Co-seismic pore pressure/groundwater level changes associated with the 2016 Kumamoto Earthquake (Mj7.3) in and around Mizunami Underground Research Laboratory

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Clear exponential pore pressure/groundwater level changes associated with the 2016 Kumamoto Earthquake (Mj7.3) were observed at borehole observation sites "STG200 and STG200N" in Mizunami Underground Research Laboratory (MIU), and TGR350 borehole observation site located approximately 500m south of MIU, in the Tono region, central Japan (Hypocentral Distances are approximately 665km). Amount of pore pressure changes in STG200 and STG200N are 30 and 28 kPa-rise, respectively and groundwater level in TGR350 is 2.3m-rise. Although those are different features, co-seismic pore pressure /groundwater level changes were also observed at STG300 site in MIU and SBS105 site located approximately 1km north-east of MIU.
We will present the details of these pore pressure/groundwater level changes, and attempt to clarify the qualitative/quantitative model for the co-seismic pore pressure/groundwater level changes.

Keywords: The 2016 Kumamoto Earthquake (Mj7.3), Co-seismic pore pressure/water level changes, Tono region, Gifu, central Japan

Postseismic Well Water Level Changes at the Dogo Hot Spring in Japan

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The Dogo hot spring, situated in Matsuyama City, Ehime Prefecture, Japan, is one of the oldest and most famous hot springs in Japan. The well water level or discharge at the spring often decreased coseismically and increased postseismically related to the past Nankai earthquakes. We analyzed well water level data recorded at the spring immediately after the 1946 Nankai earthquake and over the period from 1985 to 2015. From this analysis, we have got five postseismic well water level increases related to the earthquakes whose seismic intensities were four or greater at Matsuyama city in JMA scale. The pattern of the five postseismic increases is very similar and shows a tendency of exponential convergence. We found that these postseismic increases can be explained by a basic equation of groundwater motion, which is a kind of diffusion equation. We also tried to detect the change in the diffusion coefficient or hydraulic diffusivity. However we did not detect it.

Keywords: Groundwater , Dogo hot spring, Diffusion equation, Seismic shaking, Nankai earthquake

Changes in permeability in the Hirabayashi well estimated by long-term groundwater-level observation

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The Hirabayashi well encountered the Nojima fault at the depth of 623.1 - 625.3 m, and we have been observing groundwater level until now. The groundwater-level observation shows that estimated permeability was constant between 1996 and 2006, then slightly decreased, and suddenly increased after the 2011 Tohoku-oki and the 2013 Awaji-island earthquakes. Pumping tests are carried out on 1996, 2000 and 2016. Permeability estimated by the three pumping tests is consistent with that estimated by groundwater-level observation. The temperature logging just after the 2016 pumping test indicates that main aquifer is not at the depth of 630 - 650m where the casing of the well was perforated, but is shallower than at the depth of 200 m.

Keywords: permeability, groundwater level, pumping test

Improvement of the response of groundwater level to crustal strain by the sealing of the observation well at the Hokusei observation site

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One of the problems is the lack of high quality crustal deformation/groundwater observation sites in the western part of Aichi prefecture and the northern part of Mie prefecture, in terms of the estimation of short-term SSEs occurring at the plate boundary of the Nankai Trough. In May 2016, the inner pipe of the observation well at the Hokusei observation site located in the northern part of Mie prefecture was sealed with a packer in order to improve the response of groundwater level to crustal deformation.
Because the permeability of the target aquifer at this site is low, the groundwater level before sealing was poor in response to crustal strain changes. After sealing, tidal fluctuation clearly appeared in the groundwater level/pressure, then we found the response of the groundwater level/pressure to crustal deformation to be clearly improved. The response of the groundwater level /pressure to crustal strain after sealing improved about 10 times than before the sealing.
By eliminating the tidal component, barometric pressure response, and rain response from the groundwater level/pressure data, the changes in groundwater level/pressure were detected at the timing of the deep low frequency tremor activities occurred around Ise Bay in July and December 2016. Since it is expected that the changes of groundwater level/pressure are caused by the crustal deformation due to short-term SSEs, we compare the changes in groundwater level/pressure calculated from the fault models of the short-term SSEs with the detected changes.

Keywords: groundwater, strain sensitivity, closed well, slow slip event

Helium measurements by passive diffusion samplers hanged in a borehole in Beppu, Japan

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Helium concentrations and its isotopic ratios in spring water are potentially powerful tools for crustal tectonic and thermal events, and could serve as tracers in resolving contribution of mantle-derived fluid. However, helium gas in spring water is directly sampled on sites and often collected with its coexisting water. A new passive diffusion sampler, which is just set up at any sites, can collect only helium gas dissolving in water (Dame, 2015). The sampling devices allow gas exchange between the head space in the sampler volume and the dissolved gases in the water though gas permeable silicon tubing. Here, we measured helium concentrations and its isotopic ratios in a borehole in Beppu, Japan, and obtained their depth profile.
Beppu is located 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 situated 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). Therefore, it is worthwhile to attempt to find depth profile of helium signal in this area.
The sampling devices were installed every 50 m from near bottom of the well to the surface in the periods of July 13th-15th, August 21st-24th, 2015 and May 31st-June 3rd, 2016. 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 ($^3He/^4He$) are gradually lower, as setting depth becomes shallow. The $^3He/^4He$ ratios ranges from 1.0-2.2 R_a under water surface to 6.3-7.1 R_a (R_a=1.4×10^{-6}) at the bottom of a borehole. The high $^3He/^4He$ ratios are within range reported for mantle-derived magma at subduction zones (e.g., Hilton et al., 2002). The MORB-type helium could enter the borehole with hot spring water around the bottom. The observed variation in the $^3He/^4He$ ratios are the result of binary mixing of magma and air components.

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Keywords: helium, isotope ratio, passive diffusion sampler, borehole in Beppu

Fluid behavior in fracture and its representative elementary volume using Lattice Boltzmann Method

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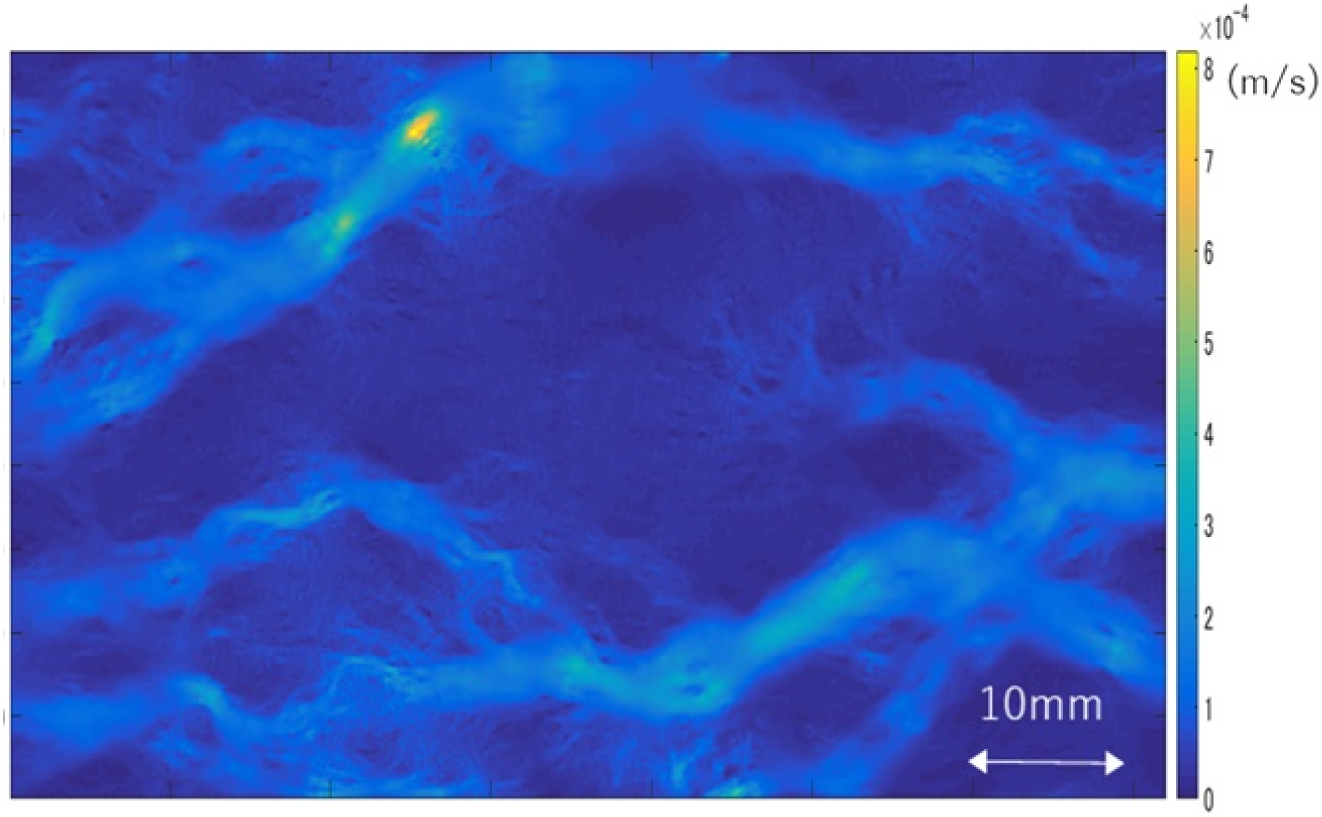
Characterization of fluid flow in the fault zone (e.g., fractures) is related to the fault activities, because pore pressure along fault zone was controlled by its hydraulic properties (e.g., permeability). The fluid behavior along the fault is further related to the fault healing process after the earthquake, and mineralization process. Permeability of fracture is usually measured by laboratory experiments, however few studies focused on calculating permeability by using flow simulation on digital fracture models. Here we use Lattice Boltzmann Method (LBM) to calculate the fluid velocity and permeability. Using LBM fluid flow simulation, we can easily change the reservoir parameters, such as temperature and aperture length of fracture. Here we use two natural fracture data: (1) sheared, and (2) non-sheared fracture models obtained by Ishibashi et al. (2014). After we digitalized these natural fractures, we numerically injected water into the two fracture models using LBM. To validate our simulation results, we compare the calculated permeability with the laboratory experiments. We then discussed the Representative Elementary Volume (REV) of the hydraulic properties of these fracture models. In this study, we extract several subdomains_ (i.e., small fracture models) from the whole model and estimate permeability of the subdomains. When the size of fracture model is smaller, the permeability estimated using LBM are scattered. However, the permeability is uniformly estimated when the model size is close to the whole model (0.1×0.15m). Therefore, the REV of the fracture model used in this study is ~0.1m. Because the hydraulic properties of fracture models smaller than REV are largely influenced by local heterogeneity, it is important to calculate hydraulic property by considering REV of sample.

Keywords: fracture, permeability, Lattice Boltzmann Method, Representative Elementary Volume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