THE CASE FOR MAWRTH: RATIONALE FOR SELECTING THE MAWRTH VALLIS REGION AS THE MSL LANDING SITE.
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Introduction: After the most recent Mars Science Laboratory (MSL) landing site workshop in October 2007, six possible landing sites, including one in the Mawrth Vallis region, have been selected as top candidates for the MSL mission in 2009 [1]. The purpose of this presentation is to evaluate the up-to-date scientific rationale for sending MSL to the Mawrth Vallis region. This region provides a mineralogically and geomorphologically diverse landscape to explore for clues to Mars' past habitability.

Geologic Overview: Ancient, layered, light-toned rocks of possible sedimentary origin were described in the Mawrth Vallis region with high-resolution MOC images [2]. Using near-infrared spectral data from the Mars Express OMEGA instrument [3], ferruginous and aluminous clay minerals were detected in association with these rocks. Later observations with OMEGA and the Mars Reconnaissance Orbiter CRISM experiment confirm the presence of the clay minerals nontronite and montmorillonite [4], and show additional, localized exposures of kaolinite and hydrated silica [4]. The rocks are interpreted as sedimentary and/or pyroclastic because the clay minerals occur within a geomorphically diverse, complex (100s of layers), thick (>600 m) section of rocks present over a large area (>80,000 km^2) [5-6]. In simplest terms, this is the rationale for exploring the region with MSL: The occurrence of abundant smectite clay minerals argues for a habitable environment in the past because smectite clays commonly form in aqueous environments, under moderate pH, low P-T conditions that could be suitable for life.

The Landing Site: Four possible landing ellipses are proposed in the Mawrth Vallis region [Figure 1]. Each ellipse is approximately 25 km by 20 km. Two of the ellipses (Sites #2 and #3) were chosen to land directly on the light-toned, clay-bearing rocks. In these cases, the advantage is that the rover will have immediate access to the highest priority science targets. Both sites #2 and #3 are in the vicinity of aluminous and ferruginous clay minerals and both sites will allow the opportunity to study this mineralogical transition. It is inferred that the change in mineralogy is probably tied to lithologic variance and representative of ancient environmental change [7]. The disadvantage of these two sites is some concern about the surface roughness (i.e. surface slopes at the scale of meters to tens of meters) associated with the intrinsic geomorphic properties of the deeply eroded, light-toned unit. In case surface roughness is found to be a problem, two other ellipses have been proposed (Sites #1 and #4) which are positioned to land on the smoother dark-toned surfaces. In these cases, the rover would have to drive approximately 10-13 km (~150 sols), to visit the closest intact, high priority science targets. However, Site #1 is positioned adjacent to a thick (>300 m) thick sequence of well exposed stratigraphic section, which makes this location enticing. Site #4 is positioned within driving distance of perhaps the most mineralogically intriguing part of the Mawrth Vallis region – a section of rocks including not only montmorillonite and nontronite, but also kaolinite and hydrated silica.

Together, these four sites represent the best locations to land based on a balance of safeguards against Entry Descent Landing (EDL) hazards with high priority science objectives. However, as we move toward the possible selection of the Mawrth Vallis region as a final site, several key issues will be topical.

Outstanding Questions: Some questions remain with regard to the origin of the clay minerals and the geologic context in which they occur, including:

Abundance of clay minerals. The detection of clay minerals alone does not imply habitability. If the clays occur only in trace abundances, it has very different implications for the MSL mission than if abundant clay minerals are present. However, this region has the strongest spectral signature of clay minerals of any location on Mars and spectral modeling of near-infrared spectra suggests large abundances of clay minerals (30-65% in different pats of the Mawrth Vallis region) [8]. Thermal infrared spectral data suggest the presence of silica in addition to clay minerals [9].

Lithologic context. The lithologic context of clay minerals in the Mawrth Vallis region is not known for certain. However, clay minerals occur throughout much of a thick section of rocks with 100s or 1000s of geomorphically diverse units. Such a thick, dynamic section of rocks could only be deposited in dynamic surface conditions (either in time, or in space – *i.e.* Walther's Law). The total thickness of the section of light-toned rocks, the observation of complex internal layering, and the presence of unconformities within the section indicate that the clay-bearing rocks were deposited over a duration of time rather than in a single catastrophic event, as has been proposed before [10].

No single idea of lithologic context is likely to capture the diversity of the Mawrth Vallis region. Layering is present at the scale of meters to decimeters, over a large area, and is, to the limit of resolution of the instruments, coupled mineralogic variation [3-8]. Therefore these rocks probably represent an ancient, regional-scale aqueous geologic environment – exactly the type sought for exploration by the MSL rover. The geomorphic diversity is key. It is certainly possible that many of the competent, cliff-forming clay-bearing rocks in this region may be altered pyroclastic deposits, impactites, or sediments with little alteration. But by contrast, the layers within this section that are incompetent and apparently clay mineral-rich also require and explanation. These layers could well be shales or other clay-rich materials with a good possibility of preserving biologic matter.

Conclusions: Four landing ellipses are proposed for MSL to explore the Mawrth Vallis region. There are several strong lines of scientific evidence to suggest this should be the landing region for MSL: 1) This region has the strongest spectral signal of clay minerals of any place on Mars; 2) Alteration minerals in this region are diverse, including nontronite, montmorillonite, hydrated silica, and kaolinite; 3) the section of rocks probably represents an ancient, regional-scale aqueous geological environment on early Mars that could have been suitable for life; and 4) the clay minerals are present throughout a thick, geomorphically/lithologically diverse section of rocks that are certain to represent a range of depositional environments.

References: [1] Grant, J. et al., (2007) *2nd MSL Landing Site Workshop*. [2] Malin, M. and K. Edgett (2000), *Science*, 290, 1927- 937. [3] Poulet, F. et al. (2005) *Nature* 438, 623-627. [4] Bishop, J. L. et al. (2007) *EOS Trans. AGU*, Abstract #P13D-1559, [5] Loizeau, D. et al. (2007), *JGR*, 112, (E8), E08S08. [6] Michalski, J. and E. Noe Dobrea (2007), *Geology*, 35; no. 10; 951-954. [7] Loizeau, D. et al., LPSC XXXIX, (this meeting). [8] Poulet, F. et al. (2007), *Eos Trans., AGU*, 88(52), abstract # P11E-07. [9] Michalski, J. et al. (2007), *Eos Trans., AGU*, 88(52), abstract #P11E-06. [10] Tornabene, L. et al. (2007), Seventh Mars Conf, abstract #3288.

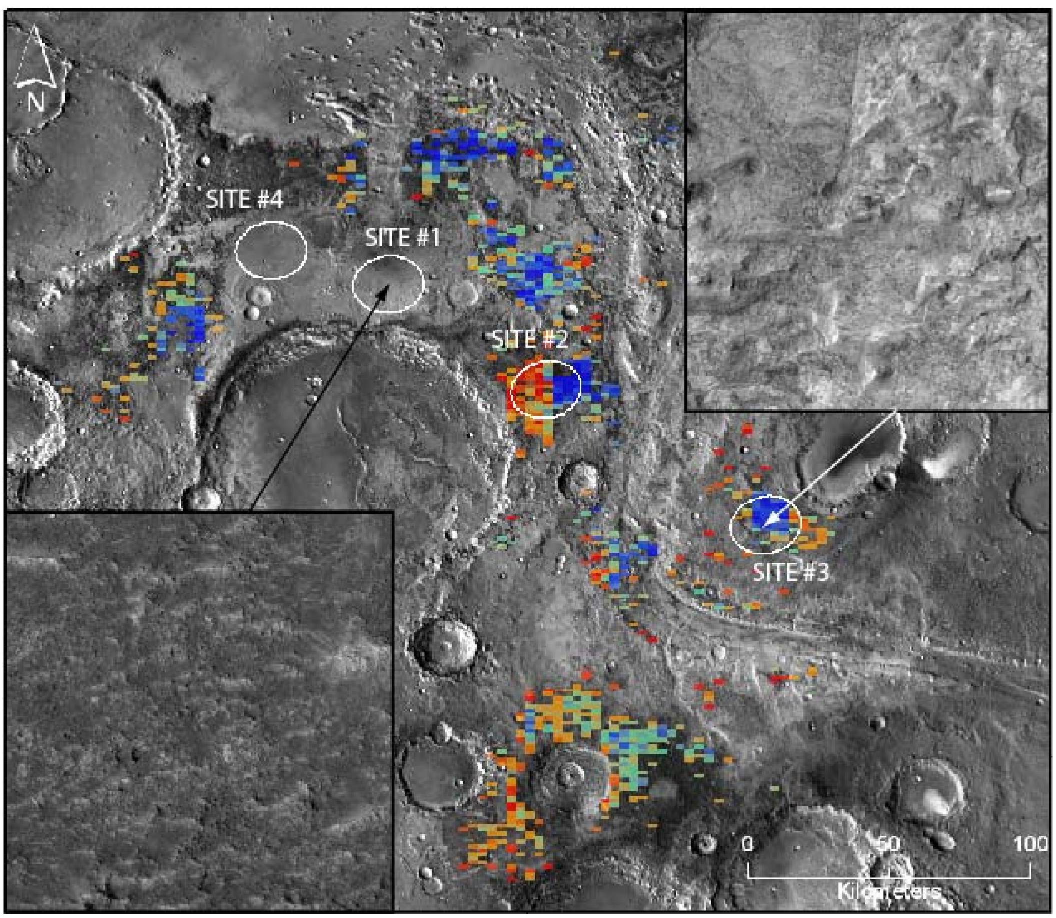

Figure 1: Map showing the four proposed landing ellipses in the Mawrth Vallis region. The background image is a THEMIS daytime IR mosaic. Red colors correspond to montmorillonite spectral detections (2.2 μm scaled band depth) and blue colors correspond to nontronite spectral detections (2.3 μm scaled band depth). Insets are HiRISE images (PSP_001388_2035 and PSP_003063_2050) showing the surface roughness of ellipses at high resolution.