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Discussion of the paper by Wimbledon *et al.*, 2020b, entitled "The proposal of a GSSP for the Berriasian Stage (Cretaceous System): Part 1" [*Volumina Jurassica*, XVIII (1)]

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Abstract. The current definition of the Jurassic/Cretaceous boundary results from a 50 year long "*status-quo*" that postponed decision making on the matter. That the temporary nature of this situation had become permanent has been rarely questionned until recently. This long-lasting situation is symptomatic of the fact that selection of the Tithonian/Berriasian boundary as the default option was probably not the best solution. Today the Berriasian Working Group is still defending this conservative option whereas the present authors refer to the reformist option known as Oppel's view (or Granier's diversion) with the Berriasian/Valanginian boundary as the system boundary. In that sense this position paper can be considered a counterproposal for the system boundary (not for the stage boundary) because it corrects some errors found in the first part of the Berriasian WG proposal as well as it opens minds to the best alternative according to the present authors.

INTRODUCTION

The paper entitled "The proposal of a GSSP for the Berriasian Stage (Cretaceous System): Part 1" (Wimbledon *et al.*, 2020b) roughly corresponds to part of a text proposal initially submitted by the Berriasian Working Group to the ISCS – International Subcommission on Cretaceous Stratigraphy in December 2019. This proposal has undergone a thorough process of consultation over a six-week period and it was expected that a revised version would go for a vote within a relatively short time frame. It is worth mentioning that the Berriasian WG defends a very conservative view (misleadingly called Kilian's view) regarding the Jurassic/Cretaceous system boundary that they identify with the base of the Berriasian. On the other hand, we believe that the definition of a Berriasian GSSP – Global Boundary Stratotype [Section and] Point, and the choice of a system boundary should be treated as discrete issues (Granier, 2019a, 2020b).

Regarding the latest contribution on the topic of Wimbledon *et al.* (2020b), the 'story telling' of their "Historical part" immediately drew our attention because it contains factual inaccuracies in the information that is given to be compared with the recent review paper by one of us (Énay, 2020). It is not intended here to report all of the errors and oversights found in the entire proposal but to discuss a selection of them in order to promote an alternative reformist view, recently called Granier's "small diversion", but known as Oppel's view (Énay, 2019, 2020; Granier, 2019b, c, 2020a, b), which is still or was shared by Le Hégarat (1973), Pomerol (1974), Flandrin, Énay, Thieuloy, Le Hégarat and Drushchits (in Flandrin *et al.*, 1975), Rawson (1990), Weissert (quoted in Granier, 2019a), and many other people (*cf.* Granier, 2019a: p. 95–96, 2019c).

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THE 1973 COLLOQUIUM: A PARTIAL SUCCESS OR A PARTIAL FAILURE?

The narrative of the "Historical part" of Wimbledon *et al.* (2020b) significantly alters the chronology of events that occurred in a survey following the "Colloque sur la limite Jurassique/Crétacé" held in Lyon and Neuchâtel in 1973 (Flandrin *et al.*, 1975). As a matter of fact, these authors claim that the binary yes/no quiz came *after* the multiple-choice questionnaire dealing with 12 motions, whereas the truth is the exact opposite (Flandrin *et al.*, 1975: p. 390–393). Two of us (J.C. and R.É.) did attend the 1973 Colloquium and one (R.É.) was even a member of the "Comité d'organisation". Hence, let us reset the sequence in the right order: the binary yes/no quiz came **before** the multiple-choice questionnaire.

Regarding the results of the 1975 binary yes/no quiz, an absolute majority of the 84 answers went to the Berriasian as a stage (58%) or substage (6%) of the Cretaceous (Fig. 1A); other answers went to the Berriasian as a stage (20%) or substage (7%) of the Jurassic and the rest of the participants (9%) did not express any opinion.

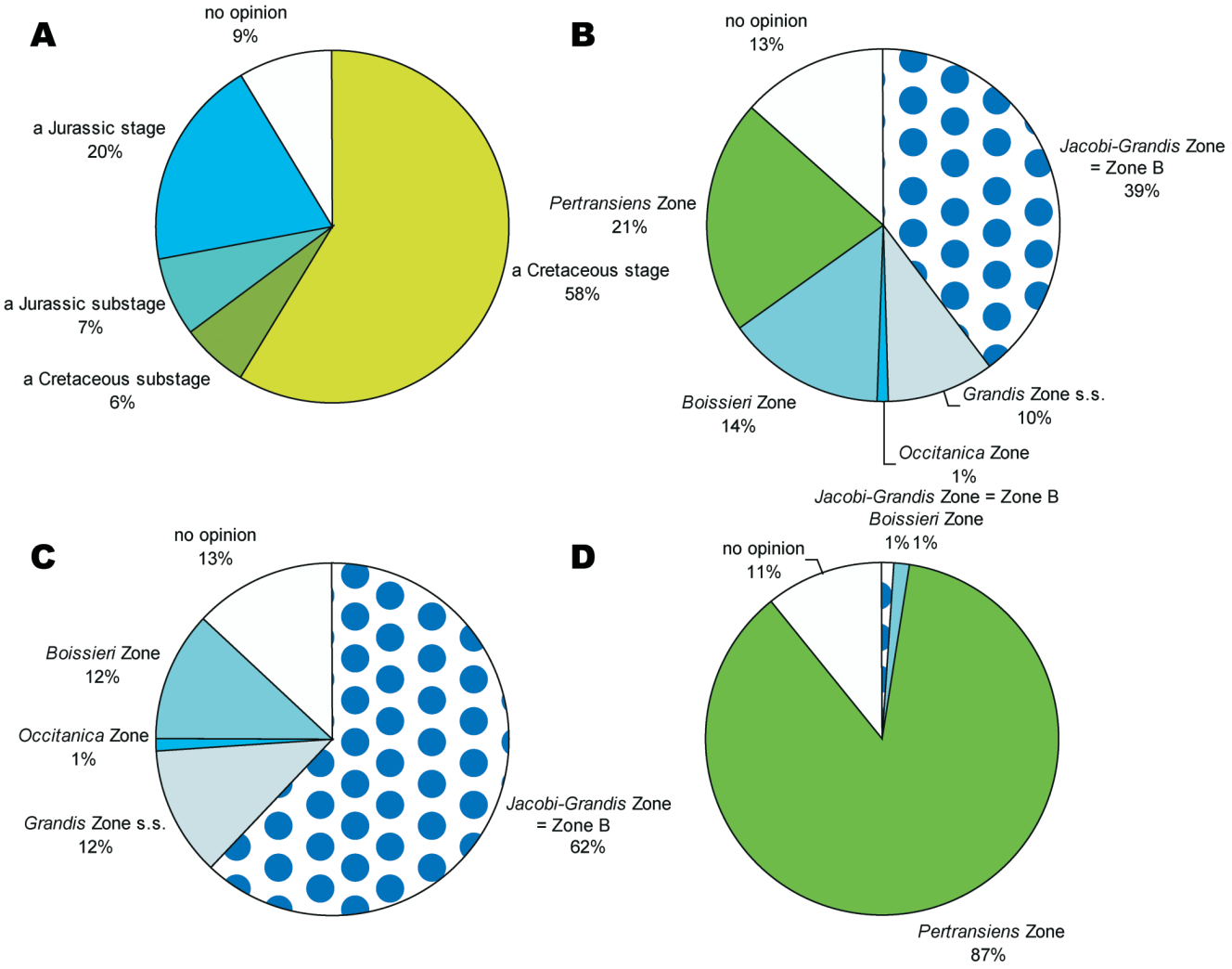

Fig. 1. Pie charts illustrating the distribution of the 84 answers to the binary yes/no quiz preceding the multiple choice questionnaire dealing with 12 motions, which only received 70 answers

A – vote on the status of the Berriasian as a stage or substage of the Jurassic or of the Cretaceous; **B** – vote on the Jurassic/Cretaceous boundary; **C** – vote on the Tithonian/Berriasian stage boundary; **D** – vote on the Berriasian/Valanginian stage boundary

At this point one could have concluded that the debate was closed. However, in order to tentatively balance these quiz results, several issues should be clarified:

1. No absolute majority identified the base of the Cretaceous (Fig. 1B) at the base of the Jacobi–Grandis Zone [Fig. 2.2, marker 2]. In fact, this conservative view (Kilian's view) earned 39% of the "yesses" (consequently the "noes" had it by an absolute majority of 61%). In contrast the reformist view (Oppel's view), *i.e.*, the base of the Pertransiens Zone [Fig. 2.8, marker 5], scored a lower but not negligible 21%. Moreover, the base of the Boissieri Zone [Fig. 2, marker 4], *i.e.*, another reformist view (Casey's view), scored 14% whereas the base of the Grandis Zone *sensu stricto* = Grandis Subzone [Fig. 2.1, marker 1], *i.e.*, close to the conservative view, received only 10% of the answers. Finally, the rest of the participants (13%) did not express any opinion.
2. The base of the Jacobi-Grandis Zone was then assumed to coincide with the base of the *Calpionella alpina* Zone (*cf.* both Motion I and Motion III in Flandrin *et al.*, 1975), an erroneous assumption that since then has proved to be wrong. Today it is well established that the base of the acme of *Calpionella alpina* [Fig. 2.4], also known as the "*Crassicollaria/Calpionella* turnover" (Wimbledon, 2017; Wimbledon *et al.*, 2020a, b), falls between the base of the Jacobi-Grandis Zone [Fig. 2.2, marker 2], below, and the base of the Grandis Zone *sensu stricto* = Grandis Subzone [Fig. 2.1, marker 1], above (*op. cit.*). This misleading assumption introduced a serious bias in the data and the results of the quiz were subsequently distorted.

   Despite or perhaps partly because of this flaw an absolute majority of 62% agreed to identify the base of the Berriasian (Fig. 1C) as the base of the Jacobi-Grandis Zone [Fig. 2.2, marker 2]. Furthermore, in addition to the supporters of a Cretaceous Berriasian, some supporters of a Jurassic Berriasian also ticked the "yes" box of this ammonite-based option for the stage boundary (Flandrin *et al.*, 1975: p. 393). However, this choice of the base of the Jacobi-Grandis Zone was recently definitely dismissed by the Berriasian Working Group (Wimbledon, 2017; Wimbledon *et al.*, 2020a, b). Finally, the base of the Valanginian (Fig. 1D) at the base of the Pertransiens Zone [Fig. 2.8, marker 5] earned an even higher majority of 87% whereas 11% only did not express any opinion.
3. In contrast to the binary yes/no quiz that received 84 answers, the multiple-choice questionnaire regarding the 12 motions received only 70 answers. Fourteen participants did not contribute to the questionnaire, which was possibly intended as an exercise requiring much more expertise and knowledge on the questions addressed. As a result, the votes on the motions gave a quite different figure for the Jurassic/Cretaceous boundary: there was a perfect equality of votes for the conservative Motion XI and for the reformist Motion III, which both received 22 votes. It is suggested here that the fourteen answers missing in the second part (questionnaire) may have contributed to the success of "the Berriasian as a full stage of the Cretaceous" (that sums up different opinions on the base of the stage itself) in the first part (quiz): 48 of 84 = 57% to compare with 48 – 14 of 70 = 49%. That cannot be definitely proven but it remains a serious hypothesis.

Still with respect to the quiz, Wimbledon *et al.* (2020b) state that "*A completely new question was posed, one not devised by the involved specialists who had identified their own priority motions. It was: 'Should the Berriasian be moved to the Jurassic?' Only 16 (of 84) attendees agreed with this proposition*". However, this was not a question posed. Actually, the question that received 16 "yesses" was whether the Berriasian is a stage of the Jurassic (Fig. 1A).

Moving to the 1975 multiple-choice questionnaire, it dealt with 12 motions including some that already more closely reflected today's radically opposed visions: the conservative Kilian's view (Berriasian WG) versus the reformist Oppel's view (our group). Although Wimbledon *et al.* (2020b) claim that "*No motion from the floor suggested that the base of the Cretaceous should be anywhere except at or close to the base of the Berriasian, in the Jacobi/Grandis subzonal interval*", that was obviously not the case (*cf.* Fig. 1B).

Another erroneous point concerns Motion III ascribed inaccurately to "*Frandrin, Thieuloy, Le Hégarat and Druschits*" [sic] that, according to Wimbledon *et al.* (2020b), states: "*J/K should be Tithonian/Berriasian boundary, and be placed at the base of Jacobi-Grandis Zone*", whereas Motion III of Frandrin, **Énay**, Thieuloy, Le Hégarat and Drushchits actually can be summarized as follows: **J/K should be Berriasian/Valanginian boundary, and be placed at the base of Pertransiens Zone**.

Alteration of the text of the motions varies from one motion to the next. For this reason, the 12 motions are all duplicated below allowing comparison with their transcript in Wimbledon *et al.* (2020b). Nine of them were originally written in English and the three remaining ones that were in French have been translated into English. They are all re-arranged here in decreasing "order of popularity":

- Motion VIII of N.F. Hughes, F. Dilley, J.-P. Verdier, A. Gollestaneh, R. Gygi, R. Haak and P. Morgenroth (25/70 votes): "Having considered the evidence presented, the following participants: Accept that a Tithonian/Berriasian regional limit may be selected in France approximately below the *Grandis* Zone" (Comment: it does not contribute much to the

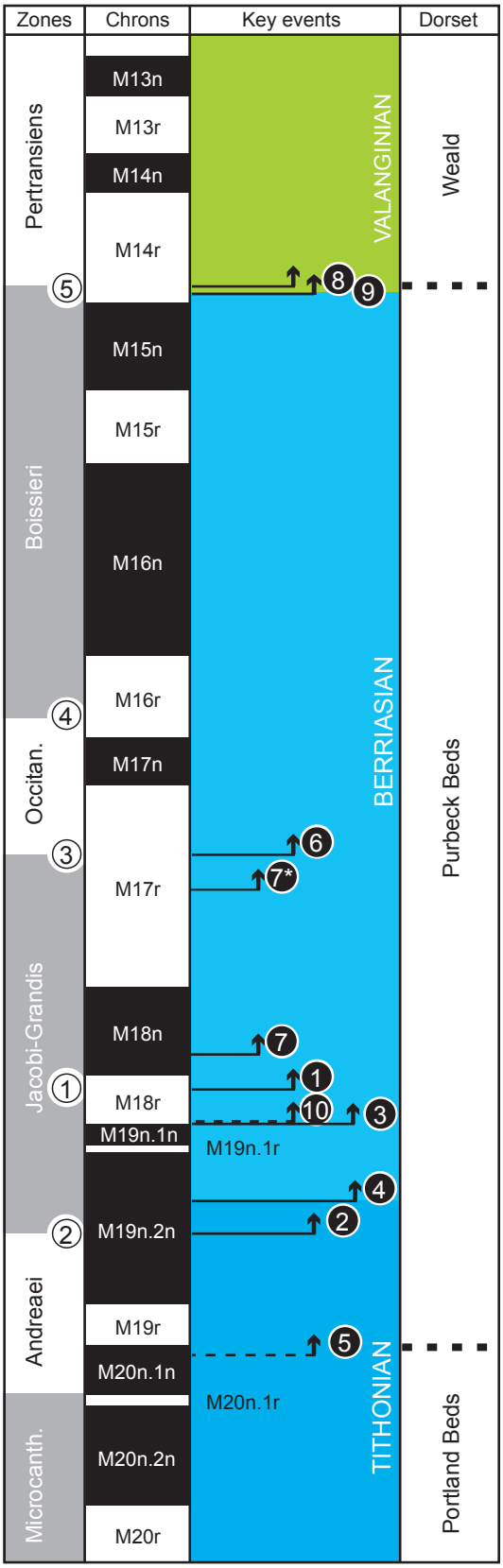

Fig. 2. The black labels points to the various locations of the Tithonian/Berriasian, the Volgian/Ryazanian, and the Berriasian/Valanginian stage boundaries

Tithonian/Berriasian placements: 1 – base of Grandis Subzone (Lyon 1963: anonymous, 1965), 2 – base of Jacobi-Grandis Zone (Lyon-Neuchâtel 1973: "*status-quo*" in Flandrin *et al.*, 1975), 3 – base of Magnetochron M18r according to GTS 2012 (Ogg, Hinnov, 2012), 4 – base of Zone B (base of an abundance biozone), primary marker of the Berriasian WG (Wimbledon, 2017), 5 – base of 'Unitary Association' Zone – UAZ 13 (Baumgartner *et al.*, 1995), Radiolarian turnover, 6 – base of Occitanica Subzone (Hoedemaeker, 1981, 1987; Zakharov, 1987; Mitta, 2017).
Volgian/Ryazanian placement: 7 – base of Sibiricus Zone (*fide* Houša *et al.*, 2007; modified from Granier, 2019c, 2020b), 7* base of Sibiricus Zone (*fide* Bragin *et al.*, 2013; Wierzbowski, Grabowski, 2013; Schnabl *et al.*, 2015).
Berriasian/Valanginian placements: 8 – base of Pertransiens Zone, 9 – base of Zone E (a FAD), primary marker of the VWG; a "notable proxy" of 4 (Wimbledon *et al.*, 2020b): 10 – base of UAZ 14 (Baumgartner *et al.*, 1995).
The white labels points to the standard ammonite zones as identified by Reboulet *et al.* (2014).
The Dorset column (to the extreme right) is derived from Ogg *et al.* (1994)

J/K debate. The issue addressed here is the base of the Berriasian Stage, not the base of the Cretaceous System).

- Motion IV of N.F. Hughes, F. Dilley, J.-P. Verdier, F. Middlemiss, A. Gollestaneh, R. Gygi, R. Haak and P. Morgenroth (24 votes): "Having considered the evidence presented, the following participants: Suggest that the global Jurassic/Cretaceous boundary should be taken as near as possible in time to the present tradition, to coincide with the Tithonian/Berriasian boundary when this is selected; and that this should not be changed by reason of any distribution of fossils" (Comment: it does not contribute much to the J/K debate, because multiple options were considered for the base of the Berriasian Stage, and hence for the base of the Cretaceous System).
- Motion IX of N.F. Hughes, F. Dilley, J.-P. Verdier, F. Middlemiss, A. Gollestaneh and R. Gygi (23 votes): "Having considered the evidence presented, the following participants: Suggest that no decision should be taken on the global Jurassic/Cretaceous limit until more candidate sections have been examined".
- Motion III of J. Flandrin, R. Énay, J.-P. Thieuloy, G. Le Hégarat and V. Drushchits (22 votes):
  1. The Tithonian/Berriasian boundary is located at the base of the Jacobi–Grandis Zone [Fig. 2.2, marker 2] and at the base of the Calpionellid B Zone [Fig. 2.4]. This boundary can be pinpointed in the Haute-Beaume section (Hautes-Alpes, France).
  2. The Berriasian/Valanginian boundary is located at the base of the Pertransiens Zone [Fig. 2.8, marker 5]. This boundary can be pinpointed in the field at Barret-le-Bas (Hautes-Alpes, France).
  3. The Jurassic/Cretaceous is located at the base of the Valanginian as above defined [Fig. 2.8, marker 5].

The text of this Motion III is translated from the original French text [with supplementary information as regard Fig. 2]:
"1. La limite Tithonique-Berriasien se situe à la base de la Zone à *Jacobi-Grandis* et de la Zone B des Calpionelles. Cette limite peut être matérialisée dans la coupe de la Haute-Beaume (Hautes-Alpes).
2. La limite Berriasien-Valanginien se situe à la base de la Zone à *Pertransiens*. Cette limite peut être matérialisée sur le terrain à Barret-le-Bas (Hautes-Alpes).
3. La limite Jurassique-Crétacé se place à la base du Valanginien comme définie ci-dessus".
[Comment: as already reported above, the base of the *Jacobi-Grandis* Zone [Fig. 2.2, marker 2] does not match with the base of the Calpionellid B Zone (Fig. 2.4)].

- Motion XI of J. Remane and K. Barthel (22 votes):
  1. Proposal that the base of the Berriasian should be positioned the base of the Calpionellid B Zone [Fig. 2.4] and that the base of the Valanginian should be the base of the Pertransiens Zone [Fig. 2.8, marker 5]. This option would have the advantage of changing the definition of the Berriasian as little as possible.
  2. Because a Jurassic/Cretaceous boundary cannot be defined on a global scale today it is proposed to provisionally have it coincide with the Tithonian/Berriasian boundary in the Mesogean domain [Fig. 2.4].
  3. Reference sections should be selected in coming years – not right now – to refine the proposed boundaries.
  Again, the text of this Motion XI is translated from the original French text [with supplementary information as regard Fig. 2]:
  "1. Proposition de placer la base du Berriasien à la base de la Zone à *Calpionella*" [Fig. 2.4] "et de situer la base du Valanginien à la base de la Zone à *Pertransiens*. Cette solution aurait l'avantage de changer le moins possible le contenu du Berriasien.
  2. Une limite Jurassique–Crétacé ne pouvant pas être définie à l'échelle mondiale dès maintenant il est proposé de la faire coïncider provisoirement avec la limite Tithonique/Berriasien dans le domaine mésogéen.
  3. Des coupes de référence devront être choisies dans les années à venir – et non maintenant – pour préciser les limites proposées".
  [Comment: it is the first time, long before the Berriasian WG's decision, that the base of the Calpionellid B Zone (Fig. 2.4) is proposed as the base of the Berriasian].
- Motion I of K. Birkenmajer (19 votes):
  "1. The Jurassic/Cretaceous boundary placed as in proposal no. 1, *i.e.*, between the Tithonian and Berriasian. Base of the Cretaceous = base of the *Jacobi* Zone" [Fig. 2.2, marker 2] "(and at the same time at the boundary of A/B Calpionellid zones)" [Fig. 2.4].
  "2. Base of the Berriasian = base of the *Jacobi* Zone" [Fig. 2.2, marker 2].
  "3. Valanginian: Base of the Valanginian = base of the *Pertransiens* Zone" [Fig. 2.8, marker 5].
  "4. Subdivision of the Tithonian into lower, middle and upper (sub) stages based on Ammonites zones. Substages (lower, middle, upper) left unnamed until further elaboration of type sections (stratotypes).
  5. Lower Tithonian lower boundary: lower boundary of *Hybonotum* Zone.
  6. Middle Tithonian lower boundary: lower boundary of *Semiforme* Zone.
  7. Upper Tithonian lower boundary = lower boundary of *Microcanthum* Zone (and not the lower boundary of *Calpionellidae* Bonet)."
  (Comment: as already reported above, the base of the *Jacobi-Grandis* Zone [Fig. 2.2, marker 2] does not match with the base of the Calpionellid B Zone [Fig. 2.4]).
- Motion V of N.F. Hughes (12 votes): "Having considered the evidence presented, the following participants: Suggest that this boundary be taken in a low palaeolatitude".
- Motion VI of N.F. Hughes, F. Dilley, J.-P. Verdier, A. Gollestaneh, R. Gygi and P. Morgenroth (9 votes): "Having considered the evidence presented, the following participants: Suggest that palynologic correlation is required in the limit section".
- Motion VII of N.F. Hughes and J.-P. Verdier (11 votes): "Having considered the evidence presented, the following participants: Accept a point at Barret-le-Bas for the regional boundary Berriasian/Valanginian, although palynologic correlation is not available."
- Motion II of R. Casey (8 votes):
  "1. That the base of the Cretaceous system be drawn at the base of the Zone of *Fauriella boissieri*" [Fig. 2, marker 4].
  "2. That the term Berriasian be restricted to the *F. boissieri* Zone" [from Fig. 2, marker 4, to Fig. 2.8, marker 5] "and the Berriasian be regarded as an independent stage below the Valanginian".

(Comment: it is another very reformist view that actually sticks to the Kilian's (1890, 1895b) definition of the Berriasian, and not to the so-called Kilian's view).

- Motion X of S. Marek and J. Dembowska (8 votes): From a paleogeographic perspective, the best location for the Jurassic/Cretaceous boundary would be the base of the Boissieri Zone [Fig. 2, marker 4] (= base of the Rjasanensis Zone in Poland).

  Again, the text of this Motion X is translated from the original French text [with supplementary information as regard Fig. 2]: "Du point de vue paléogéographique le mieux est que la limite Jurassique/Crétacé soit placée à la base de la Zone à *Boissieri* (= base de la Zone à *Rjasanensis* en Pologne)".
- Motion XII of A. Zeiss (6 votes):

  "1. Tithonian is the upper stage of the Jurassic system.

  2. Tithonian is divided into 4 substages:

  a) Danubian (*Hybonotum-Palatinum* zones);

  b) Neuburgian (*Bavaricum* Zone *s.l. = Semiforme-Ponti* zones);

  c) Ardescian (*Microcanthum-Durangites* zones = *Transitorius* Zone *s.l.*; Calpionellid A Zone);

  d) Berriasian (*Jacobi-Boissieri* zones" [from Fig. 2.2, marker 2 to Fig. 2.8, marker 5]; "B-D Calpionellids zones)" [from Fig. 2.4 to Fig. 2.9]. "Comments. The major faunal break in the Ammonites of the upper Tithonian–lower Valanginian occurs above the *Boissieri* Zone. New Ammonite genera appear, providing the best possibility of a correlation between the Mediterranean and the Boreal provinces. This approximately coincides with the D/E boundary by Calpionellids. The other boundaries proposed do not allow correlation between the two realms with the same accuracy, namely at the base of the *Grandis* Zone. The boundary at the base of the *Boissieri* Zone is not very far from the proposed boundary and would only divide the Berriasian which does not seem desirable".

To summarize, and as already stated above, "there was a perfect equality of votes for the conservative Motion XI and the reformist Motion III that both received 22 votes". However, the votes for the conservative Motion XI were based on the biased argument that the base of the Jacobi-Grandis Zone [Fig. 2.2, marker 2] matches with the base of the Calpionellid B Zone [Fig. 2.4], *i.e.*, an argument which, given the current state of knowledge, is wrong (Wimbledon, 2017; Scott, 2019; Benzaggagh, 2020; Wimbledon *et al.*, 2020a, b). Similarly, the base of the Pertransiens Zone [Fig. 2.8, marker 5] does not match with the base of the Calpionellid E Zone [Fig. 2.9], but this last argument was not considered in 1975. The "Historical part" of Wimbledon *et al.* (2020b) twisted some facts to favor the conservative option.

We regard the Lyon-Neuchâtel "Colloque sur la limite Jurassique/Crétacé" as a partial failure because no motion reached a general agreement nor an absolute majority. Because neither a conservative nor a reformist view prevailed, it was decided to postpone any decision and continue with a "*status-quo*" for the time being, *i.e.* the position that existed before the meeting took place. Hence, the Berriasian remained in the Cretaceous until further notice. Although it was agreed that this "Kilian's option" was provisional, pending later investigations, the temporary position has become permanent. In almost half a century no definitive solution has been adopted regarding the base of the Berriasian and consequently the base of the Cretaceous. Surprisingly this delay does not seem to worry the advocates of a Cretaceous Berriasian although it is symptomatic that something is wrong with this option.

A dedicated International Working Group on the Jurassic/Cretaceous Boundary led by Remane (1991, 1994) suggested on several occasions that a system boundary "*placed at the top of the Berriasian*" would offer a very robust alternative to the conservative option. Premoli Silva (2004) also reminded people of the ICS – International Commission on Stratigraphy and of the ISCS – International Subcommission on Cretaceous Stratigraphy that "*Even which stage to place the J/K boundary at is debatable: base of Berriasian to most, but base of Valanginian to some*". Recently, thanks to JK2018, an International Meeting around the Jurassic/Cretaceous Boundary (Granier, 2019a, c, 2020b), the reformist view with the Berriasian/Valanginian boundary as the Jurassic/Cretaceous boundary escaped from oblivion. Accordingly, we regard the Genève JK2018 as a partial success because, if it did not close the case, it definitely helped to remove blinkers from some attendees' eyes.

OPPEL, KILIAN AND THE ORIGINAL SIN

Wimbledon *et al.* (2020b) write "*Mid 19th century knowledge could be more or less summarised by Oppel's* (*1865*) *presumption that his Tithonian facies was the approximate equivalent of the Portland and Purbeck beds of northern Europe: that is the Portlandian* (*d'Orbigny 1842–1849 definition*) *and Purbeckian* (*relegated to the Cretaceous by d'Orbigny*)*, and that somewhere above was the Valanginian*". Here again facts are distorted as will be demonstrated below with excerpts

from Oppel's original publication (1865). Undoubtedly, Kilian was not as modest, courteous and visionary as Oppel was. Not aware of Coquand's 1870 "valenginien berriasien" [sic], which was introduced four years after his passing, Oppel (1865) defined his "titonische Etage" as duplicated below (and translated from the original German text by F. Schlagintweit):

With the numerous and diverse outcrops, known as Portland-Purbeck and Wealden beds, so far reported thanks to the exploration of Upper Jurassic and Lower Cretaceous boundary formations outside the Alps, it has became urgent to provide information about the time-equivalent deposits that span the transition from the Jurassic to the lowermost Cretaceous in the Alps ("*Bei den zahlreichen und mannigfaltigen Aufschlüssen, welche die Erforschung der oberjurassischen und untercretaceischen Grenzbildungen nach deren ausseralpinem Vorkommen als Portland-Purbeck- und Wealden-Schichten bisher geliefert hat, drängt es, auch über die Ablagerungen, welche innerhalb der Alpen den Uebergang der jurassischen Formation in die untersten Kreide-Stufen vermitteln, Einiges mitzutheilen*").

It is presented here by means of publication of the results obtained from the study of cephalopods occurring in the Jurassic/Cretaceous boundary strata ("*Es geschieht dies hier durch Veröffentlichung der Resultate, welche aus der Untersuchung der in den Grenzgliedern zwischen Jura und Kreide vorkommenden Cephalopoden hervorgingen*").

Not to necessarily ascribe these boundary strata located between the Kimmeridge level and the lowermost strata of the Neocomian to one of the two adjacent systems and at the same time to enable naming them in the future, I sum them up as the special group of formations as the Tithonic Stage, thereby indicating the relationship of this set of strata to the Cretaceous system directly overlying it ("*Um diese Grenzglieder nicht ohne Weiteres einer der beiden benachbarten Formationen zutheilen zu müssen und um zugleich einen Ausdruck für ihre künftige Bezeichnung wählen zu können, fasse ich dieselben als eine zwischen der Stufe von Kimmeridge und den tieferen Neocom – Schichten befindliche, besondere Formationsgruppe zusammen, welche ich tithonische Etage benenne, indem hierdurch die Beziehung dieser Schichtengruppe zu der unmittelbar darüber beginnenden Kreideformation angedeutet werden soll*").

Without doubt, the Tithonic Stage will someday be divided into discrete zones and correlated with marine and continental deposits outside the Alps ("*Ohne Zweifel wird sich die tithonische Etage später in einzelne Zonen zerlegen nnd auch mit den ausseralpinen Meeres- und Süsswasser-Bildungen in genaue Parallele stellen lassen*").

However, even if these sedimentary deposits are partly equivalents of the Tithonic Stage, one cannot attempt to apply one of the existing names such as Purbeck Beds, Solenhofer Schist, Portland Limestone, *etc.* to the layer complex in question because that does not seem to be sufficiently feasible at present ("*Da dies aber gegenwärtig noch nicht zur Genüge ausführbar erscheint, so kann auch der Versuch nicht gemacht werden, eine der bereits vorhandenen Bezeichnungen wie Purbeck-Strata, Solenhofer Schiefer, Portland-Kalk u.s.w. auf den fraglichen Schichtencomplex zu übertragen, wennschon diese Bildungen die theilweisen Aequivalente der tithonischen Etage darstellen*").

Similarly, I would not dare to one-sidedly assign a permanent definition to the horizontal and vertical ranges of this stage by means of the local designation of an Alpine origin (such as selecting the Stramberg Beds) ("*Ebensowenig möchte ich wagen, durch eine locale Bezeichnung alpinen Ursprungs (wie Stramberger Schichten) der Etage für ihre weitere horizontale und vertikale Verbreitung jetzt schon eine allzu bestimmte und einseitig fixirte Bedeutung beizumessen*").

Because a more precise definition of the Tithonic Stage boundary will only be the result of more accurate comparisons and stricter correlations, we choose here at least to serve as preliminary information the Kimmeridgian beds with *Ammonites lallierianus* Orb., *Am. longispinus* Sow., *Amm. eudoxus* Orb., *Amm. mutabilis* Sow., *Amm. eumelus* d'Orb. *etc.* as the preceding unit, and the lowermost zone of the Neocomian with *Amm. grasianus* Orb., *Amm. semisulcatus* Orb., *Amm. verrucosus* Orb., *Amm. roubaudianus* Orb., *Amm. neocomiensis* Orb., *Amm. asperrimus* Orb., *Amm. astierianus* Orb. as the next unit, *i.e.*, the unit directly overlying the Tithonic Stage ("Während eine schärfere Feststellung der eigentlichen Grenzglieder der tithonischen Etage erst das Ergebniss eingehenderer Vergleiche und bestimmterer Parallelen sein wird, so wählen wir wenigstens zur vorläufigen Orientierung die Kimmeridge-Schichten mit *Ammonites Lallierianus* d'Orb., *Am. longispinus* Sow., *Amm. Eudoxus* d'Orb., *Amm. mutabilis* Sow., *Amm. Eumelus* d'Orb. u.s.w. als Basis, und die unterste Neocom-Zone mit *Amm. Grasianus* d'Orb., *Amm. semisulcatus* d'Orb., *Amm. verrucosus* d'Orb., *Amm. Roubaudianus* d'Orb., *Amm. Neocomiensis* d'Orb., *Amm. asperrimus* d'Orb., *Amm. Astierianus* d'Orb. als unmittelbar über der tithonischen Etage folgende Abtheilung").

In conclusion, the "titonische Etage" of Oppel was an inclusive superstage spanning both the Tithonian and the Berriasian as presently definited. As an example of the directly overlying stage, the fauna he listed consists mostly and unambiguously of the pyriteous small ammonites commonly found in the yellow marls from the Valanginian outcrops of SE France.

Wimbledon *et al.* (2020b) write "*As the end of the 19th century approached, Kilian (1889) reaffirmed the position of the Berriasian Stage at the base of the Cretaceous. Connected studies of further regions in western Tethys and beyond prolifer-*

ated" (...) "*and even if many contradictions about macrofaunas were still to be addressed*" (...) "*there was stability in stratigraphic nomenclature*". Again, the narrative of their "Historical part" alters the facts.

For those people who know some part of the story it is obvious the location of the base of the Berriasian was all but stable over the decades (*e.g.*, Breistroffer, 1964; Énay, 2019, 2020; Granier, 2019b, c, 2020b): compare Kilian [Fig. 2, marker 4] with Mazenot (1939) and Le Hégarat (1973) [Fig. 2.1, marker 1], the "*status-quo*" in Flandrin *et al.* (1975) [Fig. 2.2, marker 2], and Wimbledon (2017) [Fig. 2.4]. As stated earlier, Kilian's (1887, 1890, 1895a, b) definition of the Berriasian does not fit with the so-called Kilian's view. It restricts the Berriasian to its third and uppermost ammonite zone, *i.e.* to the sole Upper Berriasian as currently defined. For instance, Kilian (1895b: p. 31) wrote that the main part of what is called Berriasian belongs to a zone (*Hoplites boissieri* Zone), which is already clearly Neocomian according to its faunal contents [translated from the original French text: "La partie principale de ce qu'on a appelé Berriasien appartient à une zone (zone à *Hoplites Boisssieri*" [sic] ") qui par sa faune, est déjà nettement néocomienne"]. That was the motions II and X [Fig. 2, marker 4] defended respectively by Casey and by Marek and Dembowska, both in Flandrin *et al.* (1975). From this point of view, the Lower Berriasian as currently defined was then referred to as the "Tithonique supérieur".

Mazenot (1939: p. 257–262), Breistroffer (1964) and Énay (2019, 2020) attempted to summarize the many changes in the definition of the Berriasian, its related units and their possible stratigraphic relationships. Kilian who was probably motivated by ego-centric and nationalistic ideals (*cf.* Granier, 2020b) contributed in large measure to generating the confusion that has existed since then. For instance:

1. In 1887, Kilian subdivided the 'superstage'/series "Néocomien *sensu stricto*" into four substages, with from top to bottom (following the reading order that corresponds to the arrangement of his table, p. 54): the Barremian, the Hauterivian, the "Valangien" and the "Infranéocomien (Calcaire de Berrias)".
   It should be recalled here that the preposition "infra-" stands for "below", not "lower part of"; hence his Infraneocomian should never have been part of the Neocomian, contrary to what Kilian was already stating.
2. In 1895, Kilian refers to "Infravalanginien ou Berriasien" (1895a: p. 706, 715), to "Infranéocomien" (1895a: p. 774), to a "Zone à *Hoplites Boissieri* et *occitanicus*" as "Infravalanginien (Berriasien)" (1895a: Pls. 11, 12). Accordingly, based on the principle of priority, the Berriasian should never have been included in the Neocomian, then the first stage of the Cretaceous.
3. In 1908, Kilian (p. 27), replying to a comment from Toucas, clearly stated that the word Berriasian introduced by Coquand (*i.e.*, "le terme de Berriasien, de Coquand") was definitely abandoned by Kilian himself (*i.e.*, "définitivement abandonné du reste par M. Kilian"), as documented in *Lethæa geognostica*, 1907: p. 22. The "Zone à *Hoplites Boissieri*" was then ascribed to the Lower Valanginian.
4. Mazenot (1939: p. 262) claims that the stratigraphy of the Jurassic/Cretaceous boundary should be amended and clarified (...) within the framework defined by Kilian himself and with reference to the sites and sections that this author described in order not to alter his thoughts [translated from the original French text: "*la stratigraphie de la limite jurassico-crétacée doit être modifiée et précisée. On le fera ci-dessous, dans le cadre tracé par Kilian lui-même, en se reportant pour ne pas altérer sa pensée, aux gisements décrits et aux coupes établies par lui*"]. Although he was refering to Kilian's guidelines, Mazenot (1939) significantly distorted the concepts of the "savant de Grenoble" as, for instance, the location of the system boundary by extending downward the range of the Berriasian, *i.e.*, in adding a lower "Horizon" characterized by his newly described *Berriasiella grandis*. By doing so, part of the typical Tithonic Stramberg fauna became Early Berriasian in age.

LONG DISTANCE OR INTER-DOMAIN BIOCORRELATIONS

PURBECKIAN

Calibration of the Purbeck Beds on the international stratigraphic scale was not an easy task.

In 1895, Kilian (1895b: p. 31) wrote that the Purbeckian has often been correlated with the Berrias beds *to which it does not correspond in any way*, translated from the original French text: "le Purbeckien a souvent été mis en parallélisme avec les couches de Berrias *auxquelles il ne correspond en aucune façon*". One century later, Ogg *et al.* (1994), calibrating biomagnetostratigraphic data of Portland and Purbeck beds in Dorset sections, came to the exact opposite conclusion, *i.e.*, "*The Purbeck Beds are equivalent to the complete Berriasian stage in the Tethyan realm*".

The boundaries in the Dorset stratigraphic column of Fig. 2 (extreme right column) are derived from Ogg *et al.* (1994). This column does not take into account the many time gaps at subaerial exposure surfaces that probably occured in the shallow-marine and continental Purbeckian succession as is the case in many localities at the Berriasian/Valanginian boundary (Charollais *et al.*, 2008; Aurell *et al.*, 2019; Granier, 2019b, 2020a, b; Granier, Clavel, 2019; Mircescu *et al.*, 2019; Neamţu *et al.*, 2019; Scott, 2019; Maksoud *et al.*, 2020). Accordingly, these boundaries were merely tentatively located here.

The 19th century authors (*e.g.*, Kilian) considered that the Jurassic ended with the Purbeck beds that marked the maximum of the Upper Jurassic regression, *i.e.*, a discontinuity that was more specifically located at the beginning of the Purbeckian. The current conservative definition of the Tithonian/Berriasian boundary places the system boundary somewhere in the lower Purbeck Beds splitting this unit in a Jurassic Purbeckian and a Cretaceous Purbeckian. This does not make much sense. The same situation arises with the Volgian that should be subdivided in a Jurassic Volgian and a Cretaceous Volgian. In contrast a reformist definition of the system boundary coinciding with the Berriasian/Valanginian boundary, the top of the Purbeckian (Fig. 2) and (?) the top of the Ryazanian, should resolve this anomaly. As a matter of fact, modern sequence stratigraphic analyses taught us that the maximum Late Jurassic regression occurred at the end of the Purbeckian, *i.e.*, at the end of the Berriasian (*e.g.*, Haq, 2014; Ray *et al.*, 2019). This argument was promulgated by Rawson (1990) and more recently by Granier (2015) in support of the reformist view and the inclusion of the Berriasian in the Jurassic.

HIMALAYAN AND MEXICAN AMMONITES

Many ammonites were cosmopolitan during Tithonian – Berriasian times but also many were endemic taxa and homeomorphs.

Although there should be no direct impact on the location of the Jurassic/Cretaceous boundary at the bottom or the top of the Berriasian, the citation of "endemic *Kossmatia*" finds in Mexico [also reported from the USA, Texas and California] stands out and is worth updating. According to one of us (R.É.), the ammonitologists of the Berriasian WG (Wimbledon *et al.*, 2020b) did refer to the most recent work on the subject matter (Villaseñor, Olóriz, 2019) but obviously overlooked its contents. The ascription of these American forms to the Himalayan genus *Kossmatia* Uhlig was initiated by Uhlig (1907) and Burckhardt (1912, with *Perisphinctes victoris* Burckhardt, 1906: Pl. 26, figs. 1–6). It has been repeatedly discussed since then in Imlay (1943), Verma and Westermann (1973), and Cantú Chapa (1993) who summarized the opinions of all earlier authors. In his recent monograph on the Himalayan faunas of Nepal, Énay (2009) addresses this question again and casts serious doubts about the ascription of the American forms to the genus *Kossmatia*. However, he does not take advantage of the situation to introduce a new genus for all or part of these forms, because that would have required a comprehensive revision of the entire group, especially because Cantú Chapa (1993) had already introduced a new generic name, *i.e.*, *Fierrites*, for one of these species. In the volume of the revision of the "Treatise on Invertebrate Paleontology" dedicated to the "Perisphinctoidea", recently published online (Énay, Howarth, 2019), Énay takes a clear stand and proposes using the genus *Fierrites* Cantú Chapa for these so-called "*Kossmatia*" from Mexico and the USA. Later, the same year, Villaseñor and Olóriz (2019) released the revision of the Mexican "*Kossmatia*", a revision eagerly awaited by Énay (2009). These authors discarded the genus *Fierrites* Cantú Chapa and introduced two new genera, namely *Burkhardtieia* and *Aguilerites*. Although these conclusions have been discussed and disputed by Rogov (2020), with a reply from Villaseñor and Olóriz (2020), that does not negate the fact that genuine *Kossmatia* are absent in both Mexico and the USA.

BENTHIC FORAMINIFERS AND CALCAREOUS ALGAE (FIG. 3)

As for the Purbeckian, correlation of the shallow-water tropical carbonates and deeper water facies with ammonites and calpionellids is not an easy task either. Charollais *et al.* (2008) have mapped out a road whereas Granier (2019b) has built a dual biozonation scheme consisting of assemblage zones and subzones.

According to Wimbledon *et al.* (2020b), Granier (2019b) "*defined an* A. lusitanica *biozone for the Tithonian to earliest Berriasian (based on the total range of the nominate taxon), succeeded by a* P. ultragranulata *biozone for the Berriasian (representing the lower part of the range of the nominate taxon)*". However, all 5 biostratigraphic units defined by Granier (2019b) spanning the Tithonian – Lower Valanginian interval are assemblage biozones. The *Anchispirocyclina lusitanica* Zone is not an exception and it is not the total range zone of *A. lusitanica* (Egger). Besides, the *Protopeneroplis ultragranu-*

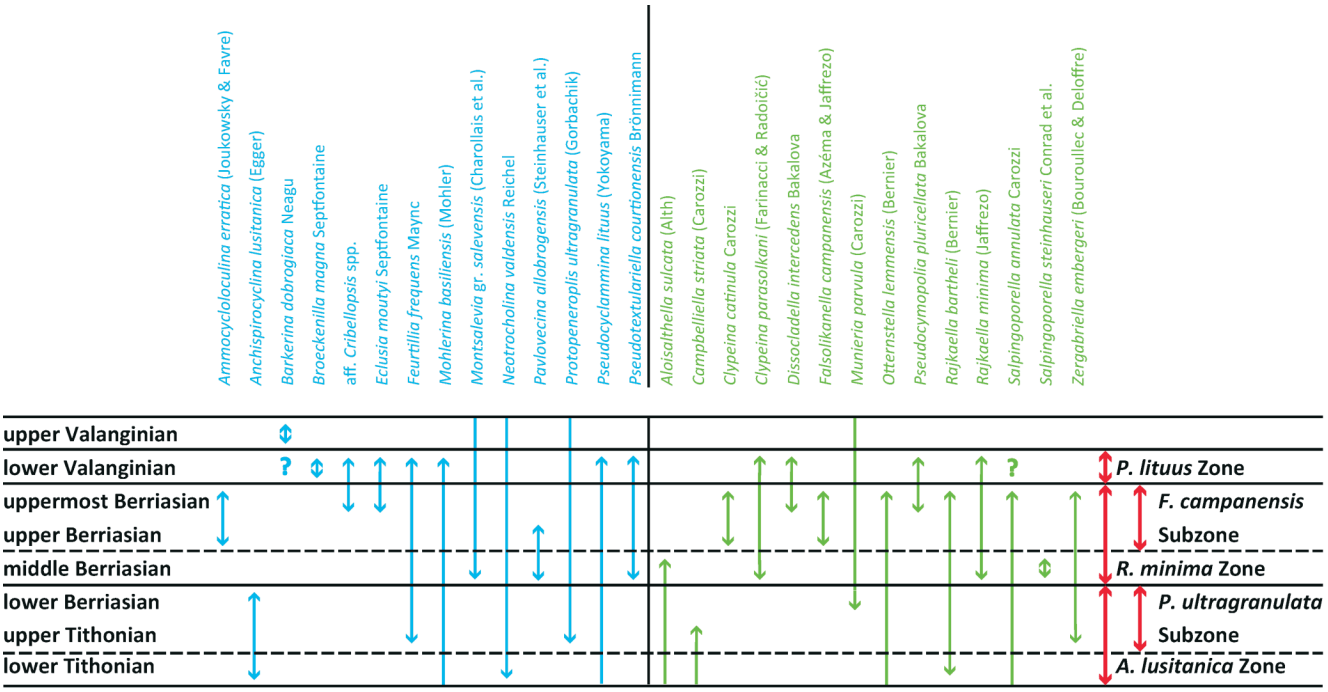

Fig. 3. Stratigraphic distribution of shallow-water tropical microfossils arranged into 2 categories (foraminifers: blue lettering; calcareous algae: green lettering) and in alphabetic order

The left column indicates the standard stratigraphic scale; arrows downward or upward correspond to first and last occurrence intervals respectively; the right column displays the dual biozonation introduced by Granier (2019b). All of these individual units are assemblage zones or subzones (modified from Granier, 2019b: fig. 14, 2020b)

lata Subzone does not succeed the *A. lusitanica* Zone because this subzone (Upper Tithonian – Lower Berriasian) corresponds to the upper part of the zone itself (Tithonian – Lower Berriasian). Today, the first author (B.G.) considers that the Tithonian – Lower Valanginian interval can be split as follows from base to top: 1) the *A. lusitanica* Zone for the Tithonian – Lower Berriasian, the upper part of which is the *P. ultragranulata* Subzone for the Upper Tithonian – Lower Berriasian; 2) the *Rajkaella minima* Zone for the Middle – Upper Berriasian, the upper part of which is the *Falsolikanella campanensis* Subzone for the Upper Berriasian (this unit is demoted from a zone to a subzone because it can be identified only from western European countries); 3) the *Pseudocyclammina lituus* Zone for the Lower Valanginian. The resolution of this dual biozonation is not as good as those using ammonites and calpionellids, but it allows identification of the Berriasian/Valanginian boundary. In addition, according to Granier (2019b), "*it is impossible to distinguish the (upper) Tithonian from the lower Berriasian*". Extending this claim, Granier (2019b) stated that "*the early 20th century Kilian's view on the system boundary*" (...) "*is obsolete and should be seriously reconsidered*", and that "*the two step extinction of the base of the Valanginian*" is a strong argument to "*reverting to the original 19th century*" Oppel's view and to "*shifting the system boundary back to the Berriasian/Valanginian stage boundary*".

PRIMARY MARKER AND SOME SECONDARY PROXIES IDENTIFIED BY THE BERRIASIAN WG

Calpionellids, including the primary marker, nannoconids and radiolarians are more or less abundant in the various hemipelagic and basinal facies of Tithonian and Berriasian age:

1. According to Wimbledon *et al.* (2020b), the primary marker identified by the Berriasian WG is "*the base of the Alpina Subzone (and the calpionellid turnover it indicates) in mid M19n.2n*". Besides the fact that calpionellids are absent in Austral and Boreal areas and rare in shallow-water tropical marine settings (Benzaggagh, 2020), some authors (Ferry,

Granier, 2019; Scott, 2019; Granier *et al.*, 2020; Granier, 2020b) have recently demonstrated the difficulty of precisely identifying the location of the boundary in at least three sites (Fiume Bosso, Le Chouet, Tré Maroua), where several specialists have provided different heights in the measured sections.

2. According to Wimbledon *et al.* (2020b), the primary marker "*is closely matched by the FO of* Nannoconus steinmannii minor". In their figure 3 (*op. cit.*), *N.s.m.* is reported to first occur:

- in the Alpina Zone ~1, ~2, ~5 m above the boundary in the Tré Maroua, Le Chouet and Saint-Bertrand sections respectively, and
- in the Ferasini Zone ~17 m above the boundary at Belvedère.

In addition, their figure 2 (*op. cit.*) clearly documents significant diachronicities when using the nannofossils as a biostratigraphic tool.

3. According to Wimbledon *et al.* (2020b), "*the base of radiolarian zone UZ 14, close above the base of the Alpina Subzone,*" provides another key proxy for the primary stage marker. However, going back to the original definition of UAZ 14 (Baumgartner *et al.*, 1995), it is not younger than magnetozone M18r (Fig. 2.10), which means it is above the boundary by at least 3 m at Belvédère, Saint-Bertrand, Le Chouet and Tré Maroua (in hiatal sections), and more than 22 m at Charens. Radiolarians were not studied in the French Tré Maroua section, only in the Italian Fiume Bosso section (Matsuoka *et al.*, 2020).

CONCLUSIONS

This discussion paper takes advantage of oversights or factual errors in the Berriasian WG proposal to expose some relevant facts in favour of the reformist option:

- Oppel (1865) described his "tithonische Etage" as the all-inclusive interval existing between two framing units, Kimmeridgian below and Valanginian above;
- the Infraneocomian can not be part of the Neocomian, nor can the Infravalanginian be part of the Valanginian (because "infra" means below, not lower);
- the genuine Kilian's definition of the Berriasian was restricted to the Boissieri Zone (and possibly the Occitanica Zone), excluding the current Lower Berriasian;
- Mazenot (1939) significantly altered Kilian's definition of the base of the Berriasian;
- in the 1975 survey, the reformist Motion III received as many votes (22) as the conservative Motion XI;
- motions I and III stated that the base of the *Jacobi-Grandis* Zone [Fig. 2.2, marker 2] coincides with the base of the Calpionellid B Zone [Fig. 2.4]. This has since then been proved wrong (*e.g.*, Wimbledon, 2017; Scott, 2019; Benzaggagh, 2020);
- the current Tithonian/Berriasian boundary falls somewhere in the Purbeck Beds. The situation is similar with respect to the Volgian/Ryazanian boundary [Fig. 2.7, 2.7*];
- the maximum Late Jurassic regression appears to coincide with the end of the Purbeckian, *i.e.*, the end of the Berriasian (*e.g.*, Ogg *et al.*, 1994; Haq, 2014: "KVa1"; Ray *et al.*, 2019);
- in many places worldwide, including SE France, the current Tithonian/Berriasian boundary is a basal submarine erosional surface overlain by the associated calcareous turbidite or debris flow (*e.g.*, Remane, 1970; Ferry, Granier, 2019; Granier *et al.*, 2020);
- in shallow-water carbonate platforms, microfossil assemblages identify the Berriasian/Valanginian boundary, not the Tithonian/Berriasian boundary;
- at the JK2018 (Énay, 2019; Granier, 2019a, c) the reformist view escaped from obluvion.

In conclusion, the arguments presented above, new data regarding the biological crises in the early Valanginian (Granier, 2019b, 2020b; Vörös *et al.*, 2019; Énay, 2020; Salazar *et al.*, 2020) and the geological flaws of the Berriasian GSSP candidate itself (erosional surfaces, conglomerates, fault, *etc.* reported by Granier *et al.*, 2020) all plead for a real reconsideration of the reformist hypothesis that the Berriasian/Valanginian boundary is the best alternative option for the system boundary. It looks like that, in a few years' time, the Berriasian could be to the Jurassic what the Rhaetian is currently to the Triassic. Finally, because the Berriasian/Valanginian boundary has been neglected for years, the present authors hope that their contributions will revitalize interest in this boundary.

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