Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SVC049-01 Room:105 Time:May 23 16:30-16:45

Remote temperature sensing on volcanic fumaroles from hydrogen isotopic compositions of molecular hydrogen in the plume

Urumu Tsunogai[1*], Kanae Kamimura[1], Saya Anzai[1], Fumiko Nakagawa[1], Daisuke Komatsu[1]

[1]Faculty of Science, Hokkaido University

Molecular hydrogen (H_2) in a high-temperature volcanic fumarole (> 400 degreeC) reach to the hydrogen isotope exchange equilibrium with coexisting fumarolic H_2O under the outlet temperature of the fumarole. In this study, we applied this hydrogen isotope exchange equilibrium of fumarolic H_2 as a tracer for the remote temperature sensing on volcanic fumaroles, by deducing the hydrogen isotopic composition of fumarolic H_2 remotely from those in volcanic plume. To verify this new remote temperature sensing actually works or not, we determined both concentrations and hydrogen isotopic compositions of H_2 in volcanic plumes emitted from the fumarolic areas showing the outlet temperatures of 630 degreeC (Tarumae), 203 degreeC (Kuju), and 107 degreeC (E-san), and compared the results with those in the fumaroles. The average and the maximum mixing ratio of fumarolic H_2 within the plume H_2 were 97 % and 99 % in Tarumae, 89 % and 96 % in Kuju, 97 % and 99 % in E-san, respectively. In accordance with the enrichment of H_2 in each volcanic plume, we found depletion in the hydrogen isotopic compositions of H_2, showing linear correlation with the reciprocal of H_2 concentration. Besides, the estimated endmember hydrogen isotopic composition for each H_2-enriched component (-260+-30 per mil vs. VSMOW in Tarumae, -509+-23 per mil in Kuju, and -437+-14 per mil in E-san) coincided well with those observed in each fumarole (-247.0+-0.6 per mil in Tarumae, -527.7+-10.1 per mil in Kuju, and -432.1+-2.5 per mil in E-san). Furthermore, the calculated isotopic temperatures in fumaroles almost corresponded with the observed outlet temperature in Tarumae and Kuju, within 20 degreeC difference. We conclude that hydrogen isotopic composition of fumarolic H_2 was quenched within volcanic plume, so that both concentrations and hydrogen isotopic compositions of H_2 in an volcanic plume enable us to deduce those in the fumarole remotely and thus the outlet temperature of fumaroles, at least for those having the outlet temperatures more than 400 degreeC. The remote temperature sensing using hydrogen isotopes (HIReTS) developed in this study can be applicable to obtain more accurate and precise fumarolic temperature in many volcanoes.

Keywords: fumarolic gases, volcanic plume, molecular hydrogen, stable isotopes, isotope exchange equilibrium, remote temperature sensing

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SVC049-02 Room:105 Time:May 23 16:45-17:00

Temporal variations of heat discharge rates from the geothermal area formed during the 2000 eruption of Usu volcano

Akihiko Terada[1*], Shin Yoshikawa[2], Hiromitsu Oshima[3], Tokumitsu Maekawa[3], Nobuo Matsushima[4]

[1]Tokyo Institute of Technology, [2]Kyoto University, [3]Hokkaido University, [4]AIST

We estimate heat discharge rates for a geothermal area formed during the 2000 eruption of Usu volcano, Japan. Airborne surveys and field observations carried out in September 2010 reveal that heat discharge rates from fumaroles, areas of steaming grounds and crater lakes are ˜0, 5.6, and ˜0 MW, respectively. The total heat discharge rate measured in September 2010 represents below 1% of the rate immediately following the eruption.

Integration of the heat-discharge rate from April 2000 to September 2010 yields an accumulated discharge, corresponding to cooling of several percent of the total intruded magma volume estimated from analyses of ground deformation associated with the 2000 eruption. Compared with the 1977 eruption, the 2000 eruption involved the discharge of large amounts of heat from fumaroles. Fumaroles that developed during the 2000 eruption showed a decline in activity in short time. Areas of steaming ground associated with the 2000 eruption showed more rapid growth compared with those of the 1977 eruption but discharged less heat. We suspect that differences in the hydrological environments of the two eruptions (e.g., permeability around the intruded magmas) led to contrasting patterns of propagation of the hydrothermal systems around the intruded magmas.

Keywords: heat discharge rate, Usu volcano, steaming ground, airborne IR survey, hydrothermal system

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SVC049-03 Room:105 Time:May 23 17:00-17:15

Geomagnetic Total Force Observation, Self Potential and VLF-MT Survey around the Oana Crater, Azuma Volcano

Akira Yamazaki[1*], Takeshi Owada[1], Nobuyuki Yamazaki[1]

[1]Kakioka Magnetic Observatory

The Oana crater of which the diameter is about 200m is located in the geothermal fumaroles zone at southeast slope of Mt. Issaikyo, Azuma Volcano. In the recent years, a new 300m height fumarole named W-6 appeared inside the crater on November, 2008, and volcanic micro-tremors were observed after an interval of five years in 2010. It seems the volcanic activity of Azuma Volcano has been gradually activated.

In order to monitoring hydrothermal activity beneath the Azuma volcano, a repeat measurement of the geomagnetic total force with 12 observation points has been carried out near the Oana crater since 2003 by the volcanological center of Sendai district meteorological observatory cooperated with Kakioka magnetic observatory. Continuous secular variations in the geomagnetic total force have been observed within a 500m radius area from the center of the crater. Since the variation pattern is increasing at northern and decreasing at southern area of the crater, it suggests that the demagnetization has been progressing beneath the crater. Annual change rate of geomagnetic total force at each observation point is almost constant from started observation year, the maximum change of total intensity amounted to under -20 nT at southern side observation point of the crater. As the demagnetization occurred at geothermal active zone, we think it is a thermal demagnetization caused by hydrothermal activity.

On the other hand, according to the geodetic observation, a pressure source is estimated about 500m under the Oana crater. The pressure source is regarded as a hydrothermal reservoir, and we suppose the pressure of the reservoir depends on a balance of hydrothermal fluid supplements from magma and discharge to the surface. And the depth of pressure source and demagnetization source is almost the same. We suppose the thermal demagnetization is progressing at surrounded area of the reservoir.

Further, we measured self-potential (SP) distribution in 2009 around the Oana crater to detect a SP anomaly caused by hydrothermal convection system. As the results, the observed SP distribution is very flat, so the relation of the SP and the hydrothermal convection system is not clear. We also surveyed surface resistivity structure by VLF-MT method around the SP measured area in 2010. It is found that the resistivity is very low around the Jodo-Daira to the Oana crater.

Keywords: Azuma Volcano, geomagnetic total force, hydrothermal reservoir, thermal demagnetization, self-potential, resistivity

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SVC049-04 Room:105 Time:May 23 17:15-17:30

Approach to evaluating mass flux of volcanic fluids using the electrical conductivity structure of a volcano

Shogo Komori[1*], Tsuneomi Kagiyama[2], Jerry Fairley[3]

[1]Earth and Planetary Sci.,Kyoto Univ., [2]Graduate School of Science, Kyoto Univ., [3]Idaho Univ.

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; Kagiyama, 2008). Therefore, it is possible to quantify the constraint condition which controls these phenomena by evaluating the mass flux of volcanic fluids. 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 presicely. 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 fluid has a high electrical conductivity due to the high salinity of the pore water.

So far, the authors have developed the dissipation model of volcanic fluids by assuming the aquifer with simple geometry and physical property, and have examined the quantitative relation between mass flux of volcanic fluids and electrical conductivity structure using the numerical simulations (Komori and Kagiyama, 2008, 2009; Komori et al., 2010). It was found that the attenuation of the conductance of pore water essentially corresponds to the mass flux of volcanic fluids.

In this presentation, the authors attempt to evaluate mass flux of volcanic fluids from the bulk conductivity structure of a volcano obtained from MT survey.

In general, bulk conductivity of a volcano contains both contributions of the pore water and the matrix. The contribution of the matrix to the bulk conductivity affects the pore water conductivity. This means that the contribution of the matrix also affects the evaluation of volcanic fluids mass flux using the bulk conductivity of a volcano. Therefore, it is necessary for evaluating mass flux of volcanic fluids to take the both contributions into account. The quantitative relation between mass flux of volcanic fluids and the spatial distribution of pore water conductivity has been revealed by our previous studies as mentioned above; on the other hand, the spatial distribution of the matrix conductivity has not been revealed yet. In this study, we assumed that the matrix conductivity is a function of temperature and salinity of pore water. The estimated distribution of matrix conductivity is connected to the distribution of pore water conductivity by Revil's model (Revil et al., 1998, 2002) to obtain the distribution of bulk conductivity. The distribution of bulk conductivity is converted into the conductance as a function of the distance of volcanic center. The mass flux of volcanic fluids is estimated by comparing the conductance obtained by MT survey with the catalogs of the conductance vs. the mass flux of volcanic fluids.

These methods are applied to the bulk conductivity of Unzen Volcano obtained by wide-band MT (Komori et al., 2010). In this presentation, some assumptions about the distribution of matrix conductivity are considered. The mass fluxes of volcanic fluids estimated under these assumptions are examined.

Keywords: electrical conductivity structure, bulk conductivity, pore water conductivity, matrix conductivity, mass flux of volcanic fluids

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Conceptual and numerical models of the hydrothermal system at Unzen volcano

Sachio Ehara[1*], Hiroaki Koga[1], Tatsuya Wakeyama[1]

[1]Kyushu University

There are three main active geothermal manifestations, that is, Obama hot springs(Natural heat discharge rate Q=50MW), Unzen fumarolic field(Q=21MW) and Shimabara hot springs(Q=0.4MW) from west to east across Unzen volcano, western Kyushu, Japan. A geothermally altered zone is also found on the western flank of the volcano. There are no active geothermal activities at the surface but subsurface temperatures show higher than 240 degree C at a depth of 1000m.

Ohta(1972,1973)presented a comprehensive hydrothermal model based on the discharging of magmatic emanations from the deep magama reservoir beneath Tachibana Bay which is located west of Unzen volcano. The above three geothermal manifestations were generated by transfer of magmatic emanations from west to east and also by differentiation of magmatic emanations. Ohta(2006) presented a modified model later but the essential idea of geothermal fluid flow is the same as the previous model.

Ohsawa(2006) and Fujimitsu et al.(2006) pointed out contribution of lateral flows. Fujimitsu et al.(2006) constructed a numerical model to generate three main geothermal manifestations and a deep high temperature zone with two heat sources beneath the western flank of Unzen volcano. However, it was very difficult to simulate the observed natural heat discharge rates, especially in the Obama hot spring area.

Therefore we constructed new conceptual and numerical models with another heat source beneath Obama hot springs. The presented model well simulated the patterns of geothermal fluid flow and the observed heat discharge rates. The new model with three heat sources beneath the western flank generated all the four geothermal features on Unzen volcano.

Keywords: Unzen volcano, hydrothermal system, conceptual model, numerical model

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SVC049-06 Room:105 Time:May 23 17:45-18:00

Flow of thermal and groundwaters in the Owakidani and Gora area, Hakone

Kazuhiro Itadera[1*], Joji Kikugawa[1], Akio Yoshida[1]

[1]Hot Springs Research Institute

Oki and Hirano (1970) proposed a synthetic model that combines formation and flow of thermal waters in Hakone caldera with the uprising of volcanic gases, structure of base rocks and thermal conditions. To explain the model simply it is occasionally expressed as "hot eye and cold eyelid". The expression describe their idea that cold stratified ground waters are being warmed while they flow from the west around Lake Ashinoko toward the east through the hot region (hot eye) beneath central cones where volcanic gases are rising from magma reservoir existing in the depth. However, having examined in detail data about hydraulic head in the Gora area obtained in the period from 1960 through 2000, Machida et al. (2007) considered that ground waters are rather flowing vertically toward the depth, although the flow has also a component parallel to the inclination direction of the topography. Based on the result, they presented an idea that the zone in the WNW-ESE direction where hot NaCl springs are distributed is not related to the stream of volcanic hot water as considered by the Oki and Hirano model, but represents the extension of the area where reservoir of volcanic hot water rich in NaCl is underplayed,

By having examined concentrations of major anions and their relative concentrations as well as relationships between the oxygen isotope ratio and each concentration of those anions for thermal waters that are flowing out in Gora and Sokokura in detail, we (Kikugawa et at., 2010; Itadera et al., 2010) presented a new model to classify thermal waters in the areas that differs from the Oki and Hirano model. In the new model, existence of $HCO3^-$ in the Zone II springs in the Oki and Hirano model is attributed to the mixing of volcanic gases into the ground water recharged in the site. On the other hand, in the Oki and Hirano model origin of $HCO3^-$ in the Zone II springs was regarded as organic matters buried in the Hayakawa tuff breccia. We consider, as like Machida et al. (2007), that the belt-like zone in the WNW-ESE direction where hot springs rich in NaCl are distributed does not represent route of streams along which volcanic hot waters are diluted by ground waters, for any trend of changes in that direction is observed in temperature, concentration of anions and oxygen isotope ratios. The result by Itadera et al. (2010) that has showed that the uprising of temperature in thermal waters in 1967 in the Gora area occurred first in Sokokura, eastern end of the zone, also strongly supports the above supposition. In the new model, thermal waters in Sokokura is thought to be being formed by the mixing of ground waters and hot springs rich in NaCl that does not flow into the area from the west around Soun hell, but rise up in that site from the depth.

Hot springs that are rich in NaCl are observed only in the Gora area located on the eastern side of central cones. Thermal waters flowing out in base rocks are seen only along Hayakawa and Sukumo rivers that flow toward east. Further, most hot springs are distributed in the eastern half side of the caldera and a tendency of non-overlapping is seen between the spatial distribution of hot springs and hypocenter distribution of swarm earthquakes (Yoshida, 2010). We think all of these characteristics are closely related to the existence of Tanna and Hirayama fault systems that run through in the central part of Hakone caldera in the north-south direction.

Keywords: Hakone volcano, thermal water, groundwater

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Geothermal acvitity dominance in Tatun Volcanic Group, Taiwan

Tsuneomi Kagiyama[1*], Mitsuru Utsugi[1], Chang-Hwa Chen[2]

[1]Graduate School of Science, Kyoto Univ., [2]Academia Sinica, Taiwan

Tatun volcanic group (TGV) is located at northern Taiwan. More than 20 volcanic domes and cones have been created around the area 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 6 ka BP (Belousov et al., 2010) have been identified. Yang et al.(1999) found magmatic contribution in fumarolic gas. Kagiyama(2008) proposed that volcanism has a wide range of diversity represented by two typical end members controlled by the easiness of magma storage beneath volcano; 'Eruption dominant (ED) volcanism' in difficult condition and 'Geothermal activity dominant (GD) volcanism' in easier condition. According to the previous paper on VLF-MT, TVG has wide high conductivity area, and this result indicates geothermal activity of TVG might be comparable with that of Beppu geothermal area in Japan. Feature of lava flow indicates viscosity of magma is significantly high than normal viscosity expected by SiO2 content.

These evidences suggest TVG has extruded low temperature magma or degassed magma, and may be consistent with the cause of Geothermal activity dominance.

Keywords: Tatun Volcanic Group, Geothermal activity, Eruption

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DEVELOPMENT OF A NEW SIMPLE HYDROSTATIC EQUILIBRIUM MODEL FOR SUSTAINABLE EVALUATION IN GEOTHERMAL LIMITED RECHARGE

yayan sofyan[1*]

[1]Aso Volcanological Laboratory, [2]University of Indonesia

Geothermal energy is a renewable energy, that is, the energy removed from the geothermal reservoir is continuously replaced on time scales similar to those required for energy removal. Supplied energy to the geothermal reservoir comes from natural recharge and injection. Sustainable production in the geothermal energy development is the ability of the production system applied to sustain the stable production level over long times. It is very important to manage the mass balance between production, injection and natural recharge in the geothermal reservoir during exploitation. A new simple hydrostatic equilibrium model is developed by this mass balance model of geothermal reservoir.

New simple hydrostatic equilibrium model in this paper is built to estimate hydrostatic connection between recharged reservoir and discharged reservoir. Principle of transmission of fluid-pressure in the physical sciences states that pressure exerted anywhere in a confined incompressible fluid is transmitted equally in all directions throughout the fluid such that the pressure ratio remains same. Hydrostatic equilibrium occurs when compression due to gravity is balanced by a pressure gradient force in the opposite direction. Mass changes data in this hydrostatic equilibrium model is estimated by gravity changes from repeat gravity measurement method. The equation result between these parameters estimates recharge factor from discharged reservoir. This model also assumed a relatively constant of entered fluid flow rate from the surface that continues working during the production and injection well activity. This new simple hydrostatic equilibrium model is applied for sustainable evaluation in the geothermal field with limited natural recharge.

Keywords: Hydrostatic equilibrium model, Recharge factor, Geothermal reservoir with limited recharge, Sustainable evaluation