Borehole Strainmeters in Yellowstone Reveal Surface Deformation is Influenced by Upper Crustal Magma

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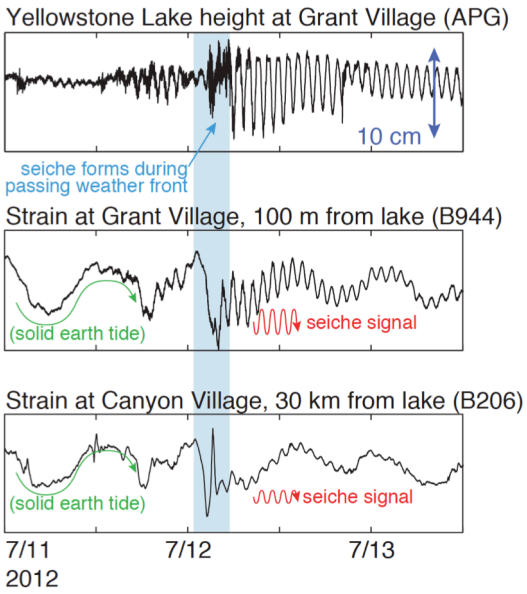
Following the installation of PBO strainmeters in Yellowstone, one of the more suprising signals observed has been the solid earth deformation resulting from seiche waves in Yellowstone Lake. These resonant standing water waves have amplitudes up to 10 cm and characteristic periods up to 78-minutes. Strainmeter B944, ~100 m from the lake, records strains from these seiches that are comparable in amplitude to the solid earth tide, up to 20 – 50 nanostrain (ns). More surprisingly, strainmeter B206, ~30 km from the lake, records strains about one order of magnitude less, up to 1 – 5 ns, which are observed at the same time (with little or no delay) as the strains at B944 and the seiche in Yellowstone Lake. Similar seiche signals have also been observed at two other ~30 km distant strainmeters (B205 and B207) and one other ~1 km distant station (B208).

Models of deformation expected from a lake seiche via the mechanisms of pore pressure diffusion or loading of a homogeneous elastic crust predict strains at distant stations that are either subject to a significant delay (~days predicted) or whose amplitudes are significantly smaller than those observed (~0.01 – 0.1 ns predicted). Deformation predicted from a two layer model representing an upper elastic crust overlying a viscoelastic partially molten layer can successfully recreate the observed strainfield. These models indicate this more viscous material is present up to 3 – 6 km below the surface, with a Maxwell viscosity less than 10^{11} Pa s (corresponding to ~35% melt), though these observations do not constrain the total volume of the material.



Observations of a Yellowstone Lake seiche that began on 12 July 2012, apparently initiated by a passing weather front. Seiche is directly observed by an Absolute Pressure Gauge (APG) in Yellowstone Lake (top), and resulting crustal deformation is observed on Borehole Strainmeters 100 m from lake (B944, middle) and 30 km from lake (B206, bottom).

These estimates of the location and material properties of partial melt in Yellowstone are consistent with those from other geophysical and geochemical observations. The particular sensitivity of the seiche strain observations to the shallowest crustal structure make it a valuable complimentary source of information relevant to potential future volcanic unrest. Monitoring of such strain signals continues at Yellowstone and other volcanic centers. This research has been featured in social media outreach efforts of the Yellowstone Volcano Observatory, aimed at engaging and educating the interested public about the Yellowstone Volcano and its associated hazards.