GLOBAL PATTERN OF DISSECTION ON MARS AND THE NORTHERN OCEAN HYPOTHESIS. T. F. Stepinski[1] and W. Luo[2], [1]Lunar and Planetary Institute, Houston, TX 77058, tom@lpi.usra.edu. [2]Department of Geography, Northern Illinois University, DeKalb, IL 60115, wluo@niu.edu.

Introduction: Recently updated global map of valley networks (VN) on Mars [1] revealed larger than previously thought dissection density pointing to precipitation-fed runoff erosion as the mechanism for valleys formation and renewing interest in the climate on early Mars. On the global scale, the dissected terrain forms a wave-like region located in the Noachian terrain and extending roughly from the equator to mid southern latitudes. In the light of the new evidence for precipitation as the ultimate source of VN, we expect that the region of dissection coincides with the region of precipitation. This invites a question of why the precipitation on early Mars was restricted to a specific region as depicted by the map of the VN? Here we propose that the existence of the northern ocean, caused by a hemispheric dichotomy of Martian topography, was responsible for a climate that restricted most of the precipitation to the region directly south of its shoreline, leaving large portions of the southern hemisphere dry and thus devoid of VN.

Global dissection pattern on Mars: An updated map of VN on Mars has been recently generated [1] using a computer algorithm that parses global MOLA topographic data for features having geomorphometric signature of valleys. One way of showing the mapping result is through a raster depicting locally-defined values of drainage density at each pixel. Such map is shown on Fig.1 where green-to-orange color gradient indicates increasing dissection density and the gray color indicates lack of dissection. The dissected region has the following major features: (1) It is located in a latitudinally restricted zone of Noachian terrain located directly southward of the topographic dichotomy boundary. (2) An estimated depth of the VN is the largest immediately south of the dichotomy boundary and decreases southward (see Fig. 2).

The northern ocean scenario: We hypothesize that, given the relatively high density of dissection by VN indicating their origin via precipitation–induced process, the major features of the dissected region can be explained by the existence of a northern ocean. We assume that early Mars was warm enough to support liquid water on its surface. A qualitative assessment [2] of climate controlling factors indicates that a large reservoir of standing water (i.e. "ocean") is required for precipitation to occur; the planet would not experience precipitation without such reservoir (or reservoirs) even if significant amount of liquid water was present on its surface. The existence of topographic dichotomy on Mars implies that water would accumulate in the topographic lows of the northern plains to form the "northern ocean.'' The geologic and topographic evidence for such ocean has been previously discussed [3-7], and the two possible shorelines are shown on Fig.1.

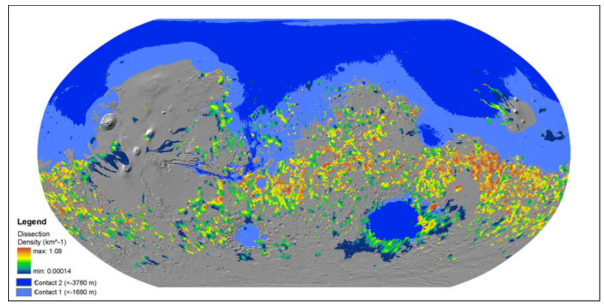

Fig.1: Global map of Mars showing density of dissection (green-to-orange gradient), dissection-free regions (gray) and the two putative ocean shorelines (lighter blue for contact 1 and darker blue for contact 2).

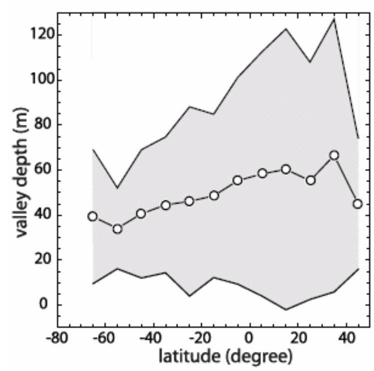

Fig.2: Zonal statistics of valley depths with respect to latitude. Circles indicate mean values, the regions spanning the values of mean ± standard deviation are shown in gray.

The confinement of an ocean to northern plains restricts the transfer of water vapor to the regions located directly southward of the shoreline. Global atmospheric circulation will carry moisture from northern mid latitudes southward resulting in precipitation when the air mass rises orographically upon encountering the dichotomy boundary. The supply of moisture to the regions located farther from the ocean would be limited. Thus, southern regions of Mars would experience an arid, ‘‘continental’’ climate with little or none precipitation not because of the lack of liquid water on the surface of the planet, but because of the physical separation of the water reservoir and the southern landmass. This hypothesis accounts for the two major features (listed above) of the dissected region. Additional evidence comes from a correlation between topographic relief and dissection density along the proposed shoreline. We have calculated a relief map within 1000 km zone located directly southward from the shoreline (contact 1). Fig. 3 shows the maps of relief (top panel) and dissection density (middle panel) in this zone and Fig.3 (bottom panel) shows the correlation between them. The relief explains about 50% of variance in dissection density. Such correlation is expected if the precipitation is induced by an orographic rise of the air mass.

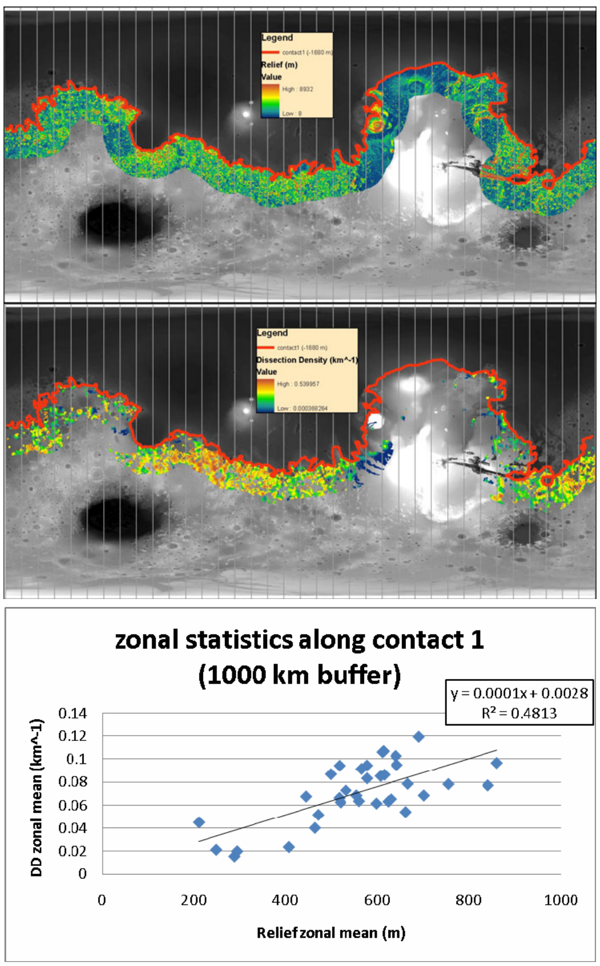

Fig.3. (Top) Map of Mars showing the contact 1 shoreline (red) and topographic relief (green-to-orange gradient) in the zone located directly below the shoreline. (Middle). The same map but for the dissection density. (Bottom) The zonal statistics (by longitudinal zones) of relief versus dissection density.

Discussion: The hypothesis presented here connects the two longstanding issues in Martian geomorphology: the origin of the valley networks and the existence of the northern ocean. In this abstract we have given some initial support for such hypothesis including the overall correspondence between the extent of the dissected region and the shoreline of the putative ocean, the shallowing of valley depths southward of the shoreline, and some correlation between relief and dissection density along the shoreline. (Note that correspondence between the shoreline and high dissection appears to break down at the Tharsis region, but in this location the surface directly southward of the shoreline is not Noachian, so the absence of dissection can be attributed to subsequent modifications.) The shallowing of valleys can be explained by terrain softening at mid-to-high southern latitudes, but all global properties of VN are best explained by the ocean hypothesis.

A more quantitative coupling between global distribution of dissection and GCM models is necessary to further develop the VN-ocean hypothesis. One unresolved issue is the existence of Hellas and Argyre basins — ancient topographic lows expected to accumulate water and to become “lakes” potentially capable of supplying precipitation-causing moisture to the southern regions. Lack of extensive dissection around these basins may be due to the details of the Martian global circulation, or due to the fact that these basins never became lakes. Another unresolved issue is the patchy character of dissection, local high values of dissection density are interweaved with local lows where the values of dissection are much lower or the surface lacks dissection altogether. Reconciling such pattern with erosion through precipitation needs further studies. Possible explanations include high hydraulic conductivity on Mars, erosion by powerful episodic storms, or the combination of such factors.

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References: [1] Luo, W. And Stepinski, T.F., JGR-Planets 114, E11010 (2009). [2] Richardson, M.I. and Soto, A., in 2nd Workshop on Mars Valley Networks, 62-65, (2008). [3] Parker T. J. et al., Icarus 82, 111 (1989). [4]. Parker T. J. et al., J. Geophys. Res. 98, 11061 (1993). [5] Baker V. R. et al., Nature 352, 589 (1991). [6] Head, J.W., Science 286, 2134–2137, (1999). [7] Perron, J.T. et al., Nature 447, 840-843, (2007).