HAS THE VOLATILE CONTENT OF THE MARTIAN SUBSTRATE VARIED OVER TIME?

N. G. Barlow, Dept. Physics and Astronomy, NAU Box 6010, Northern Arizona University, Flagstaff, AZ 86011-6010 Nadine.Barlow@nau.edu.

Introduction: The martian substrate is proposed to be volatile-rich based on analysis of geologic features such as channels, gullies, fluidized crater ejecta morphologies, and possible thermokarst features as well high-latitude terrain-softened features [1]. But has the volatile content of these subsurface reservoirs changed over time? Commonly accepted models of the hydrologic evolution of Mars suggest warm, wet periods were concentrated during the planet's earliest history (i.e., the Noachian) [2], with the possibility of only short-lived warm, wet episodes in more recent times [3]. One might expect that without continuous replenishment the volatile content of the subsurface reservoirs would gradually decline with time. We are utilizing the record of impact craters with fluidized ejecta morphologies to investigate this question.

Method: The single layer ejecta (SLE) morphology (Figure 1) is commonly believed to result from impact into ice-rich target material [4, 5, 6, 7]. The SLE morphology is the most common of the layered ejecta morphologies and is seen around fresh impact craters on every terrain across the planet. The radial extent of the ejecta blanket is believed to provide information about the amount of subsurface volatiles present at the time of impact [4, 8, 9]. The ejecta extent is normalized to the crater size through the use of the ejecta mobility (EM) ratio:

$$\mathrm{EM} = \frac{\text{(maximum radial extent of ejecta)}}{\text{(crater radius)}}$$

We have calculated EM values for 4000 SLE craters throughout the equatorial region (±30° latitude range) of Mars. These craters are found on terrain of all ages (Noachian, Hesperian, and Amazonian), although size-frequency distribution analysis indicates that the oldest ages for these craters are early Hesperian [10]. This implies that we can test the hypothesis of a temporal decline in subsurface volatiles at least from the early Hesperian (~3.1-3.8 Gyr).

However, one additional piece of information is needed—an indication of the age of each invidual crater since the EM ratio provides information about volatile content ***at the time*** of crater formation. We have attempted to constrain the ages of individual craters through characterization of their preservational state. We have instituted a 0 to 7 scale, where pristine craters are a 7.0 and "ghost" craters (i.e., those completely buried except for a hint of the original rim) are a 0.0. The categories are assigned based on information such as existence and preservational state of an ejecta blanket (categories 4 through 7), existence and preservational state of interior features such as central peaks, wall terraces, etc., height of the crater rim, and depth of the crater floor. This information has been acquired through analysis of Viking, MGS MOC, and MGS MOLA data (we plan to begin including MO THEMIS data soon). We have updated the preservational classes of 14,141 craters in the MC08 through MC19 quadrangles.

1633 SLE craters have been classified in this way with both a preservational class and an EM value within the ±30° latitude zone. These are the craters which are utilized in this analysis. Our technique compares the EM ratio with the crater preservational state to determine if any clear correlations occur. Possible results from this analysis are:

1) an increase in EM with preservational class, implying that either erosion is severely affecting the earlier preservational categories or there has been an increase in volatile concentration over time (opposite of what the currently accepted models would predict).

2) a decrease in EM with preservation category, implying a decrease in volatile concentration with time.

3) no correlation between EM and preservation category, implying that the concentration of volatiles has remained constant over time.

Craters with preservational classes 4 through 7 display an ejecta blanket, although ejecta blankets surrounding category 4 craters show evidence of servere degradation. The EM ratios for category 4 craters are much lower than for the higher classes, which we interpret as further evidence of erosion. As such, we have focused this analysis on craters in preservational categories 5 through 7. We compare the preservational class and EM ratio as a function of terrain and diameter (which can affect the preservation classification) on both a local and a regional distribution.

Results: Our results show no indication of major variations in the concentrations of subsurface volatiles over the period of martian history recorded by the fresh impact craters used in this analysis. Figure 2 shows an example graph of mean EM ratio versus preservational class for the Amazonian-aged volcanics in subquadrangle MC15SW. Statistical uncertainties in EM are estimated at ±0.2 for all graphs. Within the uncertainties, there is little evidence for any change in EM with time in this region.

Figure 3 shows an example graph for a regional area, in this case all the Noachian cratered terrain considered in this analysis. The size-frequency distribution analysis suggests that the craters superposed on these terrains have a maximum age in the Early Hesperian, so we are sampling the subsurface volatiles over a time span of about 3.5 Gyr. Again, within the uncertainties of the study, there is no clear change in EM ratio with time, indicating that the concentration of volatiles within the substrate has remained constant over this period of time.

Figure 4 shows an example graph which displays diameter effects on preservation and EM. This graph again shows the variation in median EM with decreasing age (i.e., higher preservation class) but has been subdivided into craters 5 to 10 km and craters 10-20 km in diameter. The results for the smaller craters show little variation, but the larger crater population shows an initial decline in EM value followed by a sudden increase in EM with the most pristine craters. However, the low number of craters in the 10-20 km diameter size range makes these results suspect. The best analysis (due to the number of craters involved and the rate at which degradation proceses erase the smallest craters) seems to occur when considering only those craters 5 to 10 km in diameter.

The results of this study show no strong variation of EM ratio with crater preservational class, indicating that the concentration of volatiles at the depths sampled by these craters (~500 meters and deeper) has remained constant at least since the Hesperian. This is consistent with computer simulations by Mellon and Jakosky [11] which also found no long-term variation in subsurface volatile concentrations at depths below a few meters.

References: [1] Carr M.H. (1996) *Water on Mars*, Oxford Univ. Press, New York. [2] Craddock R.A. and A.D. Howard (2002), *JGR*, 107, 10.1029/2001JE001505. [3] Baker, V.R. (2001) *Nature*, 412, 228-236. [4] Mouginis-Mark P. (1981) *Icarus*, 45, 60-76. [5] Barlow N.G. and T.L. Bradley (1990) *Icarus*, 87, 156-179. [6] Baratoux D. et al. (2002) *GRL*, 29, 10.1029/2001GL013779. [7] Stewart S.T. et al. (2002), submitted to Nature. [8] Costard F.M. (1989), *Earth Moon Planets*, 45, 265-290. [9] Woronow A. (1981) *Icarus*, 45, 320-330. [10] Barlow N.G. (1990) *JGR*, 95, 14191-14201. [11] Mellon M.T. and B.M. Jakosky (1995) *JGR*, 100, 11781-11799.

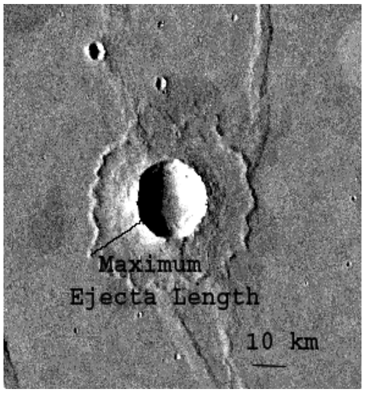

Figure 1: Example of an SLE crater. Line shows the maximum ejecta length, part of the calculation of EM ratio.

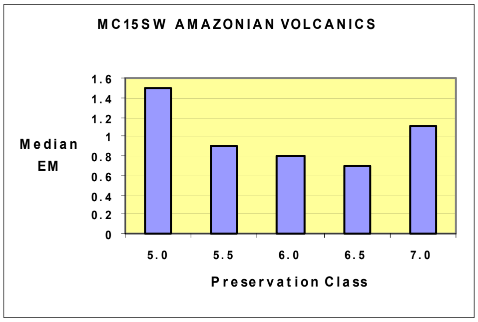

Figure 2: Example EM vs Preservation graph of a local region, the Amazonian-aged volcanics in MC15SW. Uncertainities are ±0.2 in median EM.

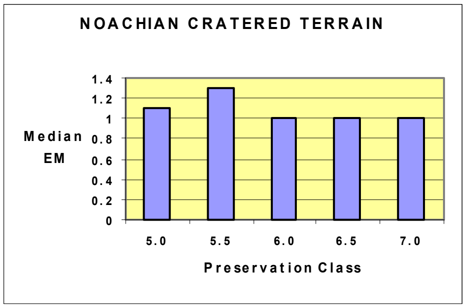

Figure 3: Example EM vs Preservation graph of a regional area, all of the Noachian-aged terrain in the study area. Uncertainties are ±0.2 in median EM.

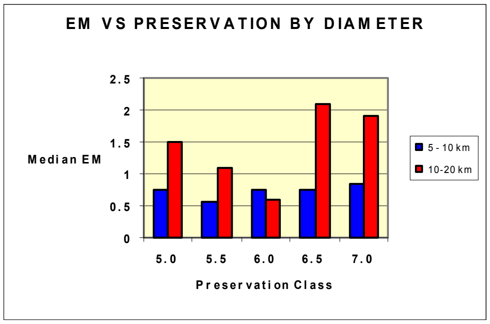

Figure 4: Example EM vs Preservation graph of Amazonian–aged volcanics in MC15SW as a function of diameter.