THE FORMATION TIMESCALE AND AGES OF MID-LATITUDE PEDESTAL CRATERS ON MARS.

S. J. Kadish[1], J. W. Head[1] and N. G. Barlow[2]. [1]Department of Geological Sciences, Brown University, Providence, RI 02912 USA (Seth_Kadish@Brown.edu), [2]Department of Physics and Astronomy, Northern Arizona University, NAU Box 6010, Flagstaff, AZ 86011.

Introduction: Recent evidence suggests that pedestal craters (Pd) on Mars form via a sublimation of a surrounding ice-rich terrain [1-3], rather than by eolian deflation of a dry layer [4,5]. Our work supports a model that relies on impact into volatile-rich targets to produce Pd during periods of higher obliquity [3], when mid- to high-latitude substrates were characterized by thick deposits of snow and ice [6]. The area proximal to the crater becomes armored during the impact event. During return to lower obliquity [7], the regional ice-rich unit sublimated, except below the protective cover of the armored pedestal surfaces. These intervening volatiles eventually migrated poleward.

In this model, the ages of individual Pd and the timescale of formation of the Pd population have significant implications for the timing and recurrence of the accumulation of ice-rich material at mid latitudes. Here, we provide evidence that Pd are young (Mid to Late Amazonian) and formed from multiple episodes of emplacement of ice-rich material at mid latitudes.

Morphologic Evidence: Pd are generally morphologically fresh [3], with well-preserved crater rims and minimal degradation of pedestal surfaces. One feature in particular, pits in the marginal scarps of some Pd [2], may implicate recent or current sublimation of the ice-rich material composing the pedestal. Given our current understanding of the diffusive exchange of water between the regolith and the atmosphere [e.g. 8], it is possible that marginal pits represent an active sublimation process and are still developing, forming connected pits and moat-like structures around Pd.

Stratigraphic Evidence: A significant portion of the Pd population is located on Amazonian-aged units in the northern lowlands and in the north polar region [e.g. 9]. This superposition of Pd on young surfaces requires that the Pd are also young; any resurfacing of the surrounding terrain would have destroyed or drastically altered the Pd, and as such, Pd are likely younger than the units on which they are emplaced.

In addition to stratigraphic relationships between Pd and the intercrater terrain, we have identified Pd which are partially draped over the scarps or completely superposed on the surfaces of other Pd. Although these examples do not provide Pd ages, they do support the interpretation of a recurring ice-rich deposit at mid latitudes. Many partially draped Pd are topographically influenced by the underlying Pd scarp. This requires one Pd to form completely, followed by an impact into a subsequent deposit that contours to the topography of the underlying Pd.

Crater Counting: Although crater counting cannot provide an absolute age for the entire Pd population, it can provide a lower limit for how long the population took to form, assuming continuous presence of the mid-latitude, ice-rich deposit. Using the diameters of the mid-latitude Pd population and the corresponding area on which they form, we derive a best-fit of formation timescale of ~100 Myr [10]. However, the time required to form the observed population is necessarily greater than 100 Myr because the deposit is not currently present and a robust solution for the last 20 Myr of Martian obliquity history [11] shows low obliquity periods for the last 3-5 Myr, and potentially widely variable obliquity for the last 250 Myr.

We have also performed crater counts on the surfaces of 22 individual mid-latitude pedestals using HiRISE (25 cm/pix) and CTX (6 m/pix) data (Fig. 1). The best fits for these data yield an age range of ~1 Myr to ~1.26 Gyr and a median of ~100 Myr (Fig. 2). Although crater counts on such limited areas are prone to uncertainties due to the statistics of small numbers, secondary craters, and erosion/removal of small craters, crater counting on numerous pedestal surfaces may provide more robust results; groups of Pd with the same age could provide insight into the timing and frequency of ice-rich deposition at mid latitudes. When plotted on size-frequency distributions, our data do show the effects of erosion/removal of small craters (Fig. 3), resulting in slopes that are shallower than the isochrons [10]. Although more data are required to establish statistically significant trends, this is an ongoing aspect of our research and will continue and as additional HiRISE and CTX data are released.

Discussion and Conclusions: The recurrence of this mid-latitude, ice-rich deposit is supported by the known variations in Martian obliquity over the past 20 Myr [11]. The obliquity of Mars over the last 5 Myr has oscillated between 15° and 35°, and during the previous 15 Myr, it oscillated between 25° and 45°. Given the modeled exchange of volatiles between the poles, mid latitudes, and equatorial regions at these obliquities [e.g. 6], and the high frequency of the recent obliquity variations [e.g. 7,11,12], it is expected that ice-rich material has been repeatedly deposited and removed at mid latitudes throughout the Late Amazonian. Assuming an accumulation rate of 10 mm/yr [6], it would take only 5 kyr to form a deposit thick enough to produce an average pedestal (~50 m in height). Even the tallest mid-latitude pedestals (<200 m) could form from deposits that accumulated in 20 kyr.

On the basis of our morphologic and stratigraphic observations, and our current crater counting efforts, we conclude the following: (1) Pd are morphologically fresh, and marginal sublimation pits may represent recent or active sublimation of the pedestal material, implying a young ice-rich deposit. (2) Pd are superposed on Amazonian-aged units, and must be younger than those units. (3) Instances where Pd are completely superposed or partially draped over other Pd require multiple episodes of emplacement of an ice-rich deposit at mid latitudes. (4) Crater counting techniques for the entire Pd population suggest a minimum timescale of formation of ~100 Myr. Given that the ice-rich deposit has not been continuously present for this duration, the timescale of formation is necessarily longer than 100 Myr. (5) Crater counting on individual Pd surfaces provides an age range of ~1 Myr to ~1.26 Gyr, with a median age of ~100 Myr.

References: [1] N. Barlow (2005) *RVAMIC*, #3041. [2] S. Kadish et al. (2008) *GRL*, *35*, L16104. [3] S. Kadish et al. (2009) *JGR*, *114*, E10001. [4] J. McCauley (1973) *JGR*, *78*, 4123. [5] R. Arvidson (1976) *Icarus*, *27*, 503. [6] J.-B. Madeleine et al. (2009) *Icarus*, *203*, 390. [7] B. Levrard et al. (2004) *Nature*, *431*, 1072. [8] M. Mellon et al. (2004) *Icarus*, *169*, 324. [9] K. Tanaka et al. (2003) *JGR*, *108*, 8043. [10] W. Hartmann (2005) *Icarus*, *174*, 294. [11] J. Laskar et al. (2004) *Icarus*, *170*, 343. [12] J. Head et al. (2009) *LPSC 40*, #1349.

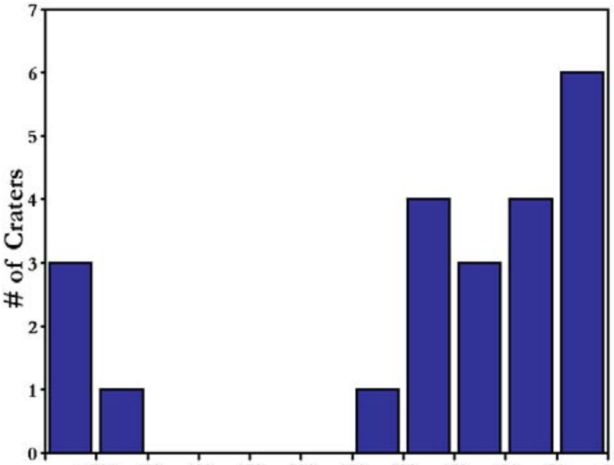

Figure 2 – A histogram of the best fit ages for the 22 pedestal surfaces counted on to date. These data show that Pd tend to be young – 17 of 22 have a best fit age of <200 Myr. More data, however, are needed to confirm this trend.

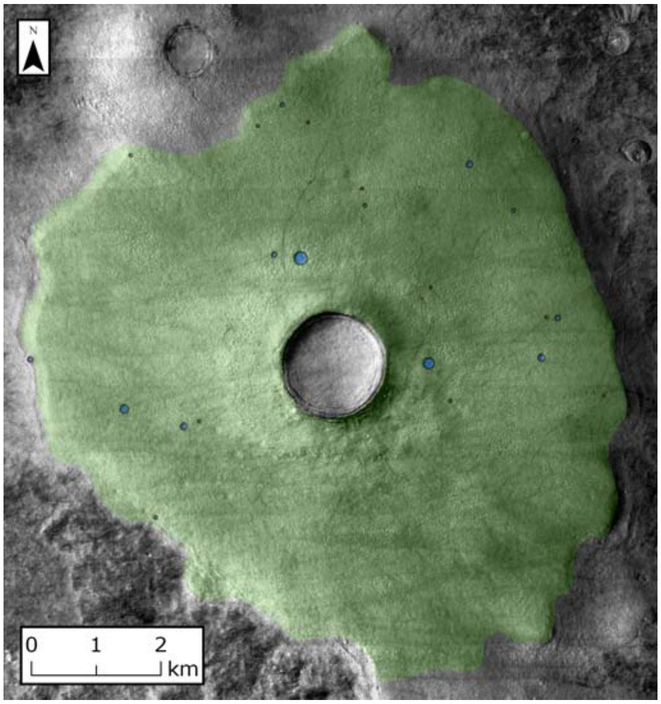

Figure 1 – A subscene of CTX image P22_009549_2289 (48.3°N, 8.2°E), showing crater #4 from Table 1. Craters (blue) were counted on the pedestal surface (green).

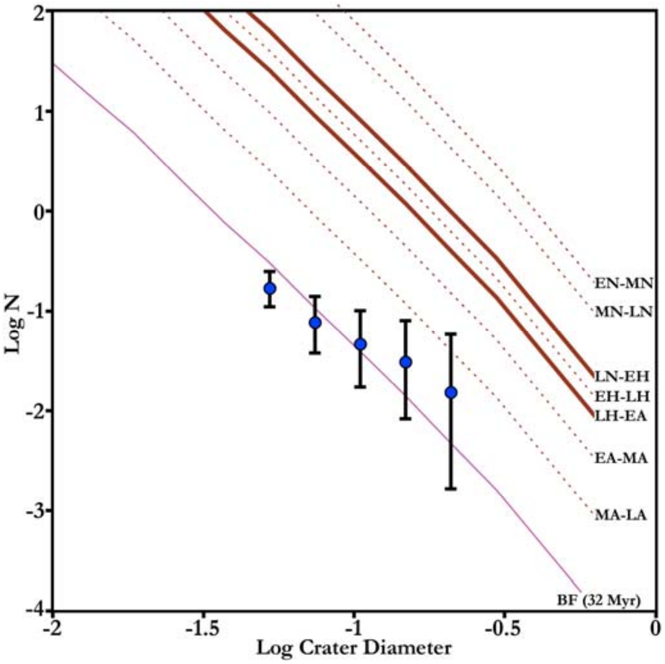

Figure 3 – The size frequency distribution for crater #4, shown in Fig. 1. The best fit age is ~30 Myr.