FIRST INSIGHTS ON DEPOSITIONAL ENVIRONMENTS RECORDED IN THE "CLAY-SULFATE" TRANSITION AT GALE CRATER. W. Rapin[1], G. Dromart[2], D. Rubin[3], L. Le Deit[4], S. Le Mouélic[4], O. Gasnault[1], G. Caravaca[4], N. Mangold[4], V. Fox, J.L. Dickson[5], B.L. Ehlmann[5], K. Herkenhoff[6], L.A. Edgar[6], R.B. Anderson[6], P. Pinet[1], S. Maurice[1], R.C. Wiens[7]. [1]IRAP, université de Toulouse, France, william.rapin@irap.omp.eu; [2]Univ. Lyon, LGLTPE, France; [3]University of California, Santa Cruz; [4]LPG, CNRS-Univ. Nantes, France ; [5]Caltech-JPL, Pasadena CA; [6]Astrogeology Science Center, USGS, Flagstaff AZ; [7]LANL.

Introduction: Gale crater preserves a 5-km-thick sequence of stratified rocks, the lower-most section of which exhibits orbital spectra signatures of clay minerals transitioning up to sulfates over several hundred meters of stratigraphy [1,2]. Understanding the reason for this wet-to-dry change recorded in the mineralogical signature is one of the primary objectives for the Curiosity rover. The rover is currently positioned at the base of the Layered Sulfate unit (LSu) exposed over a thousand meters of elevation, which is characterized from orbit by its general-layered texture and spectral signatures of monohydrated and polyhydrated Mg-sulfates [1–3]. Most of the LSu is composed of subparallel beds that vary in albedo, texture, and thickness [4]. The lower ~150 m interval of the LSu is topped by a distinctive layer referred to as the "marker bed" (Figure 1).

Here we reconcile orbital data with new *in situ* analyses using MastCam and the ChemCam instrument's Remote Micro-Imager (RMI) to provide an updated documentation of the LSu stratal components at large outcrop scales and at the highest available resolution. We then propose provisional models for the depositional systems and their evolution in the sulfate unit, hypothesized to reflect overall a history of the diminishing availability of liquid water on Mars.

Dataset and Methods: The ChemCam RMI can perform long-distance image acquisitions, i.e. several kilometers away with the smallest discernable features between 4-10 cm at 1 km [5,6]. Beyond 5 kilometers the spatial resolution of HiRISE orbital images is better than that of the RMI, yet both still complement each other by offering orthogonal views. Usually a series of individual images are acquired forming a mosaic of the target, which are first processed, including dark and flat field correction, then stitched, denoised and slightly sharpened to highlight small scale contrasts [7].

Hiatal surfaces in the transition interval: The cliff-forming lithology of the lowest part of the LSu stratigraphy reveals massive outcrops marked by one, or possibly several, unconformable planar surfaces (Figure 2a). Textural features appear to vary across that surface, including vein pattern similar to satin-spar [8], nodular texture density, dark- and light-toned heterogeneities forming deposits close to the surface itself. The erosion-resistant outcrops show evidence for large trough cross-bedding that could be either eolian or fluvial, and that are topped by recessive intervals with apparent even, horizontal, tabular beds, possibly reflecting wet depositional environment such as sheet flooding.

Large-scale eolian crossbedding: Structures characteristic of large-scale trough and planar cross-bedding are observed in the lower section of the LSu, with large sets bounded by a variety of erosive surfaces (Figure 2b). Such cross-bedding forming 5- to 8-meters-thick bedsets is indicative of aeolian dunes due to their large scale [9]. Overall, no clear tabular cross-bedding associated with sand-sheet strata has been identified, and structures correspond instead to trough cross-bedding which could be formed by 3-D or 2-D dunes with superimposed dunes migrating in different directions.

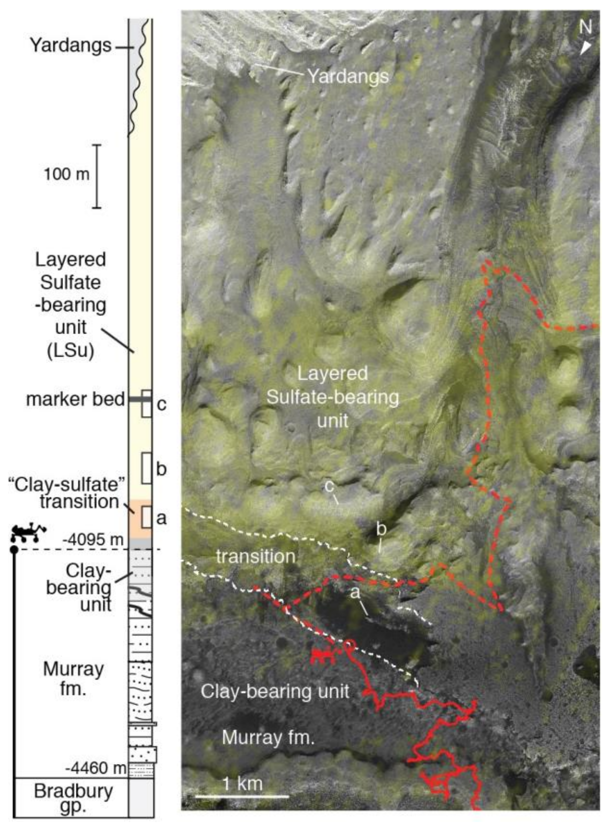

Figure 1: Stratigraphic context and close-up map of Mt. Sharp with layered sulfate-bearing unit to be explored by the Curiosity rover. The column represents units elevation (**left**) along with intervals covered by RMI (Figure 2). Close-up map uses HiRISE MSL basemap overlaid with CRISM S-index in shaded yellow (**right**). Elevation contours for the sulfate-clay transition (dashed white) are shown with rover path (red) and planned route (dashed red).

The marker bed as a major deflationary surface: The marker bed is a regionally extensive, thin, smooth, dark-toned layer distinguishable from orbit for 10s of km at a similar elevation around Aeolis Palus [2]. Curiosity now observes it in cross-section at higher resolution, revealing a variably prominent, few meters thick, resistant lip which crosscuts underlying strata (Figure 2c). The heterogeneous texture includes patches of planar bedded deposits similar to underlying strata and lens-shaped zones of disrupted bedrock. Based on geometric and textural evidence, we hypothesize that the marker bed represents a super bounding surface, a type of erosional surface common to terrestrial eolian sequences and due to changes in climate, or due to the migration of the dune field [10].

Discussion: Based on these observations, we propose a general predictive model for the evolution of depositional environments: heterolithic mudstones currently observed in the Murray formation should transition to eolian sandstones, interrupted by possible wetter intervals, within the next hundred meters of stratigraphy indicating the progression toward a drier environment. The marker bed then marks a hiatus in the eolian deposition. This model suggests climatic changes that would affect the water table, likely triggering the precipitation of sulfates along with other salts. Yet the relationship with sulfates, their nature and distribution in the bedrock, remains to be explored *in situ*. As the rover starts its ascent into the LSu, it will document whether sulfates reflect processes analoguous to Meridiani Planum [11], or early diagenetic deposition as previously suggested in the Murray fm. [12], or new formation scenarios.

References: [1] Fraeman A. A. et al. (2016) *J. Geophys. Res. Planets* **121**, 1713–1736. [2] Milliken R. E. et al. (2010) *Geophys. Res. Lett.* **37**, L04201. [3] Powell K. E. et al. (2019) *LPSC*, p. 1455. [4] LeDeit L. et al. (2018) *LPSC*, p. 1437. [5] Le Mouélic S. et al. (2015) *Icarus* **249**, 93–107. [6] Herkenhoff K. E. et al. (2018) *LPSC*, p. 2155. [7] Le Mouélic S. et al. (2019) *LPSC*, p. 2132. [8] Gustavson T. C. et al. (1994) *J. Sediment. Res.* **64**, 88–94. [9] Bradley R. W. and Venditti J. G. (2017) *Earth-Sci. Rev.* **165**, 356–376. [10] Kocurek G. (1988) *Sediment. Geol.* **56**, 193–206. [11] McLennan S. M. et al. (2005) *Earth Planet. Sci. Lett.* **240**, 95–121. [12] Rapin W. et al. (2019) *Nat. Geosci.* **12**, 889–895.

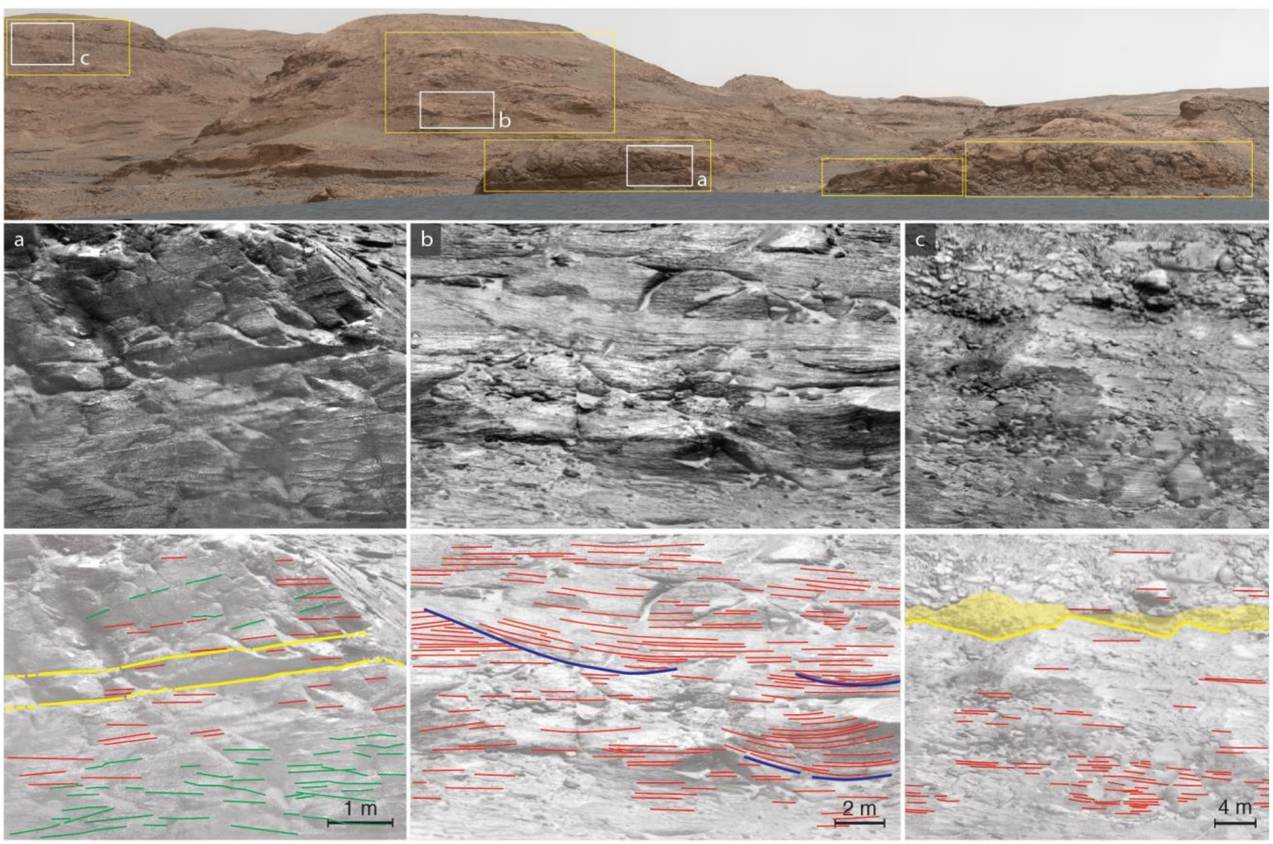

Figure 2: MastCam image of buttes in the sulfate-bearing unit (**top**, mcam15492) with areas recently covered with high-resolution RMI (yellow) and location of closeups shown below (a-c). RMI mosaic close-ups on sedimentary structures (**a-c**) overlaid with tracings. Structures observed: (**a**) massive cliff-forming crossbedded interval with possibly several planar unconformable surfaces (yellow) and variable presence of veins similar to satin-spar vein pattern (green); (**b**) large trough crossbedding with bounding surfaces (blue) and sets of cross-strata (red) of likely eolian origin; (**c**) unconformable boundary at the "marker bed" (yellow) with disrupted bedrock representing possible lag deposits (shaded yellow) and surrounding strata (red).