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A critical look at Tré Maroua (Le Saix, Hautes-Alpes, France), the Berriasian GSSP candidate section

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Abstract: The Tré Maroua site in SE France was recently selected by the Berriasian Working Group (BWG) of the International Subcommission on Cretaceous Stratigraphy (ISCS) as the candidate locality for the reference section of the Berriasian Global Boundary Stratotype Point (GSSP). However, on the basis of our preliminary investigation at this site and also from field observations over a larger area, this candidate section is paleogeographically located on a deep-water slope riddled with successive erosional surfaces, stratigraphic hiatuses and breccias. It does not meet at least four of the five "geological requirements for a GSSP". Accordingly, in our opinion, its candidacy must be definitely precluded.

Key-words:

- Jurassic;
- Cretaceous;
- Tithonian;
- Berriasian;
- GSSP;
- France;
- sedimentology;
- calpionellids

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Résumé : *Un regard critique sur Tré Maroua (Le Saix, Hautes-Alpes, France), la coupe candidate pour le PSM du Berriasien*.- Le site de Tré Maroua en SE France a récemment été sélectionné par le Groupe de Travail Berriasien de la Sous-Commission Internationale de Stratigraphie du Crétacé comme la localité candidate pour la coupe de référence du Point Stratotypique Mondial (PSM) du Berriasien. Cependant, sur la base de nos recherches préliminaires effectuées sur ce site et dans les environs, il apparaît que cette coupe est paléogéographiquement située sur un paléotalus profond comportant des surfaces d'érosion emboîtées, des hiatus stratigraphiques importants et des brèches de resédimentation. Elle ne répond pas à au moins quatre des cinq "exigences géologiques pour un PSM". Par conséquent, à notre avis, sa candidature devrait être définitivement écartée.

Mots-clefs :

- Jurassique ;
- Crétacé ;
- Tithonien ;
- Berriasien ;
- Point Stratotypique Mondial (PSM) ;
- France ;
- sédimentologie ;
- calpionelles

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1. Introduction

At the latest meeting of the Berriasian Working Group (BWG) of the International Subcommission on Cretaceous Stratigraphy (ISCS) in Bratislava (June 23th, 2019) and later again at STRATI2019 (July 4th, 2019), it was announced that the French site of Tré Maroua (Le Saix, Hautes-Alpes) received 80 % of the votes in the group as the Berriasian GSSP candidate section whereas the Italian site of Fiume Bosso (Cagli, Province of Pesaro and Urbino) received only 20%. Although it is not clear how this single French site was pulled out of the "plexus of sites (Le Chouet, Font de St Bertrand, Haute Beaume, Charens & Tré Maroua)" (WIMBLEDON *et al.*, 2019), this result came as the culmination of extensive investigations over a period of some twelve years (*i.e.*, three times four years for the ISCS mandate, starting with a first meeting in Bristol on July 8th, 2007) in order to identify a primary marker and secondary markers, then a GSSP site for the Berriasian stage boundary (WIMBLEDON *et al.*, 2019, 2020). During the same period, more than 60 sites were evaluated worldwide by the BWG members. The final screening process led to discarding most of them except for the one site in Italy, *i.e.*, Fiume Bosso, and five sites from SE France, *i.e.*, the "plexus", hence including the Tré Maroua section, that all went for the ballot.

Using on the criteria defined by the BWG (*e.g.*, WIMBLEDON *et al.*, 2019), the Tithonian/Berriasian boundary in SE France has to be found in the "Calcaires blancs" Formation. However, examination of the Tithonian-Berriasian cliffs in the whole area by the present authors reveals rapid vertical and lateral changes in facies and thickness, which should have raised the question about the significance of looking for a GSSP candidate in such a geological context. As a matter of fact, although reworking and erosion played a less prominent part in this lithostratigraphic unit than in the underlying Tithonian sedimentary breccias, these phenomena are far from being negligible in the "Calcaires blancs" Formation as recently demonstrated by the revision of the Le Chouet section (FERRY & GRANIER, 2019). Similarly, the successfully voted section, *i.e.*, the Tré Maroua section, had to be checked too in order to further explore the influence of sedimentological factors --an aspect that has not been much investigated by the BWG (WIMBLEDON, personal communication, January 2nd, 2020)--, as well as to evaluate its completeness and its suitability as a GSSP.

2. Location of the section, material and method

The Tré Maroua section is sited some 500 m south of the village of Le Saix (Hautes-Alpes, France) on the left bank of the Maraize stream near its junction with the Tré Maroua stream, one of its small tributaries (GPS coordinates: 44°28' 00.2"N, 5°49'42.0"E). Its location (Fig. 1) corresponds to the SW corner of the geological map at 1/50,000 scale of Gap (GIDON, 1971).

Based on the information presented by the BWG in Bratislava and Milano, a transition interval was logged and samples taken around the candidate boundary at Tré Maroua (Fig. 3.B). Until recently, the only published description of the section was the one briefly outlined by LE HÉGARAT (1973: p. 392-395, Fig. 27; here Fig. 2.B). According to the original text description (LE HÉGARAT, 1973: p. 392-395), the section comprises only one "mince passée bréchique (0,20-0,25 m) à éléments multicolores" [thin breccia layer (0.20-0.25 m) with multicoloured clasts] labelled TT22 (Fig. 2.B). More recently, WIMBLEDON *et al.* (2020) reported 2 breccia layers in the transition interval whereas the present authors report at least 6 breccia layers and associated erosional surfaces (Fig. 3.B). In the "notice explicative" of the geological map of Gap, GIDON (1971) refers to such breccias as "poudingues".

More than 40 samples were collected through this short outcrop, *i.e.*, a 15-meter measured section. All rock pieces were later cut to better docu ment the macroscopic fabrics (Table 1). Some were then photographed and others scanned (Figs. 4 - 5). Only 10 thin sections (Fig. 6) were pre pared from a set of samples chosen to frame the boundary in order to study the microfacies and the calpionellid assemblages (Pls. 1 - 3). The preliminary microbiostratigraphic results are rather puzzling because calpionellid Zone B (*e.g.*, REMANE, 1970, BENZAGGAGH, 2019), the base of which is the primary criterion of the BWG (WIMBLEDON *et al.*, 2019, 2020), is found to extend at least 2.5 m below the boundary location of the BWG.

The locations of the plugs taken by the BWG for their (bio-) magnetostratigraphic study were still visible (Fig. 2.A) and are reported on our log (Fig. 3.B), thus allowing a short comment on the relevant results presented by the BWG (WIMBLEDON *et al.*, 2020).

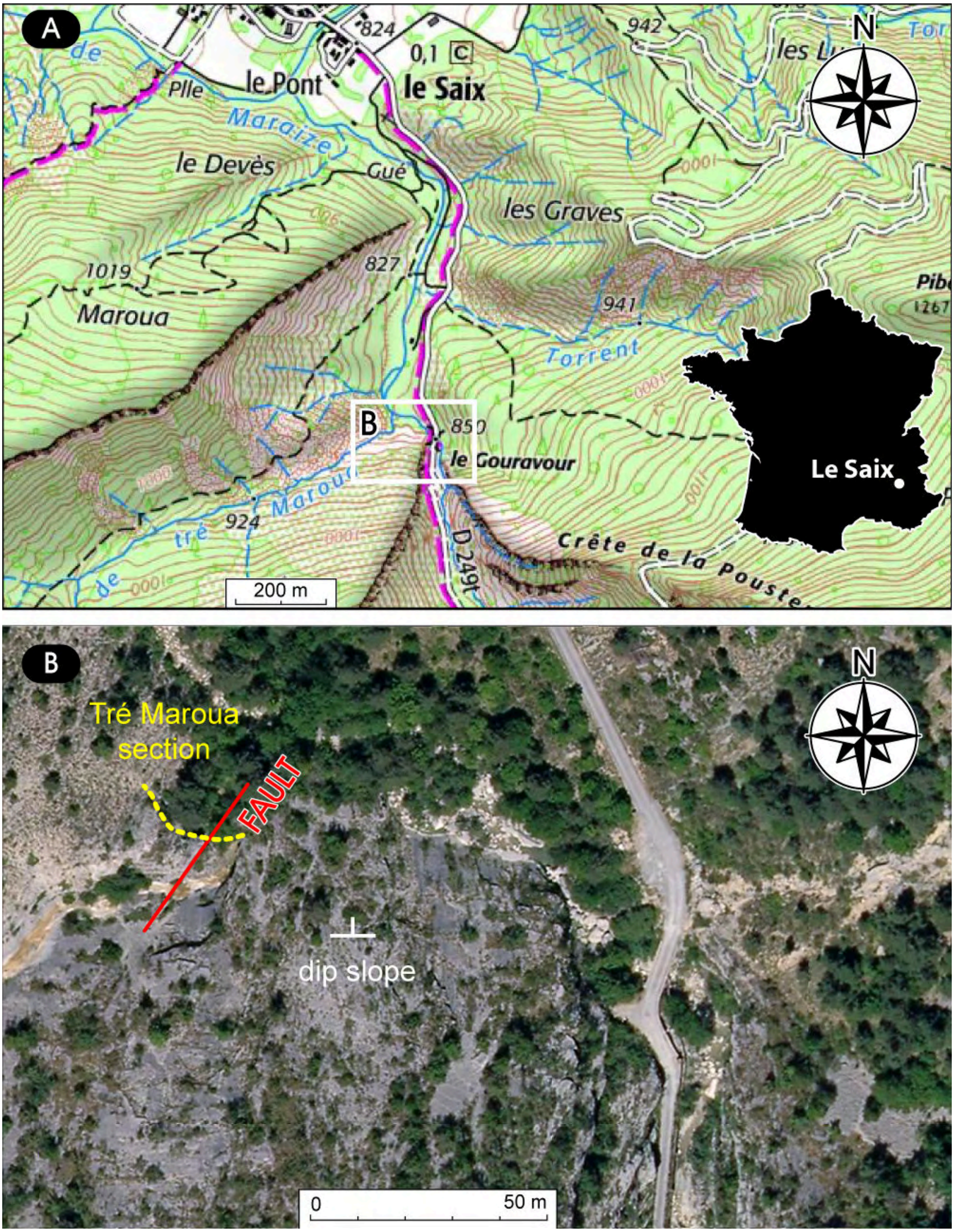
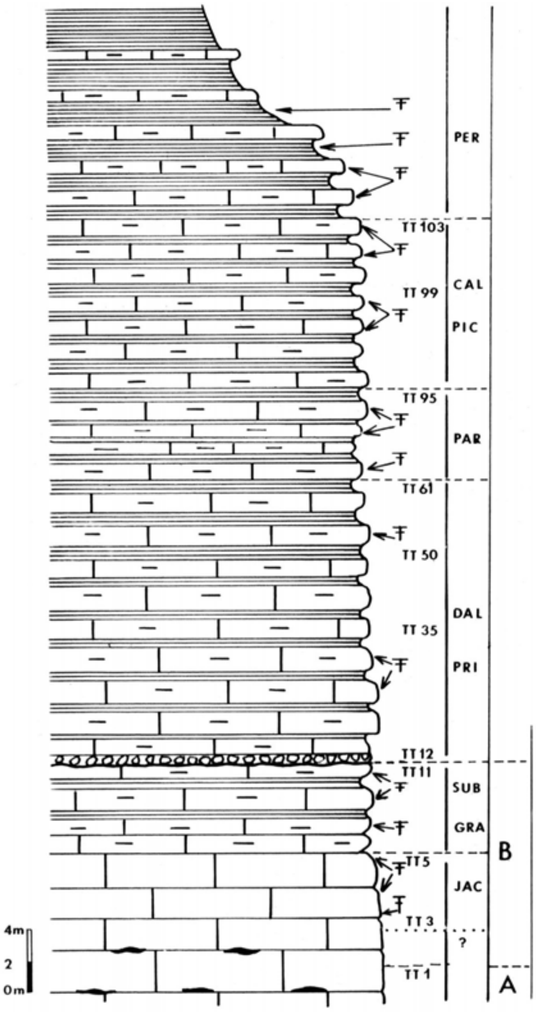


Figure 1: A) Topographic map of the area S of Le Saix, centered on the Tré Maroua section (white frame); **B)** Satellite image of the Tré Maroua section (yellow dots) and the fault (red line) affecting it. Map and image backgrounds © IGN 2020.



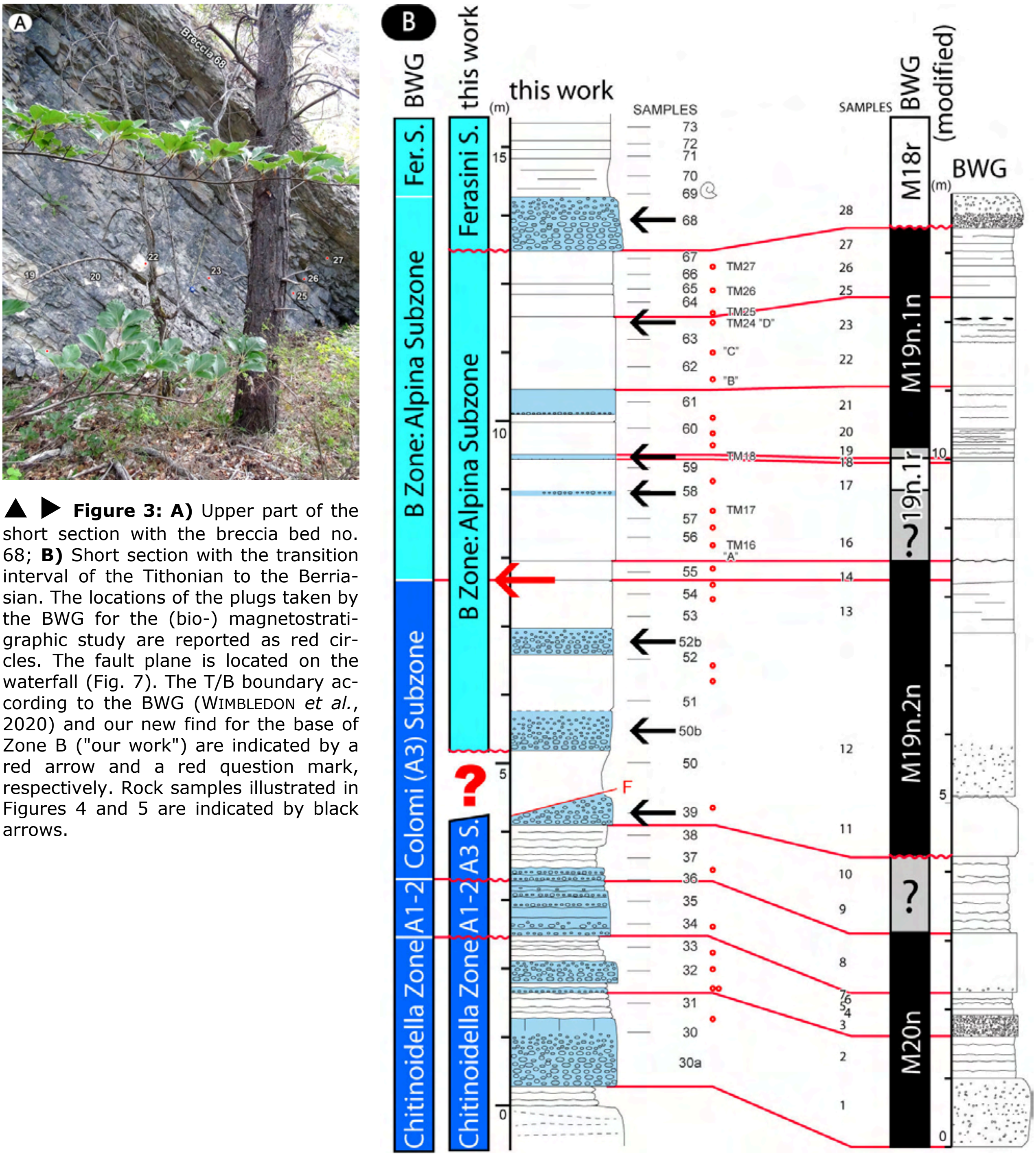
Ⓑ Fig. 27 – Coupe du torrent de Tré Maroua (05).

◀ ▲ **Figure 2: A)** The Tré Maroua valley; **B)** The Tré Maroua section according to Le Hégarat (1973: Fig. 27): JAC Jacobi Zone, GRA Grandis Zone, SUB Subalpina Subzone, PRI Privasensis Subzone, DAL Dalmati Subzone, BOI Boissieri Zone, PAR Paramimounum Subzone, PIC Picteti Subzone, CAL Callisto Subzone, RPU Roubaudi Zone, PER Petransiens Subzone.

3. Regional geological context

Outcrops of the Tithonian-Berriasian interval in SE France are riddled with breccia and mud turbidite beds together with stratigraphic hiatuses that are hard to identify without an accurate biostratigraphy (*e.g.*, Alliot *et al.*, 1964; Remane, 1970; Le Hégarat, 1973). Courjault (2011) did extensive field work in Tithonian strata across the Diois and Baronnies regions, including a detailed study of the Drôme River lobe (Courjault *et al.*, 2011). His contribution was recently completed in higher strata in the Le Chouet area (Ferry & Granier, 2019) where a large number of cryptic mud turbidites have been found in the "Calcaires blancs" Formation together with some more breccia beds.

The Tré Maroua section (Le Hégarat, 1973: Fig. 27; here Fig. 2.B) partly revised herein was situated on a peeled and gullied slope between two deep-water terraces, on the distal edge of the Drôme River lobe. Gravity reworkings on this paleoslope fed the Céüse lobe to the NE (Ferry *et al.*, 2015) and the section itself was located southwestward along this slope.



▲ ▶ **Figure 3: A)** Upper part of the short section with the breccia bed no. 68; **B)** Short section with the transition interval of the Tithonian to the Berriasian. The locations of the plugs taken by the BWG for the (bio-) magnetostratigraphic study are reported as red circles. The fault plane is located on the waterfall (Fig. 7). The T/B boundary according to the BWG (Wimbledon *et al.*, 2020) and our new find for the base of Zone B ("our work") are indicated by a red arrow and a red question mark, respectively. Rock samples illustrated in Figures 4 and 5 are indicated by black arrows.

4. Remarks on lithostratigraphy and sedimentology

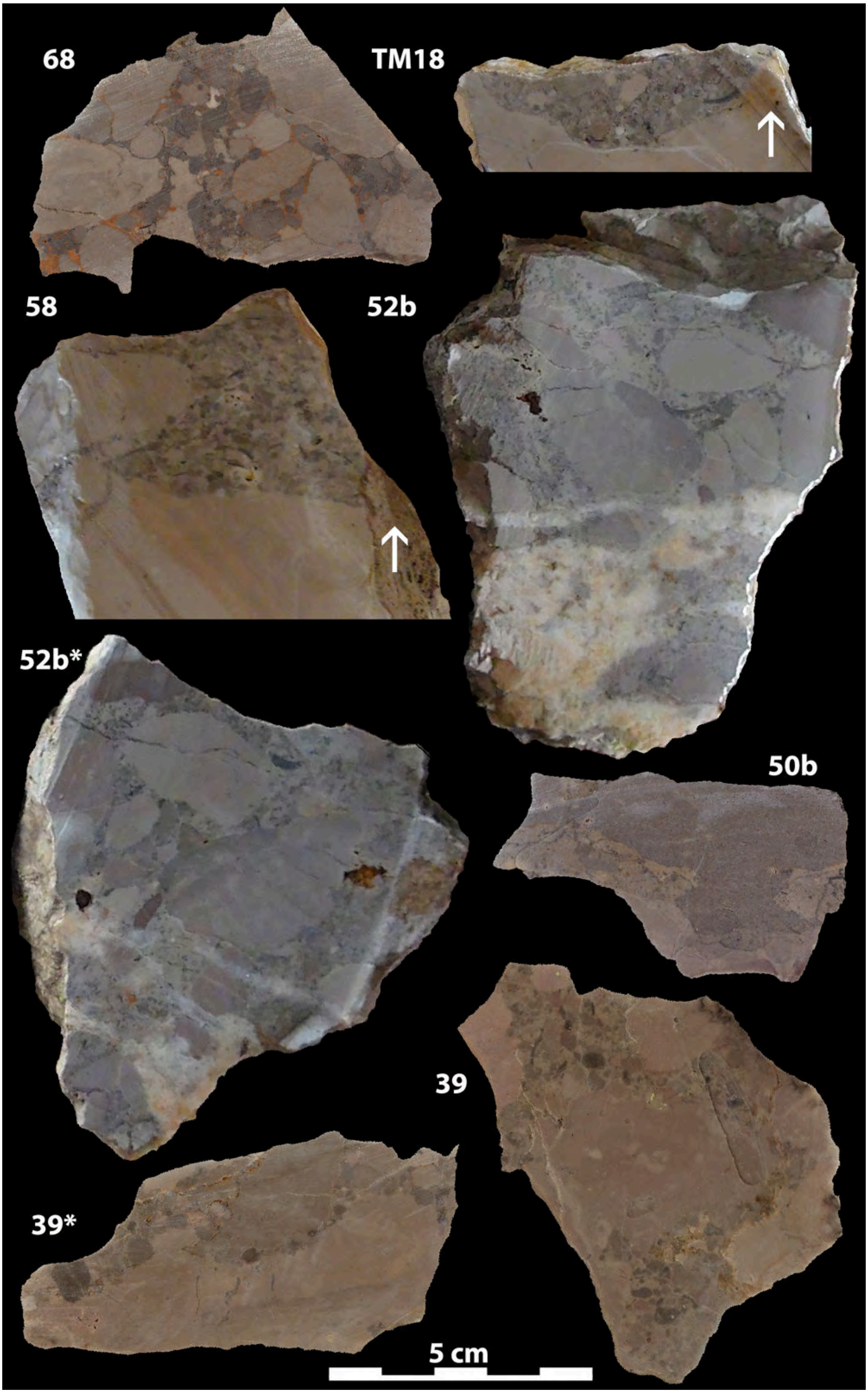
A long section (not illustrated here) was measured along the narrow road at the entry of the Gouravour gorge. Starting from the bottom, the first fifteen meters, which consist mostly of well-bedded limestones, locally argillaceous, are ascribed to the Kimmeridgian whereas the following forty meters of slump and "breccia" beds are ascribed to the Tithonian (*e.g.*, Ferry & Grosheny, 2013; Ferry, 2017). The transition interval of the Tithonian to the Berriasian itself is found in the next unit, *i.e.*, in the "Calcaires blancs" Formation. The short section (Fig. 3.B) covering the lowermost part of this last unit was measured along a small cliff with a waterfall that marks the end of the Tré Maroua ravine (see § "*Location of the section, material and method*").

According to the log of the BWG (Wimbledon *et al.*, 2020: Fig. 4), the 8 to 9 meter thick transitional interval in which is located the Tithonian/Berriasian boundary begins and ends with decimetric to metric conglomeratic layers, which correspond respectively to our samples no. 50b and no. 68 (Fig. 4). Contrary to a statement of the BWG (Wimbledon, personal communication, January 2nd, 2020), the interval sandwiched by these breccias was not the site of continuous sedimentation. As a matter of fact, the present authors document here unreported occurrences of several additional conglomeratic layers (of which at least 3 were sampled) and their associated basal erosional surfaces/disconformities (Fig. 4): *ca.* 1 m below the boundary (sample no. 52b), *ca.* 1 m and 1.5 m above the boundary (samples no. 58 and no. TM18). The fabrics of these conglomerates correspond mostly to rudstones (or quite a few floatstones) with wackestone or packstone matrices. Pebbles and cobbles are polygenetic (which can be detected from their color); they are subrounded in shape and have a medium sphericity (Fig. 4). Our preliminary investigation suggests there are also some unreported mud turbidites and associated basal erosional surfaces, *i.e.*, features that are generally harder to identify directly in the field (*e.g.*, sample no. TM24, Fig. 5) and would require a more systematic sampling program. As a consequence, contrary to the views of the BWG, the interval sandwiched between these breccias was also affected by changes in the rate of sedimentation: positive but low for the pelagic ooze (0.01 m/k.y. as an order of magnitude), positive and very high for turbidites and debris flows (1 m/hour as an order of magnitude), negative and very high for the erosional surfaces at the bottom of turbidites and debris flows (-1 m/hour as an order of magnitude). Whether a breccia bed is thin or thick, the base of any unit (biozone or biomagnetozone) should be necessarily located at its bottom, not at its top.

Table 1: Sample analyses and plate captions.

Sample number	Macrofacies	Microfacies	Microbiostratigraphy (Plate captions)
68 (Fig. 4)	extraclastic rudstone (pebbles up to 35 mm in length)		
TM24 (Fig. 5)	contact of a mudstone and a turbidite mudstone		
TM18 (Fig. 4)	contact of a bioturbated mudstone and an extraclastic rudstone (pebbles up to 15 mm in length)	mudstone (Fig. 6, BR2973), rudstone with mudstone extraclasts (with calpionellids and radiolarians) and a bioclastic and extraclastic packstone matrix (Fig. 6, BR2982): ooids, aptychii, rhyncholites, bryozoans, gastropod, echinoid remains, miliolid, *Lenticulina* sp., *Neotrocholina* sp., *Nautiloculina* sp., ...	
58 (Fig. 4)	contact of a mudstone and an extraclastic rudstone (pebbles up to 25 mm in length)	rudstone with mudstone extraclasts and a bioclastic and extraclastic wackestone matrix (Fig. 6, BR2979-2980): ooids, aptychii, rhyncholites, belemnite rostrum, echinoid remains, miliolid, *Lenticulina* sp., *Neotrocholina* sp. (Pl. 3, fig. C, "N"), *Tubiphytes* sp., *Coskinobullina socialis*, ...	BR2979/58 extraclasts: mostly from Zone B (Subzone B1); some with more *Crassicollaria* spp., *i.e.*, *Cr. intermedia* and *Cr. brevis*, and rare *Calpionella elliptalpina* could be ascribed to Zone A. (Pl. 3, figs. A-C)
56	mudstone	mudstone with calpionellids (Fig. 6, BR2978)	
55	bioturbated mudstone	mudstone with calpionellids (Fig. 6, BR2981): aptychii	
53	mudstone	mudstone with calpionellids (Fig. 6, BR2977)	
52b (Fig. 4)	extraclastic rudstone (pebbles up to 40 mm in length)	rudstone with mudstone extraclasts and a bioclastic and extraclastic wackestone matrix (Fig. 6, BR2975-2976): ooids, aptychii, echinoid remains, *Coscinoconus* sp., *Neotrocholina* sp., *Tubiphytes* sp., *Thaumatoporella parvovesiculifera*, ...	BR2976/52b large extraclast: numerous small and medium-sized spherical forms of *Calpionella alpina* with common *Crassicollaria parvula*; few ? *Tintinnopsella carpathica* and rare *Calpionella grandalpina*. Zone B (Subzone B1) (Pl. 2, figs. A-B)
51	bioturbated mudstone	mudstone with calpionellids (Fig. 6, BR2974)	BR2974/51: small and medium-sized spherical forms of *Calpionella alpina* dominate over rare *Crassicollaria parvula*. Zone B (Subzone B1) (Pl. 1, figs. A-B)
50b (Fig. 4)	extraclastic rudstone (pebbles up to 20 mm in length)		
39 (Fig. 4)	contact of a mudstone and an extraclastic rudstone (pebbles up to 40 mm in length)		

▶ **Figure 4:** From top to bottom, unless otherwise stated, mostly some randomly cut polished slabs of the "breccia" samples observed on the occasion of our preliminary investigation on the transition interval: scanned surface of no. 68 (upper conglomerate), photographed surface of no. TM18 oriented (arrow pointing upward), photographed surface of no. 58 oriented (arrow pointing upward), photographed surfaces of no. 52b, scanned surface of no. 50b (lower conglomerate), scanned surfaces of no. 39.


68
TM18
58
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52b*
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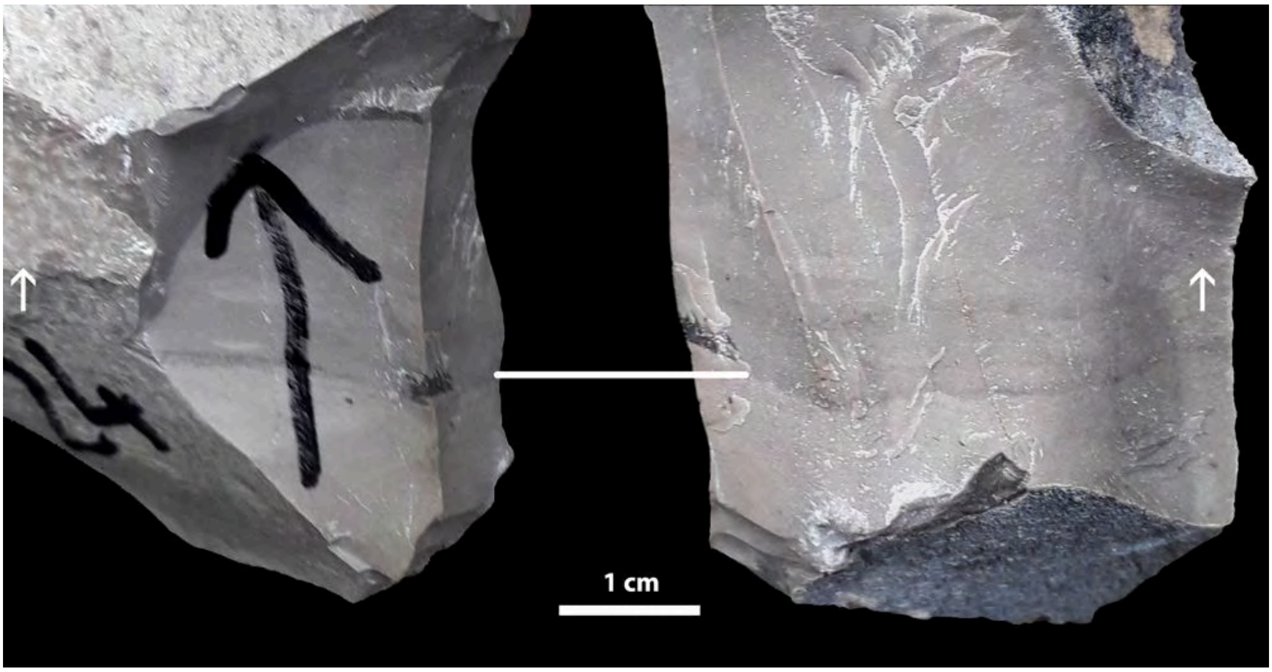

Figure 5: One example of a mud turbidite with its erosional base identified from the field: photographed surface of no. TM24 oriented (arrows pointing upward).

The situation is almost the same as in the Le Chouet section. As recently highlighted by FERRY and GRANIER (2019) and contrary to the opinion of WIMBLEDON *et al.* (2013), this "complementary" section of the BWG, which is duly listed as such in their "plexus of sites", also does not comply with the fundamental criterion consisting of an "essentially continuous sedimentation, uninterrupted by marked diastems".

Furthermore, contrary to a statement of the BWG (WIMBLEDON, personal communication, January 2nd, 2020), a fault affects the section. The corresponding fault plane (Fig. 7), *ca.* 3 m below the boundary, is partly visible at the waterfall that marks the end of the Tré Maroua ravine (videos at http://paleopolis.rediris.es/cg/2001/TMF.mp4 or http://paleopolis.rediris.es/cg/2001/TMF.avi).

5. Remarks on microbiostratigraphy

The primary criterion defined by the BWG to identify the base Berriasian (*e.g.*, WIMBLEDON *et al.*, 2019) is the base of calpionellid Zone B, *i.e.*, the base of the acme of *Calpionella alpina*, also called the "*Crassicolaria*/*Calpionella* turnover" because there the small and medium-sized spherical forms of *Calpionella alpina* take over the *Crassicolaria* spp.

According to WIMBLEDON *et al.* (2020: Fig. 4), the Tithonian/Berriasian boundary should be located between our samples no. 54 and no. 55. However, our sample no. 52b was taken from a breccia bed *ca.* 1 m below the boundary and at least one pebble was found to contain an assemblage characteristic of Zone B (Pl. 2, figs. A-B, red circles: *Crassicolaria* spp.; yellow circle: *Calpionella* sp.). Furthermore our sample no. 51 was taken *ca.* 2 m below the boundary and again the corresponding thin section displays an assemblage characteristic of Zone B (Pl. 1, figs. A-B, red circles: *Crassicolaria* spp.). Consequently, the Tithonian/Berriasian boundary is probably lower in the section, thus getting closer to breccia beds and to the fault. According to FERRY and GRANIER (2019), this same boundary defined by WIMBLEDON *et al.* (2020) was also found 2 meters higher than that defined by REMANE (1970) at Le Chouet.

Besides, the calpionellid Zone A *sensu* WIMBLEDON *et al.* (2020), *i.e.*, the Crassicolaria Zone, which represents the most part of the upper Tithonian, is only some 6 meters thick at Tré Maroua whereas it could be less than 3 meters according to the present authors (Fig. 3.B).

Our sample no. 58 was taken from a breccia bed *ca.* 5 m above the boundary. The many extraclasts observed in the corresponding thin sections are barren or contain discrete assemblages, either from Zone B or older from Zone A (Pl. 3, figs. A-C: *Crassicolaria* spp.; yellow circle: *Calpionella* sp.; blue N: *Neotrocholina* sp.). They document significant erosional events and coeval reworkings taking place in the whole area in the late Tithonian - early Berriasian interval.

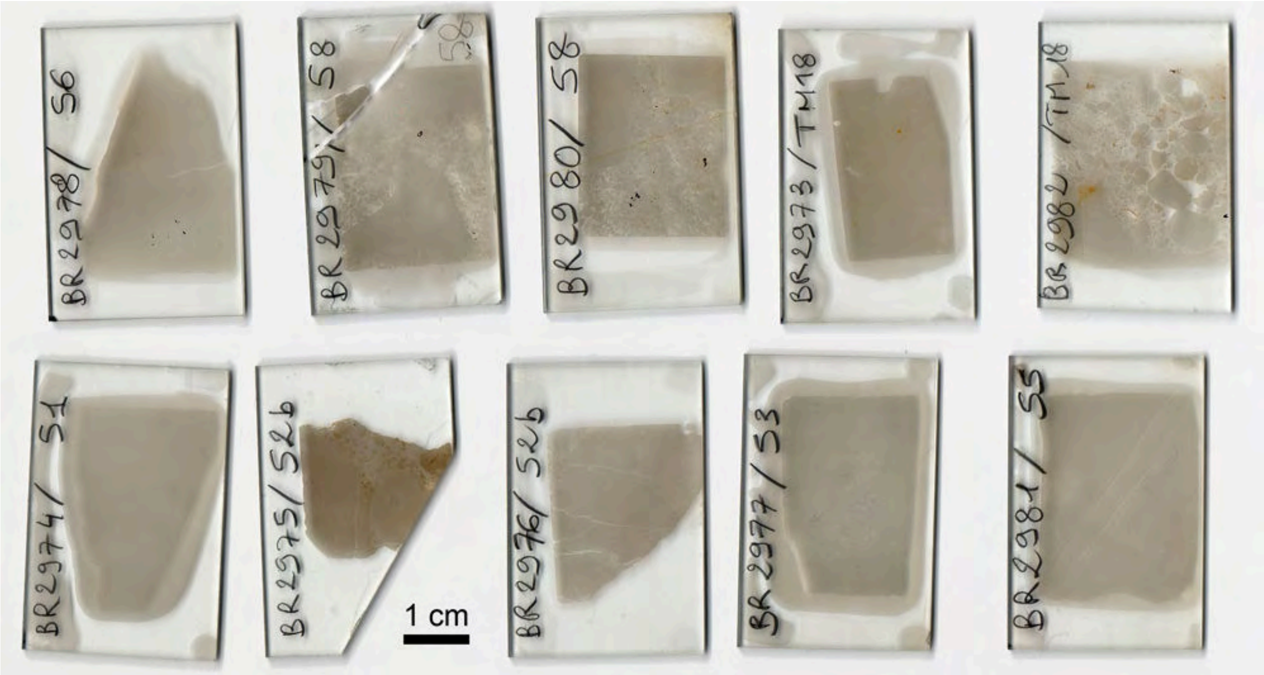

Figure 6: The limited set of thin sections [from samples no. 51, no. 52b (2), no. 53, no. 55, no. 56, no. 58 (2), no. TM18 (2)] studied herein. Extraclasts are visible in BR2975-2976, 2979-2980, and 2982.

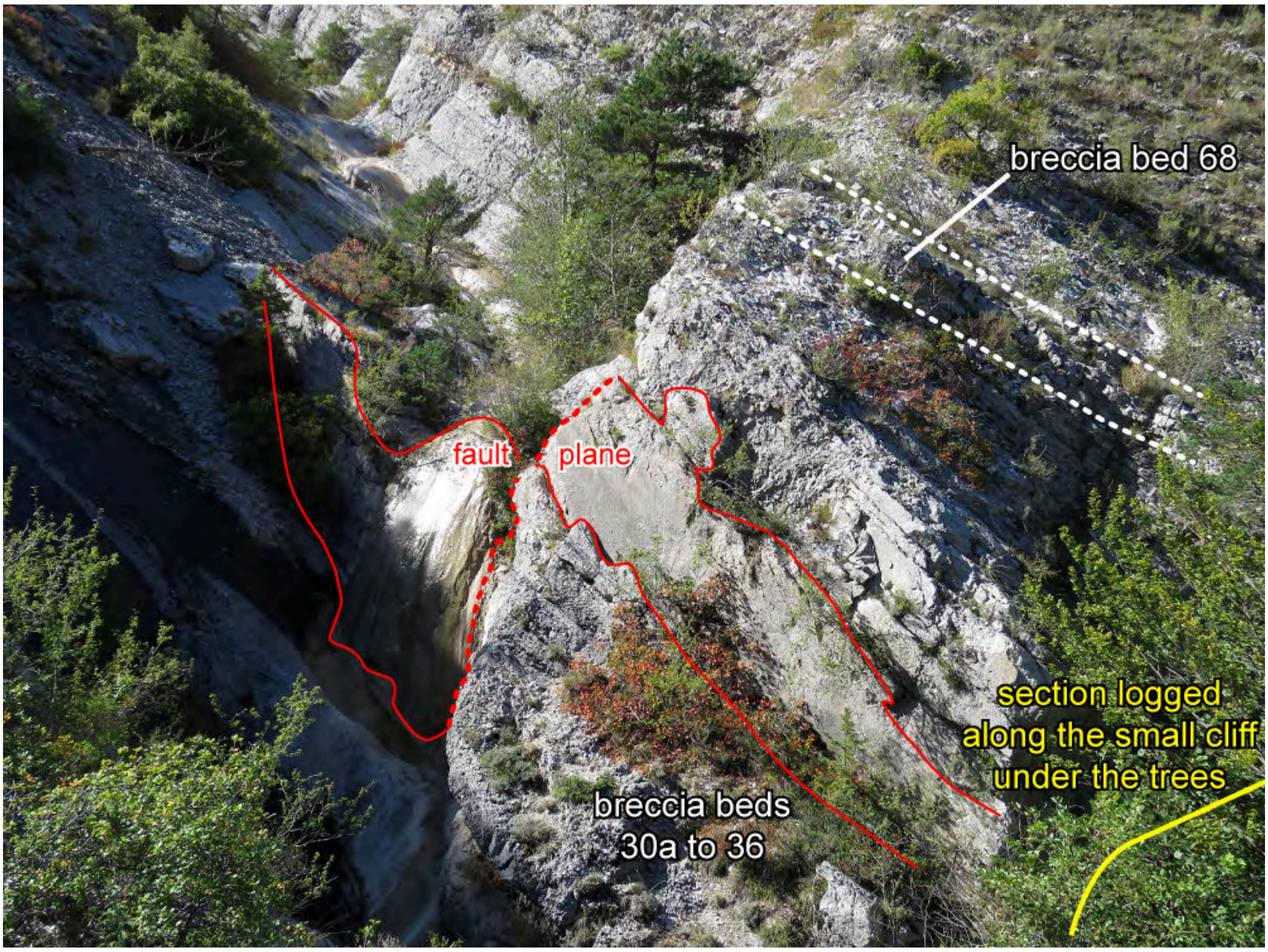

Figure 7: The fault plane on the waterfall that marks the end of the Tré Maroua ravine (see the video at http://paleopolis.rediris.es/cg/2001/TMF.mp4 or http://paleopolis.rediris.es/cg/2001/TMF.avi).

6. Remarks on biomagnetostratigraphy

One self-defined requirement of the BWG was that the Berriasian GSSP candidate section should have a complete record of a transition interval spanning the whole Magnetozone M19n (WIMBLEDON *et al.*, 2020: Fig. 9), which is a secondary correlation marker bracketing the primary marker.

On one hand, the base of the Magnetozone M18r at Tré Maroua is located at the bottom of the breccia bed no. 68, not at its top (Fig. 3.B), which implies that the top of M19n corresponds to an erosional surface with an associated hiatus. On the other hand, the Magnetozone M20r was not identified; therefore, the base of M19n could not be properly defined. Accordingly, the record of Magnetozone M19n is incomplete.

Additionally, the whole transition interval comprises several episodes of erosion accompanied by the deposition of mud turbitides and conglomerates resulting from debris flows (Fig. 5), as it is also the case at Le Chouet (FERRY & GRANIER, 2019). These episodes do not appear on the log of WIMBLEDON *et al.* (2020: Fig. 4).

To summarize, the sedimentary record of M19n is clearly incomplete and fragmentary.

Finally, remember that a fault is also visible (Fig. 7) and that it affects the section within the Magnetozone M19n, most specifically near its base (Fig. 3.B).

7. Conclusions

1) According to REMANE *et al.* (1996), a GSSP section should meet a number of "geological requirements":

i. "**Exposure over an adequate thickness** of sediments is one requirement to guarantee that a sufficient time interval is represented by the section, so that the boundary can also be determined by interpolation, using auxiliary markers close to the boundary."

see § "*Remarks on microbiostratigraphy*" Incompletness of the interval spanning the Colomi Subzone of the Crassicolaria Zone (A3) and the Alpina Subzone of the Calpionella Zone (B1): hiatuses related to erosional surfaces are identified at the bottom and the top of this Colomi-Alpina interval.

see § "*Remarks on biomagnetostratigraphy*" Incompletness of Magnetozone M19n: a hiatus related to an erosional surface is identified at the its top whereas its base could not be precisely identified.

ii. "**Continuous sedimentation**: no gaps, no condensation in proximity of the boundary level."

In the transition interval, LE HÉGARAT (1973) reported only one breccia layer whereas WIMBLEDON *et al.* (2020) report two breccia layers. The present authors documented at least 6 breccia layers and associated erosional surfaces (Fig. 3.B), plus some mud turbidites and associated erosional surfaces.

see § "*Remarks on microbiostratigraphy*" Fragmentary record of the interval spanning the Colomi Subzone of the Crassicolaria Zone (A3) and the Alpina Subzone of the Calpionella Zone (B1): hiatuses related to erosional surfaces are identified within this Colomi-Alpina interval. As documented herein, it is more than possible that the (A3/B1) boundary itself coincides with the erosional surface at the base of the breccia bed no. 50b (Fig. 3.B), located more than 2.5 m below the base of Calpionella Zone (B) *sensu* WIMBLEDON *et al.* (2020).

see § "Remarks on biomagnetostratigraphy" Fragmentary record of Magnetozone M19n: hiatuses related to erosional surfaces are identified within the Magnetozone M19n.

iii. "The **rate of sedimentation** should be sufficient that successive events can be easily separated."

see § "*Remarks on lithostratigraphy and sedimentology*"
The rate of sedimentation was changing from highly negative (-1 m/hour as an order of magnitude) to highly positive (1 m/hour as an order of magnitude), then to still positive but very low (0.01 m/k.y. as an order of magnitude).

iv. "**Absence of synsedimentary and tectonic disturbances**."

see previous items i) and ii) for the breccia beds, mud turbidites, and associated erosional surfaces.

The present authors report a fault *ca.* 3 m below the base of Calpionella Zone (B) *sensu* WIMBLEDON *et al.* (2020). As documented herein, it is more than possible that the (A3/B1) boundary itself is located even closer (*ca.* 1 m) to the fault (see Fig. 3.B).

v. "**Absence of metamorphism and strong diagenetic alteration** (identification of magnetic and geochemical signals)."

Some rock samples are fractured and cemented by calcite (for instance, our sample no. 52b is a tectonically-brecciated sedimentary breccia, see Fig. 4).

As demonstrated above, the Berriasian GSSP candidate section at Tré Maroua (Fig. 3.B) does not meet at least four of the above five "geological requirements for a GSSP". Although this candidacy reached the absolute majority of the votes of the BWG, it must be dismissed for the sake of stratigraphers' confidence in the selection of GSSPs. Looking ahead, a careful regional investigation should be the prerequiste to any future attempt to identify a better location for a re-casted Berriasian GSSP.

2) As a result of the inability to present a tenable Berriasian stage boundary within the Jacobi-Grandis standard ammonite zone interval, as well as the instability of the proposed boundary location over decades and the obvious lack of a significant biological crisis (see GRANIER, ed., 2019a; GRANIER, 2019b, 2019c, 2019d; VÖRÖS *et al.*, 2019; ÉNAY, 2020; SALAZAR *et al.*, 2020), one should definitely close the chapter of its candidacy as the Jurassic/Cretaceous system boundary opened by KILIAN (*e.g.*, 1910) almost a century ago. It would be obtuse to keep on looking for a system boundary where one can hardly identify a stage boundary. It is suggested here again to revert to the pre-KILIAN historical boundary, *i.e.*, the boundary of OPPEL (*e.g.*, 1865, for the last stage of the Jurassic), TOUCAS (*e.g.*, 1908), or ORBIGNY (*e.g.*, 1842, for the first stage of the Cretaceous). It should be now a reality that the only valid option remaining consists of shifting the Jurassic/Cretaceous boundary back to the base Valanginian (as has been urged in some recent discussions, *e.g.*, GRANIER, 2019c; ÉNAY, 2020).

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Bibliographic references

ALLIOT C., FLANDRIN J. & MOULLADE M. (1964).- Les sédiments grossiers du Berriasien de la "Fosse vocontienne". Étude particulière du Berriasien de Marignac au N.O. de Die (Drôme).- *Travaux et Documents des Laboratoires de Géologie de Lyon* (nouvelle série), no. 11, p. 161-182.

BENZAGGAGH M. (2019).- Discussion on the calpionellid biozones and proposal of a homogeneous calpionellid zonation for the Tethysian Realm. *In*: GRANIER B. (ed.), *Virtual Special Issue on* "The transition of the Jurassic to the Cretaceous: an early XXIth century holistic approach".- *Cretaceous Research*. DOI: 10.1016/j.cretres.2019.07.014

COURJAULT T. (2011).- Brèches gravitaires sous-marines du Tithonien subalpin (S-E France).- PhD thesis, Université de Strasbourg, 339 p.

COURJAULT T., GROSHENY D., FERRY S. & SAUSSE J. (2011).- Detailed anatomy of a deep-water carbonate breccia lobe (Upper Jurassic, French subalpine basin).- *Sedimentary Geology*, vol. 238, no. 1-2, p. 156-171.

ÉNAY R. (2020).- The Jurassic/Cretaceous System Boundary is at an impasse. Why not go back to OPPEL's 1865 original and historic definition of the Tithonian?.- *Cretaceous Research*, vol. 106, no. 104241, 20 p. DOI: 10.1016/j.cretres.2019.104241

FERRY S. (2017).- Summary on Mesozoic carbonate deposits of the Vocontian Trough (Subalpine Chains, SE France). *In*: GRANIER B. (ed.), Some key Lower Cretaceous sites in Drôme (SE France).- Carnets de Géologie, Madrid, Book 2017/01 (CG2017_B01), p. 9-42.

FERRY S. & GRANIER B. (2019).- 12. Looking for the Jurassic-Cretaceous system boundary in the Vocontian Trough (S-E France): sedimentological problems. *In*: GRANIER B. (ed.), JK2018 - International Meeting around the Jurassic-Cretaceous Boundary (Geneva, December 5-7, 2018). Abstract volume.- Carnets de Géologie, Madrid, Book 2019/01 (CG2019_B01), p. 24.

FERRY S. & GROSHENY D. (2013).- Turbidites et brèches carbonatées (Jurassique et Crétacé du bassin subalpin).- Livret-Guide Excursion ASF-GFC, 20-23 septembre 2013, 101 p. URL: http://hal.archivesouvertes.fr/docs/00/90/81/77/PDF/2013_Turbidites_SE_ExcuGFC.pdf

FERRY S., GROSHENY D., ATROPS F. & BACKERT N. (2015).- The base-of-slope carbonate breccia system of Céüse (Tithonian, S-E France): occurrence of progradational stratification in the head plug of coarse granular flow deposits.- *Sedimentary Geology*, vol. 317, p. 71-86.

GIDON M. (1971).- Gap.- *Carte géologique détaillée de la France au 1/50 000*, BRGM, Orléans-la-Source, Feuille 001III - 38, 15 p., 1 map.

GRANIER B. (ed., 2019a).- JK2018 - International Meeting around the Jurassic-Cretaceous Boundary (Geneva, December 5-7, 2018). Abstract volume.- Carnets de Géologie, Madrid, Book 2019/01 (CG2019_B01), 100 p.

GRANIER B. (2019b).- Dual biozonation scheme (benthic foraminifera and "calcareous" green algae) over the Jurassic-Cretaceous transition. Another plea to revert the system boundary to its historical ORBIGNY's and OPPEL's definition. *In*: GRANIER B. (ed.), *Virtual Special Issue on* "The transition of the Jurassic to the Cretaceous: an early XXIth century holistic approach".- *Cretaceous Research*, vol. 93, p. 245-274. DOI: 10.1016/j.cretres.2018.08.024

Granier B. (2019c).- JK2018: International Meeting around the Jurassic/Cretaceous Boundary - Chairperson's Report.- *Volumina Jurassica*, Warszawa, vol. XVII, p. 1-6.

Granier B. (2019d).- Carbonate platforms of the Tethys Ocean at the Jurassic-Cretaceous transition: case studies. *In*: Fekete K., Michalík J. & Reháková D. (eds.), Field Trip Guide and Abstracts Book, XIVth Jurassica Conference & Workshop of the ICS Berriasian Group (June 10-14, 2019, Bratislava, Slovakia).- Earth Science Institute, Slovak Academy of Sciences & Faculty of Natural Sciences, Comenius University, Bratislava, p. 113-114.

Kilian W. (1910).- La faune des couches à *Hoplites boissieri* (Pictet) (Berriasien p.p. - Valanginien inférieur) du Sud-Est de la France.- Association française pour l'Avancement des Sciences, Congrès de Lille, p. 476-496.

Le Hégarat G. (1973).- Le Berriasien du Sud-Est de la France.- Thèse Docteur ès Sciences naturelles, no. 149, Université Claude Bernard - Lyon; *Documents du Laboratoire de Géologie de la Faculté de Lyon*, no. 43 (1971), 2 fasc., 576 p. (55 Pls.).

Murphy M.A. & Salvador A. (1999).- International Stratigraphic Guide - An abridged version.- *Episodes*, vol. 24, no. 4, p. 255-271.

Oppel A. (1865).- 2. Die Tithonische Etage.- *Zeitschrift der Deutschen geologischen Gesellshaft*, Berlin, Band XVII, p. 535-558.

Orbigny A. d' (1842-1851).- Paléontologie Française, Terrains Jurassiques, I. Céphalopodes.- Bertrand, Paris, 642 p.

Remane J. (1970).- Die Entstehung der resedimentären Breccien im Obertithon der subalpinen Ketten Frankreichs.- Dissertation (1969), Göttingen; *Eclogae geologicae Helvetiae*, vol. 63, no. 3, p. 685-740.

Remane J., Bassett M.G., Cowie J.W., Gohrbandt K.H., Lane R.L., Michelsen O. & Wang N. (1996).- Revised guidelines for the establishment of global chronostratigraphic standards by the International Commission on Stratigraphy (ICS).- *Episodes*, vol. 19, no. 3, p. 77-81.

Salazar C., Stinnesbeck W. & Álvarez M. (2020).- Ammonite biostratigraphy and bioevents in the Jurassic - Cretaceous boundary of central Chile. *In*: Granier B. (ed.), *Virtual Special Issue on* "The transition of the Jurassic to the Cretaceous: an early XXIth century holistic approach".- *Cretaceous Research*, vol. 107, no. 104282, 16 p. DOI: 10.1016/j.cretres.2019.104282

Salvador A. (ed., 1994).- International Stratigraphic Guide.- I.U.G.S. & Geological Society of America, 214 p.

Toucas A. (1908).- Sur le Tithonique et le Berriasien.- *Compte Rendu Sommaire des Séances de la Société géologique de France*, Paris, Séance du 6 janvier 1908, p. 25-27.

Vörös A., Főzy I. & Szives O. (2019).- Brachiopod distribution through the Jurassic-Cretaceous transition in the western Tethyan pelagic realm: Example from the Bakony Mountains, Hungary. *In*: Granier B. (ed.), *Virtual Special Issue on* "The transition of the Jurassic to the Cretaceous: an early XXIth century holistic approach".- *Cretaceous Research*, vol. 104, no. 104182, 9 p. DOI: 10.1016/j.cretres.2019.104182

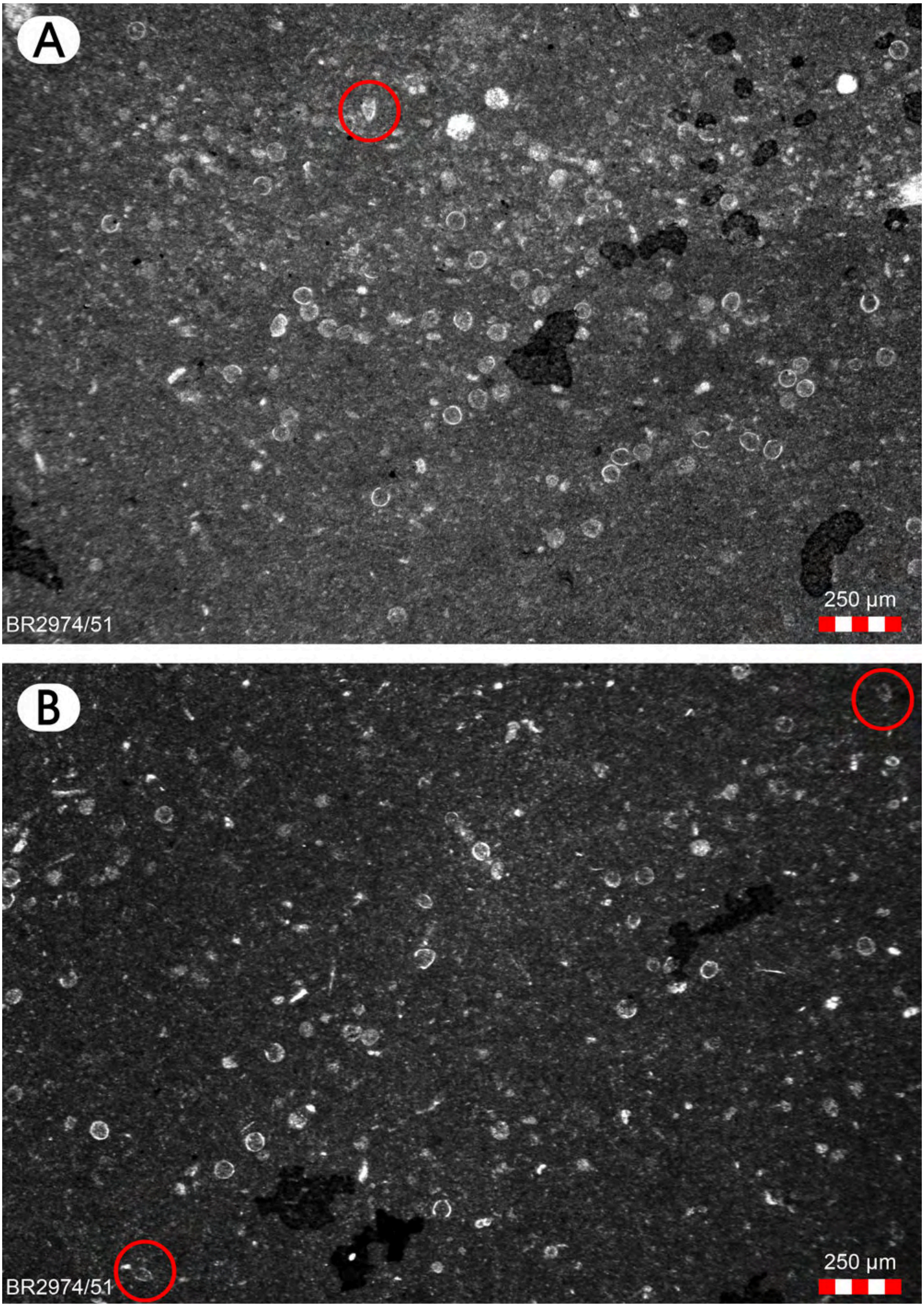
Wimbledon W.A.P, Reháková D., Halásová E., Lintnerová O., Michalík J., Pruner P., Schnabl P., Svobodová A., Čížková K., Elbra T., Košťák M., Arnaud-Vanneau A.M., Galbrun B., Gardin S., Bulot L.G., Frau C., Grabowski J., Wierzbowski A., Pszczółkowski A., Stoykova K., Ivanova D., Lakova I., Tchoumatchenko P., Sha J., Li G., Cao M., Wan X., Li J., Andreini G., Satolli S., Erba E., Poulton T.P., Galloway J., Riccardi A., Leanza H., Kietzmann D., Vennari V., Aguirre-Uretta B., Dzyuba O., Bugdaeva E., Markevich V., Guzhikov A., Vuks V., Riding J., Hunt C., Copestake P., Munsterman D., Verreussel R., Bakhmutov V., Főzy I., Mojon P.O., Mohialdeen I.J., Bardhan S., Lopez-Martinez R., Benzaggagh M., Alsen P., Vajda V., Ogg J. & Lucas-Clark J. (2019).- Progress with selecting a GSSP for the Berriasian Stage (Cretaceous) - illustrated by sites in France and Italy. *In*: Fekete K., Michalík J. & Reháková D. (eds.), Field Trip Guide and Abstracts Book, XIVth Jurassica Conference & Workshop of the ICS Berriasian Group (June 10-14, 2019, Bratislava, Slovakia).- Earth Science Institute, Slovak Academy of Sciences & Faculty of Natural Sciences, Comenius University, Bratislava, p. 186-187.

Wimbledon W.A.P., Reháková D., Pszczółkowski A., Casellato C.E., Halásová E., Frau C., Bulot L.G., Grabowski J., Sobień K., Pruner P., Schnabl P. & Čížková K. (2013).- An account of the bio- and magnetostratigraphy of the Upper Tithonian-Lower Berriasian interval at Le Chouet, Drôme (SE France).- *Geologica Carpathica*, Bratislava, vol. 64, no. 6, p. 437-460.

Wimbledon W.A.P., Reháková D., Svobodová A., Schnabl P., Pruner P., Elbra T., Šifnerová K., Kdýr Š., Frau C., Schnyders J. & Galbrun B. (2020).- Fixing a J/K boundary: a comparative account of key Tithonian-Berriasian profiles in the departments of Drôme and Hautes-Alpes, France.- *Geologica Carpathica*, Bratislava, vol. 71, no. 1, p. 24-46.

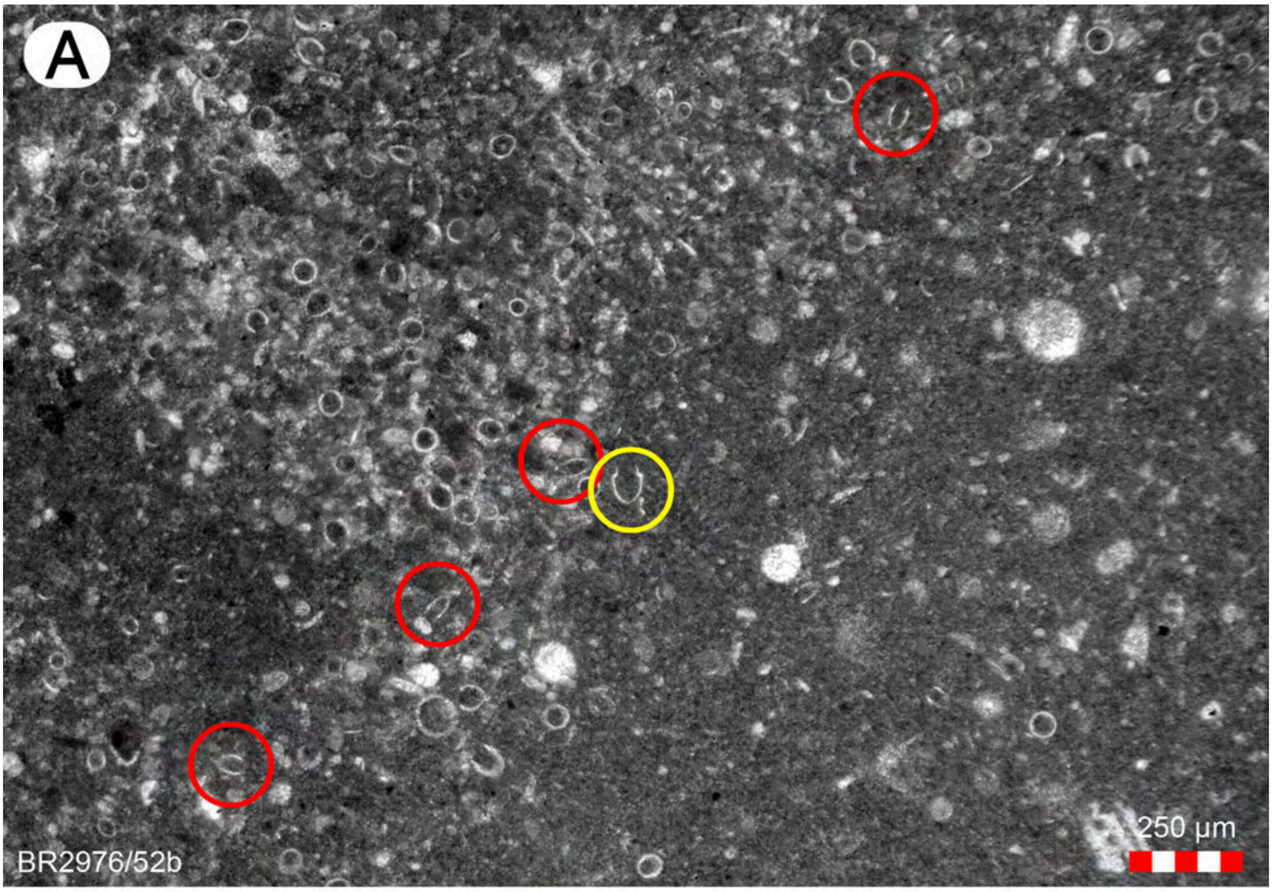
▶ **Plate 1, figs. A-B:** BR2974/51: small and medium-sized spherical forms of *Calpionella alpina* dominate over rare *Crassicollaria parvula*.
Zone B (Subzone B1)

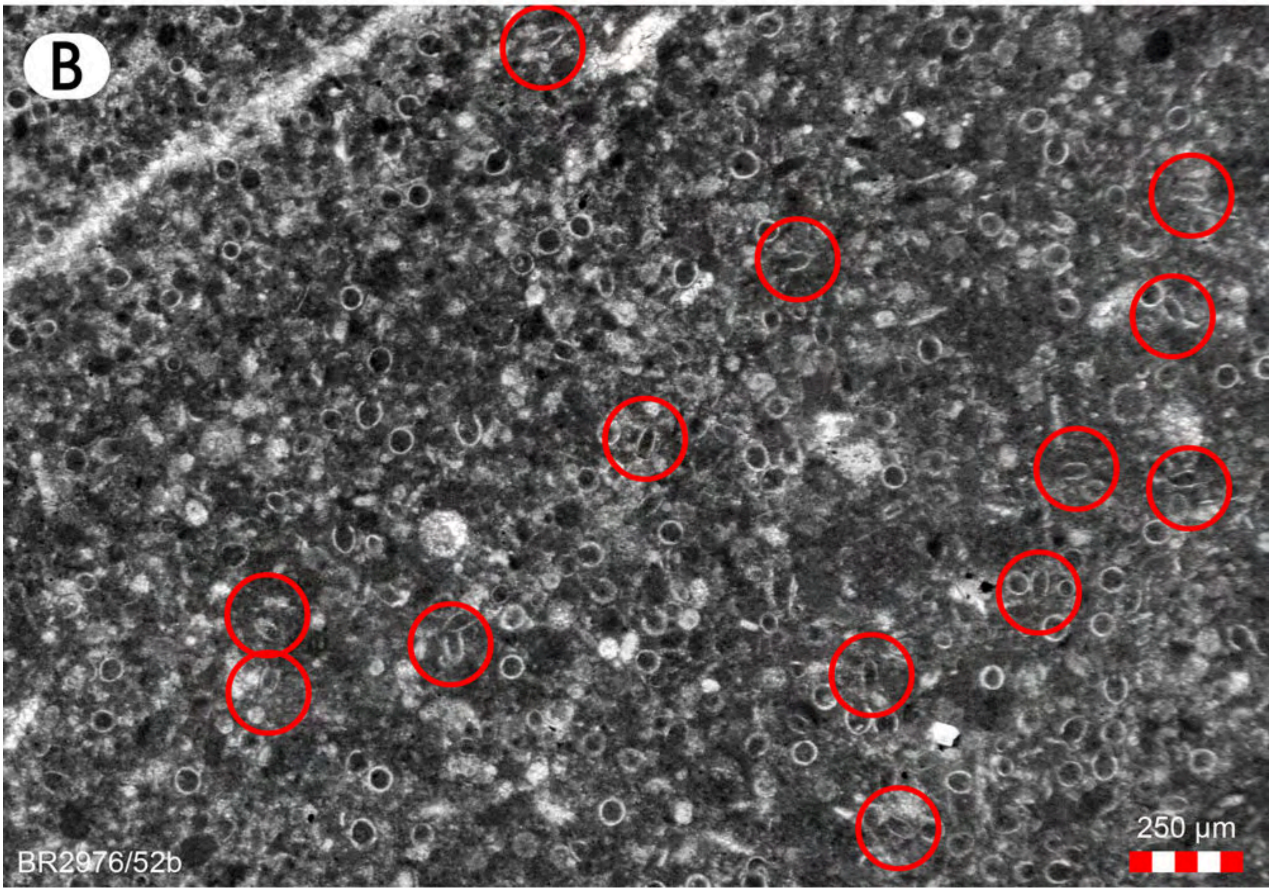
All photos: graphical scale bar = 250 µm.


A
250 µm
BR2974/51
B
250 µm
BR2974/51

▶ **Plate 2, figs. A-B:** BR2976/52b large extraclast: numerous small and medium-sized spherical forms of *Calpionella alpina* with common *Crassicollaria parvula*; few ? *Tintinnopsella carpathica* and rare *Calpionella grandalpina*.
Zone B (Subzone B1)

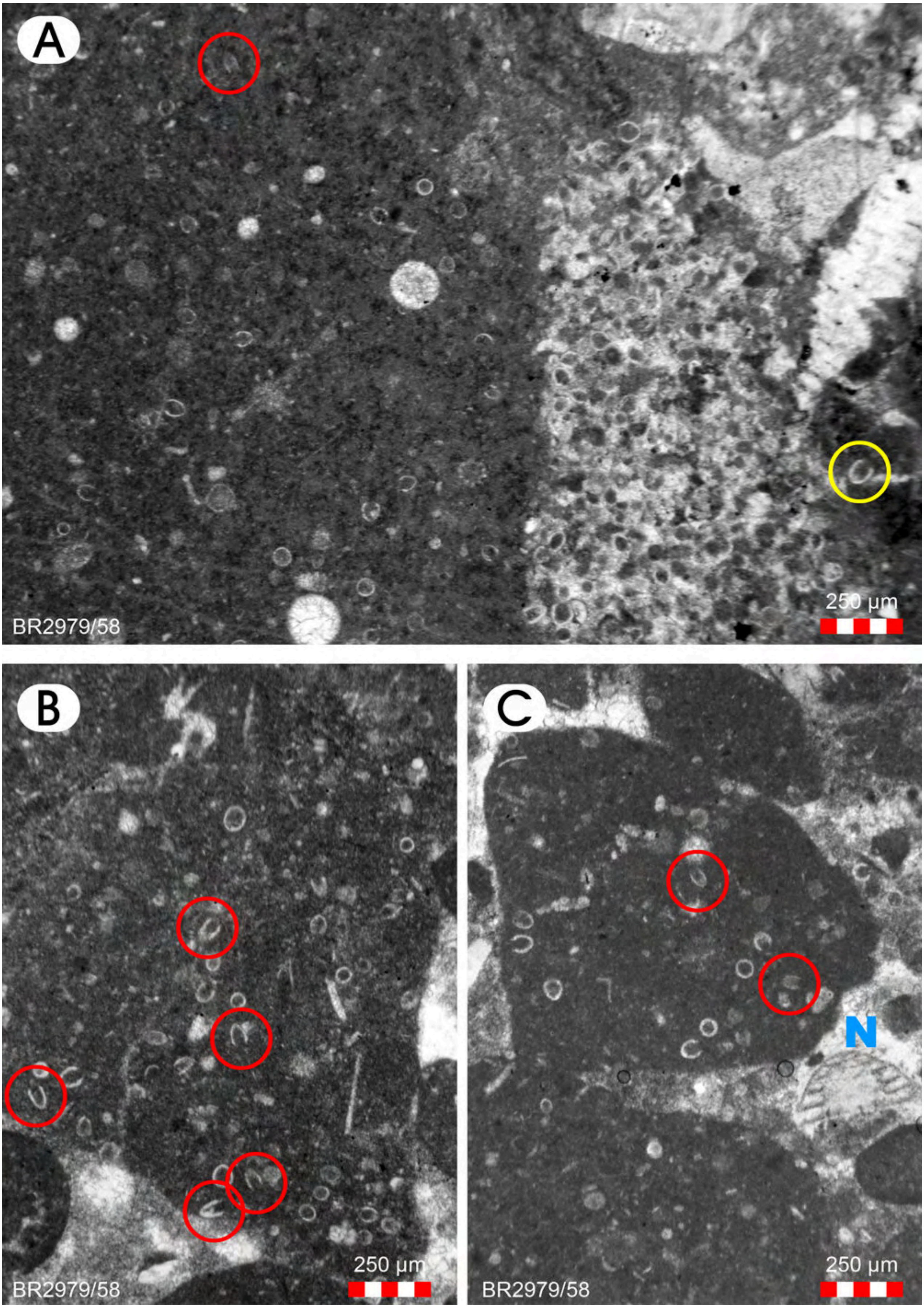
All photos: graphical scale bar = 250 µm.


A
BR2976/52b
250 µm


B
BR2976/52b
250 µm

▶ **Plate 3, figs. A-B:** BR2979/58 extraclasts: mostly from Zone B (Subzone B1); some with more *Crassicollaria* spp., *i.e.*, *Cr. intermedia* and *Cr. brevis*, and rare *Calpionella elliptalpina* could be ascribed to Zone A.

All photos: graphical scale bar = 250 µm.


A
BR2979/58
250 µm
B
BR2979/58
250 µm
C
N
BR2979/58
250 µm