DEVELOPMENT OF KASEI VALLES THROUGH MECHANICAL AND THERMAL EROSION BY VOLUMINOUS LOW-VISCOSITY LAVA FLOWS.
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Introduction: Kasei Valles is the largest outflow channel on Mars. The system extends more than 3000 km from its head at Echus Chasma to the lowlands of Chryse Planitia and Acidalia Planitia, and descends ~3 km over this distance [1,2]. Kasei Valles is characterized by anastamosing reaches and the presence of streamlined erosional residuals, cataracts, chaotic terrain, inner channels, longitudinal grooves, and volcanic mantles [3]. As with other Martian outflow systems, the channels of Kasei Valles are widely interpreted as the products of catastrophic aqueous outbursts from the subsurface [1-6]. However, realistic mechanisms by which hypothesized aqueous outbursts might have taken place on Mars have not yet been confidently identified, partly due to the remarkably high permeabilities required of models involving rapid and voluminous flow from aquifers [e.g., 7,8].

A volcanic origin for the Martian outflow systems is considered compelling by some workers, partly on the basis of strong similarities between the properties of these systems and those of large volcanic outflow systems of the inner solar system [8]. Hypothesized igneous processes, which involve the surface flow of magma sourced from large upper-mantle reservoirs, are realistic mechanisms by which the Martian outflow channels could have formed [8,9].

Are the Properties of Kasei Valles Consistent with Volcanic Origins?: The channels of Kasei Valles have superficial appearances that are comparable to those of terrestrial landscapes incised by catastrophic aqueous floods [1,3]. However, the absence at Kasei Valles of clear depositional units of fluvial or diluvial character suggests that this correspondence may be limited to features formed by erosional processes. Also, the volume of the head depression of Kasei Valles is insufficient for the depression to have acted as a surface store for channel-forming floodwaters, and the permeabilities required of aquifer outburst scenarios cannot realistically be expected to have existed across large volumes of crust or regolith [8].

Though there is a broad community consensus in favor of aqueous channel origins, the basic properties of the Kasei Valles system are most consistent with volcanic origins. These properties include the volcanotectonic context of the system, the widespread mantling of component channels by volcanic flows including those clearly erupted from the system's head, and the existence of extensive volcanic plains at the terminal basin. Volcanic origins are consistent with the properties of the Viking 1 landing site (located near the mouth of Kasei Valles), and with global mineralogical evidence suggesting the predominance of dry conditions in the Late Hesperian and Amazonian (a timeframe of substantial channel development here).

Incision Processes: The large outflow systems of the Moon, Venus, and Mercury appear to have formed through mechanical and/or thermal erosion by magma [10-13]. Development of Kasei Valles through analogous volcanic mechanisms would require that a proportion of locally-erupted lava flows had properties conducive to relatively high rates of channel incision, including low lava viscosities, large flow volumes, and high rates of flow [8,9]. The generally low slopes of Kasei Valles **(Fig.1)**, though consistent with those expected of large volcanic channels, would have inhibited channel incision. Nevertheless, physical principles [14-17] suggest that eruption of lavas with lunar-like viscosities of ~1 Pa s would have been sufficient to support mechanical incision of channels, with daily incision rates of meters to tens of meters predicted for flows of 5-20 m depth **(Fig.2)**. Consistent with previous results [18], the erosive effects of thermal processes should be relatively small but should exceed those of mechanical processes for the lowest channel slopes (e.g., less than ~0.08^{o}) **(Fig.3)**. Volcanic processes appear to be viable mechanisms for development of Kasei Valles, but may require the past eruption of lava volumes comparable to those of some of the largest terrestrial volcanic provinces.

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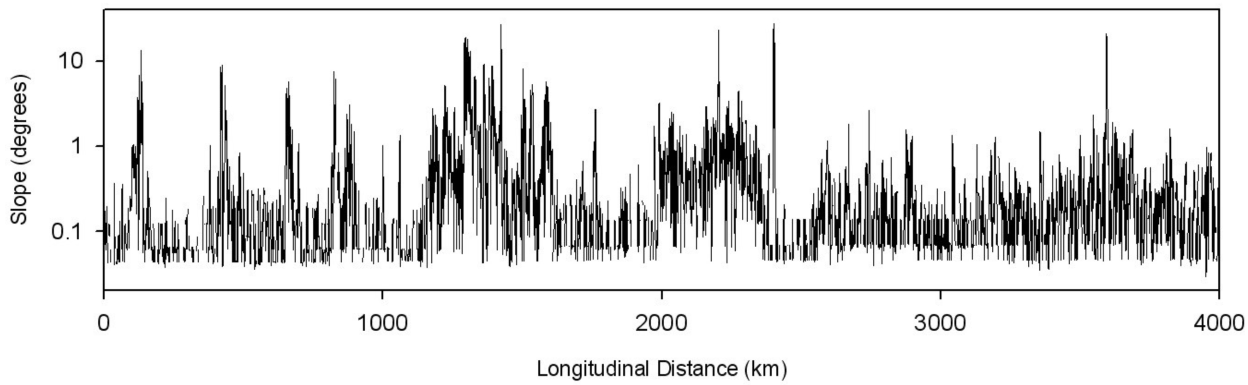

Figure 1 Semi-log plot of kilometer-scale topographic slopes for one of several possible longitudinal profiles of Martian outflow channel Kasei Valles. The system is characterized by the widespread presence of slopes of less than 0.5°. Along this route, the median slope is 0.13° and the average slope is 0.43°. Some of the steepest slopes here are associated with impact features and other landforms that postdate channel development. MOLA gridded data after [19].

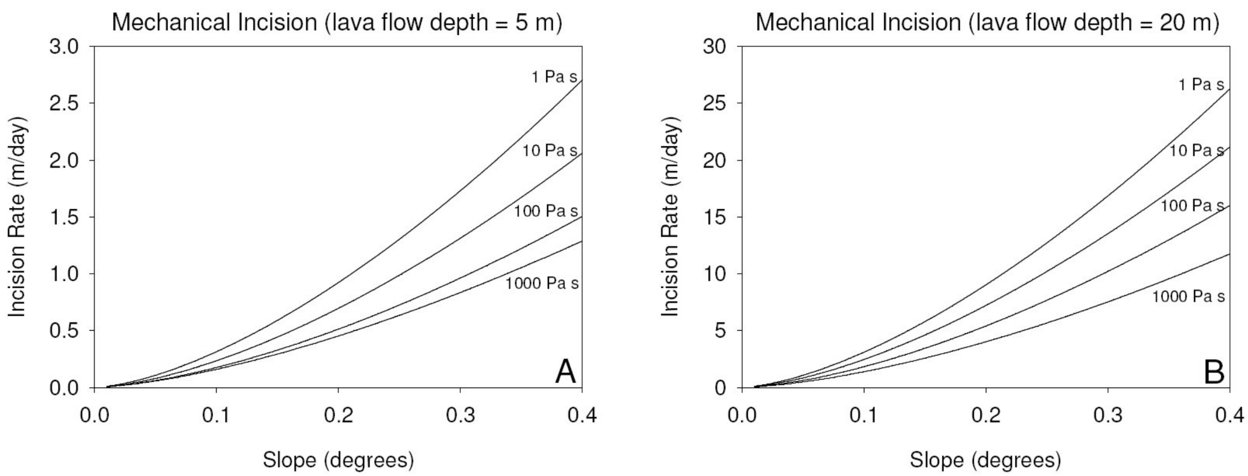

Figure 2 Mechanical incision rates predicted for lava flow depths of 5 m (*A*) and 20 m (*B*). Incision rates are given for dynamic viscosities of 1, 10, 100, and 1000 Pa s.

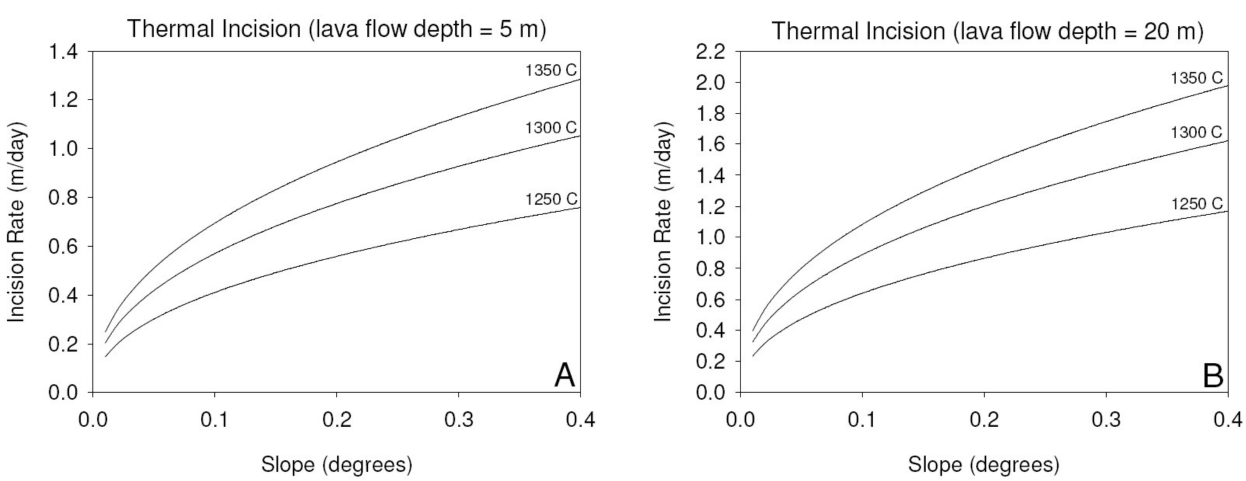

Figure 3 Thermal incision rates predicted for lava flow depths of 5 m (*A*) and 20 m (*B*). Incision rates are given for initial lava temperatures of 1350, 1300, and 1250°C. A dynamic viscosity of 1 Pa s is assumed in these calculations.