MULTI-SCALE ANALYSIS OF ALLUVIAL SEDIMENTARY OUTCROPS IN UTAH USING EXOMARS 2020 PANCAM, ISEM, and CLUPI EMULATORS.

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Introduction: As the launch date for the ESA/Roscosmos ExoMars 2020 rover draws near, the need for analysis tools to exploit the wealth of data to be returned by its Panoramic Camera (PanCam) [1], Infrared Spectrometer for Mars (ISEM) [2], and CLose-UP Imager (CLUPI) [3] instruments becomes increasingly important; the exploitation of integrated data from these instruments will be invaluable in detecting evidence of past habitability on Mars and identifying drilling locations.

Together, PanCam, ISEM, and CLUPI offer multi-scale analysis capabilities in both spatial (~140-1310 µm/pixel at 2 m working distance), and spectral (350-3300 nm) dimensions. In the case of PanCam, whose left and right "eyes" look at different portions of the spectrum (440-1000 nm), spectral matching with ISEM must be performed between multi- and hyperspectral datasets across multiple portions of the spectrum.

To address such challenges, we present results from our development and testing of image analysis tools for PanCam, ISEM, and CLUPI imagery. These tools have been constructed as extensions to ENVI + IDL, and combine procedures from [4,5] to perform pre-processing and generate false colour band depth visualisation products for PanCam images. For this, we use instrument emulator datasets acquired from Mars analog sites in Utah, USA.

Field area: Fieldwork was undertaken in Southern Utah, USA, near the towns of Green River (41.52°N, 109.46°W) and Hanksville (38.37°N, 110.71°W). Alluvial deposits are preserved as inverted channel features in the Brushy Basin and Salt Wash Members of the Jurassic Morrison Formation, and the Ruby Ranch member of the Cretaceous Cedar Mountain Formation. These channel features preserve a record of flowing water on the surface, and provide a proving ground for the observation and integration capabilities of the PanCam, ISEM, and CLUPI instruments.

Further west, outside of the town of Torrey (38.29°N, 111.41°W), Triassic gypsum vein exposures were also imaged to test the multi-scale capabilities of our instrument trio. These have been interpreted [7] as late-stage diagenetic features and are analogous to martian veins due to their textural and geometric characteristics. Across all study regions, a total of seven sites with varying compositions, textures, and structural characteristics were selected for analysis.

Instrument emulators were deployed at each site to simulate the PanCam, ISEM, and CLUPI instruments onboard ExoMars 2020. These were: the Aberstwyth University PanCam Emulator (AUPE) [8] (spanning 440-1000 nm), a Spectral Evolution spectrometer (ISEM-E) spanning 440-2500 nm with hyperspectral reolution, and CLUPI-E - a Sigma DSLR camera configured to CLUPI specifications [3]. AUPE and CLUPI-E mosaics were collected at each site, and ISEM-E data points were collected either as vertical logs, or spanning each distinct unit. Soil and rock samples were also collected for each imaged unit at the study sites to provide spectral and mineralogical ground truth after Q-XRD analysis.

Figure 1: Layered alluvial plain deposits at "Ice Cream Mountain" in the Brushy Basin Member of the Jurassic Morrison Formation, near Hanksville. The Brushy Basin Member here is characterised by mud and silt grade material in varying oxidation states, and is capped by coarse to granular, and very poorly sorted fluvial channel sandstones.

Methods: AUPE images were processed using our ENVI + IDL based processing pipeline. Steps include flat fielding, radiometric correction, and conversion to R* reflectance using the in-scene Macbeth ColourChecker. Construction of band depth and ratio products [5,9] was also performed within the pipeline as their combinations are able to highlight regions of distinct composition.

To provide initial insight into the number of distinct spectral units within an image, AUPE Left Wide Angle Camera (LWAC) and Right Wide Angle Camera (RWAC) band depth products were examined, and compared to the results of a Minimum Noise Fraction (MNF) transform which was performed on the R* data.

From each distinct class highlighted by the above analyses, Regions Of Interest (ROI) were constructed and their mean spectra saved in site-based spectral libraries. Note that these ROIs were also selected to overlap with locations which had also been targeted by the ISEM emulator in the field. These libraries were

used as input for supervised classification using the Spectral Angle Mapper algorithm (SAM). The SAM algorithm was chosen as it is not adversely affected by changes in illumination conditions - several images contain shadowed regions due to the morphology of the outcrops. Output from this classification highlights areas of similar composition in each LWAC and RWAC. Spectra of interest spanning the full 440-1000 nm range were then constructed from these regions and compared (visually, and with resampling into AUPE wavelengths) with point spectra of the same region collected with ISEM-E (spanning 440-2500 nm) to examine hydration absorption features in the NIR. Spectral comparison between these two datasets has previously been attempted by [5], and results were found to be variable, particularly in the NIR portion of the spectrum. We find similar variation, particularly in images where lighting conditions were changeable at the time of capture. However, in images where lighting conditions were stable, we propose that where AUPE/ISEM-E spectral matches are below a set threshold (using either SAM or Euclidean distance as a similarity measure), ISEM-E spectra may be extrapolated to the nearby neighborhood.

CLUPI-E (and High Resolution Camera (HRC) on PanCam [1]) images were mosaicked and overlain with AUPE imagery to provide high-resolution morphological information, particularly with respect to entrained clasts and grains.

Preliminary results: Figure 2 shows preliminary results from an inverted channel formation "Triangle" in Hanksville, nearby the previously investigated MURFI UK rover field trial site [10]. An AUPE RGB visible mosaic provides the context for all overlain image combinations. CLUPI-E images show both a clay deposit and a gypsum vein, plus a rounded deposit containing small nodules, within the surrounding oxidised matrix. The AUPE band depth product clearly differentiates between an uppermost clay layer (shown in magenta and confirmed with ISEM-E) and an Fe-rich layer (shown in green).

Discussion: Working distance from the studied outcrop is an important consideration, particularly with respect to the combined spatial resolution of ISEM-E, HRC-E, and CLUPI-E and their utility for clast and grain size measurements. For all our field sites working distances of less than 5 m were not possible if entire outcrops were to be imaged with AUPE, thus our minimum CLUPI-E resolution was 394 µm/pixel at a distance of 5 m [3]. In turn, the 1° FOV of ISEM-E at a working distance of 5 m is approx. 12 cm. In this size area, spectral unmixing is an important consideration. To aid in spectral umixing between ISEM-E and CLUPI-E, high-resolution CLUPI-E RGB images could be used to estimate endmember abundances within each ISEM-E footprint using image segmentation. We are currently working to incorporate and test this functionality in our processing pipeline. We anticipate these tools will greatly facilitate the analysis of ExoMars 2020 PanCam, ISEM, and CLUPI data and will make them publicly available upon their completion.

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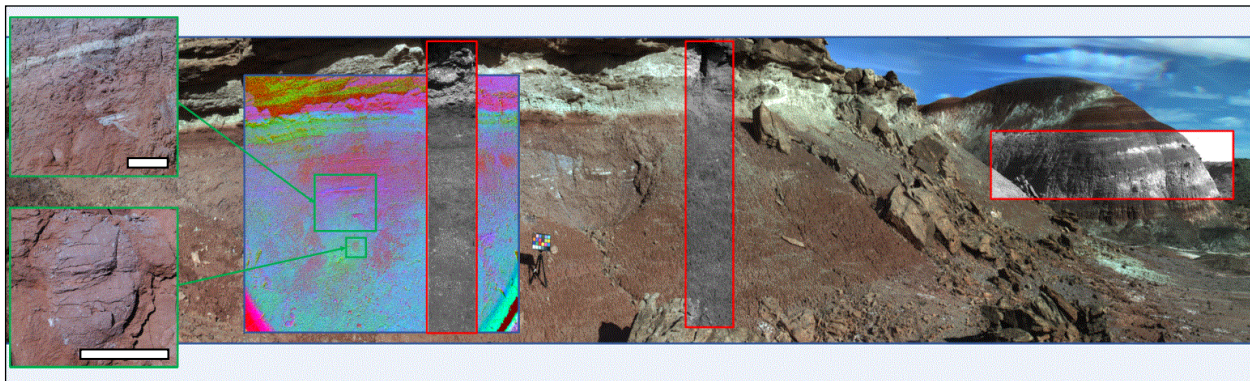
Figure 2 (above): AUPE, HRC-E, and CLUPI-E imagery obtained for the "Triangle" outcrop near Hanksville. Two CLUPI images show a gypsum vein exposure (top) and a rounded deposit with nodules within an oxidised matrix (bottom). Both scale bars are 20 cm. Band assignment for the LWAC multispectral image is R: Red/Blue ratio, G: BD532, B: BD610. Bright red regions are indicative of ferric minerals and dust, green regions are indicative of Fe^{3+} containing minerals, particularly hematite, blue regions can indicate goethite development and can be influenced by olivine vs pyroxene. Three HRC-E mosaics are overlain on the context image to show fine scale detail at both short and long-range distances.