Remote Exploration: Understanding Martian Surface Processes

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Project 1: Gully Morphology

- Gullies are narrow channel networks composed of an alcove, a channel, and a debris fan or apron containing sediments that were transported down the gully (Figure 1).
- Gullies can be located on crater walls, central peaks, valley walls, dunes (linear gullies), and on polar pits.
- The location studied here is the polar pit gullies of Sisyphi Cavi at -68.5 latitude (Figure 2).
- These gullies are located in an ice-rich environment. They erode into rocky head walls, cut through layers, and deposit aprons with evidence of episodic flow.
- Recent activity has been detected in one of these gullies [1].

Figure 1: Annotated image of a gully in the polar pit, displaying its dendritic alcove, narrow channel, and apron.

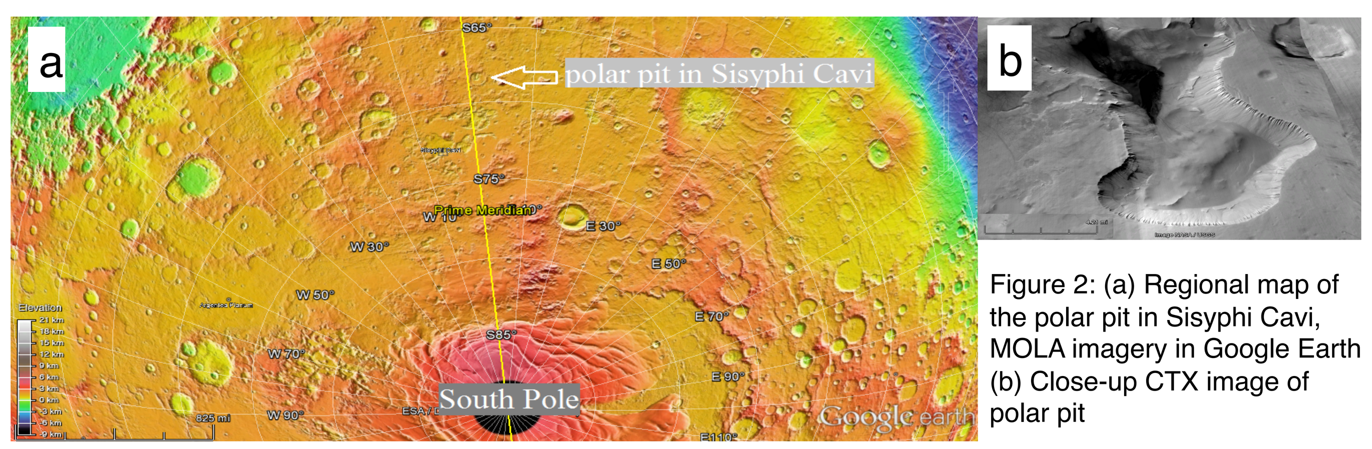

Figure 2: (a) Regional map of the polar pit in Sisyphi Cavi, MOLA imagery in Google Earth (b) Close-up CTX image of polar pit

Procedure

1. Using ENVI, we drew a transect across the center stream line, creating a cross section (Figure 3). Moving along the cross section profile (in green), we determined the two bank stations (circled in yellow) and took the lower elevation of the two to calculate the volume removed (volume beneath the yellow line).

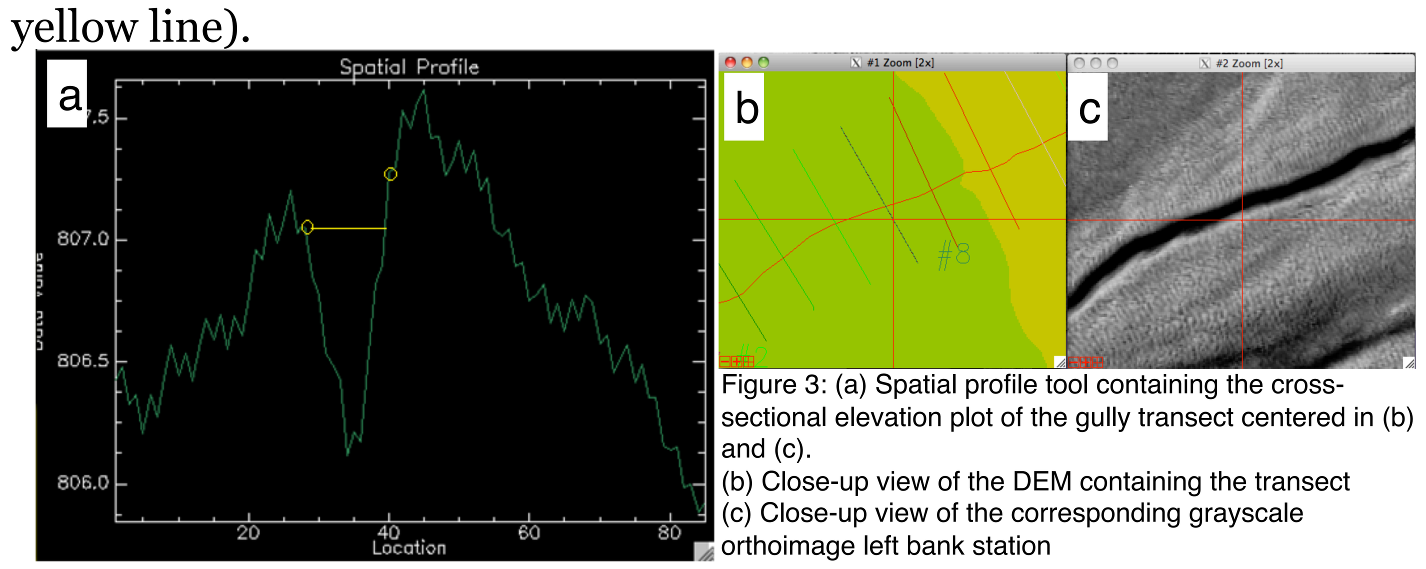

Figure 3: (a) Spatial profile tool containing the cross-sectional elevation plot of the gully transect centered in (b) and (c).
(b) Close-up view of the DEM containing the transect
(c) Close-up view of the corresponding grayscale orthoimage left bank station

2. We continued drawing transects across each entire gully, recording the bank stations and elevations for each transect (Figure 4). We used a MATLAB script to calculate the volume removed from within the alcove and down the channel.

Figure 4: (a) DEM containing all gully transects (b) Grayscale containing all transects going up the gully

3. We used a similar transect method on the apron to compare the volume removed to the volume deposited in the apron for gullies A-H in the study.

ABSTRACT

Earth and Mars share many similar physical features, including canyons, valleys, craters, volcanoes, ice, and gullies. My research focused on two distinct projects. The first concentrated on the formation of gullies on Mars. Debated gully-forming processes include the melting of snowpacks, sublimation of accumulated CO_2 frost, melting of snow-rich dusty mantle material, and groundwater flows. Using High Resolution Imaging Science Experiment (HiRISE) images of gullies and working with Digital Elevation Models (DEMs) in ENVI, we performed detailed studies of gully morphology, including volume calculations using slope, distance, and elevation.

Project 2 focused on determining the mineral composition of Martian rocks. Using Raman spectroscopy, I tested the mineral composition of igneous rocks and recorded spectral peaks for key rock-forming minerals. These samples and spectra will be used to help create an automated computer mineral identification algorithm that could be used on future Mars rover missions. These remote exploration projects provide a better understanding of Martian surface processes.

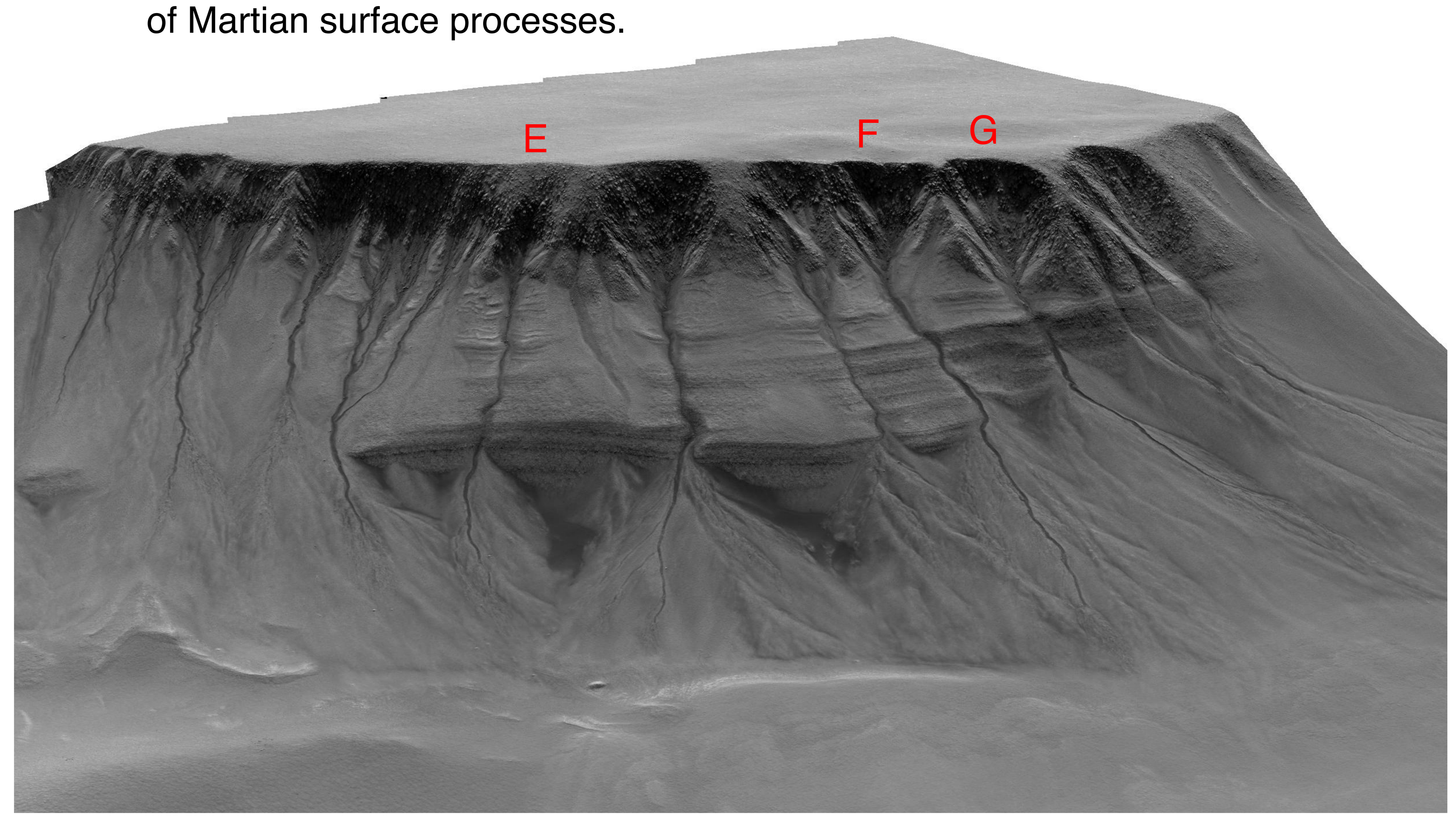

Figure 5: 3-D perspective view of HiRISE stereo pairs ESP_013097_1115 and ESP_013585_115, created using ENVI with 2x vertical exaggeration. Image of the south wall of the polar pit in Sisyphi Cavi containing gullies E, F, and G.

CONCLUSION

After calculating the volumes removed from each gully's alcove and channel, and comparing it to the volume deposited in the apron, we found that the volumes removed and deposited were within the same order of magnitude, with volume removed averaging $1.23 \times 10^6\ m^3$ and volume deposited averaging $1.72 \times 10^6\ m^3$. Comparing these results to the geomorphology, we can conclude either (a) the possibility of frozen terrain reduced material lost, or (b) older gullies with overlapping aprons contributed to the volume deposited in the analyzed gully's apron, resulting in a larger calculated apron volume. Other gully sites, Corozal crater and a small unnamed crater in Kaiser crater, located in the mid-latitude region at $-46°$ and $-38°$ latitudes respectively, yielded results that volume deposited was reduced roughly by half [4]. All gullies studied have comparative average slopes to those in the polar pit. It's important to study a range of latitudes, which is why we chose to study this particular site.

With Raman spectroscopy, we acquired over 400 spectra from over 50 rock samples from various sites, focusing on igneous plutonic rocks with a few sedimentary. This will contribute to the database which we will use to train the mineral classifier. Additionally, we recorded key minerals found in each spectra, which established ground truths for each spectrum.

Project 2: Raman Spectroscopy

- Raman spectroscopy is a technique that relies on inelastic scattering of monochromatic light, usually in the form of a laser [2].
- We used Raman spectra of terrestrial rock samples to identify key rock-forming minerals, such as olivine, plagioclase, potassium feldspar, quartz, calcite, gypsum, and pyroxene.
- The end goal is to train a mineral identification algorithm to identify minerals in Martian rocks using spectral data.

Procedure

1. We took 9 spectra of each rock sample in a 3x3 matrix (Figure 6). We took spectra using 785 nm red laser and 585 nm green laser.
2. We recorded spectral peaks taken by each laser. The granite rock sample s000r02 has peaks at 462 and $509\ cm^{-1}$ (Figure 7).

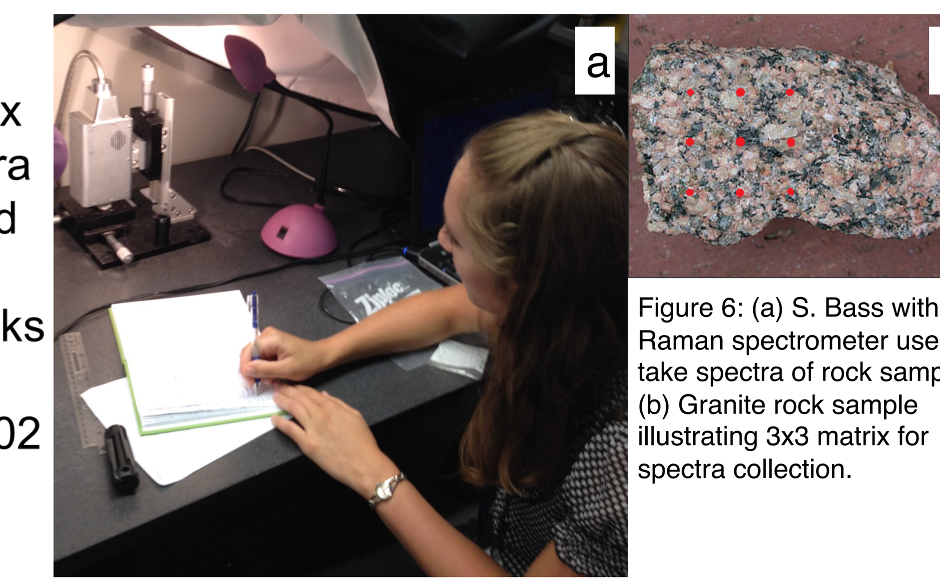

Figure 6: (a) S. Bass with the Raman spectrometer used to take spectra of rock samples. (b) Granite rock sample illustrating 3x3 matrix for spectra collection.

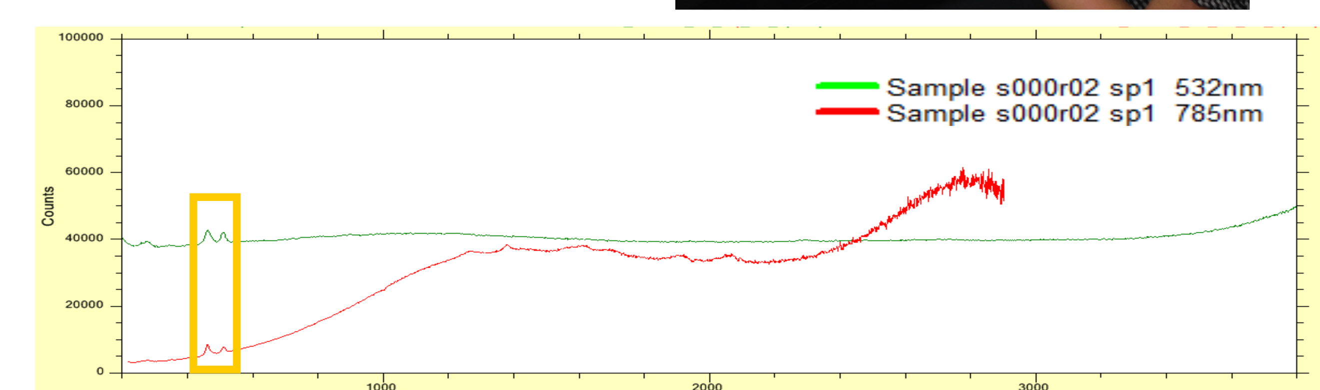

Figure 7: Raman spectra, with peaks at 462 and 509 cm^{-1}, outlined in yellow.

3. We compared spectra from the sample against spectra of known minerals, included below (Figure 8). Based on the similarities in spectral peaks, this granite sample contains quartz and potassium feldspar.

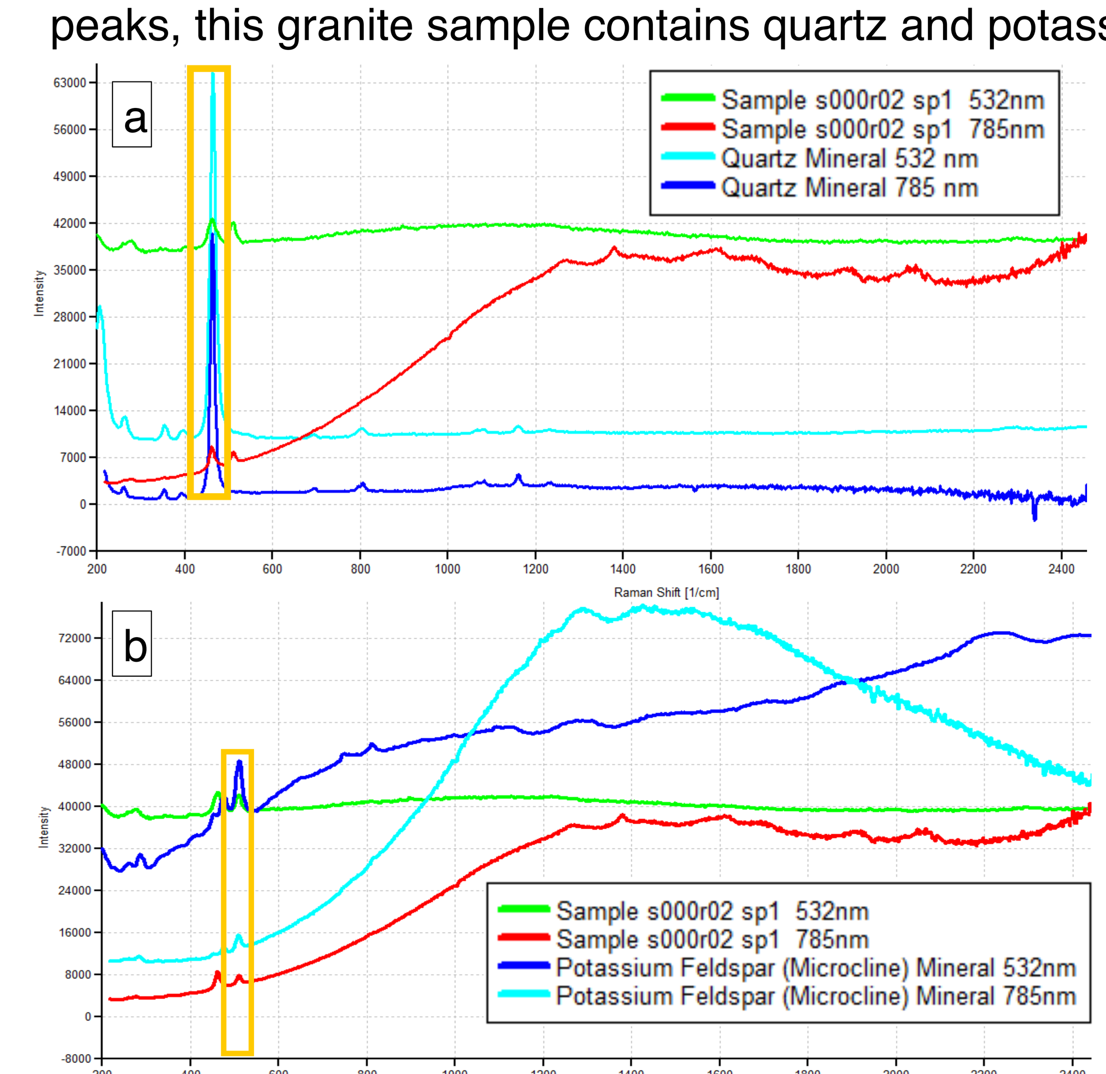

Figure 8: (a) Intensity vs. Raman Shift normalized plot of rock sample $s000r02$ spectrum 1 and a known quartz mineral using both a 532 nm green laser and a 785 nm red laser to compare their spectral peaks. The shared peak is at $462\ cm^{-1}$, outlined in yellow.

(b) Intensity vs. Raman Shift normalized plot of rock sample $s000r02$ spectrum 1 and a known potassium feldspar mineral, microcline, using both a 532 nm green laser and a 785 nm red laser. By comparing the spectra, their shared peaks is at $509\ cm^{-1}$, outlined in yellow.

4. We used this data to build a database to train an automated mineral classifier [3].

References: [1] Raack J. et al. (2014) Icarus 4-8. [2] McMillan (1989) Ann. Rev. Earth Planet. Sci. 1-2. [3] Ishikawa S.T. and Gulick V.C. (2013) Computers and Geosciences 54, 259-268. [4] Gulick, V.C. et al. 2014., 8th Mars Conf., abs. #1490.

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