MINERAL COMPOSITION OF GULLY FEATURES WITHIN HALE CRATER, MARS. E. J. Allender[1,2], A. Lucieer[2]. [1]Space Informatics Lab, University of Cincinnati, Cincinnati, Ohio, USA (allendej@mail.uc.edu). [2] Department of Geography, University of Tasmania, Hobart, Tasmania, Australia.

Introduction: The origin of the martian gullies remains debatable. In [1] it was found that the majority of gullies within Hale crater were likely emplaced by fluidized flows rather than dry, granular flow. This conclusion was drawn exclusively on the basis of measuring gully apex slopes using the 1 m/pixel resolution DEM (from the High Resolution Imaging Science Experiment or HiRISE). The purpose of this study is to follow up on [1] by investigating the mineral composition of those gullies using hyperspectral imagery (from the Compact Reconaissance Imaging Spectrometer or CRISM). The working hypothesis is that the gullies within Hale crater show the presence of hydrated minerals, as predicted by [2], thus further indicating their fluvial origin in agreement with the findings in [1].

Data and Methods: The study site at Hale crater covered a small region (<10 km x 10 km) of the north-eastern rim with the central coordinates -35.2° S, 324.7° E. For hyperspectral analysis, the CRISM Analysis Toolkit (CAT) v.6.6 plug-in was used with ENVI software. VNIR and IR CRISM images spanning the study site (FRT00004af7_if164l_TRR3.img and FRT00004af7_07_if164s_TRR3.img) were pre-processed to remove the effects of instrument noise and atmospheric effects using the standard procedure as documented in [3]. Additionally, all available spectral parameter summary products developed by [4] were generated using the CAT in order to determine locations of mineral classes within Hale crater. These summary products are band ratio mineralogical maps which are used to aid in the extraction of mineral spectra from an image and were developed specifically for the coverage and spectral resolution of the CRISM instrument. For example, summary product BD1900 is a band depth ratio designed to highlight pixels possessing an absorption feature at 1.900 μm. The depth of this feature is reflected in the brightness of the resulting mapped pixel. Next, nine browse products (from the 15 documented in [5]) were created. These browse products are typically generated by the PDS team for selected Full Resolution Targeted (FRT) images to highlight specific mineral classes of interest for further analysis and are based on RGB band combinations of specific spectral summary products from [4]. With regard to interpretation, if a strong absorption feature is present at 1.900 μm and BD1900 is the summary product assigned to the red band, the pixel will be bright red in color. If strong absorption features are present at each wavelength represented by summary products within a browse image, the resulting pixel will appear white, the resulting color mixture of red, green and blue bands. The browse products generated in this study were: TRU – a true color image of the study site comprised of bands 0.600 μm, 0.530 μm and 0.440 μm. FEM – a composite of VNIR summary products BD530, SH600 and BDI1000VIS designed to highlight Fe mineralogy. FM2 – an additional Fe composite image comprised of BD530, BD920 and BDI1000VIS. MAF – a composite of the summary products OLINDEX2, LCPINDEX and HCPINDEX which highlights mafic mineralogy. HYD – a composite of summary products SINDEX, BD2100 and BD1900 designed to highlight hydrated mineralogy with absorption features at 1.400 μm /1.900 μm, 2.100 μm and 2.400 μm respectively, such as hydrated sulfates, carbonates and phyllosilicates. PHY – a composite of D2300, BD2210 and BD1900, designed to highlight hydroxylated minerals and hydrated phyllosilicates. PH2 – a composite of BD2350, D2300 and BD2210 which further refines the composition of hydroxylated minerals present in browse product PHY. ICE – a composite of summary products BD1900, BD1500 and BD1435 designed to determine if H_2O or CO_2 ice is present in the image. CAR – a composite of summary products D2300, BD2500H and BD1900, designed to highlight Mg-carbonates and Fe/Ca-carbonates.

The 1 m/pixel DEM was obtained for the study site (courtesy of Oded Aharonson) which had previously been used for the measurement of gully apex slopes in [1] and each browse image was then combined with topographic data from the HiRISE DEM in order to visualize the locations of mineral classes within gully alcoves, channels and depositional aprons.

Results: The results of this study indicated that hydrated minerals were present within the gully features at Hale crater as part of mineral mixtures which additionally contain pyroxenes, phyllosilicates, carbonates, olivine and ferric minerals. To illustrate a portion of the results of this study the HYD and CAR browse products of the study site are displayed draped over the HiRISE DEM, as seen in Figures 1 and 2 below. The HYD browse product highlights the locations of minerals with diagnostic absorption features at 1.400 μm, 1.900 μm, 2.100 μm and 2.400 μm such as hydrated sulfates, carbonates and phyllosilicates [Figure 1]. Red pixels in this image could therefore

suggest the presence of minerals such as hydrated sulfates, which have diagnostic absorption features at 1.400 μm/1.900 μm and 2.400 μm. Yellow pixels contain a mixture of red and green bands and are representative of hydrated mineral mixtures with absorption features at the wavelengths 1.400 μm/1.900 μm, 2.100 μm and 2.400 μm. These mixtures may include hydrated sulfates, carbonates and phyllosilicates. Deep blue pixels, which can be seen in gully channels and alcoves throughout the image, represent spectra containing evidence of an absorption feature at the 1.900 μm which is also indicative of hydration.

Browse product CAR highlights the locations of minerals with diagnostic absorption features at 1.900 μm, 2.300 μm and 2.500 μm such as hydrated sulfates and Mg/Fe/Ca carbonates [Figure 2]. Blue pixels contain spectra possessing an absorption feature at 1.900 μm which is diagnostic of hydrated minerals such as sulfates and carbonates. These pixels can clearly be seen in the central gully channel within the image as well as in smaller gully alcoves in the northwest. Red pixels in the image are diagnostic of spectra possessing a 2.290 μm absorption feature indicative of Mg carbonates and Fe/Mg phyllosilicates, as per [5]. The depth of this band affects the intensity of the pixel colour, and some clusters of light red pixels can be seen throughout the image extending from gully alcoves and channels. Clusters of light green pixels can also be seen in remaining gully alcoves and channels, indicating that the spectra of these features contains an absorption feature with a shallow 2.500 μm band depth. The combination of all three of these image bands highlights the presence of Mg carbonates which are depicted with cyan/white pixels. The presence of carbonates in this image is consistent with the HYD browse image in Figure 1.

Conclusion: The findings of this study were in agreement with the conclusions reached by [1] and [2] as gully features within the study site at Hale crater were found to contain evidence of hydrated mineralogy. This study was able to further refine the both the spatial and spectral resolution of [2] with the use of CRISM hyperspectral data, and additionally enable the improved visualisation of hydrated mineral deposits within the study site while investigating the relationship between these mineral deposits and landform with the use of a HiRISE DEM. It should be noted, however, that hydrated mineralogy is not only apparent within gully features, but also in the areas surrounding these features. Without further study it cannot be confirmed if these gullies were formed as a result of some fluidized mechanism or exhibit evidence of hydrated mineralogy as a result of aeolian or other erosional processes within the surrounding area.

References: [1] Kolb K.J. et al. (2010) *Icarus, 208(1*), pp. 132-142. [2] Fan C. et al. (2009) *Planetary and Space Science, 57(1),* pp. 93-104. [3] Morgan F. et al. (2009) CRISM Data Users' Workshop, Nili Fossae Walkthrough. [4] Pelkey S.M. et al. (2007) *JGR, 112(E8),* pp. 1-18. [5] Murchie S.L. et al. (2011) CRISM DPSIS, PDS Geosciences, pp.110-113.

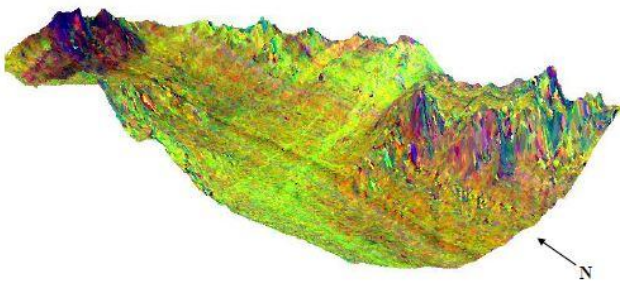

Figure 1: The HYD browse product in combination with the HiRISE DEM. A large gully feature is seen to extend through the center of the image containing yellow pixels representative of mineral mixtures with absorption features at wavelengths 1.400 μm/1.900 μm, 2.100 μm and 2.400 μm. Smaller features are also apparent in the SE and NW sections of the image wich contain blue/magenta pixels with absorption features at 1.400 μm/1.900 μm and 2.400 μm, representative of hydrated mineralogy.

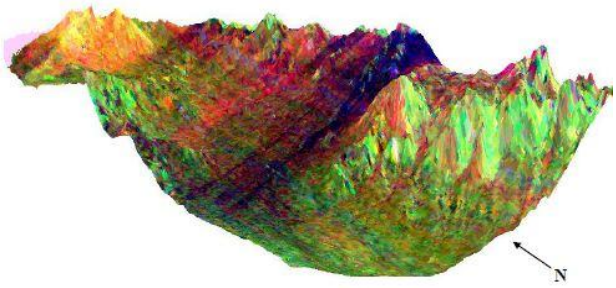

Figure 2: The CAR browse product in combination with the HiRISE DEM. The large gully feature in the center of the image contains blue pixels representative of hydrated carbonates. Smaller gully features containing light red/green pixels representative of absorption features at 2.290 μm and 2.500 μm respectively are also apparent in the SE, NW and NE sections of the image.