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

SVC47-01 Room:303 Time:May 26 09:00-09:15

Precursory eruption for a large ignimbrite eruption; example of Osumi pumice fall deposit from Aira caldera

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Caldera collapse and emission of voluminous ignimbrite follow the decompression process of magma chamber during precursory eruption. Rapid withdrawal of massive magma from a chamber causes decompression of magma chamber and results collapse of the roof of magma chamber. A massive eruption from Aira caldera at 29 calBP produced a massive ignimbrite which covered the southern half of Kyushu Island, and formed the structure of Aira caldera. A voluminous pumice fall deposit (Osumi pumice fall deposit, ˜100 cubic kilometer in bulk volume; Kobayashi et al. 1983) was erupted prior to the emission of Ito ignimbrite and caldera collapse. The eruption of Osumi pumice fall caused the decompression of the magma chamber to induce the collapse. We are analyzing the sequential change of pumice fall deposit to understand the mechanism of large scale eruption associating caldera formation and voluminous ignimbrite. Osumi pumice fall deposit shows clear upward coarsening as pointed by Kobayashi et al. 1983, and is directly covered by the ignimbrite. An outcrop at ˜15km from the vent along the distribution axis shows ˜10 m thick of the deposit. The lowest part within ˜2 m from the base is finer than the overlying unit, and thin finer bed exist at ˜4.5 m from the base. Other part is homogeneous and no clear fall unit is recognized. Maximum size of pumice is 3 cm at the base and increases up to 8 cm at the top of the deposit. Total amount of lithic fragments is ˜5 % in volume. The lithic fragments consist of shale and sandstone derived from the basement (Shimanto Group) and Quaternary volcanic rocks (rhyolite-dacite lava, and aidesite lava and scoria). The ratio of basement fragments against the surface volcanic rock decreases from the base to the top. These observations suggests the model that the enlargement of the conduit caused the increase of the eruption rate and results the rapid decompression of the magma chamber to induce the collapse of the magma chamber roof.

Keywords: Ignimbrite eruption, caldera-forming eruption, Aira caldera, Eruption

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

SVC47-02 Room:303 Time:May 26 09:15-09:30

Mixing, end-member components and origin of felsic and mafic magmas erupted by Aira caldera-forming eruption

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Aira caldera, located in southern Kyushu, is a collapse caldera with ~20 km in diameter and was formed by a caldera-forming eruption occurred at ~29 ky ago. The Aira eruption effused voluminous white pumices basically formed from homogeneous felsic magma. They show the following disequilibrium petrographic features: (1) dark pumice (Arakawa et al., 1998) and banded pumice erupted along with the white pumice, and (2) cores of the plagioclase phenocrysts possess wide compositional range in both An content and Sr isotope composition. These suggest that the Aira eruption was caused not only by the felsic magma but also by the mafic magma, generated from different sources.

The An content of the plagioclase cores ranges from An_{33} to An_{88}. These phenocrysts can be divided into two types such as high-An (type-A: An >70), low-An (type-B: An <60) based on An contents of their cores and rims. Sr isotope ratios of the type-A and B phenocrysts coincide with those of the dark pumice and the white pumice, respectively. These values are distinct from Shirahama basalt which is assumed to be derived from upper mantle and basement rocks such as the Shimanto sedimentary rocks and the Takakumayama granite. Therefore, the mafic and felsic magmas which crystallized type-A and type-B plagioclase are not simply derived from upper mantle and basement rocks, respectively.

U-Pb dating of the zircon crystals in the white pumice shows concordant ages ranging from 249 to 2517 Ma. The age range is identical to those of the zircons from the basement rocks (Shimanto sedimentary rocks). However, no older zircons in white pumice show overgrowth structure. It is thus likely that older zircon is not source material but one of end-member components.

End-member components for magmas were estimated using element partitioning data (Bindeman et al., 1998; Bindeman and Davis, 2000). The mafic magma (SiO_2 = 59 wt.%, Sr = 391, $^{87}Sr/^{86}Sr$ = 0.7066) which crystallized the type-A plagioclase can be derived from mixing between the basement rocks (Shimanto sedimentary rocks) and the basaltic magma (Shirahama basalt) derived upper-mantle. The felsic magma (SiO_2 = 75 wt.%, Sr = 103, $^{87}Sr/^{86}Sr$ = 0.7060) which crystallized the type-B plagioclase was derived from the middle-lower crustal rocks based on the Sr isotope ratio. The composition of the dark pumice in the Ito ignimbrite can be explained by mixing between the mafic and the felsic magmas. Therefore, it is possible to propose that a cryptic magma should contribute to felsic magma production in association with Aira eruption.

Keywords: Aira caldera, caldera-forming eruption, magma mixing, end-member components, zircon, plagioclase

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

SVC47-03 Room:303 Time:May 26 09:30-09:45

Cooling process of mafic magma by texture analysis of mafic inclusions in An-ei lava, Sakurajima volcano

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The origin of mafic inclusions is interpreted as relics of mafic end-member magma associated with magma mixing. So, the mafic inclusions record the important information about mafic end-member magma and the mixing processes. Yanagi et al. (1991) suggested binary magma mixing process in the historical eruptions of Sakurajima volcano, according to the fact that plagioclase phenocrysts show a bimodal compositional distribution with two distinctive peaks at about An58 and An85, and reported the presence of mafic inclusions in An-ei lava of 1779 eruptions. Therefore, in order to obtain insights into the behavior of mafic inclusion (especially, magma cooling process) during the magma mixing processes in Sakurajima volcano, we conduct sampling, petrographic description and texture analyses of mafic inclusion in An-ei lava.

Most of mafic inclusions in the An-ei lava are elliptic in shape, the length of the major axis is about 10-20cm. The boundary to the host An-ei lava is sharp. The mafic inclusions show porphyritic texture, the phenocrysts are mainly plagioclase, orthopyroxene, clinopyroxene, oxide and olivine in minor amounts. The microlites in mafic inclusions are plagioclase, orthopyroxene, clinopyroxene and oxide. The host An-ei lava also show porphyritic texture, the phenocrysts are mainly plagioclase, orthopyroxene, clinopyroxene and oxide, but not olivine. The microlites in host An-ei lava are mainly plagioclase and orthopyroxene. Two types of plagioclase phenocrysts are found in mafic inclusions and host An-ei lava: (1) honeycomb plagioclase phenocrysts with large inclusions in heterogeneous mozaic cores with An75-90 and An55-70; and (2) clear plagioclase phenocrysts without any inclusions in homogeneous core from grain by grain, and this plagioclase phenocrysts show an unimodal compositional distribution with a major single peak at about An85, and small fraction of about An60, whereas those in host An-ei lava show a bimodal compositional distribution with two similar peaks at about An60 and An85 plagioclase. The length of plagioclase and pyroxene microlites in mafic inclusions are $\sim 300\mu$m, whereas those in the host An-ei lava are $\sim 50\mu$m.

We conduct microlite number density analyses in order to quantitatively estimate the cooling rate by using plagioclase microlite number density(MND)-cooling rate meter. As a result of application to measured data, the cooling rate (dT/dt) is calculated as 0.19 to 4.18×10^{-4} K/s. We estimate initial and final temperatures during microlite crystallization with core and rim compositions for the plagioclase- and alkali feldspar-liquid thermobarometer. By assuming a constant cooling rate, we calculate the crystallization-time-scale of microlites in mafic inclusions as several days to dozen days. In addition, as a result of crystal size distribution (CSD) analysis, the typical CSD plot of plagioclase microlites in mafic inclusion shows a log-linear trend. This result suggests that the annealing process is not effective and the time interval from the termination of microlite crystallization to the eruption is negligibly short. Thus, we conclude that the time scale from initial microlite crystallization in mafic inclusion to the eruption is about several days to dozen days.

Keywords: Sakurajima volcano, mafic inclusion, texture analysis, microlite number density, magma mixing process, magma cooling process

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

SVC47-04 Room:303 Time:May 26 09:45-10:00

Eruptive history of Koshikidake Volcano of the Kirishima volcanic group - A study on growing stratovolcanoes-

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The Kirishima volcano group has over 20 craters within a 25 km WNW-ESE and 15 km NNE-SSW expanse. Volcanic activity in the northwest area of this group has been reported for the recent 30,000 years by Imura (1992), Imura and Kobayashi (2001), and Tajima et al. (2014). We studied the Koshikidake Volcano, which comprises 11 tephra layers (Tajima and Kobayashi, 2011), of the Kirishima volcano group. These tephra layers are named Koshikidake-Shiratorishimoyu 1 to 11 tephra (Ks-Ss1 to Ks-Ss11) in this study because their type locality was around the Shiratori-Shimoyu Onsen. The first-stage five tephra layers indicate occurrence of small to medium vulcanian and scoria fall eruptions. The largest scoria fall (Ks-Ss6) among all Ks-Ss tephra was recorded in the sixth eruption event, which produced over 2 km^3 of lava flow to the northern part of Koshikidake Volcano. Subsequently, Koshikidake volcano erupted again, indicating repeated vulcanian and scoria fall eruptions. Peat was found in Ks-Ss7a and Ks-Ss7b, and lake deposits in Ks-Ss7b and Ks-Ss8 tephra at Jogasaki. Ko-Kakuto lake in the Kakuto Caldera had been pounded at the Ito-pyroclastic flow eruption from the Aira Caldera (Aramaki, 1968). This study shows that Ko-Kakuto lake existed before Ks-Ss5 tephra, but the lake disappeared after Ks-Ss9 or 10 at Jogasaki. A peat layer deposited in Ks-Ss7a and Ks-Ss7b and lahars deposited above Ks-Ss8, indicate shallow water conditions at the Jogasaki location.

Koshikidake Volcano has ejected the greatest volume of products in the Kirishima volcano group, and its activity has been divided into the first small or medium eruption, second climax eruption with huge lava and scoria fall, and third small to large eruption stages, similar to those of the developing Takachihonomine Volcano.

Keywords: Kirishima volcanic group, Koshikidake volcano, strato volcanoe, lava, Ko-Kakuto lake

SVC47-05 Room:303 Time:May 26 10:00-10:15

The genesis of the Minami-Shimabara basalts erupted at the pre-stratovolcao stage of Unzen

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Hydrous components derived from the subducting slab, such as aqueous fluids and hydrous melts, are generally believed to play an essential role in subduction zone magmatism. From the viewpoint of this petrologic concept, the genesis of the Unzen magmatism in west Kyushu, southwest Japan is an enigma. The Wadachi-Beniof Zone beneath Kyushu indicate that the subducted Philippe Sea Plate does not extend to Unzen, which indicates that petrologic models emphasizing the role of slab-derived hydrous components cannot explain the genesis of the Unzen magmatism. In other words, the Unzen magmatism gives us new insights into our understanding of the subduction zone magmatism. The petrogenesis of Unzen, however, has not been well understood yet, since the modern Unzen volcanism is dominated by eruptions of dacite and is devoid of primitive basalt lavas. It is, therefore, impossible to constrain physicochemical conditions of primitive magma genesis using petrologic observations for present magmatic products there. The Minami-shimabara basalts (MSBs) distributed at the southern foot of Unzen erupted at the pre-stratovolcao stage from 4.6 to 1.0 Ma. The genesis of the MSBs would give us some insights into our understanding of the Unzen magmatism.

The MSBs do not show meaningful correlations on the major element oxide vs. MgO diagrams, indicating that magmatic processes the MSBs experienced were complicated. The behaviors of compatible elements such as Ni and Cr, however, indicate that magmatic processes in the mantle would have played essential role in the compositional features of the MSBs. The Mg-Fe-Ni compositions indicate that the MSBs could have been in equilibrium with Fe-rich mantle olivines with Fo = 80 -87. On the normative olivine-quartz-Jd+Ca diagram, the MSB are plotted parallel to the adiabat of melting anhydrous peridotite. These features indicate that multi-stage partial melting at 1.5-0.5GPa would essentially have formed compositional variations of the MSBs. The low pressure where the primitive melts were last in equilibrium with the source mantle is consistent with seismic observations of Unzen suggesting that crustal thinning occurs there.

The normative compositions also indicate that the source mantle would have had relatively low temperature ($T_p \approx$ 1300 ℃). The estimated low potential temperature indicates the MSB magmatism would have caused by a passible upwelling induced by the subsidence of the Shimabara Basin. Forcal mechanisms and GPS displacements indicate that dextral transtensional strain of the Amakusa-nada Graven controls these geologic phenomena.

Keywords: the Minami-Shimabara basalts, multi stage partial melting, tectonics, dextral

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

SVC47-06 Room:303 Time:May 26 10:15-10:30

Zonal structure of Aso-4 magma reservoir as estimated from compositions of plagioclase and melt inclusions

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We measured compositions of plagioclase and melt inclusions of four flow units of Aso-4 pyroclastic flow. They are Oyatsu pumice flow, Koei ash flow, Yame pumice flow, and Benri scoria flow with pumice and banded pumice, as defined by Watanabe (1978). They represent the first cycle of Aso-4 eruption sequence.

Plagioclase in pumice shows compositional variation changing from one peak (Koei) to two peaks (Oyatsu and Yame), then back to one peak (Benri pumice). Range of compositional variation becomes wider toward later stage, with the widest peak found in Benri pumice and scoria. Median value of the larger peak is An=35 (Koei), An=45 (Oyatsu, Yame and Benri pumice), and An=90 (Benri scoria). All the samples contain small amount of An55 plagioclase. Difference between core and rim was not found among analyzed samples.

Plagioclase in pumice shows compositional variation changing from one peak (Koei) to two peaks (Oyatsu and Yame), then back to one peak (Benri pumice). Range of compositional variation becomes wider toward later stage, with the widest peak found in Benri pumice and scoria. Median value of the larger peak is An=35 (Koei), An=45 (Oyatsu, Yame and Benri pumice), and An=90 (Benri scoria). All the samples contain small amount of An55 plagioclase. Difference between core and rim was not found among analyzed samples.

Bulk composition of pumice is SiO2=68˜70 wt.% for Yame pumice, SiO2=67˜70 wt.% for Oyatsu pumice, and SiO2=66˜67 wt.% for Benri pumice. Distinct composition is found between melt inclusions hosted by plagioclase and orthopyroxene between Oyatsu and Koei pumice. Koei melt inclusions show composition in a narrow range of SiO2=73˜74%, whereas Oyatsu pumice show that of SiO2=71˜74%. Shiihara (2014) reported distinct composition of volcanic glass among tephra of Aso-4A in the east area from Aso caldera. She named them as Group-1 glass (SiO2=73-74%) and Group-2 glass (SiO2=71-72.5%), and argued that Group-1 correspond to glass of Koei ash flow deposit, and Group-2, that of Yame pumice flow deposit. Because the composition of our Koei and Oyatsu melt inclusions and those of Shiihara's (2014) Koei and Yame glass are nearly the same, we concluded that Oyatsu and Yame glass represent the same melt. Thus Oyatsu pumice flow that flowed to the west of the caldera and Yame pumice flow that flowed to east and northwest possiblly originated from the same or similar source in the magma supply system.

Water content of Koei melt inclusions is more than 4 wt.%, and that of Oyatsu melt inclusions is 2-4 wt.%. Chlorine content of Koei melt inclusions is higher than that of Oyatsu, whereas, sulfur content of the former is lower than that of the latter.

In summary, we estimate that Koei pumice flow represent one magmatic melt, and Oyatsu and Yame pumice flow represent two magmatic melt. Plagioclase of An55 composition represent mafic magma in equilibrium with this plagioclase. This melt was not found as melt inclusions, however, is a possible end member of mixing event prior to the huge eruption. Benri scoria and An90 plagioclase, the final product of the first cycle Aso-4 activity, represent the most mafic magma of the magma supply system. We propose an existence of zoned stratified magma reservoir for Aso-4 magma system, from which magma was mixed, and was evacuated from the upper zones.

Keywords: Aso-4 pyroclastic flow, magma reservoir, melt inclusion, plagioclase

SVC47-07 Room:303 Time:May 26 11:00-11:15

Evolution of magmatic plumbing system and tectonics of Fuji and adjacent volcanoes since 0.4Ma.

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The evolution of magmatic plumbing system of Fuji and adjacent volcanoes, the Ashitaka, Hakone and Izu-Tobu, since 0.4Ma, has been controlled by the collisional tectonics in the northern tip of the Philippine Sea plate. The evolution of magmatic plumbing system of Fuji and adjacent volcanoes comprises the Stage-1 to Stage-3. In the Stage-1 (0.40 to 0.27Ma), the Ashitaka, Pre-Komitake, Hakone and Amagi basaltic to andesitic stratovolcanoes were active. The Philippine Sea plate, where the Hakone and Amagi andesitic stratovolcanoes are located, subducted along the Suruga trough and its northern extension beneath the Tanzawa block on which the Ashitaka and Pre-Komitake basaltic stratovolcanoes are situated. In the Stage-2 (0.27 to 0.13Ma), the Ashitaka, Pre-Komitake and Hakone volcanoes continued their volcanic activities. The Hakone volcano in this stage was characterized by the voluminous felsic pyroclastic eruptions, related calderas, and andesitic to felsic independent monogenetic volcano group; the NNW-SSE trending graben was probably formed in the Hakone volcano under the ENE-WSW extensional tectonics. The tensional strain caused by the westward subduction of Philippine Sea plate was probably released by the extension of the graben of Hakone, because the subduction of the Philippine Sea plate along the Kannawa fault was stopped and it completely stacked to the Tanzawa block. In the Stage-3 (0.13Ma to present), the volcanism of Komitake, Fuji, central cone of Hakone, and Izu-Tobu monogenetic volcano group were active. The amalgamation of Philippine Sea plate with Tanzawa block along the Kannawa fault was resulted in the formation of the Tanna-Hirayama left lateral strike-slip fault. The central cone of Hakone was developed in the pull-apart portion of the Tanna-Hirayama strike slip fault. The northward movement of the eastern block of the Tanna-Hirayama fault caused the extensional tectonics in the Amagi volcano, bringing the volcanic activity of Izu-Tobu monogenetic volcano group. The strain caused by the subduction of Philippine Sea plate along the Suruga trough gave rise to the opening of the deep fracture in the Philippine Sea slab beneath the Fuji volcano, which is probably the cause of the extraordinary voluminous eruption of basaltic magma of Fuji volcano.

Keywords: Fuji volcano, magmatic plumbing system, tectonics

SVC47-08 Room:303 Time:May 26 11:15-11:30

Multistage magma mixing determined by phenocryst composition and zoning of the Sessho lava, Kusatsu-shirane Volcano

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We present a detailed study of the texture and chemical zoning of phenocrysts in the Sessho lava, andesite lava flow from Kusatsu-shirane volcano, Central Japan, in order to reconstruct cooling and crystallization processes of andesite magma. The Sessho lava is estimated to have been erupted 5 ka from the Moto-shirane cone (Yoshimoto et al., 2013) and exhibits andesitic composition with SiO2 content of 60~63 wt. % (e.g., Ueki and Terada, 2012). We sampled 5 different samples to cover the whole area of the Sessho lava, and conducted textural and chemical analysis of the samples. Phenocryst assemblage of the Sessho lava is plagioclase, clinopyroxene, orthopyroxene, magnetite and rare olivine with glassy groundmass.

Disequilibrium olivine (Fo=~80) with reaction rim suggests the mixing between basaltic and evolved magmas during evolution of the Sessho lava. Orthopyroxene-magnetite symplectite, which is estimated to be formed by olivine breakdown by oxidization (e.g., Goode, 1974), coexists with the olivine phenocryst.

Pyroxene thermometry (Lindsley, 1983) based on rim compositions of opx and cpx phenocrysts suggests the mixing between high temperature (1000 degree) and low temperature (700 degree) magmas. The rim compositions of higher temperature opx show higher Al content and rim compositions of the lower temperature opx and core compositions of opx show lower Al content, suggesting these pyroxenes have been derived from different magmas both in terms of composition and temperature. The high temperature pair and the low temperature pair coexist in some samples.

We observed four different types of plagioclase phenocrysts in a single rock sample, in terms of zoning profiles, internal textures and external shape. Type 1 plagioclase exhibits euhedral shape, clear and homogeneous core with An content of 55~65. Type 2 plagioclase exhibits euhedral shape with oscillatory zoned core between An content of 50~80. Type 3 plagioclase exhibits rounded shape, rough interface and dusty core with An content of 80~90. Type 4 plagioclase exhibits clear core with An# of 55~80 surrounded by dusty mantle zone with An# of 80~90, and rough interface. All types of plagioclases have thin (~50μm) rim with An content of 60~80. This rim may represent a crystallization during upwards migration, because plagioclase microphenocryst in groundmass exhibits similar An content with the rim. Dusty core of type 3 and dusty mantle of type 4 show higher MgO and FeO contents than the clear and oscillatory parts and type 1 and type 2 plagioclases, suggesting the dusty core and mantle crystallized in higher FeO and MgO content magmas. Type 1 and type 2 plagioclases are larger (~1.5mm) than the type 3 and 4 (~1mm). Crystal size distribution analysis of plagioclase phenocryst suggests that type 1 and 2, and type 3 and 4 crystallized in different physical conditions. Clear plagioclase (type 1) may represent equilibrium crystallization process in relatively low temperature evolved magma, whereas dusty plagioclase (Type 3) may represent crystallization in relatively mafic and high temperature magma. Oscillatory zoning (Type 2) and dusty mantle (Type 4) may represent interaction between the high temperature and low temperature magmas.

Based on the above observations, we propose multi-stage magma mixing and crystallization processes during the evolution of andesite magma of the Kusatsu-shirane volcano; high temperature basaltic magma with olivine, and calcic plagioclase was recharged periodically in a crystallized lower temperature silicic magma chamber, and inhomogeneous mushy magma chamber was formed.

Keywords: lava flow, two pyroxene geothermometry, crystal size distribution, andesite, eruption, active volcano

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

SVC47-09 Room:303 Time:May 26 11:30-11:45

Low tempter Pyroclastic flow (pyroclastic density current) from phreatic eruption

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In this study, is carried out restoration of Yakedake Taishoike eruption from newly discovered record and old photographs. The 6 June 1915 Yakedake, active volcano in the central Japan, eruption produced "cold" pyroclastic flow. The pyroclastic flow was spread over an area of ca.1 km^2. The eruption products are clay rich tephra and lacking any juvenile component, there shows the characteristics of phreatic eruption. At the same time with the eruption, the lahar flowed in the gullies. The lahars deposits dammed up the Azusa River in the foot of Yakedake, and made the dam lake of length 1.9km. The dam lake is named Taishoike. Thickness of the eruption tephra is significantly thicker at near the crater; but significantly thin at distal area of the crater. Its feature is also similar to the Ontakesan 2014 eruption that low-temperature pyroclastic flows occurred. Therefore, significantly-thicker phreatic eruption tephra at near the crater, there is a possibility that the low-temperature pyroclastic flow occurred during the eruption.

Since the 19th century, steam eruption that low temperature pyroclastic flow occurs in Japan, pyroclastic flow occurs in the initial. From these eruptions sequence, it is suggested that the plume cannot obtained the buoyancy, because contains a large amount of low-temperature rock fragments in ejecta by new crater formation.

Keywords: Yakedake, phreatic eruption, Taishoike, Low tempter pyroclastic flow, pyroclastic density current, 1915

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

SVC47-10 Room:303 Time:May 26 11:45-12:00

Sedimentary facies changes of lahar deposits in distal area, Chokai volcano, NE Japan

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Chokai volcano is an andesitic stratovolcano in northeast Japan. The sector collapse of the volcano occurred about 2,500 years ago. The Kisakata debris avalanche deposit was formed by the collapse to the northern foot of Chokai volcano (Ohsawa *et al.*, 1982). The post-collapse fan (partly volcaniclastic apron) deposits, largely distributed in the northern foot of the volcano, overlies the Kisakata debris avalanche deposit. From geological survey in the proximal area, Minami *et al.* (2015) reported that the post-collapse fan deposits accumulated by a series of debris flows and hyperconcentrated flows, and then concluded that the deposits are originated from several lahar events. However, change in sedimentary facies in the distal area was not well studied. Furthermore the depositional processes changes between the proximal and distal areas of these lahar deposits have not been well understood. This study aims to understand transition of depositional processes with distance, and relationship between geomorphology formed by these lahar deposits and their depositional processes. The volcanic fan can be topographically subdivided into four areas; the steeply-sloping area, the moderately-sloping area, the gently-sloping area, and the very-gently-sloping area. We trenched and cored (by handy geoslicer; Takada *et al.*, 2002) in the distal of volcanic fan (gently sloping area, and very gently sloping area) at a total of 12 sites. Each set of trench and core by the depth of one to two meters from the surface were observed. In the distal area, the lahar deposits are composed of debris flow, hyperconcentrated flow and streamflow facies. These flows are mostly originated from lahar events. The facies variation with distance implies that lahars flowed down as debris flows in proximal areas. Then, they transformed into hyperconcentrated and stream flows, although some reached to the distal area as debris flow. Some lahar reached to the coastline that is 20 km distant from the volcanic edifice as stream flow, where highly populated towns are distributed.

Keywords: Lahar, Chokai volcano

SVC47-11 Room:303 Time:May 26 12:00-12:15

Relationship between eruptive style and fragmentation derived from the all grain size analysis for juvenile fragments

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1. Introduction

Phreatoplinian eruption is one of the phreatomagmatic eruption that occurs by the contact of vesiculated and fragmented felsic magma with external water. This eruption produces extremely fine-grained ash particles (Self and Sparks,1978), it is typical characteristics. On the other, Hayakawa(1985) makes a point that plinian eruption, the magmatic eruption, produces fine-grained ash same as phreatoplinian eruption, though a large quantity of fine particles have been lost.

Although, there are many of all grain size analysis with a number of eruption, it does not come to a conclusion (i.e. Walker,1980;1981). However, these all grain size analysis intendes all components of eruptive products, containing accidental lithic fragments. So there are some inaccuracy to degree of fracturing for juvenile fragments.

This study compare the degree of fracturing between magmatic eruption and phreatomagmatic eruption by only juvenile fragments.

2. Candidate and Method

Heian eruption, the latest silicic volcanism at Towada volcano, began with magmatic eruption, thereafter repeated magmatic and phreatomagmatic eruptions alternately within a short period, approximately a half days (Hiroi and Miyamoto, 2010). The products mainly consist of pumice fragments. Because there are very few blocky glass shards, magma has already vesiculated and fragmented before contacting external water.

This study analyzed the unit OYU-1 and OYU-2b in Heian eruptive sequence. OYU-1 is the magmatic plinian pumice fall deposit. It contains many accidental lithic fragments. Lithofacies such as grainsize and component are homogeneous, though eruptive rate is estimated to constant. Eruptive volume is about 0.21km^3. OYU-2b is the phreatomagmatic base-surge deposit, proceeded from OYU-1 almost continuous. It contains many of fine-grained ash, and eruptive volume is about 0.27km^3.

This study based on detail field surveys. We made isopach map of OYU-1 and distribution map of OYU-2b. Samples are sieved to each grain size and separated to juvenile fragments, accidental lithic fragments, and free crystals. We made isograde maps for juvenile fragments and free cryastals about each grain size, and calculated the eruptive weight about them. Fine grained ash lost by the diffused process in air are estimated by crystal method (Walker,1980), and we got all grain size distribution only juvenile fragments.

3. Result and Discussion

The lost fine grained ash are six times as many as existent coarse fragments left in OYU-1 deposits and twice in OYU-2b, and the amount of ash finer than 1mm in total eruptive weight is about 89% both of OYU-1 and OYU-2b. It shows that there is little difference between magmatic and phreatomagmatic eruption for the amount of produced fine grained ash. Yamamoto(1994) pointed out that the large volume production of fine grained ash in phreatoplinian eruption have to be deny, and this result supports this opinion. And Hayakawa(1985) pointed out that the fine grained ash are predisposed to deposit by aggregation of external water in phreatoplinian eruption, and this result is consistant with this opinion. The eruption of Mt. St. Helens in 1980 occurred plinian eruption in rainfall, and the deposit is rich in fine grained ash as phreatoplinian eruption (Carey and Sigurdsson,1982). This grain size feature is the very important instance to confirm these previous indications and this study.

Keywords: magmatic eruption, phreatomagmatic eruption, extent of fragmentation, all grain size analysis

SVC47-12 Room:303 Time:May 26 14:15-14:30

Try to draw the volcanic eruptions and earthquake activity in the same figure around Japan Part 1: in and around Japan

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The relation between the volcanic eruption and the occurrence of large earthquakes were well known. It was the famous eruption of Mt. Fuji in 1707 in Japan. It was followed 49 days after the occurrence of M9 Hoei earthquake. The 2004 Sumatra M9 earthquake followed some eruptions, too. But 2011 off Tohoku, Japan M9 earthquake did not follow eruptions, yet. The seismicity was commonly analyzed in time and space, using several database, for example ISC and PDE catalogs. But the data of volcanic eruptions were not popular and needed to analyze the relation.

The data of eruptions in and around Japan was inputted in order to search the relation between eruptions of volcanoes and occurrence of large earthquakes. The database of the Global Volcanism Program by Smithsonian Institute (http://volcano.si.edu/) was adopted. The histories of volcanoes of Onkakesan, Asosan, Kuchinoerabujima, Nishinoshima, Izu-Torishima, Kikai, loto, Kirishimayama, Miyakejima, Fukutoku-Oka-no-Ba, Asamayama, Akan, Suwanosejima, Tokachidake, Kita-loto, Hokkaido-Komagatake, Toya, Niigata-Yakeyama, Akita-Yakeyama, Adatarayama, Unzendake, Minami-Hiyoshi, Kujusan, Yakedake, Izu-Oshima, Izu-Tobu, Kusatsu-Shiranesan, Myojinsho, Kaitoku Seamount, Fukujin, Shikotsu, Nikko, Azumayama, Kasuga, Izu-Torishima, Sofugan, Chokaisan, Io-Torishima, Nasudake, Kita-Fukutokutai, Aira, Nikko-Shiranesan, Kurikomayama, Nakanoshima, Akagisan(no), Shiretoko-lozan, Iwatesan, Submarine Volcano NNE of Iriomotejima, Akita-Komagatake, Maruyama, Bandaisan, Esan, Midagahara, Fujisan, Yokoate-jima, Kuttara, and (Smisujima) were checked and only 'Confirmed' eruptions were adopted.

The format of eruption data is same as that of hypocenters. The location of the volcano, not craters, is the epicenter. The height of volcano is minus depth in 10m of hypocenter, and the volcanic explosivity index (VEI) is used as the magnitude of the earthquake. The origin time is the date of the eruption and is assumed on 00:00:00 time. The eruption was assumed every day from the start of the eruption to the end. If the start date and the stop date were only known in year, Jan. 1 was assumed for the start day and Dec. 31 for the stop date. If there was no information of the stop date, only the start date was inputted. Totally more than 153,000 eruptions were inputted from AD 20 to 2014.

Mixing this data and earthquake catalog, we can get some relations between eruptions and earthquake occurrences. One is that the 1922 M7.6 earthquake in Okinawa followed VEI 4 eruption near Miyako island in 1924. The other is some large earthquakes occurred before and after the large eruptions in NE Japan in 17 century.

Keywords: volcano, eruption, earthquake, database

SVC47-13 Room:303 Time:May 26 14:30-14:45

Roles of Basaltic Lower Crust for a Periodically Refilled Magma Chamber

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A series of primary magmas supplied from the mantle seems to be transformed by crystallization in a refilled chamber into a magma with the average composition of upper continental crust, via a series of calc-alkaline magmas. One of mechanical mechanisms that have such power is a system of coupled magma chambers. It consists of a lower chamber lying at the base of crust and an upper chamber lying at the middle of crust. They are connected by a cylinder and a plug lying between them. This mechanism is important in a sense that crystallization in it has a power to give good explanation for the genesis of calc-alkaline igneous rock series and continental crust. However, its presence has not yet been well confirmed. Therefore it is necessary to accumulate the evidence through geological surveys, and chemical and physical examination of the system.

It is well understood that those, which carry evidence, are volcanic rocks. However, Outlook of what type of investigation should be done is not easy, due to complexity of chemical differentiation of magma in a refilled chamber. One way to help it is to study characteristics and differentiation trends of magma composition through simple simulation of a simplified refilled chamber system. Here, we assumed primary magma and lower crust are well deleted in water and alkali elements, and also assumed that a heat transfer coefficient between magma and the surrounding crust, a melting point of the crust and a thickness of crust are all variables and then examined variations of magma temperature, upper chamber position in the depth direction and size of magma, in a stirring state, in a refilled chamber lying in the lower crust. Four of results are as follows. 1.High melting points is necessary for the magma chamber to grow. 2.The magma chamber rises up as the result of settling of crystalline materials formed by crystallization from the magma and digestion of the ceiling crust of the chamber by the magma. Upper and lower limits of the temperature that varies with time in a saw-tooth fashion depends on magnitude of heat transfer coefficient, melting point of ceiling crust and thickness of overlying crust. The points are that lower limit rises more, though at decreasing rate with time, depending on higher melting point of crust and thinner overlying crust and finally becomes constant. This is confirmed by the evidence observed on compositional variations of volcanic rocks plotted on MgO vs. K2O diagram. 4. If the overlying crust becomes too thin, then the digestion of crust comes to stop. This is confirmed by the corresponding variation of strontium isotopic composition of volcanic rocks.

Keywords: refilled chamber, calc-alkaline volcanic rocks, continental crust, thermal chamber evolution

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

SVC47-14 Room:303 Time:May 26 14:45-15:00

Magmatic processes for somma-lavas from Usu Volcano

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Usu volcano formed mainly by eruption of basaltic and andesitic magmas (somma lavas) at 10-20 ka, followed by intermittent eruptions of felsic magmas after A.D. 1663. Magmatic processes for the historical felsic magmas have been intensively examined by e.g. Tomiya and Takahashi (1995) and Matsumoto and Nakagawa (2010), while studies on the somma lavas have been limited. Ohba (1964) and Fujimaki (1986) suggested that the geochemical variation of the somma lavas can be explained principally by fractional crystallization. However, the number of samples which they examined were limited, and the processes were not well constrained by high-quality geochemical data.

In this study, we have performed a petrological and geochemical analysis on samples from the somma lavas to understand magmatic processes. Whole-rock major element compositions were determined for ˜90 samples, and trace element and Pb isotopic data were also obtained for 40 samples, as well as lower crustal xenoliths from Ichinomegata volcano. Whole-rock SiO_2 content of the lavas ranges 49.6-54.9 wt.%, and they are divided into basaltic samples ($SiO_2<52.0$ wt.%) and andesitic samples ($SiO_2>52.4$ wt.%). The andesitic samples can further be subdivided into high-P_2O_5 (0.13-0.19 wt.%) type and low-P_2O_5 (0.08-0.13 wt.%) type. The phenocryst assemblage of the basalt is olivine + cpx + opx + pl, and that of the andesite is cpx + opx + pl. The phenocryst content is variable, ranging from ˜10 to ˜35%. P2O5 contents of the somma lavas correlate negatively with $^{206}Pb/^{204}Pb$ ratios, and the ratio decreases from 18.63 to 18.53 with increasing P2O5 content. The lower crustal xenoliths are significantly lower in $^{206}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ ratios than those of the somma lavas.

We have performed a principal component analysis (PCA) for the whole-rock major element data of the lavas to understand what processes were involved in the evolution of the somma lavas. The analysis shows that some elements including SiO_2 and P_2O_5 are important in PC1, while two elements, Al_2O_3 and CaO, play a dominant role in PC2. The contribution of PC1 and PC2 is 58% and 24%, respectively, and these two components sum up to >80% of the total contribution. We found that PC1 shows a good correlation with Pb isotopic ratios and La/Yb ratios, and PC2 correlates positively with the modal abundance of plagioclase phenocryst. These results suggest that PC1 reflects a mixing process between a less radiogenic component and a more radiogenic component, whereas PC2 reflects separation and/or accumulation processes of plagioclase phenocrysts.

The high-PC1 end-member component is likely to be a less differentiated basaltic magma because of the low P_2O_5 feature of the component. On the other hand, the low-PC1 end-member component has a differentiated feature (i.e. high P_2O_5), but it has less radiogenic Pb isotopic composition than the somma lavas. Therefore, it is plausible that the low-PC1 component would be partial melt of the lower crust. This scenario is supported by the observation that the lead isotopic data of the lower crustal xenoliths plot mostly on the linear extension of the trend formed by the lava data in a $^{207}Pb/^{204}Pb$-$^{206}Pb/^{204}Pb$ and a $^{208}Pb/^{204}Pb$-$^{206}Pb/^{204}Pb$ compositional space. For these considerations, we conclude that the somma magma evolved through mixing of a less differentiated basalt magma and partial melt of the lower crust, followed by differentiation and re-distribution of plagioclase phenocrysts in a crustal magma reservoir.

Keywords: Usu Volcano, Somma lava, Magma process, Lower Crust

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

SVC47-15 Room:303 Time:May 26 15:00-15:15

Formation history and magma evolution of Asahidake Volcano of Taisetsu volcanic field, central Hokkaido, Japan

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Taisetsu volcanic field, located in the northern part of Taisetsu-Tokachi volcanic chain, central Hokkaido, consists of Quaternary volcanoes. Its activity started at 1.0 Ma accompanied with voluminous lava flows and many lava domes and cones widely. The youngest activity has occurred in the center of the volcanic field as follows: Ohachidaira caldera-forming eruption occurred at 35 ka, and after that, the volcanic edifices, namely Ushiro-Asahidake, Kumagatake and Asahidake, have been formed at the southwestern rim of the caldera (Katsui *et al*. 1979). There are several previous studies about eruptive history and magma plumbing system of Asahidake, which is the youngest active cone (e.g. Sato & Wada 2007). However, the stratigraphic relationship between Asahidake and the other volcanoes (Kumagatake and Ushiro-Asahidake) is still unclear. In addition, the petrological study of these volcanoes has not been carried out sufficiently. Therefore, we performed geological and petrological study of Asahidake Volcano (Asahidake, Kumagatake, and Ushiro-Asahidake), in order to reconstruct the formation history and to reveal the magma evolution of Asahidake volcano.

Asahidake (2,291 m) consists of a pyroclastic cone formed above the 1600 m altitude and many lava flows on the west side. The horseshoe-shaped explosion crater called Jigokudani crater exists on the west side of the cone and the fumaroles still active. Ushiro-Asahidake lava dome (2,216 m) and Kumagatake pyroclastic cones (2,210 m) locate in the 1 km to the east from the summit of Asahidake and both are covered with the edifice of Asahidake. Based on the difference in volcanic edifice, the volcanic activity can be divided into 3 stages: Kumagatake, Ushiro-Asahidake, and Asahidake stages, in ascending order.

Kumagatake stage is characterized by the formation of pyroclastic cone with multiple craters. The eruptive materials are subdivided into 3 units by the difference in crater. The total eruptive volume of Kumagatake stage is 0.35 km^3 DRE.

In Ushiro-Asahidake stage, lava flowed down southward. After that, the lava dome was built on the summit. Total volume of this stage is 0.33km^3 DRE.

Asahidake stage is divided into two substage by the difference in eruption style. Early substage is mainly composed of magmatic eruptions. They are subdivided into lower and upper units on the basis of the stratigraphic relationship and magma type. The lower and upper units can be respectively subdivided into L1 - L3 and U1 - U5 subunits. The latest magmatic eruption of Asahidake is ca. 5 ka (Okuno 2005). The total volumes of lower and upper units are 4.50 and 0.99 km^3 DRE, respectively.

Asahidake late substage is characterized by phreatic explosions forming Jigokudani crater. The last small phreatic explosion might occur in 250 years ago (Wada *et al*. 2003).

The rocks of three stages are 2px basaltic andesite to dacite, often contain mafic inclusions. They sometimes include olivine and hornblende phenocrysts. On whole-rock chemistry, the SiO_2 contents of host rocks are 54.7-65.4 wt.% . Mafic inclusions show 54.0-59.0 wt.%. Dacitic rocks exhibits little variation in petrological features through all the stages. In contrast, mafic rocks are distinguishable according to stage and unit. Kumagatake stage can be clearly distinguished from the other stages by high Ni and low Cr contents. Ushiro-Asahidake stage and the lower unit of early Asahidake stage show similar, lower Ni and Cr contents. In contrast, the mafic rocks of upper unit of early Asahidake stage exhibit much wider variations

Heterogeneous textures suggest that magma mixing is the main magmatic process in the activities of Asahidake volcano, as mentioned by previous studies. This study revealed that magmatic compositions, especially mafic compositions, has changed in every stages, and units. That is, the mafic end-member magmas has replaced in each volcanic edifice and craters.

Keywords: Asahidake, Formation history, Transition magma, geology, petrology, Taisetsu volcanic field

SVC47-16 Room:303 Time:May 26 15:15-15:30

Slab-mantle thermal structure beneath northeast Kamchatka Peninsula constrained from high-Mg basalts and andesites

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The Kamchatka Peninsula is one of the most active volcanic arcs and corresponds to subduction of slab near the northwestern edge of the Pacific Plate. The northeastern part of Kamchatka Peninsula involves (i) triple junction including the edge of the Pacific Plate, and (ii) subduction of the seamount chain. As a result, the world-most active volcanic group (Kliuchevskoy Volcanic Group; KVG) with a wide across-arc volcanic zone (~ 400 km) is seen in this area, associated with systematic spatial variations in rock type and chemistry, including adakite near the slab edge (Portnyagin and Manea, 2008; Bryant et al., 2011). This study aims at understanding the physical-chemical conditions beneath the northeastern Kamchatka Peninsula, by studying monogenetic volcanoes and the primitive lavas near the northeastern end of the volcanic chain.

We have performed field survey and sampling of the monogenetic volcanic group (East Cones; EC) in the Kumroch Range where the Eastern Volcanic Front (EVF) terminates. EC are located above the slab of 50-80 km depth (i.e., in a fore-arc region) (Gorbatov et al., 1997) and 60-100 km south from the slab edge. About 15 monogenetic cones are distributed along the eastern cast over ~ 60 km distance. The samples from eight cones have been newly analyzed to yield the first data set on major-trace-isotopic compositions and, the K-Ar age.

The mineral assemblage of EC lavas is uniform: olivine, clinopyroxene, plagioclase, and magnetite. Based on the SiO_2, MgO, and Al_2O_3 contents, the EC lavas are classified into 5 rock-types: high-Mg basalt (HMB), high-Al basalt (HAB), high-Mg andesite (HMA), and other basalts (B) and basaltic andesites (BA). Most of the EC lavas have primitive compositions (FeO/MgO$<$1, Mg#$>$0.63) except for HAB.

All EC lavas have the common geochemical feature of the subduction-related magmas (e.g., HFSE depletion relative to LILE), suggesting important roles of water. Based on hydrous melting experiments of HMB and HMA (Tatsumi, 1982), the water contents for individual primitive magmas are estimated as follows: HMB: 2 wt.%, HAB:4 wt.%, HMA: 4-7 wt.%, B: 2.6 wt.%, BA: 3.3 wt.% respectively. Melting temperature of these primitive melts in the mantle (1.5 GPa) is estimated to be 1100-1200 ℃ , based on modeling for HREE abundances and the water contents estimated above, using the hydrous melting relations (Iwamori, 1998). The melting temperature is comparable to numerical model with an average thermal condition in arc setting (Iwamori and Zhao, 2000; Manea and Manea, 2007). Combining these information with the previously published genetic PT and water conditions in the neighboring areas, horizontal heat transport from the slab edge region (i.e., roughly from north to south) as was suggested in the previous studies (Yogodzinski et al., 2007) is not supported. We also estimate the slab surface temperature by using H_2O/Ce thermometer (Cooper et al., 2012). The estimated slab surface temperature is 620 ~ 730 ℃. Unifying the estimated slab surface temperature and the mantle melting temperature, together with trace element and isotopic characteristics, we propose that a subducted seamount which inherited a local thermal anomaly could have enhanced the flux of slab-derived fluid (not slab melt), and caused flux-melting to produce the high-Mg andesite and basalts, in the for-arc region.

Keywords: mantle thermal structure, arc volcano, high-Mg andesite, slab, subducting seamount

SVC47-17 Room:303 Time:May 26 15:30-15:45

Eruption history of Nyos volcano, northwestern Cameroon

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Lake Nyos (2 x 1.2 km), a maar volcano in northwestern Cameroon, exploded a large amount of CO2 that killed 1746 people 1986. We performed field survey in and around Lake Nyos to establish its eruptive history and formation processes.

Eruptive deposits of Nyos maar lie on Pre-Cambrian granitic basement and can be seen at the north to eastern lakeshore. These include tuff breccia (Unit A-1), scoria fall (A-2), lava flow (A-3) and base surge (A-4), in ascending order. We see no evidence of time breaks between these units as can be typified by paleosol and reworked deposits. A-1 is rich in lithic fragments, such as basaltic bombs with chilled margins (juvenile) and granitic (crustal) and peridotitic (mantle) xenoliths. Its limited areal distribution in the eastern lakeside indicates a nearby vent location (Vent 1). A-2 is clast-supported and mainly composed of well sorted basaltic scoria. The thickness increases from east to north lakeshore. A-3 is deposited 20 m above lake level with covering basement rock and A-2 in the north lakeshore. Its depositional level decreases to the lake level in other parts surrounding the lake. These evidences suggest that the vent that erupted A-2 and -3 was located at the north part of the lake (Vent 2). Distribution of A-3 extends northeastward for more than 10 km along valleys from Lake Nyos. A-4 (most voluminous) is base surge deposits characterized by cross-laminated and fines-poor facies. It consists of dominant basalt, isolated crystals and accidental lithics. The thickness is more than 30 m at the lakeside and it makes a depositional surface 1 km around Vent 2. The distal facies shows well-sorting and parallel laminations containing accretionary lapilli, which can be interpreted as air fall deposits.

A scoria cone is situated 1.5 km northeast of Lake Nyos. Ejecta from the cone (scoria fall) overlies A-4 around the lake, suggesting that activity of the cone started immediately after the Nyos maar-forming event. The cone is not a single cone but a complex structure. The main cone structure is divided into west and east, and the southern slope is collapsed. Several hummocks, which might be debris avalanche deposits from the sector collapse are found at the south to southwestern foot of the main cone. A remarkable crater (NE Vent), cutting part of the main cone is located near the northeast side. Products from the scoria cone consist of scoria fall (B-1), volcanic bombs (B-2) and lava flow (B-3). B-1 is characterized by highly vesiculated basaltic scoria whose thickness and diameter increase towards the main cone. B-2, made of basaltic bombs, was emplaced on B-1 and scattered within about 500 m around the cone. There are two types of bombs: xenolith-poor and -rich. Xenolith-poor bombs are a few meters in size and occur near the main cone and on the hummocks. Xenolith-rich bombs are abundant near the NE vent. This kind of distribution suggests that xenolith-poor bombs were produced from the main cone and xenolith-rich bombs from the NE Vent. B-3 is a small, blocky lava flow less than 500 m long on the southwest side of the main cone.

Existence of accretionary lapilli and chilled margins of juvenile materials in Unit A suggest that phreatomagmatic eruption occurred during the Nyos maar-forming eruption. Although conditions of conduit changed from wet to dry during A-1 to A-3 with shifting of the vent locations (Vent 1 to 2), catastrophic base surge caused by interaction of water and voluminous magma formed Lake Nyos consequently. After that, the locus of eruption moved to the scoria cone. B-1 formed the main part of the scoria cone, and then the cone collapsed to generate debris avalanche deposits on the southern foot. Finally, eruptive activity terminated with small effusion of lava flow from the collapsed cone and formation of NE crater ejecting xenolith-rich bombs. The volcanic activity is characterized by various products and styles of eruptions with changes in vent locations northeastwards.

Keywords: Lake Nyos, Eruption history, Maar, Scoria cone, Phreatomagmatic eruption

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

SVC47-18 Room:303 Time:May 26 15:45-16:00

Petrology of Rinjani volcano, Indonesia: The magmatic processes before and during AD 1257 caldera-forming eruption

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In order to compare distinct types of caldera volcanoes, we start to study the AD 1257 caldera-forming eruption of Rinjani volcano, Indonesia, which occurred at the summit of a large startovolcanoto. On the other hand, there exist no a large preceding stratovolcano in Japan. Thus, the volcano must be different type. The volcano started its activity ca. 0.10 Ma. The activity can be divided into four major stages, stratovolcano-building, low activity (pre-caldera), caldera-forming and post-caldera stages. Eruption rate had decreased since the low activity stage from 0.6 km^3/ky to 0.15km^3/ky. The caldera-forming stage occurred in AD 1257. The total eruptive volume during the stage is estimated to be more than 10 km^3 DRE. Activity of the post-caldera stage has continued within the caldera. The rocks of the stratovolcano-building stage, ranging from SiO_2=44.8 to 63.7%, are mainly basaltic andesite. Type of rocks has clearly changed since the low-activity stage and are amphibole dacite. The rocks of the caldera-forming one are less silicic compared with those of the low activity one. The rocks of the post-caldera stage are olivine-pyroxene andesite (SiO_2~55). Based on whole-rock chemistry, the rocks of the volcano can be grouped into two, stratovolcano-building and post-caldera stages, and low activity and caldera-forming ones. The two groups can be easily distinguished according to two distinct chemical trends in many SiO_2 variation diagrams for major (Al_2O_3, MgO, FeO, CaO and K_2O) and trace (V, Rb, Y, Zr, Ba and Th) elements. Ratios of incompatible elements and Sr isotope ratios of the rocks from two groups are also distinct. These suggest that the dacitic magmas from the low activity and caldera-forming stages could be produced not by crystallization differentiation of the basaltic magma but by additional processes, such as crustal melting and/or AFC process. Although the rocks from low activity and caldera-forming stages are similar amphibole dacite, these rocks can be distinguished in terms of two distinct trends in many SiO_2 variation diagrams. Contents of LIL elements, such as K_2O, Rb and Ba, of the rocks from each stage increase with increasing of whole-rock SiO_2. Thus, nearly parallel, positive trends are formed in such SiO2 variation diagrams. Contents of LIL elements of the rocks from caldera-forming stage are lower contents than those from low activity one at the same SiO_2 content. On the other hand, HFS elements, such as Nb, Zr and Y, show different variations of the rocks between two stages with increasing of whole-rock SiO_2 contents. Although the elements of the rocks from the caldera-forming stage show positive correlation with SiO_2 in SiO_2 variation diagrams, those from the low activity stage show negative one. Thus, the contents of LIL elements from two stages are similar in silicic dacite, whereas those are largely different in andesitic dacite. The andesitic dacite of the low activity stage is characterized by high contents of HFS elements. Considering these chemical difference in dacites between low activity and caldera-forming stages, these rocks cannot be formed by simple crystallization differentiation and/or contamination from the same primary magma. According to the temporal change of volcanic activity and erupted magma since late Pleistocene, it would be possible to consider the low activity stage as preceding stage for caldera-forming eruption. During the stage, eruption rate had rapidly decreased and magma type has also changed to be dacitic one, which is similar to the magma of the caldera-forming stage. Thus, it seems that caldera-forming, voluminous dacitic magma had been formed and accumulated during the low activity stage. However, our study revealed that the dacitic magma from these two stages are different. Thus, this would not be the case that the same dacitic magma had been continuously formed and accumulated until the caldera-forming stage.

Keywords: caldera, caldera-forming eruption, magma process, silicic magma, Rinjani volcano