AN OVERVIEW OF KEY FINDINGS FROM THE *CURIOSITY* ROVER'S CAMPAIGN IN GLEN TORRIDON, GALE CRATER, MARS. K. A. Bennett[1], V. K. Fox[2], A. Bryk[3], W. Dietrich[3], and the MSL Team. [1]U.S. Geological Survey, Astrogeology Science Center, Flagstaff, AZ, 86001, kbennett@usgs.gov. [2]Department of Earth and Environmental Sciences, University of Minnesota, Minneapolis, MN 55455. [3]Department of Earth and Planetary Science, University of California Berkeley, Berkeley, CA, 94720.

Introduction: The Mars Science Laboratory *Curiosity* rover has been exploring Gale crater since it landed in 2012. The traverse up the slopes of Mount Sharp (a ~5 km high sedimentary central mound formally known as Aeolis Mons) has revealed strata that were deposited in lake and lake margin settings [i.e. 1,2]. The Mount Sharp group is divided into nine lithostratigraphic members based on subtle changes in lithology and facies associations [2-4]; the members are for the most part dominated by finely laminated mudstones punctuated with sandstone deposits.

From January 2019 through January 2021, Curiosity explored Glen Torridon, which is an inclined trough that is bounded to the north by Vera Rubin ridge [5] and to the south by both the Greenheugh pediment and the steepening slopes of the sulfate unit (Fig. 1). Strata within Glen Torridon exhibit distinct smectite clay spectral signatures based on orbital observations [6]. Furthermore, these units underlie layered sulfate-bearing deposits and have been interpreted to record a climatic transition from wetter to drier conditions that may have been regional to even global in extent [6].

The goals of the Glen Torridon campaign were to characterize the geology of this area, record evidence of habitable environments, and to document the onset of what may have been a potentially global climatic transition. The campaign also included a brief expedition to investigate the Greenheugh pediment starting on sol 2693 and ending on sol 2733. Here we present a summary of key findings from this campaign.

Traverse description: *Curiosity* investigated the Glen Torridon region for two Earth years (sol 2300 to sol 3072). The rover performed a north to south traverse of Glen Torridon, from the Vera Rubin ridge to the northern margin of the Greenheugh pediment (Figure 1). *Curiosity* acquired samples from 11 drill holes during this campaign, 10 from Glen Torridon and 1 from the Greenheugh pediment. The first martian thermochemolysis-based organics detection experiment with the Sample Analysis at Mars instrument suite was conducted [7].

Key Findings: *Sedimentology:* Rocks within Glen Torridon are mapped into three stratigraphic members: Jura, a predominately fine-grained mudstone, Knockfarril Hill, which is dominated by cross-bedded sandstones (Fig. 2), and Glasgow, which exhibits a variety of diagenetic textures overprinting laminated mudstones, particularly in locations adjacent to the Greenheugh Pediment [8, 9]. Mount Sharp group strata continue through and beyond Glen Torridon, though the Jura marks the top of the Murray formation and a new formation is defined starting with the Knockfarril Hill member [8]. The newly defined Carolyn Shoemaker formation indicates a progressive transition from the generally low-energy lacustrine depositional environment of the Murray formation [2,8] to a higher-energy lake margin environment with increased fluvial deposition [10], as evidenced by the greater occurrence of cross-bedded sandstones.

The geomorphic contact between Vera Rubin ridge and the Glen Torridon trough (Fig. 2) did not correspond to a change in the physical stratigraphy: these regions are stratigraphically equivalent [2, 8], and the distinct geomorphology is interpreted to be a result of different overprinting diagenetic histories.

Greenheugh pediment: The pediment is capped by a unit that contains medium-grained crossbedded sandstones (Fig. 3) [11]. Based on their stratigraphic position, sedimentary texture and architecture, plus their geochemical signature, the pediment capping unit is interpreted to be part of the Stimson formation that belongs to the Siccar Point group [11, 12]. These rocks are evidence of an extensive sand sea. The multiple episodes of diagenesis required to cement these sandstones indicate that water was stable in Gale crater after the deposition and erosion of Mount Sharp [12].

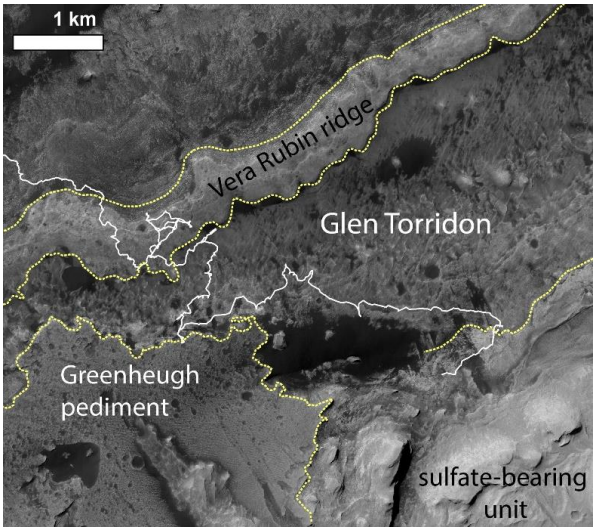


Figure 1: HiRISE image (ESP_053732_1750) showing geomorphic features. Yellow lines show the boundaries between the features and the white line shows the traverse path.

Habitability and Preservation of Organic Molecules: Glen Torridon samples carry the greatest diversity and abundance of sulfur-bearing organics thus far detected [13], and organic C [14] and both oxidized and reduced sulfur are present [15]. Although a lack of N may have provided a constraint on microbial activity, the combination of evidence for water, organic C, and redox sensitive minerals indicates that Glen Torridon was a potentially habitable environment.

Mineralogy: Glen Torridon hosts the highest clay mineral abundances observed thus far in Gale crater (34 wt. %), yet also remains in family with the rest of the Mount Sharp group [16]. Two new minor phases were identified for the first time in Glen Torridon samples: Fe-carbonate and an 9.2 Å phase whose identity remains debated [16,17].

Diagenesis: Glen Torridon strata experienced variable levels and types of diagenesis. The most clay mineral-rich areas in Glen Torridon are hypothesized to have experienced a lower degree of diagenetic modification than the surrounding terrain. Diagenesis is the main contributor to the differences between the Jura member that outcrops in Vera Rubin ridge as compared to the Jura member that outcrops in Glen Torridon. A diagenetic event(s) caused Vera Rubin ridge to be cemented and erosion-resistant [5], and this event(s) did not impact the equivalent strata within Glen Torridon [17,18], causing these strata to be relatively softer and erode more quickly to form a trough. Within Glen Torridon, the anomalous Hutton interval (distinct in color and mineralogy) that occurs in the Greenheugh pediment scarp just below the basal Siccar Point unconformity likely experienced extensive diagenesis [18, 19].

Acknowledgments: All data from the Glen Torridon campaign are available on the Planetary Data System. Results from this campaign are reported in manuscripts submitted to the JGR Planets special issue: "The Curiosity rover's investigation of Glen Torridon and the surrounding area."

References: [1] Grotzinger et al., (2015) *Science, 350(6257)*. [2] Edgar et al. (2020) *JGR Planets, 125*, (3). [3] Fedo et al. (2018) *49th LPSC*, #2078. [4] Stack et al. (2019) *Sedimentology*, *66*(5), 1768–1802. [5] Fraeman et al., (2020) *JGR Planets, 125*, (12). [6] Milliken et al., (2010) *GRL*, *37*(4). [7] Williams et al., (2021) *52nd LPSC*, #1763. [8] Fedo et al., (in prep) *JGR Planets*. [9] Dehouck et al., (submitted) *JGR Planets.* [10] Caravaca et al., (submitted) *JGR Planets.* [11] Banham et al., (submitted) *JGR Planets.* [12] Bedford et al., (submitted) *JGR Planets.* [13] Milan et al., (submitted) *JGR Planets.* [14] McAdam et al., (submitted) *JGR Planets.* [15] Wong et al., (submitted) *JGR Planets.* [16] Thorpe et al., (submitted) *JGR Planets.* [17] Bristow et al. (2021) *Science, 373*(6551). [18] Rudolph et al., (submitted) *JGR Planets.* [19] Gasda et al., (submitted) *JGR Planets.*

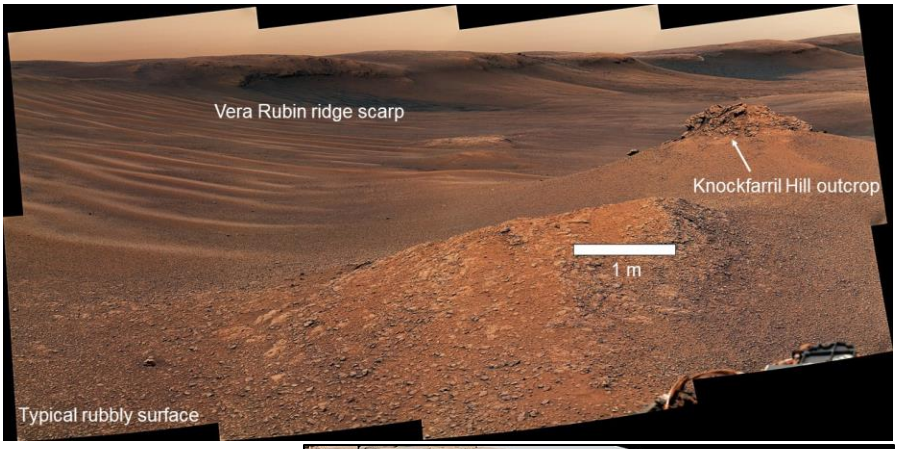
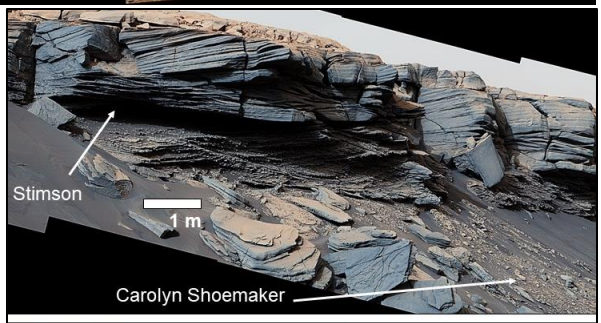


Figure 2: (above) Mastcam mosaic (2309-ML012330; NASA/JPL-Caltech/MSSS) showing Vera Rubin ridge and the cross-bedded Knockfarril Hill outcrop.



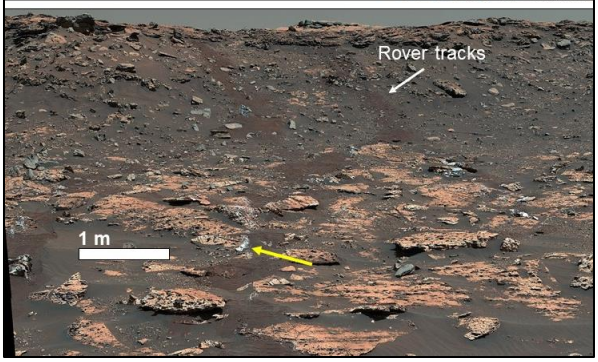


Figure 3: (above) a) Stimson formation sandstones and underlying Carolyn Shoemaker formation mudstones. (2685MR014053; NASA/ JPL-Caltech/MSSS). b) The 32° slope Curiosity ascended at the pediment. Also shows the altered, light-toned Hutton interval (yellow arrow points to dust-free light-toned area). (2737MR014348; NASA/ JPL-Caltech/MSSS)