CHEMISTRY OF MERIDIANI OUTCROPS.
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Introduction: The chemistry and mineralogy of the sulfate-rich sandstone outcrops at Meridiani Planum, Mars, have been inferred from data obtained by the Opportunity rover of the MER mission and reported in recent publications [1-6]. Here, we provide an update on more recent samples and results derived from this extensive data set.

Compositional Trends: Analyses of the chemistry and mineralogy of outcrops are available in [2], up through the exploration of Endurance Crater. Since leaving this crater, several additional outcrop samples have been analyzed, as float material and as part of larger expanses of exposed outcrop at small craters and in the current position at Erebus crater. The highest sulfur concentration so far encountered at Meridiani is in the Gargarin sample, with SO_3 > 27 wt %, Figure 1. This is low-Cl material, in distinction with Cl enrichments in the lower-lying layers in Endurance.

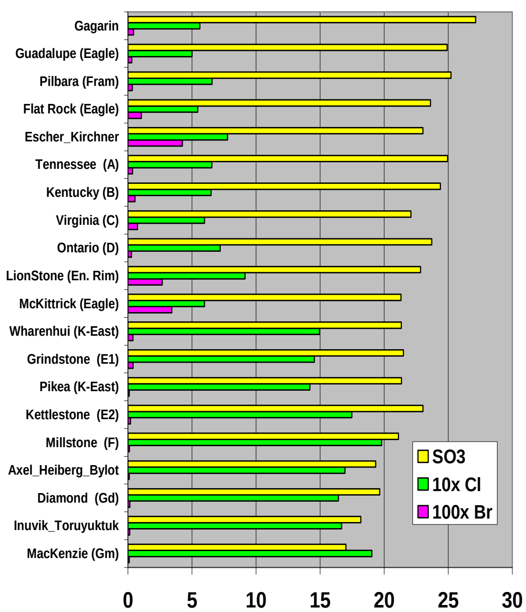


Fig. 1. Sulfur, chlorine, bromine values for the most S-rich outcrop samples

Solubility and pH: Meridiani salts span a range of solubilities, some of which change dramatically with pH. $MgSO_4$ is systematically depleted in the lower portions of the sequence, while Cl is enriched [4]. Although Mg and Na sulfates, and all candidate chlorides (Na, Mg, Ca, Fe) are soluble over a wide range of pH, the (K, Na) jarosites react only at low pH. Ca sulfates and phosphates are soluble at medium-low pH, and hydronium jarosite can be transported near neutral pH. Because jarosite concentrations are constant across all outcrop samples [4], the period of low pH must have preceeded the subsequent transport of $MgSO_4$ and chlorides. Acidic environments undoubtedly evolved to more neutral ones, as further reaction occured with residual mafic minerals in the mix.

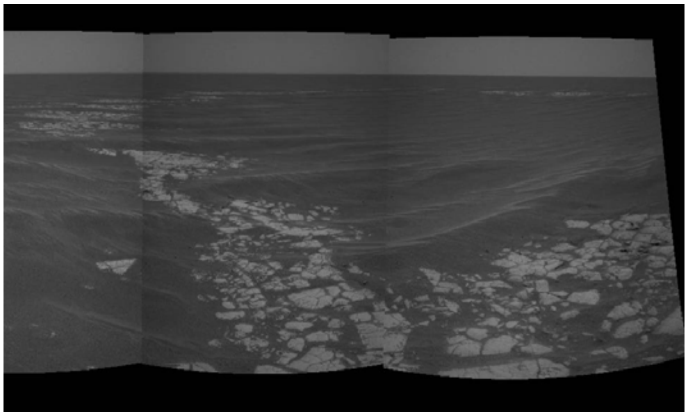
Basaltic Source Material: Clark et al. [4] suggested that a source material composed of martian bright soil plus an ultramafic component could account for the chemistry of the Meridiani outcrops if it were altered by a fluid containing abundant SO_3, as well as some Cl, P, K and Zn, presumably as an acid brine, followed by aqueous vertical transport of sulfate and chrloride. We have now further considered the possibility that the original source material did not include soil but rather was wholly basaltic and reacted with an acid brine enhanced in the above volatiles, including Zn. The derived makeup of this putative igneous source material is given in Table 1, where it is seen to be intermediate to certain martian basaltic meteorites such as the EETA 79001-A and -B lithologies, which generally bracket its composition.

Table 1. Composition of putative basaltic source material .

	EETA 79001-A	"Source"	EETA 79001-B
SiO2	48.50	**49.01**	49.00
TiO2	0.63	**1.06**	1.17
Al2O3	5.69	**8.15**	10.70
FeO	18.60	**20.20**	17.40
MnO	0.48	**0.39**	0.43
MgO	16.40	**11.34**	7.12
CaO	7.22	**6.30**	11.20
Na2O	0.84	**2.04**	1.61
K2O	0.20	**0.44**	0.20
P2O5	0.60	**0.80**	1.28
Cr2O3	0.61	**0.26**	0.17

Pore Fillings: Alteration of basic igneous minerals to create secondary products, many of which are hydrated, will general result in a volumetric increase of the original material due to the lower densities of the most or all of the resultant products and due to the chemical and physiccal incorporation of H_2O, OH, and in the case of Meridiani, the anions of SO_3, Cl, and possibly CO_2. We have now performed a series of calculations to estimate these volumetric changes. Following period(s) of saturation by an aqueous solution, the evaporites that form will be highly hydrated, such as epsomite (compared to less-hydrated kieserite) or gypsum (compared to anhydrite), resulting in the highest volumetric increases. Under these conditions, the original material would increase in volume by up to 87% (Tennessee sample, highest SO_3 in Endurance sequence), which could fill or nearly fill typical pore volumes of 40-60% for granular material (e.g., ash or regolith). However, if as we believe, this is a setting involving extensive eolian reworking as well as aqueous processes, the sediment would adjust in total volume and the current pore filling could be much less. Microscopic images were taken of a large number of processed outcrop samples, but the grinding process creates fines which can migrate into shallow pores by gravity and the action of the brushes. Direct observation of porosity is difficult, but studies are underway [7]. The energy required for RAT grinding was found to significantly increase with $MgSO_4$ content [4], indicating pore filling and cementation. Although it is possible that pore fillings are reaching volumetric saturation, it cannot be precluded that much higher concentration of salts will be found as Opportunity continues to explore along a general traverse that leads to somewhat higher elevation and hence may be moving up-section, along the trend of increasing Mg and S. Lower down in the analyzed section, the outcrops denoted layers Gd and Gm (Diamond and MacKenzie) are calculated to have salt depletions of 7 and 12%, respectively, with concommittant increases in porosity. The RAT grinding energies for these two samples is as much an order of magnitude less than for the Tennessee (A) layer (see Fig. 15 and Table 4 of [4]).

References: [1] Squyres, S.W. et al. (2004) *Science* 306, 1709-14. [2] Rieder, R. et al., *Science* 306, 1746-9. [3] Squyres and Knoll (2005) *EPSL*, 240, 1-10. [4] Clark, B.C. et al. (2005) *EPSL*, 240, 73-94. [5] Grotzinger J. P. et al. (2005) *EPSL*, 240, 11-72. [6] McLennan, S. M. et al. (2005) *EPSL 204*, 95-121. [7] Perl, S.M. et al. (2006) *LPSC 37*.



Setting for Gagarin outcrop sample.