Japan Geoscience Union Meeting 2012
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SVC52-01 Room:301A Time:May 21 13:45-14:00

Effects of relationship between temperature and melt fraction of crustal rock on magma generation by crustal melting

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Crustal melting by injection of hot magmas is an important process for magma genesis in continental crust. Most magmas in arc magmatism in continental crust like Japan are probably produced by crustal melting. An aim of this study is to understand constraints of composition, amount, and generation timescale of magmas produced by crustal melting due to hot magma injections. So far, we investigated amounts of mafic and silicic magmas and timescale of magma production by crustal melting using a one-dimensional physical model. In the model, it is assumed that crustal rocks have almost linear relationship between temperature and melt fraction (the relationship is referred to be as melt fraction as function of temperature, F(T)). On the other hand, F(T) is not linear in general cases. For example, F(T) of hydrous granite steeply increases without temperature increase near its solidus, while F(T) of hydrous basalt less increases with temperature near its solidus. Thus, F(T) affects amount of magmas generated by crustal melting. We report effects of F(T) on magma generation by crustal melting in this presentation.

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. It is considered that hot magmas repeatedly inject at the same level and that no segregation between liquid and crystal occurs in our model. Additionally, effects of water in the hot magma were also taken into account. The hydrous hot magma melts the crust, solidifies itself, becomes saturated in water, and releases free water into the overlying crust.

We carried out calculation for a gabbroic crust that produces magmas by melting and assumed various F(T) of it. Calculation conditions are as follows. Initially, the surface temperature and temperature gradient of the gabbroic crust with 2 wt% water are 0 deg.C and 20 deg.C/km (the initial temperature of the melted is determined by its depth). Injected hot magmas have basaltic composition, the initial temperature of 1250 deg.C, and the initial water content of 2 wt%. Thickness of a single injection of the hot magma is 50 m. the critical melt fraction of convection is assumed as 0.6. In the calculation, we changed the injection depth of the hot magmas (pressure range is between 0.25-1.0 GPa) and injection rate of the hot magmas (2-20 m3/m2ky). The calculations for 300 ky are carried out.

The calculation results indicate that as a rate of increase of F(T) is smaller near the solidus, total amount of melt produced by crustal melting due to a certain amount of injected magmas becomes smaller while amount of melt produced with relatively low degree of partial melting becomes larger. Melts produced with relatively high and low degrees of partial melting are interpreted as mafic and silicic melts, respectively. Therefore, crusts that have a small rate of increase of F(T) near solidus are favorable to produce voluminous silicic magmas.

Keywords: crustal melting, silicic magma, melt fraction, gabbro, physical model

SVC52-02 Room:301A Time:May 21 14:00-14:15

Upper mantle and basaltic magmagenesis at an arc-arc junction: Chemical spatial variation of mafic rocks in Hokkaido

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Few studies are directly compared the spatial variation of volcanic rock composition and magma-generation processes in the Northeast Japan (NEJ) arc and Kurile arc. Previously, we have clarified the spatial chemical variation of mafic rocks from Hokkaido, which is located at the junction of these two arcs, and indicated that the southwestern part of Hokkaido can be considered as the northern end of the NEJ arc, but the central part of Hokkaido as the southern end of Kurile arc. Unmodified mantle, which refers to a mantle source before a subduction component (SC) addition, beneath the NEJ and Kurile arcs is heterogeneous. Enrichment increases toward the trench side of the NEJ arc and toward the southern side in the Kurile arc. In this study, we discuss the degree of melting (F), SC composition and the transfer process, as well as clarify the difference in magma-generation processes between the NEJ-arc side and Kurile-arc side in Hokkaido.

The $<$1.7Ma mafic rocks from Hokkaido can be divided by their distribution and composition into four volcanic fields: the eastern margin of the Japan Sea (EJS), the southwestern Hokkaido (SWH), the Taisetsu-Tokachi-Shikaribetsu (TTS) and the Akan-Shiretoko (AKS) volcanic field. While ^{143}Nd/^{144}Nd is same among EJS, TTS and SWH, it is higher at AKS. ^{87}Sr/^{86}Sr increases from EJS to AKS to TTS to SWH. EJS shows the highest contents of incompatible elements and the steepest REE pattern. AKS shows the lowest Nb and Ta contents. At the trench side of SWH and AKS, volcanoes contain low K. These trench-side volcanoes also have lower contents of incompatible elements, larger spikes of Pb and Ba, and flatter REE pattern than rear volcanoes. Moreover, trench-side volcanoes in AKS often show a depleted LREE pattern.

In a Nb/Y-Zr/Y diagram, four areas show linear and parallel trends that can be divided into three groups based on location (SWH, EJS and TTS, AKS: in descending order of Nb/Y at similar Zr/Y). This indicates the compositional heterogeneity of unmodified mantle, which cannot be explained by the degree of prior melt extraction from a single mantle source. According to these Nb/Y values at similar Zr/Y, we assume the Enriched-Depleted MORB Mantle (E-DMM), DMM and Depleted-DMM (D-DMM) of Workman and Hart (2005) for SWH, EJS and TTS, and AKS as unmodified mantle composition, respectively. F and prior melt extraction from assumed initial DMM are calculated by the contents of HFS elements that are conservative and not added from SC. The results indicate that the composition of trench-side volcanoes in SWH and AKS can be explained to some extents by prior melt extraction. In this case, AKS trench-side magma is generated from the most depleted mantle source in Hokkaido–a source that is D-DMM with prior melt extraction. Estimated F is 20% for SWH trench side, 12% for SWH rear side, 7~10% for TTS, 7~12% for AKS and 3~12% for EJS.

Using these estimated F, we determine metasomatized mantle source compositions of Hokkaido magma. Pb of a metasomatized mantle source shows positive correlation with F. In Ba, Th and U vs. F diagrams, several positive correlation trends can be recognized: EJS shows the highest trend and SWH and AKS frontal volcanoes show the lowest trend. The trends of TTS and rear-side volcanoes in SWH and AKS are in the middle. These data indicate the variation of SC composition in Hokkaido.

The difference of magma-generation processes between the NEJ-arc side and Kurile-arc side in Hokkaido are recognized as follows. Solute-rich SC is supplied on NEJ-arc side, as in EJS volcanoes, but not on the Kurile arc side. At the trench side in the NEJ-arc side, magma with the highest F in Hokkaido is generated. In contrast, magma at the trench-side of the Kurile-arc side is generated with relatively low F from the most depleted mantle source in this region. Such a feature of magma-generation processes in Hokkaido may reflect differences in mantle-slab geometry and thermal structure between the two arcs.

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Experimental study on magma plumbing system beneath Fuji volcano

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Fuji volcano, largest in volume and eruption rate in Japan, is located at the center of Honshu, where North Amer-ica, Eurasia and Philippine Sea plates meets. Beneath Fuji volcano, subduction of both Pacific and Philippine Sea plates are undergoing. Eruption of Fuji volcano may be related to large magnitude interplate earthquakes at least in some cases. Magma chamber beneath Fuji volcano is considered to be unusually deep compared with other volcanoes in Izu-Mariana arc. Fujii (2007) interpreted that unusual depth of Fuji magma chamber is due to thickened low density granitic crust by collision of Izu peninsula. Because of the significance of Fuji volcano both in tectonic settings and potential volcanic hazard, there are a great number of studies on Fuji volcano. However, studies focused on magma plumbing system beneath Fuji volcano are limited and there are no high-pressure experiments on Fuji basalt so far. The purpose of this study is to determine the conditions of the magma chamber (P, T, fO2, etc) of Fuji volcano through high pressure melting experiments.

Basalt scoria Tr-1 which represents the final ejecta of Hoei eruption in 1707, was adopted as a starting material. Experiments at 4kbar were carried out using an internally heated pressure vessel (HIP-5000) at the Magma Factory. Temperature conditions were 1050, 1100 and 1150?C, and H2O contents were 1.3, 2.7 and 4.7wt.%, respectively. The fO2 was controlled at NNO-buffer. At 4kbar, magnetite is the first liquidus phase and plagioclase is the second liquidus phase and is followed by clino- and orthopyroxene. Compositions of melts at 4 kbar were determined by EPMA analysis of quenched run products. SiO2 content of melt increases with crystallization and is different from silica non-enrichment compositional trend of Fuji basalt.

In order to explain silica non-enrichment differentiation trend of Fuji volcano, Fujii(2007) suggested that ortho-pyroxene may play important role at the deep magma chamber. Experiments at 7 kbar are in progress using another internally heated pressure vessel (HIP-8600) at the Magma Factory. Phase relations and melt compositional trend at 7 kbar will be reported. Based on high-pressure melting experiments and petrologic study, mechanism of Hoei sub-plinian eruption and origin of the dacite which was erupted at the initial stage of Hoei eruption will be discussed.

Keywords: Fuji volcano, magma, Experimental petrology, Subduction zone, High-pressure experiment

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SVC52-04 Room:301A Time:May 21 14:30-14:45

The 1883 eruption of Krakatau and its subsurface structure

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The present discussion is composed of 2 parts: The first part deals with the Verbeek's estimation (1885) of volume of the ejecta from the 1883 Krakatau eruption. Finally a balance sheet between the volume of juvenile material and that of lithic material is drawn. The second part discusses the subsurface structure of the Krakatau complex deduced by gravimetric and seismological methods.

In Part 1, the Verbeek s method is criticized from a viewpoint of methodology: Even evaluation of the errors in his surveys is difficult. Using his original data, the present author revises his estimation of the ejecta volume: For an example, volume of the total ejecta should be revised from 18.2 to 16.6 km^3. And also volume of the lithic material produced by the eruption is estimated at 11 km^3. Further, volume of the caldera deposits is estimated at 5 km^3 by gravity anomaly observed on the caldera. As a whole, a balance sheet between volume of the deposits in the Krakatau area and their sources can be shown with unavoidable ambiguity.

In Part 2, development of geophysical study of the subsurface structure of Krakatau caldera is historically reviewed and discussed:

Yokoyama (1981) measured gravity on Krakatau Islands and assumed caldera deposits of funnel-shape, about 5 km^3 in volume on the base of gravity anomaly. He calls the deposits 'fallback' that is produced by explosions. He did not discuss magma reservoirs because magma reservoir had not been detected definitely and because cavities in the earth crust do not always collapse due to rigidity of the crust. He emphasized gigantic explosivity of the 1883 eruption that caused strong pressure waves simultaneously occurring with the large tsunami.

Harjono et al. (1989) set up 10 temporary seismic stations on the both sides of the Sunda Straits and one on Anak Krakatau, all being equipped with a single vertical seismometer, and examined wave paths from 14 local earthquakes occurring in summer of 1984 and detected two bodies of shear-wave attenuation near the Krakatau complex: one is about 9 km deep directly beneath the Krakatau complex and the other is voluminous and deeper (about 22 km deep at the top) extending towards the SW.

Deplus et al. (1995) got a detailed bathymetry in the caldera area and supplemented gravity survey on land and sea. They interpreted the gravity anomalies observed at the caldera and reached the similar conclusion to Yokoyama's. They assumed the caldera deposits as the collapsed volcano body, not fallbacks and modeled the deposits by various types of cylinder.

Jaxybulatov et al. (2011) carried out temporary seismometric observation at 14 onshore stations on Krakatau Islands (3 on Anak Krakatau) and on the coasts of Java and Sumatra. During about 8 months, more than 700 local earthquakes were recorded, and tomographic inversions for P and S velocities and for the Vp/Vs ratio were performed. They obtained a zone of high Vp/Vs ratio nearly beneath the Krakatau complex though the network configuration and the distribution of the events were not favorable for high quality tomographic imaging. At depths from the surface down to 4 km deep, they observed Vp/Vs ratio higher than 2 and assumed it as a probable indicator of the presence of partially molten material.

The present author attributes the anomalous values of Vp/Vs ratio deduced by Jaxybulatov et al. (2011) to the caldera deposits proposed by Yokoyama (1981) considering the resolution capacity of their tomography in the Krakatau area. A problem should be what is the origin of the caldera deposits. At many calderas in Japan, we have much knowledge on caldera deposits: They are usually fallbacks of low density deposited in funnel-shape.

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Characteristics of a caldera volcano, and process to a caldera-forming eruption in Indonesia

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There are various volcanoes in the world. Almost volcanoes erupted frequently. However, some volcanoes seem to be quite for preparing a large-volume eruption with caldera formation. What is a caldera-forming eruption? Compared with usual eruptions, a caldera-forming eruption, erupted volume˜ 10-1000 km3, causes huge direct damages, wide-spread pyroclastic flow, air fall, lahar, tsunami, and global impacts such as climate change; The recovering time is more than 10 years for climate, ocean, food, human health, traffic, buildings, and 100-1000 years for land use. Japanese have forgotten a caldera-forming eruption, because the last one occurred 7,000 years ago. Indonesia was suffered twice for the last 200 years, and three times within 1000 years. The total victims amount to 130,000, which is 55 % of the total ones from eruptions in the world during the last 200 years.

We have questions on the caldera-forming eruption. (Q1) Can we get a precursor sign for the eruption (where, when, what volume)? (Q2) Is not the eruption infrequent (< once / 100 years)? (3) Can we evaluate the next candidate for hazard mitigation? We carried out the JST-JICA project as follows. The first is to study the process to the caldera forming eruption, that is, the quantitative eruptive history of target volcano to caldera-forming eruption, especially, multi-caldera volcanoes in Bali (Furukawa et al., 2012). (2) The second is to clear the frequency of the caldera-forming eruption, that is, the temporal and spatial distribution of the eruption in East Java and Bali (Toshida et al., 2012). The third (this paper) is to evaluate volcanoes base on the obtained geological data, in order to answer (Q1) and (Q2). The results will contribute to the answer of (Q3).

The short-term evolution: During the last a few months, we may catch the short-term process as the progressive activity to the climax eruption. We compiled the example of Pinatubo 1991 eruption, Philippine (Harlow et al., 1996; Hoblitt ea al., 1996; White et al., 1996; Wolfe and Hoblitt, 1996), that of Krakatau 1883 (Rampino and Self, 1982), that of Tambora 1815 (Junghuhn, 1854; Self et al., 1984, Stothers, 1984; Yamamoto et al., 2000; Takada and Yamamoto, 2008). There occurred a lot of small eruptions and hydrothermal explosions during the last a few months just before the climax. Moreover, there occurred unusual wide-range hydrothermal activity, 2-5 km-wide, before the climax, suggesting the existence of an active large volume magma beneath the summit.

The long-term evolution: There was a large shield or stratovolcano constructed with a large eruption rate before the caldera forming eruption, for example, Tambora, and Tenggar. In contrast with those volcanoes, Kelute has never cause the caldera-forming eruption. The long-term eruption rate is far smaller than those of volcanoes with caldera. The Kelute is composed of several volcanoes with repose periods. Next, we compiled the eruptive histories of caldera volcanoes which were studied as corporation projects between GSJ and VSI: Tambora (Takada et al., 2000; Matsumoto et al., 2000), and Rinjani (Takada et al., 2003; Nasution et al., 2003; Furukawa et al., 2004; Furukawa et al., 2005). We got the scenario that, during the last 10,000 years before the caldera formation, the eruption rate decreased, eruption style changed to more explosive, and chemical composition changed.

Keywords: Caldera-forming eruption, Indonesia, Large-volume eruption, long-term eruption rate, precursor, eruptive history

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Origin of temporal pattern change of small-scale convection in the mantle wedge and volcano distribution on the NE Japan

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Spatial and temporal variation of volcano distribution may be controlled by the temperature change associated with the mantle flow within the mantle wedge. Recent volcano distribution on the NE Japan is characterized by finger-like groups whose axes are almost perpendicular to the strike of plate boundary. This feature is similar to the temperature pattern caused by the small-scale convection (SSC) under the strong shear. Because of this similarity, we have proposed an existence of SSC in the mantle wedge. However, the volcano distribution on the NE Japan in the past shows a different pattern as that observed at present. They may be interpreted as flip-flopping, that is, the region with volcanoes switch to the region without them later, or vice versa. Our previous numerical modellings of SSC in the mantle wedge also show such a pattern change. However, most recent studies show the existence of non flip-flopping also. In this study, we explore possible causes of such different time-dependent behavior by changing the speed of subduction and the geometry of low viscosity wedge where SSC may emerge. We found that the wavelength of roll-type SSC perpendicular to the direction of large-scale flow has two characteristic scales which may be produced by the inclined bottom of the low viscosity mantle wedge. When SSC is in the early stage or the speed of subduction is small, the long-wavelength rolls become prominent. As the convection evolves or the speed of subduction increases, short-wavelength rolls take over the long-wavelength rolls. The transition from the long to the short-wavelength rolls occurs in a several way. We show that flip-flopping is the transitional stage from the long wavelength to the short wavelength rolls. We will discuss possible implications of our results on the temporal and spatial variation of volcano distribution on the NE Japan.

Keywords: small-scale convection, volcano distribution, temporal change

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Comparing long-term variation of pre-caldera volcanic activity in Bali and in Tengger caldera region, East Java

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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 and Tengger caldera region, East Java. Modal abundance analysis, as well as on-going analysis on whole-rock chemistry and K-Ar dating, are preformed at CRIEPI. Mass fractionation correction method is used for the K-Ar dating. Lava samples having pilotaxitic or intergranular groundmass texture are selected for dating analysis in order to obtain accurate and precise ages.

We have identified three periods of volcanic activity in Bali. They are 1.6 m.y. BP, 0.7-0.5 m.y. BP, and 0.2 m.y. BP to present. Large somma of both Batur and Bratan caldera volcanoes are constructed by 0.2-0.1 Ma activity, and partly covers 0.6-0.5 Ma volcano to form large shield volcano. Both Batur and Bratan systems have produced caldera-forming eruptions multiple times in the past 30 ky. The calderas have formed between the aprons of volcanoes from different ages.

For andesites, some mafic phenocryst assemblages are limited to particular period. Hornblende phenocryst is mostly limited to early Quaternary andesites, and orthopyroxene phenocyst is limited to 0.5 Ma andesite. Clinopyroxene phenocrysts are common to andesites of all periods, except for aphyric andesites of 0.2 Ma activity. They are light-colored in thin sections, indicating their high Mg# and relatively high temperature of magma. The large shield volcanoes of 0.2 Ma consist of aphyric andesite lava layers. The aphyric andesite lavas have relatively higher K2O, TiO2 content and FeO∗/MgO ratio. The 0.2 Ma aphyric andesite has also erupted outside of somma at the small volcano located 10 km to the NW of Batur caldera rim.

We have identified at least four active periods in Tengger, East Java; they are 1.7 m.y. BP, 0.5 m.y. BP, 0.3 m.y. BP, and 0.1 m.y. BP to present. The start of volcanic activity is similar to Bali, but the two caldera-forming eruptions (Ngadisari and Sand Sea) are much older than Bali. The age of the basalt lava erupted during the second (Sand Sea) caldera eruption is 0.3 Ma. The somma of Sand Sea caldera consists of volcanoes formed at 0.5-0.45 Ma (basalts of the north wall) and 0.3 Ma (basaltic andesites of the south wall). Based on our K-Ar ages, the first (Ngadisari) caldera and the intra-caldera units have formed between 0.45-0.3 m.y. BP.

Long-term variations similar to Bali are found in Tengger region. (a) Large shield volcano is constructed prior to caldera-forming eruption as a result of overlapping volcanoes formed in multiple periods. (b) Clinopyroxene is common phenocryst of basaltic andesite to andesite, and occurence of orthopyroxene andesite is limited to pre-caldera active periods. (c) The clinopyroxene phenocrysts are light-colored in thin sections which indicate their high Mg# and high temperature of magma. (d) Activity of aphyric andesite started during the intra-caldera period. (e) The younger aphyric andesites have relatively higher K2O, TiO2 content and FeO∗/MgO ratio.

During the intra-caldera activity, temporal transition from heterogenous basaltic andesite to homogeneous, aphyric andesite is observed, suggesting accumulation of andesite magma. The lava and spatter bomb of the central cones, including the present vent (Bromo), are andesites which have similar whole-rock chemistry to the andesites of intra-caldera period and caldera-forming eruptions, although they have heterogenous texture.

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: caldera, phenocryst modal abundance, K-Ar dating, Quaternary, Sunda arc, Indonesia

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Explosive eruptions associated with Batur and Bratan calderas, Bali, Indonesia

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In Sunda Arc, caldera forming eruption is frequent as occurring 3 times in recent 1000 years. The future caldera forming eruption in Bali should be evaluated from scientific procedure. Our geological study is a corporate work between Indonesia and Japan supported by Japan International Cooperation Agency (JICA) and Japan Science and Technology Agency (JST). We highlights long-term volcanic history of Bali Island, especially focusing on Batur and Bratan calderas including some peripheral volcanoes. We offer a significant contribution towards hazard mitigation at the forthcoming volcanic eruption. Bratan and Batur calderas are the most famous tourist places in Bali Island and are probable candidate of world geopark. The calderas have prominent depression of 12x8 km and 14x10 km respectively. The calderas are surrounded by flat plateau consist of major pyroclastic flow deposits with subordinating pyroclastic fall deposits and soils. Mt. Agung lying on east of Batur is a undissected stratovolcano with no caldera. As Bratan and Batur calderas are formed by multiple caldera forming eruptions, we need to evaluate long-term forecast of probable caldera-forming eruption. From 2009 to 2011, we have described more than 200 exposures and have made stratigraphic logs to correlated each deposit which allow us to reconstruct the eruptive history of Bali Island. We newly identified 7 extensive pyroclastic flow deposits which correspond to formation of Batur and Bratan calderas respectively. Radioactive carbon ages of carbonized wood and underlying soil ranges from ca. 29 to 6 ka. We also discovered more than 10 plinian pumice and/or scoria fall deposits extensively blanketing west of the Batur caldera. We identified scoria fall deposit from Agung volcano covering Batur area. It suggests sustaining concurrent activities of the Bali volcanoes. Oldest eruptive products we identified is 29 thousand years before made of plinian pumice fall and overlying pyroclastic flow deposit. Both deposits respectively thicken toward the present Batur caldera suggesting their source. Southern distribution of pyroclastic flow deposit is not sure, because this area is densely populated and lucks outcrops. But southern part of Bali supposed to be isolated island and connected by the sediment supply from the Northern volcanic regions to erupt. Caldera rim formed by this eruption is not confirmed. Carbonized wood root beneath this pyroclastic flow deposit has radioactive carbon date of 23760+/-70 years B.P. Next large eruption is 17 thousand year before consists of pumice fall to the southwest and overlying pyroclastic flow deposit. Outer caldera rim would be formed and proximal welded pyroclastic flow deposit filling inside of the caldera. At the lower non-welded pyroclastic flow deposit we found buried carbonized wood showing 14C age of 14370+/-70 years B.P. The next large eruption is 6ka also made of pumice fall deposit to the southwest and extensive pyroclastic flow deposit. The inner caldera rim must be formed. Sutawidjaja (2009) reported radiocarbon age for this pyroclastic flow deposit as 5500 years B.P. and we also obtained consistent age dating as 5550+/-50 years B.P. (calibrated to 6310 cal.y.BP). Youngest large eruption is four thousand years before. Pumice fall deposit blanketing west of Batur and relatively minor pyroclastic flow deposits intervened. Pyroclastic cone (Sayang) was also formed in southwest of caldera. We obtained the chronology and magnitude of large-scale explosive eruptions from Batur and surrounding volcanoes. Older volcanoes are basalt and andesite stratovolcanoes with no evidence of caldera formation. Age of them are shown by Toshida et al. (2010). For Batur and Bratan calderas, there are three caldera forming eruptions among last 30000 years (once in 10000years). We have less information from 4ka to present, and from 0.2 Ma to 30 ka.

Keywords: Bali, Batur caldera, Bratan caldera, explosive eruption, geology, eruptive history

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Petrological characteristics of Takayubaru lava flow, which extruded just before Aso-4 pyroclastic flow

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Takayubaru lava flow was extruded during the formation of Omine pyroclastic cone which is located 5 km from the western caldera rim of Aso. Aso-4 pyroclastic eruption occurred just after the extrusion of this lava with a short interval time. It was confirmed by the fact that Aso-4 pyroclastic deposit overlies Takayubaru lava without recognizable soil formations. It was also confirmed by nearly identical K-Ar ages for Takayubaru and Aso-4 volcanic products. Takayubaru lava flow has a thickness of 80-120 m, width of 9 km east west, 4 km north south and a volume of 2.0 km^3.

We collected lava samples from the edge of Takayubaru lava flow, and scoria samples from Omine pyroclastic cone. We were also provided drilling core samples by Kumamoto River National Highway Office. We analyzed their chemical compositions and made petrological descriptions. Observation of drilling core samples shows that Takayubaru lava has upper clinker part, massive part and lower clinker part. The upper clinker part is overlain by Aso-4 tephra without intercalated soil.. The upper massive part has jointing at and weathering.Clinkers are not observed inside the massive part indicating that Takayubaru lava is a single flow unit. Takayubaru lava contains about 20 vol.% phenocrysts. They are clinopyroxene ($<$1.8 mm, about 1.5 vol.%), orthopyroxene ($<$2.0 mm, about 2.2 vol.%), plagioclase ($<$1.5 mm, about 13 vol.%) and opaque minerals ($<$0.6mm, about 1.4vol.%). Takayubaru lava also contains hornblende microphenocryst ($<$0.3 mm, about 3.9 vol.%). Most of plagioclase phenocrysts show characteristic fractured texture, indicating melting along cleavage and fractures. The hornblende microphenocrysts vary from fresh to completely opacitized. Formation of hornblende and decomposition of plagioclase suggest physical and chemical changes just before eruption. The groundmass consists of microlites of plagioclase, mafic minerals, opaque minerals, and glass. It sometimes shows flow structure and inhomogeneous appearance. There is no correlation between phenocryst abundance and chemical composition of Takayubaru lava. Takayubaru lava and Omine scoria show no clear difference in phenocryst abundance and in chemical composition. They both have greater abundance of phenocryst than Aso-4 pumice. Silica content varies from 63 to 66 wt. % for Takayubaru lavas, and 61 to 66 wt. % for Omine scoria samples. The upper to middle part of drilling core samples have less than 1% variation in silica content. In contrast, the samples from the lowest part and the farthest part have less silica than others, with about 2% variation. Aso-4 pyroclastic deposits contain basalt to basaltic andesite scoriae (SiO_2=49-56 wt.%) and dacite pumice (SiO_2=65-72 wt.%). In comparison, Omine scoria and Takayubaru lava do not show mafic magma as observed in Aso-4 eruption. Compositional trend of Takayubaru lava is the same as that of the silisic member of Aso-4 deposit, although they are slightly silica-poor than the latter. It seems that the injection of mafic magma was not a possible mechanism to trigger the eruption of Omine cone and Takayubaru lava.

Keywords: Takayubaru lava, Omine pyroclastic cone, Aso-4 pyroclastic flow

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SVC52-P05 Room:Convention Hall Time:May 21 17:15-18:15

Two-type Submarine volcanoes reconstructed in greentuff in the Miocene in Ou Backbone Ranges, NE Japan

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We reconstructed two-type submarine volcanoes in greentuff in the Early to the Middle Miocene in Ou Backbone Ranges in Nishiwaga town, Iwate Prefecture, NE Japan. The first type (Type A) is very flat polygenetic submarine volcano which is mainly composed of massive lavas, hyaloclastites and no pillow lavas. One of the volcanoes of this type reconstructed in the Oarasawa Formation (the lowermost formation in the study area) was formed related to the extensional tectonics forming half-graben in the Early Miocene (Nakajima et al., 2006). The second type is submarine lava domes (Type B) which consists of massive lavas in central part, perlite and hyaloclastite in the marginal part. Type B was formed when the sea was the most deepest in this area. Prior to these volcanism, explosive volcanism occurred. We concluded that the intensity of eruption of submarine volcano in this study area was due to the water depth. This conclusion supports the idea that the eruption at shallow depth is explosive and that at deep depth is effusive (Allen et al., 2010). Kuroko deposits were formed under the quiet environment after formation of type B lava domes.

[Reference]

Allen, S.R., Fiske, R.S., Tamura, Y., 2010, Effects of water depth on pumice formation in submarine domes at Sumisu, Izu-Bonin arc, western Pacific. Geology, 38, 391-394.

Keywords: greentuff, submarine volcanos, facies analysis, Ou Backbone Ranges, Miocene, Kuroko deposits

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The Seto Composite Cone Sheet around the Middle Miocene Odai Cauldron, SW Japan

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1. Introduction

To the northern margin of the Odai cauldron in central Kii peninsula, many composite dikes are exposed (Wada *et al*., 2009; 2011; Takashima *et al*., 2010), formed with the middle Miocene caldera volcanism (Miura and Wada, 2007). Then, in the results of detailed field survey of dikes we found the intrusive bodies in Seto area compose a cone sheet which inclines to the center of the Odai cauldron. In this presentation we report the distribution and field occurrence of the cone sheet, and discuss the time of the cone sheet emplacement on the caldera formation.

2. Distribution and Field Occurrence of the Seto Cone Sheet

We surveyed 2 km x 1 km area in Seto area, and observed 14 boundaries between the sheet and the host rock. Host rocks are chert, sandstone, mudstone and green rocks which are comprised in the Daifugen complex of Chichibu terrain (Sato and YORG, 2006). Locally low angle shear fractures are developed in host rocks.

In surveyed area the observed strikes of the cone sheet are varied from E-W in the eastern part to NE-SW in the western part, which are similar tendency to tuffite dike as an arcuate pyroclastic conduit (Wada and Iwano, 2001) and Shionoha-Kamataki fault as collapse fault (Sato and YORG, 2006) of the Odai cauldron. On the other hand, inclination of the sheet is approximately 30S through the area, with locally horizontal intrusive plane. Thus, the Seto sheet is inferred to be cone-shaped with horizontal steps.

Maximum thickness of the sheet is ca. 26 m. In any outcrops marginal basaltic andesite (0.2~0.4 m thick) and central rhyolite (6~25 m thick) are observed. While the boundaries between the margin and the center are clear because of the difference of rock facies, there is no chilled structure in both parts at the boundary. In addition the central rhyolite often includes some amoeboid mafic enclaves, closely resembling to the texture of marginal basaltic andesite. Therefore, the Seto cone sheet is a composite intrusion formed by separate magma injections with little time gap between two magmas.

3. Caldera and Cone Sheet Formations

Seto composite cone sheet is considered to be a member of Takegi arcuate dike swarm by Sato and YORG (2006). Takegi dikes are composed of composite intrusions such as Seto sheet and mafic simple dikes. Wada *et al*. (2011) concluded that Takegi dikes were intruded at the same time, based on field occurrence, rock texture and bulk rock chemistry, and that they were injected with mingling and mixing of mafic and felsic magmas from the chamber by collapse of the caldera floor, as proposed by Kennedy and Stix (2007) and Kennedy *et al*. (2008). According to those ideas, it is possible to explain that Takegi dikes were emplaced just after caldera collapse event. This is supported by field observations such as southward inclination of the Seto cone sheet and its focusing toward the center of Odai cauldron, and thus it is plausible that the time of emplacement of the Seto composite cone sheet or Takegi dike swarm is just after the Odai caldera formation.

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Kennedy *et al*., 2008: Nature Geosci., 1, 385.
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Sato and Yamato Omine Research Group, 2006: Earth Sci. (Chikyu Kagaku), 60, 403.
Takashima *et al*., 2010: J. Geol. Soc. Japan, 116, 496.
Wada and Iwano, 2001: J. Volcanol. Soc. Japan, 46, 107.
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Keywords: Kii peninsula, middle Miocene, caldera, composite intrusion, cone sheet, cauldron

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Stress conditions affected by pressure from magma reservoirs inferred from Miocene dikes in the Shitara area, Japan

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Paleostress conditions were investigated from the attitudes of igneous dikes around Middle Miocene cauldrons in the Shitara area, Central Japan, by means of the methods of Yamaji et al. (2010) and Yamaji and Sato (2011). The former method determines the three stress axes and the stress ratio with their 95% confidence limits from the strikes and dips of dikes. If dikes in question were formed under different stress conditions, the latter one is a statistical method that distinguishes and infers the conditions.

There are two cauldrons and hundreds of dikes in the area. One cauldron has ring and radial dikes. The stress conditions inferred from the dikes had E-W or NW-SE trending sigma3-axes. It was found that sigma1-axes were inclined and pointing the center of magma reservoirs, the position of which were inferred by Geshi (2003) and others, suggesting that we detected the local stress conditions affected by the pressure from the reservoirs.

Keywords: tectonics, cauldron, stress, magma pressure

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Dike length and maximum width estimated by open fracture amount observed from its tip

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In previous studies on estimation of magma overpressure from open fracture amount of dike (e.g., Delaney and Pollard, 1981; Pollard and Segall, 1987) and/or of regional stress field from aspect ratio (Length/Width) of dike (e.g., Gudmundsson, 1983), well known simple and famous equation given by Sneddon and Lowengrub (1969) has been applied. However, if we apply the equation to dike data observed in field and estimate an overpressure, it needed to know center or a total length of dike before analysis. In general, it is difficult to know them, and it would be commonly that a part of dike could be observed in field. In fact, for examples, the other tips of dikes shown by Geshi et al. (2010) have not been found in spite of outcropping on very ideal caldera wall in the Miyake-jima, Japan, and their length and maximum width have not been known yet. In this case, it is difficult to estimate the magma overpressure from open fracture amount of dike.

In this study, we suggest procedure estimating a total length of dike from open fracture amount observed from its tip. We employ the coordinate system that the origin of coordination put on the tip of dike. We rewrote the equation in this coordinate system, and estimate a total length and maximum width of dikes from their open fracture amounts by means of the non-linear least squares method.

Numerical tests we carried out gave excellent results, and we expected that our procedure would be applicable to field data. Then, we applied our procedure to non-feeder dikes observed on caldera wall in the Miyake-jima, Japan. As a result, it was estimated that a total length and maximum width of dikes distribute in between 80m and 270m, and in between 0.3m and 2.4m, respectively. Average aspect ratio (width/length) was estimated as 0.0083. The correlation between aspect ratio and dike length was negative. If Young's modulus and Poisson's ratio of parent rock would be assumed to be 1 GPa and 0.25, it was estimated that all magnitudes of the overpressure of magma were less than 10 MPa. Because this value is less than extensional strength of general rock, these non-feeder dikes might be arrested in the mountain.

[References]

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Keywords: Dike, Length of dike, Maximum width of dike, magma overpressure

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Structural evolution of matured collapse caldera

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Collapse calderas develop increasing their depth / diameter ratio (S/D). To properly characterize caldera evolution, a topographic S/D (ratio between topographic depth and topographic diameter; S/Dt) and a structural S/D (ratio between structural subsidence and ring fault diameter; S/Ds) are considered. The structure of a collapse caldera sifts from a fault-controlled structure with two-concentric ring faults at earlier collapsing stages, to erosion of its wall, accumulating debris on the floor, at later collapsing stages. While S/Dt and S/Ds show a similar increase at initial stages, when S/Ds˜0.33 the S/Ds becomes significantly different from S/Dt: while continuous caldera subsidence increases S/Ds, the erosion of the wall and the filling of the floor decrease S/Dt. These natural and modeling results show that the control on the shape of mature calderas (S/Ds>0.07) and approaching S/Ds = 0.3-0.4 passes from a mainly structural to a mainly erosional control. Both S/Dt and S/Ds are needed to describe the evolution of a collapse and the processes accompanying it. Evaluating S/Dt and S/Ds allows proper description of the precise evolutionary stage of a caldera and of the relative importance of the structural and erosional processes and allows making semi-quantitative comparisons between evolutionary stages.

Keywords: caldera, collapse, structure, volcano, eruption

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Geological characteristics of depression structures distributed off the coast of the Habu-port, Izu-Oshima Is.

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Izu-Oshima volcano is an active volcano locating on about 100km south-southwest of Tokyo, about 12km east offing sea of Izu Peninsula. Fissure emission occurred in 1986, and all islanders took refuge. The observation of Oshima volcano activity is performed around the land, and there are little observation examples in the sea area. In 2010, Tokai Univ. and AIST group performed seafloor topography investigation around the Habu-port. This survey was performed in West costal area and East sea area across the Habu-port. Dredge survey and ROV seafloor observation survey by R/V BOSEI-maru were also performed in 2011.

In the West coastal area, many rugged hill structures with 1 to 3m in height formed on the uncurbed seafloor surface. The ropy and tensional cracks like structure were observed on the surface of these hills. So, we estimated that this topographical structure would be lava, which flowed from the land.

In the Eastern area, there are some depression structure, which formed 100-500m in diameter, and 5-10m in height. These depression distributed NNW-SSE trend, which is same as the trend of on land volcanic activity. Some volcaniclastic materials were sampled from this depression. And angular shaped rocks that over 50cm size were observed by ROV survey carried out around the wall of depression. We also estimated that the depression would be a scoria cone, which formed by the phreatic explosion.

Keywords: Izu-Oshima, Submarine topographic survey, submarine volcanic vent

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Pressure relief theory of magma genesis

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[1]non

The depression at the 1914 eruption of Sakura-jima was centered in the northern Kagoshima bay neighboring the volcano. Omori (1916; Bull. Imp. Earthq. Inv. Comm., vol.8, no.2, 152-179) estimated magma underlying the depressed area. He indicated the same situation in other areas where the combination of volcanoes and lakes/bays were seen. Such idea of lateral and shallow magma generation was disregarded since then, and the subduction zone magmatism in the deep became the established theory. The vertical vent and vertical migration of magma is believed by the absolute majority without doubt.

Apart from such common knowledge a new theory of vent-forming process was proposed last year (Iida, 2011a; shock-wave fracturing pipe model). In this model the vent is subhorizontal near the reservoir. The dip is getting steep upward to be subvertical at the crater. While the current model looks like a thermometer, the new model is similar to the plesiosaur that looks upward. Examples of such curve shape are as follows. (A) The distribution of focuses before and after the eruption of Unzen (Ohta, 1993; Jour. Geol. Soc. Japan, 99, 835-854; Fig.28). (B) Seismic depth imaging in the Death Valley (Chavez-Perez et al.; 1998; Geophysics, 63, 223-230; Fig.6). A conduit of magma along a normal fault from the bright spot to a cinder cone is interpreted here. (C) 3-D seismic structure of the Kirishima (Nishi and Kagiyama, 2002; Abstracts, Japan Earth Planet. Sci. Joint Meeting, V032-034; and material for 119th meeting of Coordinating Comm. Predict. Volc. Erupt. Japan). A low velocity zone extends from 4 km below the Ebino-dake to the crater of Shinmoe-dake.

Taking into account of the cases of estimated magma generation under the caldera, it was considered that the magma was generated by the sudden unload at the caldera-forming event, and such process was succeeded as a chain reaction (Iida, 2011b). The caldera chain forms the graben or lift in the continent, the moat in the sea floor, and the plain in plateau basalt region. As the chain reaction is non-contact type, the generated magmas in a chain are not always the same type.

The mechanism of magma generation is classified as follows. (1) The slow growth of huge magma reservoir in shallow level makes the underlying rocks increase in temperature and pressure. The sudden unload with formation of caldera induces magma generation within or underneath the crust below the caldera. (2) The lateral migration of magma generated with mechanism 1 reduces the pressure of underlying rocks that turns to be a new magma generation zone. (3) The kimberlite magma is generated by the pressure relief with the abrupt melting of ice sheet. (4) The mid-oceanic ridge magma is produced by the pressure relief under the tension field.

Yoder (1952) already proposed the stress relief concept of magma generation. He thought of gentle arching and faulting of overlying rock as the mechanism of pressure relief. The arching may be the mechanism for the petit-spot (Machida et al., 2005) in the outer-rise. The faulting applies to the case of (4) with normal faulting in the ridge.

The characteristic of subduction magmatism such as the zonal distribution of rock types is not the proof of magma generation by subduction. It can be interpreted that the distribution is formed by the zonal crust structure.

Iida (2011a) http://www2.jpgu.org/meeting/2011/yokou/SVC047-P10_E.pdf

Iida (2011b) http://www2.jpgu.org/meeting/2011/yokou/SVC070-P01_E.pdf

Keywords: pressure relief theory, curved vent, caldera chain, kimberlite