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Factors controlling sulfur concentrations in volcanic apatite

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ABSTRACT

Apatite crystals from two types of samples were analyzed by electron microprobe for 15 major and trace elements: (1) apatite in H_2O- and S-saturated experimental charges of the 1982 El Chichón trachyandesite and (2) apatite in volcanic rocks erupted from 20 volcanoes. The SO_3 contents of the experimental apatite increase with increasing oxygen fugacity (f_{O_2}), from ≤ 0.04 wt% in reduced charges buffered by fayalite-magnetite-quartz (FMQ), to 1.0–2.6 wt% in oxidized charges buffered by manganosite-hausmanite (MNH) or magnetite-hematite (MTH). The SO_3 contents of MNH- and MTH-buffered apatite also generally increase with increasing pressure from 2 to 4 kbar and decreasing temperature from 950 to 800 °C. The partition coefficient for SO_3 between apatite and oxidized melt increases with decreasing temperature but appears to be independent of pressure.

Apatites in volcanic rocks show a wide range of SO_3 contents (<0.04 to 0.63 wt%). Our sample set includes one group known to contain primary anhydrite and a second group inferred to have been free of primary anhydrite. No systematic differences in apatite S contents are observed between these two groups. Our study was initiated to define the factors controlling S contents in apatite and to evaluate the hypothesis that high S contents in apatite could be characteristic of S-rich anhydrite-bearing magmas such as those erupted from El Chichón in 1982 and Pinatubo in 1991. This hypothesis is shown to be invalid, probably chiefly a consequence of the slow intra-crystalline diffusion that limits re-equilibration between early formed apatite and the evolving silicate melt. Contributing factors include early crystallization of most apatite over a relatively small temperature interval, common late-stage magmatic enrichment of S, progressive oxidation during magmatic evolution, and strong controls on S contents in apatite exerted by f_{O_2}, temperature, and pressure.