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Low-Q related to partially saturated pores within the reservoir beneath The Geysers area in the northern California

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A large reservoir is located beneath The Geysers geothermal area, northern California. Previous studies revealed high-velocity (high-V) and low-Vp/Vs zones in the reservoir (Julian et al., 1996) and a decrease of Vp/Vs from 1991 to 1998 (Guasekera et al., 2003) owing to withdrawal of steam from the reservoir by seismic tomography. I perform attenuation tomography in this region in order to investigate the state of vapor and liquid within the reservoir.

The target region, 38.5-39.0N and 122.5-123W, covers The Geysers geothermal area. The Northern California Earthquake Data Center recorded 65,810 events from 2002 to 2008 in the target region. I use seismograms of 1,231 events whose focal mechanism are determined among them. The band-pass filtered seismograms are analyzed for collecting the maximum amplitude data. There are 26 stations that have a three-component seismometer among 47 seismic stations. I use the P- and S-wave maximum amplitudes during the two seconds after the arrival of those waves in order to avoid coda effects. A total of 8,545 P- and 1,168 S-wave amplitude data for 949 earthquakes recorded at 47 stations are available for the analysis using the attenuation tomography derived from the velocity tomography (Matsubara et al., 2005, 2008) in which spatial velocity correlation and station corrections are introduced to the original code of Zhao et al. (1992). I use 3-D velocity structure obtained by Thurber et al. (2009). The initial Q value is set to 150, corresponding to the average Q of the northern California (Ford et al., 2010).

The Geysers geothermal area is bounded by Collayomi fault zone to the northeast and the Mercuryville fault zone to the southwest. The Geysers Peak fault runs from northwest to southeast about 3 km southwest of the Mercuryville fault. The Mercuryville fault dips to northeast and the Geysers Peak fault dips to southwest. High-Q zone is located between these faults and the width of this zone broadens as the depth increases corresponding to the fault geometry.

At sea level, low-Q zones are found extending from the middle of the steam reservoir within the main greywacke to the south part of the reservoir. At a depth of 1 km below sea level, a low-Q zone is located solely in the southern part of the reservoir. However, at a depth of 2 km a low-Q zone is located beneath the northern part of the reservoir. At depths of 1 to 3 km a felsite batholith in the deeper portions of the reservoir, and it corresponds with a high-Q zone. The low-Q zone is consistent with the reservoir as it extends through the main greywacke and into the uppermost part of the felsite. Most of the felsite has high-Q, however, the portion of the reservoir that extends into the felsite has low-Q.

The presence of liquid water introduces high-Vp/Vs, however, steam rich zones become low-Vp/Vs. Near the transition zone between the water and steam, laboratory experiments indicate that the amplitude becomes extremely small (Ito et al., 1979). A partially saturated zone has lower Q than a fully saturated zone, and a dry zone has high-Q. A low-Q zone with low-Vp/Vs corresponding to the reservoir indicates that the reservoir is partially saturated with steam and water near transition zone.

Keywords: Geothermal area, Attenuation tomography, Transition zone, Low Q, Low Vp/Vs