KASEI VALLES, MARS (II); THE ICE STORY; B.K. Lucchitta, U.S. Geological Survey, Branch of Astrogeology, 2255 N. Gemini Dr., Flagstaff, AZ 86001.

Morphologic features in the Kasei Valles outflow channels resemble those of cataclysmic floods on Earth [1], an observation that leads to an inferred origin for these channels by similar large outbursts of water [1, 2, 3]. Yet, outflow-channel features in Kasei Valles are generally an order of magnitude larger than those caused by terrestrial catastrophic floods, implying that Kasei floods were much larger, perhaps by as much as one to three orders of magnitude than those on Earth and in other Martian outflow channels [4]. Releasing such gigantic volumes of water from the ground in one sudden event is difficult, and explanations offered for such releases [5, 6] are not entirely satisfactory. As an alternative to flooding, many of the morphologic features in the Kasei Valles possibly were carved by ice and sub-ice water channels [7, 8], an idea supported by several observations.

The morphology [4] of the Kasei Valles region is consistent with an origin by ice. About 500 km downstream of the Kasei Valles chaotic terrain, the channels abandon their northward course and turn to the east, where they break through the Lunae Planum Plateau and split into two incised branches (the north and south channels). The north channel and other scoured incised channels are U-shaped and have smooth transitions from valley walls to valley floors, like glaciated valleys on Earth. Scour marks occur both on the walls and on unburied parts of floors of incised channels. Grooving on valley walls is very common in glaciated terrain, but not in flood-scoured valleys. Grooves on the wide, scoured platform upstream from the channel bend to the east are also U-shaped. The grooves on these platforms are more than 40 km long in places, 300-500 m wide, and 30-200 m deep (from shadow measurements) and are an order of magnitude larger than those commonly found associated with cataclysmic floods on Earth. Flood-formed grooves in the scablands of Washington and Oregon are about 50 m wide and 5 m deep. A statistical comparison of grooves in the Kasei Valles and other channels on Mars with glacially carved grooves in Alaska and the Northwest Territories of Canada show that the widths of grooves in the Kasei Valles overlap with those carved by ice on Earth as seen on Landsat images. The comparison also shows that grooves in the Kasei Valles are of similar shape but somewhat larger than those in the Kahiltna Valley in Alaska, as measured on a topographic map. However, ice features exhibit fractal behavior over certain ranges of spatial scale (including those applicable here [9]), indicating that similarities in shape may be significant. Measurements on ice stream B in Antarctica also reveal large longitudinal grooves below this rapidly moving ice mass [10].

Grooves made by floods are thought to have formed by roller vortices [11]. It is difficult to envision that roller vortices would not have disintegrated on certain pre-existing gaps on the floor of the Kasei Valles (joints in the channel beds) that are as much as 400 m wide and are crossed by grooves without deflections or offsets. Also, some ridges at the downstream side of gaps have drumlin-like shapes. Craters as much as 6 km wide are similarly overridden without deflection in the scour marks. Ice would readily overtop obstacles in the flow path without divergence. Furthermore, the overridden craters have no recognizable sediments in their interiors, as would be expected if flooded. This observation is more compatible with filling and overriding by ice, because ice would leave no trace after evaporation or sublimation [12].

Robinson and Tanaka [2] described a "mega pothole," located in a segment of the north channel of Kasei. This feature is a smooth depression 100 km long and 350 m deep with linear, parallel scour marks on its floor. Its origin is attributed by them to intense erosion facilitated by supercritical flow and cavitation. However, the morphology of this depression is more like that of hollows in glaciated terrain on Earth. The carving of hollows and overriding of swells is typical for ice, whose movement is controlled by the ice-surface gradient.

Deeply incised, V-shaped channels that cut the grooved valley floor of Kasei Valles locally acquire a labyrinthine appearance. Sub-ice channels, such as the labyrinth of the Dry Valleys of Antarctica, are common underneath glaciers and icestreams.

I offer the following explanation for the conspicuous "ice sculpture" in the Kasei Valles. The gradient of the upper Kasei Valles, where they trend parallel to the regional slope and upstream from where they break through the barrier of Lunae Planum and the Chryse Basin rim highlands, is near 0 [4], so that the water may have ponded and frozen. According to Clow [13], the ice thickness on a river is very sensitive to the discharge and the slope, mostly because of the importance of the frictional heating. If ice carved the features in Kasei Valles, there is no need to invoke gigantic outbursts of water; moderately sized springs

could have supplied the flow. And if the water ponded behind the barrier of Lunae Planum, the surface gradient would be 0 and the term for frictional heating would have been eliminated in the flow equations, so that the water froze. Also on Earth, ice jams commonly form where river beds are constricted, such as would have occurred at the breakthrough of the Kasei Valles through the Lunae Planum highlands. Ice drives occur mostly in spring during breakup, when the discharge of water increases from behind [14]. Analogous situations may have been obtained in the Kasei Valles region, where discharges may have occurred in several pulses.

Overall, floods of moderate volume may have come from Echus, the chaotic terrain below it, and from Tharsis, but the water was blocked and ponded where it encountered the highlands at the Kasei Valles bend. The ponding accelerated freezing of water that was probably already loaded with frazil ice, and gigantic ice jams piled up. Increased discharge from Echus and the Tharsis volcano region may eventually have floated and mobilized the ice masses and forced them through openings in the highlands. Such openings were probably present because the area is structurally disturbed and weakened, showing many pre-existing joints [3, 12]. The ice, when forced through the highlands, carved the conspicuous, deeply incised, U-shaped channels. North Kasei Valles consequently now looks like a valley in terrestrial glaciated terrain. South Kasei Valles may have looked similar, as indicated by still visible local scour marks, but it was later modified by masswasting and sapping processes [1, 12, 15].

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