Origins and Evolution of Ceres – Clues from Surface Chemistry

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The water in Earth's oceans may have been delivered by icy planetesimals that formed outside the water snow line. The terrestrial planets and their precursors formed closer in, from a volatile-depleted source. Heating by short-lived radionuclides such as ^{26}Al, injected into the protoplanetary disk by a supernova, drove igneous differentiation, resulting in the formation of planetesimals with an iron core, silicate mantle, and crust. Further out, heating diminished due to dilution of aluminum-bearing silicates by ice and/or the time scale for accretion, allowing the retention of volatiles. The main belt, which marks the transition between rocky and volatile-rich bodies, is a mass-depleted region that contains many small objects, most of which are collisional fragments of planetesimals. Some large main belt objects, such as Vesta and Ceres, the targets of the NASA Dawn mission, are nearly intact and thus preserve a record of early planet formation. Migration of the gas giants ("Grand tack" and "Nice" models) has been invoked to explain the mixture of rocky and icy bodies found in the main belt and the delivery of water-rich planetesimals to the inner solar system. Given its size, the dwarf planet Ceres is probably unlike most icy planetesimals. Analyses of data acquired by Dawn show that the surface of Ceres is rich in hydrogen in the form of water ice, hydrated minerals, and possibly organic matter. The ice-free regolith resembles the aqueously altered carbonaceous chondrites, thought to have formed on parent bodies smaller than Ceres near the main belt. Differences between Ceres' surface elemental composition and that of the primitive CI chondrites indicate Ceres experienced ice-rock fractionation or formed further from the Sun than the CI parent body. Composition data acquired by Dawn provide additional constraints on Ceres' origins, hydrothermal evolution, and present condition, putting Ceres in context with other ice-rich bodies.