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Volatiles in excess in crystallising magmas: Consequences of crystal mush degassing, outgassing, and pressurisation in the Earth's crust

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Water and carbon dioxide are the most abundant volatile species in the Earth's crust. The finite solubility of volatiles in felsic magmas at shallow depth drives the formation of exsolved gas bubbles during magma transport and emplacement in the crust. While existing solubility models predict the amounts of carbon dioxide and water dissolved in the silicate melt phase, very little is known about the minimum excess gas fraction required for the release of volatiles from crystallising magmas and the amount of residual gas trapped in such magmas. Here we present new experimental results on synthesised, volatile-saturated, crystal-bearing (crystal fractions of 0.3 to 0.7 on gas bubble-free basis) haplogranitic systems under high-temperature (1100 °C) and -pressure conditions (1240 to 2070 bar) within large volume (∼850 cm3) stainless-steel capsules. The degree of volatile saturation was modulated by increasing the amount of carbon dioxide, from 0 to 5 wt%. Microstructural investigations reveal how crystallinity controls the threshold of gas volume fraction required for outgassing: a) carbon-dioxide-free, water-saturated systems achieve gas permeability starting from a crystal fraction of 0.6, with not-outgassed gas fractions up to 0.23 at a crystal fraction of 0.7; b) carbon dioxide-saturated systems attain gas permeability at crystal fractions as low as 0.5 and the residual trapped gas fraction decreases to 0.1 at the equivalent crystal fraction of 0.7. These results testify that the increase of volume of fluids in excess facilitates early release of gas from crystal-rich systems and diminishes the total volume of gas trapped with increasing crystal fraction at depth. This implies that crystallising magmas with excess gas may likely contribute to passive degassing and not erupt violently as gas-rich systems.