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Biogeosciences Discussions

Interactive comment on "Subseafloor basalts as fungal habitats" *by* M. Ivarsson

M. Ivarsson

magnus.ivarsson@nrm.se

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Reviewer comment: Abstract (1-2): here possibly many people would argue that we know and do a lot of research already about the deep biosphere. Please rephrase.

Author response: The sentence is rephrased as follows: "The oceanic crust is believed to host the largest potential habitat for microbial life on Earth, yet, still we lack substantial information about the abundance, diversity, and consequence of its biosphere. The last two decades have involved major research accomplishes within this field and a change in view of the ocean crust and its potential to harbour life."

Reviewer comment: (18): do you have evidence for that? Even if the observed structures are fossilized fungus this does not mean that the fungus are still active today. This is a logical false argument. Please rephrase.

Author response: The present sentence is as follows: "The results support a fungal presence in deep subseafloor basalts and indicate that such habitats were vital between 81 and 48 Ma, and probably still is". I agree that the results only show that fungi were present between 81-48 Ma and have, thus, removed the last phrase: ", and probably still is".

Reviewer comment: (19-20): here I miss a justification for this claim.

Author response: I agree and the sentence has been removed.

Reviewer comment: Introduction (21) the subseafloor basalts are with a few exceptions – change "are" to "is".

Author response: "Are" is changed to "is".

Reviewer comment: (22) remove "basically", change "from a" to "from the".

Author response: "Basically" has been removed and "from a" has been changed to "from the".

Reviewer comment: (24) I think there is still discussion if the structures described by Furnes and his co-workers are actually ichnofossils or not. In this respect it would be also appropriate if you could cite some work maybe discussing non biological origin of such textures. Also it would be appropriate to cite studies not published by the group around Furnes et al.

Author response: I have extended the part on ichnofossils and included references that discuss non-biological explanations. I have also included new references that are not part of the group around Furnes et al such as Lepot et al., 2009 and Walton 2008. The extended and rephrased section is as follows: "The biosphere of the subseafloor basalts is with a few exceptions (Orcutt et al. 2010; Mason et al., 2010) known from the fossil record. The best known fossil structures are granular and tubular ichnofossils in volcanic glass (Furnes et al., 2008; Staudigel et al., 2008; McLoughlin 2009). The production of such structures by biological dissolution has been extensively described

in various reports (Thorseth et al., 1992, 1995; Staudigel et al., 2008; McLoughlin et al., 2009, 2010) but still today the microorganisms responsible for the production of these structures have not yet been found and characterized. Abiotic alternatives have been proposed, i.e. several authors have commented upon the resemblance between ichnofossils and ambient inclusion trails (AITs) (Staudigel et al., 2008; Walton, 2008), which is an abiotic process where a mineral grain is propelled through a substrate by elevated fluid pressure leaving a hollow tube behind. Lepot et al (2009) described a process in which AITs in basalts were formed by chemical dissolution of quartz by migrating carbonaceous particles, thus the formation of ichnofossils in volcanic glass is still debated."

Reviewer comment: Page 2279 (9): Please provide a reference for the staining. Please discuss if check if this could be an artefact - I am always a bit worried that all dye which is not bound to organic matter is removed prior to fluorescent detection and not retained e.g. by capillary forces in small cracks of the sample.

Author response: The reference for the staining is: Ivarsson, M., Bengtson, S., Belivanova, V., Stampanoni, M., Marone, F., and Tehler, A.: Fossilized fungi in subseafloor Eocene basalts, Geology, 40, 163-166, 2012. The staining procedure is described in that paper. Precautions were made to exclude native fluorescence and the samples were carefully washed with distilled water prior to examination in fluorescence microscopy. The analyses were repeated on several samples and it was clear that the dye bound to the cell walls and that it was not remains of dye in cracks that was detected.

Reviewer comment: Page 2282 (3): please provide arguments that it is not a alteration rind.

Author response: The sentence where I state that the crusts not are alteration rinds is removed from the result section. Such conclusions should not be included in the Result section. Instead I discuss the crusts and why they seem to be more of precipi-

tations/biofilms in the Discussion section 4.3. In that section do I compare the crusts to palagonitization and the alteration of basalts and conclude that they differ somewhat. The main differences are that palagonitization produce parallel alteration rinds while the crusts in these samples are irregular and contain incorporated structures such as the large body-like structures. Another argument is that the composition of the crusts does not correspond to the known mineralogy of palagonite and secondary mineralisations formed during palagonitization.

Reviewer comment: Page 2290 (5-15): how can you be sure that the element budgets you describe here are not derived from an ex-situ source. If you have clays in your structures these clays can adsorb all you want from an ex-situ source. Do you have any indication on fluid flow? Also I wonder why you did not attempt to mineralogically characterize your clays (e.g. by TEM).

Author response: It is true that clays adsorb organics, and hydrothermal systems are known to contain organics in the fluids so theoretically organic molecules could have been adsorbed by the clays. Prior to the carbonate formation fluids probably circulated the cracks and could have been in contact with the clays. However, previous analyses of clays, palagonite, iron oxides and various amorphous phases not associated with microfossils in these samples have shown no or negligible enrichment of carbon (see references below*). Carbon is only detected in structures that have been interpreted morphologically as biological remains such as fossilized hyphae or, for example, the outer membranes of the larger body-like structures discussed in this manuscript. Seeing this behaviour of carbon repeatedly throughout the samples it is most likely, in my opinion, that the carbon represents decomposed remains of the actual microorganisms, and not carbon molecules adsorbed by the clay phases or the result of diagenetic processes. We have also, lately, found identical fossilized mycelium in open vesicles where the microfossils not are preserved in a carbonate phase. These microfossils have been exposed to decomposing agents such as fluids, bacteria etc and they contain no carbon at all. Thus, the carbon molecules are obviously a result of preservation.

I have tried to identify the clays mineralogically, mostly with raman, without success. The reason for this is probably poor crystallinity. TEM has not been used since I don′t have access to such instruments at the moment. XRD has been used on similar samples in open cavities with some success. Those analyses indicated the presence of a montmorillonite phase. This will be included in a manuscript in preparation.

* Ivarsson, M., Lausmaa, J., Lindblom, S., Broman, C. and Holm, N.G. (2008) Fossilized microorganisms from the Emperor Seamounts: implications for the search for a sub-surface fossil record on Earth and Mars. Astrobiology 8, 1139-1157. Ivarsson, M. and Holm, N.G. (2008) Microbial colonization of various habitable niches during alteration of oceanic crust. In Links between Geological Processes, Microbial Activities and Evolution of Life (eds. Dilek, Y., Furnes, H. and Muehlenbachs, K.). Springer Publications. 69-111.

Ivarsson, M., Gehör, S. and Holm, N.G. (2008) Micro-scale variations of iron isotopes in fossilized microorganisms. International Journal of Astrobiology 7, 93-106.

Ivarsson, M., Lindblom, S., Broman, C. and Holm, N.G. (2008). Fossilized microorganisms associated with zeolite-carbonate interfaces in sub-seafloor hydrothermal environments. Geobiology 6, 155-170.

Ivarsson, M., Broman, C. and Holm, N.G. (2011) Chromite oxidation by manganese oxides in subseafloor basalts and the presence of putative fossilized microorganisms. Geochemical Transactions 12:5

Reviewer comment: Figures: I miss a overview picture over a bigger area of the thin sections.

Author response: An overview of a larger area can definitely be included.

Interactive comment on Biogeosciences Discuss., 9, 2277, 2012.