

***Interactive comment on* “Testing the potential of OSL, TT-OSL, IRSL and post-IR IRSL luminescence dating on a Middle Pleistocene sediment record of Lake El’gygytgyn, Russia” by A. Zander and A. Hilgers**

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Received and published: 20 December 2012

Answer to the referee: We thank the referee for his attentive and detailed review and his constructive feedback. In the following, we respond to his questions and remarks one by one into his text labelled with “...”.

“1. The introductory chapter mainly gives an overview about possible problems related to the application of luminescence dating techniques in general and problems related to luminescence dating of lacustrine sediments in particular. This is followed by a very

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brief introduction of the research area. The chapter is concluded by a statement of the main objective of the study: “: : :to test different approaches of luminescence dating : : : and provide complementary information on the core stratigraphy.” (page 4782, lines 27-29). This statement contradicts the main objective as provided in the abstract: “This study tests the paleomagnetic and proxy data-based Mid- to Late-Pleistocene sediment deposition history : : :” The analyses and results presented in the paper fit the first objective much better than the latter, which needs to be clarified in the abstract and throughout the introduction. The introduction is also lacking an overview about the results of previous dating studies dealing with samples from Lake El’gygytgyn (Forman et al., 2007; Juschus et al., 2007). With regard to the research area, I would suggest to introduce a more detailed, individual chapter.”

The overall aim of the study will be stressed much more clearly in the abstract and the introduction. The aim in fact is not to evaluate and compare various luminescence approaches, but to provide a reproducible and reliable luminescence chronology for the samples under investigation. To achieve this aim the application of various techniques was finally required to evaluate the most appropriate technique.

“Apart from the general setting, I think it is important to describe the sampled sediments and the relevant depositional processes in more detail, because this may help to better understand the results observed in the luminescence measurements: - All luminescence measurements were conducted using the fine grain fraction of 4-11 μ m – grains of that size may be transported as suspended load in air and/or water. Is it possible to identify the primary type of transport of the sediments before they were deposited in the lake?”

Juschus et al., 2007, 2009 and Niessen et al., 2007 have described mass movement deposits and debris flow deposits, indicating a significant transport of local sediment from the shelf to the deeper basins. Schwamborn et al. (2012) have observed a virtual absence of fine grain material in the alluvial fan delta on the western margin of the lake. They conclude, that the finer portions of the sediment load are transported

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further downslope where they build up graded layers in the deeper basin, which define the basin floor record. On the other hand, a significant aeolian sediment import is also very likely and therefore the feldspar and quartz minerals do probably represent a mixture of local, re-deposited and long distance transport minerals.

“If the primary source is Aeolian material and far distance transport, bleaching (cf. chapters 4.4 and 5) and poor sensitivity should ideally not be an issue. However, even if the primary sediment source is from a fluvial environment, the bleaching conditions in the lake itself are closely linked to the lake circulation. The circulation in the ice free summer months in a monomictic lake should prevent the suspended load from being deposited and may enable the signal to be reset even in the lake environment itself. - Today, you describe Lake El'gygytgyn to be a lake with a very small catchment area and low sediment input from the catchment – is there any indication that that may have changed over time and therefore altered the input of fluvial material? How did climate change during the lake's history influence possible sediment input (cf. Melles et al., 2007, page 95)?”

These are very interesting questions but do not intend to present an extensive review on influence of climate change on the sedimentation history of Lake El'gygytgyn. We will leave this to the specialists but will add some more references in our manuscript. You have already mentioned the paper of Melles et al. 2007 who present a comprehensive climatic and environmental history of Lake El'gygytgyn. Schwammborn et al. 2012 give a review and interpretation about the sediment record of the western margin of the lake. Another paper about classification and distribution of mass movement deposits is submitted by Kukkonen et al. (2012, submitted) and supposed to be published in this special issue, too.

“- Is the mineralogy/ geochemistry of the catchment area significantly different from the mineralogy/ geochemistry of the sediments deposited in the lake? If so, this may indicate dominant Aeolian, far distance transport.”

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Wennrich et al. 2012 presented mineralogical analyses of modern lake sediments. They described 26.9 % quartz, 26.0 % Plagioclase and 10.4 % K-feldspar from a bedrock sample of the Ergyvaam Formation and 26.1 % quartz, 20.8 % Plagioclase and 5.5 % K-feldspar for the fine grain sediments from the central basin. They observed an obvious enrichment of quartz in the silt fraction and an enrichment of feldspar in the coarse fraction of the sediments and explain this by cryogenic weathering processes within the active layer of the permafrost in the lake surrounding. Schwamborn et al. (2012) have observed an virtual absence of fine grain material in the alluvial fan delta on the western margin of the lake. They conclude that the finer portions of the sediment load are transported further downslope where they build up graded layers in the deeper basin, which define the basin floor. If this scenario is transferable to the earlier sedimentation history of the lake, the feldspar and quartz minerals very likely represent a mixture of local, re-deposited and long distance transport minerals, i.e. Fedorov et al. (2012, under discussion, Fig. 4)

“ The analysis of reference samples from the inflow areas of the recent rivers and the comparison of the luminescence properties of the suspended load deposited in a fluvial environment vs. the lake sediments would be of great help to solve the previously outlined issues. However, if I understand it correctly from your concluding remarks (page 4796, lines 23-25), such samples are currently not available.” This is right, we have no modern analogues but currently we have some samples in the laboratory, which were taken from a shore bar consisting of coarse sandy gravel. They may serve as reference samples to compare the luminescence properties in a future publication.

“Nevertheless, I suggest adding information on the depositional environment and the main relevant depositional processes to a new chapter “Research area”. This also holds true for processes possibly causing significant post depositional mixing of sediments (one of your samples is from a turbidite layer) after deposition in the lake. Please add information about the basic characteristics of the sediment layers the samples were taken from.”

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We will add a new small chapter with information about regional setting and a few basic information about the assumed sediment transport processes as described above (Schwamborn et al. 2012, Melles et al. 2007, 2012, Wennrich et al. 2012, Fedorov et al. 2012).

“2. Concerning the determination of the water content, I would suggest estimating the saturation water content for the samples if that is still possible. Doing so would at least help to evaluate the results from the fictive water content calculations (tables 3 and 6).”

The measured water content (in % of dry bulk sediment) used for age calculation and given as water content 2 in table 1 was measured soon after coring. Regarding the effects of settling and sediment load we assume that this value is probably more representative for the true environmental conditions over geological times than a saturation water content. Water contents measured at a 13 m sediment core recovered from Lake El'gygytgyn in 1998 (Melles et al. 2007) seem to be more dependent on the grain size distribution and the organic matter than on the sediment depth. The water contents (given in % of wet bulk sediment) show no significant trend but a strong scatter between ~30 and 60 %. Only the upper few cm of the core have a water content of more than 70%. The trend and the values are comparable to the results of our study. Given in the following table are the water contents in % to dry bulk sediment and to wet bulk sediment to enable a comparison with the values of Melles et al. 2007.

——in % of dry—in % of wet

1A-1H-2—94.7—47.9

1A-1H-3—122.0—45.9

1B-2H-2—52.9—34.5

1A-3H-1—42.8—28.8

1A-3H-2—74.8—40.8

1B-3H-2—67.4—41.4

1A-4H-2—70.5—41.3

1A-6H-1—61.0—37.8

1A-9H-2—61.5—38.0

“3. Please decide whether you regard the detected radionuclide disequilibria as being significant or not. In the caption of Figure S1 you use the following definition: “If the decay series is in equilibrium the activities of all daughters agree within 2-sigma errors with the activity of the mother.” (Please also use 2-sigma error bars in Figure S1.) According to that definition, all your samples are in equilibrium. In the main text however, you still assume an impact on your dose rate and age calculations. In that case you should try to quantify that impact. A number of models to correct for the effects of radionuclide disequilibria have been put forward (e.g. Degering & Krbetschek, 2007; Guibert et al., 2009). If you decide to regard the disequilibria as not significant, please back up that decision by giving references.”

Uranium contents determined for the Lake Elgygytgyn sediments range between 2.85 and 6.17 ppm. Total dose rates range between 2.2 and 3.8 Gy ka⁻¹ for polymineral samples and between 1.9 and 3.1 Gy ka⁻¹ for quartz samples using the measured water content. An underestimation of about 1 ppm Uran would result in age overestimations of about 6 to 8 %. We will add some more model calculations, rework the whole dosimetry chapter and include some more references.

“3.1 Are the fictive water content values you used within a realistic framework of the saturation water content (cf. comment 2) of the sampled material (cf. comment 1 - sample characteristics)?”

The fictive water content values cover the range of the measured water contents and were used to demonstrate the influence of the water content on the effective age. From this data set one can deduce age estimate for higher and lower water contents.

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“4. In chapter 4 methodology and results sometimes get mixed up. If you decide to stick to the suggestion of Preusser and create a new “methods” chapter, all information concerning the measurement setup and the applied protocols could be moved there. If you would like to maintain the current structure, I would suggest introducing subchapters, e.g. “4.1 SAR-OSL on fine grain quartz, 4.1.1 measurement setup (which should include instrumentation and protocols), 4.1.2 Results (from SAR-OSL), 4.1.3 Discussion (of SAR-OSL results). Maintaining this structure would deserve the introduction of an overall discussion before the conclusions chapter as well. I think both structures (with or without a general “methods” section) are possible.”

As the aim of the study was not to compare the potential of all the methods we finally had to test, it does not make much sense to put all methodical aspects in one section on methodology. To allow the reader to follow the evaluation process we had gone through it seems more appropriate to explain why we started with one technique, why we decided that it failed and why we turned to the next technique. The aim of this study is not to evaluate the methods as such but to find the appropriate one to handle the sediments under study here. Nevertheless, we will restructure this part of the manuscript and add some subchapters to separate the measurement conditions from discussion and results.

“4.1 Early background subtraction did not improve the dataset (page 4786, lines 5-9). Please be more specific: Which effects did you observe when using early background subtraction? Did you have to reject more aliquots, because they did not match the quality criteria? “

Using the EBS method did not change the D_e values but simply reduced the signal intensity. We will explain this statement in more detail.

“A short remark: In line 25 on the same page you refer to figure 5, but I assume you mean figure 6 instead.”

Yes, right.

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“I order to back up your findings concerning the erroneous sensitivity correction above saturation, resulting in the linear part of the fine grained quartz growth curve, I would strongly recommend comparative measurements of samples below the saturation limit of fine grained quartz in the specific setting of Lake El’gygytyn (<400Gy, equivalent to about 200ka, page 4786, lines 25-28), in order to show that within its limits, the fine grained quartz from Lake El’gygytyn does actually function as a reliable dosimeter.” Sample 1A1H3 with an expected age of 165 ka is the youngest sample of the data set which provided quartz after etching with hexafluorosilicic acid. Multiple aliquot additive dose TT-OSL measurements of this sample resulted in a De of 408 ± 35 Gy. There is no quartz sample available at the moment with an equivalent dose < 400 Gy.

“4.3 Please be more specific about the modifications of the SAR-IRSL50 protocol (page 4789, lines 24-25). I think a more thorough discussion is needed to clarify why the SAR-IRSL50 worked for Juschus et al. (2007) and Foreman et al. (2007) and why it cannot be successfully applied in this study.”

We have repeated the DRT-PHP test in the meantime and this new plateau test resulted in a stable PHP between 250 and 290 °C and measured to given dose ratios between 1.01 and 1.05. We therefore assume a technical problem during the measurement of the first pre-heat plateau and decided to measure the samples with the standard SAR-IRSL50. In this context we will also explain the modifications of the SAR-IRSL50 protocol.

“4.4 Concerning the successful dose recovery test after six month storage I strongly support the comment of Lowick. Was the time span of six months randomly chosen? I think it would be worth trying to investigate the minimal time span of storage resulting in a successful dose recovery and accordingly in a probably more reliable De.”

We admit that this observation requires further investigations and repeated measurements at different samples but they would presumably go beyond the scope of this paper. We intent to prepare a methodological paper in the future to investigate this

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performance more detailed. We have no satisfactory explanation yet for this performance and why storage time between bleaching and irradiation is the crucial factor but we wonder if it could be induced by some kind of phosphorescence. But we do not presume that this effect has any influence on De determination because under natural conditions - as in our storage experiment - the minerals receive no large radiation dose within a short time but are re-deposited in the sedimentary body after bleaching and very slowly accumulate a new dose. Apart from the storing experiment, we were also able to recover an artificial dose after a hot bleach was administered in the reader prior to the first radiation dose, so we do not expect a problem with our measuring protocol.

“5. The apparent age overestimation of samples from the age range between 200 and 300 ka deserves a more thorough discussion with respect to the depositional environment (cf. comment 1). If you consider insufficient bleaching as a possible reason, please discuss the conditions that may have caused this effect to occur. Is there possibly a correlation between sediment type/ sediment structure (a more detailed sample description is essential here, cf. comment 1) and the occurrence of the age overestimation? As a second possible reason you again consider radionuclide disequilibria – if you think they may have a significant influence on the dating results I recommend considering to correct for these effects (cf. comment 3). 6. The conclusion that insufficient bleaching may have resulted in age overestimation needs to be backed up by a thorough discussion, as already pointed out in previous paragraphs.”

We do not really consider insufficient bleaching as a possible reason for the underestimation but simply state, that fine grain samples do not allow to determine, if samples are sufficiently bleached or not because of the large number of grains on the disc. Nevertheless, we will restructure some parts of the manuscript and extend the discussion about the possible reasons for the overestimation between 200 and 300 ka.

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Schwamborn, G., Fedorov, G., Ostanin, N., Schirrmeister, L., Andreev, A. and the El'gygytgyn Scientific Party, Depositional dynamics in the El'gygytgyn Crater margin: implications for the 3.6Ma old sediment archive, *Clim. Past*, 8, 1897–1911, 2012, doi:10.5194/cp-8-1897-2012.

Wennrich, V., Francke, A., Dehnert, A., Juschus, O. , Leipe, T., Vogt, C., Brigham-Grette, J., Minyuk, P. S., Melles, M. and El'gygytgyn Science Party, Modern sedimentation patterns in Lake El'gygytgyn, NE Russia, derived from surface sediment and inlet streams samples, *Clim. Past Discuss.*, 8, 2007–2039, 2012.

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