Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SVC52-01 Room:101A Time:May 21 16:15-16:30

Tracer test at Minami-Izu hot spring area, Shizuoka

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Tracer test is carried out in high temperature hot spring fluid layer at Minami-Izu geothermal field, Shizuoka, Japan. In Minami-Izu field, the temperature of several hot spring wells is about 100 degree C at a depth around 150 m. About 500g uranine tracer was injected at 16 September. We monitored tracer appearance at 5 wells using optical fiber system and lab spectrometer.

1)At Daigaku-yu (K-13) well, the first tracer appeared 9 hours after tracer injection and tracer concentration rapidly increased and showed peak at three days after injection. The return ration at K-13 is estimated about 30%.

2)In other wells, at Tamagawa-yu (K-11) about 150 meter from injection well, the first tracer appear at 10 days after injection and earlier than Kyodou-yu (K-3).

3)The main flow injected tracer is along with the large fault between injection well and K-13 and the main flow in hot spring reservoir seem to the right angle of fault and ENE direction.

Keywords: Tracer test, Uranine, Hot spring, Optical fiber system, Fault, Horizontal flow

SVC52-02 Room:101A Time:May 21 16:30-16:45

Geochemical characteristics of hot springs in Bulusan Volcanic Complex, Southern Luzon, Philippines.

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Bulusan Volcano located in the southernmost part of the Bicol Peninsula is one of the active volcanoes in the Philippines. This paper reveals geochemical characteristics of hot springs in the Bulusan Volcanic Complex (BVC).

All of the hot springs except Buhang shows the HCO3-SO4 and/or HCO3 types, and also is plotted within the immature water area in the Na-K-Mg diagram, suggesting no strong outflow of neutral Cl-rich deep waters in the BVC. Isotopic compositions (delta D and delta 18O) of the hot springs indicate the local meteoric water origin. On the other hand,Buhang hot spring shows the Cl-HCO3 type formed by mixing of meteoric origin CO2-rich hot fluid and sea water.

Acidic pH of river water was observed during a small lahar caused by heavy rain, probably this is due to erosion of newly sedimented pyroclastics by the rain and dissolving the volcanic gases absorbed on the surface grains of the pyroclastics.

San Benon hot spring was monitored for chloride and sulfate ions to detect any precursor of volcanic eruption. The variation of chloride and sulfate ions were directly proportional with each other, ranging from 81 to 168mg/l and 270 to 601mg/l, respectively. This suggests that these ions are strongly affected by the mixing of groundwater in the area. Therefore, chemical monitoring using chloride and sulfate ions at San Benon will not be recommended.

Keywords: Hot spring, Geothermal, Bulusan Volcanic Complex, Philippine

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Implications of a large hydrothermal reservoir beneath Taal Volcano (Philippines) as revealed by magnetotelluric surveys

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Located in the island of Luzon and 60 km south of the capital city of Manila, Taal Volcano is one of the most active volcanoes in the Philippines. The first recorded eruption was in 1573 and since then it has erupted a total of 33 times, with the last eruption in 1977. These eruptions resulted in thousands of casualties and considerable damage to property. In 1995 it was declared one of the '1990s decade volcano' by IAVCEI. Although the volcano remained fairly quiescent after the 1977 eruption, at the beginning of the 1990s it began to exhibit several phases of abnormal activities, such as episodes of seismic swarms, ground deformation and fissuring, and hydrothermal activities, all of which continues to the present. Examining past eruptions of Taal Volcano however, it has been observed that these can be divided into 2 distinct cycles, depending on the location of the eruption: eruptions centered at the Main Crater (1572-1645 and 1749-1911); and eruptions occurring at the flanks (1707-1731; 1965-1977).

We conducted (as part of the PHIVOLCS-JICA-SATREPS Project), magnetotelluric and audio-magnetotelluric surveys on Volcano Island, in March 2011 and March 2012. The objective of this survey was to create a resistivity model of the hydrothermal system beneath the volcano. Initial (2-D) inversion modeling revealed a prominent and large zone of relatively high resistivity between 1 to 4 kilometers beneath the volcano and almost directly beneath the Main Crater and surrounded by zones of relatively low resistivity. The anomalous zone of high resistivity is hypothesized to be a large hydrothermal reservoir filled with volcanic fluids in a gaseous phase. Three-dimensional forward modeling reveals the size of the reservoir to be as large as 3 km in diameter and between 1 km to 4 km in depth. This reservoir appears to be overlain by an impermeable cap, which exhibits a lower resistivity signature compared to the hydrothermal reservoir. Past eruptive activities of Taal Volcano (which are characterized by repeated changes in eruption sites, i.e. alternating between the Main Crater and the flanks and separated by long repose times), could be related to the presence of such a large hydrothermal. During the cycle of Main Crater eruptions, this hydrothermal reservoir is depleted, whereas during a cycle of flank eruptions this reservoir is replenished with hydrothermal fluids. In particular, the 1911 January 30 eruption showed an anomalous feature similar to a gas explosion, which can be attributed to the large hydrothermal reservoir collapsing catastrophically.

Keywords: hydrothermal reservoir, phreatic eruption, magnetotellurics, Taal Volcano

SVC52-04 Room:101A Time:May 21 17:00-17:15

Gravity variation in Akita-Komagatake volcano and thermal expansion model

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(1) In Akita-Komagatake volcano, we have monitored volcanic condition after the 1970-eruption by repeated observations at fixed points, on ground-temperature, geomagnetic total intensity, and gravity. After the end of the eruption in 1971, ground temperature rose in the surrounding area, though the crater itself cooled rapidly. The peak of this geothermal activity was about 1977-78. After then the activity decayed, and the temperature lowered to almost normal level in 1995-98. This high geothermal (HG) period is called the post-eruption HG period. Geothermal activity again revived since about 2006, and the active area is now expanding to almost east-half of Medake (the present HG period). Variation of gravity is focused in this paper, though that of geomagnetic intensity was also conformable to the above geothermal activity. Gravity remarkably increased with drop of ground temperature, and lowered with rise of it.

(2) In both HG periods (the post-eruption and the present), the ground temperature has not yet exceeded the boiling point of water and volcanic gas has not yet been detected. Hence, increase of the geothermal activity until now does not mean new magma intrusion to shallow zone. The post-eruption HG activity was probably caused by transfer of heat from the magma, which had been intruded and remained near and in the vent originally at the eruption, to the surrounding zone through convection of thermal water. The present HG activity may be caused by new upward intrusion of thermal water from deeper zone. Accumulation of aqueous vapor in the ground often behaves as effective pressure source to cause crustal deformation. This mechanism, however, seems unlikely in Medake, whose formation composed of much pyroclastic material seems to be permeable. In this condition, thermal expansion of the formation is considered to be rather appropriate mechanism to cause gravity variation, which results primarily from variation of the surface altitude (free-air effect) and secondarily from that of the formation density.

(3) As the relevant model, it is assumed that temperature of a particular zone in the semi-infinitive homogeneous isotropic elastic medium is raised uniformly by t, compared with the surrounding zone. A semi-infinitive vertical cylindrical column is assumed as the heated zone. Its upper surface is coincident with the media surface. The thermal expansion causes the surface upheaval and the density decrease. The solution is as follows: A vertical infinitive cylindrical column zone with radius r is set up in the infinitive homogeneous elastic medium, and is heated by t. Stresses and deformations in and outside the zone are estimated by application of known formulas. The horizontal surface (the O-surface) is set up across the center (O) of the column. We focus on the lower half side of the O-surface. Normal stress (p) exists on the O-surface. New stress (q) is added, to make total stress zero on the O-surface. Hence p+q=0, then q=-p. By this process the O-surface is converted to the free surface (=the ground surface). The O-surface is upheaved with q, which is tension. At the O-point the upheaval (h) and the corresponding gravity variation are estimated by application of known formulas.

(4) The above model was applied to the variation of gravity at the post-eruption HG period (1977) from the succeeding quiescent period (1998). The observed gravity variation was -0.25mGal at the top of Medake. The same value was obtained by assuming parameters conformable to the volcanic feature as the following; r=200m, t =130K, linear thermal expansion coefficient $=10^{-5}$ /K, density=2.5g/cm^3, Poisson's ratio=0.25. In this case, h was estimated as 0.65m. Direct application of the same method to the present geothermal activity is not appropriate because the geothermal area is shifted from the gravity observation points.

Keywords: Akita-Komagatake, volcanic monitoring, ground temperature, thermal expansion, elevation variation, gravity variation

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Repeated gravity measurement for hydrothermal monitoring beneath Aso volcano

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At the end of 2010, the water level in the Nakadake crater in Aso volcano reduced and then was followed by a small eruption in May 2011. The eruption and water level variation in the crater has strong relation to hydrothermal dynamics beneath volcano. To monitor hydrothermal dynamics, the relative gravity measurements were performed with Scintrex CG-5 (549) and LaCoste Romberg type G-1016 gravimeter at 28 benchmarks before the eruption in April 2011 and some measurements after the eruption in 2011 and 2012. It covered the area more than 60 km2 in the west side of Aso caldera. In another measurement, we installed a new microgravity network on May 2010 at seven benchmarks using A10-017 Absolute gravimeter, which we re-occupied in October 2010, and June 2011.

Gravity changes in the monitoring study clarify mass variation in the subsurface. Large residual gravity changes between the surveys are found at benchmarks around Nakadake crater and Ikeno kubo, a southwestern area from Nakadake crater. The changes between April and August 2011 significantly raise about 60 microGal near to Nakadake crater. The next period gravity monitoring from August to November 2011 shows the broad positive anomaly shifted to Ikeno kubo area. The large positive gravity variation in second period is up to 80 microGal. The opposite variation trend of previous period appears in gravity variation between November 2011 and April 2012.

The gravity changes around crater have good validation from water level variation in Nakadake crater. The water level variation of Nakadake crater is supplied from groundwater, high temperature fluid supply from depth, and precipitation. The 3D inversion models of 4-D gravity data deduce density contrast distribution beneath Aso volcano. The model of the microgravity data in short period indicates mass variation or density contrast dynamically occurred at shallow depth beneath Aso volcano. The gravity monitoring can contribute to understanding the process of eruption.

Keywords: Repeated gravity measurement, Hydrothermal dynamics, Aso volcano

SVC52-06 Room:101A Time:May 21 17:30-17:45

Modeling of Geothermal System from Gravity Monitoring at the Takigami Geothermal Field, Oita Prefecture, Japan

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In order to utilize the geothermal resources sustainably, it is necessary to monitor and recognize the behavior of geothermal reservoirs. Micro-gravity measurement is one of the serviceable methods for geothermal reservoir monitoring. Because of the underground mass change caused by the groundwater flow, the gravity change on ground surface is detected. Therefore, the gravity measurements have been introduced in the various geothermal fields. In the Takigami geothermal area, we have continued the geothermal reservoir monitoring by using Scintrex CG-3, CG-3M and CG-5 relative gravimeters since before the commencement of the Takigami geothermal power plant.

In order to estimate the gravity change caused by the mass redistribution in geothermal reservoir, it is necessary to remove the gravity change caused by the effect of the ground water flow in shallow parts. In this study, we tried to calculate a gravity response to precipitation by using G-WATER [E](Kazama et al., 2011).

We introduced an A10 absolute gravimeter (Micro-g LaCoste, Inc.) in 2008. Although it was impossible that the A10 absolute gravimeter was applied at all of the stations because the condition of the measurement was strict, we utilized the A10 gravimeter for not only the assessment of the gravity changes at the reference station, but also the detection of the absolute gravity change caused by the subsurface fluid mass changes at some other measurement stations. We chose 4 stations (T13B, T22A, T26A and T27A) to conduct the repeat absolute gravity measurement. T26A lies in the reinjection area, and there are the other 3 stations in the production area. As a result of absolute gravity measurements, the gravity change at the reference station T1 of the relative gravity measurements is small enough for this evaluation, within about 10 microgal. Therefore, we estimated that this reference station is appropriate for the relative gravity measurements.

As a result, shortly after the Takigami geothermal power plant had started power generation, a sharp gravity decrease occurred in the production area, after that, the gravity changed stably for 2 years in entire area, and then gradually decreased until 2002, and the gravity has increased since 2002. We divided the Takigami geothermal area into 3 areas from the pattern of the gravity change after the commencement of the Takigami geothermal power plant, and we estimated the 5 stages of geothermal fluid flow pattern from temporal gravity change. Based on these classifications, we led a conceptual reservoir model of the Takigami geothermal area.

Keywords: Repeat Gravity Measurement, Absolute Gravimeter, Relative Gravimeter, Takigami Geothermal Area