Conditions for a magma reservoir that is easy to activate: a comparison between Usu and some other volcanoes

*Akihiko Tomiya[1]

1.Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology

Understandings of magma reservoirs, preeruptive magma processes, and their time scales are being developed [see the review by Tomiya (2016: Bull. Volcanol. Soc. Japan) and references therein]. A magma reservoir is rapidly cooled and solidified, and tends to form a crystal mush with a high (>40-50%) crystal content and virtually immobile state if there is no heat supply. It is necessary to remobilize the mush and to form an eruptible (low-viscosity) magma before an eruption. In this case, there will be a long time lag between an eruption trigger (e.g., an injection of a hot magma) and the eruption. On the other hand, if there is already sufficient eruptible magma, the time lag will be shorter. Thus, we can expect a positive correlation between the repose time since the last eruption and the time lag after the eruption trigger as shown below. This can explain the positive correlation between repose times and run-up times found by Passarelli and Brodsky (2012: Geophys. J. Int.).

An active volcano with a repose time of less than tens of years probably keeps eruptible magma. The historical activity (since 1663 AD) of Usu volcano is such a case. Zoning profiles of phenocrysts in the eruptive products demonstrate that the Usu magma has been in a condition where crystal growth and diffusion are effective (Tomiya and Takahashi, 2005: J.Petrol.). From diffusion analysis for magnetite, the time scale of the preeruptive magma processes for each historical eruption is several days, which is consistent with the duration of the precursory seismicity. Thus, a magma reservoir with an eruptible magma can be triggered in several days.

A volcano with a repose time of hundreds of years probably has little (insufficient) eruptible magma. The 2011 eruption of Shinmoedake, Kirishima volcanic group, is such a case. Petrographic study demonstrates that the main eruptive product is mixed andesite formed by remobilization of the mushy magma reservoir and that the time scale for the remobilization is more than tens of days, probably about one year, corresponding to the duration of the precursory crustal deformation (Tomiya et al., 2013: Bull.Volcanol.).

A volcano with a repose time of thousands of years probably has no eruptible magma. The 1663 eruption of Usu, the 1667 eruption of Tarumai, and the 1640 eruption of Hokkaido-Komagatake are such cases. Crystal size distribution (CSD) analysis demonstrates that the residence time of the Usu magma before the 1663 eruption is 10^2 to 10^3 years (Tomiya and Takahashi, 1995: J.Petrol.), although the error may be an order of magnitude. Thus, at least tens of years was needed to prepare the eruptible magma for the 1663 eruption.

Depth (pressure, water content) of magma reservoir is also an important factor. At a higher pressure with a higher water content, melting of a crystal mush can proceed effectively at a lower temperature, producing much silicic melt (e.g., rhyolite). The high water content also reduces the viscosity of the melt, promoting segregation and accumulation of the interstitial silicic melt. The magma of the 1663 eruption of Usu volcano was nearly aphyric rhyolite, and the reservoir was at ca. 250MPa (10km) and 780°C., according to high-pressure melting experiments (Tomiya et al., 2010: J.Petrol.). The high-pressure, high-water condition probably promoted production, segregation, and accumulation of the rhyolitic melt before the eruption. On the other hand, the magmas of the 1667 eruption of Tarumai and the 1640 eruption of Hokkaido-Komagatake were porphyritic andesite, and the reservoirs were at ca. 100MPa (4-5km) and 900-950°C, according to MELTS calculations. The low-pressure, low-water condition required a high temperature for melting, and also suppressed

segregation of the interstitial melt. This caused the eruption of the porphyritic magma, a mixture of the melt and the crystals from the mush.

Keywords: eruption trigger, eruptible magma, magma reservoir, Usu volcano, time scale, crystal mush remobilization

