FLUVIAL AND LACUSTRINE PROCESSES IN MERIDIANI PLANUM AND THE ORIGIN OF THE HEMATITE BY AQUEOUS ALTERATION.
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Introduction: The prime MER landing site in Meridiani Planum is located on layered materials, including hematite, whose origin as lacustrine or aeolian sediments, or volcanic materials is uncertain. Our detailed mapping of the region provides important constraints on the history of the region. Our mapping of the location of fluvial and lacustrine land forms in the region relative to the layered deposits provides new evidence of a long history of erosion and deposition as has long been noted [1]. In addition, our detailed mapping of the southern boundary of the hematite deposit strongly supports an association between long-lived fluvial channels and lacustrine basins and the strongest hematite signatures. This evidence supports an origin of the hematite deposits by interaction with water under ambient conditions in contrast to suggestions of hydrothermal processes due to volcanic or impact crater processes. An important part of the story is the evidence for the localization of the layered deposits due to topographic control induce by the presence of a large early basin we have identified that extends to the north-east of the landing site.

Distribution of current channel networks, drainages, and basins

Channel systems leading to the southern boundary of the hematite-rich surface deposit can be observed originating from a large highlands region that extends south-eastwards from the hematite regions for hundreds of kilometers (Fig. 1, inset). These channels appear to terminate near the boundary with the hematite deposit. Based on the Viking data, Edgett and Parker [1] identified this boundary as the edge of an ocean or large body of water. However, careful examination of the high resolution MOC images and the MOLA topography clearly shows that these highly visible channels flowed into a system of paleo-lakes and channels that currently appear to drain westward into the unnamed 150 km diameter crater, and further east towards Iani Chaos. A possible extension of the drainage area to the south of Schiaparelli basin includes Evros Vallis. Because the topography is so flat in the area between the two drainages, the topographic gradient cannot be easily determined, and may have varied in direction at different times in the past. The total area of the drainage region is impressive, 580,000 km^2, about the size of the state of Texas. The area for the northwestern portion of the drainage area closest to the hematite area is 200,000 km^2, about the size of Kansas. The area for the Evros Vallis portion is 380,000 km^2. There is also a large system of highland valleys (not mapped in this study) that fed into the lowland region east of the hematite area. If flooded, this lowland would currently drain to the north.

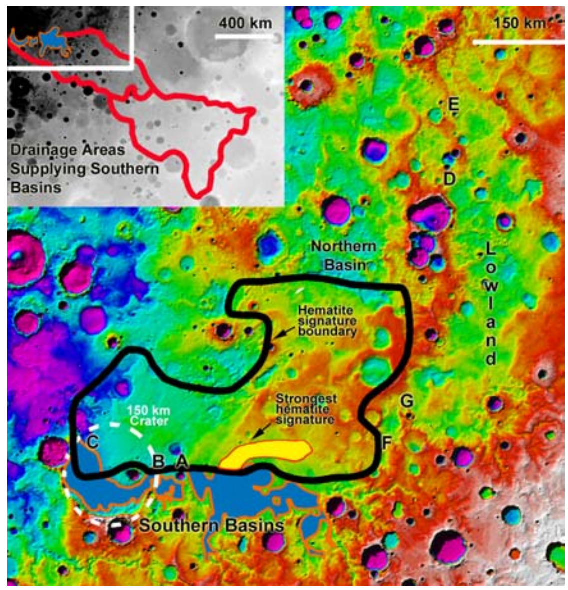

Fig. 1 Study area in Meridani Planum. MOLA topography map (Latitude 7 N to 5.6 S, Longitude 351.1 E to 5.5 E) showing the regional setting of the hematite-rich surface deposit labeled with areas and basin barriers [1]. The inset shows the drainage areas feeding the southern basins.

Fluvial and lacustrine environments along the southern boundary of the hematite deposit are currently constrained by topographic barriers that serve to define three linked basins, including the southern part of the 150 km crater (Fig. 3, a-d, Fig. 4, a). These basins are progressively lower from east to west, and evidence exists for fluid flow through channels that have partially breached the barriers.

The western basin is located within the 150 km diameter crater, where a channel leads south around the lobe of hematite-rich material that covers the northern portion of the crater. High-resolution images of the floor of the channel (Figs. 3 a-c) show characteristic evidence of fluvial erosion of ancient cratered terrain, very similar to images from the Gusev crater (e.g. Fig. 5). Evidence of recent fluid flow in this system of basins may include the erosion of ejecta blanket material from a 21 km diameter crater superimposed on the hematite deposit (Fig. 4a). The western basin is constrained by a barrier (C, Lat. 2.09 S, Long. 352.22 E), at an elevation of -1760 m where a channel leads to a smaller crater (19 km diameter) superimposed on the rim of the 150 km diameter crater. The area of the western basin is approximately 9,000 km2, with an average depth of 40 m and a volume of 1100 km^3.

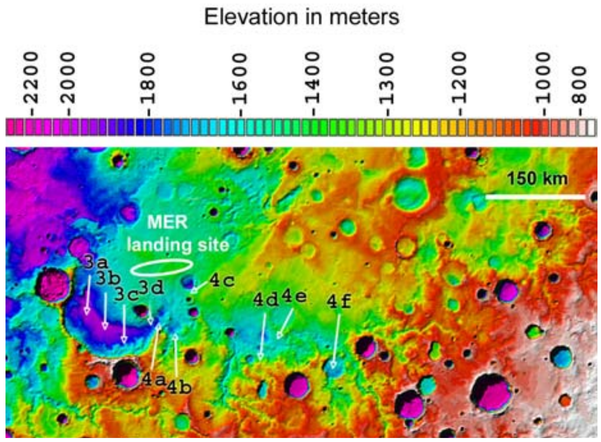

Fig. 2. Detail of the southern paleo-lake basins and channels in the study area. The locations of high-resolution images Figs. 3 and 4 are shown. Also shown is the approximate location of the prime "Hematite Site" landing ellipse for the 2003 MER mission.

The central basin of the three is constrained by a barrier (B, Fig. 1) at an elevation of -1620 m, originally formed by the rim of the l50 km diameter crater to the west. The current area of the central basin is somewhat less than 2000 km^2, with an average depth of 40 m and a volume of approximately 80 km^3. At the point where several channels flow into this central basin from the south, evidence exists for possible shorelines and erosion, although exposure of layered deposits cannot be ruled out (Fig. 4b). The elevation of the putative shorelines is consistent with the elevation of the barrier ("B" Fig. 1) that constrains the height of this basin.

In the eastern basin, water flowing in from the south is constrained by a barrier (labeled A Fig. 1, Lat. 2.78 S, Long. 354.68 E) at -1450 m elevation that is partly formed by a relatively young crater (6 km diameter) and there is evidence from the formation of a channel eroded in the ejecta blanket for flow around the north of this crater (Fig. 4c). Evidence for possible shorelines or eroded layered deposits is seen in Figs. 4d, and 4e. The elevation of the area in 4e (-1495 m) is consistent with the elevation of the barrier "A" (Fig. 1) that constrains the elevation of this possible lake. Fig. 4f shows eroded deposits where a major channel enters the basin. The current area of the eastern basin is about 20,000 km^2 with an average depth of about 100 m and a volume of approximately 2,000 km^3. The current base level for this eastern lake may have been lower earlier in martian history. For example, channels entering this basin (Fig. 2) are present down to the -1615 m elevation, a level, more appropriate for the basin defined by the barrier down stream (B, Fig. 1, Lat. 2.80 S, Long. 354.12 E, -1623 m).

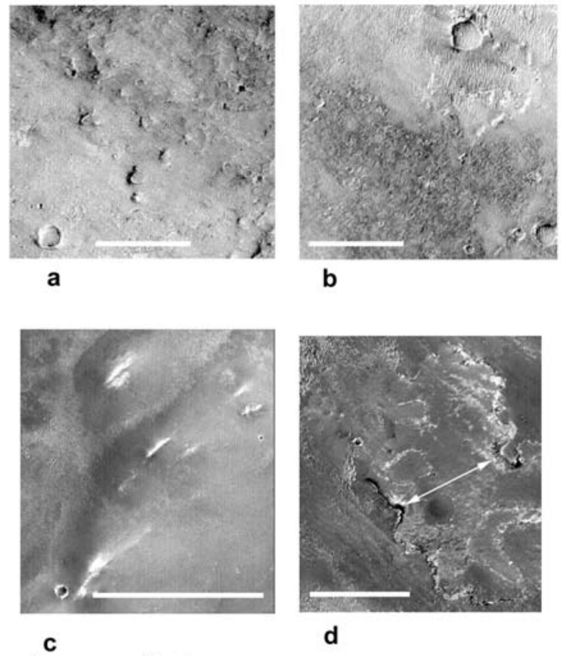

Fig. 3. a, b, c. MOC images of the channel floor on the bottom of the 150 km diameter crater. The ancient cratered surface exhibits evidence for fluvial erosion consistent with flow around the circumference of the floor of the crater. All scale bars are one kilometer in length (a, M1300898, b, M0300371; c M1301419). d. Part of the channel leading down into the 150 km diameter crater is shown with an arrow denoting the breadth of the channel (M0301632).

A broad lowland area is present along the eastern boundary of the hematite deposit. This lowland is approximately 80 km wide and extends for 450 kilometers to the north where it then heads back to the west. There are at least two areas where water in this lowland may have escaped to the west (D, Fig.1, Lat. 6.60 N, Long. 1.60E, elevation -1220 m and E, Fig. 1, Lat. 4.94 N, Long.1.97 E, elevation -1235 m). This eastern lowland has a heavily cratered topography with an extremely gentle gradient (≈ 30 m over 450 km, slope <0.01%). This lowland area appears to be fed by channels from the vicinity of Schiaparelli basin and the older basin just to the south of Schiaparelli (not mapped). There is another basin area separating the eastern lowland area from the chain of basins along the southern boundary of the hematite. The western barrier of this basin (F, Fig. 1, Lat. 2.66 S, Long. 359.22 E) is at an elevation of -1220 m, and the eastern barrier (G, Fig. 1, Lat. 0.94 S, Long. 0.47 E) is at an elevation of approximately -1260 m, and includes an impact crater (9 km diameter) that may have recently created a higher dam between the two drainages.

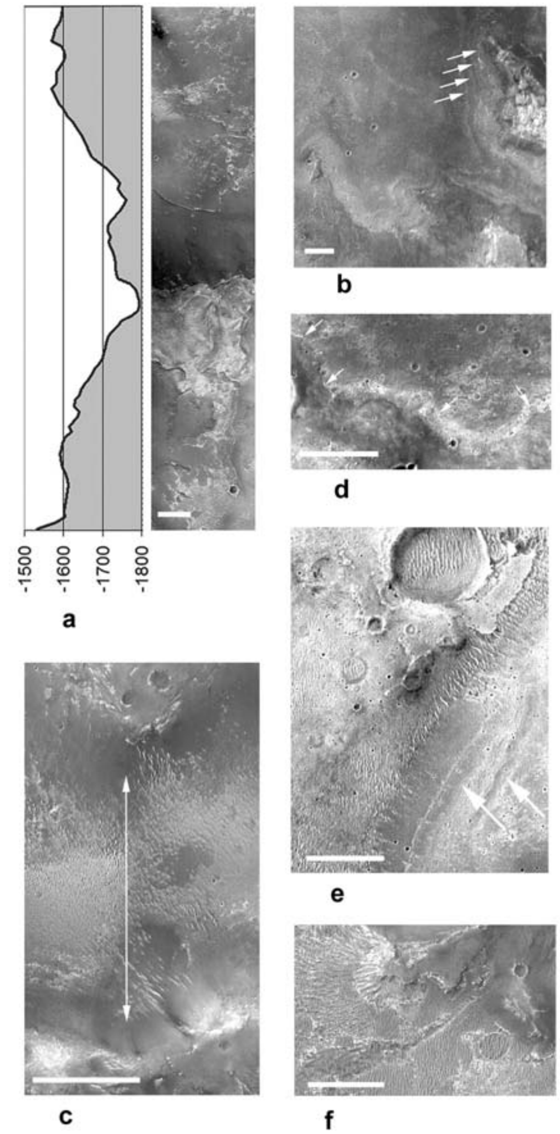

Fig. 4. Channel and basin features. All scale bars are one kilometer. a. An image of the channel leading into the 150 km diameter crater, just upslope of Fig. 3d, with the corresponding MOLA profile. The deeper channel has no apparent impact craters on the surface (M0201539, 2.94 km width). b. Possible shorelines in the central basin (mosaic of AB107704, M0901839). c. A channel eroded into ejecta deposits north of a relatively young crater that makes up part of barrier A (M1001349). The breadth of the channel is denoted with an arrow. d. Possible shorelines at approximately –1600 m on the south shore of the eastern basin (M0204225). e. Possible shorelines in the eastern basin where an outlier of hematite fills the floor of a small basin (M1003047). f. Channels eroded on the floor of the eastern basin where a major channel enters the basin (M0700487).

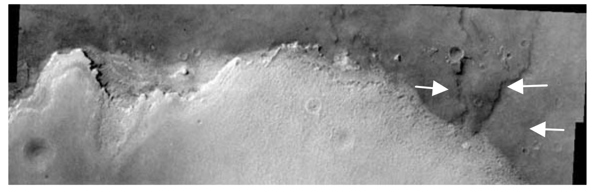

Fig. 5. Contact of layered material representing a hematite outlier with the floor of the northern basin in the center of the 800 km diameter impact structure (THEMIS visible image V03208003). Previously eroded channels (arrows) on the floor of the basin are being revealed by the erosion of the layered material. Image width is 30 km.

The northern boundary of the hematite deposit is characterized by a poorly integrated system of basins and channels that drains westward. This system of channels and depressions is not fed by a distinctive set of channels from higher elevations, but does represent a lower area surrounded by both the hematite deposit on the south, and cratered terrain to the north. The water in this system could have come from groundwater supplied from the paleo-lakes along the southern boundary and the eastern boundary of the hematite area since the elevations in the northern basin area just north of the hematite (Figs. 1, 5) are as low as -1700m and are generally lower than –1500 m.

History of the channel and lake systems

The geologic history of this region is complex and occurred over a time period extending to before 3.8 billion years. The hematite area occupies the southern half of an ancient basin or circular structure approximately 800 km in diameter (Fig. 6) [3]. This evidence includes a central basin, a 200 m high raised ring at a radius of 200 km (400 km diam.), and an annular trough at a maximum radius of about 400 km (800 km diam.). The western edge of the annular trough is missing, probably due to later erosion. The structure is very similar in size to the Cassini structure, which has a 400 km diameter rim and an 800 km diameter annular trough. The overall relief of the structure is currently very small (<500m), but there is strong evidence for extensive erosion, especially on the western side. The presence of a magnetic anomaly in the center of this structure suggests a very ancient age [4]. The presence of this structure probably controlled the deposition of the layered materials and the location of the fluvial channels and lacustrine basins in this area.

The formation of layered deposits of unknown composition throughout the Sinus Meridiani also occurred early in Mars history [2]. The origin of these deposits is not clear, but may include basin ejecta, air-fall dust, volcanic, and sedimentary deposits. Edgett [5] has mapped the occurrence of dark mesa-forming units in 116 MOC images of craters throughout western Arabia Terra. All six occurrences of the dark mesa-forming units are located within the 800 km diameter feature, supporting the importance of this structure to the history of the area. These dark units are emplaced on previously eroded lighter material [6]

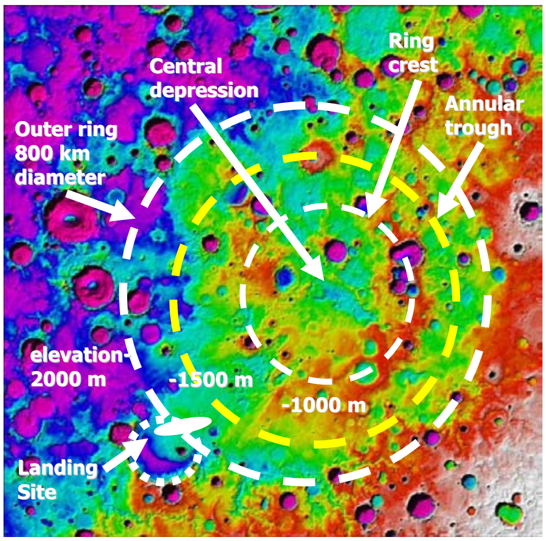

Fig. 6 Color coded MOLA topography showing concentric circular features in Meridiani Planum consistent with the presence of an 800 km diam. multi-ringed impact structure. The location of the MER landing site inside a 150 km diam. crater is also shown.

The formation of the current system of basins and fluvial channels in the region developed over a long period, with substantial resurfacing events extending into the Hesperian and chaos formation extending into the Amazonian and possibly into the very recent history [7]. The channel networks were periodically disrupted by cratering events that created or destroyed barriers. For example, at the present time the channels that extend into the eastern and central basins are incised to elevations well below the current elevation of the barriers (Fig. 2). This implies that earlier in martian history the barriers were at a lower base level before the late cratering events created new dams at higher elevations (e.g. barriers A, and G).

The origin of the smooth layered material as a lacustrine sedimentary deposit is difficult to explain as some of the areas containing the hematite signature are at an elevation (-1200 m) that is 150 m above the elevation of the present barrier constraining the large eastern basin on the southern side of the hematite region. However, sedimentary deposition had to occur down stream from the very extensive areas eroded during channel formation in the drainage areas. The most likely candidate for a sedimentary deposit overlain by a hematite-rich surface is the lobe of material that fills the northern part of the 150 km diameter crater, and the area just to the north of the crater rim, which is at least partially dammed by several large craters (21 km, 19 km, and 31 km in diameter) now largely buried but still visible on the western edge of the area covered by the hematite deposits. Based on a thickness ranging from 200 m up to 500 m in the northern portion of the 150 km diameter crater, the volume of the partly layered material filling the crater is approximately 4,000 km^3. The estimated volume of deposits within the crater could be supplied by uniform erosion of a layer less than 4 m deep over the drainage area that possibly supplied water to the system.

Conclusions

The evidence for abundant fluvial and lacustrine activity and the discovery of the 800 km diameter structure provides a link between the Meridiani and Aram basin (500 km diameter) occurrences of hematite [8]. Both deposits share the combination of location on an elevated region within a large impact feature combined with a long history of fluvial and lacustrine activity suggesting that the hematite formed by a process involving the presence of water during wetter periods of martian history [9]. The MER rover may be able to provide evidence for the involvement of water with the formation of the hematite in terms of both rock studies and evidence for fluvial activity. The rover may also be able to determine the sedimentary vs. volcanic origin of the deposits.

References: [1] Edgett and Parker, *GRL 24* 2897, 1997 [2] Edgett and Malin 2000, *Science. 105*, 1927-1937, 2000. [3] Newsom et al., (2003) *JGR*, submitted. [4] Acuna et al., *Science 284*, 790, 1999. [5] Edgett (2002) *J. Geophys. Res.*, *107*(E6), doi:10.1029/2001JE001587. [6] Hynek and Phillips, (2002) *Geology* 29, 407. [7] Grant and Parker, *J. Geophys. Res., 107,* 5066, doi: 10.1029/2001JE001678, 2002. [8] Christensen P.R., et al. (2001), *JGR 106*, 23,873. [9] Kirkland et al. (2002) *Lunar and Planetary Science XXXIII*, CD rom #1218.

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