

Dispersion and Chemical Equilibration of Planetesimal Cores in Accretionary Collisions

H. J. Melosh and J. Kendall, EAPS Department, Purdue University, West Lafayette IN 47907 USA. jmelosh@purdue.edu

The degree of chemical equilibration between iron in the cores of accreting planetesimals with the silicate mantles of growing planets has long been a source of interest and contention. Early attempts to explain the concentration of moderately siderophile elements in the Earth based on 1-bar partition coefficients between iron and silicate liquids predicted abundances that were far too low. Later, it was realized that the partition coefficients of these elements approached the observed values only at high pressure and temperature, deep within the mantle of the growing Earth. It is now understood that most of the planetesimals that accrete to form the Earth will have already differentiated large iron cores themselves, and it becomes problematic to understand how these large masses of iron, with their inventory of dissolved moderately siderophile elements, have time to chemically equilibrate with the silicate mantle of the growing planet. Rubie et al (2003) argued that the iron in these bodies would have to disperse into cm-size droplets deep within the Earth for equilibration to occur rapidly enough to impart the observed abundances of moderately siderophile elements to the Earth's mantle. It has been unclear how this could happen, given the large size of planetesimal cores during the later phases of accretion. Studies by Dahl and Stevenson (2007) and Deguen et al (2012) show that such dispersion occurs only for relatively small iron masses (ca. 10 km scale), starting from a condition in which the iron is localized in a compact mass at the top of a magma ocean. However, this initial state is highly unrealistic for an accreting planetesimal, which typically impacts the growing planet at velocities at least as large as the escape velocity, 8-11 km/sec near the end of accretion. We have investigated the initial fate of iron cores of planetesimals using an Eulerian hydrocode, iSALE, to demonstrate that the iron is widely dispersed during the impact, before the iron comes to rest and begins to sink. Moreover, if the growing Earth is not molten before the impact, the iron is initially dispersed in the transient melt pool created by the impact shock wave itself. The iron droplets must thus equilibrate as they sink to the bottom of the melt pool, gather there into a dense compact mass, and then sink together in a large mass to join the core of the growing Earth without further chemical equilibration. In this case, the bottom of the melt pool limits the maximum depth of chemical equilibration, hence only a few of the largest impact can have been responsible for establishing the moderately siderophile element abundances of the final Earth.