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論　文　内　容　の　要　約

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Petrological and geochemical study on evolution of magma plumbing system of Aira caldera volcano
（姶良カルデラ火山のマグマ供給系進化に関する岩石学的および地球化学的研究）

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Abstract

Caldera volcanoes can discharge voluminous (over 100 km^3) reservoirs of magma in single supereruptions. Despite the catastrophic environmental and societal hazards that these events pose, petrogenetic processes in the magma plumbing systems of caldera volcanoes are still poorly constrained. In order to advance the understanding of the origin and temporal evolution of magmas in these locations, I selected Aira caldera as a case-study volcano and examined the petrological and geochemical characteristics of volcanic rocks that have erupted there during the last 100,000 years. This volcano produced two eruptions with a volcanic explosivity index (VEI) of 6 at 90 ka and 50 ka, and an over VEI-7 supereruption at 30 ka, which was associated with forming a caldera with a 20 km diameter. Since 30 ka, volcanic activity from vents within the caldera has produced Sakurajima and Wakamiko volcanoes.

In order to achieve the purpose of this study, a detailed volcanic history for Aira caldera needed to be clarified, therefore, new field surveys, some ^{14}C dating, and a compilation of geological and archeological data from previous studies were carried out. As a result, valuable new constraints on the volcanic history of Aira caldera have been obtained. One of a key finding was the discovery of a phase of explosive eruptions at ~60 ka that were caused by the generation of mafic magmas in the plumbing system. The mafic magmas have similar geochemical characteristics to those erupted at 50 ka and 30 ka. These observations indicate that the generation of mafic magmas in the magma plumbing system had already started ~30 kyr before the 30 ka supereruption. Furthermore, volumes for each eruption at Sakurajima volcano were estimated to constrain its eruption rates through time. Sakurajima volcano has produced 14.6 km^3 (5.82 km^3 as dense-rock equivalent, DRE) of fallout tephra deposits, and 8.8 DRE km^3 of proximal deposits (lavas and pyroclasts) comprising the volcano edifice. The revised magma discharge rates for Sakurajima volcano are as follows: 0.051 km^3/kyr (26–24 ka), 2.9 km^3/kyr (13–8.0 ka), 0.067 km^3/kyr (8.0–4.8 ka), 1.1 km^3/kyr (4.5–1.6 ka), and 4.1 km^3/kyr (1.6 ka–present). The high magma discharge rates (>1 km^3/kyr) with the same order of magnitude as those in pre-supereruption explosive volcanism (1.9–5.9 km^3/kyr) are observed at 13–8.0 ka and 4.5 ka–present. The ejecta erupted during the two periods are important to clarify the temporal change of the magma plumbing system at pre- and post-supereruption stages that have caused explosive activities.

The petrogenesis and temporal evolution of magmas erupted at Aira caldera have been investigated in the context of the above volcanic history using petrological and geochemical analyses to determine the element and isotope compositions of whole-rock samples and plagioclase phenocrysts. The Sr isotope data of the volcanic rocks suggest that the magmas erupted at Aira caldera were formed from four source materials: amphibolitic lower crust with mafic composition (~0.7055 $^{87}Sr/^{86}Sr$), sediment or granite in the shallow crust (>0.709 $^{87}Sr/^{86}Sr$), tonalitic upper crust (~0.7052 $^{87}Sr/^{86}Sr$), and the mantle (~0.7045 $^{87}Sr/^{86}Sr$). Variations in the compositions of erupted magmas were generated by different degrees of partial melting of the source materials, magma mixing of the generated magmas, and fractional crystallization. The most important magmas for the 30 ka supereruption and the eruptions before it are silicic and mafic magmas generated by low- and high-degree partial melting of the amphibolitic lower crust, respectively. Silicic magma mixed with a small amount of mafic magma and erupted as the 90 ka dacite magma and 50 ka rhyolite magma. Mafic magma from the amphibolitic lower crust assimilated shallow crust with a higher Sr isotope ratio (>0.709 $^{87}Sr/^{86}Sr$) in the shallow crustal magma storage region, and erupted as basaltic andesite to andesite magmas from ~60 ka to 30 ka. The voluminous rhyolite magma ejected during the 30 ka supereruption was a mixture of rhyolite magma and a small amount of andesite magma, both of which were the same as those of the 50 ka eruption. After the 30 ka supereruption, a part of the andesite magma remained in the crust and differentiated to form rhyolite magma. This rhyolite magma was the source of volcanic activity at Wakamiko volcano. Sakurajima volcano's magmas exhibit an isotopic signature that indicates involvement of mantle material during petrogenesis. The magmas erupted during 13–8 ka were formed by a three-components mixture of upper crustal melt, lower crustal melt, and mantle-derived mafic melt. On the other hand, the andesite-dacite magmas erupted during AD 764 were predominantly formed by a two-components mixture of upper crustal melt and mantle-derived mafic melt with lesser involvement from lower crustal melt. These temporal variations in magmatic sources and processes have controlled the origin and evolution of magmas erupted in the last 100,000 years at Aira caldera.