Analytical and experimental study of dual-slope effects on Gilbert and hyperpycnal deltas over bedrock

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Deltas preserve a vast of sediment prism at the shoreline at different spatiotemporal scales and with diverse environmental settings. The sediment prism subjects to homopycnal (or hypopycnal) flows usually yields a Gilbert-type delta, which has an upward-concaved mild topset, a steep foreset rested at the angle of repose and a relatively flat bottomset. Unlike Gilbert deltas, the sediment prism formed by hyperpycnal flows (or turbidity currents) may yield a delta with its subaqueous foreset upward-concaved and bed slope much milder than the angle of repose. However, our knowledge about the morphodynamics of deltas that prograde over bedrock basements with different subaerial and subaqueous slopes is still lacking. In this study, we investigate the effects of the subaerial and subaqueous basement slopes on Gilbert and hyperpycnal deltas by using analytical and experimental approaches. We propose two newly derived analytical solutions for describing the formation of Gilbert and hyperpycnal deltas over different dual-slope settings, respectively. The exact solutions are quantitatively verified by well-controlled physical experiments, and yield good agreements in both delta profiles and moving trajectories: bedrock-alluvial transition and shoreline. Under constant influx conditions, the scaled delta profiles at different times collapse to a single profile, confirming that the morphological self-similarity would establish over single-slope or dual-slope basements, thus enabling us to use the analytical similarity solutions as a tool for quantifying the relative effects of dual-slope to single-slope basement. Our results reveals that the effects of the subaerial and subaqueous slopes are asymmetric for both Gilbert and hyperpycnal deltas. An increase of the subaerial slope would push the delta forward and upward, leading to an enhanced forward migration of shoreline, a raised yet compressed topset, and a suppressed headward migration of bedrock-alluvial transition. On the contrary, an increase of the subaqueous slope would pull down the delta, suppressing the headward migration of bedrock-alluvial transition, forward migration of shoreline and topset dimensions while increasing the foreset length. Thus, with our analytical framework and in light of the scale independence of delta morphology, our results are likely to apply beyond experimental scales.

Keywords: Gilbert delta, hyperpycnal delta, dual-slope, self-similarity, analytical solution, physical experiment

