Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SVC53-01 Room:413 Time:April 28 14:15-14:30

Variations of basaltic magmas and their timing of injection into the magma system of Sakurajima volcano since AD 1779

EBIHARA, Kaho[1] ; NAKAGAWA, Mitsuhiro[1*] ; YOSHIMOTO, Mitsuhiro[1] ; KOBAYASHI, Tetsuo[4]

[1]Earth & Planetary System Sci., Hokkaido Univ., [2]Earth & Planetary System Sci., Hokkaido Univ., [3]Earth & Planetary System Sci., Hokkaido Univ., [4]Earth & Enviromental Sci., Kagoshima Univ.

Sakurajima volcano has repeated plinian eruptions three times during the last 600 years and changed the mode of eruptive activity since the AD 1914 plinian eruption. Frequent vulcanian eruptions has continued since AD 1955. Nakagawa et. al(2011) concluded that two-end-member magma mixing of silisic magma(S-magma) and andesite magma(A-magma) occurred in 1471 and 1779, and three-end-member magma mixing of mixed magma(S+A) and basaltic magma(B-magma) since the 20th century. They concluded that the injection of the B magma has frequently occurred since then to change the mode of eruptive activity. Their evidences of the injecting were presence of Olivine and An=90 plagioclase phenocrysts and different mixing trend in SiO2 variation diagrams between the 20th century and previous products. However, petrological features of AD 1779 submarine eruptive products just after the terrestrial plinian eruption have not been revealed in detail. In this study, newly collected 1779 submarine products are investigated to discuss the magma plumbing system.

The AD 1779 submarine products are banded pumice and slightly vesiclated lavas. These contain plagioclase, orthopyroxene, clinopyroxene and magnetite as phenocryst associated with small amounts of olivine microphenocrysts, which were not recognized in the AD 1779 terrestrial products. These olivine phenocrysts do not have reaction rims of orthopyroxene. Average core compositions of these are about Fo=77. Compositional variations of other phenocrysts, except for magnetite, are nearly the same as those in the AD 1779 terrestrial and 20th eruption products. These olivine phenocrysts are diequilibrium with pyroxenes on the basis of Fe-Mg partitioning, suggesting that the basaltic magma injected into the mixed magma between the S and A magmas, which erupted as the AD 1779 terrestrial products. It should be noted that the injection of the basaltic magma had started just before the submarine eruption. On the other hand, olivine phenocrysts in the 20th century products are composed of two types, with or without reaction rims of orthopyroxene. Average core compositions of those without reaction rims are Fo=81, whereas those with reaction rims are less than Fo=74. These suggest that the 20th century products had been repeatedly injected by the basaltic magmas and that the basaltic magma injecting just before each eruption had olivine phenocrsyts with Fo=81. Although the injections of the basaltic magma has occurred just before the AD 1779 submarine eruption, two types of basaltic magma have injected . The basaltic magma in AD 1779 was less magnesian and contained olivine pehnoctysts with Fo=77, whereas those in 20th century were magnesian, having olivine phencorysts with Fo=81. This is consistent with distinct two chemical trends of AD 1779 submarine and 20th century products in SiO2 variation diagrams, such as P2O5 and MgO. Considering the presence and absence of the relict olivine phenocrysts, with reaction rims, the erupted magma during the 20th century were effected by previous injections of basaltic magmas. After the injection of olivine (Fo=77) in AD 1779, these olivine phenocrysts were reacted with more silicic melt not only to form the reaction rim but also to change their chemical compostions with less magnesian. Just before AD 1914 eruption, voluminous another basaltic magma with more magnesian olivine (Fo=81) had injected just before the AD 1914. The injected magma since AD 1955 has been similar to that of AD 1914, whereas volume of the magma has become smaller. However frequent, small scale of injection has continued to cause number of small, but explosive vulcanian eruptions.

Keywords: Sakurajima volcano, magma system, magma mixing, olivine, volcanic eruption

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SVC53-02 Room:413 Time:April 28 14:30-14:45

Bulk density change of juvenile clasts during the climactic phase of the 2011 Shinmoe-dake eruption

SUZUKI, Yuki[1*] ; ICHIHARA, Mie[1] ; MAENO, Fukashi[1] ; NAGAI, Masashi[2] ; NAKADA, Setsuya[1]

[1]ERI, Univ. of Tokyo, [2]NIED

In the 2011 eruption of Shinmoe-dake, three sub-Plinian events occurred intermittently between Jan 26 PM and Jan 27 PM (1/26PM, 1/27AM and 1/27PM). This was followed by lava accumulation in the crater (Nakada et al. 2013, EPS). Based on Suzuki et al. (2013a, JVGR) that clarified characteristics and plumbing system of the erupted magmas, we reveal evolution of conduit magma flow during the climactic phase as above, by using groundmass textures. The questions we would like to address are, 1) mechanisms that led to the intermittent sub-Plinian events, including triggering process of each event, 2) timing and condition of syneruptive magma ascent that were responsible for the shifting eruption intensity and style.

As a preliminary result, we here present bulk density data for samples (gray and brown pumices and lava) of the same chemical and storage conditions just prior to ascent from the reservoir. If lithic fragments in sub-Plinian deposit can be judged juvenile (i.e. from the 2011 magma) based on whole rock composition and appearance under the microscopy, they were included in the sample set for the bulk density analysis. Generally, the bulk density data reflect syneruptive ascent condition and resultant degree of syneruptive outgassing. This time, the data allowed us to select representative samples for further textural analyses. The bulk density data also helped us newly define the horizon corresponding to the start of the second sub-Plinian event.

Following the results in Maeno et al. (revised) and Nakada et al. (2013, EPS), the sub-Plinian deposit was collected at locations on dispersal axes and 2-3km from the crater. The following unit numbers are after Nakada et al. (2013). We had no difficulty in identifying the deposit of the third sub-Plinian event (Layer5), because the field survey was in progress at the time of occurrence. The lower units (Layer2, 3 and 4) exhibit reverse grading from layer2 to layer3 and normal grading from layer3 to layer4, as if it was generated in a single event. This occurrence had prevented us from identifying the boundary between the first and second sub-Plinian events. As far as area of the sampling is considered, we believe no deposition during the resting phase between the first and second sub-Plinian events (Jan 26, 19:00 - Jan 27, 2:00) . The most likely deposit for the resting phase is ash, if plume height of 3.5km and lower (Shimbori and Fukui, 2012; lower than 6-7km during the sub-Plinian events) is considered. We did not find ash layers between the two of the three layers (layer2, 3 and 4).

The bulk densities of the samples change systematically with the subunits; 1.0-1.7 g/cm^3 from Layer2-low to Layer3-low, 1.0-2.0 g/cm^3 in Layer3-up, and 0.8-1.4 g/cm^3 from Layer4-low to Layer4-up. The average densities for the subunits are 1.25 g/cm^3, 1.28 g/cm^3, 1.27 g/cm^3, 1.44 g/cm^3, 1.14 g/cm^3, 1.17 g/cm^3 in order from Layer2-low.

We propose that Layer3-up corresponds to the start of the second sub-Plinian event, based on a judgment that high-density pumices in Layer3-up are from upper-conduit degassed magma that was generated during the resting phase (Jan 26, 19:00 - Jan 27, 2:00). The infrasound and seismic data (Ichihara et al., submitted) recorded no explosion for the resting phase. Therefore, we infer the degassed magma did not block the conduit completely.

We could not know exact time of the Layer4 deposition. However, the lower bulk densities in Layer4, in comparison with those of layer3-up, is consistent with the temporal increase of plume height (e.g. ca. 5km at AM2 of Jan 27 <ca. 7km at AM4 of Jan 27) and mass eruption rate (Ueda et al., 2013) during the second sub-Plinian event. In this model, we however must explain smaller pumice sizes in Layer4 in comparison with those of Layer3-up.

Keywords: Shinmoe-dake, Sub-Plinian eruption, Bulk density, Outgassing, Infrasound, Plume height

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SVC53-03 Room:413 Time:April 28 14:45-15:00

Hypocentral migration associated with magma intrusion in the 2000 Miyakejima eruption

MATSUYAMA, Ryotaro[1*] ; MORITA, Yuichi[1] ; SAKAI, Shin'ichi[1] ; UEDA, Hideki[2]

[1]ERI, Univ. of Tokyo, [2]NIED

A dike intrusion is a phenomena that large amount of magma emplaces in the shape of vertical plane. It is much controlled by tectonic stress. A dike intrusion process is one of the important key informations to understand the relation between tectonic stress and volcanoes. In the case of the Miyakejima eruption in 2000, it is confirmed that a large scale dike intruded beneath sea floor from the following observations; Hypocenters migrate from inland area of Miyakejima to the area near by Kozushima and Niijima. Large ground inflation is measured by nation-wide GNSS network. However, the detail process in this event has been unsolved because hypocenter locations cannot be estimated precisely. Therefore, we try to relocate hypocenters and to reveal the dike intrusion process of the 2000 Miyakejima eruption in this study.

Because hypocenters migrated to the offshore of Miyakejima, hypocenters could not be located precisely from the data recorded at inland of islands surrounding hypocenter area. Eight days after the initiation of the activity, ocean bottom seismometers(OBSs) were installed just above hypocenters. The hypocenter locations was improved very much using the OBSs data. However, analysis of OBS's data did not cover a whole period of the activity. We try to relocate hypocenters that has no OBS's data (approximately 30,000 events) relative to the reference hypocenters (approximately 3000 events) that are located precisely using OBSs data. In our analysis, we modify Double Difference method to give constraints not to move the reference hypocenters and apply it to all earthquakes occurring during 26 June and 31 August, 2000. We also use the velocity structure that is smoothly varying in the depth because of prevention of artificial hypocenter concentration.

From the relocated hypocenters, we find out the following features in the seismic activity associated with the 2000 Miyakejima eruption. 1) There are two groups in the seismic activity. One is the hypocenters aligned from the summit of Miyakejima to the point around 8km off the coast line (near coast activity), the other is the seismic activity distributed on a sub-vertical plain located beneath sea floor at the area surrounded by Miyakejima, Kozushima and Niijima (main activity). The alignment of the hypocenters match with the direction of the maximum tectonic stress. 2) The near coast activity began with an initiation of the volcanic activity and concluded on July 1st. The seismicity in this area was active only in the first week of the whole volcanic activity, and earthquakes did not occur after the period at all. 3) The main activity lasted during two months, and it was accompanied with gradual ground deformation measured by nation-wide GNSS network that represents a large scale of dyke intruded at hypocentral area. The vertical section of the hypocenters shows that the vertical alignment changes at the depth of 12 km where the structure discontinues is implied from a seismic survey. 4) In the later periods of the activity, there are many earthquakes at the area next to the main activity. Their focal mechanisms were strike slip types that agree with the direction of tectonic stress.

Considering the features of the hypocentral distribution mentioned above and other observational facts, we can conclude that there are two types of the magma flow during the 2000 Miyakejima eruption. One is horizontal emplacement just after an initiation of the volcanic activity and the other is gradual upward migration from deep zone to the main activity. Because the cost activity was inactive after July 1st, we suppose that the two magma flow is independent during almost whole period except at the beginning of the activity. In other words, the magma that generate the main activity is not supplied horizontally from Miyakejima but from just beneath hypocenter area.

Acknowledgments: We are much grateful to JMA, NIED, Tokyo Pref. for permitting to use their seismic data.

Keywords: dike intrusion, 2000 Miyakejima eruption, hypocenter migration, seismic activity, tectonics

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SVC53-04 Room:413 Time:April 28 15:00-15:15

Temporal variation of mineral composition of Hanafusa Formation distributed in the western area of Aso caldera

SUGIYAMA, Fumiko[1*] ; HASENAKA, Toshiaki[1]

[1]Guraduate school of Science and Technology,Kumamoto university

Aso volcano made four large-scale pyroclastic eruptions, with magma composition changing with time, so that hornblende phenocryst appeared in the latest Aso-4 pyroclastic flow deposits (Watanabe, 1979). Hornblende becomes a key mineral to detect the physicochemical change, as it also appeared as microphenocryst in volcanic products of Omine volcano and associated Takayubaru lava flow, which erupted just before Aso-4 event (Kurokawa et al., 2012). Hanafusa Formation is a lake deposit forming 20 km west of Aso caldera just before Aso-4 pyroclastic eruption, thus it is suitable for finding the appearance time of hornblende from the minerals included in the deposits.

Hanafusa Formation consists of silt and sand with thickness of up to 10 m, and formed between Aso-3 and Aso-4 pyroclastic flow events. We collected samples from pumice deposit and overlying sand in Kajisako, Kikuchi city. We also collected samples from silt layer just below the contact with Aso-4 pyroclastic deposit, and from the type locality of Hanafusa Formation in Kikoji, Kikuchi city. We divided silt layer into upper unit and lower unit with boundary at the tephra layer, which we identified as Ata regional tephra by its mineral assemblage and existence of abundant bubble-shape glass and estimated age of 100 ka.

(1) The lower unit contain plagioclase, clinopyroxene and orthopyroxene. Plagioclase crystals indicate auhedral and have the surface which give a dirty impression.

(2) The upper unit contains euhedral hornblende and euhedral plagioclase crystals which are not observed in the lower unit. The upper unit contains clinopyroxene and orthopyroxene crystals. The mineral assemblage and their ratios are the same as observed among Aso-4 pyroclastic flow deposit.

(3) Chemical compositions of pumice fragments in Pumice layer resembled those of all Aso-4 pyroclastic flow deposits. However, in detail, Oyatsu pumice flow deposit, Benri scoria flow deposit and Omine volcanic products show distinct compositional trends from this pumice layer(Kurokawa et al., 2012; Yamasaki et al., 2013).

(4) Observed crystals in sand just above the pumice layer include plagioclase, clinopyroxene, orthopyroxene, opaque minerals and olivine, which isnot included in the lower pumice layer.

Our findings suggest that the appearance of hornblende was 10,000 years before Aso-4 pyroclastic eruptions, however their source is unknown, because we did not find obvious tephra layers other than Ata regional tephra.

Keywords: Hanahusa formation, hornblende, Aso-4 tephra, Aso-4 pyroclastic flow

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SVC53-05 Room:413 Time:April 28 15:15-15:30

Estimating composition of primitive magma by using opx, and temporal and spatial change of HMA magmatism in NE Shikoku

MORISATO, Fumitoshi[1*] ; OZAWA, Kazuhito[1]

[1]School of science, The University of Tokyo, [2]School of science, The University of Tokyo

In the subduction zone, oceanic plates start sinking into the mantle, and continental crusts are generated and eroded. So it is important for understanding the evolution of plate-tectonics. As for the subduction initiation, temporal change of thermal structure and water content of the mantle wedge is mainly estimated by numerical simulations (Iwamori, 2000 *etc*.), but there are few constraints from material informations. Using magma information is a possible method to estimate thermal structure of the Earth (Green, 1981). Although it is necessary to estimate chemical composition of the primitive magma, the effects of crystal differentiation and, especially in subduction zone, crustal process (magma mixing, crustal assimilation, and degassing) should be evaluated. Moreover, the magmatism in subduction zone is assumed to be affected by mantle flow in mantle wedge (Tatsumi *et al*., 1983; Tamura, 2003). To estimate such upwelling, Sakuyama *et al*. (2009) investigated temporal and spatial change of the magma generation field.

SW Japan is an example of juvenile subduction zone. Shikoku basin initiated to sink 17 Ma ago, and magamatisms migrated from forearc to reararc (Kimura *et al*., 2005). In the Setouchi volcanic zone, the generation of high-Mg andesite (HMA) has been discussed from the view of thermal structure of the mantle wedge and subducting plate (Tatsumi & Hanyu, 2003 *etc*.), but there remains some questions about magma mixing and degassing, and about temporal and spatial change of magma generation field.

In this study, we suggest a method to estimate the primitive magma composition by using oscillationally-zoned opx, and apply to the HMA in the Setouchi volcanic zone. And we try to estimate the magma generation mechanism by evaluating temporal and spatial change of magmatism in the area.

Firstly, we investigated a HMA in Mt. Kiyama, central part of NE Shikoku, Japan (Sato, 1982 *etc*.). It has the most primitive composition (SiO_2: 57.3wt%, MgO: 8.56wt%, Mg#: 69.3), and it contains olivine, opx, and cpx as phenocrysts. The olivine phenocrysts are normally-zoned, and their highest Mg# (87.6) is lower than the equilibrium value calculated from whole rock composition of the HMA (88.7). Therefor the olivine phenocrysts are considered to be crystallized in closed system. On the other hand, opx phenocrysts are reversely-zoned, and their composition boundaries are sharp. Moreover they have higher Mg# (up to 91.5) than calculated equilibrium value (88.8). Accordingly, these opx could record the composition of more primitive melts. And zoning pattern among opx is consistent, so they could reflect compositional change of the same melt.

According to Putirka (2005), the composition of primitive magma can be estimated by adding fractionated olivine or opx until the melt's composition become in equilibrium with the opx which has the highest Mg#. But we must remove the effects of magma mixing before it. Kuritani (1998) used the fact that the An content of plagioclase phenocryst can be changed in a magma chamber reflecting the difference of temperature or water content. He investigated the pattern of zoning and quantity ratio of them, and estimated mixing ratio.

We estimated the change of melt composition. (1) Calculating the melt compositions from opx composition by using distribution coefficients. (2) Comparing the change of the melt composition and modeled composition in Rayleigh fractionation or magma mixing. (3) Estimating mixing ratio by evaluating the pattern of zoning in opx and their quantity ratio, and estimating end member of mixing. (4)According to the true fractionation trend, determining primitive magma composition which is in equilibrium with opx having the highest Mg#.

By applying this method to the HMA in Mt. Shichihousan, western part of NE Shikoku (Kawabata & Suto, 2000), we estimated the spatial change of primitive magma composition and magma generation field.

Keywords: subduction, Southwest Japan, primitive magma, magma mixing, High-Mg andesite

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SVC53-06 Room:413 Time:April 28 15:30-15:45

The relation of volcanic stages for the recent 10000 years of Kirisima and Southern Kyushu volcanoes

TAJIMA, Yasuhisa[1*]

[1]Nippon Koei Co., Ltd.

In this study the eruption ages of tephra and lava generated from Shinmoedake volcano and Ebinokogen volcanic area by 14C dating were determined. Those ages indicate that the Kirishima volcanoes have three eruptive stages among the recent 10,000 years. The eruptive stage C started from 9.0 to 8.0 cal ka BP with RyD-L from Shinmoedake volcano and Fd-TmA tephra and Fudoike lava from Ebinokogen volcanic area. Old-Takachihono volcano and Takachihonomine volcano grew rapidly in this stage. The eruptive stage B continued from 5.6 to 2.3 cal ka BP growing the Shinmodedake and Nakadake volcanic edifices. Three eruptions at the same time, which were the Miike plinian eruption at 4.6 cal ka BP from Miike maar, Sm-Sy eruption at 4.5 cal ka BP from Shinmoedake volcano and Kn-EbD eruption at 4.3 cal ka BP from Ebinokogen volcanic area in this stage. The time interval between eruptive stage B and eruptive stage A was 2.3 to 1.6 cal ka BP. The yougest eruptive stage A started with Fd-EbC tephra from Ebinokogen volcanic area at 1.6 ka. In this stage, the Ohachi volcano grew from 6th century and Shinmoedake volcano erupted from 18th century. This result indicates that the Kirisima volcanoes repeated a few thousand years of eruptive stages and 500 to 1000 years intervals. The current eruptive stage A pasts about 1600 years. The relation of eruption ages of Kirishima volcanoes and Sakurajima volcano is well.

Keywords: Kirishima Volcano, Volcanic stage, Shinmoedake, Ebinokogen, Long term activity

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SVC53-07 Room:413 Time:April 28 15:45-16:00

Investigation report of rootless cone in Iceland -as an analogue of that of on Mars-

NOGUCHI, Rina[1*] ; SARUYA, Tomotaka[1] ; SUZUKI, Yuki[1] ; KURITA, Kei[1]

[1]Earthquake Research Institute, the University of Tokyo

Rootless cone is a pyroclastic cone which has a variety of shape. It's formed by lava-water interaction [e.g. Fagents et al., 2002, Hamilton et al., 2010], but details such as formation conditions are still unknown. Since pervasive existence of various types of rootless cones has been clarified on the martian surface, terrestrial rootless cones are key to understand Martian volcanism and strong interests have been paid in the field of planetary science. We surveyed rootless cones in Iceland by RTKGPS (Real-Time Kinematic GPS) with material-scientific investigations on the constituent materials.

We investigated 3 rootless cone fields; Myvatn (northern Iceland), Landbrot (eastern Iceland), and Thjorsardalur (western of Hekla volcano). In this presentation, we will focus on Myvatn area. In Myvatn, rootless cones were formed by lava-lake water interaction. The lava is basaltic, and emanated from the fissure which locates in east of the lake [Thorarinsson, 1951], and flowed into the lake. We mapped more than 500 rootless cones by aerial photo survey. Most of cones locate around the lake, but some cone locates in in the down-flow region (40 km far from the lava source) area. In Myvatn, here exists unique rootless cone which has an inner cone in the summit crater. We named this as <u>double cone</u>. We focus on this type and conducted detailed morphological survey.

We found that slope angle of rootless cone depends on its size. For double cone, inner cone has gentler slope than that of outer cone. In case of single cone (no inner cone), large cones have steeper slope than that of small cones. Also, large cones have constant slope (repose angle: 32-33 degree), despite the slope angle of small cone varies. In case of the double cone, we found that the constituting material of the inner cone differs from that of the outer cone. The component material of the outer cone is lapilli - coarse ash size pyroclast. On the other hand, that of the inner cone is welded pyroclasts or agglutinate. For small cones, the summit part is covered with agglutinate. These differences should indicate different condition of the formation such as the amount of available water/heat supply by magma.

A We measured bulk chemical composition of the lava and the pyroclasts by XRF confirming no significant change along lava flow traveling. We also measured bulk density and size distribution of the pyroclasts of the rootless cones. We found density of the lava concordantly increases with traveling distance, which means bubbles progressively escaped from the lava during traveling while the formation of rootless cone seems not to be influenced by the vesicularity of lava. The size distribution seems to be correlated with the slope value of the cone, which strongly suggests the control of fragmentation on the formation of rootless cone.

Keywords: rootless cone, Iceland, Mars, Myvatn, double cone

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SVC53-08 Room:413 Time:April 28 16:15-16:30

Volume of magma chamber and eruption ratio for caldera collapse

GESHI, Nobuo[1*]

[1]Geological Survey of Japan, AIST

Mechanism of caldera collapse is modeled with a comparison of a piston-cylinder caldera model and the compiled data of caldera size and eruptive volume in nature.

Collapse caldera is formed by the fracturing and subsidence of the roof of magma chamber with rapid withdrawal of massive magma from a magma chamber. As the fracturing and subsidence of the roof of magma chamber may enhance the additional eruption of magma inside the magma chamber, understanding of the mechanisms of the precursory eruption is crucial to evaluation of the potential eruption from caldera volcanoes.

Collapse calderas are formed only by the largest eruptions of its life, though, in many cases, caldera volcanoes repeat many eruptions with various scales before and after caldera formation. Smaller eruptions have no significant contribution for collapse. Aira caldera in Japan was formed at 29ka eruption during which ~400 km^3 of magma was erupted. Though many smaller eruptions including Fukuyama pumice eruption (10km^3DRE) and Sz-S eruption (4km^3DRE) occurred from the Aira caldera, no significant collapse was occurred. During the 29 ka eruption, Osumi pumice fall was erupted prior to the onset of collapse, and the emission of Ito pyroclastic flow followed the collapse. The erupted volume of Osumi pumice fall (~40 km^3DRE) is larger than those of the eruptions without collapse. This relationship is commonly observed in other caldera volcanoes. The erupted volume during the precursory eruption is in correlation with the size of caldera.

The volume of magma withdrawal to induce collapse is modeled with piston-cylinder model. The driving force of collapse is the decompression in magma chamber by the magma extraction. The friction in the ring fault sustains the roof. Competition between the decompression of magma chamber and the friction controls the onset of collapse. The decompression of magma chamber is in the function of the eruption ratio (volume of magma withdrawal / total volume of magma chamber). This model shows that a larger volume of magma withdrawal is required for the onset of collapse with larger diameter. The critical eruption ratio for collapse is smaller for the larger caldera.

Though this model has potentially large ambiguity from the simplified shape of caldera fault and the assumption of the bulk modulus of magma, this model can give the total volume of magma chamber associating collapse caldera. In the case of Aira caldera, with 15 km in diameter and 6 km to the roof of magma chamber, the total volume of magma chamber before the eruption is estimated as 600 km^3. The caldera collapse occurred when the erupted volume reached to 8% of the total magma chamber, and 60 % of magma was erupted as Ito pyroclastic flow after the onset of collapse.

Keywords: large eruption, caldera volcano, magma chamber