DIAGNOSTIC GEOCHEMICAL AND MINERALOGICAL FINGERPRINTS FOR MARS: A CRITICAL REASSESSMENT. H. Y. McSween[1] and G. J. Taylor[2], [1]Department of Earth & Planetary Sciences and Planetary Geosciences Institute, University of Tennessee, Knoxville, TN 37996-1410, USA, mcsween@utk.edu; [2]Hawaii Institute of Geophysics and Planetology, Honolulu, HI 96822, USA, gjtaylor@higp.hawaii.edu.

Introduction: The compositions of Martian (SNC) meteorites provide geochemical parameters thought to be diagnostic for Mars [1,2]. The validity of these geochemical fingerprints is important because SNC element ratios are the basis for estimates of the planet's bulk composition [3]. The compositions of minerals in these meteorites are distinct from terrestrial rocks and are also hypothesized to be characteristic for Mars [4]. But are these parameters really diagnostic?

Volcanic rocks in Gusev crater now constitute the most thoroughly characterized igneous province on Mars, and the geochemistry [5] and mineralogy [6] of the rocks and soils analyzed by the Spirit rover provide a means of assessing these diagnostics. Although the outcrops in Meridiani Planum are too altered to preserve primary compositions, Bounce Rock analyzed by the Opportunity rover is compositionally similar to some Martian meteorites [7]. The Mars Odyssey GRS [8] also provides global measurements for Fe and for one diagnostic element ratio, K/Th.

Methods: Only APXS analyses of RAT-brush or -abraded Gusev rocks are used. Gusev soils are chemically similar to the rocks and their compositions are also compared. Mineral compositions are based on Mossbauer measurements and norms calculated from APXS analyses [6]. GRS data [8] were rebinned to 5^ox5^o grid points, resulting in large spatial resolution.

Geochemical Diagnostics: Martian meteorites are depleted in Al relative to terrestrial rocks, and the Mg/Si vs. Al/Si diagram (Fig. 1) has been commonly used to distinguish these materials [3]. This discriminant has been previously criticized as arising from crystal accumulation in SNCs [9], rather than from melting of an Al-depleted mantle. Gusev rocks and soils generally plot between the SNC and terrestrial trends; cumulate rocks plot on or near the SNC line, and somewhat more altered rocks plot past the Earth line. Bounce rock plots near the SNC line. These data support the view that the low Al/Si signature of SNCs results from crystal accumulation, or at least that the Al-depleted source for SNCs is not a universal characteristic of the Martian mantle.

Two distinct fractionation lines for SNCs and terrestrial basaltic and ultramafic rocks are observed in the Ni vs. Mg diagram (Fig. 2) [2]. However, Gusev rocks and soils, as well as Bounce Rock, plot along the terrestrial line. Although the higher Ni abundances in Gusev data might be attributed to a meteoritic component [10], most RATed rock compositions are still high. The Cr vs. Mg diagram (Fig. 3) [2] shows a more coherent relationship between SNCs and Gusev data.

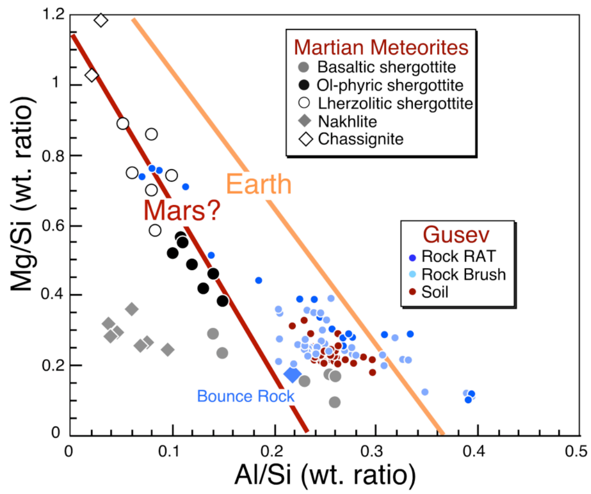

Fig. 1. Mg/Si vs. Al/Si ratios.

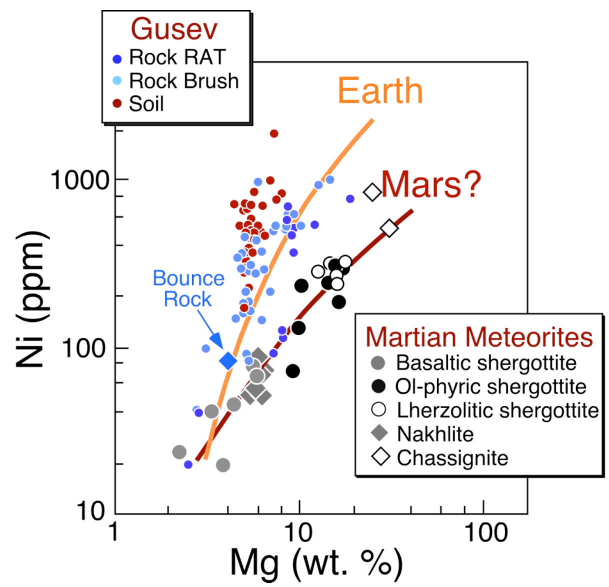

Fig. 2. Ni vs. Mg.

Based on SNC compositions, a high Fe content and a Fe/Mn wt. ratio of ~39.5 are thought to be diagnostic for Martian samples [2]. Gusev samples have lower Fe abundances than global GRS data but distinctly higher Fe/Mn ratios than SNCs (Fig. 4). This pattern is not due to depletion of Fe, as Fe/Mn appears to increase with decreasing Fe abundance.

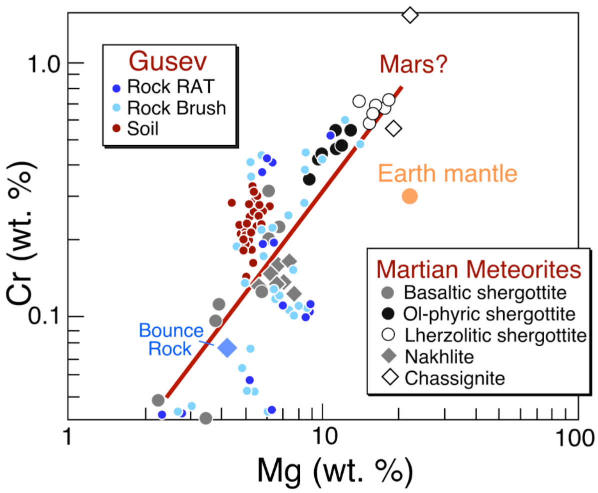

Fig.3. Cr vs. Mg.

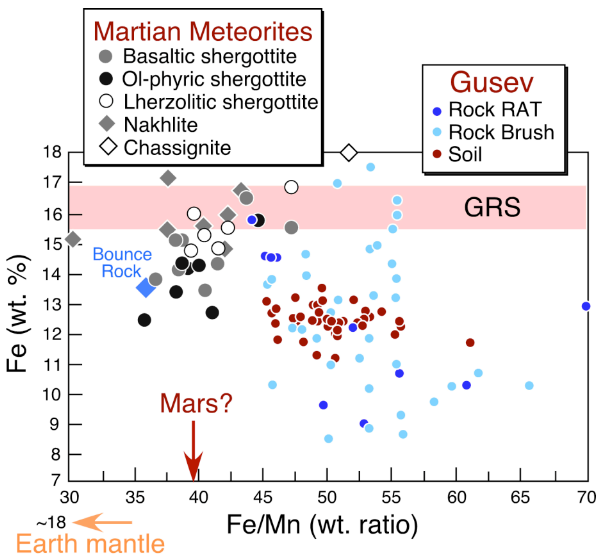

Fig. 4. Fe vs. Fe/Mn.

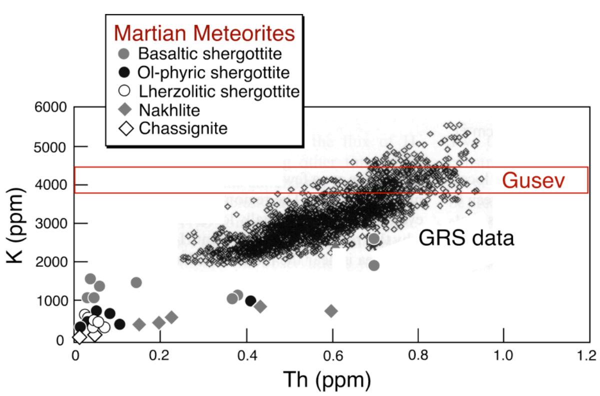

Fig. 5. K vs. Th.

GRS measurements of global K and Th allow a comparison with SNCs (Fig. 5). K and Th concentrations for SNCs are commonly lower than for GRS data (ave. 5300 [8], and Gusev rocks mostly have higher K values. However, both meteorites and GRS analyses of the Martian surface all have K/Th greater than the terrestrial value 2900 [8]. The Mars surface appears to be more volatile-rich than suggested by SNCs.

Mineralogical Diagnostics: The chemical compositions of important rock-forming minerals are thought to be distinctive for Mars. Olivine in SNCs is more Fe-rich than in terrestrial rocks, averaging Fo23-80 in shergottites and Fo17-30 in nakhlites [11]. Normative olivine compositions in Gusev rocks range from Fo42-73, in good agreement with constraints from Mossbauer and Mini-TES spectra [6]. A global TES survey of olivine compositions indicates that Fo53 and Fo68 are the most widely distributed compositional endmembers [12]. These compositions are consistent with the high global Fe abundances determined by GRS.

Plagioclase compositions in SNCs are more sodic than most terrestrial basalts, ranging from An43-66 in shergottites and An23-26 in nakhlites [11]. Normative plagioclase compositions in Gusev rocks range between An16-47 [6]. Global TES deconvolutions indicate that the most abundant plagioclase compositions are An34-66 [13]. High Na is consistent with global enrichment in K/Th and in moderately volatile elements in Mars relative to Earth.

These data support the hypothesis that ferromagnesian minerals are more ferroan and plagioclase is more sodic on Mars than in terrestrial basalts.

Conclusions: Most of the geochemical discriminants for Martian rocks, based on analyses of SNC meteorites, may not be valid in light of data from Gusev or GRS. These discriminants have also been questioned based on comparison with some uncommon terrestrial rocks [14]. Mars is more geochemically complex than can be deduced from SNC data alone. However, the compositions of major rock-forming minerals appear to be broadly consistent among the various datasets. All these datasets provide insights into planetary bulk chemistry and differentiation, but they do not all give the same conclusions.

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