Thermal models of incremental pluton emplacement

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Thermal modeling of pluton assembly via incremental addition of sheet-like intrusions yield the following general observations: 1) partial melting of wall rock is absent early in the history, but becomes more prevalent through time, 2) an amorphous zone of interconnected melt is formed independent of intrusion geometry, 3) melt percentages averaged over the assembled body are low, 4) temperatures cycle near the granitic solidus for protracted periods of time. In the models, early intrusions are emplaced into a cool geothermal gradient (relative to later intrusions) and quickly cool below the solidus. Later intrusions intrude into progressively hotter environments and remain at elevated temperature for longer times. We suggest that this progression from a rapidly to slowly cooled system may erase contacts between increments, promote megacryst growth, and yield a progression from simple to complex zircon systematics, and protracted cooling. Emplacement as small increments does not develop a zone of voluminous interconnected melt, instead the active magma body is only a small portion of the total volume intruded. Models are consistent with geophysical data from active magmatic zones that fail to image regions likely to contain more than 20% melt. Incremental emplacement precludes large-scale pluton convection, and as such, inhibits large-scale internal differentiation by magmatic processes. The incremental emplacement model may require a re-evaluation of connections between volcanism and plutonism. If plutons form from small episodic sheet-like intrusions and only develop minor zones of interconnected melt, the idea that plutons are sub-volcanic crystallized remnants of large volume ignimbrite eruptions may be problematic.

Near-equilibrium investigations of quartz and forsterite dissolution

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While many kinetic studies have focused on dissolution and precipitation reactions under far from equilibrium conditions, few studies have focused on the near equilibrium region. Recent studies of boehmite dissolution conducted by Bénézeth and coworkers [1] have used continuous pH monitoring at high temperatures to follow a reaction as it approaches equilibrium. We have used similar techniques to better understand the near equilibrium behavior of quartz and forsterite. Experiments were conducted at undersaturated and supersaturated conditions to look at both dissolution and precipitation kinetics. While dissolution was expected to follow a simple first order kinetic model, quartz studies at pH 8-10 and 125-200°C indicate a more complex dissolution mechanism not easily normalized by solution chemistry. Therefore, a more complex analysis of dissolution data has been undertaken. Nucleation theory was initially used to explain crystal growth but Dove [2] extended it to explain the kinetics of silicate minerals including quartz. Unlike quartz, understanding forsterite dissolution is complicated by incongruent magnesium-to-silicon release, leached layer formation, and the precipitation of a secondary magnesium-rich phase. Forsterite dissolution kinetics in acidic solutions cannot be followed with respect to silicon in the same manner as quartz since only [Mg^{2+}] can be extrapolated from pH through charge balance. To identify a possible secondary phase and probe leached layer formation, solid-state nuclear magnetic resonance (NMR) has been used in conjuction with additional analytical techniques including wet chemical analysis, transmission electron microscopy, and x-ray and neutron diffraction. Here we present our studies of near equilibrium kinetics for quartz, as well as evidence of precipitate formation during forsterite dissolution.

[1] Benezeth, Palmer, & Wesolowski. (2007, submitted) *Geochemical et. Cosmochimica Acta.* [2] Dove, Han & Yoreo. *Proceedings of the National Academy of Sciences* **102**, 15357-15362.