A First Experimentally Derived Classification of Submarine Sediment Gravity Flows

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Our ability to interpret the deposits of marine sediment gravity flows (SGF) has been greatly restricted by a lack of understanding of their flow processes. This limitation is reflected in the numerous classification schemes and the difficulty in using terms such as low (LDTC) and high-density turbidity currents (HDTC).

Here we report a novel experimentally-derived classification scheme that for the first time identifies flow types and quantifies their transition points. A series of 25 runs of three types of turbidity currents ranging from 2.5% to 35% concentration by volume with non-cohesive (silt-sized glass beads) and cohesive (kaolin) sediment were performed at different clay-silt ratios. Digital camcorders, Ultra-High Concentration Meters, Ultrasonic Velocity Profiler and a Rheometer were used to acquire flow and rheological data.

The hydrodynamic properties of the flows were determined using changing flow geometry, and high-frequency time-series, depth-average values and vertical profiles of velocity and sediment concentration. Moreover, the deposits were studied using Scanning Electron Microscopy.

Six types of flows were distinguished based on a comparison of hydrodynamic, depositional and rheological properties. A 3D phase diagram was created, showing the boundaries between these flow types in terms of rheological behaviour, bulk volumetric and clay concentration. The main characteristics of the flow types are:

Type I: Newtonian; grains supported by turbulence; segregation of grains and normally graded beds. Types II and III: Newtonian; grains supported by turbulence, hindered settling; undulating high-concentration near-bed layer (stronger in type III); partial size segregation forming partially graded beds. Type IV: non-Newtonian; viscous flow; formation of plug (flow freezing) and shear flow generating graded beds of muddy sand. Types V and VI: non-Newtonian; viscous flow with thick mud layer; grain support by matrix strength; cohesive freezing forms ungraded muddy sand with coarse-tail grading near to the top.

A new process-related classification of sediment gravity flows is proposed. Type I resembles classic LDTC behavior, and Type V and VI are similar to the debris flow behavior. Types II and III are classified as inertial HDTC, due to flow turbulence and Type IV represents a viscous HDTC, due to cohesive clay influence on flow and deposit.

The implications of the new classification scheme for natural deposits of SGF will be discussed.