

Radiocesium outflow related to the forest floor conditions in mountainous forest of the Abukuma Mountains, Fukushima

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The outflow of Cs-137 from the mountainous forest floor was estimated in the Abukuma Mountains, Fukushima. The outflow rates are decreased with a cover rate of the forest floor by a litter layer. The result shows the important role of the litter layer and undergrowth on a migration control of the radiocesium outflow from the forest floor.

Keywords: radiocesium, mountainous forest, TEPCO' Fukushima Dai-ichi nuclear power plant accident

Expansion and alteration behaviors of NH₄-montmorillonite

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Bentonite will be used as a buffer material in the geological disposal of radioactive waste due to the high swelling and cation exchange capacity of the main bentonite constituent Na-montmorillonite (Na-MMT). Replacement of the interlayer Na by other cationic species, however, can cause a significant reduction in the swelling behavior of MMT. Nitrate salts found in transuranic wastes can be reduced to form NH₄⁺ in deep underground conditions. NH₄⁺ ions could replace the interlayer Na cations of Na-MMT to form NH₄-MMT, but the swelling behavior of NH₄-MMT is not well known.

To improve understanding of the swelling behavior of NH₄-MMT, the expandability of a suite of homoionic MMT, including Na-MMT, K-MMT, Cs-MMT, and NH₄-MMT were investigated by XRD under controlled relative humidity (RH) conditions and supported by molecular dynamics (MD) calculations.

Differences in the swelling behavior of the suite of homoionic MMT were observed by XRD and could be largely explained in terms of the valence, the radius and the hydration energy of the interlayer cations. All these properties, however, are very similar for K⁺ and NH₄⁺ and so could not be used to explain the reduced swelling of K-MMT compared to NH₄-MMT under low RH conditions. Although it has been well known that K-MMT lost expandability by dehydration, it has not been well known whether this process would occur on NH₄-MMT or not.

First-principles MD calculations were conducted in a previous study (Shi et al., 2013) for NH₄-MMT containing only a small number of water molecules (less than 1.25 molecules per NH₄-MMT half unit cell). The hydrogen bonding and the network between the surface oxygen, interlayer NH₄⁺ ion and water were reported to be increased by adding more water molecules to the interlayer. The basal spacing measured by XRD under controlled RH in the current study are consistent with the interlayer containing less than one layer of water, although the interlayer charge may be different between samples. It is also difficult to make direct comparisons with Shi et al.'s calculations and experimental results because the number of water molecules in the interlayer cannot be precisely controlled experimentally.

The classical MD simulations in the current study described the mixing enthalpy of MMT / water molecules system by including the number of interlayer water molecules as a variable. The potential functions and parameters of MMT and water molecules proposed by Nakano and Kawamura (2006) and Kawamura (2008) were employed in this study. Parameters on NH₄⁺ are determined to reproduce NH₄Cl structure. The mixing enthalpy was used as an index to evaluate the swelling state stability. To consider the RH effect, the mixing enthalpy (H_{mix}) was calculated by: $H_{\text{mix}} = H_{(\text{MMT}+n\text{H}_2\text{O})} - (H_{\text{MMT}} + n\mu_{\text{H}_2\text{O}})$, where the chemical potential of water, $\mu_{\text{H}_2\text{O}}$ includes the effect of RH by: $\mu_{\text{H}_2\text{O}} = \mu^0 + RT \ln(P/P_0)$ (μ^0 : standard chemical potential, R : gas constant, T : temperature(K), P_0/P : partial pressure of water) The minimum of H_{mix} indicates the stable hydration state of the MMT. In this study, $n = 0$ to 20 water molecules were added to homoionic MMT to understand the different swelling behavior of K-MMT and NH₄-MMT under each RH condition. It was found that the series of calculated mixing enthalpy was consistent with the XRD results under controlled RH. In the NH₄-MMT system, the hydrogen bond between NH₄⁺ and surface oxygen on clay was confirmed from the radial distribution function. These hydrogen bonds make large basal spacing of NH₄-MMT rather than that of K-MMT at 0%RH, which lead to hydration at low RH condition compare to K-MMT because the expansion of smectite occurs when hydration of interlayer cation exceeds the electrostatic attraction between silicate layer and cation. This result indicates that NH₄-MMT is more

difficult to become non-expandable or less expandable mineral than K-MMT.

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Keywords: Expansion, Alteration, Ammonium, Potassium, Montmorillonite, Molecular Dynamics

Formation of magnesium silicates and its geochemical modeling at high alkaline conditions

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In geological disposal of waste generated from reprocessing of spent fuel, a large amount of cement material is used for vitrified waste and grout, and the disposal site is predicted to be a high alkaline environment over time. Therefore, it is urgent to understand radionuclides migration and alteration of the barrier materials under high alkaline environment. In general, most mineral surfaces are negatively charged under high alkaline conditions. Therefore, negatively charged anions are poorly adsorbed to the mineral surface. Although the nuclide is considered to be poorly adsorbed in the safety assessment, the nuclide would be delayed by the dynamic processes such as precipitation and solid solution formation without adsorption. For example, layered double hydroxides (LDH), calcium silicate hydrate (C-S-H) and magnesium silicate hydrate (M-S-H) with positively charged surface and a high anion exchange capacity even at a high alkaline environment (Goh, Lim, and Dong 2008)(Evans 2008). In this context, the objective in this study is to clarify the Mg-bearing phases produced by mixing the interstitial water of cement (high alkaline) and the groundwater of Mg-HCO₃ system in the geological disposal environment. For formation of LDHs, 50 mM of each of Mg ion solution (Mg(NO₃)₂ · 6H₂O), Al or Fe ion solution (Al(NO₃)₃ · 9H₂O or Fe(NO₃)₃ · 9H₂O), and silicate anion solution (Na₂SiO₃) as an initial solution was mixed with different ratios. After the mixing, these mixed solutions were adjusted to pH 9 or pH 12 and left at 25 °C for 24 hours. The reason for paying attention to silicate ions is that they are concerned about dissolution from cement materials and vitrified bodies used in waste disposal and considered to be analogues of ⁷⁹Se and ⁹⁹Tc.

In Mg-Al system, at pH 9, in the case of adding above 15 mM silicate ions, M-S-H and amorphous aluminium (with Al ion), or M-S-H and smectite (without Al ion) were precipitated. On the other hand, in the case of below 15 mM silicate ions, LDH (Mg/Al 0.5) and gibbsite or boehmite (Mg/Al 0.5) were precipitated. At pH 12, in the case without Al ion and with Mg ion, brucite was confirmed. Moreover, M-S-H (Mg/Al 0.1) or LDH (Mg/Al 0.3) instead of gibbsite and boehmite were generated. In other systems, no change was observed with the precipitates at pH 9.

In Mg-Fe system, formation of LDH was confirmed in a system containing less silicate ion and much Mg ion, but ferrihydrite or M-S-H was precipitated in other systems containing Fe ion.

In order to investigate these results thermodynamically, by calculating and incorporating M-S-H and LDH database based on previous study (Hase et al. 2017), we could represent thermodynamically precipitated mineral species.

Keywords: magnesium silicate, layered double hydroxide

Background of assessing geological materials for a potential low and intermediate level radioactive waste repository in Bangladesh

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Low and Intermediate level wastes (LILW) in Bangladesh are being generated from operation, repair and maintenance of 3MW TRIGA MARK-II research reactor (RR), 14 MeV Neutron Generator and research & commercial irradiators such as Co-60 and isotope production for medical purposes. The wastes arising from these sources are generally spent ion exchange resins, graphite, lead and polythene plugs, contaminated vials, hand gloves, plastic syringes, tissue papers, shoe-covers, protective cloths, plastic and metallic wares, spent and disused sources (SRS), activated carbon, gaseous discharges, etc. The radionuclides involved with these wastes are- Co-60, Cs- 134 & 137, Sr-90, Ir-192, Tc-99m, I-131, I-125, C-14, H-3, Ra-226, Am-Be neutron sources, Cm-244, Am-241, Cr-51, Mn-54, Zn-65, P-32, Sc-46, etc. Solid radioactive wastes are collected, segregated at the place of generation and stored in interim-storage rooms of the Central Radioactive Waste Processing and Storage Facility (CWPSF), developed by Bangladesh Atomic Energy Commission (BAEC) in cooperation with International Atomic Energy Agency (IAEA). Short lived radionuclides containing solid wastes are managed by delay-and-decay storage and released into the environment. Others are safely transported & stored in shielded enclosures within CWPSF. Besides, Bangladesh is implementing Nuclear Power Plant (NPP) projects by constructing two reactors of 1000 MW each. It is expected to have more LILW from this NPP which needs to be disposed safely. For safe disposal of LILW, a National Radioactive Waste Management Plan (NRWMP) has been formulated by BAEC where site investigations and processes for site selection for waste disposal facilities is one of the key issues.

For selecting a potential site for safe disposal of radioactive waste, Bangladesh have several apparently suitable geological formations, such as basement hard rock at more than 100 m depth and clay formations exposed at many locations to few meters only. The basement hard rocks of Bangladesh are tonalitic and granodioritic rocks, variously deformed to granitic gneiss and intruded by younger monzogranite having mineralogical composition of plagioclase, quartz and hornblende, with lesser amounts of biotite and potash feldspar and trace amounts of clinopyroxene, titanite and iron oxides. (Ameen et al., 2007). On the other hand, the tropical clays of the central part of the country, called Madhupur Clay Formations are typically highly weathered and reddish brown color. They are mainly composed of kaolinite, illite, chlorite and illite-smectite mixed layer minerals along with some non-clay minerals like quartz, cristobalite, orthoclase, microcline, plagioclase, calcite, siderite and dolomite and of intermediate to high plasticity inorganic clay (Haque et al., 2013; Hossain and Toll, 2006). Physical and engineering properties of these two types of geological materials have been studied by various researchers to some extent. However, their detail geochemical characteristics, specially the migration behavior for radionuclides and associated studies have yet to be investigated. The present study will review these two materials' properties for potentiality of hosting LILW repository with suggestions for future investigations.

Keywords: Basement hard rock, Madhupur Clay, Radioactive waste repository, Bangladesh

Backfilling test in the groundwater recovery experiment (2) Effective factors on saturation of backfilling material

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The purpose of this study is to identify effective factors that dominate the saturation process of backfill material for drift closure by numerical simulation of the Groundwater REcovery Experiment in Tunnel (GREET). The GREET, where a part of experiment gallery is filled with in-situ groundwater, is being currently performed at 500m depth of Mizunami Underground Research Laboratory. The backfill test is conducted in the experiment gallery using drilling pits filled with backfill material to obtain fundamental data of its hydro-mechanical behavior during the GREET.

In this study, sensitivity analysis focused on the effect of swelling deformation, hydraulic conductivity and unsaturated characteristics of the backfill material has been carried out. The results showed that the unsaturated characteristics is the sensitive factor for saturation process of backfill material.

Keywords: Backfill material, Saturation process, Numerical simulation

Estimation of hydrogeological properties of a fault by geochemical analysis of groundwater and mass transport analysis

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Geological disposal is investigated for disposal of high-level radioactive waste. In geological disposal, it is required that radionuclides in the waste does not affect the biosphere even if they are transferred by action of groundwater. Therefore, understanding of groundwater flow regime around disposal site is important. Fault acts as conduit and/or barrier dependent on its internal structure and its hydrogeological property is not sufficiently understood. In this study, spatial and temporal variations of groundwater chemistry around a fault was estimated from geochemical analyses of groundwater samples and past data. Groundwater flow and mass transport regimes around the fault was interpreted by comparing the spatial and temporal variations and simulation results using three dimensional hydrogeological model.

Study area is the region around Mizunami Underground Research Laboratory of Japan Atomic Energy Agency (JAEA), Gifu prefecture, Japan. Main shaft of the laboratory is located adjacent to a fault referred to as Main Shaft Fault (MSF) with NW-SE strike and almost vertical dip. Groundwater samples were collected from 12 intervals of 5 boreholes on both sides of the MSF. Concentrations or isotope ratios of dominant dissolved ions, alkalinity, hydrogen and oxygen isotopes, sulfur hexafluoride, tritium were determined, and the spatial distribution and temporal change were considered by combining with geochemical monitoring data conducted by JAEA (Sai et al., 2011; Shingu et al., 2011; Shingu et al., 2012; Omori et al., 2013a; Omori et al., 2013b; Omori et al., 2014). In addition, a three dimensional hydrogeological model was developed, and groundwater flow analysis was carried out. Its results were used as boundary conditions in groundwater flow and mass transport analyses conducted using another model partly refined around the fault. The analytical results were compared with the actually measured values.

The sample analyses and past data revealed that spatial distributions of calcium, chloride, bromide ion concentrations, hydrogen and oxygen isotope ratios, and tritium concentration were different between both sides of the fault. Concentrations of calcium, chloride, and bromide ions similarly decreased with time only on the southwestern side of the fault. The results of the mass transport analysis considering the influence of the water drainage in the shaft excavation also showed decrease of chloride ion concentration only on the southwestern side of the fault. Head calculated in the groundwater flow analysis was different between both sides of the fault. In contrast, the mass transfer analysis of tritium showed infiltration of surficial young groundwater containing tritium along the damage zones on both sides of the fault. Estimated infiltration rate was larger on the southwestern side of the fault. These results indicated that the MSF acts as both of barrier and conduit.

This research was conducted under support of a grant from the Ministry of Economy, Trade and Industry (METI).

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Keywords: groundwater, environmental tracer, mass transport analysis

Estimation of fracture frequency on the basis of Rock Quality Designation

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Introduction

Science Council of Japan mentioned importance of establishment of technology to search rock body with minor fractures. As a first step towards this subject, it is significant to understand the fracture frequency in many rock bodies in Japan.

Therefore the data widely obtained such as by borehole investigation should be available to characterise the fracture frequency. In this study, the speaker discussed the relationship between RQD (Rock Quality Designation) and fracture frequency focused on the Toki granite, central Japan, where a large number of borehole investigations have been carried out and the data on fracture were obtained.

Method

Fracture data used in this study were obtained by investigations in the boreholes drilled from the ground surface (17 vertical and 2 declined holes) and the underground research galleries (1 vertical and 4 horizontal holes). The total length of boreholes drilled in granite is 16,180 meters. Fracture data were obtained by the BTV investigation. The total number of fractures is 43,658 including 24,737 sharply defined fractures which has clear surface with high continuity. RQD values were calculated by sum of the intact lengths that are 10 cm or longer at 1 meter intervals.

Result and Discussion

Average RQD value of each borehole ranges from 79.9 to 98.6 with fracture frequency ranging from 0.7 to 6.6 fractures per one meter (for sharply defined fracture, RQD: 79.9 to 98.6, fracture frequency: 0.5 to 3.8 fractures per one meter). There is a significant correlation between RQD value and fracture frequency. Drilling lengths of boreholes drilled in granite are, from 329 to 1,185 meters in boreholes drilled from ground surface, 331 meters in vertical borehole and from 30 to 106 meters in horizontal borehole drilled from underground galleries.

This implies that correlation between RQD and fracture frequency is not affected by drilling length. The data are then divided into 100 meters length and those RQD values are compared with fracture frequency. Average RQD values at 100 meters intervals ranges from 68.0 to 100.0 (average value: 92.9) and fracture frequencies range from 0 to 9.2 fractures per one meter (average value: 2.8). The RQD value is also associated with fracture frequency.

This result indicates that the method proposed in this study can be ubiquitously applied to various lengths of borehole. Further examination on the additional data from granitic rock besides Toki granite is required.

Keywords: fracture frequency, Rock Quality Designation, Toki granite

Risk management of downward erosion in the coastal area for disposal of radioactive waste

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1. Introduction

In the report related to the selection of scientifically preferable areas for geological disposal of HLW in Japan, the coastal area was regarded as a more suitable area. The Research Group on Technical Issues of Geological Disposal at the coastal seafloor said that it was necessary to improve both survey and evaluation methods related to uplift/erosion. Meanwhile, in the deliberation on the regulation of medium-depth disposal, it is discussed that at least 100,000 years avoid the influence of remarkable erosion and securing the depth necessary for isolation even in consideration of erosion effect.

In coastal areas, rivers erode the ground downward. This research discusses the risk management framework of evaluation related to downward erosion in coastal areas, the way of risk-related decision making.

2. Outline of the framework of risk management of downward erosion for geological disposal

(1) Risk management policy

The law of geological disposal in Japan says that the influence of remarkable erosion must be avoided at the site selection. For example, facilities for geological disposal will not be exposed to the ground surface at least 100,000 years.

(2) Risk assessment

Following are conceivable about the amount of downward erosion in the coastal area for future 100,000 years.

[A] The amount of maximum erosion in the future 100,000 years is smaller than the sum of the maximum decrease and uplift of the sea surface for about last 100,000 years.

[B] In Japan, the amount of downward erosion during the glacial / interglacial one cycle is less than that of uplift after late Pleistocene plus 100m (Hataya et al. 2016).

[C] The amount of downward erosion that actually occurred in the past 100,000 years in each area is regarded as the downward erosion in the future 100,000 years.

(3) Risk treatment

In general, risk treatment is classified into four category: avoiding, reducing, sharing, and retaining. For examples, the former three issues are to exclude from the site, deepen the burial depth, select and develop multiple points respectively.

3. Discussion of risk criteria

For smooth decision-making, we often decide on the risk criteria for some risk, and compare it with the results of the survey and evaluation. In the chapter 3, I introduced the idea of risk assessment of three river downwards. From these, we can think about the following three risk criteria for the downward erosion in about 100,000 years in the future.

[A] Less than the sum of the maximum decrease amount and uplift amount of the sea surface for about last 100,000 years

[B] Less than the amount of uplift after late Pleistocene plus 100m

[C] Less than the amount of uplift after late Pleistocene plus depth of bottom of alluvium layer

Criterion-A accepts sea level fluctuation. If the sea level maximum decrease amount is larger than the assumed value in the future, the downward erosion becomes deeper. Furthermore, criterion-B holds the influence of uncertainty related to the depth distribution of the alluvium base. Criterion-C holds not only

the sea level fluctuation but also the uncertainty of the topography/geological survey. When future river channels can't be specified, we can select criteria-A and B, but we can't adopt Criterion-C.

4. Conclusion

This presentation doesn't state which of the risk standards is appropriate. I'd like to say the following. Accepting future projections, determining risk response policies, risk criteria, and risk response are to retain the underlying risks. This is commonplace. In the radioactive waste disposal project, which is required to see the long-term future, I believe that the following will provide effective information in decision making: They are to show the framework of risk management, to express concretely the research of risk analysis which is mostly carried out individually in this framework, and to explain the retaining risks. **[Reference]** Hataya et al., 2016, Journal of the Japan Society of Engineering Geology, 57, 15-26.

Keywords: geological disposal, coastal area, erosion, risk management

Assessing the probability of concealed active faults existing through Bayesian analysis of known active faults, historical seismicity and helium isotopes

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Assessing the stability of the geological environment including the spatio-temporal distribution of active faulting is of particular concern in the context of site selection of critical facilities such as nuclear power plants, spent fuel reprocessing facilities as well as geological repositories or surface storage facilities of radioactive waste etc. Understanding the spatial distribution of active faulting is one of the challenges facing geologists in that not all active faults have surface expressions. This is especially so for active faults that initiated within the last 0.5 Ma due to their smaller cumulative displacements compared with older and more mature active faults (e.g. faults that have been active for 1 –2 Ma or longer) (Doke et al., 2012).

The western Tottori regions is an area where two recent earthquakes occurred along two separate unknown faults; the 2000 Tottori earthquake (6 October 2000; Mw 6.6) and the 2016 Tottori Earthquake (21st October 2016; Mw 6.2).

We present here a probabilistic approach based on Bayesian statistics that can be used to combine multiple datasets (in this case historic seismic data and helium isotopes sampled from wells) to produce hazard maps showing the likelihood of active faults existing or not.

In order to assess the spatio-temporal distribution of active faults, we start by looking at mapped active faults to estimate spatial frequencies and orientations. This data is sporadic as active faults listed in current databases do not necessarily represent all active faulting, as not all active faults have a surface evidence and their existence might be unknown. In this case, additional datasets are needed that may imply the existence of active faulting. Datasets such as high He-3/He-4 ratios which tend to be found in volcanic regions have been attributed to degassing from the mantle. Studies carried out in the western Tottori district have shown the potential of using He-3/He-4 ratios as a means of providing indirect evidence of the existence of source fault(s) that caused the 2000 and 2016 Tottori earthquakes (e.g., Umeda and Ninomiya, 2009).

We applied our Bayesian model in the Tottori district as a case study. In the first step, present known active faults are divided into equal fault segments. 2-D prior probability distributions are calculated using probability density functions (PDFs) centered over the fault segments with varying values of standard deviation depending on the degree of conservatism required. A non-conservative PDF is assigned in the first step so that probability is never zero. In the second step, statistical tests are used to remap additional datasets, here He-3/He-4 and estimated historic seismic source zones into a likelihood PDF. The prior PDF from the first step above is then combined with the likelihood PDF using Bayes' rule to produce a posterior PDF. The posterior PDF is then evaluated using recent seismic activity.

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Keywords: Active Fault , Bayesian, Probability

Meso and microstructures of non-active crush zone in granite at the Monju site

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Examples of meso- and microstructures of non-active minor crush zones are useful for an activity evaluation of minor crush zones. Crush zones to be evaluate (active or non-active) during important building constructions are usually minor crush zones. Research on the deformation structures of such minor crush zones is rare. We show the example of meso- and microstructures from non-active minor crush zones in granite located near the prototype of fast breeder reactor Monju. The activity of the minor crush zone ceased at intrusion of basaltic dyke (ca. 19 Ma; Sueoka et al., submitted). A right-lateral slip (ca. 10 cm) along the principal slip zone is observed along one of the minor crush zones. Along the principal slip zone, dragged strain maker indicate mean shear strain of 1.6 within 9.3 mm thick zone assuming that the deformation was simple shear. These mesoscopic observations suggest that the deformation was ductile. A 1-cm-thick cataclasite zone mainly consists of quartz, plagioclase, K-feldspar and biotite. Clay minerals due to alteration of plagioclase are observed. Dynamic recrystallization of quartz is not observed. Most of the quartz and feldspar fragments are between 0.5 and 1 mm in size. Biotite in the zone is typically stretched and defining foliation of the cataclasite. The sigmoidal shape of the biotite indicates a right-lateral sense of shear for the foliated cataclasite. The coexistence of the intracrystalline plastic deformation of biotite and the crushing of other granular minerals in the foliated cataclasite indicates that the most recent slip is the semi-brittle flow. The deformation microstructure of biotite indicates that the deformation condition of the latest slip is high-temperature and the minor crush zone is non-active fault.

References: Sueoka et al., Fission-track dating of faulting events accommodating plastic deformation of biotites. JGR-SE submitted.

Keywords: crush zone, Monju, granite

Installation of observation device for soil loss in a decontaminated forest

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We installed an observation device for soil loss in a decontaminated forest of Fukushima Prefecture. 4,491 g of soil were gathered in the device. There is a correlation between volume of soil loss and rainfall.

Keywords: accident at the Fukushima Daiichi Nuclear Power Station, forest decontamination

Fracture visualization by resin injection and rock texture observation

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Fractures developing in the rock can play as a main path for nuclide released from the deep geological repository. Fracture width is one of the important parameters for evaluating transport properties in the rock, therefore its measurement method of visualized fractures injected by fluorescence-doped resin has been developed at Grimsel test site in Switzerland. Fracture visualization technique by using resin injection has been advanced for applying to the domestic crystalline rock sites. In this study, we observed thin sections using a drill core sample which was drilled at -300m stage in the Mizunami Underground Research Laboratory of Japan Atomic Energy Agency (JAEA) after injecting yellow-colored epoxy resin into the fracture in a laboratory. The thin sections were made across the resin-filled fracture with some filling minerals. As a result, under a polarizing microscope, the width of the resin filled fracture is around 0.17mm on average, and the small scale of calcite (around 0.05mm) and the smaller scale of calcite (around 0.005mm) are recognized. In the former type, opaque minerals and fragmented plagioclase also are seen together. On the other hand, the latter type has no other minerals in calcite and it is relatively observed at uppermost part of the fracture surface. Furthermore, we measured the widths of the fractures injected by blue colored resin pressed under 15-17MPa before making thin sections and it was around 0.006mm on average. Blue resin filled fractures are seen along grain boundary of minerals or in cracks inside quartz. In future works, we will make thin sections of core samples -500m stage and apply the same methods of resin injection. This study is commissioned by the Agency for Natural Resources and Energy in the Ministry of Economy, Trade and Industry. Resin injection tests were conducted as a part of a collaborative research with JAEA.

Keywords: geological repository, resin injection, fracture visualization, crystalline rocks, Toki granite, Mizunami URL

The backfilling test in the groundwater recovery experiment

(1) Observation of saturation and swelling process

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The Groundwater REcovery Experiment in Tunnel (GREET) is conducted by making the Closure Test Drift (CTD) recovered with water at the depth of 500m. Backfilling test is conducted as a part of GREET to acquire physical property change of the backfill material.

Bentonite mixture was constructed into two pits excavated 1m in depth on the floor of the CTD. Hydraulic pressure, soil pressure and moisture content were measured to grasp the groundwater saturation process and the swelling process of backfill material.

The moisture content in the pits got almost fully saturated till one month after. During water filling event, both hydraulic pressure and soil pressure reached 3.1 MPa at maximum. The swelling pressure of the backfill was calculated as 0.03-0.09 MPa.

Observation inside the pit will be continued, and characteristics of backfill material will be investigated again. Changes of hydraulic pressure and soil pressure will be simulated and the construction method will be validated.

Keywords: Groundwater recovery experiment in tunnel, Backfilling test, Backfill material, Bentonite

Geochemical analysis of groundwater chemistry after the drift closure in granite

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This study aims to understand the hydrogeochemical condition and dominant process after the drift closure. To this aim the drift closure experiment was conducted in the granitic rock of 500 m below ground level of Mizunami Underground Research Laboratory. The groundwater chemistry such as major chemical component, pH and redox condition has been monitored in closed drift for 1 year. Dominant processes on chemical evolution of isolated groundwater in the closed drift were identified as follows; continuous replacement by surround rock water, microbial reduction, water –mineral interactions with evaporite, shotcrete and granite.

Keywords: groundwater chemistry, granite

Geochemical Modeling of long-term evolution for granitic groundwater

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To understand long-term geochemical stability at deep underground condition in Toki granitic area, we consider about water-rock interaction by thermodynamics calculation using typical granitic minerals, such as anorthite, calcite, quartz, albite and K-feldspar. pH ranges were estimated by the PHREEQC program using measured values for residence time of groundwater and mineral composition in the Toki area. This study indicates that pH values of the granitic-groundwater would be alkaline (ca. 8-10) when the meteoric water is the main source in the area.

Acknowledgement: This study was carried out under a contract with METI as part of its R&D supporting program for developing geological disposal technology.

Keywords: granite, groundwater, geochemical modeling

Estimation of geological strain rates in the Japanese Islands

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For the deep geological disposal of high-level radioactive waste, it is important to assess the long-term stability of the geological environment around a repository for time frames greater than 100,000 years. Under the current framework, empirical laws, which indicate uniform modes and rates of crustal movements of the Japanese Islands, have been determined from previous research on the crustal deformation in the latter half of the Quaternary period (Kasahara and Sugimura, 1978; Matsuda, 1988). Applying the empirical laws to estimate the condition of future geological environments, extrapolation of well known crustal velocities has been done as one approach for making long-term predictions. However, strain rates estimated from geodetic data are about one order of magnitude larger than those estimated from geological data (Ikeda, 1996; Sagiya, 2004; Shen-Tu et al, 1995). Accordingly, it is necessary to consider spatiotemporal variation of crustal deformation in order to estimate future geological environments with higher reliability. Therefore, we have endeavored to establish a method to estimate long-term crustal movements by considering deformation patterns from past to present based on geological data and by conducting numerical simulations introducing the heterogeneous viscoelastic structure of the crust and mantle derived from geophysical observations.

To this end, we estimated the geological strain rate of the Japanese Islands using inland active fault data. Applying the dislocation theory of Okada (1985), we calculated crustal velocities accompanied with fault slips on 443 active inland faults in an elastic half space, based on the fault parameters such as average slip rate for 1,000 years, fault strike, dip, rake, length, and fault location. This calculation illustrates the geological velocities of crustal deformation when earthquakes occur on active inland faults. Next, we calculated geological strain rates from the crustal velocities. In this study, the average strain rate at any specific grid point is determined by assuming that the crustal deformation progresses with a uniform strain rate within a certain radius around the grid point (Shen et al., 1996).

From the calculations, horizontal crustal velocities of less than 4 mm/yr and vertical velocities varying between -1 mm/yr to 3 mm/yr were determined. For the vertical deformation, we determined uplift of ~0.3 mm/yr across the entire Japanese Islands, and subsidence of ~1 mm/yr along the Niigata Kobe Tectonic Zone and on the Pacific side of the Tokai district. Subsidence of up to 5 mm/yr on the Pacific side of Northeast Japan has been shown from the results of GPS observations and leveling (Murakami and Ozawa, 2004). The deformation pattern indicated from geodetic data seems to be the reverse of the pattern determined from geological data. A feature of the estimated strain rate field is that the Japanese islands are characterized by crustal shortening in the direction of oceanic plate subduction. We found that crustal shortening of the Ou Backbone Range is in the E-W direction, in the Niigata Kobe Tectonic Zone it is in the NW-SW direction. Crustal shortening and extension which reflects the right-lateral strike slip of the faults along the Median Tectonic Line and extension of the Kyushu district in the N-S direction were found. These results are generally consistent with those in geodetic observations (e.g., Sagiya et al., 2000). In future, we plan to compare the strain rate derived from GNSS data and to develop a method to estimate long-term crustal movement.

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Keywords: active fault, geological strain rate, dislocation