L'Estellon (Baronnies, France), a "Rosetta Stone" for the Urgonian biostratigraphy

Bruno GRANIER [1]

Bernard CLAVEL [2]

Michel MOULLADE [3, 4]

Robert BUSNARDO [5]

Jean CHAROLLAIS [6]

Guy TRONCHETTI [3, 7]

Pierre DESJACQUES [8]

Abstract: Shallow-water assemblages of transported ("freshly reworked") bioclasts (mainly orbitolinids and dasycladales) are observed in the deeper facies of the "Vocontian Trough" (SE France). There these benthic assemblages can be directly correlated with ammonite zones. These new finds give an Early Barremian age to the earliest record of *Palorbitolina lenticularis* as well as those of four so-called "typical Early Aptian" representatives of the genus *Orbitolinopsis*. Actually most orbitolinid species recorded from the Late Barremian interval are now found present in Lower Barremian strata at L'Estellon. Some currently used correlation schemes for the Urgonian platforms, that are based on partial stratigraphic distribution ranges for the orbitolinids, --and consequently derived conclusions and hypotheses-- require at least in-depth revisions when they are not definitively refuted.The study of the ammonite fauna in the L'Estellon section (Drôme department, SE France) allows us to date episodes with gravitational deposition in this area of the "Vocontian Trough". They span most of the Barremian Stage, from the Nicklesi Zone up to the Giraudi Zone. We did not identify any Bedoulian redeposits, the "Bedoulian ridge" *auct.* being latest Barremian in age.

Key Words: Barremian; Urgonian ; orbitolinids; Dasycladales; ammonites; biostratigraphy; biostratigraphic calibration.

Citation: GRANIER B., CLAVEL B., MOULLADE M., BUSNARDO R., CHAROLLAIS J., TRONCHETTI G. & DESJACQUES P. (2013).- L'Estellon (Baronnies, France), a "Rosetta Stone" for the Urgonian biostratigraphy.- *Carnets de Géologie* [*Notebooks on Geology*], Brest, Article 2013/04 (CG2013_A04), p. 163-207.

[1] *Département des Sciences de la Terre, UFR des Sciences et Techniques, Université de Bretagne Occidentale (UBO), 6, avenue Le Gorgeu, F-29238 Brest Cedex 3 (France)*
bgranier@univ-brest.fr
[2] *24 ch. des Champs d'Amot, 74140 Messery (France)*
b.clavel2@gmail.com
[3] *Laboratoire de Géologie des Systèmes et des Réservoirs Carbonatés, Aix-Marseille Université, Campus St-Charles, Case 67, 3 Pl. Victor Hugo, 13331 Marseille Cedex 03 (France)*
[4] *Centre de Recherches Micropaléontologiques, Muséum d'Histoire naturelle, 60 Bd Risso, 06000 Nice (France); Michel.Moullade@unice.fr*
[5] *Chemin du Méruzin, 69370 St-Didier-au-Mont-d'Or (France)*
robert.busnardo@wanadoo.fr
[Editor and copy editor: Christian C. EMIG; language editor: Stephen EAGER]
[6] *Département de Géologie et Paléontologie, Université de Genève, 13 rue des Maraîchers, 1211 Genève 4 (Suisse)*
jdcharollais@bluewin.ch
[7] *guy.tronchetti@orange.fr*
[8] *24 avenue de Bel-Air, 1225 Chêne-Bourg (Switzerland)*
pi_desjacques@bluewin.ch
Manuscript online since July 22, 2013
[Scientific editor: Christian C. EMIG; technical editor: Bruno GRANIER; language editor: Stephen EAGAR]

Résumé : ***L'Estellon (Baronnies, France), une "Pierre de Rosette" pour la biostratigraphie de l'Urgonien.-*** Des associations d'organismes habituellement caractéristiques de faibles tranches d'eau (des orbitolinidés et des algues, en particulier) ont été identifiées dans des faciès relativement profonds de la "fosse vocontienne" (SE de la France), où ces éléments ont été transportés gravitairement et précocement resédimentés. Dans un tel contexte paléoenvironnemental, ces associations benthiques peuvent être directement calibrées sur les zones d'ammonites. D'après ces nouvelles observations, entre autres résultats, la première apparition de *Palorbitolina lenticularis* ainsi que celles de quatre représentants du genre *Orbitolinopsis*, soi-disant typiques de l'Aptien inférieur, sont datées du Barrémien inférieur. De fait la plupart des espèces d'orbitolinidés connues dans le Barrémien supérieur sont déjà présentes au Barrémien inférieur à L'Estellon. Concernant les plates-formes urgoniennes, les schémas de corrélations couramment utilisés, qui s'appuient sur des distributions biaisées (tronquées) d'orbitolinidés -- et par conséquent les conclusions et hypothèses qui en sont dérivées --, nécessitent au moins des révisions en profondeur, sinon un rejet définitif.

Mots-Clefs : Barrémien ; Urgonien ; orbitolinidés ; Dasycladales ; ammonites ; biostratigraphie ; calibration biostratigraphique.

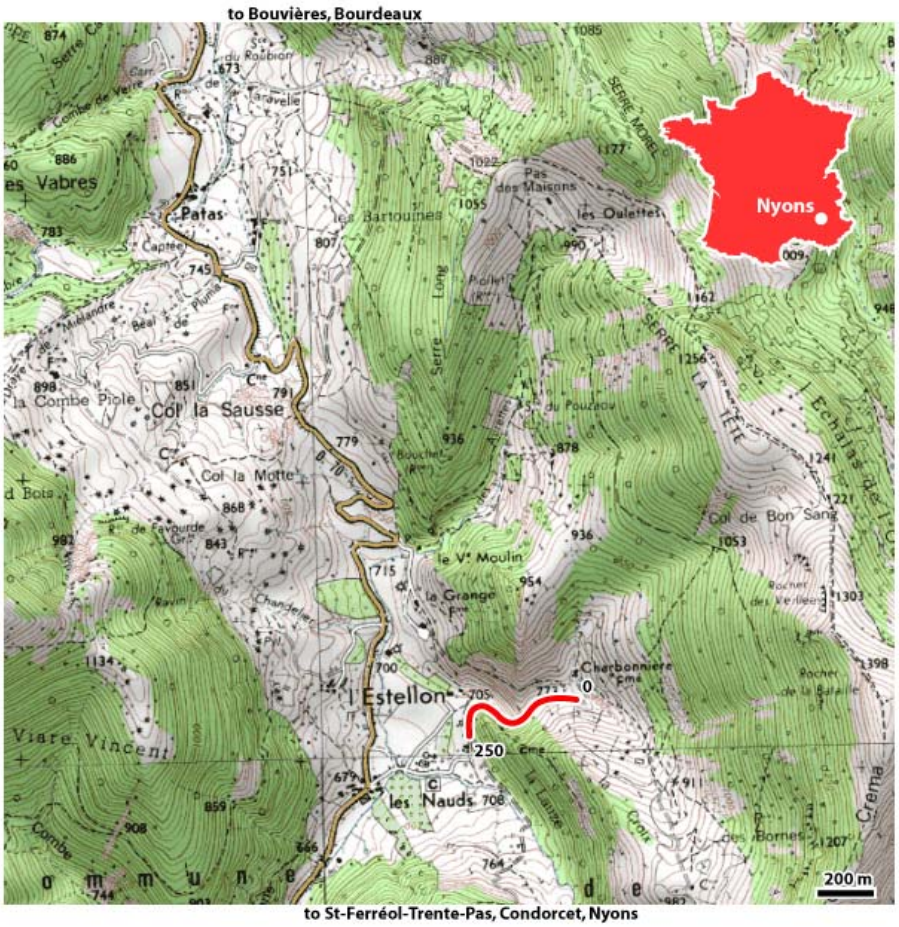
Introduction

L'Estellon section (GRANIER *et al.*, 2013) is located some twenty kilometres north to the locality of Nyons in the Drôme department, SE France (Fig. 1), a few kilometres north to the Chaudebonne section (MOULLADE, 1966) and south to the Crupies section (FERRY, 1976). As in both aforementioned sections the succession, which consists mostly of basinal marls and associated vermicular limestones (Fig. 2.C) includes a number of intercalations made of conglomerates (debris-flows) and oobioclastic allodapic calcarenites (turbidites). These coarse-grained floatstone and oobioclastic wackestone facies contain numerous foraminifers and calcareous algae thought to be transported ("freshly reworked") laterally from neighbouring carbonate shelves. While measuring the section (Fig. 3) we also collected in the argillaceous and muddy limestones a rather diversified ammonite fauna composed of Late Hauterivian and (Early and Late) Barremian forms (BUSNARDO *et al.*, 2013). The co-occurrence of both shallow- and deeper- water fossils allowed us to reconfirm the calibration of the First Appearance Datum - FAD - (and eventually the Last Appearance Datum - LAD -, because this parameter may be affected by late reworking phenomena) of these benthic foraminifers (MOULLADE, 1966, 1974; CLAVEL *et al.*, 2007, 2010a, 2010b, 2010c) and algae (CLAVEL *et al.*, 2007; GRANIER, 2013a) using the ammonite biozones. In other words L'Estellon section helped us correlating the distribution of allochtonous neritic ("shallow-water") assemblages with time-equivalent subautochtonous pelagic ("deeper-water") components of the fossil record and it provides therefrom a mean to transcript them into ages. Thus, L'Estellon section can be regarded as a "Rosetta Stone" for the Urgonian biostratigraphy. A comparison of these updated microfossil appearances with their ranges shown on current orbitolinid charts (ARNAUD-VANNEAU *et al.*, 2005; CLAVEL *et al.*, 2007, 2010a) provide contrasting results: for instance, our results call for the definitive withdrawal of one chart (ARNAUD-VANNEAU's that denies Lower Barremian occurrences as documented herein) and lead to question the conclusions of the several publications relying on such biostratigraphic framework (see similar discussions in CONRAD *et al.*, 2012, and CHAROLLAIS *et al.*, 2013).

Lithostratigraphy of L'Estellon section

One of the initial objectives when measuring the section at L'Estellon (Chaudebonne commune, Drôme department) was to revise and better characterize a lithostratigraphic unit labelled with a double-barrelled name, *i.e.*, "Barrémo-Bédoulien", on the regional geological maps (Nyons: BALLESIO *et al.*, 1975; Dieulefit: FLANDRIN, ed., 1969). We used a JACOB's staff (Fig. 4.D) to measure the section along the track (L'Adret et Crema) going down from the Charbonnière farm to the Borne farm, east of the hamlet of Les Nauds (L'Estellon). There strata are oriented N130 to N150° E with a dip 50 to 60° SW.

The section starts near the Charbonnière farm (Fig. 1) at an altitude of about 780 m (upstream) in the more or less regular alternating marls and limestones classically referred to the Hauterivian (Fig. 3). At level 26.5m we observed an isolated calcarenitic bed (1.1m thick) followed by occurrences of more or less thick calcarenitic, as well as conglomeratic, intercalations at levels 49.3 (Fig. 4.B), 60.7, 77.2, 81.7, 92.1, and 117.4m. Higher in the section, two very thick and dominantly calcarenitic intervals at 137.0 to 174.1 (c. 37m thick) and 217.0 to 240.0 (c. 23m thick, Fig. 2.A-B) correspond to the so-called "Barremian" and "Bedoulian" ridges respectively. The section, which almost reaches 250m in thickness, ends at an altitude of about 710m (downstream) without reaching the next lithostratigraphic unit (*i.e.*, Aptian-Albian "Marnes bleues").



◀ **Figure 1:** Geographic location of L'Estellon section. © www.geoportail.fr & IGN - Institut Géographique National, 73 avenue de Paris, F-94165 Saint-Mandé Cedex (France).

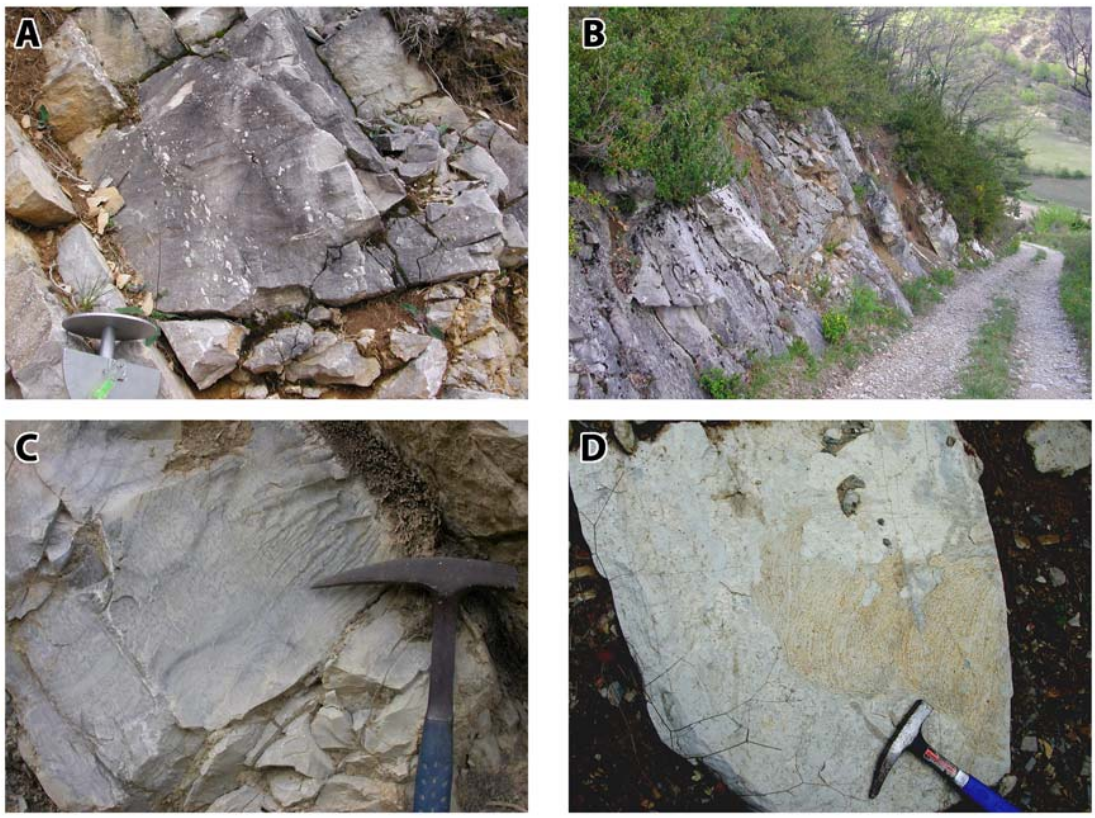


Figure 2: A: cherts in calcarenites of the interval 227.1 to 228.2; **B:** uppermost part of the section, temporary end at level 243.7; **C:** typical vermicular (bioturbated) facies; **D:** *Zoophycos* at level 241.2.

Biostratigraphy of L'Estellon section

A parallel objective when measuring the section was to revise the biostratigraphy of the so-called "Barrémo-Bédoulien". This revision is based on a significant number of ammonites collected in the section and also consideration that the planktonic and deeper-water benthic for aminifers from four marly samples taken at levels 63.3, 77.2, 116 and 242m are autochtonous.

A. Ammonites

The inventory of our first collection (2012 campaign) led to identify Late Hauterivian and Barremian taxa, as well as some taxa that straddle the Barremian-Bedoulian boundary, but no typically Bedoulian taxa (BUSNARDO *et al.*, 2013). Actually, as shown by several authors (*e.g.*, MOULLADE, 1966; BRÉHÉRET, 1997; HERRLE & MUTTERLOSE, 2003) in the Vocontian Basin the Bedoulian interval, which is sited at the bottom of the "Marnes bleues", is condensed and even partly lacunary.

Based on the sole ammonite record, the studied interval was first subdivided as follows (BUSNARDO *et al.*, 2013):

- the Hauterivian-Barremian boundary is located in the interval between level 10, with the last *Parathurmannia sarasini* (SARKAR), and level 17, with *Taveraidiscus hugii* (OOSTER), the index of the first Barremian zone;
- the Lower-Upper Barremian boundary is below level 125, containing both *Heinzia sayni* (HYATT) and *Toxancyloceras vandenheckei* (ASTIER);
- the Barremian-Bedoulian boundary was probably not seen, as we did not collect any specimens of the genus *Deshayesites* KAZANSKY.

Most Barremian ammonite zones have been detected but their boundaries were not accurately defined. For instance, in the Lower Barremian interval, we were not able to separate the Hugii and Nicklesi zones. As for the Upper Barremian interval the assemblage at level 125 is diagnostic of the Vandenheckei Zone; the index of the Sartousiana Zone is found in levels 187-188 and the Sarasini Subzone of the Giraudi Zone possibly begins above level 195.5 with *Hemihoplites* sp. and *Acantholytoceras* sp. and below level 202 with *Heteroceras* sp. As said above, the Bedoulian (*sensu* MOULLADE *et al.*, 2011) was not identified in the section.

B. Foraminifera (M. MOULLADE)

1) Biostratigraphic markers

MOULLADE (1966) already reported scarce occurrences of small planktonic foraminifers and deep-water benthic foraminifers from Vocontian Barremian sections, such as that of Chaudebonne, a few kilometres from L'Estellon. Similar microfaunas have been found in the washed residues of the four marly samples quoted above, including specimens that contributed to date some intervals.

At levels 60.3 and 77.2 (marly samples 1 and 2), the occurrence of rare and evolutionary-primitive forms of *Praehedbergella eocretacea*, a planktonic marker of the upper Lower Barremian (MOULLADE, 1966), suggests that these levels should be ascribed to the Compressissima Zone.

At level 242 (marly sample 4), we found *Praehedbergella primare* (KRETCHMAR & GORBATCHIK). The FAD of this species falls in the "vire à *Heteroceras*" *auct.* (*i.e.*, in the interval between the so-called "Barremian" and "Bedoulian" ridges) in the Vocontian Basin (at Angles for instance, cf. GUILLAUME & SIGAL, 1965; MOULLADE, 1966). Among the deeper-water benthic for aminifers occurs the species *Lenticulina cuvillieri* MOULLADE, the LAD of which has been found near the Barremian - Bedoulian boundary at Cassis (MOULLADE *et al.*, 1998), and *Gavelinella* sp. aff. *barremiana* (*sensu* MOULLADE, 1966), common in Barremian strata, but very rare in Bedoulian ones. Therefore on the basis of for aminifers level 242 can be ascribed to the latest Barremian. This result is consistent with the dating based on our ammonite record.

2) Taxonomic notes

Praehedbergella eocretacea (NEAGU, 1975) – Specimens of this Lower Barremian complex of tiny planktonics were initially reported from the Angles section (Vocontian Basin) by GUILLAUME & SIGAL (1965) as "*Hastigerinella* gr. *simplex*" and "*Hastigerinella* sp. 19970". In 1966 MOULLADE fully described and illustrated these forms found throughout the Vocontian area as a unique taxon but left under open nomenclature as "*Hedbergella* (*Clavihedbergella*) sp., aff. *Simplex*". The author pointed also the biostratigraphic interest of this upper Lower Barremian marker, which was later on formally described as *Clavihedbergella eocretacea* by NEAGU (1975) on the basis of specimens from Romania.

Praehedbergella primare (KRETCHMAR & GORBATCHIK, 1986) - Originally depicted in the Angles section as "*Globigerina* sp. 1973" by GUILLAUME & SIGAL (1965) and then as "*Hedbergella* sp., aff. *planispira*" from the entire Vocontian Basin by MOULLADE (1966), this taxon was finally formally described in Crimea as *Praehedbergella primare* by KRETCHMAR & GORBATCHIK (1986). This Early Cretaceous homeomorph of the Middle Cretaceous *H. planispira* (TAPPAN) may also have been misidentified under other specific names as "*similis*" or "*kuznetsovae*" and quoted as such in range charts by several authors.

▶ **Figure 3:** Lithostratigraphic column of L'Estellon section.

L'ESTELLON SECTION
(April 2012)
floatstone
coarse grainy limestone
fine grainy limestone
mudstone
marl
METERS
(?) log matching
Zoophycos
chain
(?) log matching

Figure 4: A: *Phyllopachyceras* sp. at level 17; **B:** conglomerate with marl pebbles (intraclasts) at level 54.5, see also Fig. 5 ; **C:** calciturbidite with E. MUTTI's F7 facies (flat lamination capped by small unidirectional ripples); **D:** measuring of the section with the JACOB's staff.

Figure 5: rounded mudstone pebble (intraclast) floating in a bioclastic grainy matrix at level 194.5.

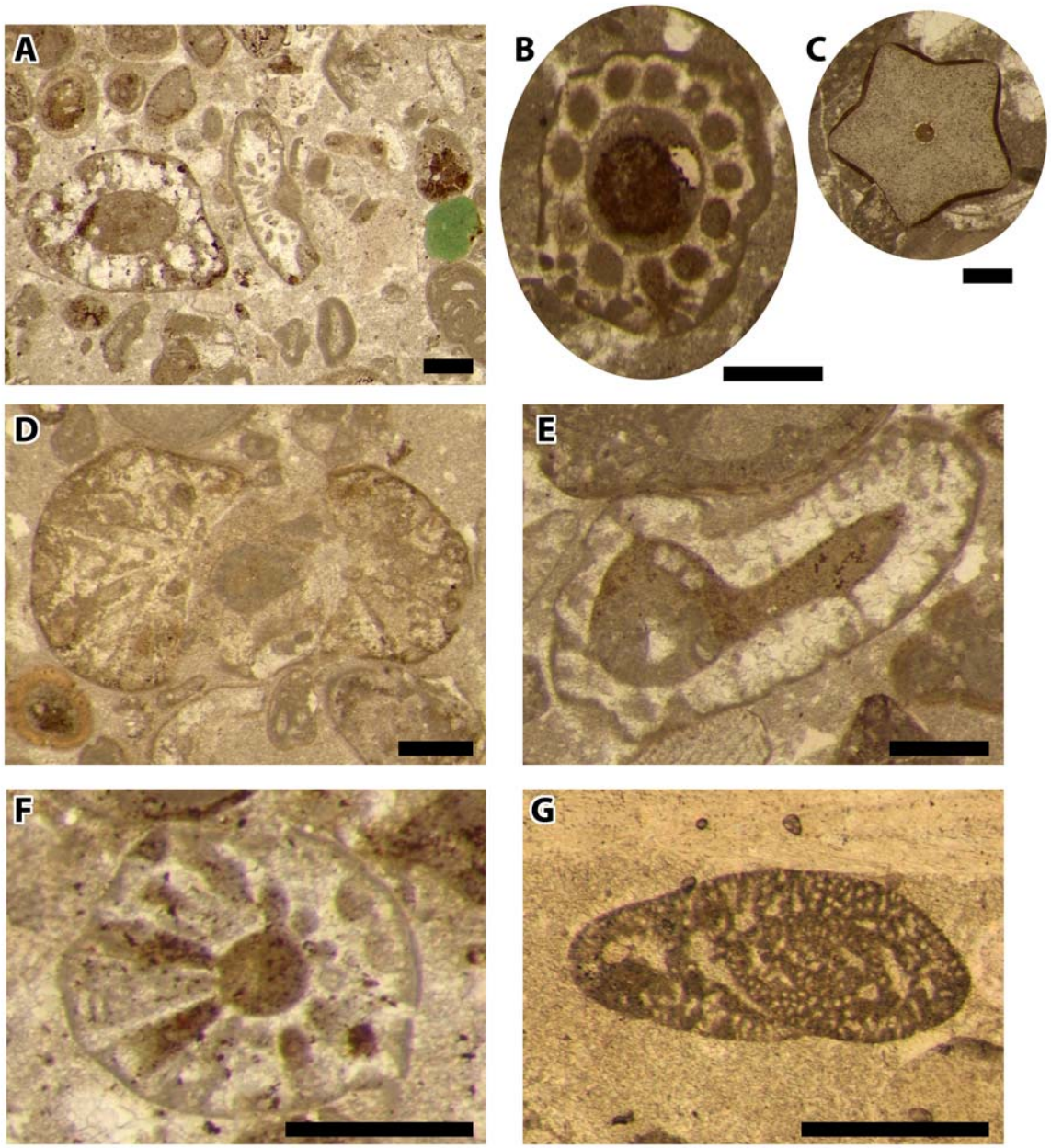


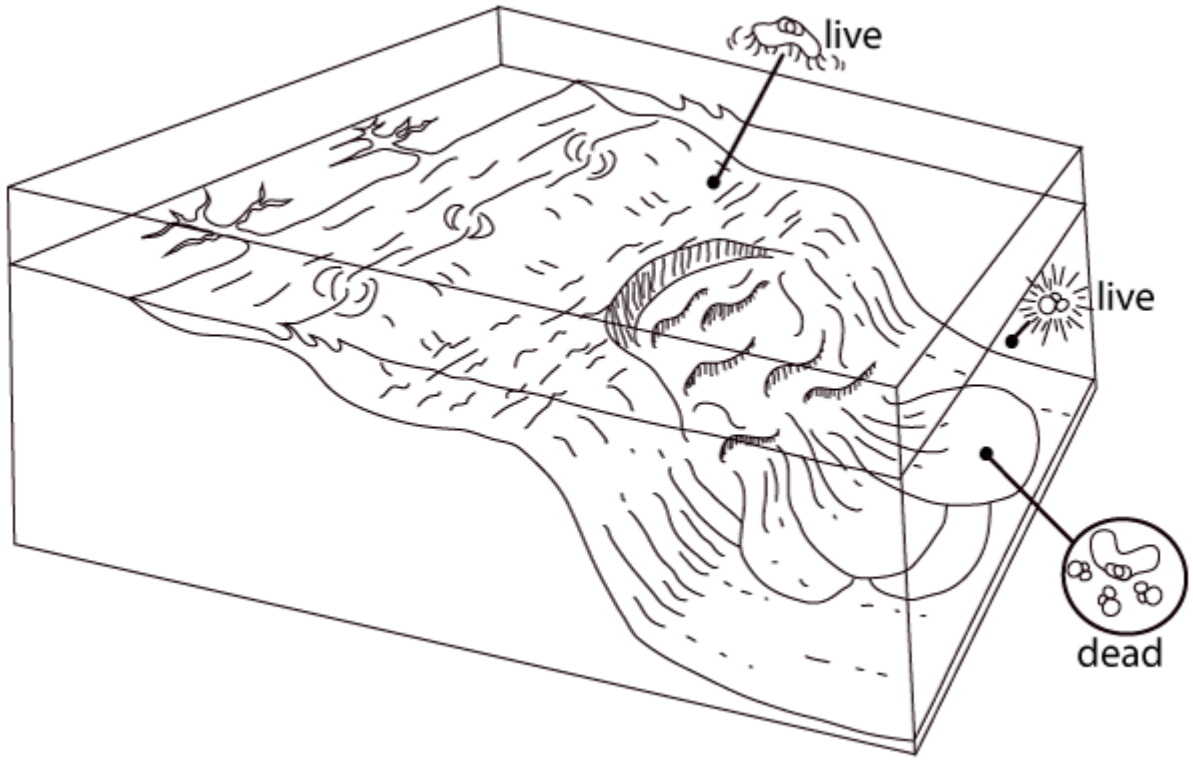
Figure 6: A: slightly glauconitic oobioclastic wackestone with the algae *Salpingoporella genevensis* (oblique section) and *Actinoporella* gr. *podolica* (oblique section) - Sample 26.5m; **B:** subtransverse section of a charophyte stem - Sample 218.1m; **C:** transverse section of a crinoid columnal - Sample 218.1m; **D:** oblique section of the alga *Falsolikanella danilovae* - Sample 92.3m; **E:** branching thallus (rare) of the alga *Salpingoporella muelhbergii* - Sample 92.3m; **F:** oblique section of the alga *Pseudoactinoporella fragilis* - Sample 26.5m; **G:** the benthic foraminifer *Choffatella decipiens* - Sample 49.8m. Scale bar = 500µm.

3) Microfaunal contents

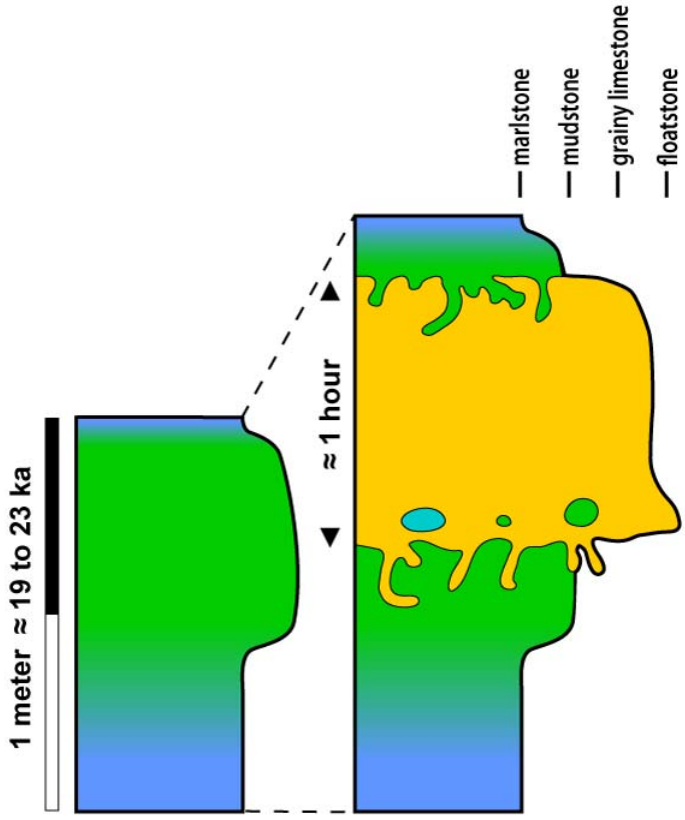
- Overall composition

The ≥ 200 µm size fraction of three of the four samples collected from L'Estellon section included a more or less important amount of fragments from various Invertebrates (such as Bivalves, Echinids, Gastropods, Sponges, Algae, …) and abraded tests of shallow water benthic larger foraminifers, mostly Orbitolinids. The < 200 µm fractions contained some abraded medium sized shallow water benthic for aminifers (Miliolids, Lituolids, …). In all samples, finer fractions included rare smaller, better preserved, supposedly deeper water benthic foraminifers (Lenticulinids, Gavellinids, Praedorothias, …) and also very rare tiny planktonics (Praehedbergellas).

The bioclasts and abraded shallow water benthic microfossils are thought to originate from the neighbouring carbonate platforms such as the Vercors, northern Diois or Ardèche. They were submitted to intraformational reworking and rapidly transported in the Vocontian Basin. The tiny and scarce better preserved benthics and planktonics are interpreted as being the autochtonous basinal microfauna.



A



B

Figure 7:

▲ **A:** a model for the sourcing of the Urgonian calciturbidites, the strata where the neritic microfossils meet the basinal index fossils (according to GRANIER, 2013b);

◀ **B:** a model of the sedimentation rate for calciturbidites in alternating marl-limestone: for an equal thickness a calcarenitic interval represents a much higher sedimentation rate than a marl-limestone interval.

- Level 60.3

Benthic foraminifers : *Lenticulina gibba*, *Neotrocholina paucigranulata*, *Spirillina minima*, *Patellina subcretacea*, Nodosariidae sp. pl., indet. small abraded rotaliiforms, *Conorboides* sp., *Epistomina* sp., *Gavelinella* sp. aff. *Barremiana* (*sensu* MOULLADE, 1966), *Spiroplectammina* sp., *Praedorothia ouachensis*. Few abraded Orbitolinids and Miliolids.

Planktonic foraminifers : *Gorbachikella kugleri*, *Praehedbergella eocretacea*, *P. sigali.*

- Level 77.2

Benthic foraminifers : *Neotrocholina infragranulata*, *N. paucigranulata*, *Spirillina minima*, *Patellina subcretacea*, *Praedorothia* sp. pl., including *P.* sp. gr. *hechti-subtrochus*, *P. trochus*, *P. ouachensis*, *Globorotalites bartensteini bartensteini*, *Lenticulina cuvillieri*. Numerous abraded shallow-water larger foraminifers, such as Orbitolinids, Miliolids, Choffatellas, Pseudocyclamminas, *Trocholina aptiana*, and smaller ones, as *Arenobulimina* sp.pl., *Nezzazata*, *Nautiloculina*, *Conorboides* sp. pl., various undetermined rotaliiforms.

Planktonic foraminifers : *Praehedbergella sigali*, *P. eocretacea*, *P. aptiana*.

- Level 116

Benthic foraminifers : *Lenticulina crassa*, *L. gibba*, *Reophax* sp. gr. *minuta-guttifer*, *Trochammina* cf. *vocontiana*, *Neotrocholina infragranulata*, *N. paucigranulata*, *Spirillina minima*, *Patellina subcretacea*. This level does not contain abraded "reworked" elements of a shallow water allochtonous microfauna.

Planktonic foraminifers : *Praehedbergella sigali*, *P. aptiana*.

- Level 242

Benthic foraminifers : common *Lenticulina cuvillieri*, rare *L. ouachensis ouachensis*, *L. ouachensis multicella*, *Gavelinella* sp. aff. *Barremiana* (in MOULLADE, 1966). Few abraded forms, such as Orbitolinids, Miliolids (*Triloculina* sp., *Spiroloculina* sp., ...), *Pseudolituonella* ? sp.

Planktonic foraminifers : *Praehedbergella sigali*, *P. aptiana*, *P. primare*.

C. "Calcareous algae", the Dasycladales

As for the calcareous algae, we did not use them to date the turbidites. However it is noteworthy to mention that we do not report out of range occurrences. For instance, the LAD of the recently revised *Clypeina paucicalcarea* is found at L'Estellon up to level 92.3 (GRANIER, 2013a) in the Moutonianum Zone, *i.e.*, in the uppermost ammonite zone of the Lower Barremian, that is consistent with our current knowledge of its stratigraphic range. Another species, *Salpingoporella genevensis*, which was never reported in strata higher than the Lower Barremian, is found at L'Estellon in the first calcarenitic bed in samples 26.5 (Fig. 6.A) and 72.

In Serre de Bleyton, a locality 6 km eastward of L'Estellon, a "sand sheet" dated "middle to late Early Barremian" by its ammonite assemblage (LUKENEDER, 2010) also contains for aminifers and algae. But only the algae were studied by BUCUR (2011) who lists: *Clypeina* (as "*Pirifirella*") *paucicalcarea*, *Actinoporella* "gr." *podolica* (see discussion in GRANIER, 1995), *Angioporella fouryae*, *Deloffrella quercifoliipora*, *Falsolikanella danilovae* (see discussion in GRANIER *et al.*, 2000), *Montiella* ? *elitzae*, *Pseudoactinoporella fragilis*, *Pseudoclypeina* sp., *Russoella radoicicae*, *Salpingoporella genevensis*, *S. melitae*, *S. muehlbergii*, and *Triploporella* sp.

Some Dasycladales, which are easy to identify, proved to be useful fossils to discriminate Lower from Upper Barremian strata. There are cases where some authors purposely do not deliver such information because it might contradict their biostratigraphic interpretation (see discussions in CONRAD *et al.*, 2012, or CHAROLLAIS *et al.*, 2013).

Cyclo- and sequence stratigraphy of L'Estellon section

L'Estellon is located only c. 20 km westward of La Charce, a candidate for the GSSP - Global Boundary Stratotype Section and Point - of the Hauterivian. In most localities of the Vocontian Basin the stratal pattern of Hauterivian marl-limestone alternations is correlated to cyclic variation in the pelagic carbonate *Praedictyorbitolina*, which is interpreted as the record of climatic oscillations, which in turn are controlled by orbital parameters (see SCHWARZACHER, 1993). In fact, a marl-limestone couplet would correspond to a c. 21 kyr precession of the equinoxes cycle. A couplet, 0.8 to 1.0m thick in average, took some 21 kyr for sedimentation whereas discrete calcarenitic intercalations, ranging from 0.01 to 1.0m in thickness, were probably deposited in less than one hour (Fig. 7.A). The sand-sized allochems found in these mud-supported (wackestone) or eventually grain-supported (grainstone) textures are mostly bioclasts: echinoderms, bryozoans, pelecypods, benthic foraminifers, calcareous green algae, *etc.* The coarser grains floating in the muddy or grainy matrices are intraclasts (basinal mudstones and marlstones) and extraclasts (shallow-water carbonate facies). At L'Estellon, except for the intraclasts (Figs. 4.B - 5), the source for this reworked material is to be found in the carbonate shelves surrounding the Vocontian Basin, probably from the West (see FERRY, 1976), *i.e.*, from the neighbouring Vivarais (Ardèche department), according to the paleocurrent directions and orientation.

Calcareous turbidites differ from siliciclastic turbidites in that they are not linked to upflow canyons incising the platform but most probably result from collapses of the unconsolidated accumulations at the platform edge (Fig. 7.B). Theorically, it is almost excluded that such syn-sedimentary events occur at times of faster relative sea-level rise, *i.e.*, during transgressive intervals (TST); instead, they may occur at times of slow relative sea-level rise, *i.e.*, mostly during both late hightstand (HST) and lowstand

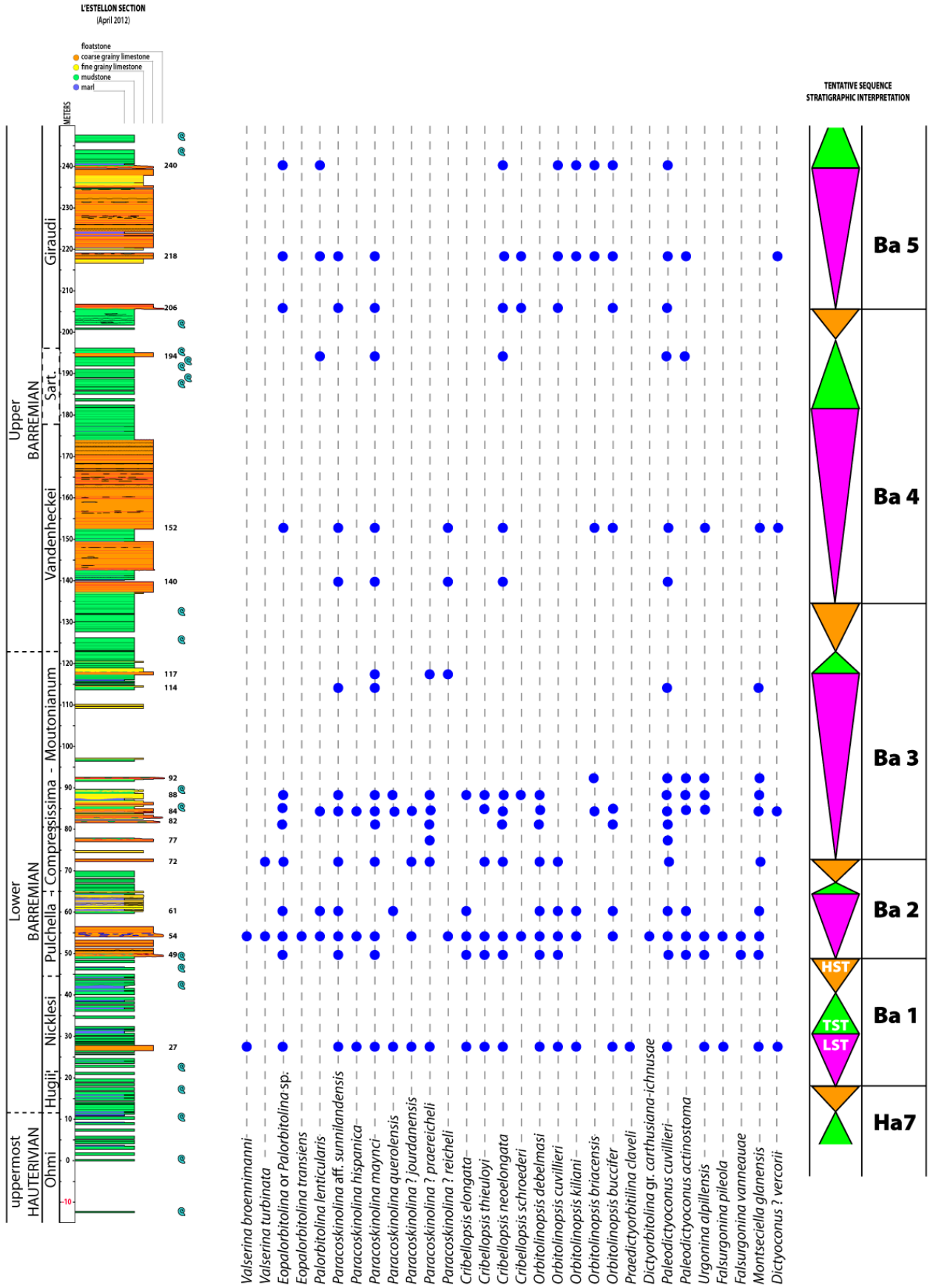


Figure 8: Orbitolinid records together with the latest biostratigraphic interpretation of L'Estellon section as documented by ammonites and planktonic foraminifera (and tentative sequence stratigraphic framework).

(LST) intervals, and obviously at times of relative sea-level fall, *i.e.*, mostly during "falling-stage" intervals (early LST).

In a parallel paper (BUSNARDO *et al.*, 2013) we identified a number of sand flow units at L'Estellon, ascribing them ammonite-derived ages and referring them to discrete LST in a set of sequences labelled Ba1 to Ba5, as identified by CLAVEL *et al.* (2010a, 2010b, 2010c, 2012). The list of units, their relative datings and their labellings follow:

- the first calcarenitic bed at 26.5m (Niklesi Zone) is referred to the LST "Ba1" of CLAVEL *et al.* (2010a, 2012),
- the second set starting from 49.3m (Pulchella Zone) to the LST "Ba2",
- the third starting from 72.4m (spanning Compressissima and Moutonianum zones) to the LST "Ba3",
- the so-called "Barremian" ridge (Vandenheckei Zone) to the LST "Ba4", and
- the so-called "Bedoulian" ridge (Giraudi Zone) to the LST "Ba5".

One can agree or not with these interpretations, but this will not affect our dates, which are consolidated herein using planktonic and deeper-water benthic foraminifera.

The Orbitolinidae of L'Estellon section

A) Material and methods

About 100 kg of calcarenites were collected while measuring L'Estellon section. Though we sampled the whole section, we decide to focus on its Lower Barremian part. This material was cut and polished in order to locate and then obtain the best diagnostic sections of the several Orbitolinid taxa. As a result the 75 kg of polished samples correspond to a total surface area of some 5m², *i.e.*, a surface equivalent to about 5750 classical petrographic slides (each representing a 8.64 cm² surface). The 670 most diagnostic and better preserved specimens observed on these polished sections were photographed. Then part of this material (304 samples) was used to manufacture petrographic/micropaleontologic slides, *i.e.*, regular thin sections 30µm thick in average. During the mechanical processing, some specimens were unfortunately destroyed: however they are figured here with the label "polished sections". Owing to the reworking and transport of the L'Estellon material, a very large amount of the several thousands of orbitolinids collected are eroded, broken or recrystallized: therefore the best preserved specimens are those showing two or more clearly identifiable structures. It is worth mentioning that, in some cases, the polished sections give a better picture than the classical thin sections. Our Figure 9.A, for instance, illustrates this fact: there the vertical marginal plates at the top of a *Cribellopsis schroederi* are clearly visible in the polished section while they can only be inferred in the resulting petrographic slide.

B) Systematics of the Orbitolinidae (B. CLAVEL)

Class Foraminifera d'ORBIGNY, 1826
Subclass Textulariia
MIKHALEVICH, 1980
Order Loftusiida KAMINSKI, 2004
Suborder Orbitolinina
KAMINSKI, 2004
Superfamily *Orbitolina*cea
MARTIN, 1890
Family Orbitolinidae MARTIN, 1890
Subfamily Dictyoconinae
MOULLADE, 1965

1) Genus *Cribellopsis* ARNAUD-VANNEAU, 1980

Type-species: *Orbitolinopsis* ? *neoelongata* CHERCHI & SCHROEDER, 1978.

Diagnosis (after ARNAUD-VANNEAU, 1980):

- embryonic apparatus simple, at the top of a small subapical or slightly eccentric trochospire;
- marginal zone divided by vertical plates ("beams" *sensu* HOTTINGER, 2006);
- central zone divided by radiant septules forming a central reticulum and chamber walls with oblique and vertical pores.

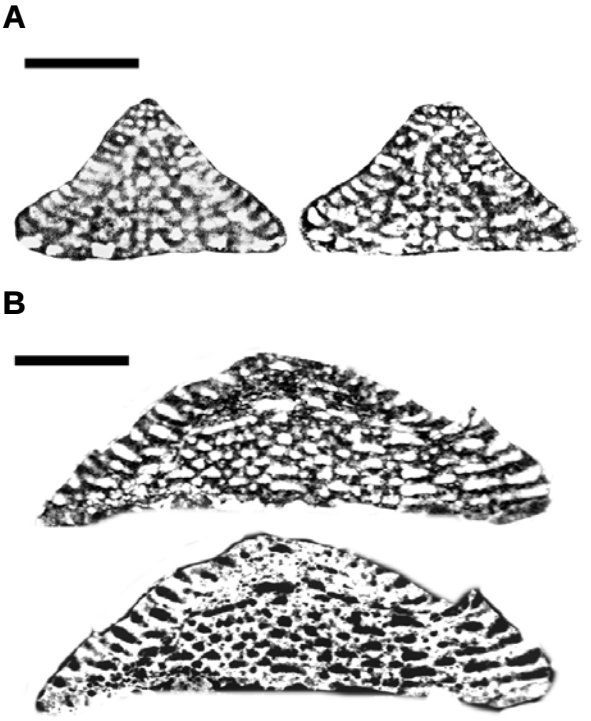


Figure 9: A: polished section (left) and slide (right) of *Cribellopsis schroederi* - sample LEST-72; **B:** positive (up) and negative (down) subtangential sections of *Orbitolinopsis buccifer*, Pont de Laval section (Vivarais) - sample PL77. Scale bars = 500µm.

Cribellopsis elongata (DIENI *et al.*, 1963)

Pl. 5, figs. 1-5, 18 & 20

This small species, characterized by a narrow central zone and a relatively voluminous trochospire, is common in the Upper Hauterivian and Lower Barremian strata, with its LAD in the Moutonianum Zone.

Illustrated specimens from samples 27, 49.5, 53.5 and 54.

Cribellopsis neoelongata (CHERCHI & SCHROEDER, 1978)

Pl. 5, figs. 9-14; Pl. 9, fig. 9; Pl. 10, fig. 10

Cribellopsis neoelongata differs from *C. elongata* by its larger size, sharp eccentric apex, widest central zone and by its adult chambers tending to shrink in diameter. Rarely found in Upper Hauterivian strata, this species becomes common in the Lower Barremian, where -- sometimes depending on the orientation of the section-- it can be confused with *C. elongata*.

Illustrated specimens from samples 53.5, 54, 72, 84.5, 152.5 and 205.8.

Cribellopsis schroederi (ARNAUD-VANNEAU, 1980)

Fig. 9.A ; Pl. 5, figs. 15-16; Pl. 10, figs. 9 & 11

Cribellopsis schroederi has a very large central zone and a sharp slightly eccentric apex. Unlike *C. neoelongata*, its adult chambers increase regularly in diameter. It is known from the Early Barremian to the late Bedoulian, but it is always rather uncommon .

Illustrated specimens from samples 54 and 218.

Cribellopsis thieuloyi ARNAUD-VANNEAU, 1980

Pl. 5, figs. 6-8 & 17

This large-sized cylindro-conical *Cribellopsis* shows a reduced central zone and a marginal zone widening out in its adult chambers. It is restricted to the uppermost Hauterivian-Lower Barremian interval.

Illustrated specimens from samples 54, 72 and 88.2.

2) Genus *Dictyorbitolina* BLANCKENHORN, 1900

Type-species: *Patellina egyptiensis* CHAPMAN, 1900.

Diagnosis (after ARNAUD-VANNEAU, 1980):

- embryonic apparatus simple, located at the beginning of an involute planispire or trochospire;
- marginal zone divided by vertical ("beams" *sensu* HOTTINGER, 2006) and sometimes horizontal ("rafters" *sensu* HOTTINGER, 2006) plates;
- central zone divided by pillars arranged in regular concentric rings and chamber walls with vertical and oblique pores.

Dictyorbitolina ? vercorii ARNAUD-VANNEAU, 1980

Pl. 8, figs. 10-12; Pl. 9, fig. 7; Pl. 10, figs. 4

Provisionally attributed to the genus *Dictyorbitolina*, *D. ? vercorii* is rare in Lower Barremian strata but common in the Upper Barremian-lower Bedoulian interval. This species presents a small trochospire, a well developed marginal zone, and a central zone with short massive pillars, thick chamber walls and very large oblique or vertical pores.

Illustrated specimens from samples 26,6, 54, 72, 84.5, 152.5 and 218.

3) Genus *Falsurgonina* ARNAUD-VANNEAU & ARGOT, 1973

Type-species: *Falsurgonina pileola* ARNAUD-VANNEAU & ARGOT, 1973.

Diagnosis (after ARNAUD-VANNEAU, 1980):

- embryonic apparatus simple, at the top of an evolute eccentric trochospire;
- marginal zone divided by septules issued from infoldings of the chamber floor;
- central zone divided by septules which may or may not reach the top of the chamber, and chamber walls with oblique or subvertical pores.

Falsurgonina pileola ARNAUD-VANNEAU & ARGOT, 1973

Pl. 6, figs. 4-7, 11-12 & 14-15 & 18

Falsurgonina pileola presents both small microspheric as well as wider megalospheric conical forms. Most of the time, both are laterally compressed.

Illustrated specimens from samples 26.2, 27 and 54.

Falsurgonina vanneauae CLAVEL *et al.*, 2009b

Pl. 6, figs. 8-10

Compared with *Falsurgonina pileola*, *F. vanneauae*, first described as *Falsurgonina* sp. 1 by ARNAUD-VANNEAU (1980), is mainly characterized by its concave chambers and by the thickness of their structures. The existence of both micro- and megalo- spheric forms has not yet been evidenced.

Illustrated specimens from sample 54.

4) Genus *Montseciella* CHERCHI & SCHROEDER, 1999a

Type-species: *Paleodictyoconus glanensis* FOURY, 1968.

Diagnosis (after CHERCHI & SCHROEDER, 1999a):

- embryonic apparatus simple, at the top of a strongly developed trochospire;
- marginal zone divided by vertical and sometimes horizontal plates;

- central zone divided by thin, vermicular partitions forming a labyrinthic structure, and chamber walls with oblique and vertical pores.

Montseciella glanensis (FOURY, 1968)

Pl. 6, figs. 13, 16-17 & 19-21;
Pl. 8, fig. 13; Pl. 9, fig. 5

This species is the only representative of the genus which does not have horizontal plates in the marginal zone. Axial/subaxial sections show a very developed marginal zone with large chamberlets decreasing in size and height in the central zone. Oblique subtangential sections exhibit chamberlets broader than high and hexagonal in outline.

Illustrated specimens from samples 26.6, 27, 54, 72, 84.5, 88.2 and 152.5.

5) Genus *Orbitolinopsis* (SILVESTRI, 1932)

Type-species: *Orbitolina* ? *kiliani* SILVESTRI, 1932.

Diagnosis (after ARNAUD-VANNEAU, 1980):

- embryonic apparatus simple, at the top of a small subapical or slightly eccentric trochospire;
- marginal zone exhibiting convex chamberlet floors forming cupules and sometimes divided by vertical plates;
- central zone showing a radial part with elongated cupules and a central part with hemispheric cupules, and chamber walls with oblique pores arranged in diagonal lines in axial and subaxial sections.

Orbitolinopsis briacensis ARNAUD-VANNEAU, 1980

Pl. 2, figs. 17 & 20; Pl. 10, figs. 1-3

Orbitolinopsis very similar to *O. kiliani*, except the presence of vertical plates in the marginal zone.

Illustrated specimens from samples 54, 84.5 and 218.

Orbitolinopsis cf. *briacensis* ARNAUD-VANNEAU, 1980

Pl. 9, fig. 4

Illustrated specimen from sample 152.5.

Orbitolinopsis buccifer ARNAUD-VANNEAU & THIEULOY, 1972

Pl. 2, figs. 11, 13-14 & 18-19;
Pl. 9, figs. 11-15; Pl. 11, fig. 7

Large conical to flattened *Orbitolinopsis* with the size of the marginal zone widening out up to constitute the whole annular chamber layer.

Illustrated specimens from samples 26.6, 54, 61 (sample 58), 82.7, 152.5, 205.8, 218 and 240.

Orbitolinopsis cuvillieri MOULLADE, 1960

Pl. 2, figs. 1-5, 8-10, 12, 16 & 21;
Pl. 9, figs. 16-19

Orbitolinopsis cuvillieri is the most commonly collected species in the whole section. It presents a conical to cylindro-conical section, with large-sized cupules separated by a rather wide interval.

Illustrated specimens from samples 26.6, 27, 50, 54, 205.8, 217.85, 218 and 240.

Orbitolinopsis debelmasi MOULLADE & THIEULOY, 1965

Pl. 7, figs. 1-5

The numerous specimens collected at L'Estellon are strictly identical to the types described and figured from another Chaudebonne outcrop, a few kilometers further (MOULLADE, 1966). Their main specific characters are the presence of vertical plates in the marginal zone and the large development of the central zone with regularly alternating cupules.

Illustrated specimens from samples 54 and 88.2.

Orbitolinopsis kiliani (SILVESTRI, 1932)

Pl. 2, figs. 6-7 & 15; Pl. 9, figs. 20-21;
Pl. 11, fig. 8

Orbitolinopsis of equal width and height, showing a pronounced alternation between large and very small bright areas ("lumina") in the axial sections and triangular cupules in close proximity.

Illustrated specimens from samples 27, 54, 61 (sample 58) and 218.

6) Genus *Paleodictyoconus* FOURY & MOULLADE, 1966

Type-species: *Dictyorbitolina cuvillieri* FOURY, 1963.

Diagnosis (after ARNAUD-VANNEAU, 1980):

- embryonic apparatus simple, at the beginning of an involute planispire or trochospire, sometimes strongly developed;
- marginal zone divided by vertical and horizontal plates (the latest being absent in the most primitive species);
- central zone divided by pillar-like or septule-pillar structures, and chamber walls with oblique pores arranged in diagonal lines.

Paleodictyoconus cuvillieri (FOURY, 1963)

Pl. 5, fig. 19; Pl. 7, figs. 6-8; Pl. 9, fig. 8

Paleodictyoconus characterized by convex chamber layers up to the adult stage.

Illustrated specimens from samples 54, 82.7, 84.5 and 152.5.

Paleodictyoconus actinostoma ARNAUD-VANNEAU & SCHROEDER, 1976

Pl. 7, figs. 9-10; Pl. 10, fig. 12

Paleodictyoconus essentially defined by its sigmo-septal to annular adult chambers.

Illustrated specimens from samples 54, 61 (sample 58) and 218.

7) Genus *Urgonina* FOURY & MOULLADE, 1965

Type-species: *Urgonina protuberans* FOURY & MOULLADE, 1965.

Diagnosis (after ARNAUD-VANNEAU, 1980):

- embryonic apparatus simple, at the top of a large evolute eccentric trochospire;
- marginal zone divided by septules issued from infoldings of the chamber walls;
- central zone divided by pillars and chamber walls with subvertical pores.

Urgonina alpillensis (FOURY, 1963)

Pl. 6, figs. 1-3; Pl. 9, fig. 6

This species is considered in this work as the sole representative of the genus. On the basis of the huge amount of material collected from the Swiss Jura to the French Provence, we assume that the forms named *protuberans* (FOURY & MOULLADE, 1965), "forme B" (FOURY, 1963: Pl. 3, figs. 1-2 & 5), "? sp. 1" and "cf. *alpillensis*" (ARNAUD-VANNEAU, 1980) has strictly identical structures (including in their variations) and same time range.

Illustrated specimens from samples 54 and 152.5.

Subfamily Praedictyorbitolininae SCHROEDER, 1990

8) Genus *Dictyorbitolina* CHERCHI & SCHROEDER, 1975

Type-species: *Dictyorbitolina ichnusae* CHERCHI & SCHROEDER, 1975.

Diagnosis (after ARNAUD-VANNEAU, 1980):

- embryonic apparatus complex (proloculus and deuteroloculus with subepidermal septules);
- marginal zone divided by vertical and horizontal plates;
- central zone divided by alternating pillars, and chamber walls with vertical or subvertical pores.

Dictyorbitolina gr. *carthusiana* SCHROEDER *et al.*, 1990 - *ichnusae* CHERCHI & SCHROEDER, 1975

Pl. 4, figs. 10 & 12

Both *Praedictyorbitolina carthusiana* and *Dictyorbitolina ichnusae* are here provisionally treated as a single group: the embryonic apparatus, representing the most important - over even unique, according to SCHROEDER *et al.* (1990) - character allowing to discriminate both species, cannot be observed in our specimens.

Illustrated specimens from sample 54.

9) Genus *Praedictyorbitolina*

Type-species: *Praedictyorbitolina carthusiana* SCHROEDER *et al.*, 1990.

- Diagnosis (after SCHROEDER *et al.*, 1990):
- embryonic apparatus simple, eccentric;
- marginal zone divided by vertical and sometimes horizontal plates;
- central zone divided by alternating pillars, and chamber walls with vertical or oblique pores.

Praedictyorbitolina claveli SCHROEDER, 1994

Pl. 4, figs. 13-14

P. claveli differs from *P. carthusiana* (see above under *Dictyorbitolina* gr. *carthusiana* SCHROEDER *et al.*, 1990 - *ichnusae* CHERCHI & SCHROEDER, 1975) by its smaller size and its acute apical angle. Its identification in L'Estellon section is based on the size of the collected specimens.

Illustrated specimens from sample 26.6.

10) Genus *Paracoskinolina* MOULLADE, 1965

Type-species: *Paracoskinolina sunnilandensis* MAYNC, 1955.

Diagnosis (after ARNAUD-VANNEAU, 1980):

- embryonic apparatus simple, at the top of an apical or slightly eccentric trochospire;
- marginal zone divided by vertical and sometimes horizontal plates;
- central zone divided by non alternating pillars which, sometimes, do not reach the top of the chamber ("hemipillars"), and chamber walls with vertical or subvertical pores.

Paracoskinolina hispanica PEYBERNÈS, 1976

Pl. 3, figs. 1-6

The main characteristic of this large-sized conical species is the presence of hemipillars.

The "*P.* cf. *hispanica*" of ARNAUD-VANNEAU (1980) from Chartreuse and southern Vercors have to be ascribed to *P. querolensis* CANÉROT & PEYBERNÈS, 1981 (see this species).

Illustrated specimens from samples 26.6, 27 and 54.

Paracoskinolina ? jourdanensis (FOURY & MOULLADE, 1965)

Pl. 4, figs. 6-7

This species, as well as *Paracoskinolina* ? *praereicheli* and *P.* ? *reicheli*, are provisionally ascribed to the genus *Paracoskinolina* MOULLADE, 1965. It presents a well-developed trochospire, a relatively important marginal zone with some vertical plates, and a clearly differentiated cen-

tral zone. Depending of the section orientation, mostly in deep tangential sections, the central part of each chamber is shifted downward with respect to its marginal counterpart; in axial sections, the structure of this central part becomes indistinguishable.

Illustrated specimens from samples 54 and 72.

Paracoskinolina maynci (Chevalier, 1961)

Pl. 3, figs. 7-13; Pl. 9, fig. 3; Pl. 10, figs. 5-7

High cylindro-conical large-sized *Paracoskinolina* with flanks tending to become rapidly sub-parallel. The marginal and central zones, approximately of the same width, are sometimes not easily distinguishable.

Illustrated specimens from samples 27, 54, 72, 84.5, 88.2, 117, 152.5, 205.8 and 218.

Paracoskinolina ? *praereicheli* (Clavel et al., 2009a)

Pl. 4, figs. 1-4; Pl. 8, fig. 14

Paracoskinolina ? *praereicheli* differs from *P.* ? *reicheli* (see this species) by the lack of horizontal plates in the marginal zone.

Illustrated specimens from samples 61, 72, 77, 88.2 and 117.

Paracoskinolina querolensis Canérot & Peybernès, 1981

Pl. 4, figs. 8-9

Small size highly cylindro-conical *Paracoskinolina* with a discrete but complete initial spire and a well-developed marginal zone. There is no more than 6-7 chamberlets in each chamber layer.

Illustrated specimens from samples 27 and 53.5.

Paracoskinolina ? *reicheli* (Guillaume, 1956)

Pl. 4, figs. 4 & 11; Pl. 9, figs. 1-2

Cylindro-conical to widened species with a slightly eccentric trochospire. The marginal zone shows conspicuous horizontal plates.

Illustrated specimens from samples 54, 117 and 152.5.

Paracoskinolina aff. *Sunnilandensis* (Maync, 1955)

Pl. 3, figs. 14-18; Pl. 9, fig. 10; Pl. 10, fig. 8

Paracoskinolina sunnilandensis (Maync, 1955) is the type of the genus. Our specimens are typical conical *Paracoskinolina* with slightly convex chamber layers, narrow marginal zone and central zone constituted by non alternating septules arranged in radiating straight lines. A comparison of our material with Albian specimens from the Bahamas Islands leads us to consider that both forms are likely identical: however, pending a systematic revision, the Hauterivian-Bedoulian European forms are treated as affine.

Illustrated specimens from samples 27, 54, 72, 84.5, 88.2, 140.5 and 218.

Subfamily Orbitolininae Martin, 1890

11) Genus *Eopalorbitolina* Schroeder *in* Schroeder & Conrad, 1968

Type-species: *Eopalorbitolina charollaisi* Schroeder *in* Schroeder & Conrad, 1968.

Diagnosis (after Arnaud-Vanneau, 1980):

- embryonic apparatus complex slightly eccentric, with subepidermal septules at the top of the deuteroconch and without or with a rudimentary periembryonic ring which does not completely surround the embryonic chamber as in *Palorbitolina* Schroeder, 1963;
- marginal zone divided by vertical and horizontal plates;
- central zone divided by meandering septules, and chamber walls with oblique pores arranged in diagonal lines.

Eopalorbitolina transiens (Cherchi & Schroeder, 1999b)

Pl. 8, fig. 9

Eopalorbitolina with a slightly eccentric embryonic apparatus showing a small alveolar layer in its uppermost part. As already noticed by Cherchi & Schroeder (1999b), this species appears under the name of "*E. charollaisi*" in Arnaud-Vanneau's (1980) work from the southern Vercors.

Illustrated specimen from sample 54.

12) Genus *Palorbitolina* Schroeder, 1963

Type-species: *Madreporites lenticularis* Blumenbach, 1805.

Diagnosis (after Arnaud-Vanneau, 1980):

- embryonic apparatus complex in central apical position, with subepidermal septules at the top of the deuteroconch and completely surrounded by a periembryonic ring;
- marginal zone divided by vertical and horizontal plates;
- central zone divided by meandering septules, and chamber walls with oblique pores arranged in diagonal lines.

Palorbitolina lenticularis (Blumenbach, 1805)

Pl. 1, figs. 1-13; Pl. 11, figs. 1-6 & 9

Palorbitolina lenticularis was the sole representative of the genus until the description of *P. ultima* by Schroeder *et al.* (2010). The latter gets a periembryonic ring that extends "downwards to the base of the embryonic chamber, but without covering completely its basal sur-

face". In *P. lenticularis*, the diameter of megalospheric embryo varies from 0.185 to 0.225 mm.

Illustrated specimens from samples 54, 61 (sample 58), 84.5, 194.5 and 218.

13) Genus *Valserina* Schroeder & Conrad, 1968

Type-species: *Valserina brönnimanni* Schroeder & Conrad, 1968.

Diagnosis:

- embryonic apparatus simple slightly eccentric or central with subepidermal septules;
- marginal zone divided by vertical and sometimes horizontal plates;
- central zone divided in a external "radial" part with meandering septules and in an innermost part reticulated, and chamber walls with oblique pores arranged in diagonal lines.

Valserina broennimanni Schroeder & Conrad, 1968

Pl. 8, figs. 1-3, 5-6 & 8

Valserina broennimanni is characterized by its eccentric embryonic apparatus, which looks like occupying a central position when the section is perpendicular to the axis of symmetry.

Illustrated specimens from samples 26.6, 27 and 54.

Valserina turbinata (Foury, 1968)

Pl. 8, figs. 4, 7 & 15

Valserina turbinata is defined by the presence of subepidermal, discrete to conspicuous septules in the embryonic apparatus, and of a periembryonic ring more or less developed and visible. The diameter of their megalospheric embryo, ranging from 0.070 to 0.120mm, excludes any confusion with *Palorbitolina lenticularis*.

Illustrated specimens from samples 54, 61 and 72.

Remark: As in other southeastern France or north Tethyan outcrops, serious questions arise in L'Estellon about the group including the genera *Valserina*, *Eopalorbitolina* and *Palorbitolina*: besides some orbitolinids showing clearly the specific structures described and figured in the original diagnoses and in authors following comments, there are a lot of other specimens that do not respect the assigned specific characters (and were never raised in early works).

Discussion

Compared to the orbitolinid fauna collected in the surrounding platforms (Vivarais and southern Vercors), the material from L'Estellon has the advantage of being issued from a single continuous outcrop covering the entire Barremian period, dated by significant ammonites and planktonic foraminifers.

In order to test the validity of existing scales (Schroeder *et al.*, 2002; Arnaud-Vanneau *et al.*, 2005; Clavel *et al.*, 2007, 2010a), we needed a reference framework. We selected the "distribution chart of Orbitolinids" given by Arnaud-Vanneau *et al.* (2005) because with almost 50 taxa it was intended to give the most comprehensive list of species. However, to make this chart easier to read we introduced some but few simplifications. For instance, we did not discriminate between the varieties of *Urgonina alpillensis*, nor between primitive and advanced forms of *Orbitolinopsis debelmasi*, nor between *Dictyorbitolina* ? *vercorii* and *Dictyorbitolina* aff. *Vercorii*. In addition, *Valserina* sp. 1 Arnaud-Vanneau and *Valserina broennimanni* are treated as *V.* (gr.) *turbinata* whereas *Praedictyorbitolina carthusiana* is included in the group *Dictyorbitolina ichnusae-carthusiana*. Finally *Rectodictyoconus* ? cf. *giganteus* appears as *Montseciella alguerensis* and *Falsurgonina* sp. 1 Arnaud-Vanneau as *Falsurgonina vanneauae*.

As for the Orbitolinids, we plotted our findings at L'Estellon on both the range chart given by Arnaud-Vanneau *et al.* (2005; herein Fig. 10) and on that presented by Clavel *et al.* (2007, and from then regularly updated, the last time in 2010a; herein Fig. 11). The highest discrepancies are with Arnaud-Vanneau's chart (Arnaud-Vanneau *et al.*, 2005; herein Fig. 10): for instance, our first record of the well-known *Palorbitolina lenticularis* dates back from the Pulchella Zone of the Lower Barremian strata, instead of from the top of the Sartousiana Zone of the Upper Barremian; another example is given by four representatives (*kiliani*, *buccifer*, *briacensis*, and *cuvillieri*) of the genus *Orbitolinopsis*, which have been said to be Bedoulian (= "Early Aptian") in age, whereas we found that these taxa already occur in Lower Barremian strata. On the contrary, the best match was obtained with Clavel's (2007, 2010a; herein Fig. 11).

We did not plot our findings on the tentative phylogenetic lineage proposed by Schroeder *et al.* (2002) because it deals with 7 species only; in addition one of them been restricted to the sole Late Hauterivian. However, the plot of Schroeder's chart *ichnusae* Clavel's shows that these are in good accordance with the ranges given therein except for the two *Valserina*, *V. primitiva* (the first occurrence of which was brought down) and *V. turbinata* (the total range of which was shifted down).

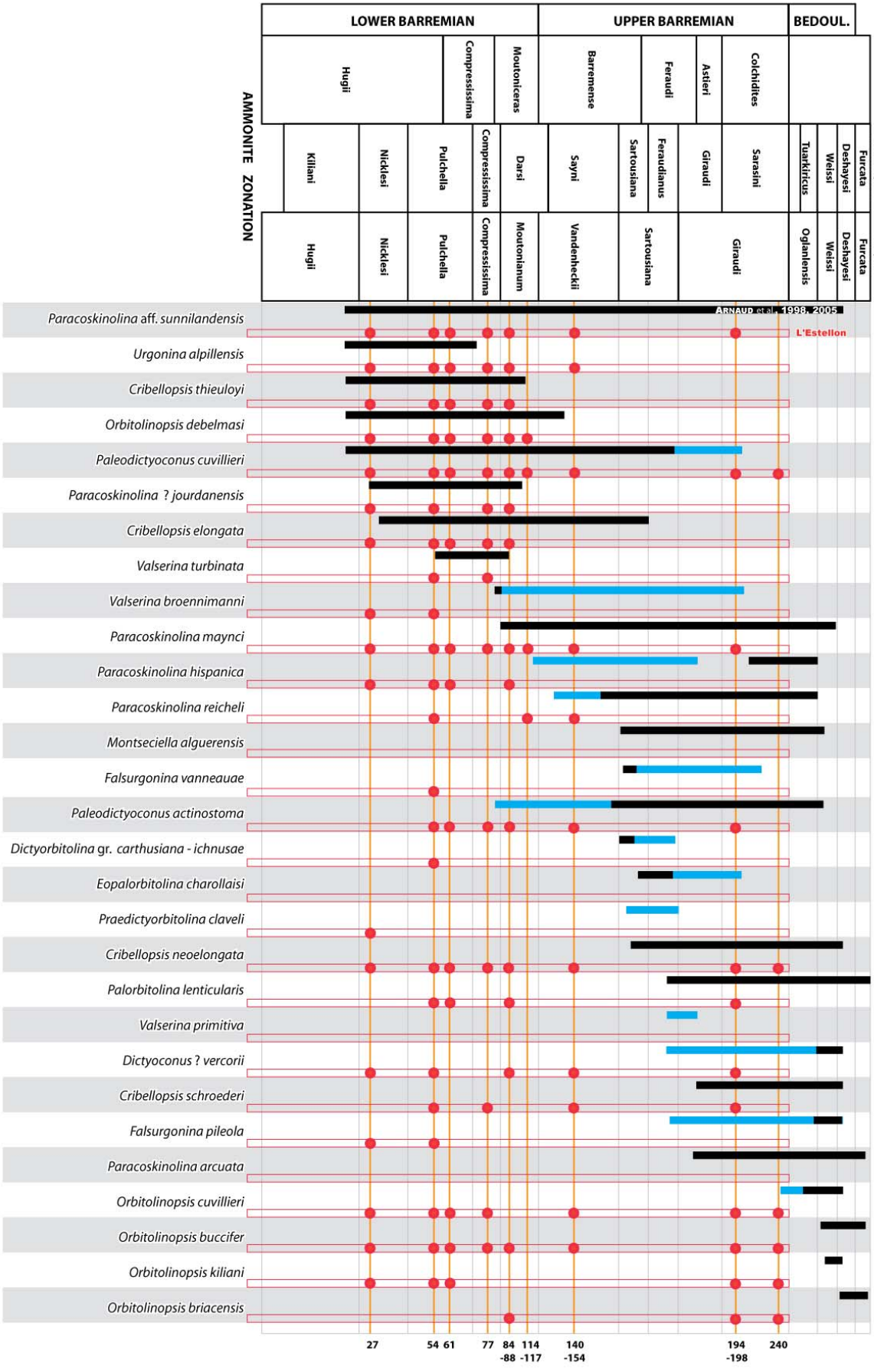


Figure 10: Orbitolinids found at L'Estellon versus the distribution chart of Orbitolinids proposed by ARNAUD-VANNEAU *et al.* (2005): black bars for the typical forms, blue bars for the related forms (primitive, advanced, cf., aff.).

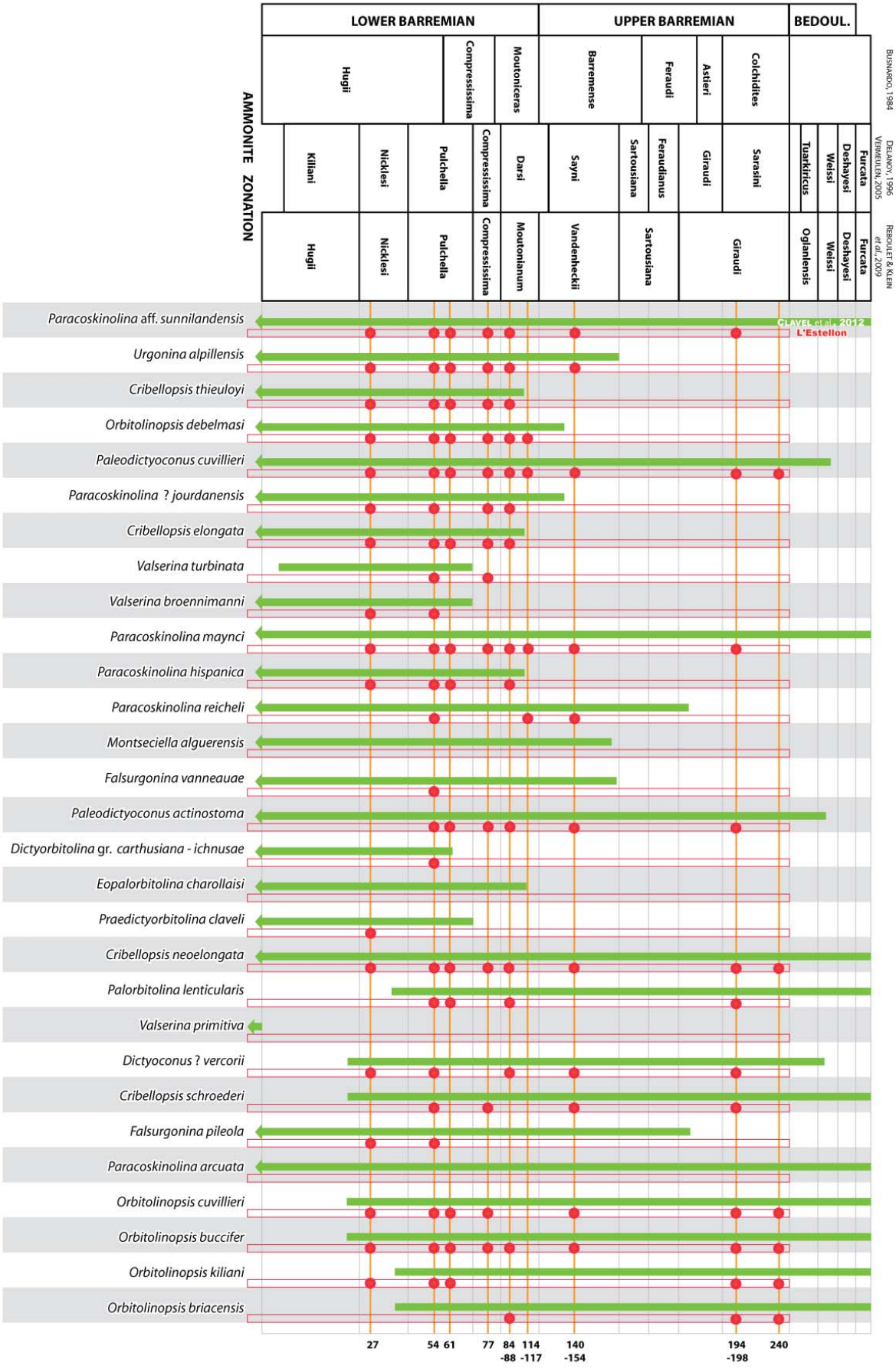


Figure 11: Orbitolinids found at L'Estellon versus the distribution chart of Orbitolinids proposed by CLAVEL *et al.* (2007, 2010a).

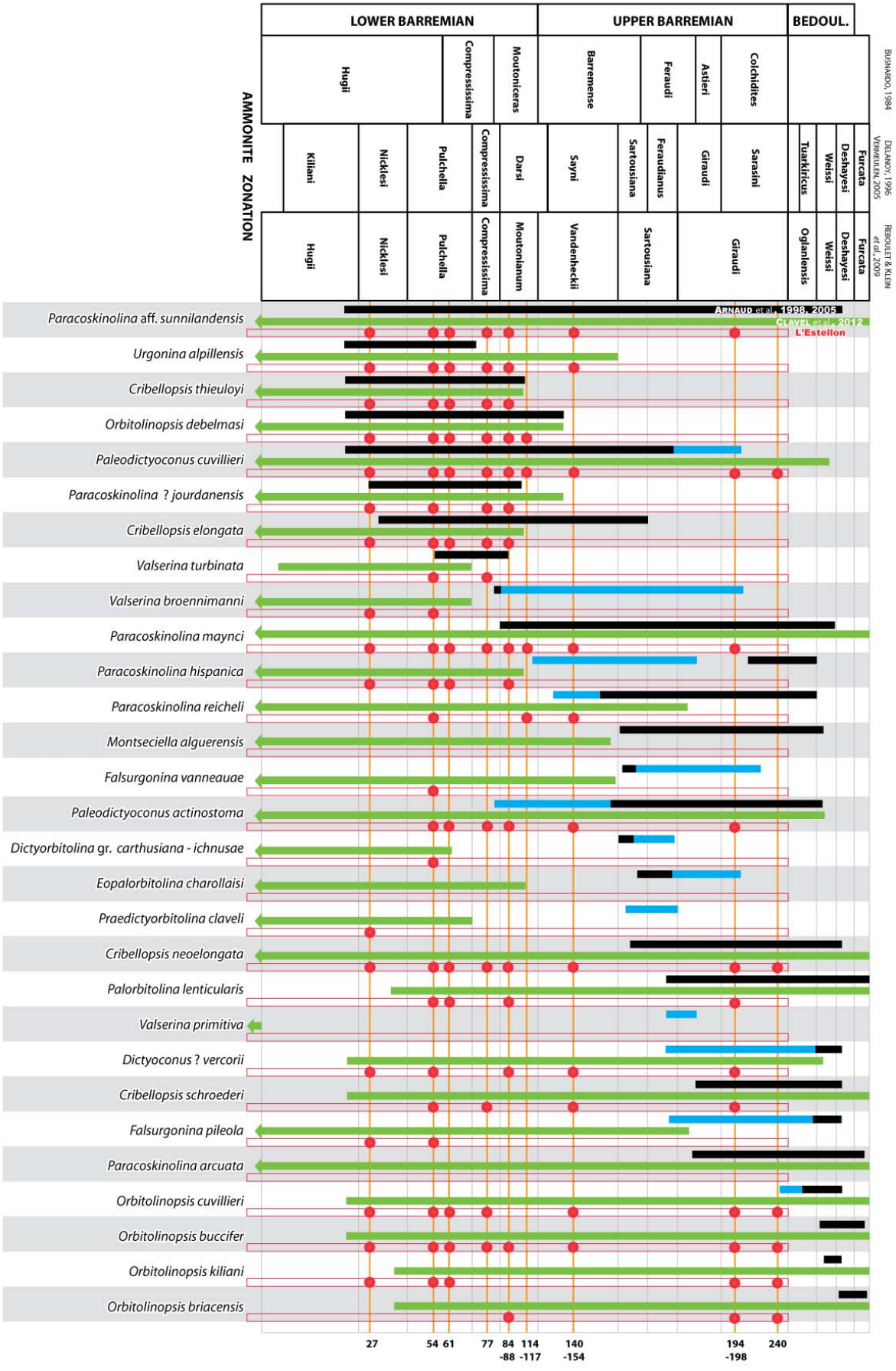


Figure 12: Combination of the previous figures, that is the Orbitolinids found at L'Estellon versus the distribution charts of Orbitolinids proposed by ARNAUD-VANNEAU *et al.* (2005) and by CLAVEL *et al.* (2007, 2010a).

In conclusion, the basinal section at L'Estellon fully confirms the synthetic orbitolinid ranges established on the basis of the study of 17 sections of south-eastern France as partly defended and announced at STRATI2010 (CLAVEL *et al.*, 2010a, 2010b, 2010c, 2012, *etc.*, and additional work nearing completion). There, in external platform settings, short orbitolinid-rich intervals are sandwiched by strata with significant ammonites: for instance, the subtangential sections of large-sized Early Barremian *Orbitolinopsis buccifer* from L'Estellon (Pl. 2, figs. 11 & 14) correspond to a characteristic subaxial section (Fig. 9.B), which was not integrated in the material figured by CLAVEL *et al.* (2010a) for the Nicklesi Zone in the Pont de Laval section (Vivarais).

Conclusion

After testing the validity of two distribution charts of Orbitolinids (ARNAUD-VANNEAU *et al.*, 2005; CLAVEL *et al.*, 2007, 2010a), we find that the highest discrepancies appear with ARNAUD-VANNEAU's (ARNAUD-VANNEAU *et al.*, 2005; herein Fig. 10) and that by far the best match is obtained with CLAVEL's (CLAVEL *et al.*, 2007, 2010a; herein Fig. 11), *i.e.*, a range chart that is regularly consolidated by new sections (such as our new **Rosetta Stone**, L'Estellon section; herein Fig. 12). As for previous publications (CONRAD *et al.*, 2012; CHAROLLAIS *et al.*, 2013), we question the relevance of the conclusions and hypotheses of any published work based on the biased stratigraphic distribution ranges for the orbitolinids, *i.e.*, any work based on ARNAUD-VANNEAU's (ARNAUD-VANNEAU *et al.*, 2005, and earlier versions).

Acknowledgements

The first author (B.G.) would like to thank his colleagues from the University of Brest, Alain COUTELLE, who first guided him in the studied area in 2005, Jean-Alix BARRAT and Pascal LE ROY, who assisted him on the field (for instance, during the last campaign in 2012), and a number of third year students who over the past eight years were successively requested to complete geological mapping exercises in that area under his supervision and whose enthusiasm and curiosity were highly motivating factors. The JACOB's staff used to measured the section (Fig. 4.D) was manufactured by Tanguy CALVEZ, during a training period at the Université de Bretagne occidentale, under the supervision of Bernard CALVEZ. Special thanks go to Mr. and Ms. Jean-Claude PATONNIER (Borne) and Mr. and Ms. Ronald BREUKERS (Charbonnière) for permitting access to their properties. This research was sponsored by the Association "*Carnets de Géologie*". We also acknowledge the contribution of Stephen EAGAR, who ultimately revised the English text of the manuscript, and of two anonymous reviewers.

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Plates

Plate 1:

1. *Palorbitolina lenticularis* (BLUMENBACH) - subaxial polished section LEST54a1.
2. *Palorbitolina lenticularis* (BLUMENBACH) - oblique transverse section, slide LEST54-9a.
3. *Palorbitolina lenticularis* (BLUMENBACH) - subaxial section, slide LEST54-14a.
4. *Palorbitolina lenticularis* (BLUMENBACH) - subaxial section, slide LEST54-8a.
5. *Palorbitolina lenticularis* (BLUMENBACH) - subaxial section, slide LEST54-17a.
6. *Palorbitolina lenticularis* (BLUMENBACH) - subaxial section, slide LEST54-9b.
7. *Palorbitolina lenticularis* (BLUMENBACH) - subaxial section, slide LEST54-12a.
8. *Palorbitolina lenticularis* (BLUMENBACH) - subaxial section, slide LEST54-10a.
9. *Palorbitolina lenticularis* (BLUMENBACH) - subaxial section, slide LEST58 (61m) -1a.
10. *Palorbitolina lenticularis* (BLUMENBACH) - slightly oblique section, slide LEST54-18a.
11. *Palorbitolina lenticularis* (BLUMENBACH) - subaxial section, slide LEST58 (61m) -2a.
12. *Palorbitolina lenticularis* (BLUMENBACH) - subaxial section, slide LEST54-11a.
13. *Palorbitolina lenticularis* (BLUMENBACH) - subaxial section, slide LEST54-18b.
14. *Palorbitolina lenticularis* (BLUMENBACH) - subaxial section, slide LEST84.5-3a.

[graphical scale bar = 500µm]

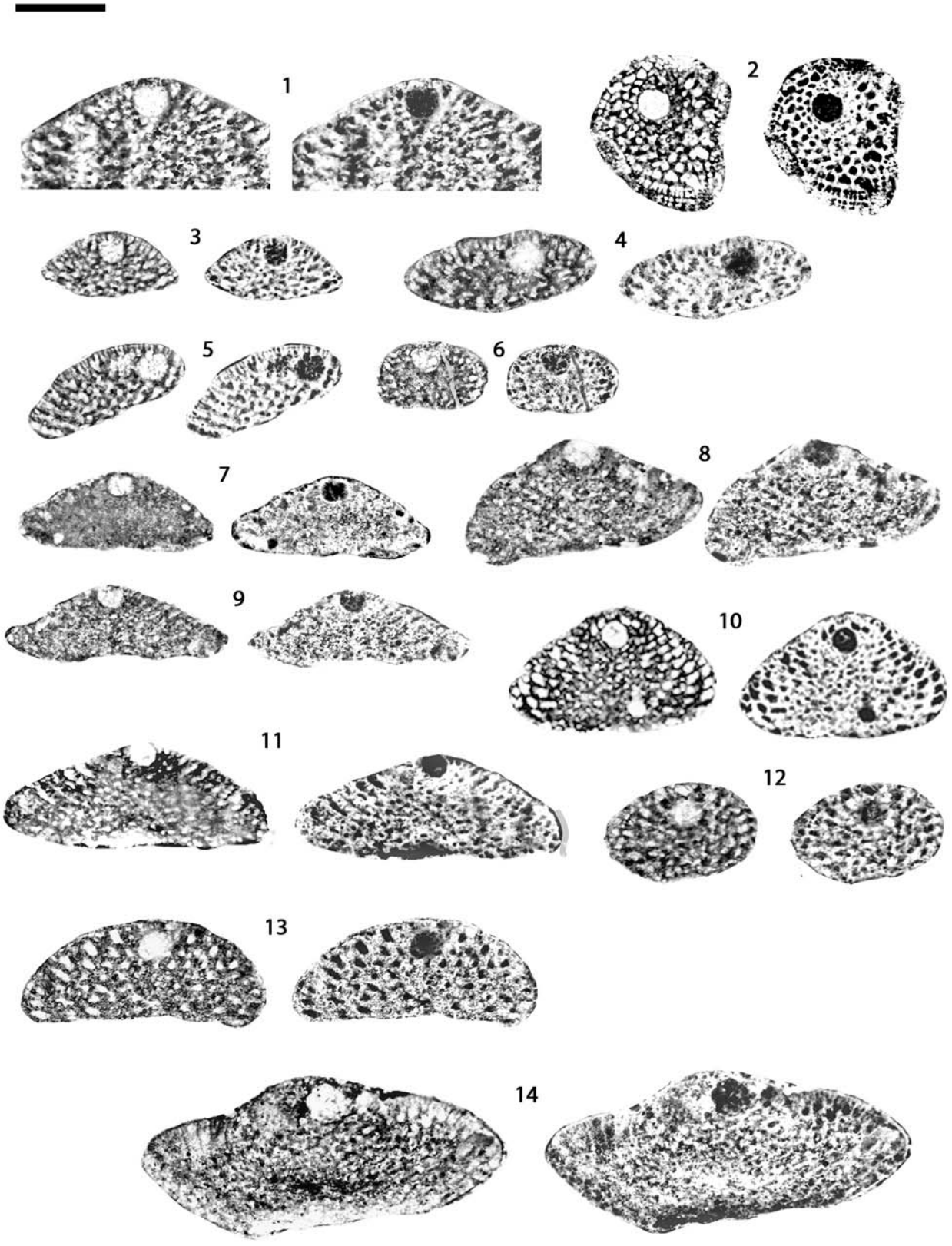
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Plate 2:

1. *Orbitolinopsis cuvillieri* MOULLADE - subaxial section, slide LEST27-2a.
2. *Orbitolinopsis cuvillieri* MOULLADE - subaxial section, slide LEST27-4b.
3. *Orbitolinopsis cuvillieri* MOULLADE - tangential section, slide LEST72-2b.
4. *Orbitolinopsis cuvillieri* MOULLADE - tangential section, slide LEST54-5a.
5. *Orbitolinopsis cuvillieri* MOULLADE - subaxial section, slide LEST27-5a.
6. *Orbitolinopsis kiliani* (SILVESTRI) - axial polished section LEST58 (61m) -a29.
7. *Orbitolinopsis kiliani* (SILVESTRI) - subaxial section, slide LEST54-34b.
8. *Orbitolinopsis cuvillieri* MOULLADE - oblique section, slide LEST27-5b.
9. *Orbitolinopsis cuvillieri* MOULLADE - transverse oblique section, slide LEST26.6-8a.
10. *Orbitolinopsis cuvillieri* MOULLADE - subaxial polished section LEST26.6-7a.
11. *Orbitolinopsis buccifer* ARNAUD-VANNEAU & THIEULOY - tangential section, slide LEST26.6-12b.
12. *Orbitolinopsis cuvillieri* MOULLADE - axial section, slide LEST50-2c.
13. *Orbitolinopsis buccifer* ARNAUD-VANNEAU & THIEULOY - subaxial section, slide LEST58 (61m) -3a.
14. *Orbitolinopsis buccifer* ARNAUD-VANNEAU & THIEULOY - tangential section, slide LEST54-2a.
15. *Orbitolinopsis kiliani* (SILVESTRI) - subaxial polished section LEST27b12.
16. *Orbitolinopsis cuvillieri* MOULLADE - subaxial section, slide LEST27-1a.
17. *Orbitolinopsis briacensis* ARNAUD-VANNEAU - subaxial polished section LEST84.5a19.
18. *Orbitolinopsis buccifer* ARNAUD-VANNEAU & THIEULOY - subaxial section, slide LEST26.6-10a.
19. *Orbitolinopsis buccifer* ARNAUD-VANNEAU & THIEULOY - tangential section, slide LEST82.7-1c.
20. *Orbitolinopsis briacensis* ARNAUD-VANNEAU - subaxial polished section LEST84.5a1.
21. *Orbitolinopsis cuvillieri* MOULLADE - subaxial section, slide LEST27-7a.

[graphical scale bar = 500µm]

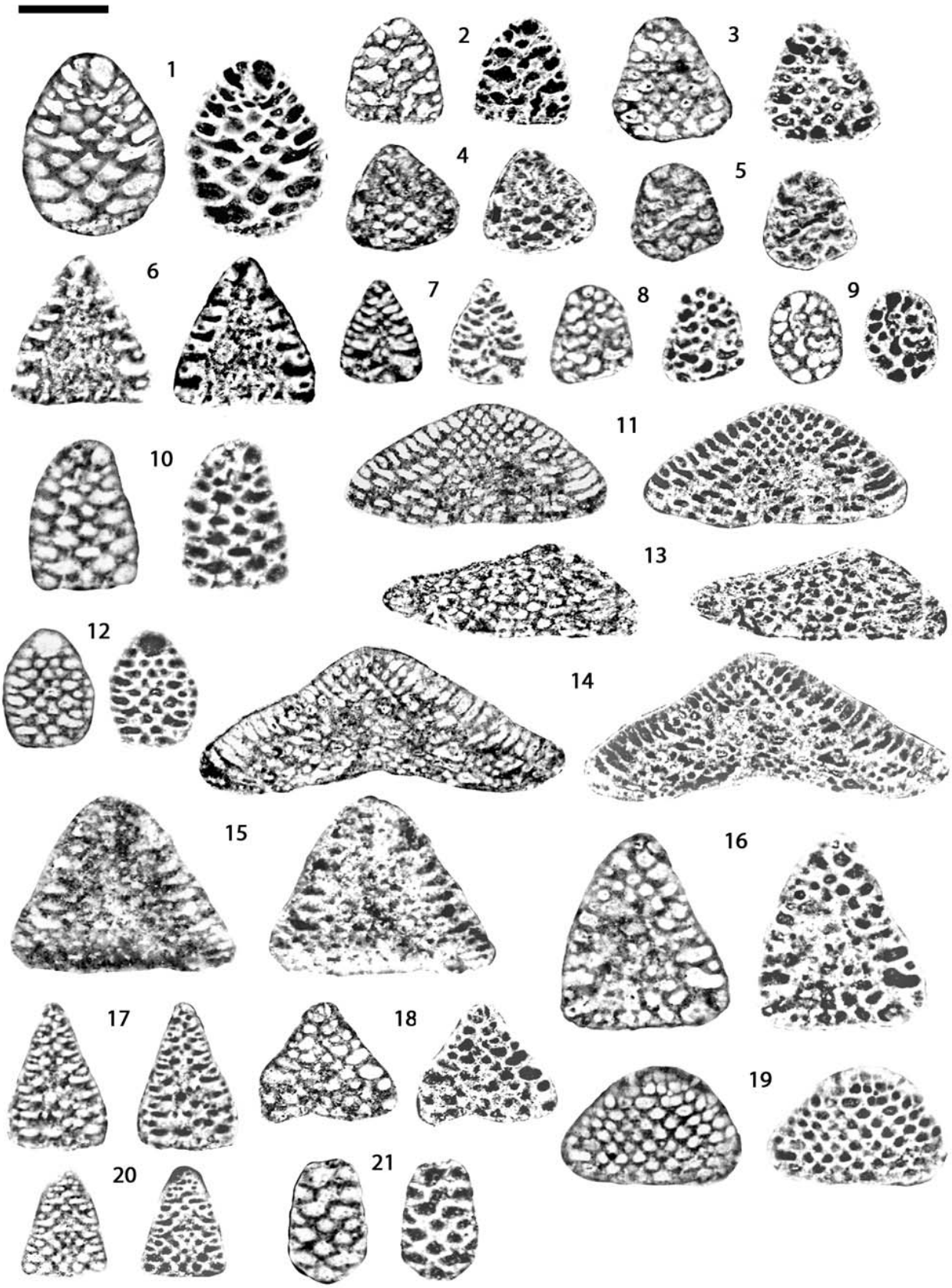
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Plate 3:

1. *Paracoskinolina* hispanica PEYBERNÈS - subaxial section, slide LEST54-21b.
2. *Paracoskinolina* hispanica PEYBERNÈS - subaxial section, slide LEST26.6-2a.
3. *Paracoskinolina* hispanica PEYBERNÈS - subaxial polished section LEST27a31.
4. *Paracoskinolina* hispanica PEYBERNÈS - subaxial section, slide LEST27-8b.
5. *Paracoskinolina* hispanica PEYBERNÈS - subaxial polished section LEST27a57.
6. *Paracoskinolina* hispanica PEYBERNÈS - subaxial section, slide LEST26.6-6a.
7. *Paracoskinolina maynci* (CHEVALIER) - tangential section, slide LEST54-26b.
8. *Paracoskinolina maynci* (CHEVALIER) - subaxial polished section LEST27a48.
9. *Paracoskinolina maynci* (CHEVALIER) - subaxial section, slide LEST72-4a.
10. *Paracoskinolina maynci* (CHEVALIER) - subaxial section, slide LEST72-6a.
11. *Paracoskinolina maynci* (CHEVALIER) - tangential section, slide LEST84.5-3b.
12. *Paracoskinolina maynci* (CHEVALIER) - subaxial section, slide LEST88.2-3a.
13. *Paracoskinolina maynci* (CHEVALIER) - tangential section, slide LEST117-1a.
14. *Paracoskinolina* aff. *sunnilandensis* (MAYNC) - subaxial section, slide LEST27-15a.
15. *Paracoskinolina* aff. *sunnilandensis* (MAYNC) - subaxial section, slide LEST72-7b.
16. *Paracoskinolina* aff. *sunnilandensis* (MAYNC) - tangential section, slide LEST54-31b.
17. *Paracoskinolina* aff. *sunnilandensis* (MAYNC) - tangential section, slide LEST88.2-2a.
18. *Paracoskinolina* aff. *sunnilandensis* (MAYNC) - tangential section, slide LEST84.5-3c.

[graphical scale bar = 500µm]

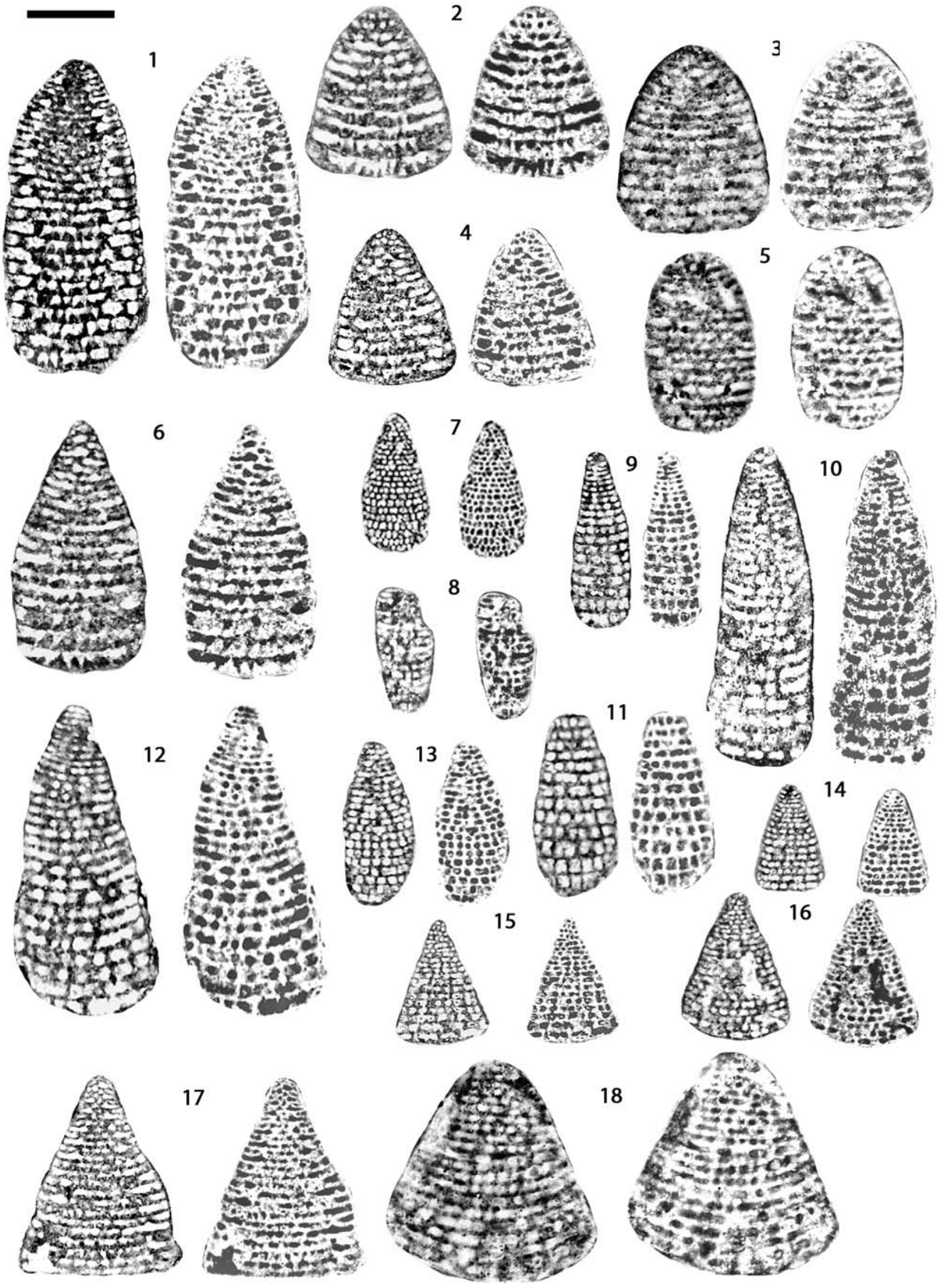
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Plate 4:

1. *Paracoskinolina* ? *praereicheli* (CLAVEL *et al.*) - subaxial section, slide LEST88.2-1a.
2. *Paracoskinolina* ? *praereicheli* (CLAVEL *et al.*) - subaxial section, slide LEST72-7a.
3. *Paracoskinolina* ? *praereicheli* (CLAVEL *et al.*) - tangential polished section LEST117a5.
4. *Paracoskinolina* ? *praereicheli* (CLAVEL *et al.*) - subaxial section, slide LEST77-1a.
5. *Paracoskinolina* ? *reicheli* (GUILLAUME) - subaxial section, slide LEST117-2b.
6. *Paracoskinolina* ? *jourdanensis* (FOURY & MOULLADE) - subaxial section, slide LEST54-22a.
7. *Paracoskinolina* ? *jourdanensis* (FOURY & MOULLADE) - subaxial section, slide LEST72-2a.
8. *Paracoskinolina querolensis* CANÉROT & PEYBERNÈS - subaxial section, slide LEST27-8a.
9. *Paracoskinolina querolensis* CANÉROT & PEYBERNÈS - subaxial section, slide LEST53.5-1b.
10. *Dictyorbitolina* gr. *carthusiana* SCHROEDER *et al.* - *ichnusae* CHERCHI & SCHROEDER - tangential section, slide LEST54-24c.
11. *Paracoskinolina* ? *reicheli* (GUILLAUME) - transverse polished section LEST54c1.
12. *Dictyorbitolina* gr. *carthusiana* SCHROEDER *et al.* - *ichnusae* CHERCHI & SCHROEDER - tangential section, slide LEST54-24b.
13. *Praedictyorbitolina claveli* SCHROEDER - tangential section, slide LEST26.6-10b.
14. *Praedictyorbitolina claveli* SCHROEDER - tangential section, slide LEST26.6-5a.

[graphical scale bar = 500µm]

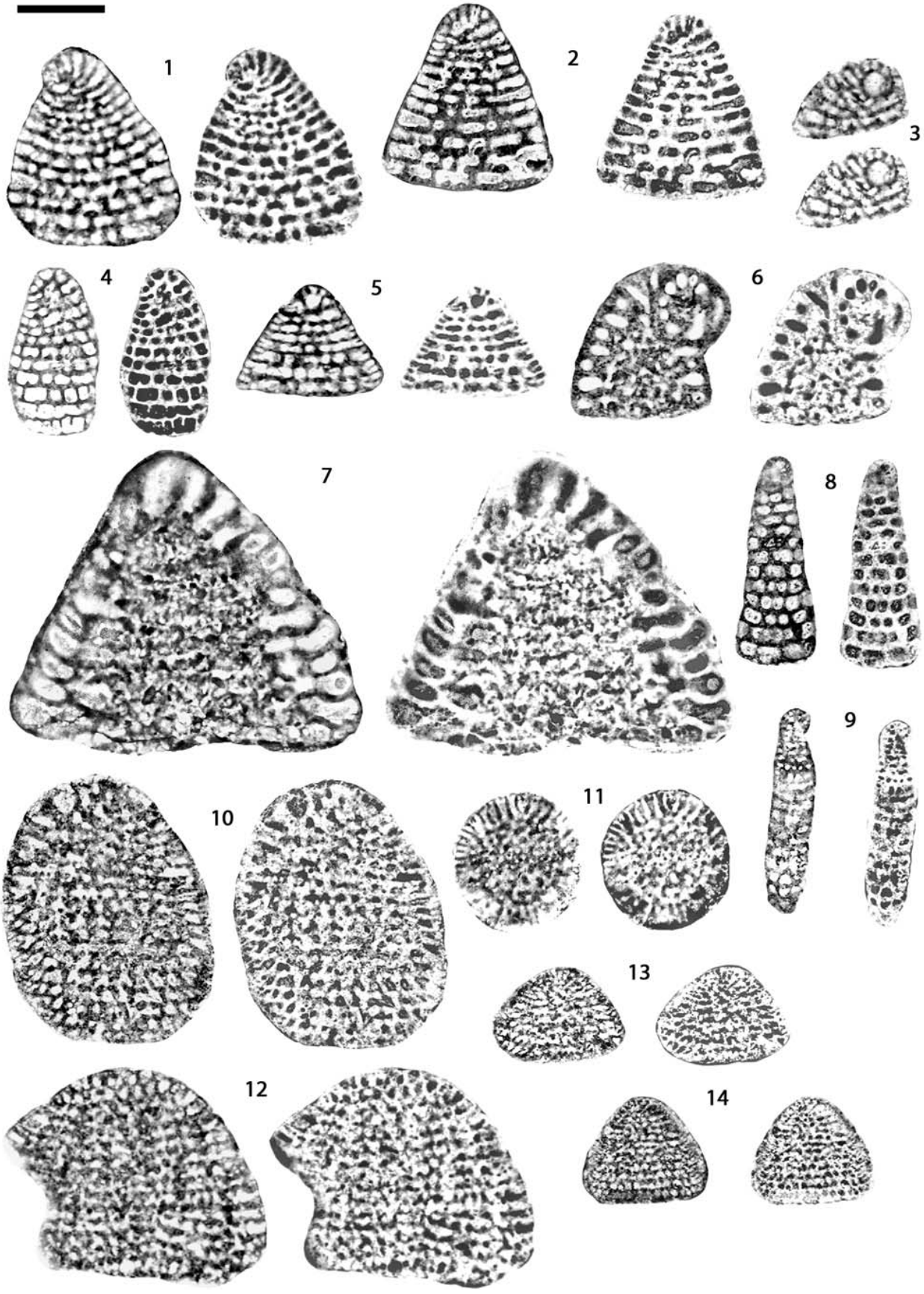
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Plate 5:

1. *Cribellopsis elongata* (DIENI *et al.*) - subaxial section, slide LEST49.5-1a.
2. *Cribellopsis elongata* (DIENI *et al.*) - tangential section, slide LEST27-17a.
3. *Cribellopsis elongata* (DIENI *et al.*) - subaxial section, slide LEST53.5-2a.
4. *Cribellopsis elongata* (DIENI *et al.*) - tangential section, slide LEST54-19a.
5. *Cribellopsis elongata* (DIENI *et al.*) - subaxial section, slide LEST53.5-2b.
6. *Cribellopsis thieuloyi* ARNAUD-VANNEAU - subaxial section, slide LEST88.2-3b.
7. *Cribellopsis thieuloyi* ARNAUD-VANNEAU - subaxial section, slide LEST54-28a.
8. *Cribellopsis thieuloyi* ARNAUD-VANNEAU - subaxial-oblique section, slide LEST88.2-1b.
9. *Cribellopsis neoelongata* (CHERCHI & SCHROEDER) - subaxial section, slide LEST54-24a.
10. *Cribellopsis neoelongata* (CHERCHI & SCHROEDER) - subaxial section, slide LEST54-31a.
11. *Cribellopsis neoelongata* (CHERCHI & SCHROEDER) - subaxial section, slide LEST72-5a.
12. *Cribellopsis neoelongata* (CHERCHI & SCHROEDER) - subaxial section, slide LEST53.5-1a.
13. *Cribellopsis neoelongata* (CHERCHI & SCHROEDER) - subaxial section, slide LEST54-36a.
14. *Cribellopsis neoelongata* (CHERCHI & SCHROEDER) - subaxial section, slide LEST84.5-4a.
15. *Cribellopsis schroederi* (ARNAUD-VANNEAU) - subaxial section, slide LEST54-3a.
16. *Cribellopsis schroederi* (ARNAUD-VANNEAU) - subaxial polished section LEST54b20.
17. *Cribellopsis thieuloyi* ARNAUD-VANNEAU - subaxial section, slide LEST72-8b.
18. *Cribellopsis elongata* (DIENI *et al.*) - subaxial section, slide LEST49.5-2.
19. *Paleodictyoconus cuvillieri* (FOURY) - subaxial section, slide LEST82.7-1b.
20. *Cribellopsis elongata* (DIENI *et al.*) - axial section, slide LEST49.5-1c.

[graphical scale bar = 500µm]

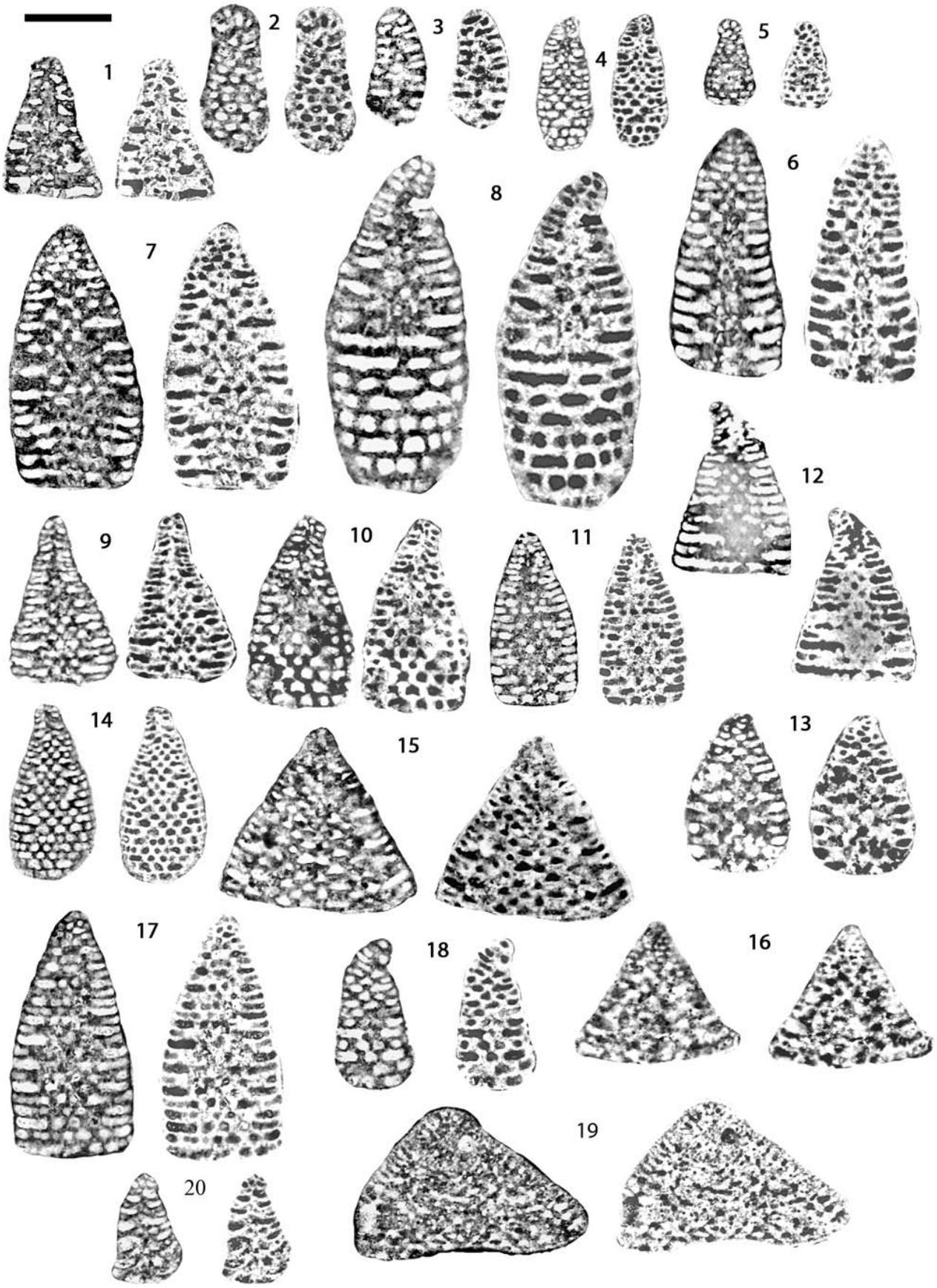
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Plate 6:

1. *Urgonina alpillensis* (FOURY) - subaxial section, slide LEST54-25c.
2. *Urgonina alpillensis* (FOURY) - subaxial section, slide LEST54-32a.
3. *Urgonina alpillensis* (FOURY) - subaxial section, slide LEST54-33b.
4. *Falsurgonina pileola* ARNAUD-VANNEAU & ARGOT - subaxial section, slide LEST27-9a.
5. *Falsurgonina pileola* ARNAUD-VANNEAU & ARGOT - subaxial section, slide LEST27-14a.
6. *Falsurgonina pileola* ARNAUD-VANNEAU & ARGOT - tangential section, slide LEST54-17c.
7. *Falsurgonina pileola* ARNAUD-VANNEAU & ARGOT - subaxial section, slide LEST54-23b.
8. *Falsurgonina vanneauae* CLAVEL *et al.* - subaxial polished section LEST54b84.
9. *Falsurgonina vanneauae* CLAVEL *et al.* - subaxial polished section LEST54b85.
10. *Falsurgonina vanneauae* CLAVEL *et al.* - subaxial section, slide LEST54-14b.
11. *Falsurgonina pileola* ARNAUD-VANNEAU & ARGOT - subaxial polished section LEST27a43.
12. *Falsurgonina pileola* ARNAUD-VANNEAU & ARGOT - subaxial section, slide LEST54-27a.
13. *Montseciella glanensis* (FOURY) - subaxial polished section LEST27a24.
14. *Falsurgonina pileola* ARNAUD-VANNEAU & ARGOT - subaxial section, slide LEST26.6-7b.
15. *Falsurgonina pileola* ARNAUD-VANNEAU & ARGOT - subaxial section, slide LEST26.6-5b.
16. *Montseciella glanensis* (FOURY) - tangential section, slide LEST88.2-1c.
17. *Montseciella glanensis* (FOURY) - tangential section, slide LEST72-8a.
18. *Falsurgonina pileola* ARNAUD-VANNEAU & ARGOT - tangential polished section LEST26.6a5.
19. *Montseciella glanensis* (FOURY) - tangential section, slide LEST84.5-4b.
20. *Montseciella glanensis* (FOURY) - tangential section, slide LEST72-6b.
21. *Montseciella glanensis* (FOURY) - tangential section, slide LEST54-33a.

[graphical scale bar = 500µm]

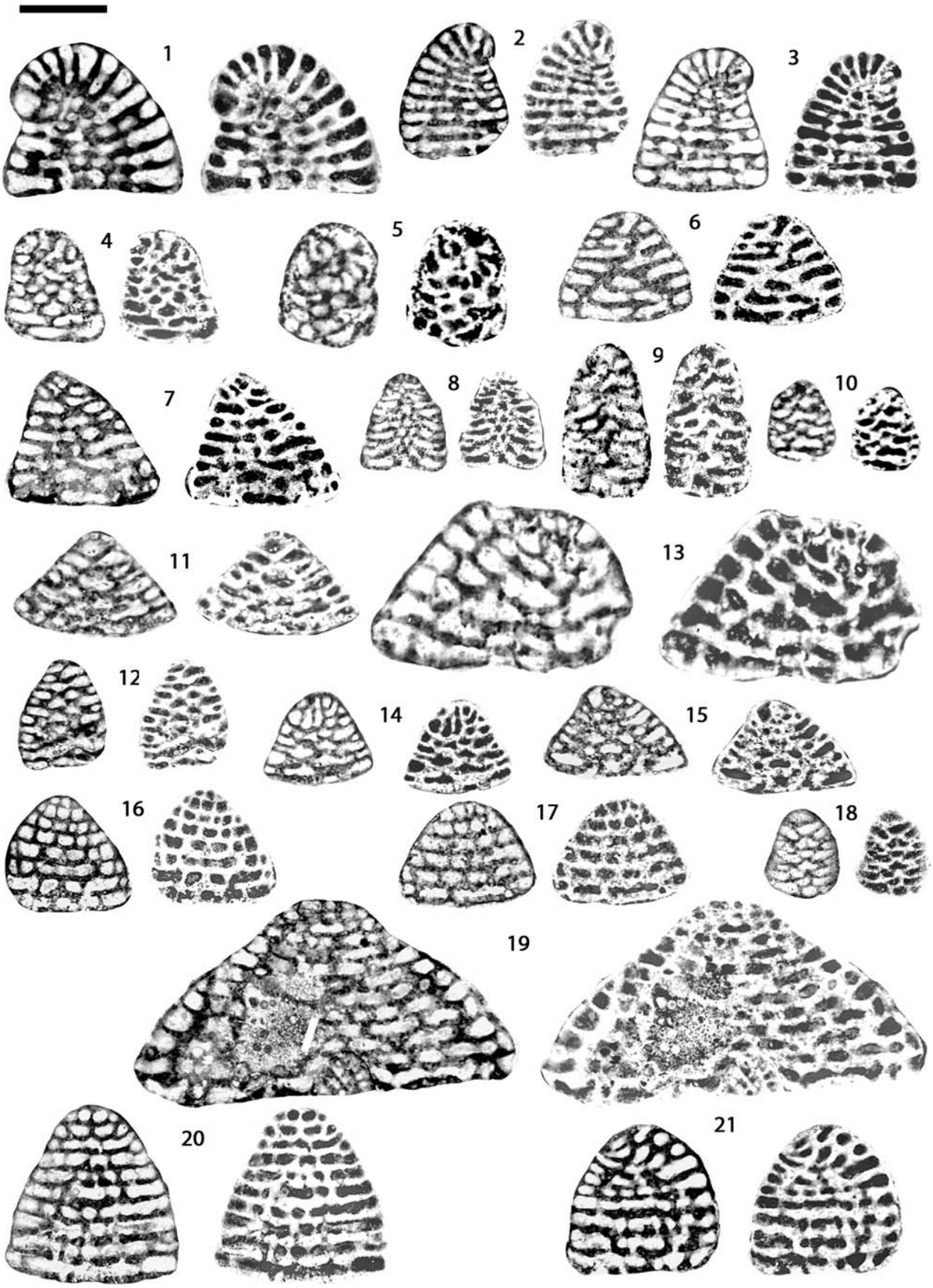
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Plate 7:

1. *Orbitolinopsis debelmasi* MOULLADE & THIEULOY - subaxial section, slide LEST54-4b.
2. *Orbitolinopsis debelmasi* MOULLADE & THIEULOY - subaxial section, slide LEST54-23a.
3. *Orbitolinopsis debelmasi* MOULLADE & THIEULOY - subaxial section, slide LEST54-27c.
4. *Orbitolinopsis debelmasi* MOULLADE & THIEULOY - subaxial section, slide LEST54-4c.
5. *Orbitolinopsis debelmasi* MOULLADE & THIEULOY - subaxial section, slide LEST88.2-2d.
6. *Paleodictyoconus cuvillieri* (FOURY) - subaxial polished section LEST54a41.
7. *Paleodictyoconus cuvillieri* (FOURY) - tangential section, slide LEST54-34a.
8. *Paleodictyoconus cuvillieri* (FOURY) - subaxial section, slide LEST84.5-5b.
9. *Paleodictyoconus actinostoma* ARNAUD-VANNEAU & SCHROEDER - subaxial section, slide LEST54-35b.
10. *Paleodictyoconus actinostoma* ARNAUD-VANNEAU & SCHROEDER - subaxial section, slide LEST58 (61m) -4a.

[graphical scale bar = 500µm]

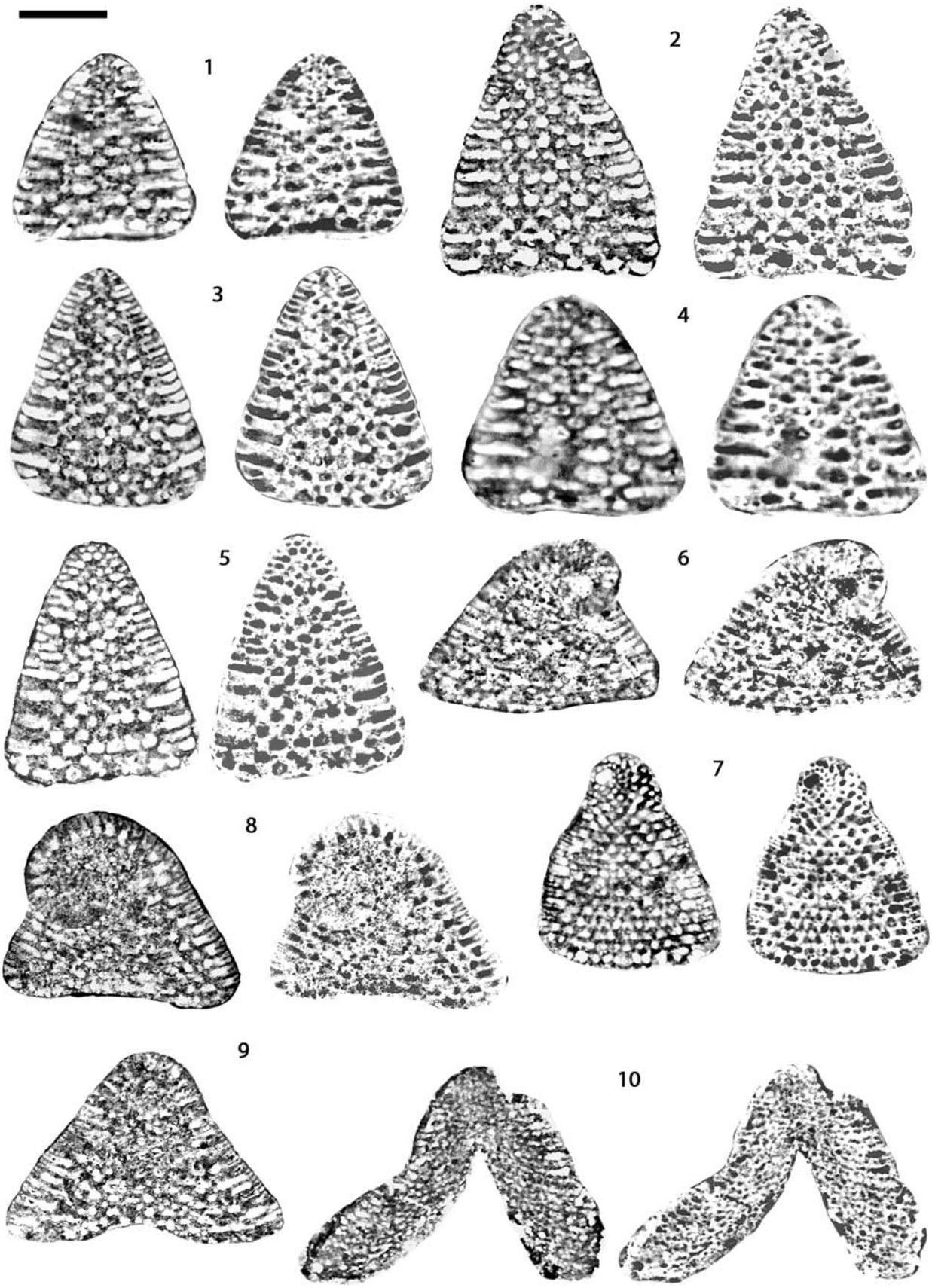
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Plate 8:

1. *Valserina broennimanni* SCHROEDER - subaxial section, slide LEST27-10b.
2. *Valserina broennimanni* SCHROEDER - oblique-tangential section, slide LEST27-4a.
3. *Valserina broennimanni* SCHROEDER - subaxial section, slide LEST27a35.
4. *Valserina turbinata* (FOURY) - transverse-oblique section, slide LEST54-20b.
5. *Valserina broennimanni* SCHROEDER - tangential section, slide LEST54-4a.
6. *Valserina broennimanni* SCHROEDER - subaxial section, slide LEST54-25a.
7. *Valserina turbinata* (FOURY) - subaxial section, slide LEST72-3b.
8. *Valserina broennimanni* SCHROEDER - subaxial polished section LEST26.6a35.
9. *Eopalorbitolina transiens* (CHERCHI & SCHROEDER) - subaxial eroded section, slide LEST54-11b.
10. *Dictyorbitolina* ? *vercorii* ARNAUD-VANNEAU - subaxial section, slide LEST26.6-6b.
11. *Dictyorbitolina* ? *vercorii* ARNAUD-VANNEAU - subaxial section, slide LEST72-8c.
12. *Dictyorbitolina* ? *vercorii* ARNAUD-VANNEAU - subaxial section, slide LEST54-36a.
13. *Montseciella glanensis* (FOURY) - tangential section, slide LEST26.6-12a.
14. *Paracoskinolina* ? *praereicheli* (CLAVEL *et al.*) - subaxial section, slide LEST84.5-5a.
15. *Valserina turbinata* (FOURY) - subaxial section, slide LEST58 (61m) -2b.

[graphical scale bar = 500µm]

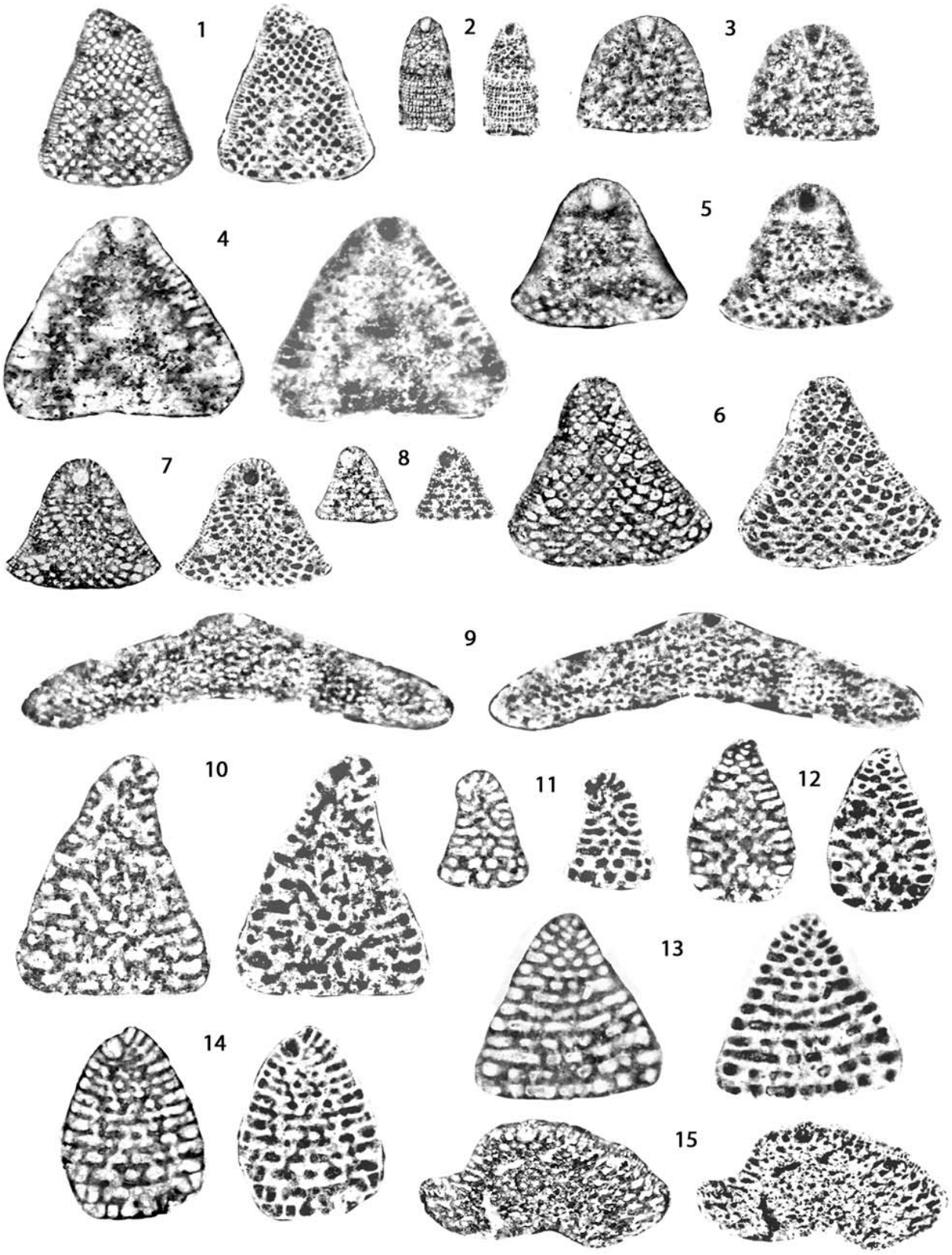
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Plate 9:

1. *Paracoskinolina* ? *reicheli* (GUILLAUME) - subaxial section, slide LEST 152.5-5a.
2. *Paracoskinolina* ? *reicheli* (GUILLAUME) - subaxial section, slide LEST 152.5-4a.
3. *Paracoskinolina maynci* (CHEVALIER) - subaxial section, slide LEST 152.5-6a.
4. *Orbitolinopsis* cf. *briacensis* ARNAUD-VANNEAU - subaxial section, slide LEST152.5-1b.
5. *Montseciella glanensis* (FOURY) - tangential section, slide LEST152.5-3b.
6. *Urgonina alpillensis* (FOURY) - subaxial section, slide LEST152.5-6b.
7. *Dictyorbitolina* ? *vercorii* ARNAUD-VANNEAU - subaxial section, slide LEST152.5a11.
8. *Paleodictyoconus cuvillieri* (FOURY) - tangential section, slide LEST152.5-1a.
9. *Cribellopsis neoelongata* (CHERCHI & SCHROEDER) - subaxial section, slide LEST152.5-2b.
10. *Paracoskinolina* aff. *sunnilandensis* (MAYNC) - subaxial polished section LEST140.5a4.
11. *Orbitolinopsis buccifer* ARNAUD-VANNEAU & THIEULOY - subaxial polished section LEST152.5a10.
12. *Orbitolinopsis buccifer* ARNAUD-VANNEAU & THIEULOY - subaxial section, slide LEST205.8-1b.
13. *Orbitolinopsis buccifer* ARNAUD-VANNEAU & THIEULOY - tangential section, slide LEST218-4c.
14. *Orbitolinopsis buccifer* ARNAUD-VANNEAU & THIEULOY - subaxial section, slide LEST218-1b.
15. *Orbitolinopsis buccifer* ARNAUD-VANNEAU & THIEULOY - subaxial section, slide LEST240-1a.
16. *Orbitolinopsis cuvillieri* MOULLADE - tangential section, slide LEST205.8-1a.
17. *Orbitolinopsis cuvillieri* MOULLADE - subaxial polished section LEST217.85b1.
18. *Orbitolinopsis cuvillieri* MOULLADE - tangential section, slide LEST218-9a.
19. *Orbitolinopsis cuvillieri* MOULLADE - subaxial section, slide LEST240-1e.
20. *Orbitolinopsis kiliani* (SILVESTRI) - subaxial section, slide LEST218-8c.
21. *Orbitolinopsis kiliani* (SILVESTRI) - subaxial section, slide LEST218-8a.

[graphical scale bar = 500µm]

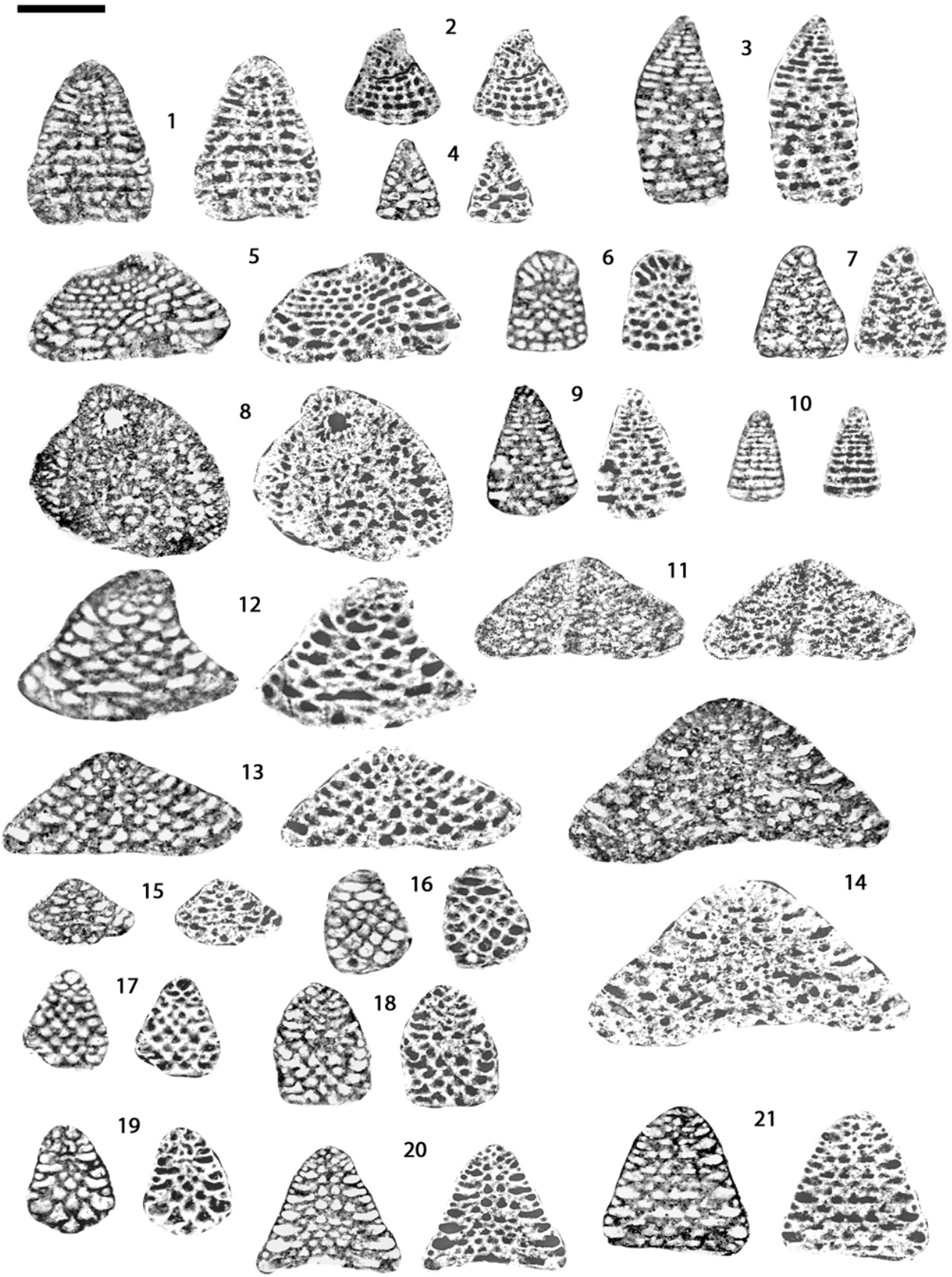
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Plate 10:

1. *Orbitolinopsis briacensis* ARNAUD-VANNEAU - subaxial section, slide LEST218-4a.
2. *Orbitolinopsis briacensis* ARNAUD-VANNEAU - subaxial section, slide LEST 218-4b.
3. *Orbitolinopsis briacensis* ARNAUD-VANNEAU (= "O. pygmaea A. A.-V." pars) - subaxial polished section LEST 18b23.
4. *Dictyorbitolina* ? *vercorii* ARNAUD-VANNEAU - subaxial section, slide LEST218-2a.
5. *Paracoskinolina maynci* (CHEVALIER) - tangential section, slide LEST205.8-2a.
6. *Paracoskinolina maynci* (CHEVALIER) - subaxial polished section LEST218b17.
7. *Paracoskinolina maynci* (CHEVALIER) - subaxial polished section LEST218a6.
8. *Paracoskinolina* aff. *sunnilandensis* (MAYNC) - subaxial section, slide LEST218-5b.
9. *Cribellopsis schroederi* (ARNAUD-VANNEAU) - subaxial section, slide LEST205.8-3c.
10. *Cribellopsis neoelongata* (CHERCHI & SCHROEDER) - subaxial section, slide LEST205.8-2b.
11. *Cribellopsis schroederi* (ARNAUD-VANNEAU) - subaxial section, slide LEST218-9d.
12. *Paleodictyoconus actinostoma* ARNAUD-VANNEAU & SCHROEDER - subaxial section, slide LEST218-3a.

[graphical scale bar = 500µm]

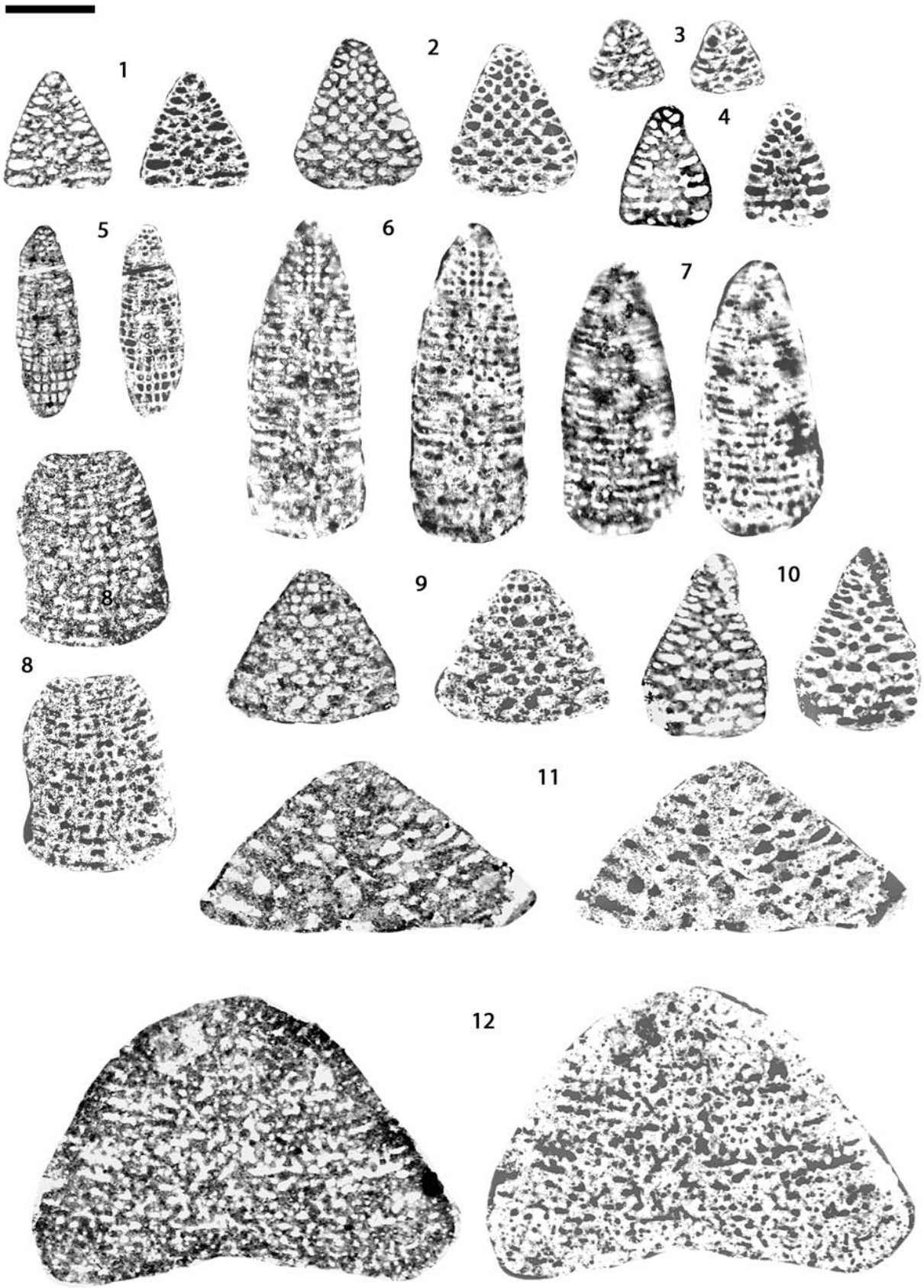
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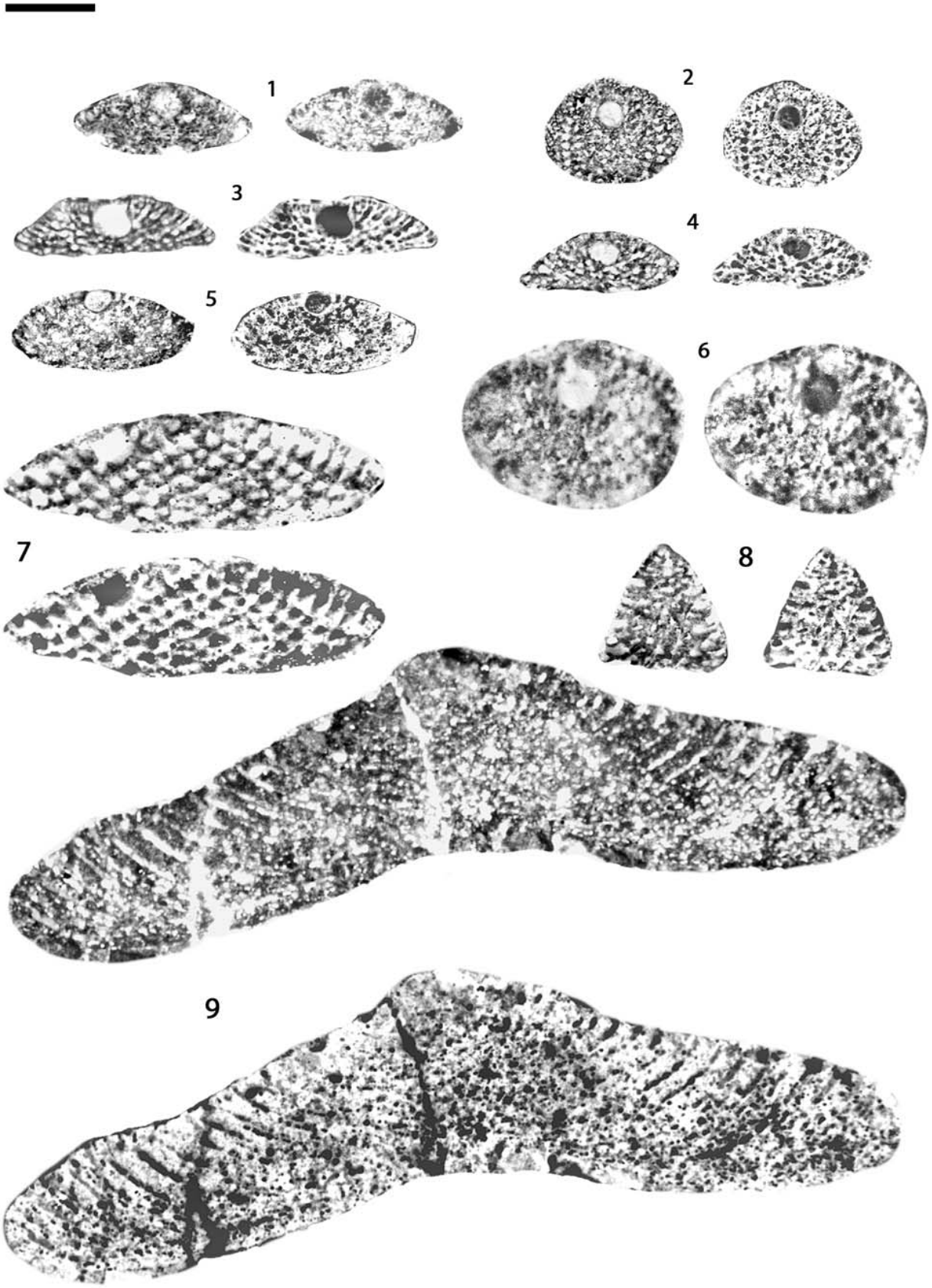
Plate 11:

1. *Palorbitolina lenticularis* (BLUMENBACH) - subaxial polished section LEST218b21.
2. *Palorbitolina lenticularis* (BLUMENBACH) - oblique section, slide LEST218-5a.
3. *Palorbitolina lenticularis* (BLUMENBACH) - subaxial section, slide LEST194.5-1b.
4. *Palorbitolina lenticularis* (BLUMENBACH) - subaxial section, slide LEST194.5-1a.
5. *Palorbitolina lenticularis* (BLUMENBACH) - subaxial section, slide LEST218-6a.
6. *Palorbitolina lenticularis* (BLUMENBACH) - oblique polished section LEST218b25.
7. *Orbitolinopsis buccifer* ARNAUD-VANNEAU & THIEULOY - tangential polished section LEST218b28.
8. *Orbitolinopsis kiliani* (SILVESTRI) - subaxial polished section LEST218b28.
9. *Palorbitolina lenticularis* (BLUMENBACH) - subaxial section, slide LEST218b

[graphical scale bar = 500µm]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