Groundwater anomalies related to the 2004 Niigata Chuetsu Earthquake

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The 2004 Niigata Chuetsu Earthquake occurred on October 23, 2004. A series of aftershocks including some M6 class events have been following the main shock. The Chuetsu area of Niigata Prefecture including the aftershock area is characterized by many active faults-and-folds and the Shibata-Koide Tectonic Line (SKTL) with a NNE-SSW trend. As is well-known, the formation of these faults and folds have resulted in the high relief of the basin and range structure in the Niigata Prefecture.

There are many snow-melting wells in the Chuetsu area. Oki et al. (1998) have shown many anomaly areas and zones in temperature and electric conductivity of groundwater in the Niigata Prefecture before the earthquake. They have concluded that the anomalies indicate the flow of deep water upward along active faults associated with earthquakes in the Niigata Prefecture. We examined changes in groundwater temperature, electrical conductivity, and chemistry related to the earthquake, using the snow-melting wells, and infer the behavior and nature of groundwater around the epicentral area.

The groundwaters from more than 10,000 wells at the depth of 40-100m have been utilized for the snow-melting. Considering the average aquifer depth of 70m for the wells, the local geothermal gradient of 30˚C/km, and the annual mean temperature of 11.5 to 12oC in research area, we decided the temperature of higher than 15˚C was anomalous.

The earthquake produced some new anomaly areas in temperature, electrical conductivity, and chemistry of groundwater around the epicentral area. In several thermal anomaly areas exsisted before the earthquake, considerable increases in groundwater temperature are also observed as follows. Groundwater temperatures have increased up to 20oC in the preexisted anomaly along the Yukyu-zan active fault. The fault with a NNE-SSW trend is located at the boundary of the Nagaoka plain and the Higashi-yama Hill and in the western margin of the epicentral area. Considerable increase in groundwater temperature up to 25oC are also found in and around the preexisting anomaly of the downtown area of Ojiya City located in the inferred southwestern extension of the Yukyu-zan active fault. We found a spring water discharged at the eastern margin of the epicentral area close to SKTL. The water shows higher temperature and extremely higher electric conductivity than the surrounding shallow groundwaters. We also found some groundwaters with anomalous temperature and electric conductivity in the southeastern margin of the epicentral area where SKTL is located between the Higashi-yama Hill and the Echigo Mountains.

We conclude that these new anomalies of groundwater have been formed in relation to the earthquake. These new anomalies of groundwater resulted from the flow of deep geothermal water to the near-surface along faults and fractures activated during the earthquake. The deep geothermal water have injected into shallow aquifers and mixed with shallow groundwater, resulting in the anomalies in temperature, electrical conductivity, and chemistry. The faulting and fracturing during the earthquake may have enhanced deep circulation of groundwater, and consequently thermal springs discharge through fault planes. The excess fluid pressure and the friction heat induced by a series of earthquake might be released through seismic ruptures along the Yukyu-zan active fault, SKTL, and the inferred northern extension of the Muikamachi active fault. It is likely that these new anomalies of groundwater indicate the seismic faulting near the surface along the Yukyu-zan active fault, SKTL, the inferred northern extension of the Muikamachi active fault, and buried active faults.