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Lethe Vallis, Mars: a "fill and spill" flood-carved channel

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Lethe Vallis is an approximately 230 km long, 1.5 km wide, sinuous channel connecting two shallow basins in the Elysium Planitia region of Mars. Lethe is of particular interest because the main basin (which we term the Western Elysium Basin) from which it begins is fed by outflow from Athabasca Vallis, a 300 km long, 30 km wide, geologically recent, catastrophic flood-carved channel. Lethe therefore appears to be an overspill channel that formed as the Western Elysium Basin breached a topographic divide at its south-western margin.

The flood deposits in this region are marked by a distinctive platy-ridged-polygonised surface texture. We have mapped the extents of this texture in and around Lethe Vallis. From this mapping, we have constructed topographic long profiles of the Lethe Vallis thalweg and of the north and south contacts between the platy-ridged-polygonised either side of the channel and older underlying terrain.

The upstream half of Lethe Vallis has a slightly concave topographic profile with a very shallow gradient of about 0.0001. The distal half of the channel has a slope about three times greater, with a stepped profile. These steps match the locations of cataract systems within the channel. Each cataract system is defined by a series of amphitheatre-shaped scarps heading long inner channels within the main valley.

In plan view the Lethe system is divided into four separate zones, defined by constrictions where the contacts draw close to the channel margins. Each of these constrictions marks the downstream end of a basin, and are also associated with breaks in slope of the contact long profiles. The cataracts are each located a few kilometres upstream of the margins of the basins, but the inner channels below the head scarps of the cataracts terminate at the basin margins. In addition, the mapped contact for at least three of the basins (and only not so for the smallest basin) closely follow an equipotential surface – suggesting that the contacts are high-stand marks and indicate ponding. That, within basins, both north and south contacts are at the same topographic height reinforces this view. The cataracts therefore appear to represent upstream migration of knickpoints into overflowing fluvial basins.

In addition to the cataract systems, a variety of other landforms associated with catastrophic flooding are seen in Lethe. These include streamlined islands, anastomosing distributary systems, fluvial hanging valleys, and paired and unpaired terraces on the channel margins. There are also possible depositional features, dunes and/or antidunes, located just downstream of the cataracts. These features reinforce the fluvial nature of the flow that carved the Lethe Channel and suggest that there was an alluvial element to the system.

Palaeo-discharge estimates based on channel cross section and thalweg slope are of the order of 1-5$\times 10^4$ $m^3 s^{-1}$; of the order of the flow in the Mississippi River on Earth. The volume of fluid within the high stand contacts in the largest of the zones divided by the Lethe system discharge gives an estimate for the minimum length of time the system was active: about 10-50 days, but probably much longer.

In summary, the geomorphology of Lethe Vallis points to formation as a fluvial “fill and spill” catastrophic flood system. This fits in closely with the wider observations of linked basins within Elysium Planitia.