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Erosional threshold for the formation of bedrock canyons carved by megafloods on Earth and Mars

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Enormous canyons have been carved into the surfaces of Earth and Mars by catastrophic outbursts of water. On Mars, these bedrock canyons, known as the planetary-scale outflow channels, are the most important indicator of large volumes of flowing water in the planet's history. Despite their importance and now decades of observations of canyon morphology, we lack a basic understanding of how the canyons formed, which limits our ability to reconstruct flood discharge, duration, and water volume. In this presentation I will summarize recent work - using mechanistic numerical models and field observations of similar landforms on Earth – that suggests that bedrock canyons carved by megafloods may rapidly evolve to a size and shape in which boundary shear stress just exceeds that required to entrain fractured blocks of rock. Recent advances in theory for plucking, sliding and toppling of fractured rock allow for quantitative constraints on erosion thresholds. Coupling these erosional constraints with 2-D hydrodynamic models at waterfalls shows that cataracts in basalt, which are common in megaflood terrain, evolve to a threshold state such that canyon width accurately reflects flood discharge. The erosional threshold hypothesis also is consistent with the formation of gravel bars in the Channeled Scablands of the Missoula Floods, USA, and with observations of a small flood-carved canyon from a dam overflow event in 2002 in Texas. Together, these studies suggest that canyons progressively erode in concert with megaflooding, such that flood waters never fully filled the final canyon relief, implying smaller flood discharges and longer durations than models that assume near canyon-filling floods routed over modern topography.