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Relationships between caldera size and eruptive volume of magma

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We compile a dataset of topographic volumes of caldera depression and volume of erupted materials of 20 calderas in various geological settings. The selected calderas are younger than 15 ka, well preserve their original topography, and well determined the total volume of the erupted materials. Size of the depression of the considered calderas ranges from 0.1 km^3 (Piton de la Fournaise) to 60 km^3 (Kikai) and half of the calderas are <10 km^3. The data includes two caldera types: calderas formed by explosive eruptions, for example, Tambora, in 1815 and Pinatubo, in 1991, and collapse calderas without remarkable eruptions from the caldera floor as the case of Katmai, in 1912.

The compiled data shows a positive correlation between the volume of the caldera depression and the total volume of erupted magma discharged outside of the caldera area. In the case of calderas associated with explosive eruptions, the DRE volume of the erupted material is almost same or larger than the topographic depression of the calderas. The volume ratios of the erupted magma in DRE volume against the caldera are concentrated between 1.0 and 2.4 times larger than the topographic volume of the caldera. Small calderas less than 0.5 km^3 have wider range of the ratio ranging up to 6.8. Moreover, some eruptions discharged more than several km^3 of magma did not form significant caldera depression, as in the case of the 1600 eruption of Huaynaputina, Peru.

The volume discrepancy between the erupted magma and the caldera depression suggests that the withdrawal of the collapse of the caldera at the surface is associated with an increase of the volume by chaotic material assemblage. This effect becomes more evident for smaller calderas, as these have a larger volume ratio of erupted magma against their caldera depression. Assuming the same thickness of the roof rock, smaller calderas are associated with a larger roof aspect ratio: therefore, the chaotic assemblage of material during collapse is expected to be more relevant for higher aspect ratio calderas. As the size and caldera depression increase, the roof aspect ratio decreases and, consequently, the style of collapse changes to more coherent subsidence. This possibility is consistent with the results of as analogue and numerical experiments.

Discharge of the rock fragments by explosive eruptions may also enlarge the caldera depression. However, there is widespread evidence that the main parts of the erupted material during caldera formation are magmatic and the total volumes of the exotic rock fragments are much smaller than the topographic depression of the caldera. This implies a limited effect of mechanical erosion during collapse.