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Experiments on the hydrodynamic behaviour of settling carbonate grains: Implications for calciturbidites

Max de Kruijf (1), Rosa A. de Boer (1), Jonathan Kranenburg (1), John J.G. Reijmer (2), Arnoud Slootman (2), Jean Borgomano (3), and Emmanuelle Poli (4)

(1) Vrije Universiteit Amsterdam, Faculty of Science, Geology and Geochemistry Research Cluster, Amsterdam, The Netherlands (maxdekruijf@hotmail.com), (2) King Fahd University of Petroleum & Minerals (KFUPM), College of Petroleum Engineering & Geosciences (CPG), Dhahran, Saudi Arabia, (3) Centre Européen de Recherche et d'Enseignement de Géosciences de l'Environnement, Université d'Aix-Marseille, France, (4) TOTAL CSTJF, Pau, France

Calciturbidite beds are deposited by particle-transporting subaqueous density flows in a variety of carbonate slope environments. Such carbonate turbidity currents can form thick sedimentary successions that host important hydrocarbon reservoirs worldwide (e.g. Adriatic Sea, Red Sea, China Sea). Hydraulic particle-sorting patterns are important for understanding the distribution of porosity and permeability within calciturbidite reservoirs. Whilst siliciclastic turbidite systems have been extensively studied, depositional mechanisms of calciturbidites remain underexplored. Carbonate turbidity currents carry heterogenic bioclastic particles that vary in composition-dependent density, size and shape (the latter specified by form, roundness and surface texture). This study investigates the hydrodynamic behaviour of carbonate particles using settling velocities observed in experiments. Settling velocity is a fundamental parameter of physical sedimentary processes that govern the entrainment, transport and deposition of particles in a multitude of depositional environments. The hydrodynamic behaviour of 661 grains collected from four different carbonate environments in the Bahamas, Tahiti and Italy was examined using settling tube experiments and shape analysis. It was found that density and grain size are not the sole parameters controlling the falling velocity of a settling particle. Settling velocity is (co-)dependent on particle shape, which was measured in terms of elongation and flatness and classified using the Zingg-shape classes: spheres, rods, discs and blades. Equant shapes settle fastest, then rods, then flattened shapes. Digital shape analysis reveals that form, roundness and surface textures observed for larger particles is retained also for smaller grain sizes. This is most likely due to the skeletal nature of bioclastic particles. A revised sequential set of falling regimes was developed on the basis of particle shape and Reynolds number. Modelled settling velocities calculated with common, universal settling equations from the literature deviate at grain sizes exceeding 0.5mm. A published compilation of settling velocity data was further expanded to better constrain settling velocities of bioclastic particles that were discriminated on the basis of biogenic composition and grain shape. Bioclast settling velocities range predominantly from 0-25 cm/s for grain sizes smaller than 10 mm. A model for the settling velocity of carbonate grains at three common grain size intervals is presented. Hydraulic sorting patterns in calciturbidites have previously been attributed primarily to grain-size-dependent settling. These new results suggest that species-specific and shape-dependent hydraulic sorting should be included in the evaluation of hydrodynamic processes in carbonate turbidity currents, and calciturbidites.