Testing the Efficacy and Uncertainty of Outcrop- and Model-Based Studies through Collaboration: *A Field Geologist's Perspective*

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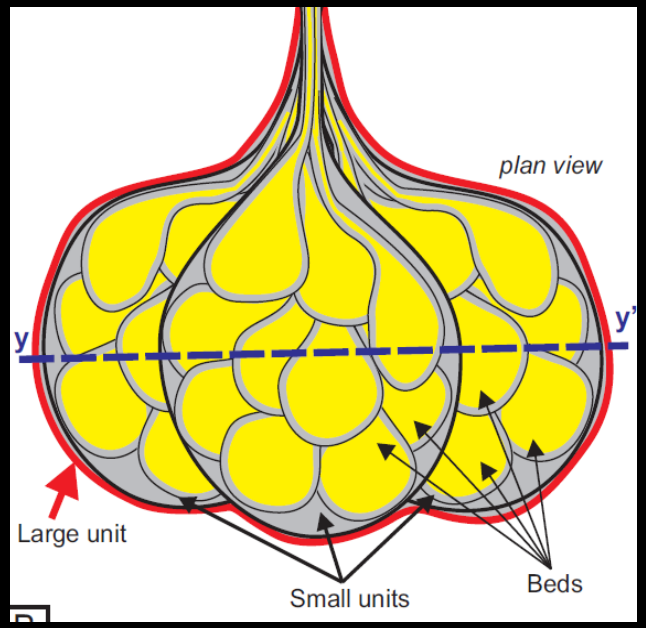
Inspiration: James Syvitski, Irina Overeem, Michael Pyrcz



Goal

- The goals of this presentation are to review some techniques that can be used to evaluate model (and outcrop) uncertainty and test natural variability in sediment transport systems.
- Share my vision for how field geologists and modelers can leverage from each other's perspectives.

Shallow Marine

Fluvial

Deep Water

Context

- There are numerous ways to address stratigraphic problems….

Outcrop Studies

Numerical Simulations

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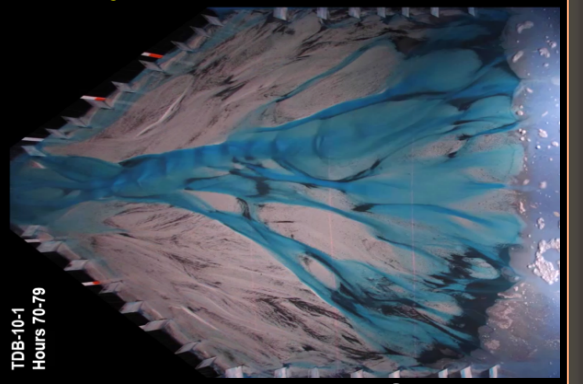
Overeem *et al*. (2005)

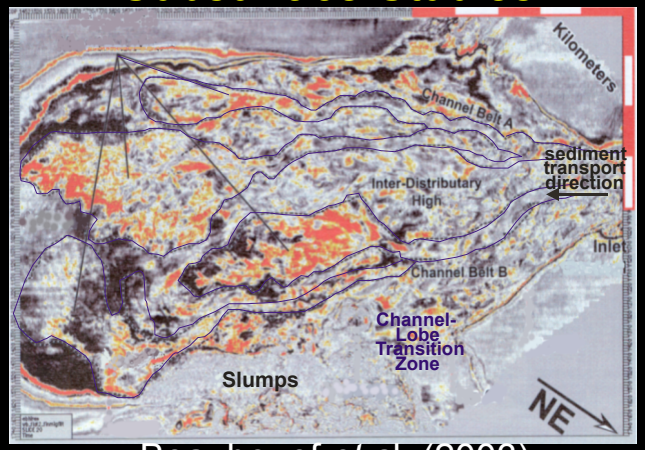
Physical Experiments



Tulane Delta Tank (Straub)

Stratigrapher's World

Subsurface Studies



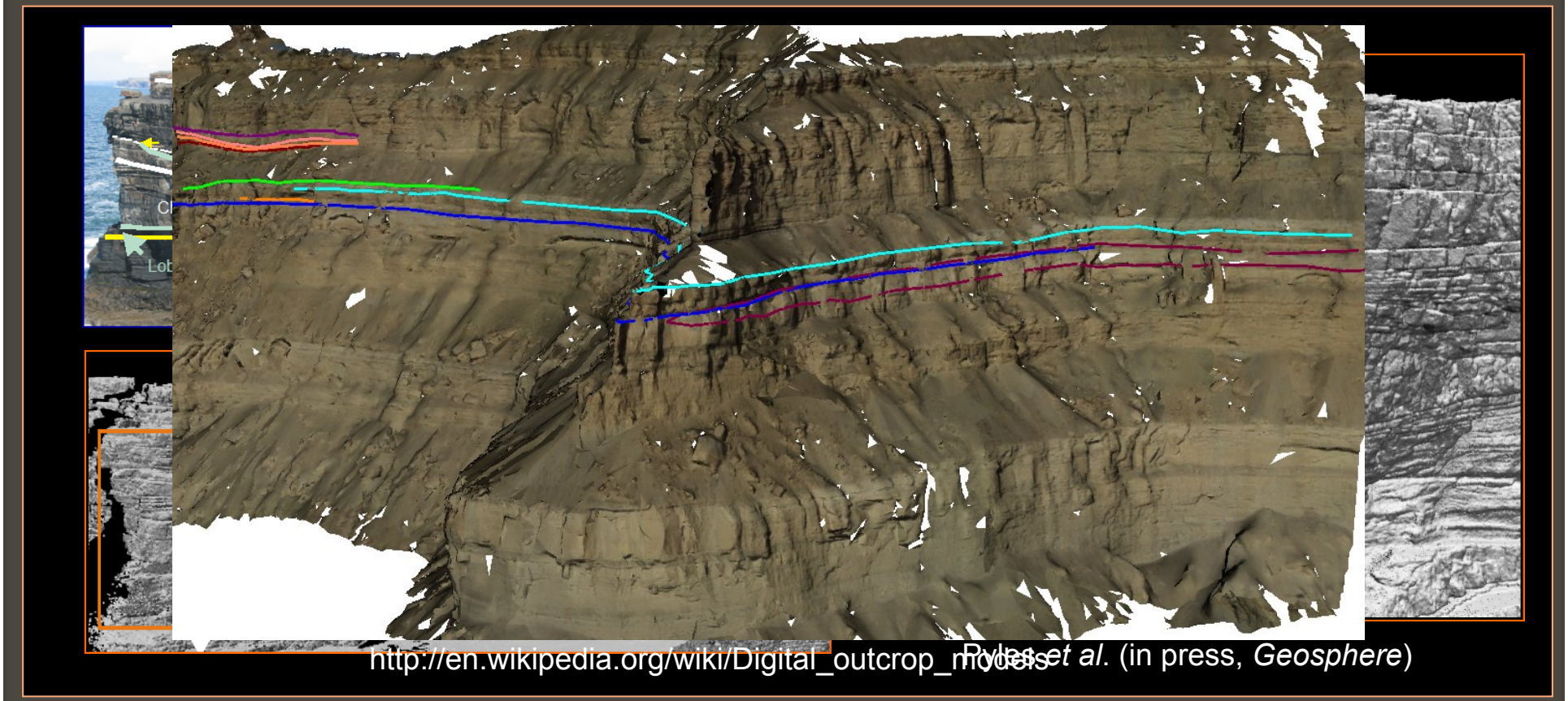
Beaubouef *et al*. (2003)

Land- and Seascape Studies

- *The whole is different that the sum of its parts* (Aristotle, ~360 BC, *Metaphysics*)

Context

- Recent technological advances in data collection techniques have yielded opportunities to better quantify stratigraphic stacking patterns and spatial distributions of deposits from outcrops of ancient sediment transport systems (e.g. lidar studies, photogrammetry, 3D models).

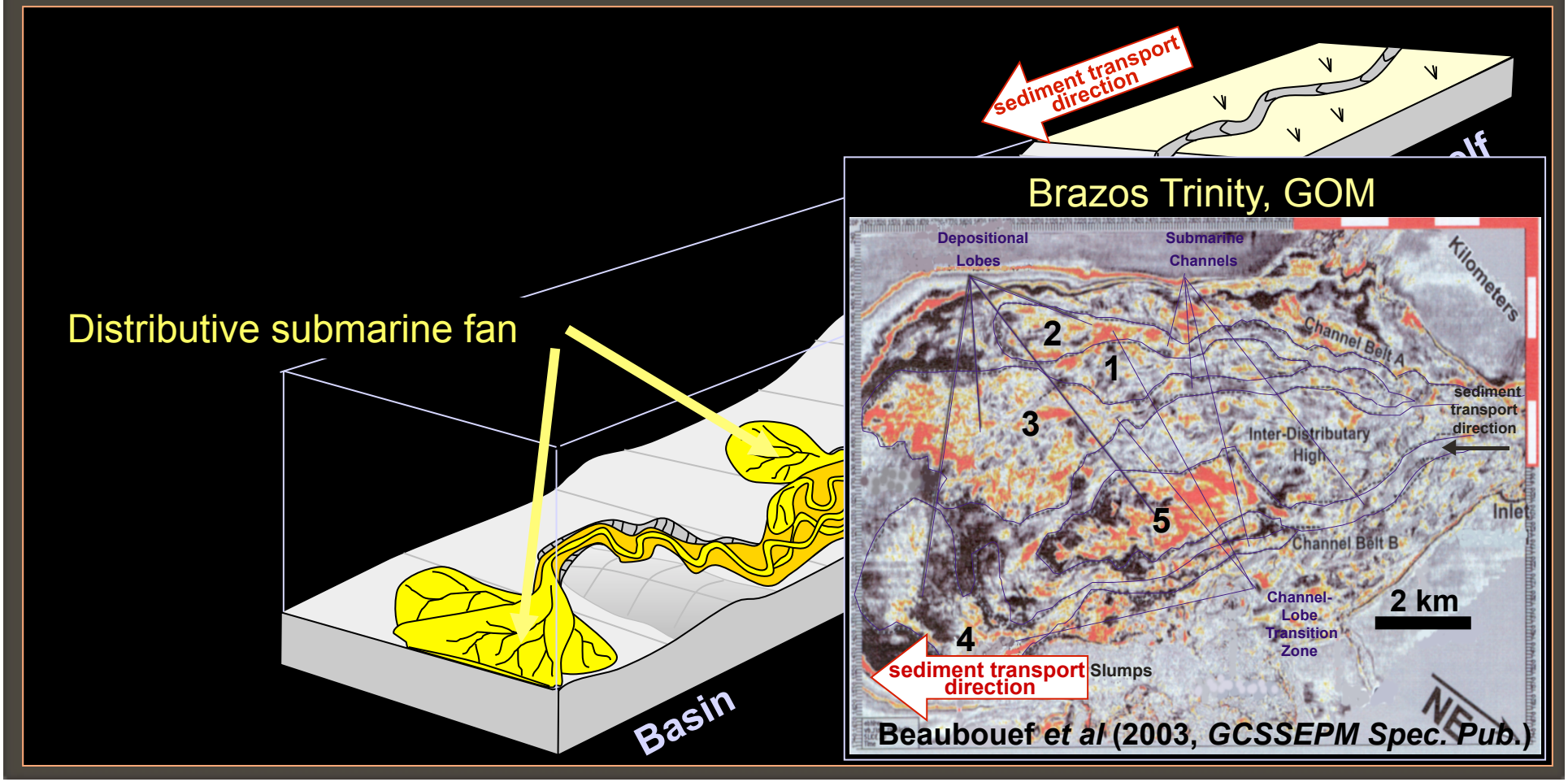


http://en.wikipedia.org/wiki/Digital_outcrop_models

Pyles *et al.* (in press, *Geosphere*)

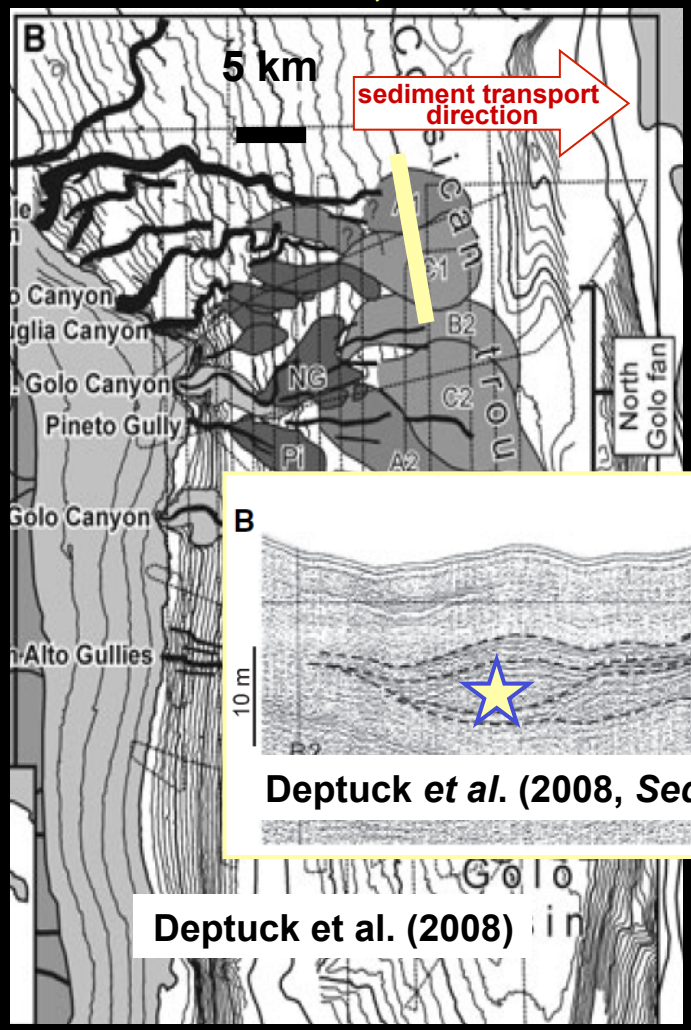
Example: Compensational Stacking

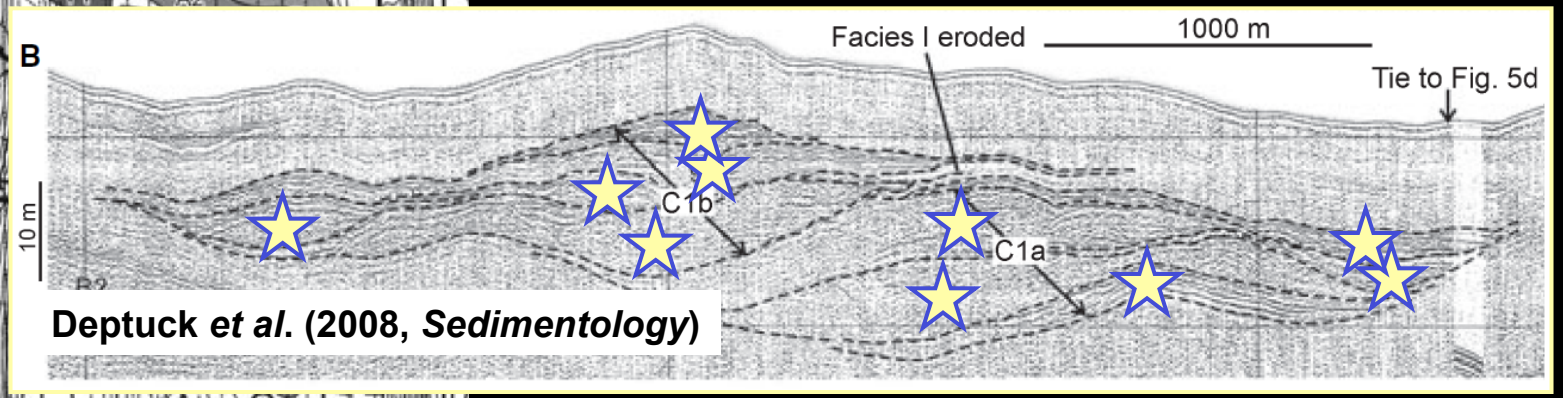
- What is compensational stacking?
  - The tendency for sediment transport systems to fill topographic lows (Straub et al. 2009, JSR). Results in spatial changes in the locus of deposition (via avulsion).



Example: Compensational Stacking

Corsica Fan, Corsica





Deptuck *et al*. (2008, *Sedimentology*)

Deptuck et al. (2008)

Example: Compensational Stacking

- Where else does compensational stacking occur?
  - Deltas
  - Fluvial systems

Part of Mississippi River Delta

GoogleEarth

Tarim basin

Weisman *et al*. (2010, *Geology*)

Example: Compensational Stacking

- Straub et al. (2009, JSR) developed a metric for quantifying compensation.
- The metric requires knowledge of subsidence and sedimentation rates (assumes sedimentation → subsidence over long time scales).

Local sedimentation rate

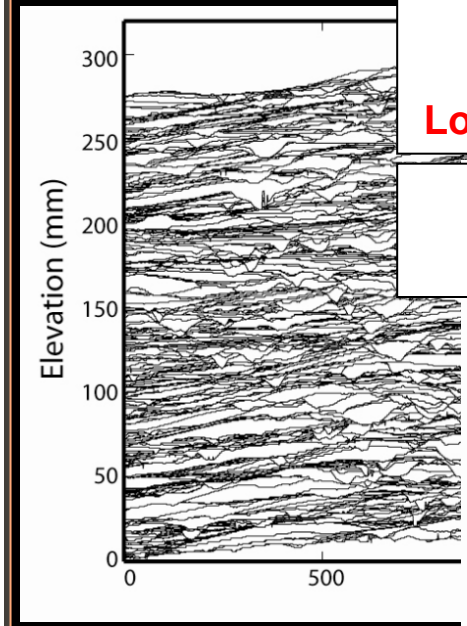
$$\sigma_{ss}(T) = \left(\int_L \left[\frac{r(T;x)}{\hat{r}(x)} - 1 \right]^2 dL \right)^{1/2}$$

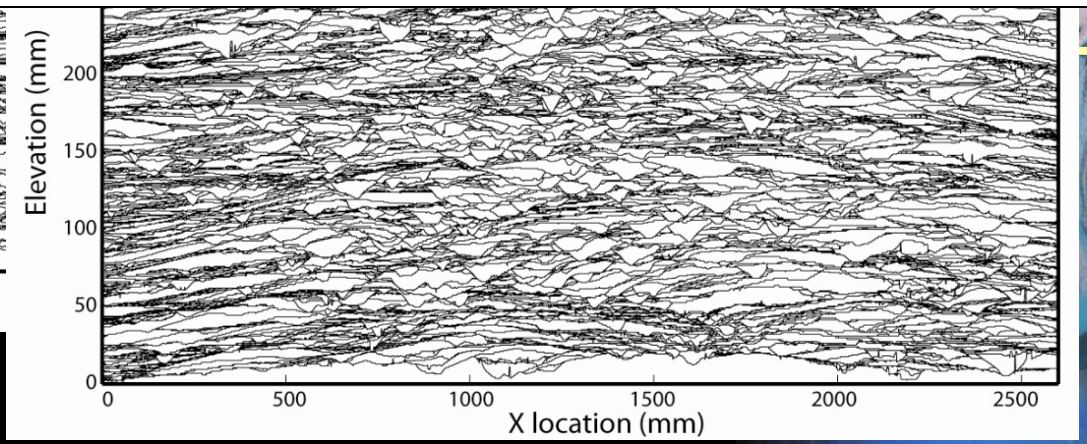
Long-term subsidence rate

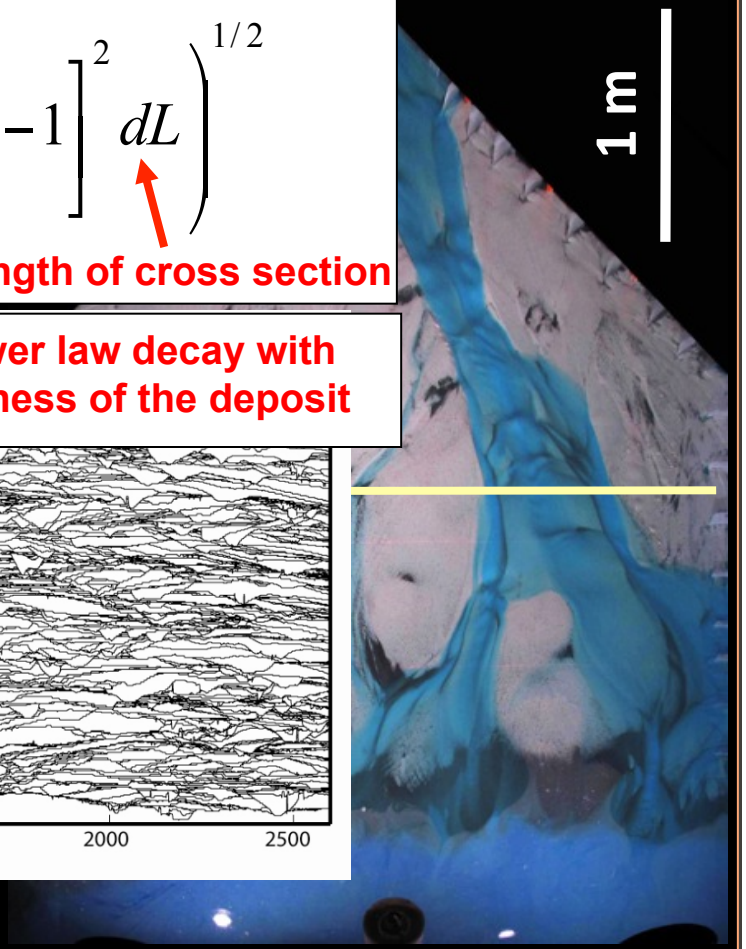
Total length of cross section

$$\sigma_{ss} = a\,T^{-\kappa}$$

Exponent of power law decay with increasing thickness of the deposit



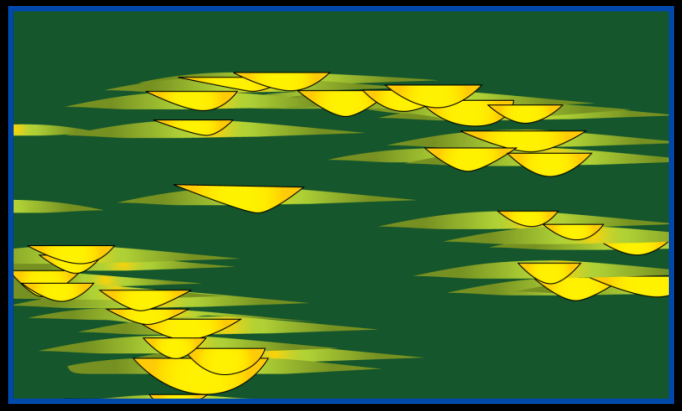


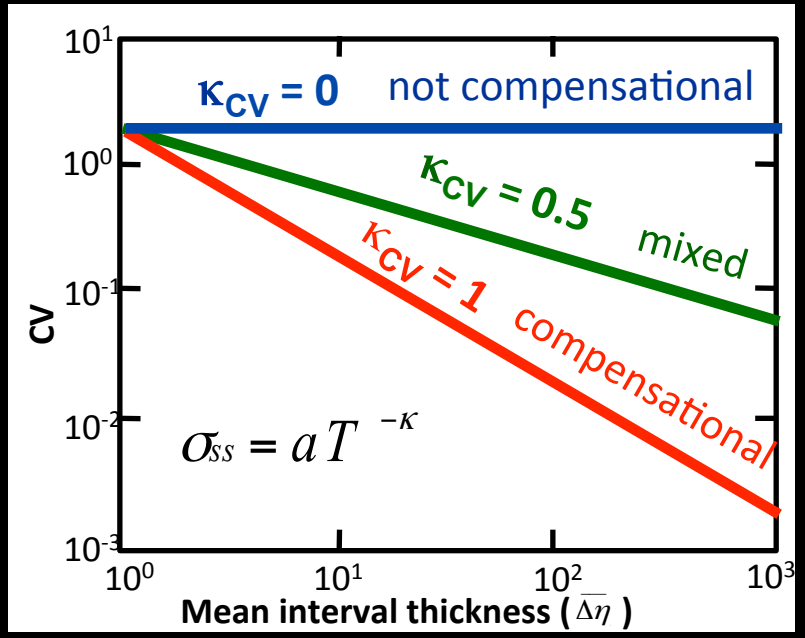


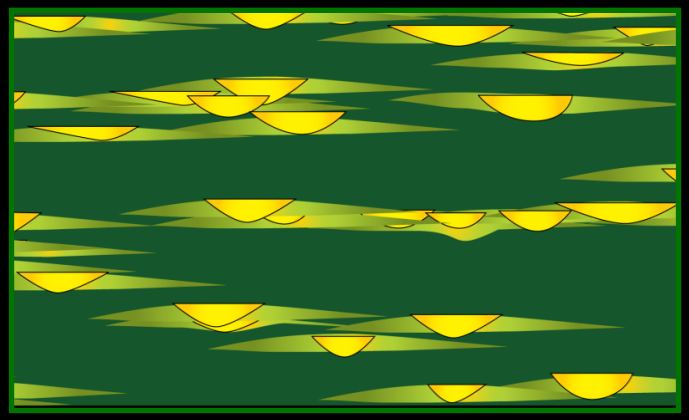
Straub *et al.* (2010, *JSR*)

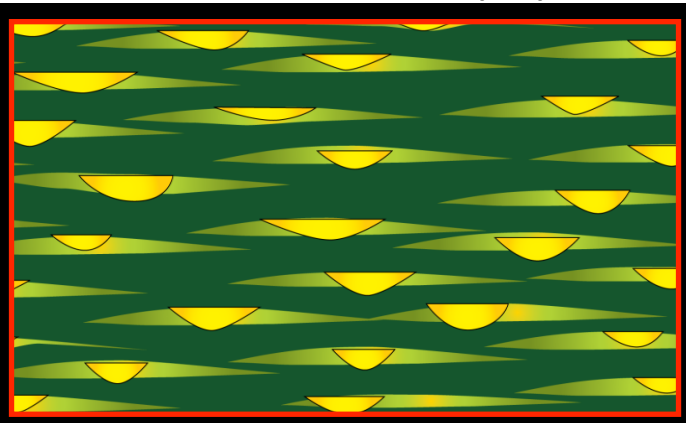
Example: Compensational Stacking

- Diagrammatic application of method.







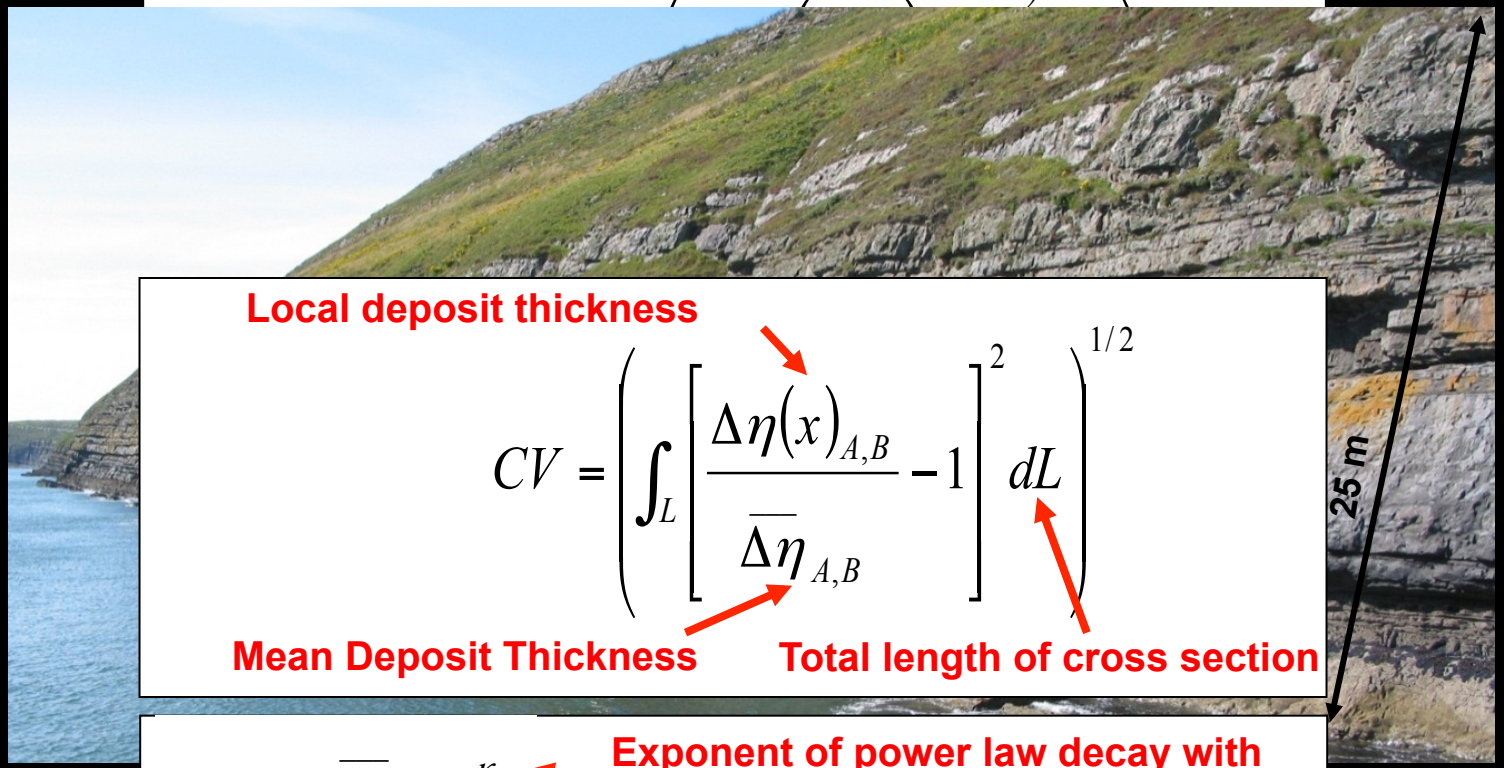


- *..every observation must be made for or against some view if it is to be of any service* (Darwin, 1861, correspondence with the Geological Survey).

Example: Compensational Stacking

- The metric requires knowledge of subsidence and sedimentation rates (assumes sedimentation → subsidence over long time scales).
- We modify the method so it is applicable to field-based data sets (Straub and Pyles, 2012, *JSR*).

Local sedimentation rate



Local deposit thickness

$$CV = \left(\int_L \left[\frac{\Delta\eta(x)_{A,B}}{\overline{\Delta\eta}_{A,B}} - 1 \right]^2 dL \right)^{1/2}$$

Mean Deposit Thickness

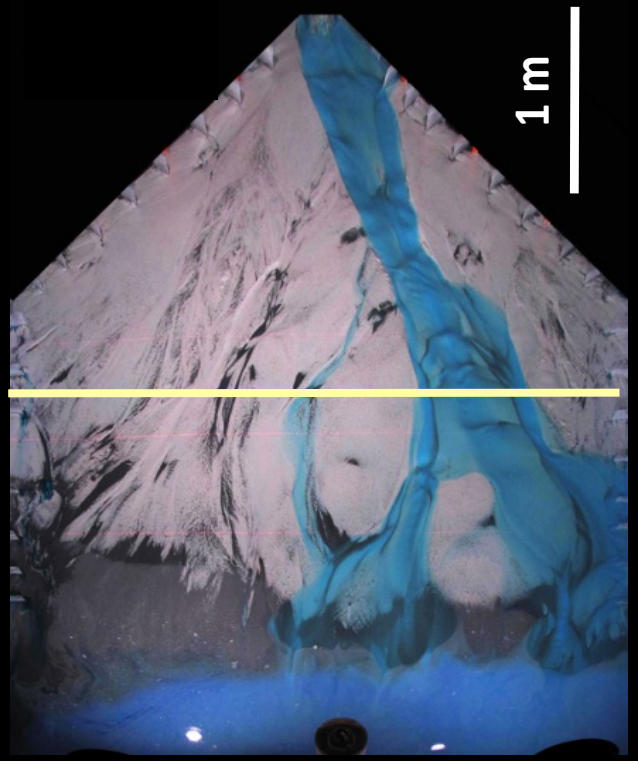
Total length of cross section

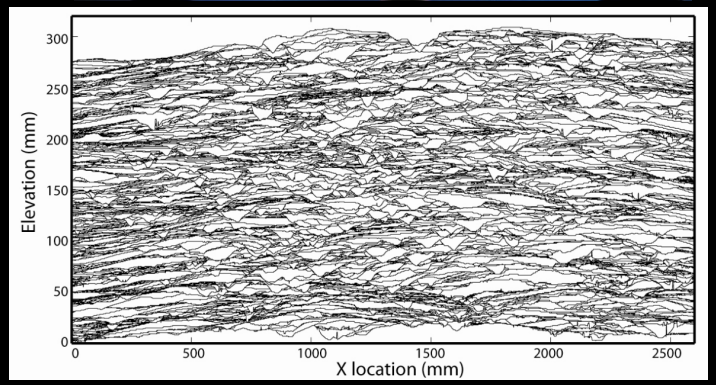
$$CV = a\,\overline{\Delta\eta}_{A,B}^{\;-\kappa_{CV}}$$

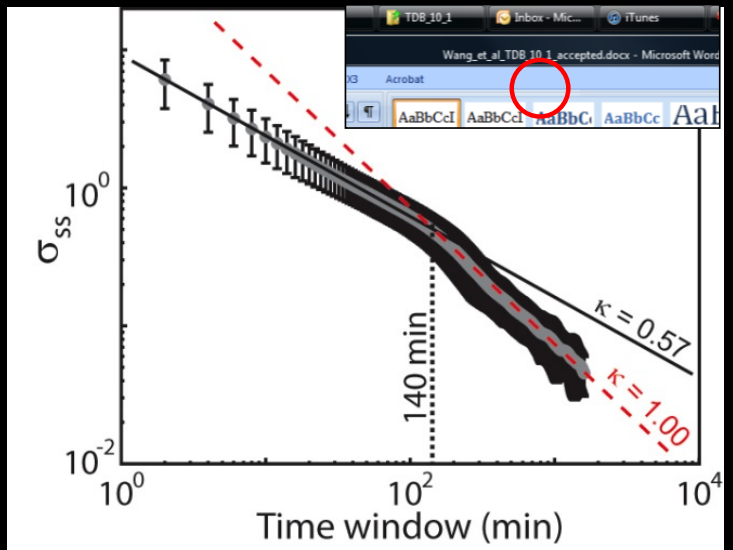
Exponent of power law decay with increasing thickness of the deposit

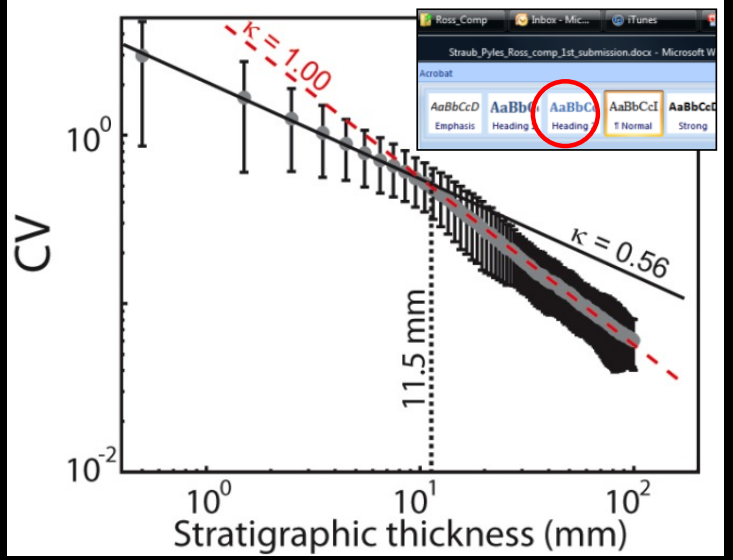
Straub *et al*. (2010, *JSR*); Straub and Pyles (2012)

Example: Compensational Stacking





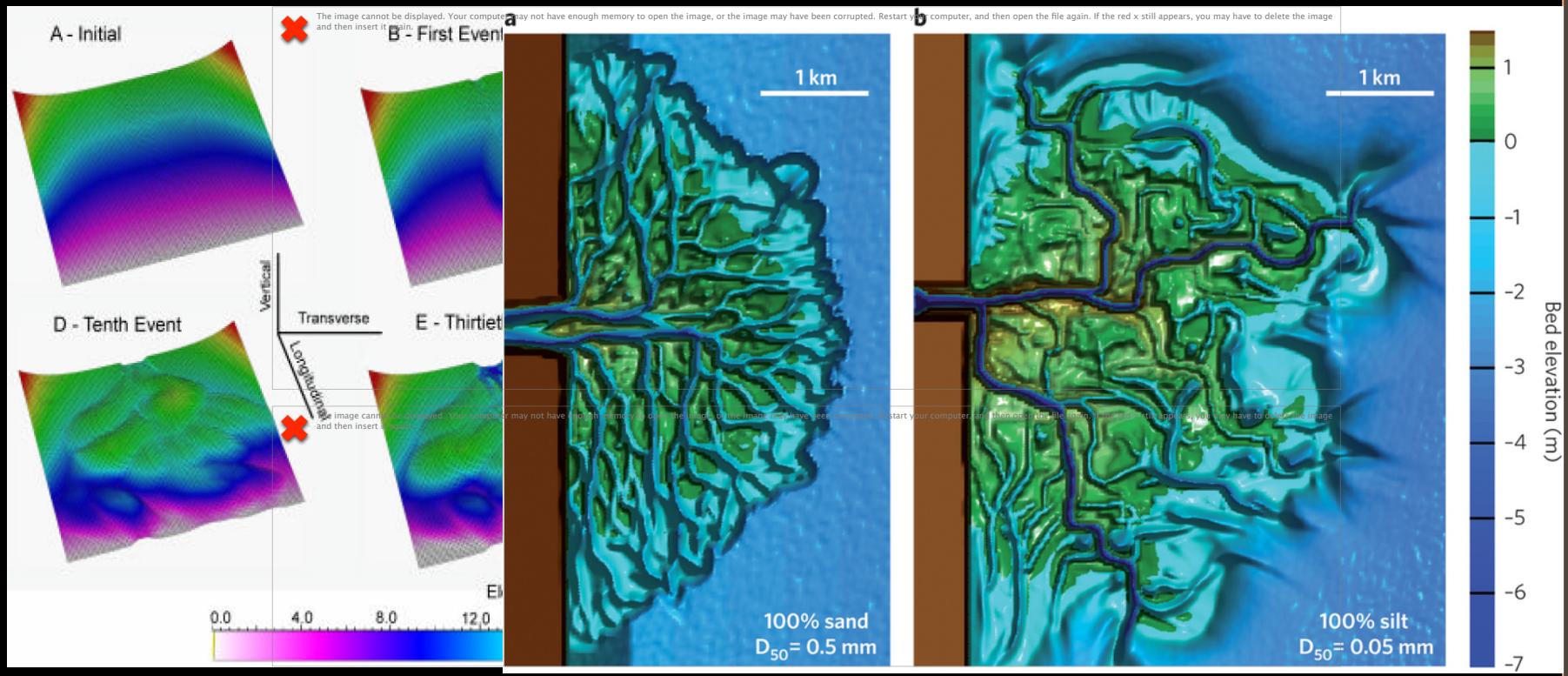




Straub *et al*. (2010, *JSR*); Straub and Pyles (2012)

Example: Compensational Stacking

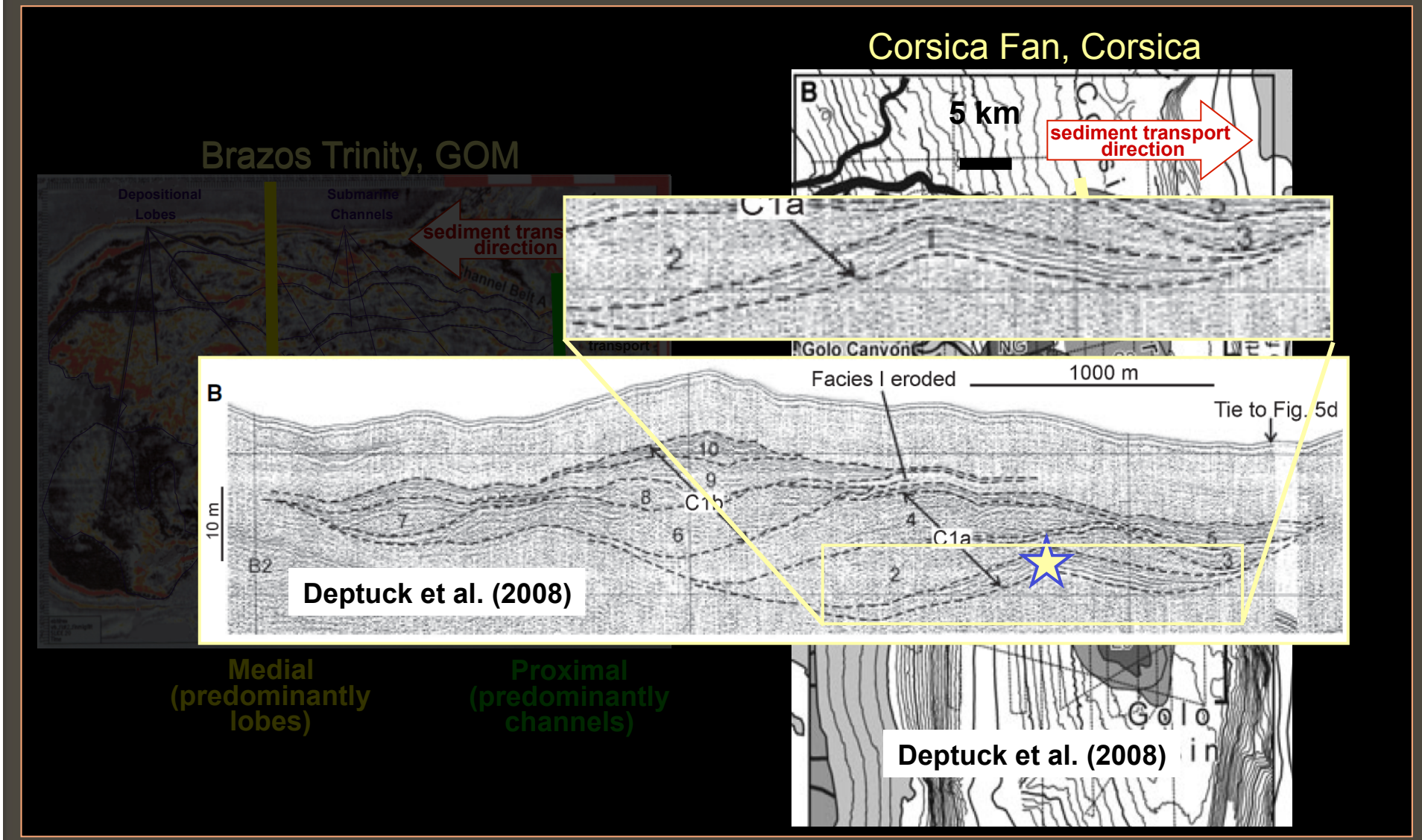
- This approach can be transferred to forward models that track stratal surfaces.
- Allow us compare measurements from natural systems and physical experiments to model outputs:
  1. Test of efficacy and uncertainty?
  2. Provides insight



Pyrcz et al. (2006, *GCSSEPM Spec. Pub.*) Overeem et al. (2005, *SEPM Spec. Pub.*) Edmonds and Slingerland (2010, *Nature Geosciences*)

Example: Compensational Stacking

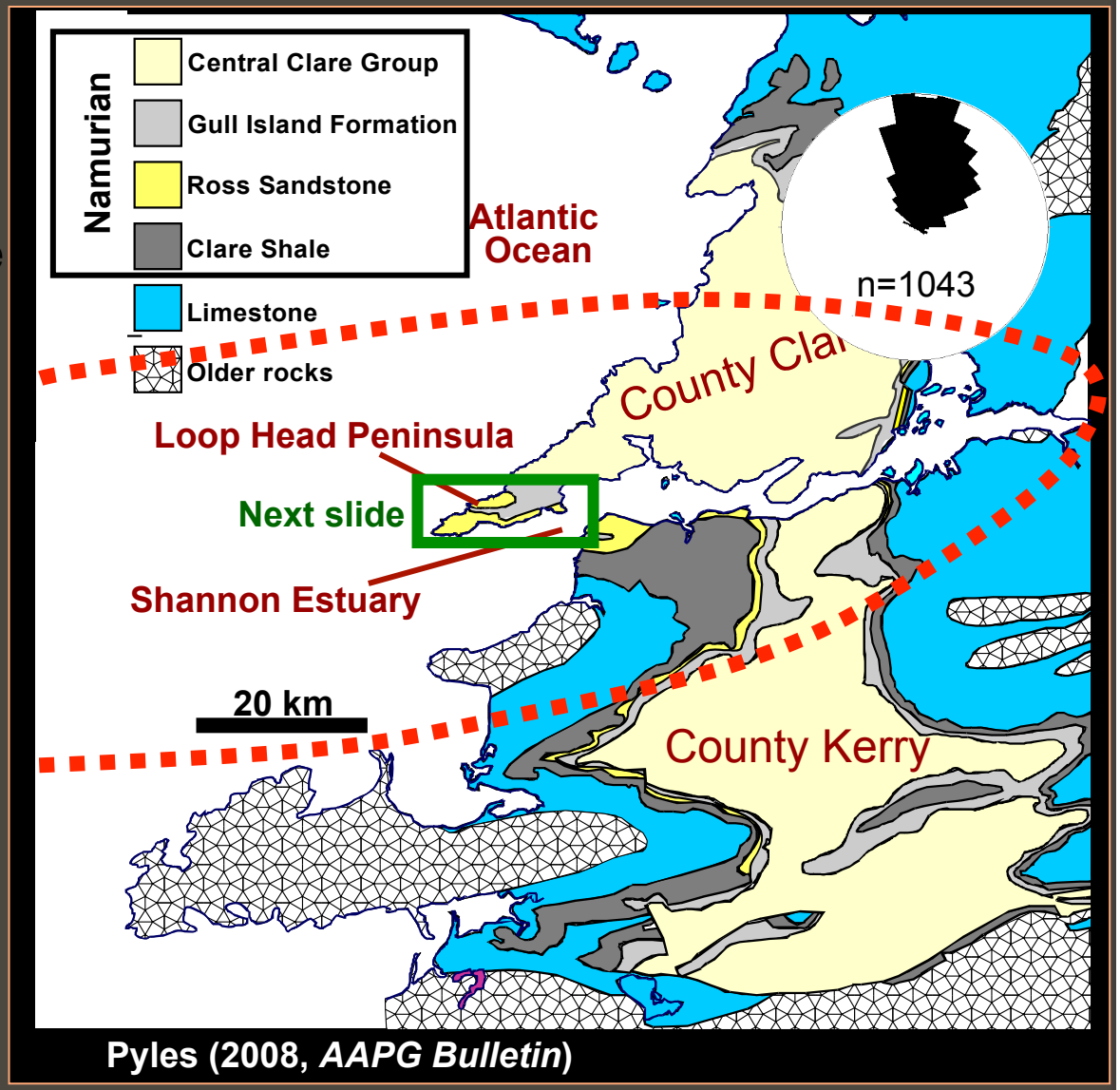
- Does compensation vary spatially in distributive submarine fans?
- Does compensation vary by scale?



Example: Compensational Stacking

- The Carboniferous Ross Sandstone crops out in western Ireland.
- The formation was deposited as a ponded, distributive submarine fan in a structurally confined basin (Pyles, 2008).

NASA



Pyles (2008, *AAPG Bulletin*)

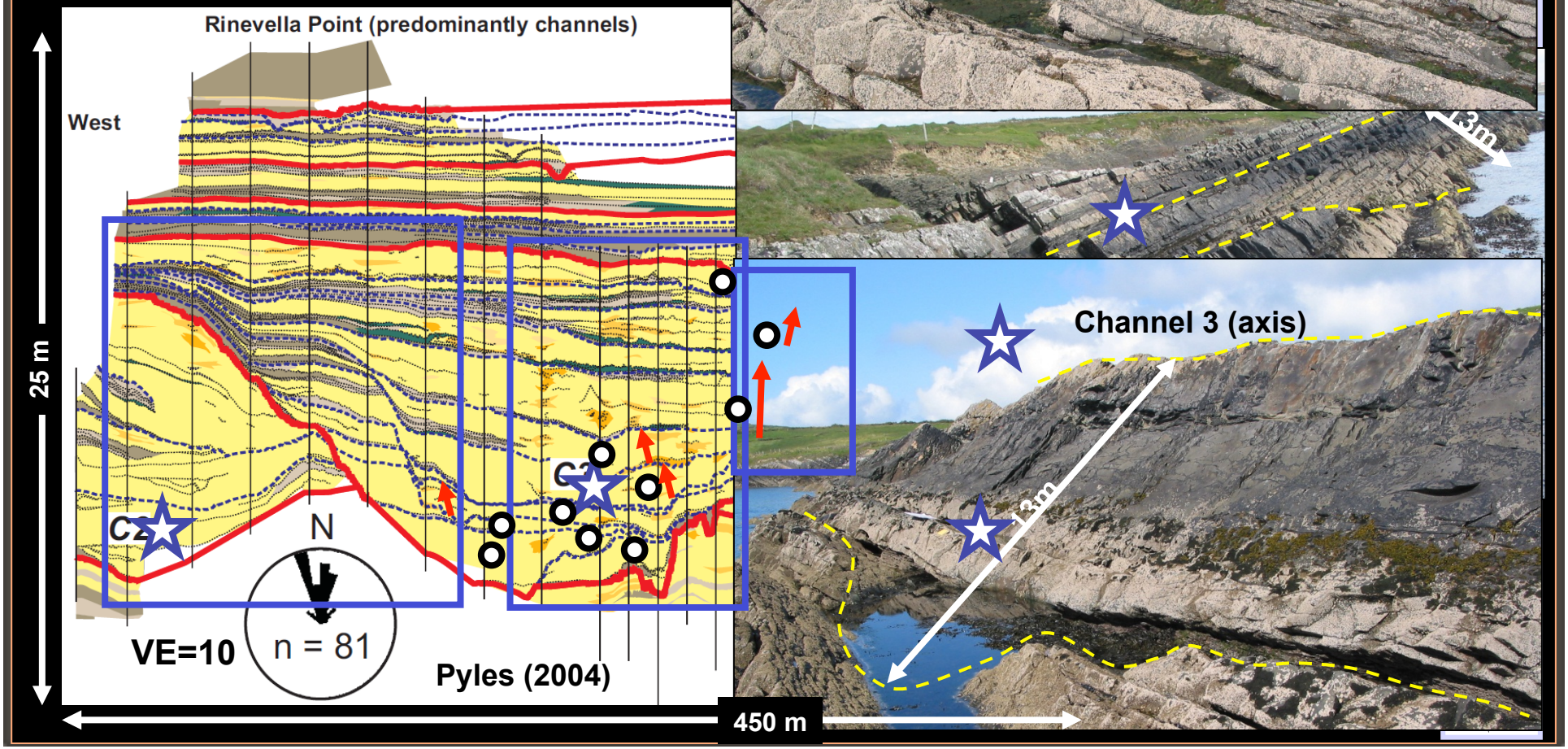
Example: Compensational Stacking

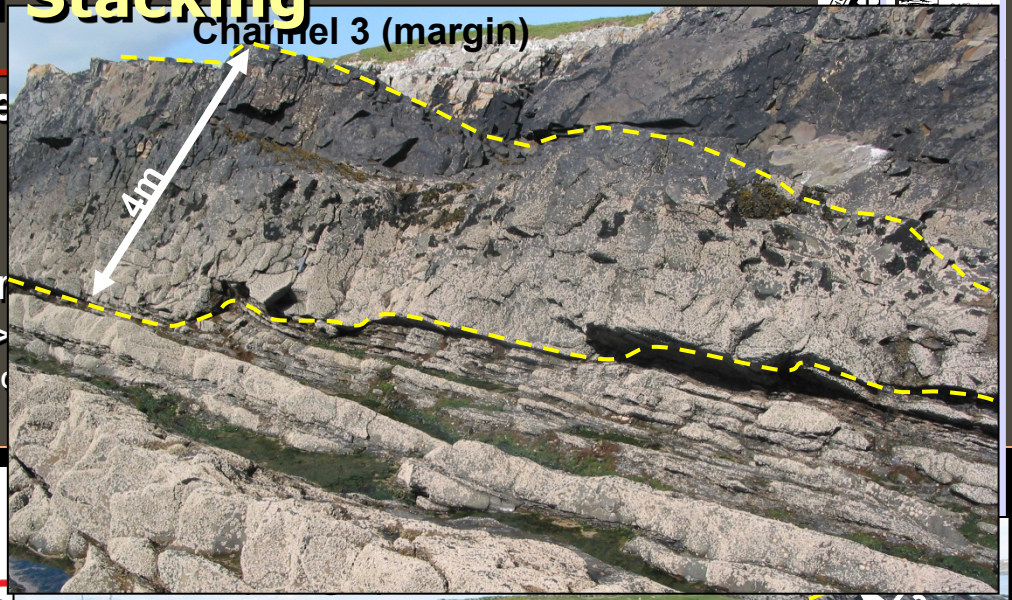
- Outcrops of the Ross Sandstone are exceptionally well exposed and ideal for addressing the questions.
- Two outcrops are analyzed to determine how compensation varies by: (1) position in a distributive submarine fan, and (2) size of stratal unit.

Example: Compensational Stacking

Rinevella Point (predominantly channe

- Statistics:
  - •450 m wide, 35 m thick
  - •Oriented parallel to depositional str
  - •23 detailed strat columns totaling >
  - •Contains 1 lobe and 5 channels (5

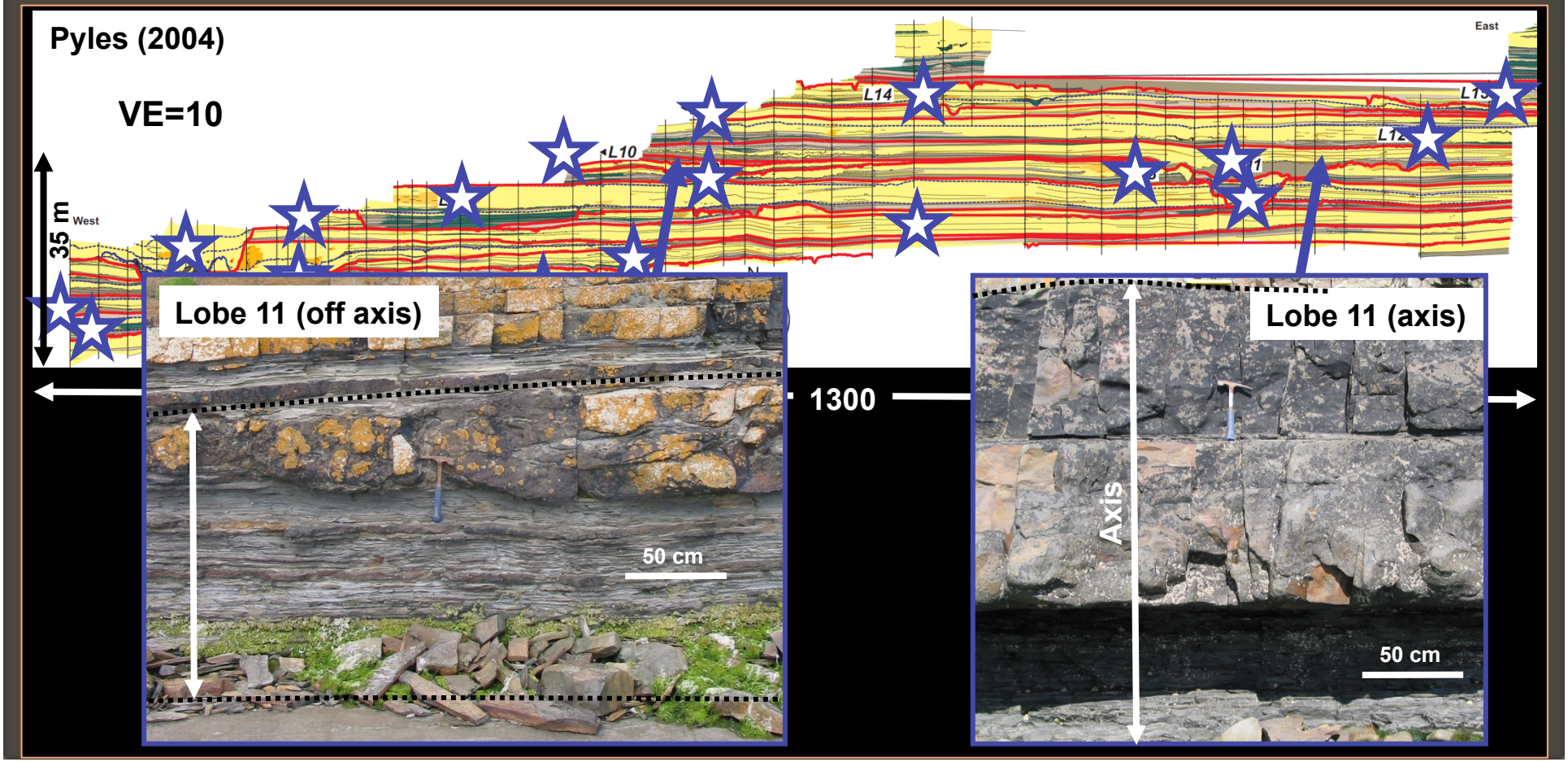




Example: Compensational Stacking

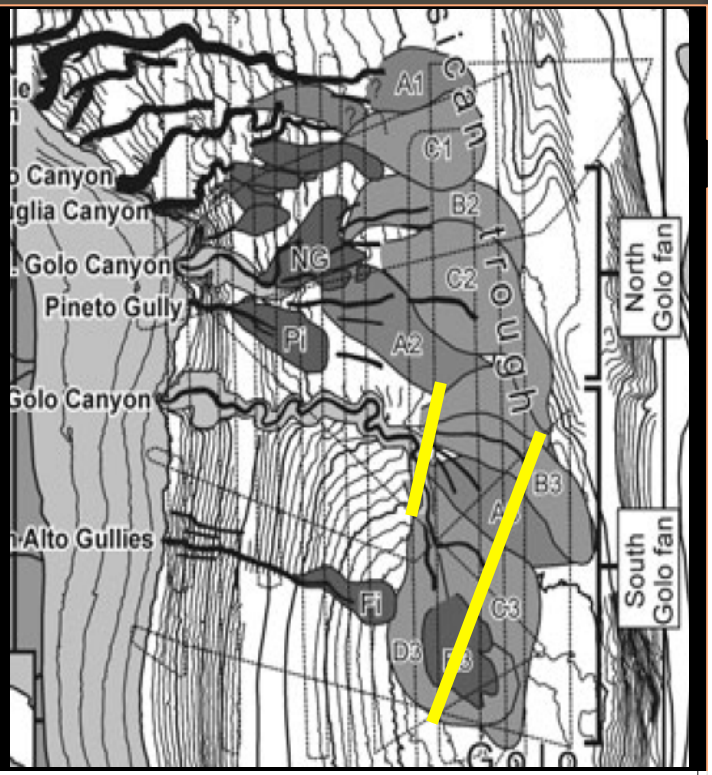
Kilbaha Bay (predominantly lobes):

- Statistics:
  - 1300 m wide, 30 m thick
  - 54 detailed strat columns totaling >1000m
  - Oriented parallel to depositional strike
  - Contains 15 lobes and 3 channels (95%, 5% by area respectively)

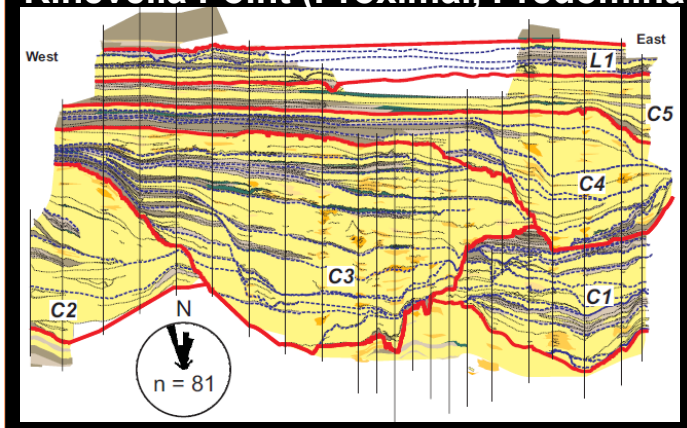


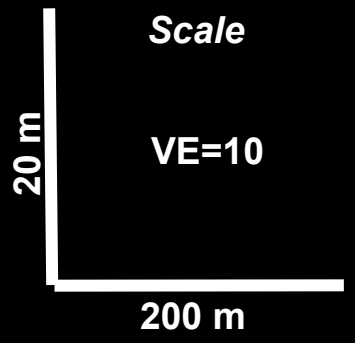
Example: Compensational Stacking

- We are comparing two architecturally distinct parts of a submarine fan:
  - Proximal, predominantly channels (Rinevella Point)
  - Medial, predominantly lobes (Kilbaha Bay)

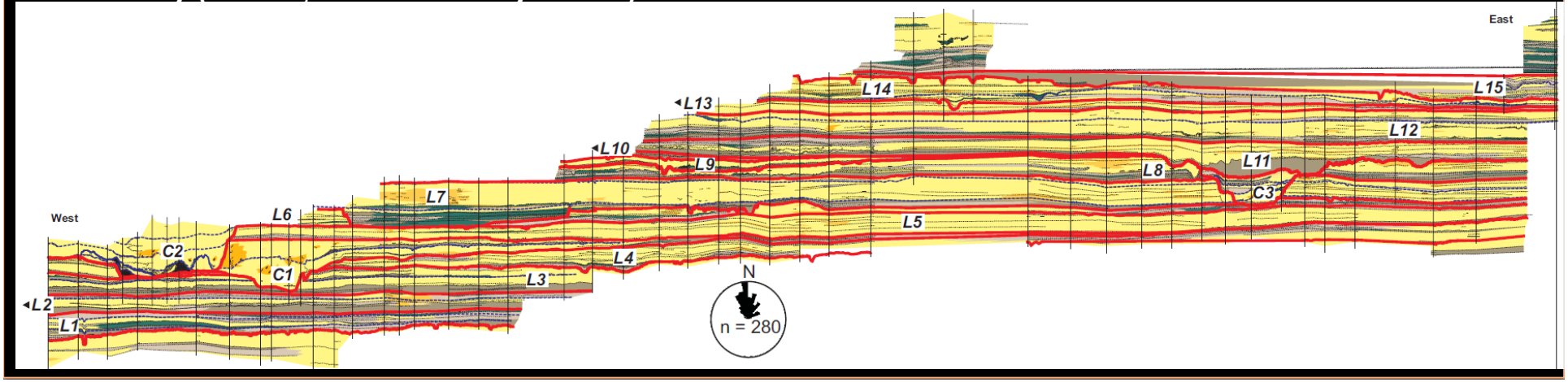


Rinevella Point (Proximal, Predominantly Channels)



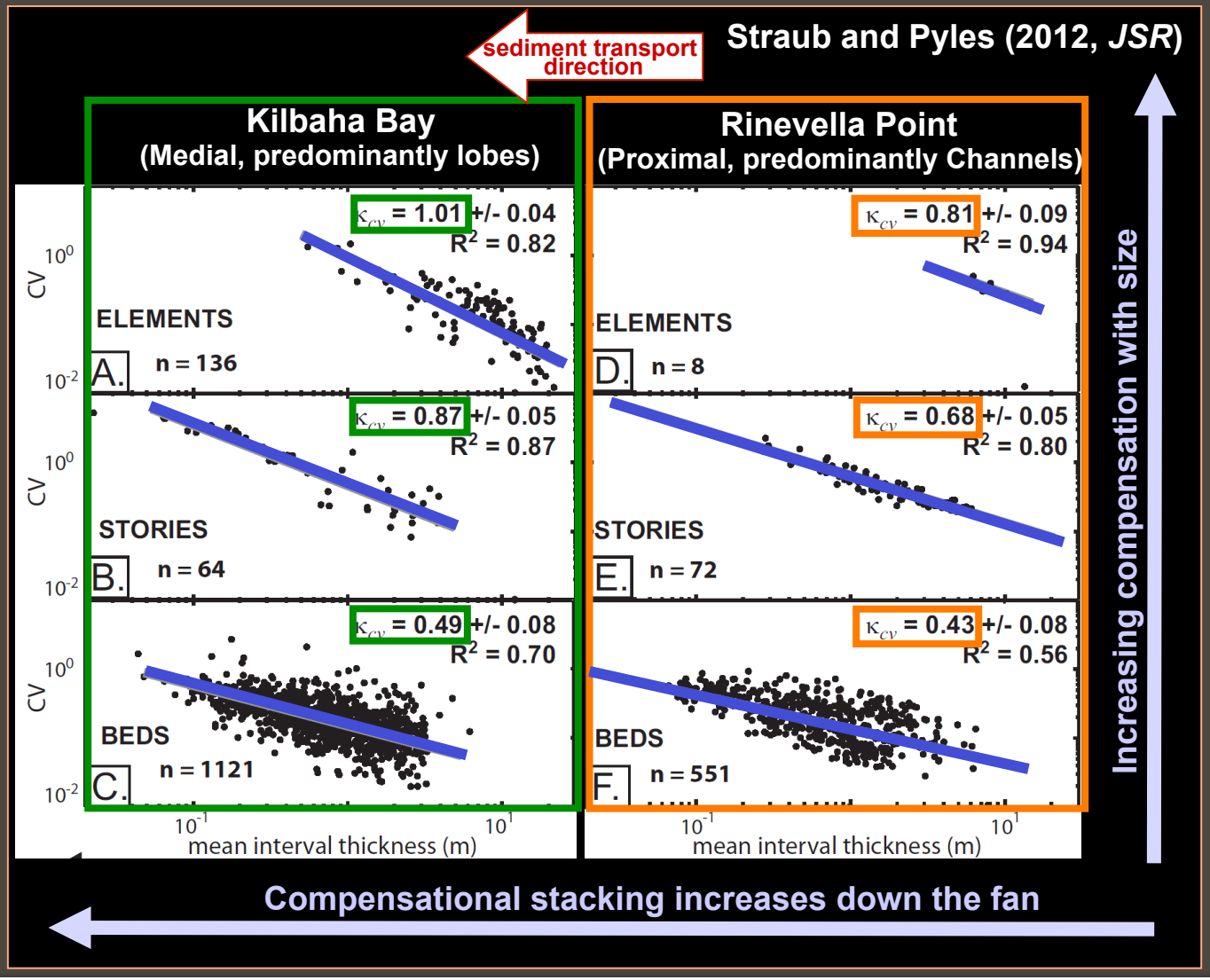


Kilbaha Bay (Medial, Predominantly Lobes)



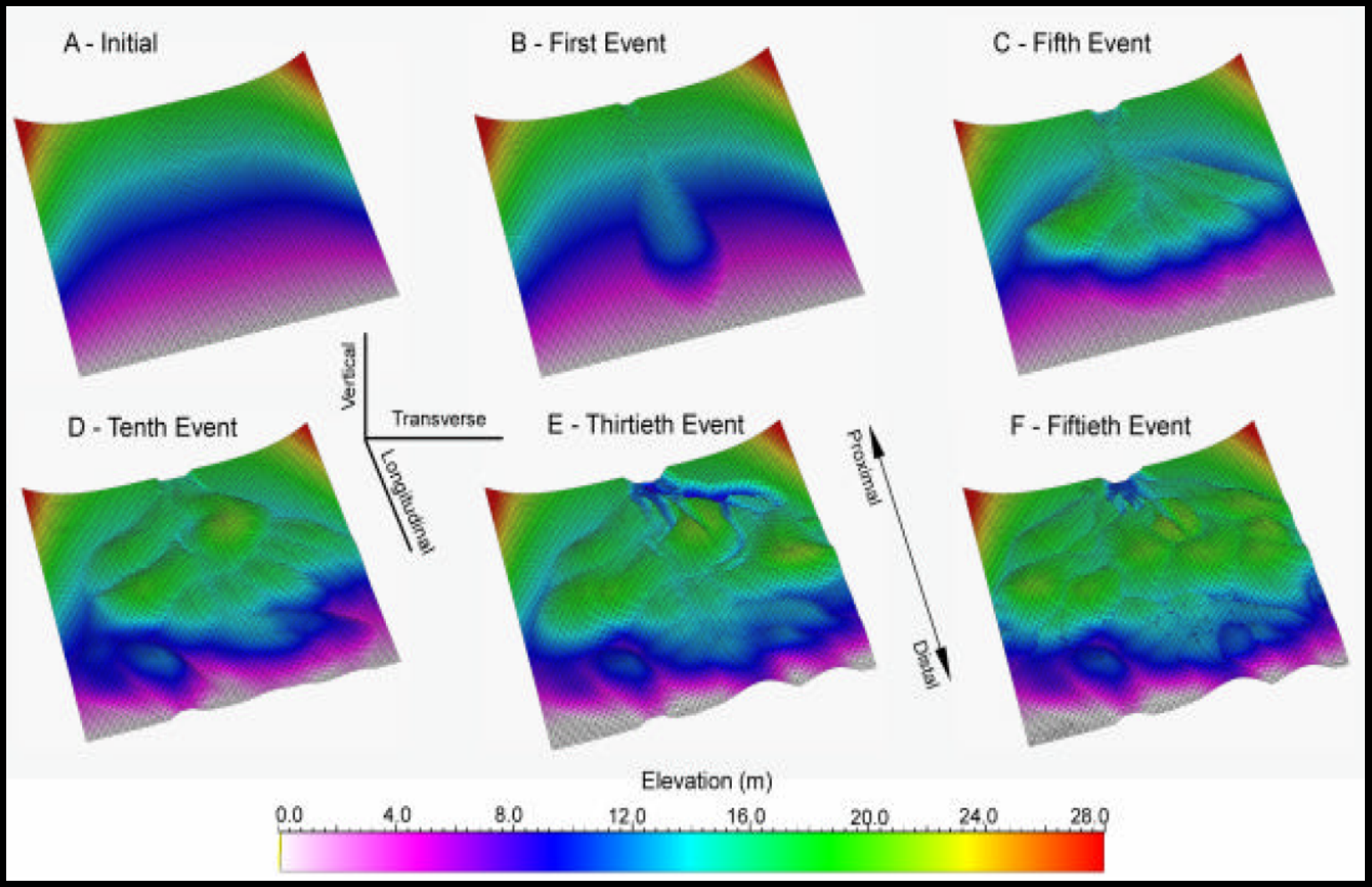
Example: Compensational Stacking

- At both field localities, compensation increases with hierarchical scale.
- Lobes are more compensational than channels (compensation increases along a proximal-to-distal transect).



Example: Compensational Stacking

- We can use measurements from outcrops of natural systems to evaluate the efficacy of forward models—not yet been done!

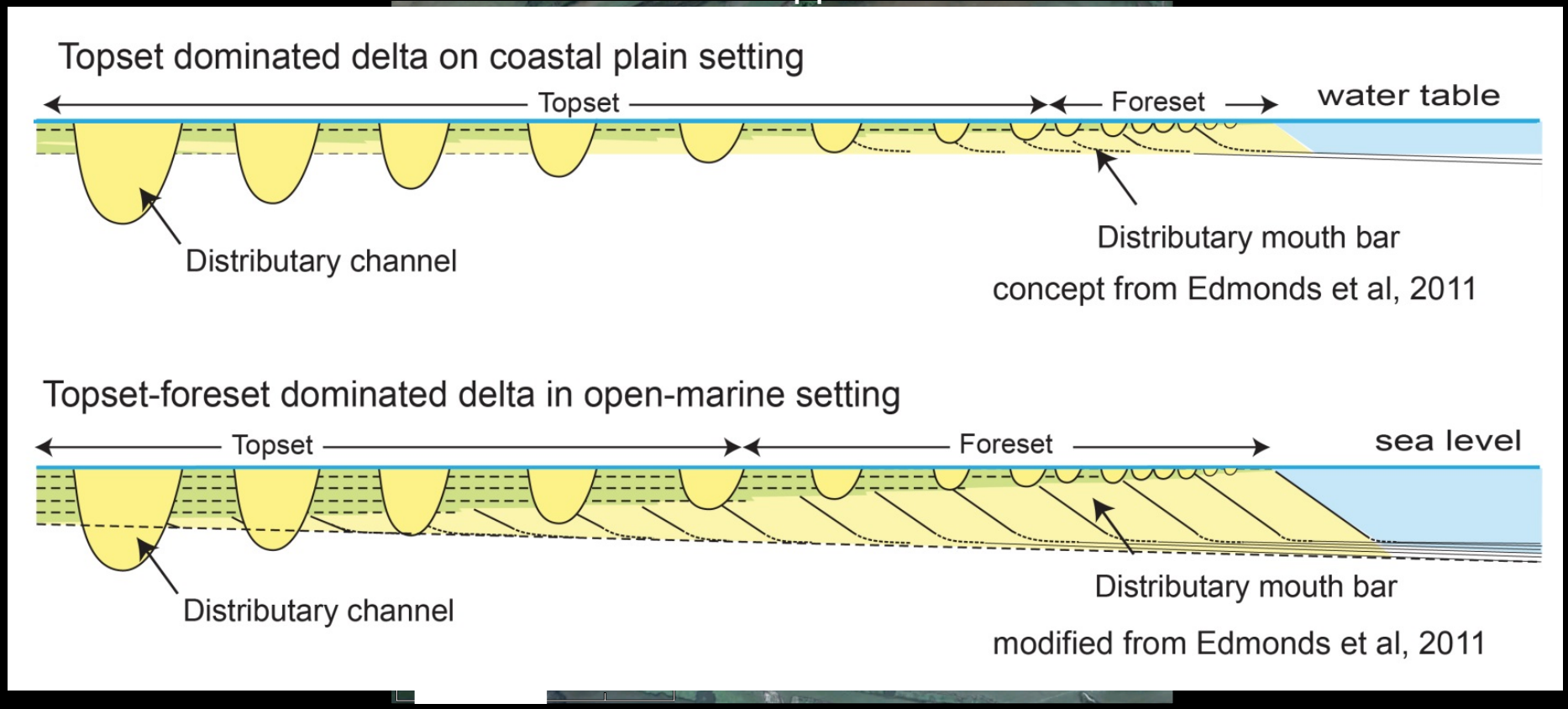


Pyrcz et al. (2006, *GCSSEPM Spec. Pub.*)

Example: Water Depth and Gradient on Deltas

- Edmonds et al. (2001, *Geology*) proposed a geometrical model that evaluates how water depth and gradient influence stratigraphic architecture of deltas.

Part of Mississippi River Delta

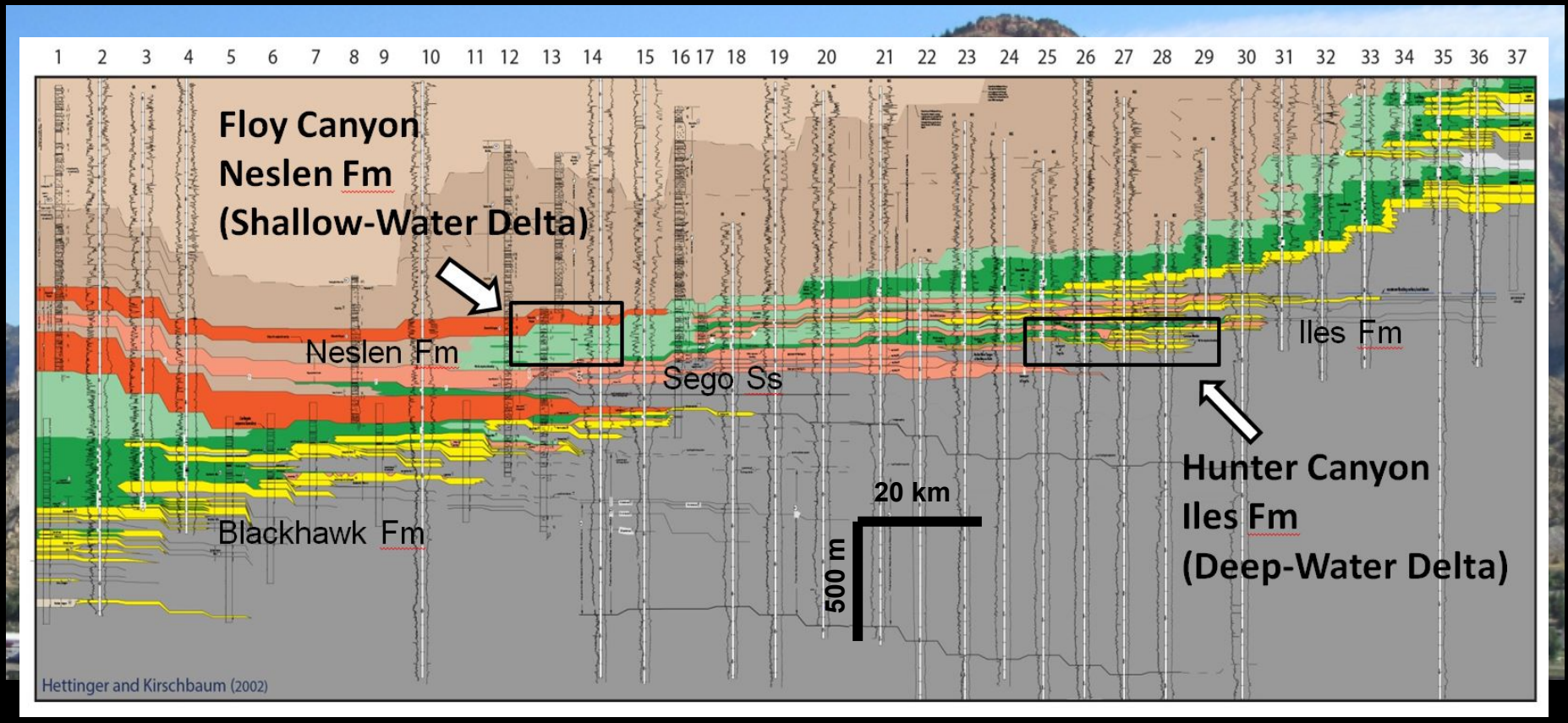


GoogleEarth

- *..every observation must be made for or against some view if it is to be of any service* (Darwin, 1861, correspondence with the Geological Survey).

Example: Water Depth and Gradient on Deltas

- Field test: Cretaceous Strata in the Book Cliffs Utah



Hettinger and Kirschbaum (2002, USGS Open File Report)

Example: Water Depth and Gradient on Deltas

- Field test: Cretaceous Strata in the Book Cliffs Utah

Shallow water (Neslen Fm., Floy Canyon, Utah)

Deep water (Iles Fm., Hunter Canyon, Colorado)

Example: Water Depth and Gradient on Deltas

- This approach can be transferred to a number of forward models.
- Allow us compare measurements from natural systems and physical experiments to model outputs:
  1. Test of efficacy and uncertainty?
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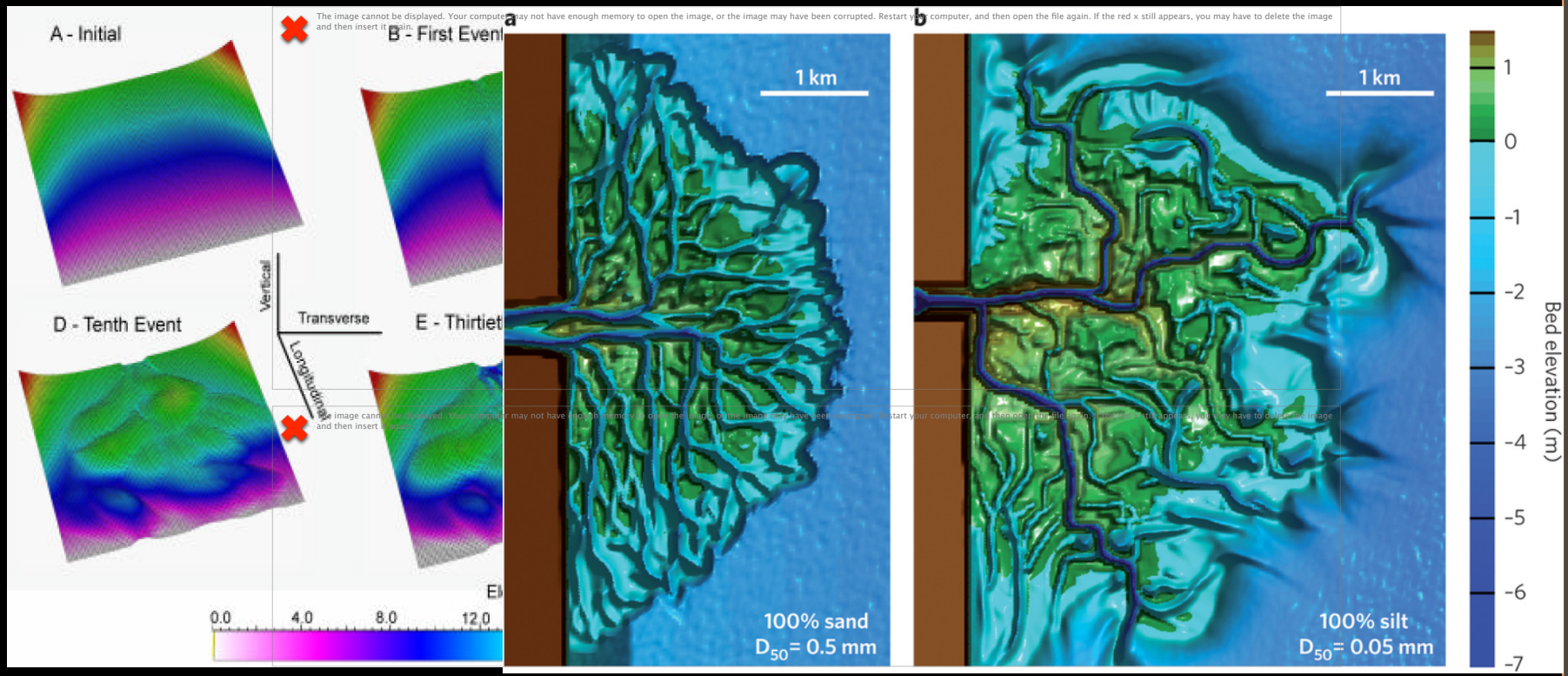
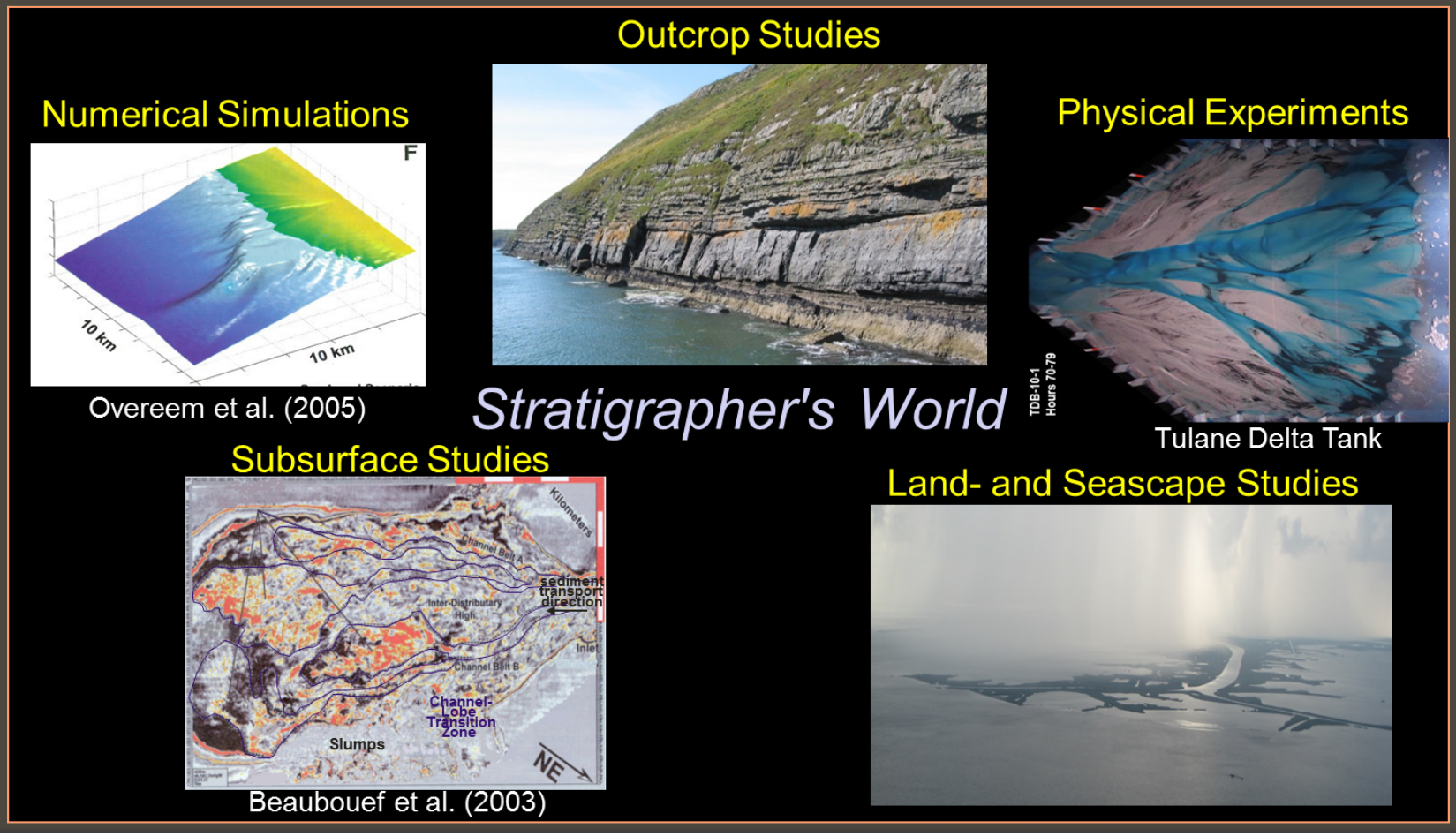


Pyrcz et al. (2006, *GOSEPM Spec. Pub.*) Cossey et al. (2005, *SEPM Spec. Pub.*) Edmonds and Slingerland (2010, *Nature Geosciences*

Conclusions

- Common workflows can provide a means to relate results of numerical modeling to natural systems: efficacy, natural variability.
- Coupled perspectives (outcrops, numerical models, ….) provide insight that can be used to develop new questions about sedimentary systems and their deposits.
- Let's start (keep) talking!



Thank you