The Geology of Aram Chaos.

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Introduction. The Thermal Emission Spectrometer (TES) instrument aboard the Mars Global Surveyor (MGS) spacecraft located deposits of gray, crystalline hematite in Sinus Meridiani, Aram Chaos, and Valles Marineris [1-2]. Since the initial discovery, most work has focused on the Sinus Meridiani site, primarily because of its large size and its probable choice as a landing site for one of NASA's 2003 Mars Excursion Rover (MER) rovers [3-5]. Christensen et al., [1-2] provided five testable hypotheses regarding the formation of crystalline hematite on Mars: 1) low-temperature precipitaion of Fe oxides/hydroxides from standing, oxygenated, Fe-rich water, followed by subsequent alteration to gray hematite, 2) low-temperature leaching of iron-bearing silicates and other materials leaving a Fe-rich residue (laterite-style weathering) which is subsequently altered to gray hematite, 3) direct precipitation of gray hematite from Fe-rich circulating fluids of hydrothermal or other origin, 4) formation of gray hematitic surface coatings during weathering, and 5) thermal oxidation of magnetite-rich lavas. The study of Aram Chaos provides another geologic setting with which to test these hematite formation processes.

Aram Chaos is a 280 km diameter crater centered at 2.5N, 338.5 E. Like other nearby craters, it has been filled with a large amount of material since its formation [2]. It is connected to the Ares Vallis outflow channel by a small, 15 km wide channel that flowed outward, from Aram Chaos to Ares Vallis. The association of Aram Chaos with the outflow channels, as well as its obvious basin morphology, indicates a possible connection to past surface and subsurface water in the region.

Approach. Several data sets, including TES, the Thermal Emission Imaging System (THEMIS), and the Mars Orbiter Laser Altimeter (MOLA) are used in this investigation. TES emissivity spectra, and albedo and thermal inertia datasets were used to initially characterize the mineralogy and thermophysical properties of Aram Chaos. The increased spatial sampling (100 m thermal and 18 m visible) of THEMIS makes it an excellent tool to more closely investigate geological relationships in the area. In addition, the nighttime imaging capability of THEMIS has provided important insights into the thermophysical properties of the terrain within Aram Chaos high spatial scales. THEMIS has filters that measure absorptions between ~7.5 and 14.5 µm. Because hematite fundamental absorptions occur in much longer wavelengths, THEMIS cannot detect the presence of hematite. Three-band, decorrelation-stretched images can however, provide information about any additional mineralogical variability that may be present in the area.

Individual MOLA tracks were used to characterize the regional sloping and tilting occurring within the crater. In addition to the individual tracks, a 100-meter contour map created from the 128 ppd gridded data set was overlayed onto a THEMIS daytime mosaic to understand regional topographic trends.

Results and Discussion. The topmost stratigraphic unit in Aram Chaos covers roughly 20% of the interior of Aram Chaos. It is unique among the units in Aram Chaos in that it has a relatively high thermal inertia (550-700 $J/m^2Ks^{1/2}$), indicating a layer composed of sand and pebble-sized particles [6], or alternatively, smaller particles cemented together. The latter hypothesis is more likely, given that THEMIS visible imagery displays dunes traveling across the surface of this unit. TES spectra of the unit show a basalt-like composition, although the spectral contrast is considerably less than basalts seen elsewhere on Mars. Outliers of this "cap unit" are present, indicating that the unit had a larger extent than it currently does. This unit can also be seen in some of the large cracks of the chaos terrain, indicating that chaos formation occurred prior to the deposition of this unit.

Just below the cap unit lies the hematite deposit in Aram Chaos. Hematite spectra can have significant variation depending on the hematite formation process [7-9]. Following the methods of Bandfield et al. [10], we extracted the average Aram Chaos hematite spectrum. Spectrally, the Aram Chaos hematite deposit is identical to the Sinus Meridiani hematite, suggesting a common formation process. Comparison of TES and MOLA data show that the crystalline hematite in Aram Chaos is confined to a discreet layer in the middle of a stratigraphic column that shows no other evidence of aqueous mineralization. Analysis of TES spectra and THEMIS multi-band imaging show that no other units in Aram Chaos are spectrally or thermophysically distinct.

Integration of topographic data with THEMIS imagery and TES spectra indicates that the units in Aram Chaos do not lie horizontally. Specifically, there are numerous areas where the hematite unit and the cap unit can be seen at the same elevations. Individual MOLA profiles show a broad dome-shaped topography in the interior of Aram Chaos.

Tilting of units could serve as an explanation for the lack of hematite in western Aram Chaos.

Chronology Based on analysis of the combined TES, THEMIS and MOLA datasets, we propose the following model for the geologic history of Aram Chaos:
1) A pre-existing crater was filled with sediments that were likely transported by aeolian processes. 2) These sediments were disrupted by the catastrophic release of water from the subsurface, resulting in the classic chaotic terrain seen in Aram Chaos. 3) Water ponded in the interior of the crater, and more sediments were deposited, including the hematite and cap units. At some point during the process, iron in the water became saturated, and iron oxide, possibly goethite, was deposited along with other sediments. Later, as the amount of iron in the system decreased, precipitation of oxide ceased. Burial by further sediments in addition to residual geothermal heat altered the precipitated oxide to crystalline hematite. 4) Regional uplift occurred, resulting in the "dome" structure in the interior of Aram Chaos. 5) Erosion to the current state exposed the hematite layer in eastern Aram Chaos.

Conclusions. Aram Chaos has had a rich and complex geological history, very likely including the ponding of liquid water. Because of the spectral similarities between the Aram Chaos and Sinus Meridiani hematite deposits, the two sites should be considered together when generating a model for crystalline hematite formation on Mars. The timing, of the formation of the deposits, however, could be different. Previous work [1] has indicated that the Sinus Meridiani deposit is associated with ancient terrain. The association of Aram Chaos with outflow events, however, points toward a Hesperian age.

References [1] Christensen, P.R. et al. (2000) *JGR*, 105, 9623-9642 [2] Christensen, P.R. et al. (2001) *JGR*, 106, 28873-28886 [3] Lane, M et al. (2002) *JGR*, 107, 5126-5140 [4] Hyneck, B. et al. *JGR*, in press [5] Arvidson, R. et al. *JGR*, in press [6] Mellon et al. (2000) *Icarus*, 148, 437-455 [7] Glotch et al. (2002) *LPS XXXIII* CDROM [8] Glotch et al. (2002) *Eos Trans. AGU, 83(47), Fall Meet. Suppl., Abstract* P72A-0439 [9] Glotch et al. (2003) *LPS XXXIV* CDROM [10] Bandfield et al. (2000) *JGR*, 105, 9573-9587