# COMPARISON OF ROCK SPECTRAL CLASSES OBSERVED AT CAPE YORK AND SOLANDER POINT ON THE RIM OF ENDEAVOUR CRATER BY THE OPPORTUNITY PANCAM

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## (1) Introduction:

The VNIR multispectral capability of the Pancam on the Opportunity rover has been used to distinguish several rock spectral classes on the segment of the rim of Endeavour crater known as Cape York [1,2]. Several of these spectral classes have also been observed on the rim segment further to the south, Solander Point, that is currently being examined by Opportunity [3]. In this work, we focus on a subset of these spectral classes and compare spectra and derived spectral parameters of these materials with terrestrial analog materials.

## (2) Spectral Classes Considered:

Six primary rock spectral classes were defined in [1] based on observations made by Opportunity's Pancam from the southern tip of Cape York, along its western flank and to its winter-over site at Greeley Haven (**Fig. 1A**). In a follow-on paper [2], six main rock spectral classes were also defined from observations made at the northern tip of Cape York and in its exploration of the Matijevic Hill area on the eastern ("in-board") side of Cape York (**Fig. 1B**). The main spectral classes defined in [2] were the light-toned veins, the Grasberg Fm., the Matjievic Fm., the hematitic spherules ("blueberries") on the bench unit of Cape York and in scattered occurrences on Matijevic Hill, the spherules ("newberries") found within the Matijevic Fm., and the Shoemaker Fm. (**Fig. 2**). On Solander Point, the Grasberg Fm., and the Shoemaker Fm. have also been observed to date. Here we present comparisons with terrestrial analog materials for the Grasberg Fm., Matijevic Fm. and sub-classes of the light-toned veins.

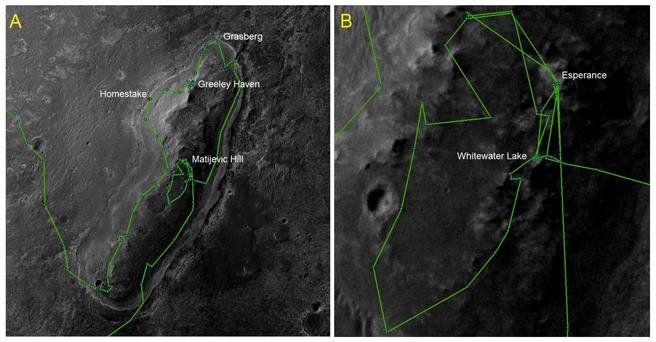


**Fig. 1**. **A**. Overall View of Cape York traverse. **B**. Zoom in on traverse around Matijevic Hill.

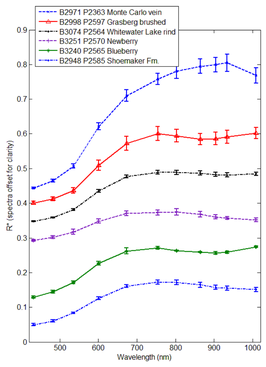


**Fig. 2**. Main spectral classes from [2] observed on northern Cape York and Matijevic Hill. Error bars represent standard deviation of pixels averaged together for these average spectra.

## (3) Analysis of VNIR Class Spectra:

Light-toned veins were observed on the bench unit of Cape York [3, 4] and also along the traverse from Cape York to Solander Point. As noted in [2 and 4], these veins were different in size and occurrence from those observed in the Matijevic Fm. and both were distinct from the light-toned veins/fracture fills surrounding the polygonal blocks in the boxwork occurrences seen on Matijevic Hill [5] (**Fig. 3** and **4**). **Fig. 5** shows distinctions between these veins in terms of their 535 nm band depth and their 934 to 1009 nm slope.

The Matijevic Fm. matrix and dark-toned coatings (**Fig. 6**) are distinct from each other in several spectral parameters including blue-to-red slope and 754 to 1009 nm slope.

Clean surfaces of the Grasberg Fm. have spectra which are broadly similar to those of the Burns Fm. [e.g., 6]. However, Grasberg is distinct from Burns both in terms of its fitted NIR band minimum position and in terms of 535 nm band depth (**Fig. 7**).

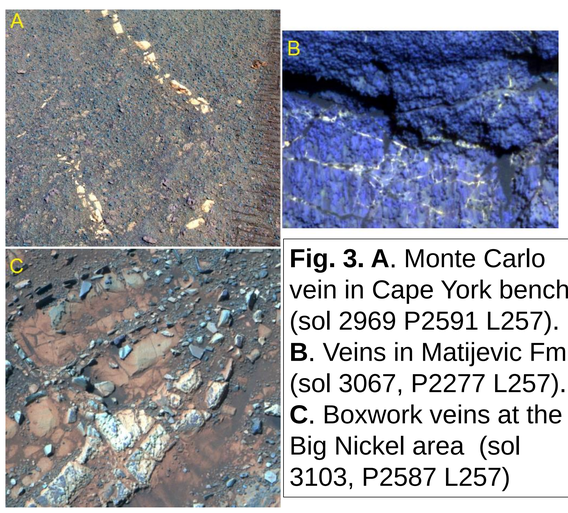


**Fig. 3. A**. Monte Carlo vein in Cape York bench (sol 2969 P2591 L257). **B**. Veins in Matijevic Fm. (sol 3067, P2277 L257). **C**. Boxwork veins at the Big Nickel area (sol 3103, P2587 L257)

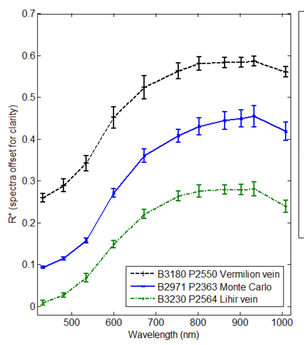


**Fig. 4**. Spectra of vein sub-classes. Error bars represent standard deviation of pixels averaged together for these average spectra.

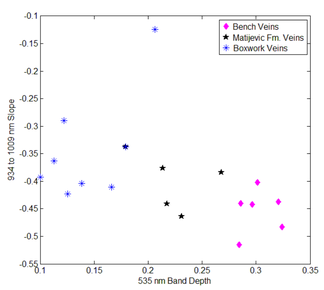


**Fig. 5**. 934 to 1009 nm slope vs. 535 nm band depth for sub-classes of veins.

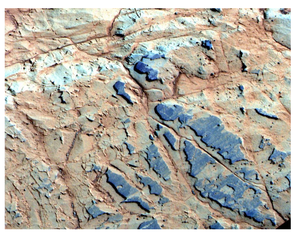

**Fig. 6**. Sol 3074 P2564 L357 view of Whitewater Lake showing light-toned matrix and dark-toned coatings.

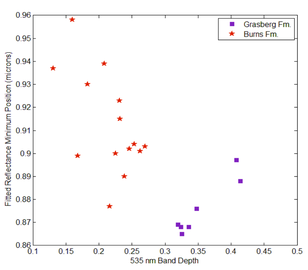


**Fig. 7**. Plot of fitted NIR band minimum position vs. 535 nm depth for representative spectra of Grasberg surfaces compared against Burns Fm. surfaces.

## (4) Comparisons to Terrestrial Analog Materials:

The veins in the bench and those on Matijevic Hill have been interpreted as gypsum on the basis of APXS data showing enrichments of Ca and S and Pancam evidence of a negative 934 to 1009 nm slope which matches a similar downturn in laboratory spectra of gypsum attributed to a $H_2O$ overtone band (**Fig. 8**). The boxwork veins have a different composition with low Fe, high Al and Si and have been chemically modeled as containing Al smectites and hydrated silica [5].

In a plot of fitted reflectance peak position vs. 803/904 nm ratio (**Fig. 9**), Grasberg Fm. surfaces from northern Cape York plot closest to the fields of lab spectra of ferrihydrite and hematite. Clean Grasberg surfaces have a band minimum position of 864 nm which is consistent with red hematite.

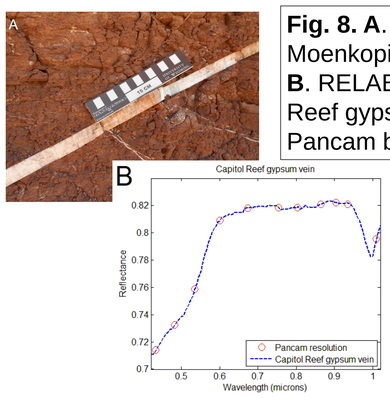


**Fig. 8. A**. Gypsum vein in Moenkopi Fm., Capitol Reef, UT. **B**. RELAB measure of Capitol Reef gypsum and convolved Pancam bandpasses.

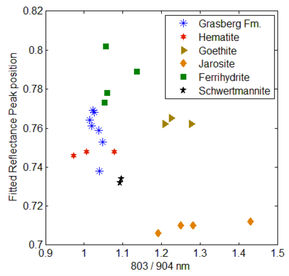


**Fig. 9**. Fitted reflectance peak position vs. 803/904 nm ratio for Grasberg surfaces compared to USGS library spectra

## (5) Matijevic Fm. Comparisons:

A compelling reason for the investigation of Matijevic Hill was the detection at that location of absorption features consistent with nontronite from CRISM data [5]. A plot of 754 to 1009 nm slope vs. 904 nm band depth of Matijevic Fm. surfaces (matrix and coatings) (**Fig. 10**) has the same trend and plots in the same field as ashes and tuffs from several hydrovolcanic eruption centers sampled in Idaho [7] (**Fig. 11A**), but pedogenically weathered [8] palagonitic soils from the summit of Mauna Kea [9] (**Fig. 11B**) plot away from that trend. This plot, explored further at this meeting in [10], suggests that the nominally smectite-bearing Matijevic Fm. might have been altered at elevated temperature analogously to the hydrovolcanic tuffs as opposed to the ambiently weathered Mauna Kea soils.

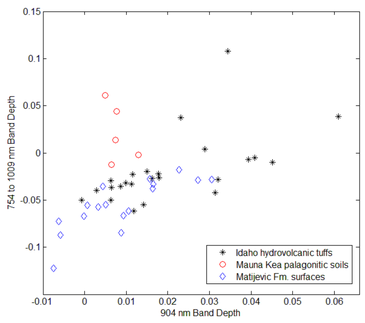


**Fig. 10**. 754 to 1009 nm slope vs. 904 nm band depth for Matijevic Fm. surfaces compared with hydrovolcanic ashes and tuffs and pedogenically weathered Haleakala soils

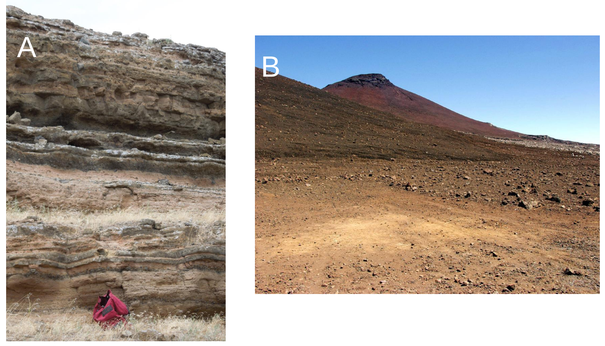


**Fig. 11**. **A**. Palagonite tuffs at Sinker Butte tuff cone, Idaho. **B**. palagonitic soils on Mauna Kea, Hawaii.

## (6) Conclusions:

Of the spectral classes considered here, the light-toned bench unit and Matijevic Hill veins are consistent with gypsum and the boxwork veins with some material with a 1 μm water overtone band. The Grasberg Fm. is consistent with its containing red hematite, perhaps with some variable admixture of ferrihydrite. Finally, the Matijevic Fm. matrix and coatings could have followed a palagonitic alteration sequence similar to hydrovolcanic tuffs, but different from pedogenically weathered basaltic ashes

**References**: [1] Farrand, W.H. et al. (2013) *Icarus*., **225**, 709-725. [2] Farrand, W.H. et al. (2014) submitted to JGR-Planets. [3] Squyres, S.W. (2012) *Science*, **336**, 570-576. [4] Farrand, W.H. et al. (2013) *LPSC 44*, #2482. [5] Arvidson, R.E. et al. (2014) *Science*, **343**, doi:10.1126/science.1248097. [6] Farrand, W.H. et al. (2007) *JGR*, **112**, 10.1029/2006JE002773. [7] Farrand, W.H. et al. (2013) *LPSC 44*, #2249. [8] Schiffman, P., et al. (2000) *Geochem., Geophys., Geosyst*., **1**, 2000GC000068. [9] Hamilton, V.E. et al. (2008) *JGR*, **113**, 10.1029/2007JE003049. [10] Farrand, W.H. et al. (2014) *LPSC 45, #1597.*

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