

PITTED CRATER FLOORS IN THE CIRCUM-HELLAS REGION, MARS: NEW INSIGHTS INTO POSSIBLE GLACIAL ORIGINS FROM PIT DEPTH MEASUREMENTS. B. D. Boatwright and J. W. Head, Dept. of Earth, Environmental, and Planetary Sciences, Brown University, Providence, RI 02912 USA (benjamin_boatwright@brown.edu).

Introduction and previous work: We have recently described two instances of Noachian-aged craters in the circum-Hellas highlands of Mars that contained evidence of past fluvial and lacustrine activity but were hydrologically isolated from their surroundings [1-2]. These “closed-source drainage basins,” or CSDBs, were distinct from previously described open- and closed-basin lakes on Mars [3-4]. Evidence of remnant cold-based glacial morphologies in these craters led us to hypothesize that top-down melting of cold-based crater wall glaciers had occurred in these locations, potentially providing observational evidence in support of climate models that predict a Noachian Mars dominated by an adiabatic cooling effect and altitude-dependent accumulation of snow and ice in the highlands [5-9].

In searching for additional examples of these features, we found that several nearby craters contained pitted floors with steep walls consisting of light-toned layered deposits. Previous studies of circum-Hellas pitted crater floors and layered deposits suggested that the pits may have formed through the removal of ice masses or other volatile-rich materials within Noachian lacustrine sediments [10-13]. Because the pits are irregularly shaped and offset relative to crater centers, they are unlikely to be related to central pits [e.g. 14] or other remnant impact structures [12].

We recently described three pitted crater floors that contained linear ridges radiating from pit boundaries (Fig. 1 inset) and interpreted them as either transverse aeolian ridges (TARs) or small inverted fluvial channels [2,15]. However, aeolian modification is unlikely to have been effective at removing material from the pits given their depth and steep walls [10]. A fluvial origin for the linear ridges would be more consistent with melting of pit-forming ice deposits leading to proglacial fluvial activity [15]. Thus, the formation of pitted crater floors and linear radiating ridges could have occurred under the same conditions as proglacial fluvial channel and paleolake formation in CSDBs during episodes of top-down glacial melting in the Noachian [16].

Here, we report new measurements of pitted crater floor depths and their correlations with crater depth-diameter ratio and elevation. We consider how our new observations inform our understanding of pitted crater floor formation and its potential relationship to Noachian highland glaciation.

Methods: To measure pit depths, we chose a subset of Noachian-aged pitted crater floors that had been independently verified by at least two previous studies [10-13], resulting in 27 craters with diameters ranging from 41–172 km. We removed four craters whose pits

did not have clearly defined boundaries. Pit depths for the remaining 23 craters were measured in ArcMap by overlaying 1x1 km grids of MOLA elevation values on the pitted areas. A 5 km exterior buffer was drawn around the pit boundaries to obtain an average pit exterior elevation, and the same method was used to obtain an average elevation for the pit interiors. These two values were then subtracted to obtain an average pit depth. For Terby crater, we purposely avoided including the “benches” on the northern side of the pit and instead only measured the depth of the pit relative to the surrounding crater floor to the south.

Pit depth measurements: The depths of the pits we measured range from ~50–470 m with a median depth of ~215 m (Fig. 1). Among the morphometric parameters we compared, crater depth-diameter ratio and elevation were weakly correlated with pit depth (Fig. 2) with R^2 values of 0.22 and 0.13, respectively. Craters with smaller depth-diameter ratios generally had shallower pits, while craters at lower elevation generally had deeper pits compared to those at higher elevation. Pit depth was uncorrelated with crater diameter ($R^2 < 0.01$).

Lower depth-diameter ratios are typically correlated with a greater extent of crater floor infilling and rim lowering through redistribution of sediment into crater floors [e.g. 17-19]. If the pits formed soon after crater emplacement, then a similar trend of sediment infilling and shallowing should have affected the pits; if the pits were relatively young features, then we would not necessarily expect the same correlation. Thus, the pits appear to be ancient features, consistent with the findings of past studies [10-13]. If the crater floor pits formed through the removal of ice or volatile-rich deposits, then higher mean annual temperatures deeper within the Hellas basin [5] may have promoted more effective removal, leading to the observed elevation-dependent effect in our depth measurements.

Discussion and conclusions: The formation of pitted crater floors in the circum-Hellas region of Mars has been ascribed to the removal of glacial ice or volatile-rich deposits as one possible origin [10-13], an interpretation for which our observations lend support. We observed linear radiating ridges surrounding pits in three crater floors (Fig. 1 inset) that may have arisen as pit-forming ice deposits in crater floors melted, leading to proglacial fluvial channel formation [2,15]. The initial emplacement of the ice may have occurred through cold-based glacial flows and concentric crater fills [e.g. 20] or pingo-like extrusions of volatile-rich materials [e.g. 21]. Subsequent ice removal would have involved an initial melting phase to form proglacial fluvial

channels with a combination of melting and ablation possible thereafter as the ice level fell below the elevation of the pit boundary.

Our new measurements of 23 crater floor pit depths from MOLA global topography have revealed correlations between pit depth and crater depth-diameter ratio as well as crater floor elevation. The pit depths are consistent with the depths of ~100s of m of ice in Amazonian concentric crater fills [20] and predicted ice thicknesses for Noachian highland glaciation [8]. Likewise, pit formation relatively soon after crater emplacement would match the predicted timing of highland glaciation in the Noachian [6-8,22-23]. Finally, the elevation of most pitted crater floors (except Terby) falls near or above the predicted equilibrium line altitude (ELA) of +1 km where Noachian glacial flow and melting is anticipated [5-9].

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