## The Architecture and Dynamics of Coupled Failure and Fluid Flow in Magmatic-Hydrothermal Systems: Insights from Swarm Seismicity, Hakone Caldera, Japan

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A seismically very active hydrothermal system at depth beneath the Hakone caldera (Japan) provides new insights about the controls on permeability enhancement, fluid migration pathways and flow rates in fracture-controlled, magmatic-hydrothermal systems.

Seismicity at Hakone is dominated by migratory swarm activity that occurs when failure, permeability generation and fluid migration are driven by fluid pressurization within an overpressured, high fluid flux regime. From 1995 to 2019 eight major injection-driven earthquake swarms occurred within an area of 70 $km^2$ that extends to depths up to 7 km. Seismicity in this period involved 29,000 events in the magnitude range $-0.6 < Mw < 3.7$, driven by injection of approximately 500,000 $m^3$ of fluid. Recorded ruptures have diameters ranging from < 10 m to 500 m. Swarms typically last between several days and 250 days and involve cascades of many 1000s of ruptures that illuminate well-defined faults. Individual swarms exhibit diffusion-like migration of seismicity fronts and provide insights about fluid pathways, migration rates and flow directions. The seismically quiescent intervals between swarms last up to several years.

Seismicity occurs within a fault complex comprised mostly of small, conjugate, strike-slip faults that are nearly optimally-oriented relative to the NW-SE trending maximum principal stress. Many swarms activate just a few small fault segments, each having areas up to about 1 $km^2$. However, the largest swarms activate many hundreds of small faults that are distributed across the entire Hakone system. These are associated with injection of up to 100,000 $m^3$ of fluid at injection rates transiently as high as several $m^3/s$.

Injection-driven swarms cause episodic, large fluctuations in fluid pressures, fluid pressure gradients and flow rates during rapidly recurring slip events. This dynamic fluid regime has implications for processes and rates of ore formation that involve thousands of swarms over timescales of $10^4$ – $10^5$ years.