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The ascent of water-rich magma and decompression heating: A thermodynamic analysis

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ABSTRACT

The ascent of hydrous, silica-rich magmas from the lower crust drives volcanic eruptions, builds the upper crust, and concentrates metals such as Cu, Au, and Mo into ore deposits. Owing to the negative slope of the melting curve for granitic materials in the presence of water, it has long been assumed that water-saturated magmas move into the subsolidus field and freeze upon ascent; therefore, for magma to rise it must be water-undersaturated at a temperature well above the solidus. This assumption ignores the considerable energy released by crystallization. Here I show that if magma ascent is treated as an adiabatic, reversible process, then water-saturated magma can rise to the surface, following the solidus to shallow depth and higher temperature as it undergoes modest crystallization and vapor exsolution. Decompression heating is an alternative to magma recharge for explaining pre-eruptive reheating seen in many volcanic systems and accounts for paradoxical growth of quartz during a heating event. The viscosity increase that accompanies vapor exsolution as magma rises to shallow depth explains why silicic magmas tend to stop in the upper crust rather than erupting, producing the observed compositional dichotomy between plutonic and volcanic rocks.

Keywords: Thermodynamics, magma, decompression, adiabatic, granite, rhyolite