

Simulation of basaltic glass alteration by hot magmatic gas

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Basalts are ubiquitous in volcanic environments on the terrestrial planets and some moons (e.g., Io, the Moon) and are commonly associated with persistent SO₂-rich magmatic degassing. There is ample opportunity for high temperature reactions between SO₂ and basalt glasses to produce coatings of sulfate and oxides. These reactions also modify the underlying glass that loses Ca, Mg, Na, Fe, Ti, resulting in changes to the glass structure and crystallization.

We use nanoscale secondary ion mass spectrometry (CAMECA NanoSIMS 50L) to map cross-sections through tholeiitic basalt glasses which were reacted with SO₂ at 700 °C for 24 h. The samples were analyzed for ²³Na, ²⁴Mg, ²⁷Al, ²⁸Si, ⁴⁰Ca, ⁴⁸Ti and ⁵⁶Fe in multicollector mode over a field of view of 50 μm² and a spot size of 100 nm.

Modified basaltic glasses are found within 10 μm of the surface and contain crystalline spherulites and needles including SiO₂ and Fe-Na-rich spherulites surrounded by Mg-rich silicates. The latter phases are likely pyroxenes. The alteration is zoned with a Si-rich layer within 2 μm of the surface, followed by a zone enriched in Fe and Na. Deeper in the glass we observe a slight enrichment of Mg.

The alteration is a consequence of the diffusive loss of Ca, Mg and Na to sulfate coatings and both the diffusion of Fe and Fe oxidation. The outward diffusion of Ca, Mg, Na and Fe is accompanied by the counterdiffusion of electron holes which oxidize the glass [1]. As Fe is oxidized to Fe³⁺ it changes its structural role in the glass network and becomes tetrahedrally coordinated. This requires charge compensation by alkali or alkaline earth elements. We attribute the correlation of Fe and Na in the altered glass to this oxidation and charge compensation by Na.

The altered glasses correspond chemically and mineralogically to basalts with high concentrations of Al-rich minerals [2-4]. We hypothesize that these basaltic protoliths were exposed to SO_{2(g)} at high temperature for prolonged periods of time.

[1] Cooper *et al.* (1996) *GCA* **60**, 3253-3265. [2] MacRae, N.D. (1974) *Can J Earth Sci*, **11**, 246-253. [3] Del Moro *et al.* (2011) *J. Petrol.* **52**, 541-564. [4] Sutherland, F.L. (1996) *J Geol Soc Aust*, **43**, 323-343.