SALTY SOILS AT GUSEV CRATER AS REVEALED BY MARS EXPLORATION ROVER SPIRIT

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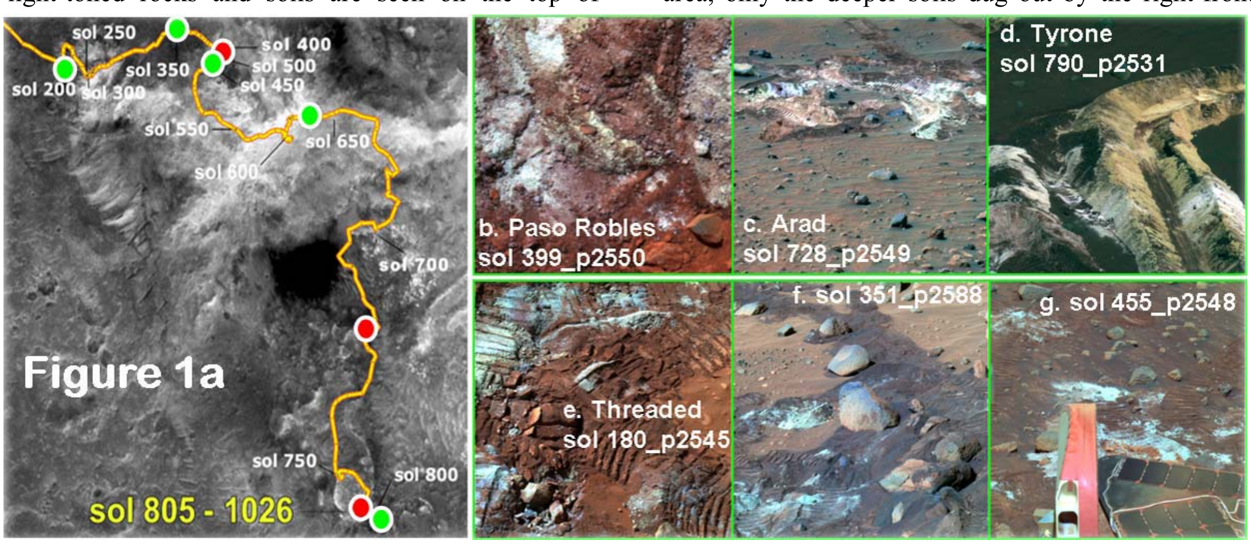
Exposure of salty soils at Gusev: Salty soils (enriched with Mg-sulfates) were exposed in two trenches made by the Mars Exploration Rover Spirit at the basaltic plain between Bonneville Crater and Columbia Hills, Gusev Crater [1, 2, 3] . During its traverse within the Columbia Hills region, light-toned salty soils were found again at eight locations (Fig.1a). These areas were all originally covered by reddish surface dust, but light-toned soils were exposed by rover's wheels [4, 5, 6]. In some of these locations, i.e. at Paso Robles, Arad, and Tyrone (Fig. 1b,c,d), the accumulated loose materials almost caused the Spirit rover to become stuck. After a few sols' manipulation to extract Spirit, large amounts of light-toned salty soils were exposed. In many other locations, the rover traversed through the areas without obvious difficulties, with small amounts of light-toned salty soils being exposed in the wheel tracks (Figure 1e,f,g).

Geomorphic setting: The sites of Arad and Tyrone occur in local topographic minima, which are almost totally enclosed by surrounding ridges. Some of the other exposures of light-toned salty soils occur at the base of hills/ridges with steep slopes. This type of site geography suggests a potential origin for the light-toned salty soils as the accumulation by wind- or water-related process. The salty materials may have been either formed at other locations and transported to where Spirit found them, or formed locally by precipitation from salt-rich fluids. The salty soils at Tyrone area are especially interesting, because a large patch of light-toned rocks and soils are seen on the top of McCool Hill, directly above the Tyrone lowlands.

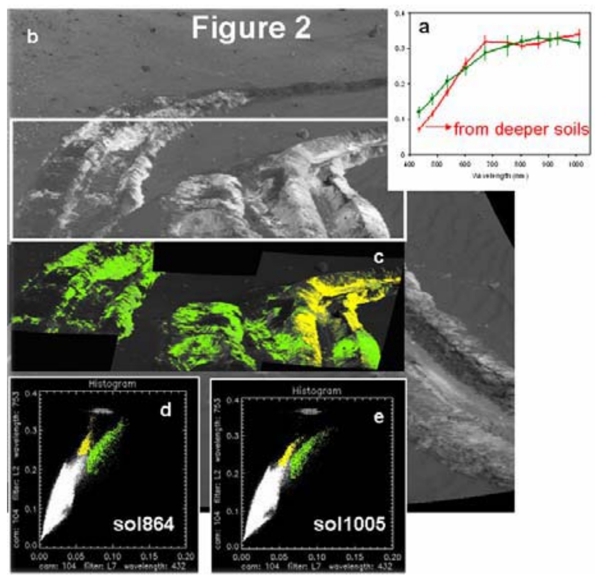
Chemistry and Fe-mineralogy of three soils: Three sets of IDD investigations were made at Paso Robles, Arad, and Halley (red spots in Fig. 1a). Mössbauer data indicate abundant (among all Fe-bearing minerals) ferric sulfate in the soils at Paso Robles and Arad, and ≥ 50 % of hematite among Fe-bearing materials at Halley [7]. APXS data show a positive Fe vs. SO_3 correlation and negative SiO_2 & Al_2O_3 vs. SO_3 correlation at Paso Robles and Arad, but a positive CaO vs. SO_3 correlation at Halley [7]. Most of the targets at Halley are materials crushed by rover wheels and may originate from the light-toned laminated outcrop that extends widely at "Low Ridge" (Spirit's winter heaven). On the basis of IDD data from Paso Robles and Arad, ferric sulfates would be the important constituent of light-toned salty soils, although Mg- and Ca-sulfates cannot be excluded.

The salty soils at Tyrone: The salty soils at all eight locations were imaged with the Pancam 13 "geology" filter set that covers the visible and near infrared wavelength region from 430 to 1010 nm [8]. The VIS-NIR spectra extracted from these Pancam images all show steep slopes from 432 nm to 735 nm and in some cases an absorption band centered around 830 nm (Fig.2a).

After sol 784, the right-front wheel on Spirit stopped rolling. Thus, it was dragged through Tyrone area. The force of dragging caused deeper light-toned soils to be dug out by this wheel (Fig.2b). At Tyrone area, only the deeper soils dug out by the right-front



wheel posses the 830 nm absorption band in their Pancam spectra (Fig.2a,b,c). In addition, these soils have a stepper slope in the spectral region from 432nm to 753nm than the soils exposed by other five wheels (Fig.2a). Therefore, we infer that there is a layered texture for the salty soils at Tyrone, i.e. the “yellowish” salty soils with the 830 nm band (ferric sulfates) occur deeper while the “whiteish” salty soils without the 830 nm band (Fe-sulfates, Ca- and Mg-sulfates, as well as perhaps halides) occur at a shallower depth right beneath the thin layer of surface dust.



Furthermore, similar two types of Pancam spectra were observed at Paso Robles and Arad areas also, where the light-toned salty soils dominate. Although no direct correlation with burial depth can be derived at these two locations, we can, however, confirm that the co-existence of these two types of salty deposits are quite common in Columbia Hills region.

MiniTES spectra obtained from the salty soils at Paso Robles, Arad, and Tyrone all exhibit a 6 μm spectral feature that further suggests that these salts are hydrated [9].

Variation of salty soils with time: Over 200 sols during Spirit’s winter campaign, periodic Pancam images using all 13 “geology” filters were taken of the Tyrone area. The purpose of these observations was to monitor the potential changes that might occur in the Pancam spectra of the freshly-exposed Tyrone soils, possibly indicating a change in mineralogy and/or hydration state. The “yellowish” and “whiteish” soils are spatially well-separated and can be distinguished even from tens of meters distance in Pancam imaging.

After 175 sols’ exposure to current Martian surface conditions (diurnal and seasonal cycles of temperature, dust, relative humidity, and water vapor pressure), a relative change in the spectra of “yellowish” soils was detected. For example, when plotting the sol 864 reflectance values of each pixel in Pancam images taken using the L2 filter (753 nm) versus the L7 filter (432 nm) as a 2-D histogram, the pixels from “yellowish” and “whiteish” soils appear as two well separated branches in the histogram (Fig.2d, yellow colored spots for “yellowish” soils, and green colored spots for “whiteish” soils). However starting from sol 959, the histograms based on Pancam Tyrone observations show a trend of reduction in the separation of these two branches (sol 1005 in Fig. 2e), when compared with the similar observation from sol 864 (Fig. 2d). This reduction appears to be caused by the decrease of R_{753nm}/R_{432nm} in “yellowish” soils relative to “whiteish” soils. In other words, the “yellowish” soils appear to become more spectrally similar to the “whiteish” soils since the time of their exposure to Martian surface conditions.

This observation supports our model of the layered structure of salty soils at Tyrone. Indeed, we hypothesize that the “yellowish” soils were originally not in equilibrium with surface conditions because they were buried deeper. Over time, the equilibrium has been developing thus the “yellowish” soils are becoming similar to “whiteish” soils, which were more or less in equilibrium with surface conditions because of their originally much shallower burial depth.

We have performed laboratory experiments on $Fe_2(SO_4)_3$•$7H_2O$ that suggest that dehydration can introduce the reduction of the R_{753nm}/R_{432nm} spectral slope similar to what we see in the Pancam data. Further decomposition (to Fe_2O_3) can introduce further reduction of that spectral slope. Pancam observation of Tyrone soils will continue to be made at regular intervals, as long as Spirit can still see Tyrone. More laboratory experiments on dehydration and decomposition of ferric sulfates are also planned. Finally, while evidence for these time-variable changes occurs in a relative sense within individual images, we are still continuing to explore other possible origins for these changes, including illumination effects and instrumentation/calibration issues related to changing atmospheric and calibration target dust conditions.

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