A View of Meridiani From Above: Evidence for Deposition in Standing Water From THEMIS, TES, and MOLA. Philip R. Christensen, Dept. of Geological Sciences, Arizona State University; phil.Christensen@asu.edu,

Introduction: The Meridiani Planum region, centered near 0°N, 0°E, has received special attention following the discovery of gray crystalline hematite from thermal infrared spectra measured by the Mars Global Surveyor (MGS) Thermal Emission Spectrometer (TES) instrument [1-7]. The likely role of water in the formation of the hematite deposit [1, 2, 4-6, 8] led to the selection of this site for in situ exploration by the Mars Exploration Rover Opportunity. The Meridiani hematite is a primarily basaltic unit that lies at the top of a sequence of layered, easily-eroded rocks that are stratigraphically above and post-date the ancient cratered terrain [1, 2, 4, 6, 9, 10]. The hematite is found in an irregularly shaped deposit centered at ~357º E and 2º S spanning roughly 500 km in the E–W direction and 300 km N-S.

The formation modes for the gray crystalline hematite detected by TES were grouped into two classes by Christensen et al. [2000, 2001]: (1) chemical precipitation; and (2) thermal oxidation of magnetite-rich volcanic materials. The chemical precipitation models they proposed were (1a) low-temperature precipitation of Fe oxides/oxyhydroxides from standing, oxygenated, Fe-rich water, followed by subsequent alteration to crystalline hematite, (1b) low-temperature leaching of iron-bearing silicates and other materials to leave a Fe-rich residue (laterite-style weathering) which is subsequently altered to crystalline hematite, (1c) precipitation of Fe-oxides or crystalline hematite from Fe-rich circulating fluids of hydrothermal or other origin, and (1d) formation of crystalline hematitic surface coatings during weathering. Models (1a) and (1b) require an alteration process (e.g., burial metamorphism) to convert Fe-oxide/hydroxide assemblages (e.g., goethite, red hematite, ferrihydrite, and siderite) to crystalline gray hematite.

On the basis of the analysis of TES, MOC, and MOLA data Christensen et al. [2001] could not exclude any of these models, but favored the two models in which the deposits of gray hematite were formed either by chemical precipitation of hematite (or a goethite precursor [11]) from Fe-rich aqueous fluids under ambient (model 1a) or by hydrothermal processes (model 1c). Subsequent analysis by Lane et al [5] proposed the precipitation of Fe-oxides that were metamorphosed by burial to platy hematite and subsequently exposed by erosion. Hynek et al [4] favored precipitation from Fe-rich circulating fluids (model 1c) or thermal oxidation of volcanic ash during eruption (model 2). Newsom et al [8] suggest, but do not distinguish between, precipitation from standing water, precipitation as coatings from groundwater, or oxidation of pre-existing minerals.

Results: Data from THEMIS, TES, and MOLA have been used to investigate the composition, thermophysical characteristics, stratigraphic relationships, and morphology of Meridiani Planum [12]. The hematite varies in abundance from 0-20%, was most likely derived from a Fe-oxyhydroxide precursor such as goethite [Glotch, submitted #2461], shows no coherent spatial variation in abundance or spectral character, and is mixed with a low-albedo, plagioclase/pyroxene basalt as the major component. The hematite-bearing material appears to be a relatively thin (10s to <200 m thick) upper layer within the smooth, hematite-bearing plains unit (Ph), with higher inertia material immediately below. Key insights into the origin of hematite are found in three regions within Ph that do not have hematite exposed on the surface. These hematite-free units are up to 40 meters above the hematite-rich plains. There is a distinct topographic break in slope at the contact between the hematite-bearing and hematite-free units, suggesting that these units form a distinct stratigraphic layer immediately above the hematite-bearing layer. A THEMIS visible images shows that the morphology and crater abundance of both of these units are similar. Isolated remnants of the overlying unit occur, indicating that this unit was removed by erosion. The gradational character of the contact also indicates that there are no significant differences in the competency of the two units. The upper unit appears to lie conformably on the hematite-bearing unit, with no evidence that Ph underwent erosion prior to the deposition of the overlying unit. This relationship suggests that there was no significant gap in time between the deposition of the two units. The general similarity in surface character suggests that the two units were deposited under similar conditions and processes.

The hematite unit appears to embay pre-existing channels, occurs as outliers within closed crater basins, and is absent from the surrounding plains, suggesting that it may have been deposited in a dense fluid, rather than as a distributed air-fall. The hematite unit lies within a topographic trough over ~3/4 of its circumference, with the remaining perimeter <150 m lower in elevation.

The three leading candidates for the formation of the hematite-bearing unit in Meridiani Planum all have shortcomings to varying degrees. The model of oxidation of ash suffers from the poor spectral fit to a magnetite precursor, the dissimilarities of the hematite unit to proposed ash deposits elsewhere, and the spectral dissimilarity between volcanic ash and basaltic sediments. The hydrothermal alteration model suffers primarily from the need to reconcile the very confined vertical extent of the hematite layer over huge distances and across disconnected occurrences. A model of the deposition of precursor Fe-oxyhydroxides in water-filled basins requires minor erosion or tilting in order to account for the present-day lack of a completely closed basin for the main Ph unit. A model of deposition in standing water is favored, however, because it does account for the following observations: (1) the occurrence of a thin hematite unit with sharp upper (and possibly lower) contacts; (2) spectral evidence for goethite as a precursor to hematite; (3) the presence of a finely-layered, friable texture on Ph in sharp contrast to the morphology of the Etched units; (4) embayment relationships on the southern margin of Ph; (5) the occurrence of remnants of hematite-bearing unit in isolated craters surrounding of the main Ph unit; (6) the lack of other hydrothermal minerals; (7) the presence of low-albedo, coarse-grained basalt, rather than ash, as the major component of the hematite-bearing unit; and (8) the differences in morphology between Ph and proposed ash units [12].

It is expected that in situ observations from the MER Opportunity rover will address some of these questions. The origin of hematite from oxidation of ash would be supported by observations from microscopic and panoramic imaging of the rock and sediment textures indicative of ash, and by the detection of precursor magnetite or partially hematitzed magnetite grains using infrared and Mössbauer spectroscopy [13]. A hydrothermal origin can be tested using the Miniature Thermal Emission Spectrometer [14] to look for other associated hydrothermal minerals, and microscopic images can be used to determine if the hematite occurs along grain boundaries and in veinlets indicative of post-depositional fluid migration and alteration. Hematite originating in water-filled basins can be tested by looking for large- and small-scale sedimentary structures. Mineralogic, elemental, or textural evidence can be used to detect a precipitated hematite precursor, such as goethite, that was deposited as a continuous layer, rather than from a later hydrothermal fluid. Rounded grains or hematite/Fe-oxyhydroxide spheroids would be compelling evidence for this model. In addition, the occurrence of coarse-grained basalt as a major component and as sedimentary, rather than a primary igneous component, can be used to distinguish a sedimentary versus volcanic origin.

References:

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