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LATE NOACHIAN CLIMATE OF MARS: CONSTRAINTS FROM VALLEY NETWORK SYSTEM FORMATION TIMES AND THE INTERMITTENCIES (EPISODIC/PERIODIC AND PUNCTUATED).

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Formation of Late Noachian-Early Hesperian (LN-EH) valley network systems (VNS) signaled the presence of warm/wet conditions generating several hypotheses for climates permissive of these conditions. To constrain options for the ambient Noachian climate, we examine estimates for time required to carve channels/deltas and total duration implied by plausible intermittencies. Formation Times for VN, OBL, Deltas, Fans: A synthesis of required timescales show that even with the longest estimated continuous duration of VN formation/intermittencies, total time to carve the VN does not exceed 10^6 years, $<\sim$0.25% of the total Noachian. Intermittency/episodicity assumptions are climate-model dependent (e.g., most workers use Earth-like fluvial activity and intermittency). Noachian-Early Hesperian Climate Models: 1) Warm and wet/semiarid/arid climate: Sustained background MAT $>$273 K, hydrological system vertically integrated, and rainfall occurs to recharge the aquifer. Two subtypes: a) *"Rainfall/Fluvial Erosion-Dominated Warm and Wet Model"*: "Rainfall and surface runoff" persist throughout Noachian to explain crater degradation, and a LN-EH short rapidly ending terminal epoch. b) *"Recharge Evaporation/Evaporite Dominated Warm and Wet Model"*: Sustained period of equatorial/mid-latitude precipitation and a vertically integrated hydrological system driven by evaporative upwelling and fluctuating shallow water table playa environments account for sulfate evaporate environments at Meridiani Planum. Sustained temperatures $>$273 K are required for extended periods (10^7-10^8 years). 2) Cold and icy climate: Sustained background temperatures extremely low (MAT $\sim$225 K), cryosphere is globally continuous, hydrological system is horizontally stratified, separating groundwater system from surface; no combination of spin-axis/orbital perturbations can raise MAT to 273 K. Adiabatic cooling effects transfer water to high altitudes, leading to "Late Noachian Icy Highlands Model". VNS cannot form in this nominal climate environment without special circumstances (e.g., impacts or volcanic eruptions elevate of temperatures by $>\sim$50 K to induce melting and fluvial/lacustrine activity). 3) Cold and Icy climate warmed by greenhouse gases: The climate is sustained cold/icy model, but greenhouse gases of unspecified nature/amount/duration elevate MAT by several tens of Kelvins (say 25 K, to MAT 250 K), bringing annual temperature range into the realm where peak seasonal temperatures (PST) exceed 273 K. In this climate environment, analogous to the Antarctic Dry Valleys, seasonal summer temperatures above 273 K are sufficient to melt snow/ice and form fluvial and lacustrine features, but MAT is well below 273 K (253 K). Fluvial systems driven by *episodic/periodic intermittency* typically involve short intermittency time-scales (10-10^6 years) but require a warm climate (MAT $>$273 K) to be sustained for $>$0.4 x 10^9 years. Fluvial systems driven by *punctuated intermittency* typically involve short duration time-scales (10-10^5 years) but only require a warm climate (MAT $>$273 K) for the very short duration of the climatic impact of the punctuated event (10^2-10^5 years). We conclude that a *cold and icy background climate with punctuated intermittency of warming and melting events* is consistent with: 1) the estimated durations of continuous VN formation ($<10^5$ years) and 2) VN system estimated recurrence rates (10^6-10^7 years).