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Biogeosciences Discussions

Interactive comment on "Endolithic Boring Enhance the Deep-sea Carbonate Lithification on the Southwest Indian Ridge" *by* Hengchao Xu et al.

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RC1: This manuscript evaluates the impact of macrofaunal activity on the lithification of deepsea carbonates. This appears to be an interesting and previously not very thoroughly explored topic, and has the potential to advance our understanding of both the impact of bioturbation, as well as the controls on carbonate lithification. I especially appreciate the fact that this paper is very to the point, and not overly extended (although it does require some in depth discussion on some points, see below).

Reply: Thank you very much for your appreciation on the overall performance of the research work.

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Discussion paper

RC1: One immediate problem with the manuscript in its current form is the sometimes confusing writing style.

Reply: We took the utmost care to refine our English in the revised version.

RC1: Additionally, most of the discussion rests on speculation, rather than data, which undermines the value of this manuscript. I believe the authors should expand their observations, and especially include a thorough, quantitative assessment to elucidate the relative importance of bioturbation for carbon lithification.

Reply: Thank you for your comments on the discussion part. We have made efforts to improve the discussion basing on your suggestions. In revised manuscript, (1) CT images are further analyzed by line scanning of pixel values to play with the contrast of density change around the burrow; (2) Geochemical evidence that indicate the diagenetic differences of different types of samples are discussed thoroughly. To be fair, pore water chemical data around the burrow are valuable to quantitative assessment of bioturbation and carbonate lithification. Nevertheless, carbonate samples in this study were collected by TV-grabs bucket, which were too difficult to take the measurement of pore water chemistry. Thus, discussions of lithification enhanced by bioturbation are based on the evidence from CT images, microstructures and geochemical data.

Major specific comments: RC1: Language: While this is not the case for the manuscript as a whole, there are a lot of parts which suffer from bad spelling and grammar (see the technical corrections for specific examples, that list is not exhaustive). Before this manuscript can be accepted, it should be thoroughly revised for language.

Reply: Thank you very much for your reminding in English language and specific corrections. We have deeply checked for English language.

RC1: Interpretation of the figures: I have some difficulties with following the interpretation of the images presented in Fig. 2 and 3. On P7L6-7 you state that it is difficult to know the real depth of each burrow. How exactly do you then go from the pictures in

Fig.2a-d to the burrow shapes in Fig. 2e? How do you know they are J-shaped, and not just U-shaped, but broken off? Did you do this by eye, or did you use a cast, or scanning techniques?

Reply: Sorry for the confusion. In revised manuscript, burrow shape and Fig 2e are interpreted and discussed in detail. The depth and shape of burrow are summarized form close inspection of CT images. Especially with the help of CT analysis, we can classify burrows in straight branched or J- and U-shaped (Fig r1). If the J-shaped burrow is mistaken by broken U-shaped, it can be showed by the symmetrical difference of density distribution. The evidence that no density change symmetrically (Fig r1c, Yellow arrow), make it classified as J-shaped burrow. Based on the CT images, we give the sketch for different burrow structures.

RC1: Please expand the same remark for Fig. 3, you state (P5L22-23) that 'the most readily observable feature is the localized enhancement of density around the boring'. I have looked at the images, and even with the arrows, I have a lot of difficulties finding these enhancements. Since most of your discussion rests on these observations, I think you should expand and more clearly explain on what this statement is based. You might want to consider playing with the contrast, or other visual techniques, to make these features more clear (cause now I cannot see them).

Reply: Thanks for your advice. We have used multiple image analytical approaches to make these features more clear. We pick the pixel values of the CT image to contrast the changes of density around burrows. It is showed by the line scan profile that pixel values around the bioturbated area are higher than the matrix. This evidence supports the localized enhancement of density around burrows (Fig 3d). 3D reconstruction of the sample by CT shows more visible density contrast (Fig 4c).

RC1: Additionally, you need to expand on the statistics used to generate the linear correlations in Fig. 5.

Reply: Function of "polyfit" in MATLAB is used to estimate the difference between bioturbated area and the control with 95% confidence intervals. (Fig. 5). Function "polyfit" returns a polynomial p(area) that is best fit for the data of integrated density. With 95% confidence bounds, the functions of bioturbated area and control are discrete with a statistical significance.

RC1: Discussion: I believe the biggest problem with this manuscript is the lack of data, and a quantitative discussion. I am supportive of the authors efforts, and I do believe that bioturbation could play a role in carbonate lithification. However, to make this case based on a few images, without any quantitative discussion, seems a bit of a short-cut. The authors should expand on these observations, and give a better mechanistic explanation on how bioturbation would enhance lithification, and include a thorough quantitative assessment of the relative importance of this process.

Reply: Thank you very much for your comments. In revised manuscript, we take the comparison of density change from CT images by line scanning of pixel values. Area near the burrow always show higher pixel value than area away far from the burrow (Fig 3d). The evidence that enhanced density near the burrow supports our deduction that carbonate lithification is enhanced by bioturbation. Enhanced lithification is also supported by micro-structure of nanofossil. Furthermore, geochemical records including elemental and stable isotopic results indicate the lithification influenced by bioturbation. Organic matter re-distribution by bioturbation acceleration the microbial oxidation around the burrow. If pore water profile around the burrow is obtained, more quantitative assessment of bioturbation and carbonate lithification can be done. Nevertheless, carbonate samples in this study were collected by TV-grabs bucket, which is too difficult to take the measurement of pore water chemistry.

Minor specific comments: RC1: The authors use 'boring' throughout the manuscript when they discuss the burrowing of macrofaunal organisms. This is rather confusing, as in my experience, it is more common to use 'burrowing' and 'burrow(s)'. I would suggest to change this throughout the manuscript to improve readability

Reply: Thanks for your advice. In revised manuscript, boring are replaced by burrow or bioturbation.

RC1: Additionally, I had to google the word ‘endolith’. While it is correctly used, I again would suggest to avoid the use of this word, and use the more common ‘macrofaunal’, ‘benthic fauna’ or others, to improve readability

Reply: It has been changed. The revised title is “Macrofauna bioturbation Enhance the Deep-sea Carbonate Lithification on the Southwest Indian Ridge”. “endolith” used in the manuscript are also changed.

RC1: Results: at the start of the results (P5L3) it is immediately stated that the macrofaunal burrows were lined with ferromanganese crusts. While this assumption is used aplenty throughout the manuscript (see for example Fig. 7), you do not provide evidence that these are indeed ferromanganese crusts. Please justify this assumption (or say it is just an assumption, but then explain why).

Reply: They are named basing on the elemental composition. In revised manuscript, “Mn- and Fe-oxide precipitates” are used instead of “Ferromanganese crusts” because that "Mn- and Fe-oxide precipitates" is a better term to describe our samples. Elemental composition of Mn- and Fe-oxide precipitates by SEM-EDS Element C O Na Mg Al Si Cl Ca Mn Fe Total Wt % 3.9 19.44 0.93 3.19 1.95 2.63 2.13 42.64 18.89 4.31 100 Elemental composition of chalk by SEM-EDS Element C O Mg Al Si Ca Total Wt % 3.81 19.5 1.49 1.47 2.14 71.59 100

RC1: P6L21-25: a lot of discussion about Sr, but it is not shown? Table 1 is too long to be readable. I would suggest to make this a supplementary table, and take out the most important trends and plot those in a figure.

Reply: It is visible to plot the important trend (e.g. Sr/Ca) in a figure and show elemental data in a supplementary table.

RC1: P6L33: how exactly does bioleaching deplete the isotopic value?

Reply: Stable isotope values of carbonate rock reflect a mixture of calcareous biogenic debris which is equilibrium with sea water during the growth of organisms and the alteration of diagenetic fluid. One of mechanism that bioturbation can enhance the carbonate lithification is the microbial oxidation of organic matter increasing the pore-water CO2 concentration. Microbial metabolic reaction usually leads to enrichment of biospheric carbon in 12C. Thus, the dissolution and reprecipitation of carbonate influenced by bioturbation could enrich in heavy carbon in the interior of carbonate. Meanwhile, light carbon enriched in newly burrowing portion like the gray excrements. This has been further discussed in revised manuscript.

RC1: P7L15-16: why do these carbonate deposits form a favourable environment? What is special about them?

Reply: Sorry for misleading. This sentence has been deleted.

RC1: P7L5-11: I cannot follow the reasoning behind this estimation. You cannot find the real depth of the burrows, but assume 6 cm, with is the median value. How do you get a median value if you cannot determine the real burrow depth? How do you get to 12 holes per 1dm2 surface? Should you not compare volume to volume? Please be more explicit.

Reply: Sorry for the confusion. We want to estimate the volume of burrows occupied in carbonate samples. So a comparison of volume to volume is used. Although real depth of burrow is hardly to measure, we can make the estimation from the CT image. CT images are helpful to peer inside the carbonates. For one burrow in different CT slides, the slides with longest size is taken to estimate the burrow length (Fig r3 left). At the same time, the density of burrow is also enumerable from the CT images.

Technical corrections: RC1: - P1L11: ‘macrofaunal inhabitants’ -> not correct, better: ‘benthic macrofauna’

Reply: Thanks for your correction. We have checked through the manuscript.

RC1: - P1L15-16: 'Our study reports an unfamiliar phenomenon : : : and interested by the : : :' -> this sentence is very vague, and also wrong (what is interested?), please rephrase

Reply: Thanks for your reminding. It has been rephrased. Here, we report the lithification of deep-sea carbonate associated with macrofunal burrowing.

RC1: - P1L16-17: 'These carbonate rocks may : : :' -> it is not the carbonate rocks that provide a mechanism, please rephrase: : :

Reply: It has been rephrased. Macrofaunal burrowing provides a novel driving force for deep-sea carbonate lithification at the seafloor, illuminating the geological and biological importance of deep-sea carbonate rocks on global mid-ocean ridges.

RC1: - P1L29: 'remains' -> remain

Reply: Thanks for your correction.

RC1: - P2L10: 'Burrowing and boring' -> I believe these are synonyms 'because it enhances'-> because they enhance

Reply: The sentence has been rephrased. Benthic fauna drilling into the substrate play a critical role in sediment evolution

RC1: - P2L13: 'organismic burrowing and boring' -> same remark as above, and organismic can be removed

Reply: Thanks for your correction.

RC1: - P21L21: 'between the bioturbation' -> 'between bioturbation'

Reply: Thanks for your correction.

RC1: - P2L30: 'it has been well proved' -> it has been well proven 'bursting' -> what does this sentence mean? Biogenic bloom was bursting?

Reply: The sentence has been rephrased. It has been widely reported that primary productivity increased substantially at the Indian Ocean during the Latest Miocene–Early Pliocene

RC1: - P2L32-P3L2: I understand the sentence, but he is not constructed correctly : : :

Reply: The sentence has been rephrased. This phenomenon known as “biogenic bloom” promoted significantly high quantities of carbonates deposit at the seafloor between 9 to 3.5Ma.

RC1: - P5L9: ‘herald’ -> indicate

Reply: Thanks for your correction.

RC1: - P5L10-11. What does this sentence mean?

Reply: We have rephrased in a comprehensible way. Burrows can be classified in three categories.

RC1: - P5L14-16: the message you are trying to convey is unclear, please rephrase

Reply: The sentence has been rephrased. It has been suggested that Mn- and Fe-oxide precipitates grow at very slow rate of 1-10mm/Ma. Coating of black Mn- and Fe-oxide precipitates on the surface of the latter two burrows indicate that they may form much earlier than other burrows.

RC1: - P5L31 ‘quart’ -> quartz?

Reply: Thanks for your correction.

RC1: - P6L13-15: sentence does not make much sense

Reply: The sentence has been rephrased. It is common to observe the accretionary overgrowth of calcite around the foraminifera test form SEM image (Fig. 6c). Dissolution of the coccolith plates is evident both on the surface of the thin black Mn- and Fe-oxide precipitates and in the interior of carbonate rocks (Fig 6e)

RC1: - P6L17: ‘dipartite evolutionary of diagenesis’ -> what does this mean?

Reply: This sentence has been rephrased. Smooth surfaces of the coccoliths in gray excrements reveal that dissolution commonly occurs influenced by bioleaching of benthic fauna (Fig 6f).

RC1: - P6L21-25: ‘character’ -> characteristic, ‘is highly variable of Sr’ -> is the highly variable Sr, ‘different portion of’ -> different portions of, ‘mainly accounted for the substitution’ -> mainly caused by substitution ‘recrystallization, resulting in’ -> recrystallization results in ‘The loss of’ -> the decrease of ‘could also a response’ -> could also be a response

Reply: Thanks for your correction. This paragraph has been carefully revised. Three types of samples (chalk, gray excrements and thin black Mn- and Fe-oxide precipitates) exhibit similar elemental concentration patterns for high CaO content, reflecting the strong dilution effect of biogenic calcium. One of the main characteristics of major and rare elements is the highly variable Sr concentrations in different portions of the carbonate. The storage of Sr on seafloor is mainly caused by substitution of Ca in calcium carbonate while the diagenetic recrystallization results in the decrease of Sr from the sediment (Plank and Langmuir, 1998; Qing and Veizer, 1994). The lower of Sr/Ca in chalk compared to the gray excrements could also be a response to the lithification of carbonate (Fig 7). Although biogenic calcium diluted the detrital REE fraction, it made little direct contribution to bulk REE concentrations (Xiong et al., 2012). REE patterns of the three types of sample do not exhibit any hydrothermal anomalies, e.g. positive Eu anomaly, but inherit the characteristics of sea water by enrichment of HREE compared with LREE and negative Ce anomaly (except the Mn- and Fe-oxide) (Fig. 8). The influence of nearby hydrothermal system and other detrital input to the studied carbonate area should be negligible during the lithification history.

RC1: - P6L31: statement needs a reference (‘typical values for biogenic carbonates’)

Reply: A classical references was added.

RC1: - P7L12 'several boring purposes are served for the benthic animals' -> does not make any sense, benthic fauna form burrows for certain purposes.

Reply: Thanks for your reminding. It has been rephrased. Benthic fauna form burrows for certain purposes of gaseous exchange, food transport, gamete transport, transport of environmental stimuli, and removal of metabolites.

RC1: - P8L1-2: 'Alternatively, bacteria and organic detritus are considered to the major source of benthic fauna in deep-sea' -> this sentence means that benthic fauna originates from bacteria and organic detritus. While this is possibly true from an evolutionary perspective, I do not think this is what you want to say here : :

Reply: Sorry for misleading. It has been corrected. Alternatively, bacterial metabolites and organic detritus are considered to the major source of food for benthic fanua in deep-sea environment which is limited by availability of organic matter.

Please also note the supplement to this comment:
https://www.biogeosciences-discuss.net/bg-2018-46/bg-2018-46-AC2-supplement.pdf

Interactive comment on Biogeosciences Discuss., https://doi.org/10.5194/bg-2018-46, 2018.

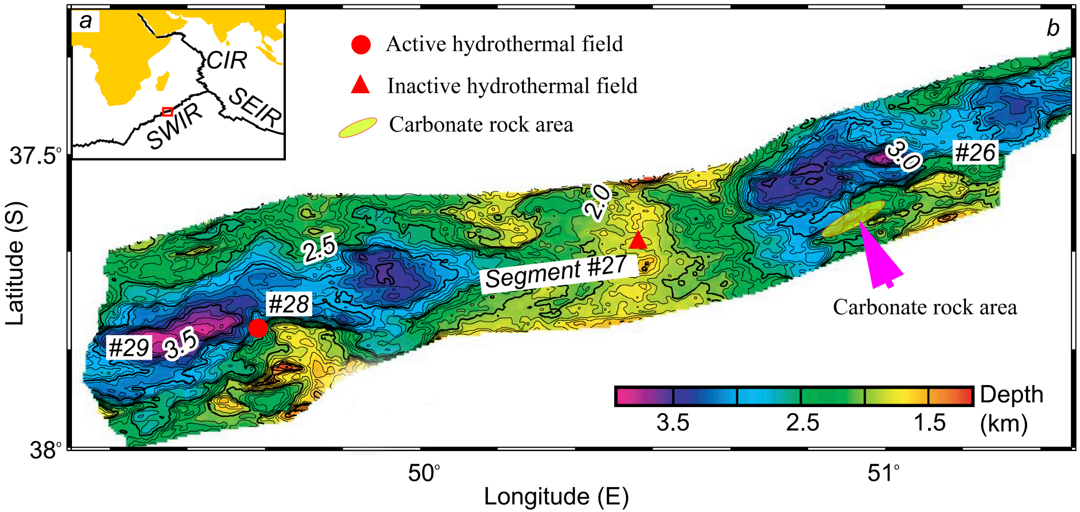

Fig. 1.

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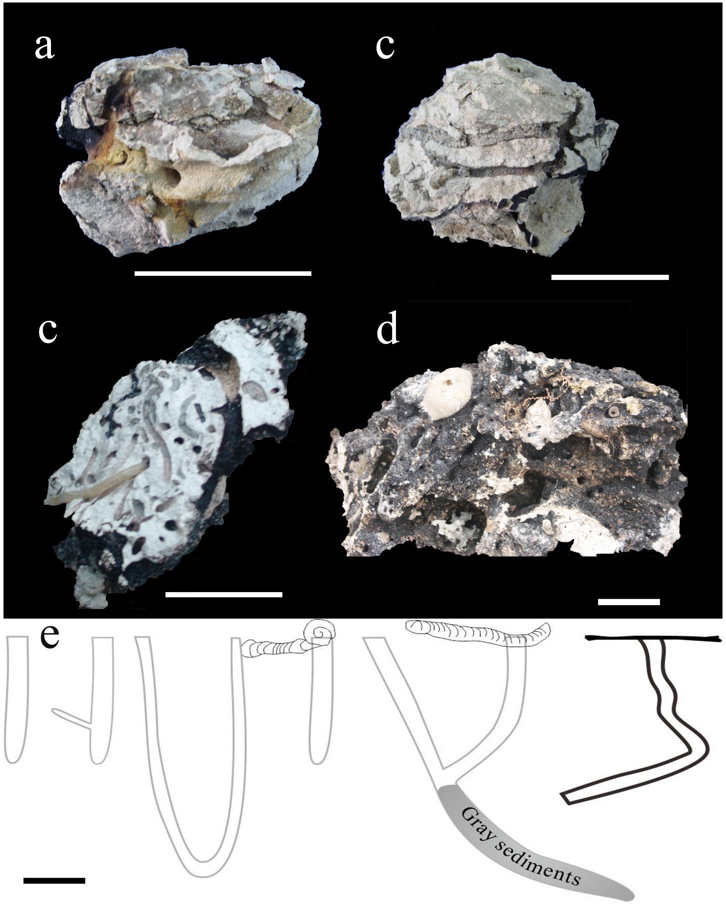

Fig. 2.

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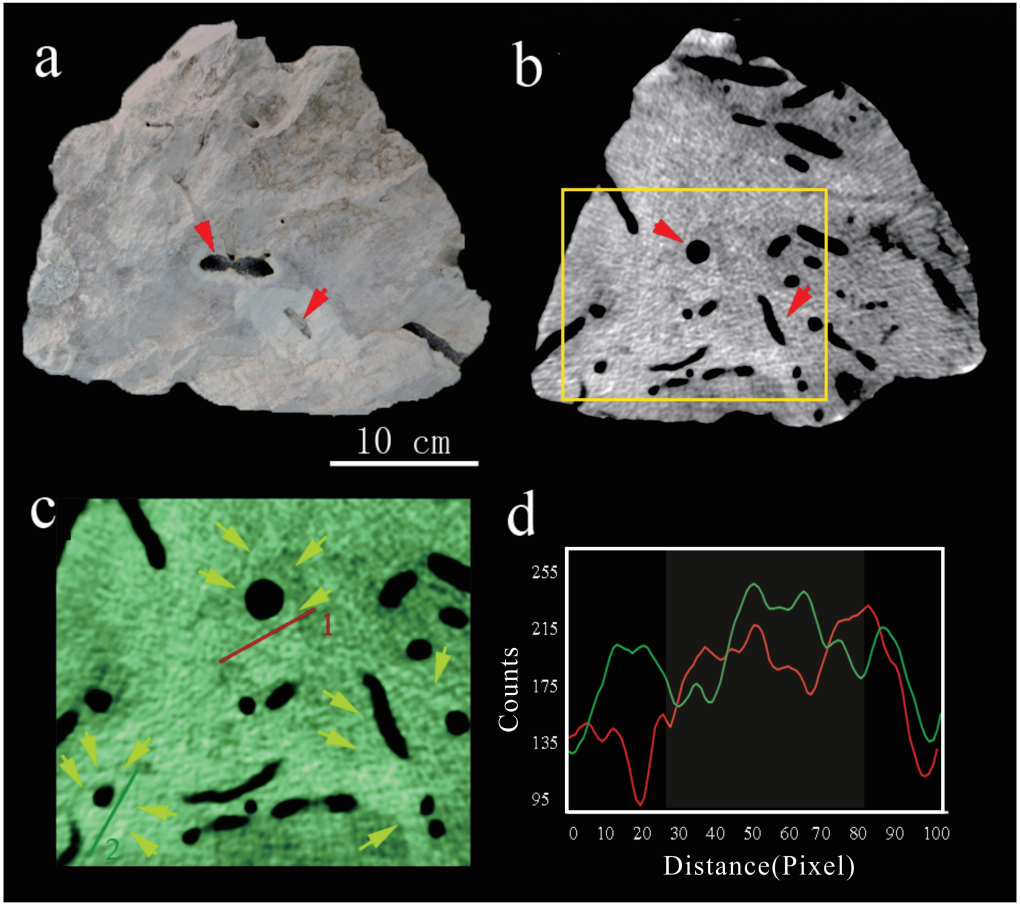

Fig. 3.

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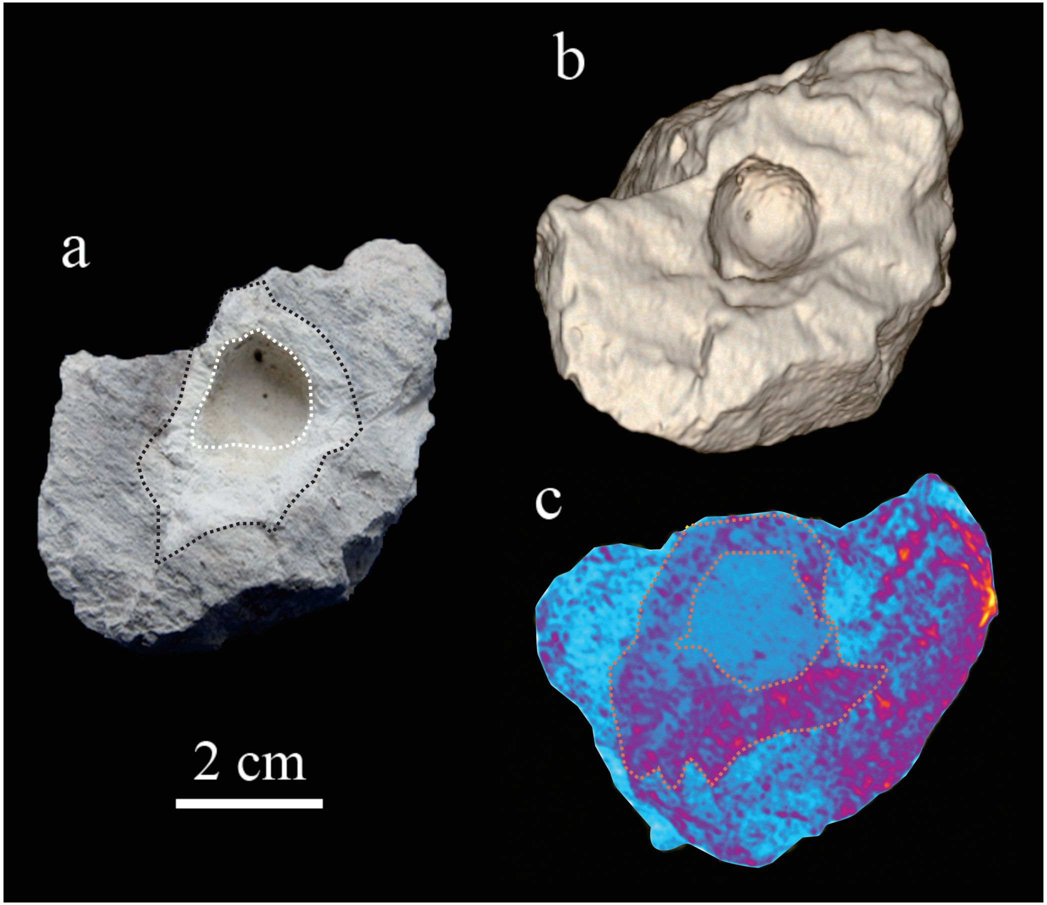

Fig. 4.

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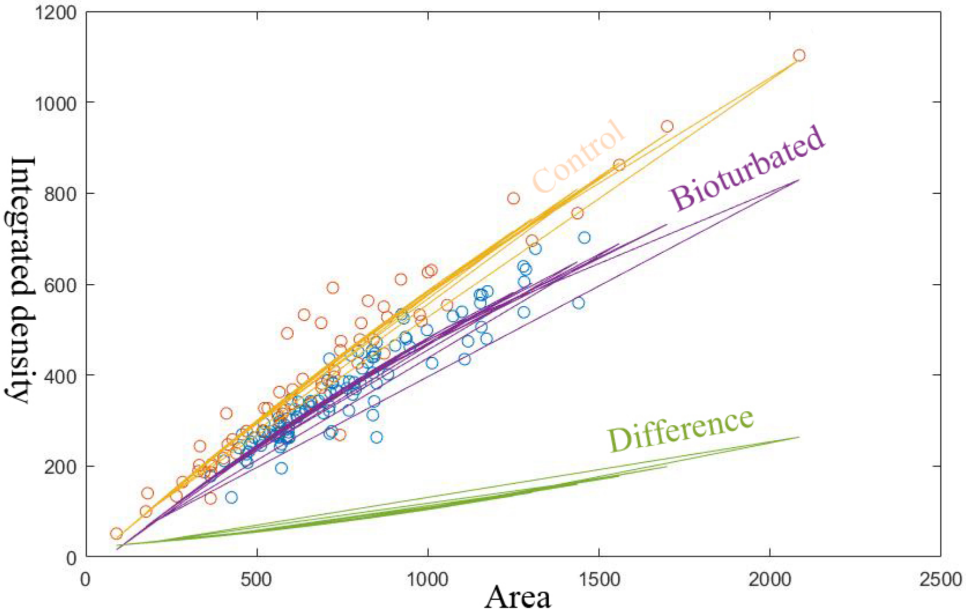
1200
1000
800
600
400
200
0
0
500
1000
1500
2000
2500
Integrated density
Area
Control
Bioturbated
Difference

Fig. 5.

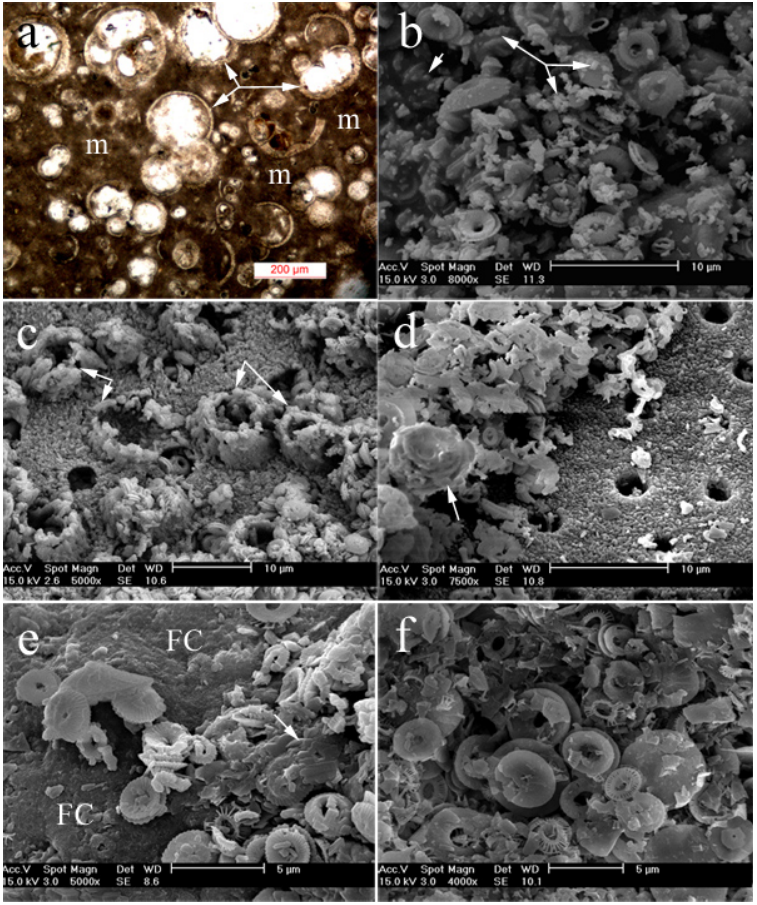

Fig. 6.

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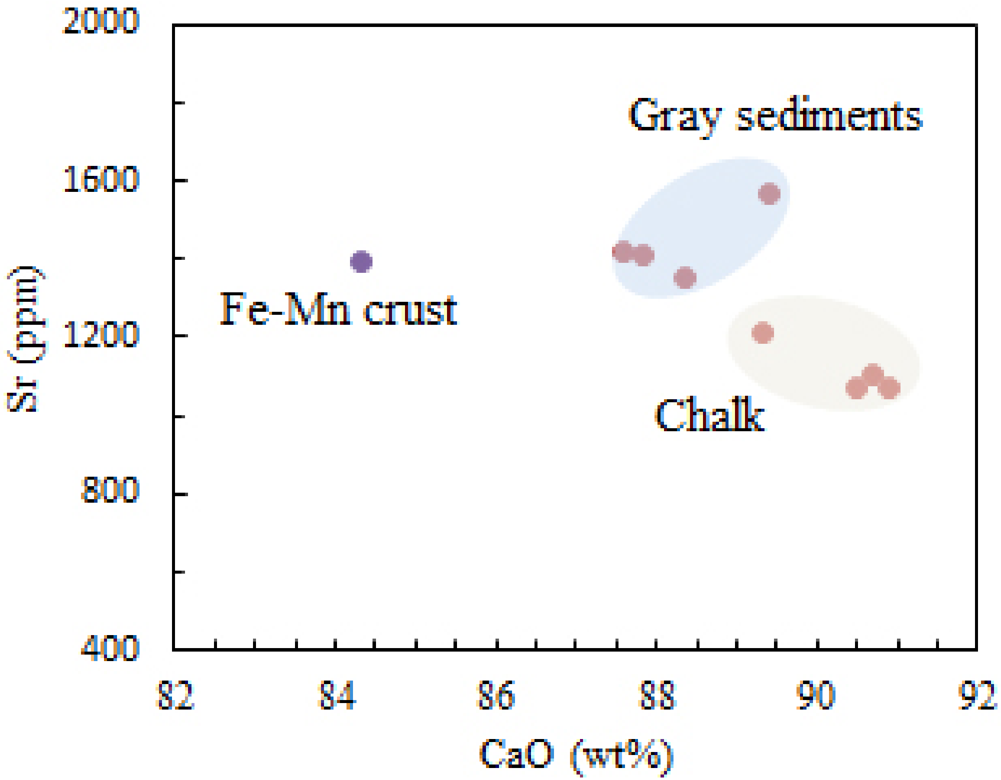

Fig. 7.

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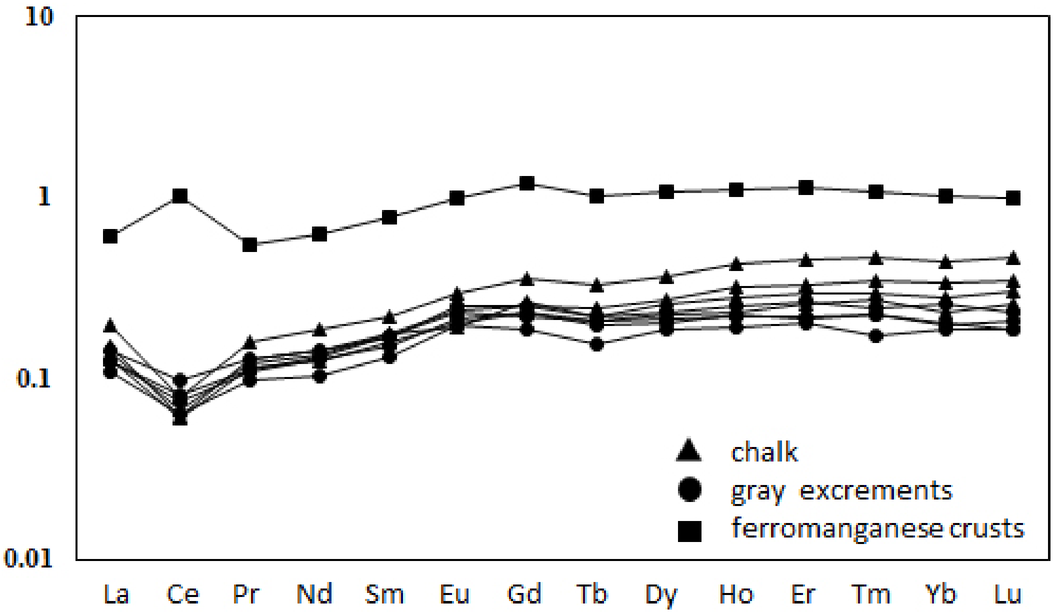

Fig. 8.

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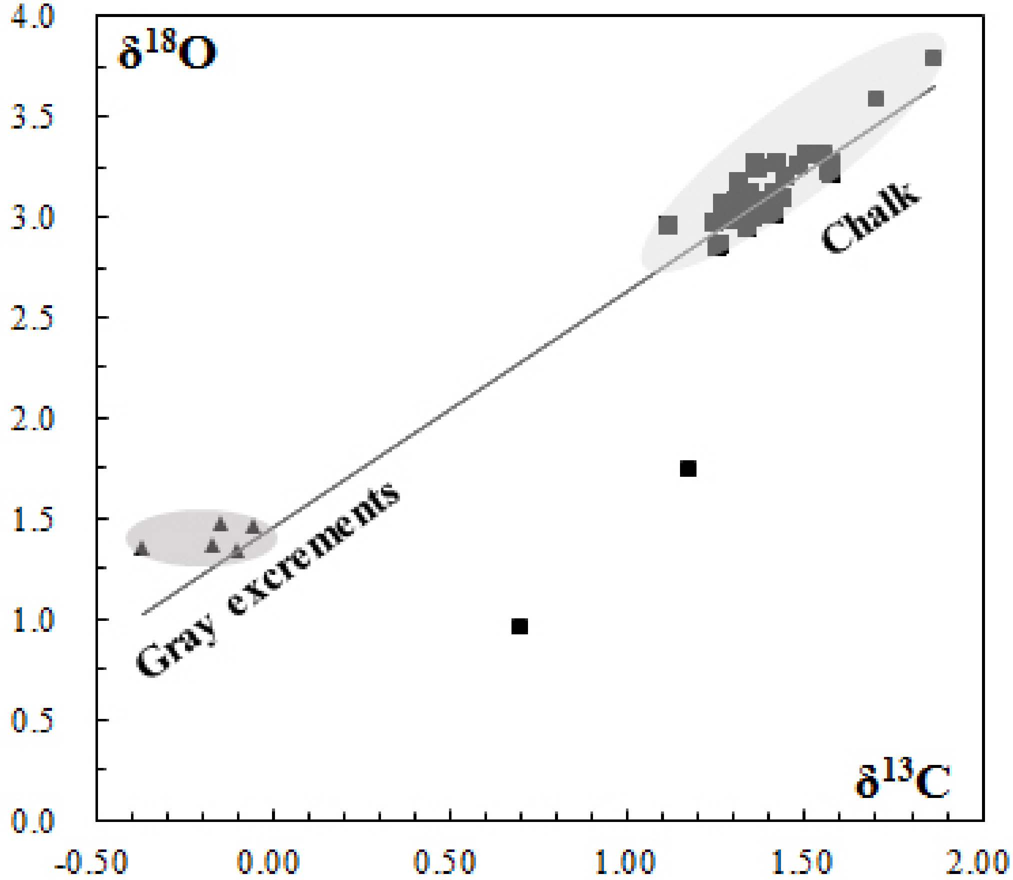

Fig. 9.

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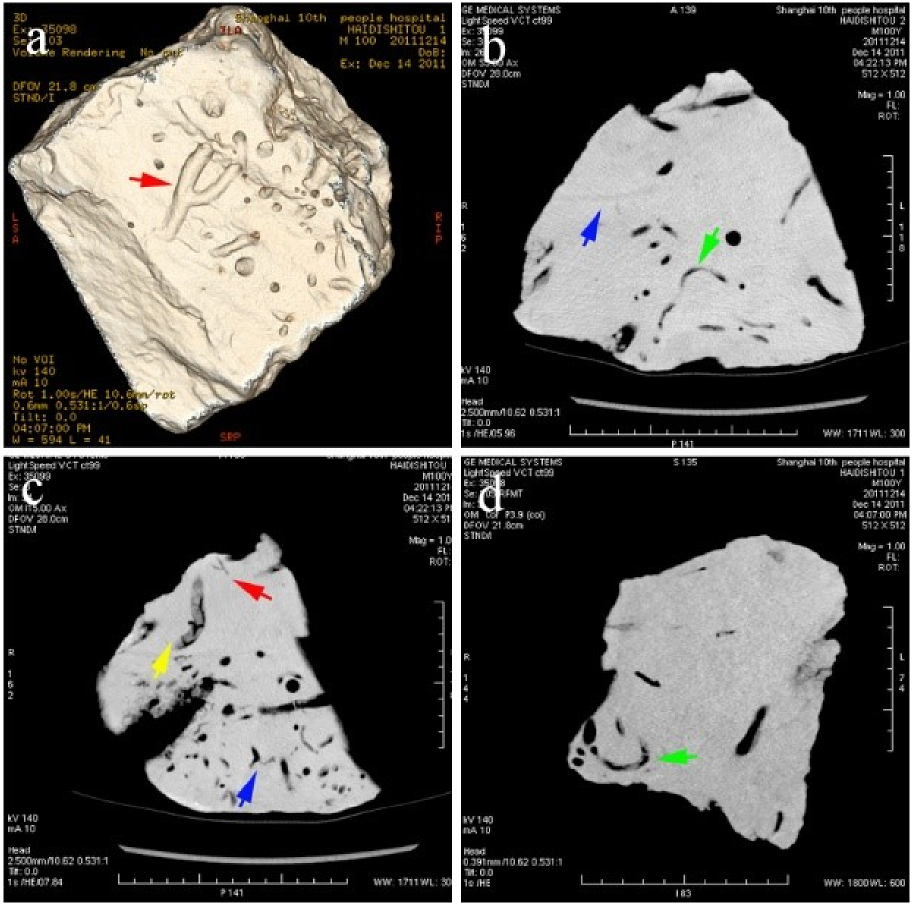

Fig. 10.

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