CHARACTERISTICS OF THE FRACTURED INTERMEDIATE UNIT FROM ORBITAL AND CURIOSITY-BASED DATA. M. N. Hughes[1], R. E. Arvidson[1], A. A. Fraeman[2], and S. J. VanBommel[1], [1]Department of Earth and Planetary Sciences, Washington University in St. Louis, St. Louis MO 63110 (mnhughes@wustl.edu), [2]Jet Propulsion Laboratory, Pasadena CA 91109

Introduction: Curiosity's exploration of Glen Torridon has produced a wealth of information on the nature and extent of the fluvial-lacustrine-aeolian deposits that outcrop in this broad valley. To help understand the spatial distribution and to facilitate an understanding of the stratigraphic order of the various deposits we have generated a geomorphic map of Glen Torridon from HiRISE image data based on texture and color (Figure 1). In some cases, the map units correlate with inferred stratigraphic levels. This is the case for what is termed the fracture intermediate unit (FIU) and its overlying FIU-rubbly unit. The focus of this abstract is to both present the map units and to focus on Curiosity's measurement campaigns in these two units.

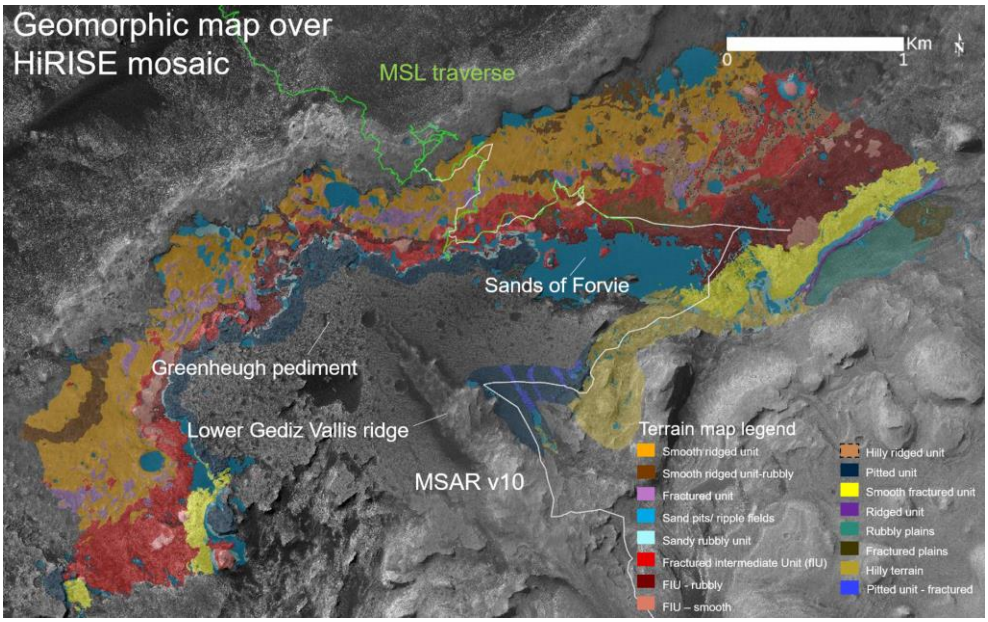

Figure 1. Geomorphic Map over HiRISE mosaic. MSL traverse to sol 2979 is shown as well as the Mount Sharp Ascent Route (MSAR).

Geomorphic Mapping: From north to south, the geomorphic units are the Smooth Ridged Unit (SRU), which is characterized by periodic bedrock-capped ridges with regolith-dominated slopes. This unit primarily corresponds to the Jura member of the Murray formation [1]. The areally extensive Fractured Unit (FU) exposures lack the periodic ridges that dominate the SRU and in some cases are mapped as small outcrops on the SRU ridge crests. The unit primarily corresponds stratigraphically to the Knockfarril member [1]. The Fractured Intermediate Unit (FIU) is relatively bright and is characterized by areally extensive outcrop. The Smooth Ridged - rubbly Unit (SRU-rubbly) exhibit periodic bedrock ridges with an extensive rubble cover. The FIU-rubbly unit is a rubbly equivalent to the FIU, with discrete boulders and extensive wind-blown sands. Modern sand fields are labeled as such. The Smooth Fractured Unit is characterized by extensive, smooth, fractured outcrop and has been hypothesized to be the sulfate-bearing unit at the base of the extensive sulfate stratigraphic section that underlies Mount Sharp [2]. Stratigraphically, both the SRU-rubbly and FIU-rubbly directly underlie the SFU, depending on location.

FIU and FIU-rubbly Units: The FIU and FIU-rubbly both tend to exhibit relatively steep spectral reflectance slopes from ~1 to 1.6 micrometers [3]. Both ferrous smectites and jarosite have been invoked to explain these spectra [3]. Curiosity has acquired extensive remote sensing and contact science observations for both of these units. This includes a series of measurements on boulders within the FIU-rubbly located to the north of the Sands of Forvie sand ripple field (Figure 2).

Mastcam mosaics acquired during the north to south traverse through the FIU-rubbly on the way to Sands of Forvie show that it consists mainly of large boulders surrounded and underlain by basaltic sand. The APXS targets 'Cod_Baa' and 'Carn_Mor' were taken on two different outcrops that represent typical boulder surfaces. The target 'An_Dun' was taken on a nodule located near the 'Cod_Baa' target. These measurements were meant to complement the previous FIU-rubbly bedrock measurements acquired after leaving Bloodstone Hill on the boulder target 'Capercaillie' (Figs. 2, 3).

Compositional Trends: To explore relationships between geomorphic units and Curiosity-based composi-

tion measurements we employed Aitchison-space correspondence analysis (CA) using APXS measurements for all measurements acquired in Glen Torridon. The oxide concentrations data were normalized to log ratios to remove artifacts associated with use of a closed number system [4]. The first and second component vector loadings account for 63% of the variance of the multivariate composition data (Fig. 4). This fraction explains the dominate trends in the data set. Targets taken on sand and regolith were not included, as well as outliers not representative of the bedrock, and targets where white veins were likely in the APXS interrogation footprint. In addition, Br measurements were not included in the analysis because of their wide variance among measurements.

The CA plot shows that SO_3 and CaO are positively correlated, as are MnO and Zn. Both pairs are negatively correlated with K_2O. The FIU measurements cluster toward the left side of the plot, indicating that they are lower in MnO and Zn as compared to the FU measurements. The FU data plot toward the upper right portion of the plot, indicating they are higher in SO_3, CaO, MnO, and Zn as compared to the other geomorphic units. An outlier within this unit is the Glen_Etive target, which plots near the FIU measurements. The SRU rubble-dominated measurements group in the lower left portion of the plot, indicating they tend to be lower in SO_3 and CaO than the other geomorphic units. although there is some variability. FIU-rubbly data lie within the region of the FIU measurements, indicating they are compositionally similar to the FIU.

Summary: In summary, both the FIU and FIU-rubbly geomorphic units show a similar compositional trend in APXS data and one that is different than found for other geomorphic units within Glen Torridon. This includes units that correspond stratigraphically to both the Jura and Knockfarril Hill members of the Murray formation. The FIU and FIU-rubbly composition data do not directly point to a mineralogical explanation for the relatively steeply sloped spectra for these units as observed in CRISM data. This is not surprising given the lack of correspondence between composition and mineralogy in other outcrops on Mars, e.g., for the hematite occurrences on the Vera Rubin Ridge [5]. Composition does not uniquely map to mineralogy**.**

References: [1] Fedo C. M. et al. (2020) *LPS LI*, Abstract #2345 [2] Arvidson R. E. et al. (2021) *LPS LII*. [3] Fraeman A. A. et al. (2016) *JGR:P*, *121*, 1713-1736. [4] Aitchison J. (1986) *Chapman and Hall*. [5] Fraeman A. A. et al. (2020) *JGR:P*, *125*.

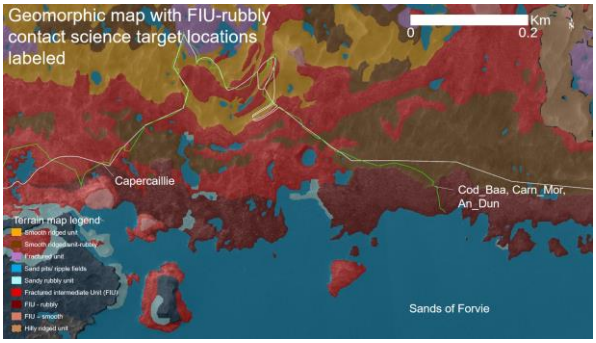

Figure 2. A view of the Geomorphic map zoomed in on the FIU-rubbly unit. Contact Science locations are labeled for targets within the FIU-rubbly.

Figure 3. MAHLI images over the contact science targets within the FIU-rubbly, each at 25 cm standoff.

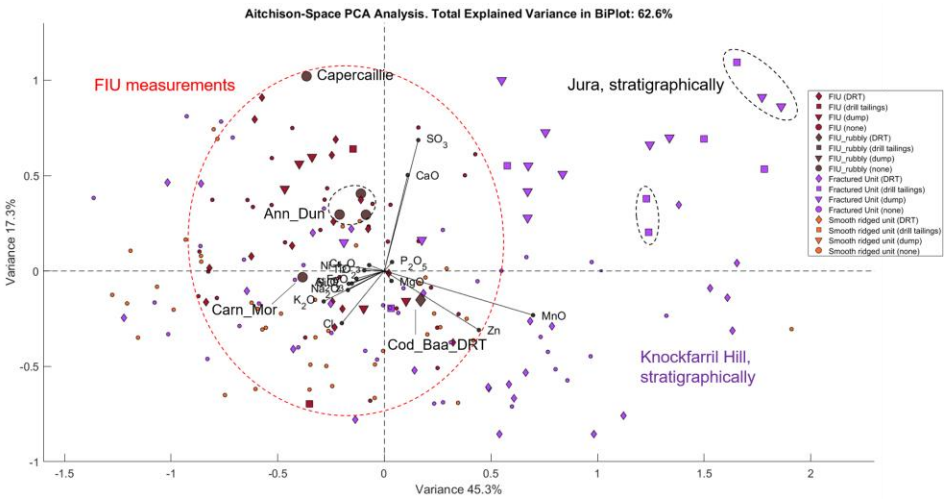

Figure 4. Aitchison-Space Correspondence Analysis plot for APXS measurements taken within geomorphic map area. Measurements on brushed targets (DRT), drill tailings, and dump piles have a larger marker since they better represent the composition of the bedrock. Marker sizes for FIU-rubbly measurements were also increased. The general region where FIU measurements plot is circled and measurements taken within the FIU-rubbly are labeled. The measurements that were within the geomorphic unit FU, but stratigraphically within the Jura member, are circled. The remainder of the FU drill tailings and dump measurements were within the Knockfarril Hill member.