

Authors' answers to referees

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Interactive comment on “What makes seep carbonates ignore self-sealing and grow vertically? The role of burrowing decapod crustaceans” by Jean-Philippe Blouet et al.

Anonymous Referee #1

Received and published: 1 December 2020

General comments I have carefully read this manuscript and found it to be of interest. The manuscript focuses on the role of bioturbation in creating fluid pathways at methane seeps. Burrows, in particular those of decapod crustaceans, are suggested to favor the vertical aggregation of seep deposits despite of the self-sealing effect of carbonate crust formation. By providing a detailed description of the burrow network of a Jurassic seep deposit, this work adds to the literature on seep environments. Two of my comments are of a more general nature.

Our responses are highlighted in green after each specific point

- (1) It is a missed chance that silicification, formation of chalcedony, and precipitation of euhedral quartz crystals are not put into perspective with the same phenomena [at] other seeps described in the literature. Like for the studied Aurel seep deposit, silicification and silica authigenesis have been observed to postdate the precipitation of methane-derived carbonate, but to predate later diagenetic phases lacking C-13 depletion. This relationship has now been described for many seep deposits and a hypothesis to explain the observed paragenetic sequence has been developed (Kuechler et al., 2012, *Lethaia* 45, 259-273; Smrzka et al. 2015, *Palaeogeography Palaeoclimatology Palaeoecology* 420, 13-26). Discussing the context of silicification and silica authigenesis will help to elaborate the postulated timeline of events.

We have now discussed the issue in more detail (end of section 5.4.2, l. 580-600), but the association of the main phase of silicification with high-temperature saddle dolomite suggests that the main silicification episode post-dates AOM demise. On the other hand, the hypothesis developed by Kuechler and Smrzka could well account for the less pervasive early silicification episode.

- (2) It is mentioned that carbonate crusts may grow downward at seeps (Bayon et al. 2009). Yet possible implications of downward aggregation are not discussed. If, indeed, seep deposits will preferentially grow downward into the sedimentary column, the impact of bioturbation on maintaining fluid flow on longer time scales will be more limited than suggested in this manuscript. Based on the study of mesofabrics of seep limestones, it had been suggested that the aggregation of methane-derived carbonate may proceed downward (Greinert et al. 2002, *Int. J. Earth Sci.* 91, 698-711; Peckmann et al. 2002, *Sedimentology* 49, 855-873). While downward growth may indeed occur, the work of Liebetrau et al. (2014, *Int. J. Earth Sci.* 103, 1845-1872) suggested that upward growth is typically more pronounced. These findings, particularly the work of Liebetrau and co-workers, should be discussed and their relevance should be put into perspective to the inferred role of bioturbation in the formation of the Aurel seep deposit. The authors seem to suggest preferential upward aggregation in case of the Aurel deposit, but this needs to be clarified and should be discussed in more depth.

We have rewritten the discussion in section 5.5 and tried to make it clearer than in the previous version of the manuscript..

I found it difficult to follow the captions of the figures with photomicrographs. Figure captions should be self-explanatory on the one end – these are not – and should be succinct on the other end – which they are not either. Consider to focus on what is really needed for the description of the micrographs and what can be moved to the main text. The paragenetic sequence should be apparent from the caption itself.

We have done our best to simplify and focus.

The authors manage to get the message across, but the standard of the English is less than ideal. The manuscript would benefit from linguistic editing of a native speaker.

Authors' answers to referees

In conclusion, I recommend publication of this interesting work after moderate to major revision.

A brand new publication that should be considered during revision: Gay et al. (2020) Poly-phased fluid flow in the giant fossil pockmark of Beauvoisin, SE basin of France. BSGF-Earth Sciences Bulletin 2020, 191, 35.

Read and cited where appropriate

Specific comments on the manuscript Note: I do not use special characters in this web-based review

(#1) Line 45: I do not want to be nit-picking, but the precipitation of dolomite requires magnesium ions in addition to calcium. *Fixed*

(#2) Line 141: Chemosymbiosis can only be assumed in case of ancient taxa *Fixed*.

(#3) Lines 239 to 240: What would be an "altered peloid" – please specify. *Fixed*

(#4) Line 264: The work of Rolin et al. (1990) is not the latest publication on the Beauvoisin lucinids. A new species has been formally described by Kiel et al. (2010; Zootaxa 2390, 26-48). *Thank you, Fixed*

(#5) Result chapter, petrography (e.g. page 10): The circumstance that the mineral phases of the paragenetic sequence are not described in chronological sequence impedes comprehensibility.

We have now replaced the "main silicification surface (MSS) / below MSS / above MSS order, which was admittedly an unnecessary complication by a straight succession: early (pre-silicification) / silicification / late (post-silicification).

(#6) Chapter 5.2: The reasoning about carbon stable isotopes is mostly okay. Yet, based on the carbon stable isotope data alone, a relation to methane seepage cannot be proven. The described limestone deposit should be compared with the nearby Beauvoisin seep deposits, for which the involvement of anaerobic oxidation of methane in carbonate formation has been proven with lipid biomarkers. *Fixed*

(#7) Lines 509 to 510: "limestone column" – The sedimentary strata do not consist of limestone only. *Fixed with limestone-dominated*

(#8) Line 533, and throughout: "MDAC" – This abbreviation has not been introduced. But why would you like to use it anyway? 'Seep carbonates' are one type of 'methane-derived authigenic carbonates'. Carbon-13 depleted phases of seep carbonates are another example. The designation 'seep carbonate' is consequently more specific than the acronym 'MDAC'. *MDAC replaced by "seep carbonate" throughout the manuscript*

(#9) Line 535: Silicification predates the formation of burial cement. I would not call such silicification 'late', although it is admittedly later than the formation of methane-derived cement. *"late" removed*

(#10) Line 537: "calcite precipitation" – You cannot exclude that much of the calcium carbonate precipitated as aragonite cement like at most modern and Phanerozoic seeps. *"calcite" replaced with "calcium carbonate"*

(#11) Line 543: "brown color of BM spar – Based on its position in the paragenetic sequence, I consider it more likely that this phase corresponds to primary yellow or brownish aragonite (e.g., Zwicker et al. 2015; Marine and Petroleum Geology 66, 616-630). *That was our first idea, based on previous study of seep carbonate bodies less affected by diagenesis. However, we find it difficult to reconcile the "aragonite" hypothesis with the fact that the brown character is strictly related with filament bushes whose morphology does not appear to match that of published aragonite botryoids.*

(#12) Lines 554 to 572: This is where authigenic silica formation and silicification at seeps needs to be discussed (see general comment) *Done.*

(#13) Chapter 5.3.3.: This chapter does not add much to the manuscript – the discussion is vague to say the least. *Section removed*

(#14) Line 607: "burrowers feeding on chemosymbiotic microbial communities" – 'Chemosymbiosis' refers to the association of a metazoan host (e.g., bivalve, tubeworm) with endosymbiotic, chemotrophic bacteria. The term 'chemosynthetic' would work in this instance. *Fixed*

Authors' answers to referees

(#15) Lines 609 to 610: See also Zwicker et al. (2015, see above) for the role of burrows as part of the shallow plumbing systems in sediments affected by seepage. *Zwicker included for this point and others, as appropriate*

(#16) Line 640: "methane generation zone" – This should be replaced by 'methanic sediments' (i.e., sediment containing methane). Methanogenesis (i.e., methane formation) occurs at greater depth, although minor methanogenesis may also occur at or close to the sulfate-methane transition zone. *Fixed*

(#17) Fig. 7 (E) and (F): Could this be *Beauvoisina carinata* (see comment 4)? The shell seems pretty asymmetric, maybe more asymmetric than in *B. carinata*. *We finally keep the question mark, the carinate character cannot be observed on the internal mold available, and the shell is definitely more asymmetric than the type samples*

Technical corrections and suggestions

Many thanks to the reviewer for taking the time to spot and report all these mistakes, there is not much to comment or respond to here, we will just correct as requested in the resubmission.

(T-1) Line 26 and throughout: omit blank between numbers and per mil symbol. *Fixed*

(T-2) Line 30: "post-dating the burial" is an ambiguous formulation. It could be misinterpreted in the sense that this phase formed after uplift during telogenesis. *Fixed*

(T-3) Line 31: "late final blocking" – I do not understand. Do you mean that the fluid pathways have been plugged at some point? *We have changed the wording to insist on the fact that the tubes remained open long after the pseudobioherm was buried rather than on the fact that they were eventually plugged, in a phase largely post-dating all the phenomena discussed in the manuscript.*

(T-4) Line 45 and 46, and throughout: "H₂S and HS" – Why do you use formula instead of words? Before you used the word methane and not its formula. Be consistent. If chemical formula are used, charges (HS⁻) need to be indicated too. *Fixed*

(T-5) Line 65: improve wording. *Fixed*

(T-6) Line 94: 'implies' instead of 'imply'. *Fixed*

(T-7) Line 141: "PBH's (pseudobioherms) – You use many abbreviations and acronyms; this does not make reading any easier. What is the benefit of replacing the word 'pseudobioherms' by the abbreviation 'BHPs'? Saving space? Consider to refrain from introducing yet another new abbreviation. *Fixed*

(T-8) Line 144: Consider to use 'perimeter' instead of 'circle'. *Fixed*

(T-9) Line 171: Same as for per mil. Omit blank between numbers and per cent symbol. *Fixed*

(T-10) Line 246: Add blank before "As". *Fixed*

(T-11) Line 257, and throughout: It is 'gray' in American English. *Fixed*

(T-12) Line 261: add blank after "of". *Fixed*

(T-13) Line 268: "fabric is " not "fabricis". *Fixed*

(T-14) Line 294: "burrows have" not "burrow shave". *Fixed*

(T-15) Line 296: add blank after "Burrow". *Fixed*

(T-16) Line 310: add blank after "10". *Fixed*

(T-17) Line 313: rather "Taken together". *Fixed*

(T-18) Line 383, and throughout: "main silicification surface (MSS)" – the use of such abbreviation impedes comprehensibility. *Fixed, MSS only appears in figures and is explicated in the caption*

Authors' answers to referees

(T-19) Line 410: "measurements" not "mearurement" when "are" is used **Fixed**

(T-20) Line 412: blank after per mil symbol **Fixed**

(T-21) Line 412: "pole" – I do not understand. Do you mean 'pool'? But even than such wording would be less than ideal. *Sorry, that was Frenlish. The term "pole" is commonly used in French for pure phases in a ternary phase diagram. That will be corrected with the help of a native speaker (end-members of a mixing trend?):...*

(T-22) Line 414: blank after "and" **Fixed**

(T-23) Line 422: insert blank after "limited" **Fixed**

(T-24) Line 467: "whereas" instead of "where as" **Fixed**

(T-25) Line 467, and throughout: "depleted values" – Colloquial wording. What is it, a value would be depleted in? A values is a number; in this case 'low values' or 'negative values' would be appropriate. A mineral phase, for example, can be depleted in one isotope, in this case C-13, but not a value. **Fixed**

(T-26) Line 486: delete "depletion" **Fixed**

(T-27) Line 492: add blank before "of" **Fixed**

(T-28) Line 501: insert blank before "signature" **Fixed**

(T-29) Line 531: What is "biodeformation"? Is this a good term? **Wording has been modified and appropriate references added.**

(T-30) Line 599 to 600: "... starting from the top shallow within the seafloor" – improve wording **Fixed**

(T-31) Fig. 10 (B) seems out of focus. **This is UV fluorescence, and diffusion of light emitted within the sample likely blurs the image irrespective of focusing issues**

(T-32) Line 1041: Add full stop after 'side'.

(T-33) Fig. 12 (D) seems out of focus **We have replaced the image by the best quality we could obtain, but there is still a sense of "out of focus". This is probably due at least in part to the high magnification and the fact that it is difficult to have perfect focus on the whole 30-m thickness of the thin section.**

(T-34) Line 1093: 'gray' in American English **Fixed**

(T-35) Line 1108: add blank between numbers and units **Fixed**

(T-36) Line 1111: '13' in superscript **Fixed** comments are also provided in a pdf document I will upload Please also note the supplement to this comment: <https://se.copernicus.org/preprints/se-2020-187/se-2020-187-RC1-supplement.pdf>

Authors' answers to referees

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Interactive comment on “What makes seep carbonates ignore self-sealing and grow vertically? The role of burrowing decapod crustaceans” by Jean-Philippe Blouet et al.

Anonymous Referee #2

Received and published: 7 February 2021

General comments: The manuscript describes a Jurassic seep carbonate body cropping out in the Aurel area (SE France basin) and focuses particularly on the control exerted by the bioturbation on the vertical growth of the carbonate body. Authors interpret that intense burrowing by callianassid-type shrimps in the central part of the seep enhanced vertical permeability during a long time, which avoided the self-sealing process in the seep deposits and allowed the vertical aggradation of the carbonate body. This work contributes to a better understanding of the sedimentation in seep environments and particularly on the formation of high aggrading carbonate bodies. I find this work interesting and it adds to the knowledge about seep-related processes and products. Therefore, I recommend its publication after moderate to major revision. In the manuscript, I find particularly well described, interpreted and discussed the sedimentary facies architecture and C isotopes. Nevertheless, I have two major general comments about the origin of the tubular structures and burrowing.

Our responses are highlighted in green after each specific point

- 1) Origin of tubular structures: It is presented the tubular structures within the seep carbonates as biogenic, e.g. trace fossils, but a discussion about other possible origins (abiogenic gas conduits) is missing. In this regard, abiogenic conduits have been well documented in the literature, both in present-day and ancient seeps, and some of their complex networks resemble that of the Aurel pseudobioherm. In addition, I find the interpretation as burrows should be supported on more data or evidences (the only macroscopic sample presented correspond to a single 11 cm-long rock fragment) and then a discussion on the origin would be relevant.

There are two comments here: first about the fact that most of the macroscopic interpretation is based on a single sample. We have now included 3 more samples, and described in more detail the sample of Figs. 8 and 10 (revised numbering), so that the description is now based on 5 macroscopic samples.

The second comment is about the discussion of bioturbation vs. mechanical (fluid expulsion) cause for the tubular structures. This point has now been put as the first subsection of the discussion (section 5.1, alternatives to the bioturbation interpretation).

- 2) Burrowing: Burrows are classified in three size categories (large, medium and small) each of which is interpreted (based on crosscutting relationships) as formed in three consecutive phases at progressively deeper tiers. However, manuscript's Figure 8 shows that large burrow (Ba) contains centered medium burrows (B1-B3) and they present a parallel and no cross-cutting relationship. It seems, at least from that figure, that medium burrows are actually cement-filled holes of the large burrow and not different burrows. *This results from our previous choice to show only our “Rosetta sample” that best showed the three sets of burrows.*

Authors' answers to referees

In this sample, a significant subset of burrows appear as observed by the reviewer to occupy a central position in large burrows. Adding other, more typical samples shows that phase-3 burrows are seldom located in the center of peloid limestone patches filling large burrows. Moreover, Thalassiniodes/Spongiomorpha, well characterized here from the variability of diameter and orientation, never show a central tube in the middle of a 3 times wider actively filled burrow.

Nor do the figures show a clear crosscutting relationship between small and larger burrows. I think that this is a key point to interpret the temporal and spatial (depth) distribution of the burrows and, therefore, cross-cutting relationships among burrows should be better illustrated or with more figures (they could be in the "supplementary material"). *We have now included additional samples to illustrate the variability of facies F4, with a specific focus on cross-cutting relationships between successive bioturbation phases.*

Specific comments:

- #0 Lines 201: Show the three units in Figure 3 *Fixed*.
- #1 Line 280. It is not clear in Fig. 8 that medium burrows cut through large burrows *Fair enough, see response above*.
- #2 Line 289. Indicate figure (Fig. 8?). t3 in Figure 8 is too small to observe concentric bioclast orientation. *Sorry, T3 was actually a typo for B3. We have amended the text so as to correct this point*.
- #3 Lines 313-315: Add reference. *Fixed*
- #4 Line 324. Smooth wall character does not indicate that it be Trypanites but other criteria as cut bioclasts, etc. *Here again, the previous description was very confusing in part due to the above-mentioned typo that suggested active fill around interpreted Trypanites. The text has been revised accordingly*
- #5 Line 335-336. Why does homogeneous micrite-rich fabric reflects high bioturbation if there is no evidence of burrowing? Why sediment homogenization or mixing could not be due to other process, as for example gas bubble ascending? *This point is discussed in new section 5.1 with appropriate references*.
- #6 Line 354: Description of microfacies and diagenesis (section 4.5) is organized in tiers 1, 2, and 3, but these tiers are interpretative, and interpretations should be located in the discussion. Therefore, I recommend to delete them from that section *One of the co-authors having worked extensively on bioturbation in general, and in particular on burrowing in seep carbonates, we are confident about the interpretation of the well-expressed burrows and the succession of events. We have changed the title of the section from "results" to "results and interpretation", and discuss alternative interpretations (in particular mechanical interaction between, ascending fluids and host sediment) in the "discussion" section*. Moreover, description of carbonate phases would be more understandable if they will be presented following cement *Both reviewers made that remark. We have rewritten the corresponding section, which was admittedly confusing in the previous version. We hope the new organization of section 4.4, paragraph "tier 3" will be easier to follow*. In general, I miss comparison with and references to other papers on seep carbonates and particularly on paragenetic sequences *We have added references further to recommendations by both reviewers*.

Authors' answers to referees

- #7 Line 356: What was bioturbated, the original marl or the later micrite carbonate? *Sorry, the wording was not clear. Shallow homogenization by meiofauna affected the original marl and interstratified calcilutite in the first ca. 10 cm below seafloor, before the sediment was cemented by AOM-mediated carbonate precipitation in the porous network, i.e. while the sediment was still soupy. The last phase of bioturbation (Trypanites) predominantly affects micrite pheno-intraclasts, i.e. cemented residual patches of the homogenized sediment.*
- #8 Line 397. It is used in this line and through the text “synsedimentary cements” (also “sedimentary cements”) to indicate early diagenetic cements. I would be better to use always “early diagenetic cements” in contrast to “late diagenetic cements” *Fixed.*
- #9 Line 495: Most D18O values (table in Appendix I and Fig. 13A) corresponding to saddle dolomites are about -1 to -2 per mil. These values are very strange, are higher than reference sediments and early diagenetic cements, and they are not compatible with hot fluids (>60-80 °C) from which saddle dolomites precipitate. Common D18O values for saddle dolomites documented in the literature are around -6 per mil or lower. It needs some discussion *Discussed the best we could in the last paragraph of section 5.3. Actually, we could only acknowledge the difficulty and follow Peckmann et al. (2003) and Zwicker et al. (2015), who state that “Oxygen isotopes of seep carbonates are more challenging to interpret than carbon isotopes, [...] mainly due to the ease of oxygen isotope exchange during diagenesis, as the oxygen pool of waters [...] involved in late diagenesis is much larger than their carbon pool ». In addition, the focus of this manuscript is more on sedimentation / bioturbation / early diagenesis than on late diagenesis.*
- #10 Line 575: “sediment-cement alternations” change by “sediment-cement sequences”. Always use the same terminology for the same things *Fixed.*
- #11 Line 593: Add reference to Fig.3 (“ . . .A and B; Fig.3”) *Fixed.*
- #12 Line 597: It is mentioned the downward growth of concretionary crusts. However, it is not clear whether this interpretation corresponds only to layers A and B or to the entire pseudobioherm. It should be state more explicitly. *The corresponding section has been entirely rewritten.*
- #13 Line 605: It is mentioned that the axis of vertically stacked carbonates shows two lateral shifts coinciding with marker beds A and B. Then, these shifts are interpreted that hydrocarbon-charged fluids migrated upslope. However, Fig. 3B suggests that the axis of the PBH migrated in opposite directions, first westward and then eastward. How can this apparent contradiction be explained? *Fig 3D indicates a ca. 5 times higher northward than westward shift across marker bed B. What is shown in 3B is thus an apparent shift. Moreover, the axis is drawn as a best guess to illustrate a visual perception and cannot be defined from the outcrop with the precision suggested by the thin dash-dot line. The text has been revised accordingly.* What was the regional and/or local paleoslope orientation at Middle Callovian times? *Actually, there is no clue in this area where outcrop continuity is limited, and that has been subjected to several orogenic phases so that regional geology cannot help as regards the local setting, the one that influences local bubble migration. The interpretation we propose is the simplest we can think of, based on Casenave et al., 2017, which observes this type of upslope shift on a present-day slope offshore W Africa. We will refer to this paper.*
- #14 Line 608: Change “chemosymbiotic microbial communities” by “chemosynthetic microbial communities” *Fixed.*

Authors' answers to referees

#15 Figure 8: The legend of this figure is fragmentary and very complex with a lot of symbols, colors (not easily identifiable), etc. It should be a single and simpler legend. *(After reorganization, this has become Fig. 9). Panel D (the one with colors) has been simplified, with two unnecessary categories removed, which should help identification. And the legend has been much simplified and grouped in a single box.*

Technical corrections: - Omit blank spaces front and back “/” and “-“symbols *Fixed*. Revise throughout the document. - Omit blank spaces between number and °C symbol. *Fixed* Revise throughout the document. - Omit blank space between number and per mil and per cent symbols. *Fixed* Revise throughout the document. - Insert blank space between two words *Fixed*. In many places of the text, blank spaces between words are missing *Fixed*. Revise throughout the document.

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