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The Mechanics of River Avulsions on Deltas

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River deltas are highly dynamic, often fan-shaped depositional systems that form when rivers drain into a standing body of water. They host over a half billion people worldwide and are currently under threat of drowning and destruction by relative sea-level rise, subsidence, and anthropogenic interference. Many river deltas develop planform fan shapes through avulsions, whereby major river channel shifts occur via “channel jumping” about a persistent spatial node, thus determining their fundamental length scale. Emerging theories suggest that the size of deltas is set by backwater hydrodynamics; however, these ideas are difficult to test on natural deltas, which evolve on centennial to millennial timescales. Here, using physical experiments coupled with observations of the dynamics of modern deltaic evolution, we show that deltas grow through successive deposition of lobes that maintain a constant size that scales with backwater hydrodynamics. The preferential avulsion node in our experiments is a consequence of multiple river floods and Froude-subcritical flows that produce persistent nonuniform flows and a peak in net channel deposition within the backwater zone of the coastal river. Moreover, because the backwater hydrodynamics are controlled by the downstream boundary condition of constant sea level, the backwater-mediated avulsion sites translate seaward in step with shoreline progradation. In contrast, experimental deltas without multiple floods produce flows with uniform velocities and delta lobes that lack a characteristic size. Results have broad applications to sustainable management of deltas and for decoding their stratigraphic record on Earth and Mars.