CIRCULAR FEATURES LOCATED ON LINEATED TERRAIN, ISMENIUS LACUS REGION, MARS: IMPLICATIONS FOR POST-IMPACT CRATER MODIFICATION ATTRIBUTED TO SUB-SURFACE ICE DEFLATION. B. S. McConnell[1], H. E. Newsom[2], G. L. Wilt[3], A. Gillespie[4], [1]Highland High School, Albuquerque, NM 87108 bmcconne@unm.edu [2]Univ. of New Mexico, Institute of Meteoritics, Dept. of Earth & Planetary Sciences, Albuquerque, NM 87131 newsom@unm.edu [3] Pennsylvania State University, PA [4]California Institute of Technology, Pasadena, CA 91125

Objective: This study involves analyzing small modified craters on lineated terrain in the northern and southern hemispheres of Mars to determine their origin and the nature of the target material. The structures are small (50m-500m diameter), circular, presumably impact features that contain central layered deposits and mounds as well as collapsed crater rims and single an multiple inner rings. These traits are possibly related to the presence of ice deposited during high obliquity [2].

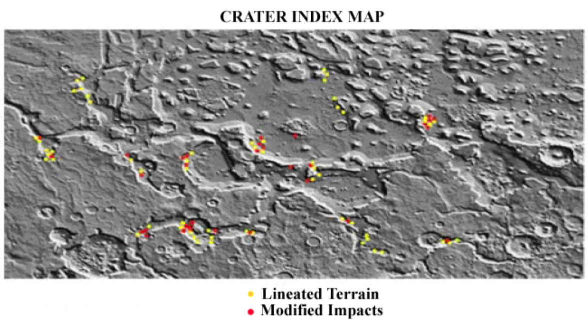

Fig. 1. Index map of MOC and THEMIS images examined in this study.

Background: Dramatic changes in climate occur on Mars because of the obliquity changes. According to Mustard et al. [1], if the obliquity exceeds 30°, the ice at the north and south poles becomes very unstable and relocates by sublimation to the mid to high latitudes. The last Martian Ice Age caused primary ice deposits to locate to the 30°-60° latitude bands as a result of Mars's 35° obliquity. Under current obliquity conditions, the ice is not stable and is being removed by sublimation.

Observations:

Evidence of Ice-Bearing Target Materials The modified craters occur on lineated terrain, which is interpreted to originally consist of glacier ice or a mixture of rock and ice which is partly or completely deflated due to sublimation of the ice component (Figure3a, I, II)[1]. Lineated terrain is commonly located at the foot of debris aprons at the floor of glacial valleys and gullies. The lineations are usually parallel to the valley walls. An example observed in the southern hemisphere provides additional evidence that ice plays a major role in the modification of small impact craters. Although this study was mainly confined to Ismenius Lacus in the northern hemisphere, we observed features identical to those located in Ismenius Lacus in the southern hemisphere (38°S) (Fig. 2.). Obvious characteristics of the target materials on the large crater floor included evidence of ice flow and deflation. A modified crater located on this material is shown in Figure 2 (inset) with a characteristic collapsed crater rim and central mound. This example strengthens the case for the role of sub-surface ice in post impact modification.

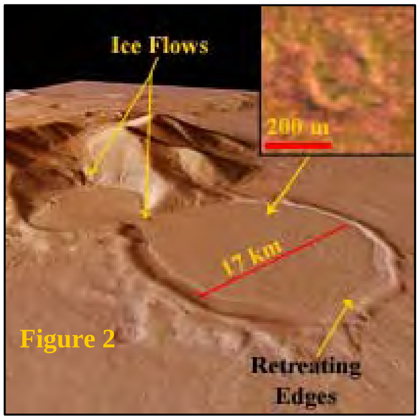

Fig. 2. This Mars Express image shows two large ice-filled craters in the 38° southern latitude band. The retreating edges of the floor material are evidence of sub-surface ice deflation. The floor deposit contains a modified impact crater similar to those in Ismenius Lacus.

Crater Modification Most of the circular features have single inner rings however a handful have one or more inner rings. These inner rings appear within the collapsed crater rim and around the central mound (Fig. 3a, IV). All modified impacts contain collapsed crater rims (Fig. 3a, V).

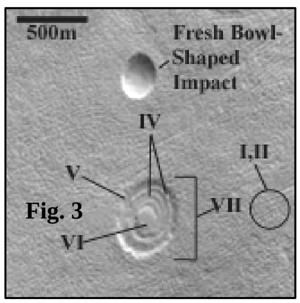

Fig. 3. This THEMIS image (left) compares a fresh bowl-like impact crater (above) with an older modified impact structure (below).

All modified impacts contain central mounds which are variable in size and relief (Figure3a, VI). The modified impacts range from 50m to 500m in diameter (Fig. 3a, VII). We documented up to eleven categories of circular structures but four types seem to be the most common (Fig. 4). All categories were classified by certain characteristics of the impacts (inner rings, central mounds, etc.). The impacts differ in these characteristics presumably because of the different amounts of sub-surface volatiles in the target present during impact as well as different amounts of post-impact deposition.

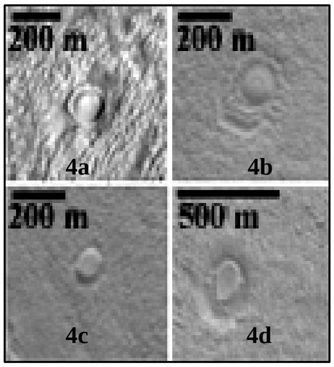

Fig. 4. The THEMIS images (left) classify the four most common modified impact structures. Single Inner Ring with Central Mound (SIRCM) (4a), Multiple Inner Rings with Central Mound (MIRCM) (4b), No Inner Ring with Central Mound (NIRCM) (4c), and No Inner Ring with Convex Central Mound (NIRCCM) (4d).

Modeling: Images acquired from MOC and THEMIS were thoroughly examined leading to the observation of modified circular features on lineated terrain ranging from approximately 50m to a maximum of 500m in diameter.

Numerical Model Numerical experiments simulated crater formation in an ice-rich target, followed by burial and loss of volatiles on Ismenius Lacus in conjunction with previous observations. Select layers were used to simulate sediment and volatile deposition. Some trials included different ratios of ice in the crater fill as well as in the sub-surface. To produce an accurate sublimation effect, layers of ice were deleted. The resulting profiles reproduced the characteristics of the modified circular features in Ismenius Lacus.

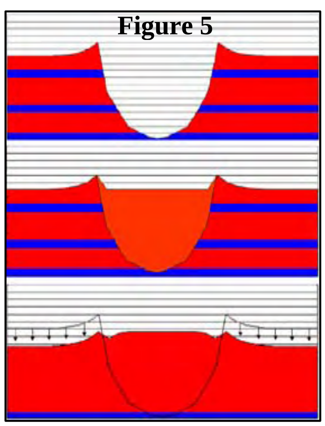

Fig. 5. Numerical simulation of the three major sequences involved in ice-altered impact formation. The first figure shows a fresh bowl-shaped crater. The blue layers represent the sub-surface ice deposits. This simulation represents a relatively low fraction of sub-surface ice. The second image represents the process in which the crater is filled in with debris. The third figure is the concluding phase, after the ice sublimates.

Physical Model A controlled physical model was fabricated using medium grain surface soil, representing Martian crust, and frozen CO_2, simulating subsurface ice deflation. The physical model coincided with the numerical model. A volatile-rich (frozen CO_2) surface was established followed by the fabrication of a bowl-shaped crater. The crater was then filled in with sediments and set in the sun for sublimation. This experiment was repeated with different crater fill sediment/ice and surface sediment/ice ratios. The product looked similar to those features located in Ismenius Lacus.

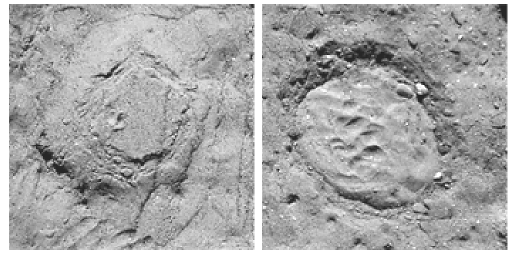
Fig. 6. These structures are the products of the Physical Model. The image on the left was the product of an ice-rich subsurface and no ice in the crater fill. The image on the right had a smaller amount of ice in the sub-surface and no ice in the crater fill.

Discussion and Conclusions: Based on observations and research, we assume that the formation of the features began when the Martian surface was impacted in the last ice age and the resulting crater penetrated several meters of dust and ice. After their formation, they gradually filled back in with new layers of sediment and volatiles. As the tilt changed back to a less dramatic and current obliquity of approximately 22°-26°, the ice sublimated. The layers and central mounds observed today suggest crater deposition of sediments and ice followed by sub-surface ice deflation and surface collapse over the past several million years.

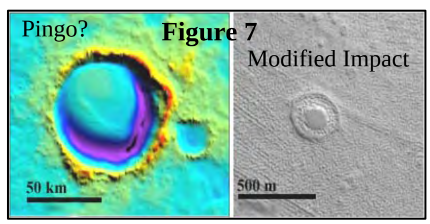

Fig. 7. Comparison of possible pingo (left) [6] and modified crater on lineated terrain (right).

An alternative pingo process to form the structures seems less likely and involves a larger scale impact ((>1km) Fig. 7) deep enough to tap a massive water deposit thus causing it to freeze and swell to form a mound [6]. This is not realistic for smaller impacts (<500m) because they are not deep enough to tap massive water deposits required for pingo formation. Additional constraints on the crater modification process will require high resolution topographic information on these small structures from the HighRISE camera.

References: [1] Mustard J.F. et al. (2003) *MPSC III.* [2] Kargel J.S. et al. (2003) *MPSC III*, Abstract # 8112. [3] Head J.W. et al. (2003) *MPSC III*, Abstract # 8105. [4] Costard F. and Dollfus A. (1987). *LPS XVIII*, 199. [5] De Hon R.A. (1987) *Icarus*, 71, 287-297. [6] Sakimoto S.E.H. (2005) *The Role of Volatiles and Atmospheres on Martain Impact Craters* LPI Abstract # 1273. Funding provided by NASA PG&G Program.