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GALE'S YARDANG UNIT REVEALED BY CHEMCAM REMOTE MICROSCOPIC IMAGER ON MARS

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Introduction: The ChemCam instrument onboard the Curiosity rover provides high-resolution imaging capabilities thanks to its Remote Microscopic Imager (RMI) camera [1, 2]. RMI images are a powerful tool to investigate the detailed texture and morphology of soils and rocks, and to perform geologic investigations at long distance in Gale crater. We discuss here the observations acquired while looking toward the base of the so-called Light-toned Yardang unit [3], hereafter referred to as the “Yardang unit”.

Observation at long distance with RMI: The RMI uses a compact Schmidt-Cassegrain telescope, with a fixed primary mirror and a movable secondary mirror, to acquire black and white images [1, 2]. Whereas RMI was originally designed to document ChemCam laser shots at few meters only, it was recognized during the first year of operations on Mars that it could also serve as a powerful long distance imaging tool, thanks to its 700 mm-long focal length [2] and capacity to automatically focus up to infinity [4]. This capability is highly complementary to the color Mastcam 100 mm focal-length camera. With an angular pixel size of 19.6 μ rad on a 1024x1024 detector, RMI has a pixel size of \sim 20 cm when observing at 10 km, providing a pixel size smaller than HiRISE at distances lower than \sim 10 km. It also provides viewing angles and lighting conditions complementary to orbital imaging. Occasionally, RMI images at long distance can suffer from a bright halo due to scattered light. This effect can be mitigated using empirical corrections [5].

Observations toward the Yardang unit: The first RMI observations pointing toward the Yardang Unit occurred on Sol 1183 (Fig. 1).

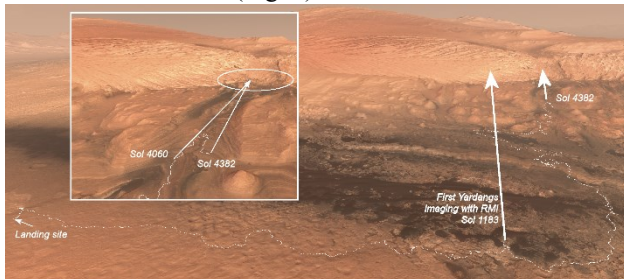
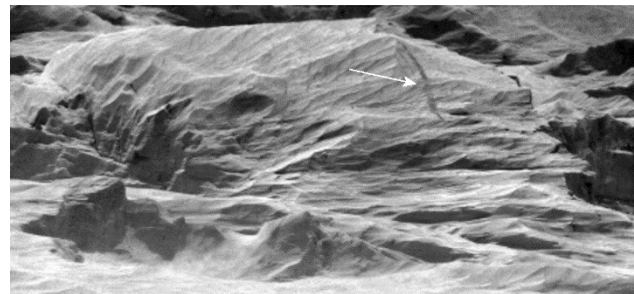


Fig. 1: Context of the observations. The white line corresponds to Curiosity's traverse. The first RMI observation toward the Yardangs occurred on Sol 1183. More systematic observations were acquired later on, in particular between sols \sim 4000 and 4382.

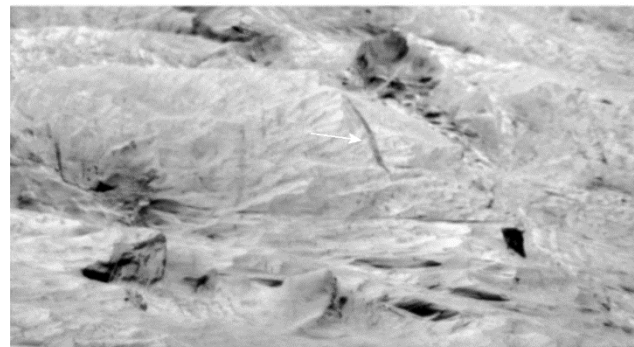
These first Yardangs observations were analyzed in [6]. RMI images helped to identify successive sequences of aeolian deposition-erosion in the Yardang Unit, probably generated by cyclic changes from semi-arid to arid conditions, coupled with climatic cycles, including wind regime changes. Other sets of single observations were acquired occasionally during the traverse. More recently, a systematic imaging campaign was carried out when Curiosity climbed along the upper part of Gediz Vallis Ridge (inset of Fig. 1), building a set of adjacent mosaics with the highest resolution on the Yardangs achieved so far due to the short distance, reaching less than \sim 4 km.

Comparison between multi-date observations:

Observations of the same area performed at different times in the mission can be used to look for surface changes. An example is shown in Fig. 2. Despite a different viewing angle and a different image resolution, a dark slope streak identified on sol 1994 from a distance of \sim 7 km does not seem to have changed when observed 6 years later on sol 4280 from a distance of \sim 3.5 km.



sol 4280



sol 1994

Fig. 2: observations of a dark slope streak on a 6 years interval. No change is observed on the slope streak.

Getting closer: views from the upper Gediz Vallis ridge:

Between Sols 3671 and 4382, several RMI long distance observations have been acquired pointing at the base of the Yardang unit. Despite small parallax and resolution effects, this set of observations can be used to progressively build a mosaic of the lowest part of the Yardang unit just above upper Gediz Vallis. Fig. 3 corresponds to an assemblage of 137 single RMI images from 14 individual mosaics acquired between Sol 4060 and Sol 4299. It reveals multiple morphologies and features such as fine-scale layering, wind erosion patterns, scallops, a slope streak, or slope avalanches. The observed finely-dipping beds are interpreted as aeolian dune foresets [6].

Fig. 4 shows a single mosaic acquired Sol 4297, from a distance of ~4 km. At such a distance, the RMI pixel size is ~8 cm, allowing the identification of meter-scale features, such as scallops patterns (inset of Fig. 3).

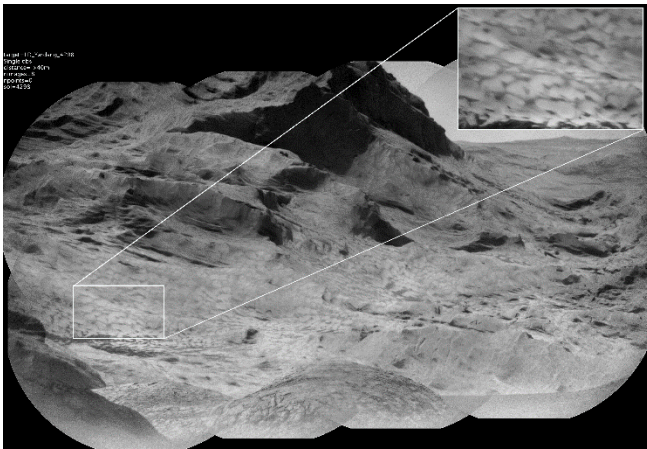


Fig. 4: RMI Mosaic acquired Sol 4297, revealing various landforms such as scallops.

Retrieving information from multiple lighting and 3D stereoscopic RMI pairs:

The central part of the mosaic has been targeted at several occasions with a slightly different viewpoint. In addition to emphasizing variations due to lighting conditions, this should in theory allow to perform 3D reconstruction, as

was done in [7]. This could help in understanding the attitude of sedimentary structures and deduce their origin. Fig. 5 illustrates an example of outcrop with fine-scale layering seen from a different viewing perspective.

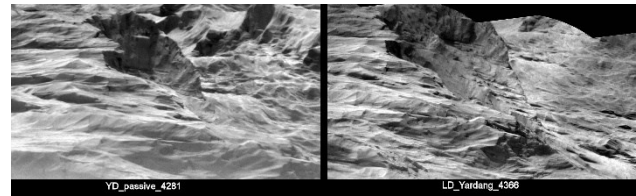


Fig. 5: Example of parallax between two sequences taken 85 sols apart on Sols 4281 and 4366.

Finally, the sequence labeled YD_passive_4281 (ccam05280) also included passive spectroscopy acquisitions [8], to document the spectral features of the Yardang unit. No strong diagnostic spectral signature was found at this occasion. This is either due to the dust coverage, or to the intrinsic neutral nature of the bulk materials in the 0.4-0.8 μm range sampled by ChemCam.

Conclusion: ChemCam's RMI is a powerful tool for long distance investigations. Year after year, Curiosity is getting closer to the Yardang unit. The current shortest distance (<4 km) allows to reveal morphologies such as scallops, or fine-scale layering, which were not accessible from orbital imagery only. If Curiosity ever reaches the base of the Yardang unit [9], it would provide the opportunity to sample it directly and reveal its bulk composition.

References: [1] Maurice et al., Space Sci. Rev. 170, 95-166, 2012. [2] Le Mouélic et al., Icarus 249, 93-107, 2015. [3] Le Deit et al., J. Geophys. Res. Planets, 118, 2439-2473, 2013. [4] Perret et al., 14th International Conference on Space Operations, 2016. [5] Le Mouélic et al., LPSC, abstract #1318, 2024. [6] Dromart et al., EPSL 554, 116681, 2021. [7] Caracava et al., Remote Sensing 13(20), 4068, 2021. [8] Johnson et al., LPSC, this issue. [9] Vasavada et al., LPSC, this issue.

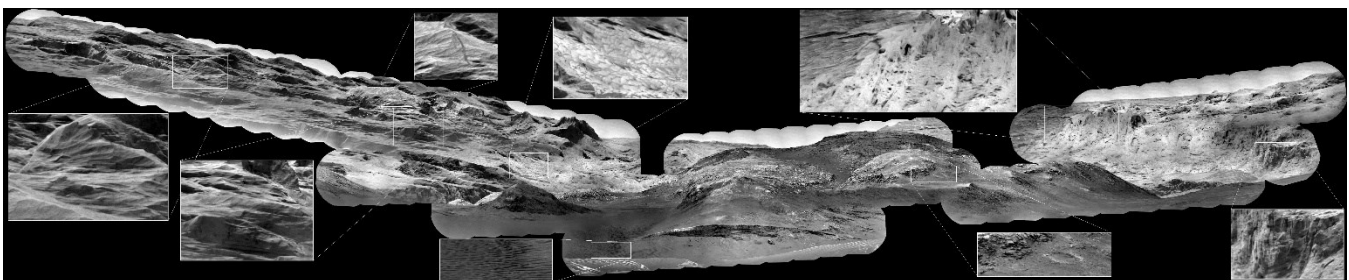


Fig. 3: Long Distance imaging of the Yardangs area with 137 individual RMI images acquired between Sols 4060 and 4299