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The Fate of Venusian Chlorine

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Venus' geological and atmospheric evolution remains enigmatic, particularly regarding the fate of chlorine. Chlorine is highly incompatible and hydrophilic, and efficient mantle outgassing on Earth has concentrated terrestrial chlorine in surface reservoirs, notably the oceans. Venus, with its thick, oxidized atmosphere and vast volcanic plains, likely experienced similar early volatile transport and magmatic degassing. Nevertheless, the Venusian atmosphere today contains only trace levels of HCl, whilst extensive NaCl deposits appear absent from the surface.

We propose that a substantial chlorine budget was similarly outgassed from the Venusian mantle but was subsequently sequestered in crustal minerals as surface temperatures rose. Recent studies have demonstrated chlorine to be highly soluble in silicate melts, and under Venusian conditions its incorporation into alkali-rich, low-degree melts will be efficient. Upon cooling, these Cl-rich melts may crystallize halide-bearing minerals such as sodalite and apatite, which act as mineralogical hosts for Venusian chlorine. *In-situ* compositional data and extensive rifting suggest the generation of alkaline volcanics capable of crystallizing sodalite are widespread on Venus, and hence atmospheric Cl concentrations may be buffered by surface mineralogy.

To test this hypothesis, we conducted sealed Si-tube experiments to determine chlorine partitioning between sodalite and alkaline silicate melts representative of the putative Venusian surface. Our results suggest that alkaline partial melts and their differentiates are an efficient petrological ‘sink’ for chlorine, with surface over-plating of 1 to 3.75 km of phonolitic or trachytic material capable of sequestering an Earth-like surface chlorine budget. When compared to past volcanic flux estimates, these findings support a model whereby chlorine is efficiently removed from the Venusian surface and sequestered back into its crust. This mechanism offers insights into Venus’ volatile evolution and its divergence from terrestrial geochemical pathways, and may explain the apparently smooth, low viscosity nature of Venus’ volcanic plains.