A governing equation of non-deltaic transgressive profile: 2D numerical simulation and flume experiments

*Junhui Wang[1,2,3], Tetsuji Muto[3]

1. China University of Petroleum (Beijing), 2. State Key Laboratory of Petroleum Resources and Prospecting, China, 3. Nagasaki University

An alluvial river subject to relative sea level rise has a critical length (L_{crt}), beyond which the river can no longer sustain deltaic sedimentation but behaves to develop an estuarine environment. In such cases, there occurs non-deltaic rapid transgression. It is not difficult to imagine that non-deltaic transgression is pervasive in geological records, since most of the world large rivers would have "over-extended" to as far as the shelf edges during glacial or lowstand sea level periods. The configuration of non-deltaic transgressive profiles deserves a study because (1) it would provide a criterion for identifying non-deltaic transgression in the past and thus the fact of over-extension of the feeder alluvial river, and (2) it would constrain arguments on sediment transportation to the deep-water depositional systems.

Suppose that a river has an over-extended alluvial length of L ($>>L_{crt}$). During non-deltaic transgression, all the sediment fed by the river is consumed for alluvial aggradation and thus allocated in the subaerial realm. On the assumption that the supplied sediment is evenly distributed along the river profile which is approximately regarded as linear and has an averaged slope of α, the local transgressive slope Ψ can be expressed as:
$\Psi = \alpha L / [L - \Lambda_{2D}(1+\alpha^2)^{0.5}]$ (1)

We set an x–z coordinate system (x: basinward horizontal, z: vertical) that originates from the intersection of the initial horizontal line and the hinterland profile. Let x to be positive downstream and z to be positive upward. Equation 1 can be rewritten as:
$\Psi_{x,z} = \alpha(\gamma x+z) / [(\gamma x+z) - \Lambda_{2D}(\gamma - \alpha)]$ (2)
where γ is the averaged hinterland slope.

Equation 2 can be regarded as the derivative function of the governing equation of the non-deltaic transgressive profile, which can be expressed as:
$\partial \eta_{x,z} / \partial x = \alpha(\gamma x+z) / [(\gamma x+z) - \Lambda_{2D}(\gamma - \alpha)]$ (3)
where $\eta_{x,z}$ denotes the non-deltaic transgressive profile expressed as the pathway of shoreline. Note that sediment compaction is not considered.

Equation 3 can hardly be solved analytically but by numerical simulation. The solutions that we have obtained indicate that $\eta_{x,z}$ takes a concave-upward geometry with upstream-increasing gradient.

To test our numerical model, a series of 2D physical experiments was performed at Nagasaki University. The experiments were conducted using a 4 m-long and 2.0 cm-wide, open flume, from the upstream end of which sediment and water were fed at constant rates. Before each experimental run, we built a sufficiently long river profile inside the flume, to model the initial over-extended alluvial river ($L >> L_{crt}$). The initial river lengths were different by runs (L_0, ranging from 120–350 cm) and were set to be within a range of 0.139–0.158 (α). The hinterland slope was set as a constant value of 0.612 (γ). In each run, there occurred non-deltaic transgression as soon as base level started to rise.

©2019. Japan Geoscience Union. All Right Reserved.

Any of the resulting profiles of non-deltaic transgression shows a concave-upward geometry. The downstream end of the profile was tangent to the initial river profile (thus α~ Ψ). To the upstream, Ψ gradually increased, and approached a value as large as γ when the alluvial river was sufficiently shortened. The non-deltaic transgressive profiles generated in the experiments match well with the numerical model, implying that equation 3 can account for the non-deltaic transgressive profile in nature.

Keywords: Autostratigraphy, Non-deltaic transgressive profile, Numerical simulation, Flume experiments

©2019. Japan Geoscience Union. All Right Reserved.