The genesis of high magnesium andesites and basalts from Shodoshima in the Setiuchi district, southwest Japan

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The genesis of high magnesium andesite (HMA) magmas in subduction zones is one of the most important issues of earth science. Results of high pressure melting experiments of peridotites demonstrated that two processes could form HMA magmas in the mantle, partial melting of hydrous peridotites at P ≥1GPa and partial melting of anhydrous peridotites at P ≤0.6 GPa (Kushiro, 1969, 1972, 1974, 1996; Falloon et al., 1988; Hirose and Kawamoto, 1995; Hirose, 1997; Wood and Turner, 2009) .
The Setouchi HMAs distributed Shodoshima in SW Japan is considered to be formed by a reaction between slab-derived felsic melts and the mantle, a type of flux melting of peridoties (Shimoda et al., 1998; Tatsumi, 2006). The mantle/melt reaction model, however, has an insolvable petrological problem. Results of high pressure melting experiments indicate that the model requires additional processes forming a temperature difference larger than 150 °C in the mantle at a given pressure to explain the genetic relationships between HMAs and basalts coexisting in Shodoshima (Shimoda et al, 1998). The additional process has not been proposed by researchers advocating the mantle/melt reaction model.
Addition to this petrological incongruity, the mantle/melt reaction model is not consistent with seismic and geologic background of Shodoshima. The model considers that hydrous felsic melts would have been derived from sediments on the subducting Shikoku Basin lithosphere. The deep seismic zone representing the subducting slab, however, is not clear beneath Shodoshima, which implies that the subducting slab would not extend there even at the present day. The Setouchi magmatism occurred at around 14 Ma, which is the post period of the Takachiho Orogeny (20 -15 Ma). During the orogeny, the Shimanto accretional belt was uplifted (Sakai, 1990), which indicates a strong mechanical coupling between the SW Japan lithosphere and the Shikoku Basin lithosphere at that time. Under such a strong mechanical coupling between lithospheres, sediments on the Shikoku Basin would not have subducted effectively in the mantle. Instead, sediments would have been accreted to the SW Japan lithosphere. Sediments on the Shikoku Basin therefore would not have been transported beneath Shodoshima if the subducting slab reached there at that time. These seismic and geologic incongruities erode the confidence of the mantle/melt reaction model for the genesis of the Setouchi HMA magmas in Shodoshima.
Instead, these petrologic, seismic and geologic features indicate that the association of basalts and HMA in Shodoshima would have been formed by multi-stage partial melting of relatively anhydrous source mantle. The basalt magmas would have segregated at P > 1GPa and the HMA magmas would have finally segregated at P = 0. 5 GPa. In the context of the multi-stage partial melting model, geochemical features of the HMAs attributed to subducting sediments would be a result of involvements of accretional oceanic sediments at the base of the crust in the source mantle. This is consistent with results of an integrated seismic experiment across Setouchi implying forearc accretional belts such as the Sambagawa belt and/or the Shimanto belt gwould extend to the base of the crust beneath Shodoshima (Ito et al., 2009).

Keywords: high magnesium andesite, basalt, multi-stage partial melting

Genesis of Quaternary volcanism of high-Mg andesitic rocks in the northeast Kamchatka Peninsula

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Arc magmatism is a product of subduction factory, involving thermal and chemical interactions between a subducted slab as a material input and mantle wedge as a processing factory. In turn, the compositions of arc magma provide invaluable information concerning the material input and the interactions. The northeast Kamchatka Peninsula is an ideal field to examine such interactions and relationships, being characterized by (1) subduction of the Emperor Seamount Chain (Davaille and Lees, 2004), and (2) possible material and thermal interaction among the subducted slab, the overlying mantle wedge and the sub-slab mantle via the edge of subducted Pacific slab (Portnyagin and Manea, 2008). Within this area, a monogenetic volcanic group occurs along the east coast, including high-Mg andesitic rocks and relatively primitive basalts (East Cones, EC (Fedorenko, 1969)). We have conducted geochemical studies of the EC lavas, with bulk rock major and trace elements, and K-Ar and Ar-Ar ages, based on which a possible contribution of subducted seamounts and its relation to the tectonic setting are discussed.

The elemental compositions indicate that the lavas from individual cones have distinct mantle sources with different amounts and/or compositions of slab-derived fluids. Based on mass balance, water content and melting phase relations, we estimate the melting P-T conditions to bet ~1200 ℃ at 1.5 GPa, while the slab surface temperature is 620 –730 ℃ (at 50-80 km depth). Compared with the southern part of Kamchatka, the slab surface temperature beneath EC seems to be high due to the thinner Pacific slab associated with the seamount chain and/or the plate rejuvenation from a mantle plume impact (Davaille and Lees, 2004; Manea and Manea, 2007).

The K-Ar and Ar-Ar ages of the Middle Pleistocene are consistent with the tephrochronological study (Uspensky and Shapiro, 1984) and the present tectonic setting after 2 Ma (Lander and Shapiro, 2007). The high-Mg andesite with the highest SiO_2 content in the EC lavas shows the oldest age (0.73 ±0.06 Ma) within not only EC but also the northeast part of Kamchatka (e.g., Churikova et al., 2015, IAVCEI). On the other hand, the rest of EC lava samples show relatively younger ages to 0.18 ±0.07 Ma. These results suggest that the EC lavas including high-Mg andesite and basalt were generated by mantle flux-melting induced by dehydration of a subducted seamount inheriting a local thermal anomaly (Nishizawa et al., 2014, JpGU; 2015, JpGU).

Keywords: high-Mg andesite, island arc magma, Kamchatka arc, seamount subduction

Geology and petrology of Taisetsu volcano group, Japan; Evolution of magma and activity ages.

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Taisetsu volcano group is located in the northern part of the Taisetsu-Tokachi volcanic chain, which is situated at the southern end of Kuril arc. The volcano group started its activity ca. 1 Ma and is composed of andesitic lava domes and stratovolcanoes.
Geological studies of the whole area in Taisetsu volcano group were carried out by Konoya *et.al*. (1966) and Katsui *et.al*. (1979). In these studies, the volcanic stratigraphy was investigated mainly based on the preservation state of the terrain, however, radiometric age data and petrological features were not considered. K-Ar ages reported in survey by NEDO (1990) are inconsistent with the stratigraphy, resulting in difficulty of re-examination of the stratigraphy. We performed a detailed geological survey, petrological study and K-Ar dating of the whole area of the volcano group, in order to investigate the structure of volcanic edifice, the formation history and the magma transition.
According to the preservation state of the terrain, petrological features and K-Ar ages of 26 samples, the activity of the volcano group can be divided into two stages; Older stage and Younger stage. During Older stage (ca. 1-0.7 Ma), fluidal andesite lavas were effused from several eruption centers to form flat-shaped volcanic edifices. These volcanic edifices are arranged in a N-S direction, and have been dissected by erosion. During Younger stage (< ca. 0.2 Ma), several stratovolcanoes and lava domes were formed in the northern - central part. Many of these volcanic edifices have the steep terrain, and are distributed irregularly. Younger stage is subdivided into three sub-stages (Y1, Y2 and Y3) in the difference of eruption style. In Y1 (0.16-0.06 Ma), stratovolcano and several lava domes were formed in the northwestern - central part. In Y2 (ca. 30 ka), the volcanic activities were the most explosive in the history. A plinian column and related pyroclastic flows were occurred, and formed the Ohachidaira caldera with 2 km in diameter. In Y3 (< ca. 30 ka), main eruption centers moved to the southwestern part of the caldera, and formed several stratovolcanoes and a lava dome.
K-Ar ages of the samples in Older and Younger stage are in the range of 1.02-0.66 Ma and 0.16-0.06 Ma, respectively. No ejecta are found between 0.66 Ma and 0.16 Ma, suggesting that there is a dormant period for ca. 0.5 Myrs in the history.
Petrological features of the ejecta of Taisetsu volcano group have greatly changed between the Older stage and Younger stage. All of the rocks are basaltic-andesite to dacite. These rocks contain Pl, Cpx, Opx and Mt as phenocrysts, associated with minor amounts of Ol, and Qz phenocrysts in some rocks. In addition, the rocks of Older stage do not contain Hb phenocrysts, while those of Younger stage usually include Hb phenocrysts. The host rocks from Older stage is characterized by high contents of incompatible element such as P_2O_5, Zr,Y,Nb, compared with those of Younger stage.
The magma discharge step diagram of the volcano group was constructed based on the age data and estimated eruptive volume. The eruption rate of Older stage was >0.08 km^3 /ky, while Younger stage is >0.28 km^3 /ky. For Older stage, the eruption rate is maximized with 0.36 km^3 /ky in the period from 0.82 Ma to 0.74 Ma. For Younger stage, the eruption rate of each sub-stage is as follows; >0.20 km^3/ky for Y1, >1.2 km^3/ky for Y2, and >0.30 km^3/ky for Y3. In addition, for the Y1, the eruption rate is the highest in 0.11 Ma to 0.09 Ma with 0.76 km^3/ky.
Based on incompatible element contents and occurrence of Hb phenocryst in andesite, we consider

that magma type had changed largely during the possible long dormancy from 0.66 Ma to 0.16 Ma. This may be related to the tectonic change at the junction between NE Japan and Kuril arcs.

Keywords: Volcano, Eruption rate, Formation history, Transition of magma, Taisetsu volcano group

^{14}C dating for the Holocene tephra deposits at the Esan volcanic complex, northern Japan

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Phreatic explosion is a smaller-sized eruption that is randomly generated from the pressurized steam chamber above a heat source. Thereby, the phreatic explosion may become hazardous, in the case where the social facilities or residential areas or people are very close to the active craters. Indeed, such a phreatic hazards has come arisen at the 2014 Ontake eruption, and then, it has widely become recognized as one of critical issues in volcanic hazards of Japan.
GSJ/AIST has a geological map project of “Esan Volcanic Complex (EVC)” since FY 2014. In the EVC, a large number of residential areas with tourist accommodations are located at the aprons where the distance to active fumarole craters is only 1-2 km. This spatial relationship implies a high risk of volcanic hazard even by a small phreatic explosion. Substantial information on the risk of phreatic explosions at EVC should be unraveled accurately. Yet, the spatial and temporal relationships of Holocene tephra deposits have been uncertain. We have therefore performed twelve measurements of ^{14}C datings into the soils between Holocene tephra units.
The stratigraphic sequence of Holocene tephra units has been determined by the geological and geochronological studies, based on those originally established from Arai (1998 MS) (Okuno et al., 1999; CDPCEV, 2001; Miura et al., 2013). The sequence from the oldest to the youngest is EsMP, Es-1, Es-2, Es-3, Es-4, Es-5 and Es-6. EsMP is the episode of Esan lavadome (Ed) and block-and-ash flow (PDC) deposit, and is the largest in the Holocene eruption units. A charcoal in the PDC deposit has revealed the reliable ^{14}C age of 8,648-8,594 cal yBP (1 sigma) for the EsMP. Es-1, 2, 3, 4, 5 and 6 are the unit originated from phreatic explosions at the Ed lavadome, and are constituted by phreatic ash-fall, pyroclastic surge (PDC) and/or lahar deposits. Previously obtained ^{14}C ages (cal yBP) for these phreatic units are the followings. Es-1: 5,909-5,680 (bottom soil, 2 sigma), Es-3: 2,435-2,344 (a charcoal soil in PDC, 1 sigma), Es-4: 1,894-1,829 and 636-551 (bottom and cover soils, 1 sigma). Eruption ages of Es-5 (AD1846) and Es-6 (AD1874) have been determined by certain reliable documents.
Our new measurements of 12 samples (bottom and cover soils) for ^{14}C dating have revealed a certain constraints into the eruptive ages of Holocene tephra units (cal yBP, 2 sigma). Es-1: 5,595-3,984, Es-2: 4,150-3,477, Es-3: 3,341-1,822 and Es-4: 681-536. These constrained ranges of eruption ages are consistent to the previously obtained ^{14}C age results. The further constraint by all of available measurements implies that the Es-4 unit might have erupted at 681-551 cal yBP.

Keywords: 14C dating, phreatic explosion, Holocene, Esan volcanic complex

The effect of external water to plinian and phreatoplinian eruption

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Phreatoplinian eruption is one of phreatomagmatic eruption that occurs when vesiculated and fragmented felsic magma come into contact with external water. This eruptive style has not been observed yet, and it is defined by typical characteristics of deposits, which include enriched fine-grained ash particles produced by water cooling contraction granulation (Houghton et al., 2000) or phreatomagmatic explosion (Self and Sparks, 1978). Results of experiments on water-magma interaction (Hiroi and Miyamoto, 2012) and analyses of whole-grainsize distribution (Hiroi and Miyamoto, 2015) are contradictory to both fragmentation mechanisms, and therefore, this fine-grained feature must be the result of accretion by liquid water during transportation (Self and Sparks,1978). Generally, the eruptive style is controlled by magma-water ratio, and magmatic eruptions occur when the amount of water is small enough than magma (Wohlets and Heiken, 1984). Koyaguchi and Woods(1996) simulated the behavior of an eruptive column affected by external water and showed that the column has been kept even if containing water account for 30wt%. Both plinian and phreatoplinian eruptions form eruptive columns; therefore, their borders appear to be dependent on the amount of water in the column. This study examines the effect of external water on plinian and phreatoplinian eruptions. The latest activity in Towada volcano is the Heian eruption, where the inner caldera lake in a double caldera was the vent, and all eruptions occurred through the lake water. Although the first unit OYU-1 erupted in contact with external water, it has been classified as a plinian eruption considering the features of the deposit such as facies, sorting, and F-D plot (Hiroi et al., 2015). OYU-1 contains cauliflower pumice (Heiken, 2006), which is rare although plinian eruptions are very common in the world. In addition, it does not exist in older plinian deposits in Towada volcano. The formation of cauliflower pumice requires an amount of water greater than that in the aquifer. However, the presence of cauliflower pumice implies that phreatoplinian eruptions do not occur unless external water is taken into the eruptive column even though magma come into contact with a large amount of external water. OYU-2 mainly consists of base-surge, and its characteristics such as fine-grained feature and vesiculated tuff correspond to phreatoplinian eruptions (Hiroi et al., 2015). The eruptive rate of OYU-2 is possibly larger than that of OYU-1. Although the water-magma ratio indicates magmatic eruption, OYU-2 is definitely a phreatoplinian eruption. The heat transfer efficiency from magma to water is expected to have increased because bubble growth in magma before contacting water increases successively from OYU-1 to OYU-2 (Hiroi and Miyamoto, 2011). Through heat transfer, steam is generated and the amount of water taken into the column is increased, effectively creating a wet column for phreatoplinian eruption. Plate-like glass shards indicating large expanded bubbles are outstanding in many phreatoplinian ejecta (Wohlets and Heiken, 1985). Cauliflower pumice did not form under quenching in phreatomagmatic activity, indicating that efficient heat transfer occurred. These suggest that bubble growth and heat transfer efficiency are very important for phreatoplinian eruptions to occur. With the abovementioned results, this study proposes that plinian eruptions affected by external water are common, because of non-existence both phreatomagmatic explosion and water cooling contraction granulation, the initial condition of phreatoplinian and plinian eruptions are the same, and phreatoplinian eruptions may occur if both the conditions of sufficient water and bubble growth are satisfied.

Keywords: phreatoplinian eruption, plinian eruption, Towada volcano, cauliflower pumice, heat transfer efficiency

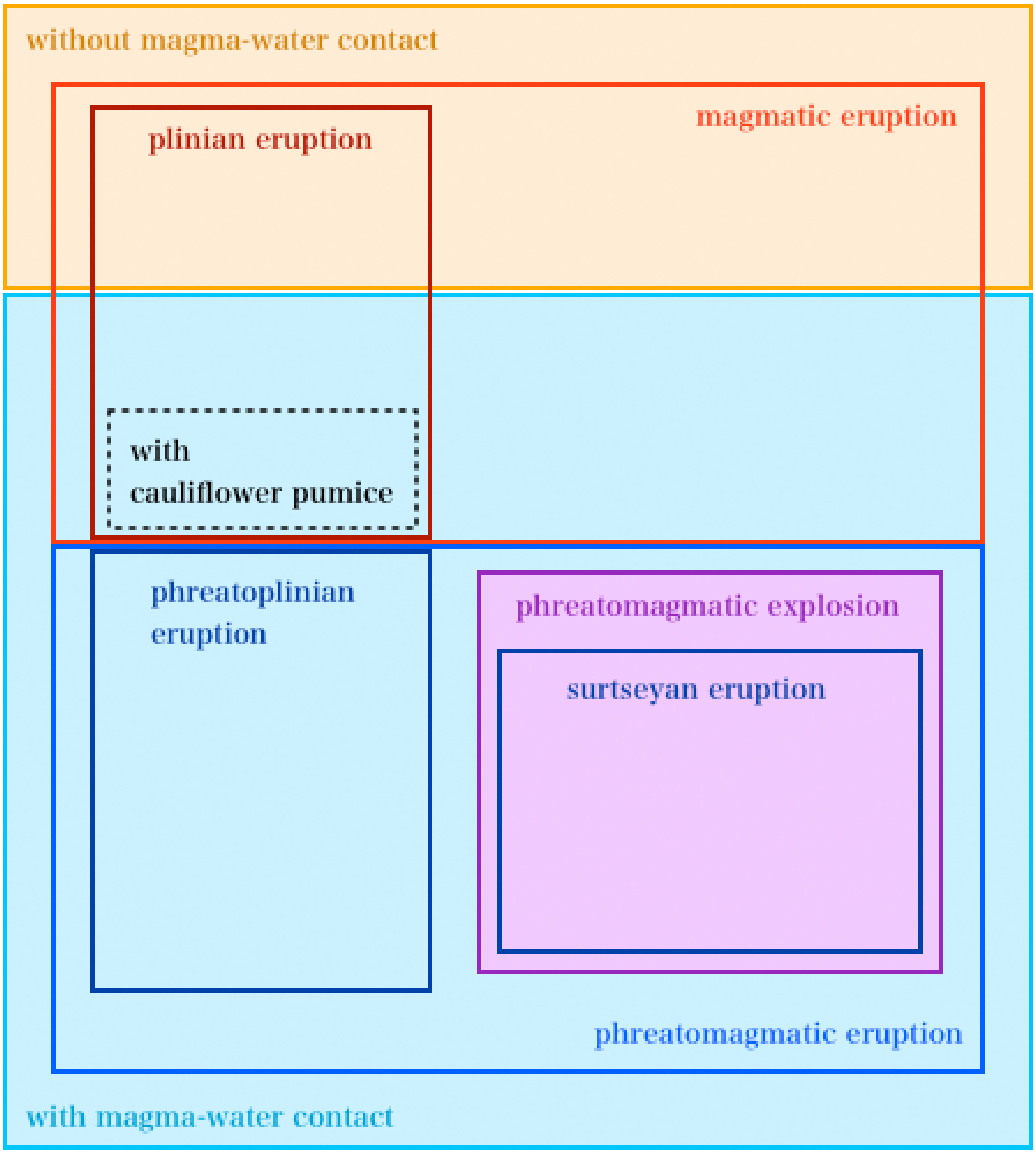

図. 本研究の結論から導かれる外来水の関与と噴火形態及び噴火様式の関係分類図

Fig. The new classification diagram of eruptive style on magma-water contact from this study.

Geologic and petrologic study on basal part of the Goshikidake and adjacent lavas of the Zao volcano

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Zao volcano is an active stratovolcano in NE Japan, and has a long-eruption history of ca. 1 million years. Horse shoe shaped Umanose caldera was formed in the summit area at the beginning of the newest stage (ca. 35ka to present). The Goshikidake, the youngest cone, began to grow in the caldera at ca. 2ka. The present crater Okama is in the western part of the Goshikidake. We performed geologic and petrologic study on the basal part of the Goshikidake and adjacent lavas to reveal their magma feeding systems.
The Goshikidake is composed of Goshikidake pyroclastics, which is divided into 5 units. The lowest unit can be further divided into Goshikidake-nanbu pyroclastics, Goshikidake-toubu pyroclastics (pyroclastics main units). Near these pyroclastics, the Furikodaki lava and the Goshikidake-nanpo lava and pyroclastics (lavas main units) distribute.Goshikidake-nanbu pyroclastics are consisted of pyroclastic surge deposits and vent breccias. The latter intrude nearly vertically into the surge deposits. The Goshikidake-toho pyroclastics are composed of stratificated tuff ~ lapilli tuff ~ tuff breccia including various amounts of volcanic bombs. The Furikodaki lava flowed down from the northeastern base of the Goshikidake cone along a stream. The lava shows elongated shape with ca. 750m in length and 20~30m in width. The Goshikidake-nanpo lava and pyroclastics cropped out in a narrow area of ca. 650m south from the summit of Goshikidake. This unit is composed of upper brecciated lava with coarser lateral and finer vertical joints, and lower hyaloclastite-like tuff breccia.
All rocks are medium-K calc-alkaline olv bg. cpx-opx andesites (56-58wt% $SiO_{2,}$ 0.89-1.02 wt% K_2O). Most of plagioclase phenocrycrysts has dissolution textures such as dusty zone and patchy zoning. We note that plagioclase phenocrysts in lavas main units lack the dusty zones.
The peak compositions of opx, cpx phenocrycryst core compositions are similar among units. These are 64-65 Mg# and around ca. 66 Mg#. The compositions of Mg-rich mantles of opx phenocrysts within ca. 30 um from rims are wider in rocks from the lavas main units than the pyroclastics man units. The core compositions of plagioclase phenocrycrysts show wide range of An_{62-92}. The main peak compositions in the lavas main units are in An_{68-70} and around An_{78}, and subordinate peak is in An_{90}. Those of the pyroclastics main units are in An_{64-66}, An_{76-78}, and An_{90}. These petrologic features suggest the products were formed by magma mixing of mafic and felsic end-member magmas.
Bulk SiO_2 contents of the lavas main units are 57.5-58wt%, while those of the pyroclastics main units are 56-57.7wt%. As a whole, all products are plotted on same variation trends in silica variation diagrams, but looking at detail, rocks from the pyroclastics main units show higher trend in FeO, TiO_2, Rb/Zr diagrams and lower trend in MgO diagram than the other products.
Although the bulk compositions are slightly different between the pyroclastics main and lavas main units, the bulk SiO_2, phenocryst assemblage, and T-P-H_2O conditions of the felsic end-member are similar for all units. These are estimated to be 62 wt% SiO_2, Mg# 63-66 opx + Mg#65-70 cpx + An_{60-70} plg, ca. 1000 ℃, 1.7-2.7kb, 2.5wt% H_2O, while those of mafic end-member are 48-49wt% SiO_2, An_{90} plg + olvine (Fo_{78}),ca 1100 ℃, <2kb, 2.0wt% H_2O.
We calculated the time scales from magma mixing to the eruption by comparing the zoning profiles and calculated diffusion ones for olv, plagioclase, and opx phenocrysts. The obtained time scales

for olv, plagioclase, and opx are 1 year to 3 years, 80 to 300 days, and ~ 100 years. The percentage of longer lived opx is higher in the lavas main units.

Keywords: Zao volcano, Andestic lava, Pyroclastic surge, Magma mixing

Stratigraphical study on the Middle Pleistocene pyroclastic flow deposits, northern Tochigi and southern Fukushima Prefectures and the eruptive history of Takahara volcano

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Introduction Middle Pleistocene pyroclastic flow deposits are distributed in northern Tochigi and southern Fukushima Prefectures. Shiobara-Otawara pyroclastic flow deposit (So-OT; Suzuki et al., 2004) is widely distributed in the northern Tochigi Prefecture. Moreover, fall-out tephra of So-OT is distributed into southern Aizu region (Suzuki et al., 2004), off Shimokita Core (Suzuki et al., 2012). However, there are controversy on stratigraphy and ages of So-OT and its related tephras. This is caused from the difference in the identifications of APms (Suzuki & Hayakawa, 1990) and KMT (Suzuki, 2000). This paper discusses the stratigraphy and ages of So-OT and its related tephras, and refers to the source of two newly defined tephras. Finally, we discuss the eruptive history of Takahara volcano.

Characteristic properties of the pyroclastic flow deposits We recognized three pyroclastic flow deposits, that is, So-OT, First Shiobara-katamata Tephra (So-KT1; new defined), and Second Shiobara-katamata Tephra (So-KT2; new defined) in descending order. So-OT is roughly divided into lower and upper parts. Lower part is a pumice fall deposit. Upper part is pyroclastic flow deposits. This pyroclastic flow deposits are divided into pumice flow deposit (lower), pumice flow deposit (middle), and scoria flow deposit (upper). Middle pumice flow deposit is widely distributed in the area from Utsunomiya City to Nasu Town, and is cropped out in the Yaita Hills as the thickest deposit. So-KT1 is divided into Unit a-d. Unit b is a pyroclastic flow deposit, and widely distributed in the east part of Yaita Hills. Refractive index of orthopyroxene in So-KT1 is higher than those in So-OT and So-KT2. Major chemical composition of volcanic glass shards of So-KT1 is distinguishable from those of So-OT and So-KT2. So-KT2 is a pumice flow deposit. The differences between So-KT1 and So-OT are mineral assemblage (only So-KT2 contains quartz and small amount of hornblende), and major chemical composition of volcanic glass shards.

Stratigraphy and ages of the pyroclastic flow deposits Pyroclastic fall deposits of So-OT are observed at 6 points on land. The most northern point is located in the southern Fukushima City. We newly defined Sawada fall pumice deposit (SwdP) at Tsurugaike in Shimogo Town, Fukushima. SwdP is sandwiched between lower APms and upper So-OT, and distribution and layer thickness are similar to So-OT fall tephra. SwdP has maximum refractive index of orthopyroxene similar to So-OT. Stratigraphy of the pyroclastic flow deposits shown above and other<s>s</s> tephras in descending order is So-OT, So-KT1, A_2Pm (Suzuki & Hayakawa, 1990), So-KT2 and A_1Pm (380-410 ka; Suzuki and Hayakawa, 1990; Suzuki, 2000; Machida & Arai, 2003), and BT72 (349 ka; Yoshikawa & Inouchi, 1991; Nagahashi et al., 2004) is positioned under So-KT1. A_2Pm is positioned under Kkt (334 ka; Machida & Arai, 2003; Nagahashi et al., 2004)(Suzuki & Hayatsu, 1991). Correlation of A_1Pm and A_2Pm is confirmed by mineral composition and refractive index of orthopyroxene. These stratigraphical relationships indicate that ages of So-OT and So-KT1 is 300-349 ka and that of So-KT2 to be 334-410 ka.

Source of pyroclastic flow deposits and the eruptive history of Takahara volcano It is assumed the source of So-OT, So-KT1 and So-KT2 is the Shiobara caldera due to grain size of essential products in pyroclastic flow deposits, and distribution, grain size and thickness changes of fall deposits. From the results shown above and previous studies (Inoue et al., 1994; Okuno et al., 1997; Tsurumaki et al., 2013 etc.), we considered the eruptive history of Takahara volcano, and concluded that it is roughly divided into 5 stages. Eruptions of the three pyroclastic flows equivalent to the second stage is Formation of caldera had occurred, within 100,000 years.

Keywords: Pyroclastic flow deposit, Takahara volcano, Shiobara Otawara tephra, Middle Pleistocene, Tephrochronology,

Eruptions during 6000 years at Nikko-shirane volcano, Central Japan

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1.Geological Survey of Japan

Six tephra layers are recognized in the Nikko-shirane volcano, central Japan without 1872-73 and 1889-90 AD eruptions. The top tephra layer at the foot of Mt. Nikko-shirane (Nks-1) is considered to be produced by 1649 AD eruption, which is the biggest one of the record. We show geology, petrography and radioactive carbon dating of these tephra at summit and foot of the Mt. Nikko-shirane, and discuss about the volcanic history in the last 6000 years. Mode compositions of tephra 250-500 μm in diameter were analyzed after washed out and separated into 250, 250-500, 500-1000 and >1000 μm particles by wet sieve.
At the foot of Mt. Nikko-shirane, four tephra layers from the Nikko-shirane volcano and three alien tephra layers were recognized. The Nikko-shirane tephra layers are named Nks-1, 2, 3, 4 downward (Okuno, 1993). We subdivide the Nks-1 tephra deposit into Nks-1a, 1b, 1c, 1d downward based on the color and grain size differences at the sampling point. The Nks-1a-d tephra contain vesicular and transparent−light-colored glass (pumice), non-vesicular and light-colored glass, non-vesicular and dark-colored glass, lithic clast, altered clast, and plagioclase, quartz, clinopyroxene and orthopyroxene crystals. The Nks-1a-c also contain a small amount of vesicular and dark-colored glass (scoria). The Nks-1 tephra deposit contains 16% pumice in maximum.
Two of three alien tephra layers are the Asama-B and Haruna-ikaho tephra deposits downward, and both are intercalated between the Nks-1 and 2 (Okuno, 1993; Tsutsui et al., 2005). We found an alien tephra layer just beneath the Nks-3 tephra. It is brownish silty ash with altered orangey pumice at the sampling point. The tephra contains 15% vesicular and colorless glass and they have similar major element composition to the Asama-D tephra.
At the summit of Mt. Nikko-shirane, we found a 0.17 m thick tephra layer beneath 0.07 m thick surface soil. Lower part of the tephra shows grayish white and the upper part shows yellowish brown ash. More than 80% components of the tephra are lithic clast, altered clast, and colorless minerals. Radioactive carbon dating of black soil beneath the tephra indicates 1686-1731 and 1808-1927 cal AD (^{14}C dating: 110 ±20 yrBP). Based on the ^{14}C dating, the tephra layer would be produced by 1872-73 or 1889-90 eruption.
We propose that the Nks-1 might be magmatic eruption due to the Nks-1 tephra deposit contains 16% pumice in maximum. On the other hand, the tephra at the summit of Mt. Nikko-shirane should be the product of a phreatic eruption because of absence of pumice or scoria.

Keywords: Nikko-shirane volcano, Tephra stratigraphy, Holocene

Historical eruption of Nikko Shirane Volcano

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It summarizes the eruptive history of Nikko Shirane volcano on the basis of the historical records. The historical eruption of Niko Shirane Volcano was occurred at 1649, 1872-73, 1889-90 from historical records. All, after the fumarolic or rumbling activity, phreatic eruption has occurred. In addition, lahars occurred. Lahars were generated by overflowing water (hot springs) from the crater with the eruptions.

Keywords: Nikko Shirane, eruption, historical record, lahar, phreatic eruption

Two eruptive events occurred around 40 ka at the Akagi volcano in North Kanto, NE Japan: Eruptions of the Akagi-Kanuma and Akagi-Shimizu Lithic Tephras

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Mt. Akagi, located in the northern Kanto, Northeast Japan, is a large Quaternary stratovolcano. The Mizunuma Chert Lapilli Pumice (CLP) dominated by accidental lithic fragments had been reported by Moriya (1968). The aim of this study is to clarify (i) distribution, (ii) stratigraphic position, (iii) sedimentary structure, (iv) petrological features, (v) mineralogical features, (vi) volume and (vii) eruption style, for CLP in more detail. We found new features of CLP then, the deposit was re-defined as the “Akagi Shimizu Lithic Tephra (Ag-SLT)”. The Ag-SLT is distributed to eastern region from Mt. Akagi. The Ag-SLT exists on the Akagi Kanuma Pumice (Ag-KP), erupted at 44 ka. The Ag-SLT is composed of four units: 1L, 2P, 3P, 4L, with lithic fragments from Ashio Belt. Unit 1L has accretionary lapilli (φ13 mm) in its bottom layer. The yellow pumice clasts within the unit 2P has high SiO_2 (77.5 - 80.0 wt.% : in major elements chemical composition in volcanic glass), compared to that in Ag-KP (76.0 -77.5 wt.%). Unit 3P is Plinian deposits with pumice and lapilli. Unit 4L is Phreatomagmatic eruption deposits. The Volume of Ag-SLT is about 6 km^3 (VEI=5) as the same as the Hoei eruption of Mt. Fuji in 1707. The pumice within the Ag-SLT was formed with crystallization differentiation in magma reservoir. The interval of eruptions (dormant period) was suggested by the existence of the volcanic soil deposits (Tephric loess, so-called Loam) between Ag-KP and Ag-SLT.

Keywords: Mt. Akagi, Plinian eruption, lithic tephra, Ag-KP, Ag-SLT

Holocene eruption history of the Motoshirane Pyroclastic Cone Group, Kusatsu-Shirane Volcano

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The Kusatsu-Shirane Volcano, one of the most active volcanoes in Japan, is situated near the boundary of the Gunma and Nagano Prefectures. The summit of the volcano consists of three young pyroclastic cones, i.e., the Motoshirane Pyroclastic Cone Group (MPCG), the Ainomine Pyroclastic Cone, and the Shirane Pyroclastic Cone Group (SPCG). All historical (phreatic) eruptions occurred in the summit area of the SPCG. In contrast, the eruptive history of the MPCG has not yet been studied in detail. In order to decipher the eruption history of the MPCG, correlations between eruptives constituting the pyroclastic cone edifices and dispersed tephra are investigated. Petrological affinities, such as whole rock major-element chemistry and mineral assemblages, are utilized to identify eruptives contemporaneous with various modes of emplacement. The MPCG consists of a group of overlapping pyroclastic cones, including Kagamiike-kita, Kagamiike, Younger Motoshirane, and Older Motoshirane, which are arranged from north to south. The summit of each cone is cut by overlapping craters. In addition, three lava flows, i.e., the Isidu, Sessho, and Furikozawa lavas, poured out from the bases of the Younger Motoshirane, Kagamiike, and Kagamiike-kita cones, respectively. Stratigraphic relations suggest that each cone consists of three eruption stages; the initial lava-flowing stage, the subsequent cone-forming stage (accompanied by dome extrusion), and the final crater-enlarging explosion stage. The surface of the Older Motoshirane cone is covered by a bomb layer, which formed during the crater- enlarging stage of the adjacent Younger Motoshirane cone. In turn, the surface of the Younger Motoshirane cone is covered by the bomb layer that formed during the crater- enlarging stage of the adjacent Kagamiike cone. The proximal eruption products of the Kagamiike cone can be correlated with the 12L Volcanic Sand (4.9 cal ka BP; Yoshimoto et al., 2013) on the eastern foot based on geochemical affinities. We identified six new phreatic tephra layers sandwiched by soil layers on the southern flank of the Kagamiike cone. Here, the volcanic bombs from the Kagamiike-kita cone (probably formed during the crater-enlarging stage of the Kagamiike-kita cone) rest on the brown soil of ca.1.5 cal ka BP. In summary, the volcanic activity of the MPCG sifted from south (Older Motoshirane cone) to north (Kagamiike-kita cone), lasting until ca. 1,500 yr. BP.This study was supported by a grand-in-aid for young scientists from PaleoLabo Co. Ltd.

Keywords: Kusatsu-Shirane Volcano, Holocene, etruption history

Clues to Reconstruction of Sequence of Eruptions in the Early Stage of the Asama-Maekake Volcano

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The Asama-Maekake volcano has been active for about 10,000 years. Little information, such as the distribution and stratigraphy of the eruptive products including pyroclastic fall deposits, pyroclastic flow deposits, and lava flows, is available for eruptions predating the 12^{th} century owing to the lack of outcrops, especially in the proximal area. However, many pyroclastic fall deposits have been recognized in the distal area, mainly in the southeast direction, in previous studies, indicating that large-scale eruptions occurred repeatedly in the history of the volcano. In this study, the distribution of a pyroclastic fall deposit called Miyota pumice (referred to as As-My hereafter), which is distributed south of the summit crater, was mapped. The C14 ages of the samples of black humus soil that is covered with As-My, were dated to ca. 6400 cal.YBP. These ages are almost the same as that of the pyroclastic fall deposit As-UB distributed on the northern flank. The As-UB contains many fall units and is associated with a small-scale pyroclastic flow deposit in the proximal area. Bulk-rock chemical compositions of the pumice grains from As-My and As-UB were plotted in similar area to those for As-E on a SiO_2-MgO variation diagram. These data suggest that the As-My, As-UB, and As-E are products from eruptions that occurred around 6000 years ago or a single eruption. Although the stratigraphic relation among these deposits distributed in different directions is difficult to determine, the fragmental information described above is expected to be helpful for reconstructing the sequence of eruptions in the early stage of this volcano.

Keywords: Pyroclastic fall deposit, stratigraphy, Asama-Maekake Volcano

What happened during the climactic stage of Tenmei eruption of Asama-Maekake volcano in 1783AD ?: detailed process of the eruption of Agatsuma pyroclastic flow and Onioshidashi lava flow.

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The detailed process of eruptions of Agatsuma pyroclastic flow and Onioshidashi lava flow during the climactic stage of Tenmei eruption (1783AD) of Asama-Maekake volcano is reexamined, based on the occurrence of volcanic deposits, their stratigraphy and old documents. The Agatsuma pyroclastic flow deposit comprises four stages: the earliest, early, A-scoria flow and late stages. The pyroclastic flows of the earliest stage and A scoria flow were the column-collapsed type. Those of the early stage were the boilover type and those of late stage were the fountain-collapse type. The Onioshidashi lava flow is clastogenic and consists of three units: L1, L2 and L3. The L1 and L3 are the slope-collapsed (rootless) type; the formation of L1 was synchronous with the last stage of Tenmei pumice fall deposits (21p), which were the climactic sub-Plinian eruption. The L2 is the spatter-fed type, outpouring from the crater of Kamayama welded pyroclastic cone. The erliest stage of Agatsuma pyroclastic flow was small-scale and occurred during the eruption of Tenmei pumice fall deposit around 18:00 in August 3 (corresponding to 10a to 14a). The early stage of Agatsuma pyroclastic flow began during the dormant stage of eruption of Tenmei pumice fall deposit from 16:00 to 18:00 in August 4 (corresponding to 20a). The pyroclastic flow deposits of the early stage with low aspect ratio are abundant in matrix ash, the essential clasts of which are high in SiO_2 (62 to 64wt. %). The A-scoria flow was small-scale and erupted during the eruption of Tenmei pumice fall deposit around 20:00 and 24:00 in August 4. The late stage of Agatsuma pyroclastic flow deposit erupted from 3:00 to 6:00 in August 5 just after the cessation of Tenmei pumice fall deposit. They show high aspect ratio and are relatively poor in matrix ash, the essential clasts of which are low in SiO_2 (61 to 62wt. %). The L1 of Onioshidashi lava flow with relatively high SiO_2 content (60.5 to 64wt. %) began to flow down around 18:00 in August 4 during the eruption of Tenmei pumice fall deposit and continued to 3:00 in August 5. The onset of effusion of L2 with relatively low SiO_2 content (60 to 63wt. %) was around 3:00 in Augusut 5 concurrent with the eruption of late stage of Agatsuma pyroclastic flow. The flowing down of L3 (60.5 to 61.5wt. %) of the Onioshidashi lava formed by the collapse of slope of Kamayama pyroclastic cone was later than 3:00 in August 5.

Keywords: Asama volcano, Tenmei eruption, pyroclastic flow, clastogenic lava flow

Lava tubes and lava tube caves are formed in the lava flow of Nishinoshima volcano in Ogasawara islands?

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[Introduction] Nishinoshima which consists of andesite lava continues an eruption since November 20,2013. Various reports [1),2)] on the previous 1973 year eruption and on this 2013 eruption are referring about existence of "lava tunnel" (lava tube or lava tube cave). Here, the possible formation of "lava tunnel" was considered based on hydrodynamic model as Bingham fluid. Because a lava tube cave (lava tunnel) exists clearly in a basalt lava flow, however, any lava tube caves have not been found hitherto in an andesite lava flow [3),4)] .
[Hydrodynamic model of a lava tube and hollow (lava tube cave) formation] A considered model is indicated on figure 1 where M is head height by magma pressure, L is length of lava tube and R are the lava tube radius, and αis slope angle of a lava tube. Case(A) shows the lava spouted from a crater goes down a slope and forms a lava tube. The flow in the lava tube is controlled by the magma pressure and gravity (forced flow). After the termination of eruption, two cases (B) and (C) are considered. Case(B) shows a “filled lava tube” in which lava is stayed in the tube without drained out from the tube. Case (C) shows a “lava tube cave” in which the lava in the tube can be drained out by the gravity (free flow), a hollow is formed in the tube. For Case (A), M/L>0 and $\tau_W = (\rho\ g\sin\alpha + \rho gM/L)\ R/2 > f_B$, for Case(B), or Case(B), M/L=0 and $\tau_W = (\rho\ g\sin\alpha)\ R/2B$, for Case(C), M/L=0 and $\tau_W = (\rho\ g\sin\alpha)\ R/2 > f_B$, where
τ_w is shear stress on the tube wall, f_B is Bingham yield strength of lava, g is the gravity force and ρis lava density.
[Estimate of a presence of a lava tube and a lava tube cave] From the correlation line between SiO_2wt% and Bingham yield strength of Hulme [5)], the Bingham yield strength for 58~60 % is $5x10^4$~10^5 N/m2. The slope angle of lava flow is estimated as 6 degree from “Cross section of Nishinoshima for 2013.12.4.~2015.7.28”of Japanese Geological Survey. The estimated limiting lava tube height(H=2R) calculated for M/L= 1.0 and 0.5 and also M/L= 0 is shown in table 1. In case of M/L=0, the formation of a lava tube cave is impossible. On the other hand, in case of M/L>0 where pressurization by a magma is existing in the tube, there is a possibility of the lava tube formation depending on lava flow thickness. The followings are summary from the estimation based on the model:
(1) The magma pressure enough to overcome the high Bingham yield strength of andesite lava should be acting in the lava tube to make flow the lava in a lava tube.
(2) Even if a lava tube is formed, and when magma pressure is deleted, the lava will not be drained out from the lava tube. Then, lava tube cave will not be formed, only filled lava tube will be found.
[Conclusions] For the Nishinoshima lava flow of andesite, a lava tube cave will not be able to be found. Instead, there is a possibility to find a filled lava tube. The inspection of the lava flow thickness, the lava tube length/the height, the degree of the slope in Nishinoshima after landing is expected[6)]. A clear definition as a technical term of the lava tunnel or the lava tube is necessary. Use of active lava tube, filled(plugged) lava tube and drained lava tube(lava tube cave) is proposed.
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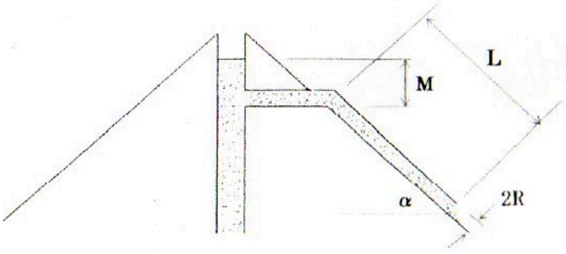
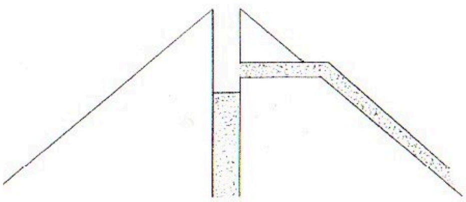
Keywords: Lava tube cave, Nishinoshima, Andesite lava flow

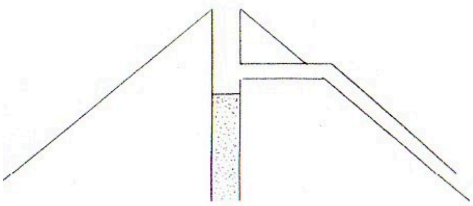
Fig.1 Hydrodynamic Model of Bingham Fluid



(A) Active lava tube: $(\rho g \sin\alpha + \rho g M/L)R/2 > f_B$



(B) Filled lava tube: $(\rho g \sin\alpha)R/2 < f_B$



(C) Drained lava tube: $(\rho g \sin\alpha)R/2 > f_B$

Table1 SiO_2wt% and Lava tube/cave height(Slope angle=6°)

SiO_2wt%, Yield strength	Acting pressure : M/L= 1.0,0.5,0	Required tube height:H	Comparison with lava thickness:h(<50m)
SiO_2 58%: *5×10^4 N/m^2	1.0 (Magna+Gravity)	7m	<h?(Tube formation?)
	0.5 (Magna+Gravity)	13m	<h?(Tube formation?)
	0 (Gravity)	80m	>h(No cave formation)
$SiO_2$61%: *1×10^5N/m^2	1.0 (Magna+Gravity)	15m	<h?(Tube formation?)
	0.5(Magna+Gravity)	26m	<h?(Tube formation?)
	0 (Gravity)	120m	>h(No cave formation)

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Restudy of the eruptive history on Daisen Volcano, SW Japan

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Daisen is a Quaternary volcano situated in SW Japan, and consists of adakite lava domes, pyroclatic flows and Plinian fall deposits. Although the eruptive history of this volcano has revealed by Tsukui (1984), the large frames of the history do not reach the quantification. Particularly, ca. 50-ka Daisen-Kurayoshi eruption which was the largest Plinian-type one, but was not understood whether this eruption was the thing which got up in the long-term volcanic activity of this volcano how. Therefore, this study performed revision of the stratigraphy of the past approximately 200,000 years of this volcano, radiocarbon dating and a re-measurement of the magma discharge quantity. In the point that is important by the revised stratigraphy, the Misen pyroclastic flow of Tsukui (1984) is divided into the Shimizuhara pyroclastic flow derived from the Sankoho lava dome in the north foot and the Masumizuhara pyroclastic flow derived from the Misen lava dome in the west - southwest foot; their essential materials differ in chemical compositions. The new radiocarbon calendar ages are 18,960-18,740 calBC and 26,570-26,280 calBC for the former and latter, respectively. Therefore, the youngest eruption was the formation of the Sankoho lava dome in approximately 20,000 years ago. Furthermore, this study rewrote the isopach maps for the tephra layers of this volcano origin and measured quantity of tephra volumes by the Legros (2000) method again. The tephra which quantity of volume came to largely have a bigger than a value conventionally is the ca. 80-ka Daisen-Namateke eruption, and its the smallest volume is 2 km^3DRE. The revised magma discharge rate shows that a high state continued in this volcano for approximately 100,000 years, and the Daisen-Kurayoshi eruption is not specifically big in activity at this time of Daisen Volcano.

Keywords: Daisen Volcano, eruptive history

Direction of natural remanent magnetization of rhyolite lava with clearly marked flow structure

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Volcanic rocks have long been recognized as good recorders of the geomagnetic field corresponding to the time of their formation. Rhyolite lava is a common volcanic rock in continental regions and can also be considered to be a useful source of paleomagnetic data. However, only few studies have focused on paleosecular variation, magnetostratigraphy or plate reconstruction analysis using the remanent magnetization of rhyolite lavas. Being highly viscous, rhyolite lavas often show heterogeneous texture, unlike andesitic and basaltic lavas. Flow structure, one of the characteristics of rhyolite lava, may offer a clue about the changes in the direction of remanent magnetization in rhyolite lava during the development of the structure: heterogeneous texture in rocks may cause the deflection of the remanent magnetization to a direction different from the original one. The disagreement between the observed paleomagnetic direction of rhyolite lava and the expected one may be a function of the development of the flow structure.

In this study, we examined a thick rhyolite lava flow with clearly marked flow structure to assess its ability to records a consistent paleomagnetic direction, using material penetrated by two drill cores.

Progressive thermal demagnetization isolated two natural remanent magnetization components. The remanence was almost unblocked at around 580 degrees C during thermal demagnetization and is inferred to be carried by magnetite. A high-temperature component from each of the two cores yields inclinations that differ from each other. The low-temperature component had those that agreed with each other, and were also consistent with the direction expected from a geocentric axial dipole field. The modification of direction of the high-temperature component may be explained by post-magnetization acquisition tilting. In the case of silicic lava, the low-temperature component may retain directions parallel to the ambient field direction at the time of lava emplacement.

Keywords: Rhyolite lava, Remanent magnetization, Drill cores

Petrological characteristics of Aso-ABCD tephra which erupted before Aso-4 pyroclastic eruption

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Several tephra layers such as Aso-A, B, C, D, , , M, N, α, β, , , η, between Aso-4 (89 ka) and Aso-3 (123 ka) pyroclastic eruptions have been described by Ono et al. (1977). Among them, Aso-ABCD is located at the top of all, and represent a series of continuous eruption events. Nagahashi et al. (2007) estimated their age as 97.7 ka. Ono et al. (1977) estimated the eruption source to be the south of present central cones from the isopach maps. Machida and Arai (1992) estimated their volume to be 3.5 km^3. Just before the eruption of Aso-4 event occurred the formation of Omine pyroclastic cone and associated Takayubaru lava flow. This lava flow is overlain by Aso-4 tephra with no intercalated soil. The volume estimate is 2 km^3. The most voluminous felsic eruption after Aso-4 event was that of Kusasenri-ga-hama volcano with 1.4 km^3 volume (Miyabuchi, 2003). Thus, Aso-ABCD and Omine volcanoes represent voluminous precursory eruptions before caldera-forming Aso-4.
Pumice and volcanic ash was sampled 20 km east of Aso caldera, where the thickness of Aso-ABCD tephra in total is 3 m. The samples were analyzed for XRF bulk-rock chemical analysis, EPMA mineral analyses, FT-IR analyses of melt inclusions. Phenocryst assemblage is plagioclase, clinopyroxene, orthopyroxene, and magnetite, with no hornblende which is common in Aso-4 products. Bulk composition of pumice ranges 63-66 wt. % silica, and mostly plot on Aso-3 trend, and not on Aso-4 trend of Kaneko et al. (2007, 2015). Melt inclusions in plagioclase and pyroxenes also show compositions similar to glass of Aso-3 with silica range mostly in 70-72 wt. %. Compositional range of phenocryst cores are An40-64 for plagioclase, Mg# =70-74 for orthopyroxene, and Mg#=74-81 for clinopyroxene. Water content was estimated to be 1.0-4.8 wt.% for melt inclusions in host minerals of An40-64 plagioclase, Mg#=70-74 orthopyroxene, and Mg#=74-81 clinopyroxene.
Equilibrium relationship between melt inclusion and host clinopyroxene provides temperature estimate of 860-950 ℃ and pressure estimate of 1.1-2.7 kbar (Putirka, 2008). The pressure corresponds to the depth of 3-9 km, comparable to the estimated depth (6 km) of present Kusasenri-ga-hama magma reservoir. Furukawa et al. (2006) showed a gradual change of tephra composition, estimated temperature, estimated water content, and estimated oxygen fugacity from Aso-3 to Aso-4. However, our study showed similarity of magma composition between Aso-ABCD tephra and Aso-3 products. Aso-4 magma reservoir was not yet prepared 9000 years before Aso-4 eruption. Or Aso-4 reservoir at that time was independent from, and had no interaction with, other magma supply system then.

Keywords: Aso, caldera-forming eruption, melt inclusion, Aso-ABCD tephra, Aso-4 pyroclastic eruption

CSD (Crystal Size Distribution) analysis for plagioclase phenocrysts in historical lavas of Sakurajima volcano -The control of magma plumbing system for the eruptive style and frequency-

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In order to obtain insights into roles played by magma plumbing system in the long-term behavior of eruptive activity, we conducted crystal size distribution (CSD) analysis of plagioclase phenocrysts in four historical lavas of Sakurajima volcano, located in southern Kyushu, Japan: Bunmei eruption (1471-76), An-ei eruption (1779-82), Taisho eruption (1914-15), and Showa eruption (1946). Bunmei, An-ei, and Taisho eruptions firstly fell pumice by Plinian eruptions from newly formed flank vents, and subsequently flowed lavas. Showa eruption firstly had fell ash frequently for about three months, and subsequently flow lava from the Showa crater. After Showa eruption, Vulcanian eruptions occurred frequently, indicating the temporal change of eruptive style from large volume Plinian eruptions with lava flows (c.a. 1 km^3 DRE) to small volume frequent eruptions (one event less than 10^{-3} km^3).
In four historical lavas, plagioclase phenocrysts are classified into 3 types. Type-A is represented by the clear texture and lower An content (around An60) in core and rim. Type-B shows the clear texture and higher An content (around An80) in core and lower An content (around An60) in rim, and the sharp compositional contrast between the core and the rim. In addition, the length of rim varies by a wide range as 10-200μm in all lavas. Type-C has the sieve texture and heterogeneous compositions in core. From above chemical analysis, the magma plumbing system consist of two magma reservoirs (felsic magma chamber and mafic magma chamber) where the crystallization proceeds to form phenocrysts. Type-A crystallizes in the felsic magma chamber in which the compositions gradually changes from felsic to mafic during hundreds years by repeated injections of mafic magmas. Type-B crystalizes in the mafic magma chamber, and the mafic magma continuously injects to the felsic magma chamber.
The CSD plots of both type-A and type-B can be approximated by log-linear CSDs. Slopes of type-A are constant regardless of eruptive ages, and those of type-B become steeper with time, that is, Showa has the steepest slope. From the CSD analysis, the residence time in the felsic magma chamber is nearly constant with time, whereas the residence time in the mafic magma chamber becomes shorter with time, indicating that both mantle-derived mafic magma supply rate and extraction-rate to the felsic magma chamber increase with time. The magmatic behavior such as crystallization and accumulation rates in the felsic magma chamber keeps a constant pace and has no influence on eruptive phenomena. On the other hand, the mafic magma chamber located at deeper level controls the surficial behavior in eruptive phenomena, such as frequency of eruptive events and dominant eruption styles of Vulcanian type, through increasing rates of mantle-derived mafic magma supply.

Keywords: Crystal size distribution, Plagioclase phenocryst, Magma plumbing system

Tsunamis generated by the 7.3 ka catastrophic eruption at Kikai caldera, Japan: constrains from tsunami traces around the Koseda coast, NE Yakushima, Japan

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Timing and mechanism of volcanogenic tsunamis are important to constrain nature, processes, and hazards of volcanic eruptions in marine and lacustrine environments. In this presentation, we report the event deposits caused by pyroclastic flows and tsunamis during a catastrophic caldera-forming eruption at Kikai caldera, Japan, and discuss their origin. There are some hypotheses on the tsunami generation and propagation during the 7.3 ka eruption at Kikai caldera. Previous numerical simulations showed that huge tsunamis might hit Yakushima Island (e.g., Maeno et al., 2006), but so far no clear and convincing evidence has been found in this region. We investigated traces of the tsunamis caused by this eruption in the northeast of Yakushima Island, and found the deposits, originated from the pyroclastic flow and tsunami event at 7.3 ka, near the Onagawa river mouth at the Koseda coast. Our study includes reinterpretation of a previously studied outcrop (Moriwaki et al., 2006). The deposits at the Koseda coast consist of two major units and lie on a wave cut bench (WB-4) of ~8.4 m above sea level or more. The lower unit is a poorly sorted, ~30-cm gravel bed with sandy matrix, and the upper unit is a massive, 0.3-1-m thick pyroclastic flow deposit from the 7.3 ka eruption. A reworked deposit and a 1-2-m thick gravel bed cover the pyroclastic flow deposit. Based on the outcrop and trench surveys, the lower gravel bed is traceable at least 120 m toward inland and has a similar component to modern beach gravels distributed around the Onagawa river mouth. The matrix of the lower gravel bed also contains pumice clasts (up to a few cm in diameter) originated from the 7.3 ka eruption, as evidenced by glass chemical composition and fibrous texture. The grain-size of the matrix component decreases toward inland. The local observations of Holocene marine terrace distributed in the northeast of Yakushima suggest that the highest sea level phase (+9.7 m) occurred between 7.3 and 5 ka. Thus, we interpret that WB-4 emerged before 7.3 ka, the sea level at 7.3 ka was less than 8.4 m, and a transgression of 1~2-m continued after 7.3 ka. Based on our data and interpretation, we would conclude that gravel in the lower bed was transported from the river mouth to the top surface of WB-4 by a relatively high concentration, energetic current associated with a tsunami at 7.3 ka, and that the timing of the tsunami is constrained after the beginning of the 7.3 ka eruption and before or during the climactic phase that produced large-scale pyroclastic flows.

Keywords: volcanogenic tsunamis, pyroclastic flows, Kikai caldera, Koseda coast, Yakushima

Role of thermal boundary layer on microlite crystallization: constraints from shear-deformation experiments

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Microlite crystallization in ascending hydrous magmas has been widely believed to be driven by decompression and resulting liquidus temperature increase, because thermal conductivity of magma is low and cooling is less effective for magmas ascending at a common velocity in a conduit. In the thermal boundary layer along conduit walls, however, effect of thermal conduction is imposed on the undercooling produced by decompression, thus microlite nucleation is supposed to be enhanced. The conduit walls may work also as a site for heterogeneous nucleation. In order to evaluate the potential role of thermal boundary layer on the microlite crystallization in ascending magmas, we have investigated experimentally the effect of temperature gradients and shear flow on the textural evolution and crystallization kinetics of trachyandesitic melt using an image furnace. The shear deformation was applied by twisting two rods, fixed to the upper and lower shafts. The rods of alumina were used in Series1 experiments. In Series2 experiments, dacite lava was used for the upper rod. The starting materials were initially heated at a temperature higher than the liquidus temperature for 60–120 minutes, then once quenched and reheated at a run temperature below the liquidus. The difference between the initial heating temperature and the liquidus was defined as superheating, -DT. The difference between the run temperature and the liquidus temperature, was defined as supercooling, DT. The experiments were performed at different degrees of superheating (-DT = 33, 98 and 233°C), supercooling (DT<138°C) and rotation rates (0, 0.08 and 0.8 rpm). In Series 1, run products had high crystal fraction only at low superheating (33°C), in which minute relict crystals worked as a nucleation sites. At higher superheating experiments (98 and 233°C) and static experiments without shear, no crystal was observed in the central part of the run products. On the other hand, the run products of Series2 had high crystal fractions even at a high superheating (-DT = 233°C) when the shear rate was high (>10^{-1} s^{-1}: 0.8 rpm). The difference between Series1 and Series2 can be summarized as follows. The surface of the rods, both alumina and dacite, induced heterogeneous nucleation of plagioclase. However, the crystals formed on the alumina rod surface were spherite-like, whereas those on the dacite rod surface had a shape similar to natural microlites. The nucleated plagioclase crystals were removed from the rod surfaces by shear flow only from the dacite surface in Series2. The plagioclase crystals were brought to the inside of the samples, resulting in high crystal number density and volume fraction.
Assuming a simple plug flow with conductive cooling from the walls, the thermal boundary layer with DT=20°C can be formed from the conduit wall with a thickness of a few percentage of the conduit radius. The strain rate at which the crystal can be removed from the boundary layer, i.e., 10^{-1} s^{-1} , is achieved near the conduit wall if the ascent rate of magma is higher than 5.0×10^{-2} m s^{-1}. These rates were observed in some eruptions such as Mount St. Helens. Crystal number density of the eruptive materials may, therefore, include the crystals formed at the thermal boundary layer near the conduit wall as well as the crystals nucleated in the conduit center solely by decompression. The effect of thermal boundary layer crystallization should be considered for number density and morphology of microlites in volcanic rocks.

Keywords: microlite, undercooling, magma ascent

FT and K-Ar ages of the Middle to Late Pleistocene volcanic products erupted from Rausu-Shiretoko Io Volcano Group

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We report three new radiometric age data of the Middle to Late Pleistocene volcanic products from Rausu-Shiretoko Io Volcano Group, southern Kurile arc, to revise the 1:50,000 scale geological map. A fission track (FT) age, 0.36±0.10 Ma, was obtained from andesite pyroclastic flow deposits (Kamuiwakka Welded Tuff) at the northern flank, indicating that the large-scale eruption occurred the initial stage of the volcano group. Two K-Ar ages, 0.16±0.01 Ma and 0.05±0.01 Ma, were obtained from andesite lava flows at the eastern and southeastern flank of the volcano group, respectively. Considering these ages with previous studies, the volcanic activity of the volcano group occurred while shifting the eruption sites during the Middle to Late Pleistocene. This characteristic continues to the activity during Holocene.

Keywords: Rausu-Shiretoko Io Volcano Group, eruption, chronology, geological map, Kurile arc

The Ohachidaira caldera-forming eruption and associated deposits, Taisetsu volcano group, Japan

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The Sounkyo member was produced during the Ohachidaira caldera-forming eruption that occurred in the central part of Taisetsu volcano group, central Hokkaido, Japan. At distal sites, the member comprises a pumice-fall deposit and the overlying Sounkyo ignimbrite (about 6.5 km^3), previously named Px-type pyroclastic-flow deposit by Sato and Wada (2012). Proximal deposits, occurred around the Ohachidaira caldera, comprise the following pyroclastic sequence from base to top: pumice and scoria-fall deposit (SK-A); ignimbrite (SK-B); lithic breccia (SK-C); scoria-fall deposit (SK-D); and pyroclastic-surge deposit (SK-E). SK-A mantles the land surface, attains a maximum thickness of 60 m in the caldera rim exposures, and shows an outward decrease in thickness, grain-size, and the degree of welding. SK-B is a valley-filling ignimbrite as much as 45 m thick composed mainly of pumice and scoria clasts up to 70 cm in diameter and gray ash matrix with a small amount of lithic fragments, and varies vertically from massive facies (up to 15 m thick) to crudely parallel-stratified facies. SK-C (up to 27 m thick) is massive and poorly sorted, consisting predominantly of coarse lithic blocks, up to 2.6 m in diameter, and subordinately of pumice lapilli, with fines-depleted coarse ash matrix, and varies from clast-supported to matrix-supported. SK-C thickens into topographic depressions, contains abundant rounded pumice clasts, lacks impact structures even beneath meter-sized lithic blocks, and grades downward into SK-B ignimbrite and laterally into a fine-bearing, matrix-supported, lithic breccia, indicating a flow origin. SK-D is locally exposed and has an average thickness of 1 m. SK-E (up to 15 m thick) is a cross-stratified pyroclastic-surge deposit. The grain-size and component characteristics of SK-E are similar to those of SK-B. Field evidence shows that the distal pumice-fall deposit represents a lateral counterpart of SK-A. Hence the Sounkyo ignimbrite might be a distal equivalent of SK-B. The coarse lithic breccia (SK-C) overlies the voluminous ignimbrite (SK-B), implying that a vent widening occurred at the end of the climactic eruption.

Keywords: Ohachidaira caldera, Taisetsu volcano group, caldera-forming eruption, ignimbrite, lithic breccia

Occurrence of a low-temperature dilute pyroclastic density current just before the caldera-forming eruption in a water-rich environment : a case study of Hachinohe ash, Towada volcano, NE Japan

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Hachinohe ash and Hachinohe ignimbrite are volcanic products of Episode L of eruption (13,000 b.p.y.) in the Towada volcano. Towada volcano has a caldera lake that was formed by three such episodes accompanying a large-scale pyroclastic flow. Episode L is the latest and most voluminous of the caldera-forming eruptions in Towada. Hachinohe ash consists of alternating fine ash and ash-coated pumice clast layers. Both ash and pumice are widely dispersed. The ash layers contain accretionary lapilli, which indicates the involvement of external water. Hayakawa (1983) concluded that these ash layers were derived from a phreatoplinian eruption, formed by the interaction between fragmented magma and lake water.
Most phreatoplinian deposits are interpreted as fallout deposits from wet eruption columns. Ash layers in Hachinohe ash are inferred as fallout deposits from their distribution and grain size characteristics. However, in fine ash deposits affected by large quantities of water, it is difficult to determine the mode of emplacement from grain-size features alone. In addition, the simulation of the behavior of the eruption column following the mixing of magma and external water indicates the development of a wet eruption column and the occurrence of cold, wet ashflow derived from wet column collapse (Koyaguchi and Woods, 1996). Thus, the purpose of this study is to re-examine the emplacement process of Hachinohe ash, based on field surveys.
We mainly surveyed the eastern area, within 45 km from the Towada caldera. As a result, Hachinohe ash consists of 6 units (HP1- 6 in ascending order) same as previous studies, but the further complexity of each unit is recognized. In particular, it was found that HP1, which mainly consists of fine ash, can be divided into two parts, a lower part (HP1a) and an upper part (HP1b). Although the grain size characteristics make the emplacement process ambiguous due to the presence of ash aggregates, their sedimentary structures indicate that there are significant differences between HP1a and HP1b. HP1b is composed of fine ash with accretionary lapilli and uniformly mantles the ground surface just before the eruption. These features indicate that HP1b is a phreatoplinian fallout deposit. On the other hand, HP1a is characterized by a weakly cross-stratified lithofacies, and is mainly composed of thin, coarse ash layers. HP1a forms an infill at a topographical low, and is, thus, affected by topographical obstacles. These features indicate that HP1a is a dilute flow deposit. Although HP1a is deposited as far as 45 km from the vent, it includes some chips of wood with charred surfaces 25 km away from the caldera, which implies that HP1a was emplaced at a relatively low temperature (but >100°C) at this distance. Thus, HP1a is a low-temperature dilute pyroclastic density current (PDC) depositing at large distances from the source due to a phreatoplinian eruption, and not a fallout deposit as suggested in previous studies.
Although the occurrence of base-surges as dilute PDCs is often observed in phreatomagmatic explosions, the surge deposits are limited to within several kilometers from the vent. While these deposits form at scales much smaller than that of HP1a, some examples of distant emplacement of dilute PDC, similar to HP1a have been documented, such as: 7.3 ka Kikai caldera eruption Unit B_l, 12 ka Neapolitan Yellow Tuff eruption LM1, 160 ka Kos Plateau Tuff eruption Unit B, 7.6 Ma Akdag-Zelve ignimbrite eruption Upper/Lower surge series. All of these PDC deposits were formed during silicic caldera-forming eruptions in a shallow sea or lacustrine basin. Moreover, these

dilute PDCs are products just before the caldera collapse accompanying an ignimbrite, and the contribution of external water in the source vent generates the dilute PDC. Therefore, the occurrence of dilute PDCs might be a universal phenomenon during such huge eruptions in a water-rich environment.

Keywords: Towada volcano, Hachinohe ash, phreatoplinian eruption, caldera-forming eruption, dilute pyroclastic density current

The forming process of the Nakanoumi caldera based on component analysis for deposits of Eruptive Episode C (Chuseri tephra), Towada volcano, NE Japan

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The Towada volcano is a double caldera volcano. The outer caldera, Towada caldera, was formed during three large pyroclastic eruptions before 13 ka. The inner caldera, Nakanoumi caldera, is a summit crater of the Goshikiiwa volcano, which is a basaltic post-caldera volcano. The Nakanoumi caldera was formed by the explosive activities from felsic magma.
The products of Eruptive Episode C (6.2 ka) consist of the following three units in ascending order: Chuseri pumice (CP), Kanegasawa pumice (KP), and Utarube ash (UA); the total eruptive volume was 3.0 km^3. CP is a Plinian pumice deposit, KP is stratified lithic-rich pumice fall deposits, and UA is phreatomagmatic ash deposits. Although Hayakawa (1985) considered that the Nakanoumi caldera was formed in this episode from both lithic-rich features in KP and an eruptive sequence from magmatic (CP) to phreatomagmatic (UA), the details are still not clear.
The change of the amounts and components of the lithic fragments in pyroclasts are indicative of vent enlargement or the opening of new vents. Their temporal variation has been examined in connection with the change in eruptive style and caldera forming processes. Therefore, to discuss the formation process of the Nakanoumi caldera, we investigated the temporal variation of lithic fragments in CP and KP deposits, by a component analysis on both deposits.
CP is an almost homogeneous coarse pumice deposit except for the finer part at the bottom and uppermost, and this indicates that the eruption rate of the main part was constant. KP consists of alternating pyroclastic fall deposits and fine ash layers with short dormancy. Each pyroclastic fall deposit gradually changes from a lithic-rich layer to a pumice-rich one without clear boundaries, and the contained lithics are accessory or accidental materials.
Lithic contents in CP are under 10 wt% through most of the main part. However, in the top of the main part, the content increases up to 40 wt% with increases in the maximum pumice size (MP). The amounts in KP show pronounced contrast. While lithic-rich layers have over 80 wt% lithics, pumice-rich layers have 40–50 wt%, which are the same as the contents at the top of the main part of CP.
The Goshikiiwa volcano is composed of basaltic lava, agglutinate and a little silicic welded pumice. Dacitic lava dome exists on the northeast slope. Beneath the Goshikiiwa volcano, there are lavas and welded tuffs that were produced during the pre-Towada caldera stage, and basement rocks like slates and charts are present in deeper areas. Lithic components in the main part of CP are mainly mafic rocks derived from the Goshikiiwa volcano. At the top of the main part of CP with increases in lithic contents, brown altered and silicified lithics come into the deposit. Components of KP deposits are similar to the top of the main part of CP but with small quantities of obsidian. Both deposits do not contain the lithics from deeper depths.
The increasing amounts of lithics are not related to the timing of the shift in eruptive units, but occur at the top of the main part of CP. Although MP in CP increases with this change, it is difficult to explain this feature by only the amplification of volcanic intensity given the lack of change in the median grain size.
The lithics in CP and KP are mainly shallow components from the Goshikiiwa volcano, so all of the lithic clasts were produced by the destruction of the Goshikiiwa volcano around the surface. The total lithic contents, which are estimated to be 0.16 km^3, are deficient to fill up the Nakanoumi

caldera; however, Episode A, the latest eruption, contained 0.6 km^3 of lithics. Moreover, because Nakanoumi is over 200 m deeper than the floor of the Towada caldera, the rocks under the Goshikiiwa volcano need to be eroded. Hence, the Nakanoumi caldera may be formed stepwise by multiple eruptions after Episode C and not only during this episode.

Keywords: Towada volcano, Chuseri tephra, lithic fragment, component analysis

Stratigraphy and radiometric ages of borehole core from the Matsukawa observation well, Sengan volcanic region, Northeast Japan.

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The Matsukawa observation well in the 200 m-depth class was drilled by NIED at northwest side of Iwate volcano (N39.88346° E140.93582°). Based on the lithologic features, the borehole core consists of three stratigraphic groups. The upper part (0-106.0m in depth) consists mostly of andesitic volcanic breccia and tuff breccia. K-Ar age of an andesitic block in volcanic breccia in depth of 75.3m is 0.94 ±0.03Ma. In addition, the results of ^{14}C dating by humus soil block and wood chips in the depth of 40.2m to 69.9m are about 3600-4800 cal.BC. The middle part (106.0-134.7m in depth) is composed mainly of hydrothermal altered volcanic breccia and tuff breccia. Their matrix have partially horizontal sheared structure. K-Ar age of an andesitic block in volcanic breccia in depth of 121.4m is 1.04 ±0.07Ma. The lower part (134.7-203.0m in depth) consists heavil altered volcanics. Steep shear zone was formed in the altered rocks in depth of 148-150m. The rocks in the depth of 157-167m consist of an andesitic lava flow or intrusive body. There is a possibility of the green gray consolidated lapilli tuff deeper than depth of about 170m are welded tuff since unclear eutaxitic texture is recognized.
The most characteristics of the lower part of Matsukawa core are unknown as strong alteration,but might be correlated to member of the Tamagawa Welded Tuffs. Volcanic rocks contained in the upper and middle part are likely derived from Matsukawa andesite and / or Nakakura (Marumori) volcano since K-Ar dating results of andesite blocks exhibited around about 1Ma. On the other hand ^{14}C age of soil block and woods included are indicate depositional age of the upper part likely to be Holocene. The drilling site is located in ”Marumori landslide”. ^{14}C age of 2390 ±90yrBP have been reported from the soil that covers the surface structure of Marumori landslide body(Sumi, et.al.,1988). Since shear structure was developed in the middle part, the upper and middle part of Matsukawa core are considered that belong to the landslide body of Marumori landslide. And presumably the topsoil and vegetation were engulfed at the time of the occurrence of landslides at a few thousand years ago. However, the steep shear zone of the lower part is also likely to relate to reverse faults that were developed along eastern margin of the backbone range of NE Japan. There are required further research.

Keywords: Sengan geothermal area, volcanic history, borehole core, landslide

Eruptive history and structural development of Quaternary Sanzugawa caldera, Yuzawa, Akita

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Intra-caldera ignimbrites record more complete information about the onset, climax, and aftermath of the caldera-forming eruption than extra-caldera ignimbrites. However, it is often more inaccessible because it is occupied by a thick caldera-fill. Therefore, there are fewer studies on the stratigraphy, structure and lithofacies of intra-caldera ignimbrite than that of extra-caldera ignimbrite. This study report Torageyama Formation within Sanzugawa caldera as an ideal instance continuously capable of observing intra-caldera ignimbrite sequence, structure and lithoface, and discuss the eruptive history and structural development of the caldera.
Sanzugawa caldera, located in southern Akita prefecture, formed by caldera-forming eruption associated with large volume pyroclastic flows. The caldera is filled with pumice flow deposits (Torageyama Formation), which deposited during the caldera-forming eruption. The Pleistocene Torageyama Formation (1.21 Ma) consists of mainly crystal-rich, dacitic lapilli-tuff, breccia and tuff, has a thickness of >1500 m and overlies basement of Onagawa to Nisikurosawa formation, having an unconformable relationship. The Torageyama Formation is distinguished five lithofacies: (1) Eutaxitic, massive lapilli-tuff, mLT; (2) Massive lithic breccia, mlBr; (3) Cross-stratified lapilli-tuff, xsLT; (4) Parallel-stratified tuff, //sT; (5) Diffuse-stratified lapilli-tuff, dsLT. The emLT is common lithoface of the Torageyama Formation, which repeatedly distributed over this area. The mlBr and xsLT develop at the base of the emLT, //sT and dsLT respectively develop at the top of and in the middle of the emLT with sharp or gradational contacts. The author can estimate that the Torageyama Formation is a sequence of intra-caldera ignimbrite because these lithofacies and relationships indicate a characteristics of intra-caldera ignimbrite lithofacies. This study suggest that a caldera collapse triggered the caldera-forming eruption in 1.21 Ma and initiated ignimbrite-forming phase lacking initial Plinian phase, is supported from; (a) the lack of precursory fallout deposits in many of ignimbrites; (b) the space required to enclose the large volume of the intra-caldera ignimbrite; and (c) the distribution of the Torageyama Formation limited to the intra-caldera setting. The Torageyama Formation is divided into seven pyroclastic flow units (PDC-1 to PDC-7) by repeated patterns of ignimbrite lithofacies. Pyroclastic flow supplied more than seven pyroclastic flow pulses repeating waxing and waning, suggested by the number of pyroclastic flow layers. The flow direction is estimated from northeast to southwest, supported from dune structure and imbrication of ignimbrite lithofacies, and Otoriyasawa is relatively crystal-poor and interbedded more mlBr. In addition, ring-like distribution of strike surrounds Takamatsudake and their dips incline outward of the caldera. This structure implies a resurgent dome in post-caldera stage, resulted in uplift of Takamatsudake area where the center of the caldera after the formation of the Torageyama Formation.

Keywords: Sanzugawa caldera, Torageyama Formation, Intra-caldera ignimbrite

Eruption process of pyroclastic flows in Ikezuki Tuff

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Ikezuki Tuff (Onikobe-Ikezuki tephra), which was erupted during 0.2-0.3 Ma from Onikobe caldera, is a voluminous pyroclastic flow deposit with pumice fallouts, over 18 km^3 in volume. The distribution and stratigraphy of Ikezuki Tuff is well investigated in the eastern area from the source caldera. Pyrocalstic flow deposits consist of two parts, lower and upper parts, for the difference of degree of welding. The lower part, within 20 km from caldera, has flowed distance shorter than one of upper part. Because upper current flowed on the flat plane after lower flows buried all the topographical obstacles, this difference was caused (Sakaguchi and Yamada, 1988). On the other hand, the distribution of pyroclastic flow is restricted because the western area of Onikobe caldera is topographically high. Although outcrops of Ikezuki Tuff are reported in Mukaimachi and Shinjo basins (Yagi and Soda, 2002; Matsuura, 2003), the details are still not clear as compared with eastern area. In this report we investigate the distribution in Mukaimachi and Shinjo basins based on the field survey and the major compositions analysis of volcanic glass in pyroclasts by FE-SEM-EDS, and we discuss the eruption process at Ikezuki Tuff eruption.
As a result of glass composition analysis to all products collected from the type locality of Ikezuki Tuff in eastern area, glass type from their composition in pyroclastic flow deposits was divided into two groups. These two groups are corresponding to the two flow parts, lower part (K_2O-poor, FeO-rich) and upper part (K_2O-rich, FeO-poor), classified by lithofacies. Therefore the distribution of both parts in pyroclastic flows can be reconstructed by using glass compositions. The ditribution of pyroclastic flow in Mukaimachi basin is in contrast to one in Shinjo basin. At the northwestern area in Mukaimachi basin a thick welded tuff over 100 m in thickness forms the plateau by accumulating pyroclastic flows. At the northern area in the basin two thin (a few meters in thickness) pyroclastic deposits, which is Ikezuki Tuff and Shimoyamasato Tuff in ascending order, cover on the older terrace composed of the conglomerate. An elevation, where Ikezuki Tuff can be observed on the terrace, is same as a height of the top of pyroclastic plateau. In addition, all of pyroclastic flow deposits correlated into Ikezuki Tuff in Mukaimachi basin are lower part, and upper part is not observed in this basin. On the other hand all of pyroclastic flow deposits in Ikezuki Tuff within Shinjo basin is non-welding and under 60 m in thickness. From their glass compositions, both lower and upper parts in Ikezuki Tuff co-exist within Shinjo basin in contrast to Mukaimachi basin. The large quantity of upper part in Ikezuki Tuff has achieved to Shinjo basin. Although it is estimated that the pyroclastic flow initiating from Onikobe caldera has achieved to Shinjo area through Mukaimachi basin to avoid the topographical obstacle in northwest, upper part is not deposited within Mukaimachi basin. Such as the strathigraphy in eastern area from caldera, however, an upper part overlies thickly the lower part on the way to the pathway, when following flow pass through on the plateau formed by the precede flows. Therefore it is difficult to consider that upper part has flowed on the surface of plateau formed by lower part, given lack of upper part in Mukaimachi area. It is possible to explain the distribution of Ikezuki Tuff in western area if upper part passes through a channel carved in thick lower part pyroclastic flow deposit, not over the plateau in Mukaimachi area. Consideration to the existence of the large quantity of upper part in Shinjo basin, this channel needs to be deeper for passing without over the channel. This indicates that the transition from lower part activity to upper part one has a short quiescence to form deep channel, and eruption of Ikezuki Tuff was not continuous.

Keywords: Ikezuki Tuff, Onikobe Ikezuki tephra, Mukaimachi and Shinjo basins, Onikobe caldera

Geology and Petrology of Torikabutoyama-Yokokurayama, Old Kumanodake, and Nakamaruyama volcanic edifices in Zao volcano

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Zao volcano is Quaternary stratovolcano located in the middle part of the volcanic front of northeast Japan. The activity is divided into six stages (Stage Ⅰ : ca.1 Ma, Stage Ⅱ: ca.500 ka, Stage Ⅲ: ca.350-250 ka, Stage Ⅳ: ca.250-200 ka, Stage Ⅴ: ca.130-40 ka, Stage Ⅵ: ca.< 35 ka). We performed geological and petrological study on Torikabutoyama-Yokokurayama, Old Kumanodake, and Nakamaruyama volcanic edifices of Zao volcano.

The eruption products of these three volcanic edifices can be divided into eleven units. These units can be grouped into three (the early period, the middle period, the late period). The early period, the middle period, and the late period eruption products are composed of thick andesitic to dacitic lava flows (Yokokurayama-Torikabutoyama lavas, Gorodake lava, Naganohoppo lava, Sanpokouzinsan lava, Oiwake lavas), thin basaltic andesite to andesitic lava flows (Zaosawatyuryu lavas and pyroclasts, Zaosawajoryu lavas and pyroclasts, Senninsawa lavas and pyroclasts, Zaoseibu lava), thin basaltic andesite lava flows (Nakamaruyama-lower lavas, Nakamaruyama lavas), respectively. The early period is mainly equivalent to Stage Ⅱ. The middle period and the late period are equicalent to Stage Ⅲ.

Most of rocks are ol bg. cpx-opx andesites. Most of plagioclase phenocrysts have dissolution texture such as dusty zone and/or patchy zoning. All rocks of the early period and some of the late period contain dissolutive quartz. Quartz, orthopyroxene, and olivine sometimes have a reaction rim. Mafic inclusions are observed in all andesitic to dacitic rocks. These are several millimeters to tens of centimeter in length. The groundmass texture of most of rocks is hyalo-ophitic, while that of mafic inclusions is dikty-taxitic. We note that troctlite inclusions are characteristically observed in Senninsawa lavas and pyroclasts.

All products belong to medium-K calk-alkaline series. SiO_2 contents of the early period, the middle period, and the late period are 57-62wt. % (some are >65wt. %), 57-62wt. %, 58-63wt. % (some are 55wt. %), respectively. The early period eruption products and the late period show relatively low trends in K_2O-SiO_2 diagram, while the middle period eruption products show relatively high trend. The compositional trends of the volcanic units in these three edifices are slightly different each other.

Keywords: Zao volcano, andestic lava, calc-alkaline series

Petorologic Study of the Stage IV Eruptives of Myoko Volcano

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Myoko Volcano (2445 m a.s.l.), a near-conical composite stratovolcano with a summit horseshoe-shaped depression ~1.5 km wide, is located at the western Niigata Prefecture. To date, the eruptive history and characteristics of this volcano have well studied. The volcanic activity started at 0.3 Ma and is divided into four eruption stages on the basis of K-Ar and ^{14}C ages (Hayatsu, 2008; hereafter H08). In order to decipher the magmatic evolution of the composite volcano, petrographic features and whole-rock compositions of the Stage IV eruptives are investigated.

The stage IV, the youngest stage of Myoko Volcano, consists of three sub-stages, i.e., pre-collapse (43 ka-), collapse (21 ka-6 ka), and post-collapse stages (6 ka-present) (stage names are modified from those in H08). The volcanic activity during the pre-collapse sub-stage formed the dacitic to andesitic Shibutamigawa Pyroclastic Flow Deposit (SPFD; 55.2-62.9 wt.% SiO_2; 42190 ±380 yr BP) and the directly overlying, basaltic Nishikawadani Scoria Flow Deposit (NSFD; 50.5-52.8 wt.% SiO_2). (^{14}C age is from 08). The SPFD shows a hydrous phenocryst assemblage (Pl + Amp + Opx + Cpx ± Ol ±Opq) whereas the NSFD shows an anhydrous phenocryst assemblage (Pl ±Opx + Cpx + Ol ±Opq). The volcanic activity during the central cone stage formed two andesitic to dacitic pyroclastic flow deposits, i.e., the Akakura Pyroclastic Flow Deposit(APFD; 5510 ±70 yr. BP, 60.3-64.4 wt.% SiO2)and the Ohtagirigawa Pyroclastic Flow Deposit (OPFD; 4060 ±60 yr. BP, 56.9-64.1 wt.% SiO_2) (^{14}C ages are from H08). The APFD and OPFD show hydrous phenocryst assemblage (Pl + Amp + Opx ±Cpx ±Ol ±Qtz ±Opq) and contain quenched mafic enclaves (55.2-57.1 wt.% SiO_2; phenocryst assemblage Pl ±Amp + Opx + Cpx ±Ol ±Opq). Eruptives of pre- and post-collapse sub-stages show distinct linear mixing trends on many Harker diagrams. Although major and trace elements are broadly similar in all dacites erupted between pre- and post-collapse stages, there are slight differences in K_2O contents. In addition, the mafic magmas erupted between pre- and post-collapse stages are differ in TiO_2, Al_2O_3, K_2O, P_2O_5, V,and Sr contents. These petrological features indicate that the eruptions of the pre- and post-collapse sub-stages were fed by different and transitory silicic magma chambers, repeatedly recharged by mafic magmas of diverse compositions.

Keywords: Myoko Volcano, magma mixing, magma system

The formation process of lava domes in Sambe volcano

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Sambe volcano is an active volcano laying astride the volcanic front of the SW Japan arc. The latest eruption of this volcano was *ca.* 3800 ybp and may formed the present volcanic topography showing lava domes with four peaks (Mt. Osambe, Mt. Mesambe, Mt. Kosambe, Mt. Magosambe). The formation process of these topographically isolated four domes has been controversial. In order to access this problem, rocks from these peaks have been analyzed petrographically, which provide the following results:
(1) Rocks from Osanbe and Mesanbe are poorer in quartz phenocrysts than those from Magosanbe and Kosanbe,
(2) Al_2O_3, CaO, and Na_2O contents decrease with increasing SiO_2 for all rocks from four peaks, which may correspond the change in the amount of plagioclase phenocrysts,
(3) Rocks can be divided into 2 groups, the Osambe-Mesambe and the Kosambe- Magosambe groups, based on the difference in K_2O, Sr, Zr and Nb concentrations,
(4) Osambe and Mesambe rocks can be identified by the SiO_2 and the plagioclase phenocryst contents,
(5) High-T oxidation is recognized even for rocks that form the valley between peaks, showing the original distribution of these rocks at the kava surface.
These lines of evidence may lead to the conclusion that the four domes formed independently rather than that a large lava dome has been reshaped into four peaks by subsequent eruption and/or erosion.

Keywords: Sambe volcano, dacite, bulk-rock composition

Magma process of alkali basalt magma: a case study of the Kannabe monogenetic volcano group

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In the Southwest Japan inner zone of Southwest Japan, whose basement rocks are mainly Sanin granitic rocks, a number of active volcanoes have been observed.
In San'yo-San'in area, the volcanoes are originated in both the subducting Philippine Sea Plate (PHS) and the opening of the Japan Sea back-arc basin (Kimura *et al.*, 2003). However Huang *et al.* (2013) proposed the absent of the Philippine Sea Plate beneath some volcanoes suggesting that the volcanoes in such area are not derived from the dehydration of the PHS slab. In order to reveal the origin of these volcanoes, detailed study of magma process in each volcano is requiered. This study deals with the Kannabe monogenetic volcano group, which is located in the PHS slab-absent area. The Kannabe monogenetic volcano group is composed of six volcanic activities:Nishiki, Ohtsukue, Buri, Tada, Kiyotaki, Kannabe (Furuyama, 1973; Kawamoto, 1990). We collected 37 samples from four volcanoes except for Tada and Kiyotaki. Kawamoto (1986) proposed that the variation of bulk composition among Kannabe monogenetic volcano group cannot be explained by the fractional crystallization of olivine and accretion of plagioclase. Takahashi (2005) considered the crystallization differentiation of olivine and plagioclase, which also failed to explain it. These previous studies ignored crustal assimilation and magma mixing processes. Furthermore, crystallization differentiation process of basaltic magma should be related to other minerals than olivine and plagioclase. In this study, we considered crystallization differentiation including olivine, plagioclase, titanoaugite, and titanomagnetite and the effect of crustal assimilation to investigate magma process of the Kannabe monogenetic volcano group.
We obtained distinct bulk compositions for each lava, especially classified by MgO content. The observed compositional trend of the Kannabe monogenetic volcano group cannot be explained by the assimilation with basement rock of studied area (San'in granitoid: Nishida *et al.*, 2013). On the other hand, crystallization differentiation including abovemetioned four minerals successfully explained the compositional variation of major components (SiO_2, TiO_2, Al_2O_3, FeO, MgO). These results suggest that crystallization differentiation played a major role in the magma process of the Kannabe monogenetic volcano group. The effect of the magma mixing process inferred by textural observations (Kawamoto, 1986) would be discussed in further study.

Keywords: alkaline basalt , Southwestern Japan, petrology

Chemical composition of Omine volcanic products which actived before Aso-4 pyroclastic flow

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Eruption of Omine pyroclastic cone and effusion of associated Takayubaru lava occurred just before the caldera-forming Aso-4 pyroclastic eruption. Composition of Omine scoria and that of Takayubaru lava are similar, but the former shows a wider variation and a little more felsic than the latter. Whole-rock chemical composition of Takayubaru lavas overlaps with that of Aso-4 pyroclastic flow deposits in some elements, however they show distinct compositional trends in other elements such as TiO_2 and Na_2O.

We further examined the composition of melt inclusions in the phenocrysts of plagioclase and orthopyroxene in Omine scoria by FT-IR. Composition of Omine melt inclusions in plagioclase is plotted in a narrow range of 67-70 SiO_2, contrasting with 71-74 wt.% SiO_2 of Aso-4 pyroclastics. Omine melt inclusions show distinct trends in MgO, FeO, TiO_2 vs. SiO_2 plots, and have more SO_3 and less H_2O than Aso-4 pyroclastics. Melt inclusions in plagioclase are SiO_2-poor and less fractionated than groundmass glass. Thus they probably represent earlier stage of magma supply system.

The plagioclase phenocryst composition of Omine scoria shows a unimodal distribution. Whereas, those of Aso-4 pyroclastic flow deposits often show bimodal distribution and are more Ab-rich. Plagioclase phenocrysts of Omine scoria are either clear or with honeycomb structure. They both are in the similar compositional range; the latter showing a little wider range.

All the results indicate that the magma supply system of Omine volcano was different from that of Aso-4.

Keywords: Omine volcano, Takayubaru lava flow, Omine scoria, Melt inclusion

Topographic features of the lava flows of Iimoriyama volcano, Kirishima volcanoes, Japan

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We studied the topographic features of lava flows of Iimoriyama volcano, located in the northwestern part of Kirishima volcanoes. We discriminated volcanic landforms of Iimoriyama volcano using the aerial photographs. Based on the topographic features, we recognized 18 flow units at the Iimoriyama lava. And many characteristic surface features on lava flow were identified, such as lava wrinkles, lava levees. Then, we also identified eight hollows in the marginal part of the lava field. Some field evidences indicate that these holes are pseudocraters.

Keywords: lava flow, pseudocrater

Difference of lithofacies of Ikeda pyroclastic-flow deposit based on the basement topography

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[Intruduction]

The Ikeda caldera was formed by the phreatic eruption, and following fallout pumice and Ikeda pyroclastic flows.

The lag breccia exists near Ikeda caldera. A massive pyroclastic-flow deposit and a laminated pyroclastic-flow deposit occur in topographically lower and higher areas, respectively. In this study, we discuss the influence of the basement topography for sedimentation of the pyroclastic flow.

[Lithofacies of Ikeda pyroclastic flow deposits]

Ikeda pyroclastic-flow deposits vary in the sedimentary structure according to the basement topography. They are classified into two lithofacies.

The first is the massive deposit that is named the massive layer (ML) and ponds in topographic depressions and is widespread. The components are rhyolitic pumice, lithic fragments and volcanic ash. ML is widely distributed in the north, west and south of the caldera. According to the boring data of the south of the caldera, the thickness is about 90~100 m (Kawabe and Sakaguchi, 2005). The massive pyroclastic-flow deposits composed of the lower coarse grained pyroclastic-flow deposit and the upper fine grained pyroclastic-flow deposit (Iwakura et al., 2001)

The second is the stratified or cross-stratified deposit that is named the laminated layer (LL) and is distributed in topographically higher area of the northwest and west of the caldera. The components are rhyolitic pumice, lithic fragments and volcanic ash. LL overlies Kikai-Akahoya tephra and the paleosol lying between them. In near-vent exposure (about 1 km from the caldera rim), LL has the thickness of about 8 m, is rich in coarse pumice, and lacks fine ash. Moreover, it locally contains laterally-discontinuous lenses of coarse pumice and the banding is marked by variations in the content of coarse pumice and the maximum pumice size. At the exposure of 1.5 km from the caldera rim, thickness of LL is about 1 m. The matrix is rich in fine ash. It locally contains thin layer or laterally-discontinuous lenses of coarse ash. At the outcrop of 3 km from the rim, LL contains little pumice, and is rich in fine ash. The thickness and the grain size of LL decrease rapidly with distance from source.

[Grain-size characteristics of ML and LL]

The grain-size characteristics were obtained by sieve analyses of LL (15 horizons of 9 sites) and ML (19 horizons of 13 sites). The cumulative curves of LL overlap with that of ML ,and the points of LL and ML in $Md\phi$-$\sigma\phi$plot are plotted similar area. Difference of grain-size characteristics of ML between upper and lower unit corresponds to that of LL between upper and lower part. Therefore, the grain-size characteristics of LL and ML are similar.

[Discussion]

We propose that LL and ML are heteropic facies of Ikeda pyroclastic-flow eruption on the basis of the following four reasons. First, the pumice which is included in both LL and ML contains hornblende as phenocryst. Second, the components of LL and ML are same. Third, LL and ML do not occur at the same exposures and the both overlie Kikai-Akahoya tephra and underlie Ikedako-Ash. Ikeda pumice fall deposit exists directly under ML but does not exist under LL because the dispersal axis of the Ikeda pumice fall is eastward. Fourth, sieve analyses showed that grain-size characteristics of LL were very similar to that of ML. Ikeda pyroclastic flow that had been caused by eruption column collapse moved into topographic depressions in response to gravity and deposited ML, because it was dense density current. Simultaneously, dilute flow occurred at the collapsed region at the same time and surmounted topographic obstacles and deposited LL, because it was low density current.

Eruptive sequence of Koya pyroclastic-flow deposit distributed on Tanega-shima

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Koya pyroclastic flow (Ui, 1973) is a large-scale pyroclastic flow formed at the 7.3 ka (Fukuzawa, 1995) Akahoya eruption of Kikai caldera. Akahoya eruption started from large-scale Plinian eruption which formed plinian pumice fall deposit and intraplinian pyroclastic-flow deposit and terminated with eruption of Koya pyroclastic flow (Machida and Arai, 2003; Maeno and Taniguchi, 2007; Fujiwara and Suzuki, 2013). The pyroclastic-flow deposit is considered to travel across the sea and distributed over the adjacent islands (Tanega-shima, Yaku-shima and Kuchinoerabu-jima) and the mainland of south Kyusyu (Satsuma-Osumi Peninsula) around Kikai caldera (Machida and Arai, 1978; Maeno and Taniguchi, 2007). This pyroclastic flow is traceable up to 80 km away from the source.
Products of Akahoya eruption contain two types of volcanic glass shards. The one is “high-SiO_2 glass” (ca. 75 SiO_2 wt. %), and the other is “low-SiO_2 glass” (ca. 65 SiO_2 wt. %). The ratio of both types of glass shards shows vertical variation within the pyroclastic-flow deposit (Fujiwara and Suzuki, 2013). Based on the ratio of both types of glass shards, Fijiwara and Suziki (2013) showed that the early phase products of Koya pyroclastic-flow eruption traveled and deposited on the northward of Kikai caldera. But, the areas southward of the caldera have not been studied.
In Yaku-shima, which locates 30 km south of the caldera, the pyroclastic-flow deposit are 2-3 m thick in north-west coastal area. In addition, the pyroclastic-flow deposit occur in highly inland area (Geshi, 2009). In contrast, in Tanega-shima, which locates 50 km east- to southeastward of the caldera, the pyroclastic-flow deposits are thin (< 0.5 m) and show partially lack in north area (Fujiwara and Suzuki, 2013) although this island has lesser relief (topographic barrier) than Yaku-shima. 5 lack sites were identified in the north area, furthermore, new 2 lack sites in the south-central area were recognized in this geological survey of Tanega-shima.
To reveal the cause of the lack of the pyroclastic-flow deposit, we attempted to correlate the eruptive sequence for deposits on Tanega-shima based on Fujiwara and Suzuki (2013). Matrix samples of Koya pyroclastic-flow deposit in Tanega-shima were sampled from base to top with regular level interval. 50-200 volcanic glass shards were selected at each level and measured the major element composition by EPMA. Until now, lower-most level of the pyroclastic-flow deposit at 3 sites and upper-most level at 2 out of 3 sites were measured.
In the lower-most level at every 3 sites, only the high-SiO_2 glass shard was detected. The low-SiO_2 glass shards were detected at upper-most level in 1 site.
The early phase products of the Koya pyroclastic-flow eruption arrived and deposited on Tanega-shima because the same characteristics with the deposits of the main island of south Kyusyu, that is, only high-SiO_2 glass shards are recognized in the lower most level, and low-SiO_2 glass shards were coexisted with high-SiO_2 glass shards in the upper level. Existence or lack of the pyroclastic-flow deposit in Tanega-shima seems to be due to deposited or not rather than arrived or not. It is difficult to explain this existence or lack by flow arrival or not because no topographic barrier exists between caldera and this island, and this island is relatively flat and low altitude.

Keywords: Kikai caldera, Koya pyroclastic flow, volcanic glass, Tanega-shima

Emplacement process of the Shiroyama obsidian lava in Himeshima Island, SW Japan

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The Shiroyama lava is distributed in northwestern part of the Himeshima Island in Oita prefecture, and the K-Ar age is 0.32± 0.05 Ma (Kaneoka and Suzuki, 1970). The dark-gray colored dense obsidian is partly developed in the Shiroyama lava (Itoh et al., 1997). Although distribution of the obsidian is restricted in the narrow area of Kannonzaki cape where is northern margin of the lava, the good exposure provides an opportunity to understanding the formation process. The obsidian gradually changes to light-gray colored, highly vesicular rhyolite lava (Itoh et al., 1997) that comprises a large part of the lava. The welded-pyroclastic rocks (Kannonzaki pyroclastic rock; Itoh et al., 1997), which are contacted with the dense obsidian, are also occurred in Kannonzaki cape. In this study, we show the geological characteristics of the Shiroyama lava and discuss about its emplacement process.

The flow direction of the Shiroyama lava, inferred from the topography and flow banding morphology, is from north (Kannonzaki cape) to south. This means that the obsidian is distributed around the source region and was emplaced at the final stage of the extrusion. The internal structure of the obsidian is characterized by pervasive brecciation. The brecciated clasts are commonly elongated in length from a few cm to several tens of cm and frequently show ductile deformation. This means that the brecciation was occurred during ductile-brittle transition temperature. The elongated clasts are aligned nearly vertically, and the foliation is nearly parallel to the plane of contact with the Kannonzaki pyroclastic rocks. In the boundary between the brecciated obsidian and the pyroclastic rocks, the cataclastic zone with <1m in width is developed. The cataclastic materials are composed of both the obsidian and pyroclastic rocks. The foliation and lineation of the cataclasite defined by the alignment of the fragments are consistent with those of the brecciated obsidian. These mean that the obsidian breccia and the cataclasite were formed by shear stress under the same sense.

The vertical-orientated brecciated clasts indicate that the obsidian suffered vertical shear stress. This observation shows that the obsidian corresponds to the ascending magma within the shallow conduit rather than the advancing lava on the land surface. It has been considered that the magma fracturing and brecciation are caused by intense shear at the conduit walls (e.g. Gonnermann and Manga, 2003; Tuffen et al., 2008). The cataclastic zone between the obsidian and the Kannonzaki pyroclastic rocks would be caused by accumulation of the shear stress at the conduit wall. The development of the cataclastic zone in the conduit margin is consistent with observation of the silicic lava extrusions at Unzen and St. Helens volcanoes (Nakada et al., 1999; Pallister et al., 2013). Since the transient fractures within the magma is expected to act as degassing pathways (Tuffen et al., 2003, Okumura et al., 2015), the pervasive brecciation of the obsidian shows that the magma experienced extensive degassing within the conduit. Cabrera et al. (2015) proposed that the formation of the dense obsidian is promoted by magma degassing using the fractures. In the Shiroyama lava, the restricted distribution of the dense obsidian in the conduit may be explained by the extensive degassing due to the magma fracturing and brecciation that predominantly occurred at the final stage of the extrusion.

Keywords: Obsidian, Lava, Degassing, Conduit, Himeshima

Magma ascent and outgassing processes of obsidian lava
-Insights from structures, textures and water concentration profiles -

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Structures of obsidian lava are mainly divided into two regions; obsidian and rhyolite. These are defined based on the differences in appearance of hand specimens and rock texture. Rhyolite has perlitic cracks in the glass and contains some amounts of crystalline materials, namely, spherulite and lithophysae, whereas obsidian includes no such material at all.
Recent observation on Cordon Caulle (Chile, 2011-12) reported that explosive-effusive hybrid activity (Schipper et al., 2013), and we can consider that these differences are reflecting heterogeneous processes such as vesiculation and outgassing in volcanic conduit, and forms obsidian and rhyolite. In order to reveal such heterogeneous vesiculation and outgassing processes of viscous magmas, we performed water concentration analyses with comparing rock texture of samples from Sanukayama (SN) obsidian lava at Ko-zu island and Akaishiyama (AK) obsidian lava at Shirataki, Hokkaido.
A cross-section of the SN lava shows the following sequence from the bottom up: a lower rhyolite region (SN-LRhy), a lower boundary banded region (SN-LBB: 40 [m]) of obsidian and rhyolite, obsidian region (SN-Ob), upper boundary banded region (SN-UBB) and a clinker region (SN-CL) that is composed of vesiculated rhyolite and fine matrix. The SN obsidian is aphyric and contains microlites of plagioclase, biotite and oxides. Phenocrysts are plagioclase and biotite.
AK lava is characterized by well-growth spherulite. A cross-section of the AK lava is the following sequence from the bottom: lower obsidian region (AK-LOb), lower boundary banded region (AK-LBB), rhyolite region (AK-Rhy), upper boundary banded region (AK-UBB) and Upper obsidian region (AK-UOb). The AK obsidian contains oxide microlite, and no phenocrysts are contained. At AK lava, we can observe flow bands which are composed of the cm-scale spherulites in BB and Rhy regions. Sometimes spherulites include the obsidian particle. We can also observe the tuffisite structure.
The water concentration was determined using Karl Fischer Titration at the Hokkaido University of Education at Asahikawa. First, we powdered rock samples making sure that there were no crystal fragments. Next, we handpicked powders with an accuracy of $\pm 10^{-3}$ g for titration. The samples were heated to 120 [°C] for about 1 h to eliminate all adsorbed H_2O. Finally, we heated the samples to a temperature of 1000 °C to calculate the amount of dissolved water (Westrich, 1987). The titrations were finished when Time-Water amount slope become flat. The duration of analyses was up to 1[h].
Water concentrations in SN samples are following; 0.07 -0.27 [wt.%] in L-Rhy, 0.22 -0.99 [wt.%] in L-BB, 0.01 -0.29 in Ob, 0.01 -0.21 [wt.%] in Ob, 0.08 -3.06 [wt.%] in rhyolite region, respectively. The degree of hydration is higher in clinker region than lower rhyolite. Shields et al. (2016) suggested that the amounts of hydration of rhyolite lava samples have positive correlation with the connected vesicularity. According to their study, connected vesicules were highly developed in upper regions.
Water concentrations in AK obsidian were in the range of 0.01 -0.03 [wt.%], and no systematic change relating to lava structure can be observed. Spherulite shows 1.1 [wt. %] water concentration. We can consider that this value reflects that flow band structure, which is composed of spherulites, has connected vesicularity.
We compared the water concentration profile with lava structure and rock texture at SN and AK lava. Water concentration profiles give us the useful information to reveal the vesiculation and

outgassing processes in obsidian lava.

Keywords: obsidian, outgassing, water concentration

Foaming temperature and textural classification of vesicular substance by heating experiments of obsidians

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Obsidian includes H_2O component in the glass. The H_2O component is vesiculated when heated at a high temperature, and their foams surrounded by dense obsidian glass expand to porous material, referred to as “perlite”. We have carried out heating experiments with an electric furnace for 11 obsidian samples from each different locality to determine the foaming temperature (Tf) and perlite-formation temperature (Tp) of their obsidians. The results are as follows; Akaigawa obsidian Tf=780℃; Tp=830℃, Okushiri obsidian Tf=790℃; Tp=850℃, Kozushima obsidian Tf=890℃; Tp=950℃, Shirataki obsidian (IK outcrop) Tf=900℃; Tp=1030℃, Tokachi-Mitsumata obsidian Tf=930℃; Tp=1060℃, Oketo obsidian (Tokoroyama) Tf=990℃; Tp=1100℃, Oketo obsidian (Kita-Tokoroyama) Tf=1010℃; Tp=1090℃, Shirataki obsidian (Tokachi-Ishizawa outcrop) Tf=1030℃; Tp=1160℃, Shirataki obsidian (Kyukasawa outcrop) Tf=1060℃; Tp=1150℃, Shirataki obsidian (Nishi atelier) Tf=1070℃; Tp=1190℃, Shirataki obsidian (Ajisainotaki outcrop) Tf=1070℃; Tp=1190℃.
Perlite texture was classified into three types (type-A, -B and -C) based on the diameter, morphology and number density of vesicles. Type-A has discrete spherical forms with about 1 mm in diameter, which belongs to Tf>990℃, Tp>1060℃ group. Type-B, Tf=900-930℃, Tp=1030-1060℃ group, has distorted spherical forms with 1.5 to 5.0 mm in diameter. Type C is characterized by high number density and small size of vesicles (< 0.5 mm) connecting with each other, belonging to low Tf (<890℃) and Tp (<950℃) group.
The texture of perlite made by obsidian heat experiment is different from that of natural vesicle substance such as pumice and vesiculated obsidian. Lower number density of vesicles in the experimental product perlite is due to low H_2O content in quenched obsidian after degassing of H_2O in obsidian magma. The difference in vesicle morphology between the spherical form of perlite and reticulated irregular-shaped vesicle of natural vesicle substance is related to the difference in the static or dynamic condition of formation environment.

Keywords: obsidian, perlite, heating experiment, foaming temperature, volcanic glass

Internal structure of obsidian lavas in the south of Kamchatka Peninsula

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In the south of Kamchatka Peninsula (53.04N, 157.78E), obsidian lavas are exposed from north-northeast to south-southwest direction over 400 m. The cross-section of the obsidian lavas is divided into upper and lower parts. Each part is about 15 m thick. The internal structure of the upper part is divided into two parts: the top part is composed of rhyolite and the interior comprises alternating pumiceous and massive obsidian layers. The massive obsidian layers are classified into three layers (B, D, and E). On the other hand, the internal structure of the lower part consists of alternating pumiceous and obsidian layers. The obsidian layers are classified into at least three layers. Typical structure of obsidian lava is thought to consist of an outer obsidian region and an interior rhyolite region (Cas and Wright, 1987; Stevenson et al., 1994; Sano et al., 2015; Wada and Sano, 2015). In general, the rhyolite has perlitic cracks in the glass and contains some amounts of crystalline materials, namely, spherulite and lithophysae, whereas the obsidian contains none of such features and materials. In the study area, however, the internal structure of the obsidian lavas is complex and different from the typical structure.

The obsidian rock samples were collected from the three massive obsidian layers (B, D, and E) in the upper part and from one obsidian layer (F) in the lower part. We estimated glass compositions and water contents of the four obsidian samples (B, D, E, and F). The glass compositions of B, D, and E are divided into three regions according to FeO contents and that of F shows the intermediate compositions between D and E. Water contents in the four obsidian samples are following; 0.52-0.54 [wt.%] in E, 0.33-0.37 [wt.%] in F, 0.04-0.18 [wt.%] in B, and 0.04-0.10 [wt.%] in D. The four obsidian samples are different in the glass compositions and water contents. Thus these obsidian lavas may be formed from different magmas in chemical compositions and/or heterogeneous magmas in water contents (Seaman et al., 2009).

Keywords: Kamchatka Peninsula, Obsidian lava, Internal structure

Emplacement and Solidification processes of off-axial large submarine lava field: Petrology of V3 flow of Oman Ophiolite

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Large submarine lava with thicknesses >100 m and volumes exceeding a few cubic kilometers are not uncommon volcanic constructs of mid-ocean ridges and around Hawaii Islands, yet details of the physical processes of emplacement of these large lava flows are poorly understood. The V3 Volcanics of the Oman Ophiolite extruded at 90 Ma far off the paleospreading axis as thick lava flows with an areal extent of >11 km by 1.5 km and the maximum thickness >270 m, yielding an estimated volume of several cubic kilometers. The V3 flow was fed by a thick feeder dike in the SW of the flow field and buried off-axial fault-bounded basins. V3 flows consist of massive core sandwiched between columnar jointed lava crusts. V3 flow is divided into the Upper and the Lower flow by the presence of pillow lava with interstitial mudstone. Unlike the Lower flow with massive cores, the Upper flow comprises piled up flow lobes showing dome-like structures with thicknesses varying from 2 m to 20 m. The Upper flow consists at least of seventeen flow lobes along a transect at 6 km from the feeder dike.

Low-T hydrothermal alteration and weathering affected LILE compositions of the V3 flow. However, strong positive correlations among incompatible HFSEs and REEs, and relatively good correlations with Zr show that these elements were less mobile and preserve primary characteristics. V3 flow comprises trachybasalt to basaltic trachyandesite dolerite with intermediate trace element characteristics between OIB and E-type MORB. Whole-rock major and trace element variations through a stratigraphic transect at 8.7 km from the feeder dike show fractional crystallization of augite, plagioclase and magnetite. By contrast, other samples of V3 flow show highly scattered whole-rock compositions, which may be explained by internal mixing of variably differentiated magmas.

Yb of the basal crust show increases downflow to ~4.5 km, then decreases to 6 km, high value at 7 km from the feeder dike and decreases further downflow. Because the basal crust is the quenched lava that came to rest first at that place, samples farther away from the feeder were extruded and emplaced later in the eruptive event. The downflow variations show extrusion of differentiated lava in the middle stage of the eruption and less differentiated lava in early and late stages.

The Lower flow was initially emplaced as a thin sheet of lava, and was inflated to become a thick sheet lava as lava was injected into the core of the flow. Meanwhile, the lava was mainly cooled from above and solidified downward. Yb stratigraphic variation shows decreases from the basal crust to the core at 26 m in stratigraphic height, then increases to the upper crust at 83 m in height and then decreases to the top of the Lower flow at 136 m in height. The Yb concentrations of 2.07 μg/g in the core are comparable to those of the later flows frozen in the proximal basal crust. It is consistent with the model where the core was formed by the lastly supplied and solidified lava. Besides the lava at height 259 m, the variation in Yb concentration from 145 m in height to the top of the Upper flow are correlatable to the temporal variation of the extruded lava, consistent with interpretation that the Upper flow formed by welded flows which were emplaced one on top of the other.

N-MORB normalized primitive V3 trace element patterns show LREE enrichment in spite of similar HREE abundances to N-MORB. Geochemical partial melting model of depleted MORB mantle indicates that the

primitive V3 trace element compositions can be reproduced by the mixing of melts formed by 0.2 wt% partial melting of garnet lherzolite and 1.5 wt% to 3.0 wt% partial melting of spinel lherzolite.

Keywords: Oman Ophiolite, large submarine lava flow, chemical variation, Emplacement processes , partial melting, magma genesis

Eruptive dates of tephras from Ilopango Caldera, El Salvador, C. A.

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The mineralogical properties and chemical composition of volcanic glass were analyzed for four felsic tephra named TBJ, TB2, TB3 and TB4 from Ilopango Caldera, El Salvador, C. A. by microscopic observation and EPMA analysis. Although these properties of the four tephra are similiar to one another, a slight differnece of the chemical composition of volcanic glass discovered in this study make it possible to identify each tephra. It enables us to correlate two vitric ash named La Periquera ash and El Refugio ash, which are observed in the area around Santa Ana Volcano, ca. 80 km from Ilopango Caldera, to the TB2 and the TB4 tephras, respectively. Depositional dates of the two tephra, illustrated previously as about ca. 7 ka and 30-45 ka, indicate that four large felsic eruptions occurred in the recent 40,000 years at Ilopango Caldera.

Keywords: TB4 tephra, large caldera eruption, chemical analysis of volcanic glass

The recent trend survey of Probabilistic volcanic hazard assessment methods

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Forecasting of the volcanic eruption is challenging issue in the field of volcanic hazard assessment because of its uncertainties. On the occurrence of volcanic eruption, it may cause to human loss, Great environmental change, economic loss and fatal damage for infrastructures such as electric and water supply, traffic, railway and so on. A probabilistic hazard assessment that treat a volcanic eruption based upon statistical methods has been developed since 1960's (e.g. wickman, 1966a; Reyment, 1969; Decker, 1986; Connor and Hill, 1995; Marzocchi and Bebbington, 2012). Here in Japan, the probabilistic method is not so popular to assessing a risk of volcanic hazard though, some approaches have been tried to investigate the impact of volcanic activities. The volcanic hazard assessment via probabilistic method has more possibility and potential to apply for evaluating a volcanic hazard in Japan. In this study, we researched the trend and proportions of probabilistic assessment method that developed all over the world and brought out a possibility and agenda which adapt to these methods to Japanese risk survey.

Keywords: Probabilistic volcanic hazard assessment, long-term prediction, short-term forecast

