

Magma ascent process inferred from textural analysis in Tokachi-Ishizawa obsidian lava, northern Hokkaido, Japan

Kyohei Sano^{1*}, Atsushi Toramaru², Keiji Wada³

¹Department of Earth and Planetary Sciences, Graduate School of Sciences, Kyushu University, ²Department of Earth and Planetary Sciences, Faculty of Sciences, Kyushu University, ³Hokkaido University of Education at Asahikawa

Formation process of obsidian is poorly understood, while it is thought that gas loss (outgassing) plays an important role. Glass formation needs the high-effective supercooling resulted from a high ascent and decompression rates. However the high-effective supercooling increases magma viscosity, so the rapid ascending process of such a highly viscous magma is an enigma. In this study, we conducted textural and chemical analyses for Tokachi-Ishizawa (TI) obsidian lava, one of Shirataki rhyolite lava, Hokkaido, northern part of Japan, in order to elucidate the magma ascent and outgassing process, and obtain clues to solve the problem.

In Shirataki rhyolite lava area there are monogenetic volcanoes composed of 10 obsidian lava flow units, which were erupted at 2.2Ma. Rhyolite lava area with well-exposed outcrops allow us to observe the internal structure of obsidian lava flow. The stratigraphic sequence of TI lava 50 m in height is a brecciated perlite layer, obsidian layer (7m), banded obsidian layer, and rhyolite layer from the bottom. It is uncertain that brecciated perlite layer is essential. In this study, we define the obsidian and rhyolite based on the difference in appearance of specimen and rock texture, especially crystallinity. Rhyolite has perlitic cracks on glass, and contain the crystalline materials (i.e. spherulite and lithophysae). Banded obsidian layer which is located at the boundary between the obsidian and rhyolite layer, is composed of fine layer of obsidian and rhyolite. Volume fraction of the crystalline materials in rhyolite layer is up to 40 vol.%.

Obsidian in TI lava is almost aphyric, composed of glass (>98 % in volume), rare plagioclase phenocrysts, plagioclase microlites, magnetite microphenocrysts, oxide microlite, and rare biotite. The nanoscale crystals in obsidian glass are identified as plagioclase, based on transmission electron microscope (TEM) and field emission scanning electron microscopy (FE-SEM). This type of crystals forms microscopic layering structure in obsidian glass.

Chemical compositions of obsidian glass, plagioclase and magnetite were analyzed by electron microprobe (EPMA). Water content in obsidian glass was determined by Karl Fischer Titration (0.5-0.6 wt.%).

The maximum depth of magma chamber is estimated as <300MPa from the rhyolite-MELTS (Gualda et al., 2012) and petrographic characteristics. Magmatic temperature is calculated as $T = 800-820$ [deg C] from the plagioclase-melt geothermometer (Putirca, 2005). Magma viscosity is estimated as $4.9-8.7$ [log Pa s] (Giordano et al., 2008).

We measured length, width and number of oxide microlite based on three-dimensional measuring method (Castro et al. 2003), and oxide microlite number density (N_v [$/m^3$]) was obtained. From N_v value of oxide microlite, $10^{13}-10^{14}$, and glass chemical compositions, water exsolution rate and ascent rate are inferred as $10^{-8}-10^{-7}$ [wt.%/s], and $10^{-5}-10^{-4}$ [m/s] respectively (Toramaru et al., 2008). These results means that obsidian and rhyolite experienced the same degassing rate, that is, ascent rate. This provides a constraint on the formation process of obsidian.

Keywords: obsidian, rhyolite, textural analysis

Simultaneous generation of multiple silicic magmas and their zoned magma chamber related to a caldera-forming eruption:

Mitsuhiro Nakagawa^{1*}, Jun-ichi Kitagawa¹, Hiroko Wakasa¹, Akiko Matsumoto¹, Takeshi Hasegawa²

¹Earth & Planetary System Sci., Hokkaido Univ., ²Department of Earth Sciences, College of Science, Ibaraki University

It has been widely believed that a large scale, caldera-forming eruption was derived from a zoned magma chamber, which was composed of single, voluminous silicic magma associated with a small amount of mafic magma. In almost all the cases, the mafic magma injected into the silicic magma before the eruption to erupt as mixed or mingled magma with the silicic one. This is consistent with both of the temporal change of eruptive magma during the eruption and evidence of magma mingling and/or mixing. However, there also exist several eruptions in which distinct types of silicic to intermediate magmas erupted with mafic magmas. In this study, we show two examples from Hokkaido, Japan, in which distinct silicic magmas coexisted in addition to mafic magma. During 40 ka caldera-forming eruption of Shikotsu volcano, eruptive materials can be divided into two types, aphyric (A-type) and porphyritic (P-type) ones. A type is voluminous rhyolitic magma and the mixing product of high-Si and low-Si rhyolitic magmas. These can be distinguished by Sr isotope ratios, indicating that these two magmas are no genetic relationship explained by fractional crystallization. On the other hands, the P type magma is also mixing products and several dacitic and andesitic magmas. There is no mixing relationship between A and P types, indicating that the climactic caldera-forming eruption derived from simultaneous eruption of multiple magma chambers. In summary, the silicic magmas during the caldera-forming eruption of Shikotsu caldera consisted of two types of rhyolitic magmas and one or two types of dacitic magmas. In the case of 120 ka caldera forming eruption of Kuttcharo volcano (KpIV eruption), voluminous silicic magma erupted with small amount of mafic (andesite) magmas. The silicic magma is the mixing products of rhyolite and dacite magmas, which can be clearly distinguished by Sr isotopes. Thus, as in the case of Shikotsu volcano, the silicic magma of KpIV eruption consisted of multiple silicic magmas, which should be independently formed. However, these magma would be simultaneously formed. It has been widely believed that mafic magma plays as a heat source to produce silicic magma. If the silicic magmas were produced by crustal melting, partial melting of heterogeneous crustal materials might occur to produce several distinct silicic melts. It should be noted that the simultaneous generation of several types of felsic magma would be common especially in the case of large scale silicic magmatism such as caldera-forming eruptions. In such a case, mafic magma as a heat source would be enough large to melt crustal materials extensively.

Keywords: magma, silicic magma, caldera-forming eruption, crustal melting, magma genesis, zoned magma chamber

Analysis of fractionation process of the volcanic rocks based on principal component analysis with trace element

Kenta Ueki^{1*}, Hikaru Iwamori²

¹Volcanic Fluid Research Center, Tokyo Institute of Technology, ²Department of Earth and Planetary Sciences, Tokyo Institute of Technology

Detailed information of fractionation process in the crust is a fundamental issue to discuss magma generation processes in the mantle and crust, and evolution of the mantle-crust system. Major element fractionation is non-linear process which involves thermodynamic relation. On the other hand, trace element processes can be regarded as linear process, because its partition coefficient between phases considered to be unity in many cases. Hence, trace element can be a good tracer for magma mixing and involvement of a particular phase (e.g., Depaolo, 1981). To discuss fractionation process in a multi-component and multi-phase system, multivariate statistics analysis is necessary. Here we employ a principal component analysis to analyze bulk compositional trends of series of lavas from quaternary Akita-komagatake and Hachimantai volcanoes in the Northeastern Japan arc to discuss fractionation process of each volcano. Based on the principal component analysis with trace element concentrations, and petrological analysis with the major element concentrations and mineralogy, we discuss a variation of fractionation processes in the crust and also propose a possibility of employing a principal component analysis to the volcanic process.

Three principal components account for the trace element variation of the Akita-komagatake volcano. The three principal components show correlation with the major element concentration, suggesting trace and major element processes are coupled in the Akita-komagatake volcano. The three principal components can be attributed to the various degree of closed system fractionation or accumulation of olivine, pyroxene and/or plagioclase. The result is consistent with the fractionation model based on analysis with the major element composition and mineralogy or calculation using MELTS (Ghiorso and Sack, 1995).

For the Hachimantai volcano, three principal components account for the trace element variation. The first principal component represents the two component process between relatively lithophile elements rich component and incompatible elements rich component. The third principal component represents indicates involvement of mantle derived Cr and Ni rich mafic component, as have been suggested in Ohba et al. (2009). The first and the third principal components show correlation with the major element concentration. The second principal component does not show any relationship between major element composition. The third trace element component may represent selective assimilation of trace element during melt/crustal rock interaction (Watson, 1982).

Result of this study demonstrate that multivariate statistics with trace element concentrations of volcanic rock can decompose multiple fractionation process in a single volcanic suite. Our result also suggests the existence of the decouple between major and trace element processes.

Keywords: Volcanic rock, Crystal fractionation, Magma mixing, Quaternary volcano, Fractionation process

Volcanic history of the Oomurodashi, northern Izu-Bonin Arc

Kenichiro Tani^{1*}, Hiroshi Shukuno¹, Yuka Hirahara¹, Yuka Masaki¹, Alexander Nichols¹, Osamu Ishizuka², Richard S. Fiske³, Katharine V. Cashman⁴, Philip T. Leat⁵, Rebecca Carey⁶, Iona M. McIntosh⁷, Ayaka Onoue⁸, Mitsuya Asagoe⁹, Shin Toyoda⁹

¹JAMSTEC, ²Geological Survey of Japan/AIST, ³Smithsonian Institution, ⁴University of Bristol, ⁵British Antarctic Survey,

⁶University of Tasmania, ⁷University of Durham, ⁸Shizuoka University, ⁹Okayama University of Science

Oomurodashi is a bathymetric high located ~20 km south of Izu-Oshima. Using the 200 m bathymetric contour to define its outline, the diameter of Oomurodashi is ~20 km, similar in size to the Hachijyojima Volcano. Previous dredge surveys conducted on Oomurodashi had recovered fresh pumice clasts (Hamuro et al., 1983, Bull. ERI), but since then it has been ignored, largely because it has a vast flat-topped summit at 100 - 150 meters below sea level (mbsl), and has been regarded as inactive.

However, during cruise NT07-15 of R/V Natsushima in 2007, we conducted a dive survey using the remotely-operated vehicle (ROV) Hyper-Dolphin of the small crater, Oomuro Hole, located in the center of the flat-topped summit of the Oomurodashi. The heat flow measurement conducted on the floor of Oomuro Hole recorded an extremely high value of 4,200 mW/m². Furthermore, ROV observations revealed that the southwestern wall of Oomuro Hole consists of fresh rhyolitic lava flows.

These findings suggest that Oomurodashi is in fact an active silicic submarine volcano. To confirm this hypothesis, we conducted detailed geological and geophysical surveys of Oomurodashi in July-August 2012, again using the R/V Natsushima and ROV Hyper-Dolphin (cruise NT12-19). In addition to further ROV surveys, we carried out single-channel seismic (SCS) surveys across Oomurodashi in order to examine the shallow crustal structures beneath the current edifice.

The ROV surveys revealed numerous active hydrothermal vents on the floor of Oomuro Hole. The maximum water temperature measured at the hydrothermal vents reached 194°C, almost equivalent to the boiling temperature of water at the ~200 mbsl water depths of the floor of Oomuro Hole. We also conducted comprehensive heat flow measurements across the floor of Oomuro Hole, with very high heat flows up to 29,000 mW/m² being detected. ROV observations revealed that the area surrounding Oomuro Hole on the flat-topped summit of Oomurodashi is covered by extensive fresh rhyolitic lava and pumice clasts with minimum biogenetic or manganese cover, suggesting recent eruption(s). Furthermore, the SCS surveys revealed the presence of a buried caldera-like structure, ~8 km in diameter, beneath the flat-topped summit of Oomurodashi.

These findings strongly indicate that Oomurodashi is an active silicic submarine volcano, with recent shallow-sea eruption(s) occurring from Oomuro Hole. Since Oomurodashi is situated in a shallow-sea environment, in close proximity to the inhabited northern Izu Islands, further volcanological surveys are essential to understand the detailed volcanic history and potential hazards of this volcano.

Eruption history of Miyakejima Volcano, in the 9-20th century

Teruki Oikawa^{1*}, Nobuo Geshi¹

¹Geological Survey of Japan/ AIST

To make an effective forecasting of the volcanic activity in Miyakejima Volcano, it must be understand history of the post Hachodaira Caldera eruptions and the pre A.D. 2000 Caldera. Based on the caldera wall observation, tephrochronology, and radiocarbon dating, we clarify the eruption history of Miyakejima Volcano in the 9-20th century. After the 9th century the eruption number of pre-A.D.2000 Caldera is 17 times. These eruptions are flank fissure eruption in most cases. The frequency of eruption is 1-2 times in 100 years. Just before the formation of the A.D. 2000 Caldera, the 19-20th century, the frequency of eruption was slightly larger (3 times in 100years). But it is not a significant difference.

Keywords: historical eruption, radiocarbon dating, volcanic stratigraphy, tephrochronology, basaltic volcano, Miyakejima Volcano

Estimating accurate chemical composition of primitive magma by using mantle derived Opx: Targeting at the HMA in Kiyama

Fumitoshi Morisato^{1*}, Tsuyoshi Iizuka¹, Hiroko Nagahara¹, Kazuhito Ozawa¹

¹School of science, the University of Tokyo

High-Mg andesite (HMA) is a peculiar magma erupted in the Setouchi Volcanic Belt (SVB). On the basis of petrologic/experimental studies, Tatsumi (2006) et al. showed that HMAs in the SVB were in equilibrium with mantle peridotite and estimated the generation conditions. Petrologic study of HMA in the Kiyama district, Kagawa prefecture, shows that various crust-mantle processes were involved before its eruption. It is, therefore, necessary to accurately estimate the true composition of melt separated from the mantle by considering the processes that the HMA magmas underwent.

Chemical composition of a primitive magma is commonly estimated from an erupted differentiated magma by adding olivine in equilibrium with the melt (Tamura et al., 2000). Because the mantle olivine composition is not known, it must be assumed with or without information from phenocrysts or xenocrysts (Putrika, 2005). We discovered mantle derived Opx crystals in HMA in the SVB, the rim of which has a record of a primitive melt composition. We were successful to obtain accurate composition of the primitive magma of the HMA by using the information.

We conducted field survey in Kiyama and Kanayama (Sato, 1982), central part of Kagawa Prefecture. We also observed thin sections and analyzed whole-rock and mineral chemical composition by XRF and EPMA, respectively, and evaluated the chemical composition and generating pressure and temperature of the primary magma of the HMA.

The Sanuki Group (middle Miocene series) in Kiyama and Kanayama, referred by Sato (1982), consists of rhyolitic tuff breccias and dacitic volcanic breccias covered by sanukitoid lava flows (1, 2, 4). Lava 4 can be subdivided into 3 types according to their phenocryst combination, whole-rock composition, and amount of xenocrysts. Lava2 is abundant in olivine and Opx phenocrysts, while Lava1 and Lava4 are poor in them. Lava2 is classified into HMA and rich in Ni and Cr (8.6wt%, 180ppm, 560ppm for MgO, Ni, Cr content and 0.4 for FeO*/MgO atomic ratio), and the chemical composition is comparable to that of HMA lava flow in Goshikidai (Henmi et al., 1976).

The Lava 2 contains normally-zoned euhedral olivine phenocrysts, whose core $Mg\# = 100 \times MgO / (MgO + FeO^*)$ is in equilibrium with the whole-rock composition. The olivine phenocrysts are thought to have been crystallized from the HMA melt in a closed system. The HMA also contains Opx crystals, which are either euhedral or anhedral surrounded by polycrystalline olivine rim. The Opx is reversely zoned and has $Mg\#$ much higher than that in disequilibrium with the whole-rock composition, suggesting xenocrystic origin. The very high- $Mg\#$ at the rim (up to 92.2) and Cr_2O_3 content (up to 1.2 wt%) suggests that they were in contact with a mantle derived melt. The Opx contains about 1.4 % CaO, from which a minimum temperature of 1100 degrees Celsius is estimated by using QUILF program (Andersen, 2008).

Because the rim of Opx probably records chemical signature of a primitive magma, from which the HMA was derived, it is possible to estimate its composition by the following procedure. First, the $Mg\#$ of olivine and melt in equilibrium with the HMA is calculated by using Fe-Mg exchange partition coefficient between olivine and melt (Beattie, 1993). The composition of primary magma is then calculated by adding fractionated olivine to the HMA until it is equilibrated with the Opx rim in terms of Mg-Fe exchange. The obtained primary magma composition is still HMA. Since olivine could have been fractionated before reaching the $Mg\#$ recorded on the Opx rim, the primitive magma could be much higher in MgO.

The composition of primitive magma of HMA in other areas might be estimated if similar mantle derived Opx is available.

Keywords: HMA, Setouchi Volcanic Belt

Petrological comparison between products of large caldera-forming eruptions and their precursory events

Toshiaki Hasenaka^{1*}, Kiyoshi Kurokawa¹, Hideto Yamasaki¹, Yasushi Mori²

¹Grad School Sci. & Tech., Kumamoto Univ., ²Kitakyushu Museum of Natural and Human History

We report precursory volcanic events of large caldera-forming eruptions from Kyushu, which include (1) a series of tephra occurring 3500 years and 1000 years before the Aira pyroclastic eruption, and (2) Takayubaru lava flow extrusion just before Aso-4 pyroclastic eruption. (1) The compositions of pumice of small-scale eruptions 3500–1000 years before Aira eruption are almost identical to those of Aira pumice. (2) The compositions of lavas from Takayubaru lava lying below Aso-4 tephra without recognizable soil show a little silica-poor composition when compared to Aso-4 earliest pumice. Although both show small but definite fractionation trends, the two trends are unrelated with each other by crystal fractionation. Magma mixing, as observed in the later stage of Aso-4 eruption, was not obvious in both precursory eruptions.

Magma reservoir model of Hildreth (1981) was the first to depict the relationship between large silicic magma reservoir in shallow crustal level and the mafic magma originated from deeper source. This model is a good springboard for discussion of precursory event of the large caldera-forming eruption, which was tested by the above observations. The case (1) corresponds to the spill out of magma from the upper part of shallow silicic crustal reservoir. The case (2) follows the estimation of spill-out event of an independent branch reservoir of large silicic magma body.

Keywords: Takayubaru Lava, Aso caldera, Aira caldera, Aso-4 pyroclastic eruption, magma supply system, Precursory eruption

Determination of hydrogen diffusivity in Ca-rich plagioclase

Morihisa Hamada^{1*}

¹Department of Earth and Planetary Sciences, Tokyo Institute of Technology

Introduction: Compared to studies on hydrogen diffusivity in olivine and pyroxenes, studies on hydrogen diffusivity in feldspars are very few. Plagioclase is one of the most common nominally anhydrous minerals in arc basaltic rocks, and hydrogen diffusivity in volcanic plagioclase can be applied as an useful indicator of degassing from arc basaltic magmas. Here, we performed preliminary experiments to determine hydrogen diffusivity in Ca-rich plagioclase. We also combined the obtained experimental results and analytical results of plagioclase from the 1986 summit eruption of Izu-Oshima volcano to estimate magma ascent rate.

Experimental: Hydrothermal annealing experiments of Ca-rich plagioclase were carried out at 300 MPa using an internally-heated pressure vessel to constrain hydrogen diffusivity in plagioclase. Experiments were performed at temperature ranging from 1000 to 1200 degree C and at fO_2 close to NNO buffer. Experiments were quenched after run duration of 1 to 10 hours depending on temperature. For diffusion experiments, only the relative change of hydrogen concentration is necessary and no independent calibration is required. Thus, we did not quantify hydrogen concentration in plagioclase using polarized infrared spectroscopy (Johnson and Rossman, 2003, *Am. Mineral.*) and instead we measured infrared absorption area per unit thickness using unpolarized infrared beam.

Results: The profile of infrared absorption area per unit thickness across the plagioclase crystal was converted to hydrogen diffusivities, which ranged from about 10^{-11} m²/s at 1200 degree C to about 10^{-12} m²/s at 1000 m²/s. These results are consistent with extrapolated hydrogen extraction diffusivity determined at 1 atm under N₂ gas (Johnson, 2003).

Application: The hydrogen concentration in Ca-rich plagioclase (about An₉₀) from the 1986 summit eruption of Izu-Oshima volcano shows variation ranging from < 50 wt. ppm H₂O through 300 wt. ppm H₂O as a result of polybaric degassing (Hamada et al., 2011, *EPSL*). Hydrogen concentration in each plagioclase is almost uniform across the crystal. The hydrogen diffusivity at eruptive temperature (about 1100 degree C) is about 10^{-12} m²/s, which gives that plagioclase with high hydrogen concentration (300 wt. ppm H₂O) was brought from magma chamber to surface within a few hours to keep hydrogen at the core and to lose minimal amount of hydrogen at the rim. In agreement with this estimation, estimated magma ascent rate at the onset of the 1986 eruption was of the order of 10³ m/h based on the discharge rate of magma at that time ($> 2 \times 10^5$ m³/h). As demonstrated here, hydrogen diffusivity in plagioclase can be useful as an ascent rate meter of hydrous arc basaltic magmas during explosive eruption.

Keywords: Water in nominally anhydrous minerals, plagioclase, Hydrogen diffusivity

Is magma modeled as a hard-sphere suspension or soft-sphere suspension?

Aika Kurokawa^{1*}, Kei Kurita¹

¹Earthquake Research Institute, University of Tokyo

Magma is known as a complex fluid composed of three phases; silicate-melt, crystals and gases. Generally the rheology of suspension changes drastically depending on the mutual volume fraction from gaseous behavior to solid one. The rheology of magmatic system consisting of crystals and silicate melt has been modeled via hard-sphere suspensions such as a mixture of glass beads and viscous fluid. With respect to such solid-liquid system, [A. A. Arzi, 1978] introduced an important concept, Rheological Critical Melt Percentage (RCMP) 20%, which separates solid behavior and liquid behavior. RCMP is understood as a kind of jamming transition and important value since it predicts freezing rheologically above the thermodynamic freezing point. But even at larger melt percentage than RCMP, another type of significant change in the magmatic rheology has been clarified experimentally. That is the emergence of yield strength at the crystal volume fraction of around 20%. From this critical value to (100% - RCMP), magma behaves as a yield stress fluid. On the other hand, models for simple hard-sphere suspension predict this behavior at much higher volume fraction of approximately 60% e.g. [M. Otsuki et al., 2010]. Thus the range in which hard-sphere suspension behaves as a yield stress fluid is quite limited compared to laboratory-determined magmatic rheology. This is because the shape of silicate crystals in magma is generally elongated, which should be modeled as prolate or oblate ellipsoids with high aspect ratio and crystals in magma can easily form networked structures known as crystal clots, crystal cluster, synneusis, crystal chain and so on even if the particle volume fraction is small. Therefore to estimate effective volume fraction, the excluded volume should be considered [A. P. Philipse, 1996].

In this presentation we discuss whether the hard-sphere suspension is an adequate model for the magma and what are needed for proper modeling. Although individual silicate crystals are hard enough in the time scale of magma dynamics, the networked structure of crystals is quite weak and it easily breaks upon flowing stress. Yield stress emerges during breakage of the network. To look at this behavior, we consider the system should be composed of soft-sphere instead of hard-sphere, where widespread repulsive potential as well as a kind of attractive potential are needed.

We utilized an analog material, a polymer, p-NIPAM to conduct rheology characterization of suspension to see complex behaviors of magma by the deformability associated with the networked structures. In a series of our model experiments, firstly it was revealed that p-NIPAM aqueous suspension has the critical volume fraction, which is almost equivalent to that of magma. This indicates p-NIPAM aqueous suspension can be an analogue of magma to see complicated behaviors in magma caused by networked structures of crystals. At the same time it was found that this suspension has a multiplicity relationship between shear stress and shear rate and this multiplicity and the yield stress are inextricably linked together via aging effect. We consider this should be a universal characteristic for two-phase mixture system such as suspension, which has networked structures. Since magma suspension is known to have the yield stress and the networked structures of crystals empirically, this result indicates that magma can possess the multiplicity, which can trigger self-induced oscillation phenomena.

Volcanoes of Japan (Third edition) published in 2013

Shun Nakano^{1*}, Kuniaki Nishiki¹, Shinji Takarada¹, Hideo Hoshizumi¹, Yoshihiro Ishizuka¹, Jun'ichi Itoh¹, Yoshihisa Kawanabe¹, Teruki Oikawa¹, Ryuta FURUKAWA¹, Nobuo Geshi¹, Osamu Ishizuka¹, Takahiro Yamamoto¹, Kiyoyuki Kisimoto¹

¹Geological Survey of Japan, AIST

The Geological Survey of Japan issued the new map in 2013, Volcanoes of Japan (Third Edition), geological compilation covering volcanoes in the Quaternary Period in Japan. The first edition (Isshiki et al., 1968) and the second edition (Ono et al., 1981) were issued in 1968 and 1981. The second edition covered Quaternary volcanoes in land areas and submarine volcanoes only with eruption records. Thereafter, there was dramatic progress with radiometric dating technology and chemical analysis methods, enabling a great volume of dating measurement values and chemical compositions to be collected. The third edition covered Quaternary volcanoes in land areas, in addition to the results of studies on such dating measurement values and chemical compositions since the publication of the second edition. Due to changes to the definition of geologic period definitions (the base of the Quaternary Period was changed from approximately 1.8 Ma to approximately 2.6 Ma) by IUGS in 2009, the third edition has a significantly greater number of volcanoes compared to the second edition.

The distribution map was created based on the Seamless Digital Geological Map of Japan at the scale of 1:200,000, and some of the latest knowledge was added to this edition. In order to basically have a single type of volcano or volcano group for a single classification, geological boundaries on the seamless geological maps were integrated or removed, because the seamless geological maps which had been created until 2012 adopt the later part of the late Miocene and Pliocene (from approximately 7 Ma to 1.7 Ma) as a single period classification, and are not only based on the new geologic age definitions. Extracting individual volcanic rocks of the Gelasian Stage (from approximately 2.6 Ma to 1.8 Ma), which has been newly included in the Quaternary Period, has been manually carried out.

A large number of land volcanoes have been added due to the redefinition of geologic periods. In addition to these, there are some volcanoes which were not in the second edition but have been included in the third edition, because they were found to be in the Quaternary Period, based reasons such as age measurement. Information on such volcanoes is essentially based on the database by Nishiki et al. (2012). Quaternary volcanoes according to the former definition are based on website, Quaternary Volcanoes in Japan, by the Geological Survey of Japan. A large volume of unpublished age measurement data was also referred to in looking into active periods.

The caldera volcanoes, which erupt a large volume of pyroclastic materials, include pre-caldera stage, caldera-forming stage, and multiple post-caldera stages. In this case, each volcano name was given according to the stage. In some cases where it is deemed that there are no chronological gaps between individual active stage or where such gaps are unknown, or if the details of the caldera volcano itself are unknown, such cases are treated as a single volcano.

Neighbouring volcanoes which are deemed to have relatively similar active periods and active ranges are sometimes treated as a single volcano group. The definitions of individual volcanoes and volcano groups include those in the second editions issued in 1981, those based on names and definitions which had been used in previous studies, those newly classified, and those which have been redefined.

In addition to obvious submarine eruption points, sites with which any volcanic phenomena such as discolored water, floating pumice and submarine hydrothermal activity are found, are displayed as submarine volcanoes.

Keywords: Volcanoes of Japan, Quaternary volcano, volcano map

Geology and petrology of Taisetsu volcanic field ; Formation history and Transition of magma

Kosuke Ishige^{1*}, Mitsuhiro Nakagawa¹

¹Department of Natural History Sciences, Graduate School of Science, Hokkaido University

Taisetsu-Tokachi volcanic field, extending in the direction of NE-SW over 80km, locates at the southern end of Kuril arc, in which arc type volcanism has continued at least since late Miocene. In order to reveal the temporal change of magma generation processes and related tectonics at the arc-arc junction, we focus on the northern part of the field, Taisetsu volcano group. In the group, after large silicic pyroclastic eruptions during 2-1 Ma, andesitic stratovolcanoes and lava domes have been built up until now. Although previous studies (eg., NEDO, 1990; Saito, 1996) revealed the outline of structure and eruptive history of the group, detail chronological and petrological studies have not been carried out. In this paper, we report preliminary results of volcano geology and K-Ar age dating of the volcano group.

Based on the temporal shift of eruption centers, mode of activity and petrological features of the rocks, the activity can be divided into five stages. Stage 1: Andesite lava flows were effused from several fissure vents to flat-shaped volcanic edifices which extends N-S direction. Stage 2: Relatively large stratovolcanoes were formed at the northwestern part of the group. After the formation, eruption centers had moved to the central part. Stage 3: Many eruptive centers were active to form lava domes and cones. Stage 4: The most explosive and voluminous pyroclastic eruption had occurred ca. 30 ka to form a small caldera 2km in diameter. Effused pyroclastic flows filled the deep valleys and were exposed as welded tuffs. Stage 5: After the formation of the caldera, the activity has continued at the southwestern part of the caldera to form several stratovolcanoes, including Asahidake edifice (2291 m). The latest magmatic eruption occurred 5000 years ago. Phreatic explosions have repeated since then to form many craters. All of the rocks usually contain plagioclase, clinopyroxene, orthopyroxene and Ti-magnetite phenocrysts. In some of the rocks also include minor amounts of hornblende, olivine, and quartz phenocrysts. These volcanic rocks often contain mafic inclusions. The SiO_2 contents range from 56.4 to 68.5 wt.% for host rocks and from 52.2 to 56.2 for the inclusions. Almost all the rocks are defined as medium-K in SiO_2 - K_2O and CA type in SiO_2 -FeO/MgO- SiO_2 diagram. Although some of major and trace elements of these rocks could be distinguished among stages and/or eruption centers, there exists no distinct features among these rocks especially in incompatible elements. Thus, it seems that similar primary magmas have been formed and differentiated by similar crustal processes during the last 1 My.

Keywords: Taisetsu, volcano, Transition of magma, Formation history, Geology and petrology, magma generation processes

Magma mixing indicated by heterogeneous texture in the Mikurasawa lava, the Taisetsu volcano, central Hokkaido, Japan

Hikaru Baba^{1*}, Keiji Wada¹, Eiichi Sato²

¹Earth Science Laboratory, Hokkaido University of Education at Asahikawa, ²Institute for Promotion of Higher Education, Kobe University

The eruption products of the Taisetsu volcano in central Hokkaido show the heterogeneous structure such as mafic inclusions and banded lavas, caused by magma mixing. The Mikurasawa lava erupted from a vent of outside the Ohachidaira caldera (about 30 Ka) at younger stage (<10-20 Ka) of the Taisetsu volcano. This andesitic host lava has various types of mafic inclusions and both dacitic and mafic elongated parts as banded structure. These heterogeneous structures in the Mikurasawa lava are the most case of characterizing the Taisetsu volcano particularly. The key to elucidate magma mixing processes with petrological technique is to understand the factors of forming heterogeneous structures in the Mikurasawa lava.

The host lava is characterized by coexisting phenocrysts which crystallized from different end-member magmas. The plagioclase phenocryst is classified into three types by An content of the core. Type-A plagioclase phenocryst ($An > 82$) indicates no zoning in the core, but indicates strong normal zoning in the rim. Type-B plagioclase phenocryst ($60 < An < 82$) indicates heterogeneous zoning in the core; the compositional range is from $An = 47$ to $An = 82$. The core composition partially overlaps with that of type-C plagioclase phenocryst. Type-C plagioclase phenocryst ($An < 60$) indicates continuous zoning overall phenocryst; this characters are good agreement with those of the dacitic part. Type-C phenocryst in the host lava indicates reverse zoning in the rim. The augite and orthopyroxene phenocrysts are classified into two types based on Mg# versus Ti and Al content respectively. Using two pyroxene thermometer (Wells, 1977), temperatures of mafic and felsic end-member magmas were estimated 1000 °C and 900 °C.

Mafic inclusions in the host lava are classified into two types by color of interstitial glass; clear glass and brown glass. These inclusions were originated from two kinds of mafic end-member magmas. Each type of mafic inclusions is classified into two sub-types by granularity of groundmass minerals; fine-type and coarse-type.

Heterogeneous structures at the outcrop, phenocrysts compositional variety in the host lava, and diversity of mafic inclusions suggest that three mixed (andesitic, dacitic and mafic) magmas were minglingly erupted and those magmas were precedingly formed at different stage of mixing events in the zoned magma chamber with mush layers injected by two kinds of mafic end-member magmas.

Keywords: the Taisetsu volcano, the Mikurasawa lava, magma mixing, mafic inclusion

The Oropirika pyroclastic flow deposit: Large-scale pyroclastic flow deposit from the Shirataki basin, Hokkaido

Masashi NAGAI^{1*}, KANNARI, Taro², Kensuke TSURUMAKI², SHIBATA, Toru³, SUGIHARA, Shigeo², YAHATA, Masahiro⁴

¹NIED, ²Meiji Univ., ³Tokai Univ., ⁴Geological Survey of Hokkaido

The Shirataki basin and the Horokayubetsu sedimentary basin in Shirataki area are situated in the northeast end of the Taisetsu-Tokachi volcanic chain that consists of Plio-Pleistocene large-scale pyroclastic flow deposits and overlying stratovolcanoes. The Shirataki basin is 11km-wide topographic lowland buried by lacustrine deposit and volcanic products of Tengudake volcano. The Horokayubetsu sedimentary basin is 5km wide depression of basement rocks that is filled by lacustrine deposit and rhyolitic lavas. Welded pyroclastic flow deposits are widely distributed in surrounding mountains. These basins were considered to collapsed caldera by large-scale explosive eruption(Yamagishi,1976;Yamamoto,2004), however detailed evidence is insufficient. Since this area is not fully covered by the younger-stage volcanics and hydrothermal alteration has not progressed, we regard as significant field in considering the geologic evolution of the Taisetsu-Tokachi volcanic chain that has been regarded as a volcanic-tectonic depression. In this time, we define for large-scale pyroclastic flow deposit erupted from this area.

The dacitic welded pyroclastic flow deposit distributed mainly in the outside of the Horokayubetsu and Shirataki basins is called the Oropirika pyroclastic flow deposit. The deposit has dacitic whole-rock compositions ($\text{SiO}_2=65.5\text{-}71.5\text{wt\%}$, $\text{K}_2\text{O}=2.1\text{-}3.5\text{wt\%}$) and contains about 30vol% phenocrysts. The phenocryst assemblage consists of plagioclase, quartz and orthopyroxene(R.I. gamma=1.735-1.737). The chemical compositions of volcanic glass shards in non-welded part is rhyolitic ($\text{SiO}_2=77.3\text{-}78.5\text{wt\%}$, $\text{K}_2\text{O}=4.3\text{-}5.0\text{wt\%}$).

Based on geochemical and petrographical correlation of welded tuff blocks, essential pumice and accidental obsidian fragments, the Oropirika pyroclastic flow erupted from the buried small-scale caldera (Shirataki caldera; Yahata *et al.*, 2003) occurred beneath Tengudake volcano within the Shirataki basin. Since this pyroclastic flow deposit has remained as thick welded tuff in the area within 20-25 km from the vent, this would be a large-scale pyroclastic flow the erupted volume exceeds tens of cubic kilometers. The estimated eruption age is about 1.2 million years ago from the stratigraphic relationships with other volcanic edifices and the results of radiometric dating. This result corresponds roughly to the time of eruption style change of the Taisetsu-Tokachi volcanic chain from large felsic pyroclastic eruption to andesitic stratovolcano formation.

The Oropirika pyroclastic flow deposit can not be confirmed on the ground surface of Shirataki basin. On the other hand, older sediments and pyroclastic flow deposits outcropped within the basin. In order to know the timing for the formation of these basins will need to investigate the relationship between the other older large-scale pyroclastic flow deposits.

Keywords: eruptive history, tephra, caldera

The transition of Magma Activity between 1962 and 1988-89 eruptions in Tokachidake Volcano, Central Hokkaido

Hironobu Hinata^{1*}, Keiji Wada¹, Yu Nakatsuka¹

¹Earth Science Laboratory, Hokkaido University of Education at Asahikawa

Tokachidake volcano, located in Taisetsu-Tokachi volcanic group in central Hokkaido, is one of the most active volcanoes in Japan; recently magmatic eruptions occurred 1926, 1962, and 1988-89. Eruption styles between 1962 and 1988-89 are different; 1962 eruption is characterized by sub-plinian eruption which raised high eruption column, whereas 1988-89 eruption is by magmatophreatic explosion, caused by almost same the basaltic andesite magma as 1962 eruption. We observed groundmass textures and the bubble morphology using polarizing microscopes. Groundmass texture of 1962 scoria is glassy but that of 1988-89 bomb is relatively crystalline. The bubbles in 1962 scoria are mostly rounded in shape and connected each other, showing a porosity of 70.3%, but those in 1988-89 bombs are almost irregular and isolated, a porosity of 38.0%. The compositions of plagioclase phenocryst cores in the 1962 and 1988-89 ejecta range widely from An=92 to An=60. Most of plagioclase phenocrysts in both of ejecta have resorbed texture in the core. The rims in plagioclase phenocrysts in both 1962 and 1988-89 ejecta are reversely zoned, but some plagioclase rims in 1988-89 bomb show two-step reverse zoning. Olivine and titanomagnetite microphenocrysts in 1988-89 bombs are widely ranging in composition. The Cl contents in groundmass glass in 1988-89 bombs were depleted as compared with glass inclusions in phenocrysts, but those in 1962 scoria not depleted. These features suggest that before in both eruptions magma mixing caused by injection of basaltic magma into andesitic magma chamber occurred in common, but in 1962 eruptions since magma ascending velocity was probably fast because of high injection of basaltic magma, degassing was insufficient and explosive eruption was a large-scale. However in 1988-89 eruptions, since magma ascending velocity was slower because of low injection of basaltic magma, sufficient degassing was performed and crystallization was facilitated, resulting in small scale of eruption.

Keywords: Tokachidake, magma mixing, eruptive styles, magma plumbing system

Characteristic Eruption Sequence and its Magma Plumbing System at the Nakamachineshiri Stage-I in the Me-Akan Volcano

Keisuke Anzai^{1*}, Keiji Wada¹

¹Hokkaido University of Education at Asahikawa

Throughout the eruption history of Me-Akan volcano on the Akan caldera, eastern Hokkaido, the largest eruptions occurred about 13000 years ago, which are referred to as Nakamachineshiri eruptive stage-I (Nak-I). Nak-I can be subdivided into two eruption stages. The initial eruptive stage is characterized by pumice-rich pyroclastic flows followed by lava eruptions (Nak-I-E), whereas the following main eruptive stage by continuously eruptive sequence of lava fragment-rich pumice and scoria pyroclastic flows, Plinian pumice and scoria eruption, and pyroclastic flow eruptions (Nak-I-M). This study elaborated multi-stage processes of magma mixing and mingling in the magma plumbing system during Nak-I through mineralogical and petrological analyses of the eruption products. Deposits of Nak-I contain pumice ($\text{SiO}_2=63\text{wt.}\%$), scoria ($\text{SiO}_2=55\text{wt.}\%$) and heterogeneous scoria. The core composition of plagioclase phenocrysts of these scoria and pumice shows a same bimodal distribution of compositions such as low-An plagioclase ($\text{An}=59$) and high-An plagioclase ($\text{An}>70$). This indicates that heterogeneous ejecta were exactly mingling products of both mixed mafic and felsic magmas, which were derived from continuous magma mixing of felsic and mafic end-member magmas in a zoned magma chamber.

Keywords: Me-akan volcano, Nakamachineshiri, eruption sequence, magma plumbing system, pyroclastic flow

Volcanic stratigraphy and magmatic differentiation in the northern Kita-Hakkoda volcanic group

Sho Komatsu^{1*}, Tsukasa Ohba¹

¹Akita Univ.

Stratigraphy of northern Kita-Hakkoda volcano, consisting of Mae-dake, Tamoyachi-dake, Narusawa-daichi cones, was established. Combined with the stratigraphy, differentiation process was investigated from whole-rock chemistry and mineralogy. Eruption products were divided into 9 units: the Hakkoda 2nd Stage Pyroclastic Flow deposit, Northern Kita-Hakkoda Basaltic Andesite Lavas, the Lower Kansuisawa Pumice Flow deposit, the Lower Tamoyachi-dake Andesite Lavas, the Upper Kansuisawa Pumice Flow deposit, the Upper Tamoyachi Andesite Lavas, Maedake lavas, Narusawadaichi Andesite Lavas and the Okuzuresawa Pyroclastic Flow deposit in stratigraphic order. Chemical analysis following the stratigraphy elucidated the temporal variation in magmatic compositions. The activity initiated with the effusion of differentiated tholeiitic basaltic magma around 0.4 Ma (Northern Kita-Hakkoda Basaltic Andesite Lavas). After a dormancy, the activity (deposition period of Tashiro-tai Lacustrine Deposit), the activity resumed around 0.2 Ma with effusion of andesitic magma (60 wt% SiO₂) (Lower Tamoyachi-dake Andesite Lavas, Upper Tamoyachi Andesite Lavas, and lower Maedake Lavas), followed by a series of activity of low-silica calc-alkaline andesite (middle Maedake Lavas) and tholeiitic basalt magmas (upper Maedake Lavas). Then, the magma composition jumped to high silica (60 wt% SiO₂) calc-alkaline andesite (Narusawadaichi Andesite Lavas). Each rock from the all units contains plagioclase, augite, orthopyroxene, olivine, and magnetite as phenocrysts. Some calcalkaline andesite (Upper Tamoyachi-dake Andesite Lavas) contain embayed quartz phenocrysts. No evidence for open system process is recorded in phenocrysts in the tholeiitic rocks. Previous studies accounted for the chemical variation of tholeiitic magma by crystallization differentiation, and our new data is consistent with the model. Disequilibrium mineral assemblages in calc-alkaline rocks, e.g., coexistences of magnesian olivine and embayed quartz, and of reversely zoned pyroxenes and normally zoned pyroxenes, imply open system processes. As indicated by the linear trend between tholeiitic basalt and the high-silica andesite, magma mixing is a plausible process to produce the series. Stratigraphic chemical variation might be caused by temporal variation in mixing ratios. Focused on the magmatic activity after the dormancy, initial stage was dominated by felsic end-member to produce high-silica andesite (60 wt% SiO₂). Then, contribution of the mafic end-member increased and chemical composition gradually shifted to basic. The composition of erupted magma finally achieved to the pure mafic endmember magma composition which is a tholeiitic basalt. Then mixed magma with a high silica content (60 wt% SiO₂) erupted again.

Keywords: Kita Hakkoda Volcanic Group, calc-alkaline series, magma-mixing

Evolutionary Processes of the Coexisted Tholeiitic and Calc-alkaline Magma Series, Marumori volcano, Iwate Prefecture.

Saabu Tsuchiya^{1*}, Akihiko Fujinawa²

¹Ibaraki university, ²Ibaraki university

Introduction

Takakura volcanic chain is located at the southern end of the Sengan geothermal area extending near the volcanic front of the northeast Japan around 40N. This volcanic chain consists of Kotakakura, Takakura, and Marumori volcanoes sitting in a row from NE to SW. Although magma plumbing system for the tholeiitic (TH) series of Takakura volcano was examined in detail by Nakaya(2010MS), petrology of the Marumori volcano has not been well-characterized yet. In order to reveal the evolutionary processes of the coexisting tholeiitic(TH) and calc-alkaline(CA) magma series and genetic relationship between the two series, geology, petrography, and petrochemistry of the two magma series at the Marumori volcano were investigated in this study.

Geology

Eighteen (9 tholeiites, 9 calc-alkaline) lava flows originated from a common eruption vent were identified on the bases of the topographic features, lithofacies, and petrological characteristics. Although the lavas effused continuously with no dormancy, the development history of the Marumori volcano could be divided 4 stages by alternately changed dominant magma types of TH and CA.

Evolutionary processes of tholeiitic magma

TH series can be further divided into two temporally coexisted groups showing distinctive LIL/HFS ratios. The low-LIL/HFS groups show basaltic ($\text{SiO}_2=52-54\text{wt}\%$) composition, whereas high-LIL/HFS group are andesitic ($\text{SiO}_2=55-60\text{wt}\%$). In each of the two TH groups, good parallelism in the spidergram patterns are observed among the members, suggesting that the members were related through fractional crystallization. A major element least-squares calculation supports the fractional crystallization as the most plausible evolutionary mechanism in the two isolated TH magma chambers.

Evolutionary processes of calc-alkaline magma

The CA series displays a linear variation trend in the Harker's diagram, suggesting that magma mixing process was the essential effective evolutionary process for the CA magma plumbing system. There are petrological evidence which supports this hypothesis including: 1) Heterogeneous lithofacies and lithology in the autolith-bearing lavas, 2) bimodal plagioclase core composition, with coexistence of normal zoning in the An-rich grains, and reverse zoning in the An-poor rim, and 3) disequilibrium coexistence of orthopyroxene and clinopyroxene phenocrysts.

Genetic relationship

Distinctive incompatible element characteristics between the low- and high-LIL/HFS TH series must be reconciled with a view that the two series were derived independently from their distinct parent magmas.

CA magma series were to have evolved by mixing of non-cognate magmas, with mafic endmember of 53-55wt% SiO_2 (similar to that for the mafic inclusion) and felsic endmember of 65wt% SiO_2 (just like IM4 lava unit). The chemical characteristics suggest that incorporation of alkali elements with silica to the low-LIL/HFS TH parent magma might give rise to the CA mafic endmember.

Keywords: Sengan geothermal area, tholeiite, calc-alkali, crystallization differentiation,, magma mixing

Radiocarbon age of the phreatic-eruption deposits from the eastern-craters at the northern flank of Kurikoma Volcano

Nobuo Doi^{1*}

¹Faculty of Education, Iwate University

The Kurikoma volcano was active in a magmatic-eruption of the Tsurugidake Lavas, and in a phreatic-eruption of the Zettazawa Phreatic-eruption Deposits at the northern flank of the volcano in Holocene. The Tsurugidake effused lava flows at least two times during 7,245-5,650yBP. The forty-seven craters of the Zettazawa Phreatic-eruption Deposits have been found in the eastern, central, and western areas of the northern flank and other sites (Doi,2006). The western craters were formed by the seven phreatic-eruptions which occurred four times during 7,245-3,725yBP, and three times in 815yBP, 120yBP, and AD1944 (Doi,2012).

It is revealed in this study that the eastern craters were formed by at least six phreatic-eruptions. The ages of the first and second eruption are uncertain, but they may be old to a certain extent because their deposits have been weathered. The third and fourth eruptions occurred in 3,710yBP and 2,770yBP, respectively. The fifth and sixth eruptions occurred in 730yBP and 145yBP, respectively, after being dormant two thousand years.

The volcanic activities of the eastern and western craters are similar to each other. The phreatic-eruptions occurred about four times before 3,725yBP or 2,770yBP from both craters, and there were dormant periods of about two to three thousand years after the last eruptions. The historical eruptions started in cal.AD1200's after the dormant periods and followed in AD1744 at the western craters and near the same year at the eastern craters.

Keywords: Holocene volcanic activity, phreatic-eruption, radiocarbon age, Kurikoma Volcano

Time scale from mixing to eruption for historical lavas of Chokai volcano: Estimation by olivine residence times

Takanori Sato^{1*}, Masao Ban², Tsukasa Ohba³, Shintaro Hayashi⁴

¹Graduate School of Science and Engineering, Yamagata Univ., ²Faculty of Science, Yamagata Univ., ³Faculty of Engineering and Resource Science, Akita Univ., ⁴Faculty of Education and Human Studies, Akita Univ.

Chokai volcano is an active strato-volcano situated in the rear arc side of northeast Japan arc. The magmatic activity occurred at least three times between AD 871 and 1801. Based on petrologic data of the historical lavas, previous study deduced that the erupted products were formed by magma mixing. However, time intervals between mixing and eruption are not well determined. Here we estimate the time intervals based on Fe-Mg and NiO zoning of olivine phenocrysts in the historical lavas.

Samples for this study are lavas erupted during AD 871 to 1801. Lavas are divided into the Senjadani lower and upper lavas (AD871), the Kohjingatake lower and upper lavas, Kohjingatake agglutinate (some period between AD 871 and 1801) and Shinzan lava dome (AD1801). All lavas, except for Senjadani upper lavas, possess mafic inclusions, and bulk compositions of lavas and inclusions are depicted on same linear trends in silica variation diagrams. Phenocryst assemblages are similar in all samples, and the phenocrysts are divided into mafic magma derived (An-rich plg and olv) and felsic magma derived ones (An-poor plg, opx, cpx, and hbl). Silica contents of host rocks and mafic inclusions are 56-58 and 51-55% in Senjadani lower lavas, ca. 51% in upper lavas, 59-60 and 52-57% in Kohjingatake lower lavas, 62-63 and 55-58% in Kohjingatake upper lavas, 66-69 and 56-58% Kohjingatake agglutinate, 61-62% and ca. 54% in Shinzan lava dome.

Olivine phenocrysts are subhedral in shape, and most olivine crystals have the reaction rim of orthopyroxene but some do not. These olivines have broad homogeneous cores and narrow, normally zoned rims. Fo content of core spans 74 to 79, and that of rim decreases to around 64. NiO content of core is ca. 0.02 wt% and that of rim decreases to ca. 0.002 wt%. We calculated residence times for the olivine crystals on the assumption that the zoning was produced by diffusion of the elements after the magma mixing event.

We used diffusion coefficients for Fe-Mg and Ni calculated by the equations of Costa et al. (2008) and Petry et al. (2004). We measured compositional profiles across these zoned olivine crystals by electron microprobe. We compared modeled diffusion profiles by the methods of Costa and Chakraborty (2004) with the observed ones, and determined the residence times required to produce the measured profiles. We obtained the residence times of one month to one year for the Senjadani lower lavas, one year to one year and a half for the Senjadani upper lavas and two months to eight months for the Kohjingatake lower lavas.

Keywords: Chokai volcano, olivine, diffusion, residence time, magma mixing

Generation processes of mafic inclusions of Fujiyama volcano in northern part of Takahara volcano, northeast Japan

Yoshiyuki Tajima^{1*}, ARAKAWA, Yoji², IKEHATA, Kei², KANAI, Hiromichi¹

¹Life and Environmental Sciences, University of Tsukuba, ²Faculty of Life and Environmental Sciences, University of Tsukuba

Takahara volcano is a Quaternary stratovolcano located on volcanic front in the southern part of northeast Japan arc. This study focused on Fujiyama volcano formed in northern part of Takahara volcano. It is a small lava dome composed of dacites. Takahara volcano was presumed to have finished its volcanic activity ca. 100 ka (Inoue et al., 1994), but Fujiyama volcano was clarified to have been formed at 6.5 ka (Okuno et al., 1997; Takashima, 1999).

Magma mixing is accepted as one of the important processes leading to the formation of mafic inclusions (e.g., Eichelberger, 1975; Koyaguchi, 1986). The presence of mafic inclusions was already reported in Fujiyama volcano (Ikeshima and Aoki, 1962). However, there are no investigations for the mafic inclusions in Fujiyama volcano, and petrogenesis of the inclusions is not yet fully investigated. Therefore, we carried out the detailed microscopic observations and chemical analysis of minerals and whole-rocks for understanding genetic processes of these mafic inclusions and host dacites, and for presuming magma mixing mechanisms in Fujiyama volcano.

The mafic inclusions in Fujiyama dacites ($\text{SiO}_2=67.4\text{--}70.4$ wt.%) have andesitic composition ($\text{SiO}_2=60.7$ wt.%). They are dark in color and most inclusions have spherical to oblate in shape. In the boundary between host rock and inclusion, a few phenocrysts straddle the boundary. All inclusions have abundant vesicles. These features are similar to the mafic inclusions reported from other volcanoes, and clearly indicate that the inclusions were liquid when they were entrained by the silicic magma (e.g., Heiken and Eichelberger, 1980; Bacon, 1986). The host rocks (dacite) contain phenocrysts of plagioclase, quartz, orthopyroxene, hornblende, Fe-Ti oxides and rarely augite. The inclusions contain phenocrysts of plagioclase, orthopyroxene, augite, Fe-Ti oxides and rarely include hornblende and quartz. Groundmass of the inclusions contains acicular grains that are coarse compared to those of the host rocks, which indicates that they were formed by rapid growth (Lofgren, 1980).

Whole-rock major and trace element composition of the inclusions have composition between host dacites and basalts erupted during the earliest activity in Takahara volcano. In outline, chemical compositions have liner data trend in element variation diagrams which may be evidence of magma mixing between dacitic and basaltic magma. Plagioclase and orthopyroxene phenocryst cores in the host rocks and inclusions have a large variation in composition. Both rocks contain Ab-rich plagioclase, An-rich plagioclase, Fe-rich orthopyroxene and Mg-rich orthopyroxene. Reversely zoned textures are often seen in most Ab-rich plagioclase and Fe-rich orthopyroxene in the inclusions. Sr isotopic ratio ($^{87}\text{Sr}/^{86}\text{Sr}$) of the inclusion is slightly lower than that of the host dacite, which is also consistent with mixing of magma with two end-members.

From these results, it is presumed that magma mixing occurred between silicic magma and mafic magma in Fujiyama. Silicic end-member might have been close to in composition to the host Fujiyama dacitic magma, and mafic end-member might have been basaltic magma having similar composition to the products erupted during the earliest stage in activity of Takahara volcano. Therefore, it is suggested that the mafic inclusions were formed from resultant andesitic magma by the magma mixing.

Keywords: Takahara volcano, Fujiyama lava dome, Mafic inclusion, Magma mixing

Geology and Petrology of the Post-caldera Stage Lava flows originated from Azuma-Kofuji cone, East Azuma volcano

Mamoru Ozaki^{1*}, Akihiko Fujinawa²

¹Ibaraki Univ., ²Ibaraki Univ.

1. Introduction

Azuma volcano is situated at the central part of Quaternary volcanic front of the Northeastern Japan arc. Azuma volcano is topographically divided into the West Azuma, Naka Azuma and East Azuma Volcanos. The largest eruption of Higashi Azuma volcano in Holocene era occurred at 7ka built up the Azuma-Kofuji cone in the horse-shoe shaped caldera at eastern part of East Azuma Volcano, and magmatism had been active between 5ka B.P.to 6ka B.P., by ejecting fall out tephra and the Azuma-Kofuji lava flow (Yamamoto, 2005).

2. Topography and geology

Based on the stratigraphy of 17 individual lava lobes and their surface structure, the Azuma-Kofuji lava flow is divided into 3 groups. The Groups 1, 2, and 3 consist of 6, 6, and 5 units, respectively, in descending order of eruption. Mingling texture is observed only in the lava (Am5) erupted in the latter half of Group 2. The estimated volume of magma in the stages 1, 2, and 3 are $2\text{--}3 \times 10^{-1}$, 1.5×10^{-1} and 1×10^{-2} (DRE km³), respectively.

3. Petrological features

The compositional variations of these lavas create a linear trend in the Harker's diagram. In several lavas of the group 1 (Al1, 2, 3, and 5), heterogeneity of more than a few square meter in size is recognized. One portion shows a compositional range from 59 to 61wt.% SiO₂ (1A), whereas the other covers 62-63wt.% SiO₂ (1D). The rest of the Group 1 lavas (Al4, 6) are consistently in the range for the 1A. In the group 2, later members (Am4-6) show evident petrological in homogeneity, compared with the earlier members (Am1-3). Group3 lavas are homogeneous through the members from Ah1 to Ah5.

Modal abundances of mafic minerals are higher in the 1A than in the 1D. Euhedral or subhedral olivine phenocryst of 0.9mm in maximum diameter is observed in 1A. The olivine in the 1D is generally corroded with 0.3mm in diameter. Although all the Group2 lavas contain olivine phenocrysts, the olivine in the latter lava samples tend to be large and highly euhedral, relative to those in the earlier lava samples. Only small amounts of olivine phenocryst of corroded shape were observed in every Group3 lava sample.

A mingled texture composed of light gray part and dark gray part is recognized in the latter members of the group 2 (Am5). The dark gray part shows glass-rich texture with high silica content, compared with the lighter colored part.

4. Magma plumbing system brought Azuma-Kofuji lava flow

Azuma-Kofuji lava flow displays a linear variation trend on the Harker's diagram, with 1A and 1D samples come to the poorest and richest silica ends, respectively. Therefore, a variety of lavas were basically resulted from mixing of the two distinct magmas 1A and 1D. Also, mingled texture, and euhedral olivine observed in the later members of the group2 implies intermittent incorporation of mafic magma.

Sequential change of the magma plumbing system is summarized as follows:

Andesitic (1A) and dacitic (1D) magmas were erupted simultaneously in the stage 1 to make up heterogeneous lavas.

The magma in the chamber became homogeneous after Stage1 eruption.

In the latter half of the stage 2, mafic magma added to the homogenized magma chamber to cause disequilibrium petrological features.

Magma became homogeneous again in stage 3.

Keywords: Azuma volcano, lava flow, magma mixing, calc-alkaline

Crystal size distribution of plagioclase phenocryst of the Sessho lava of the Kusatsu Shirane volcano

Kazuki Oshio^{1*}, Kenta Ueki², Mutsuko Inui¹, Kenji Nogami²

¹Kokushikan University, ²Volcanic Fluid Research Center, Tokyo Institute of Technology

In this study, we present a detailed analysis of crystal size of plagioclase phenocryst in Sessho lava of Kusatsu-shirane volcano, central Japan, to discuss textural evolution of andesitic magma and to constraint crystallization and cooling process during eruption of the large volume andesitic lava flow. Plagioclase phenocryst in erupted volcanic materials can be a tracer of cooling and eruption process of magma, because its liquidus temperature, morphology and crystal size are very sensitive to the degree of supercooling at the crustal to surface pressure (e.g., Suzuki, 2006). The Sessho lava is estimated to have been erupted 3 ka from the Moto-shirane cone (Hayakawa and Yui, 1989) and exhibits andesitic composition with SiO₂ content of 60-63 wt. % (e.g., Ueki and Terada, 2012). We corrected 5 different samples to cover the whole area of the Sessho lava.

Phenocryst assemblage of the Sessho lava is plagioclase, clinopyroxene, orthopyroxene, magnetite and rare olivine with glassy groundmass. We majored crystal size of plagioclase phenocryst and conducted EPMA analysis to determine chemical compositions of phenocrysts. Length of the major axis of plagioclase ranges from 0.04-0.5mm. We found that crystal size distribution of plagioclase in each sample shows variation in a single lava flow. The aspect ratio of plagioclase phenocryst shows systematics with the crystal size of plagioclase; larger plagioclase (>1mm in major axis) exhibits aspect ratio of near 1 (subequant morphology), whereas smaller plagioclase (<1mm in major axis) exhibits aspect ratio of 12-1 (tabular-subequant morphology). The large and subequant plagioclase phenocryst show wide range of variation in core composition (An# = 55~84). Both normal zoning and reverse zoning are observed. The wide range of zoning pattern and composition of plagioclase phenocryst suggest there existed a temperature or H₂O heterogeneity in a magma chamber beneath the Kusatsu shirane volcano. Core composition of the olivine phenocryst show Mg# (molar ratio of Mg/(Fe+Mg)) of ~83, which is too magnesian to be in equilibrium with its host andesite. The disequilibrium olivine are accounted for by mixing between olivine bearing mantle derived mafic magma and felsic magma.

As whole rock composition show relatively narrow variation, the textural variation in terms of plagioclase phenocryst may represent a variation in crystallization process, rather than chemical composition of host magma. The small and tabular shape plagioclase represents a crystallization by large degree of supercooling, whereas large and subequant shape represents small degree of supercooling (e.g., Hammer and Rutherford, 2002). Small and tabular plagioclase may have crystallized at shallower depth during ascent whereas larger and subequant plagioclase may have crystallized in a crustal magma chamber. The variation of the large/small plagioclase ratio in a single lava flow indicates that these exist a variation of degree of supercooling even in the single lava flow. We propose that andesite magma of the Sessho lava containing tabular smaller plagioclase may represent magma that stored in a shallower depth as a dyke before eruption. The smaller tabular plagioclase could be crystallized by cooling, degassing and crystallization in a shallower dyke. Magma without the smaller plagioclase may represent magma that ascended directly from the magma chamber by continuous eruption.

Keywords: Lava flow, Crystal size distribution, Eruption, Andesite, Active volcano

The source and age of the Awakawa Pumice Bed in Urizura Hills, Ibaraki Prefecture

Akihiko Kikuchi^{1*}, Takeshi Hasegawa¹

¹College of Science, Ibaraki University

Awakawa Pumice Bed (AWP) composes the top of Urizura Hills, in the middle of Naka River area, Ibaraki Prefecture. Although the AWP has been described as a volcanic secondary deposit, its source volcano, detailed age and sedimentary processes remain unclear. We carried out geological and petrological investigations to reveal the source and age of the APW.

AWP covers Tokoronuki Gravel Bed with an erosional contact at Urizura Hills. The thickness of AWP is approximately 5 m. The deposit can be divided into block facies (DB) and matrix facies (DM). DB is composed of pieces of pyroclastic flow deposits, maximum diameter of which is 6 m. DM consists of very poorly-sorted, un-stratified mixture of angular andesitic lavas, pumices, scoriae, pebbles and cobbles. These field occurrences suggest that the AWP is a debris avalanche deposit.

Yosagawa and Kuroiso Debris Avalanche deposits (YDA and KDA, respectively), which are the largest debris avalanche deposits derived from Nasu Volcanic Group, are distributed in the upper area of Naka River. We can observe the relationship between YDA (lower) and KDA (upper), interbedded by a gravel bed at Batou and Kurobane, Tochigi Prefecture. A pumiceous sand bed is recognized beneath YDA at Kurobane. DB of YDA are composed of not only peaces of pyroclastic flow deposits but also andesitic lavas showing jigsaw cracks at Kurobane. Maximum size of the DB of YDA (10 m) is larger than that of KDA (3m), although the thicknesses of both YDA and KDA are approximately 4-5 m.

We determined petrological features of contained andesitic lavas for identification of debris avalanche deposits. More than 20 largest fragments were sampled from AWP at Urizura Hills, and KDA/YDA at Kurobane. All samples of AWP are pyroxene andesite to dacite, except for one sample of qz-bearing pyroxene andesite. Almost of samples in YDA is pyroxene andesite to dacite, but 2 samples are qz-bearing pyroxene andecite and another is qz-bearing olivine pyroxene andesite. Samples of KDA are pyroxene basaltic-andesite to andesite with one exception of olivine pyroxene andesite. Whole rock compositions of the samples of AWP is similar to that of YDA within a range of SiO₂=58-63 wt. % and FeO*/MgO=1.7-2.1. In addition, mineral assemblage and glass chemistry of pumice sand, overlain by YDA at Kurobane, are the same as those of Kanewazaki Pyroclastic Flow deposit (KN-pfl).

We discuss the source and age of AWP on the basis of geological and petrologic data. In general, travel distance of debris avalanches would be increase with their scales, that is, volumes. Geological data of well-documented debris avalanche deposits show a tendency that larger scaled debris avalanches show larger maximum size of DB at a given distance from the source. The review and our geological data infer that the scale and travel distance of YDA is larger than those of KDA. There exist no debris avalanche deposits under AWP in Urizura Hills, indicating that AWP can be correlated with YDA, which might be the largest debris avalanche in this studied area. This conclusion is consistent with the petrologic correlation of included andesitic lavas between APW and YDA. The YDA had been derived from Nasu Volcanic group, suggesting that AWP had traveled long-distance (> 90 km) from the source volcano. On the assumption of collapse height of 2,500m, the H/L ratio is estimated to be 0.03. The age of APW, correlated with YDA, can be also constrained as after 0.64 Ma, which is the reported age of KN-pfl.

Keywords: Debris avalanche deposits, Naka River, Nasu Volcanic Group, Petrological features

Reexamination of the volcanic sequence based on the borehole core excavated in Manazuru-cho, SE Japan

Toshifumi TAKASUKA^{1*}, YAMASHITA, Hiroyuki², MANNEN, Kazutaka³, FUJIMOTO, Koichiro¹

¹Tokyo Gakugei University, ²Kanagawa Prefectural Museum of Natural History, ³Hot Spring Research Institute of Kanagawa Prefecture

The southeastern part of Hakone volcano was formed about 130 to 230 thousand years ago by some monogenetic volcanic eruptions. The area is widely covered by younger lava flows and studies on borehole core samples should contribute to clarify the volcanic sequence. In this study, we examined borehole samples excavated in 706, Iwa, Manazuru-cho, Kanagawa Prefecture, as well as samples derived from surface exposures along the coast.

Methods are macro-scopic observation, thin section observation, XRD analysis, and whole-rock chemical analysis by XRF.

Three lavas were recognized in the borehole. Thin section observation revealed that lavas in the borehole were aphyric to nearly aphyric andesites with plagioclase, Cpx, Opx and opaque mineral. The mineral assemblages obtained by XRD is plagioclase, cristobalite, tridymite, Cpx, and Opx. The results of whole-rock chemical analyzes by XRF are as follows. The andesite samples between 2.6 and 13.2 m depth are rich in TiO_2 , Fe_2O_3 , MnO, P_2O_5 , and Al_2O_3 and K_2O are relatively poor. Between 35.2 and 44.6 m depth, andesites are similar to the andesite mentioned before. They are rich in TiO_2 , Fe_2O_3 , MnO, P_2O_5 and Al_2O_3 content is relatively low. In contrast, andesites between 54.7 and 70 m depth are rich in TiO_2 , Fe_2O_3 , MnO, K_2O , P_2O_5 and Al_2O_3 content is relatively low.

There are three eruptions accompanied with andesitic lava flow. The first (2.6 -13.2 m depth) and second (35.2 ? 44.6 m depth) lava flows are attributed to Iwa lava group and third one (54.7 ? 70 m depth) is attributed to Nebukawa lava group based on lithology and chemical compositions compared to the previous studies (e.g., Nagai and Takahashi, 2007).

Keywords: hakone volcano, lava

Magma plumbing system Ofunato and Tsubota stage in Miyakejima volcano based on high-pressure experiments and melt inclusions

Masashi Ushioda^{1*}, Eiichi Takahashi¹, Toshihiro Suzuki², Morihisa Hamada¹

¹Earth and Planetary Sci., Tokyo Tech, ²IFREE, JAMSTEC

Miyakejima is an active tholeiitic volcanic island located at about 200 km south of Tokyo in Izu-Mariana arc. Miyakejima is a typical volcano in immature arc crust. For the last 10,000 years of Miyakejima volcano, geologic studies (e.g. Tsukui and Suzuki, 1998), petrologic studies (e.g. Niihori et al., 2003) and geochemical studies (e.g. Yokoyama et al., 2003) were extensively carried out. Tsukui et al. (2001) divided the volcanic activity of the last 10,000 years into four stages: 10-7ka (Ofunato Stage), 4-2.5ka (Tsubota Stage), 2.5ka to AD1154 (Oyama Stage) since AD1469 (Shinmio Stage). Niihori et al. (2003) said products of the Ofunato Stage were basalts and they were relatively primitive. On the other hand, products in Tsubota Stage were andesites and those in the latter two stages were mixed products of basalt and andesite. Precise knowledge of depth, temperature, water content and fO₂ of magma chamber are essentially important in discussing evolution of magma plumbing system. The purpose of this study is to investigate the evolution of the magma plumbing system in Miyakejima in the last 10ka based on high-pressure experiments and petrology. We show that a simple system in the Ofunato Stage developed into a complex one and this accounts for the change in chemical and petrological features in the subsequent stages of Miyakejima volcano.

To understand the evolution of the magma plumbing system, first we studied the magma chamber in Ofunato Stage by high-pressure experiments. Experiments were performed at 1.0, 1.5, 2.0, 2.5kbar with various H₂O content using IHPVs (SMC-2000 and SMC-5000) at the Magma Factory, Tokyo Tech. Based on the experimental results and petrology of products in Ofunato Stage, magma chamber in Ofunato Stage was reconstructed. The magma chamber was located at 5~6km depth (~1.5kbar) and water-rich (~3wt.%) basalt magma crystallized olivine and calcic plagioclase (which is the typical phenocryst assemblage throughout Ofunato Stage). Volatile content (H₂O, CO₂, S and Cl) of melt inclusions were analyzed by FTIR and EPMA. Maximum H₂O and CO₂ content of a melt inclusion in olivine are 3.3wt.% and 160wt.ppm, respectively. The gas saturation pressure of magma indicates that the pressure of magma chamber in Ofunato Stage should be at least ~1.5kbar.

Whole rock compositions in pre-Ofunato, Ofunato and Tsubota stage, some of which were new data, were analyzed by XRF. A series of crystallization trends were calculated using MELTS program (Ghiorso and Sack, 1995), and it is found that andesites erupted in Tsubota Stage can be formed by fractional crystallization of OFS basalt at pressure less than 1.5kbar which corresponds with that of shallow level chamber in the two-layered magma chamber after Shinmio stage (e.g. Amma-Miyasaka and Nakagawa, 2003, 2005; Saito et al. 2005, 2010). Postulated water content in magma (~0.6 wt.%; water-saturated pressure of basalt for this water content is less than 1.0kbar), however, is much lower than in Ofunato Stage (~3 wt.%). Accordingly, it is suggested that magma chamber has been significantly degassed in the shallow level chamber (0.6 wt.% H₂O in magma) during the dormant period (4~7kyBP).

Keywords: Miyakejima, Magma plumbing system, Magma chamber, High-pressure experiments, Melt inclusions

K-Ar ages of volcanic rocks from Nekodake volcano in Aso, Kyushu, Japan -different magma systems within a caldera-

Taro Shinmura^{1*}, Hirochika Sumino², Yasuhiro Ueda³, Yasushi Mori⁴, Masaya Miyoshi⁵, Keisuke Nagao², Hasenaka Toshiaki⁶, Yoji Arakawa⁷

¹Fac. Econ., Kumamoto Gakuen Univ., ²GCRC, The Univ. Tokyo, ³Mitsubishi Corporation Exploration Co., Ltd., ⁴Kitakyushu Mus. Nat. Hist. & Hum. Hist., ⁵Fac. Edu. & Regional Studies, Univ. Fukui, ⁶Grad. Sch. Sci. & Tech., Kumamoto Univ., ⁷Grad. Sch. Life & Environmen. Sci., Univ. of Tsukuba

Aso volcano, situated in central Kyushu, produced four gigantic caldera-forming pyroclastic eruptions between 270 and 90 ka. Volcanos within the Aso caldera (central volcanic cones) consists of multiple volcanic vents and products at the post-caldera stage (after 90 ka), and Nekodake volcano situated at the most eastern part of the volcanic cones. Detailed K-Ar age dating of ACVC (Aso central volcanic cones) except for Nekodake was reported by Miyoshi *et al.* (2012). Although Nekodake situated within the Aso caldera, Ono *et al.* (1982) reported that Nekodake was not a part of ACVC, but pre-Aso volcanic products produced before caldera forming stage (mainly distributed at somma), because 1) characteristics of chemical components were not similar to volcanic products of ACVC but to of pre-Aso volcanic rocks, 2) lower than Aso-3 pyroclastic flows, 3) obtained K-Ar age was 590 $\pm$ 220 ka (older than Aso-1 pyroclastic flows). Itaya and Nagao (1988) reported that K-Ar ages, 150 $\pm$ 60 and 140 $\pm$ 40 ka of pyroxene andesite from Nekodake were reported (Itaya and Nagao, 1988) and these ages were consistent with volcanic successions but younger than pre-Aso volcanic products. Matsumoto (1992) determined K-Ar age with correction of mass-dependent fraction and obtained age of 110-80 ka, and pointed that this range is not consistent with volcanic succession (lower than Aso-3) because the data depend on volcanic succession was determined by geographical features and not correct, and they implied obtained age were correct. Shinmura *et al.* (2012) determined Sr and Nd isotopic ratios and bulk rock chemical component of volcanic rocks from Nekodake and pointed that these geochemical characteristics were different from those of ACVC but there were relations with those of pre-Aso volcanic rocks and granodiorite of basement rocks. Ueda *et al.* (2012) reported features of chemical components and variation of rock type at Nekodake volcano.

In this study, several volcanic rocks were collected with rock type and spatial variety from Nekodake volcano, and K-Ar ages were determined of those samples. The argon isotopic ratio was measured using a noble-gas mass spectrometer MS-IV (modified VG-5400) in the Geochemical Research Center, Graduate School of Science, The University of Tokyo. The radiogenic ⁴⁰Ar contents of samples were determined by using the sensitivity method. In this method, the unknown concentration of ⁴⁰Ar contained in a samples is determined with correction of mass-dependent fraction based on measured ³⁸Ar/³⁶Ar ratio (Takaoka *et al.*, 1989). Two samples for Ar isotopic analysis were prepared in each rock sample for reproducibility decision.

K-Ar age of nine samples were obtained as follows.

61 $\pm$ 27, 62 $\pm$ 39, 64 $\pm$ 6, 69 $\pm$ 6, 72 $\pm$ 65, 81 $\pm$ 39, 82 $\pm$ 7, 87 $\pm$ 70, 117 $\pm$ 94 ka (weighted mean in each data)

Three of these were very precise and errors were within 10 ka. Eight of these were 9-6 ka, and these ages were younger than the ages reported before. These ages show that volcanic activity of Nekodake volcano was also in post-caldera stage, and this implies that different magma systems were just under the same caldera in post-caldera stage of Aso.

Keywords: Nekodake, K-Ar age dating, unspiked method, Aso, post-caldera volcanism, central cones

Evaluation of Holocene eruptive activity in South Kurile, inferred from Age, Source, and Distribution of tephra

Akiko Matsumoto^{1*}, RAZZHIGAEVA, Nadezda G.², Mitsuhiro Nakagawa¹

¹Department of Natural History Sciences, Graduate School of Science, Hokkaido University, ²Pacific Institute of Geography, Russian Academy of Sciences, Vladivostok, Russia

Kurile arc is one of the most active volcanic zones in the world, composed of many islands locating from eastern Hokkaido to Kamchatka peninsula. Despite such high-level activity, its eruption history is still unknown. Recently, the systematic geological investigations have been carried out in Hokkaido (Kishimoto et al., 2009; Hasegawa et al., 2009) and in Central and North Kurile Islands (Nakagawa et al., 2009), to reveal the history of volcanic activity. In order to understand the evolution of volcanic activity in Kurile arc as a whole, it is essential to clarify the eruption history in South Kurile Islands. We had precious opportunities to investigate in South Kurile Islands (in Habomai, Shikotan and Kunashir islands). In this study, we reconstruct the stratigraphy of Holocene tephra in South Kurile Islands using the petrological features of volcanic ashes and ¹⁴C ages of beneath or above tephra layers.

We identified 22 Holocene tephra layers in South Kurile Islands. Only 5 ash layers from the volcanoes in South Kurile Islands can be recognized: Mendeleev (ca. 2.5 ka), Tyatya volcanoes (1420 cal. yBP and AD 1973), and two local tephra layers (source is unknown, but probably from the volcano in Kunashir island: 9230 and 11190 cal. yBP). These tephra almost distribute locally. Main parts of Holocene tephra are generated from the volcanoes in Hokkaido: Mashu and Rausudake volcanoes in eastern Hokkaido; and Tarumai and Hokkaido-Komagatake volcanoes in southwestern Hokkaido (belonging to NE Japan arc). These results suggest that Holocene volcanic activity in South Kurile Islands is relatively lower than those in eastern Hokkaido. Focusing on eruptive scale and eruption age, the large caldera-forming eruptions occurred at Mashu volcano in eastern Hokkaido about 12-8 cal. ka. It is also reported the caldera-forming eruption of Lvinaya Past volcano in Iturup Island (10630 cal. yBP: Braitseva et al, 1995). This implies that the period of 12-8 cal. ka is characterized by powerful volcanic activity in the southern area of Kurile arc. After that, however, eruptive scale became smaller. In eastern Hokkaido, the silicic explosive eruptions had occurred several times with interval of a thousand year approximately. On the other hand, a small scale of silicic eruption occurred only three times in South Kurile Islands (Kunashir Island). Considering that Tyatya volcano had continued the effusive eruptions at the summit until AD 1812 (Nakagawa et al., 2002), it is interpreted that the eruptive activity in South Kurile Islands has been gentle accompanied with mafic magma since 8 ka.

Keywords: tephrostratigraphy, South Kurile Islands, Holocene eruptive activity, eastern Hokkaido

Amount, composition, and generation timescale of magma produced by melting of lower crust

Katsuya Kaneko^{1*}

¹HES, Kyoto Univ.

Magmatisms are various in continental margins and continental hot spots. Magmas with various petrologic features erupt at a certain volcano and are also different from other neighbor volcanoes. For the variety of the continental magmatism, magma genesis by crustal melting can be a key process. In this study, we try to understand variation of composition, amount, and generation timescale of magmas produced by melting of a lower crust due to repeated injections of hot magmas using a one-dimensional physical model.

The model of crustal melting by Koyaguchi and Kaneko (2000) is followed. When a crust is melted by a hot magma injected into a crust, large heat flux from the convecting injected magma rapidly melts the overlying crust up to the degree of partial melting large enough to convect (~100 yr timescale). After that, the injected magma and convecting region of partially-molten crust decrease in temperature and melt fraction, and hence cease to convect for melt fraction to decrease down to the critical melt fraction where the mixture of solid and liquid cannot convect. At this stage, heat transfer becomes only conductive and slow (>10,000 yr). When a new injection of a hot magma occurs, the above processes repeat. A characteristic of our model is that voluminous crustal melt close to the critical melt fraction tends to be produced. Additionally, we consider that the injected hot magma is hydrous, and an effect of crust wet by the water supplied from them is taken into account.

We carried out calculations considering that gabbroic amphibolite with 2 wt. % water is melted by repeated injection of hot basaltic magmas with initial temperature of 1250 deg. C at 1 GPa. It is assumed that the critical melt fraction above which the materials are convective is 0.5. In the calculations, we change the initial temperature of the crust (500-700 deg. C) and injection rate (2-30 m/ky), thickness in a single injection (10-800 m), and water content (2-12 wt. %) of the injected hot magmas as parameters. It is assumed that the hot magmas repeatedly inject at the same level and that no segregation between melt and crystals occurs in our model.

The calculation results indicate that the generation of magma by crustal melting occurs on 10,000-year timescale and that various amounts of magma with various degrees of partial melting are generated by crustal melting for the four changed parameters. The injection rate of the hot magmas basically governs total melt amount produced by melting; larger injection rate produces larger amount of melt. On the other hand, the initial temperature of crust and the injection thickness of the hot magma affect the degree of partial melting of the crust. Thin intrusions in warm crust produces relatively much melt with small degree of partial melting (i.e. silicic melt) whereas thick intrusions in cold crust produces much melt close to the critical melt fraction (relatively large melt fraction) (i.e. mafic melt). The water content of the injected hot magmas gives a minor effect (larger water content tends to increase total amount of crustal melt and ratio of mafic melt amount).

The calculation results give many implications about composition, amount, and timescale in crustal melting. For example, magma generation timescale of 10,000 years is consistent with time interval of large silicic eruptions in some caldera volcanoes. Individuality of each volcano about composition and eruption amount of magma may be governed by the conditions in our model. Verification of our model with geological and petrological data of natural volcanoes is needed in future work.

Keywords: magma, crustal melting, large scale silicic magmatism, one dimensional physical model, water content of mafic magma