Rivers in the lab

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Alluvial rivers transport sediment, and build their own bed out of it. The flow entrains sediment grains and deposit them downstream, thus deforming the channel that confines it. This fluid-structure coupling generate ripples, dunes, bars and meanders through various instabilities. More fundamentally, it also selects the size and the slope of a river. Indeed, to entrain a sediment grain, the flow-induced shear stress must overcome its weight. This threshold, typical of granular materials, sets the characteristic size of alluvial rivers [3,4,8,5]. Beyond this threshold, however, gravity pulls the traveling grains toward the center of the stream. To maintain its banks, a river thus needs to balance this transverse flux of sediment [6].

Creating small rivers in laboratory experiments is an old idea, but only now can we track thousands of individual grains as they travel downstream, to reveal the statistics of sediment transport [7]. In a small laboratory flume, we track plastic grains entrained by a laminar flow. Their trajectories show that the roughness of the underlying sediment layer causes the particles to disperse across the bed's surface as they travel downstream. This random walk induces a Fickian flux which tends to homogenize the sediment flux across the stream [9]. Meanwhile, the bed assumes a convex shape which gathers the traveling grains near its center. As a result, the sediment flux distributes itself in this self-organized potential well according to Boltzman statistics.

The same mechanism allows laboratory rivers to adjust their cross-section and their width to the sediment discharge : they widen and shallow to accommodate a larger input. Beyond a critical sediment discharge, however, a river destabilizes into a braid of intertwined channels. We suggest that a new instability, driven by bedload diffusion, might explain this transition [1].

Finally, we investigate how these dynamics express themselves in large sedimentary structures deposited by rivers : alluvial fans [2].

Références

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