AUTOGENIC DELTA PROGRADATION DURING SEA-LEVEL RISE WITHIN INCISED VALLEYS

MATLAB CODE

```
% Calculate Incremental 3D accommodation within the experimental  
% tetrahedric incised valley, during sea-level rise  
% from Guerit et al, Autogenic delta progradation during sea-level rise within incised  
% valleys
```

%-----PARAMETERS TO SET

```
% These values are for the experiment
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alpha = 0.0613 ; % incised valley slope          (no unit)
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beta = 0.0125 ; % alluvial slope before incision  (no unit)
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W = 0.8          ; % valley width at the slope break  [L]
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H = 0.1256       ; % total height of the valley      [L]
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T = 120          ; % total duration of sea-level rise [T]
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%-----PARAMETERS DEFINED FROM THE PREVIOUS ONES

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h = H*(1-beta/alpha) ; % valley depth at the slope break  [L]
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23  hs = beta*H/alpha    ; % subaerial valley height at the slope break [L]

24  Lv = H/alpha        ; % total valley extension inland    [L]

25  theta = 2*H*(1-beta/alpha)/W ; % valley side slope      (no unit)

26

27  R = H                ; % total sea-level rise            [L]

28  dt = 1               ; % time step                        [T]

29  inc = R/T*dt         ; % increment of sea-level rise per time step [L]

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31  %-----Calculus below slope break (with variable = hh)

32  h1 = 0:inc:h         ; % sea-level elevation below h [L]

33  V1 = (h1.^3)/(3*alpha*theta);

34  A1 = [0 diff(A1)]    ;

35

36  %-----Calculus above slope break (with variable = ha)

37  h2 = h+inc:inc:h+hs ; % sea-level elevation from h to H [L]

38  V2 = (1/6).*W.*((Lv-(ha-h)./beta)./Lv).*(ha./alpha-(ha-h)./beta).*(hs+h-ha);

39  A2 = [abs(diff(V2)) 0] ;

40

41  %-----Plotting

42  plot([h1 h2],[A1 A2])

43  xlabel('Base level [L]'); ylabel('Rate of volume change [L^3T^{-1}]')

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46 *Figure S1: Impact of the valley geometry and duration of infilling on auto-advance.*
 47 *We start from a conceptual incised valley (red) with a valley basal slope $\alpha = 0.06$, an*
 48 *interfluvial slope $\beta = 0.02$, a width $W = 1$ km, a height $H = 100$ m, and a total dura-*
 49 *tion of infilling $T = 100$ kyrs. We then divide (black) or multiply (blue) by 2 the A)*
 50 *valley basal slope, B) the interfluvial slope, C) the valley width, D) the valley height,*
 51 *and E) the total duration of infilling. F) Same as E, but the time is divided by the total*
 52 *duration. The stars indicate the onset of the auto-advance for each scenario. See text*
 53 *for discussion.*

54 The creation of accommodation in the valley is sensitive to the geometry of the
55 valley (length, height, slopes) and to the duration of infilling. Here, we explore how
56 these five parameters affect the A/S curve and may affect the amplitude and the tim-
57 ing of auto-advance. We start from a conceptual incised valley with a valley basal
58 slope $\alpha = 0.06$, an interfluvial slope $\beta = 0.02$, a width $W = 1$ km, a height $H = 100$ m,
59 and a total duration of infilling $T = 100$ kyrs. We then sequentially divide or multiply
60 each parameter by 2 (Fig. S1), to illustrate the global trends in a simple way. The rate
61 of accommodation creation is calculated from the geometry of the valley using a con-
62 stant rate of sea-level rise during the time T . The rate of sediment supply is calculated
63 by dividing the total volume of the valley by the time T .

64 The alluvial slope α controls both the absolute rates and the duration of each
65 stage, and larger slope leads to higher rates and earlier auto-advance with respect to
66 the reference model (Fig. S1A). The interfluvial slope β also controls both the rates
67 and the duration of the stages but in a different way: larger slope leads to higher rates
68 but later auto-advance (Fig. S1B). The width W and the total height H of the valley
69 have no impact on the timing but they have a strong control on the rates: larger width
70 or higher valley lead to higher rates (Fig. S1C and D). The duration of infilling T af-
71 fects both the rates and the duration of the stages, and long duration is associated with
72 lower rates and later auto-advance (Fig. S1E). However, if the time is normalized by
73 the total duration, we observe that the auto-advance always initiates at ~90% of the
74 total duration for the specific valley geometry used here (Fig. S1F).

75 Here, we consider the sediment supply as the average sediment rate required to
76 fill the valley during a time T . A different sediment supply would affect the A/S in the

77 valley and the occurrence of the three stages. For a given geometry and rate of sea-
78 level rise, a lower sediment supply would lead to a longer Stage 2 (i.e., thicker depos-
79 its) and the auto-advance might be extremely limited in duration and intensity. On the
80 contrary, a higher sediment supply would lead to a very reduced Stage 2 - if any - and
81 the whole valley could be filled by progradational facies.

82 Based on the sensitivity analysis, we suggest that the preservation of auto-ad-
83 vance in stratigraphic series may be favored by an early occurrence of Stage 3 as this
84 leads to the greatest thickness of prograding facies (Fig. S1). We thus propose from
85 this simple analysis that the preservation of an auto-advance is favored by low valley
86 basal slope, high interfluvial slope and short duration. Large width and high total
87 height may also support auto-advance preservation.

88 The shape of valleys (e.g., widening vs narrowing downstream), the valley's
89 thalweg profile (e.g., linear, concave, convex upward), and the location and style of
90 sediment sources (e.g., single-point fluvial system vs laterally extensive clastic coast-
91 line) will vary in each sedimentary basin, but the key, underlying interacting varia-
92 bles (i.e., A/S) are the same. Therefore, the fundamental phenomenon of auto-ad-
93 vance should be generalizable. The geometries of the resultant stratigraphy may vary,
94 but we postulate that a bayhead delta diastem should by default be generated during
95 steady base-level rise post-dating incised valley formation.

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102 *Figure S2: Experiment setup, pictures and analysis. A) Schematic view of the experi-*
 103 *mental setup. B-E) Pictures of the experiment from the ceiling camera with illustra-*
 104 *tion of (B) Stage 1, (C) Stage 2, (D) Stage 3 and (E) of the final complete flooding of*
 105 *the valley.*

106 The experimental setup consists of a non-erodible V-shape valley of 2.05 x
 107 0.80 x 0.12 m with a slope of 0.06 inserted within a larger 0.6 x 5 x 5 m tank ("Delta
 108 Basin") with a fixed horizontal floor where water and sediment can accumulate (Fig.
 109 S2A). Sediment flux is provided by a computer-controlled feeder located in the mid-
 110 dle of the northern side of the model, and base level modified by a computer-con-

111 trolled weir and attached siphon (Fig. S2A). Water is provided by a computer-con-
112 trolled pump, and a small amount of titanium dioxide (TiO_2) is added to the water to
113 provide more contrast for photographic analysis (it gives the water a bluish color).
114 The sediment feeder and water input are located 5 cm away from the apex of the val-
115 ley. Several previous studies have used this Delta Basin, and specifics on data collec-
116 tion techniques, instrumentation, calibrations, and measurements can be found in
117 those studies (Kim et al., 2006; Paola et al., 2001; Sheets et al., 2002). We use a
118 50:50 mixture of quartz sand (mean grain size $110\ \mu\text{m}$, specific gravity 2.65) and coal
119 sand (bimodal distribution with mean grain sizes of 190 and $460\ \mu\text{m}$, specific gravity
120 1.3) to represent coarse and fine components of sediment. Despite the difference in
121 mean grain size, the specific gravity is the main driver of sediment mobility/deposi-
122 tion. Accordingly, the quartz sand (light grey on Fig. S2) corresponds to the coarse
123 fraction that is transported as bedload and deposited first, while the coal sand (black
124 on Fig. S2) corresponds to the fine fraction (i.e., suspended load) in natural systems
125 and deposited secondarily. The experiment initiates with an empty tank, and a base-
126 level rise at a constant rate of 1 mm/min is imposed. Concurrent with steady base-
127 level rise, sediment and water fluxes are provided at a constant rate of 0.004 L/s and
128 0.2 L/s respectively, to insure a sediment concentration of 0.02 similar to other exper-
129 iments (Kim et al, 2006; Sheets et al; 2002; Reitz and Jerolmack, 2012). As a conse-
130 quence, the valley is slowly filled by the sediments in response to the transgression
131 imposed by the base-level rise. Total experimental runtime was 120 min.

132 Images were taken of the evolving experimental system every minute with a
133 ceiling-mounted, overhead camera (Nikon D100, 2480 x 960 pixels covering the area

134 of interest with a resolution of 1 mm/pixel). We analyzed the evolution of the delta
135 front by tracing the position of the coarse grain delta front (approximately topset-
136 foreset break) from orthorectified images (Fig. S2B, C, D and E). We also provide an
137 annotated movie to illustrate the evolution of the experiment (Data Repository).

138 As with many experimental approaches, the purpose is not to capture or simu-
139 late a specific field case or scenario, but instead to represent the fundamental or gen-
140 eral qualities of field systems (Paola et al., 2009). In this case those encompass the
141 stratigraphic consequences of a freely-evolving sedimentary system given the bound-
142 ary conditions of constant sediment supply, water discharge, and base level rise
143 within the geometric constraints of an incised valley. Such an approach provides
144 more generalizable insights into the controls on stratigraphy (Paola et al., 2009).

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151 **PREDICTED AND OBSERVED STAGES IN THE PHYSICAL MODEL**

152 *Figure S3: Rate of accommodation creation A (blue) and input sediment rate S (red)*
 153 *in the physical model of incised valley fill with respect to the duration of the experi-*
 154 *ment.*

155 Based on our geometric model, we predict that Stage 2 (retrogradation) starts
 156 after 65 min (first black dotted line) whereas it started after only 35 min. We hypoth-
 157 esize that this early occurrence is related to the formation of the fluvial fan (Fig. S2)
 158 which traps part of the input sediment flux. The effective sediment supply to the val-
 159 ley should thus be lower, consistent with the early retrogradation. Once deposition
 160 started in the valley, virtually all the sediments are deposited there and the experi-
 161 ment is consistent with the conceptual model. In fact, the onset of the auto-advance
 162 occurs exactly when predicted (around 115 min).

168 **GEOMETRY OF THE TRINITY AND BRAZOS INCISED VALLEY**

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		Trinity River	Brazos River
Elevation at slope break	h	40 m	40 m
Valley width	W	15 - 20 km	20 - 25 km
Valley length	Lv	300 - 350 km	300 - 350 km
Alluvial slope	β	$1.9 \cdot 10^{-4}$	$2.4 \cdot 10^{-4}$
Rate of sea-level rise	R/dt	$4.3 \cdot 10^{-2}$ m/yr	$4.3 \cdot 10^{-2}$ m/yr
Sediment supply	qs	$3.8 \cdot 10^6$ m ³ /yr	$7.6 \cdot 10^6$ m ³ /yr

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172 *Table S1: Geometry and characteristics of the Trinity River and Brazos River incised*

173 *valleys, reconstructed from Rehkemper et al. (1969), Simms et al. (2007), Taha*

174 *(2007), Milliken et al. (2008), and Anderson et al. (2016).*

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