MARTIAN MICROCRATER PRODUCTION AT LOW AND HIGH ELEVATION IN RESPONSE TO OBLIQUITY-DRIVEN ATMOSPHERIC PRESSURE VARIATIONS.

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Introduction: Climate models have predicted that obliquity-forced changes in the distribution of solar radiation on Mars' surface result in large-scale variations in atmospheric mass as a response to condensation and sublimation of the CO_2 residual polar caps [1-3]. During periods when polar insolation is at its lowest, it is possible that almost all CO_2 is tied up in the ice caps, leaving only the non-condensable N_2 and Ar component [4].

The theory of obliquity-driven climate variations is consistent with observations of finely layered deposits at the poles and at lower latitudes [5-7]. Still, there is a definite need for more observational evidence to substantiate the theory. In this study, we investigate the possibility that large scale atmospheric mass variations, if they exist, would have an observable effect on the size frequency distribution of the impact crater production on Mars.

Vasavada, Milavec and Paige (1993) [8], documented that the observation of small (1 cm) hypervelocity microcraters, similar to those observed on the lunar surface [9] would strongly support the occurrence of past periods of significantly lower atmospheric pressure, given that the current ~600Pa atmosphere prevents the formation of such craters. If Mars' atmosphere is subject to the predicted large-scale mass variations, then during low obliquity periods the rate of microcrater production should be high enough to create an observable record, with the quantity and smallest sizes of hypervelocity craters giving an indication of lengths and magnitudes of these episodes.

Examination of Viking and Pathfinder images failed to return any evidence of microcraters on the Martian surface, and although the two MER rovers have the capability to resolve craters as small as 1-2cm, no cm-sized hypervelocity craters have thus far been identified at either of the MER sites [10]. In this study, we more fully characterize the potential effects of obliquity-driven climate variations on impact crater production rates through Monte Carlo simulations at mean Martian surface elevations, and at elevations characteristic of high altitude Tharsis calderas.

Methods: We have used a Monte Carlo cratering model that simulates the effects of atmospheric deceleration and ablation on the rates of primary hypervelocity impact crater formation at the surface of Mars. The model employs the same asteroidal velocity and angular distribution as [8], but includes an extrapolated impactor mass flux distribution based on observations of bolides in the Earth's atmosphere [11] scaled up by a factor of 2. This production function is consistent with the Hartmann steep branch production function [12] and is also consistent with the distribution of recent impact craters on the surface of Mars observed by MOC [13]. We also employ the asteroidal composition and ablation properties assumed by Chappelow and Sharpton [14], which gives an asteroidal impactor population consisting of 75% carbonaceous, 16.25% stony and 8.75% iron impactors by mass. We employ the same crater diameter scaling law as [8], but assume a threshold velocity of 2 km/sec for the creation of hypervelocity impact features in rock. The results of four simulations are presented here as described in Table 1.

Simulation	Surface CO_2 Pressure (Pa)	Total Surface Pressure (Pa)	Surface Elevation (km)
Surface Present	575.00	600.00	0
Surface Low Obliquity	0	25.00	0
Caldera Present	41.20	43.00	21
Caldera Low obliquity	0	3.81	21

Table 1. Monte Carlo cratering simulation parameters.

Each simulation included a starting population of 14,490,000 impactors at the top of the atmosphere within a mass range of 10^{-6} to 10^{2} kg. This corresponds to a 498.8Ma period of uniform cratering rate.

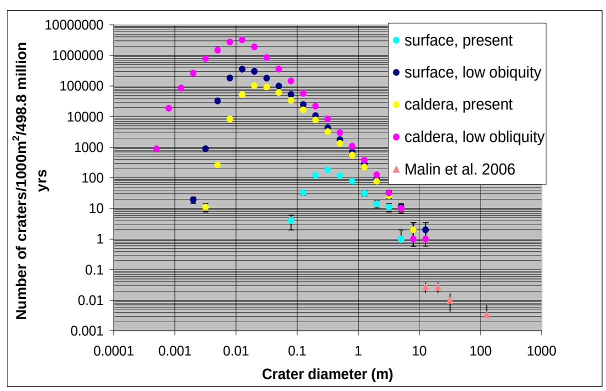

Figure 1. Incremental crater production curves calculated for four simulations of obliquity and elevation.

Results: Fig. 1 shows the incremental number of craters per 1000 m^2 as a function of diameter (in $10^{0.2}$ m bins) for each simulation. Also shown on the plot, are scaled recent crater production data from Malin et al. (2006) [13].

Our estimates for the present surface are consistent with recent crater production data from Malin et al. 2006 [13]. As expected, the total number of craters produced decreases in response to increases in the mass and thickness of the atmosphere that the meteors have to travel through. This effect becomes more pronounced as diameter decreases.

The results show that although projectiles impacting present day Mars at 0 km elevation are not able to produce craters with diameters less than 6cm; during the lowest extremes of Mars' obliquity, impactors could potentially produce craters with diameters up to 40 times smaller, thus confirming the findings of Vasavada et al. (1993) [8] and Paige et al (2006) [10], that cm-sized craters could form on Mars' surface during times of low obliquity.

In addition to this, the model predicts that the meteors currently impacting Olympus Mons Caldera at an elevation of 21000m can produce craters up to 25 times smaller than those on the present-day surface. There is therefore some similarity between crater production at this elevation today, and at the surface during past periods of low obliquity.

Discussion: Both elevation and atmospheric pressure have a significant effect on the distribution of small crater production on Mars. While cm-sized craters are prevented from forming on Mars' present day surface, our model results show that the reduced thickness of atmosphere above high altitude Tharsis calderas allows the formation of craters in this size range. As such, these sites could potentially serve as present-day analogues to the Martian surface during low obliquity.

The identification of hypervelocity microcraters at these sites given their absence at the MER sites would therefore point to one of two possibilities – either the erosion rates at the MER sites are a lot higher than previously estimated [15] in order to have erased any record of previous periods of low atmospheric pressure; or the Martian atmosphere has not been subject to such extreme variations in pressure as previously thought. Unfortunately, current high-resolution orbital images of young surfaces in the calderas of the Tharsis volcanoes are not likely to reveal the presence of the large number of cm-sized hypervelocity impact craters that our simulations predict. Our calculations suggest that the density of primary impact craters in the 1-10 m diameter range on the Tharsis calderas should not be dissimilar to surfaces of equivalent age elsewhere on the planet.

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