

ESTIMATING THE EXTENT OF THERMAL VERSUS MECHANICAL EROSION AT A RILLE-LIKE LAVA CHANNEL AT RAGLAN, NORTHERN QUÉBEC, CANADA. V. Cataldo¹, D. A. Williams¹, M. W. Schmeekle² ¹School of Earth and Space Exploration, Arizona State University, Tempe, AZ, 85287-1404 (Vincenzo.Cataldo@asu.edu); ²School of Geographical Sciences and Urban Planning, Arizona State University, Tempe, AZ, 85287-5302.

Introduction: The Proterozoic Raglan Formation of the Cape Smith Belt, New Québec, Canada comprises two regionally mappable members [1]: a lower *Cross Lake Member* comprising rock units interpreted to represent channelized sheet flows or very high-level sills, and a *Katinniq Member*, comprising mesocumulate peridotite facies, interpreted to represent a system of lava channels or the remnants of an individual, sinuous, meandering submarine komatiitic basalt lava channel [2,3,1,4]. The latter hypothesis appears to be supported by 3-D magnetic inversion models and deep stratigraphic drilling, which indicate that the units are continuous in the subsurface, and suggest that they might represent long linear lava conduits analogous to the sinuous rilles on Mars, Venus, and the Moon [5, Fig. 1].

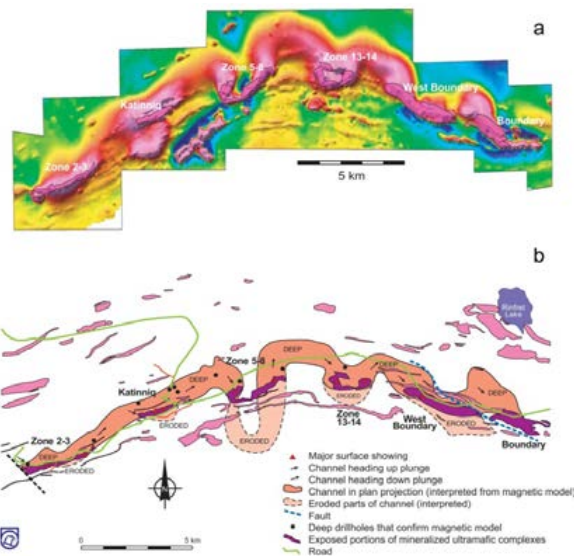


Figure 1: a) Magnetic map of the Raglan block. Red and blue colors indicate areas of high and low magnetic susceptibility, respectively; (b) Meandering lava channel exploration model for the Raglan mineralized ultramafic complexes (from [1]).

The *Katinniq Member* has a true thickness of the order of 100 m and a true width of the order of 500 m. The individual lava units are 10-50 m thick, and the *Member* progressively cuts downward through a <10-m thick horizon of sediments and gabbros, forming a broad, concave, V-shaped embayment with numerous smaller hourglass-shaped, re-entrant embayments that typically localize Fe-Ni-Cu sulfides [1]. This set of

embayments is best interpreted to have been produced by thermal erosion of komatiitic lava [6,1].

Our 3-D model of thermal erosion by turbulently flowing lava [7] was created for the purpose to assess how channel bank erosion relates to erosion at the channel bed at the Raglan site. Here, we present a few preliminary results that show that a 3-D model of thermal erosion can also be used to derive an estimate of the extent to which mechanical erosion might have contributed to shaping the channel we see in the field.

Channel meander parameters: Thermal erosion across a sinuous, meandering channel is extremely sensitive to channel geometry, with special emphasis on the $(\lambda/2A)$ ratio, i.e. the ratio of meander wavelength, λ , to meander amplitude, $2A$ (Cataldo *et al.*, 2019, this meeting). The Raglan meandering channel has a λ value of ~4.4 km, its true width is equal to ~500 m, and the measured amplitude is ~1.96 km.

The 3-D model: Our 3-D model has the advantage to calculate erosion rates at both channel bed and banks. As a result, it has the potential to reveal whether or not rille meanders are indeed regions of enhanced thermal erosion. A detailed description of the model is provided in Cataldo *et al.* [7]. Concisely, it is a fluid-dynamic model that simulates turbulent behavior by time-averaging the Navier-Stokes momentum equations in the x, y, and z direction. Reynolds Averaging Simulations (RAS) are inherent in turbulent modeling, and are adopted in steady-state as well as transient simulations. Here, we are concerned with the latter, because we already presented results concerning steady-state simulations at the Raglan site [8]. Transient simulations have the advantage to model turbulence and erosion rates over time and for increasing downstream distances from the lava source. The model uses the OpenFOAM C++ Computational Fluid Dynamics (CFD) software that is extremely versatile because it comes with a vast choice of solvers to suit the CFD problem in question, and is designed to perform pre-and post-processing tasks like those involved in mesh generation.

Model assumptions. We chose an eruption temperature and viscosity consistent with those inferred for the komatiitic basalt of the *Katinniq Member*, 1406°C and 1 Pa s, respectively [4]. Also, we chose a value of lava thickness that could be most representative of an individual flow unit, i.e. 20 m. Finally, we designed

two 12-km-long channel sections: one (Fig. 2a) that has the $(\lambda/2A)$ ratio measured at the Raglan channel; and another (Fig. 2b) that has a higher $(\lambda/2A)$ ratio.

Results: Fig. 2(a) shows evidence for thermal erosion by lava across a 12-km-long portion of the Raglan sinuous, meandering channel. Expectedly, peak erosion rates are found near the lava source, and there is evidence for enhanced erosion over the bends. At the bends, maximum erosion rates are found over the top part of the meander flank (shown in green). Each meander apex displays limited evidence for thermal erosion.

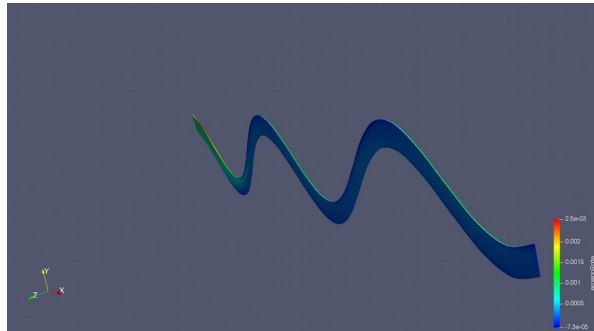


Figure 2(a): 12-km-long segment of the Raglan sinuous, meandering channel that shows evidence for thermal erosion by lava at both the channel bed and over the meander flanks.

Fig. 2(b) shows a sinuous, meandering channel with a higher value of the $(\lambda/2A)$ ratio. The meander wavelength is held the same whereas the $2A$ value (amplitude) is reduced from 1.96 km to 0.9 km. Erosion rates do not peak at each meander apex, but making each meander smaller in amplitude causes erosion to be more evenly distributed over the bend.

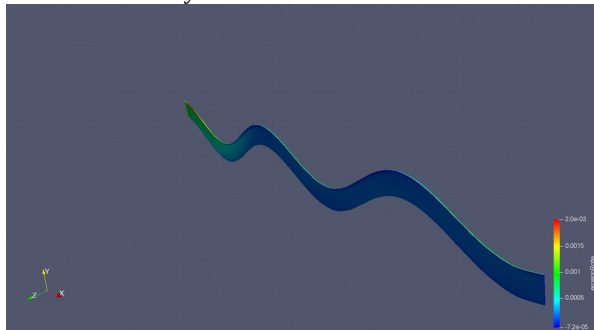


Figure 2b: 12-km-long sinuous, meandering channel that has the same λ as the Raglan channel (4.4 km) but a lower value of $2A$ (amplitude). Erosion appears to be more evenly distributed over the bend.

Discussion: Our 3-D model confirms that there is evidence for thermal erosion by turbulently flowing lava on channel bed AND at meander bends at the Raglan sinuous, meandering channel. The $(\lambda/2A)$ ratio

appears to control whether thermal erosion is concentrated over the meander flanks – almost disappearing on each meander apex – or instead is more evenly distributed over the whole bend.

Based on the observed scarce evidence for thermal erosion at each meander apex, we suggest this might be indicative of the potential interplay of thermal with mechanical erosion. Of course, other factors – such as sudden variations of the slope of the ground or the occurrence of obstacles in the way of the flow – could also interfere with the meandering pattern. That being said, the departure from regularity in meander amplitude which is observed in the field might be used to derive a first-order estimate of the amount of mechanical erosion that has interplayed with thermal. Coupling such an observation with field data on local variations in surface lithology, mechanical properties of the lava substrate and local variations in slope of the ground will help constrain the importance of the two erosion mechanisms better.

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