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Making rhyolite in a basalt crucible

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Iceland has long attracted the attention of those concerned with the origin of rhyolitic magmas and indeed of granitic continental crust, because it presents no alternative for such magmas other than deriving them from a basaltic source. Hydrothermally altered basalt has been identified as the progenitor. The fact that rhyolite erupts as pure liquid requires a process of melt-crustal separation that is highly efficient despite the high viscosity of rhyolite melt.

Volcanoes in Iceland are foci of basaltic magma injection along the divergent plate boundary. Repeated injection produces remelting, digestion, and sometimes expulsion or lateral withdrawal of material resulting in a caldera, a "crucible" holding down-dropped and interlayered lava flows, tephras, and injected sills. Once melting of this charge begins, a great deal of heat is absorbed in the phase change. Just 1% change in crystallinity per degree gives a melt-present body an effective heat capacity >5 times the subsolidus case. Temperature is thus buffered at the solidus and melt composition at rhyolite.

Basalt inputs are episodic ("fires") so likely the resulting generation of rhyolite by melting is too. If frequent enough to offset cooling between events, rhyolite melt extractions will accumulate as a rhyolite magma reservoir rather than as discrete crystallized sills. Evidently, such magma bodies can survive multiple firings without themselves erupting, as the 1875 eruption of Askja Caldera of 0.3 km3 of rhyolite equilibrated at 2-km depth without previous leakage over a ten-millennium period and the surprise discovery of rhyolite magma at 2-km depth in Krafla suggest.

Water is required for melting; otherwise melting cannot begin at a temperature lower than that of the heat source. Because the solubility of water in melt is pressure-dependent and almost zero at surface pressure, there must be a minimum depth at which basalt-induced melting can occur and a rhyolite reservoir sustained. In practice, the storage limit is likely near 2-km depth at which IDDP-1 and other Krafla boreholes encountered rhyolite melt. Rearrangement of components within the crucible during brewing produces little in terms of a gravity or deformation signals, hence the surprise in finding newly intruded magma.

Below 2 km much of the charge in the crucible is near the basalt solidus, so that pockets, sills, and chambers of near-liquidus rhyolite magma will all be close to thermal and chemical equilibrium. Heat is advected upwards from the mantle first by basalt to the crucible, then by rhyolite magma within the crucible, then by hydrothermal fluid to the surface. A major portion of the thermal energy is stored as latent heat of crystallization of rhyolite magma. Such a view challenges some basic tenets of volcano hazard assessment and geothermal energy. The Krafla Magma Drilling Project of the International Continental Scientific Drilling Program will provide a critical test in 2017 by coring from subsolidus granite to liquidus rhyolite, wherein the transitions of heat advection by hydrothermal fluid, to heat conduction, to heat advection by rhyolite magma must occur.