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The Aptian-Albian of the Costa Blanca (SE Spain): Implications for identifying the Aptian/Albian boundary in the neritic zone within the Tethys realm

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Abstract: The Aptian-Albian interval of the Costa Blanca (SE Spain) has been studied to provide new insights into the evolution of the neritic domain of carbonate platforms in the Tethys. Three areas have been re-examined: Serra Gelada, Puig Campana, and Cabeçó d'Or. The biozonations of large benthic foraminifers (LBF) have been revised based on ammonite biostratigraphy. Updated ammonite datings and stratigraphic revisions reveal that several LBF and calcareous algae (CA) taxa previously attributed to the late Aptian actually originated in the early Albian. These findings correct and refine the calibration of LBF and CA biozones and ranges with standard ammonite zones. Furthermore, the identification of a significant local hiatus during the middle Albian at Cabeçó d'Or is likely linked to halokinesis.

Keywords:

- Alicante;
- Aptian;
- Albian;
- large benthic foraminifers;
- calcareous algae;
- ammonites;
- biozones

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Résumé : *L'Aptien-Albien de la Costa Blanca (sud-est de l'Espagne) : Implications pour l'identification de la limite Aptien/Albien en zone néritique dans le domaine téthysien.-* L'intervalle Aptien-Albien de la Costa Blanca (sud-est de l'Espagne) a été étudié afin de fournir de nouvelles perspectives sur l'évolution du domaine néritique des plates-formes carbonatées dans la Téthys. Trois secteurs ont été réexaminés : Serra Gelada, Puig Campana et Cabeçó d'Or. Les biozonations de grands foraminifères benthiques (LBF) ont été révisées sur la base de la biostratigraphie des ammonites. Les datations par ammonites mises à jour et les révisions stratigraphiques révèlent que plusieurs taxons de LBF et d'algues calcaires (AC), auparavant attribués à l'Aptien supérieur, sont en réalité apparus à l'Albien inférieur. Ces résultats corrigent et affinent la calibration des biozones et des répartitions stratigraphiques des LBF et des AC sur la zonation standardisée des ammonites. En outre, une importante lacune locale identifiée au cours de l'Albien moyen au Cabeçó d'Or est probablement liée à l'halocinèse.

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- Alicante ;
- Aptien ;
- Albien ;
- grands foraminifères benthiques ;
- algues calcaires ;
- ammonites ;
- biozones

1. Introduction

Currently, the Lower Cretaceous ranges and biozonations of large benthic foraminifers are still based on early, partially empirical, biozonal schemes proposed by SCHROEDER (1963) and FOURCADE (1967, 1970; here: Fig. 1.A) more than half a century ago. Up until the 1980s and even the 1990s, several authors (*e.g.*, PEYBERNÈS, 1976; here: Fig. 1.B; GARCÍA HERNÁNDEZ, 1978; JAFFREZO, 1980; MASSE *et al.*, 1992) refined the original biozonation, eventually introducing some regional schemes that incorporated a few endemic species. These authors almost reached an agreement regarding the relative ranges of most key taxa, including overlaps (or lack thereof) and the relative orders of both first and last occurrences. However, no significant progress has been made since then in calibrating these total ranges and related biozones to the ammonite standard scale (SZIVES *et al.*, 2024).

Exposures of Lower Cretaceous strata in the Costa Blanca (Province of Alicante, SE Spain: Fig. 2) are rather scattered on the 1:50,000 scale geological maps of Alicante (872), Altea/Benidorm (848), Elda (871), and Villajoyosa (847). Among these areas, Serra Gelada (Fig. 3), Puig Campana (Fig. 4), and/or Cabeçó d'Or (Fig. 5) have been investigated to varying extents by numerous researchers since the pioneering work of NICKLÈS in 1892 (*e.g.*, AZÉMA, 1977; ESTÉVEZ *et al.*, 1984; and the first author: GRANIER, 1987). These three areas form the core of this new study, which focuses exclusively on the Aptian-Albian interval, comprising both ammonite-rich facies and carbonate platform facies with large benthic foraminifers (LBF) and calcareous algae (CA).

According to second author (E.R.), some ammonites collected by the first author (B.R.C.G.) in the eastern Cabeçó d'Or area, which were initially assigned to early Aptian and middle Albian ages, should be reassigned to the late Aptian and the late Albian, respectively. These biostratigraphic observations warrant a revision of earlier conclusions because they imply that the correlation scheme for the Aptian-Albian interval in the Costa Blanca, initially proposed by the first author (GRANIER, 1987: Fig. 55; 1988: Fig. 1), requires at least slight adjustments. Similarly, as noted by GRANIER and PERTHUISOT (2009), the wider lithostratigraphic correlation scheme of CASTRO *et al.* (2001, 2008) for the eastern Prebetic Zone erroneously considers the lower Albian strata at Serra Gelada (*e.g.*, '*Cylindroporella* oolithes', 'coral biolithites', and 'rudistid limestones') as a member of the non-coeval upper Aptian Seguili Formation.

Finally, given the lack or scarcity of ammonite data in most earlier works on the large benthic foraminifers - LBF (*e.g.*, FOURCADE, 1970; here: Fig. 1.A; PEYBERNÈS, 1976; here: Fig. 1.B; GARCÍA HERNÁNDEZ, 1978; JAFFREZO, 1980; MASSE *et al.*, 1992), these revised ammonite datings call into question the reliability of the calibration of the Aptian-Albian biozones or that of the LBF-specific ranges on the standard ammonite biozones (SZIVES *et al.*, 2024). One goal of this paper is to replace the empirical approach to LBF biozones (which may also incorporate certain phycological proxies) with a more pragmatic approach by calibrating their stratigraphic ranges against the ammonite scale.

2. The foundations of the Aptian-Albian biozones based on large benthic foraminifers

SCHROEDER (1963, p. 323) and FOURCADE (1967, p. 844) are the inventors of a set of biozones based on large benthic foraminifers (LBF) including for the latter from base to top:

a) the *Pseudochoffatella cuvillieri* biozone, the original definition of which is: 'This biozone, of reduced thickness, constitutes an excellent marker level that I place in the upper Aptian; however, it is not excluded that it may extend partially into the Albian. *Simplorbitolina manasi* CIRY et RAT, as well as *Mesorbitolina texana-texana* (ROEMER), are also found there' [translated from the French in FOURCADE, 1967: 'Cette biozone, d'épaisseur réduite, constitue un excellent niveau repère que nous situons dans l'Aptien supérieur ; il n'est cependant pas exclu qu'elle puisse s'étendre en partie dans l'Albien. On y rencontre également *Simplorbitolina manasi* CIRY et RAT, ainsi que des *Mesorbitolina texana-texana* (ROEMER)'].

b) the *Simplorbitolina manasi* biozone, the definition of which is: 'Generally poor in fossils, it has until now been characterized only by this foraminifer and *Mesorbitolina texana-texana*. We assign this biozone to the lower Albian' [translated from the French in FOURCADE, 1967: 'Généralement peu fossilifère, elle n'est caractérisée jusqu'à maintenant que par ce Foraminifère et *Mesorbitolina texana-texana*. Nous rattachons cette biozone à l'Albien inférieur'].

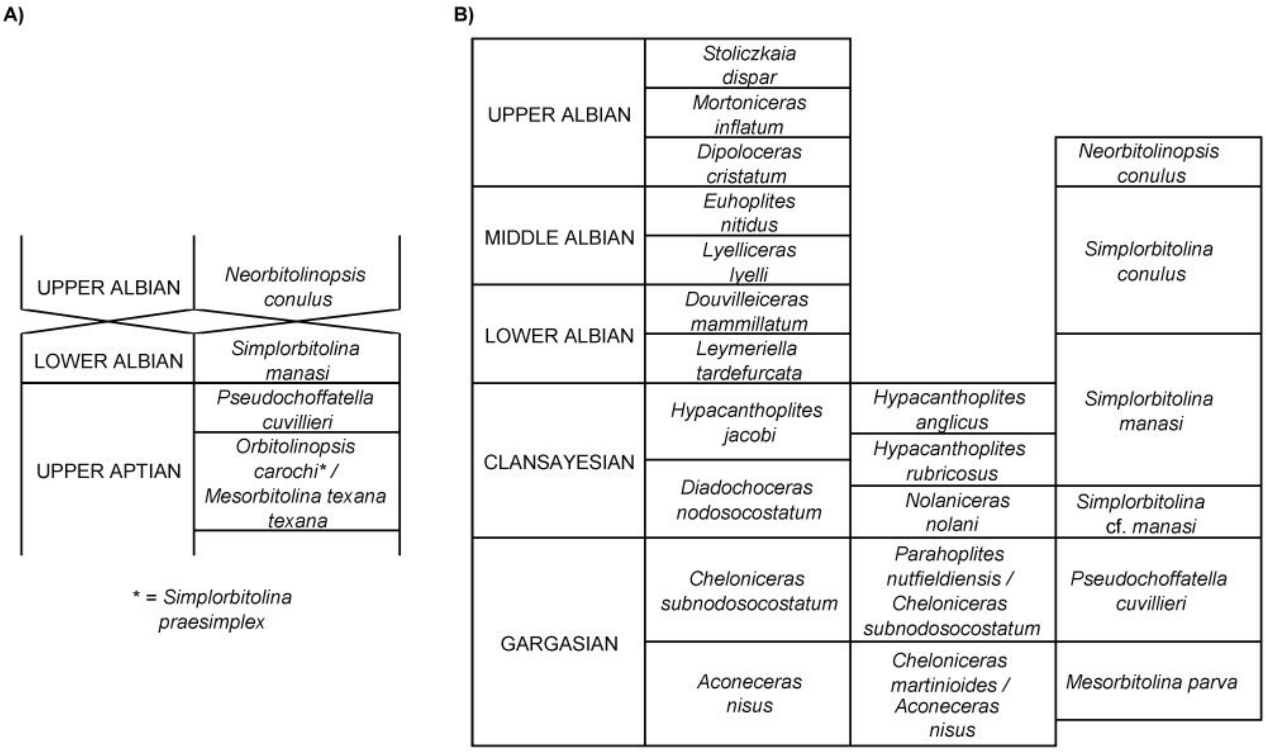

Figure 1: Pre-existing large benthic foraminifer - LBF biozonal schemes: A) FOURCADE, 1970; B) PEYBERNÈS, 1976.

c) the *Neorbitolinopsis conulus* biozone, the definition of which is: 'This biozone begins a few meters above levels with ammonites (*Knemiceras*, which can be compared to *K. deserti* DOUVILLÉ and *K. gracile* MAHMOUD, which in Algeria characterize the lower Albian). The foraminifer that characterizes this biozone is accompanied by an assemblage including *Mesorbitolina texana-texana*, *Cuneolina* gr. *pavonia-parva* HENSON, and *Trocholina* gr. *lenticularis* HENSON' [translated from the French in FOURCADE, 1967: 'Cette biozone débute quelques mètres au-dessus de niveaux à Ammonites (*Knemiceras* que l'on peut rapprocher de *K. deserti* DOUVILLÉ et de *K. gracile* MAHMOUD qui en Algérie caractérisent l'Albien inférieur). Le Foraminifère, qui caractérise cette biozone, est accompagné d'un cortège comprenant : *Mesorbitolina texana-texana*, *Cuneolina* gr. *pavonia-parva* HENSON, *Trocholina* gr. *lenticularis* HENSON'].

Regarding the *Pseudochoffatella cuvillieri* biozone, FOURCADE (1970: p. 131) wrote 'I hypothesize that this zone (…) is situated in the upper Aptian. (…) However, the precise age remains uncertain due to the inability to correlate it with an ammonite level' [translated from the French: 'nous situons à titre d'hypothèse cette zone (…) dans l'Aptien supérieur. (…) Il subsiste toutefois le problème de son âge précis, faute d'avoir pu le relier à un niveau à ammonites'].

FOURCADE (1967, 1970) also stressed that *Simplorbitolina manasi* was already present in the *Pseudochoffatella cuvillieri* biozone. The stratigraphic range of this species was considered to extend downward into the upper Aptian. This last hypothesis was not questioned until now. However, a valid alternative could have been to consider that both *Simplorbitolina manasi* and *Pseudochoffatella cuvillieri* lived in the early Albian, not in late Aptian times. The range overlap of both species is not necessarily well documented in early publications because the definition of the species *Simplorbitolina manasi* CIRY & RAT, changed over time, notably with the introduction of new species.

Here, we will examine a pragmatic approach to revising SCHROEDER's and FOURCADE's biozones, which were sometimes based on empirical methods and conclusions.

3. Aptian-Albian sequences along a part of the Mediterranean coast of Alicante

This chapter provides a summary of the lithostratigraphy and biostratigraphy of Serra Gelada, Puig Campana, and Cabeçó d'Or, the three key areas forming the core of the study. All descriptions start at the base of the sedimentary sequences and move upwards.

At Serra Gelada (Fig. 3), the sedimentary sequence begins above the Jurassic limestones (possibly including Berriasian strata at their uppermost part: Fig. 3.C), with a condensed interval less than 0.5 meter thick, characterized by ferruginous ooids and oncoids floating in a calcareous muddy matrix (GRANIER, 1987). It spans part of the Valanginian to lower Aptian interval and contains numerous late Barremian and early Aptian ammonites (*e.g.*, *Deshayesites deshayesi* Zone). This condensed interval is overlain by a unit approximately 150 meters thick, containing early and late Aptian ammonites and, as evidenced

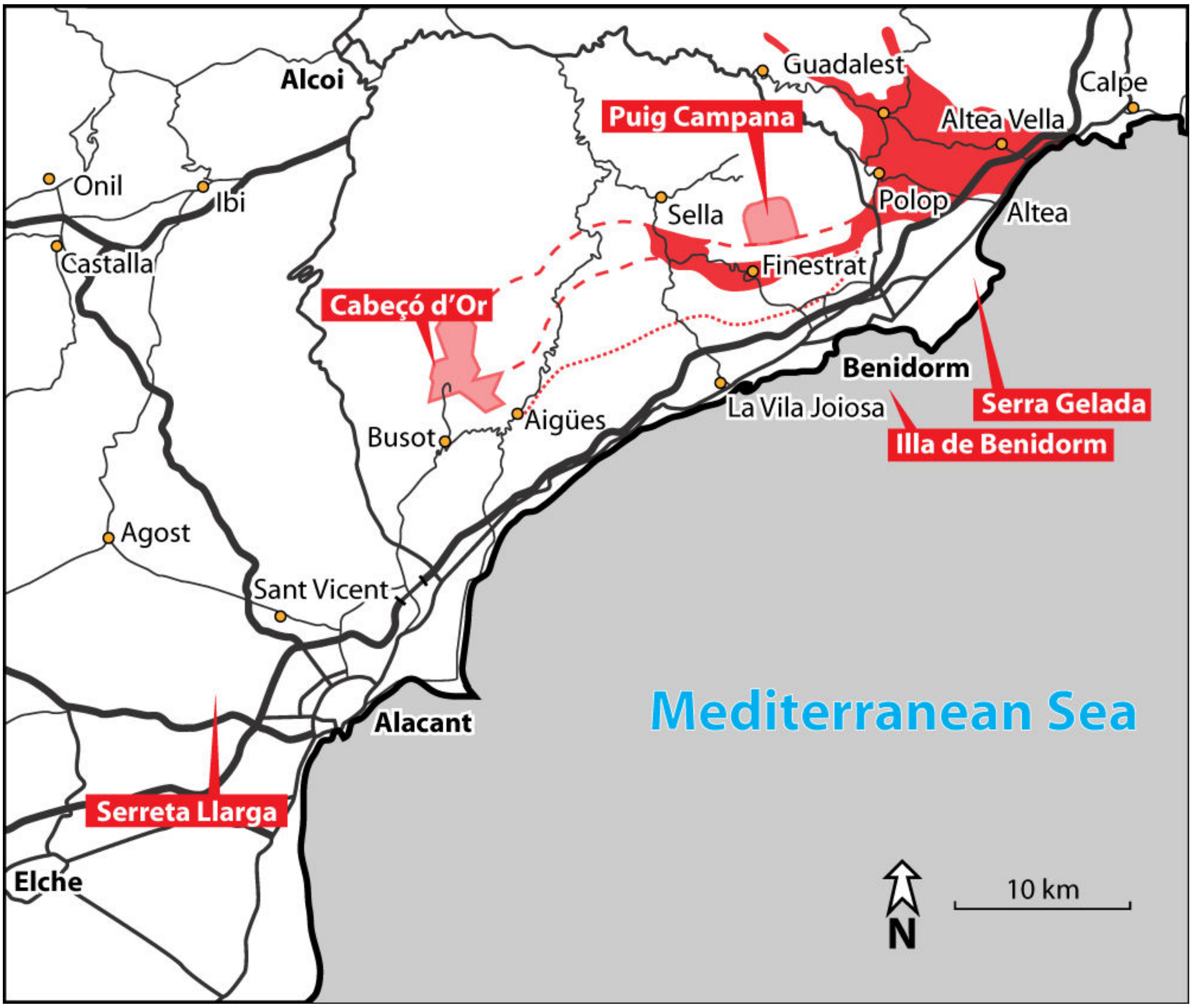

Figure 2: Location map with key localities of the Costa Blanca (Province of Alicante, SE Spain): Cabeçó d'Or (Sanatorio section), Puig Campana (Cluse, Realet d'Alt, and Rafel sections), Serra Gelada (Morro San Jordi, Punta de les Caletes, Relais, Calle Dos Callas, and Camí del Far sections), Illa de Benidorm, and Serreta Llarga.

here for the first time, early Albian ammonites (HL 60). This unit consists of a lower succession composed of alternating argillaceous limestones and marls, and an upper succession that is predominantly marly. The next unit consists of roughly 150 meters of 'siltstones and calcisiltites with *Favusella*' [*Favusella washitensis* (Carsey, 1926): Pl. 1, figs. A-E, J-L, N-P, X-Y], forming the main seaside cliff of Serra Gelada (Fig. 3.D). This interval is followed by a unit, approximately 90 meters thick, consisting of '*Cylindroporella* oolithes' (*Cylindroporella barnesii* Johnson, 1954; here: Pl. 2, figs. F, K-L) and 'coral biolithites'. The abraded tops of these bioherms pass laterally into bored hardgrounds (Fig. 6.A-D). Calcareous microfossils identified in thin sections include *Epistomina* spp. [Relais 1 (HL 704) - Relais 13 (HL 726); Pl. 3, fig. F], *Sabaudia minuta* (Hofker, 1965), *Pseudochoffatella cuvillieri* Deloffre, 1961 [Relais 12 (HL 722); Pl. 4, fig. C], *Mesorbitolina texana* (Roemer, 1849) [*e.g.*, Relais 7 (HL 709); Pl. 5, figs. A-D, L, R-S], *Mesorbitolina birmanica* Sahni, 1937 [*e.g.*, Carabiniers 1 (HL 72); Pl. 5, figs. E-K; Pl. 6, fig. G], and *Agardhiellopsis cretacea* Lemoine, 1966 (Cueva de la ballena, HL 52). Except for *Epistomina* spp. and *Mesorbitolina texana*, these microfossils are also present in the next unit, which consists of approximately 20 meters of 'rudistid limestones', the top of which marks the maximum of the progradation of this carbonate platform. According to Granier (1987) and Granier and Perthuisot (2009), these microfossil assemblages are characteristic of the lower Albian, whereas Castro *et al.* (2008) identify all the units overlying the Aptian marls as the Helada Member of their Seguilí Formation and ascribe this interval, more than 250 meters thick, to the late Aptian. The next unit corresponds to the beginning of a transgression; it consists of an alternation of 'orbitolinid calcarenites and marls', approximately 200 meters thick according to Giannetti *et al.* (2014). Castro *et al.* (2008) identify this last unit as their Sácaras Formation and its lower boundary as the Aptian/Albian boundary.

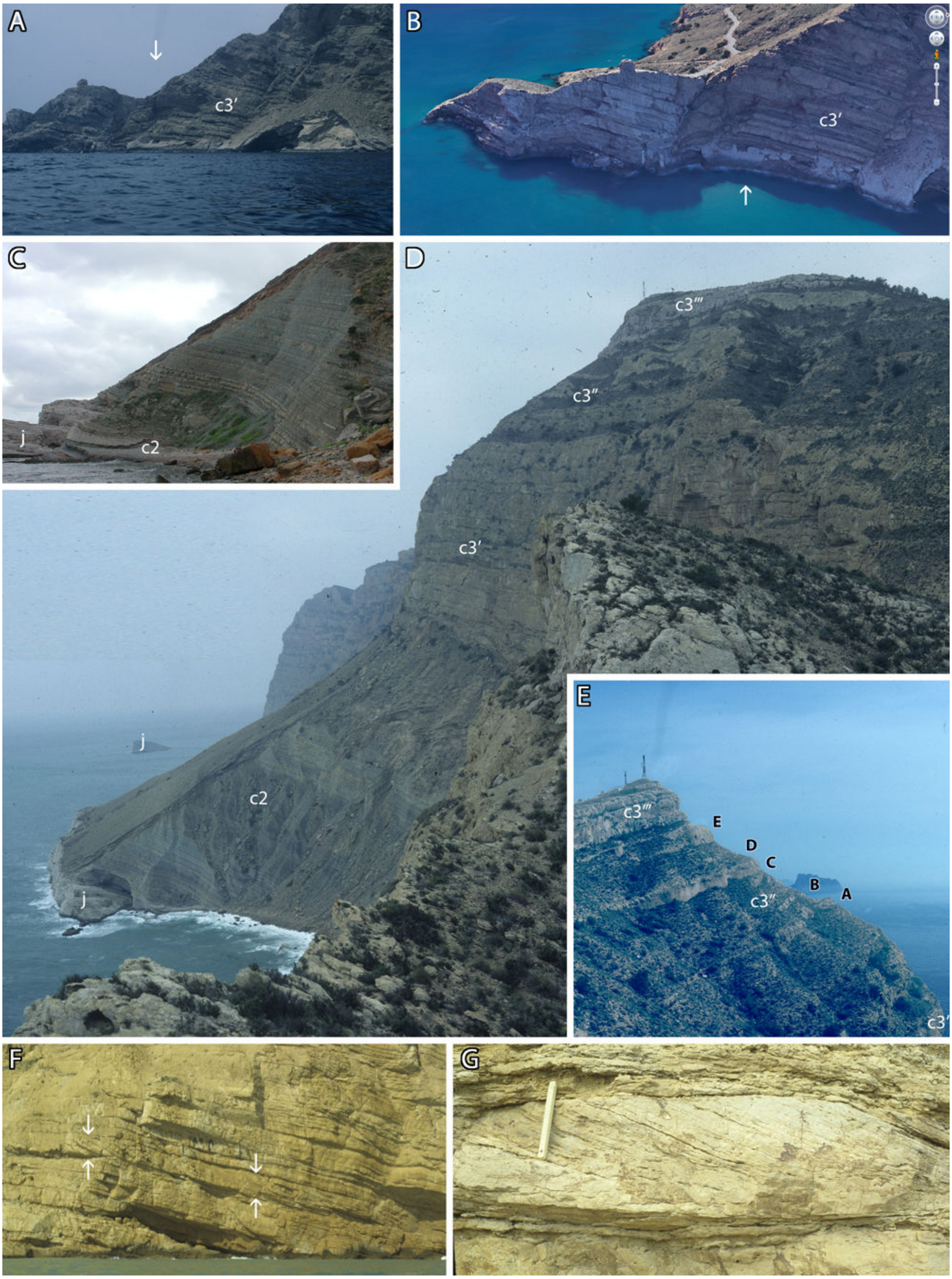

Figure 3: Serra Gelada: **A-B)** Punta de las Caletes section, arrowed (GRANIER, 1987: Fig. 22): A) 25/07/1984; B) Google Earth view © 2024 Airbus. **C)** lower part of the ammonites marls and contact with the Jurassic at Morro Sant Jordi, 22/09/2010. **D)** Panoramic view from the mirador next to Far de l'Albir, 14/04/1984. **E)** The Relais section (GRANIER, 1987: Fig. 23) with 5 coral bioherms (labeled A-E) intercalated within '*Cylindroporella* oolithes', 09/04/1984. They pass laterally to hardgrounds, and are abraded and bored at their top. **F)** Meter-scale sand waves visible on the cliff face below the Far de l'Albir, 10/1985. **F)** Decimeter-scale sand wave on the side of Camí del Far (1986). It exhibits tidal bundles that document the semi-diurnal lunar control of sedimentation. Figure captions: j: Jurassic limestones (Berriasian and older strata), c2: ammonite marls (mostly Aptian), c3': 'siltstones and calcisiltites with *Favusella*', c3": '*Cylindroporella* oolithes', c3'": 'rudistid limestones'.

At Puig Campana (Figs. 4, 7), on top of lower Valanginian '*Pseudocyclammina* calcarenites and sandstones', the sedimentary sequence begins with a condensed interval, characterized by the occurrence of ferruginous ooids and oncoids, followed by glauconite grains, all of them floating in a calcareous muddy matrix (Granier, 1987: Fig. 9). Almost 2 meters thick, it spans part of the Valanginian to lower Aptian interval (Fig. 4.B). It is overlain by a poorly exposed marly interval, roughly 40 meters thick, where pyritous ammonites dated to the latest Aptian (*Diadochoceras nodosocostatum* Zone) were collected. These argillaceous strata were likely tectonically stretched and squeezed, which could explain their relatively reduced thickness compared to the other areas. The next two units consist of the '*Pieninia* calcarenites' and the 'coral biolithites', 20 and 30 meters thick respectively (Fig. 4.C). Calcareous microfossils identified in thin sections include *Mesorbitolina birmanica* Sahni, 1937 (Pl. 5, fig. U), *Mesorbitolina* sp. (Pl. 5, figs. V-W), and *Agardhiellopsis cretacea* Lemoine, 1966 (Pl. 2, fig. A). According to Granier (1987) and Granier and Perthuisot (2009), based on LBF biozonation, this microfossil assemblage was considered characteristic of the upper Aptian, a view that is revised here. The overlying '*Simplorbitolina* limestones', which are more than 110 meters thick, consist of lagoonal muddy facies with *Simplorbitolina* spp. (Pl. 8, figs. A-Z), *Involutina hungarica* (Sidó, 1952), and *Pseudochoffatella cuvillieri* (Pl. 4, figs. D, F-J). Unfortunately, the fault system surrounding the Puig Campana on its western side interrupts it upward. On the other side of the fault, a new sequence begins with an alternation of silty marls and argillaceous limestones more than 170 meters thick followed by about 30 meters of '*Hensonina* calcarenites' with *Neorbitolinopsis conulus* (Douvillé, 1912) (Pl. 9, figs. A-F, U-X), and a more than 650-meter-thick alternation of '*Hemiaster* marls and argillaceous limestones', still Albian in age. These '*Hensonina* calcarenites' are also exposed at Serreta Llarga, near the Serra de Fontcalent, westward of Alicante city (Azéma, 1977).

At Cabeçó d'Or (Fig. 5), similar to Puig Campana, the lower part of the sedimentary sequence begins on top of lower Valanginian '*Pseudocyclammina* calcarenites and sandstones' with a condensed interval characterized by the occurrence of ferruginous ooids and oncoids. Almost 2 meters thick, it spans part of the Valanginian to lower Aptian interval, and numerous late Barremian and early Aptian ammonites (*e.g.*, *Deshayesites deshayesi* Zone) may be collected there. This condensed interval is overlain by a marly unit, more than 150 meters thick on the eastern side of Cabeçó d'Or, containing early and late Aptian ammonites (*e.g.*, *Deshayesites deshayesi*, *Dufrenoyia furcata*, and *Diadochoceras nodosocostatum* zones). Approximately 50 meters of 'silty limestones, calcisiltites, and calcarenites with *Favusella*' follow. As demonstrated for the first time in this location, they contain ammonites from the latest Aptian and possibly the early Albian (BT 64). These are overlain by approximately 20 meters of 'coral biolithites', which form a second topographic crest (a first, distinct topographic crest is visible in the underlying calcarenites, Fig. 5.A-B). A bored erosional subaerially-exposed surface (Fig. 5.C-D) marks the top of these 'coral biolithites' and the base of several tens of meters of '*Hemiaster* marls and argillaceous limestones', the first meters of which contain early late Albian ammonites.

4. The ammonite collections of the Université Claude Bernard Lyon 1 (E.R.)

Most ammonites collected by the first author (B.R.C.G.) in the Costa Blanca (SE Spain) were temporarily housed in Robert Busnardo's collection in Saint-Didier-au-Mont-d'Or, awaiting their transfer to the 'Collections de l'Université Claude Bernard Lyon 1'. During this time some were lost. On April 20, 2024, the first author (B.R.C.G.) and Eric Monteil visited a site near Aigües where the top of the Sanatorio section is exposed to collect new specimens. All these ammonites are deposited in the 'Collections de l'Université Claude Bernard Lyon 1' (with the UCBL-FSL label, as mentioned in the plate legend).

At Serra Gelada, specifically at Morro San Jordi (25/07/1984, circa 38°33'16.4"N, 0°03'27.3"W), above the 0.5-meter-thick condensed interval containing late Barremian and early Aptian ammonites, additional specimens were collected from the *Deshayesites deshayesi* Zone (lower Aptian) and the *Epicheloniceras martini* Zone (upper Aptian). However, the youngest ammonites from Serra Gelada were collected *in situ* at Punta de les Caletes (Fig. 3.A-B, 13/04/1984, circa 38°31'31.3"N, 0°05'46.3"W). These specimens (HL 60) include *Tegoceras* sp., indicative of the upper part of the *Douvilleiceras mammillatum* Zone (lower Albian) (Robert *et al.*, 2009; Jaillard *et al.*, 2024).

The youngest ammonites from Puig Campana ('*Acanthohoplites*' *bigoureti*, '*A.*' *nolani*, *A.* sp., *Aconeceras* sp., and *Diadochoceras* sp.) were collected in the Cluse section (Fig. 5.C, Cluse 20 = ZC16503, 20/03/1983; ZC16631, 13/05/1985; 38°35'39.3"N, 0°12'30.2"W). They are ascribed to the *Diadochoceras nodosocostatum* Zone of the upper Aptian (Giraud *et al.*, 2021).

At the aforementioned Sanatorio section of the Cabeçó d'Or, north of Aigües (Fig. 5.A-B, 26/04/1985, starting circa 38°31'07.0"N, 0°22'06.3"W, and ending circa 38°30'53.5"N, 0°21'51.6"W), the same *Diadochoceras nodosocostatum* Zone is at least 40 m thick there (samples BT43 to BT51). Ammonites collected in this interval comprise '*Acanthohoplites*' *bigoureti* (Seunes, 1887), '*A.*' *nolani* (Seunes, 1887), '*A.*' sp., *Epicheloniceras* sp., *Diadochoceras* sp. and *Neodufrenoyia* sp. Lower in the section (samples BT24 to BT27), the

Figure 4: Puig Campana: **A)** western side of Puig Campana (Cluse section arrowed), 12/03/1983. **B)** condensed section above the '*Pseudocyclammina* calcarenites and sandstones' (lower Valanginian) and below the ammonite marls (Barremian-Aptian), 15/03/1983. **C)** Cluse section, 1993. Figure captions: j: Jurassic limestones (Berriasian and older strata), c1: '*Pseudocyclammina* calcarenites and sandstones' (lower Valanginian), c2: ammonite marls (Barremian-Aptian), c3: calcisiltites, biolithites, and rudistid limestones, c5: marls and argillaceous limestones (Albian), Cg: 'mortadella' conglomerate (Quaternary), dotted lines: faults.

assemblage consists of '*Acanthohoplites*' *bigoureti*, '*A.*' *nolani*, '*A.*' sp., *Aconeceras* sp., *Colombiceras* sp., *Eogaudryceras* sp., *Epicheloniceras* sp., *Mathoceras matho* (PERVINQUIÈRE, 1907), *Parahoplites* sp., *Phylloceras* (*Hypophylloceras*) sp., ? *Valdedorsella* sp., and *Zuercherella zuercheri* (JACOB *et al.*, 1906), which suggests the *Parahoplites melchioris* Zone. Ammonites from samples BT 28 and BT29 do not allow us to discriminate the *Parahoplites melchioris* Zone from the *Diadochoceras nodosocostatum* Zone.

The ultimate ammonite zone of the Aptian, the *Hypacanthoplites elegans* Zone (SZIVES *et al.*, 2023, 2024), was not identified in any of the three areas examined. However, a questionable *Fallotermiericeras* sp. (BT 64) was found in the silty limestones with *Favusella* within the Sanatorio section, approximately 50 meters above the *Diadochoceras nodosocostatum* Zone. This occurrence corresponds to either the uppermost part of the *Diadochoceras nodosocostatum* Zone (uppermost Aptian), the '*Hypacanthoplites*' *elegans* Zone (marking the Aptian-Albian transition), or the *Douvilleiceras leightonense* Zone (lowermost Albian). To explicitly identify the *Hypacanthoplites elegans* Zone, further material must be collected from Serra Gelada and Cabeçó d'Or.

Back at Cabeçó d'Or, the ammonites collected above the discontinuity at the top of the Sanatorio section (26/04/1985, 38°30'53.5"N, 0°21' 51.6"W), previously illustrated (GRANIER, 1987: Pl. 47), are indicative of the lower upper Albian. These include *Hysteroceras* sp., *Dipoloceras* sp., and *Brancoceras* sp. The most representative specimens are re-illustrated here (Pl. 10, figs. A-I). New ammonites from Aïgues, recently collected by one of us (B.R.C.G.) and Eric MONTEIL, include *Hysteroceras* sp., *Dipoloceras* sp., *Hamites* sp., *Anisoceras* sp., and *Pusozia (Puzosia)* sp. (Pl. 10, figs. J-W). This association confirms an early late Albian age.

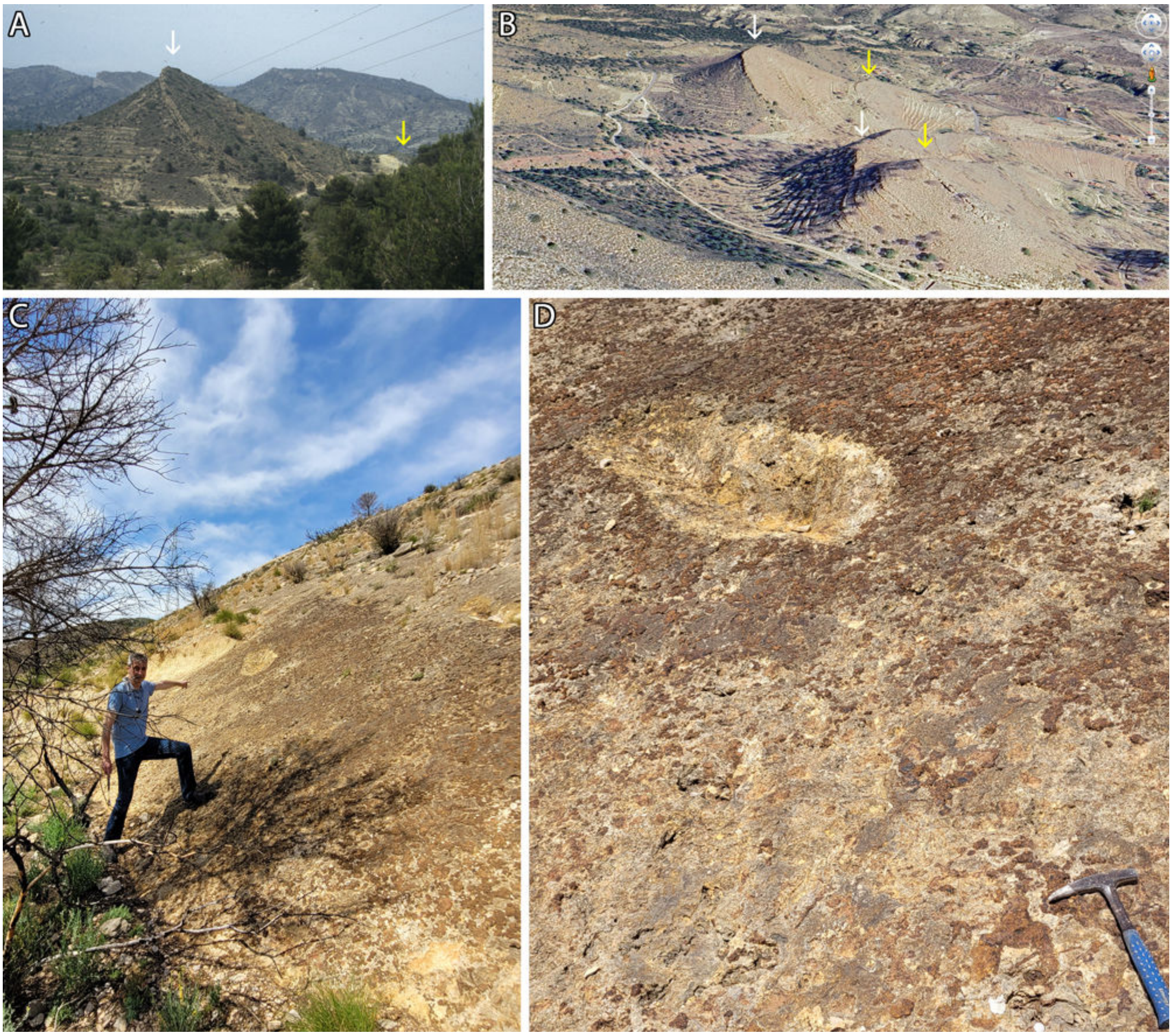

Figure 5: Cabeçó d'Or: **A-B)** Sanatorio section (GRANIER, 1987: Fig. 43): white arrows: first crest, yellow arrows: second crest, A) 1993, B) Google Earth view © 2024 Airbus. **C-D)** Sanatorio section, exposure surface at the top of the second Albian crest (GPS coordinates: 38°30'53.5"N, 0°21'51.7"W), C) Photo courtesy of Eric MONTEIL, 20/04/2024, D) 20/04/2024.

In 1970, in the Province of Valencia (SE Spain), FOURCADE described the Solana del Alambin section starting from the ruins of Casa de Anton Julian (38°59'22.1"N, 0°54'48.8"W) to the summit (1098 m), a few hundreds of meters north of Casa del Alto (38°59'19.5"N, 0°56'03.7"W). He stated that 'This series from the Solana del Alambin shows that *Neorbitolinopsis conulus* appears immediately above the *Knemiceras*' [translated from the French in FOURCADE, 1970: 'Cette série de la Solana del Alambin permet de montrer que les *Neorbitolinopsis conulus* apparaissent immédiatement au dessus des *Knemiceras*']. He also reported other records of these same ammonites from 1) Casa del Alambín (presently Casa María Rodevar) at 39°2'9.13"N, 0°51'37.64"W, and 2) Casa de la Canaleja, 7 km SW (not SE, as stated in the thesis text) of Solana del Alambín, at 38°56'12.75"N, 0°57'4.76"W. Since then, these ammonite findings have supported the attribution of *Neorbitolinopsis conulus* to the late Albian. However, these ammonites, which are also part of the 'Collections de l'Université Claude Bernard Lyon 1', are not *Knemiceras* sp. but *Parengonoceras* sp. (Pl. 11, figs. A-E), based on their characteristic alternating elongated ventrolateral clavi (LATIL & JAILLARD, 2024). Although its internal calcareous mold is poorly preserved, one specimen retains the diagnostic morphology of *Parengonoceras ibericum* (ARIAS & WIEDMANN, 1977) (Pl. 11, figs. D-E), which corresponds to the *Douvilleiceras mammillatum* Zone (and possibly the *Lyelliceras pseudolyelli* Zone) of the upper lower Albian.

5. Discussion

The following paragraphs address some nomenclatural errors or misidentifications from the past (Granier, 1987, 2019; Granier & Perthuisot, 2009). They also integrate recent taxonomic and stratigraphic updates:

1) *Hensonina lenticularis* (Henson, 1947) *nom. nud.*, *comb. nud.*, was cited by the first author from both the Puig Campana and Serra Gelada areas, specifically from the Realet d'Alt and Rafel sections in the Puig Campana area, as well as the Relais section in the Serra Gelada area (Granier, 1987, 2019; Granier & Perthuisot, 2009). Recently, both its generic and specific status were examined (Rigaud *et al.*, 2023), leading to the revision of the genus *Hensonina* Rigaud & Consorti *ex* Moullade & Peybernès, 2023 (non 1973)[*], and the establishment of the species *Hensonina canalicula* Rigaud & Consorti *in* Rigaud *et al.*, 2023.

Earlier reports of this species comprise:

a) in Granier (1987: p. 108, no illustration) or in Granier and Perthuisot (2009: p. 1021-1022, no illustration) in the Albian '*Cylindroporella* Oolithes' from the Relais section of the Serra Gelada (Granier, 1987: Fig. 23), samples Relais 10 - HL 712, Relais 12 - HL 722, and Relais 13 (not 14) - HL 726, correspond to *Epistomina* spp. (Granier, 2019: Pl. 3, figs. A-H). This trochospiral aragonitic foraminiferal genus is a useful marker for paleoenvironments, as it is commonly found in outer platform environments; however, it has no biostratigraphic value. For instance, *Epistomina* is also known from the Berriasian slope deposits of Busot (Granier *et al.*, 2024).

b) in Granier (1987: p. 58, Pl. 8, figs. f-i) in the Albian '*Simplorbitolina* Limestones' from the Realet d'Alt section of the Puig Campana (Granier, 1987: Fig. 12), samples Realet d'Alt 13 - ZC19368 to Realet d'Alt 28 - ZC19351, correspond to *Involutina hungarica* (Sidó, 1952) (Granier, 2019: Pl. 2, figs. H-AB; Pl. 3, figs. L-AH). According to Rigaud *et al.* (2023), this species ranges from the upper Aptian to the middle Albian. However, none of these datings are directly correlated with ammonite finds; therefore, they lack rigorous calibration against ammonite biozones.

c) in Granier (1987: as *Hensonina lenticularis*, p. 63, Pl. 10, figs. a-b, e; 2019: as *Involutina hungarica*, p. 446, Pl. 3, figs. AI-AJ, Pl. 4, figs. A-V) in the Albian '*Hensonina* Calcarenites' from the Rafel section of the Puig Campana (Granier, 1987: Fig. 13), sample Rafel 41 - PC19499, correspond to genuine *Hensonina canalicula* Rigaud & Consorti, 2023. According to Rigaud *et al.* (2023), this species is only known from the Albian interval.

2) *Mesorbitolina subconcava* (Leymerie, 1878) was reported by the first author from the Puig Campana, Serra Gelada, and Cabeçó d'Or areas, specifically in the '*Pieninia* Calcarenites' from the Cluse and Realet d'Alt sections in the Puig Campana area, in the '*Cylindroporella* Oolites' and 'rudistid limestones' from the Relais and Carabiniers sections in the Serra Gelada area, and in the '*Favusella* Calcarenites' from the western Cabeçó d'Or area (Granier, 1987; Granier & Perthuisot, 2009). Although Schroeder (letter to the first author, 26/11/1987) initially ascribed these specimens to *M. subconcava* (Leymerie, 1878), they should be reascribed to *Mesorbitolina birmanica* Sahni, 1937, a species that escaped from oblivion (Schlagintweit & Wilmsen, 2014).

3) According to Schlagintweit (2023), the specimen of *Coskinolinoides texanus* Keijzer, 1942, from the 'rudistid limestones' of the Illa de Benidorm, illustrated by Granier (1987: Pl. 27, fig. c; here Pl. 2, fig. M), should be assigned to the species *C. fleuryi* (Decrouez & Moullade, 1974). However, since this specimen is an early representative of the genus, we have chosen to retain Fourcade's (in Granier, 1987) original attribution.

4) Schlagintweit *et al.* (2021) document the *Simplorbitolina* lineage with *S. aquitanica*, *S. manasi*, and *S. conulus*, which appears to provide strong support for biozones based on first occurrences of these species (*e.g.*, Granier, 1987: Fig. 12). They have treated *S. chauvei* as a junior synonym of *S. aquitanica*. However, 'The original description of *Orbitolinopsis aquitanica* by Schroeder in Schroeder & Poignant (1964) was obviously based on an assemblage of juvenile specimens' (Schlagintweit *et al.*, 2021: p. 5) or megalospheric specimens (Moullade & Peybernès, 1979). It is assumed that making *S. aquitanica* and *S. chauvei* synonymous would require an in-depth revision of the original material of Schroeder and Poignant (1964), and that of Fourcade (1978).

Simplorbitolina spp. are only known from Puig Campana in mud-dominated facies, which are absent or scarce at Cabeçó d'Or and Serra Gelada. The *Simplorbitolina* lineage with *S. chauvei*, *S. manasi*, and *S. conulus* (Fourcade, 1978), apparently provided strong support for biozones based on the first occurrences of the three species (Schlagintweit *et al.*, 2021). Granier (1987: Fig. 12) used them, combined with the occurrences of *Involutina hungarica* (as '*Hensonina lenticularis*') and *Pseudochoffatella cuvillieri*, to split the rudistid limestones of the Realet d'Alt section at Puig Campana into 4 intervals:

1. from the base of the section up to the last occurrence of *Simplorbitolina chauvei* in sample Realet 10, upper Aptian;
2. then up to the first occurrence of *Involutina hungarica* in sample Realet 13, locally with the presence of *Simplorbitolina manasi*, upper Aptian to lower Albian;
3. then up to the last occurrences of *S. manasi* and *Pseudochoffatella cuvillieri* in sample Realet 23, lower Albian;
4. finally, above this level to the top of the section, locally with the presence of *Simplorbitolina conulus* in sample Realet 28, lower to middle Albian.

[*] *https://en.wikipedia.org/wiki/Author_citation_(botany)*

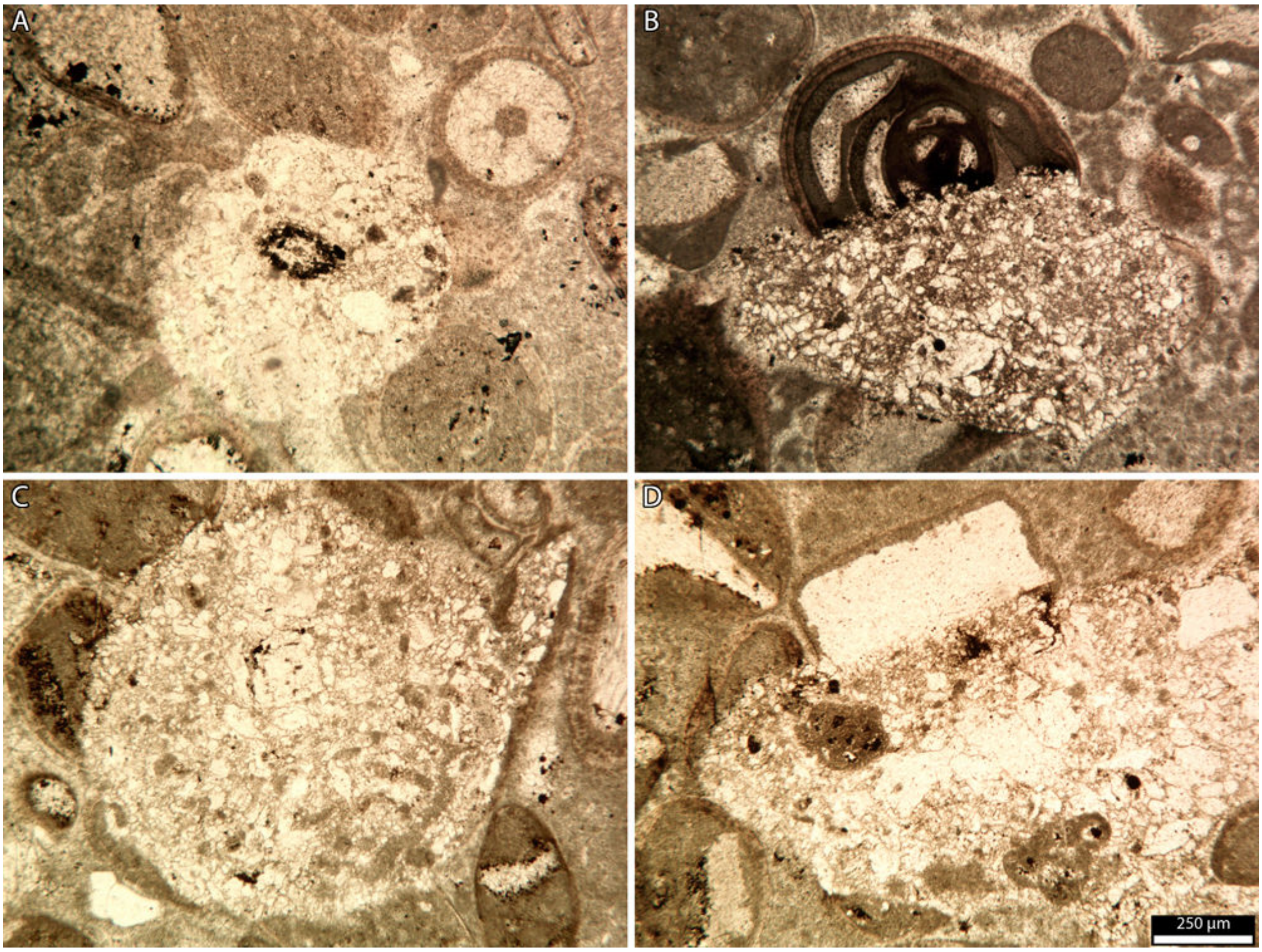

Figure 6: Borings from the hardground, equivalent to the sommital surface of bioherm D. **A-D)** Relais 15 (HL 724 bis), *Cylindroporella* oolithes, Relais section, Serra Gelada, 01/05/1985. Scale bar (on fig. D) = 250 µm.

Nonetheless, subsequent to the recent revision of GRANIER's (1987) original material during the preparation of this manuscript, species delimitation - based on the presence or absence of intercalary beams and, when the intercalary beams are present, the presence or absence of rafters - has yielded somewhat different results.

The first species of the evolutionary lineage, *S. chauvei*, has no intercalary beams and no rafters (Pl. 2, figs. O-R; Pl. 8, figs. A-B, N). The following species, *S. manasi*, is characterized by the presence of intercalary beams, but has no rafters (Pl. 2, figs. T-U; Pl. 8, figs. F-G, O). The last species, *S. conulus*, is characterized by the presence of both intercalary beams and rafters (Pl. 2, figs. V-W; Pl. 8, figs. C-E, H-L, Q-T). Locally, some intermediate forms may be found, *e.g.*, an intermediate form between *S. manasi* and *S. conulus* in sample Realet 14 (Pl. 8, fig. P). Here, we argue that these transitional forms should be assigned to the successor species epithet, rather than the ancestor species epithet, because it cannot be ruled out that, in some cases, they represent teratological specimens.

5) *Sabaudia minuta* (HOFKER, 1965) and related species are quite common in the ?upper Aptian – Albian strata of the studied area. *Textulariella minuta* HOFKER, 1965, is the type species of the genus *Sabaudia* CHAROLLAIS & BRÖNNIMANN, 1965. Recently, ÖZDIKMEN (2009) pointed out that this genus name was initially occupied by *Sabaudia* GHIGI, 1909, necessitating the adoption of a replacement name. Accordingly, ÖZDIKMEN (2009) introduced the new genus name *Akcaya* to replace *Sabaudia* CHAROLLAIS & BRÖNNIMANN, 1965. However, *Sabaudia liguriae* GHIGI, 1909, the type species of the genus *Sabaudia* GHIGI, 1909, proved to be a junior synonym of *Hormiphora australis* (BENHAM, 1907). Consequently, the genus name *Sabaudia* GHIGI, 1909, which is synonymized with *Hormiphora* AGASSIZ, 1860, is no longer in use. The replacement name *Akcaya* introduced by ÖZDIKMEN (2009) is unnecessary because the name *Sabaudia* CHAROLLAIS & BRÖNNIMANN, 1965, is no longer preoccupied. The genus *Sabaudia* CHAROLLAIS & BRÖNNIMANN, 1965, is valid and the species *Sabaudia minuta* (HOFKER, 1965) CHAROLLAIS & BRÖNNIMANN, 1965, retains its genus name, as the preoccupation by the earlier *Sabaudia* GHIGI, 1909, is resolved through synonymization under *Hormiphora* AGASSIZ, 1860. The lowest record of *Sabaudia minuta* is from lower Valanginian strata at 'Les Quatre Confronts', northward of Toulon, Var, France (MASSE, 1976: Pl. 14, figs. 20-21). Therefore, its total range spans the Valanginian - Albian (-? lower Cenomanian) interval, not the upper

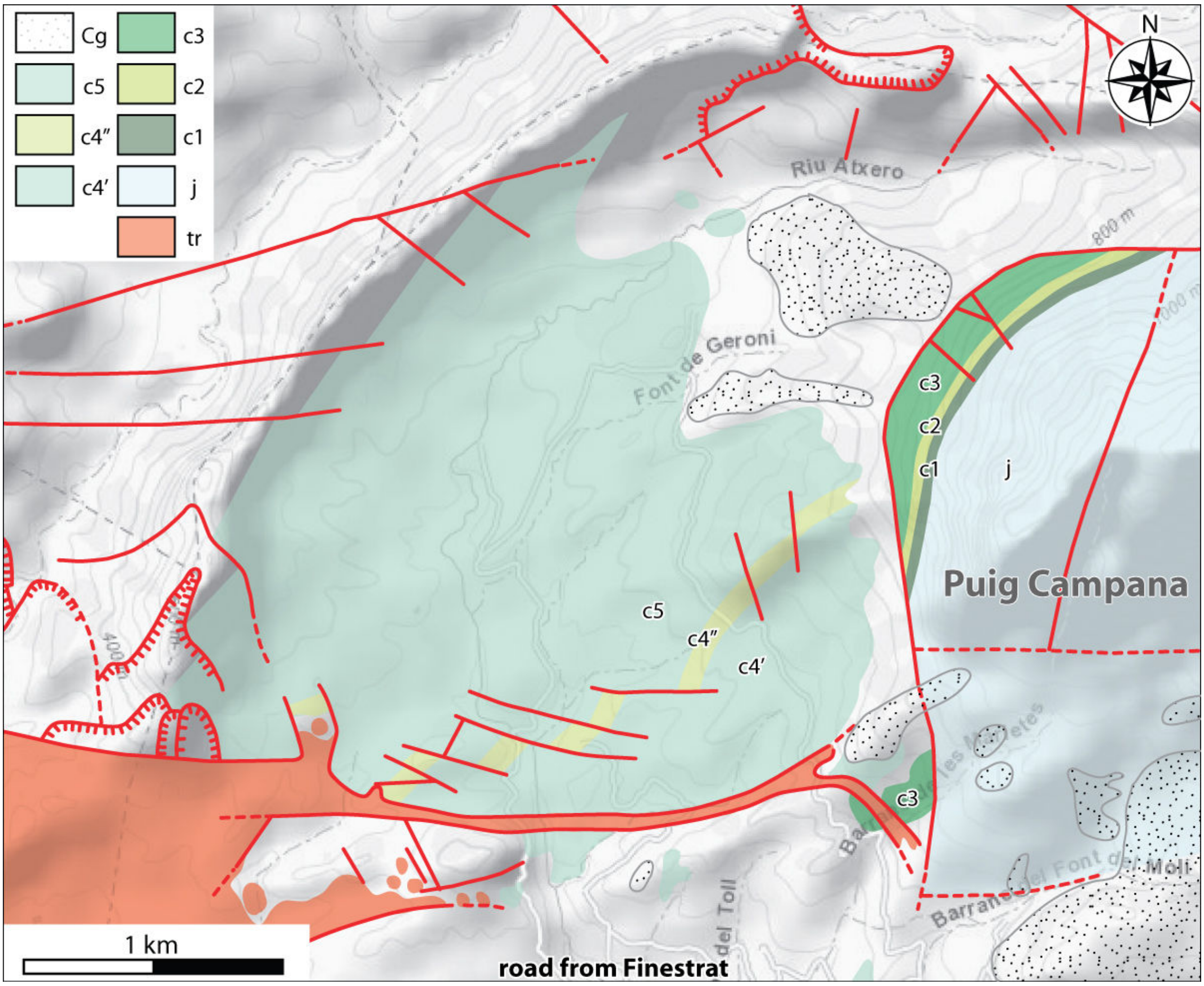

Figure 7: Geological map of Puig Campana (excerpt from GRANIER, 1987). Figure captions: tr: Trias, j: Jurassic limestones (Berriasian and older strata), c1: '*Pseudocyclammina* calcarenites and sandstones' (lower Valanginian), c2: ammonite marls (Barremian-Aptian), c3: calcisiltites, biolithites, and rudistid limestones, c4': silty marls and argillaceous limestones, c4": *Hensonina* calcarenites, c5: marls and argillaceous limestones (Albian), Cg: 'mortadella' conglomerate (Quaternary).

Hauterivian - lower Cenomanian interval, as stated by ARNAUD-VANNEAU and CHIOCCHINI (in SCHROEDER & NEUMANN, 1985).

6) *Favusella washitensis* (CARSEY, 1926) was considered a marker of the Albian stage. However, according to https://www.mikrotax.org/pforams/index.php?id=110109, this species is now thought to span the late Aptian to the middle Cenomanian interval.

7) The calcareous green alga, *Cylindroporella barnesii* JOHNSON, 1954, was first described from the Edwards Formation (middle to early late Albian in age, SCOTT *et al.*, 2019) of the Gillespie County (Texas, U.S.A.). In the Costa Blanca, it is found in the '*Simplorbitolina* limestones' in the Realet d'Alt section at Puig Campana (from sample Realet 8 up to sample Realet 28), and in the '*Cylindroporella* oolithes' in the Relais section (from sample Relais 2 up to sample Relais 19) and the 'rudistid limestones' in the Carabiniers section (in samples Carabiniers 10 and 13) at Serra Gelada.

8) The calcareous red alga, *Agardhiellopsis cretacea* LEMOINE, 1966, was originally described from P. FEUILLÉE's material collected at Uztegui (Navarra, Spain) in strata ascribed to 'Albien approximatif'. Besides Spain, the author (LEMOINE, 1966) mentions several localities in the 'Vimport facies' of southern France, including Ariège, Aude, Basses-Pyrénées, and Les Landes. In the Costa Blanca, this alga is found in the '*Pieninia* calcarenites' in the Cluse section (in sample Cluse 30) and in the Realet d'Alt section (in sample Realet 4) at Puig Campana, in the 'orbitolinid calcarenites and marls' in the 'LM' section (in samples LM 11 to 18) at Serra Gelada, and in the 'calcarenites with *Favusella*', north of Sanatorio, at Cabeçó d'Or (in sample BT 8).

Table 1: List of occurrences of algae and LBF in the studied areas.

	Serra Gelada	Illa de Benidorm	Puig Campana	Cabeçó d'Or	Serreta Llarga
Agardhiellopsis cretacea	X		X	X	
Cylindroporella barnesii	X				
Coskinolinoides texanus		1		1	
Involutina hungarica			X		
Hensonina canalicula			X		X
Neorbitolinopsis conulus			X		X
Mesorbitolina birmanica	X	X	X	X	
Mesorbitolina texana	X			X	
Pseudochoffatella cuvillieri	X	X	X		
Simplorbitolina aquitanica			X		
Simplorbitolina chauvei			X		
Simplorbitolina manasi			X		
Simplorbitolina conulus			X		

6. The fate of the Aptian-Albian LBF biozones

At Puig Campana, GRANIER's (1987) original material was revised by sticking to the strict rules used to discriminate the three *Simplorbitolina* species. *S. chauvei*, the oldest species, first occurs in the Realet d'Alt section, approximately 15 meters above the 'coral biolithites' (in samples Realet 8-10). The next species, *S. manasi*, first occurs 35 meters above the same unit (in sample Realet 12). Although the youngest species, *S. conulus*, is present approximately 60 meters above the same unit (in sample Realet 14), it is likely that it first occurs approximately 30 meters below, *i.e.*, approximately 5 meters below the first occurrence of *S. manasi* (in sample Realet 11: Pl. 2, fig. S; Pl. 8, fig. M). Surprisingly, the *Simplorbitolina manasi* Zone is not evidenced here because the first occurrence of *S. conulus* precedes that of *S. manasi*.

Involutina hungarica first occurs approximately 50 meters above the 'coral biolithites', in the *Simplorbitolina conulus* Zone, and its range extends up to the top of the '*Simplorbitolina* limestones' in the Realet d'Alt section at Puig Campana where its total range falls within the *Simplorbitolina conulus* Zone.

Still, at Puig Campana, *Pseudochoffatella cuvillieri* first appears in the Realet d'Alt section, approximately 80 meters above the base of the 'rudistid limestones', which is approximately 110 meters (sample Realet 14; Pl. 4, fig. D) from the base of the '*Pieninia* calcarenites' and 'coral biolithites', which are, in turn, above strata containing ammonites of the *Diadochoceras nodosocostatum* Zone. Consequently, in this area, the first appearance of *Pseudochoffatella cuvillieri* is more than 130 meters above these same latest Aptian ammonites (with sample Realet 14). In addition, the *Pseudochoffatella cuvillieri* (Sub-) Zone falls within the *Simplorbitolina conulus* Zone, not within the *Simplorbitolina manasi* Total Range Zone as stated before (*e.g.*, FOURCADE, 1970; PEYBERNÈS, 1976).

At Serra Gelada, *Pseudochoffatella cuvillieri* first appears in the Relais section (Pl. 4, fig. C) approximately 25 meters below the 'rudistid limestones', *i.e.*, approximately 65 meters from the base of the '*Cylindroporella* oolithes', and approximately 215 meters from the base of the 150 meters of 'siltstones and calcisiltites with *Favusella*', which is in turn approximately 40 meters above strata containing *Tegoceras* sp., which is attributed to the *Douvilleiceras mammillatum* Zone. Accordingly, the first appearance of *Pseudochoffatella cuvillieri* is more than 250 meters above this early Albian ammonite.

Mesorbitolina texana also first appears in the Relais section at Serra Gelada (Pl. 5, figs. L, R-S), about 60 meters below the 'rudistid limestones', which is approximately 30 meters from the base of the '*Cylindroporella* oolithes'. Thus, the first appearance of *Mesorbitolina texana* is approximately 220 meters above the early Albian ammonite.

Mesorbitolina birmanica is found at Serra Gelada in the 'rudistid limestones' (Pl. 5, figs. N-Q; Pl. 6, figs. A-D, H-AM; Pl. 7, figs. A-AO), but also both a few meters below (Pl. 5, figs. E-K; Pl. 6, fig. G) or above this unit (Pl. 5, fig. M). Therefore, its first appearance is more than 250 meters above the early Albian ammonites. At Puig Campana, the latter first appears in the Cluse section (Pl. 5, fig. U), only 30 meters above the latest Aptian ammonites. It is worth noting that the relatively reduced thickness of the 'ammonites marls' there likely results from the peculiar structural setting of Puig Campana. At Cabeçó d'Or, this species first appears in the Sanatorio section (Pl. 5, fig. Y), approximately 50 meters above ammonites of the *Diadochoceras nodosocostatum* Zone and about 20 meters below a questionable *Fallotermieriiceras* sp. (BT 64), which is attributed to either the uppermost part of the *Diadochoceras nodosocostatum* Zone, the *Hypacanthoplites elegans* Zone, or the *Douvilleiceras leightonense* Zone.

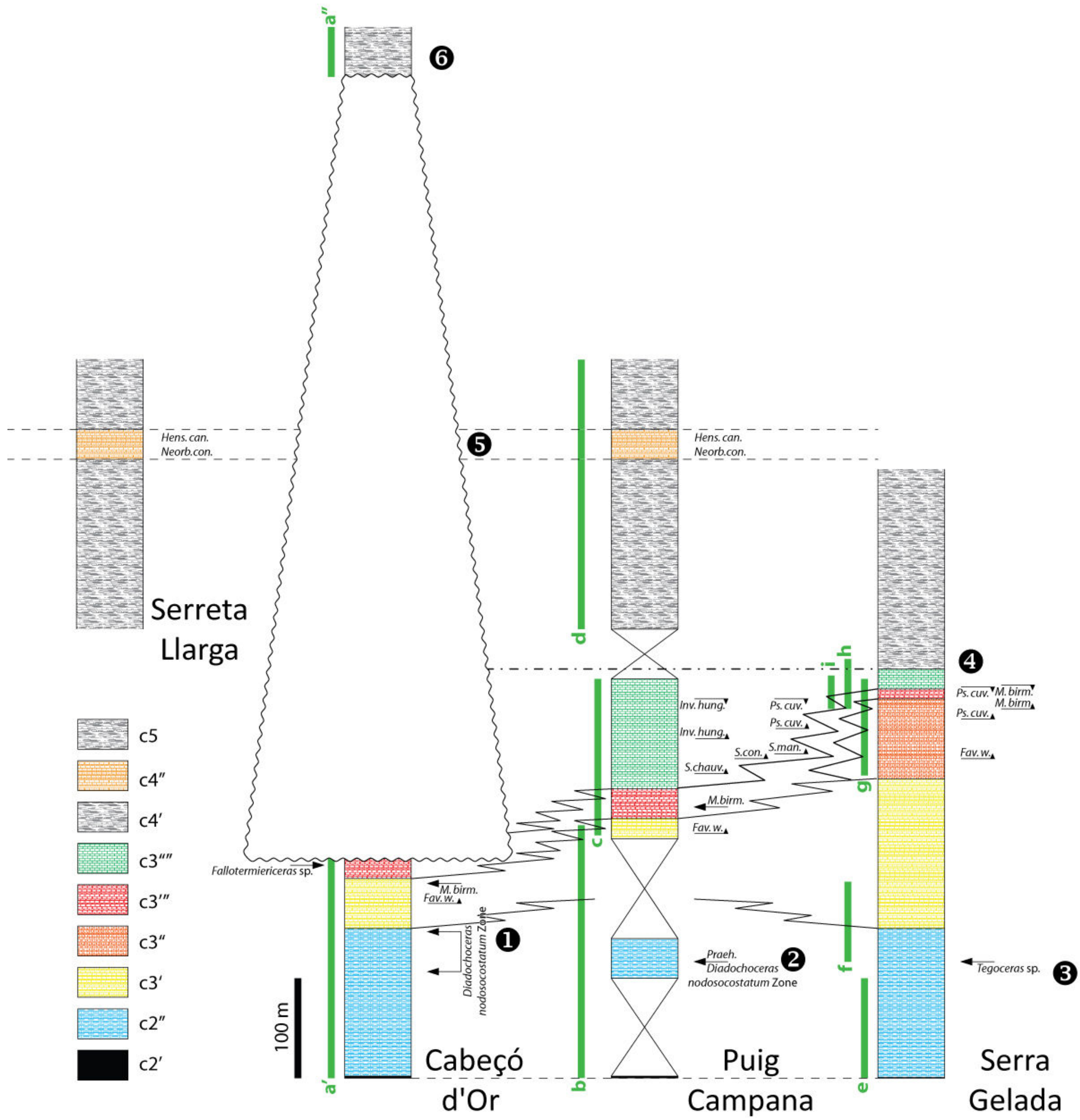

Figure 8: Correlations of the sections from Cabeçó d'Or (a: Sanatorio section), Puig Campana (b: Cluse section, c: Realet d'Alt section, d: Rafel section), Serra Gelada (e: Morro San Jordi section, f: Punta de les Caletes section, g: Relais section, h: Calle Dos Callas and Camí del Far sections), Illa de Benidorm (i, with Serra Gelada), and Serreta Llarga. Figure captions: c2': condensed sections, c2": ammonite marls (offshore facies, below storm wave base), c3': calcisiltites (lower shoreface facies, above storm wave base and below fair weather wave base), c3": oolites (upper shoreface facies, above fair weather wave base), c3'": biolithites, c3"": rudistid limestones, c4': silty marls and argillaceous limestones, c4": calcarenites, c5: marls and argillaceous limestones, Praeh.: *Praehedbergella* spp., Fav.w.: *Favusella washitensis*, M.birm.: *Mesorbitolina birmanica*, S.chauv.: *Simplorbitolina chauvei*, S.man.: *S. manasi*, S.con.: *S. conulus*, S.chauv.: *Involutina hungarica*, Ps.cuv.: *Pseudochoffatella cuvillieri*, Neorb.con.: *Neorbitolinopsis conulus*, Hens.can.: *Hensonina canalicula*. 1-3, uppermost layers with ammonites below the carbonate platform facies at Cabeçó d'Or, Puig Campana, and Serra Gelada respectively; 4, the regression-transgression reversal found at Serra Gelada and likely also occurring at Puig Campana; 5, the *Hensonina* calcarenites pinch in (*i.e.*, thin out) as they approach the Cabeçó d'Or high; 6, lowermost layer with ammonites above the carbonate platform facies at Cabeçó d'Or.

In the Costa Blanca, the green CA, *Cylindroporella barnesii* JOHNSON, 1954, is found at Puig Campana (Pl. 2, figs. E, G-J) and Serra Gelada (Pl. 2, figs. F, K-L); it was not found at Cabeçó d'Or. The red CA, *Agardhiellopsis cretacea* LEMOINE, 1966, is also found both at Puig Campana (Pl. 2, fig. A) and Serra Gelada (Pl. 2, figs. C-D), as well as at Cabeçó d'Or (Pl. 2, fig. B).

Ordering the *Simplorbitolina* species by their order of appearance should document their lineage (FOURCADE, 1978; SCHLAGINTWEIT *et al.*, 2021), with *S. chauvei* appearing first, followed by *S. manasi* and *S. conulus*, providing strong support for biozones based on the first occurrences of these species (*e.g.*, GRANIER, 1987: Fig. 12). However, the revision of the succession at Puig Campana slightly disrupted this model, as the *S. conulus* was identified before the first occurrence of *S. manasi*. This could be related to sparse sampling intervals.

Considering the youngest ammonite record at Punta de les Caletes (Serra Gelada), the Aptian/Albian boundary likely lies near the top of the ammonite marls, below the 150-meter-thick siltstones and calcisiltites with *Favusella*. Similarly, at Cabeçó d'Or and Puig Campana, it is expected to be near the top of the ammonite marls, below the calcisiltites and calcarenites with *Favusella* and beneath the *Pieninia* calcarenites, respectively. The shallow-water facies at Serra Gelada, Puig Campana, and Cabeçó d'Or, which represent the upper part of a shallowing-upward sequence, are likely of the same early Albian age. Accordingly, the presence of most previously mentioned species (*i.e.*, *Favusella washitensis*, *Mesorbitolina texana*, *M. birmanica*, *Agardhiellopsis cretacea*, *Simplorbitolina chauvei*, *Cylindroporella barnesii*, *Involutina hungarica*, *Simplorbitolina conulus*, *S. manasi*, *Pseudochoffatella cuvillieri*, and *Coskinolinoides texanus*, ranged by time-relative order of appearance) in lower Albian strata is confirmed. However, this sorting could be misleading, as it merely reflects the regional shallowing-upward trend, which causes facies changes from ammonite marls to rudistid limestones at Serra Gelada, to *Simplorbitolina* limestones at Puig Campana, or to coral biolithites at Cabeçó d'Or. Besides evolutionary processes, the appearance or disappearance of species in a shallow-water marine sequence are controlled by the presence or absence of the corresponding facies. *Favusella washitensis* (Pl. 1, figs. A-Z) and *Epistomina* spp. (Pl. 3, figs. D-F) are predominantly found in outer-shelf mud-dominated facies, while *Mesorbitolina texana* and *M. birmanica* are mostly found in outer-shelf grain-dominated facies. In contrast, *Coskinolinoides texanus*, *Involutina hungarica*, *Simplorbitolina chauvei*, *S. conulus*, and *S. manasi* are primarily found in inner-shelf mud-dominated facies, which are mainly present at Puig Campana. *Agardhiellopsis cretacea*, *Cylindroporella barnesii*, and *Pseudochoffatella cuvillieri* can be found in both environments and in intermediate shoal facies. These ecological features justify treating *Pseudochoffatella cuvillieri*, *Mesorbitolina*, and *Simplorbitolina* zones in separate columns.

Neorbitolinopsis conulus (Pl. 9, figs. A-F, U-W) and *Hensonina canalicula* are reported not only from the '*Hensonina* calcarenites' at Puig Campana but also from the Serreta Llarga (AZÉMA, 1977). Based on the revision of FOURCADE's '*Knemiceras*' by the second author (E.R), the first species should no longer be regarded as an upper Albian marker but is likely a marker characterizing the upper lower Albian. Every earlier reference in the literature to a late Albian dating based on the presence of *Neorbitolinopsis conulus* should be re-examined carefully. For instance, in the Albian strata of the 'cove of Baforeira' section, west of Lisboa (Portugal), BERTHOU and SCHROEDER (1978: Pl. 2, figs. 1, 5-7; Pl. 3, figs. 1-5) documented the occurrence of *Neorbitolinopsis conulus* just below a bored surface (*ibid.*: Pl. 9, fig. 3), which marks the boundary with Cenomanian strata containing alveolinids. Initially, BERTHOU (1971) regarded the entire section as Cenomanian in age, whereas BERTHOU and SCHROEDER (1978) assigned the strata containing *Neorbitolinopsis conulus* to the upper substage of the Albian. In light of the new hypothesis regarding the stratigraphic range of *Neorbitolinopsis conulus*, the stratigraphic gap at the Albian/Cenomanian boundary near Lisboa could be more significant than previously thought.

7. Conclusions

Although it cannot be excluded that some species (*e.g.*, *Favusella washitensis*, *Mesorbitolina texana*, *M. birmanica*, *Agardhiellopsis cretacea*, *Simplorbitolina chauvei*, *Cylindroporella barnesii*, *Involutina hungarica*) may have existed in the latest Aptian or earlier in other geographic areas, it is most likely, based on our local finds of ammonites and until further evidence emerges, that they did not appear before the early Albian in the Costa Blanca. In conclusion, although the implementation of biozones from other authors in different geographic areas (*e.g.*, SCHROEDER, 1963; FOURCADE, 1970; PEYBERNÈS, 1976; GARCÍA HERNÁNDEZ, 1978; JAFFREZO, 1980; MASSE *et al.*, 1992) proves useful at the start of any new study, the use of their empirical datings is strongly discouraged.

Biozonations and total ranges of large benthic foraminifers (LBF) and calcareous algae (CA) still in use today are partially based on earlier empirical biozonal schemes, some of which date back more than half a century, as proposed by SCHROEDER (1963), FOURCADE (1967), and others. Since then, no significant progress has been made in calibrating LBF and CA ranges (Table 1), or the associated biozones, onto the ammonite standard scale. For instance, the revision of FOURCADE's '*Knemiceras*' and the subsequent re-dating of strata containing *Neorbitolinopsis conulus* suggested that the correlation scheme for the Aptian-Albian interval in the Costa Blanca, initially proposed by the first author (GRANIER, 1987: Fig. 55; 1988: Fig. 1), required revision.

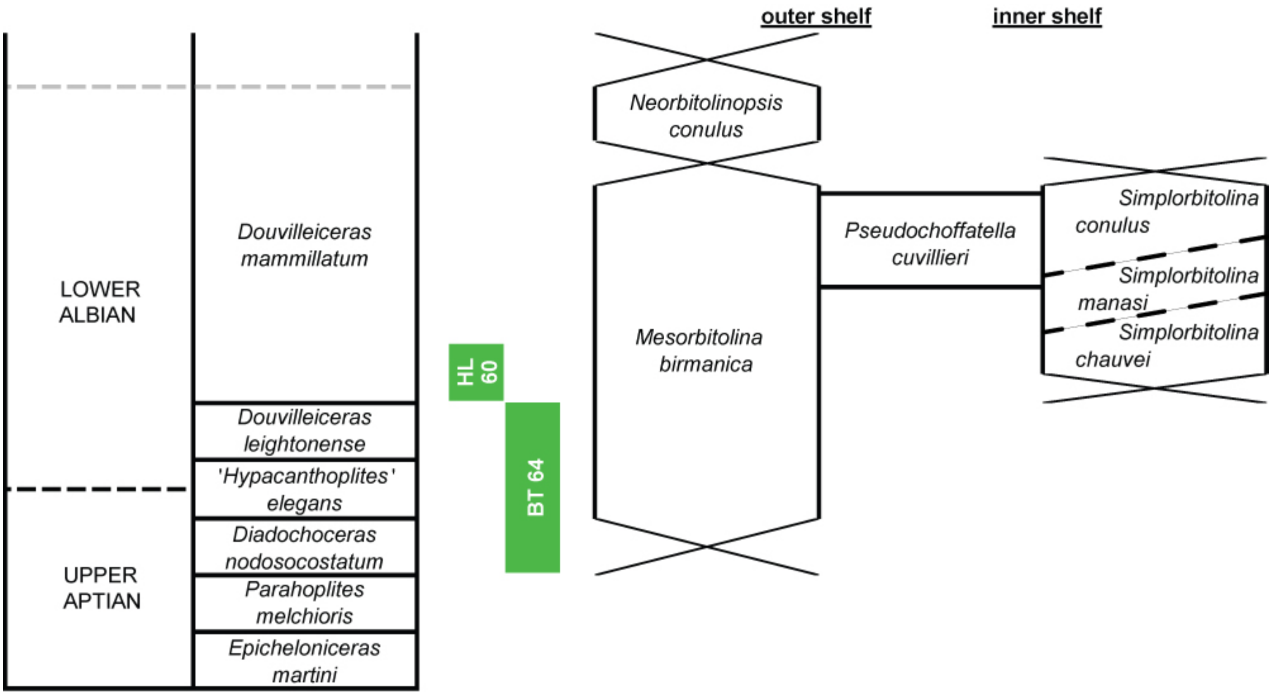

Figure 9: LBF biozonal schema calibrated onto the standard ammonite scale for the Costa Blanca (Alicante). The graphical representation of the evolutionary trend in the *Simplorbitolina* lineage shows the coexistence of both an ancestor and its direct successor.

Based on this study, the biozones defined by the total range or the first occurrence of *Mesorbitolina birmanica*, *Simplorbitolina manasi*, *S. conulus*, *Pseudochoffatella cuvillieri*, and *Neorbitolinopsis conulus* appear to fall within the early Albian substage (Fig. 9), rather than in the late Aptian to late Albian interval, as indicated in most biostratigraphic schemes.

The Albian Global Boundary Stratotype Section and Point were defined a few years ago, and this stage boundary can be identified in most basinal sections of the Tethys realm. However, none of the proxies selected by the Albian Working Group of the International Commission on Stratigraphy is useful for identifying this stage boundary in any nearby shallow-water sections.

The regression-transgression reversal observed at Serra Gelada also occurs at Puig Campana (Fig. 8.4). At Serra Gelada, the transgression is gradual, whereas at Puig Campana (north of Barranc de les Marietes), it was likely less gradual. The thick hemipelagic succession that follows at Puig Campana contrasts with the incomplete stratigraphic record at Cabeçó d'Or, suggesting a collapse of the seabed in the first area, correlated in time with a ground heave in the second. These significant seabed movements may be related to vertical shifts within the substratum, driven by the lateral migration of Triassic salts.

Based on the new dating of the strata with *Neorbitolinopsis conulus*, our study reveals a significant local hiatus at Cabeçó d'Or during Albian times, which is wider than previously suspected, spanning at least the entire middle Albian, as indicated by evidence of erosion and non-deposition (Fig. 8, in the interval 1 to 6). The *Hensonina* calcarenites found in the thick Puig Campana and Serreta Llarga deep-water sections likely pinch out around a local high at Cabeçó d'Or. The origin of this high may be related to halokinesis of Triassic salts during Albian times (see GRANIER & PERTHUISOT, 2009: Fig. 8). In fact, GRANIER (1987: Pl. 25, figs. d-h) already reported the presence of reworked Triassic material (Triassic quartz with salt inclusions) in the lower Albian *Cylindroporella* oolithes at Serra Gelada, suggesting evidence of nearby piercement or fault injection. However, more pieces of evidence are needed to better constrain the halokinetic hypothesis.

Acknowledgements

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Plates

Plate 1: Samples A-E, J-L, N-P, X-Y from Serra Gelada, I, Z from Puig Campana, and F-H, M, Q-W from Cabeçó d'Or. ***Favusella washitensis* (Carsey, 1926)**, **A-B:** Relais 2 (HL 705), *Cylindroporella* oolithes, Relais section, 25/04/1985, **C-E, K-L, N-O, X-Y:** HL 60*, *Cylindroporella* oolithes, Punta de les Caletes (13/04/1984, circa 38°31'31.3"N, 0°05'46.3"W); **F, W:** BT 61, calcarenites with *Favusella*, Sanatorio section, 26/04/1985; **G-H, M, Q-R, U-V:** BT 72, calcarenites with *Favusella*, Sanatorio section, 28/04/1985; **I:** Rafel 9 (ZC15931), Rafel section, 01/08/1982; **J:** Relais 1 (HL 704), *Cylindroporella* oolithes, Relais section, 25/04/1985; **P:** AB 21, *Cylindroporella* oolithes, Cueva de la ballena, 10/06/1984; **S-T:** BT 59, calcarenites with *Favusella*, Sanatorio section, 26/04/1985; **Z:** Realet 2 (ZC19384), *Pieninia* calcarenites, Realet d'Alt section, 19/04/1983. Scale bar (on fig. G) = 250 µm.

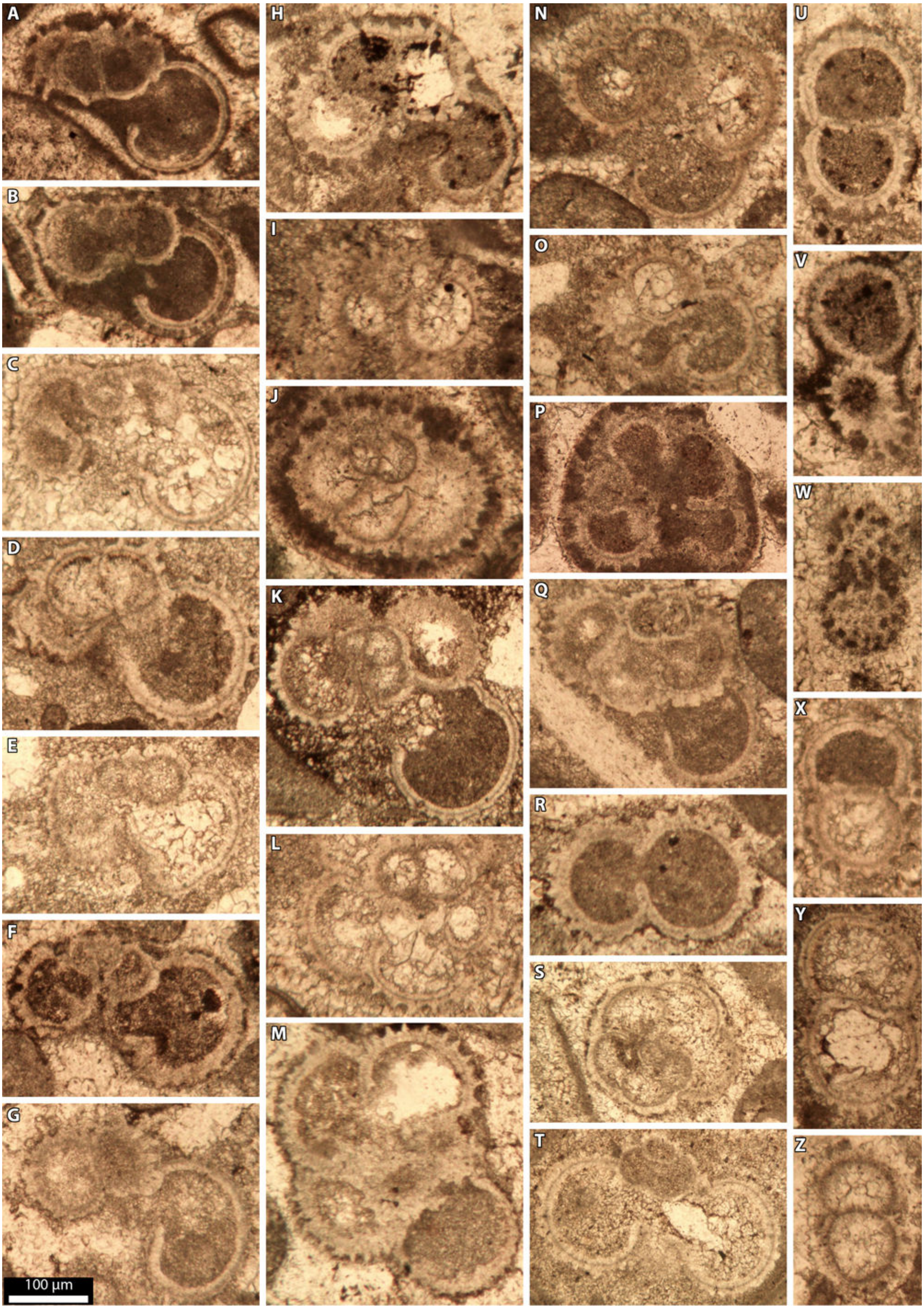
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Plate 2: Samples A, G-J, O-W from Puig Campana, B, N from Cabeçó d'Or, C-F, K-L from Serra Gelada, and M from Illa de Benidorm. ***Agardhiellopsis cretacea* LEMOINE, 1966**, **A:** Realet 4 (ZC19382), *Pieninia* calcarenites, Realet d'Alt section, 19/04/1983; **B:** BT 8, calcarenites with *Favusella*, north of Sanatorio, 16/04/1985; **C-D:** HL 48, rudistid limestones, Calle Dos Callas, 'LM' section, 08/04/1984. ***Cylindroporella barnesii* JOHNSON, 1954**, **E:** Realet 8 (ZC19377), *Simplorbitolina* limestones, Realet d'Alt section, 19/04/1983; **F, K:** Relais 15 (HL 724bis), **L:** Relais 13 (HL 725), *Cylindroporella* oolithes, Relais section, 01/05/1985; **G-I:** Realet 22 (ZC19359), **J:** Realet 19 (ZC19362), *Simplorbitolina* limestones, Realet d'Alt section, 09/04/1983. ***Coskinolinoides texanus* KEIJZER, 1942**, **M:** ISL 2, rudistid limestones, 1984, **N:** BT 331, north of Sanatorio, calcarenites with *Favusella*, 09/05/1985. ***Simplorbitolina* sp.** (O-R, T-U: *S. manasi*, S, V-W: *S. conulus*), **O-R:** Realet 10 (ZC19375), O = GRANIER, 1987: Pl. 9, fig. d, **S:** Realet 11 (ZC19374), **T-U:** Realet 12 (ZC19373), **V-W:** Realet 14 (ZC19367), *Simplorbitolina* limestones, Realet d'Alt section, 09/04/1983. Scale bar = 250 µm.

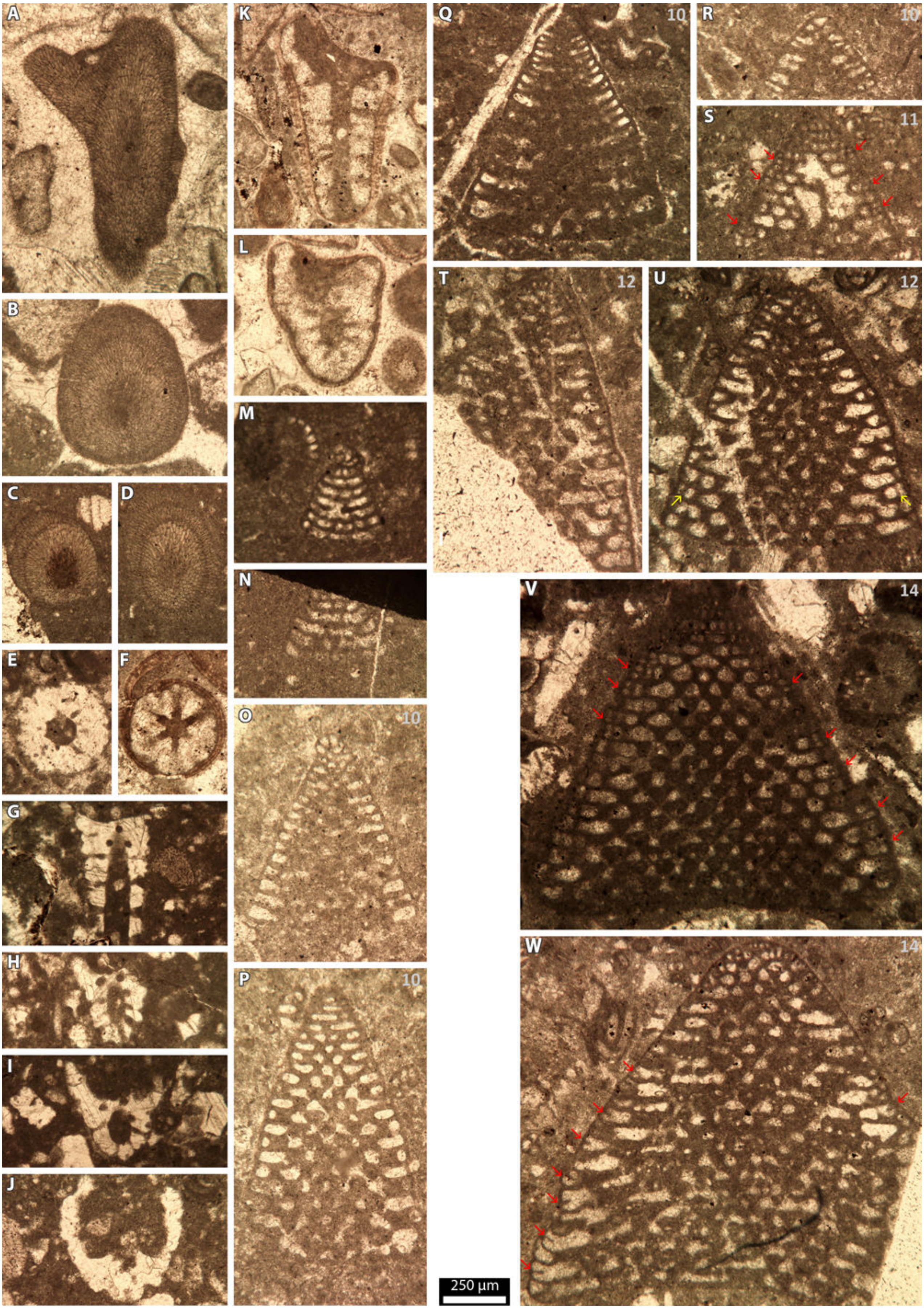
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Plate 3: A-C: Micritic envelopes with sedimentary infills providing evidence of subaerial exposure and leaching of the aragonite shells. A: BT DJ1, ca. 38°31'50.4"N, 0°24'20.7"W, coral biolithites, Cabeçó d'Or, 14/05/1985 (GRANIER, 1987: Pl. 46, fig. g); B: BT 331, calcarenites with *Favusella*, first crest, Sanatorio section, Cabeçó d'Or, 09/05/1985 (GRANIER, 1987: Pl. 46, fig. h); C: BT 456, coral biolithites, second crest, Sanatorio section, Cabeçó d'Or, 14/05/1985 (GRANIER, 1987: Pl. 46, fig. i). **D-F:** *Epistomina* spp. D: BT 73, calcarenites with *Favusella*, Sanatorio section, Cabeçó d'Or, 28/04/1985; E: Realet 3 (ZC15383), *Pieninia* calcarenites, Realet d'Alt section, Puig Campana, 19/04/1983; F: Relais 1 (HL 704), *Cylindroporella* oolithes, Relais section, Serra Gelada, 25/04/1985. All scale bars = 250 µm (D-F have the same magnification).

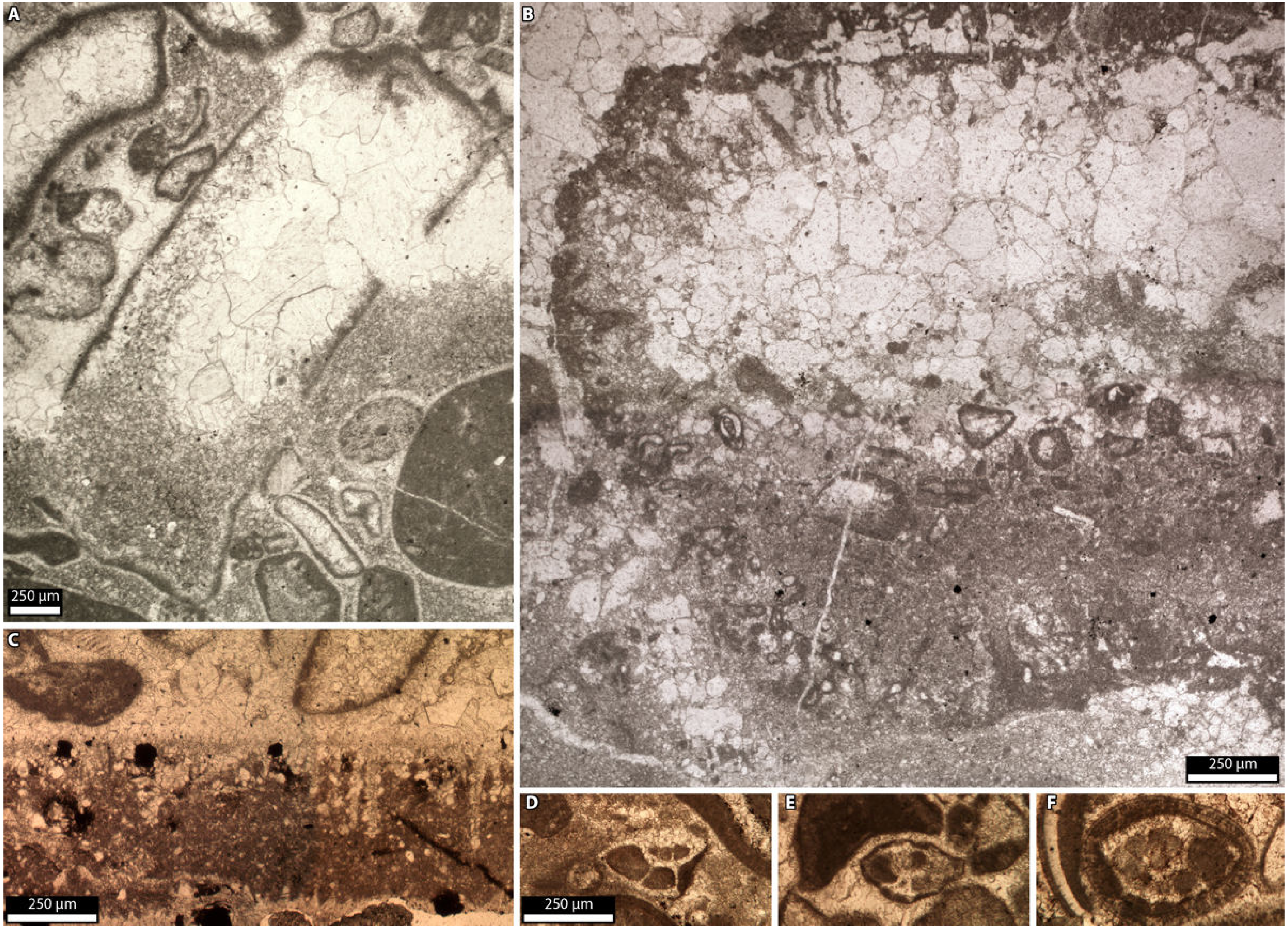
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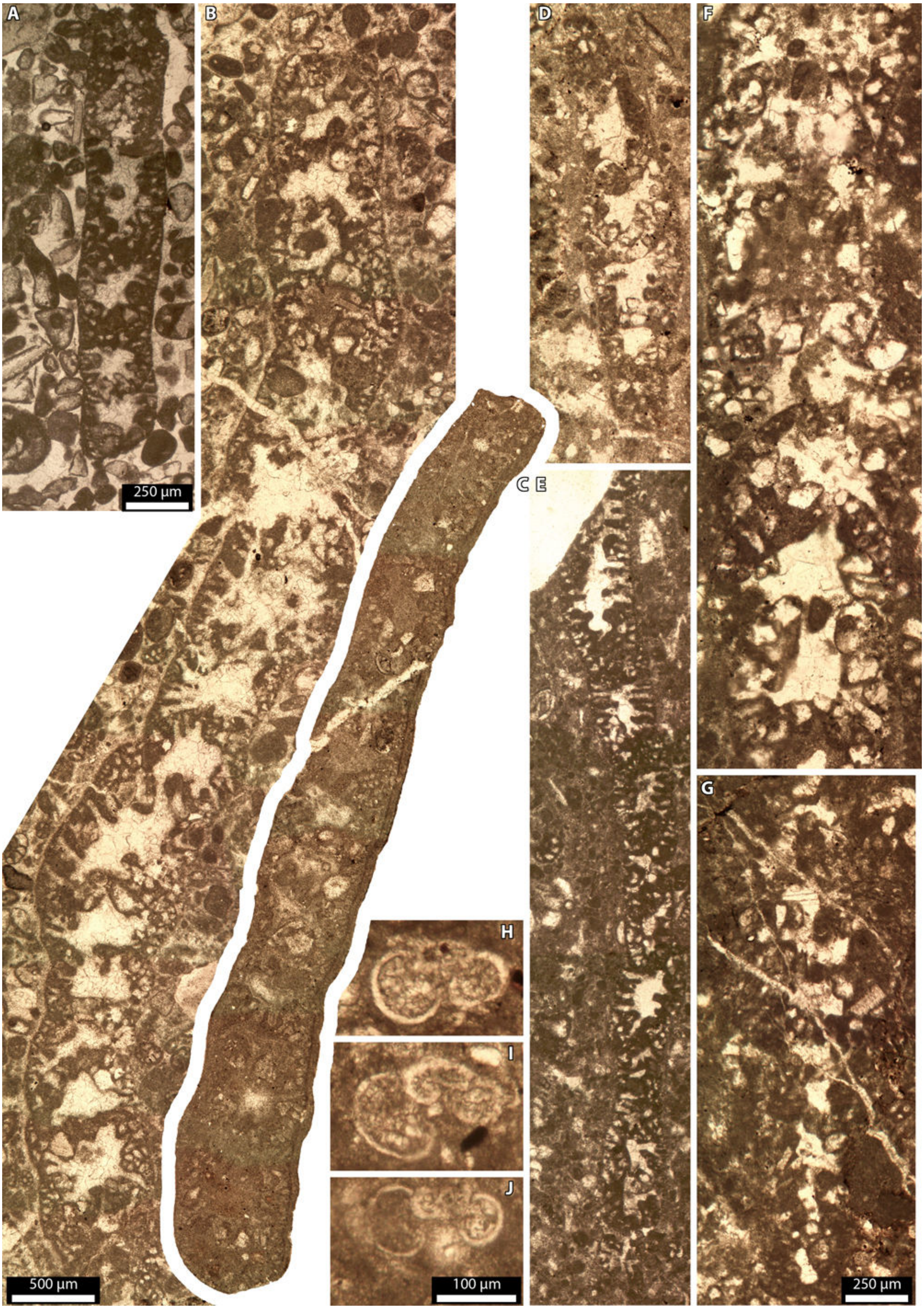
Plate 4: Samples A-C from Serra Gelada, D, F-J from Puig Campana, and E from Illa de Benidorm. ***Pseudochoffatella cuvillieri*** **Deloffre, 1961**, **A:** HL 44, **B:** HL 48, rudistid limestones, Calle Dos Callas, 'LM' section, 08/04/1984, **C:** Relais 12 (HL 722), *Cylindroporella* oolithes, Relais section, 01/05/1985, **E:** ISL 4, rudistid limestones, 1984, **D:** Realet 14 (ZC19367), **F:** Realet 23 (ZC19357), **G:** Realet 22 (ZC19359), *Simplorbitolina* limestones, Realet d'Alt section, 09/04/1983. ***Praehedbergella*** **spp.**, **H-J:** Cluse 20 (7832), condensed section, Cluse section, 19/04/1983. A, D-G, same scale bar (on figs. A and G) = 250 μm; B-C, same scale bar (on fig. B) = 500 μm; H-J, same scale bar (on fig. J) = 100 μm.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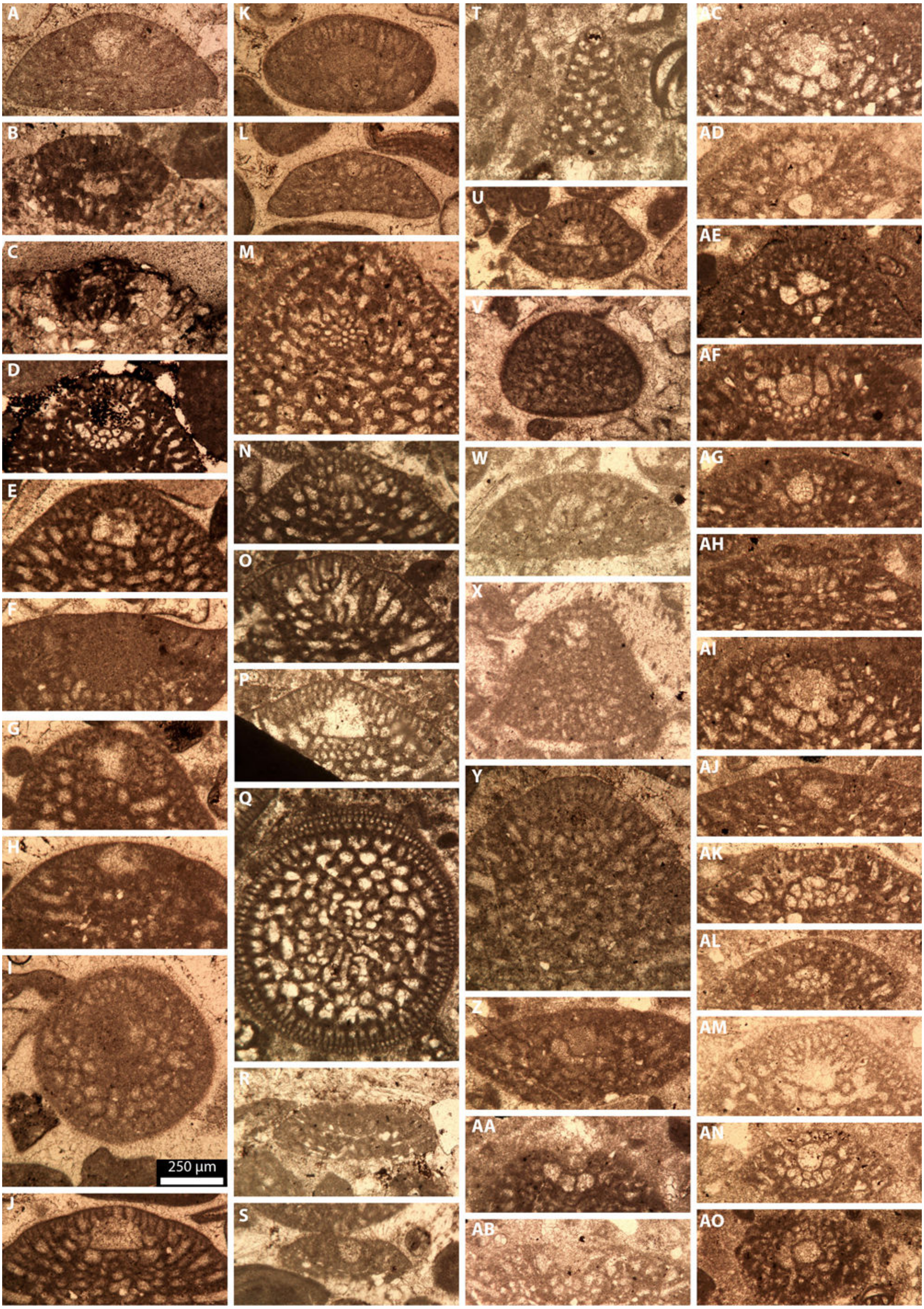
100 µm
250 µm

Plate 5: Samples A-T from Serra Gelada, U-W from Puig Campana, and X-AE from Cabeçó d'Or. Serra Gelada: ***Mesorbitolina texana* (Roemer, 1849)**, **A:** AB 5, **B:** AB 8, **C:** AB 10A, **D:** AB 12B, *Cylindroporella* oolithes, Cueva de la ballena, 10/06/1984; **L:** Relais 13 (HL 726), *Cylindroporella* oolithes, Relais section, 01/05/1985; **R-S:** Relais 7 (HL 709), *Cylindroporella* oolithes, Relais section, 25/04/1985, **Z:** BT 0A-2, **AA-AB:** BT 0A-1, **AC-AE:** BT 0A-3, **AF:** BT 0A-4, **AG:** BT 0A-5, **AH-AK:** BT 0A-7, **AL-AO:** BT 0A-8, calcarenites with *Favusella*, north of Sanatorio, 13/04/1985. ***Mesorbitolina birmanica* Sahni, 1937**, **E:** SH-Bb1060, **F:** SH-Bb1057, **G:** SH-Bb1055, **H:** SH-Bb1053, **I:** SH-Bb1052, **J:** SH-Bb1045, *Cylindroporella* oolithes, Camí del Far, 24/09/2010; **K:** Relais 13 (HL 726), *Cylindroporella* oolithes, Relais section, 01/05/1985; **M:** HL 141, orbitolinid calcarenites, Calle Dos Callas, 'LM' section, 12/06/1984; **N-Q:** HL 78, rudistid limestones, Punta de les Caletes section, 17/04/1984, **U:** Cluse 30 (MC19420), coral biolithites, Cluse section, 19/04/1983, **Y:** BT 59, calcarenites with *Favusella*, Sanatorio section, 26/04/1985. ***Orbitolinopsis* sp.**, **T:** HL 225, rudistid limestones, '3P', 24/07/1984. ***Mesorbitolina* sp.**, **V:** Realet 4 (ZC19382), **W:** Realet 2 (ZC19384), *Pieninia* calcarenites, Realet d'Alt section, 19/04/1983, **X:** BT 456, coral biolithites, Sanatorio section, 14/05/1985. Scale bar (on fig. I) = 250 µm.


A
B
C
D
E
F
G
H
I
250 µm
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y
Z
AA
AB
AC
AD
AE
AF
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AH
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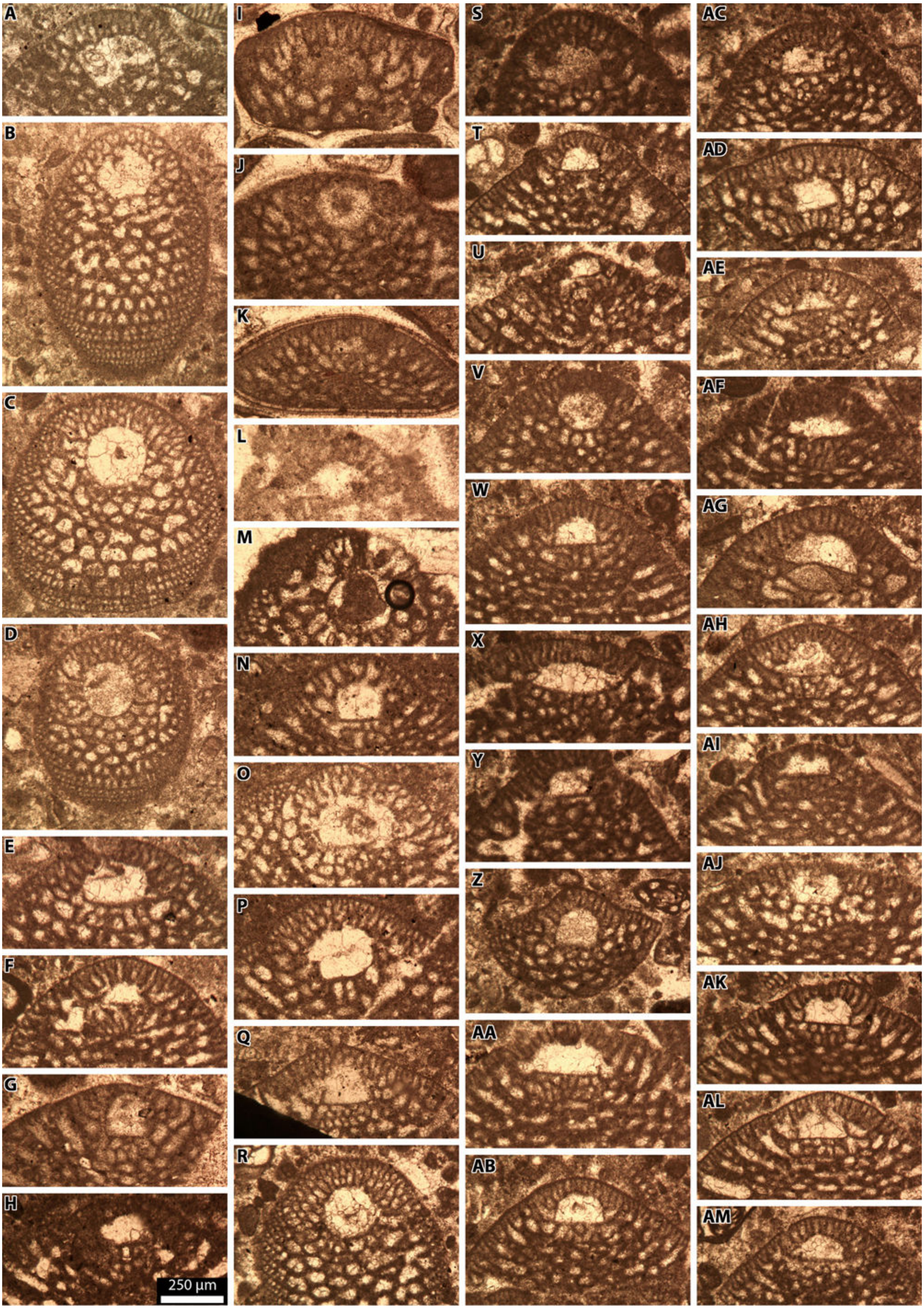
AJ
AK
AL
AM
AN
AO

Plate 6: All samples from Serra Gelada. ***Mesorbitolina birmanica* SAHNI, 1937, A-D:** HL 225-1, **E-F:** HL 225-2, rudistid limestones, '3P', 24/07/1984; **G:** HL 251, *Cylindroporella* oolithes, above Camí del Far, 26/07/1984; **H:** HL 110, rudistid limestones, Carabiniers 10, Camí del Far, Carabiniers section, 07/04/1984; **I-K:** HL 39, rudistid limestones, Punta de les Caletes section, 07/04/1984; **L:** HL 42bis, **M:** HL 44, rudistid limestones, Calle Dos Callas, 'LM' section, 08/04/1984; **N-O:** Relais 24 (HL 740), **P:** Relais 23 (HL 742), rudistid limestones, Relais section, 01/05/1985; **Q-Z:** HL 78A, **AA-AM:** HL 78B, rudistid limestones, Punta de les Caletes section, 17/04/1984. Scale bar (on fig. H) = 250 µm.


A
B
C
D
E
F
G
H
250 µm
I
J
K
L
M
N
O
P
Q
R
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U
V
W
X
Y
Z
AA
AB
AC
AD
AE
AF
AG
AH
AI
AJ
AK
AL
AM

Plate 7: Sample from Serra Gelada. ***Mesorbitolina birmanica*** **SAHNI, 1937, A-S:** HL 225-3, **T-AC:** HL 225-2, **AD-AO:** HL 225-1, rudistid limestones, '3P', 24/07/1984. Scale bar (on fig. K) = 250 µm.

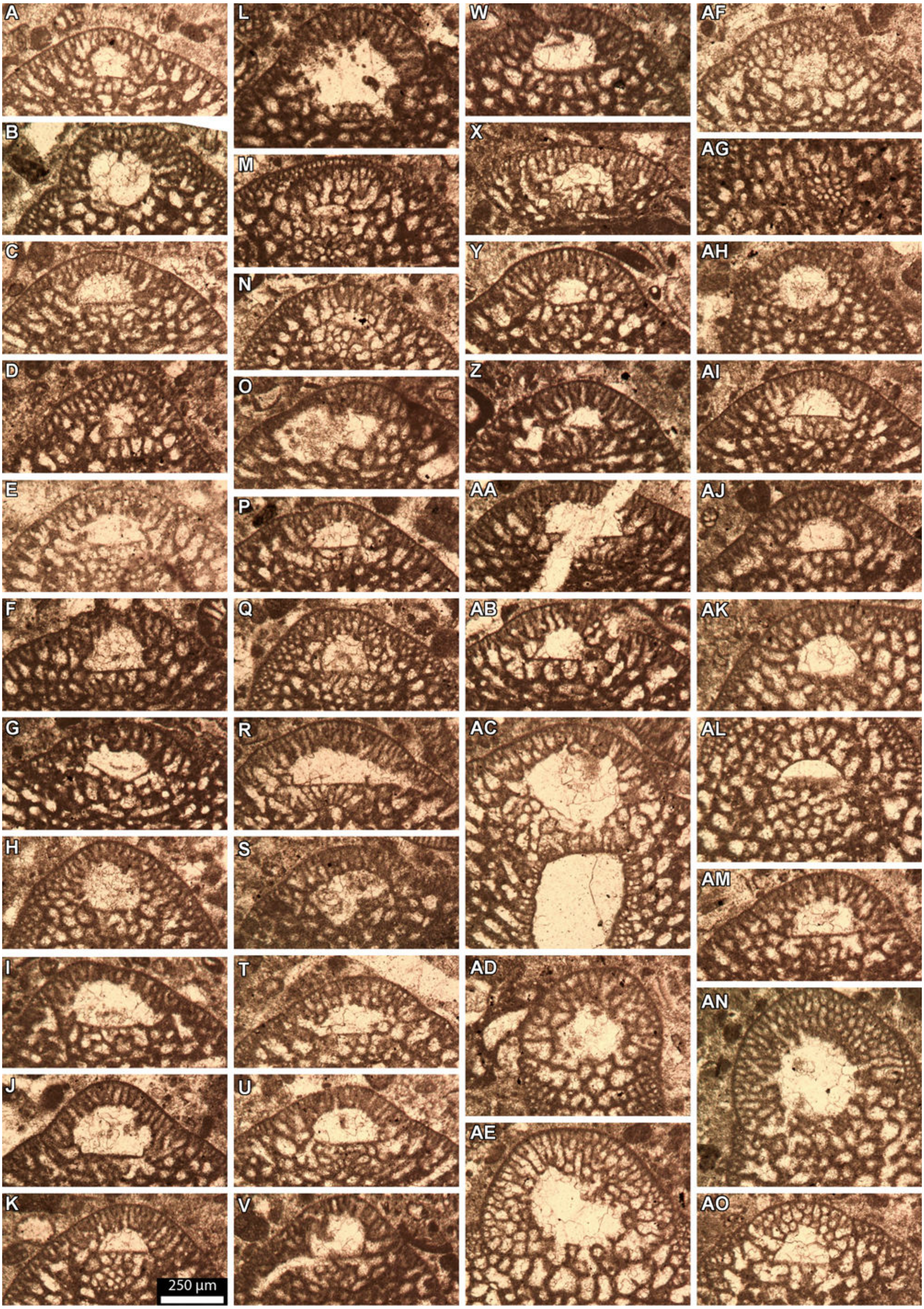
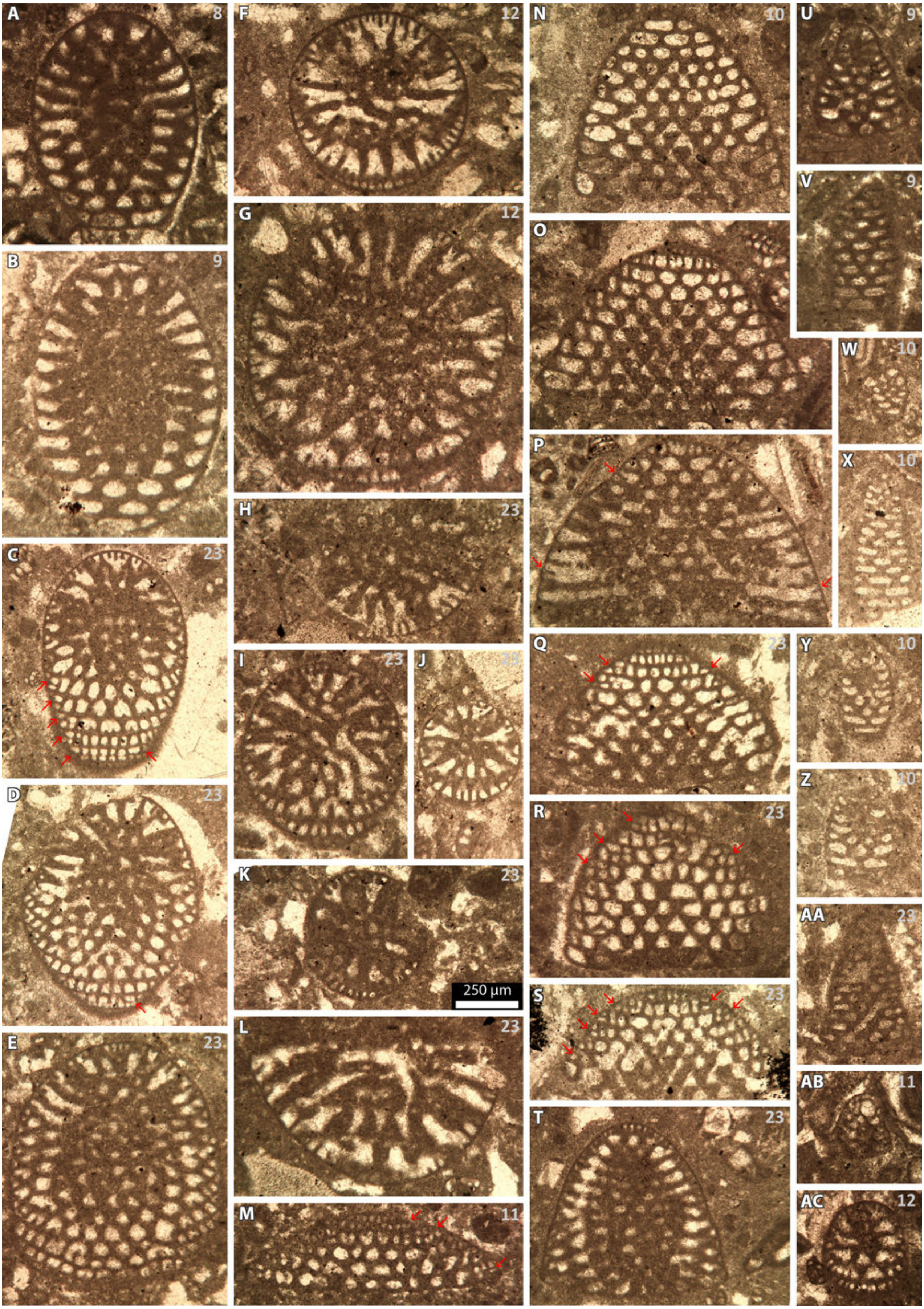
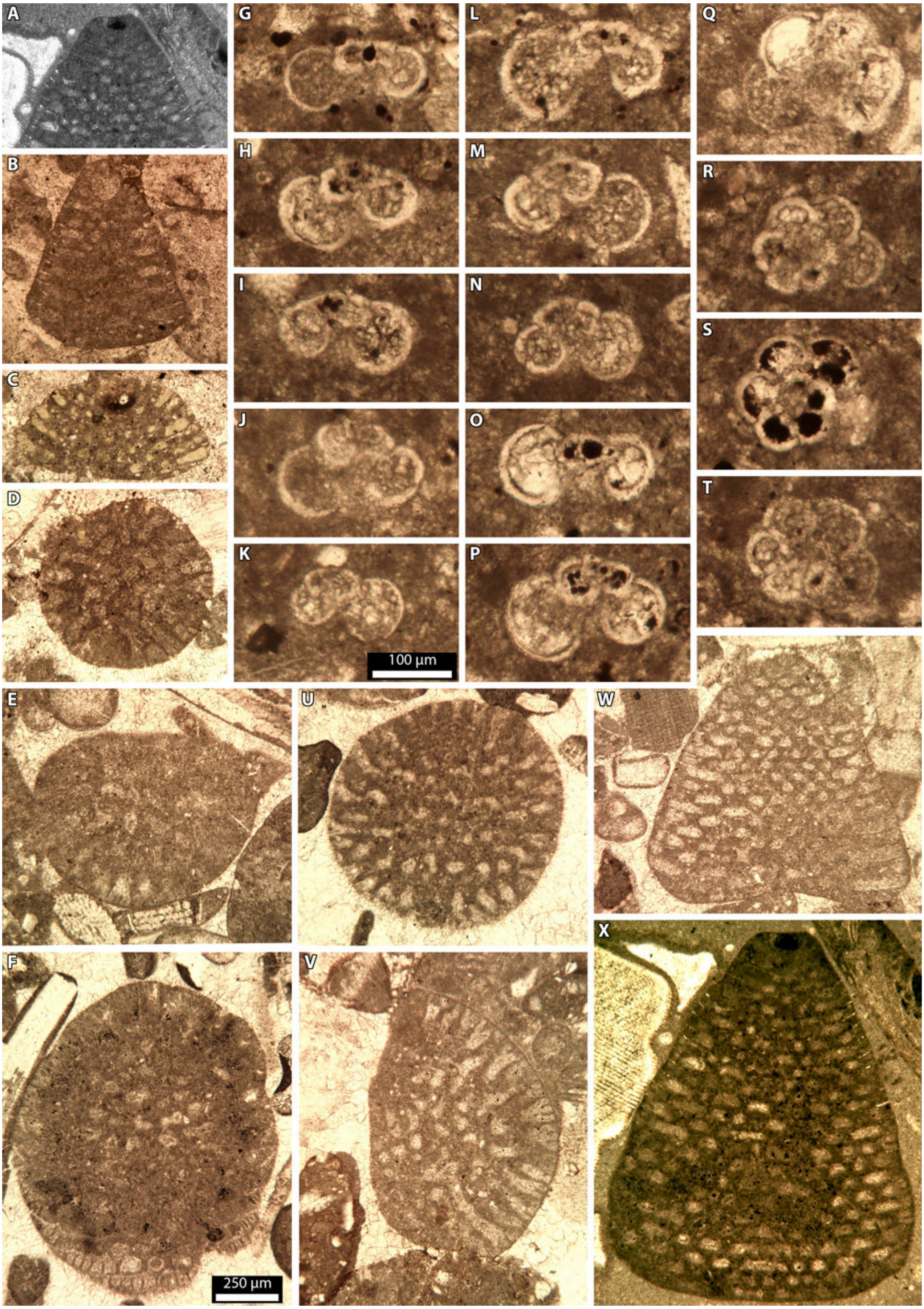

A
B
C
D
E
F
G
H
I
J
K
250 µm
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y
Z
AA
AB
AC
AD
AE
AF
AG
AH
AI
AJ
AK
AL
AM
AN
AO

Plate 8: All samples from Puig Campana, *Simplorbitolina* limestones, Realet d'Alt section, 09/04/1983. S***implorbitolina chauvei*** **FOURCADE, 1978**, **A:** Realet 8 (ZC19377), **B:** Realet 9 (ZC19376), **N:** Realet 10 (ZC19375). ***Simplorbitolina conulus*** **SCHROEDER, 1965**, **C-E, H-L, Q-T, AC:** Realet 23 (ZC19357), J = GRANIER, 1987: Pl. 9, fig. e, **F-G:** Realet 12 (ZC19373), F = GRANIER, 1987: Pl. 9, fig. c, **M:** Realet 11 (ZC19374). ***Simplorbitolina manasi*** **CIRY et RAT, 1953**, **O:** Realet 12 (ZC19373),**? AB:** Realet 11 (ZC19374). 'Transitional form', intermediate form between *Simplorbitolina manasi* CIRY et RAT, 1953, and *Simplorbitolina conulus* SCHROEDER, 1965, **P:** Realet 14 (ZC19367). ***Simplorbitolina aquitanica*** **(SCHROEDER & POIGNANT, 1964)**, **U-V:** Realet 9 (ZC19376), **W-Z:** Realet 10 (ZC19375), **AA:** Realet 23 (ZC19357). Scale bar (on fig. K) = 250 µm.



A 8
B 9
C 23
D 23
E 23
F 12
G 12
H 23
I 23
J 23
K 23
250 µm
L 23
M 11
N 10
O
P
Q 23
R 23
S 23
T 23
U 9
V 9
W 10
X 10
Y 10
Z 10
AA 23
AB 11
AC 12

Plate 9: All samples from Puig Campana. ***Neorbitolinopsis conulus* (DOUVILLÉ, 1912)**, **A, F, U-V:** equivalent Rafel 41 (MC19499), 04/08/1982; **B-E, W:** Rafel 41 (BG82813), 04/08/1982 (GRANIER, 1987: Pl. 10, fig. d); **X:** equivalent Rafel 41 (MC19493), 04/08/1982, *Hensonina* calcarenites, Rafel section. ***Praehedbergella* spp.**, **G-T:** Cluse 20 (7832), condensed section, Cluse section, 19/04/1983. A-F, U-X, same scale bar (on fig. F) = 250 µm; G-T, same scale bar (on fig. K) = 100 µm.


A
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F
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I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
100 µm
250 µm

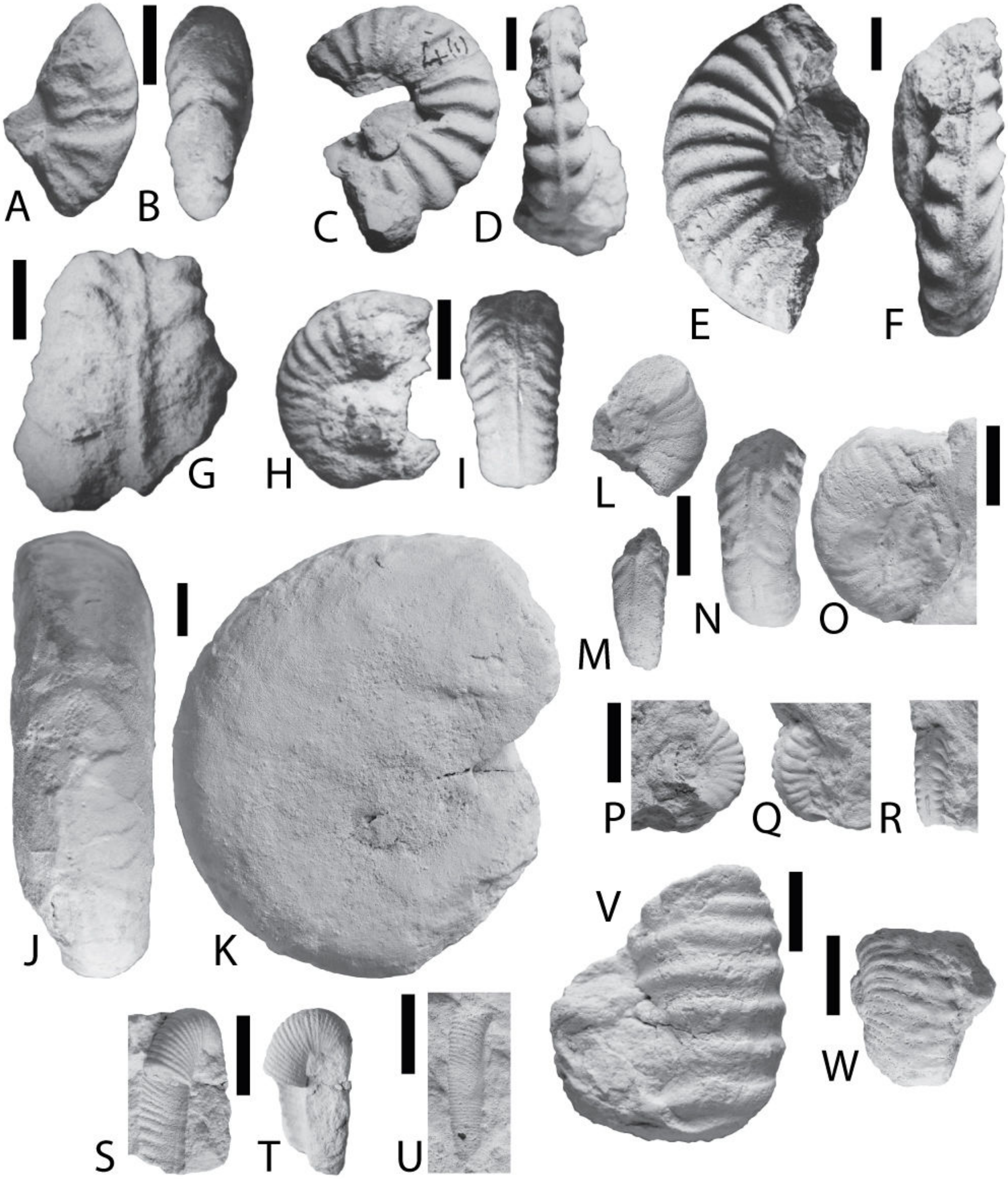

Plate 10: Ammonite specimens from Sanatorio Section, Aïgues de Busot, Cabeçó d'Or. A-I first illustrated in GRANIER (1987). J-W newly collected in 2024. **A-B:** *Brancoceras* sp. (GRANIER, 1987: Pl. 47, fig. 4.a-b), **C-D:** *Hysteroceras* sp. (GRANIER, 1987: Pl. 47, fig. 6.a-b), **E-F:** *Hysteroceras* sp. (GRANIER, 1987: Pl. 47, fig. 1.a-b), **G:** *Dipoloceras* sp. (GRANIER, 1987: Pl. 47, fig. 5.a), **H-I:** *Dipoloceras* sp. (GRANIER, 1987: Pl. 47, fig. 2.b-c), **J-K:** *Puzosia (Pusozia)* sp. (UCBL-FSL 471979). This specimen displays a constricted cross-section (more compressed than in *Desmoceras*, excluding its ascription to the latter genus) and weakly convex flanks. The involution of the whorls is difficult to ascertain due to the concealment of the internal whorls. **L-M:** *Dipoloceras* sp. (UCBL-FSL 471989), **N-O:** *Dipoloceras* sp. (UCBL-FSL 471991), **P-R:** *Hysteroceras* sp. (UCBL-FSL 471990), **S:** *Hamites* sp. (UCBL-FSL 471983), **T-U:** *Hamites* sp. (UCBL-FSL 471982), **V:** *Hamites* sp. (UCBL-FSL 471984), **W:** *Anisoceras* sp. (UCBL-FSL 471985). All scale bars = 1 cm.

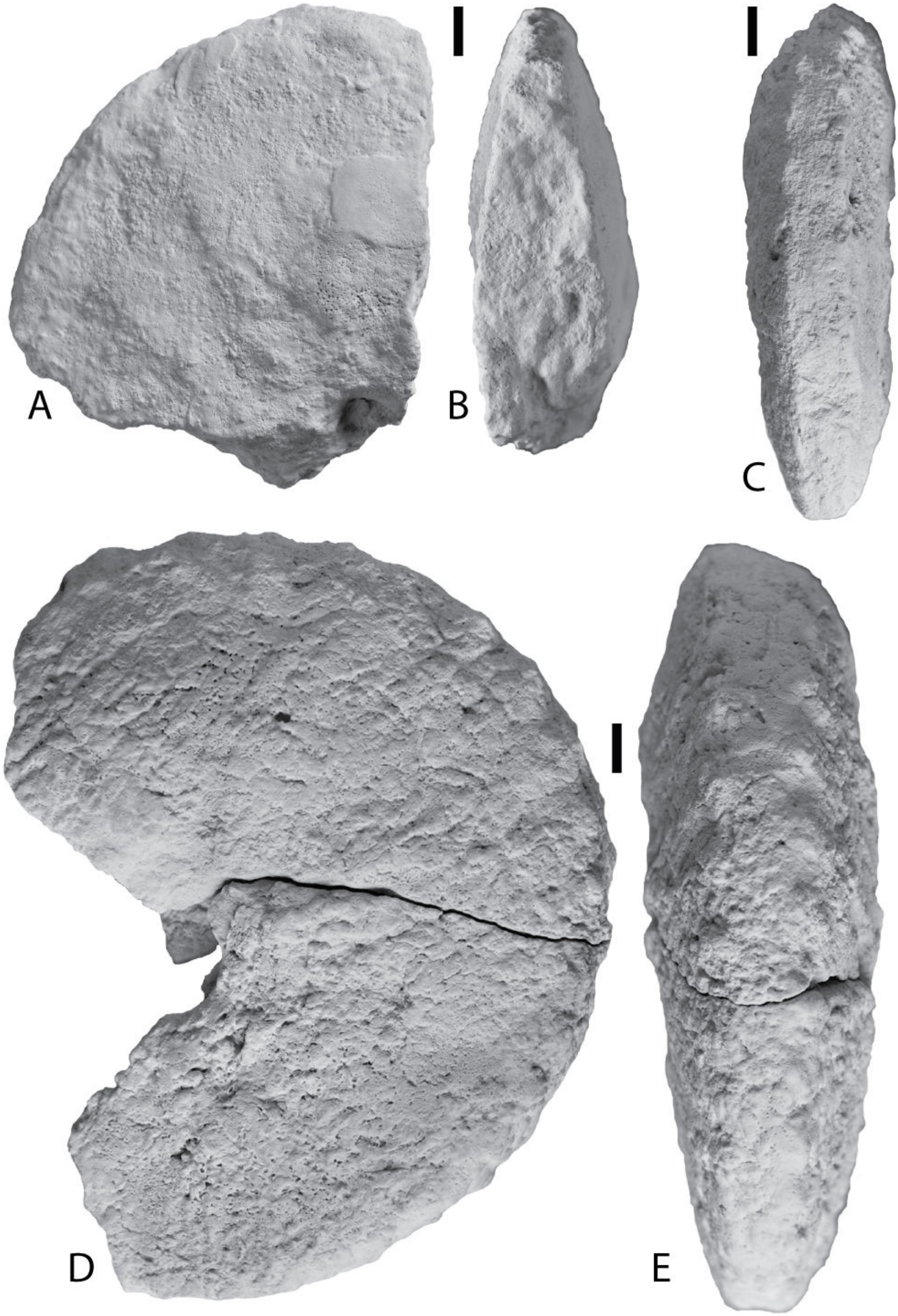

Plate 11: Ammonite specimens from Caroch Massif, East of Ayora. **A-B:** *Parengonoceras* sp. (UCBL-FSL 471991), **C:** *Parengonoceras* sp. (UCBL-FSL 471997), **D-E:** *Parengonoceras* cf. *ibericum* (ARIAS & WIEDMANN, 1977), (UCBL-FSL 471994). All scale bars = 1 cm.