SOILS, EOLIAN DUNE SANDS AND MEGA-RIPPLE SANDS IN GALE CRATER, MARS.

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Introduction: Martian unconsolidated, surficial sediments are subdivided here into (a) dust, (b) eolian dune sand, and (c) soil [e.g., 1, 2]. Eolian dune sands are defined by both their mean grain size (62 µm to 2000 µm) [5], and location within dune systems where saltation is actively occurring, such as the Bagnold dunes [e.g., 6, 7]. Other unconsolidated sediments are routinely classified as "soil" – these are typically "unstructured" deposits, not clearly associated with recent transport process [e.g., 8], whose grain size is heterogeneous, ranging from fine grained particles (including dust) to coarser "pebbly" material (>2 mm) [1].

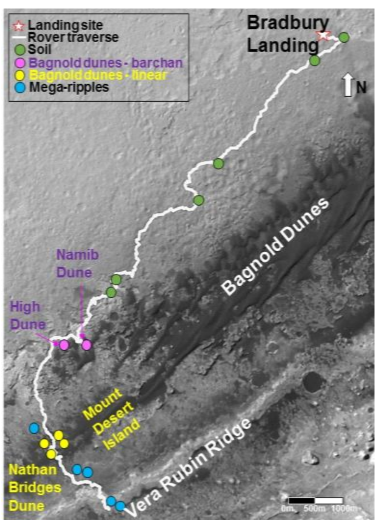

Fig. 1. *Location map, showing sampling locations.*

The Canadian-built MSL-APXS has analyzed a variety of unconsolidated sediments within Gale crater, including soils, sands of the active Bagnold dune field, and sands from a series of smaller, less active ripple fields and sand deposits (post-Bagnold dunes).

Soils: The Gale "soils" (unsorted, unconsolidated sediments) are, to a large degree, similar to Martian basaltic soils quantified by APXS, at Gusev crater (MER-A_Spirit) and Meridiani Planum (MER-B_Opportunity). Some local contributions are indicated by, for example, the enriched K levels (relative to a martian average basaltic soil [ABS]) [1, 4], within coarser Gale soil samples, and a Cr, Mn, Fe enrichment within finer-grained samples.

Sands of the Bagnold dunes: The Bagnold dune field comprises both barchan and linear dunes [9].

Barchan dune sands: Barchan dunes were analyzed by APXS (High dune and Namib dune, Fig. 1) in Phase 1 of the Bagnold campaign [e.g., 1, 2]. These samples comprise: **(1) Unprocessed** samples: including both undisturbed sand and sand within wheel "scuffs" – analyzed at High dune and Namib dune; **(2)** The main focus of this part of the campaign was on **Processed** samples: sieved, and divided into fine and coarse portions (e.g., <150 µm, > 1mm) – analyzed at Namib dune - referred to as the *Gobabeb* samples. One sample (*Gobabeb*, <150 µm) was analyzed by CheMin [10].

Linear dune sands: Linear dunes (Nathan Bridges Dune and Mount Desert Island, Fig. 1), further south and along our traverse towards Mount Sharp, were analyzed by APXS in Phase 2 of the Bagnold campaign [2]. Sampling protocol differed here, consisting of **unprocessed** samples only, but with an **emphasis on location** within a dune – crest, off-crest, scuffs (i.e., the disturbed sand within scuffs made by the rover wheels). One sample (*Ogunquit Beach*, <125 µm) was analyzed by CheMin [11].

Comparison of barchan sands and linear sands: The sands of the active Bagnold dunes, generally, exhibit Na, Mg, Al, Si, K and P contents similar to (or slightly depleted, relative to) the ABS (Fig. 2); with more noticeable depletions in S, Cl and Zn, indicating high activity levels and low dust. Compositional differences, related both to position within a dune (i.e., crest versus off-crest sand), and between dune morphologies (linear versus barchan), are identified.

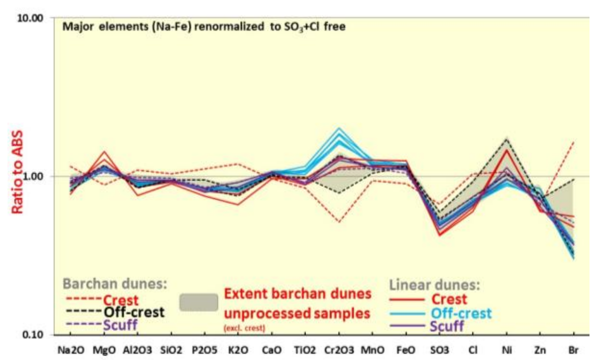

Fig. 2 *Comparison: barchan and linear dune sands.*

(1) Crest sands of the linear dunes contain very high Mg and Ni (relative to the ABS), indicating enrichment in olivine and pyroxene (Fig. 3). Whilst all sand shows low dust levels, depletion in S, Cl and Zn is greatest in the linear crest sands. It should be noted that the (single) barchan crest sample ["*Barby*"] has an anomalous composition, with depletion in Mg, and enrichment in felsic elements, not seen in any other dune sands, and with the highest dust levels (implied by S, Cl and Zn content).

(*2*) *Off-crest sands* are broadly similar within both barchan and linear dunes, showing some enrichment in Mg, but are typically depleted in Ni. However, variations in Cr abundances are one of the most striking features of the Bagnold sands. Off-crest samples from the barchan dunes have Cr, Mn, Fe, and Ti abundances similar to those in the Gale soils. In contrast, Cr is significantly enriched (as are, to a lesser degree, Mn, Fe, Ti) in the off-crest sands of the linear dunes. Additionally, whilst there is a strong relationship within the linear sands for Ti and Cr (Pearson correlation coefficient r=0.97), no such relationship is identified within the barchan sands (r=0.26).

(3) Scuff samples, from within rover wheel tracks, represent material not currently exposed to the atmosphere, and exhibit lower dust levels, as might be expected in sub-aerial samples. Scuffs in both barchan and linear sands are broadly compositionally similar to off-crest sands in general; however, Cr and Ti levels are similar to those of the barchan crests and off-crests, suggesting that this enrichment is a surficial process, and not representative of the overall dune composition.

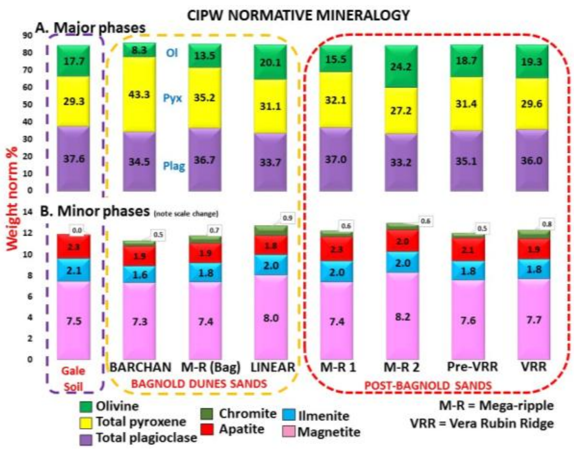

Fig.3. *CIPW Normative mineralogy. A. Major phases (plagioclase = albite + anorthite; pyroxene = diopside + hypersthene). B. Minor phases.*

Mega-ripples: A series of small, isolated (from dunes) sand bodies have been analyzed during the traverse through the Bagnold dunes and up onto the Vera Rubin Ridge (VRR) (Fig. 1). Although topographies are not as pronounced as within the active Bagnold dunes, these sand deposits follow the same general compositional trends as the Bagnold sands, particularly barchan off-crest sands (Fig. 4). Dust levels are comparable to those in the active dune sands. Highest Mg and Ni enrichments are found in crest samples. Fe and Mn are, again, enriched (relative to ABS) for most samples. Cr concentrations are comparable to those of the barchan off-crests. Similar to the barchan sands, no relationship between Ti and Cr is identified within the mega-ripples (r=0.35). Interestingly, the smaller deposit examined, M-R 1, although classified as a sand (by grain size etc.), is geochemically similar to Gale soils (more dust, enriched P-Ca).

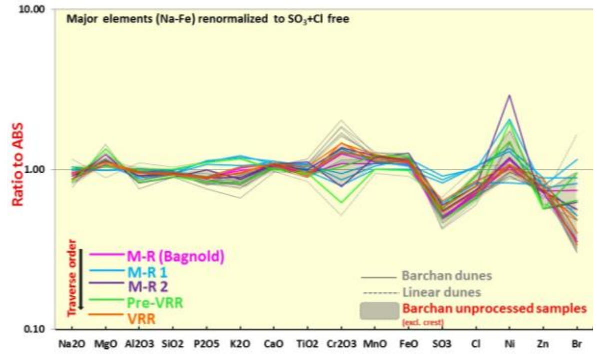

Fig. 4 *Comparison: mega-ripples and Bagnold dune sands.*

Conclusion: Investigation of the active Bagnold dunes in Gale crater reveals that sand and soil are often compositionally distinct. Gale soils are similar to the basaltic soils at Meridiani and Gusev, but with some evidence of local contributions (enrichment in K, Cr, Mn, and Fe). The Bagnold dune sands show the following trends (*relative to the ABS*): overall depletion in felsic elements (Na, Al, Si, P, K), and in Br; enrichment in Mg, Ni, Mn, Fe, Cr and Ti for some samples; depletion in S, Cl and Zn, indicating low dust levels, and higher activity.

Furthermore, there are geochemical differences between the barchan and linear dunes. Significant Ti and Cr enrichment is confined to the off-crest sands of the linear dunes. Mg and Ni enrichment is seen primarily within the crests of the linear dunes, and within the coarsest portions of the (sieved) barchan sands.

Mega-ripples, which are smaller, less active bodies of sand, are similar to the off-crest sands of the barchan dunes. However, the smaller *M-R 1* deposit most closely resembles (geochemically) a soil, indicating a relationship between size of a sand body and its composition.

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References: [1] O'Connell-Cooper, C. D. et al., (2017) *JGR-Planets*, *122* (10). [2] O'Connell-Cooper, C. D. et al., (2017) AGU, Abstract #279257. [3] O'Connell-Cooper, C. D. et al., (2017) *LPS XXXXVII*, Abstract #2403. [4] O'Connell-Cooper, C. D. et al., (2016) *LPS XXXXVI*, Abstract #2477. [5] Wentworth, C. K., (1922), *Journal Geology*, 30 (5). [6] Anderson, R. B., & J. F. Bell III, (2010), *Mars*, 5, 76-128. [7] Silvestro, S., et al., (2013), *Geology*, 41(4). [8] Cabrol, N. A., et al., (2008), *Geophys. Res. Planets*, 113, E06S05. [9] Lapotre, M.G.A., et al. (2016) *Science*, 353, 6294, 55-58. [10] Achilles, C. N., et al., (2017), *JGR-Planets*, 122 (10). [11] Rampe, E. B. et al., *this meeting*.