USING DISTRIBUTIONAL CHARACTERISTICS OF SUPERPOSED LARGE-SCALE CRATER CLUSTERS AS TEMPORAL INDICATORS OF GEOLOGIC PROCESSES. R. A. Nava[1,2], J. A. Skinner, Jr.[1], and T.M. Hare, [1]Geography Department, Northern Arizona University, Flagstaff, AZ, 86011; [2]Astrogeology Team, U. S. Geological Survey, 2255 N. Gemini Dr., Flagstaff, AZ 86001 (rnava@usgs.gov).

Introduction: Improving the temporal constraints of Martian geologic processes is essential for understanding the formational history of the planet and providing adequate context for exploration. Martian surfaces are generally delineated into discrete packages based on morphological, compositional, and/or temporal characteristics, the latter of which are derived through (1) apparent cross-cutting relationships between geologic units and tectonic features and (2) the size and density of impact craters of any given surface [e.g., 1]. Size-frequency distributions of impact craters on the Martian surface have long been used as a proxy for dating the age of Martian geologic units [1-3]. What have not been systematically applied to stratigraphic studies are large crater clusters (those ≥20 km in length and containing ≥10 individual craters ≥300 m in diameter [4]). Herein, we present progress toward a new method for refining the current Martian time-stratigraphic scheme by using publicly available global datasets and Geographic Information Systems (GIS) technologies.

Rationale: Present workflows for the temporal subdivision of Martian geologic terrains are not straightforward, particularly when attempting to use full array of current dataset resolutions. Our method intends to establish a systematic and repeatable approach of stratigraphic studies that uses the spatial distribution and cross-cutting relationships of large crater clusters (LCCs). The goal is avoid many of the interpretive nuances that often plague stratigraphic analyses using crater density assessments.

Martian surfaces are generally delineated through temporal characteristics that include crosscutting relationships of geologic units and the size and frequency of impact craters [1]. These two, along with other morphological and compositional properties are the basis for defining the boundaries of geologic events through time. This type of interpretive temporal-assessment is complex, because of the many characteristics that are taken into account when placing time constraints on the surfaces. Our new methodology, presented here, focuses on the identification and classification of LCCs as a means to provide stratigraphic markers.

Our method uses the distributional characteristics of LCCs as a proxy for partitioning the current stratigraphic framework. To this end, we are required to find out if the clusters were formed (1) as primary impacts, via swarms of meteoroids that entered the atmosphere virtually simultaneously, or (2) as secondary impacts resulting from the ejection of complement blocks from a primary source. We have begun developing a methodical and reproducible approach that uses GIS tools to backtrack LCCs to plausible source craters and find temporal relationships between the source crater and the cluster.

GIS-based methodology: Using the Environmental Systems Research Institute™ (ESRI) ArcGIS® software package, we include global image datasets to roughly delineate apparent LCCs. We then use the newly-created GIS boundary polygons to process, download and register THEMIS IR daytime images by intersecting the polygons with corresponding image footprints. Using this higher resolution dataset (100 m/px), GIS points are then digitized on each individual identifiable crater within a LCC.

The next step is determining groups of points that are spatially auto-correlated (clustered). ArcGIS software offers a suite of geoprocessing tools for the analysis of geospatial data. The suite includes “cluster and outlier analysis”, routines that implement statistical formulae for the spatial grouping of auto-correlated data. As any other non-deterministic approach, most of the statistical routines for calculating indexes of spatial auto-correlation have significance values associated with them (z-score). As a result, the calculated index of correlation between points cannot be objectively used without applying it in the context of the significance level for the calculation. Having a statistical significance also affects the amount of variation of the output when running the routine multiple times with slightly different input parameters.

To avoid the amount of prediction needed to efficiently and systematically repeat the process of clustering and obtain useful results, we reduce the number of input parameters and make the method deterministic by getting rid of any significance measurements needed for the resulting calculations. Instead of using pre-packaged formulae, we rely upon our own step-by-step process. This process is automated using Visual Basic development tools. The resulting “script” assembles multiple core ArcGIS geoprocessing tools that do not yield statistical results.

In order for the process to be repeatedly implemented and tested, we developed a program to take the input parameters from the user and run through the sequence in code form (Fig 1). All of the parameters needed for the program to run are specified by the user through a form (or GUI). The form passes the parameters to the variables on the code and runs it sequentially utilizing in each step the output form the previous step.

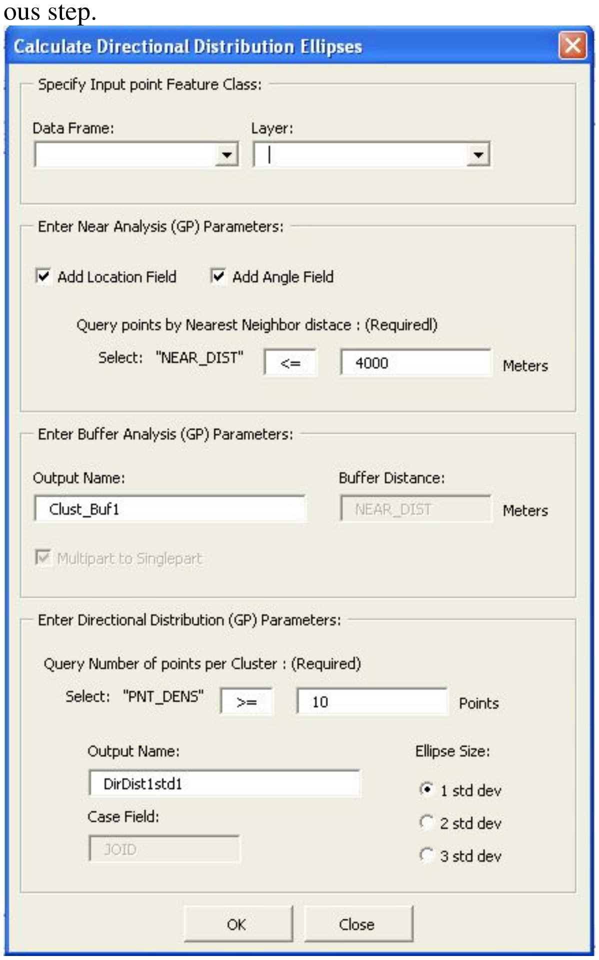

Figure 1. User interface for the developed statistical script, which assembles multiple core ArcGIS geoprocessing tools.

Step 1: The program will select the GIS-points (clustered craters) that are within a user-specified distance from their nearest neighbor (e.g. 4000 km). This provides a threshold for selecting only points with short distances from each other (clustered) and ejects outliers that do not meet this criterion.

Step 2: We then buffer only the selected points to their nearest neighbor distance to create a polygon around each point with a radius equal to the point's nearest neighbor distance. The process will also allow for each new polygon buffer to be merged with overlapping polygons to create larger areas containing all points close together, thus delineating the clusters. Each of the independent polygons has a unique identifier (ID) providing an inventory of clusters.

Step 3: In order to comply with our own predetermined LCC specifications, clusters that have less than 10 craters are excluded from the cluster inventory. This value can be varied through the user interface (Fig. 1). A point density analysis is performed on the clusters by spatially joining the ID of each cluster polygon to each of the points within them, making it possible to know what cluster each point belongs to. Another selection query (or filtering) is used to select only those cluster polygons that contain ≥10 crater points.

Step 4: The selection is then used to create standard deviational ellipses for each cluster. These are new polygons that are embedded with properties that are particular to each cluster: direction of the cluster, center coordinates (X,Y), and major and minor axes lengths for each ellipse. The area covered by each ellipse polygon accounts for one standard deviation of the crater points within each cluster. Optionally, the program allows the user to choose use 2 or 3 standard deviations for the size of the ellipse (Fig. 1).

Work in progress: To backtrack possible secondary crater chains to source craters, we extend the major axes of the standard deviational ellipses 180 degrees around the globe in opposite directions from the center of the ellipse ensuring that they create great circles (a great circle segment is the shortest distance between two points on a sphere or ellipsoid). Beginning at the center of each ellipse, we implement Vincenty's Direct formula to find a point on the geodesic given the initial latitude/longitude and the azimuth and distance values for the ending point. By running the formula multiple times at increasing distances, we begin to create a line that accurately follows a great circle. Formula iterations will stop once the extents of the coordinate system (Geographic Lon ±180, Lat ±90) are reached to avoid repetition of lines.

Next Steps: This script is under development and we hope to present refined results in March. Our goal is to identify all LCC within the boundaries of the Martian northern plains and run statistics to identify potential parent craters as well as cross-cutting relationships. Each standard deviational ellipse and extended great circle will harbor stratigraphic information that can be used to derive relative timing of intersecting lines.

References: [1] Tanaka, K.L. (1986), JGR 91 (E139-E158). [2] Scott, D.H. and Carr, M.H. (1978), *USGS I-1083*, 1:25M scale. [3] Scott et al. (1986-87) *USGS I-1802A-C*, 1:15M scale. [4] Popova et al. (2007).