HEMATITE-BEARING MATERIALS IN CANDOR CHASMA, MARS: IDENTIFICATION OF NEW LOCALITIES, ANALYSIS, AND IMPLICATIONS.
R. L. Fergason[1], L. R. Gaddis[1], and A. D. Rogers[2], [1]U.S. Geological Survey, Astrogeology Science Center, 2255 N. Gemini Drive, Flagstaff, Arizona 86001, rfergason@usgs.gov. [2]Stony Brook University, Department of Geosciences, Stony Brook, NY 11794.

Introduction: The Valles Marineris (VM) canyon system on Mars is of enduring scientific interest in part due to the presence of interior mounds that contain extensive layering and water-altered minerals, such as crystalline gray hematite and hydrated sulfates [1-6]. Although the locations of many hematite-bearing units in Candor Chasma have been identified [1;5], the origin and post-emplacement modification history of these and associated deposits is unclear and the relationship between hematite- and sulfate-bearing materials is ambiguous. A clearer understanding of these relationships is necessary to better understand the role of water in the geologic history of Candor Chasma specifically and Mars in general.

This work has several objectives: (1) to accurately identify the location of hematite-bearing materials and verify previous studies; (2) to constrain the physical properties of the hematite-bearing materials, the associated low albedo deposits, and light-toned materials; (3) to define the relationship between hematite-bearing materials and low albedo (presumably aeolian) deposits and layered materials; and (4) to develop hypotheses describing the formation history and the post-emplacement modification (including transport) of these hematite-bearing and associated materials. Due to the similar geologic context associated with hematite-bearing and layered materials throughout the VM canyon system [e.g., 1;3;5;6], the insight gained from studying these materials in Candor Chasma can likely be applied to similar deposits throughout VM.

Background: Gray, crystalline hematite was identified by the Thermal Emission Spectrometer (TES) in Sinus Meridiani, VM, and the chaos terrain [7]. All hematite-bearing deposits have common characteristics with respect to their remotely measured composition and their meters-scale morphology [e.g., 6]. Hematite-bearing materials are associated with friable, sulfate-rich layered deposits that appear easily eroded and are believed to be sedimentary in origin. These hematite-bearing materials are observed in low-albedo sand at the base of the deposits, mantling these deposits, or possibly interbedded [e.g., 1;3;5-6]. TES spectral properties are similar in Sinus Meridiani, Aram Chaos, and Candor Chasma, thus the composition and maximum abundances of hematite in all three of these regions are likely similar [1].

The coordinated analysis of model results, mineralogic observations from TES, Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité (OMEGA), and Compact Reconnaissance Imaging Spectrometer for Mars (CRISM), and the analysis of morphology in high-resolution images illuminate similar mineral associations and morphologies between VM and Sinus Meridiani. These similarities include: (1) the spectral similarity in TES of the hematite in Candor to that at Sinus Meridiani and Aram Chaos [e.g., 1;5;8]; (2) the presence of nanophase ferric oxide spectral features in OMEGA and CRISM data in Candor Chasma and Sinus Meridiani [e.g., 2-4;6]; (3) discrete strata exhibiting spectral signatures of monohydrated (kieserite) and polyhydrated sulfates in association with the ILD at Candor, Sinus Meridiani, and Aram Chaos [e.g., 2-4;6;9-10]; (4) the morphologic similarity between the hematite-bearing units at Candor to those at Sinus Meridiani [e.g., 5-6]; and hydrologic modeling [6;11]. These observations suggest that the sulfate- and hematite-bearing materials in VM may have formed in a manner similar to that at Sinus Meridiani and chaos terrain, and that a common regional process may have been responsible for their formation at all sites [e.g., 3;5-6]. Thus, a formation mechanism similar to that developed by the Mars Exploration Rover Athena science team [e.g., 12] has been invoked for the VM region to describe the sulfate and hematite materials formed in close proximity and within morphologies, as viewed from orbit, similar to those observed at Sinus Meridiani both in-situ and from orbit [e.g., 3;5;12].

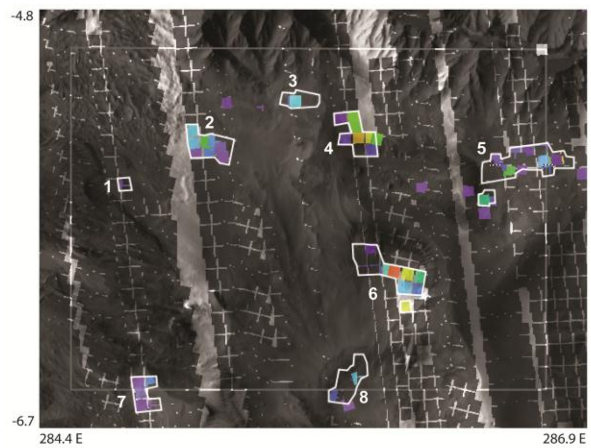

Figure 1. Hematite-bearing regions in the study area, as identified using TES data, overlaid onto a THEMIS daytime IR mosaic. Areas 1, 3, 7 and 8 are newly identified sites that have not been previously investigated. Red, orange, and yellow tones have a higher hematite abundance and blue and purple tones have a lower hematite abundance. Hematite abundance ranges from 5-17%.

Method: There are eight exposures of hematite in western Candor Chasma identified using TES data, four of which were identified previously and studied in detail [1;5] (Figure 1). Two strong bands, centered at ~316 and ~415 cm^{-1}, can be observed in TES spectra [7]. A spectral index optimized for detecting these strong bands in TES data [5] was first used to locate potential hematite-bearing surfaces in the study region. This hematite index value was then mapped to a Thermal Emission Imaging System (THEMIS) IR daytime map to show the location and relative abundance of gray hematite. Using the above described hematite identification methods, we refined the location of these hematite-bearing areas, identified additional hematite-bearing deposits, and integrated available remote sensing data to assess these hematite exposures and the surrounding materials. We also incorporated a more detailed analysis than reported previously of the physical properties of the hematite-bearing and associated materials using both TES [13-14] and THEMIS [15] data. All data were imported into a Geographic Information System (ArcGIS 10.1) and georeferenced to MOLA shaded relief.

Results: The eight hematite concentrations identified here all are associated with kieserite-bearing materials and some correspond to iron-oxides, as identified using OMEGA data [4]. Three of the hematite concentrations are in close proximity to Candor Mensa, where ILDs are found. The remaining five are associated with sulfate-bearing layered materials, but the exposed layered units are less extensive than those observed in Candor Mensa.

Thermophysical data provide information regarding the properties of low albedo, presumably mobile [e.g., 6], materials in the study area and their possible relationship to hematite concentrations. For example, one region (see High Resolution Imaging Science Experiment (HiRISE) image PSP_010027_1745) contains hematite-bearing low albedo materials that corresponds to a mantle or sand sheet. This hematite region also contains some aeolian bed forms or dunes. To the south where there is no hematite signature, bed forms are observed in much higher concentrations. The hematite-bearing sand sheet has a thermal inertia ~50 units higher than the region to the south, possibly indicating a larger grain size that may not be easily mobile.

Two potential source regions for dark aeolian materials have been identified: (1) “pasted-on” material that occurs near six sites and is topographyically higher than the hematite-bearing materials; (2) dark layers observed in several places in associations with the floor material and wall rock. Based on our analysis, the pasted-on material is not thought to be a source region for the dark, hematite-bearing materials. Although these materials are associated with hematite-bearing deposits in six cases, there are at least a dozen more examples in our study area where hematite is not associated. We conclude that this material is a source region for dark sand that sometimes is intermixed with hematite-bearing materials. The dark layers are spatially and stratigraphically associated with hematite-bearing materials (Figure 2), and appear as dark, mobile material being shed from these layers. This observation suggests that hematite-rich units may be interbedded with sulfate-bearing layered deposits, as was previously suggested by *Murchie et al.* [6]. Dark layers are observed in association with only four of the eight hematite-bearing regions in the study area, but this observation may be due to sparse HiRISE coverage over some of the regions. These sites do, however, provide insight into the origin of the hematite-bearing material. Our analysis suggests that the hematite may in some areas erode from distinct hematite-rich units, which then collect as a lag deposit at the base of these layers, similar to what is observed at Sinus Meridiani.

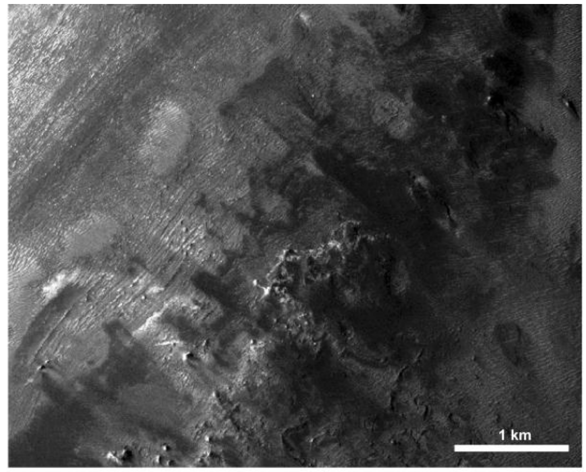

Figure 2. CTX image (P03_002274_1736) illustrating dark, mobile materials begin shed from dark layers and is a potential source for hematite-bearing materials. This region corresponds to hematite-bearing materials in region 8 in Figure 1.

References: [1] Christensen P. R. et al. (2001) *JGR*, *106*, 23-873-23,885. [2] Gendrin A. et al. (2005) *Science*, *207*, 1587-1591. [3] Bibring, J. P-. et al. (2007) *Science*, *317*, 1206-1210. [4] Mangold N. et al. (2008) *Icarus*, *194*, 519-543. [5] Weitz C. M. et al. (2008) *JGR*, *113*, doi:10.1029/2007JE002930. [6] Murchie S. et al. (2009) JGR 114, doi:10.1029 /2009JE003343. [7] Christensen P. R. et al. (2000) *JGR*, *105*, 9623-9642. [8] Glotch T. D. and P. R. Christensen (2005) *JGR*, *110*, doi:10.1029/ 2004JE002389. [9] Arvidson R. E. et al. (2006) *JGR*, *111*, doi:10.1029/2006JE002729. [10] Griffes J. L. (2007) JGR, 112, doi:10.1029/2006JE002811. [11] Andrews-Hanna J. et al. (2007) *Nature*, *446*, 163-168. [12] Squyres S. W. et al. (2004) *Science*, *206*, 1731-1733. [13] Mellon M. T. et al. (2000) *Icarus*, *148*, 437-455. [14] Putzig N. E. and Mellon M. T. (2007) *Icarus*, *191*, 68-94. [15] Fergason R. L. et al. (2006) *JGR*, *111*, doi:10.1029/2006JE002735.