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The fate of Venusian halogens

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Venus's geologic evolution is poorly understood, particularly regarding the fate of halogens such as chlorine and fluorine. Despite evidence for extensive mantle degassing and widespread volcanism, the atmosphere of Venus contains only trace HF and HCl, and the surface shows no signs of salt deposits. These observations raise fundamental questions about halogen solubility, degassing behaviour, and long-term sequestration in Venusian magmatic systems.

To quantify fluorine cycling between mantle, crust, and atmosphere, we conducted solubility experiments in silicate melts at 0.5–1.5 GPa and 1200–1400°C across a range of oxygen fugacities and melt compositions representative of Venus- and Earth-like systems. We find that fluorine is highly soluble in experimental melts, with no clear evidence of saturation under most experimental conditions. This apparently inexhaustible solubility suggests fluorine will remain strongly melt-compatible during mantle melting and should be efficiently retained in erupted lavas rather than degassing into the atmosphere. For chlorine, we modelled the production of alkaline, low-degree partial melts on Venus and conducted experiments at 1 atmosphere to quantify Cl partitioning between alkaline melts and halide-bearing minerals, particularly sodalite. Chlorine is highly soluble in alkali-rich melts and is efficiently sequestered upon crystallization into sodalite and apatite. Our results indicate that <1 km of phonolitic overplating could sequester an Earth-like surface chlorine budget, providing a viable long-term reservoir for chlorine in Venus's crust.

Dissolved fluorine and chlorine significantly reduce the viscosity, density, and liquidus temperature of silicate melts. Enrichment of these halogens in the Venusian crust would therefore enhance melt mobility, promote prolonged magma storage and differentiation, and increase eruptive efficiency. Such effects may have played a key role in shaping the rheology, flow behaviour, and the vast areal extent of Venus's global volcanic plains. Together, these experimental constraints provide a new framework for evaluating halogen cycling on Venus and its role in shaping the planet's magmatic and crustal evolution.