EARLY HABITABILITY POTENTIAL OF DWARF PLANET CERES. J. C. Castillo[1], C. A. Raymond[1], M. C. De Sanctis[2], A. Ermakov[1], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, Julie.C.Castillo@jpl.nasa.gov, [2]Istituto di Astrofisica and Planetologia Spaziali, INAF, Roma, Italy.

Introduction: Ceres, the largest object in the asteroid belt and most water rich object after Earth in the inner solar system, has been explored in detail by the Dawn mission from 2015 to 2018. From the mineralogical, elemental, geological, and geophysical observations returned by Dawn has emerged the picture of a body that hosted protracted activity for 100s My. We summarize the Dawn results and the constraints they bring on Ceres' early habitability potential.

Key Results: Combined geophysical and topography data indicate that Ceres is partially differentiated in a water-dominated crust and a hydrated and porous mantle [1,2]. This, combined with a globally homogeneous surface composed of phyllosilicates, carbonates, and a dark component [3] suggest the occurrence of a global ocean inside Ceres for some period of time. Models indicate that volatile melting on a global scale required heat from aluminimum-26 [4], leading to the presence of a deep ocean for <200 My [4]. However, in alternative thermal evolution models, the ocean may persist until present [5]. The surface mineralogy constraints the conditions in the oceanic environment to be less than 50°C, pH=7-11, log pH_2>-6 [6,7]. The discrepancy between the inferred pH_2 and the theoretical pressure that can be achieved in Ceres suggests it was an open system early on, potentially due to an intensive impact history. As the ocean frozen, it incorporated an increasing amount of salts, in particular sodium carbonate, and organics. The latter are found in discrete places across the Ernutet Crater region [8]. While their origin inside Ceres is most likely [9], the mechanism for bringing them to the surface remains to be elucidated.

References: [1] Ermakov A. I., et al. (2017) *JGR* 122, 2267–2293. [2] Fu R. R., et al. (2017) *EPSL* 476, 153-164. [3] De Sanctis M. C., et al. (2015) *Nature* 528, 241-244. [4] Castillo-Rogez J. C. and McCord T. B. (2010) *Icarus* 205, 443-459. [5] Travis B. J., et al. (2018) *MAPS* 53, 2008-2032. [6] Neveu M., et al. (2017) *GCA* 212, 324-371. [7] Castillo-Rogez J. C., et al. (2018) *MAPS* 53, 1820-1843. [8] De Sanctis M. C., et al. (2017) *Science* 355, 719-722. [9] Bowling et al., *EPSL* submitted.

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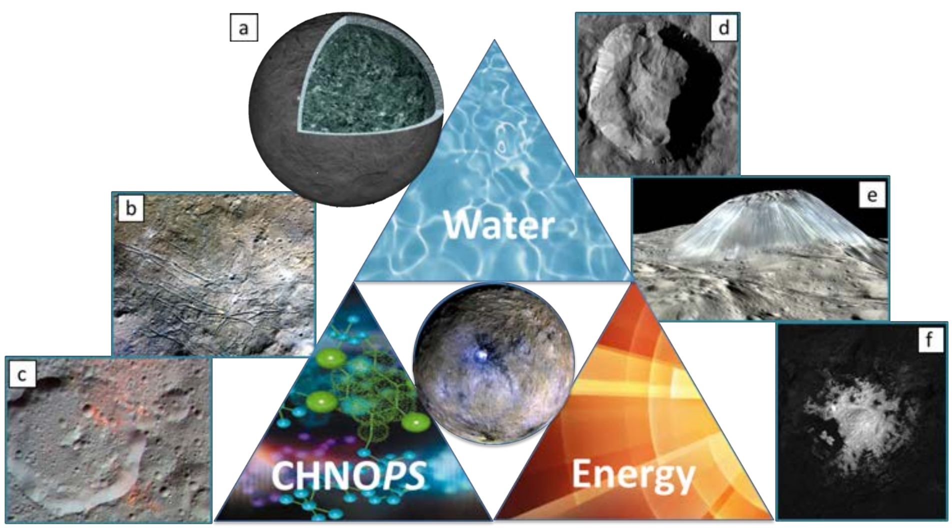

Figure 1. The Dawn mission at Ceres observed evidence of the ingredients for life: water, C-H-N-O-P-S elements, and energy. (a) Geophysical data confirm the presence of extensive water ice and the need for salts and/or clathrate hydrates to explain the observed topography and crustal density. (b) Various types of carbonates and ammonium chloride have been found in many sites across Ceres' surface (e.g., salts exposed on the floor of Dantu crater). (c) Ernutet crater (~52 km) and its area present carbon species in three forms (reduced in CxHy form, oxidized in the form of carbonates and intermediate as graphitic compounds.) (d) Ceres shows extensive evidence for water ice in the form of ground ice and exposure via mass wasting and impacts (image: Juling crater, ~20 km.) (e) Recent expressions of volcanism point to the combined role of radiogenic heating and low-eutectic brines in preserving melt and driving activity (image: Ahuna Mons, ~4.5 km tall, ~20 km diameter.) (f) Impacts could create local chemical energy gradients in transient melt reservoirs throughout Ceres' history (image: Cerealia Facula, ~14 km diameter.)