**Introduction:** Impact craters are ubiquitous on most planetary surfaces and provide enclosed topography that is readily exploited by hydrologic activity to form lake basins. Crater-hosted lake basins are observed on Earth [e.g., 1-3], and are abundant on Mars [e.g., 4-7]. A defining geomorphic feature of impact craters is the rim, which sits elevated above the background terrain [8-10], typically by about \(1.5–2\%\) of the crater diameter on Mars [11]. For tens-of-kilometer-scale craters, as is typical for crater-hosted lakes on Mars [4-6], this represents relief on the order of hundreds of meters.

The majority of crater-hosted paleolakes on Mars have incised inlet valleys that allowed flow of water into the basin. An obvious question thus arises: how was the topographic barrier of the crater rim originally breached by an inlet valley(s) to allow water to flow into the basin? This question is critical for understanding the formation and evolution of crater-hosted lakes on Mars (and Earth); however, it remains a poorly constrained problem.

Past work on the Holden crater inlet valley indicates the inlet breach formed due to high-energy overflow flooding from a temporary lake in Uzboi Vallis [12-14]. In contrast, preliminary numerical modeling by [15] suggests that inlet valley breaching most likely occurs via ongoing impact cratering that works to remove the topographic barrier of the crater rim. This problem is also somewhat analogous to the classic geomorphology problem of forming transverse valleys that cut across mountain chains on Earth [e.g., 16,17].

**Mechanisms for Inlet Valley Formation:** Based on past work, our expectations for this problem, and analogy with formation of transverse valleys on Earth, we propose four mechanisms for the development of crater lake inlet valleys (Fig. 1). These hypothesized mechanisms are an attempt at a framework within which to consider this problem, and we are entirely open to the possibility of additional, or combinations of, formation mechanisms.

The first two mechanisms are similar, and involve removal of the topographic barrier of the crater rim through: (1) erosion and lowering of the crater rim at a rate higher than erosion of the surrounding terrain (Fig. 1a); or (2) deposition and raising of the exterior terrain to the elevation of the crater rim (Fig. 1b). In either case, a new, or previously existing, fluvial system would then be able to flow into the crater unimpeded [e.g., 15].

The third mechanism involves incision of the crater wall, initiated by surface runoff (from rainfall, snowmelt, or groundwater exfiltration). With ongoing runoff and incision, retreat of the valley headwall could be sufficient to establish a hydraulic connection with the exterior terrain, capturing any upstream drainage [e.g., 17].

In the final mechanism, if the topography upslope of the crater rim is a closed basin, upstream fluvial activity would lead to ponding behind the natural dam formed by the rim. Sufficient ponding could overtop the rim and erode through it as the temporary upstream lake drained via a dam-breach flood [e.g., 12-14,18,19].

![Schematic cartoons of a crater rim cross-section outlining four hypothesized mechanisms for inlet valley formation.](image-url)
Preliminary Study: We present preliminary results from a study to test between the four proposed mechanisms for a martian closed-basin lake contained in a ~73 km diameter impact crater (Fig. 2). We used two CTX [20] DEMs, produced using the NASA Ames Stereo Pipeline [21, 22], and MOLA topography [23] to extract a longitudinal profile of the inlet valley (Fig. 2b), a profile across the inlet valley breach (Fig. 2c), and average topography from 10 radial profiles (Fig. 2d).

From these data, we note three primary observations: (1) there is no evidence of high-standing crater rim topography near the breach (Fig. 2d; green dashed line is at expected crater rim position based on estimated crater diameter); (2) the inlet breach is not located at the lowest elevation location along the crater rim/margin (Fig. 2c); and (3) there is only one inlet valley, and no obvious evidence for dissection of the interior crater wall aside from this inlet. Of the four mechanisms outlined above, we suggest our observations are most consistent with formation via rim erosion and/or upstream infilling.

Discussion: Several hundred crater-hosted paleolake basins exist on Mars, and they provide some of the best constraints on the activity of liquid water on the early martian surface [e.g., 4-7]. It has also been hypothesized that impact craters had a strong control on the fluvial evolution of early Mars by acting as a threshold and control for regional landscape integration [e.g., 6, 24-26]. A first step in forming a valley-fed, crater-hosted paleolake is establishing a hydraulic connection between the basin interior and exterior terrain, a process that remains poorly constrained. Here, and in planned future work, we aim to test competing hypotheses for how this process might have occurred, and whether there is a dominant mechanism(s) for this phenomenon across the planet.