THE STRATIGRAPHY OF CENTRAL AND WESTERN BUTTE AND THE GREENHEUGH PEDIMENT CONTACT

A. B. Bryk[1], W. E. Dietrich[1], V. K. Fox[2], K. A. Bennett[3], S. G. Banham[7], M. P. Lamb[2], J. P. Grotzinger[2], A. R. Vasavada[4], K. M. Stack,[4] R. Arvidson[5], C. M. Fedo[6], S. Gupta[7], R. C. Wiens[8], R. M. E. Williams[9], R.E. Kronyak[6], M. L. Turner[10], K. W. Lewis[10], D. M. Rubin[11], W. N. Rapin[2], L. Le Deit[12], S. Le Mouélic[12], K. S. Edgett[13], A. A. Fraeman[4], M. N. Hughes[5], L. C. Kah[6], C. C. Bedford[13]. [1]University of California, Berkeley, CA (bryk@berkeley.edu). [2]Division of Geological & Planetary Sciences, Caltech, Pasadena, CA. [3] USGS Astrogeology Research Center Flagstaff, AZ. [4]Jet Propulsion Laboratory, Caltech, Pasadena, CA. [5]Washington University in St. Louis, St. Louis, MO. [6]University of Tennessee, Knoxville, TN. [7]Imperial College, London, UK. [8]Los Alamos National Laboratory (LANL), Los Alamos, NM. [9]Planetary Science Institute, Tucson, AZ., [10]Johns Hopkins University, Baltimore, MD. [11]University of California, Santa Cruz. [12]Université de Nantes. [13]Malin Space Science Systems, San Diego, California.[14]Lunar and Planetary Institute, Houston, TX.

Introduction: The Greenheugh pediment at the base of Aeolis Mons (Mt. Sharp), which may truncate units in the Murray formation and is capped by a thin sandstone unit, appears to represent a major shift in climate history within Gale crater [1, 2]. The pediment appears to be an erosional remnant of potentially a much more extensive feature [3, 4, 5]. Curiosity's traverse through the southern extent of Glen Torridon (south of Vera Rubin ridge) has brought the rover in contact with several new stratigraphic units that lie beneath the pediment. These strata were visited at two outcrop-forming buttes (Central and Western butte- both remnants of the retreating pediment) south of an orbitally defined boundary marking the transition from the Fractured Clay-bearing Unit (fCU) and the fractured Intermediate Unit (fIU) [6]. Here we present preliminary interpretations of the stratigraphy within Central and Western buttes and propose the Western butte cap rocks do not match the pediment capping unit.

Butte Stratigraphy: The units above the Glen Etive drill site **(Fig 1)** consist of heterolithic strata beginning with the Knockfarril Hill member (KHm) [7], followed by units exposed in the buttes. At the base of the two buttes lies a red mudstone with distinct pitting that resembles the Jura member of the Murray fm. and may be laterally discontinuous and/or repeat leading up-section to the base of Central butte.

The stratigraphy within the two buttes comprises several distinct facies **(Fig 2a-c)** and is marked by zones of extensive diagenetic alteration. Alteration consists of dark-toned nodules of varying size and number (density). Various intervals of light-toned rock may also indicate diagenetic alteration. The base of Central butte includes a finely laminated *light-toned* fractured unit densely riddled with millimeter scale nodules. Above this lies a cross-bedded 'Hunda' facies characterized by low-angle trough cross-stratification as well as decimeter-scale planar foresets. The top of Central butte comprises a gray-toned densely packed nodular unit with abundant $CaSO_4$ veins and dispersed relatively large nodules.

The two buttes lie along a NE-SW trend approximately parallel to the hypothesized strike of the Murray sediments [8]. All the units within Central butte have correlative facies outcropping in Western butte, although the top of Central butte corresponded to the 'shoulder' of Western butte – a prominent plateau on the NE side of the butte. Above this plateau the stratigraphy consisted of light-toned laminated nodular sandstone with the nodules decreasing in density up-section. **Fig. 3** shows a topographic profile with a simplified graphic log delineating the units found in the two buttes.

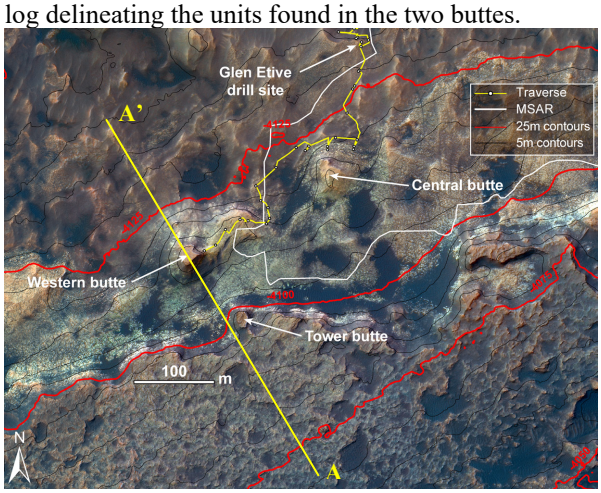

Fig. 1: map with cross-section for **Fig 5.**

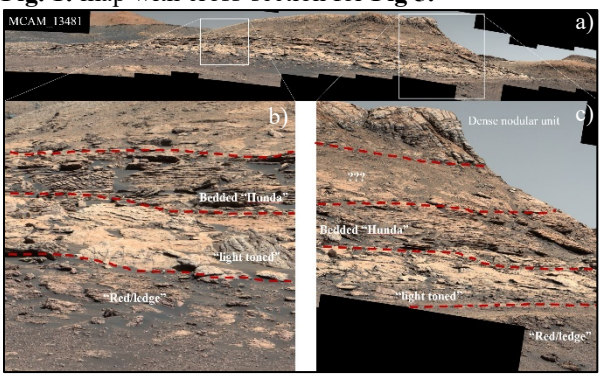

Fig. 2a-c: Mastcam images of Central butte indicating approximate stratal boundaries. *Note butte is ~10m tall*

Observations of the Greenheugh contact: Orbital observations indicate a washboard pattern with 5-10m wavelength on the Greenheugh upper surface. This has been interpreted as representing planform-preserved bedform crest lines [3]. Recent Mastcam observations of the Greenheugh pediment indicate an undulating

lower contact with up to 0.5m relief between the truncated underlying sediments and the overlying sandstone that comprises the capping unit. The capping unit contains extensive half-meter scale cross-bedding that can be traced over ~1-3m laterally at several locations **(Fig. 4)**. The scale of the bedforms contained within the pediment capping unit suggests smaller bedforms than the 5 to 10 m wavelengths identified from HiRISE [4].

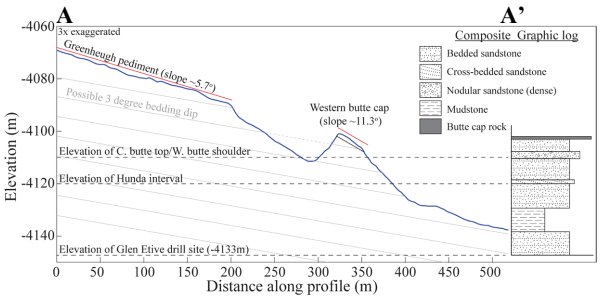

Fig. 3: cross-section A-A' (**Fig. 1**) with composite graphic log of facies correlated across the two buttes.

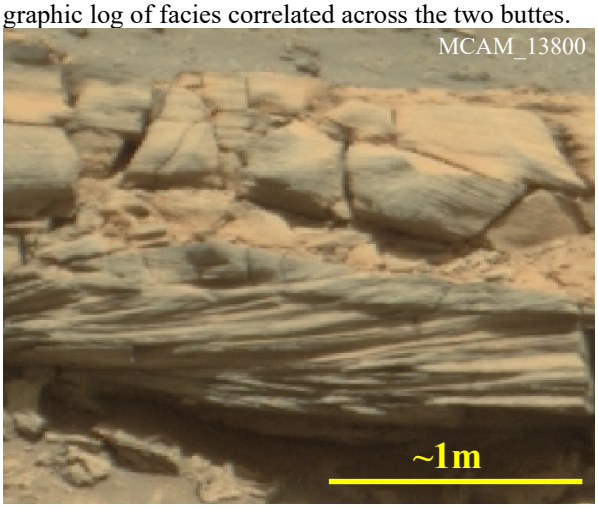

Fig. 4: Mastcam image of the pediment capping unit near Tower butte **(Fig.1)** showing undulating lower contact and 0.5m scale cross-stratification.

The capping unit at Western: Unlike Tower butte **(Fig 1)**, which reveals intact the cross-stratified sandstone of the capping unit **(Fig. 4)** [9]**,** the top of Western butte is mantled by a rubbly dark material without clear bedding. The boulders and gravel shed from this top commonly are ovoid and irregular shapes, exhibit elongated pits, and fine-grained (**Fig. 5a, c**). **Fig. 5b** shows the typical tabular, angular blocks of cross-bedded sandstone shed from the pediment capping unit **(Fig. 4)**.This suggests a different origin for the Western butte capping unit than the adjacent pediment cap. CCAM data also suggest that the Western butte blocks differ compositionally from the Aeolian Stimson formation [9,10,11].

The top surface of Western butte is inclined at about ~11.3 degrees, which is 2x greater than the ~5.7 degree characteristic slope of the distal pediment surface **(Fig. 3)**. Additionally, unlike at Tower butte, the basal contact with the capping unit is not visible and coherent bedding cannot be identified. These observations suggest that the material topping Western butte is a poorly preserved continuous layer, was transported as boulder-rich sediment, or is remnant scree from a retreating cliff.

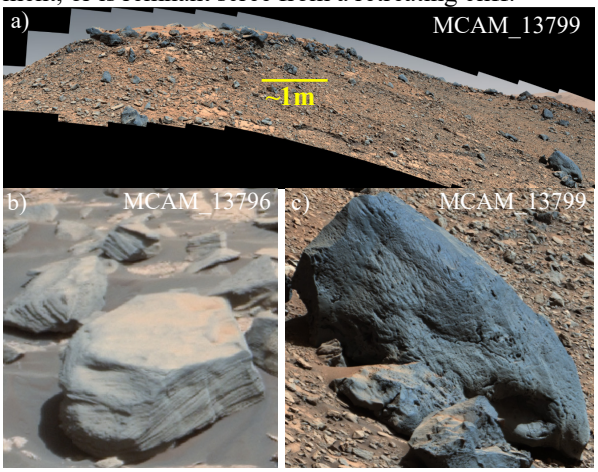

Fig. 5: a) Mastcam image of the capping unit at Western butte (**Fig.1**). **b)** block of fallen pediment near Tower butte (**Fig. 1**). **c)** block of fallen Western butte cap. *Note: b and c are both roughly meter-scale boulders.*

Conclusions and future investigations: Initial investigations of the fIU indicate multiple distinct facies with extensive diagenetic overprinting particularly in the form of mm-to cm-scale nodules. The density of these nodules appears to diminish up-section. Given the location of these units at near the base of Mt Sharp, the role of groundwater should be considered [12].

Stratigraphic correlations made between Central and Western buttes along a NE-SW transect demonstrate the lateral continuity of these units. Initial correlations are consistent with a bedding dip of 2-4 degrees to the NW within the buttes [7].

The capping unit on the pediment which exhibits extensive ~0.5m scale cross-bedding, suggesting smaller bedforms than interpreted from surface imagery obtained from orbit. It remains uncertain what erosional processes truncated the underlying sediments at the base of the pediment and what processes planed off the surface of the capping sandstone unit. Finally, Curiosity's preliminary investigations of the Western butte capping unit suggest it is unrelated to the pediment cap.

References: [1] Malin M.C. & Edgett K.S. (2000) *Science*, *290*, 1927-1937. [2] Anderson and Bell (2010) Mars, 5, 76-128. [3] Bryk A.B. et al. (2019) *9th Int. Conf. Mars* abstract #2089 [4] Bryk A.B. et al. *LPSC L* abstract #2132 [5] Fraeman et al. (2016) *JGR*, 121, 1713–1736. [6] Fox V.K. et al., this meeting [7] Fedo C.M. this meeting. [8] Turner M.L.(2019) *AGU* P31A-3424. [9] Banham S.G. this meeting. [10] Banham S.G. et al. (2018) *Sedimentology*, 65, 993-1042. [11] Wiens, R. C. this meeting. [12] Siebach, K. L. et al. JGR-Planet, 119(1), 189-198