Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SVC49-01 Room:102B Time:May 25 14:15-14:30

Geostatistical analysis of VLF-MT resistivity data at the Tatun Volcano Group, Taiwan

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Tatun Volcano Group (TVG) is composed of over twenty volcanoes, which were formed within faults at the northern tip of Taiwan. Its active heat discharge from fumaroles and springs also suggests a large amount of volcanic fluids released from a potentially-existing magma beneath Chishinshan volcano (e.g., Yang et al., 1999; Ohba et al., 2010; Konstantinou et al., 2007). Komori et al. (2014) conducted AMT surveys for a better understanding of this magma degassing, and found low resistivity anomalies associated with the hydrothermal activity of the TVG.

In the TVG, we also conducted VLF-MT, which uses an electromagnetic wave with a singular frequency such as 22.1 kHz. Generally, its high simplicity of use enables a huge numbers of measurements at low cost, compared to AMT surveys. Therefore, VLF-MT could easily and extensively trace a surface distribution of hydrothermal fluids discharged from a deeper part, although its sounding depths are only a few tens to hundreds meters. However, it is quite often that there are many missing data points, mainly due to inaccessibility and high-level noises. Consequently, a sparse distribution of the surface resistivity is obtained, which might result in wrong spatial features of the resistivity at the survey areas.

Geostatistics is potentially a good tool to solve the above problem. It was theoretically developed by Krige (1951) to evaluate a quality of mines by estimating data values at unsampled points from a viewpoint of statistics. To date, it has been widely used for explorations of oils and geothermal/groundwater resources, by applying to data such as temperature, crack density, porosity, permeability, and chemical composition (e.g., Koike and Ichikawa, 2006; Anderson and Fairley, 2008). Because this method is mathematically based on statistics, it would enable a fair inference with regard to a spatial property of the obtained data.

The present study applied the Geostatistics to over 300 VLF-MT resistivity data of the TVG, which were conducted in 2009-2010 by Kagiyama et al. (2010, JPGU meeting) and in 2012-2013 by Komori et al. (2014, CA meeting). The numerical code GSLIB (Deutsch and Journel, 1998) was used for our geostatistic works. The data were first processed to make an experimental semivariogram. It was used to estimate a model variogram by assuming values of nugget, sill, and range, on the basis of the criteria put by Kitanidis (1997). The modeled variogram was input to Simulated Annealing (SA) process to estimate a statistically-plausible spatial distribution of the surface resistivity. In the presentation, we will show preliminary results by the above processes, and examine its relation to structural features and hydrothermal activity of the TVG.

Keywords: Tatun Volcano Group, hydrothermal activity, VLF-MT, geostatistics, simulated annealing

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SVC49-02 Room:102B Time:May 25 14:30-14:45

Hydrothermal system beneath the Jigokudani valley, Tateyama volcano, inferred from AMT surveys and hot spring chemistry

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We carried out AMT surveys and the analyses of hot spring water in the Jigokudani valley (JV), Tateyama volcano, Japan. The JV was formed by repeated phreatic eruptions some 40,000 years ago, and has laminated lacustrine sediments that are located at the base of an extinct crater lake. Currently, the JV is an active solfatara field dotted with hot springs and fumaroles, and has experienced several anomalous events indicating the increase in volcanic activity. The objective of this study is to clarify the characteristic of electrical resistivity structure where multiple phreatic eruption events occurred, and to investigate the spatial relationship between subsurface structure and recent volcanic activity. We collected the AMT data at 25 locations in and around the JV, and estimated a 3D resistivity structure using the inversion code of Siripunvaraporn and Egbert (2009). Electrical conductivity, temperature and pH were measured in 50 hot springs, and chemical analyses were performed on representative 12 samples of those springs. Hot springs in the JV showed features of strong acid Cl-SO4-type, and turned out to be derived from magmatic hydrothermal fluids because of the high ratio of Cl/SO4 concentration. A highly conductive region with thickness of approximately 50m was detected beneath the most active geothermal field, and was interpreted as representing clayey sediments. A slightly resistive portion was present beneath this layer and hot spring water of this area showed high ionic concentrations, which suggests that there are high temperature gases of magmatic origin. A deep feature of 3D resistivity structure suggests that such magmatic gases are provided from east of the JV, which is consistent with the location of seismically inferred magma reservoir.

Keywords: Resistivity structure, AMT, Tateyama volcano, Phreatic eruption, Hydrothermal system, Clay cap

SVC49-03 Room:102B Time:May 25 14:45-15:00

Hydrothermal system around the active crater of Aso volcano inferred from a three-dimensional resistivity structure

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This paper presents a three-dimensional (3-D) electrical resistivity model around the active crater of Aso volcano using the audio-frequency magnetotelluric (AMT) data obtained during 2004-2005. The AMT data were collected at 43 locations on an approximately 300-m grid in and around the Nakadake crater, the summit of the central cone complex, and were already interpreted by two-dimensional models (Kanda et al., 2008).

Over the past 80 years, all of the volcanic events within Aso volcano have originated from the 1st crater of Nakadake. The volcanic activity of Aso has showed a cyclic activity pattern: a crater lake is formed at a quiet period and a Strombolian eruption occurs at an active period. From November 2014, Strombolian eruptions have been observed at the 1st crater, which is considered to be a part of a similar activity cycle. This cyclicity of the volcanic activity implies that a specific structure that acts to accumulate the energy required to trigger eruptions develops at approximately the same location beneath the 1st crater. The objective of this study is to reveal such specific subsurface structure.

As a result of 3-D inversion using the code of Siripunvaraporn and Egbert (2009), we have obtained the following features in the 3-D resistivity model. A highly conductive zone is present at depths between 100 and 300 m beneath the 1st crater, but unexpectedly the resistivity of the shallow subsurface around the Nakadake crater is not low in general. The low resistivity zone widely distributed at a depth around sea-level which was found in the previous studies is seen only beneath the northern half of the Nakadke crater including the 1st crater. We will discuss these features in connection with the variation sources inferred from other geophysical studies.

Keywords: Aso volcano, resistivity structure, active crater, audio-frequency magnetotellurics, hydrothermal system

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SVC49-04 Room:102B Time:May 25 15:00-15:15

Time variation in the chemical and isotopic composition of fumarolic gases at Hakone volcano, Japan

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The driving force of eruption is the degassing of magma or the explosion of hydrothermal reservoir. The volcanic gas contains the component originating in the degassing magma or the hydrothermal reservoir. Therefore, the volcanic gas is essentially important object for the understanding of eruption and the eruptive prediction.

Although no historical eruption was recorded at Mt Hakone, the swarm of volcanic earthquakes has been observed several times. For example, in 2001 the swarm of volcanic earthquakes was observed with the deformation of volcanic body suggesting a pressure source the depth of which was estimated to be 7km (Daita et al, 2009). In parallel to the swarm of earthquakes, the steam pressure in the borehole located in the geothermal area of Owakudani significantly increased.

Sampling and analysis of fumarolic gas

The Owakudani geothermal area is developed on Mt Kamiyama, one of the central cones of Hakone caldera. The fumarolic gases have been sampled and analyzed at two outlets in Owakudani geothermal area almost every month since May 2013 to Jan 2015. One fumarolic gas (T) is located near the parking for sightseeing people of Owakudani geothermal area. Another fumarolic gas (S) is located on the north flank of Mt Kamiyama, 500m far from the fumarole T. The temperature of gas at the outlets was about 96C, which is close to the boiling temperature of the altitude of the fumaroles. The fumarole T associates the discharge of hot spring water. The fumarolic gas was sampled in the evacuated glass bottle containing 20ml of 5M KOH solution. For the determination of SO2/H2S ratio, KIO3-KI solution was reacted with fumarolic gas at the sampling site. For the sampling of condensed water of gas, a double glass tube was used for cooler. The solution in the evacuated glass bottle was analyzed along the method by Ozawa (1968) to determine the amount of H2O, CO2, total S (=H2S + SO2) and R-gas. The R-gas was analyzed by GC with Ar and He carrier gases to determine the relative concentration of He, H2, O2, N2, CH4 and Ar. The isotopic ratio of condensed water was determined by use of an IR-laser cavity ring down analyzer (Picarro). The isotopic ratio of H2 in R-gas was determined by use of the continuous flow system combining a mass spectrometer (Thermo Fischer Scientific Delta V).

Result and Discussion

The both fumarolic gases, T and S was composed by mainly H2O vapor the relative concentration is about 98%. The secondary dominant component was CO2, the concentration was 1 to 2%. The T and S fumarolic gases contained H2S of 0.2 to 0.4% and 0.04 to 0.05%, respectively. The CO2/H2O ratio of T decreased in May 2013 until Oct 2013, then stable until Sep 2014. In Oct 2014, a small increase was observed in the ratio. A similar change was observed in the S fumarole. In Oct 2014, about 50 of earthquakes occurred at Mt Hakone, the number of which was higher than the preceding months. The increase of CO2/H2O ratio in Oct 2014 looks to be correlated with the occurrence of earthquakes. The change in CO2/H2S was almost similar the change in CO2/H2O ratio for both T and S fumaroles. An interesting change was found in the He/H2O ratio of T fumarole. The ratio increased in Sep 2014, which is one month before the increase in CO2/H2O ratio. The increased He/H2O ratio decreased in Oct 2014, which looks like a precursor of the change in CO2/H2O ratio and also the swarm of earthquakes. For the estimation of hydrothermal reservoir temperature, the apparent equilibrium temperature (AET) was calculated between H2O and H2 assuming the exchange of D between those species. The AET was high as 140C in May 2013 at T fumarole. The AET deceased quickly down to 100C. A small increase was observed in Dec 2013 and Aug 2014. The AET of S fumarole was almost stable, showing a gradual increase from 92C in May 2013 to 104C in Aug 2014. The AET seems to be useful for the estimation of reservoir temperature.

Keywords: Hakone, Volcanic gas, Chemical composition, Volcanic earthquake, CO2, He

SVC49-05 Room:102B Time:May 25 15:15-15:30

Volcanic plume measurements of Ontake volcano by unmanned aerial vehicle (UAV)

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On Sept. 27, 2014, a phreatic eruption occurred at Ontake volcano, central Japan, caused unprecedented disaster and took the lives of many tourists. The explosion plume rose up to nearly ten thousand meters and ash fall was observed as far as about 100 km east in Yamanashi Prefecture (JMA, Sept., 2014). The plume activity gradually decreased but the volcano still vigorously emits white plume as of Feb. 2015.

We made plume observation using a multicopter UAV on Nov. 20 and 21, 2014 to carry out following four kinds of measurements; sulfur dioxide flux, in-plume multiple gas concentrations, thermal images of the crater area and collection of fine particles inside the plume. In Ontake volcano measurements, the UAV was expected to fly 4000 m roundtrip distance at the altitude of 3000 m. Thus, the respective instruments were made compact and light to fit the payload of 1kg. The SO_2 flux measurements was carried out by traversing below the plume with a compact UV spectrometer operated by a single-board-computer. In the multiple gas concentration measurements, H_2S, SO_2, CO_2, H_2 sensors and a thermohygrometer (H_2O)were loaded to the UAV and flew inside the plume. In these in-plume flights, an adhesive film was used to collect fine particles inside the plume. An infrared thermography camera mounted on the UAV was used to image Jigokudani crater area to reveal the thermal condition. On Nov. 20, takeoff and landing of the UAV was located at Iimorikougen ropeway station about 3.5 km ENE due to NE plume direction. On Nov. 21, the UAV was operated from Tanohara park about 3 km SE from the crater area to approach the plume flowing in ESE direction.

Sulfur dioxide flux and SO_2/H_2S molar ratio obtained by the UAV plume measurements were 130-140 ton/day and about 0.09 for Nov. 20-21, 2014. No volcanic H_2, CO_2 and H_2O were clearly detected due to high mixing ratio of atmosphere. The thermal images of Jigokudani crater showed maximum temperature of 90.6 ℃ corresponding to the boiling point of the local altitude. Although some fine particles including crystalline minerals were found on the adhesive films, they were probably dusts from the ground.

Prior to the UAV measurements on Oct. 9, in-plume multiple gas concentration measurements were carried out using Multi-GAS analyzer onboard a helicopter and we obtained SO_2/H_2S molar ratio of about 0.3, indicating a significant decrease of the ratio by Nov. 20-21, 2014. Sulfur dioxide flux was over 1000 ton/day just after the eruption and was 400-500 ton/day (JMA, Oct. 2014) on Oct. 9 and decreased to 130-140 ton/day in two months after the onset of the eruption. In contrast, a total sulfur flux on Oct. 9 was about 1000 ton/day and was about 800 ton/day on Nov. 20-21 showing no significant change. The plume activity of 2014 Ontake volcano eruption is characterized by high total sulfur flux, however, low fumarolic temperature and low SO_2/H_2S ratio suggest that volcanic gas at Ontake volcano is not directly emitted from magma.

After 1979 Ontake volcano eruption, SO_2/H_2S molar ratio showed significant decrease from 5 soon after the eruption to 0.1 an year after the eruption (Ossaka et al., 1983). The decrease of SO_2/H_2S molar ratio after the eruption is the common characteristic of the two eruptions in 1979 and 2014. Detailed comparison of the two eruptions would be important to understand the future of ongoing Ontake volcano's activity.

Keywords: Ontake volcano, volcanic gas, UAV

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SVC49-06 Room:102B Time:May 25 15:30-15:45

Case study of the behavior of isotope in several hot-spring and geothermal field part2

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The Oxygen and hydrogen isotope data provide information about the origin and evolution of geothermal waters and relationship with hot spring reservoir and river water.

According to Enhanced Geothermal System (EGS), stable isotope data show the water source in reservoir or injected water. Recently, several EGS project are carried out in USA, Australia and Europe. And after nuclear power plant accident at 2011, we need new EGS project and the review of previous project at Hijiori. At Hijiori EGS site, the long term circulation test was carried out from 2000 to 2002. The tracer response changed with circulation (Yanagisawa et al., 2002, 2003) and calcium carbonate and anhydrite scale precipitated in circulation system (Yanagisawa et al., 2008). This shows the geochemical condition change in Hijiori system. And to develop EGS project, we have to survey the relationship between hot spring and EGS reservoir. Then, this presentation shows the results of stable isotope change of production and injection well at Hijiori test site and discuss the reservoir condition during circulation test.

During this test, hydrogen and oxygen isotope composition of production wells (HDR-2 and HDR-3), injection well, river water and hot springs were analyzed.

The isotope ratio of the river water and hot springs plot along the meteoric water line. The isotope ratio of hydrogen and oxygen ratio of HDR-2 increased with circulation and reached value of -45 ‰ of δD and -4.6 ‰ of δ^{18}O at end of May 2001, respectively. However δD and δ^{18}O rapidly decreased to -54.4 ‰ and -8.6 ‰ respectively from May to June and came close to meteoric line. The isotope ratio of HDR-3 plot at higher δ^{18}O than that of HDR-2 and the change of the isotope ratio of HDR-3 is similar as that of HDR-2.

The change of δ^{18}O value of HDR-2 is corresponds with Cl concentration change during the circulation progress.

Keywords: hot spring, geothermal, isotope, Hijiori, EGS

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SVC49-07 Room:102B Time:May 25 15:45-16:00

Numerical modeling for a broad geothermal system of Kuju Volcano

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The Kuju volcanic field is located in the southwestern part of Oita prefecture, Japan, and consists of some andesitic volcanoes. There are many hot springs and several geothermal power stations (Hatchobaru, Otake, Takigami etc.) in this field. In the previous studies on the Kuju volcanic field, the numerical models were mainly for the power station areas or the center of Kuju Volcano where fumarolic activity appears. Therefore, we constructed a new conceptual model that includes the center of the volcano and all of the geothermal power station areas in order to attempting to construct an integrative numerical model of a broad geothermal system that has the scale of the volcanic field to explain the existence of the hydrothermal systems, which are generated by a heat source like a magma chamber in the volcanic field. Based on this conceptual model, we constructed a numerical model that replicates the hydrothermal systems of the geothermal power station areas roughly although the numerical model is relatively simple.

Keywords: Kuju Volcano, broad geothermal system, hydrothermal system, numerical model

SVC49-08 Room:102B Time:May 25 16:15-16:30

Re-evaluation of hydrothermal activity based on magnetic measurements at Kusatsu-Shirane volcano, Japan

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Kakioka Magnetic Observatory, Japan Meteorological Agency commenced geomagnetic measurements around the summit crater lakes of Kusatsu-Shirane volcano in 1976 to monitor the thermal activity of the volcano. We re-analyzed the geomagnetic data over 36 years starting in 1978 and evaluated the long-term thermal activity beneath the crater lakes.

Changes in the geomagnetic total intensity due to thermal activity were observed in three periods: 1982-1985, 1988-1991, and 1996-2012. A thermal-demagnetization source related to phreatic eruptions during 1982-1983 was estimated to be 400 m below Mizugama crater lake during 1982-1985. The demagnetized body was also detected at a depth of 600 m below Mizugama crater lake in 1988-1991 when substantial thermomagnetic signals and numerous volcanic earthquakes were observed without an eruption. These demagnetization sources represent a hydrothermal fluid reservoir beneath the summit area. We suggest a possible mechanism of the phreatic eruptions during 1982-1983, based on our thermomagnetic model and previous geophysical and geochemical studies.

In contrast, magnetization associated with cooling of rocks beneath the crater lakes was recorded from 1996 to 2012. According to our thermomagnetic modeling of this period, the source of the magnetization was 400 to 700 m below an area immediately northeast of Yugama crater lake. In addition, we found that the cooling migrated gradually to shallower depths during this period. These suggest that the decline phase of the volcanic activity was under way at this period.

Changes in the geomagnetic total intensity after 2013 show a different tendency from those before 2013. Therefore, these suggest that the decline of volcanic activity came to an end in 2013.

Keywords: Kusatsu-Shirane volcano, geomagnetic measurement, thermomagnetic effect, phreatic eruption, hydrothermal fluid

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SVC49-09 Room:102B Time:May 25 16:30-16:45

Evolution of a hydrothermal system of Kusatsu-Shirane volcano inferred from aerial infrared surveys in the nighttime

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Kusatsu-Shirane volcano is one of the most active volcano in terms of release of a large amount of heat as volcanic gas and hot springs. In addition to steaming grounds and fumaroles, the Shirane pyroclastic cone contains a hot crater lake, locally referred to as Yugama, which shows interesting variations of water temperature and chemical concentrations.

Intense earthquake swarms have occurred at shallow depth of the Shirane pyroclastic cone since March 2014, accompanied by a ground deformation, changes in geomagnetic field and chemical concentration of volcanic gas. A location of the pressure source is determined by network of our tilt meters at 550 m depth from Yugama crater lake. These unusual activities may be caused by an accumulation of hydrothermal hot water at shallow depth of Yugama crater lake, so we expect changes in thermal activities around the Shirane pyroclastic cone.

To detect changes in thermal activities on Kusatsu-Shirane volcano, an aerial infrared survey was carried out on 25 October 2014. The observation was done in the nighttime because even slight anomalies in ground surface temperature can be detected. Images of detailed ground temperature enable us to estimate precisely heat- and water-discharge rates from steaming ground as well as Yugama crater lake.

Steaming grounds around Yugama crater lake show no significant changes compared with the record obtained in 2012, although changes in chemical compositions of volcanic gas emitted here were observed. On the other hand, we detect an increase in water surface temperature of Yugama crater lake. Water evaporation rate in 2014 is estimated approximately to be 5 kg/s, which is 2.5 times higher than that of the value in 2012. Such an increase in water temperature occurred in May 2014 suggested by monitoring of Yugama crater. Records of tilt meters indicate that an accumulation rate of the hydrothermal water decreased after May 2014. We consider that the reservoir of hydrothermal water fractured gently in May 2014. Consequently, an additional input of hydrothermal water started at the bottom of Yugama crater lake.

Keywords: Kusatsu-Shirane Volcano, airborne IR surveys, hot crater lake, steaming ground, hydrothermal system, heat-discharge rate

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SVC49-P01 Room:Convention Hall Time:May 25 18:15-19:30

Near surface structure of a Crater on mountain side of Mt. Shiretokoiozan and its mechanism of molten sulfur eruption

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Mt. Shiretokoiozan, located in the middle of the Shiretoko Peninsula in Hokkaido Japan, is famous as molten sulfur eruption. Since 1857, Mt. Shiretokoiozan has erupted with molten sulfur four times. At the last eruption from February through October in 1936, approximately 200,000 tons of molten sulfur welled out of the Crater I, located on the northwestern mountain side, and the brown liquid sulfur flowed into the Kamuiwakka Creek. The eruption was closely observed and documented for ten days in September by Watanabe. He presumed the underground structure and possible existence of a molten sulfur reservoir under the crater based on the periodic activity.

Since 2005 we have implemented further researches to find out the near-surface underground structure of the Crater I for discussing the mechanism of molten sulfur eruption. The methods are various; geological survey, DC resistivity survey, self-potential exploration, and chemical analysis of gas and hot spring.

As a result, we found that the crater had been created by depression due to hydrothermally altering of andesite lava sheet and the following running-off of material. We suggest that there is a chamber under the crater and molten sulfur is supplied from the aquifer at the eruption where the sulfur had been generated during the inter-eruption period by chemical reactions of volcanic gasses.

The geology of the Crater I and its vicinity is mostly composed of hydrothermally altered clay, gravel and onion structured floats. Originally this area was composed of several-meters-thick sheet lava layers of andesite, which had flowed from the summit of mountain. The volcanic gasses, mostly hydrogen sulfide and carbon dioxide, come out through fumaroles and craters located directionally along conjugate faults cutting through this area. Original andesite rocks suffered weathering by the reaction with those acid gasses into onion structured boulders and seems to change to white gravels and clay. Because the small clay particles and the gravel at ground surface have been drained, large boulders in several meters were left on the ground and they covered most of this area.

In the cross section around the Crater I, we conclude that the crater is a depression hole opening in the hydrothermally altered lava. An aquifer among sheet lava goes under the Crater I and hot spring wells in the crater. At the higher elevation than the Crater I, there is a small creek called the Io Creek. And at the lower altitude, the Kamuiwakka Creek is located. We interpret that the underground water comes from the Io Creek and flows through lava-sheet aquifer, and upwells at the Crater I as well as hot springs in the Kamuiwakka Creek.

Volcanic gasses, hydrogen sulfide and sulfur dioxide, dissolve into the underground water, and were involved in the chemical reaction to generate the accumulation of sulfur in the aquifer. At the fumarole in the Crater I, water soluble sulfur dioxide is just barely detected. At the same time, the gas temperature has never been higher than boiling point of water. These are the evidences that most of volcanic gas passed through underground water.

We suggest that the sulfur in the aquifer melts and flows into the chamber under the Crater I at the active term of volcano, and may eject molten sulfur periodically. The amount of the molten sulfur erupted in 1936 was approximately 200,000 tons. If the chamber had reserved all amount of sulfur erupted in 1936, its volume might have been as much as 100,000 cubic meters. We suppose the possible chamber size is much smaller than the estimation. It is concluded that the aquifer supplied the molten sulfur continuously to the chamber, while the chamber made a periodic eruptions.

Keywords: Molten sulfur eruption, Hydrothermal alteration, Shiretokoiozan, The Crater I, DC resistivity survey, Hot springs in the Kamuiwakka Creek

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SVC49-P02 Room:Convention Hall Time:May 25 18:15-19:30

Mineralogical study of non-juvenile material in volcanic products at Tokachidake volcano, Japan

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Temperatures, depths, and fluid chemistry of sub-volcanic hydrothermal system were estimated based on mineralogical analysis of eruptive products of the 1926 and the 4.7-3.3ka eruptions at Tokachidake volcano, Japan. The deposit of the 1926 eruption can be divided into three layers according to volcanic phenomena; the lower debris avalanche deposit, the middle hydrothermal surge deposit and the upper debris avalanche deposit. The deposits of the 4.7-3.3 ka eruption can be divided into four pyroclastic flow deposits layers; one from the 4.7 ka eruption and other three from the 3.3 ka eruption. Every deposit contains abundant hydrothermally-altered lithic fragments. Three layers of the 1926 eruption exclusively consist of altered lithic fragments without any juvenile fragments. Minerals identified in the bulk sample of the 1926 eruption deposit are cristobalite, smectite, sericite, kaolinite, alunite, gypsum and pyrite, and those in the deposits of the 4.7-3.3ka eruptions are cristbalite, tridymite, quartz, sericite, pyrophyllite, alunite, plagioclase and hyperthene. Mineral assemblages of individual fragments were also determined with combination of SEM-EDS and XRD. The 1926 eruption product is characterized by the coexistence of cristobalite, alunite and/or smectite in the fragments, whereas the 4.7-3.3 ka eruption product is characterized by the coexistence of pyrophyllite and quartz. The mineralogical contrast implies difference in hydrothermal condition between the 4.7-3.3 ka and the 1926 eruptions. The former eruptions were derived from hotter ($>$230 C) and deep (1-2 km) hydrothermal systems and the latter from a colder ($<$100 C) and shallow (near-surface) hydrothermal system, although both volcanic products are characterized by sulfuric acid fluid which is typical in hydrothermal systems at volcanic centres.

Keywords: sub-volcanic hydrothermal system, hydrothermally-altered lithic fragment, Tokachidake volcano, eruption products in 1926, pyoroclastic flow deposits in 4.7-3.3 ka

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SVC49-P03 Room:Convention Hall Time:May 25 18:15-19:30

Resistivity structure of geothermal area at south area of Yakedake Volcano

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Resistivity structure of geothermal system at south area of Yakedake Volcano

Sugano, K., Y. Yamaya, T. Mogi, M. Shigefuji and M. Okuda

Some hot-springs and fumaroles are seen around the Yakedake Volcano. High temperature hot springs such as Nakanoyu and Shirahone hot springs are located at the south area of the Yakedake volcano, but the relations between the volcano and geothermal system have not been clarified yet. Geophysical studies concerning the structure of geothermal fluid reservoir and heat source of the hot springs have never been performed in this area.

Hokkaido University carried out a MT survey to clarify the subsurface structure at six sites between Sirahone hot spring and Sawando area in 2013 and indicated distribution of geothermal fluid reservoir beneath Shirahone hot springs and Sawando area (Yamaya et al., 2014). But they did not clarify the extent of geothermal fluid reservoir under these area. We installed two additional MT sites each at outside of the previous survey area in 2014 to investigate extension of these reservoirs.

We recorded MT signals for about 48 hours at each site, and obtained the apparent resistivity and phase at a frequency range of 0.03-100Hz. We applied the remote magnetic reference (Gamble et al., 1979) and manual data editing by MTEDITOR to remove local electromagnetic noises.

The magnetotelluric phase tensors (Caldwell et al., 2004) and induction vectors were calculated to verify structural dimensionality and to determine the 2D strike direction for the 2D inversion. According to the phase tensor ellipse and induction vector at the lower frequency range, the deeper layer have 2D structure and we decided that 2D strike direction is N60W in this area.

We performed two types of 2D inversion, which used the TM mode and TE+TM modes, respectively. We used the inversion code proposed by Ogawa and Uchida (1996), which minimized ABIC as convergent criterion in the iteration process. The ABIC criterion includes smoothness, least square mean error and static shift correction.

As a result, we indicate that geothermal fluid reservoir correspond with low resistivity is extending at directly under the Shirahone hot spring area, and it ranges in the limestone body. Dissolved limestone is origin of milky hot spring that characterizing the Shirahone hot spring. The low resistivity zone was also found at the depths of 500m down in the Sawando area. Although no geothermal manifestation is recognized at the surface of the Sawando area, but this low resistivity zone probably indicates a geothermal reservoir.

Furthermore, these two low resistivity structures corresponding each geothermal fluid reservoir join together at the depths of 2 km below. The columnar low resistivity zone extends to deep. Comparing the geology, the Sakaitouge fault runs through at the columnar low resistivity zone. The resistivity structure suggests that geothermal fluid ascends from deeper zone along the Sakaitouge fault. Based on this result, we can propose two possibilities of the heat source of geothermal fluid. One possibility is that hot volcanic fluid flows out from the Yakedake volcano along the fault. The other is that heating water is ascending along the fault from the hot rock area extending in the Japanese Northern Alps area.

Keywords: Geothermal area, Resistivity structure, Yakedake

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Conductivity distribution of the surface layer around volcanic area in central Kyushu

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Kagiyama and Morita (2008) indicated magma degassing is one of the important factors to control magma ascending. Discharge rate of volatiles from magmas through a crater has been estimated by direct observations of CO2 and SO2 gases, such as COSPEC and DOAS, and by geochemical methods. However, discharge rate of volatiles through a volcanic aquifer has not been clarified because of difficulty of obtaining geochemical samples spatially from deeper part of volcanic aquifer. Electrical conductivity of ground strongly depends on the conductivity of pore water, and VLF-MT survey is a powerful tool to clarify the distribution of hydrothermal water in the shallow depth. On this aspect, the authors carried out VLF-MT survey around volcanoes in central Kyushu, Japan.

Aso Caldera: Aso Caldera has acid crater lake in Nakadake Volcano, which is one of the post caldera cones, and has many hot springs within the caldera such as Uchinomaki, Jigoku & Tarutama. Conductivity distribution shows two typical features; caldera floor has almost homogeneous and high conductivity (>10mS/m), while the post caldera cones show wide range. Most cones have lower conductivity (<3mS/m), except active geothermal fields around Naka-dake Craters and western part of post caldera cones (>30mS/m). Just north and south of Naka-dake Craters, high conductivity (3-10mS/m) was identified. This suggests down flow of hydrothermal water from Naka-dake Craters to the flank of post caldera cones. Caldera floor has almost homogeneous conductivity. This feature is explained by the fact that the caldera floor was under the lake until 9 ka and is covered by lake deposit. However, extremely high conductivity (>30mS/m) was found at several areas in the caldera floor. These high conductive zones and Naka-dake are located along the NNW-SSE line. Hydrothermal water may be supplied along this tectonic line.

Kuju volcanic group: Central cones have lower conductivity (<3mS/m), except active geothermal fields around Iwo-yama (>30mS/m). Around volcanic cones, high conductivity zone was identified. This suggests down flow of hydrothermal water from volcanic cones to the flank. On the other hand, another high conductivity zone is identified along the tectonic line; Oita-Kumamoto tectonic line, Yufuin Fault, etc. Hydrothermal water may be supplied along this tectonic line.

Tsurumi&Garan volcanoes (Beppu geothermal area): Many lava domes show low conductivity (<3mS/m), except active geothermal spots in Tsurumi and Garan domes. High conductivity zones are identified along some tectonic faults; E-W trend from Garan crater to Kan'nawa hot spring, along Asamigawa Fault, etc. The area size of high conductive (>30mS/m) zone around northern Beppu hot springs (320MW) is estimated about 4 km2.

These results suggest Geothermal activity dominant volcanoes have wide high conductivity area related with degassing from magma. And VLF-MT survey will be effective method to identify tectonic line around volcanic and geothermal field.

Keywords: Active volcano, Electrical conductivity, Central Kyushu, Geothermal activity