

Porosity and permeability changes during fracture experiments of Inada granite as a pilot study of Hot Dry Rock geotherm

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Hot Dry Rock geothermal system can produce energy from previously unusable site, which does not require natural convective hydrothermal resources, and therefore it has large potential as a sustainable power generation. In this system, artificial reservoir is produced by hydro-fracturing in the basement due to water injection, and then water travels through fractures in the rock and inject back into the ground. To test time-scale of water circulation in this system, we investigate porosity and permeability changes during fracture experiments in the laboratory.

Inada granite was used as an experimental sample, which has been deformed by uniaxial compression test. Porosity and permeability were measured using intra-vessel apparatus at our institute, which is capable to generate pressure as high as 500 MPa at room temperature. The intact sample before compressional test has porosity of 0.8-0.9% and permeability of $1.0 \times 10^{-18} \text{m}^2$ at confining pressure $P_c = 10 \text{ MPa}$, which is similar values reported by previous studies (Takeda et al. 2000). The fractured samples after deformation show systematic increase of porosity and permeability, 7.0% and $2.0 \times 10^{-15} \text{m}^2$.

Using these hydrological data of fractured rock, water migrating velocity is estimated to be $3.3 \times 10^{-5} \text{m/s}$. This results travel time of water circulation as long as 670 hours in the Ogachi HDR test site. However, chemical tracer test shows approximately 70 hours as a water travel time in this site (reported by Central Research Institute of Electric Power Industry), which is one order of magnitude shorter than that expected from our experimental data. The discrepancy might be caused by different fracture structures in the laboratory compression test relative to the hydro-fracturing in natural test. We plan to perform water injection test in the laboratory and try to simulate more realistic system as a Hot Dry Rock geothermal test.

Keywords: porosity, permeability, granite, fracture experiments, Hot Dry Rock geothermal system

Distribution of minor elements within the unconsolidated sediments covered active shallow-seafloor hydrothermal system

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On the seafloor off northeast Sakurajima volcano in the innermost part of the Kagoshima bay, south Kyushu, Japan, an active volcano "Wakamiko" is located, and the volcano is characterized by vigorous fumarolic activity. The "Wakamiko" volcano is considered one of the craters of Aira caldera, which occupied the bay head area, and is formed small depression of 200 m in depth deeper than the caldera floor of about 140 m in depth. In the depression, i.e., Wakamiko crater, at least three active hydrothermal vents have been identified and maximum temperature emitting the vents reach 200 degC. In addition several hydrothermal fluid shimmering sites have been found, distribution of them have been continuously surveyed by ROV and AUV.

The coastal line is close to the crater, therefore, much clastic sediments include volcaniclastics emitted from surrounding volcanoes are filled the crater. The unconsolidated sediments in the crater is considered to reach up to 80 m by seismic observation. The venting and shimmering hydrothermal fluids penetrate the unconsolidated sediment layer, then several commercially important elements, it means rare metals, have been precipitated and condensed in the sedimentary layer. Actually, vein formed antimony sulfide, stibnite, has been often observed in the 5 - 6 m long core sediments obtained by piston coring. However, hydrothermal minerals currently precipitated from hydrothermal fluid are small grain and degree of crystallinity is still low. Therefore, it is difficult to find visible grain of such minerals and even to detect by XRD analysis. This study aim to clarify the distribution of minor elements, such as rare metals, in the bulk sediment samples obtained from the Wakamiko hydrothermal field using neutron activation analysis (NAA).

Sediment core samples obtained during KT08-9 cruise by RV/Tansei was provided for this study. Those sediment samples already have studied pore water chemistry and clay mineral compositions. We used two core samples, which are significantly affected by hydrothermal fluid. Subsamples picked up each 20 cm interval were freeze-dried and packed about 30 - 40 mg dried sediment into polyethylene bag. NAA was carried out at Kyoto University Research Reactor Institute.

In, Se, V, Mn, Au and so on in addition to As, Sb and Hg, which are previously reported anomalous condensation in this area, were detected by NAA. As, Sb, Hg and Au were condensed at the layer where present contribution of hydrothermal fluid was obvious. On the other hand, condensation of Mn, V and In was observed at about 50 cm depth below seafloor from the both core samples.

As, Sb and Hg are expected to precipitate directly from the hydrothermal fluid, while Mn, V and In were even condensed at the hydrothermal fluid-free layer. It may suggests that Mn, V, and In are precipitated from hydrothermal plume once emitted from the vents under suitable physicochemical condition.

Keywords: shallow-seafloor hydrothermal system, Wakamiko crater, neutron activation analysis, rare metals, unconsolidated sediments

Water chemistry of lakes Nyos and Monoun, Cameroon in 2011

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1. Introduction

The explosive discharges of CO₂ gas (= limnic eruption) at Lake Nyos and Monoun killed about 1800 people around the lakes in mid-1980s. The cause of the limnic eruption was the excessive accumulation of CO₂ gas in lake water. The CO₂ gas originated from a degassing magma. A mineralized water containing CO₂ gas is expected to be discharged on the lake floor. The accumulation of the dissolved CO₂ gas facilitated strong stratification of lake water. Investigation on the water chemistry and the formation of stratification is important for the prediction of the next limnic eruption.

2. Observation

The lake water was sampled on January 2011 at various depths on lake Nyos and Monoun. The anionic components were analyzed by a Dionex ion chromatograph. The stable isotope ratio of H₂O was measured by a Picarro laser absorption isotope analyzer. The carbonic (=CO₂aq + HCO₃⁻) concentration was determined by the combination of the method by Kusakabe (2001) and micro diffusion volumetric analysis.

3. Lake Nyos

The carbonic concentration was high between the bottom (= about -210m) and -200m extending to 372 mmol/L. The concentration decreases gradually along ascent to -80m, being 6 mmol/L at -60m. The concentration of Cl⁻ and SO₄²⁻ was less than 1 and 0.5 mg/L, respectively. The dD of H₂O was -8 permil between surface and -80m. The dD decreased to -10 permil deeper than -80m and stable to -200m. The dD again decreased gradually until -11.2 permil at -210m. The summation of the NO₂⁻ and NO₃⁻ concentration was high as 0.3 mg/L between surface and -50m. The concentration decreased to 0.02 mg/L between -80 to -170m. The NO₂⁻ and NO₃⁻ were not detected at the depth deeper than -175m.

4. Lake Monoun

The carbonic concentration was high as 73 to 93 mmol/L between -98 to -86m. The concentration decreased quickly along ascent until 6 mmol/L at -70m. The dD of H₂O was -18 to -17 permil between the surface and -70m. The dD was low as -21 to -20 permil at the depth deeper than -80m. The total concentration of NO₂⁻ and NO₃⁻ was high at -98 and -40m as 2.6 mg/L. The concentration other than the above depth was less than 0.1 mg/L. The NO₂⁻ was detected at the depth near the bottom.

5. Stratification of lake water

The isotope ratio of lake water between the surface and -80 or -70m for both Nyos and Monoun suggests the effect of evaporation. The low isotopic ratio of water near the bottom suggests the discharging of mineralized water with isotope ratio similar to local meteoric water. Mixing of water is taking place in the intermediate depths. Cattle grazing is seen around Lake Nyos. This activity results in inflow to lake of nitrogenous constituent to the lake giving rise the source of NO₂⁻ and NO₃⁻ in the lake. Nitrogenous component were found down to -170, suggesting the influence of surface water at Lake Nyos. In Lake Monoun, the influence of surface water reaches near the lake bottom.

6. Magmatic component

For both lakes, concentration of Cl⁻ and SO₄²⁻ concentration is proportional to the carbonic concentration. The Cl/CO₂ molar ratio is 5.08E-5 and 5.31E-4 for Lake Nyos and Monoun, respectively. The SO₄/CO₂ molar ratio is 5.31E-6 and 6.41E-5 for Lake Nyos and Monoun, respectively. The gas phase equilibrated with basaltic magma should have Cl/CO₂ and S/CO₂ ratios of (1.5~10)E-6 and (5~13)E-4, respectively (Giggenbach, 1996). The SO₄/CO₂ ratio for both lakes is much lower than the magmatic S/CO₂ ratio. It is speculated that sulfur species in the magmatic fluid was reduced during migration through a hydrothermal system which might develop beneath the lakes.

Keywords: Nyos, Cameroon, CO₂, Limnic eruption

Audio frequency Magneto-Telluric Survey on Tatun Volcanic Group, Taiwan.

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Tatun volcanic group (TGV) is located at northern Taiwan. More than 20 volcanic domes and cones have been created within and around Tatun Graben, which is bounded by Chinshan Fault in the north and Kanchiao Fault in the south. Most volcanoes have been created before 0.3 M (Wang and Chen, 1990), and no historical record of eruption at TVG. However, eruptions in 18 ka BP (Chen and Lin, 2002) and 3 ka BP (Chen, unpublished data) have been identified. Yang et al.(1999) found magmatic contribution in fumarolic gas. In our study, we would like to carried out MT (Magneto-Telluric) survey around TVG to clarify subsurface electrical conductivity distribution, which is the sign of degassing around volcanoes. On TVG area, we made Audio-frequency Magneto-Telluric(AMT) survey on 10 points. All points are located inside the Yanminshan national park. On this survey, survey line is arranged to cross Seven-star volcano north-west to south-west. The total length of survey line is about 10km. The purpose of this survey is to clarify the geothermal distribution beneath the active area of this volcano. We used three MTU-5A equipments (Phoenix Geophysics Inc.), and made observation during 5-6 hours on each points.

Keywords: Audio frequency Magneto-Telluric survey, Tatun volcanic group

Hydrothermal system at Kuchi-erabu-jima volcano, inferred from surface temperature and self-potential distribution

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The hydrothermal system at Kuchi-erabu-jima volcano, which induces phreatic eruptions frequently, is investigated by means of the surface temperature and self potential observations. The surface temperature measurement was conducted on March 11, 2008. The observation was operated by the airplane which has a hole on the floor for aerial photo of vertical direction. The portable infrared thermal camera (AVIO TVS-620) was fixed on the hole to face the ground perpendicularly using the stand designed for this survey. The airplane kept the constant speed and height during the measurement over the volcano. The respective thermal images with suitable condition were combined considering the horizontal orientation, vertical angle and the position. The resultant image represents the overall surface temperature distribution at the selected field. The temperature anomalies up to 40°C at maximum are observed widely on and around Shin-dake and Furu-dake craters. The similar observation was also conducted at Satsuma-iwojima volcano, which is active volcano showing the persistent high temperature gas discharge at the summit crater. The total amount of the gas discharge is one order of magnitude larger than that of the Kuchi-erabu-jima volcano. The comparison of two volcano shows that the area of surface temperature anomaly of Kuchi-erabu-jima volcano is quite smaller than that of Satsuma-iwojima volcano, and the temperature of kuchi-erabu-jima volcano is sufficiently low. The self potential observation was conducted on November 26-29, 2009. The result indicates that the distribution at western mountainside has the positive correlation with topography, contradicting to the terrain effect. The anomaly reaches 300mV at the summit. The self potential at eastern mountainside has not correlation with topography and shows the flat distribution. This eastern flat distribution is probably related to the subsurface low resistive altered layers. The wide ranging positive anomaly at western mountainside suggests the active hydrothermal circulation within the mountain edifice.

Keywords: surface temperature, self potential, hydrothermal system, numerical simulation

Evaluation of the mass flux of volcanic fluids using the electrical conductivity structure

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The efficiency of degassing of volcanic fluid in magma is one of the key parameters controlling the explosibility of eruption and the diversity of the volcanic activity (Eichelberger et al., 1986; Kagiya, 2008). Therefore, it is possible to quantify the constraint condition which controls these phenomena by evaluating the mass flux of volcanic fluids released from magma. A portion of released volcanic fluids is discharged from the crater to the atmosphere; the rest is considered to be dissipated by groundwater flow of the aquifer under a volcano. The latter part has not yet been quantified precisely. The electrical conductivity structure of a volcano has a potentiality for estimating the volcanic fluid mass flux by groundwater flow of the aquifer, because the pore water dissolving volcanic fluids has a high electrical conductivity due to high salinity of the pore water. As well as pore water conductivity, matrix conductivity is also increased by hydrothermal alteration. Electromagnetic surveys on a volcano reveal the bulk conductivity, which contains both contributions of pore water and matrix. Therefore, it is required for the estimation of volcanic fluid fluxes using bulk conductivity to take both two conduction components into account.

In this study, the quantitative relation between mass flux of volcanic fluids and electrical conductivity structure is examined, by developing the simple model and using numerical simulations. Numerical simulations calculate the spatial distributions of salinity and temperature of pore water under the controlled condition of the mass flux of the volcanic fluids which are injected from the volcanic center (Komori and Kagiya, 2008, 2009; Komori et al., 2010). Using these distributions, the spatial distributions of pore water conductivity and surface conductivity are estimated (Komori et al., 2011). Eventually, the spatial distribution of bulk conductivity is estimated using these two conduction components by Revil's model (Revil et al., 1998; 2002).

These methods are applied to the bulk conductivity structure of Unzen volcano and Aso volcano obtained by wide-band MT (Komori et al., 2010; Utsugi et al, 2009). There is distinctive difference of the eruption style between these two volcanoes. To clarify the quantitative relationship between these eruption styles and the efficiency of magma degassing, the volcanic fluid fluxes at Unzen and Aso are evaluated.

Keywords: electrical conductivity structure, volcanic fluids, magma degassing, eruption style