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Interactive comment on "Laminae type and possible mechanisms for the formation of laminated sediments in the Shaban Deep, northern Red Sea" *by* I. A. Seeberg-Elverfeldt et al.

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Final response to referees #1 and #2 concerning manuscript OSD-2005-0008

My co-authors and I would like to express our thanks to the reviewers for their constructive criticism on the manuscript.

Below, we address each to the issues raised by the referees.

Referee #1:

Seawater-brine interface (SBI) influence on the sediment fabric:

Referee #1 raised the question of whether the SBI may exert any influence on the sediment fabric type or whether the sediments would still look the same if no SBI would exist. We believe that the presence of the SBI is not promoting lamina formation but

particle concentration and preservation. The type of aggregation of sinking particles seems to determine the kind of fabric we find within the sediment: for example, if diatoms are sinking in aggregates we find the pocket-like structure and if diatoms sink in mats we have alternating layers. We therefore think that the brine itself is important for the preservation of the material but the role of the SBI on laminae formation is unclear and most probably very small. Because of the importance of this issue we have included a comment within the discussion of our manuscript. In our manuscript we cited the work by Elisabetta Erba (1991) which is, to the best of our knowledge, the only work available that deals with the formation of laminated sediments within brine-filled basins in the Mediterranean Sea.

Bacterial involvement in the formation of laminae:

Referee #1 was wondering about our statement that we found no bacterial involvement in the formation and asked if we had done any SEM study on untreated material like Erba had done in her paper. We would like to point out that the sediment fabric in our cores from the Red Sea shows no resemblance with the sediments from the Mediterranean Sea. Although extensive SEM work was carried out within the scope of my PhD research, no pellicle structure could be found that could be indicative of bacterial involvement. That leads us to believe that bacteria take no part in the formation of the laminae. It is very likely that bacteria may be present within the Shaban Deep sediments though not recognizable in the SEM (probably, a topic for future biomarker studies). A working group at the University of Regensburg, Germany is investigating the bacteria associated with the seawater -brine interface. So far they found a new group of bacteria within the Kebrit Deep, another brine-filled basin in the northern Red Sea which is also sufidic. They also investigated the seawater-brine interface of the Shaban Deep and also found new bacteria there (Antunes et al., 2003, Extremophiles, 7, p. 29-34). Research on this topic is very much in its early stages, and as far as we know no data exist about bacteria within the sediments of the Shaban Deep.

Comparison to Black Sea sediments (Pilskaln & Pike, 2001):

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Pilskaln and Pike (2001) investigated the fluff layer that can be found on top of Holocene laminated sediments in the Black Sea and state that this fluff layer “acts as a geochemical transition layer within which all sedimentary particles are hydraulically sorted and particles subject to dissolution or organized remineralization are altered prior to accumulation”. In contrast to the Black Sea sediments, diatom frustules in the very surface sediments of the Shaban Deep are intact and not “highly etched” as was described by Pilskaln and Pike (2001) for the Black Sea. In addition, very fragile species could be found within these sediments which were not preserved in non-brine sediments of other locations within the Red Sea (Seeberg-Elverfeldt et al., 2004, Marine Micropaleontology, 51, p. 193-211). Moreover, the species composition of the diatom assemblage in the surface sediments within the Shaban Deep showed great similarities with the overlying plankton samples (Seeberg-Elverfeldt et al., 2004, Marine Micropaleontology, 51, p. 193-211). Thus, dissolution of diatoms in the Shaban Deep seems not as important as within the fluff layer of Black Sea sediments. Our observations lead us to believe that the sediment-water geochemical environment in the Shaban Deep must be very different than the one described for the Black Sea and therefore not directly comparable.

Referee #2:

Shaban Deep lamina model and modification for elsewhere:

Referee #2 wondered how our presented model of lamina formation must be modified to explain the occurrence of laminated sediments elsewhere. The lamina formation model presented in our article was especially developed for the unique environment of the Shaban Deep, northern Red Sea, and includes the results of our sediment and water column investigations (Seeberg-Elverfeldt et al., 2004, Marine Micropaleontology, 51, p. 193-211; Seeberg-Elverfeldt et al., 2004, Marine Geology, 209, p. 279-301) as well as information from earlier studies. Evidently, research on laminated sediments from brine-filled basins is in its early stages of development, and more and more brine-filled basins are being discovered and their novelty in biogeochemical cycles is being

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assessed. To the best of our knowledge the model we present in our article is the first one that attempts to analyze in detail the possible mechanisms of lamina formation in the Shaban Deep. To answer ref. 2 question: We believe that the seawater-brine interface (SBI) of any brine-filled basin can act in the same way as we described for the Shaban Deep. However, it seems important that to understand the actual laminae formation process, the material involved in the formation needs to be considered. Diatoms in mats or aggregates are pretty light so that they can accumulate at the seawater-brine interface (SBI) first before sinking to the bottom. Heavier material like large foraminifers or others will probably sink through the interface without accumulating first. Within anoxic basins that are not filled with high-saline water and where a pronounced SBI is not developed, particles should easily sink through the water column to the basin floor, as has been described in several synoptic models developed for southern California margin basins (see works of Drs. Kemp, Pike, Grimm, Lange, etc). However, the geochemical environment of the sediment-water interface will vary among geographical sites, imparting a more localized signal for each case.

Agglutinated foraminifers:

Referee #2 was also wondering if there is an already existing technique to investigate if agglutinated foraminifers were present within the sediment. We do not have an answer to that question. We used the accumulations of silt particles as possible indicators of remains of agglutinated foraminifers, following ideas put forward by other researchers when studying anoxic laminated sediments from the Guaymas and Santa Barbara basins, and within the Peruvian upwelling sediments. Although Berggren and Boersma (1969) found low abundances of benthic foraminifers (including agglutinated species) within Red Sea brine cores, preserved shells of agglutinated foraminifers were not observed within any of our investigated sediments from the Red Sea.

Interactive comment on Ocean Science Discussions, 2, 331, 2005.