NOACHIAN VALLEY NETWORK DENSITIES TRACK ANCIENT ITCZ FLUVIAL PRECIPITATION

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Introduction:

Geological Evidence for A Warm and Wet Mars
Ample geological evidence exists supporting a "warm and wet" scenario of early Mars; referring to a sustained habitable climate capable of supporting liquid surface water. This evidence includes a continuous spectrum of erosional and depositional water features consistent with sustained intense fluvial activity, including widespread valley networks (VNs)[1-5] emptying into lacustrine and deltaic deposits [6,7] and finally, into a circumpolar northern ocean[8]. This global network of water erosion and depositional features points to an integrated, active and long-lived hydrosphere that existed on early Mars.

One of the most conspicuous features of atmospheric circulation on Earth is the low-latitude Intertropical Convergence Zone (ITCZ). The ITCZ is the region of moist, low-pressure uplift of Hadley Cell circulation, characterized by low-level wind convergence, high precipitation and deep convection. Also known as the thermal equator, Earth's ITCZ migrates from ~10°S during the Austral Summer to ~30°N during the Northern Hemisphere Summer. Latent heat budget balance between planetary hemispheres drives ITCZ mean latitudinal migration.

Only Earth currently has an ITCZ, however, recently developed 3-dimensional Paleo-Martian Global Climate Models (PMGCMs[9,10] assume a $CO_2/H_2O/H_2$ atmosphere (CO_2 atmosphere, Ps=1.5 bar, 3% H_2)[9,10] would be able to maintain stable liquid water precipitation for geologically sufficient time to incise valley networks (VNs) beneath a Noachian ITCZ under Faint Young Sun conditions (insolation ~75% modern values) by collision-induced absorption (CIA). LNIH Hypothesis proponents[11-15] refute a clement Noachian Mars with a mean annual temperature > 273 K. They suggest that VNs were emplaced during the Noachian by exotic mechanisms, including top-down subglacial melting and impact melting of a permanent ice-cap at elevations >1 km.

I refute the LNIH and propose that I am able to statistically determine patterns of VN incision caused by stable precipitation under a Noachian ITCZ.

Methods: Statistical examination of VN distribution and density over the Martian low-latitudes (20°N to 20°S) may determine if an ancient ITCZ existed. Timing of this ITCZ relative to Tharsis emplacement and True Polar Wander (TPW)[11] as well as varying obliquity[12] with respect to VN incision can be tested by VN mapping and statistical analysis.

To test this hypothesis, I utilized VN distributions together with updated high resolution MOLA elevation data[16] to examine what, if any, spatial relationship results could be determined, including analyzing VN density by elevation for 1 km elevation bins, to either support or refute LNIH assumptions. I utilized the recent 1:20M-scale global geologic map of Mars to confine our study area to Noachian (>3.7 Ga) terrains. Noachian geologic units mapped in Tanaka et al. (2014)[17] were subdivided into 1 km elevation increments using MOLA data[16] for an Area of Interest (AOI) defined as 20°N to 20°S and 30°W to 180°E, covering 11,422,066km^2.

Valley Density Mapping For our AOI VN density map, I used a VN database and inverted channel database[8,18], and the ArcMap Arc Toolbox Line Density Tool. I plotted VN density against the LNIH equilibrium-line altitude (ELA) (Fig. 1). An ELA defines the zone where glacial annual ablation equals annual accumulation. I measured height and orthogonal distances from VN hotspots to the LNIH ELA[16] using the ArcMap planar line measurement tool.

Valley Network Density Statistics If the LNIH is correct, VN incision at the 1 km ELA due to periodic ice cap retreat should be seen. I tested VN density as a function of elevation. I extracted the number of VN's per each 1km MOLA[16] interval, normalizing the number of VNs to spatial area for each 1 km elevation intervals.

Results and Discussion:

Valley Network Density Map VN distributions in our globally scaled AOI reveal a pattern of global scale system energetics coupled to geomorphology (Fig. 1). Figure 1.) VN Distribution (upper) and VN density versus 1 km Elevations (km).

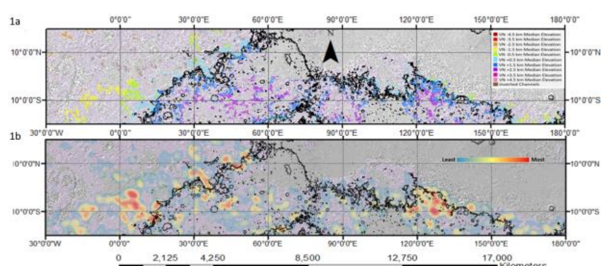

Fig. 1). VN distributions versus 1 km elevation bins, centered on median elevations (km) are continuous from over +4.5 km elevation, continuous to VN extinction at -2.78 km. VN networks are continuous and undisrupted across the purported ELA (black line at +1.0 km) (1a). The lower figure (1b) shows VN density with the Western VN density Hotspot at Meridiani Terra centered at 718.03 km west and -1784m below the +1.0 km ELA as well as 408.20 km west and +1639 m above the +1.0 km ELA located in Terra Sabea. The Meridiani Terra VN density Hotspot cannot be reproduced within current climate models with Tharsis topography due to rain shadow effect.

No relationship between VN density and a purported LNIH ELA exists.VN distributions versus 1 km elevation bins are continuous from over +4.5 km elevation (and across the ELA) with VN extinction at

-2.78 km (Fig. 1a). The lower figure (Fig. 1b) shows a western VN density hotspot at Meridiani Terra, 718.03 km west of the LNIH ELA. An eastern VN density hotspot centered near Terra Sabea and Tyrrhena Terra and 408.20 km west of the LNIH ELA was also revealed. Both the western and eastern hotspots are also above and below the proposed ice cap ELA (-1784m below and +1639m above, respectively).

Both VN hotspots center near 7°S [3°N - 10°S], consistent with Kamada et al. PMGCM results (2020)[10] for CIA warming along a latitudinal band underlying the ascending limb of Hadley Cell circulation[9,10], or (ITCZ).

Valley Network Statistics The entire AOI VN density versus Median Elevation (km) [-4km to +4km) can be modeled a simple discontinuous linear function, inflecting at +0.5 km, inclusive (Fig. 2).as

Figure 2.) VN density Versus Median Elevation (km) [-3 km to 4 km]

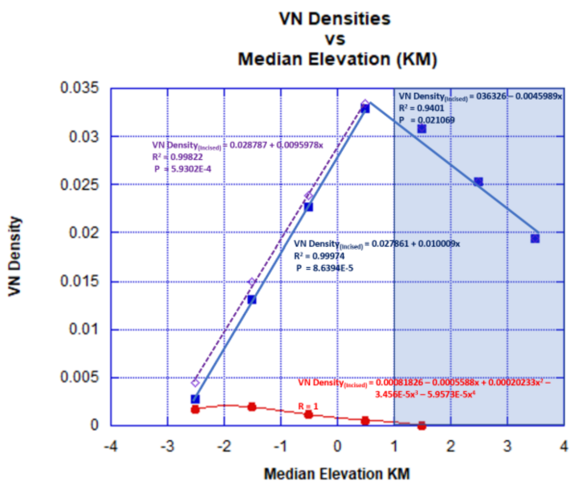

Fig. 2.) I captured a robust, global signal for VN density for an area of ~1.14x10[7]km[2]. Water and sediment source regions above +0.5 km (R^2= 0.9401) corresponding to the Southern Highlands transition to water and sediment sinks (R^2= 0.99974) for the Noachian lowlands below +0.5 km. Incorporating both inverted channels and incised VNs did not significantly alter this pattern (R^2= 0.99822) The blue field indicates the purported LNIH icecap ≥ +1.0 km.

VN density in the highlands above 0.5km increases with decreasing elevation consistent with higher order fluvial channels and longer runs with decreased elevation. Below +0.5km, VN density decrease linearly. These results are inconsistent with predictions for VNs created under a glacier, where low order VN's would have longer linear runs, but consistent with incision by water and sediment source at high elevation. There is also no stepwise function adjacent to the ELA (+1.0 km).

The simple linear fits for both > +0.5 km and < +0.5 km of the equatorial region of the Southern Highlands implies that VN incision was global and widespread, corresponding to stable and pronounced precipitation[9,10], likely prior to TPW[11] along a latitudinal band underlying a stable martian ITCZ. Inverted channels are continuous with incised VN's but are highly eroded.

Conclusions:

This VN density study does not support the LNIH. Three distinct findings support this conclusion; (1) Our VN density map does not reflect sinusoidal distribution expected for true polar wander TPW[11] or obliquity >0[5]. (2) Global VN density statistics encompassing 6.5 km of elevation [+3 km to -3.5 km], reflect net water/sediment source and sinks, (Fig.2).

(3) Erosional extinction of incised VN's occur at -2.87 km, within 1σ (1.126 km) of 52 deltaic deposits mean elevation values of -1.848 km and -2.540 km[8].

VNs density mapping best reflect recent PMGCM outputs for ITCZ precipitation for model boundary conditions of mean annual temperature of ~283K 3% H_2, 1.5 bar[9,10], invoking CIA and latent heat from northern circumpolar and Hellas Basin oceans and lakes. I propose that VN density hotspot at Meridiani Terra formed in the absence of a Tharsis rain shadow (pre-TPW). Future PMGCMs should utilize pre-Tharsis topography.

In conclusion, VN density mapping (Fig. 1), statistical results (Fig.2) reveal a Noachian ITCZ during the early to mid-Noachian and the low-latitudes of Mars enjoyed protracted, geological scale periods of precipitation and surface habitability. Statistics from this study should be used to constrain future 3-dimensional PMGCMs and LEMs as a target parameter results, rather than the converse; which is unproductive.

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