

## Relationship between progress of borehole investigations and the geometric data of fractures at the crystalline rocks

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In order to evaluate deep geological environment for geological disposal of high level radioactive waste (HLW) and underground storage of liquefied petroleum gas, understanding of the geometry of water conducting features such as fractures is essential. Geometric data of fractures are obtained by borehole investigations. But, methodology to understand the geometry of fractures has not been established in terms of planning borehole investigation such as number and total length of boreholes. Thus, relationship between progress of borehole investigation and increase of the geometric data of fractures is studied.

In this study, discrete fracture network models with the size of  $100 \times 100 \times 100$ m cube were used as virtual fractured rock mass, and virtual boreholes were drilled in the virtual rock mass. Five boreholes with the length of 100m each were located in four directions. One dimensional fracture intensity (as the number of fractures per unit length; P10) of virtual boreholes is calculated. The P10 is depending on the relationships borehole directions and fracture orientations. In addition, The P10 is become constant at each direction of borehole as investigations progressed.

These results suggest that in order to obtain the geometric data of fracture, the borehole investigation should be planned in consideration of distribution of the fracture orientations.

Keywords: Borehole investigation, DFN model, Methodology, Fracture intensity

## Characterization of the fracture zone on the basis of fracture spacing, case study at the Toki granite, central Japan

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In order to evaluate deep geological environment for geological disposal of high level radioactive waste, understanding of the geometry of water conducting features such as fractures is essential. The fracture zones have been divided based on the fracture intensity that has been obtained deep boreholes. But fracture intensity could be changeable in different portion of the rock body. The method to divide the fracture zones based on fracture spacing is studied. In this study, cumulative frequency curve of fracture spacing based on fifteen deep borehole with the total length of ca.12,000 meters was used. Cumulative frequency curve shows that half of fracture spacing is lower than 1m. Thus, fracture could exist in fracture zones. The fractures with the dip of middle to high angle are needed to divide into fracture zones based on the fracture spacing. In the future, we will establish the methodology to divides the fracture zones coupled with spatial distribution of fracture spaces.

Keywords: fracture zone, fracture spacing, Toki granite

## Examination of realistic conceptual model of near-field process in HLW repository

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Since 2000, data of deep underground has been accumulated through the URLs in-situ studies and related underground investigation. Based on these data, here we show the result on the examination of realistic conceptual model of near-field process in HLW repository.

Keywords: Geological Disposal of Radioactive Waste, Near filed processes

## An approach to establish information basis of Weathered zone for the Safety Assessment to HLW Disposal over long-term.

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The consideration of evolution on geological environment is required in the safety assessment of geological disposal for the high level radioactive waste (HLW). The HLW repository can be expected to come close to ground surface assuming a continuous uplift and erosion for a long-term period. Therefore, the consideration of shallow zone (weathered zone) environment is also required. Since the geological condition in the near-surface underground is different from that in the deep underground due to weathering, the basic information and understanding for the near-surface condition are essential for the scenario development. Therefore, information regarding weathered zone is surveyed and arranged based on available literatures.

As a result, 37 data of depth (thickness) of weathered zone were extracted. Then the data distribution and these characteristics for the thickness of weathered zone were discussed. In order to understand the formation process of weathered zone, the relation between weathered zone and landform was also discussed and categorized into four patterns. The key factors which account for the patterns are also analyzed in a qualitative manner.

Regarding the geological property/condition in the weathered zone, although information on hydraulic and chemical conditions are very limited, information on tensile strength and porosity are available.

For the sake of condition setting for near-surface underground in the long-term safety assessment, continuous research and development for the characterization on weathered zone are important.

Keywords: HLW, Long-term, Safety Assessment, Weathered Zone, Landform, Geological Environmental Conditions

## A Bayesian approach to assess the probability of concealed active faults existing using helium isotope ratios

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In Japan, numerous studies have been carried out to assess the stability of the geological environment including in particular, the spatio-temporal distribution of active faulting in the context of site selection of a radioactive waste repository and/or assessing the safety of current nuclear facilities etc. One key concern is the existence of active faults that do not show any surface rupture.

High He-3/He-4 ratios which tend to be found in volcanic regions have also been measured in non-volcanic regions. This has been attributed to degassing from the mantle with faults potentially acting as conduits (e.g., Kennedy et al., 1997). 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 6 Oct 2000 Tottori earthquake (Mw 6.8), but which had no apparent surface indication prior to the earthquake (Umeda and Ninomiya, 2009).

Here we introduce a new technique based on Bayesian inference in an effort to quantify this theory. In the Bayesian paradigm, we make *a priori* assumptions based on the tectonic setting of the study area as a starting point. 'Known' active faults are divided into equal distant fault segments. The *a priori* assumption here is that 'unknown' fault segments do not exist far from 'known' fault segments. It is also assumed that the probability of 'unknown' faults existing decreases with distance from the 'known' faults.

2D *a priori* probability distributions of unknown fault(s) existing are then calculated using kernel functions (Martin et al., 2003) centered over the known fault segments. A Cauchy probability density function (PDF) is assigned here conservatively as the *a priori* distribution in the first step so that probability is never zero.

In the second step, the method developed by Martin et al. (2004, 2012), is adapted to remap He-3/He-4 ratios into a PDF, called a likelihood function based on Kolmogorov-Smirnov statistical tests. The *a priori* PDF from the first step above is then combined with the likelihood PDF using Bayes's rule to produce a *a posteriori* PDF.

Carrying out the calculation using data from before the Tottori 2000 earthquake, the *a posteriori* 2D probability maps showed increased probability of unknown active fault(s) existing in the region above the source zone of the 2000 earthquake. Thus, in the case of the Tottori region, the *a posteriori* probabilities corroborate the theory that faults could be acting as conduits for mantle helium.

The potential of the methodology to incorporate other information such as gravity and crustal strain rates will also be presented and discussed.

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Keywords: Active fault, Bayesian, Helium isotope ratio

## An active shear zone, southwest Japan: electromagnetic geophysics and noble gas geochemistry

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In 1997, the Kagoshima earthquake doublet with two  $M_w \sim 6$  strike-slip events struck 5 km and 48 days apart in southwest Japan, where an E-W trending discontinuity along 32 degree N latitude in GPS velocities across southern Kyushu Island is clearly defined, indicating a highly active left-lateral shear zone. However, there was no obvious pre-faulting indication at surface (active fault) in relation to the shear zone. Three-dimensional inversion of magnetotelluric sounding data observed in the source region of the earthquake doublet reveals a near-vertical conductive zone with a width of 20 km, extending down to the base of the crust and perhaps into the upper mantle. The prominent conductor corresponds to the western edge of the active shear zone. Elevated  $^3\text{He}/^4\text{He}$  ratios of groundwaters sampled around the seismic source region suggest the emission of mantle-derived helium from the electrical conductor. The geophysical and geochemical observations provide significant evidence that the invasion of mantle fluids into the crust, driven by upwelling asthenosphere from the Okinawa trough, triggers off the notable left-lateral shear zone in the present-day subduction system. In addition, the conductive fluids enhance stress concentration in the seismogenic layers leading to mechanical failure of strong asperities, resulting in the occurrence of the 1997 earthquake doublet.

Keywords: 1997 Kagoshima earthquake doublet, active shear zone, magnetotelluric sounding, helium isotope

## Predominant process for transport of radiocaesium released by the TEPCO's Fukushima Daiichi Nuclear Power Plant Accident

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Understanding the environmental dynamics of the radiocaesium (particularly Cs-134 and 137) released from the Fukushima Daiichi Nuclear Power Plant provides the firm foundation for a remediation of the Fukushima environment because it is the main radionuclide to radiological dose within the contaminated area. One of the main sources of radiocaesium under the current situation is a mountain forest, where the decontamination work has not been carried out as yet. Therefore, transport process, flux and chemical form of the radiocaesium flowing from the mountain forest are crucial issues for an evaluation of a radiation exposure, taking into a dynamics behavior of radiocaesium from the highest contaminated mountain forests down through the river to eventual deposition in the sea. This paper discusses the predominant process of the radiocaesium transport in the mountainous region, Fukushima, Japan.

The four investigation areas, which have different characteristics of vegetation, geomorphology and soil type, were selected in the Abukuma Mountain, eastern part of Fukushima. The soil samples were obtained from ridge, slope, and valley bottom in the areas by soil sampler and scraper plate to the depth about 40 cm and 20 cm, respectively. The observation plots, which have an area of 40 to 60 m<sup>2</sup>, for a monitoring of surface runoff and soil loss are also installed. The concentration of radiocaesium in the uppermost soil horizon is related to the geomorphological aspects, that is, the concentration trends to be higher in the depositional area than in the erosional area. Additionally, the radiocaesium concentration of solid phases (soil particles and fragmented organic materials) including in surface runoff is one to two orders of magnitude greater than that of a liquid phase (running water).

Therefore, predominant process of the radiocaesium transport is the surface runoff accompanied with a detachment of soil particles from the mountain slope.

Keywords: radiocaesium, environmental dynamics, mountain forest, nuclear accident, Fukushima

## Current State of the additional geological surveys of crush zones at the fast breeder prototype reactor "Monju" site

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**Background:** In the fast breeder prototype reactor Monju of the Japan Atomic Energy Agency (JAEA), a report of the additional geological survey regarding the crushed zones at the Monju site was submitted to the Nuclear Regulation Authority (NRA) on April 30, 2013. The NRA instructed to develop a further additional research plan on September 25. Accordingly, JAEA compiled and submitted the plan on October 3, followed by a "preliminary report" on November 29, and a "complete report" in March 2014.

**Overview of additional research:** The instructions from the NRA of September 25, 2013 were as follows:

1. to implement the dating of materials within the crushed zones, to research the displacement markers, and to understand their formation age, etc., in order to enhance understanding of the activity of crushed zones at the Monju site in the bedrock of the site investigation area; 2. to investigate the distribution of the fracture zones, the relationship of the sediment layer, and the depositional age of the sediment layer (14C dating, tephra analysis, etc.) for data expansion of the extended portion of the L-2 lineament located near the Monju site; and 3. to implement marine seismic surveys in the coastal sea area and geographical and geological surveys of the coast, etc., in order to understand the geological structure and activities of the coastal seabed in the extended portion of the Shiraki-nyuu active fault and the L-2 lineament.

JAEA developed a research plan in response to these instructions and conducted the stripping investigation over an expanded area, the additional detailed geographical and geological surveys around the mountains/terrace boundary, and the marine seismic surveys in the coastal waters.

**Summary of findings:** The basement rock of the northern Tsuruga peninsula where the Monju site is located is composed of the Late Cretaceous-Paleogene granite known as the Kojyaku granite. In the on-site investigation, the stripping area was extended in the northern direction of the longest fracture zone in the reactor building foundation rock. The fracture zones were grouped into 2 systems called  $\alpha$ -system and  $\beta$ -system. We examined the cross-cutting relationships and displacements of the fracture zones and confirmed that the  $\alpha$ -system was formed after the  $\beta$ -system. The  $\alpha$ -system fracture zones are left-lateral faults that have mesh-like clay veinlets, and the width of the  $\alpha$ -system fracture zones is several centimeters. The K-Ar ages of the basalt dyke displaced by the  $\alpha$ -system fracture zones were about 19Ma. In addition, U-Pb and FT dating of apatite and zircon separated from the fracture zone materials and granite were conducted to reconstruct their thermal histories. The investigation results so far obtained were similar to the survey results of April 30, 2013, offering no clear evidence that the on-site crushed zones are of an active fault. It can be considered that these crushed zones are small-scale older (pre-Quaternary?) geological structures formed under the hydrothermal environment of the deep part before exposure of the granitic body. On the detailed geographical and geological surveys around mountainous/terrace boundary, no fracture zone along the strike of the boundary was observed. From the C-14 dating and tephra analysis of the depositional layer covering the granite, the distribution of sediments from about 40,000-50,000 years ago was confirmed in a few outcrops. The marine seismic surveys in the coastal waters were performed in conjunction with the bathymetric survey in December 2013. Currently, the data are being analyzed.

**Upcoming:** In order to further enhance the reliability of the investigation results and accumulate further data related to on-site geology and the underground, voluntary investigations are being conducted on a continuous basis. In addition, a basic study is also being carried out on the evaluation method of the activity of the fault zone not applicable to the overburden strata method.

Keywords: fast breeder reactor Monju, survey of crush zone, Kojyaku granite, Nuclear Regulation Authority

## The linearity of geographical features and a planation surface along the seashore around the fast breeder reactor Monju

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We have not only conducted a survey of crush zones near the reactor building in the fast breeder prototype reactor Monju site but also carried out geographical investigations such as terrace classification and lineament investigation around the site. This presentation reports the results of the geographical and geological survey on the linearity of geographical features and a planation surface along the seashore around the site.

### 1. An investigation into the linearity of the mountain/terrace boundary

It is estimated that the lineament of the NW-NNW direction, also called the L-2 lineament, exists to the south of the Monju site. Geographical and geological surveys by JAEA suggest that this lineament is highly likely to be a structural landform. The mountain/terrace boundary to the north of this lineament extends in a straight line-like form in the NW direction. During an expert meeting of the Nuclear Regulation Authority, it was suggested that an active fault might exist along this boundary. It was in response to this suggestion that we carried out the geographical and geological survey.

**Geographical investigation:** We carried out a terrace classification, field survey, and analysis of the survey data for regions around the mountain/terrace boundary. The mountain slope directly faces the sea; the slope of the present stream bed and terrace surfaces is comparatively steep in the investigation area. In the topographical map before artificial change, we can recognize that the stream makes the loosely curved dissected topography without winding greatly and that the mountain/terrace boundary is loosely curved similarly.

**Geological survey:** Outcrop investigation was conducted on the mountain/terrace boundary by paying attention to the existence of crush zones and the development style of the joints. In addition, we also estimated the age of the sedimentary layers.

The results clearly indicate that the joints are progressing mainly in the NW or the NE direction, and the comparatively hard granite is also distributed. Moreover, although crush zones were observed in some outcrops near the mountain/terrace boundary, we could not detect crush zones that continue in the same direction as the mountain/terrace boundary. In the outcrop near the northwestern end of the mountain/terrace boundary, it was observed that the covering layer, which was deposited after about 40,000-50,000 years ago and covers a crush zone, is not displaced.

The results of the above-mentioned geographical and geological survey suggest that the linearity of the mountain/terrace boundary has not originated from fault displacement.

### 2. An investigation into the linear coastline and planation surface along the seashore

A linear coastline extending in the NE direction can be seen around the Monju site. In addition, a planation surface is observed in parts along the seashore. We performed a geographical and geological survey to determine the origin of such a geographical feature and whether such a planation surface could exist elsewhere.

**Geographical investigation:** While carrying out the air photograph interpretation, the contour line maps and topographic profiles were created using a digital elevation map created from aviation laser survey data. As a result, except for one place which is present at an altitude of about 5 m, a geographical feature that can be recognized as a comparatively flat field was not observed.

**Geological survey:** We carried out an outcrop investigation that paid attention to the development of joints and searched for evidence that suggested the upheaval of land. The results suggest that the direction of the coastline and the direction of developing joints are similar. Moreover, we could not observe the remains of living things which suggest the possible upheaval of land.

Keywords: fast breeder reactor Monju, survey of crush zone, lineament

## On the turn determination of crush zone activity, a lesson from granitic basement rock holding the fast breeder reactor

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Activity evaluation of crush zones encountered in basement rock is an issue of the seismic safety assessment of nuclear plant and geological isolation of radioactive wastes. The selection of crush zone of which has been evaluated should be defined as the latest one by means of turn determination of crush zone activity based on stratigraphic or structural geological method. A lesson from granitic basement rock (Kojaku granite) holding the fast breeder reactor "Monju" is presented. The Kojaku Granite form the oval Tsuruga peninsula (ca. 8km in width) on the southeastern coast of the Sea of Japan and the age is  $68.5 \pm 0.7$ Ma (Zircon U-Pb age).

### 1. Stratigraphy-oriented turn determination of crush zone activity.

#### (1.1) Turn determination using cover sediments

The age determination of undeformed cover sediments indicates the activity of crush zone older than the sediments. In the case of crush zones observed at separate outcrop, deformation of the same strata can be utilized for the turn determination.

Trenching evidence (with tephra chronological analyses) of the active Shiraki-Nyu fault near the Monju site indicate repeated activity after ca. 30ky strata (including AT-tephra). On the other hand, crush zones in the Monju site affect no deformation on the strata of identical age observed during the site construction. These data indicate the last movement of the latter is older than the active fault, and no movement in sympathy with the active faulting repeatedly during, at least, ca. 30ky.

#### (1.2) Turn determination using dyke, mineral and clay vein ("Dyke", hear after)

Undeformed dykes intersecting crush zones indicate that the movements of crush zones are older than the dyke formation. Age determination of the dyke constrain the latest age of the crush zone activity.

Excavation survey of basement rocks at the Monju site shows a basaltic dyke (ca. 19Ma, Plagioclase K-Ar age) cut by the crush zone (crush zone alpha-3 and alpha-4) indicate that the movements of these crush zones are later than the dyke formation.

### 2. Structural-oriented turn determination of crush zone activity

Intersecting relationship between crush zones indicate which of them is the latest one at least locally. This rule can be hold in the case of conjugate set, although they suggest the contemporaneous development in one tectonic stage. Conjugate relations should be judged from traditional Griffith-Coulomb failure criterion as well as the Maximum effective moment criterion<sup>(1)</sup>. Despite of the development of remarkable clay rich zone, cross cutting crush zone with meso- and microstructures developed under the higher temperature and pressure indicate the movement of the clay rich zone is older.

Excavation survey of basement rocks at the Monju site shows conjugate like development of the crush zone beta and younger alpha-3 with 50-55 degrees between them. The crush zone beta is composed of clay rich vein. Along the crush zone alpha-3, dragged sigmoidal quartz veins, dragged biotite along shear layers and preferred orientation of quartzo-felspathic lenses composed of foliated cataclasite with P-Y-R<sub>1</sub> fabric are observed. These ductile features suggest that relatively higher temperature and pressure during the development of crush zone alpha-3. Hence, the crush zone beta is old structure.

These stratigraphic and structural evidences for the turn determination indicate that the activity of crush zone alpha-3 is the object of the evaluation.

(1)Zheng et al., 2004, Journal of Structural Geology, 26, 271-285.

Keywords: fast breeder reactor Monju, survey of crush zone, Kojaku granite

## Depth-dependent coseismic groundwater level changes by seismic ground motion of the 1999 Chi-Chi earthquake, Taiwan

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The coseismic water level change (Cw) has been reported (Montgomery and Manga, 2003; Koizumi, 2013). One of the causes of the Cw is crustal displacement (static strain change and vertical displacement etc.), and seismic ground motion (dynamic volumetric strain change and hydraulic conductivity change etc.) (Lee *et al.*, 2002; Lai *et al.*, 2004; Wang *et al.*, 2001). The static strain change has been assumed as one of the main factor of the water level change from the comparison of water level change with static strain change in the earthquakes. However, the relation between water level change and static strain change doesn't correspond clearly. Although the dynamic strain change by the ground motion would be more effective to the cause of Cw, the effect has not been known yet.

The Chi-Chi earthquake (Mw7.6) occurred in central Taiwan at 1:47 (local time) on September 21, 1999. The earthquake was the largest event which occurred recently in the inland of Taiwan. Since the both networks of strong motion seismometer (Lee *et al.*, 1999) and water level monitoring system (Koizumi, 2001) are distributed densely around the source fault of the Chi-Chi earthquake, good seismic waveform and the data of Cw has been obtained.

For the previous study of Cw in the Chi-Chi earthquake, Wang *et al.* (2003) has been analyzed the relationship between Cw and seismic ground motion from the point of view of liquefaction at the shallow groundwater in the alluvial plain part. They showed that there is correlation between the spectrum velocity or acceleration and water level. However, they did not account much for the effects of the permeability or other characteristics in each aquifer although they analyzed the Cw of all wells at once. Since the hydrogeological conditions effects to the occurrence of liquefaction similar to the effect of ground motion, the effect for the hydrogeological conditions, that is the geological characteristics and permeability of aquifer in confined aquifer or unconfined aquifer, must be investigated.

We divided the aquifer to similar hydrogeological categories and examined the Cw response by the ground motion in each aquifer. We put target groundwater of two aquifer, the shallow aquifer 1 (unconfined aquifer) and underlying aquifer 2 (confined aquifer), and investigated whether there are the different character in those. I measured the degree of Cw. Therefore the wells observed Cw were 84 wells, fall wells were 14 wells in these wells. I used the observation wells with water level rises in the alluvial plain part, because the mechanism of water level change for water level fall is different. We investigated the relationship spectral response of seismic wave and groundwater level change, because spectral response can read the effect to the ground in comparison spectrum of normal. We calculated the response of Cw against the frequency of 1 Hz (high-frequency) and 0.1 Hz (low-frequency) to evaluate the groundwater level change as a function of frequency. We calculated the acceleration, velocity, and displacement spectral response of vertical, horizontal, and 3 components from acceleration waveform data. I investigated the correlation coefficient between spectrum and Cw in each aquifer. The result frequency band in those show different response was obtained. Correlation between the response spectrum and water level change in the high-frequency side (1 Hz) was higher in the aquifer considered unconfined aquifer, but the correlation in low-frequency side (0.1 Hz) was higher in the aquifer considered confined aquifer. In common to both aquifer, correlation between hydraulic conductivity and water level change showed strong positive correlation.

Keywords: Groundwater level changes, The 1999 Chi-Chi earthquake, Taiwan, Seismic ground motion

## Occurrence of faults and water conducting features at 350m gallery of the Horonobe URL project

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In the Horonobe Underground Research Laboratory Project, methodology development for the investigation of geological structure in sedimentary rocks has been carried out through construction of underground facility. As part of the methodology development, hydrogeological models have been constructed and the geological structure associated with water-conducting features (WCFs) has been conceptualized on the basis of the surface-based investigations including geophysical survey, outcrop observation and borehole investigation. The horizontal gallery named ' 350m gallery ' and having approximately 740m long in total has been excavated at a depth of 350m below the surface by January 2014. This study presents the predictive distribution of geological structures contributing to WCFs in 350m gallery based on the surface-based investigations and the characteristics of geological structures observed in 350m gallery.

Keywords: Hydrogeological model, Fault, Water-conducting feature

## Permeability variation in Toki granite and its relationships with crack structure and alteration processes

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Understanding of physical and chemical properties of rock mass is essential to implement the geological disposal of the high level nuclear waste. Especially, extraction of highly permeable zone that acts as channel of fluid flow is required. In this study, permeability measurements of Toki granite were carried out to reveal the permeability variation in rock mass and to understand factors causing that. Image analysis was applied to disc-like specimens and thin sections of the granite, for quantitative characterization of crack structure. Additionally, fluorescent X-ray analysis (XRF) was carried out to obtain elemental compositions of granite cores showing various degrees of alteration and to consider the relationship of the permeability with the alteration degree.

Permeability was measured using the gas permeameter. The samples are cores collected from about 1 kilometer depth range boreholes in Tono area (Mizunami, Gifu, Japan) drilling by Japan Atomic Energy Agency (JAEA). Over 40 granite cores were sampled at 25-meter intervals ranging from 100 to 1000 meters depth to measure the permeability. Permeability was larger in the altered and fault zones. In addition, the anisotropy was appeared around the fault part and the permeability was enhanced along E-W direction. This direction is consistent with the fault strike, and thus the anisotropy of the permeability was presumably caused by the cracks developed in the fault movement.

Next, the crack structures were quantitatively characterized using an image analysis and compared with the permeability data to clarify their relationship. The specimens were impregnated with fluorescent resin and images were acquired to characterize the mesocrack structure using a fluorescent scanner equipped with ultraviolet ray source. Additionally, thin sections were made from the specimens and microphotographs for characterizing microcracks were taken with a stereomicroscope. Cracks were extracted from these images and length and direction of each crack were determined by the image analysis, following segmentation of crossing cracks. Positive correlation was observed between the permeability and cumulative crack length. These results suggest that cracks cause the permeability anisotropy and microcrack can be a factor controlling the permeability.

XRF was carried out to examine relationships between the permeability and the alteration processes of Toki granite. Positive correlations were recognized between the permeability and Ca concentration in the cores. Hydrothermal alteration of Toki granite is considered to follow three steps, 1) chloritization of biotite, 2) illitization of plagioclase, and 3) precipitation of calcite (Nishimoto and Yoshida, 2010). Considering that precipitation containing Ca is formed in the illitization of plagioclase, strong hydrothermal alteration presumably occurred in the altered and fractured zones that show relatively high Ca concentration. It implies that these zones were highly permeable as forming flow paths of hot water in the past. Although the fault-zone core had high permeability, its Ca concentration was relatively low. Fault movement caused development of fault gouge in addition to fracturing of granite. Permeability was enhanced by the fracturing, but the impermeable fault gouge occurred in the fault interfered circulation of hot water and addition of Ca precipitation.

These results suggest that fractured zone accompanying densely distributed microcracks and altered zone can be groundwater flow paths. Distribution of the highly permeable zones is essential to understand the hydrogeological structure.

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Keywords: fracture system, permeability, microcrack, altered zone, hydrogeological structure, Toki granite

## The relation between imaging of soil structure with GPR and depth profile of radioactive cesium

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Radionuclides such as radioactive cesium, now the main radiological contributor, were released in the environment by the Fukushima Dai-ichi nuclear power plant accident. The government and local governments have proceeded with decontamination plans to reduce dose rate in living spheres. But most areas of forests have been still contaminated. Japan Atomic Energy Agency initiated a project entitled 'Long-Term Assessment of Transport of Radioactive Contaminant in the Environment of Fukushima' (F-TRACE project) in November 2012. Main objective of this project is to implement a comprehensive system for predicting radioactive cesium transport in the future and the impact of various countermeasures by understanding transport of radioactive cesium from forests to living spheres and the sea through rivers and dams.

To understand radioactive cesium transport in forest, we have conducted forest investigation at Ogi district, Kawauchi Village and Yamakiya district, Kawamata Town, Fukushima Prefecture since December 2012. As a part of the investigation, we carried out geophysical exploration of soil structure with ground penetrating radar (GPR) with 100MHz and 500MHz radio wave.

In this presentation, we report correlation between imaging of soil structure obtained by GPR survey and depth profile of radioactive cesium in soil.

Keywords: ground penetrating radar, depth profile of radioactive cesium, F-TRACE project

## Current situation and improvement of methylene blue adsorption testing method for bentonite

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Large amount of bentonite will be required as shielding material for radioactive waste disposal from nuclear power plant and contaminated soil management of Fukushima disaster. The testing methods of bentonite performances are important in terms of the safety of the disposal facility. Methylene blue (MB) adsorption test, which has generally been used for determining either cation exchange capacities (CEC) or surface areas of bentonite, is one of the important testing methods. However, current testing method of MB adsorption is different for each company and it is difficult to compare the performance of bentonite products. Since the current standard testing methods, which are developed by JBAS in the 1970s, are obsolete already, it is necessary to renew the standard testing methods. Therefore, we are planning to propose new standard testing methods for bentonite as JIS, based on this study.

In this study, we interviewed 13 companies and conducted questionnaire about the details of the current MB adsorption testing method. As the result, 10 companies are currently doing MB adsorption test. Of the 10 companies, MB adsorption test based on conventional JBAS method is conducted in eight companies. In addition, four companies are using their own methods, such as colorimetric method which is not defined in the JBAS, including 2 companies using compound of JBAS and colorimetric methods. The tests based on conventional JBAS methods have variation among companies in terms of determining the end point, reagents and sample preparations. Short testing time and simple decision of end point were raised by several companies, as the reasons for using their own methods such as colorimetric method.

As consider in result of interview, the method which aims to propose in this study is required of eliminating the ambiguity of the conventional method, minimal use of consumables, and streamlining for time saving. At the same time, sufficient accuracy is required with this method for ensuring safety in waste disposal. In future, it needs to consider time of reaching adsorption equilibrium, and dispersion and adsorption properties of bentonite by different localities and conditions.

Keywords: bentonite