VALLES MARINERIS TECTONISM: QUESTIONS AND SUGGESTIONS; Baerbel K. Lucchitta, Mary G. Chapman, and Nancy K. Isbell, U.S. Geological Survey, Flagstaff, Arizona 86001

Much has been learned about the Valles Marineris, and stratigraphic relations inside the troughs have been reasonably well established. However, many questions remain, especially questions pertaining to tectonism and origin.

What is the age of the troughs?

The central Valles Marineris troughs disrupted lavas of Lunae and Syria Plana of Early Hesperian age [1]. Accordingly, they may be as old as Early Hesperian. The Noctis Labyrinthus troughs, which disrupted Upper Hesperian or Amazonian lavas [2], may be of Early Amazonian age. An analysis of shallow grabens that parallel the Valles Marineris and of wrinkle ridges that trend perpendicular to them suggests that wrinkle ridges developed first, grabens second [3,4], and the Valles Marineris either at the same time as the grabens or last [5,6], all perhaps in Early Hesperian time.

Interior layered deposits were emplaced on top of chaotic materials in the eastern and northern troughs that merge with outflow channels of middle to Late Hesperian age. Therefore these troughs are at least as old as the channels, but the deposits are younger.

Geologic relations suggest that some troughs may be split lengthwise into older segments filled by interior layered deposits and younger segments that are devoid of interior layered deposits and locally expose former plateau materials on their floors [7]. Hebes Chasma and the southern parts of Ophir, eastern Candor, and Melas Chasmata appear to be older, as are the peripheral troughs that merge with outflow channels. The northern parts of Ophir and eastern Candor Chasmata are younger, as may be the entire length of the Ius and Tithonium, central Melas, and Coprates Chasmata system [8]. Overall, the opening of the troughs seems to have had several episodes, extending in time from Early Hesperian to Amazonian.

What is the evidence for tectonic origin?

Blasius et al. [9] advocated a tectonic origin for the troughs, because they lie on the flanks of the Tharsis rise and are radial to its center, are paralleled by grabens, and are bounded by fault scarps having triangular facets on truncated spurs. Yet, an erosional origin remained attractive because of an apparent morphologic continuum between pit chains of probable erosional origin and large troughs. A recent morphometric study comparing the width-to-depth relations of all the depressions in the area [10] showed that a continuum between pit chains and large troughs does not exist, suggesting that the large troughs probably formed through deep-seated coherent failure. However, our work in progress shows that erosional back wasting from fault scarps on the major troughs may have played a significant role. Thirty-two percent of the area of the troughs is attributable to such erosion. We are currently using a digital terrain model of the troughs to calculate the volumes of the materials removed from the walls.

How do the Valles Marineris relate to the Tharsis rise?

Geophysical models indicate that isostatic adjustment of the Tharsis rise would have caused circumferential tensile stresses in the western part of the Valles Marineris, whereas external loading (flexing the elastic lithosphere downward) would have caused such stresses in the eastern chasmata [11-15]. Thus, these stress models require two distinct events. The different ages of the troughs as outlined above do not agree with an age difference between western and eastern troughs. Perhaps local structural inhomogeneities perturbed the regional stress system.

The Valles Marineris are paralleled by shallow, east-trending grabens that are part of graben systems radial to Tharsis. However, the sector north of the Valles Marineris is almost devoid of such grabens. It appears that the Tharsis stresses at Valles Marineris were released by a few major, deep faults rather than by distributed shear.

The structural relief of the Valles Marineris, which is 8-10 km throughout the central troughs, decreases uniformly eastward to 3-5 km in Coprates Chasma. This decrease would indicate less strain toward the outer periphery of the Tharsis rise, but the stress models do not predict this decrease. The discrepancy is not yet explained.

The amount of strain on the Valles Marineris also depends on the attitude of fault planes. Carr [16] postulated near-vertical planes, whereas Golombek and Davis [17] found planes with dips near 60°. We are currently studying fault-plane attitudes by mapping fault traces on stereophotogrammetric models across areas of high relief.

What additional factors may have influenced the origin of the Valles Marineris?

Carr [16] mentioned that the location of the troughs may be related to subterranean aquifers. The 4-km contour on the plateau adjacent to the Valles Marineris coincides approximately with the appearance of chaotic materials in the eastern (Capri, Eos, and Gangis) and northern (Juventae) chasmata that merge with channels. This observation suggests that an aquifer is intersected near the 4-km-elevation horizon. Perhaps subterranean water, transported from the Tharsis center toward the outflow channels along the Valles Marineris, may have increased the pore pressures and lowered the strength of the crust, permitting failure to occur more readily.

The Valles Marineris lie along the crest of a regional, elongated topographic bulge extending eastward from Tharsis. Wise et al. [18] suggested that the troughs represent a "key-stone" collapse of the crest of this bulge, formed by the extension accompanying arching. Alternatively, the elongated bulge may have formed from isostatic rebound after trough formation. Another explanation for both arching and rifting is aborted plate tectonism [19]. However, most terrestrial rifts have many parallel faults in en echelon patterns that taper out along strike, and the rifted beds are tilted. By contrast, the Valles Marineris faults are more widely spaced, trough ends are blunt, fault planes appear to be steep, and tilted beds are relatively few. Perhaps the difference is due to a thicker or more homogeneous crust on Mars than commonly occurs in rift zones on Earth [19].

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