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Cosmic-ray muon radiography of volcanoes

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We developed a radiographic technique to image a subsurface conduit using cosmic-ray muons. The principle of the technique is that by measuring muon absorption along different nearly horizontal paths through a solid body, one can deduce the density distribution in the interior of the object. The measurements would be ideal for studying the shallow structure of the crust at sites which cannot be well resolved because of their strong structural heterogeneity and potential difficulty to be accessed, and which therefore cannot have their structure determined by conventional electromagnetic or seismic techniques. We use a single detector (emulsion cloud chamber) set up in an underground vault at an elevation of 2250 m on the eastern flank of Asama, 310 m below the summit of the edifice and 1 km away from the crater. The results point to two high-density anomalies located between the original pre-2004 eruption crater floor and post-2004 eruption crater profile. A third low-density anomaly is imaged immediately below the pre-2004 eruption crater floor. The spatial extent of each density anomaly is about 100-200 m. To know if this method, applied to other volcanoes, would produce contrasting results, we performed the measurement in 1944 Usu lava dome. We confirmed a bulbous shape measuring approx. 300 m in diameter and narrowing downwards. The result obtained is consistent with the model deduced from the pseudo growth curves (see the talk by Yokoyama) [1-2]. The diameter of the uppermost part of the conduit is estimated at 100±15 m at an elevation of 260 m a.s.l. and 50±15 m at an elevation of 217 m a.s.l., demonstrating a resolution that is significantly better than that typically achieved with seismic tomography based on picks of first arrival times from earthquakes or artificial sources.

References

[1] Yokoyama, I. (2002) Proc. Jpn. Acad., Ser. B 78, 6-11.

[2] Yokoyama, I. (2004) Ann. Geophys. 47, 1811-1825.