THE IMPORTANCE OF LAKE OVERFLOW FLOODS FOR EARLY MARTIAN LANDSCAPE EVOLUTION: INSIGHTS FROM LICUS VALLIS. T. A. Goudge[1] and C. I. Fassett[2], [1]Jackson School of Geosciences, UT Austin, [2]NASA Marshall Space Flight Center. (Contact: tgoudge@jsg.utexas.edu)

Introduction: Open-basin lake outlet valleys are incised when water breaches the basin-confining topography and overflows. Outlet valleys record this flooding event and provide insight into how the lake and surrounding terrain evolved over time [1–5]. Here we present a study of the paleolake outlet Licus Vallis, a >350 km long, >2 km wide, >100 m deep valley that heads at the outlet breach of an ~30 km diameter impact crater (**Fig. 1**). Multiple geomorphic features of this valley system suggest it records a more complex evolution than formation from a single lake overflow flood. This provides unique insight into the paleohydrology of lakes on early Mars, as we can make inferences beyond the most recent phase of activity.

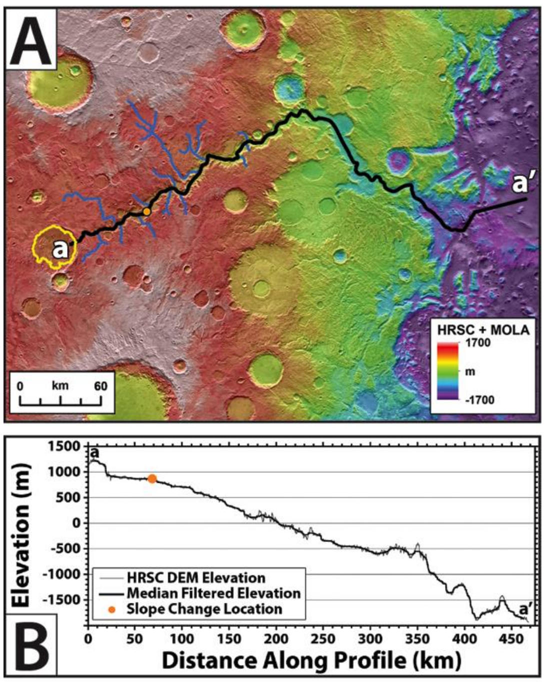

Fig. 1. ***(A)*** *Overview of the Licus Vallis system. Main valley shown in black and tributary valleys shown in blue. Outline of open-basin lake at the head of the valley shown in yellow. Orange circle shows location of major slope change. HRSC DEM mosaic and MOLA gridded topography overlain on the ~100 m/pixel THEMIS global daytime infrared mosaic. North is right.* ***(B)*** *Profile a–a' along Licus Vallis. Note the change in valley slope at ~70 km (orange circle). Profile location shown in (A). Moving window of 10 km used for median filter. Elevation data are from HRSC DEM mosaic.*

Methods: We studied the topography and geomorphology of the Licus Vallis system using: CTX images [6]; the THEMIS ~100 m/pixel global daytime infrared mosaic [7,8]; a 75 m/pixel mosaic of six HRSC DEMs [9,10]; and a CTX-derived DEM produced using the NASA Ames Stereo Pipeline [11–13]. Centerlines of Licus Vallis and contributing tributary valleys were mapped, and longitudinal profiles extracted from HRSC and/or CTX DEMs.

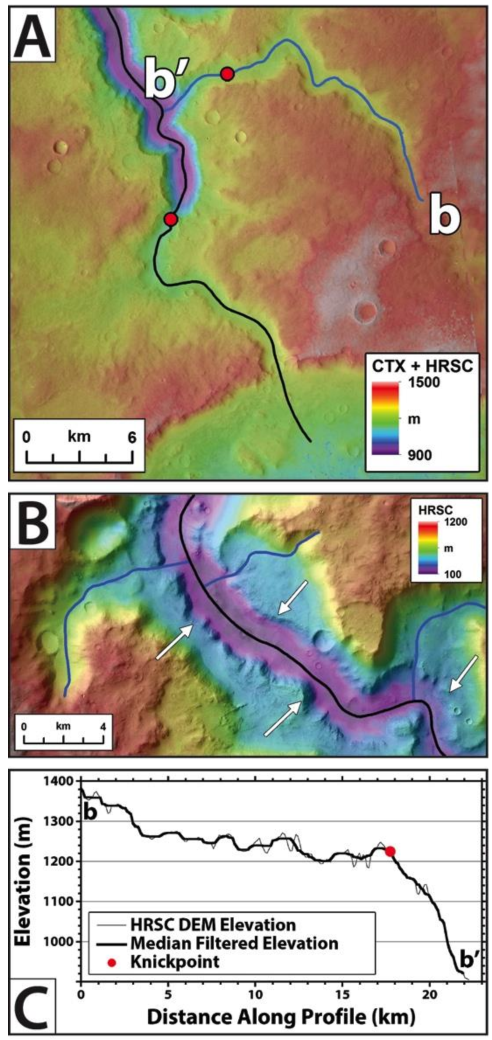

Fig. 2. ***(A)*** *Major knickpoint (red circle) in Licus Vallis near the head of the valley. HRSC DEM mosaic and CTX DEM overlain on a CTX mosaic.* ***(B)*** *Paired terraces (white arrows) within Licus Vallis. HRSC DEM mosaic overlain on CTX.* ***(C)*** *Profile b–b' along an upstream tributary to Licus Vallis. Profile location shown in part (A). Moving window of 1 km used for median filter. Elevation data are from HRSC DEM mosaic.*

Results: The Licus Vallis longitudinal profile has an abrupt change in slope at ~70 km that separates two reaches with approximately constant slopes of ~1.4x10^{-3} (upstream) and ~6.4x10^{-3} (downstream; **Fig. 1**). At ~20 km along the profile there is a major knickpoint where the valley drops ~200 m in elevation over ~2 km (**Fig. 2A**). Downstream of approximately the slope change location, Licus Vallis has paired interior terraces that can be continuously mapped for tens of km (**Fig. 2B**).

Licus Vallis has 13 main tributary valleys, which start just downstream of the major knickpoint (**Fig. 2A**). Longitudinal profiles of the tributary valleys show that the 10 most upstream tributary valleys have knickpoints along their length, near the topographic level of the Licus Vallis rim (**Fig. 1C**). We estimated the total retreat distance of each knickpoint from the Licus Vallis centerline along the tributary valley centerline. Knickpoint retreat distances are positively correlated with the position of the tributary junction, with the largest retreat distances for downstream tributary valleys (**Fig. 3**).

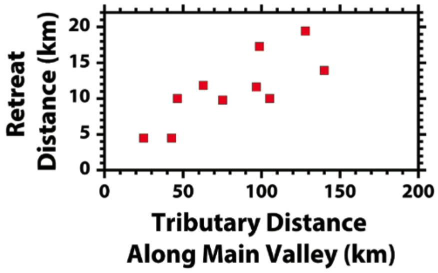

Fig. 3. *Licus Vallis tributary valley knickpoint retreat versus tributary junction distance along main valley*.

Evolution of Licus Vallis: The topography and geomorphology of Licus Vallis show several signs of disequilibrium that suggest the system did not adjust to stable fluvial boundary conditions. Taken together, we interpret these features as recording two discrete episodes of valley incision – one to form the steeper downstream portion of the valley, and one to form the shallower upstream portion as well as the interior valley bounded by the paired terraces.

Given the large size of the valley, we hypothesize that the first episode of incision was driven by overflow flooding of a large paleolake contained within a now degraded inter-crater basin (**Fig. 4**). This is supported by the observation that valley networks upstream of Licus Vallis do not extend below approximately the 1400 m MOLA contour (**Fig. 4**, white arrows), consistent with the presence of a standing body of water in this region. The 1400 m contour above Licus Vallis is not closed, but the topography responsible for enclosing the basin to the north would likely have been significantly eroded/obscured during the overflow flood event.

Subsequently, overflow flooding from the lake currently at the head of the valley pirated the pre-existing Licus Vallis, forming a major knickpoint, establishing the upstream section of the valley at a lower slope, and incising an interior valley bounded by paired terraces.

Overflow Floods vs. Background Activity: Given our hypothesized scenario for the evolution of Licus Vallis, the regional tributary valleys can offer insight into how background fluvial incision compared to incision from lake overflow flooding. We note that knickpoints in downstream tributary valleys have retreated more than knickpoints in upstream tributary valleys (**Fig. 3**). This is consistent with the tributary valley knickpoints forming from wave of incision [14–16] that incompletely swept up Licus Vallis as incision rates from overflow flooding outpaced rates from background surface runoff. Comparing retreat distances between the upstream tributary valley knickpoints and the knickpoint in the main valley suggests retreat rates at least 4x larger in the main valley. This is likely to be a significant underestimate as the tributaries were likely active longer than the catastrophic lake overflow flood [4,5]. This conclusion points to the importance of lake overflow floods in setting the pace of landscape evolution on early Mars and in shaping the martian surface [e.g., 2,3].

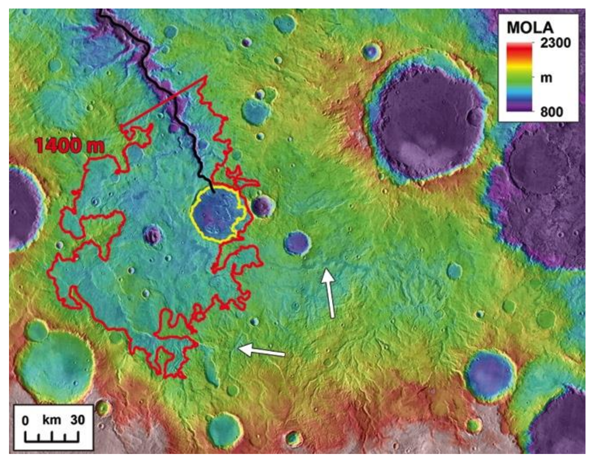

Fig. 4. *Potential inter-crater basin that sourced overflow flooding responsible for incision of downstream portion of Licus Vallis. Main valley shown in black, open-basin lake at the head of the valley shown in yellow, and MOLA contour at 1400 m shown in red. MOLA gridded topography overlain on the ~100 m/pixel THEMIS global daytime infrared mosaic. North is up*

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