CONSTRAINTS ON THE TIMING OF OBLIQUITY VARIATIONS DURING THE AMAZONIAN FROM DATING OF GLACIAL-RELATED CONCENTRIC CRATER FILL DEPOSITS ON MARS. M. J. Beach and J. W. Head, Dept. of Geological Sciences, Brown University, Providence, RI 02912 (Michael_beach@brown.edu).

Introduction: Spin axis/orbital variations during the Amazonian prior to ~20 Ma ago are uncertain [1]; higher obliquities can lead to instability of polar ice deposits, forcing migration of water ice to non-polar latitudes [2-5]. As polar ice migrates from the poles, where it is unstable at higher than current obliquity, to the mid-latitudes, where it is more stable, it can be buried and preserved as debris-covered ice deposits [2]. When such deposits form within craters they produce Concentric Crater Fill (CCF) [6]. When periods of higher obliquity end, surface ice migrates back to the poles, leaving only the debris-covered CCF deposits. Dating of mid-latitude CCF deposits using superposed Crater Size-Frequency Distributions (CSFD) thus provides direct evidence for periods of high obliquity in the Amazonian. Active debris-covered glaciers would deform and destroy superposed craters. Very few deformed craters are observed, thus we interpret the population of undeformed craters to date the time of cessation of glaciation and glacial flow.

Here, we use the CSFD of undeformed superposed craters on the surface of CCF to estimate the timing of flow cessation of CCF deposits throughout the northern and southern hemisphere. With these data we address the following questions: (1) What is the timing of cessation of flow within CCF deposits? (2) Can the calculated ages of these deposits help constrain the nature of obliquity variations during the Amazonian?

Methods and Analysis: Identification of CCF deposits was performed using both the ~230 m/pixel THEMIS daytime IR Global Mosaic, as well as a CCF flow direction map from Dickson et al., 2012 [7]. Once CCF deposits were identified, ~5m/pixel CTX images were used for more detailed analysis of the individual deposits.

Only CCF deposits with pristine CCF flow lineation texture were considered for analysis here. Examples of CCF with excessive superposed Latitude Dependent Mantle (LDM) [8], which fills and obscures the CCF surface, were not considered for analysis.

Deposits were selected based on representative latitudinal and longitudinal coverage throughout the formation areas of CCF deposits in both hemispheres (Figure 1). The northern hemisphere has many fewer total craters due to Hesperian and Amazonian volcanic resurfacing and thus many fewer craters that contain CCF

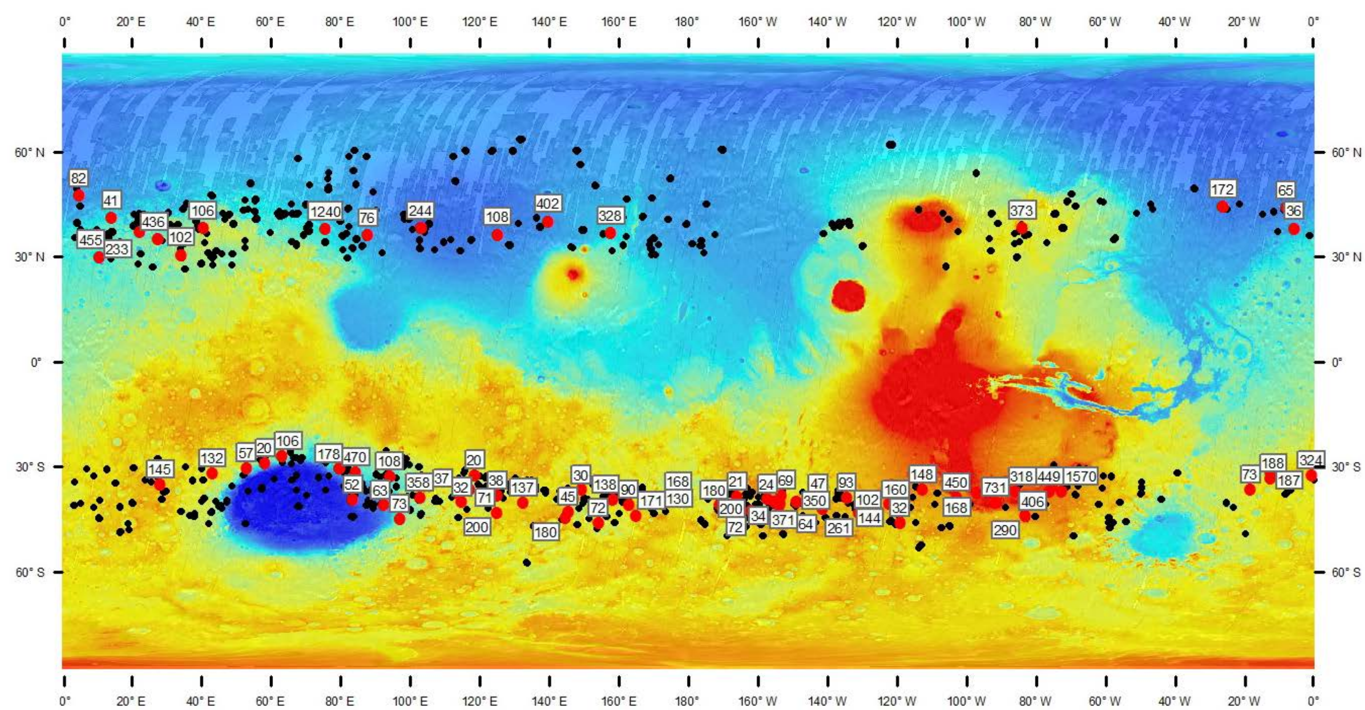

Figure 1. Age distribution map of CCF deposits in the Northern and Southern hemispheres. Basemap is ~230 m/pixel THEMIS day IR Global Mosaic with global MOLA topography overlain. Black dots are locations of CCF deposits from Dickson et al., 2012 [7]. Red dots are locations of CCF deposits dated by this study with the calculated ages (Myr) in white boxes.

deposits.

CCF CSFD were compared to the Neukum isochron [9] to calculate the timing of cessation of flow in each of the craters. Deposits were also given a "confidence rating" based on the shape of the CSFD relative to the ideal Neukum distribution. Deposits with a distribution of superposed crater sizes that are similar to the ideal fit are given a "linear" rating while distributions that differ from the ideal fit are given a "variable-slope" rating (e.g. dog-leg shape or other slope variability).

Results: Using these methods we selected eighty-one craters for analysis (Figure 1). The age distribution of the 64 dated CCF deposits in the Southern Hemisphere (SH) are shown in Figure 2 (blue). Of the 64 total SH deposits 47 (73%) have calculated ages less than 250 Ma, while 14 (22%) have ages between 250 and 500 Ma, and only 3 deposits (5%) have ages older than 500 Ma. Over half of the dated SH craters have a linear rating and in general, the linear rated CCF ages tend to correspond to the younger calculated ages.

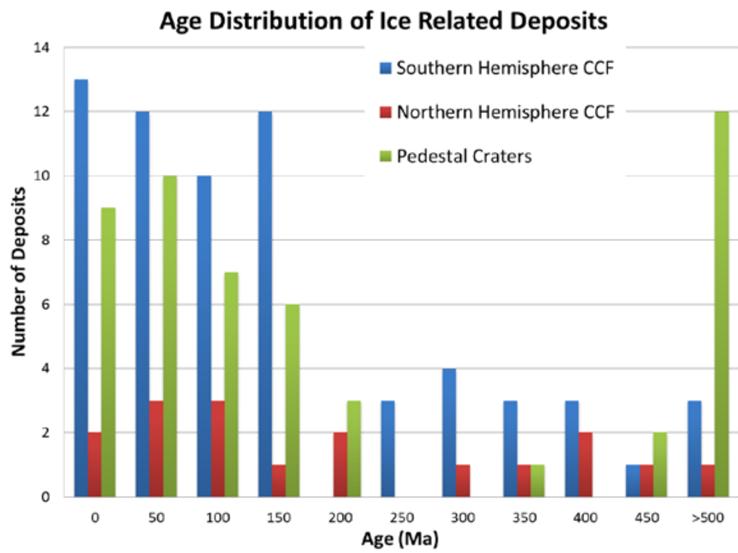

Figure 2. Age distribution histogram for the northern (red) and southern (blue) hemisphere dated CCF deposits (Figure 1, red dots) as well as Pedestal Crater ages [10] (green) for comparison with other ice-related deposits in the intercrater areas between CCF occurrences.

The age distribution for the 17 craters dated in the Northern Hemisphere (NH) are shown in Figure 2 (red). Here, 11 of the 17 deposits (65%) have calculated ages less than 250 Ma with 5 deposits (29%) between 250 and 500 Ma and one deposit (6%) older than 500 Ma. More than half of the NH deposits have a linear confidence rating, and the linear rating is again associated with younger ages.

Conclusions: The candidate population of possible Amazonian obliquity histories over the last 250 Myr is widely variable, and includes examples of both consistently high and consistently low obliquities [1]. The distribution of CCF ages analyzed in this study indicate that the majority of CCF deposits in the mid-latitudes in both the northern and southern hemisphere on Mars were deposited during the first of two periods from 0 to ~250 Myr. During the second period, from ~250 to 500 Myr ago, many fewer CCF deposits were formed. Deposits in the first period have a higher confidence due to the "linear" nature of the CSFD for most of the deposits there. Older deposits have more examples of "variable-slope" confidence level, which may be related to greater degradation of superposed craters through time either by resurfacing (dog-leg distributions) or by additions of secondary impact clusters producing anomalous distributions in part of the CSFD.

These results provide firm support for the conclusion that the actual obliquity history of the late Amazonian involved significant periods of time in which the obliquity was characterized by the intermediate values (~35 degrees), that have been shown to produce mid-latitude glaciation [10]. This result is consistent with dating of other ice-rich features, such as pedestal craters (green in Figure 2.) [11,12], which show a similar range of ages. Furthermore, the combination of this study and the Pedestal Craters study [11,12] may indicate more frequent periods of intermediate obliquity during the last 250 Myr as compared with earlier times (Figure 2).

References: [1] Laskar J. (2004) Icarus 170, 343-364; [2] Head J. W. and Marchant D. R. (2009) LPSC 40, 1356; [3] Mischna M. A. (2003) JGR 108, E6; [4] Levrard B. et al. (2004) Nature 431, 1072-1075; [5] Forget F. et al. (2006) Science 311, 368-371; [6] Levy J. S. et al. (2010) Icarus 209, 390-404; [7] Dickson J. L. et al. (2012) Icarus 219, 723-732; [8] Mustard J. F. (2001) Nature 412, 411 - 414; [9] Neukum G. et al. (2001) SSR 96, 55; [10] Madeleine J.B. et al. (2009) Icarus 203, 390-405; [11]Kadish S.J. (2012) Brown University Ph. D Thesis, 211-288; [12] Kadish S.J. and Head J.W. (2011) Icarus 215, 34.