Overview of the Special Issue

“Progress of Studies on Caldera-forming Eruptions and Future Problems”

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Large-scale pyroclastic eruptions (LSPE) can eject 10s–100s km³ of silicic magma onto the Earth's surface as pumice falls and ignimbrites. The evacuation of voluminous magma from a shallow magma chamber may result in the collapse of a caldera. The frequency of LSPE is “low”, with less than 10 eruptions of VEI 7 or more recorded during the last 10,000 years on the Earth. However, LSPE can cause fatal disasters both near the eruption site and at a distance from it, while also seriously impacting the global climate. Pyroclastic fall-outs, ignimbrite flows, and tsunamis during the 1815 eruption of Tambora (Self *et al.*, 1984) and the 1883 eruption of Krakatau (Self and Rampino, 1981) caused destructive damage in areas surrounding the volcanos, although magmas ejected during these eruptions totaled less than 100 km³. Large volumes of volcanic ash in the atmosphere also resulted in a climatic aberration, known as the Year Without a Summer, in Europe (Robock, 2000). Although these eruptions are the largest known in history, many geological records indicate that some pre-historic LSPE discharged magmas in volumes of an order one or two times larger than these Indonesian examples. Many collapsed calderas surrounded by massive ignimbrite deposits are distributed in subduction zones and continental hot spots. A detailed analysis of deposits surrounding these collapsed caldera reveals that on average more than one mega-eruption VEI > 8 occurs

on the Earth every 10,000 years.

Recently, the possibility of LSPE and related potential disasters occurring have been highlighted with a consensus about the risk of low-frequency natural disasters (e.g., Tatsumi and Suzuki-Kamata, 2014). There have been many volcanological studies, taking various approaches, on the mechanisms of LSPE and caldera collapses. Given these trends, the Commission on Collapse Calderas (CCC) was established in 2008 as a scientific commission of the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI), to encourage and promote a wide spectrum of research on collapsed calderas and LSPEs, from the perspectives of geology, geophysics, numerical and analogue modelling, hazard assessment, and risk management, as well as economics and the environment. The first workshop was held at the Las Cañadas Caldera Complex on Tenerife Island, Spain, to discuss issues to be clarified relating to the origins and behaviors of calderas. Subsequently, the commission has held international workshops every two years. All of the workshops were held in caldera-volcanic fields to permit on-site field discussions as well as indoor lectures. The 6th workshop was held in September 2016 at the Kitayuzawa hot-spring site, Hokkaido, located in the Shikotsu-Toya-Kuttara caldera field, which is one of the most active caldera volcanic fields in Japan. Forty-seven researchers from ten

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countries attended the workshop and discussed the mechanisms of caldera-forming eruptions and associated topics. Prior to the workshop, a training course on caldera volcanism was also held at the Otaki Seminar House of Hokkaido University, at the Kitayuzawa hot-spring site. The course particularly targeted early-career researchers. The course included some high-level lectures by leading researchers and field-indoor training to reconstruct the eruption sequence from geological records.

This special issue presents topics and associated research results discussed at the workshop. The workshop highlighted the importance of geological approaches to caldera volcanism. In particular, it is still critical to collect individual examples, in order to obtain a general understanding of LSPE and caldera-forming eruptions, because modern volcanology has almost no real-time observations of LSPE with caldera-formation, except for the case of the 1991 Pinatubo eruption, which formed a very small caldera. In Japan, there have been more than 10 examples of caldera-forming LSPE within the last 100,000 years in Hokkaido and Kyushu. Research to reconstruct detailed eruption sequences, to precisely date eruptions, and to perform petrological investigations of their magma systems has been encouraged. Based on these case studies, a generalized model of the sequence of caldera-forming eruptions and their controlling mechanisms is expected to be constructed.

The process whereby large volumes of magma accumulate in the crust is also fundamental to LSPE studies. Mechanical and tectonic controls on the accumulation of magma at shallow levels in the Earth's crust are among the main topics of recent caldera research. In particular, ground deformation in and around the magma chamber provides direct signals associated with the accumulation of magma beneath the potential eruption sites of LSPE. To reconstruct the underground activities of a magma body, we should know the physical properties of the host rock surrounding the magma body (Yamasaki, 2018), as well as the magma itself. Identifying

the physical properties and structures of the rock hosting an active magma body is one of the challenging targets for understanding the activities of caldera volcanoes. To understand magma chamber collapse and caldera collapse formation, it is crucial to investigate deformation and faulting structures inside collapse calderas. Goto and Danhara (2018) provide interesting data on the subsurface electrical resistivity of Toya caldera.

It is also important to construct a general view of the activities of caldera volcanoes based on individual examples, in order to understand caldera volcanism (Geshi, 2018). In particular, the relationships among the driving mechanism of LSPE, caldera collapses, and massive ignimbrite eruptions can be understood based on a physical model with many examples accumulated of eruption sequences and development of magmatic systems. Geological investigations into the eruption sequences of individual caldera-forming eruptions are also important. Goto *et al.* (2018), Miyasaka and Nakagawa (2018), and Nakagawa *et al.* (2018) provide detailed reconstructions of eruption sequences of these important caldera-related eruptions in Hokkaido. The results clarify that these caldera-forming eruptions can be divided into several stages with clear time gaps. This provides important constraints on the dynamics of the magma plumbing system of a caldera volcano. Simultaneous eruptions from discrete magma systems are proposed for several caldera-related eruptions based on detailed petrological investigations (e.g., Shadai eruption of the Shikotsu caldera, Nakagawa *et al.*, 2018). The resurgence of a magmatic system after a caldera collapse is also an important target. Goto and Wada (2018) re-construct the post-caldera eruption sequence of the Kucharo caldera based on a detailed tephra chronology.

Hasegawa *et al.* (2018a) also attempt to evaluate the time scale of an eruption using the paleo-magnetic method. Understanding the control mechanism for stopping and re-opening large-scale eruptions is one of the main targets of volcanology. These studies are based on field

observations of erupted materials. To improve methods of analyzing field deposits, detailed observations of outcrops are fundamental. Hasegawa *et al.* (2018b) describe several key outcrops of the calderas investigated at the workshop.

The long-term development of the magma plumbing systems of caldera-forming LSPE is also an important topic for caldera volcanology, because LSPE need an accumulation of magma within the plumbing system before the onset of an eruption. The time scale of the maturation of a magma plumbing system and expected precursory signals for LSPE are also interesting targets not only for volcanology but also for risk management associated with volcanic disasters caused by LSPE. The potential impacts of caldera-forming LSPE on local and global environments are also important targets of research using geological approaches.

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