A GLOBAL ASSESSMENT OF MARS MUD VOLCANISM PRODUCTS: PRELIMINARY RESULTS PROVIDED BY CRISM. A. M. Dapremont[1] and J. J. Wray[1], [1]Georgia Institute of Technology (adap@gatech.edu).

Introduction: Debate regarding the interpretation of positive-relief landforms on the surface of Mars as the result of igneous or mud volcanism (MV) is ongoing [1,2,3,4]. Previous studies have taken advantage of orbital remote sensing datasets (e.g. CTX, THEMIS, HiRISE) to argue in favor of one volcanism style over the other [5,6,7,3]. Mars MV compositional characteristics have previously been investigated from orbit [5,8,9] however, data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) remains an underutilized tool. Here, we present preliminary results of a global assessment of the mineralogical characteristics of Mars MV products. We seek to address existing knowledge gaps pertaining to the diversity of these features on the Martian surface. Our work also serves as a significant step toward improved differentiation and characterization among Mars igneous and mud volcanism products.

Methods: Our global assessment locations were sourced from an extensive literature review of existing Mars MV studies, and HiRISE-based identification of hypothesized mud volcanoes. The following CRISM targeted S (~0.4 – 1.0 microns) and L (~1.0 – 3.9 microns) detector data were used in this investigation: FRT (~18 m/pixel), HRL (~36 m/pixel), and FRS (~18 m/pixel). Standard photometric and atmospheric correction techniques [10] were applied to these data using the ENVI CAT tool. We improved upon previous CRISM analysis through the use of Map-Projected Targeted Reduced Data Records (MTRDRs). We acquired spectral signatures using the spectral ratio method in ENVI for all datasets.

Results: *Acidalia/Chryse.* Pitted cones and mounds within Acidalia and Chryse Planitia exhibited nanophase ferric oxide enrichment, and were less enriched in mafics compared to surrounding material. MTRDR analysis revealed no mineral related features above noise in the CRISM infrared (IR) range (~ 1.0 – 3.9 microns).

Candor Colles. Landforms broadly described as rounded knobs identified by [3] within Candor Colles, Valles Marineris were consistent with the presence of hydrated minerals. The interpreted massive core of an injectite exhibited a 1.9 micron absorption consistent with the presence of structurally bound water (H_2O bend + stretch), while spectral signatures of the sub-horizontal layers of this feature were indicative of sulfate-bearing species based on 1.9 and 2.1 micron absorption positions [11] (Fig. 1). 1.9 micron absorptions were also identified on the sub-horizontally layered material and summit depression of proposed mud volcanoes (Fig. 1).

Arabia Terra. Spectral signatures acquired from mounds within several Arabia Terra craters indicated the presence of hydrated minerals. 1.4 (H_2O overtone OH stretch) and 1.9 micron absorptions were identified in Firsoff Crater (Fig. 2). Firsoff and Kotido crater mounds also exhibited 1.9, 2.1, and 2.4 micron absorptions suggesting the presence of monohydrated sulfate or a mono-/polyhydrated sulfate mixture. We interpret these potential sulfate identifications with caution, as the relevant spectral features are not dissimilar in magnitude to artifacts attributed to noise.

Melas. A Melas Chasma landform may exhibit morphologic characteristics indicating a MV origin based on HiRISE observations. Acquired spectral signatures from the rim and flanks of this feature were consistent with olivine (Fig. 3).

Discussion/Conclusions: *Acidalia/Chryse*. The lack of diagnostic mineral absorptions using the highest quality CRISM data in the form of MTRDRs, combined with textural observations noted by previous workers (e.g. smooth surface texture) [5], supports our conclusion that the visible and near-infrared spectral signatures of Acidalia and Chryse suggested mud volcanoes are likely dominated by fine-grained surface materials. Spectral signatures could also be indicative of ferric material coatings. We advocate for an investigation of these features beyond the CRISM IR through a search for diagnostic absorptions in the thermal infrared.

Candor Colles. Our CRISM analysis corroborates the predicted sulfate composition for mud volcanoes and associated flows in specific regions of Valles Marineris [3]. Our observations provide support for water as a component in the formation history of proposed mud volcanoes and injectite features, as well as the groundwater upwelling contribution to mud volcanism and presence of near-surface ground water during sediment mobilization hypothesized by [3].

Arabia Terra. Our hydrated mineral identifications correlate with previous CRISM analysis of Arabia Terra equatorial layered deposits [7]. If sulfates are indeed present in association with Arabia Terra mounds, these observations would support a spring deposit interpretation for these features. In this scenario, mounds may have originated from groundwater/fluid upwelling or sulfate-rich fluid expulsion associated with fracture pathways [7,12]. We are not prepared to exclude MV as a viable mound formation explanation. Further clarification (e.g. MTRDRs) of spectral signatures exhibiting water overtone absorptions is necessary to assign more specific mineral identifications (e.g. Fe/Mg smectite) that could support a MV hypothesis.

Melas. The location from which spectral signatures of the Melas Chasma landform were acquired (Fig. 3) is noteworthy. Extrusion of mafic crustal material to the surface from depth with mud has been invoked to explain the presence of mafic material near the summit crater of a Chryse Planitia mud volcano [9]. This interpretation may apply to our Melas feature of interest given the identification of a mineral consistent with an igneous origin. We plan to incorporate additional knowledge of the morphometry and geologic setting of this landform to further decipher its volcanic origin.

Future Work: Compositional analysis of Mars MV products using CRISM S and MTRDR data will continue. We also plan to apply the methodologies described here to igneous landforms (e.g. cinder cones, rootless cones, tuff cones) for spectroscopic criteria assignment and comparison with MV spectral signatures.

References: [1] Skinner, J.A. and Tanaka, K.L. (2007) *Icarus 186,* 41–59. [2] Brož, P. and Hauber, E. (2013) *JGR Planets 118,* 1656–1675. [3] Okubo, C.H. (2016) *Icarus 269,* 23–37. [4] Brož, P. et al. (2017) *Earth and Planet. Sci. Letters 473,* 122–130. [5] Oehler, D.Z. and Allen, C.C. (2010) *Icarus 208*, 636–657. [6] Pondrelli, M. et al. (2011) *Earth and Planet. Sci. Letters 304,* 511–519. [7] Pondrelli, M. et al. (2015) *GSA Bulletin 127,* 1064–1089. [8] Kite, E.S. et al. (2007) *AGU FM 2007,* Abs. ID V13B-1346. [9] Komatsu, G. et al. (2016) *Icarus 268,* 56–75. [10] Murchie, S. et al. (2007) *JGR Planets 112,* E05S03. [11] Bishop, J.L. et al. (2009) *JGR Planets 114,* E00D09. [12] Franchi, F. et al. (2014) *Planet. and Space Science 92,* 34–48. [13] Viviano-Beck, C.E. et al. (2014) *JGR Planets 119,* 1403–1431.

Acknowledgements: This work was supported by NSF GRFP Grant No. DGE-1650044. We thank the CRISM SOC for providing MTRDRs and Chris Okubo (USGS) for providing HiRISE images.

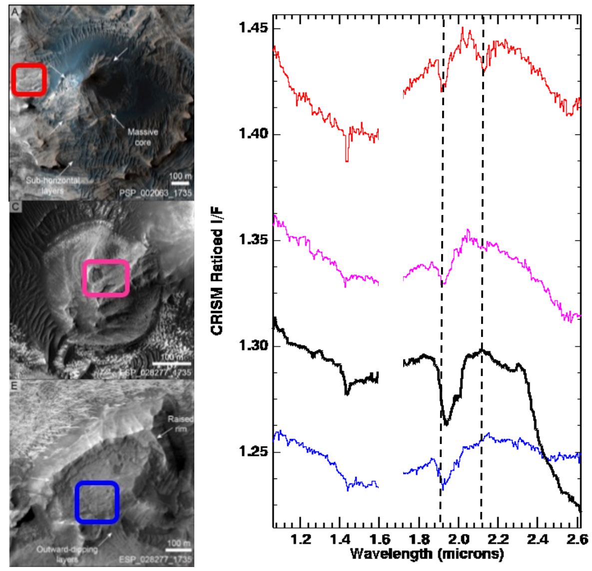

Figure 1. Left: Candor Colles proposed injectite (top) and mud volcanoes (middle and bottom). Colored boxes denote spectral signature locations. Figure modified from [3]. Right: HRL000033B7 MTRDR spectral plot with colors corresponding to boxes in left image. Dashed lines at 1.9 and 2.1 microns. 1.6 micron detector boundary region is masked. Black reference spectrum is polyhydrated sulfate [13].

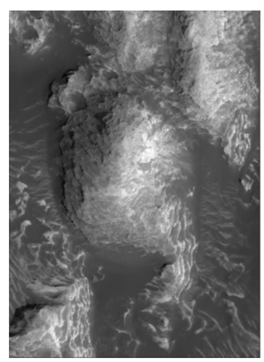

Figure 2. Example of Firsoff Crater mound (ESP_054568_1820) exhibiting evidence of hydration. Mound is ~ 400 meters in diameter. North is down.

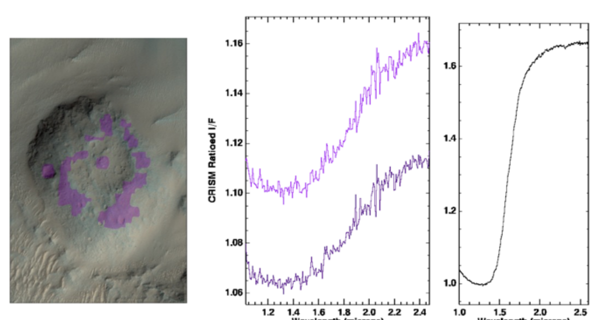

Figure 3. Left: Melas Chasma landform (ESP_034606_1680) with overlain geologic unit denoting location of spectral signatures. Middle: FRS0002CB6B spectral plot of olivine identifications. Right: Fe-olivine reference spectrum [13]. Landform is ~ 600 meters in diameter. North is down.