

The origin of a coarse lithic breccia and its implication for the formation of small calderas

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Small calderas associated with explosive eruptions have been inferred to be formed either by collapse of the roof of a magma chamber due to magma withdrawal, “caldera collapse” (e.g. Pinatubo, Ceboruco, and Ksudach) or by enlargement of a vent as a result of explosive erosion and failure of the shallow part of conduit walls, “vent widening” (e.g. Nigorikawa, Novarupta, and Caldeira). Even if such caldera formation models may partially explain the dynamics of caldera formation, to develop a comprehensive understanding of the formation mechanisms and eruptive dynamics of small calderas it is necessary to link and explain the relationship among the subsurface structures, dynamics of eruption and caldera formation, and lithology and stratigraphy of the eruptive products. In order to achieve this, we have investigated the 34 ka Sounkyo eruption associated with the formation of the 2-km-diameter Ohachidaira caldera in the Taisetsu volcano group, central Hokkaido, Japan.

The Sounkyo eruption products are made up of five eruptive units (SK-A to -E) in proximal regions, corresponding to the distal deposits, a 1- to 2-m-thick pumice fallout and the Px-type ignimbrite up to 220 m thick. The eruption began with a fallout phase, producing a <60-m-thick, pumice-dominated fallout (SK-A and the distal fallout). The second phase, the climax of the eruption, produced a widespread, valley-filling ignimbrite in both proximal and distal regions (SK-B and the Px-type ignimbrite). This phase culminated in the generation of dense, lithic-rich, low-mobile pyroclastic flows to form a >27-m-thick, coarse lithic breccia (SK-C). After a short eruptive hiatus, the eruption resumed with the production of a <6-m-thick scoria fallout (SK-D). Finally, it ended with the emplacement of a smaller-volume ignimbrite in the proximal area (SK-E). The caldera volume (0.35 km^3) is an order of magnitude less than that of magma ejected ($\sim 5 \text{ km}^3$) and is comparable with that of lithic fragments ejected (0.28 km^3), suggesting that the Ohachidaira caldera was not essentially formed by caldera collapse but, instead, by vent widening. The dominance of shallow-origin volcanic rocks in the lithic fraction throughout the Sounkyo eruption products implies the development of a flaring funnel-shaped vent, as observed in the Nigorikawa caldera. Lithic breccias often overlie climactic ignimbrite/fallout deposits in small caldera-forming eruptions and are commonly inferred to mark the timing of caldera collapse. We, however, propose a new model for the formation of such lithic breccias, based on their lithic assemblages and stratigraphy along with the subsurface structures of some Japanese small calderas examined by geothermal drilling: (1) the shallow conduit gets explosively eroded and enlarged with consequent fragmentation and brecciation of the walls before and during an eruption climax; (2) subsequent waning of the eruption leads to collapse of the unstable fractured walls; (3) finally, the abundant lithic debris gets incorporated into the eruption column to form lithic breccias. We conclude that small calderas may be formed by vent widening rather than by caldera collapse, and that the large-scale vent collapse, which may play a significant role in establishing the overall size of the calderas, produces a coarse lithic breccia sheet at the end of the main phase of the explosive sequence.

Keywords: Ohachidaira, Taisetsu volcano group, small caldera, lithic breccia, vent widening, vent collapse