AN OBJECT-BASED IMAGE ANALYSIS OF THE SWISS CHEESE TERRAIN EVOLUTION ON THE MARTIAN SOUTH POLE. R. D. Cleveland1, V. Chevrier1, and J. A. Tullis2. 1University of Arkansas Center for Space and Planetary Sciences Stone House North (STON) 346½ North Arkansas Avenue, Fayetteville, AR, 72701 USA, 2University of Arkansas Center for Advanced Spatial Technologies 321 JBHT Fayetteville, AR, 72701 USA.

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).

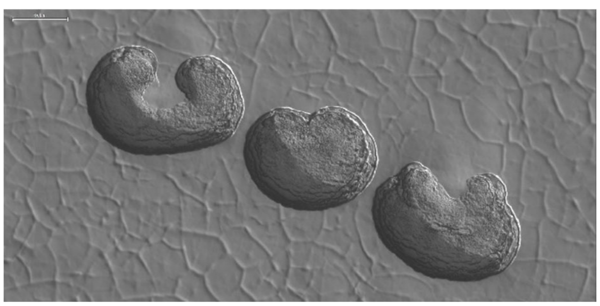

Figure 1. CO2 sublimation pits, also referred to as Swiss Cheese Features. A portion of HiRISE image esp_023570_0930.

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 to 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. The spectral differences will give way to growth rates to every area classified as a pit. Here we present the preliminary results of the OBIA testing.

Methods: The image used was collected from the High Resolution Imager and Science Experiment (HiRISE) on the Mars Reconnaissance Orbiter (MRO) [6]. The initial image used was portioned down from the complete esp_023570_0930 image taken on August 7th, 2011. This study is aimed at analyzing the growth evolution of CO_2 sublimation pits as a function of time.

This question will be answered by surveying an arbitrary SPRC image taken by the HiRISE camera, developing a rule-set that uses OBIA to identify, classify, and measures pit growth in terms of areal size. This information and the pit polygons will be extracted. Extracted files will be in shape file format for input into a Geographic Information System for further analysis. The quantification will be done using GIS tools based on the OBIA selected area to understand the growth evolution as a factor of time.

Preliminary Results:

Object-Base Image Analysis

The software eCognition by Trimble is the chosen tool to perform the OBIA ruleset. eCognition utilizes a hierarchical approach that allows each process to be re-used in a non-linear way. Other OBIA software's 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 the three varieties of pits in this image portion and simultaneously measured their area (Fig. 2). Image 1 shows the results from the segmentation tool of the rule-set. Image 2 shows the outcomes from the classification section. Image 3 is the product of merging the segmented classes together. Image 4 shows how morphology tools can clean up the edges and bring the shape of the pit to the shape of the polygon (Fig. 2).

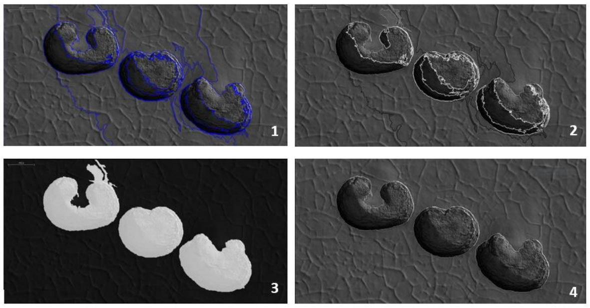

Figure 2. Results from each portion of the OBIA ruleset.

Geographic Information Systems

Geographic Information Systems is the integration of manipulating and compiling of spatial data into a single forum for spatial analysis to be done. Digitizing objects in an image is the current working to understanding geological processes. This requires the user to go in and hand pick the vertices to form the polygons around the objects and add them to the shapefile. These polygons are over-laid on-top of the base image (Fig. 1), the areas are calculated using the pixel size and the number of pixels in the polygon. The software ArcMap by ESRI was used for this task. This was done as a verification system against the OBIA ruleset.

Pit Area in Meters Squared			
Pit	OBIA	Hand	% Diff.
Left	41798	41388	0.9809
Center	37582	37492	0.2395
Right	43228	42796	0.9994

Table 1. This table displays the calculated areas of each pit with the OBIA and the hand digitized in ArcMap in meters squares. The percent of difference between the polygons was calculated in Microsoft Excel.

The simultaneous measurement of the three selected pits was successful. The left pit was 410 meters squared area difference between the OBIA polygon and the hand-drawn polygon, the center pit was 90 meters squared area difference, and the right pit was 432 meters squared area difference. Compared to hand measurements done in ArcMap, eCognition separated by less than 1% margin of error (Table 1). This small margin can be attributed to human error, precision of pixel-segmentation selection and will be re-evaluated for future work. The success of this preliminary work leads to a positive outlook towards the further work of this study using OBIA.

Discussion: This eCognition rule set and ArcMap model was the preliminary step in what will 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 current ruleset has been used as a base step to analysis six different images with more in the future.

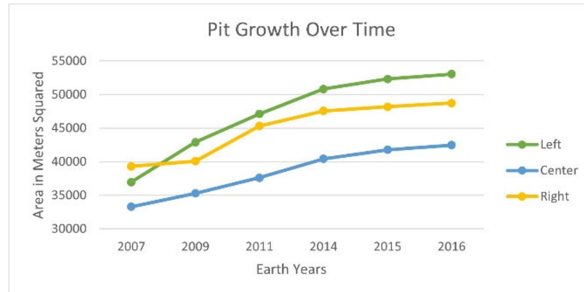

Figure 3. This graph displays the surface area of the selected sublimation pits (Fig. 2) as a function of time (earth years). The surface area was determined using automatic identification of the pits with OBIA.

These 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 ~1000 m^2 per year. While there are outliers (for example the right pit in 2009) that need to be reassessed to confirm the outlier stance, th These numbers are based on a 2-D area and do not include the depth of the pits. The success of this project will set up future work to study the change in volume of ice in the pits during the winter months and how much of that volume is released back into the atmosphere during the summer months.

Acknowledgments: Special thanks to Paul Knightly of University of Arkansas. Funding for this project is provided by the NASA Mars Data Analysis grant #80NSSC21K1089.

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] Schiewe J. (2002) *Symposium on Geospatial Theory, Processing and Applications.* [9] McEwen A. S. et al. (2007) *J. Geophys. Res., 112, E5.*