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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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RC2: The manuscript titled "Endolithic Boring Enhance the Deep-sea Carbonate Lithification on the Southwest Indian Ridge" details observations and analyses of deep-sea carbonate samples that appear to be experiencing enhanced lithification associated with benthic faunal burrowing. The study employs computed X-ray tomography, visual and microscope observation, and geochemistry to evaluate the relationships between burrowing and the degree of carbonate lithification. The main conclusion is that burrowing is likely an important process accelerating carbonate lithification in the deep-sea. The findings are intriguing and certainly of interest to a wide readership.

Reply: We are very thankful to the anonymous reviewer for constructive feedbacks and insightful comments on our manuscript.

RC2: My main reservations about this manuscript are twofold: (1) it is not immediately clear in some CT-scan images that there are density contrasts (enhanced lithification) surrounding the burrows (Figure 4).

Reply: Thanks for your reminding. In order to make the density contrasts clearly, we pick the pixel values of the CT image to contrast the change of density around burrow. It is showed by the line scan profiles that pixel values around the bioturbated area is higher than matrix indicating the localized enhancement of density around burrows (Fig 3d). 3D reconstruction of the sample by CT analysis also has been added in revised manuscript (Fig 4). You can find new figures in response to specific comments.

RC2: (2) it is not clear based on the data treatment that there is true statistical significance in the difference in density between bioturbated zones and control zones (Figure 5). See specific comments on these below. If the authors can address the above major points then I can see this manuscript being of interest to a wide readership. I agree with the authors that burrowing-enhanced lithification would appear to be an important process if it can extrapolated to deep-sea carbonates world-wide.

Reply: Thanks very much for your advisable suggestions to promote the quality of data treatment. In revised paper, function "polyfit" in MATLAB as you advised is used to generate the polynomial p(area) that is a best fit for the data for integrated density (with 95% confidence bounds). The functions of bioturbated zones and control zones are discrete with a statistical significance (Fig 5). We show an example of the density change around the burrow by line scanning in Fig 3d. When comes to the Fig 5, whose data are generated from 113 burrows, the statistical results support our conclusion that macrofaunal burrowing enhance the deep-sea carbonate lithification on the Southwest Indian Ridge.

RC2: While the English is already commendable for authors for whom English might be a second language, and it is possible to follow what the authors are saying throughout the manuscript, there remain minor issues with English throughout the manuscript. This should be easily fixed with a careful proofread by a native speaker.I would consider the revisions required to address the general comments above and specific comments below to be major - significant blocks of text should be revised and additional statistical treatment should be applied to the dataset.

Reply: Thank you very much for your reminding in English language. We took the utmost care to refine our English in the revised version.

Specific Comments RC2: Abstract, line 9: I'm not sure that one can say that lithification of deep-sea carbonates is a "mystery"; there is a respectable body of literature on lithification mechanisms and rates dating back over three decades. Perhaps better would be something like "the role of deep-sea macrofauna in their lithification remain poorly understood".

Reply: The sentence has been revised. the role of deep-sea macrofauna in carbonate lithification remains poorly understood.

RC2: Abstract, line 12: "in the sample" makes it read as if there was only a single hand sample, when it appears that grab buckets provided multiple samples. This occurs elsewhere in the manuscript as well.

Reply: Thanks for reminding. It has been modified and we have checked the whole manuscript to avoid this mistake.

RC2: Abstract line 16: "interested by" doesn't make much sense - please re-phrase.

Reply: The sentence has been deleted.

RC2: Abstract, last sentence: these results don't really speak to the importance of deep-sea carbonate sediments, simply the mechanisms of their formation. Please re-phrase.

Reply: The sentence has been revised. 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.

RC2: Main text in general: while I find that the text is written in a clear and straight-forwards manner, there remain minor grammatical errors throughout. If english is the authors' second language, then they should be commended - this manuscript already reads decently well. Nonetheless, further editing by a native english speaker is necessary to wrap up the grammatical loose ends that are apparent throughout the manuscript.

Reply: whole manuscript has been deeply checked for English language.

RC2: Page 2, line 24: it might offend researchers in diverse fields to say that the entire Indian Ocean is "poorly understood".

Reply: Thanks for the comment. This sentence has been deleted.

RC2: Page 2, line 30-34: grammatical issues, please re-phrase.

Reply: It has been modified. This phenomenon known as "biogenic bloom" promoted significantly high quantities of carbonates deposit at the seafloor between 9 to 3.5Ma (Gupta et al., 2004; Dickens and Owen, 1999)

RC2: Materials and Methods: certain phrases in the methods have been reproduced wordfor-word from previous work. For example, page 4, lines 12 through 14 - these identical lines are also found in Li et al. (2014). Even if the same methodology was used for both studies, it would be prudent to re-word the text in the methods.

Reply: The text has been re-phrased. Small fragments of the dried samples were fixed onto aluminum stubs with two-way adherent tabs, and allowed to dry overnight. They were sputter coated with gold for 2-3 minutes before being examined on a Philips XL-30 scanning electron microscope equipped with an accelerating voltage of 15kV at the State Key Laboratory of Marine Geology, Tongji University.

RC2: Page 4, line 21: there should be no "elution" step in this technique. Also line 22, how was precision evaluated? Repeat measurements of standards? Finally, how were these measurements standardized - using multi-element solutions or by measurement of geostandards? The methods are not sufficiently detailed here.

Reply: Sorry for my mistake. There is no “elution” step.

Analytical precision was monitored using the Chinese national carbonate standard, GBW04405. Conversion of measurements to the Vienna Peedee Belemnite (PDB) scale was performed using NBS-19 and NBS-18.

RC2: From page 5 onwards: these are not ferromangense crusts in the strict sense of the word. Perhaps "Mn- and Fe-oxide precipitates" is a better term.

Reply: thanks for your advice. It has been changed.

RC2: Page 5, line 10: I suggest re-phrasing this sentence.

Reply: This sentence has been re-phrased. Burrows can be classified in three categories.

RC2: Page 6, line 16-17: I suggest re-phrasing.

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

RC2: Page 6, line 24–25: you can’t lose a ratio (but you can lower it).

Reply: Thanks for reminding. It has been corrected.

RC2: Page 7 line 1: I suggest re-phrasing.

Reply: This sentence has been re-phrased. Positive correlation of δ13CPDB andδ18OPDB values of chalk and gray excrements (r = 0.91) reveals minor environmental influence on early lithification (Fig. 8) and bioturbation should be a critical factor

during the lithification.

RC2: Discussion in general: it would be nice if the authors could elaborate on why a decrease in carbonate saturation state (leading to dissolution) promotes lithification (as opposed to an increase in carbonate saturation state leading to precipitation).

Reply: Thanks for your comments. We have made efforts to explain the dissolution and reprecipitation of calcite to cement in revised manuscript. The dissolution of carbonate in the ocean is primarily controlled by the degree of pore water undersaturation with respect to the biogenic carbonate phase. Bioturbation could redistribute the organic matter around the burrow. Thus, oxidation of organic matter will accelerate the concentration of pore water CO2 leading to the undersaturation of calcites. Furthermore, thin Mn- and Fe oxide precipitates may prevent the rapid ion exchange between bottom water and pore water within carbonate rocks because larger grain surfaces and porosity of fine-grained poorly sorted carbonate oozes compared to Mn- and Fe oxide precipitates. The products of CaCO3 dissolution may trend to diffuse toward to the interior of carbonate rocks, and lead to an enhanced CO32- ion gradient in pore water profile and ultimately promoting the reprecipitation of calcites as cements around the burrows in carbonate rocks.

RC2: Also, while aerobic respiration decreases the local carbonate saturation state, sulfate reduction will increase it. Can the authors include a statement about oxygen penetration and the depth of sulfate reduction (even if it is simply based on the findings of others in similar settings)?

Reply: Thanks for your valuable comment. We cannot exclude the potential that sulfate reduction had happened in our chalk samples. This can be illustrated for the present study by examining the observed variations in ion content of the pore water. However, carbonate samples here were collected by TV-grabs bucket. It is too difficult to take the measurement of pore water chemistry. Several literatures support our discussion that pore-water CO2 by oxidation of organic matter is responsible for the carbonate dissolution. (Broecker and Peng 1982; Jahnke et al. 1994; Noé et al. 2006; Croizé et al. 2013). Metabolic activity may disintegration of organic material causing dissolution of carbonate and increasing the degree of supersaturation. In the condition that bioturbation processes succeed in redistribution of organic matter around the burrow, concentration of CO2 in pore water could increase. Although we could not elaborate the influence of sulfate reduction, aerobic respiration is reasonable to the decrease of carbonate saturation state.

RC2: Figure 1 Legend: The legend indicates that the red triangle is an inactive hydrothermal field while the caption indicates that it is active - this contradiction needs to be resolved. Also at the end it should read "red circle".

Reply: It has been corrected. The red circle is active hydrothermal field and the red triangle indicates inactive fields.

RC2: Figure 2e should have a scale bar.

Reply: The scale bar has been added. Scale bar of Figure 2e is 3cm. We make the estimation of burrow depths from the CT images which are usually of 6- 10cm penetrating into chalk.

RC2: Figure 4b: Contrary to the caption, it is difficult to see any enhanced of density in this image. Figure 4c and d: what do the different arrows represent? In a related vein, for Figures 4 b, c, and d in general - the areas of higher density are not obvious at all. Perhaps circle them or find some better way of highlighting these areas? Also could another presentation method be employed (e.g., an additional panel with contrast adjustments to better show the differences, perhaps shown alongside an un-modified version of the same figure for traceability)? Reply: Thanks for your advice. Both Fig. 3 and Fig. 4 have been changed. We pick the pixel values of the CT image to contrast the changes of density around burrows. It is showed by the line scan profiles that pixel values around the bioturbated area is higher than matrix indicating the localized enhancement of density around burrows.

Figure 5: This is not a statistical analysis in the sense that it does not provide any measure of confidence in the comparison between the two slopes (e.g. whether they can be considered different with 95% confidence). For this you would need to use something like the function "polyfit" in MATLAB (for example). No statistical evidence is presented that these slopes are indeed different... this is a major point as the paper hinges on the importance of burrowing effects.

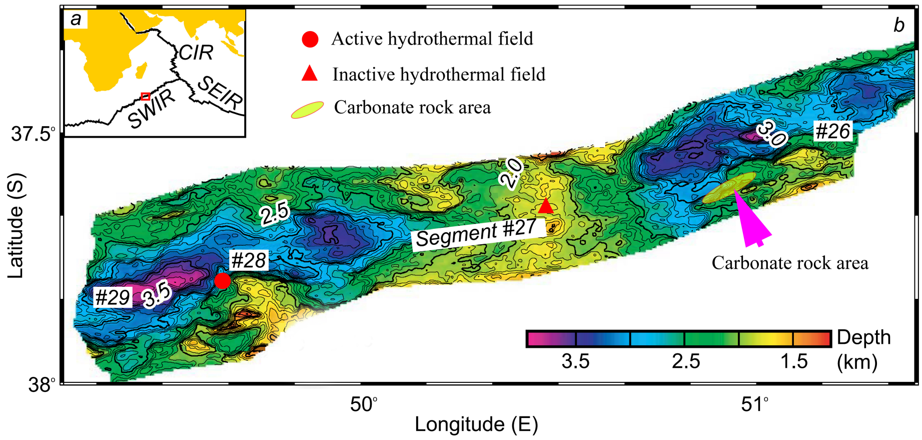
Reply: Thanks very much for your valuable suggestions. The figure has been revised. Difference can be showed with the function “polyfit” with 95% confidence intervals.

RC2: Figure 8: As a Kiel carbonate device was used, these are not "bulk" C isotope measurements, but C_carb measurements (same for oxygen isotopes). That is to say, organic matter in the sample is not measured during the analyses when a Kiel carbonate device is used, only carbonate - this should be clarified.

Reply: Sorry for the mistake. It has been corrected.

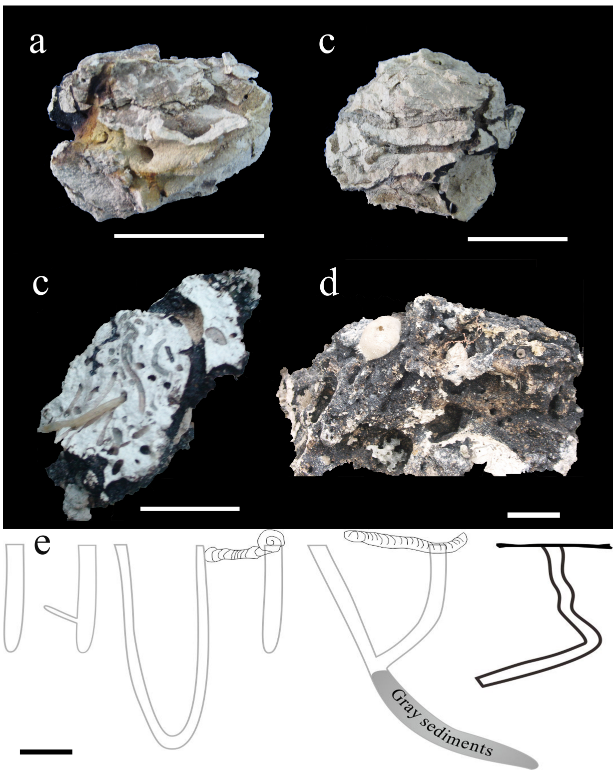
Please also note the supplement to this comment:
https://www.biogeosciences-discuss.net/bg-2018-46/bg-2018-46-AC1-supplement.pdf

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



a
CIR
SEIR
SWIR
b
Active hydrothermal field
Inactive hydrothermal field
Carbonate rock area
37.5°
38°
Latitude (S)
#26
3.0
2.0
2.5
Segment #27
#28
#29
3.5
Carbonate rock area
Depth
(km)
3.5
2.5
1.5
50°
51°
Longitude (E)

Fig. 1.



a
c
c
d
e
Gray sediments

Fig. 2.

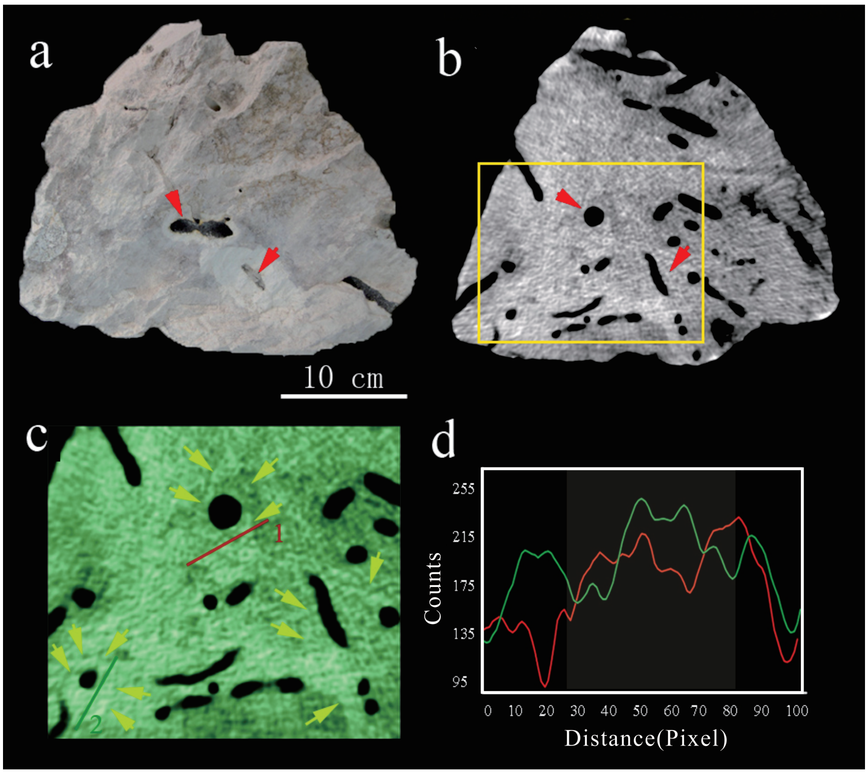

a
b
10 cm
c
1
2
d
Counts
255
215
175
135
95
0 10 20 30 40 50 60 70 80 90 100
Distance(Pixel)

Fig. 3.

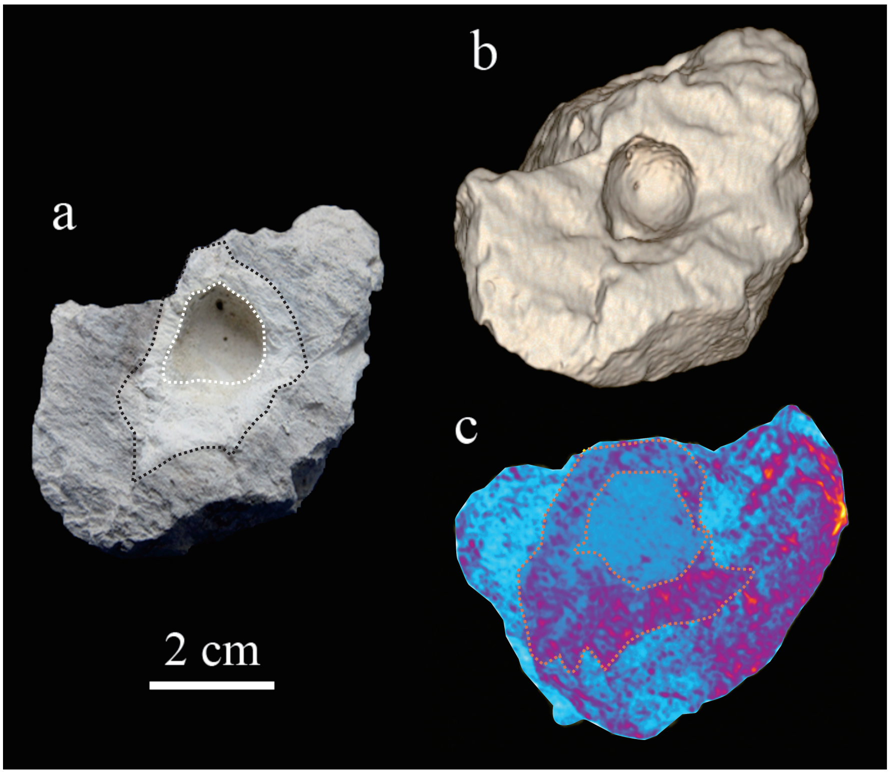
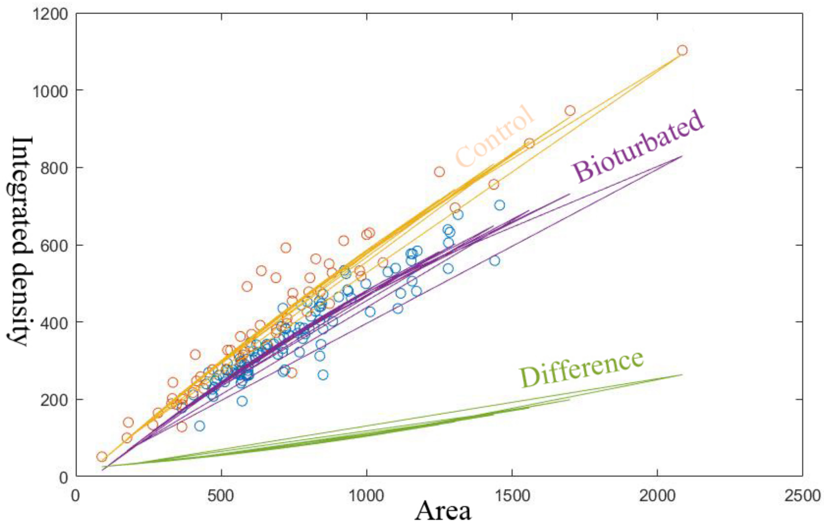
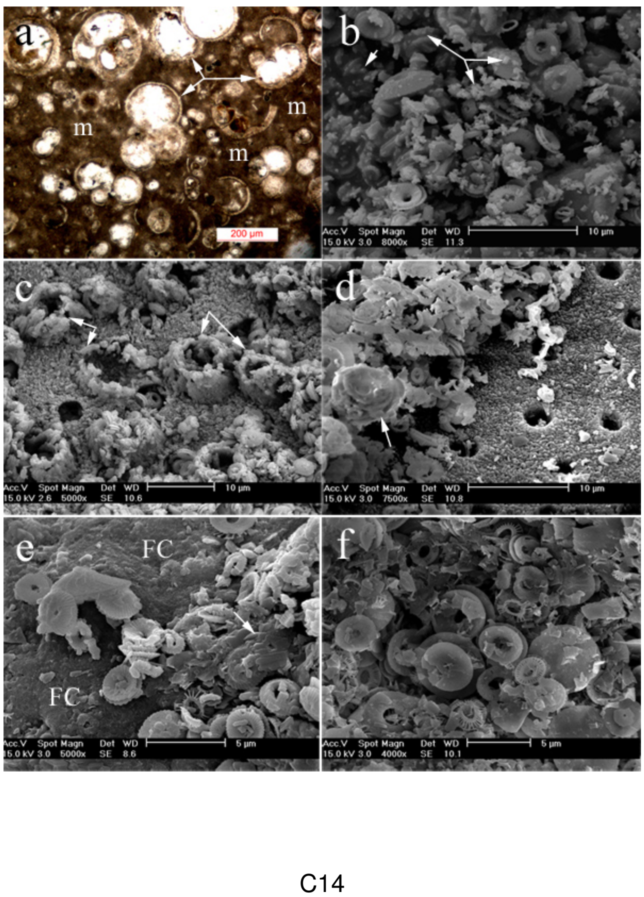

a
b
c
2 cm

Fig. 4.



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

Fig. 5.



a
b
c
d
e
f
m
m
m
FC
FC
200 µm
10 µm
10 µm
10 µm
5 µm
5 µm

Fig. 6.

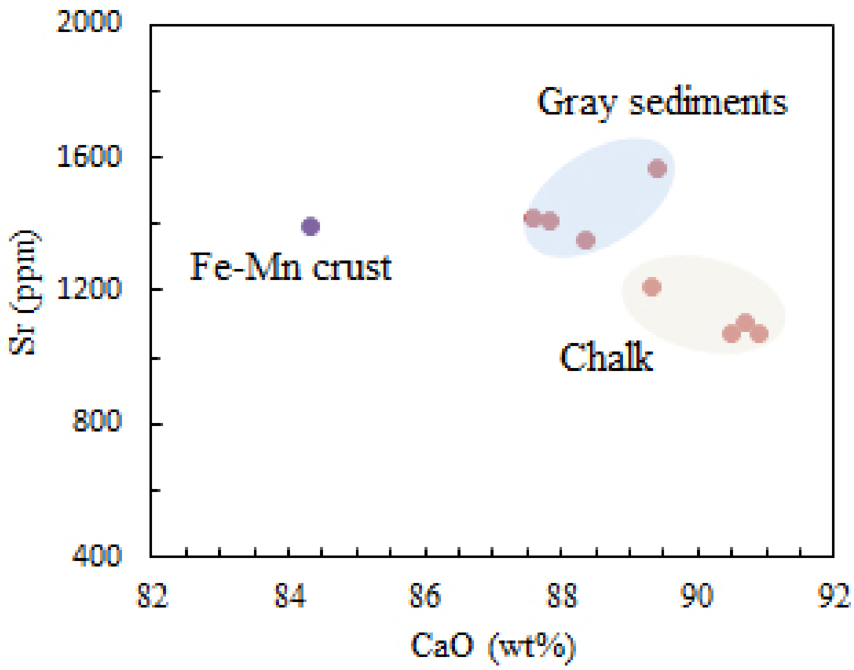

Gray sediments
Fe-Mn crust
Chalk
Sr (ppm)
CaO (wt%)
2000
1600
1200
800
400
82
84
86
88
90
92

Fig. 7.

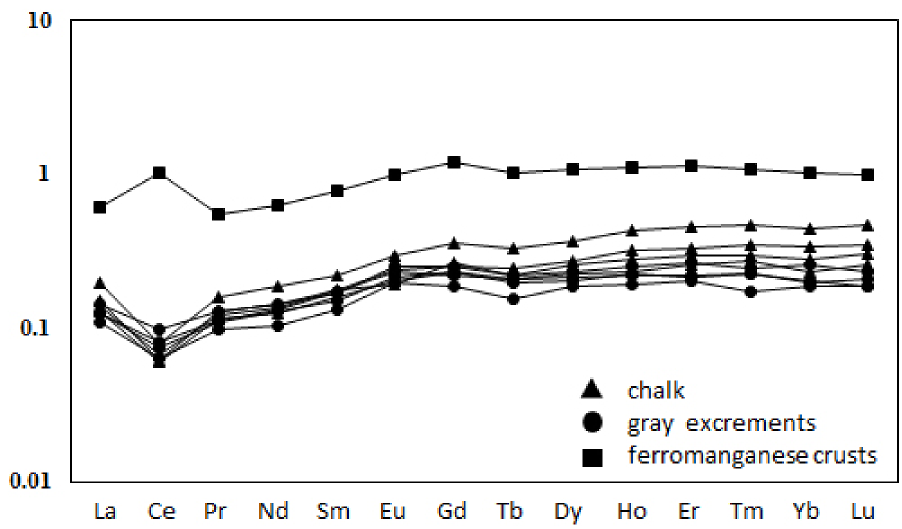

10
1
0.1
0.01
chalk
gray excrements
ferromanganese crusts
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Tm
Yb
Lu

Fig. 8.

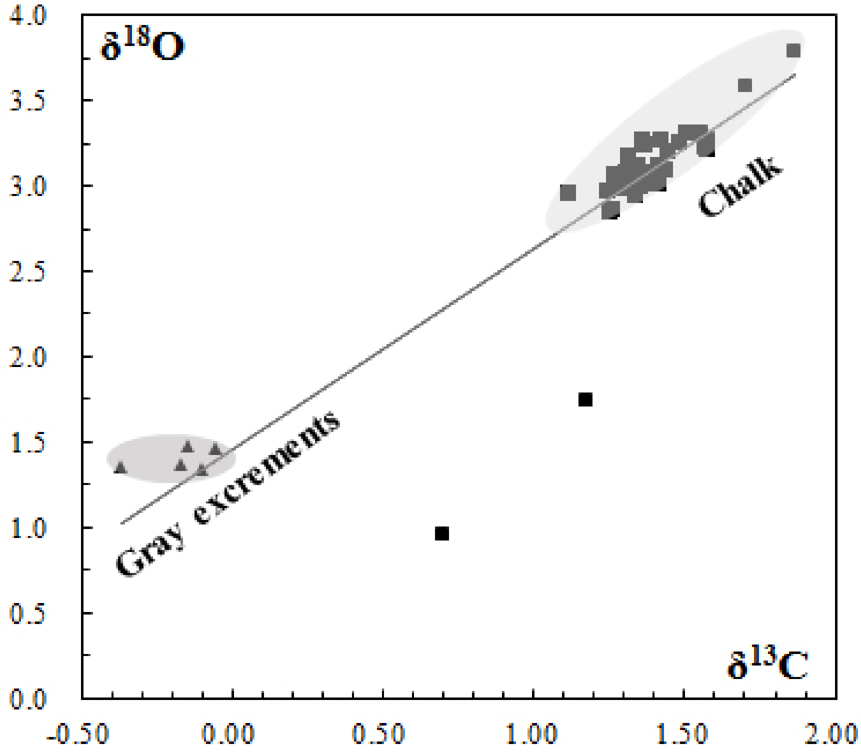

δ18O
δ13C
Chalk
Gray excrements
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.50
0.00
0.50
1.00
1.50
2.00

Fig. 9.

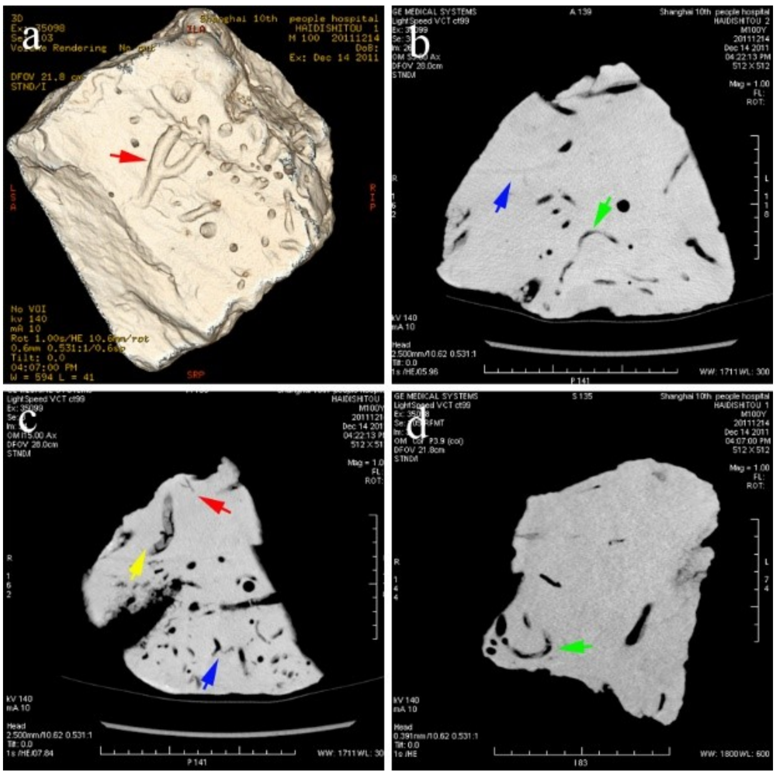

a
b
c
d

Fig. 10.