# A rationale of shoreline autoretreat provided by the grade index model

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The dynamics of delta distributary channels can be intensely affected by basin water depth in front of the delta, particularly in terms of a long time scale. The previous experiments conducted in use of tank facilities suggest that with deeper basin water, delta distributary channels have lower rates of alluvial aggradation and lateral migration. If the delta faces very deep water, the channels attain alluvial grade and are stabilized in a particular position in the delta plain. This effect of basin water depth can be numerically expressed with grade index ($G_{index}$), which ranges between 0 (perfect alluvial aggradation) and 1 (alluvial grade). Given basin water depth ($h$), delta plain radius ($x$) and alluvial slope ($S_a$), we define dimensionless basin water depth as $h^*=h/S_a x$. Assuming a set of particular geometrical conditions that (1) the basin floor is flat and horizontal, (2) the delta is always attached with a vertical wall on the back, and (3) base level is stationary, grade index is given as $G_{index}=(1+2h_*+S_{a*}h_*^2)^{-1}$, where $S_{a*}$ is alluvial slope normalized with the delta's foreset slope $S_f$ (i.e. $S_{a*}=S_a/S_f$).
In a hypothetical setting where (1) base level rises at a constant rate (i.e. $h$ also increases in proportion to time), (2) the entre sediment supplied from the outside of the system is constant (rate $Q_s$) and accumulates as part of the delta, and (3) the delta's angle parameters are always retained constant, time derivative of the delta's volume $V(x,h)$ is equal to $Q_s$. Based on this relation, easy calculation leads to a dimensionless progradation rate ($R_{pro*}$) of the delta: $R_{pro*}=(1-A_{B*})G_{index}$, where $A_{B*}$ is the delta's bottom surface area that is made dimensionless with autostratigraphic 3D length scale $L_{3D}$. It follows that shoreline autoretreat starts when $A_{B*}$ exceeds unity. By a similar procedure, we find that the dimensionless rate of alluvial aggradation ($R_{agg*}$) is given by: $R_{agg*}=A_*+(1-A_{B*})G_{index}$, where $A_{B*}$ is the delta plain's horizontal cross section area that is made dimensionless with autostratigraphic 3D length scale ($L_{3D}$). When the retreating shoreline arrives at the back wall, alluvial plain disappears and the entire depositional system is drowned (autodrowning). At this critical moment, $G_{index}=0$ and $A_*=0$, thus $R_{agg*}=0$.
The argument above brings a proposition that the shoreline autoretreat-autodrowning sequence, as a non-equilibrium response of the delta to steady sea level rise, is closely related to grade index. This sequence is due to the delta's progressive expansion and increasing basin water depth (i.e. sea level rise), and thus clearly related to grade index. The grade index model provides a novel rationale for the occurrence of the autoretreat-autodrowning sequence.

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