A panorama of the fossil algae: from cyanobacteria and calcimicrobes to the green calcareous algae

A tribute to Erik Flügel and the Erlangen School

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Initiated in the first half of the 19th century, investigations of calcareous algae flourished after the Second World War, in connection with the intensification of oil exploration in carbonate reservoirs. This field of research immediately provided a new micropaleontological tool for stratigraphic and paleoecological characterization of sedimentary strata. When a representative community working on fossil calcareous algae had become established by the 1970s and 1980s, such investigations reached a peak. This community gathered at specialized international meetings, where the top results were shared. The late Professor Erik Flügel was the one who organized the first international symposium on fossil algae in Erlangen in 1975. Eric Flügel was well known in the international scientific community for his studies on carbonate rocks, especially on fossil calcareous algae. More than that, he was widely appreciated for his exceptional mentoring qualities, from which numerous generations of students in this field benefited. At Erlangen, he founded the carbonate microfacies and calcareous algae school; in 1979 he initiated the journal *Facies*, currently one of the most prominent publications in the field. As a sign of our deep appreciation, we dedicate this volume to his memory.

The symposium organized in Erlangen represented the start of a quadrennial series of international reunions that successively took place in Paris (1979), Golden, Colorado (1983), Cardiff (1987), Capri (1991), Ankara (1995), Nanjing (1999), Granada (2003), Zagreb (2007), and Cluj-Napoca (2011). These scientific meetings encouraged the development of the study of calcareous algae, as well as international collaborations in the field. Accordingly, the

International Fossil Algae Association (IFAA) decided to initiate an additional conference series, timed in-between the international meetings. The latter were defined as “regional meetings”, being organized as fieldwork-based workshops. Nevertheless, they always had an international character, from the participants and topic point of view. The first regional IFAA symposium took place in Granada (1989), followed by the ones in Munich-Vienna (1993), Krakow (1997), Cluj-Napoca (2001), Ferrara (2005), and Milan (2009). In the last decades, the proceedings of these international and regional symposia summed up the state of the art in calcareous algae research. We hope that the current issue of *Facies* will continue this trend.

The current volume gathers some of the presentations given at the 10th International Symposium on Fossil Algae (Cluj-Napoca, September 2011), as well as some other recent results in the study of calcareous algae. The contributions cover a wide range of topics, from the study of some end-products of cyanobacteria and calcimicrobes to studies of red and dasycladalean green algae.

Basso et al. (2013) describe in their contribution the present-day formation of microbialites containing cyanobacteria, bacteria, and microalgae colonies in southern Sinai (Egypt). Based on macroscopic morphology, texture, and degree of lithification, four categories of microbialites were recognized. Their presence in the area is considered to result from the combination of local sedimentary dynamics and accommodation space in a peritidal tropical environment with high variations of temperature and salinity.

Various fossil microbialites associated with micro-encrusts are described by Pleş et al. (2013) from Upper Jurassic limestones in the Southern Carpathians (Romania). The deposits mainly consist of massif reef limestones including a variety of microbialites associated with micro-encrusts. The high abundance of dense micrite, the presence of

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laminated structures, of clotted, thrombotic or peloidal microfabrics, of biogenic encrustations and cement crusts—all represent the contribution of microbialites to the reef construction. Such bioconstructions, defined as “coral-microbial-microencruster boundstones”, are considered to represent important paleobiogeographic features.

Recently, the potential relationship of *Lithocodium aggregatum* to calcimicrobial structures has been debated intensely. In this volume, Cherchi and Schroeder (2013) revisit the type material stored in the British Museum (Natural History). Based on their results, *L. aggregatum* is considered as a calcimicrobial crust infested by boring sponges (ichnotaxon *Entobia*).

Another microorganism considered for decades as problematic, *Bacinella*, is studied by Schlagintweit and Bover-Arnal (2013) in Lower Aptian rocks of the western Maestrat Basin (Spain). The authors revise the genus *Bacinella* and the various associated species. *Bacinella* is interpreted as an excavating organism producing branched channels by perforating biogenic hardgrounds. The genus is assigned to the filamentous-septate endolithic algae of the Class Ulvophyceae. Also, the authors consider that almost all the currently reported occurrences of “*Bacinella irregularis*” should not be assigned to this taxon; instead, they represent vesicular crusts that should be defined as bacinellid fabrics.

In an extensive paper, Senowbari-Daryan (2013) investigates representatives of the genus *Tubiphytes* and of some similar organisms from Triassic reefs of the Tethys. The author emphasizes the differences between Paleozoic and Triassic *Tubiphytes* and describes the new taxa *Tubiphytes carnicus*, *T. alcornis*, and *Plexoramea cylindrica*. Additionally, the new genus *Carniphytes* is proposed, as well as two new combinations, *Carniphytes multisiphonatus* and *Plexoramea gracilis*.

Halysis, another organism with debated systematic assignment, is discussed by Frisch et al. (2013). The specimen-rich samples from Upper Ordovician rocks of South China allowed a detailed investigation. The authors offer a 3-D computer model of *Halysis*; virtual sections through the model could be compared with images obtained from actual thin-sections. As a result, this microfossil was reconstructed to consist of parallel, juxtaposed, and partly branched tubes.

In this volume, red algae are the object of a single study (Nebelsick et al. 2013). The authors have investigated Lower Oligocene limestones from Monti Berici (Southern Alps, Italy) in order to document paleoecological changes within a monotonous sedimentary succession. They recognized four carbonate facies types, in which red algae play a significant role. The Corallinaceae content is interpreted in relation to light intensity, hydrodynamic energy, biotic interactions, and substrate stability. The succession of facies suggests asymmetric sea-level changes with rapid regressions and gradual transgressions.

Dasycladalean algae are investigated in several papers that provide significant new paleontological results. Parvizi et al. (2013) describe an interesting association of calcareous algae and microproblematic organisms from the Zagros Mountains (SW Iran). Dasycladaleans dominate the associations; in addition, Gymnocodiaceae, phylloid algae, and microproblematic organisms were identified. The detailed analysis of Epimastoporaceae led to the emendation of the algal genera *Epimastopora* and *Epimastoporella*.

In their paper, Barattolo et al. (2013) provide a new description for *Triploporella remesi*, a dasycladalean alga described more than 100 years ago from Upper Jurassic deposits in the Western Carpathians. The study of the new specimens identified in the Kotouč quarry—the assumed type locality for the species erected by Steinmann in 1903—not only adds significant details to the morphology, but also allowed re-assessing the development of the cyst containers within the lateral ramifications.

Representatives of the genus *Triploporella* from Lower Cretaceous rocks in Romania were studied by Bucur et al. (2013). The authors used this opportunity to review some species previously assigned by various authors to *Triploporella*; according to the current results, they should be either affiliated to other genera through new combinations, or excluded from the genus.

Until recently, dasycladalean algae from Middle Cretaceous deposits of South America were hardly known. In two papers in this volume, Granier et al. (2013a, b) provide some new data on this subject. In one of the papers a new genus, *Brasiliporella*, is introduced based on the study of a well-preserved specimen of former *Holosporella nkossaensis*, for which the new combination *Brasiliporella nkossaensis* is proposed. Moreover, the discussion on the systematic position of the taxon led to the introduction of two new families, Bornetellaceae and Thyrsoporellaceae. At the same time, the families Dasycladaceae and Triploporellaceae were emended. The second paper includes the description of a new species of *Neomeris* (*Neomeris srivastavai*), identified in the same deposits in Brazil. The description is followed by the subdivision of the genus *Neomeris* into three subgenera: *N. (Neomeris)*, *N. (Larvaria)*, and *N. (Drimella)*.

Hosseini et al. (2013) propose another new dasycladalean genus, *Iranella inopinata* n. gen., n. sp. This alga was originally described by Gollestaneh (1965) as *Salpingoporella? inopinata*. For the latter, Hosseini et al. provide a new description and interpretation based on the rich fossil material collected from the Zagros Mountains.

The Upper Cretaceous dasycladalean algae of the Lower Gosau Subgroup, Northern Calcareous Alps, are investigated by Schlagintweit et al. (2013a), who point out their similarity with the Upper Cretaceous dasycladalean flora of

the peri-Adriatic area. The authors regard the scarcity of the association in the Alps as a distinctive feature.

Only a single contribution deals with Cenozoic dasycladaleans (Schlagintweit et al. 2013b). In the Upper Eocene rocks of the Swiss Alps the authors have identified extremely well preserved specimens of *Clypeina helvetica*. These allowed a more detailed description of the species, including biometric data and excellent microscopic images of thin-sections.

Finally, the importance of dasycladaleans for delimiting paleobiogeographic provinces is demonstrated in the paper by Taherpour et al. (2013). Based on the distribution of the dasycladalean species *Kopetdagaria sphaerica* and of the foraminifer *Balkhanian balthica*, the authors define the Carpathian-Cimmerian paleogeographic province. Additionally, detailed stratigraphic and paleoecological information on these microfossils is provided.

In summary, the current volume provides a synthetic panorama on some of the most recent research directions and results concerning the study of calcareous algae. The numerous significant results offer new perspectives for future investigations.

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