Relationship between occurrence of mercury in groundwater and active faults in Sennan area, Osaka Prefecture

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Thirty one groundwaters containing detectable mercury was found among 4513 groundwaters monitored by Osaka Prefecture based on the Water Pollution Control Law. Most of those were found in the two areas; i.e, northeastern part of the prefecture along the active Ikoma Fault system(Osaka Prefecture, 2009), and the southwestern part of it. The mercury was mostly inorganic and two groundwaters from Hirakata, in the northeastern area had δ^{202}Hg of groundwater was -0.65‰~-0.85‰ indicating geogenic of these mercury(Sakamoto et al., 2016). This study was planned to reveal the origin of mercury in the groundwater of southwestern Osaka Prefecture and the relationship of occurrence of mercury to active faults.

The groundwater was sampled from 27 wells in August 2016 in December in Kishiwada and Izumi cities. All the wells were <10m depth, and the water levels ware 1~2m from the ground.

This study area includes the wide plateau comprising the Pleistocene sedimentary rocks at the center and alluvial low land along Osaka bay, and Ryoke Granite is exposed on the southern Izumi mountains. Sennan fault runs on the border between alluvial low land and plateau along coast of Osaka bay, Uemachi fault runs from north to south in the center of the study area, and Uchihata fault borders the plateau from Ryoke Granite. Many small faults accross these faults. The faults appear has large flexure zones in the Pleistocene stratum. No groundwater contains excess mercury than the value (0.5ppb) in this study, while several ten ppt mercury was detected from 14 wells, and the highest concentration was 200 ppt, of which well was located near the Uemachi fault. The wells containing mercury were found mostly near the Uemachi fault, and aligned along it. Also, some other wells including mercury were found along the Sennan fault.

Major chemistry of the studied groundwaters were Ca^{2+}-HCO_3^- and Na-Cl- (SO_4+NO_3) types, and the waters containing mercury tended to include SO_4^{2-} and NO_3^- more than the others. Such an characteristic is different from the major chemistry of the mercury-detected groundwaters in northeastern part of Osaka Prefecture, previously studied. In that area, mercury concentration of groundwaters including anthropogenic component such as SO_4^{2-} , NO_3^- and Cl^- was lower than Ca^{2+}-HCO_3^- type grandwaters. The NO_3^- and SO_4^{2-} would be oxidants to ionize gaseous mercury in the studied groundwaters. The mercury would be captured in aerobic groundwaters after issuiing from the deep along the faults in this area.

The fluids released from the subducting slab are found in many place of the Japanese islands. It is reported that saline waters were found in such places, where coincidentaly epicenters of Deep low-Frequency earthquakes occurred(Kazehaya, 2014). Deep low-Frequency earthquakes were observed in our studied areas where geogenic mercury was detected in the groundwaters. In this study area, many active faults belonging to the Uemachi fault system including conjugate faults and flexure zones in Osaka group(Pleistocene sedimentary formation). Combining those observations, the mercury would be released in association with dehydration of slab fluid and issue along the active faults. The origin of mercury will be

revealed by analyzing mercury isotope ratio of groundwater and soil gas.

Keywords: mercury, groundwater, isotope

Geochemical analysis of shallow and deep end members by use of brine discharging at Kashio area, Nagano prefecture, central Japan

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Hot springs in Japan are classified, mainly in terms of oxygen and hydrogen isotopic ratio of water, into four groups: green tuff type, coastal type, volcanic type, and Arima type. Arima type hot springs are considered to be formed by mixing of deep brine and meteoric water. Chemical and isotopic composition of the deep brine, however, is not revealed, and two hypotheses about the origin of it, “magma water origin” and “slab-related fluid origin”, have conflicted. It is an important goal in studies of hot springs to reveal the composition and origin of the brine. Helium isotopic ratios are as high as mantle component in some water or gas samples from Arima type hot springs, which means mantle is involved in forming or ascending processes of the deep brine. Therefore it is thought that Arima type hot spring is associated with water circulation in subduction zones. In order to understand water mass balance in subduction zones, it is necessary to estimate fluxes of the deep fluids. Kashio hot spring, discharging near the Median Tectonic Line in central Japan, is considered as one of Arima type hot springs. In this study water samples are collected at Kashio area. Then oxygen and hydrogen isotopic ratios ($\delta^{18}O$, δD), Cl^- concentrations, HCO_3^- concentrations, tritium concentrations, rare gas concentrations, and rare gas isotropic ratios of the collected samples are measured. At the same time, flow rates and Cl^- concentration of river waters at Kashio area are measured. By use of seasonal variations of values measured from the samples, it is revealed that water of Kashio hot spring is a mixture of the deep brine and young groundwater originating from meteoric water. With tritium and ^{20}Ne concentrations, chemical and isotopic composition of the Kashio deep brine is estimated as follows: $\delta^{18}O$ = -1‰, δD = -49 ‰, Cl^- = 25000 mg/L. The δD value of the brine is not explained by magma water. This oxygen and hydrogen isotropic composition might be interpreted as a result of oxygen isotopic fractionation between minerals and slab-derived fluid which occurs at relatively shallow depth inside crust. A flux of the Kashio brine is also estimated, using the flow rates and Cl^- concentrations of river waters, at 0.63 L/sec. This value is similar to that of Arima hot spring and Kobe area.

Exploration of Tachikawa Fault by Groundwater Radon Concentration

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We explored Tachikawa fault by use of groundwater radon concentration. Radon concentrations in shallow groundwater samples around the fault were comparable to that expected from the geology on the Kanto plane, and they were consistent with previous studies. Almost of all radon concentrations in deep groundwater from the bedrock-deep aquifer were also comparable to that in shallow groundwater. However radon concentrations in groundwater samples that were obtained at wells close to the fault were markedly higher than the expected radon concentration. This disparity can be explained by the existence of fracture zones spreading on both sides of the fault. The radon concentration distribution of deep groundwater samples suggests that a fault exists even at the southern part of the traditional line of Tachikawa fault.

Keywords: Radon, Groundwater, Tachikawa fault

Helium isotope anomalies in the San-in shear zone

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A concentration zone of deformation corresponding to the active zone of microseismicity has been identified in an eastern part of the San-in region. This deformed zone, called “San-in shear zone”, is more than 200 km long along the coast of the Japan Sea and accommodates right-lateral shear motion. Its width is variable, that is, less than 20 km in the eastern part of Tottori Prefecture and 50~70 km in a western part of Tottori Prefecture and the eastern part of Shimane Prefecture. Elevated 3He/4He ratios in groundwaters sampled from hot spring and drinking water wells are observed around the shear zone, suggesting the emission of mantle-derived helium. The deformation may be attributed to the low viscosity in the crust because the concentrated supply of mantle fluids with high 3He/4He ratios may weaken the lower crust.

Keywords: helium isotope, San-in shear zone

Crustal resistivity structure beneath the source region of 2014 northern Nagano earthquake

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In this study we have determined two dimensional (2-D) resistivity structure beneath the source region of 2014 northern Nagano earthquake. Seventeen magnetotelluric (MT) stations were deployed in the study area. The MT data were collected using five component wide-band MT instruments (Phoenix MTU-5 system). A simultaneous remote reference measurement was carried out at the Sawauchi site (400 km northeast of the study area). The observed apparent resistivity and phase data were inverted simultaneously using the 2-D inversion code of Ogawa and Uchida [1996]. The obtained resistivity model through the inversion show as follows: (1) The mainshock hypocenter is located in a prominent conductive zone. (2) This anomaly is imaged in the depth range of 3 to 20 km. (3) These results indicate that the conductive zone may be due to crustal fluids that contributed to the occurrence of the large earthquake.

Keywords: 2014 northern Nagano earthquake, resistivity structure, crustal fluids

Changes in P and S wave velocity associated with the two-staged reflood of the underground galleries

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We detected changes in P and S wave velocity of the Toki granite around the Tono mine observed by the seismic ACROSS signal during the back-filling of underground galleries. The back-filling in the underground galleries at the Tono mine was started in March 2012. The main drainage pump (altitude 160 m) was stopped on December 9, 2014, and the closure of the galleries and the vertical shafts were completed in March 2015. After the termination of the main drain pump, the reflood started in the buried galleries and the remarkable change in S-wave travel time was observed at the borehole accelerometer installed in the Toki granite, where is located beneath the ACROSS transmitter [Kunitomo et al.(2016)JpGU]. In this study, we analyzed the data of the TRIES borehole observation network and Hi-net and investigated the velocity change of P waves as well as S waves around the mine from a distance. As a result, the advance of the P wave traveltimes were detected from the middle of 2014 at the north and south observation points. Around June 2014, the water level rose from the level of the lower gallery (altitude 152 m) to the upper galleries (altitude 160 m) caused by the failure of the pump in the lower gallery. It is thought that the increase of the P wave velocity of the surrounding rock was caused by the penetration of groundwater.

Keywords: seismic ACROSS, seismic velocity change, groundwater

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 ($R_a=1.4\times10^{-6}$) 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