NEW GLOBAL MAP OF FLUVIAL SINUOUS RIDGES ON MARS: EVIDENCE FOR LARGE, GLOBALLY-DISTRIBUTED NOACHIAN/HESPERIAN DEPOSITIONAL RIVERS. J. L. Dickson[1], M. P. Lamb[1], R. M. E. Williams[2], A. T. Hayden[1] and W. W. Fischer[1], [1]California Institute of Technology, Division of Geological and Planetary Sciences, 1200 E. California Blvd., Pasadena, CA, 91125,USA (jdickson@caltech.edu). [2]Planetary Science Institute, Tucson, AZ, USA.

Introduction: Sedimentary rocks are the archives of environmental history and, on Earth, their study has led to our current understanding of the evolution of the atmosphere, oceans, continents and life [1]. On Mars, the global distribution of eroded rivers [2-3] is far better characterized than their associated sedimentary deposits. While orbital data [e.g. 4] and rover-based observations [e.g. 6] now reveal a sedimentary record in local traps (craters), the global catalog of depositional river systems from early Mars is unknown.

We used a new CTX global mosaic to map the distribution of fluvial sinuous ridges (FSRs) on Mars. FSRs [e.g. 7] are landforms that have the appearance of river channels or river channel belts in planform but stand as topographic highs. These landforms are likely a key indicator of the occurrence of depositional basins that have yet to be analyzed systematically on global scale. In this contribution we documented key distributive relationships, including (1) latitude, (2) elevation, (3) host terrain age, (4) and proximity to valley networks. Further, we documented the range of morphologies that these features exhibit, reflecting a diversity in surface processes and host terrain properties that are important for proper classification.

We found evidence for large, depositional rivers and basins on Noachian Mars, even in terrain outside of craters, that may be the downstream sediment sinks of sediment sourced from valley networks during the Noachian.

Methods: We used the global CTX mosaic of Mars from the Caltech Murray Lab as the foundation for mapping FSRs on Mars [8]. Our survey was systematically conducted across the entire planet at ~35 m/px with closer inspection of specific features of interest at full CTX resolution. Our survey, thus, omitted hyper-localized ridges that have been documented with HiRISE [9], and focused on more volumetrically substantial ridges comparable in scale to valley networks. Criteria for FSRs on Mars (Fig. 1) included (1) sinuosity/meandering, (2) topographic trends along regional topography/do not cross drainage divides, (3) branching/anabranching patterns, (4) generally flat crests, and (5) spatial association with sinuous valley features. With regard to context, we interpreted sinuous ridges being exhumed from sedimentary sequences to be FSRs. Like local crater basins, broader basins that we predicted would yield river deposits are likely to have been sites for subsequent emplacement of sedimentary and volcanic units, thus our catalog is likely a minimum of river deposits on Mars as many

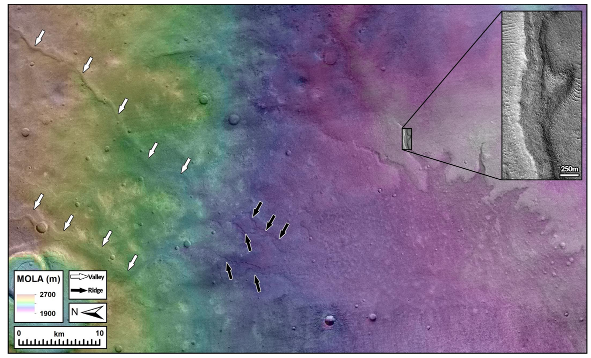

Figure 1. Valley networks (white arrows) that transition to FSRs (black arrows) within intercrater plains. CTX mosaic overlain by MOLA topography northwest of Argyre and southeast of Thaumasia (-67.6°E, 43.1°S). Sinuous ridges comprise the margins of a low-albedo unit, down-gradient from well-incised valley networks trending from Thaumasia. HiRISE inset: ESP_050997_1365.

have not been exhumed. We included sinuous ridges interpreted as eskers [e.g. 10] as a subset of our survey, but did not include ridges within volcanic terrain with clear flank flow morphologies [11].

Ridges that satisfied our morphologic criteria for inclusion as fluvial sinuous ridge deposits were evaluated based on several properties, including: (1) qualitative size, (2) length, (3) stream order, (3) regional inversion (i.e., are other nearby landforms inverted), (4) elevation (extracted from MOLA after mapping), (5) local context (e.g., within craters or intercrater plains).

Locations of regional inversion were included to provide contextual information. There are regions of Mars where entire landscapes have been inverted, most noticeably craters that host fill material that resisted the erosion that removed the crater's rim.

Results: *Morphology.* We identified 68 separate networks of FSRs with stream orders from 1 to 4 (Fig. 2). FSRs on Mars exhibit a range of morphologies consistent with local studies [17]. FSRs are flat-crested at CTX scale with the exception of large ridge networks previously interpreted as eskers [24-26]. Branching and anabranching ridges are common across the southern highlands. Ridges are typically < 20km in length. While outlier examples were observed, the majority of FSRs are found in closely-associated networks and in contact with broader flat sedimentary units undergoing erosion.

Geologic context. Nearly all FSRs occur within terrain that has valley networks within their regional watersheds (Fig. 1). In specific terrains, ridges ema

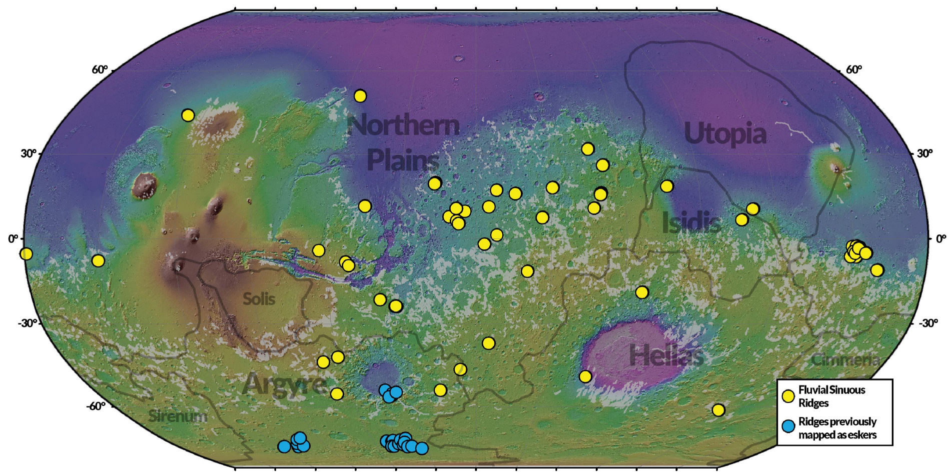

Figure 2. Global distribution of FSRs on Mars. Mapped valley networks [2] are shown in gray. All FSRs not previously mapped as eskers can be traced upgradient to ancient valley networks, (Figure 1).

nate directly from valley networks. FSRs are frequently found in proximity to but not in contact with inverted craters. These are regions where (1) the deposits that created the ridges may not be directly related to the process that filled the craters (infilling by a more regional process [28-29]), or (2) the inverted craters were once in contact with river systems but the evidence is missing due to erosion.

Elevation. FSRs broadly occur at lower elevations than valley networks and open basin lakes and comparable elevations to closed basin lakes. Most of the FSR networks mapped (61/68, 89.7%) occur within poorly defined intercrater plains. The densest concentration of FSRs are in the Medusa Fossae Formation (MFF), within the greater Aeolis region, which contributes to the general low-elevation trend of FSRs.

Age. FSRs are not observed in young terrain anywhere on Mars. Almost all FSRs are found within terrain mapped as Late Noachian or Early Hesperian [30]. These ages all coincide with buffered crater counting measurements of cessation ages for valley networks [2]. The two exceptions are the MFF, whose age is challenging to ascertain [7, 15-16], and, based on stratigraphic relationships, could be considerably older than ages from its retained crater population [15], and the ridges of the Dorsa Argentea Formation (DAF) [10]. The DAF unit that hosts the sinuous ridges is mapped as early Hesperian [13], while the superposed crater population of the ridges themselves is consistent with a Late-Noachian/Early-Hesperian age [17].

Discussion: FSRs show spatial/temporal patterns at the global scale that indicate that they are closely associated with valley networks on Mars. In specific cases, ridges are interpreted as directly in line with deposits from valley networks upslope. These examples provide the most compelling evidence that FSRs are sedimentary records of large depositional rivers on Mars. While FSRs are most densely concentrated in well-studied regions like Arabia Terra and the MFF, our mapping shows that FSRs are a global feature within exposed Noachian/Hesperian terrain.

FSRs are found in the same regions and at lower elevations than valley networks, consistent with them being sites of river deposits, though their precise composition is not known: some may represent channel fill from a non-fluvial process (e.g. eolian, volcanic). Likewise, FSRs are only found within host units [30] that have ages reasonably interpreted to be at or before the cessation of major valley network activity [3] on Mars. These relationships hold true within all of the major drainage basins on Mars that host Noachian terrain.

FSRs are a globally distributed feature that has potential to record conditions at the time of valley network activity, perhaps akin to terrestrial sedimentary basins. The exact composition of any specific ridge will require more study, as any topographic low can become a trap or funnel for deposits not genetically related to the river that carved the valley. But the wealth of examples of ridges directly connected to valley networks (Fig. 1) and ridges that are found within existing valleys provide strong evidence that FSRs represent a sedimentary archive of river processes on early Mars.

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