BASALTIC SOIL OF GALE CRATER: CRYSTALLINE COMPONENT COMPARED TO MARTIAN BASALTS & METEORITES.

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A significant portion of the soil of the Rocknest eolian bedform 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 [1]. The only minerals unlikely to have formed in an unaltered basalt are hematite and anhydrite [1]. 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 [2,3] on soil of the Rocknest eolian bedform, from scoop portions #3, #4, & #5 (the last was analyzed by SAM for volatiles) [1]. Each scoop of raw soil was sieved in the MSL CHIMRA instrument, which delivered to CheMin a portion of <150 µm size fraction of each. Those portions were analyzed by CheMin over several successive nights each. 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 [1] (Fig. 1). The soil contains a significant proportion of X-ray amorphous materials [4,5], which appear as a background under the sharp diffractions. Diffraction angles (2Θ) 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 parameters, and compositions of crystalline phases present [1].

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 [1]. 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 [5]. 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.

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 [13], there are no detections of Fe-Mg amphibole, serpentines, talc, chlorites, epidote, zoisite, scapolite, muscovite, illite, carbonate minerals, sulfides, and clay minerals. Among possible pedogenic products, there are no detections of sulfates other than anhydrite, carbonate minerals, clay minerals, perchlorates, and halides.

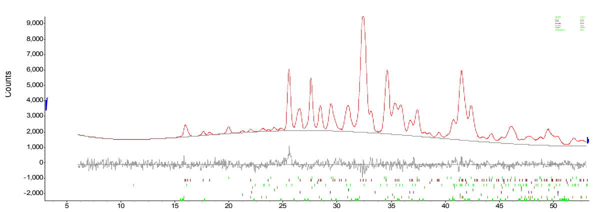

Figure 1. CheMin X-ray diffraction pattern, 1-D, for Scoop #5 of the Rocknest soil. Blue is pattern as measured, red is fitted pattern, gray is difference. The difference peak at ~25.5° 2Θ is diffraction from the Al filter on the CCD light shield.

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 [14]. Among known solar system basalts, only those from the Earth and Mars contain such sodic plagioclase [14].

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

Rocknest Soil by CheMin [1], 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 [7] ignoring S & Cl; Fe^{3+}/Fe_{tot} for Backstay and Irvine taken as 0.17, the value for RATted Adirondack basalt [7]. CIPW norms (weight) of Martian meteorites from bulk compositions [8-12]; 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.

[1], are closely similar to those of Adirondack olivine basalt from Gusev (Table 1). 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, except the Bounce Rock basalt, are richer in plagioclase than the martian meteorites (Table 2). The crystalline component of the Rocknest soil is similarly rich in plagioclase.

Adirondack Class Basalts. 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. 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 shows no sign of significant contributions from the rocks analyzed so far at Gale crater (e.g., Jake_Matijevic, Bathurst_Inlet, Rocknest_3), which are all relatively rich in potassium [15]. 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 primarily 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 [16].

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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