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Hypersolidus geothermal energy from the moving freeze-fracture-flow boundary

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Rhyolitic magmas at low pressure undergo much of their crystallization over a small temperature interval just above the solidus. This hypersolidus material has a high energy density and effective heat capacity because of stored heat of crystallization, yet may sustain fractures and therefore admit heat exchange with fluids because of its interlocking crystal framework.

Rhyolitic magmas emplaced near the liquidus should at first cool rapidly, owing to internal convection, modest crystallization with declining temperature, and extreme temperature gradients at their boundaries. However, once the solidus is approached the rapid rise in effective heat capacity should result in low temperature gradients and rates of heat flow within the bodies. They are suspended for a time in the hypersolidus state. Prodigious quantities of heat can be released from these thermal masses by hydrothermal systems, natural or perhaps stimulated, fracturing their way inward from the margins. The fracture front drives the solidus isotherm ahead of it. Heat of crystallization in front of the advancing solidus is transferred across the thin, moving boundary zone to the external fluid, which advects it away. Once the material is below (outboard of) the solidus, it behaves as normal rock and cools rapidly, having a heat capacity only about 20% that of water. Variations on this theme were published by Lister (1974) for mid-ocean ridges, Hardee (1980) for lava lakes, and Bjornsson et al (1982) for Grimsvotn and Heimaey, who cited possible geothermal energy exploitiation.

This scenario is consistent with a number of observations:
1. The geophysical rarity of imaging mostly liquid magma in the shallow crust, despite common petrologic evidence that silicic magma has undergone shallow storage.
2. More common imaging of "partial melt" volumes, whose inferred properties suggest some, but not dominant proportion of melt.
3. Evidence that pure-melt rhyolitic eruptions may have drained relatively shallow hypersolidus plutons.
4. Downward propagating thin conductive boundary zone observed in repeated coring of Kilauea Iki lava lake, Hawaii
5. Record enthalpy flow and temperature during flow-testing of Iceland Deep Drilling Project (IDDP)-1 in Krafla Caldera by Landsvirkjun Co. Production came from a 2.1-km-deep 500oC "magma" contact zone, from the vicinity of which fresh rhyolite glass-bearing felsite and crystal-poor rhyolite glass fragments were recovered.

The hypothesis of a moving freeze-fracture-flow boundary raises the possibility of ultra-high-temperature, natural or engineered geothermal systems in volcanic areas. We believe that this prospect, as well as the benefit to understanding volcanic hazards at restless calderas, gives merit to further exploration of the hypersolidus regime beneath Krafla Caldera.