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Seismic properties of fluid bearing formations in magmatic geothermal systems: can we directly detect geothermal activity with seismic methods?

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Seismic methods are amongst the most common techniques to explore the earth's subsurface. Seismic properties such as velocities, impedance contrasts and attenuation enable the characterization of the rocks in a geothermal system. The most important goal of geothermal exploration, however, is to describe the enthalpy state of the pore fluids, which act as the main transport medium for the geothermal heat, and to detect permeable structures such as fracture networks, which control the movement of these pore fluids in the subsurface. Since the quantities measured with seismic methods are only indirectly related with the fluid state and the rock permeability, the interpretation of seismic datasets is difficult and usually delivers ambiguous results.

To help overcome this problem, we use a numerical modeling tool that quantifies the seismic properties of fractured rock formations that are typically found in magmatic geothermal systems. We incorporate the physics of the pore fluids, ranging from the liquid to the boiling and ultimately vapor state. Furthermore, we consider the hydromechanics of permeable structures at different scales from small cooling joints to large caldera faults as are known to be present in volcanic systems.

Our modeling techniques simulate oscillatory compressibility and shear tests and yield the P- and S-wave velocities and attenuation factors of fluid saturated fractured rock volumes. To apply this modeling technique to realistic scenarios, numerous input parameters need to be indentified. The properties of the rock matrix and individual fractures were derived from extensive literature research including a large number of laboratory-based studies. The geometries of fracture networks were provided by structural geologists from their published studies of outcrops. Finally, the physical properties of the pore fluid, ranging from those at ambient pressures and temperatures up to the supercritical conditions, were taken from the fluid physics literature.

The results of this study allow us to describe the seismic properties as a function of hydrothermal and geological features. We use it in a forward seismic modeling study to examine how the seismic response changes with temporally and/or spatially varying fluid properties.