ELLIPTICAL CRATERS ON MARS: EVIDENCE FOR POLAR WANDER OF MARS. D. Boutin[1] and J. Arkani-Hamed[2], [1]Earth & Planetary Sciences, McGill University, 3450 University St. Montreal, Quebec, Canada H3A 2A7 (dboutin@eps.mcgill.ca), [2]Department of Physics , University of Toronto 60 St. George St. Toronto M5S 1A7 Ontario, Canada (jafar@physics.utoronto.ca).

Introduction: Impacts have created multitude of craters on terrestrial planets. Laboratory experiments suggest that a projectile with an impact angle of about 5^o relative to the horizontal surface of a target creates an elliptical crater [Grey et al., 2002]. However the exact value of the impact angle is a matter of debate. Christiansen et al. [1993] found that projectiles shot into aluminum targets at angles smaller than 25^o create elliptical crater.

We examine the usefulness of elliptical craters as a tool to estimate paleo equator, and polar motion path, of Mars. It is assumed that an elliptical crater is formed when a projectile hits the equator at a low angle. A total of 130 craters are examined and 77 of them yield reliable results. Figure 1 shows the locations of the 77 craters.

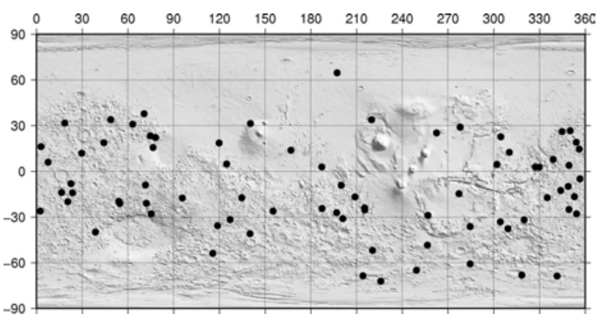

Figure 1: This figure represents all the 77 craters that yielded good fits between the model ellipses and the contours chosen to represent the craters' shape.

Method: We use high resolution (128 pixels/degree) MOLA data to model the shape of elliptical craters. MGS provided elevation data and planetary shape data. Both data sets are used in this study. The craters are extracted from the Mars Consortium Crater database [Nadine Barlow, personal communication]. For each crater in the Barlow database we extract elevation and planetary shape data in a 4 by 4 degree area centered on the crater. This yield elevation and planetary shape values in a spherical coordinates system centered at the center of mass of the planet. The data are on a regular grid at 128 pixels/deg. We then transfer the data into a rectangular coordinate system with the origin at the surface of Mars and at the center of the crater. The surface grid resolution is 0.5 km.

In the next step we build contour maps of each crater and extract the contour that best represent the shape of the crater. The contour is then fitted to the biggest possible ellipse by varying the major axis and minor axis of the model ellipse at 1 km increments. For given values of the major and minor axes the ellipse is rotated at 1 degree increment from 0 to 180 degrees. The angle is measured counter clockwise relative to the x axis (positive pointing east). The orientation of the ellipse denotes the best estimate of the orientation of the crater. The orientation values obtained in this study have been compared to values provided in the Barlow's database and correlation is excellent. Figure 2 shows examples of craters with their best fit ellipse.

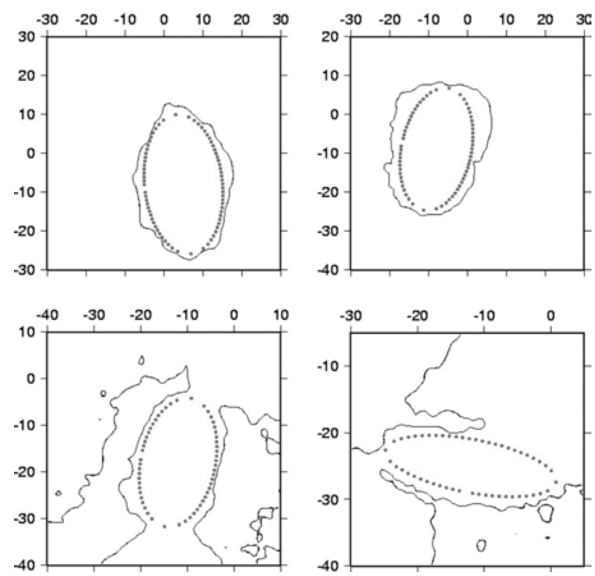

Figure 2: Model ellipses for 4 craters. Top row represents two fresh craters. Bottom row represent degraded craters. Also shown is the contour that is considered the best approximation of the shape of the crater, which is used to calculate the model ellipse. Both axes are in km.

A paleo-rotation pole of Mars is determined from the orientation of a given crater by assuming that the crater formed by a projectile that was orbiting on the equatorial plane of the planet prior to impact. For each crater an equatorial plane is defined by using two end points of the major axis of the crater and the center of Mars. The corresponding rotation pole is determined by

$$\mathbf{R} = \mathbf{R}_1 \times \mathbf{R}_2$$

where $\mathbf{R}$, $\mathbf{R}_1$ and $\mathbf{R}_2$ are unit vectors along the rotation axis, the position vector of the western end point of the crater and the position vector of the eastern end point of the crater, respectively. $\mathbf{R}$ points to the north at the time of impact, regardless of the orbital revolution of the projectile about Mars, whether it was prograde or retrograde.

The paleo-poles obtained in this study spread roughly over the entire surface of the planet (figure 3), indicating that the elliptical craters do not reveal the polar motion path. However, none of the pole positions are at the present pole, emphasizing that Martian rotation axis has wandered in the past.

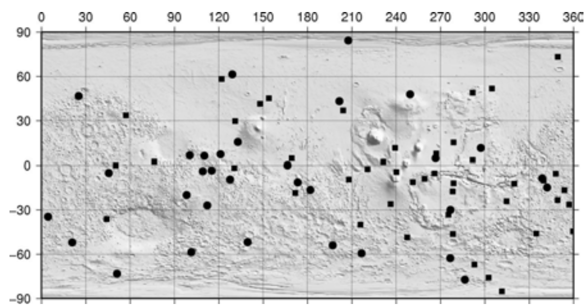

Figure 3: The paleo rotation poles obtained from the 77 elliptical craters that yield good models. Circles represent poles obtained from degraded craters, squares represent poles obtained from fresh craters. The Poles are distributed more or less uniformly all over the surface of the planet, regardless of the degree of erosion.

Conclusion: Experimental studies suggest that the characteristics of an elliptical crater depend on parameters for which there are no firm constraints. Our results do not support Schultz & Lutz-Garihan [1982] contention about the usefulness of elliptical craters for establishing the possible path of the polar motion, and that young craters are mostly parallel to the equator and old ones have different orientations. We also note that the degradation state of crater is not dependent on age alone, but is also strongly influenced by local erosion conditions. These conditions are basically unknown in most cases, which make elliptical craters an unreliable tool to determine the polar wander path.

References:

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