IS VALLES MARINERIS A SPREADING BASIN DUE TO A DIVERGENT PLATE BOUNDARY?

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Introduction: Valles Marineris is a huge "canyon" and a major feature on Mars, larger than any canyon on Earth. The origin of Valles Marineris has been debated, including a water-carved canyon [1,2] or a strike-slip feature or other tectonic feature [3,4].

Looking for answers for the origin of such a prominent feature (with length of 4000 km, 1.2 times the radius of Mars; width of 200 km, about 6% of the radius of Mars, and up to 7 km deep) on Mars, I look at similarly major features on Earth, but realizing that Earth is a water planet. Subduction on Earth produces oceanic trenches that can be longer and narrower with similar depth. However, the two sides of an oceanic trench do not have similar elevation. Continental collision (such as the subduction of the Indian subcontinent below Eurasia) does not produce a deep trench. Spreading at divergent plate boundaries can produce huge "canyons" or basins (e.g., the Atlantic Ocean, Red Sea, etc) if water is removed. Here I propose a new hypothesis that Valles Marineris represents a basin produced by a divergent plate boundary on Mars. This is consistent with the suggestion of that the floors of Valles Marineris are volcanic flood lavas [5-7].

Hypothesis: I propose that Valles Marineris is a narrow basin due to spreading of a divergent plate boundary on Mars, similar to Red Sea on Earth. Fig. 1 and Fig. 2 compare the topography (and bathymetry) of the Martian Valles Marineris area and the terrestrial Red Sea area.

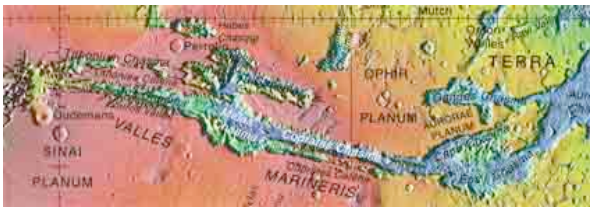

Fig. 1. Topography map of Martian Valles Marineris area. (USGS, 2003, Topographic Map of Mars)

There is general resemblance between Valles Marineris and Red Sea although the former has more complexity. Red See is about 2200 km long, 350 km wide and up to 2.2 km deep. That is, it is shorter, wider and shallower compared to Valles Marineris. Spreading can easily produce a longer and narrower valley. If spreading of Red Sea stopped now and if weathering were not significant, the deep oceanic floor would cool and become deeper (e.g., 5 km or more), approaching the depth of Valles Marineris. Valles Marineris is also steeper compared to Red Sea. The steepness might be attributed to the weaker gravity (slower mass wasting) and slower weathering on Mars.

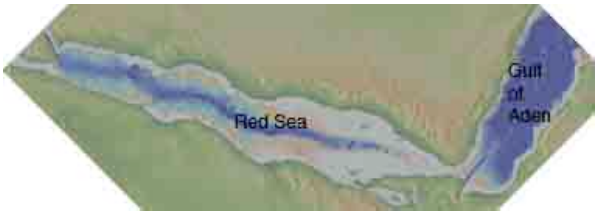

Fig. 2. Topography-bathymetry map of the Red Sea area (rotated by 45° so that it is aligned similar to Valles Marineris). Prepared using GeoMapApp [8].

Discussion: If Valles Marineris is a spreading basin, meaning plate tectonics is operational in some form on Mars in its history [9], one would infer the presence of other spreading basins with ridges, and subduction zones. Yin [9] has discussed tectonic thrusting (subduction) on Mars.

The identification of spreading basins on Mars cannot be simply done by comparison with present-day Earth, on which the mid-ocean ridges can be easily seen if water is removed. However, one might think of what a dry Earth would look like after tectonics dies out. The Earth would consist of "highlands" (continents) and "lowlands" (water-free "oceanic" crust). The ridges on the lowlands would have subsided due to cooling, and hence would not be visible. If tectonics stopped when all continents were together (Pangea), then about 60% of Earth surface would be continuous low lands and 40% would be semi-continuous high lands. This would be about the same as the present-day Mars (though the proportion of highlands is greater). If this hypothesis is correct, we need to look for other ways to identify plate tectonic features.

References:

[1] Spencer and Finale, 1990, JGR, 95, 14301. [2] Cattermole, 1992, Mars, Chapman&Hall. [3] Courtillot et al., 1975, EPSL, 25, 279. [4] Yin, 2011, LPSC abstr 1529. [5] Lucchitta, 1987, Science, 235, 565. [6] McEwen et al., 1999, Nature, 397, 584. [7] Dohm et al., 2009, JVGR, 185, 12. [8] Ryan et al., 2009, G3, 10, Q03014. [9] Yin, 2010, Fall AGU abstract.