FEEDER DIKES AS THE SOURCE OF VOLCANIC PLAINS IN THE VICINITY OF VALLES MARINERIS. C. Brustel[1,2], J. Flahaut[3], E. Hauber[4], F. Fueten[5], R. Stesky[6], C. Quantin[2] and G.R. Davies[1], [1]FALW, VU University Amsterdam, 1081 HV Amsterdam, The Netherlands, Email: c.brustel@vu.nl, [2]LGL-TPE, CNRS - Université Lyon 1 – Ens de Lyon, 69622 Villeurbanne Cedex, France, [3]IRAP, CNRS - Université Paul Sabatier, 31400 Toulouse, France, [4]German Aerospace Center, Institute of Planetary Research, 12489 Berlin, Germany, [5]Department of Earth Sciences, Brock University, St. Catharines, ON, Canada, [6]Pangaea Scientific, Brockville, ON, Canada.

Introduction: Valles Marineris (VM) is the largest canyon system in the Solar System but the mechanism(s) responsible for its formation remain unclear. In particular it is debated whether VM formed through simple normal faulting (as a result of Tharsis load) [1], or in response to magmatic intrusions [2]**.** In the latter case, dikes and grabens should have the same orientation.

VM walls are composed (from bottom to top) of (1) a massive bedrock enriched in low-calcium pyroxene, (2) a phyllosilicate-rich layer (1500 m thick), (3) a talus slope (2500 m thick) composed of lava flows but not always outcropping, and the top most unit, (4) stacks of lava flows (>500 m thick of continuous layers) [3]. In the end, the upper part of VM walls consists of ~4 km thick Noachian and early Hesperian basaltic lava flows of undetermined origin [4].The presence of three large-scaled dikes (up to 70 m wide and 600 m long) in VM walls has recently been reported [5].These dikes are sub-parallel to VM orientation and in the direction of the Tharsis Montes 3000 km away.

In order to understand the role of dikes in the tectonic and volcanic history of Valles Marineris, the overall distribution, orientations, altitudes and dips of more than a hundred dikes exposed in the walls of the canyon were measured. Eruption rates were estimated using a rheologic model [6] to test the hypothesis of the formation of the Hesperian basaltic lava flows on top of Coprates Chasma by feeder dikes.

Study area and methods: This study is focused on Coprates Chasma which is a 1000 km long, 100 km wide, linear trough of central VM. We used imaging and altimetry data from the CTX (Context camera), HiRISE (High Resolution Imaging Science Experiment) and MOLA (Mars Orbiter Laser Altimeter) instruments available in the eastern part of Coprates Chasma, where better exposures (less dust and landslides) were reported [3]. Dikes dimensions, elevations and azimuths were measured using ArcGIS tools. Dikes dips were measured with the software program Orion [7] where HiRISE Digital Terrain Models (DTMs) were available. Using methods described in [6], we have estimated the hypothetical amount of magma erupted by a dike, based on its dimensions and assumed magma properties. Equation 1a and 1b give the magma flow speed for laminar and turbulent flow regime, respectively:

1a) $u=(W^2.dP/dz)/(12\eta)$; **1b)** $u=[(W.dP/dz)/(f\rho)]^{(1/2)}$

with W the measured dike width; dP/dz the pressure gradient driving magma motion (set to 500 $Pa.m^{-1}$); η the magma viscosity (from 10 to 1000 Pa.s); ρ the magma density (set to 2500 $kg.m^{-3}$) and f the friction coefficient (set to 0.01) (see [6,17]). The total lava volume flux E ($m^3.s^{-1}$) of each dike is given by: **E=u.W.L**

The dikes lengths L were estimated using empirical values of aspect ratios (L/W) reported in the literature. These ratios range between 10^2 and 10^4 [8]. The value of 10^3 was chosen for our calculations.

Results: *Dikes mapping.* Over a hundred linear features were mapped as dikes (**Figure 1)** in the North and South walls of Coprates Chasma, but also in the walls of the central horst. Exposed dikes are narrow (< 80 m, with an average of 13 m), generally linear and show symmetrical relief as they are relatively resistant to erosion. Dikes mostly intrude the bright massive bedrock at the bottom of the walls, as previously reported by [5], but they are also found at higher elevations in the walls (up to 1500 m).

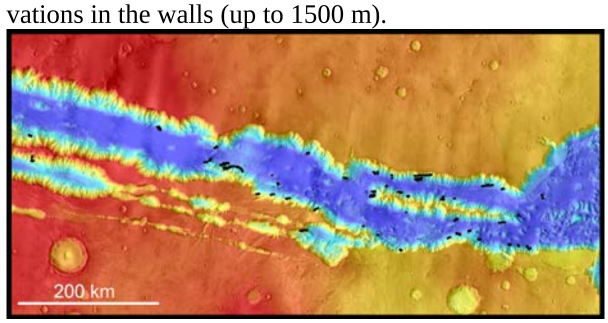

Figure 1: Map of Coprates Chasma with MOLA altimetry data overlaid on THEMIS mosaic. Black lines are the mapped dikes from this study. Red +4000 m; Blue : -4700 m.

The longest dikes can be traced for 20 km. Using HiRISE color images (IRB), dikes can be distinguished from the host rock as they are filled with a spectrally distinct material. Distinct borders with variable widths often outline the largest dikes and are interpreted as contact metamorphism borders (**Figure 2**). Dikes orientations have an average azimuth of 88°.Wider dikes (> 20 m in width), are oriented 90° and 70° in the eastern part of Coprates Chasma and found until 1500 m and 0 m, respectively. A third set of dikes striking 110° (similar to VM walls) is observed in the western part of the chasma until elevations of -800 m. Fifteen dip measurements were made using HiRISE DTMs; dip values range from 55 to 90° with an average of 72°. The distribution of dikes suggests they mostly predate the canyon opening, and are ancient (Noachian) features.

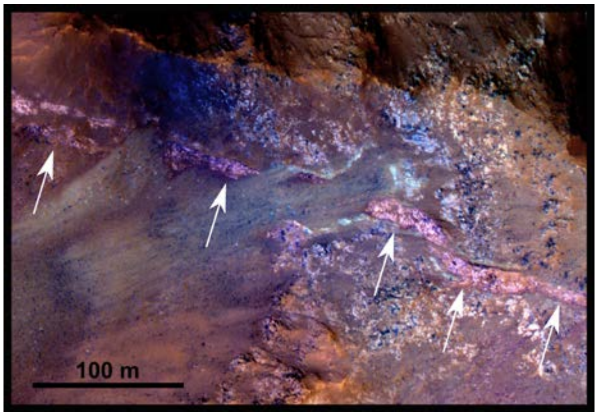

Figure 2: HiRISE (ESP_022303_1670) colour composite (IRB) showing a possible dike (white arrows) in a wall of Coprates Chasma.

Dikes eruption rates. Eruption rate modeling was used to estimate eruption rates for each dike mapped in Coprates Chasma. Resulting eruption rates using measured lengths are respectively 8.1×10^5 $m^3.s^{-1}$, 1.1×10^6 $m^3.s^{-1}$ and 1.5×10^6 $m^3.s^{-1}$ for viscosities of respectively 10, 100 and 1000 Pa.s (chosen to cover the range of viscosities corresponding to fissural eruptions previously studied in the Tharsis region [6,9]). However if we used dike lengths estimated from aspect ratios, eruptions rates range from 2.7×10^3 to 2.5×10^8 $m^3.s^{-1}$, 1.8×10^8 to 2.7×10^2 $m^3.s^{-1}$, and from 27 to 1.3×10^8 $m^3.s^{-1}$ respectively.

Discussion: Estimations of dike eruption rates rely on various assumptions as discussed in [17]. As measured lengths are likely underestimated (it is difficult to track a dike along its entire lengths outside of HiRISE images), a second set of calculations was performed using theoretical lengths estimated from aspect ratio [8,10], resulting in higher eruption rates. However, the assumed aspect ratio is influenced by magma viscosity, host rock composition and density, crustal thickness, gradient pressure etc, which are poorly constrained [11]**.** One spectral study of a dike was performed so far, revealing a strong olivine signature, possibly related to the presence of large crystals [5]. It is however not possible to be certain that this composition is representative of all dikes. It is also likely that all dikes were not active contemporaneously, and/or were not active along their entire length during an eruption. During the Deccan traps emplacement, a terrestrial flood basalt province, intermittent magmatic activity have been documented. The Deccan traps were emplaced in less a Myr by a series of individual pulses with durations of several years, with a cumulative active eruption duration spanning only 0.01 % of the total formation duration [12] and [13]**.** It is difficult to estimate the duration of dike activity with remote sensing data, therefore, these results probably give peak eruption rates and might not be representative of the entire eruption duration. Previous Mars studies include ridges associated with an early Hesperian lava plain in the region of Hellas Basin, which have been interpreted as dikes [14]. Based on dike dimensions, eruption rates were estimated to range between 10^5 and 10^6 $m^3.s^{-1}$, which is similar to the eruption rates we calculated for Coprates Chasma' dikes. Based on such eruption rates, dikes in Coprates Chasma would only require a minimum time of a few 100 to 1000's of years to form the ~4 km thick Noachian and early Hesperian lava flows observed at the top of the canyon's walls.

The 90° dikes have been observed at elevations lower than 1500 m; the 70° dikes were observed until 0 m, therefore they are likely to be older. We infer that this change in dikes orientation records a change in the regional stress field over time [16, 17]. Emplacement of 90° dikes could be due to an early uplift of the Syria Planum province, which was associated with radial dikes emplacement over long distance. A change in dikes orientation is also observed between the western and the eastern Coprates Chasma, which support the idea of a large East-West dichotomy [15- 17]**.**

Conclusion: Our study shows that dikes could have been the source of the voluminous lava flows observed in the upper walls of Valles Marineris. With > 100 dikes mapped in Coprates Chasma and eruption rates > 10^6 $m^3.s^{-1}$, the emplacement of these flows could have been rapid (< a few 1000 yrs). Dikes also recorded the tectonic history of the region, provided insights into the early geologic history of VM.

References:

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