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Plateau geology south of Valles Marineris, Mars: Implications for canyon formational history

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Abstract

Geologic mapping and crater-density dating of the plateaus flanking the south side of Ius-Melas-Coprates Chasmata of Valles Marineris, Mars suggests Late Noachian coeval canyon formation and accumulation of altered, sulfate-bearing light-tone layered deposits followed by deposition of plateau material and surface fracturing driven by domical uplift and other deformation. Later, Early Hesperian lava or debris flows in northwestern Thaumasia Planum trend southeastward from Melas Chasma, whereas Early Amazonian, east- to northeast-trending lava flows pre-date Louros Valles incision along the south edge of Ius Chasma.

1. Introduction

The Valles Marineris (VM) on Mars (Fig. 1) constitutes the most spectacular and yet perhaps most puzzling canyon system known. The complex geology of VM and adjacent plateaus include linear, interconnected as well as isolated troughs and pit chains, narrow grabens, contractional (wrinkle) ridges, tectonic rises including possible diapiric structures, sulfate-bearing light-toned layered deposits (LTLD), dense drainage networks, outflow channel systems, alluvial fans and fan deltas, volcanic flows, layered canyon wall rock, landslides, sites of groundwater discharge, numerous impact structures, eolian landforms, and more. Although such aspects of VM have been the target of numerous studies, many key and fundamental aspects to the origin and possible interplay of these features largely remain topics of controversy and continued study.

Here we investigate the geologic history of plateau materials and features on the plateaus south of the southern and longest trough system of VM, Ius-Melas-Coprates Chasmata. The plateaus are continuous and include Sinai Planum (south of Ius Chasma) and Thaumasia Planum (south of Melas and Coprates Chasmata (Fig. 1). We use geologic mapping and crater-density dating techniques to reconstruct the geologic history, based on geospatially matched image data sets at various spatial resolutions and wavelength ranges (THEMIS day time and night time IR and VIS, CTX, HRSC, and HiRISE) and topographic models from HRSC stereo image data mostly at 100 m/pixel built and from MOLA altimetry data at 460 m/pixel.

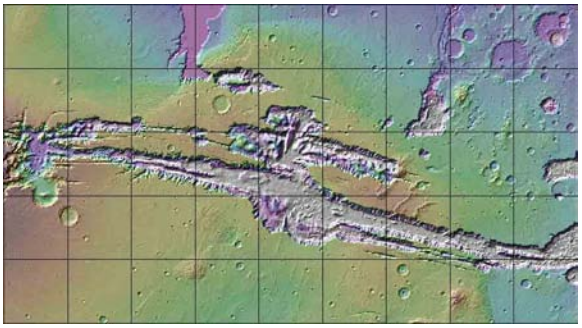

Figure 1: Color elevation shaded relief of Valles Marineris (5° N. to 20°S., 265° to 310° E.), which cuts across a rise (green to brown region at center) that stands 3 to 5 km above terrains to the north and east. Scene width is ~2650 km.

2. Mapping and age-dating results

The geologic map is shown in Figure 2. The caption gives the sequence of units and crater-density ages. Most units have two to four areas where crater counts were performed. The oldest unit is the LTLD, which underlie the densely faulted older plateau material. The older plateau material extends hundreds of kilometers and mostly rises above the surrounding plains by hundreds of meters (locally 1500 m), and the faulting indicates that they are high-standing due to uplift. One area forms an ovoid, 500-m deep depression. In turn, the Thaumasia Planum unit embays the older plateau material. It includes flow forms indicative of lava or water discharge from

Melas Chasma and southeastward transport across the plateau surface. The unit is deformed by wrinkle ridges, arcuate grabens (Nia Fossae) along a shallow rise, and other linear ridges and shallow troughs. Melas and Coprates Chasmata cut into this unit, so the canyons have retreated since the unit was emplaced. East-trending lava flows in Sinai Planum are sourced from west of the study region and embay all older units. In turn, those flows are cut by latest retreat of Louros Valles. Finally, unconsolidated dark mantle material is draped over parts of the LTLD and other surfaces along the southern margin of Ius Chasma.

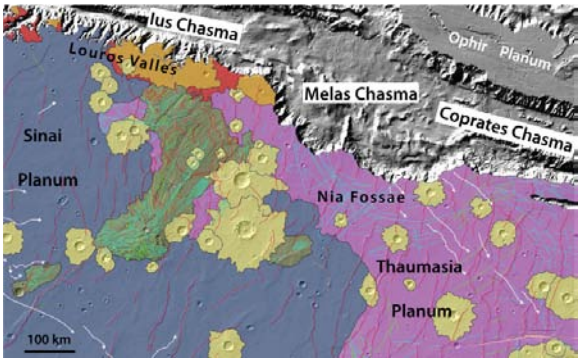

Figure 2: Geologic map of study region (7.8-20° S., 275-295° E.). Map units (oldest to youngest, their crater ages, and chronological epoch): Light-toned layered deposits (red, >3.7 Ga, Late Noachian and possibly older), older plateau material (brown, ~3.7 Ga, Late Noachian/Early Hesperian), Thaumasia Planum unit (pink, ~3.7 Ga, Late Noachian/Early Hesperian), Sinai Planum unit (gray, ~1.7 Ga, Early Amazonian), craters (yellow), and dark mantle material (orange). Line features: Flow directions (white arrows), grabens (blue-green), wrinkle ridges (red), scarps marking flow boundaries or controlled by strata (black hachured), valleys (blue), and other structurally controlled ridges (green) and scarps (brown).

3. Interpretations

Previous stratigraphic and structural studies indicate that Valles Marineris developed in the Noachian and Hesperian, based on oldest recognized surfaces cut by the chasmata and constraints on ages and relationships of associated tectonic structures deforming adjacent plateau surfaces [2, 5]. In this study, we recognize diverse plateau deposits associated with VM growth. We infer that the LTLD that occur on the plateau adjacent to Ius Chasma are associated with trough development and thus date some episode of it. LTLD generally appear to be superposed on canyon wall rocks [5] but also have been proposed to make up VM wall rocks [3]. In any case, the uplifted as well as depressed areas in the older plateau material may reflect salt diapirism [1] at a time when the surface was undergoing extensional tectonics [2].

Extrusion of flows from Melas Chasma is another new finding. The flows are thin, and it is unclear whether they are low-viscosity lavas or debris flows. Given that the canyon wall stratigraphy may be largely lava flows as well [4], it is possible that much of the VM rise (Fig. 1) is a stack of Noachian lavas sourced from the troughs.

Much younger flows of Sinai Planum are cut by Louros Valles, indicating that at least the latest dissection of those valleys occurred during the Early Amazonian or later.

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