INVERTED MARTIAN CRATERS IN LINEATED GLACIAL VALLEYS, ISMENIUS LACUS REGION, MARS. B. S. McConnell[1], G. L. Wilt[2], A. Gillespie[3] , H. E. Newsom[4], [1]Highland High School, Albuquerque, NM 87108 bmcconne@unm.edu [2]Shikellamy Senior High School, Sunbury, PA 17801 grierwilt@gmail.com [3]UT aimeeg@unm.edu [4]Univ. of New Mexico, Institute of Meteoritics, Dept. of Earth & Planetary Sciences, Albuquerque, NM 87131 newsom@unm.edu

Objective We studied small, uniquely-shaped craters found on the surface of lineated terrain in the Ismenius Lacus region of Mars [1]. By utilizing MOC and THEMIS satellite images, we located terrain including lineations (viscous flow features), smoothing of topography, and morphologic features such as polygons and gullies, which appear to be strong evidence of preexisting ice deposits.

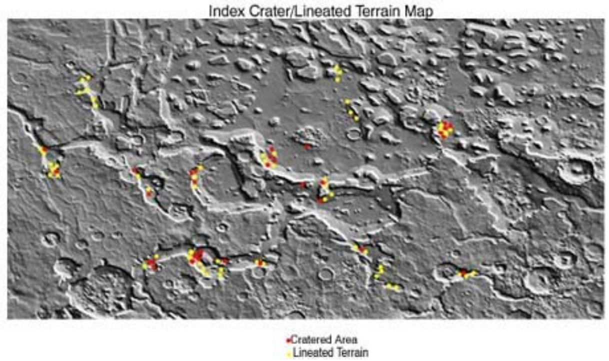

Figure 1. Index map of MOC and THEMIS images examined in this study.

Background Because of Mars's dynamic obliquity, a consistent tilt pattern is evident in which it cycles through every several million years. According to Mustard et al. [1], if the obliquity exceeds 30^o, the ice at the north and south poles become very unstable and relocates by sublimation to the mid to high latitudes. This is known as a Martian Ice Age. The most recent Ice Age occurred about 10 Myrs ago when the obliquity was at a steep 35^o and the primary water ice was located in the 30-60^o latitude bands.

Hypothesis A specific region, Ismenius Lacus with the latitude range of 30-65^o, was selected because it has a vast array of heavily cratered canyons and gullies and evidence of unusual features suggesting the presence of preexisting ice in the region [2]. The comparison of craters in both lineated and non-lineated terrain led us to the discovery of very unusually structured craters located in the lineated terrain. The craters located in these areas often consisted of multiple rim rings and plateau-like centers [2].

We developed and tested models for the origin of these unusual circular features. Based on our observations, we suggest that meteors impacted the Martian surface sometime in the last ice age and the meteors penetrated several meters of dust and ice. After their formation, they gradually filled back in with new layers of sediment and debris. As the tilt changed back to a less dramatic and current obliquity of roughly 22-26^o, the ice sublimated. As the icy layers sublimated, the surface collapsed and left the uniquely structured inverted morphology [e.g. 3,4].

Methods Images were utilized to observe crater morphology in the Ismenius Lacus region. High resolution Images were examined from the Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) on the Malin Space Science Systems (MSSS) website, and from ASU's Thermal Emissions Imaging System (THEMIS) website.

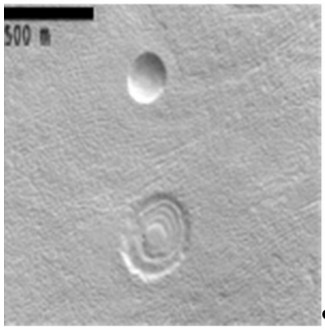

Figure 2 Example comparing a fresh bowl-shaped crater (above) and an older inverted crater (below).

We viewed every MOC image in the southern region of Ismenius Lacus by this process. After the high-resolution MOC images were inspected, the photograph was copied and pasted into Adobe Photoshop. In Photoshop, we searched the pictures for craters and then cropped each crater, with respect to the image size. The image size was vital for scaling the craters. Each high-resolution photo had different meter/pixel resolution, so an MS Excel record had to be kept for each image, and a template of 100x100 pixels was used per image. This process was done for and approximate total of 100 craters. After the craters were cropped and recorded, they were printed out to be thoroughly examined and analyzed.
Based on our sample, the inverted craters range in size from 150-400 meters in diameter. Resolution of the images limited the recognition of the smallest inverted craters.

Observations After careful and complete examination of the high-resolution images, we observed that there were relatively few craters in the lineated terrain and even fewer fresh bowl-shaped craters when compared to the surrounding area. The fact that there are so few craters suggests that the surface is young and reflects a fairly recent chain of events, such as an Ice Age, which caused this phenomenon.

Experiments In testing our hypothesis, we used multiple methods.

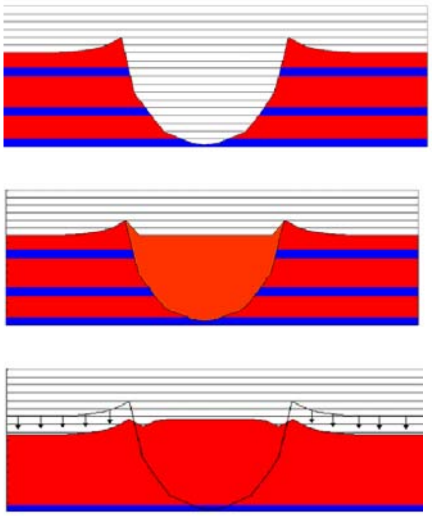

Figure 3. Numerical simulation of the three major sequences involved in inverted crater formation. The first figure shows a fresh bowl-shaped crater. The blue layers represent the sub-surface ice deposits. This simulation represents a relatively low fraction of ice in the sub-surface. The second image simulates the process in which the crater is filled in with debris. The third figure is the concluding phase, after the sub-surface ice sublimates.

Excel Model The Excel Model proved to be very useful in simulating layering and sublimation effects. With Excel, a series of rows and columns were used to simulate the surface and sub surface dust and ice layers of Mars (e.g. figure 3). Once the surface was established, a symmetrical crater was formed by deleting several layers. Each individual column was summed up in a “Totals” row and the totals were then graphed. The graph, when finished, looked very similar to a typical bowl-shaped crater. To simulate dust storms and other weathering factors, new rows of dust and ice were formed inside the crater. To simulate the departing ice age, the ice layers were deleted and the graphs symbolized the shape and structure of the concluding craters.

Physical Model The physical experiments were extremely useful in this project because our simulation was almost identical to the proposed inverted Martian crater process. In this experiment, the beginning phase consisted of three different materials; tin catering trays (to hold the surface that harbored the crater), dry ice (to simulate the sublimation of icy layers), and sand (to represent the Martian surface material). The tin was filled with layers of sand and ice to represent an ice age surface. After the surface was established, a crater was constructed by scooping out several layers in a confined area. Following the fabrication of the crater, several additional layers of sand and ice were applied. After this was complete, the tins were set in the sun so the ice would sublimate. Several hours later, the finished product looked identical the formations observed on the Martian surface in the high-resolution images.

Conclusion We have come to the conclusion that the unique features of the selected craters are due to a recent Martian Ice Age. These craters originally formed on an ice-rich surface and were subsequently covered by sediments and additional ice. Due to the alteration in Mars’ obliquity, the ice sublimated back to the poles and consequently, the surface collapsed causing strange features such as multiple rim rings and central plateaus. Through numerical and physical experimentation, we have shown that the proposed inverted Martian crater process is plausible.

References

[1] Mustard J.F. Head J.W. Kreslavsky M.A Milliken R.E. Marchant D.R.(2003) Geological Observations, Climate Modeling, and Ice Stability: Evidence for a recent Martian Ice Age. *Third Mars Polar Science Conference.* [2] Kargel J.S.* Molina B. Tanaka K.L. (2003) Martian Polar Ice Sheets and Mid-Latitude Debris-rich Glaciers, and Terrestrial Analogs, Gullies, and Long-Term Glacial History; Head J.W. Shean D.E (2003) Tropical Mountain Glaciers on Mars: Evidence for Amazonian Climate Change. [3] François Costard Audouin Dollfus (1987)Thermokarstic Evolution of Impact Craters on Mars. *Lunar and Planetary Science XVIII*, 199. [4] Rene A. De Hon (1987)Ring Furrows: Inversion of Topography in Martian Highland Terrains

Acknowledgments

This project was supported by NASA SHARP program (G.L. Wilt, A. Gillespie), and NASA PG&G and broker facilitator programs (B. McConnell, H. Newsom).