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Volcanoes of Japan (Third edition) published in 2013

Shun Nakano[1*], Kuniaki Nishiki[1], Shinji Takarada[1], Hideo Hoshizumi[1], Yoshihiro Ishizuka[1], Jun'ichi Itoh[1], Yoshihisa Kawanabe[1], Teruki Oikawa[1], Ryuta FURUKAWA[1], Nobuo Geshi[1], Osamu Ishizuka[1], Takahiro Yamamoto[1], Kiyoyuki Kisimoto[1]

[1]Geological 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-formig 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

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

Kosuke Ishige[1*], Mitsuhiro Nakagawa[1]

[1]Department 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 northen 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 build 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. Stgae 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. Stgae 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 sevarl stratovolcanoes, including Asahidake edifice (2291 m). The latest magmatic eruption occurred 5000 years ago. Phreatic explosions has 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

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

Hikaru Baba[1*], Keiji Wada[1], Eiichi Sato[2]

[1]Earth Science Laboratory, Hokkaido University of Education at Asahikawa, [2]Institute 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 ^{o}C and 900 ^{o}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

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

Masashi NAGAI[1*], KANNARI, Taro[2], Kensuke TSURUMAKI[2], SHIBATA, Toru[3], SUGIHARA, Shigeo[2], YAHATA, Masahiro[4]

[1]NIED, [2]Meiji Univ., [3]Tokai Univ., [4]Geological 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 ware 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 (SiO_2=65.5-71.5wt%, K_2O=2.1-3.5wt%) 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 (SiO_2=77.3-78.5wt%, K_2O=4.3-5.0wt%).

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

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

Hironobu Hinata[1*], Keiji Wada[1], Yu Nakatsuka[1]

[1]Earth 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

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

Keisuke Anzai[1*], Keiji Wada[1]

[1]Hokkaido 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 (SiO_2=63wt.%), scoria (SiO_2=55wt.%) 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 (An=59) and high-An plagioclase (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

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

Sho Komatsu[1*], Tsukasa Ohba[1]

[1]Akita 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 Tashirotai Lacustrine Deposit), the activity resumed around 0.2 Ma with effusion of andesitic magma (60 wt% SiO_2)(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% SiO_2) 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 Tamoyachidake 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% SiO_2). 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% SiO_2) erupted again.

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

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

Saabu Tsuchiya[1*], Akihiko Fujinawa[2]

[1]Ibaraki university, [2]Ibaraki 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 alternatedly 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 (SiO_2=52-54wt%) composition, whereas high-LIL/HFS group are andesitic (SiO_2=55-60wt%). 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

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

Nobuo Doi[1*]

[1]Faculty 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

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

Takanori Sato[1*], Masao Ban[2], Tsukasa Ohba[3], Shintaro Hayashi[4]

[1]Graduate School of Science and Engineering, Yamagata Univ., [2]Faculty of Science, Yamagata Univ., [3]Faculty of Engineering and Resource Science, Akita Univ., [4]Faculty 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 Senjagadani 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

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

Yoshiyuki Tajima[1*], ARAKAWA, Yoji[2], IKEHATA, Kei[2], KANAI, Hiromichi[1]

[1]Life and Environmental Sciences, University of Tsukuba, [2]Faculty 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 (SiO_2=67.4-70.4 wt.%) have andesitic composition (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 ($^{87}Sr/^{86}Sr$) 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

SVC53-P12 Room:Convention Hall Time:May 21 18:15-19:30

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

Mamoru Ozaki[1*], Akihiko Fujinawa[2]

[1]Ibaraki Univ., [2]Ibaraki 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 2-3$*10^{-1}$, 1.5$*10^{-1}$ and 1$*10^{-2}$ (DRE km^3), 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.% SiO_2 (1A), whereas the other covers 62-63wt.% SiO_2 (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 pluming 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

SVC53-P13 Room:Convention Hall Time:May 21 18:15-19:30

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

Kazuki Oshio[1*], Kenta Ueki[2], Mutsuko Inui[1], Kenji Nogami[2]

[1]Kokushikan University, [2]Volcanic 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 textual 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 form 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

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SVC53-P14 Room:Convention Hall Time:May 21 18:15-19:30

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

Akihiko Kikuchi[1*], Takeshi Hasegawa[1]

[1]College 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.

Yosasagawa 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

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

Toshifumi TAKASUKA[1*], YAMASHITA, Hiroyuki[2], MANNEN, Kazutaka[3], FUJIMOTO, Koichiro[1]

[1]Tokyo Gakugei University, [2]Kanagawa Prefectural Museum of Natural History, [3]Hot 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, Manaduru-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

SVC53-P16 Room:Convention Hall Time:May 21 18:15-19:30

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

Masashi Ushioda[1*], Eiichi Takahashi[1], Toshihiro Suzuki[2], Morihisa Hamada[1]

[1]Earth and Planetaly Sci., Tokyo Tech, [2]IFREE, 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 Sinmio 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: Miyakejim, Magma plumbing system, Magma chamber, High-pressure experiments, Melt inclusions

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

Taro Shinmura[1*], Hirochika Sumino[2], Yasuhiro Ueda[3], Yasushi Mori[4], Masaya Miyoshi[5], Keisuke Nagao[2], Hasenaka Toshiaki[6], Yoji Arakawa[7]

[1]Fac. Econ., Kumamoto Gakuen Univ., [2]GCRC, The Univ. Tokyo, [3]Mitsubishi Corporation Exploration Co., Ltd., [4]Kitakyushu Mus. Nat. Hist. & Hum. Hist., [5]Fac. Edu. & Regional Studies, Univ. Fukui, [6]Grad. Sch. Sci. & Tech., Kumamoto Univ., [7]Grad. 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+-220 ka (older than Aso-1 pyroclastic flows). Itaya and Nagao (1988) reported that K-Ar ages, 150+-60 and 140+-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 ^{40}Ar contents of samples were determined by using the sensitivity method. In this method, the unknown concentration of ^{40}Ar contained in a samples is determined with correction of mass-dependent fraction based on measured $^{38}Ar/^{36}Ar$ ratio (Takaoka *et al*., 1989). Two samples for Ar isotopic analysys were prepared in each rock sample for reproducibility decision.

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

61+-27, 62+-39, 64+-6, 69+-6, 72+-65, 81+-39, 82+-7, 87+-70, 117+-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

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

Akiko Matsumoto[1*], RAZZHIGAEVA, Nadezda G.[2], Mitsuhiro Nakagawa[1]

[1]Department of Natural History Sciences, Graduate School of Science, Hokkaido University, [2]Pacific 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

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

Katsuya Kaneko[1*]

[1]HES, 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 (lager 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 conent of mafic magma