APXS Gale soil and Bagnold sand compositions. C. D. O'Connell-Cooper[1*], L. M. Thompson[1], J. G. Spray[1], R. Gellert[2], J. A. Berger[3], N. I. Boyd[2], E. D. Desouza[2], G. M. Perrett[4], M. Schmidt[5], S. J. VanBommel[2], and the MSL APXS team, [1]*Planetary & Space Science Centre, University New Brunswick, Fredericton, NB, Canada, O.Connell-Cooper@unb.ca, [2]University of Guelph, Guelph, ON, Canada. [3]University of Western Ontario, London, ON, Canada [4]Cornell University, Ithaca, USA [5]Brock University, St. Catharines, ON Canada

Introduction: APXS has been used to analyze both soil and sand on Mars for the past twenty years. The basaltic sands of the active Bagnold Dune field are compared to the basaltic soils of Gale Crater, Meridiani Planum and Gusev Crater.

APXS soil analyses, Mars. APXS instrumentation has been used to analyze both consolidated bedrock and unconsolidated material at Gusev Crater (MER-A, Spirit), Meridiani Planum (MER-B, Opportunity) and Gale Crater (MSL, Curiosity). The term "soil" is routinely used when talking of this loose, unconsolidated material; however, unlike its terrestrial analogue, using the term "soil" on Mars does not imply the presence (either current or past) of organic materials or any living matter [e.g., 1, 2, 3].

Gale Soils – part of a global unit. The Gale Soils exhibit relatively uniform composition, both compared to each other, and to the basaltic soils at Meridiani and Gusev. Some minor compositionial differences – slight depletion in Si, and enrichment in Fe, Mn and Cr within the Gale Soils relative to the MER soils –may be related to local Gale bedrock (e.g., Bradbury Group), which is similarly enriched [4]. This minor, local contribution appears to have been homogenized within the soils at Gale crater, which, as a group, exhibit a relatively uniform composition, indicating an ongoing homogenization process [4, 5]. This fits with a general concept of martian soils as a broadly homogenized global unit [6, 7].

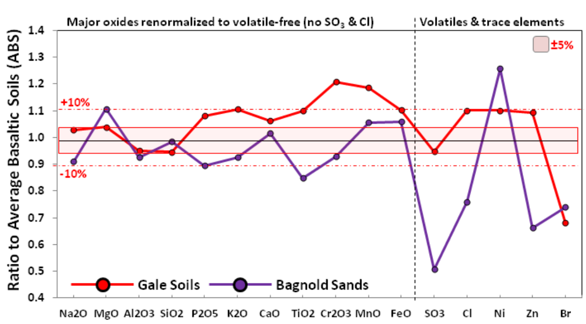

Figure 1. *Gale Soils ratioed to an average Basaltic Soils [O'Connell-Cooper et al., submitted], based on APXS analyses of basaltic soils (n=83), from MER-A, MER-B and MSL.*

Basaltic martian soils as an analogue for ancient deposits. The eolian deposits of the Stimson Formation (Fm) (Siccar Point Group) [8, 9] (and to a lesser degree, the mudstones and sandstones of the Sheepbed Member (Yellowknife Bay Fm, Bradbury Group) [10], bear the greatest compositional resemblance of any Gale Crater bedrock to the predominantly basaltic martian soils, as identified at Meridiani, Gusev and Gale [4]. For all elements, the Stimson Fm is the best compositional fit to the Gale Soils. This suggests that the basaltic martian soils are an analogue for ancient eolian deposits such as the Stimson Fm.

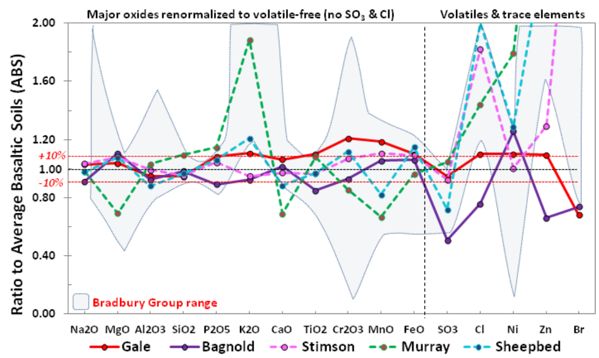

Figure 2. *Comparison of the Gale Soils and Bagnold Sands to the Bradbury (Sheepbed Member), Mount Sharp (Murray Fm)* [11] *and Siccar Point (Stimson Fm) Groups. All units ratioed to the ABS.*

The active Bagnold Sands are distinctly different. The unconsolidated sediments of the Bagnold Sands, within the actively migrating [0.4 m per Earth year] Bagnold Dune field [11] do not classify as martian soils, in the strict sense [e.g., 1, 4]; however, comparisons to other unconsolidated materials help our understanding of their formation mechanism. The Bagnold Sands have been sampled at three locations, to date: (1) High Dune (initial engineering tests and sampling); (2) Namib Dune (the main focus of the Bagnold campaign); and (3) opportunistic samples along the traverse through the dune field, on the rover's journey towards Mount Sharp.

Inverse relationship between grain size and felic content. The sieved and separated samples of the Namib Dune (Gobebeb samples) reveal that the sand becomes more felsic as grain size decreases [4, 5]. Conversely, coarser samples are more mafic in composition. Crest-and-trough paired targets from the High Dune reveal a differential gradation, whereby crest and disturbed targets contain higher levels of felsic material, whilst trough and undisturbed targets are more mafic (high Fe+Mg+Mn+Ni) [4, 5].

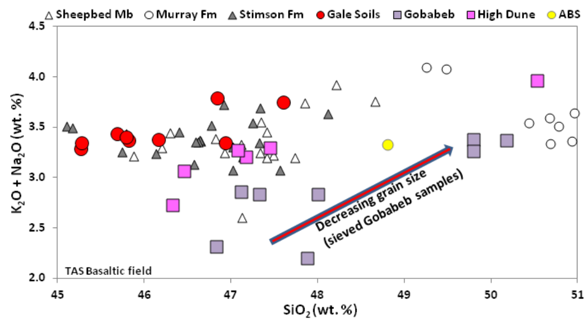

Figure 3. *Grain size - felsic content relations for the sieved Gobabeb samples, at Bagnold Dunes*

Olivine enrichment. Bagnold Sands Mg, Ni and Fe contents (Fig. 4) confirms olivine enrichment, as predicted by orbital CRISM observations [e.g., 11, 12].

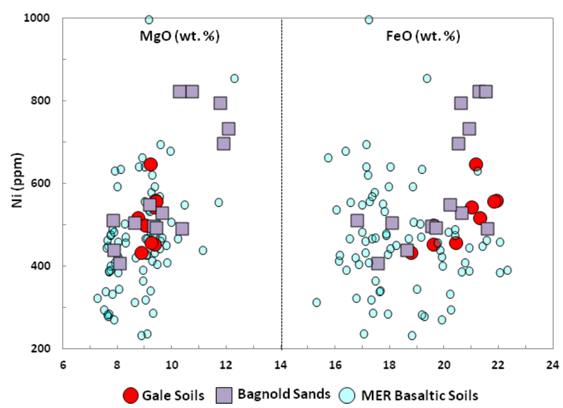

Figure 4. *Mg, Fe and Ni within the coarser Gobabeb fraction of the Bagnold Sands.*

Dust ratios in Gale Crater. The low abundances of S, Cl and Zn observed throughout the Bagnold Sands are one of their most distinctive. Abundances are uniformly low in all samples. In addition, S/Cl ratios are lower (Fig. 5) than would be expected if dust is a well-homogenized unit, as theorized [e.g., 6, 7].

Conclusions: The primarily basaltic soils from Meridiani Planum, Gusev Crater and Gale Crater are broadly similar in major elemental trends. Enrichment of the Gale Soils in K, Cr, Mn and Fe may signify a minor local contribution from the Gale Crater bedrock (e.g., Bradbury Group), which is similarly enriched. Within Gale Crater, the Stimson Fm bedrock is the most compositionally similar of all the Gale bedrock analyzed at both the Gale Soils and to a global soil, defined by the Average Basaltic Soil. The predominantly basaltic soils may therefore be viewed as an analogue for the eolian deposits of the Stimson Fm.

The active Bagnold Dunes are distinct from the average basaltic martian soil. There is an inverse relation between grain size and composition, with

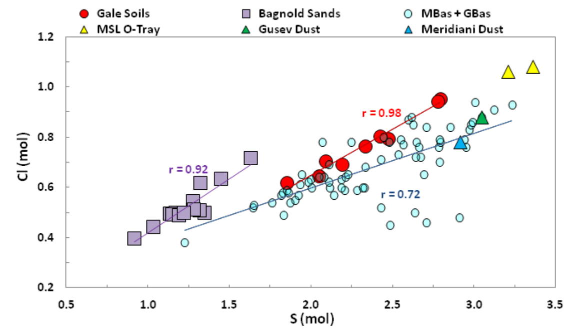

Figure 5. *S/Cl molar ratios. r = Pearson correlation coefficient. MSL O-tray observations* [13] *Gusev Dust: Gobi1_soil sol 71* [14]. *Meridiani Dust: MontBlanc _ LesHauches Sol 60* [15]

sands becoming more felsic with decreasing grain size. Crest and trough sample pairs reveal a differential gradation, whereby crest and disturbed targets contain more felsic material, whilst trough and undisturbed targets are more mafic (high Fe+Mg+Mn+Ni). The Bagnold Sands are enriched overall in Mg and Ni, confirming olivine enrichment, as indicated from orbit. The sands exhibit uniformly low levels of S, Cl and Zn. This suggests that dust content is uniformly low throughout the dune field, and may not be solely a function of dune activity.

The S/Cl for all soils within Gale Crater is lower than that of other martian soils, whilst the Bagnold Sands have significantly lower S/Cl than all martian basaltic soils. These findings indicate that dust may not be globally homogenized, and more susceptible to local influences than previously suspected.

Acknowledgements: MSL-APXS science team funding is provided by the CSA and NASA. Much appreciation goes to JPL for their support, dedication, and invaluable expertise.

References: [1] Bell, J.F. et al., (2000) JGR-Planets, 105(E1), 1721-1755. [2] Soderblom, L.A., et al., (2004) Science 306 (5702), 1723-1726. [3] Squyres, S.W., et al. (2004a), Science 305 (5685), 794-799. [4] O'Connell-Cooper et al., (2017) submitted to JGR. [5] O'Connell-Cooper et al., 2016, *LPS XXVII*, Abstract #2477. [6] Yen, A.S., et al., (2006), JGR-Planets, 111, E12S11. [7] Yen, A. S., et al., (2013), LPS XXIV, Abstract #2495. [8] Banham et al., 2017, LPS XXVIII. [9] Fraeman, A.A., et al., (2016), JGR-Planets 121(9). [10] Grotzinger, J.P., et al. (2015), Science 350(6257). [11] Silvestro, S., et al. (2013), Geology, 41(4). [12] Lapotre, M.G., et al., (2014), 8th Int. Con. Mars, Abstract. #1126. [13] Berger, J.A., et al. (2015), Geophys. Res. Letters 43, 67-75. [14] Gellert, R., et al. (2006), J. Geophys. Res. 111, E02S05. [15] Morris, R.V., et al., (2006), JGR-Planets 111, E12S15.