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Squeezing porous basaltic rocks: Understanding compaction of basaltic aquifers due to groundwater extraction at Tenerife Island

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The successive emplacement of variably porous (and permeable) rocks in volcanic edifices provide ideal environments for water infiltration, flow and entrapment. Any change in the groundwater pore pressure of established aquifers, shifts effective pressure conditions. For instance, depression of groundwater table has been linked to the consolidation of aquifer system material (Terzaghi's consolidation theory). However, this theory has largely been tested and applied to observed compaction affecting sedimentary granular (alluvial), and/or fine-grain (lacustrine) materials, exhibiting poroelastic (aquifers) and anelastic (aquitards) behaviour respectively. Additional experimental studies (e.g., Heap et al., EPSL 2011) have shown that compaction through creep deformation can be achieved at effective stresses lower than the material's compressive strength. Importantly, the compaction rate depends on the level of the applied effective stress, with higher effective stress conditions resulting in faster creep rates.

In the island of Tenerife, the vast majority of freshwater is obtained by drilling horizontal water tunnels (local name, galerias). Since around 1900, hundreds of water tunnels have been drilled for agriculture, industrial and freshwater supply. This resulted in a sustained extraction of groundwater larger than the natural recharge, leading to groundwater table decline. Since 2000, satellite radar interferometry (InSAR) applied to measure surface deformation has located several subsidence bowls (e.g., Fernandez et al., GRL 2009). The localized surface deformation patterns have been correlated with water table changes and hence aquifer compaction. However, no further investigations have been carried out to confirm which volcanic materials can compact significantly in such predominantly basaltic island, and to which extent porous basaltic units (the most favorable aquifer material in Tenerife) can compact to explain the observed surface deformation.

Here, we carry out a joint study to compare recent InSAR surface deformation measurments with laboratory experiments to determine porosity, permeability and volumetric deformation of porous basaltic samples from Tenerife under relevant hydrostatic conditions. In lab experiments, samples are axially loaded to 30, 50, 70 and 90% of their maximum compressive strengths at low effective pressure conditions. Pore pressure is then removed and creep deformation monitored to determine whether the compaction of porous basaltic rocks through groundwater depletion is a feasible mechanism to explain the observed surface deformation in Tenerife. We foresee that this study will have implications on the water resource availability, management and exploitation in volcanic regions.

Fernandez, J., et al. (2009), Gravity-driven deformation of Tenerife measured by InSAR time series analysis, Geophys. Res. Lett., 36, L04306, doi:10.1029/2008GL036920.
Heap, M. J., Baud, P., Meredith, P. G., Vinciguerra, S., Bell, A. F., & Main, I. G. (2011). Brittle creep in basalt and its application to time-dependent volcano deformation. Earth and Planetary Science Letters, 307(1), 71-82.