

Core formation in the Earth and the terrestrial planets

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Accretion of the terrestrial planets occurred through a series of impacts/mergers with smaller differentiated embryos and planetesimals (e.g. [1]). In addition to adding Fe metal to proto-planets, impacting bodies provide sufficient energy to cause large scale melting, the establishment of deep magma oceans and therefore episodes of metal-silicate segregation. In our recent model of multistage core formation [2], collisions result in an impactor's core partially or fully equilibrating in a magma ocean before merging with the planet's proto-core. Compositions of metal and silicate that result from the equilibration process are determined from the bulk composition by a novel approach involving mass balance combined with element partitioning. In the case of the Earth, model parameters (e.g. metal-silicate equilibration pressures) are determined by a least squares regression based on constraints provided by the concentrations of major and trace elements in the Earth's mantle. Results show that accretion of the Earth was heterogeneous: early accreting material was highly-reduced and volatile-poor and later accreted material was more oxidized and volatile-rich. This is consistent with dynamical simulations which suggest that late-accreting material originates from greater heliocentric distances and should thus be more volatile rich [1]. Oxygen fugacity and the FeO content of the mantle both increase during accretion due to (a) the dissolution of Si into the core by a reaction that releases oxygen and (b) the late addition of oxidized material. In contrast to early models of heterogeneous accretion, equilibration at pressures up to 60-80 GPa and a significant degree of disequilibrium both play a critical role.

The model is currently being integrated with N-body accretion simulations [1] in order to investigate the chemical evolution of all the terrestrial planets simultaneously. Some simulations suggest an increase in mantle FeO contents (e.g. from 4 to 14 wt%) and a decrease in mantle Mg/Si ratios and core mass fractions as heliocentric distance increases from 0.5 to 2 AU [3]. Finally, the model is used to investigate the causes of ¹⁸²W anomalies in planetary mantles.

[1] O'Brien *et al.* (2006) *Icarus* **184**, 39–58. [2] Rubie *et al.* (2011) *EPSL* **301**, 31–42. [3] Rubie *et al.* (2011) *42nd LPSC*, Abstract #1061.

Do erupted mafic lavas accurately reflect mantle magmatic timescales?

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Mantle melting and melt transport encompass a range of processes that vary in duration, magnitude and length scale, and depend upon variables such as tectonic setting, volcano maturity, volcano spacing, and mantle physical characteristics (e.g. thermal state, composition, lithology, upwelling rate). Multiple compositional attributes of mantle derived magmas provide information on melting processes and conditions. The U-series nuclides are nearly unique in their ability to provide information about rates of such processes because chemical fractionation creates radioactive disequilibria between decay chain nuclides, which then decay away on characteristic timescales once fractionation ceases. Some surprising results from this literature suggest that the duration of melting is highly variable over short temporal and spatial scales in the mantle, and that melt transport is generally quite fast. But how trustworthy are these interpretations? Early studies were content to use the presence or absence of radioactive disequilibria in magmas to crudely estimate the duration of magma generation and transport in the mantle. Yet since the 1970s, development of much more sophisticated melting models and of analytical methods for nuclide activity measurements with 100-fold precision improvements have led to more specified time scale assessments in the U-series literature. Despite these refinements, the geological errors introduced by the melting and melt transport processes in the mantle place severe and often underestimated limits on our ability to tell time with these tracers in erupted magmas. Situations such as multiple melting lithologies, magma mixing, fluid-addition (at convergent margins) and reactive transport create a large amount of non-uniqueness to the way U-series data sets can be interpreted. Add crustal/magma chamber processes to this list and the challenge of deriving a unique temporal solution to the duration of magmagenesis and transport using a combined U-series, major/trace element and radiogenic isotope data set is nearly insurmountable. Nevertheless, results from U-series studies have much to tell us about magmatic timescales so long as data are not over-interpreted or modeled with a false sense of precision to the parameterization. This presentation will discuss the current state of the art and successful strategies for limiting the uncertainty of timescale assessments from magma chemistry, and present examples where results are generally consistent with independent geological and geophysical observations.