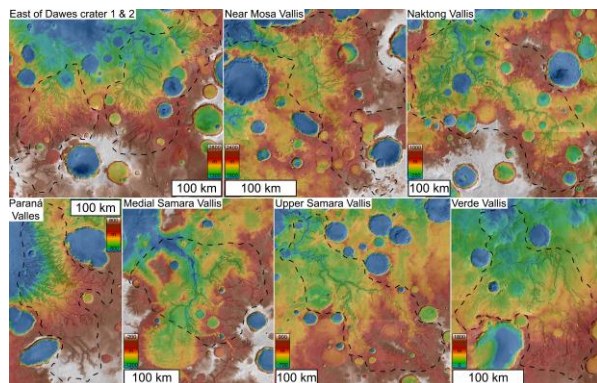**EVIDENCE FOR PROLONGED AND EPISODIC FLUVIAL ACTIVITY RECORDED IN MARTIAN VALLEY NETWORK MORPHOLOGY.**

A. M. Morgan[1,2]*, [1]Planetary Science Institute, 1700 East Fort Lowell, Tucson, AZ, [2]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, DC, *amorgan@psi.edu.

Motivation: Martian valley networks are branching, quasi-dendritic valleys that provide compelling evidence for a climate on early Mars that supported liquid water on or near the surface. This geomorphological record is difficult to reconcile with constraints imposed by climate models, which tend to support a dominantly cold climate with a mean annual temperature < 273 K [1]. Estimates of valley eroded volume provide constraints on the necessary magnitudes of water runoff [e.g., 2-7], but the climatic implications of these volume estimates remain debated [e.g., 3,4].

Many valley networks are within much larger eroded watersheds [e.g., Figs. 1-2]. The valley networks may thus represent only the final episode(s) of fluvial activity. Most previous estimates of valley network volume [e.g., 2-6] have not included these watersheds; the total erosion necessary to form these landscapes thus remains unquantified. Estimates of runoff magnitude, and inferences on cumulative water volumes and the prevailing climate [e.g., 3,4], may significantly undervalue the total amount of fluvial erosion and thus the surface liquid water inventory on early Mars.

Watershed versus valley network volumes: For a study set of valleys (Fig 1.), eroded volumes are calculated for both the sharply incised valley network and the broader eroded watershed. This is done using a natural neighbor interpolation of digitized points inferred to represent the pre-eroded surface (see Bashkaus Valles case study, Figs. 2-3). The difference between the interpolated surface and the current topography is the eroded volume.
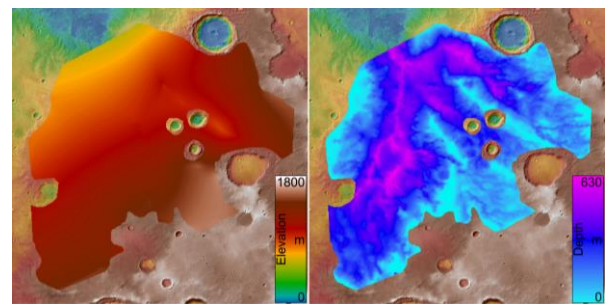
Watershed eroded volumes are up to 20x greater than their respective valley networks. This suggests that the cumulative runoff magnitudes volumes on early Mars far exceed those found by [3]. As suggested by [4], such values require a hydrologic cycle to replenish highland water sources.
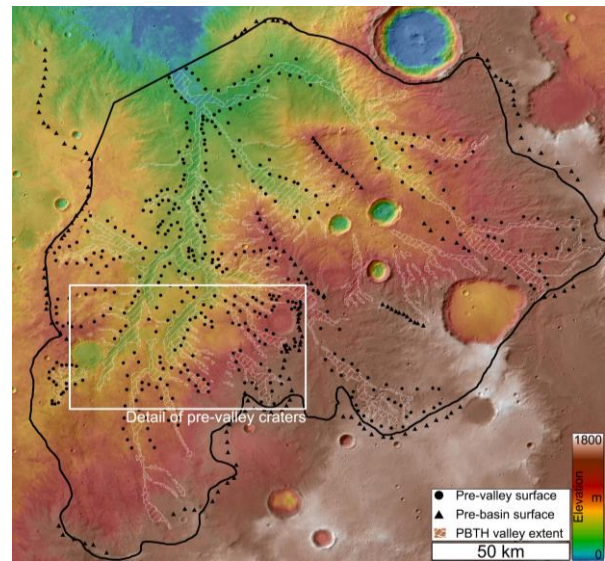
Fig 2. Bashkaus Valles, located at 26°S, 3°W in the Margartifer Sinus region, has been previously described as recording a complicated erosional history [8]. The extent of the eroded watershed is roughly outlined in black. Shaded in white is the extent of the valley network as determined by a progressive black top hat transformation [4] and used by [3] to estimate valley volume. Dots are digitized elevation points interpreted to represent the pre-erosional surface.

Fig 1. Examples of valley networks within their broader watersheds. Shaded area is the valley extent as determined by an algorithm [4].

Fig 3. Interpolated pre-erosional surface (left) and the inferred erosion depth (right). The total eroded volume is ~5,000 km³, approximately 20x greater than the ~200 km³ calculated using the approach of [4].

Valley network erosion rates: Crater counts indicate that most valley networks formed around the time of the Noachian-Hesperian transition, but the time it took for valley networks to incise is less constrained. This parameter is important in interpreting the early martian climatic environment, as the formative timescale can be used in conjunction with erosion depth to estimate erosion rate.

Consider three populations of impact craters:

(1) The pre-fluvial activity crater population. These craters formed prior to both the valley canyon and enclosing basin. Basin denudation should have erased most of these craters, but some large craters may still be preserved near the basin's upper headwaters with have undergone less denudation.

(2) Craters that post-date the formation of the basin but pre-date valley canyon incision (Fig. 4). Smaller craters in this population would be erased by the erosional activity during valley canyon formation, but larger craters may be preserved. The crater counting area is restricted to the upper portions of the watershed, as lower elevation areas have been completely resurfaced by the fluvial activity that formed the valley network canyons.

(3) Craters that post-date the deeply incised valley network canyon. This is the population typically used for dating valley networks [e.g., 9].

The total formative timescale of the valley network is calculated as the difference between populations (2) and (3).
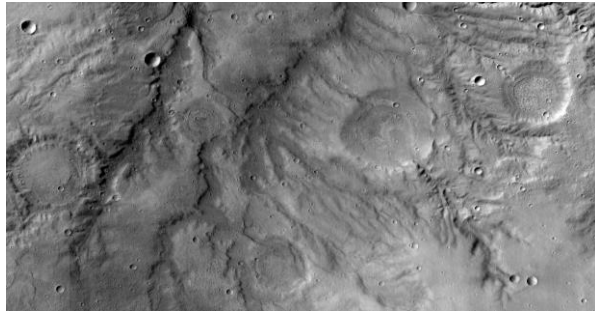
Fig 4. Examples of degraded craters that pre-date the valley networks in the upper portions of the Bashkaus watershed.

For valley network depths of ~200 to ~300 m, this translates to long-term average erosion rates of ~.5 m/Ma, similar to erosion rates during the Middle to Late Noachian [10] and hillslopes in the modern Atacama Desert [11]. Such rates are notably less than those calculated using sediment transport formulae [e.g., 6], implying that erosion may have been episodic, with long eras of quiescence punctuated by brief eras of intense erosion.

These results are preliminary and approximate, with obvious inherent uncertainty in the estimation of the pre-valley network surface ages.
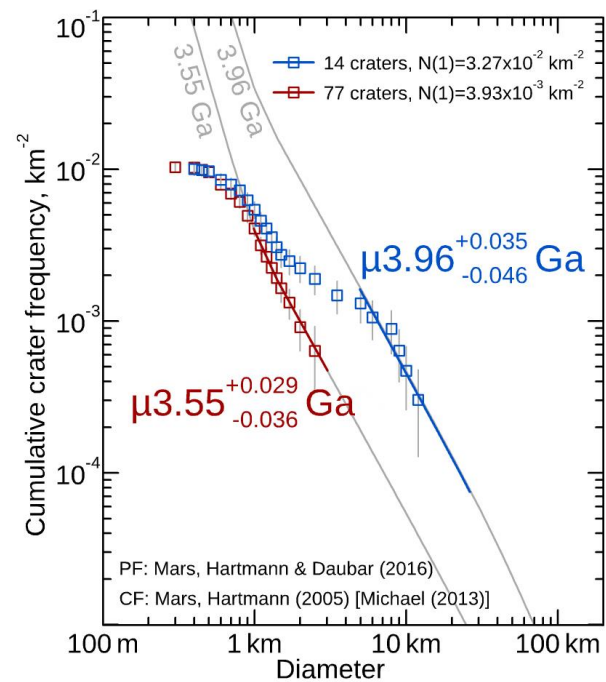
Fig 5. Upper (blue, based on degraded craters in the upland areas that pre-date the Bashkaus Valles valley, see Fig. 4) and lower (red, based on craters throughout the Bashkaus watershed) bounds on the timing of valley incision in Bashkaus Valles. Modeled using CraterStats [12] with the production function of [13] and chronology function of Hartmann (2005) [14].

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