BRITTLE-PLASTIC SHEAR ZONES ON VALLES MARINERIS FLOOR: IDENTIFICATION AND IMPLICATIONS. D. Mège[1], J. Gurgurewicz[1], S. Douté[2] , F. Schmidt[3] and R. A. Schultz[4], [1]Space Research Centre PAS, Warsaw, Poland (dmege@cbk.waw.pl, jgur@cbk.waw.pl), [2]Institut de Planétologie et d'Astrophysique de Grenoble, UMR CNRS 5274, France (sylvain.doute@univ-grenoble-alpes.fr), [3]Géosciences Paris-Sud, UMR CNRS-UPS 8148, Orsay, France (frederic.schmidt@u-psud.fr) [4]Orion Geomechanics LLC, Cypress, Texas, USA (oriongeo@gmail.com).

Introduction: The presence of a dense swarm of dikes several tens of meters thick on the floor of Ophir Chasma, which do not cut the surrounding Interior Layered Deposits (ILD), indicates that kilometers of bedrock must have been eroded or are missing in this part of Valles Marineris [1]. We report on the existence of brittle-plastic, NE-SW oriented dextral shear zones similarly exposed in the deepest parts of Ophir Chasma, as well as Hebes Chasma. We discuss their identification, kinematics, age, the nature of the deformed rock, and their role in the tectonic, erosional, and geomorphological evolution of Valles Marineris.

Identification of brittle-plastic shear zones: Several shear zones are located in Ophir Chasma, 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 (Figures 2 and 3), with an association of well-developed dextral C-type and C'-type shears, each associated with their own S-type shears. In western Ophir, the identified shear zone is less well exposed but its orientation and kinematics appear similar.

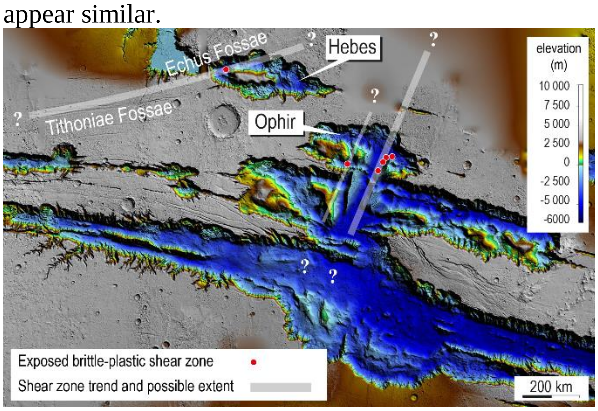

Figure 1. Location of the main shear zone exposures and extrapolated trends. The base map is the HRSC digital elevation model of Valles Marineris.

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.

Displacement: 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 identified 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 kilometers [2], probably implying total shear zone length of one to several thousands of kilometers (e.g., [3]). This implies that the crust of Valles Marineris and its neighboring regions is divided into distinct tectonic blocks that moved horizontally relative to each other.

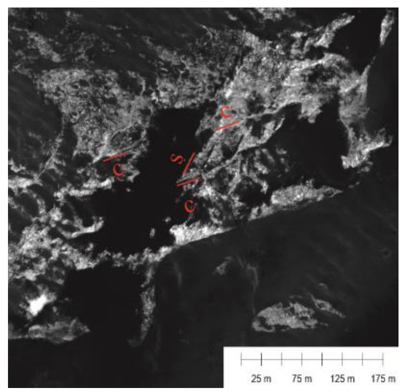

Figure 2. Part of the shear zone exposed on the eastern Ophir Chasma floor. HiRISE image ESP_017754_1755_RED

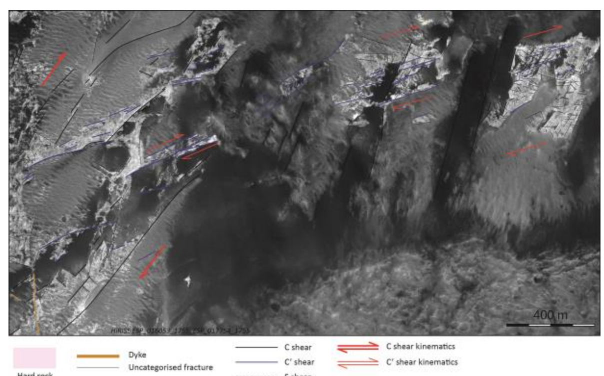

Figure 3. Kinematic interpretation of the part of the easternmost shear zone in Ophir Chasma.

Age: The shear zones are not observed to cut across ILD, are not identified on chasma walls. nor in any other floor unit of Valles Marineris. They are therefore early tectonic features in the history of Valles Marineris. Nevertheless**,** alignment of the Hebes Chasma shear zone with the Tithoniae and Echus narrow grabens (Figure

1), the kinematics of which appears to be purely extensional, suggests that the shear zone was reactivated in extension during or after the formation of the rocks in which the narrow grabens are observed, i.e. Early Hesperian (unit eHh, [4]). The Hydrae Cavus pull-apart basin, east of Candor Chasma [5] also indicates that shearing oblique to the main Valles Marineris trend continued, or was reactivated after Early Hesperian (unit eHv, [4].

Nature of the deformed rock: Observation of hard rock is hampered by widespread dark sands. They overlie the base of the ILD, which appear undeformed. Deformation occurs in the underlying unit, which appears bright, massive, and locally densely fractured (Figure 4). ILD are more abundant than the bright unit, and dominate the CRISM spectra with their sulfate signature in the near-infrared [7]. The bright unit exposures are reminiscent of a bedrock unit identified in the Coprates Chasma walls below the thick layered volcanic unit [8] in which low-calcium pyroxene and plagioclase have been interpreted [9,10], and rocks exhumed in central peaks elsewhere on Mars [11, 12]. The brightness of exposures and fracturing patterns are also reminiscent of fractured quartzite or marble. Analysis of CRISM data will help constrain more the composition of the bright unit, opening the possibility of constraining heat flux at the time of deformation.

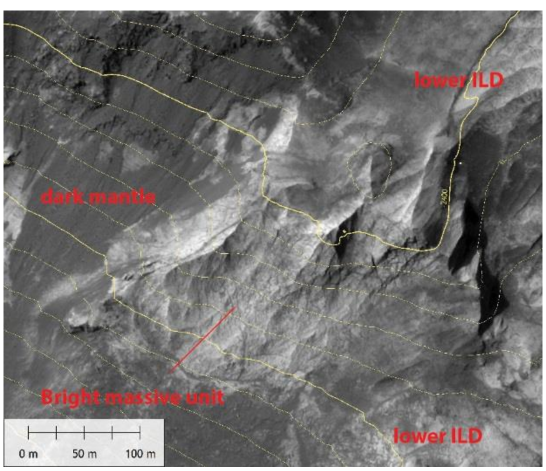

Figure 4. 100 m-high exposure of the exhumed bright massive unit in Hebes Chasma. The digital terrain model combines photogrammetry (HiRISE DTM HI_042413_1795_042914_1795) using the Ames pipeline, and photoclinometry [6]. Contour spacing: 20 m.

Locally, the outcrops of the bright unit exposed on the Ophir Chasma floor are morphologically similar to pseudotachylite (Figure 5). Such a rock fragmentation may result from impacts on the Noachian megaregolith, or tectonic activity along the identified shear zones.

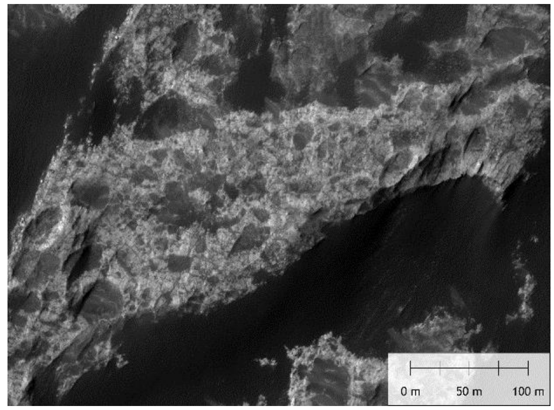

Figure 5. Possible pseudotachylite exposed on the floor of central Ophir Chasma. HiRISE image PSP_007535_1755_RED.

Geometric control of the main chasmata: Because of the alignment between some shear zones with 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 perpendicular to these troughs, shearing along the identified shear zones may have decoupled the eastern and western regions of Valles Marineris both tectonically and geomorphologically. The shear zones along the Ophir-Candor corridor might then be akin to transfer faults in terrestrial continental rift zones, explaining that the tectonic features bounding the main chasmata on both sides do not match geometrically. This intensely fractured zone could have also controlled chasma erosion along the Ophir-Candor corridor. It has been argued that glaciers and ice streams should have been efficient erosional agents in Valles Marineris, and the Ophir-Candor corridor may have formed by preferential glacial erosion along the shear zones [1].

Conclusion: The identification of major brittle-plastic shear zones on the floor of the Ophir and Hebes chasmata makes necessary a deep rethinking of many aspects of the evolution of Valles Marineris.

References: [1] Mège D et al. (2017) *48th LPSC*, 1087. [2] Fossen H (2016) Cambridge Univ. Press. [3] Schultz R.A. et al. (2006), *J. Struct. Geol. 28*, 2182-2193. [4] Tanaka K.L. et al. (2014) *USGS Sci. Investig. Map* 3292. [5] Tesson P.A. et al. (2019), *Geophys. Res. Abstracts 21*, EGU2019-11425-2. [6] Douté S, Jiang C (2017) *EPSC Abstracts 11*, EPSC2017-932. [7] Wendt L. et al. (2011) *Icarus 213*, 86-103. [8] Williams J.-P. et al. (2003), *Geophys. Res. Lett. 30*, 1623. [9] Flahaut J. et al. (2012) *Icarus 221*, 420-435. [10] Viviano-Beck C.E. et al. (2017) *Icarus 284*, 43-58. [11] Ding N., et al. (2015) *Icarus 252*, 255-270. [12] Brustel C. et al. (2018) *EPSC Abstracts 12*, EPSC2018-804.