Iron Meteorite Finds Across Lower Mt. Sharp, Gale Crater, Mars: Clustering and Implications

#3058

D. F. Wellington[1] (dfwellin@asu.edu), P.-Y. Meslin[2], J. Van Beek[3], J. R. Johnson[4], R. C. Wiens[5], F. J. Calef III[6], J. F. Bell III[1]

[1]Arizona State Univ., [2]IRAP, UPS-CNRS, Univ. Toulouse, [3]Malin Space Science Systems, [4]Johns Hopkins Univ., APL, [5]LANL, [6]JPL/Caltech

Why Study Meteorites on Mars?

- Meteorites, and iron meteorites in particular, are well-represented in datasets from multiple different rovers [1,2,3].
- Meteorites are well-studied from samples retrieved on Earth, which provides constraints for interpreting evidence of physical and chemical weathering conditions encountered post-fall [e.g., 4].
- Apparent differences in the abundance of meteorite finds across different rover datasets suggest that these populations could provide unique evidence for local environmental histories.

Identifying Iron Meteorites Within Gale Crater

- Iron meteorites are recognized and identified in three ways on MSL:
  1. Differences in color, morphology, and/or texture versus locally-derived float material (see Fig. 1)
  2. Unusual near-infrared reflectance properties that are different from surrounding material (see e.g. Fig. 3) and not consistent with common mineral phases
  3. Chemical data from the ChemCam LIBS instrument that demonstrates an iron/nickel-rich composition (see next poster, loc. #759)

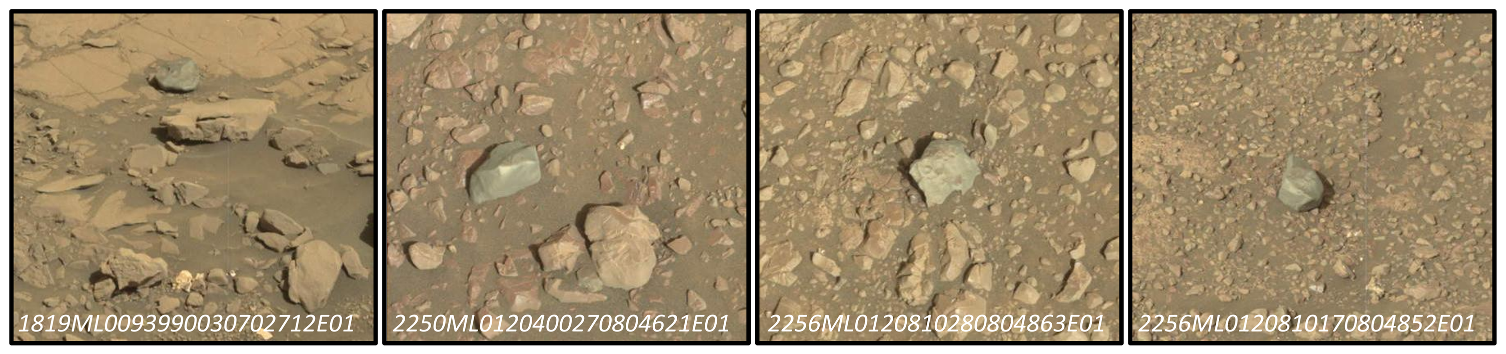


Figure 1: Mastcam color images of suspected or confirmed iron meteorites that were noticed by their unusual appearances with respect to local material. From left to right, these are: Mustards Island, Newburgh, Gometra, and an unnamed float rock from the same imaging sequence as the previous. For scale, the meteorites are approximately 4-5 cm in size. The annotation is the image product ID, beginning with the four-digit sol.

- We have found that using spectral reflectance data (#2 above) from Mastcam multi-filter imaging is very effective at surveying for candidate iron meteorites. Many recent finds (other than the above) were initially recognized from multispectral data.

Meteorite Locations Along MSL's Traverse

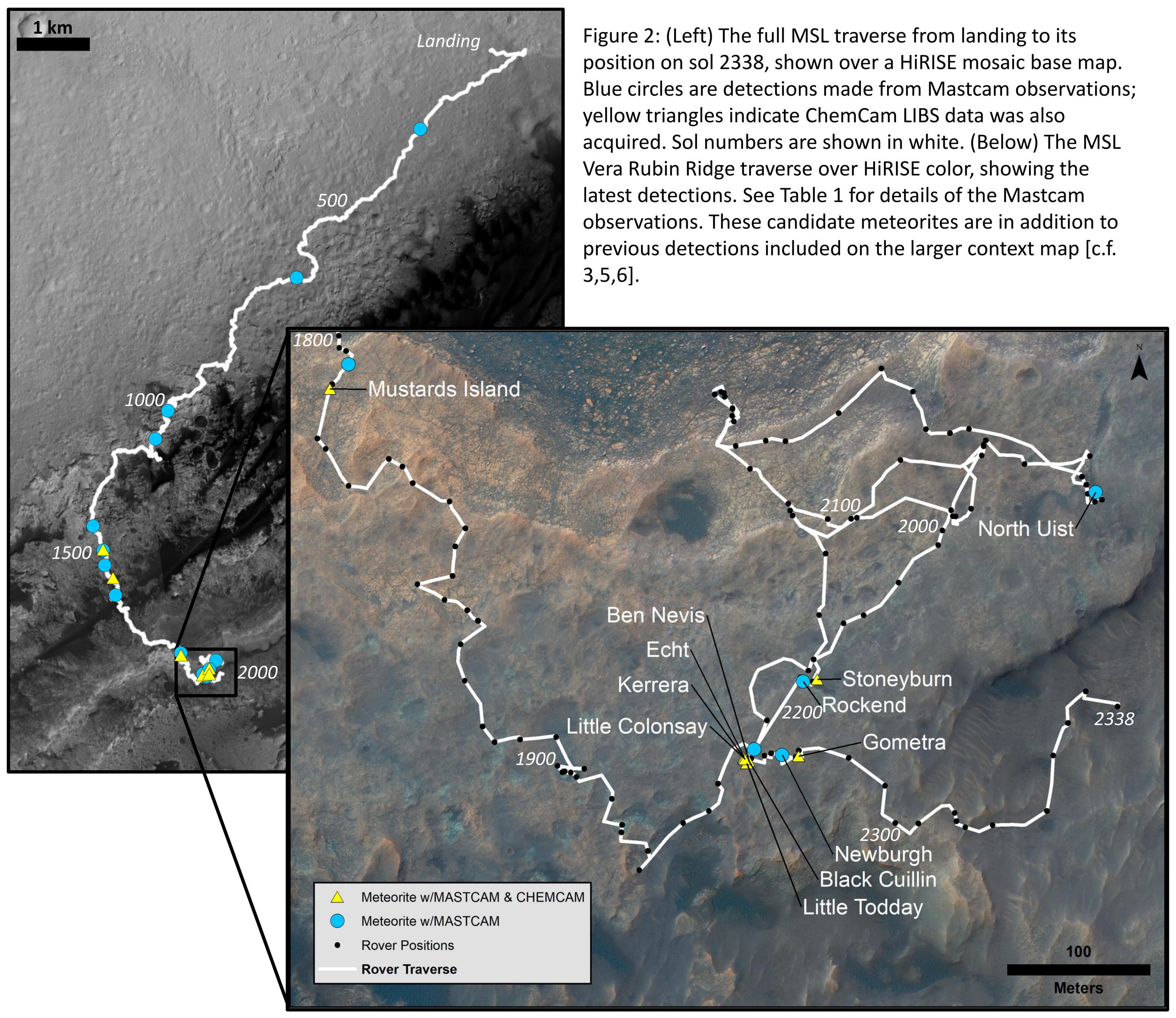
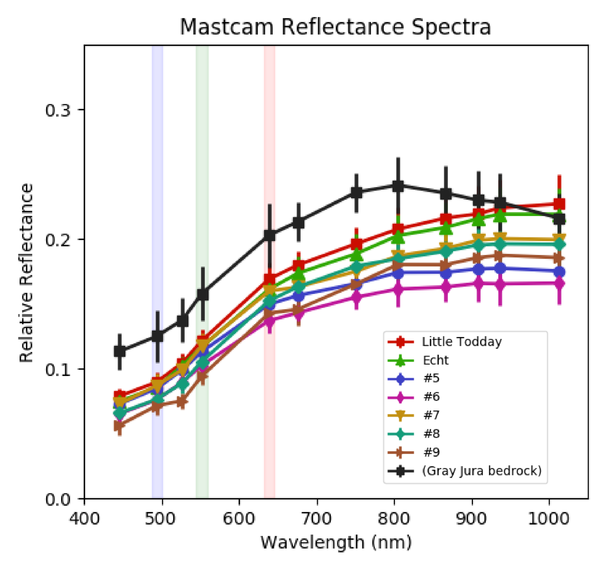


Figure 2: (Left) The full MSL traverse from landing to its position on sol 2338, shown over a HiRISE mosaic base map. Blue circles are detections made from Mastcam observations; yellow triangles indicate ChemCam LIBS data was also acquired. Sol numbers are shown in white. (Below) The MSL Vera Rubin Ridge traverse over HiRISE color, showing the latest detections. See Table 1 for details of the Mastcam observations. These candidate meteorites are in addition to previous detections included on the larger context map [c.f. 3,5,6].

Investigation at the Highfield Site

- From sols 2222-2250, Curiosity was stopped at the Highfield drill site to acquire a sample, providing an opportunity to survey the site with multi-filter Mastcam mosaics.
- This location had been visited previously (sols 1962-1985), during which time two meteorites (Black Cuillin and Ben Nevis) had been discovered.
- Further imaging on the second visit turned up over a dozen additional candidate meteorites suspected on the basis of their spectral properties. Four of these were targeted by the ChemCam laser (Fig. 4, named targets).
- ChemCam data confirmed those targets were meteorites and suggested some compositional variability between them [7].

Highfield Site: Mastcam Spectra



- Mastcam multi-filter images calibrated to I/F can be used to extract 12-point reflectance spectra (Fig. 3). Iron meteorites show similar positively-sloped reflectance values through the near-IR that often differ quite clearly from local materials.

Figure 3: (Left) Mastcam spectra of Highfield suspected iron meteorites with full-filter coverage. Numbers correspond to individual float labeled in Fig. 4 (below).

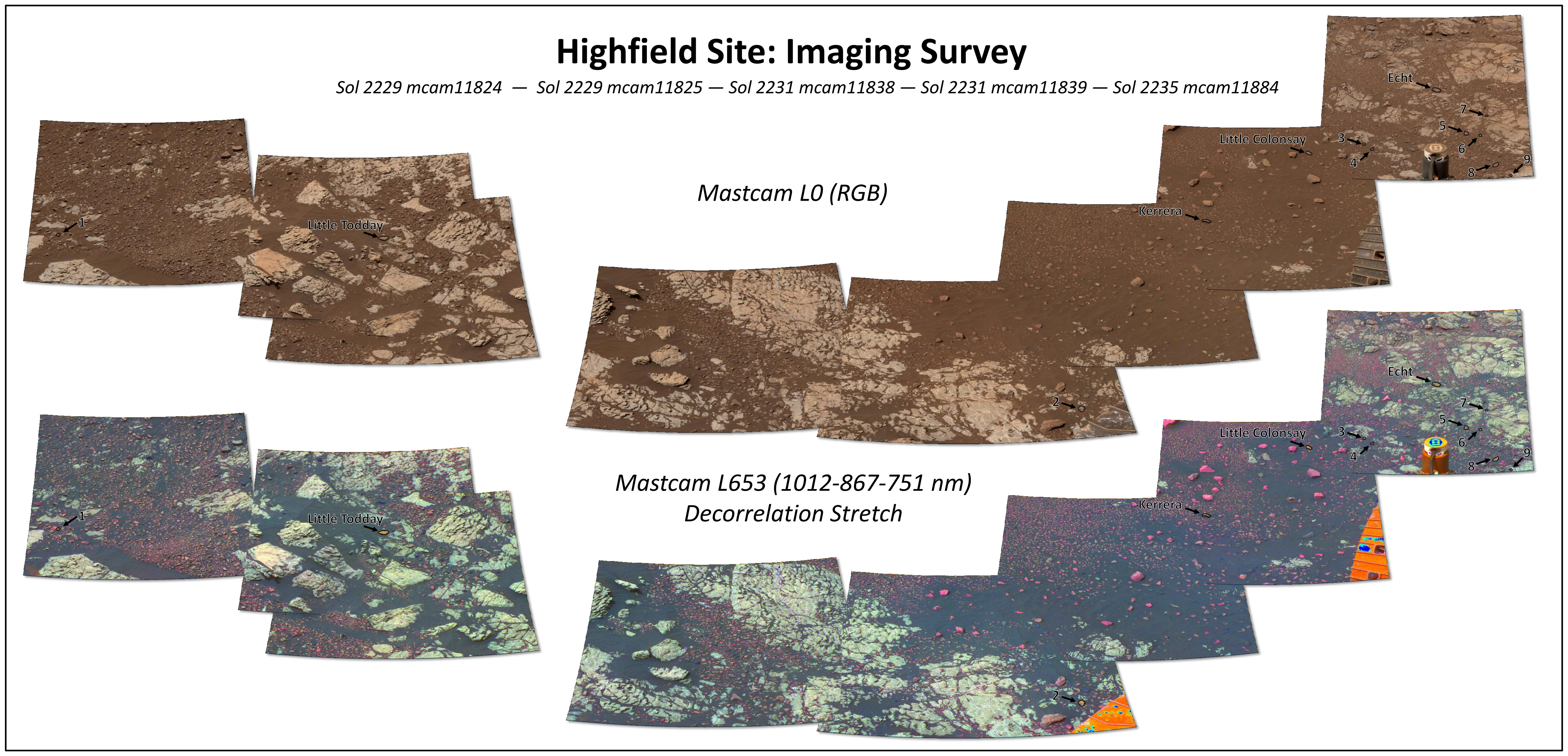


Figure 4: Mastcam imaging acquired as part of a meteorite survey campaign while the rover was stationed at the Highfield (gray-toned Jura) drill site. The top mosaic shows the RGB color view from Mastcam broadband Bayer imaging. The bottom mosaic covers the same area as above in a false color decorrelation stretch used here to show variability in Mastcam near-infrared filter images. Within the false color mosaics, pale green colors correspond to gray Jura bedrock with weakly negative near-IR slopes, pinkish hues to ferric material (here, as float rocks most likely derived from nearby reddish-toned ridge units), blues are materials with a ferrous absorption feature (sand, and more strongly on presumably out-of-place float), and orange colors are spectrally consistent with iron-nickel metal (probable meteorites), and also present on some rover hardware. Putative meteorites are outlined and labeled with either a target name (if a ChemCam LIBS target) or a number if unnamed. Each of the four ChemCam observations returned a composition consistent with an iron-nickel meteorite.

Table 1: MSL Candidate Meteorites, Vera Rubin Ridge

Informal Names[1]	Sol(s)	Count[2]	Size(s)[3]	Mastcam Obs.	Filter Coverage[4]
(unnamed cluster)	1814 1819	many	< 15 cm	mcam09364 mcam09396	L0356 R0-6
Mustards Island	1821	1	~ 5 cm	mcam09401	L0-6, R0-6
Ben Nevis	1964	1	~ 2 cm	mcam10267	L0-6
Black Cuillin	1964	1	~ 4 cm	mcam10269	L0-6, R0-6
North Uist	2013 2016	1	~ 10 cm	mcam10610 mcam10633	L0-6 R0
Stoneyburn, Rockend	2161 2163 2169 2173	2	~ 7 cm each	mcam11638 mcam11652 mcam11681 mcam11719	L0356 L0356 L0-6, R0-6 R0-6
(unnamed)	2222	1	~ 2 cm	mcam11774	L0356
Little Todday, **Echt**, **Little Colonsay**, **Kerrera**, (many unnamed)	2229 2229 2231 2231 2235	14+	< 5 cm each	mcam11824 mcam11825 mcam11838 mcam11839 mcam11884	L0356 L0356 L0-6, R0-6 L0-6, R0-6 L0356
Newburgh	2250 2255	1	~ 4 cm	mcam12040 mcam12069	L0 L0-6, R0-6
(unnamed) **Gometra**	2256 2259	2	~ 4 cm each	mcam12081 mcam12088	L0 L0-6, R0-6

Table 1: [1]Bolded target names indicate ChemCam LIBS data was acquired as well [7]. [2]Unresolved or inconclusive spectral image data complicates exact counting. [3]Estimate is based on the longest axis and is approximate. [4]Band center wavelengths are 527-445-751-676-867-1012 nm (L1-6, left camera) and 527-445-805-908-937-1013 nm (R1-6, right camera); 0 is broadband RGB in each [8,9].

Conclusions

- Fragments of iron meteorites appear to be quite common along MSL's traverse. They are typically cm-sized, occur as clusters, and sometimes show patchy surfaces of weak chemical alteration.
- These meteorites appear to be more numerous on the Vera Rubin Ridge (and non-VRR Upper Murray?) than earlier along the traverse. Whether this might be due to changes in ease of detection, imaging strategies, or other sources of observational bias, or actual differences in abundance, is still being investigated.
- In total, MSL has reported more finds than either of the MER missions [1,2], which had similar capabilities to detect iron meteorites by multispectral imaging. Considering these recent detections from MSL together with previous finds [3,5,6], MSL has likely encountered well over 40 individual fragments to-date (of uncertain pairing relationships). An exact count is difficult due to uncertainties of detection near the limit of resolution.
- The abundance and close clustering of these meteorites suggests the action of some combination of post-impact fragmentation or weathering, or the existence of local transport and concentration processes, such as occurs in Antarctic ice fields on Earth.

References

[1] Schröder et al. (2008) JGR, 113, E06S22. [2] Fairén et al. (2011) *Meteoritics & Planet. Sci., 46*, 1832-1841. [3] Wellington et al. (2018) *49th LPSC*, 1832. [4] Ashley et al. (2011) *JRG, 116*, E00F20. [5] Johnson et al. (2014) AGU Fall Mtg., P51E-3989. [6] Wiens et al. (2017) 80th Met. Soc. Mtg., 6168. [7] Meslin et al., this session, #3179, loc. #759. [8] Malin et al. (2017) *E&SS, 4*, 506- 539. [9] Bell et al. (2017) *E&SS, 4*, 396-452.