A SAND-LENS IN THE UPPER MURRAY FORMATION AT GALE CRATER, MARS: A LIKELY LOWSTAND DEPOSIT OF A DYNAMIC ANCIENT LAKE.

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Introduction: A sandstone outcrop examined along the uphill traverse of the Curiosity rover across the upper Murray formation at Gale crater consists of poorly sorted (very fine to coarse) sandstone beds with mudstone pebbles and interlayers of reddish mudstone. The sandstone interval is considered to be part of the Murray formation and thus part of the lacustrine succession that accumulated in Gale [1]. The sandstone shows likely casts of evaporite minerals, has Ca-sulfate in the matrix [2], and has interbeds of reddish mudstone. The latter show complex and intricate crack patterns that appear to mark desiccation of a wet mud at the time of deposition, as well as an overprint of burial-related hydraulic fracturing associated with Ca-sulfate filled fractures. In combination, the grain size and poor sorting of the sandstone, evaporite casts, and desciccation cracks suggest powerful transporting currents and a very shallow water environment for this interval. This is in contrast to observations made in the Murray formation below and above this interval, documents an intermittent drop of lake level, and points to a dynamic lacustrine system with fluctuating water level. In terrestrial lacustrine systems such periods of gain versus evaporation are important drivers for the evolution of lacustrine successions and their value as paleoclimate archives [3].

Observations: Examination of HiRISE images prior to arrival showed localized areas with contrasting albedo and sharp contacts relative to the bulk, adjacent Murray formation rocks (Fig. 1).

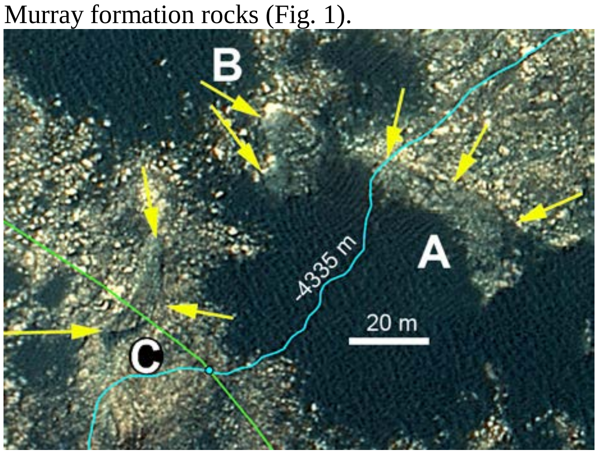

Figure 1: Detail from HiRISE. Areas with albedo contrast marked by yellow arrows. Turquoise line = -4335 m contour. Area C, along rover route (green line) was examined. Assuming near horizontal bedding of Murray, the features marked as A, B, and C appear to be incised into underlying Murray mudstones.

Overview imaging by the rover (Fig. 2) shows that the triangular area marked C is sandwiched between Murray mudstones and therefore part of the Murray formation.

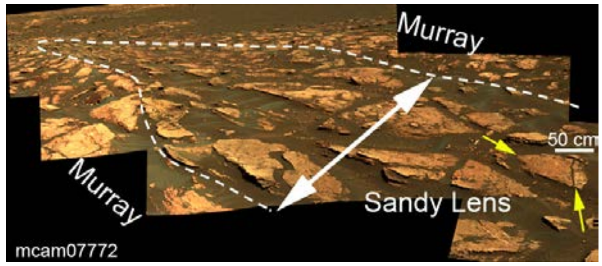

Figure 2: Rover view of the eastern portion of area C, with under- and over-lying mudstones. The sandy sediment is clearly bedded. The block marked with yellow arrows is a place where desiccation cracks were found.

Although the exposure consists of an expanse of disconnected blocks, the lower/upper boundaries of the interval are rather clear and, under the assumption that the blocks are approximately in-place, a qualitative rendering of the lithofaces arrangement can be compiled with the aid of target elevations (Fig. 3).

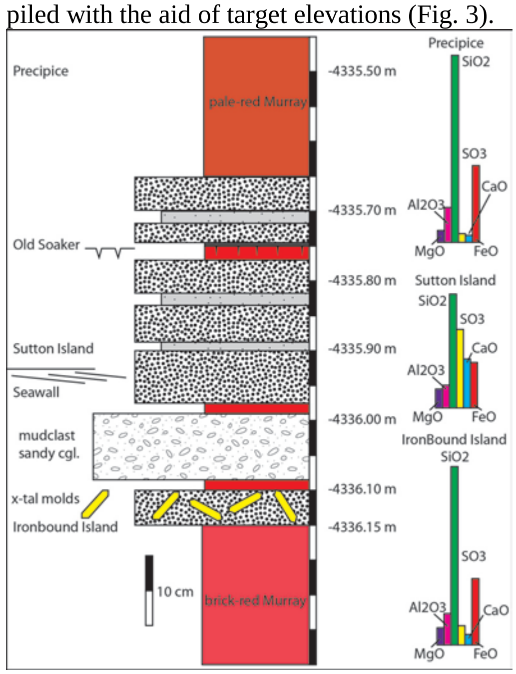

Figure 3: Mastcam image-derived lithofacies arrangement in sandy lens from Fig. 2. Poorly sorted sandstones and a conglomerate bed are interbedded with

finer/softer layers (gray~fine sandstone-siltstone; red=clay drapes), occurrence of evaporite crystal molds, desiccation cracks, and low angle cross-stratification. Chemical data from APXS show high Ca-sulfate in the sandstones and compositional differences between the Murray below and above this lens.

In addition to chemical differences, the Murray below and above the lens differs in color and textural features, suggesting that depositional parameters of the Murray changed after emplacement of the sand lens.

The sandstones have a large proportion (20-50%) of fine grained, soft eroding, areas of reddish color between recognizable mineral grains. The latter can be immersed in this fine matrix, suggesting that the matrix may actually be mudstone lithics [4]. This assumption is supported by the observation that the layer marked as a conglomerate bed in Fig. 3 has a vuggy weathering appearance and MAHLI closeups show mm-cm size oval shaped regions of fine grained reddish material in a sandy matrix. These are considered mudstone clasts that together with the lithics resulted from incision into previous deposited Murray (Fig. 4).

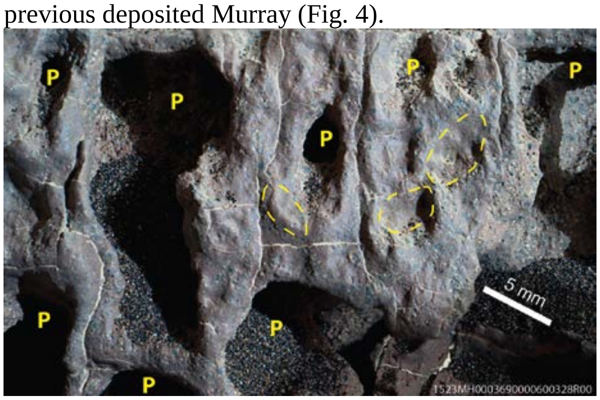

Figure 4: Vuggy layer with mudstone clasts (dashed ellipsoids) and vugs (P) that may represent locations of weathered-out clasts.

Another critical observation is the presence of desiccation cracks near the top of the interval (Fig. 3) in a reddish mudstone layer. This layer is riddled with multiple generations of fractures, some of which likely relate to desiccation [5]. There is an early generation of polygon-forming (5-10 cm) cracks, filled with a darker mudstone that definitely qualifies as desiccation cracks. We see sharp straight boundaries between the dark infill and the red mudstone polygons (Fig. 5), remnants of a dark gray cover layer that appears to be the same as the crack fill material still adhere to the top of the red layer, and the polygon angles have evolved away from initial rectilinear intersections. The latter suggests multiple wetting and drying periods before infill of the cracks and subsequent burial [6].

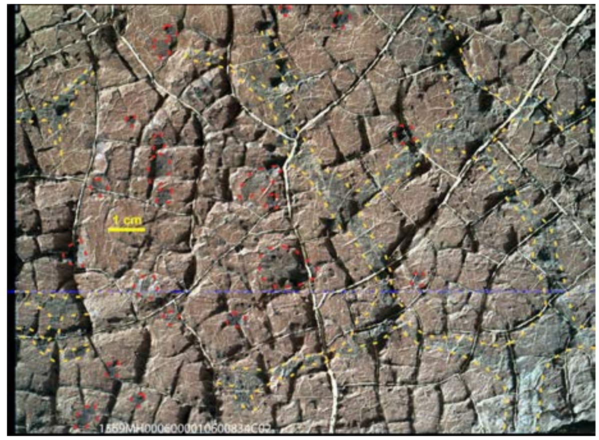

Figure 5: Mud filled desiccation cracks (dashed yellow lines) are subtle but visible because color contrast between infill and host rock. The same material also clings in small patches to the bed surface (red dashed lines) and is the remnant of a sediment layer that buried the red layer and infilled the open cracks. Mastcam multispectral images also detect a unique spectral signature for the dark fill and cover material.

Conclusions: Geometric considerations indicate that this sandy lens is in erosional contact with underlying Murray formation mudstones. Incision is also indicated by an abundance of mudstone clasts and pebbles in the sandy beds of the deposit. Because eroding consolidated muds requires current velocities on the order of several m/sec, very powerful transporting currents and shallow flows are indicated. The desiccated mud drapes and crystal molds attest to retreat of lake waters from the incision channel and further bolster the argument that this sandy lens records a significant lake level drop and areal shrinkage of the water body in the crater.

Given that in terrestrial lakes clearly identifiable lowstand deposits form only at some locales along lake margins, it is likely that the lowstand described here is just one example that we were lucky enough to encounter with the rover. It is likely that there were several that preceeded it but lacked outcrop expression, and others that we may yet encounter as Curiosity progresses through the stratigraphy of Mt. Sharp. What this deposit clearly illustrates is that the Gale crater lake was a dynamic system that oscillated and evolved through the eons and provided a wide range of environments along its shores and its interior.

References: [1] Grotzinger J.P. et al. (2015) Science, 350, aac7575. [2] Newsom H. et al. (2017) LPSC 48. This conference. [3] Bohacs K. et al. (2000) AAPG Studies in Geology 46, 3-34. [4] Schieber, J. (2016) Sedimentary Geology, 331, 162-169. [5] Stein N. et al, (2017) LPSC 48. This conference. [6] Goehring L. et al. (2010) Soft Matter, 6, 3562-3567.