Evidence suggesting crustal fluids beneath earthquake source regions

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Electrical resistivity is highly sensitive not only to the temperature and bulk composition of rocks, but also to the presence and connectivity of melt, volatiles, and aqueous fluids. A great deal of effort has been made using MT soundings to obtain information on subsurface electrical conductivity anomalies around seismically active regions in subduction zones. Strike-slip intraplate earthquakes such as the 1997 Kagoshima (M6.6), the 2000 western Tottori (M7.3) earthquakes, tend to occur near the boundaries between conductive and resistive crust, generally resistive side. Rheological heterogeneities driven by aqueous fluids in the crust would produce strain concentrations within resistive crust due to anelastic deformation under strike-slip fault type stress. In the case of the 2011 Hamadori swarm earthquakes, which are thought to be triggered the 2011 Tohoku-Oki earthquake, an anomalous conductor with a width of 20 km has been detected below the seismic source region, extending down to the base of the crust. The swarm activity is likely caused by increased pore pressure, within resistive crust, as a result of fracturing stimulation. Assuming that aqueous fluids produce the low-electrical resistivity, the plausible explanations for the generation of fluids are limited to the following: (1) sediment porosity reduction and from smectite-illite and opal-quartz reactions in the subducting deep-sea sediments, (2) metamorphism of fore-arc basin sediments, sedimentary and/or volcanic rocks detached from the plate or (3) dehydration reactions in the subducted oceanic crust and/or hydrated mantle below the fore-arc mantle wedge.

Keywords: helium isotope, electrical resistivity structure

Relation among crustal deformation, precipitation and groundwater in Kosei area of Shiga Prefecture

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It is said that around 20% of the water flowing into Lake Biwa is groundwater. The main part of it is considered to be the groundwater in the Kosei area of Shiga Prefecture or the west coast area of Lake Biwa. In the Kosei area there are many mountains. The precipitation in the mountain area supplies a lot of water to the groundwater in the Kosei area. Using an autonomous underwater vehicle, Kumagai et al.(2015) found the vent, which is an outlet of groundwater and gas, around the deepest part of Lake Biwa or the northwestern part of Lake Biwa in December 2008. In addition Kumagai et al.(2015) found that the area of the vent has been magnified since December 2010 and suggested that the magnification should have some relation to crustal deformation in and around Lake Biwa. The area in and around Lake Biwa is actually included in the Niigata-Kobe Tetonic Zone and has been in large contraction (10^{-7}/year) for at least a recent few decades. However, it has not been reported that the contraction rate was changed around 2010. Daily positional information of the Geospatial Information Authority of Japan (GSI) shows that length of the east-west baseline across Lake Biwa (Hikone-Takashima baseline) has been uniformly contracted at 10^{-7}/year since 1996. On the other hand it was found that precipitation in and around Lake Biwa has been increased since 2010. Since 2010 groundwater pressure has been also increased at HNO groundwater observation station of Geological Survey of Japan, AIST, which is located in the Kosei area. Therefore it is possible that the increased precipitation in and around Lake Biwa raised the groundwater pressure at Kosei area, which in turn increased groundwater flow to Lake Biwa. If it is right, the increased groundwater flow can magnify the area of the vent. In the presentation, I will show the relation among precipitation, groundwater pressure and crustal deformation in and around Lake Biwa.

Keywords: Lake Biwa, crustal deformation, precipitation, groundwater, Niigata-Kobe Tectonic Zone

Hydraulic properties, water chemistry and gas composition at Hongu observatory, Wakayama Prefecture

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In order to explore potential sites for in-situ continuous $^{3}He/^{4}He$ gas mass spectrometer which is under development, we performed temperature and electric conductivity logging and hydraulic tests at a 1000 m well at the Hongu observatory. We also collected groundwater and gas samples from the well after the hydraulic tests. There are several reasons why we selected the Hongu observatory as the potential site: (i) High $^{3}He/^{4}He$ ratio were observed in the hot springs near the Hongu observatory; (ii) Several ancient texts reported that discharge of hot spring at the Hongu area were stopped in response to past Tonankai or Nankai earthquakes, and (iii) we have been observing groundwater, crustal deformation and seismic data near the Hongu observatory to detect non-volucanic tremors and short-term slow slip events occurring at plate boundary directly underneath the Hongu area. As a result, we obtain medium transmissivity of the aquifer (2.0 - 2.8 x 10^{-5} m^{2}/s), high $^{3}He/^{4}He$ ratio (4.69 Ra) in the gas sample and similar chemical composition of the sampled water to the surrounding hot springs.

Keywords: hydraulic property, water chemistry, gas composition, deep well

Time series of gas composition in groundwater monitored at Atotsugawa Well

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We discuss on time variation of gas composition dissolved in groundwater of Atotsugawa observatory from October 2010 to February 2013. An observation well of Atotsugawa observatory was drilled in southern-west part of Atotsugawa fault located in Gifu Prefecture. Groundwater is sampled directly from an aquifer with a TEFLON pipe by 1 L/min. Dissolved gas makes may bubbles in the TEFLON pipe because the pumping reduces the pressure of groundwater. All bubbles are collected in a gas-water separator on the ground, and are introduced into a quadrupole mass spectrometer in the observatory. A gas composition is analyzed by the mass spectrometer equipped with a gas dryer every 1 hour. Results are transported to our server computer, and all spectra are automatically analyzed. A gas ratio of He-N2-Ar tri-component is calculated from a mass spectrum. This ratio is corrected by oxygen component in order to subtract air contamination. Tri-component ratio scatters on a mixing line of the air and the crust. Some data point on a line between the air and the mantle. Time series of the tri-component plot might have a potential to monitor gas migrated from a deep part to the ground surface.

Keywords: Groundwater, Dissolved gas, Time variation

Depth profile of helium concentration in a hot-spring well in Beppu, Japan

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Volatile components degassing from the crust provide important information on Earth interior. Helium fluxes from the crust because of its inert property are important precursors of crustal tectonic and thermal events. Helium isotopic ratios in crustal fluid serve as tracers in resolving groundwater age in the crust and contribution of mantle-derived fluid. Here, we will describe depth profile of helium concentration in a hot-spring well in Beppu, Japan using new sampling devices. The sampling devices allow gas exchange between the headspace in the sampler volume and the dissolved gases in the water though gas permeable silicon tubing, and we collected helium gases dissolving in well water by the devices.

Beppu is situated on east end of subsidence of the Beppu-Shimabara Graben in Kyushu Island, southwest Japan (Matsumoto, 1979), and is a famous area as a geothermal system. The geothermal system is located on the eastern flanks of the Tsurumi-Garandake volcanic center and spread until the coastline to the east. The geothermal activity is mostly concentrated in two areas, on the northern and southern sides of the fan deposit. These two areas are known as the Kamegawa and Beppu thermal zones, which are along with two faults, the Kamegawa and Asamigawa faults, respectively (Allis & Yusa, 1989).

The sampling devices were installed every 50 m from near bottom of the well to the surface in the periods of July 13-15 and August 21-24, 2015. The collected gases were measured by a noble gas mass spectrometer (Helix SFT; GV Instrument) installed at Atmosphere and Ocean Research Institute, University of Tokyo.

Helium concentrations and isotope ratios ($^{3}He/^{4}He$) is gradually lower, as setting depth becomes shallow. The highest in the isotope ratio shows 6.79 and 7.08 Ra (Ra=1.4E-6) around the bottom, and its high ratio can be of mantle origin. The screen of the borehole ranges 278-300 m, mantle helium could enter the well with hot spring water through the screen, and could go to the surface.

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Keywords: helium, isotope ratios, hot spring, depth profile of concentration

Water flux model around TRIES/MIU to explain the gravity change - II

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Gravity measurement has been operated in three observation stations in and around the Tono Research Institute of Earthquake Science (TRIES) since 2003, and detected the gravity change in the 2011 off the Pacific coast of Tohoku Earthquake. The change was about 10 micro Gal (1×10^{-4} m/s^2) decrease in all three stations which exceeds the effect of ground deformation, moreover it is opposite sense of change for the 14 m of ground water level increase in nearby station. We have constructed the ground water flux model to explain the gravity decrease and the water level increase simultaneously. Based on gravity change simulations on hydraulic geological structure in the study area, we confirmed that the water flux which flows down to the deeper area can explain both the gravity and the ground water level. Niwa et al. (2012) reported the coseismic ground water level changes of the Tohoku Earthquake in several wells in and around the Mizunami Underground Research Laboratory (MIU, JAEA), which is near by the TRIES.

In this report, we first reviewed the effect of ground deformation including the afterslip to the gravity data obtained in and around the TRIES/MIU. Ground water level is almost recovering in this 5 years, nevertheless the gravity values are still same as of just after the earthquake. Coseismic vertical displacement is less than 1 cm in the study area, which gravitational effect is about 1 micro Gal. Postseismic vertical displacement shows about 4 cm uplift in the last 5 years. This is an amount of 9 micro Gal decrease for the gravity, which cancels the coseismic step. We conclude that the gravitational effect of the ground water level recovery is masked by the effect of postseismic displacement. We also studied the individual coseismic ground water level response for all the wells in the study area, including reported in Niwa et al. (2012). For each well, we compiled the amount of change, time to the peak of the change, duration for the recovery and so on. The correlation was found between the recovery speed and the water catchment area on the basement topography. We also quested for the implication of downward water flow in the wells where the water pressure is monitored by multi packer system.

Keywords: Gravity, Ground Water, Coseismic Response

Groundwater and crack behaviors after underground gallery closure inferred from observation of S-wave travel time change by the seismic ACROSS

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Constant monitoring of temporal seismic velocity change by the seismic ACROSS has been practiced for more than 13 years since 2002 at Tono mine (Toki City, Gifu Prefecture). At Tono mine, back-filling of underground galleries were started from March 2012 and completed in March 2015. The drainage pump stopped on December 9, 2014. In this study, we report the significant changes of the S-wave travel time associated with reflood of the underground galleries. In addition, we conclude that S-wave velocity change has occurred in the Toki granite under sedimentary formation (Mizunami Group, about 90m thick), and discuss that groundwater flow in and around the packed gallery control the opening and closing of cracks and the S-wave velocity change.

Keywords: seismic ACROSS, Tono mine, reflood, seismic velocity change

