EPSC Abstracts
Vol. 12, EPSC2018-739-1, 2018
European Planetary Science Congress 2018

Mapping of regional C-C'-S shear zones on the floor of Valles Marineris troughs

Daniel Mège and Joanna Gurgurewicz
Space Research Centre PAS, Poland (dmege@cbk.waw.pl, jgur@cbk.waw.pl)

Abstract

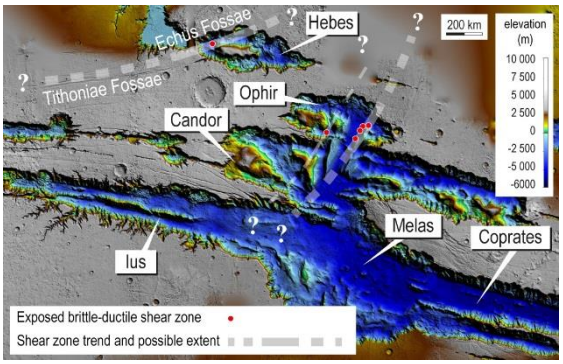
The floor of Hebes Chasma and Ophir Chasma, the two elliptical and deepest troughs of Valles Marineris, displays NE-SW to ENE-WSW several kilometres wide dextral brittle-plastic shear zones. Structural maps of these areas are presented. Mapping suggests that the northern part of Valles Marineris is probably composed of large sheared tectonic blocks that moved relative to each other while Valles Marineris was being stretched perpendicular to its main, ESE trend. The block boundaries played a role in guiding the further tectonic and geomorphologic evolution of Valles Marineris.

1. Introduction

The formation mechanisms of the large northern troughs of Valles Marineris, especially Ophir Chasma and Hebes Chasma, has remained poorly understood because of the lack of obvious tectonic structures that would have guided floor subsidence. On the one hand, tectonics was probably involved because we do see narrow grabens parallel to these troughs being cut by the troughs, and dykes exposed on the floor of Ophir Chasma. On the other hand, floor erosion must have been intense too in order for deep exposures of these dykes to be visible today [1], severely restricting the role of tectonic subsidence. We present structural maps based on interpretation of HiRISE imagery that provide further constraints on the role of tectonics, but also erosion, in the formation of these troughs. The maps demonstrate the existence of huge brittle-plastic shear zones in Ophir Chasma and Hebes Chasma, the implications of which for the formation and evolution of Valles Marineris are discussed.

2. Shear zones

HiRISE images reveal shear zones in the deepest parts of Hebes and Ophir chasmata (Figure 1) that were active before the ILDs were deposited. The sheared rocks are unstratified. Some occurrences have been interpreted as sulfate-rich, based on CRISM data [2], and have similar brightness and morphology as sulfate-rich deposits that precipitated during the opening of Valles Marineris in Ius Chasma [3]. Nevertheless, some outcrop geometric patterns are reminiscent of plutonic bodies. Dykes of thickness up to tens of metres are also observed. The shear zones display brittle-plastic structural fabrics, which on Earth are found in mylonite zones. They include S/C, S/C', as well as a combination of C, C' and S-type shears. The geometry of the S-type shears points to overall dextral shear zone kinematics.



Location of the main shear zone exposures and extrapolated trends. The base map is the HRSC digital elevation model of Valles Marineris.

The Ophir Chasma shear zones are located in eastern Ophir, along the corridor that connects Ophir Chasma and Candor Chasma, and in southwest Ophir (Figure 1). The NE-SW orientation of the C-type shears matches the general orientation of the corridor. The most complex shear zone geometry is found in eastern Ophir, with an association of well-developed dextral C-type and C'-type shears, each associated with their own S-type shears. A more detailed account of this shear zone is provided in [4]. In western Ophir, the identified shear zone is less well exposed but its orientation and kinematic appear similar.

The Hebes Chasma shear zone is geometrically more

simple than those observed in Ophir Chasma, with textbook successions of C-type shears and associated S-type shears. It is approximately parallel to, and perhaps connects, ENE-oriented narrow grabens of Tithoniae Fossae and the southeasternmost grabens of Echus Fossae.

3. Implications

Shear zone width is difficult to ascertain due to the sedimentary cover on the chasma floor, such as the ILDs, landslide deposits, dunes, and moraines. Nevertheless, the same shear system is crossed over more than 3 km perpendicular to strike in eastern Ophir Chasma, and 8 km in Hebes Chasma. Such widths are on Earth correlated with shear zone horizontal displacements one order larger, i.e. tens of kilometres [5], probably implying total shear zone length of one to several thousands of kilometres (e.g., [6]).

Because of the alignment between one of the shear zones and the Ophir-Candor corridor, and the consistency between shear zone kinematics and normal faulting parallel to the main Valles Marineris troughs, it may be reasonably proposed that while being stretched, the Valles Marineris crust was undergoing dextral shearing that decoupled the eastern from the western portions of Valles Marineris along a line going through Ophir Chasma and Candor Chasma. C'-type shears preferably form in extensional tectonic context on Earth [7], supporting simultaneity of strike-slip faulting along the Ophir-Candor corridor and normal faulting of the whole Valles Marineris tectonic system (e.g., [8]). The shear zone located along the Ophir-Candor corridor would then be akin to transfer faults on terrestrial continental rift zones, which in general are inherited structures (e.g., [9]).

Alignment of the Hebes Chasma shear zone with the Tithoniae and Echus narrow grabens, the kinematics of which appears to be purely tensional after the latest lava outpourings, suggests that the shear zone was reactivated in tension during or after the Early Hesperian [10].

If formed in pure tensile mode, the kinematics along the identified dykes are not always consistent with the shear zone kinematics inferred from the S/C and S/C' fabrics. In Hebes Chasma, the stress regime that would be appropriate to dyke propagation would imply sinistral shearing. Such dykes, of orientation close to N-S, have been identified elsewhere in Valles Marineris as well [11]. No evidence has been found, however, that the dykes themselves are deformed by the shears; they might testify to post-shear E-W extension.

4. Conclusions

Structural mapping reveals huge brittle-plastic shear zones that affect the deepest parts of Hebes Chasma and Ophir Chasma. Similar deformation has been sought in other chasmata unsuccessfully, at least because of the widespread sedimentary cover. These shear zones, exposed after removal of kilometres of crust, are an important element of the evolution of Valles Marineris, for instance by delimiting large tectonic blocks during Valles Marineris formation, mechanically decoupling its eastern and western parts, and probably guiding the erosional corridor between the Ophir and Candor troughs.

Acknowledgements

This work was funded by the OPUS/V-MACS project no. 2015/17/B/ST10/03426 of the National Science Centre, Poland.

References

[1] Mège, D. and Gurgurewicz, J.: The Ophir Chasma Dyke Swarm: description and implications for the genesis of the Valles Marineris northern troughs, Acta Geol. Sin.-Engl., Vol. 90, pp. 180-182, 2016. [2] Wendt, L. et al.: Sulfates and iron oxides in Ophir Chasma, Mars, based on OMEGA and CRISM observations. Icarus, Vol. 213, pp. 86-103, 2011. [3] Roach, L.H., et al.: Hydrated mineral stratigraphy in Ius Chasma, Valles Marineris. Icarus, Vol. 206, pp. 253–268, 2010. [4] Gurgurewicz, J., and Mège, D.: Deep tectonics exposed in northern Valles Marineris, Mars, EPSC Abstracts, Vol. 12, EPSC2018-430, 2018. [5] Fossen, H.: Structural geology, Cambridge Univ. Press, 2016. [6] Schultz, R.A., et al.: Displacement-length scaling relations for faults on the terrestrial planets, J. Struct. Geol., Vol. 28, pp. 2182-2193, 2006. [7] Passchier, C.W.: Geometric constraints on the development of shear bands in rocks, Geol. Mijnbouw, Vol. 70, pp. 203-211, 1991. [8] Mège, D. and Masson, P.: A plume tectonics model for the Tharsis province, Mars, Planet. Space Sci., Vol. 44, pp. 1499-1546, 1996. [9] Bellahsen, N., et al.: Pre-existing oblique transfer zones and transfer/transform relationships in continental margins, Tectonophysics, Vol. 607, pp. 32-50. [10] Tanaka, K.L., et al.: Geologic map of Mars: U.S. Geological Survey Scientific Investigations Map 3292, 2014. [11] Mège, D. and Gurgurewicz, J.: On Mars, location and orientation of dykes exposed along the Valles Marineris walls reveal expected and unexpected stress fields, Acta Geol. Sin.-Engl., Vol. 90, pp. 177-179, 2016.