MINERAL AND LITHOLOGIC SPECTRAL MAPPING OF THE TUNNUNIK IMPACT STRUCTURE IN THE CANADIAN ARCTIC USING LANDSAT ETM 7+ AND ASTER DATA. B.-H. Choe[1], L. L. Tornabene[1], and G. R. Osinski[1,2]. [1] Centre for Planetary Science and Exploration, Department of Earth Sciences, University of Western Ontario, London, ON, Canada, [2] Department of Astronomy and Physics, University of Western Ontario, London, ON, Canada.

Introduction: Meteorite impact structures are very important geological features for understanding the formation and modification of planetary surfaces. Impact-exposed subsurface lithologies provide useful information for reconstructing local and regional stratigraphic columns [1]. Recently, these structures are also attracting significant interest in terms of economic geology due to their abundance of resource deposits [2]. Therefore, remote predictive mapping of terrestrial impact structures is deemed necessary to provide rapid access and broad spatial coverage of these structures to facilitate or supplement traditional geological mapping produced from multiple seasons of fieldwork [3].

In this study, we investigate Visible-Near Infrared (VNIR) and Thermal Infrared (TIR) multispectral data of the ~28-km diameter Tunnunik impact structure (72°28'N, 113°56'W) identified on northwestern portion of Victoria Island in the Canadian Arctic (Fig. 1) [4,5]. Both Landsat Enhanced Thematic Mapper 7+ (ETM 7+) and Advanced Spaceborne Thermal Emission Radiometer (ASTER) data were analyzed to provide a spectral mineral and lithological map of the structure. The Tunnunik target rocks are comprised of predominately of carbonates (limestones and dolostones), sandstones and minor amounts of shale mapped as the Cambrian-Ordovician Victoria Island Fm, the Cambrian Stripy Unit and the Shaler Group (undivided) by Dewing et al. [4,5]. This information will be used to help inform our spectral mapping efforts presented below.

Data and pre-processing: ETM 7+ 30-m VNIR (Bands 1-7) and ASTER 15-m VNIR (Bands 1-3) and 90-m TIR (Bands 10-14) data acquired over the site were used. ETM 7+ VNIR data were calibrated into spectral reflectance. ASTER Level 1A were calibrated into level 1B data and then processed into Level 2 products including VNIR reflectance and TIR emissivity.

Methods: Several techniques including color composites, band ratios and Principle Component Analysis (PCA) were used to classify distinctive spectral units observed in the ETM 7+ and ASTER data. ASTER and ETM+ Color Infrared (CIR) images can be used to distinguish vegetated areas that are not conducive to mineral and lithological mapping. The information from these images was combined with the other techniques to constrain the best areas for surface mapping. Band ratio images and (band 5/band 4, band 4/band 3, and band 3/band 2) were derived and then they were reconstructed to the color composite image of band 5/ band 4 (R; sensitive to ferrous iron (Fe^{2+})), band 4/ band 3(G; sensitive to vegetation), and band 3/ band 2 (B; sensitive ferric iron (Fe^{3+})) (Fig. 2). For ASTER TIR data, a minimum noise fraction (MNF) transform was applied (Fig. 3). The MNF transform is type of PCA that generates a distinctive spectral map by separating noise from coherent data using the spectral variation of all the bands [1]. The MNF transformed ASTER TIR image was compared to the ETM 7+ band ratio color composite image from in order to define spectral units in both image composites (Table 1). A maximum of four spectral lithological units are recognized in the MNF composite. Finally, the ASTER TIR emissivity spectra were matched with spectra derived from a whole-rock spectral library provided by Arizona State University using spectral angle mapper (SAM) and spectral feature fitting (SFF) algorithms [6]. Various techniques using averaged spectra were used to derive statistically consistent and representative spectra for each of the four units.

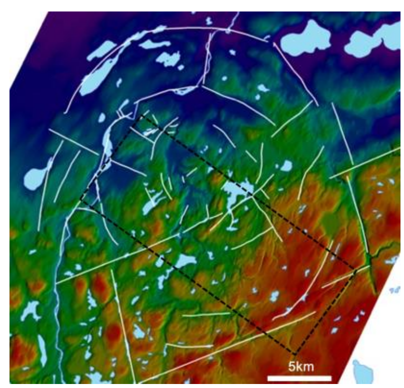

Figure 1. Preliminary structural map of the Tunnunik impact structure superposed on a digital elevation model. White lines are faults. The black-dashed square indicates the coverage of Landsat ETM 7+ data in figure 2. North is up.

Results: The study area was classified into four spectral units from the ASTER TIR MNF composite, which are represented in orange, magenta, dark green, and light green.

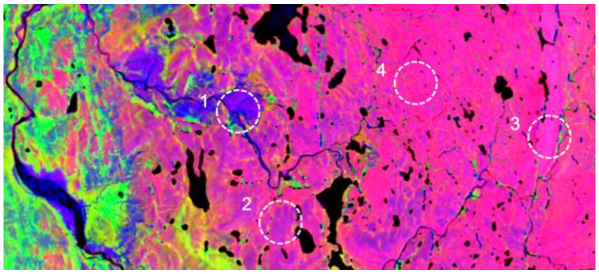

Figure 2. Landsat ETM 7+ color composite image of the Northwestern portion of the Tunnunik Structure using the band ratios of. The white-dashed circles represent the selected spectral unit 1, 2, 3, and 4.

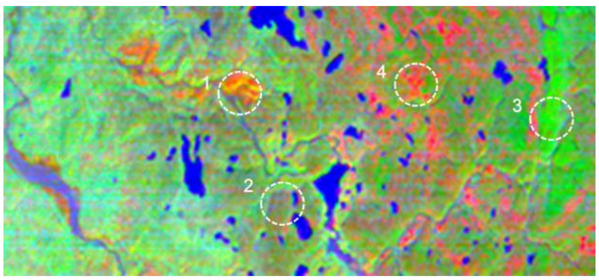

Figure 3. MNF transformed ASTER TIR color composite image of the Northwestern portion of the Tunnunik Structure. MNF band 2, 1, and 3 are colored in RGB, respectively.

Table 1. Color matching of spectral units from the color composite image of Landsat ETM 7+ band ratios and the MNF transformed ASTER TIR image.

Spectral unit	Landsat VNIR	ASTER TIR
1	Blue	Orange
2	Purple	Dark green
3	Magenta	Light green
4	Magenta	Magenta

Green areas in the ETM+ band ratio represents higher values in the ratio of band 4/ band 3, which, combined with the CIR images from ETM+ and ASTER, indicates that they are highly vegetated areas. These areas were avoided for further analysis. ETM+ composite blue, purple, and magenta units possess spectral contributions possibly related to the presence of ferric (Red) and ferrous iron (Blue). These were similarly matched with the spectral units defined in the ASTER TIR MNF composite (see Table 1). A representative sample spectrum of ASTER TIR emissivity from the unit 1 matched with ASU rock library spectra for siltstone (Fig. 4). The best matches for unit 2 were cherty limestone. For unit 3, dolomitic limestone was the most promising candidate. Unit 4 represented spectra similar to unit 1.

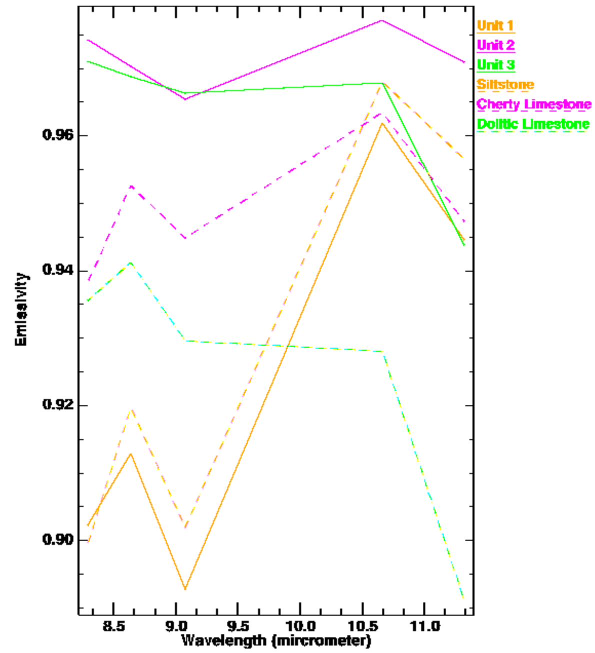

Figure 4. Spectral matching results. The averaged ASTER TIR emissivity spectra of unit 1, 2, and 3 were represented by orange, magenta, and green solid line, respectively. The dashed lines were the best matched rock spectra of siltstone (orange), cherty limestone (magenta), and dolomitic limestone (green).

Discussion and Conclusions: The results show that the lithologies are mainly composed of a siliclastic component (i.e., siltstone) and carbonates (limestone and/or dolostone) consistent with the target lithologies reported [4,5]. It is suggested that the overall chemical composition is comprised of silicates (based on absorptions in TIR bands 10, 12) and carbonates (band 14 absorption) including iron oxides (based on VNIR) components and the rock types represented in the data are slightly different depending on the proportion of the mixed components. Further work and analysis are planned to produce a final spectral map based on ETM+ and ASTER data, which can be used to facilitate mapping during future field seasons at the structure.

References: [1] Tornabene L. L et al. (2005) *Meteoritics & Planet. Sci.*, 40, 1835-1858. [2] Grieve R. A. F. (2012) *Impact Cratering: Processes and Products*, 177–193. [3] Harris J. R. et al. (2012) *Earth Sciences*, 495-524. [4] Dewing et al. (2013) *Meteoritics & Planet. Sci.*, 1-13. [5] Osinski G. et al. (2013) *LPS XLIV*, Abstract #2099. [6] Kruse et al. (1993) *Remote Sensing of Environment*, 44, 145-163.