Pyrrotite oxidation as a proxy for air entrainment in eruption columns

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Entrainment of air by turbulent mixing into eruption columns is a primary control of explosive eruption styles. Pyrrhotite (Po; $Fe_{1-x}S$) in erupted materials is oxidized to form magnetite (Mt) and hematite (Hm) at the oxygen fugacity (fO_2) on the Earth's surface and at magmatic temperature. Degree of Po breakdown has been proposed as a proxy for magma oxidation and cooling by entrained air through examination of the Plinian pumice and lavas from the 1914 eruption at Sakurajima volcano (VEI4). To verify and further investigate the potential use of Po oxidation for estimating eruption intensities from pyroclasts, we have examined the pumice clasts from three andesitic explosive eruptions with similar magmatic temperature and different eruption intensity: the 1783 Plinian eruption of the Asama volcano (VEI4), the 2011 sub-Plinian eruption of the Shinmoedake volcano (VEI2) and the 2010 Vulcanian explosion of the Sakurajima volcano (VEI1).
Mineral phases of magmatic sulfide and occurrence of pseudomorph (Mt and Hm) are different among the three eruption samples. Po is observed in the groundmass of the pumice from the Asama 1783 eruption and the Sakurajima 2010 eruption, whereas the sulfide in the Shinmoedake 2011 groundmass is intermediate solid solution (iss; $Cu_{1-x}Fe_{2+y}S_{2-z}$). Po is sometimes replaced to form pseudomorph, while iss shows no replacement. The porous texture of the Po pseudomorph, which indicates a reaction of Po with air, is similar to that observed for the oxidation product having columnar microstructure reported in the pumice from the Sakurajima 1914 eruption (Matsumoto and Nakamura, 2017). Approximately half of the Po grains are partly or entirely replaced by the pseudomorph in the Asama 1783 pumice, as observed in the Sakurajima 1914 samples. On the other hand, proportion of the pseudomorphic Po grains is less than 20% in the Sakurajima 2010 pumice. This difference indicates that the Asama 1783 pumice, together with the Sakurajima 1914 pumice, has been more efficiently oxidized than the Sakurajima 2010 pumice. The preservation of iss in the Shinmoedake 2011 pumice is probably due to the difference in oxidation mechanism between iss and Po. The efficient oxidation of Po during the two Plinian eruptions (i.e., the Asama 1783 and the Sakurajima 1914 eruptions) can be attributed to the longer duration in which temperature of pumice were kept high in the eruption columns than that in the Vulcanian column. These results underscore the potential use of Po oxidation for the purpose of constraining the temperature and fO_2 of eruption columns that reflect eruption intensity of explosive eruptions.

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