# Can We Use Aquifers to Monitor Magma Chambers? Using COMSOL Multiphysics® to Investigate Subsurface Strain Changes and Their Effect on Hydrological Systems

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## Abstract

Groundwater-bearing geological layers respond to and modify the surface expressions of magmatic activity, and they can also become agents of volcanic unrest themselves. Interpretations of unrest signals as groundwater responses to changes in the magmatic system can be found for many volcanoes and include a wide range of phenomena and suggested processes to explain them (e.g., Newhall et al., 2001). On one hand, they imply that some monitoring signals, which have previously been interpreted as magmatic unrest, might be influenced - or even caused completely - by hydrological processes, consequently changing forecasting conclusions. But they also suggest that aquifers could be used as valuable indicators of volcanic unrest. To improve eruption forecasting, we need to improve our understanding on how monitoring signals are generated; but only very few of the suggested mechanisms for hydrological unrest have been sufficiently quantitatively tested.

One of the most reported hydrological responses to magmatic activity is a change in hydraulic head, which is easily observable via well water levels, but also influences the signals of gravimeters and ground deformation. These changes are mostly thought to be due to variations in the pore pressure, caused by volumetric strain or the opening/closing of fractures, whereas the latter can also be a consequence of strain (e.g., Shibata & Akita, 2001). Inflating magma chambers or intruding dykes are the most common causes for strain changes in volcanic areas.

For sufficiently small strains, the deformation of an aquifer is described by poroelasticity, a theory combining the governing equations for solid mechanics (linear elastic behavior) and porous flow (e.g., Wang, 2000). This hydrogeophysical study uses the Poroelasticity physics interface from the Subsurface Flow module of COMSOL Multiphysics® to investigate how an inflating magma chamber or an intruding dyke affects aquifers and how the presence of an aquifer can change purely linear elastic signals. The generic models simulate the subsurface strain changes resulting from a pressurizing magmatic source and predict pore pressure induced hydraulic head changes in the aquifers as well as strain induced fluid migration. In the monitoring practice, volcano observatories can track these hydrological effects for example with potential field investigations or the monitoring of well water levels. The models also allow us to explore the parameter space; they showed that the head changes are mainly controlled by the poroelastic

properties and the geometry of the aquifer, the source characteristics and the topography of the volcano. Our results contribute to a better understanding of the coupling of hydrological and magmatic systems, working towards the full utilization of aquifers as strainmeters and monitoring instruments. After adapting the generic models to individual volcanoes, they can also be used to test hypotheses for observations at these specific sites.

Thereby we will gain further insight into the subsurface processes at volcanic systems and aid the evaluation of unrest signals with potential for improved eruption forecasting.

## Reference


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