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The KALKOWSKY Project - Chapter I

Ooid - stromatoid relationship in a stromatolite from the Maiz Gordo Fm (Argentina)

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Abstract: The comparative study of oolites and stromatolites demonstrates striking similarities between KALKOWSKY's German Triassic material (drawn from the scientific literature) and our Argentinian Paleogene material. However, the latter better illustrates that ooids and stromatoids, hence oolites and stromatolites, which share the same dual (*i.e.*, organic and mineral) nature, are merely the end-members of a continuum of microbial carbonate structures.

Key-words:

- ooid;
- stromatoid;
- microbial carbonates;
- Salta;
- Argentina;
- Paleogene

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Résumé : *Le Projet KALKOWSKY - Chapitre I. La relation ooïde - stromatoïde dans un stromatolithe de la Formation Maiz Gordo (Argentine).-* L'étude comparative d'oolithes et de stromatolithes démontre des similitudes frappantes entre le matériel triasique allemand de KALKOWSKY (d'après des informations disponibles dans la littérature scientifique) et notre matériel paléogène argentin. Cependant, ce dernier est mieux à même d'illustrer qu'ooïdes et stromatoïdes, donc oolithes et stromatolithes, qui partagent la même nature duale, organique et minérale, ne sont que les membres extrêmes d'un ensemble de structures carbonatées d'origine microbienne.

Mots-clefs :

- ooïde ;
- stromatoïde ;
- carbonates microbiens ;
- Salta ;
- Argentine ;
- Paléogène

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1. Introduction

The central idea behind the concept of the KALKOWSKY Project is that much on microbial carbonates can still be learned from the mere petrographic analysis of thin sections.

Most geologists are not familiar with the word "stromatoid", which was first introduced by KALKOWSKY (1908). As an oolite is made of ooids, a stromatolite is made of stromatoids. A stromatoid is merely one of the thin laminae, the accumulation of which creates a stromatolite (MONTY, 1977; KRUMBEIN, 1983; PAUL *et al.*, 2011), *i.e.*, the stromatoids are the building blocks of the stromatolites. The recent reinterpretation of the historical locality of KALKOWSKY, *i.e.*, Heeseberg (Helmstedt, Lower Saxony, Germany), by KÄSBOHRER and KUSS (2021) pushed us to write and publish this contribution in order to share a slightly different opinion on the topic. Although we could not directly study the Lower Triassic German material, a strikingly similar material from an Argentinian Paleogene series was available to us.

2. Material and general setting

The material studied was collected by one of us (P.L.) accompanied by three IFP colleagues (namely Bernard COLLETTA, Jean LETOUZEY, and Roland VIALY) on October 8, 1988. The section they measured crops out at 24°22'23.82"S 64°58' 30.56"W (Province of Jujuy, Argentina), on the eastern side (opposite side) of the junction of road 66 to San Salvador de Jujuy with road 34 from San Pedro de Jujuy to General Güemes and Salta (Fig. 1). This intersection is some 35 km ESE of San Salvador de Jujuy and some 65 km NE of Salta. It is located in the Salta Basin, in a corridor joining its southern Metán-Alemania subbasins to its eastern Lomas de Olmedo subbasin. Green to grey clays dominate the 7 meter thick interval studied, which is ascribed to the Maiz Gordo Fm (MORENO, 1970) of the Santa Barbara Subgroup, Thanetian-Ypresian [Late Paleocene – Early Eocene in age (*e.g.*, DEL PAPA, 1999)]. Since the 1988 field work, the road bank has become overgrown by vegetation and the few limestone beds are hardly visible today. Only two petrographic thin sections were prepared from a piece of rock labelled ARA 288 that comprises both oolitic and stromatolitic facies: The first thin section (ARA 288) is probably lost, the second thin section (AG 288 B) was prepared from an offcut of the first.

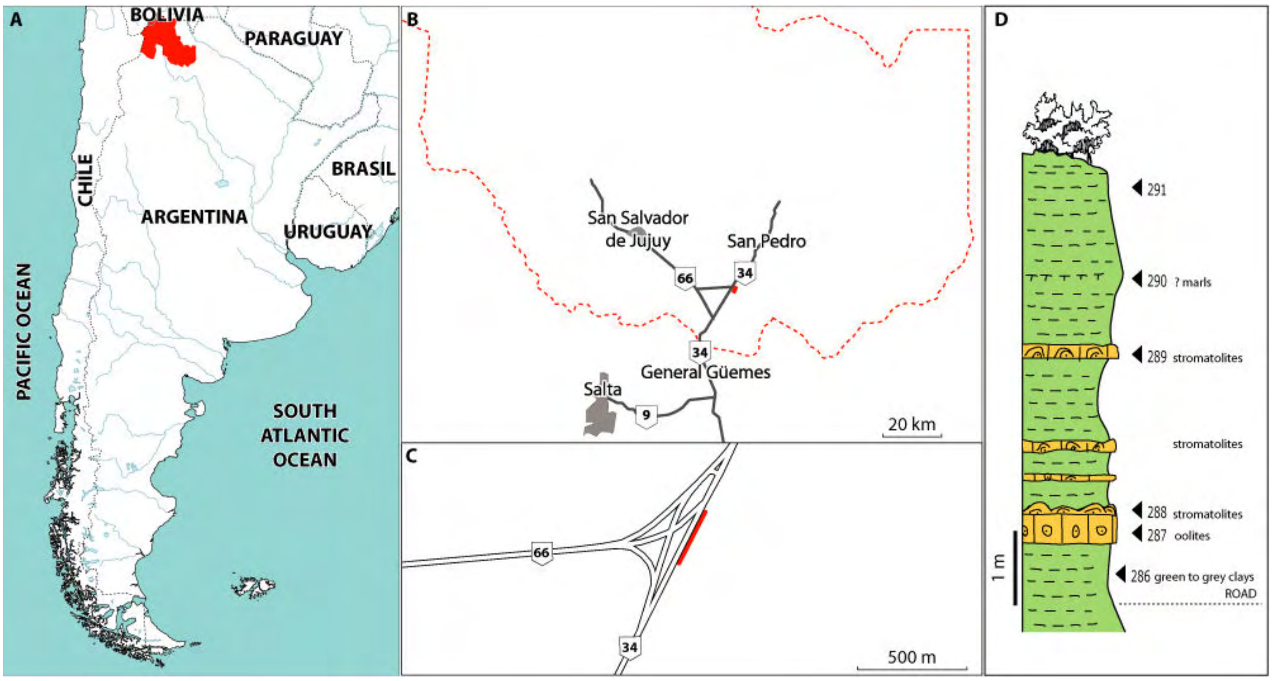

Figure 1: A) Location map of the Province of Jujuy, Argentina. **B)** Map of the southeastern corner of the Province of Jujuy. **C)** Location of the section at the junction of road 66 and road 34. **D)** Schematic lithologic log of the section with the location of the sampling points.

3. Description of ARA 288 and comparison with Kalkowsky's material

The microfacies observed in thin sections ARA 288 (Pl. 1) and AG 288 B are: 1) a grain-supported texture with radial-concentric ooids (="Ooid mit Lagenstruktur" *sensu* Kalkowsky, 1908, Pl. IV, fig. 1), in the lower parts of both thin sections, and 2) a microcolumnar stromatolitic architecture with mud-supported texture between the columns, in their upper parts. In both sections, one counts three columns and three interstitial spaces. This material presents some features similar with those illustrated by Kalkowsky (1908, Pl. IX and Pl. VII, fig. 2) as "Grenze zwischen Oolith und kompaktem Stromatolith mit Wurzeln (links)".

The lower part consists of an oolitic grainstone. Ooids are all about the same size, *i.e.*, 0.5-1.0 mm in diameter, which suggests some mechanical sorting. Most of them are connected by micritic bridges in the manner of some meniscus cements. Some ooids are broken ooids (Pl. 1, figs. l, t), not necessarily hemiooids *sensu* Kalkowsky (Pl. 1, fig. a). The broken ooids *sensu stricto* (Pl. 1, figs. j-k, n, p-q, u) display a fresh cut surface whereas Kalkowsky's hemiooids (1908, Pl. V, fig. 2) are broken ooids with "restoration" / rejuvenation phases. Contrary to Carozzi's (1961) opinion, we do not assume the ooid breakage is due to a mechanical cause. This last point, which is outside the scope of this paper, will be addressed in another publication. Some biooids (Pl. 1, figs. e, o, r-s), *i.e.*, ooids with two nuclei (= "Ooid mit (…) zwei Kernen" *sensu* Kalkowsky, 1908, Pl. IV, fig. 4), polyooids (Pl. 1, fig. v) and even botryoidal lumps (= "Ooidbeutels" *sensu* Kalkowsky, 1908, Pl. V, fig. 4) are also observed. In addition to the ooids, allochems also include a few calcium phosphate fish bones, small (1 to 2 mm in length) subrounded micritic extraclasts, including once-hollow extraclasts (Pl. 1, fig. x), or fibrous sparitic fragments of stromatolites (Pl. 1, fig. y), commonly with a superficial ooidal coating, and larger (commonly more than 1 cm in length) subangular flakes without coating, including mudstones with numerous desiccation cracks (a reworked piece of a ? paleosoil, Pl. 1, fig. w) and fragments of stromatolites. Within this grainy fabric, large drusy-cemented cavities commonly occur and are interpreted here as former keystone vugs (Pl. 1, figs. b-d). It is suggested here that this facies could mark the swash zone on a shore of the Salta giant lake.

The upper part consists of a bind- to bafflestone fabric with a silty and oolitic wackestone trapped in spaces between the microcolumns of the stromatolite. This pattern is quite similar to that illustrated by Kalkowsky (1908, Pl. VI, fig. 2) as "Zwei Äste von Stromatolith mit Lagenstruktur und mit Interstitium". However, there are some discrepancies because, for instance, our stromatolitic columns are made of relatively thick layers with spongiostromate [*], either micritic or spongious, fabrics alternating more or less regularly with thin fibrous sparitic crusts, each of which may pass laterally to a micritic layer. Both types of stromatoids, *i.e.*, the micritic layers and the fibrous sparitic crusts, locally jump from one column to the next and bind the wackestone of the common instertitial space, which makes it possible to evaluate the relative height of a column when the stromatolite was growing. The top of a column rarely exceeds more than 5 mm above the lowest point of its surrounding interstitial spaces. The growth of a column is determined by variation in volume of the spongious layers and, to a minor extend, by trapping of some formerly aragonitic bioclasts (? Gastropods) and fewer ooids.

4. Ooid - stromatoid relationship

The historical locality of Kalkowsky, *i.e.*, Heeseberg in Germany, was recently revisited by Käsbohrer and Kuss (2021). Although much was expected from their study, it includes some interpretations that, in our opinion, could be erroneous. For instance, these authors (Käsbohrer & Kuss, 2021) state that their stromatolitic crusts (LFT2) were formed by "light sparite laminae" of abiotic origin. However, it looks like the fibrous sparitic crusts in their material (as in our material) are rarely hyaline but commonly slightly colored, as some ooid cortices are (Pl. 2, figs. m-q); hence they are not a palisadic fibrous cement. This feature suggests that organic matter is embedded in the calcite crystals and it points to a biological origin or influence (Granier, 2020). In the caption of their Figure 15.D, Käsbohrer and Kuss (2021) describe "Syntaxial overgrowths by fibrous calcite (...) on ooids with radially arranged cortices" (*op. cit.*). However, the corresponding photomicrograph shows a very narrow field of view of a zone affected by pressure-solution joints. In our opinion, their "syntaxial overgrowth" interpretation should be discarded because growth breaks in the concentric cortices of the ooids are also observed in the subsequent fibrous sparitic crusts. Actually, it is here assumed that such photomicrographs capture a genuine transition from ooids to stromatoids. In the same figure caption (Käsbohrer & Kuss, 2021, Fig. 15.E), these authors state that "Debris with (broken) ooids (...) and angular quartz grains (…) fill cavities (…) at the top of stromatolitic crusts" whereas, in our opinion, their so-called "broken ooids" are rather ooids with sutured boundaries and their alleged "cavity" is a thin dolomitic layer sandwiched between stylolitic joints.

[*] These are spongiostromate microstructures *sensu* Monty, 1981 (derived from the Spongiostromata Pia in Hirmer, 1927).

Back to KALKOWSKY (1908), he was the first to conceive the idea that the ooids result from the activity of organisms related to the stromatolites, *i.e.*, to microbes, an opinion that was not accepted by most (*e.g.*, CAROZZI, 1964) until recently (*e.g.*, BREHM *et al.*, 2004; O'REILLY *et al.*, 2017; DIAZ & EBERLI, 2019, and references therein). What he did not see in his material is a very small detail enlightening the true nature of the ooid - stromatoid relationship. For instance, it is possible that he interpreted as "Teil eines Ooidbeutels mit Fortwachsung des Ooide in der Beutelhülle", *i.e.*, botryoidal lumps (KALKOWSKY, 1908, Pl. V, fig. 3), what could be seen as the genuine transition from oolite to stromatolite, *i.e.*, from ooids to stromatoids. He also documents the transition from ooids to the fibrous sparitic crusts of a botryoidal lump (KALKOWSKY, 1908, Pl. V, fig. 4) and obviously the same reasoning can apply to the transition from ooids to the fibrous sparitic crusts of stromatoids. As already summarized by PAUL *et al.* (2011) and earlier by KRUMBEIN (1983), KALKOWSKY "regarded 'Ooids' and 'Stromatoids' as end members of a continuum, with 'poly-ooids' and 'Ooid bags' as intermediate stages".

As a matter of fact, in our Argentinian material, we do observe genuine cases of such a transition from ooids to stromatoids (Pl. 1, figs. f-i, m; Pl. 2, figs. m-q). Such features cannot be interpreted as "Syntaxial overgrowths by fibrous calcite (...) on ooids with radially arranged cortices" as suggested by KÄSBOHRER and KUSS (2021) because, contrary to their photomicrograph (*op. cit.*, Fig. 15.D), our fibrous sparitic stromatoids clearly extend laterally and occasionally change gradually into micritic stromatoids (Pl. 2, figs. m-r) as reported earlier.

5. Conclusion

Having both being deposited in giant paleolakes, KALKOWSKY's German Triassic material and our Argentinian Paleogene material present striking similarities. However, the continuum from ooids to biooids, polyooids, botryoidal lumps, and stromatoids is better documented by our Argentinian material. Amongst the discrete stromatoids, those forming fibrous sparitic laminae clearly extend laterally, where they eventually gradually change into micritic stromatoids. The continuum is working both ways, which implies that, as anticipated by KALKOWSKY (1908), both stromatoids and ooids inherently share the same dual nature, organic and mineral, and the same microbial origin.

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Plates

Plate 1: Photomicrograph of thin section ARA 288 (probably lost) with enlargements of some details of interests. **a)** hemiooid with a broken ooid nucleus; **b-d)** keystone vugs; **e, o, r-s)** biooids; **f-i, m)** transition from an ooid to fibrous sparitic stromatoids; **j-k, n, p-q, u)** broken ooids; **l, t)** partly broken ooids; **v)** polyooids; **w)** detail of a large subangular mudstone flakes with numerous desiccation cracks; **x)** hollow micritic extraclast, possibly after the spongiostromate coating of an algal thallus or a small plant stem; **y)** fibrous sparitic fragment of stromatolitic crusts. Graphical scale bar of the photomicrograph = 5 mm; graphical scale bar for the details = 1 mm.

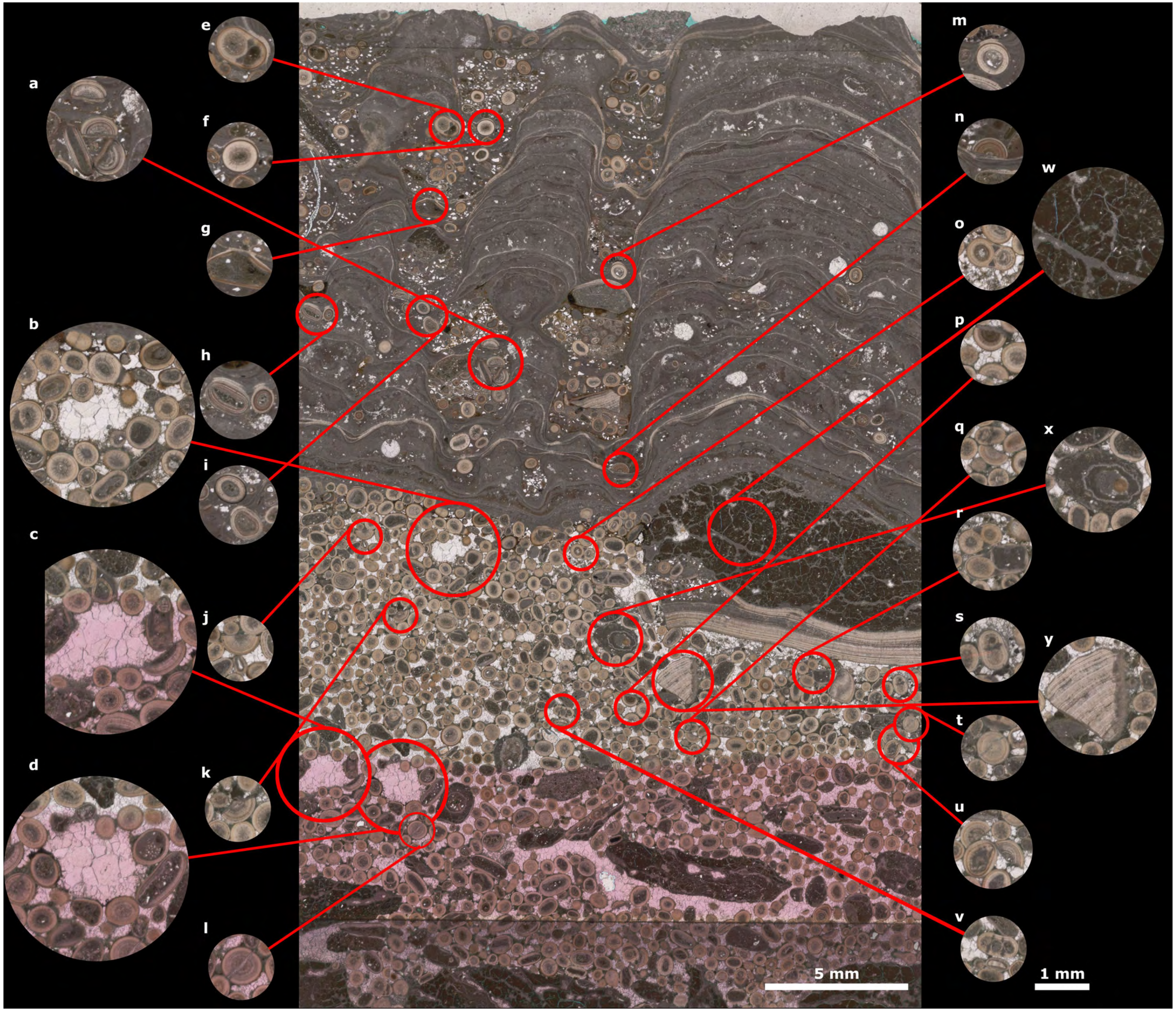
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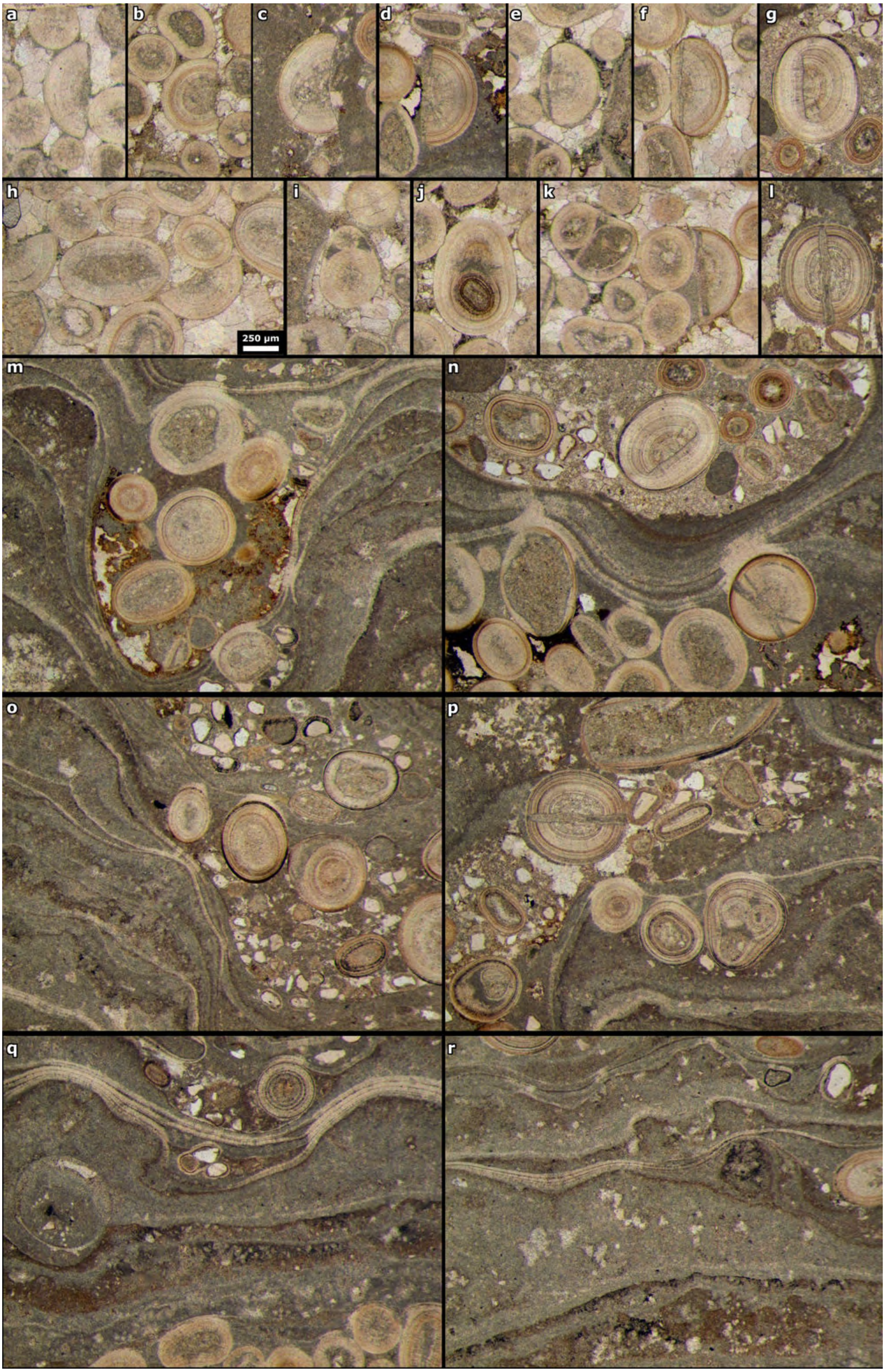
Plate 2: Photomicrographs of thin section AG 288 B. **a-c, h)** broken ooids; **d-f)** partly regenerated broken ooids; **g)** hemiooid (see fig. n); **i-j)** biooids; **k)** biooid with a lump of ooids; **l)** interrupted ooid breakage (see fig. p); **m-q)** transition from ooids to fibrous sparitic stromatoids. Note the gradual lateral change of the fibrous sparitic laminae to micritic stromatoids; **r)** combination of spongiostomate, micritic and spongious, fabrics with fibrous sparitic laminae. Graphical scale bar for all photomicrographs = 250 µm.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