TRUE POLAR WANDER RECORDED BY THE DISTRIBUTION OF MARTIAN VALLEY NETWORKS

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Introduction: Hesperian-Noachian (older than 3.5 Ga) Martian valley networks (VNs) are essentially located on the highlands [1,2,3] within a domain of latitudes ranging from – 60°S to +30°N and are considered to be one of the best evidences for different climatic conditions during early Mars [e.g., 4,5]. In this study, we show that their distribution suggest a reorientation of Mars' rotation axis with respect to the mantle, or true polar wander (TPW) . The timing and characteristics of this true polar wander event appear to be also supported by other independent observations.

Valley networks (VNs) distribution: The density and spread in latitude of VNs show large variations with longitude [3]. For instance, there is a lack of VNs between 30°S and 60°S from the Argyre basin (30°W) to the East of Hellas basin (120°E) and a very low density in Arabia Terra. VNs form a band that appears to follow a small circle tilted with respect to the present equator (Fig. 1). If this hypothesis is correct, VNs may have formed in a latitudinal band, but their present distribution would be the result of a TPW event following their formation. This hypothesis is tested by the least-square adjustments of the VNs density map to a small circle. It is found that VNs formed within a latitudinal band of 28° centered at 24°S, for a paleo north-pole north of the Tharsis bulge, along the meridian passing through the center of Tharsis (118°W, 69°N) (Fig. 1). This noteworthy position of the paleo north-pole is consistent with TPW driven by the formation of the Tharsis, with a migration of Tharsis to its current position near the equator (TPW along the meridian of Tharsis). The corresponding south-pole is located at 62°E 69°S, south of the Hellas basin. The present poles and paleopoles and the distribution of VNs are presented on Fig. 1 in cylindrical projection for the planet's configuration before and after the TPW.

True Polar Wander scenario: TPW in the case of Mars is theoretically feasible and several episodes of TPW have been suggested for the early history (> 4 Gyrs) in relation with the formation of the dichotomy or Tharsis [6,7,8,9,10]. Minor TPW events after the formation of Tharsis, with a different reorientation geometr, have also been suggested to explain the offset between the youngest polar deposits and the adjacent paleopolar deposits [11], and the elevations of putative paleoshorelines of the northern ocean [7]. However, the latter hypothesis was not confirmed by the elevations of deltas [13]. Once again, the position of the paleopoles inferred from the VNs distribution is consistent with TPW driven by the formation of Tharsis. Estimates of the paleopole location prior to the formation of Tharsis using gravity data are consistent with the paleopoles found in this study (95°W, 65°N, [6], 100.5 ± 49.5°E, 71.1+17.5°N [10]). The paleo south-pole (62°E, 69°S) is also close to the center of the crustal dichotomy (80°E, 60°S) [9]. Estimations of paleopoles using inversions of magnetic field are less reliable and not constrained in time [14].

Additional evidence of inferred paleopoles positions: The paleonorth-pole is located in Scandia Colles, a knobby terrain likely representing the only Noachian geological unit exposed in the North Polar Region [15]. Some of the landforms of the Scandia region (Scandi Cavi, Tholles and Colles) are attributed to polar ice activity, retreat or melting [16, 17]. The paleo north-pole is also surrounded by anomaly of low thermal, epithermal, and fast neutron counting rates (centered at 125°W, 70°N) [18] associated with high water-equivalent hydrogen content. The preservation of a shallow subsurface ground-ice anomaly related to a paleopolar cap would be possible in the context of basal melting and development of deep systems of water circulation beneath the polar ice. A similar H_20 rich anomaly is observed near the paleo south pole located in the noachian volcanic unit, Malea Planum. This region displays erosional lineated terrains that are consistent with erosion by meltwater in the subglacial and/or proglacial environments of retreating ice sheets [19] Finally, an abnormal concentration of double-layered ejecta craters is also observed in this unit [20] indicating a former ice glacial substratum [20, 21]

Conclusion: In summary, our scenario is consistent with a TPW event driven by the formation of Tharsis. [8]. The formation time of valley networks in a tropical band spans the Noachian and the early Hesperian periods [22][23] and is contemporaneous to the birth of the Tharsis bulge. The prolonged magmatic activity at Tharsis during Hesperian and Amazonian periods causes TPW and moves Tharsis close to the present equatorial position after the end of fluvial activity. This

scenario differs from the one proposed by [24] with a VNs orientation controlled by, and hence postdating most of the formation of Tharsis. However, VNs orientation appear to be essentially controlled by the topography of Hellas and the hemispheric dichotomy and VNs orientation is also compatible with the topography of Mars without a fraction of the present Tharsis bulge. We also note that a thin Noachian lithosphere [25] would hardly support the Tharsis bulge. Last, petrological constraints and surface imagery indicate extensive resurfacing of the Tharsis region until recent time [26,27] whereas rifting models are also consistent with significant crustal growth during the Amazonian in this region [28]. A decisive test of this scenario will be performed by simulating early climate scenario for icy/cold and wet/warm Mars with a topography of Mars estimated for its past configuration.

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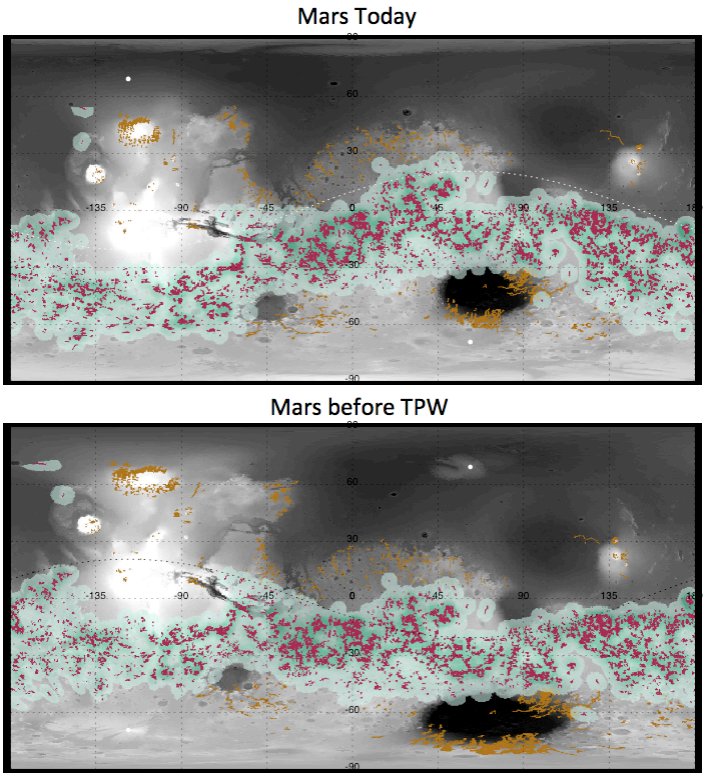

Figure 1. Distribution of valley networks observed today (top) and before True Polar Wander (bottom) over MOLA shaded relief. In red, Noachian-Hesperian VNs. In orange, Hesperian-Amazonian VNs. In green, VNs density (with dark green for higher density) [3]. White dots represent the ancient paleopoles (top) and the present poles (bottom). White dotted line represents the paleoequator in the present configuration (top) and black dotted line reprsentes the present equator in the ancient configuration (bottom).