

Accretion and chemical evolution of the terrestrial planets

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Classical dynamical models of planetary accretion have been successful in reproducing the general characteristics of the terrestrial planets of the solar system [1]. However, they have been less successful in reproducing the small mass of the outermost terrestrial planet, Mars, which appears to require a strong depletion of mass beyond ~1 AU [2]. The recent "Grand Tack" model, based on the early inward and then outward migration of Jupiter and Saturn, provides a solution to this problem [3]. We are using a geochemical approach to test the validity of the Grand Tack and other accretion models. Accretion occurs through impacts between growing planets and smaller bodies. Each impact delivers energy (magma ocean formation) and metal and thus an episode of core formation. The chemical evolution of the mantles and cores of growing bodies is modeled based on the bulk composition of the accreting material combined with a mass balance/element partitioning approach [4]. The main constraint is the composition of Earth's primitive mantle and the FeO contents of the mantles of Mercury and Mars (3-4 wt% and ~18 wt% respectively). Bulk composition is defined in terms of solar system (CI) relative abundances of the non-volatile elements with an oxygen content that determines the metal-silicate ratio. Accretion simulations that produce synthetic planets closely resembling those of the solar system are tested. Model parameters (metal-silicate equilibration pressure, starting compositions of embryos and planetesimals) are refined by a least squares regression in order to produce a synthetic Earth that matches Earth's mantle chemistry.

The mantle chemistries of Earth and Mars can be reproduced well when the compositions of bodies that originate in the inner solar system (<~1.6 AU) are highly reduced and those forming further out are more oxidized. However, the current Grand Tack simulations result in an inner planet ("Mercury") that accretes too much material from the outer regions of the planetesimal disk and is thus too massive and too oxidized.

[1] Raymond *et al.* (2009) *Icarus* **203**, 644-662. [2] Hansen (2009) *ApJ* **703**, 1131-1140. [3] Walsh *et al.* (2011) *Nature* **475**, 206-209. [4] Rubie *et al.* (2011) *EPSL* **301**, 31-42.

Timescale and petrogenesis of 2009 and older W. Mata boninite magmas

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The first active boninite eruption was observed by ROV in 2009 at West Mata, a small, submarine rear-arc volcano in the NE Lau Basin. Globally, boninite is a rarely erupted, arc-fluid-enriched magma. We examine rates and processes of W. Mata boninite generation, ascent, and storage, with implications for arc magma and volatile source-to-surface transport. A number of characteristics indicate magma differentiation during rapid ascent from the mantle within a poorly developed magma storage system: large, very short-lived ²¹⁰Pb-²²⁶Ra disequilibria of 20-40% in glasses, Ni diffusion profiles in olivine, and a complex range of mineral textures, including rapid crystal growth and magma reactions. Geochemical and petrological studies of fresh-appearing lavas collected in 2009 and on two subsequent cruises indicate limited lithological variability throughout the volcano. W. Mata erupts a highly vesicular, crystal-rich (ca 40%) magma, having opx>>cpx>ol and a continuum of mineral compositions (e.g., opx and ol Mg# 92-82). Whole rocks (WR) are boninite *sensu strictu* but have more evolved coexisting glass (WR and glass have MgO=11-15 and 3.5-6.5 wt%, SiO₂=54-57 and 55-58 wt%, TiO₂=0.3-0.45 and 0.4-0.6 wt%). Older, non-summit lavas define distinct but similar major element trends, with variable radiogenic isotope and trace element ratios. Slab influence is indicated by glasses with extreme ²³⁸U-²³⁰Th disequilibria (40% excess U), high Fe oxidation (Fe³⁺/ΣFe=0.2-0.25), strong fluid-mobile element enrichments (Ba and U to 160 ppm and 0.4 ppm), high Cl/K, plus up to 3 wt% H₂O in melt inclusions.