



DAWN'S GRAND FINALE: HIGH SPATIAL-RESOLUTION ELEMENTAL MEASUREMENTS REVEAL AN ANOMALY AT OCCATOR CRATER. T

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DAWN'S GRAND FINALE: HIGH SPATIAL-RESOLUTION ELEMENTAL MEASUREMENTS REVEAL AN ANOMALY AT OCCATOR CRATER. T. H. Prettyman¹, N. Yamashita¹, M. E. Landis¹, J. C. Castillo-Rogez², B. L. Ehlmann², H. Y. McSween³, M. J. Toplis⁴, S. Marchi⁵, C. M. Pieters⁶, N. Schorghofer¹, C. T. Russell⁷, M. D. Rayman², C. A. Raymond², ¹Planetary Science Institute, Tucson AZ (prettyman@psi.edu), ²Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA, ³University of Tennessee, Knoxville, TN, ⁴CNRS/IRAP, University of Toulouse, Toulouse, France, ⁵Southwest Research Institute, Boulder CO, ⁶Brown University, Providence RI, ⁷University of California, Los Angeles CA.

Introduction: During Dawn's primary mission, coarse, global maps of Ceres' elemental composition (about 400 km spatial resolution) were determined from data acquired by Dawn's Gamma Ray and Neutron Detector (GRaND) [1, 2]. GRaND is sensitive to the composition of the bulk regolith to depths of a few decimeters, providing geochemical constraints on the formation and evolution of Ceres' outermost crustal layer. Elements measured during the primary mission included H, Fe, and K as well as bounds on C.

Elemental and mineralogical constraints support extensive aqueous alteration within Ceres' interior, similar to processes that occurred within the parent bodies of the CI chondrites [1-4]. However, differences between the elemental composition of Ceres' ice-free regolith and the CI chondrites indicate Ceres underwent chemical fractionation [1]. This is consistent with geophysical observations that indicate a layered interior, with a crust rich in ice, salts and/or clathrates covering a brine-rich layer, possibly the remnants of a subsurface ocean and a source region for cryovolcanism [5-7]. Ceres' carbon-rich, global regolith contains high concentrations of H, in the form of water ice, phyllosilicates, ammoniated species, and perhaps organic compounds, with unknown exogenic contributions [1, 2, 8-10]. The elemental data acquired by Dawn will help understand the relationship between Ceres' regolith and bulk crustal composition, providing new insights into crustal processes.

Here, we describe preliminary results of the analysis of high spatial-resolution gamma ray and neutron data acquired in Dawn's second extended mission (XM2). We find that concentrations of hydrogen within Occator crater and its immediate surroundings are anomalously high in comparison to other regions at similar latitudes. This may result from the presence of subsurface ice, excavated by the impact and concentrated in a melt sheet and/or the presence of water bound to salts emplaced by cryovolcanism or impact induced hydrothermal activity [11, 12]. Interpretation of the elemental data is supported by results of geochemical and thermophysical modeling and constraints on surface mineralogy.

High resolution data: In June of 2018, the spacecraft maneuvered into a highly eccentric elliptical orbit with a periapsis altitude as low as 30 km. The orbit was

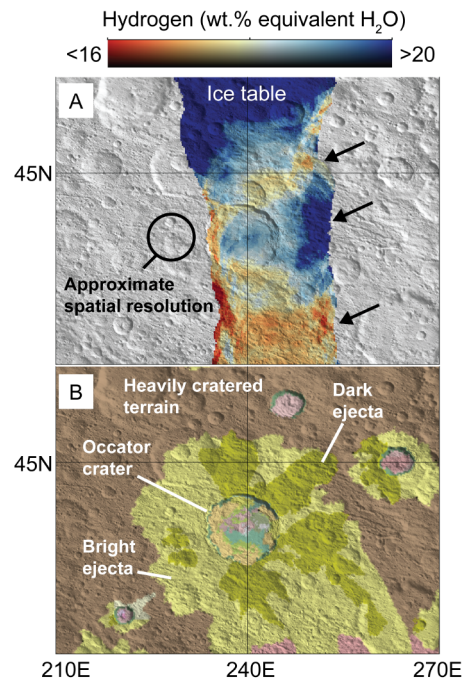


Figure 1. (A) Map derived from GRaND data acquired at altitudes less than 100 km reveals relatively high concentrations of hydrogen within Occator crater (19.86N, Ø 92 km) and its eastern ejecta blanket (arrows). The map resolution is smaller than the diameter of Occator (B) Geologic map provides context, including the extent of the ejecta and the heterogeneous crater interior [priv. comm., A. Nass; 13].

in a 3:1 resonance with Ceres, enabling the acquisition of data along a meridional arc and providing multiple, low-altitude passes over diverse geologic regions in the eastern and western hemispheres (along longitudes 60E and 240E). The elliptical campaign continued until the spacecraft ran out of hydrazine on October 31, marking the end of the mission. Data were acquired under nearly ideal solar conditions with negligible data loss. Elemental analyses used data from 113 of the 123 completed orbits.

The low altitude data acquired in XM2 enabled the determination of the elemental composition of the regolith on fine spatial scales, comparable to geologic features imaged by Dawn's optical instruments, including the interior of Occator crater and the surrounding ejecta blanket (Fig. 1). The orbits also sampled ejecta from the Yalode and Urvara basins, the interior of Ur-

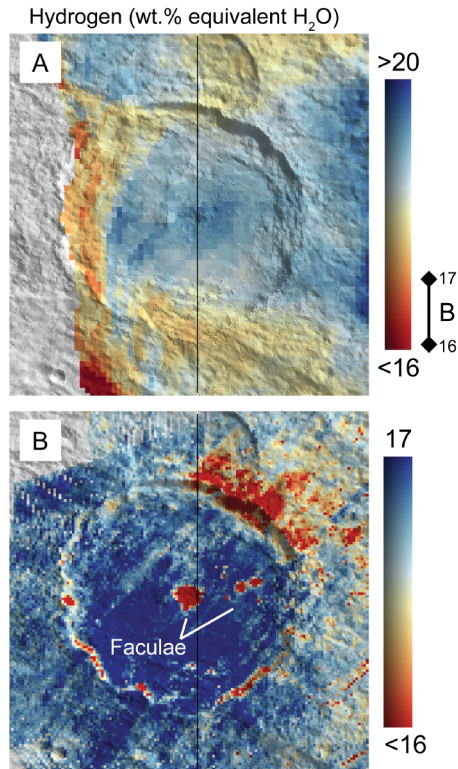


Figure 2. GROUND map of subsurface hydrogen (A) is compared to a map of surficial hydrogen (B) determined using a mineral mixing model [9] with mixing ratios determined by [14] from Visible and Infrared Mapping Spectrometer (VIR) data. The vertical bar in A shows the range of hydrogen in B. The ice-rich southern high latitudes, and older, heavily cratered terrain.

As the spacecraft moved closer to Ceres, the flux of gamma rays and neutrons increased and background contributions from the spacecraft decreased due to shielding of cosmic rays by Ceres. An approximately five-fold increase in signal to background was achieved in XM2 for gamma ray spectra compared to the primary mission. This enables improved accuracy for elements measured during the primary mission and the acquisition of new elemental signatures and bounds. Additional signatures targeted in XM2 include elemental mass ratios (Fe/Si, Mg/Si and C/O) and brine tracers such as Cl.

Preliminary results: A high resolution map of subsurface hydrogen was determined from thermal and epithermal neutron counting data acquired at altitudes <100 km (Fig. 1). Methods described by [1] were used to convert mapped counting data to hydrogen concentration. The distribution of hydrogen along the 60E and 240E meridians is consistent with global maps [1], with high concentrations near the poles and lower concentrations near the equator, indicating the presence of a receding ice table. The new data enable improved

characterization of the depth distribution and concentration of subsurface ice and hydration state of minerals. Notably, the interior of Occator crater (centered at about 20N) and its eastern ejecta blanket have anomalously high concentrations of hydrogen.

Analyses of regional gamma ray spectra acquired at low altitude are in progress. Chlorine was not detected; however, based on modeling of analog materials, the regolith may contain up to 5 wt.% Cl.

Interpretation: The concentration of hydrogen measured by GROUND in the bulk regolith is higher and more variable than in the outermost surface layer sensed by VIR (Fig. 2). Excess hydrogen detected by GROUND within and around Occator may be in the form of subsurface water ice. Ice may be concentrated in lobate deposits, which fill a significant fraction of the crater floor [13]. Icy crustal material may have been excavated by the impact and deposited in the ejecta blanket. Given Occator's age (about 20 Myr) [15], it is plausible that ice has survived within the outermost meter of the surface [16].

A portion of the hydrogen sensed by GROUND may also be in the form of hydrated and/or ammoniated salts; however, their contributions are likely small given the extent of the faculae. In addition, hydrated salts such as natron and hydrohalite are unstable at predicted subsurface temperatures [16, 17]. Ammonium chloride was detected in the faculae by VIR [14].

Chlorine-bearing minerals should be a major component of the Ceres' crust [7]. However, GROUND measurements indicate Cl is a minor component of the regolith. The dearth of Cl in the regolith may indicate a large-scale gradient in crustal composition with depth, perhaps resulting from chemical fractionation as the crust froze from a muddy brine.

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