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 Mdφ-σφplot 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

