

**UBIQUITY OF UNINCISED MARTIAN DELTAS HOLDS CLUES TO UNDERSTANDING HYDROLOGY ON MARS.** Vincent A. Soldano<sup>1</sup>, Scott W. McCoy<sup>1</sup>, Wendy M. Calvin<sup>1</sup> and Kenneth D. Adams<sup>2</sup>, <sup>1</sup>Department of Geological Science and Engineering, University of Nevada – Reno, [vsoldano@nevada.unr.edu](mailto:vsoldano@nevada.unr.edu). <sup>2</sup>Desert Research Institute.

**Introduction:** Deltas are created when rivers laden with sediment debouch into lakes or oceans. Gently sloping subaerial delta tops give way to steep subaqueous slopes, such that the level of standing water is marked by this abrupt slope break (topset-foreset transition in Figure 1). If lake levels fall below the topset-foreset transition, subsequent river flows will incise a new channel that smoothly enters the lake. On Earth, which has a persistent hydrologic cycle, such fluvial incision is particularly evident in the deep trenches cutting deltas in dry paleo lakes or desiccating modern lakes (Figure 1).

On Mars, over a hundred step-fronted landforms have been observed both in impact craters and along the topographic boundary separating the southern highlands from the northern lowlands [e. g. 1-3]. These landforms have been interpreted to be deltas and thus suggest a past in which water flowed across the Martian surface. A casual look at these deltas reveals that many are not incised like their Earth counterparts (Figure 1, inset), suggesting that water discharge in Martian rivers must have stopped before lake levels fell.

In this study, we examined previously compiled locations of Martian deltas [1-4] to determine the relative level of incision. The classification of Martian deltas based on their level of fluvial incision allows constraints to be placed on the activity of the Martian hydrologic cycle through time.

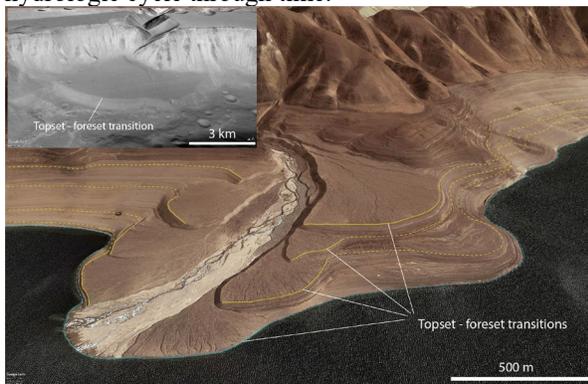


Figure 1: Illustration of key delta features in an oblique view of Gyesar Co lake on the Tibetan Plateau. Note the deep fluvial incision in the upper delta surface caused by fluvial erosion keeping pace with the progressive drop in lake level. This strongly contrasts with the unincised nature of a Martian delta in Shalbatana Vallis shown in the inset.

**Methods:** We created a database from previously published locations of Martian step-fronted deltas and compiled a library of associated CTX and HiRISE

imagery. We then classified each delta by three levels of fluvial incision, as illustrated in Figure 2 (on the next page). Level 1 - pristine delta with no incision, Level 2 - moderately incised by fluvial-looking trenches, and Level 3 - heavily incised. To visualize the distribution of deltas and delta incision globally we used JMARS and ArcGIS, including layers for channel networks and major geologic boundaries from [2 and 5]. Next, we classified the channels connected to the deltas into three groups based on length between headwaters and outlet (small (< 10 km), medium (10 km to 48 km), and large (> 48 km)). Finally, we categorized each delta by the relative age of the unit in which it occurs.

**Results:** Martian deltas are predominately *not* incised by fluvial erosion, a trend opposite to that on Earth. Of the 159 deltas observed, 107 are pristine, 32 exhibit sparse fluvial erosion, and 20 are heavily incised (Fig. 3). All heavily incised deltas were connected to a channel greater than 10 km in length (Fig. 4). Most of the deltas can be found in the Middle Noachian highland unit, and all the heavily incised deltas are in this unit (Fig. 5). Figure 6 illustrates these trends in map view.

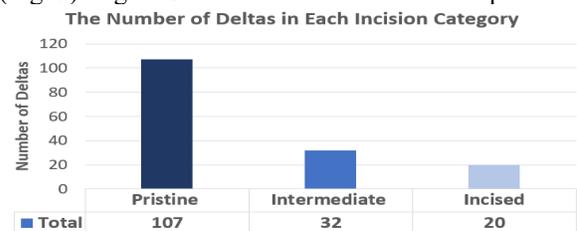


Figure 3: Histogram of deltas by degree of incision.

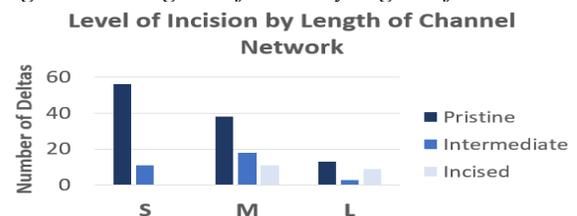


Figure 4: Histogram of number of deltas in each incision class and their associated channel network length, S (< 10 km), M (10 km to 48 km), L (> 48 km).

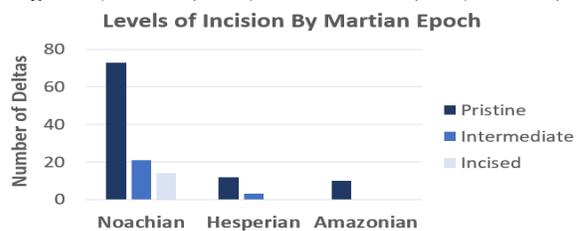


Figure 5: Histogram of number of deltas by incision type and associated age.

**Discussion:** Most of the deltas on Mars are in a pristine state, with little to no evidence of post-depositional fluvial erosion. This is in strong contrast to deltas on Earth, indicating a very different closeout of the Martian hydrologic cycle responsible for delta formation. To preserve Martian deltas as observed, the water discharge responsible for delta formation must have abruptly stopped, or at least dropped below that needed to transport sediment, before lake levels began to fall. This observation provides a new constraint that valid hydrologic models must meet, that is, the upstream hydrologic system must cease transporting sediment, before lakes begin lowering. Not all deltas are unincised, however. The minority class of heavily incised deltas were fed by networks that were at least 10 km in length and are found in the Middle Noachian

highland unit, offering evidence that this was the most hydrologically active time in Martian history and that the persistence of river flows in large channels in the Noachian were potentially the most Earth like.

**Acknowledgements:** This work was funded by NASA Solar System Workings # 80NSSC19K0165.

**References:** [1] Di Achille, G., & Hynek, B. M. (2010). *Nature Geoscience*, 3(7), 459–463. [2] Goudge, T. A., Morgan, A. M., Stucky de Quay, G., & Fassett, C. I. (2021). *Nature*, 597(7878), 645–649. [3] Rivera-Hernández, F., & Palucis, M. C. (2019). *Geophysical Research Letters*, 46(15), 8689–8699. [4] Wilson, S. A., Morgan, A. M., Howard, A. D., & Grant, J. A. (2021). *Geophysical Research Letters*, 48(4), e2020GL091653 [5] Tanaka, K. L. (2014). *Geologic Map of Mars* (USGS Scientific Investigations Map)

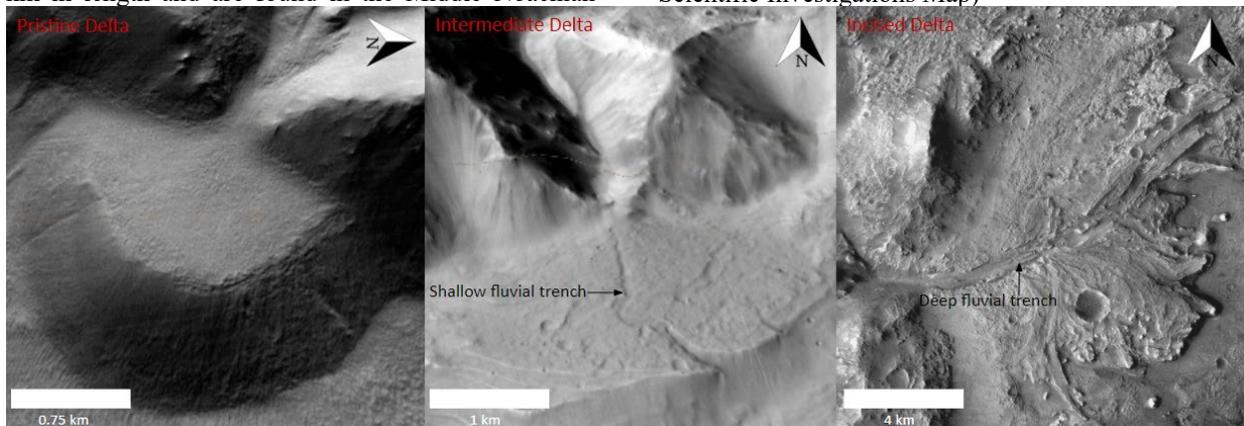
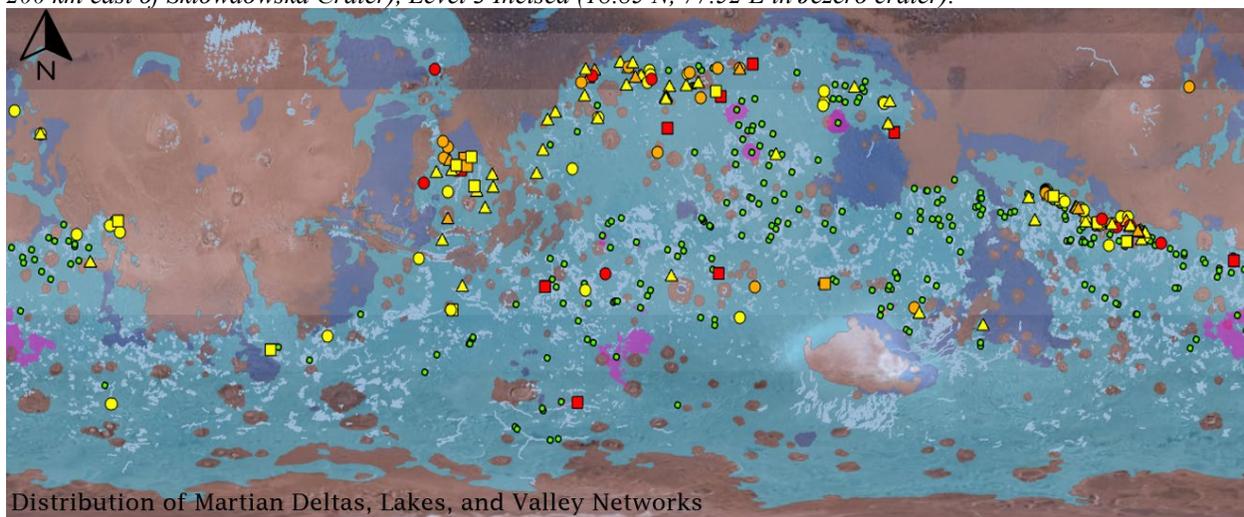


Figure 2: Example CTX images of Martian deltas with varying levels of incision. From left to right: Level 1 Pristine (31.95 N, 20.65 E in unnamed crater, west of Cerulli Crater), Level 2 Intermediate (33.39 N, 2.45 E in unnamed crater 200 km east of Sklowdowska Crater), Level 3 Incised (18.85 N, 77.52 E in Jezero crater).



Distribution of Martian Deltas, Lakes, and Valley Networks

<b>Deltas</b>			<b>Lakes and Terrain</b>	
▲ Pristine, Small	▲ Moderate, Small	▲ Incised, Small	■ Noachian - Older	■ Early Hesperian - Older
● Pristine, Medium	● Moderate, Med	● Incised, Medium	● Ancient Crater Lakes	■ Terrain 45S - 45N
■ Pristine, Large	■ Moderate, Large	■ Incised, Large	■ Crater Lake Breach	■ Terrain 30S - 30N
			— Valley Network	

Figure 6: Global map of deltas classified by degree of incision, associated channel length, and geologic age.