LANDING SITE SELECTION AND MIYAMOTO CRATER, MARS – WHY NO HYDROTHERMAL DEPOSITS?

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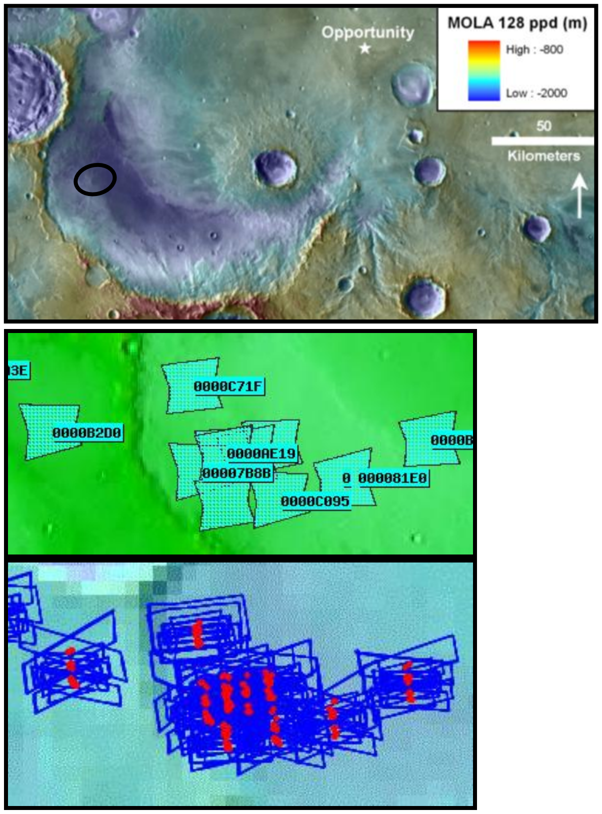

Fig. 1.a. Location of Miyamoto crater and proposed MSL landing ellipse in southwestern Meridiani Planum, MOLA topography overlain on THEMIS day IR. **b**. Locations of nadir CRISM images relative to the floor and rim of Miyamoto crater. Note that rim of Miyamoto crater is not included in the abundant CRISM data. **c**. Locations of CRISM data from the 5 CRISM images taken before and after the nadir images shown in b. This image was created using the PDS orbital data explorer. The base map is MOLA, the blue outlines are the CRISM FRT observations within and nearby Miyamoto. The area covered by the off-nadir images represent a large amount of data for the crater rim not yet examined at high spectral resolution for evidence of aqueous or hydrothermal processes.

Introduction: The current landing site candidates for the Mars Science Laboratory involve sedimentary deposits in impact craters, including Hale, Gale, an unnamed crater in Nili Fosse, and Miyamoto crater [1]. Miyamoto crater is a 160-km-diameter impact crater of Noachian age (Fig. 1). The floor of the Miyamoto crater, southwest of Meridiani Planum is a potential site for studying aqueous processes on Mars. The crater floor contains raised curvilinear features that are suggestive of past fluvial activity. Unfortunately, the potential for identifying and studying hydrothermal deposits in this location has been handicapped by the lack of high resolution CRISM data from the crater rim, due to the focus of providing data only on potential landing site ellipses. A search for evidence of hydrothermal activity in crater rims and central uplifts could provide important alternative targets for future rovers and sample return missions.

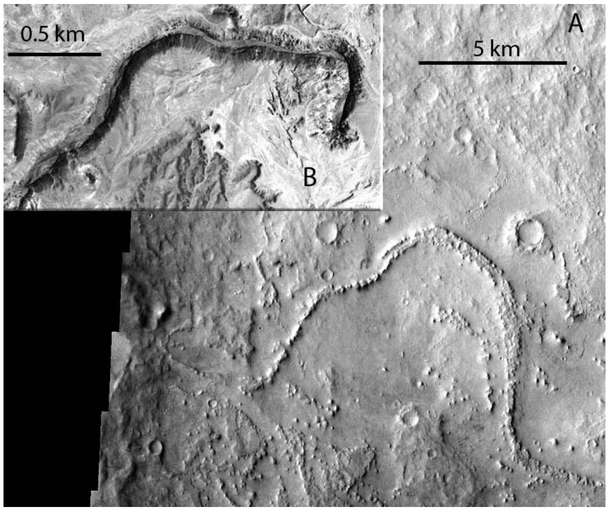

Fig. 2. A) THEMIS VIS image of the floor of Miyamoto Crater with positive-relief ridge or mesa features interpreted as a complex of inverted paleochannel deposits. Most notably, a long sinuous ridge runs from near the wall of the crater to the eastern edge of this image. B) Inverted paleochannel deposit in the Cedar Mountain Formation near Green River, Utah (Google Earth).

Evidence for aqueous processes on the western floor of Miyamoto crater: Geologic mapping of the area using HiRISE images shows three principal units: (1) a lower phyllosilicate-bearing unit [2], with fractures spaced meters to tens of meters apart unit, striped of material exposing large areas of outcrop and locally covered by recent mobile fines, (2) a middle horizon "unit" that appears to be a residual surface or capping unit remaining after striping of the basal unit, and (3) an upper, plains forming unit that onlaps the residual surface and basal unit from the east and is characterized by significantly greater impact crater retention. The middle unit forms distinct curvilinear positive-relief 'ridges' or 'ridge complexes' (Fig. 2).

The most prominant curvlinier ridge complex is a narrow, sinuous, flat-topped ridge about 25 km in length, north of the proposed landing site (Fig. 2, also noted by [3]). Topography from the MOLA DEM suggest a height of approximately ~30 - 50 m. In HiRISE images, the sides of the feature are formed by a lighter colored fractured basal unit, capped with a material darker than the surrounding terrain. HiRISE images and stereo analglyphs of this feature reveal layering in the upper walls (Fig. 3).

The Miyamoto ridge complexes appear similar to positive relief channel deposits seen on Earth [e.g. 4] that are interpreted as exhumed, inverted, fluvial paleochannel deposits (Fig. 2B). A spectacular set of inverted paleochannels can be seen in the Cedar Mountain Formation near Green River, UT, USA, [5]. The morphology of the Cedar Mountain examples are remarkably similar to the Miyamoto crater structures, including flat-topped ridges, areas where the ridges are breached or eroded into a series of buttes. The Miyamoto structures have a surface slope of < 2 m/km (HRSC), which compares with gradients of paleochannel segments in Utah, ranging from 0.23 to 0.4 m/km [6, 7]. The Cedar Mountain paleochannels consist of sediments with large gravel-sized particles and are largely carbonate cemented [6, 7, and 8] although silica cement has also been reported [8].

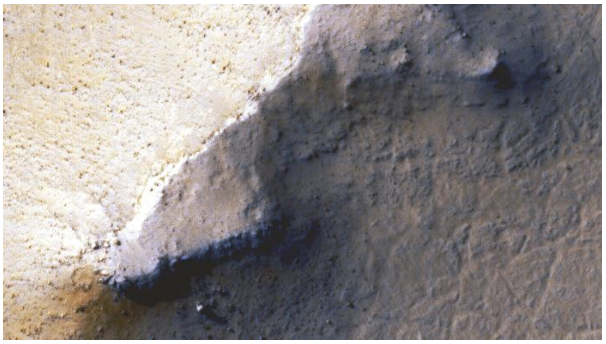

Fig. 3. HiRISE image showing layering in the capping deposit of one of the ridges and possibly in the underlying basal unit. Image no. PSP_009985_1770, 27 cm/pixel, width ~ 100 m.

The most likely cementing materials on Mars are iron oxides, silica, and sulfates [4]. Mechanisms may include evaporation of surface water soon after sediment deposition, fluid mixing during regional groundwater flow or cooling of hydrothermal or basinal fluids as they near the surface [4]. Chlorides may also be important given the high Cl abundance in the martian soil and the discovery of chloride deposits [9]. Cementation can be preferentially localized to the channels by the cooling or evaporation processes.

Formation of the Miyamoto features by other processes are unlikely. Eskers usually have rounded or sharp crests and do not generally have a resistant top layer [10], in contrast to the Miyamoto ridge complex. The features also do not exhibit the features of lava flows or lava filled channels, including flow lobes, levied channels, and pressure ridges. The formation of channel deposits by surface runoff released by an impact into a water/ice-rich subsurface target [e.g. 11] is unlikely given the evidence that the underlying phyllosilicate bearing material is a widespread relatively flat deposit that probably post-dates the formation of the Miyamoto crater. Based on the available evidence, a fluvial origin for the inverted features in Miyamoto seems most likely. The possibility that this area was originally buried and exhumed by Meridiani Planum layered rocks suggests an early age for the fluvial episode, consistent with that of nearby incised ancient river valleys at ~3.74 Ga [13].

Impact generated hydrothermal processes in candidate landing sites in impact craters - The missing data problem: Although the proposed landing sites are often located in impact craters, the most likely locations for finding impact generated hydrothermal deposits, namely crater walls and central peaks are often not imaged. This is unfortunate as the possible presence of such materials would provide an alternative kind of deposit that could potentially represent a habitable environment. A site with evidence for sedimentary and hydrothermal deposits will therefore have a much geater chance for mission success in terms of important kinds of deposits to study. The problem with providing context image data for landing site ellipses is not a new one. During the MER landing site selection process, almost no high resolution MOC images were taken of the area surrounding the landing site ellipse in Gusev crater. This oversight contributed to the misidentification of the nature of the crater floor, which turned out to be basalt, not the expected sedimentary deposits. Only the combination of landing near the Columbia Hills and the unexpected longevity of the Spirit rover, led to the remarkable success of that mission.

In the case of impact generated hydrothermal deposits in Miyamoto crater, the data examined for our published studies [1,9] involved only the CRISM nadir pointing data seen in Figure 1b. This area on the crater floor was also well covered by HIRISE images. Unfortunately, the source of the inverted channels at the base of the crater wall and the wall itself were not imaged by either nadir pointing CRISM images or HIRISE images, although the desirablity for such images was communicated to the teams. The potential for finding interesting deposits in this region is shown by the data from an area near the western rim of Miyamoto Crater, also proposed as a candidate landing site (Figure 4.). This area has evidence for two kinds of phyllosilicates and hydrated minerals.

However, we recently became aware of the presence of high resolution off-nadir CRISM images (Fig. 1c) that provide a substantial increase in coverage of the rim of Miyamoto Crater. These images have high spectral resolution although somewhat lower spatial resolution than the nadir CRISM images. We plan to examine these image in the near future for mineralogical evidence of aqueous and hydrothermal deposits on the crater wall of Miyamoto, in addition to requesting further nadir pointing data. Similar CRISM data in other areas of critical scientific interest or importance for landing site studies needs to be as easily available as the nadir pointing data. The discovery of evidence for impact generated hydrothermal deposits or aqueous spring deposits along the crater wall could add substantially to the interest in this site for future landed missions.

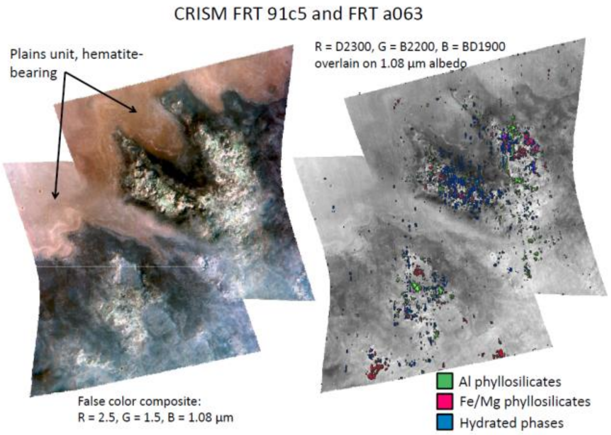

Fig. 4. CRISM data from Wiseman (MARSOWEB - MSL site selection page) showing phyllosilicates in highlands material on or near the western rim of Miyamoto crater. A search for similar materials with high resolution CRISM images near the proposed landing site on the south western part of miyamoto crater is yet to be done.

Conclusions: The Miyamoto crater floor contains inverted paleochannel deposits. that appear remarkably similar to terrestrial examples, as seen in the Cedar Mountain Formation near Green River, UT. In this interpretation, the capping material represents cemented river paleochannel deposits. CRISM spectral observations [2,12] indicate the presence of Fe/Mg phyllosilicates in close association with the putative fluvial deposits, supporting a fluvial origin for the ridge features. As a potential landing site for MSL, the desirability of the site would have been enhanced with evidence for hydrothermal activity, even if this activity was not actually in the proposed ellipse. The most likely location for such activity, the crater rim has not been imaged by CRISM at its highest resolution with nadir observations. However, there are high spectral resolution off-nadir CRISM images that provide a substantial increase in coverage of the crater rim. We hope to examine these images in the near future for mineralogical evidence of aqueous and hydrothermal deposits. Future investigations of potential landing sites should include careful selection of context images as well as coverage of the landing site ellipses in order to have the best available information on a site. In particular, the rims and central uplifts of impact craters represent important locations for aqueous and hydrothermal deposits as discussed in a recent white paper submitted to the Decadal planning process by S.P. Schwenzer and colleagues.

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Acknowledgements: Supported by NASA NNX 08AL74G (HEN), the NASA/JPL/LANL/MSL-ChemCam project (HEN, Co-I.), and NASA/MRO/CRISM (TLR).