Interrogating the lava hypothesis for the origin of Kasei Valles with analyses of streamlined island morphometry

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Introduction

Martian outflow channels are the largest erosive structure in the solar system. Their formations during the Hesperian/Amazonian climate transition make them key markers of Mars' early climate termination.

Three hypotheses have arised to explain the formation of Kasei Valles (Fig.1,A), the largest and best preserved one: Mega-floods [1,2,4,5], Ice streaming [1,3,8,9,10], Lava flows [6,7].

Here we focus on testing the lava hypothesis by comparing the shape of streamlined islands in Kasei Valles with the ones in two known, smaller, Martian lava channels [11,12]:

- Athabasca Valles [12], located south of the Elysium Rise (Fig.1,B)
- Olympica 1b [11], located between Alba Mons and Olympus Mons (Fig.1,C)

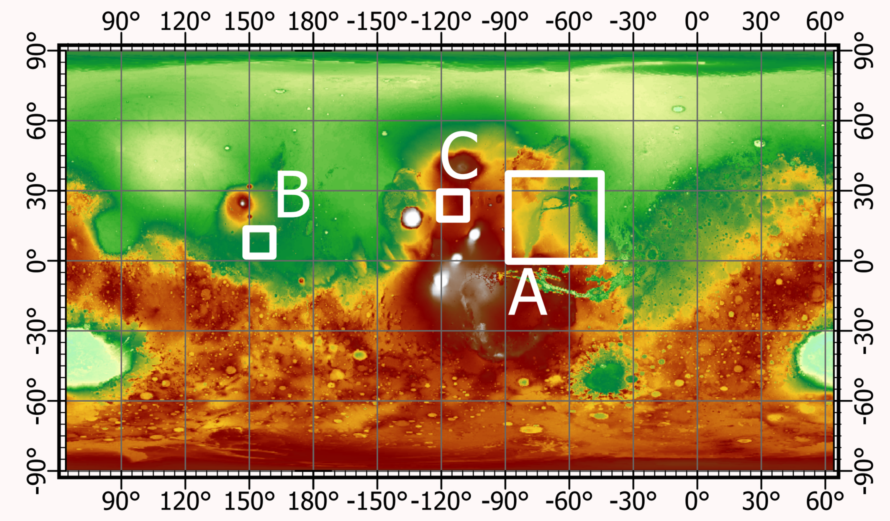


Figure 1: Topographic map of Mars with location of (A) Kasei Valles, (B) Athabasca Valles and, (C) Olympica 1b channel.

Methods: The shape of streamlined islands

Definitions:

- **Streamlining** is the **process** of reshaping of obstacle by a flow to minimize the drag induced by the obstacle.
- A **Streamlined island** is the result of the streamlining process of an obstacle in a flow by erosion and/or deposition. Its shape depends on the flow properties.
- The **Reynolds number** (Re) is the ratio of inertial force to viscous force.

Fluid velocity
Characteristic length of the obstacle

$$R_e = \frac{\rho u L}{\mu}$$

Fluid density
Fluid viscosity

The Length/Width ratio of streamlined islands is expected to scale linearly with the Reynolds number (Re) [5], irrespectively of the fluid considered (lava, ice, liquid water).

Changes in flow properties are thus correlated to changes in L/W.

In lava channels, the drop of lava temperature downflow is increasing the lava viscosity (μ), leading to the decrease of the Re number [12] and the decrease of the L/W [5].

To observe this behaviour we use ArcPro to :

- calculate contours (Fig.2A) using the MOLA-HRSC DEM (200 m/px) and CTX images (6 m/px) [11].
- compute minimum bounding rectangles and their L/W using ArcGIS Pro (Fig.2B) [11].

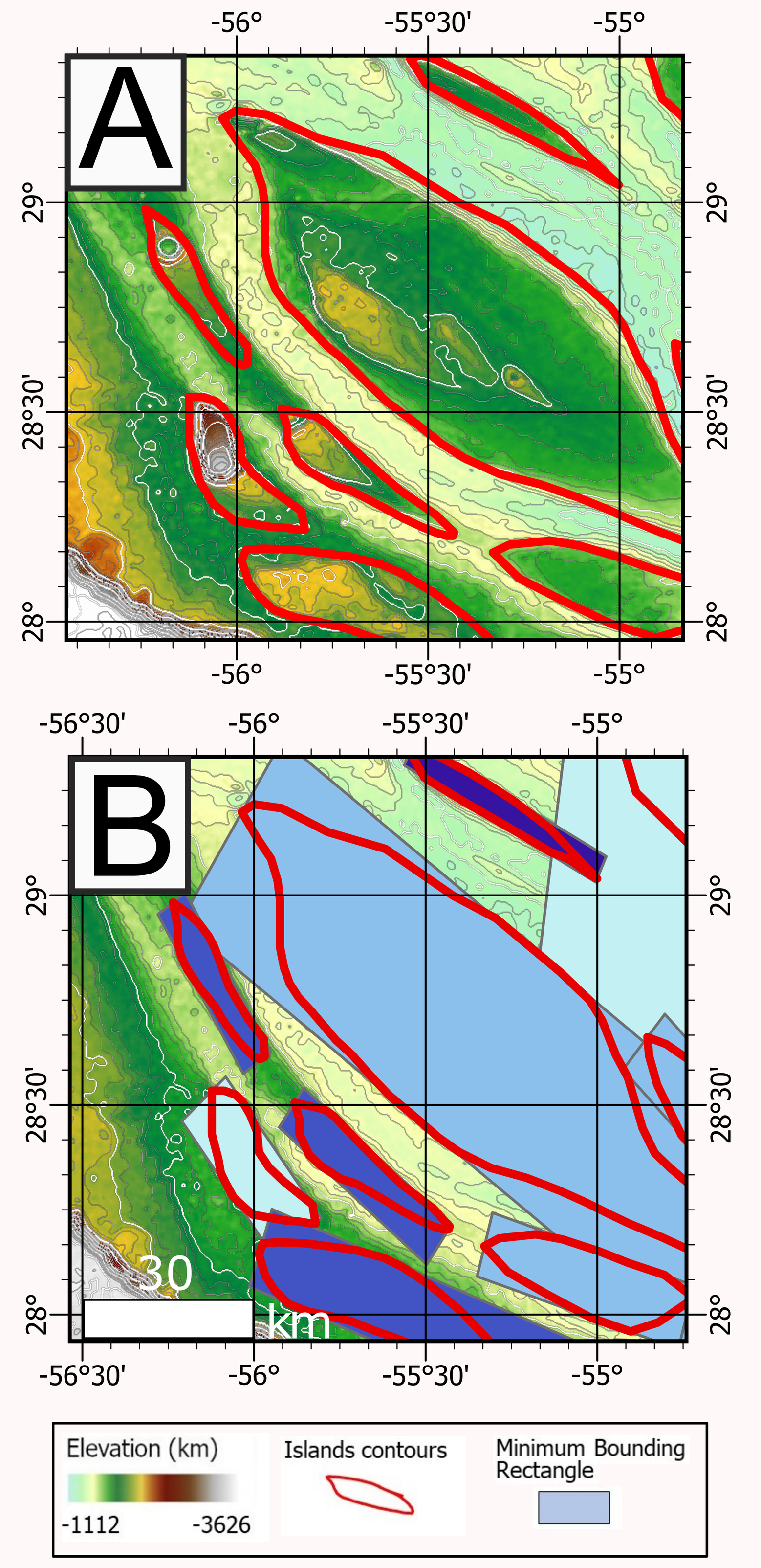
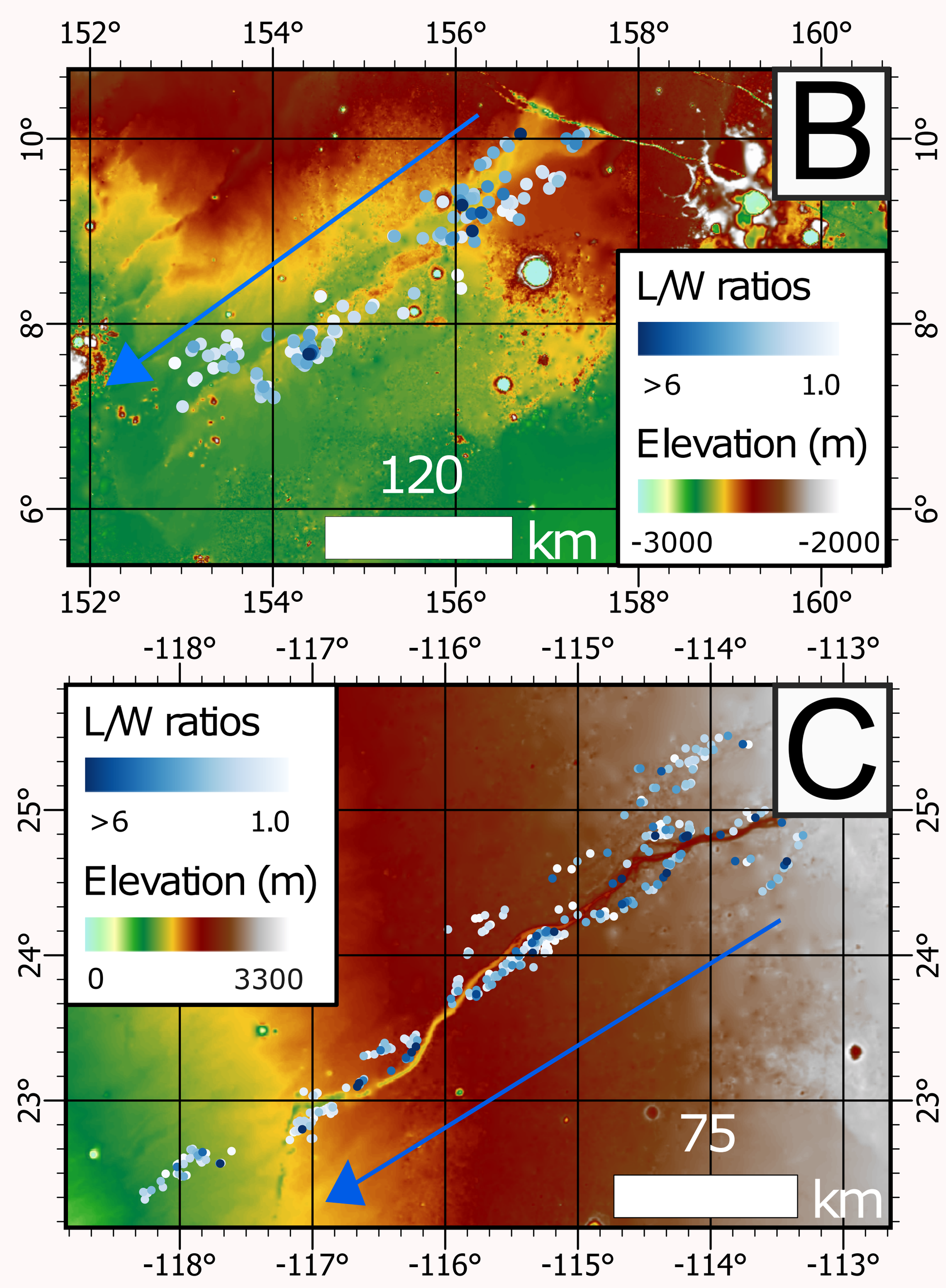


Figure 2: Example of L/W measurements step by step in Kasei. (A) Contours of streamlined islands. (B) Computed minimum bounding rectangles



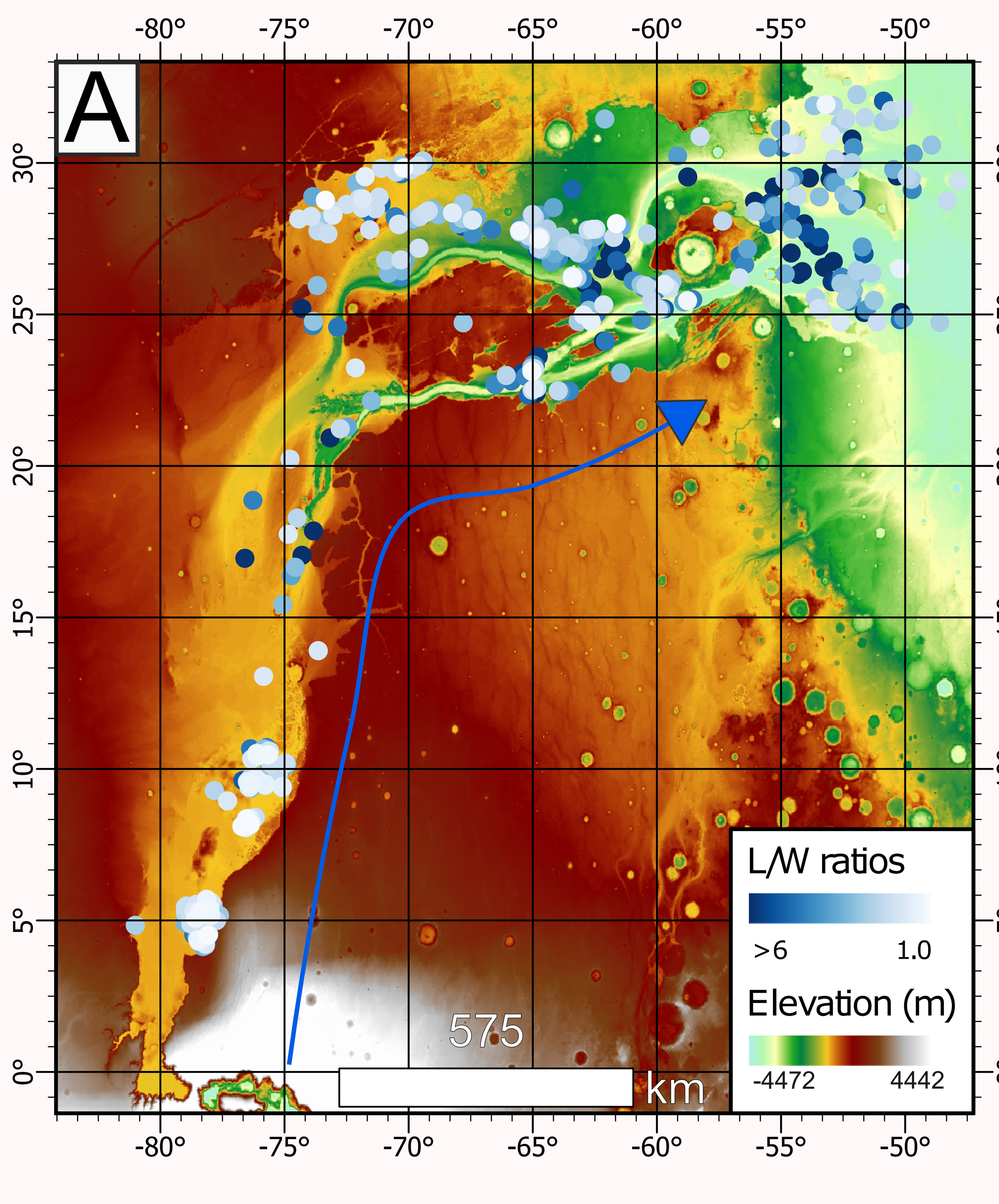


Figure 3: (A) Map of Kasei Valles displaying the elevation and Length-to-Width ratios. (B) Map of Athabasca valles with elevation and Length-to-Width ratios. (C) Map of Olympica 1b lava channel with elevation and Length-to-Width ratios. The flow directions are indicated by the blue arrow. The elevation range is adapted to each frame but the Length-to-width ratio color bar is the same.

Results and Discussion

How does the L/W evolve downvalley?

On average, L/W **increases** moving downflow in **Kasei Valles** (Fig.3,A).

On average, L/W **decreases** moving downflow in **Athabasca** (Fig.3,B).

On average, L/W **decreases** moving downflow in **Olympica 1b** (Fig.3,C).

Observations of streamlined islands morphology and setting show that L/W gradient is unaffected by topography, island area, or type of obstacle (crater vs. outcrop).

Is lava the main erosive agent in Kasei Valles?

In Kasei Valles, islands tend to lentgthen towards the end. This behavior does not correspond to expectations and observations for a lava channel.

Our results also indicate that **the increasing L/W gradient in Kasei is a consequence of changes in the flow dynamics.** This suggests Kasei saw either a flow acceleration or a decrease of fluid viscosity downstream.

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Take home message

These new results implie that Kasei was formed either by a megaflood or by an ice stream, and that lava contributed only in a limited manner to its formation, flooding the canyon rather sculpting it.

At the Hesperian/Amazonian transition, due to its scale, Kasei transported a significant fraction ot the total amount of water available on Mars.

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