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Experimental simulation of crustal volatile release in magmatic conduits

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Magma-crust interaction in magma reservoirs and conduits is a significant process during magma evolution and ascent. This interaction is recorded by crustal xenoliths that frequently show partial melting, inflation and disintegration textures by internal degassing. Frothy xenoliths are widespread in volcanic deposits in all tectonic regimes, and they indicate crustal gas liberation into magmatic systems. To unravel the observed phenomena of frothy xenolith formation, we experimentally simulated the behaviour of crustal lithologies in volcanic conduits. A high pressure - high temperature experimental series was conducted on various sedimentary lithologies, which were subjected to varying magmatic conditions in closed-system autoclave vessels. The experimental series was conducted with a maximum temperature of 916°C and a maximum pressure of 160 MPa, and samples were held at constant PT-conditions for 24 hours up to 5 days at the longest. Subsequent cooling and decompression simulated xenolith ascent, pressure release was from 160 MPa (at the most) down to atmospheric pressure. Decompression was a function of temperature decline in our set-up, both following an exponential path. The mean rate during the first 10 minutes following the onset of cooling was 28.2°C/min and 4.8 MPa/min, whereas the mean temperature- and decompression lapse rate during subsequent 10 minutes were 16°C/min and 2.7 MPa/min, respectivley. Eventually, room temperature was reached after approximately 5.5 hours of cooling. The experimental products have been analysed for internal textures by synchrotron X-ray μ-CT at a resolution of 3.4 – 9 microns/pixel. This method permits visualisation and quantification of internal vesicle volumes, -networks and -connectivity in 3D.

Experimental products closely reproduced textures of natural frothy xenoliths in 3D 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. Experimental P-T-t conditions and especially rock lithology proved decisive for degassing behaviour and ensuing bubble nucleation during decompression. Progressive bubble nucleation leads to subsequent bubble coalescence to form interconnected bubble networks. This, in turn, enables efficient gas liberation and release. Our results attest to significant potential of even very common crustal rock types to release volatiles and develop interconnected bubble networks upon heating and decompression in magmatic systems. Crustal volatile input from xenoliths affects magma rheology and may drive magmas to sudden explosive eruptions. Our experiments offer insight into the mechanism of how such crustal volatile liberation is accomplished.