LITHOCHEMICAL ROCK SUITES OF PERSEVERANCE VALLEY, ENDEAVOUR CRATER, MARS

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Perseverance Valley: Perseverance Valley (PV) contains the highest density of rock lithologies observed by Opportunity since Cape York, and the four rock suites of the valley indicate possible vertical offset of pre-impact lithologies, aqueous alteration, and wind and mass wasting erosion. On ~Sol 4730 Opportunity began a campaign to explore the 250 m long, ~30 m wide, anastomosing feature that cuts west to east across the remnant rim of Endeavour crater [1-11].

Spirit of St. Louis & Marathon Valley: On Sol 3973 Opportunity encountered the Spirit of St. Louis feature [12-15]. Spirit of St. Louis (SoSL) is a 25-35 m ovoid feature located near the entrance of Marathon Valley [13]. Marathon Valley is another feature that cuts west to east across the rim of Endeavour crater that was chosen for rover exploration based on CRISM detections of smectite [16]. SoSL has been eroded down to the same topographic level as the slope of Marathon Valley and is rimed by an alteration zone that is enriched in Si and Al and is called a "red zone" because of its appearance in false color L257 (753, 535, 432 nm composite) Panoramic Camera (Pancam) images.

Occurrence of "Blue" Rocks: Throughout its traverse through Meridiani Planum and along the rim of Endeavour crater, Opportunity has encountered rocks that appear "blue" in false color L257 Pancam images. A competent outcrop of "blue" rocks was analyzed at *Sergeant Charles Floyd* on a rim overlooking Marathon Valley (Fig. 1). A ~3 m tall feature of "blue" rocks is also present in SoSL and was analyzed with the APXS at a target named *Roosevelt Field*. The aphanitic texture and Alpha Particle X-Ray Spectrometer (APXS) measurements that indicate a broadly basaltic/tholeiitic composition support an igneous or impact-melt origin for these "blue" rocks [1, 13]. The "blue" rock's slight geochemical differences and geologic context has been interpreted as different generations of basalt that both pre-(*Sgt Charles Floyd*) and post-date (*Roosevelt Field*) Endeavour crater [13].

Data and Methods: In-situ investigations of rock and soil targets are accomplished with the arm-mounted APXS and Microscopic Imager (MI), and the mast-mounted Pancam, providing bulk chemistry, rock texture, and context, respectively [17-18]. In this work, rock target compositional relationships and rock suites are established using a statistical grouping model that includes a hierarchical cluster analysis and an error-weighted χ^2 similarity index [19]. Imagery from the Pancam and MI provide information on rock texture and geologic context to help assess model result.

Rock Suites of Perseverance Valley: The MER team performed contact science (APXS analyses) on 16 discrete targets within the valley, and the statistical grouping model is used to divide them into four distinct lithochemical groupings.

San Miguel Type "Blue" Rocks: The lowest point in PV reached by the rover was in the "North Fork" past *Ysleta Del Sur*, where the *San Miguel* outcrop was investigated (*Jornada Del Muerto*, Fig. 2). This outcrop has a distinctive "blue" hue in L257 imagery and is similar enough in bulk composition and fine-grained aphanitic texture to classify it as another location of "blue" rocks. The same outcrop was also analyzed ~16 m up the valley (*Nueva Vizcaya*). Two more locations were analyzed in the "South Fork" *(Inde, La Joya*, Fig. 3) that also fit within this rock suite. All of the PV Blue rocks exhibit surficial lineations that likely are a secondary erosion feature and also orient parallel to the valley strike. Of the previously analyzed "blue" rocks the *San Miguel* type rocks are highly similar to the pre-Endeavour impact "blue" rock outcrop examined on the ridge overlooking Marathon Valley (*Sgt Charles Floyd*), indicating that the *Jornada Del Muerto* could be from the same pre-impact unit (Fig. 2).

Pitted, Silica Rich Rocks: Adjacent to the linear tabular outcrop of "blue" rocks (*Inde, La Joya*, Fig. 3) lies an outcrop of distinctly pitted rocks (*Allende, Tome, Nazas*, Fig. 4). These fine grained rocks have several-cm-diameter surficial pits and appear "dark blue to purple to tan" in false color Pancam images [7]. These rocks also have among the highest SiO_2 content in any rock outcrop examined by Opportunity (53-63 wt%). Some pits in the outcrop appear to be filled with material that could be a secondary mineral (e.g., a zeolite), and Pancam spectra indicate the presence of a crystalline ferric oxide [7-8]. Another outcrop of relatively high silica, "purple" rocks with smaller pits (*Sgt Nathaniel Pryor*), lies adjacent to the "blue" outcrop (Sgt Charles Floyd) overlooking Marathon Valley.

Valley Floor Fill Material: The floor of PV can be characterized as a loose collection of regolith and sub-cm to several-cm sized cobbles, and was sampled at five locations (*Zacatecas*, *Albuquerque*, *Carrizal*, *Durango*, *Bernallio*, Fig. 1). This group has a tight SiO_2 and Al_2O_3 distribution with minor MnO enrichment compared to other PV materials. A multi-component mixing model was used to test end-member components within the APXS integration field of view. An average of this suite of targets is best represented as a three component mixture of: Meridiani soil (~13-28%),

a material of similar composition to the floor of SoSL (~47-55%, represented by the *Harold M Bixby*, *Donald A Hall*, and *Roosevelt Field* APXS targets), and cobbles of the San Miguel type "blue" rock (~21-31%) [2].

Ysleta Del Sur Outcrop: HiRISE imagery of PV shows morphology reminiscent of bifurcating channels. These features are striking in satellite imagery but the local topographic difference is muted to only a few centimeters. Opportunity investigated the nose of one of the "channel forks" at *Ysleta Del Sur*. The outcrop appears to be a breccia with sub-cm sized angular "blue" clasts in a fine-grained homogenous "tan" matrix. These clasts are more resistant than the surrounding matrix and wind tails form behind the clasts indicating modern wind erosion in an up-valley direction.

The outcrop was sampled at two target locations (*Guanajuato*, *Aguas Calientes*). Generally the composition overlaps with most other PV material except for a lower MnO and higher MgO content in RATed targets. This outcrop is particularly similar in composition to the San Miguel type "blue" rocks, but is not classified as such based on its distinct breccia texture.

Valley formation mechanisms: While PV formation mechanisms are still an open question [1-13], interpretations based on these rock suite and texture classifications contribute to working hypotheses: 1) the presence of valley-trending lineations across all competent rock outcrops and wind-tails on *Ysleta Del Sur* indicate aeolian erosion is a modern mechanism in the valley, 2) local enrichment in Mg and S, visible alteration minerals filling vugs in pitted rocks, and observed "red" zones along valley-trending fractures point to local aqueous alteration, and 3) "channel" depressions with a mixture of local materials (valley floor fill unit) due to mass wasting, and the possibility that a radial fault graben lowered a segment of the adjacent "blue" and pitted units of Marathon Valley overlook into PV.

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Acknowledgements: We appreciate support from NESSF grant 80NSSC17K0490 (MB), JPL contract 1536058 (BJ), and NASA's continuation of the extended MER mission.

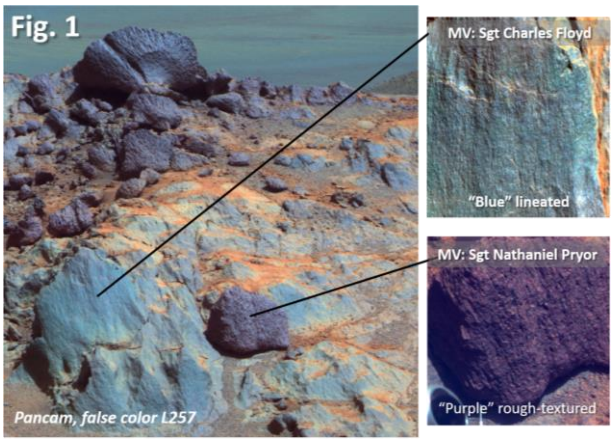

Figure 1: Lineated "blue" and rough "purple" rocks juxaposed on the rim overlovooking Marathon Valley, Sol 3948.

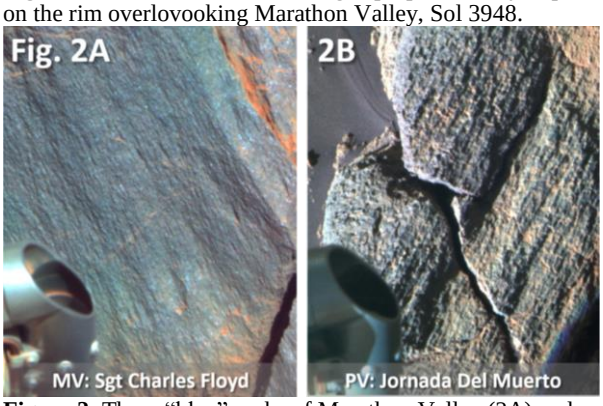

Figure 2: These "blue" rocks of Marathon Valley (2A) and Perseverance Valley (2B) are aphanitic, lineated, and are highly similar in composition.

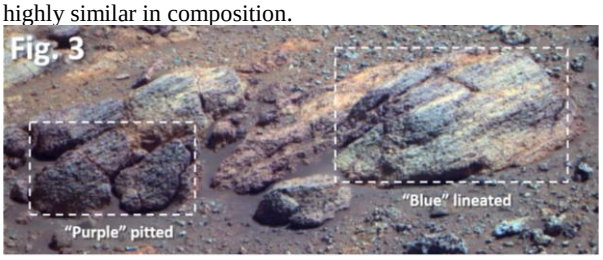

Figure 3: *Inde*, a lineated "blue" rock of Perseverance Valley (right box), Sol 5048, appears to be part of a continuous outcrop of "purple," pitted rocks (left box).

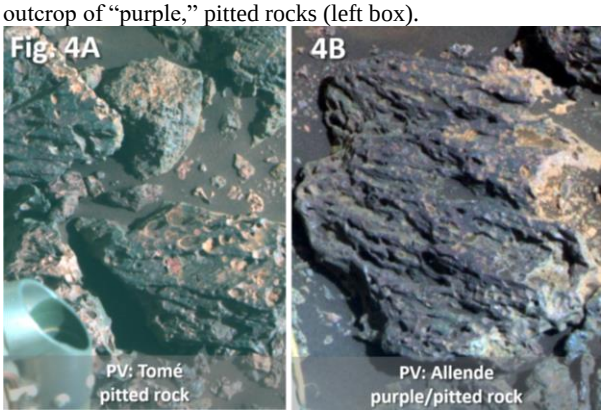

Figure 4: Pitted rocks analyzed near the outcrop in Fig. 3. *Allende* is similar in composition to *Sgt. Nathaniel Pryor* of the Marathon Valley over look.