LEAVING GLEN TORRIDON: BEDROCK GEOCHEMISTRY MEASURED BY CHEMCAM EN ROUTE TO THE SULFATE UNIT OF GALE CRATER. E. Dehouck[1*], A. Cousin[2], N. Mangold[3], J. Frydenvang[4], O. Gasnault[2], W. Rapin[2], O. Forni[2], P. J. Gasda[5], G. David[2], G. Caravaca[3], J. Lasue[2], P.-Y. Meslin[2], C. C. Bedford[6], N. L. Lanza[5], V. K. Fox[7], K. A. Bennett[8], A. B. Bryk[9], S. Maurice[2], and R. C. Wiens[5]. [1]LGL-TPE, Lyon, France; [2]IRAP, Toulouse, France; [3]LPG, Nantes, France; [4]Univ. Copenhagen, Denmark; [5]LANL, New Mexico, USA; [6]LPI, USRA, USA; [7]Univ. Minnesota, USA; [8]USGS Astrogeology, Arizona, USA ; [9]Univ. California, Berkeley, USA. *erwin.dehouck@univ-lyon1.fr

Introduction: Since January 2019, the Mars Science Laboratory (MSL) rover *Curiosity* has been exploring the Glen Torridon (GT) region of Gale crater, which corresponds to the topographic trough between the Vera Rubin ridge and the Greenheugh pediment (Fig. 1). From orbit, this region stands out due to the relatively strong near-infrared signatures of clay minerals [1,2]. The data collected on the ground by *Curiosity* have allowed the MSL team to confirm and quantify the presence of these clay minerals [3], to characterize their organic content [4], and to document in detail their geochemical and sedimentological settings [5].

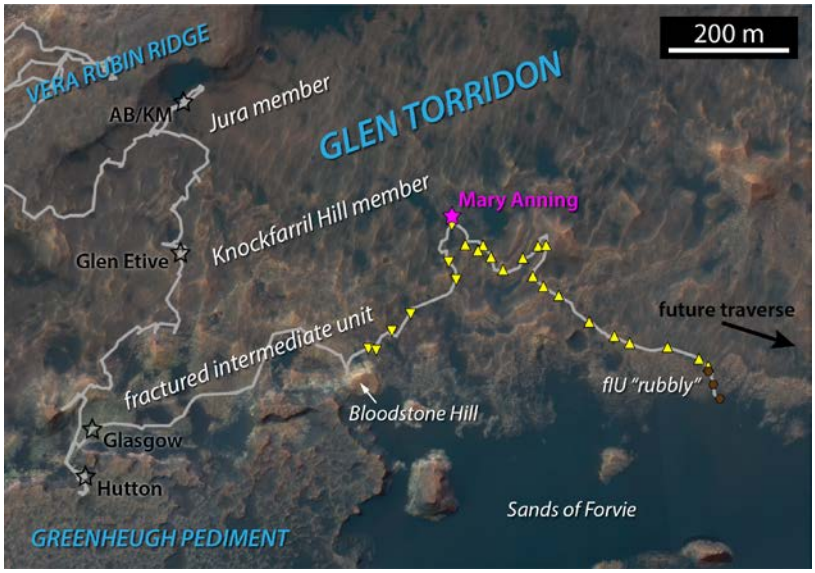
In particular, the bedrock chemistry measured by ChemCam shows elevated values of the Chemical Index of Alteration (CIA) throughout most of Glen Torridon [6,7], which indicates an open-system type of alteration [8]. In addition, the ChemCam observations suggest the presence of illite in the fine-grained rocks [9] and reveal a possible relationship between grain size and geochemical variations [10]. Finally, they show that the light-toned rocks located just below the unconformity at the base of the Greenheugh pediment (and drilled at Hutton; Fig. 1) are associated with "anomalous" bedrock compositions that may be related to a late-stage diagenetic event at Gale [7].

Here, we report the findings of the ChemCam instrument during the last stretch of the GT campaign, from Bloodstone Hill to the Sands of Forvie (Fig. 1). At the conference, we will also present the data acquired in early 2021, as *Curiosity* approaches the transition into the sulfate-bearing unit.

Dataset: ChemCam measures the chemical composition of targeted rocks and soils within a few meters of the rover using laser-induced breakdown spectroscopy (LIBS). Quantification of eight major rock-forming oxides is performed routinely [11]. Each ChemCam analysis consists of a raster of several points a few millimeters apart from each other, and each point itself consists of a series of laser shots (typically 30). For bedrock targets, this approach allows removal of unwanted contributions from Ca-sulfate veins or soil material by discarding the corresponding points [e.g., 8].

Rover path: After a lateral traverse within the "fractured Intermediate Unit" (fIU) and a brief visit of a light-toned outcrop named Bloodstone Hill (Fig. 1), *Curiosity* drove downhill to acquire additional drill samples within the underlying Knockfarril Hill member (KHm). This was done at a site called Mary Anning, where the rover remained for about 90 sols. Then, *Curiosity* returned to the fIU, driving across a series of bench-like geomorphological features. Finally, on sol 2972 (~Dec. 15th, 2020), it reached a section of the fIU with a distinct "rubbly" texture as seen in orbital imagery [12].

Results: Variations in MgO, K_2O and FeO_T abundances along the rover path are shown in Figure 2. The down-section traverse from the fIU to the KHm was accompanied by a clear but progressive increase in MgO content, from ~2–4 wt% to ~8–12 wt%. Conversely, a steady decrease in MgO content was observed during the up-section traverse. The first targets of the "fIU rubbly" show an intermediate MgO content (~5–8 wt%). Regarding K_2O, the abundances are variable but lower at Mary Anning and in the "fIU rubbly".



► **Figure 1:** context map of *Curiosity*'s traverse through Glen Torridon. The colored symbols correspond to the rover stops in the area covered by Figure 2. North is up. AB/KM = Aberlady/Kilmarie.

Overall, the bedrock at Mary Anning has a composition in line with other areas of the KHm previously visited [6], but with an even higher MgO content. The most recent fIU targets are also remarkably similar to those observed at the beginning of the lateral traverse, near the Glasgow drill site (~1 km to the west; Fig. 1).

Although the FeO_T content is overall stable along the traverse, local variations are observed in two groups of targets. The first group (analyzed around sol 2875; Fig. 2) is located at the Mary Anning site within a bedrock layer characterized by a knobby texture and a lower MgO content. The second group (analyzed between sols 2954 and 2965) is characterized by the presence of dark nodules [13] similar to those previously observed in the fIU, for example around the Glasgow drill site. The high FeO_T abundances are associated with the dark nodules, whereas the points in between the nodules show low FeO_T (down to ~12.5 wt%). The targets from the first group do not display dark nodules nor low-Fe points, which suggests a different formation process. Nonetheless, together with the Mn-rich materials discovered at the Mary Anning site [14,15], they likely indicate diagenetic remobilization of redox-sensitive elements in the KHm.

Finally, the CIA values are stable and elevated (~55-60; data not shown) along the part of the traverse documented here.

Discussion and conclusion: Although potential contacts (between the KHm and the fIU, and between the fIU proper and the "fIU rubbly") have been identified using orbital imagery, there is no evidence for abrupt changes in bedrock geochemistry in the ChemCam dataset. As previously observed in GT [6,7,10], Mg and K are the two elements most clearly varying with stratigraphic position; however, their variations are not always well correlated, as illustrated by the trends observed before and after Mary Anning (Fig. 2). In addition, FeO_T displays some local variations, but these are likely of diagenetic origin.

So far, we have not observed a reoccurrence of the "anomalous" fIU compositions measured around the Hutton drill site (which were characterized by a marked drop of the CIA; ref. 6), even though the rover is now more than 10 meters higher in elevation. This may indicate that the Hutton "horizon" is of limited extent (e.g., present only under the Greenheugh pediment), or that its elevation varies laterally. As the rover progresses eastward and uphill, ChemCam will continue surveying the bedrock in search of more Hutton-like material or the first chemical indications of the clay-to-sulfate transition.

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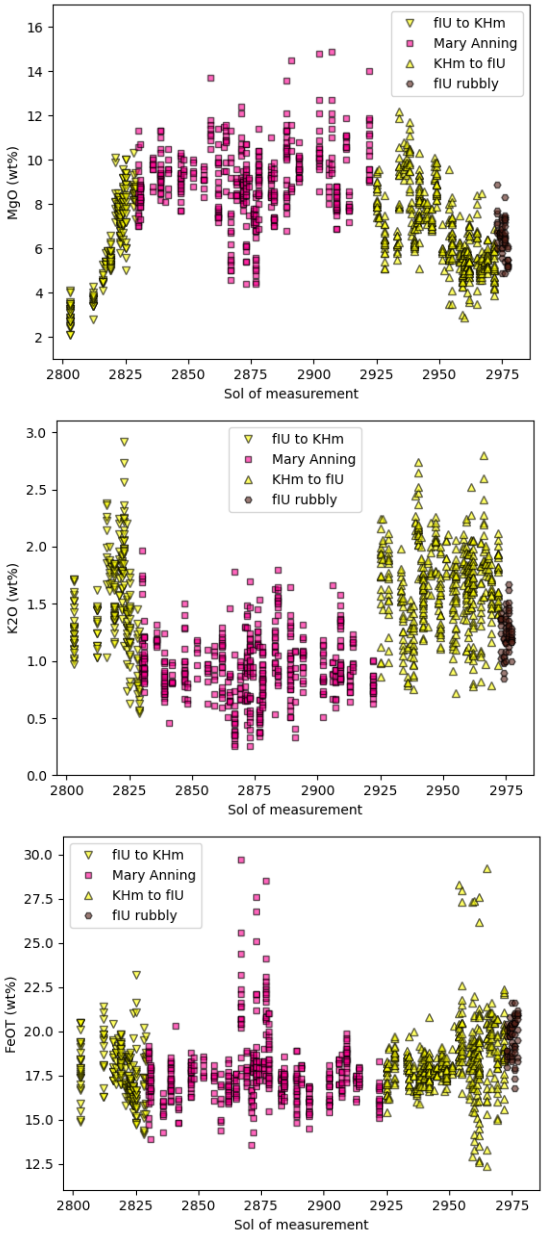

▲ **Figure 2:** variations in MgO, K_2O and FeO_T abundances (wt%) along the traverse. The x axis shows time of measurement and does not reflect horizontal distance. The diagrams start just after the departure from Bloodstone Hill and ends at the Sands of Forvie (see Figure 1 for localization of the rover stops). Each symbol corresponds to a single LIBS point on a bedrock target, excluding Ca-sulfate veins and soils.