Relation between Earthquakes and Volcanic Eruptions –Messages from the Natural History –

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1.none

Relation between earthquakes and volcanic eruptions is a big and important problem since a proposal by Nakamura(1971) following Plate Tectonics. After the big earthquake and tsunami event in NE Japan on March 11, 2011, a large volcanic eruption has been expected by many scientists, though enlargement of magma chamber(s) for future formation of caldera(s) has also been anticipated by a small number of (?) volcanologists including by the present author. In order to make more clear relation between earthquakes and volcanic eruptions, historical data have been clarified in this poster. New targets of study will be pointed out.

Keywords: earthquake, volcanic eruption, natural history, geology

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Is there any causality between the 2002-2005 volcanic activity of Baitoushan volcano and the 2011 Tohoku M9 earthquake?

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From 2002 to 2005, the Baitoushan volcano on the border between China and North Korea showed an abnormality on the seismicity, temperature of hot spring, and on the summit elevation. The analysis using the ENVISAT SAR interferometry indicated the accumulation of magmatic fluid at about 5km under the summit of Baitoushan volcano. After the activity of Baitoushan volcano, in 2011, megathrust earthquake of M9 occurred in Japan. Many peoples feared the eruption of Japanese volcanoes including Fuji volcano under the influence of the megaquake.
The same kind of questions was born even for Baitoushan volcano, which is away 1300km from the epicenter. Is there any causality between the 2002-2005 volcanic activity of Baitoushan volcano and the 2011 megaquake?
To answer this problem, we need the knowledge of historical relationship between the Baitoushan eruption and the megaquake in Japan. For this we are required the knowledge of correct eruption age based on the ancient documents, and the analysis of relationship between the ages of eruption and megaquake in the past. After the analysis of old documents, we got four data sets of age differences; the average age difference is 1.3 year with a standard deviation of 7.2 year. Using these, we are able to estimate the corresponding age of eruption from the megaquake age. If we assume the eruption in relation to 2011 megaquake, the corresponding age of eruption with 3σ accuracy will be from 1991 to 2034. This time interval covers the present activity interval of 2002 to 2005. Thus the Baitoushan activity from 2002 must be related to 2011 megaquake in Japan.

Keywords: Baitoushan volcano, 2011 Tohoku earthquake, Time correlation

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The characteristics of the Late Cenozoic calderas in the northeastern Japan arc

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The uplift of the present Ou Backbone Range began in the island-arc period at 10 Ma, and was associated with an increase of horizontal compression. Between 8 and 1.7 Ma, active felsic volcanism created more than 80 calderas associated with subordinate andesites to basalts in the northeastern Japan arc (Ito et al., 1989; Yamamoto, 1992; Sato and Yoshida, 1993; Sato, 1994; Yoshida et al., 1999; Prima et al., 2012). There are two peaks in caldera formation interrupted by a short period of dormancy at 5-4 Ma, which is related to a short transgression, and the number and size of collapse calderas decreased from the late Miocene to the Pliocene.
These late Cenozoic calderas have an average diameter of about 10 km and an average aspect ratio of 1.24 in diameter. They are divided into three groups related to their diameter size (about 5, 10 and over 14 km), and are mainly classified into piston-cylinder type with subordinate funnel type. The spatial and size distributions of calderas are comparable with those of the Cretaceous granitic plutons from the Kitakami Mountainland in northeast Honshu. The collapse of such calderas would bave formed in a neutral to weakly compressive stress field (Sato and Yoshida, 1993; Sato, 1994), and this would have resulted in the rise of felsic magmas into the crust where large intra-crustal magma chambers were formed (Yoshida et al., 1993; Aizawa and Yoshida, 2000; Aizawa et al., 2006). It has been argued that the regional stress field controlled the volcanic activity in the northeast Japan arc (Sato and Yoshida, 1993; Yoshida et al., 1993, 1997, 1999, 2014; Acocella et al., 2008), and that basaltic magmas derived from the mantle wedge, underplated and stagnated near the Moho, which acts as a density barrier (e.g. Ryan, 1987; Takada, 1989). These magmas would then have fractionated, re-mobilized or re-melted from solidified mafic precursors or the pre-existing arc crust, to form the felsic magmas in the inland area of the northeast Japan arc, with a thick crust (Sato and Yoshida, 1993). Such an event is confirmed by the existence of large felsic effusives in the eastern margin of the back-arc basin rift system (Yamada et al., 2012). During the neutral stress condition between 13.5 and 10 Ma, the felsic magmas would have risen diapirically through the ductile lower crust owing to their buoyancy (Aizawa and Yoshida, 2000; Aizawa et al., 2006), and the mode of ascent would have changed in the brittle upper crust to dyke or sheet. An increase in the compressional stress field occurred between 10 and 8 Ma, and it is likely that this increase led to the formation of sills and laccolithic shallow reservoirs in the upper crust (Sato and Yoshida, 1993; Aizawa and Yoshida, 2000). The regional change in the stress field was, therefore, the major control of caldera-dominated volcanism with laccolithic shallow reservoirs that occurred in the earlier half of the island-arc period. Felsic magma at this level could then have intruded along subsurface low-angle thrust sheets, and it is possible that magma migration along the thrust sheets caused the uplift of the Ou Backbone Range (Sato and Yoshida, 1993; Sato, 1994; Yoshida et al., 1993, 2014).
The clockwise rotation of SW Honshu (Otofuji and Matsuda, 1983) and the collision with the Kuril forearc sliver (Kimura, 1986) caused an oblique (NE-SW trending) compression of the northeast Japan arc during the Miocene to Pliocene, and triggered felsic magmatism along the areas of localized extension (Acocella et al., 2008). After about 5 Ma, the Pacific plate accelerated (Pollitz, 1986). Pollitz(1986) suggested that the change in Pacific plate motion introduced a large component of compression normal to the Japan trench. This strong ENE-WSW compression closed the caldera-feeding

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systems and favoured the development of stratovolcanoes with deeper magma plumbing systems directly connected to the basaltic mantle source region.

Keywords: Late Cenozoic calderas, northeastern Japan arc, felsic volcanism

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Variation of mineral chemistry of mafic inclusions in the 1991-1995 dacite of Unzen volcano: variable degree of annealing of microlites in low temperature stagnant magma reservoir and its implications for the magma plumbing system

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Mafic inclusions in the 1991-1995 dacite of Unzen volcano show chemical and textural variability, such that bulk SiO_2 contents range from 52 to 62 wt.% and fine to coarse microlite textures. In this paper we show variations of mineral chemistry of hornblende and plagioclase and classify the mafic inclusions into type-I, type-II and type-III; i.e., type-I includes high-Mg plagioclase and low-Cl hornblende as microlites, and type-III includes low-Mg plagioclase and high-Cl hornblende, and type-II has intermediate mineral chemistry. Type-I mafic inclusions tend to show finer-grained in the matrix, have slightly higher bulk rock SiO_2 contents (56-60 wt%), compared with the type-III mafic inclusions (SiO_2=53-59 wt%), but overall bulk rock compositions are similar to the basalt-dacite eruption products of Quaternary monogenetic volcanoes around Unzen volcano. The origin of the variation of mineral chemistry in mafic inclusions is interpreted to reflect the different degree of diffusion relaxation of minerals in low temperature dacitic magma reservoir; i.e., older intrusion produced mafic inclusions, whose constituent minerals were subsequently annealed at low-temperature to be in equililbrium with the rhyolitic melt (type-III), whereas the latest intrusion retained high-temperature mineral chemistry corresponding to those of the type-I mafic inclusions. Mg contents of plagioclase are modeled in terms of temperature and X(An) for hydrous Unzen magma, suggesting that plagioclase microlite in type-III initially crystallized at high temperature subsequently reequilibrated in low temperature stagnant magma reservoir. Compositional profiles of MgO in plagioclase suggest that older mafic inclusions spent at least several hundred years for annealing at ca. 800°C in the stagnant magma reservoir before incorporation into mixed dacite of the 1991-1995 eruption of Unzen volcano. A magma plumbing system that afforded variably annealed mafic inclusions in 1991-1995 dacite of Unzen volcano is discussed and illustrated.

Keywords: Unzen volcano, mafic inclusions, magma plumbling system

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Petrological constraints on magma plumbing system beneath Izu-Oshima volcano

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[Introduction]
During the past 1,500 years, Izu-Oshima volcano, a frontal-arc volcano in the Izu arc, has experienced 12 major eruptions with an average interval of 100 to 150 years. Among them, three eruptions during 50 years in the 9th century could be linked to a huge earthquake and/or regional tectonics at that time. Since the 19th century, smaller scale eruptions have been occurring with an average interval of 30 to 40 years. Thirty years have passed since the last eruptions in 1986~1987; therefore, the next eruption may be coming soon. However, we are not sure whether it might be triggered by an aftereffect of the huge earthquake on March 11th, 2011. Here, we review the magma plumbing system beneath Izu-Oshima volcano based on petrological studies, which will be useful for volcanologists to deal with the next eruption.
[Geochemical variation of volcanic rocks]
Two endmember trends, referred to here as a higher-Al/Si trend and a lower-Al/Si trend, can be distinguished among the aphyric volcanic rocks, which represent the liquids of Izu-Oshima volcano. The liquids are bracketed by these two endmember trends, and thus may be mixtures of the two endmembers or may have been derived under intermediate conditions between those responsible for these two endmembers. An experimental study by Hamada and Fujii (2008) suggests that the higher-Al/Si and lower-Al/Si trends can be reproduced by upper crustal crystallization differentiation of high-Mg basalt under moderately hydrous (~3 wt% H_2O) and almost dry conditions, respectively.
[Hydrous melting experiments]
Island arc low-K tholeiite magma is characterized by the presence of Ca-rich plagioclase (An≥90), with a Ca-poor rim (~An75). Hydrous melting experiments on two volcanic rocks from Izu-Oshima volcano, MA43 and MA44 (MgO~5 wt%), were conducted to constrain the origin of Ca-rich plagioclase (Hamada and Fujii, 2007). MA43 and MA44 represent less differentiated liquid compositions in the higher-Al/Si and lower-Al/Si trends, respectively. The hydrous melting experiments were conducted at 250 MPa using an internally-heated pressure vessel. In the melting experiments on MA43, plagioclase crystallized as the liquidus phase at all H_2O content (1~6 wt% H_2O) and the crystallization temperature of plagioclase was linearly suppressed, and anorthite content of the plagioclase increased from ~An80 under nearly dry conditions to An≥90 with ~6 wt% H_2O. In the melting experiments on MA44, plagioclase crystallized as the liquidus phase under low-H_2O (≤2 wt%) conditions, but augite replaced plagioclase as the liquidus phase with more H_2O in melt. Anorthite content of plagioclase increased from about An70 under nearly dry conditions to An80 with ~4 wt% H_2O. Increases in anorthite content of plagioclase crystallized from the MA44 melt were suppressed compared with plagioclase crystallized from the MA43 melt. In short, Ca-rich plagioclase (An≥90) can be crystallized from melts on the higher-Al/Si trend with ≥3 wt% H_2O, but cannot be crystallized from melts on the lower-Al/Si trend with any H_2O. The Ca-poor rim (~An75) cannot be crystallized from melts on the higher-Al/Si trend, but can be crystallized from melts on the lower-Al/Si trend.
[Summary]
Geochemical variations in the liquids from Izu-Oshima volcano are bracketed by two endmember trends, the higher-Al/Si and the lower-Al/Si trends. The origins of these trends can be explained by crystallization differentiation under moderately hydrous conditions (~3 wt% H_2O) and almost dry

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conditions, respectively. We propose that polybaric crystallization of H_2O-saturated melts, at a depth range between the ~4-km-deep magma chamber (~3 wt% H_2O) and near the surface level (nearly dry), proceeds beneath Izu-Oshima volcano.

Keywords: Izu-Oshima volcano, Magma plumbing system, Experimental petrology

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Deep Structure of Fuji volcano

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Fuji volcano is known for its perfect cone shape and it is the largest among Japanese Quaternary volcanoes. In the last 100kya, Fuji has erupted only basalt magma (>>99 vol%), but its eruption style changed (from debris flow and tephra dominant Ko-Fuji or Older Fuji, to lava flow dominant Shin-Fuji or Younger Fuji) at ~15 kya BP. Origin of the voluminous yet monotonous basalt production in Fuji volcano have been discussed but remain unanswered. Here we report the first high-pressure melting experimental results on Fuji basalt (Hoei-IV, AD1707) and demonstrate that its main magma chamber is located at ca.25km depth. We show seismic tomographic images of Fuji volcano for the first time, which reveals the existence of strong upwelling flow in the mantle and its connection to the voluminous lower crustal magma chamber .
Very frequent low frequency earthquakes just above the magma chamber may be due to the injection of basalt magma and/or fluids. The total lack of silica-rich rocks (basaltic andesite and andesite) in Fuji volcano must be due to the special location of the volcano. The plate boundary between the Eurasia plate and the subducting Phillipine sea plate is located just beneath Fuji volcano (~5 km depth). Large tectonic stress and deformation associated with the plate boundary inhibit the survival of a shallow level magma chamber, which would allow the evolution of basalt to silica-rich magma (as observed in all other volcanoes in Japan, e.g., Hakone, Izu Oshima).

Keywords: Fuji volcano, plate boundary, deep structure

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