Alluvial grade attained in the regime of shelf growth during multiple cycles of relative sea level

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An autostratigraphic theory supported with model experiments of fluvio-deltaic systems has renewed the ever-longstanding concept of grade, and suggests that the graded state of downstream alluvial rivers can never be attained if the delta keeps prograding with stationary base level, but only be possible when accompanied by a particular pattern of base level fall. One of the suggested models is that with slope conditions of alluvial slope (α) equal to basin slope (ϕ), the feeder downstream river will attain grade autogenically as response to steady external forcing characterized by constant rate of sea level fall ($R_{sl} < 0$) and constant rate of sediment supply (Q_s). Once grade has been attained, a deterministic delta-front thickness (h_{set}) is reached, as all the sediment would bypass toward the subaqueous realm to build delta front without development of an alluvial topset. In 2D consideration:
$h_{set} = Q_s/[|R_{sl}|*(1+\alpha^{-2})^{1/2}] = \Lambda_{2D}/(1+\alpha^{-2})^{1/2}$
where Λ_{2D} is two dimensional autostratigraphic length scale forced by R_{sl} and Q_s and expressed by $Q_s/|R_{sl}|$.

This autogenic grade has been proven by modeling a delta which progrades onto a shelf with a slope (i.e. ϕ) that equals the delta-top slope (i.e. α). In nature, such slope conditions might also be formed by non-deltaic rapid transgression ($R_{sl} > 0$) that leaves a drowned alluvial surface that was nearly or precisely graded. This can be realized when the alluvial length (L) is sufficiently larger than a critical value (L_{crt}), which is set by Λ_{2D} for the relative sea level rise:
$L_{crt} \sim \Lambda_{2D}$

It is theoretically possible that natural sea level cycles (alternating rise and fall) induce graded rivers. To examine this prediction, a series of 2D experimental runs was performed at Nagasaki University. The experiments were conducted by using a narrow (2.0 cm wide), open-ended flume, in which sediment and water mixture was inflowed with constant rates. The flume is designed with a nearly horizontal base, conjunct with a landward slope of ~30°. The three moving boundaries of the delta system, i.e. upstream end (alluvial basement transition), downstream end (foreset toe) and the shoreline, are free to move during the experiments. During each run base level changes were kept constant in amplitude (Ap) and rate (R_{sl}), but between comparative runs, either Ap or R_{sl} varied.

The experiment results show that the fluviodeltaic system can continually extend far beyond the critical alluvial length ($L >> L_{crt}$) in the 2D section as long as sea level cycles continue. And then: 1) during sea level rising, transgression leaves a concave-upward sediment-starved surface, the downstream of which nearly parallels with the extension of overlying alluvial surface (thus $\alpha \sim \phi$), but the upstream slope gradually increases ($\alpha < \phi$); 2) during sea level fall, as soon as the delta progrades onto the downstream part of the submerged shelf (where $\alpha \sim \phi$), it approaches grade by erosion if the pre-developed delta foreset slope (h) is thicker than h_{set}, or by aggradation if $h < h_{set}$; and 3) the length of the shelf (L_{shelf}, where $\alpha \sim \phi$) or the time span of sea level fall (T) determine whether or not grade can be attained. If L_{shelf} and/or T are much larger than their critical values (L_{shelf_crt} and T_{crt}, respectively), autogenic grade is attained; otherwise, the system continues to degrade (in case $h > h_{set}$) or aggrade in spite of base level fall (in case

$h < h_{set}$).

This contribution illustrates that: 1) autogenic grade can be realized in multiple cycles of relative sea-level fall and rise. The pessimistic view that grade is no more than a mere concept and hardly realized in natural fluvio-deltaic systems, may be a thing of the past, in consideration of the eustatic history; 2) relative sea level fall is not necessarily accompanied by degradation. It thus makes sense to re-examine the relationship between stratal stacking patterns and cyclic base level changes, a fundamental theme of sequence stratigraphy.

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