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Ceres evolution and present state

T. McCord (1), and C. Sotin (2)

(1) University of Hawaii, HIGP/SOEST, Honolulu HI, (2) University of Nantes, Lab. de Planet. et Geodyn., Nantes, France

mccordtb@aol.com; Fax: 5099963772

We have explored the possible evolution scenarios for Ceres from accretion to present day in order to understand this small planet and its sisters, Vesta and Pallus, and to help plan and execute the DAWN mission to Vesta and Ceres. We used a one-dimensional spherical model and assumptions based on current knowledge of Ceres and the history of solar system formation and we followed the approach used previously to study smaller possible parent bodies for carbonaceous chondrite meteorites. We start with a cold body composed of a uniform mixture of 74% silicates (density 3.44) and 26% water ice as indicated by Ceres' bulk density of about 2.1. Even if only long-lived radionuclide heating is assumed, the water ice in Ceres melts quickly, a water mantle forms, but the crust does not melt. The circulating warm water would alter the silicates, leading to carbonaceous chondrite-like compositions. As heat is lost by conduction through the frozen crust, which reaches a minimum thickness of about 10 km, water begins to freeze out at the base of the crust. Solid state convection begins at about a crust thickness of 20 km and is continuous when the crust reaches a thickness of about 28 km, transporting more heat as well as perhaps material dissolved or entrained in the water below to or near the surface. Ceres' water layer eventually (mostly but perhaps not entirely) freezes, forming a layered density structure with perhaps some liquid water remaining today. We find that Ceres' existence and evolution depend critically on it containing water at formation and this depends strongly on the combination of when it accreted and the amount of ^{26}Al present in the pre-Ceres $\sim$1 km-sized objects. A slightly greater combination of more ^{26}Al and earlier accretion produces a dry Vesta-like object rather than a Ceres. Water may play a buffering effect in the temperature evolution of such bodies, Water and altered minerals could be entrained in the convecting ice, creating deposits near or on the surface, which might also

be distributed by impacts. Melting and freezing plus mineralization would lead to several dimensional changes over time, creating topographic features, zones of weakness and perhaps disruptions in the crust. Water volcanism is possible. Thus, measurements of present day compositional units and topographic features on Ceres' surface and its internal density structure, such as by the Discovery Program DAWN mission, will be of considerable help in constraining the nature of Ceres' history and that of its sister mini-planets, who helped form Earth and the other terrestrial planets.