Excursion du
Groupe Français du Crétacé

association partenaire de la
Société Géologique de France

Société Géologique de France
Des géologues au service de la société

Some key Lower Cretaceous sites in Drôme (SE France)

May 17-19, 2017

Bruno Granier (ed.)

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Agenda

Day One (May 17th)

P.M.: journey from Valence TGV station at Alixan to Nyons (START),

then to Montbrun-les-bains

GSSP candidates for the Valanginian and for the « Upper Valanginian »

first night in Nyons

Day Two (May 18th)

A.M.: Tithonian and Berriasian breccias and slumps at St-May and Rémuzat, and in the gorge of the Arnayon stream

Valanginian-Hauterivian boundary in the gorge of the Arnayon stream

P.M.: Picnic lunch at La Charce

GSSP candidate for the Hauterivian

GSSP of the Albian near the Pré Guittard pass (1053 m)

La Pertie pass (972 m) and the « rabbit hole » at Serre de Bleyton

second night in Nyons

Day Three (May 19th)

A.M.: Barremian calcareous turbidites dated by ammonites at L'Estellon, *i.e.*, the « Rosetta Stone » for the Urgonian

P.M.: Picnic lunch at Bouvières

Barremian calcareous turbidites near Crupies (END)

journey back to Valence TGV station at Alixan

List of the Attendees

Francesca FALZONI (Italy)

Maria Rose PETRIZZO (Italy)

Mr Chaim & Mrs Sharon BENJAMINI (Israel)

Mr Elliott & Mrs Donna BURDEN (Canada)

Mr Eric GROESSENS & Mrs Marie-Claire GROESSENS-VAN DYCK (Belgium)

André CHARRIÈRE (France)

Andy GALE (United Kingdom)

Bruno GRANIER (France), leader

Brian HUBER (USA)

Jacques MALOD (France)

Andreas STRASSER (Switzerland)

Pablo SUÁREZ GONZÁLEZ (Spain)

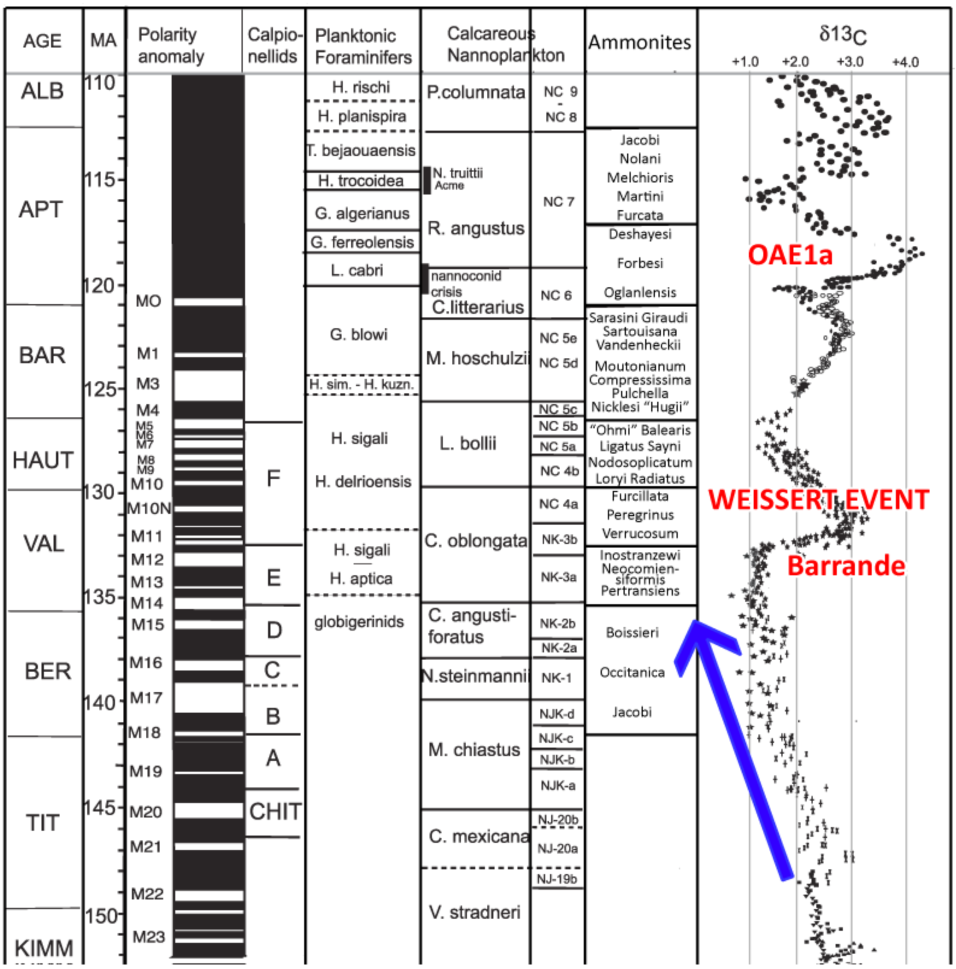
Introductory remarks

Any opinions, findings, and conclusions or recommendations expressed hereafter are those of the author(s) and do not necessarily reflect the views of the « Groupe Français du Crétacé » or of the « Société géologique de France ».

The excursion presents two main opposite types of geological sections:

- the « Global Boundary Stratotype Section and Point (GSSP) » category, including a recently voted GSSP (Albian) and potential GSSP candidates (Valanginian, Upper Valanginian, and Hauterivian), that were originally selected because the stratigraphic record in these localities is supposedly continuous or not affected by perburbation such as sedimentary hiatuses, resediments and/or slumps;
- outcrops with slumps, at all scales (decimetric to decametric), calcareous breccias and/or turbidites, that reflect either a general tectonic instability (for instance, in the Tithonian and Berriasian times, which should make the whole area unsuitable to define à Tithonian-Berriasian boundary) or relative sea-level changes (for instance, in the « Urgonian » Barremian times).

Part of the material that follows was already published either in an earlier GFC field trip guidebook in the same area (REBOULET, 2015) or in *Carnets Geol.* Another part is still unpublished, eventually presenting preliminary results that will be develop further in forthcoming publications.



Excerpt from WEISSERT & ERBA (2004), modified. Note that there is no break on the δ13C curve at/near the Jurassic-Cretaceous boundary (blue arrow).

1. Global Boundary Stratotype Section and Point (GSSP)

Voted, candidate or potential Cretaceous GSSP are all located in basinal sections from former tropical areas. As much as feasible their authors try to comply with the historical definition of the stages, but a GSSP is not necessarily defined in the historical area of the stage it refers to, *e.g.*, Albian (formerly from Aube, FR, now located in Drôme, FR), Ceno-manian (formerly from Sarthe, FR, now located in Hautes-Alpes, FR), Turonian (formerly from Indre-et-Loire, FR, now located in Colorado, USA), Santonian (formerly from Charente-Maritime, FR, now located in Navarra, SP), Maastrichtian (formerly from the Netherlands, now located in Gers, FR).

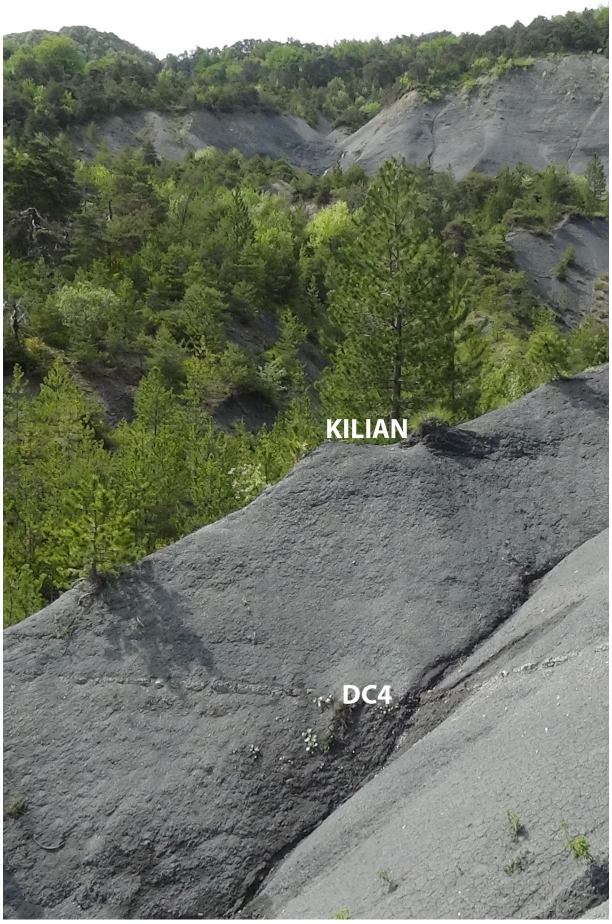
For a long time, macrofossils, mostly ammonites, were the primary fossil indexes used to define Cretaceous but, because microfossils are obviously more abundant in many sedimentary successions, they came into play. Planktonic foraminifers (starting from the Aptian) and calpionellids (for the Tithonian-Hauterivian* interval) were recently used as primary indexes to define GSSP : the Albian GSSP based on the FAD of *Microhedbergella renilaevis* at Pré Guittard and the Cenomanian GSSP based on the FAD of *Rotalipora globotruncanoides* at Mont Risou ; base of Calpionellid Zone B is considered as the potential primary marker for the Berriasian and base of Calpionellid Zone E for the Valanginian.

Note : Base of Zone E is the FAD of *Calpionellites darderi* but base of zone B is the base of a « quasi constant predominance » of *Calpionella alpina*. Shall we agree that the latter is a very poor primary index for a stage GSSP?

Besides the primary indexes come a number of secondary indexes, including chemostratigraphical or magnetostratigraphical proxies. Regarding geochemical events or paleomagnetic signals, a preliminary assessment of their biostratigraphic position is a prerequisite to their use, which should justify they should never be treated as primary indexes.

On day 1 (Wednesday, May 17th), we visit GSSP candidates for both the Valanginian and the Upper Valanginian at Vergol near Montbrun-les-Bains (44°12' 10.5"N 5°25'06.5"E) or near Aulan (44°13' 52.7"N 5°25' 21.7"E).

On day 2 (Thursday, May 18th), we visit the Hauterivian GGSP at La Charce (44°28'09.8"N 5°26'37.4"E) and the Albian GSSP at Arnayon (44°30'28.3"N 5°17' 50.1"E).



KILIAN level, *i.e.*, the base of the Albian, at the GSSP site near Pré Guittard, Arnayon [Photo B.G.].

* contrary to REMANE's opinion who considered they did not reach the Hauterivian.

2. Details about some stops of the excursion devoted to gravity-reworked deposits

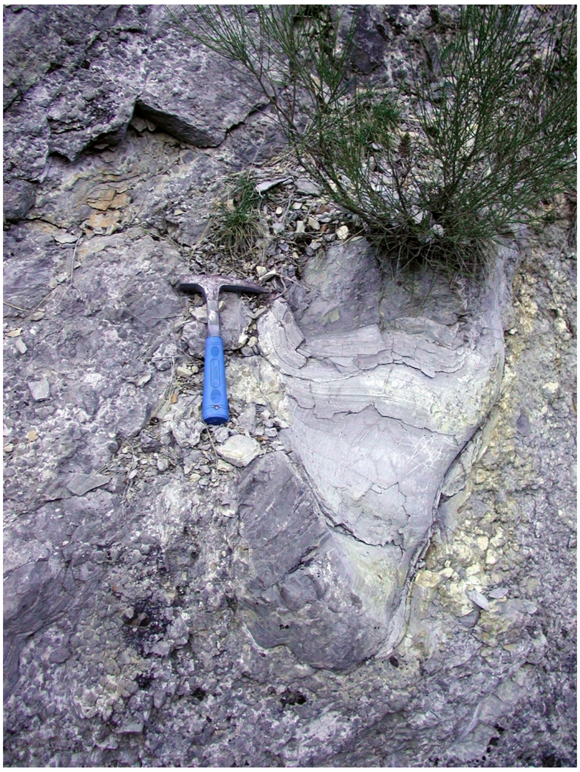
On day 2 (Thursday, May 18th), we examine the Tithonian - Berriasian transition.

[S.F.:] «Coming from Nyons, just after Sahune, the Aygues valley narrows. The cliffs bordering the gorge consist of the bedded calcarenites of the Tithonian lobe of the Aygues river (see Figs. 12-13). A possible stop to look at the cliff is just at the exit of the road tunnel after crossing the small village of St-May (picture on Fig. 13). Observing graded beds is possible all along, but a nice place is along the small road (D 570) to Villeperdrix, about 200 m after the crossing with the main road (D 94). It is the place where turbidite sequences with strongly irregular erosive base have been found (the so-called «dentelles» of SEGURET *et al.*, 2001), and judged to be impossible to be created by a turbidity current, in support of their interpretation of the breccias and calcarenite as tempestites. Be careful, the crossing is within in a turn of the road D 94, with poor visibility.

Note: The Aygues river, as many Mediterranean rivers, may be subjected to severe floods. A water level mark corresponding to the flood of 1868 has been incrusted in the rock, on the road side, about one metre above the road.

A stop to view the updip to downdip continuity of beds within the calcarenite lobe is indicated on Fig. 14. This continuity has also been found across the lobe, therefore indicating a draping system, contrary to the breccia lobe of the Drôme river to the north, where channelling updip and avulsion downdip are dominant processes (Fig. 5).

(It time permits) After exiting La-Motte-Chalancon village to the north, take to the left the road D135 to St-Nazaire-le-Désert. Stop after crossing the Chalancon hamlet before entering the gorge. You can touch the facies of the Tithonian breccias and have a look at the huge upper mega-slump (Fig. 16).



Slump in a mud flow in the Berriasian part of the Arnayon gorge section [Photo B.G.].

The Tithonian-Berriasian breccias of Arnayon can be seen (Fig. 15) on the side of the narrow road. A possible stop is when the road turns at the gorge entrance (see panorama on Fig. 15). The breccias can be touched in the gorge. The upper mega-slump is overlain by alternating limestone and marlstone beds of early Berriasian age (B2 calpionellid zone).»

Marks (made by ammonitic shells) on top of a Berriasian bed in the Arnayon gorge section [Photo B.G.].

On day 2 (Thursday, May 18th), on the way back to Nyons, we stop at the small outcrop of Serre de Bleyton, which is located in front and below of the Mt Angèle thrust. The way in which bioclasts can be easily extracted from the matrix is amazing. Several papers dealing with this single lower Barremian outcrop have been published in the *Annalen des Naturhistorischen Museums in Wien* (JANSSEN, 2010; KROH A. *et al.*, 2010; LÖSER, 2010; LUKENEDER, 2010; RIEGRAF & MOOSLEITNER, 2010; TAYLOR, 2010; VILLIER, 2010; BUCUR, 2011).

The « Rabbit Hole » in lower Barremian strata at Serre de Bleyton [Photo G. MOOSLEITNER, March 2007].

On day 3 (Friday, May 19th), we examine the Barremian at L'Estellon and near Crupies.

Mudstone cobbles in Barremian calcareous turbidites near Les Oulettes at l'Estellon [Photo B.G.].

[S.F.:] « After the L'Estellon section, we follow the road D 70 to the north over a ten of km to reach the outcrop after crossing the Bouvières hamlet (see map in box of Fig. 21) and we reach the Crupies section. The upper Barremian limestones, thickened here by the many intercalations of calcarenite turbidite bundles (Figs. 21 & 22), form a crest dipping to the west. Calcarenite turbidites can be observed along the road. Be careful of cars passing by, the road is narrow. Mid-Aptian G1 sandstones (Fig. 24) can be seen after the tunnel. Mid-Albian massive sandstones make a yellowish cliff in the distance. These massive ungraded sandstone beds outcrop farther north along the road, before entering the village of Bourdeaux. »

Acknowledgments

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Montbrun-les-Bains (Drôme, France, Vocontian Basin): a Berriasian-Valanginian boundary

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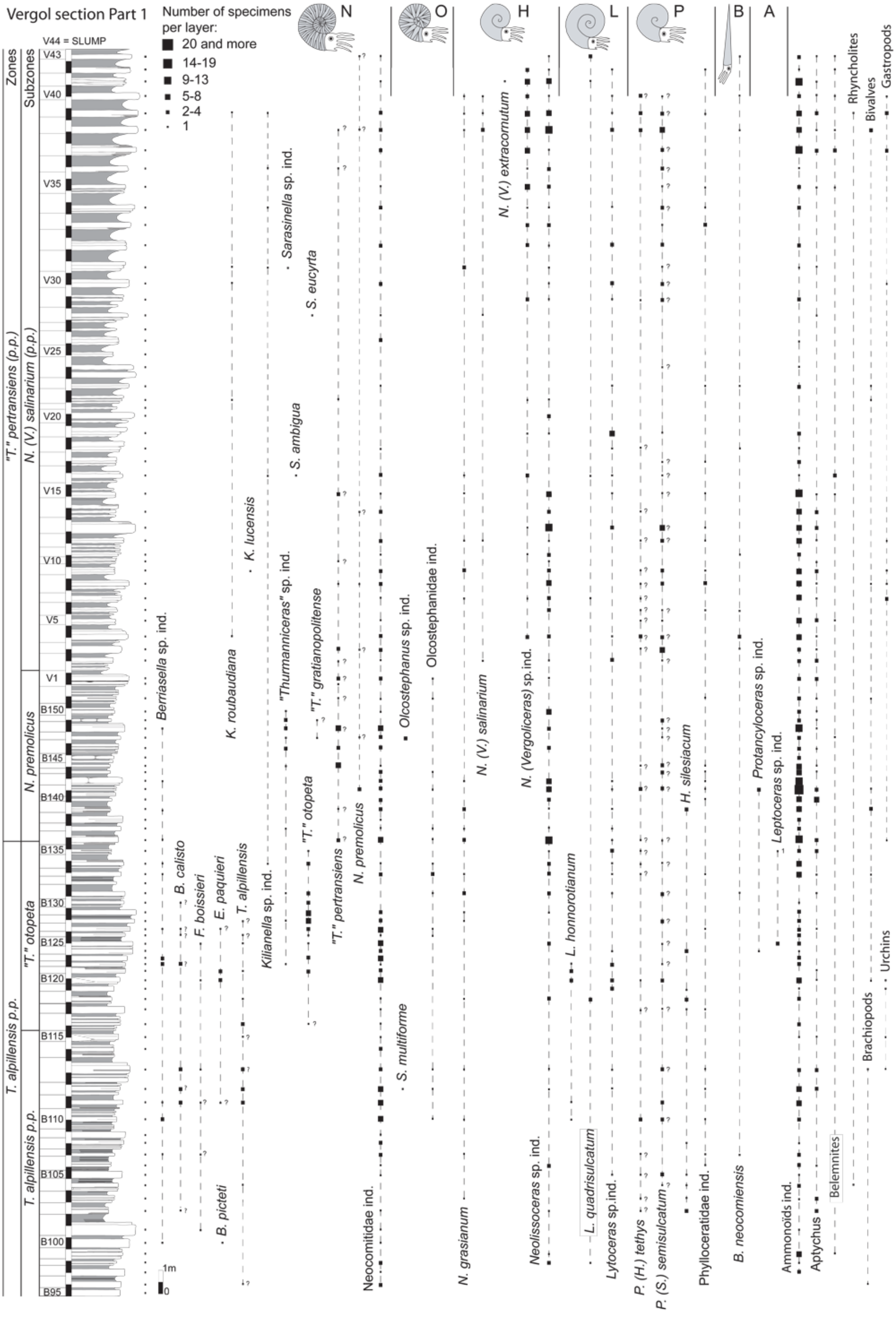

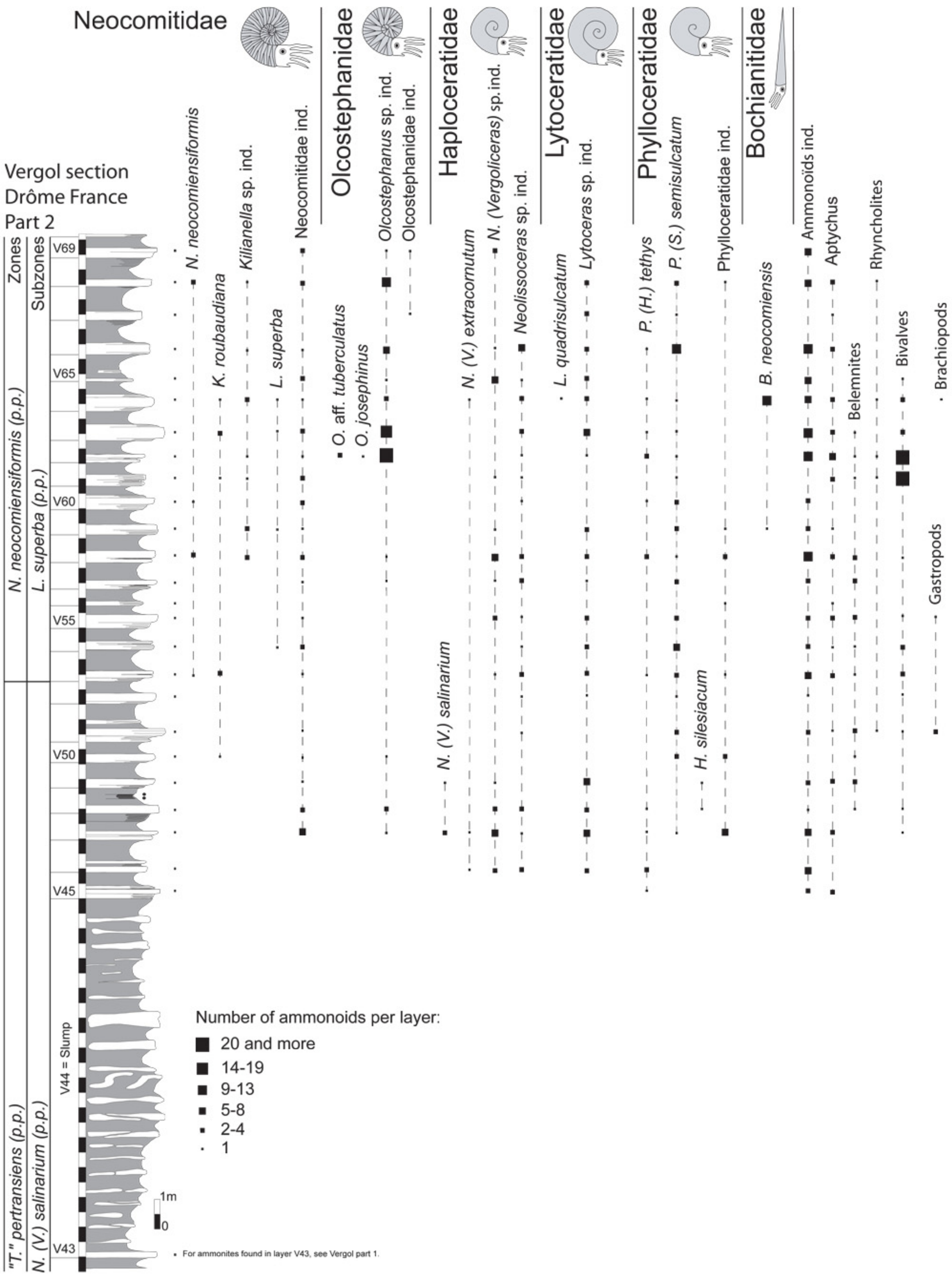

Modified after REBOULET *et al.* (2003) and REBOULET (2015).

Montbrun-les-Bains (Drôme, France, Vocontian Basin): a lower-upper Valanginian boundary

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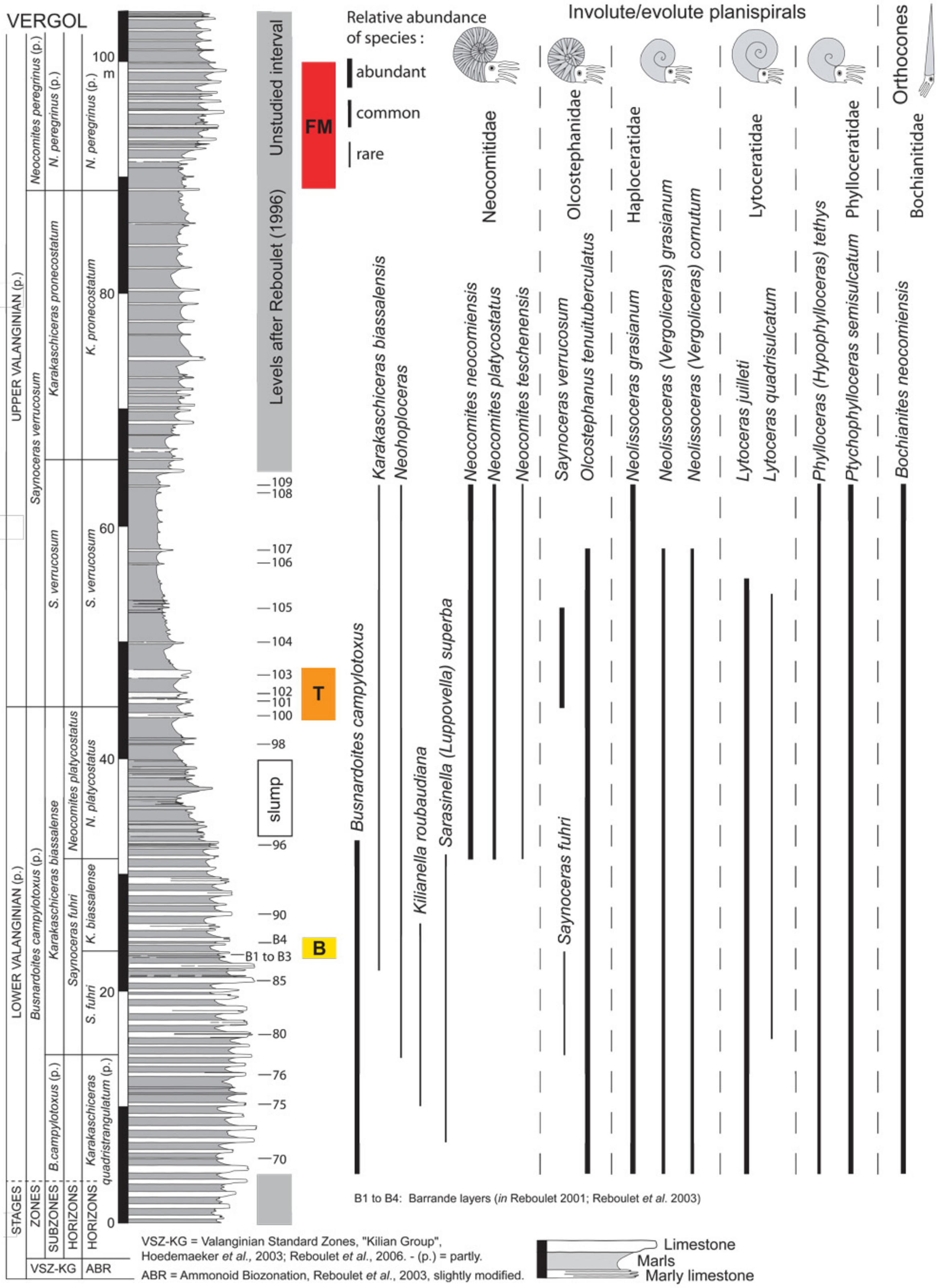

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Summary on Mesozoic carbonate deposits of the Vocontian Trough (Subalpine Chains, SE France)

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Introduction

In the southern subalpine chains (Fig. 1), the Vocontian Trough VT (Paquier, 1900) is a W-E oriented paleogeographic feature slowly born in the Early Cretaceous through a contraction of a larger Liassic to Late Jurassic basin (Fig. 2). The Vocontian Trough proper is located between the Vercors Plateau to the north and the Ventoux-Lure chain to the south. It covers the Diois and Baronnies regions. In the literature, the basinal area of the southeastern subalpine chains (Digne thrust and tectonic arc of Castellane) is often included in a Vocontian domain *lato sensu*.

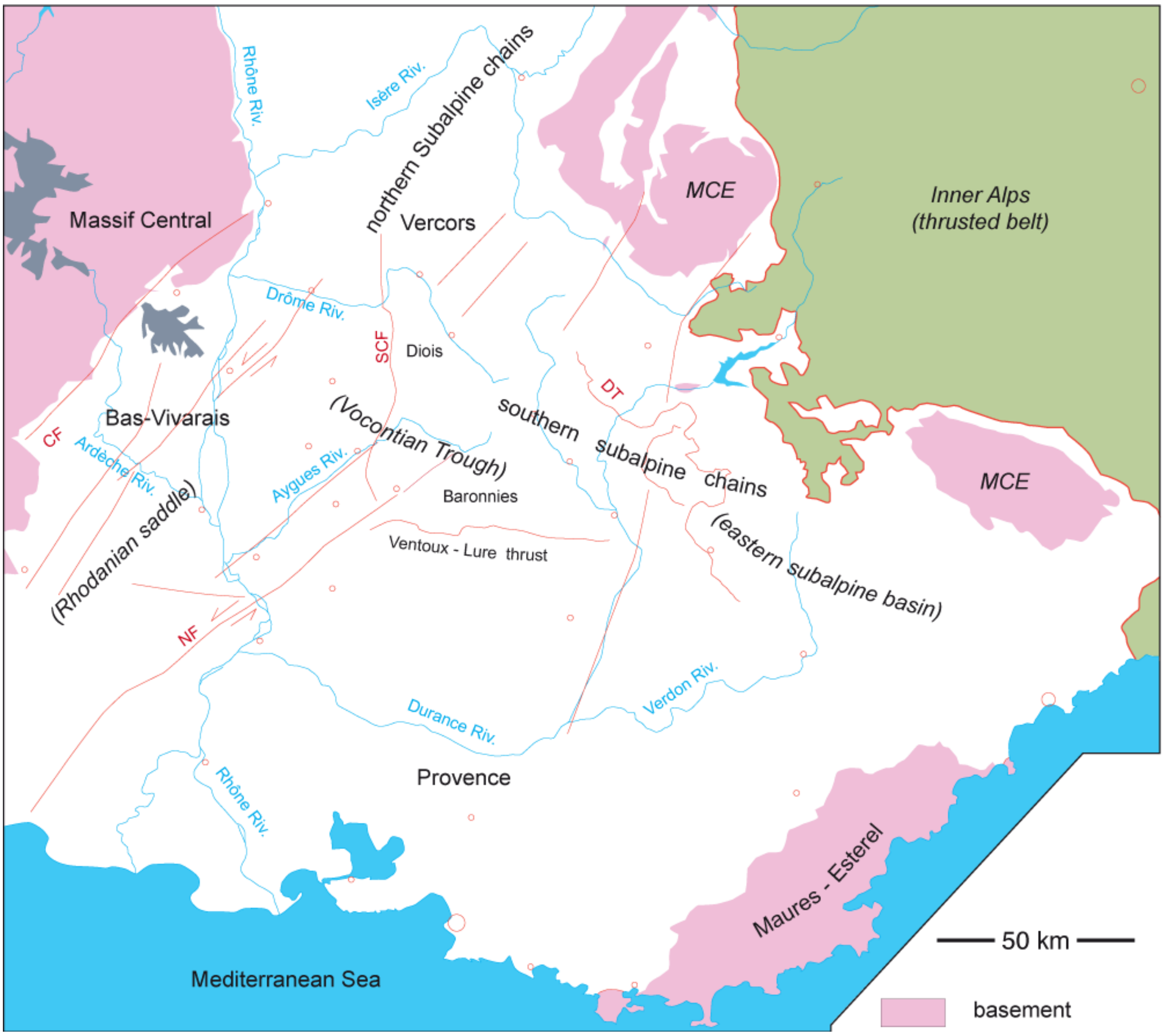


Fig. 1. The southeastern France basin. CF, Cevennes fault; DT, Digne thrust; NF, Nîmes fault; SCF, Saillans-Condorcet fault. MCE, external crystalline massifs.

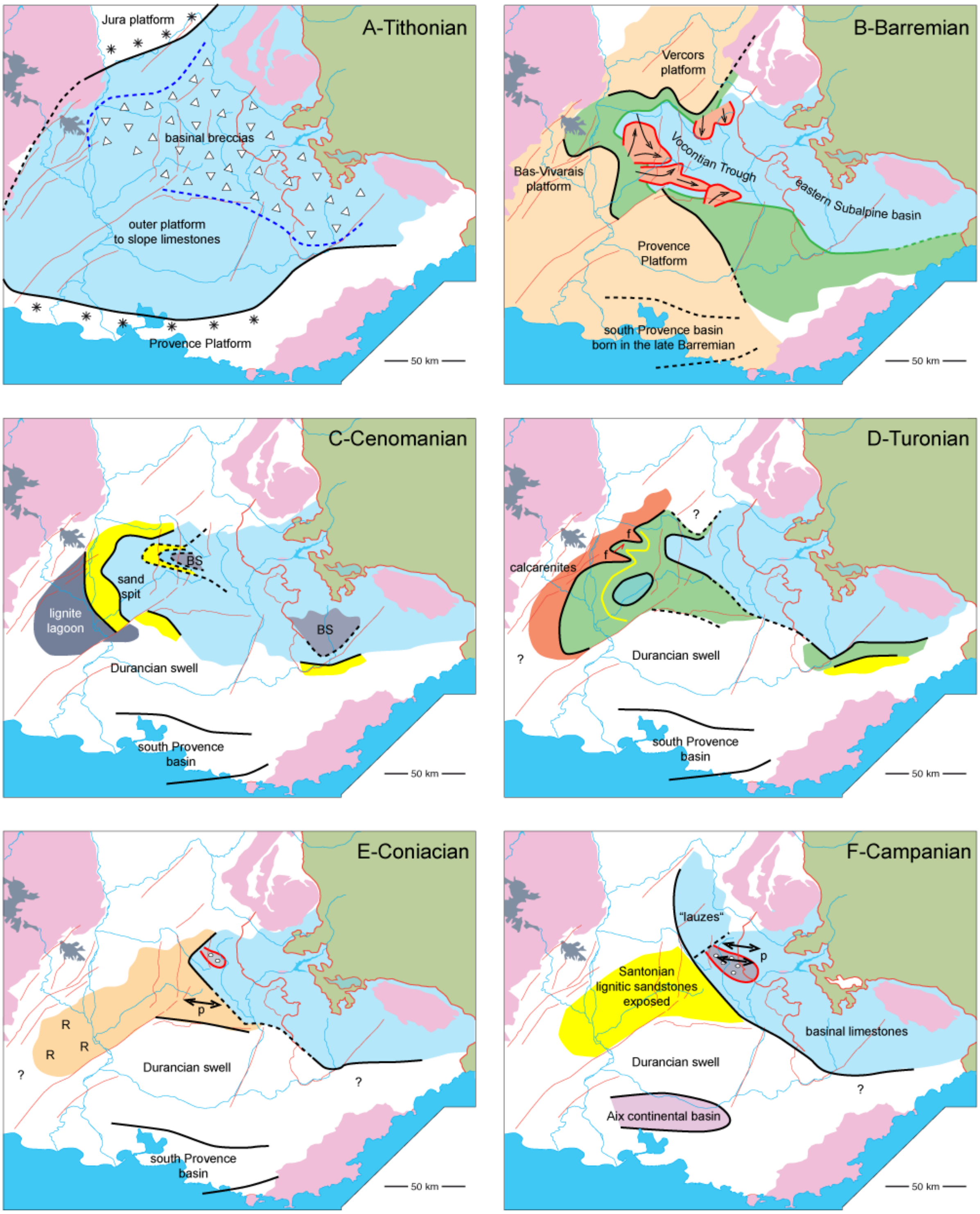
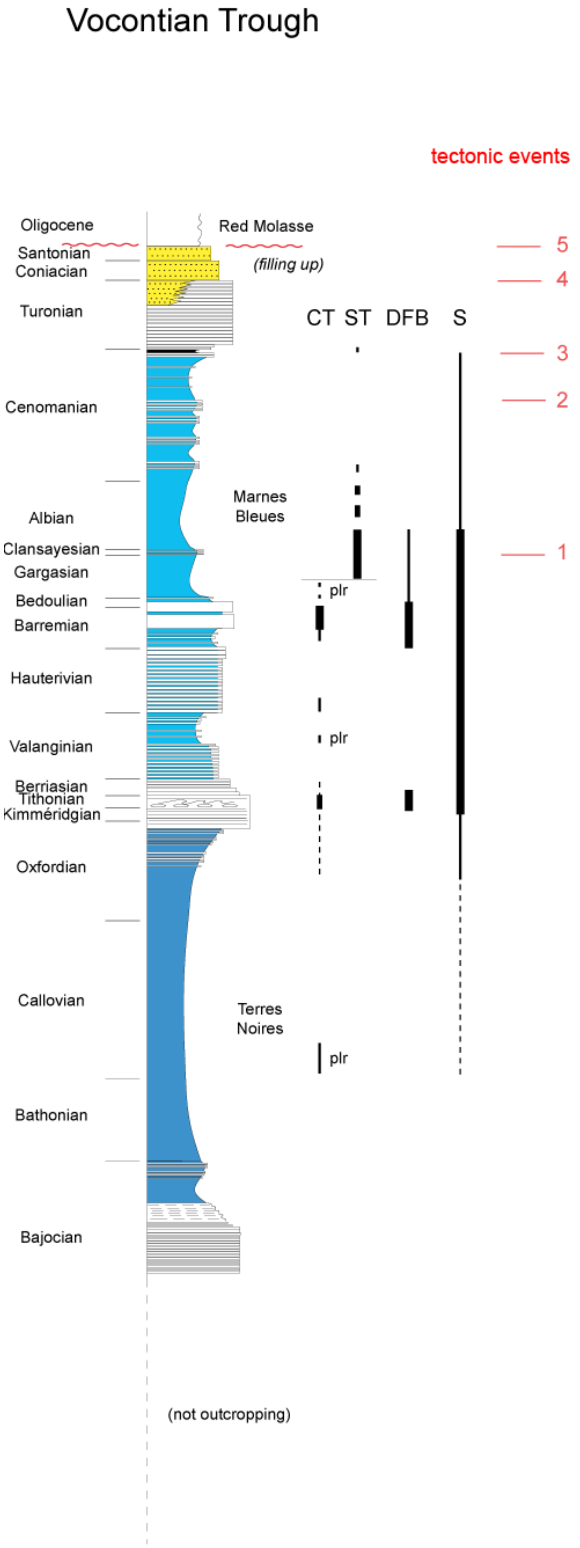


Fig. 2. Paleogeographic history of the Vocontian Trough and nearby areas from the Late Jurassic to the Late Cretaceous (after FERRY & GROSHENY, 2013). **Barremian**: orange, max. extension of Urgonian platformal carbonates; green, slope limestones; blue, basinal limestone-marl alternation; red, carcarenite turbidites lobes. **Cenomanian**: black-lined yellow, sand spit bordering a back-barrier lignite lagoon, blue, basinal limestones and marlstones, dotted lines, residual basin after the forced regression of the C-T boundary on the western margin, and location of the black shales in the restricted basin; the forced regression is strong on the Rhodanian saddle, mild or non existent in the eastern part of the basin. **Turonian**: solid lines, paleogeography around the upper lower to mid Turonian, yellow line, max. progradation of upper Turonian deltaic sandstones in the Rhodanian saddle; p, ramps folds born in the early Turonian, their heads being capped by shallow-water calcarenites. **Coniacian**: orange, shallow-water deposits (sandstones, calcarenites, rudist-bearing limestones); blue, basinal limestones; grey, calcarenite and conglomerate slope apron of Les Gâs; p, Chauvac fold (60° angular disconformity between transgressive Coniacian calcarenites and vertical basinal Turonian limestones). **Campanian**: blue, undiff. fine-grained limestones, a turbiditic facies (« lauzes ») developped on the ancient Vercors platform now drowned; grey, conglomerate and calcarenite slope apron of Glandage; p, pre-Campanian folds of the Dévoluy; also note the northward shift of the Aix continental basin *vs.* the older south-Provence marine basin. On maps C to E, facies belts of the south-Provence basin are not detailed.



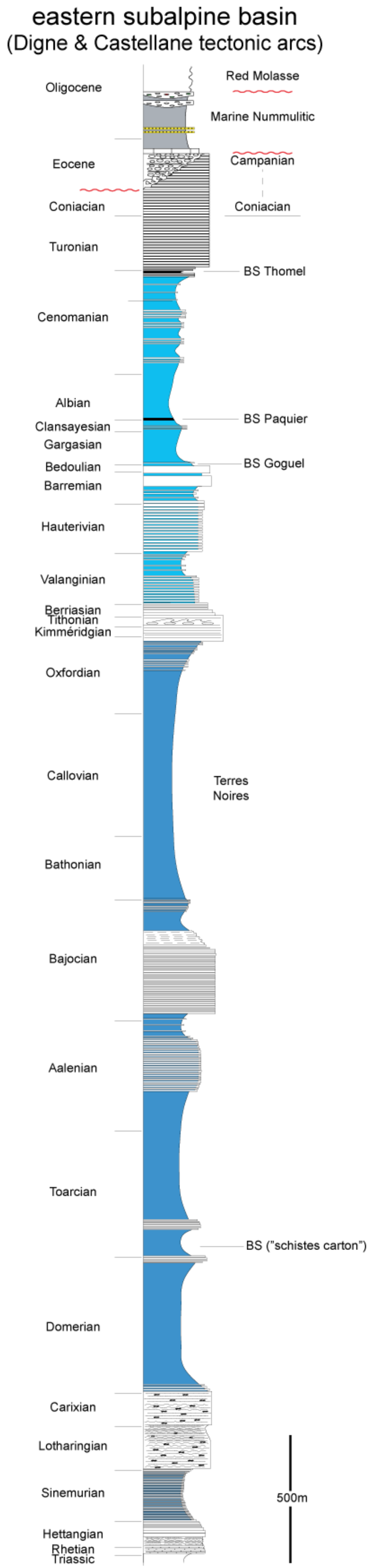
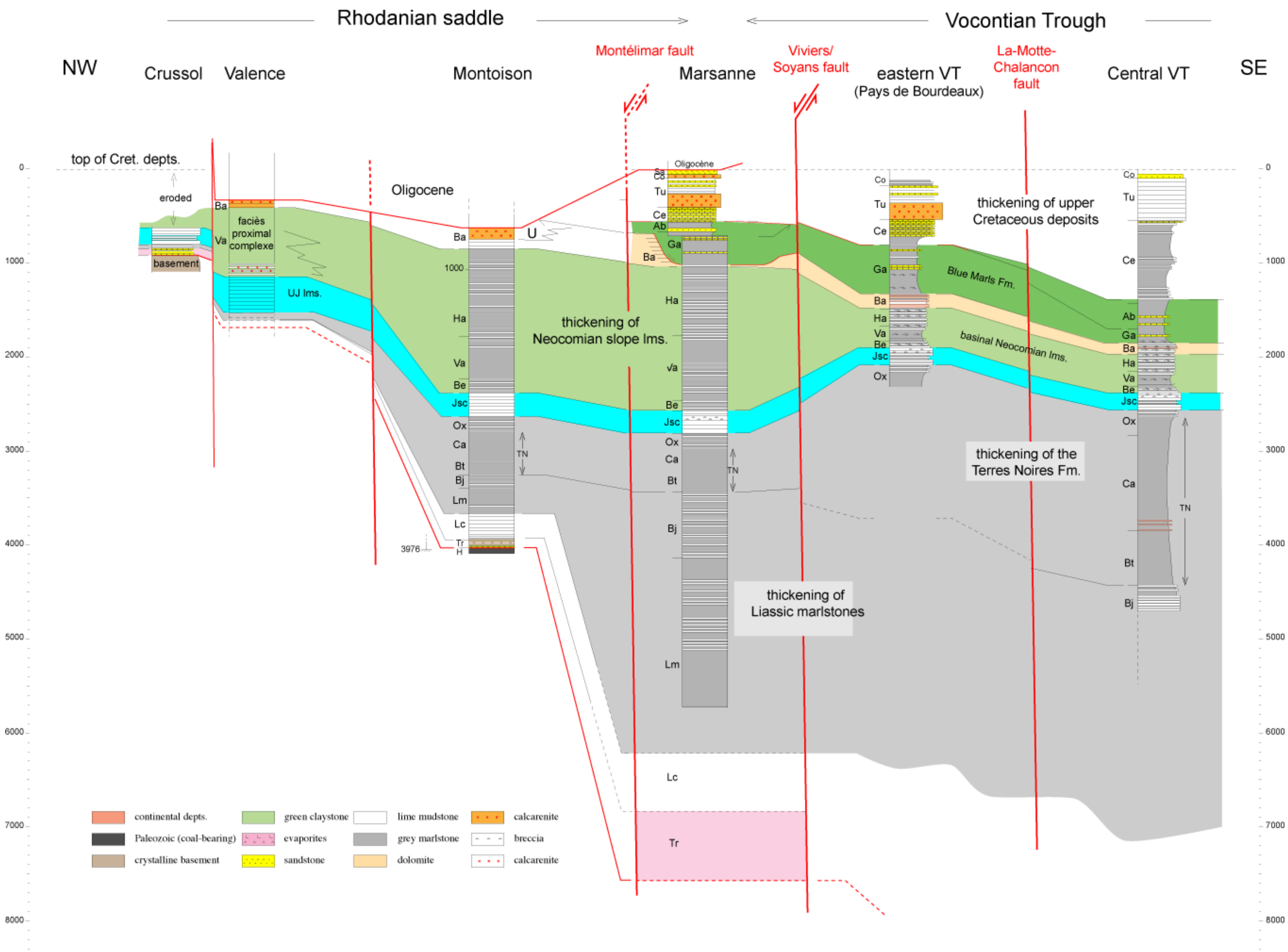


Fig. 3. The Vocontian Mesozoic succession. Gravity reworked deposits: CT, calcarenite turbidites; ST, sandstone turbidites; DFB, debris flow beds (including large Mass Transport Deposits or MTDs); S, slump deposits; plr, thin-bedded turbidites. Mostly present in the VT proper. Tectonic events: 1 to 3, inferred from strong forced regressions on the Rhodanian Saddle (see text); 4, Turonian folding culminating in the latest Turonian; 5, pre-Campanian phase (folding, strong paleogeographic reorganization at the end of the Santonian, deep basin remaining only in the southeastern subalpine chains).


Rhodanian saddle
Vocontian Trough
NW
SE
Crussol
Valence
Montoison
Marsanne
eastern VT
(Pays de Bourdeaux)
Central VT
Montélimar fault
Viviers/
Soyans fault
La-Motte-
Chalancon
fault
top of Cret. depts.
eroded
basement
faciès
proximal
complexe
UJ lms.
Oligocene
Oligocène
thickening of
Neocomian slope lms.
thickening of upper
Cretaceous deposits
Blue Marls Fm.
basinal Neocomian lms.
thickening of the
Terres Noires Fm.
thickening of
Liassic marlstones
TN
3976
Co
Tu
Ce
Ab
Ga
Ba
Ha
Va
Be
Jsc
Ox
Ca
Bt
Bj
Lm
Lc
Tr
H
U
0
1000
2000
3000
4000
5000
6000
7000
8000
continental depts.
Paleozoic (coal-bearing)
crystalline basement
green claystone
evaporites
sandstone
lime mudstone
grey marlstone
dolomite
calcarenite
breccia
calcarenite

◀ **Fig. 4.** NW-SE transect along the axis of the western part of the Vocontian Trough (based on exploration wells, completed with outcrops in the upper part of the successsions).

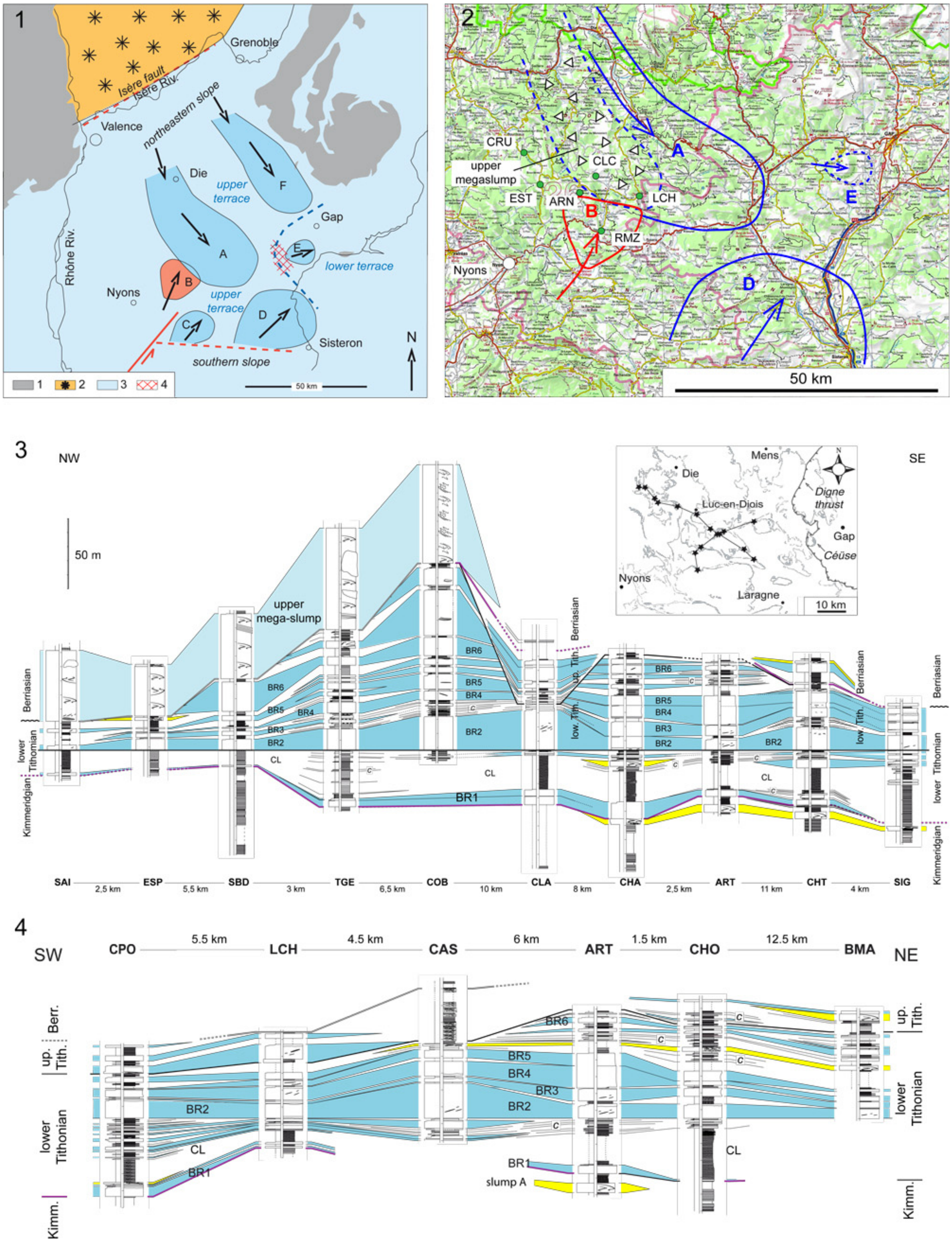


Fig. 5. Tithonian breccia lobes in the Vocontian Trough. 1, Location of the lobes (A to E); 2, Detail showing the convergence between the breccia lobe of the Drôme river (A) and the calcarenite lobe of the Aygues river (B) in the Arnayon-La Charce area. Also note the lateral shift to the right of the upper mega-slump *vs.* the axis of the lobe; 3, longitudinal (axial) section across the lobe; 4, transverse section across the distal part of the lobe showing deposition through avulsion and morphological compensation; breccia beds in blue, slump beds in yellow (after Courjault *et al.*, 2011). Points of interest during the field trip in green (ARN, Arnayon; CLC, Chalencon; CRU, Crupies; EST, L'Estellon; LCH, La Charce; RMZ, Remuzat).

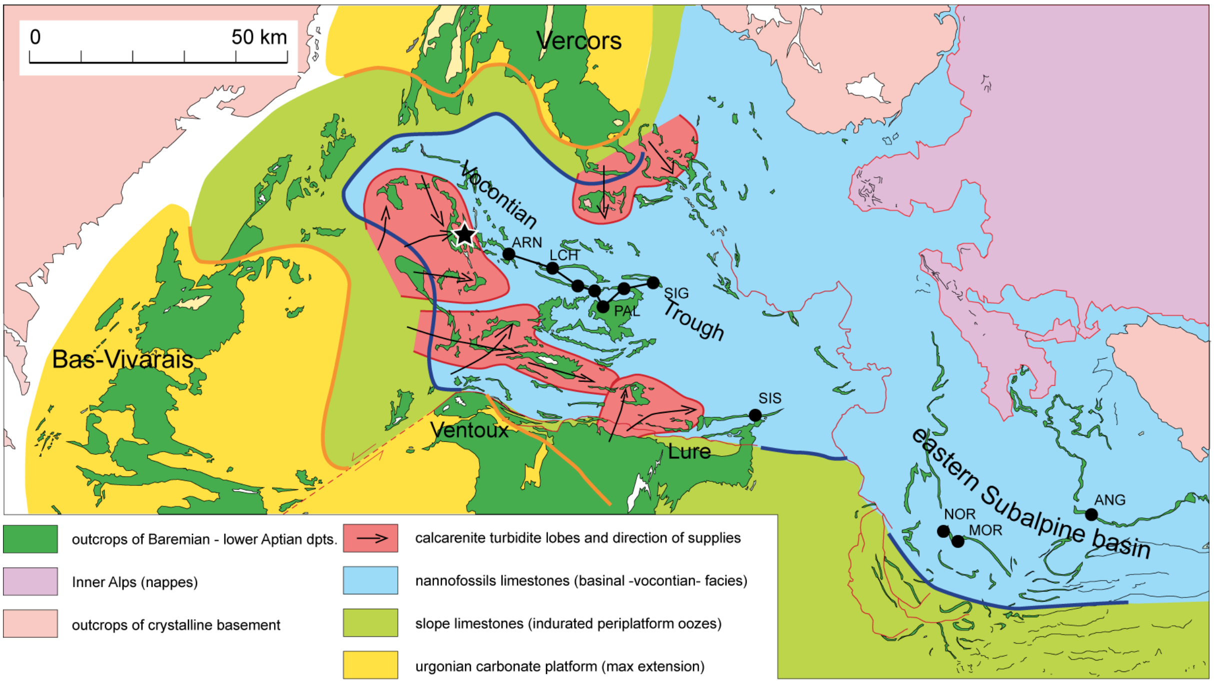
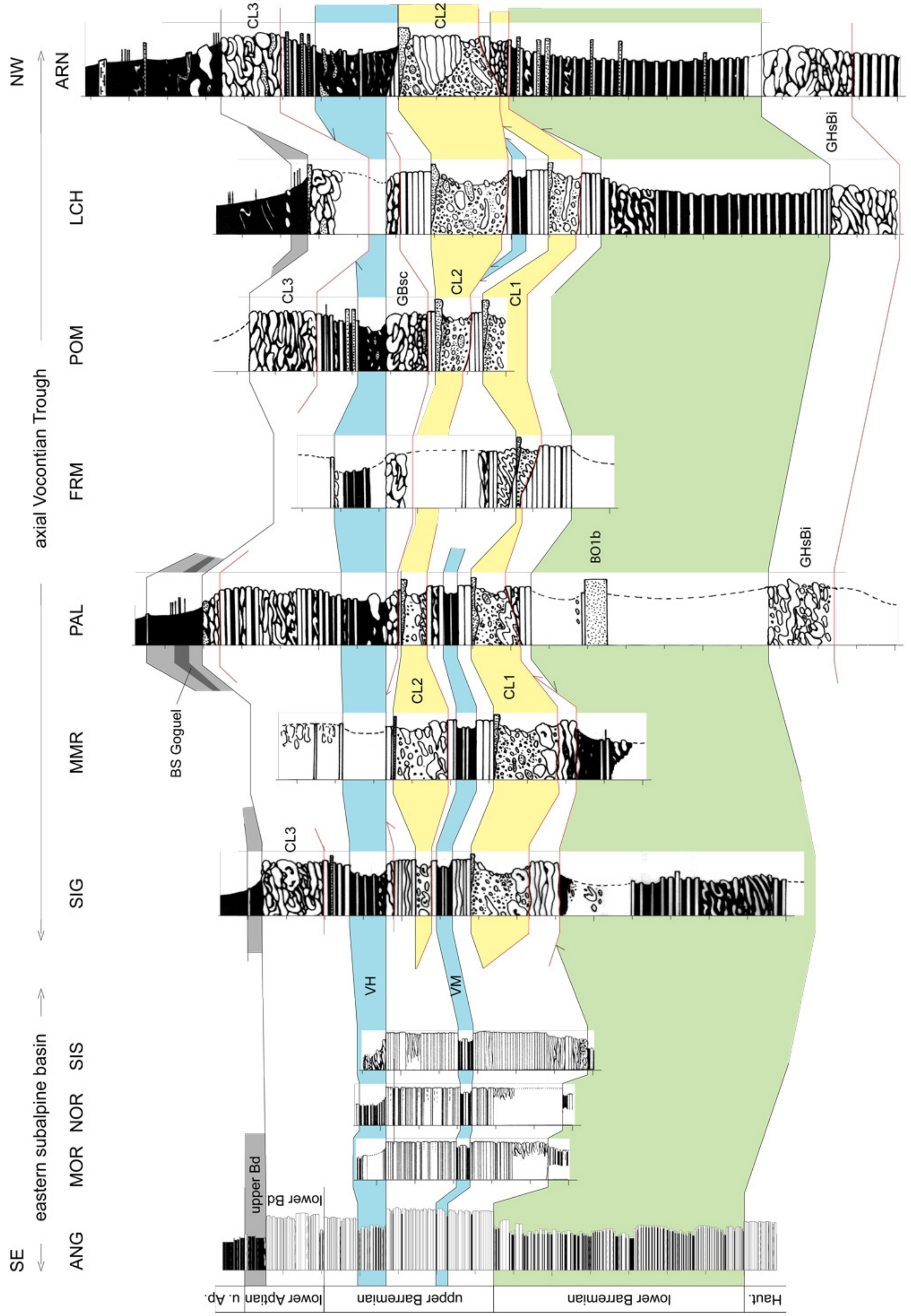


Fig. 6. Maximal areal extension of Barremian to lower Aptian calcarenite turbidite lobes in the Vocontian Trough (from FERRY & GROSHENY, 2013; after FERRY, 1978, 1979, 1984; FERRY & FLANDRIN, 1979). Black star, Crupies-L'Estellon area; dots, sections shown in the axial transect of Fig. 7.

The Vocontian Mesozoic sedimentary pile (Fig. 3) is exceptionnally thick (possibly approaching 10,000 m under the present-day middle Rhône valley), mainly through the thickness increase of Upper Liassic to Middle Jurassic deposits during peak Alpine extension. This raises the question of the geodynamic significance of such a narrow external basin, oriented roughly perpendicular to the Alps. Could it be a relay between the Biscay Gulf - Pyrenees system and a controversial Valais Ocean in the Alps, through the transform corridor of the Cevennes faults bordering the Massif Central, where accumulation rates are also very high? Evidences of submarine hydrothermalism in the Late Jurassic (ROLLIN *et al.*, 1990; GAILLARD *et al.*, 1992) and the Early Cretaceous (THIEULOY, 1972; LEMOINE *et al.*, 1982) could support the hypothesis of an aborted rift segment between the two oceans, but the closure of the Alpine Ocean in the Late Cretaceous has left too few remains in front of the thrusted belt to fully understand the early paleogeography of its French western border. In addition, an unsolved problem remains: the original location of some « Alpine zones » such as the Briançonnais that could be exotic southern terranes, now pushed to the west in front of the frontal thrust, after a S->N early move in the Late Cretaceous (RICOU, 1980, 1984), and therefore fully obliterating the above early paleogeographic connections.

Post-Variscan extension began in the Triassic (BAUDRIMONT & DUBOIS, 1977) with the development of an evaporite basin, probably limited to the east by swells corresponding to the the present-day External Crystalline Massifs (MCE, Fig. 1). Subsidence incrased dramatically in the Liassic and the middle Jurassic (Fig. 4) with the deposition of very thick successions dominated by dark marlstones (Terres Noires Fm.) alternating with bundles of alternating lime mudstone and marlstone beds (Fig. 3). Conversely, the scarcity of gravity reworkings, except for thin-bedded turbidites at some stratigraphic levels, is evidence of a limited depositional depth. Redeposited carbonates (mostly slumps deposits) appear in the Oxfordian (Fig. 3) to reach a first maximum in the Tithonian with the extensive but short-lived development of breccias. The development of these carbonate-gravity reworkings is indirect evidence of the beginning of the formation of the VT proper (narrowing of the basin, increasing depositional depth).

▶ **Fig. 7.** Correlation of the Barremian to lower Aptian successions across the Vocontian Trough. CL1 to CL3, GBsc, GHsBi, main debris flow beds identified (see FERRY & FLANDRIN, 1979, FERRY, 1987). VH, Heteroceras marls; VM, thin recessive marly interval in the middle part of the limestone package under the VH; BS, black shale. BO1b, « barre à orbitolines » (see Fig. 18).


SE
NW
eastern subalpine basin
axial Vocontian Trough
ANG
MOR
NOR
SIS
SIG
MMR
PAL
FRM
POM
LCH
ARN
upper Bd
lower Bd
BS Goguel
CL3
CL2
CL1
GBsc
VH
VM
BO1b
GHsBi
u. Ap.
lower Aptian
upper Barremian
lower Barremian
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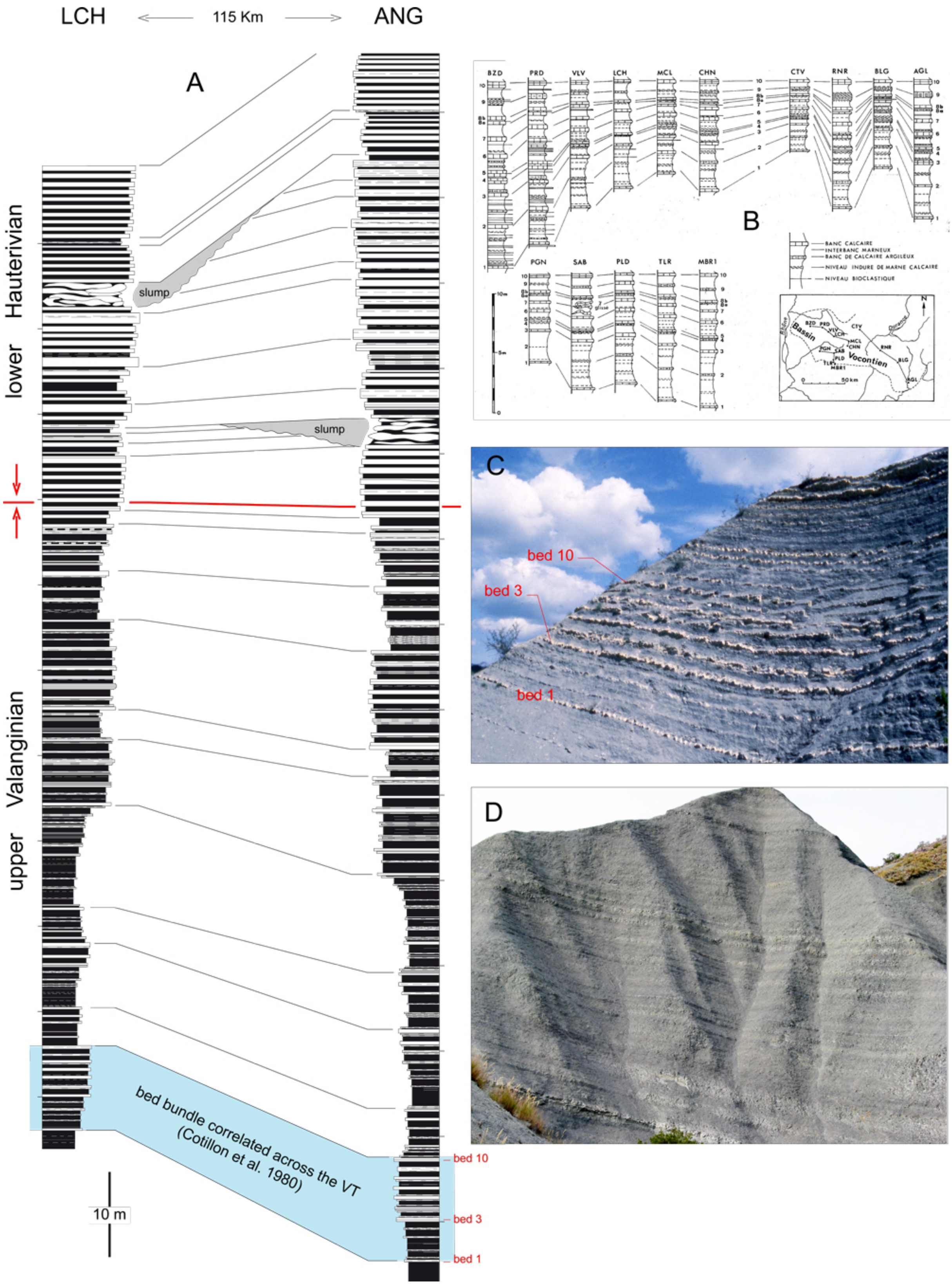


Fig. 8. The bed-scale limestone-marl alternation characteristic of the Mesozoic of the Vocontian Trough. A) Correlation between the upper Valanginian to lower Hauterivian bed bundles between the sections of La Charce (LCH) and Angles (ANG); red line, base of the Radiatus ammonite Zone (REBOULET & ATROPS, 1999). B) First attempt of bed by bed correlation in the limestone-marl alternation of the Vocontian Trough by COTILLON *et al.* (1980); the bed bundle is in the middle of the upper Valanginian. C) picture of the bed bundle correlated by COTILLON *et al.* (stratigraphic position in A, lower left). D) subdued alternation in the lower part (upper Aptian) of the Blue Marls Fm. (Reynier-Esparron, eastern subalpine basin).

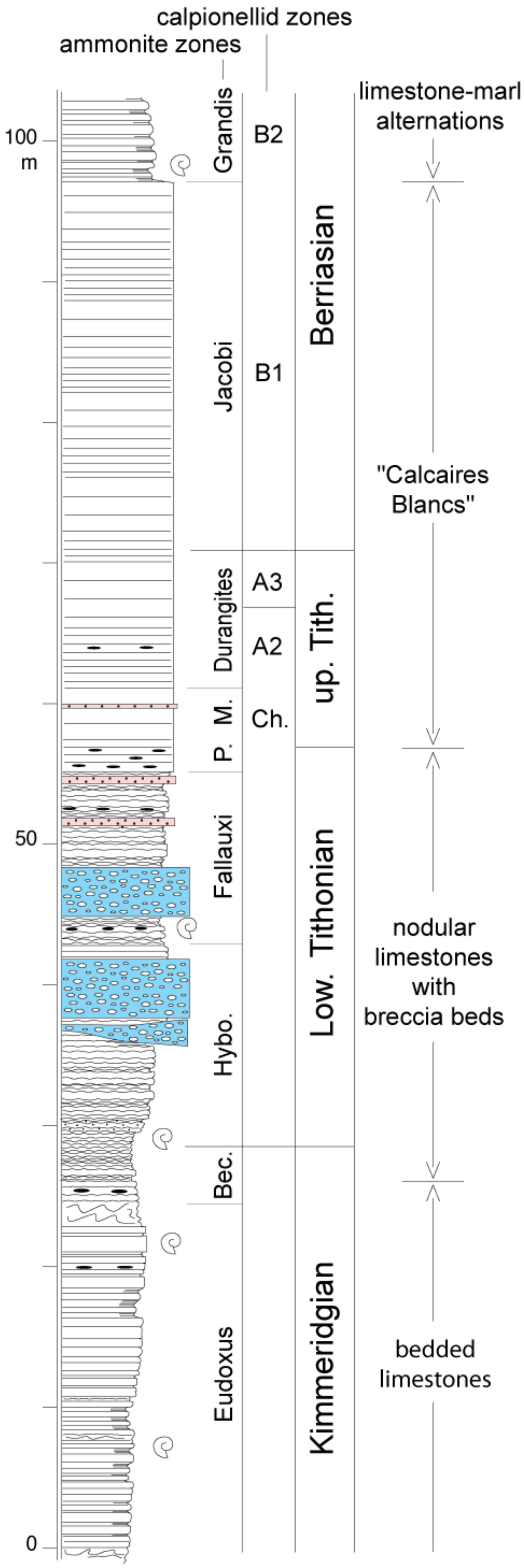
The Tithonian breccias have been interpreted in different ways since the end of the 19th century, but they are now acknowledged as coming from the gravity-reworking of mostly slope mudstones (REMANE, 1960, 1970; BEAUDOIN, 1977; JOSEPH *et al.*, 1988). Recent studies (COURJAULT *et al.*, 2011; FERRY & GROSHENY, 2013; FERRY *et al.*, 2015) have suggested that the breccias did not fill submarine canyons (absence of onlaps against the supposed walls, lateral deposits actually onlapping the main breccia bodies and not the contrary that would be expected in the canyon interpretation) as proposed earlier (REMANE, 1966; BEAUDOIN, 1977; JOSEPH *et al.*, 1988). They instead accumulated as lobes in slight positive relief on the sea bottom (Fig. 5). The style of gravity-reworked deposits changed in the « Neocomian » (late Berriasian to Hauterivian) to being almost exclusively of the slump type, bearing only contorted beds (Fig. 3). The quick progradation of Urgonian platformal carbonates in the Barremian-early Aptian allows identification of the boundary of the Vocontian Trough proper (VT), as early defined by PAQUIER. During this time interval, a second burst of gravity reworkings occurred (Fig. 3), with calcarenite turbidite lobes developping in the basin (Fig. 6), together with thick debris flow beds or mass-transport deposits (MTDs) able to carry large undeformed blocks, hundred metres long and several tens of metres thick of slope carbonates over more than tens of kilometres (FERRY & FLANDRIN, 1979). After the demise of Urgonian carbonate platforms in the late early Aptian (late Bedoulian), of ill-understood causes (? climate change, transgression, both), the basinal sedimentation changed to monotonous marlstones (Blue Marls Fm.) hosting sandstone packages, early known as « grès sus-aptiens ». These sandstones can be massive and structureless but their association with classical graded turbidite beds led to their interpretation as some kind of mass flow deposits. They are best developped west of the N-S Saillans-Condorcet fault (Fig. 1), in Pays de Bourdeaux. In the centre of the Vocontian Trough (Arnayon, La Charce, Rosans), they are almost absent in Albian deposits, only developped in Aptian ones. Present knowledge of Aptian sandstones have been summarized in a paper by FRIES & PARIZE (2003). For Albian sandstones, see RUBINO (in FERRY & RUBINO, 1989). Stratigraphic information on the Blue Marls Fm. at the basin scale, as well as on black shales can be found in BRÉHÉRET (1995). The problem of the Albian (changing paleogeography, relationship with the PAQUIER black shale) will be discussed further in this document.

Ongoing research (FERRY and coll.) brings a great deal of evidence that the progressive closure of the Vocontian Trough began around the Aptian-Albian boundary, that is during a tectonic phase known elsewhere as the « Austrian phase ». The closure continued in a stepped way up to the Santonian when the trough proper was completely filled with « deltaic sandstones » (PORTHAULT, 1974). The « pelagic » sedimentation then moved to the east (Digne-Castellane basin) (Fig. 2).

From Cenomanian times on, the depositional depth in the Vocontian Trough diminished (scarcity of gravity reworkings, shallower basinal limestone facies), probably as a consequence of the ongoing tectonic closure. However, the thickness of deposits (about 2,000 m of Cenomanian to Turonian limestones in the Meouge and the Pommerol synclines in the basin centre, according to PORTHAULT, 1974) clearly indicates uninterrupted strong subsidence. Evidences of ramp folds have been found (research in progress) in Turonian deposits in the western VT as a consequence of sinistral strike-slip movement of N40 oriented faults. Around the Turonian-Coniacian boundary in the central VT, local angular disconformities reaching 60° have been found. These results confirm the earlier feelings of FLANDRIN (1966) on late Cretaceous S-N compressive tectonics in the VT, prior to the Eocene « Pyrenean phase ».

More information about Vocontian Mesozoic carbonate gravity reworkings, including bibliographic references, can be found in FERRY & GROSHENY (2013).

The monotonous limestone-marl alternation that characterises the VT succession from the Liassic to the Turonian is therefore more or less impacted by the gravity-reworked deposits. An example is given for Barremian-lower Aptien deposits (Fig. 7). In intervals devoid of slump deposits, early



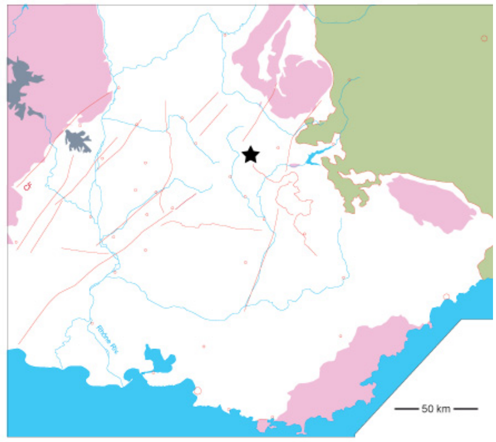


Fig. 9. The Veynes section (from COURJAULT *et al.*, 2011, after ATROPS in BACKERT, 2004). Blue, breccia beds; pink, calcarenite beds. P, M, Ponti and Microcanthum ammonite zones. The Calcaires Blancs is a limestone-dominated Formation defined on the western border of the Subalpine Basin (Ardèche area) but which can be traced in some basinal areas when gravity reworkings are scarcer. The Tithonian-Berriasian boundary as defined by the boundary between the A and B calpionellids zones is within it. The change to a marl-limestone alternation is around the base of the Grandis ammonite Zone.

studies (COTILLON *et al.*, 1980) have shown that individual beds can be traced all over the deep-water area without changes in thickness (Fig. 8). This was later used to map in a very precise way the areal changes in clay mineral assemblages (FERRY *et al.*, 1983; LEVERT & FERRY, 1988) and to propose interpretations deciphering areal depositional changes *vs.* diagenetic changes. In slope deposits, FERRY & MONIER (1987) showed that the individual basinal beds can expand into bundles of hemipelagic beds up to 15 to, 20 times thicker, but the rule is not strict. In a general way, high-resolution correlations become difficult or impossible when approaching slope successions, although the main limestone packages in third-order depositional sequences can be traced from basinal successions to platform carbonates proper.

The climatic significance of the bed-scale basinal limestone-marl alternation was first suggested by COTILLON *et al.* (1980). Changes in mineralogical and faunal changes (ratio of pelagic organisms) between limestone beds and marlstone interbeds (DARMEDRU *et al.*, 1982) indicated environmental changes possibly under astronomical control due to frequencies close to those of the terrestrial orbit (RIO *et al.*, 1989), following the MILANLOVITCH theory of climate changes in the Quaternary. Later, the development of FOURRIER transform analysis on such limestone-marl successions led to the emergence of a way to calibrate geological time (BOULILA *et al.*, 2008, 2010; CHARBONNIER *et al.*, 2013; MARTINEZ *et al.*, 2013). In this respect, the VT is a good candidate, given that most of its Jurassic to Lower Cretaceous stratigraphic column presents this primary alternating pattern. In the Terres Noires and Blue Marls formations, subtle changes in gray shades are the subdued expression of that alternating pattern.

The following developments will mainly focus on:

1) a description of the gravity-reworked carbonates (calcarenites and breccias) around the Jurassic-Cretaceous boundary, and in the Barremian to Albian deposits in the central Vocontian Trough;

2) a brief discussion on the local expression of the « Austrian » tectonic phase around the Aptian-Albian boundary;

3) the local context of the Cretaceous so-called Ocean Anoxic Events (OAEs), with their black shales also present in the VT, in the light of recent research.

Uppermost Jurassic to Berriasian breccias in the Central Vocontian Trough and the regional problem of the Tithonian-Berriasian boundary

The huge development of breccias in the Tithonian, and the last widespread massive reworked intervals (Mass Transport Deposits, or MTDs) in the early Berriasian leaves no candidate section for accurately defining the Tithonian-Berriasian boundary in the Vocontian Trough proper. A possible section could be the Veynes section (Fig. 9) located in the eastern part of the basin where breccia beds are few, and restricted to the lower Tithonian. Comments on the depositional system and facies, especially in the Remuzat-Arnayon-Chalancon-La Charce area, as seen during the field trip, now follow.

The stratigraphic position of the breccia beds in the Drome river lobe (lobe A, Fig. 5) is given on Figure 10. Such a scheme is also roughly found in the other systems, according to COURJAULT (2011). Breccias are mostly occuring in the lower Tithonian, but late events may rework lower Tithonian breccias up into the lower Berriasian. This is the case in the upper mega-slump (Fig. 10) which is sealed by lower Berriasian mudstones (age of its emplacement) but carry lower Tithonian ammonites. There are other evidences of multiple reworkings like clasts of microbreccia matrix floating in mud-supported breccias. The reason why breccias were most commonly emplaced during the early Tithonian probably comes from the original pattern of the slope to basinal mudstones deposited at that time. In basinal areas insulated from the reworkings, unlike the pattern of the common bed-scale limesto-ne-marl alternation, uppermost Kimmeridgian to lower Tithonian deposits bear a nodular or very finely bedded pattern whose disrupted slabs are often found in the breccias. So, the disruption of the bottom sediments in the initial slumps, progressively transformed into breccia during the downslope travel, was probably made easier, due to the original nodular pattern of the deposits. The material carried in the breccia beds are mostly lime mudstones (slope to basinal). When the travel distance increased, the clast size diminished to the calcarenite size. This is the case of the Aygues river calcarenite lobe (lobe B, Fig. 5) in which calcarenite beds contain very few platformal debris but do contain pellet-size lime mudstone clasts. It probably originated farther south and travelled along a canyon oriented close to the path of the present-day Nîmes fault (Fig. 1). Lobes C and D (Fig. 5), bearing classical breccias and slumps, probably originated on a deep-water talus located along the Ventoux-Lure chain, with a shorter travelling range.

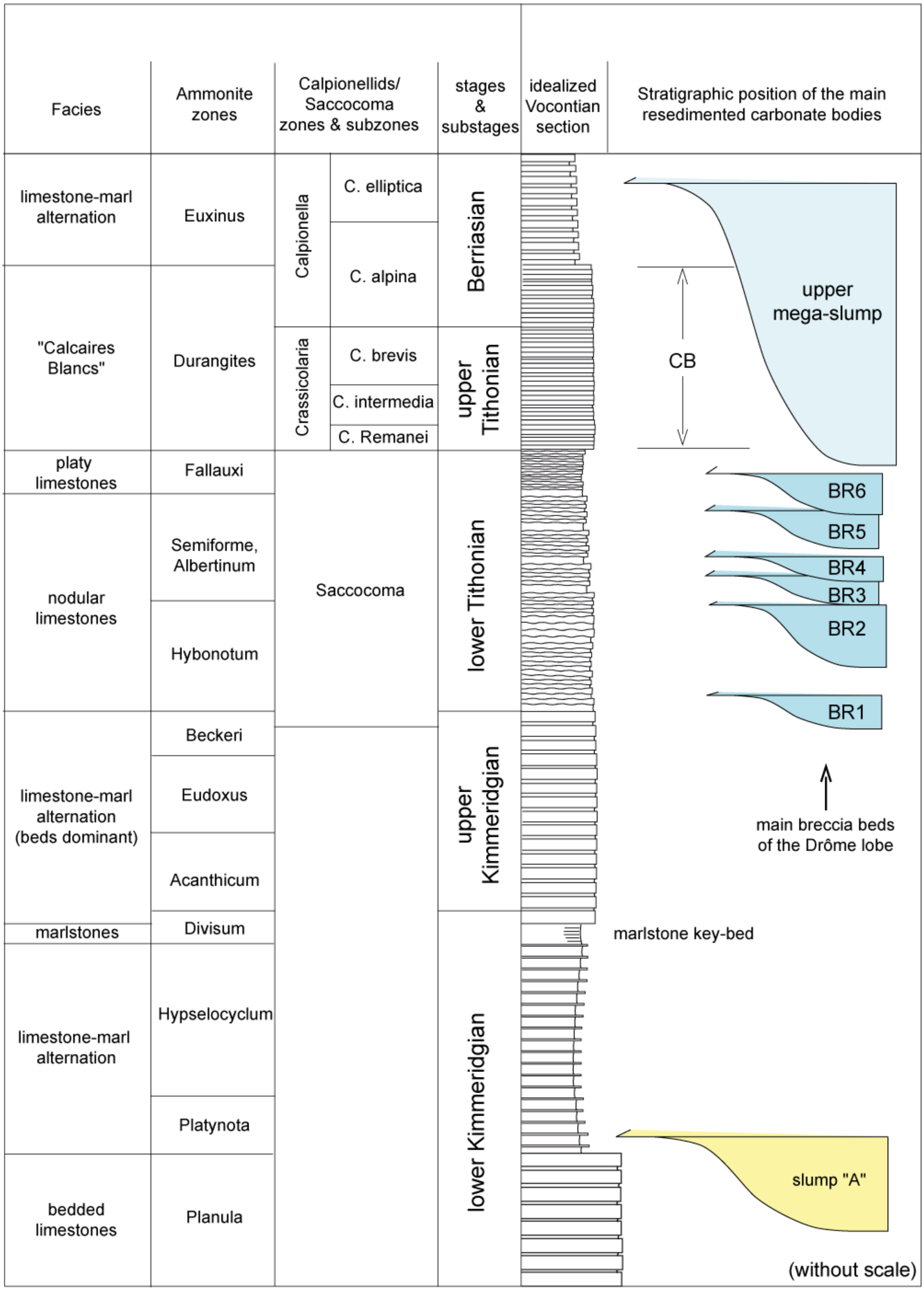
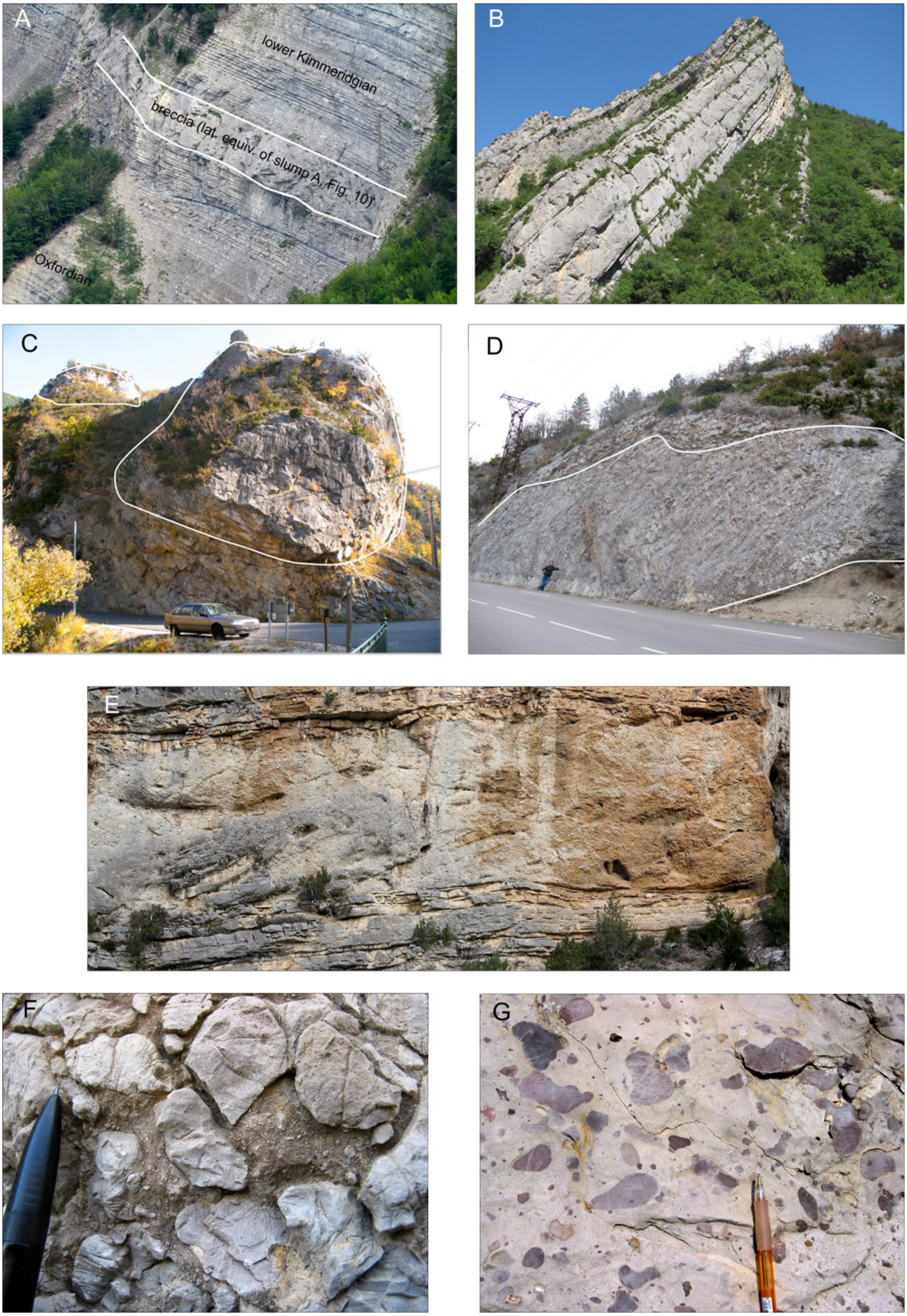


Fig. 10. Stratigraphic position of the main gravity-reworked deposits in the Drôme Lobe (after COURJAULT *et al.*, 2011, modified). Note that the Planula Zone is the last zone of the Oxfordian *sensu gallico;* CB, "Calcaires Blancs" Fm.

▶ **Fig. 11.** Facies of Tithonian deposits in the subalpine basin. A) View of the typical limestone-marl bed-scale alternation around the Oxfordian-Kimmeridgian boundary; B) Typical aspect of the « Tithonique cliff » *auct.* in the southern subalpine chains, in which thick beds are breccia beds; C and D) large blocks of undeformed mudstone carried in the « upper mega-slump » of COURJAULT *et al.* (2011) (Fig. 5); E) view of the mid-cliff key (.../...)



(.../...) bed (a breccia carrying large clasts of fine-grained slope limestone and marls) in the calcarenite lobe of the Aygues river; F and G) close-view of clast- and mud-supported breccias (the matrix in F is a fine-grained micro-breccia coming from ultimate fragmentation of the same material of larger clasts; in G, the matrix is a mixture of microclasts and slope to basinal mudstone.

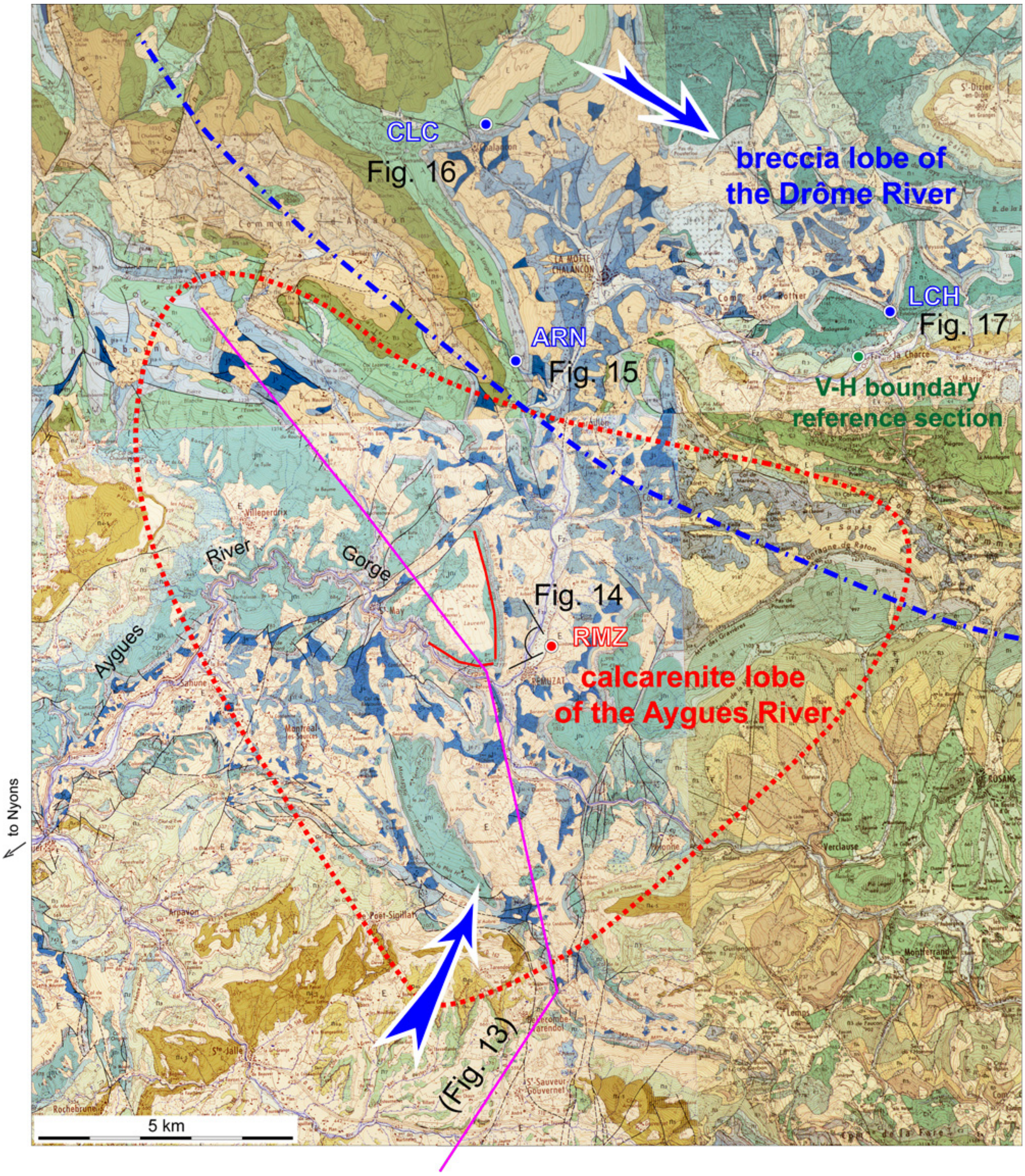


Fig. 12. The Arnayon-La Charce area at the confluence between the breccia and calcarenite lobes of the Aygues and Drôme rivers. ARN, Arnayon; CLC, Chalancon; LCH, La Charce; MRZ, Rémuzat.

Figure 11 displays some typical facies. Calcarenite beds are mostly graded and often show BOUMA-type sequences, classical in turbidite deposits. Breccia beds are commonly massive and ungraded but their top may bear a graded top-turbidite bed going up from microbreccia to mudstone, either progressiveley or with a grain size break between the calcarenite and the mudstone material. The internal geometry of the head of the breccia beds may show progradational features, like in the tiny Céüse lobe (lobe E, Fig. 5) (FERRY *et al.*, 2015). The finding of HCS-like features in some beds has been at the origin of a recent controversy (BOUCHETTE *et al.*, 2001; SEGURET *et al.*, 2001) about the mechanisms of emplacement of the breccias and therefore the actual depth of the basin (see discussion in FERRY *et al.*, 2015).

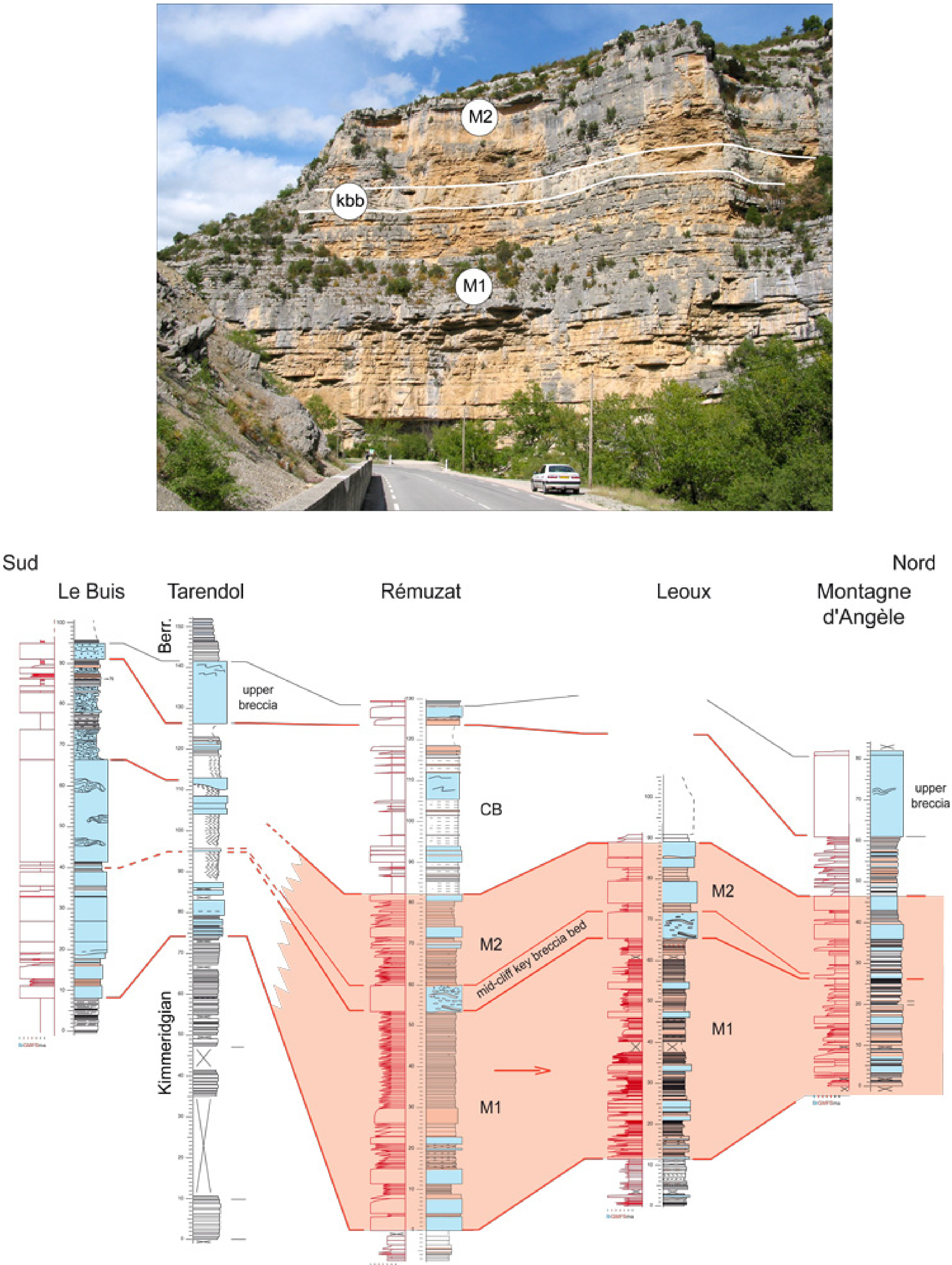
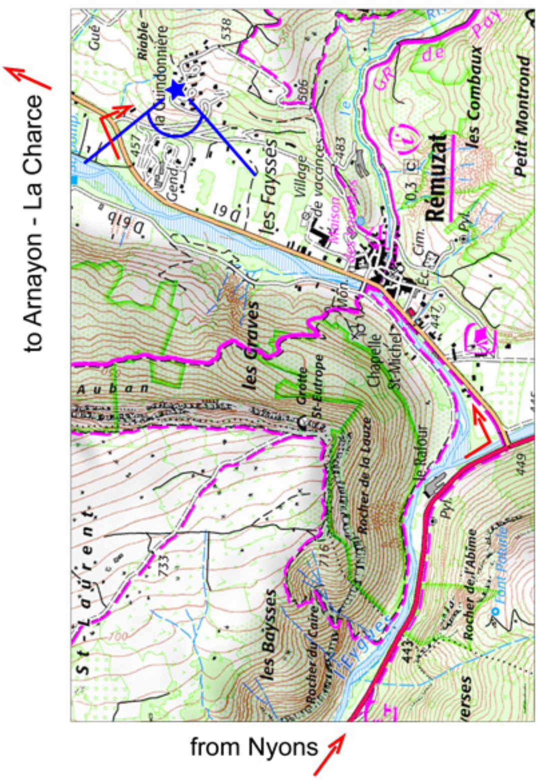


Fig. 13. The calcarenite lobe of the Aygues river. Above, view of the two calcarenite units M1 and M2, separated by the key breccia bed (kbb) in the Aygues river Gorge. Below, updip to downdip correlation across the lobe (location of sections in Fig. 12). Blue, breccia beds; pink, calcarenite beds; on left of lithologic columns are granulometric curves; CB, upper Tithonian to lowermost Berriasian « Calcaires Blancs » Fm.; red arrow, direction of transport.

The field trip will mostly be in the Arnayon-La Charce area, in an axial position of the Vocontian Trough. This area is at the junction between two gravity systems (Fig. 12), that of the Aygues river lobe coming from the south, finishing against the right flank of the Drome river lobe coming from the NW.

The lobe of the Aygues river is mostly calcarenitic on a grain size point of view (very few bioclasts, mostly pellet-size lime mudstone clasts). It is made of two units separated by a key breccia bed in the middle of the cliff in the Aygues river gorge (Fig 11D and 13). This key bed is found within the Drôme river lobe at Chalancon. It allows to make stratigraphic correspondences with the NW breccia system (Fig. 16). The lobe is made of laterally-continuous, graded calcarenite beds probably making a draping system, in very low relief on the sea bottom (Fig. 14).

Fig. 14. The Tithonian calcarenite lobe of the Aygues river near Remuzat. A, location of the view point; B, view of the Remuzat cliff about parallel to the direction of supplies (updip to the left); C, detail of the upper slump which is possibly a distant effect of the emplacement of the upper mega-slump of the Drôme lobe to the north. The lateral continuity of the beds is evidence of a draping system.



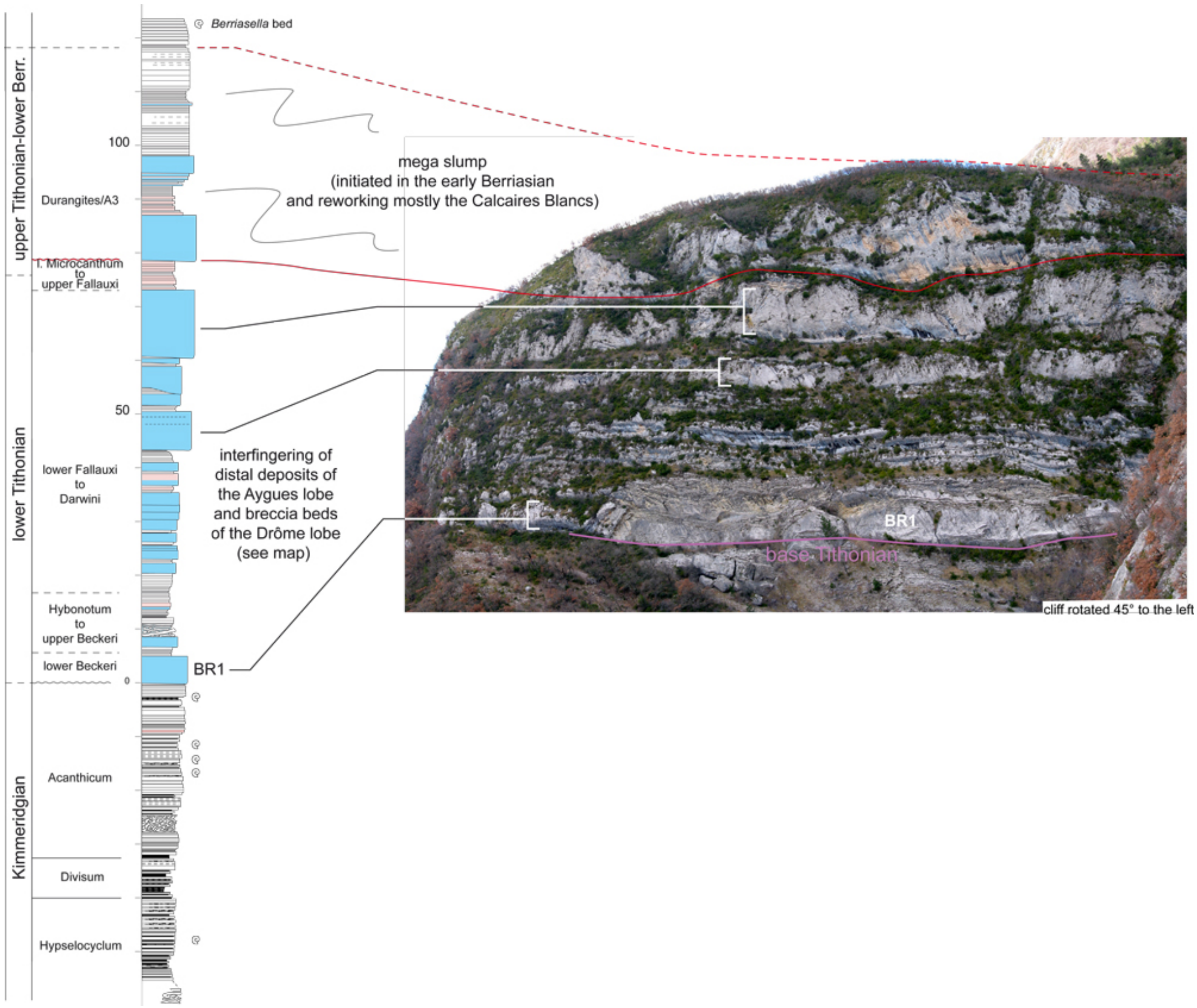


Fig. 15. Kimmeridgian to Tithonian succession of the Arnayon Gorge. (dated by ammonites, calpionellids, micro-facies, after F. ATROPS, unpubl.).

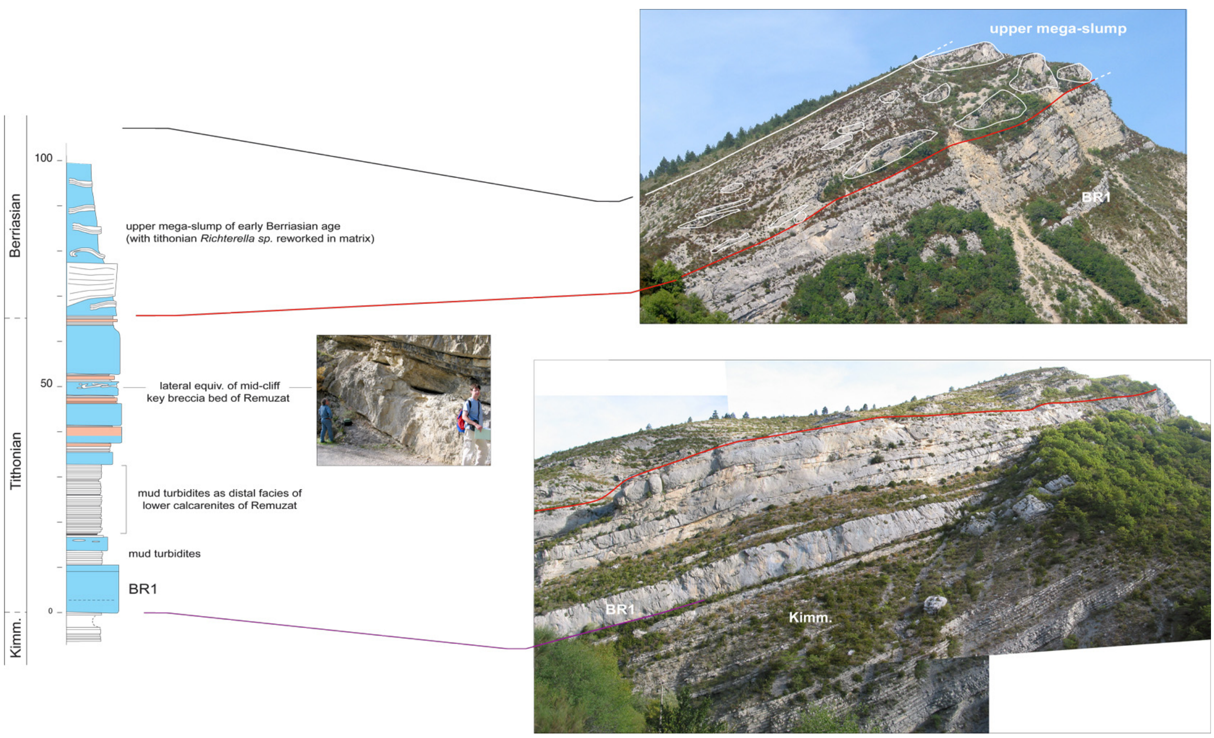


Fig. 16. The Chalancon section.

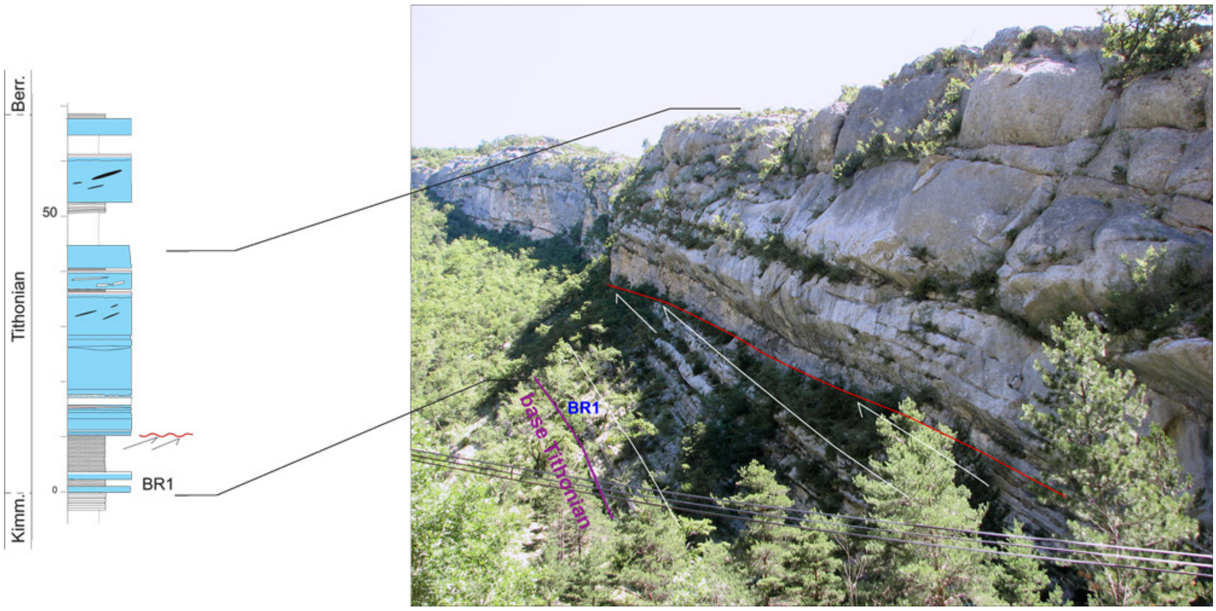


Fig. 17. Tithonian breccias in La Charce section.

The materials of the Drôme river lobe are mostly made of breccias, overlain by the upper mega-slump of COURJAULT (Fig. 5-2) which carryies large olistoliths (Fig. 11C). These deposits can be seen in the sections of Arnayon (Fig. 15), Chalancon (Fig. 16) and La Charce (Fig. 17). See locations of these sections on Figure 12.

Barremian-Aptian calcarenites and mass-transport deposits

The quick progradation of platformal urgonian carbonates in the early Barremian was accompanied by a second burst of gravity-reworked deposits in the Vocontian Trough proper. The resedimented material came from the three peripheral platforms (Fig. 6), the Vercors to the north, the Bas-Vivarais (« Ardèche ») to the west, and, a little later (latest Barremian), the north Provence on the southern margin of the Trough. The installment of shallow-water carbonates was early (earliest Barremian) on the Bas-Vivarais platform (COTILLON *et al.*, 1979; GRANIER *et al.*, 2013a). All lower Barremian resedimented calcarenites in the Vocontian Trough come from the Bas-Vivarais platform. The other sources operated in the late Barremian. Calcarenite turbidites disappeared just before the Barremian-Aptian boundary. The stratigraphic position of the main calcarenite bursts in the basin are on Figure 18. Debris-flow beds -- that are beds carrying debris of all sizes within a supporting matrix -- appeared in the lowermost Barremian (GHsBi) and finished at the base of the upper Aptian (CL4). In the Blue Marls Fm. it is more difficult to make the difference between debris flow beds and slump beds (see synthesis of FRIES & PARIZE, 2003). Slump beds (comprising only contorted beds, no. matrix) are frequent (not indicated on Figure 18, except for the largest like Gbis and GBsc). Debris flow beds covered large areas in the Vocontian Trough. They can be easily traced (Fig. 7). For instance, CL3 (Fig. 19) removed about 6 km^3 of deposits (FERRY & FLANDRIN, 1979), and GHsBi probably twice that volume (FERRY & RUBINO, 1988).

Autochtonous mudstones are of two main types, slope and basinal. Slope mudstones often have a macronodular pattern (they are called « faciès à miches or « loafy » limestones) (Fig. 19-B). When very thick (high subsidence rate) they are organized into bed bundles (Fig. 19-A). Basinal limestone-marl alternations (Fig., 19-C) are thinner, and individual beds are laterally-continuous over the whole basin (Fig. 8). Slope mudstones show large channels (Fig. 19-D) that are supposed to have been the conduits funnelling the calcareous periplatformal sands to the deep. On figure, 20 are some facies of Barremian calcarenite turbidites.

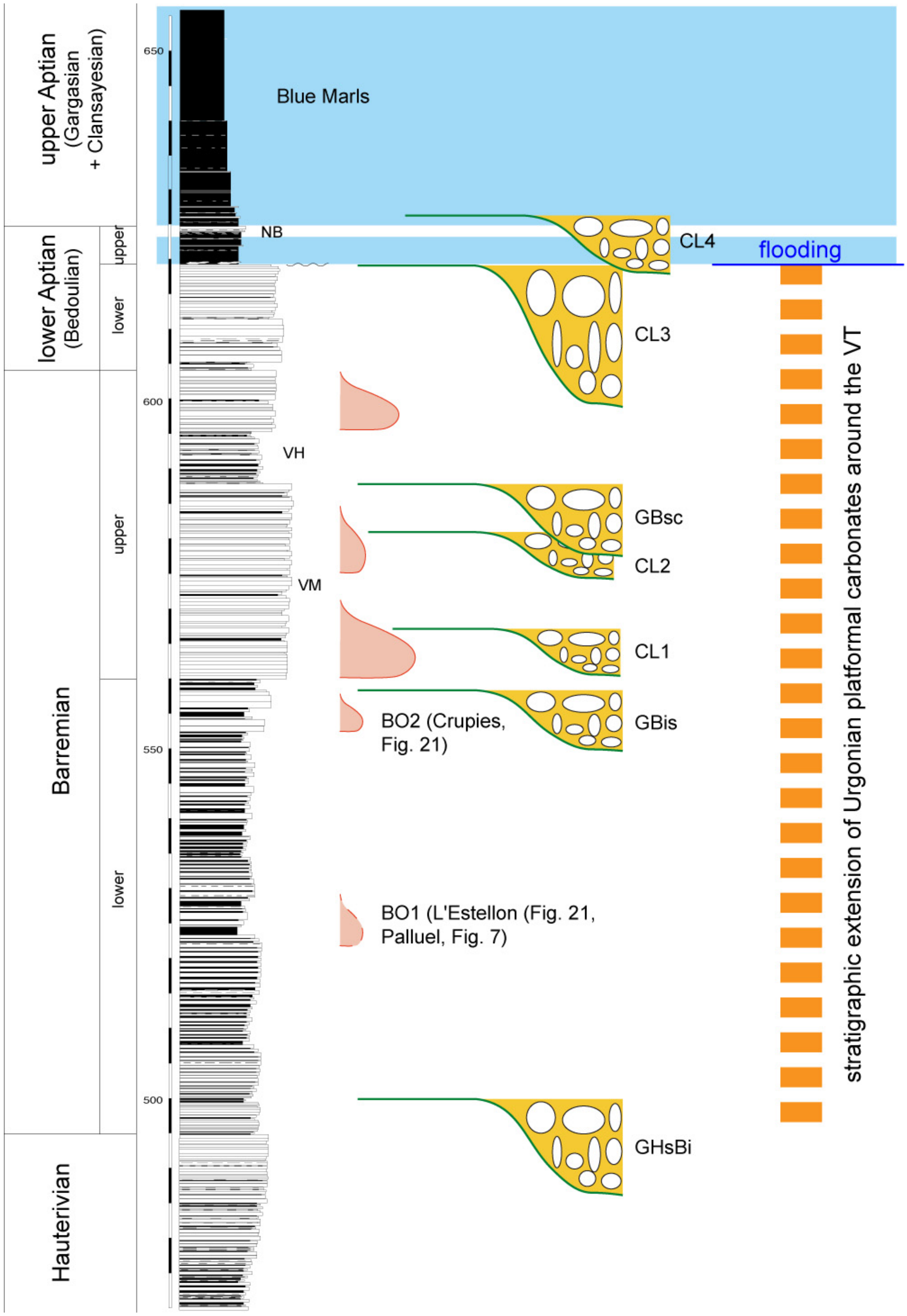
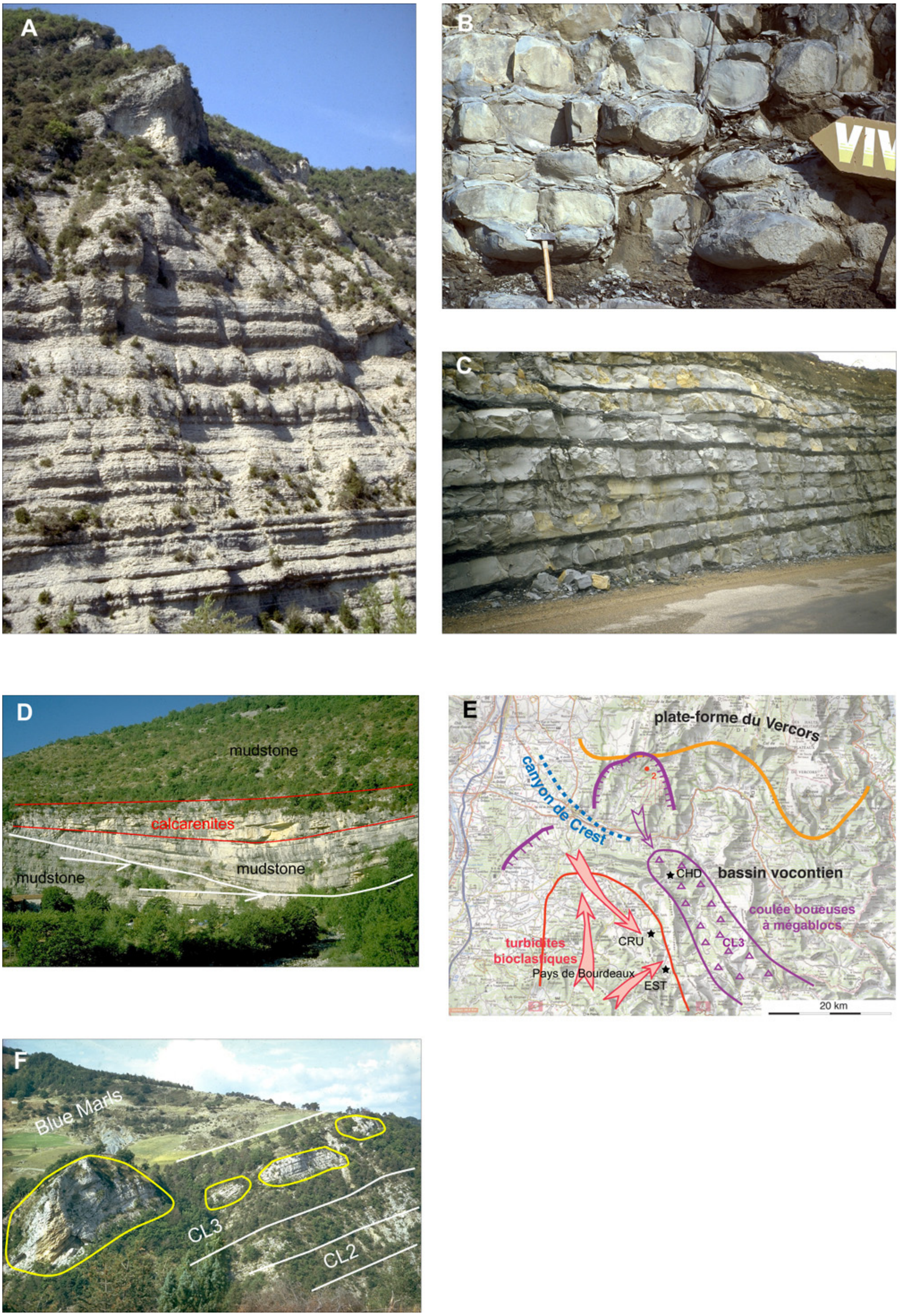


Fig. 18. Timing of deposition of the main Barremian to lower Aptian gravity reworkings in the Vocontian Trough against the limestone-marl succession of the Barremian hypostratotype of Angles. Based on ammonites and high-resolution lithologic correlations (see Fig. 8); blue background, flooding facies of Urgonian platforms correlated with a quick transgression in the Paris Basin; pink background, main calcarenite supplies (turbidites) in the Vocontian Trough; BO, lower Barremian « barres à orbitolines » *auct.* (orbitolina-bearing calcarenite beds), stratigraphic position approximate; GHsBi to CL4, main debris flow beds. VH and VM, marly recessive intervals traced basinwide within the upper Barremian limestones (Fig. 7).



Fig, 19. Barremian deposits of the Vocontian Trough. A, thick upper Barremian slope mudstones made of bundles of nodular limestones (B); C, deep-water limestone-marl alternation; D, slope channel funneling the calcarenite turbidites in the Pays de Bourdeaux (E) (NW Vocontian Trough); F, debris-flow beds CL2 and CL3 in La Chaudière (CHD) section; E, map showing the areal extension of calcarenites turbidites in the Pays de Bourdeaux, and the debris flow beds coming from the Crest submarine canyon; underlined in violet is the large slump scar which fed the CL3 debris flow bed of La Chaudière (FERRY & FLANDRIN, 1979); The sections of Crupies (CRU) and L'Estellon (EST) seen during the field trip are indicated.

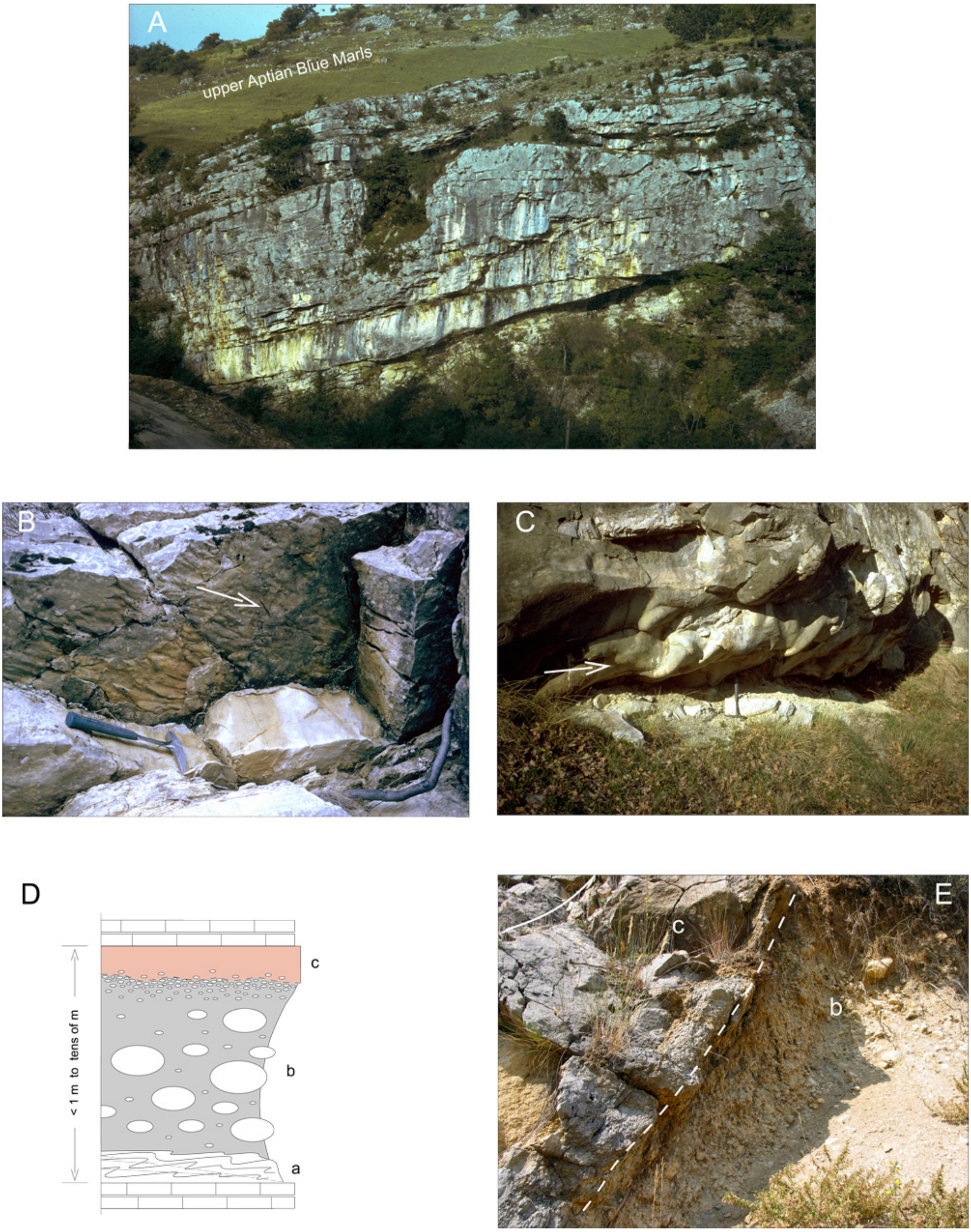


Fig. 20. Some facies of the Barremian calcarenite turbidites of the Vocontian Trough. A, typical appearance of a calcarenite turbidite package with internal erosional surfaces (current oblique from left background to right foreground; B and C, flute-casts of different sizes at base of graded (B) or coarse-tail graded (C) calcarenite beds; D, typical vertical organization of debris flow beds (a, highly deformed sole of basinal mudstones; b, main body, ungraded, floating clasts; d, associated top-turbidite bed with poorly-defined base (continuous deposition), E, example of D in the field.

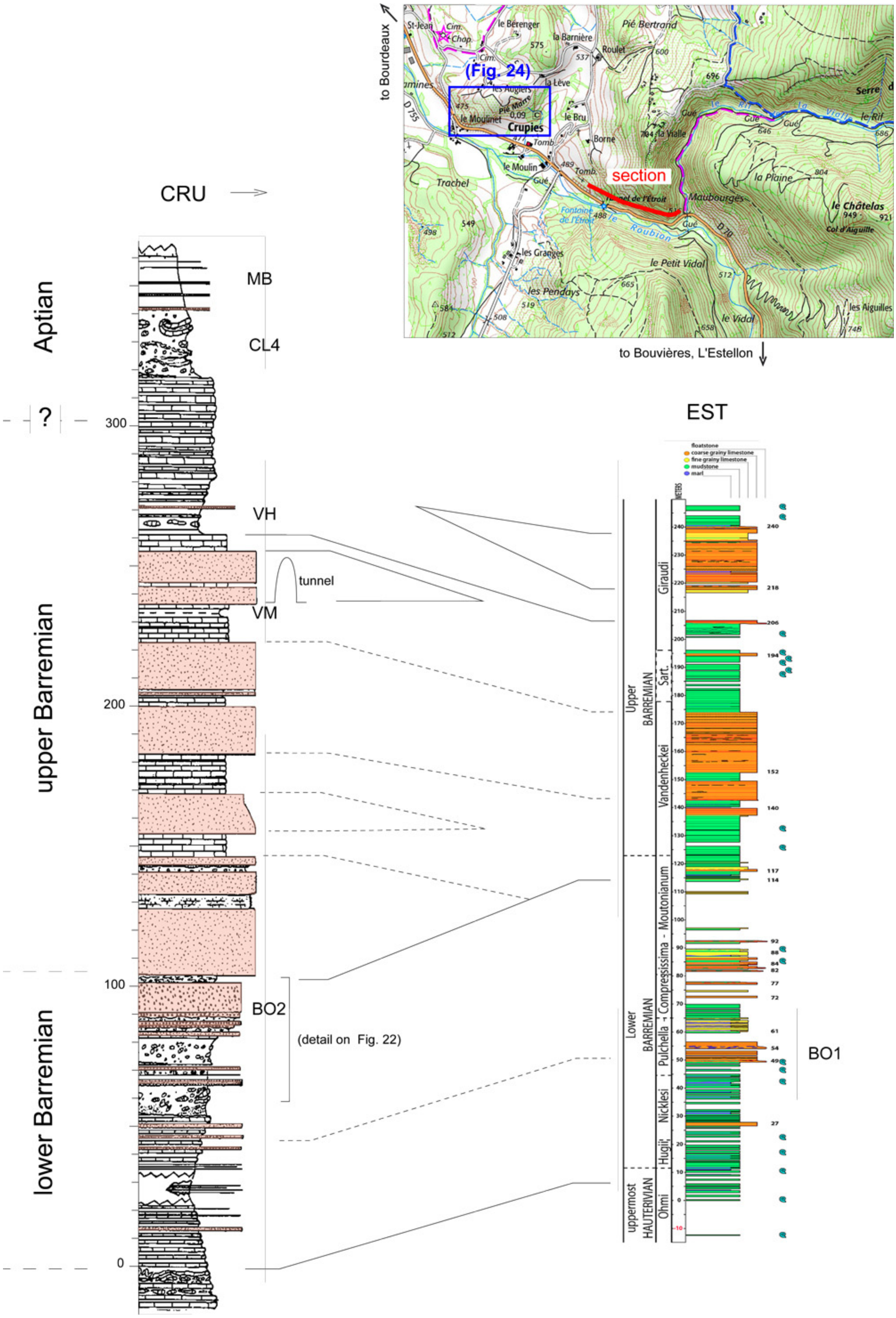


Fig. 21. The Crupies (CRU) and L'Estellon (EST) sections. Crupies section from FERRY (1976) (see also MOULLADE, 1966), pink, main calcarenite beds; L'Estellon section from GRANIER *et al.* (2013a); BO1 an BO2, see Fig. 18.

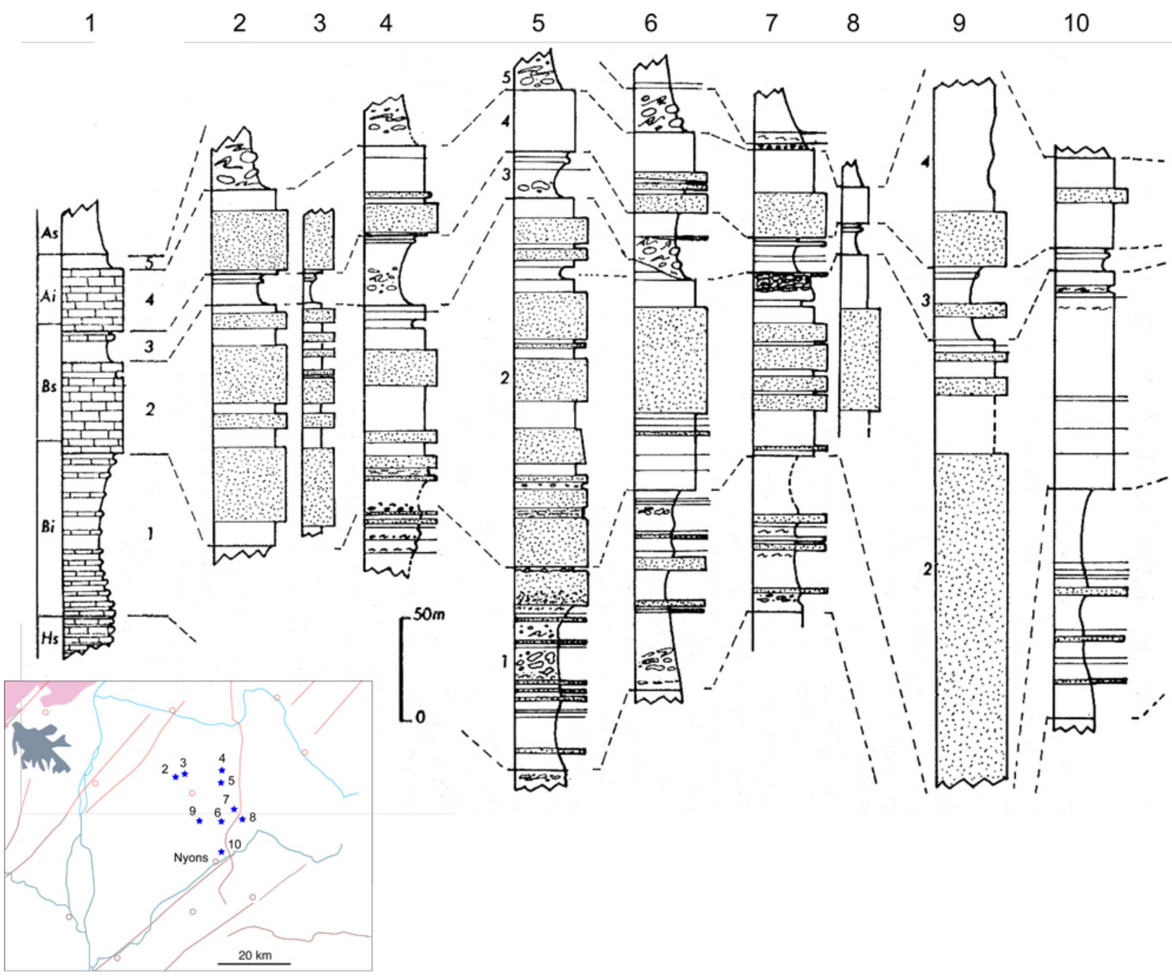


Fig. 22. Correlation of upper Barremian calcarenite turbidite packages (dotted) in the Pays de Bourdeaux (NW Vocontian Trough) and surrounding areas (FERRY, 1978). 1, Angles (simplified), see Fig 18; 2, Rochebaudin; 3, Felines; 4, Les Tonils, 5, Crupies; 6, Valouse; 7, L'Estellon; 8, Chaudebonne; 9, La Lance; 10, La Rochette (Nyons).

Two sections will be visited during the field trip, the Crupies (CRU) and L'Estellon (EST) sections (Fig. 21). They are close to the eastern end of the lobes of the Pays de Bourdeaux. The Crupies section (Fig. 20) shows thick packages of calcarenite turbidites because, as in other places of the Pays de Bourdeaux (Fig. 22), supplies coming from the northwest (-> N150) and the west (-> N80) merged (Figs. 6 & 19-E). The L'Estellon section was recently studied by GRANIER *et al.* (2013a) to test the *Orbitolina* zonation used in the Vercors *vs.* the basinal sections better dated through ammonites (*cf.* the CLAVEL and coll. *vs.* ARNAUD and coll. decades-long controversy about the Urgonian stratigraphy and paleogeography). The Crupies section shows interesting turbidite sequences within the « Barre à Orbitolines » (Fig. 23). Diverse forms of grading in the overlying calcarenite packages can be observed along the road.

Time permitting, the first sandstone turbidite package in the lower part of the Blue Marls Fm. can be seen a bit farther towards the Bourdeaux village (Fig. 24). It is an amalgamation of turbidite channels affected by large scale loadcasting.

Paleogeographic changes in the midle Rhône Valley and the western Vocontian Trough in the Aptian-Turonian interval

The exploration work of the French Agency for Nuclear Waste (ANDRA) in the middle Rhône valley (Gard Rhodanien) in the nineties allowed better understanding of the stratigraphy of the western margin of the Vocontian Trough (FERRY, 1999), now hidden by Cenozoic Molasse deposits. It particularly showed that the middle Rhône valley, as part of the Alpine margin, did not subside steadily but recorded episodic uplifts. A stong one occurred in the latest Aptian, and spanned locally the whole Albian. This event is time equivalent to the uplift of the Durancian Isthmus on the north Provence platform (MASSE & PHILIP, 1976).

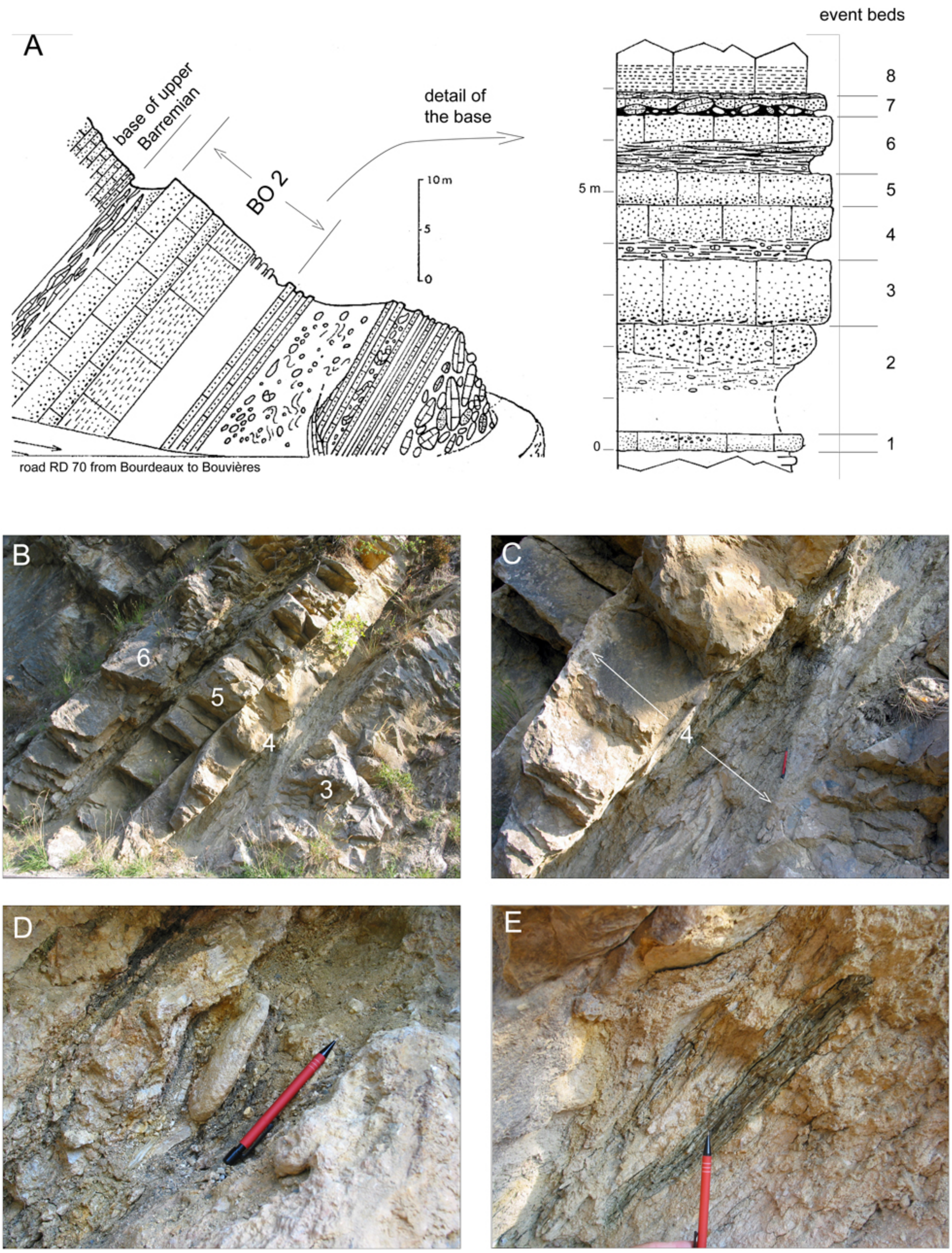


Fig. 23. The BO2 unit (or « barre à orbitolines » of MOULLADE, 1966) in the Crupies section. A, Detail of the unit showing event beds, some of them belonging to the debris flow bed case illustrated on Fig. 20-D-E; B, detail of the base with event beds numbered (see A) (from WALTER *et al.*, 1975); C, debris-flow bed here reduced in thickness but with its associated calcarenite turbidite cap), note the poorly-defined transition from the mixture at base and the calcarenite at top; D and E, enlargement of the base of units 4 and 6 showing either calcarenite or marlstone clasts in the unsorted matrix.

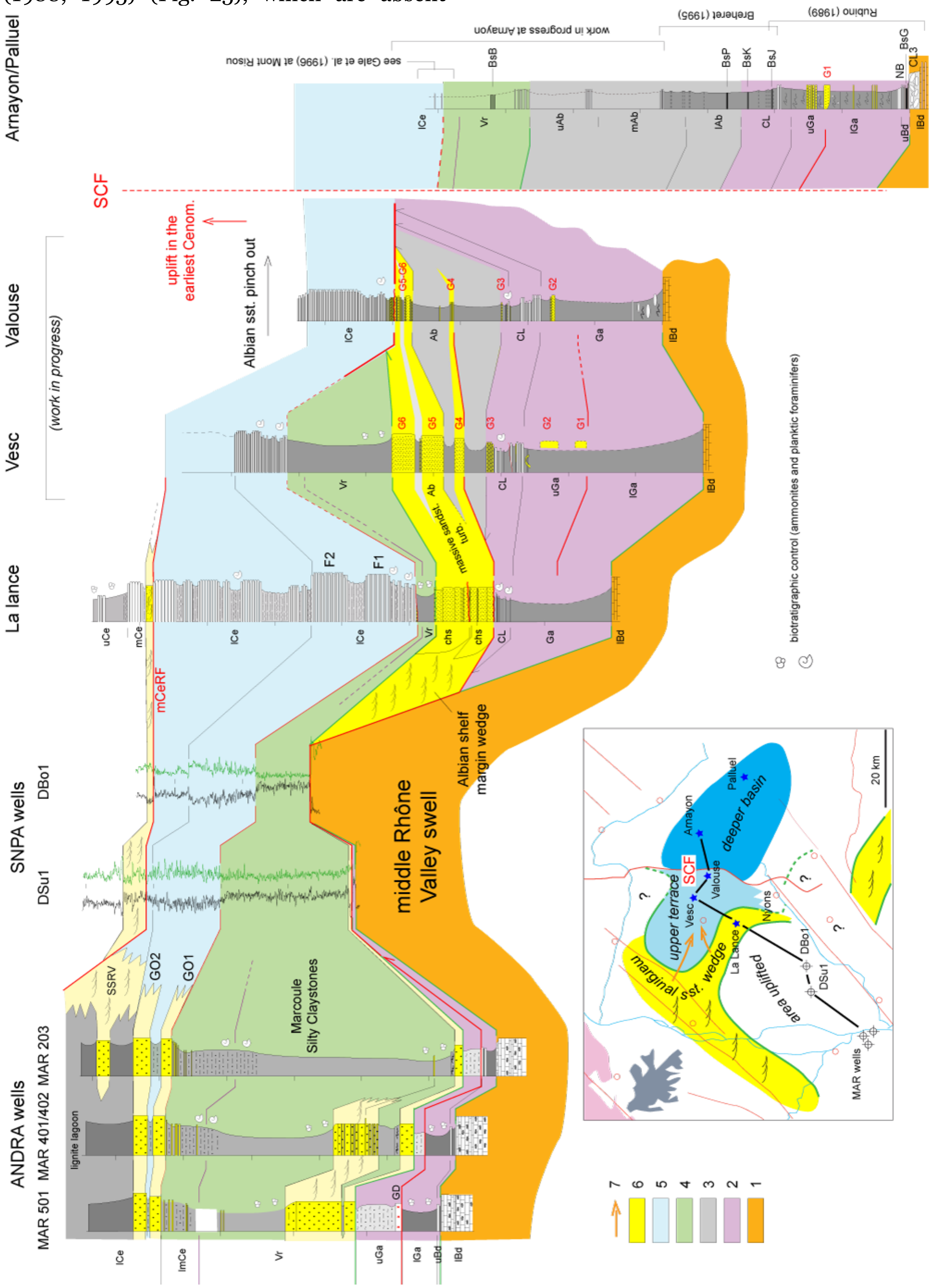
New stratigraphic data acquired in the western Vocontian Trough are combined with earlier results fron the ANDRA works. They allow drawing of a transect from the Rhodanian area to the Vocontian Trough (Fig. 25), and integration of the ancient oil exploration wells of the SNPA.

Fig. 24. The lower sandstone turbidite body (mid-Gargasian) in the upper Aptian-Albian Blue Marls Fm. in the Crupies section. It consists of a package of channelled sandstones more or less disturbed by large load-casting. White arrow indicates the direction of transport. This turbidite unit is called G1 sandstones by RUBINO (in FERRY & RUBINO, 1989), or T1 sandstones by FRIES & PARIZE (2003). Correlation with deposits of the western margin (FERRY, 1999) show that this event correspond to a strong relative sea-level fall.

Above the Barremian to lower Aptian limestones, the upper Aptian to Albian Blue Marl Fm. thins to the west. In addition, Gargasian deposits clearly show two depositional sequences in the MAR wells. The lower Gargasian marls are dark marls, similar to those of the Vocontian Trough but a little more sandy. The thin upper Bedoulian sequence of Angles (Fig. 18) is present (uBd, Fig. 25) but without the GOGUEL black shale. An erosional unconformity bounds at base the second Gargasian sequence (uGa, Fig. 25) the facies of which is a shallower bioturbated clayey sandstone. The basal unconformity is overlain with an echinoid-bearing bioclastic sandstone (Grès à *Discoidea*, CONTE, 1985). Small incised valleys have been found in the Gard Departement. This sequence boundary correlates in the Vocontian Trough with the base of the G1 turbidite sandstone (RUBINO, 1989), or T1 of FRIES & PARIZE (2003).

The Albian represents a stratigraphic interval which is hard to understand. Contrary to earlier deposits that show a regular thinning toward the western margin, Albian sandstones are lacking in the Middle Rhône valley (Fig. 25). This has been interpreted (FERRY, 1999) as a result of an uplift coeval with the one known as Durancian Isthmus (MASSE & PHILIP, 1976) on the north Provence platform. In the Gard Rhodanian area, upper Albian megarippled sandstones are known west of the uplifted area. They rest on Gargasian deposits through a transgressive lag bearing lower to middle Albian ammonites. They are overlain by the uppermost Albian (Vraconnian) transgressive sandy marlstones (BREISTROFFER, 1940). Albian megarippled sandstones are shifted seaward north of the middle Rhône valley swell to make a marginal wedge (Fig. 25, lower box) that stretches to the north following the path of N40 oriented faults. The exact age of the Albian sandstones of La lance (Fig. 25) is not known. There is a curious relationship found by RUBINO (1989) between the megarippled sandstones and the massive sandstones interpreted as turbidites in the Vocontian Trough (G4 to G6 turbidite packages at Vesc, Valouse, Fig. 25). Massive channelled sandstones, interpreted as turbidites, pinch out within the megarippled sandstones along La lance anticline. Based on its turbidite interpretation, RUBINO interpreted the megarippled sandstones as outer shelf sands deposited by a large contour current. But the discovery of strong stratigraphic hiatuses in the western part of the Vocontian Trough where the turbidite packages are developped raises a lot of questions. In a number of sections, Vraconnian marls rest directly on Clansayesian or (?) lower Albian marls. The turbidite sandstones G4 to G6 seems to be channelled in a narrow corridor north of the Dieulefit syncline. In addition, they quickly thin to the east when approaching the Saillans-Condorcet fault (SCF, Fig. 25). The paleogeographic picture that is emerging under the light of new field work is that of a shallow marine terrrace that was the conduit for the Albian « turbidites » north of the La Lance anticline. It is even possible that the margins of this terrace underwent prolonged exposures to explain the stratigraphic hiatuses found. A strong paleogeographic change therefore occurred, beginning around the Aptian-Albian boundary, after the deposition of the thick (250-300m) Aptian marls. The peak of the overall shallowing trend is not dated. It could be middle

Albian in age. The Albian must therefore be considered as overall regressive on the middle Rhône valley and the westen Vocontian Trough. East of the Saillans-Condorcet fault, Albian marls are thick. They bear the black shale levels named by BRÉHÉRET (1988, 1995) (Fig. 25), which are absent west of the fault. The fault had clearly a synsedimentary role in limiting the deep Albian basin to the east (Fig. 25, lower box). It should be remembered that this fault involves the basement (FLANDRIN & WEBER, 1966) based on gravimetric data. It is hypo-



thesized that the local tectonic disturbances during the Albian represent a first pulse in the transpressional trend that ended in the complete infilling of the Vocontian Trough in Santonian times.

In the latest Albian (Vraconnian), a major transgression occurred over the whole S-E France basin. It was accompanied in the Gard Rhodanian by a spectacular reversal of the subsidence rate, with the thick Marcoule Silty Claystones deposited on the previous middle Rhône valley swell (Fig. 25). Its full submergence occurred in the late Vraconnian or locally the early Cenomanian.

Another event occurred in the earliest Cenomanian. The *Orbitolina* sandstones (GO1 and GO2, Fig. 25) represent two short-lived progradational phases of swell-dominated glauconitic sandstones, each finishing with a beach facies (FERRY, 1999). They pass seaward to a double package of bedded sandy limestones (F1 and F2, Fig. 25). These reach a maximun thickness in the La Lance anticline where they are channelled. In the axial position of the channel, a sandstone bed, up to 10 m thick is found. This double bed package progressively thins basinward without any evidence of erosion at the base. However, in the Valouse area, close to the Saillans-Condorcet fault, the lower Cenomanian basinal limestones rest unconformably on the thinned distal G5-G6 Albian turbidite sandstones (Fig. 25). Again, this is interpreted as a new movement of the Saillans-Condorcet fault. The lowermost Cenomanian GO1-GO2 interval is therefore coincidental with a flexuration of the La Lance anticline and an uplift of the eastern boundary of the upper terrace defined in the Albian. This is interesting from a sequence stratigraphic point of view. In the Gard area (MAR wells) the Vraconnian to lowermost Cenomanian deposits are arranged in a shallowing-up trend, without any evidence of a sequence boundary close to the Albian-Cenomanian boundary. In the La Lance section, the erosive base of the F1-F2 limestone packages could be called a sequence boundary. Basinward, again, there are no evidence of any facies break. But at Valouse, there is clearly a sequence boundary at base of the Cenomanian deposits. This example is particularly demonstrative of how tectonics may alter a possible eustatic sea-level signal, if such exists.

◀ **Fig. 25.** Stratigraphic transect across the western margin of the Vocontian Trough (Aptian to middle Cenomanian). **Stages** (in ascending order): lBd, lower Bedoulian; uBd, upper Bedoulian (cycle comprising the black shale GOGUEL); lGa, lower Gargasian; uGa, upper Gargasian; CL, Clansayesian (uppermost Aptian); Ab, Albian (Vraconnian excluded); Vr, Vraconnian (uppermost Albian); lmCe, lowermost Cenomanian; lCe, lower Cenomanian; mCe, middle Cenomanian; uCe, upper Cenomanian. **Background colours:** 1, Barremian to lower Aptian slope to basin limestones; 2, uppermost lower Aptian to Clansayesian deposits; 3, Albian (Vraconnian excluded); 4, Vraconnian major transgressive cycle; 5, Cenomanian slope to basin limestones and marlstones; 6, sandstones undifferenciated; 7, direction of transport (Albian turbidites). **Sedimentary units:** chs, channelled sandstone; GD, « Grès à *Discoidea* » (*Discoidea* sandstone) (CONTE, 1985); GO1 and GO2, « Grès à orbitolines » (*Orbitolina*-bearing sst.); F1 and F2, bundles of sandy slope limestone corresponding to, respectively, GO1 and GO2; G1 to G6, packages of sandstone turbidites defined by RUBINO (in FERRY & RUBINO, 1988, 1989); SSRV, Cenomanian sandstone spit of the middle Rhône Valley, on the margin of a backbarrier lignite lagoon. **Black shales:** BsG, GOGUEL; BsJ, JACOB; BsK, KILIAN; BsP, PAQUIER; BsB, BREISTROFFER. mCeRF, mid-Cenomanian forced regression; SCF, Saillans-Condorcet fault (FLANDRIN & WEBER, 1966). Albian-Cenomanian boundary in the MAR wells according to AMÉDRO & ROBASZINSKY (2000).

Another event is known in the mid-Cenomanian. From the sandstone spit that fringed the lignite lagoon during the lower Cenomanian, a strong seawardshift of mega-rippled coastal sandstones is recorded in La Lance anticline (Fig. 25).

The Cenomanian-Turonian boundary is also marked by a strong uplift of the western margin of the Vocontian Trough that is responsible for a forced regression that shifted the coastal sandstones seaward about 80 km to the east (MALARTRE & FERRY, 1993; GROSHENY *et al.*, 2017) (see also Fig. 2C).

This summary of the behaviour of the western margin of the Vocontian Trough (the Rhodanian Saddle of PORTHAULT, 1974) during the Cretaceous clearly shows that it was a tectonically unstable margin, subjected to short-lived uplifts or accelerated subsidences which clearly begin in the Albian.

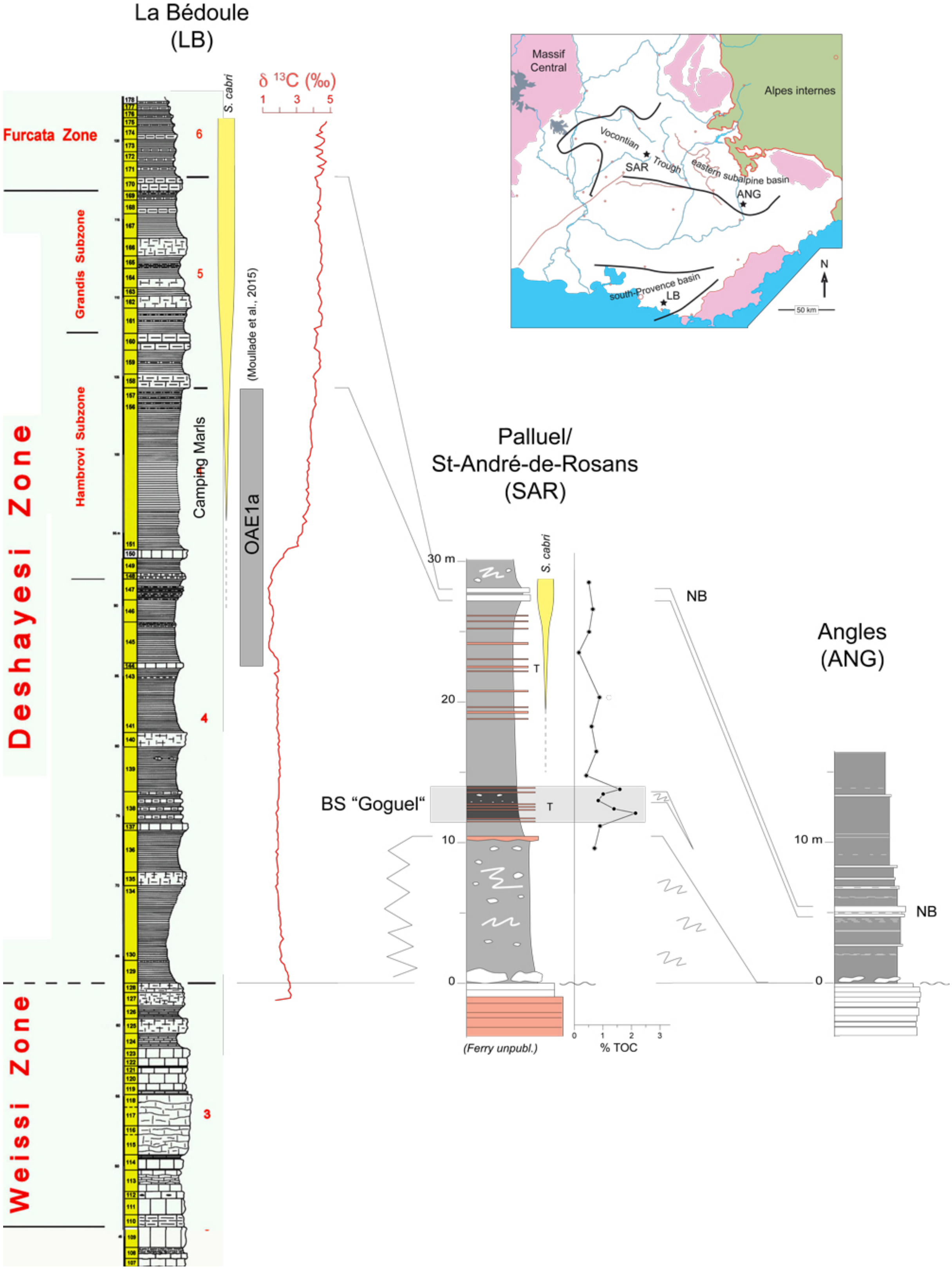


Fig. 26. The upper Bedoulian sequence in basinal areas of S-E France. ANG, cf Fig. 18; SAR (Ferry, unpubl. data); LB, from Moullade *et al.* (1998), Ropolo *et al.* (2006), Lorenzen *et al.* (2013), Moullade *et al.* (2015). NB, uppermost Bedoulian « White Bed » of Fries & Parize (2003), T, thin-bedded turbidites, TOC, Total Organic Carbon.

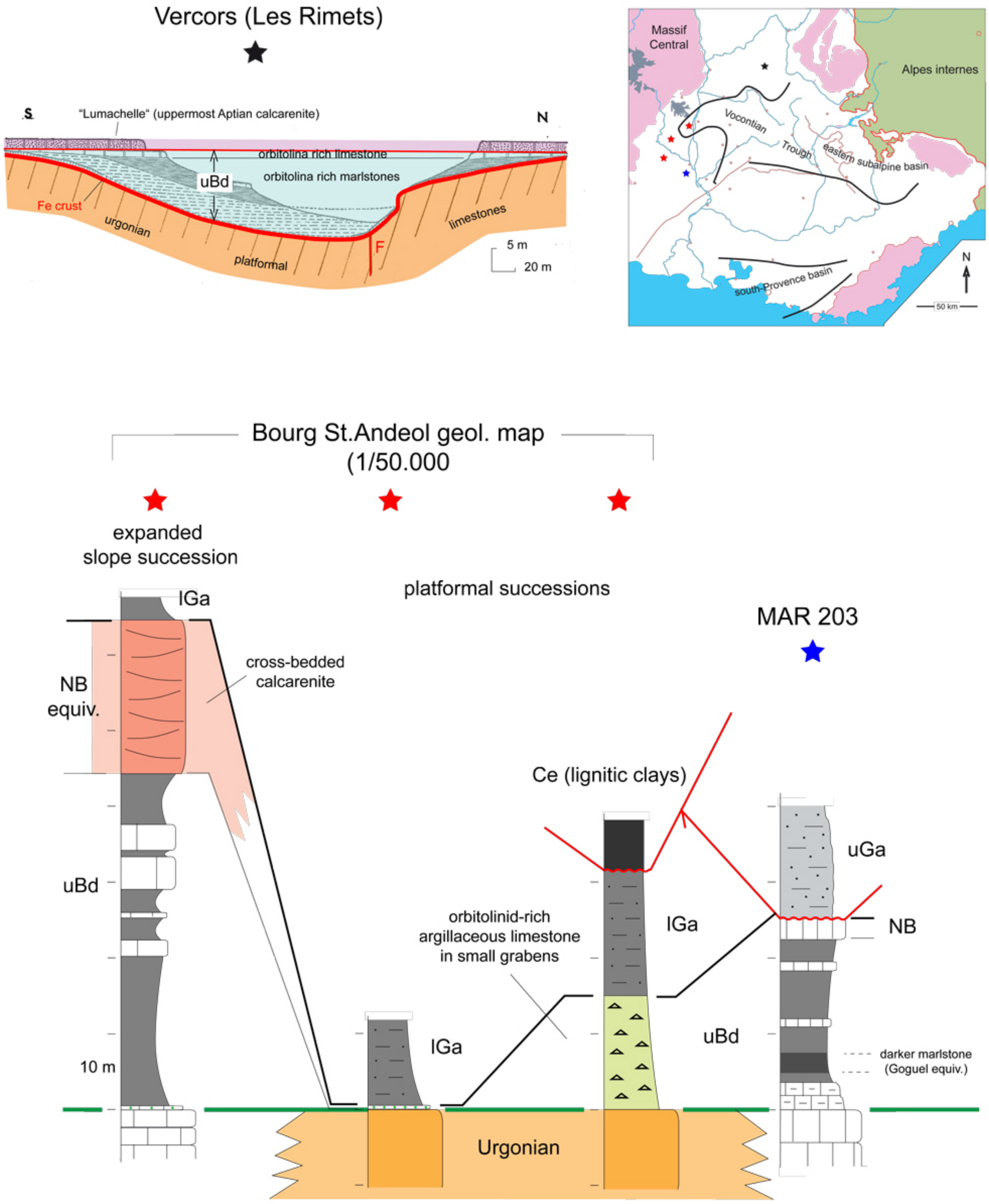
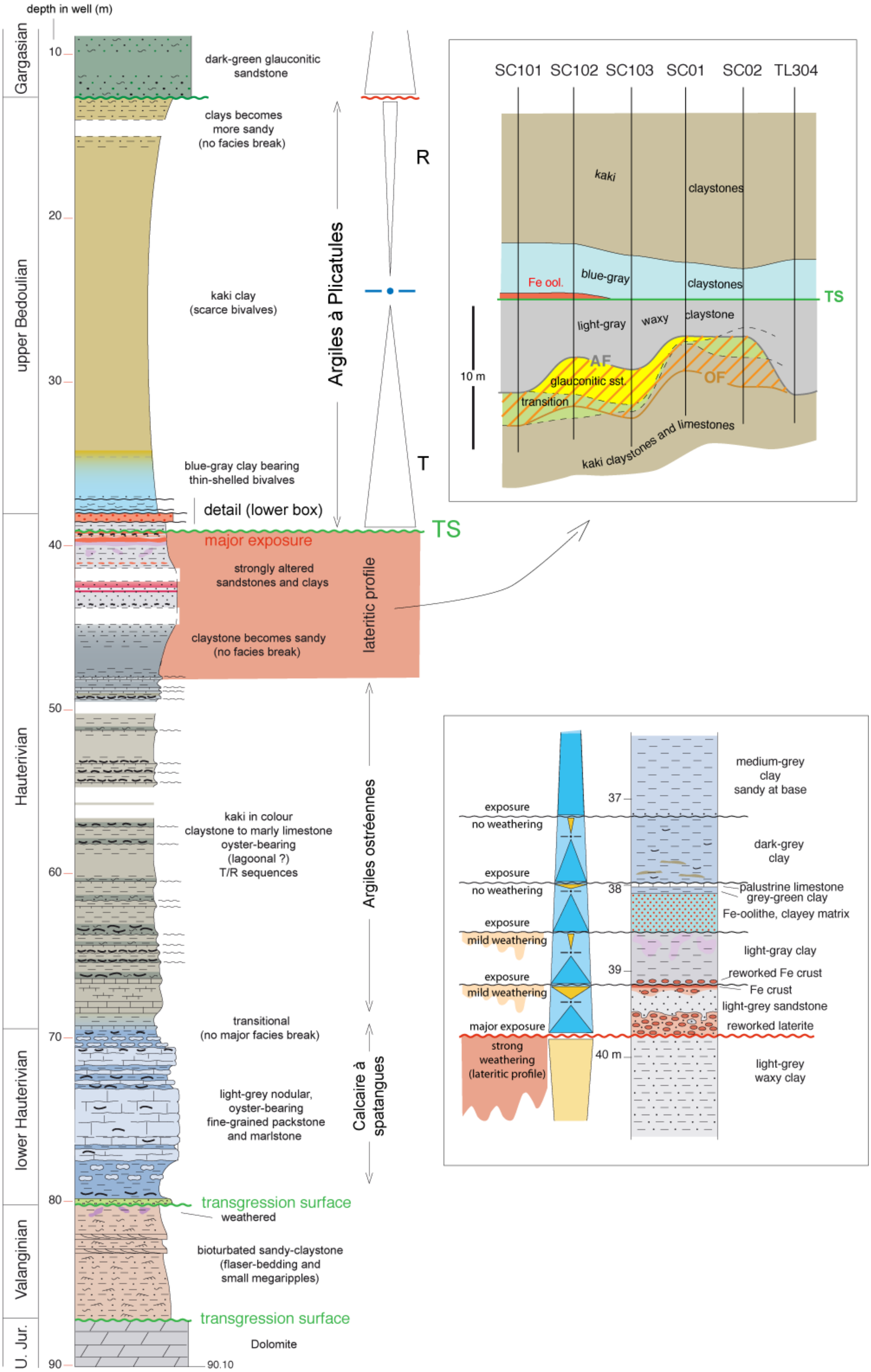


Fig. 27. The upper Bedoulian sequence on platforms around the Vocontian Trough. Vercors from ARNAUD-VANNEAU & ARNAUD (1970); Ardèche Urgonian platform and slope from BUSNARDO in explanatory booklet of the geological map of Bourg-St-Andéol (1/50.000), also see PICTET & DELANOY (2017); MAR, 203 well from FERRY, 1999 (also see Fig. 25). uBd, upper Bedoulian; lGa, lower Gargasian; uGa, upper Gargasian.

Cretaceous Ocean Anoxic Events (OAEs) in their local sequence stratigraphic context

Of the many black shale events recorded in the Vocontian Trough, only three are addressed here: the late early Aptian OAE1a, the early Albian OAE1b, and the latest Cenomanian OAE2. In the Vocontian Trough, they have been named, respectively, the « GOGUEL », « PAQUIER » and « THOMEL » levels (BRÉHÉRET, 1988; CRUMIÈRE, 1989). The purpose of the following text is is not to discuss their origin. This has been addressed by a huge volume of international literature over the last decades, VT included, especially on the PAQUIER level. Rather, it is to give a precise definition of their comparative sequence stratigraphic and paleogeographic context at the scale of the French Alpine margin.


depth in well (m)
Gargasian
upper Bedoulian
Hauterivian
lower Hauterivian
Valanginian
U. Jur.
dark-green glauconitic sandstone
clays becomes more sandy (no facies break)
kaki clay (scarce bivalves)
blue-gray clay bearing thin-shelled bivalves
detail (lower box)
TS
major exposure
strongly altered sandstones and clays
claystone becomes sandy (no facies break)
lateritic profile
kaki in colour claystone to marly limestone oyster-bearing (lagoonal ?) T/R sequences
transitional (no major facies break)
light-grey nodular, oyster-bearing fine-grained packstone and marlstone
transgression surface
weathered
bioturbated sandy-claystone (flaser-bedding and small megaripples)
transgression surface
Dolomite
90.10
Argiles à Plicatules
Argiles ostréennes
Calcaire à spatangues
R
T
SC101 SC102 SC103 SC01 SC02 TL304
kaki
claystones
blue-gray
claystones
Fe ool.
TS
light-gray
waxy
claystone
AF
glauconitic sst.
OF
transition
10 m
kaki claystones and limestones
exposure
no weathering
exposure
no weathering
exposure
mild weathering
exposure
mild weathering
major exposure
strong weathering (lateritic profile)
37
38
39
40 m
medium-grey clay sandy at base
dark-grey clay
palustrine limestone
grey-green clay
Fe-oolithe, clayey matrix
light-gray clay
reworked Fe crust
Fe crust
light-grey sandstone
reworked laterite
light-grey waxy clay

1) Late early Aptian OAE1a

This OAE is associated with a $\delta^{13}C$ shift, first negative then positive, recognized on a large scale outside the VT. International literature discussing this event is growing. The positive isotope excursion is maximum in the upper part of the cycle, above the black shale level when present, and continues into the lower upper Aptian.

The OAE1a is represented in the central Vocontian Trough by the GOGUEL black shale (Fig. 25) which occurs within a thin marl-limestone cycle found in Vocontian Trough sections, when not removed by slumping. The lower marl of this cycle, including the GOGUEL black shale, is lacking in the Angles section (Fig. 18), probably due to slumping but it is present in the Vocontian Lesches-en-Diois syncline (MOULLADE, 1966, 1995; GHIRARDI *et al.*, 2014). The upper limestone bed is known as the « Niveau Blanc » (White Level or White Beds of FRIES & PARIZE, 2003). It can be traced atop of the same marlstone interval (with some changes in thickness) in many Vocontian sections (when preserved from slumpings) to the western border of the Trough in the Gard Department area (Marcoule exploration wells of ANDRA, Fig. 25). This cycle begins at the very time when Barremian to lower Aptian Urgonian carbonate platforms surrounding the VT ceased to function due to drowning (Fig. 18). As the drowning was accompanied by tectonic disturbances and paleogeographic changes, this cycle may be lacking on the platforms (hiatus either by exposure or by condensation on drowned plateaus), or reduced in thickness, or very expanded depending on location (the south Provence basin, for instance, MOULLADE *et al.*, 1998, 2015). More details on the western border of the trough can be found in PICTET & DELANOY (2017). On the Vercors Plateau, this cycle is represented by the upper *Orbitolina* beds that correspond to the infilling of channels on top of the Urgonian platform at the beginning of its drowning (ARNAUD-VANNEAU & ARNAUD, 1970). A correlation scheme is given to illustrate the changes in thickness and facies of this cycle in S-E France, either in basinal settings (Fig. 26) or in platform ones (Fig. 27).

◀ **Fig. 28.** The upper Bedoulian sequence in the SC101 ANDRA well in the southeastern Paris Basin from FERRY (unpubl. ANDRA report), modified, and COURTINAT *et al.* (2006), modified. Upper right box, detail of the facies relationship between closely spaced wells (0,3 to 2,5 km apart) in the repository site. Note the crossing of the primary stratification by the two weathering fronts of the probable lateritic profile: OF, front of Fe concentration; AF, front of argilisation (primary rock, probably a marine clayey sandstone, fully altered into clay. T, transgressive trend; R, regressive trend; TS, transgression surface.

A reexamination of the ANDRA wells in the southeastern Paris Basin (Fig. 28) led to understanding the pattern of the late early Aptian transgression in the Paris Basin. In the SC101 well, the « Argiles à Plicatules », of late early Aptian age (Deshayesi and Bowerbanki ammonite zones) according to AMÉDRO & MATRION, 2004b) rest on a lateritic weathering profile affecting marine sandstones and claystones of Barremian age, based on ostracods (DAMOTTE, 1971) and dinoflagellates (COURTINAT *et al.*, 2006). The « Argiles à Plicatules » are sharply overlain (sequence boundary) by glauconitic sandstones of probable late Aptian age (Nutfieldensis ammonite Zone according to AMÉDRO & MATRION, 2004a, 2008), which are referred to here as upper Gargasian (uGa) (Fig. 25). This sandstone unit is the southern counterpart of the lower Greensand in southern England (AMÉDRO & MANIA, 1976). On the basis of plant remains, dinoflagellates and nannofossils, the « Argiles à Plicatules » correspond to a full transgressive-regressive cycle (Fig. 27). This cycle has an equivalent in south England, the Atherfield Clay (AC) overlain by the sandy limestone of the Hythe Beds (HB). Given its late early Aptian age (CASEY, 1961), the couple AC/HB is the boreal equivalent of the marl limestone cycle in E France (Fig. 26).

The « Argiles ostréennes » (oyster-bearing claystones) under the weathering profile (Fig. 28) were dated Barremian on the basis of ostracods by DAMOTTE (1971). The stratigraphic assignement was later confirmed by COURTINAT *et al.* (2006) from dinocysts. However, a reexamination of the stratigraphic range of dinoflagellates in the Lower Cretaceous (MONTEIL, 1985; LONDEIX, 1990; OGG, 1994; ...) showed that most of the species considered as Barremian were already present in the Valanginian or appeared in the lower Hauterivian.

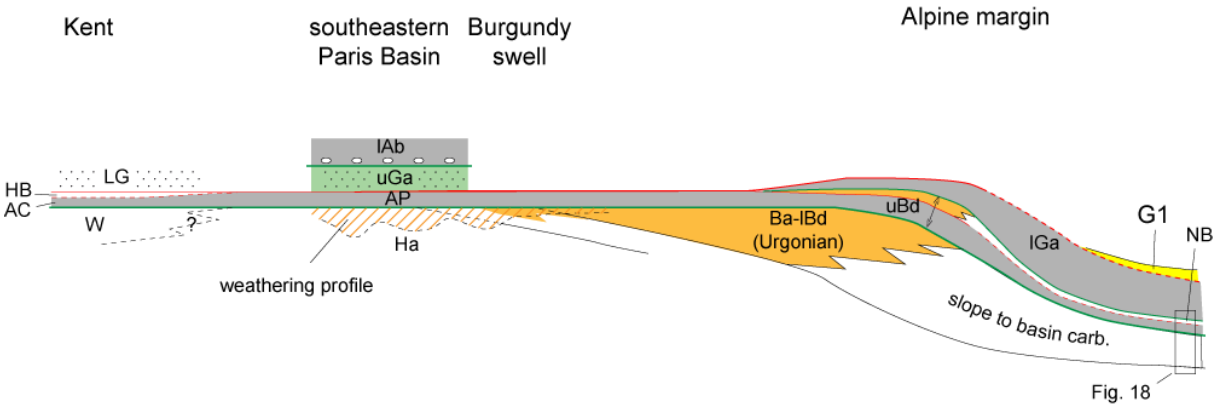


Fig. 29. Schematical stratigraphic correlation between the London-Paris Basin and the subalpine margin, especially regarding the upper Bedoulian sequence. AC, Atherfield Clay; AP, Argiles à Plicatules, Ba, Barremian; Ha, Hauterivian; HB, Hythe Beds; LG, Lower Greensand; lAb, lower Albian; lBd, lower Bedoulian; lGa, lower Gargasian; uBd, upper Bedoulian; uGa, upper Gargasian; W, Wealden deposits; G1, mid-Gargasian sandy turbidites of RUBINO (*in* FERRY & RUBINO, 1989) (Fig. 25).

The Barremian age of the Argiles ostréennes thus remains based on ostracods. However, an age problem arises from the sequence stratigraphic approach. no. facies break was found between the lower Hauterivian Calcaires à Spatangues dated by ammonites and the Argiles ostréennes (Fig. 28), nor was any break found at their top. For this reason, the exact age of the Argiles ostréennes remains poorly established. It could by Hauterivian, not Barremian. On the other hand, CLAVEL *et al.* (2007, 2012) showed that Urgonian platformal carbonates prograded from the late Hauterivian to the early Aptian from the Jura to the French Subalpine chains on the Alpine margin. Therefore, it is probable that the updip area (Burgundy swell, southern Paris Basin) may have been exposed from the late Hauterivian, explaining the lateritic profile found in the Andra site of the Departement de l'Aube (Fig. 28). The submergence came at the beginning of the upper Bedoulian cycle. On a large scale, the Argiles à Plicatules/Atherfield Clay therefore represent a very quick transgression after the demise of Urgonian platforms of the north Tethyan margin. The Burgundy swell was submerged, and the paleosols and/or Wealden deposits of the Anglo-Paris basin were suddenly flooded by marine claystone (Fig. 29).

All available data (Figs. 26-28) therefore point to a « flash » transgression at base of cycle uBd, accompanied by tectonic deformations coincidental with the demise of Urgonian carbonate platforms (Fig. 27). The GOGUEL black shale was clearly deposited in a transgressive setting.

2) Early Albian OAE1b

From the above discussion, the Albian interval is clearly a time of relative sea-level drop in the SE France basin. The uplift of the Rhodanian saddle, together with a severe shallowing of the upper Vocontian terrace, (Fig. 25) led to a narrowing of the deep area where is found the PAQUIER black shale. The change is severe enough to wonder if this black shale is the result of a large scale environmental event or if it is just the result of a short-lived confinement in a restricted basin.

The new sequence stratigraphic data are therefore in accordence with geochemical results of HEIMHOFER *et al.* (2006) and OKANO *et al.* (2008). The geochemical data suggested that the PAQUIER level was more influenced by riverine input than the GOGUEL level, which bears an opposite « geochemical » transgressive signal. From the above, the enhanced riverine input these researchers found can be easily related to the regressive trend found on the Alpine margin, beginning around the Aptian-Albian boundary.

This regressive trend is not found in the Paris Basin. In contrast, the Albian « Argiles à tégulines » are transgressive on the upper Aptian « Sables verts de l'Aube » through a veneer of phosphate nodules that contain ammonites of the basal Tardefurcata Zone (AMÉDRO & MATRION, 2007). These opposite trends suggest again a tectonic control of the changes in relative sea-level. In other words, a sequence boundary (relative sea-level fall) may correlate laterally to a transgression surface.

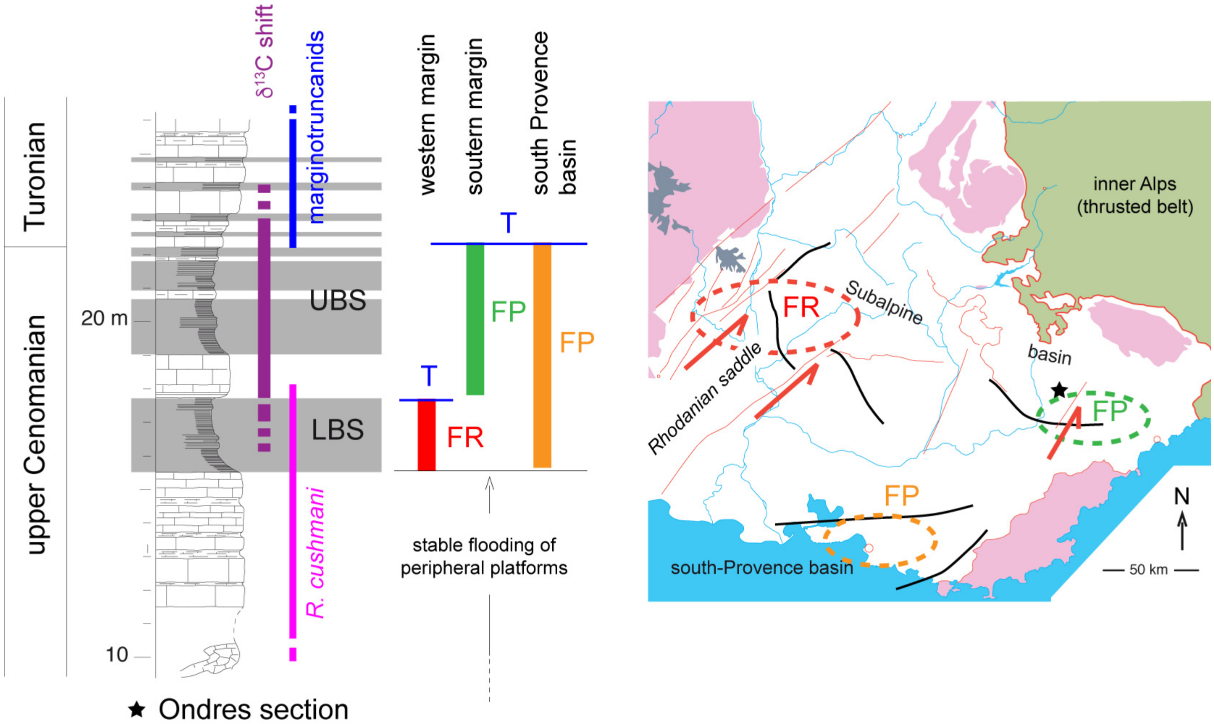


Fig. 30. Exact timing of relative sea-level changes as a result of a probable overall transpressional tectonic movement in the southern subalpine basin during the Cenomanien-Turonian boundary δ13C shift. Events situated against the basinal Ondres section (after GROSHENY *et al.*, 2017, modified, and work in progress). FR, forced regression due to uplift in the Rhodanian saddle; FP, forced progradation of the carbonate platform east of the strike-slip Rouaine fault and in the south Provence basin; LBS, UBS, lower, upper black shale of Vocontian sections; MPB, equiv. of the mid-Plenus bed of the Eastbourne reference section in southern England (see correlation in GROSHENY *et al.*, 2017), T, beginning of the relative sea-level rise in each area, based on platform to basin stratigraphic transects constrained by isotope data (work in progress).

3) Latest Cenomanian OAE2

The Cenomanian-Turonian boundary (CTB) is marked by a triple crisis: (1) deposition of organic-rich shales in deep basins (Atlantic, Tethys, marginal basins like the Vocontian Trough) as a result of a supposedly global anoxic event (although data about anoxy in the Pacific Ocean are scarce), (2) a positive δ13C shift that has been recognized worldwide, and (3) a paleontological crisis through the temporary disappearance of keeled planktic foraminifers (replacement of rotaliporids by globotruncanids). The CTB event (CTBE), as defined by the isotope anomaly, is mostly latest Cenomanian in age according to the many recent studies on a worldwide scale. The recovery to average values is within the lowermost Turonian. Black shales are known to cover a larger stratigraphic range on a global scale, locally beginning in the lower Cenomanian (Venezuela, southern Moroccan Atlantic margin), and finishing more or less late in the Turonian, especially in marginal basins like those of the Saharan Atlas in Algeria (GROSHENY *et al.*, 2008). Since the early work of SCHLANGER & JENKYNS (1976), analysis of the event has generated a huge amount of literature over the past decades seeking to understand its causes and mechanisms.

This OAE is represented by the THOMEL black shale (CRUMIÈRE, 1989) in the basinal area of the southeastern subalpine chains (Castellane tectonic arc). The black shale is also present in the La Charce syncline along the axis of the Vocontian Trough. A recent synthesis (GROSHENY *et al.*, 2017) has shown that the event is not accompanied by a transgression in the French Alps (Fig. 30). On the western margin (Rhodanian saddle and western Vocontian Trough), a forced regression reminiscent of that of the mid-Cenomanian (mCeRF, Fig. 25) occurred during the first half of the δ13C anomaly. The shift of the shoreline was stronger than the former. The Vocontian Trough narrowed dramatically (Fig. 2C). On the southeastern margin of the basin, a very strong increase of the subsidence rate during the second half of the isotope shift was followed by a forced progradation of the Turonian carbonate platform east of the Rouaine fault, as a result of a sinistral strike-slip movement on this fault. Work in progress shows that the upper Cenomanian rudist-bearing carbonate platform bordering the south Provence basin underwent a forced progradation (sharp base of platformal carbonates) exactly beginning with the rise of the isotope shift. The platform was flooded in ealy Turonian times. All these events contrast with the relative stability found during the late Cenomanian that was a period of flooding over the whole S-E France basin, without any clear changes in relative sea-level. The early Turonian was a time of uniform transgression. Therefore, the disturbances found are exactly coincidental with the CTBE.

Other data (GROSHENY *et al.*, submitted) support the idea that the tectonic pulse is global, given the heterogeneity of the sequence stratigraphic record that has been found to occur on a larger scale exactly during the event.

In SE France, the THOMEL black shale of the so-called OAE2 is not associated with a transgressive trend, as has been suggested by many authors from geochemical data acquired in deep basinal sections, but rather with a narrowing of the deep area, a probable shallowing of the residual basin, and maybe some restriction of the bottom waters, given that bottom life was not fully suppressed during the THOMEL black shale deposition (COURTINAT & HOWLETT, 1990; GROSHENY & TRONCHETTI, 1993).

In summary, of the three OAEs investigated in the subalpine basin, only one (OAE1a) exists within a real transgressive setting. The two others (OAE1b and OAE2) are clearly within local regressive setting. All three are closely associated with tectonic disturbances.

Acknowledgements

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The Global Boundary Stratotype Sections and Points (GSSP) of the Hauterivian: La Charce section (Drôme, France, Vocontian Basin)

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Introduction

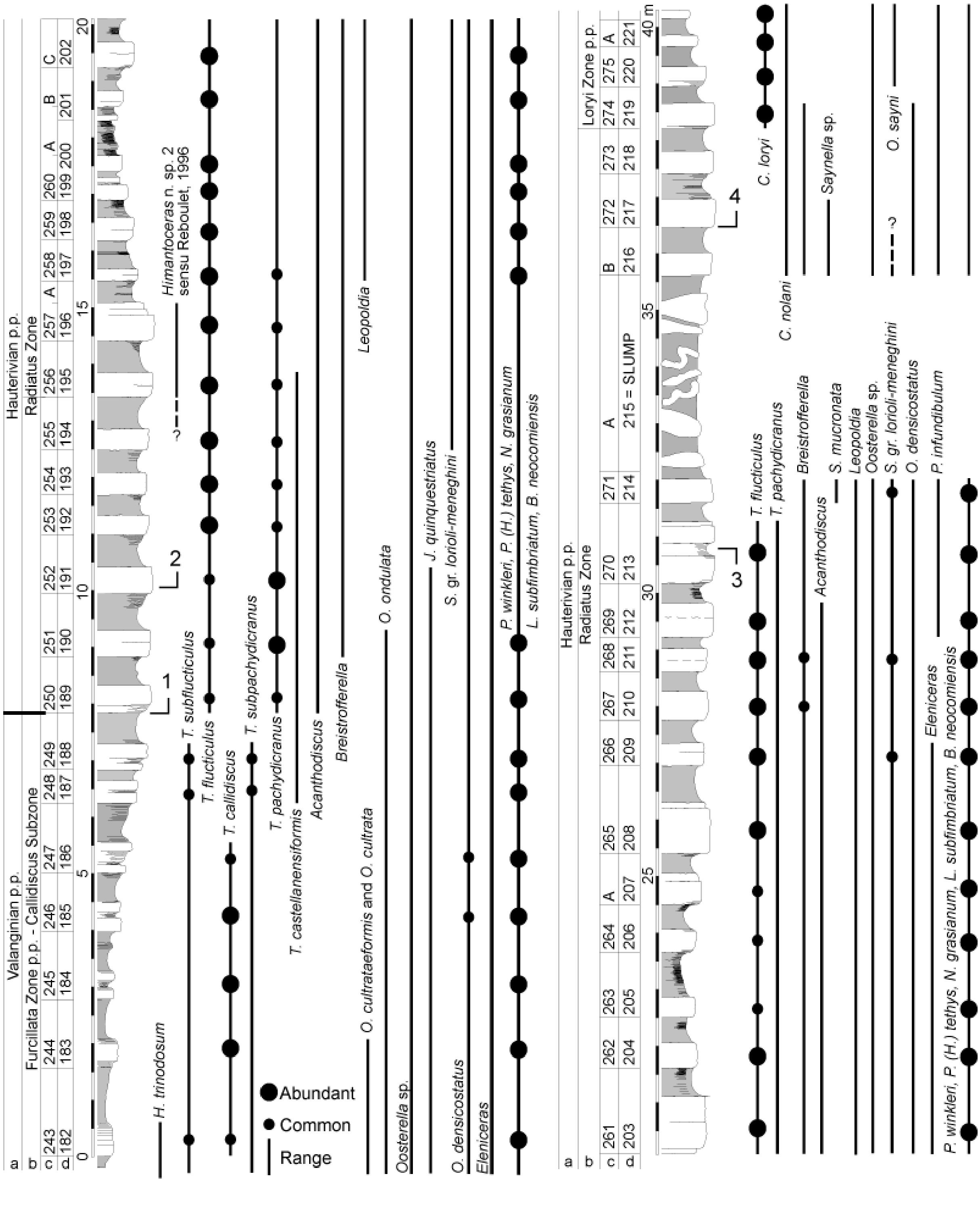
The La Charce section is located in the French department of Drôme. The biostratigraphy of the section has been well-studied. In the last four decades a considerable number of works on palaeontology and biostratigraphy have been published: on ammonoids (THIEULOY, 1977a; REBOULET *et al.*, 1992; BULOT *et al.*, 1993, 1996; BULOT, 1995; REBOULET, 1996; REBOULET & ATROPS, 1997, 1999, and references therein), on belemnites (JANSSEN & CLÉMENT, 2002), on trace fossils (GAILLARD, 1984; GAILLARD & JAUTÉE, 1987; OLIVERO, 1996), on foraminifers (MOULLADE, 1966; MAGNIEZ-JANNIN, 1992; MAGNIEZ-JANNIN & DOMMERGUES, 1994), and on calcareous nannofossils (THIERSTEIN, 1973; GARDIN, this volume). Sedimentological, geochemical and palaeomagnetic data are also available (COTILLON *et al.*, 1980; FERRY *et al.*, 1989; FERRY, 1991; HENNIG *et al.*, 1999; SCHOOTBRUGGE *et al.*, 2003; GRÉSELLE, 2007, and references therein). Here, we present the lithological evolution of the La Charce section, along with a synthesis of the biostratigraphic work on ammonoids.

Lithology of the La Charce section

A detailed lithology of the Valanginian-Hauterivian portion of the La Charce section is presented in REBOULET (1996) and REBOULET & ATROPS (1999). So here we discuss only the stratigraphy of the sequence encompassing the boundary between the stages (Fig. 2.1). There the lithology is characterized by marl-limestone alternations. The section is intensively bioturbated, with both limestones and marls affected (GAILLARD, 1984). *Zoophycos* feeding burrows are common in the limestones (OLIVERO, 1996). Carbonate-rich marl-limestone alternations predominate the lowest Valanginian beds (Pertransiens ammonite Zone), then gradually become richer in argillaceous content in the uppermost part of the lower Valanginian (Campylotoxus ammonite Zone). The Verrucosum ammonite Zone of the upper Valanginian (Fig. 2.2a) is also the site of an increase in argillaceous content. The relative abundance of carbonate in the marl-limestone succession increases gradually upward toward the Valanginian/ Hauterivian boundary. The marls and limestones of early Hauterivian age show a marked contrast: white limestones quite regularly alternate with dark marls (Fig. 2.2b). Their thicknesses are comparable.

The alternation of marl and limestone has been interpreted as the result of cycles in the production of calcareous nannoplankton caused by climatic fluctuations in the MILANKOVITCH frequency band (COTILLON *et al.*, 1980; GIRAUD, 1995). Alternatively, REBOULET *et al.* (2003) have proposed for the Vocontian Basin a model of cyclic export of carbonate mud from shallow platform environments towards the basin. Occasionally, synsedimentary slumping and turbidites (rust-coloured calcarenites) occurred in the basin. These calcarenites are particularly well-exposed in portions of the Campylotoxus and Verrucosum zones of the La Charce section (REBOULET, 1996, and references therein).

LA CHARCE



1. FO *S. mitcheneri* 2. FO *Staurolithites* sp. 3. LO *E. windii* 4. *FO D. galiciense*

Figure 2.1. Ranges of the ammonoids in and zonation of the La Charce section based on data from REBOULET *et al.* (1992), BULOT *et al.* (1993, 1996), BULOT (1995), REBOULET (1996), REBOULET & ATROPS (1997, 1999). This figure is the fruit of a collaboration with Luc BULOT. (a) Stages; (b) ammonoid zones; (c) bed numbers according to L. BULOT; (d) bed numbers according to S. REBOULET. The main nannofossil events recorded in the La Charce section are also shown (data from Silvia GARDIN, unpublished).

A B

C

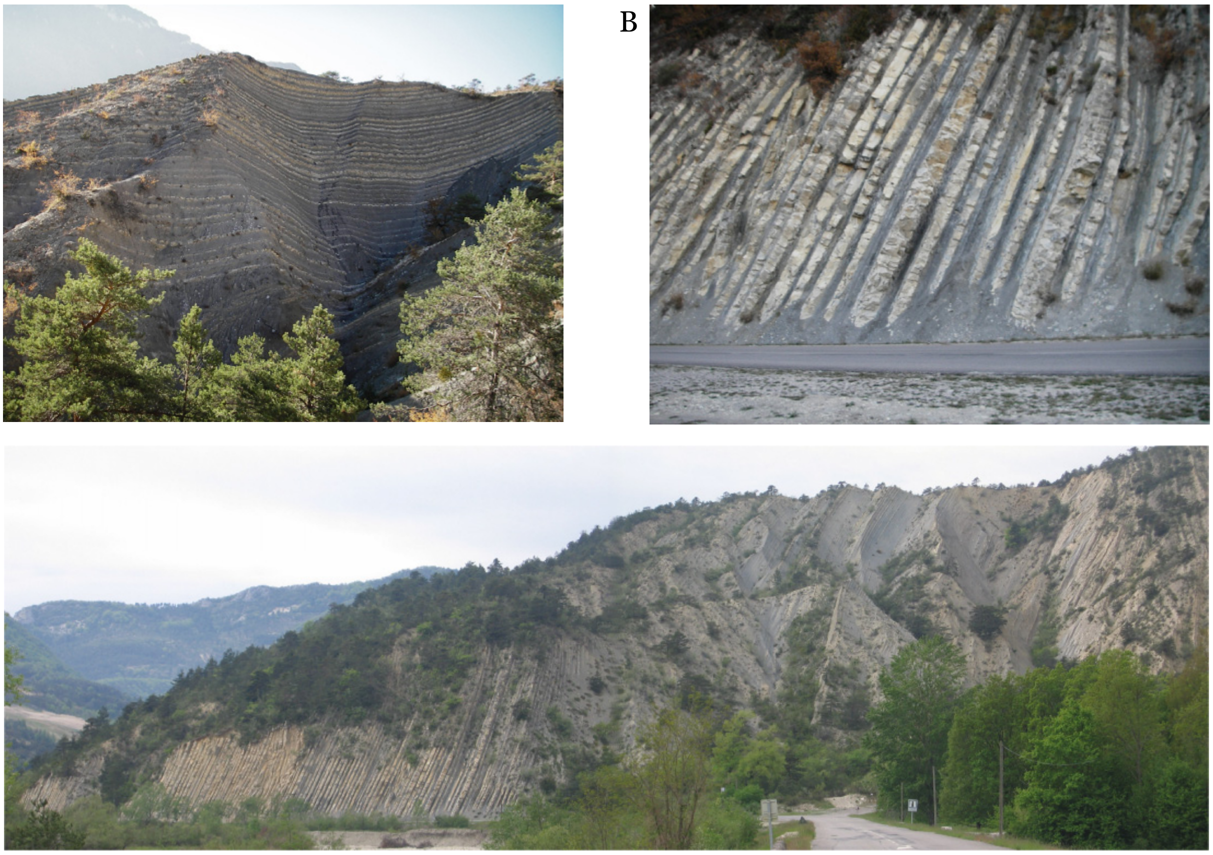


Figure 2.2. La Charce section. (a) Picture showing upper Valanginian marl-limestone alternations (Verrucosum ammonoid Zone). (b) Marl-limestone alternations at the base of the Hauterivian Stage. (c) Panorama of the La Charce section.

Recent research (FESNEAU *et al.*, 2009) on some outcrops in the Vocontian Basin (La Charce and Vergol sections in the Drôme, Montclus in the Hautes-Alpes) has revealed the occurrence of centimetre-thick goethite-rich horizons. These horizons (reddish in colour), already mentioned by BEAUDOIN *et al.* (2003), resemble Oxfordian and Aptian bentonites described in other sections of the Vocontian Basin (DAUPHIN, 2002; PELLENARD & DECONINCK, 2003).

Biostratigraphy of ammonoids

The La Charce section is well dated because of the important number of ammonoids, which comprise almost all of the macrofauna (REBOULET *et al.*, 1992; ATROPS & REBOULET, 1995; REBOULET, 1996; REBOULET & ATROPS, 1999, and references therein). But other nektonic macrofossils are present: belemnites are common and there are a few nautiloids. Bivalves and gastropods are rare.

More than 15,000 ammonoids were collected in a hundred metre section (REBOULET, 1996). The assemblage consists of six families. Most turnovers took place during the evolution of the Neocomitidae and Olcostephanidae. The ammonoid spectra are often dominated by: Haploceratidae, Bochianitidae, Phylloceratidae, and Lytoceratidae; their abundance indicates a deep-water palaeoenvironment (REBOULET, 1996).

An ammonoid turnover occurred at the boundary of the Valanginian and Hauterivian, and has been interpreted as the response of nektonic organisms to eustatic and climatic changes (REBOULET *et al.*, 1992; REBOULET & ATROPS, 1995; REBOULET, 1996). The biozonation reflects the evolution of the ammonoid fauna (REBOULET & ATROPS, 1999). The zonal scheme of these authors has been adopted by the Lower Cretaceous Ammonite Working Group (= KILIAN Group) of the IUGS Subcommission on Cretaceous Stratigraphy and is included in the Cretaceous Standard Zonation (HOEDEMAEKER & REBOULET (reporters) *et al.*, 2003; REBOULET & HOEDEMAEKER (reporters) *et al.*, 2006).

The Hauterivian stage and the Global Boundary Stratotype Sections and Points

RENEVIER (1874) defined the Hauterivian stage in the Hauterive area (Neuchâtel, Northwest Switzerland). For a long time this locality has been considered to be unsatisfactory as the stratotype due to the condensation of some parts of the section, its poor exposure and the scarcity of ammonoids. For most of the 20th century and thereafter KILIAN and other French authors have investigated the expanded sections of the Vocontian Basin, where rich ammonoid faunas are recorded in the marl-limestone alternations of the hemi-pelagic successions.

As regards the Valanginian/ Hauterivian boundary, the La Charce section is the best documented. It was proposed by THIEULOY (1977a, p. 125) as a candidate for the boundary stratotype. The IUGS retained this proposal during the Copenhagen meeting in 1983 (BIRKELUND *et al.*, 1984). Because no other supplementary section has been proposed in Spain, the Caucasus or in the Crimea (all are areas in which the Valanginian-Hauterivian is well-documented), during the Brussels meeting in 1995 (MUTTERLOSE *et al.*, 1996), the Hauterivian Working Group agreed to recommend the La Charce section as the global boundary stratotype for the base of the Hauterivian. The IUGS-ICS Subcommission on Cretaceous Stratigraphy recommended the La Charce section for the Hauterivian GSSP during the 32nd International Geological Congress at Florence in 2004 (OGG *et al.*, 2004). The members of the Hauterivian Working Group are currently preparing a formal proposal in accordance with this recommendation. The village of La Charce has agreed to preserve the section outcropping along the road.

The *Acanthodiscus radiatus* Zone (Radiatus Zone) and the Golden Spike of the Hauterivian

The base of the Hauterivian in the Tethyan realm was traditionally defined by the first appearance of the index-species *Acanthodiscus radiatus* (THIEULOY, 1977a). This choice was recommended during the 1st and 2nd international symposia on the Cretaceous Stage Boundaries (Copenhagen, 1983 and Brussels, 1995; BIRKELUND *et al.*, 1984; MUTTERLOSE *et al.*, 1996). Due to the scarcity of the index-species in deep-water distal environments it was also suggested that the base of the Radiatus Zone be made concomitant with the first appearance of the genus *Acanthodiscus* (*A. radiatus* and related species). This proposal was reported in the Geologic Time Scale of OGG *et al.* (2004); further discussion can be found in KLEIN (1997) and REBOULET & ATROPS (1999). REBOULET (1996, p. 263 and figure 22) also supports this definition of the Radiatus Zone. This author shows that the genus *Acanthodiscus* is probably a biological species with a great variability in macroconchs (*A. radiatus*, *A. rebouli*, *A. vaceki*, *Leopoldia leopoldina*), and in microconchs (*Breistrofferella peyroulensis*, *B. castellanensis* and *B. varappensis*; REBOULET, 1996). Therefore, when *Acanthodiscus* is very rare or absent in deep-water palaeoenvironments, the recognition of the Radiatus Zone is possible using the species of *Breistrofferella* that are also generally abundant on platforms. In addition, the faunal assemblage of the Radiatus Zone is well characterized by other genera, like *Teschenites*, *Eleniceras*, *Olcostephanus*, *Spitidiscus* and *Oosterella* (Fig. 2.1; REBOULET, 1996).

In accordance with these recommendations and considerations the Golden Spike of the Hauterivian stage (= the base of the Radiatus Zone) is placed at layer 189 of the La Charce type-section (Fig. 2.1), which is the first occurrence of *Acanthodiscus rebouli* (REBOULET, 1996). Bed 189 corresponds to bed 250 in the system of numbering proposed by BULOT *et al.* (1993).

The chronologic age of the base of the Hauterivian is either 123 Ma (+6/-2 Ma, ODIN, 1994), 136.4 Ma (±2 Ma, OGG *et al.*, 2004), 124.1 Ma (±0.4 Ma, FIET *et al.*, 2006) or 133.9 Ma (±2 Ma, MCARTHUR *et al.*, 2007). It is practically coincident with the base of subchron M10n (FERRY *et al.*, 1989; MCARTHUR *et al.*, 2007), or with chron M11n (OGG *et al.*, 2004).

Conventionally, the base of the Amblygonium Zone of the Boreal Realm is correlated with the base of the Radiatus Zone (THIEULOY, 1973; RAWSON, 1983, 1993; MUTTERLOSE *et al.*, 1996; JACQUIN *et al.*, 1998; OGG *et al.*, 2004). Recent $^{87}Sr/^{86}Sr$ data suggest that the base of the Amblygonium Zone may correlate with the uppermost part of the Furcillata Zone (upper Furcillata Subzone; MCARTHUR *et al.*, 2007). This correlation is in agreement with similar proposals by other authors (THIEULOY, 1977b; KEMPER *et al.*, 1981; RAWSON, 1983; MUTTERLOSE *et al.*, 1996; figure 6 *in* RAWSON & HOEDEMAEKER (reporters) *et al.*, 1999).

Palaeoecology and palaeogeography of *Acanthodiscus*

In southeastern France, *Acanthodiscus* is common or even relatively abundant in hemipelagic palaeoenvironments (Vivarais/ Cévennes area, BUSNARDO *in* ELMI *et al.*, 1989, 1996; REBOULET, unpublished data) and in shallow-water, proximal environments (Provence platform, THIEULOY *et al.*, 1990; AUTRAN, 1993; BULOT, 1995; REBOULET, 1996; Jura platform, BUSNARDO & THIEULOY, 1989). Conversely, it is reported as rare in deeper-water, distal palaeoenvironments (Vocontian Basin, REBOULET, 1996; Veveyse de Châtel area, Switzerland, BUSNARDO *et al.*, 2003). A similar distribution is observed in other Tethyan and Atlantic basins (Betic Chains, Spain, COMPANY, 1987; HOEDEMAEKER, 1995; Atlantic High Atlas, Morocco, ETTACHFINI, 1991).

In the Boreal realm, *Acanthodiscus* occurs mainly in the shallow-water facies of NW Germany, the Polish seaway and Crimea (KEMPER *et al.*, 1981). In North Germany, *Acanthodiscus*, which is generally rare in the Endemoceras beds (KEMPER, 1973; RAWSON, 1973), seems to be restricted to the Noricum Zone (THIEULOY, 1977b; QUENSEL, 1988) in deep-water environments, but it is recorded in the upper part of the Amblygonium Zone in shallow-water settings (KEMPER *et al.*, 1981; MUTTERLOSE *et al.*, 1996). The presence *versus* absence of *Acanthodiscus* in the upper part of the Amblygonium Zone in the Boreal Realm may be controlled in large part by palaeoenvironmental factors (bathymetry and/or a proximal *versus* a distal location). The same pattern was observed in southeastern France (MCARTHUR *et al.*, 2007, and references therein).

Despite the fact that the presence or absence of *Acanthodiscus* is in part controlled by palaeoenvironmental factors, this genus has a wide palaeobiogeographic distribution and thus is a very good index for the base of the Hauterivian in Europe (KEMPER *et al.*, 1981; MCARTHUR *et al.*, 2007), North Africa (Morocco, ETTACHFINI, 1991, 2004; WIPPICH, 2001; ATROPS *et al.*, 2002), and Chili (MOURGUES, 2007). For further information on the palaeogeographic distribution of *Acanthodiscus*, see also the synonymies of type species of *Acanthodiscus*, *Leopoldia*, and *Breistrofferella* in KLEIN (2005).

The nannofossil succession of la Charce across the Valanginian-Hauterivian boundary

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Modified from: GARDIN S. (2008).- Chapter 3. The nannofossil succession of la Charce across the Valanginian-Hauterivian boundary.- *Carnets Geol.*, Madrid, vol. 8, no. B01 (CG2008_B01), p. 11-13.

Citation: GARDIN S. (2017).- The nannofossil succession of la Charce across the Valanginian-Hauterivian boundary. *In*: GRANIER B. (ed.), Some key Lower Cretaceous sites in Drôme (SE France).- Carnets de Géologie, Madrid, CG2017_B01, ISBN 978-2-916733-13-5, p. 48-51.

Calcareous nannofossils around the Valanginian/ Hauterivian boundary

Although there are several publications concerning Lower Cretaceous calcareous nannofossils, the biostratigraphic resolution of nannofossils across the Valanginian/ Hauterivian boundary has increased little. In the published literature few datums are proposed to delineate the Valanginian/ Hauterivian boundary. SISSINGH (1977) suggested using the FO (first occurrence) of *Cretarhabdus loriei* as a marker for the early Hauterivian, though this particular occurrence proved to be much younger (Aptian). PERCH-NIELSEN (1979, 1985) acknowledged the difficulty of using *Cretarhabdus loriei* due to problems in recognizing or differentiating this species from other species of *Cretarhabdus*. ROTH (1978, 1983) and THIERSTEIN (1976) proposed the LOs (last occurrences) of *Diadorhombus rectus* and *Tubodiscus verenae* to mark the top of the Valanginian; however, these species have much younger extinctions.

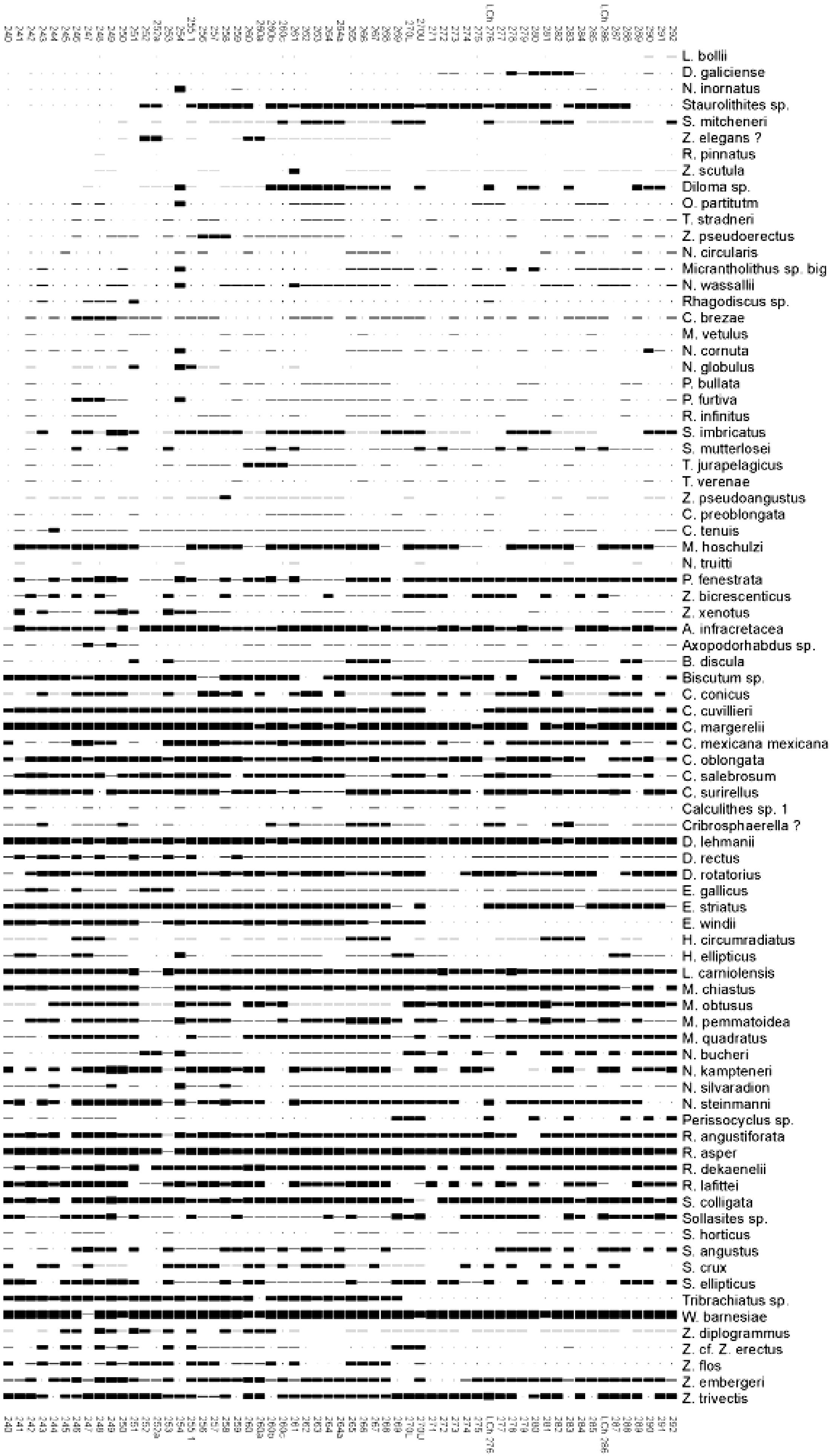
In terms of nannofossil biozones, the Valanginian/Hauterivian boundary (as defined by ammonoid fauna) falls within Biozone CC4a of APPLEGATE & BERGEN (1989) who modified the standard zonation of SISSINGH (1977). This zone is defined by the FAD (first appearance datum) of *Eiffellithus striatus* and the FAD of *Litraphidites bollii*. Biozone CC4 also corresponds to the NC4a Zone of ROTH (1978), as modified by BRALOWER *et al.* (1995). It is noteworthy that the last common occurrence of *Tubodiscus verenae* corresponds approximately with the FO of *Eiffellithus striatus* in the late Valanginian.

Nannofossil biostratigraphy of the La Charce section

Splits from the marly intervals were processed using standard preparation techniques and were examined under a light microscope. All these samples were productive, with abundant calcareous nannofossil assemblages (Fig. 3.1); the number of species is usually high (about 80 species), preservation is moderate. Identification of specimens with the light microscope was not hampered by diagenetic etching and/or overgrowths of calcite that can affect nannofloral assemblages (Fig. 3.2).

Analysis of the complete and expanded Valanginian-Hauterivian sequence at La Charce has allowed a sequence of local events to be evaluated in relation to the established European sequence. *Nannoconus bucheri* and *Nannoconus wassalli* occur sporadically starting at the Callidiscus ammonoid Zone; their occurrence is always rare and spotty. These taxa are more abundant and from the Loryi ammonoid Zone upward are continuously recorded. *Tubodiscus verenae* and *Tubodiscus jurapelagicus* occur sporadically up to the end of the late Hauterivian (Ligatus ammonoid Zone). *Staurolithithes mitcheneri* was first seen in bed 251 of BULOT *et al.* (1993; Radiatus ammo-noid Zone, Castellanensis Horizon). The LO of *Eiffellithus windii* is in bed 270, and the FO of *Diloma galiciense* in bed 272 (Radiatus ammonoid Zone, Buxtorfi Horizon; Fig. 2.1). These two species are rare but their stratigraphical ranges are reasonably consistent.

▶ Figure 3.1. Distribution chart of nannofossil taxa in the La Charce section across the Valanginian/ Hauterivian boundary.


L. bollii
D. galiciense
N. inornatus
Staurolithites sp.
S. mitcheneri
Z. elegans ?
R. pinnatus
Z. scutula
Diloma sp.
O. partitutm
T. stradneri
Z. pseudoerectus
N. circularis
Micrantholithus sp. big
N. wassallii
Rhagodiscus sp.
C. brezae
M. vetulus
N. cornuta
N. globulus
P. bullata
P. furtiva
R. infinitus
S. imbricatus
S. mutterlosei
T. jurapelagicus
T. verenae
Z. pseudoangustus
C. preoblongata
C. tenuis
M. hoschulzi
N. truitti
P. fenestrata
Z. bicrescenticus
Z. xenotus
A. infracretacea
Axopodorhabdus sp.
B. discula
Biscutum sp.
C. conicus
C. cuvillieri
C. margerelii
C. mexicana mexicana
C. oblongata
C. salebrosum
C. surirellus
Calculithes sp. 1
Cribrosphaerella ?
D. lehmanii
D. rectus
D. rotatorius
E. gallicus
E. striatus
E. windii
H. circumradiatus
H. ellipticus
L. carniolensis
M. chiastus
M. obtusus
M. pemmatoidea
M. quadratus
N. bucheri
N. kampteneri
N. silvaradion
N. steinmanni
Perissocyclus sp.
R. angustiforata
R. asper
R. dekaenelii
R. lafittei
S. colligata
Sollasites sp.
S. horticus
S. angustus
S. crux
S. ellipticus
Tribrachiatus sp.
W. barnesiae
Z. diplogrammus
Z. cf. Z. erectus
Z. flos
Z. embergeri
Z. trivectis

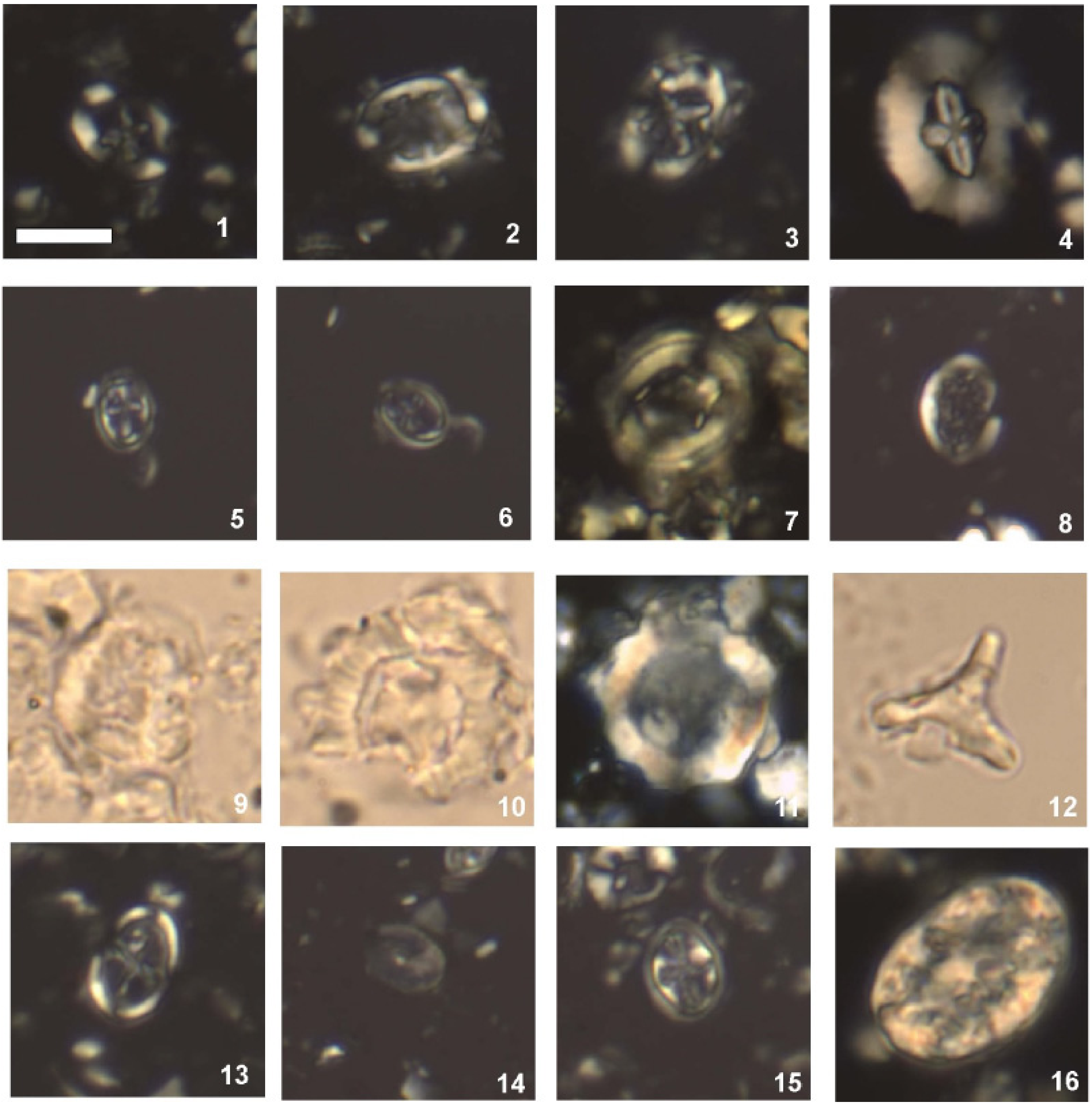


Figure 3.2. Micrographs showing some nannofossil taxa recorded in the La Charce section. Scale bar is 5 µm. 1. *Eiffellithus windii*, sample LCH 251; 2-3. *Eiffellithus striatus*, LCH 255. Same specimen rotated; 4. *Cruciellipsis cuvillierii*, LCH 255; 5-6. *Staurolithites mitcheneri*, LCH 255. Same specimen rotated; 7. *Tubodiscus verenae*, LCH 272; 8. *Rhagodiscus asper*, LCH 270; 9. *Nannoconus bucheri*, LCH 260; 10. *Nannoconus cornuta*, LCH 260; 11. *Nannoconus circularis*, LCH 266; 12. *Tribrachiatus* sp., LCH 251; 13. *Diloma galiciense*, LCH 278; 14. *Corollithion silvaradion*, LCH 272; 15. *Staurolithites* sp., LCH 272; *16. Calcicalathina oblongata*, LCH 272.

The first *Litraphidites bollii* was observed in bed 292 (Loryi/ Jeannoti ammonoid Zone) but its occurrence is common only upward from bed 296 in the Nodosoplicatum/ Variegatus ammonoid Zone (Fig. 3.1). The last occurrence of *Rhagodiscus dekaeneli* is at the top of this zone ("non-nome" subzone). All these events are summarized in Figure 3.1. The value as markers in other geographical areas must be carefully evaluated. No important originations or extinctions are coincident with the boundary (Callidiscus/ Radiatus ammonoid Zones). At La Charce, the nannofossil event that best approximates the Valanginian/ Hauterivian boundary is the LO of *Eiffellithus windii*.

Calcareous nannofloras at La Charce have a predominantly low-latitude (Tethyan) affinity (common *Cruciellipsis cuvillieri*, *Speetonia colligata* and *Calcicalathina oblongata*) though Nannoconids, which are known to prefer low-latitude, warm surface waters, and hemipelagic settings (THIERSTEIN, 1976; MUTTERLOSE, 1992; ERBA, 1994; KRUSE & MUTTERLOSE, 2000) are very rare. Taxa more commonly associated with higher latitudes such as *Sollasites* spp., *Crucibiscutum salebrosum*, *Corollithion silvaradion*, are consistently present at La Charce although in much lower quantities than in boreal sites. This is due to the northern Tethyan location of the Vocontian Basin, which acted as a "gateway" to boreal domain of northwestern Europe.

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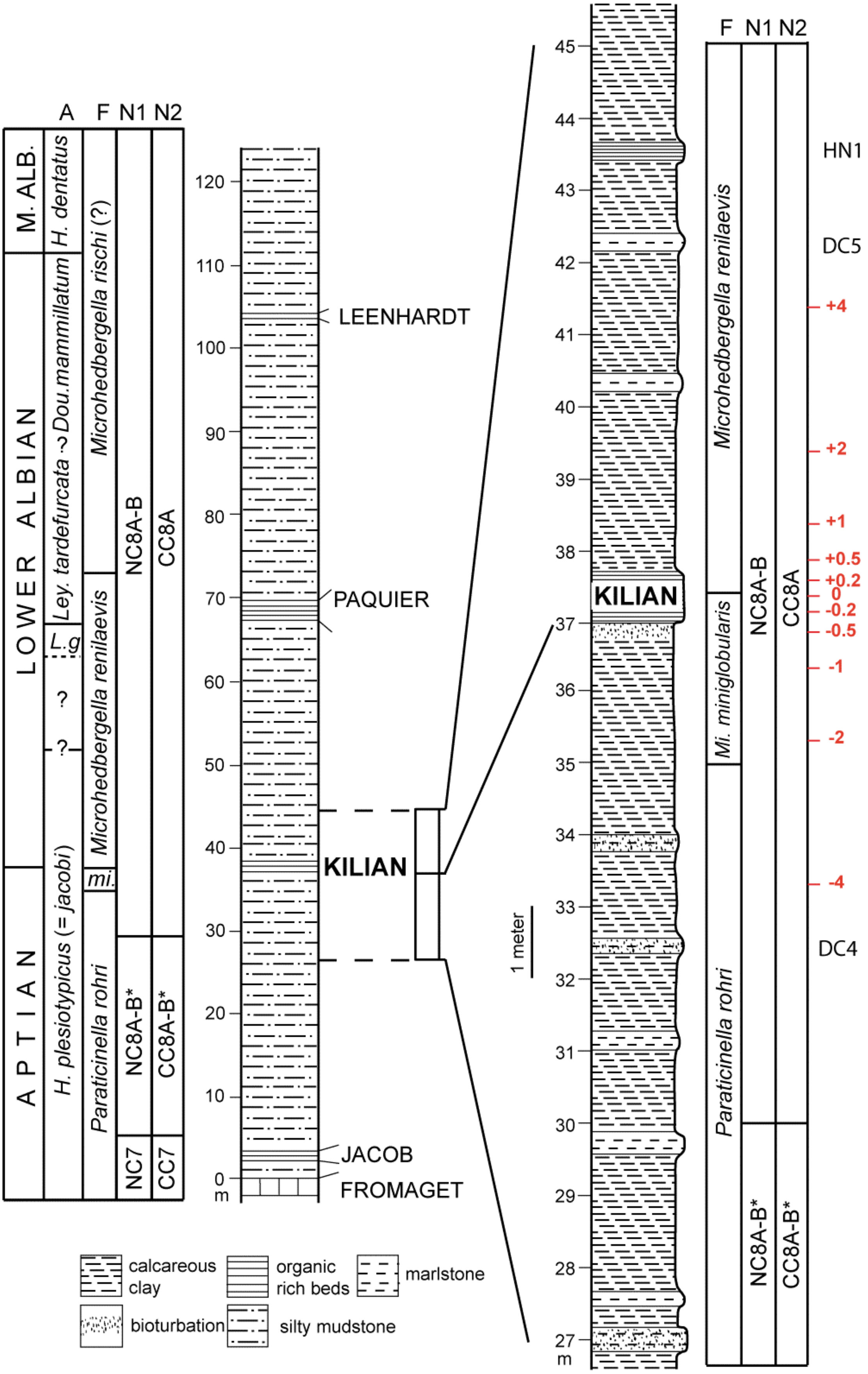
Pré-Guittard, Arnayon (Baronnies, France)

W.J. Kennedy, A.S. Gale, B.T. Huber, M.R. Petrizzo, P.R. Bown & H.C. Jenkyns



Palynomorphs from Aptian-Albian transition (France): Preliminary results

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Introduction

The Albian GSSP is sited on the territory of the municipality of Arnayon (France). According to Granier (this volume), it is located in Forêt Domaniale d'Aiguebelle at 44°30'28.3"N 5°17'50.1"E, not at 44°29' 47.78"N 5°18'36"E as stated earlier in the draft version of Kennedy *et al.* (in press). There eleven samples collected by Granier in the interval adjacent to the Aptian-Albian boundary have been analysed for palynomorphs (M. Arai), but also for calcareous nannofossils (R.L. Antunes, this volume).

The samples were collected in the following levels:

Sample B: level +4.0 m
Sample K: level +2.0 m
Sample G: level +1.0 m
Sample X: level +0.5 m
Sample W: level +0.2 m
Sample E: level 0.0 m
Sample M: level −0.2 m
Sample L: level −0.5 m
Sample J: level −1.0 m
Sample N: level −2.0 m
Sample D: level −4.0 m

Material and method

All samples have a dark greyish argillaceous lithology.

For palynological analysis, the samples were immersed in 30% HCl until reaction ceased for carbonate removal. After washing with water, they were left in sodium hexametaphosphate solution for 8 hours within a magnetic agitator. After agitation, the solution was kept undisturbed for 12 hours to remove argillaceous components. This operation was repeated as necessary until the liquid became clear. The organic residues containing palynomorphs were separated by 2 g/ml-density $ZnCl_2$ solution. Finally, the dried residue was mounted on a glass slide with epox resin for microscopic examination.

Out of 11 samples, 6 contained rich palynological assemblages. The remainder (slides B, D, E, L and X) had relatively poor assemblages - containing less than 100 specimens per slide (Table 1). For each palynological slide prepared all palynomorphs were identified taxonomically and counted wih an optical microscope using transmitted light. The optical photomicrographs were taken using a Leica DFC310FX camera coupled with a Microscope Leica DM 2500P in a laboratory of UNESPetro. The palynological slides which were examined are deposited in the collection of São Paulo State University - UNESP, IGCE-UNESPetro, in Rio Claro, São Paulo, Brazil.

Palynological content

The assemblages consist of spores (18 taxa), gymnospermic pollen grains (12 taxa), dinoflagellate cysts (49 taxa) and few palynomorphs belonging to other groups, as listed below.

Spores

- Psilate trilete spores (Plate 1A, B)
- Scabrate trilete spore (Plate 1C)
- Verrucate trilete spore (Plate 1D)
- Cingulate trilete spores
- Trilobate cingulate spore (Plate 1F)
- Zonate trilete spores
- *Aequitriradites* sp. (Plate 1M)
- *Appendicisporites* sp. (Plate 1H)
- *Cicatricosisporites* aff. *avnimelechi*
- *Cicatricosisporites* aff. *berouensis* (Plate 1I)
- *Cicatricosisporites* aff. *venustus* (Plate 1J)
- *Cicatricosisporites* sp. (Plate 1G)
- *Cicatricososporites* sp.
- *Contignisporites* ? sp. (Plate 1K)
- *Echitriletes* sp.
- *Foveotriletes* sp. (Plate 1L)
- *Klukisporites* sp.
- *Rugutriletes* sp. (Plate 1E)
-

Pollen grains

- *Araucariacites australis*
- *Araucariacites* spp.
- *Callialasporites dampieri* (Plate 1T)
- *Callialasporites triangularis*
- *Callialasporites* sp.
- *Circulina* spp.
- *Classopollis* sp. (Plate 1N, O)
- Disaccites (*Podocarpidites*-type pollen) (Plate 1Q, R, S)
- Gnetaceaepollenites sp. (Plate 1P)
- Inaperturopollenites turbatus
- Inaperturopollenites spp.
- Uesuguipollenites callosus

Dinoflagellate cysts

- *Achomosphaera neptuni* (Plate 3L)
- *Achomosphaera* ? sp.
- *Aptea polymorpha* (Plate 2T)
- *Batiacasphaera* ? spp.
- *Callaiosphaeridium trycherium* (Plate 2P)
- *Cauca parva* (Plate 4A)
- *Chlamydophorella nyei* (Plate 3C)
- *Circulodinium brevispinosum* (Plate 2X)
- *Circulodinium colliveri*
- *Circulodinium distinctum* (Plate 2V, W)
- *Circulodinium* spp.
- *Cribroperidinium intricatum* (Plate 3O)
- *Cribroperidinium muderongense* (Plate 3R)
- *Cribroperidinium* spp. (Plate 3N, P, Q, S, T)
- *Dapsilidinium* sp. (Plate 2S)
- *Florentinia mantelli*i (Plate 2K)
- *Florentinia* spp. (Plate 2L, M)
- *Fromea amphora* (Plate 4D)
- *Fromea* spp.
- *Hafniasphaera* sp. (Plate 3E)
- *Hapsocysta peridictya* (Plate 4B)
- *Heterosphaeridium* sp. (Plate 3A)
- *Hystrichosphaeridium* spp. (Plate 2N, O)
- *Impletosphaeridium* ? spp. (Plate 4G)
- *Kallosphaeridium ringnesiorum* (Plate 4C)
- *Kallosphaeridium* sp.
- *Odontochitina operculata* (Plate 4E, F)
- *Odontochitina singhii* (Plate 4I)
- *Oligosphaeridium asterigerum* (Plate 2B)
- *Oligosphaeridium complex* (Plate 2C, G)
- *Oligosphaeridium djenn* ?
- *Oligosphaeridium* aff. *tenuiprocessum* (Plate 2A)
- *Oligosphaeridium* spp. (Plate 2D, E, F, H, J)
- *Palaeoperidinium cretaceum* (Plate 4H)
- *Pervosphaeridium cenomaniense*
- *Pseudoceratium* aff. *anaphrissum* (Plate 2U)
- *Pterodinium cingulatum* (Plate 3K, M)
- *Pterodinium* spp.
- *Spinidinium* ? sp.
- *Spiniferites* spp. (Plate 3F, G, H, I, J)
- *Stiphrosphaeridium anthophorum* (Plate 2I)
- *Subtilisphaera* spp.
- *Surculosphaeridium trunculum* (Plate 2R)
- *Systematophora granulosa* (Plate 2Q)
- *Systematophora* sp. (Plate 3B)
- *Tanyosphaeridium* ? sp.
- *Trichodinium* sp.
- *Wrevittia cassidata* (Plate 3D)
- *Wrevittia* ? /*Gonyaulacysta* ? spp.

Miscellaneous

- Prasinophytes
- Palynoforaminifera:
  - Uniserial palynoforaminifera (Plate 4O, P)
  - Biserial palynoforaminifera (Plate 4Q)
  - Trochospiral palynoforaminifera (Plate 4J, K, L, M, N)
- Fungal remains
- Hyphae
- Microthyriaceae (fruiting bodies)
- *Phragmothyrites* spp. (Plate 1V, W)
- Copepod eggs (Plate 4R, S)

Palynostratigraphy

Among palynomorphs identified, only dinoflagellates provided stratigraphically important species, according to a species stratigraphic range given by WILLIAMS & BUJAK (1985) and COSTA & DAVEY (1992). The ranges of 14 selected dinoflagellate species are shown in Figure 1.

Table 1: Quantitative rough palynological data of the studied samples (absolute count).

SAMPLING LEVEL (m)		-4	-2	-1	-0.5	-0.2	0	0.2	0.5	1	2	4
SLIDE IDENTIFICATION		D	N	J	L	M	E	W	X	G	K	B
MARINE PALYNOMORPHS	*Achomosphaera neptuni*			1								
	Achomosphaera ? sp.				1							
	Aptea polymorpha		1									
	Batiacasphaera ? spp.				1							1
	Callaiosphaeridium trycherium				1							
	Cauca parva											1
	Chlamydophorella nyei		1									
	Circulodinium brevispinosum				1							
	Circulodinium colliveri				1							
	Circulodinium distinctum	7	7	25	7	2			2	3		
	Circulodinium spp.		1		2		1		10			
	Cribroperidinium intricatum			1								
	Cribroperidinium muderongense									1		
	Cribroperidinium spp.	7			2		1	3	1	13	10	8
	Dapsilidinium sp.											1
	Florentinia mantellii		1	1						1		
	Florentinia spp.						1	1		1	1	1
	Fromea amphora				2	4	1	1	1	2		
	Fromea spp.	1	1					1				
	Hafniasphaera sp.			1								
	Hapsocysta peridictya				1			2				
	Heterosphaeridium spp.		2		2			2				
	Hystrichosphaeridium spp.			2				1				
	Impletosphaeridium ? spp.	1		1							1	1
	Kallosphaeridium ringnesiorum										1	
	Kallosphaeridium sp.		1									
	Odontochitina operculata				2			1				
	Odontochitina singhii				1							
	Oligosphaeridium asterigerum				1							
	Oligosphaeridium complex			1	1		1	1				1
	Oligosphaeridium djenn ?											1
	Oligosphaeridium aff. *tenuiprocessum*				3					1		
	Oligosphaeridium spp.	2			10		1	3	4			5
	Palaeoperidinium cretaceum				1					1		1
	Pervosphaeridium cenomaniense			1								
	Pseudoceratium aff. *anaphrissum*							2				
	Pterodinium cingulatum							3		1		
	Pterodinium spp.	1		1						2		
	Spinidinium ? sp.		1									
	Spiniferites spp.	2	7	2	1	1	1	10	8	21	5	7
	Stiphrosphaeridium anthophorum				1							
	Surculosphaeridium trunculum							1				
	Systematophora granulosa							1				
	Systematophora sp.			1								
	Tanyosphaeridium ? sp.											1
	Trichodinium sp.											1
	Wrevittia cassidata	1		1								
	Wrevittia ? /*Gonyaulacysta* ? Spp.				1			1			1	
	Subtilisphaera spp.											3
	Dinoflagellate indet.	2	3	3		1	1	1	8	4		1
	Prasinophytes					2						
	Palynoforaminifera uniserial						1					
	Palynoforaminifera biserial							1				

SAMPLING LEVEL (m)		-4	-2	-1	-0.5	-0.2	0	0.2	0.5	1	2	4
SLIDE IDENTIFICATION		D	N	J	L	M	E	W	X	G	K	B
SPORES (PTERIDOPHYTES)	Trilete psilate	2	55	6	2	110	4	55		2	13	2
	Trilete verrucate	1	4		1	1			1	2	4	
	Trilete ornament.		2			2		10		1		
	Trilete cingulate			2	1	2	1	1			4	
	Trilete cingulate trilobate							1				
	Trilete zonate					1						
	Echitriletes sp.							1				
	Foveotriletes spp.				1		1					
	Klukisporites spp.					1			1			
	Rugutriletes spp.										2	
	Cicatricosisporites spp.					8	1	5		7	2	
	Cicatricosisporites aff. *avnimelech* i						1					
	Cicatricosisporites aff. *berouensis*						1					
	Cicatricosisporites aff. *venustus*			1								
	Appendicisporites / *Plicatella* spp.				1	1		1				
	Cicatricososporites sp.					1						
	Contignisporites ? sp.									1		
	Aequitriradites spp.			2								
POLLEN (GYMNOSPERMS)	*Classopollis* / *Circulina* spp.	5	3	3	5			10	1	35	10	
	Classopollis in tetrad		2	3			1	1		4		
	Gnetaceaepollenites sp.				1							
	Araucariacites spp.		4			5	1	10			3	
	Araucariacites australis				1							
	Uesuguipollenites callosus					1						
	Callialasporites sp.			1								
	Callialasporites dampieri					2		1				
	Callialasporites triangularis			1						1		
	Disaccites	25	95	75	20	101	42	95	8	70	100	8
	Inaperturopollenites spp.				1				3			
	Inaperturopollenites turbatus				3	1						
OTHERS	Fungi (hyphae)									5		
	Fungi (Microthyriaceae)			3						1		
	Copepod egg				1							
	Trichomes			1	2			1				
	Palynomorph indet.			1	1							

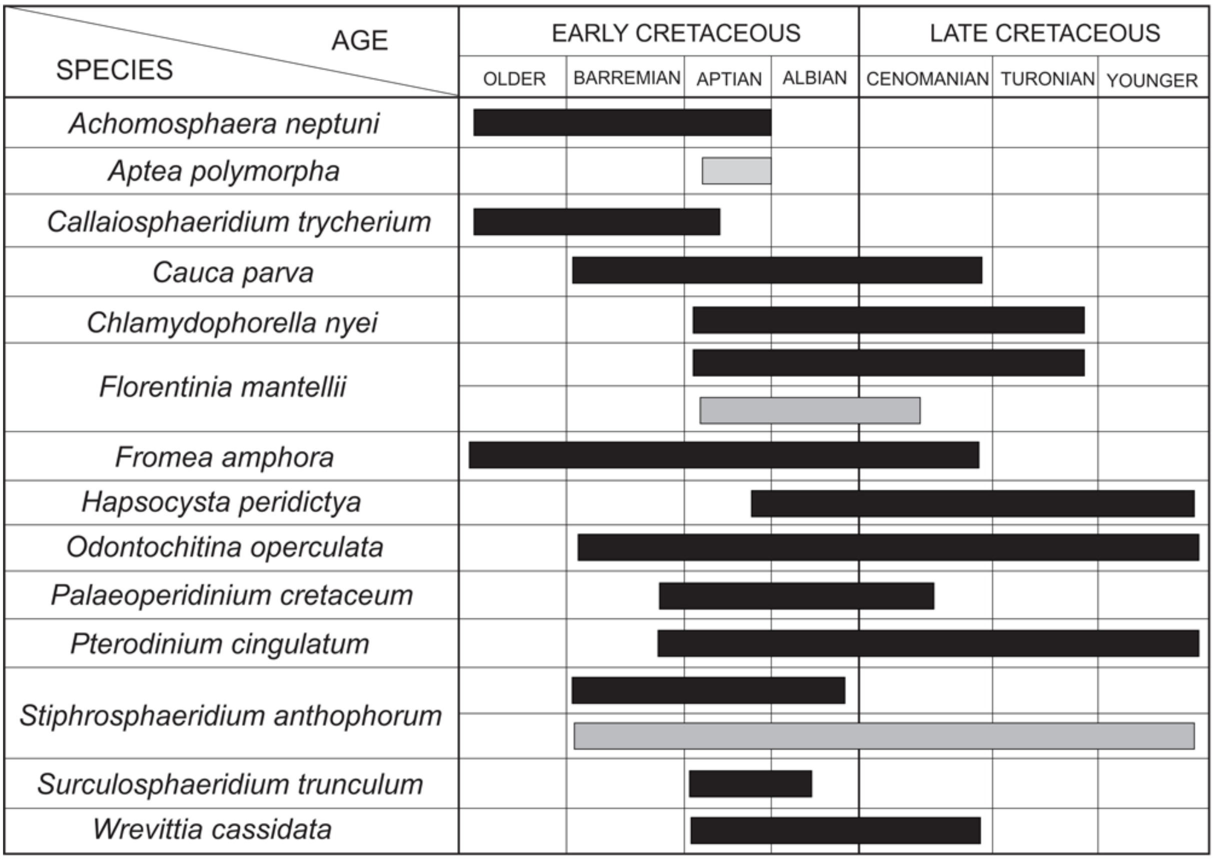


Figure 1: Stratigraphic range of selected dinoflagellate species. Grey bars are ranges given by WILLIAMS & BUJAK (1985) and black bars are ranges given by COSTA & DAVEY (1992).

Based on the COSTA & DAVEY (1992) range chart, the presence of *Callaiosphaeridium trycherium* suggests that the interval below level -0.5 m (slide L) is not younger than early Aptian. On the other hand, the same sample contains *Hapsocysta peridictya*. This co-occurrence constitutes a problem, because, according to COSTA & DAVEY (1992), these two species should not be found at the same stratigraphic level because they are not coeval. In the biostratigraphic scheme of these authors, the LAD (Last Appearance Datum) of *Callaiosphaeridium trycherium* is situated below the FAD (First Appearance Datum) of *Hapsocysta peridictya* (Figure 1). Consequently, based on the range chart of COSTA & DAVEY (1992), the level -0.5 m would be close to the lower-upper Aptian subtage boundary, which is obviously not the case here. To explain this, there are two options: (1) the extinction event of *Callaiosphaeridium trycherium* was younger than that supposed by COSTA & DAVEY (1992); or (2) *Callaiosphaeridium trycherium* was introduced into this stratigraphic level by reworking.

The palynological study was not able to identify the Aptian-Albian boundary. The only species having LAD at the boundary is *Achomosphaera neptuni*, but this species was observed only in level -1 m (slide J). No species with FAD at the Aptian-Albian boundary was observed in the studied material.

Palaeoenvironment

The presence of marine palynomorphs (mostly dinoflagellate cysts and palynoforaminifera) in all samples assures that the depositional environment was marine. However the ratio between continental palynomorphs and marine palynomorphs (C/M Ratio) varied significantly in the studied section (Figure 2). This fact suggests that the amount of continental water input varied. However we must pay attention to fact that the most abundant continental palynogroup is the Disaccites group that is dominated by anemophilous pollen grains (wind-transported pollen grains). Therefore, they are not indicative of continental input.

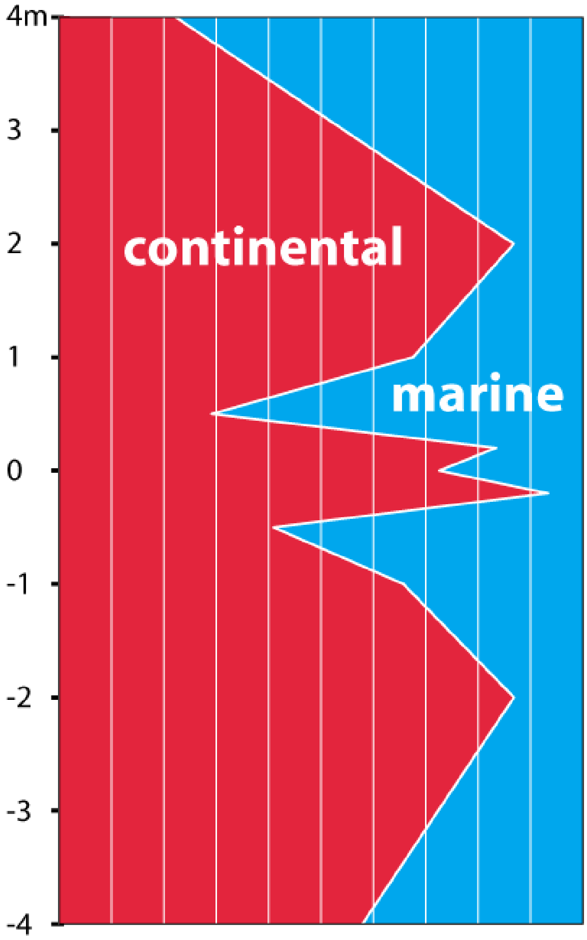


Figure 2: Continental and marine palynomorph ratios from studied samples.

Conclusions

The original material was deposited in a marine environment but the amount of continental input varied significantly.

Unfortunately it looks like palynological studies cannot help identifying the Aptian-Albian boundary.

Plate 1: Spores, pollen and fungal remains

A. Psilate trilete spore. Level –4.0 m (slide D).
B. Psilate trilete spore. Level +4.0 m (slide B).
C. Scabrate trilete spore. Level +1.0 m (slide G).
D. Verrucate trilete spore. Level +1.0 m (slide G).
E. *Rugutriletes* sp. Level –2.0 m (slide N).
F. Lobate trilete spore. Level +0.2 m (slide W).
G. *Cicatricosisporites* sp. Level –0.2 m (slide M).
H. *Appendicisporites* sp. Level +1.0 m (slide G).
I. *Cicatricosisporites* aff. *berouensis*. Level 0.0 m (slide E).
J. *Cicatricosisporites* aff. *venustus*. Level –1.0 m (slide J).
K. *Contignisporites* ? sp. Level +1.0 m (slide G).
L. *Foveotriletes* sp. Level –0.5 m (slide L2).
M. *Aequitriradites* sp. Level –1.0 m (slide J).
N. *Classopollis classoides*. Level –4.0 m (slide D).
O. *Classopollis classoides* in tetrad. Level +0.2 m (slide W).
P. *Gnetaceaepollenites* sp. Level –0.5 m (slide L2).
Q. *Podocarpidites* sp 1. Level +1.0 m (slide G).
R. *Podocarpidites* sp 2. Level –0.2 m (slide M).
S. *Podocarpidites* sp 3. Level +0.2 m (slide W).
T. *Callialasporites dampieri*. Level +0.2 m (slide W).
U. *Callialasporites* aff. *dampieri*. Level –0.2 m (slide M).
V. *Phragmothyrites* sp. (fungal fruiting body). Level –1.0 m (slide J).
W. *Phragmothyrites* sp. (two fungal fruiting bodies). Level –1.0 m (slide J).

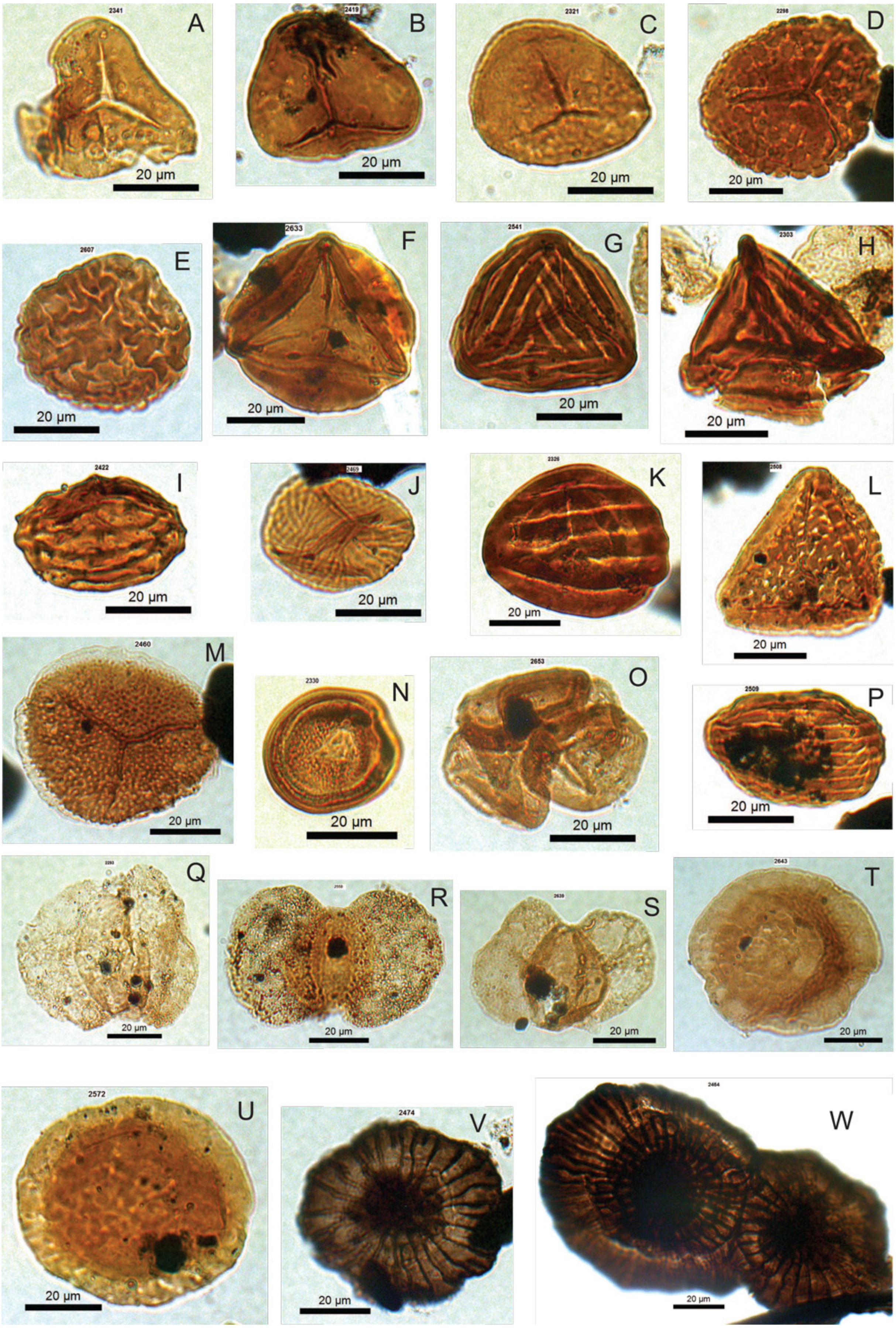

A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
20 µm

Plate 2: Dinoflagellate cysts (Dinocysts)

1. *Oligosphaeridium* aff. *tenuiprocessum*. Level –0.5 m (slide L).
2. *Oligosphaeridium asterigerum*. Level –0.5 m (slide L/LD-1).
3. *Oligosphaeridium complex*. Level –0.5 m (slide L2).
4. *Oligosphaeridium* sp. 1. Level +0.5 m (slide X2).
5. *Oligosphaeridium* sp. 2. Level +0.5 m (slide X2).
6. *Oligosphaeridium* sp. 3. Level –0.5 m (slide L/LD-1).
7. *Oligosphaeridium complex*. Level –0.5 m (slide L/LD-1).
8. *Oligosphaeridium* sp. 4. Level –4.0 m (slide D).
9. *Stiphrosphaeridium anthophorum*. Level –0.5 m (slide L2).
10. *Oligosphaeridium* sp. 5. Level +0.5 m (slide X2).
11. *Florentinia mantellii*. Level +1.0 m (slide G).
12. *Florentinia* sp. 1. Level +1.0 m (slide G).
13. *Florentinia* sp. 2. Level +2.0 m (slide K).
14. *Hystrichosphaeridium* sp. 1. Level –1.0 m (slide J).
15. *Hystrichosphaeridium* sp. 2. Level –1.0 m (slide J).
16. *Callaiosphaeridium tricherium*. Level –0.5 m (slide L/LD-1).
17. *Systematophora granulosa*. Level +0.2 m (slide W).
18. *Surculosphaeridium trunculum*. Level +0.2 m (slide W).
19. *Dapsilidinium* sp. Level +4.0 m (slide B).
20. *Aptea polymorpha*. Level –2.0 m (slide N).
21. *Pseudoceratium* aff. *anaphrissum*. Level +0.2 m (slide W).
22. *Circulodinium distinctum*. Level +1.0 m (slide G).
23. *Circulodinium distinctum*. Level –1.0 m (slide J).
24. *Circulodinium brevispinosum*. Level –0.5 m (slide L/LD-1).

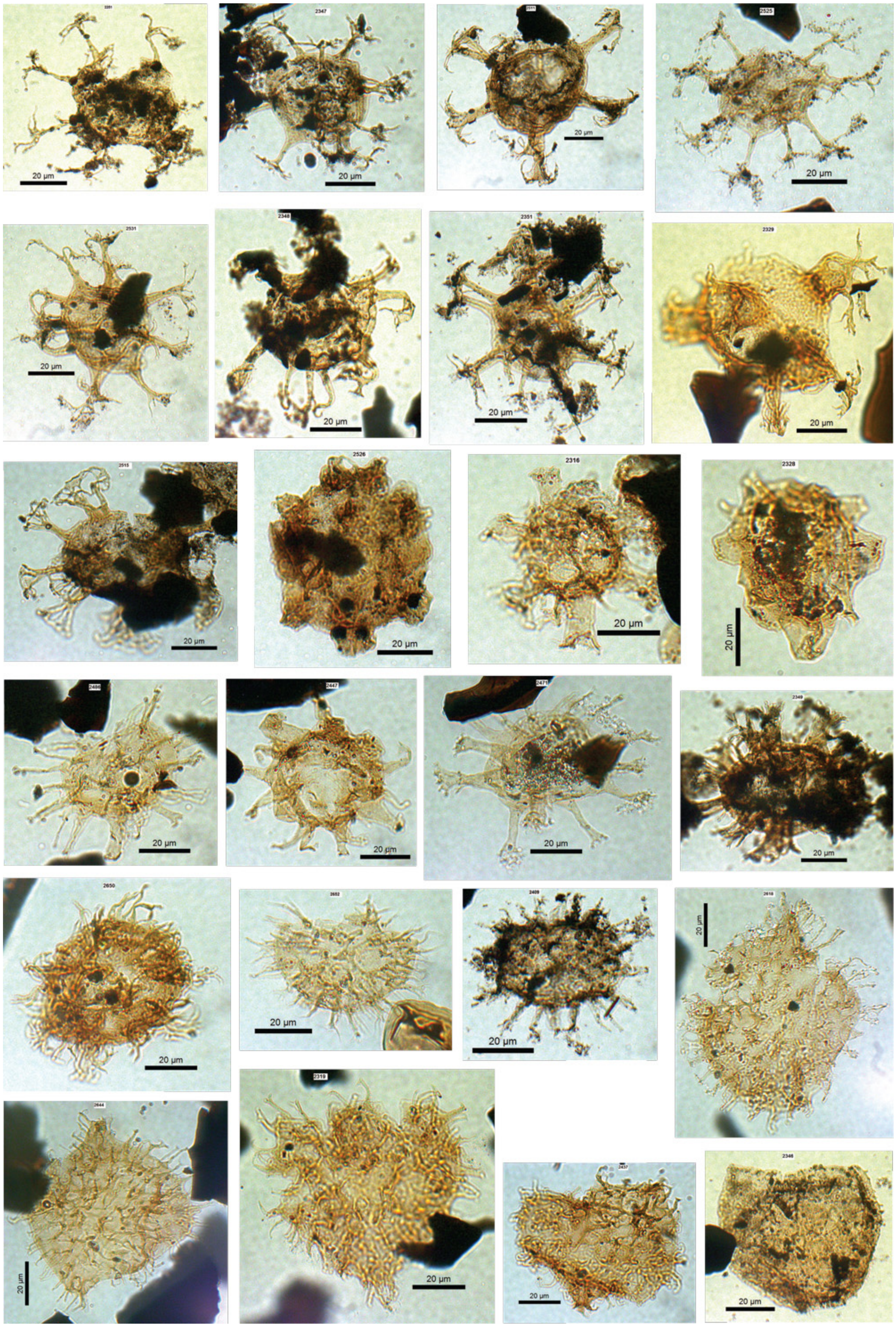


Plate 3: Dinocysts

1. *Heterosphaeridium* sp. Level −0.5 m (slide L2).
2. *Systematophora* sp. Level −1.0 m (slide J).
3. *Chlamydophorella nyei*. Level −2.0 m (slide N).
4. *Wrevittia cassidata*. Level −4.0 m (slide D).
5. *Hafniasphaera* sp. Level −1.0 m (slide J).
6. *Spiniferites* sp. 1. Level −1.0 m (slide J).
7. *Spiniferites* sp. 2. Level +2.0 m (slide K).
8. *Spiniferites* sp. 3. Level +2.0 m (slide K).
9. *Spiniferites* sp. 4. Level +0.2 m (slide W).
10. *Spiniferites* sp. 5. Level −2.0 m (slide N).
11. *Pterodinium cingulatum*. Level +1.0 m (slide G).
12. *Achomosphaera neptuni*. Level −1.0 m (slide J).
13. *Pterodinium cingulatum*. Level +0.2 m (slide W).
14. *Cribroperidinium* sp. 1. Level −4.0 m (slide D).
15. *Cribroperidinium intricatum*. Level −1.0 m (slide J).
16. *Cribroperidinium* sp. 2. Level +1.0 m (slide G).
17. *Cribroperidinium* sp. 3. Level −2.0 m (slide N).
18. *Cribroperidinium muderongense*. Level +1.0 m (slide G).
19. *Cribroperidinium* sp. 4. Level +2.0 m (slide K).
20. *Cribroperidinium* sp. 5. Level −4.0 m (slide D).

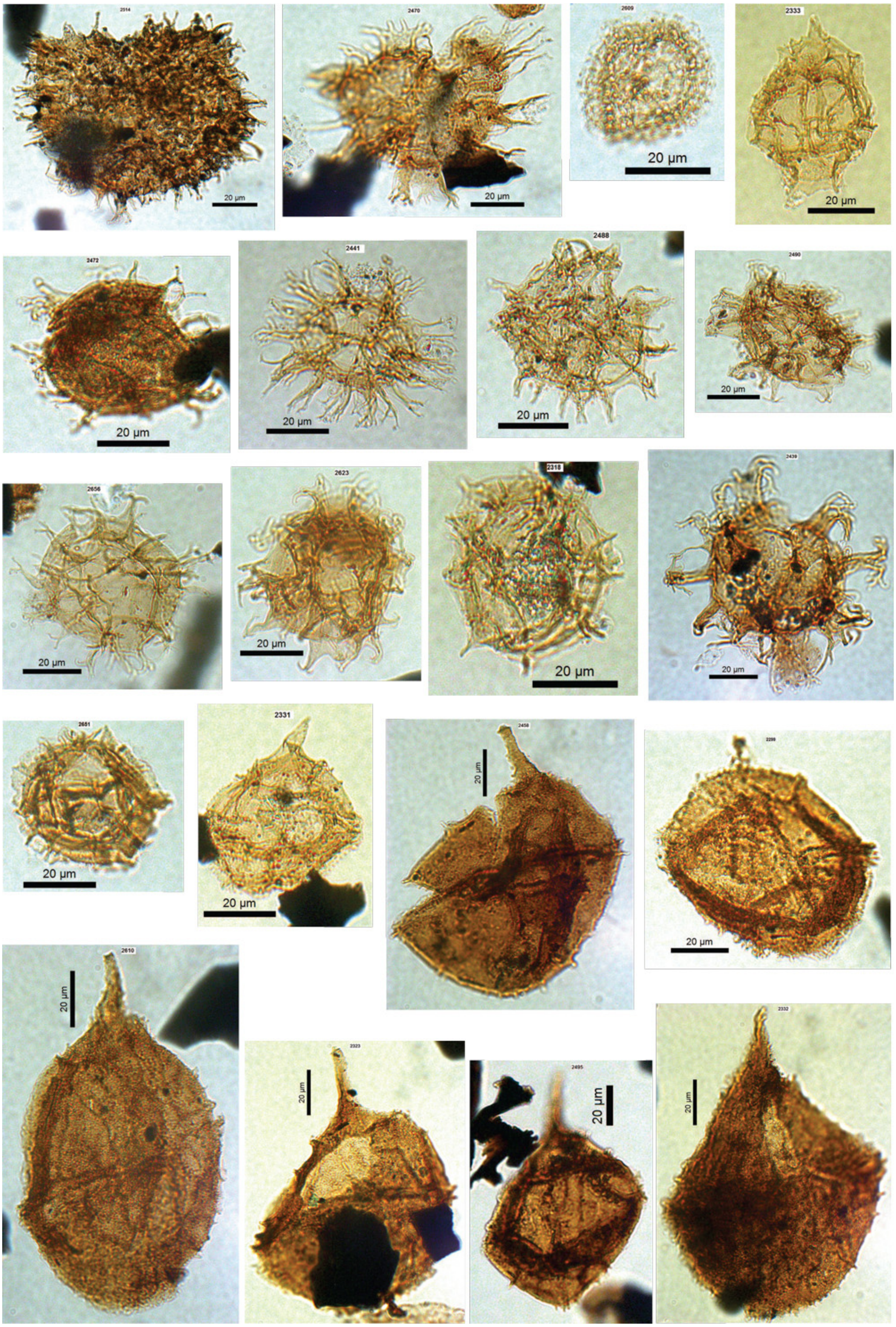
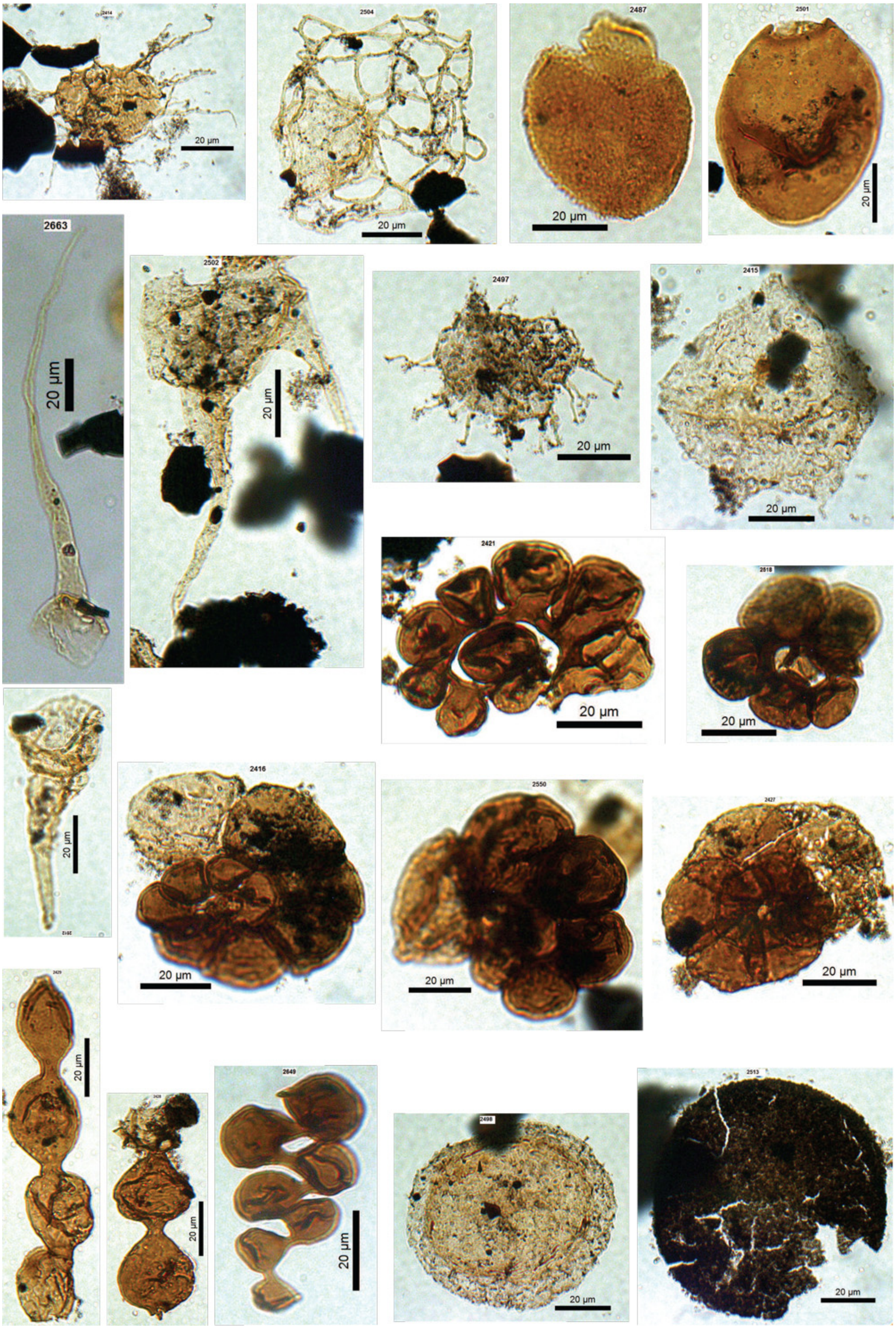

2333
2441
2488
2318
2331
20 µm

Plate 4: Dinocysts and other marine palynomorphs

1. *Cauca parva*. Level +4.0 m (slide B).
2. *Hapsocysta peridyctia*. Level −0.5 m (slide L2).
3. *Kallosphaeridium ringnesiorum*. Level +2.0 m (slide K).
4. *Fromea amphora*. Level −0.5 m (slide L2).
5. *Odontochitina operculata* (operculum). Level +0.2 m (slide W).
6. *Odontochitina operculata*. Level −0.5 m (slide L2).
7. *Impletosphaeridium* ? sp. Level −0.5 m (slide L2).
8. *Palaeoperidinium cretaceum*. Level +4.0 m (slide B).
9. *Odontochitina singhii*. Level −0.5 m (slide L2).
10. Trochospiral palynoforaminifer (foraminiferal lining). Level +4.0 m (slide B).
11. Trochospiral palynoforaminifer. Level 0.0 m (slide E).
12. Trochospiral palynoforaminifer. Level −0.5 m (slide L2).
13. Trochospiral palynoforaminifer. Level −0.2 m (slide M).
14. Trochospiral palynoforaminifer (with closed umbilicus). Level 0.0 m (slide E).
15. Uniserial palynoforaminifer. Level 0.0 m (slide E).
16. Uniserial palynoforaminifer (fragment). Level 0.0 m (slide E).
17. Biserial palynoforaminifer. Level +0.2 m (slide W).
18. Copepod egg (type 1). Level −0.5 m (slide L2).


2504
2487
2501
2663
2502
2497
2415
2421
2416
2550
2649
2498
2513
20 µm

Calcareous nannofossils from Aptian-Albian transition (France): Preliminary results

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Plate 5: Calcareous nannofossils

A. *Bukrylithus ambiguus*. Level +4.0 m (slide Bn).
B. *Bukrylithus ambiguus*. Level −0.5 m (slide Xn).
C. *Chiastozygus litterarius*. Level −4.0 m (slide Dn).
D. *Chiastozygus litterarius*. Level −4.0 m (slide Dn).
E. *Loxolithus armilla*. Level −0.5 m (slide Xn).
F. *Loxolithus armilla*. Level −0.5 m (slide Xn).
G. *Staurolithites crux*. Level −0.5 m (slide Xn).
H. *Staurolithites crux*. Level −2.0 m (slide Nn).
I. *Staurolithites gausorhethium*. Level −0.5 m (slide Xn).
J. *Staurolithites gausorhethium*. Level 0.0 m (slide En).
K. *Staurolithites glaber*. Level −0.5 m (slide Xn).
L. *Staurolithites glaber*. Level −0.5 m (slide Xn).
M. *Staurolithites mitcheri*. Level +0.2 m (slide Wn).
N. *Staurolithites mitcheri*. Level +0.2 m (slide Wn).
O. *Staurolithites siesseri*. Level −2.0 m (slide Nn).
P. *Staurolithites siesseri*. Level −0.2 m (slide Mn).
Q. *Tranolithus gabalus*. Level +4.0 m (slide Bn).
R. *Tranolithus gabalus*. Level −0.2 m (slide Mn).
S. *Zeugrhabdotus burwellensis*. Level −0.2 m (slide Mn).
T. *Zeugrhabdotus burwellensis*. Level −0.2 m (slide Mn).
U. *Zeugrhabdotus diplogrammus*. Level +0.2 m (slide Wn).
V. *Zeugrhabdotus diplogrammus*. Level +0.2 m (slide Wn).
W. *Zeugrhabdotus embergeri*. Level −0.5 m (slide Xn).
X. *Zeugrhabdotus embergeri*. Level −0.5 m (slide Xn).

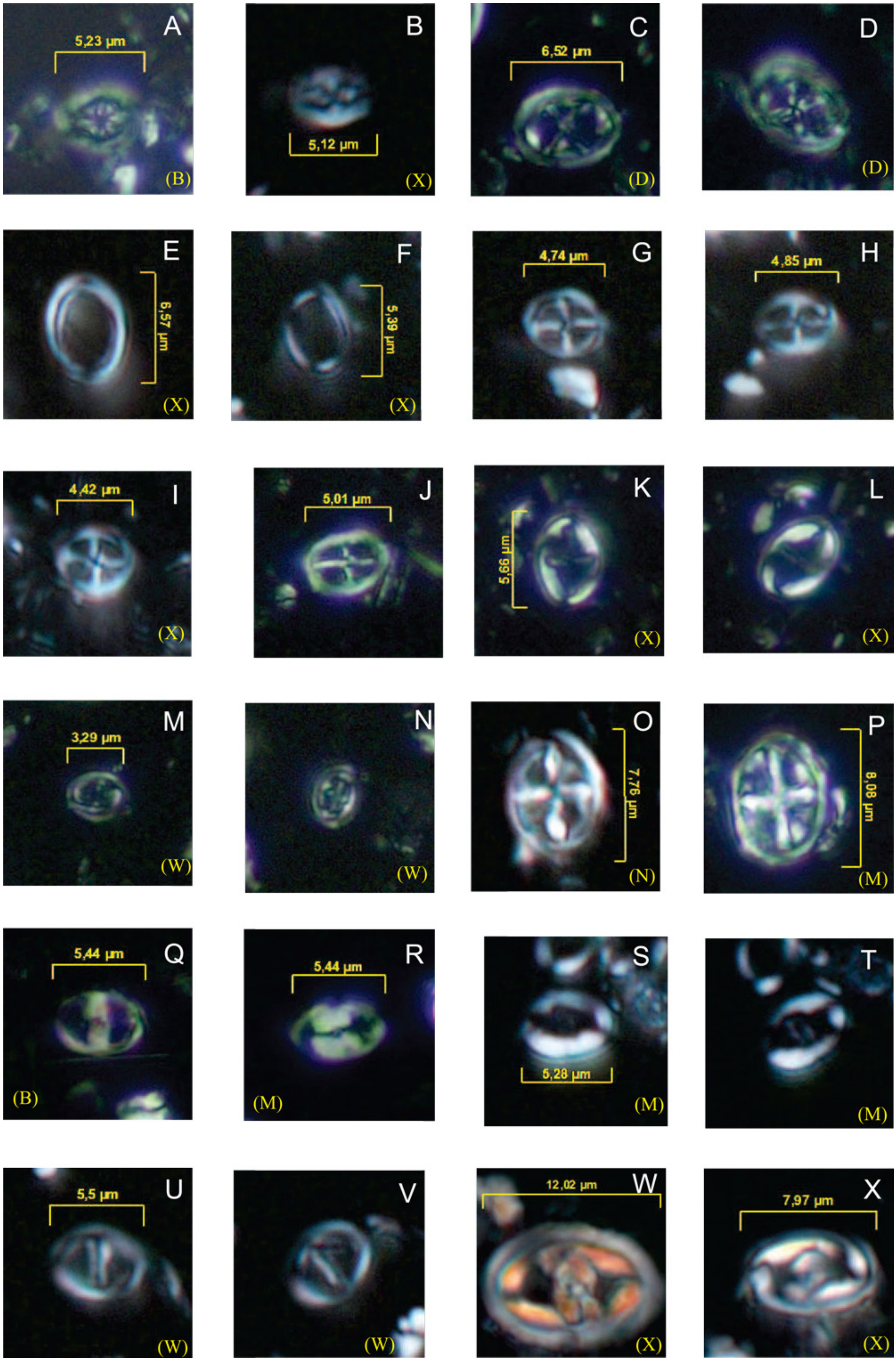

A
5,23 µm
(B)
B
5,12 µm
(X)
C
6,52 µm
(D)
D
(D)
E
6,57 µm
(X)
F
5,39 µm
(X)
G
4,74 µm
H
4,85 µm
I
4,42 µm
(X)
J
5,01 µm
K
5,66 µm
(X)
L
(X)
M
3,29 µm
(W)
N
(W)
O
7,76 µm
(N)
P
8,08 µm
(M)
Q
5,44 µm
(B)
R
5,44 µm
(M)
S
5,28 µm
(M)
T
(M)
U
5,5 µm
(W)
V
(W)
W
12,02 µm
(X)
X
7,97 µm
(X)

Plate 6: Calcareous nannofossils

A. *Zeugrhabdotus howei*. Level +4.0 m (slide Bn).
B. *Zeugrhabdotus howei*. Level +4.0 m (slide Bn).
C. *Zeugrhabdotus scutula*. Level −0.2 m (slide Mn).
D. *Zeugrhabdotus scutula*. Level +2.0 m (slide Kn).
E. *Zeugrhabdotus streetiae*. Level −0.2 m (slide Mn).
F. *Zeugrhabdotus streetiae*. Level +2.0 m (slide Kn).
G. *Zeugrhabdotus trivectis*. Level −0.5 m (slide Xn).
H. *Zeugrhabdotus trivectis*. Level −0.5 m (slide Xn).
I. *Zeugrhabdotus xenotus*. Level −0.5 m (slide Ln).
J. *Zeugrhabdotus xenotus*. Level −0.5 m (slide Ln).
K. *Eiffellithus hancokii*. Level +4.0 m (slide Bn).
L. *Eiffellithus hancokii*. Level +4.0 m (slide Bn).
M. *Helicolithus trabeculatus*. Level +4.0 m (slide Bn).
N. *Helicolithus trabeculatus*. Level −1.0 m (slide Jn).
O. *Tegumentum stradneri*. Level +4.0 m (slide Bn).
P. *Tegumentum stradneri*. Level 0.0 m (slide En).
Q. *Percivalia fenestrata*. Level −0.5 m (slide Ln).
R. *Percivalia fenestrata*. Level −0.5 m (slide Ln).
S. *Rhagodiscus achylostaurion*. Level −2.0 m (slide Nn).
T. *Rhagodiscus achylostaurion*. Level −0.5 m (slide Xn).
U. *Rhagodiscus angustus*. Level −2.0 m (slide Nn).
V. *Rhagodiscus angustus*. Level −2.0 m (slide Nn).
W. *Rhagodiscus asper*. Level −0.2 m (slide Mn).
X. *Rhagodiscus asper*. Level −0.2 m (slide Mn).

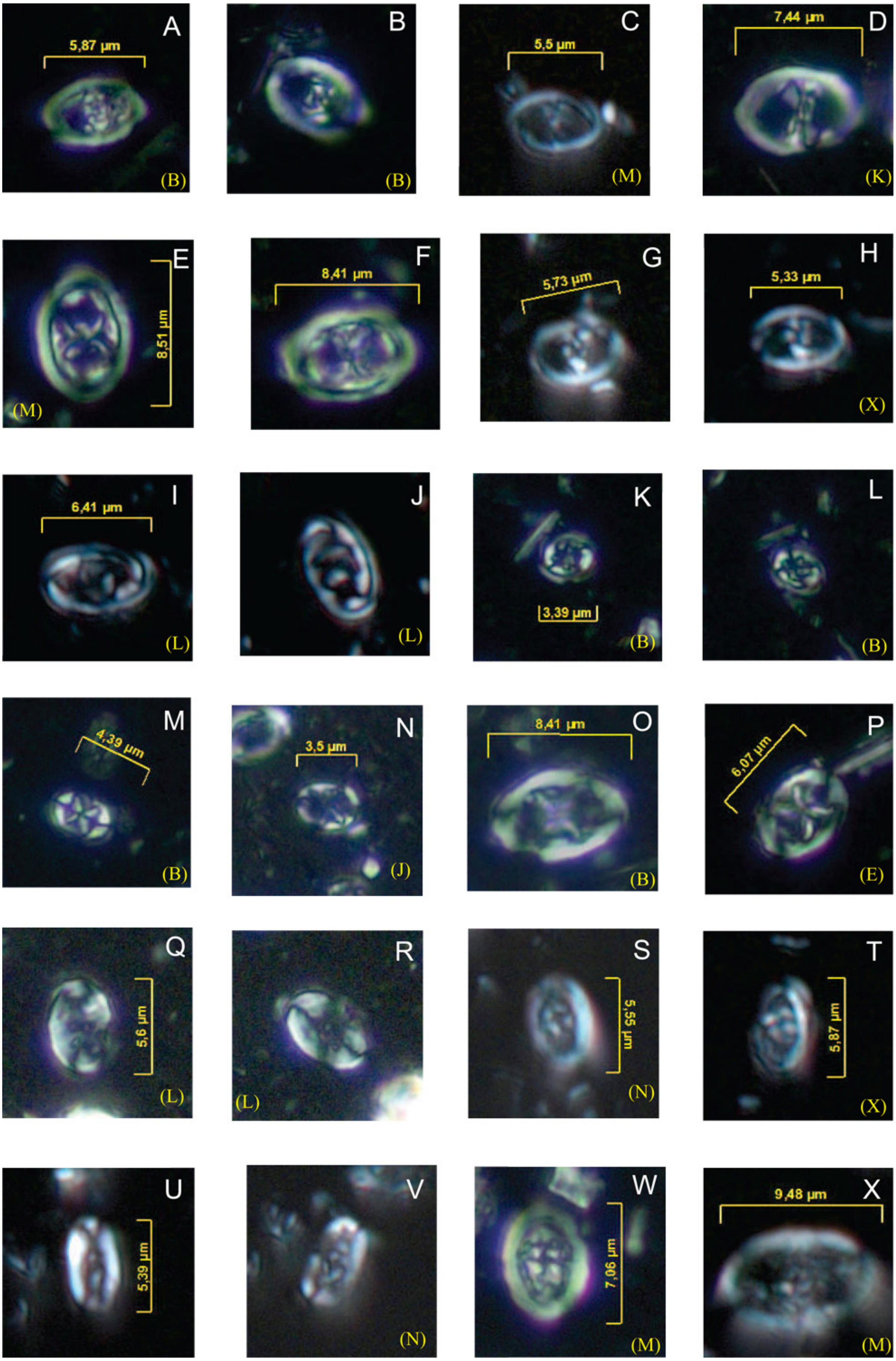

A
5,87 µm
(B)
B
(B)
C
5,5 µm
(M)
D
7,44 µm
(K)
E
8,51 µm
(M)
F
8,41 µm
G
5,73 µm
H
5,33 µm
(X)
I
6,41 µm
(L)
J
(L)
K
3,39 µm
(B)
L
(B)
M
4,39 µm
(B)
N
3,5 µm
(J)
O
8,41 µm
(B)
P
6,07 µm
(E)
Q
5,6 µm
(L)
R
(L)
S
5,55 µm
(N)
T
5,87 µm
(X)
U
5,39 µm
V
(N)
W
7,06 µm
(M)
X
9,48 µm
(M)

Plate 7: Calcareous nannofossils

A. *Rhagodiscus gallagheri*. Level −0.5 m (slide Xn).
B. *Rhagodiscus gallagheri*. Level −0.5 m (slide Xn).
C. *Rhagodiscus hamptonii*. Level +2.0 m (slide Kn).
D. *Rhagodiscus hamptonii*. Level +2.0 m (slide Kn).
E. *Rhagodiscus infinitus*. Level 0.0 m (slide En).
F. *Rhagodiscus infinitus*. Level 0.0 m (slide En).
G. *Rhagodiscus splendens*. Level +4.0 m (slide Bn).
H. *Rhagodiscus splendens*. Level −0.2 m (slide Mn).
I. *Stephanolithion laffitei*. Level −2.0 m (slide Nn).
J. *Stephanolithion laffitei*. Level −2.0 m (slide Nn)
K. *Stoverius achylosus*. Level −1.0 m (slide Jn).
L. *Stoverius achylosus*. Level −0.2 m (slide Mn).
M. *Tetrapodorhabdus coptensis*. Level −1.0 m (slide Jn).
N. *Tetrapodorhabdus coptensis*. Level −1.0 m (slide Jn).
O. *Biscutum constans*. Level −2.0 m (slide Nn).
P. *Biscutum constans*. Level −0.5 m (slide Xn).
Q. *Biscutum gaultensis*. Level +0.2 m (slide Wn).
R. *Biscutum gaultensis*. Level −1.0 m (slide Jn).
S. *Crucibiscutum hayi*. Level 0.0 m (slide En).
T. *Crucibiscutum hayi*. Level −1.0 m (slide Jn).
U. *Discorhabdus ignotus*. Level +0.2 m (slide Wn).
V. *Discorhabdus ignotus*. Level 0.0 m (slide En).
W. *Prediscosphaera columnata* (C-type). Level −0.2 m (slide Mn).
X. *Prediscosphaera columnata* (C-type). Level 0.0 m (slide En).

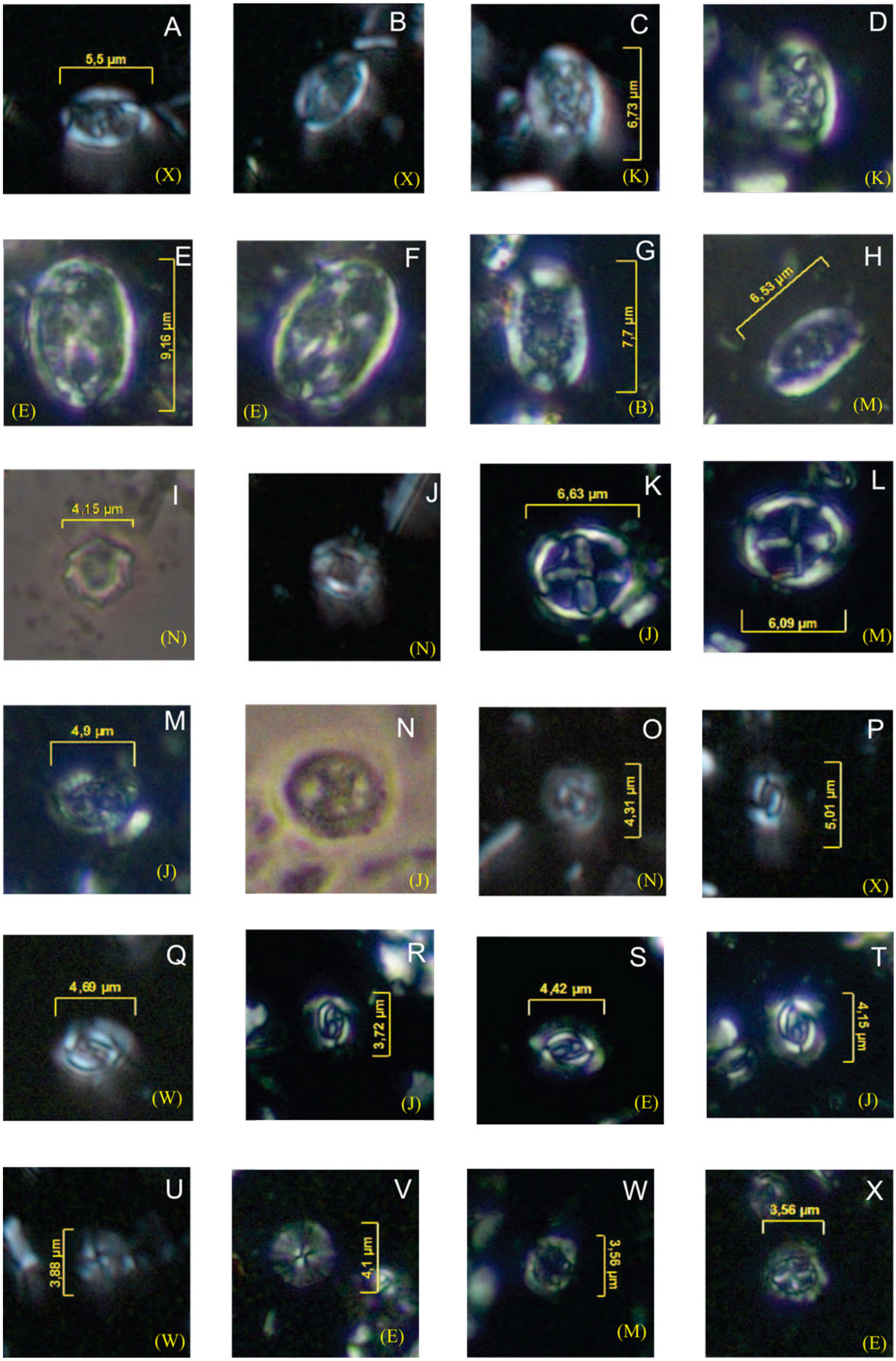

A
5,5 µm
(X)
B
(X)
C
6,73 µm
(K)
D
(K)
E
9,16 µm
(E)
F
(E)
G
7,7 µm
(B)
H
6,53 µm
(M)
I
4,15 µm
(N)
J
(N)
K
6,63 µm
(J)
L
6,09 µm
(M)
M
4,9 µm
(J)
N
(J)
O
4,31 µm
(N)
P
5,01 µm
(X)
Q
4,69 µm
(W)
R
3,72 µm
(J)
S
4,42 µm
(E)
T
4,15 µm
(J)
U
3,88 µm
(W)
V
4,1 µm
(E)
W
3,56 µm
(M)
X
3,56 µm
(E)

Plate 8: Calcareous nannofossils

A. *Prediscosphaera columnata* (S-type). Level –0.5 m (slide Ln).
B. *Prediscosphaera columnata* (S-type). Level +4.0 m (slide Bn).
C. *Prediscosphaera spinosa*. Level –0.2 m (slide Mn).
D. *Cretarhabdus conicus*. Level –0.5 m (slide Ln).
E. *Cretarhabdus striatus*. Level –0.2 m (slide Mn).
F. *Cretarhabdus striatus*. Level –1.0 m (slide Jn).
G. *Flabellites oblongus*. Level +0.2 m (slide Wn).
H. *Flabellites oblongus*. Level +0.2 m (slide Wn).
I. *Grantarhabdus cononadventis*. Level +0.2 m (slide Wn).
J. *Grantarhabdus cononadventis*. Level +0.2 m (slide Wn).
K. *Helenea chiastia*. Level –2.0 m (slide Nn).
L. *Helenea chiastia*. Level –0.5 m (slide Xn).
M. *Retecapsa crenulata*. Level +0.2 m (slide Wn).
N. *Retecapsa crenulata*. Level +0.2 m (slide Wn).
O. *Retecapsa surirella*. Level +4.0 m (slide Bn).
P. *Retecapsa surirella*. Level +4.0 m (slide Bn).
Q. *Manivitella pemmatoidea*. Level 0.0 m (slide En).
R. *Manivitella pemmatoidea*. Level –0.2 m (slide Mn).
S. *Tubodiscus burnettiae*. Level –0.2 m (slide Mn).
T. *Tubodiscus burnettiae*. Level –0.5 m (slide Xn).
U. *Cylindralithus nudus* ?. Level –4.0 m (slide Dn).
V. *Cylindralithus nudus* ?. Level –0.2 m (slide Mn).
W. *Watznaueria barnesiae*. Level –0.2 m (slide Mn).
X. *Watznaueria biporta*. Level –0.2 m (slide Mn).

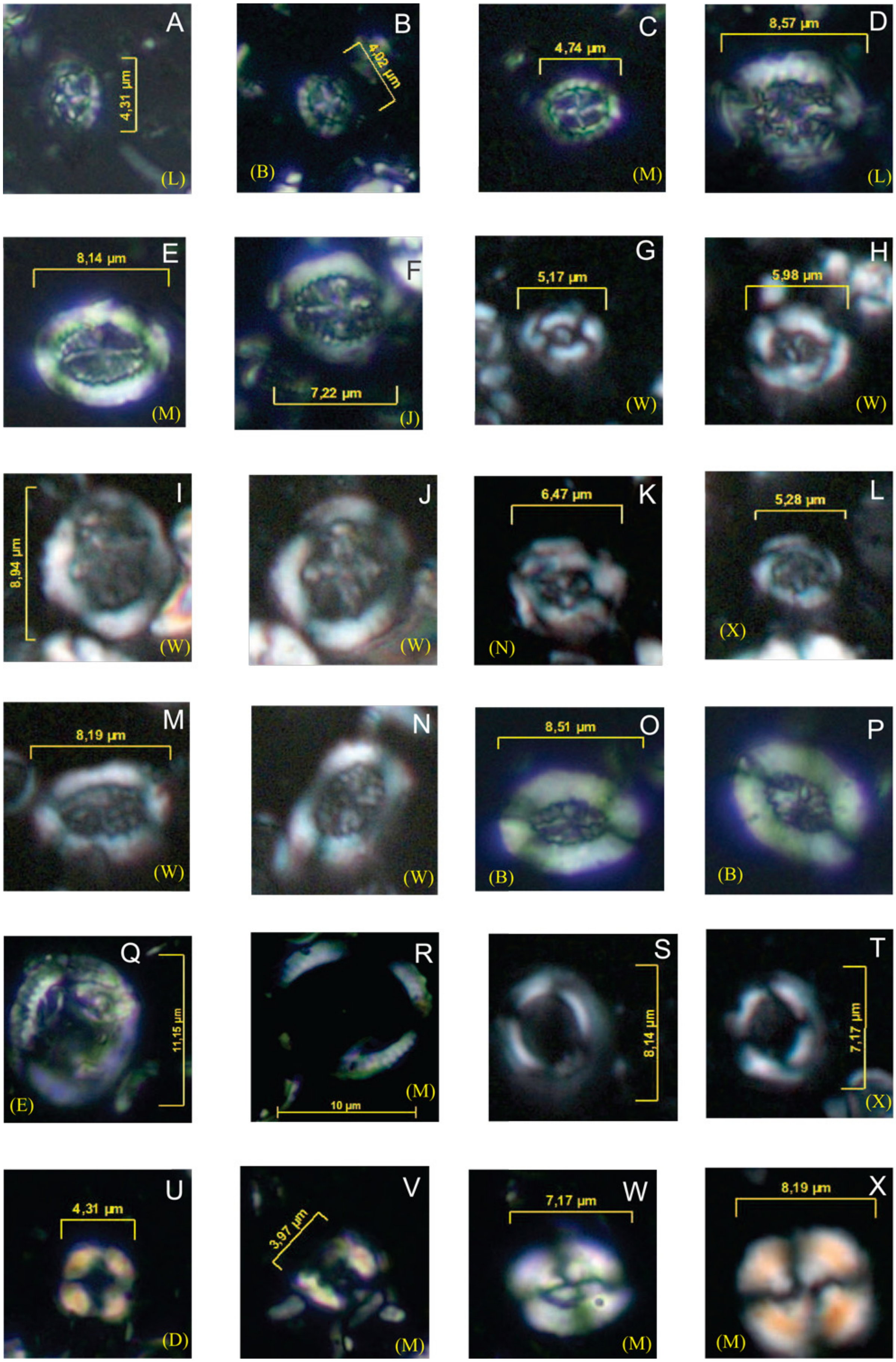

A
4,31 µm
(L)
B
4,02 µm
(B)
C
4,74 µm
(M)
D
8,57 µm
(L)
E
8,14 µm
(M)
F
7,22 µm
(J)
G
5,17 µm
(W)
H
5,98 µm
(W)
I
8,94 µm
(W)
J
(W)
K
6,47 µm
(N)
L
5,28 µm
(X)
M
8,19 µm
(W)
N
(W)
O
8,51 µm
(B)
P
(B)
Q
11,15 µm
(E)
R
10 µm
(M)
S
8,14 µm
T
7,17 µm
(X)
U
4,31 µm
(D)
V
3,97 µm
(M)
W
7,17 µm
(M)
X
8,19 µm
(M)

Plate 9: Calcareous nannofossils

A. *Watznaueria brittanica*. Level –0.5 m (slide Xn).
B. *Watznaueria fossacincta*. Level +0.2 m (slide Wn).
C. *Watznaueria manivitiae*. Level –1.0 m (slide Jn).
D. *Watznaueria ovata*. Level –2.0 m (slide Nn).
E. *Broinsonia* cf. *galloisii*. Level +2.0 m (slide Kn).
F. *Broinsonia galloisii*. Level –4.0 m (slide Dn).
G. *Broinsonia matalosa*. Level –0.5 m (slide Xn).
H. *Broinsonia matalosa*. Level –0.5 m (slide Xn).
I. *Broinsonia matalosa*. Level –2.0 m (slide Nn).
J. *Broinsonia matalosa*. Level –0.5 m (slide Xn).
K. *Gartnerago stenostaurion*. Level –0.5 m (slide Ln).
L. *Gartnerago stenostaurion*. Level –0.5 m (slide Ln).
M. *Gartnerago stenostaurion*. Level –0.2 m (slide Mn).
N. *Gartnerago stenostaurion*. Level –0.2 m (slide Mn).
O. *Haqius circunrariatus*. Level –0.2 m (slide Mn).
P. *Repagulum parvidentatum*. Level –0.5 m (slide Xn).
Q. *Lapideacassis mariae*. Level 0.0 m (slide En).
R. *Lapideacassis mariae*. Level –0.5 m (slide Ln).
S. *Nannoconus* sp. Level –4.0 m (slide Dn).
T. *Nannoconus* sp. Level +4.0 m (slide Bn).
U. *Nannoconus truitti frequens*. Level –2.0 m (slide Nn).
V. *Eprolithus floralis*. Level 0.0 m (slide En).
W. *Eprolithus floralis*. Level +4.0 m (slide Bn).
X. *Eprolithus floralis* (lateral view). Level –0.2 m (slide Mn).

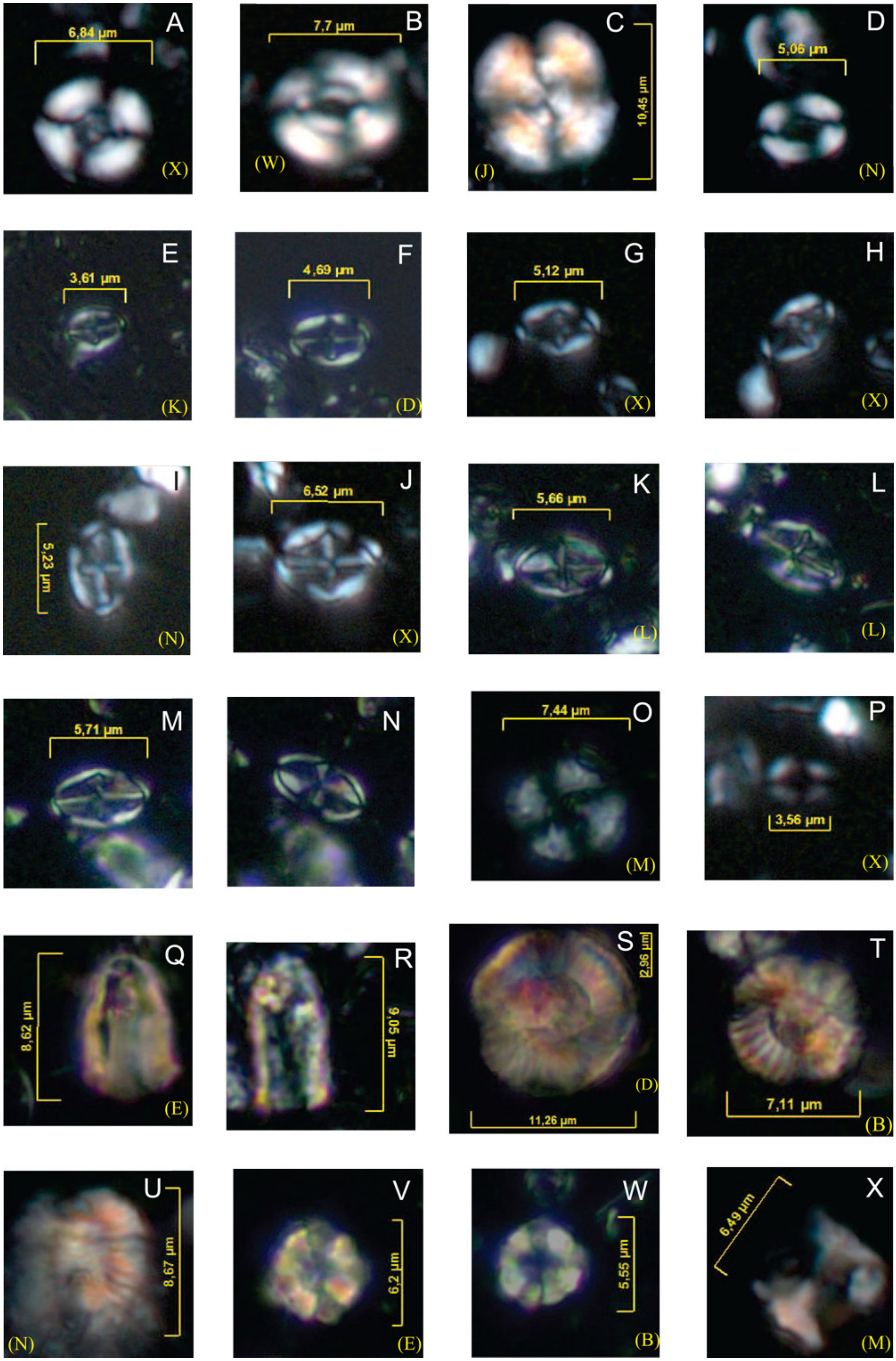
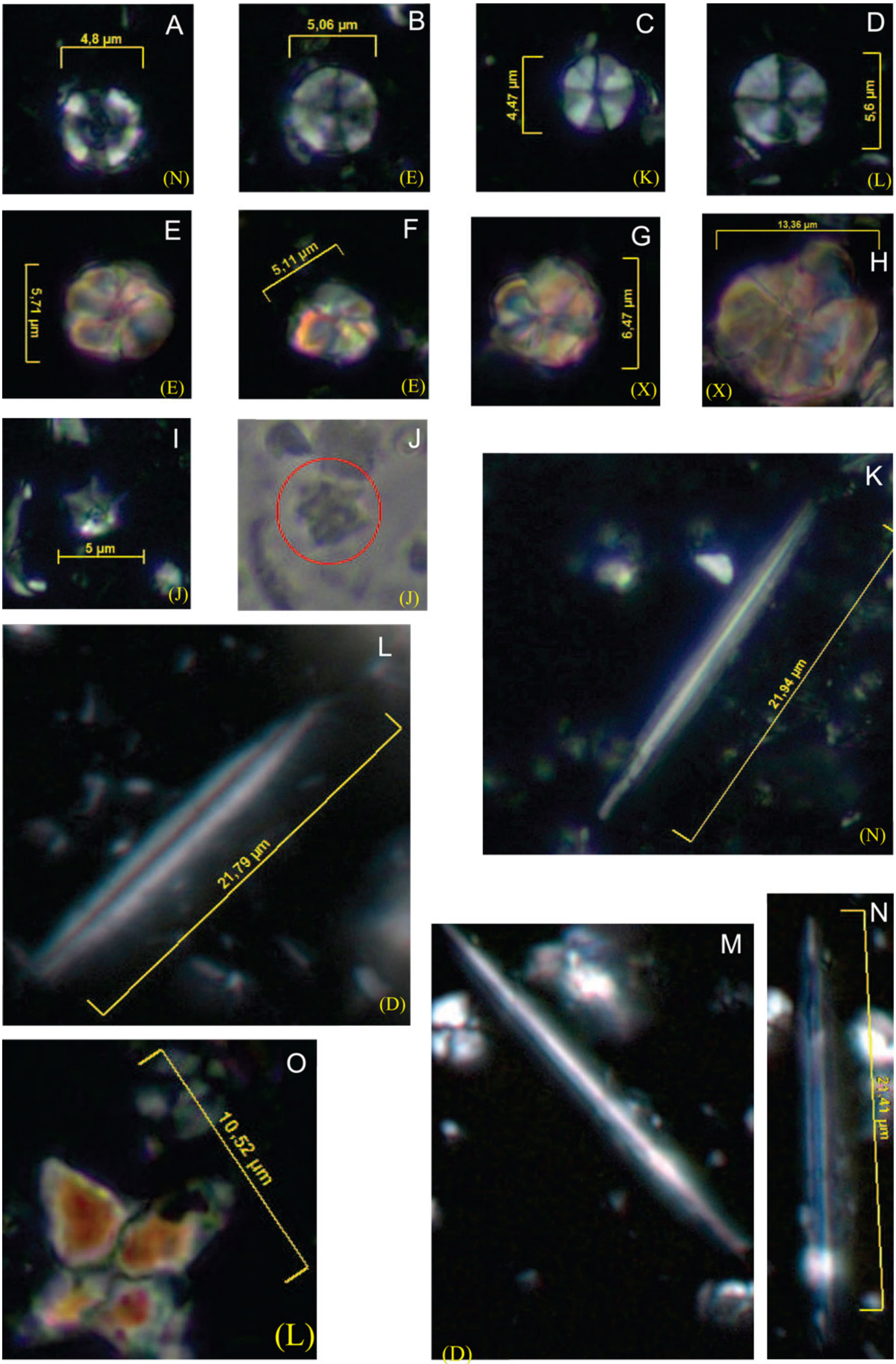

A
6,84 µm
(X)
B
7,7 µm
(W)
C
10,45 µm
(J)
D
5,06 µm
(N)
E
3,61 µm
(K)
F
4,69 µm
(D)
G
5,12 µm
(X)
H
(X)
I
5,23 µm
(N)
J
6,52 µm
(X)
K
5,66 µm
(L)
L
(L)
M
5,71 µm
N
O
7,44 µm
(M)
P
3,56 µm
(X)
Q
8,62 µm
(E)
R
9,05 µm
S
2,96 µm
11,26 µm
(D)
T
7,11 µm
(B)
U
8,67 µm
(N)
V
6,2 µm
(E)
W
5,55 µm
(B)
X
6,49 µm
(M)

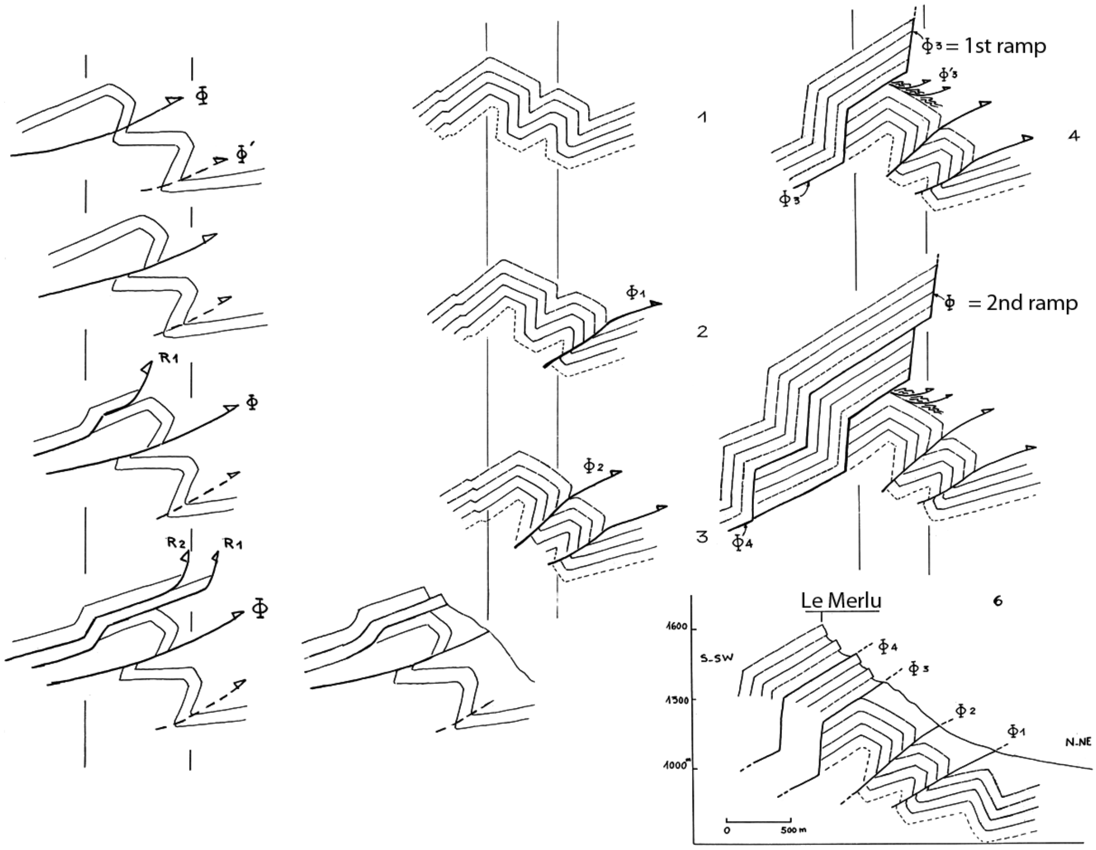
Plate 10: Calcareous nannofossils

A. *Radiolithus hollandicus*. Level –2.0 m (slide Nn).
B. *Radiolithus hollandicus*. Level 0.0 m (slide En).
C. *Radiolithus planus*. Level +2.0 m (slide Kn).
D. *Radiolithus planus*. Level −0.5 m (slide Ln).
E. *Assipetra terebrodentarius* s.l. Level 0.0 m (slide En).
F. *Assipetra terebrodentarius* s.l. Level 0.0 m (slide En).
G. *Assipetra terebrodentarius* s.l. Level −0.5 m (slide Xn).
H. *Assipetra terebrodentarius* s.l. Level −0.5 m (slide Xn).
I. *Hayesites* ? sp. Level −1.0 m (slide Jn).
J. *Hayesites* ? sp. Level −1.0 m (slide Jn).
K. *Lithraphidites carniolensis*. Level −2.0 m (slide Nn).
L. *Lithraphidites carniolensis*. Level −4.0 m (slide Dn).
M. *Lithraphidites carniolensis*. Level −4.0 m (slide Dn).
N. *Lithraphidites carniolensis*. Level −4.0 m (slide Dn).
O. Ascidian spicule. Level −0.5 m (slide Ln).


A
4,8 µm
(N)
B
5,06 µm
(E)
C
4,47 µm
(K)
D
5,6 µm
(L)
E
5,71 µm
(E)
F
5,11 µm
(E)
G
6,47 µm
(X)
H
13,36 µm
(X)
I
5 µm
(J)
J
(J)
K
21,94 µm
(N)
L
21,79 µm
(D)
M
(D)
N
21,41 µm
O
10,52 µm
(L)

Le Merlu and La Pertie pass

René BLANCHET & Michel GRAVELLE



Folds and thrust faults (ramp system) affecting the Tithonian bars at Le Merlu (BLANCHET & GRAVELLE, unpublished).

Thrust fault at La Pertie Pass, with upper Aptian-Albian « Marnes bleues » overlain by folded Valanginian strata.

Barremian ammonite fauna from L'Estellon section (Baronnies, SE France): Preliminary biostratigraphic results

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Abstract

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 (lower Aptian) redeposits, the "Bedoulian ridge" *auct.* being latest Barremian in age.

Modified from: BUSNARDO R., GRANIER B., CLAVEL B. & CHAROLLAIS J. (2013).- Ammonitofaune du Barrémien de la coupe de L'Estellon (Baronnies, France) : Résultats biostratigraphiques préliminaires.- *Carnets Geol.*, Madrid, vol. 13, no. A03 (CG2013_A03), p. 117-138.

Citation: BUSNARDO R., GRANIER B., CLAVEL B. & CHAROLLAIS J. (2017).- Barremian ammonite fauna from L'Estellon section (Baronnies, SE France): Preliminary biostratigraphic results. *In*: GRANIER B. (ed.), Some key Lower Cretaceous sites in Drôme (SE France).- Carnets de Géologie, Madrid, CG2017_B01, ISBN 978-2-916733-13-5, p. 79-101.

Introduction

The village of L'Estellon (Chaudebonne district, Drôme department) is located some twenty kilometres north to the town of Nyons, SE France (GRANIER *et al.*, 2013a, 2013b). The initial purpose of the section survey (Fig. 1) was the sedimentological and paleontological reconnaissance of a lithostratigraphic unit known as "Barrémo-Bédoulien" on local geological maps (Nyons: BALLESIO *et al.*, 1975; Dieulefit: FLANDRIN, éd., 1969).

The measured section reaches a total thickness of some 250 metres. It begins with a more or less regular alternation of marls and argillaceous limestones, classically ascribed to the Hauterivian (*op. cit.*). This rhythmicity is soon disrupted by conglomeratic intercalations (with more or less hard pebbles and cobbles) and calcareous turbidites. Thus, in the lower part of the section, we identify first sandy debris flow at 26.5 m ("Ba1" on Fig. 2), a second bundle ("Ba2") from 49.3 m and a third bundle ("Ba3") from 72.4 m. In the upper part of the section the bundle known as the "barre barrémienne" *auct.* corresponds to the 137.0-174.1 m interval (~37 m in thickness) and the bundle known as the "barre bédoulienne" *auct.* to the 217.0-240.0 m interval (~23 m in thickness).

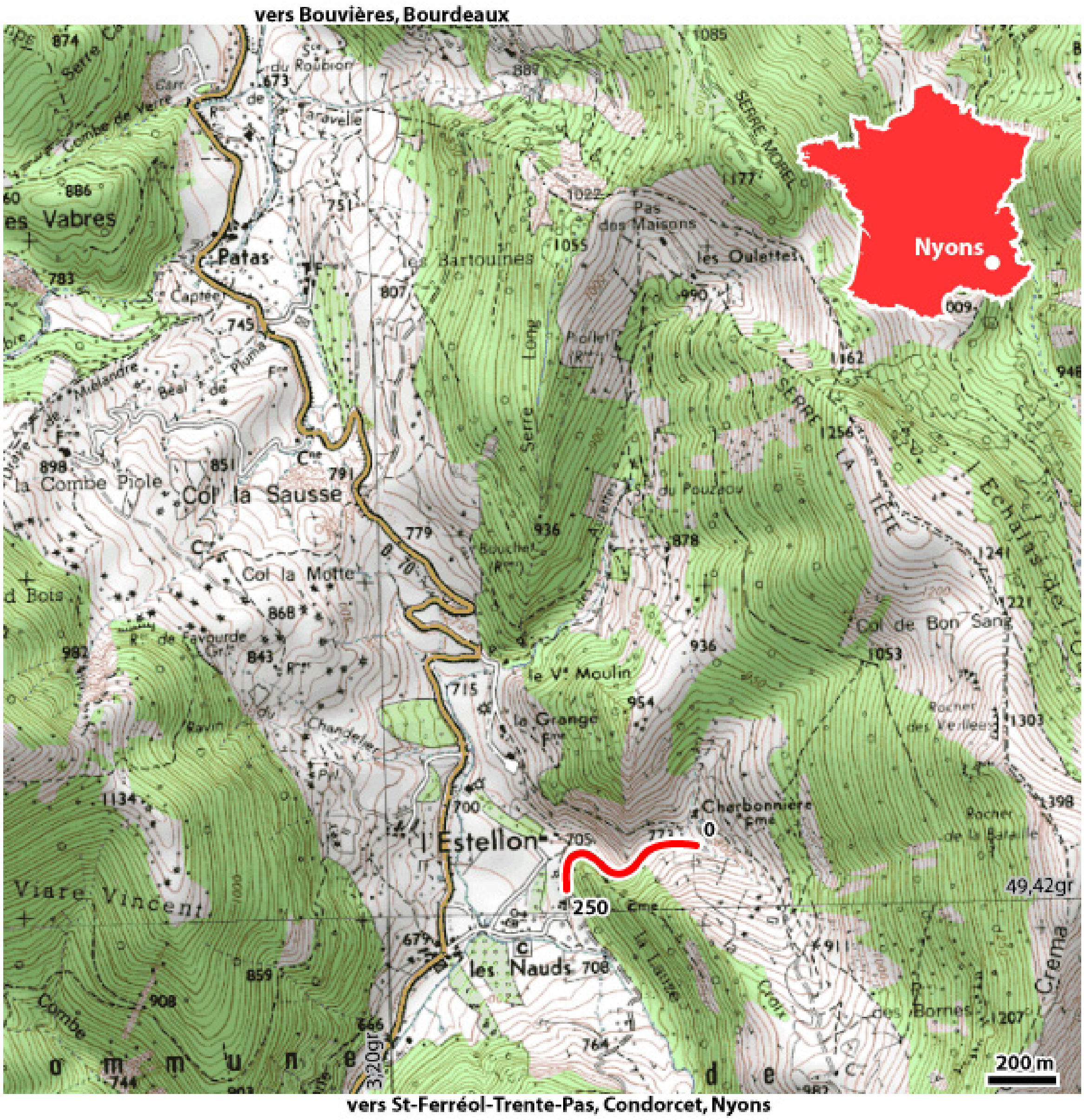


Figure 1: Geographic location of L'Estellon section, some 20 km kilometres north to Nyons (Drôme department, SE France). © www.geoportail.fr and IGN - Institut Géographique National, 73 avenue de Paris, F-94165 Saint-Mandé Cedex (France)

One of the main values of this section is the presence of a diverse ammonite fauna that allows identification of a number of biozones and establishes a precise biostratigraphic framework for these basinal sedimentary deposits. Another point of interest is the occurrence of redeposited sediments. At Serre de Bleyton, 6 km eastward of L'Estellon, a single debris flow was dated using its exceptional ammonite assemblage as "middle to late Early Barremian" in age (LUKENEDER, 2010). At L'Estellon most redeposited material came from localities at the edge of Urgonian carbonate platforms fringing the Vocontian trough, most likely from the neighbouring Ardèche on the basis of the transport directions measured for turbidity paleocurrents (FERRY, 1976). Sand-sized allochems (*i.e.*, calcareous grains) are mostly bioclasts, including numerous large benthic foraminifera and green algae, as well as ooids. In addition, ammonites present in this section allow better constraint of the first (and eventually last) occurrences of some Dasycladalean algae (GRANIER, 2013) and large benthic foraminifers. This is the subject of a parallel publication (GRANIER *et al.*, 2013b).

The inventory of our first ammonite finds comprises taxa ranging in age from the latest Hauterivian to the Barremian (BUSNARDO, 1984; BUSNARDO *et al.*, 2003; VERMEULEN, 2005; BERT *et al.*, 2008, 2010), as well as other taxa that are known from both side of the Barremian-Bedoulian boundary (BUSNARDO, 1984; ROPOLO *et al.*, 1998, 2008). However, none are typically Bedoulian (lower Aptian). The so-called "Barrémo-Bédoulien", as it is currently indicated in the 1/50 000 geological maps of Nyons and Dieulefit, is most likely soley Barremian. If so, the Bedoulian (lower Aptian) may be condensed or even partly missing, considering that in other localities of the Vocontian domain, its upper part was identified in the very first meters of the next unit, *i.e.*, the "Marnes bleues" (MOULLADE, 1966; DAUPHIN, 2002; HERRLE & MUTTERLOSE, 2003; *etc.*).

Material and method

In April 2012, the section was measured with a JACOB's staff (GRANIER *et al.*, 2013b), permiting accurate evaluation of the intervals that are not exposed. Some ammonites were collected on this occasion. In September 2012, a second collection completed the collection phase of this study. All the material illustrated herein was registered (with FSL numbers), then deposited at the "Faculté des Sciences de Lyon". Some specimens are not illustrated: *Lytoceras* spp. [among which *L. anisoptychum* UHLIG, 1883, *L. densifimbriatum* (UHLIG, 1883), and *L. subfimbriatum* (ORBIGNY, 1841)], *Phyllopachyceras* spp. [among which *P. infundibulum* (ORBIGNY, 1841) and *P. baborense* (COQUAND, 1880)], and *Leptoceratoides* sp.

Preliminary inventory of the ammonite fauna (R. BUSNARDO)

Taxa are sorted by order of appearance along the section, *i.e.*, according to their relative stratigraphic position from bottom to top (Fig. 2), with level numbers corresponding to their height measured in meters from the bottom of the section.

Parathurmannia sp.

Pl. 1, figs. 2 and 5-7, level -12.5 (*i.e.*, 12.5 m below level 0 of the section measured)

Parathurmannia sarasini (SARKAR, 1955)

Pl. 1, figs. 1 and 3, levels -12.5, 0 and 10.5

Crioceratites cf. *duvali* (LÉVEILLÉ, 1837)

Pl. 1, fig. 4, level –12.5

Lytoceras densifimbriatum (UHLIG, 1883)

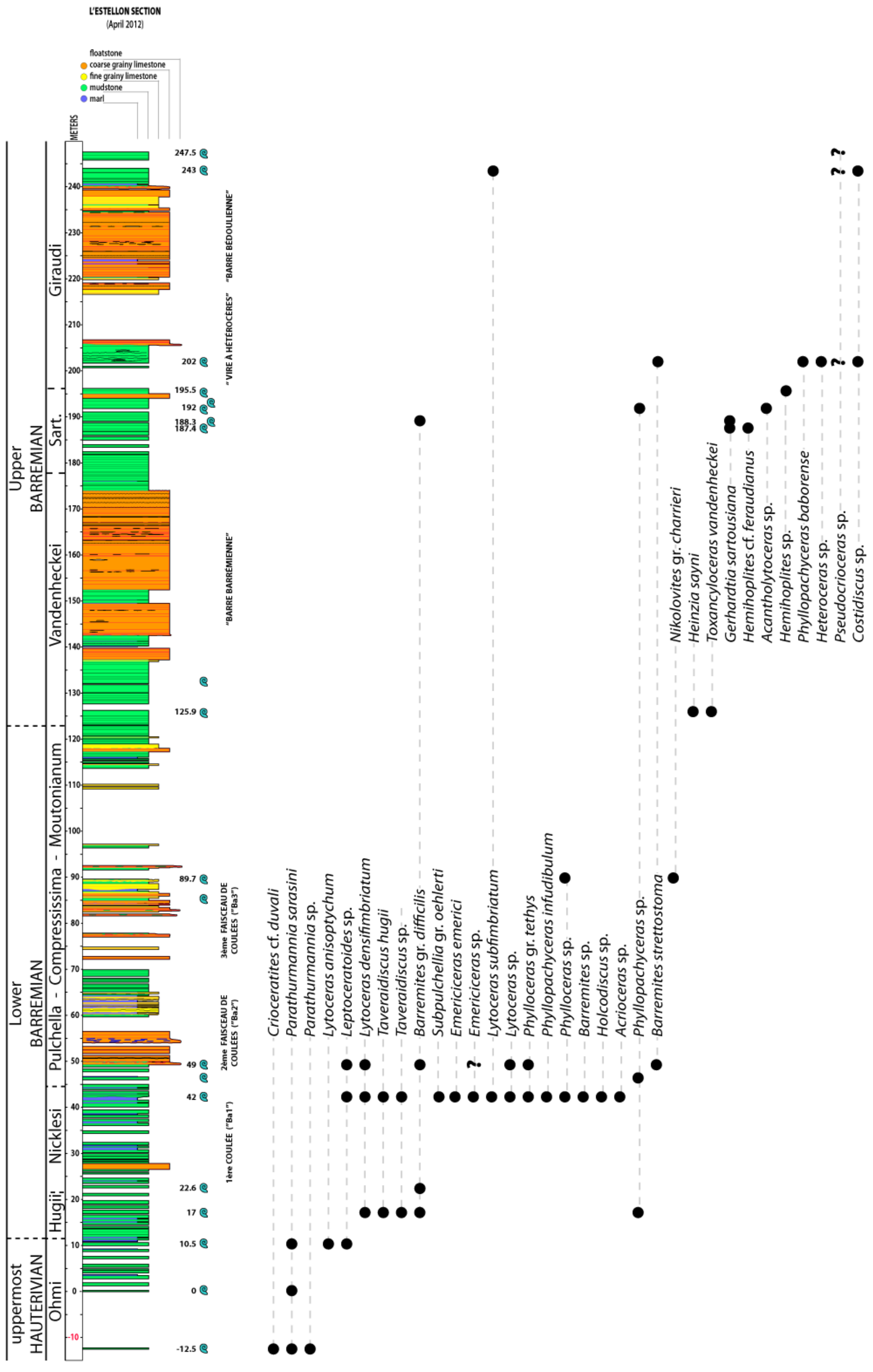
levels 17 to 49

Ammonite with a large umbilicus and an oval section. The shell ornamentation consists of a fine striation oriented in both transverse and longitudinal directions. This results in an amazing grid pattern remarkably well drawn by UHLIG (1883: Pl. VI, fig. 1a -1e). This form, rather rare, occurs in the lowermost Barremian. This is a pretty good stratigraphic marker.

Phylloceras gr. *tethys* (ORBIGNY, 1841)

Pl. 4, figs. 3 and 6, levels 42 and 49

Several specimens were collected in levels 42 and 49. The are strongly distorted but the shell ornamentation, with its fine sinuous costulae covering the upper side of the flanks, is quite typical. They are pelagic forms abundant both at la Veveyse (BUSNARDO *et al.*, 2003) and in the Vocontian domain, both in upper Hauterivian and in Barremian strata.



L'ESTELLON SECTION
(April 2012)
floatstone
coarse grainy limestone
fine grainy limestone
mudstone
marl
METERS
uppermost HAUTERIVIAN
Lower BARREMIAN
Upper BARREMIAN
Ohmi
Hugii
Nicklesi
Pulchella - Compressissima - Moutonianum
Vandenheckei
Sart.
Giraudi
1ère COULÉE ("Ba1")
2ème FAISCEAU DE COULÉES ("Ba2")
3ème FAISCEAU DE COULÉES ("Ba3")
"BARRE BARRÉMIENNE"
"VIRE À HÉTÉROCÈRES"
"BARRE BEDOULIENNE"
-12.5
0
10.5
17
22.6
42
49
89.7
125.9
187.4
188.3
192
195.5
202
243
247.5
Crioceratites cf. duvali
Parathurmannia sarasini
Parathurmannia sp.
Lytoceras anisoptychum
Leptoceratoides sp.
Lytoceras densifimbriatum
Taveraidiscus hugii
Taveraidiscus sp.
Barremites gr. difficilis
Subpulchellia gr. oehlerti
Emericiceras emerici
Emericiceras sp.
Lytoceras subfimbriatum
Lytoceras sp.
Phylloceras gr. tethys
Phyllopachyceras infudibulum
Phylloceras sp.
Barremites sp.
Holcodiscus sp.
Acrioceras sp.
Phyllopachyceras sp.
Barremites strettostoma
Nikolovites gr. charrieri
Heinzia sayni
Toxancyloceras vandenheckei
Gerhardtia sartousiana
Hemihoplites cf. feraudianus
Acantholytoceras sp.
Hemihoplites sp.
Phyllopachyceras baborense
Heteroceras sp.
Pseudocrioceras sp.
Costidiscus sp.

Barremites gr. *difficilis* (ORBIGNY, 1841)

Pl. 2, figs. 5-6; Pl. 5, figs. 1-2 and 4-5, levels 22.6, 42, 49 and 188.35

Small ammonites made of light grey argillaceous limestone. The umbilicus is reduced and poorly visible. The ventral area is well rounded. A slight lateral flattening of the living chamber, which is visible on a half whorl, has created several microfissures. Usually this ammonite in more common in lower Barremian strata (BUSNARDO & VERMEULEN, 1986). It is associated with *Taveraidiscus* VERMEULEN, 1999, and with *Emericiceras* SARKAR, 1954, of the Hugii Zone (BUSNARDO *in* GAUTHIER, 2006).

Barremites strettostoma (UHLIG, 1883)

Pl. 5, fig. 6; Pl. 7, fig. 5, levels 49 and 202.5

This species is thinner than is *B. difficilis* and is characterized by a complex, highly dissymetric suture line. It occurs in lower Barremian strata, but is dominant in upper Barremian strata.

Taveraidiscus sp.

Pl. 2, figs. 1 and 4; Pl. 3, fig. 4, levels 17 and 42

Taveraidiscus hugii (OOSTER, 1860)

Pl. 2, figs. 2-3; Pl. 3, figs. 3, 5 and 10, levels 17 and 42

These few pieces of ammonites are dislocated, distorted, streched, or even flattened, but the ornamentation, with fine costulae, slightly fascicular, sometimes bearing a small basal tubercle, is obvious and well preserved.

◀ **Figure 2:** Ammonite occurrences and ranges plotted on the simplified lithostratigraphic log of the L'Estellon section (modified from GRANIER *et al.*, 2013b) along with their preliminary biostratigraphic interpretations (Pulchella, Compressissima and Moutonianum zones, which are likely to be represented, were not properly identified on the ammonite finds alone).

These ribs run through the ventral area without attenuation. In this group, variability is significant and goes together with the multiplication of individuals, especially at level 17 but also at level 42. These forms define the Hugii Zone of the lowermost Barremian. At La Veveyse (BUSNARDO *et al.*, 2003), the acme of this species (*op.cit.*, Pl. XXV) is found at level 96 of the section in the lowermost Barremian strata. Because it is a good stratigraphic reference marker, the fossiliferous bed 42 at L'Estellon should be regarded as being in lateral equivalent position to bed 96 at La Veveyse.

Holcodiscus sp.

Pl. 3, figs. 1-2; Pl. 4, figs. 2 and 4, level 42

Two specimens (Pl. 3, figs. 1-2) are distorted and their flanks are flattened. Neither the umbilicus, nor the whorl profile are visible. The strong costulation is made of slightly proverse ribs, almost steadily bifurcated by the middle of the flanks. There is no visible tuberculation. They could be compared to *Holcodiscus caillaudianus* (ORBIGNY, 1850). However, polymorphism with or without tubercles in association with weak constrictions explains the many assignations found in the literature (KILIAN, 1888; UHLIG, 1883; KARAKASCH, 1907; *etc.*). The same is true for two pieces shown as figs. 2 and 4 of Pl. 4, level 42.

Subpulchellia gr. *oehlerti* (NICKLÈS, 1894)

Pl. 4, fig. 1, level 42

At level 42, so rich in ammonites, one can see a small imprint that is ascribed to the genus *Subpulchellia* HYATT, 1903. The umbilicus is narrow and the sides are slightly curved. At the start of the shell its sides are smooth. Sigmoidal ribs then gradually appear and strengthen. They abruptly end on the marginal carina. The ventral area is decidedly flattened and looks like it is bordered by a double carina. This structure is reported from some other pulchellies, among which are *Kotetischvilia armenica* AKO-

PIAN, 1962, or *K. sauvageaui* (HERMITE, 1869) of the lower Barremian.

Acrioceras sp.

Pl. 4, fig. 5, level 42

Shaft of an uncoiled ammonite. The rib ornamentation with large "peridorsal" (basal) tubercles does not seem to have been found so far. The acrioceratic form consists of -- sequentially from the top of the organism to its base -- an initial spire, a straight or slightly curved shaft, a hook crosse and the living chamber, which is partly preserved here. This morphology is common to several small-sized species illustrated and described by SARKAR (1955) as well as to a number of large-sized species generally referred to the genus *Emericiceras*, in the middle part of the lower Barremian.

Emericiceras emerici (LÉVEILLÉ, 1837)

Pl. 3, figs. 6-9, level 42

In level 42, we notice the multiplication of this species, in association with *Barremites* KILIAN, 1913, and *Taveraidiscus* of the lower Barremian. *Emericiceras emerici* is characterized by its dense and spiny ornementation, which consists of an alternation of trituberculate main ribs and simple fine ribs. The tubercles probably bore spines which are only occasionally preserved during fossilisation and which are sometimes illustrated in the literature. The first whorls of the shell are almost circular; the next whorls tend to be more open but remain coiled. Individuals are small in the Vocontian domain, but reach large sizes in hemipelagic platforms.

Emericiceras sp. juv.

Pl. 3, fig. 11, level 42

It is a small coiled ammonite. It is distorted, broken at the base of the shaft but the trituberculate ribs, which are typical of the genus *Emericiceras*, are still visible.

Emericiceras ? sp.

Pl. 5, fig. 3, level 49

Nikolovites gr. *charrieri* (ORBIGNY, 1841)

Pl. 5, fig. 7, level 89.7

It is a part of a whorl that is severely corroded and with worn flanks. The umbilicus is large. There are two sigmoidal grooves. This form corresponds to numerous more or less evolute Barremian Desmoceratids. Species *Barremites fegirensis* DIMITROVA, 1967, from Bulgaria, "*Desmoceras ligatum* (d'ORB.)" illustrated by SARASIN and SCHÖNDELMAYER (1902: Pl.VI, fig. 5), and the "*Nikolovites* sp." from La Veveyse (BUSNARDO *et al.*, 2003: Pl. XXVII, fig. 4) have been reported as synonyms.

Toxancyloceras vandenheckei (ASTIER, 1851)

Pl. 6, figs. 2-3, level 125.9

These two slightly streched pieces are part of the same specimen. They correspond to the spire extension, most likely located next to the shaft (if there is one). The strong ornamentation consists an alternation of trituberculate main ribs with one or two thin and spineless intermediary ribs.

Remark: This form closely resembles *Gassendiceras alpinum* (ORBIGNY, 1850), which has no shaft. A recent study (BERT *et al.*, 2010) demontrated that the latter actually corresponds to forms until recently interpreted as *Barrancyloceras barremense* (UHLIG, 1887) by VERMEULEN (2011) resulting *de facto* in the replacement of the Barremense horizon by the Alpinum horizon. This horizon corresponds to an interval of the median part of the Vandenheckei Zone of the upper Barremian.

Heinzia sayni (HYATT, 1903)

Pl. 6, fig. 1, level 125.9

This species has high stratigraphic value because its range is restricted to the Vandenheckei Zone.

Hemihoplites cf. _feraudianus_ (ORBIGNY, 1841)
Pl. 6, figs. 4 and 6-7, level 187.45

These heavily worn ammonites pieces were previously labelled as *Hemihoplites soulieri* (MATHERON, 1878) but they could as well have been referred to the species *H. cornagoae* BERT *et al.*, 2006.

Gerhardtia sartousiana (ORBIGNY, 1841)
Pl. 6, fig. 5; Pl. 7, figs. 1-4, levels 187.45 and 188.35

Four pieces more or less strongly distorted are ascribed to this species. Its costulation is easily identifiable with its large sigmoidal ridges, sometimes bifurcated, clearly interrupted on the ventral side. This quite common ammonite is the index of the eponymous upper Barremian zone.

Acantholytoceras sp.
Pl. 7, fig. 8, level 192

This ammonite piece is provisionally ascribed to the genus *Acantholytoceras* SPATH, 1923, but it could as well be a piece of *Pseudocrioceras* SPATH, 1924.

Hemihoplites sp.
Pl. 7, fig. 6, level 195.5

This broken and worn ammonite piece is provisionally ascribed to the genus *Hemihoplites* SPATH, 1924, but it could as well be a piece of *Martelites* CONTE, 1989.

Heteroceras sp.
Pl. 7, fig. 7, level 202

Procheloniceras gr. _pachystephanum_ (UHLIG, 1883)
Pl. 8, fig. 1-3, level 247.5

According to ROPOLO *et al.* (2008), this ammonite is known from the last subzone of the upper Barremian, *i.e.*, from the Waagenoides Subzone (Giraudi Zone), and from the lower part of the Bedoulian, *i.e.*, from the Forbesi Zone (synonym of the Weissi Zone).

Remark: Because of the fragmented nature of the material collected in the highest levels of the section (levels 245 and 247.5), it has proved difficult to identify species and even genera. For example, some pieces can be referred to genus *Pseudocrioceras* SPATH, 1924, or genus *Kutatissites* KAKABADZE, 1970. *Pseudocrioceras* species are known from the uppermost part of the Giraudi Zone. At La Bédoule, for instance, they are not present below the Barremian-Bedoulian boundary (ROPOLO *et al.*, 1998). It would therefore have been useful to validate one of these identifications. Ideally, new field surveys should be undertaken to find new ammonite specimens and possibly index species.

Biostratigraphy

On the basis of the first ammonites collected, the stratigraphic divisions of the L'Estellon section should be as follows, in ascending order:

- the Hauterivian-Barremian boundary is found within an interval between level 10, with the last *Parathurmannia sarasini* (SARKAR), and level 17, with *Taveraidiscus hugii* (OOSTER), the index species of the first Barremian zone;
- the lower-upper Barremian boundary is located above (probably a few beds) level 125, with both *Heinzia sayni* (HYATT) and *Toxancyloceras vandenheckei* (ASTIER, 1851);
- the Barremian-Bedoulian boundary is out of the section (above it). The Bedoulian (lower Aptian), in its modern definition (*i.e.*, *sensu* MOULLADE *et al.*, 2011), was not identified. Due to the lack of representatives of the genus *Deshayesites*, the "barre bédoulienne" *auct.* is assigned to the uppermost Barremian.

At this stage, we have identified most of the Barremian ammonites zones, although we did not clearly locate their boundaries. This is the case within the lower Barremian strata for the Hugii and Niklesi zones [with the last representatives of *Taveraidiscus hugii* and *Emericiceras emerici* at level 42, two species that are disappearing in the lower part of the Nicklesi Zone at Angles (VERMEULEN, 2005)] and also within the upper Barremian strata for its three constituent zones:

1. Vandenheckei, with the assemblage of level 125,
2. Sartousiana, with the index species in levels 187-188,
3. Giraudi, probably above level 195.5 due to the occurrence of some ammonite pieces herein referred to as *Hemihoplites* sp. and *Acantholytoceras* sp., but below level 202, due to the occurrence of one *Heteroceras* specimen. Incidentally, the absence of *Deshayesites* up to the top of the section suggests that its 50 uppermost meters are still (uppermost) Barremian in age.

Conclusion

On the basis of this first investigation, regarding the lower Barremian (Fig. 2), we ascribe:

A. the first debris flow bundle at level 26.5 m to the Nicklesi Zone (part of the LST "Ba1" of CLAVEL *et al.*, 2010, 2012),
B. the second bundle of debris flows starting from level 49.3 m possibly to the Pulchella Zone (part of the LST "Ba2"),
C. the third bundle starting from level 72.4 m possibly to the Compressissima and Moutonianum zones (part of the LST "Ba3").

Similarly, regarding the upper Barremian (Fig. 2), we ascribe:

D. the fourth bundle, *i.e.*, the "barre barrémienne" *auct.*, from level 137 m possibly to the Vandenheckei Zone (part of the LST "Ba4"),
E. the fifth bundle, *i.e.*, the "barre bédoulienne" *auct.*, from level 217 m to the Giraudi Zone (part of the LST "Ba5").

Acknowledgments

Special thanks go to Mr. and Ms. Jean-Claude PATONNIER (Borne), and Mr. and Ms. Ronald BREUKERS (Charbonnière) for permitting access to their properties. We are also grateful to the editor, Michel MOULLADE, and the two reviewers, Didier BERT and Michel DELANOY, the comments of whom helped improving the final version of our manuscript. This research was sponsored by the Association "*Carnets de Géologie*" as part of the project "L'Estellon".

Plate 1:

1) *Parathurmannia sarasini* (SARKAR, 1955).- level 10.5 (FSL 391045), l_{max} = 3.3 cm [*Pseudothurmannia* aff. *picteti* according to BERT, this volume]

2) *Parathurmannia* sp.- level-12.5 (FSL 391046), l_{max} = 3.5 cm

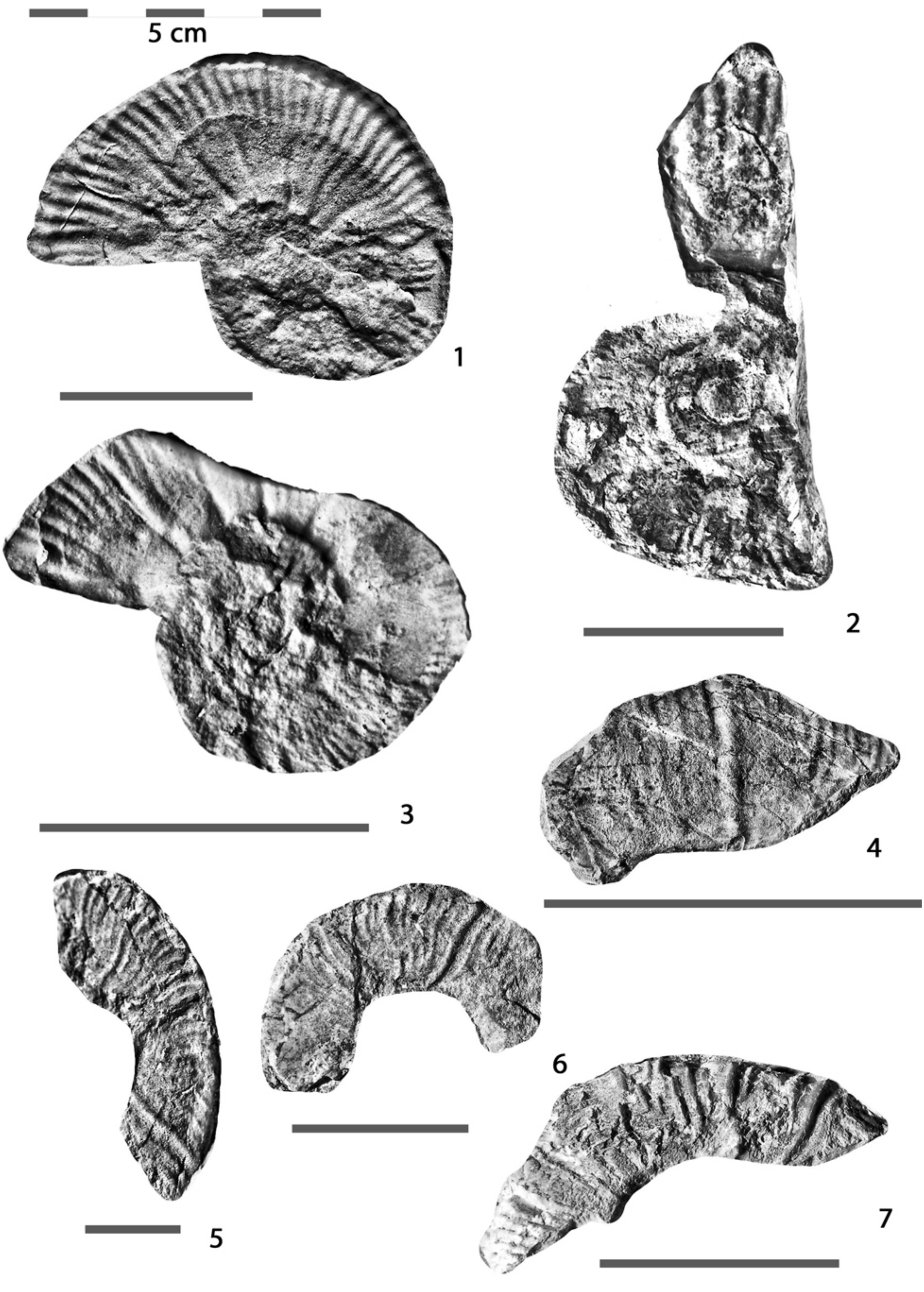
3) *Parathurmannia sarasini* (SARKAR, 1955).- level-12.5 (FSL 391047), l_{max} = 5.7 cm

4) *Crioceratites* cf. *duvali* (LÉVEILLÉ, 1837).- level-12.5 (FSL 391048), l_{max} = 6.5 cm

5) *Parathurmannia* sp.- level-12.5 (FSL 391049), l_{max} = 2.8 cm

6) *Parathurmannia* sp.- level-12.5 (FSL 391050), l_{max} = 1.7 cm

7) *Parathurmannia* sp.- level-12.5 (FSL 391051), l_{max} = 4.0 cm



Remark: The bar below each figure corresponds to the larger width (measured horizontally, *i.e.*, l_{max}) of the silhouetted photograph with respect to a fixed graphical scale (here 5 cm), independently of the viewing or printing formats. For instance, measurements of the specimen in figure 1 (l_{max} = 3.3 cm in its larger width) have increased by a factor of two with respect to the fixed graphical scale.

Plate 2:

1) *Taveraidiscus* sp.- level 17 (FSL 391052), l_{max} = 2.2 cm

2) *Taveraidiscus hugii* (OOSTER, 1860).- level 17 (FSL 391053), l_{max} = 3.7 cm [*Taveraidiscus hugii* according to BERT, unpublished]

3) *Taveraidiscus hugii* (OOSTER, 1860).- level 17 (FSL 391054), l_{max} = 3.0 cm [*Taveraidiscus hugii* according to BERT, this volume]

4) *Taveraidiscus* sp.- level 17 (FSL 391055), l_{max} = 2.0 cm

5) and 6) *Barremites* gr. *difficilis* (ORBIGNY, 1841).- level 22.6 (FSL 391056), l_{max} = 3.5 cm

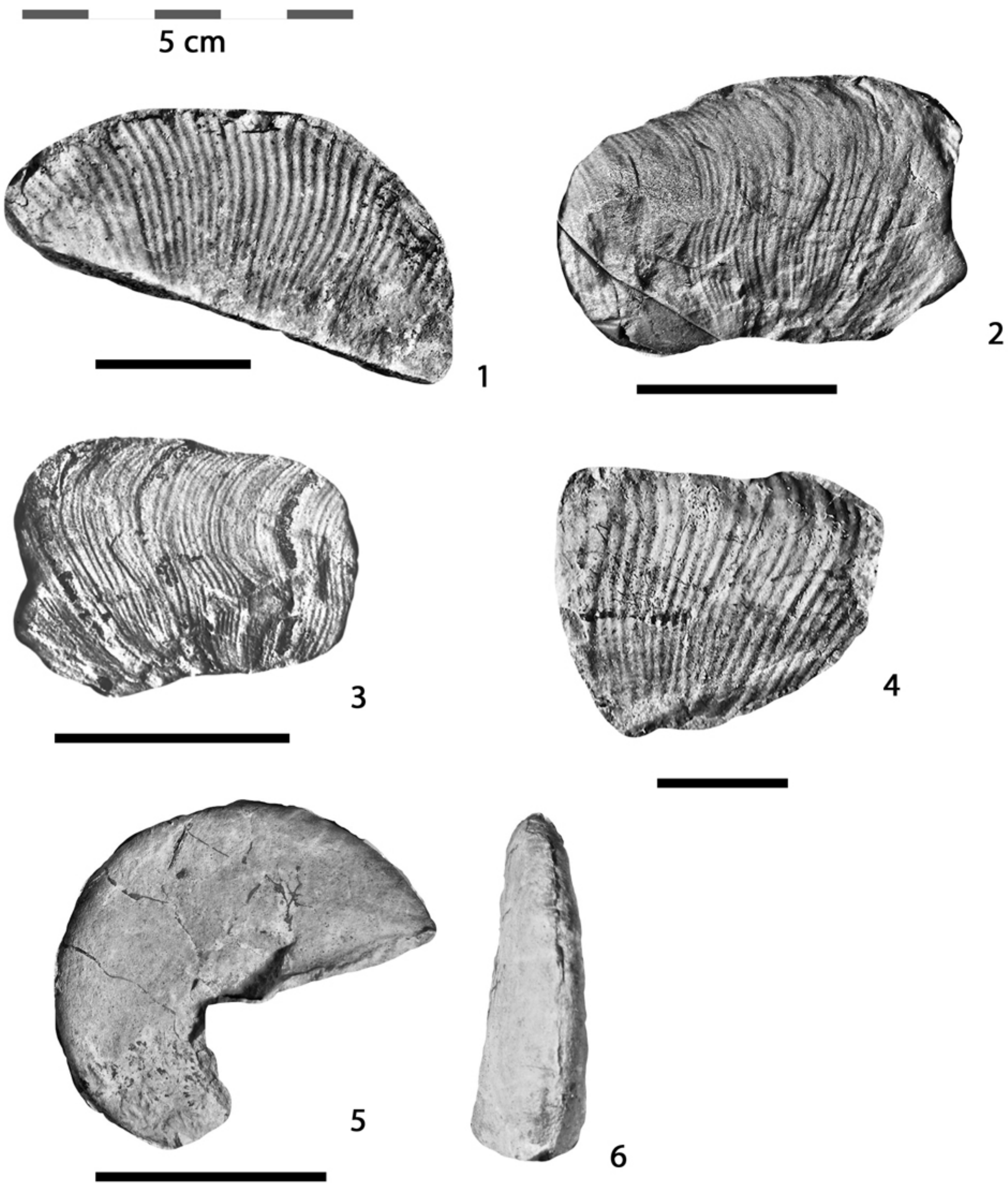

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Plate 3:

1) *Holcodiscus* sp.- level 42 (FSL 391057), l_{max} = 4.5 cm

2) *Holcodiscus* sp.- level 42 (FSL 391058), l_{max} = 3.5 cm

3) *Taveraidiscus hugii* (OOSTER, 1860).- level 42 (FSL 391059), l_{max} = 1.3 cm [*Avramidiscus intermedius* according to BERT, this volume]

4) *Taveraidiscus* sp.- level 42 (FSL 391060), l_{max} = 2.5 cm [*Avramidiscus intermedius* according to BERT, this volume]

5) *Taveraidiscus hugii* (OOSTER, 1860).- level 42 (FSL 391061), l_{max} = 1.2 cm [*Avramidiscus intermedius* according to BERT, this volume]

6) *Emericiceras emerici* (LÉVEILLÉ, 1837).- level 42 (FSL 391062), l_{max} = 3.5 cm [*Emericiceras emerici* according to BERT, this volume]

7) *Emericiceras emerici* (LÉVEILLÉ, 1837).- level 42 (FSL 391063), l_{max} = 1.5 cm [*Emericiceras emerici* according to BERT, this volume]

8) *Emericiceras emerici* (LÉVEILLÉ, 1837).- level 42 (FSL 391064), l_{max} = 1.8 cm [*Emericiceras emerici* according to BERT, this volume]

9) *Emericiceras emerici* (LÉVEILLÉ, 1837).- level 42 (FSL 391065), l_{max} = 3.8 cm [*Emericiceras emerici* according to BERT, this volume]

10) *Taveraidiscus hugii* (OOSTER, 1860).- level 42 (FSL 391066), l_{max} = 2.0 cm [*Avramidiscus intermedius* according to BERT, this volume]

1 1) *Emericiceras* sp. juv.- level 42 (FSL 391067), l_{max} = 2.8 cm

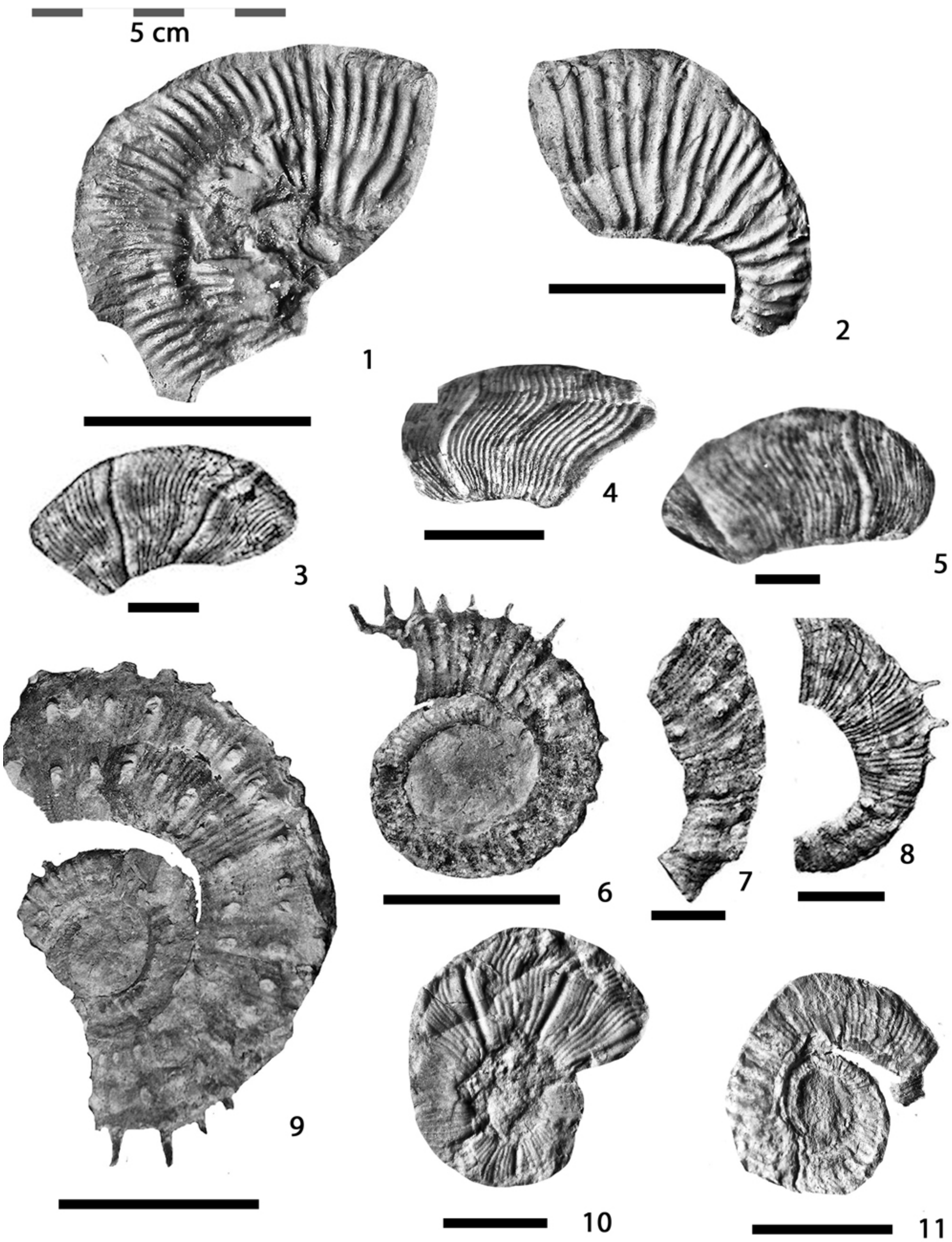
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Plate 4:

1) *Subpulchellia* gr. *oehlerti* (NICKLÈS, 1894).- level 42 (FSL 391068), l_{max} = 1.7 cm [*Subpulchellia oehlerti* according to BERT, this volume]

2) *Holcodiscus* sp.- level 42 (FSL 391069), l_{max} = 3.0 cm

3) *Phylloceras* gr. *tethys* (ORBIGNY, 1841).- level 42 (FSL 391070), l_{max} = 2.0 cm

4) *Holcodiscus* sp.- level 42 (FSL 391073), l_{max} = 4.0 cm

5) *Acrioceras* sp.- level 42 (FSL 391071), l_{max} = 3.0 cm [*Acrioceras* aff. *terveri* according to BERT, this volume]

6) *Phylloceras* gr. *tethys* (ORBIGNY, 1841).- level 42 (FSL 391074), l_{max} = 3.0 cm

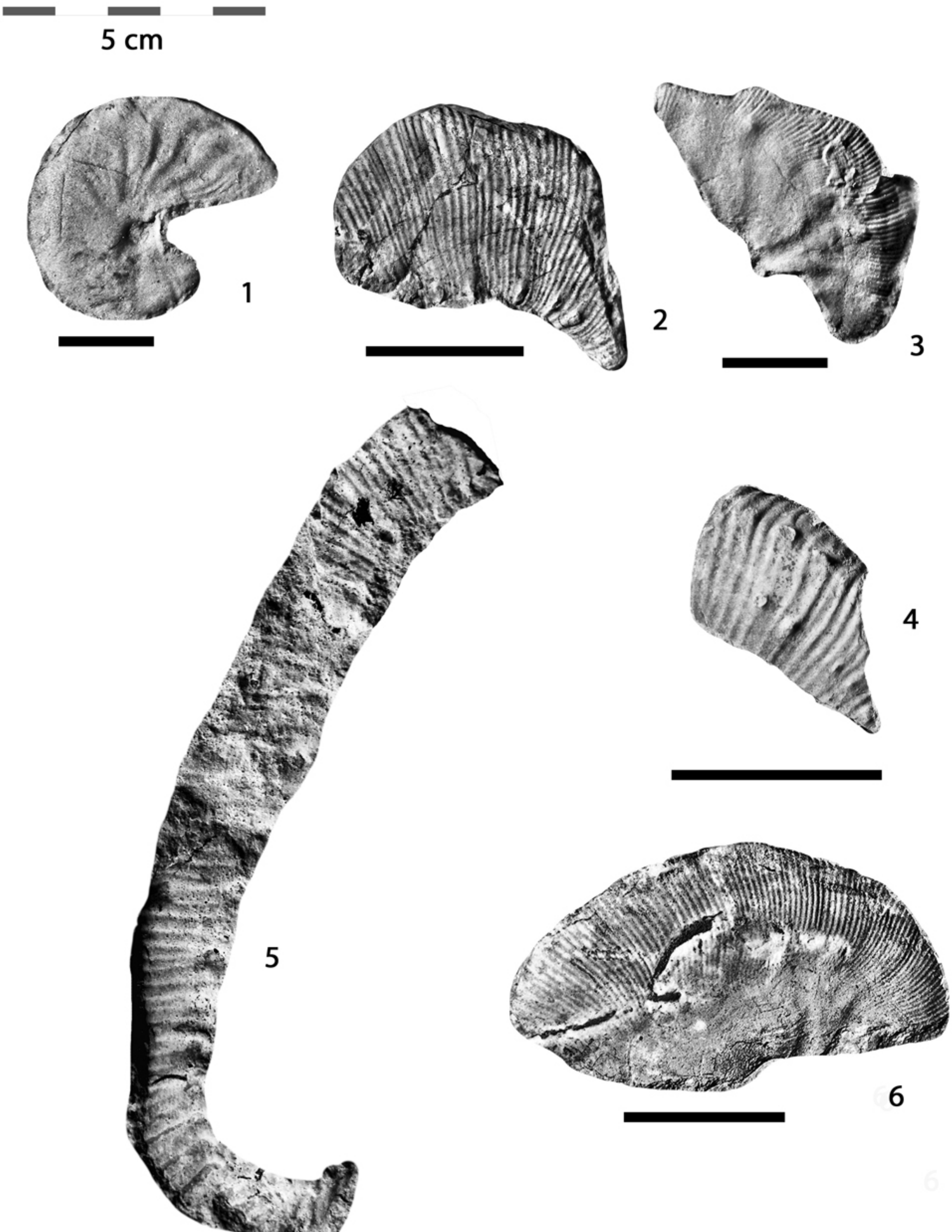
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Plate 5:

1) *Barremites* gr. *difficilis* (ORBIGNY, 1841).- level 49 (FSL 391075), l_{max} = 3.5 cm
2) *Barremites* gr. *difficilis* (ORBIGNY, 1841).- level 49 (FSL 391076), l_{max} = 3.5 cm
3) *Emericiceras* ? sp.- level 49 (FSL 391077), l_{max} = 2.4 cm
4) *Barremites* gr. *difficilis* (ORBIGNY, 1841).- level 49 (FSL 391078), l_{max} = 3.5 cm
5) *Barremites* gr. *difficilis* (ORBIGNY, 1841).- level 49 (FSL 391079), l_{max} = 4.5 cm
6) *Barremites strettostoma* (UHLIG, 1883).- level 49 (FSL 391080), l_{max} = 4.0 cm
7) *Nikolovites* gr. *charrieri* (ORBIGNY, 1841).- level 89.7 (FSL 391081), l_{max} = 3.0 cm

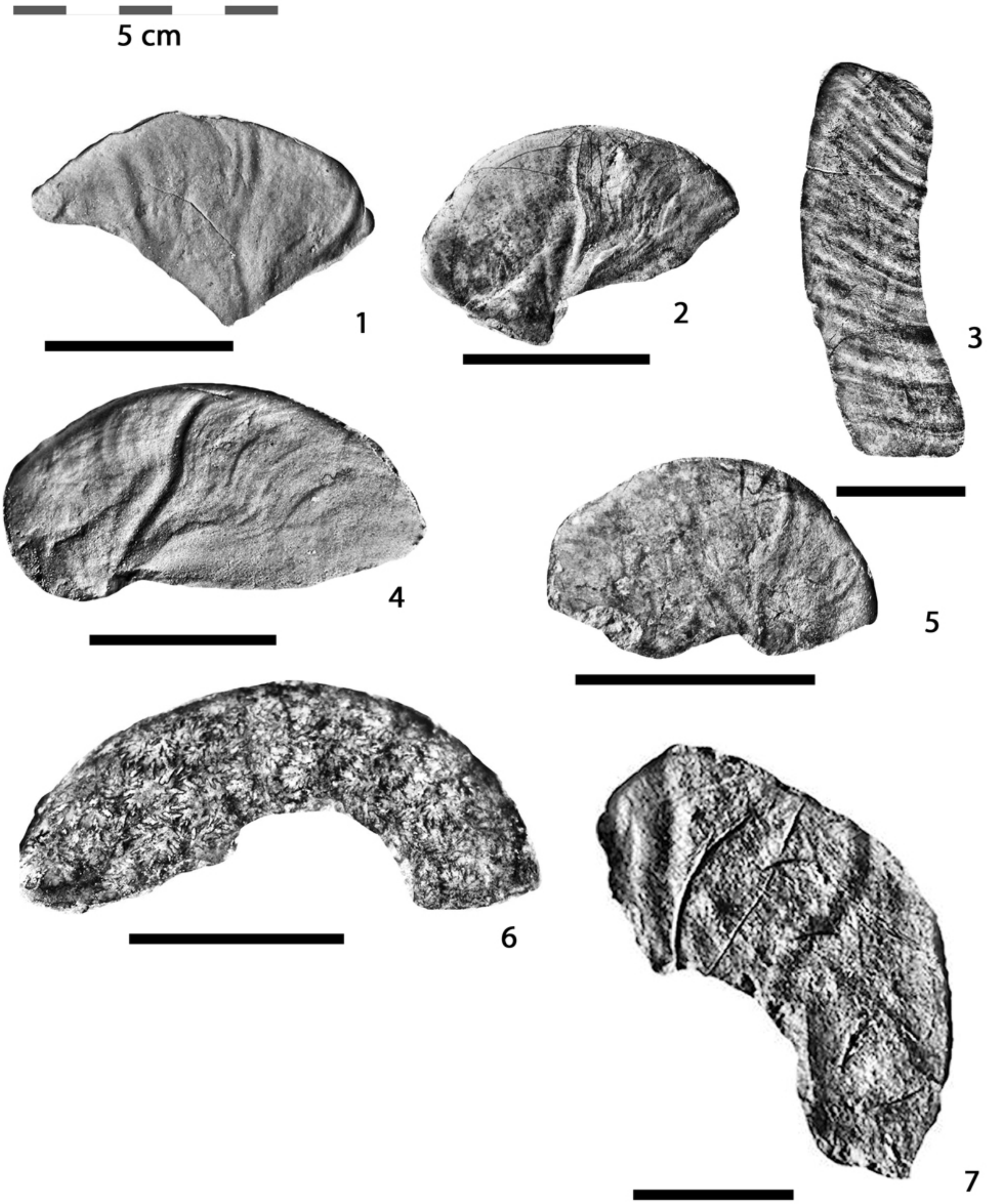
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Plate 6:

1) *Heinzia sayni* (HYATT, 1903).- level 125.9 (FSL 391082), l_{max} = 1.5 cm [*Heinzia sayni* according to BERT, this volume]

2) *Toxancyloceras vandenheckei* (ASTIER, 1851).- level 125.9 (FSL 391083), l_{max} = 9.0 cm [*Toxancyloceras vandenheckei* according to BERT, this volume]

3) *Toxancyloceras vandenheckei* (ASTIER, 1851).- level 125.9 (FSL 391084), remaining part of the previous sample, l_{max} = 6.0 cm [*Toxancyloceras vandenheckei* according to BERT, this volume]

4) *Hemihoplites* cf. *feraudianus* (ORBIGNY, 1841).- level 187.45 (FSL 391085), l_{max} = 8.5 cm

5) *Gerhardtia sartousiana* (ORBIGNY, 1841).- level 187.45 (FSL 391086), l_{max} = 3.2 cm [*Gerhardtia sartousiana* according to BERT, this volume]

6) *Hemihoplites* cf. *feraudianus* (ORBIGNY, 1841).- level 187.45 (FSL 391087), l_{max} = 5.5 cm

7) *Hemihoplites* cf. *feraudianus* (ORBIGNY, 1841).- level 187.45 (FSL 391088), l_{max} = 10.0 cm

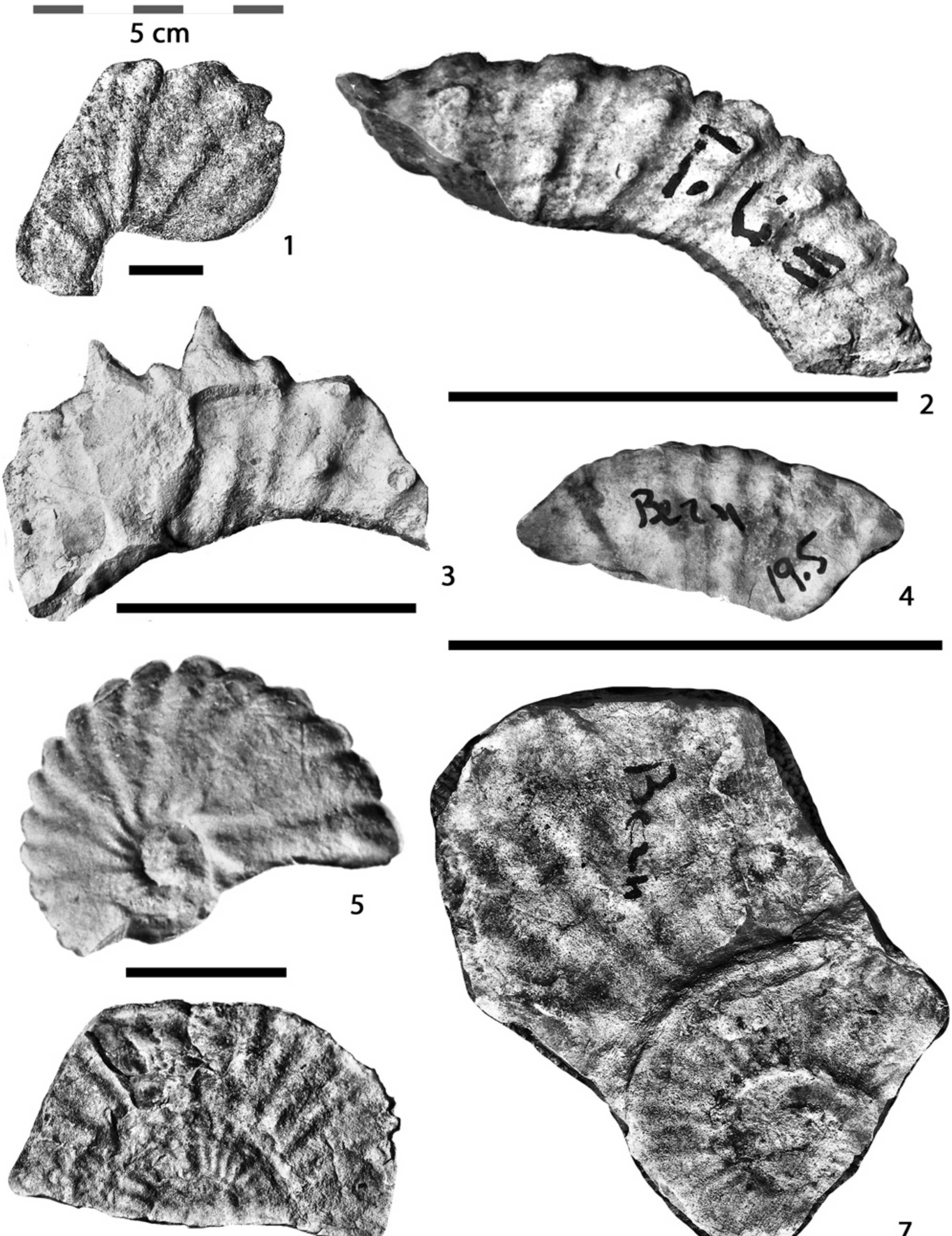
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Plate 7:

1) *Gerhardtia sartousiana* (ORBIGNY, 1841).- level 188.35 (FSL 391089), l_{max} = 4.2 cm [*Gerhardtia provincialis* according to BERT, this volume]

2) *Gerhardtia sartousiana* (ORBIGNY, 1841).- level 188.35 (FSL 391090), l_{max} = 1.5 cm [*Gerhardtia provincialis* according to BERT, this volume]

3) *Gerhardtia sartousiana* (ORBIGNY, 1841).- level 188.35 (FSL391091), l_{max} = 4.2 cm [*Gerhardtia provincialis* according to BERT, this volume]

4) *Gerhardtia sartousiana* (ORBIGNY, 1841).- level 188.35 (FSL 391092), l_{max} = 3.0 cm [*Gerhardtia provincialis* according to BERT, this volume]

5) *Barremites strettostoma* (UHLIG, 1883).- level 202.5 (FSL 391095), l_{max} = 8.2 cm

6) *Hemihoplites* sp.- level 195.5 (FSL 391093), l_{max} = 8.5 cm [*Hemihoplites feraudianus* according to BERT, this volume]

7) shaft of *Heteroceras* sp.- level 202 (FSL 391097), l_{max} = 4.7 cm

8) *Acantholytoceras* sp.- level 192 (FSL 391094), l_{max} = 13.6 cm

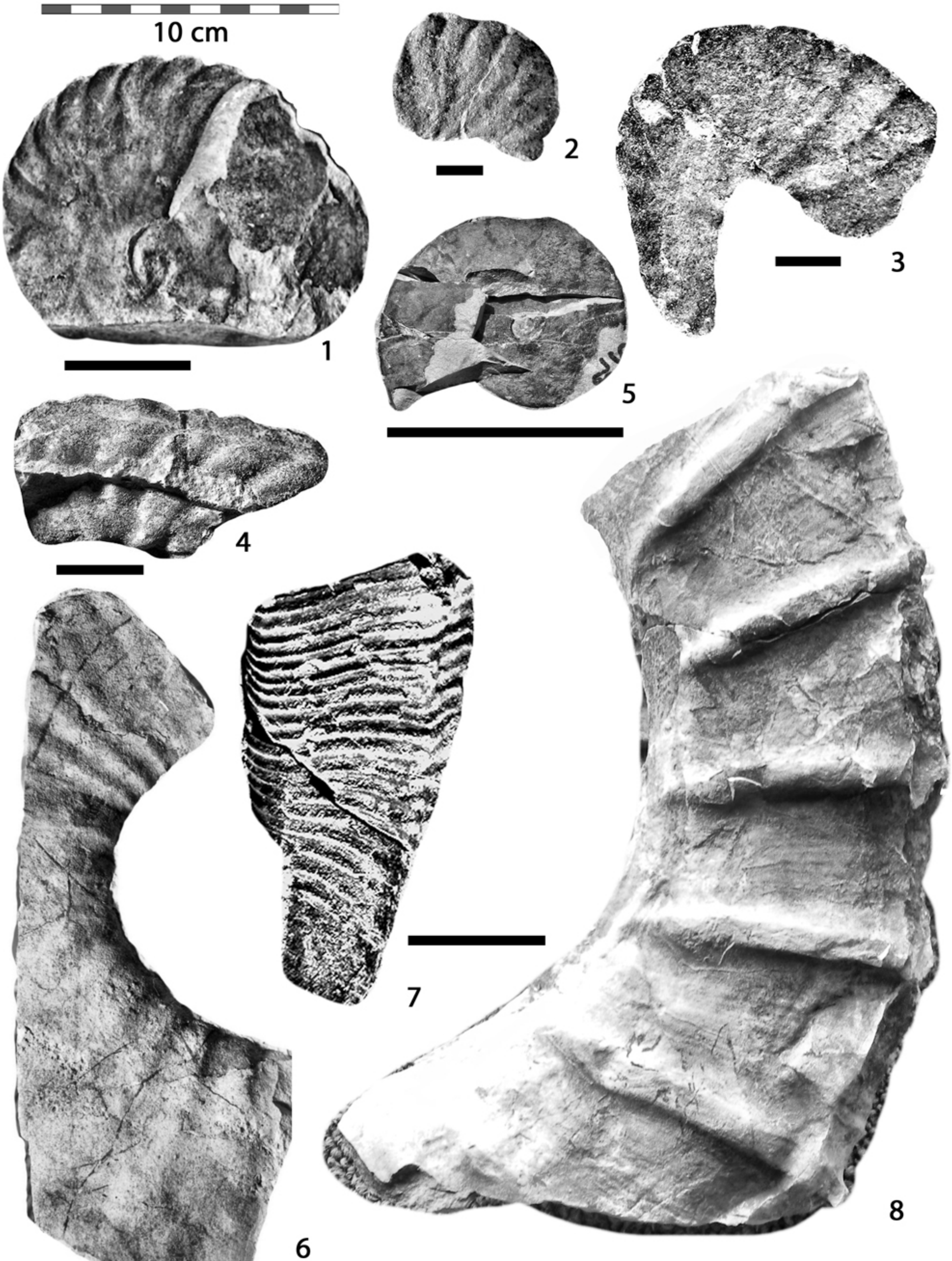
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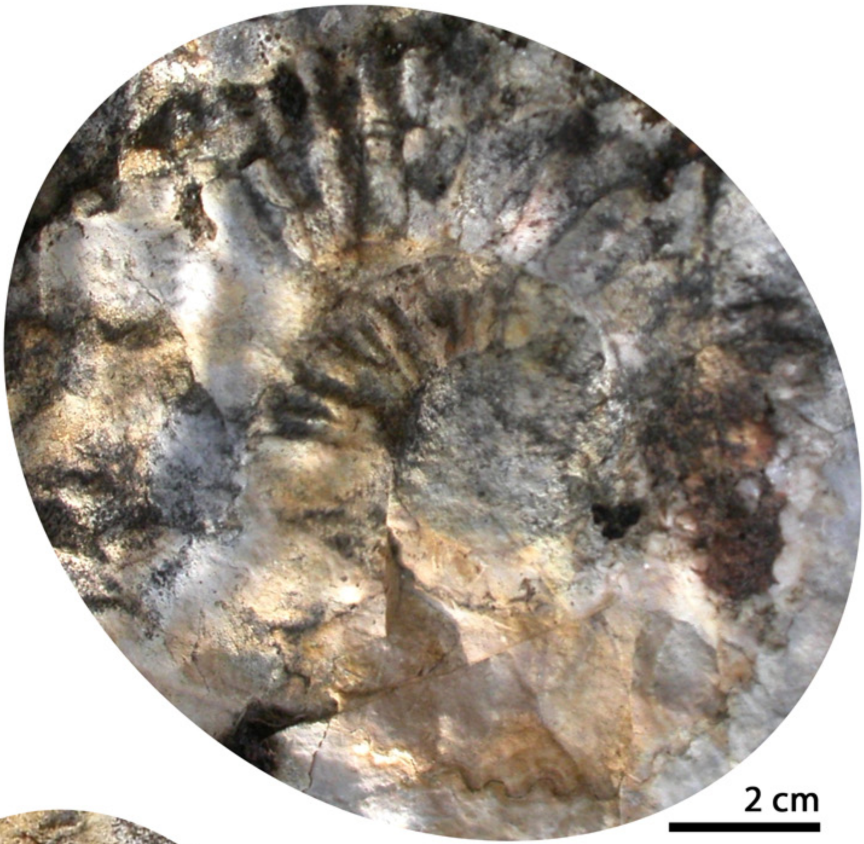
Plate 8:

1) *Procheloniceras* gr. *pachystephanum* (UHLIG, 1883).- uppermost surface, on the side of road D70, laterally to level 247.5 [*Procheloniceras* gr. *pachystephanum* according to BERT, this volume]

2) *Procheloniceras* gr. *pachystephanum* (UHLIG, 1883).- uppermost surface, on the side of road D70, laterally to level 247.5 [*Procheloniceras* gr. *pachystephanum* according to BERT, this volume]

3) *Procheloniceras* gr. *pachystephanum* (UHLIG, 1883).- uppermost surface, on the side of road D70, laterally to level 247.5 [*Procheloniceras* gr. *pachystephanum* according to BERT, this volume]

Each graphical bar equals 2 cm.


2 cm


2 cm


2 cm

Barremian ammonite fauna from L'Estellon section (Baronnies, SE France):

Additional identifications

Didier Bert

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Citation: Bert D. (2017).- Barremian ammonite fauna from L'Estellon section (Baronnies, SE France): Additional identifications. *In*: Granier B. (ed.), Some key Lower Cretaceous sites in Drôme (SE France).- Carnets de Géologie, Madrid, CG2017_B01, ISBN 978-2-916733-13-5, p. 102-109.

Plate 1:

A) *Honnoratia honnoratiana*.- level 6.5

B-C) '*Raspailliceras cassida*'.- level 13.5

D-E) *Barremites psilotatum*.- level 12

F) *Avramidiscus intermedius*.- level 30

G) *Crioceratites angulicostatus*.- level -12.5

White squares are 1 cm on each side.

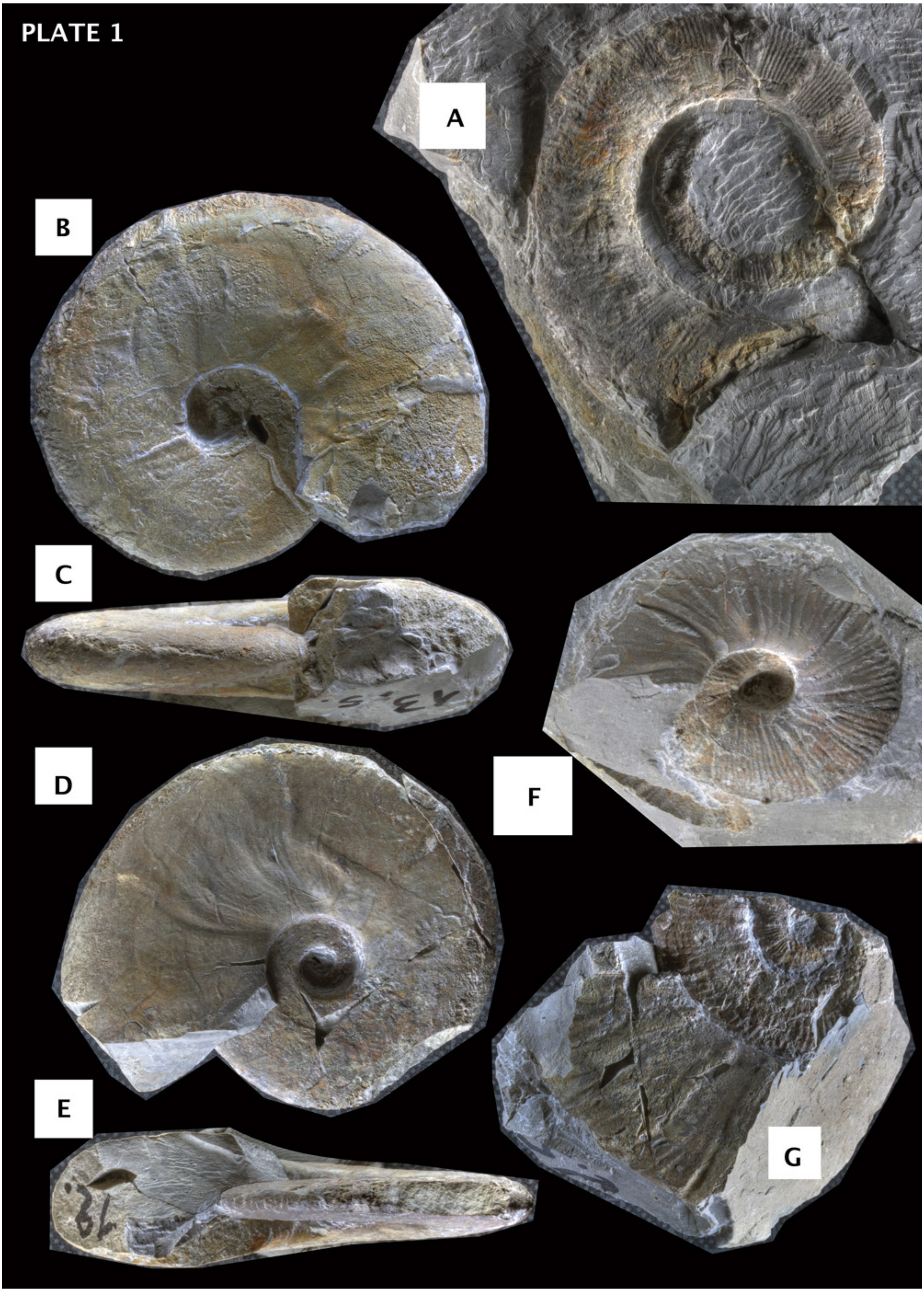

PLATE 1
A
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G

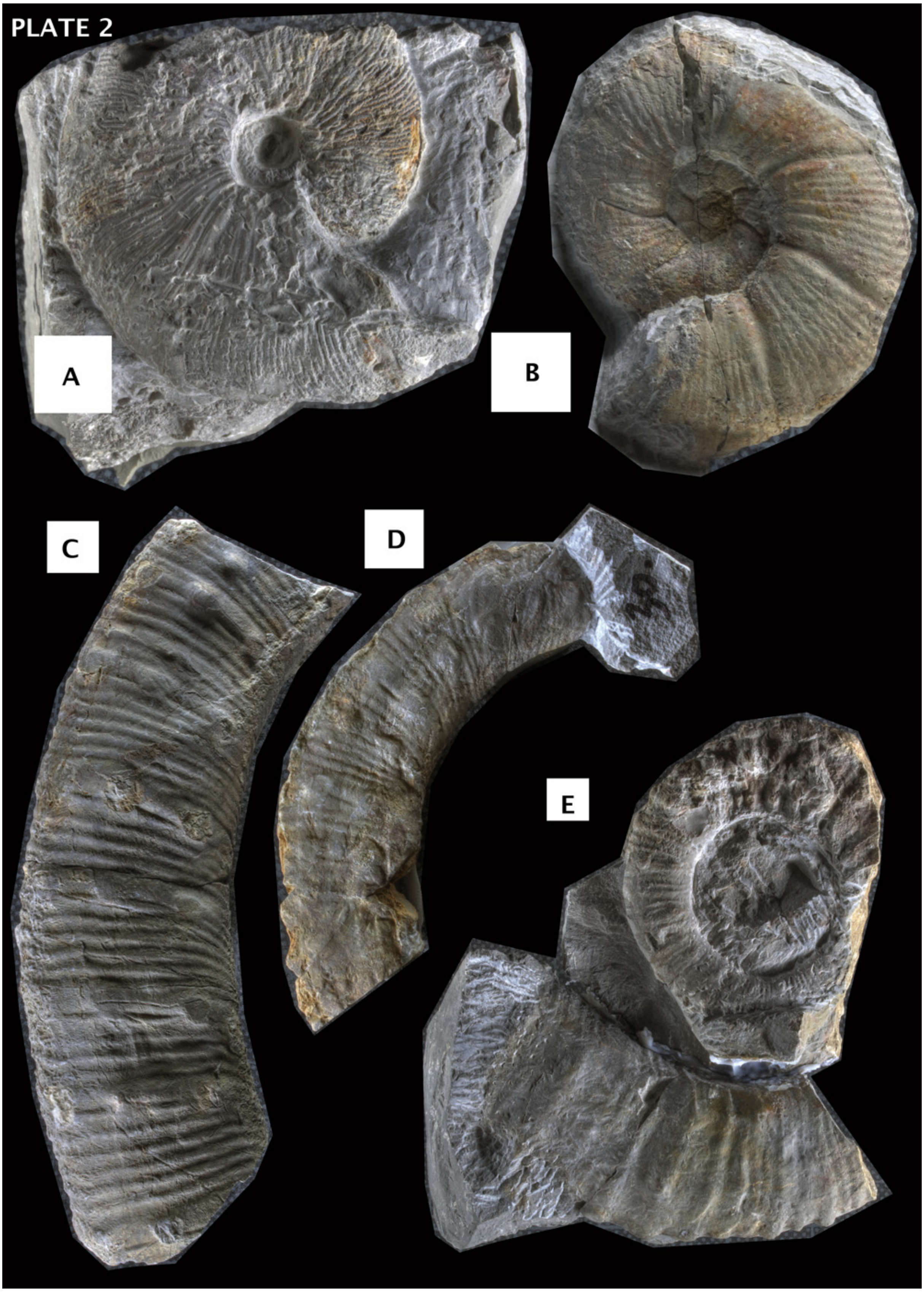


Plate 2:

A) *Taveraidiscus hugii*.- level 17.5 ; B) *Avramidiscus kiliani*.- level 28 ; C-D) *Honnoratia thiollierei* .- level30 ; E) *Toxancyloceras ebboi*.- level 140.5

White squares are 1 cm on each side.

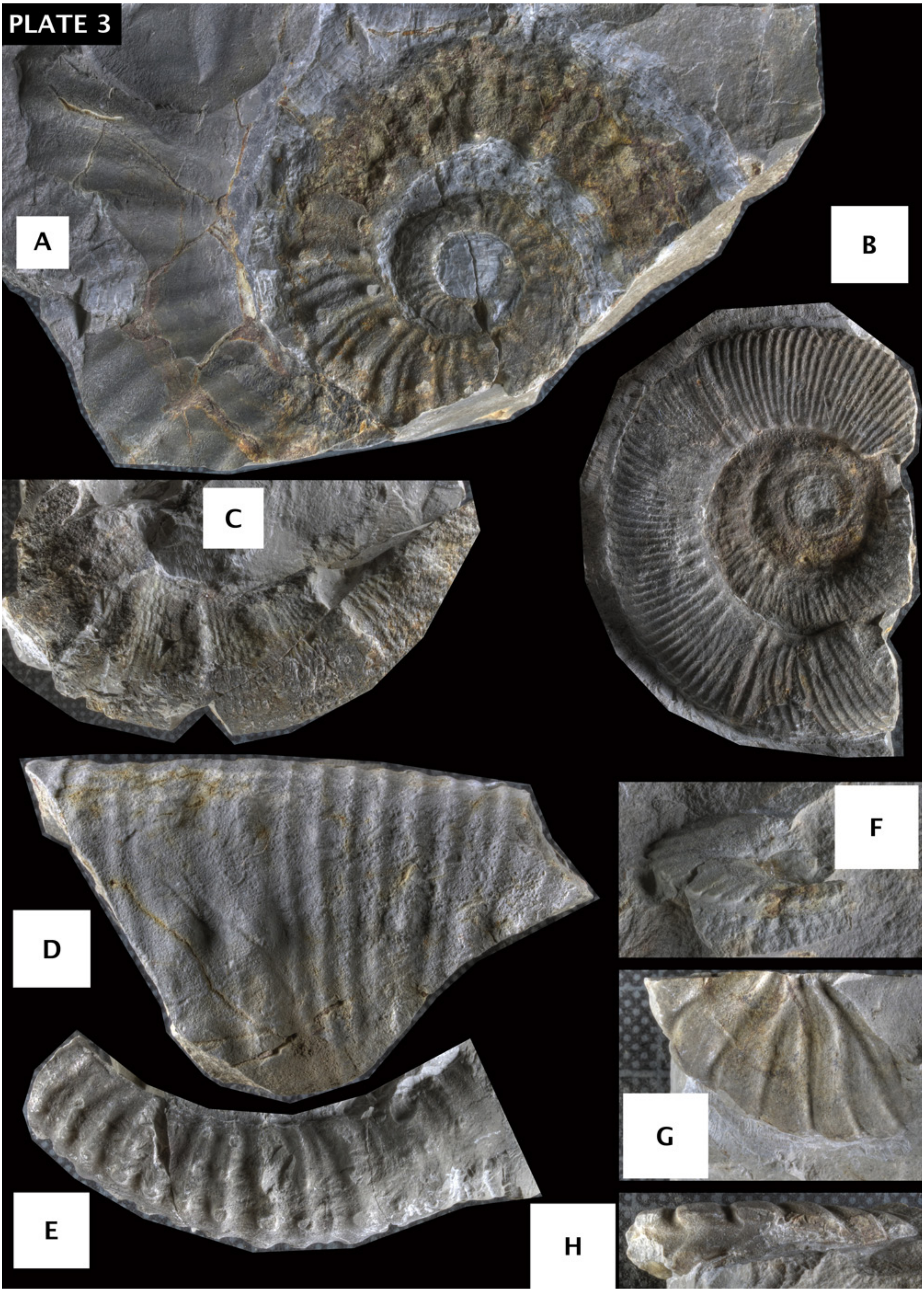


Plate 3:

A) *Gassendiceras quelquejeui*.- level 174.5 ; B) *Macroscaphites binodosus*.- level 174.5 ; C) *Acantholytoceras tenuicostatum*.- level 187.5 ; D-E) *Jaubertites* sp.- level 187.5 ; F-H) *Gerhardtia sartousiana*.- level 187.5

White squares are 1 cm on each side.

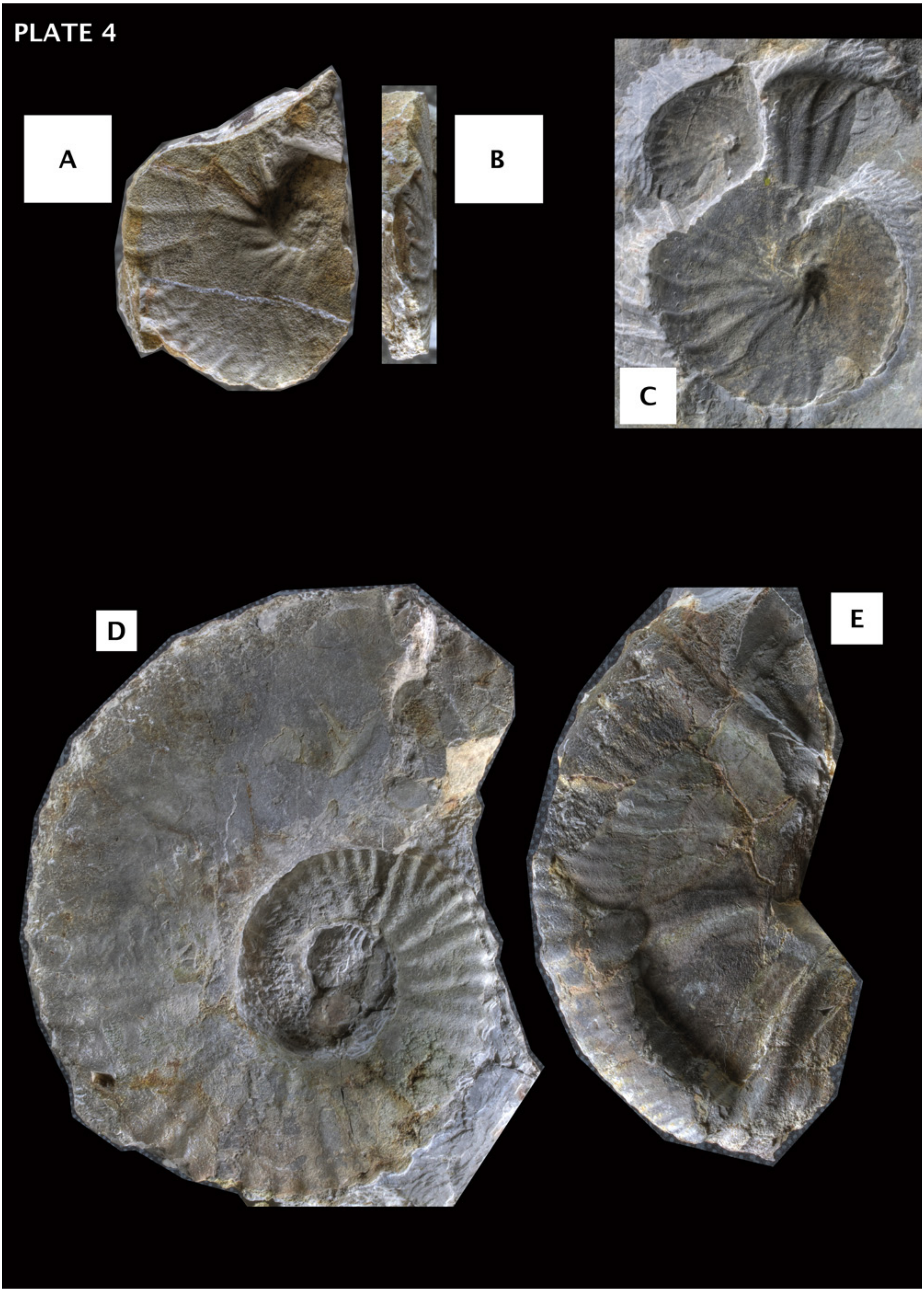


Plate 4:

A-C) *Gerhardtia provincialis*.- level 192 ; D) *Martelites sarasini*.- level 243.5 ; E) *Pseudohaploceras matheroni*.- level 246.5

White squares are 1 cm on each side.

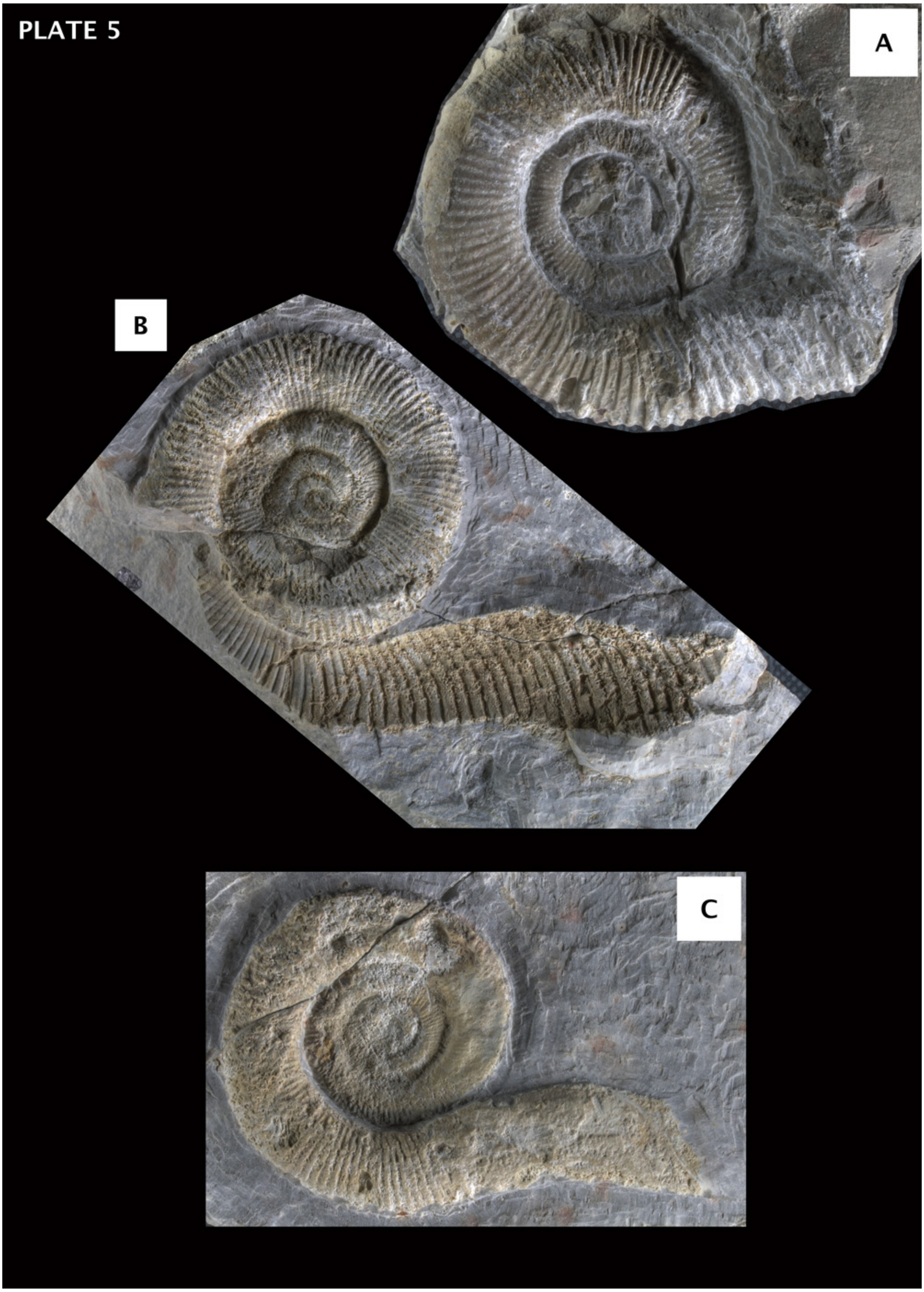
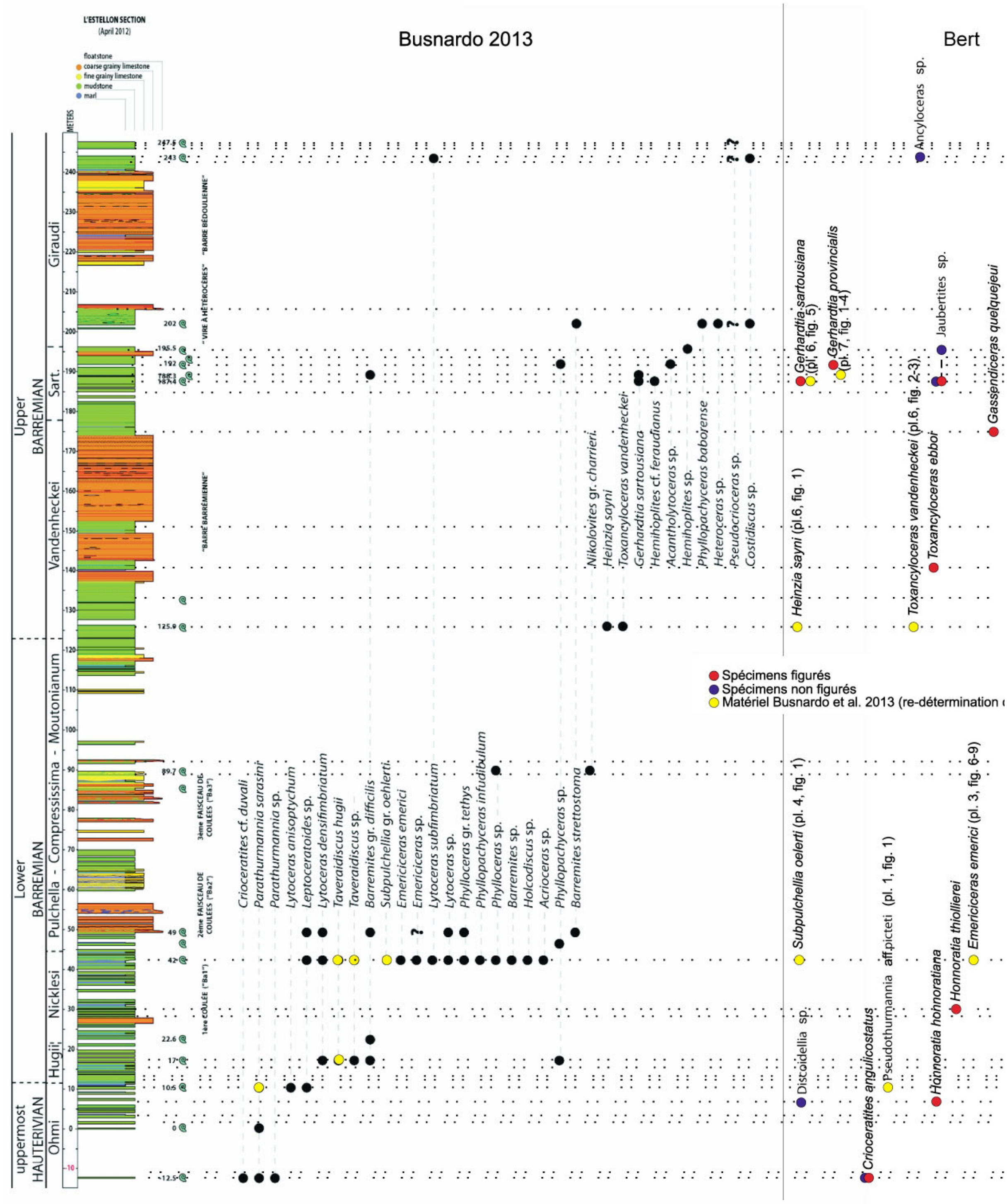
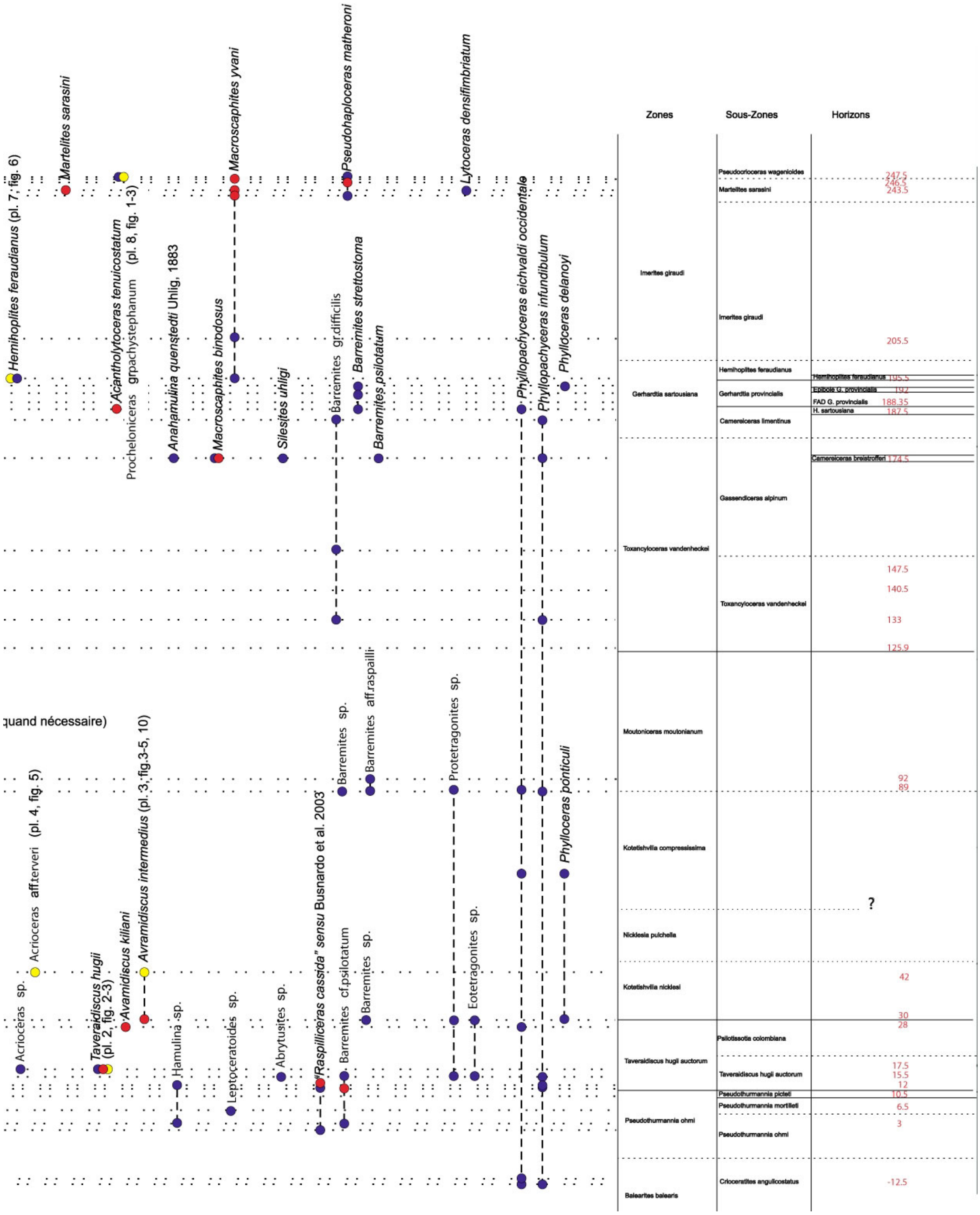


Plate 5:

A) *Macroscaphites yvani*.- level 242.5 ; B) *Macroscaphites yvani*.- level 237.5 ; C) *Macroscaphites yvani*.- level 247.5

White squares are 1 cm on each side.


L'ESTELLON SECTION
(April 2012)
Busnardo 2013
Bert
floatstone
coarse grainy limestone
fine grainy limestone
mudstone
marl
METERS
uppermost HAUTERIVIAN
Lower BARREMIAN
Upper BARREMIAN
Ohmi
Hugii
Nicklesi
Pulchella - Compressissima - Moutonianum
Vandenheckei
Sart.
Giraudi
Spécimens figurés
Spécimens non figurés
Matériel Busnardo et al. 2013 (re-détermination


Zones
Sous-Zones
Horizons
Imerites giraudi
Gerhardtia sartousiana
Toxancyloceras vandenheckei
Moutoniceras moutonianum
Kotetishvilia compressissima
Nicklesia pulchella
Kotetishvilia nicklesi
Taveraidiscus hugii auctorum
Pseudothurmannia ohmi
Balearites balearis
Hemihoplites feraudianus (pl. 7, fig. 6)
Martelites sarasini
Acantholytoceras tenuicostatum
Procheloniceras gr. pachystephanum (pl. 8, fig. 1-3)
Anahamulina quenstedti Uhlig, 1883
Macroscaphites binodosus
Macroscaphites yvani
Silesites uhligi
Barremites gr. difficilis
Barremites strettostoma
Barremites psilotatum
Pseudohaploceras matheroni
Lytoceras densifimbriatum
Phyllopachyceras eichvaldi occidentale
Phyllopachyceras infundibulum
Phylloceras delanoyi
quand nécessaire)
Acrioceras aff. terveri (pl. 4, fig. 5)
Acrioceras sp.
Taveraidiscus hugii (pl. 2, fig. 2-3)
Avramidiscus kiliani
Avramidiscus intermedius (pl. 3, fig. 3-5, 10)
Hamulina sp.
Leptoceratoides sp.
Abrytusites sp.
"Raspiliceras cassida" sensu Busnardo et al. 2003
Barremites sp.
Barremites cf. psilotatum
Barremites aff. raspailli
Protetragonites sp.
Eotetragonites sp.
Phylloceras ponticuli
?

L'Estellon (Baronnies, France), some geochemical data

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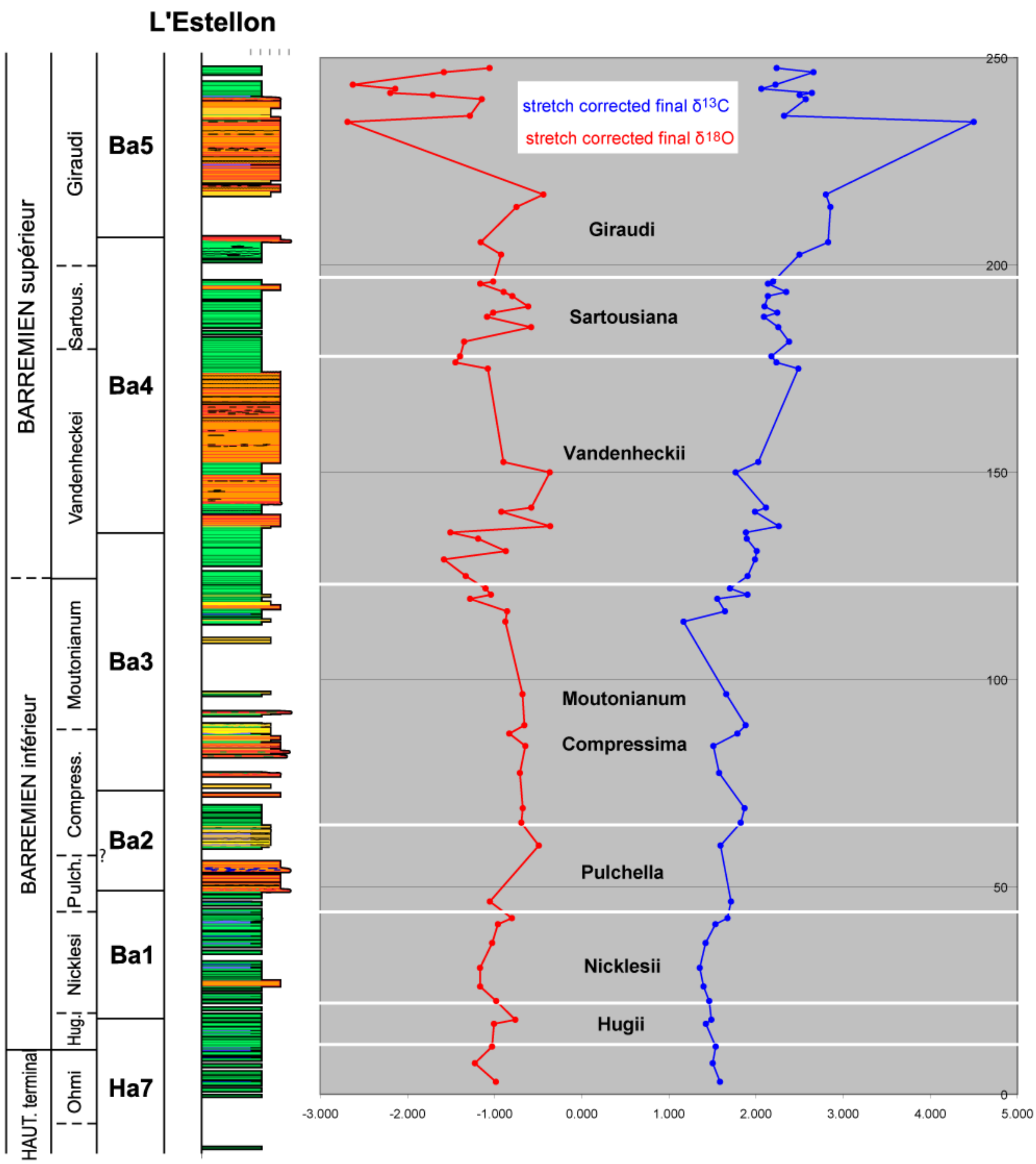

L'Estellon (Baronnies, France), a "Rosetta Stone" for the Urgonian biostratigraphy

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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.

Modified from: 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 Geol.*, Madrid, vol. 13, no. A04 (CG2013_A04), p. 163-207.

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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 lime-

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): see BUSNARDO *et al.* (this volume)

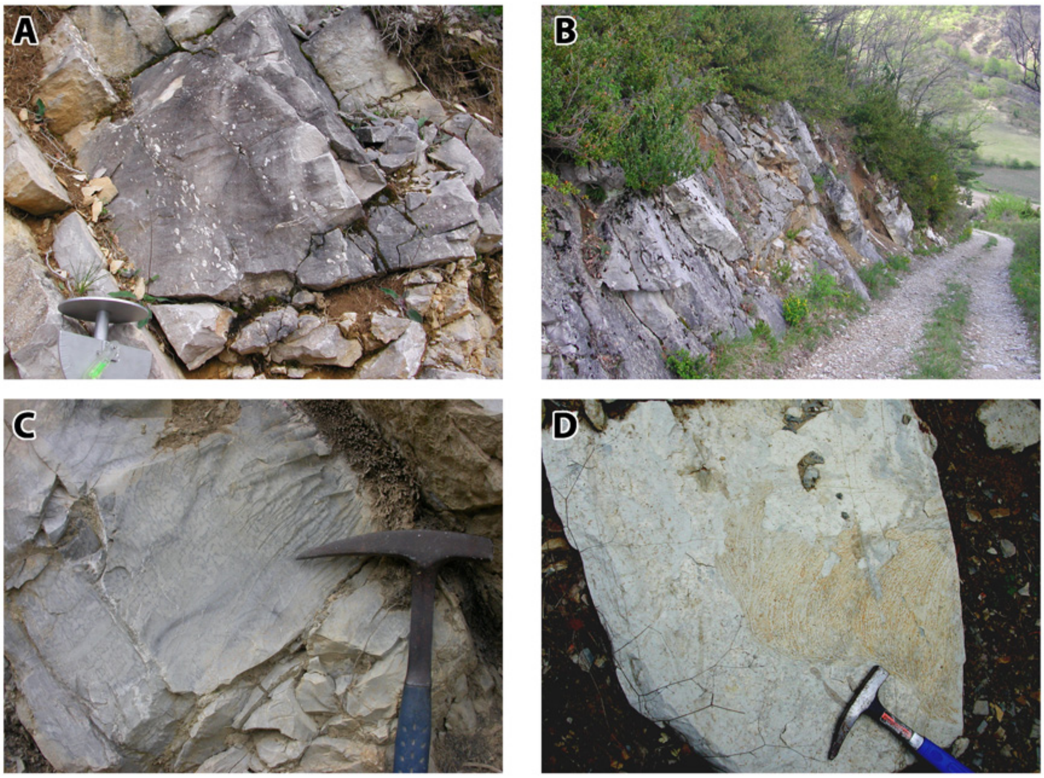
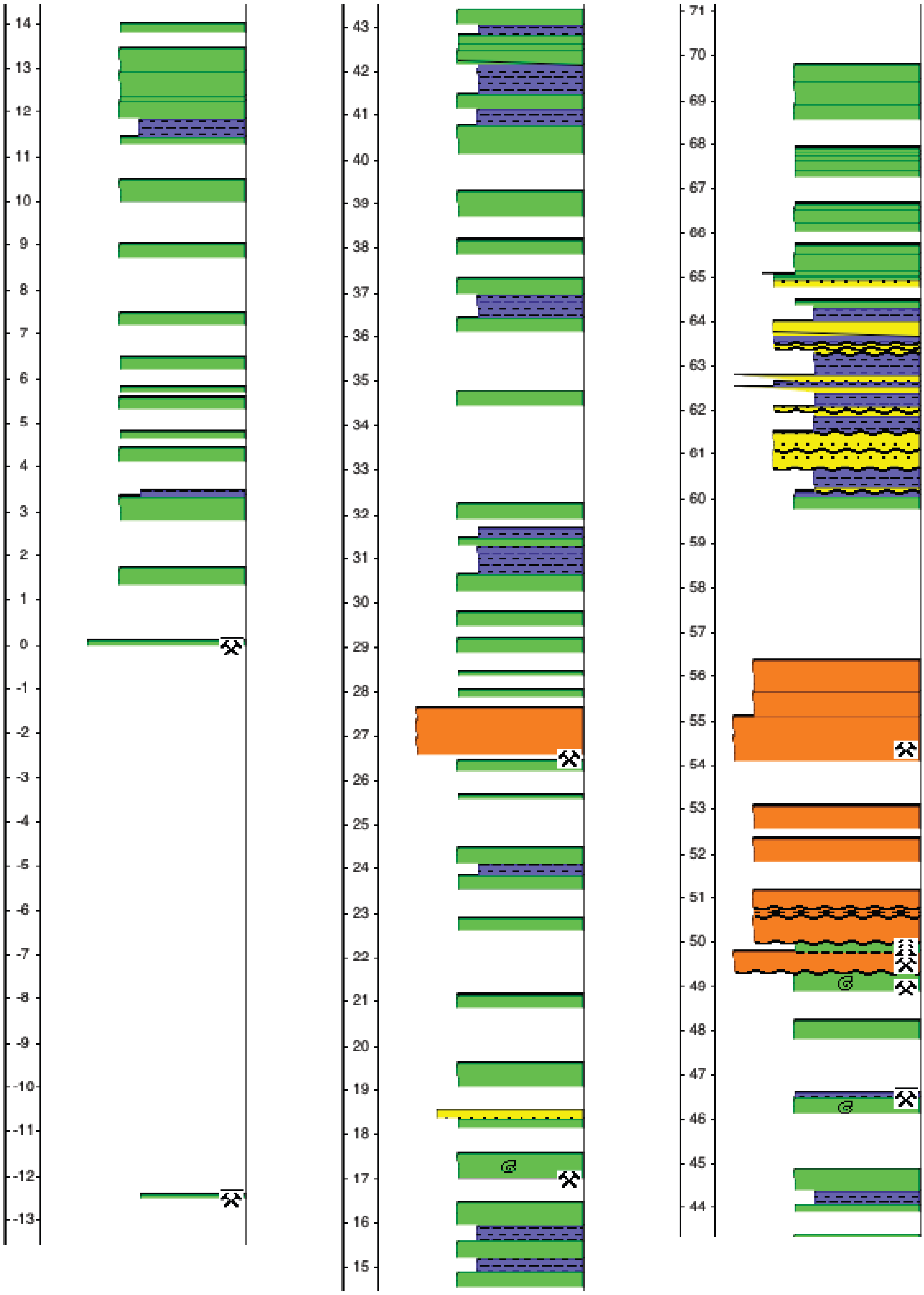


Figure 2: A: cherts in calcarenites of the interval 227.1 to 228.2; **B:** uppermost part of the section, temporary end at level 243.7; **C:** typical vermicular (bioturbated) facies; **D:** *Zoophycos* at level 241.2.

stones (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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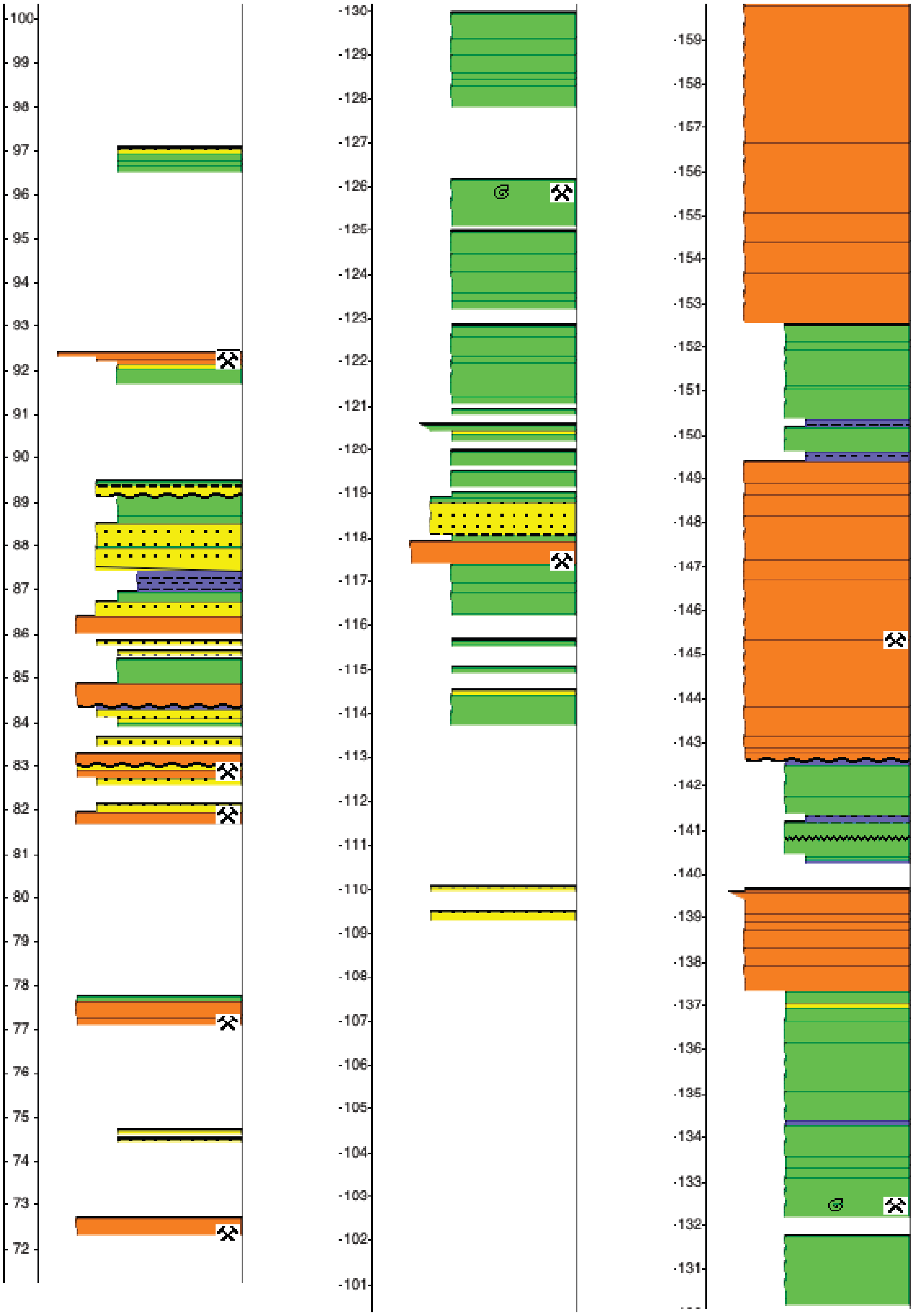
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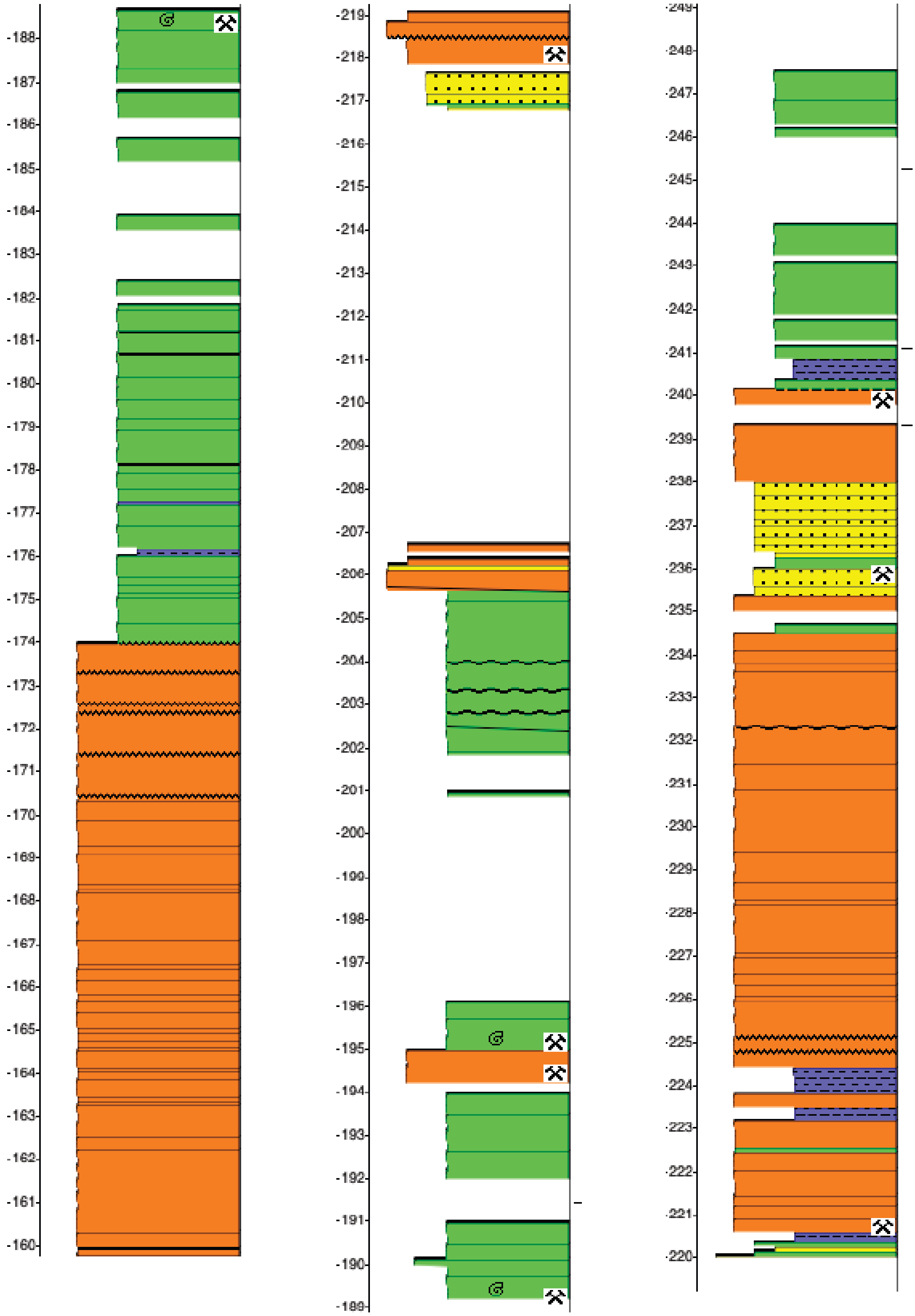

Figure 3: Lithostratigraphic column of L'Estellon section.

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).

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.

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").

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 foraminifers 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 foraminifers 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 foraminifers level 242 can be ascribed to the latest Barremian. This result is consistent with the dating based on our ammonite record.

2) Taxonomic notes

1. *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.
2. *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.

3) Microfaunal contents

A. 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 foraminifers (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.

1. Level 60.3

Benthic foraminifers: *Lenticulina gibba*, *Neotrocholina paucigranulata*, *Spirillina minima*, *Patellina subcretacea*, Nodosariidae spp., 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*.

1. Level 77.2

Benthic foraminifers: *Neotrocholina infragranulata*, *N. paucigranulata*, *Spirillina minima*, *Patellina subcretacea*, *Praedorothia* spp., 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* (* recently reascribed to the genus *Coscinoconus*), and smaller ones, as *Arenobulimina* spp., *Nezzazata*, *Nautiloculina*, *Conorboides* spp., various undetermined rotaliiforms.

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

A. 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*.

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

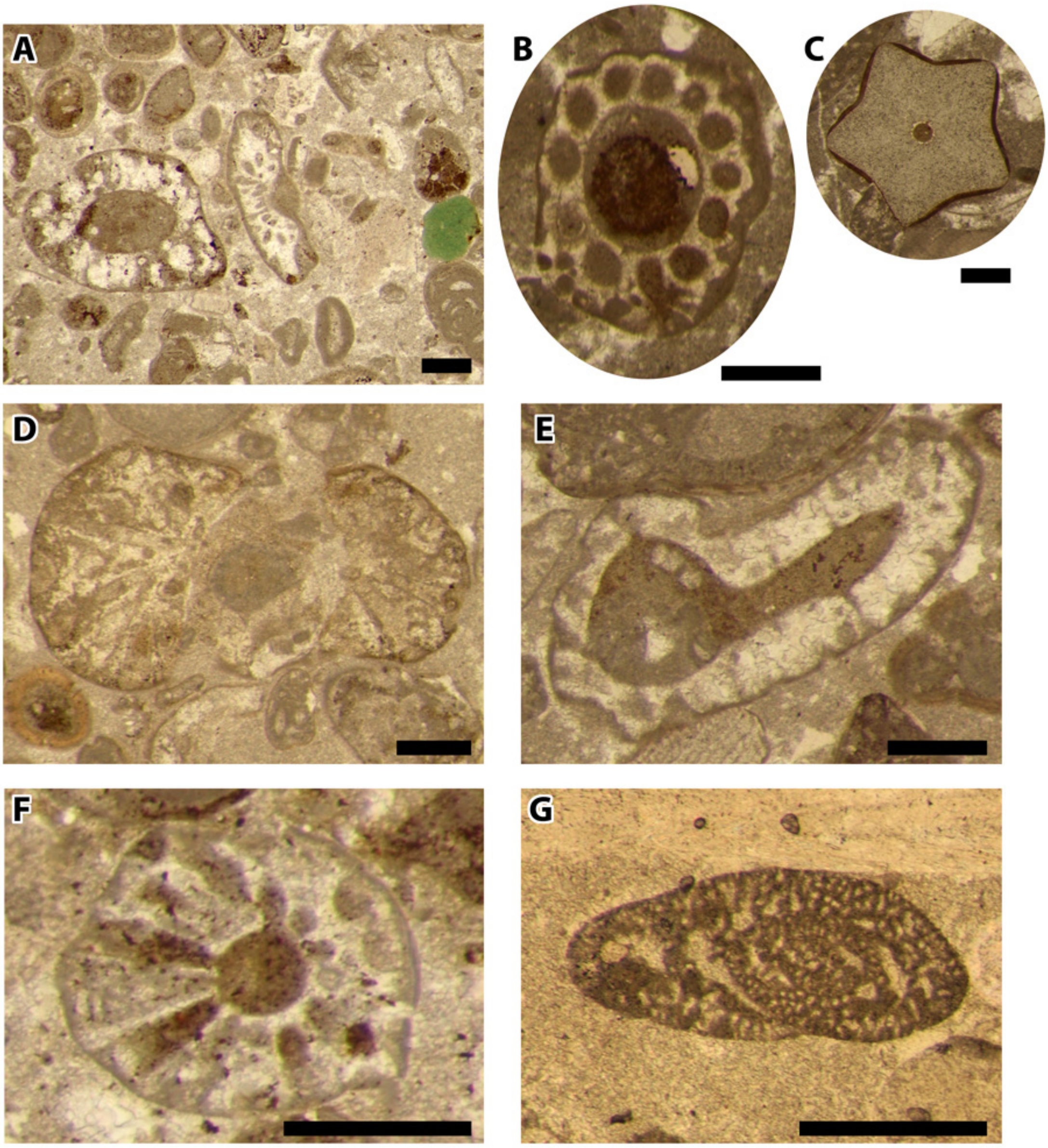

Figure 6: A: slightly glauconitic oobioclastic wackestone with the algae *Salpingoporella genevensis* (oblique section) and *Actinoporella* gr. *podolica* (oblique section) - Sample 26.5m; **B:** subtransverse section of a charophyte stem - Sample 218.1m; **C:** transverse section of a crinoid columnal - 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.

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:

A. the first calcarenitic bed at 26.5m (Niklesi Zone) is referred to the LST "Ba1" of CLAVEL *et al.* (2010a, 2012),
B. the second set starting from 49.3m (Pulchella Zone) to the LST "Ba2",
C. the third starting from 72.4m (spanning Compressissima and Moutonianum zones) to the LST "Ba3",

A

B

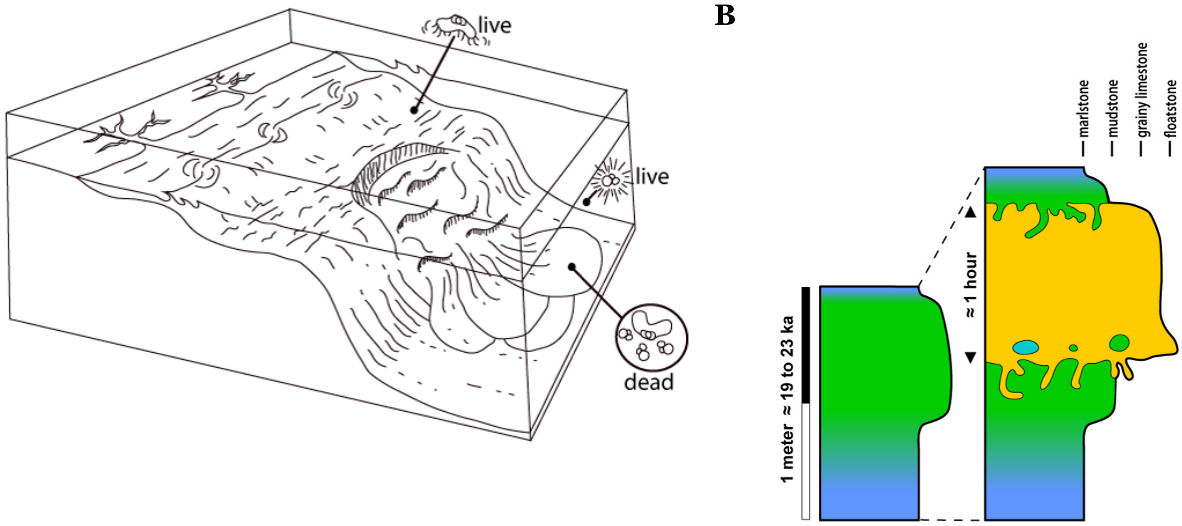

Figure 7: A: a model for the sourcing of the Urgonian calciturbidites, the strata where the neritic microfossils meet the basinal index fossils (according to GRANIER, 2013b); **B:** a model of the sedimentation rate for calciturbidites in alternating marl-limestone: for an equal thickness a calcarenitic interval represents a much higher sedimentation rate than a marl-limestone interval.

D. the so-called "Barremian" ridge (Vandenheckei Zone) to the LST "Ba4", and

E. 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 5 m², *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.

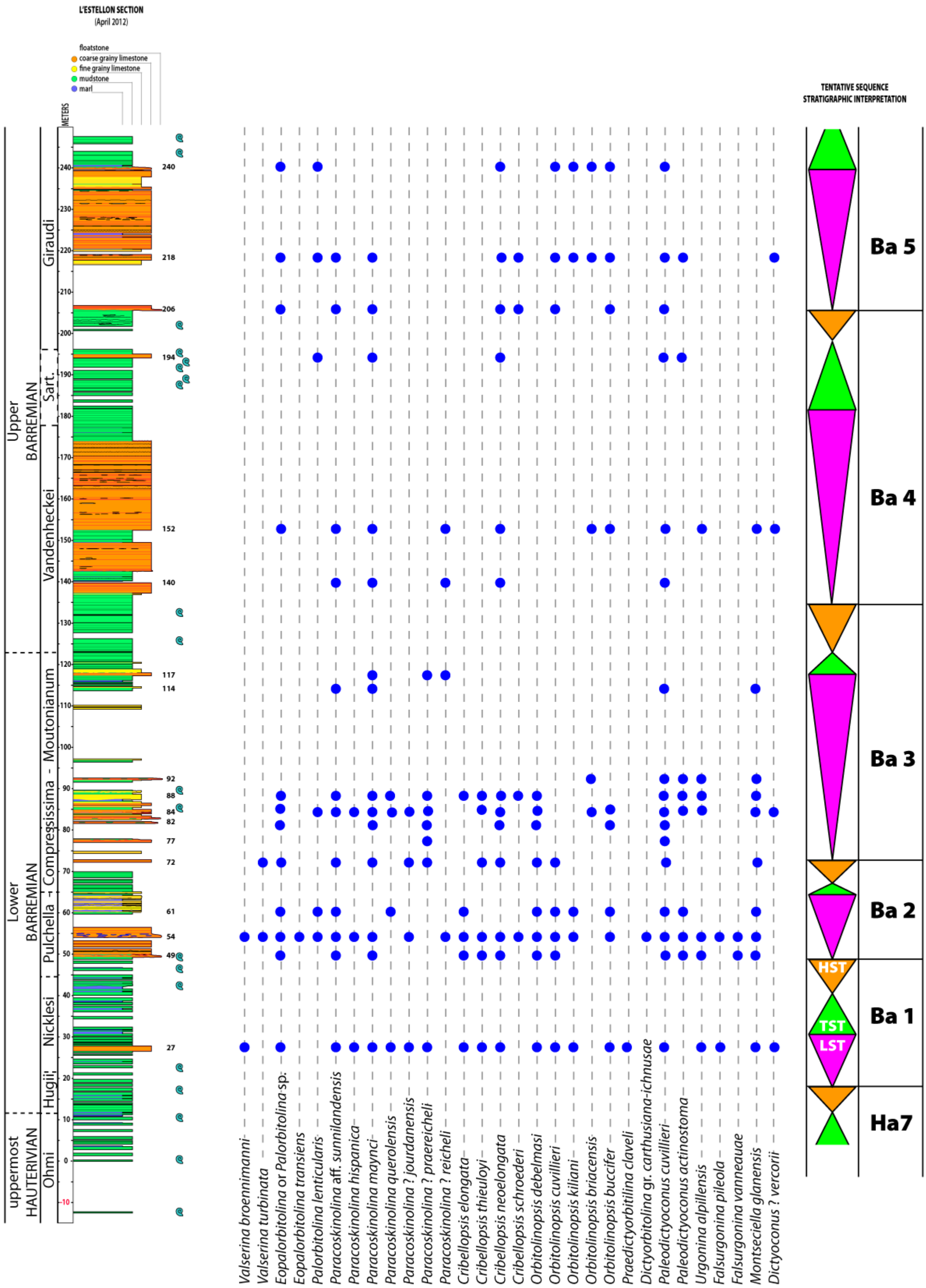

Figure 8: Orbitolinid records together with the latest biostratigraphic interpretation of L'Estellon section as documented by ammonites and planktonic foraminifera (and tentative sequence stratigraphic framework).

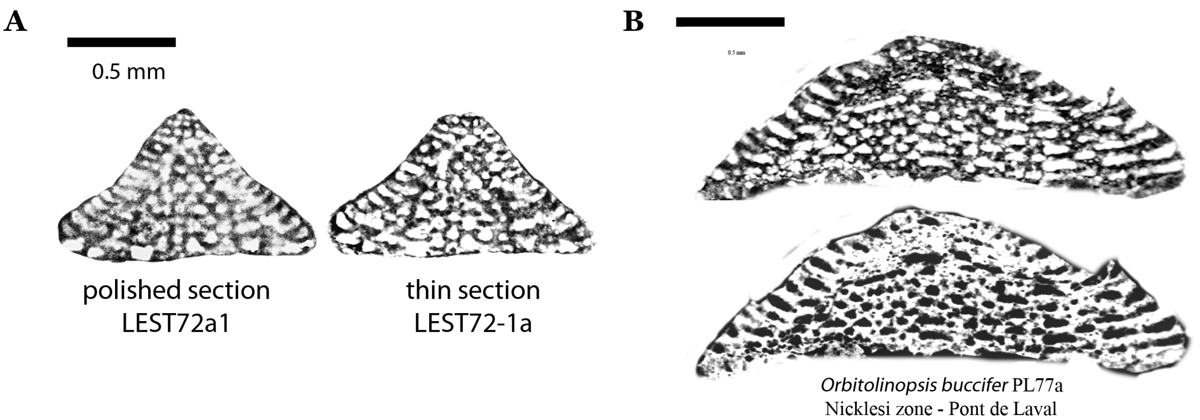

Figure 9: A: polished section (left) and slide (right) of *Cribellopsis schroederi* - sample LEST-72; **B:** positive (up) and negative (down) subtangential sections of *Orbitolinopsis buccifer*, Pont de Laval section (Vivarais) - sample PL77. Scale bars = 500µm.

B) Systematics of the Orbitolinidae (B. Clavel)

Class Foraminifera Orbigny, 1826

Subclass Textulariia Mikhalevich, 1980

Order Loftusiida Kaminski, 2004

Suborder Orbitolinina Kaminski, 2004

Superfamily Orbitolinacea 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.

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 *Dictyoconus*
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.

Dictyoconus ? vercorii
ARNAUD-VANNEAU, 1980
Pl. 8, figs. 10-12; Pl. 9, fig. 7;
Pl. 10, figs. 4

Provisionally attributed to the genus *Dictyoconus*, *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 cylindroconical 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_
SCHROEDER _et al._, 1990

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

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 *Dictyoconus* ? *vercorii* and *Dictyoconus* 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).

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 southeastern 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).

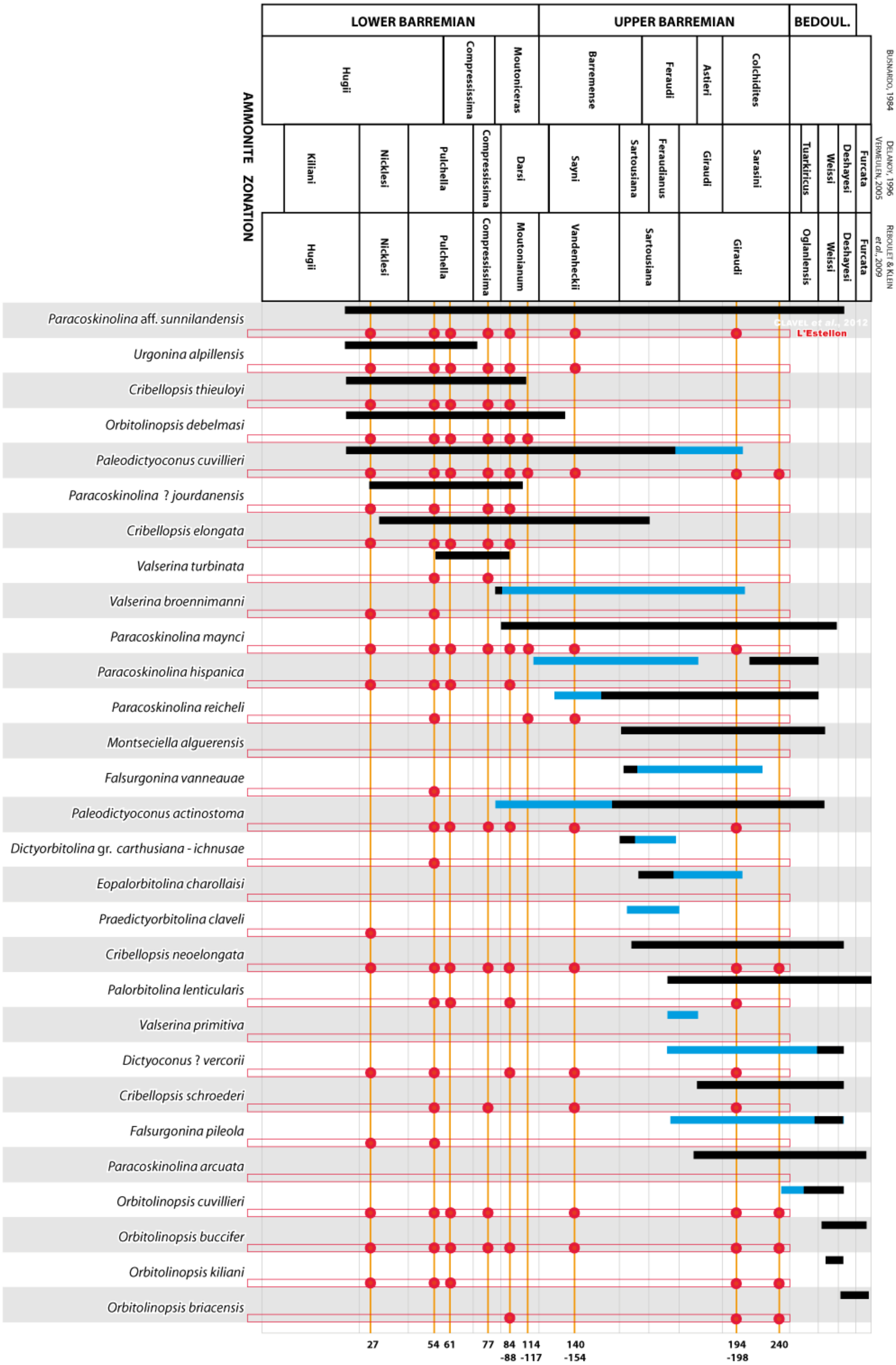

Figure 10: Orbitolinids found at L'Estellon versus the distribution chart of Orbitolinids proposed by ARNAUD-VANNEAU *et al.* (2005): black bars for the typical forms, blue bars for the related forms (primitive, advanced, cf., aff.).

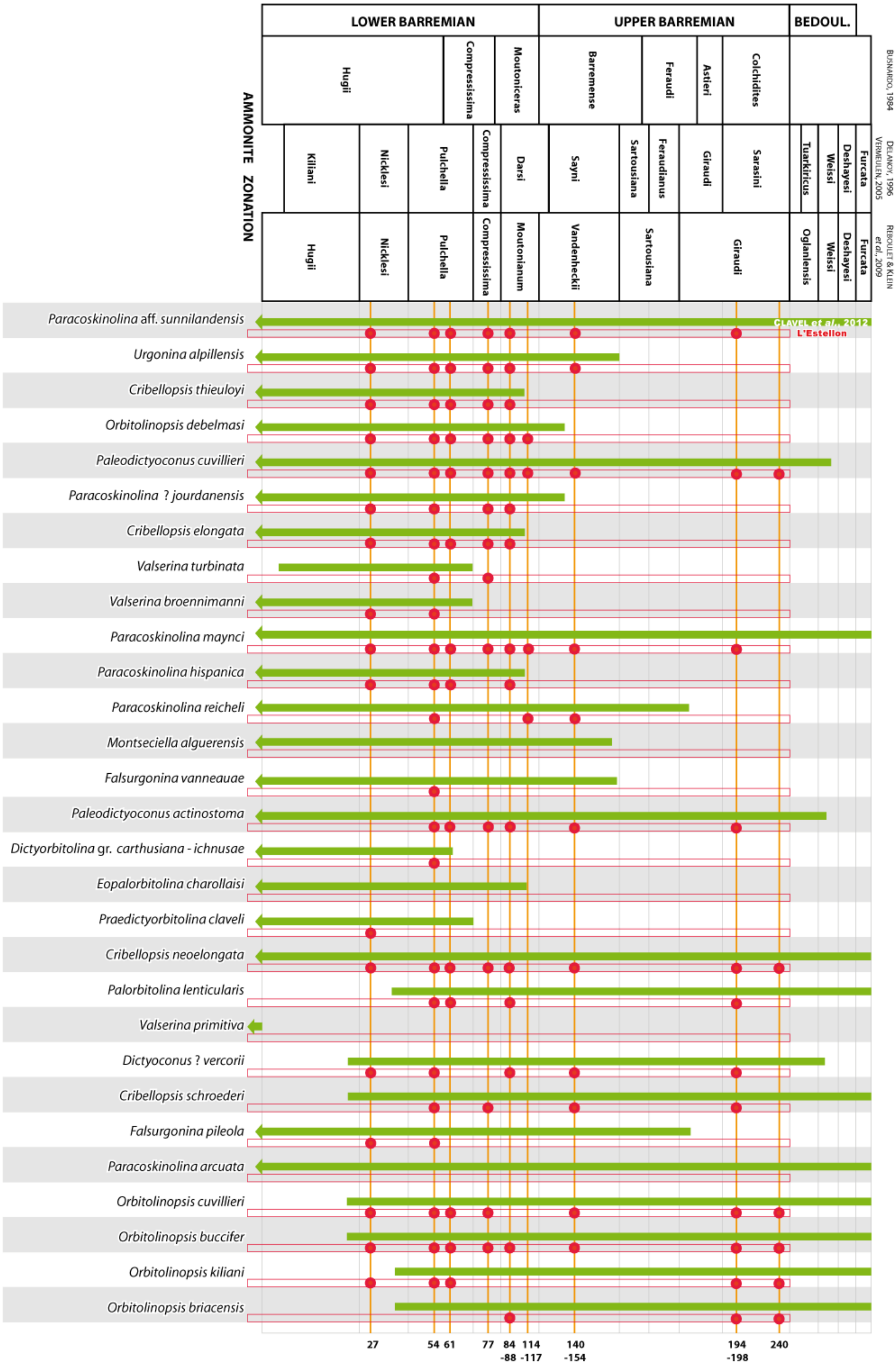

Figure 11: Orbitolinids found at L'Estellon versus the distribution chart of Orbitolinids proposed by CLAVEL *et al.* (2007, 2010a).

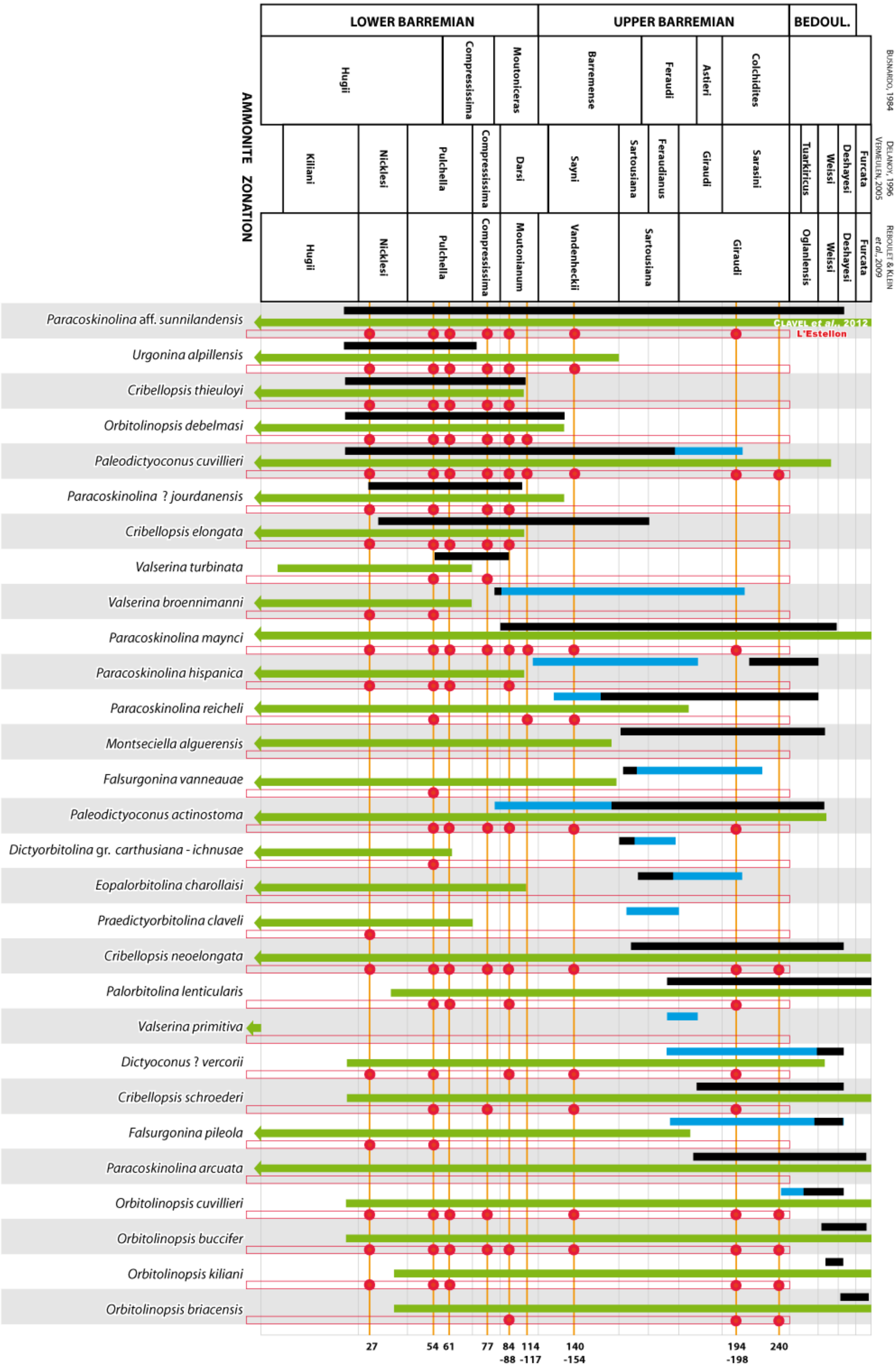

Figure 12: Combination of the previous figures, that is the Orbitolinids found at L'Estellon versus the distribution charts of Orbitolinids proposed by ARNAUD-VANNEAU *et al.* (2005) and by CLAVEL *et al.* (2007, 2010a).

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.

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]

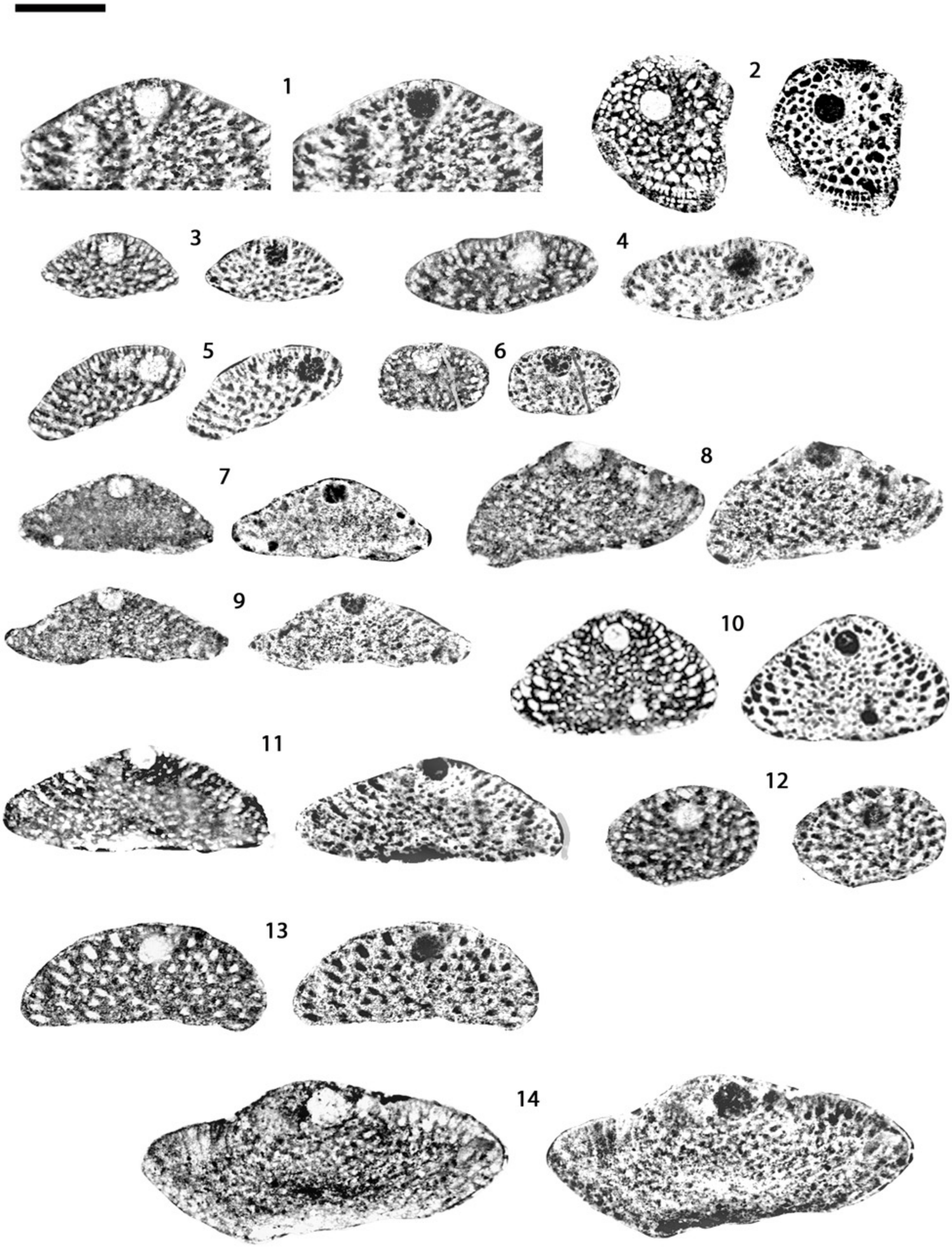
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Plate 2:

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]

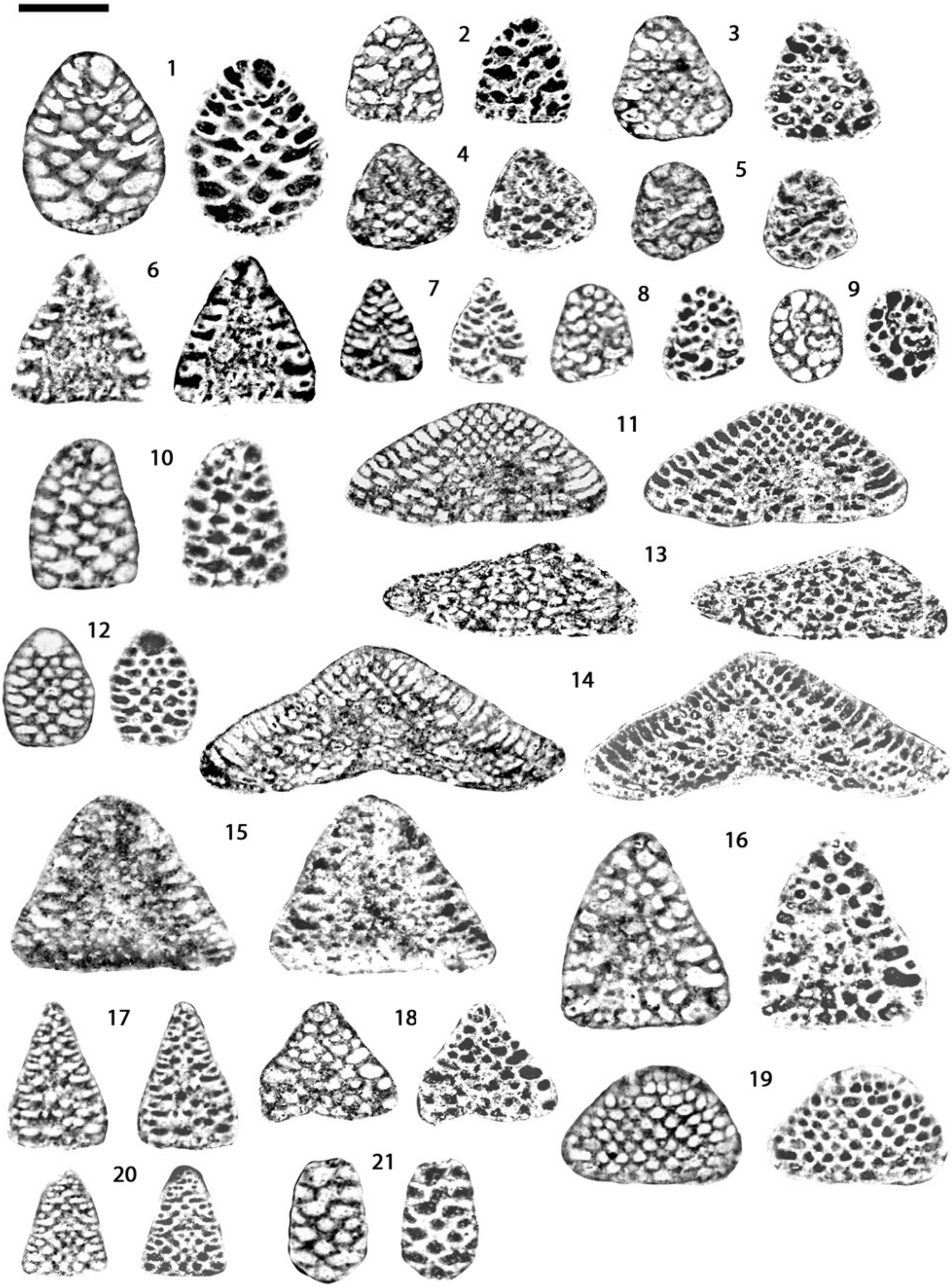
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Plate 3:

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]

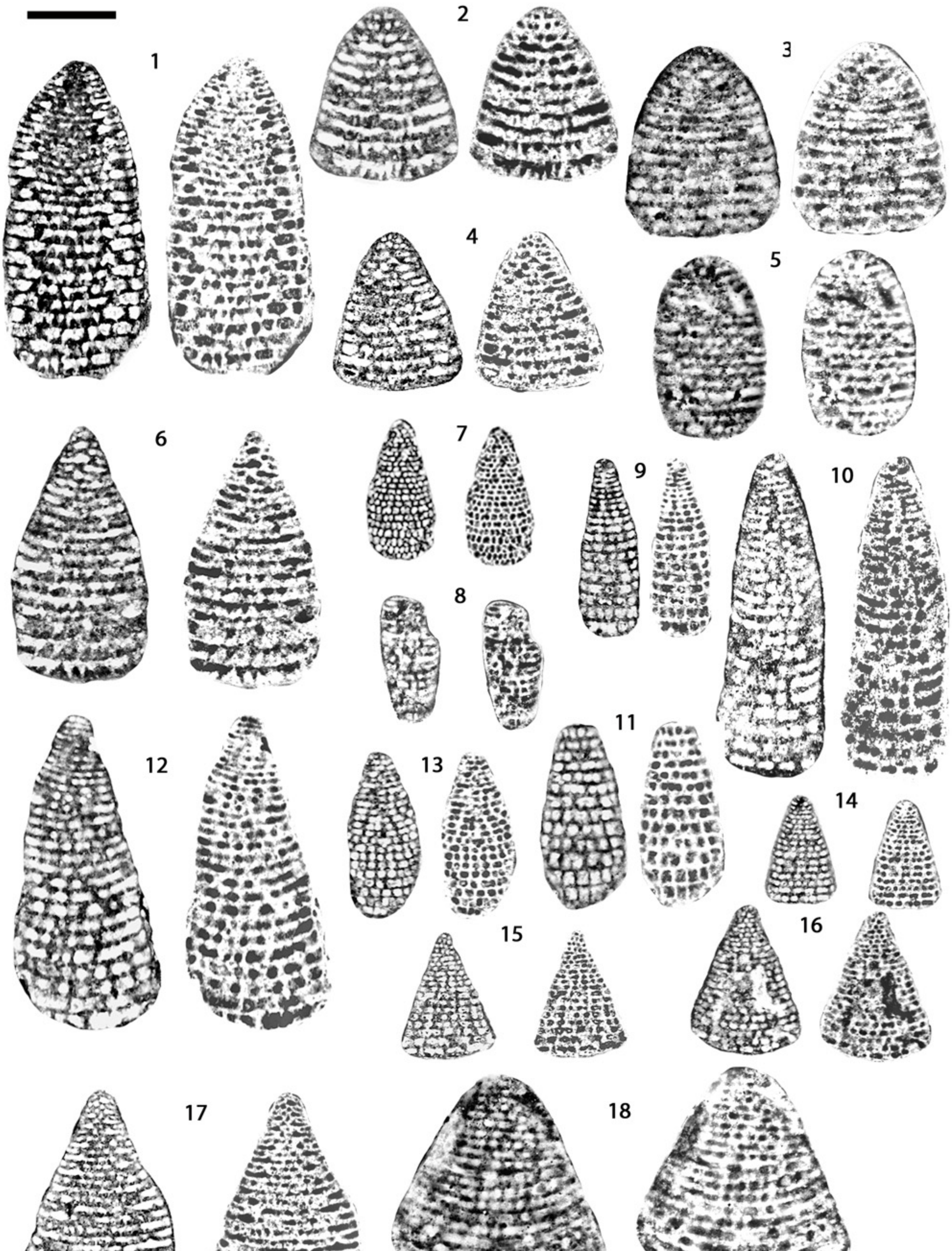
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Plate 4:

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]

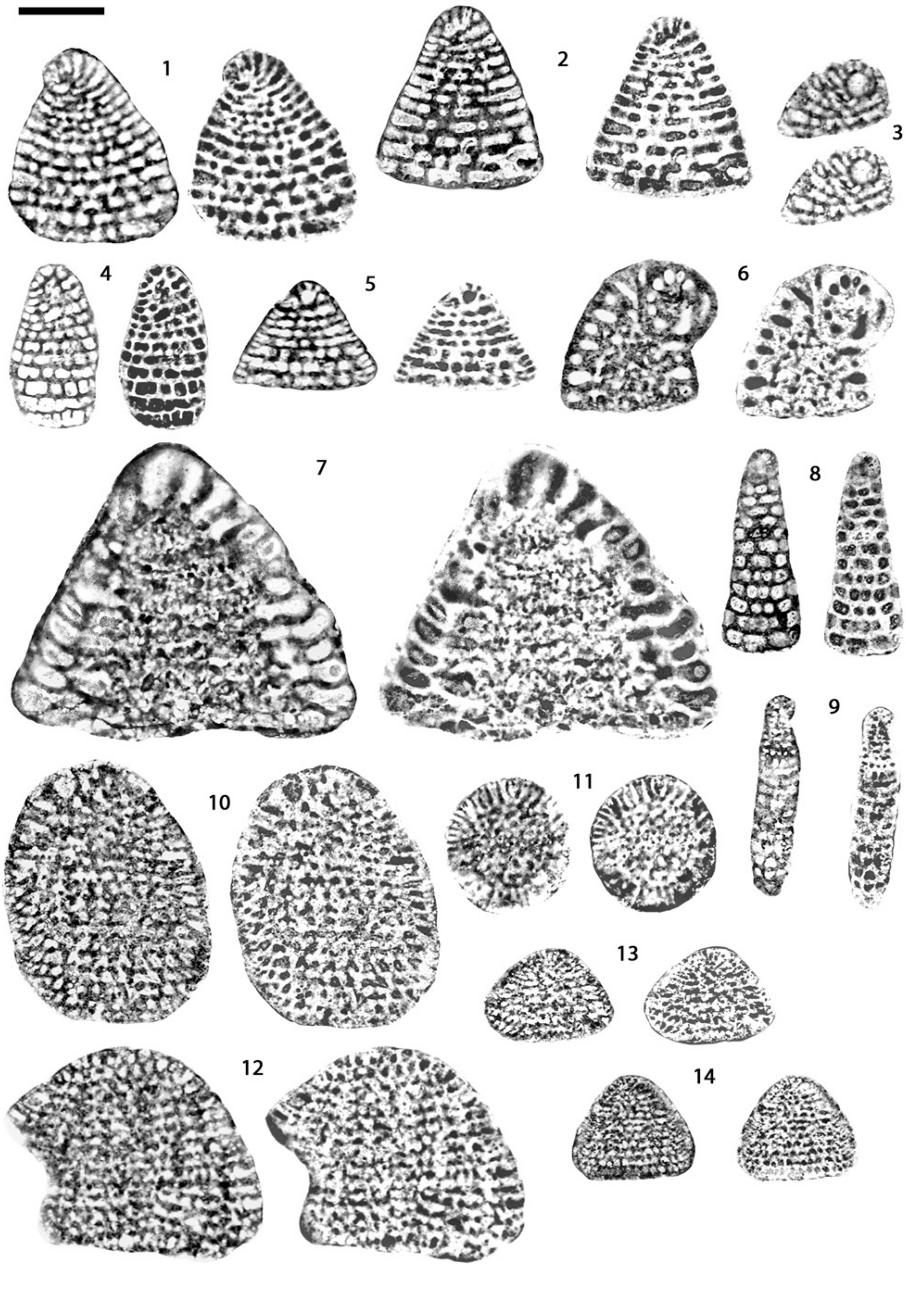
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Plate 5:

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]

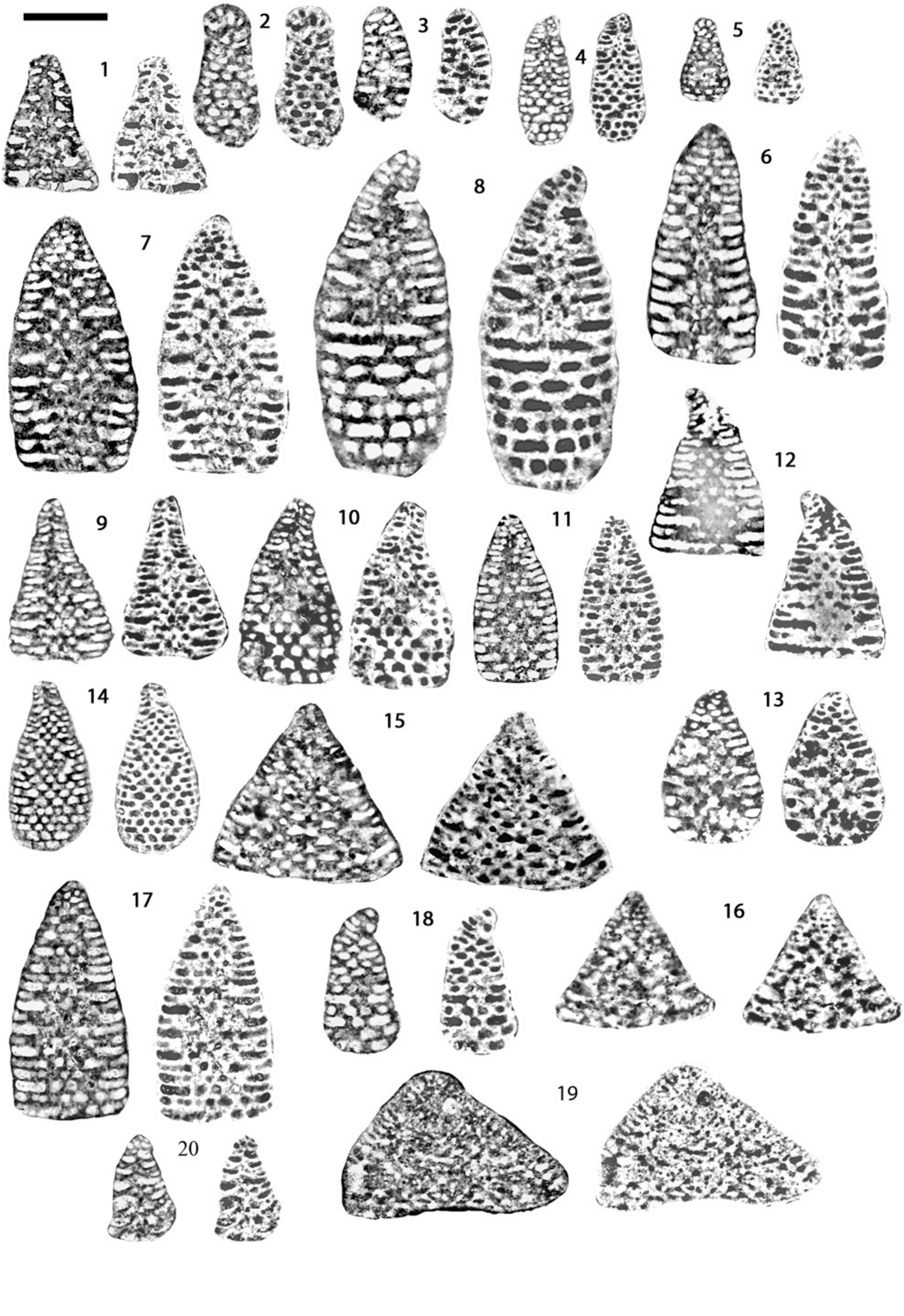
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Plate 6:

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]

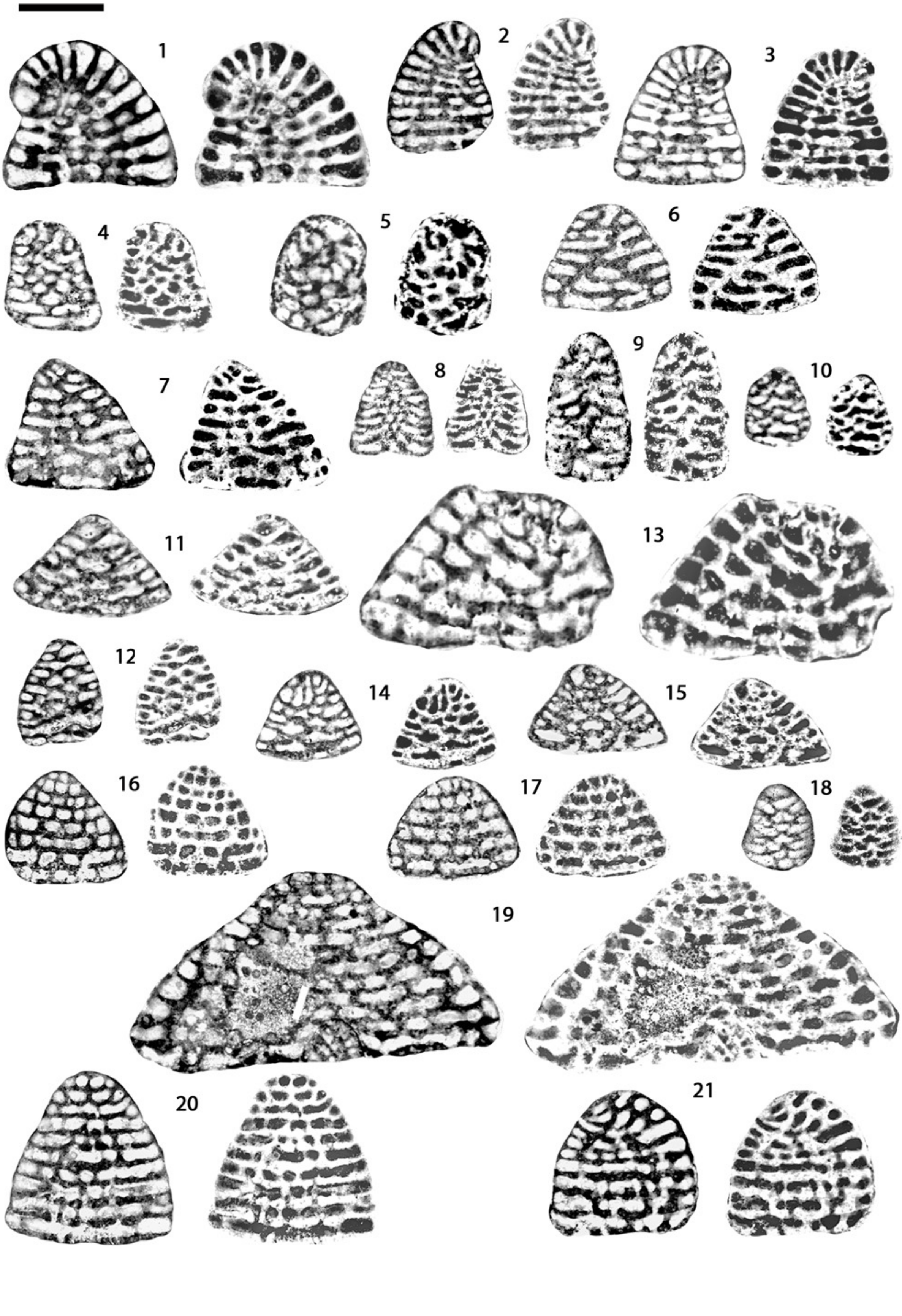
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Plate 7:

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]

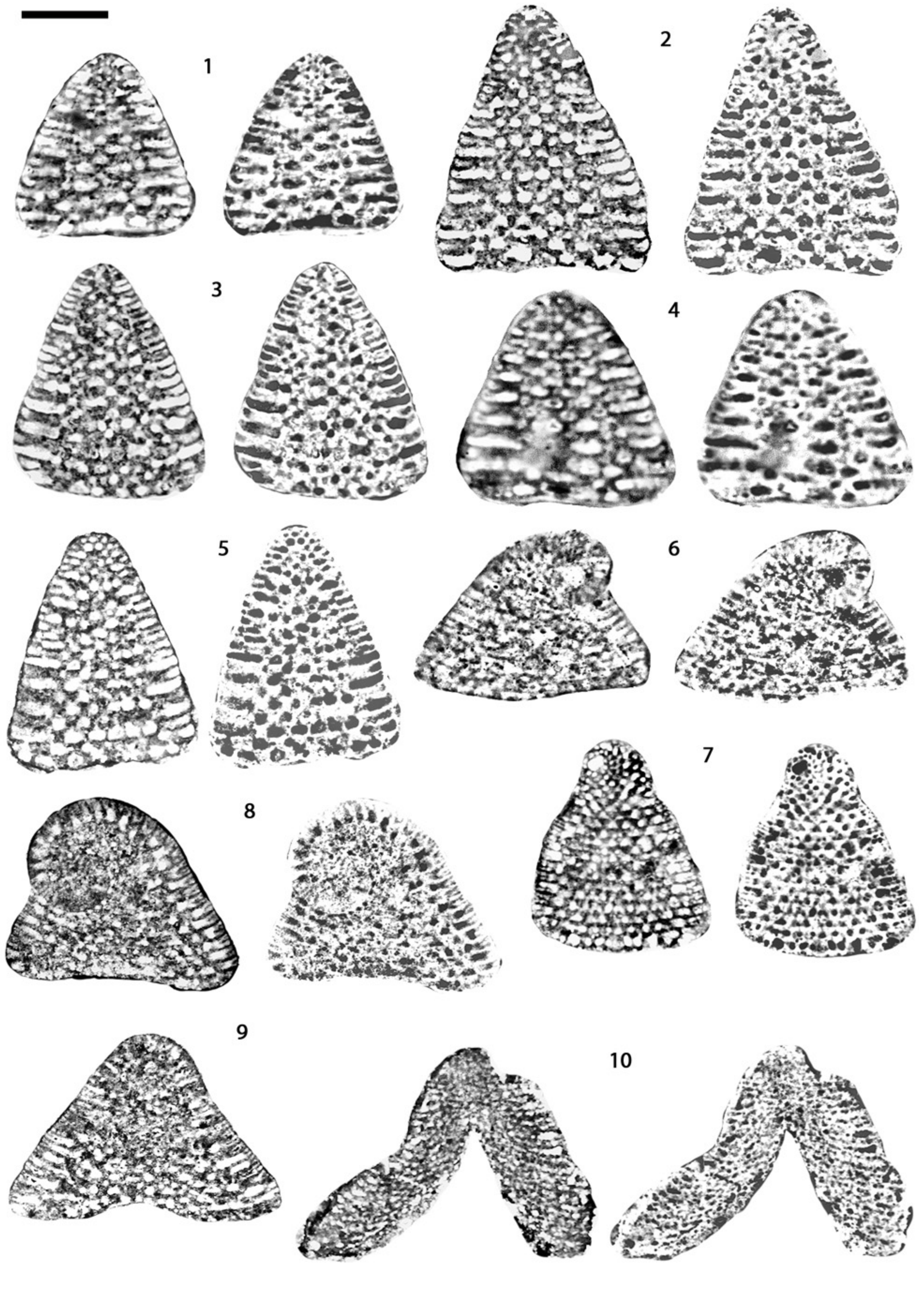
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Plate 8:

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. *Dictyoconus* ? *vercorii* ARNAUD-VANNEAU - subaxial section, slide LEST26.6-6b.
11. *Dictyoconus* ? *vercorii* ARNAUD-VANNEAU - subaxial section, slide LEST72-8c.
12. *Dictyoconus* ? *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]

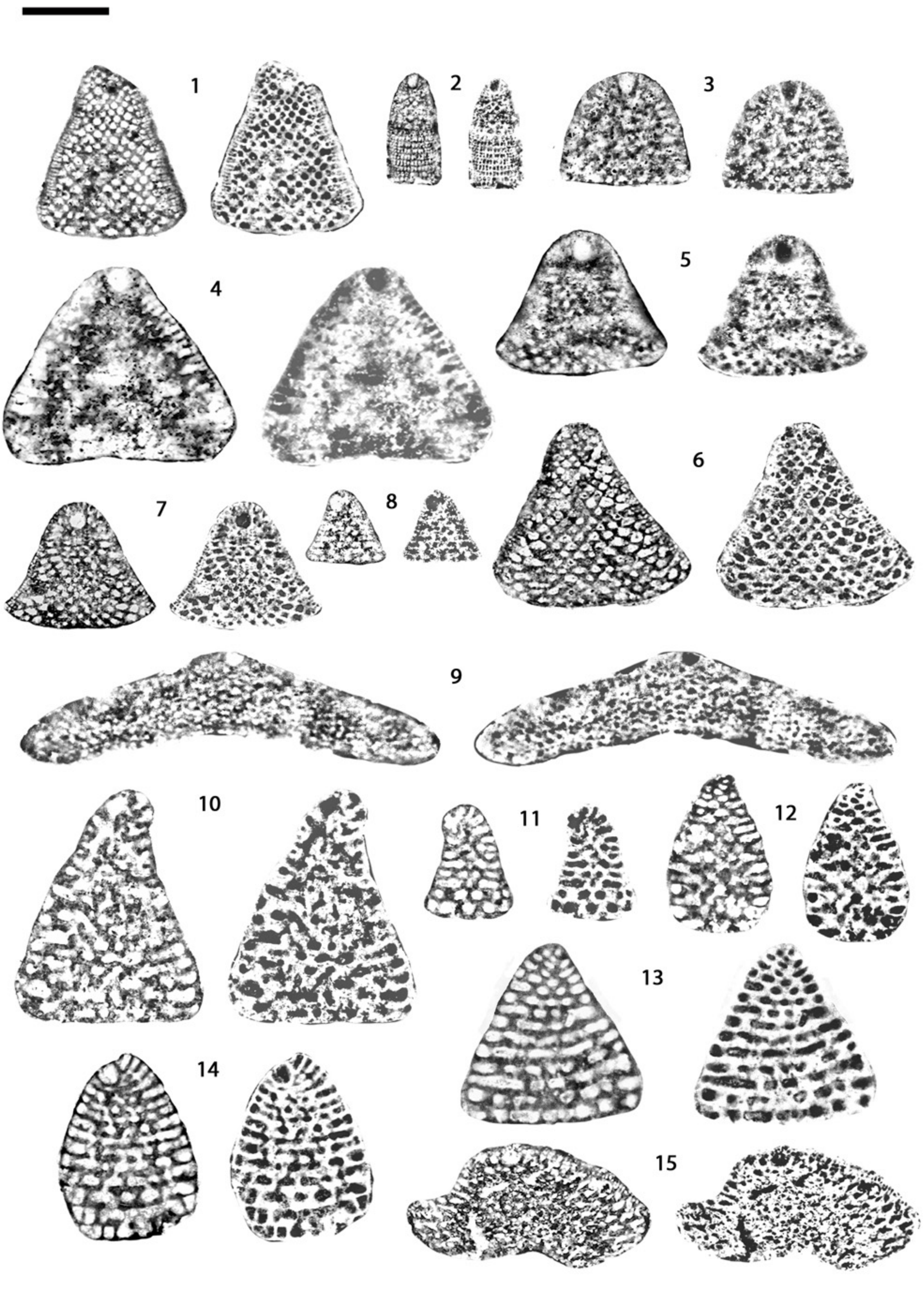
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Plate 9:

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. *Dictyoconus* ? *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]

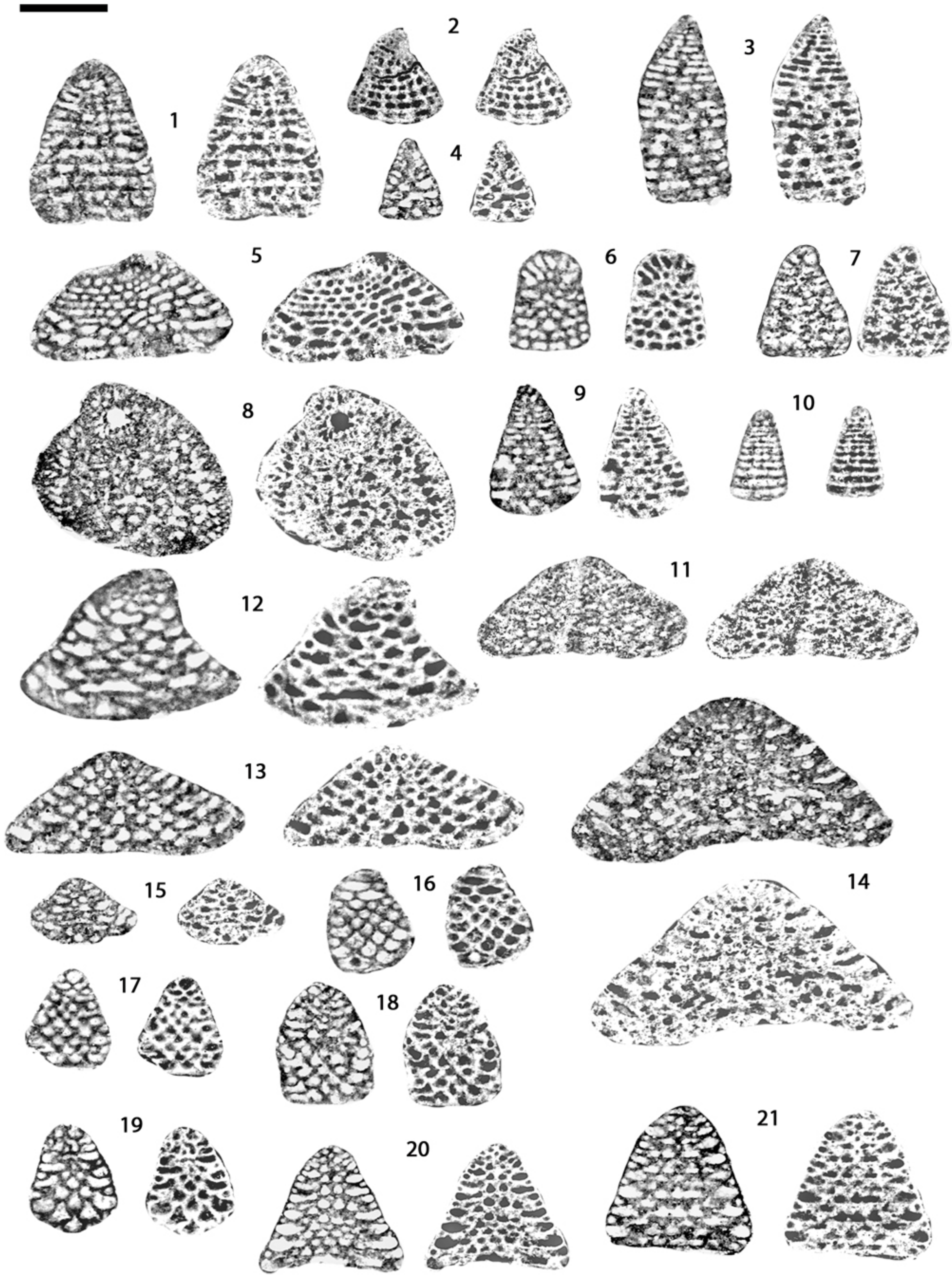
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Plate 10:

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. *Dictyoconus* ? *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]

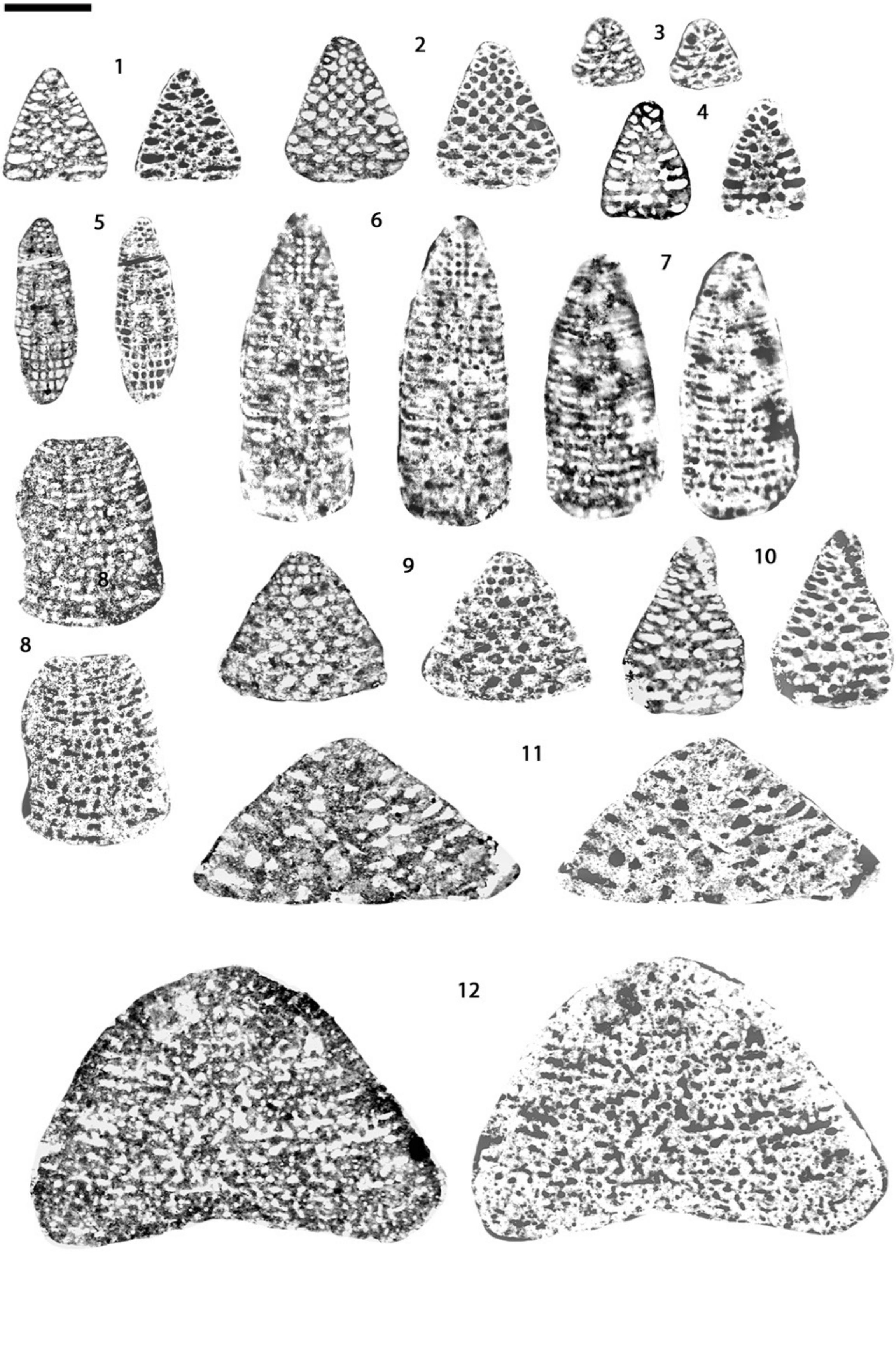
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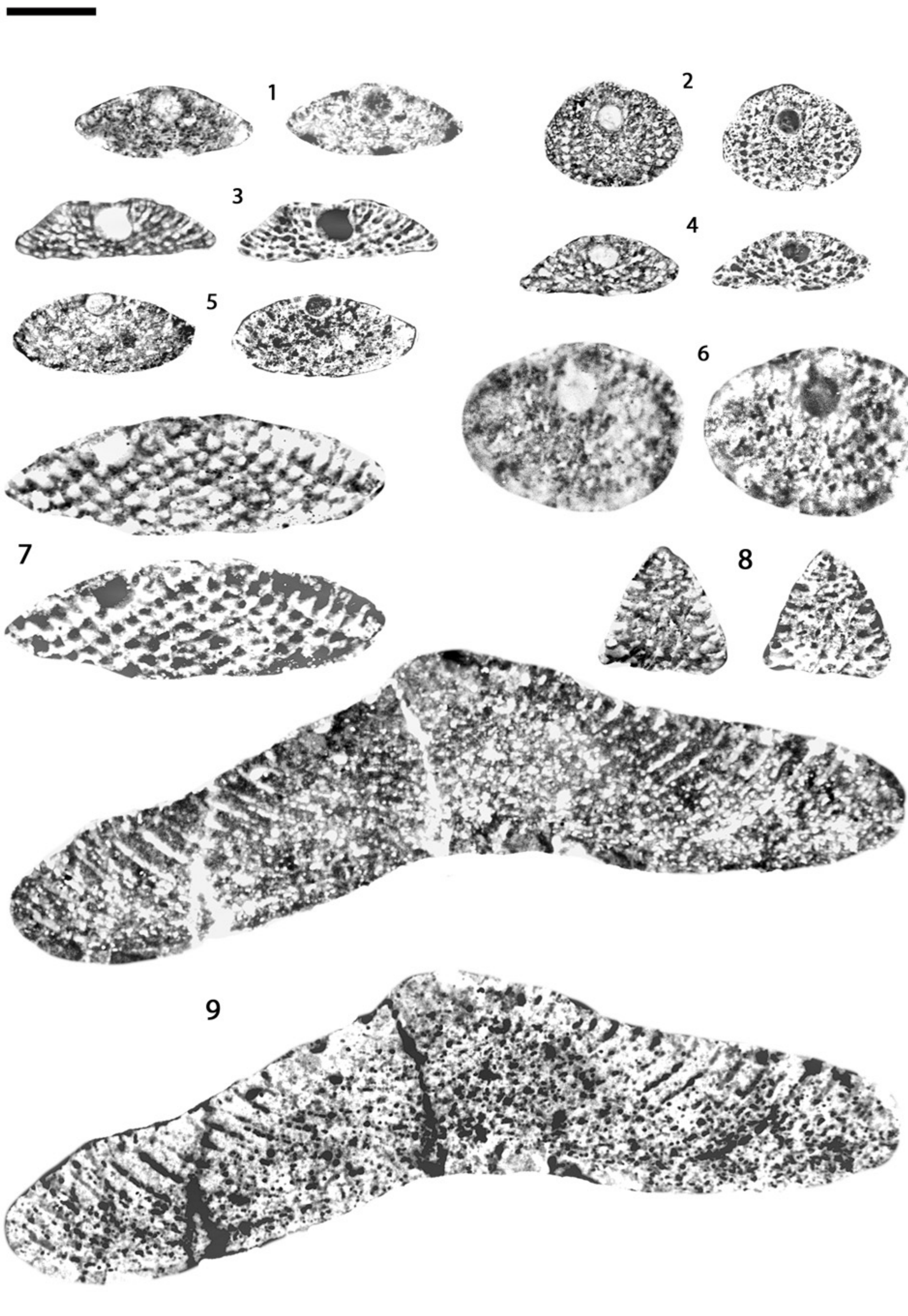
Plate 11:

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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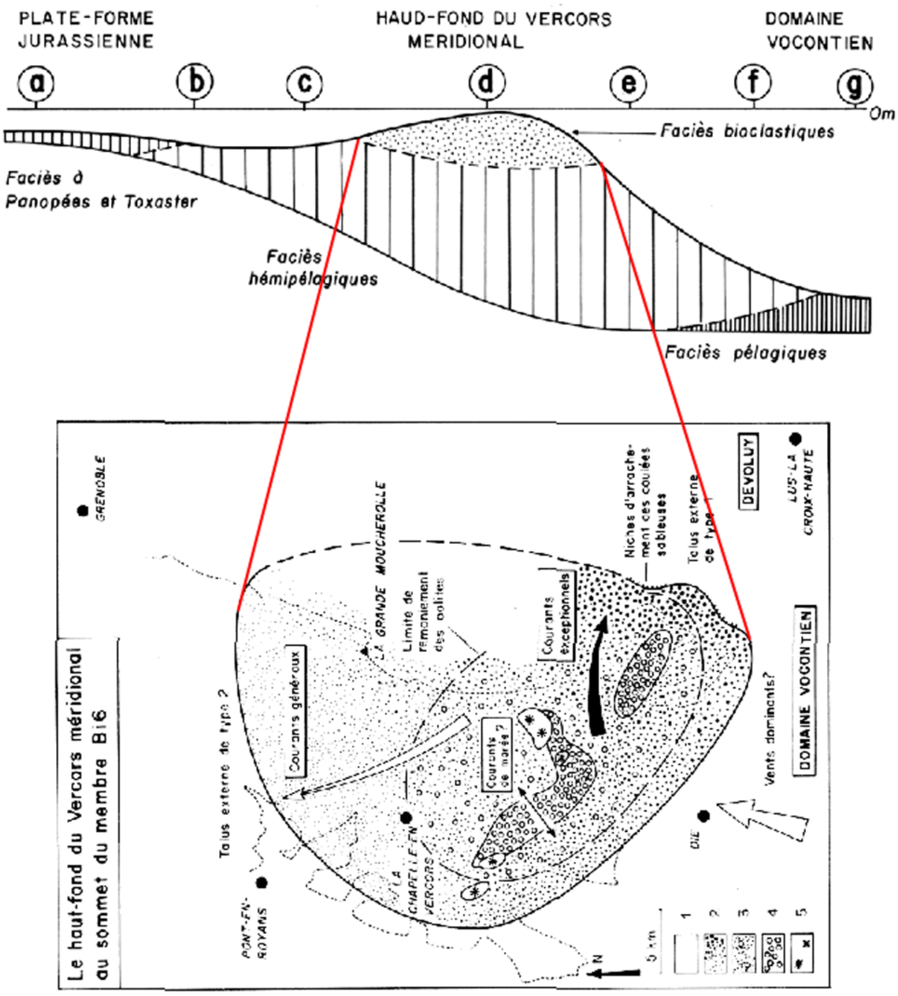
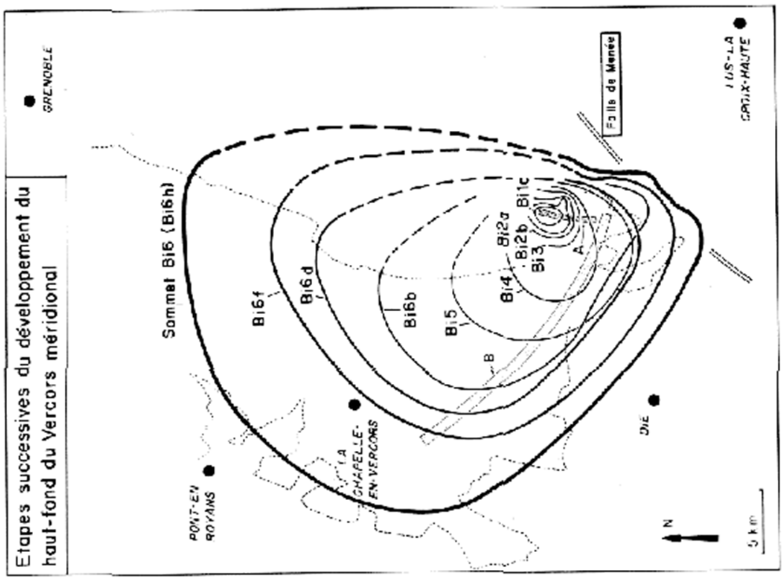
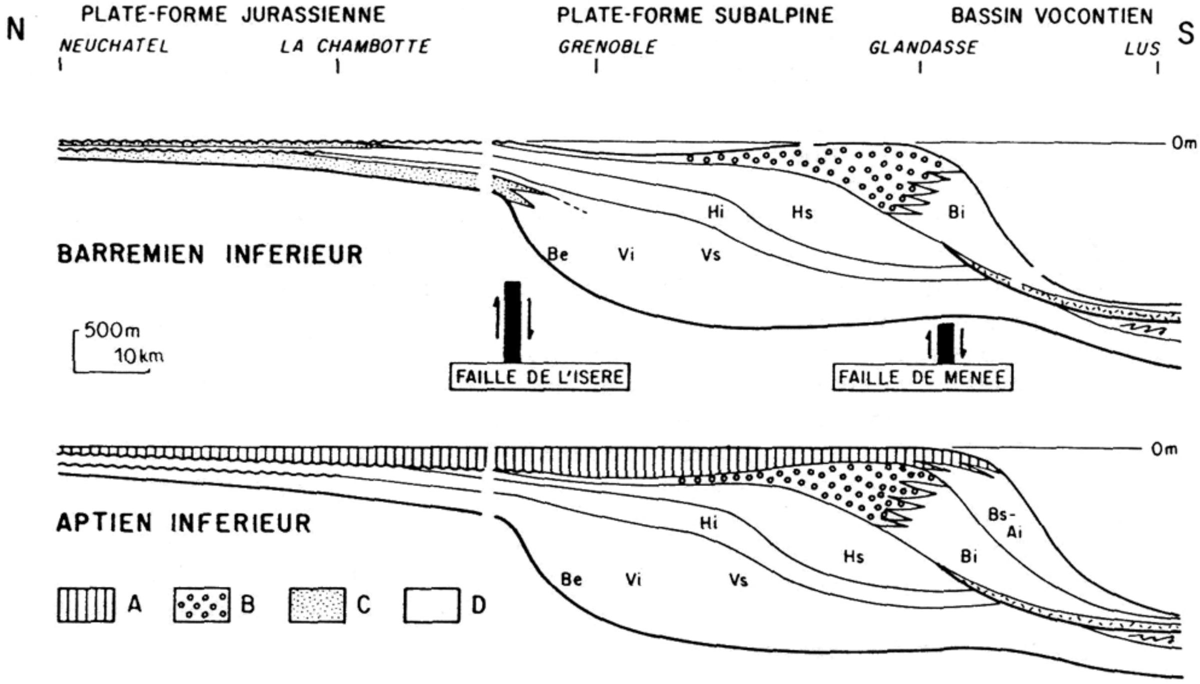
Amazing erroneous stratigraphic models

compiled by Bruno GRANIER

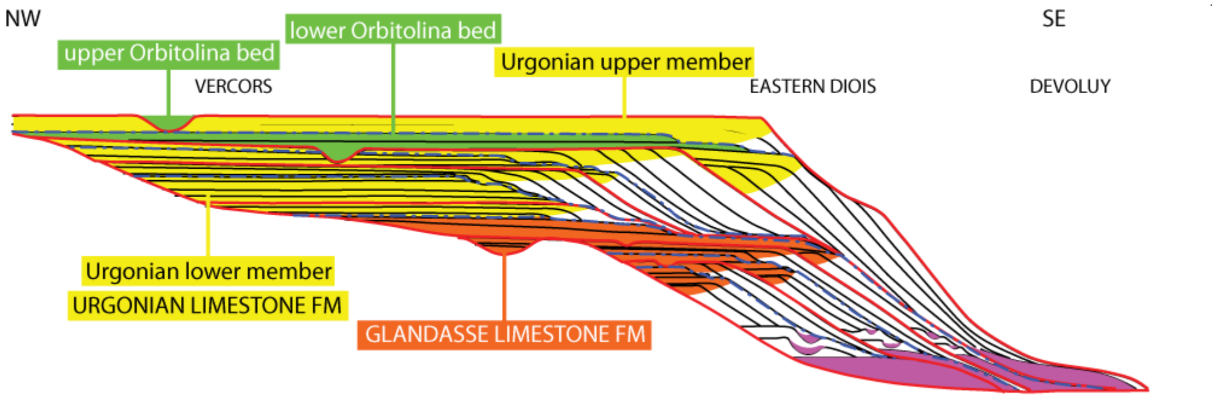
Following a concept first proposed in ARNAUD-VANNEAU and ARNAUD (1975), the second author (ARNAUD, 1979) gives a description of his “Haut-Fond du Vercors méridional”, *i.e.*, his Southern Vercors shoal. According to him it is an isolated « paleotopography ». According to him, « infralittoral » bioclastic facies are surrounded by « circalittoral » and « hemipelagic » facies (see figures, excerpts from ARNAUD, 1979, Figs. 5.B & 2).



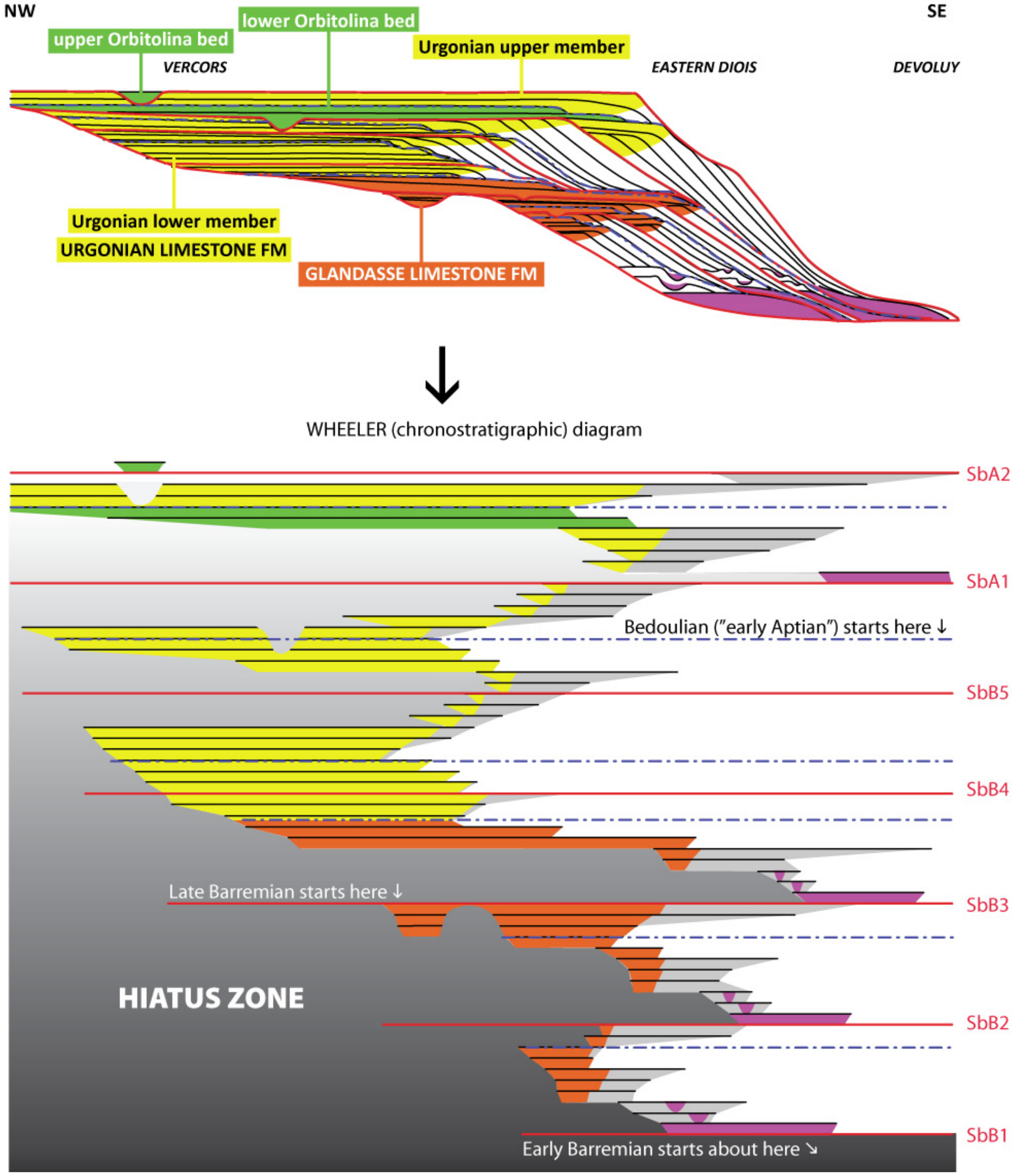




In 1989, ARNAUD and ARNAUD-VANNEAU embrace the emerging concepts and terminology of « sequence stratigraphy ». Bioclastic facies that in the earlier model were conformably overlying hemipelagic facies are now onlapping these facies, a geometrical pattern that requires an unconformity. They now refer to their « southern Vercors shoal » as the « lower Barremian lowstand wedge ».



In 2005, ARNAUD-VANNEAU *et al.* publish a memoir entitled « Urgonian deposits and Barremian-Early Aptian sequence stratigraphy in the Vercors Massif ». The figure above is redrawn from their Figure 15 (*op. cit.*). According to them « The Urgonian limestones formations appears therefore as a transgressive formation ». Again the bioclastic Glandasse facies and the Urgonian facies are onlapping hemipelagic facies, geometrical patterns that require an unconfomity, ... and significant hiatuses. CLAVEL *et al.* (2014) have already pointed out these inconsistencies, as well as many flaws within the publications of ARNAUD and ARNAUD-VANNEAU.



When ARNAUD and ARNAUD-VANNEAU converted to « sequence stratigraphy », they merely modified their earlier cross-sections so that the layout of their units resembles a VAIL « slug » model. One easy way to dismantle the model they fabricated is to unfold the slug and convert thickness into time, *i.e.*, to make a WHEELER diagram. The resulting display suggests that there should be a significant hiatus in areas corresponding to the left hand side of the diagram and that the time gap is increasing leftward. This model, which is not supported by data, is untenable. An alternative model was developped by CLAVEL *et al.* (see CLAVEL *et al.*, 2014, and earlier related contributions).

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