ALBEDO-BASED TEXTURAL ANALYSIS FOR MAPPING WATER-RICH LITHOLOGIES ON ASTEROID BENNU. L. Richards[1,2], M. C. Nolan[3], G. R. Osinski[2], E. Frost[2], C. S. Dickinson[4] A. Gremm[5] H. H. Kaplan[6] [1]Vancouver Island University, Nanaimo, BC, Canada (lindsay.richards@walkaboutexploration.ca), [2]Department of Earth Sciences, University of Western Ontario, London ON, Canada, [3]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA, [4]MDA, Brampton, ON, Canada, [5]University of Alberta, Edmonton, AB, Canada [6] NASA Goddard Spaceflight Center, Greenbelt, MD, USA.

Introduction: Data from the OSIRIS-REx spacecraft showed that asteroid (101955) Bennu is a carbonaceous rubble-pile asteroid containing 5.72wt% to 6.79wt% water [1]. Water produced in space is likely to be a critical resource for future missions, and hydrated phyllosilicate minerals on Bennu could be mined and processed to produce water [2]. We use Structural Feature Set (SFS) textural analysis of an albedo basemap based on imagery obtained by OSIRIS-Rex [3] to predict the locations of water-rich boulders for a potential asteroid mining mission.

Background: Previous work has shown that hydrogen distribution [1], albedo [3], and thermal inertia [4] have similar patterns of spatial distribution on Bennu's surface. Albedo and thermal inertia are good predictors of lithology [4,5]. This relationship implies that lithology is the dominant control of water content. Any mining mission would need to target areas with the greatest number of suitably sized water-rich boulders to maximize Production.

At least four types of endemic boulders are present on Bennu [5], characterized by differences in texture and albedo. Generally, type A and B boulders have low (3.5% to 4.5%) normal albedo and henceforth are collectively referred to as "Low Albedo" boulders. Type C and D boulders (collectively referred to as "High Albedo" Boulders) have a normal albedo of 4.9% to 7.4%. They likely formed deeper within Bennu's parent body than the low albedo boulders and experienced a greater degree of hydrothermal alteration. High-albedo boulders appear to be positively correlated with water content, which is supported by the fact that the most hydrogen-poor areas on Bennu are large low albedo boulders [1]. OSIRIS-Rex will return a sample from Bennu in summer 2023, which will allow the relationship between lithology and water content to be ground-truthed.

Methods: The distinct textural and albedo differences between low and high albedo boulders mean they are readily visually distinguished in panchromatic imagery. However, many supervised and unsupervised image classification methods including K-Nearest Neighbor, Maximum Likelihood, ISODATA, and Support Vector Machine (SVM) performed poorly when used to classify both the albedo basemap and a texture map derived from the basemap using Haralick texture extraction. There are several reasons for this poor performance. Low-albedo boulders can contain clasts of high-albedo material which are easily misclassified as separate boulders. Additionally, cracks and shadows can cause the overall albedo values of high-albedo boulders to appear statistically similar to low-albedo boulders. Traditional shifting-window textural analysis cannot account for the location of boulder edges and often computes statistics for an area comprising multiple boulder types or regolith, causing misclassification.

Structural Feature Set Textural analysis is a method developed for classification of high-resolution satellite imagery of urban areas [6]. Unlike most textural analysis methods, SFS does not use a shifting window. Instead, a number of radial lines are drawn outwards from each pixel. Each line terminates when it reaches a specified distance (spatial threshold) or change in pixel value (spectral threshold). Statistics for the pixel are then calculated from the albedo histogram of each line. Because there is generally a change in pixel value at the edge of boulders, this method greatly reduces the mixing of boulder types in the resultant image.

We used QGIS with the Orfeo Toolbox (OTB) image processing plugin to preform SFS textural analysis on the −60° to +60° latitude albedo basemap of Bennu created by Golish et al. [3]. The resultant image was classified using a per-pixel SVM classifier trained on a sample of high and low albedo boulders and regolith from various regions on Bennu. The classified image was then smoothed and reclassified to reduce noise. Validation was performed using a separate set of 44 randomly selected samples.

Results: Our classification resulted in good discrimination of high albedo boulders, with 86% accuracy compared to the validation set. Only 14% of high-albedo boulder pixels were incorrectly classified as regolith or low albedo boulders. However, discrimination of low albedo boulders and regolith is poor, with 2.9% and 23.2% accuracy, respectively. This is likely due to the textural similarities between low albedo boulders, which have been interpreted as regolith breccias [5] and regolith. Both contain a mixture of high and low albedo clasts and have similar albedo distributions. Interestingly, training on only a few "type

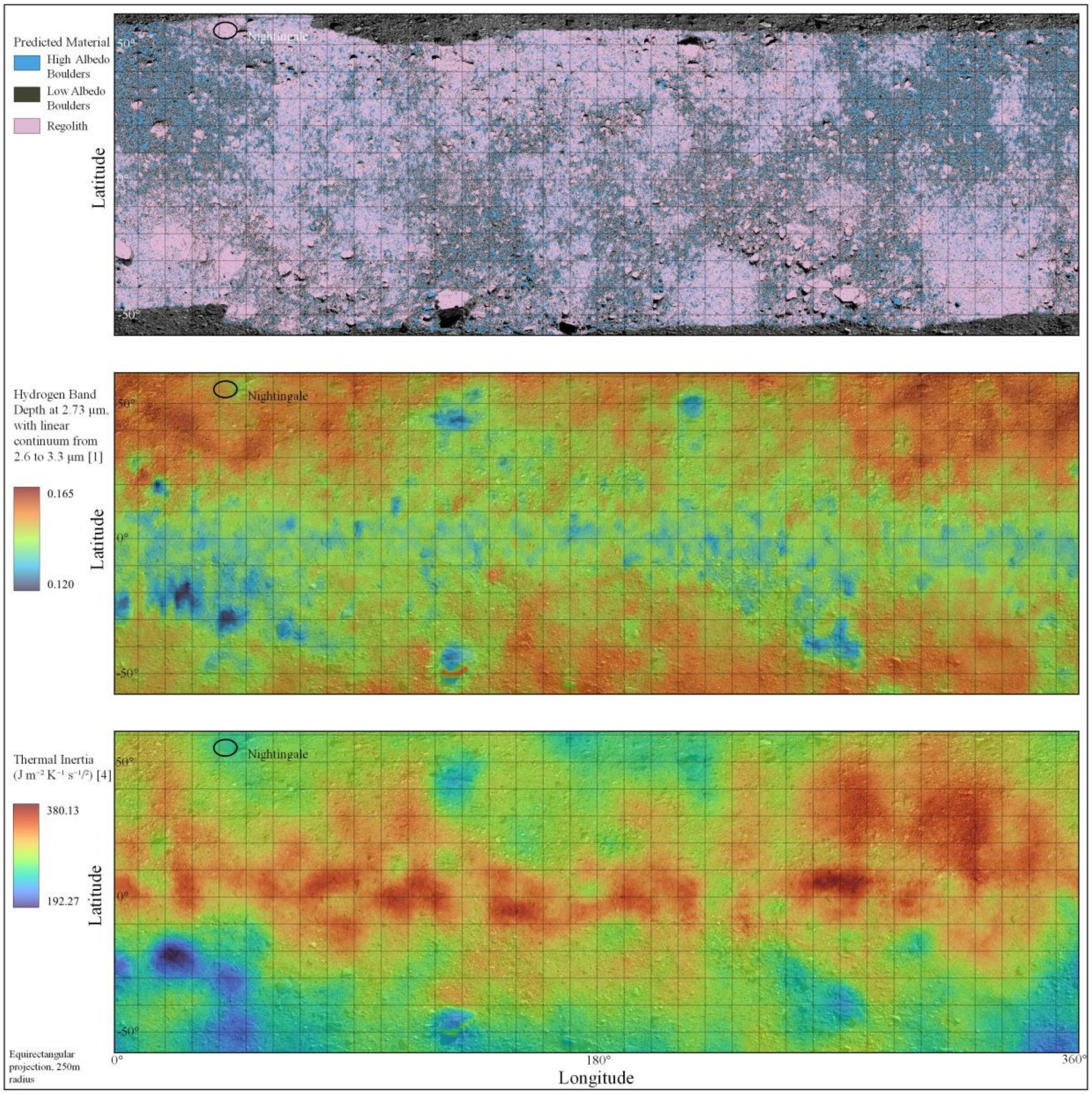

Fig. 1**:** Predicted locations of high-albedo boulders (top), compared to hydrogen absorption band depth [2] (middle), and thermal inertia [4] (bottom).

examples" gave better accuracy than training on a wider variety of examples.

The spatial distribution of high-albedo boulders predicted by our classification visually align with areas of high hydrogen content [1], high albedo [3], and high thermal inertia [4] (Fig. 1). This result further supports the relationship between lithology and hydrogen content on Bennu. In the case of a water mining operation, the large patch of high-albedo boulders in the nothern hemisphere could be "high graded" at the start of operations, providing increased production and profitibility, before moving to areas with lower water content.

Acknowledgments: The authors would like to thank Ben Rozitis and Carina Bennett for sharing data that made this work possible, the Western USRI program for helping fund this research, and everyone who participated in the Khepri project for sharing their expertise in ISRU.

References: [1] Praet et al. (2021) *Icarus. 363.* 1-11. [2] Gowtham et al. (2022) *Educational Research Archive. https://doi.org/10.7939/r3-74mh-6146.* 1-4. [3] Golish et al. (2021) *Icarus. 355.* 1-18. [4] Rozitis et al. (2020) *Sci. Advances. 6(41)* 1-18. [5] Jawin et al. (2022) *LPS LIII* Abstract # 2066 [6] Huang et al. (2007) *IEEE Geoscience & Remote Sensing Letters*. 260-264.