**DOES THE GREENHEUGH PEDIMENT CAPPING UNIT REPRESENT A CONTINUATION OF THE STIMSON FORMATION?**

S.G. Banham[1], S. Gupta[1], A.B. Bryk[2], D.M. Rubin[3], K.S. Edgett[4], W.E. Dietrich[2], C.M. Fedo[5] , L.A. Edgar[6] and A.R Vasavada[7], [1]Imperial College London (s.banham@imperial.ac.uk), [2]EPS, UC Berkeley, CA, [3]EPS UC Santa Cruz, CA, [4]Malin Space Science Systems, San Diego, CA, [5]EPS U. Tennessee, Knoxville, TN, [6]U.S.G.S., Astrogeology Science Center, Flagstaff, AZ, [7]Jet Propulsion Laboratory, CA.

**Introduction:** The Greenheugh pediment and associated capping unit is one of the most distinctive landforms in Gale crater [1]. Lying downslope of Gediz Vallis at the base of north-flank of Aeolis Mons (Mt. Sharp), it comprises an erosional unconformity that is overlain by a ~2-6 m thick resistant unit that is covered in well-organised relatively evenly spaced ridges and troughs that have been inferred to be preserved bedforms. The Greenheugh pediment likely represents a major breaks in deposition that signifies a dramatic shift in depositional processes within Gale crater. After 2600 Sols of traversing toward the foothills of Aeolis Mons, the Mars Science Laboratory (MSL) rover maneuvered into a position to resolve key features exposed within the vertically exposed sections of the capping unit. Initial observations of the Greenheugh capping unit indicated large-scale cross-bedding reminiscent of those observed within the Stimson formation: a unit which overlies the base Siccar Point group unconformity at lower topographic elevations within Gale crater. The Stimson formation is a sandstone that represents the preserved expression of an aeolian dune field [2]. This sandstone has been observed in detail at several locations across the traverse, notably: Emerson Plateau (Sols 987-1154), Naukluft Plateau (1281-1353), and the Murray Buttes (1417-1454). Here, the characteristics of these two units are compared to determine if they were generated by similar processes and could be stratigraphically related.

**Stratigraphic context:** The Stimson formation and Greenheugh capping unit are expressed in orbital images as erosion-resistant stratal units, which drape inclined erosional surfaces interpreted to be unconformities. The Stimson formation of the Siccar Point group is distributed across the break-in-slope between Aeolis Pallus and the foothills of Aeolis Mons. The Stimson unconformably overlies the Murray formation, with a relief of 150 m recorded over a distance of 2 km [3]. The upper surface of Stimson is an eroding geomorphic, and no units are observed to overlie it.

Orbital mapping of the contact between the Greenheugh pediment and the pediment capping unit indicates ~150 m of relief on the pediment-forming unconformity, over a distance of ~1300m. The upper surface of the Greenheugh capping unit has a washboard pattern, and dips at ~5.7°[4]. Currently, the Greenheugh capping unit is thought to overlie strata within the Mount Sharp group, as the underlying strata has similar visual characteristics to the Murray formation observed elsewhere along the traverse.

**Greenheugh capping unit:** As of Sol 2633, the closest observation of the Greenheugh unit is of Tower butte, at a distance of ~85 m. While this view distance hampered detailed architectural analysis of the outcrop, key characteristics, and broad architectural arrangements can still be discerned. The pediment-capping is composed of a blocky, grey-coloured cliff-forming layer of rocks, which overlie an angular unconformity cut into the top of what appears to be Mount Sharp group strata. Orbital spectrometer studies indicate that these are clay-bearing strata, and may have a Murray formation affinity [5,6] Locally, this unconformity undulates at a decimeter scale, over a distance of several meters. The unit beneath the unconformity is horizontally laminated, and is frequently cross-cut with white-coloured veins.

Tower Butte is a key outcrop where compound cross-sets are present in the north-facing section of the capping unit. These are composed of cross sets between 0.3-0.7 m thick, forming cosets up to 2.5m thick. The north-east-facing side of the butte contains bounding surfaces that are inclined, with an apparent dip toward the north (Fig.1: Yellow inclined bounding surfaces). These are interpreted to be superposition surfaces[2,7]. Cross-bed sets bounded by these superposition surfaces are observed, in places, with apparent dips approximately toward the north-east (Figure 1,2: White cross laminations). Elsewhere, trough-cross sets can be observed, suggesting that the axis of transport could be oriented in a north-south direction (Fig.2).

**Stimson formation:** The Stimson formation (collectively exposed at the Emerson plateau, Naukluft

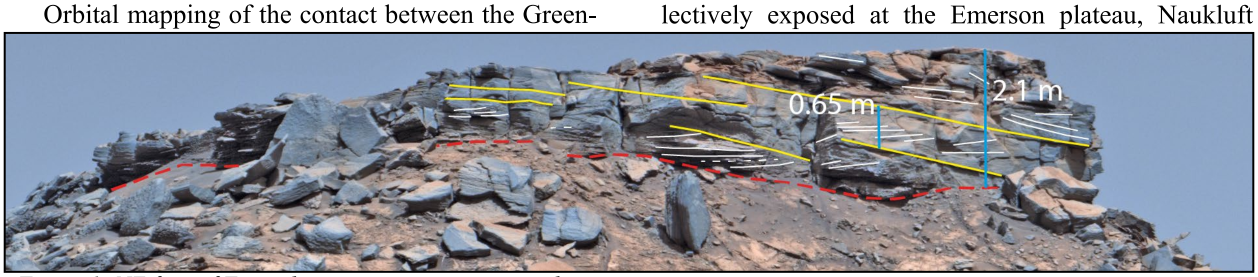


*Figure 1: NE face of Tower butte, containing compound cross sets.*

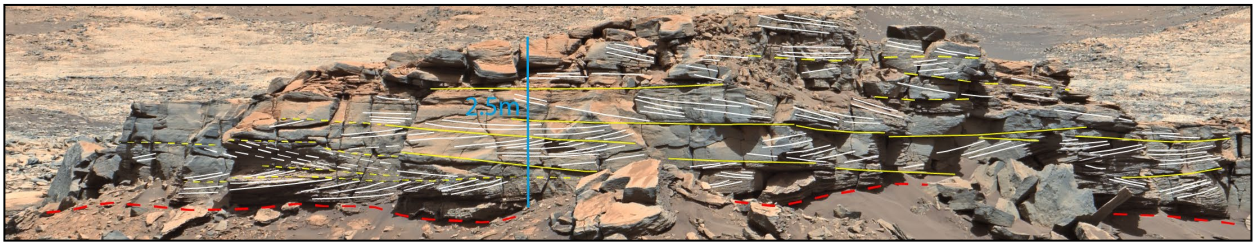


*Figure 2: North face of Tower Butte.*

plateau and Murray buttes) are dark-grey, blocky, weathering-resistant, and cliff-forming strata. They unconformably overlie and cross-cut bedding within the Murray formation. The defining characteristic of the Stimson is metre-scale cross bedding, which is composed of uniform-thickness (2-4 mm thick) cross-laminations [2]. On the Emerson Plateau, the cross-bedding is composed of simple sets, of 0.5-1.0 m thickness. The sets are bounded by sub-horizontal, laterally extensive bounding surfaces, interpreted to be dune bounding surfaces, scoured as simple dunes migrated in the direction of net sediment transport.

Textural analysis of the Stimson formation at the Williams outcrop demonstrated that the sands were originally transported and deposited by aeolian processes [2]. These grains are well rounded relative to fluvially-transported sand grains observed elsewhere in Gale crater, and have a distinct bimodal grainsize distribution [2]. In the Murray buttes area, cross-sets are compound 0.4-0.7m thick cross-sets are bounded by inclined bounding surfaces, in cosets between 1-3 m thick (Fig.3). This arrangement of sets is interpreted to have formed by superimposed bedforms migrating across larger main dunes, forming a draa.

**Comparison of the Stimson and Greenheugh capping unit:** Both outcrops have similar stratigraphic relations and architectural characteristics when observed across their full extent and at the decimeter scale. At the scale of their extent, both outcrops unconformably overlie Mount Sharp group strata, although at different topographic elevations (the Greenheugh capping unit may not overlie the Murray fm as the Stimson does). Both of these unconformities dip toward the north. It would not be unreasonable to interpret that these unconformities are the same, or are genetically related [1,8]. The unconformity beneath the Stimson is interpreted to be a regional aeolian deflation surface that mimics the present-day land surface[2,3], and if the Greenheugh capping unit accumulated on the same unconformity, it could be a lateral stratigraphic equivalent to the Stimson. At a metre scale, both the Stimson and the Greenheugh capping unit are composed of cross bedded sandstones, containing compound cross-sets. Compound cross-sets observed in Tower butte resemble those seen at the Murray Buttes. In both examples, this suggests that the architecture was generated by migration of compound dunes.

**Implications for the Greenheugh capping unit being Stimson formation:** The relationship between the Greenheugh capping unit and the Stimson currently remains unclear. The capping unit may be an aeolian sandstone similar in facies to the Stimson. In this case it could be either a distinct aeolian unit or the lateral equivalent of the Stimson. If the Greenheugh Pediment represents an upslope extension of the Stimson formation, then the Stimson Erg would have had a greater extent than previously assumed, possibly covering an area of several 100s $km^2$. Foreset and superposition surface dip-azimuths in the Stimson formation and north margin of the Greenheugh capping rock indicate sediment was generally transported toward the north, which would imply that sediment forming the Stimson and Greenheugh capping unit was derived from the upper flanks of Mount Sharp.

**References:** [1] Bryk *et al*. (2019), 9th Mars Con. Abstract #6296. [2] Banham *et al* (2018) *Sedimentology* doi:10.1111/sed.12469 [3] Watkins et al. (2016) *LPSC47,* Abstract #2939. [4] Bryk *et al*. (2020) *LPSC51* The Stratigraphy of Central and Western Butte & the Greenheugh contact. [5] Milliken *et al.* (2010), *Planets*, doi: 10.1029/2009GL041870 [6] Fraeman *et al.* (2016), JGR-P, doi: 10.1002/2016JE005095. [7] Brookfield (1977), *Sedi.* doi:10.1111/j.1365-3091.1977.tb00126.x [8] Anderson & Bell, Mars 5, doi:10.1555/mars.2010.0004

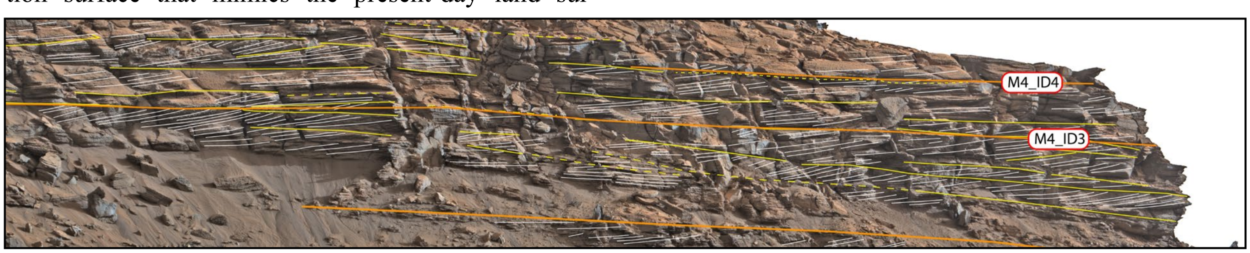


*Figure 3: Butte M4, Murray Buttes*