Migrating Activity of the 2010 Madison Plateau, Yellowstone National Park, Earthquake Swarm: Evidence for Fluid Triggering?

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Yellowstone National Park includes one of Earth's largest volcanic-hydrothermal fields and a youthful caldera. The 2010 Madison Plateau earthquake swarm, near the northwest rim of the Yellowstone caldera, was one of the three largest swarms recorded in the park since monitoring began in the 1970s. This swarm lasted from January 17 to February 6 and consisted of ~2200 cataloged events, including 17 M 3+ events, with the largest being M 3.9.

To fully explore the activity and evolution of the swarm, we combined waveform-based event detection with precise double-difference relative relocation. Detection and location goals were accomplished in tandem, using cross-correlation with continuous seismic data and waveform templates constructed from cataloged events. Using this procedure, we detected ~8700 events that could be precisely located, a factor of ~4 more events than included in the Yellowstone Seismic Network standard catalog.

These newly detected and relocated hypocenters reveal distinct migration of activity. Most events are located on a NNW-striking, ENE-dipping structure, with dimensions of approximately 3 by 3 km, between 8 and 11 km depth. Activity initiated abruptly at about 10 km depth, and expanded systematically outward (both shallower and deeper) along this structure over time. We hypothesize that the swarm may have been triggered by the rupture of a confined high-pressure fluid system into neighboring pre-existing crustal fractures. Double-couple-constrained fault solutions suggest strike-slip faulting on this dipping structure, which may be a reactivated Basin and Range normal fault.

While strike-slip motion on a dipping fault is not mechanically optimal, it could occur if the fault is sufficiently weak relative to its surroundings, perhaps as a result of locally high fluid pressure. Repeated earthquake swarms in Yellowstone may facilitate transport of aqueous fluids exsolved from crystallizing magma beneath the caldera.

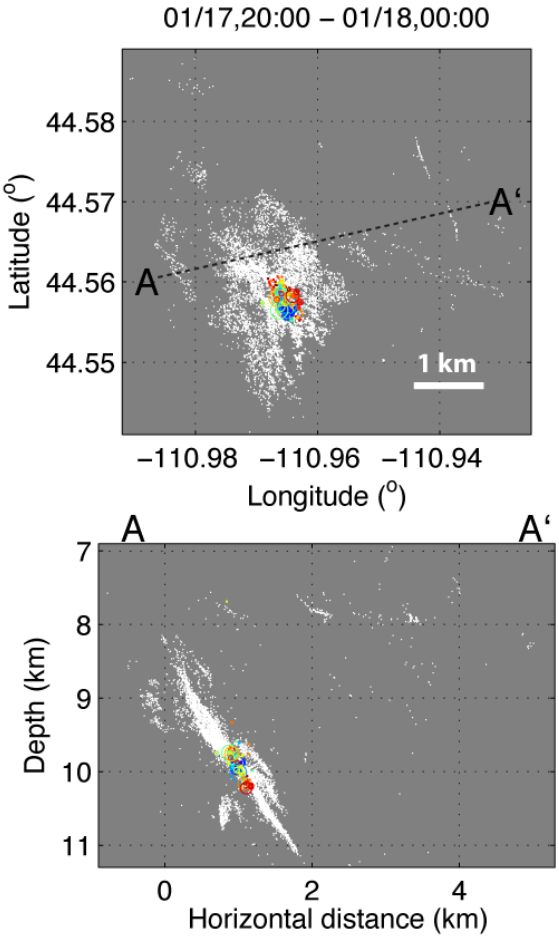

Figure 1. Outward propagation of relocated earthquake centroids during the first 4 hours of the swarm in map view (top) and cross-section (bottom). Colored dots are those during the first 4 hours, color-coded from early (blue) to red (late). White dots show events from later in the swarm.