

COEXISTENCE OF SI-RICH & S-RICH MATERIALS AT GUSEV CRATER, COLUMBIA HILLS. Alian Wang¹, James F. Bell III², M. Rice², E. A. Cloutis³, ¹Department of Earth & Planetary Sciences and the McDonnell Center for the Space Sciences, Washington University, St. Louis, MO, 63130 (alianw@levee.wustl.edu), ²Department of Astronomy, Cornell Univ., 402 Space Sciences Bldg., Ithaca, NY 14853, ³Dept. of Geography, Univ. of Winnipeg, Winnipeg, MB, Canada R3B 2E9.

Light-toned soils were excavated by the Spirit rover at ten locations at Gusev Crater; eight of them occurred within Columbia Hills regions [1]. At three major exposures, Si-rich materials were found coexisting with S-rich soils. Current hypotheses for their origins include volcanic degassing, hydrothermal events, and precipitation from salt-rich aqueous solutions [3].

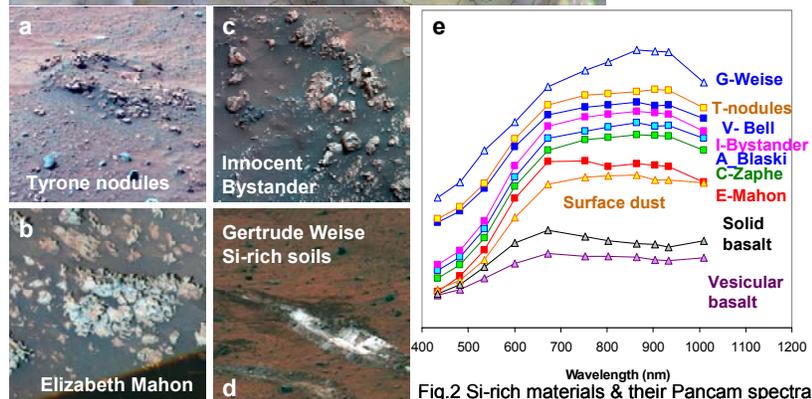
On Husband Hill: APXS measurements on "Ben's Clod" at "Paso Robles" indicate its Si-rich and Fe-poor nature [2]. Vis-NIR spectra extracted from multicolor Pancam imaging show two distinct spectral features: (1) a steeper spectral slope from 434 nm to 673 nm that may imply a higher oxidation state; and (2) a negative spectral slope from 934 nm to 1009 nm that may be diagnostic of hydrated species [7]. In the "Dead Sea" area, the coexistence of light-toned nodules with S- and Si-rich soils was observed in Navcam and Hazcam images, but neither *in situ* nor remote sensing measurements were made on them.

Near Tyrone and Eastern Valley: In the vicinity of the "Tyrone" S-rich soils exposed by Spirit, large numbers of light-toned nodules were observed. A

Mini-TES spectrum obtained from a patch of nodules near the Tyrone S-rich soils, "Tyrone-nodules," (Fig. 1, 2a) first revealed its Si-rich nature [3]. The Pancam spectrum (Fig. 2e) of this patch of nodules shows similar spectral features to those seen in the Si-rich Ben's Clod-like nodules at Paso Robles.

During the exploration after Spirit's 2nd winter on Mars, large numbers of nodular patches were encountered in "Eastern Valley," located between Home Plate and Mitcheltree Ridge and within the same topographic lowland as Tyrone (Fig. 1, blue colored 45 m contour). A number of them were investigated by Spirit using Pancam and Mini-TES and *in situ* instruments (APXS, MB, MI, RAT). APXS results [4] indicate that they are all enriched in Si (62 - 72 wt.% SiO₂). MiniTES spectral analyses confirm their Si-rich nature and further suggest that the silica is amorphous [3]. Furthermore, a patch of light-toned soil named "Gertrude Weise" (GW) was excavated (Fig. 2d) near several Si-rich nodular patches, and was found to have the highest silica content on Mars (>90 wt.% SiO₂, [3, 4]). It was also found to be quite homogeneous in the Pancam Vis-NIR spectral range. The spatial distributions of Si-rich nodules and soils targets, as well as S-rich soil targets within the topographic lowland that includes Tyrone, are shown in Figure 1.

Figure 2e shows the Vis-NIR spectra extracted from multicolor Pancam images of several nodular patches that were confirmed to be Si-rich by either APXS or Mini-TES. Compared with the spectra of surface dust, solid basalt, and vesicular basalt in the area, the Si-rich nodules have a common type of Pancam spectral pattern similar to that of Si-rich Ben's Clod-like nodules at Paso Robles, *i.e.*, a positive spectral slope from 434 nm to 673 nm and a negative spectral slope from 934 nm to 1009 nm. There are differences in their spectral details. For example, the steepness of the slope from 434 nm to 673 nm varies among different nodular patches (Fig. 2e), although it is relatively consistent among the different spots from the same nodular patch (not shown). In general, GW Si-rich soils have a spectrum with a much steeper slope from 943-1009 nm and a shallower slope from 434-673 nm (top in Fig. 2e) than those of nodular patches, which may be a characteristic



of their higher SiO₂ content. Nodular materials may contain additional Fe-bearing phases (oxides, hydroxides, and/or salts) that contribute to the steepness of the red slope. Nevertheless, in most cases, the nodular patches are redder than general surface dust (Fig. 2e), which suggests that simple surface dust coverings on nodular patches is not the only reason for the nodules' redder color compared with GW soils. In addition to the variations in spectral slopes of Si-rich nodules, the spectrum from "Elizabeth Mahon" target contains an absorption band centered at 800 nm. These and other possible spectral variations are suggestive of complex natures in composition and mineralogy of Si-rich nodules.

Pancam spectral features of Si-rich materials: It is important to emphasize that the Pancam spectral features found so far to be diagnostic of Si-rich materials based on studies at Paso Robles and Tyrone are probably not a direct reflection of their Si-rich nature (Si-bearing phases are not particularly "spectrally active" in the Vis-NIR), but rather likely to be a reflection of more general properties of nodular materials, such as oxidation state, transition metal substitutions, and possession of water or hydroxyls related to the processes from which they formed. Nevertheless, these empirical Pancam spectral features (currently under investigation [6,7]) can be used as criteria to search for similar type of Si-rich species that potentially exist in other locations at Gusev [7], especially when combining them with other criteria, such as morphologic features and, whenever available, Mini-TES spectra of the same targets.

Near West Spur: Fig. 3 shows an example of applying the above empirical criteria to the targets in the vicinity of Hank's Hollow, near the rocks "Pot of Gold" (POG), "Breadbox" and "String of Pearls". Features with distinct morphologic characteristics in this area include the rectangular shaped "case" of Bread-Box, and two pieces of similar "cases" near POG (Fig. 3a, features indicated by purple colored circles). Such

cases have been interpreted as the residuals outer shells of rocks that were hardened by possible aqueous alteration processes and thus have survived subsequent physical weathering [5]. *In situ* measurements (APXS, MB, MI, RAT) were made on POG and BreadBox (Fig. 3a, white colored squares), but not on the residual cases. Multicolor Pancam imaging with high spatial resolution is helpful for investigating these type of several-pixel-scale features, which were not reachable by the *in situ* instruments. Pancam spectra extracted from the rectangular shaped residual cases of Bread-box and POG (Fig. 3b, purple colored spectrum) exhibit spectra features similar to those of Si-rich nodules at Paso Robles and near Tyrone. Because the morphology of these "cases" suggests a hardened outer shell compared to the interior of the original rocks, extrapolating from their Pancam spectra supports a hypothesis for their Si-rich nature. In addition, there are two rectangular shaped rock shards (indicated by yellow colored circles in Fig. 3a) having spectra with even steeper slopes in the 434 to 673 nm and in the 934 to 1009 nm regions than the other "cases", further supporting a hypothesis that these shards are themselves broken pieces of former residual "cases". Pancam spectra of adjacent light-toned soils show flat or positive spectral slopes in the 934 to 1009 nm region (Fig. 3b), similar to some spectra of salty soils at Paso Robles and Dead Sea, but very different from that of GW Si-rich soils. Furthermore, we found negative slopes in the 934 to 1009 nm region of Pancam spectra from "yellowish" Dead Sea soil patches. One of them, "Samara" contents 34 wt.% excess SiO₂ [8].

Conclusion: Si-rich and S-rich materials coexist in many locations within Columbia Hills. In places where *in situ* compositional measurements were not made, we use remote sensing signatures to attempt to constrain the S- or Si-rich nature of anomalous exposed light-toned soils and rocky nodular materials. Evidence is presented that some materials with distinctive morphologies seen earlier in Spirit's traverse in the Columbia Hills may have also been Si-rich.

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References : [1]. Wang *et al.*, 38th LPSC, abs#1196 (2007). [2] Gellert *et al.*, *JGR*, 111, E02S16 (2006). [3] Ruff *et al.*, (2008), *this volume*. [4]. Ming *et al.*, *JGR*, *in prep.* (2007) [5] Squyres *et al.* *Science*, 316, 738-742 (2007). [6] Cloutis *et al.*, *Icarus*, *in press*, (2007). [7] M. Rice *et al.*, *this volume*. [8] Yen *et al.*, *JGR*, *submitted* (2007).

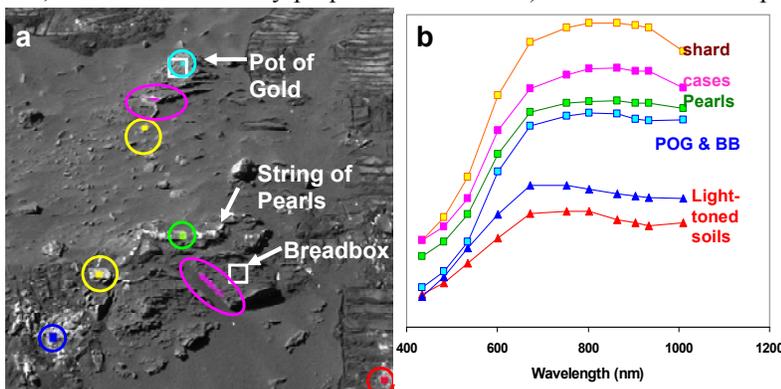


Fig. 3 Potential Si-rich materials near POG & BB rocks at the foot of West Spur