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PROW & CO.: INSIDE THE FLUVIAL LENSES OF GALE'S LAYERED SULFATE UNIT. G. Caravaca^{1*}, S. Gupta², W. Rapin³, J. Schieber⁴, L. Le Deit⁵, N. Mangold⁵, S. Le Mouélic⁵, C. O'Connell-Cooper⁶, C. A. Mondro⁷, J. M. Davis², E. S. Kite⁸, O. Gasnault³, N. L. Lanza⁹, A. Fraeman¹⁰, A. Vasavada¹⁰. ¹GET, CNRS, Univ. Toulouse, France; ²Imperial College London, UK; ³IRAP, CNRS, Univ. Toulouse, France; ⁴Dept. Of Geol. Sci., Indiana University, Bloomington, IN, USA; ⁵LPG, CNRS, Nantes Univ., France; ⁶Univ. of New Brunswick, Fredericton, NB, Canada; ⁷Caltech, Pasadena, CA, USA; ⁸Univ. of Chicago, Chicago, IL, USA; ⁹LANL, Los Alamos, NM, USA; ¹⁰JPL, Pasadena, CA, USA; *gwenael.caravaca@univ-tlse3.fr

Introduction: For three years, the *Curiosity* rover has been exploring the layered sulfate unit (LSu) of Gale crater, Mars. Not only interesting as a potential record of a monotonic environmental shift towards arid conditions at the Noachian-Hesperian transition, we now know that this interval evidences complex environmental parameters which are characterized by alternating wetter and drier conditions at various timescales [1-3]. Such changes in depositional setting are particularly apparent within the Contigo mbr. of the Mirador fm. There, the LSu strata is dominated by stacked, large-scale cross-stratified aeolian sandstones, tens of meters in thickness, that are punctuated by erosion-resistant, decameter-wide, darker-toned and mostly lens-shaped sandstone bodies that suggest a fluvial deposition [4].

Using image data acquired with Mastcam and ChemCam's RMI, we detail a wealth of sedimentary structures distributed across these lenses, focusing at the Prow outcrop and neighboring buttes (Fig. 1). We also provide a first assessment of the chemical compositions seen by ChemCam's LIBS at the Prow.

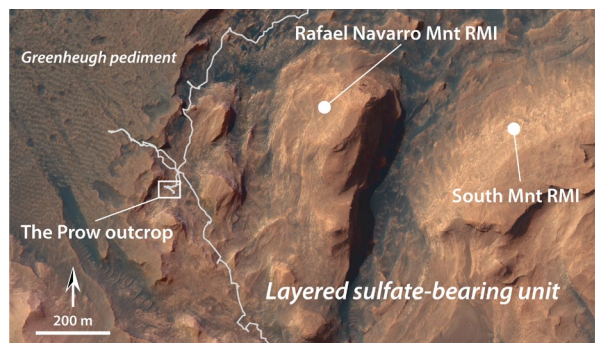


Fig. 1: Localization of the Prow outcrop and similar lenses on Rafael Navarro Mountain and South Mountain buttes in Gale crater's LSu (HiRISE images).

The Prow outcrop: The Prow outcrop was explored and investigated by the *Curiosity* rover between Sols 3349 and 3379. The outcrop itself is a ~20 meter-long, ~0.5-1 meter-thick, bench-forming, erosion-resistant sandstone body that contrasts with surrounding bedrock (Fig. 2a). Closer inspection and reconstruction in 3D [5] (<https://skfb.ly/o8DJZ>) highlight an overall concave shape for the outcrop (Fig.

2b). The lens mainly consists of medium to coarse sandstones (with possible pebble conglomerate at the very base), with an overall fining-upward pattern.

At the outcrop scale, we observe several sets of amalgamated, lens-shaped packages (red lines in Fig. 2b). Within these bodies, we note the presence of decimeter-thick, cross-stratified beds, mostly concentrated in the lower part of the outcrop (blue lines in Fig. 2b). These suggest subaqueous deposition in a dynamic, high-energy setting, most compatible with river channels.

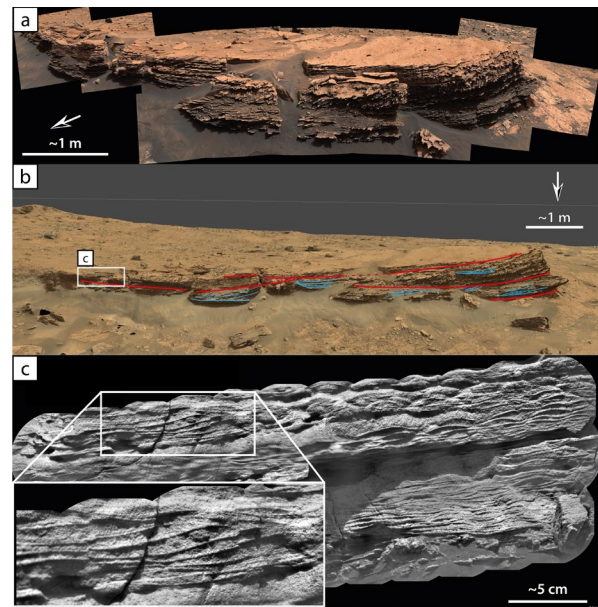


Fig. 2: Observations at the Prow outcrop. a) General view of the Prow outcrop (Mastcam sequence mcam01285). b) 3D photogrammetric reconstruction of the Prow outcrop, with large-scale structures indicated: lens-shaped bodies (red) and cross-stratification (blue). c) Example of small-scale structures seen with ChemCam's RMI (sequences ccam01364 to ccam05364). Inset shows a well-preserved set of climbing ripples.

In close-up, we observe several small-scale sedimentary structures supporting this interpretation (Fig. 2c), especially in the lower and middle parts of the channels. We note the presence of several sets of cm-scale asymmetric ripples, but also the occurrence of well-preserved climbing ripples (inset in Fig. 2c). The upper parts of the channels show different kind of

structures. Among them are symmetric ripples, similar to that observed at the Marker Band higher in the Mirador fm. [3] and interpreted to form within stationary bodies of water. We also observe “flaser-like” bedding, composed by alternating sandstone ripples and mm-scale siltstone draping (possibly mudstone). Both these textures suggest changing and less energetic depositional parameters, such as combined flow (current plus waves), that are more compatible with a lake or pond.

The vertical succession of these higher- and lower-energy structures without any distinct break indicates a rapid change in depositional setting, with incision of fluvial channels, followed by accumulation of cross-bedded sandstones, finally evolving into transient ponds, possibly oxbow lakes, as channels were abandoned and/or water and sediment input dramatically diminished.

Lenses across the regional buttes: Remote observations using ChemCam’s RMI have been carried out toward the buttes surrounding the rover’s traverse to look for similar outcrops (Figs. 1 and 3).

On the western flank of Rafael Navarro Mountain, we observe a ~15 m-wide and up to ~2 m-thick lens (Fig. 3a). It conspicuously pinches out toward the South (right in Fig. 3a), and exhibits an incomplete concave lens shape (probably buried at the left margin). Inside that lens, we observe a series of sandstone beds arranged in meter-scale cross-stratification (blue lines in Fig. 3a).

On the north-western flank of South Mountain, we observe a well-exposed lens-shaped body ~12 m-wide and up to ~3 m-thick at its largest point. This lens shows a sharp concave bottom contact, and contains well-expressed, meter-scale cross-stratification (blue lines in Fig. 3b). Contrary to the Prow and Rafael Navarro Mountain outcrops, this lens is completely capped by conformable, lighter-toned deposits of the regional aeolian cross-bedded Mirador fm. This indicates that the lens’ formation was contemporaneous with the deposition of the aeolian dunes that comprise most of the Mirador fm.

Unfortunately, the distance of these observations prevents us from clearly discerning any structures smaller than the meter-scale, and therefore assessing any of the potential local variations such as those observed for the Prow.

Geochemical composition of the Prow seen by ChemCam: The ChemCam LIBS data acquired on several targets at the Prow highlight a distinct composition from the regional bedrock of the Mirador fm. Mg content is consistently higher than the average (> 5 wt.%) and K content is slightly higher than average

(~1 wt.%). Cr and Li also differ from the overall bedrock, with Cr being consistently lower than average, and Li largely above average. While data analysis is ongoing, this trend agrees with data from APXS on similar targets [6].

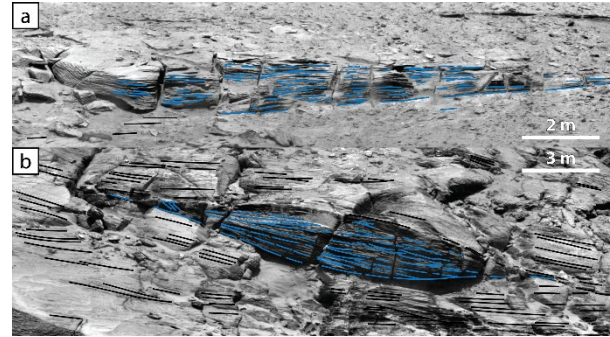


Fig. 3: RMI long-distance observations of “Prow-like” lenses at Rafael Navarro Mountain butte (a, sequence ccam02245) and at South Mountain butte (b, sequence ccam03151). Both lenses show a concave base and inner cross-stratification (blue lines). See Fig. 1 for localization.

Conclusions and perspectives: Long-distance and close-up observations of erosion-resistant lenses in the Contigo mbr. of the Mirador fm. has enabled us to identify multi-scale sedimentary structures indicative of subaqueous conditions, evolving from energetic, fluvial channels to less energetic, lacustrine conditions. The chemical composition of these lenses, different from that of the overall aeolian bedrock, also indicates that they result from input of “fresh” material and not a local reworking. These data support a fluvio-aeolian setting for the Contigo interval, that saw recurrent episodes of fluvial incursions, with channels and ponds being incised within the substrate of aeolian dune fields (e.g., [7]). Thus, rather than recording a monotonic drying-out of Mars, the LSu records a complex and quickly-evolving climatic pattern that requires further analyses [8].

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