FAULT-CONTINUATION RIDGES IN THE VALLES MARINERIS, MARS: EVIDENCE FOR GROUNDWATER CIRCULATION. Allan H. Treiman[1], Karen Spiker[2]. [1]Lunar and Planetary Institute, Houston TX 77058. [2]Department of Geology, New Mexico Institute of Mining and Technology, Socorro, NM 87801.

The walls of the Valles Marineris (VM) are marked in many places by high-standing ridges that continue the traces of graben bounding faults on the plains adjacent to the VM. These fault-continuation ridges (FCR) are most prominent at Melas Labes and Candor Labes, where they form the boundaries between Ophir, Melas, and Candor Chasmae. FCR are as long as 100 km, and extend from the plains surfaces downward ~ 3-6 km in elevation. Available data suggests that FCR are fault zones cemented and hardened by groundwater deposits.

METHOD: Basic data comes from high-resolution (<50 m/px) Viking orbiter imagery, all through clear or red filters. Large-scale mapping used U.S.G.S. controlled photomosaics and topographic maps. Elevation data were obtained from VO imagery using TVSTEREO in the PICS image processing system, and as automated by P. Schenk.

RESULTS: Plateaus near the VM are cut by many graben [1], many of which intersect the edges of the VM. The bounding faults of some graben extend onto the VM walls as distinct topographic highs, or fault-continuation ridges, FCR (Fig. 1) [2,3]. As with graben-forming faults, FCR are commonly paired and show *en echelon* offsets. Most (or all) FCR appear related to set V faults [1] of late Hesperian - early Amazonian age. The FCR are, or follow, significant controls on the topography of the VM. The western boundary between Ophir and western Candor Chasmata is a pair of FCR emanating from Candor Labes, and the boundary between Candor and Melas Chasmata is a complex of FCR emanating from Tithonium Mensa and Ophir Planum. The NW rim of Coprates Chasma follows an arcuate set of graben-forming faults, marked in places by FCR.

We examined the Candor Labes FCR in detail. They have slopes of ~30°, the angle of repose, and can be traced from the plateau surface at ~+10 km elev. down the VM walls to ~6 km below the plateau. These FCR can be traced for ~100 km. The north and south FCR at Candor Labes approach each other with depth and merge at ~3 km below the plateau surface, a depth consistent with those inferred for other graben-bounding faults [4]. These FCR have dips of ~60°, consistent with exposed fault traces of other graben [3]. Surfaces at FCR crests appears as bright or brighter (in red & clear) than the local plateau surfaces, but it is difficult to separate albedo differences from geometric effects. At least one FCR has a distinctly higher albedo than its surroundings in Candor Chasma (Fig. 2).

INTERPRETATION: FCR are unusual geomorphic features. Eroded fault lines are usually expressed as swales or valleys, because rock in and near fault zones is more broken and easily eroded than its surroundings. So, FCR must form by hardening or cementation of fault zones [5]. From our terrestrial experiences we suggest three possible hardening processes: igneous intrusion (dikes), hydrothermal mineral deposition (episodic infusion of hot fluid), and mineral deposition from groundwater (long-term percolation of water at ambient T).

A critical constraint on FCR formation is that the fault zones were hardened both above and below the current graben floors. If the hardening is related to the fault zone (and not to a rock-air interface), hardening must have begun before significant fault movement. Otherwise, fault zones would not have been hardened above the graben floors, and the FCR would not extend up

to the plateau surface. Continued fault motion would tend to break earlier-hardened material, so hardening would need to continue throughout the time when the faults moved.

Igneous intrusion of dikes along graben faults seems the least likely of the above explanations. The relatively short timescale of dike emplacement and cooling seems inconsistent with the constraint that the hardening process act throughout the active life of the faults.

The other hypotheses, hydrothermal and groundwater deposition, involve aqueous fluids, which can flow in fault zones and produce significant mineral deposits [5], some of which can be light-colored (e.g., carbonates, sulfates, silica, some clays). Hydrothermal systems may not satisfy the constraints on FCR formation. It is not clear that hydrothermal systems could operate over the whole active lifetimes of these graben-forming faults. And, it is not obvious that a hydrothermal event could cement a 100-km long fault zone.

Thus our favored mechanism for the origin of the FCR is mineral deposition from groundwater. Groundwater was present in the VM area at approximately the same time as formation of FCR, abundant and persistent enough to form regional hardpan horizons [6,7]. And groundwater need not rely on a transient phenomena for its existence, and so could persist throughout graben formation. This mechanism is also problematic: how could groundwater be emplaced and maintained at an elevation of +10 km on Mars relatively late in its history?

IMPLICATIONS: FCR in the Valles Marineris appear to record a time in late Hesperian to early Amazonian [1,8,9] when groundwater was present and actively depositing material in fault zones. Groundwater is not now stable in the VM region (e.g., [10]), suggesting that climate in the VM region was significantly more humid during FCR formation than at present. This humid episode may be the same as required formation of the hardpan horizon of the VM region [6,7].

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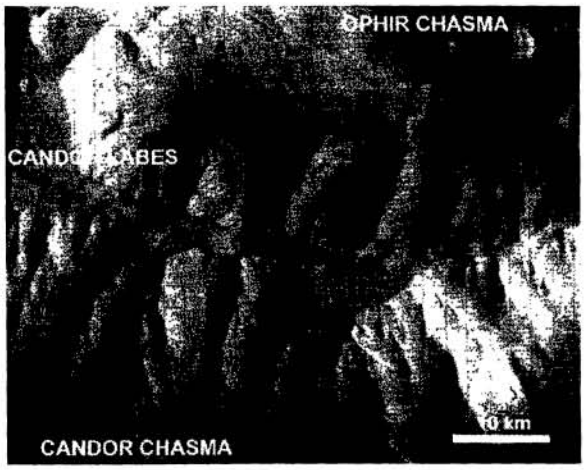

Figure 1. Fault Continuation Ridges at the boundary between Ophir and W. Candor Chasmata. North is up. Red filter, 46 m/px. VO 917A15.

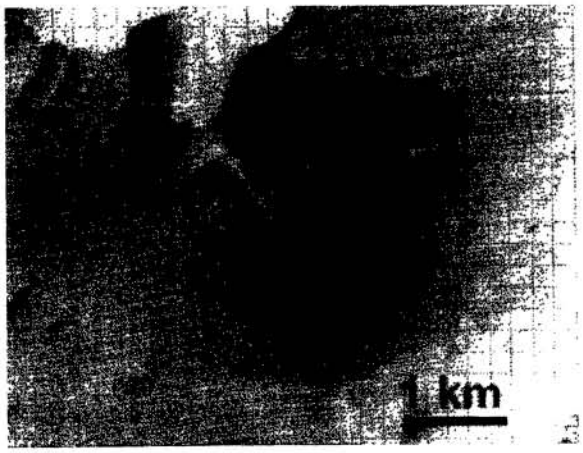

Figure 2. Light-colored FCR on floor of Candor Chasma; north is up (0°), sun az 305°, ina 34°. FCR curves lower center to upper left. Clear filter, 20 m/px, VO 815A78.