Relationship between crater size and eruption rate for three recent eruptions of Kirishima volcano, Japan

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We examined the relationship between crater diameter and eruption rate for three volcanic eruptions of Kirishima volcano, Japan. Three craters are Miike (diameter=1150m), Ohachi (530 m), and Shinmoedake (790 m) craters, each of which corresponds to Miike pumice fall deposit (3.1 km3; ca. 3000 y.b.p), Takaharu scoria fall deposit (0.28 km3; A.D. 788), and Shinmoedake-Kyoho pumice fall deposit (0.21 km3; A.D. 1716-1717), respectively. Isopleths for the clast size of 2-4 cm in diameter show the eruption column height of 22 km (Miike), 14 km (Takaharu), and 20 km (Shinmoedake-Kyoho), from which the eruption rate was calculated to be 8*10^4 m3/sec; 1.1*10^4 m3/sec; and 3.8*10^4 m3/sec, respectively. The eruption rates are proportional to the cube of the crater diameter.

Crater size is roughly proportional to the cube root of ejecta volume of an eruption. However, crater size is expected to be better correlated with the intensity of the eruption rather than the total volume of the ejecta. This paper deals with the three recent plinian to subplinian eruption products and associated craters of Kirishima volcano, southern Kyushu, Japan, to obtain the eruption rate and compare them with the crater size. Among 33 tephra deposits from the Kirishima volcano, we chose three recent large eruption products for detailed study on the relation between crater size and eruption intensity. They are, Shinmoedake-Kyoho pumice fall deposit (A.D.1716-1717, from Shinmoedake crater), Takaharu scoria fall deposit (A.D.788, from Ohachi crater), and Miike pumice fall deposit (ca.3000yr.b.p., from Miike maar).

The Miike maar has an average diameter of 1150 m. The pumice fall deposit from the Miike maar has a total volume of 3.1 km3. Size of fragments in the pumice fall deposit was measured basically according to the method of Carey and Sigurdsson[1987], which counts average of maximum three fragments in 0.1 m3 of deposit. We carried out the same measurement, but also measured average of maximum three fragments in an area of 1 m2 at the same place. The relation between the averages of maximum three fragments for both 0.1 m3 and 1m3 showed good 1:1 relationship. Therefore, we measured average size of maximum three fragments in 1 m2 for convenience. The average diameter of Ohachi crater is 530 m. Takaharu scoria deposit is distributed to the east of Ohachi crater, and the total volume of the deposit is 0.28 km3.
The maximum and average diameters of the Shinmoedake crater is 790 m,. Six pyroclastic fall deposits were produced from the Shinmoedake crater (Table 1), among which the Shinmoedake-Kyoho pumice fall deposit, identified as A.D. 1716-1717 eruption products, is by far the largest. The total volume of the Shinmoedake-Kyoho pumice fall deposit is 0.21 km3.

Present study employs the method of Carey and Sparks(1986) to estimate the eruption column height and eruption rate. We first measured the density of pumice and scoria fragments to normalize their sizes for the equivalent terminal fall velocity of the lithic fragments (density=2500kg/m3). The average and standard deviation of pumice density from Miike pumice fall deposit is 499+-87 kg/m3 for 14 fragments. There is no correlation between size and density of the clasts. The density of scoria fragments of Takaharu fall deposit ranges from 814 to 1160 kg/m3, with average of 997+-140 kg/m3 for eight fragments. The fragments in the Shinmoedake-Kyoho pumice fall deposit ranges from 810 to 1546 kg/m3, with average of 1311+-240 kg/m3 (n=8). Next step for calculation of the eruption column height and eruption rate is to obtain maximum down-wind range and cross wind range of the clast size for the three eruptions from the isopleth data

Among the three eruptions of Kirishima volcano, the diameters of the craters are in the order of Miike maar (1150 m), Shinmoedake crater (790 m), and Ohachi crater (530 m). The ejecta volumes are not in this order. The Miike pumice fall is about ten times larger than the other two eruptions, and Takaharu scoria fall deposit is slightly larger (0.28 km3) than the Shinmoedake-Kyoho pumice fall deposit (0.21 km3). The apparent discrepancy may be reconciled when we take the eruption rate for the total ejecta volume. The relationship between the eruption rate and crater diameter show good correlation, with a power of ca. 1/3. Because the crater diameter is proportional to the cubic root of explosion energies, the correlation suggest that the eruption rate is proportional to the explosion energy that caused excavation and collapse of the crater formation.