Morphodynamic Modeling of Response of River Deltas to Sea Level Rise

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1. INTRODUCTION

River deltas have shown a variety of responses to Holocene sea level rise. The mouths of the Thames, Humber and Severn Rivers display deep embayments similar to those of Delaware River and Chesapeake Bay. The mouths of the Maas/Schelde River System show an intermediate degree of embayment, whereas the mouths of the Po and Ebro Rivers show actively prograding deltas similar to that of the Mississippi River. Most of morphodynamic modeling of the response of a river mouth to sea level rise has relied on the normal flow assumption; that is, the effect of backwater has not been considered in treating river flow. Most large rivers have much lower Froude numbers near their mouths, implying that backwater effects cannot in general be neglected. Here a 1D morphodynamic model of delta response including backwater effects is employed to clarify the response of river delta to sea level rise and compared with one that does not include them.

2．OUTLINE OF SIMULATION

Muto and Steel (1992) have identified a condition under which rising sea level gradually starves a delta foreset of sediment, eventually leading to rapid transgression (shoreward movement) of the shoreline. They have called this response “autoretreat.” Muto (2001) have verified autoretreat experimentally in a small flume (Figure 1). Here the effects are studied at field scale in a river with bankfull width B = 100 m, bankfull discharge Q_w = 600 m^3/s, floodplain width B_f = 1500 m, sediment size D = 0.5 mm, flood intermittency (fraction of time per year the river is in flood) I_f = 0.1, and rate of sea level rise v_{sea} = 1 cm/year. Two upstream boundary conditions are considered: a) sediment feed over an alluvial bed at a fixed point x = 0 upstream (UPFIX) and b) sediment feed at x = 0 over bedrock, with a freely migrating alluvial-bedrock transition downstream (UPFREE). Two methods of calculation are considered: a) a normal flow calculation based on local equilibrium in momentum balance, according to which the boundary shear stress is given by the depth-slope product (NF), and b) a full backwater calculation upstream from the point of standing water (BW).

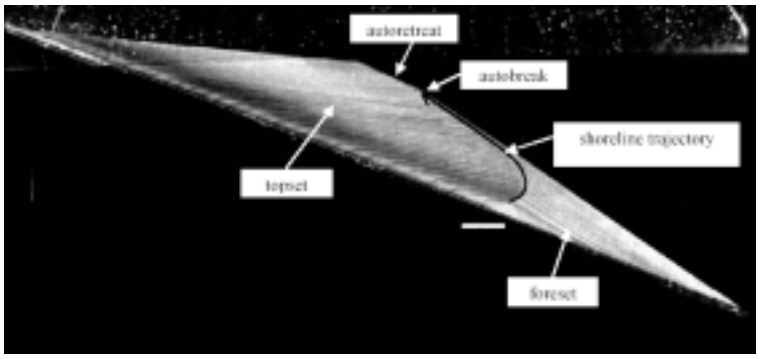

Figure 1. Image from the end of one of the experiments of Muto (2001). Flow was from left to right.

3. RESULT OF COMPUTATIONS

A numerical simulation was conducted under the conditions of UPFIX and BW to know the delta response to sea level rise. The result of calculation in three cases is represented in Figure 2 (a), (b) and (c). Under the condition of constant sea level (Figure 2 (a)), the delta progrades over 3000 years. When the sea level rise, the shoreline progrades less rapidly and the sea level rise causes the shoreline to retreat backward. The autoretreat seen in the experiment (Figure 1) occurrs from

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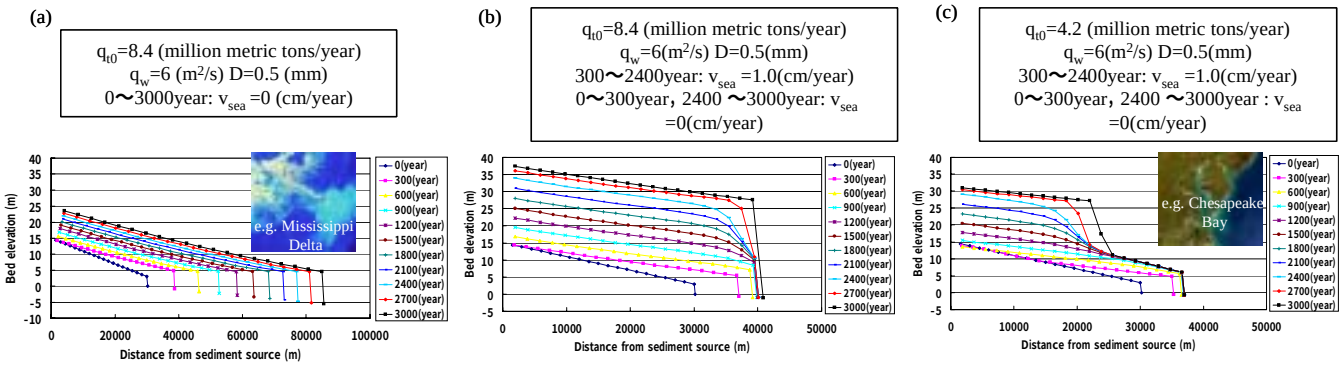

Figure 2. Simulation for three different cases under the conditions of UPFIX and BW (q_{to}=sediment supply from upstream end)

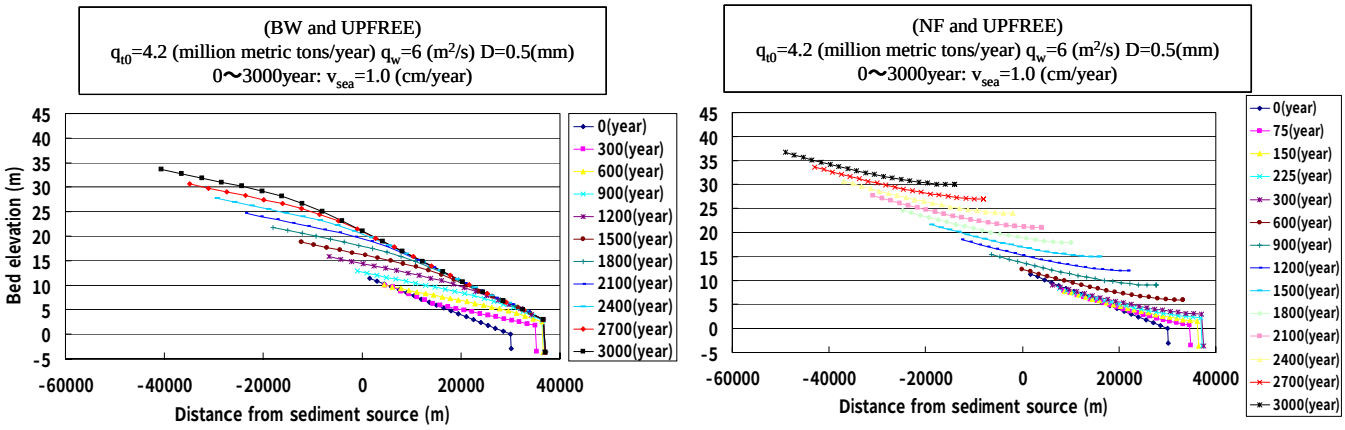

Figure 3. Comparison between the simulation including backwater effect and one that does not include them.

1200 to 2400 years in Figure 2 (b). In the case that the sediment supply from upstream end (q_{to}) is not sufficient in addition to rising sea level, the formation of embayment can take place as shown in Figure 2 (c). The model of delta response including backwater effects (under the conditions of UPFREE and BW) was compared with one that does not include them (under the conditions of UPFREE and NF). Figure 3 shows the result of comparison, indicating that the effect of autoretreat is expressed sharply in terms of a normal flow formulation, but more diffusely in terms of the more accurate backwater formulation.

4. CONCLUSION

The interaction between sediment supply and sea level rise determines whether or not a) the delta continues to prograde under conditions of sea level rise, or b) the delta begins to transgress and eventually goes into autoretreat. If sea level rise is continued indefinitely, the delta will always go into autoretreat. The effect of autoretreat is expressed sharply in terms of a normal flow formulation, but more diffusely in terms of the more accurate backwater formulation.

ACKNOWLEDGEMENT

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