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How do aquifers respond to volcanic strain changes?

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Well water level changes have been reported pre-, syn- and posteruptive for various volcanoes and eruption types. They are often interpreted as a result of pore pressure changes in the aquifers due to poroelastic deformation. Many magmatic processes, such as magma chamber inflation or dyke intrusions, lead to subsurface strain changes and can induce this deformation. These considerations raise the question whether and to what extent wells can be used to monitor strain changes in volcanic environments.
Previous works (e.g., Matsumoto et al. (2002)) calculated the strain sensitivity of aquifers, using observed water level variations associated with known excitations such as earth tides, and used this value to derive the strain responsible for observed water level changes during volcanic unrest. These strain values are then interpreted in terms of magmatic processes, usually applying simple deformation models such as the "Mogi Model" (Mogi (1958)). This method, however, does not always fully explain observed monitoring data, which is likely due to the necessary use of strong assumptions.
We present a suite of more detailed geophysical models that investigate the effect of inflating magma chambers on close-by hydrological systems. Flow and deformation processes are fully coupled and numerically simulated time-dependently. The use of Finite Element Analysis allows us to include different magma chamber shapes, crustal heterogeneities and test the influence of various parameters.
Results show that the pure strain change induced by a recharging magma chamber can cause hydraulic head changes in overlying aquifers on the order of centimeters to meters, depending on aquifer and source properties. The models also simulate the change in time of both strain and head change in the aquifer that is due to porous flow and was often neglected in previous studies. Allowing the chamber to be a non-Mogi source drastically changes results – chamber morphology and crustal heterogeneity are two of the most important influences on the simulated hydraulic head change. Especially the elastic stratigraphy needs to be carefully considered when inverting signals: In certain elastic settings, the resulting hydraulic head change is of opposite sign than what would be expected from poroelastic theory for a homogeneous earth.
The generic setups developed to study poroelastic responses to volcanic strain changes now also provide the platform to study reported real cases in more detail and test hypotheses for the observed changes in hydrological systems. Candidate volcanoes include Souffrière Hills Volcano (Montserrat), Unzen (Japan), Kilauea (Hawaii) and Hekla (Iceland).

References:
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