FLUIDIZATION STRUCTURES WITHIN THE STIMSON FORMATION: EVIDENCE FOR WATER POSTDATING THE EXHUMATION OF AEOLIS MONS.

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Introduction: Evidence for ancient surface water in the form of aqueous depositional structures are abundant in the strata infilling Gale crater [1]. Since 2012, the Mars Science Laboratory (MSL) rover Curiosity has investigated a variety of fluviolacustrine environments represented by the Bradbury and Mount Sharp groups [2,3]. However, the upper parts of the Mount Sharp group formed in a dominantly aeolian environment. The Mount Sharp group is unconformably overlain by the Siccar Point group, the basal strata of which – the Stimson formation – have been interpreted to have been deposited in an arid aeolian dune field [4]. Here, we present evidence of sedimentary structures that record the presence of groundwater in the shallow-subsurface in strata considered to be aeolian, thus documenting a secondary habitable environment.

Background: The Stimson formation is part of a broader mound skirting unit which has been directly investigated by the MSL rover. This mound skirting unit unconformably drapes the northern flank of the present-day Aeolis Mons [5]. Where encountered on the traverse, the Stimson formation represents the preserved expression of an ancient aeolian dune field [4]. Specifically, the stratigraphic record and the sedimentary architecture indicates that it was a dry dune field: water played no role in the accumulation of this sediment body [4]. This fact is betrayed by the absence of fine-grained interdune deposits, microtopography, or other facies which are characteristic of water at or near the depositional surface. At the time of Stimson accumulation, Gale was devoid of surface water (at least locally).

Observations: Around Sol 3434, as Curiosity traversed onto the eastern side of the Greenheugh pediment, it encountered prominent erosion-resistant bedrock ridges which formed a polygonal (boxwork) network. These structures were observed in the basal portion of the Stimson formation, just a few meters above the base Stimson formation unconformity. Internally, these structures consist of convolute, folded and warped laminations. Laterally, these structures are juxtaposed against undeformed Stimson formation: large-scale cross-bedding composed of well-sorted medium-grained sandstones.

Closer inspection of these internally-deformed ridge structures yields evidence of two types of deformation: ductile deformation; and destruction (fluidization) of primary stratification. The displacement and destruction are localized to the polygonal, linear ridges.

Where stratification is displaced, laminations are folded into upright closed antiforms, with a tight bend radi on the hinge (Example: Figure 1). Often, these are adjacent to open-folded synforms. Folding of laminations become tighter and more prominent with increasing vertical distance through the antiforms. Some original cross-laminations exhibited complex, recumbent folding where the underlying bounding surface exhibited open folded synforms.

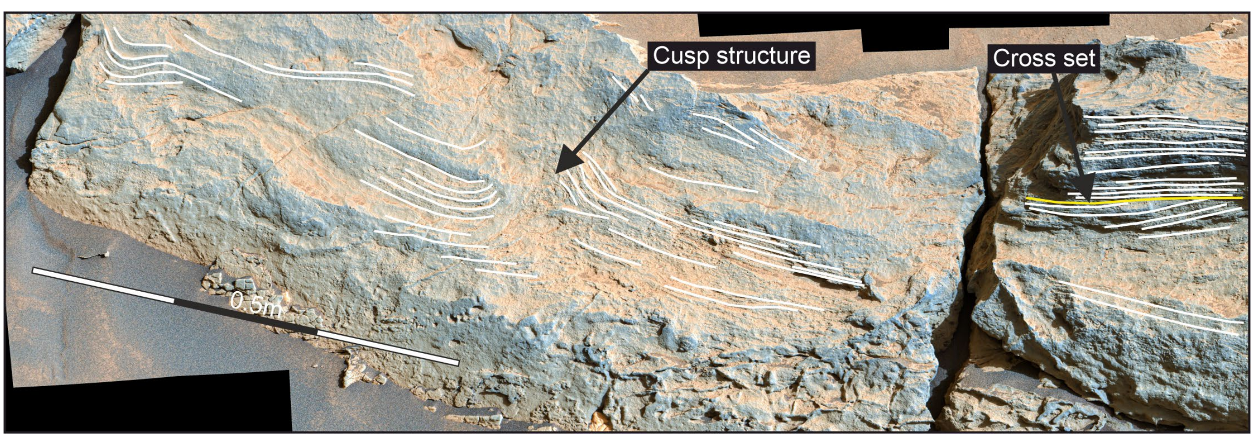

Figure 1: Soft sediment fluidization cusps at Brackenbury (MSSS/JPL-Caltech/NASA)

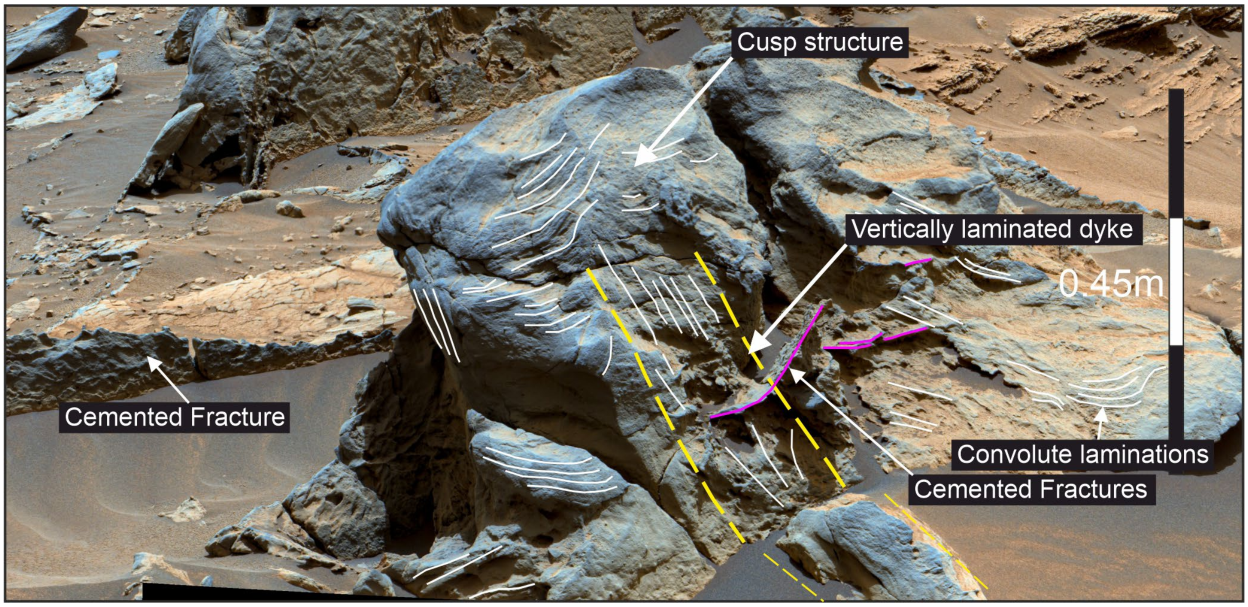

Figure 2: Fluidization dyke at Up Helly Aa (MSSS/JPL-Caltech/NASA)

In some ridges, exemplified at the Up Helly Aa target (Figure 2), original stratification is not preserved, and was replaced by continuous, vertically-oriented laminations that cross-cut horizontally-orientated laminations adjacent to the ridge. These laminations are oriented parallel to the long axis of the ridges, occasionally displaying vertical fold structures.

In some locations these erosion-resistant ridges contained vertically oriented fractures, with a few subordinate horizontal fractures, which were found to cross-cut some of the ductile deformation.

Interpretation: The structures observed at Brackenbury are interpreted to represent fluidization of sediment caused by water escaping through unconsolidated sediment, under pressure. The linear ridge at Up Helly Aa are interpreted to represent well-cemented sand dykes. Both fluidization and clastic dyke emplacement result is the partial or complete destruction of primary sedimentary structures (e.g. cross-bedding).

The tight antiforms are interpreted to be cusps while the vertical laminations are interpreted as pipes [6]. Synforms, cusps and pipes exhibit pervasive vertical shear [6]. Recumbent folding is also interpreted as evidence of vertical shear due to the displacement of the underlying bounding surfaces into vertical synforms. The vertical shear seen in cusp and synforms, and the vertical laminations observed in the dykes are evidence for the fluidization of sediment caused by upward fluid drag supporting the grain weight as water escapes through an open system under pressure [6]. The source of the fluid may include groundwater upwelling or pore water from liquefaction occurring below the Stimson. As brittle deformation overprinted the soft sediment deformation, the trigger or cause of the fluidization may have been cyclic and caused brittle failure after the sediment regained its strength. Earlier fluidization pipes associated with the Murray formation [7], formed while the Murray formation was still unconsolidated, and likely predate both the exhumation of Aeolis Mons and the Stimson dune field.

Discussion: Regardless of the origin of the water, these fluidization structures provide evidence of shallow groundwater within sediments of the Stimson dune field indicating late-stage aqueous conditions were present in Gale crater in the near surface. Presence of this groundwater indicates:

1. Water percolated into the base of the Stimson formation, either from fractures within the Mount Sharp group, from strata higher up on Mount Sharp, or from meteoric sources.
2. Water was present at the time which the Stimson formation was unconsolidated: which would be penecontemporaneous with dune field formation.
3. This may represent a secondary habitable environment within the shallow subsurface.

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