IDENTIFICATION AND CLASSIFICATION OF SUPERVOLCANOES IN ARABIA TERRA ON MARS.

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Introduction: The Arabia Terra region of Mars contains various forms of craters that have been assumed to be of impact origin. However, some of these structures do not seem to fit the physical profile of an impact crater and often exhibit volcanic features in and around them. Previous authors have proposed that some of these structures have a non-impact origin and are instead large (11-35 km in diameter) explosive, volcanic calderas that are consistent with supervolcanoes [1,2]. Therefore, we hypothesize that there are previously undetected potentially volcanic calderas on the Martian surface, especially in and around the Arabia Terra region.

Previous research found that despite extensive evidence of volcanic activity, only about 75 ancient volcanic edifices have been identified or proposed [1,2,3] to justify the planet's large-scale volcanic resurfacing. Our analysis attempts to expand this number of volcanic edifices particularly in and around the Arabia Terra region. We tested our hypothesis by searching for, identifying, and classifying these possible calderas that have previously escaped detection using topography and images obtained from the JMARS software. These new volcanic candidates may lead to more insight into the volcanic history and interior evolution of Mars.

Methods: We conducted an analysis of geologic surface features within the coordinates 10-40°N and 16-40°E of Arabia Terra to determine if any craters demonstrated evidence of an origin as supervolcano calderas. We first limited this analysis to all craters with a depth to diameter ratio greater than 0.03 using the Martian Crater Database [4] to eliminate many shallow craters which are more likely to be of impact origin. Crater rim shape, topography, and attributes of the surrounding areas were then examined using topography data from the Mars Orbiter Laser Altimeter (MOLA), visible images from the Context Camera (CTX), and nighttime infrared images from the Thermal Emission Imaging System (THEMIS). We developed a flowchart to systematically look for features which seemed inconsistent with typical impact craters and could instead suggest a volcanic origin (Figure 1).

Our first analysis was of crater topography to look for evidence of a central peak or pit. Craters lacking central peaks or pits, having exceptionally flat floors (demonstrating evidence of possible flood lavas or lava lakes) or rough floors (possible collapse textures) were considered the first pieces of evidence of a non-impact origin. The next step included investigation of the surrounding area of potential calderas. Craters which lacked evidence for an ejecta blanket typical of impact craters were considered significant. We then analyzed crater rim shape. Rim shapes that were complex or seeming to have multiple overlapping calderas were considered significant evidence of volcanic origin.

Topography of the remaining candidates was investigated in more detail to search for signs of collapse consistent with typical supervolcano calderas. This included terraces in the interior of the caldera, representative of a lava lake or multiple caldera stages, as well as any other irregular texture in the floor which would have been inconsistent with impact crater fill. Unusual geologic features such as rilles, circular graben, and other depressions consistent with volcanism were then searched for and noted. Those not containing any of these irregular surrounding features, evidence of collapse, or evidence of multiple calderas were categorized as either being of impact or "other" possible origins, including impact craters modified by glacial, fluvial, or aeolian processes. Candidates who qualified in all tests of the flowchart were considered as possible supervolcano calderas as they would have been egregiously conflicting with geologic features typical of impact cratering. It is important to note that erosion could play a part in the absence of these impact features, though this was seriously considered when investigating the possibility of volcanic origin. Only craters which seemed exceptionally irregular were considered significant in the search, showing clear signs of volcanic origin which could not be explained by impact means.

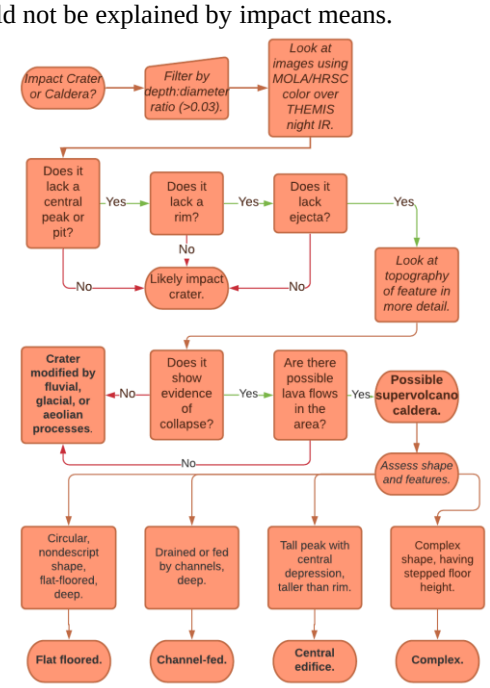

Figure 1. *Flowchart showing steps to evaluate volcanic, impact, or other origins for craters from orbital data.*

Results: We found 14 candidates whose features do not seem to fit the physical profile of an impact crater in Arabia Terra, in addition to the 5 candidates from previous work [1,3]. Their depth to diameter ratios were significantly larger than most impact craters and all had complex features in and around them. Consequently, their formation could not be easily explained by an impact crater model. To further understand these complex features, we have classified them into four different categories. These categories are channel-fed, complex, flat floored, and central edifice (Figure 2). We found 3 channel-fed craters that appeared to have some topographic evidence for flows either feeding into or draining the central region. The 3 complex candidates do not have a uniform floor in their central regions, instead containing stepped floor height and a textured floor (Figure 3). These could indicate caldera collapse or the existence of more than one overlapping caldera. We identified 5 flat floored candidates that are extremely large in diameter but lack a central peak. Most of these candidates have surrounding craters of the same size that do have central peaks. We hypothesize that these anomalous flat floored structures may have a non-impact origin. Finally, we found 2 craters with a central edifice whose peaks are about 800 m higher than their surrounding rims (Figure 3). These features also have central depressions at the peak which, coupled with their extreme height with respect to their rims, provides compelling evidence for a volcanic origin.

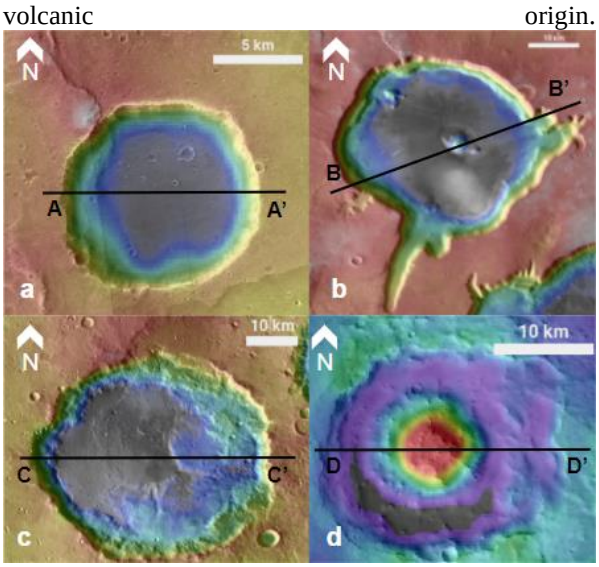

Figure 2. *Examples of the four new categories of non-impact related features. (a)Flat floored (b)Channel-fed (c)Complex (d) Central edifice.*

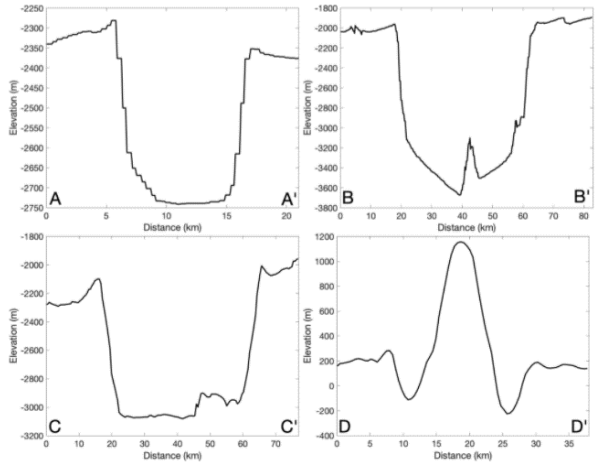

Figure 3. *Topographic profiles of the non-impact related features. Each profile line corresponds to cross sections pictured in Figure 2.*

Conclusions and Future Work: We find that there is sufficient topographical evidence to suggest that some irregular craters in the Arabia Terra region of Mars are potential supervolcano calderas. Additionally, we find that some other abnormal craters may have other origins, such as fluvial or glacial. The discovery and identification of such potential supervolcano calderas represents a more whole volcanic history of Arabia Terra and Mars overall. Further, this could have implications for potential tectonism in Mars history. Our next steps are to recognize more volcanic features around previously identified supervolcanoes to further develop our method of identification. We will then expand our research to other regions of Mars to look for similar evidence of ancient supervolcanoes.

References: [1] Michalski et. al. (2013), *Nature* 502, 47–52. [2] Chu et. al. (2021), *GRL* 48(15). [3] Whelley et. al. (2021), *GRL* 48(15). [4] Robbins et al. (2012), *JGR* 117, E5.