OBJECT-BASED IMAGE ANALYSIS OF "SWISS CHEESE" PITTED TERRAINS' EVOLUTION ON THE MARTIAN SOUTH POLAR CAP.

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Introduction: During the Martian winters, clouds form over the poles. Under the southern clouds, CO_2 falls to the ground as snow or frost and accumulates [1]. During the summer months, this seasonal layer is sublimated back into the CO_2 rich atmosphere [2]. This process creates pits into the South Polar Residual Cap (SPRC). Swiss Cheese Terrain/Feature (SCF) is the common name for the region of Planum Australe that is home to these CO_2 sublimation pits (Fig. 1) [3]. These pits are known to increase over time, however, that rate changes relative to the SCF location. SCF sitting at a higher latitude were presented with slower growth rates compared to those below 89°S [4].

These pits have been studied individually by hand for a few decades [2]. Growth rates of the pits in terms of the location and geographic attributes have not been studied collectively over the entire pole. This is due to the sheer number of pits per image and large number of images to analyze. This problem can be fixed with Object Based Image Analysis (OBIA).

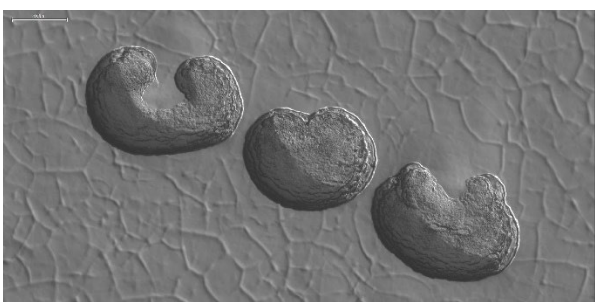

Figure 1. CO2 sublimation pits, also referred to as Swiss Cheese Features. A portion of HiRISE image esp_023570_0930.

OBIA is a land change technique that uses high-resolution image segmentation to identify similar regions of an image to classify objects into like categories. Successful work in the past using OBIA consisted of crater detection, volcanic geomorphology, and sand dune classification [5-7]. Pixel-based imaging analysis has been used for determining differences in spectral characteristics and classifying as such. However, pixel-based is unreliable in the case of our study. The technique would separate classification of the pits into shadowed areas and non-shadowed areas without the ability to join the two detached categories (Fig 1) [5]. Alternatively, OBIA uses multiple tasks such as homogeneity, aspect, texture, and shape of objects for classification. This technique is able to simultaneously calculate spectral differences between images taken at different solar longitudes (Ls) or Martian year over the same location. The spectral differences will give way to surface growth rates to every area classified as a pit. To be able to faster process larger sets of data, batch processing is needed. Batch processing is a technique built to analyze multiple images at a time with the same tasks without needing to have end-user interface for each image. Here we present the preliminary results of the OBIA batch processing.

Methods: Images were collected from the High Resolution Imager and Science Experiment (HiRISE) on the Mars Reconnaissance Orbiter (MRO) [6]. The purpose of this abstract is to explain the process of batch processing HiRISE images for the purpose of analyzing the growth evolution of CO_2 sublimation pits as a function of time.

To be able to work through this problem, roughly 3,500 red band images were downloaded from the Mars Planetary Data Systems (PDS) Geoscience Node to then be uploaded to two different mapping software for the tasks of batch processing. For example, images need to be compressed and converted to run on the network server for faster analysis. The network server enhances multiuser and enterprise geographic information system (GIS) within the local network. The network server is needed for several reasons such as the roughly 7TB of data we have obtained from the PDS, the variety of the pit classification, and the meta data of the images. These images, once downloaded were uploaded into our GIS software for sample selection.

The software ArcGIS Pro by ESRI is a GIS platform for integration of manipulation and compiling of spatial data into a single forum for further analysis to be done. Once these images are placed into a map document, a feature class is then created to select the image with the most promising features for detection (Fig. 2). Due to the high volume of data, this helps with the batch processing time of creating a OBIA rule-set, or task list, within the software.

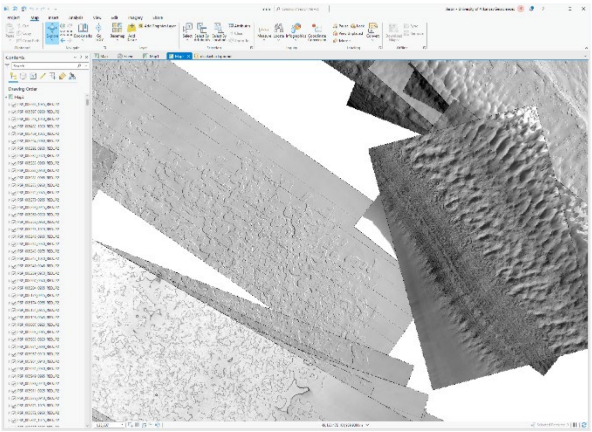

Figure 2. Snip-it of ArcGIS Pro and the ability to overlay collected HiRISE images for sample selection.

The software eCognition by Trimble is the chosen tool to perform the OBIA batch processing. eCognition utilizes a hierarchical approach that allows each process to be re-used in a non-linear way. Other OBIA software use a one directional approach starting only at the pixel level and working its way up the workflow. Our chosen software uses four main tools that are held in a rule-set that can be reran over any selected image. The hand-picked rule-set identified and segmented pits in the images while simultaneously measured their area and growth rate over time.

Results:

An eCognition rule set and ArcMap model was the preliminary step in what has become a multi-run process. OBIA is the next step in image analysis for planetary science and will be helpful in lander missions and future human cultivation on the lunar surface.

The preliminary ruleset has been used as a test-run to analyze six different images with more being processed currently.

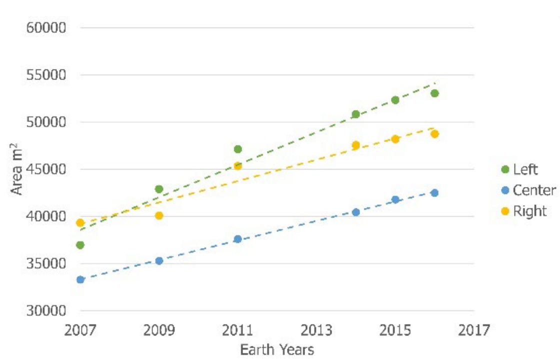

Figure 3. Surface area of the selected sublimation pits (Fig. 1) as a function of time (earth years). The surface area was determined using automatic identification of the pits with OBIA [8].

The six initial polygon sets have given us a good information on places where more detail can be taken on the ruleset, a rough estimate on the growth rate and shows a clear forward progress of this project. Figure 3 shows a quasi-linear growth rate as a function of time. Towards the last three years of the provided images, there is an average area increase of ~1000m^2 per year.

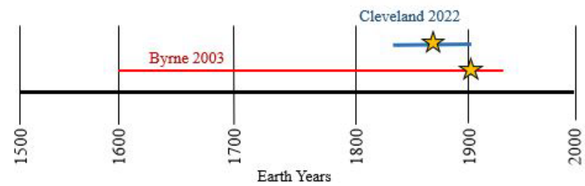

Figure 4. Timeline of starting ranges from both [8] and [9]. The yellow stars indicate where the average start year is for the data.

These results correlate with the model created by [9], which found an initial feature creation aging around 1600-1920 Earth years (EY) ago. They found a most likely start range is around ~1900 EY, while our measurements deduce a range of ~1830-1900 with an average start year of ~1862 EY.

While the initial sample size was small, this brings in the need for batch processing. By utilizing this exploratory step, we can move forward with our next steps with a faster momentum.

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References: [1] Neumann G. A. et al. (2003) *J. Geophys. Res.: Planets*, *108, E4.* [2] Thomas P. C. et al. (2000) *Nature, 404, 161-164.* [3] Thomas P. C. et al. (2009) *Icarus*, 203, 2, 352-375. [4] Knightly J. P. et al. (2019) *LPSC L2132* [5] Vamshi G. T. et al. (2016) *Adv. In Space Research, 57, 9, 1978-1988*. [6] Pedersen G. B. M. et al. (2013) *LPSC XLIV 2238.* [7] Emran A. et al. (2019) *LPSC L 1157.* [8] Cleveland R. D. et al (2022) *LPSC 2580.* [9] Byrne S. et. al (2003) *Science 299, no. 5609*