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Morphodynamics and sedimentary structures of bedforms under supercritical-flow conditions: new insights from flume experiments

M.J.B. Cartigny, D. Ventra, G. Postma, and J.H. Van den Berg
University of Utrecht, Faculty of Geosciences, utrecht, Netherlands (m.cartigny@geo.uu.nl)

Particulate density currents, such as pyroclastic flows and turbidity currents, are prone to flow in a supercritical state, due to their small density difference in relation to the ambient fluid. Facies deposited in supercritical-flow conditions are therefore likely to be common, yet their recognition and analysis remain difficult in the stratigraphic record. This is commonly ascribed to the poor preservation potential of deposits from high-energy supercritical flows. However, the number of documented flume datasets on supercritical-flow dynamics and sedimentary structures is very limited compared to available experiments on subcritical flows, and our inability to identify and interpret such deposits might also be due to insufficient knowledge. This work presents the results of systematic experiments spanning the full range of supercritical-flow bedforms (antidunes, chutes-and-pools, cyclic steps) developed over mobile sand beds of variable grain sizes. Flow character and related bedform patterns are constrained through time-series measurements of bed configurations, flow depths, flow velocities and Froude numbers. The results allow the refinement and extension of current bedform stability diagrams in the supercritical-flow domain. Sedimentary structures associated with the development of supercritical bedforms under variable aggradation rates are revealed by means of a synthetic aggradation technique and compared with examples from field and flume studies. Image sequences show the direct coupling of flow processes, bed configurations and resultant sedimentary structures for selected supercritical bedforms. Aggradation rate, which is highly variable in pyroclastic events, is observed to bear an important influence on the geometry of supercritical-flow structures, and it should be held in consideration for the identification and mutual distinction of supercritical bedforms in the volcaniclastic record.