BASALTIC SOIL OF GALE CRATER: CRYSTALLINE COMPONENT COMPARED TO MARTIAN BASALTS & METEORITES. A.H. Treiman[1], D.L. Bish[2], D.W. Ming[3], R.V. Morris[3], M. Schmidt[4], R.T. Downs[5], E.M. Stolper[6], D.F. Blake[7], D.T. Vaniman[8], C.N. Achilles[3], S.J. Chipera[9], T.F. Bristow[7], J.A. Crisp[10], J.A. Farmer[11], J.M. Morookian[10], S.M. Morrison[5], E.B. Rampe[3], P. Sarrazin[12], A.S. Yen[10], R.C. Anderson[10], D.J. DesMarais[7], & N. Spanovich[10]. [1]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston TX 77058 (treiman#lpi.usra.edu), [2]Indiana U., [3]NASA JSC, [4]Brock U., [5]U. Arizona, [6]Caltech, [7]NASA ARC, [8]Planetary Science Institute, [9]Chesapeake Energy, [10]JPL, [11]Arizona State U., [12]In-Xitu.

A significant portion of the soil of the Rocknest dune is crystalline and is consistent with derivation from unweathered basalt. Minerals and their compositions are identified by X-ray diffraction (XRD) data from the CheMin instrument on MSL Curiosity. Basalt minerals in the soil include plagioclase, olivine, low- and high-calcium pyroxenes, magnetite, ilmenite, and quartz. The only minerals unlikely to have formed in an unaltered basalt are hematite and anhydrite. The mineral proportions and compositions of the Rocknest soil are nearly identical to those of the Adirondack-class basalts of Gusev Crater, Mars, inferred from their bulk composition as analyzed by the MER Spirit rover.

Sample & Methods: XRD data were obtained by the MSL CheMin instrument [a,a'] on soil of the Rocknest Dune, from scoop portions #3, #4, & #5 (which was analyzed by SAM for volatiles) [b]. The raw soil was scooped and sieved in the MSL CHIMRA instrument, which delivered to CheMin ~0.02 gram of the <150 µm size fraction. Those portions were analyzed by CheMin over several successive nights, for total integrations of ~12 and ~16 hours respectively. The raw 2-dimensional data were filtered for only CoKα diffractions, summed to yield 2-D XRD patterns, integrated circumferentially to give typical 1-D XRD patterns, and then summed to a single combined pattern [b] (Fig. 1). The soil contains a significant proportion of X-ray amorphous materials [c,d], which appear as a background under the sharp diffractions investigated here. Diffraction positions were calibrated against a quartz-beryl standard within CheMin.

The 1-D XRD pattern was analyzed by Rietveld refinement (Bruker AXS Topas) to retrieve the proportions, unit-cell, and compositions of crystalline phases present [b].

Results: CheMin XRD patterns of the Rocknest soil imply that its crystalline component is relatively simple, and composed almost entirely of minerals characteristic of fresh basalts. Mineral proportions are shown in Table 1, based on Rietveld refinement of the summed XRD pattern [b]. The presence of plagioclase, olivine, and two pyroxenes is certain. The compositions of the olivine and plagioclase are nearly uniquely defined by their unit-cell parameters – olivine at Fo58±3 (taken as the Mg# of the silicates) and feldspar at An50±3. Pyroxene compositions are not uniquely defined by their unit-cell parameters, and work is in progress. Among other detections, those of hematite (~1%), magnetite, quartz, and anhydrite (~1%) are nearly certain; those of ilmenite and sanidine (a high-temperature potassium feldspar, i.e. K-spar) are likely but not certain.

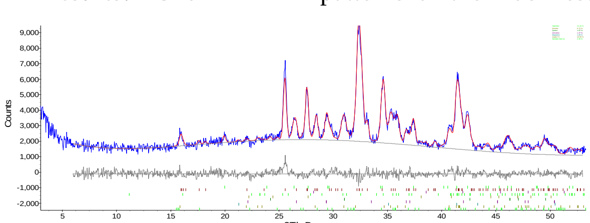

Figure 1. CheMin X-ray diffraction pattern, 1-D, for Scoop #5 of the Rocknest soil. Blue is pattern as measured, red is fitted pattern, gray is difference. The difference peak at ~25.5° 2Θ is diffraction from the Al filter on the CCD light

Many minerals, likely or possible in a basalt, were not detected at the percent mass level. Among possible igneous minerals, there are no detections of Ca-amphibole, biotite, nepheline, and Ca-phosphates. Among possible alteration minerals [i], there are no detections of Fe-Mg amphibole, serpentines, talc, chlorites, epidote, zoisite, scapolite, muscovite, illite, goethite, carbonate minerals, sulfides, and clay mineralss. Among possible pedogenic products, there are no detections of sulfates other than anhydrite, carbonate minerals, clay minerals, perchlorates, and halides.

implications:

Mineral compositions derived from CheMin XRD data (unit-cell parameters) are consistent, in general, with compositions of minerals in martian meteorites, and those inferred from bulk compositions of martian basalts. Plagioclase in the soil is andesine (~An50), Table 1, as inferred for little-altered olivine basalts from Gusev crater (Table 1), and as in martian meteorites, Table 2 [g]. No planetary basalts other than martian and terrestrial contain such sodic plagioclase [g].

Olivine in the Rocknest soil is of intermediate composition (Fo = Mg# ~58), consistent with the Mg#s of little-altered olivine basalt from Gusev crater (Table 1), and similar to the Mg#s of martian meteorite basalts (Table 2). Actual average Mg# of olivines in the martian meteorite basalts may be slightly higher than predicted by Mg# alone (unpublished data), although the differences are small.

Mineral proportions in the Rocknest soil, derived by Rietveld refinement on the CheMin XRD patterns

Table 1. Mineral Proportions of Rocknest Soil (CheMin XRD) and Normative Mineralogies of Basaltic Materials from Gusev Crater and of Martian Meteorites. Rocknest Data are Amorphous-Free Values.

Location	Gale	Gusev				Meteorites			
Sample	Rocknest Soil	Adiron-dack	Backstay	Irvine	El Dorado	Shergotty	NWA 6234	EETA 79001A	QUE 94210
Quartz	*2*	0	0	0	0	0.2	0	0	3
Plagioclase	43	39	49	32	41	23	19	19	32
K-spar	*2*	1	6	6	2	1	0.5	0	0
Low-Ca Pyx	11	15	14	21	20	46	30	47	15
High-Ca Pyx	17	15	5	13	10	25	16	16	38
Olivine	21	20	15	16	15	0	27	13	0
Fe-Cr oxides	*3*	6	4	6	5	3	4	2	0
Ilmenite	*1*	1	2	2	1	2	2	1	4
Apatite	-	1	3	2	2	2	2	1	6
Anhydrite	*1*								
Mg#	58±3	57	62	55	62	51	63	63	40
An	50±3	42	29	19	33	51	50	60	62

Rocknest Soil by CheMin [b], average of scoop 5, proportions of crystalline phases normalized to 100%; values in italics uncertain, see text. CIPW norms (weight) for Gusev basaltic materials from MER APXS chemical analyses [e] ignoring S & Cl; Fe^{3+}/Fe_{tot} for Backstay and Irvine taken as 0.17, the value for RATted Adirondak and El Dorado [f]. CIPW norms (weight) of Martian meteorites from bulk compositions [t-x]; Fe^{3+}/Fe_{tot} as analyzed, and estimated at 0.1 for NWA 6234 and 0 for QUE94201. 'K-spar' is sanidine for the Rocknest soil, and normative orthoclase for others. 'Low-Ca Pyx' is pigeonite for the soil, and normative hypersthene for others. 'High-Ca Pyx' is augite for the soil, and normative diopside for others. 'Fe-Cr oxide' includes magnetite, hematite and chromite. All phosphorus in analyses calculated as normative apatite.

[b], are closely similar to those of Adirondack olivine basalt from Gusev (Table 1), and like those of the El Dorado sand except for proportion of the pyroxenes. The Rocknest mineral proportions are not (in general) similar to those of martian meteorites. As noted by others, fresh martian basaltic materials analyzed by the MER rovers are richer in plagioclase than the meteorites (Table 2) except the Bounce Rock basalt. The crystalline component of the Rocknest soil is similarly rich in plagioclase.

Adirondack Basalt. The Adirondack basalt, analyzed at the MER Spirit landing site, is conspicuously similar to the crystalline component of the Rocknest soil in mineralogy, mineral proportions, and mineral chemistry (Table 1). The similarity is so great that these two materials may be identical within uncertainties. Perhaps the most obvious difference, quartz in the Rocknest crystalline component, may not be petrologically significant. Quartz and olivine of intermediate-Mg# are not stable together but can be present in a crystalline basalt that cooled rapidly and underwent fractional crystallization [h]. In that case, quartz would be present in the rock but not appear in the normative mineralogy.

Regional Setting. The source of the crystalline component of the Rocknest soil is not known. It is not related to any rock analyzed so far at Gale crater (e.g., Jake_Matijevic, Bathurst_Inlet, Rocknest_3). Surprisingly, the Rocknest soil is not rich in crystalline sulfates, as might be expected from its proximity to the sulfate-rich rocks of the Gale Crater mound, Mt. Sharp. The crystalline component of the soil could, as it appears, be derived from a single basalt surprisingly like Adirondack (Table 1). This would require that basalts like Adirondack occur both at Gusev and Gale, even though the Adirondack-class basalts are significantly fractionated, and are not primary mantle products [h].

It is also possible that the crystalline component of the sand is a mixture of many different basalts, although one would expect differential weathering, comminution, and sorting during extended eolian transport. In this case, the similarity of the Adirondack basalt to the crystalline component of the Rocknest soil would be coincidental.

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