Referee Comments by M. Strasser, MARUM, Univ. Bremen, June 2010

of Discussion Paper entitled:

Stratigraphic analysis of lake level fluctuations in Lake Ohrid: an integration of high resolution hydro-acoustic data and sediment cores

by:

K. Lindhorst et al.,

submitted for publication in Biogiosciences:

This clearly and concisely written paper presents excellent new results from high-resolution acoustic data (parametric echosounder, multibeam, sidescan scan sonar and multichannel seismic) and core data (lithology, geochemistry and chronology) reconstructing past lake level changes in Lake Ohrid. The presented data and inferred lake level reconstructions allow the authors to convincingly link their findings to changing paleoclimate conditions and to discuss effects of lake level changes on the expansion of endemic species within ancient Lake Ohrid, which is known for its high degree of endemic diversity. This study thus makes some important new advancement on understanding and quantifying past hydrologic conditions of Lake Ohrid, how it related to paleoclimate and its effect on biodiversity. I thus think, the paper addresses relevant scientific questions within the scope of the special issue on Lake Ohrid in *Biogioscience*.

The data presented are novel, the scientific methods used valid and clearly outlined, and results are sufficient to support the interpretation and substantial conclusion. The overall presentation of the study is well structured, clear and written in a fluent and precise English language. Both abstract and title provide a concise and complete summary and clearly reflect the content of paper. The authors give proper credit to related work and the number and quality of references is appropriate. Figures and Tables presented are in excellent quality.

Having said this generally very positive evaluation, I do have, however, several comments concerning details of data description and inferred interpretation (see specific comments #1-5). In particular, what I have missed is a more objective discussion about uncertainties and possible alternative interpretation. Also, I challenge the authors interpretation of one of their seismic units and lithological facies (seismic unit G, lithofacies II). In fact, I think that a more thoughtful interpretation/discussion on this may allow the author to elaborated more on the early stage of the last glacial period providing additional strength to the paper. I do not think that a substantial amount of additional work is needed here; yet the authors may want to demonstrate that it is their careful evaluation of their data along with discussion of uncertainties and alternative interpretation that make the new scientific advancement of this paper to be sound and of high scientific standard.

In conclusion, I strongly recommend that this paper merits publication in *Biogioscience* after revision. Below, I have listed some specific comments and suggestions that should be addressed. There are also a number of minor comments, corrections and suggestions for improvement that I have listed line by line in the technical comments below.

Michi Strasser

Specific comments:

Comment # 1: Quantification/Discussion of uncertainties in lake level reconstruction:

On Page 3653: Lines 27ff the objective of the study is put into the context of: " in order to improve our knowledge on how lake level fluctuations influence biodiversity and speciation in lakes, uncertainties in magnitude and timing of lake level changes need to be quantified"

As much as I agree with this statement, I cannot see an in-depth discussion presented in this manuscript about uncertainties of the reconstructed lake level position. In contrast, the two main lake level lowstands reconstructed on the basis of the presented data from Ohrid Bay are given with different numbers throughout the text (e.g. as ca 60 and 35 m below present water level on page 3652, line 7, or as 30 and 55 m in Figure 8). Whereas this is a tiny detail, I also was wondering a bit about other influences that may add uncertainties to lake level reconstruction. What is known about the subsidence rate related to the tectonically active graben system? Would it affect significantly lake level reconstruction back to the penultimate glacial period?).

Furthermore, it would be interesting to learn a bit more about the Northern shore area as briefly introduced on page 3669 Lines 19-22. I would expect that the reconstructed lake level lowstands should have also affected this area by means of either similar terrace formations or at least facies shifts. Additional information from there may help to constrain uncertainties in paleo-lake level position as inferred from the Ohrid Bay area and make sure that local subsidence by tectonic movements does not bias inferred absolute values of paleo lake level lowstands.

I do not think that this requires substantial additional work, but rather think (i) being consistent with presented absolute number, and (ii) briefly discussing their uncertainty would add strength to this study and inferred conclusion.

Comment # 2: Interpretation of seismic unit G / lithofacies II and the concept of sequence stratigraphy

I challenge the interpretation of seismic unit G and Lithofacies II. Throughout the text, seismic Unit G and H are somewhat kept together as one "sedimentary sequence" that discordantly covers seismic unit F on the upper terrace and E on the lower terrace (e.g. Page 3661 Lines 5 – 17) and that is interpreted as one High Stand System Tract (HST 9; Figure 4, Table 3 and Page 3668 Lines 13-15). However, seismic reflections, in particular within unit G, clearly onlap onto the steep basinward slope of the upper terrace, suggesting that the lower part of unit G overlying the lower terrace may not be correlative to the lower part of unit G overlying the upper terrace. This may also be inferred from the significant differences in age and thickness of the lower part of lithofacies II in cores Co1200 and Co1201. The thickness of lithofacies II in Core Co1200 recovered at the upper terrace is only ~ 165cm and it appears that the lower part (including tephra layers C-20 and X5) is missing compared to core Co1202, where lithofacies II is ~280cm thick and covers a longer depositional history ranging back to at least 105ka, likely more. Therefore, I suspect that the lake level reconstruction presented in Figure 8 and described on page 3667 Lines 3-9, in fact, might be missing part of the story for the first part of the last glacial period, where lake level might have been lower or at similar position as during early MIS5 for quite some time and transgression and flooding of the upper terrace may only have occurred during the second part of the last glacial period (as indicated by the stratigraphic hiatus represented by gravel and mollusk shells at the boundary between lithofacies III and II in core Co1200 (page 3662 lines 23-24)).

Hence, I suggest evolving a bit more on this period (MIS 4, 3 and 2), discussing alternative interpretation as outlined above and possibly also including an additional sketch to figure 8 (i.e. between Figure 8c and 8d).

This may also be considered with respect to the general concept of sequence stratigraphy (e.g. Vail and Mitchum 1977 rather than Allen and Allen, 2005): For instance, I do not agree with the sentence on page 3654 Line 13 ff "Transgressive system tracts (TST) suggesting a rapid relative lake level rise often show an erosional surface (Allen and Allen, 2005)". Where would that erosional surface be? Within the TST? or at the base of the TST? I think the latter is true and the erosional surface was formed during sea level lowering (regression) when strata became emerged. This "erosional surface"

along with its stratigraphic correlative conformable surface in the deeper part not emerged during sea level lowstand then defines the sequence boundary, where TST-reflections onlap onto the sequence boundary (erosional surface) in a landwand direction.

Comment # 3: Seismic Stratigraphy vs. Lithostratigraphy (Basin-to-Ohrid Bay correlation)

It is not clear to me how the correlation between the seismic units described in the southern area to the seismic units described in the Bay of Ohrid has been established. From Page 3665, lines 1 – 11, I understand that the correlation is based on seismic-to-core correlation in the basin (correlation to core Co1202 recovered from 145m water depth at the lower slope in the distal part of the Bay of Ohrid; Vogel et al., 2010a b) and then by core-to-core correlation from Co1202 to cores Co1200 and 1201 described in this manuscript. It appears to me that this core-to-core correlation is based solely on the age models and not – as stated on Page 3665 Line 8 – on the basis of lithofacies, because core Co1202 described by Vogel et al., 2010a b, in fact, only contains two lithofacies (1 and 2) whereas lithofacies IV is not described for Co1202.

Nevertheless, it appears to me that the correlation from the southern area to the shallow Ohrid Bay is reasonable. I only caution the authors not to mix different concepts of seismic stratigraphy and lithostratigraphy and clearly state which correlation is based on which dataset.

Having said this, a definition of how seismic units were defined / correlated throughout the basin may be helpful for the readers somewhere before page 3660, line 22, because there data description starts with seismic unit E, which is somewhat confusing. Only later it becomes clear that that this is based on the basin-wide seismic stratigraphy.

Comment # 4: Subaqueous springs and lake level fluctuations:
I am somewhat confused about the positions of the subaqueous springs and how their position may have been relative to reconstructed paleo-shoreline positions. On page 3655 (line 26) subaqueous springs are mentioned but no further information is provided where and in what water depth they occur. Later, on page 3656 (line 1-2), in figure 2, on page 3668 (line 22) and on figure 9, springs on land are described and discussed in the context of the reconstructed up to 60m lake level changes. However, since these springs are located on land (or am I missing something here) I do not understand the relationship between these springs and the past lake level fluctuation between 0 and -60m?

As the location of the springs relative to lake level is inferred to be important for the endemism in Lake Ohrid, I think this aspects are worth to evolve a bit more and/or explain in more detail.

Or is it that the authors are referring to the reconstructed higher lake level position as indicated by ostracods found within cores on land (Page 3667 lines 23-26) that may affect springs close to the present shoreline? If so, this need to be stated more clearly and it may be worth to provide some more information on this. Also, could it be that the discussed higher paleo lake level is older than the forced regression system tract (FRST 6)? How the sentence (Page 3667 lines 23-26) is written now, this is not clear to me. In contrast and also because on page 3666 (line 3) it is stated that Lithofacies IV (associated to FRST 6 in table 3) is interpreted as deposition close to a river mouth with a paleo-shore line up to 55m lower than today, an older age of such a higher paleo-lake level would be a more reasonable explanation for me? What is known about the ages of the ostracods-bearing deposits found onland today?

Comment # 5: Non-unique interpretation of Lithofacies III
Page 3666 Line 27-28: “The observed sediment characteristics and location of the upper terrace indicate warm and dry climate conditions during its formation”.
This inferred interpretation is not unique and I cannot follow on which data it is based on. Which proxy points to warm conditions? Which one to dry conditions? I guess the latter may come from the fact that the MIS5-paleoshoreline was located ~30m below present day lake level. If so, this should be stated. However, paleo-shoreline position may not only represent past humid/dry climatic condition, as water supply may be complicated a bit more due to the karst system which (at least today) accounts for

up to 50% of the net inflow to Lake Ohrid. *Hence, discussing alternative interpretation of low sea level conditions and their uncertainties would be appropriate here* (see also specific comment # 1 – uncertainties and short comment posted by Jens Holtvoeth)

Technical corrections:

Page 3652

Line 2: steep-sided
Line 6: ….at ca. 32 and 55m water depth
Line 8: Define abbreviation when used for the first time (MIS = marine isotope stage)
Line 11: "shallower areas": it is not clear to me to what "shallower" is referring to here?
Line 13: ….clearly image several……
Line 16: water-filled body

Page 3653

Line 10: climate-sensitive
Line 14: Matzinger et al., 2007 is missing in the reference list
Line 19: climate-related
Line 25: (Martens, 1997)

Page 3654

Line 14: erosional surface of TST? (see specific comment #2)
Line 21: organogenic vs. organic (check!)

Page 3655

Line 4: consider providing approximate depth estimation for BG-readers not familiar with TWT
Line 24: precipitation in the surrounding mountain ranges

Page 3658

Line 4: Check TOca! If correct define abbreviation
Line 17: depth ranges given in text are not the same as depth ranges given in table 2! Make sure this is consistent

Page 3659

Line 2: depth range given in text is not the same as depth range given in table 2! Make sure this is consistent
Line 4: ICP: define abbreviation when used for the first time
Line 17: ZAF correction: define abbreviation when used for the first time
Line 24: 15 m water depth
Line 25: …in an east-west direction, data? show a second…..

Page 3660

Line 12-13: "The distribution of macrophytes in littoral areas of Ohrid Bay is traceable by side scan sonar data." How? I cannot see anything particular in the Side Scan Sonar data shown in Figure 3. Or is it the patchy appearance indicating some low backscatter areas on the upper terrace? It´s hard to see on the figure. Please considering changing contrast of the image to highlight this observation.
Line 16: "The net of seismic lines" should be "the grid of seismic lines"
Line 18: Add space between 100 m
Line 22: At this stage, it is not clear how seismic units where defined (e.g. here it starts with seismic unit E) – see specific comment # 3
Line 23: reflector should be reflection
Line 24: …and a toplap surface as upper boundary
Line 27: missing word?: Sub-unit E2, characterized (or similar?) by prograding clinoforms with……

Page 3661

Line 3: dipping in which direction? E.g. ….indicate slightly basinward-dipping strata?
Line 8: lakeshore should be paleo-lakeshore in order not to confuse readers, shouldn´t it?
Line 9: A prominent horizon (prominent in respect of what? A high-amplitude refelction?)
Line 13-15: Sentence? missing words? The cores recovered…..are 2.63 and 5.97 m long?
Line 28: Fig. 2 should be Fig. 6 and or table 2:

Page 3662
Line 5: (remove "to") This indicates …insufficient bleaching…..or post-sedimentary
Line 14: mollusk shells or their fragments
Line 4 (OM) define abbreviation when used for the first time

Page 3663
Line 13: what is OT0700-1? Here and also later in the text? Sample numbers? How defined? Or thephra-chronology?

Page 3664
Line 11: …..Lake Ohrid reflecting significant…..or …..Lake Ohrid that reflect significant…..
Line 12: reflectors should be reflections
Line 14: reflectors should be reflections
Line 14: …each wedge that are numbered as 1 to 5
Line 17: reflections-bounding clinoform structures
Line 21: reflectors should be reflections
Line 22: reflectors should be reflections
Line 23: reflectors should be reflections

Page 3665
Line 1: reflectors should be reflections
Line 7-8: "bottomset of the lower terrace assigned to Lithofacies IV (Vogel et al., 2010b)"
This is confusing, and I suggest rephrasing (see specific comment #3 above)

Page 3666
Line 1-2: "….clastic material, …,along with relative large and in combination of the width of the lower terrace, implies……."
Meaning of the sentences? Is there (along with relative large…?) a part missing?
Line 3: "..close to a river mouth" is it that you infer the lower terrace to have formed in a delta-environment? If yes, why not say so?
Line 12: Galicica Mountains: not shown on Fig.2. consider indicating it in the upper right corner of the figure.
Line 20: Table 1 should be Table 3

Page 3667
Line 7: reflectors should be reflections

Page 3668
Line 6: Based on the superposition of HST 7 on top of……..
Line 22: Looking at Figure 9, the springs discussed in the text appear to me to be above today´s lake level. Is this correct? If so, I do not understand the relationship between springs and lake level fluctuation between 0 and -60m? (see specific comment #4 above)

Pages 3672 – 3677 References:
Matzinger et al., 2007 (cited in page 3653, Line 14) is missing in the reference list
Reference Watzin et al., 2002 as listed in the reference list is not cited in the manuscript

Page 3678:
Table 1: 1954 AD: I think to remember that the reference datum for radiocarbon dating is set to 1950 AD?. Therefore, I wonder about the given age of 1954 AD. Please check?

Page 3679:

Table 2: Please indicate: What is burial depth? How was it calculated and what is the reference depth?

Please indicate abbreviation De and Do

Page 3680:

Table 3: The term LGM is very confusing, because, in fact, Lithofacies II may actually cover the whole last glacial period (MIS 4-2) in core Co1201. Also, please check interpretation of systems tracts from seismic Unit G (see specific comment # 2)

Page 3682:

Figure 2: Consider labeling “Ohrid Bay” on the figure

The gray line indicating the boundary between Macedonia and Albania is hard to see, consider changing line style or color.

Figure Caption, Line 2: …can be divided into six morphological sections

Figure Caption, Line 4-5: Red dashed line indicated the two study areas

Page 3683:

Figure 3: indicated patches of macrophytes are not visible? (see also technical comment to Page 3660 Line 12-13)

Figure Caption: The second last sentence “An outline of …….” is redundant and can be deleted

Page 3684:

Figure 4b: “evidence for subaerial location” should be “evidence for subaerial exposure”

Figure 4c: Please indicate meaning of the two colored lines (blue and red) in the figure caption

Page 3685:

Figure 5: Check labeling of radiocarbon ages! Shouldn´t it be cal yr BP?

The term “dropstone” in the figure legend is misleading because it may be misunderstood as ice-rafted debris

Page 3686:

Figure 6: Check labling of radiocarbon ages! Shouldn´t it be cal yr BP?

The term “dropstone” in the figure legend is misleading because it may be misunderstood as ice-rafted debris

Page 3687:

Figure Caption, Line 4: ….evolution with a stepwise lake level rise since…..

Please indicate meaning of the two colored lines (blue and red) in the figure caption

Page 3688:

Figure 8: Consider showing an additional sketch illustrating lake level conditions during the early phase of the last glacial period (see specific comment #2 above)