

Apatite as a tool to quantify the volatile budget of crystallising plutonic rocks

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Volatile elements play a key role in the differentiation of magmas by controlling their chemical and physical properties. Volatile concentrations within the melt are commonly inferred from glassy melt inclusions which, however, may have experienced post-entrapment modification. Alternatively, hydrous minerals such as apatite represent an important archive to reconstruct the volatile history of their parental melt. Here we investigate the volatile evolution of differentiating magmas within the upper crustal Western Adamello tonalite (WAT) and the Listino Ring complex (LRC), both located in the Adamello batholith (Italy). The WAT is a tonalitic body displaying *in situ* crystal-melt segregations. The LRC exhibits a concentric structure mainly composed of tonalite, granodiorite and granitic dikes. Apatite is ubiquitous in these lithologies and exhibits a compositional trend ranging from intermediate F (≤ 1.5 wt.%) to high F (2.5-3.0 wt.%) contents. Preliminary analyses by secondary ion mass spectrometry reveal that LRC apatite contains 0.59-0.90 wt.% H₂O, 200-480 ppm S, and 40-700 ppm CO₂ with the highest values probably reflecting inherited crystals. Apatite rims display lower H₂O contents likely reflecting H₂O loss along fast-diffusing pathways. By combining existing apatite partition coefficients with mineral geothermometers and hygrometers, we find that the calculated melts from both locations are fluid saturated (~5.5 wt.% H₂O) upon the onset of apatite crystallisation (~925°C) and exhibit a trend of decreasing Cl (WAT: 1900-100 ppm; LRC: 1000-200 ppm) at roughly constant F (WAT: 400-800 ppm; LRC: 300-600 ppm) concentrations with differentiation. We interpret this evolution as the result of the incorporation of Cl into an exsolving fluid, whereas F is incompatible in the fluid phase and partitions equally between crystals and melt. Simple modelling of such a continuous exsolution process using published distribution coefficients and mass balance suggests that, at 85% crystallisation, 60-80% H₂O has exsolved while at least 75% of the bulk Cl is partitioned into the fluid phase. Fluid exsolution, recorded by miarolitic cavities, is potentially linked to compaction and shearing which might connect the exsolved products and eventually form fluid pathways. In this scenario, continuous degassing of a volumetric fluid could enhance the crystal-melt segregation process observed within the Western Adamello tonalite.