

RING-MOLD CRATERS ON LINEATED VALLEY FILL, LOBATE DEBRIS APRONS, AND CONCENTRIC CRATER FILL ON MARS: IMPLICATIONS FOR NEAR-SURFACE STRUCTURE, COMPOSITION, AND AGE. A. Kress and J. W. Head, Department of Geological Sciences, Brown University, Providence, RI, 02912 (Ailish_Kress@brown.edu).

Introduction: Ring-mold craters [1] comprise a suite of craters with unusual morphologies that have as yet been identified only on lineated valley fill (LVF), lobate debris aprons (LDA), and concentric crater fill (CCF) in the northern and southern mid-latitudes of Mars. Ring-mold craters (RMCs) are generally rimless and consist of an outer annular trough surrounding a variety of interior morphologies. They have been interpreted as indicators of buried ice in the substrate at the time of formation, supporting a debris-covered glacier mode of origin for these types of deposits [1].

Previous analyses of RMCs were conducted on MOC and THEMIS data [1-4]. We expand investigations of these unusual craters to CTX data for comparison of the size-frequency distribution of the crater populations and derived ages of LVF, LDA and CCF in the Deuteronilus Mensae region (centered at around $\sim 40\text{N}$, 20E). In conducting these studies, we use the model of [1] that RMCs form by impacting into glacial ice buried beneath a relatively thin debris cover. Impacting into nearly pure ice causes the unusual morphologies and likely also causes crater diameters to be at least two times greater than for craters with otherwise identical impact parameters in basalt, as indicated by experimental results [1, 5-7]

Observations: The principal studies of [1] and [2] were of RMCs on MOC images in Mamers Valles (Fig. 1). Mamers Valles is a $\sim 950\text{-km}$ -long valley just south of Deuteronilus Mensae, $\sim 5\text{-}10\text{ km}$ wide in its southern regions and $\sim 20\text{-}30\text{ km}$ wide in its northern regions (“downstream” of the $> 100\text{ km}$ crater it intersects). The narrower, southern parts of the valley are characteristically filled with LVF and the wider, northern parts with linear LDA that meet in the center of the valley and in some cases begin to flow down the local topographic gradient [8]. MOC images analyzed have resolutions of $\sim 3\text{-}7\text{ m/pixel}$, widths of $\sim 3\text{-}4\text{ km}$ and lengths of tens of km, and they cover a cumulative area of $\sim 2,500\text{ km}^2$ (Fig. 1).

For comparison, we looked at a CTX image that covers the area where Mamers Valles transitions from $5\text{-}10\text{ km}$ wide to $20\text{-}30\text{ km}$ wide (Fig. 1). The CTX image has a resolution of nearly 6 m/pixel , a width of $\sim 30\text{ km}$ and a length of $\sim 140\text{ km}$, giving wall-to-wall coverage of Mamers Valles at that location. The area of Mamers Valles covered in the image and used for crater counting is $\sim 1,100\text{ km}^2$ (Fig. 1).

We looked at CTX data of the T-shaped valley of [9], centered at $\sim 37.5\text{N}$, 24.2E , $\sim 200\text{ km}$ east of Mamers Valles and a $\sim 16\text{-km}$ -diameter crater at $\sim 41.0\text{N}$, 14.2E ,

in western Deuteronilus Mensae (Fig. 1). Resolution of these images was also $\sim 6\text{ m/pixel}$ and there was complete CTX coverage for both areas. The areas used for crater counting are $\sim 1,400\text{ km}^2$ and $\sim 100\text{ km}^2$, respectively (Fig. 1).

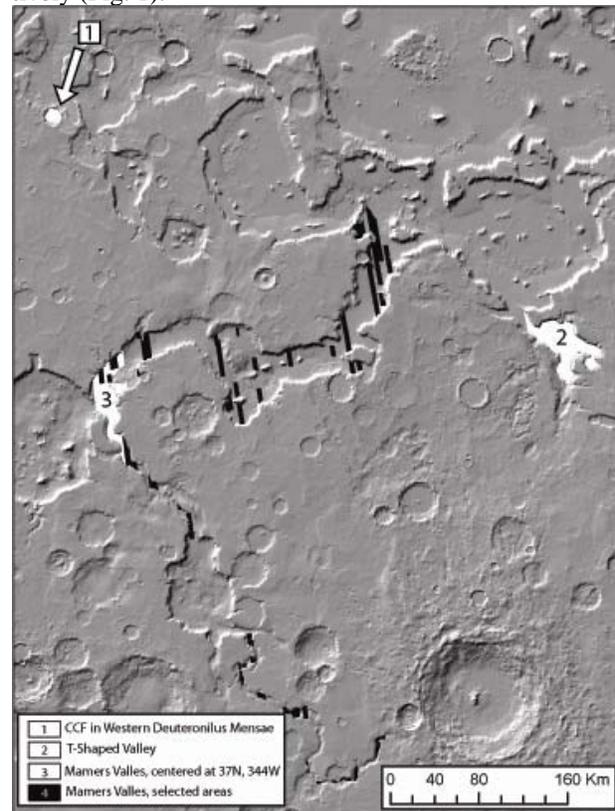


Figure 1. Southern Deuteronilus Mensae and Mamers Valles. 1) A CCF-filled crater in Deuteronilus Mensae (white shape is the count area on CTX). 2) The T-shaped valley, filled with LDA and LVF (CTX). 3) Western portion of Mamers Valles, narrow portion filled with LVF, wider portions with LDA (CTX). 4) Mamers Valles MOC coverage; black areas represent count areas.

Crater counts and size-frequency distributions: We performed crater counts on each of these datasets. On MOC data, craters were identified as either an RMC or a bowl-shaped crater [2]. On the more recent CTX counts we identified craters as a type of RMC (multi-ring, pit type, central plateau, central mound, or isolated knob) or degraded or fresh bowl-shaped crater [1]. RMCs are on average larger than bowl-shaped craters (mean RMC diameter is $\sim 106\text{ m}$; mean bowl-shaped crater diameter is $\sim 80\text{ m}$). Within the RMC population, there is no clear correlation of morphology with diameter. Degraded bowl-shaped craters are in general larger than fresh bowl-shaped craters.

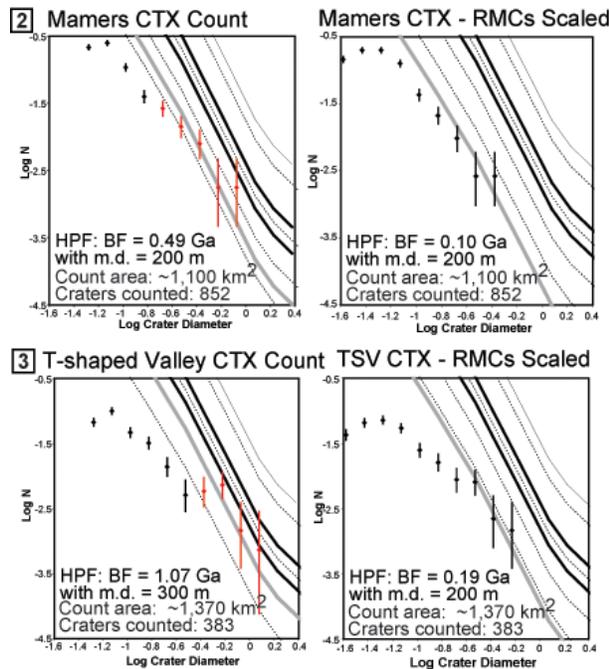


Figure 2. Crater size-frequency distribution and isochron-fitting, using the Hartmann production function [10]. The two thick black lines represent the Noachian-Hesperian and the Hesperian-Amazonian boundaries, respectively. BF = best fit and m.d. = minimum diameter used to calculate the BF. (Left) The thick grey line represents the best-fitting isochron to the data; red signifies bins that are > 87.5% RMCs. (Right) Size-frequency distributions with RMCs scaled by a factor of 2.

We observed more large craters on the CTX images than on the MOC in Mamers Valles and larger craters in general on the CTX data, due to the far greater lateral coverage of the CTX versus the MOC data. The largest crater identified on MOC data in Mamers Valles is a ~750-m-diameter RMC whereas the largest on CTX data is an RMC ~1,200 m in diameter, located in the T-shaped valley. Assuming the ice impact model, bowl-shaped craters may be used to estimate sublimation lag thickness [1]. The average diameter of all bowl-shaped craters in the four counts detailed above is ~80 m, corresponding to an upper estimate of ~16 m of lag thickness.

We used both the Hartmann and Neukum production functions to analyze these crater populations. We show the results using the Hartmann production function [10] (Fig. 2). We fit isochrons to each crater population, obtaining ages of 1) 0.29 Ga for the CCF in the crater in western Deuteronilus Mensae (CTX), 2) 1.07 Ga for the LDA/LVF in the T-shaped valley (CTX), 3) 0.49 Ga for the LDA/LVF in western Mamers Valles (CTX), and 4) 0.27 Ga for selected areas throughout Mamers Valles (MOC).

Discussion and Implications: Many factors cause uncertainty in the crater-count-derived ages (e.g., determining true crater diameter; crater loss by degradation of difficulty of detection due to the rough nature of the surface texture), and the fact that RMC diameters may be two or more times the size of comparable craters in ba-

salt or silicate regolith, if we assume the ice impact model [1]. For example, if the RMCs are indeed larger due to the physical properties of ice, then the ages derived above are likely erroneously old. Given that the size-frequency distributions we obtain from crater counts on LDA, LVF, and CCF are characterized by a shift toward older ages for larger crater sizes – precisely those bins that are dominantly RMCs (> 87.5%; red bins in Fig. 2) – we hypothesize that this shoulder in the size-frequency distribution is the effect of RMCs having comparably larger diameters than bowl-shaped craters because they form in ice [1].

To a first order, we try to evaluate the effects of the RMCs as a larger-diameter crater population by scaling the RMC diameters, using experimentally-found size-difference factors. Experimental studies of ice impacts provide scaling factors of ~2-6 for crater diameters in ice versus basalt [5-7]. We use a factor of 2 as a conservative estimate and obtain significantly different size-frequency distributions (Fig. 2). For example, with the Mamers Valles and T-shaped Valley CTX counts, this operation produces ages ~1/5 of the unscaled populations (~0.10 Ga for Mamers and ~0.19 for the T-shaped valley) as well as size-frequency distributions that show a much better fit to isochrons.

Sublimation lag thickness estimates from bowl-shaped crater depths are consistent with both ice stability models for these latitudes [11-12] as well as recent SHARAD measurements in Deuteronilus Mensae [13]. Stability models determine that ice is not stable at the surface at present [11] but that a sublimation lag could protect ice beneath it for significant periods of time [12]. SHARAD should resolve vertical changes of 20 m or greater, but it sees no surface layer on the deposits, so the lag must be fairly thin [13].

Conclusions: Analysis of the impact crater population on LDA/LVF/CCF shows that RMCs can be used to detect the presence of buried ice, to help confirm a debris-covered glacier origin for LDA/LVF/CCF, and to estimate the thickness of the overlying sublimating lag. The morphology of RMCs influences crater size-frequency distribution estimates, yielding artificially old ages, which can potentially be adjusted using information from cratering experiments.

References: [1] Kress A. and Head J. W. (2008) *GRL*, 35, L23206. [2] Kress A. et al. (2008) *LPSC 39*, Abstract #1273. [3] Mangold N. (2003) *JGR*, 108(E4), 8021. [4] McConnell B. S. (2007) *Mars* 7, Abstract #3261. [5] Kato M. et al (1995) *Icarus*, 113, 423-441. [6] Cintala M et al. (1985) *LPS XVI*, 131-132. [7] Lange M. and Ahrens T. (1987) *Icarus*, 69, 506-518. [8] Kress A. et al. (2006) *LPSC 37*, Abstract #1323. [9] Head J. W. et al. (2006), *EPSL*, 241, 663. [10] Hartmann W. (2005) *Icarus*, 174, 294-320. [11] Mellon M. and Jakosky B. (1995) *JGR*, 100, 11781-11799. [12] Helbert J. et al (2009) *LPSC 40*, this volume. [13] Plaut J. et al (2008) *GRL*, in press.