Interrogating the Origin of Kasei Valles, from Flow to Form.

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Introduction:

Mars is a hyperarid, global cryosphere, and likely has been for over 3 Gyr. But this was not always so: During the so-called early Mars period 4-3.5 Gyr ago, water flowed within thousands of valleys, in crater lakes, producing ancient deltas, building ice sheets, and possibly ponding in oceans [1, 2, 3]. This early benign climate collapsed with the loss of Mars' atmosphere coinciding with the Hesperian period, ~3.5-3 Gyr ago, as shown in Fig.1(b) [4].

Outflow channels, megacanyons among the largest erosive landforms in the Solar System (Fig.1a,b,c,d), date from this time [5, 6]. Up to two dozen systems of these large scoured megacanyons have been identified on Mars, spanning hundreds of kilometers in width, thousands of kilometers in length, and up to kilometers in depth. The largest outflow channel is Kasei Valles, located in the Mare Acidalium and Lunae Palus quadrangles, flowing from the south in Echus Chasma (NW Valles Marineris) northward and then eastward into NW Chryse Planitia in a system of canyons spanning more than 2500 km long, 300 km wide, and 2 km deep at its largest (Fig.1c). Kasei is so vast that the volumes of water involved in its formation were an important fraction of Mars' total water inventory, and its outflow could have filled an ocean on the martian lowlands [5, 7].

Owing to the similar landforms carved by the Missoula megafloods observed in the Channeled Scablands on Earth, Kasei Valles is analogously interpreted to be the result of ancient massive outburst floods [8, 5], with calculated releasing discharges even larger than the terrestrial Missoula megafloods sourced by the collapse of glacial lake Missoula at the end of the last ice age [9, 5].

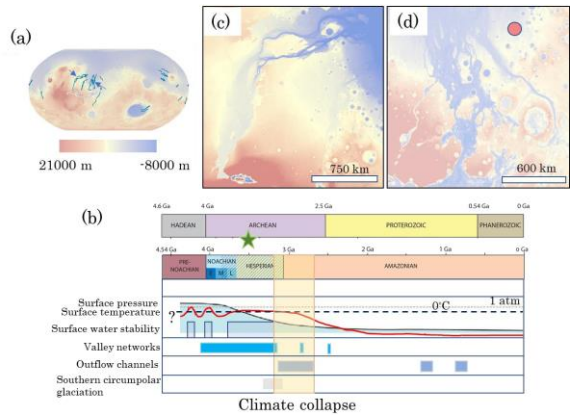

Fig. 1 Outflow channels in the context of Mars' climatic history. (a) Outflow channels on a global map of martian topography (MOLA/HRSC). Arrows highlight Kasei Valles (left arrow) and Chryse Planitia channels (right). (b) Earth and Mars climate scales, indicating the major climatic and hydrologic events that occurred on Mars. (c) Kasei Valles topography (MOLA/HRSC). (d) Chryse Planitia outflow channel topography, with the landing site of ExoMars indicated with a red dot.

Support for this hypothesis includes the presence and morphology of streamlined islands, the sheer scales of outflow channels, the presence of regularly spaced longitudinal ridges, and the presence of hanging valleys and U-shaped valleys [8, 5, 6, 10]. Debate ensues, however, regarding the near surface stability and availability of liquid water during the Hesperian period required to produce erosion at the scales of observed outflow channels. Alternative hypotheses raised to explain the formation of Kasei Valles, as well as other outflow channels, include ice streaming [11, 12] or regional construction and local erosion by turbulent lava flows [13, 9].

Methods: In this project we will explore the hypothesis that Kasei Valles was eroded by an

ice stream, a region of channelized, fast-flowing ice within an ice sheet, based on its scale, location, and geomorphology, and reinvestigate the origin of other outflow channels under this perspective. Drawing from fluid dynamic simulations, performed using COMSOL Multiphysics, we will analyze the dynamics of the flow that carved the valley along the length of Kasei Valles. This analysis will be complemented with analogue field work, which will take place in the Channeled Scablands and in the Icelandic highlands, aiming to study sites that show evidence for flooding and glacial reworking on lava floods.

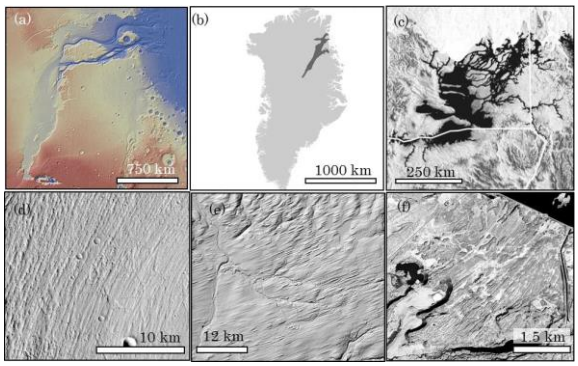

Fig 2. Overview and comparative of Kasei Valles and analogue sites and processes. (a) Kasei Valles (MOLA elevation on hillshade). (b) Graphic outline of the northeast Greenland ice stream. (c) Outline of the Channeled Scablands (US) adapted from the USGS. (d) Longitudinal grooves in Kasei Valles (CTX mosaic). (e) Megascale glacial lineations and megagrooves, Dubawnt Lake ice stream bed (ArcticDEM hillshade). (f) Grooves carved by Missoula megaflood, Channeled Scablands (Maxar, Google Earth, contrast-stretched).

Expected results: This presentation is meant as an introduction to the project, which will run from 2025-2029. During the length of this project, we will test the 'Ice flood' hypothesis, which if correct has the potential of improving our understanding of Mars' transitional Hesperian climate, the nature of its hydrological cycle, and the possibility of a Hesperian ocean. Outflow channels hold a key for understanding the collapse of Mars' early climate and hydrological system, the end of global conditions able to support life, and the rise of the global cryosphere that would come to dominate Mars' climate.

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