Geophysical Research Abstracts
Vol. 16, EGU2014-13995, 2014
EGU General Assembly 2014

Models of magma-aquifer interactions and their implications for hazard assessment

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Interactions of magmatic and hydrological systems are manifold, complex and poorly understood. On the one side they bear a significant hazard potential in the form of phreatic explosions or by causing “dry” effusive eruptions to turn into explosive phreatomagmatic events. On the other side, they can equally serve to reduce volcanic risk, as resulting geophysical signals can help to forecast eruptions. It is therefore necessary to put efforts towards answering some outstanding questions regarding magma – aquifer interactions. Our research addresses these problems from two sides.

Firstly, aquifers respond to magmatic activity and they can also become agents of unrest themselves. Therefore, monitoring the hydrology can provide a valuable window into subsurface processes in volcanic areas. Changes in temperature and strain conditions, seismic excitation or the injection of magmatic fluids into hydrothermal systems are just a few of the proposed processes induced by magmatic activity that affect the local hydrology. Interpretations of unrest signals as groundwater responses are described for many volcanoes and include changes in water table levels, changes in temperature or composition of hydrothermal waters and pore pressure-induced ground deformation. Volcano observatories can track these hydrological effects for example with potential field investigations or the monitoring of wells. To fully utilise these indicators as monitoring and forecasting tools, however, it is necessary to improve our understanding of the ongoing mechanisms. Our hydrogeophysical study uses finite element analysis to quantitatively test proposed mechanisms of aquifer excitation and the resultant geophysical signals.

Secondly, volcanic activity is influenced by the presence of groundwater, including phreatomagmatic and phreatic eruptions. We focus here on phreatic explosions at hydrothermal systems. At least two of these impulsive events occurred in 2013: In August at the Icelandic volcano Kverkfjöll and in October on White Island, New Zealand. The latter is only one example of these natural attractions that are visited by thousands of tourists every year. Additionally, these systems are increasingly used for energy generation. Phreatic explosions pose a serious risk to people and infrastructure nearby, and they are hard to predict. To improve risk assessment in hydrothermal areas, we assessed historical records and literature with regard to the frequency and mechanisms of hydrothermal explosions. Complemented by numerical models this study wants to answer the question: What determines the change of a safe to a dangerous behaviour of the system, i.e. the change from silent degassing to explosions?

Our project aims to widen our knowledge base on the complex coupling of magmatic and hydrological systems, which provides further insight into the subsurface processes at volcanic systems and will aid future risk assessment and eruption forecasting.