**CHEMICALLY STRIKING MARTIAN REGIONS AND STEALTH REVISITED** S. Karunatillake[1,2], S. W. Squyres[1], J. J. Wray[1], G. J. Taylor[3], O. Gasnault[4], S. M. McLennan[2], W. Boynton[5], M. R. El Maarry[6], and J. M. Dohm[5], [1]Cornell University, NY (swalimunidev@notes.cc.sunysb.edu), [2]Stony Brook University, Stony Brook, NY, [3]University of Hawai'I, Honolulu, HI, [4]Universite de Toulouse [UPS] France, [5]University of Arizona, Tucson, AZ, [6]Max-Planck Institut fur Sonnensystemforschung Katlenberg-Lindau Germany.

**Introduction:** In this work [1], we use the Mars Odyssey Gamma Ray Spectrometer (GRS) data to establish regions of unusual chemical composition relative to average Mars primarily on the basis of mid-latitudinal Cl, Fe, H, K, Si, and Th mass fraction maps that are representative of the surface to tens of cm depths [2]. We discuss potential genetic process for the unique chemical and physical properties of one such region that overlaps with the classic Stealth signature [3] and provide an overview of the rest. Our work is complemented by two others that analyze regions of compositional clusters [4,5].

**Chemically Striking Regions (CSRs):** The 5°×5° bins at which the mass fractions of two or more elements in the GRS-derived maps are different from the corresponding global averages by more than one standard deviation constitute a CSR. Quantitatively, we use $t_i \geq 1$, where $t_i = \frac{c_i - m}{\sqrt{s_{m,i}^2 - s^2}}$ with $c_i$ the mass fraction of a given element at the $i^{th}$ 5°×5° bin, $m$ the global arithmetic mean, $s_{m,i}$ the standard error of $c_i$, and $s$ the standard deviation of the mass fractions.

We utilize the GRS maps generated by the primary and extended mapping periods from 08 Jun 2002 – 02 Apr 2005 and 30 Apr 2005 – 22 Mar 2006, respectively. On account of the extensive spatial smoothing in GRS data [2], we generally disregard CSRs that are smaller than ≈20° across. The regions highlighted by the resulting CSRs are illustrated in Fig. 1.

**Overview of CSRs:** Several CSRs defined by varying combinations of Fe, K, Si, and Th enrichment occupy Chryse Planitia northward to Acidalia (Fig. 1, A). Others of K, Si, and Th enrichment and Cl depletion occur in the vicinity of Isidis and the western perimeter of Utopia (Fig. 1, B). These may help to constrain models that relate lowland geochemistry dominantly to aqueous alteration [6] or dominantly to igneous processes [7].

CSRs of Si enrichment and H, K, and Th depletion in the southern highlands highlight a region immediately south of Valles Marineris overlapping with Syria, Solis, and Thaumasia plana (Fig. 1, E). Those of K and Th enrichment mark the neighborhood of Sirenum Terra and Terra Cimmeria (Fig. 1, H). The CSR of Al enrichment and Fe depletion NW of Hellas (Fig. 1, F) is still tentative as the Al map is being refined. Extensive swaths of K and Th depletion are present in the high southern latitudes (Fig. 1, I and J).

Nearly 70% of the area within one of the smallest CSRs of K and Th depletion (Fig. 1, G) consists of SE Elysium lava flows. Intriguingly, such overlap is an exception rather than the rule – CSRs generally do not overlap consistently with particular geologic units. That may hint of a disassociation between surficial processes to tens of cm depths and the underlying geology. In contrast, the majority of CSRs are consistently associated with high thermal inertia [8] and low albedo [9] regions.

Lastly, several CSRs extend westward from Tharsis (Fig. 1, D), through the Medusae Fossae formation, and into Elysium Planitia (Fig. 1, C). These highlight chemical heterogeneities of a broad Cl-enriched region with Si depleted in the Tharsis construct (Fig. 1, D) while western sections are enriched in H (Fig. 1, C).

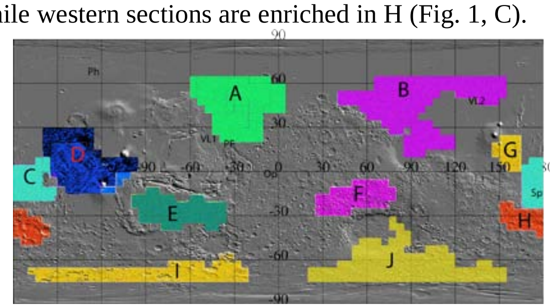


**Figure 1 Sketch of regions highlighted by CSRs.**

**Revisiting Stealth:** The Tharsis area D in Fig. 1 bears a consistent chemical trend of increasing Cl (Fig. 2, purple & lime), decreasing Si (Fig. 2, purple & lime) and decreasing Fe (sky blue). It is remarkable that the Fe and Si depleted CSR (Fig. 2, sky blue) in NW-Daedalia Planum also overlaps with the classic radar stealth signature at 3.5 cm [3] (Fig. 2, hatched). The correspondingly low bulk densities indicate high porosity at GRS sampling depths. Meanwhile, diurnal/seasonal variations in apparent thermal inertia in this region are consistent with induration at depth [10] even though the uppermost surface is likely mantled by particles of ≈40μm size [11].

Mars Reconnaissance Orbiter High Resolution Imaging Science Experiment (HiRISE) images across the region provide the most compelling evidence for induration with meter and tens-of-meter scale fresh craters failing to disrupt most bedforms. Based on the visual analysis of about 50 HiRISE images, the morphology of much of the surface appears to be of eolian origin. Given the absence of discernable topographic effects of dust devil tracks, albedo banding, and slope streaks in HiRISE images, the uppermost layer of (loose) dust inferred by thermal inertia data is unlikely to be thicker than some fraction of the tens of centimeter scale HiRISE image resolution.

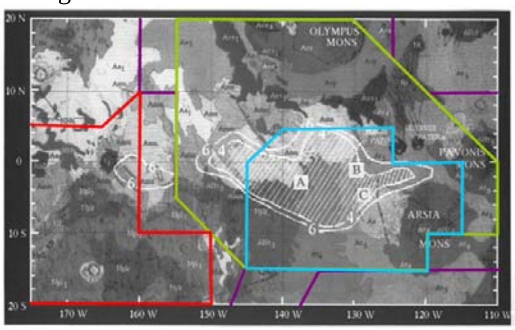


**Figure 2 Region of Cl enrichment (*t* ≥ *1.5*) and Fe (*t* ≥ *1*), Si (*t* ≥ *1.5*) depletion (sky blue) in the context of Cl enrichment and Si depletion (purple, *t* ≥ *1*; and lime *t* ≥ *1.5*). Cl, H enrichment (red; *t* ≥ *1*) is a separate area to the west. Hatched area denotes best-fit stealth adapted from Fig 4 by Edgett et al. [3].**

We integrate the convergent implications from HiRISE and thermal inertia properties with chemical comparisons involving the region (GRS data), all soil classes at Meridiani and Gusev (APXS data), all rock classes at Meridiani and Gusev (APXS), and SNC meteorites [references given by 1]. We sidestep instrumental systematic differences by using scatter plots of oxide : $SiO_2$ ratios versus $SiO_2$ renormalized to $H_2O$-free. Contrary to the anticipated Cl enrichment in the region, our scatter plots indicate an apparent enrichment of Ca in the region along with Cl, Fe, K, and Si depletion relative to surficial dust at the MER sites. This resembles simple mass dilution of dust by Ca-containing salts, such that the mass fraction of the diluents in the mix would be ≈10% . Such consistent trends are absent for in situ rocks or SNCs. Likewise, significantly lower Fe/Si but similar K/Th in the region relative to the rest of Mars eliminate alteration and mass dilution of the average crust as genetic processes.

The geologic context of the region provides a few additional constraints. Its relatively young age – especially given that it overlies mostly Amazonian formations – implies a potentially significant role for climate conditions as recent as 5Ma ago. Retrograde models suggest obliquities on the order of 40° at that time [12] for which climate models [13] predict precipitation and formation of ground $H_2O_{(s)}$. Katabatic winds may have also been stronger under potentially higher atmospheric densities [14]. In addition, much of the region is likely to have been a sink for airfall dust throughout the last few Ma [15].

The combination of airfall dust, snow, ice, and eolian conditions may have led to aqueous alteration of the earliest dust deposits, particularly if aided by scavenging of acidic aeorosols by snow and regional scale acid fog [16]. Cations including Ca may have leached from the dust [17] under such conditions and accumulated subaerially via upward-wicking of thin brine films akin to MER soil analogs [18]. More recent dust deposits would then mix with salts causing mass dilution, initial aggregation into particles large enough to saltate, and eventual induration. Provided the airfall dust was chemically similar to dust observed at the MER sites, such a scenario could easily cause the enrichment of Ca and depletion of other elements. Tentative GRS data also indicate S enrichment in the region, consistent with sulfate anions which are likely to be ubiquitous on Mars [19]. The difficulty of forming salts locally and mobilizing them upward are major caveats of this conjecture.

A less-likely scenario is the deflation and deposition of sulfates from the flanks of nearby volcanoes. Residual igneous activity and related hydrothermal processes may have conceivably produced easily friable sulfate beds – such as gypsum – on the flanks as recently as 100 Ma [20]. If that were so, the absence of a clearly discernable sulfate signature on the flanks [21] is surprising. Since massive salt beds, about $6\times10^{14}$kg to first order, would have to be deflated to yield the chemical signature of the area (Fig. 2, sky blue), significant residual salts would be expected on the flanks.

**References:** [1] Karunatillake S. et al. (2009) *J. Geophys. Res.*, submitted. [2] Boynton W. V. et al. (2007) *J. Geophys. Res. Planets 112*, E12S99. [3] Edgett K. S. et al. (1997) *J. Geophys. Res. 102*, 21545-21567. [4] Taylor G. J. et al. (2009) *Geophys. Res. Lett.* in preparation. [5] Gasnault O. et al. (2009) *J. Geophys. Res.* in preparation. [6] Dohm J. M. et al. (2009) *Planet. Space Sci. In Press*. [7] Karunatillake S. et al. (2006) *J. Geophys. Res. Planets 111*, E03S05. [8] Christensen P. R. (1986) *Icarus 68*, 217-238. [9] Christensen P. R. (1988) *J. Geophys. Res. B Solid Earth Planets 93*, 7611-7624. [10] Putzig N. E. and Mellon M. T. (2007) *Icarus 191*, 68-94. [11] Putzig N. E. et al. (2005) *Icarus 173*, 325–341. [12] Laskar J. et al. (2004) *Icarus 170*, 343-364. [13] Forget F. et al. (2006) *Science 311*, 368-371. [14] Manning C. V. et al. (2006) *Icarus 180*, 38-59. [15] Haberle R. M. et al. (2006) *Geophys. Res. Lett. 33*, L19S04. [16] McAdam A. C. et al. (2008) *Icarus 196*, 90-96. [17] Tosca N. J. et al. (2004) *J. Geophys. Res. Planets 109*, E05003. [18] Haskin L. A. et al. (2005) *Nature 436*, 66-69. [19] Halevy I. et al. (2007) *Science 318*, 1903-1907. [20] Neukum G. et al. (2004) *Nature 432*, 971-979. [21] Cooper C. D. and Mustard J. F. (2001) *32nd LPSC* Abstract 2048 at <http://www.lpi.usra.edu/meetings/lpsc2001/pdf/2048.pdf>