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Experimental and theoretical investigation of the role of clay in subaqueous sediment flows and its effect on run-out distance

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Debris flows are driven by gravity, which in the tail region is overcome by the yield strength of the flow, forcing it to freeze. These flows are capable of achieving staggeringly large run-out distances on low gradients. The case in point, described in previous publications, is the flow which resulted in the deposit of Bed 5 of the Agadir megaslide on the north-west African margin. Debrites of this flow have been recorded several hundred kilometres away from the original landslide. Previous studies have attributed such long run-out distances to hydroplaning, low yield strength, and flow transformation.

It is known that the net force acting on a volume of fluid in equilibrium is zero. In this work we show that clay-laden flows are capable of approaching equilibrium. The flows which can achieve the maximum run-out distance are cohesive enough to resist some of the surrounding disturbances, that can upset the equilibrium, and reach close to equilibrium conditions, yet are dilute enough to have low viscous stress, and relatively low yield strength and lose little sediment due to deposition. A flow that is not in equilibrium will always seek to approach equilibrium conditions by speeding up or slowing down, depositing sediment, eroding the substrate, contracting in the form of the tail approaching the head, stretching, entraining water and growing in height, or dewatering and collapsing. Here we present a theory that shows that two dimensional (2D) flows in equilibrium do not grow in height.

2D flume experiments were conducted on different mixtures of kaolinite, sand, silt, and water, on varying slopes and a transitionally rough bed (sand glued), and using various discharge rates, in order to map out different stages in the evolution of a density flow from a cohesive plug flow into a turbidity current. The following flow types were observed: high density turbidity currents, plug flows, and no flow. From the velocity profiles, certain runs demonstrated close to equilibrium behaviour. For these flows, very little flow height growth and velocity variation was observed over the length of the flume. In all cases the flow appeared to be laminar within the boundary layer with Kelvin-Helmholtz instabilities at the top which were suppressed to a large extent for higher sediment concentrations. A deposit consisting of thick muddy sand, with approximately uniform thickness, was observed for higher sediment concentrations, indicating relatively higher yield strength values, while a thinner more sandy deposit was observed for more dilute flows. It was concluded that high sediment concentrations on more moderate slopes result in slower moving plug flows which are capable of suppressing turbulence at the top, while lower sediment concentrations on steeper slopes result in faster moving, more turbulent currents. The flows which can achieve the largest run-out distance are located between these two extremes.