MARS UTAH ROVER FIELD INVESTIGATION 2016 (MURFI 2016): TARGETING, LOCALIZATION, AND IN-SITU SCIENCE OPERATIONS L.J. Preston[1], J. M. Davis[2], P. Fawdon[1], M.R. Balme[3], P.M. Grindrod[1], C.R. Cousins[4], W. McMahon[5], J.C. Bridges[6], S. Gupta[7], and the MURFI science team[8]. [1]Birkbeck, University of London, [2]University College London, [3]The Open University, [4]University of St Andrews, [5]University of Cambridge, [6]University of Leicester, [7]Imperial College London, , [6](see LPSC2017 Abstract no. 1837).

The Mars Utah Rover Field Investigations (MURFI) [1] was a rover deployment and commanding field test intended to demonstrate the capacity of the UK Space Agency (UKSA) in collaboration with international partners to deploy a rover analogue mission and carry out a geologically focused traverse.

Here we report on the science conducted during the "in sim" parts of the mission. These observations build on the current working hypotheses (CWH) made during orbital geological assessment of the "landing ellipse" (described in [2]) and is guided by the strategic framework for the mission (described in [1]).

Preliminary Landing Site Assessment. We conducted a preliminary study in line with an "ExoMars-like" mission aim (e.g., 4, 5) using a set of "Mars-equivalent" data sets [2]. From the reconnaissance photo geological map (Figure 1) we developed the following CWH and identified science targets to be tested by the in-situ operations.

(1) Resistant outcrops represent a lithified sediment unit of either aeolian, volcanoclastic or fluvial origin. Accessible for study in fall rock locations.

(2) The layered scarps represent some geochemically variable strata of a material weaker than the resistant outcrops; possibly mudstones, clays or marls.

(3) The anomalously bright regions (white/less Fe^{3+}) are possibly an end member of the layered formation.

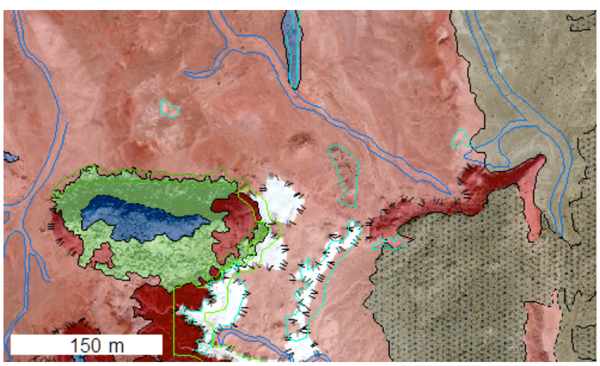

Figure 1: *A subset of the photogeological map focusing on the area in which the rover operated. Reds = upper and lower layered scarp and plains formations, blues = resistant formation, browns = bark formation, green out of situ boulders, blue lines = modern alluvial, and green lines = science targets [2]*

Traversability, Mapping and Localization (TML) In any rover mission it is imperative to know where the rover is both relative to science targets and potential hazards. To achieve this, we used the following localization and target naming protocols.

Localization. This was achieved on two scales. Firstly, for distal localization we used 360 PanCam [6] panoramas and PanCam single frame images to triangulate between pairs of orbital identifiable features that were vertically aligned in rover imagery. Secondly for proximal localization we used a combination of Pro3D [7] meshes created from PanCam mosaics and polar projected 360 PanCam mosaics to explore outcrops and to characterize the drive surface.

Naming convention. Features large enough to be identified from remote sensing analysis were given non-genetic names (e.g., "Big Mesa") that persisted, where possible, through surface operations (Figure 2). Features and targets identified from rover data were named randomly after UK towns/villages with a population less than 10,000 residents (e.g., "Wimblington").

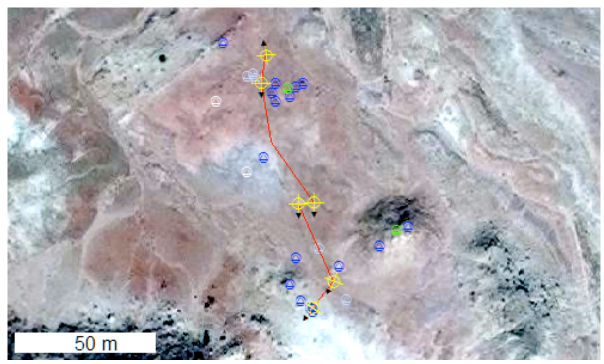

Figure 2: *TML map for the MURFI rover by Sol 9 showing rover locations (yellow cross-hairs), rover waypoints (red cross-hairs) and the rover drive path (red line). Also shown are geographic, target and navigation locations (dark blue, light blue and green circumscribed triangles respectively)*

In-mission Observations. During the 9 Sol mission and ~ 120 m traverse the following observations and working hypotheses were made.

(1) The loose float rocks that are found on the plains are compositionally immature and poorly sorted, with rounded pebble fragments observed up to 2-3 cm in diameter. They are likely water-lain sediments from laterally unconfined modern flood event(s).

(2) The resistant formation is observed capping ridges and as piles of rubble at the base of scarps (e.g.,

Big Mesa, Wimblington, and Cransford). The resistant formation appears to be made up of lithified, indurated sediment and has likely protected much of the layered formation beneath from erosion.

(3) Within the resistant formation (Figures 3 & 4), cross-stratified and planar bedding are visible, as well as recessive interbeds (Figure 3). This suggests that much of the resistant formation is a finely-bedded sandstone, either fluvial or aeolian in origin, which cannot be determined without grain size measurements. Fluvial sandstones would, however, be consistent with the CWH from orbital mapping [2]. The recessive interbeds could be eroded mudstones or fine-grained sandstones.

Figure 3: *HRC tile of Cransford, a finely-bedded sandstone with recessive interbeds.*

(4) Within the layered formation that is exposed at the edges of Big Mesa (Figure 4) and the more distant ridges, banding is visible at the scale of the outcrops, but finer scale bedding is not observable within images obtained from the rover ~ 10s of meters away. Color variations between white and dark layers within the layered formation suggest geochemical variations (e.g., Fe^{3+} content) due to modern weathering effects, or alternatively lithological variations, possibly due to different depositional environments.

(5) One CWH postulated that the layered formation is made up of mudstones or marls. This would make the layered formation an ideal environment to preserve biomarkers and organic materials, and it was therefore considered a priority target for the mission.

(6) The high albedo unit (Ab), exposed to the east of Big Mesa (Painswick Patch and the Skinningrove drill site), is visible weathering out of the base of Big Mesa. There were three CWH as to its provenance 1: bedrock, part of the layered formation; CWH 2: surficial material, possibly evaporites formed above a low permeability layer. CWH 3: bedrock that has been surficially altered (a combination of 1&2). CWH 3 was taken as the most likely scenario; if Painswick Patch/Skinningrove is part of the layered formation, they, too, may be composed of mudstones or marls.

(7) Infra-red spectral analyses indicated the presence of Al-bearing phyllosilicates, likely montmorillonite, within the layered formation. Montmorillonite can form as a weathering product. This is consistent with CWH 2 & 3.

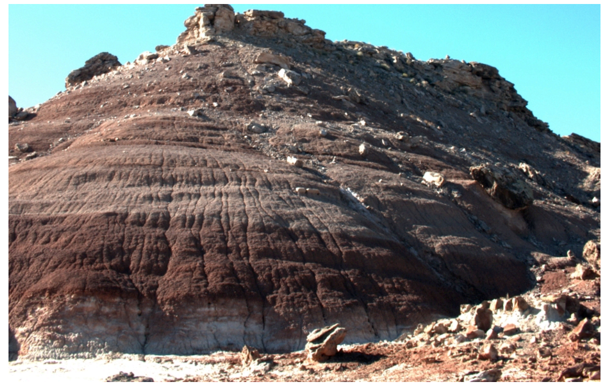

Figure 4: *HRC mosaic of Big Mesa, made up of the resistant formation (top, coarse material) and the layered formation (colored material).*

The drill site. After 8 days, in line with mission objectives [1], we identified a location to drill for the following reasons:

(1) If Painswick Patch/Skinningrove were mudstones, they would then be an ideal environment for biomarker preservation and concentrating organic material, making them good sites for drilling.

(2) Poddington (Figure 5), part of the Skinningrove area, was selected as the drill site for the rover for both scientific and accessibility reasons.

(3) Loose pebbles and detrital quartz grains (modern, surficial deposits and weathering products) were present on the material surrounding the drill site. Poddington was chosen as the drill site to avoid the larger pebbles, which could pose a hazard to the drill.

Figure 5: *Poddington, part of Skinningrove*

References: [1] Balme et al., 2017, *LPSCXLVIII, Abstr. 1837*; [2] Grindrod et al., 2017, *LPSCXLVIII Abstr 1902*; [3] Vago et al., 2017, *Astrobiology (in press)*; [4] Balme et al., 2016, *LPSCXLVII, Abstr. 2633* [5] Sefton-Nash et al., 2015, *LPSCXLVI, Abstr. 1414* [6] Coates et al., 2017, *Astrobiology (in press)*. [7] Paar et al., 2015, *EPSC Abstr. 2015-345.*