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A phase diagram for fluid-driven sediment trasport[1]

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When a fluid flows laterally over a granular bed, grains may be transported with the flow. This process shapes much of the natural world. The boundary between states with and without grain motion has been studied for decades. However, this boundary is not well understood, since the process whereby grains are transported involves the coupling of several complex phenomena: turbulent fluid flow near a rough boundary, Darcy flow through the pore structure of the granular bed, the yield strength of granular beds comprised of frictional grains with irregular shape, and inertial effects of grains that become entrained in the flow. In order to clarify the essential physics that governs the onset of granular motion, we study this process computationally by including only the minimal features and then adding complexities one by one. We start with a simple numerical model that includes only gravity, grain-grain interactions that are repulsive and frictionless, and a purely horizontal viscous fluid flow. By varying the fluid flow rate and the effective viscosity, we find behavior that is qualitatively consistent with a large collection of experimental data known as the Shields curve. Thus, our results suggest that the main features of this curve result from a competition between grain inertia and viscous damping. We find this phase diagram to be qualitatively insensitive to secondary effects, such as friction, irregular grain shape, and restitution losses.

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