CONCENTRIC CRATER FILL RIDGE SPACING AS A MARTIAN PALEOCLIMATE ARCHIVE

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Introduction: Concentric Crater Fill (CCF) deposits span a range of latitudes (Fig. 1) and encompass multiple morphological subclasses of lineated crater fill [1, 2]. The formation and evolution of CCF remains an open area of research. Numerous formation mechanisms have been proposed for CCF and related features [e.g. 3-7]. The formation mechanism that is most supported by evidence is formation by the accumulation of ice on steep slopes of crater walls which subsequently flows down into the crater and is covered by debris [6-8]. The convergence of these flows forms the broadly circular shape of "classic" CCF [8].

CCF deposits have been interpreted along with lobate debris aprons, lineated valley fill, and tropical mountain glaciers as evidence for the accumulation of ice deposits in the recent Amazonian [e.g. 1, 2, 3, 6, 8]. However, uncertainty in the obliquity of Mars before ~20 Ma inhibits our ability to understand the climatic history of the Amazonian [9]. Thus, CCF represents an important possible constraint on previous ice deposits and their evolution.

Cold-based debris-covered glaciers have been considered for their potential as climate archives [8, 10], but CCF features may be affected by both climate forcings and geometric flow conditions [10]. For CCF deposits, the concentric ridges (Fig. 2) have variable spacing but it is not known what dictates the specific geometry of individual CCF ridges. As an exploratory study to assess these deposits and their signatures as martian paleoclimate archives, we analyze the extent to which flow geometry and climate conditions control the spacing between ridges.

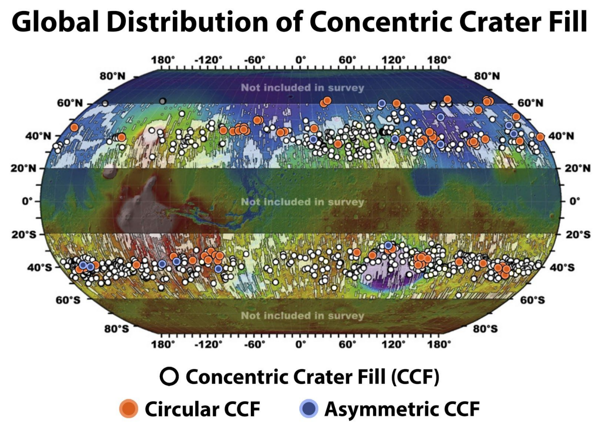

Fig. 1. Map of the global distribution of CCF as identified by [2] specifying the CCF craters used in this study (orange, blue). Adapted from [2].

Methods: It has been noted that "concentric" crater fill is not always circularly concentric and may exhibit directional flow [1, 2]. In this work, we examined the catalog of 2,176 Mars Reconnaissance Orbiter Context Camera (CTX) images containing CCF deposits [2] and identify craters which contained circular or near-circular CCF deposits. Additional criteria for the selection of a crater is that the CCF must be fully within the frame of its CTX image, large enough for ridges to be resolved, without a central peak, and free from occluding features such as debris or superposed craters. For each host crater meeting the criteria (Fig. 1), transects of pixel brightness were taken radially outward from the center of the CCF deposit to its edge at intervals of 45° (Fig. 2). An algorithm to find the troughs in each pixel brightness curve was used to

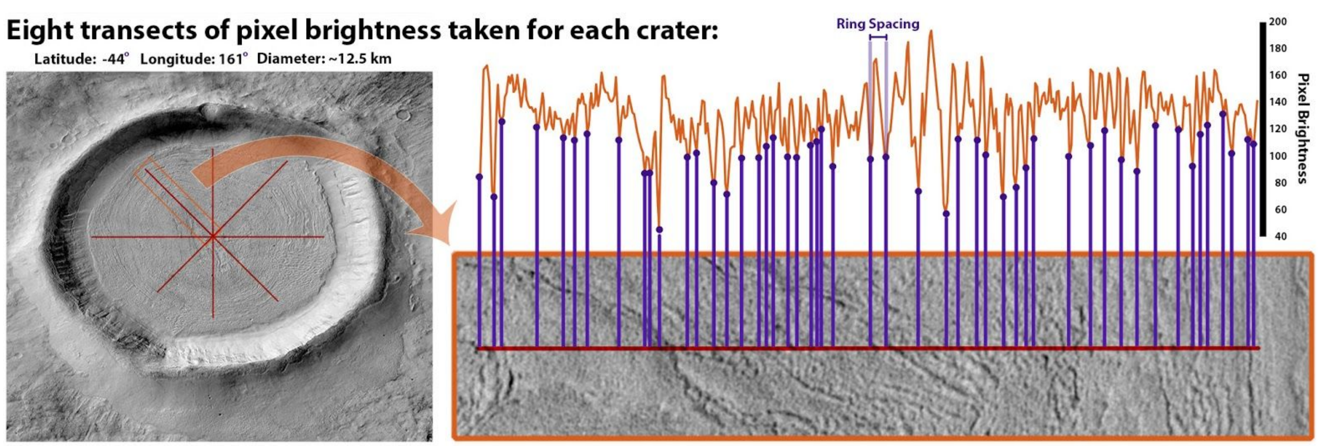

Fig. 2. Example of the extraction of pixel brightness transects and CCF ridge spacing from CTX image B12_014159_1360_XN_44S198W. Locations of pixel transects are shown in red. The troughs (purple dots) of the pixel brightness curve (orange) correlate with the dark ridges of the CCF deposit at the transect shown.

calculate the spacing between the ridges as a function of distance from the center of the crater, based on the fixed pixel width from the database entry of the associated CTX image (Fig. 2). The ridge spacing was normalized by the largest spacing within each transect to compare patterns in relative spacing between craters with different accumulation and ablation rates. This process was repeated for thirteen non-circular asymmetric "concentric" crater fill deposits with transects taken from the central part of the CCF flow to the crater wall.

Results: A total of 604 pixel brightness transects were used to calculate the normalized ridge spacing curves for our CCF sample (Fig. 3); without the normalization, nearly all ridge spacing values fell within a consistent range less than 80m. There appears to be greater variability in ridge spacing close to the crater center. While there appears to be some amount of correlation between curves within latitude bins regardless of the CCF geometry, a more robust analysis is performed next.

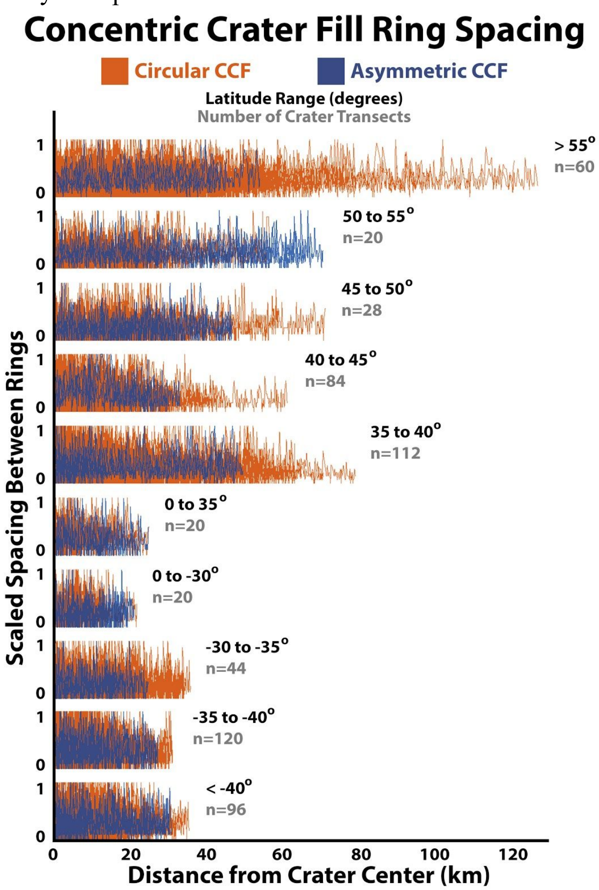

Fig 3. Normalized curves of ridge spacing plotted against distance from the crater center and binned by latitude for circular and asymmetric CCF.

Using a two dimensional cross-correlation analysis, each transect ridge spacing curve is compared to every other ridge spacing curve for further comparison with the difference in latitude for those transects (Fig. 4).

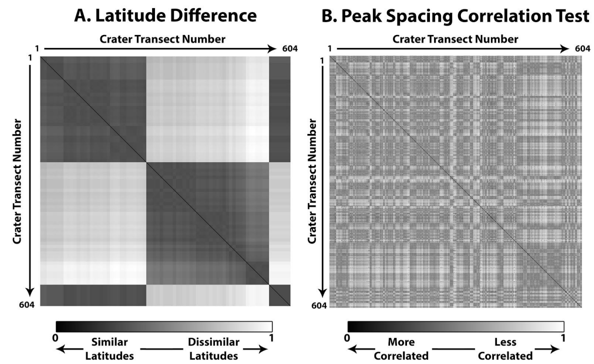

Fig 4. Each pixel is the comparison of two transects. A: Scaled absolute value of latitude difference of transect CTX images. B: Scaled 2-D cross-correlation.

The correlation analysis shows that the hemispheric latitude difference (large scale checkerboard pattern in Fig. 4A) is not significant in predicting the correlation between two transect ridge spacing curves. However, the fine scale "plaid" pattern from smaller latitude differences (Fig. 4A) is observed in the results of the correlation test (Fig. 4B). This holds true for the last 52 rows and columns in Fig. 4 which contain the asymmetric CCF transects.

Discussion: Correlation analysis of ridge spacing in CCF indicate that CCF may be sensitive to local climates but largely symmetric about the equator. This is consistent with previous work on CCF directional flow [2]. Thus, CCF ridge spacing should be considered as a potential archive for local paleoclimate conditions, but the implications for global paleoclimate conditions need more analysis. Additionally, this work suggests that central lobe convergence on circular CCF does not significantly affect the ridge spacing when compared to asymmetric CCF deposits. This prompts a need for future work to extend this analysis to non-circular CCF deposits and other ice-related features including lobate debris aprons, lineated valley fill and tropical mountain glaciers for comparison with the results presented here.

References: [1] Levy, J., J. Head, D. Marchant, (2010), *Icarus*, 209, 390-404. [2] Dickson, J., J. Head, C. Fassett, (2012), *Icarus*, 219, 723-732. [3] Head, J. et al., (2010), *Earth and Planet. Sci. Letters*, 294, 306-320. [4] Squyres, S., (1979), *J. Geophys. Res.*, 84, 8087-8096. [5] Squyres, S., M. Carr, (1986), *Science*, 231, 249-252. [6] Kreslavsky, M., J. Head, (2006), *Meteorit. Planet. Sci.*, 41, 1633-1646. [7] Levy, J., J. Head, D. Marchant. (2009), *Icarus*, 202, 462-476. [8] Fastook, J., J. Head, (2014), *Planet. and Space Science*, 91, 60-76. [9] Laskar, J. et al., (2004), *Icarus*, 170, 343-364. [10] Mackay, S., D. Marchant, J. Lamp, J. Head, (2014), *J. Geophys. Res: Earth Surface*, 119, 2505-2540.