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Comment to *"Latest-Cretaceous/Paleocene karsts with marine infillings from Languedoc (South of France); paleogeographic, hydrogeologic and geodynamic implications by P. J. Combes* et al.*"*

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In a recent paper, Combes *et al*. [1] present a new interpretation of the paleogeographic evolution of the Bas-Languedoc area during the Paleocene period. This work settles the presence of marine sediments providing rich Dano-Selandian microfauna of planktonic foraminifera and filling up channels and/or gulfs. The authors connect these occurrences with a previously described Pyrenean Paleocene Trough (PPT) and extend it eastward to the Alps and even to Italy, building up a major paleogeographic structure along Early Paleocene. We dispute hereafter the biostratigraphic, sedimentologic and geodynamic arguments especially the foraminifera determinations from which the existence of marine Dano-Selandian deposits is deduced.

1. The lastest-Cretaceous/Paleocene karsts with marine infillings from Languedoc

1.1. Datation arguments

The polyphased karst model proposed by Combes *et al*. [1] is based on the presence of cut-and-filled systems involving successive paleosurfaces (P1 to P5) and their related endokarstic Dano-Selandian continental (R1) or marine (R2 to R4) infillings. These stratigraphic attributions are evidenced by the discovery, within sandy clays, of a marine fauna including invertebrate debris associated with pelagic foraminifera, some of them (*Globigerinacea*) being typical of the considered Paleocene interval. These palaeontological data are presented in two documents, plate 1 and figure 5, analysed hereafter (see our Fig. 1).

1.1.1. Plate 1

The invertebrate debris consist mainly of chronostratigraphically worthless echinoid spines, columnal echinoderms (figs 3, 4, 5, 9), sponge-spicules (figs 6, 7, 14, 15, 16, 17) and bryozoans (fig. 2). Such remains are known for more than half a century from the Upper Cretaceous (Coniacian up to Maastrichtian) marine formations conserved in the Causses area [2; 3; 4]. The microfauna consists mainly of undetermined radiolaria (figs. 1, 12, 13), small benthonic foraminifera (fig. 8) and large benthonic foraminifera: *Anomalina* and *Conicospirillina*. These genera which are known since Jurassic intervals, cannot present any datation interest. The so-called

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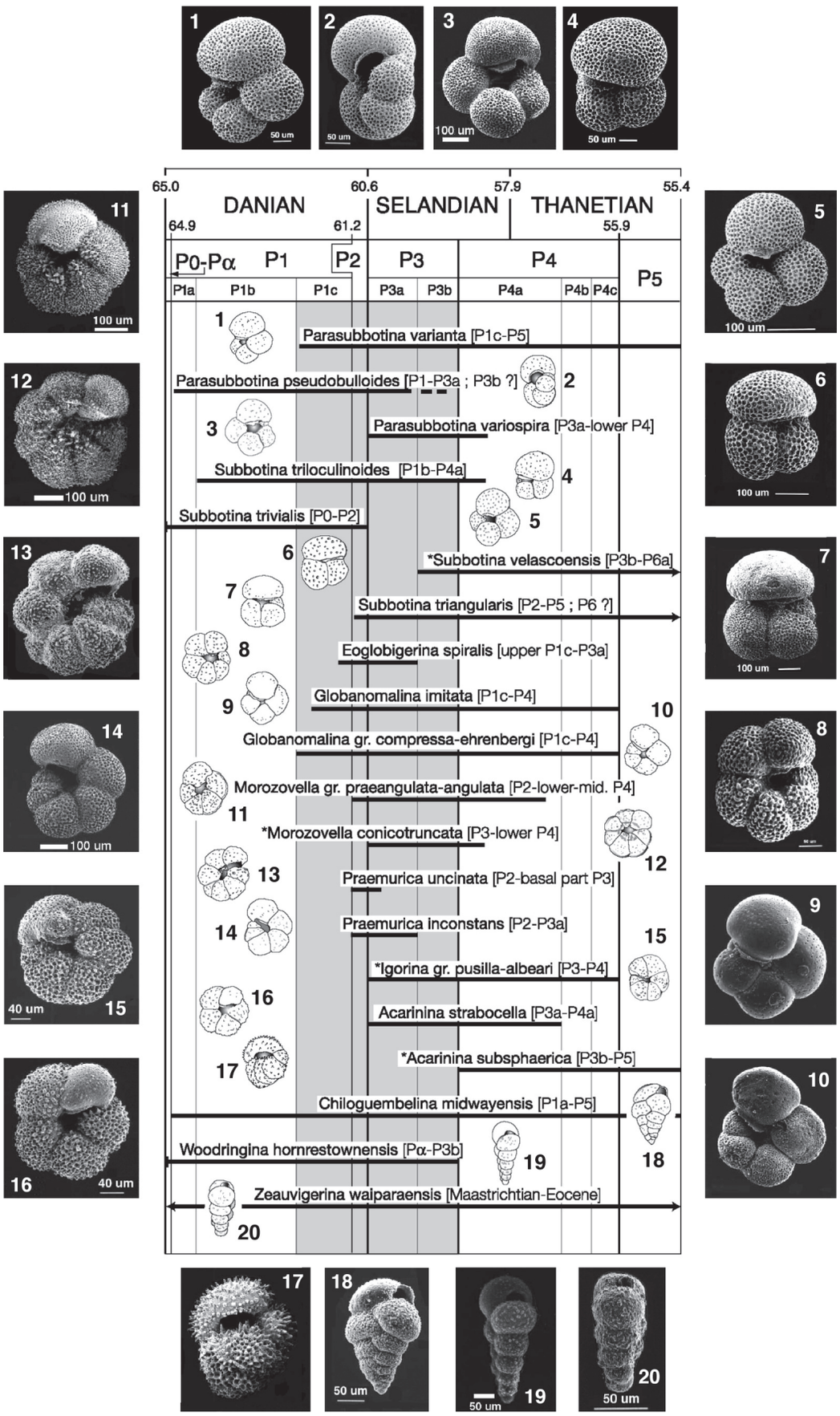


Fig. 1: Synoptic figures showing together in the centre of the plate the drawings of M.J. Fondecave-Wallez and around, the original photos of Olsson R.K, Atlas of Paleocene planktonic Foraminifera [6]. It appears clearly that all the foraminifera sketchs from Combes *et al*. [1] are directly drawn from the Atlas AND NOT from fossils found in the studied material.

"planctonic foraminifera" are taken from carbonate thin sections. In our opinion, figs. 21, 22, 25, 27, 29 and 30 are not significant. Their generic and above all specific determinations are poorly convincing and even inconsistent. So, the figs 26, 28 and 32 which represent the same species *Morozovella gr. Praeangulata-angulata* are strongly different one from the other. The triangular chambers of figs. 28 and 32 are quite different from the subspheric chambers of fig. 26. Fig. 21, assigned to *Parasubbotina variospira* has been previously published as *P. varianta* [5, fig. 5 (3)]. This assigning change is given without any explanation.

A detailed analysis of the plate shows that these different sections really do not belong to *Globigerinacea*. Figs 19, 20, 24, 31 and 32 involve a central pillar which is absent in this family but typical of the *Rotalidae*. So, figs 19 and 20 seem to represent *Rotalia mesogeensis* or *algeriana* sections. In the same way, figs 23, 26 and 28 show a structure close to the toothplate which separates the protoforamina from the deuteroforamina of the Discorbidids. This element is of course absent in the real *Globigerinacea* sections.

Except *Microcodium* (fig. 10), which characterizes the Uppermost Cretaceous/Paleogene continental deposits, we have not found any argument allowing an attribution of the karstic infillings to a possible Danian/Selandian interval. For us, the presented biophase corresponds to reworked remains of the Upper Cretaceous cover (where Rotalidids and Discorbidids are frequent) within Tertiary to Quaternary karst systems.

1.1.2. Figure 5

This figure gives the distribution of some planctonic taxa which "*sketches are drawn from the foraminifera found within washing residues*" [1].

Question: why worthless sketches when the washings provide abundant free microfauna, which presentation could put an end to critical reports? We are able to answer this question. Sketches do not represent field samples. They have been really drawn by copying the original taxa presented in the "*Atlas of Paleocene Planktonic Foraminifera of Olsson et al.*" [6]. The internet access proceeding is very easy: go to the Atlas and select a species in the image gallery. You have several images for every taxon. One of them is the selected model for the sketch presented in fig. 5 of Combes *et al.* [1]. This way, we have been able to create the plate included in the present work (fig. 1). The reader can verify that sketches and photographs are quite similar: shape, number of chambers, orientation… We note (Fig. 2) that a similar operating procedure has been previously used by the authors in their paper related to the "Danian-Selandian" Baixas breccias [9, fig. 2]

1.2. Geodynamic model

The model proposed by Combes *et al.* involves 3 transgressions (R2, R3, R4) separated by 4 regressions (P2 to P5), within a very short Paleocene interval (Upper Danian -62,5 Ma to Lower Selandian -59,2 Ma) [1, fig. 14]. During this period, several hundred metres deep canyons are excavated *in situ*, without any lateral shift [1, figs 4 and 8]. This evolution takes paradoxically place under regional compression conditions [1, fig.4], closely linked to the Late Cretaceous tectonic phase which is considered as the main stage of the Pyrenean orogenesis in the Bas-Languedoc area. Without any chronostratigraphical support (see above), this model is lapsed and cannot consequently be accepted.

In our opinion, the karstic infillings which provide Upper Cretaceous (or older) reworked marine remains are really continental (*microcodium*) and syntectonic deposits. They are Danian to Eocene in age and later involved in the Mid-Upper Eocene pyrenean compression step. These conclusions fit well with the interpretations presented by the authors of the geological maps of the Bas-Languedoc concerned domain.

2. Extension to the North: the so-called "Grands Causses Paleocene Ria"

On the Grands Causses, recent researches revealed the existence of numerous outcrops of Upper Cretaceous sediments [2, 3, 4]. These nearshore coastal deposits fossilize some paleotopographies and cover locally some ancient lapiaz. The first samples of sandy limestones, coming from the eastern part of the Causse du Larzac and the Causse de Campestre, showed the presence of a plentiful microfauna. Without ambiguity, the biological assemblages date these deposits from Coniacian. In the same region, soundings realized in several big sinkholes went through a thick clay and sandy formation, including numerous levels of lignite. Pollens analysis has shown the exclusive presence of Upper Cretaceous ones (Santonian to Campanian) without any Dinophyceae.

In a later publication, Peybernès *et al.* [5] claim to have found Dano-Selandian planktonic foraminifers and invoke later reworking of the Cretaceous deposits. However, their samples result from the same boreholes, even for some of them, of the same turn of auger! Nevertheless, the assemblages of foraminifers, we have studied are characteristic of Upper Cretaceous and no indication of tertiary fauna and flora was recognized. The continental sequences of Santonian-Campanian, several tens of meters thick, are trapped in old depressions of the bauxite karst. They locally preserve a few perturbed stratigraphy which do not suggest such an important reworking that the one the authors suppose [5]. Besides, new outcrops studied in the northern part of the Grands Causses confirm our results and show, also here, the presence of plentiful microfauna of Coniacian age (work in progress).

Finally, in the western part of the Grands Causses, a formation of estuarine sands is sealed by a Neogene volcanic flow. These sands are azoic but delivered a very rich association of pollens dating the formation from the Early Cenomanian. Once again, samples taken at a few centimetres from ours gave to the authors of this note [5] planktonic Paleocene fauna.

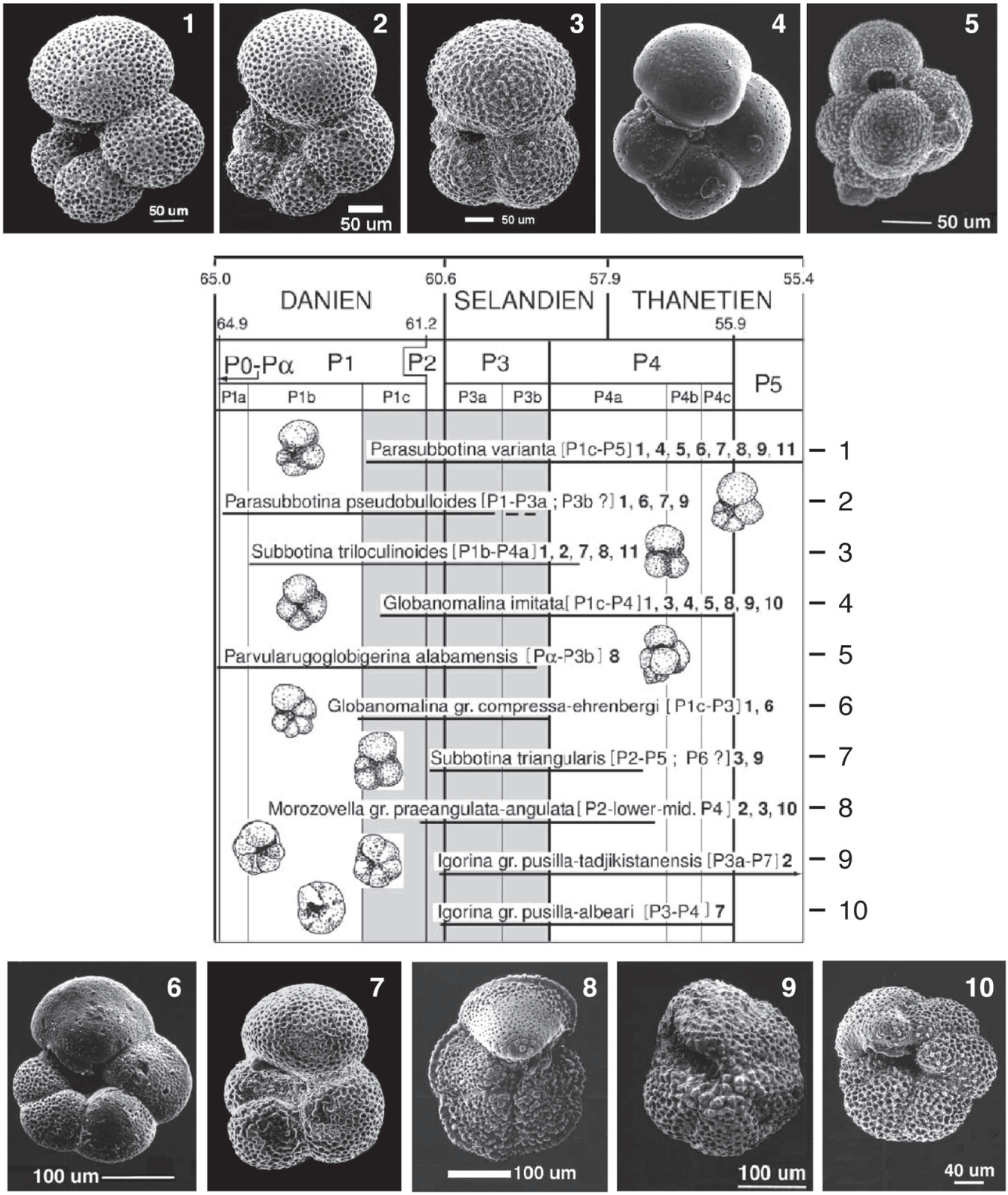


Fig. 2: Sketches of the planktonic foraminifera found by Peybernès *et al*. [9, fig. 2] within the Danian/Selandian hemipelagites and the matrix of the Baixas breccias, compared to the taxa presented by Olsson *et al*. [6]. Note, once again, that the raw drawings have been copied from the original photos of the Atlas.

So, our micropaleontological and sedimentological results confirm the Upper Cretaceous age of the marine karst infillings well known in the Grands Causses area [3, 4]. They lead us to contest their attribution to Dano-Selandian marine deposits and, consequently, to reject the presence of a supposed "Paleocene Ria" connecting Pyrenees and Causses [5].

3. Extension to the South: the so-called "Pyrenean Paleocene Trough (PPT)"

During the last seven years, 13 papers [7 to 19] provide information concerning the development of a deep (up to 800 metres) and wide (up to 60 km) trough crossing the Pyrenees (from the Atlantic Ocean to the Mediterranean Sea) along the North Pyrenean Zone and the High Range and even reaching Italy through Provence (Lubéron) and Alps (Valaisan Basin) [1, fig. 10]. This trough is supposed being filled with marine sediments (bedded breccias or chaotic megabreccias associated with hemipelagites, locally turbiditic) rich in planktonic foraminifera which characterize the Danian-Selandian interval. These deposits overlie unconformably folded structures related to the Late Cretaceous compression which corresponds to the main stage within the tectonic evolution of the Pyrenees. Our objections join and complete those we presented (without any answer from the authors) in different preceding works [20 to 24]:

3.1. Biostratigraphical arguments

Our numerous washings of the breccias and the karst infilling clays "*well known*" for their micropalaeontological (planktonic foraminifera) Danian-Selandian content [7 to 19], resulted azoic. Unfortunately, the abundant washed free microfauna has never been published. The proposed sketches, really taken from the Atlas of Olsson *et al.* [6] (see above) and associated thin sections [15, 18, 19] cannot provide conclusive datations. This situation leads us to the following critical observations: 1) every scientific fact must be reproduced. So, if the micro-biophase is abundant, it really might be present in our repeated washings taken in the same places [20, 21, 22, 24]. Unless the pyrenean outcrops result as fossiliferous as those of the preceding Bas-Languedoc ones! 2) Raw and approximate sketches cannot be considered as acceptable datation arguments. 3) Sections of the foraminifera are generally included in the carbonate elements of the breccias. So, they are older than the cement and cannot indicate the age of these materials. 4) Palaeontological code stipulates that published types (even for micropalaeontological sections) must be included in an inventory assigned to a collection and deposited in an accessible place allowing later studies. No one of these rules has been followed.

A comparative study (Figs. 3A and 3B) of the sections of "planktonic foraminifera" coming from Tardets (Bosmendiette) [18] and Amporda (Mas Blanch) [19] with the side views of the same species taken from the Atlas of Olsson *et al.* [6] leads to strange results! In our opinion, there is no unquestionable possibility to give a generic and more over specific attribution to these pyrenean taxa. So, we consider that the presented micropalaeontological data [7 to 19] are unacceptable. For us, as previously indicated [20 to 24], the various Pyrenean breccias are very different in age: Lower Cretaceous for the Béarn and Pays Basque diapiric breccias; Tertiary for the tectono-karstic breccias well known all over the range; Plio-Quaternary for some breccias and colluvia from the Central and Eastern Pyrenees.

3.2. Sedimentological arguments

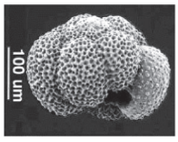
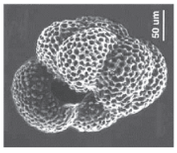
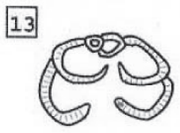
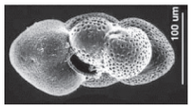
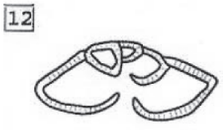
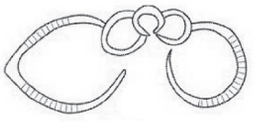
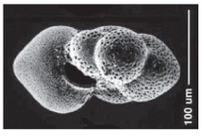
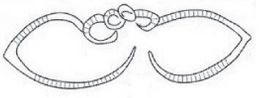
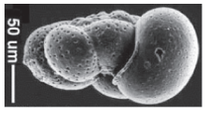
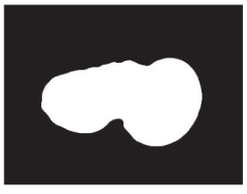
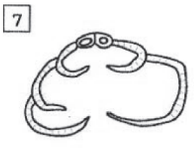
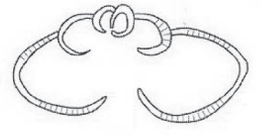
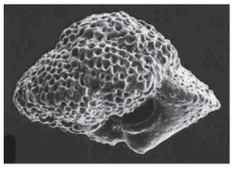
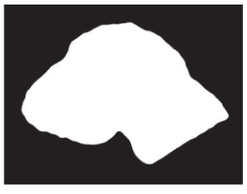
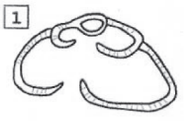
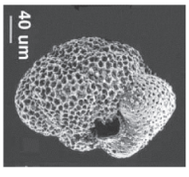
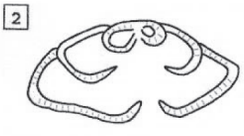
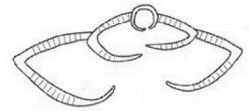
Our facies analysis of the Pyrenean outcrops is quite different from the proposed interpretation of the authors [7 to 19]. The bedded or chaotic megabreccias, the hemipelagites and the turbiditic deposits really correspond respectively to karstic storm avalanche breccias, to fair-weather karstic clays and to graded deposits within karstic pipes. The considered outcrops are generally reduced (up to some ten metres), isolated and widely distributed through the High Range and the North Pyrenean Zone. They cannot give proof of the expected sketch of continuous thick deposits within a wide marine, post-tectonic basin. The brecciated sediments are also closely linked to the underlying carbonate rocks and absent on the adjoining argilaceous or sandstone-like bedrocks [20 to 24]. Finally, the described trough is strangely lacking of platform carbonates and coastal deposits (prograding delta-fans, sandy bay loams…). So, this sedimentological assemblage doesn't fit at all with the classical models of wide post-tectonic troughs.

3.3. Paleogeographic arguments

The classical Pyrenean Paleocene paleogeographic sketch shows generally [24, 25] a deep marine basin located in the Western Béarn and Pays Basque area, close to the Biscaye trough (Fig. 4B). This basin, filled with turbidites and hemipelagites, is fringed eastward by chaotic slope breccias reworking carbonate and terrigenous elements slumped down from the neighbouring platform. This eastern plateau develops through Eastern Béarn and Western Aragon, reaching the Toulouse meridian. More to the East, the Pyrenean domain is covered by continental "Garumnian-type" deposits. This sedimentary system develops under transpression conditions which started during the Campanian times to the East and migrated westward during the Pyrenean Eocene main orogenic period.

The presence of a supposed PPT (fig. 4A) upsets completely this paleogeographic organization. This wide overstretching trough, settled the same within the western turbiditic basin as through the central carbonate platform, where a surprising "Aude strait" reduces the marine sedimentary area and the eastern Garumnian continental domain doesn't fit well with the general compression sketch proposed by the authors [1, 7 to 19].

Our observations through the whole Pyrenean realm confirm the classical sketch of the Paleocene paleogeography [25]. The Aude strait doesn't offer any field reality as it corresponds to a narrow Eocene fracturing zone which turned to a continental brecciated karst system during the following Tertiary orogenic period.

Atlas of Planktonic Paleocene Foraminifera [6]	Outline	Fondecave *et al.*, 2006 Bosmendiette [18]	Peybernès *et al.*, 2007 Emporda [19]
Acarinina strabocella 			
Eoglobigerina spiralis 			
Globanomalina compressa 			
Globanomalina Ehrenbergeri 			
Globanomalina imitata 			
Igorina albeari 		 	
Igorina pusilla 		 	

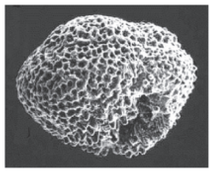
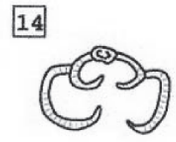
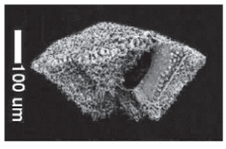
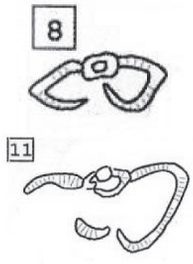
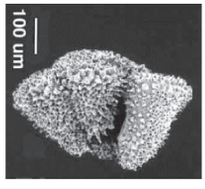
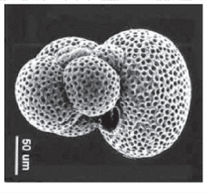
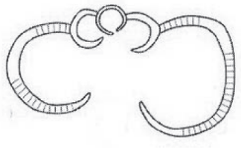
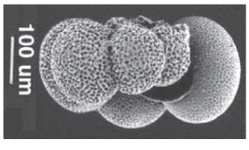
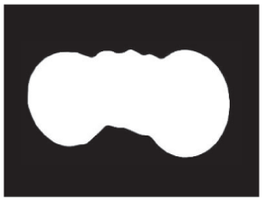
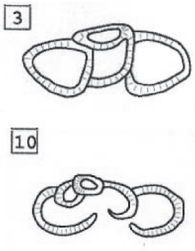
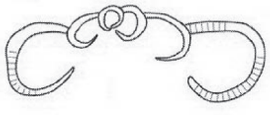
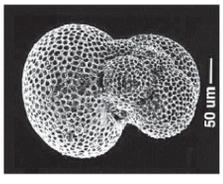
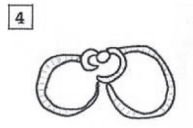
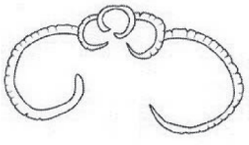
Atlas of Planktonic Paleocene Foraminifera [6]	Outline	Fondecave *et al.*, 2006 Bosmendiette [18]	Peybernès *et al.*, 2007 Emporda [19]
Igorina tadjikistanensis 			
Morozovella angulata 			
Morozovella apanthesma 			
Parasubbotina varianta 			
Praemurica inconstans 			
Subbotina triloculinoides 			

Fig. 3: Comparative sketches of the axial views presented in the Atlas of Paleocene planktonic Foraminifera [6] and related profiles with the sketches proposed for the same species by Fondecave-Wallez *et al*. [15] and by Peybernès *et al*. [19]. The sections presented by the authors for the same species are so different (see for example *Globanomalina imitata*) that they can't provide any acceptable argument for determination and datation.

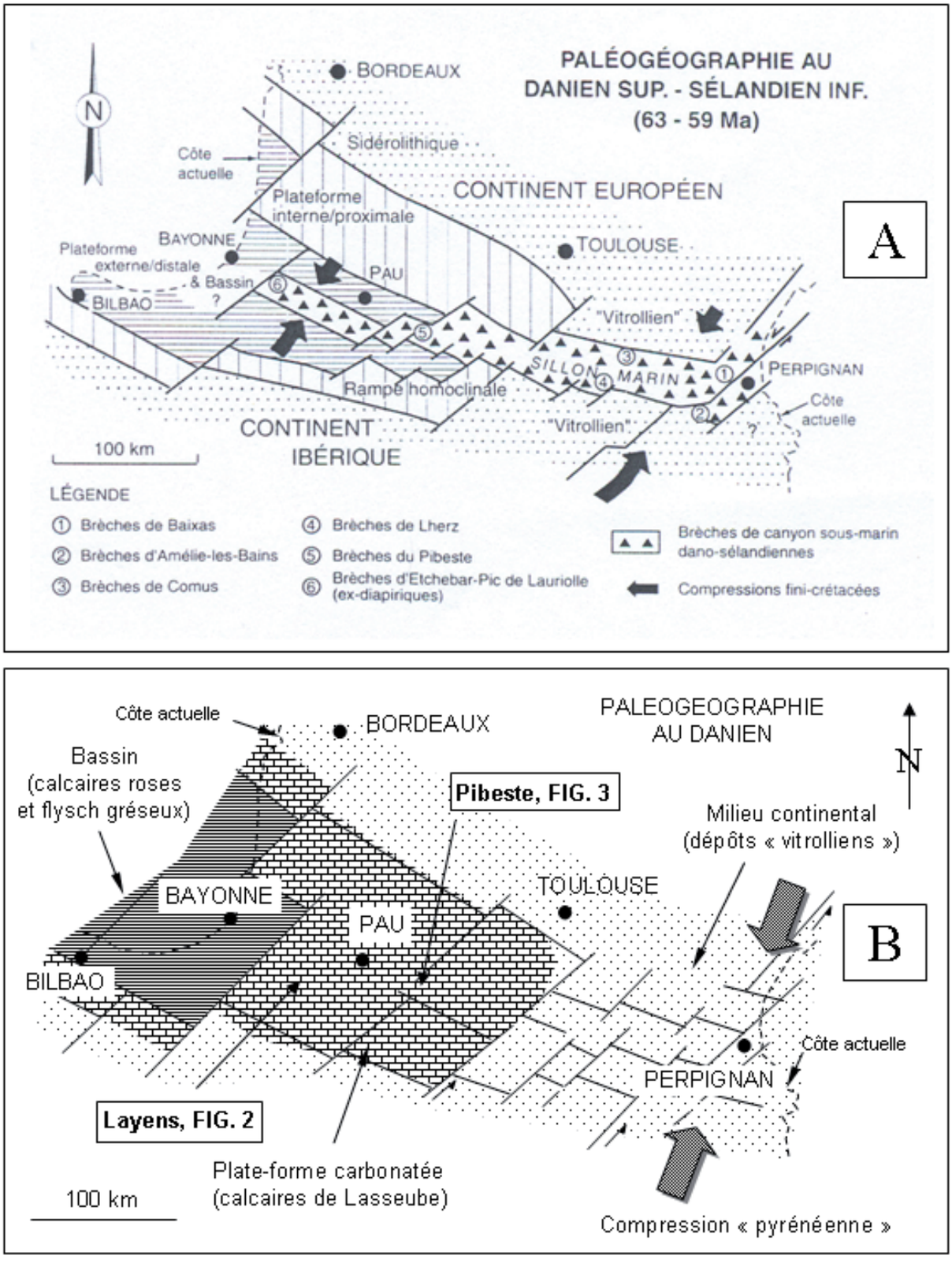


Fig. 4: Compared Danian paleogeographies in the Pyrenean realm, taken from Canérot [24]. A) After Peybernès *et al.* [10]. A NE-SW oriented Late Cretaceous compression is generalized. At the same time, a distensive marine Paleocene Pyrenean trough (PPT) develops from the Atlantic Ocean to the Mediterranean Sea. B) After Plaziat [25], Canérot [24] and the present work. The Paleocene trough does not exist. The compression phase observed in the only eastern Pyrenees during the Upper Cretaceous times involves gradually the whole Pyrenean domain during the Cenozoic with a main structural step towards the Middle-Upper Eocene.

TAKEN INTO ACCOUNT DATA	Combes *et al.* [1, 16, 17] Fondecave-Wallez *et al.* [15, 18] Peybernès [12] Peybernès *et al.* [5, 7-14, 19] **A**	Bilotte *et al.* [23] Canérot [24] Canérot *et al.* [20-21-22] **B**
STRATIGRAPHY	Paleocene (Upper Danian/Lower Selandian)	Lower Cretaceous up to Quaternary
MICRO-PALAEONTOLOGY	Rich microfauna: planktonic Foraminifera (matrix and elements)	Matrix generally azoic Elements fossiliferous (reworked faunas)
SEDIMENTOLOGY	Thinning up sequences Slope fans Turbidites and hemipelagites	Raw accumulations Bedded silt deposits (turbidites and hemipelagites absent)
PALAEO-ENVIRONMENT	Trans-pyrenean trough Deep marine canyons	Lower Cretaceous diapirs Tertiary fracturing/karst/brecciated zones Quaternary slope related continental spreadings
STRUCTURE	Well bedded, more than 1000km long infillings, overlying unconformably a folded Mesozoic bedrock	Collapse rock falls, Hydraulic shattering Pocket infillings, speadings Poorly extended deposits
PYRENEAN GEODYNAMIC EVOLUTION	Late Cretaceous folding main phase Successive Paleocene steps (compression/distension) Minor Eocene phase Insignificant Post-Paleocene erosion	Minor Late Cretaceous phase Continuous compression (transpression) from Campanian up to Present Mid-Upper Eocene main phase Important Post-Paleocene erosion

Fig. 5: Diagram showing the compared interpretations of the breccias from Bas-Languedoc and Pyrenees. A: marine deposits filling a Paleocene Pyrenean Trough (PPT); B: Diapiric, tectono-karstic or colluvium-type sediments.

3.4. Geodynamic arguments

The geodynamic interpretation proposed by the authors [7 to 19] involves a general Late Cretaceous main compression phase followed by short reduced transgression-regression steps related to eustatic and tectonic events during the Paleocene period. These events could lead to alternating erosion and submersion stages located on the only trans-pyrenean trough strangely incised within the same area during the whole considered interval. In the Eastern Pyrenees, the Paleocene sinking process is so deep as to allow the sedimentation of marine megabreccias in the lowest part of the actual valleys [16], inducing the lack of later erosion and tectonic rising!

Our attribution of the post-Vitrollian outcrops to continental karstic deposits ranging from Mid-Upper Eocene up to Quaternary intervals, leads us to reject this evolution diagram which, in our opinion, remains far away from field data and from classical interpretations. We consider that these sediments have been generated by fracturing and dissolution processes, under continental conditions, of various (Palaeozoïc up to Paleogene) carbonate formations affected by the Pyrenean regional compression (transpression). Tectonic stress began during the Upper Cretaceous period and suffered a major step towards the Middle-Upper Eocene. These events took place mainly along the collision zone between the european and iberian converging crusts, inducing the creation and development of a trans-pyrenean "*fracturing-karst-brecciation corridor*". They fit quite well with the folding and rising phases which characterize the Pyrenean geological evolution during the late 70 Ma.

Conclusion

The presence of marine Danian-Selandian deposits involving breccias, hemipelagites and turbidites repeatedly stated in different recent works [1, 5, 7 to 19)] doesn't fit with our field data, the same in the Bas-Languedoc area as in the Grands Causses and all over the Pyrenees. The determinations of the planktonic microfauna allowing such stratigraphic attributions are wrong. So, in our opinion, they result unacceptable. The described facies do not correspond at all to our observations.

Submarine chaotic breccias, turbidites and hemipelagites do not exist. The proposed Paleocene paleogeographic sketch involving a deep and complex marine trans-pyrenean trough extending from Pays Basque up to the Alps and Italy has no reality. For us, breccias and clays are diapiric, Early Cretaceous materials in the Béarn and French Pays Basque areas and more generally tectono-karstic continental syn to post-Pyrenean infillings. In the Pyrenees, the main tectonic phase is really Mid-Upper Eocene and not Late Cretaceous in age as supposed by the authors censured in the present work.

The two opposed geological interpretations of the brecciated materials coming from Bas Languedoc and Pyrenees can be summarized in a comparative diagram including the main stratigraphic, micropaleontologic, sedimentologic, paleogeographic, structural and geodynamic data (Fig. 5).

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