Developing Boundaries in Sedimentology.

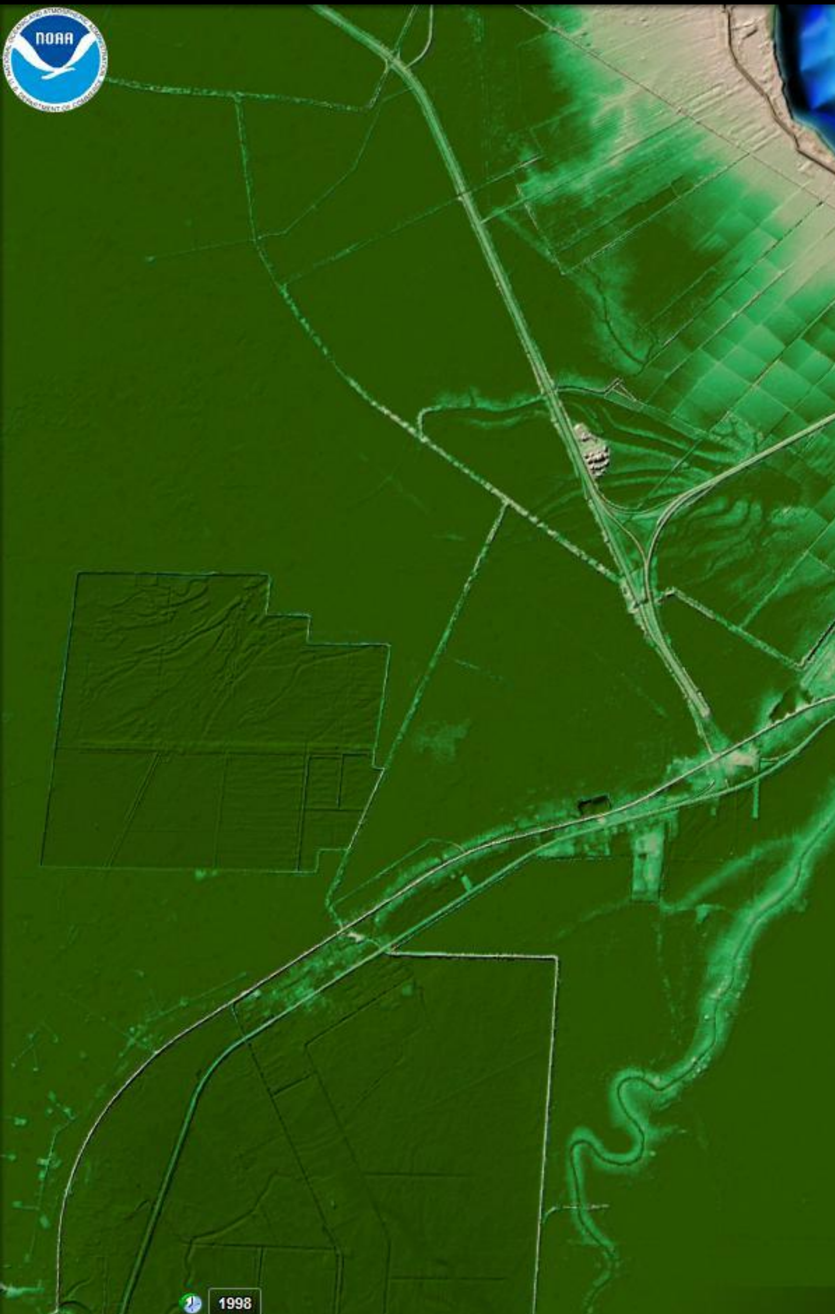
Joris Eggenhuisen

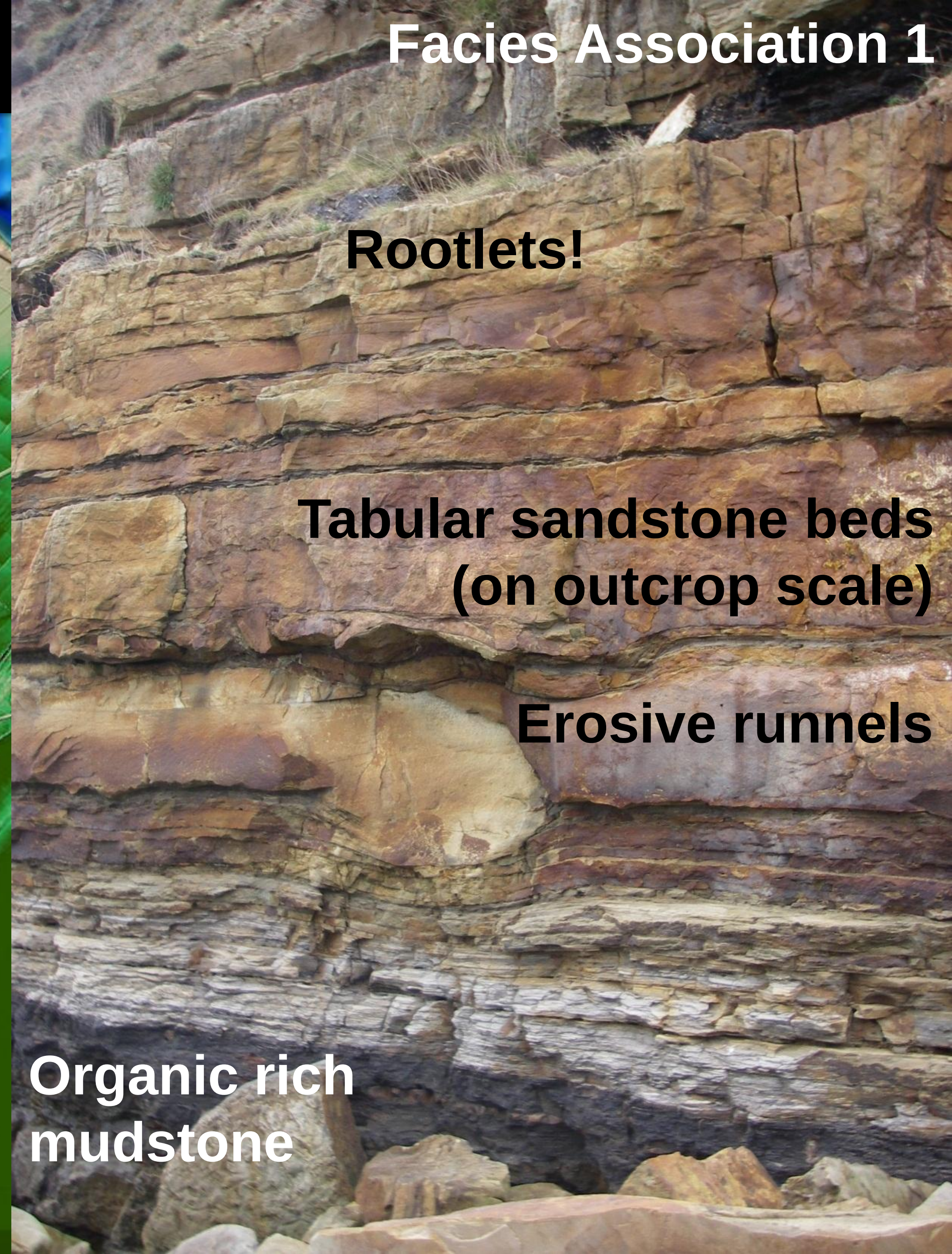
&

KITP GeoFlows Participants.

Sedimentology

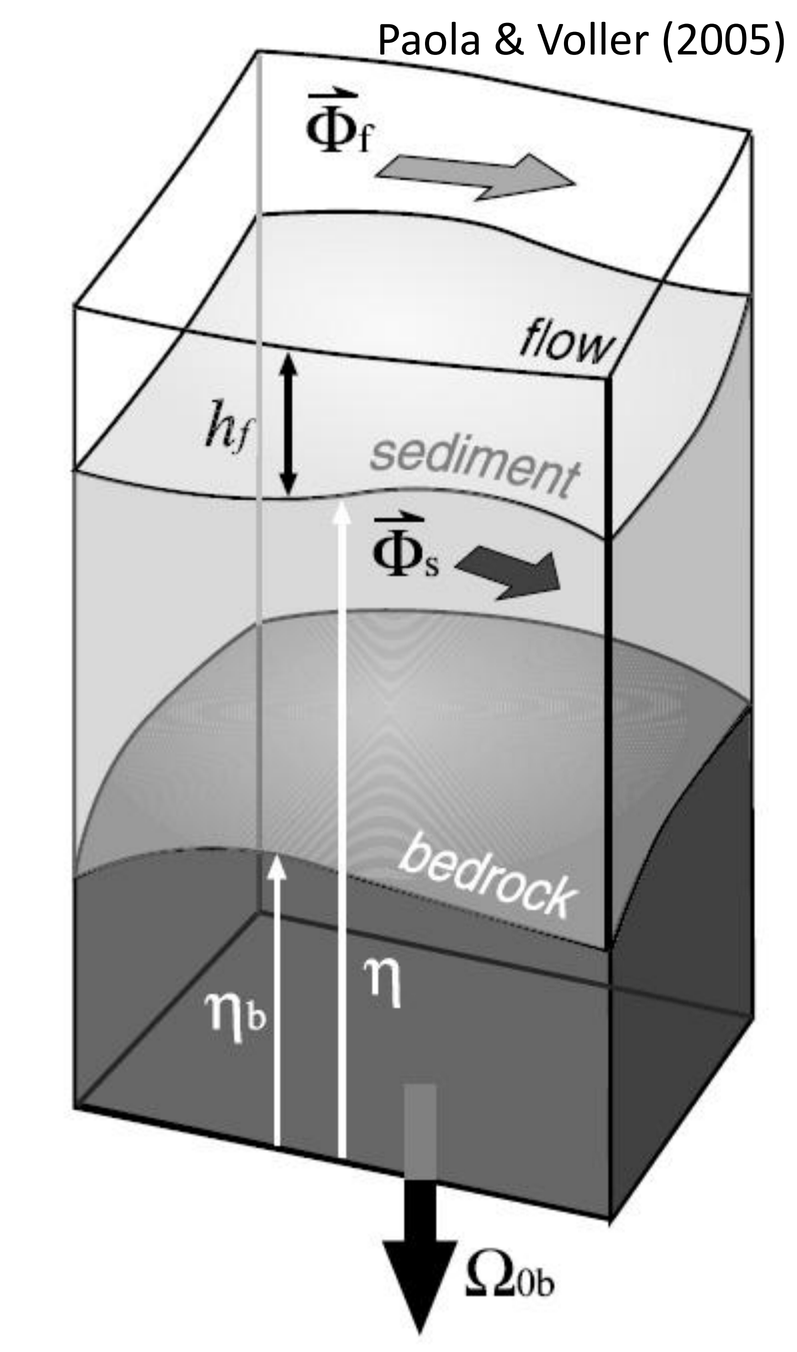
Sedimentology





Sedimentology in one equation:

$$\Phi \frac{\partial h}{\partial t} = -\nabla Q_s$$



Bookkeeping Formalised

$$\Phi \frac{\partial h}{\partial t} = -\nabla Q_s$$

$$\Omega_{0r} + (\alpha_r - \alpha_s(\eta_r))\frac{\partial \eta_r}{\partial t} + \int_{\eta_r}^{\eta} \frac{\partial \alpha_s}{\partial t} dz + \vec{\nabla}_H \vec{\phi}_s - \int_{\eta_r}^{\eta} \Gamma_s dz$$

$$+ \alpha_s(\eta)\frac{\partial \eta}{\partial t} + \frac{\partial}{\partial t}\int_{\eta}^{\eta+h_f} \alpha_f dz + \vec{\nabla}_H \vec{\phi}_f - \Omega_{in}(\eta + h_f)$$

$$- \int_{\eta}^{\eta+h_f} \Gamma_f dz = 0$$

Paola & Voller (2005)

Sedimentology: Advanced bookkeeping?

$$\Omega_{0r} + (\alpha_r - \alpha_s(\eta_r))\frac{\partial \eta_r}{\partial t} + \int_{\eta_r}^{\eta} \frac{\partial \alpha_s}{\partial t} dz + \vec{\nabla}_H \vec{\phi}_s - \int_{\eta_r}^{\eta}\Gamma_s dz$$

$$+ \alpha_s(\eta)\frac{\partial\eta}{\partial t} + \frac{\partial}{\partial t}\int_{\eta}^{\eta+h_f}\alpha_f dz + \vec{\nabla}_H\vec{\phi}_f + \Omega_{in}(\eta+h_f)$$

$$- \int_{\eta}^{\eta+h_f}\Gamma_f dz = 0 \qquad (17b)$$

Subsidence & Uplift

Metamorphosis,
Diagenesis,
Weathering

Compaction

(Soil) Creep

Dissolution &
Precipitation

"EROSION &
DEPOSITION"

Extraction
from top of
flow (?)

Dissolution,
Precipitation,
Floculation,
Fragmentation,
Abrasion

Temporal
fluctuations in
sediment load

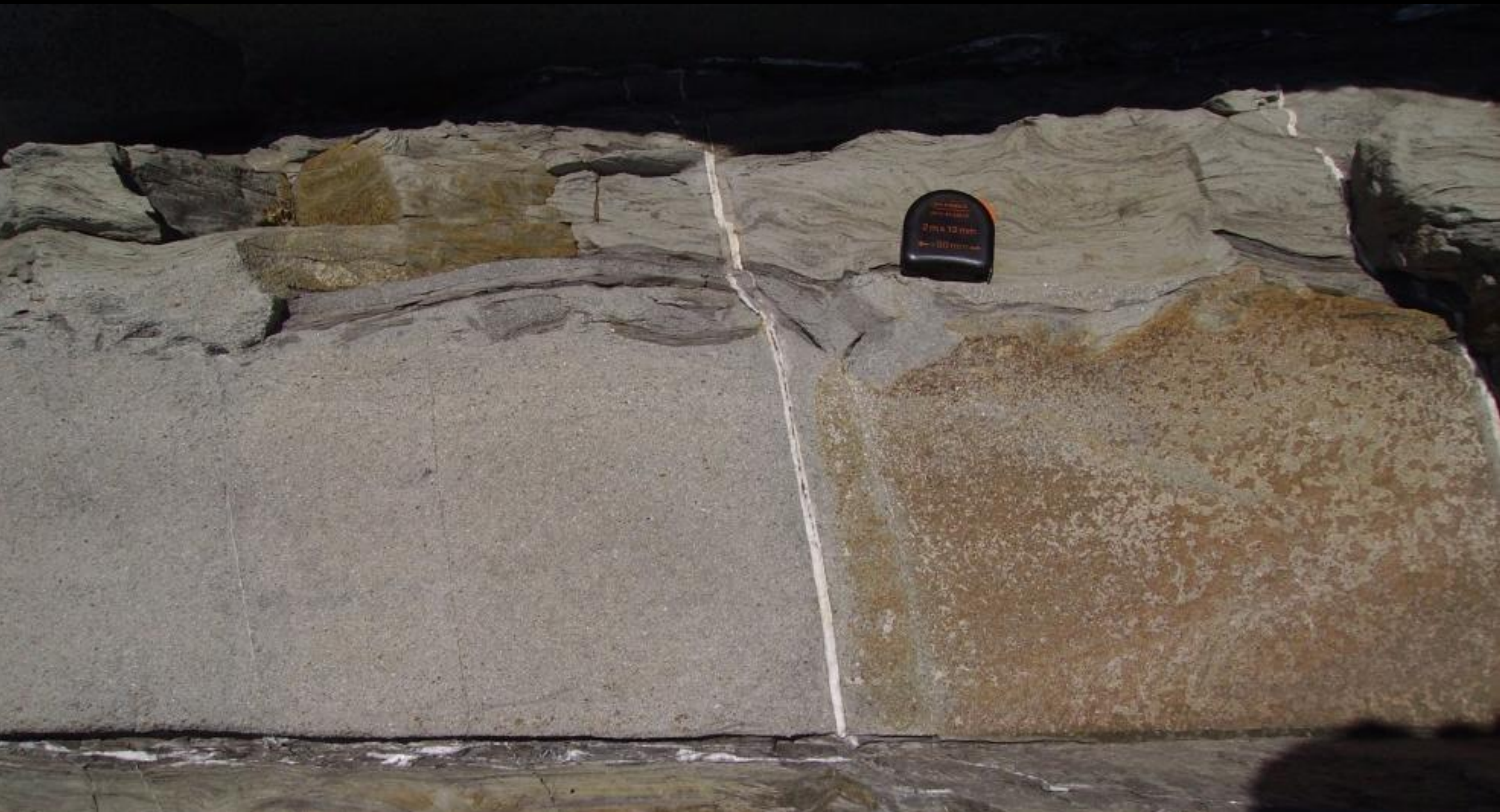
SPATIAL GRADIENT
OF SEDIMENT IN
TRANSPORT

Sedimentology: Advanced bookkeeping

$$\Phi \frac{\partial h}{\partial t} = -\nabla Q_s$$

$$Q_s?$$

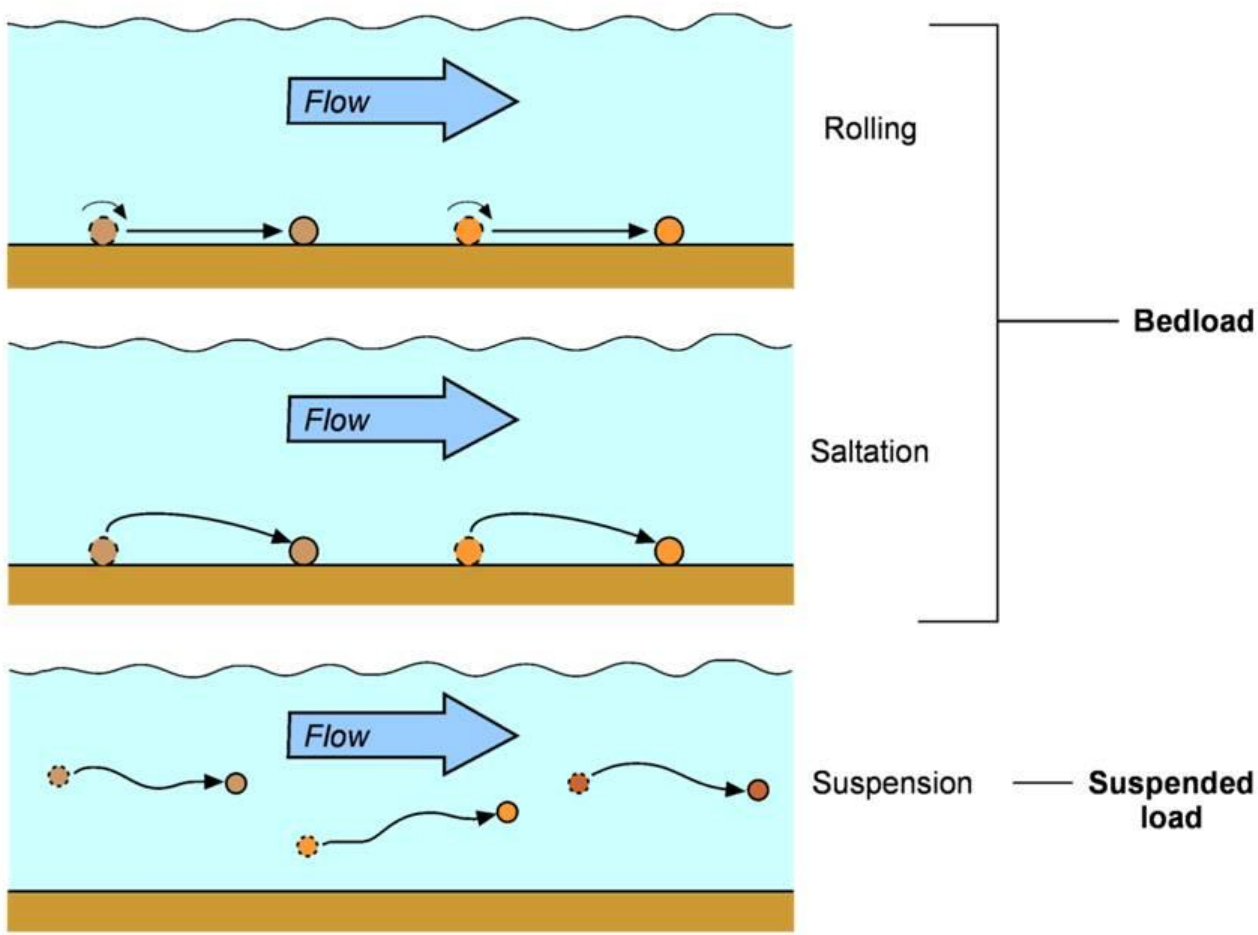
Q_s?



Q_s?

What do we tell the undergraduates?

Movement of particles in a flow

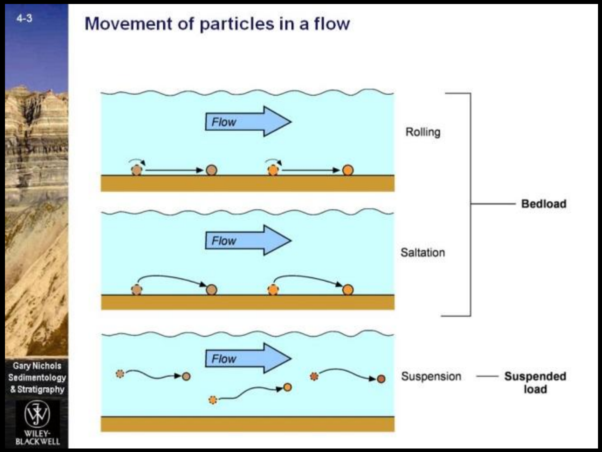


Q_s?

What do the undergraduates tell us?

John Gaffney (2008) SAFL & NCED

- Rolling
- Sliding
- Intermittent movement
- Stable orientations
- Nudging around
-



Bed Load

Sediment Transport

100g/m/s

7.0mm D_{50} Pea Gravel

http://www.youtube.com/watch?v=o3llzwvv1zc

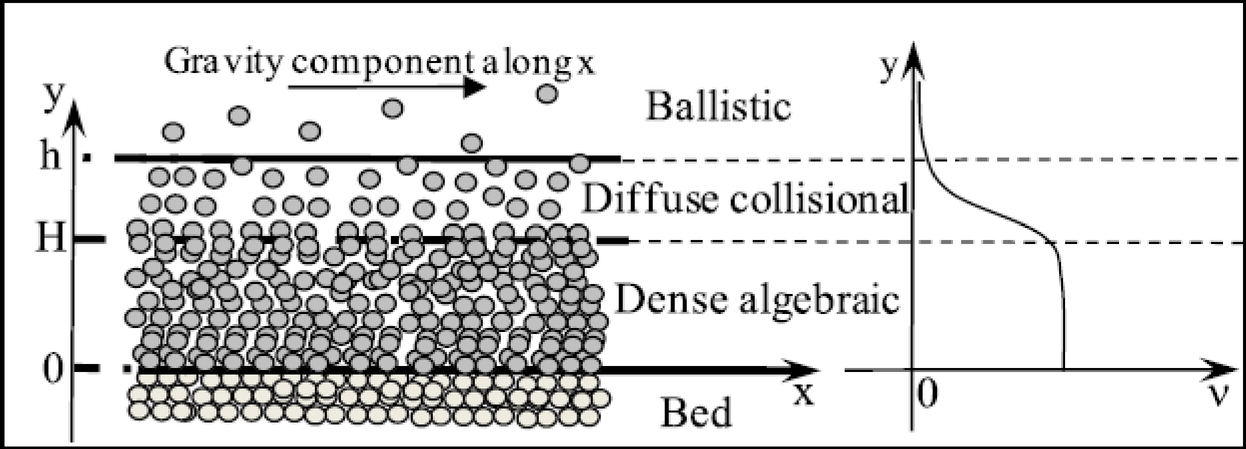
Q_s?

“Intens Bedload”

Q_s

Phenomenology

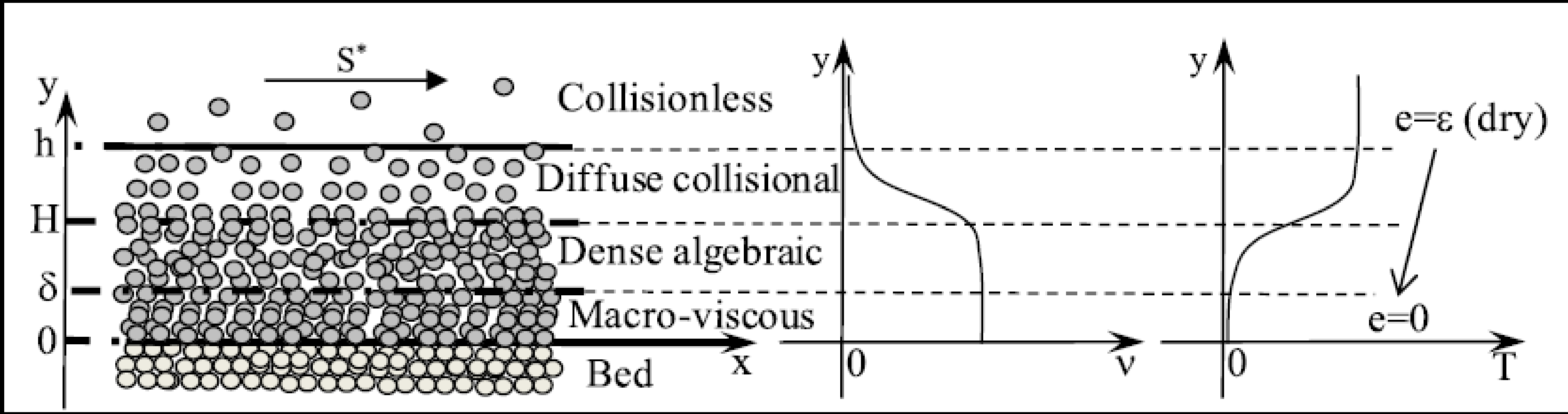
From Berzi & Jenkins 2011



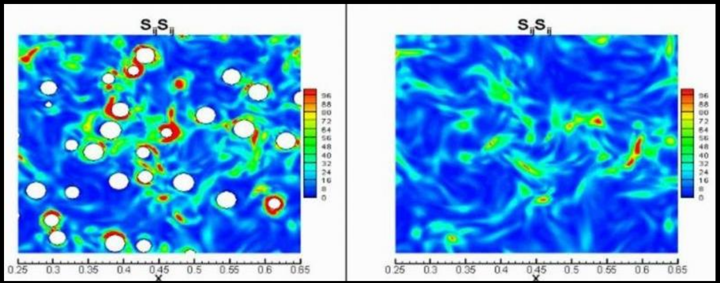
- Frequent collisions
- More than 1 grain diameter thick
- Solid fraction ~0.10-0.65
- No discontinuity in concentration

Q_s KITP: 3 approaches to quantification

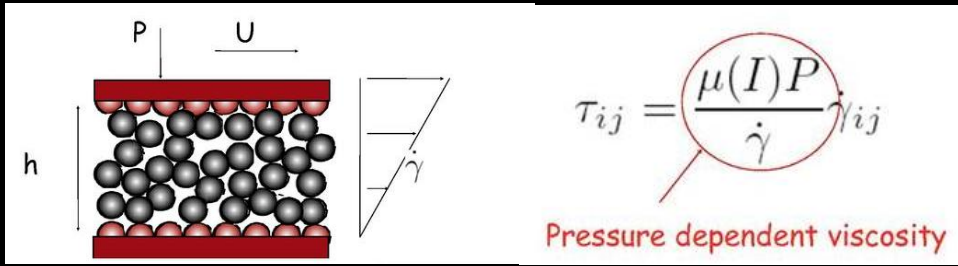
Kinetic Theory (Berzi, Larcher, Jenkins, Fraccarollo, …)



DNS & DEM

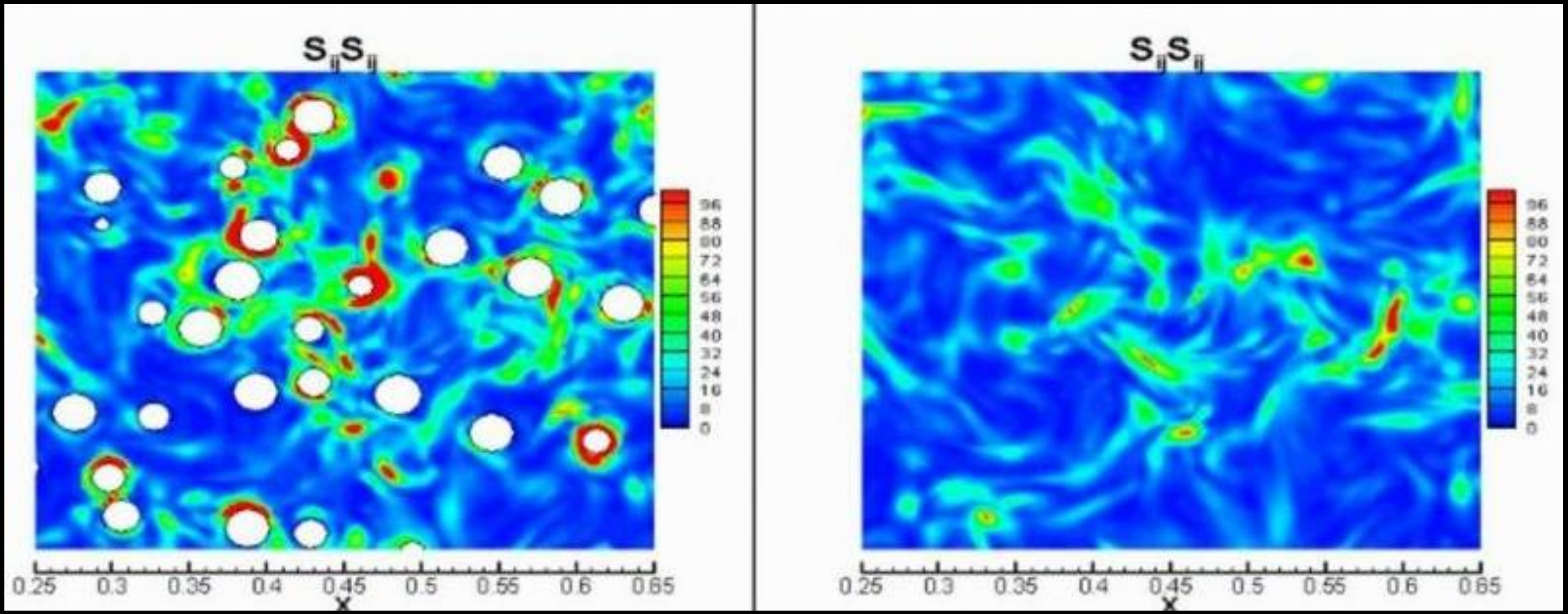


μ(I)-rheology

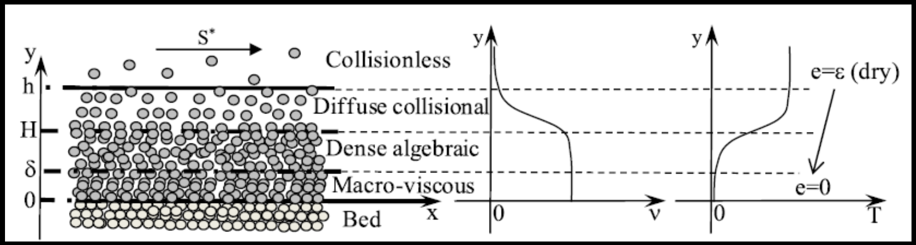


Q_s KITP: 3 approaches to quantification

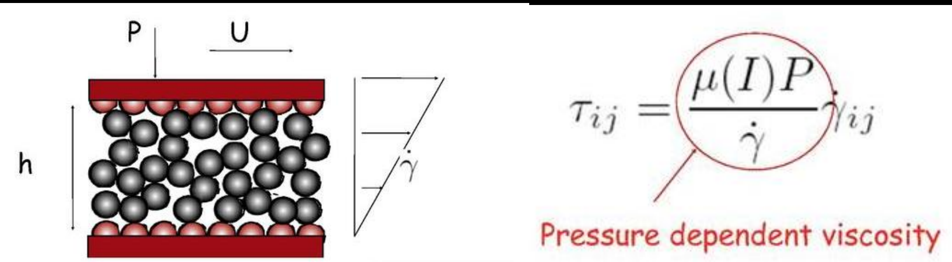
Numerical DNS (Meiburg, Elghobashi, …) & DEM (Oger, …)



Kinetic Theory

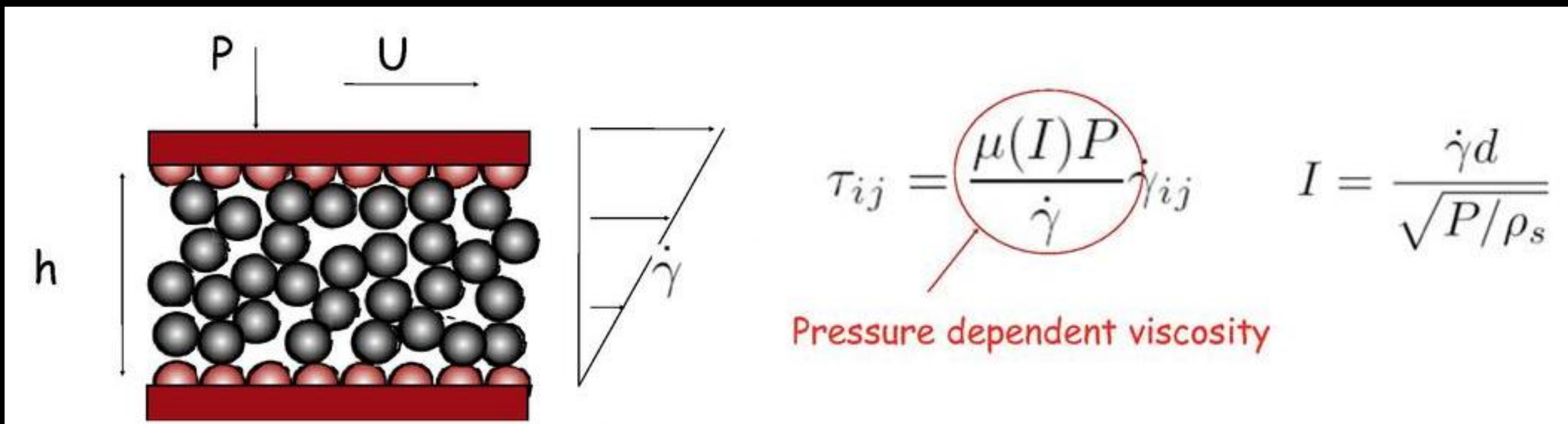


μ(I)-rheology

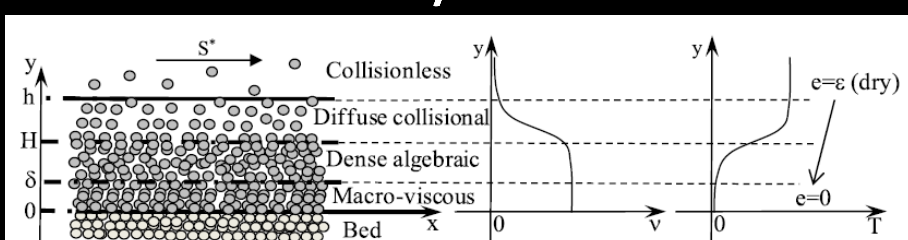


Q_s KITP: 3 approaches to quantification

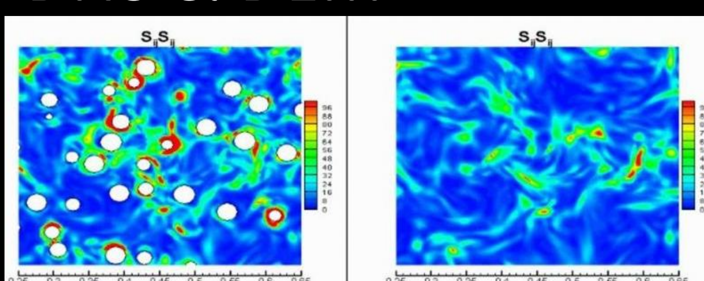
μ(I)-rheology (Pouliquen & many others)



Kinetic Theory



DNS & DEM



A developing boundary

Growth structures: deformation took place DURING deposition of the bed.

Mass exchange with the bed: Erosion

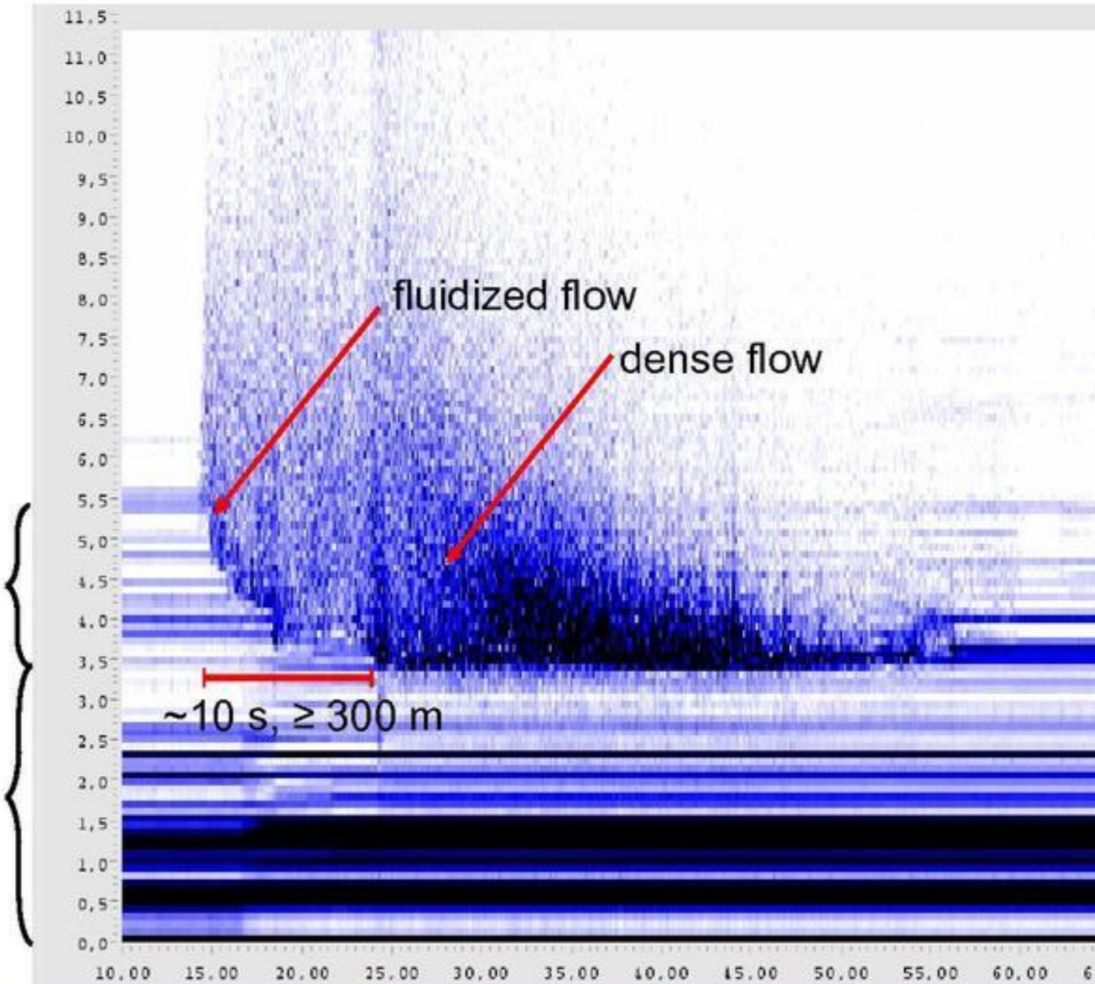
$$\Phi \frac{\partial h}{\partial t} = -\nabla Q_s$$

FMCW radar plot of snow avalanche at Vallée de la Sionne

Observed entrainment rate: **10–200 kg m^{-2} s^{-1}**, diminishing with time and erosion depth.

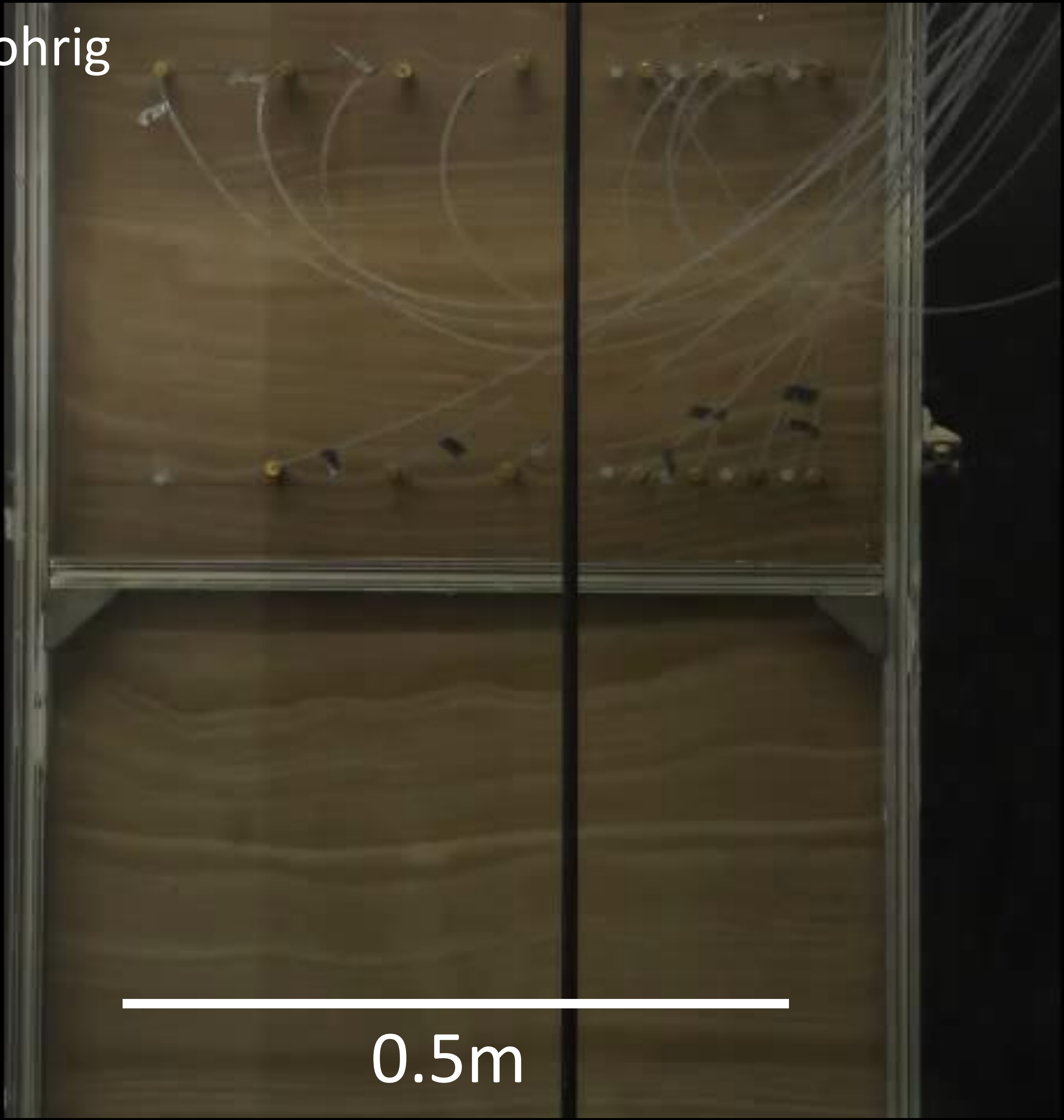
2 m of fresh snow eroded

Hard old snow not eroded



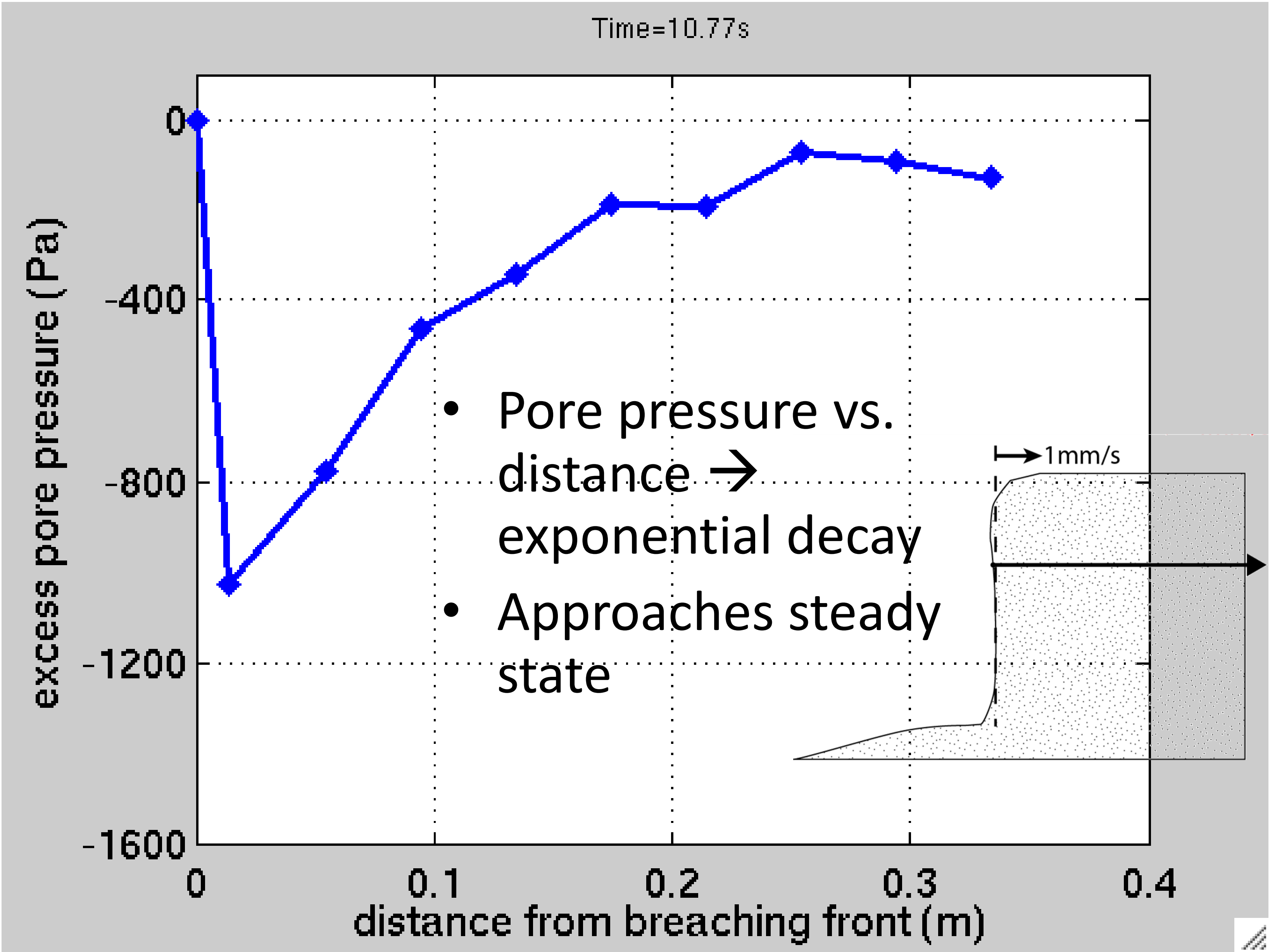
Dieter Issler (Wed PM)

You & Mohrig



Yao You & David Mohrig

Excess Pore Pressure



- Pore pressure vs. distance → exponential decay
- Approaches steady state

Developing boundaries: Breaching as a sustained source of sand.

J. H. Van den Berg et al. (2002)

Developing boundaries: Breaching as a sustained source of sand.

Cooper et al. (2013)

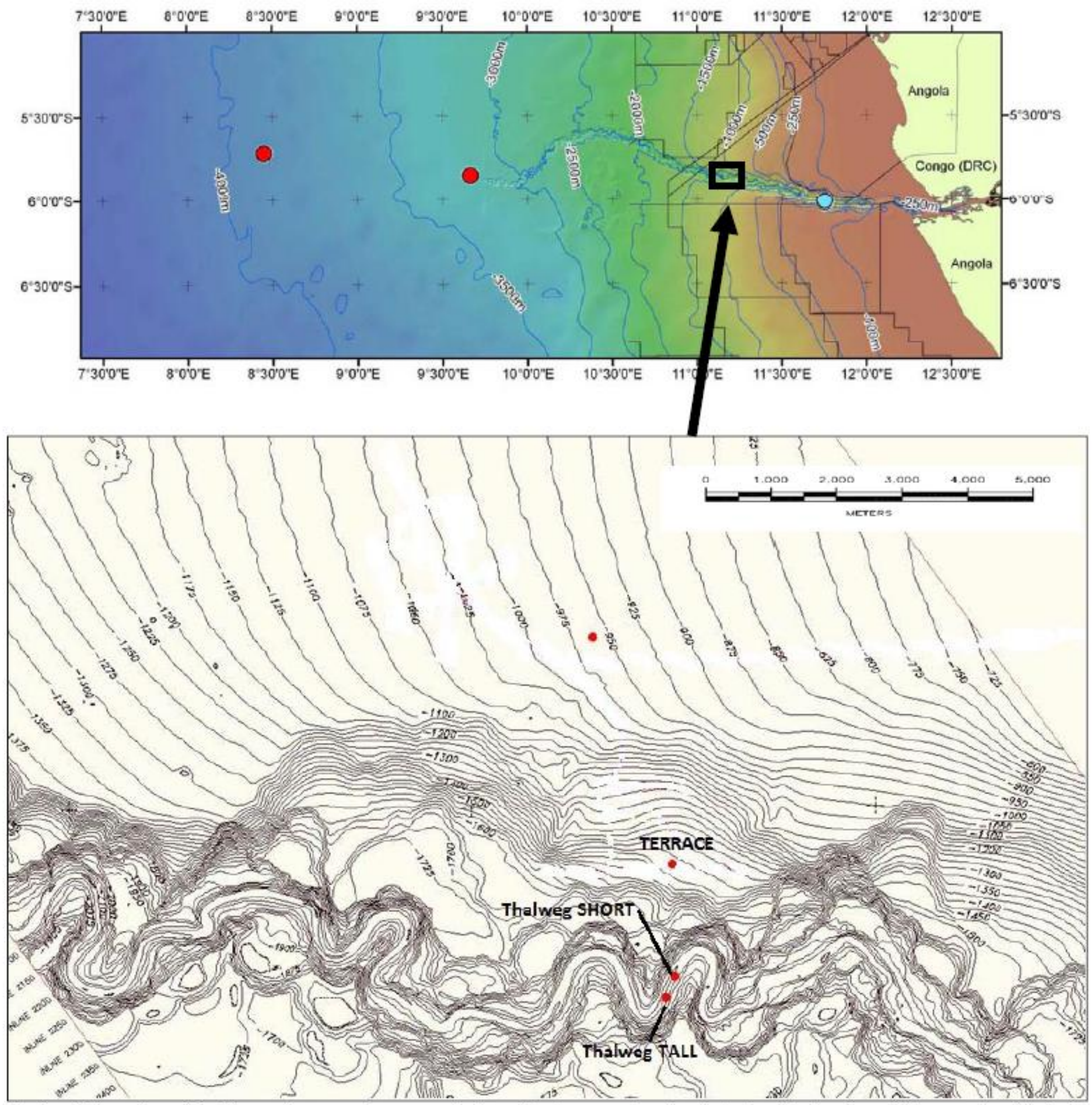


Fig. 1: Bathymetry of the Congo Canyon. Upper panel shows the larger-scale view including the location of three earlier efforts to measure turbidity currents (blue and red circles). The lower panel shows a zoomed view of the region in the black rectangle of the upper panel where the moorings described in this paper were deployed.

Developing boundaries: Breaching as a sustained source of sand.

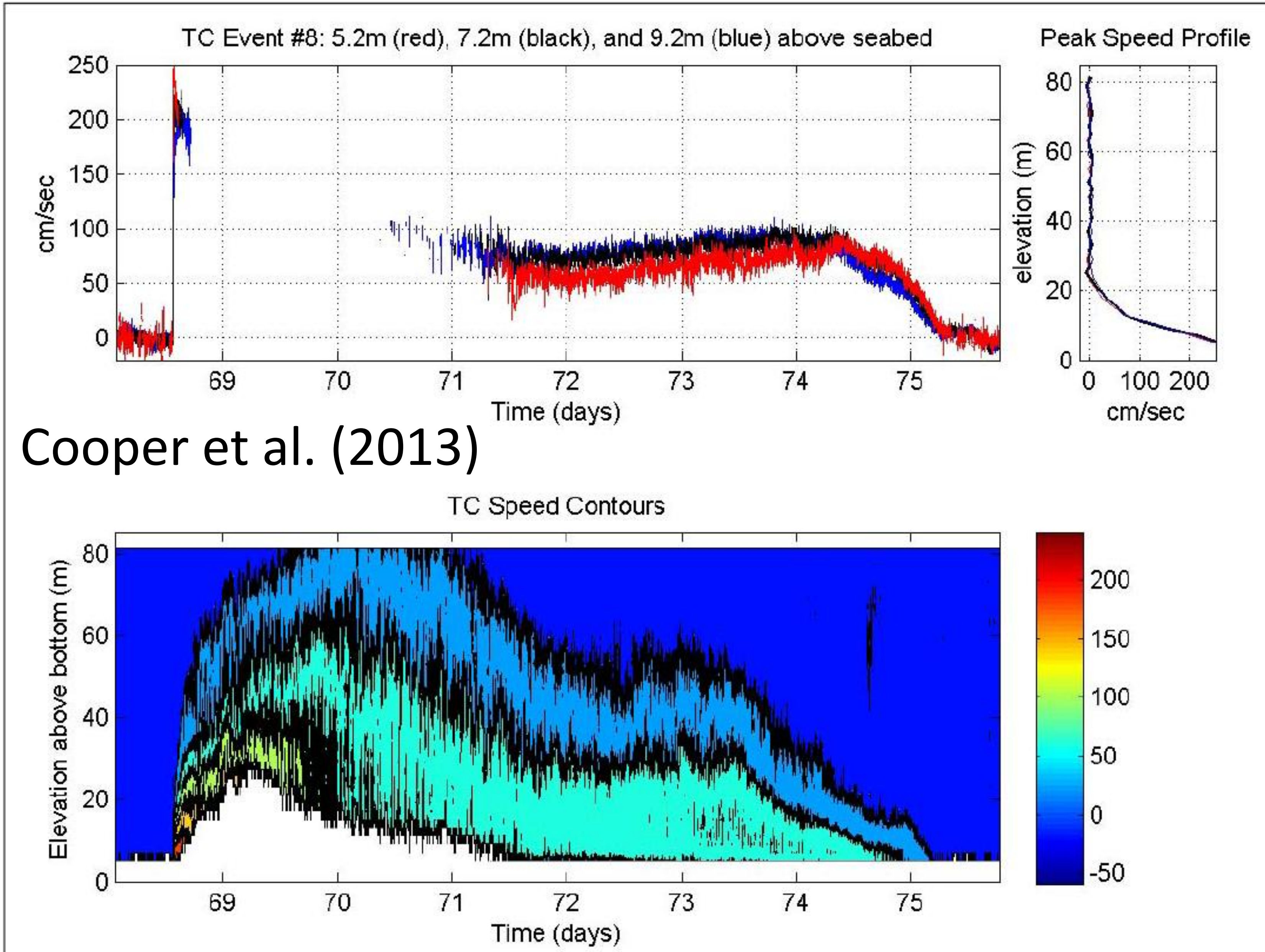
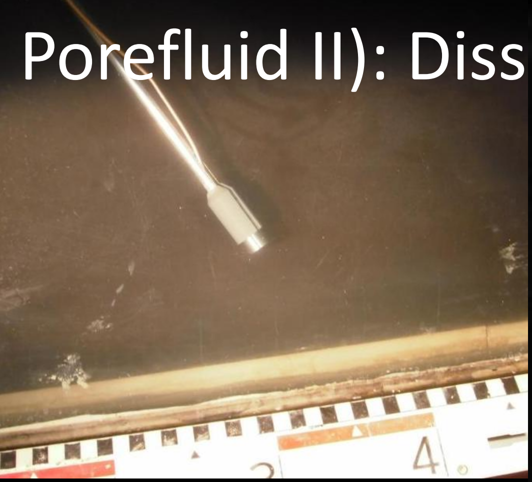
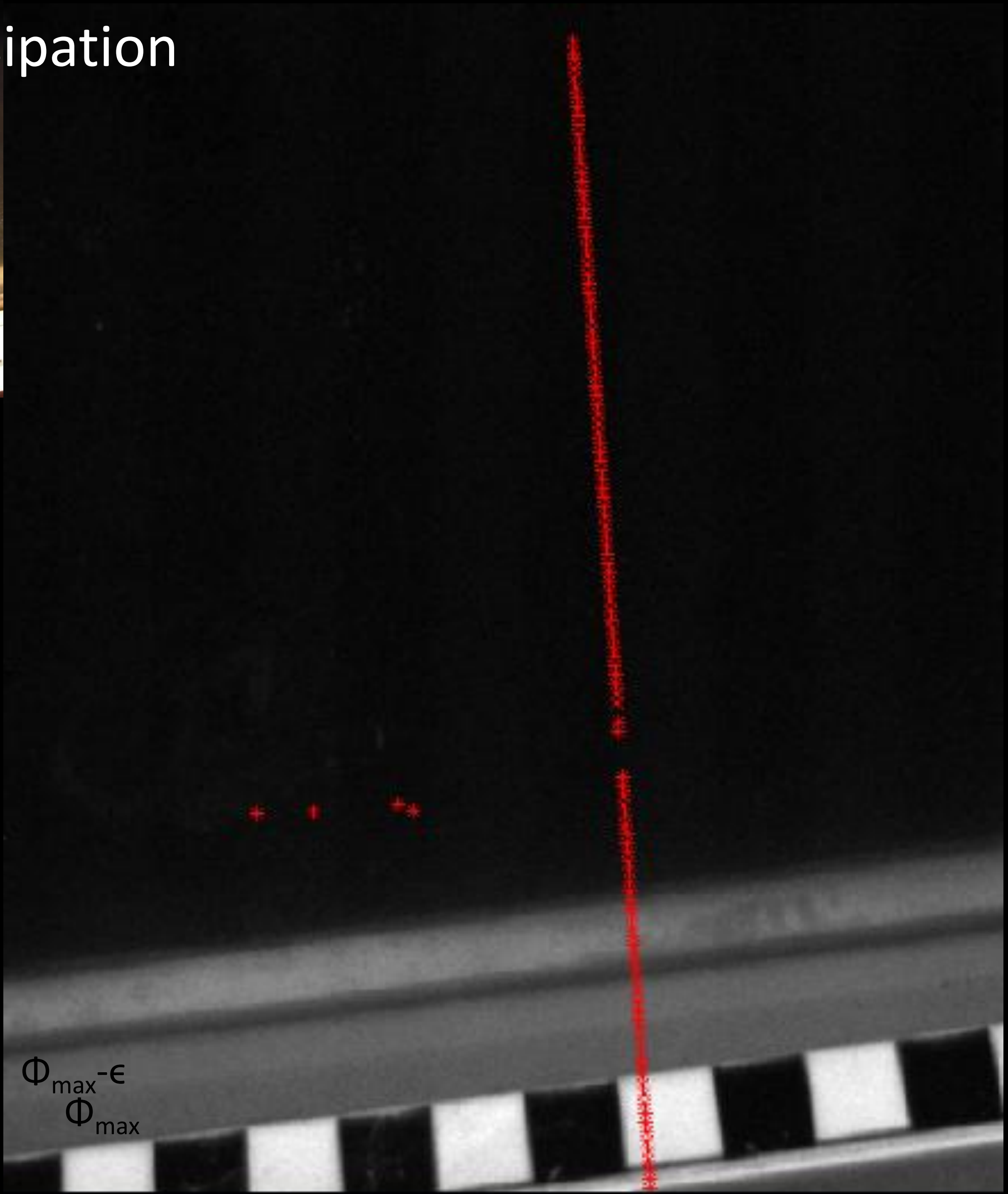


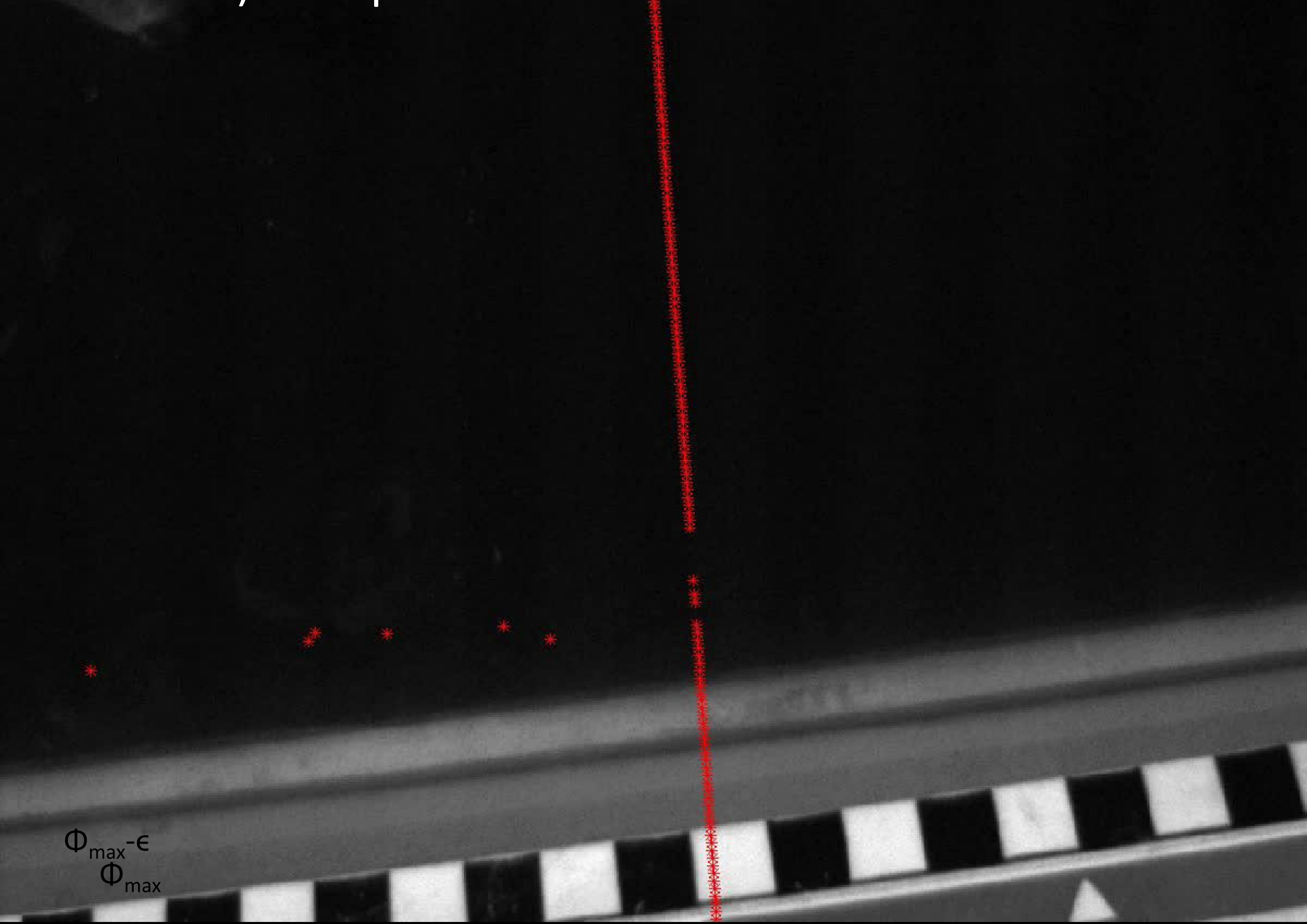
Fig. 3: Time series of the strongest TC observed which reached a peak velocity of 250 cm/sec. This event persisted for more than 6 days and reached 109m above the seabed.

Porefluid II): Dissipation



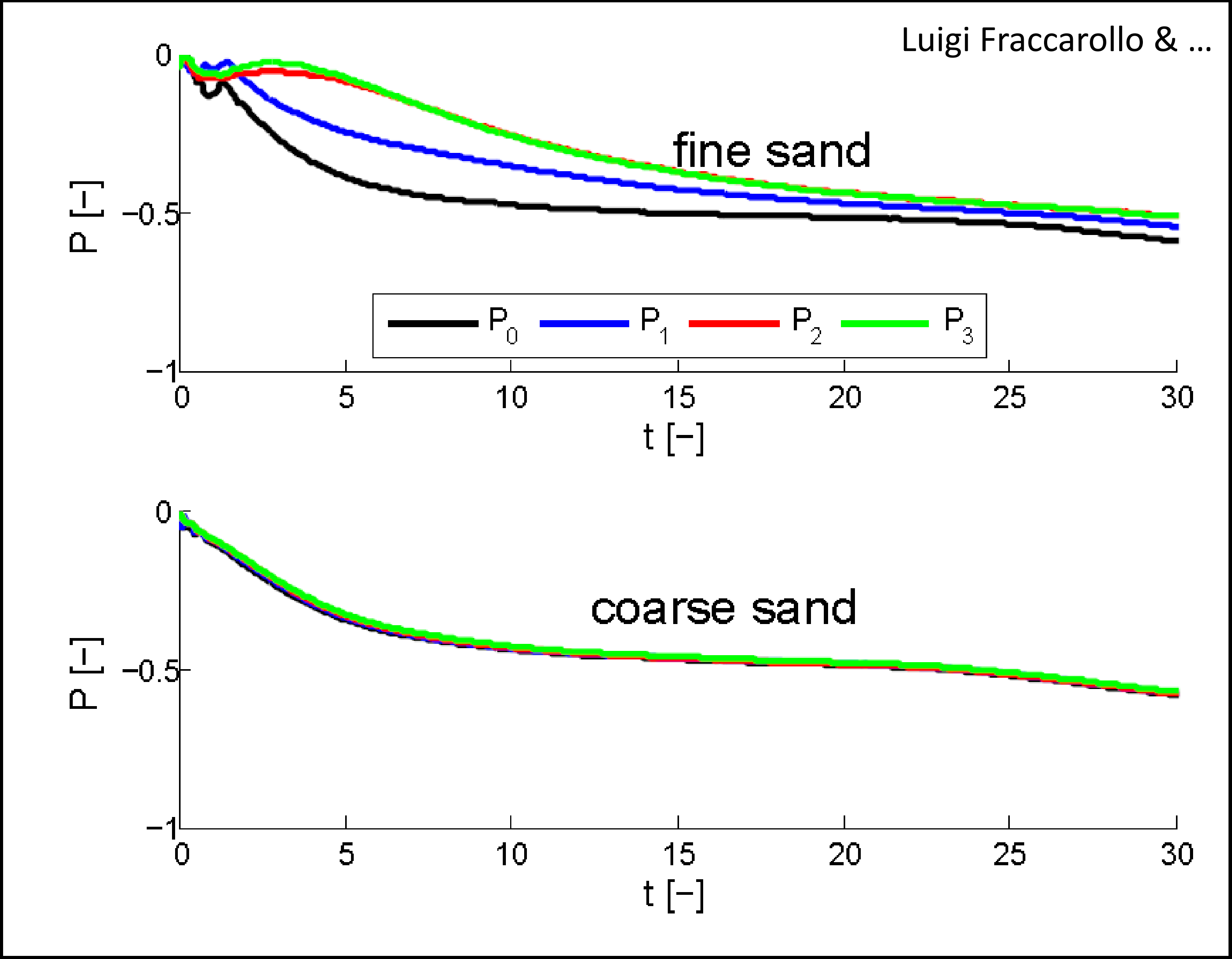


Porefluid II): Dissipation



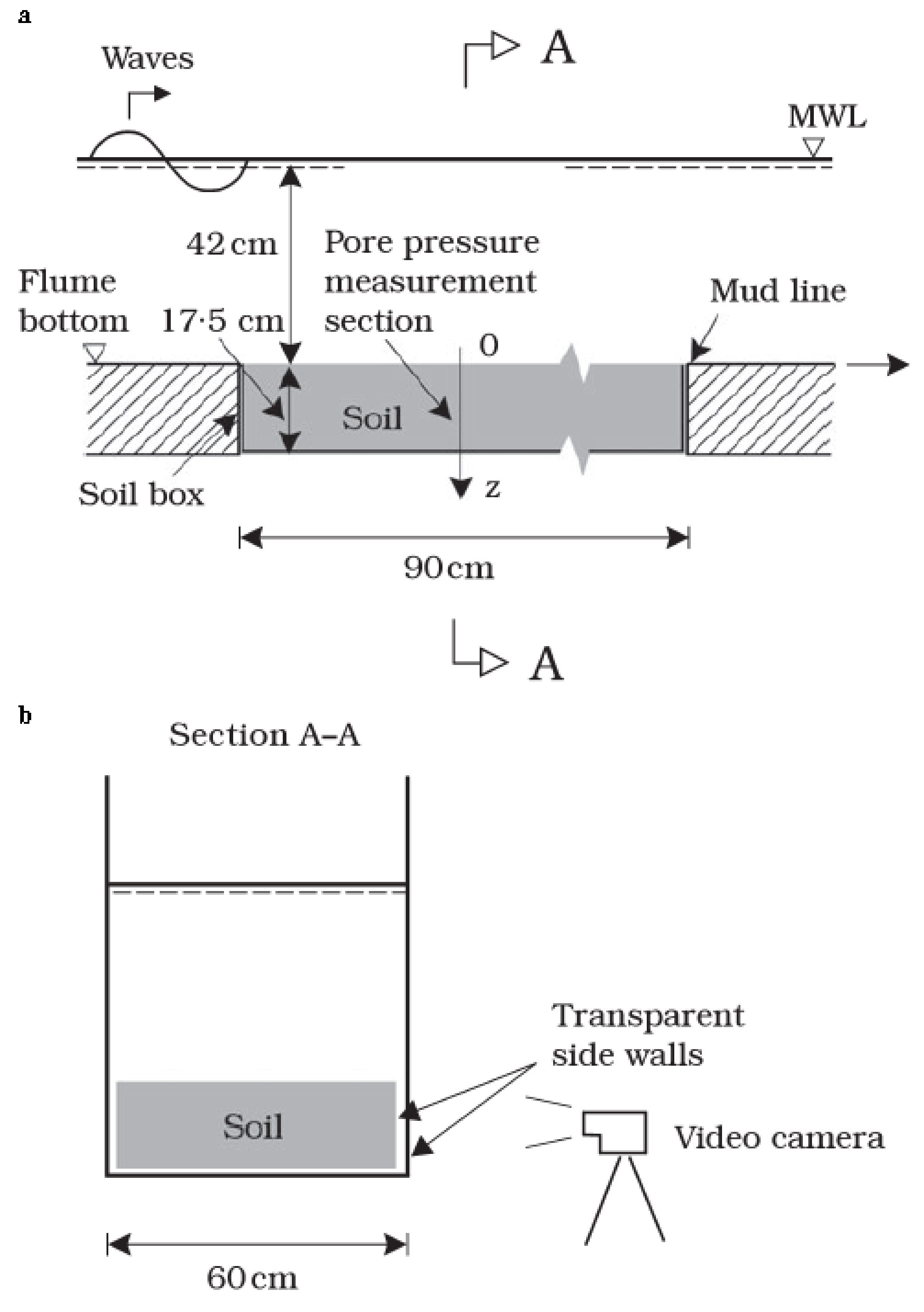
Porefluid II): Dissipation

Porefluid III): Dissipation as a function of grainsize



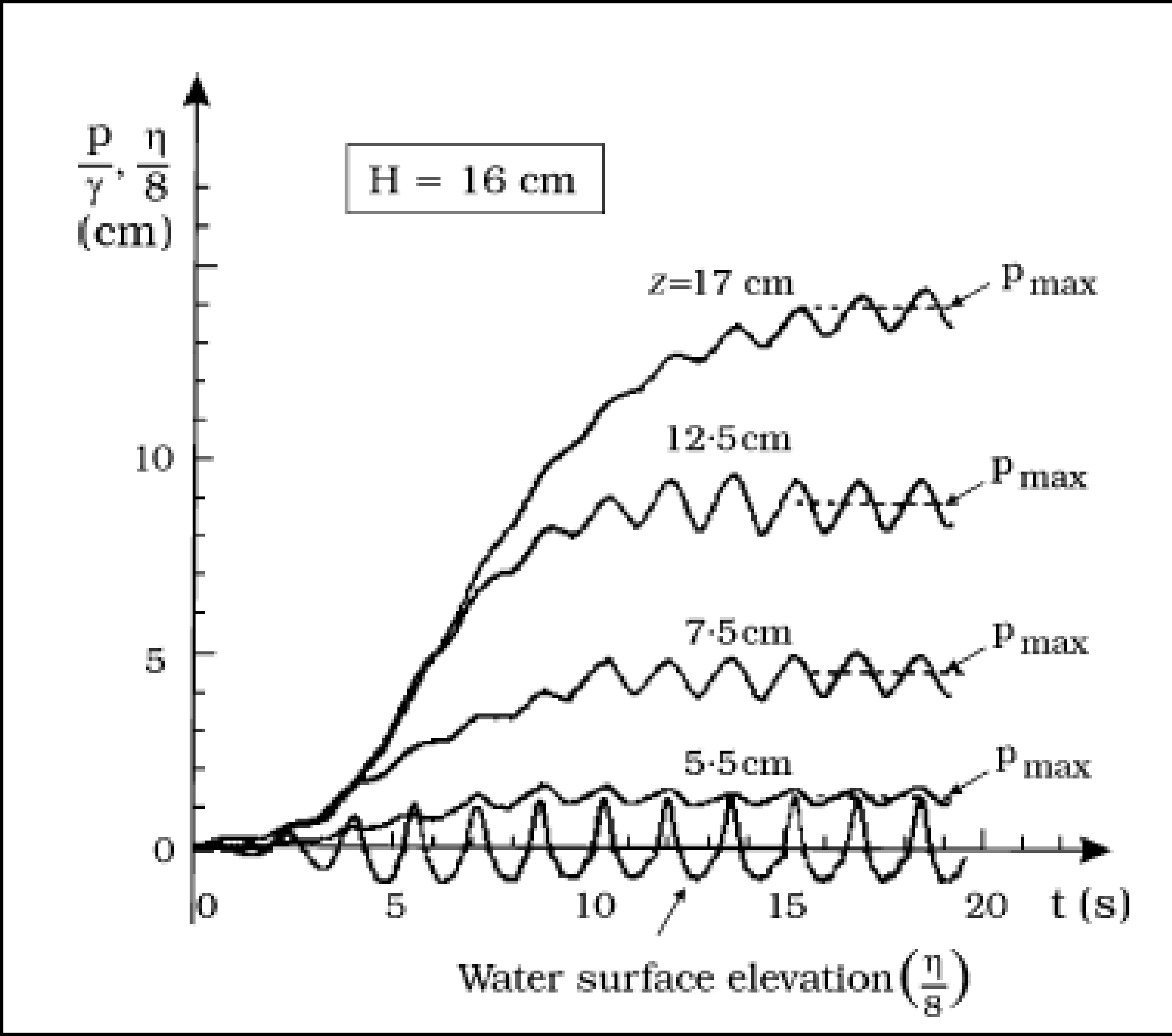
Mutlu Sumer et al.
Sedimentology, 2006

$\Phi_0 = 0.58$
$D_{50} = 60\ \mu$



Mutlu Sumer et al.
Sedimentology, 2006

Excess porefluid pressure timeseries

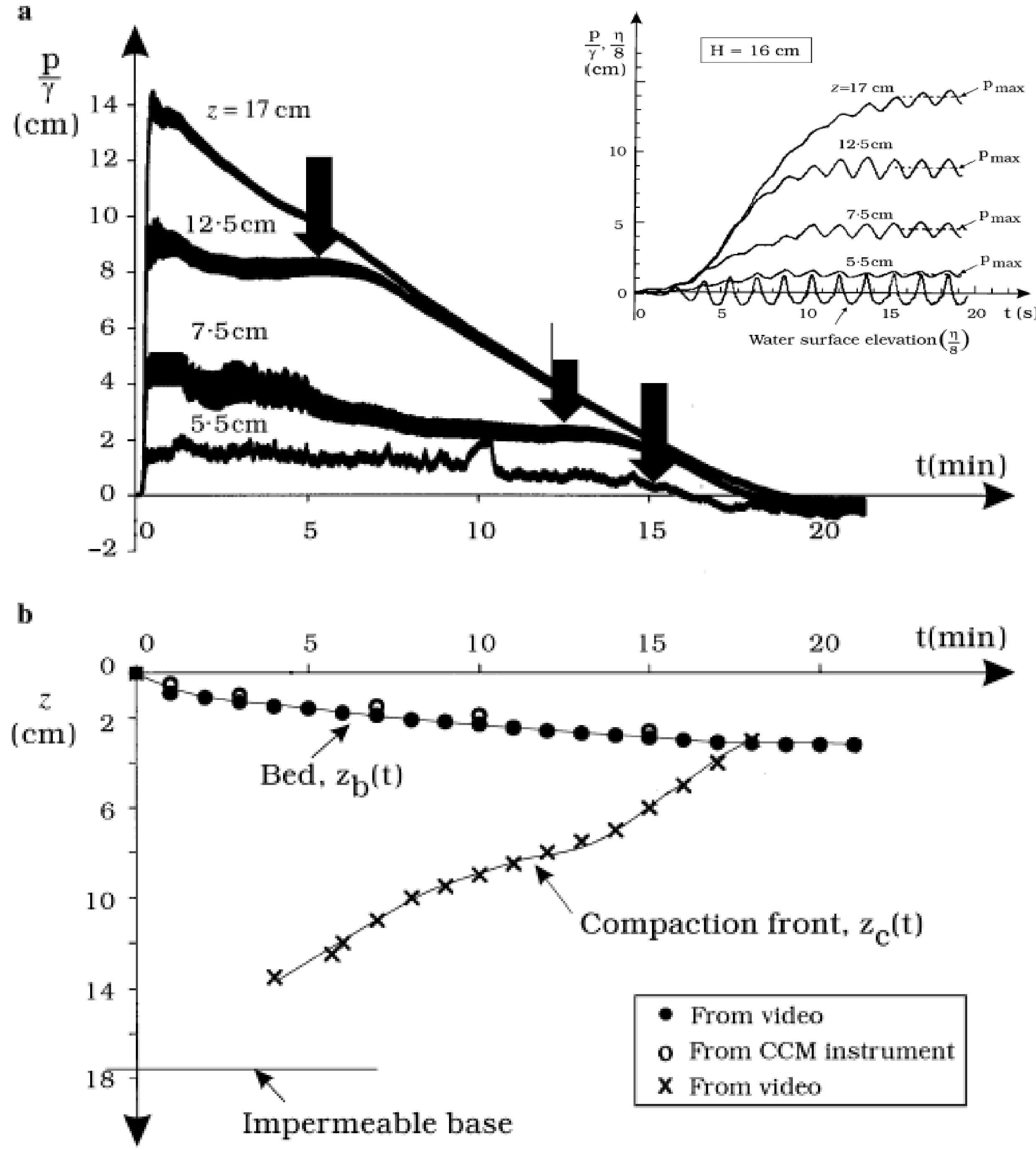


Description on granular scale:
Change in packing.
Porefluid pressure is lithostatic
>> hydrostatic.
Grains are supported by pore
fluid gradient.
Effective normal stress on
grain contacts =~0.
No frictional resistance along
grain contacts.
Grain contacts will slip at
negligable stress.

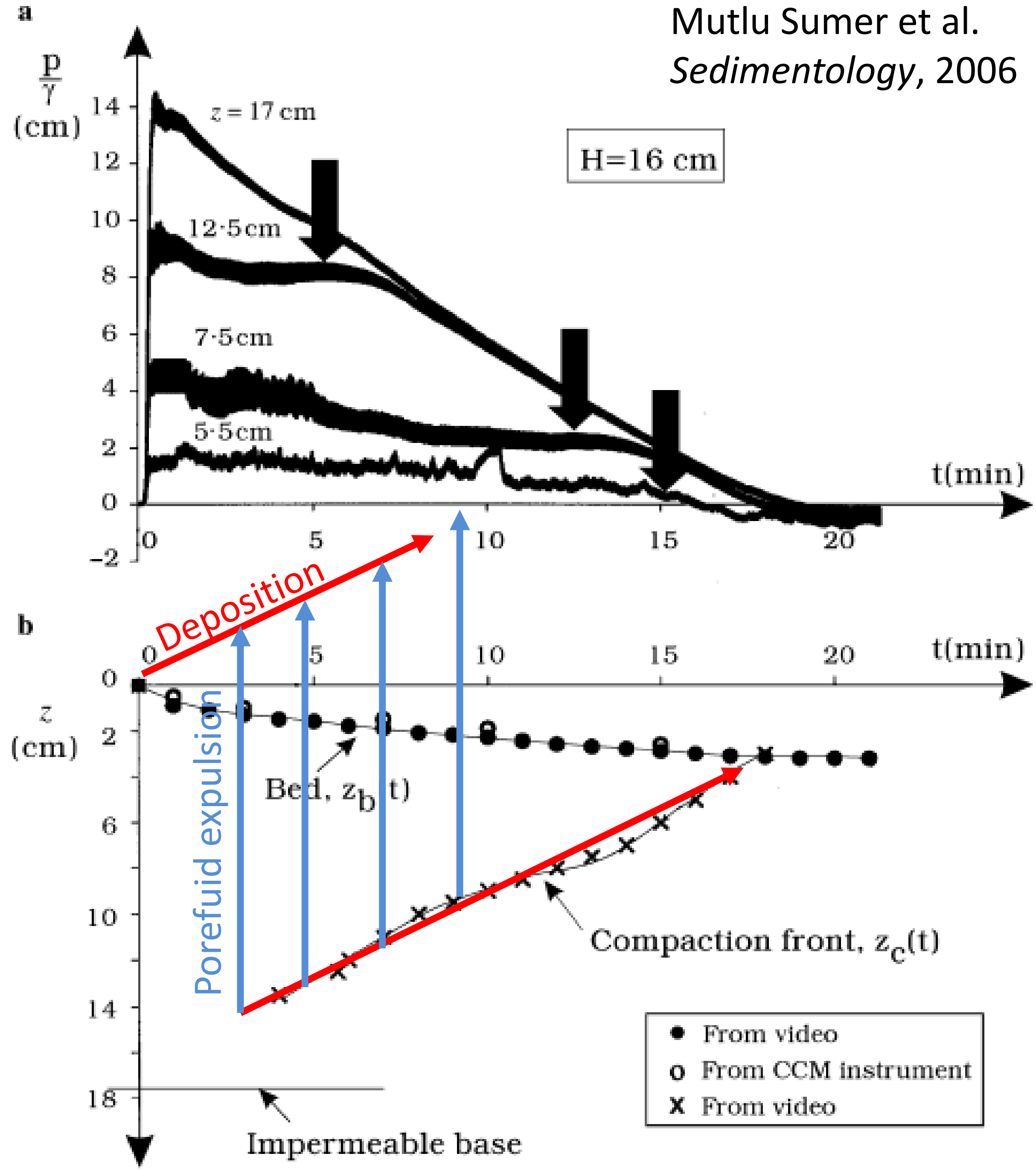
Description of continuum
rheology:
Continuum has negligable
strength at 0 shear.
Application of shear stress
results in deformation

Dissipation is a function of
porefluid migration.

Φ_0 = 0.58 to 0.64 takes
17.5 minutes



Mutlu Sumer et al.
Sedimentology, 2006



Dissipation time ~ 17.5 minutes
Dissipation front velocity
= 1 cm / min
= 170 μ/s
= 3* D50 per second

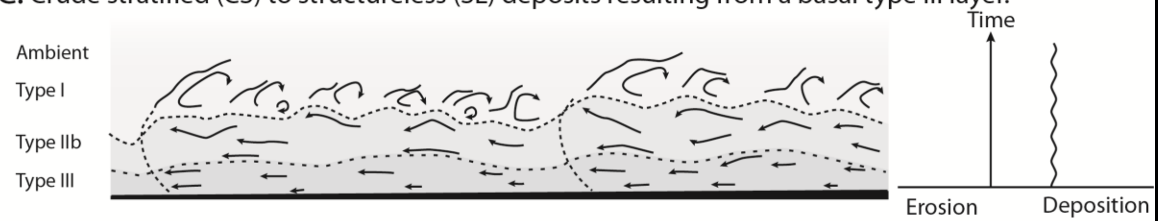
A. Spaced stratification (SS) resulting from a basal type IIa layer.

Alternating periods of ersion & deposition associated to long pulses are linked to abundant erosion surfaces, basal inverse grading overlain by ungraded intervals (Spaced Stratifiactions, SS).

B. Crude stratification (CS) resulting from a basal type IIb layer.

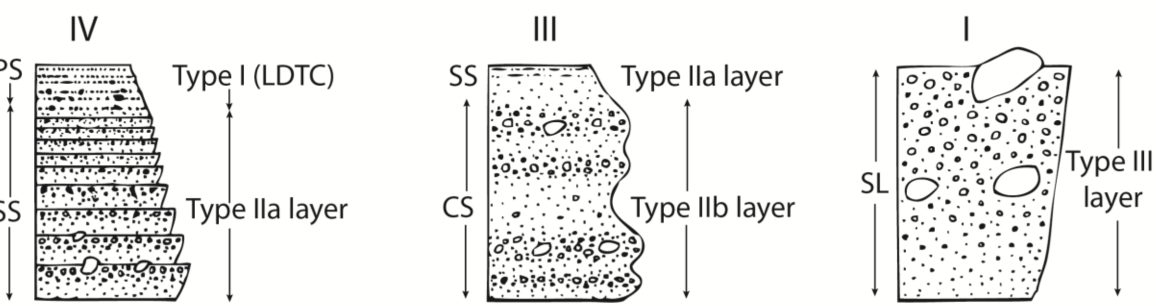
Periodical variations in aggradation rate associated to long pulses are linked to alternating patterns of coarsening and fining upwards (Crude Stratifiactions, CS).

C. Crude stratified (CS) to structureless (SL) deposits resulting from a basal type III layer.



Steadily aggradaing bed with nearly full turbulence demping are linked to minor alternating patterns of coarsening and fining upwards (Crude Stratifications, CS) or structureless deposits (SL).

D. Application to some of the traction carpet succenions of Sohn (1997)



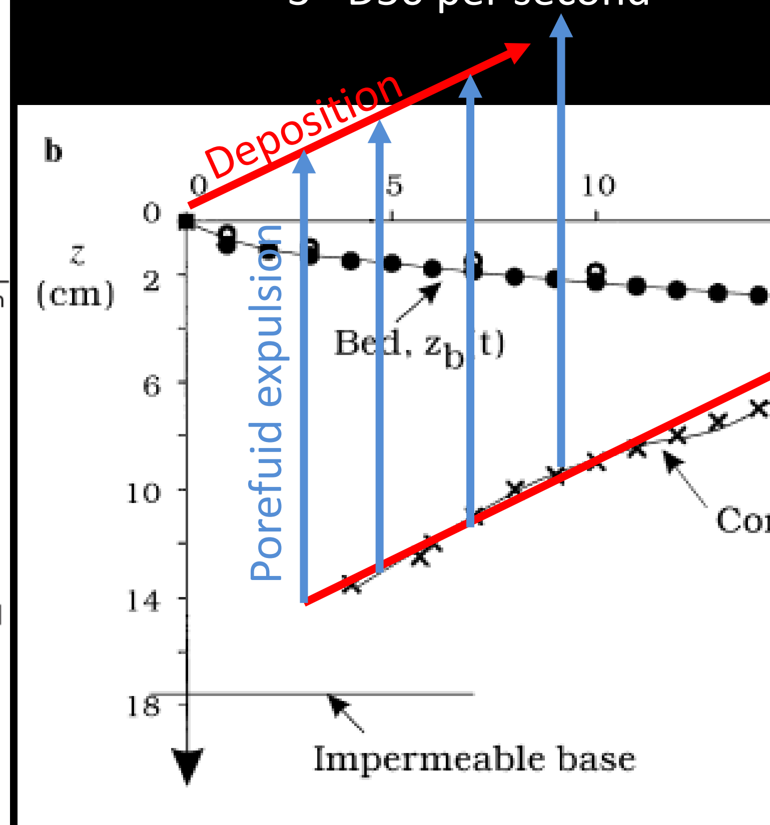
Parallel stratifications (PS) are here linked to low-density turbidity currents due to their dependence on turbulent structures. Type III layers are most likely to collect floating outsized clasts due their high density.

= 7* D50 per second

Deposition & Erosion under collisional regime never under equilibrated pore pressure gradients

= 4* D50 per second

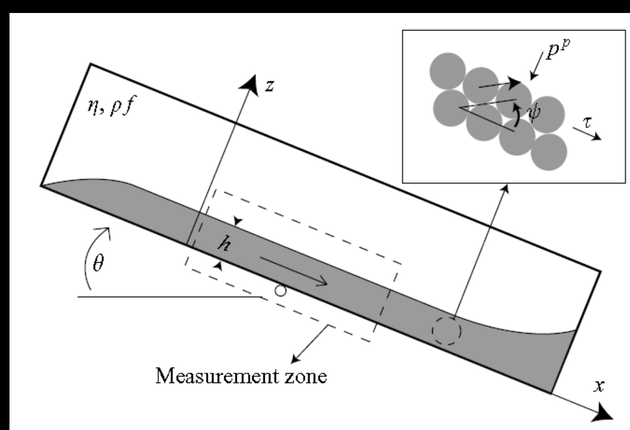
Dissipation front velocity
= 1 cm / min
= 170 μ/s
= 3* D50 per second

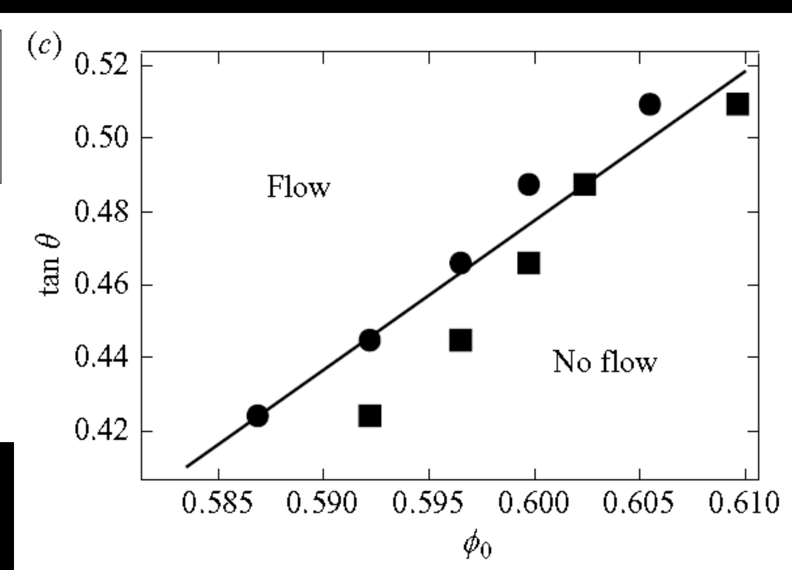


Porefluid state of the substrate governs mass transfer between bed and flow:

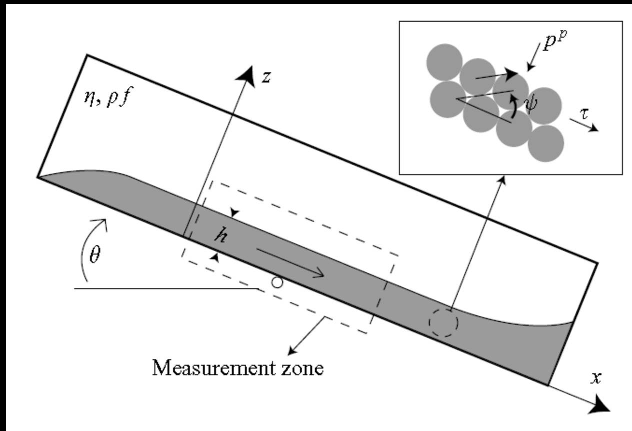
- Erosion and deposition depends on the rate and history of erosion and deposition.
- Erosion and deposition depends on the rate and history of flow unsteadiness

$$\Phi \frac{\partial h}{\partial t} = -\nabla Q_s \left\{ \int_{t_-}^{t_0} \frac{\partial h}{\partial t}, \int_{t_-}^{t_0} \frac{\partial Q_w}{\partial t} \right\}$$

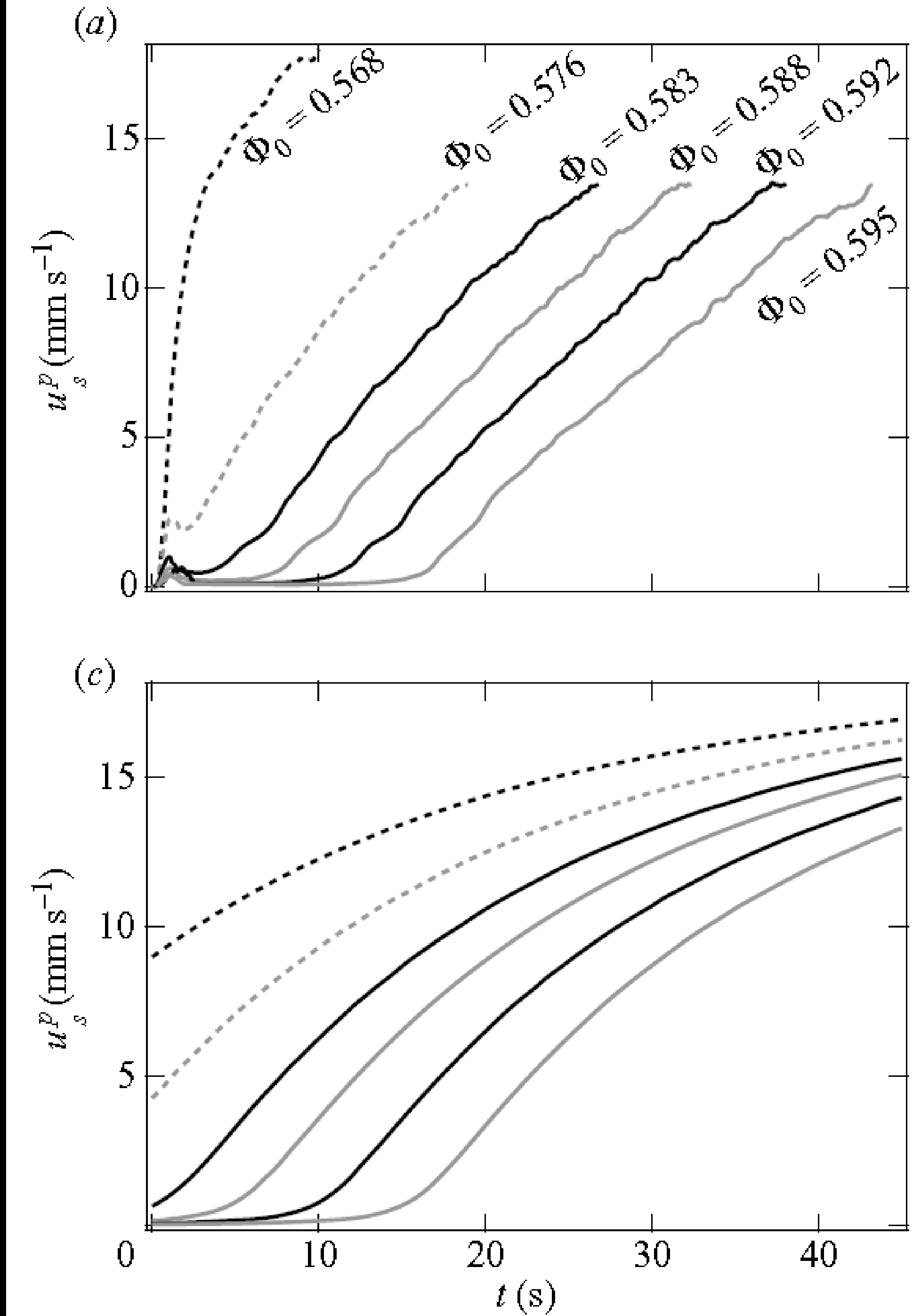




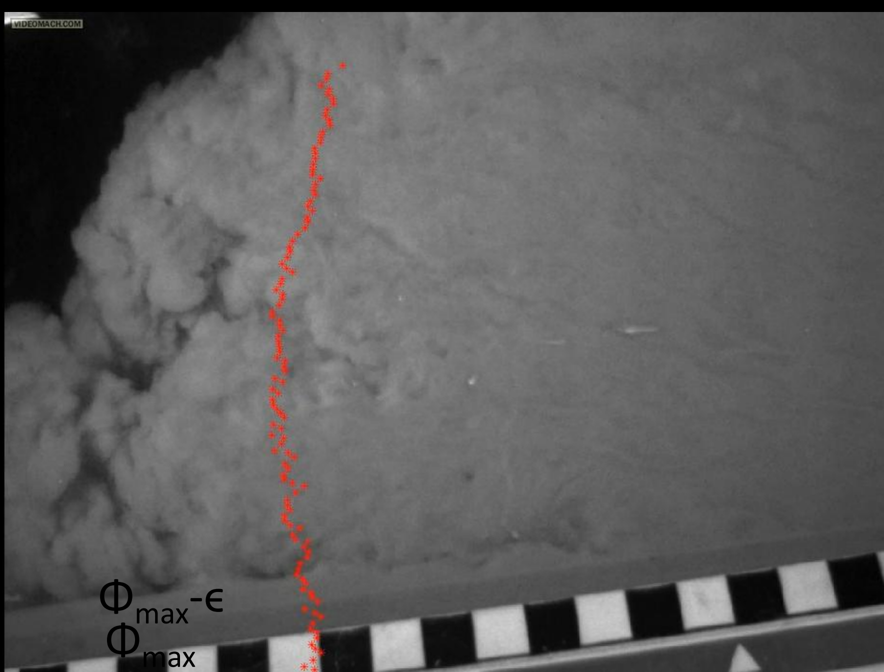
Pailha & Pouliquen (2009)



Pailha & Pouliquen (2009)



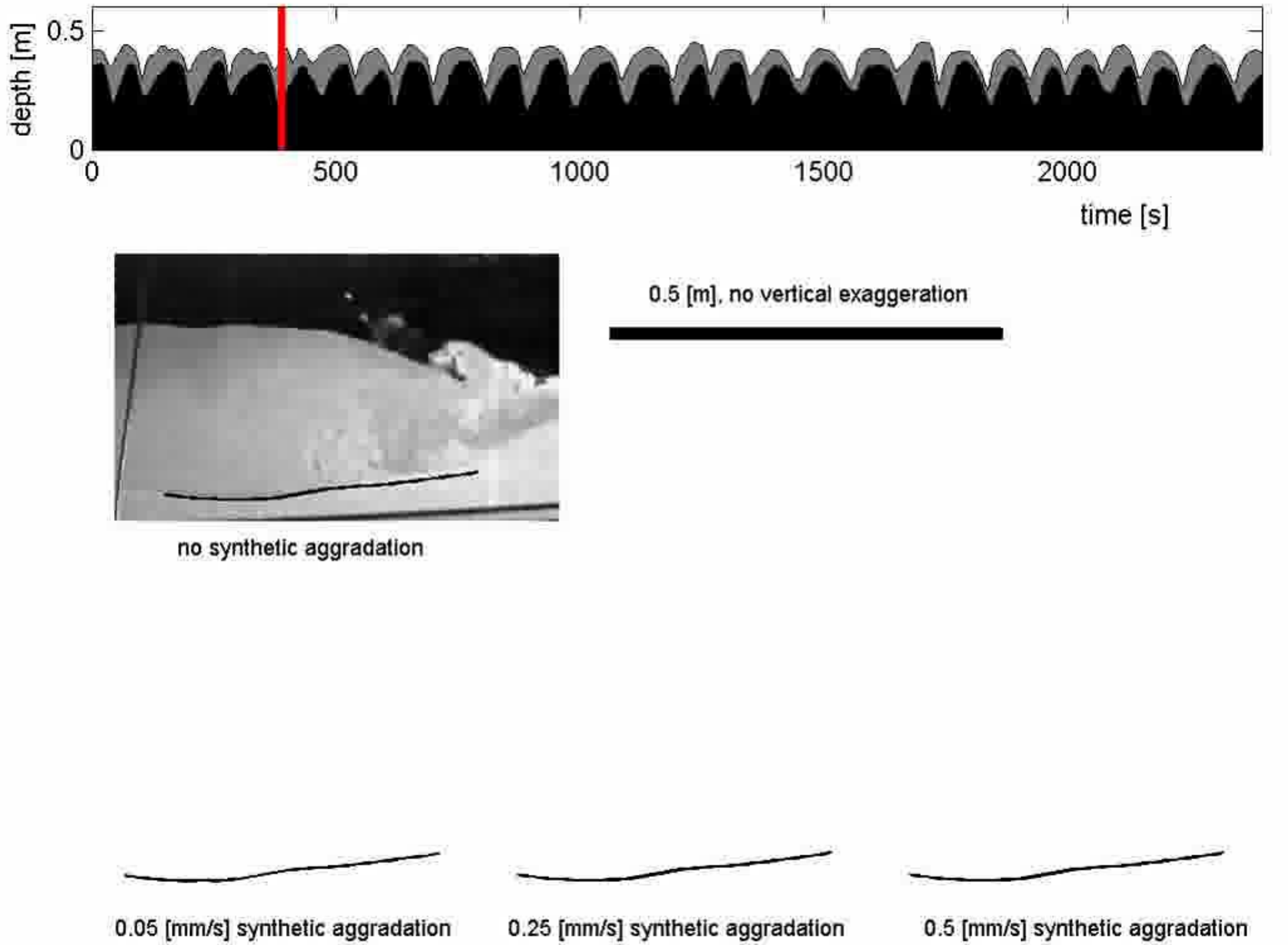
Success! But...



A developing boundary

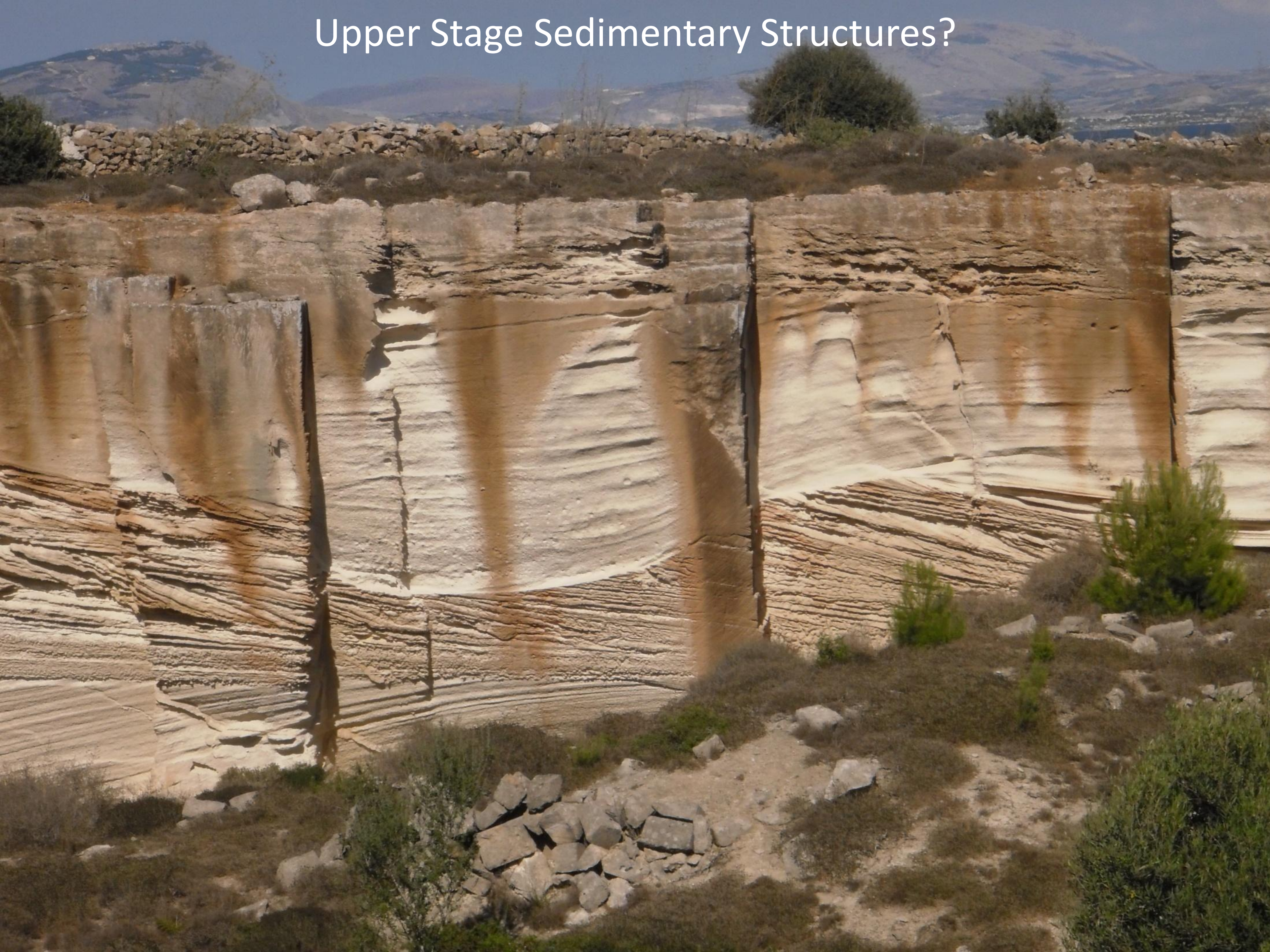
Just count the beans: $\Phi \frac{\partial h}{\partial t} = -\nabla Q_s$

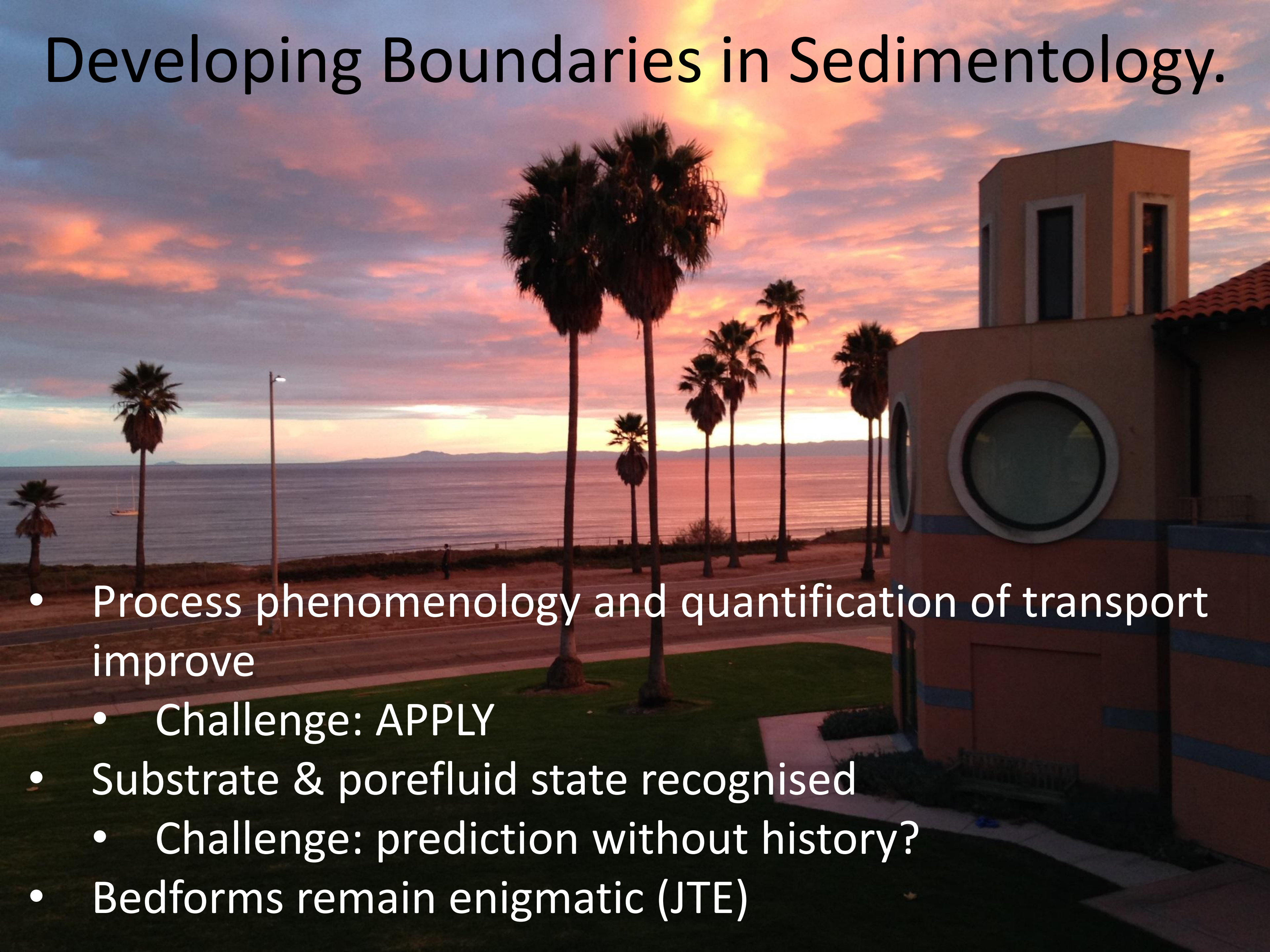
Cyclic steps By Matthieu Cartigny



Cartigny et al., Sedimentology (2013)

Upper Stage Sedimentary Structures?





Developing Boundaries in Sedimentology.

- Process phenomenology and quantification of transport improve
  - Challenge: APPLY
- Substrate & porefluid state recognised
  - Challenge: prediction without history?
- Bedforms remain enigmatic (JTE)

Developing Boundaries in Sedimentology.