

The Cryosphere Discuss., referee comment RC1  
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## Comment on tc-2022-91

Joseph Levy (Referee)

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Referee comment on "Brief communication: The hidden labyrinth: deep groundwater in Wright Valley, Antarctica" by Hilary A. Dugan et al., The Cryosphere Discuss.,  
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### General Comments:

This manuscript presents a fascinating first look at the electrical conductivity structure beneath Wright Valley, Antarctica, in order to evaluate long-standing predictions that subsurface brine conduits may link several water bodies in the valley. The work is well-argued, clearly presented, and nuanced in its analysis. The manuscript presents a compelling case that subsurface electrical conductivity anomalies are present east and west of Don Juan Pond, but that continuity between DJP and Lake Vanda could not be directly detected. High conductivity regions in the subsurface are clearly demonstrated in the North Fork of Wright Valley, which is strong evidence of conductive porewater solutions in the subsurface on that side of the Dias.

One question raised by the paper is the role of sampling geometry in the interpretation of the SkyTEM results. Line 1 in Fig. 1 seems to show highly conductive material extending from Don Quixote pond in the west, nearly all the way to Lake Vanda in the east. The high conductivity horizon in the subsurface is interrupted by the data dropout and by a highly resistive block of material shortly after 5000 m in the along-track direction. Is there any morphological or topographic evidence that could suggest that the high conductivity region could extend continuously from DQP to LV, but that the region of continuity was simply not imaged in the footprint of Line 1? Line 1 seems to have been targeted to intersect with DVDP14 and 4, but is it possible that in doing so, subsurface, high conductivity materials to the north could have been missed? If so, it seems possible that a subsurface connection between salty solutions in pore spaces in North Fork do extend downslope all the way from DQP to LV. Likewise, is it possible that the sampling geometry of Line 3 is what causes the pinch out of the conductive zone in the subsurface west of LV? Some of this could be addressed by mentioning the cross-track sampling width of the SkyTEM.

Recognizing that the SkyTEM instrument is insensitive to shallow subsurface processes (i.e., one pixel for the upper 4 m of the soil/water column), the introductory text provides

a somewhat facile or dismissive treatment of the role of surface and near-surface waters in affecting DJP chemistry and hydrology. For example, the text suggests that the variability in DJP extent and salinity indicates a hydrological driver beyond surface conditions. But surface conditions strongly control DJP lake level and extent as shown by (Dickson et al., 2013), who found a strong correlation between insolation (hence, snowmelt) and DJP spatial extent. Likewise, (Dickson et al., 2013) show input of water track solutions from the east, which also are associated with high insolation days which drive snowmelt and expansion of the active layer. (Hassing and Mayewski, 1983) and (Dickson et al., 2013) both report that these near-surface water track solutions have high Ca, low Na, and excess Ca (Ca exceeding that which can be derived from dissolution of gypsum or calcite), which together, represent a potential contributing near-surface source for Ca-rich waters in DJP. The (Toner et al., 2017) modeling work is an important contribution to the understanding of potential subsurface processes in the DJP/Vanda region, but should not be considered an exhaustive analysis of hydrological contributors in the region because it largely considers only regional freshwater systems over the near-surface brines.

#### Specific Comments:

Title: The (real) Labyrinth is a network of bedrock channels. And so, while I love the title, it seems like a network of bedrock and sedimentary fractures or pores in the subsurface really isn't what the manuscript suggests is occurring around DJP, DQP, and LV. In some ways this gets at my general comment above—there may very well be a hidden labyrinth of subsurface brine conduits—but can single TEM lines identify that geometry?

Line 8. Are brine conduits implied by the observations or brine presence? I'd interpret "conduits" to mean localized zones of high permeability, which does not seem to be implied by the observations.

Line 49. Suggest removing the editorial tone of "convincing arguments." It is a really excellent and intriguing paper, but a more neutral introduction might help readers weigh the different arguments about water sources for DJP.

Line 97. How do you interpret the abrupt stop to the high conductivity zone at depth between DQP and Vanda? Is it a bedrock spur? A cold/dry permafrost pocket? Or evidence of brine diverging off the sensor path (in which case, there really is evidence for a subsurface labyrinth!).

Line 100. It's really interesting that the low resistivity regions east and west of DJP extent up higher than the modern lake level. That could provide evidence of a perched saline aquifer that provides the hydraulic head observed in the brief artesian discharge episodes from the DJP boreholes, and would suggest that the low-resistivity zones east and west of the pond are at least partially connected to the brine in the ponds. This would be a really important finding because it differs from the classic groundwater interpretation for DJP (which is also invoked in the Toner et al, 2017 paper), which invokes cyclic deep

groundwater upwelling. Line 2 seems to show that there is brine adjacent to and higher than the lake, suggesting that DJP solutions may not be exclusively upwelling from deeper sources.

#### References.

Dickson, J.L., Head, J.W., Levy, J.S., Marchant, D.R., 2013. Don Juan Pond, Antarctica: Near-surface CaCl<sub>2</sub>-brine feeding Earth's most saline lake and implications for Mars. *Scientific Reports* 3. <https://doi.org/10.1038/srep01166>

Hassing, J.M., Mayewski, P.A., 1983. Morphology and Dynamics of the Rock Glaciers in Southern Victoria Land, Antarctica. *Arctic and Alpine Research* 15, 351. <https://doi.org/10.2307/1550831>

Toner, J.D., Catling, D.C., Sletten, R.S., 2017. The geochemistry of Don Juan Pond: Evidence for a deep groundwater flow system in Wright Valley, Antarctica. *Earth and Planetary Science Letters* 474, 190–197. <https://doi.org/10.1016/j.epsl.2017.06.039>