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Biogeosciences Discussions

Interactive comment on "Carbonate sedimentation and effects of eutrophication observed at the Kališta subaquatic springs in Lake Ohrid (Macedonia)" *by* M. Matter et al.

B. Valero-Garces (Referee)

blas@ipe.csic.es

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General Comments. The paper by M. Matter and collaborators on the carbonate sedimentation at the Kalista spring area in Lake Ohrid (Macedonia and Albania) provides new and interesting data on recent carbonate formation in lacustrine littoral settings with high spring input. The methodology is sound and included water chemistry, sediment traps, transects of short cores, and side-scan imaging. The study site is extremely interesting from a sedimentological, ecological and societal point of view (the oldest lake in Europe, a target for ICDP project, a large water reservoir). Two major conclusions of the paper are that calcite formation due to spring activity is a major

contribution of littoral carbonate productivity (and not so much to distal areas) and that recent changes in sedimentation patterns are likely caused by eutrophication and human impact. The variety of calcite crystal morphologies and the likely relation with cyanobacteria is well documented in the paper. Although is not the focus of the study I miss a more detailed description of the sedimentary facies and the depositional processes that could help to understand better the dynamics of the littoral environments. The comparison with previous sediment cores studies in the lake (although from distal zones) could also help to pinpoint them main features of spring-affected versus non-spring littoral zones. The hypothesis of eutrophication as the main cause for changes in littoral sedimentation in the last 50 years will need further testing.

Detailed comments Introduction. Water chemistry data seem to be available since 2004 but only three surveys form 2007 are included in table 1. Is there any information on seasonal changes in water chemistry of the springs?. Those could be interesting to test if maximum carbonate productivity associated to bacterial activity (summer) is also related to changes in chemical composition. Changes in carbonate productivity during the Holocene have occurred in the distal areas of Lake Ohrid, which suggest lower ion concentration (dilution) or decreased spring activity. Although the time scale of these changes is centennial or decadal, the same mechanisms could play a role in changes during the last 50 years in littoral zones. Any data on decadal changes of spring activity in the area?. One of the goals of the paper is to investigate whether spring sedimentation changed through time, although the uncertainties of the age model hampered clear conclusions.

Methods. The methodology is sound and very comprehensive. Grain size analyses are mentioned but I guess they are used mostly to define the facies since no grain size profiles are included in the paper.

Results: Sediment traps. I wonder why that particular period in May was chosen for the deployment of the sediment traps. Most carbonate formation in the lake epilimnion seems to happen in summer and it would have been interesting to be able to compare littoral sediment traps with distal sediment traps during the same periods. Are they confident that May data are representative of maximum carbonate productivity?. How those sediment rates and fluxes compare with distal areas?. A more detailed comparison of the SEM/EDX data with a similar study of distal carbonates could also help to evaluate the contribution of littoral, spring-generated carbonates to distal areas in the lake (that is likely very small). The pictures are pretty convincing of cyanobacterial activity as the main origin for some crystals. However, since macrophyte patches are common in the spring area I wonder if there are also any charophytes or some of the macrophytes could become calcite-encrusted and also contribute to carbonate sedimentation in the littoral zone.

Sediment Cores Lithologies. Short cores show a large depositional variability in the littoral zone and even more in the spring area. The side scan sonar also illustrates the presence of macrophyte patches, bedrock, spring and sediment covered surfaces. This is common in lakes and to be expected in Lake Ohrid. Although the lithology is not very diverse, more details could be given in the facies. For example, there is an indication of "coarser layers" with lower carbonate content (and higher Fe counts) and also gravel beds in the lower part of some of the cores. Have those layers more siliciclastic materials?, could they represent input from run off?. They seem to be only in unit L, which would suggest a different (more energetic) depositional environment. However, in core 13, the lower part of unit T has a similar color (lighter) and increase in Fe as one of those coarser layers (around 15-18 cm). So I wonder if currents, wave and reworking processes are of significant importance in the upper unit T, too. This is important since these processes could be more significant in total sedimentation rate than just calcite precipitation from springs. I think it would be useful to better characterize the different facies in the cores, al least the upper unit T. Core 20 is clearly different and the carbonate range is very large (9 – 67%). It is difficult to see these differences in Figure 7 and a change in scale could help.

Geochemical signatures. Si seems to be mostly related to diatom content, but smear

slides could help to check for the presence of clay minerals or other silicates. What is the reason for the increase in Fe in the upper unit?. Increase sediment delivery to the littoral zone related to run off ?, iron oxides?. A similar increase occurred in core 13 associated to coarser material, so the mechanisms could be similar. A few mineralogical observations (smear slides) or DRX analyses could help.

Particles. Is core 20 representative of distal environments of the lake?. Most of calcite crystals in core 20 come from littoral areas by downslope processes?,. How about direct calcite precipitation in the epilimnion?. Diatoms seem to be almost absent in unit L and dissolution of the frustules should be taken into consideration. In some alkaline lakes, they can be present in recent sediments, but disappear deeper in the core. Changes in past alkalinity conditions during deposition of units T and L could also have an impact on diatom preservation. Higher diatom productivity could be related to increase nutrient and eutrophication, but other possibilities should be explored. I understand this requires a diatom study and this is out of the main focus of the paper.

Core correlations Lithological units are not easy to correlate among the cores and they show a large variability. Unit T is thicker in some of the sites in the spring zone, (5) but also in the transitional cores 14 and 8. The correlation with the distal cores is even more difficult. The increase in organic matter in core 20 (unless it is at about 50 cm depth) is difficult to point. In any case, I think showing this variability is an interesting aspect of the paper. How do these cores relate to other cores taken in the lake?. I think this section could be expanded a little bit, including a short comparison with distal cores taken in previous campaigns and already published.

Age Model. The authors have tried to come up with a good age model for the sediments and this is another example of how difficult is to date littoral lacustrine cores. I agree the 1955 is a good basal date for unit T and most likely an erosional or unconformity surface is the limit with unit L. Since it is not clear the nature of the boundary the age of the basal sediments of unit T could be different in the different locations, accounting for some of the differences in sediment thickness. As the authors state, sedimentation in upper unit T could be non-continuous and other processes (reworking, waves, currents, littoral transport) could be in place. All these uncertainties make very difficult to calculate sedimentation rates. I still believe the exercise is worth it, but not much should be made of the numbers obtained.

Discussion The fact that cyanobacteria seem to be the most likely candidate for biological enhancement of calcite precipitation is a significant finding of the paper. Even with the age uncertainties, the higher sedimentation rate in littoral spring zones compared to distal areas is well documented. However, there are no data of sedimentation rates in other littoral zones not affected by spring discharge, although it is said that rates higher in spring than in non-spring shallow areas. I think this part of the discussion could be expanded including some data from the Vogel et al. 2010 and Matzinger et al. 2006 cores.

The authors claim that the depositional change between unit L and T after 1955 is mostly associated to increased eutrophication of the lake. Although I agree human impact in the watershed is likely the culprit, more discussion would be needed to support this hypothesis. Increase in TOC and diatoms suggest higher organic productivity (although the caveat with diatom preservation has to be considered too). Why Fe increases in the upper unit?, soil erosion?, What is the contribution of these processes to littoral sedimentation?, do they have an impact on spring evolution?. Is the decrease in TIC a measurement of increased eutrophication in the lake?. Actually, in some of the distal cores (Matzinger et al., 2007), a slightly increase in TIC occur at the top of the cores (with TOC, and TP). Should we expect stronger indications of eutrophication in the littoral zone (closer to the source) and weaker closer to the springs (higher input of non-polluted waters) ?, Are similar trends described in other cores in non-spring areas?. Besides the increased in nutrient to the lake since 1955, the hydrological change caused by the diversion of the river Sateska may be quite significant in terms of suspended sediment load. Could that be a reason for the Fe increase in the upper unit?. Although unlikely, this possibility could be explored since it would have a clear impact

in sedimentation rates. Changes in lake chemistry (dilution, lower alkalinity) caused by the increased river inflow could also account for better diatom preservation

Figures. It is somehow confusing that different cores are used in Fig. 6 and 7 to show sedimentological properties and geochemical properties. I would add a small map with the cores location in those figures.

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