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Biogeosciences Discussions

Interactive comment on "Experimental mineralization of crustacean eggs leads to surprising tissue conservation: new implications for the fossilization of Precambrian-Cambrian embryos" *by* D. Hippler et al.

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Answers to the referee comments:

Dear referees and dear editor,

We would like to thank the two referees for the careful and critical reading of the manuscript (BGD: ms-nr-2011-434) documenting phosphatization experiments of crustacean eggs to improve our understanding about preservational processes of Precambrian/Cambrian embryo fossils.

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We were pleased that referee 1 considered the manuscript as an important contribution to the discipline of experimental taphonomy. Following his comment, we included the conclusions of the recent Huldtgren et al. paper (Science, v. 234, p. 1696-1699), which was published shortly after we had submitted our manuscript. In this paper, Huldtgren et al. (2011) questioned recent interpretations of globular microfossils (e.g. Chen et al., 2009; Bailey et al., 2007), because they were able to demonstrate that the developmental patterns of most globular fossils have features incompatible with both multicellular metazoans embryos as well as giant bacteria. Based on their findings, they concluded that these fossils were neither animals nor embryos, showing highest affinity within nonmetazoan holozoans or even more distant eukaryote branches. However, this does not have a major impact on our manuscript, because Cambrian metazoan embryos are undoubted and all phosphatic Orsten-type preservations, both of metazoan embryos as well of dubious globular fossils and acritarchs, represent an unusual phosphatization at cellular level that requires a taphonomic explanation.

Concerning the comments of referee 2:

In our contribution, we report a succession of well-defined simplified phosphatization experiments on eggs of the parthenogenetic crayfish Procambarus fallax f. virginalis, in order to elucidate alternative scenarios for embryo fossilization. We intentionally followed a reductionist approach with the main goal to break the complex natural conditions down to an inorganic two-component system consisting of calcite and phosphoric acid. These two components represented the environment for the co-existing organic material. We wanted to create a supersaturated environment for mineralization to occur, in order to investigate the conditions that promote both the mineralization of invertebrate eggs as well as decay and preservation of organic tissue over a prolonged period of time under non-marine laboratory conditions. At this early stage of taphonomic understanding of Orsten-type preservation it was not yet our intention to approximate natural environments of Cambrian seawater or porewater.

Referee 2 claimed that phosphate precipitation in such high supersaturation levels would be pervasive and not selectively focused on embryos. However, our results show that crayfish eggs were selectively mineralized as a combination of fine-grained calcite and brushite completely replacing the outer membrane. Notably, the observed mineralization mimics the initial P concentration in untreated embryos. Mineralization is highest around the germ area (see new Fig. 5e-g and 5m-n) and continuous along the former endochorional envelope (see new Fig. 5a and 5i-j), where it is also more intense at some localized areas (new Fig. 5a-b). Incipient mineralization of the inner organic tissue (within the embryonic tissue of the germ area (new Fig. 5j-l) and the yolk (Fig. 5f-h)) was also observed.

We have re-written chapter "4.3 Preservation of the spherical egg-morphology". However, we think that it should be acceptable to provide hypotheses how a supply of heat might assist the preservation and fossilization of yolk-bearing eggs and embryos, larvae and small animals. We have mentioned that this is not a prerequisite for preservation, because spherically preserved eggs and embryos are rare in the fossil record, whereas most fossils show collapsed structures (Fig. 1a-c). If eggs and embryos are preserved at all in Cambrian rock sequences only 9.5 % of them at best indicate a pristine external preservation without collapse structures.

We have changed the statement that the endochorional envelope was not preserved into that it was replicated by a thin rind of fine-grained calcite and brushite. This is documented in several figures (Fig. 3, new Fig. 5, and Fig. 6 (= original Fig. 5)).

The clarity of the method section and the corresponding Table 1 has been improved, as well as experiment numbers (e.g. E4.5, etc) have been added for the illustrated specimens (Fig. 1 to Fig. 6).

The pH-value was not monitored during the experiments. We considered this an interesting aspect, however in such experiments pH determinations would be most valuable on the mm- to μm-scale. Therefore the application of micro probes could be desirable enabling the investigation of the micro-conditions around the embryo. This might be an approach for further studies.

Experiment E2a was performed under an N2-atmosphere as stated correctly in the text. The mistake in Table 1 has been corrected.

Scanning electron microscopy EDX analyses were not carried out on all specimens. It is now clarified in the revised text, where it was applied in order to verify the mineralogical composition (calcite vs. brushite, see new Fig. 5d and Fig. 5o).

Comment page 12054: The term was adjusted.

The reference Xiao and Knoll (1999, Lethaia) has been added.

Did mineralization occur in oxygenated experimental conditions? Subtle mineralization of the outer membrane and collapse structures were evident in experiment E1b after 6 days. However, this experiment was stopped after 6 days and was not followed up, because focus was set on the experiments under an N2-atmosphere.

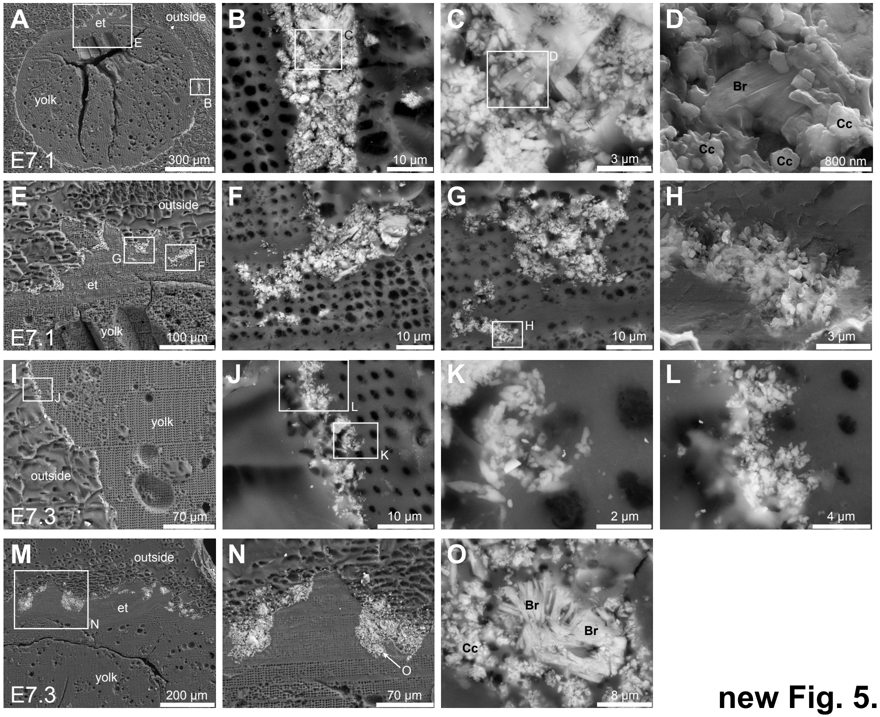
Comment page 12061: Experiment numbers were included.

Comment page 12063: The typing error was replaced.

Comment Fig. 5 (original manuscript): New high-resolution backscattered electron (BSE) images (see Fig. 5 new) were included in the revised version illustrating the crystal texture, size and distribution around and within the mineralized embryo.

Figure caption – new Fig. 5: (a-o) Backscattered electron (BSE) images and close-up views of sliced post-experimental crayfish specimens of E7.1 and E7.3 illustrating crystal texture, size and distribution of the mineralization around and within the mineralized embryos (Scale bars given for each image; Br = brushite; Cc = calcite; et = embryonic tissue of the germ area).

Interactive comment on Biogeosciences Discuss., 8, 12051, 2011.



new Fig. 5.

Fig. 1. (a-o) Backscattered electron (BSE) images and close-up views of sliced post-experimental crayfish specimens of E7.1 and E7.3 illustrating crystal texture, size and distribution of the mineralization a

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