FIRST GALE WESTERN BUTTE CAPPING-UNIT COMPOSITIONS, AND RELATIONSHIPS TO EARLIER UNITS ALONG CURIOSITY'S TRAVERSE R.C. Wiens[1], N. Mangold[2], O. Forni[3], R.B. Anderson[4], O. Gasnault[3], A. Bryk[5], W.E. Dietrich[5], J.R. Johnson[6], E. Dehouck[7], L. Le Deit[2], J. Frydenvang[8], C. Bedford[9], S. Maurice[3], and the ChemCam and MSL Science Teams; [1]LANL (rwiens@lanl.gov), [2]U. Nantes, [3]IRAP, [4]USGS Flagstaff, [5]UC Berkeley, [6]APL-JHU, [7]U. Lyon, [8]U. Copenhagen, [9]LPI, Houston

Introduction: The Curiosity rover has been traversing through the clay-bearing unit (Glen Torridon; GT), approaching Greenheugh pediment, a large, fan-shaped surface surrounding the mouth of Gediz Vallis on the lower slope of Mt. Sharp [1]. The pediment unconformably overlies the underlying bedrock, and is hence younger than units of the Mt. Sharp group. Orbital imaging of the pediment has shown it to have a slightly lower albedo and higher thermal inertia than neighboring units, to be relatively retentive of craters (e.g., erosion resistant), and to exhibit curved bedforms suggestive of lithified eolian bedforms [2]. No diagnostic spectral signature has been observed from orbit. Recent rover positions allowed remote imaging of the contact between Greenheugh pediment and the eroded Murray formation strata below it, showing that the pediment capping material is cross-bedded and relatively thin (1-3 m) [1,3], and suggesting that the pediment may have been much larger at one time [4].

As Curiosity approached the edge of the pediment, the team investigated two buttes named Central and Western. The latter butte contains dark capping material that initially looked similar to the pediment cap, but close inspection revealed important physical differences [1]. Here we report on compositions from ChemCam of two float rocks that appear to have rolled down from the capping unit, and on potential relationships to other targets along the traverse of the rover.

Blackwaterfoot and Clashnessie: The former (Fig. 1) was observed by MAHLI, APXS, ChemCam (2 rasters), and Mastcam, while the latter was only observed with ChemCam and Mastcam. Blackwaterfoot is a finely laminated sandstone or siltstone with strong cementation limiting an easy assessment of the grain size. Clashnessie texture cannot be determined remotely but it displays a faint lamination and a strong cementation. Both rocks have been strongly etched by wind.

The compositions of these targets are given in Table 1. Both are very different from others in GT; they are enriched in Fe relative to most of the targets along the entire traverse. Relative to Blackwaterfoot, Clashnessie is more enriched in Fe, Ti, Na, and K, and is significantly depleted in Mg. Clashnessie is also more homogeneous than Blackwaterfoot, as shown by the smaller standard deviations between compositions of individual observation points. Both targets have relatively low totals of the major elements.

Comparison of these compositions with others, all derived by ChemCam along the traverse, was done by dendogram of individual points and by target-averaged comparisons; passive spectra were also considered. Results indicate that several targets are good matches with targets observed earlier in the mission on Bradbury Rise northwest of Mt. Sharp. Here we focus more on Blackwaterfoot. Most of the compositional matches are in or near the Shaler outcrop [5, 6]. This region exhibits a contact between three different geological units (Fig. 2): hummocky plains (HP), a descriptive term for much of the surface on Bradbury Rise near the landing site, a bedded fractured (BF) unit characterized by observations at Yellowknife Bay (YKB), and a cratered surface (CS), an apparent erosionally resistant surface to the south and east of YKB (dark red in Fig. 2). The rover team never investigated the latter unit, although ChemCam observed some targets just beyond the Shaler outcrop.

The best target-averaged compositional matches to Blackwaterfoot are Rove, Montaigne, and Gunflint. Thomson is also a relatively good match (Table 1). The first two are located within the Shaler outcrop. Gunflint and Thomson are side-by-side float rocks observed a short distance from Shaler as the rover left the area. Dendogram results point to a number of other Shaler observations as very close matches. Passive spectral matches are good for targets near Shaler, as shown by Fig. 3. Compositional matches with Clashnessie are in the Rocknest outcrop [7], such as Pearson (Table 1).

Discussion: Greenheugh pediment capping unit has been considered part of the Siccar Point group, which also includes the Stimson formation that drapes over part of the lower Murray formation [8-10]. The observed Western butte compositions do not match the Stimson formation, whose mean SiO_2 (48.6±3.0 wt. %), Al_2O_3 (13.4±2.9), and Na_2O (3.4±0.8) are high relative to Blackwaterfoot and Clashnessie, while Stimson's Fe and K are low [11]. The Western butte capping rocks appear to be different from the capping unit exposed at the edge of Greenheugh pediment, based on recent imaging [1]. Even so, current stratigraphic models have no clear links to outcrops on Bradbury rise or at Yellowknife Bay. The implications for the origin of the capping unit of Western butte, and the connections to Shaler and Rocknest, will be discussed at the presentation.

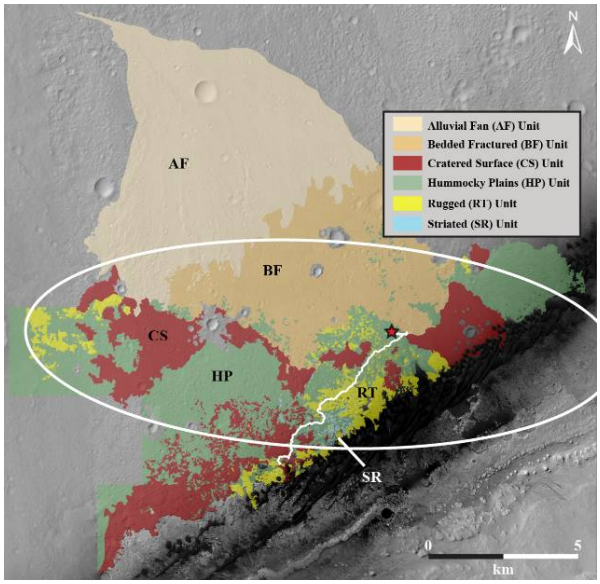

Fig. 2. Map of the landing ellipse showing occurrences of the Cratered Surface (in dark red, marked "CS") and Bedded Fractured ("BF") Units sampled at Yellowknife Bay [6]. Shaler and the similar targets to Blackwaterfoot and Clashnessie are at the triple junction just to the right of the landing site (star), at the east-most point of the traverse. The current Curiosity rover location is off the map to the south.

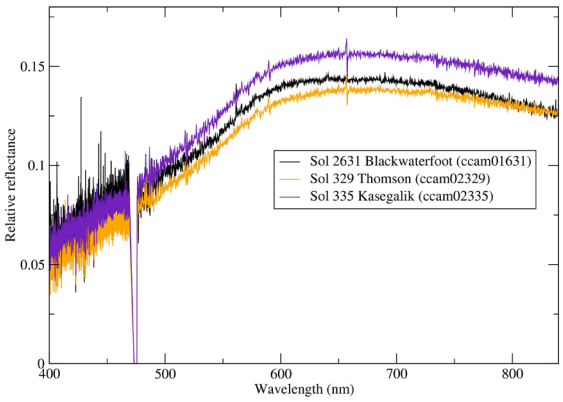

Fig. 3. ChemCam passive reflectance spectra from Blackwaterfoot and two similar targets near Shaler, earlier in the mission.

Acknowledgements: This work was supported in the US by NASA's Mars Exploration Program and in France by CNES.

References: [1] Bryk A.B. et al., this meeting. [2] Anderson R.B. and Bell J.F. III (2010) Mars 5, 77. [3] LeDeit L. et al., (2018) XXXXVIIII, 1437. [4] Banham S.G., et al., this meeting. [5] Anderson R.B., et al. (2015) Icarus, 249, 2. [6] Grotzinger J.P., et al. (2013) doi:10.1126/science.1242777. [7] Blaney D., et al. (2014) JGR 119, 2109. [8] Banham S.G., et al. (2018) Sedimentology, doi: 10.1111/sed.12469. [9] Grotzinger J.P., et al. (2015) Science, 350, aac7575. [10] Fraeman A., et al. (2016) JGR, 121, 1713. [11] Bedford C.C., et al. (2020) Icarus, in press.

	TARGET	SOL	N	SiO2	TiO2	Al2O3	FeOT	MgO	CaO	Na2O	K2O	TOTAL
Compositions	Blackwaterfoot	2631	20	41.6	1.1	8.2	23.4	9.0	5.3	2.3	0.7	91.7
	Rove	309	18	42.9	1.1	8.9	22.6	9.2	5.4	2.3	0.7	93.1
	Montaigne	317	16	44.0	1.1	8.3	21.1	9.4	4.4	2.4	0.6	91.2
	Thomson	329	10	42.9	1.4	7.1	21.7	11.8	4.9	2.0	1.1	92.8
	Clashnessie	2631	10	41.0	1.6	8.1	26.4	4.4	5.2	2.9	1.1	90.6
	Pearson	60	27	41.3	1.8	7.7	28.1	3.2	4.8	2.9	1.0	90.8
Std. Devs.	Blackwaterfoot	2631	20	2.2	0.2	1.5	3.2	1.9	1.6	0.4	0.3	1.9
	Rove	309	18	3.0	0.3	1.8	2.3	2.6	1.9	0.5	0.3	3.5
	Montaigne	317	16	2.7	0.2	1.8	0.8	3.6	1.2	0.4	0.2	3.1
	Thomson	329	10	1.7	0.3	0.6	0.9	1.6	0.7	0.2	0.2	2.0
	Clashnessie	2631	10	0.6	0.1	0.6	1.0	1.0	1.1	0.2	0.1	1.2
	Pearson	60	27	4.7	0.5	1.2	4.0	0.7	3.8	0.4	0.3	2.3

Table 1. Major-element compositions (wt. %) and standard deviations of Blackwaterfoot and Clashnessie (red) along with matches from Shaler and nearby (blue), and Rocknest (green). N = # observation points.

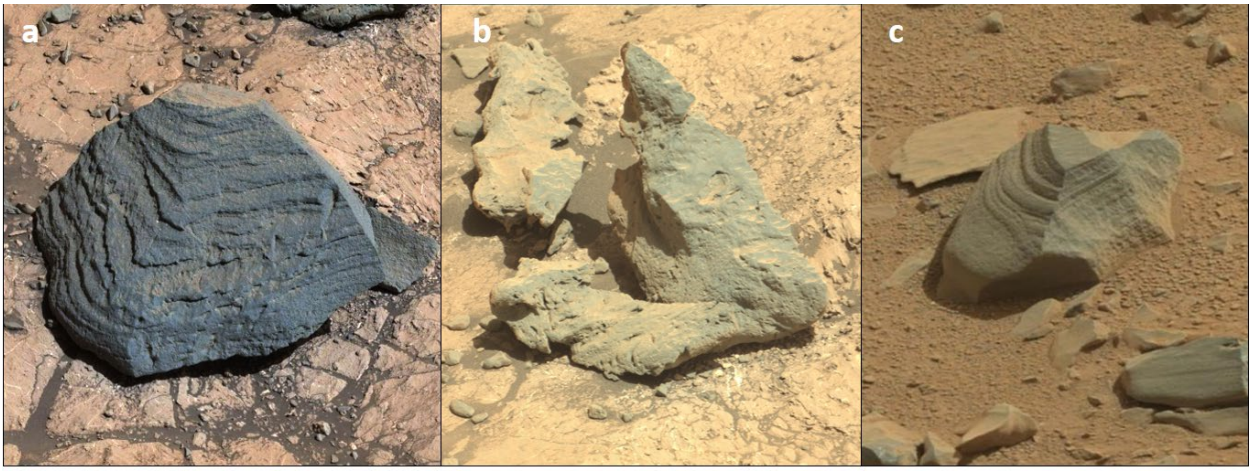

Fig. 1. Blackwaterfoot (a) and Clashnessie (b), observed on Sol 2633 on Western butte, near the edge of Greenheugh pediment (Mastcam images). These targets appear to have rolled down from the capping unit of the butte. Thomson (c) was observed near the begninning of the mission, on Sol 329, just after leaving the Shaler outcrop (Fig. 2). Shaler outcrop targets have similar compositions to Blackwaterfoot and Clashnessie. Blackwaterfoot is ~0.5 m across; Clashnessie is ~0.2 m; Thomson is ~0.2 m.