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Very large stromatoporoid indicating Early Frasnian reef core (Holy Cross Mts., Poland)

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A large stromatoporoid *Actinostroma* cf. *crassepilatum* Lecompte, 1951, at least 8.5 m in diameter and 0.85 m in height, occurs in the Śluchowice quarry in Kielce, Holy Cross Mountains. This sponge occurs in growth position within Early Frasnian (*transitans* Zone) intraclast-rich reef-rubble deposits. A unique preservation of the reef-builder close to a reef core is implied for the northern flank of the developing Dyminy Reef during its maximum expansion northward into the Kostomłoty intrashelf basin.

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INTRODUCTION

Devonian exposures in the Holy Cross Mountains, Central Poland (Fig. 1A and B) have provided important data on stromatoporoid-coral facies of the globally occurring Frasnian reef complexes; see for example Kaźmierczak (1971), Szulczewski (1971), Narkiewicz (1988), Wrzołek (1988), Nowiński (1992) and Racki (1992). Stromatoporoids were among the dominant reef builders on extensive Middle Palaeozoic carbonate shelves (Wood, 1999). This extinct group have been interpreted recently as a class of non-spiculate sponges (Stearn *et al.*, 1999), represented as fossils by their basal carbonate skeleton (but see stromatoporid stromatolites of Kaźmierczak, 2003). Stromatoporoids from the Holy Cross Mountains Devonian succession have been comprehensively described by Kaźmierczak (1971, 2003), while some palaeoecological aspects are discussed by Łuczyński (1998, 2003).

An exceptionally large stromatoporoid specimen in growth position is described here as a record of a stromatoporoid-coral reef-core. This unique occurrence, first noted in Racki (1992, p. 128), is considered in the context of facies pattern within the Frasnian Dyminy Reef complex (Narkiewicz, 1988; Narkiewicz *et al.*, 1990; Racki, 1992).

PALAEOGEOGRAPHIC AND STRATIGRAPHIC SETTING

Two distinct palaeogeographic-tectonic Devonian domains, the Kielce palaeohigh region and Łysogóry palaeolow region, coupled with the transitional Kostomłoty area, characterise the Holy Cross Mountains part of Laurussian shelf (Racki, 1992). The subsymmetrical facies plan is emphasised by the central location of the Frasnian Dyminy Reef (Fig. 1B), surrounded by deeper intrashelf basins: Chęciny–Zbrza (southern) and Łysogóry–Kostomłoty (northern), as summarised in Narkiewicz (1988), Racki (1992) and Szulczewski (1995). Developmental stages of the stromatoporoid-coral reef ecosystem, which collapsed near the Frasnian–Famennian boundary (see summary in Copper, 2002), are in an overall accordance with the Euramerican sea-level curve of Johnson *et al.* (1985).

A succession of varied Frasnian limestones (Kostomłoty Beds in Szulczewski, 1971), developed close to the northern periphery of the Dyminy Reef, is perfectly exposed in the abandoned Śluchowice quarry, located in the NW part of Kielce (Fig. 1B and C). The locality is well-known due to well exposed folding and other tectonic phenomena seen there (Lamarche *et al.*, 1999), but not very attractive in palaeontological terms because fossils only occur commonly in

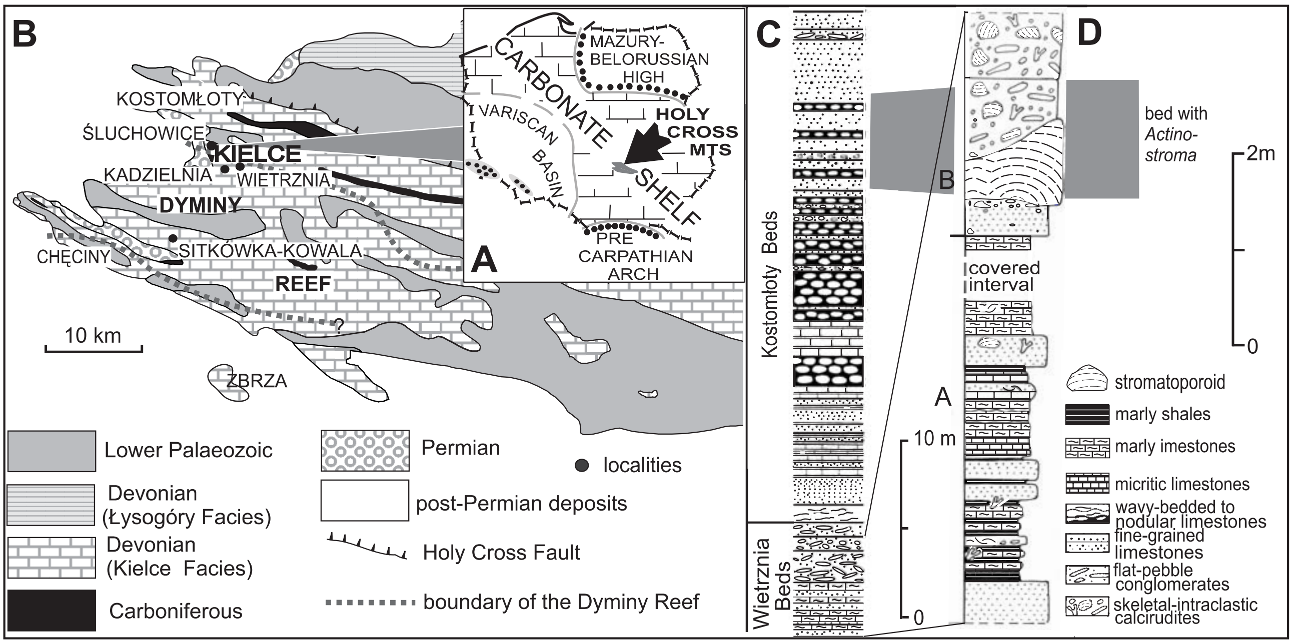

Fig. 1. **A** — location of Śluchowice quarry in Poland, **B** — the Holy Cross Mountains (based on Racki, 1992, fig. 2), **C** — general lithological column of the lower part of Śluchowice section (Szulczewski, 1971, fig. 7, modified), **D** — detailed succession of the Wietrznia Beds with the marked stromatoporoid reef at western end of the Śluchowice quarry (Racki and Bultynck, 1993, fig. 4, modified)

The Łysogóry Region is shown to be limited to the Łysogóry basin *sensu* Racki (1993), i.e. bordered by the Holy Cross Fault, but a basin facies was also partly developed in the Frasnian intrashelf basins surrounding the Dyminy Reef

Fig. 2. **A** — northern part of the eastern wall, western Śluchowice quarry at Kielce; studied part of the exposure arrowed (see Fig. 2B); **B** — northeastern wall, with arrowed stromatoporoid (*Actinostroma*) reef (Ac) in the basal interval B of the Wietrzna Beds, 0.8 m thick (see Fig. 1D)

Bthe lowermost (described below) and uppermost parts, in the Frasnian–Famennian interval where corals, brachiopods, crinoid debris are found (Szulczewski, 1971; Nowiński, 1992; Racki and Baliński, 1998). Therefore, the coarse-grained, fossiliferous and intraclast-rich limestones under study are a distinctive variety of the generally fossil-impoverished deep-slope facies, and re-assigned therefore to the Wietrznia Beds by Racki and Bultynck (1993), characterised by intermediate facies position between fore-reef and basin settings (see also Racki, 1992). This interval, *ca*. 4 m thick, occurs in the northern part of the quarry (Fig. 2) and on the nearby Czarnów Hill to the west (Szulczewski, 1971), and is precisely dated by conodonts to the Early Frasnian *Palmatolepis transitans* Zone (Racki and Bultynck, 1993).

IN-PLACE OCCURRENCE OF THE LARGE STROMATOPOROID

In the western Śluchowice quarry, protected as a geological reserve, the Wietrznia Beds crop out in subordinate northeastern wall, close to the quarry floor (Fig. 2A). The horizontally arranged thick limestone layers form the lower limb of the overturned Śluchowice fold (see Lamarche *et al.*, 1999). The oldest set A *sensu* Racki and Bultynck (1993), over 4 m thick, contains several fossil-poor calcarenites in a marly-shale succession with abundant rhynchonellid brachiopods assigned to *Phlogoiderhynchus polonicus* (Roemer) and *Styliolina domanicense* Lyashenko and *S.* ex gr. *nucleata* Karpinsky (see Biernat and Szulczewski, 1975; Hajłasz, 1992), as well as branched corals in some layers (Fig. 1D). This interval is questionably placed in the lower Wietrznia Beds in the Śluchowice-Czarnów succession due to its transitional nature to the underlying Szydłówek Beds (Racki and Bultynck, 1993), and this Givetian to Frasnian rhythmic marly unit is poorly exposed in the railway cuting to the north. The succeeding light gray biointrarudites, with dark calcarenite, 0.3 m thick, at the bottom (interval B), are marked by abundant reef-builder debris, mostly diverse dendroid and massive stromatoporoids and corals, especially alveolitid tabulates (see list of taxa in Nowiński, 1992). The reef breccia is associated predominantly with brachiopod and echinoderm (chiefly crinoid) bioclasts, calcispheroids and other microproblematica, as well as with unsorted micritic intraclasts (with peloidal-lumpy to spongy, renalcid-like fabrics in places), including large flat pebbles in conglomeratic beds (see Szulczewski, 1971, p. 60–61, pl. 24: 2, pl. 26: 1 therein; Fig. 3B).

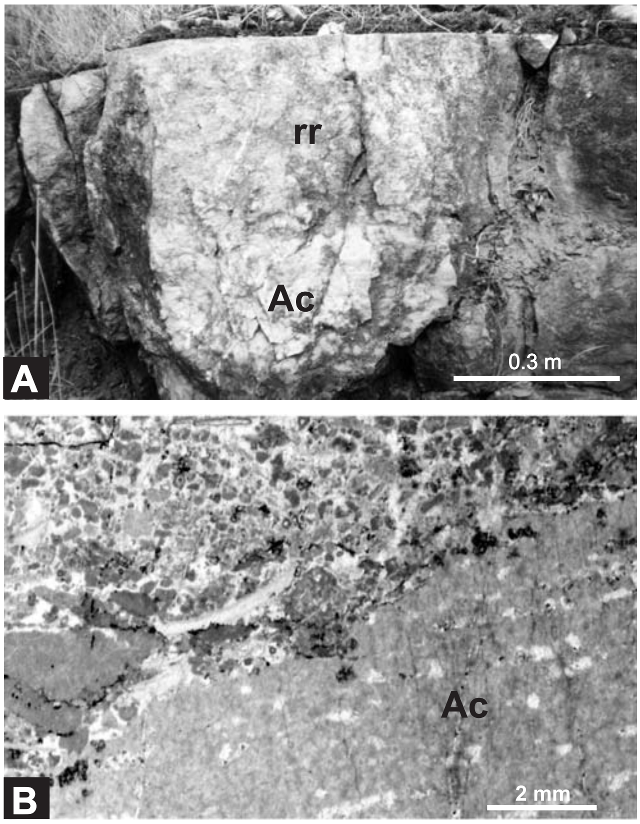

Fig. 3. **A** — close-up of the reef layer (northern part) built of *in situ Actinostroma* (Ac, see Fig. 2B) and reef rubble (rr), note the indistinct hemisphaerical-coalesced appearance of the stromatoporoid sheet; **B** — photomicrograph of the peripheral part of the *Actinostroma* skeleton, with visible poorly sorted intrabiosparenite enclosing sediment (see also biointrasparudite microfacies in Szulczewski, 1971, pl. 26: 1), and non-enveloping growth pattern

The second bed of interval B, 0.7–0.9 m in thickness, shows a stromatoporoid skeleton in growth position along most of the exposure, i.e., over a distance of *ca*. 12 m (Fig. 2B). The almost non-weathered rock surface, partly covered with ferric oxide and an organic coating, is inconvenient for detailed observations, but the stromatoporoid apparently continued laterally over at least 8.5 m. Sorted fine-grained, as well as unsorted talus-like deposits are found as the enclosing lithology, and the

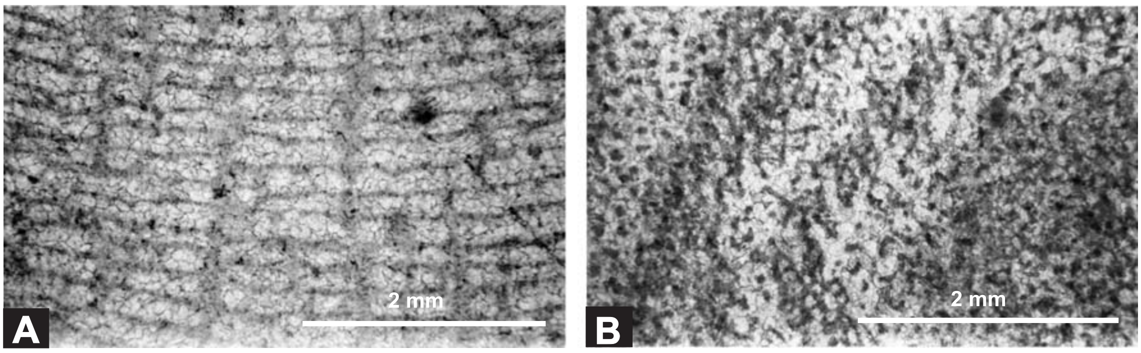

Fig. 4. *Actinostroma* cf. *crassepilatum* Lecompte, 1951 from the Early Frasnian Wietrznia Beds at Śluchowice quarry (see Fig. 1D); **A** — longitudinal section, **B** — obliquely-tangential section

Table 1

Dimensions of reticular tissue elements for *Actinostroma* cf. *crassepilatum* Lecompte, 1951 from Śluchowice (Fig. 4)

Laminae			Pillars		
max/2 mm	min/2 mm	thickness	max/2 mm	min/2 mm	thickness
10	7	0.06–0.14	7	5	0.18–0.29

moderately irregularly undulose upper contact between the pale stromatoporoid skeleton and the coral-rich biosparudite is clearly visible in the higher portion of the bed in some places (see Figs. 2B and 3). The largest stromatoporoid thickness (0.85 m) is noted in the middle part of the wall, but the partly erosional vs. burial nature of its top is unrecognised due to its poorly visible, probably non-enveloping growth pattern (*sensu* Kershaw, 1998). The low-relief profile and non-enveloping growth are typical of large examples of "massive" stromatoporoids (Łuczyński, 2003).

Thin sections from two outer parts of the stromatoporoid indicate assignment to the genus *Actinostroma* (Fig. 4). Despite differential recrystallization in both skeletal fragments, highly thickened pillars (up to 0.3 mm; Table 1) are seen in the reticular tissue. Therefore, a large tabular actinostromatid specimen is implied to be the rock-former of the layer under study, even if coalescence of several laminar individuals into one large mass is likely (*cf.* Kershaw 1998, p. 523). When compared with species described by Kaźmierczak (1971, 2003) from coeval strata of the Holy Cross Mts., this specimen is assignable only to *A. crassepilatum* Lecompte, 1951 (see Kaźmierczak, 1971, p. 137, pl. 40: 3, pl. 41: 6; 2003, p. 696, pl. 393: 3), widely distributed in European Givetian–Frasnian carbonate complexes. Notably, this single *Actinostroma* species has been determined by Kaźmierczak (1971, 2003) in the Wietrznia Beds (at the type locality), as the largest of the stromatoporoids there (up to 1.3 m in diameter and 0.75 cm high).

FINAL REMARKS AND IMPLICATIONS FOR THE DYMINY REEF

Meter-sized autochthonous *Actinostroma* sponge skeletons are not rare, because this genus is the commonest frame builder of the Givetian to Frasnian stromatoporoid-coral reefs worldwide (Stearn *et al.*, 1999, p. 33). However, its dimension is noteworthy: the speciemen described here is the largest stromatoporid reported so far from the Upper Devonian deposits from Poland. However, a giant tabular example of *Actinostroma expansum* (Hall and Whitfield, 1873), *ca.* 1.5 m high and 30 m wide, has been reported from the middle Frasnian Shell Rock Formation (Nora Member) of Iowa (Stock, pers. comm., 2003). Wood (2000) also described remarkably large actinostromatids from the Western Australian Frasnian reef that can reach sizes of up to 5 m in diameter and 1.5 m in height. The Australian species *A. windjanicum* Cockbain, 1984 is marked by highly complex platy-multicolumnar growth, which may be presumed also for the incompletely exposed specimen from Śluchowice (see Fig. 3A) that stabilised skeletal debris and fine-grained substrate.

A widespread *Actinostroma* assemblage was discerned by Racki (1992, p, 128) as a principal ecological component of the wave-resistant accretion rim of the Dyminy Reef in fairly agitated waters at most 10 m below sea level, but most "massive" stromatoporoid occurrences are post-mortem hydrodynamically reworked (Kaźmierczak, 1971; Narkiewicz *et al.*, 1990; Łuczyński, 1998, 2003). Findings of large *in situ* stromatoporoid skeletons are quoted by Szulczewski (1971, p. 86) and Racki (1992, p. 128), also from talus-like Stromatoporoid-Detrital Beds. Szulczewski (1971, p. 107–112) broadly discussed some basic limitations of reef recognition in this region, and he concluded that "part of detrital limestones with large-sized stromatoporoids make up an actual reef core" (Szulczewski, 1971, p. 112). In fact, a common feature of fossil reefs which represent diverse and complex biogenic structures, is a low preservation probability of the wave- and storm-agitated accreted rim formed by essentially *in situ* skeletons (e.g. Hoffman and Narkiewicz, 1977; Longman, 1981; Wood, 1999; Riding, 2002), even if an alternative (ramp model) explanation was highlighted by Stanton and Flügel (1995; see also Machel and Hunter, 1994).

In the case of the Wietrznia Beds under study, reef-rubble intraclastic deposits have continued both to the east (eastern Śluchowice quarry) and west (Czarnów Hill; Szulczewski, 1971; Racki and Bultynck, 1993), but the autochthonous frame-builders are limited to the western Śluchowice locality only. The spectacular *in situ* growth of *Actinostroma* cf. *crassepilatum* indicates that this species seems to live preferably in turbulent habitats that appeared to be optimal to support huge reef-building organisms. This unique framestone layer determines a portion of the Early Frasnian Dyminy Reef, representing a true reef-core (*cf.* Szulczewski, 1971) or at least very proximal fore-reef facies, during its extreme progradation northward into the Łysogóry–Kostomłoty basin. Notably, this initial developmental phase of the reef-complex (= foundation stage of Racki, 1992) was associated also with the ephemeral appearance of the distinctive Kadzielnia-type mud mounds on gentle irregular reef flanks, marked by sheet-like stromatoporoid mud binders (Kaźmierczak, 1971; Szulczewski, 1971; Racki, 1992; Łuczyński, 1998). This suggests strongly hydrodynamically changing conditions over the differentiated bioherm-fringed margin of the early "table"-type Dyminy Reef (Szulczewski, 1971; Racki, 1992). Northward progradation on a similar scale has been recorded only for the final reef-cap developmental stage of the latest Frasnian (see Narkiewicz, 1988; Racki, 1992; Racki and Baliński, 1998).

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