ERRATIC ROCKS AT GALE CRATER, COMPARISON TO GUSEV AND MERIDIANI PLANUM.

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Introduction: Currently on sol 2635, the MSL Rover Curiosity is climbing up Mount Sharp in Gale Crater to characterize the environmental conditions under which the encountered bedrock was laid down in the distant past [1]. Through extended imaging, remote and in-situ chemistry, as well as drill samples for mineralogy and wet chemistry, so far ~ 400 meters of stratigraphy were characterized from the foothills.

In general, the bedrock was found to be very homogeneous over kilometers and in most cases fragments or pebbles clearly shared chemical similarity with the intact layers [2]. Currently the rover is in the clay bearing unit (CBU). During the mission several erratic rocks were found, either igneous floats or suspected cap rocks. Recently, a pebble was measured with the APXS [3], which shows little chemical similarity with the bedrock. Two hypotheses for its origin are discussed in this abstract.

APXS results and context: The ~5 cm wide pebble dubbed GretnaGreen (GG) was found in close proximity to the Western Butte capping rock in the CBU, figure 1.

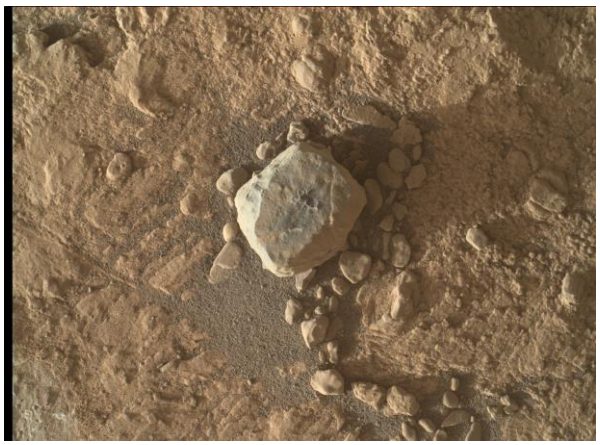

Fig 1 Gretna Green, 25 cm MAHLI context image

The pebble was large enough to cover the full APXS FOV of ~2 cm at 6 mm standoff. The results might be impacted by a thin dust cover since no dust removal was performed. The pebble has very high MgO (15.5%) and Ni (2600ppm), elevated Cr and FeO, low Ti, K and Zn, see table 1.

As figure 2 shows, GG clearly differs chemically from the dominant bedrock. Shown are the 16 elements reported by the APXS, ratioed to the soil Portage, for GG, a soil Ripogenus and a sample of the typical CBU bedrock Scotnish_DRT. GG is much more mafic than the dominating Murray formation, with very low Zn. Characteristic CBU enrichments in K and Ge (not shown in plot) are absent in GG, neither are the typical depletions in Mg and Mn.

GG bears some resemblance to the soil Ripogenus, one of the very mafic soils encountered in the active dunes in Gale Crater. These soils experienced grain size sorting and dust removal, so that they are depleted in elements like S, Cl and Zn that are enriched in the fine dust, compared to usual global soils like Portage.

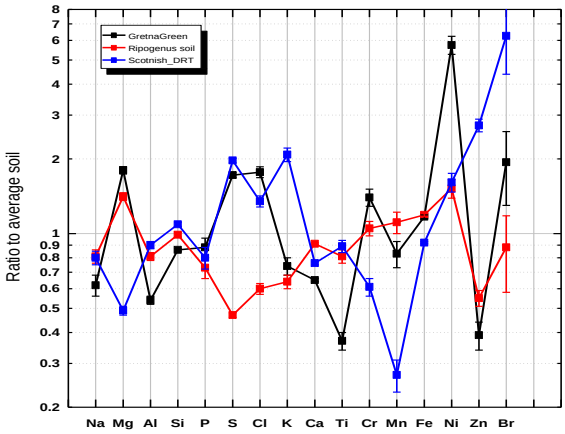

Fig 2 Elemental ratios of various Gale samples

Hypothesis 1, mafic martian origin:

Gretna Green could be a fragment of an ultramafic cap rock unit. Beside near identical soils, the MER rover Spirit documented a similar chemical signature in Gusev Crater, summarized in table 1. In the surrounding of Home Plate, a massive exposure of bedrock, called Algonquin(AG) was measured as-is and brushed, shown in the MI in fig 3 and in fig 4 in local context. This bedrock was very dusty and values for as-is and brushed (RB) allow judging possible impacts on the unbrushed GG data, which however looks less dusty than AG.

Algonquin has a similar ultramafic composition as the neighboring outcrops Seminole and Comanche, see fig 4, albeit Moessbauer identified ~ 33% Fe, Mg Carbonates in Comanche [4]. They share high Mg, Ni, low Ti, Zn with Gretna Green.

The ultramafic hypothesis for GG can be tested, when uphill more bedrock of this unique composition is encountered.

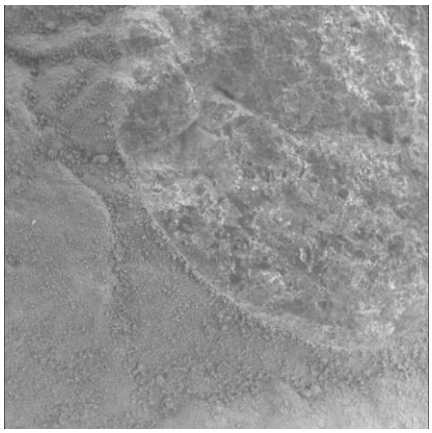

Fig 3 MI of Algonquin, sol 688 brushed

	GG	AG as-is	AG RB	SC
Na_2O	1.7	2.5	1.6	1.5
MgO	15.6	13.6	22.3	18.0
Al_2O_3	5.1	7.3	4.0	4.4
SiO_2	36.8	42.6	40.6	44.0
$P2O_5$	0.83	0.78	0.63	0.61
SO_3	9.40	5.62	4.32	5.09
Cl	1.22	0.79	0.87	0.62
K_2O	0.37	0.26	0.12	0.14
CaO	4.74	4.12	2.61	3.43
TiO_2	0.44	0.53	0.35	0.24
Cr_2O_3	0.68	0.73	0.87	0.61
MnO	0.35	0.39	0.38	0.38
FeO	22.4	20.7	21.2	20.6
Ni	2623	858	891	3207
Zn	126	169	131	164
Br	66	69	72	59

Table 1: APXS of MSL and MER samples

Hypothesis 2, meteoritic origin:

At Meridiani Planum, where the dominating, sulfate bearing Burns formation with windblown soil coverage allowed an easy identification of isolated rocks, several stony meteorite fragments were identified [5]. One key result in the chain of evidence was that 11% of the iron in Barberton, sol 122, was in the metallic α-Fe state. Barberton had similarly high Mg and Ni as GG. Table 1 shows the APXS results of a similar cobble Santa Catarina(SC), sol 551, which also had some iron in Kamacite and possibly Troilite.

As shown in table 1, both hypotheses, ultramafic Martian and meteoritic origin, have similar elemental patterns. Hypothesis 2 will be hard to prove, unless a strewn field of paired, near-identical fragments is encountered at Gale.

Discussion: The APXS results for ultramafic rocks falls within the typical calibration suite and should be good within the given accuracy levels, caused by the usual limitations for microscopic heterogeneity of the sample. If Mg is predominantly together with Fe in

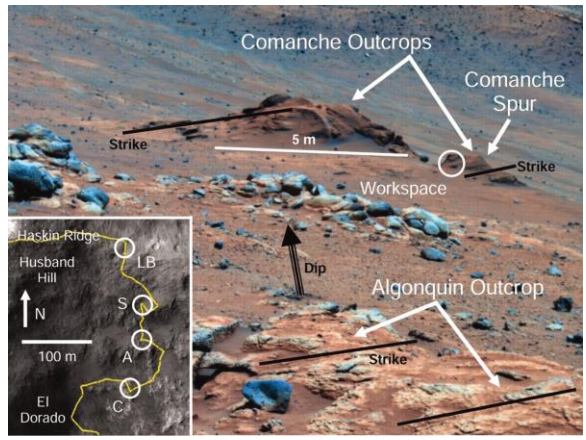

Fig 4 Algonquin and context, from [4]

Olivine, one can expect too low results for Mg, similar to possible dust coverage.

For a meteoritic origin, the assumption that all detected elements are in their usual oxide state, is possibly violated, as the Moessbauer results showed. If the majority of the 0.26% Nickel in GG is in large (>0.1mm) FeNi alloy grains, the very high absorption of Ni x-rays by Fe would cause an underestimation of the Ni content by a factor of ~3, if an alloy composition of 90Fe10Ni is assumed. However, this seems unlikely, since this would also imply that ~ 30% of the overall Fe is bound to this alloy. Therefore, it is likely that the extracted APXS composition for the high z elements above Ti represents a good average composition of Gretna Green within the FOV.

Conclusion: The very consistent composition of the Murray formation allows an easy identification of chemically distinct float rocks. While so far many floats were identified as possibly igneous rocks of different composition without context, many of them very felsic JakeM like rocks, GG could represent a mafic counterpart, possibly as part of a capping unit. Quantification of trace elements like Ni, Zn, Ge, Pb and Se, which are highly enriched in parts of the Murray formation through aqueous alteration processes, supports the major and minor elements similarities. Except Ni and Zn, none of the elements are above detection limit, indicating little interaction with the fluids that laid down the Murray formation.

References: [1]Grotzinger et al, (2012) *SSR*, Vol 170, [2] Thompson et al, this conference, [3] Gellert, Clark, (2015) *Elements*, 11(1), [4] Morris et al, (2010), *Science*, Vol 329, 5590, [5] Schroeder et al, (2010) *JGR*, Vol 115.

Acknowledgements: The MSL APXS is managed and financed by the Canadian Space Agency, with MDA as prime contractor to build the instrument. The MER APXS instruments were built and supported by the Max-Planck Institute for Chemistry. Science team funding is provided by CSA and NASA. We appreciate and acknowledge the unwavering support of dedicated engineers at JPL during operation.