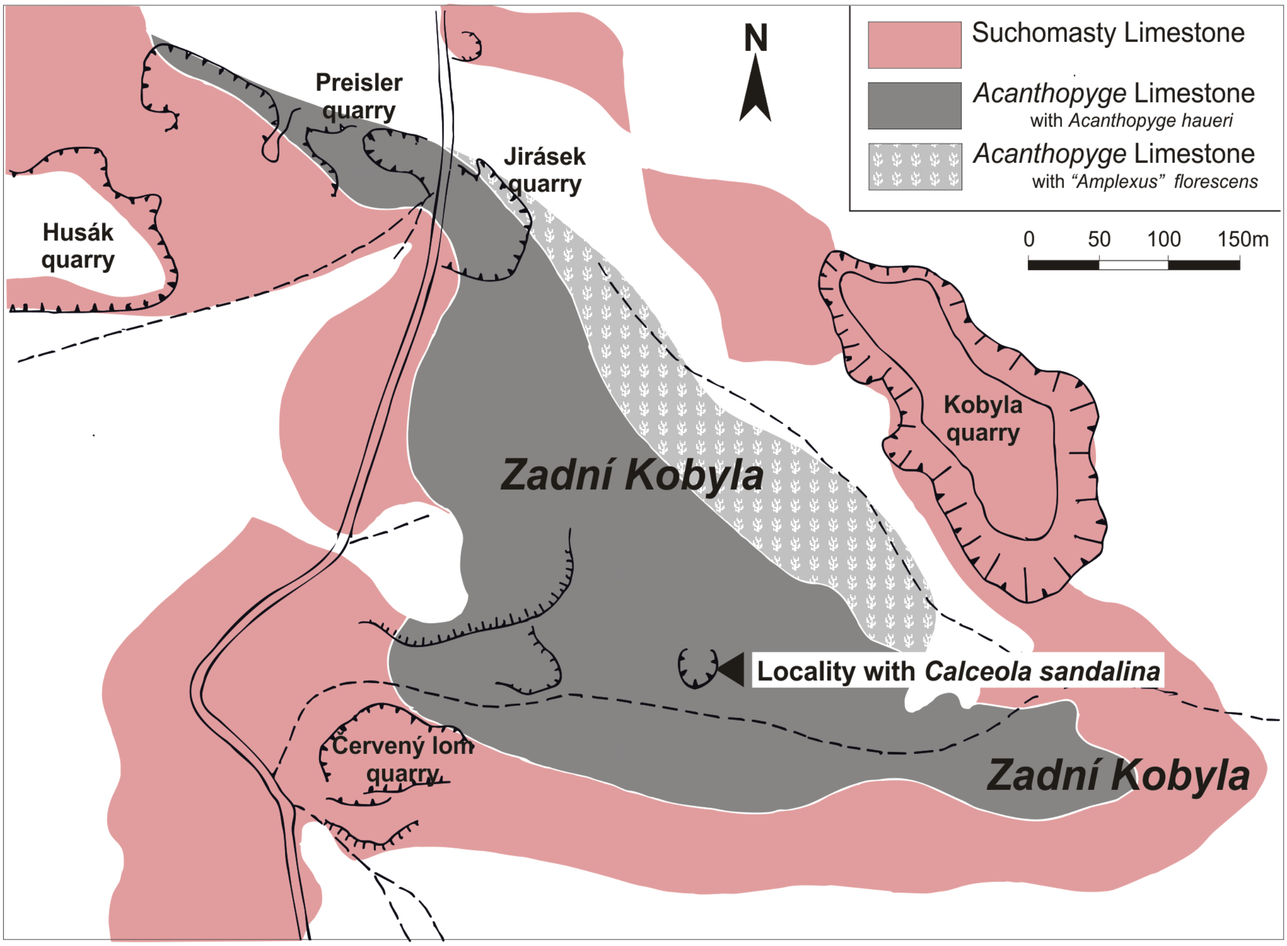

Figure 2. *General geological map of the Emsian (Suchomasty Limestone) and Eifelian (Acanthopyge Limestone) rocks at Zadní Kobyla ridge with marked Calceola-bearing locality. Modified after Svoboda & Prantl (1949).*

Givetian outside the Barrandian area. The nearest present occurrence of *Calceola sandalina* outside of the Barrandian found in the late Eifelian and Givetian of Moravia (Richter, 1928; Špinar, 1951; Strnad, 1960; Galle, 1995; Galle & Ficner, 2004; Galle & Mikuláš, 2003) and the Givetian of Poland (Pajchlowa, 1957; Stolarski, 1993; Malec, 2005; Malec & Turnau, 1997). Modern revision and comments to new occurrences were given by Wright (2010) and Wright *et al.* (2010).

Although *Calceola* is a widely distributed taxon it has never been found in the sediments of the late Emsian, Eifelian or early Givetian age in the Barrandian (Prague Basin) despite the intensive sampling of fossils in this area for more than 150 years. Prantl (1937) referred two poorly preserved specimens from the locally developed perireefal limestone accumulations of the early Emsian age (Zlíchovian) (locality Praha-Hlubočepy, Kaplička coral horizon) to *Calceola sandalina* (Linné, 1771). These two specimens were subsequently revised by Oliver & Galle (1971) and re-assigned to *Rhizophyllum* sp. Other calceolide species of *Rhizophyllum* Lindström, 1866 has been revised by Galle (1971). This unique corallite was previously described as *Rhizophyllum bohemicum* already by Počta (1902). This specimen was probably collected from the Koněprusy Limestone of Pragian age.

New material of the calceolide tetracoral has been obtained from the *Acanthopyge* Limestone (Eifelian) at Zadní Kobyla ridge of the Koněprusy area (Figs 1–3). Its morphology, stratigraphical level, ecological and palaeogeographical significance are discussed herein.

Figure 3. *View on the Zadní Kobyla locality in the Koněprusy area.*

METHODS

All specimens were sampled by hammering from the massive white crinoidal limestone. None serial sections were made, because inner corallite morphology is clearly distinct in two natural internal moulds. All figured specimens are stored in the collections of the Center of Biology, Earth and Environmental Sciences of the University of West Bohemia at Plzeň (PCZCU 1978 to PCZCU1986, and PCZCU 1988). Terminology and orientation follows Wright (2010) and Wright *et al.* (2010) with terms: OEF – opercular external face, OIF – opercular internal face, KEF – counter external face, KIF – counter internal face, and KOF – posterior external face of operculum.

MATERIAL AND PRESERVATION

In total, ten specimens of *Calceola* were collected from the 30 cm thick limestone bed. Three opercula (PCZCU 1978-1980) and seven corallites (PCZCU 1981-1986, 1988) have been sampled. All specimens are disarticulated. Except one specimen (PCZCU 1978), all other specimens have preserved slightly recrystallized sclerenchyma. Calices of all corallite are filled by limestone. One corallite (PCZCU 1982) has secondarily weathered surface showing the septa. One operculum (PCZCU 1979) exhibits abrasion. Another operculum (PCZCU 1978) is preserved as internal and external moulds. Two natural internal moulds of corallite (PCZCU 1986 and 1988) display a septal structure on the KIF. These different modes of preservation sufficiently illustrate all diagnostic features of corallites referred to *Calceola*.

Geographical and geological setting of the Barrandian material

The *Acanthopyge* Limestone is local member of the Choteč Formation, representing shallow marine deposits of the peri-reef environment at the top the Koněprusy submarine elevation. The member is built of generally well washed grainstone/rudstone, crinoidal limestone and bahamites (Havlíček & Kukal, 1990; Galle *et al.*, 1991). The topmost sequence of the dark bedded limestone has been correlated with the Kačák Member and the Kačák event (Hladil *et al.*, 1992; Hladil, 1993). Eifelian age of the *Acanthopyge* Limestone is sufficiently proved by goniatites (Chlupáč & Turek, 1983), conodonts (Zikmundová & Kalvoda in Galle *et al.*, 1991; Berkyová, 2009) and other invertebrates. The Eifelian/Givetian transitional interval above the dark interval of the *Acanthopyge* Limestone is evidenced by index tabulatomorphs and stromatoporoids (Hladil, 1993).

All specimens are from the upper part of the *Acanthopyge* Limestone outcropping in a small shallow abandoned quarry in Zadní Kobyla ridge near Koněprusy, Central Bohemia (Figs 1, 2A). Fossiliferous limestone rich in brachiopods, crinoids and corals including *Calceola* form small outcrops along the low NE slope of the quarry (Fig. 3B).

Corallites and opercula of *Calceola sandalina* have only been observed in the crinoidal white limestone bed incorporated in a several metre thick succession of white limestone at the upper one-third of the *Acanthopyge* Limestone (limestone with *"Amplexus" florescens* by Svoboda & Prantl, 1949). Richly fossiliferous white crinoidal limestone beds outcrop above about a 2 m thick bed of light to dark grey spongolitic limestone (Svoboda & Prantl, 1949). Conodonts are very rare, but the presence of *Tortodus kockelianus* indicates the *Tortodus kockelianus* Zone of the upper Eifelian.

SYSTEMATICS

Family **CALCEOLIDAE** King, 1846

Calceola Lamarck, 1799

Type species: *Anomia sandalium* Linné in Gmelin, 1790 (= *A. sandalinum* Linné, 1771).

Calceola sandalina (Linné, 1771) (Plates I, II)

Description: Corallite is typically slipper-shaped, with apical angle about 30° in early growth stages increasing to 60° in maturity in the largest known specimen. Walls of corallite are about 2 mm thick at 10 mm distance from the base of corallite. Maximum length of corallite is 28 mm. KEF is gently to moderately curved, showing growth lines, but lacking a distinct median ridge. Septal traces are seen on the KEF as fine grooves. Operculum is thick-walled, with much thickened posterior part, semiovate in outline, with prominent growth bands which are semicircular in early growth stages. KOF of operculum corresponds to the KEF of the corallite. OEF is gently convex but somewhat irregular in one specimen (PCZCU 1979). OIF is gently concave in general, with thickened posterior having gently convex surface. Eight septal blades developed on each side, with much lateral ones gently diverging each another.

Median septum is low, bifurcating posteriorly and forming the pit for articulation for the distal of the median septum of the corallite. There is a row of low rounded knobs immediately inside the posterior edge of the operculum. Eleven shallow pits are aligned along the posterior edge of corallite. 11 to 12 major septa are on each side of KIF. K-septum is clearly developed. Major septa are 0.5 mm apart, inserted minor septa are weaker than major septa. All septa are weakly curved. Rows of desmocyte attachment scars inserted between septa are clearly discernible on KIF.

Exterior of the largest corallite bears a few growth bands covered by much finer but distinct growth lines numbering 6 to 10 per 1 mm.

Remarks: The specimens, despite less favourable preservation, are morphologically undistinguishable from specimens of *C. sandalina* (Linné, 1771) from Moravia, Germany, Belgium and France. There is an extensive literature about the distribution of *C. sandalina* in West Europe (for a review see Wright *et al.*, 2010). Identification of sampled corals to species is based on the internal morphology of the operculum. Morphology of the single preserved operculum shows OIF features (Plate I, Figs 1, 4) attributed to *Calceola*. Number, size and arrangement of septal blades and K-septum of other calceolide genera (*Chakeola* Wright 2001, *Richtereola* Wright, 2006, *Rhizophyllum* Lindström, 1866, and *Savageola* Wright, 2001) differ from those of herein described Bohemian calceolide. *Calceola* represent the final genus of the generic evolutionary sequence of *Rhizophyllum* → *Savageola* → *Chakeola* → *Richtereola* → *Calceola* (Wright, 2010). The supposed upper Eifelian age of the *Calceola*-bearing bed in the Koněprusy area indirectly supports attribution of specimens to *Calceola sandalina*.

Occurrence in Bohemia: Eifelian, Choteč Formation, *Acanthopyge* Limestone (upper part with *"Amplexus" florescens*); Barrandian area, a small abandoned quarry on Zadní Kobyla ridge near Koněprusy.

Plate I.

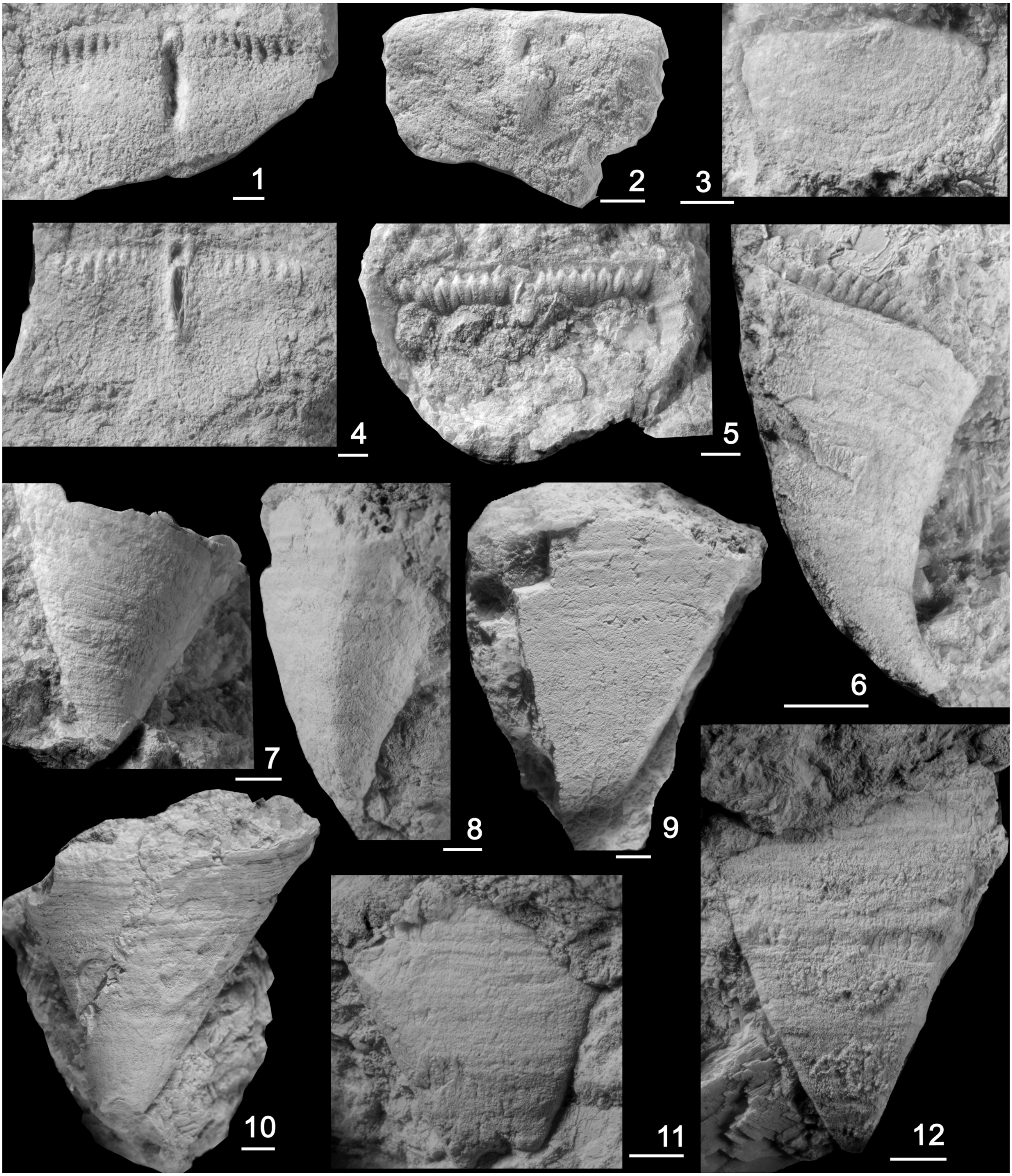

Plate I. *Calceola sandalina* (Linné, 1771). Eifelian, *Acanthopyge* Limestone, Zadní Kobyla locality, Koněprusy area, Central Bohemia; Scale bar 2 mm; 1) and 4) operculum, internal mould and its inner surface (OIF) of PCZCU 1978; 2) inner surface (OIF) of abraded operculum, PCZCU 1979; 3) small operculum, PCZCU 1980; 5) and 7) calical and lateral views to corallite, PCZCU 1981; 6) and 12) side view to corallite and its counter side (KOF), PCZCU 1982; 8) and 9) laterocardinal view to corallite and KOF of the same corallite, PCZCU 1983; 10) cardinal view to corallite, PCZCU 1984; 11) growth lines on KOF of the smallest known corallite, PCZCU 1985.

Plate II.

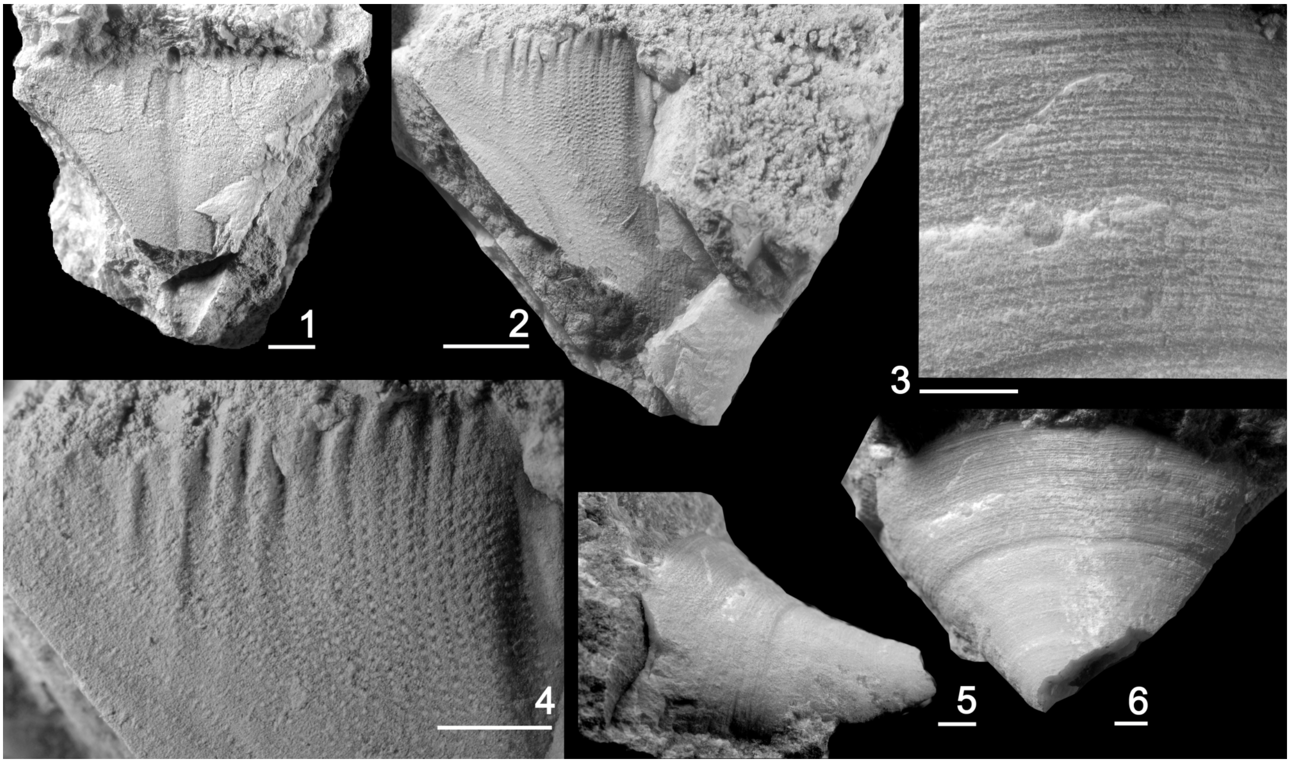

Plate II. *Calceola sandalina* (Linné, 1771). Eifelian, *Acanthopyge* Limestone, Zadní Kobyla locality, Koněprusy area, Central Bohemia. Scale bar 2 mm; 1) internal mould of KIF showing K–septum, septa, and desmocyte scars, PCZCU 1986; 2) – 6) corallite with partly broken wall showing major septa, minor septa, and part of K-septum on KIF natural internal mould (2), detail of KIF showing rows of desmocyte scars between septa and insertion of minor septa (4), lateral and cardinal views to corallite (5, 6), and detail of growth lines on surface of the corallite (3), PCZCU 1988.

DISCUSSION

Palaeoecology

In the *Acanthopyge* Limestone, *Calceola sandalina* (Linné, 1771) is commonly associated with crinoids (represented by columnalia and pluricolumnaria), rhynchonelliform brachiopods, stromatoporoids, tabulate, heliolitid and rugose corals, and other rare invertebrates (phacopid, proetid, lichid and scutelluid trilobites, platyceratid gastropods, small bivalves, fenestrate and trepostomate bryozoans, benthic tentaculitids). The absence of other gastropods, cephalopods, crustaceans, organophosphatic brachiopods and conulariids is noteworthy. Conodonts (under study) are very rare with *Belodella*, *Polygnathus*, and *Tortodus* (S. Vodrážková, pers. com.) so far having been identified.

A notably high diversity of rhynchonelliform brachiopods occur with *Calceola sandalina*. The rhynchonelliform genera and species found here are extremely rare or previously unknown from other fossiliferous localities of the *Acanthopyge* Limestone. Costate or ribbed brachiopods are much more common in the *Calceola*-bearing bed at Zadní Kobyla than among the brachiopod faunas in this limestone immediately below and above in which the smooth-shelled forms are most common. The remarkable brachiopod diversity and high morphological disparity of orthids (*Aulacella, Isorthis, Schizophoria*), large strophomenoids (*Chonostrophia, Leptaena, Leptaenopyxis*, chonetoids (*Devonaria*), rhynchonellids (*Kransia*), pentameriods (*Ivdelinia, Sieberella*), athyrids (*Merista*), spiriferids (*Amoenospirifer, Cyrtina, Myriospirifer*), costate atrypids (*Anatrypa, Atryparia, Carinatina, Desatrypa, Planatrypa, Spinatrypa, Variatrypa*) and other brachiopod groups (*Iridistrophia, Denovalosia*) indicate reef environment. High-energy environment is evidenced by the large fragments of thick-walled shells, abraded and rolled corals and stromatoporoids, and finely fragmented fenestrate bryozoans. This distinguishes the fossils of the *Calceola*-bearing limestone bed from limestone beds above and below, which are interpreted as having been deposited under significantly lower energy regimes as these fossils are less fragmented. The small to medium sized smooth-shelled spire-bearing brachiopods and arborescent corals are dominant there. This striking environmental difference may explain the absence of the *C. sandalina* from other limestone beds of the *Acanthopyge* Limestone. This confirms unique nature of the *Calceola*-bearing beds within the *Acanthopyge* Limestone succession. The mode of preservation and the taxonomic similarity between the older Koněprusy Limestone (Pragian age) and younger *Acanthopyge* Limestone (Eifelian age) biota indicate a restoration of a similar reefal environment for a short episode in the Upper Eifelian.

Paleobiogeography

Based largely on the differences of the brachiopod fauna in conjunction with the abundance of *C. sandalina* in the latest Emsian, Eifelian and the Givetian of Germany, Belgium, France, Poland and Moravia, and *C. sandalina's* heretofore absence in the Eifelian to Givetian of Central Bohemia supported the suggested palaeogeographic separation of the Barrandian marine space from that of West European, at least in the Middle Devonian (Havlíček, 1994). Immigration of Rhenish-type brachiopods into reef environment of the Barrandian in the lowest Emsian was a subject of special paper (Havlíček, 1994). He proposed that the immigration was only short-lasted and restricted to a few species. After this episode, the reestablishmentof the barrier between the Rhenish region and Central Bohemia restored. Havlíček & Kukal (1990) stated taxonomic similarity of the smooth-shelled, spire-bearing brachiopods of the *Karbous-Orbitoproetus* Community of the Eifelian age in the Barrandian with the brachiopod and trilobite fauna of the Greifenstein Limestone in Rheinishes Schiefergebirge, Germany (Siehl, 1962), but without any palaeogeographic comments and conclusions.

Presence of *C. sandalina* associated with many reef biota as seen also in the Rhenish region indicates lack of barrier for interchange of benthic biotas, at least during the Eifelian. The faunal differences reflect environmental differences rather than the presence of palaeogeographic barriers.

CONCLUSIONS

The calceolide coral collected in the *Acanthopyge* Limestone (Eifelian) in the Koněprusy area is without doubts identified as *Calceola sandalina* (Linné, 1771). The species is widespread in many late Emsian, Eifelian and Givetian sites of West Europe, Poland and Moravia. Its presence in the Barrandian area indicates absence of significant palaeogeographic barriers restricting distribution of this coral in the Middle Devonian. Presence of *Calceola* and associated diverse and highly-disparate brachiopod faunas attest for two different types of environmental setting on the Koněprusy submarine elevation during a deposition of the *Acanthopyge* Limestone. The *Calceola*-bearing beds represent a high-energy reef environment. Somewhat deeper calmer environment is characterized by spire-bearing, smooth-shelled, small to medium sized brachiopods of the *Karbous–Orbitoproetus* Community in the sense of Havlíček & Kukal (1990).

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