'HIGH' BUT NOT SO DRY ON AEOLIS MONS: TRANSIENT LAKE SYSTEMS IN HESPERIAN DESERTS IN GALE CRATER.

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Introduction: The stratigraphy preserved within Aeolis Mons in Gale crater (Mars) shows a major transition from a phyllosilicate-bearing unit, which *in situ* data show is composed of mudstone-rich strata (with subordinate sandstones) recording deposition in lacustrine to fluvial settings into a major sulfate-bearing unit that is hundreds of meters thick (the Layered Sulfate-bearing unit (LSu)) [1,2,3,4]. The origin of the LSu unit is not yet constrained. Comparison to other terrains on Mars has led to the hypothesis that the transition from clay minerals to sulfates records a planet-wide change in climate from relatively warm and wet to cold and arid [1]. ***A leading question is whether this transition is so unidirectional.*** The lower section of the LSu (clay-sulphate transition stratigraphy) contains strongy diagenetically altered strata or stacked, cross-bedded facies (Dunnideer and Port Logan mbs of the Mirador fm) that likely records a purely dry aeolian dune environment [5]. However, higher up in the studied section within the Contigo member, we observe sandstone lenses interstratified within aeolian strata that show distinctive sedimentary structures indicative of deposition by lacustrine and fluvial processes in shallow interdune depressions [6]. In late 2022, Curiosity investigated a distinctive dark-toned, resistant unit even higher within the sulfate-bearing stratigraphy of Aeolis Mons – the "Marker Band" [1,4,7,8]. Stratigraphically it has been informally designated the Amapari member of the Mirador formation (Mt. Sharp gp). This unit can be traced for tens of kilometers around Aeolis Mons [7], and from early in the mission was considered an important geologic target for investigation [1]. The key question concerning the "Marker Band" is what geological process led to its formation and how does it relate to the Layered Sulfate-bearing unit. Orbital-scale observations led to favored interpretations of the "Marker Band" as a volcanic ash deposit or a more indurated sulfate unit [7]. The first edge-on view in the distance favored an eolian deflation surface [3]. Here we describe the sedimentology of unit and go on to discuss initial implications for paleoenvironmental and paleoclimatic interpretations.

Observations: Curiosity first commenced detailed investigations of the Amapari member on sol 3640 within an erosional trough informally named Marker Band Valley [8, 9, 10]. Here we describe planform and cross-sectional views of the member based on Mastcam, MAHLI and ChemCam's Remote Micro Imager long distance mosaics (LDRMIs). The Amapari member is a dark-toned resistant tabular unit laterally traceable for hundreds of meters with a distinctive chemistry [8, 9, 10, 11, 12] (Fig. 1). It overlies planar-laminated, fine-grained sandstone facies of the Catrimani member across a sharp, locally planar discontinuity surface [9]. The planar laminated facies are interpreted as pinstripe laminations formed by wind ripple migration in aeolian sandsheet deposits. The Amapari member is overlain by planar laminated sandsheet deposits indicating a return to aeolian deposition. Aeolian sand sheets indicate conditions which are not suitable for dunes and formation of dune cross-stratification, which may be due to high water tables or surface cementation [13].

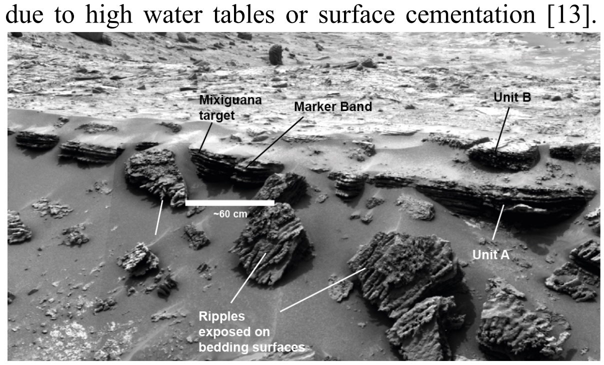

Figure 1 Sol 3639 Navcam mosaic of Amapari mb ('Marker Band'.

Beds within the Amapari member are conformable with underlying strata. Mastcam mosaics in the area where Curiosity traversed the Amapari member show that it is 0.5 m thick though can vary laterally [9]. It comprises a 2-fold stratigraphy: (1) a lower unit A that is ~0.2-m-thick comprising interstratified resistant and recessive beds with distinct wavy-laminated structures, and (2) an upper unit B characterized by thickly planar laminated beds with a basal layer of hollow nodules [14] (Fig.1). Here we focus on the lower unit A. Mastcam mosaics show that the lower wavy laminated horizon can be traced for many meters. The internal structure of the wavy beds in the lower unit A is best observed in

MAHLI mosaics obtained on sol 3644 at the Saracura workspace - target Mixiguana (Fig. 2).

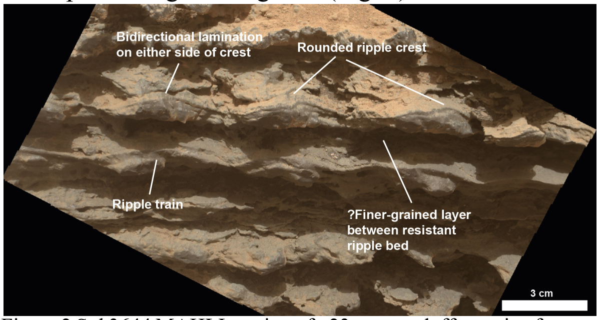

Figure 2 Sol 3644 MAHLI portion of ~23 cm standoff mosaic of target Mixiguana showing symmetrical cross-sectional shape of ripples and laminations that drape across ripple crests.

These mosaics display a vertical cross-section perpendicular to ripple crests revealing multiple vertically stacked bedsets of ripple forms with fully preserved ripple crests (Fig. 2). Ripples appear to have rounded crests and symmetrical profiles. Crest-to-crest wavelengths range between ~4.5 - 5 cm. Within ripple beds, we observe inclined laminations equally on either flank of ripple crests (bidirectionally dipping cross-stratification): laminations appear to pass continuously from ripple troughs across the crest to the adjacent trough (Fig. 2). This indicates that sediment accretion on ripples was by vertical upbuilding above crests and is suggestive of rapid sediment aggradation. The preservation of ripple form sets suggests temporary cessation of bedform accretion. Unidirectional accretion indicative of a preferred migration direction is not apparent where analysed. Mastcam images of the Amapari member locally show the 3D topography of bedsets and show linear rounded ripple crestlines plunging into the exposed scarp face. The occurrence of resistant, protruding rippled beds with recessive layers between may represent intercalation of coarser beds with finer-grained lithologies perhaps indicative of fluctuating energy conditions.

Bedding plane surfaces of the top of the lower unit exposed on loose slabs (Fig. 1) and an extensive in-situ bedding surface at the top of unit A at the Amapari workspace locality show superb preservation of well-defined, fully preserved ripple crests. The ripple forms show generally straight to weakly sinuous, parallel crestlines, with rounded crests, and appear to be symmetrical to near-symmetrical. In the area of the Amapari workspace, ripple crestlines are oriented ~120˚-300˚. Locally, crestlines appear to show bifurcations indicating a tuning-fork structure.

Interpretation: Taken together, we interpret the ripple forms as symmetrical wave ripples formed by oscillatory wave action [15, 16]. The short wavelength of the ripples suggests formation in shallow water depths by wind-generated waves in a lake setting [17]. Crest bifurcations are typical of bedform defects in wave ripples on Earth. Symmetrical ripple structures appear to be indistinctly present in LD-RMI mosaics in the lower part of the Marker Band across the area suggesting the wave-rippled facies is lateral continuous for hundreds of meters [9] suggesting deposition in a shallow lake above wave base. The vertical transition to the rhythmically laminated facies may possibly indicate a transition to deeper lake environment [14].

Discussion: Lower in the sulfate-bearing succession within the Contigo member, decameter-scale wide isolated lenses were encountered interstratified within aeolian dune cross-stratified deposits. Analysis of one of these lenses – informally named The Prow – revealed evidence for by cm-scale lenticular ripple structures with convex upper surfaces. Though not as well developed as the ripples in the Amapari mb., the symmetric form of many of the ripple structures with preservation of form sets is suggestive of formation by oscillatory flow by wave action. Notably the ripples are draped by finer-grained sediment indicating mud fallout from suspension onto ripple topography during low energy quiescent episodes. We interpret the lenses as the deposits of small, shallow interdune lakes that punctuated a dominantly arid, aeolian dune environment. The observation of multiple stacked wave-rippled bedsets within the Amapari mb. Together with extensive bedding surface exposures of wave ripples demonstrates that this member also represents deposition in a shallow lake body that intersected aeolian deposition. However, the lateral extent of the Amapari mb. indicates that the Amapari lake system was significantly greater in extent (hundreds of meters) compared to the interdune lenses like The Prow. It remains unclear if the Amapari member always contains wave-rippled facies. Tracking the distribution of such ripples will enable evaluation of lake extent. Our observations imply that arid desert systems that comprise the bulk of the Aeolis Mons Layered Sulfate-bearing unit were episodically interrupted by establishment of lake systems of variable spatial extent or potentially lakes co-existed within the aeolian landscape.

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