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Volatile Release from Crustal-Xenolith during Subvolcanic Magma Transport

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Magma-crust interaction in magma reservoirs and conduits is a crucial process during magma evolution and ascent. This interaction is recorded by crustal xenoliths that frequently show partial melting, inflation and disintegration textures. Frothy xenoliths are widespread in volcanic deposits from all types of geological settings and indicate crustal gas liberation. To unravel the observed phenomena of frothy xenolith formation we experimentally simulated the behaviour of crustal lithologies in volcanic conduits. We subjected various sandstones to elevated temperature (from 810 to 916 °C) and pressure (from 100 MPa to 160 MPa) in closed-system autoclaves. Experimental conditions were held constant for 24h up to 5 days, then controlled decompression simulated xenolith ascent. Pressure release was a function of temperature decline in our setup. Temperature lapse rate proceeded exponentially; the first 20 minutes experienced an enhanced decline of 24-20°C/min, whereas the following 6-8 hours had a slow cooling rate towards room temperature.

Experimental products closely reproduced the textures of natural frothy xenoliths and define an evolutionary sequence from partial melting to gas exsolution and bubble nucleation that eventually leads to the development of three-dimensional bubble networks. The lithology proved decisive for degassing behaviour and ensuing bubble nucleation during decompression. Increased volatile content (chiefly water) and amount of relict crystals in the partial melt promote bubble nucleation and subsequent bubble coalescence to form interconnected bubble networks. This, in turn, enables efficient gas liberation. Our results attest to significant potential of even very common crustal rock types to liberate volatiles and develop interconnected bubble networks upon heating and decompression. Volatile input from xenoliths may therefore considerably affect explosive eruptive behaviour. Moreover, H2O, CO2 and CH4 are severe greenhouse gases and their input into the atmosphere from crustal xenoliths and magma chamber wall rocks may have implications for Earth's past and present climate. Our experiments offer a detailed mechanism of how such crustal volatile liberation is accomplished.