A WET, DRY, OR HOT GUSEV CRATER?: USING THEMIS AND MER TO TEST DEPOSTIONAL HYPOTHESES.

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Introduction: The unifying theme of the Mars Exploration Program is the search for evidence of past or present liquid water [1]. The underlying assumption behind this is that areas on Mars exposed to liquid water would have had the highest probability of capturing and preserving biomarkers. As a part of this program strategy, two Mars Exploration Rovers (MERs) will launch toward Mars in 2003, with early 2004 landings. Each will carry the Athena science package [2] with instruments suitable for gathering evidence of ancient water on Mars. Thus, one of the considerations in landing site selection has been sites showing possible evidence for past water.

Gusev crater (14.64°S 175.36°E) is a site previously interpreted as a lacustrine depocenter for detritus from the 900 km long Ma'adim Vallis fluvial system [3-6]. Photogeologic interpretations cited to support this hypothesis include: fluvial terraces within Ma'adim [7], evidence of stream migration [8], debris lobes or 'deltaic' deposits at the mouth of Ma'adim [3,6], shoreline deposits [6], curvilinear ridges within Gusev analogous to sedimentary structures formed in ice-covered lakes by sub-glacial rotary currents [9]. While these interpretations are consistent with fluvio-lacustrine deposition, it is important to test this hypothesis with new data sets (THEMIS, TES, MOC, and MOLA) and to consider other plausible depositional models.

Surface Unit Deposition: Eight surface units mapped within Gusev crater vary in lateral extent from several tens of kms to basin-wide [10]. Subsequent erosion and superposition of strata make original lateral extents difficult to discern. The extent of the LB unit within Gusev, its termination against pre-existing units, and deposition at the lowest elevations within Gusev imply lateral flow during deposition. Horizontal sub-layering within surface units (Figure 1) suggests multiple depositional events. Slope changes between sub-layers suggest lithologic variation, varying degrees of induration, or changes in depositional environment. Observations of unit orientations and extents, however, are not unique indicators of a fluvio-lacustrine depositional environment.

Depositional Hypotheses: Here we utilize a new surface unit map, inferred stratigraphic sequence, and new THEMIS observations [10-11] to evaluate three depositional hypotheses for Gusev.

Fluvio-Lacustrine. The first model involves deposition of sediment under a fluvial and/or lacustrine setting [3-6]. As mentioned earlier, surface units appear are horizontal to sub-horizontal and show basin-wide or localized deposition. Thus the assumption of original horizontality would appear to be valid for these units; but this characteristic is not always diagnostic of subaqueous deposition. In a fluvio-lacustrine regime, changing base levels could account for varying geographic extents and elevations of surface units. Under this model, MOLA-derived unit elevations suggest fluctuating lake levels, with an overall drop in base level that resulted in a fluvial setting and the eventual evacuation of water from Gusev. Based on crater density measurements, most hydrologic activity would have been Hesperian in age; however, erosion of WR (a topographically low unit) appears to have occurred during the Early Amazonian. Uniquely lacustrine features (such as evaporites and definite shorelines) were not identified in the present study; however the morphologies and lateral extents of CCD and LB do suggest fluvial deposition.

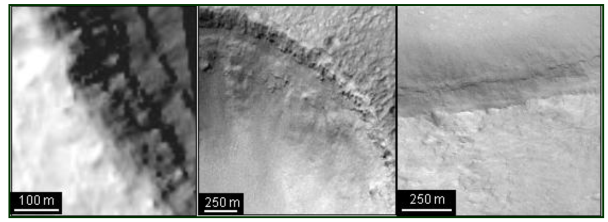

Figure 1. High-resolution MOC images showing evidence of sub-layering in crater walls.

Aeolian. Aeolian modification of the surface is the only geologic process presently active in Gusev [10]. Intracrater dunes, wind streaks, dust-devil tracks, and mobile sands have been observed [11-12]. Redistribution of the LA unit since Viking is thought to have resulted from variable wind activity. Orientations and lateral extents of older surface units could be explained by an aeolian model; however, aeolian textures within surface unit bedding cannot be resolved in current data sets.

Volcanoclastic. Volcanoclastic deposition could explain the distribution and orientation of some surface units and sub-layering within Gusev. Horizontal layering occurs in many terrestrial and martian lava flows and ash deposits. Apollinaris Patera, <288 km to the northeast, would be a candidate source for such material. TES surface types 1 and 2, thought to represent volcanic lithologies [13-14], have been detected in Gusev in LA; however, visible imagery and thermal

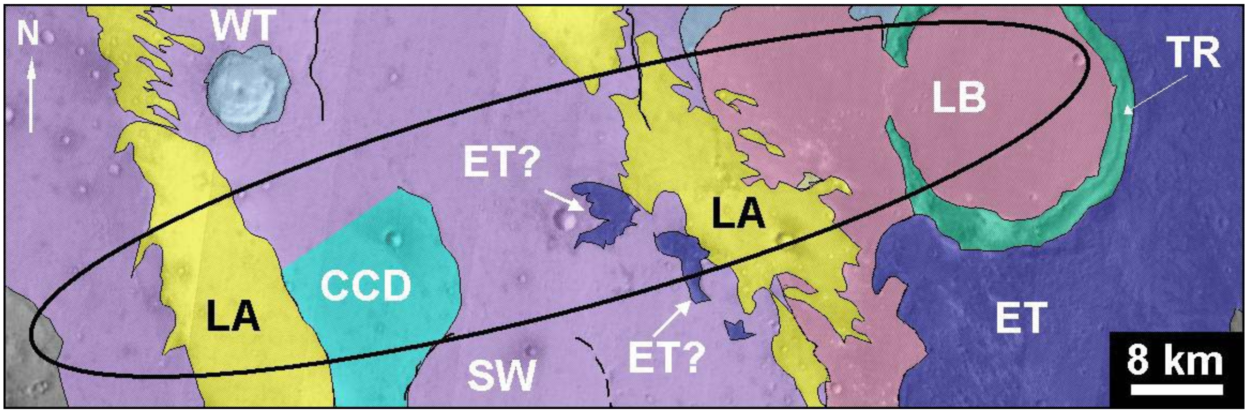

Figure 2. Surface unit map (from [10]) of Gusev crater in the vicinity of the MER-A landing ellipse (thick black line). Unit designations are as follows: TR=Thyra Rim; WR=Wrinkled; ET=Etched; LB=Lobate; MS=Mesa; SW=Swath; CCD=Cross-cut Dark; and LA=Low Albedo. Thin black lines=ridges; Dashed line=buried crater.

inertia values suggest that these are likely aeolian sand. While Apollinaris lava flows do not appear to have extended into Gusev, explosive volcanism coupled with southeast winds may have deposited ash in Gusev [15] during the Hesperian. Most surface unit ages correspond to the timing of Apollinaris volcanic activity. Under this model, variability in sub-layering could be explained by ash compositional variability or the degree of induration of pyroclastics. However, comparisons of slope angles with other martian phreatomagmatic and shield volcanoes suggest less energetic explosive activity for Apollinaris Patera and thus fewer distal fall deposits [16]. This model alone cannot account for the localized deposition of most surface units (LB, MS, CCD, ET, and SW), but may account for deposition of some basin-wide units (possibly WR, LA, and ET). Because this model considers Apollinaris Patera the most likely volcanic source, volcanoclastic deposits would be expected to thicken northwestward across Gusev, but there is no indication that such thickening occurs.

A Combined Model. Because none of the above models provide a unique solution to explain the features within Gusev and due to the proximities of Apollinaris Patera and Ma'adim Vallis, it is possible that surface units were deposited and modified by all 3 processes. Spatial resolution of present data sets does not allow for the distinction between aeolian, fluvio-lacustrine, or volcanoclastic bedding textures. Spectral data from THEMIS could provide a means of ascertaining the spectral diversity of surface units.

MER Testable Hypotheses: A MER landing in the geologically diverse Gusev crater (Figure 2) provides the potential opportunity of sampling multiple surface units and testing hypotheses proposed in [10-11]. In addition, Athena science instruments can be used to examine strata deposited by hydrologic, aeolian, and/or volcanic processes and to examine sediment possibly derived from source regions outside of Gusev. Athena instruments also provide the potential for evaluating depositional hypotheses for Gusev crater. Spectral analyses from Mini-TES, APXS, and the Mössbauer Spectrometer provide a means of determining rock type and mineral content. This would provide insight into the origin of such samples (igneous vs. sedimentary). The high spatial resolution (20μm/pixel) of the Microscopic Imager provides a means of discriminating rock textures (volcanic vs. sedimentary). Pancam images could be used near exposures to examine stratigraphic relationships of mapped surface units, such as those between LB, SW, and LA (Figure 2). Such analyses may provide insight into the depositional history of Gusev and the overall martian geologic/climatic record during the Hesperian-Early Amazonian.

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