Japan Geoscience Union Meeting 2013
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SVC48-P01 Room:Convention Hall Time:May 19 18:15-19:30

Petrological study of main stratocone eruption products in the western field of Akita-Komagatake volcano

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Akita-Komagatake volacano is located in the Sengan geothermal field of the frontal area in the northeren part of Northeast Japan arc, and consists of amain stratocone, with a caldera in the south, and several parasitic cones at its summit. Development history of this volcano is divided into two stages by caldera collapse event occurred at about 13 ka. This volcano is characterized by predominant low-K thokeiitic magma with minor medium-K calc-alkaline magma. The low-K tholeiitic magma that formed the main stratocone show complex compositional variation trends(ex.Kobatake et al.,2012).

The aim of this study is to reveal the mechanisms which gave rise to the various temporal compositional change of the tholeiitic magmas erupted in this stage, by examining the detailed stratigraphy and petrology for the eruption products of the main stratocone.

Many tongue-shaped flow lobes of fluidal lavas are observed near the foot of the stratocone and stratified lava piles were well observed on the caldera wall at the summit area. On the bases of lithology, petrology and petrography, 24 eruption units were identified, and their stratigraphic relations were also investigated. A dormancy was inferred from a thick secondary deposit intercalated between the lava flows in the middle stratigraphic horizon.

21 of the 24 eruption products were the low-K tholeiitic series, 2 were medium-K calc-alkaline series, and the rest 1 comes just boundary between the two magma series. The tholeiitic series varies from 51 to 61 wt.%silica, and the olivine-bearing basaltic lavas with the primitive compositions of 52 and 50 to 52wt.%silica have been erupted respectively, during middle and upper horizons of the stratigraphy.

Three series of magmatic evolution sequence are definable by cyclic eruption episodes of primitive basalt magmas with subsequent eruptions of evolved magmas.

The earlier 2 sequence show typical tholeiitic trends of iron-enrichment with increasing silica, whereas the variation trend for the last sequence shows a rapid increase K2O relative to the early 2 sequence. The former is probably reconciled with the fractional crystallization from basaltic parents, whereas the latter should be strongly affected either by magma mixing K2O-rich felsic endmenber or assimilation of wall rocks.

Keywords: Akita-Komagatake volcano, tholeiitic magma, bulk-rock geochemistry, pre-caldera volcanism

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The mechanisms of cyclic sub-Plinian activity and shifting eruption style in the 2011 eruption of Shinmoe-dake

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The climactic phase of the 2011 eruption of Shinmoe-dake is characterized by sub-Plinian eruptions (Jan 26-27) and lava accumulation in the crater (Jan 28-31), both of which accompanied vulcanian eruptions (Nakada et al., in review). Referring real-time observatory data on crater image, tremor and infrasound (Ichihara et al., in review) and tilt variation (e.g. Kozono et al., in review), a geological study (Maeno et al., in review) showed three sub-Plinian events (26PM, 27AM and 27PM, the most intense phase of each lasted 2.5-1.7 hours) occurred every 12 hours with a decrease of erupted magma volume and with a constant mass discharge rate.

This study reveals evolution of conduit flow through the climactic phase, by combining, a) records in groundmass microlite and vesicle textures and b) the above-mentioned, time-resolved observatory results. Based on a petrological result (Suzuki et al., in review JVGR), we judge that variable groundmass textures among the samples reflect different conditions in syneruptive magma ascent, not different characteristics of the magma at the reservoir. Although most ejecta (gray and brown ones as to pumice clasts) are products of magma mixing that resulted from syneruptive injection of basaltic andesite magma into a silicic andesite magma reservoir, the mixed magmas were homogeneous in the reservoir owing to constant mixing ratios (SiO2 57-58 wt.%, 30vol. % phenocrysts, 960-980C, 4wt. % H2O).

The volcanological questions we would like to address after we reveal evolution of conduit flow through the climax phase are, 1) mechanisms that led to the cyclic sub-Plinian eruptions, including the triggering processes of each event, 2) timing and conditions of syneruptive magma ascent that are responsible for shifting eruption intensity and eruption style (explosive and effusive). We expect this groundmass textural study also helps us newly define a boundary between the 26PM and 27AM pumice deposits. The corresponding deposit exhibits reverse and normal gradings, as if it was generated in a single event (Maeno et al., in review; Nakada et al., in review). Regardless of that, the groundmass textures of the samples may record waxing and waning phases of conduit magma flow in each sub-Plinian event.

Keywords: Shinmoe-dake, conduit flow, sub-Plinian eruption, lava emplacement, bulk density, groundmass texture

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Chlorine content and ferric-ferrous ratio of volcanic ash emitted at Minamidake, Sakurajima in the sequence of eruption

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Decompression of magma by moving toward the surface causes exsolution of volatiles, which provides the driving force for explosive eruptions. Moreover, degassing of volatiles from magma changes its viscosity and density drastically, and these can influence violence of a volcanic eruption.

At Sakurajima volcano, recent eruptive phase at Minamidake has been sustained since October 1955. Strombolian eruptions forerun vulcanian explosions, and vulcanian explosions are often followed by continuous ash emissions, which is the typical sequence of eruptive activity. Change in the mode of its eruptive activity is drastic, which is attributed to difference in source processes affected by the state of the magma conduit including gas phase. Nogami *et al.* (2006) revealed that Cl contents in the volcanic ash emitted by strombolian eruptions are higher than those values of the other modes of eruption, and the difference in the value between vulcanian explosion and continuous ash emission is not recognizable. This previous research examined the behavior of volatile component at different phase of activity. In this study, behavior of volatile components in magma is examined through the analysis of Cl in the volcanic ash collected is the sequence of eruptive activity in 1978 and 1979.

SiO_2 contents of most ash samples fall within the narrow range between 59 and 61 in wt.%, and chemical composition of the ash samples indicates that segregation of constituent minerals rarely occurred during drifting of ash cloud. Chlorine contents in volcanic ash emitted by strombolian eruption are significantly higher than those of the ash ejeceted by vulcanian explosions and continuous ash emissions, and decrease corresponding to the change in the mode of eruption.

These results indicate that volatile-rich magma ascend to the bottom of crater and caused strombolian eruption and that the mode of eruption changes due to degassing of volatile components. Degassing process control change in the mode of eruption because chemical composition of volcanic material discharged in the sequence of the volcanic activity is almost uniform. The variation of FeO/Fe_2O_3 ratio indicates that the redox state of magma is relatively reductive at strombolian eruption and become oxidative with the change in the mode of eruption. Temporal change in FeO/Fe_2O_3 ratio of the volcanic ash synchronized with that of Cl content in magma, which may indicate that degassing of HCl affect oxidation state of magma.

Keywords: Sakurajima, volcanic ash, chlorine, ferric-ferrous ratio

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SVC48-P04 Room:Convention Hall Time:May 19 18:15-19:30

Immediate Estimations of Volcanic Plume Heights without Visual Observations at Sakurajima Volcano

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Volcanic plume heights are estimated immediately in our study even when it is invisible, for example in bad weather or at night. The eruptions at Sakurajima Volcano are classified into three types according to the amplitude of infrasonic waves. The first is irrelevant to the amplitude of infrasonic waves, which is 0-20Pa. The second is featureless and the amplitude is 20-100Pa. The last has positive correlation between volcanic plume height and the amplitude of infrasonic waves which is 100Pa-. Volcanic plume heights are calculated by (1)the highest temperature of volcanic plume,(2)wind velocity at 850hPa surface and (3)the integration value of the amplitude of seismic waves in the first case, (1)the highest temperature of volcanic plume, (2)the amount of strain changes of quadrature component to source and (3)the biggest amplitude of infrasonic waves by in the second case, (1)the biggest amplitude of infrasonic waves and (2)the amount of strain changes of parallel component to source by in the last case.

Keywords: Volcanic Plume Height, Sakurajima Volcano

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Occurrence of the Take tephra distributed in the northern flank of Kitadake, Sakurajima Volcano, Japan

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Sakurajima Volcano, which is located in the southern part of Aira caldra, is one of the most active volcanoes in Japan. This volcano consists of two main edifices: Kitadake and Minamidake, which are composed of pyroclastic rocks and lava flows of pyroxene andesite and dacite. Four historic explosive eruptions in AD 764, 1471, 1779 and 1914 produced pumice fall deposits and lave flows, and damaged extensively its surrounding area.

The Take tephra distributed on the northern flank of Kitadake. The deposit is producted by the last summit eruption of Kitadake at 4900 ^{14}C years BP. Two lithofacies were identified in the Take tephra: massive facies and stratified facies. The massive facies are composed of relatively large pyroclastic flow deposits, while the stratified facies are alternating beds of small pyroclastic flow deposits and pumice fall deposits. Some small pyroclastic flow deposits contain accretionary lapilli. The large pyroclastic flow deposits are divided into pumice flow deposits and block-and-ash deposits. Most pumice flow deposits are welded within 2.2 km from the summit crater of Kitadake.

Based on the components, the Take tephra is divided into three types. Type 1 contains abundant pumice grains. Type 2 consists mostly of lithic fragments. Type 3 includes a large amount of crystal particles. Large pumice flow deposits are characterized by Type 1. Small pyroclastic flow deposits and pumice fall deposits are classified into Type 2 and 3.

These facts suggest that the pyroclastic flow is intra-plinian flows generated by successive partial collapses of the sustained plinian eruption column. Since some pumice flow deposits are fine grained and poorly sorted, and contain accretionary lapilli, they are interpreted to be formed as a consequence of an interaction of magma and water. It is suggested that a part of pumice flow deposits in the late stage are welded, and that a partial collapse of the welded pyroclastic rocks occurred.

Keywords: eruption sequence, pyroclastic flow, Sakurajima, tephra

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Re-examination of the correlation of pyroclastic deposits similar to Shimokado pyroclastic flow deposit and Ks18 tephra

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Tephra is one of the best indicators of the history of explosive eruptions. Thus, Middle to Late Pleistocene tephrochronology provides information on regional changes of the frequency, magnitude of eruptions and magma discharge rate as a function of time in a long term. So tephra study of explosive eruptions is one of the most positive approaches to volcanic hazard mitigation.

Shimokado pyroclastic flow deposit (SMPF) erupted from a certain caldera in the southern Kyushu during the middle Pleistocene is one of the stratigraphically important key beds in the whole area of the Japanese Islands. Previous study correlated SMPF to Ks18 tephra (vitric ash fall deposit) in the Kasamori Formation of the Kazusa Group at the Boso Peninsula in central Japan. This pyroclastic flow deposit has been called by various names at each local area in southern Kyushu. In addition, correlation and identification of SMPF in southern Kyushu are controversial among previous studies. Furthermoer, Ks10 tephra above Ks18, both in the Kasamori Formation, is petrographically similar to SPMF, resulting in complication in widespread correlation of SMPF.

In this study, in order to re-examine the correlation of the Shimokado pyroclastic flow deposit between southern Kyushu and central Japan, we revealed the petrographic and chemical properties of eleven pyroclastic deposits (nine pyroclastic flow deposits and two co-ignimbrite ash fall layers), using the following four different criteria; (1) types of glass shards, (2) mineral assemblages, (3) range and modal values of the refractive indices of glass shards and phenocrysts, (4) chemical compositions of the glass shards, hornblende and orthopyroxene. However, in some cases, by the similar pyroclastic deposits of which differences are not clear in these criteria, we examined the possibility of the correlation of the Shimokado pyroclastic flow deposit, taking into account the stratigraphy and ages of these pyroclastic deposits.

The results are as follows:

1. Four pyroclastic deposits (Kuwanomaru pfl, Mikaeri tuff, Matsuyama tuff, Ks18 afa) are correlated with Shimokado pyroclastic flow deposit. These pyroclastic deposits are mostly rich in fiber and sponge types of glass shards and in agreement with their stratigraphically horizons.
2. Three pyroclastic flow deposits (Fumoto pfl, Futami B pfl, Koseda pfl) are distinguished from Shimokado pyroclastic flow deposit by the refractive indices of glass shards and phenocrysts.
3. Compared with each K2O wt% in their volcanic glass shards, Hiwaki pyroclastic flow deposit which was correlated with Shimokado pyroclastic flow deposit by previous study is clearly distinguished from Shimokado pyroclastic deposit. Volcanic glass shards in Hiwaki pyroclastic flow deposit indicate higher K2O ratio.
4. Ks18 and Ks10 which have been indiscernible are easily distinguished by variation in the chemical compositions of glass shards and hornblende.

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Characteristics of grain composition of volcanic ash from each eruptive style

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Surface phenomena of eruptive activity, such as eruptive style, eruptive rate, column height, is usually variable in an activity. For understanding the mechanism of change of surface phenomena, correlation between the time series of eruptive style and characteristics of volcanic ash as direct evidence of magma is important.

We analyzed the grain compositions, morphologies and textures, groundmass chemical compositions of ash produced by the 2011 eruptive event of Shinmoedake, Kirishima Volcano, Japan. As the result, it was estimated that the highly-vesiculated magma was ascended and erupted at both sub-plinian and vulcanian eruptions, without resident in shallow conduit. This infers that the analysis of grain composition may be useful indicator for estimating the mechanism controlling eruptive styles. For these purpose, it is important to accumulate more data. Therefore, we analyzed the grain compositions of ash deposits derived from the eruptions of Showa crater of Sakurajima Volcano (recent eruptions), Suwanosejima Volcano (sampled in 2012), and Asama Volcano (2004 eruptions).

Fresh blocky, black-colored glassy particles are contained abundantly in the products from recent eruption of Sakurajima Volcano. Highly-vesiculated fresh glassy particles are contained less than 10 %. There are no significant changes for a few years, and eruptive style does not change, too.

In addition, we correlated the grain composition of ash products from Sakurajima Volcano, sampled at five localities from proximal to distal area, for the purpose of clarifying the differences of grain composition of ashes from one eruption. There are no differences about the grain compositions of these five samples.

The ash derived from the eruption of Suwanosejima Volcano consists mainly of lithic fragments characteristically. On the other hand, about 15 % of dark brown-colored fresh glassy particles are also contained.

In the 2004 eruptive event of Asama Volcano, fresh glassy particles in the ashes decrease from the eruptions of September 1 to that of 14, while, highly-vesiculated fresh glassy particles are contained abundantly in the ash of September 16. It may correspond to the continuous activity for three days. It may infer that proportions of highly-vesiculated glassy particles concerned with eruption styles, such as duration time.

We can not recognize the positive correlation between proportion of highly-vesiculated glassy particles and height of eruption column. We will discuss about the correlation between highly-vesiculated glassy particles and dulation time and eruption mass, for example.

Keywords: volcanic ash, grain composition, Sakurajima, Suwanosejima, Asama

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Measurements of Diffuse Carbon Dioxide Flux around the Summit of Asama Volcano

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Carbon dioxide is one of the volatile species which exsolves in the early stage of magma degassing. Soil CO_2 flux measurements have been conducted at many volcanoes to understand magma degassing conditions and to catch primitive signals of volcanic activities. For example, an increase of CO_2 flux was observed as a precursor of the 2000 eruption at Usu volcano, Japan, followed by a sudden decrease in the flux (Hernandez et al., 2001). Asama volcano is one of the most active volcanoes in Japan with recent eruptions in 2004, 2008 and 2009. We here report results of the first diffuse CO_2 flux measurements at Asama volcano.

The measurements were carried out at 40 sites in the Maekake-yama crater on 26th October, 2012. The data were obtained by the accumulation chamber method using portable flux meter (West Systems, Inc.). The results showed that the soil CO_2 flux values were in the background level (<10 g m^{-2} d^{-1}) in the western half of Maekake-yama crater including western flank of Kama-yama cone. In contrast, the east side of the Kama-yama cone had the fluxes more than several tens g m^{-2} d^{-1} with the highest value of 296 g m^{-2} d^{-1}. This high soil CO_2 flux area corresponds to the shallower highest conductive subsurface zone spreading beneath the eastern flank of Kama-yama cone (Aizawa et al., 2008). They interpreted this conductive zone as a hydrothermal system. Since the high flux area does not show any fumarolic activities or thermal anomalies, vapor in the hydrothermal fluid is probably condensing at subsurface and only dry residual gases including CO_2 are emanating from the area.

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Keywords: Asama Volcano, Diffuse CO_2 Flux

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Preliminary report of wide band MT survey in the summit area of Mt. Asama, Japan

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We conducted MT and AMT surveys in the summit area of Mt. Asama in September 2012 in order to elucidate the shallow structure beneath the crater summit including its conduit. The electromagnetic measurements were performed at 27 sites, the spacing of which is as short as about several hundred meters to detect the highly resolved structure.

The AMT measurements were conducted at all the 27 sites for several hours, and MT measurements were conducted at 9 sites for several days. The five-component MT and AMT data were collected using the Phoenix MTU system and the Metronix ADU system. However only telluric measurments were carried out at some sites because the summit area is very rocky and the surface is too hard to dig halls and install large magnetic sensors.

By estimating MT impedance tensors at some sites, the following facts were found:

1) At higher frequency as several hundred Hz, the sites at eastern side of the crater show low apparent resistivity as several ohm-m, while other sites show higher apparent resistivity beyond 100 ohm-m.

2) Low resistivity parts move to the center of the summit at middle range of frequency as 1 Hz, although the data error is relatively large due to the dead band of the EM source.

3) The center and western parts of the summit show the low apparent resistivity at lower frequency as 0.01 Hz.

The preliminary results will be shown in this presentation.

Keywords: Mt. Asama, MT survey, apparent resistivity

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The temporal changes of the shallower resistivity structure associated with a small eruptions at Aso Volcano, 2011.

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On Aso volcano, central Kyushu, Japan, a small eruption was occurred on May 2011. Before and after this eruption, we carried out the electromagnetic survey around Nakadake crater of Aso volcano. From these observations, we obtained the data which suggest a decrease of the subsurface resistivity in the deeper part beneath Nakadake crater just after the eruption. In our presentation, we will show the observation data and the resistivity structure obtained by the 1-D analysis of our data.

On Aso volcano, many observations and research have been made to detect the subsurface structure and detailed information about the distribution of the subsurface hydrothermal system have been obtained from previous studies. From the high-density AMT survey, Kanda et al. (2008) found a low resistivity area is localized just beneath the Nakadake first crater. This area is considered as a chamber of the hydrothermal fluid which is formed by a part of the hydrothermal fluid which is supplied from the deeper magma. In recently, the activities of the Nakadake crater were often temporarily increased. Associated with these activities, it is expected that the distribution of the subsurface hydrothermal fluid is changed and subsurface resistivity structure is temporally changed. In order to detect such a temporal change of shallow resistivity structure according to these activities, we carried out the repeated control sourced electromagnetic survey around the Nakadake crater using ACTIVE observation system (Utada et al., 2007). In these observations, we installed electric current transmitter on 1 km NNE from the crater, and magnetic receiver was also installed on the 4 points around crater. We have performed a totally five repeated electromagnetic observation from April 2011 to April 2012 across the small eruption of May 2011.

Keywords: resistivity structure, hydrothermal system, temporal changes

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Remote temperature sensing on the fumarolic area in Aso Volcano using hydrogen isotopic compositions of plume H_2

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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 the fumarolic area in the 1^{st} crater of Mt. Naka-dake (Aso volcano) where direct measurement on fumaroles was not practical, by deducing the hydrogen isotopic composition (dD value) of fumarolic H_2 remotely from those in volcanic plume. The reciprocal of H_2 concentration in the plume samples showed a good linear relationship with the dD values. The linear relationships suggested that both the concentrations and the dD values of H_2 in the plume samples can be explained by simple mixing between two end-members, both of which can be classified to a single category at least for the dD values of H_2. By extrapolating the linear relationship between $1/H_2$ and dD to $1/H_2$=0 to exclude the contribution of the tropospheric H_2 from the dD value of each sample, we estimated that the dD value of fumarolic H_2 to be -172+-16 per mil vs. VSMOW and the apparent equilibrium temperature (AET_D) to be 868+-97 degreeC. Although the estimated temperatures using the IR thermometers were much lower than the AET_D, we concluded that the AET_D represented the highest outlet temperature of the fumaroles in Aso volcano and that the dimensions of the fumaroles at surface smaller than the pixel of the IR thermometers was responsible for the temperatures lower than the AET_D. That is to say, temporal variation in the dimensions of fumaroles at surface, probably due to variation in the emission flux of fumarolic gases, was responsible for the temporal variation in the temperature determined by the IR thermometers, while the actual outlet temperature of the Aso fumaroles keeps the temperature almost equal to the equilibrium temperature of fumarolic gases.

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

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Precise Leveling Survey in Aso Caldera(September, 2012)

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In Aso volcano, leveling survey has been conducted since 1937 by Kyoto University. As a result of these surveys, subsidence in Kusasenri about 2km west-southwest of Naka-dake crater has been observed. And this subsidence was considered to be caused by a contraction source located at about 3km west of Naka-dake crater with a depth of 4 to 6 km (Sudo et al. 2006). A seismic tomography showed a low velocity zone of a 2 to 3 km diameter located at a depth of 6km in Kusasenri (Sudo and Kong, 2001), almost in accordance with the position of contraction source. Therefore, this low velocity zone is considered to correspond to a magma chamber.

We conducted a first-order leveling survey in Aso caldera in September 2012. From the obtained survey data, we calculated the relative height change of each bench mark referred to a bench mark (AVL-1) which is located at the northern foot of central cones of Aso volcano. The calculated relative heights were compared with those of the 1998, 2003, 2004 and 2008 surveys, resulting in the relative vertical displacement at each benchmark. The resultant displacements show ground subsidence with amount of 1.5cm in the Kusasenri area in the period of 2008-2012, which is almost 60% of 2004-2008 subsidence. Deflation of the magma chamber decelerated recently suggesting increase of magma supply rate to the chamber from a deeper portion.

Keywords: Aso volcano, Caldera, Precise leveling survey, Magma chamber

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An explanation of volcano deformation during an eruption at Sakurajima Showa crater: decompression of open conduit

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It is necessary to investigate spatio-temporal changes of pressure source during the eruptions to understand the dynamics of magma flow in volcanic conduit. In this study, we numerically calculate volcano deformation due to a moving pressure source to investigate the characteristic of volcano deformation during vulcanian eruptions. We compare the results with the observed data at Showa crater of Sakurajima to understand the spatio-temporal change of magma recession.

The vulcanian eruptions are considered as follows. The explosion is triggered by a removal of a ”cap” that pressurizes magma in the conduit. The magma head propagates downward as volcanic ash ejects. As magma head falls down, normal stress applied on the conduit weakens. At the same time, the drag force generated by magma flow is applied on the conduit wall, and its reaction force works on the conduit bottom.

We calculate volcano deformation by using the 3-D boundary element method. We duplicate topography of Sakurajima by 10 m meshed DEM (GSI) and make cylindrical conduit with a radius of 15 m under Showa crater. We calculate tilt and strain on ground surface by the stress as mentioned above.

We calculate radial tilt and strain changes caused by the magma depression and drag force at the ground surfaces just above Arimura and Harutayama stations which are 2.1 km and 3.2 km respectively from the Showa crater. The initial position of the top of magma is set at 650 m altitude. We firstly explain deformation at Arimura caused by normal stress. Tilt does not change remarkably during the magma head is dropped from 650 m to 0 m. Tilt starts to subside toward the crater at about 0 m and turns to uplift at about -1300 m. Strain shows extension at the beginning and turns to contract when the magma head reaches at about -950 m. The tilt caused by the drag force and its reaction force shows uplift toward the crater, and then turns to subside when the magma head reaches at about -1300 m. The strain shows contraction at the beginning, and then turns to show extension at about -950 m. Similar changes are shown at Harutayama. These calculations indicate that recession process of magma in the conduit can be quantified by the tilt and the strain data.

We compare the calculation results with observation records of Showa crater eruption on February 6, 2008, which is reported in Iguchi (2008). The observed radial strain shows a change from extension to contraction about 10 min after the start of eruption. The calculation indicates that the magma head downed to -950 to -1150 m at that time.

When the magma head becomes deeper than -2000 m, the tilt caused by normal stress shows uplift toward the crater, while such a change is not observed. This fact suggests that the eruption stopped at the depth shallower than -2000 m or that another deflation source exists at a deeper portion.

The observed uplift toward the recorded just after the start of the eruption may be explained by upward drag force due to magma ascent at shallower part of the conduit.

Keywords: volcano deformation, Sakurajima, open conduit

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Study of magma accumulation and supply processes based on ground deformation at Sakurajima volcano from 1998 to 2005

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Sakurajima is an active volcano located at the southern edge of Aira caldera. Vertical ground deformation of Sakurajima and Aira caldera during summit eruption activity from 1955 has been mainly detected by precious leveling. The vertical ground deformation has been related to the eruptive activity. The ground has been uplifting since 1946. The uplifting of ground stopped and had showed subsidence since 1974 when number of volcanic eruption began to increase. The subsidence pattern has been modeled with the 2 spherical pressure sources at the center of the Aira caldera (about 10km depth) and at beneath the summit crater (about 5km depth) (e.g. Eto and Nakamura, 1986; Eto, 1989). In contrast, the ground around the Aira caldera turned to uplift since 1993 and eruptive activity decreased except temporal increase in eruptions in 1999. Eruptive activity was shifted to Showa crater in June 2006. In this study, we analyzed GPS data to make clear process of magma accumulation and movement prior to eruptive activity at the summit crater in December 1999 and eruptive activity at Showa crater in June 2006.

GPS data observed by SVO (Sakurajima Volcano Observatory) and GEONET data during 1998-2005 were analyzed. The stations are distributed within about 30 km from Sakurajima. Variable deformation rates are found by the continuous GPS observation. In the periods of small deformation rate from January to December 1998 (phase A) and from September 1999 to November 2004 (phase C), we obtained pressure source at depths 9.6-9.7 km near the center of Aira caldera by assuming a spherical source. By contrast, in the periods of large deformation rate from December 1998 to September 1999 (phase B) and from November 2004 to March 2005 (phase D), we obtained the depths of pressure sources at depths 6-7 km, which were shallower than sources in the periods of small deformation rate. In the periods of small deformation rate (phases A and C), magma was thought to be accumulated to the magma reservoir at the center of Aira caldera. On the other hand, the periods of large deformation rate (phases B and D), pressure source migrated to shallower place. Those periods preceded the eruptive activities at the summit crater in 1999 and beginning of the eruption of the Showa crater from 2006. It is suggested that magma moved to relatively shallow place in those periods.

Volume change rates of the sources in phases A, B, and D were estimated to be $0.95*10^7$ m^3/year, which was close to average magma supply rate at Sakurajima ($1*10^7$ m^3/year). On the other hand, in phase C when the eruptive activity declined after eruptive activity in 1999, volume change rates of the source was estimated to be $0.5*10^7$ m^3/year which was about half of other phases. Increase in eruptive activity may be related to accumulate rate of magma.

Keywords: Sakurajima volcano, Aira caldera, ground deformation, GPS, precious leveling, Mogi's model

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Velocity structure beneath the Aira caldera in southern Kyushu

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Associated with the Philippine Sea plate subduction, a nearly straight chain of active Quaternary volcanism runs almost parallel to Nankai Trough in the central part of southern Kyushu. In this region, there are four large calderas: the Kakuto, the Aira, the Ata and the Kikai calderas.

We applied the tomography method with a fine grid configuration to the P- and S-wave arrival times of 829 local earthquakes well observed at 101 stations in central and southern Kyushu, and revealed the detailed three-dimensional seismic velocity structure of the crust, especially the region beneath the Aira caldera.

In a shallow range from 0 to 10 km depth, low velocity zones (LVZs) are found in the eastern part of Kyushu, where basement rocks are made up of uplifted sedimentary marine terraces (Nakada et al., 2002). The LVZs are also distributed along the volcanic front between Kirishima volcano to Kaimon volcano. Meanwhile, the hypocenters occurred in the inland area are obviously concentrated in regions with a relatively higher velocity and a low Poisson's ratio at a depth of 10 km.

At 20 km depth, the most interesting feature is that a distinctly high Poisson's ratio zone is located exactly beneath the Aira caldera. This compacted zone also extends southward and connects the Aira caldera with the Ata caldera.

At 30 km depth, a small zone with high Poisson's ratio appears to remain beneath the Aira caldera. This small zone is assumed to be a portion of the distinctly high zone at 20 km depth. We also found that the velocity distribution in the western region (Satsuma Peninsula) is quite different from that in the eastern region (Ohsumi Peninsula): the western region is characterized by high P- and S-wave velocities, while the eastern region is characterized by the low velocities.

The anomaly with a very high Poisson's ratio at 20 km depth beneath the Aira caldera possibly suggests the presence of partial melts and the source of volcanism in the area. It is also found that LF earthquakes occur in the lower crust in and around the Aira caldera. A deeper part of the focal zone of these LF earthquakes appears to overlap the high Poisson's ratio zone observed at 30 km depth. These facts lead us to postulate that magma penetrating into the crust from the upper-most mantle may construct the high Poisson's ratio zone at about 30 km depth, and move upwards through the LF focal zone, and finally be stored at about 20 km depth.

Ishihara (1990) described the magma supply system of Sakurajima volcano wherein one magma reservoir is located at about 4 km depth just beneath Sakurajima volcano and another at 8 to 10 km depth beneath the Aira caldera. Although space resolution in our tomography is insufficient to distinguish these magma reservoirs in the upper-most crust, our result puts forward a possibility of the deeper magma reservoir supplying two shallow magma reservoirs previously found.

Keywords: Aira caldera, Sakurajima, Velocity structure

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Active monitoring by using ACROSS in Sakurajima volcano - observation report 2 -

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In March, 2012, we installed the ACROSS (Accurately Controlled Routinely Operated Signal System) composed of two vibrators at the western foot of active Sakurajima volcano (Yamaoka et al., 2012).

The first test operation was carried out during a period from June 12th from September 17th, 2012. The objectives of this operation were to construct the remote monitoring and control manipulation system, and to ascertain whether the seismic stations, belonging to JMA, Hinet, Kyoto Univ. and Kagoshima Univ., located in and around Sakurajima volcano could detect the ACROSS signals. We configured one vibrator with a constant signal frequency of 10.01Hz and the other with a signal frequency range of 12.50Hz +/- 2.50Hz in a linear sweep interval of 50 sec. We found that the signals successfully propagated through the volcanic area: the transfer functions at the seismic stations located in Sakurajima island can be clearly estimated by stacking seismic data during three to five days. On the other hand, the stations around the Aira caldera need to the seven days stacked data to obtain the transfer functions.

On September 19th, we have started the second test operation under synchronized control of two vibrators: one vibrator with a signal frequency range of 7.510Hz +/- 2.50Hz and the other with the range of 12.505Hz +/- 2.50Hz. We also deployed four temporary seismic stations so as to surround the summits of Sakurajima volcano. Our purposes in this operation were to estimate a transfer function in a wide signal range from 5Hz to 15Hz at each station, and to detect temporal change of the function.

At first, we estimated the daily transfer functions for each station by every 5 days stacked data during a whole period of the operation. We simply calculate the mean transfer function for each station from the estimated daily transfer functions, and evaluated the difference (DTF) between the mean transfer function and the daily transfer functions. The DTF in the early part of the daily transfer function, which is corresponding to P wave arrivals, is found to be generally small. On the other hand, the DTF in the later phases is large. We also found that the DFT at some stations clearly and temporally changes. We supposed that the phases with a large DTF possibly indicate the temporal change of the transfer function. To verify the temporal change, we evaluated the travel time change of the phases with a large DTF by applying the cross-correlation procedure. In the presentation, we will report the observation results in detail.

Keywords: Sakurajima, ACROSS, volcano, transfer function

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Precursory eruptions of the 2011 Shinmoedake eruptions, Kirishima volcanoes

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It is important for us to have knowledge of what takes place in the pre-eruption stage of plinian or sub-plinian eruptions on the surface. We also need such information for hazard maps and the forecasting of eruptions in which new vents are opened. We therefore consider the vent position and small precursory eruptions of the 2011 Shinmoedake eruption. Sub-plinian eruptions occurred without a prior distinct increase in earthquakes or land deformations from January 26 to 27, 2011 at Shinmoedake volcano. Therefore, we need to know how to quickly evaluate unusual preliminary phenomena and eruptions for the forecasting for sub-plinian eruptions.

We were able to take fresh ashfall samples generated by the January 19, 2011 eruption, which occurred just 7 days before the January 26 to 27 sub-plinian eruptions. The ashfall deposit was characterized by a low bulk depositional density, with an increase in absorbed water and very fine grains. It is important information of bulk density of deposit meaning fragmentation degree and absorbed water content meaning alterd fragments content for earlier signal of plinian and sub-plinian hazard information in addition. We must search carefully for likely signs of the January 19 ashfall, because we did not find an increase in earthquakes or preliminary signals of the sub-plinian eruption on January 26. For this reason, we need both summaries and detailed discussion of information regarding such precursory or unplugged ashfalls that follow plinian or sub-plinian eruptions, as provided by geological and paleographical surveys in the world. In addition, we need to develop tools or methods to help in the identification of deposit characteristics, e.g., thickness, bulk density, grain size, etc.

Keywords: Kirishima volcanoes, Shinmoedake, 2011, Precursory eruption, ashfall, bulk density

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Three-dimensional seismic velocity structure of the upper crust beneath Kirishima Volcanoes

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Sub-Plinian and successive Vulcanian eruptions of Shinmoe-dake, Kirishima Volcanoes, started at January 2011. Before the eruptions, inflation of the volcano edifice had been observed by GPS monitoring network (GEONET of GJI). Combining the data of GEONET and temporal GPS observations, Nakao et al. (2012, submitted) located a pressure source (Mogi model) at 10km depth beneath northwestern part of the volcanoes (5km northwest of the Shinmoe-dake crater) for the period of magma accumulating process before the eruptions. Several previous studies used artificial explosive sources and natural earthquakes to obtain seismic velocity structures of the volcanoes. Except Yamamoto and Ida (1994), these studies solved velocity distributions limited in the shallow depth ranges from surface to about 3-5km depth (e.g., Tomatsu et al., 2001). Assuming incidence of plane P waves from regional hypocenters and dividing a target volume into blocks of constant velocity, Yamamoto and Ida (1994) calculated P-wave velocity perturbations on each block. The remaining studies did not map the velocity distributions deeper than about 5km depth by limitations of ray paths. The aims of the present research are to show three dimensional P- and S-wave velocity models below 5km to 15km depth derived from data of local earthquakes and to discuss the obtained seismic velocity structure and relation to the pressure source.

Nansei-Toko Observatory for Earthquakes and Volcanoes, Kagoshima University (NOEV) has recorded seismic data observed at seismic stations of Kagoshima Univ., Kyushu Univ., JMA, and NEID in and around southern part of Kyushu, southwest of Japan. 305 earthquakes with 15,221 P phases and 13,649 S phases recorded by 67 seismic stations during the period from 2001 to 2012 were selected to perform this analysis. In the 3-D inversion, we applied methods of grid model (Thurber, 1983), ray tracing with Pseudo-bending (Um and Thurber, 1987), Parameter separation (Pavlis and Booker, 1980), and Damped Least Squares (Aki and Lee, 1976). Damping factor (0.01) was set through the inversions after the performing several quantitative experiments using grid models and observed data. Examining different grid models, the spatial resolution for the velocity model was estimated about 5km horizontally. We also referenced results of checkerboard tests and diagonal elements of resolution matrix (DERMs) to delineate velocity models of only areas where the relative reliable velocity distributions seemed to be obtained. Consequently, we only show the velocities where the interpolated DERMs were larger than or equal to 0.8.

As a result of the 3-D inversions, we obtained reliable P- and S-wave velocities at the depth range of 5-15km beneath the area in and around the volcanoes. Because few seismic stations locate on the volcanoes, seismic ray paths passing through in the shallow part of the volcanoes were limited. Characteristics of the velocity structure at 10km depth are summarized as follows: (1) relative high P-wave velocities (high-Vp, 6.8-7.0km/s) distributed widely beneath the northwest, southwest, and southeast flanks of the volcanoes. The increases of Vp were 10-13%, (2) relative low P-wave velocities (low-Vp, 5.3-5.5km/s) areas, 11-15% decreases, were delineated beneath the whole areas of the volcano edifices, (3) an obvious low S-wave velocity (low-Vs, 2.7-3.2km/s) area, 10-26% decrease, located beneath the northwestern part of the volcanoes. The values of Vp/Vs for the characteristic low P- and S-velocity area were 1.9-2.1 (high-Vp/Vs). The obvious low velocity area contains the pressure source (Nakao et al., 2012, submitted). These features, low-Vp, low-Vs, high-Vp/Vs, and containing the location of the pressure source before the eruptions suggest that a significant volume of magma accumulation existed at the low velocity area and its environs.

Keywords: Kirishima Volcanoes, Seismic velocity structure

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Estimation of magma chamber related to the 2011 eruption of Shinmoedake volcano, Japan

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The estimation of location and geometry of a magma chamber is essential for understanding characteristics of volcanic activities including possible aspects for the future. Previous studies show that t here is a strong relationship between the movement of magma and the surface displacement (Dzurisin, 2006). Basically, when magma injection into the magma chamber causes the pressure increase at the depth, corresponding surface bulge can be observed. The surface area sinks as magma removes from the chamber. In this study, we analyzed GPS data and estimated the magma chamber related to the 2011 eruption at Shinmoedake volcano of the Kirishima volcano group in southwest Japan.

Shinmoedake volcano is one of the most active volcanoes in Japan and started to erupt in January 2011 after long-lasting earthquake swarms which occurred directly beneath the volcano. Prior to the eruption, an extending trend in displacement was observed between Ebino and Makizono from September 2010. After several explosions in February 2011, small-scale eruptions occurred intermittently till September 2011. (JMA report, 2011) There was no eruption in 2012, although the seismic activities continued. (JMA report, 2012)

The data used in this study were GEONET GPS displacement data provided by Geospatial Information Authority of Japan (GSI) from 2003 to 2012 around Shimoedake volcano. The GEONET is a permanent observation station network established for crustal deformation observations. These stations were installed with spacing of approximately 25-30km. In this study, we mainly used nine observation points around Shinmoedake volcano for our analyses. In addition to that, we included southern points from the volcano in order to evaluate ground deformation signals from Sakurajima volcano, which is another active volcano located about 40 km southwest of Shinmoedake volcano. We divided 2003-2012 into five separate terms so as to examine the variations of displacements and calculated possible magma chamber models for each term. The results showed that displacement changes may be explained by a combination of a spherical pressure source and a tensile fault with northwest trend.

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Continuous GPS observation in snow season with a hand-made radome at Mt. Meakan-dake

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Semi-continuous GPS observations were started at the northern flank (FPS), at the northeastern flank (HKT) and at the eastern flank (SMZ) of Mt. Meakna-dake in July 2011 and ended in November 2011. At the eastern part of Mt. Tokachi-dake, same GPS observations were made at two points between August and October, 2011. Those results were shown in the 2012 JpGU meeting. We use Trimble 5700 receivers and Zephyr Geodetic antennas at every station.

In May 2012, we started the observations at Mt. Meakan-dake and ended in November. There is the same seasonal change of coordinates in the both year. We cannot find the difference due to volcanic deformations. Because our observations are carried out only in no snow season, it is difficult to study the seasonal change strictly.

We try to make the observation at SMZ in snow season for the investigations of the seasonal change. There was the relatively less snow at SMZ than at the other two stations of Mt. Meakan-dake. It is thought that the antenna at SMZ will not be buried with snow. The antenna at SMZ installed in a radome. Data in every second are recorded in a 2GB CF card. An amount of data in a day is less than 14MB. It is able to store GPS data until the middle of April

For this observation, a 45cm diameter radome was made. It has a hemispherical dome and a circular sole, which are made of three millimeter thick acrylic acid resin. An Antenna with a tribrack installed in a radome. It is very hard to approach to SMZ in winter. Therefore, we made the other same dome and make observations at Hokkaido University campus in Sapporo city at the same time, for clarifying the observation condition in the snow season.

In the presentation, the results of observations through one year at SMZ will be shown and the effect of snow will be discussed.

Keywords: GPS, Mt. Meakan-dake, continuous observation, snow

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Crustal deformation of Miyakejima volcano, Japan since the eruption of 2000 using dense GPS campaign observation

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Miyakejima Island is an active volcanic Island located about 175 km south from Tokyo, Japan. Miyakejima volcano has had at least 15 historical eruptions and erupted about every 20 years in the past 100 years. The latest eruptive activities began in 2000. These activities included forming a caldera for the first time in 2500 years and gigantic volcanic gas emission that forced islander to evacuate over four and half years. This style was different from the style of the last 100 years.

A dense GPS observation campaign had begun at Miyakejima volcano in cooperation with the University of Tokyo, Kyushu University, and Nagoya University in 1995. At the eruption in 2000, the state of the magma intrusion was captured in detail from the observed displacement. However, this campaign observation had stopped from 2002 to 2010 because of the landing restrictions to the island due to the large amount of volcanic gas emission. We rebuilt the dense GPS network and restarted the campaign observation from 2011. In this study, we examined the magma-supplying system under Miyakejima volcano by means of GPS observations to get insights about the future activity of Miyakejima volcano.

We used the data of our campaign observation of 2011 and 2012 recorded by 45 stations, and the data of four GEONET sites of Geospatial Information Authority of Japan (GSI) in this analysis. The observation data were analyzed by RTKLIB (Takasu et al., 2007) using GPS precise ephemeris from IGS. We estimated the crustal deformation of Miyakejima from 2011 to 2012 from the obtained coordinate values, and calculated the position and volume of spherical source using the software named Magnetic and Geodetic data Computer Analysis Program for Volcano (MaGCAP-V). The result showed there was the small inflation source at a depth of about 3 km beneath Mt. Oyama, which is the central cone of Miyakejima volcano. From this result, we can say Miyakejima have the possibility that the magma supply to the magma chamber leading to the next eruption has begun. We will carry out the observation this year and examine whether the expansion trend continues or not.

Keywords: Miyakejima, GPS, Crustal Deformation

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A study on the oscillation of finite-length fluid-filled cracks

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To explain the observed properties of volcanic seismic signals, various models including resonator models with various geometries and flow induced oscillations have been proposed. Among these, one of the most standard source models of long-period events may be the fluid-filled crack model (e.g., Chouet, 1986). Chouet and his co-workers' studies demonstrated that many of the observed characteristics of long-period events can be well explained by the model. Furthermore, the possibilities to estimate the properties of fluid inside the crack and their temporal change from the observed seismic signals have also been discussed (e.g., Kumagai and Chouet, 2000). However, so far, the oscillation of finite-length fluid-filled cracks has been studied only by numerical methods like the finite-difference method (e.g., Chouet, 1986), the boundary integral method (Yamamoto and Kawakatsu, 2008), and the finite element method (Frechner et al., 2008), while analytical solutions for an infinite-length crack (e.g., Krauklis, 1962, Ferrazzini and Aki, 1987) and a 2-D ellipsoid (Yamamoto, 2007) have been derived. In this study, by feeding back the implications from numerical modeling into analytical consideration, we propose a simple method to obtain an approximate solution for the dynamics of finite-length fluid-filled cracks.

In this study, we consider a thin finite-length crack embedded in a 2-D infinite elastic medium. The crack is filled with an inviscid fluid, and the thickness of the fluid-filled crack is assumed to be much smaller than its length. Under the assumption, the motion of fluid inside the crack can be treated as one-dimensional one, and the distribution of normal dislocation of the crack surface can be well expressed by a series of Chebychev polynomials of the second kind with a weight depending on the position along the crack. Here, it is noted that among the series of polynomials, only the polynomials of low-degree are sufficient to expand the low-order modes of crack oscillation as demonstrated by Yamamoto and Kawakatsu (2008). The fact corresponds to the result of Spence and Turcotte (1985), who showed that the static normal dislocations due to uniform and linearly-varying changes in fluid pressure are expressed by the zeroth- and first-degree Chebychev polynomials, respectively. On the other hand, once we have an expression for distribution of the normal dislocation, we can analytically compute the motion of the fluid. In addition, using the obtained fluid motion in normal and along-crack directions, we can compute the effective bulk modulus of the fluid using the method of Yamamura (1997) and corresponding eigen oscillation of the fluid-filled crack.

For the fundamental mode of the oscillation of a fluid-filled crack, we can evaluate the effective bulk modulus using only the first-degree Chebychev polynomial, because the contribution of the first-degree polynomial to the dislocation distribution is about one order larger than those of higher-degree ones. The resultant effective bulk modulus is about half of that of the fluid, and the result is consistent with an empirical fact that the crack wave velocity corresponding to the fundamental mode is about half of the acoustic velocity of the fluid as pointed by the previous studies. For the higher modes, it is rather difficult to directly apply this method. However, considering that the crack wave velocity approaches to the fluid velocity in the limit of short wavelength, we can make a rough estimate from the result for the fundamental mode.

These results help us in understanding the physical basis of known empirical facts about the characteristics of dynamics of fluid-filled cracks, and at the same time, provide us an alternative efficient method to analyze observed volcanic seismic signals.

Keywords: fluid-filled crack, fluid-solid interaction, long-period event

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Detailed hypocenter distribution of the 2013 swarm activity in Hakone volcano

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Hakone volcano is located at the northern part of the Izu-Mariana volcanic arc in central Japan. Within the caldera of Hakone volcano, fumarolic activity has been observed around the Owakidani area. Many intense earthquake swarms have been reported. Recently, remarkable earthquake swarms were observed in 2001, 2006 and 2008-2009. Accompanying the 2001 activity, crustal deformation was detected by the tiltmeters and GNSS stations net-work (Daita et al., 2009). After the swarm activity in 2001, new fumarolic area emerged at the northern slope of the Owakidani area (Tanada, 2005). Since January 2013, the seismicity in Hakone volcano has been again activated. Synchronizing with the seismic activity, crustal deformation has been detected by the tiltmeters and GNSS stations net-work. To determine highly resolved hypocenter distribution is important to discuss mechanism of swarm earthquakes, and to clarify relationship between the swarm activity and the crustal deformation. We applied the Double-Difference method (Waldhauser and Ellsworth, 2000) to relocate the hypocenters of the swarm earthquakes using the data of the differential arrival time obtained by both manual picking and waveform cross-correlation analysis. We will present detailed characteristics of hypocenter distribution in this currently developing swarm activity.

Keywords: Swarm earthquake, Hakone volcano, Hypocenter distribution

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Geothermal activity around Owakudani at Hakone volcano: Recent growth and migrations of new vigorous steaming grounds

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Owakudani is located in the north side of the central cone at Hakone volcano, and its fumarolic activity is active. In this area, a fumarolic activity is active and the steam is rising from surface. The great earthquake swarm activity at Hakone volcano has been occurred from June, 2001. After this event, a fumarolic area crosses the ridge of Owakudani and the steam is found also along the northern side of Owakudani.

In some places, the tree has withered and broken down at the newly generated fumarolic area. Although the new fumarolic area was spread from Owakudani to Kamiyuba until 2010, it activated after 2011 on the western side. Even now, it is growth or migrations in the new fumarolic region.

We observed ground surface temperature using infrared thermal camera. We discuss about the relationship between the change of surface condition and geothermal field, and the earthquake swarm activities in Hakone volcano.

Keywords: Hakone volcano, streaming ground, infrared thermal camera observation, ground surface temperature, geothermal field, surface condition

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Crustal Deformation According to Earthquake Swarm Activities and Estimation of the Volcanic Deformation Source at Hakone

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The seismicity in Hakone volcano, central Japan, has been gradually activated since the beginning of January, 2013. The hypocenters of the earthquakes are mainly distributed in the shallow region beneath the central cone of caldera. In synchronization with this seismic activity, tilt changes were detected by the tiltmeter in and around the caldera of Hakone volcano. It is hypothesized that the crustal deformation was caused by pressure from a Mogi point source at a deep part, and a shallow open crack in the caldera. We will present the characteristic of the seismic activity and the source models for crustal deformation associated with this activity.

Keywords: Hakone Volcano, tiltmeter

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Three-dimensional electrical resistivity structure around Hakone volcano, Japan

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Seismicity around the Hakone volcano was activated just after the arrival of surface waves caused by the 2011 off the Pacific coast of Tohoku Earthquake. Most of these triggered earthquakes had similar distribution to prior occasional swarm activities. In order to image electrical properties around such seismic events, we carried out audio-frequency magnetotelluric (AMT) measurements at 39 sites in December 2011 (Yoshimura et al., 2012). The spatial distribution of the induction vectors and the phase tensor ellipses suggests that conductive bodies may lie beneath the remarkable regions around which the seismicity increased abruptly just after the occurrence of the Tohoku Earthquake.

In this study, we conducted 3D modeling of dense AMT/MT data (Yoshimura et al., 2012; Ogawa et al., 2012), to figure out electrical characteristics around the triggered seismicity. The full components the impedance tensors at 51 sites in total were inverted using the code developed by Siripunvaraporn et al. [2005]. Significant characteristics of the obtained three-dimensional resistivity model are: (1) the most of the triggered earthquakes, which occurred shallower than a depth of 4km, seem to align along resistivity structural boundaries; (2) surface conductive blocks, in which there were very few earthquakes, were observed beneath not only fumarolic areas but geothermal non-active regions.

Keywords: magnetotellurics, three-dimensional inversion, resistivity structure, Hakone volcano, triggered earthquake, earthquake swarm

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Estimation of magma migration in the initial phase of the 2000 Miyakejima eruption (1)

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1. Introduction

In the case of the Miyakejima eruption in 2000, it is confirmed that the large scale dyke intruded from the observations that hypocenter migrate from in the area of Miyakejima to Kozushima and Niijima between June 27. 2000 and July 1. 2000 as well as large ground inflation is measured by nation-wide GPS network. Several dyke intrusion models have been supposed in previous studies, but the detail process in this event has not been unsolved because hypocenter locations cannot be estimated precisely. Hypocenter migration is one of the most important information on magma migration, but is not well determined in this case, because the seismic stations are located in islands where are apart from hypocenter area. It is needed to relocate the hypocenters for improving the insight on the dyke intrusion process.

In this study, we try to relocate hypocenters occurring during June 28 ? July 1 (hereafter, target earthquakes) using the cross correlation (hereafter, CC). After the large scale dyke intrusion concluded, ocean bottom seismometers(OBSs) were installed just above the hypocenters area on July 2. Using OBSs data, the precision in hypocenter was improved very well. We try to relocate the hypocenters of the target earthquakes using waveform similarity with earthquakes (hereafter, reference earthquakes) whose hypocenters are well estimated by OBSs. From above analysis, we try to get more information of large scale dyke intrusion.

2. Data and analysis

We chose 6695 earthquakes for target earthquakes. Hypocentral migration in this period covers the main part of the area of the dyke intrusion from conventional analysis. We checked waveform similarity of the target earthquakes with the reference earthquakes. We used 1-8Hz band pass filtered waveforms of P wave onsets. We calculated CC of June 28-29 with 144 reference earthquakes firstly.

3. Results

Now, we have calculated CC and found out the pairs earthquakes with similar waveform among the target earthquakes and the reference earthquakes. Following results are revealed.

(1)The waveforms of 2110 earthquakes from whole located earthquakes occurring on June 28-29 (2886) have high CC with reference earthquakes. It demonstrates that we can relocate the many hypocenters during the large scale dyke intrusion using waveform correlation.

(2) Many earthquakes during the large scale magma intrusion have similar waveforms with those of a part of reference earthquakes (hereafter, core events) whose hypocenters are closely located at the midpoint between Miyakejima and Kozushima at depth of 8-13km. Seismic activity of the reference earthquakes is characterized by burst-type activity with upward migration. Among the reference earthquakes, the core events are located at the initial point of burst type activity. It may suggest that earthquake generating process such as localized pressurization continues during whole process of the large scale dyke intrusion. Further analysis is required to reveal the detailed process.

(3)The earthquakes which have good correlation with the reference earthquakes occurring in the area of around Kozushima started at 07:00 on June. 28 and there is no such earthquake before the time. This does not contradict the results of precious researches that showed hypocenters migrate northwestward.

4. Future study

We found the good correlation in waveforms of the events of June 28-29 with reference earthquakes, and hereafter we will relocate hypocenters of target earthquakes using CC. In addition, we will read onset of OBSs data which have not been analyzed yet and increase reference earthquakes to analyze waveform correlation. Thus, our last goal is to relocate precise hypocenters precisely and investigate the dyke intrusion in the initial phase of 2000 Miyakejima eruption.

Keywords: Miyakejima volcano, earthquake family, dike intrusion, the 2000 Miyakejima eruption, hypocentral migration

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The volcanic activity monitoring with the concentrated observation in Izu-Oshima Island

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Izu-Oshima Island is one of 110 active volcanoes which exist in Japan and is given status as the volcano where needs suitable monitoring system for volcanic disaster prevention. The cycle of middle-scale eruption is about 30-40 years on and after twentieth century. The last eruption in this volcano occurred in 1986 and about 30 years passed. So we have to prepare for next eruption.

Geospatial Information Authority of Japan is monitoring volcanic crustal movement by 6 GNSS monitoring points including GNSS-based Control Station. We have installed the automated distance and angle surveying system (Total Station) around the caldera in 2002 and have been monitoring the movement.

In 2012 we conducted the concentrated observation that is leveling and gravity survey addition to usual monitoring. The leveling that survey both bench marks and temporary points allows us to the following vertical movement. That movement has high space density and accuracy. By comparing with result in 2008, we could find the elevated area in caldera and the downward area at northeast and southwest part of the Island. In addition, it conducted gravity survey on bench marks in caldera, GNSS-based Control Stations and absolute gravity points in circumference of Island. In consequence of comparing with gravity value at 2008, it trend to increase the value of points around a crater of summit, MOTOMACHI port in west side of island and HABU port in south side, on the other hand, to decrease it at east and north side in the outer rim of a crater, and north side of island.We will report the review and a comprehensive consideration for their results.

Keywords: Izu-Oshima Island, GNSS Earth Observation, Leveling survey, Gravity survey, Automated distance and angle survey

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Geometry of pressure source beneath Izu-Oshima inferred from vertical component of volcanic deformation

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In Izu-Oshima Volcano GPS observation of volcanic deformation has been conducted since 1990s, and it is suggested that the volcano is continuously inflated in long-term. Onizawa el al.(2012) investigated intensively on the long-term change of the deformation by the GPS displacement data, picking up observation points which had no data gap caused by replacement of the GPS antenna. Analyzing the three component displacement of the long-term change using the Mogi model with altitude correction, a pressure source was estimated located beneath the northern part of the summit caldera at depth of 6.68km. We carried out further research on the deformation and on the source.

The displacement at each station, depending on the horizontal distance from the source, has following features: for horizontal component, the displacements by the observation and by the calculation using the Mogi model are similar to each other; for vertical component, the observed and calculated values are rather different, that is, the vertical displacement (uplift) is largest at 0km distance by the calculation, though the observed uplift has no clear dependence on the distance from 0km to 5km, exactly speaking, the uplift at 0km distance is a little smaller than at 2 or 3km. The observed long-term displacement in Izu-Oshima cannot be fully explained by the Mogi model especially for the vertical component in the summit area, namely the observed uplift is smaller than expected.

The difference can be caused by some factors such as topography of volcano, underground structure and a pressure source of not simple shape, all those are not accounted in Mogi model. In order to understand the long-term deformation in Izu-Oshima precisely, it is necessary to consider these factors to analyze the displacement. In our investigation finite element models with various shapes of the deformation source were utilized, assuming axisymmetric structure and topography. The source has a prolate spheroidal shape elongated vertically with aspect ratio from 1.0 to 4.0 as a parameter. The source depth, the other parameter, was in a range from 3.0km to 8.0km. The finite element analysis was carried out with all combinations of parameters to solve the horizontal and vertical displacements on the surface.

Searching in the parameter space, we found that calculated value was most similar to the observation when the source depth was about 4km and the aspect ratio was larger than 3. The uplift around the summit, that was a little less than in the surrounding area, was realized by the model. Compared with the case of the Mogi model, the source depth was quite shallow and the change of source volume was about a half. A calculation on a finite element model with the uniform structure implied that the shape of the source had larger contribution to the feature of deformation than the underground structure.

Keywords: volcano, Izu-Oshima, crustal deformation, finite element analysis

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Seismic activity beneath the Hakusan Volcano in Oct. 2012 and Jan.-Feb. 2013

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No volcanic activities have not observed since the 1659 eruption except the appearance of a blowhole in 1935. It is, however, pointed that the Hakusan volcano may reactivate its volcanic activity on the near future from studies of past activities based on tephra stratigraphy and historical records (Moriya, 2000). The seismogenic zone just beneath the Hakusan volcano is shallow, 0˜1 km (Takahashi et al., 2003), and a low velocity and high Vp/Vs region exists in the depth of 10˜14 km beneath the volcano (Takahashi et al., 2004). Four swarm activities and the largest event of Mj4.5 for recent 30 years were observed in 2005 beneath the volcano. We observed swarm activities in 2008 and 2009. We report here recent seismic activity, seismic activity in Oct. 2012 and Jan.-Feb 2013, beneath the Hakusan volcano.

We use the velocity structure of Takeuchi (1978) and the formula of magnitude of Watanabe (1971) in this study. For seismic events in Oct. 2012, most of the events are distributed 1 km off north from the summit and the hypocentral depths are 0-1.5 km. We estimate fault plane solutions using the polarity of P-waves for larger six events. Five events show strike-slip types with the compression axes of E-W and NW-SE while one event normal type with the extension axis of NW-SE. Seismic events in Jan.-Feb 2013 are characterized by two events as mainshock over M3, which has never observed since 2005. The hypocenters are distributed 0.5 km off east from the summit and 1-2 km in depth. The largest five events show strike-slip types with the compression axes of E-W and NW-SE, which are coincident with the regional stress field. We observe no volcanic tremors and low frequency events through the analysis period. These facts suggest that these seismic activities do not relate to the magmatic activity beneath the Hakusan volcano.

Keywords: Hakusan, swarm earthquakes

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Automatic hypocenter determination of deep low-frequency earthquake beneath Mt. Asama volcano

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1.Introduction

Deep low-frequency (DLF) earthquakes beneath active volcanoes are considered to occur related to magma activity in the deeper part and studied since 1980's. But since their relationship with surface phenomena such as eruptions seems not to be so clear unlike that of shallow volcanic earthquakes, accumulation of analysis of DLF earthquakes is not enough. For the further accumulation of analysis, it is very important to detect more DLF earthquakes. Japan Meteorological Agency (JMA) monitors seismic activity with Earthquake Phenomena Observation System (EPOS) using data from seismic observation points operated by JMA, universities, National Research Institute for Earth Science and Disaster Prevention (NIED) and other related organs and make the seismological catalogue of the JMA. In the catalogue, "low-frequency" flags are appended to earthquakes occurred at 10km depth or deeper. LFE earthquakes can be distinguished from other earthquakes by them. But, data of seismometers which are operated in volcanic areas is not used in this process. On the other hand, these seismometers are used mainly to monitor shallow volcanic earthquakes. Hence for monitoring of LFE earthquakes, data of seismometers in volcanic areas is not considered. Then we tried to improve detecting power of LFE earthquakes by using data of them.

2.Analysis

We examined LFE earthquakes occurred beneath Mt. Asama, one of the most active volcanoes in Japan. We use waveform data obtained at 12 observation points on the volcanic body operated by JMA (10 points) and NIED (2 points). We also used waveform data from 7 points of High Sensitivity Seismograph Network (Hi-net) operated by NIED near Mt. Asama.

We made a program for automatic detection and hypocenter determination. We used modified energy ratio (MER) method (Hang et al., 2010), which is regarded to be more useful than STA/LTA method for time-picking in noisy waveform data, for detection of earthquake signal and picking of arrival time of P-wave and S-wave. We regarded the time section where signal appeared about the same time as the time earthquake was occurring to remove the effect of non-seismic oscillation of seismometer. We calculate the hypocenter with hypomh, hypocenter calculation program by Hirata and Matsu'ura(1987) using P-wave arrival time and S-wave arrival time at the observation points obtained with MER method. After the hypocenter calculation, we.

Keywords: Mt. Asama, deep low-frequency earthquake, automatic detection, automatic hypocenter determination

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Cyclic activity of earthqaukes and ground deformation observed during the 1991-1995 dome growth at Unzen Volcano, Japan

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Unzen Volcano in SW Japan began to erupt on November 17, 1990, and growth of an associated dacite lava dome occurred from May 20, 1991 to early February 1995. The volume of extruded lava is estimated to be about 0.21km^3 (Nakada et al., 1999). Pyroclastic flows occurred frequently during the dome growth.

Just before the dome emergence and during the dome growth, cyclic tilt oscillation within a period of 1 to 3 h was observed in the EW component at the FG1 station located about 680m west from the crater. Yamashina et al. (1994) assumed that the oscillation presented the repetition of inflation and deflation at the uppermost part of the active vent, suggesting a cyclic upward flow of lava with high viscosity. They made a formula to successfully estimate the daily supply rate of lava using the magnitude of tilt oscillation. Umakoshi et al. (2011) revealed that the HF seismicity in the crater area around the dome emergence of May 20, 1991, increased and decreased repeatedly within a period of 1 to 2 h, which correlated with tilt cycles in such a way that the seismicity increased during uplifting on the side facing the crater. In contrast, when the craterward ground was subsiding, the seismicity rate was much lower. However, it has yet to be investigated whether such synchronization emerged in other periods of dome growth or not except for the period from October 1994, when a lava spine was growing (Yamashina et al., 1999). In this study, therefore, we investigated the relationship between tilt oscillation and temporal changes of seismicity level during the entire period of dome growth.

We used the tilt data at FG1, which were telemetered to the Shimabara Observatory of Kyushu University, and the earthquake list created by Umakoshi et al. (2008). Using earthquake counts in 10-min intervals and the tile data, we calculated cross-correlation coefficients in the time window of 12 h. As a result, we found three periods in which the temporal changes of the seismicity level correlated with the tilt oscillation. These were after November 1993, when the HF seismicity level was high. However, the manner of synchronization was different from that found in May 1991, that is, the seismicity rate increased gradually during the uplifting on the craterward side, and then decreased gradually during subsidence on the craterward side. This suggests that the source process of HF earthquakes is different between the cases in May 1991 and those after November 1993. No clear correlation with tilt oscillation was found in the period from June 1991 to October 1993, when the LF seismicity level was high. Also, there are some cases in which the temporal changes of HF seismicity did not correlate with the tilt oscillation. These indicate that the synchronization between tilt oscillation and seismicity level emerged only in parts of the periods when the HF seismicity level was high.

In other cases of cyclic activity of earthquakes, we found the temporal changes of the seismicity level related to the occurrences of pyroclastic flows. Also, we investigated the relation between tilt oscillation and seismicity level during the growth of a lava spine in detail.

Keywords: lava dome, tilt oscillation, cyclic activity, seismicity, high-frequency earthquake

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Geomorphological Growth of Lava Domes

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The lava dome is one of the remarkable shapes in volcanic landforms. The average height and diameter are about 540m and 170m, and the range of the aspect ratio is 0.125-0.35. Lava domes have been formed at 58 volcanoes in the world, including 3 volcanoes in Japan, since 1900, but little comparative study on the growth of a lava dome has been carried out.

In this work, we try to investigate features of the lava dome growth through the comparison with temporal changes in the height and the radius of lava domes.

It was only 9 lava domes that the height and the radius of a dome continuing to grow were observed. The normalized height-time and radius-time curves show that the height and the radius increase with the time according to logarithmic or power low, and they exceed 50% of the maximums for 5-20% of the whole growth time. The curves suggests that the termination of the dome forming activities and an ultimate size of the lava dome can be predicted from the temporal changes in the height and/or the radius of a lava dome. The height-radius relations of each lava dome reveal that growth paths branch in two directions at the transition zone from the higher growth rate to the lower one. The two directions are approximately parallel with the height-radius relation line of Peleean dome and of Low lava dome (Blake, 1990) respectively.

We also investigate a morphological feature of spines accompanying some Peleean domes. The aspect ratios of them fall between the lower limit of 0.35 and the upper limit of 3.0, and the maximum heights are less than the upper limit of 300-350m.

Although the height and the radius data from only 9 domes allow to lead two features of the lava dome growth, more detailed topographic data during the growth of a lava dome are required to better understand the feature of the dome growth. The result suggests the possibility that we can predict growth periods and size of lava dome. It will be necessary to measure even height and a diameter.

Keywords: Lava dome

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Possible application of stroboscopic muography to monitoring periodic eruptions

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Many of the muon radiography observations have been applied to static objects, but some dynamic studies have so far been performed (e.g. imaging before and after the 2009 Asama eruption; Tanaka et al., 2009). One of the reasons which makes it difficult for us to perform real time or rapid time sequence radiography is the relatively low intensity of the cosmic ray muon flux that leads to long integration times to reach an adequate contrast in radiographic images. However, such low cosmic ray muon flux can be compensated for by averaging a large number of short acquisition frames, as in the case of periodic processes. If we assume a vent, with a radius of 10 m to detect it through 400-mwe-thick rock, the horizontal penetrating muon flux will be $5x10^{?5}$ $sr^{?1}cm^{?2}s^{?1}$ and $7x10^{?5}$ $sr^{?1}cm^{?2}s^{?1}$ for the filled and vacant vent respectively. A detector with an active area of 4 m^2 and the required angular resolution of 100 mrad, located at a distance of 200 m from the vent, can therefore collect 0.02 and $0.03^{?1}$ for each condition, and 2500 eruption events can distinguish these conditions in 1 s at a 3 sigma confidence level. 2500 eruption events are not unrealistic if we consider that 110 eruptions were observed in Stromboli between 14 and 17 October 2007 (Goto et al., 2008). In this work, we evaluated this idea by utilizing a comprehensive model system that consists of a muon detector with an active area of 0.16 m^2 and an electric furnace with a diameter of 15 m as a periodic test target. The variations in the density contrast were clearly observed in the furnace with a period of 12 hours by averaging 17 frames. The result infers a possible application of stroboscopic muography to monitoring periodic eruptions.

Keywords: muon, radiography, stroboscope