BASALTIC SOIL VERSUS DUNE SEDIMENTS ON MARS: A COMPOSITIONAL ANALYSIS OF SURFICIAL SEDIMENTS BY APXS. C. D. O'Connell-Cooper[1], L. M. Thompson[1], J. G. Spray[1], S. J. VanBommel[2], J. A. Berger[3], N. I. Boyd[3], R. Gellert[3], and B. J. Wilhem[3]. [1]Planetary and Space Science Centre, University New Brunswick, Fredericton, NB E3B5A3, Canada. Email: r52bm@unb.ca [2] Washington University in Saint Louis, Saint Louis, MO, USA. [3]Guelph-Waterloo Physics Institute, University of Guelph, Guelph, ON N1G 2W1, Canada.

Introduction: In the almost seven years since the Mars Science Laboratory rover (MSL, *Curiosity*) landed in Gale crater, the Canadian-built Alpha Particle X-ray Spectrometer (APXS) has combined PIXE and XRF techniques [*1*] to determine bulk geochemical compositions of both bedrock and unconsolidated materials across a >20 km traverse of the crater. As *Curiosity* crossed the active Bagnold dune field, it deployed all ten onboard instruments to conduct the first in situ investigation of an active dune field on a rocky body other than Earth. This has generated a wealth of chemical and mineralogical data.

APXS analyses: Two distinct end-members compositions of surficial sediments have been revealed by APXS within Gale Crater: (1) inactive soils, analyzed within the first 800 sols of the traverse [*2*]; and (2) active eolian sands within the barchan [*2*] and linear [*3*] dunes of the Bagnold dune field. APXS also analyzed sediments (herein referred to as "post-Bagnold samples") within small sand deposits and ripple fields [2], on the outskirts of the Bagnold dunes, along Vera Rubin ridge (VRR) and, most recently, in the clay bearing Glen Torridon region (GT) (Fig. 1).

Soils: Soils are unsorted [e.g., *2*], inactive [e.g., *8*], surficial deposits. A given soil sample can include both fine grained particles (including dust) to coarser "pebbly" material (>2 mm) [*2*]. Soils in Gale crater have been compared to those analyzed by APXS instruments the Mars Exploration Rovers (MER) at Gusev crater (MER-A, *Spirit*) and at Meridiani Planum (MER-B, *Opportunity*) [*2*]. This ability to directly compare soils from different geographic locations allows us to add to the body of data on soils, and facilitates the updating of an Average Basaltic Soil (ABS) composition for the planet, currently comprising a total of 90 APXS basaltic soil samples [*2*] (updated from the previous Taylor and McLennan average [4].

Active sands: Active eolian dune sands are defined by grain size (62 μm to 2000 μm) [*9*], and their location within dune systems where saltation is actively occurring [e.g., *10-11*]. *Curiosity* has investigated both barchan (Namib & High dunes) and linear dunes (Nathan Bridges & Mount Desert Island dunes) (Fig. 1), allowing for a detailed comparison of the two morphological dune types, as well as a comparison with Mars soils.

APXS sampling types: Samples comprise unprocessed samples, both undisturbed "as-is" samples, and disturbed "scuff" samples, where sediment has been churned up by the rover wheels. "Scuffs" represent sub-aerial material, not exposed to the atmosphere, and, accordingly, they exhibit lower dust levels. Barchan dune sand samples include both unprocessed and processed samples (sieved, subdivided into fine and coarse portions (e.g., <150μm, >1mm) [*2*]. Sand samples within the linear dunes and later, post-Bagnold, sand bodies were unprocessed, with an emphasis on location within a dune or sand body [*3*] – i.e., crest, off-crest and "scuffs". Three processed samples (<150 μm) were analyzed by both APXS and CheMin: (1) soil (Rocknest) [*5*], (2) barchan dunes (Gobabeb) [*6*], and (3) linear dunes (Ogunquit Beach) [*7*].

Global soil, local enrichments: The Gale "soils" are broadly similar to those at Meridiani and Gusev, with a bulk basaltic composition at all three locations. This supports the concept that the martian soils are principally derived from a common source: the predominantly basaltic martian crust [e.g., *12-15*]. However, some systemic differences to the ABS are identified within the Gale soils: enrichment in Na+K (relative to the ABS) [*2*], within coarser, pebbly Gale samples; enrichment in mafic elements (Mg, Ni, Cr, Mn, Fe) in finer-grained samples; slight depletion in Si in all samples. Although the majority of Gale soil targets are underlain by the K-rich Bradbury group (which contains, in places, up to eight times the K in the martian crust) [*16*] and the Murray fm, pronounced K+Na enrichment is only identified within the pebbly Gale soils. However, concentrations for a given sample do not reflect the composition of the immediately surrounding bedrock [*2*], suggesting a degree of ongoing transportation and/or homogenization.

Similarly, the mafic enrichment within the fine-grained Gale soils is identified within local Gale bedrock but is not specific to any one unit. As a result, although examples of bedrock compositions locally influencing soil signatures have been recognized across Mars, e.g., the hematitic "blueberry" spherules at Meridiani [*14*], it is not possible to tie the enrichments identified within the Gale soils to a specific lithology [*2*], despite the broad compositional range represented by bedrock at Gale Crater.

Basaltic martian soil as an analogue for ancient deposits: For all elements, the eolian Stimson formation (fm) (Siccar Point group) bear the greatest compositional resemblance of any Gale crater bedrock to the ABS [*2*], suggesting that the basaltic soils are an analogue for ancient eolian deposits such as the Stimson fm.

Sands of the Bagnold dunes – compositionally distinct from soil: The sands of the active Bagnold dune field are compositionally distinct from the soils. Compositional differences, related both to position within a dune (i.e., crest versus off-crest sand), and between dune morphologies (linear versus barchan), are also identified. Post-Bagnold samples (typically in smaller sand bodies) vary in composition from Bagnold-sand like to more soil-like.

Inverse relationship between grain size and felsic content: Within the active sands, increasing mafic content correlates with increasing grain size, particularly along the crests of active ripples [*2-3*]. This is in contrast to the pattern of mafic enrichment in fine-grained samples and felsic enrichment in coarser samples, identified on Mars (Gale soils [*2*]; Gusev [*17*]), and with the concentration of mafic minerals in finer fractions identified in many terrestrial settings [e.g., *18-20*]. This indicates probable differences in weathering, transport and sorting (including but not limited to the effects of water) on Earth versus Mars, primarily controlled by the physical properties of the minerals, or the predominance of coarser mafic phenocrysts within martian basaltic source rocks.

Mg+Ni enrichment along crests: Crest sands of the linear dunes contain very high Mg and Ni (relative to the ABS), indicating enrichment in olivine and pyroxene [*3*]. This enrichment is also seen within coarser fractions of the barchan (sieved) material [*2*], and on crests in smaller sand-bodies/mega-ripples [*3*].

Presence of a Cr-Ti mineral phase: APXS analyses reveal that whilst barchan dune sands have Cr, Mn, Fe, Ti abundances similar to those in the Gale soils, Cr is significantly enriched (and, to a lesser degree, Mn, Fe, Ti) in off-crest sands of the linear dunes and post-Bagnold sands [3]. The strong correlation between Cr and Ti suggests the presence of a Cr-Ti mineral phase. However, scuff samples within the linear sands are not enriched, exhibiting levels similar to those seen in barchan sands. This suggests that this enrichment is a surficial process, and not representative of the overall dune composition. Preferential enrichment in a Cr-Ti mineral phase within the linear dunes and post-Bagnold sands to the south of the dune field may indicate differences in transport and sorting processes, or may be related to distance from source.

Geochemical evidence for seasonal variations in activity levels: Seasonal variations in activity levels are confirmed, via S, Cl and Zn concentrations (implied dust content). Lowest levels of dust are confirmed in the linear dunes [3], whose investigation took place in summer, when the strongest winds in Gale Crater were measured [*21*].

Post-Bagnold samples: As analyzed in ripple fields and smaller, isolated sand patches, post-Bagnold samples indicate a continuum between inactive soils and active sands [*3*]. Those with lower activity (as implied by higher dust) are more geochemically similar to Gale soil than active sand, regardless of grain size, or location.

Conclusion: The Gale "soils" are broadly similar to those at Meridiani and Gusev, with a bulk basaltic composition at all three locations. The sands of the active Bagnold dune field are compositionally distinct from these soils.

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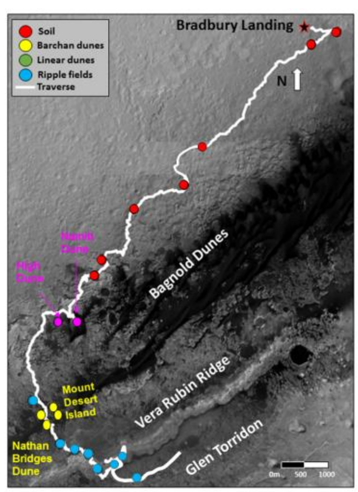

Figure 1. Location of APXS sediment samples in Gale crater, Mars.

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