AUTOMATIC DETECTION OF WATER AND MAFICS IN M^3 RADIANCE IMAGES. D. R. Thompson[1,2], M. Gilmore,[3] L. Mandrake,[2] R. Castaño,[2] B. Bue.[4] [1]david.r.thompson@jpl.nasa.gov, [2]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109, [3]Dept. Earth and Environmental Sciences, Wesleyan University, Middletown, CT. [4] Dept. Electrical and Computer Eng., Rice University, Houston TX.

Introduction: We describe the detection of water (OH/H_2O) and mafic mineralogy absorption features in Ryder crater from a fully automated search for spectral anomalies in the Moon Mineralogy Mapper (M^3) lunar catalog [1]. We employ superpixel endmember analysis [2] to detect spectral outliers. Our approach operates on M^3 radiance data without explicit thermal emissivity or illumination corrections. The resulting spectra are not formal endmembers for linear unmixing or abundance estimation. However they are qualitatively interpretable and suggest the range of spectral diversity in the scene. These discovered features include water-rich areas of Ryder crater, revealing these materials without prior direction from spectral libraries or analyst-selected band ratios. The demonstration independently supports the significance of the ~3μm water signal as an important component of the scene's spectral diversity and shows the utility of this automated method to recognize geologically meaningful materials in M^3 data.

Background: The M^3 imager aboard Chandradrayaan-1 collected 85 channels over the 430-3000 nm range with resolution of ~140 m/pixel. These data have previously facilitated large-scale maps of mafic mineralogy and provided direct evidence of water on the lunar surface [1]. As with any large hyperspectral database, analysis is complicated by noise and the natural size of the images. It is possible or even likely that aspects of local or regional spectral diversity still lie undiscovered near the level of noise. Automated anomaly detection algorithms such as endmember detection can assist the discovery process by directing analysts' attention to key surface mineralogies. These fully unsupervised approaches can complement directed methods such as band ratios; they are sensitive to a wide range of unexpected features which provides additional confidence that discovered signals are a significant component of the scene's spectral diversity.

This work considers an M^3 image of Ryder crater (M3G20090125T172601). The crater ejecta has been previously associated with the presence of water [2]. Specifically, the spectrum contains water absorption features near 3μm. These absorption features have been independently corroborated in Cassini VIMS images of the lunar surface [3]. We consider the ability to detect this feature an important prerequisite for an anomaly detection method.

Methods: We preprocess each large M^3 radiance image by breaking it into subframes of 3000 or fewer scan lines. Average scene emissivity and illumination are found to vary somewhat smoothly as a function of latitude [1]. This subframing provides piecewise constant regions that mitigate this variation. We apply several filters to the M^3 radiance data to remove spectral artifacts due to shot noise and vertical striping. A radius 2 median filter in the spectral domain eliminates the occasional detection "spikes." A radius 2 boxcar filter in the spatial domain helps to remove vertical striping caused by uncalibrated variation in detector sensitivity of the pushbroom instrument. Finally, we divide each pixel by the mean spectrum of its column in the (unprojected) image to further reduce striping.

After preprocessing we apply a superpixel endmember detection analysis [2]. This is an unsupervised endmember discovery method intended primarily for reflectance spectra; it aims to retrieve the endmember components of a linear mixture by exploiting the convex geometry of the hyperspectral data cloud. Superpixel endmember detection is of particular interest to planetary datasets with low signal to noise; it operates on small segmented regions (*superpixels*), rather than the pixels themselves, which provides additional resilience to single-pixel noise. The oversegmentation will not dilute spectral features that dominate at least one contiguous region in the image. Our oversegmentation uses superpixels of approximately 20-50 pixels in area. The mean spectra of the segments comprise a noise-reduced data cloud of features that correlate with contiguous morphological regions of interest. We then apply Sequential Maximum Angle Convex Cone endmember detection [4]. The result is a rank-ordered list of salient features for manual investigation.

Results: Eight representative spectra were selected from 30 endmembers requested and are shown in Figs 1 and 2. Three of these (#1, 3, 6) have an absorption at ~3μm interpreted to be caused by water. These are located within the wall and ejecta of Ryder crater. Spectrum #6 displays a positive feature at ~970 nm that is likely an artifact of ratioing by the mean spectrum, and indicates that this material has little to no mafic feature here as compared to the mean. The routine identifies pyroxene-rich materials exposed on the walls of the two larger craters (#3, 8), exposed by small fresh impact in the plains (#5), and along the walls of what appears to be a dike or fissure emanating radially from Ryder crater (#7). Materials surrounding what appears to be a vent at #4 are distinguished by an increased reflectance in the 3 μm region indicating that these materials are perhaps drier than the scene mean.

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References: [1] Pieters C. M. et al. (2009) *Science* 326, 568. [2] D. R. Thompson, L. Mandrake, M. Gilmore, R. Castaño. (2010) *IEEE Transactions on Geoscience and Remote Sensing* 48 (11). [3] Clark, R. N. (2009) *Science* 326, 562. [4] Gruninger et al. (2004), *SPIE Proceedings*, 5425-1.

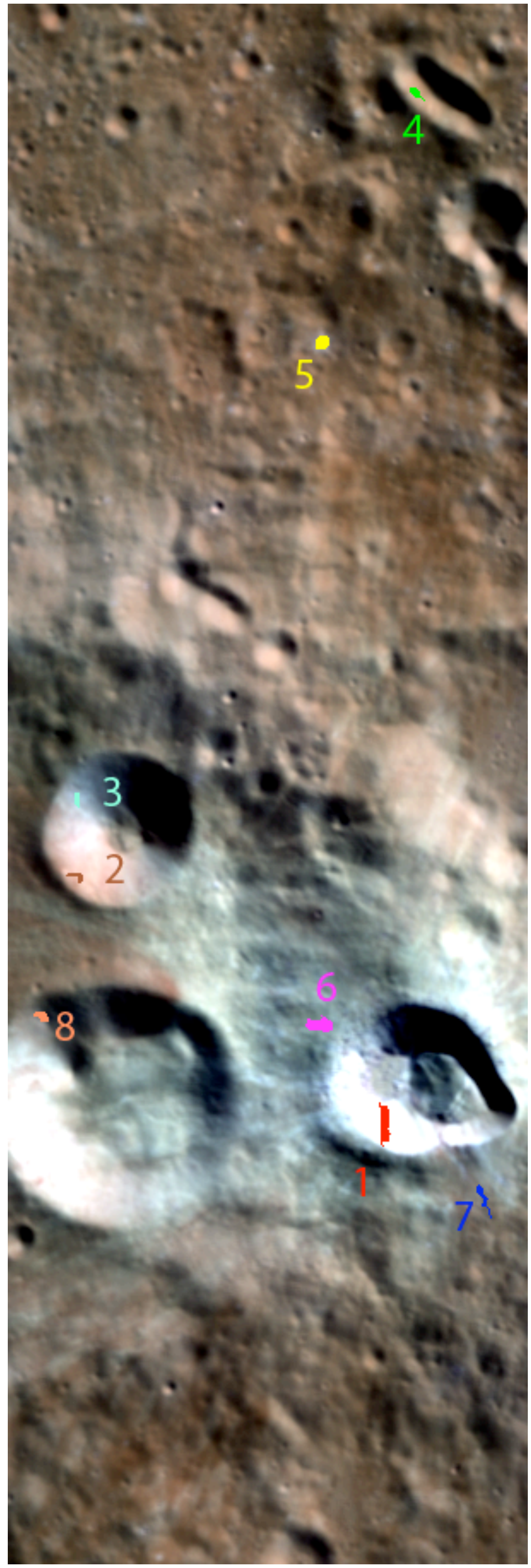

Fig. 1. (Right) Portion of the M^3 image of Ryder Crater, M3G20090125T172601. R= 2817 nm, G = 2018 nm, B = 990 nm. Bluish ejecta of Ryder has been associated with a water–rich spectral signal by [1]. Regions of interest (ROI) of selected endmembers shown and keyed to spectra in Fig, 2. Image is ~ 45 km across.

Fig 2. (Below) Average spectra of ROIs in Fig, 1.