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Constraints on lateral variations in upper mantle viscosity from Lake Bonneville shorelines

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Lake Bonneville is an extinct pluvial lake that formed and catastrophically drained at the onset of the last deglaciation ($\sim 20 - 18$ka). With a volume of just over 10 000 km^3 this lake was comparable in size to present-day Lake Michigan. During its existence the excess load of water stored in Lake Bonneville depressed the crust and upper mantle. After the drainage of the lake this area rebounded by up to 75 m, which is recorded in the paleoshorelines around the lake periphery and on islands within the lake. The rebound pattern has been used to infer the lithospheric thickness and upper mantle viscosity structure of the area (e.g. Bill et al., 1994). In agreement with the tectonic history of the Basin and Range area, the deformed shorelines point to a thin lithosphere (< 30km) and low upper mantle viscosity ($\sim 10^{19}$ Pa s). This differs from the upper mantle viscosity inferred from post-glacial data in cratonic regions (e.g., Hudson Bay, Fennoscandia), which is one to two orders of magnitude larger ($\sim 5 \times 10^{20}$ Pa s). Direct constraints on the lateral variability of mantle viscosity are invaluable but in order to utilize such constraints it is important to consider the sensitivity range of different observations before comparing the inferred viscosities.

In this study we revisit the earlier inversions of shoreline elevations for mantle and lithospheric structure with an updated dataset of paleoshoreline elevations by Chen and Maloof (2017). We construct depth-dependent sensitivity kernels for the lake rebound and compare them to kernels associated with the rebound from glacial ice sheets over Canada and Scandinavia. This comparison along with the inferred viscosities allows us to evaluate the degree to which lateral viscosity variations are required. We additionally compare our results to estimates of lateral viscosity variations based on perturbations in seismic shear wave speed in the respective areas in order to assess the consistency of our results with independent data.

The paleoshorelines of Lake Bonneville have been deflected by not only rebound post-drainage, but also the longer-term subsidence of the Laurentide peripheral bulge. The lake was located on the distal flank of the peripheral bulge of the Laurentide Ice Sheet and after its collapse the peripheral bulge subsided leading to an additional northeast trending tilt in shoreline elevations. We show that the degree of tilt is not only sensitive to shallow mantle structure but has also sensitivity in the upper half of the lower mantle, in contrast to the lake rebound pattern. We independently invert the degree of tilt for mantle viscosity and examine its trade-off with uncertainties in the ice history.