MARTIAN ROCK AND SOIL COMPOSITIONS FROM ORBIT AND THE GROUND: WHY CAN'T WE ALL JUST GET ALONG? H. Y. McSween, Department of Earth & Planetary Sciences and Planetary Geoscience Institute, University of Tennessee, Knoxville, TN 37996-1410, mcsween@utk.edu.

Introduction: Mineralogic compositions of the Martian surface have been determined from deconvolution of Thermal Emission Spectrometer (TES) spectra, and chemical compositions have been derived from the TES mineral modes. Orbital TES compositions are likely dominated by soils, and we would logically expect that soil compositions analyzed on the ground by the Mars Exploration Rovers (MER) should match the orbital analyses. But do they?

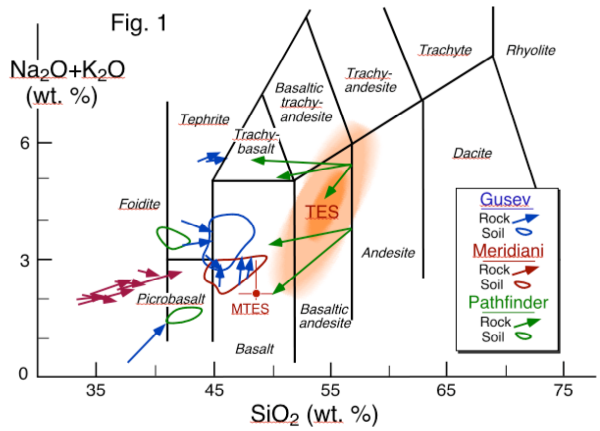
MER observations demonstrate that Martian rocks generally have alteration rinds [1, 2], and abrasion of these rinds might have produced soils. We would then predict that the chemical compositions of rock rinds should match soils or approach the compositions derived from orbital TES data. But do they?

Data Sources: TES spectral deconvolutions (binned at 4 pixels/degree) for all Mars regions not obscured by dust have been converted to chemical compositions (H_2O-free, accurate to $\pm$5 wt.%) and presented graphically [3]. The resulting TES global data clouds encompass thousands of points.

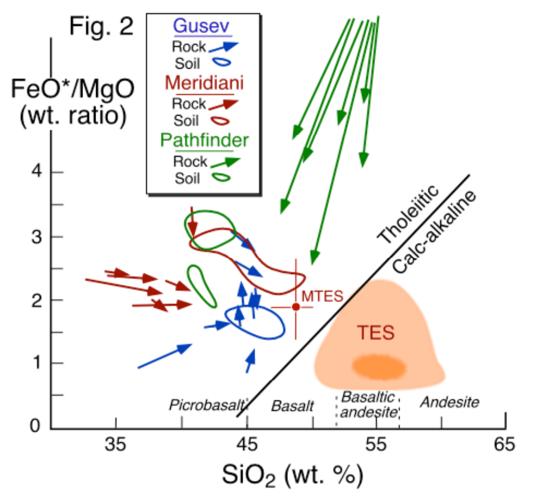
The chemical compositions of soils at the two MER landing sites have been measured by APXS [4, 5]; here we focus on average soils (omitting subsurface soils with unusual sulfate and silica concentrations or lag deposits of hematite concretions). Soil chemistry has also been calculated from MER MiniTES data for the Meridiani site [6]. The compositions of rock interiors and rinds were analyzed by APXS on RAT-ground and RAT-brushed rocks, respectively [4, 5]. APXS measurements of Mars Pathfinder rocks provided only analyses of dust-coated surfaces, but the interior compositions of rocks were extrapolated by estimating and subtracting the dust composition [7].

Results: The abundances of minor elements estimated from TES data are uncertain, because Ti- and Cr-bearing oxides, Fe-sulfides, and phosphates are not in the deconvolutions and the abundances of elements like Mn in silicate phases are unknown. Consequently, we will focus on graphical comparisons of the elements with better constrained abundances (Si, Fe, Mg, Al, Ca, Na, K).

We first consider the total alkalis – silica diagram, commonly used to classify volcanic rocks (Fig.1). The compositions of MER rocks are indicated by arrows pointing from interiors to surface rinds. Pathfinder rock compositions follow the same scheme, with arrows originating at the interior (dust-free) compositions. Two different calibrations [7] of Pathfinder data are presented. None of the soils overlap the global TES data (Fig. 1), and rock surface rinds at each site trend towards their respective soil compositions rather than towards the TES data field. The soil compositions derived from Meridiani MiniTES data have lower silica and alkali contents than TES data.



The FeO*/MgO – silica diagram (Fig. 2), used to distinguish igneous fractionation trends, shows a similar pattern. Again, all the soils are compositionally distinct from TES data. Most Gusev rock rinds trend toward soils, but a few do not. The trends of Meridiani rock rinds point below their soils and towards the TES field, but FeO in these soils may have been increased by concentrations of hematite blueberries. Pathfinder rock trends point toward both soils and TES data.



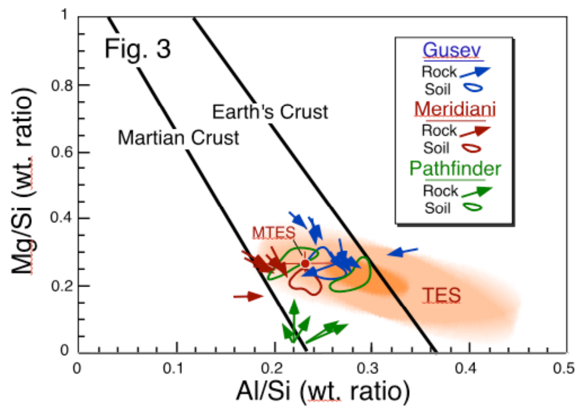
Soils overlap the TES data cloud in the Mg/Si – Al/Si diagram (Fig. 3), sometimes used to distinguish Mars samples, so these element ratios do not uniquely determine the nature of the rock alteration trends. Nevertheless, the rock trends point toward soils that plot in only half of the TES field. This diagram is at least consistent with the conclusions of previous plots.

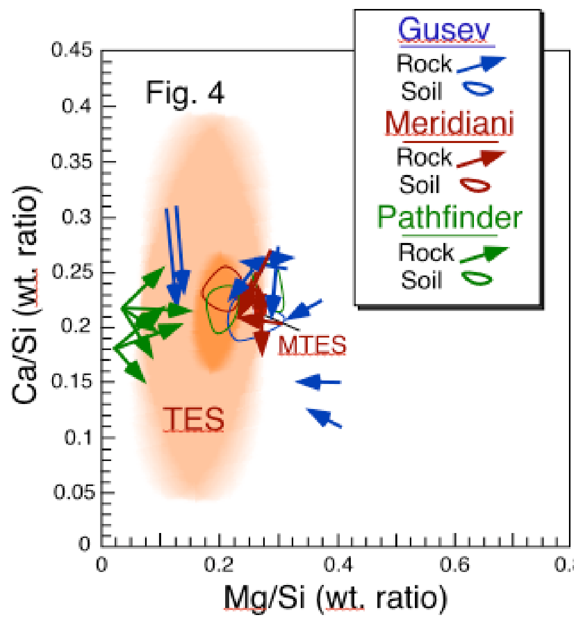
The Ca/Si – Mg/Si diagram (Fig. 4) likewise shows overlap of soil compositions and TES data. This diagram is also ambiguous in terms of rock trends, although most arrows point towards only the part of the TES data cloud where soils also plot.

Interpretation of Soil Compositions: It is now acknowledged that TES-derived compositions for Mars are consistently more silica-rich than Gamma Ray Spectrometer (GRS) analyses of the same broad areas [3]. This discrepancy reflects the differences in sampling depths of the two techniques; TES spectra sample only the outer 10-100 μm, whereas γ-rays penetrate 23-30 cm and thus sample a much larger volume. Surface alteration of rocks and soils involves dissolution of olivine [2] and consequently results in higher silica concentrations and the formation of amorphous silica, features that are detectable by TES [6, 8] but not GRS. APXS also analyzes the outer few μm, so it may be surprising that rind analyses are so different from TES. However, the difference in scale (μm versus km) probably introduces all kinds of complications in comparing these data. The consistent difference between the TES versus GRS-APXS-MiniTES data sets may suggest that TES spectra sample the surfaces of plains units partly coated by aeolian dust containing more alteration phases, whereas the other instruments analyze bulk soils containing lower proportions of dust. The dust component has higher silica, alkalis, and alumina, and lower FeO/MgO, than bulk soils.

Interpretation of Rock Alteration Trends: APXS analyses of thin rock rinds may also include some of the subjacent, less altered rock [2]. An added complication is that the APXS sampling depth is not uniform for all elements. Thus the true alteration rind compositions may be more extreme than illustrated by the arrowheads in the previous figures. Extension of these arrows in some cases might allow them to reach or even pass through soils and intersect the field of TES data, but not in other cases.

The compositions of altered surfaces on rocks at three Mars landing sites appear to point towards the local soil compositions at the same locations. One possible explanation is that the alteration rinds are simply local soils that have been cemented onto rocks, perhaps by the action of fluids when the rocks were buried. This explanation seems unlikely, however, because the granular textures of soils are unlike the smooth appearance of rinds on rocks. It seems more likely that soils are derived, at least in part, from rock coatings in that same region. A local origin for soils would be surprising, given the widespread belief that soils form a globally homogenized layer on Mars. However, it may be that airborne dust is globally distributed but that sand-size soil particles are local in origin.





References: [1] Haskin L.A. et al. (2005) *Nature*, 436, 66-69. [2] Horowitz J.A. et al. (2006) *JGR*, 111, E02S19. [3] McSween H.Y. et al. (2009) *Science*, 324, 736-739. [4] Gehlert R. et al. (2006) *JGR*, 111, E0205. [5] Ming D.W. et al. (2008) *JGR*, 113, E12S39. [6] Rogers A.D. and Aharonson O. (2008) *JGR*, 113, E06S14. [7] Foley C.N. et al. (2003) *JGR*, 108 (E12), ROV 37-1. [8] Michalski J.R. et al. (2005) *Icarus*, 174, 161-177.