ORIGIN OF THE NORTHERN VALLES MARINERIS TROUGHS: TECTONICS AND SUBGLACIAL EROSION. D. Mège¹, O. Bourgeois² and J. Gurgurewicz³,¹,¹Space Research Centre, Polish Academy of Sciences, Bartycka 18A, 00-716 Warsaw, Poland, dmege@cbk.waw.pl, ²Planetology and Geodynamics Laboratory, UMR CNRS 6112, University of Nantes, 2 rue de la houssinière, 44300 Nantes, France, ³Institute of Geological Sciences, Polish Academy of Sciences, Research Centre in Wrocław, Podwale 75, 50-449 Wrocław, Poland, jgur@cbk.waw.pl

The enigmatic formation of the Valles Marineris northern troughs: The processes that resulted in Valles Marineris trough (chasma) formation are conjectural. It is little questioned that extensional tectonics played a significant role in the opening of the chasma, as testified by, e.g., the many shallow grabens parallel to the troughs on the surrounding plateau, structural evidence [1, 2], and dilation on dykes parallel to the troughs [1, 3]. Structural control is especially well defined in the southern troughs (e.g., [4]), but looser in the northern troughs, for which some poorly characterized “ancestral basins” [5], for instance formed by collapse into huge and deep open fractures [6], have been advocated to explain the oval-shaped trough topography.

An extensive survey of the floor of Ophir Chasma reveals exposures of a deep dyke swarm, the Ophir Chasma Dyke Swarm (OCDS), suggesting that magmatic dilation as well as erosion significantly contributed to trough deepening, without any required contribution of collapse into subsurface voids.

New observations in Ophir Chasma: The Ophir Chasma floor displays a dense network of dykes (Fig. 1), which can be observed in the visible spectral range on CTX (5 m/pixel) and HiRISE (25 cm/pixel) images.

The thickest dykes are also apparent on THEMIS thermal infrared images (100 m/pixel). Many of those that can be mapped at HiRISE resolution are several tens of meters thick (Fig. 2). CRISM spectral data analysis reveal a mafic composition, with Mg-rich olivine and high-Ca pyroxene (Fig. 3). In some areas, dykes show a sulfate-rich spectral signature taken as testimony of hydrothermal weathering [7, 8], rather than transportation of sulfates weathered from chasma walls [8, 9].

Implications for chasma formation mechanism: Dyke thickness primarily depends on the Young’s modulus of the host rock (e.g., [12]), which increases with hydrostatic pressure, hence globally, with depth. The widespread occurrence of dykes several tens of meters thick on the floor of Ophir Chasma suggests that the current exposure level is closer to the level of neutral buoyancy of Martian mafic magmas, estimated to ca. 11 km [13], than to the surface. Exposure of dikes emplaced at such depths requires that the exposed chasma floor has been intensely eroded after their emplacement.
Erosional systems: Rivers. In most geomorphological systems, where erosion and deposition are controlled by subaerial river networks, large depressions are the locus of thick sedimentary infillings. Depressions that match the dimensions of the Valles Marineris chasmata on Earth include rifts as well as mountain foreland basins, which are fed by river networks and are commonly filled by kilometers of sediments. The observations reported here in Ophir Chasma are not consistent with such systems, which would deeply bury any dyke intruded in the basement.

Glaciers. Subglacial erosion by ice and meltwater is a process that allows to carve valleys efficiently without filling the floor with thick sediments. Pervasive glacial landscapes were demonstrated in Valles Marineris, where past and fossil valley glaciers have been identified [1, 14]. We suggest that the floor of the central Ophir Chasma may have followed an evolution similar to the bedrock of Antarctic ice streams (Fig. 4). Its current low elevation would thus result from a combination of dyke dilation and tectonic stretching, and subglacial erosion over kilometers.

Glacier bed erosion by several thousands of meters in Valles Marineris troughs would therefore not be exceptional, nor unrealistic in terms of required time. However, erosion of several thousand meters of glacier bed is more easily achieved by multiple cycles of ice flow, glacier bed deepening, ice melting (Earth) or sublimation (more likely in common Mars conditions), and isostatic rebound. Such a cyclicity has been observed in Antarctica and has been attributed to orbital changes [17]. Orbital cycles are exacerbated on Mars [18], due to the absence of orbit stabilization by a heavy natural satellite such as the Earth’s Moon. Multiple glacial erosion cycles, the terms of which remain to be explored, may have vigorously contributed to erosion and deepening of the Ophir Chasma floor.

Wind. ILD fluting indicates aeolian erosion of the chasma walls around the OCDS [19], and dark dunes are abundant on chasma floor [19, blue on Fig. 3]. ILD material is weak [19] but mafic dykes are much more resistant to wind erosion. It is unclear how efficient wind-carving may have been in OCDS exhumation.

Conclusion: Erosion, perhaps subglacial erosion, may have been the main mechanism by which Ophir Chasma formed. The dyke density on the Ophir Chasma floor testifies, however, to significant crustal dilation, implying significant extensional tectonics too. The first step in the formation of Ophir Chasma is thus interpreted to have been dyke dilation and tectonic stretching, then glacier bed erosion, resulting in several kilometers of additional topographic lowering. Other Valles Marineris northern chasmata might have formed in a similar way.