Accretion, Chemical Evolution, and Differentiation of the Terrestrial Planets

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Terrestrial planets grow by repeated collisions in a swarm of ~10 km-scale planetesimals and lunar- to Mars-mass embryos. N-body modeling of this process has successfully reproduced many aspects of the Solar System's terrestrial planets [eg. 1,2], although reconciling all of the available evidence is still an outstanding problem [3]. We will give an overview of the current state-of-the-art in the modeling of terrestrial planet formation, with a specific focus on its implications for the chemical evolution and differentiation of terrestrial planets.

Significant radial mixing can occur during terrestrial planet formation, delivering volatile elements into the terrestrial planet region. Large impacts, which are common during the final stages of terrestrial planet formation, can lead to volatile loss. Recent work that combines N-body accretion simulations with a nebula condensation model finds that elements such as Na, P, and S are overabundant in simulated planets, but become much more consistent with Earth's abundances when a simple model of impact heating and volatile loss is included [4]. This may have important implications for the Earth's initial water budget.

Radiogenic and impact heating leads to melting and differentiation of the growing planets, with iron and siderophile elements separating from rocky material and segregating into the core. In addition, many of the large embryos impacting the planets are likely to be differentiated themselves. The Hf-W isotopic system provides a way to understand and date this process, but is subject to some uncertainties, namely the degree to which the cores of the impacting embryos are able to mix and equilibrate with the mantle of the growing planet [5]. Analyzing N-body accretion simulations to track the Hf-W isotopic evolution of the growing planets suggests that a significant degree of equilibration during impacts is necessary to match the Hf-W isotopic signatures of Earth [6]. Constraining Mars' differentiation history is more difficult, although it is clear that it differentiated before the Earth [7].

References: [1] Chambers (2001), *Icarus* **152**, 205. [2] O'Brien et al. (2006), *Icarus* **184**, 39. [3] Raymond et al. *Icarus*, submitted. [4] Bond (2008), Ph.D. Thesis, U. Arizona. [5] Rubie et al. (2003), *EPSL* **205**, 239. [6] Nimmo and Agnor (2006), *EPSL* **243**, 26. [7] Nimmo and Kleine (2007), Icarus **191**, 497.