MARCIA CRATER, VESTA: GEOLOGY, MINERALOGY, COMPOSITION, AND THERMAL PROPERTIES.
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Introduction: The Dawn mission orbited the second most massive asteroid Vesta from July 2011 to September 2012 and is now on its way to asteroid Ceres. Dawn is equipped with three instruments, including the German Framing Camera (FC), the Italian Visible & Infrared Spectrometer (VIR), and the American Gamma Ray and Neutron Detector (GRaND) [1]. Marcia crater (190°E, 10°N; 68 x 58 km) is the largest of three adjacent impact structures, Marcia (youngest), Calpurnia, and Minucia (oldest). Marcia crater is special in that it is the largest well-preserved post-Rheasilvia impact crater, is geologically complex [2], is one of the youngest structures on Vesta [2], exhibits evidence for gully-like mass wasting [3], is the largest location of pitted terrain [4], has smooth ponds of presumably impact melt [5], shows enhanced spectral pyroxene signatures on its inner walls [2], and its dark ejecta blanket shows lower abundances of OH and H [6, 7]. In addition, the pitted floor is cooler than the surrounding terrain, due to increased local density and/or higher thermal conductivity [8]. The broad region of Marcia and Calpurnia craters is also associated with a higher Bouguer gravity, indicating denser material [9].

Results: *Geologic map:* As part of a global geologic mapping effort of the Dawn science team, Marcia crater and the surrounding terrain has been mapped by [2] (Fig. 1).

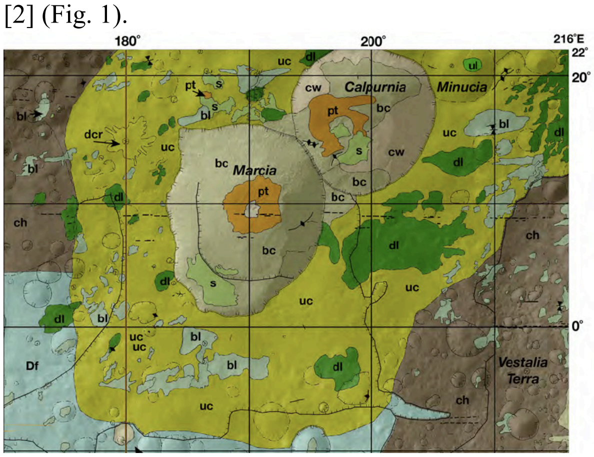

Fig. 1: Geologic map of Marcia crater [2].

Within Marcia crater are exposed units *bc* (bright crater material), *pt* (pitted terrain), and *s* (smooth material). Outside Marcia, are exposed unit *uc* (undivided crater ejecta material), *bl* (bright lobate material), *dl* (dark lobate material), and *dcr* (dark crater ray material) [2]. Because of its extensive ejecta and fresh appearance, the Marcia impact defines a major stratigraphic event, postdating the Rheasilvia impact [2].

Morphology: Marcia crater contains one of the few locations of pitted terrain on Vesta. Pitted terrain is characterized by clustered, rimless, irregular depressions, hundreds of meters across and up to 50 m deep, which often occur in otherwise smooth areas in topographic depressions [4]. The morphologic similarity to martian pitted terrain led [4] to conclude that pitted terrain on Vesta most likely formed by quick degassing of volatile-rich material during the impact event. The north wall of Marcia contains well-developed lobate deposits, many of which occur at the end of sub-curvilinear gully-like features. They originate in the crater walls, are more sinuous, more frequently intersect and have more complex network geometries than linear gully-like features observed elsewhere on Vesta [3]. The implications of these morphologies are discussed in [3]. Figure 1 shows extensive dark lobate material within the Marcia ejecta and smooth material within Marcia and Calpurnia craters. These materials onlap adjacent topography and in places form flow-like features. This morphology, together with new modeling of melt production by impacts on Vesta led [5] to suggest the presence of impact melt.

Age: Two different approaches and methods have been developed by the Dawn team to calculate absolute model ages of the Vesta´s surface. The estimated age of Marcia ejecta blanket, presented in [2], is of 120-150 Ma or 220-390 Ma (depending upon choice of chronology system). The smooth material within the crater has an apparent age of 40 Ma or 60 Ma. The reason for the age discrepancy between the ejecta and the smooth material (e.g., post-impact mass wasting within the crater, target properties, etc.) is still unclear and requires further investigations.

Composition: Using GRaND data, [10] identified a region of high iron abundance stretching from the north pole across Marcia crater towards the remnants of the Veneneia basin. It has been argued that high Fe abundances are consistent with more basaltic-eucrite-rich materials and that this region has not been blanketed by diogenitic materials from large impact events [10, 11]. Such an interpretation is supported by FC and VIR data [12, 13, 14]. In the GRaND hydrogen map, Marcia is within an area of globally-elevated hydrogen abundances of <250 µg/g, but represents a local minimum while a strong maximum with up to ~400 µg/g is located W of Marcia crater and a second, maximum with somewhat smaller abundances (<320 µg/g) is found E of Marcia [6] (Fig. 2).

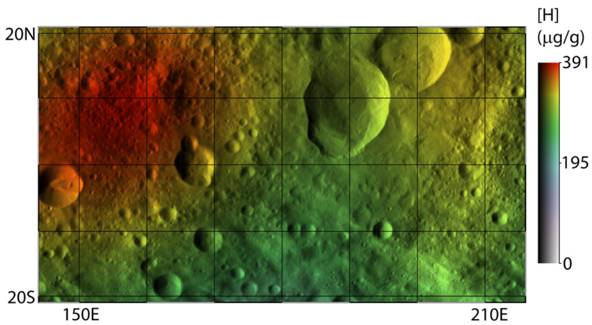

Fig. 2 GRaND hydrogen abundance map [7].

Mineralogy: Using FC data, [13] identified “gray material” associated with ejecta blanket of Marcia crater. This material is characterized by a 0.75-mm reflectance of ~15%, a shallow visible slope, and a weak $R_{(0.75\ \mu m)}/R_{(0.92\ \mu m)}$ ratio [13], which is still higher compared to immediately adjacent terrains.

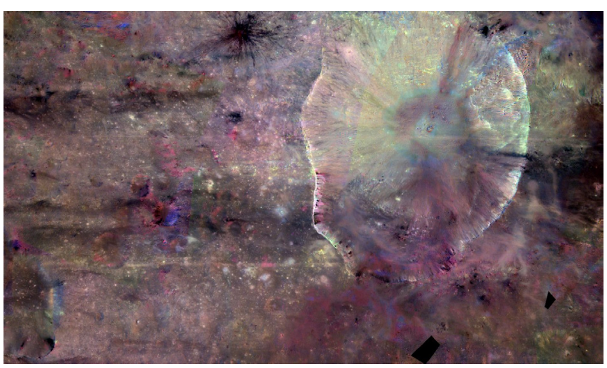
Fig. 3: FC false color ratio image of Marcia crater.

In the FC false color image (Fig. 3) reddish colors represent patches of lobate orange material as discussed by [15]. Bluish sites are characterized by unusually strong band depths and strong positive slopes between 920 nm and 960 nm. Yellowish areas show comparably shallow band depths and almost neutral slopes between 920 nm and 960 nm. Bluish and yellowish areas are almost indistinguishable between 440 nm and 750 nm. Greenish areas represent mixtures of bluish and yellowish material, while whitish areas represent bright subsurface material, generally mixtures of bluish and dark materials. VIR data indicate that equatorial regions generally show band centers at longer wavelengths (average BI = 0.93 µm and BII = 1.96 µm) and intermediate to shallow band depths, indicating more Fe-rich pyroxenes and lower pyroxene abundances, both consistent with eucritic compositions [12]. Investigating VIR data of the 2.8 µm wavelength region revealed a heterogeneous distribution of OH-bearing phases [6]. Marcia crater is characterized by low OH abundances, while regions E and W show elevated concentrations, thus a similar pattern to the H abundances derived from GRaND data. H and OH were likely delivered by dark, carbonaceous chondrite (CC) impactors, which contain H [4, 6, 7]. Some howardites, which are thought to be regolith breccias from Vesta, contain hydrated, CC clasts. The inner asteroid belt contains C-type asteroids, which could have delivered hydrated minerals to Vesta. Marcia crater might have lost its hydrated signature due to dehydration caused by the energy of the impact [4, 6, 7]. Alternatively, Marcia excavated less hydrated deeper material that now blankets older more hydrated materials. While the exact origin of the volatiles is still unknown, CCs seem to be the most plausible source rather than comets or endogenic sources [4, 6, 7].

Thermal properties: Thermally, the pitted terrain is the most prominent feature in Marcia. Pitted terrain has distinct margins in the temperature images and is cooler than nearby terrains observed under similar solar illumination conditions, even though it shows similar albedo. The lower temperatures suggest higher thermal inertia, i.e. a slower thermal response to changing insolation, which may be due to reduced local porosity (i.e., increased local density) and/or an increase in the local thermal conductivity [8]. Thermal properties are consistent with rapid degassing of volatile-bearing materials following an impact [4]. Marcia reveals other interesting features, e.g., a cold structure at the inner wall of the crater, just below its western rim. In the thermal images, this is seen as a series of dark spots, hence cooler than surrounding areas observed in the same illumination conditions. The cool areas presumably result from a higher cohesion, and therefore higher thermal inertia that characterizes the sub-curvilinear gully-like features in this part of the crater. The dark ejecta material in the walls and in the vicinity of Marcia are characterized by higher temperatures.

References: [1] Russell et al. (2007), Earth Moon Planets 101; [2] Williams et al. (2014), submitted to Icarus; [3] Scully et al. (2013), LPSC 45; [4] Denevi et al. (2012), Science 338; [5] Williams, D.A., et al. (2013) PSS, in press, j.pss.2013.06.017 [6] De Sanctis et al. (2012b) Astrophys. J. Lett. 758; [7] Prettyman et al. (2012), Science 338; [8] Tosi et al. (2014), submitted to Icarus; [9] Konopliv et al. (2013) Icarus, in press ; [10] Yamashita et al. (2013), Met. Planet. Sci. 48; [11] Prettyman et al. (2013), Met. Planet. Sci. 48; [12] De Sanctis et al. (2012a), Science 336; [13] Reddy et al. (2012), Science 336; [14] McSween et al. (2013) JGR 118; [15] Le Corre et al. (2013) Icarus 226.