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Cyclic steps in proglacial delta fronts: New insights from Upper Pleistocene-Holocene successions, St. Lawrence Estuary and Gulf, Québec, Canada

Pierre Dietrich (1), Jean-François Ghienne (1), Alexandre Normandeau (2), and Patrick Lajeunesse (2)

(1) Institut de Physique du Globe de Strasbourg UMR 7516, CNRS/Université de Strasbourg, 1 rue Blessig, 67084 Strasbourg Cedex, FRANCE (pdietrich@unistra.fr), (2) Département de Géographie, Université Laval, 2405 Rue de la Terrasse, Québec G1V 0A6, Québec, CANADA

Proglacial delta fronts in both present-day systems and in the sedimentary record frequently include sand-sized, upstream-migrating bedforms. Although several studies have recently monitored their sediment dynamics, their formative processes are still matter to debate. Here we report on two Pleistocene-Holocene proglacial deltaic successions located on the North Shore of the St. Lawrence Estuary and Gulf, Québec, Canada. Owing to a well-constrained pattern of glacio-isostatic rebound, these now-emerged successions are characterized by accurate palaeo-bathymetric reconstructions. In our case study, we describe backstepping (upstream-migrating) cross strata lying on delta foresets at shallow bathymetries ranging from 10 m to deeper part, reaching in places 50 m.
Cross strata, interpreted as being deposited by Froude-supercritical cyclic steps, are characterized by steep mean dips (up to 13°) and short-wavelength (10-20 m) undulations. They form backstepping assemblages of massive to faintly laminated sand bounded on either side by downslope-dipping erosive surfaces on which strata onlap and are truncated upslope and downslope respectively. Graded sand beds, sheared flamed mud layers, matrix- to clasts-supported pebbles or sand intraclasts occasionally occur.
In a first case study located in the St. Lawrence Estuary (Portneuf), cyclic steps are borne by gently-sloped (2-3°) foresets deposits at depositional depth less than 50 m. Related sand includes graded beds, thin (5-10 mm) muddy interbeds and terrestrial organic debris. In a second delta located in the Gulf of St. Lawrence (Moisie River), backstepping, faintly laminated gravelly sand beds are directly overlain by pebbly topsets constituted by the subaqueous termination of a sandur. They are in addition either sharply truncated or are passing gradually downslope to regular, steep-sloped gilbert-like delta foresets. Scour infills with backsets are commonly associated with these strata that were deposited at very shallow bathymetries (10 m) as inferred from the stratigraphic architecture.
These features suggest that river outflow directly derived from proglacial distributary channel(s) on the delta plain is responsible for the genesis of cyclic steps on delta foresets. The outflow maintained its inherited supercritical state without experiencing a hydraulic jump while entering the sea. This scenario is an alternative to depositional models linking cyclic steps generation and mass-wasting processes related to mouth bars oversteepening. We argue that either meltwater outburst flows issuing from a nearby ice-margin or spring low tide condition, or a combination of both, can produce adequate flow conditions, in terms of water and sediment discharge, for creating supercritical flow and related depositional structures in delta front settings.