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Deep tectonics exposed in northern Valles Marineris, Mars

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Abstract

Brittle-plastic, NE-SW oriented dextral shear zones are exposed in the deepest parts of Ophir Chasma and Hebes Chasma. We describe one of the Ophir Chasma shear zones and explore some implications for the geologic evolution of Valles Marineris and Tharsis.

1. Introduction

Oblique strike-slip faulting is ubiquitous in terrestrial rifts, where on continents it appears to be frequently controlled by older fabric, e.g. [1]. Wilkins and Schultz suggested that oblique faults explain the blunt shape of the Valles Marineris troughs, along which kinematics would be extensional rather than strike-slip [2]. HiRISE images reveal the existence of oblique tectonic structures in the northern troughs of Valles Marineris. C-S fabrics are common and point to strike-slip kinematics. Further, they indicate deformation in the brittle-plastic field, consistent with the width of the sheared zones, up to kilometres. These observations make necessary that erosion has been a major trough formation agent in northern Valles Marineris. They also reveal new tectonic elements that need to be considered while reconstructing the evolution of the Tharsis dome.

2. Brittle-plastic shear zones

A survey of HiRISE images available in the deepest parts of Ophir Chasma and Hebes Chasma has revealed several exposures of shear zones (Figure 1) trending NE-SW. Figure 2 shows an example of interpretation in one of these shear zones, located in eastern Ophir Chasma. The area is dominantly covered by recent deposits, including a mantle of dark material, dunes, and landslide deposits from the northern Ophir Chasma wall. The shear zone is exposed in hard, light-toned, unstratified rock. Fractures are also apparent in the dark material, although subdued. The shear zone orientation is emphasized by C shears, and dextral kinematics is demonstrated by S shears associated with the C and also C' shears.

The C-S fabric indicates brittle-plastic deformation, requiring pressure and temperature conditions that could probably not be met at the surface in the history of Mars. Shear zone width is up to several kilometres, and also denotes formation at depth.

The length of the shear zone exposures is up to 10 kilometres. Shear zone displacements are not known; nevertheless, in terrestrial conditions, shear zones of similar width have displacement one order larger than width [3].

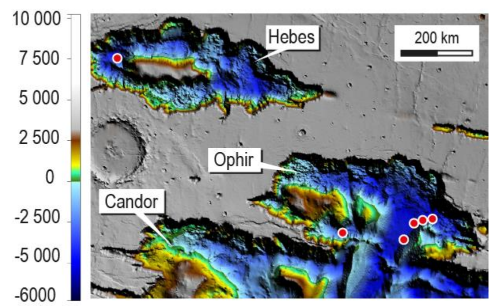

Figure 1: Location of brittle-plastic shear zones identified in Valles Marineris. Exposures are indicated by red dots. The base map is from HRSC digital elevation model.

3. Tectonic significance

Shear zone kinematics is consistent with Valles Marineris crustal stretching perpendicular to the main troughs (Figure 2). The role of tectonic extension in the formation of the northern troughs of Valles Marineris has been questioned though due to the lack of obvious brittle structures exposed at the surface [4]. Of trough formation by collapse [5], vertical subsidence [6], and erosion [7], the latter is consistent with the observations reported here. Deep subglacial erosion inferred from deep dyke exposures in Ophir Chasma [7] as well as glacial landsystem identification in other troughs [8] explain the present shear zone exposures. Giving their thickness and displacement-length scaling of faults [9], the shear zones are regional scale and therefore cannot be neglected in future Tharsis palaeotectonic reconstructions.

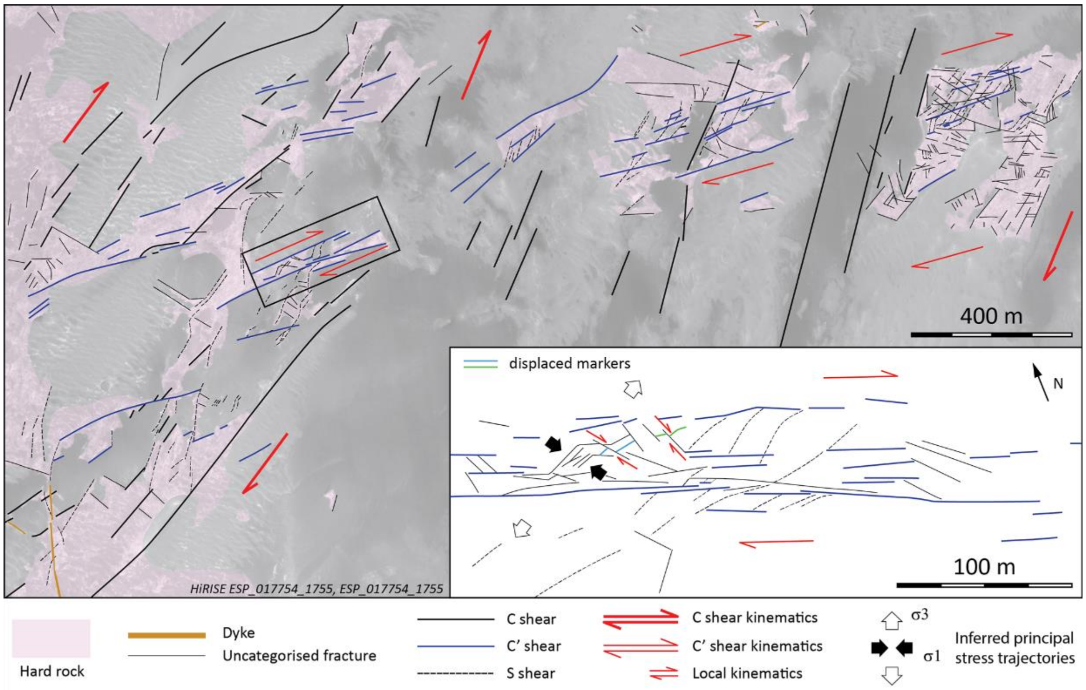

Figure 2: Geometry and kinematics of brittle-plastic shear zone in eastern Ophir Chasma.

4. Conclusions

The shear zone in eastern Ophir Chasma has structural features and size similar to e.g. the Gemini fault zone in the Sierra Nevada, which was developed at a well constrained depth of 8-11 km [10], and similarly is exposed due to glacial erosion. Other brittle-plastic shear zones have been mapped in northern Valles Marineris [11]. None has been identified in the southern troughs, perhaps because sedimentary accumulations are pervasive, or because they are restricted to the northern troughs. In the latter case, the connection between shear zones and trough formation is to be clarified. Kinematics is consistent with Valles Marineris rifting even though evidence of rift border faults is missing in the northern troughs. Mineralogical investigations are underway. Implications for Tharsis evolution are to be explored.

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