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Devonian calcareous green algal flora of the Rannach Nappe (Graz Palaeozoic, Austria)

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ABSTRACT

The Lower to Middle Devonian (Emsian – Eifelian) calcareous green algal flora of the Graz Palaeozoic (Austria) contains halimedalean representatives of Pseudolitanaia*,* Pseudopalaeoporella*,* Zeapora*,* Maslovina *and a new lanciculoid taxon. Occurrences within the Graz thrust complex are restricted to four localities in the Rannach Nappe and may be characterised as monogeneric mass occurrences. Consequently, they are interpreted as algal bafflestones originating from halimedalean meadows.*

Keywords: Devonian, green algae, mass occurrences, Graz Palaeozoic, Austria

1. INTRODUCTION

1.1. The Palaeozoic of Graz

Weakly and/or unmetamorphosed Palaeozoic successions are irregularly distributed in Austria (Fig. 1). Generally two major regions of Palaeozoic developments can be distinguished which are separated by the Periadriatic Fault, the most prominent alpine fault system. These are the Eastern Alpine Variscan sequences; (i.e. the Greywacke Zone, the Gurktal Nappe, the Graz Palaeozoic and some isolated outcrops in south Styria and Burgenland) and the Southern Alpine sequences (i.e. the Carnic Alps and the Karawanken Mountains).

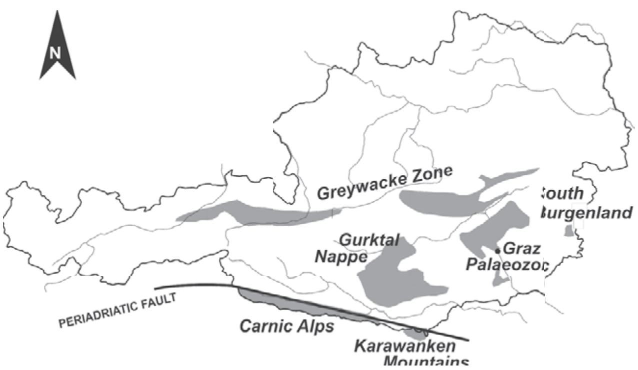

Figure 1: Austria and its disconnected Palaeozoic units (shaded areas).

The Palaeozoic Graz region extends over about 1250 km^2 and is isolated from other low grade metamorphic (anchizonal to greenschist) facies, Palaeozoic occurrences by tectonic boundaries in the North, East and West as well as by younger overlying strata in the South (Fig. 2).

The Northwestern and Western parts of the Graz Palaeozoic are bordered by polycrystalline units (Austroalpine Crystalline Zone), i.e. the Gleinalm, St. Radegund and the Raabalm. Further South, Palaeozoic successions are transgressively overlain by Neogene sediments of the "Styrian Basin" whereas the Southwestern part is unconformly overlain by Upper Cretaceous sediments of the Kainach Gosau (cf. Fig. 2).

Facies developments are characteristic of the Palaeozoic Graz as well as "polyfacial" nappes but the original relationships of these to each other have not been clearly identified. Investigations based on lithology, tectonic position and metamorphic superimposition divide the Graz Palaeozoic into basal, intermediate and upper nappe groups (FRITZ & NEUBAUER, 1990). These three nappe systems are identified by specific characteristics and contain the following units:

Figure 2: Simplified sketch of the Graz Palaeozoic. Shaded patches correspond with areas of the Rannach Nappe outcrops. Numbers of localities indicate the algal disocveries mentioned in the text.

The Basal Nappe System (Upper Silurian to Middle Devonian) consists of the "Schöckl-Hochschlag-Nappe-Group" and was deformed under upper greenschist facies conditions (HUBMANN et al., 2006). Volcanoclastics dominate the Late Silurian to Early Devonian, while in the Middle Devonian time span carbonates prevail.

The Intermediate Nappe System (Early Silurian to Upper Devonian) consists of the "Laufnitzdorf-Nappes" and "Kalkschiefer Nappes" and contains pelagic limestones, shales, volcanoclastics as well as siliciclastics.

The Upper Nappe System (Upper Silurian to Upper Carboniferous) consists of the "Rannach-Hochlantsch-Nappes". Both nappes have similar facies development in common, especially from the Emsian to the Givetian. Successions of the Rannach Nappe are characterised by volcanoclastic rocks (Early to Middle Devonian; Reinerspitz Group), siliciclastics and fossil-rich carbonates (Early to Middle Devonian; Rannach Group, Lantsch Group) of near-shore environment followed by the pelagic Forstkogel Group (Late Givetian to Bashkirian) and the shallow marine Dult Group (HUBMANN et al., 2003).

Palaeogeographic interpretations of the whole Palaeozoic succession have resulted in the assumption that the Rannach and Hochlantsch Nappes represent nearshore facies developments, whereas the "Laufnitzdorf Facies" represents the area furthest away from the shore. Successions of the Schöckl Nappe have an intermediate position in this scenario (HUBMANN, 1993). The stratigraphic sequence indicates a sedimentary area changing from a passive continental margin with continental breakup (alkaline volcanism) to shelf and platform geometries during Silurian to Devonian time (FRITZ et al., 1992). During this time, constant subsidence resulted in increasing carbonate production in the Upper Nappe System and during Pragian to Givetian time deposition changed from near-shore facies to open platform environments. When the carbonate platform drowned in the Frasnian, cephalopod limestones were deposited.

1.2. Review of stratigraphy and environmental architecture of the Rannach Nappe

The main reasons why the Rannach Nappe offers the highest probability for algal discoveries are that it has the least metamorphic overprint, and the sedimentary successions were developed nearest to the shore in moderate water depths.

Due to basal volcanoclastics (Kehr and Kötschberg Formations) and marly crinoid-rich sequences (Parmasegg Formation), the peritidal Flösserkogel Formation is assumed to range from the Lower Pragian. The formation comprises different types of dolostones, silt- to sandstones and subordinate dolomitic limestones which are interpreted as deposition in a supra- to shallow subtidal, barrier-surrounded lagoon, or tidal flats (FENNINGER & HOLZER, 1978). Near Graz, the lower parts of the succession are interpreted as sand bars whereas the upper parts (which are separated by volcanic tuffs), contain meadows of the spaghetti-like stromatoporoid *Amphipora*. The presence of very rare conodonts indicates a (Lower?) Emsian age (cf. EBNER et al., 2000, 2001).

Another formation belonging to the Rannach Group is the Plabutsch Formation. It overlies or rather interfingers with the Flösserkogel Formation and predominantly contains typical "reefbuilding organisms" (HUBMANN, 1993, 2003) which are present in all sections. Nevertheless, there is no outcrop evidence of a "true reef" rather than coral-stromatoporoid-carpets and lagoonal sediments which are the dominant features. Environmental investigations indicate deposition on a differentiated and slightly inclined carbonate platform (HUBMANN, 1993). The following features support the assumption that sedimentary conditions were unfavourable for reef formation: the rarity of in situ organisms, the intermittent but generous supply of clayey sediments (marl-limestone intercalations) and plentiful supply of lime mud, a temporary influx of large amounts of continental phytoclasts, storm impacts (several tempestite sequences within the profiles) and especially their effects on biocoenosis (HUBMANN, 1995).

This phase is terminated by a repetition of tidal flat deposits similar to the Flösserkogel Formation and obviously caused by a eustatic sea level fall. A transgression resulted in a sequence with sharp biofacies contrasts between patch-reefs and monotonous mudstones of Givetian age (the Kollerkogel, Tyrnaueralm, and Zachenspitz Formations).

During the uppermost Givetian to lower Frasnian, sedimentation of shallow platform carbonates was replaced by micritic cephalopod limestones (Steinberg Formation). This sedimentation continued up to the Bashkirian (Sanzenkogel Formation, Forstkogel Group). The sequence is terminated by shallow marine sediments, shales and limestones with birdseye structures.

1.3. Algal horizons

In two of the above mentioned formations, remains of algal thalli have been found, namely in the Lower Devonian (Pra-

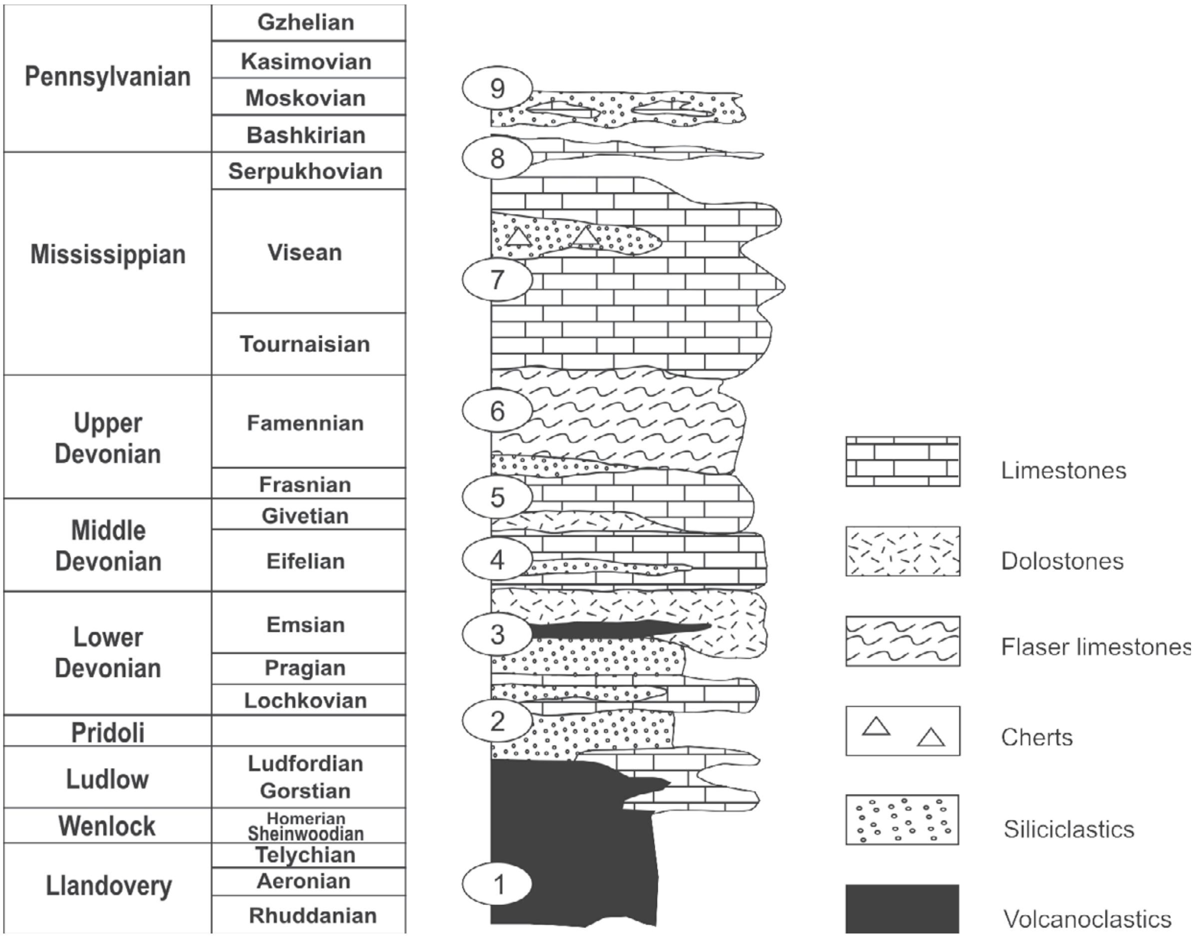

Figure 3: Stratigraphic column of the Rannach Nappe: 1) Kehr Formation, Kötschberg Formation; 2) Parmasegg Formation; 3) Flösserkogel Formation, Bameder Formation; 4) Plabutsch Formation; 5) Kollerkogel Formation; 6) Steinberg Formation; 7) Sanzenkogel Formation; 8) Höchkogel Formation; 9) Hahngraben Formation.

gian?-Emsian) Flösserkogel Formation and in the Middle Devonian (Eifelian) Plabutsch Formation. All these algal findings are monogeneric mass occurrences and therefore make up the majority of the rock. Consequently, they are interpreted as (par) autochthonous bafflestones.

According to FENNINGER & HOLZER (1978), profiles of the Flösserkogel Formation contain "dasyclads" in the skeletal grains of the tidal flat-deposits (Pfaffenkogel). Although further investigations confirm the occurrence of reworked *Ortonella*-remains and pieces of halimedaleans, algal thalli suitable for taxonomic determination have not been discovered. Well preserved, determinable algae have so far been detected only at the following four localities:

2. SAMPLING LOCATIONS

Locality 1: (Coordinates: 47°08'25"N/15°15'27"E) At a succession north of the Rein monastery (ca. 20 km North of Graz) an occurrence of little disarticulated lanciculoid algae was observed. This location is characterised by dark-grey to black, micritic to pelmicritic dolomites, (equivalent to *Amphipora* meadows), and can be assigned to a slightly subtidal depositional environment. Rocks yield a high number of algal thalli, mainly consisting of 8–15 articuli. Moreover, the thalli at the surface of weathered rocks seem to be very well preserved. Anatomic details, however, are only visible using a darkfield condensator.

Locality 2: (Coordinates: 47°03'40"N/15°22'34"E) The oldest known algal taxon of the Graz Palaeozoic, *Zeapora*, occurs in the Plabutsch Formation (formerly "Barrandeikalk"). It is restricted to one single outcrop, the former illite mine on the Southern slope of the Kollerkogel at the border to the urban area of Graz. The black, graphitic horizon containing algal thalli is located only a few dm above the illite at the base of the Plabutsch Formation. PENECKE (1894) described these fragile fossils as *Zeapora gracilis*, but assigned them mistakenly to the Bryozoans. FLÜGEL (1959) recognized their algal nature and HUBMANN (2000) later revised and emended his description.

Locality 3: (Coordinates: 47°05'25"N/15°22'11"E) The occurrence of *Pseudopalaeoporella lummatonensis* and *Pseudolitanaia graecensis* is also located near the city of Graz (at a small path on the Southern slope of the Frauenkogel). The upper parts of the Plabutsch Formation are characterised by alternating layers of clayey limestones, red mudstones and marls. In the clayey limestones of this alternating sequence, masses of *Pseudopalaeoporella lummatonensis* but only a subordinate number of *Pseudolitanaia graecensis* thalli occur.

PLATE I

1 Polished surface of algal limestone from locality 3 with an oblique section through *Pseudolitanaia graecensis*.

2 Thin-section of *Pseudolitanaia graecensis*, transverse section exhibiting dichotomous offsets of cortical filaments that branch off coarse medullary filaments. Locality 3.

3 Cross-section of *Pseudolitanaia graecensis* from the locality3.

4 Weathered surface of algal limestone of locality 3 built up exclusively by densely packed thalli of *Pseudopalae-oporella lummatonensis*. Note the minor degree of calcification in the medullary region of algal bodies.

5 Oblique longitudinal section of *Pseudopalaeoporella lummatonensis* showing a well defined cortical zone and a poorly calcified central axis from the locality 3.

6 Cross-section of *Pseudopalaeoporella lummatonensis* from the locality 3.

7 Surface of algal limestone from locality 2 (abandoned quarry at Kollerkogel) with densly packed thalli of *Zeapora gracilis*.

8 Photomicrograph of thin-section illuminated by darkfield condensor. Oblique longitudinal section of *Zeapora gracilis*. Note the large peripheral tubules filled with coarse-grained sparite.

9 Photomicrograph of thin-section illuminated by darkfield condensor. Cross-section of *Zeapora gracilis*. Cortical filaments vary due to different orientation of their clubbed shapes.

All white scale bars represent 1 mm.

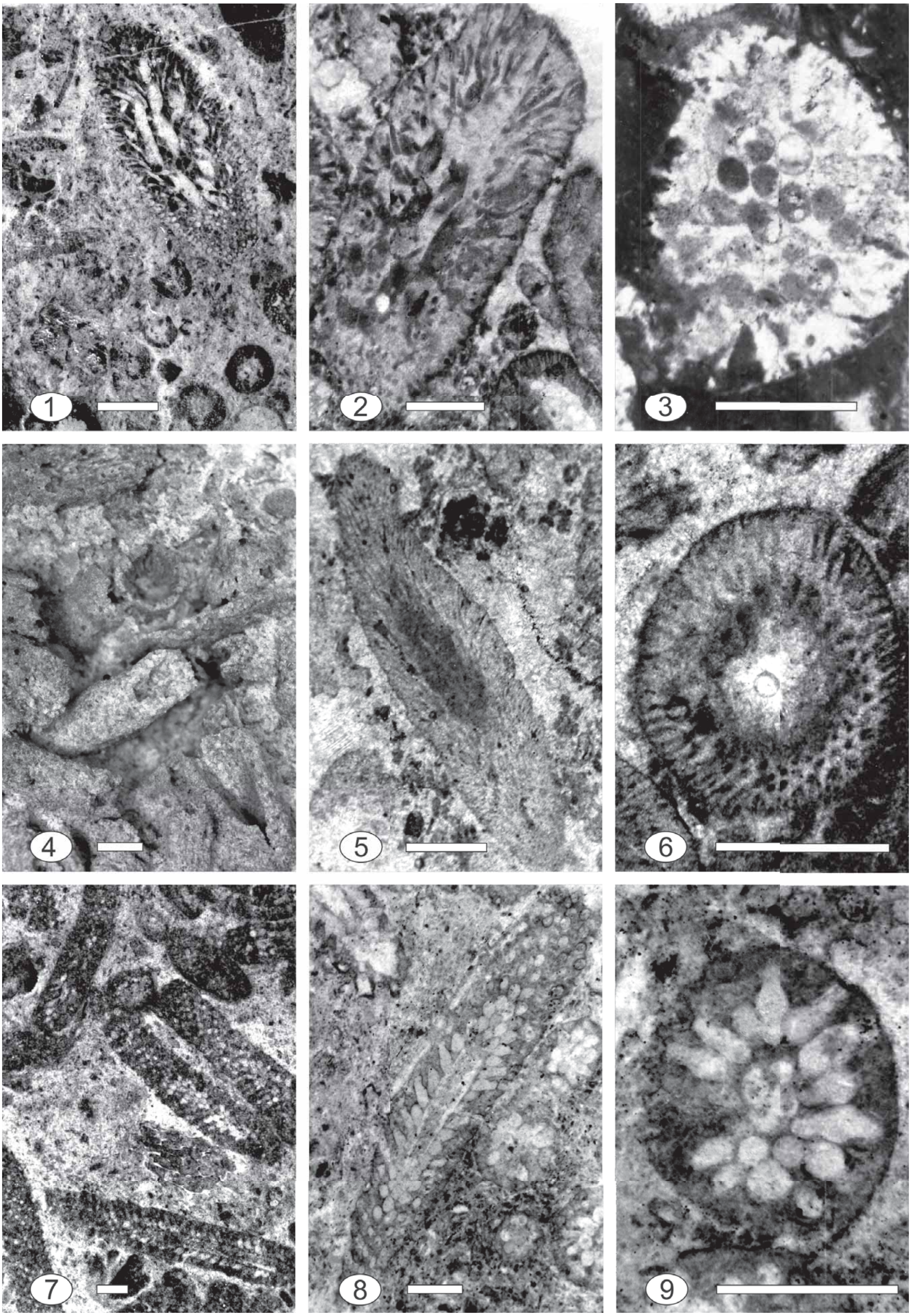
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PLATE II

1 Weathered surface of an algal bearing limestone of locality 4 (road cut St. Pankrazen) exhibiting cross sections of *Maslovina* sp.

2 Longitudinal section of a fragment of *Maslovina* sp. Note arrangement of numerous, fine medullary filaments.

3 Cross-section of *Maslovina* sp. showing a well-defined medullar zone. Note terminations of the cortical filaments (amphora-shaped utricles).

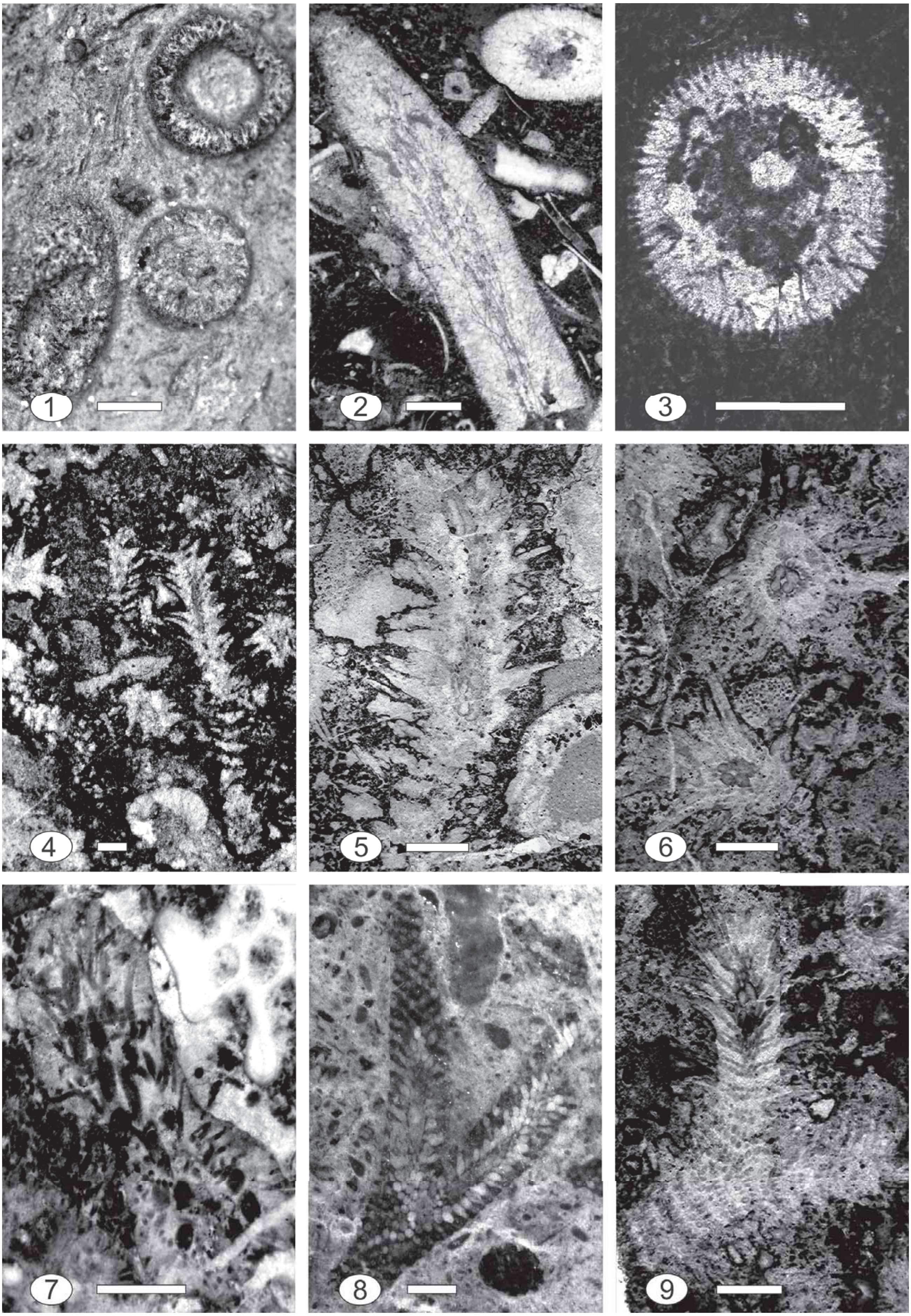
4 Weathered surface of the undetermined lanciculoid alga of locality 1.

5 Photomicrograph of thin-section illuminated by darkfield condensator. Longitudinal section the lanciculoid alga.

6 Photomicrograph of thin-section illuminated by darkfield condensator. Cross section is exhibiting four coarse medullary filaments.

7–**9** Branching thalli of (7) *Pseudolitanaia graecensis*, (8) *Zeapora gracilis*, and (9) new lanciculoid alga.

All white scale bars represent 1 mm.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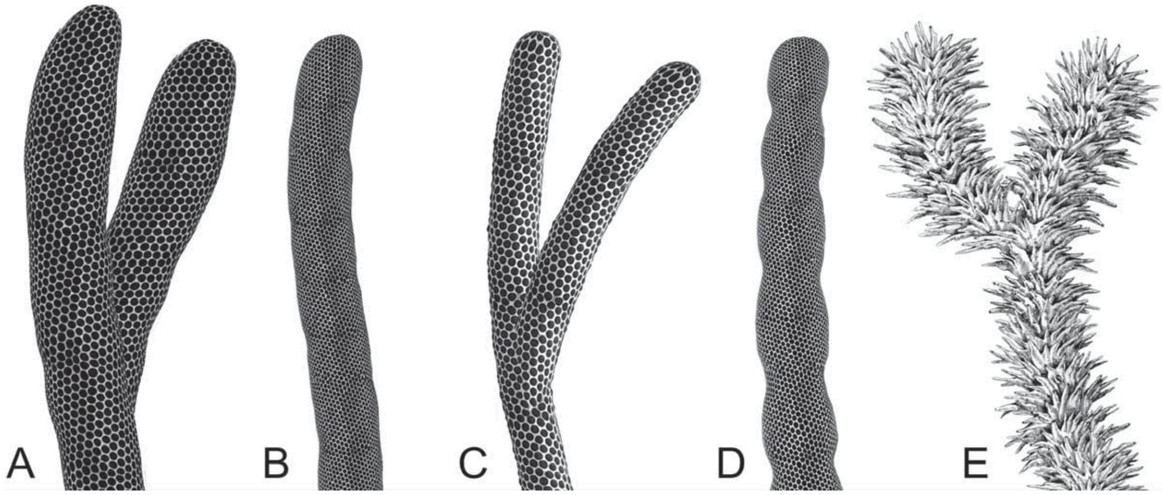

Figure 4: Green algae of the Graz Palaeozoic: reconstructions of the outer morphology of (A) *Pseudolitanaia graecensis*, (B) *Pseudopalaeoporella lummatonensis*, (C) *Zeapora gracilis*, (D) *Maslovina* sp. and (E) the undetermined lanciculoid alga.

Figure 5: Organisational differences of (A) *Pseudolitanaia graecensis*, (B) *Pseudopalaeoporella lummatonensis*, (C) *Zeapora gracilis*, (D) *Maslovina* sp. and (E) the undetermined lanciculoid alga.

The slight disarticulation of the thalli as well as their occurrence in clayey limestones, indicate a hydrodynamically low depositional environment.

Locality 4: (Coordinates: 47°08'01''N/15°11'02''E) The outcrop is situated along the road about 2 km South of St. Pankrazen (30 km NW of Graz). The lower parts of the Plabutsch Formation contain a mass occurrence of *Maslovina* which has recently been the subject of taxonomic investigation (VERDERBER, 2007). The respective horizon lays only a few dm above the basis of the shale horizon which corresponds in position to the illite horizon of the Kollerkogel.

3. RESULTS AND DISCUSSION

The Graz taxa

Genus *Pseudolitanaia* MAMET & PRÉAT, 1994
***Pseudolitanaia graecensis* (HUBMANN, 1990)**
(Fig. 4 B, Fig. 5 B; Pl. I, Figs. 1–3; Pl. II, Fig. 7)

1990 *Litanaia graecensis* – HUBMANN, p. 148–150, figs. 3–4, pl. 35, figs. 1–6
1994 "*Litanaia" graecensis* – HERRMANN & HUBMANN, p. 200, pl. 1, fig. 5
1994 *Pseudolitanaia graecensis* – MAMET & PRÉAT, p. 148

The thallus is erect, cylindrical and continuous; its central part consists of 4 to 12, generally 8 irregular filaments with appendices which develop towards a high number of cortical filaments. These cortical filaments are more or less oblique with a significantly increasing diameter and a spatula-shape. They end up as fine filaments of second order dichotomy and their termination resembles *Pseudopalaeoporella*. Average diameter of thalli is 2.8 mm, central filaments vary between 0.25 and 0.33 mm, and cortical filaments are approximately 0.88 mm thick.

Genus *Pseudopalaeoporella* MAMET & PRÉAT, 1985
***Pseudopalaeoporella lummatonensis* (ELLIOTT, 1961)**
(Fig. 4 A, Fig. 5 A; Pl. I, Figs. 4–6)

1961 *Palaeoporella lummatonensis* – ELLIOTT, p. 251–254, pl. 9, figs. 1–5; pl. 10, figs. 1–4
1983 *Palaeoporella lummatonensis* – BASSOULLET et al., p. 553–554, pl. 13, figs. 1–2
1985 *Palaeoporella lummatonensis* – ROUX, p. 564
1985 *Pseudopalaeoporella lummatonensis* – MAMET & PRÉAT, p. 70–72, pl. 3, figs. 2–8
1987 *Pseudopalaeoporella lummatonensis* – MAMET & PRÉAT, p. 441, fig. 4

1987 *Funiculus venosus* n. gen. et n. sp. – SHUYSKY & SHIRSHOVA, p. 100–101, figs. 1–4
1990 *Pseudopalaeoporella lummatonensis* – HUBMANN, p. 150–151, fig. 5, pl. 35, figs. 1–6
1992 *Pseudopalaeoporella* sp. – BUGGISCH & FLÜGEL, p. 80, pl. 1, figs. 5–6; pl. 3, fig. 2
1992 *Pseudopalaeoporella lummatonensis* – MAMET & PRÉAT, p. 55, pl. 3, figs. 1–11
1993 *Pseudopalaeoporella lummatonensis* – HUBMANN & FENNINGER, p. 648–649, fig. 1
1993 *Palaeoporella lummatonensis* – VACHARD, p. 97–98, pl. 6, figs. 6, 18, 21–25
1994 *Pseudopalaeoporella lummatonensis* – HERRMANN & HUBMANN, p. 198–200, fig. 4, pl. 1, figs. 2–4
1994 *Pseudopalaeoporella lummatonensis* – KOCH-FRÜCHTL & GEE, p. 4–7, fig. 3, pl. 1, figs. 1–6; pl. 2, figs. 7–15; pl. 3, figs. 16–23

When unbranched, thalli are cylindrical in form with a medullar zone and an extensive radial envelope. Their diameters vary between 0.8–1.8 mm (mean value about 1.4). The medullar zone (~ 0.65 mm in diameter) is composed of several central tubes (up to 20?) and makes up approximately half the entire thallus diameter in cross section. Central filaments are arranged parallel to the thallus axis and are closely spaced. Cortical filaments develop from central tubes in acute angles into numerous lateral tubes with a second and third order dichotomy. The filaments are commonly swollen just below the points of branching and widen trumpet-like towards the thallus surface.

Genus *Zeapora* PENECKE, 1894
Zeapora gracilis (PENECKE, 1894)

(Fig. 4 C, Fig. 5 C; Pl. I, Figs. 7–9, Pl. II, Fig. 8)

1894 *Zeapora gracilis* – PENECKE, p. 610, pl. 10, fig. 11
1959 *Zeapora gracilis* – FLÜGEL, p. 147–149, figs. 1–2
2000 *Zeapora gracilis* – HUBMANN, p. 31–37, figs. 3–5

The thalli clearly show numerous peripheral tubules arranged around a central axis filled with a bundle of medullar filaments. The medullar zone, usually 0.39 to 0.40 mm in diameter, consists of 4–6 (up to 10 and more) slightly interwoven filaments. Their diameters vary between 0.08–0.21 mm. The cortical zone is filled with massive carbonate deposits and perforated by roundly-elongated, densely packed filaments. Cortical filaments vary considerably in longitudinal and cross sections due to different orientation of their bowl-like shapes. In some specimens, they seem to be segmented.

Genus *Maslovina* OBRHEL, 1968
Maslovina sp.

The thallus is of a straight, cylindrical shape, occasionally undulated. Thalli vary in length between 3.0–11.5 mm, diameters measure between 0.78–2.55 mm (median value 1.9 mm), and are internally organised into a generally poorly calcified medullar area and a cortical zone. The medullar part (diameter averages 0.93 mm) consists of a high number (>40) of interwoven filaments (on average 0.04 mm wide) which give rise to finer, cortical filaments (approximately 0.02 mm in diameter). They divide dichotomously at an acute angle and reach a third order dichotomy at the outermost cortical part. At this stage cortical filaments develop towards densely packed amphora-shaped utricles which constitute the thallus surface. Reproductive organs are not observed.

Maslovina sp. differs from the type species *M. meyenii* in having more numerous medullar tubes (> 40); these numerous tubes are also a characteristic feature of the Devonian species *M. australense* (see MAMET & POHLER, 2002). The far greater thallus diameter and length is what distinguishes *Maslovina sp.* from the two other species. The most remarkable differentiating feature, however, is that *Maslovina sp.* has outermost cortical filaments developing into a layer of tightly packed utricles which are, in contrast to *M. meyenii*, amphora-shaped. *M. australense* differs from the other two species in showing irregularly spaced, thin terminal filaments forming an irregular epiderm (MAMET & POHLER, 2002; OBREHL, 1968).

Undetermined lanciculoid alga

(Fig. 4 E, Fig. 5 E; Pl. II, Figs. 4–6, 9)

Regularly segmented algal bodies only minor disarticulation exhibiting. Thalli consist of up to 25 bowl-shaped elements (articuli, chalices) surrounding a straight or slightly bent stem (rachis). Occasionally thallus ramifications are observed.

Thin-sections expose an internal assembly of four central filaments pervading the whole thallus. They apparently do not vary considerably in diameter (approximately 0.15–0.20 mm), but may be slightly curved or undulating. From medullary filaments a great number of cortical filaments branch off radially, and perpendicular to the central axis decreasing their angles with growth. Each tapered segment contains two rows of cortical filaments and increases its diameter towards the growth direction. These segments resemble the bell of a trumpet and are densely stacked one above the other.

The outer morphology of the articuli of our lanciculoid alga resembles the genus *Quasilancicula*, but its chalices are more compressed. Its tentacle-shaped chalice edges, however, show similarities with *Lepidolancicula*.

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