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Local Vp/Vs ratio estimation in earthquake swarm area around Mt. Ontake

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Mt. Ontake is a stratovolcano in the central Japan. After the first historic eruption occurred in 1979, two small phreatic explosions occurred in 1991 and 2007. Since 1976, earthquake swarm activities in the southeast area of Mt. Ontake have been observed continuously. Although the annual number of earthquakes of this swarm has sometimes been up to 2000, the magnitudes of those have been less than M1. In this area, the M6.8 western Nagano Prefecture earthquake occurred on 14 September 1984.

The relationship between occurrence of earthquake swarm and fluid has been discussed (e.g., Nur, 1974). In the earthquake swarm area, fluid supply from lower crust is suggested from electrical conductivity surveys (e.g., Kasaya et al., 2002) and an analysis of Li and Sr isotopic compositions in spring water (Nishio et al., 2009). We estimated local Vp/Vs ratio, which is sensitive to fluid existence, in the source region of earthquake swarm around Mt. Ontake.

We directly estimated Vp/Vs ratio in the source region of earthquake swarm by using method of Lin and Shearer (2007). If dTp and dTs are P and S wave travel time differences for a common station of a pair of nearby events, respectively, Vp/Vs ratio in a micro area can be expressed as Vp/Vs=dTs/dTp where seismic velocity is constant. Given a number of different stations and event pairs, plotted points (dTp,dTs) should be on a straight line with slope Vp/Vs. This slope is obtained using grid search for the line with the minimum perpendicular distance to each plot. Because (dTp,dTs) plots have errors in both dTp and dTs values, we iterated grid search to equalize both dTp and dTs error scales. First, we determined Vp/Vs ratio in a micro area for each seismic station. Then we eliminated stations data in which Vp/Vs ratio did not converge by iterated grid search when we estimate Vp/Vs in a micro area. We used earthquake data from 1997 to 2011 listed in the JMA catalog and we set dimension of a micro area as 0.01 degrees x 0.01 degrees x 1.5 km depth to analyze the data.

At the depth from 4 to 7 km, we obtained Vp/Vs values in micro areas in the earthquake swarm area to be from 1.6 to 1.9. Vp/Vs values were estimated to be about 1.8 for micro areas where many earthquakes occurred. In another area, Vp/Vs values were estimated to be up to 1.9. At this depth seismicity extends to the southeast region of Mt. Ontake. At the depth from 7 to 10 km, Vp/Vs values were larger than those at the depth from 4 to 7 km depth for the whole analyzed areas. Vp/Vs values were estimated to be up to 2.0 in several areas. At this depth seismicity is concentrated in the east and northeast regions from Mt. Ontake. In micro areas where earthquakes intensely occurred, higher Vp/Vs values of about 1.9 were found. At the depth from 4 to 10 km, Vp/Vs values were increased gradually. We also conducted the double-difference tomography using same data set to estimate velocity and Vp/Vs structures around Mt. Ontake. As a result, we found that high Vp/Vs values were estimated in the source region of earthquake swarm area by the both method.

Several high Vp/Vs areas at the depth from 6 to 7 km in this study correspond to the region where deep crustal origin fluid is suggested by the electrical survey and isotopic analysis. The estimated high Vp/Vs values in the shallow area suggest fluid existence.

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Keywords: Vp/Vs ratio, earthquake swarm