EPSC Abstracts
Vol. 11, EPSC2017-326, 2017
European Planetary Science Congress 2017


# Deep dyke exposures in northern Valles Marineris highlight the significance of erosion in chasma genesis

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## Abstract

The formation of the deep northern Valles Marineris troughs is conjectural [e.g., 1]. We report on a dyke swarm exposed on the floor of Ophir Chasma, one of the northern Valles Marineris troughs. Dyke thickness is commonly tens of meters, similar to dykes exposed in continental shields on Earth, and suggest erosion of kilometers of rocks above them. Glacial erosion is the most likely erosional process.

## 1. Introduction

An extensive survey of the floor of Ophir Chasma reveals exposures of a deep dyke swarm, the Ophir Chasma Dyke Swarm (ODS), suggesting that magmatic dilation as well as erosion significantly contributed to trough deepening.

## 2. Ophir Chasma Dyke Swarm

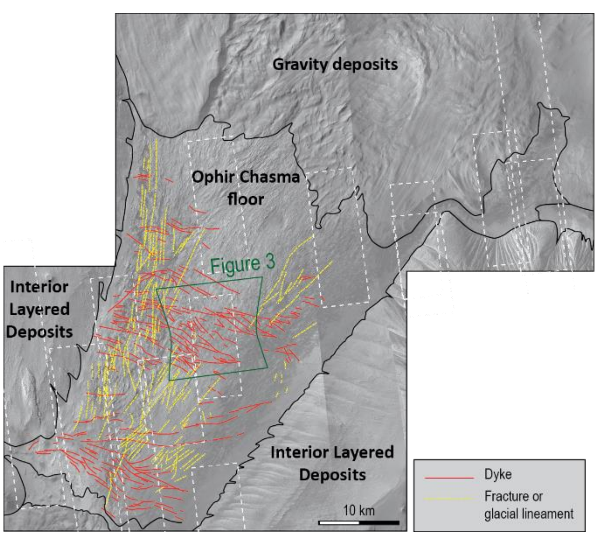


Figure 1: The Ophir Chasma Dyke Swarm (red). The background image is a CTX image mosaic (5 m/pixel). HiRISE footprints are in white.

The Ophir Chasma floor displays a dense network of dykes (Figure 1), which can be observed in the visible spectral range on CTX (5 m/pixel) and HiRISE (25 cm/pixel) images. Many of them are several tens of meters thick. CRISM spectral data analysis reveals a mafic composition, with Mg-rich olivine and high-Ca pyroxene. In some areas, dykes show a sulfate-rich spectral signature taken as testimony of hydrothermal weathering [2], rather than transportation of sulfates weathered from chasma walls.

## 3. Implications for chasma formation mechanisms

Dyke thickness primarily depends on the Young's modulus of the host rock, 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 [3], than to the surface. Exposure of dikes emplaced at such depths requires that the exposed chasma floor has been intensely eroded after their emplacement.

## 4. 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 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 [4, 5]. We suggest that the floor of the central Ophir Chasma may have followed an evolution similar to the bedrock of Antarctic ice streams (Figure 2). Its current low elevation would thus result from a combination of dyke dilation and tectonic stretching, and subglacial erosion over kilometers.

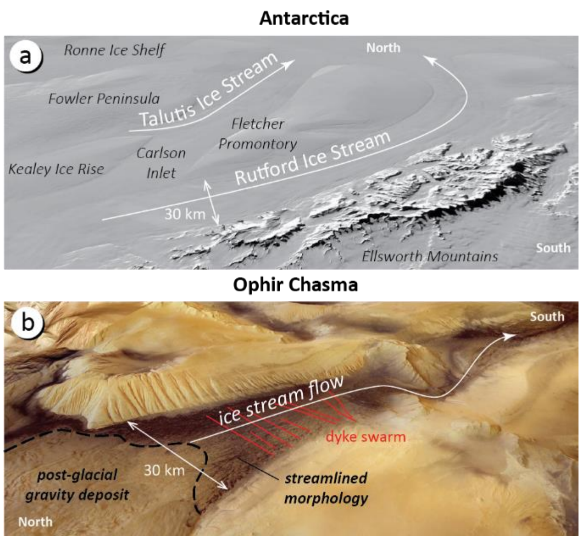


Figure 2: A former ice stream may have filled Ophir Chasma (b) and eroded the bedrock over several kilometers, following processes that are currently active in Antarctica, with (a) the example of the Rutford Ice Stream [6].

Bed erosion of 1600-2500 m since 34 Ma (0.05 – 0.07 mm/yr) was reported in the trough below the Lambert glacier East Antarctica [16]. At a similar rate of 0.050 mm/yr in Valles Marineris, 8000 m of cumulated erosion (the elevation difference between the Ophir Chasma floor and the surrounding plateau) would be achieved in only ca. 160 my. However, on Earth, glacier bed erosion rate may be significantly faster.

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 [7]. Orbital cycles are exacerbated on Mars [8], 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 ODS, and dark dunes are abundant on chasma floor. ILD material is weak [9] but mafic dykes are much more resistant to wind erosion. It is unclear how efficient wind-carving may have been in ODS exhumation.

# 5. Conclusion

Erosion, probably 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.

# Acknowledgements

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

# References

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