PHYSICAL CHEMISTRY OF IMPACT-GENERATED FLUIDS AND BRIGHT SPOTS ON CERES

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The initial Dawn data reveal the strong impact crater topography, the lack of clear latitudinal changes in crater morphology, and the apparent absence of fluidized craters on Ceres. These observations are inconsistent with a subsurface water ice mantle and may indicate an undifferentiated internal structure consisted of hydrated and porous materials similar to CI, CM, or CR carbonaceous chondrites without abundant water ice [1]. The observed impact cratering could have affected ice-poor chondritic materials which have not been altered since accretion from aqueously altered planetesimals. The unusual Ceres' surface spectra and supposed surface composition [2] could reflect impact-driven mineralization and a large-scale homogenization in impact clouds [3].

The observed association of low-albedo features (bright spots) with craters implies impact-induced mobilization and accumulation of water and/or salts. We have considered dehydration of chondritic phyllosilicates and salts; melting of ground ices; formation of salt- and gas-bearing hydrothermal solutions through chemical interaction with rocks in a 17-component system with C, S, Cl, and rock-forming elements; migration of chemically evolving fluids through rocks in a temperature-pressure (*T-P*) field; precipitation of minerals; degassing of solutions; formation of brines and deposition of salts through low-*P* boiling; and a cold-trapping of water vapor in near-surface environments leading to formation of temporal ice-rich deposits, which may constitute the bright-spots.

The models show that the temperature of aqueous solutions may not exceed ~300 ^{o}C for craters with diameter < 100 km. The temperature is limited by water boiling, which can occur at the depth of 10 km if T > ~280 ^{o}C (at 2 km, T > ~190 ^{o}C). The formation of low-solubility H_2, CH_4, and N_2 through rock alteration causes degassing at greater depth then is allowed by the water-gas saturation conditions. Low-*P* boiling prevents delivery of even cold solutions to near-surface. Carbonates precipitate readily and inorganic C species are not abundant in fluids. With the exception of low-*T* solutions, sulfates are minor species owing to precipitation of low-solubility Ca sulfates and reduction to sulfides. Both static and flow water-rock interaction models lead to formation of NaCl-type solutions, which become brines upon low-*P* boiling, consistent with terrestrial models [e.g., 4]. Although a vigorous boiling may inject NaCl grains in vapor gets at depth, an ordinary cold trapping of water vapor could produce mostly pure ice deposits imbedded in fine-grained mineral dust at the near-surface. The observed vapor plumes at Ceres [5] could be related to insolation-dependent sublimation of temporal surface ice deposits formed through cold-trapping of crater vapors.

References: [1] Zolotov M. Yu. 2009. *Icarus* 204:183–193. [2] Rivkin, A. S. et al. 2011. *Space Sci. Rev*. 101:1–22. [3] Zolotov M. Yu. 2014. *Icarus* 228:13–26. [4] Sanford, W. E. *Geofluids* 5:185–201. [5] Küppers M. et al. *Nature* 505:525–527.