SPECTRAL VARIABILITY AMONG ROCKS AND SOILS IN PERSEVERANCE VALLEY, MARS AS OBSERVED BY THE OPPORTUNITY PANCAM. W.H. Farrand[1], J.R. Johnson[2], J.F. Bell III[3], D.W. Mittlefehldt[4], C. Schröder[5], A. Tait[5], R.E. Arvidson[6], L.C. Crumpler[7]. [1]Space Science Institute, Boulder, CO, farrand@spacescience.org, [2]Applied Physics Lab, Johns Hopkins University, Laurel, MD, [3]Arizona State University, Tempe, AZ, [4]NASA Johnson Space Center, Houston, TX, [5]University of Stirling, Stirling, UK, [6]Washington University in St. Louis, St. Louis, MO, [7]NM Museum of Natural History & Science, Albuquerque, NM.

Introduction: Before the 2018 Mars global dust storm caused a loss of contact with the Mars Exploration Rover (MER) Opportunity in June 2018, the rover had been exploring the ancient channel-like feature dubbed Perseverance Valley by the MER team [1]. Among the observations made by the rover were a collection of multispectral visible/near-infrared images of rocks and soils of interest. Several spectrally distinctive materials were observed. Here we report on these observations, the spectral classes of materials that were observed, and their geologic relevance with regards to the overall extended mission objective of understanding Perseverance Valley (PV).

Pancam Multispectral Data: Full Pancam spectral coverage (432 – 1009 nm) of rock targets consists of 13 filter (13f) data collections with 11 spectrally unique channels with data processing as described in [2]. Data were examined using spectral parameters, decorrelation stretch composites, and spectral mixture analysis [e.g., 3, 4]. Note that color terms used here refer to colors in various false-color renditions, not true colors.

Spectral Classes in Perseverance Valley: To categorize the spectral variability of rocks and soils that were observed in PV during the course of mission operations, a linked self-organizing map (SOM) [5] and hierarchical clustering were used. 117 13f spectra from sol 4882 (near the head of PV) to sol 5088 were assembled and categorized using 8 spectral parameters that indicate mineralogical properties such as Fe oxidation state and the potential presence of Fe-bearing oxides or silicates (482 to 673 nm slope, 535 nm band depth, 601 nm band depth, 803/905 nm ratio, 904 nm band depth, 754 to 1009 nm slope, 934 to 1009 nm slope, and fitted reflectance peak position). Derivation of parameters were described in [3, 4].

SOM and Clustering: The specific implementation of SOM used was the SOMbrero routine in R [6] which includes a post-processing "super-clustering" hierarchical clustering step. **Fig. 1** shows the resulting hierarchical clustering dendrogram with the seven super-clusters (SCs) derived from the SOM groupings labeled. **Fig. 2** shows representative spectra from each of the super-clusters.

Materials of Interest: Here we focus on three of the distinctive spectral types that constitute the seven super-clusters.: SC 2, the dark pitted rocks; SC 4, the dark tabular rocks; and SC 5, putative coatings with red sloping spectra. **Fig. 3** shows false color image examples of these three materials.

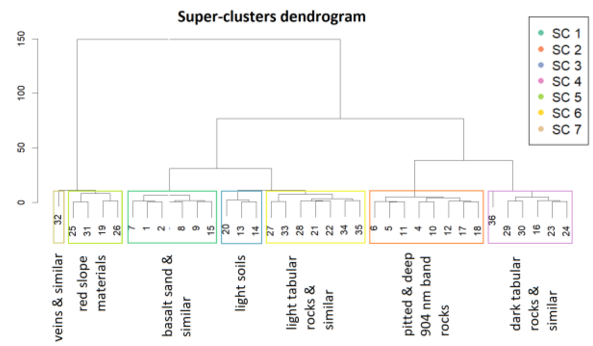

Fig. 1. Dendrogram-grouping SOM clusters into super-clusters.

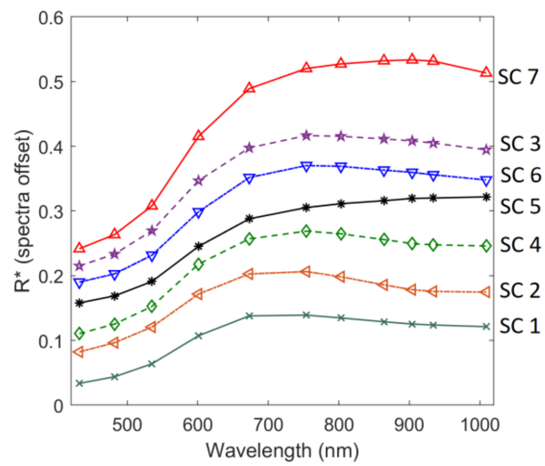

Fig. 2. Super-cluster representative spectra.

Discussion: The pitted rocks are still not fully understood. They are described in more detail in [9]. **Fig. 4** shows an example of the color differences on a single example of one of these rocks. In this 673, 535, 432 nm composite, some surfaces are dark blue, others appear more purple and others with a light-toned rind or coating. The purple surfaces have similar, but higher, reflectance spectra as the blue surfaces, the light-toned surfaces lose the distinct 904 nm band with just a negative-sloping reflectance from the reflectance peak to 1009 nm. The pitted and tabular rocks have similar appearing spectra but a plot of 904 nm band depth vs.

803/904 nm ratio shows that they are distinct with lower values for these parameters.

The dark coatings on the rocks at La Bajada have a featureless positive red slope in the NIR. At wavelengths below 700 nm, they display ferric iron charge transfer absorptions, albeit with a very low 535 nm band depth relative to other materials. While, the featureless nature of the red NIR slope hampers a definitive identification, this type of spectrum resembles that of other surfaces observed by Opportunity that were enriched in Mn [4, 10] and so they are tentatively hypothesized to be mixed Fe and Mn bearing materials.

The tabular rocks, such as that in **Fig. 3C,** were observed lower in Perseverance Valley. Their reflectance spectra, with flat to negatively sloping NIR reflectances, are consistent with previously observed exposures of the lower Shoemaker formation [7] observed in lower lying portions of the Endeavour rim, nominally associated with fractures [8]. However, in terms of fine-scale morphology and chemistry these rocks appear distinct and have been tentatively described as a pre-Endeavour impact breccia [7].

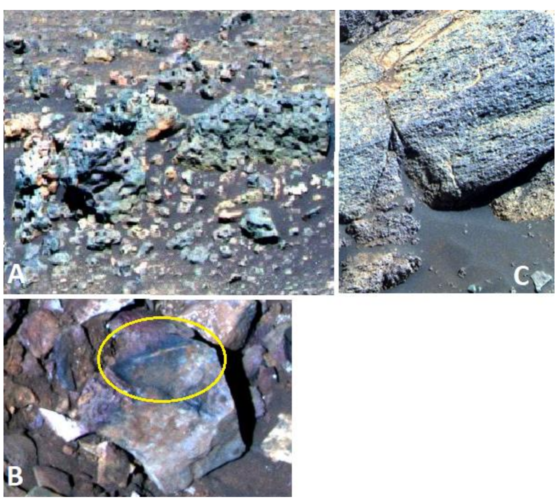

Fig. 3. **A**. Sol 5000, P2588 (673, 535, 432 nm) view of pitted rocks (SC 2). **B**. Sol 4882, P2552 view of dark coating (circled) with red slope (SC 5). **C**. Sol 5081 P2554 view of tabular rock Puenta de Diablo (SC 4).

Summary Points: While PV's formation mechanism remains unknown, it hosts a variety of rocks and soils that are spectrally distinct. Three spectrally and morphology different materials are defined from Pancam data. The dark coatings with the red NIR slope and the different colored surfaces of the pitted rocks might represent the effects of aqueous alteration. While tabular rocks represent examples of previously observed impact breccias, likely of the lower Shoemaker formation.

References: [1] Squyres S. W. et al. (2018) *LPS IL*, Abstract #1758. [2] Bell J.F. III et al. (2006) *JGR*, 111, doi:10.1029/2005JE002444. [3] Farrand W.H. (2014) *JGR*, 119, doi:10.1002/2014JE004641. [4] Farrand, W.H. et al. (2016) *Am. Min*., 101, 2005-2019. [5] Kohonen T. (2001) *Self Organizing Maps*, Springer, 3rd Ed. [6] Boelaert J. et al. (2014) Advances in SOMs and LVQ, Springer, pp. 219-228. [7] Mittlefehldt D. et al., LPS L, submitted. [8] Crumpler L.S. et al., LPS L. submitted. [9] Tait A.W. et al., LPS L, submitted. [10] Arvidson R.E. et al. (2016) *Am. Min*., 101, 1389-1405.

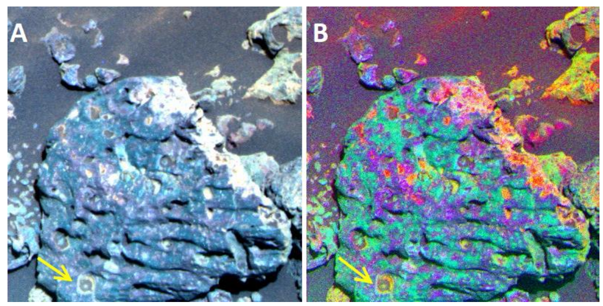

Fig. 4. **A**. L357 (673, 535, 432 nm) view of unnamed pitted rock. **B**. Decorrelation stretch of same image. Rimmed pit indicated by arrow. Note light-toned coating or rind running diagonally along the upper right border of the rock.

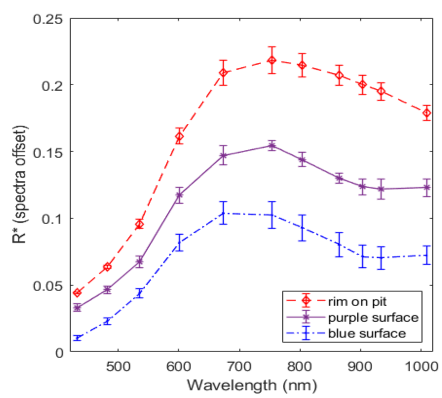

Fig. 5. Spectra of color units on pitted rock in **Fig. 4**.

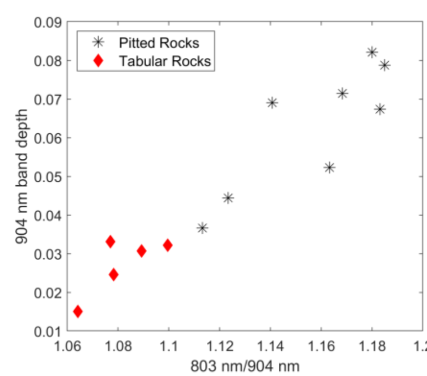

Fig. 6. 904 nm band depth vs. 803/904 nm ratio for tabular and pitted rocks.