VALLES MARINERIS AND THE MARTIAN CHASMATA AS THERMOKARSTIC POLJES. A. M. Celâl Şengör[1], Dursun Acar[1], M. Sinan Özeren[1], Semih Can Ülgen[1], İ. Emre Önsel[1], A. Tayfun Öner[1], Paul K. Byrne[2,3], Christian Klimczak[2,4], and Sean C. Solomon[2,5]. [1]Department of Geology, Faculty of Mines and the Eurasia Institute of Earth Sciences, Istanbul Technical University, 34469 Maslak, Istanbul, Turkey (sengor@itu.edu.tr); [2]Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015, USA; [3]Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, Raleigh, NC 27695, USA; [4]Department of Geology, University of Georgia, Athens, GA 30602, USA; [5]Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY 10964, USA.

Introduction: Valles Marineris remains one of the most intriguing morphological features on Mars (**Figure 1**). Notwithstanding the near-consensus that it is a rift structure [e.g., 1], created by a large-scale extensional stress field, there are serious shortcomings to this claim. The most obvious of these is that this valley system does not look even remotely like any rift structures observed on Earth.

Valles Marineris is largely devoid of tectonic structures similar to those seen in the normal-fault-bounded graben or rifts on Earth. Furthermore, if we assume it to be a rift structure, we should be able to locate at least some large-scale shape matching between its two sides, yet no such matching is evident. Had this system been extensional, such large-scale extension could not have stopped at the ends of the feature but should have been transferred elsewhere by transform faults at one or both ends, yet no such faults are known. Also absent are any remnants of far-field compensating shortening features.

Nonetheless, a typical scarp on the walls of the Valles Marineris resembles the scarp of a landslide's rupture surface. This similarity leads us to hypothesize that Valles Marineris may be a cryokarstic structure—essentially an immense polje [2–4], the largest known in the Solar System. By this idea, the valleys were formed by the catastrophic melting of one or more crustal ice layers by a giant dike system that propagated in a manner similar to the Mackenzie dike swarm in the western Canadian Shield [e.g., 5].

Laboratory modeling: To test this hypothesis, we created a laboratory-scale analogue of the karstic polje that might have created this ~7-km-deep and ~4,000-km-long Martian depression.

The experimental apparatus consisted of a rectangular basin 89 cm long and 57 cm wide, in which a resistance wire of 57 Ω was placed. The bottom of the basin was then filled with a layer of distilled water that, when allowed to freeze, formed an ice stratum 1.5 cm thick. Next, the ice layer was covered to various thicknesses by flour or bentonite; both materials simulate well the Martian crust because on Mars, gravitational acceleration is only about 38% of its value on Earth, and so (for an assumed equal crustal density) the depth to which the cohesion term remains important in the Mohr-Coulomb shear failure criterion is about 8/3 times greater. Finally, the resistance coil was switched on to simulate a shallow dike intrusion.

Each experiment was photographed continuously as it ensued, and the final configuration was mapped in three dimensions with a laser scanner. The results of an exemplar model, in which the flour layer was 1.5 cm thick, are shown in **Figure 2**. In this experiment, a linear depression formed above the resistance coil, developing in response to the melting and evacuation of the subsurface ice layer.

In this and the other experiments we conducted, we obtained morphological analogues of the Valles Marineris system above the longitudinal thermal source, including an overall near-linear structure and flat spindle shape, cuspate margins, a central ridge, parallel side faults, and parallel depressions resembling the Tithonium Chasma. When water was allowed to drain from the experimental apparatus from the onset of melting, closed depressions formed that have a very strong resemblance to Hebes Chasma (**Figure 1**).

Our hypothesis requires substantial subsurface water-ice reserves to have been melted by dike intrusions proximal to the present-day Valles Marineris. Although searches for serpentine deposits on Mars with Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) data yielded few such sites in general across the planet, at least one was identified in Juventae Chasma, neighboring Valles Marineris [6]. Further, the eastern reaches of Valles Marineris connect with several outflow channels (including Ares, Simud, and Shalbatana valles) through Eos and Aurorae Chaoses and Margaritifer Terra. And Hebes Chasma is almost in direct contact with Echus Chasma, which ultimately links with Kasei Valles and, thereafter, Chryse Planitia. Indeed, we estimate that some 1.7 million km^3 of water were evacuated through the Valles Marineris and discharged into the northern lowlands (and the postulated northern ocean [e.g., 7], should it have existed) via these scablands and outflow channels.

We speculate that the dike system that created the Valles Marineris belongs to the radial dike systems of the Tharsis uplift. Where there were subsurface ice layers in the stratigraphy, poljes such as Valles Marineris and Hebes Chasma formed. Where water was absent, no such features developed, but large graben systems such as Claritis and Thaumasia Fossae (extending from the south of Tharsis) and Ceraunius and Tantalus Fossae (from the north) formed instead.

This is not the first time that a collapse-based model has been proposed for Valles Marineris [8,9]: a number of previous proposals invoked different suggestions for void creation, such as solution of the carbonate by a variety of magma-derived groundwater acids, dictated by the thought that the process should not require extensive recycling of the available water supply. None of these models was tested in the laboratory, however. To our knowledge, ours is the first analogue experiment based on ice-melting-related polje generation on Mars. If our model is applicable, then the tectonic and morphological evolution of this region of Mars should be reappraised in terms of cryokarstic processes.

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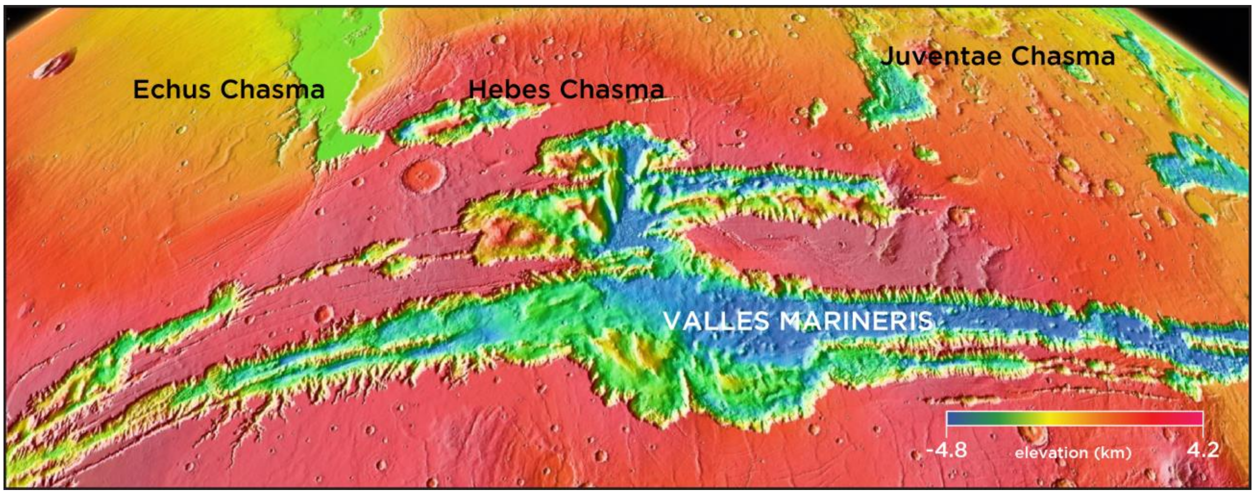

Figure 1. An orthographic view of Valles Marineris and proximal physiographical landforms (from Google Mars). Scale varies across the image. Colors correspond to elevation, from Mars Orbiter Laser Altimeter (MOLA) data. Warm colors correspond to relatively high elevations, and cool colors denote low-lying elevations.

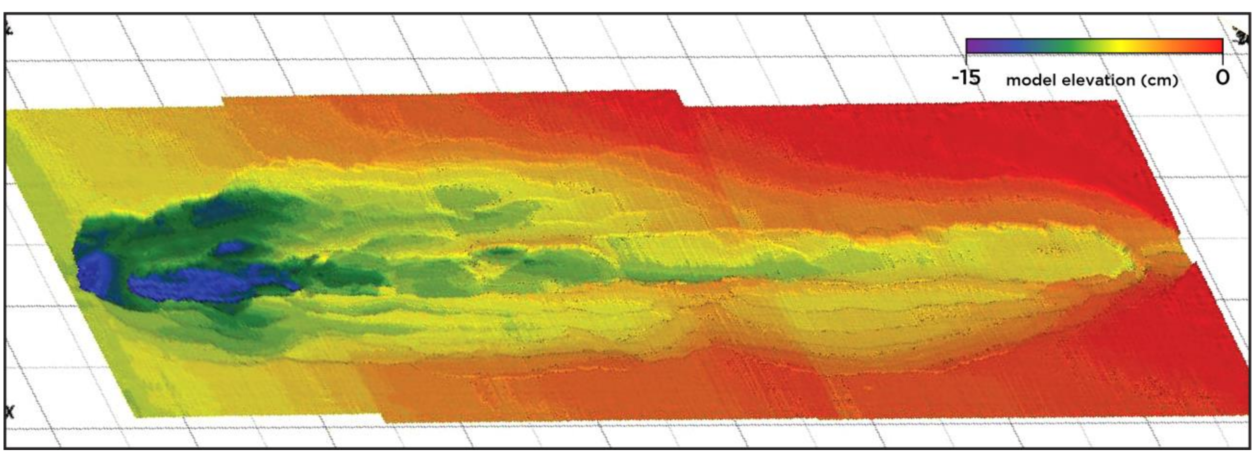

Figure 2. A 3D scan of the surface of a representative model. The color scheme is similar to that shown in Figure 1. The length of the zone of deformation in the model is about 70 cm.