Autogenic processes and deposit signatures in laboratory submarine fan experiments with supercritical alluvial channels

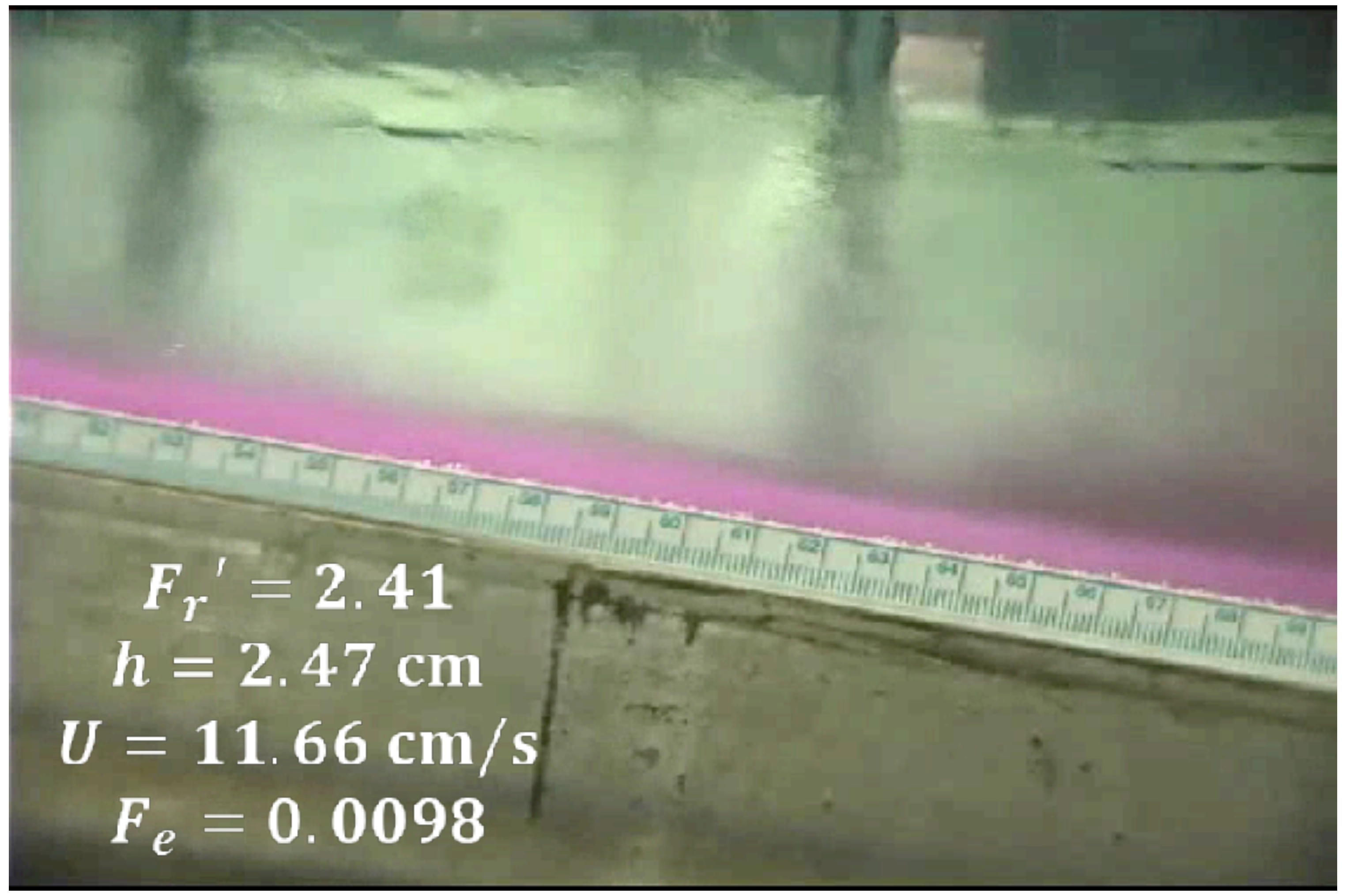
Kyle Strom and Paul Hamilton - *Virginia Tech*
David Hoyal, Juan Fedele, and Gwladys Gaillot - *ExxonMobil*

Invent the Future®

Energy lives here™

Supercritical Flows

Variable Definitions

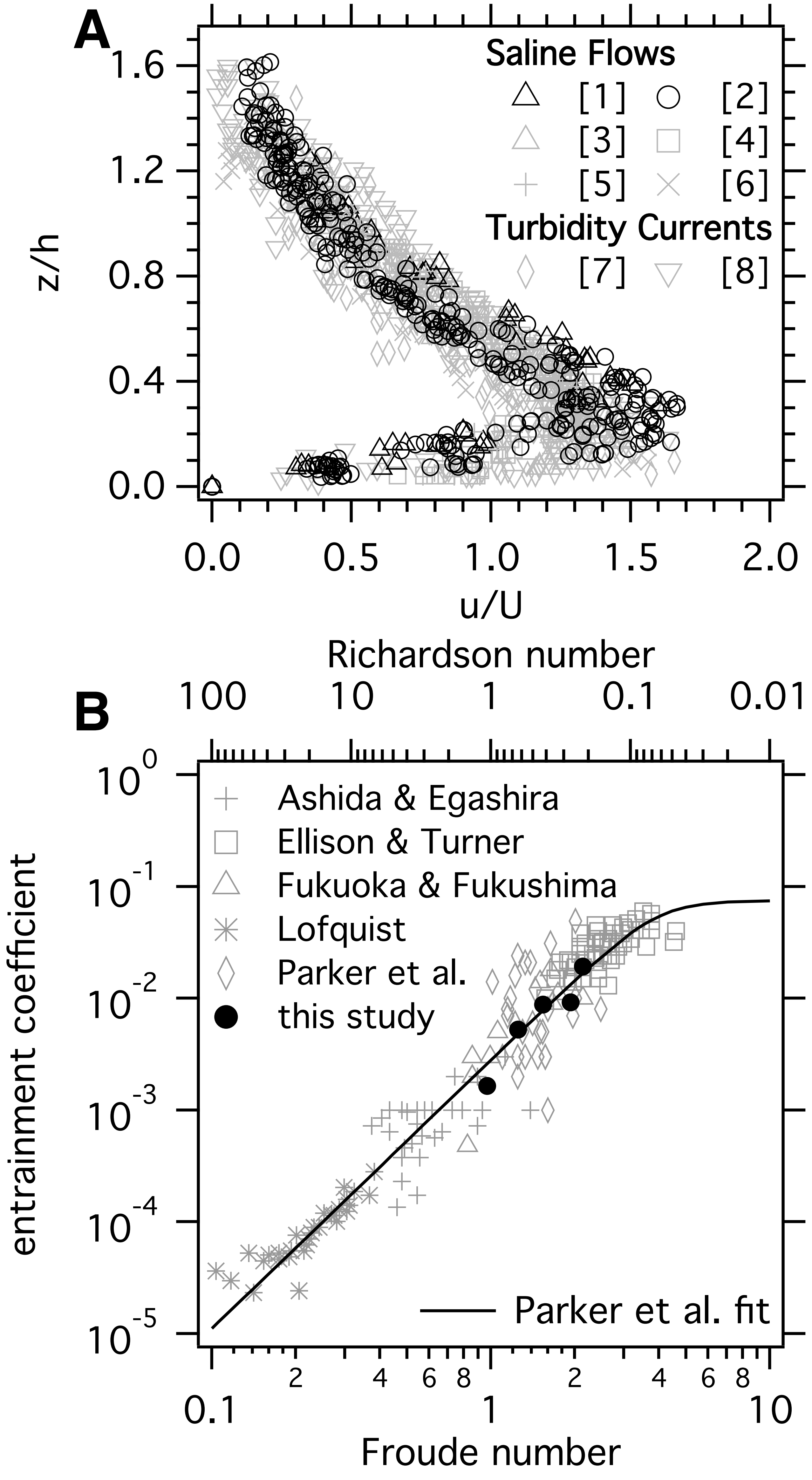


$$Uh = \int_0^\infty u \, dz$$

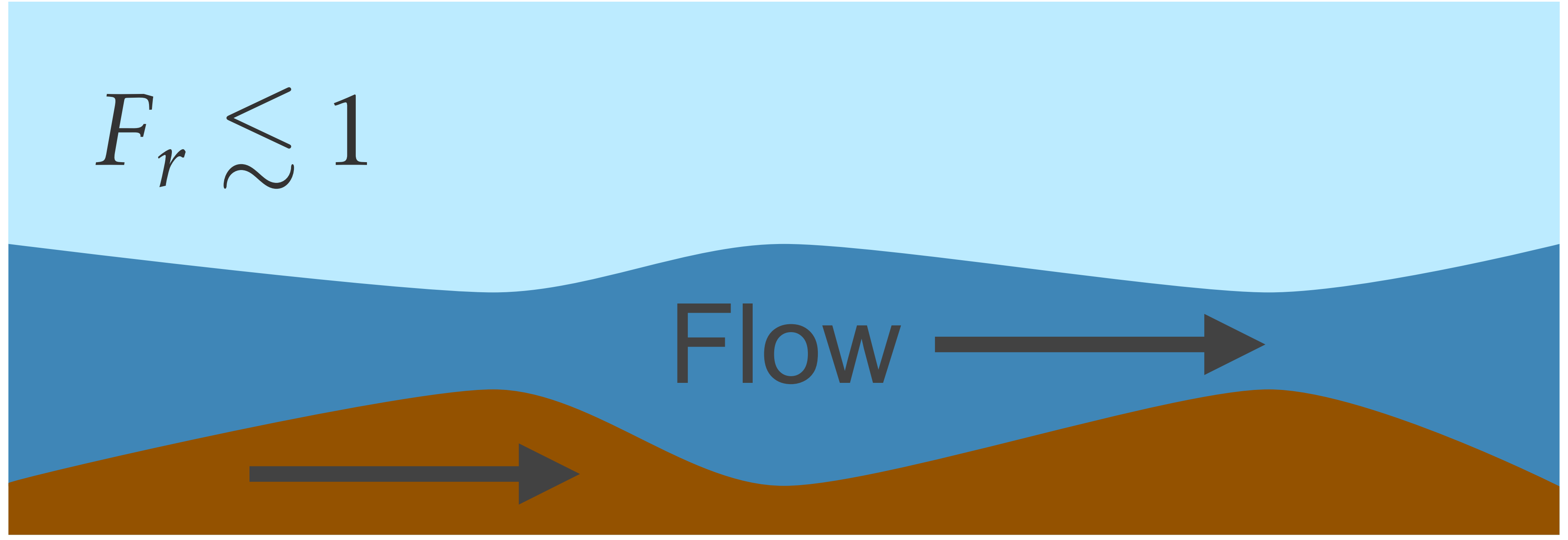
$$U^2 h = \int_0^\infty u^2 \, dz$$

$$U F_e h = \int_0^\infty u f_e \, dz$$

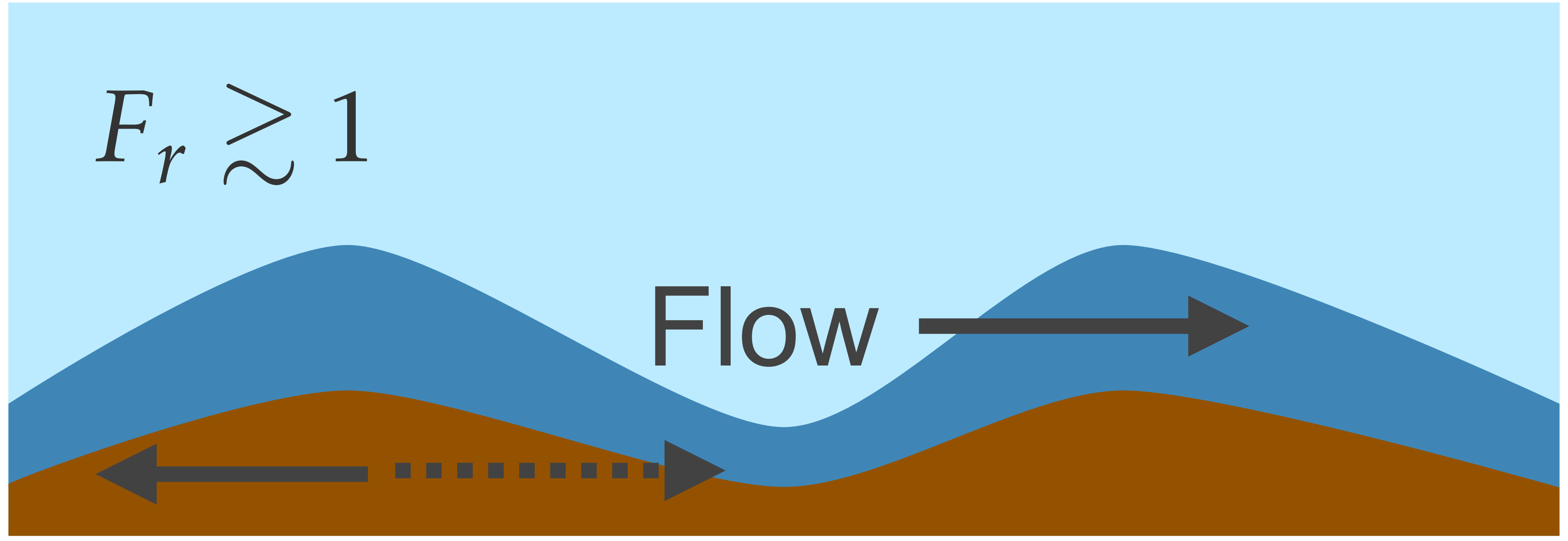
[Hamilton et al. 2015 JHE]



$$F_r = \frac{U}{\sqrt{g' h}} = \frac{1}{R_i^{1/2}} \gtrsim 1$$

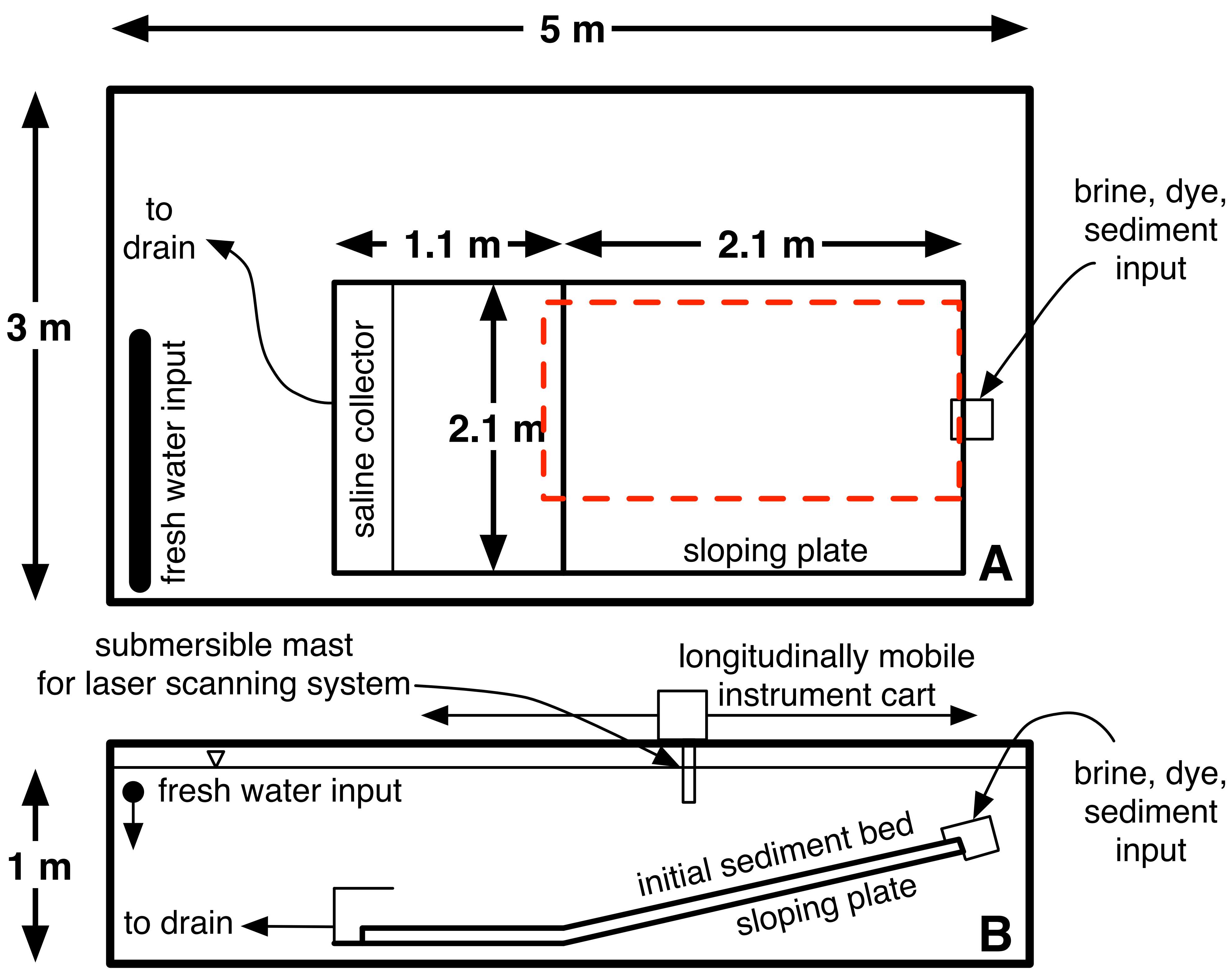


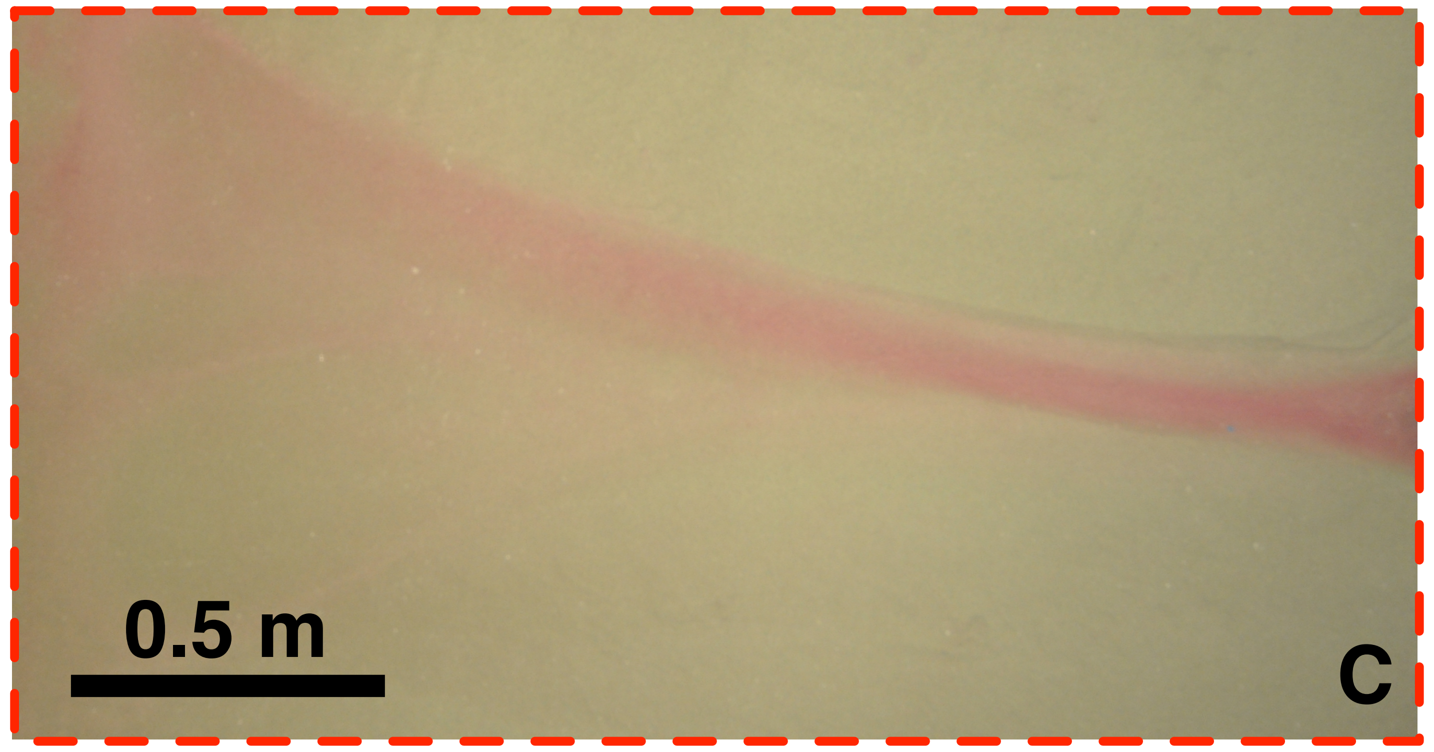
Downstream Migrating

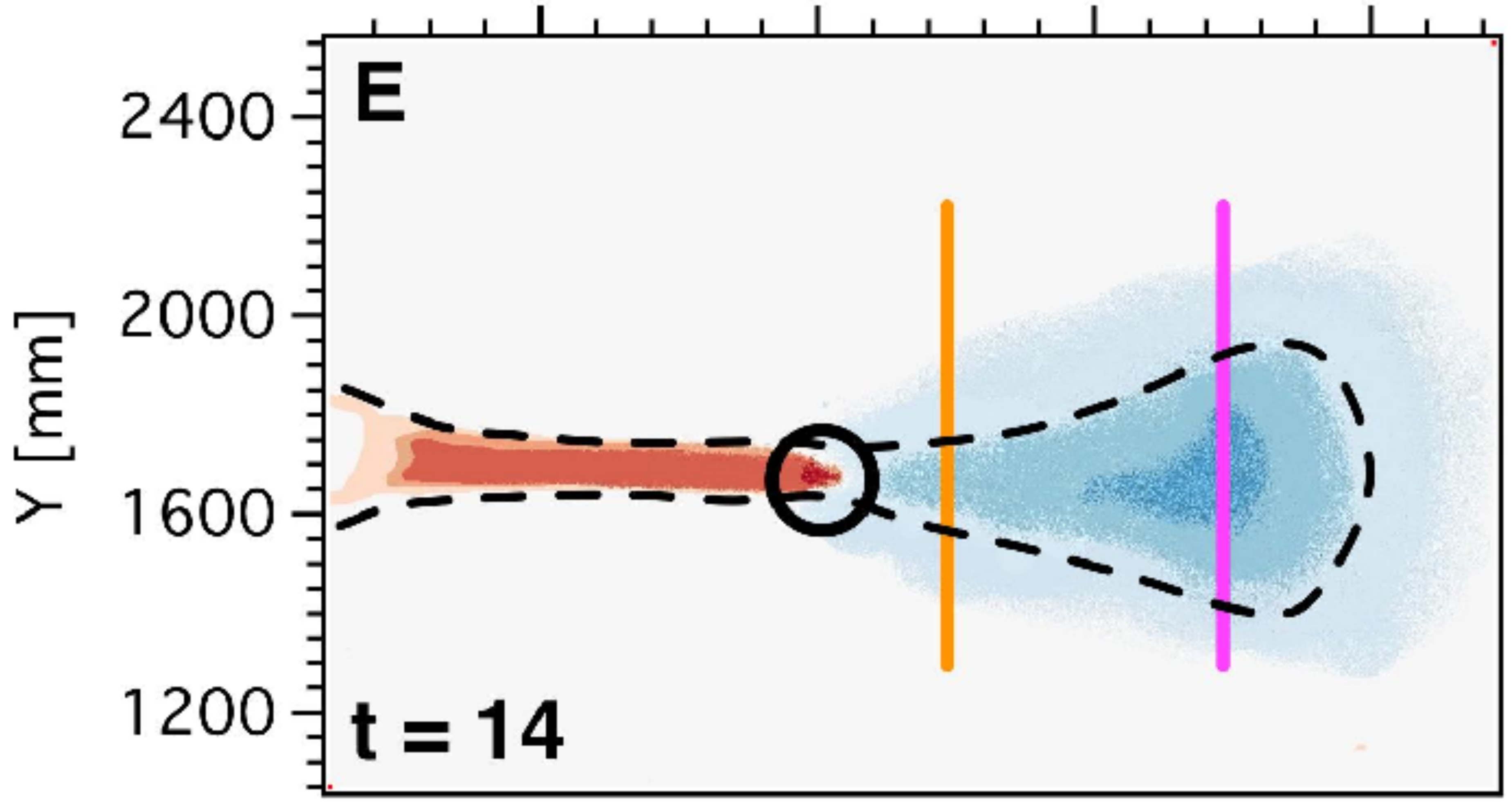


Up (or down) stream Migrating

Tank Experiments







Constant input:

$Q, Q_s, \Delta\rho$

Measure:

- $U = U(x,t)$
- $h = h(x,t)$
- $F_e = F_e(x,t)$
- $\eta = \eta(x,y,t)$

Channelized flows have,

$F_r > 1$

Self formed channels and lobate deposits

Key Outcomes

Lobes can form and force an avulsion before reaching a slope break

Supercritical avulsion cycle

[Hamilton et al. 2017 JGR]

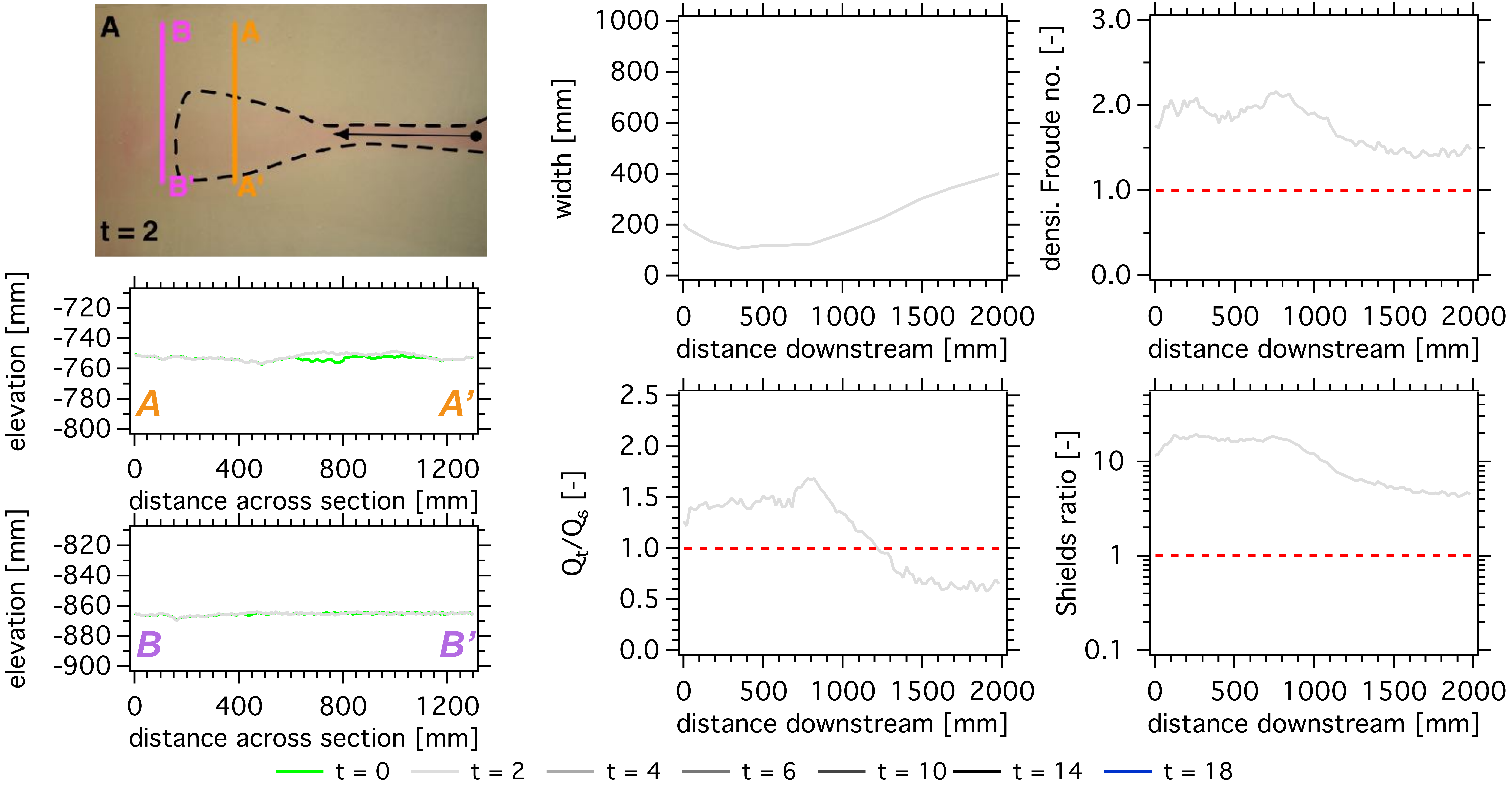
1. Initial channel extension and frontal splay
2. Channel stagnation, migration, and mouth bar aggregation up to choke
3. Hydraulic jump initiation
4. Upstream migration of jump and backfilling of channel
5. Avulsion

Vertical scale of the lobe deposit is controlled, in part, by channel hydraulics

[Hamilton et al. 2017 in review JSR]

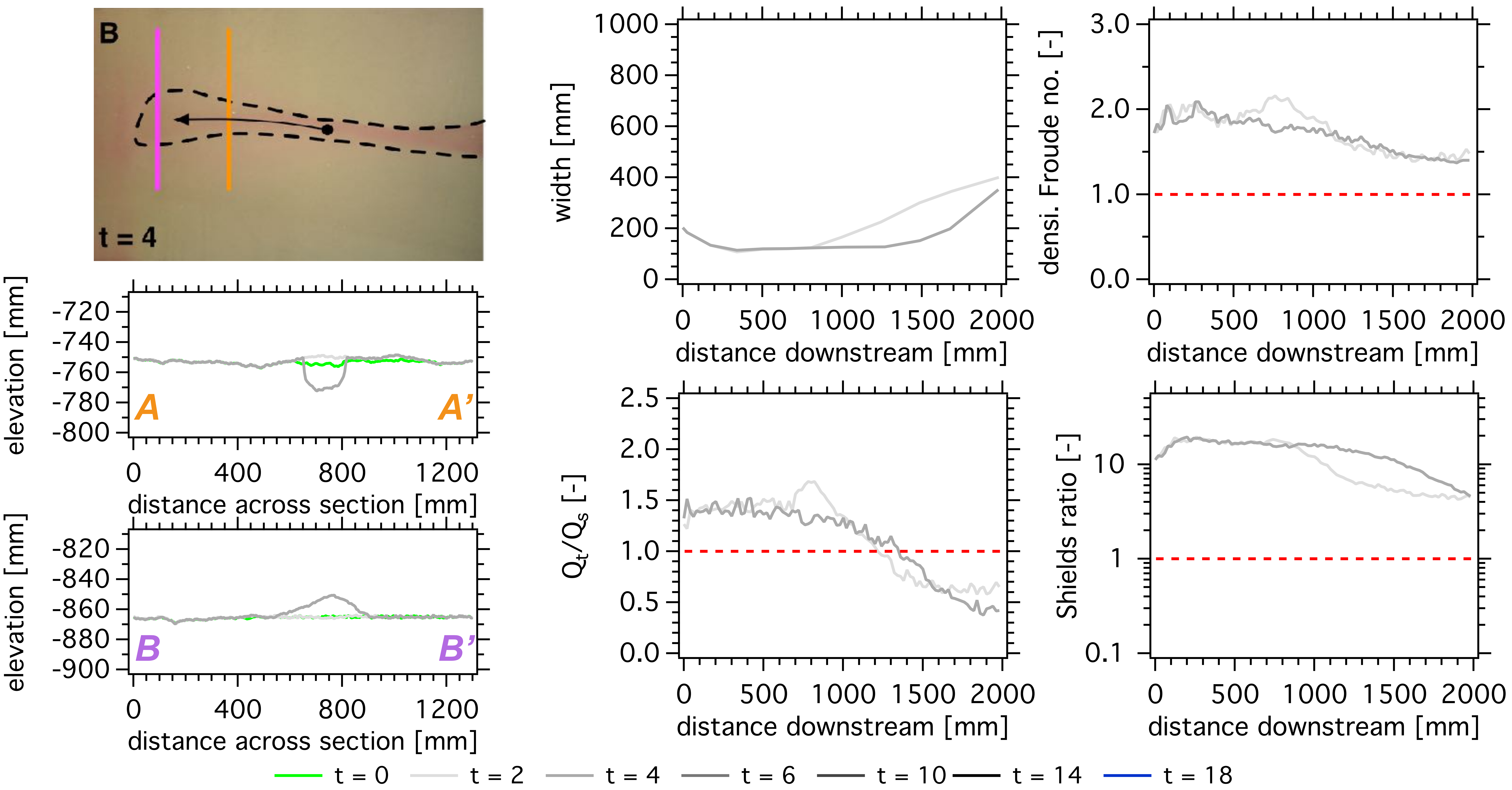
Supercritical Avulsion Cycle

Initial channel incision and basinward extension;



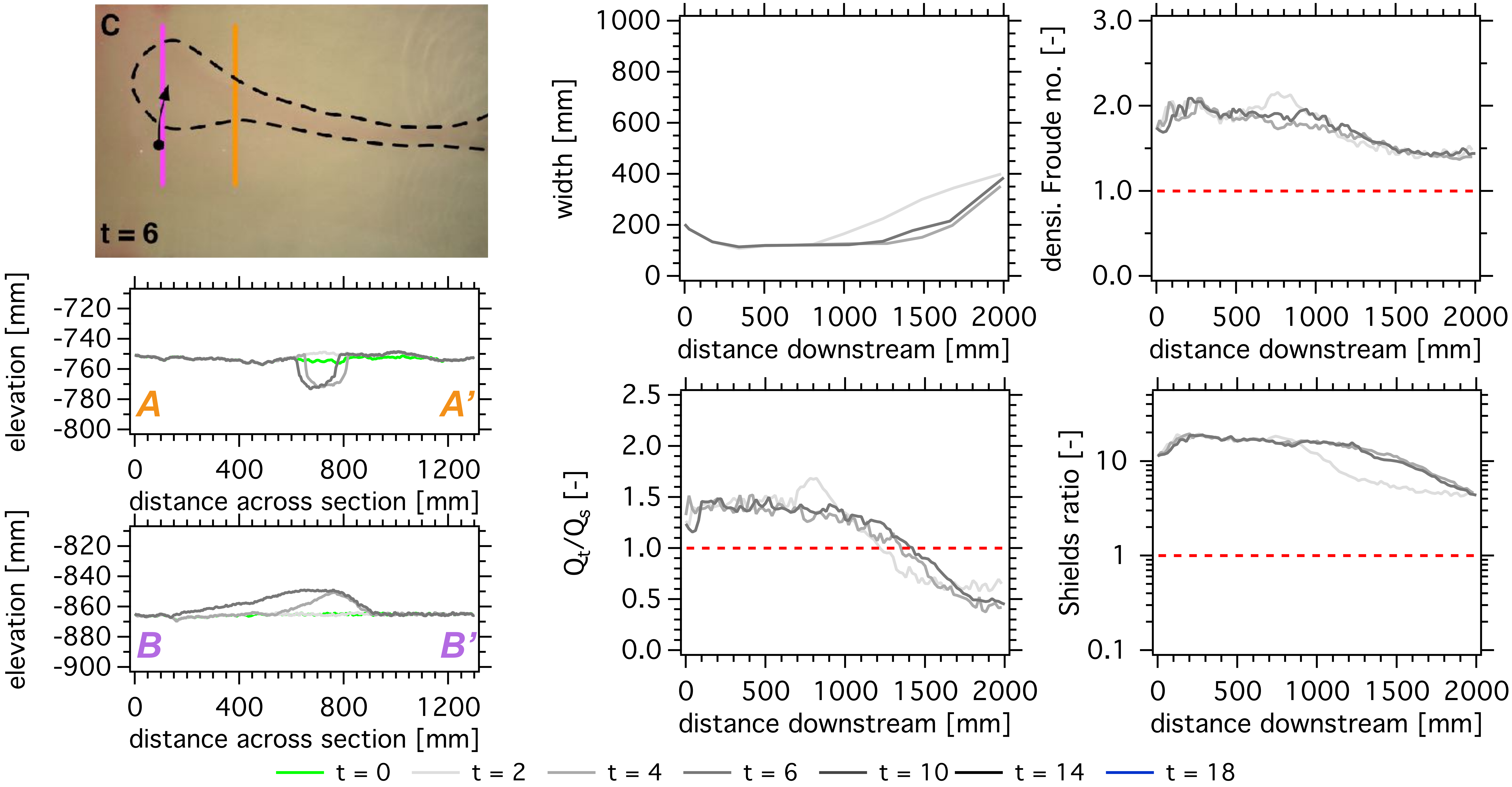
Supercritical Avulsion Cycle

channel stagnation and mouth bar aggradation;



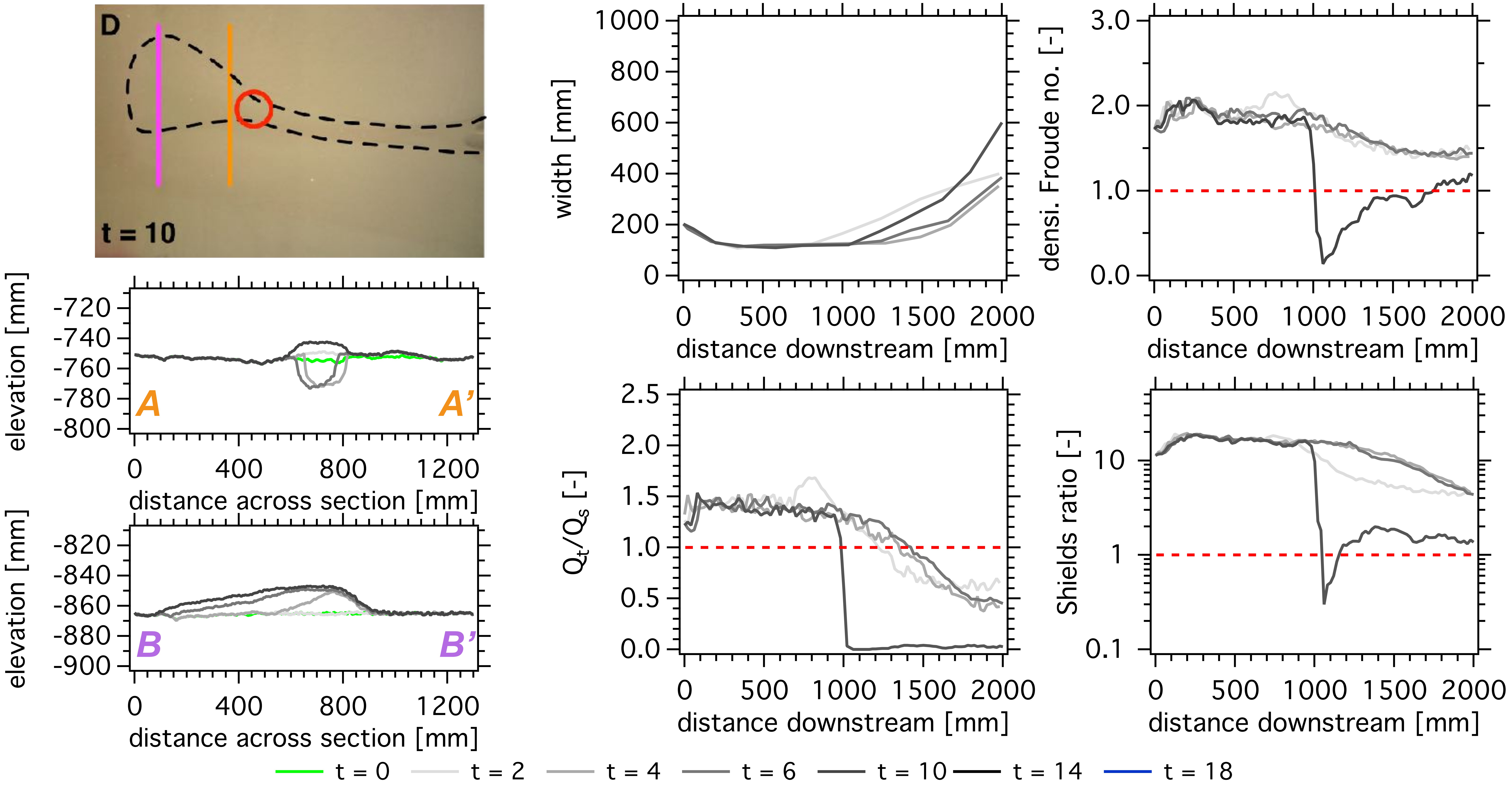
Supercritical Avulsion Cycle

channel mouth bar aggradation and migration;



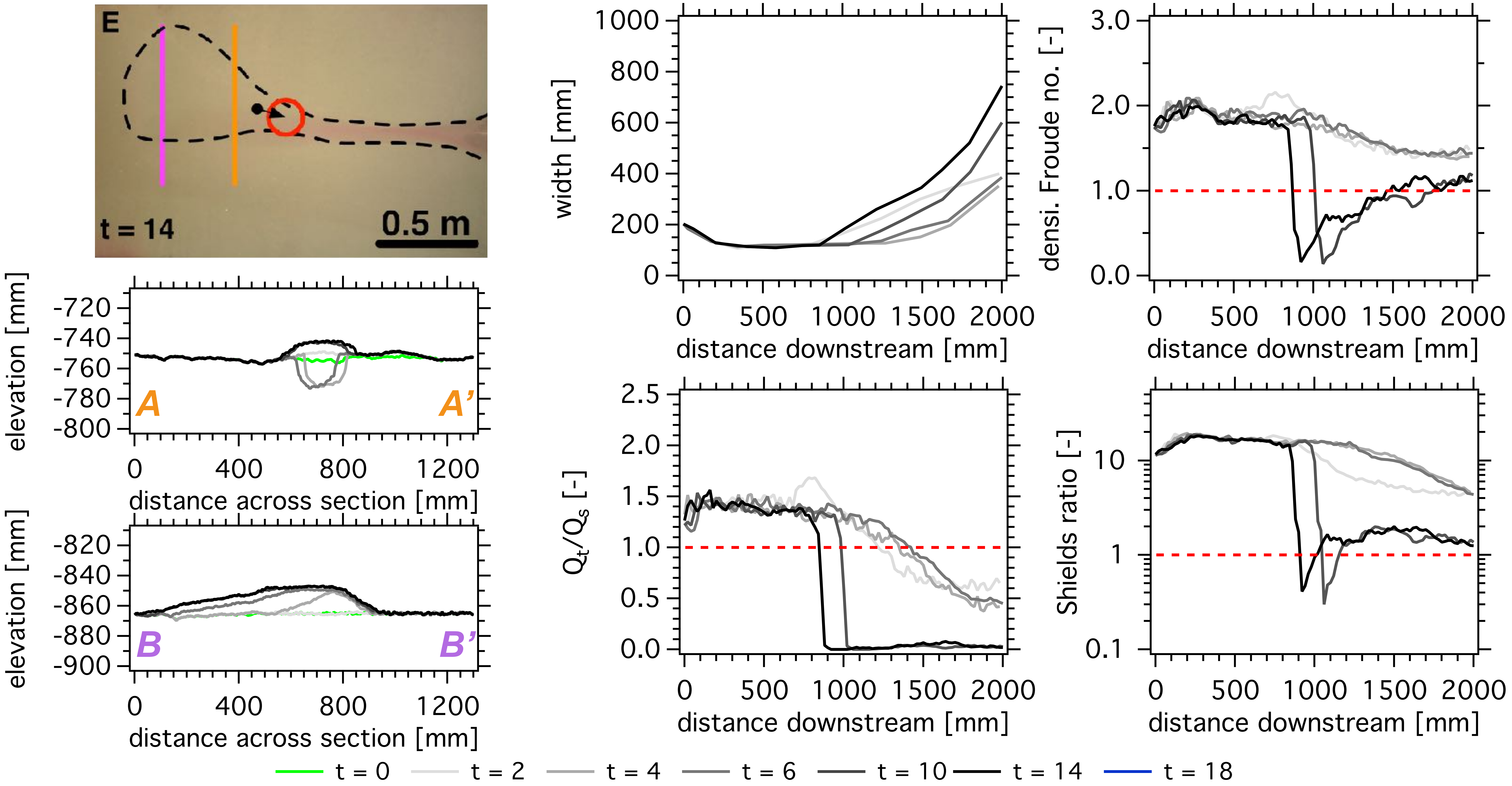
Supercritical Avulsion Cycle

hydraulic jump initiation (circled);



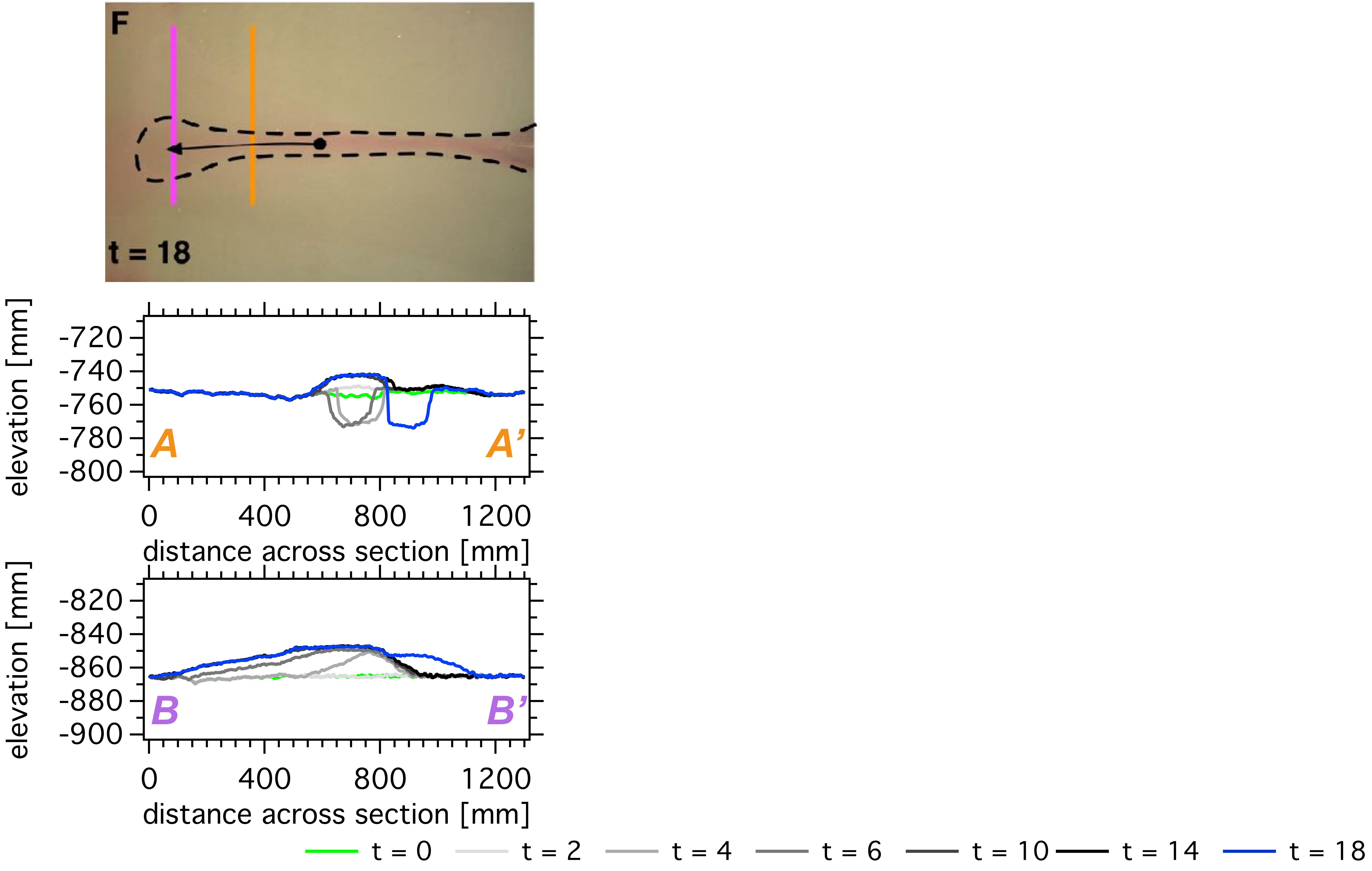
Supercritical Avulsion Cycle

upstream retreat of the hydraulic jump;



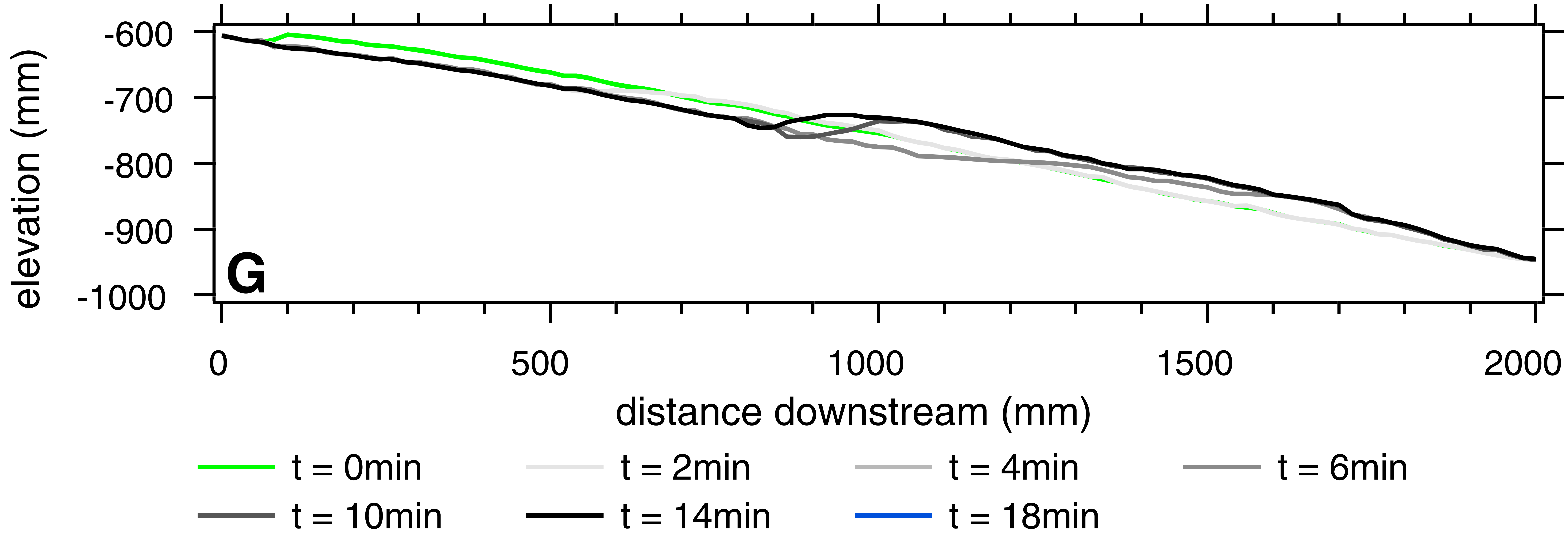
Supercritical Avulsion Cycle

channel re-incision and basinward extension to begin a new cycle.

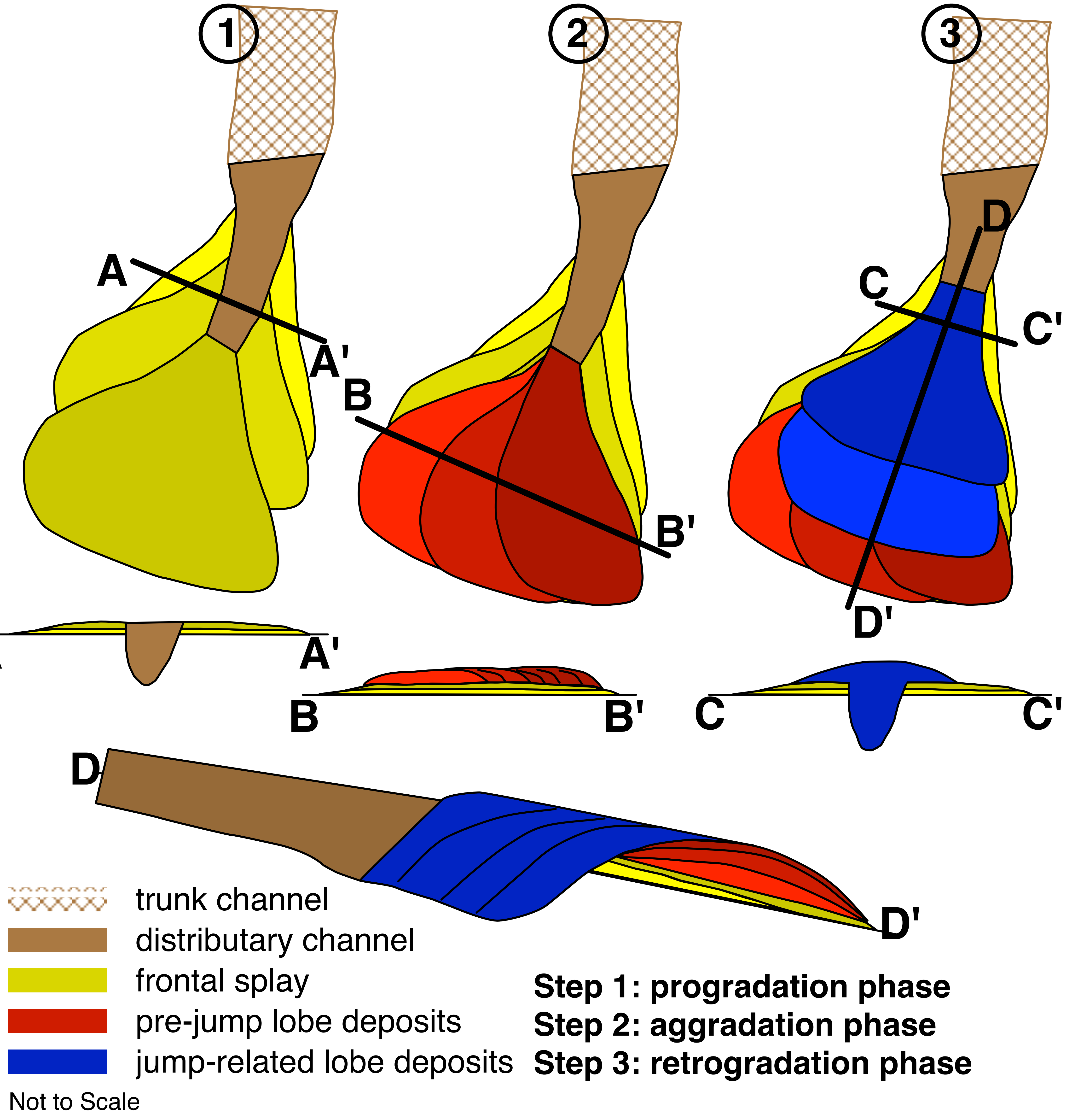


Supercritical Avulsion Cycle

Longitudinal Elevation Within the Channel



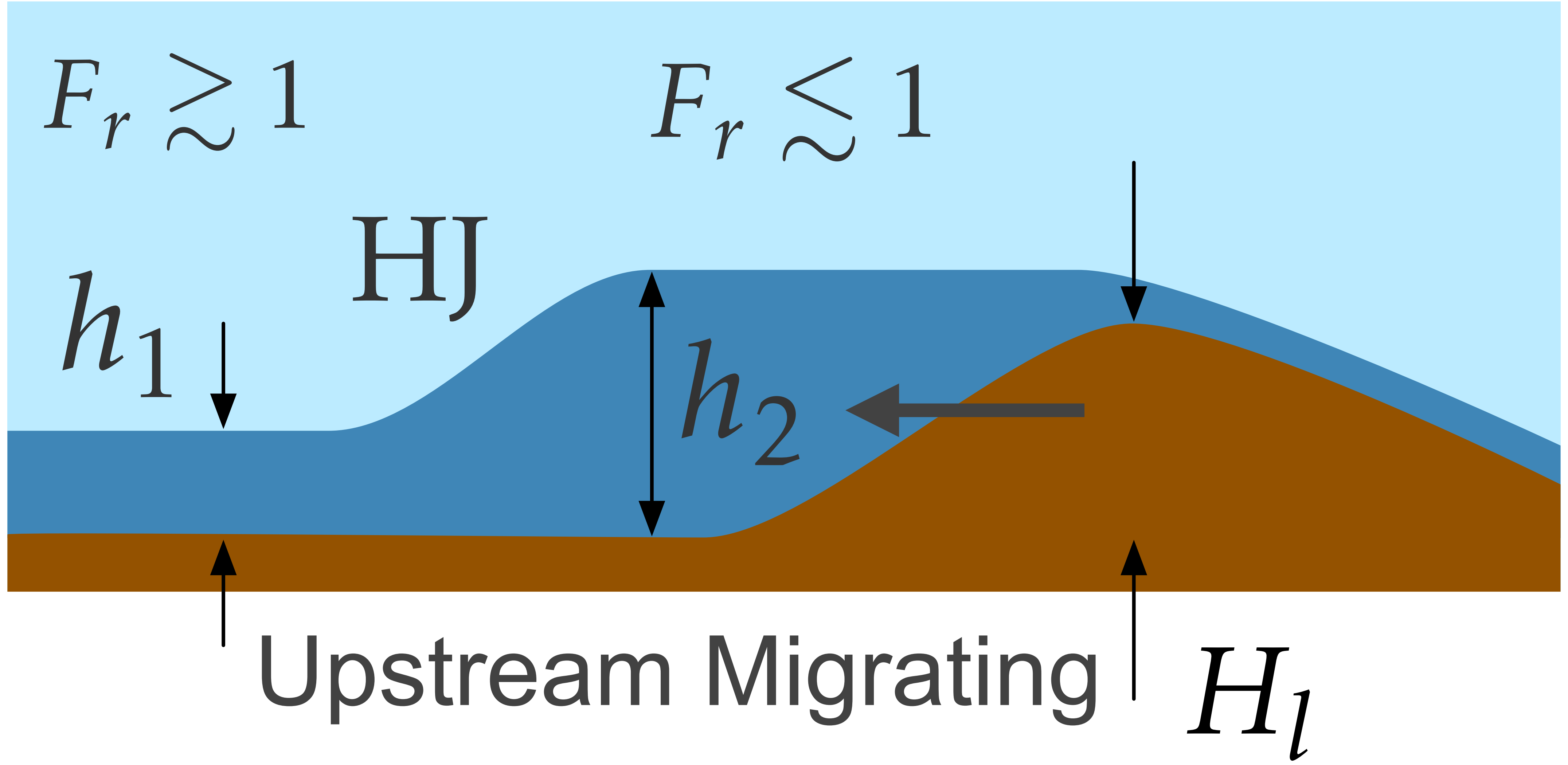
Supercritical Avulsion Cycle



Step 1: progradation phase
Step 2: aggradation phase
Step 3: retrogradation phase

Possible Hydraulic Controls on Lobe Geometry

2 Vertical Length Scales



$$\boxed{h_2} / h_1 = \frac{1}{2}\left[\sqrt{1+8F_r^2}-1\right]$$

Jump

$$h_2 \approx H_l$$

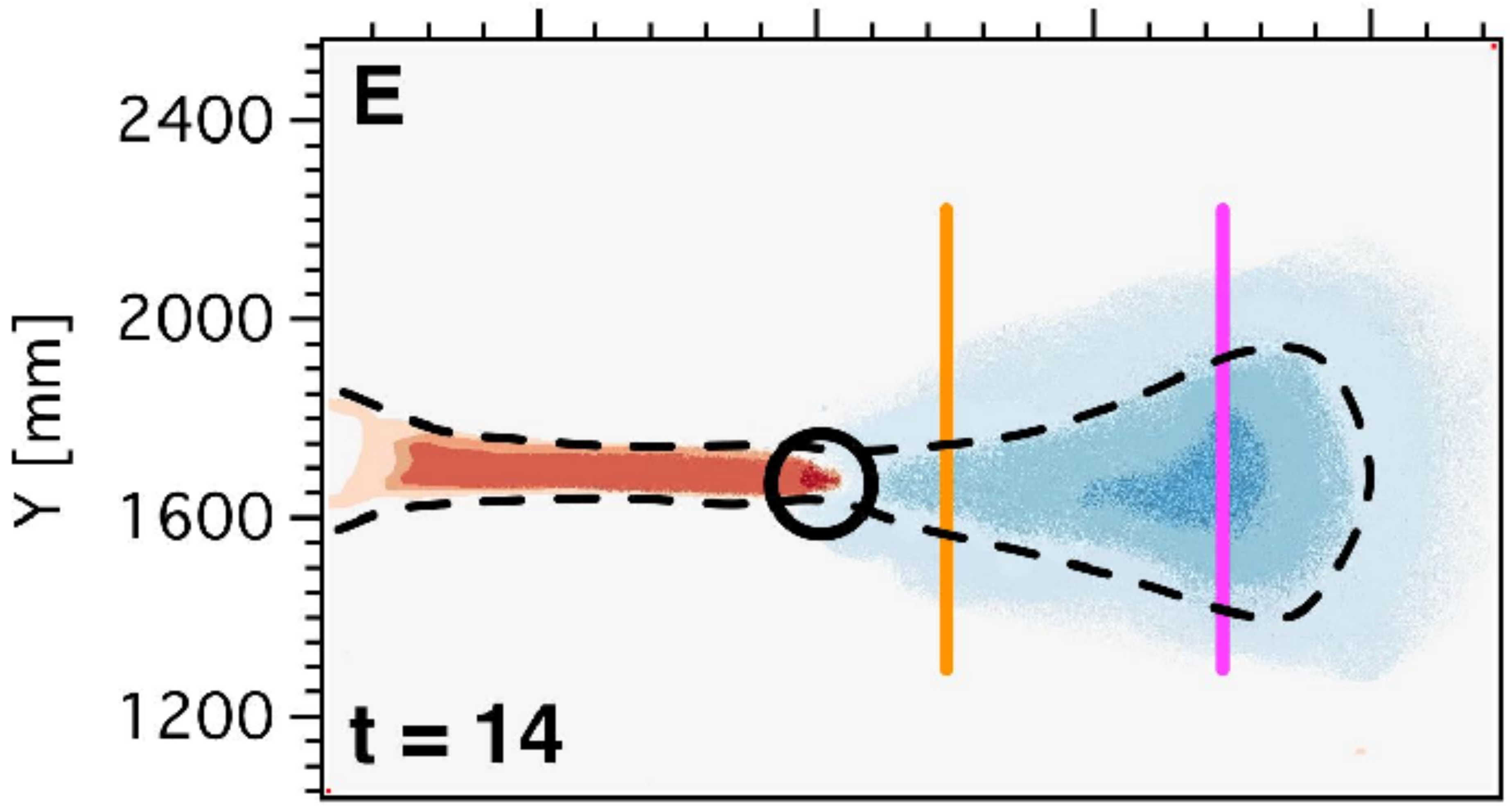
$$\boxed{H_l} / h_1 \approx \frac{1}{2}\left[\sqrt{1+8F_r^2}-1\right]$$

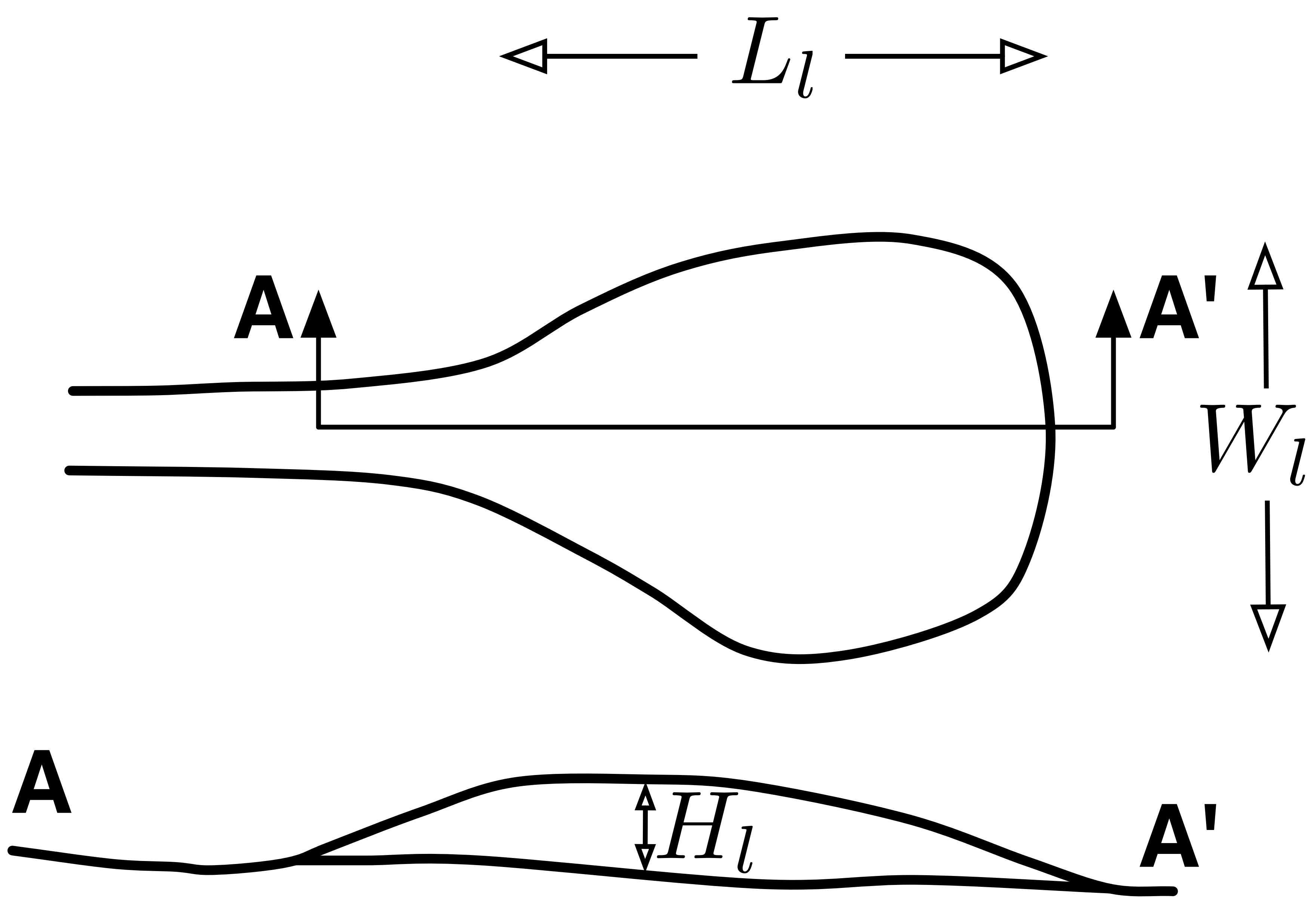
Can we use the depth of the feeder channel to help constrain the thickness of the downstream lobe?

[Hamilton et al. 2017 in review JSR]

Lab

[Hamilton et al. 2017 in review JSR]

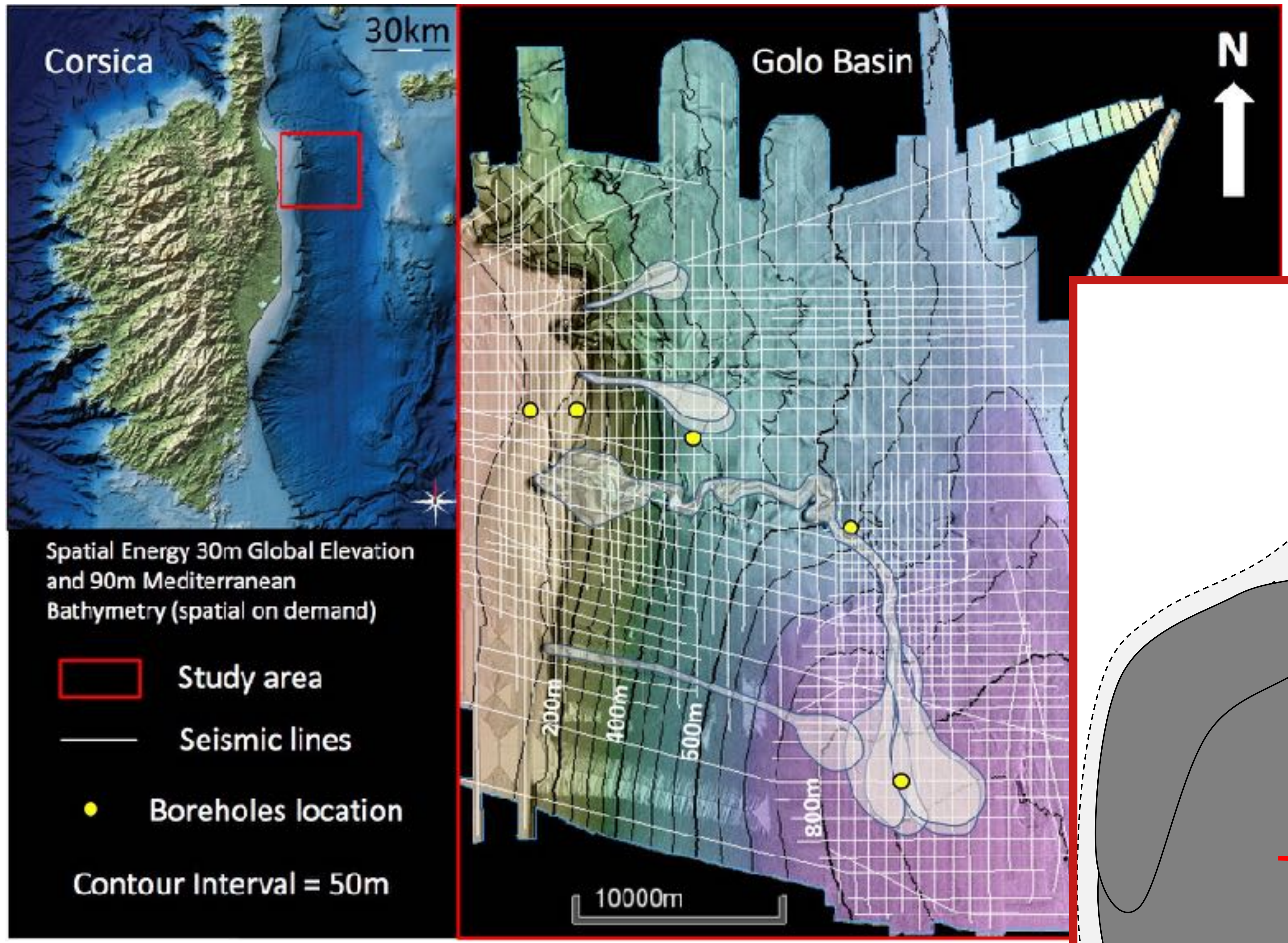


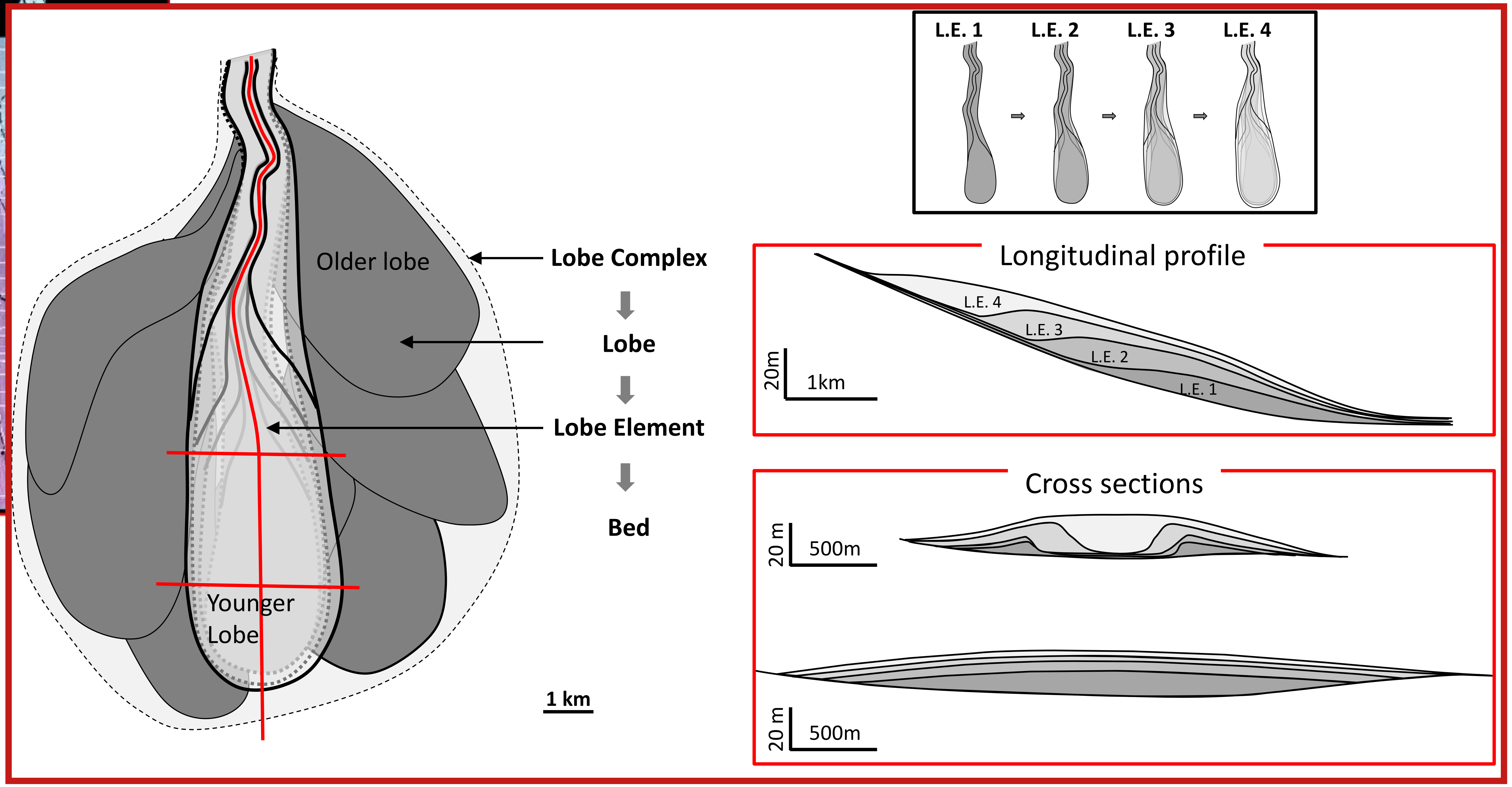


74 channel and lobe pairings

F_r $[-]$	h_1 $[mm]$	L_l $[mm]$	W_l $[mm]$	H_l $[mm]$	θ_{exp} $[deg]$	L_l/W_l $[mm]$	H_l/h_1 $[mm]$
2.08	18	663	467	56	44	1.42	3.07
2.16	25	795	703	66	48	1.13	2.64
2.17	22	833	615	57	49	1.35	2.59

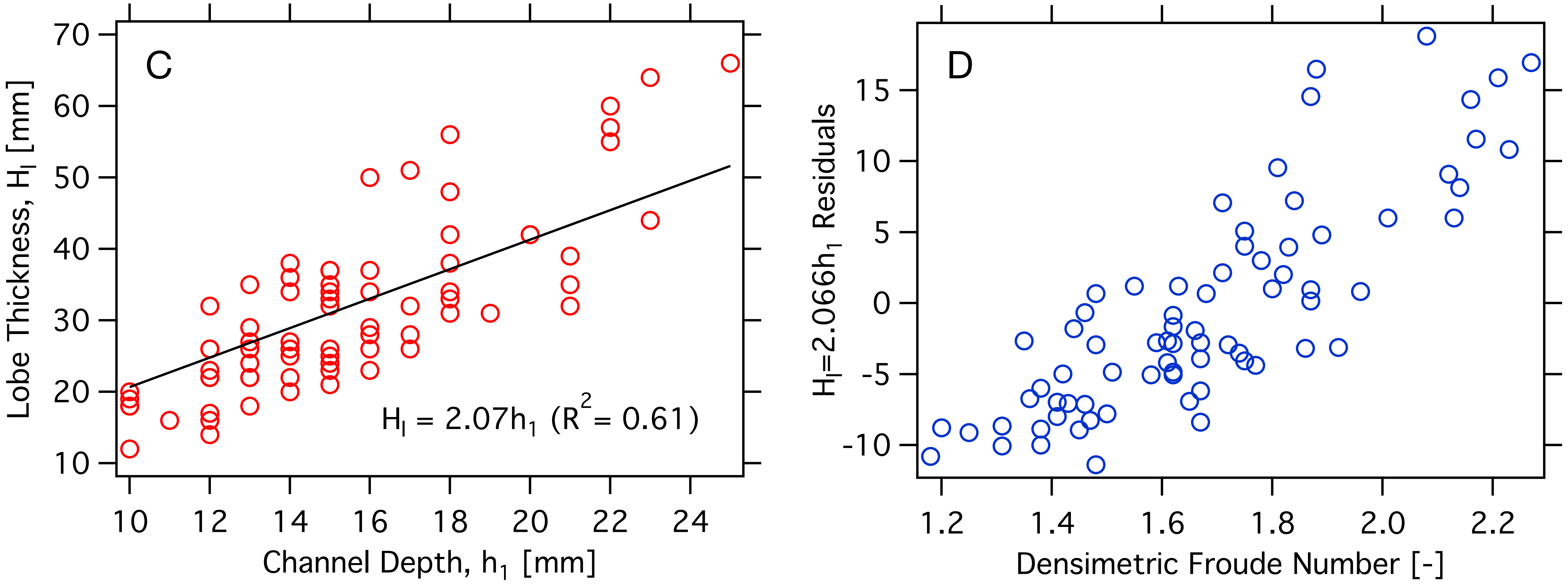
Golo: a steep, bedload dominated fan

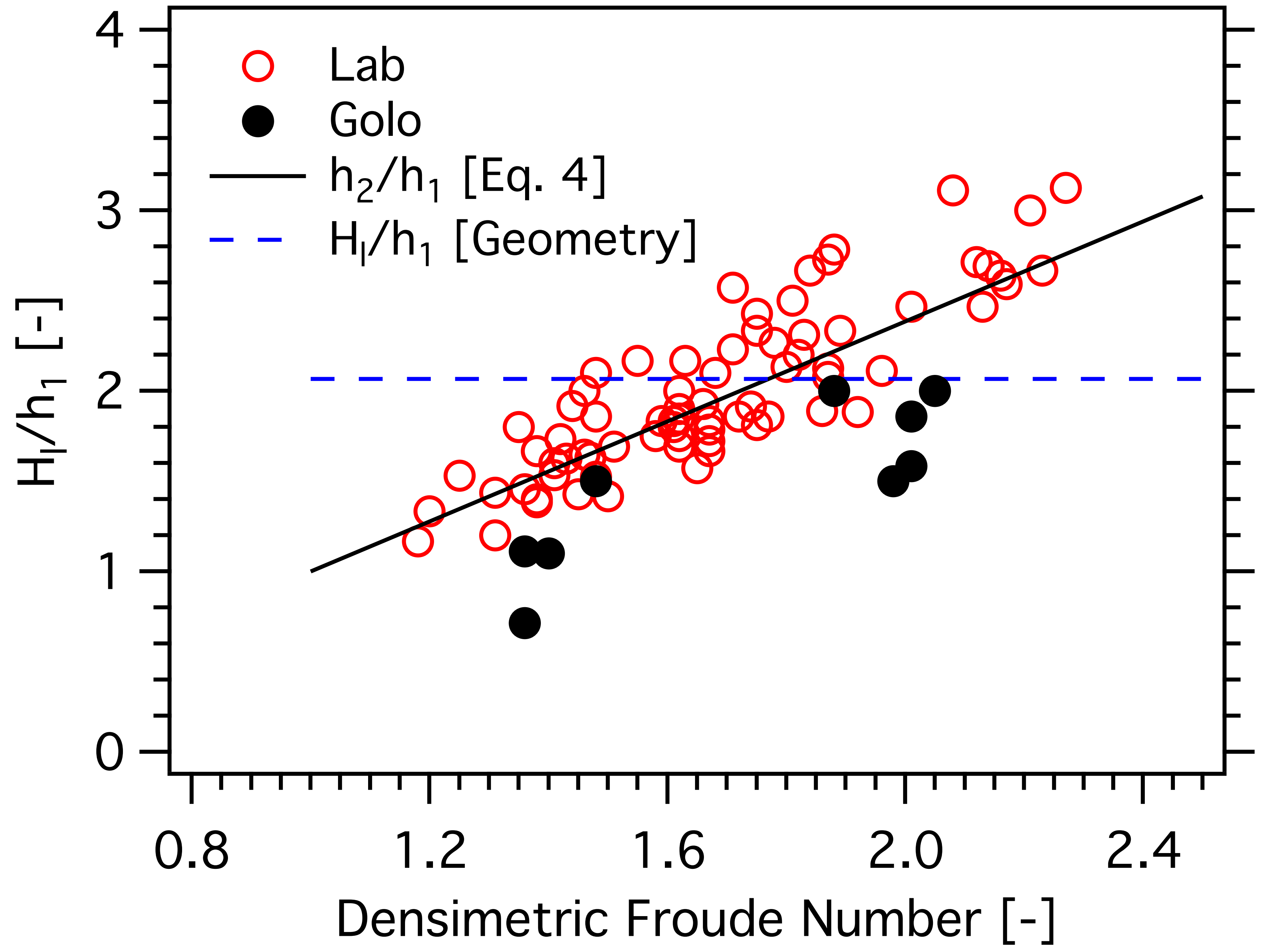




[Hamilton et al. 2017 in review JSR]

Steep Bedload Fans



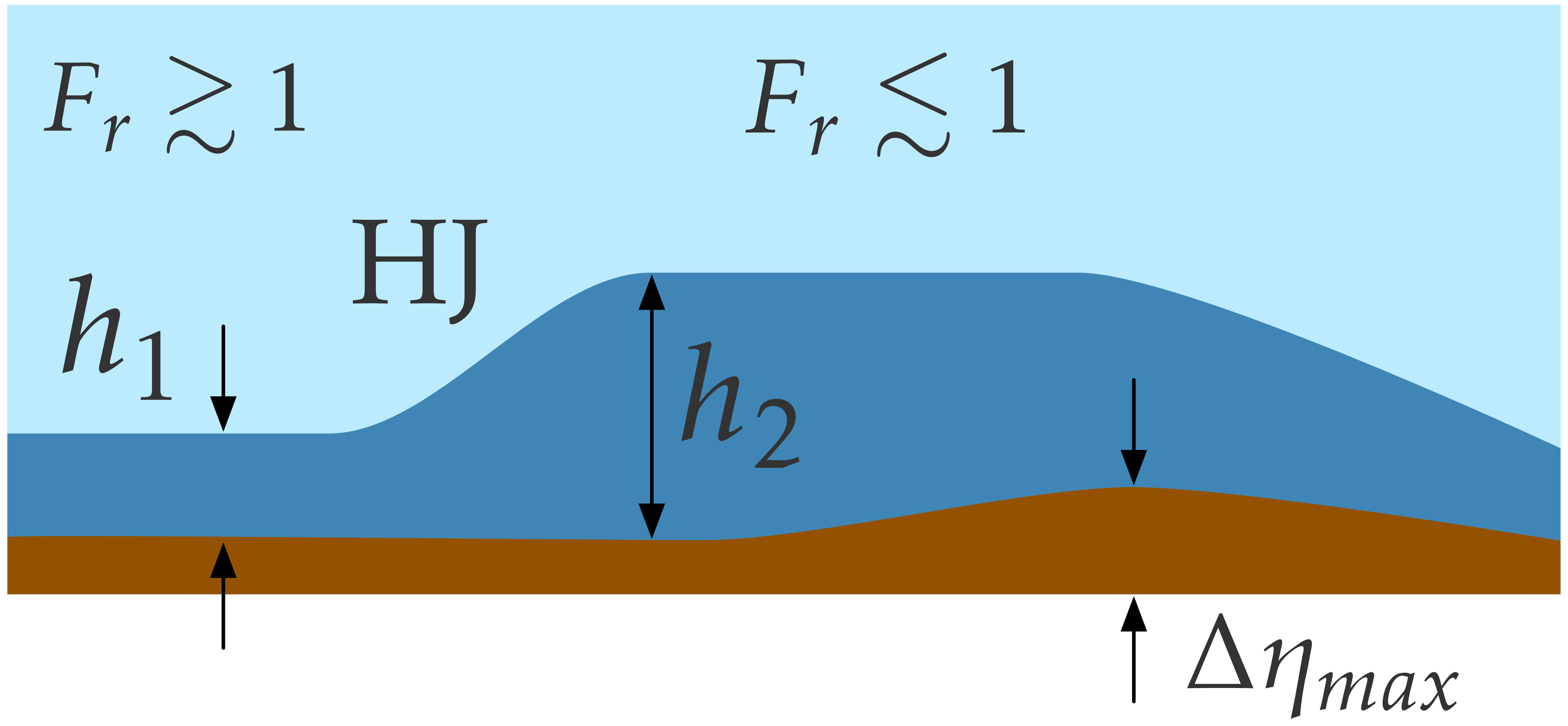


[Hamilton et al. 2017 in review JSR]

Thanks

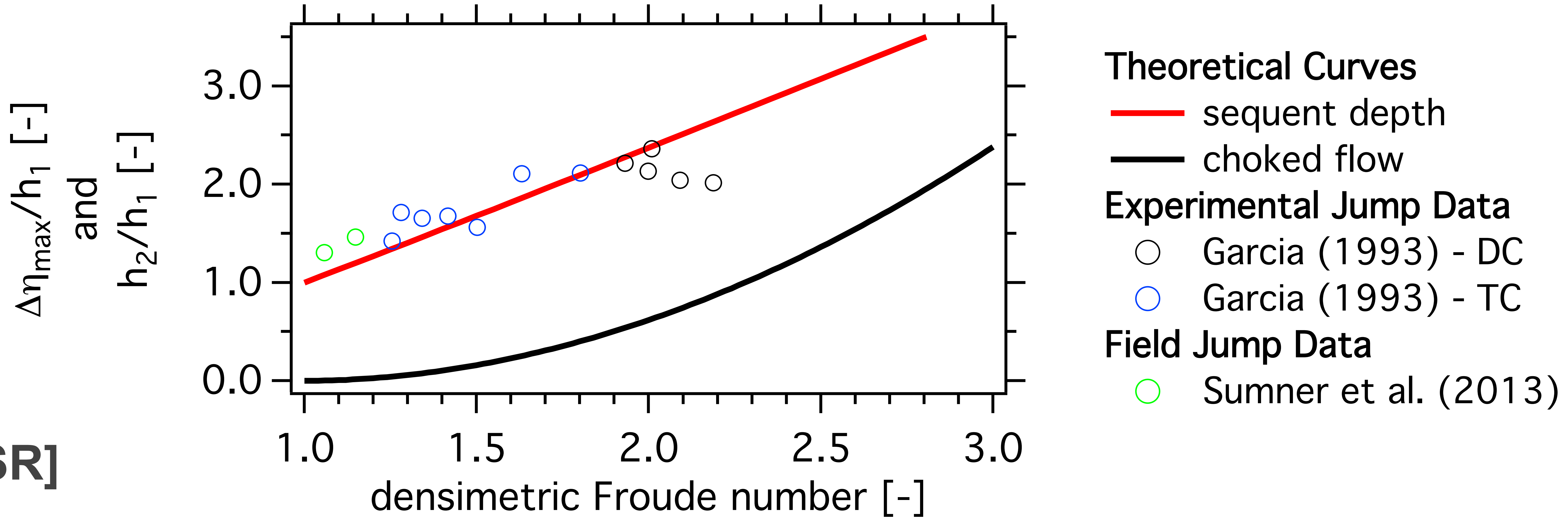
Possible Hydraulic Controls on Lobe Geometry

2 Vertical Length Scales



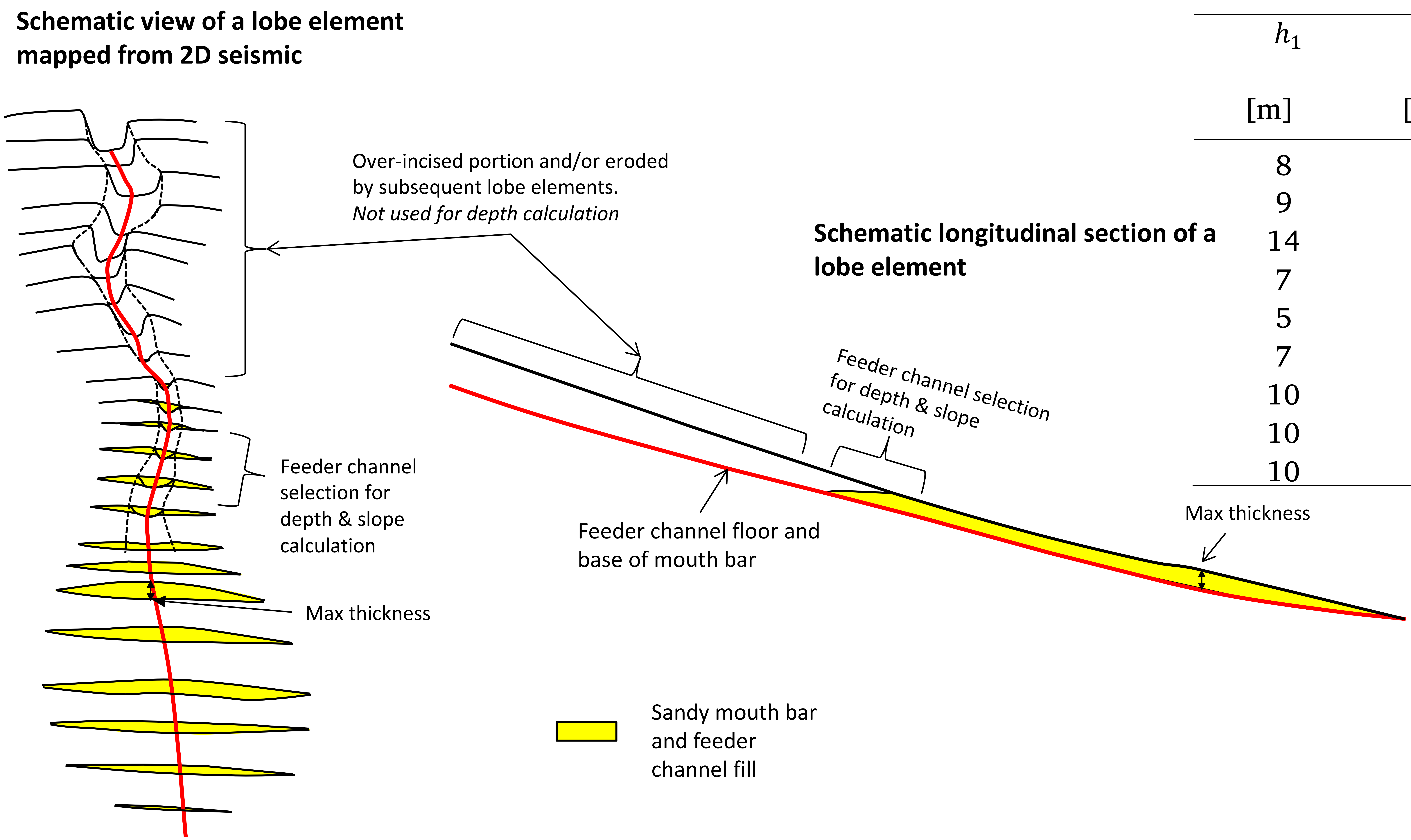
$$\frac{\Delta\eta_{max}}{h_1} = 1 + \frac{F_r^2}{2} - \frac{3}{2}\beta F_r^{2/3}$$ Choke

$$\frac{h_2}{h_1} = \frac{1}{2}\left[\sqrt{1+8F_r^2} - 1\right]$$ Jump



[Hamilton et al. 2017 in review JSR]

Golo: a steep, bedload dominated fan



h_1 [m]	H_l [m]	S [deg]	F_r [-]
8	12	1.1	1.49
9	10	1.2	1.53
14	10	0.8	1.36
7	7	0.9	1.41
5	10	2.9	1.89
7	13	4	2.02
10	20	4.5	2.07
10	20	4.5	2.07
10	15	3.7	1.99

[Hamilton et al. 2017 in review JSR]