EVIDENCE FOR A GLOBAL MARTIAN SOIL COMPOSITION EXTENDS TO GALE CRATER.

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Introduction: The eolian bedform within Gale Crater referred to as "Rocknest" was investigated by the science instruments of the Curiosity Mars rover. Physical, chemical and mineralogical results are consistent with data collected from soils at other landing sites, suggesting a globally-similar composition. Results from the Curiosity payload from Rocknest should be considered relevant beyond a single, localized region with Gale Crater, providing key insights into planetary scale processes.

Physical Characteristics: Fig. 1a shows the Curiosity wheel imprint on Rocknest, exposing darker, subsurface sand and clay-sized particles below a thin accumulation of brighter atmospheric dust, similar to the Mars Exploration Rover (MER) Spirit's wheel scuff at Gusev Crater (Fig. 1b). The Rocknest wind drift is armored with roughly millimeter-sized, subrounded coarse sand grains, consistent with observations at both MER landing sites (Fig. 2).

Figure 1: (a) *left*, Rocknest at Gale Crater, wheel imprint is ~40 cm wide, (b) *right*, Serpent at Gusev Crater, Spirit wheel width is 16 cm.

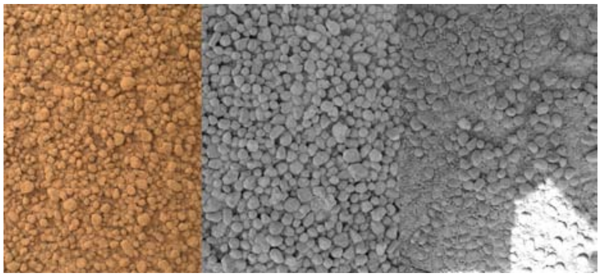

Figure 2: Coarse sand grains cover eolian drifts at Rocknest in Gale Crater (left), Meridiani Planum (center), and Gusev Crater (right). Each image ~2 cm wide.

Alpha Particle X-ray Spectrometer (APXS): The APXS method for determining elemental composition uses a combination of alpha particles and x-rays from ^{244}Cm to produce characteristic emissions from samples within the ~15 mm diameter instrument field of view. The sensor head is placed on the target of interest by the rover robotic arm. The APXS analysis of the soil exposed by Curiosity's wheel was performed on sol 89. The specific target within the Rocknest area was dubbed "Portage," and the results are shown in Table I.

APXS Cross Calibration: Other instruments in the rover science payload can assess the elemental composition of soil targets, but the APXS provides the best connection to data collected at other martian landing sites. Extensive cross calibration between the Curiosity and the Mars Exploration Rovers (MER) and Pathfinder APXS instruments using many of the same laboratory reference samples allows direct comparisons of the results from different locations on Mars.

Chemical Composition: Typical martian soils analyzed with the MER APXS have positively correlated sulfur and chlorine content (Fig. 3) where the highest concentrations are found in the finest grain sizes. Zinc (Fig. 4) and the fraction of iron attributed to nanophase iron oxide (np-Ox) by the MER Mössbauer spectrome-

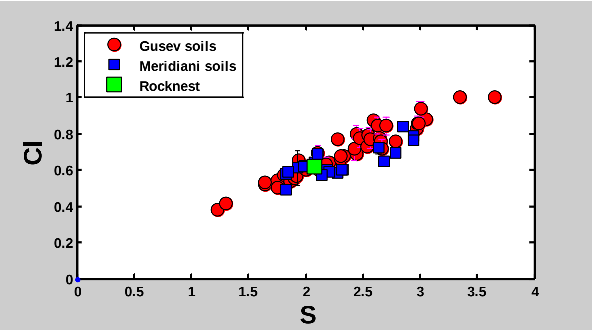

Figure 3: Consistent trend in Cl versus S for soils analyzed by MER and Curiosity APXS instruments (values in wt%).

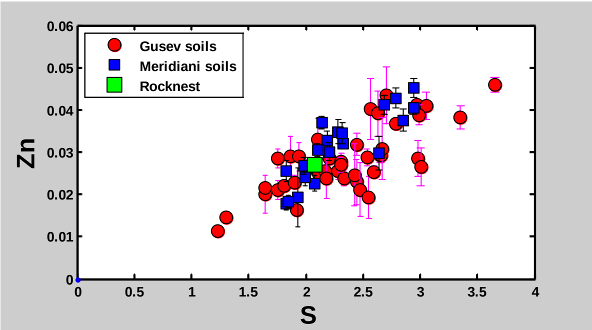

Fig. 4: Correlation of Zn and S (values in wt%).

Table I: Preliminary APXS results from Portage soil target in the Rocknest eolian bedform (reproduced from [1])															
	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	Cr_2O_3	MnO	FeO	Ni	Zn	Br
	Oxide wt%													ppm		
Concentration	2.22	6.53	9.56	43.7	0.53*	5.18	0.61	0.59	7.38	1.54*	0.42	0.44	21.0	311	269	32
Statistical error	0.15	0.17	0.2	0.4	0.1*	0.1	0.02	0.06	0.1	0.1*	0.03	0.03	0.1	20	20	10
*Pending further consideration of instrumental effects																

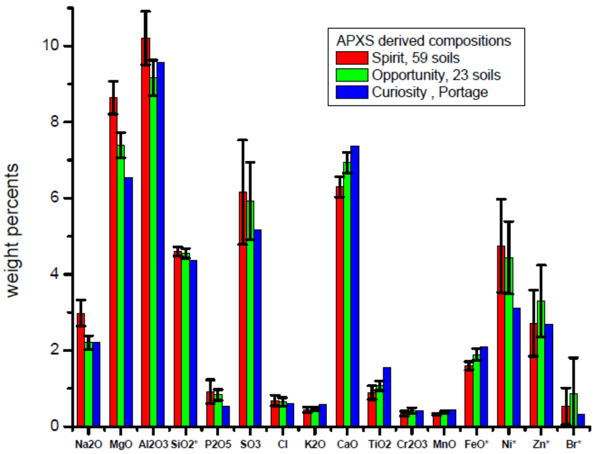

Fig 5: Chemical compositions of Gale, Meridiani and Gusev soils nearly identical in APXS measurements.

ters are also correlated with S and Cl. Interpretations of these results indicate that condensation of volcanic gases and aerosols onto basaltic sand and dust grains is an important aspect of the formation of martian soils [2,3]. The absence of clear cation associations which can account for the measured quantity of the S and Cl further support the idea that localized sulfates and Cl-compounds are formed directly on grain surfaces. These S:Cl:Zn ratios remain constant indicating the absence of significant aqueous interactions.

The Rocknest soil chemistry falls directly in line with MER results, with mid-range values in S, Cl and Zn. All other elements are roughly within the variability of MER APXS analyses for typical soils (Fig. 5) with the exceptions of Ti and Fe. While the Fe:Mn and Fe:Cr ratios remain consistent with soils at Meridiani and Gusev, the ~10% enrichment in Ti and Fe at Rocknest relative to typical MER basaltic soils may represent an additional component. At the Gusev landing site, the millimeter-sized grains armoring the surfaces of eolian bedforms were likely enhanced in titanomagnetite. A similar situation might be found at Gale Crater, as the APXS field of view in the Rocknest disturbed soil analysis contained a significant fraction of the bedform armor.

APXS analyses of rocks through sol 100 within Gale Crater show a significant enhancement in potassium (~ 2 wt% K_2O) not reflected in the Rocknest soil. The observation that the fine-grained, basaltic soils do not have a strong contribution from the local rocks is also true at the Meridiani and Gusev landing sites. The data allow up to 15% contribution from the nearby rocks analyzed by the APXS, but the bulk of the fines in the Rocknest area are predominantly from a different source.

Mineralogy and Volatile Phases: The mineral phases in the crystalline portion of the soils have been established by the CheMin x-ray diffraction (XRD) instrument [4] and are consistent with expectations from MER APXS and Mössbauer results. Subtracting the chemistry of the crystalline phases from the APXS data in Table I, ~36% of the Rocknest soil is inferred to be x-ray amorphous [5]. Significant releases of volatile species (H_2O, CO_2, SO_2, O_2) were detected by the SAM instrument upon heating the soil samples, and progress is being made in quantifying these contributions [6]. Excess oxygen (beyond standard oxides) and carbon are not directly detected by the APXS, but modeling the relative intensities of Pu scatter peaks can provide useful constraints [7]. The initial assessment suggests that the abundance of these light elements in the Rocknest soil is comparable to that of typical basaltic soils at Gusev, up to a few wt%.

The samples delivered to SAM and CheMin were sieved to exclude grains larger than 150 μm and scooped from a slightly different location than the APXS measurement. However, results from a sieved portion delivered to the observation tray show that the samples delivered to the internal instruments were not significantly different from the soil analyzed by APXS [8]. A maximum of ~10% enhancement in the finest grained S- and Cl-rich components is possible.

Conclusions: The connection established by the APXS between the Rocknest soil and samples at other landing sites allows the results from other Curiosity instruments to have global significance. Based on the consistency of S, Cl and Zn, which are relatively mobile, the Rocknest soils have experienced limited chemical weathering. Basaltic soils on Mars appear to be a distinct global unit, indicating the general similarity in the rocks from which they were derived.

Refs: [1] Gellert R. et al. (2013) *LPS44*. [2] Clark B.C. and Baird A.K. (1979) *JGR*, 84, 8395-8402. [3] Yen A.S et al (2006) *JGR, 111*, E12S11. [4] Bish D.L. et al. (2013) *LPS44*. [5] Morris R.V. et al. *LPS44*. [6] Mahaffy P. et al. (2013) *LPS44*. [7] Campbell J.L. et al. (2008) *JGR, 113*, E06S11. [8] Berger J. et al. *LPS44*.