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A new classification of cyclic steps and its application

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Cyclic steps are a type of upper flow-regime bedform consisting of trains of bed undulations with hydraulic jumps in the troughs. They form in free-surface flows and comprise a common, if not the dominant, bedform in subaqueous density flows in oceans, lakes and reservoirs. Cyclic steps originate from alternating Froude-subcritical and Froude-supercritical flow on respectively the stoss side and lee side of individual bedforms. The transition between these flow states is embodied by the hydraulic jump in the trough of the bedform, leading to the permanent or quasi-permanent morphology of cyclic steps. Over the past decade, numerous studies affirmed the dominant role of cyclic steps in generating bed undulations in modern and ancient glacial outwash, deltaic and turbidite environments. Cyclic steps were previously discriminated as net-depositional, transportational and net-erosional in different parts of such systems.

These bedforms are here classified as climbing, transportational and falling cyclic steps, respectively. In analogy to the classification of ripples and dunes, the adjectives ‘supercritically’ and ‘subcritically’ can be added to indicate the preservation or not of the lee side, respectively. To avoid confusion between the direction of crest-migration (indicated by the terms subcritically and supercritically climbing or falling) and the flow regime (Froude-subcritical and Froude-supercritical flow), it is in most cases preferable to use the following cyclic step descriptors: (1) fully depositional (supercritically climbing), (2) partially depositional (subcritically climbing), (3) partially erosional (subcritically falling) and (4) fully erosional (supercritically falling). The new classification defines distinct depositional signatures for each type of cyclic steps. The most common type of cyclic steps is partially depositional, which is associated with nested scours filled with massive to backset-bedded deposits.

The new classification can potentially be used as a predictive tool in the reconstruction of modern and ancient turbidite environments using repeat bathymetry, seismic reflection or outcrop data. To demonstrate this, the classification is applied to the deep-marine West Penghu Channel in the South China Sea, the Howe Sound fjord-delta in British Columbia, Canada and the Pleistocene carbonate slope of Favignana Island, Italy.