Primary variability in clay-rich LSSRs analogues

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Basin studies

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What are the key attributes we can get from analogues

- ***Fundamental: scales of variability – and what does this result from.***

This allows for better predictive models for:

- Variability in rock characteristics (poro-perm, geomechanics….
- 2D and 3D petrophysical data

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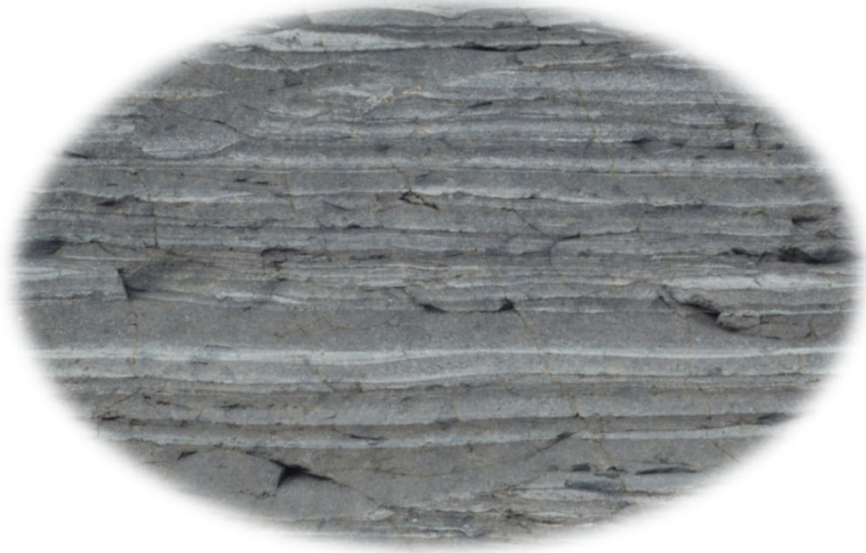
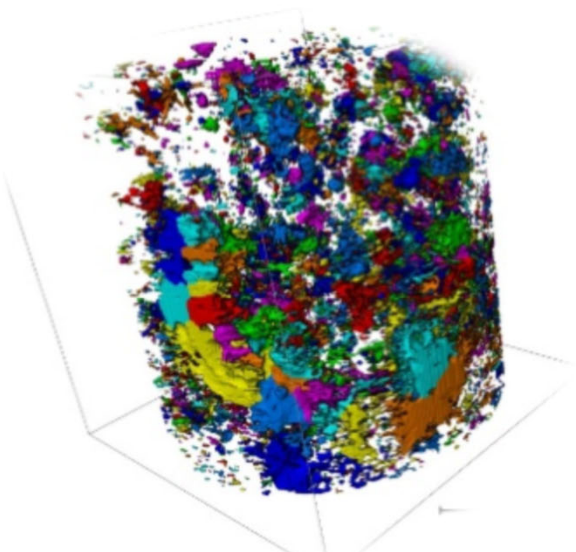
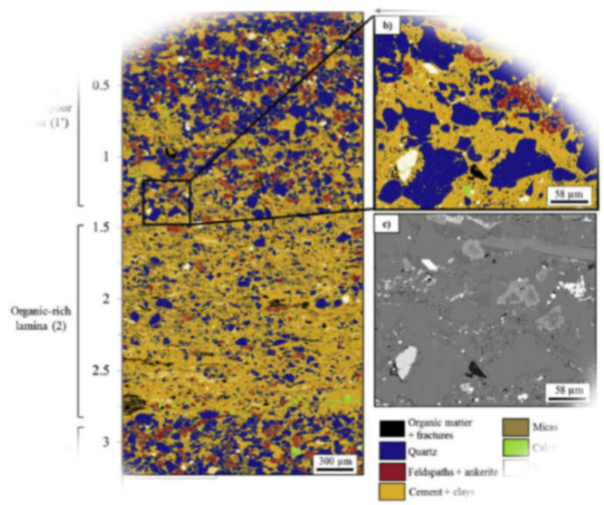
Outcrop







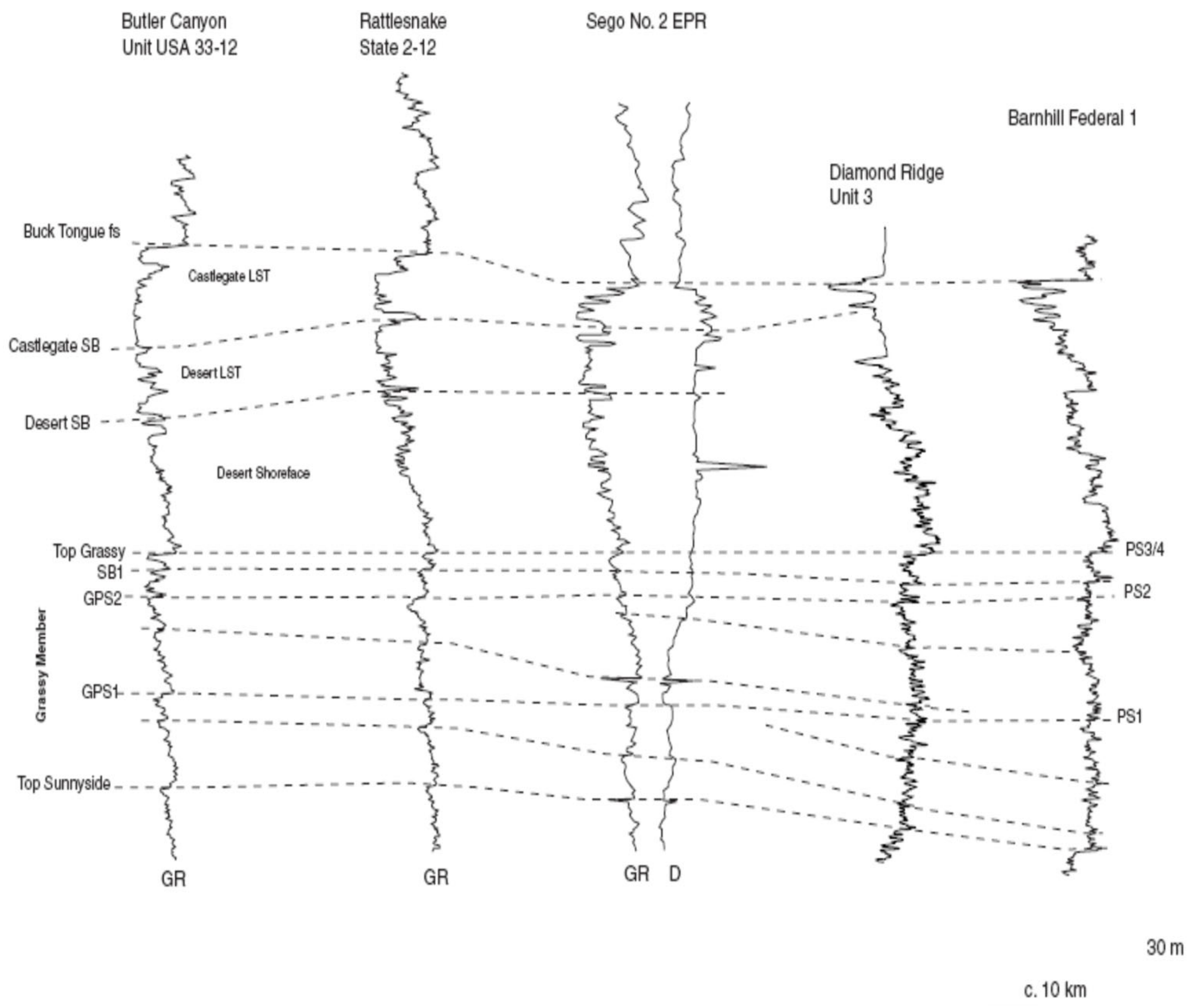
Core

3D imaging

2D characterisation


E.g. Mancos Shale, Utah
Large scale outcrop studies used to calibrate core and log interpretations

Well log geophysics tied to core

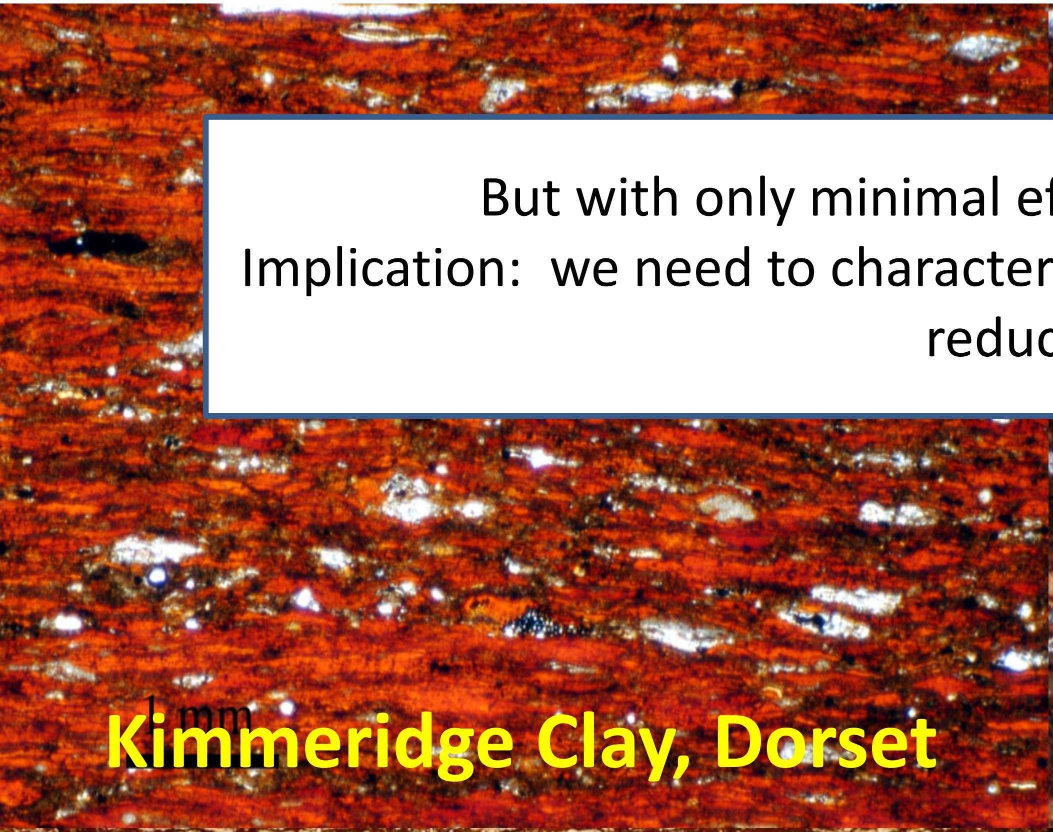


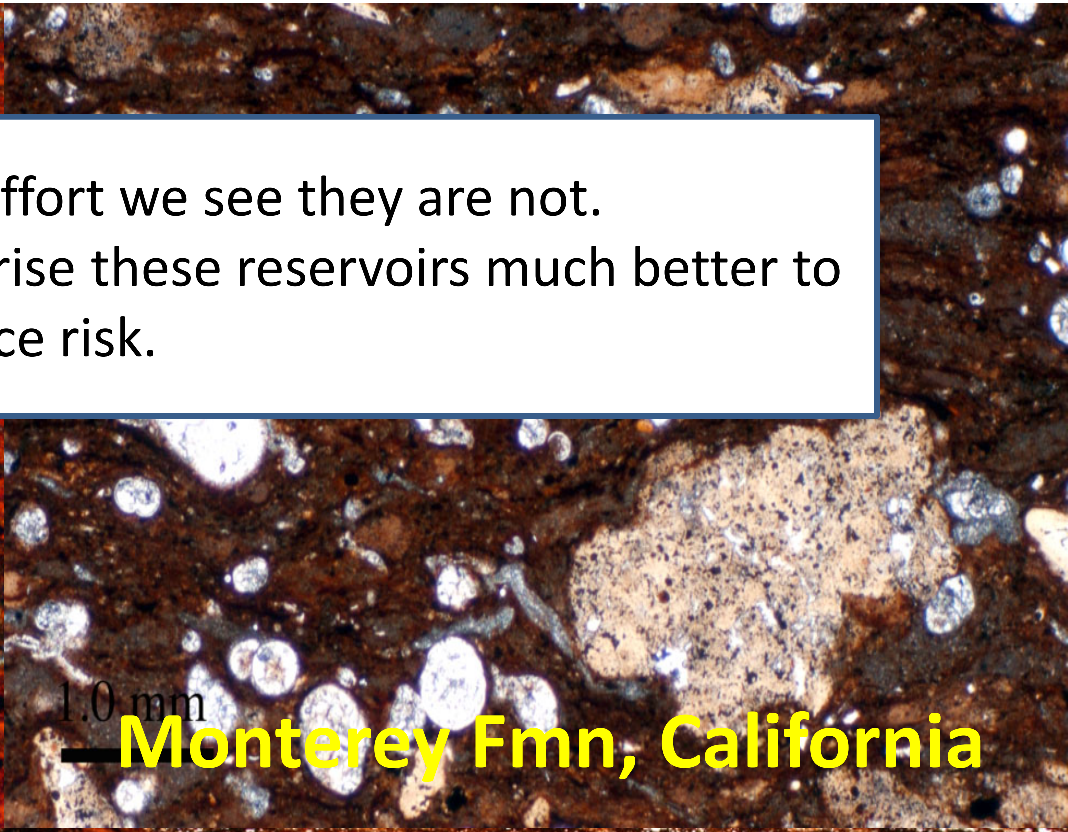
Perceptions: Homogenous with concretions

e.g. Jurassic Pyritous Shales, Yorkshire

Clay-rich mudstones appear superficially similar and homogeneous

But with only minimal effort we see they are not.
Implication: we need to characterise these reservoirs much better to reduce risk.





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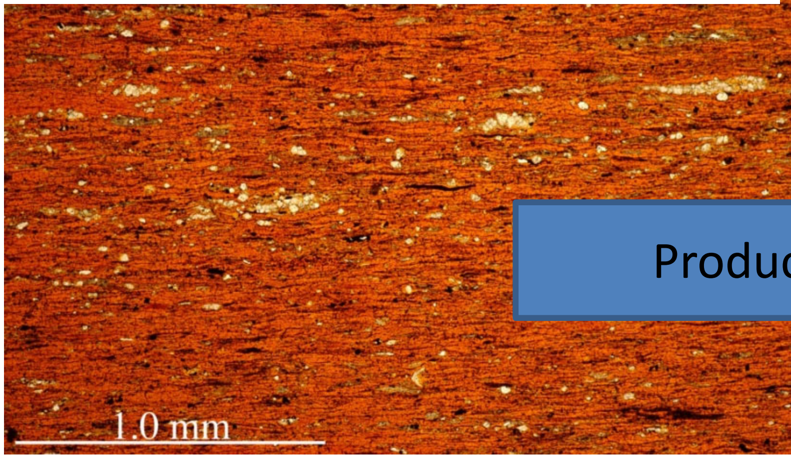
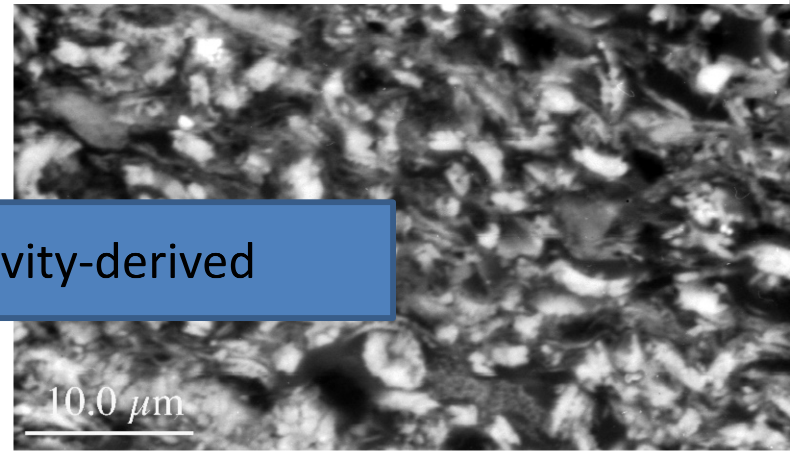
Kimmeridge Clay microfacies

Organic-rich, laminated mudstone

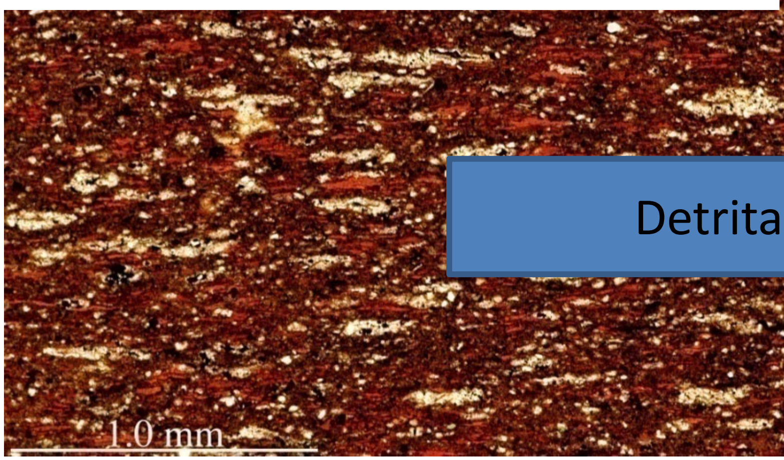


Coccolith-rich mudstone

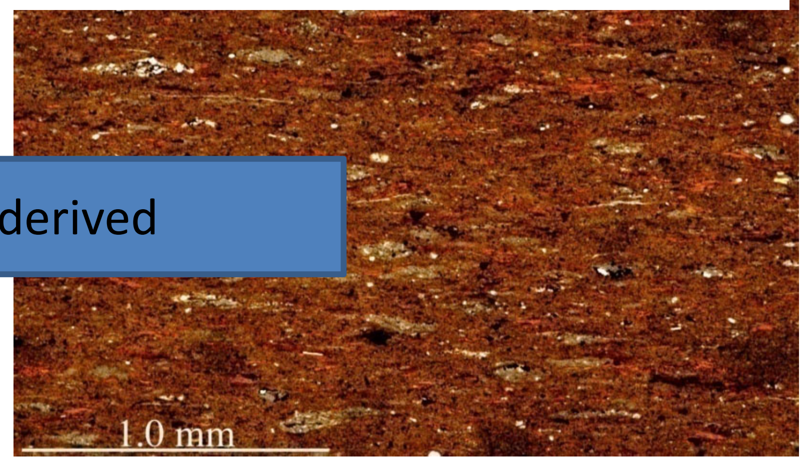


Productivity-derived

Silt-rich mudstone

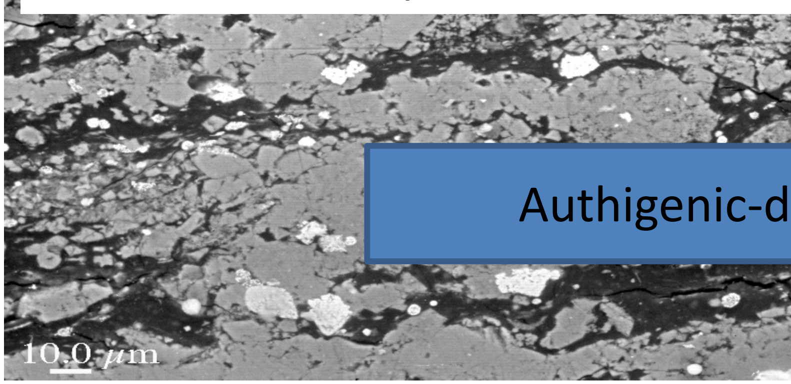


Clay-rich mudstone



Detrital-derived

Concretionary mudstone

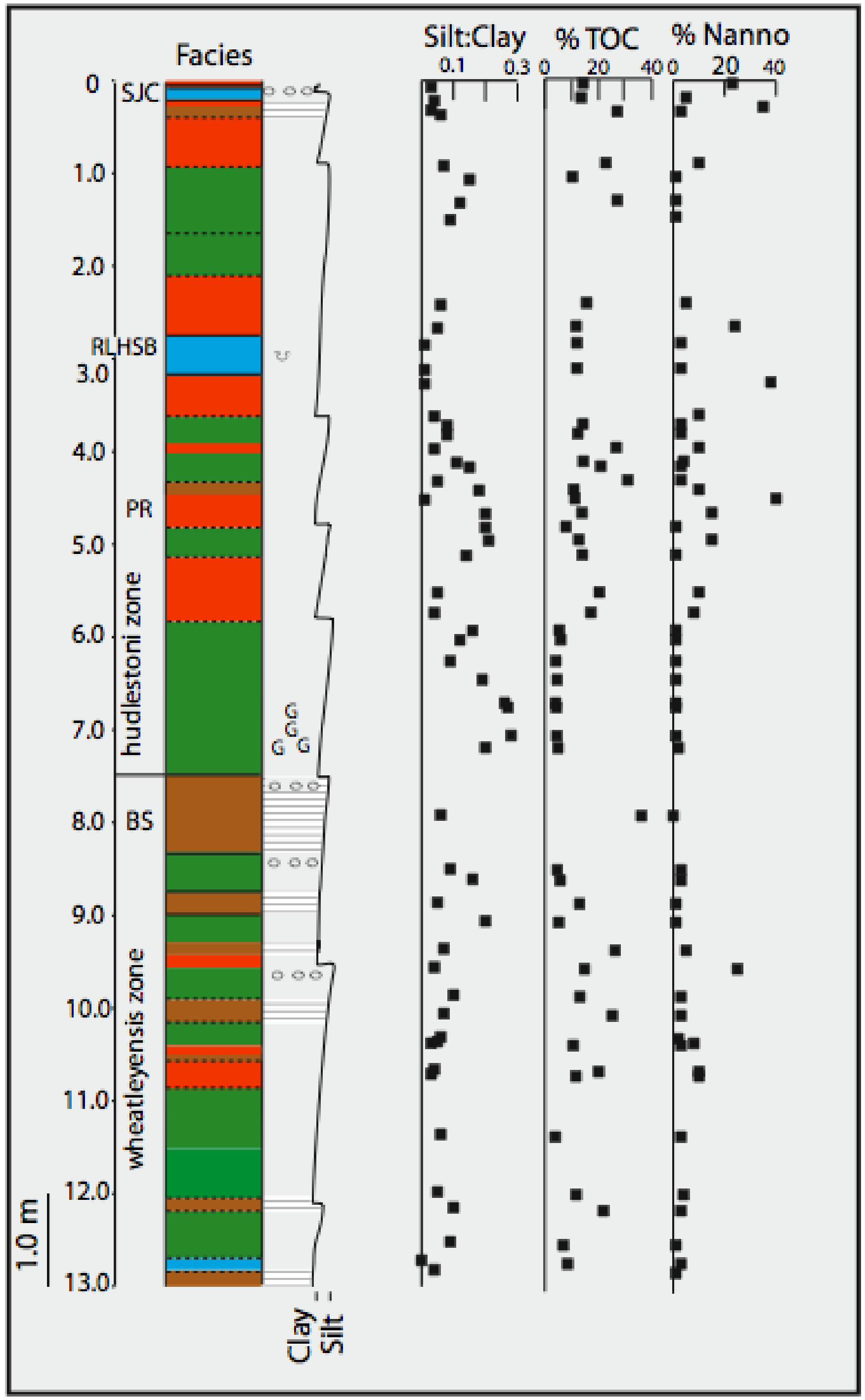


Authigenic-derived

Basin studies

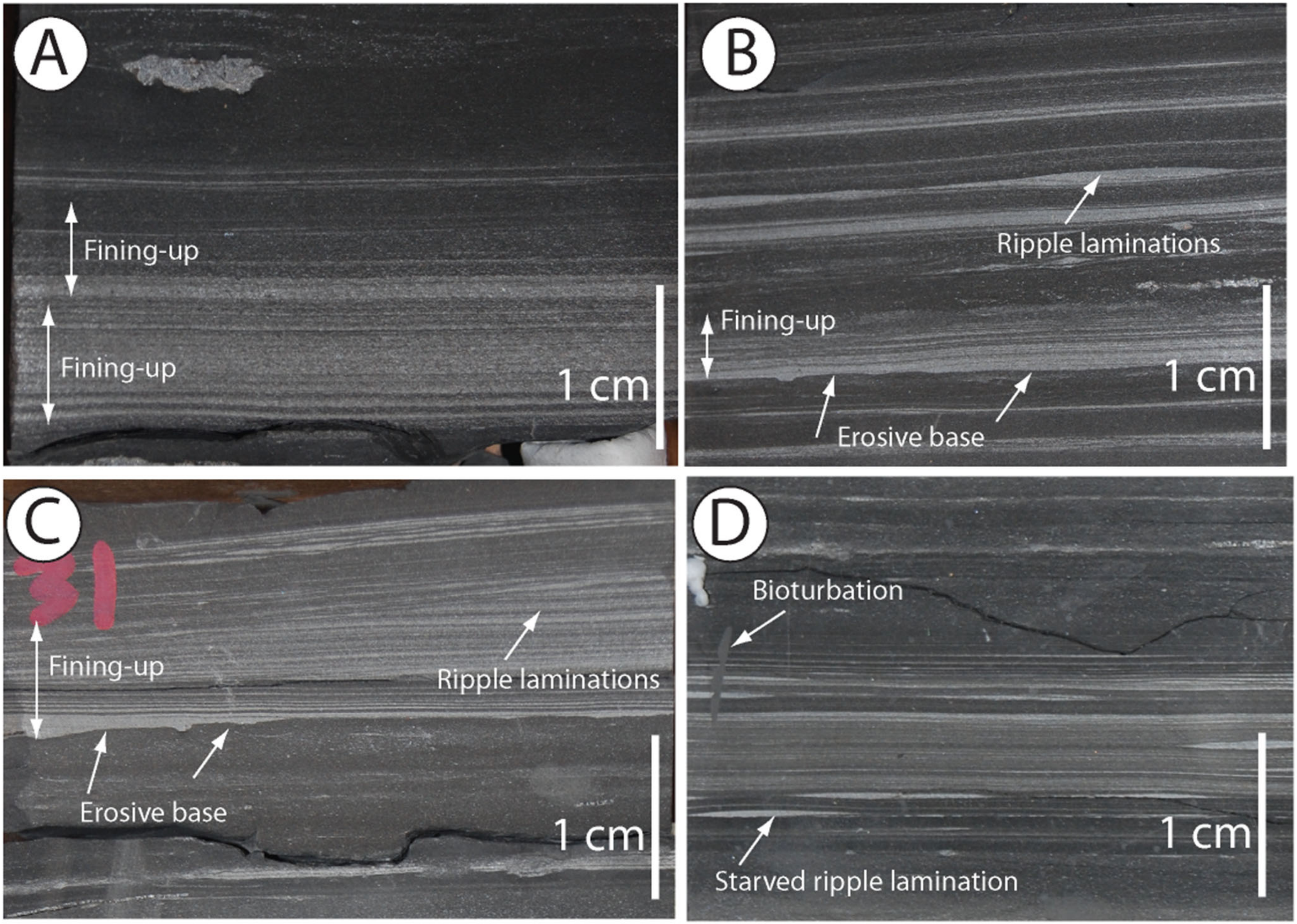
There is also clear intra-successional variability
(e.g. Kimmeridge Clay, Jurassic, UK)

Significant vertical variability

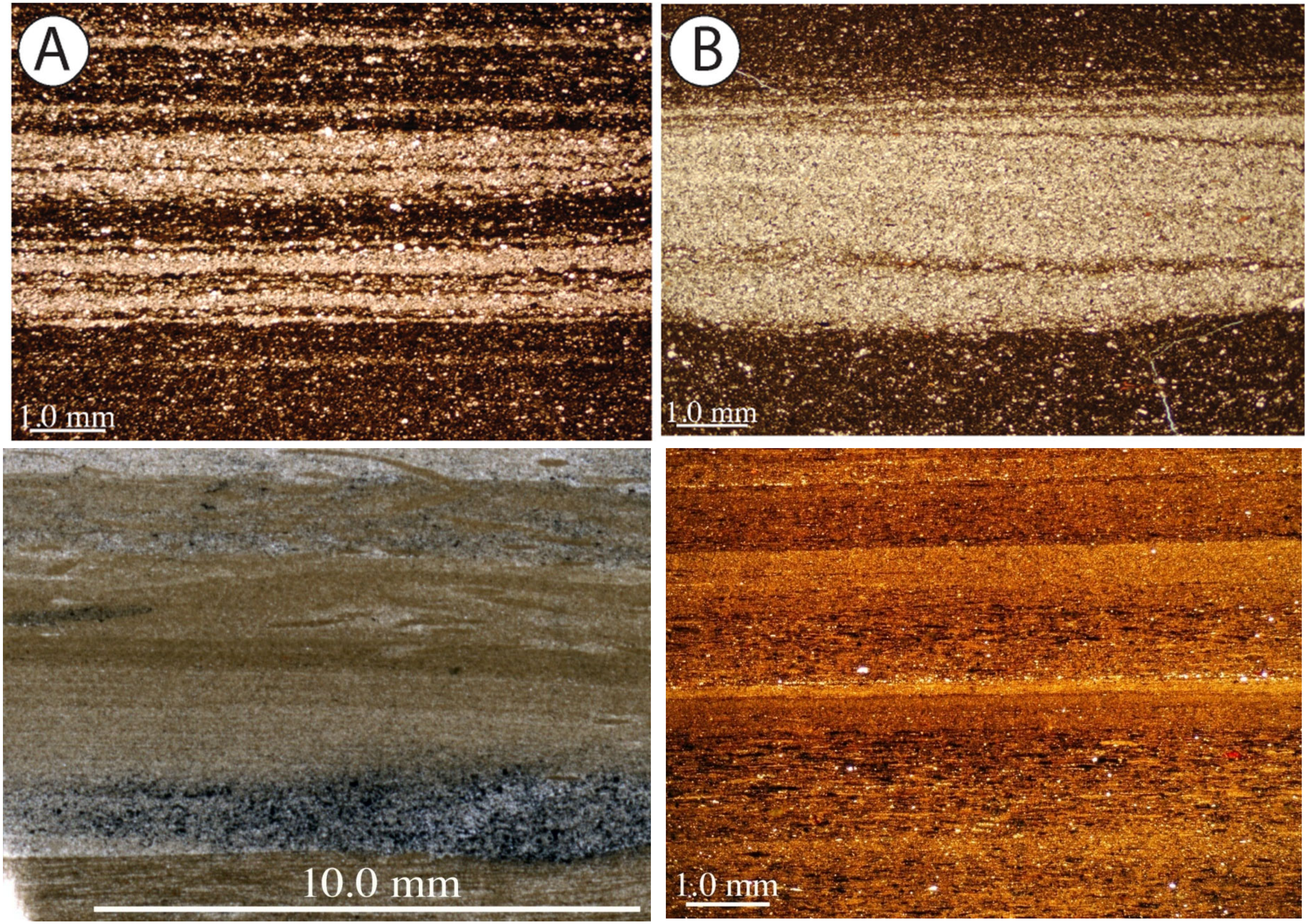


From: Maquaker, Taylor, Gawthorpe and Oates, 1998

And can show us process ...

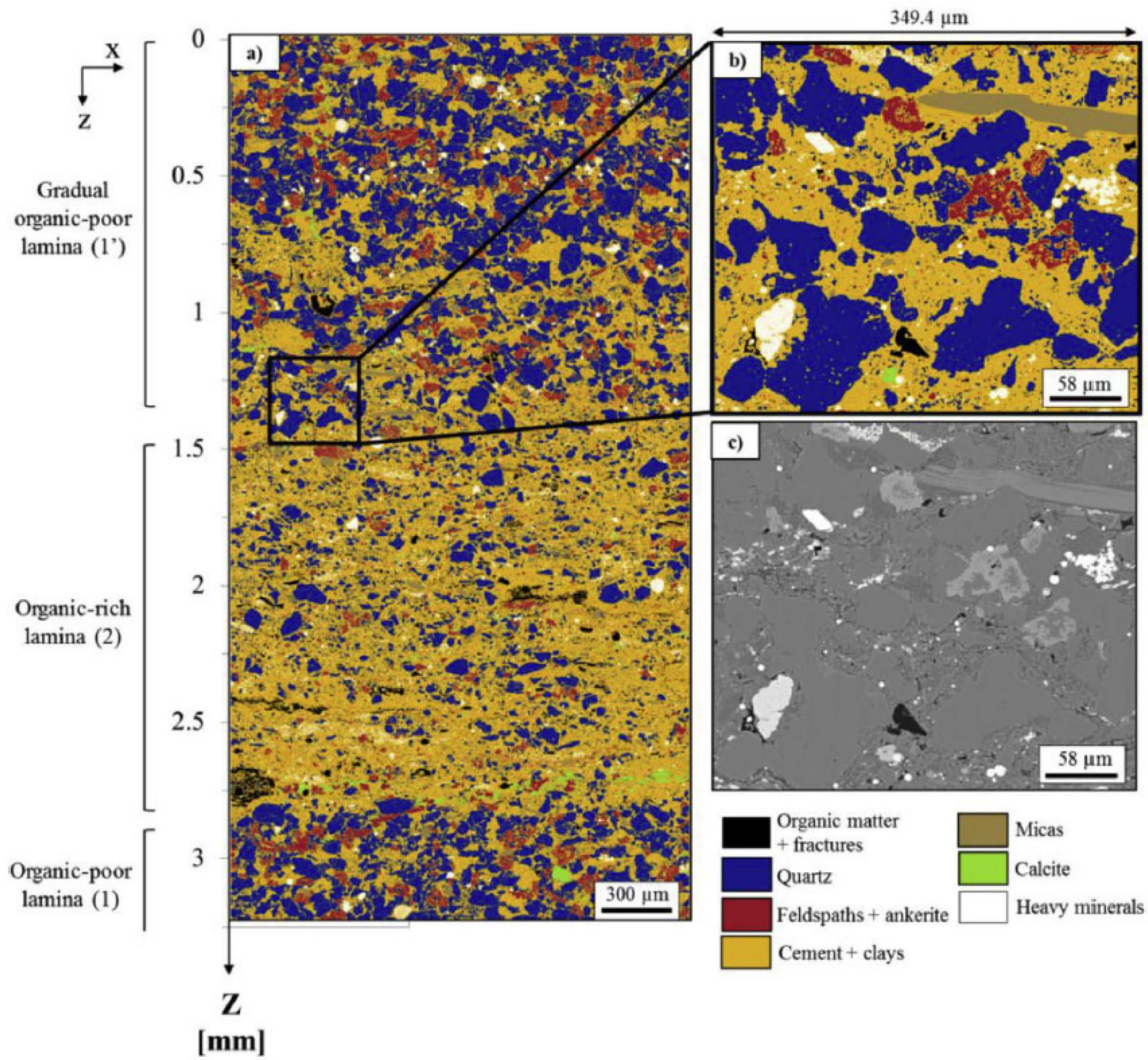


And thin sections can enhance this...



2D imaging techniques have focussed on this small scale

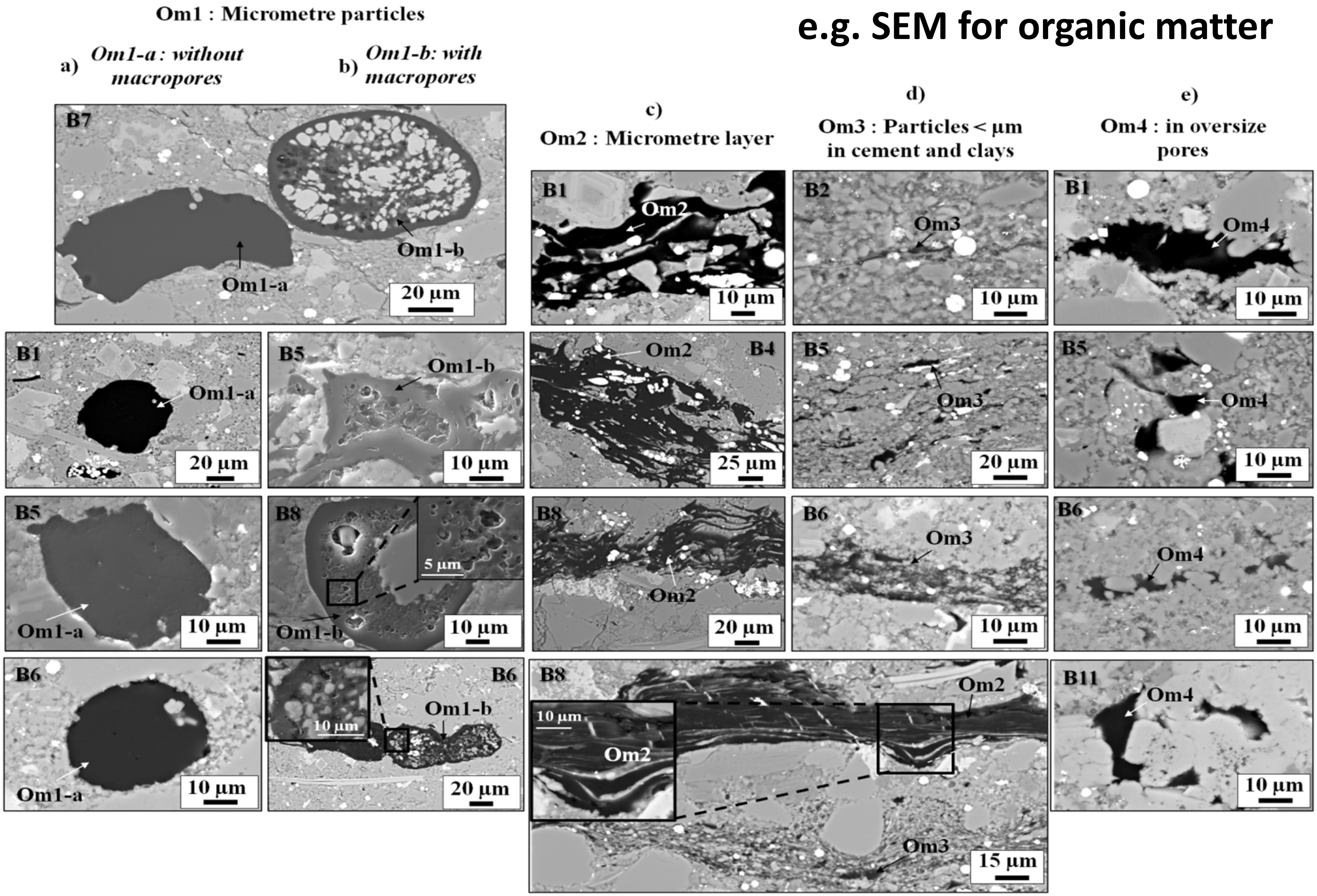
E.g. SEM and QEM-SCAN for minerals



Fauchille et al 2018

2D imaging techniques have focussed on this small scale

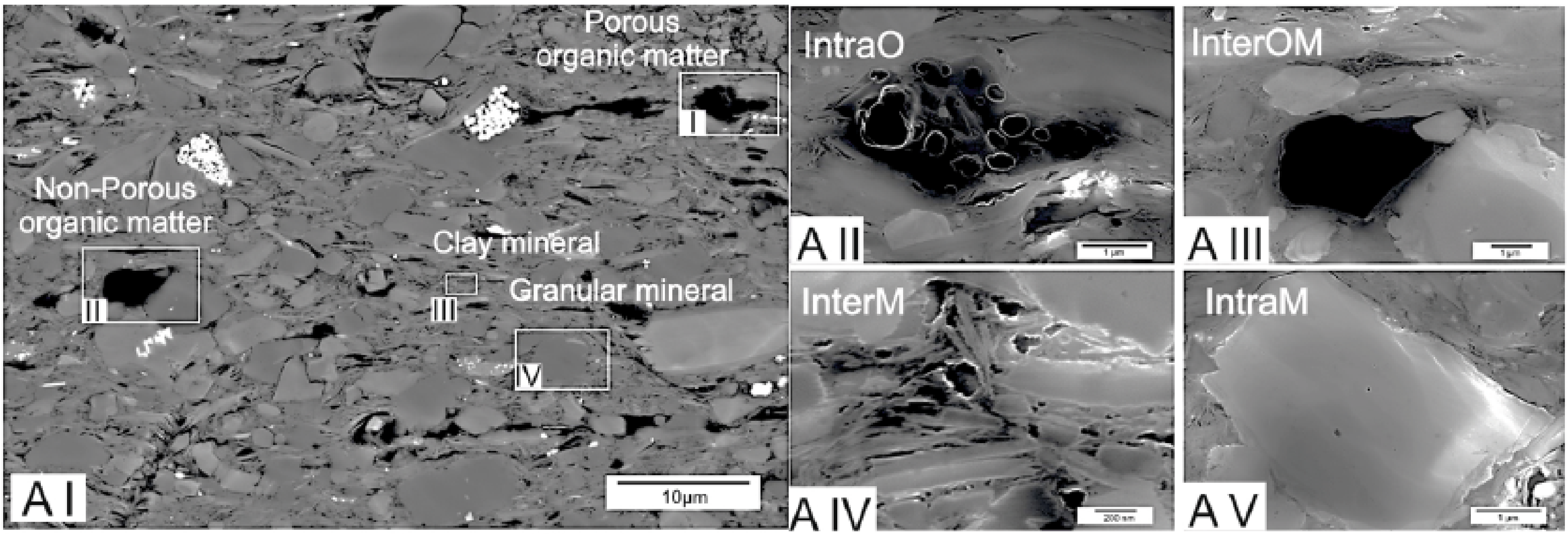
e.g. SEM for organic matter



Fauchille et al 2017

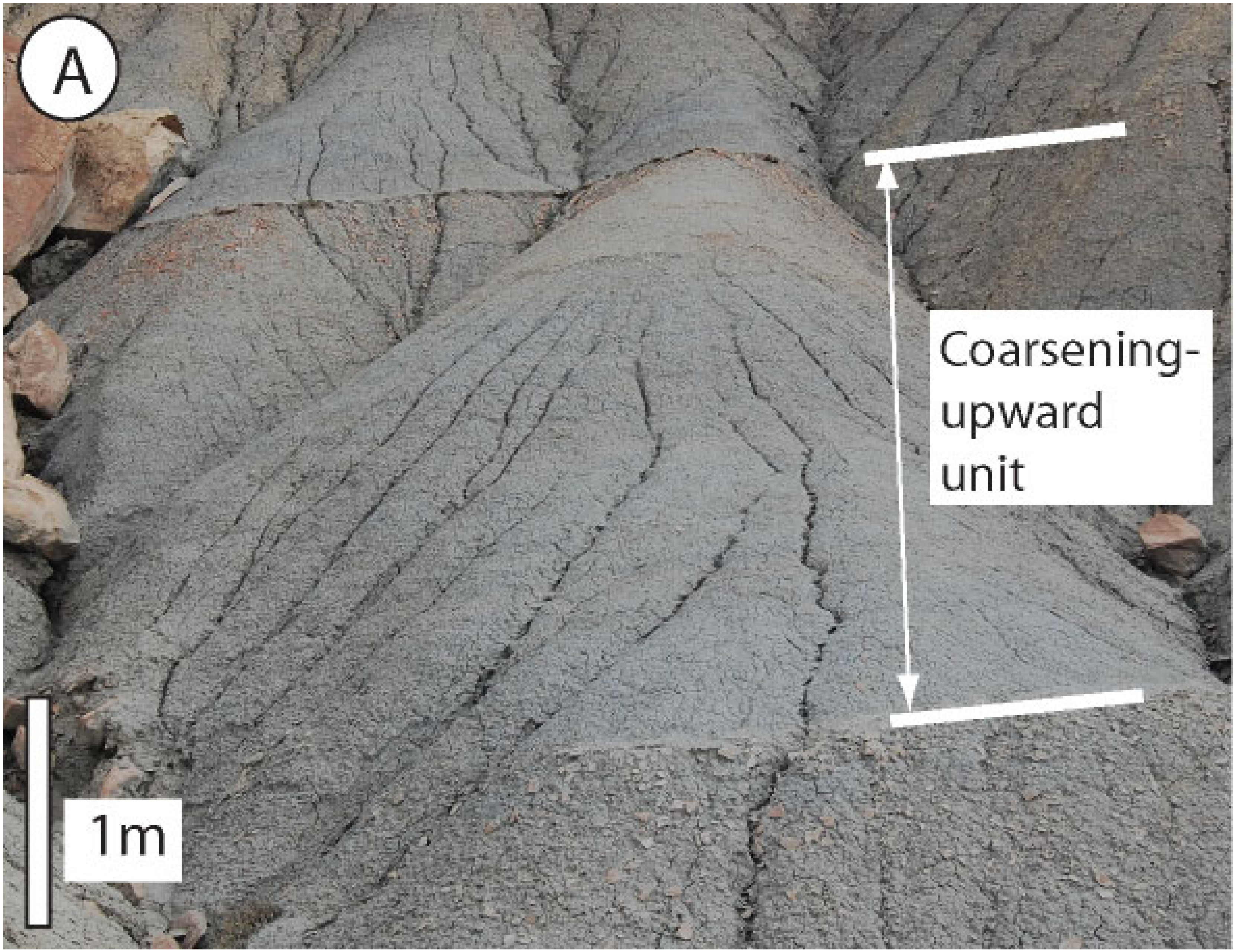
2D imaging techniques have focussed on this small scale

E.g. Pore-types

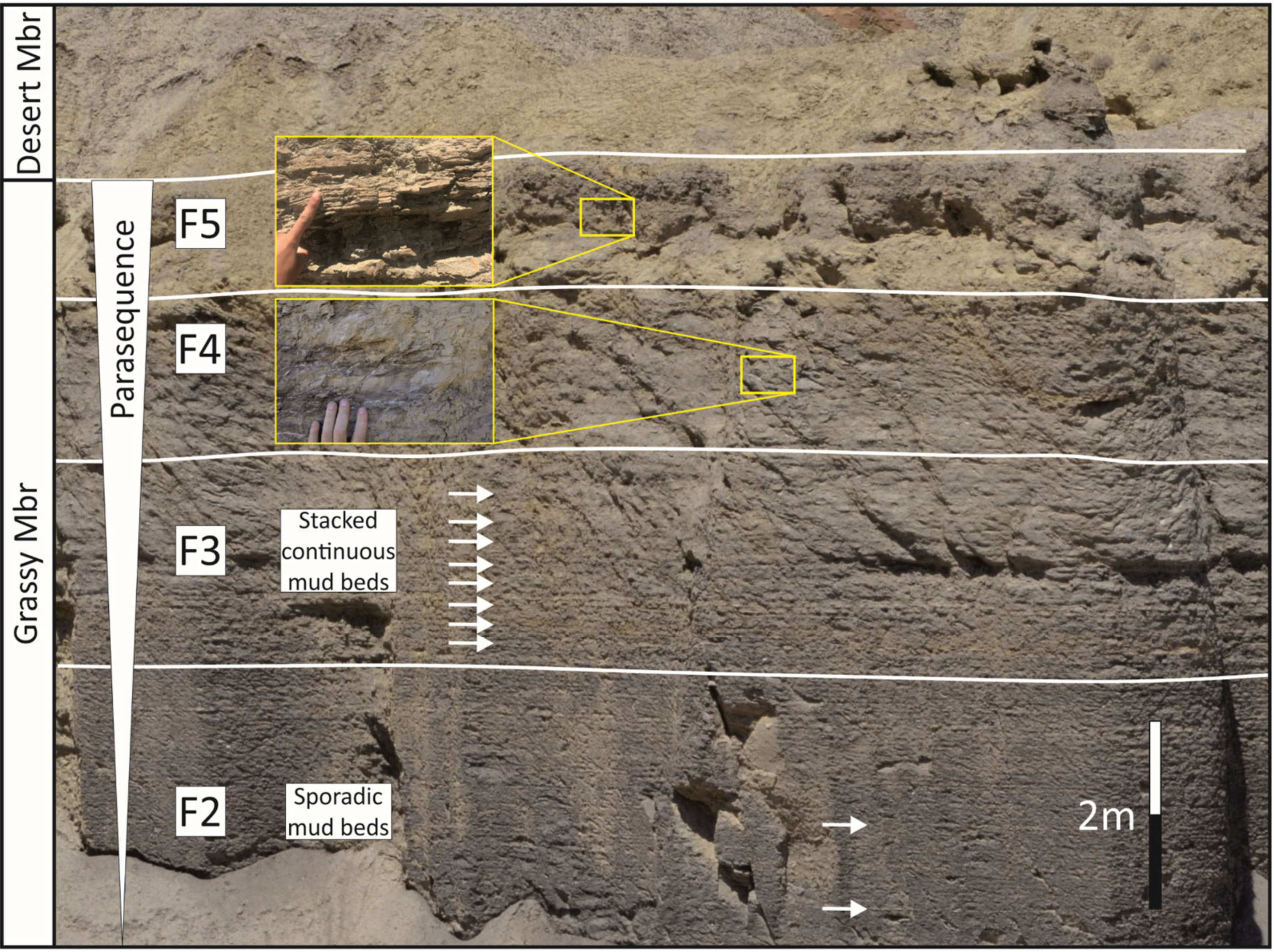


From Ma et al 2018, Scientific Reports

But also 1 to 10 m scale variability



Parasequence Outcrop Expression

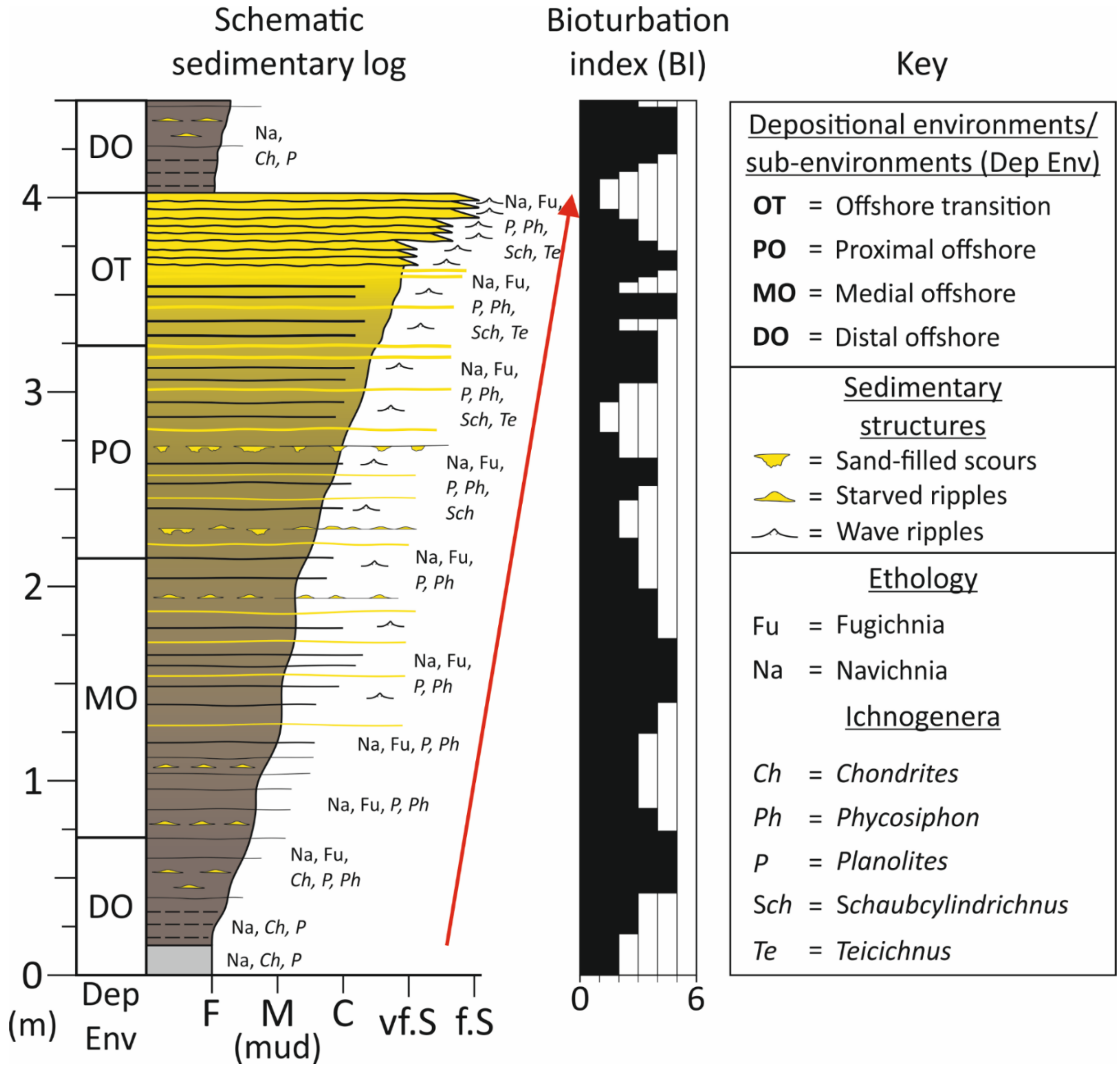


Typical facies stacking pattern:

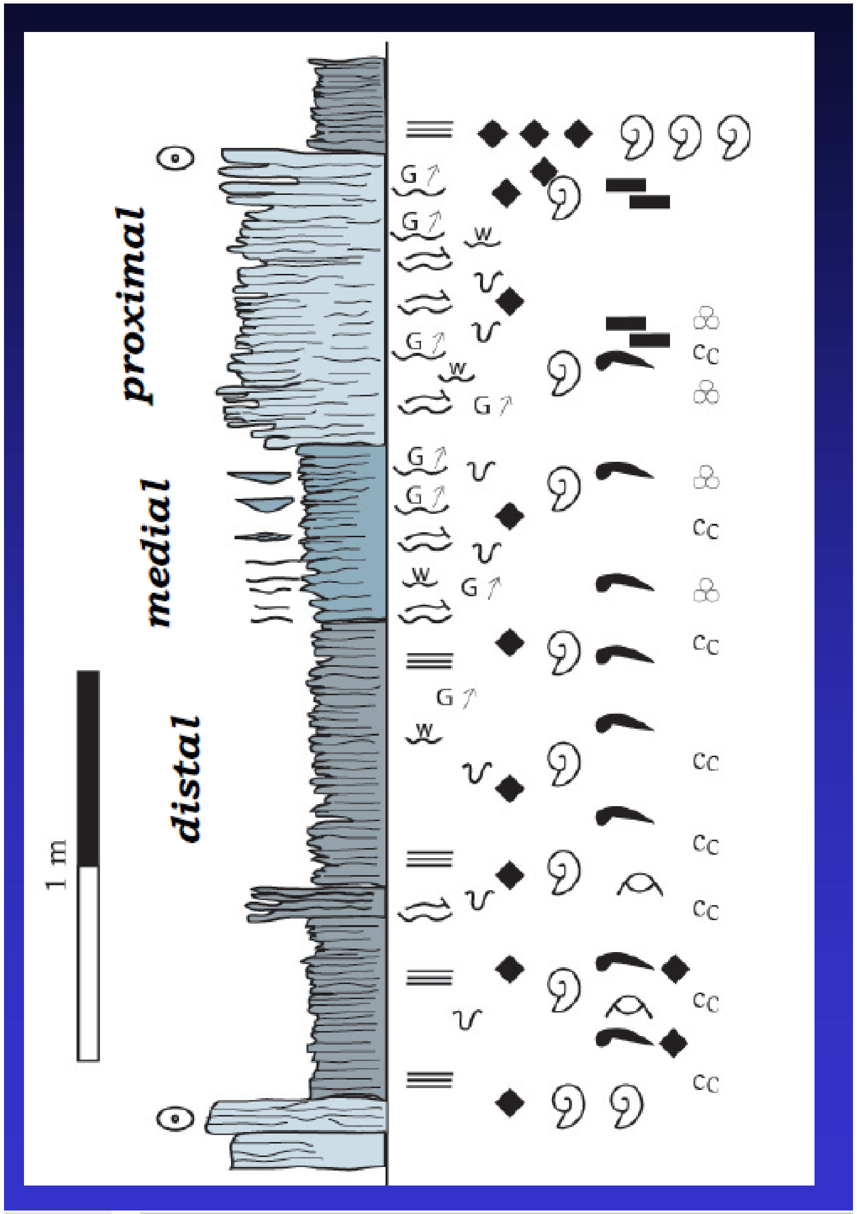
F2: Massive mudstone
F3: Thin-bedded mudstone
F4: Interbedded mudstone & sandstone
F5: Bedded sandstone

Capped by abrupt vertical juxtaposition of F2 on F5: interpreted as a rapid deepening event (flooding surface)

Parasequence Outcrop Expression



Parasequence architecture



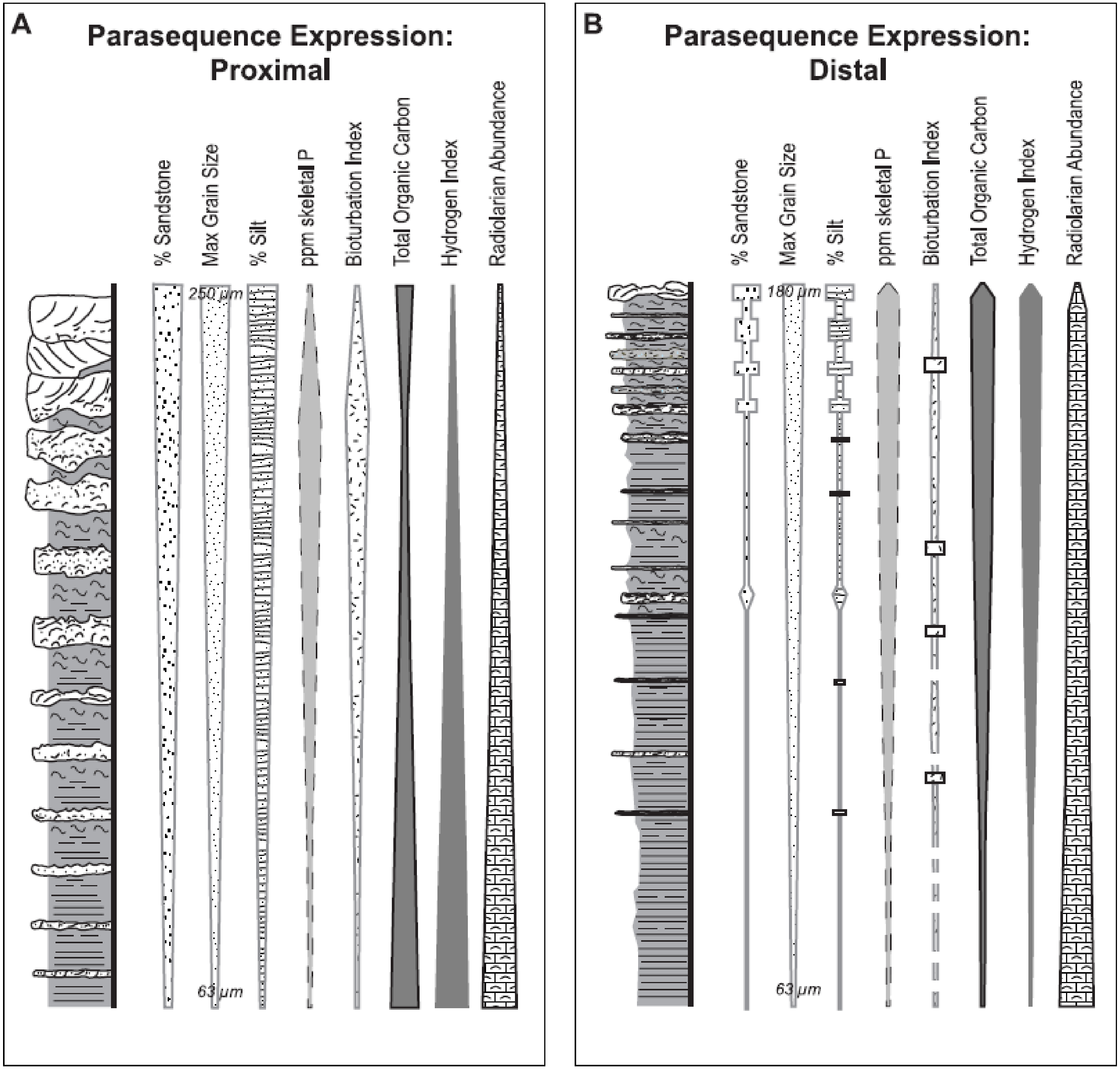
Upward increase in:

- Silt (quartz)
- Carbonate contact
- Porosity
- Permeability

Upward decrease in:

- Clay
- TOC
- Pyrite

From: Bohacs et al 2013. HGS presentation

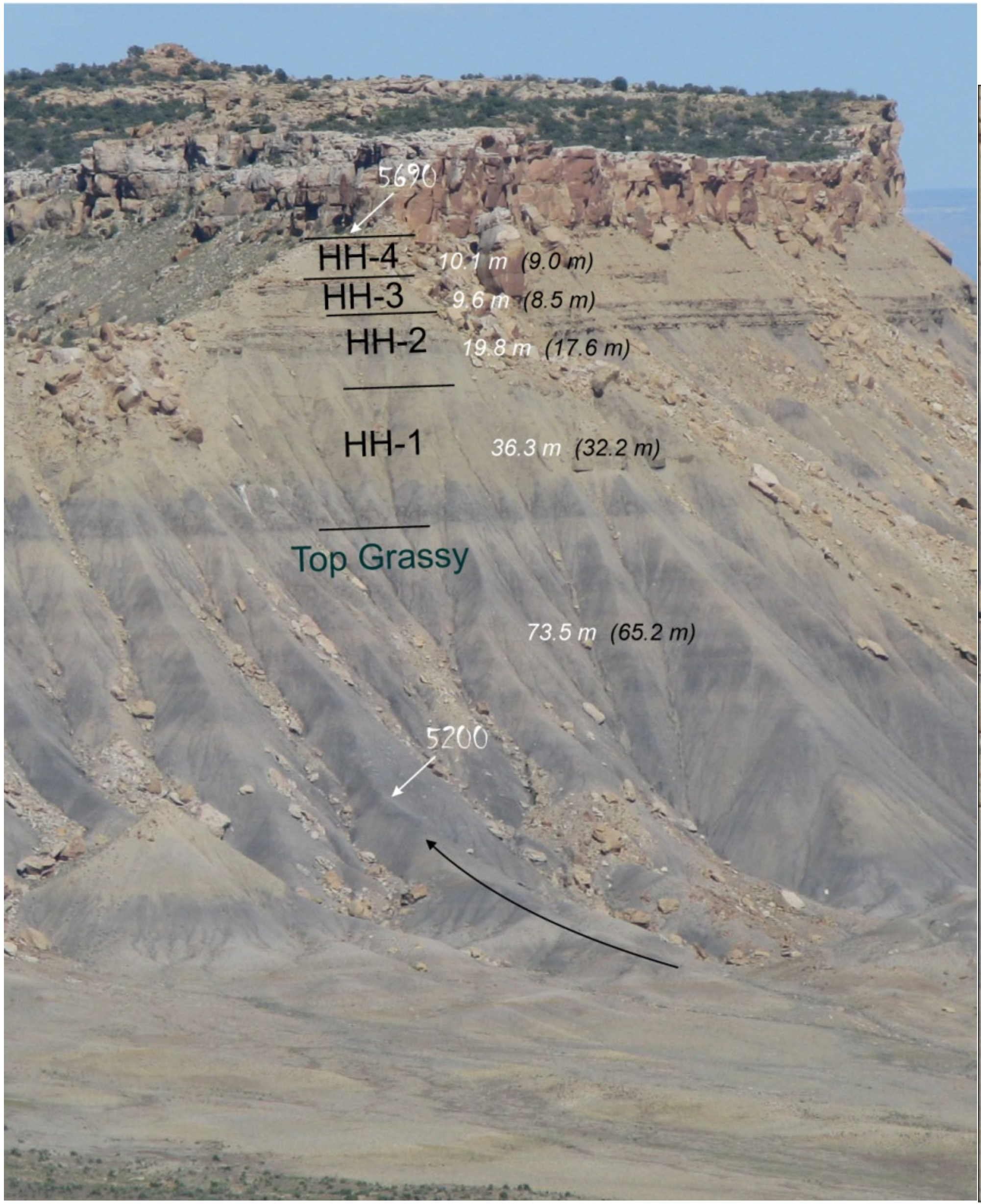


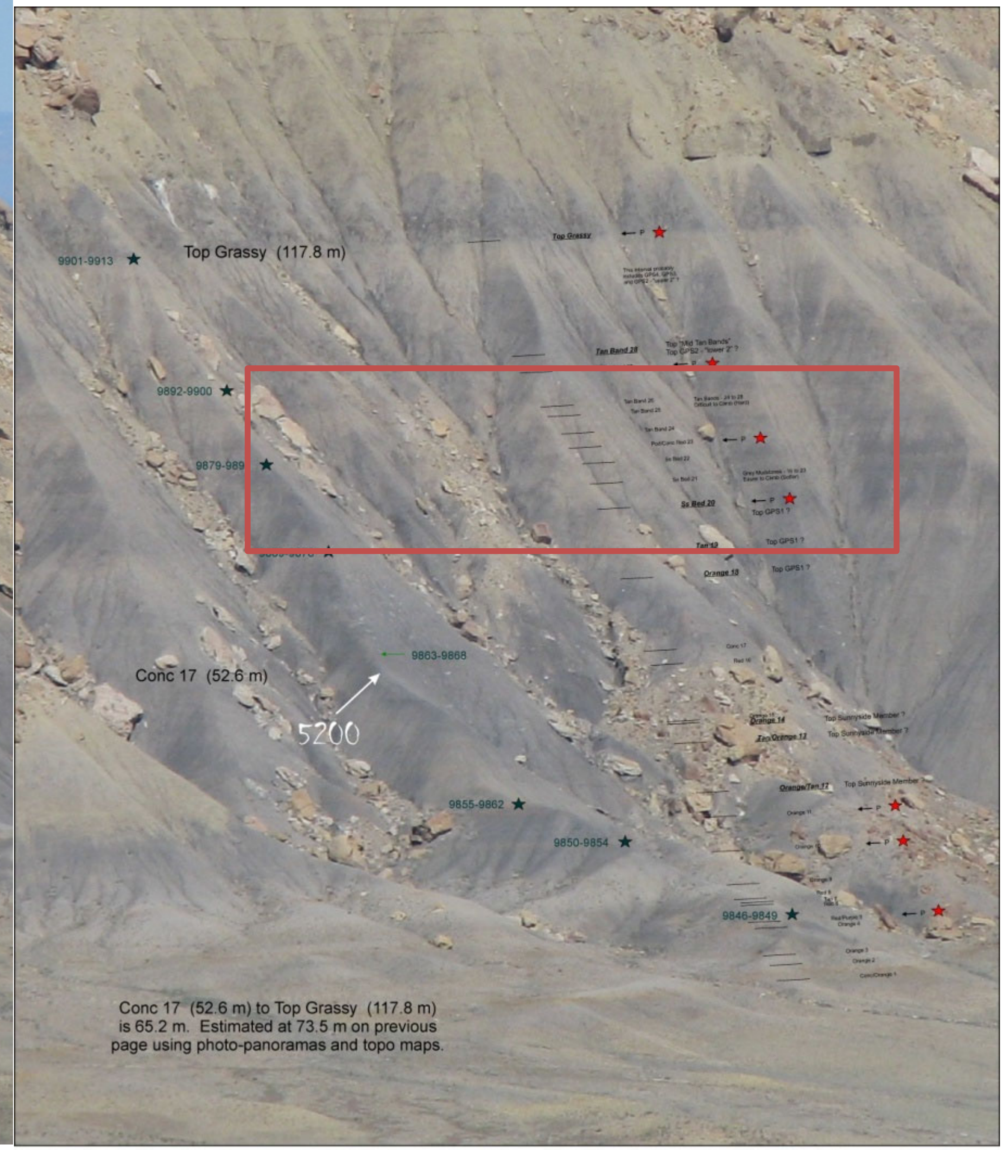
Parasequence expression in mudstones

From Bohacs et al 2005

Larger (GDF) scale? E.g. Mancos Shale, Utah

8B Horse Heaven - SW Bowl - Colour Band Correlation





Measured Section and Photographs (Sept 6, 2009)

Take-home messages

- Clay-rich mudstones are compositionally and sedimentologically variable, and not all the same.
- This variability is at several scales (cm-scale, metre-scale, tens of metre scale)
- The smaller scale tell us about depositional processes but scale too small to impact GDF safety cases
- Larger-scale variability is on GDF-scale so needs consideration.