A C T A P A L A E O N T O L O G I C A P O L O N I C A
Vol. 25 1980 No. 3—4

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STROMATOPOROIDS IN THE DEVONIAN CARBONATE COMPLEX IN MORAVIA (CZECHOSLOVAKIA)

ZUKALOVA, V.: Stromatoporoids in the Devonian carbonate complex in Moravia (Czechoslovakia). Acta Palaeont. Polonica, 25, 3/4, 671—679, December 1981.

Studies of the Paleozoic rocks in Moravia based on abundant drillings reveal the extent of the Devonian reefs (*s.l.*) beneath the Carpathian Flysh Belt and Neogene foredeeps. Reef limestones (rich mainly in stromatoporoids) are restricted to the platform part of the sedimentary basin. A gradual transgression reached this area during the Givetian and Frasnian having its culmination in the Early Frasnian. Development of reef limestones in Moravia ceased at the Frasnian/Famennian boundary.

K e y w o r d s: Stromatoporoidea, stratigraphy, Devonian, Czechoslovakia.

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The Paleozoic sedimentary basin is bounded on the west by metamorphosed crystalline rocks. Paleozoic deposits are covered by the Carpathian nappes and the Neogene foredeep fillings on the south and southeast, while they extend into Polish territory on the north and northeast.

The Silurian graptolite shales occurring near the village of Stínava are the most ancient sediments for which there is paleontological evidence in Moravia (Bouček 1935). They give evidence of the earliest marine transgression over Moravia. During Paleozoic time, deep sea conditions prevailed in this area where mainly shales with subordinate limestone intercalations were deposited.

The Lower Devonian (Siegenian) transgression took place over a restricted area. Relics of fauna in the quartzites are known at the villages of Zlaté Hory and Vrbno. The transgression continued gradually southward and southeastward culminating, probably, in the early Frasnian.

The development of corals and stromatoporoids was associated with the extensive Givetian and Lower Frasnian transgression stages over rather gentle slopes of the eastern and southern portions of the Moravian sedi-

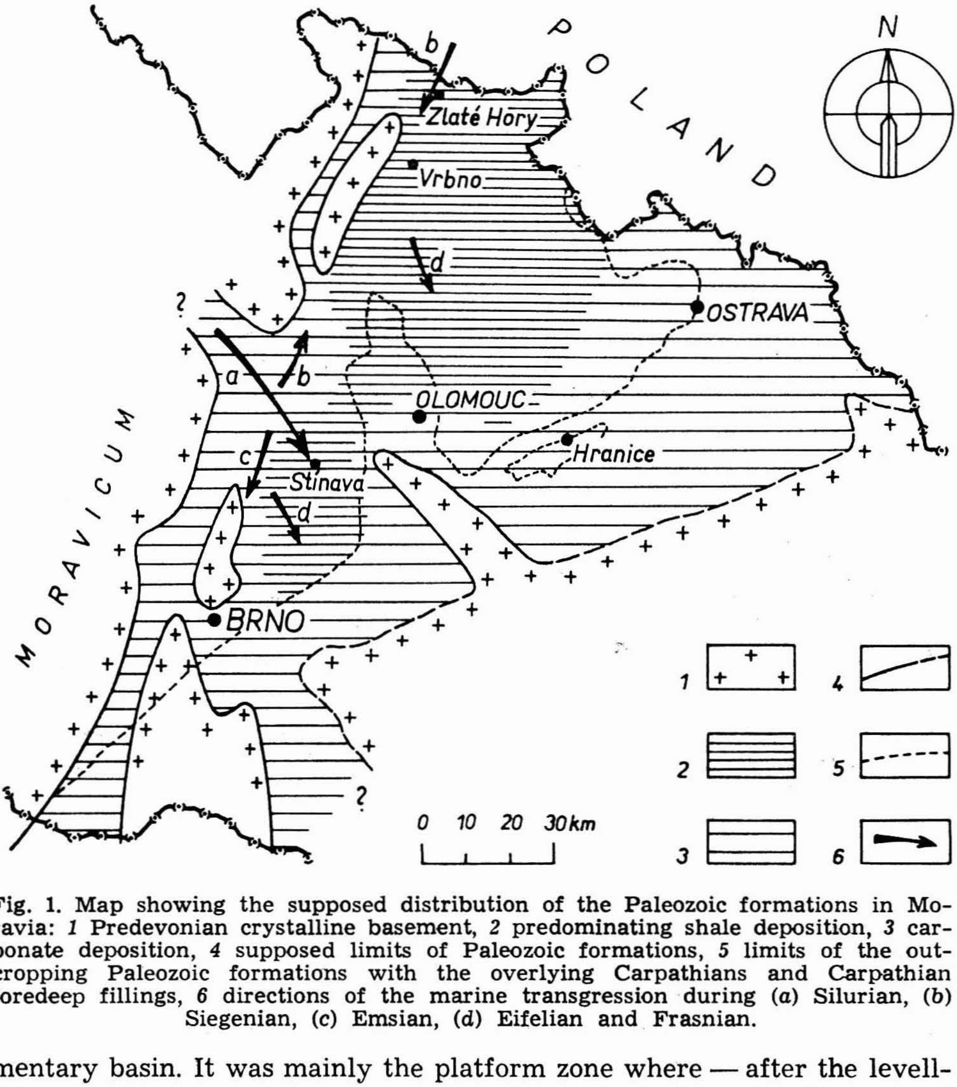

Fig. 1. Map showing the supposed distribution of the Paleozoic formations in Moravia: *1* Predevonian crystalline basement, *2* predominating shale deposition, *3* carbonate deposition, *4* supposed limits of Paleozoic formations, *5* limits of the outcropping Paleozoic formations with the overlying Carpathians and Carpathian foredeep fillings, *6* directions of the marine transgression during (*a*) Silurian, (*b*) Siegenian, (*c*) Emsian, (*d*) Eifelian and Frasnian.

mentary basin. It was mainly the platform zone where — after the levelling of the Proterozoic basement by terringenous deposits (sandstones and conglomerates) of the "Old Red Sandstone"-type — a carbonate complex up to 1800 m thick was deposited during the Devonian and Lower Carboniferous series.

The Givetian and Frasnian limestones containing abundant sessile benthic fauna can be compared to the carbonates described, for instance, as the Devonian reefs of the Rheinische Schiefergebirge (Jux 1960), the reef carbonate complex in the Dinant basin, the reef limestones according to Pajchlowa and Stasińska (1965), the stromatoporoid-coral limestones according to Kaźmierczak (1971) in Poland. From North America throughout Europe to Asia, and, in the region of the Paleozoic Tethys, from North Africa through the Alps to Asia Minor, China, Vietnam, and Australia, the distribution of these limestones can be observed on the basis of the ubiquitous fossil species. They were also associated with the equatorial zone of the shallow Devonian sea.

THE DEVONIAN CARBONATE COMPLEX

The most ancient Devonian carbonates in the platform zone form intercalations 1—50 m thick in the sandstones and conglomerates of the basal clastics and have been found in deep boreholes. The carbonates are impure, but rich in stromatoporoids, corals and shells.

The carbonate complex overlying the basal clastics consists of several lithological types, mainly differing in their fossil content.

Dark-coloured, bedded carbonates lacking fossils or with thin layers mainly composed of *Amphipora* branches (type I) occur in the deep boreholes situated close to the eastern margin of the basin. Frequently, the carbonates are dolomitic with recrystallized organisms and of varying thickness. They were deposited in the early stages of the transgression. The thickest carbonates (190—300 m) were deposited in a relatively deep zone, over the region that had been flooded first (Cho-9, Dr-1, Sl-2 boreholes). The thicknesses decrease towards the supposed shoreline (attain-

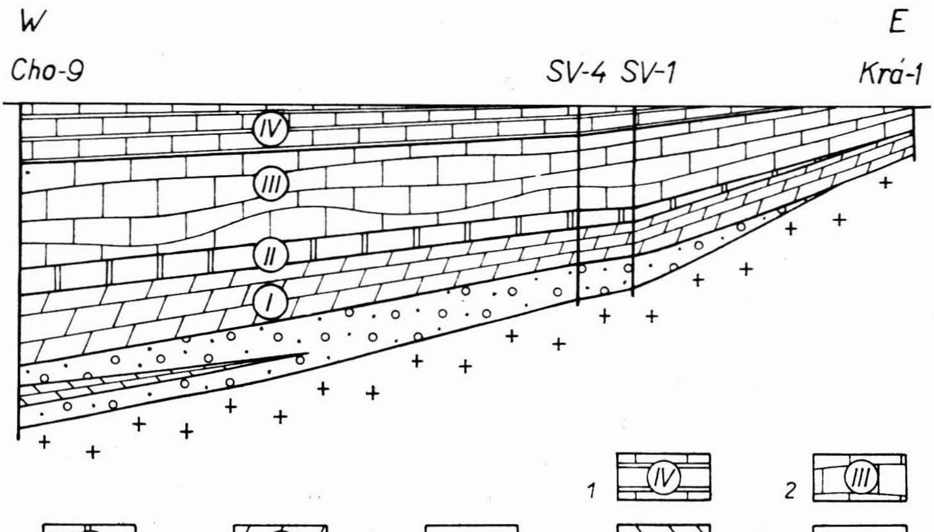

Fig. 2. Limestone types in the boreholes under study: *1* mostly light grey limestones with abundant clayey intercalations — type IV (Upper Frasnian); *2* light-grey and dark-grey limestones including horizons of massive and branched stromatoporoids — type III (Lower Frasnian); *3* dark-grey to black-grey limestones including abundant branched and massive coenostea of stromatoporoids — type II (Upper Givetian); *4* black-grey, frequently dolomitic limestones predominantly comprising *Amphipora* — type I (Givetian); *5* basal clastics (Eifelian? — Givetian); *6* limestone intercalations in the basal clastics; *7* crystalline basement of the ?Proterozoic age.

ing about 60 m in the Ja-7 borehole). Dark-coloured, bedded limestones with up to 30 cm thick layers of clustered *Amphipora* branches correspond to the above carbonates in the Moravian Karst (Zukalová 1971). The associated fauna comprises also *Stachyodes* branches and colonies of tabulate and rugose corals. The thick-walled shells of *Stringocephalus* and *Bornhardtina* are scattered, forming lumachelles only in places. Foraminifera occur frequently, while conodonts have not yet been found in these carbonates.

The overlying bedded limestones (type II) contain a rich association of stromatoporoids, corals, and, locally, of thick-walled brachiopods. The thicknesses of the limestones attain 20—50 m. Microfossils are represented by single-chambered foraminifera and by stems of algae of the *Kamaena* type.

The limestones denoted as type III are separated by an indistinct transition or by sterile limestones several meters thick. They consists of light grey to black-grey limestone beds formed almost entirely of the coenostea of stromatoporids. Layers with dominant *Amphipora* branches and with massive stromatoporoids alternate. The coenostea of the stromatoporoids are 3 to 20 (30) cm in size. The tabulate and rugose corals are abundant only locally. Among the microfossils, single-chambered foraminifera are abundant; multi-chambered *Nanicella* sp. were recognized in cross-sections. Stems of the *Issinella*-type algae are abundant in places. Conodonts are rare. Close to the eastern and southern margins of the sedimentary basin, the limestones are believed to have been deposited upon a broad, gentle slope where matlike organic growth developed. In shallow water, the sessile benthos responded rather sensitively and rapidly to varying external conditions by changing the growth forms and coenosteum shapes or by changing the association. The stromatoporoid coenostea attained larger sizes where bioherms were supposed to have been able to grow: at the steeper slopes of the Brno massif in the Moravian Karst and in the vicinity of the town Hranice (fig. 3). Dvořák (1978) believes the width of the slope where the reef limestones grew to be 6 km in the Moravian Karst and 18 km at the eastern margin of the basin. This slope was even broader in the northern portion of the basin.

The thicknesses of the Frasnian limestones vary rather widely, depending on the position in the sedimentary basin and on the subsidence rate. The smallest thicknesses are found at the eastern (near-shore) margin of the basin in the Krá-1, Ra-1, Ža-2 boreholes, where the Frasnian limestones are about 40 m thick. Their thicknesses vary from 200 to 700 m in the other boreholes.

During the Upper Frasnian. bottom subsidence became retarded or even ceased until some parts of the basin margin had emerged. More clay is thought to have been transported into the sedimentary basin due to this phenomenon. The number of clay intercalations and coatings in

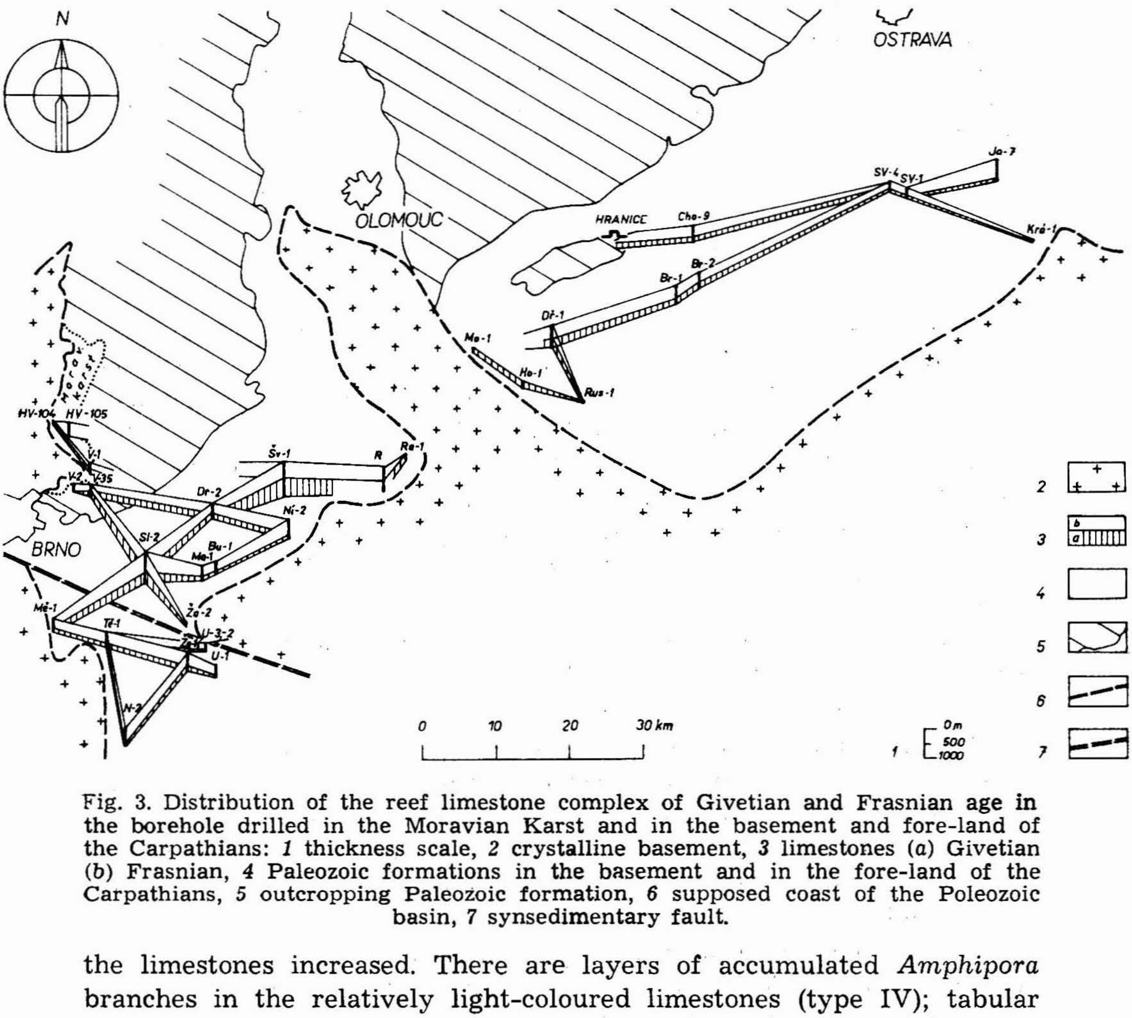

Fig. 3. Distribution of the reef limestone complex of Givetian and Frasnian age in the borehole drilled in the Moravian Karst and in the basement and fore-land of the Carpathians: *1* thickness scale, *2* crystalline basement, *3* limestones (*a*) Givetian (*b*) Frasnian, *4* Paleozoic formations in the basement and in the fore-land of the Carpathians, *5* outcropping Paleozoic formation, *6* supposed coast of the Poleozoic basin, *7* synsedimentary fault.

the limestones increased. There are layers of accumulated *Amphipora* branches in the relatively light-coloured limestones (type IV); tabular shapes dominate among the massive forms. Corals are relatively rare. Microfossils are represented by multi-chambered tests (*Tikhinella* type), while stems of the *Issinella* type, thalli of *Parachaetetes* sp. and of *Renalcis* sp. represent algae. Evidence of Upper Frasnian age was also provided by conodonts (Dvořák and Freyer 1961). However, their occurrence was restricted to certain environmental conditions only.

Abrupt and extensive facies changes occurred at the Frasnian/Famennian boundary, resulting in the deposition of less pure carbonates (nodular and organodetrital limestones) and in variations of the organic community. The sessile benthos suddenly disappeared being replaced by the vagrant benthos, or, the environment became unsuitable to organisms, causing the limestones to be almost devoid of fossils. The termination of reef limestone growth and the disappearance of sessile benthos from these limestones in the whole equatorial belt of the Devonian sea has been discussed by Zukalová and Skoček (1979). The regressive character of sedimentation, the increased transport of clay and decreasing volcanic activity could have been some of the causes that resulted in the termination of reef carbonate growth and in the disappearance of the sessile benthos (Jux 1960).

SHAPES OF STROMATOPOROID COENOSTEA

All known shapes of stromatoporoid coenostea (Khalfina and Javorskij 1972; Mori 1969; Abbot 1973, etc.) have been found in the carbonates assigned to the reef limestone complex. We believe (in agreement with Lecompte 1956; Fischbuch 1968; Mori 1969; Noble 1970; Tsien 1974; Lesovaja 1977; Kosareva 1977, etc.) that the form of coenostea were dependent on facies conditions and that their shapes changed with varying external and depositional conditions. The representatives of a genus or even of a species could produce hemispherical, tabular and dendroid forms.

Amphipora branches are the most widely distributed, because they occur in limestones the depositional environments of which did not suit other organisms (Vopni and Lerbekmo 1972).

The stromatoporoid coenostea grew into the most varied shapes and sizes in the environments represented by type II and III of limestones, displaying optimum conditions for their growth and development. Subspherical, hemispherical, tabular, and nodular shapes are recognized. They formed thin coatings on rugose and tabulate corals, on brachiopod shells, or on hemispherical stromatoporoids. *Actinostroma* produced coenostea of the forms mentioned above, but cylindrical and dendroid forms were also found. *Stachyodes* grew not only in typical branches, but also coated shells or produced hemispherical shapes due to the growth of tabular coenostea one above the other. The coenostea of the stromatoporoids contributed not only to the building of limestone, but, by coating other organisms and mutual intergrowing, performed cementing and binding functions as well.

The stromatoporoid coenostea are rarely preserved in their growth positions. Their redeposition and the destruction of their surfaces may be explained by intensive wave action in most cases. Stromatoporoid coenostea, disoriented and overturned from their growth positions were described by Noble (1970) among the "stromatoporoids of the hemispherical stromatoporoid subfacies" that is most similar to the type III limestones.

Abundant tabular or lenticular coenostea have been found in the type IV limestones. Due to overgrowths and projections forming on the coenostea, the latter changed into dendroid and cylindrical forms. The variations in the coenostea shape were explained by the increased clay supply (Zukalová 1976). Such forms of coenostea were produced mainly by the genera *Tienodictyon, Atelodictyon* and *Syringostroma.*

STRATIGRAPHICAL SIGNIFICANCE OF THE STROMATOPOROIDEA

In many cases, the stratigraphical classification of the Devonian carbonates in Moravia was accomplished mainly on the basis of the Stromatoporoidea. The phylogenesis of *Amphipora* and the evolutionary trend of the genus *Actinostroma* were applied for this purpose. The stratigraphy may be further refined byt he results of detailed studies on stromatoporoids and other associated fossil groups.

Givetian. In the lower parts of the carbonates classified as Givetian in age, characteristic branches of *Amphipora ramosa* (Phillips) and *Amphipora angusta* Lecompte are present. *Actinostroma* species with relatively dense tissue (*Actinostroma stellulatum* Nicholson, *A. clathratum* Nicholson, *A. densatum* Lecompte) represent the massive forms. The corals provide evidence that a part of these carbonates is probably Eifelian in age. Local occurrences of trilobites (Chlupáč 1964) provide evidence of the Lower Givetian age of the limestones containing them.

The Upper Givetian deposits are characterized by *Amphipora angusta* Lecompte, *A. pinguis* Javorskij, with the incipient occurrence of *A. perversiculata* Lecompte, *A. laxeperforata* Lecompte and *A. rudis* Lecompte. Among the massive forms, *Actinostroma clathratum* Nicholson and *A. devonense* Lecompte are abundant. *Synthetostroma actinostromoides* Lecompte and *Clathrocoilona crassitexta* (Lecompte) are the most abundant encrusting forms. The Givetian age of the carbonates is also indicated by the thick-shelled brachiopods *Stringocephalus* and *Bornhardtina* (Dvořák and Havlíček 1961).

The Givetian/Frasnian boundary can be hardly traced on the basis of stromatoporoids. It roughly corresponds to the boundary between the type II and type III limestones. A precise determination of the boundary will be possible on the basis of corals the genera or species of which are typical of the Givetian age. For instance, a group of caliapores similar to *Caliapora battersbyi* disappears at the Givetian/Frasnian boundary (Hladil 1974).

Frasnian. *Amphipora laxeperforata* Lecompte, *A. rudis* Lecompte, *A. perversiculata* Lecompte, *Stachyodes costulata* Lecompte and *S. lagowiensis* Gogolczyk are the most abundant among the varied stromatoporoids in the Frasnian limestones (Zukalová 1971). Within *Actinostroma*, the species with thin horizontal elements and thick vertical elements, *A. tabulatum crassum* Lecompte and *A. dehorneae* Lecompte, predominate. Among the dendroid forms, *Amphipora moravica* Zukalová is also present in the Upper Frasnian limestones (type IV). The tabular shape predominates among the massive stromatoporoids: *Stromatopora cygnea* Stearn, *Syringostroma capitatum frasniense* Zukalová, *S. vesiculosum vesiculosum* Lecompte, *S. vesiculosum tenuilaminatum* Zukalová, *Tienodictyon crassum* Zukalová. The Frasnian age of the limestones is also indicated by foraminifera (mainly by the multi-chambered forms), and by the conodonts found in a few limestone samples (Dvořák and Freyer 1961).

Acknowledgment. — The text was translated by Mrs. Maria Radevová.

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