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Origin of spatial compositional variations of volcanic rocks from the Northern Kurile Islands

Olga Bergal-Kuvikas[1*], Mitsuhiro Nakagawa[1], Gennadi Avdeiko[2]

[1]Hokkaido University, School of Science, Department of Earth and Planetary Sciences, [2]Institute of Volcanology and Seismology, Petropavlovsk-Kamchatsky, Russia

The Northern Kurile Islands form the part of Kurile-Kamchatka volcanic arc. The Pacific plate has subducted beneath the islands since the late Miocene to cause arc-type volcanism. We newly determined major and trace element compositions, Sr-Nd isotopic variations of Quaternary rocks from 7 subarial and 3 submarine volcanoes. Analysis of new and previous publications indicate that the Northern Kurile Islands belong to typical volcanic island arc. About it there are indicated Ta, Nb minimum on the spider diagrams and naturally enriched of the LILE, LREE and depleted of the HFSE, HREE from front to back arc zone. Peculiarities of petrography and whole-rock chemistry enable us to divide all volcanoes into three main zones: frontal, intermediate and rear ones. Frontal zone include Chikurachki, Tatarinova, Lomonosova, 1.3 volcanoes. The rocks are Ol-Cpx bearing Opx basaltic andesite. Fuss, Antsiferova volcanic group and Ebeko volcano locates at the intermediate zone. Hbl-Cpx-Ol-bearing Opx andesite (SiO2 ~ 49-63%) are commonly characterized by the presence of hornblende phenocryst. Alaid, Grigoreva volcanic group locate at the rear zone. Ol-bearing Cpx basalts and basaltic andesite are typical (SiO2 ~ 48-52%). In addition, Alaid and Grigorev volcanic group is characterized by the largest eruptive volume (150 km3). Frontal zone is characterized by lowest contents of incompatible elements (e.g. Rb, Ba, K) and LREES (e.g. Nd, Ce). Isotopic variations have the highest value of 143Nd/144Nd and 87Sr/86Sr as 0.7031-0.7034. In the opposite, rear and intermediate zones show narrower lower contents of 143Nd/144Nd and 87Sr/86Sr as 0.7029-0.7031. The rocks of rear zone show highest contents of LILE (e.g. K, Rb), LREES (e.g. La, Gd, Nd, Sm) and HFSEE (e.g. Nb, Ta). Both 143Nd/144Nd and 87Sr/86Sr ratios of the rocks from intermediate and frontal zones increase with increasing of silica contens. These suggest that andesitic and dacitic rocks from these zones are possibly affected by crustal component. In contrast, crustal assimilation might be minor process in the case of the rear zone, because basaltic rocks are predominant in the zone. Geochemical features of the mafic rocks investigate the spatial difference in magma sources of three zones. Rocks from rear zone are systematically enriched in Nb/Y, Th/Yb, Ta/Yb, Nb/Yb, La/Yb ratios. These data are implied by the fact that magma in the rear zone more enriched with comparing depleted frontal zone. In addition, chemical variations of fluid-mobile elements (e.g. Cs, Ba, U, Th, Sr) and immobile elements (e.g. Nd, Nb, Zr, Hf) of the mafic rocks will be explained by different types of subduction components.

In summary, the following parameters have mainly affected the observed geochemical zonation across the arc in the primary magma; variably depleted and enriched mantle source: the different type fluid flux from the slab to the mantle wedge.

Keywords: Northern Kurile Islands, subduction zone, geochemical variations

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Deep magma chamber beneath Fuji volcano estimated from high-P experiments

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

[1]Department of Earth and Planetary Sciences, Graduate School of Science and Engineering, Tokyo Instit, [2]Institute for Research on Earth Evolution, Japan Agency for Marine-Earth Science and Technology

Fuji volcano, the largest in volume and eruption rate in Japan, is located at the center of Honshu, where North America, Eurasia and Philippine Sea plates meets. Because of the significance of Fuji volcano both in tectonic settings and potential of volcanic hazard (particularly after the M9 earthquake in 2011), precise knowledge on its magma plumbing system is essentially important. Very frequent LF-earthquakes occur at about 15 km beneath Fuji volcano (Ukawa 2007). Seismic tomography beneath Fuji volcano suggests the existence of large magma chamber below 20 km (Nakamichi, 2007). Fuji volcano has released only basalt (>750 km^3) which has narrow range of SiO_2 (SiO_2 = 49-53 wt.%) in the last 100,000 years. Some incompatible elements show more than a factor of 2 variations (Takahashi et al., 2003). Variation in incompatible elements may be due to some kind of magma fractionation process. Fujii (2007) proposed that the silica-non enrichment trend of Fuji volcano is explained by pyroxene dominate fractionation in the deep magma chamber. Primary purpose of this study is to reproduce the silica non-enrichment trend by high-P experiment and reveal PT conditions and water content of magma in the deep magma chamber.

Basalt scoria Tr-1 which represents the ?nal ejecta of Hoei eruption in AD1707, was adopted as a starting material. This is because 1) 0.7km^3 of magma was discharged by subplinian eruption within 2 weeks, 2) Basaltic Hoei scoria is homogeneous, apyric and representing melt composition. Internally heated Ar-gas pressure vessels (IHPV-5000 and IHPV-8600) at the Magma Factory, Tokyo Institute of Technology were used. The f_{O2} was controlled at NNO buffer.At 4 kbar (equivalent to the depth of LF earthquakes), experiments were carried out at temperatures of 1050, 1100 and 1150 C, with H_2O contents of 1.3, 2.7 and 4.7 wt.%, respectively. At 7 kbar (equivalent to the inferred depth of Fuji magma chamber by seismic tomography; around 25 km depth) experiments were carried out at temperatures of 1075, 1100 and 1125 C, and H_2O contents of 1.0, 1.1, 3.6 and 6.3 wt.%, respectively.

Quenched run products were analyzed with EPMA. Run products from 4 kbar experiments always include magnetite and melt composition shows silica enrichment trend (SiO_2 increases with increasing K_2O). In the phase diagram at 7 kbar, multiple saturation point of opx+cpx+pl+melt exists on the liquidus at around 1120 C, 3.5 wt.% H_2O, which is the likely condition of the top of the Fuji magma chamber at the time of Hoei eruption. Melt compositions at 7 kbar shows silica non-enrichment trend until magnetite starts crystallization. Vanadium partitions strongly into magnetite ($D_V{}^{mt/melt}$ is about 20 at the NNO buffer, Toplis et al., 2002) and therefore it is a good indicator of magnetite crystallization. Judging from high vanadium content in Fuji basalts, magnetite does not crystallize in the deeper magma chamber. Origin of the monotonous basalt magma production in Fuji volcano may be due to the absence of shallow level magma chamber. Because plate boundary exists at 3-5 km beneath Fuji volcano, shallow level magma chamber may be short-lived due to high-stress and large crustal deformation.

Keywords: Fuji volcano, High-P experiment

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Long-term volcanic history preceding caldera-formation in Bali, Sunda arc

Kiyoshi Toshida[1*], Shingo Takeuchi[1], Ryuta Furukawa[2], Akira Takada[2], Supriyati Andreastuti[3], Nugraha Kartadinata[3], Anjar Heriwaseso[3], Oktory Prambada[3], Yudi Wahyudi[3]

[1]CRIEPI, [2]AIST/GSJ, [3]CVGHM

Large-scale, caldera-forming eruptions cause significant effects on both regional and global scale. Large amount of magma need to accumulate over long period of time before large-scale eruption takes place. In order to find the characteristics on the long-term variation of volcanic activity prior to caldera-forming eruptions, we observe stratigraphy and topography, and conduct comprehensive sample collection of volcanic rocks in Bali, Sunda arc. Batur and Bratan (Buyan Bratan) calderas have formed in Bali. Multiple caldera-forming reuptions have taken place from the both systems, and the volcanoes remain active. The active stratovolcano (Agung) is located to the east of Batur. Modal abundance analysis, whole-rock chemistry and K-Ar dating are preformed at CRIEPI. Mass fractionation correction method is used for the mass spectrometry of K-Ar dating, which accounts for the fractionation of initial argon ratios. In order to obtain accurate and precise ages, lava samples having pilotaxitic or intergranular groundmass texture are selected for dating through sample collection and thin section observation. These measures help decrease and the amount of non-radiogenic argon and improve accuracy. Some of the samples dated are estimated to contain initial argon ratios that are fractionated from atmospheric values, confirming the significance of utilizing mass fractionation method and careful sample selection.

We have identified three active periods of volcanism in Bali. They are 1.6-1.5 m.y. BP, 0.7-0.5 m.y. BP, and 0.2 m.y. BP to present. Volcanic rocks distributed to the west of Bratan caldera were formed by the 1.6-1.5Ma activity. Volcanoes consisting the northern aprons of caldera sommas were formed by the 0.7-0.5 Ma activities. Tapis, the small volcano covered by Agung, as well as Seroja (Seraya) volcano in the eastern part of Bali, were also formed in this period.

The most recent active period can be divided into two parts based on K-Ar ages. Between 0.2-0.1 Ma, volcanism occured extensively in Batur and Bratan region. Batukau volcano (located SW of Bratan), EL 706m volcano near Pasek (located between Batur and Bratan), and Cemara (located south of Agung) volcano were formed. The shield volcanoes consisting the somma of Batur and Bratan have started to form in the same period, covering the 0.5 Ma volcanoes.

From 0.1Ma to present, the activity continued at Batur somma and formed Abang peak. Agung volcano started to form by 0.05 m.y. BP, and constructed the edifice that partly covers older Tapis and Cemara volcanoes. Both Batur and Bratan systems have produced caldera-forming eruptions multiple times in the past 0.03 m.y. The calderas have formed between the aprons of volcanoes from different ages (0.5 Ma and 0.2 Ma or younger). Their intra-caldera activity has continued along with the activity of Agung.

Cemara volcano has smooth peak area and, contrastingly, peculiar steep cliff of the east apron. The small hills distributed in the SE of Cemara may have formed by sector collapse of Cemara volcano, and requires further study.

Clinopyroxene phenocrysts of volcanic rocks in Bali are generally light-colored under the microscope in thin sections, indicating their high Mg# and relatively high temperature of magma. The aphyric andesite lavas have relatively higher K2O, TiO2 content and FeO*/MgO ratio compared to older andesite. The large shield volcanoes of 0.2 Ma consist of aphyric andesite lava layers. We find it significant that the magmatic system posessed the ability to generate and store large amount of aphyric andesite magma prior to the calrdera-forming stage.

Field surveys of this study are conducted as a part of the FY 2009-2011 project "Multi-disciplinary Hazard Reduction from Earthquakes and Volcanoes in Indonesia", supported by SATREPS from JST, JICA, RISTEK and LIPI.

Keywords: Indonesia, K-Ar dating, Quaternary, volcanic rock

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The Seismic Velocity and Attenuation Structure beneath the Tatun Volcanic area, Taiwan

Strong Wen[1*], Yi-Zen Chang[1], Chau-Huei Chen[2], Yue-Gau Chen[3], Ta-Liang Teng[4]

[1]National Center for Research on Earthquake Engineering, Taiwan, [2]Institute of Seismology, National Chung Cheng University, Taiwan, [3]Institute of Geology Science, National Taiwan University, Taiwan, [4]Dept. of Earth Sciences, Univ. of Southern California, U.S.A.

We have investigated the structure beneath the Tatun volcanic zone north of Taipei metropolitan area of Taiwan, area of five million people. We used the data collected from a seismic network deployed for 5 years over the volcanic zone. This plus another data from Taiwan regional networks allow us to carry out tomographic inversions for Vp, Vp/Vs and Qp structures beneath the Tatun volcanic zone. Based on our results and other geological, tectonic, and seismic findings, we reconstruct the structural evolution of the crust in the Tatun volcanic zone, and discuss the implication to the surrounding faults, fractured zones, and discuss potential future volcanic activities. From the tomographic results, there appear to exist a tube-shaped, highly fractured ancient magma passage with high seismic velocities that parallel to the Chinshan fault, and magma passage extends to the southeast at the depth about 20 km. This structure suggests plutonic intrusion passage beneath the Tatun volcano group that may have been associated with the earlier subduction of the Philippine Sea plate, melting of the subducted plate at depth has generated the magma intrusion that has brought about the Tatun volcanic activities. The high seismicity today also implies a highly fractured crust due to the hydrothermal activities and induced crustal stress. The hydrothermal fluid-rich upper crust as indicated by the low Vp/Vs ratio may have important bearing on the potential hazards associated with the two active faults cutting through both the Taipei Basin as well as the Tatun volcanic groups.

Keywords: The Tatun Volcanic area, Attenuation, Tomography, Vp, Vp/Vs

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A new concept of magmatism

Yoshimasa Iida[1*]

[1]non

A new concept of magmatism consists of the shock-wave fracturing pipe model, the pressure relief theory, and the caldera chain is summarized as follows.

(1) Magma migration. The magma rapidly rises in place of the stoping rocks in vent-forming.event. Following the event the magma seeps through the vent. The whole vent is rarely filled up with magma. The magma moves according to the pressure difference that results from low density of magma and geopressure variation. It moves intermittently.

(2) Duration of vent. In case of high temperature and small scale magmatism the vent is plugged and never be alive. In the low-temperature or large-scale cases the vent acts as a conduit of magma for long.

(3) Magma reservoir (MR) after vent-forming. The reasons for forming MR are; the inverted pressure due to topographic change, plugging at the top of vent, and static condition of magma filled in the vent just below the cater.

(3-1) Inverted pressure. The magma below the caldera stays in the same position as the pressure is lower than that of the surrounding area. The magma starts moving when the pressure rises with expansion by increasing volume of magma.

The pressure inversion is also formed in front of the central part of volcanoes neighboring the caldera due to the load of mountain. An example of this is the estimated reservoir at 8 km northwest of the Shinmoe-dake that erupted in 2011. The secondary MR was formed by the magma generated below the Kakuto caldera to northwest.

An earthquake swarm occurs when the magma below the caldera starts moving as it makes the overlying ground unstable. The Ebino earthquake in 1968 is such swarm. The magma migrated around 12 km for 41 years. Similarly the earthquake swarm occurred in the caldera 46 years before the 1959 eruption of Shinmoe-dake.

Based on GSI data the swelling of the MR started in December 2009. Following the quick shrink with the eruption in January 2011, it swelled again until November 2011 when the swell reached to 90% of the limit level. The magma inflow to the MR lasted a little less than two years. Concordantly the Ebino earthquake swarm lasted for about two years. At the time of next swarm in the caldera that is the time of magma discharge next eruption will be induced with the expansion of the secondary MR caused by the pressure rise of the hypercritical water in the intermediate vent.

(3-2) Plugging. This is a case of magma accumulation in the shallow level due to the plugging of the top vent. Such plugging may happens by quick consolidation of the high temperature magma and also by viscous slow magma. Owing to low load pressure the MR is hardly collapsed and grows huge with long-term magma supply from deep. In case of collapsing a caldera is formed. In case of no collapsing it is consolidated to form a plutonic intrusion.

(4) Phenomena in the overlying levels above MR in caldera. The earthquake swarm is induced by the unstable condition caused by magma migration. The dyke intruded from the MR upward rarely burst into eruption. Majority of the magma takes its way to the curve vent. The swarm in the east of Izu peninsula is such case, and the MR beneath the swarm supplies magma to the Izu-Oshima and Mt. Fuji. The hydrothermal activity above the MR forms epithermal gold mineralization. The Matsushiro earthquake swarm is due to the migration of magma to the Mt. Asama. The anomalous rise of land with the swarm is inferred to be caused by the hydrothermal activity that induced swelling of clay in the mid-Miocene thick shale.

Keywords: magma reservoir, earthquake swarm, epithermal mineralization

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