YOUNG VALLEY NETWORKS ON MARS: PERSISTENT FLOW OF WATER IN LYOT CRATER, AN AMAZONIAN IMPACT BASIN MICROENVIRONMENT.

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Introduction: While Amazonian fluvial landforms are not abundant on Mars, remote sensing data have revealed details regarding the role of ice in non-polar regions in the Amazonian. Evidence includes 1) deposits interpreted to be remnants of cold-based glaciers at low- and mid-latitudes [1-6]; 2) mantling deposits interpreted to be a desiccating layer of ground ice [7-8]; 3) laterally-expansive units of water ice in the top-meter in the mid- and high-latitudes in each hemisphere [9-10]; and 4) viscous flow features interpreted to be the product of glacial-like flow along steep valley/crater walls [11-12].

Under peak conditions, the surface of Mars straddles the triple point of water, which motivated us to investigate the most-likely locations/microclimates for melting of these surface/near-surface ice features [13-14]. Large-scale impact craters at low elevations and mid-latitudes provide particularly optimal conditions, with 1) relatively high surface pressure, 2) reasonable solor insolation conditions and 3) the possibility of residual thermal anomalies from the impact event itself.

Lyot Crater, a ~215 km peak-ring impact basin in the northern lowlands of Mars (50°N, 30°E) was the first target of our survey as it provides an environment that meets all of these constraints. We analyzed recently obtained CTX data to document evidence of remnant glacial deposits and surface features that appear indicative of melting and drainage.

Description: The floor of Lyot shows evidence for several sinuous valley networks that have been incised exclusively into an expansive stippled mantling unit that blankets the majority of the Lyot crater floor. Twenty separate networks are observed in CTX and THEMIS data, 15 of which occur in the eastern half of Lyot. The valleys range in length from short, 2 km long, isolated valleys to 50 km long networks which have widths averaging ~250 m. Valley floors are smooth at CTX resolution, in contrast to the adjacent stippled mantling unit. Profiles extracted from the Mars Orbiter Laser Altimeter (MOLA) data set show that the valleys follow the local topographic gradient downslope. Regional slopes in the down-valley direction range from 0.36° to 6.12°, but most networks trend around the median for all valleys of 1.93°. Valleys start at a wide range of elevations, from ~-2883 m to ~-5684 m (mean = -3803 m). Valley walls appear uniformly fresh and no impact craters or ejecta blankets are observed on any of the valley floors. Valleys emanate from the upslope margins of the stippled mantling unit and from the termini of lobate debris aprons (LDAs), which are interpreted to be ice-rich [15]. Several of the valleys terminate with depositional fans. The valleys are superposed by the smoother mantling deposits observed on the flanks of isolated mesas, implying that valley formation occurred after the emplacement of the stippled mantling unit but before the deposition of the more-localized smooth mantling unit.

Chronology: It was observed in Viking data that the ejecta of Lyot Crater superposes Amazonian-aged smooth plains material in the northern lowlands (*Aps* in [16]), implying that Lyot is Amazonian itself. This stratigraphic relationship is corroborated by crater size-frequency measurements that we performed on Lyot using HRSC data, which yield a formation age of Early Amazonian in the Neukum [17] and Hartmann [18] isochron systems (~3.3 Gyr and ~1.6 Gyr, respectively). Thus, we are confident that all fluvial activity within Lyot Crater occurred well after the cessation of major ancient valley network activity on Mars at the Hesperian/Noachian boundary [19]. We also interpret the valleys of Lyot to be older than Late Amazonian gullies, which have formed within the last several million years [20], as the valleys are often superposed by a smoother mantling unit.

Tighter constraints for the formation of the Lyot valley networks can be obtained by analyzing the stippled mantling unit. Since we interpret the valleys as incising this unit, an accurate age for the stippled mantling unit is a maximum age for valley formation. CTX imagery is the only data set that adequately resolves the stippled mantling unit in sufficient detail and spatial extent to perform accurate crater counts. Therefore we constrained our mapping of the unit to the three overlapping CTX frames in the eastern half of Lyot.

We calculated the age for the stippled mantling unit using both the Neukum [17] and Hartmann [18] systems. In each system our counts yield a Middle Amazonian age (~1.5 Gyr in the Neukum [17] system and ~0.8 Gyr in the Hartmann [18] system). This crater size-frequency determination is well-matched by production model isochrons, and this young age is consistent with other stratigraphic constraints [16]. Thus, we are confident that the valleys found in Lyot are Middle Amazonian or younger. The difference in crater frequency between Lyot and its floor deposits implies that a geologically significant period of time (0.8-1.8 Gy) elapsed between basin formation and the emplacement of the stippled mantling unit.

Formation: Thermal anomalies from an impact the size of Lyot are unlikely to have persisted for the ~0.8 - ~1.9 Gyr. between the Lyot impact event and the emplacement of the stippled mantling unit [21]. Therefore, we explore the possibility that the energy for melting necessary at Lyot could have been provided by obliquity excursions in the Amazonian.

Numerical modelling has shown that Mars has undergone significant orbital excursions within the Amazonian, resulting in periods of high-obliquity [22]. At high obliquity, models predict an increase in peak surface temperature at the latitude of Lyot crater (50°N) [23-24]. For example, at 60° obliquity, Mischna et al. [23] found a maximum diurnally-averaged temperature at 50°N at Ls=90 would be ~260°K, compared to ~220°K under current orbital conditions (obliquity = 25°), meaning that peak surface temperatures would be above 273°K for significant periods of time. Given these results and the relatively high surface pressure at Lyot crater, surface conditions above the triple point of water are likely to have been achieved in the Middle to Late Amazonian at this location. Ice-deposits are observed elsewhere on Mars where conditions above the triple point are likely [e.g. 4-6], which prompted us to conduct a survey for fluvial features similar to those observed in Lyot. In a companion paper [25], we present the results of this survey of other fluvial channels found in association with remnant ice-deposits. This survey suggests that the valley networks on the floor of Lyot are among the most expansive examples of surface melting of ice deposits in the Middle to Late Amazonian.

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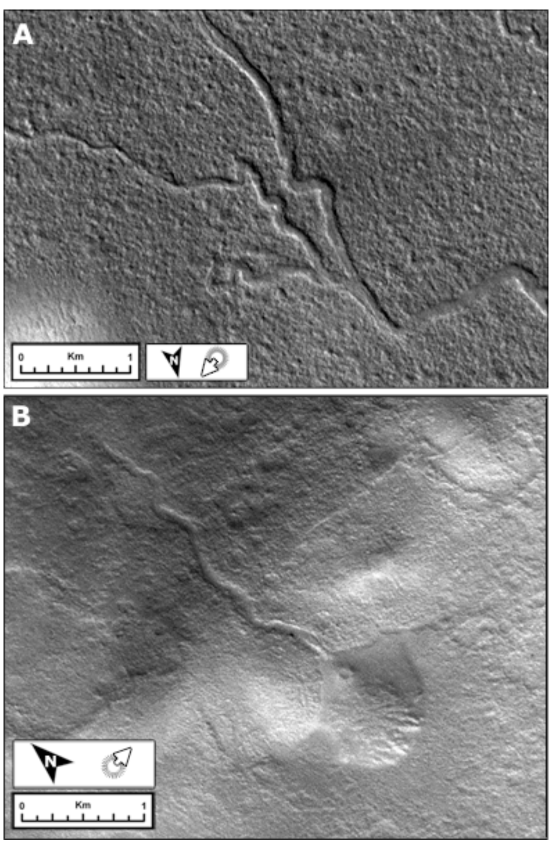

Figure 1. (A) Lyot Crater valley networks. Sinuous channels are observed to merge and trend downslope to the lower-right of the frame. Valleys incise a stippled mantling unit that we have dated as Mid-Amazonian in age. CTX orbit P04_002560_2309. (B) Example of a depositional fan associated with a young valley network. Inferred flow direction is from north to south. CTX orbit P04_002494_2310.

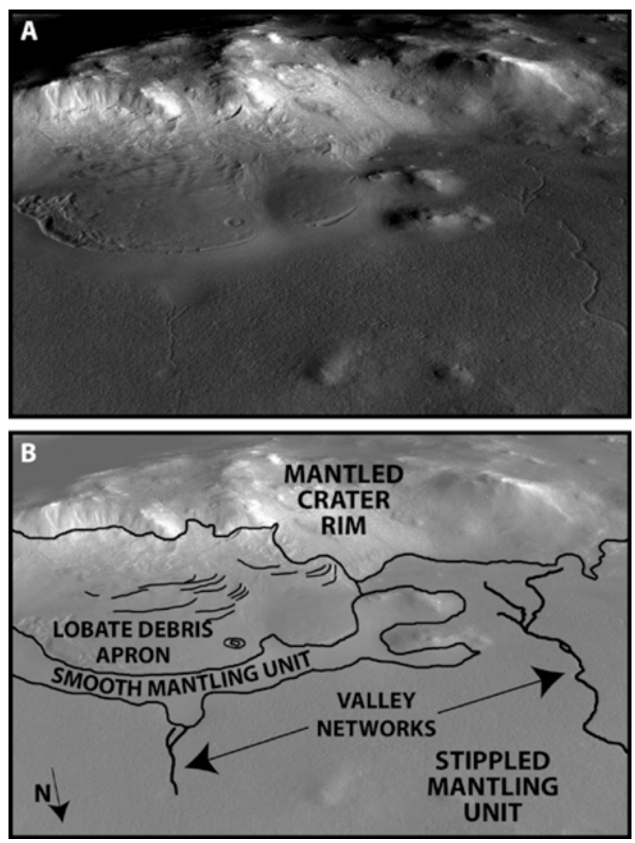

Figure 2. (A) Perspective view of the interior of the southern rim of Lyot Crater. Valley networks incise the stippled mantling unit on the floor of the crater. Valleys follow the topographic gradient downslope from the rim towards the center of the crater. Scene is ~27 km across along the crater rim. CTX orbit P04_002560_2309 draped over MOLA topography. (B) Annotated sketch map draped over the same perspective view.