Features of cyclic steps formed due to surge-type turbidity currents: morphology of the steps and grain size distribution

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Field observations of turbidity currents and seabed topography on the Squamish delta in British Columbia, Canada reveal the presence of cyclic steps formed by surge-type turbidity currents. The high-density portion of each flow event, which affects the sea floor morphology, lasted only 30-60 seconds (e.g., Hughes Clarke, 2016). There have been few experimental studies on the formative condition and depositional features of cyclic steps due to surge-type turbidity currents. Yamano et al. (2017) found that there are differences in the morphology of the steps depending on surge duration. The factors that create these differences are the flow velocity, discharge, and concentration of the turbidity currents. In this study we investigate the influence of discharge on the morphology of cyclic steps. Two kinds of plastic particles, whose grain-size distributions differ from each other, were used in this study to observe grain size distribution and sedimentary structures of the cyclic steps, with an eye to application to sediment waves in the modern sea floor and in the rock record.

The experiments were conducted at the Hydrosystems Laboratory of University of Illinois, Urbana-Champaign (UIUC) in March 2017 and at Osaka Institute of Technology (OIT) from December 2017 to January 2018. In the experiment at UIUC, a flume, which is 14.5 m long, 0.5 m deep and 0.1m wide was suspended in a larger tank, tilted at 2.5 degrees. Salt water (density: 1.17 g/cm^3) and two kinds of plastic particles (specific gravity: 1.5, D_{50}: 68 μm, 206 μm) were mixed at a weight ratio of 20:1:1 in the head tank, and then introduced into the flume as a slurry. In Case A, slurry filling the entire volume of the head tank, 58.7 L (5.87 L/cm), was supplied for single surge, which took 40 seconds to flow out. We repeated 40 such surges. In Case B, slurry filling half the volume of the head tank, 27.4 L (2.74 L/cm), was supplied for each surge, which took 10 seconds to flow out; we repeated 80 surges. The total amount of supplied sediment was about the same in both cases. The flow rate per unit time gradually decreased during a single surge. In the experiment at OIT, a flume 7.0 m long, 0.3 m deep and 2 cm wide was suspended in a larger tank, tilted at 5.5 degrees. Slurries of salt water (density: 1.12 g/cm^3) and two kinds of plastic particles (specific gravity: 1.47-1.52, particle size range: 75-150 μm, 150-250 μm) were mixed at a weight ratio of 20:1:1 in the head tank, and then introduced into the flume. The flow discharges per unit width per surge were approximately 0.46 L (Run 1) and 0.63 L (Run 2). In both cases, the surge duration was 3 seconds, and the flow rate per unit time was almost constant. We repeated 140 surges in Run 1 and 100 surges in Run 2, so that the total amount of supplied sediment was about the same.

At the end of each series, 4 steps were formed in the two series in UIUC and 2 steps were formed in the two series in OIT. Those steps moved upstream during the series of pulse runs. The wave steepness of the resulting steps were larger in the cases of larger discharge for each surge in both the experiments at UIUC and those as OIT. The sedimentary structures observed in the cyclic steps of these experiments were mainly laminae gently dipping toward the upstream side. These laminae were truncated at the downstream side of the step. Moreover, the grain size analysis of the cyclic steps at UIUC showed that D_{50}

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of the surface sediments tended to decrease toward the downstream, with the tendency being more prominent as the total discharge of the surge increased. It was also found that the D_{50} on the downstream side is smaller than on the upstream side of each step. This distribution is inferred to be caused by a hydraulic jump at the upstream side of each step.

References

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