Imaging seismic source variations throughout the eruptive sequences of volcanoes and geysers using back-projection methods

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Our understanding of the mechanisms, dynamics, and plumbing networks that characterize volcanic and hydrothermal systems is limited by our ability to remotely observe weak motions related to dynamic processes at depth. Seismic records from these systems are typically extremely noisy, making it difficult to utilize traditional seismic methods to resolve 3D subsurface structures. High-amplitude bursts within the noise (i.e. eruptions), which might be suitable for use with traditional seismic methods, occur infrequently compared to the length of the entire eruption cycle. Therefore, while these events may help us understand the dynamics of a particular eruption, they shed little insight into the mechanisms and dynamics that occur throughout the entire eruption sequence. Without a continuous temporal sampling we cannot characterize the system as a whole. However, it has been shown that much more abundant low-amplitude “noise” in these records actually represents a series of overlapping low-magnitude displacements that can be directly linked to magma and fluid movement at depth. This data, ignored by most prior studies, contains valuable information about the processes occurring in the volcanic or hydrothermal system before, during and after eruptions. New array processing has the potential to provide crucial insight into the overall behavior of the volcanic or hydrothermal system.

In this study, we present a new method that seeks to comprehensively study how the seismic source distribution of all events - - including micro-events - - evolves through a volcanic or hydrothermal systems entire eruption cycle. We apply a back-projection search algorithm to image sources of seismic “noise” at different stages in the eruptive cycle of a volcano (Sierra Negra, Galapagos) and hydrothermal system (El Tatio Geyser Field, northern Chile). By analyzing coherent seismic energy from all possible events to all available receivers, we determine how the seismic source location changes through time. This approach utilizes data from the entire seismic record before, during and after eruptions and thus allows for a more complete understanding of how seismic sources change throughout an eruptive sequence rather than only during a particular high-magnitude event or eruption. This information will help 1) answer fundamental geologic questions about volcano-tectonic processes, 2) make more accurate assessments of volcanic and hydrothermal hazards, and 3) improve our understanding of how geothermal reservoirs evolve.