Hematite through the eyes of the ExoMars 2020 Rover *Rosalind Franklin*: Simulating mineral identification with the *PanCam WAC* multispectral filters

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Introduction: We present a pipeline for evaluating the ability of *PanCam* to discriminate one particular mineral species against a defined set of background materials. We demonstrate the pipeline for the mineral hematite, an iron oxide indicative of changes in oxidation conditions, with implications for past habitability, and which has been one of the targets of interest for the *Curiosity* rover at *Vera Rubin Ridge* [1,2].

PanCam: *PanCam* [3] is the mast-mounted colour-stereo panoramic camera system for the ExoMars 2020 *Rosalind Franklin* rover [4], with an objective of visual geological characterisation, focusing in particular on signatures of ancient habitats. *PanCam* will measure the VNIR (visible/near -infrared, 380nm - 1100nm) spectral reflectance of surfaces with a multispectral suite of 12 narrowband filters [5]. The VNIR features of the expected surface mineralogy are mostly attributed to the oxidation state of iron, as the dominant transition metal [6]. The transmission profiles of the *PanCam* filter set were optimized for identifying a broad selection of minerals, expected to be encountered by *Rosalind Franklin*, as detailed by *Cousins et al.* [5]. This process considered the ability of a candidate set of filter profiles to reconstruct each of a set of mineral reflectance spectrum by linear interpolation, and also to distinguish one group of minerals against another, such as the set of phyllosilicates against the set of sulfates, via a set of 5 spectral parameters (algebraic operations between spectral bands).

Problem Statement: Now that the design and manufacture of *PanCam* is complete, there is an opportunity to further explore the spectral capabilities of the complete system. The next step is to consider the discrimination of a specific mineral species, as opposed to an entire set, against arbitrary collections of other species, as opposed to all other species, across a broad space of spectral parameters. In this study, we consider the identification of the specific mineral *hematite*, in contrast to the set of Fe/Mg phyllosilicate minerals expected at the selected *Oxia Planum* landing site [8,9], and models of martian dust [10].

Method: To perform this study, a pipeline has been developed with the intention of building a reproducible and distributable method, for studying arbitrary imaging systems, target mineral species, and background material sets. To this end, the pipeline consists of the following components:

1. **Mineral Database**: the *Western Washington Vis-NIR Database* [11] has been used as an interface to a collection of spectral libraries, including the USGS speclib06 [12], and the Uni. Winnipeg *HOSERlab* databases [13]. The extraction pipeline involves choosing a species from a mineral group, importing the multiple samples available per species, and interpolation and truncation to the range 380 nm – 1100 nm, $\Delta\lambda$=1 nm.

2. **Instrument Model**: the sampling of the reflectance spectra of *PanCam*, including instrument noise, is simulated under typical Mars illumination conditions, computed using a comprehensive software simulator developed by [14], with the current status of the software also reported here.

3. **Spectral Parameters**: are calculated according to the methods developed for the *CRISM* orbital hyperspectral imager, presented by [15,16]. Where the central wavelengths of the *PanCam* filter suite do not match those available for *CRISM*, substitutes are explored.

4. **Visualization**: in addition to plotting the computed spectral parameters, to evaluate the quantitative discrimination of hematite against a background, the success of the spectral parameter as a qualitative tool can also investigated, in terms of the target-background the contrast achieved in a 2D image. This is achieved by synthetizing spatial scenes of the target and background, via the spectral simulation software [14], and by processing the resultant images through the *ExoSpec* toolkit, a multispectral image analysis software package for ENVI, developed by the *PanCam* science team [17].

Summary and Future Work: In this work we demonstrate the ability of *PanCam* to discriminate hematite against a background set of materials representative of *Oxia Planum*, by simulating the multispectral response of the instrument, and exploring spectral parameter combinations. The method can be extended to investigate the response of comparative instruments, such as *Mastcam* and *Mastcam-Z*, and of the *Aberystwyth University PanCam Emulator, AUPE*, and to explore any target mineral against any background set for which data is available.

References: [1. Fraeman et al, 2013, *Geol.*], [2. Fraeman et al, 2018, *LPSC49*, 1557], [3. Coates et al, 2017, *Astrobiology*], [4. Vago et al, 2017, *Astrobiology*], [5. Cousins et al, 2012, *Plan. & Space. Sci.*], [6. Burns, 1993, *Min. Appl. Of Crystal Field Theory*], [8. Quantin-Nataf et al, 2019, *Mars-9*, 6317], [9. Mandon et al, 2019, *Mars-9*, 6173], [10. Kinch et al, 2015, *JGR-Planets*], [11. Rice et al, 2016, http://spectro.geol.wwu.edu/], [12. Clark et al, 2007. *USGS Digital Spectral Library*],[13. Cloutis et al, 2006, *LPSC37*, 2121], [14. Stabbins et al, 2018, *LPSC49*, 2099], [15. Pelky et al, 2007, *JGR-Planets*], [16. Vivano-Beck et al, 2014, *JGR-Planets*] [17. Allender et al, 2018, *SPIE-Remote Sensing*]