



**Rediscovery of the type locality  
of the Udoteacean alga *Boueina hochstetteri* TOULA, 1884,  
in the Lower Cretaceous of Serbia**

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**Abstract:** *Boueina hochstetteri* TOULA (type-species of the genus) was published by TOULA (1884) in the 10<sup>th</sup> report of his travel through the Balkan region. He considered this species to be a problematic organism with uncertain systematic affiliation. Later, STEINMANN (1901) assigned this fossil to the calcareous algae. Our own field work performed in the autumns of 2015 and 2016 in the Piroat area (SE Serbia) led to re-identification of the rich *Boueina hochstetteri* type level, close to the confluence of the Temska and Nišava Rivers, the type locality of TOULA. The rich *Boueina* level is part of a succession of bioclastic limestones. The fragments of *Boueina* thalli are occasionally branched, a feature supporting the interpretation of *Boueina* as an inarticulate udoteacean alga with rare branching.

**Key-words:**

- Calcareous green algae;
- Udoteaceae;
- *Boueina*;
- Lower Cretaceous;
- Carpatho-Balkanides;
- Eastern Serbia

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**Résumé :** *Redécouverte de la localité-type de l'algue udoteacée Boueina hochstetteri TOULA, 1884, dans le Crétacé inférieur de Serbie.*- *Boueina hochstetteri* Toula (espèce-type du genre) a été publiée par TOULA (1884) dans le dixième rapport de son voyage à travers les Balkans. Il a considéré cette espèce comme un organisme problématique à affinité systématique incertaine. Plus tard, STEINMANN (1901) a attribué ce fossile aux algues calcaires. Nos propres recherches sur le terrain à l'automne 2015 et à l'automne 2016 dans la région de Piroat (SE de la Serbie) ont permis de retrouver le niveau-type de *Boueina hochstetteri*, à proximité de la confluence des rivières Temska et Nišava, la localité type de TOULA. Le niveau riche en *Boueina* appartient à une succession de calcaires bioclastiques. Les fragments de thalles de *Boueina* sont parfois ramifiés, une caractéristique qui permet de justifier l'appartenance de *Boueina* aux algues udotéacées inarticulées mais occasionnellement ramifiées.

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**Mots-clefs :**

- Algues vertes calcaires ;
- Udoteacées ;
- *Boueina* ;
- Crétacé inférieur ;
- Carpatho-Balkanides ;
- Serbie orientale

## Introduction

In 1884, Franz TOULA published the 10<sup>th</sup> report of his travel through the Balkan region, more specifically the region between Pirot (SE Serbia) and Sofia (Bulgaria). In the proximity of the Temska and Nišava Rivers confluence, close to Pirot (Serbia), TOULA observed some carbonate deposits which he assigned to the Upper Neocomian. From these deposits, he illustrated and described several fossil organisms. Among others, he found a rock consisting of an agglomeration of calcareous tubes, up to 10 mm in length and 2.5-3.5 mm in diameter, for which he could not provide a clear systematic affiliation. In 1876, TOULA sent samples from this material to Wilhelm von GÜMBEL, who was an expert in "dactyloporides", *i.e.* dasycladaleans, in that time considered to be foraminifers. Following the sample investigation, GÜMBEL decided that this material could not be assigned to the "dactyloporides", but could represent some sponges. Subsequently, TOULA sent further material to Professor Karl von ZITTEL, who first interpreted the fossils as sponges, but then decided that this material is hardly comparable with other known animal or plant rests.

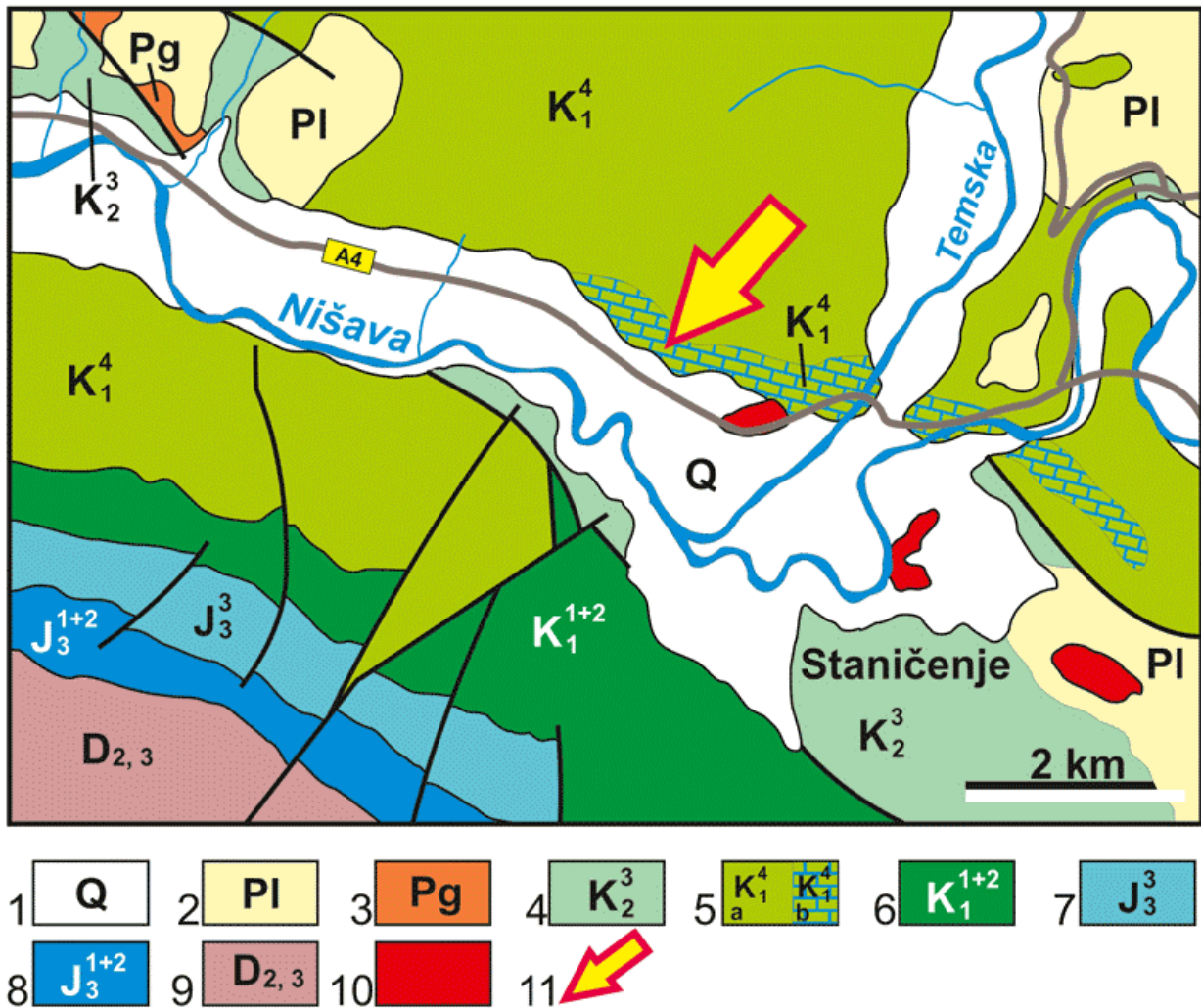
TOULA followed the advice of ZITTEL and assigned a scientific name to this fossil (*Boueina hochstetteri*), despite its problematic systematic affiliation. In 1901, Gustav STEINMANN - who also received part of the original material collected by TOULA, published a paper focusing on the similarities between the inner structure of these tubes and that of *Halimeda* segments. Accordingly, the author stated that *Boueina hochstetteri* TOULA belongs to the Codiacean green algae related to *Halimeda*. Nevertheless, STEINMANN noticed that *Boueina* does not seem to be segmented and probably also not branched - features that distinguished the newly-identified fossil from *Halimeda*. Unfortunately, the type material collected by TOULA seems to have disappeared (destroyed?) in the interval between World War I and II, in the 20<sup>th</sup> century. Later on, *Boueina hochstetteri* was assigned besides other fossil species either to Codiaceans (PIA, 1927), to Udoteaceans (*e.g.*, BASSOULET *et al.*, 1983), or even to Halimedaceans (BUCUR, 1994). Basically, like in the case of the other udoteaceans-halimedaceans, this species was considered to be a segmented green alga.

A recent publication (DE CASTRO *et al.*, 2008) has recalled the discussion about the thallus organization in the *Boueina* species. This review has revived interest in the study of the type material, in order to clarify these aspects.

Studies published in the last decades of the 20<sup>th</sup> century did not mention anymore the type locality for the species, while the profiles studied by TOULA were assumed to be currently covered by soil and vegetation. Everything suggested that the type locality for *Boueina hochstetteri* would be difficult to recover. Luckily, the recent construction works at Niš-Sofia highway have uncovered most of the carbonate deposits in the proximity of the Temska and Nišava Rivers (Fig. 1). In the framework of a collaboration project between the Romanian Academy and the Serbian Academy of Sciences and Arts, during the autumns of 2015 and 2016 we have performed field work in the above-mentioned region. Within a carbonate succession dominated by bioclastic limestones, we have found the level rich in *Boueina hochstetteri*. Undoubtedly, this must represent the same level from where some 130 years ago TOULA had described the mysterious calcareous tubes that he has scientifically named. Our own-collected topo-typic material -- partly illustrated in this work-- will be subsequently used for a review of the species *Boueina hochstetteri* TOULA.

## Geologic framework

The section containing the type locality of *Boueina hochstetteri* TOULA is situated in the central part of the Carpatho-Balkanides which in the Serbian geological literature has different names, *e.g.*, Kučaj Zone (KRSTIĆ & MASLAREVIĆ, 1989, 1990), Kučaj Terrane (KARAMATA *et al.*, 1997) or Getic Nappe (Kučaj-Ljubaš-Sredna Gora Unit) in Getic Units (KRÄUTNER & KRSTIĆ, 2003), *etc.*. It is a continuation of the Reșița-Moldova Nouă Zone of the Romanian South Carpathians and extends to the East Kraishte Unit in SE Serbia and southwestern Bulgaria. This is the largest Alpine unit in the Serbian part of the Carpatho-Balkanides. This unit is made of different Precambrian, Paleozoic, Mesozoic and Neogene igneous, sedimentary, metamorphic and volcano-sedimentary rocks with very complex geological evolution, structural fabrics, particularly in its western part.



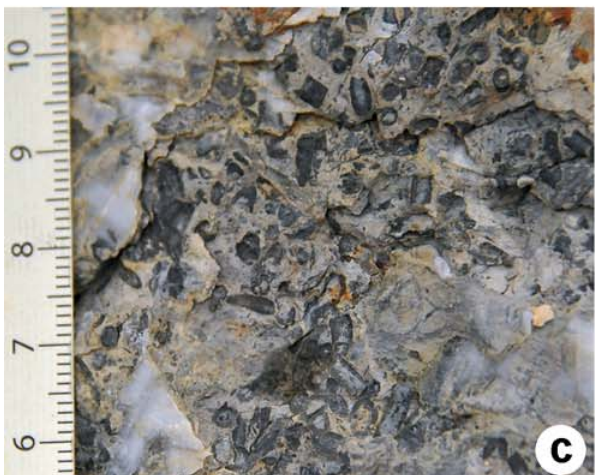
**Figure 1:** Geological map of the area near the confluence of the Temska and Nišava Rivers (Staničenje village). Legend: 1. Quaternary; 2. Pliocene; 3. Paleogene; 4. Upper Cretaceous; 5. Lower Cretaceous (Barremian-Aptian); a, bioclastic limestones; 6. Lower Cretaceous (Berriasian-Hauterivian); 7. Upper Jurassic (Tithonian); 8. Upper Jurassic (Oxfordian-Kimmeridgian); 9. Devonian; 10. Magmatic rocks; 11. Location of the studied section (Redrawn after ANĐELKOVIĆ *et al.*, 1975, and VUJISIĆ *et al.*, 1997).

The Lower Cretaceous part of the sequence has a large extent in the Kučaj Zone, especially in the areas of the following mountains: Beljanica, Kučaj, Ozren, Devica, Svrljiške Planine, Suva Planina, Belava, southwestern and western slopes of Stara Planina, Tresibaba, Grnčar, and Tupižnica. The Lower Cretaceous is represented by shallow-water carbonate platform sediments several hundreds of meters thick, and can be separated into: (a) Valanginian-Hauterivian stratified micritic limestones locally with cherts, marly limestones, marls, (b) Barremian-Lower Aptian (Urgonian facies) massive limestones, marls and oolitic limestones, and (c) Albian glauconite sandstones, sandstones and conglomerates.

Important investigations of the Urgonian sediments in the Eastern Serbia have been made by JANKIČEVIĆ (1978, 1996). On the basis of his study

JANKIČEVIĆ concluded that these Urgonian deposits of upper Barremian and lower-middle Aptian age form a single carbonate-terrigenous unit, named Tupižnica Formation. It consists dominantly of limestones with rudists ("true Urgonian"), bioclastic limestones with orbitolinids, and terrigenous rocks with orbitolinids and different macrofauna (bivalves, gastropods, brachiopods, etc.).

In the Niš-Pirot area, except for older investigations related to the geological mapping (Basic Geological Map, 1:100,000), very few publications exist, documenting Valanginian microfossils from the limestones earlier mapped as Barremian in the Jerma River canyon, south of Pirot (BUCUR *et al.*, 1995). Hauterivian orbitolinids from Kamenica section near Niš (Svrljiške Planine area) were described by POLAVDER (2014).





## The Lower Cretaceous succession in the study section

The study section is located about 10 km north-west from Pirot, close to Staničenje village in the proximity of the confluence of the Temska and Nišava Rivers (coordinates: x 7624319, y 4786680; Fig. 1). The outcrop, a few hundred meters in length and several meters in height (Fig. 2), was created as a result of the Niš-Sofia new highway construction works. In this section, bioclastic and bioclastic-oolitic limestones are interlayered with marls and sandstones (Fig. 3). In the lower part of the carbonate succession, medium-grain limestones represented by bioclastic grainstone with frequent peloids and micritized intraclasts with fragments of bivalves, gastropods, echinoderms and bryozoans, frequent foraminifers and rare fragments of *Boueina* crop out (Pl. 2.F). They are separated by a marly interlayer from the main body of the bioclastic-oolitic limestones - where the extremely rich-*Boueina* level is located.

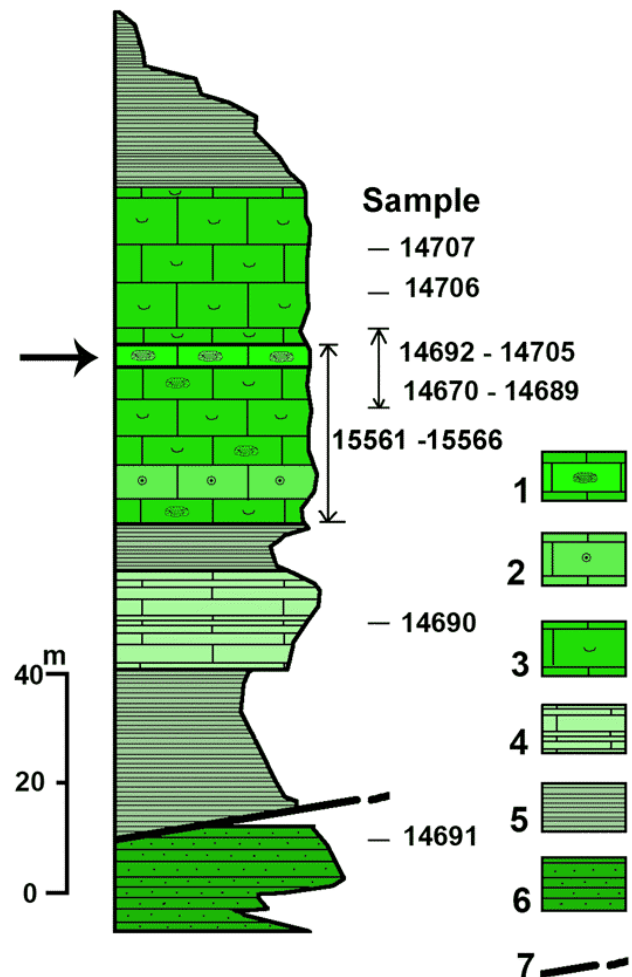
The limestones located at the base of the *Boueina*-rich level contain several microfacies types. These are mainly bioclastic grainstone and packstone/wackestone, sometimes containing frequent ooids (bioclastic-oolitic grainstone) with fragments of bivalves, gastropods and echinoderms, and locally with frequent fragments of bryozoans, brachiopods, corals and sponges, annelid worm tubes, foraminifers and calcareous algae (Pls. 1-2). The micropaleontological association of the whole succession includes benthic foraminifers and calcareous algae. Among the foraminifers occur: *Charentia cuvillieri* NEUMANN (Pl. 3.A), *Paracoskinolina? jourdanensis* (FOURY & MOULLADE) (Pl. 3.B), *?Orbitolinopsis* sp., *Pfenderina globosa* (FOURY) (Pl. 3.C), *Akcaya minuta* (HOFKER), *Everticyclammina* sp., *Coscinophragma* sp., *Ammobaculites* sp., *Mayncina* sp., *Meandrospira* sp., *Coscinoconus* sp., *Neotrocholina* cf. *theodori* (RIGAUD, SCHLAGINTWEIT & BUCUR) (Pl. 3.D), *Lenticulina* sp., miliolids and small textulariaceans. The calcareous algae are represented by: *Actinoporella podolica* (ALTH), "*Cylindroporella*" *elliptica* (BAKALOVA), *Falsolikanella* cf. *nerae* (DRAGASTAN, BUCUR & DEMETER), *Montiella elitzae* (BAKALOVA) (Pl. 4.A), *Zittelina hispanica* MASSE, ARIAS & VILAS (Pl. 4.C), *Suppiluliumaella ellioti* BAKALOVA (Pl. 4.D-E), *Neomeris* sp., *Salpingoporella muehlbergii* (LORENZ) (Pl. 4.F), *Salpingoporella pygmaea* (GÜMBEL), *Similiclypeina conradi* BUCUR, *Terquemella* sp., *Boueina hochstetteri* TOULA, *Arabico-*

◀ **Figure 2:** Outcrop aspects. A) General view of the outcrop containing the limestone bank very rich in *Boueina hochstetteri* (arrow). B) Detail with the *Boueina* bank (arrows). C-D) Weathering surfaces of the limestone showing the agglomeration of *Boueina* thallus fragments.

*dium* sp., *Nipponophycus* sp., *Permocalculus minutus* BUCUR, *Sporolithon rude* (LEMOINE), and rare rivulariacean-type cyanobacteria. The problematicum *Carpathoporella occidentalis* DRAGASTAN is also present.

Overall, the micropaleontological association points to a Barremian-Lower Aptian age. The presence of species *Paracoskinolina? jourdanensis* is more an index for Lower Barremian (FOURY & MOULLADE, 1966; CLAVEL *et al.*, 2010), at least for the succession located at the base of the rich-*Boueina* level.

Both the microfacies types and the micropaleontological association suggest an open carbonate (external) platform environment, with moderate water depth, from a few meters to several tens of meters.



**Figure 3:** Succession of the Lower Cretaceous deposits from the studied outcrop with sample location. Arrow points to the level rich in *Boueina hochstetteri* TOULA. Legend: 1. bioclastic packstone with *Boueina*; 2. bioclastic-oolitic limestone; 3. bioclastic limestone; 4. fine bioclastic-peloidal limestone; 5. marl; 6. sandstone; 7. fault.



## The *Boueina* level

The calcareous *Boueina*-rich level (Figs. 2-3, arrow) is about 1.5-2 m thick. The rock is a packstone, mainly containing fragments of *Boueina hochstetteri* TOULA (Fig. 2.C-D ; Pl. 5.E-F). Additionally, fragments of bivalves, gastropods, echinoderms, bryozoans, annelid worm tubes, fragments of sponges and small coral fragments, rare ooids and intraclasts, rare foraminifers and dasycladalean algae are also present. Among the microfossils identified in association with *Boueina hochstetteri*, we can mention: *Coscinophragma* sp. and *Ichnusella* sp. (among the foraminifers), and *Griphoporella cretacea* (DRAGASTAN) (Pl. 4.B), *Montiella elitzae* (BAKALOVA), *Suppiluliumaella eliotti* (BAKALOVA), and *Salpigoporella pygmaea* (GÜMBEL) (among the dasycladaleans).

*Boueina hochstetteri* clearly dominates the fossil assemblage; it is present as thalli fragments agglomerated as wackestone/packstone (at the base), gradually passing to compact packstone towards the top of the level (Pl. 5). The fragments of *Boueina* thalli can be easily noticed on weathering surfaces (Fig. 2.C-D ; Pl. 5.A-B) and on polished surfaces (Pl. 5.C-D). Thin sections of these samples (Pl. 5.E-F ; Pl. 6) reveal the inner structure of the alga. The inner area consists of medullary filaments (siphons) parallel to the longitudinal axis of the thallus fragments: they gently bend and bifurcate toward the exterior, thus leading to the formation of thin cortical external filaments (siphons) that slightly widen distally. Thallus branching occurs rarely (Pl. 5.A-B), a feature that additionally supports the interpretation of DE CASTRO *et al.* (2008) for the genus *Boueina*: inarticulate thallus with rare branching. Based on the rich material we collected from the type locality, we will provide additional information on *Boueina hochstetteri*'s inner structure and variability in a future publication.

## Conclusion

Outcrops referring to *Boueina hochstetteri* TOULA's type locality have been recently rediscovered, due to construction works for the Niš-Sofia highway (East Serbia, in the Carpatho-Balkanides area). The 1.5-2 m-thick very rich *Boueina* level is located within a dominant bioclastic limestone succession. It corresponds to wackestone-packstone and packstone mainly consisting of fragmented *Boueina* thalli. The thalli are sometimes branched, a feature that supports the interpretation of DE CASTRO *et al.* (2008) who defined *B. hochstetteri* TOULA as an inarticulate udoteacean alga with rare branching.

## Acknowledgements

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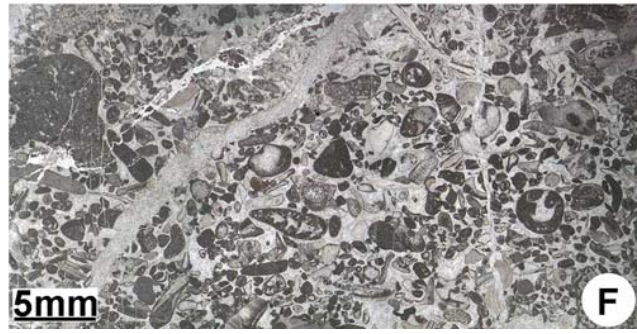
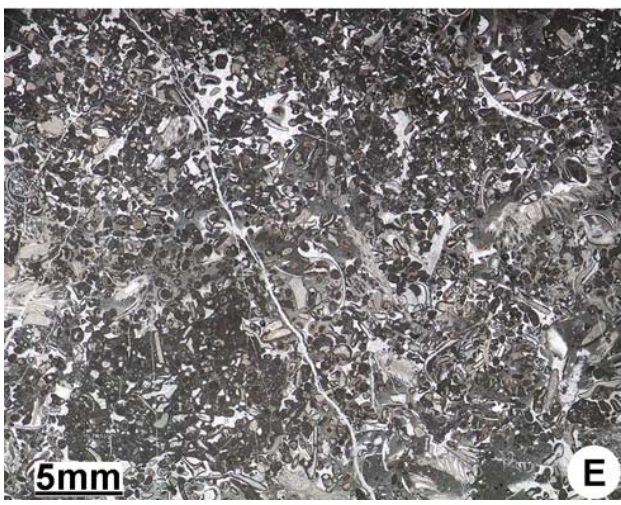
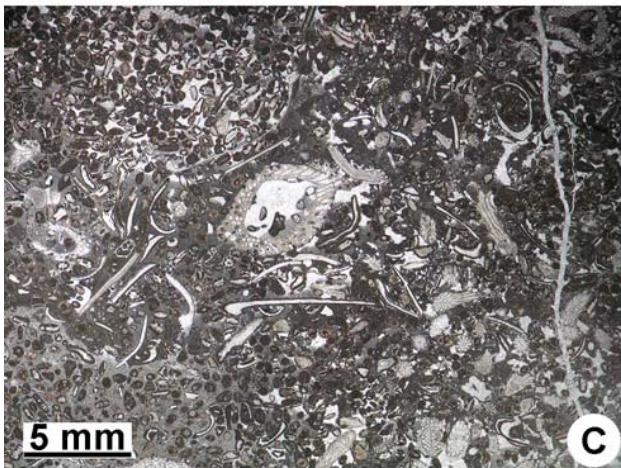
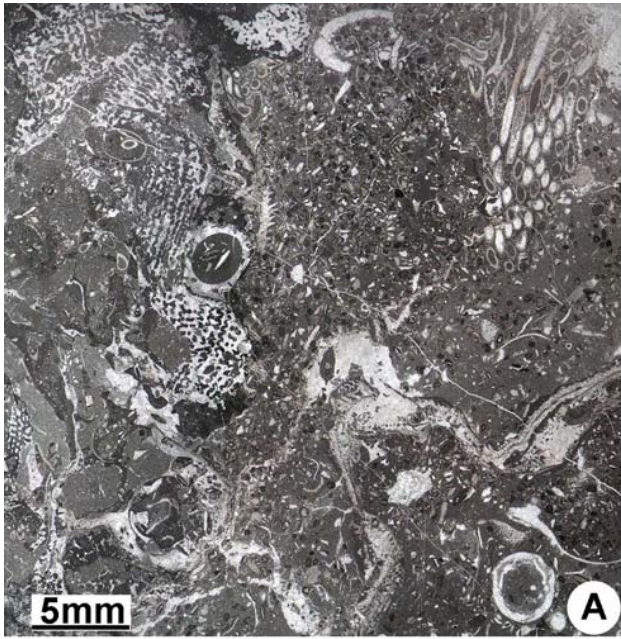


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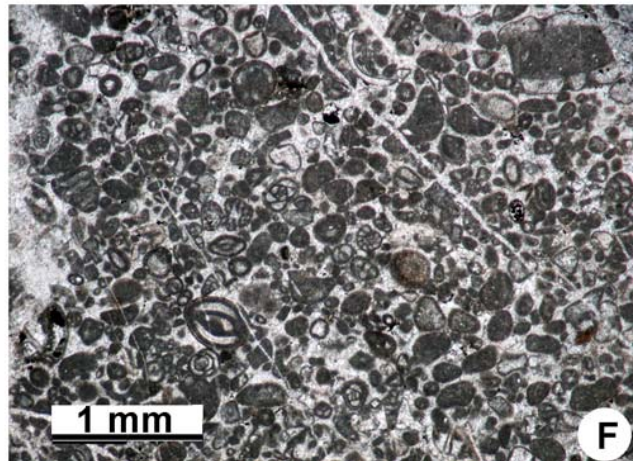
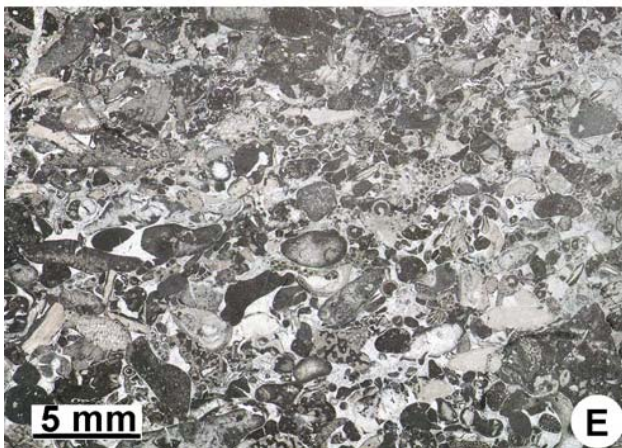
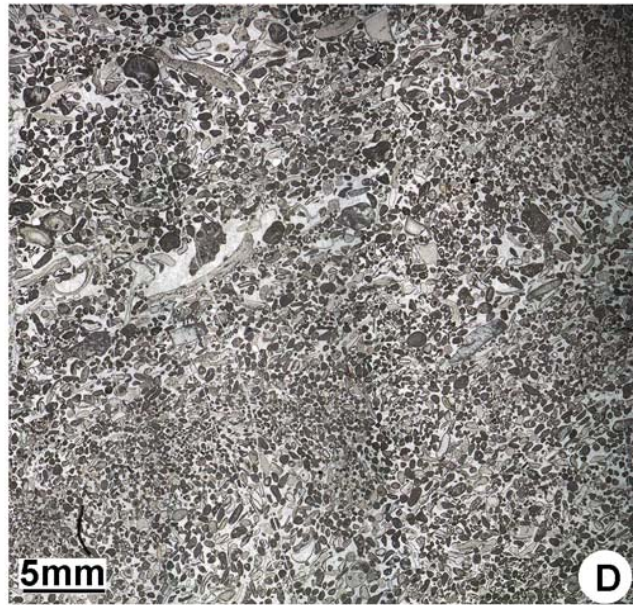
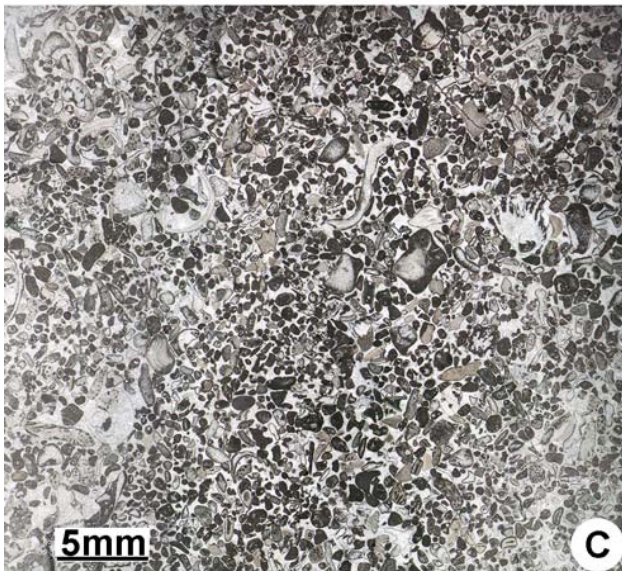
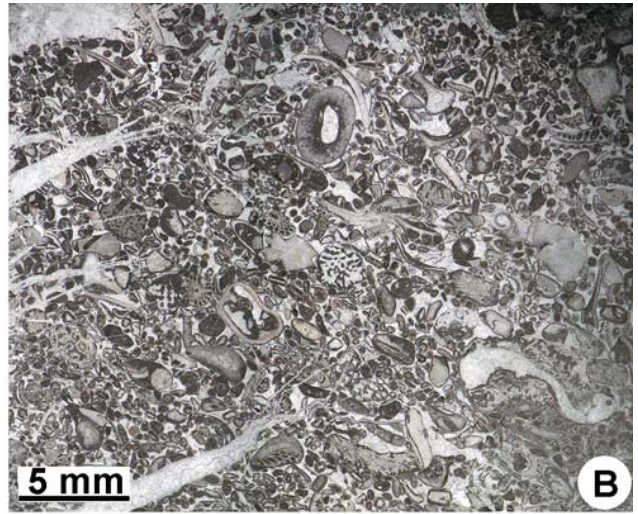
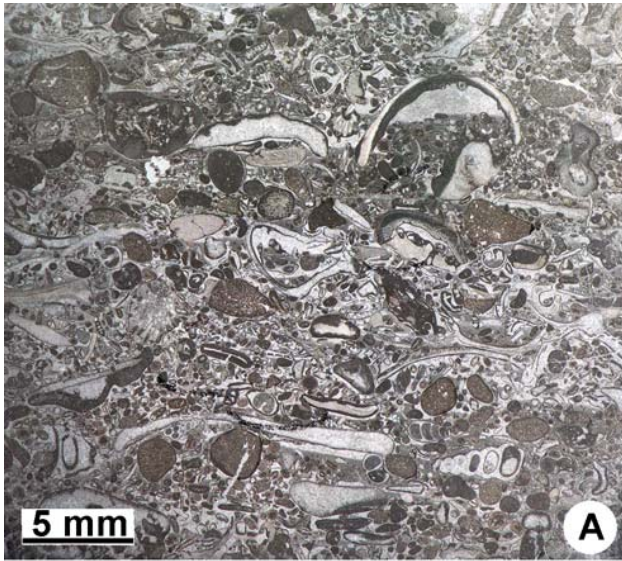
## Plates

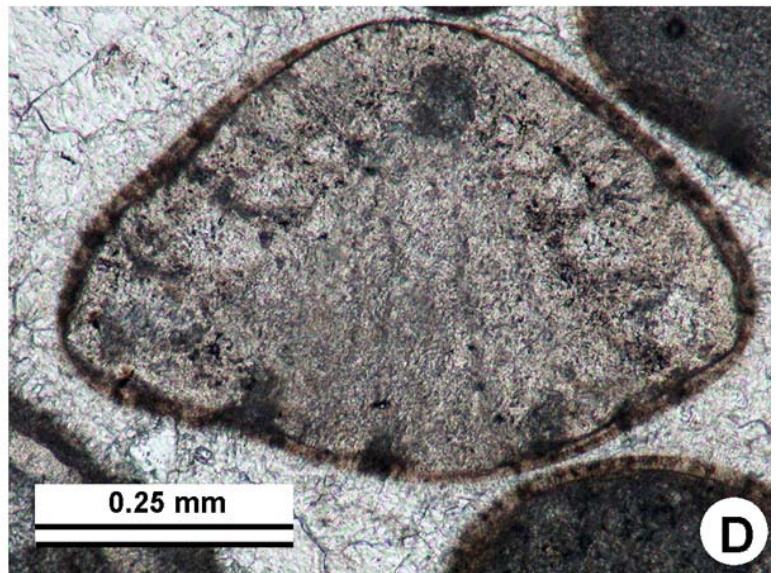
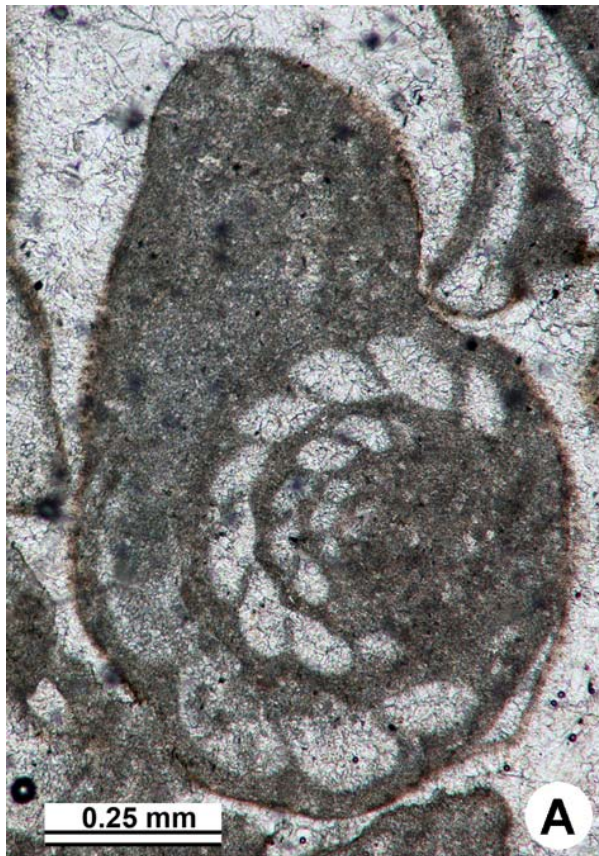
**Plate 1:** Microfacies. A) Wackestone-packstone with large fragments of corals and fragments of bivalves, gastropods, echinoderms, bryozoans and annelid tubes. Sample 14692; B) Wackestone-packstone with large fragments of sponges (Chaetetids and *Cladocoropsis*) and corals, bivalves, bryozoans, and relative frequent fragments of *Boueina*. Arrow points to a lithophagid bivalve boring. Sample 14693; C) Bioclastic-oidic packstone-grainstone with frequent bryozoans, fragments of bivalves, gastropods, echinoderms, foraminifers, and dasycladalean algae. Sample 14689; D) Packstone with large fragments of sponges and corals, bivalves, echinoderms, bryozoans, foraminifers, dasycladalean algae, and rare fragments of *Boueina*. Sample 14687; E) Packstone-grainstone with fragments of sponges, bivalves, gastropods, echinoderms, annelid tubes and bryozoans, rare ooids and intraclasts, foraminifers, and dasycladalean algae. Sample 14688; F) Coarse bioclastic grainstone with fragments of sponges, bivalves, gastropods, echinoderms, bryozoans and annelid tubes, peloids, intraclasts, foraminifers, dasycladalean algae, and rare fragments of udoteacean algae.



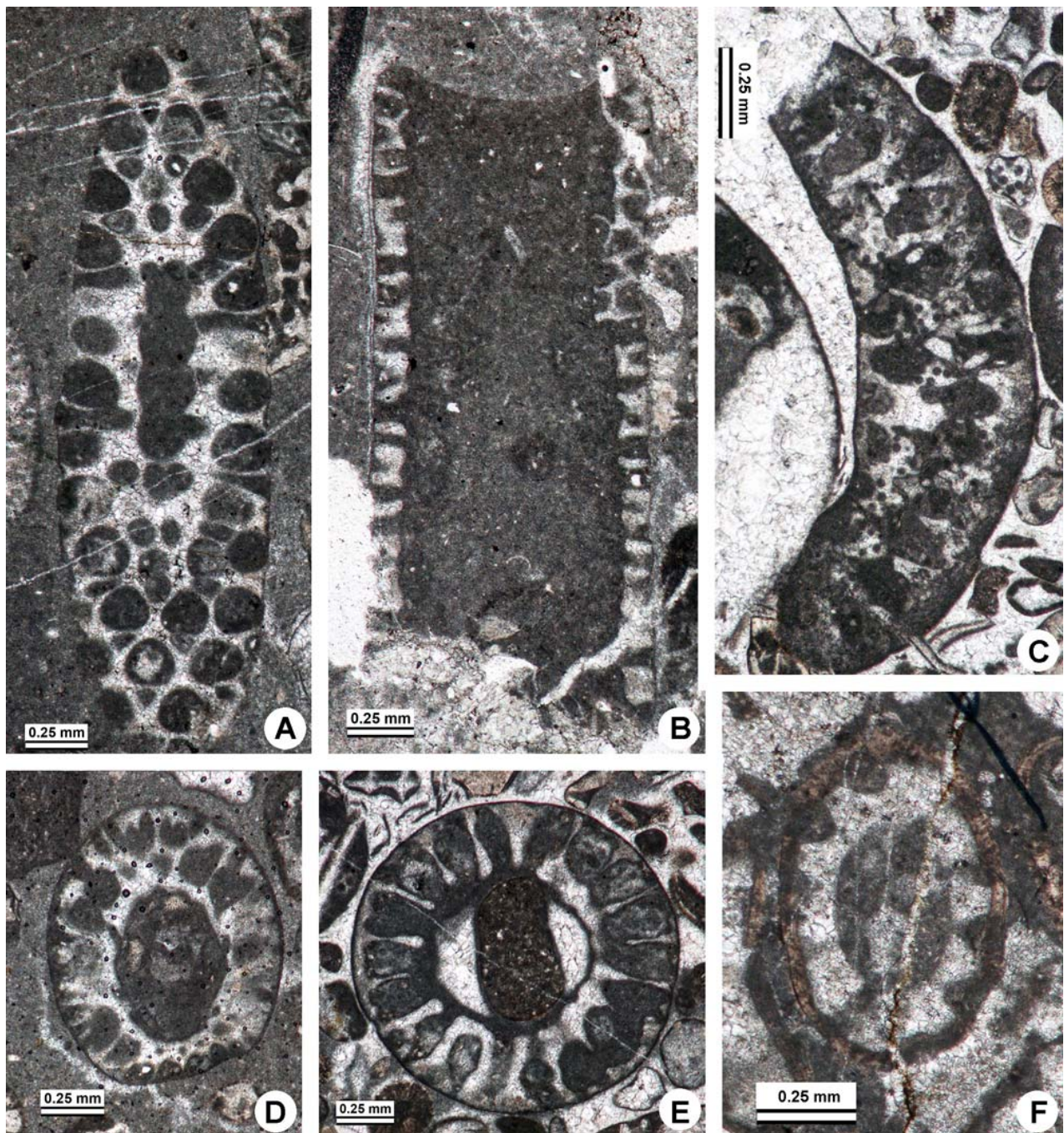


**Plate 2:** Microfacies. A) Coarse bioclastic-intraclastic grainstone with fragments of sponges, bivalves, gastropods, echinoderms, annelid tubes, bryozoans, foraminifers, and dasycladalean algae. Sample 15563; B) Coarse bioclastic grainstone with ooids and fragments of corals, bivalves, gastropods, echinoderms, bryozoans, udoteacean and dasycladalean algae. Sample 14704; C) Bioclastic-peloidal-intraclastic packstone with fragments of bivalves, echinoderms, bryozoans, foraminifers, and dasycladalean algae. Sample 14701; D) Medium-grained bioclastic-peloidal grainstone with micritized intraclasts and fragments of bivalves, gastropods, echinoderms, bryozoans, foraminifers, and udoteacean and dasycladalean algae. Sample 14690; E) Bioclastic grainstone with fragments of sponges, bivalves, gastropods, echinoderms, bryozoans, foraminifers and dasycladalean algae. Sample 14700; F) Peloidal-bioclastic grainstone with frequent miliolid and small textulariacean foraminifers, and rare dasycladalean algae. Sample 15562.

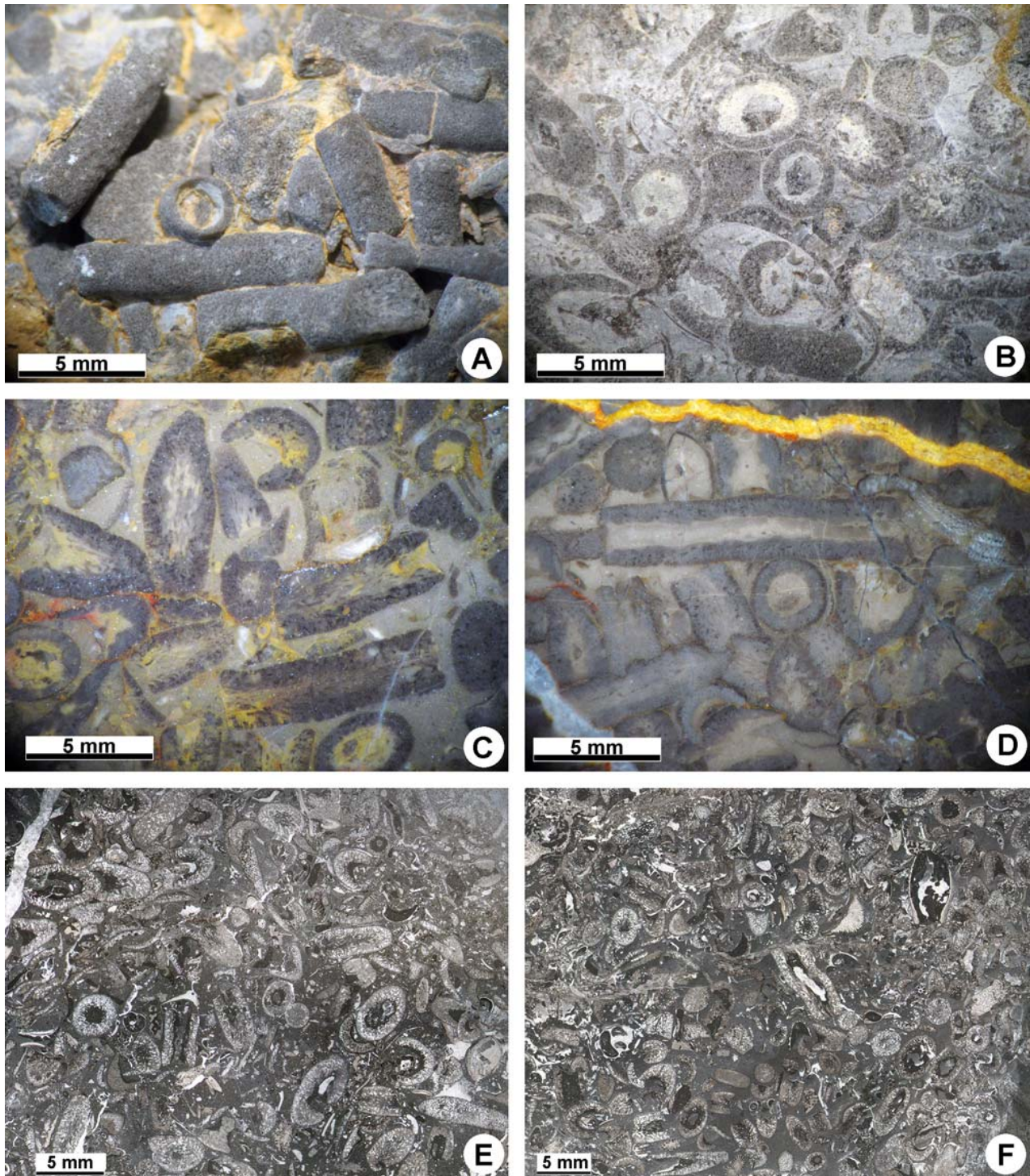




**Plate 3:** Foraminifers. A) *Charentia cuvillieri* NEUMANN. Equatorial section, sample 14690; B) *Paracoskinolina?* *Jourdanensis* (FOURY & MOULLADE). Subaxial section, sample 14700; C) *Pfenderina globosa* FOURY. Oblique section, sample 14690; D) *Neotrocholina* sp. Axial section, sample 14690.



**Plate 4:** Dasycladalean algae. A) *Montiella elitzae* (BAKALOVA). Oblique section, sample 15566; B) *Griphoporella cretacea* (DRAGASTAN). Longitudinal section, sample 14695; C) *Zittelina hispanica* MASSE, ARIAS & VILLAS. Fragment in transverse-oblique section, sample 15563; D-E) *Suppiluliumaella ellioti* BAKALOVA; D) transverse-oblique section, sample 14687; E) transverse section, sample 15563; F) *Salpingoporella muehlbergii* (LORENZ). Oblique section, sample 14688.



**Plate 5:** *Boueina hochstetteri* TOULA. A-B) Thallus fragments on a weathered surface of the rock; A, sample 14695; B, sample FN; C-D) Polished surfaces showing fragments of the thallus in longitudinal, oblique and transverse sections; C, sample 14695; D, sample 14686; E-F) Microfacies with *Boueina* in thin section (*Boueina* packstone); E, sample 14695; F, sample 14676.

► **Plate 6:** *Boueina hochstetteri* TOULA. A) Polished surface showing a branched specimen (arrow). sample 14686; B) A branched specimen of *Boueina hochstetteri* in thin section. Sample 15566; C) Longitudinal section. Sample 15566; D-E) Oblique sections; D, sample 15566; E, sample 14685; F-G) transverse sections; F, sample 14678; G, sample 15566. The medullary filaments (siphons) in longitudinal section in C and in transverse section in F and G, as well as the cortical filaments (siphons) arranged perpendicularly to the external surface are clearly visible in all specimens from B to G.

