The Cryosphere Discuss., 8, C2608–C2613, 2014
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The Cryosphere Discussions
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# *Interactive comment on* "27 m of lake ice on an Antarctic lake reveals past hydrologic variability" *by* H. A. Dugan et al.

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Received and published: 9 December 2014

The following is a response to reviewers' comments on our manuscript entitled, "27 m of lake ice on an Antarctic lake reveals past hydrologic variability". The comments and questions raised by the two reviewers have significantly improved this manuscript, and we thank them both for their time invested in critically reviewing this paper. Major areas of change include isotopic interpretation, a discussion of segregated ice, and the removal of some mineralogical data that is not pertinent to the conclusions. These major revisions are discussed here, followed by specific responses to questions raised by the reviewers.

**1) Major revision, segregated ice:** In our original manuscript, we did not include a discussion of the possibility that the lowest portion of the core was segregated ice. We



have developed this line of reasoning in our revised version.

New text:

*There are three processes by which the lower ice and sediment layers may have formed: 1) The repeated freezing of surface water and deposition of sediment layers. Increased salinity is generated from the concentration of salts through evaporation/sublimation, 2) The formation of segregated ice in lake sediments from the freezing of brine from beneath, or 3) The lower ice is remnant glacial ice. The following were a priori hypotheses:*

1. *Victoria Valley has not been occupied by a valley glacier since the Miocene (Fountain et al 1998). Combined with the presence of a glacial lake, we do not believe any remnant glacial ice could be near the surface of Victoria Valley.*
2. *If the ice were segregated ice, we would expect:*
    - (a) *A gradient in isotopic composition throughout the sediment and ice layers, as discussed in French and Harry (1990), and observed in closed system freezing (Fritz et al 2011)*
    - (b) *Diatoms present in the sediment layers, which were originally lake sediments*
    - (c) *The lower ice to have similar ionic ratios to the underlying brine*
3. *If the sediment layers were formed from surface deposition, we would expect the layers to be roughly horizontal.*

*Subsequent to our analyses, we can add:*

1. *Only the deepest sediment layer, SL26.28, contains abundant diatom frustules. This layer also begins to fine downward in grain size, and increases in total carbon*

*content (Fig. 5). This is the only layer that resembles lake sediments, and yet is underlain by ice with similar chemical composition to all ice below 21 m.*

2. *The GPR profiles reveal a horizontal layer lake-wide at 21 m (Fig. 7).*

3. *The lower ice is chemically distinct from the brine (Fig. 2).*

4. *The sediment layers are relatively enriched in the stable isotopes of oxygen and hydrogen versus the surrounding ice (Fig. 6).*

*Based on these observations, we are not led to believe the ice is segregated ice formed from brine seeping upwards through lake sediments. However, we must note that segregated ice has not been researched in a lacustrine context. Instead, we hypothesize the entire 27 m of ice and sediment was formed from surface processes, and the brine that enters the drill holes is sourced from below 27 m. Here, we explore processes that might have led to the formation of interspersed sediment layers in 27 m of lake ice.*

This is an important discussion, as a system analogous to Lake Vida does not (to our knowledge) exist on Earth, and segregated ice has not been researched in this context. We stand behind our original hypothesis on the origin of the sediment layers, but hope this paper might lead to dialogue on unusual ground ice features, and perhaps propel research on buried ground ice outside of the Arctic.

**2) Major revision, stable isotopes:** Both reviewers raised the idea of including a regression line in our isotope plot. We feel this is not justified, and all of our ice/sediment layers formed sequentially and independently, and should not be modeled as a whole. Our discussion focuses on the relative enrichment and depletions of certain samples, and is not guided by a regression analysis. We would however, expect individual layers to show a pattern in isotopic composition, but they do not, likely due to regelation processes. This is shown in the addition of isotope composition to Figure 2.

We have included a plot showing deuterium excess value in Figure 6, and believe this



strengthens our conclusion that the thick sediment layers have resulted from evaporation. The sediment layers are have lower deuterium excess values than all other samples, which suggest that evaporative fractionation has more strongly modified oxygen isotopes over hydrogen isotopes (this is due to the composition of water, where there are two hydrogen atoms to every one oxygen atom, and therefore any given oxygen atom is more readily influenced).

See attached figure.

**3) Major revision, mineralogy:** Both reviewers raise excellent questions surrounding our mineralogical data. Without referencing the individual questions, our general response is this: We agree with the reviewers that our catchment samples are not spatially representative enough to draw conclusions on transport mechanisms. Importantly, we do not have samples of the suspended sediment load in the rivers, or any samples from aeolian traps. The data we do have are difficult to differentiate, and the differences are not significant enough to substantiate the conclusions we drew comparing aeolian vs. fluvial transport.

Originally we were interested in how sediment is delivered onto the lake, however, in the end, this is not critical for the thesis of the paper. Regardless of transport mechanism, the sediment is delivered onto the lake and aggregates into layers.

To address this, we have removed most of the data/discussion surrounding aeolian/fluvial transport. We have kept some sections that are relevant to our understanding on ice processes, such as:

*If the lower ice formed from surface inflow, rather than brine, the sediment layers in the lower ice are unusual. Field observations at Lake Vida during the 1990s, when lake levels were static, and during the 2000s, when lake levels were rising, reveal that the surface of the lake is largely flat and free of surface sediment. Aeolian transport of sediment is common in Victoria Valley (Speirs et al 2008); however, aeolian deposition onto a dry, flat ice cover has a high probability of further redistribution by wind and* *may not be readily entrained into the ice column. This conclusion is supported by observations that windblown sediment largely does not get trapped on the frozen ice surface of Lake Vida, but saltates across the lake. Therefore, we propose that sediment is mainly delivered onto the surface of the lake through fluvial transport. A saturated lake surface provides a mechanism for sediment to both infiltrates cracks in the ice, as well as become frozen beneath a new layer of water.*

**Specific comments are addressed in the attached .pdf**

Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/8/C2608/2014/tcd-8-C2608-2014-supplement.pdf

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Interactive comment on The Cryosphere Discuss., 8, 4127, 2014.



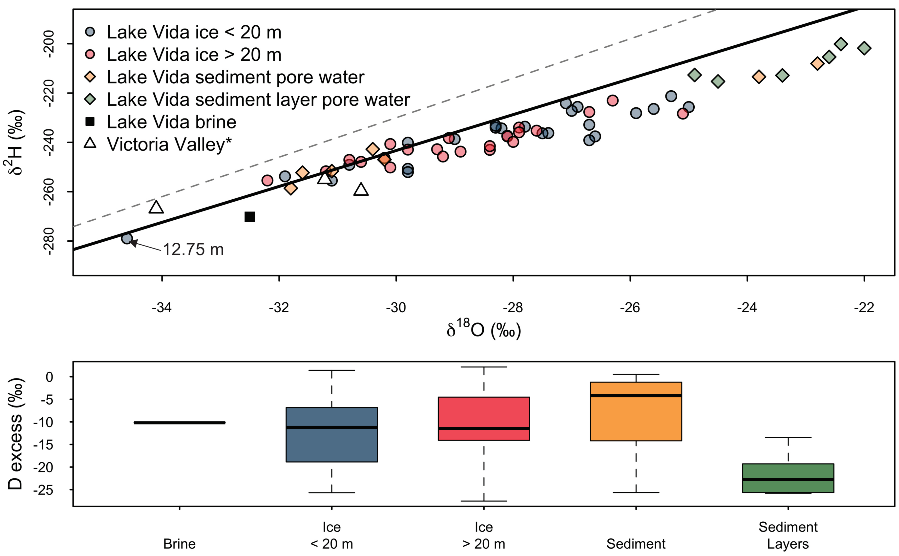


**Fig. 1.**