

Hydrodynamic Fractionation of Minerals and Textures in Submarine Fans: Implications for the Prediction of Reservoir Quality*

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Abstract

Submarine fans are excellent oil and gas reservoirs. Outcrop and subsurface studies document that these systems consist of channels and lobes that compensationally stack. Additionally, studies show that individual lobes have a thick axis and strata thin and become finer-grained toward the lateral and distal margins. No studies have documented how reservoir quality changes laterally and longitudinally in these deposits. This study uses exceptionally well-exposed outcrops of lobe strata in the Point Loma Formation, San Diego, California to test how turbidity currents hydrodynamically fractionate mineral grains of different size, shape, and density, and how this affects reservoir quality.

A single bed within a larger lobe element is studied over 2.5 km from axis to margin. Macro- and micro-scale parameters are documented along the profile and include bed thickness, primary and secondary sedimentary structures, mineral composition, sorting, grain size, and grain shape. There is a systematic axis-to-margin change in the character of the bed. In the axial position of the lobe where the bed is the thickest, it consists of 4 m of structureless sandstone, is well sorted, and ranges from coarse sand to pebble-sized shale clasts. The bed maintains a similar character for approximately 1.5 km. In the off-axis location, bed thickness decreases abruptly to 0.5 m, and consists of structureless sand, layers of shale clasts and silty laminae, sorting decreases, and ranges from silt to pebble-sized shale clasts. At the margin, the bed is only 20 cm thick, and consists of ripple laminated siltstone to very-fine sandstone, has poor sorting, and ranges from clay to fine sand. The bed continues laterally as a terminal siltstone. Preliminary data show that the

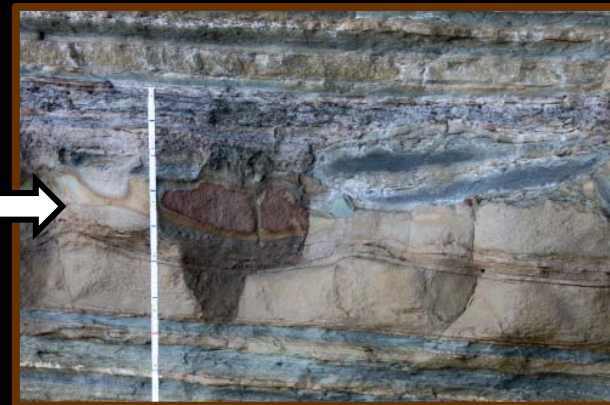
percentage of K-feldspar increases relative to quartz along the profile. Therefore, hydrodynamic fractionation of minerals and textures is an important process that operates in submarine fans.

Hydrodynamic fractionation has an impact on primary and secondary porosity and permeability. Its effect on primary porosity is controlled by sorting and packing of grains, whereas secondary porosity is greatly controlled by the diagenetic alteration of feldspars to clay minerals. Off-axis and marginal facies have poor sorting and a higher proportion of K-feldspar, which indicates that these areas are likely to have lower porosity and permeability values compared to more axial locations.

References

- Campion, K.M., A.R.G. Sprague, and M.D. Sullivan (editors), 2005, Architecture and lithofacies of the Capistrano Formation (Miocene-Pliocene), San Clemente, California: Fieldtrip guidebook for annual fall fieldtrip, Pacific Section SEPM, October 29, 2005: SEPM, Pacific Section, book 100, 42 leaves.
- Fleming, A.E., 2010, Stratigraphic architecture of lobe strata in a submarine fan setting, Point Loma Formation, California: M.Sc. Thesis, Colorado School of Mines, 133 p.

Hydrodynamic Fractionation of Minerals and Textures in Submarine Fans: Implications for the Prediction of Reservoir Quality



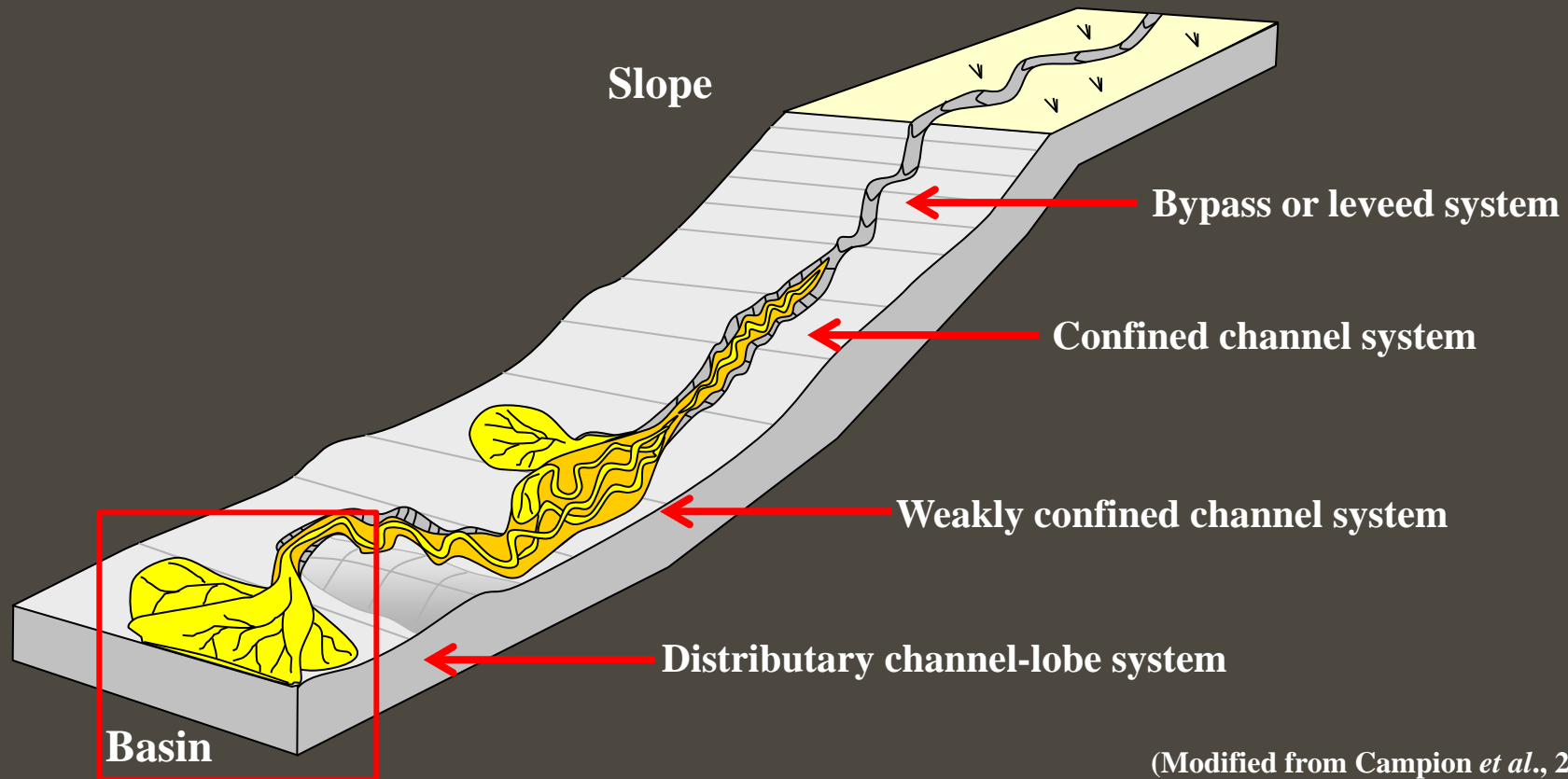
**Jane Stammer¹, David Pyles¹, Alexandra Fleming¹, Julian Clark²,
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AAPG – Annual Meeting

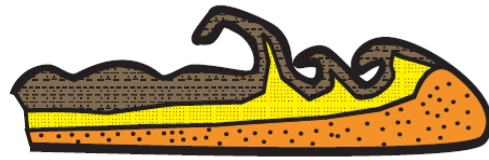
April 13, 2011

Submarine Fans



- **Importance:**
 - Major areas of deep-water exploration and production around the globe ---- especially northern Gulf of Mexico
- **Problem:**
 - Reservoir quality is variable within deep-water systems

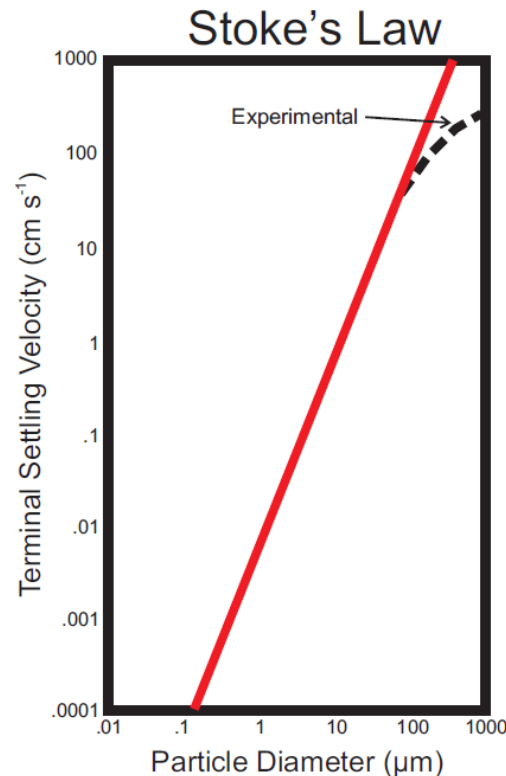
Hydrodynamic Fractionation



Distance

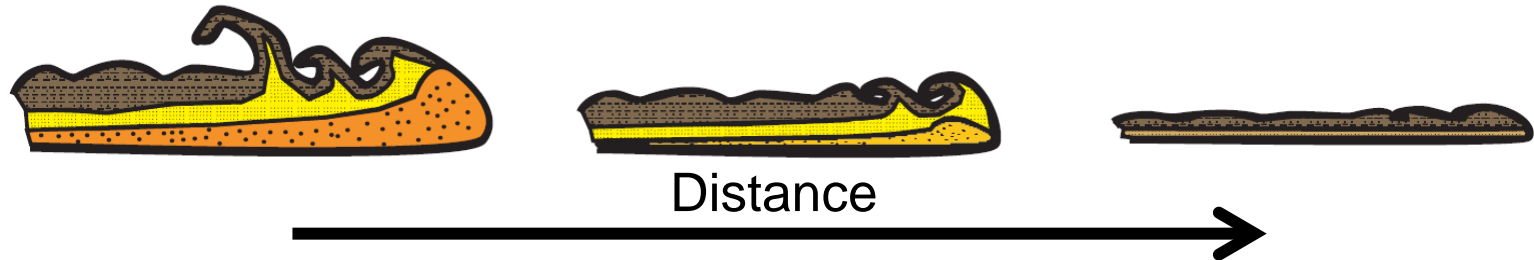


Flow travels down current and loses energy
Particle settling velocity dictates deposition

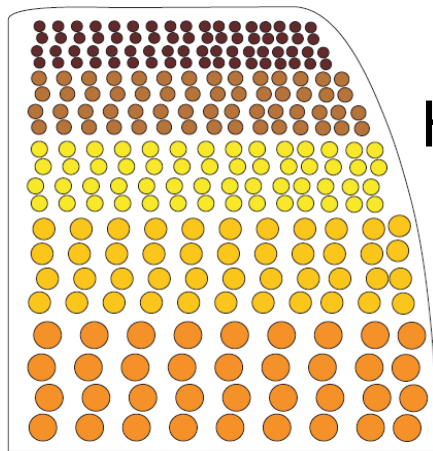


(<http://www.utsc.utoronto.ca>)

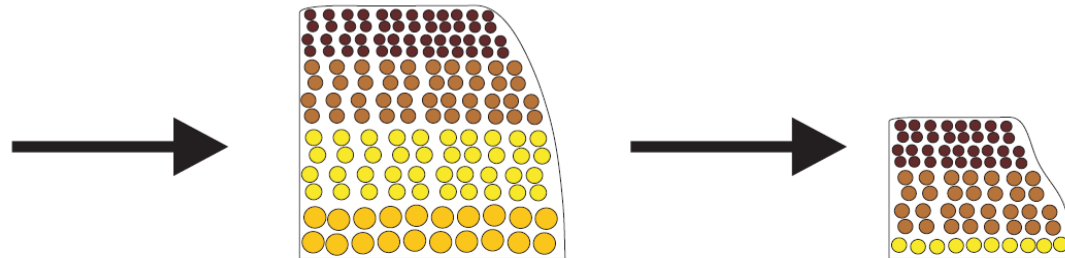
Hydrodynamic Fractionation









Flow travels down current and loses energy
Particle settling velocity dictates deposition



Hydrodynamic sorting by grain size
How does this process relate to mineralogy?



Research Questions

Mineral	Density	Shapes
Clays	2.0-3.0	
K-feldspar	2.56	
Quartz	2.65	
Plagioclase	2.62-2.72	
Micas	2.71-3.1	
Heavy minerals	4.0 +	

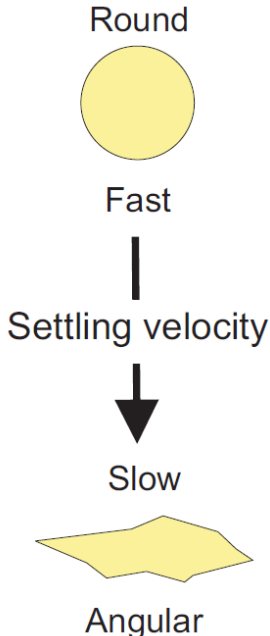
Round

Fast

Settling velocity

Slow

Angular

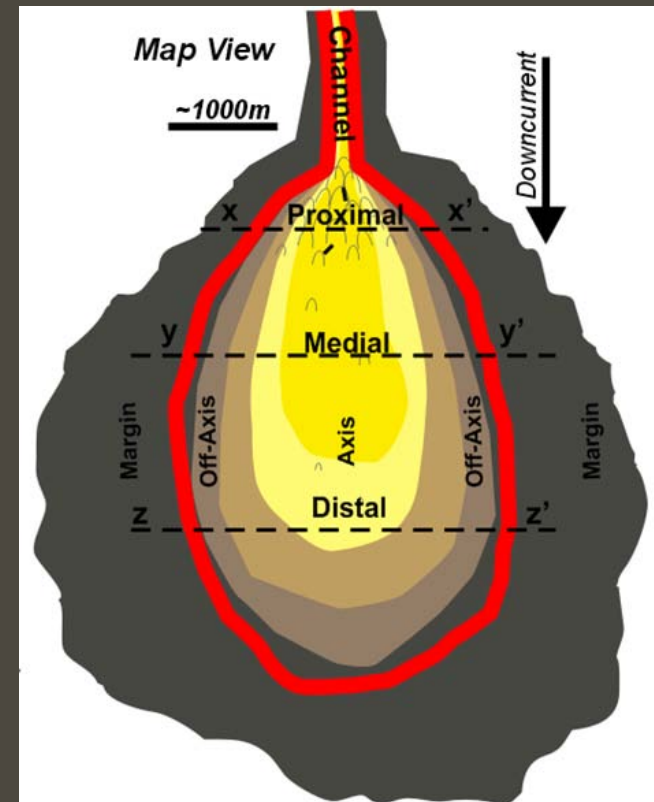
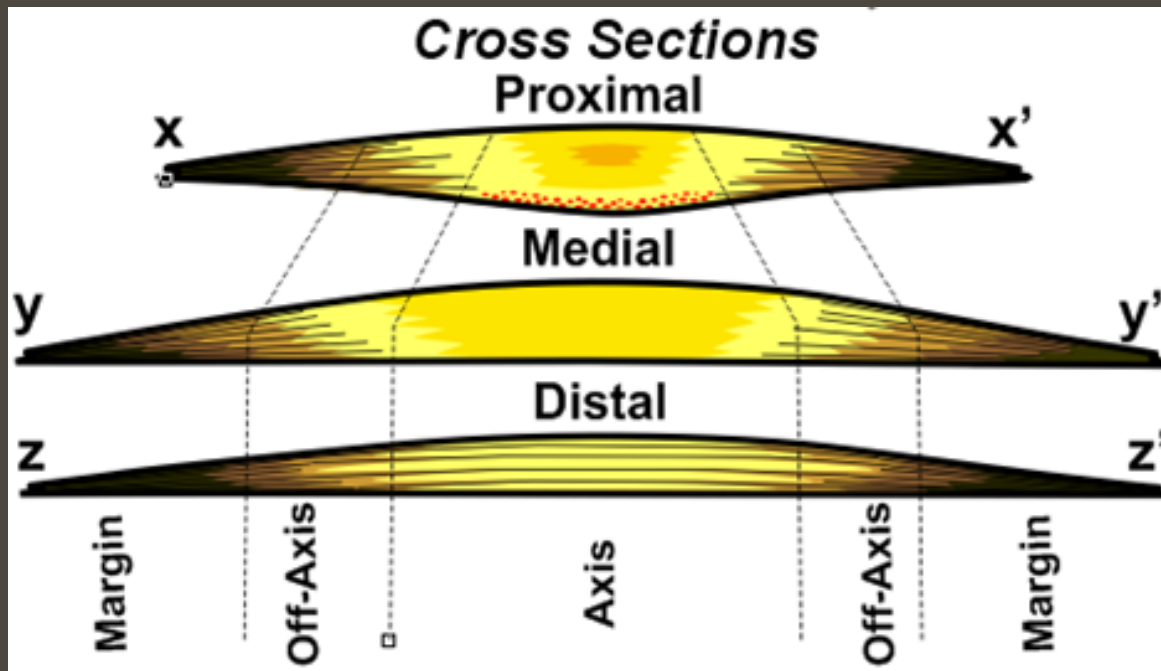


- How do **mineralogy**, texture and facies change longitudinally and laterally in submarine fans?
- What are the implications for reservoir quality?

What Do We Know?



- Submarine Fans characteristics:
 - I. Consist of channels and lobes that compensationally stack
 - II. Individual lobes have thick sand-rich axes
 - III. Lobe strata thin and become finer-grained toward lateral and distal margins



Addressing the Questions - Point Loma Fm, CA



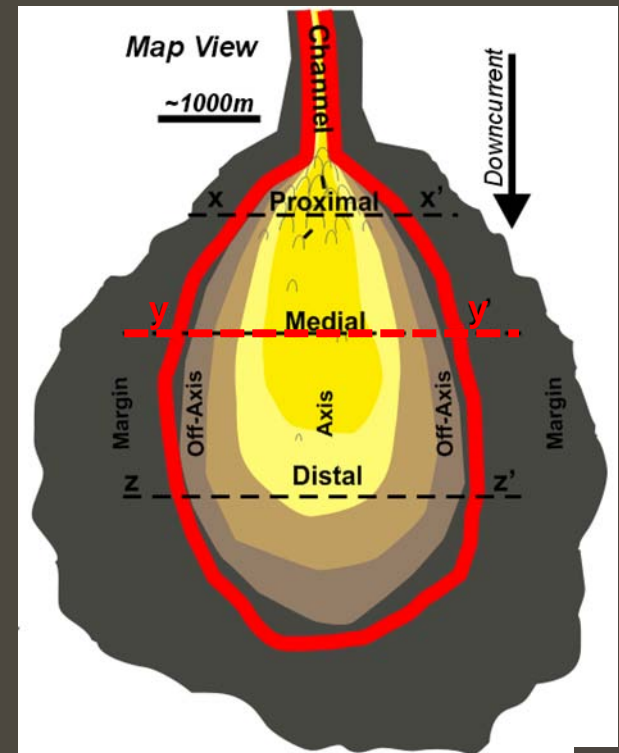
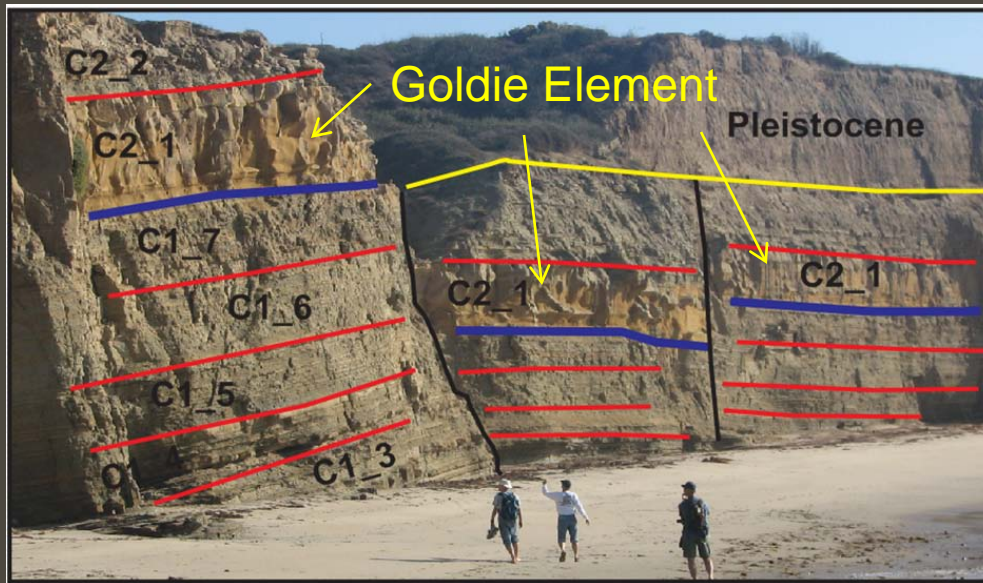
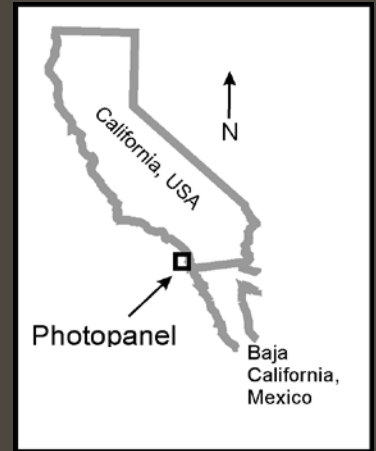
- Excellent exposures of lobe strata
- Laterally extensive outcrop and high continuity of bedding
- Large grain-size distribution (silt to coarse sand)
- Only minor post-depositional tectonics



Addressing the Questions - Point Loma Fm, CA



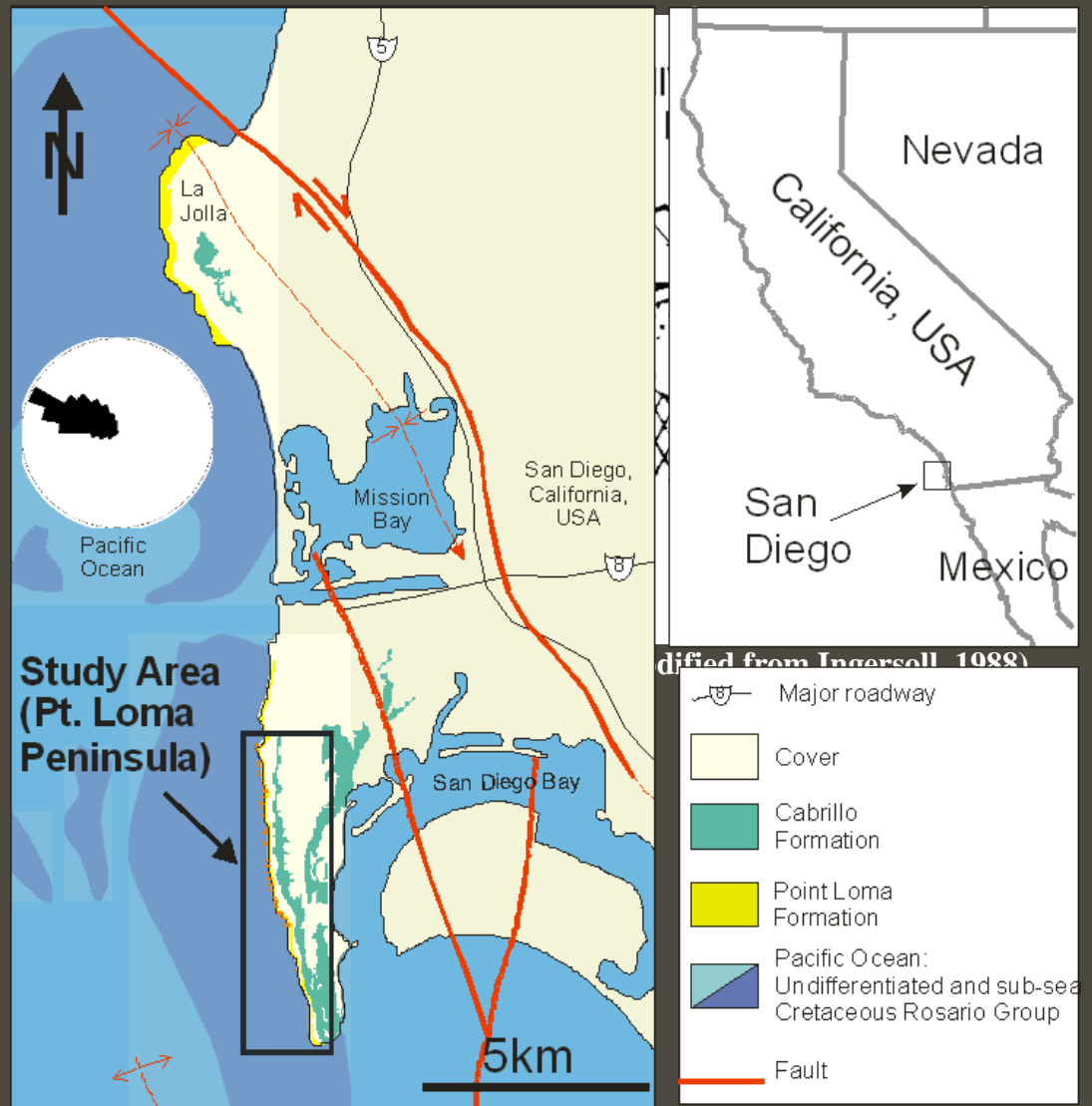
- Excellent exposures of lobe strata
- Laterally extensive outcrop and high continuity of bedding
- Large grain-size distribution (silt to coarse sand)
- Only minor post-depositional tectonics
- Outcrop is perpendicular to paleocurrent direction
- Can track a single bed and element from its axis to its margin over 2+ km



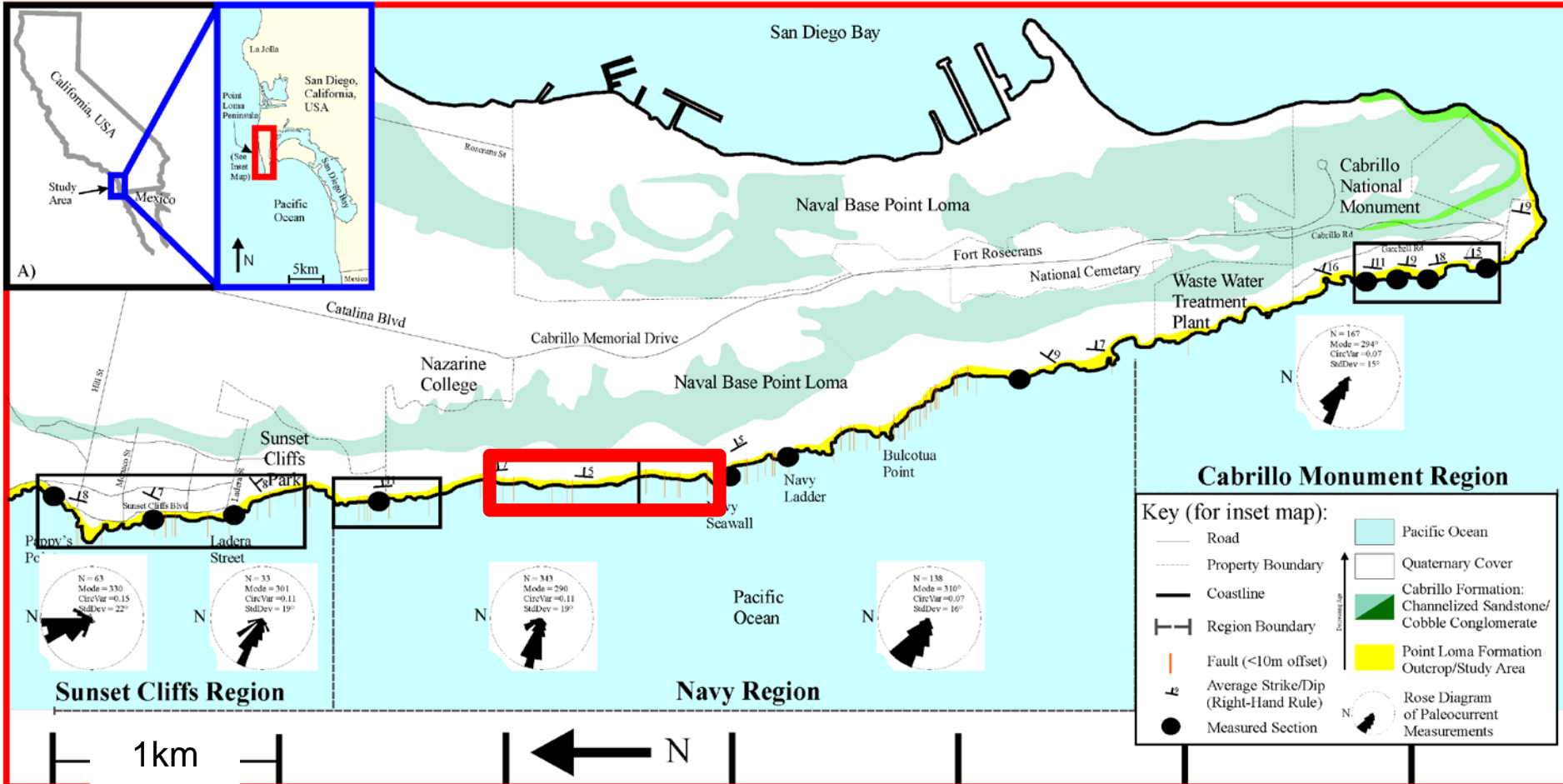
Geologic Setting- Point Loma Formation, CA



- Late Cretaceous in age
- Deposited in a forearc basin
- West-northwest sediment transport direction
- Outcrop exposure along sea cliffs



Main Field Map- Point Loma Peninsula



(Compiled from this study, USGS Topographic Map 1:25,000, and USGS Geologic Map of San Diego 1:100,000 [Kennedy and Tan, 2005])

Data and Methods



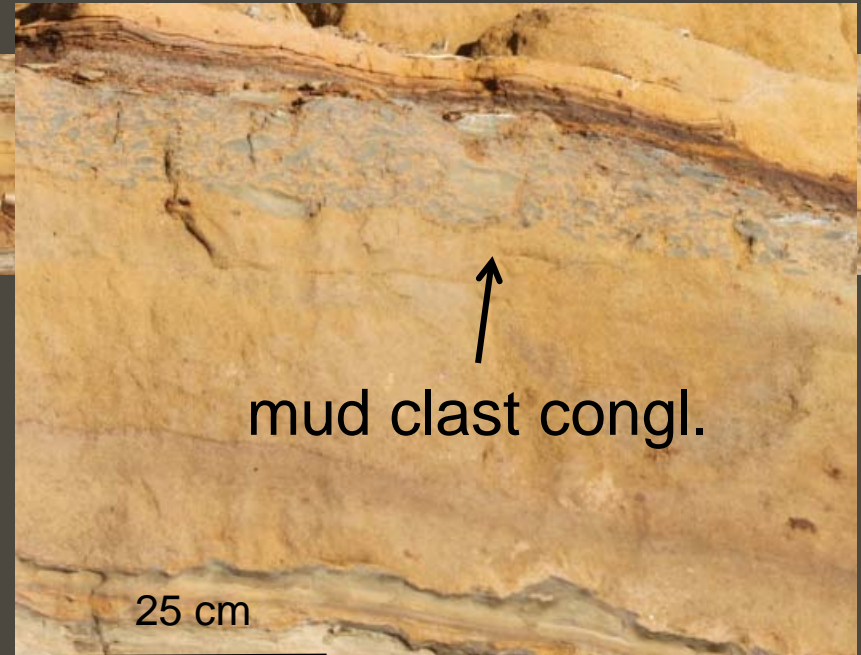
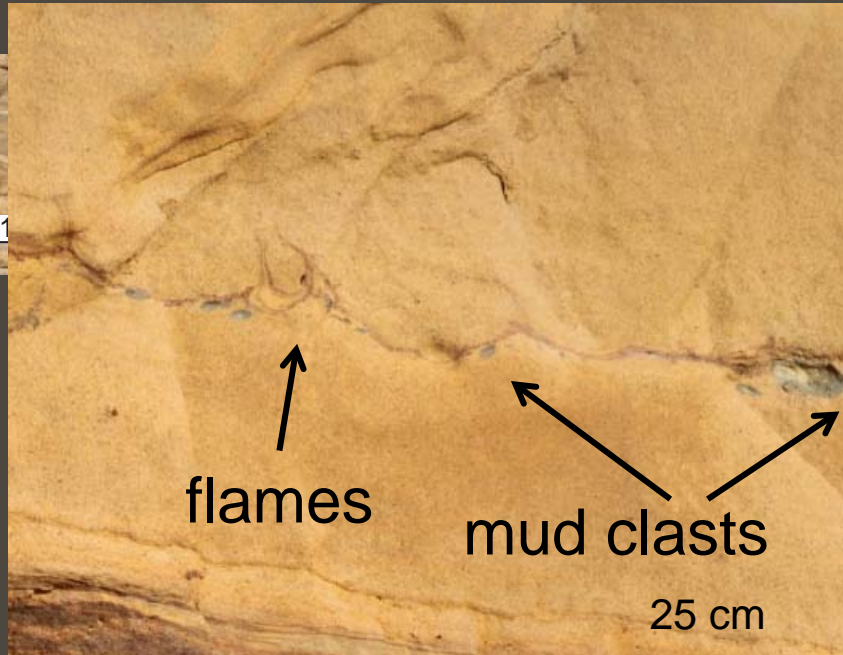
- 1) 2+ kilometers of high resolution, interpreted photopanel
using Gigapan®
 - resolution at the cm-scale



Data and Methods



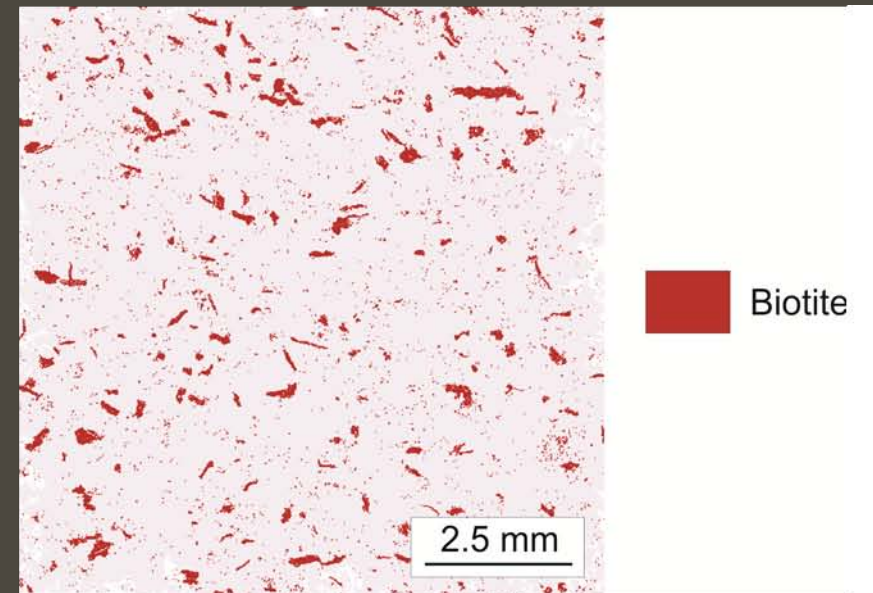
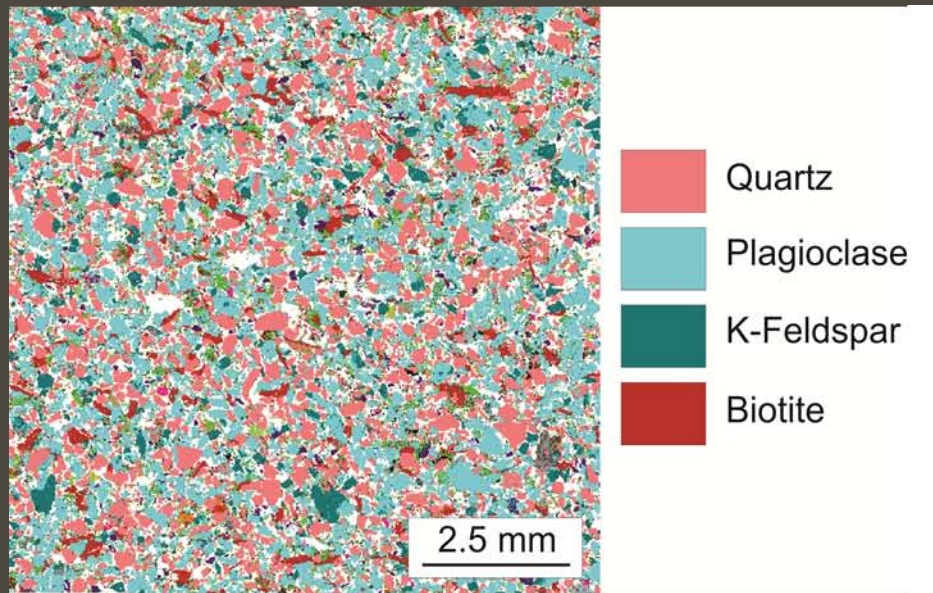
- 1) 2+ kilometers of high resolution, interpreted photopanels using Gigapan®
 - resolution at the cm-scale
- 2) 100 GPS location points
- 3) 7 measured sections documenting structures on the cm-scale
- 4) 40 samples collected from the axis to margin of a single bed
- 5) 14 samples currently analyzed by QEMSCAN



Data and Methods

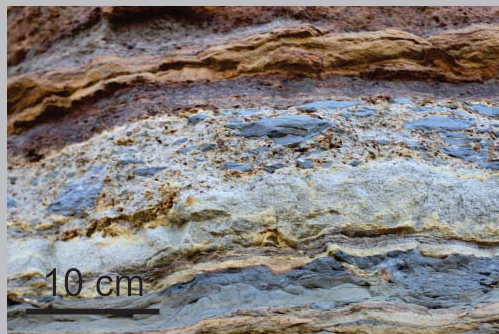
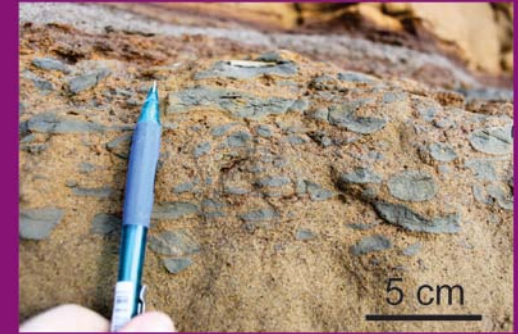
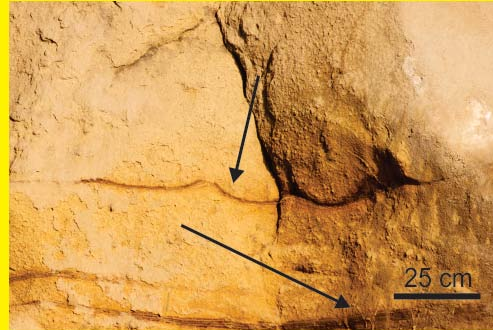


- 1) 2+ kilometers of high resolution, interpreted photopanels using Gigapan®
 - resolution at the cm-scale
- 2) 100 GPS location points
- 3) 7 measured sections documenting structures on the cm-scale
- 4) 40 samples collected from the axis to margin of a single bed
- 5) 14 samples currently analyzed by QEMSCAN
 - Provides modal mineralogy and textural data



Results - Facies

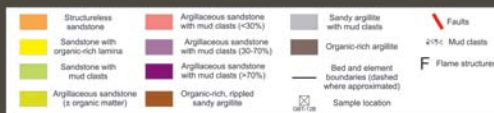
Pronounced and abrupt changes in facies from axis to margin within the bed



Cross - Section



250 M



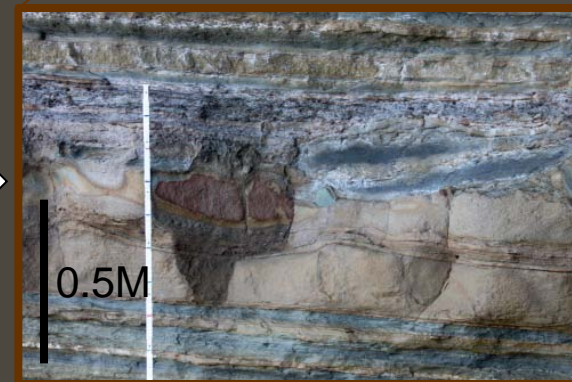
1X

Axis

Off-Axis

Margin

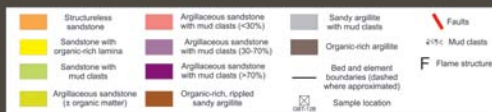
10X



Cross - Section



250 M



1X

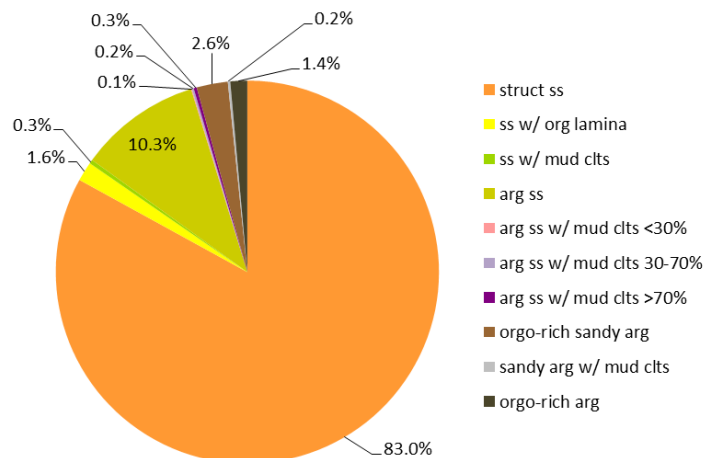
Axis

Off-Axis

Margin

10X

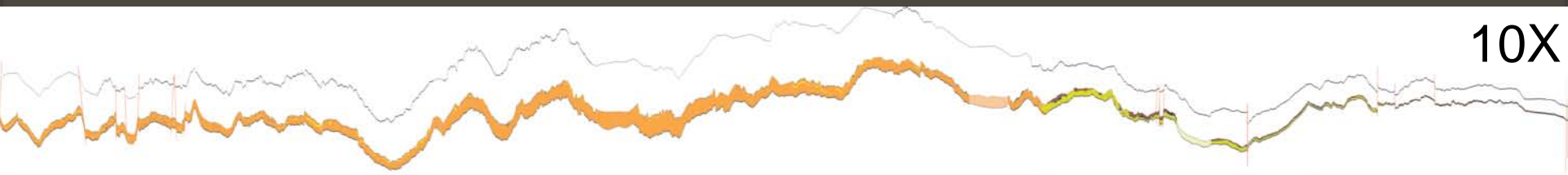
**Goldie Bed - Facies Proportions
Axis to Margin**



Axis Facies



10X



250 M

Axis

Off-Axis

Margin

Clean, Sand-Rich Facies – medium to coarse grain size

Axis Facies



10X



250 M

Axis

Off-Axis

Margin

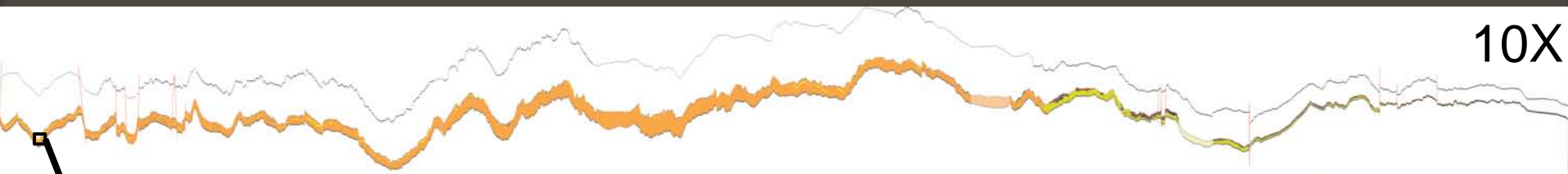
Structureless
sandstone



Axis Facies



10X



250 M

Axis

Off-Axis

Margin

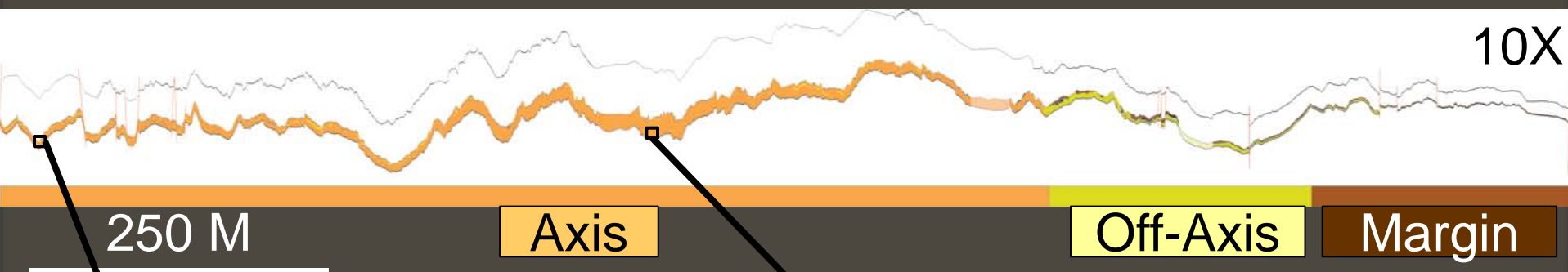
Structureless
sandstone



Axis Facies



10X



Structureless
sandstone



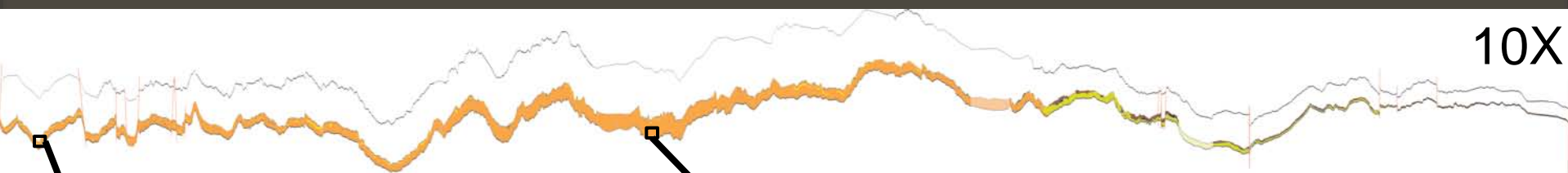
Sandstone with
organic-rich lamina



Axis Facies



10X



250 M

Axis

Off-Axis

Margin

Structureless
sandstone



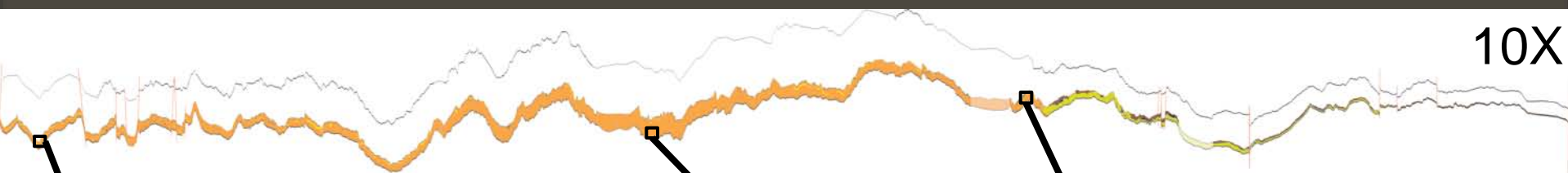
Sandstone with
organic-rich lamina



Axis Facies



10X



250 M

Axis

Off-Axis

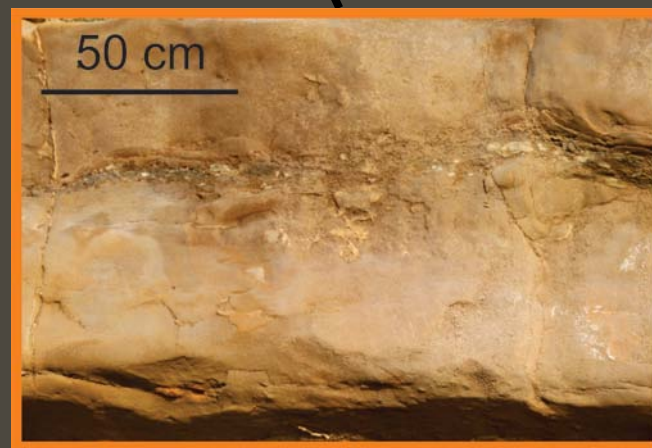
Margin

Structureless
sandstone



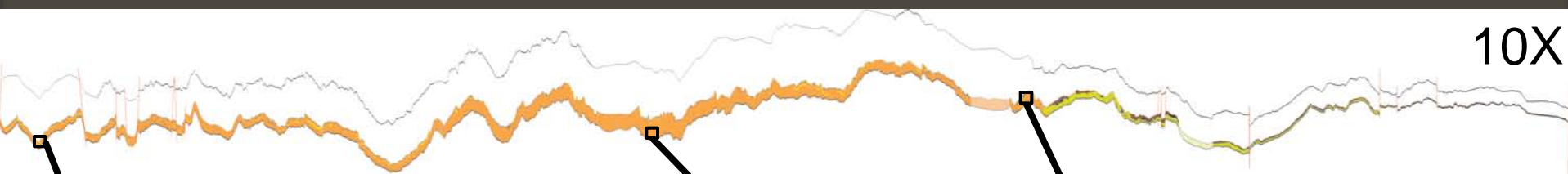
Sandstone with
mud clasts

Sandstone with
organic-rich lamina



Axis Facies

10X



250 M

Axis

Off-Axis

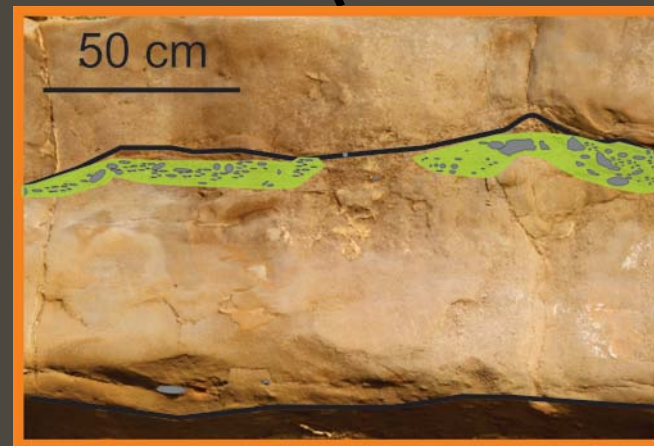
Margin

Structureless
sandstone

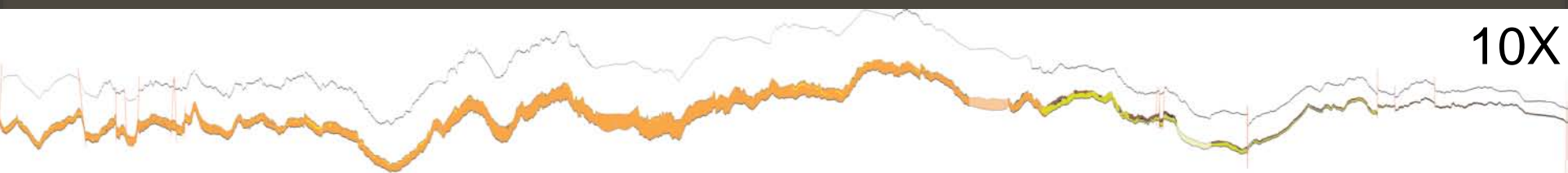


Sandstone with
mud clasts

Sandstone with
organic-rich lamina



Off-Axis Facies



250 M

Axis

Off-Axis

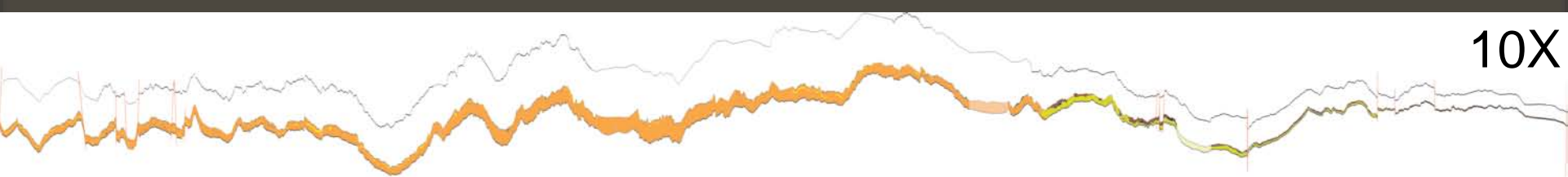
Margin

“Dirtier” sand with organic matter – fine to medium grain size

Off-Axis Facies



10X



Argillaceous sandstone (\pm organic matter)



Argillaceous sandstone with mud clasts (<30%)



Argillaceous sandstone with mud clasts (30-70%)



Argillaceous sandstone with mud clasts (>70%)



Organic-rich, rippled sandy argillite

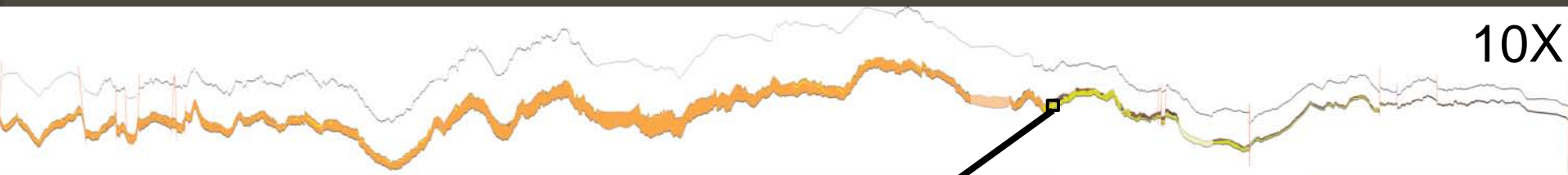


Organic-rich argillite

Off-Axis Facies



10X



250 M

Axis

Off-Axis

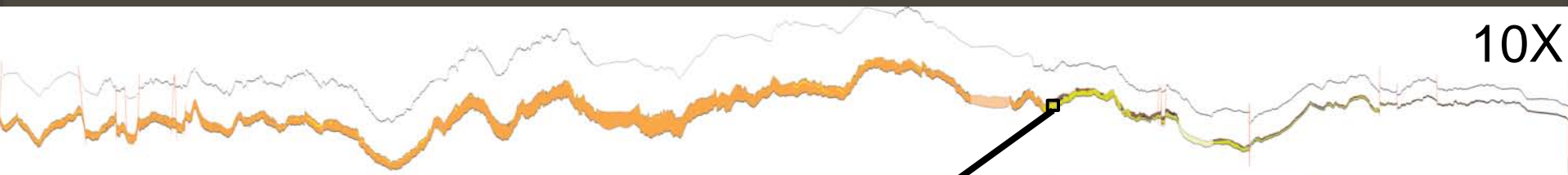
Margin



Off-Axis Facies



10X

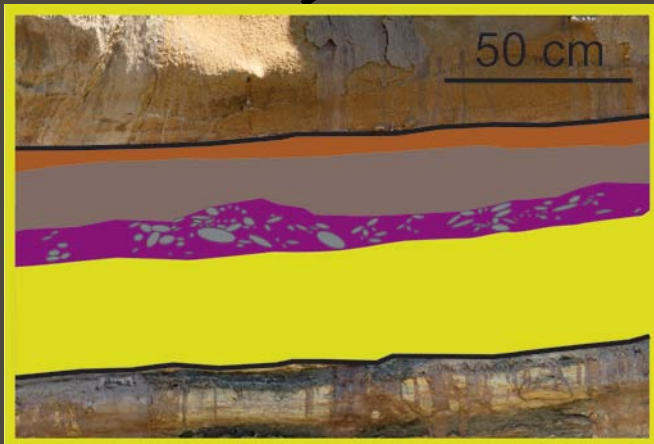


250 M

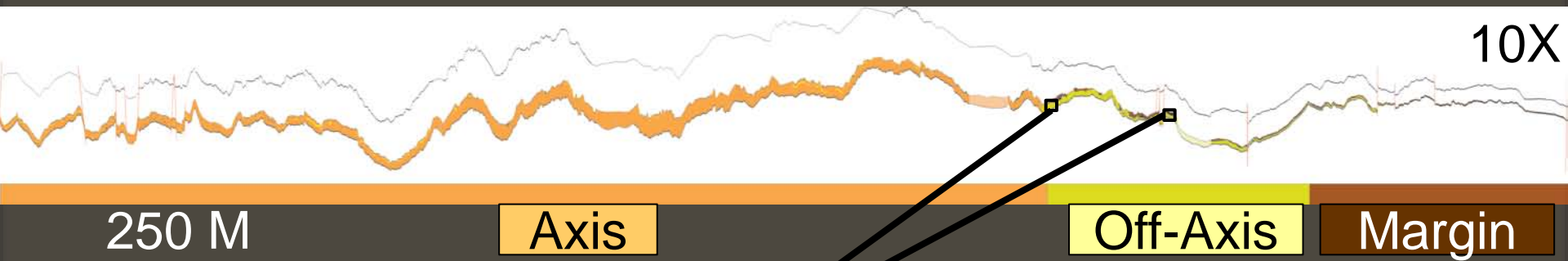
Axis

Off-Axis

Margin



Off-Axis Facies



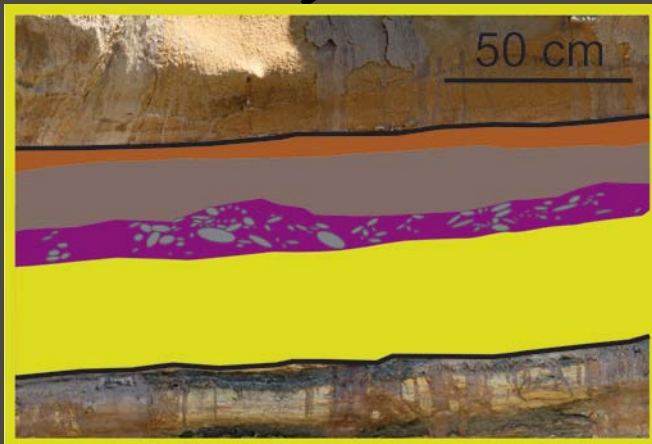
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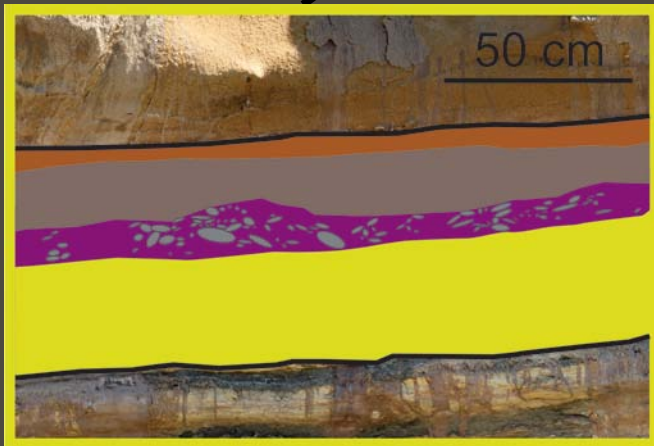
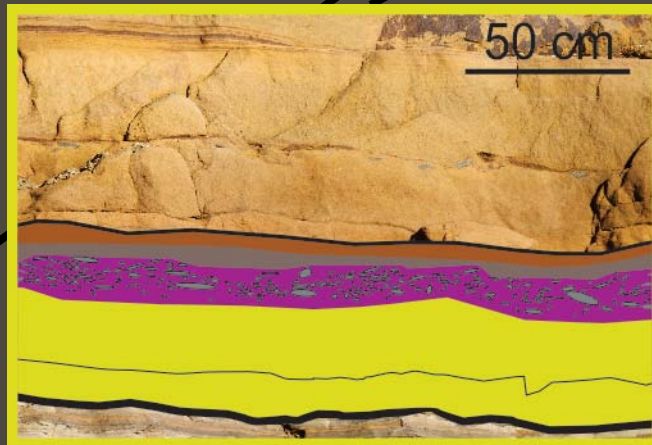
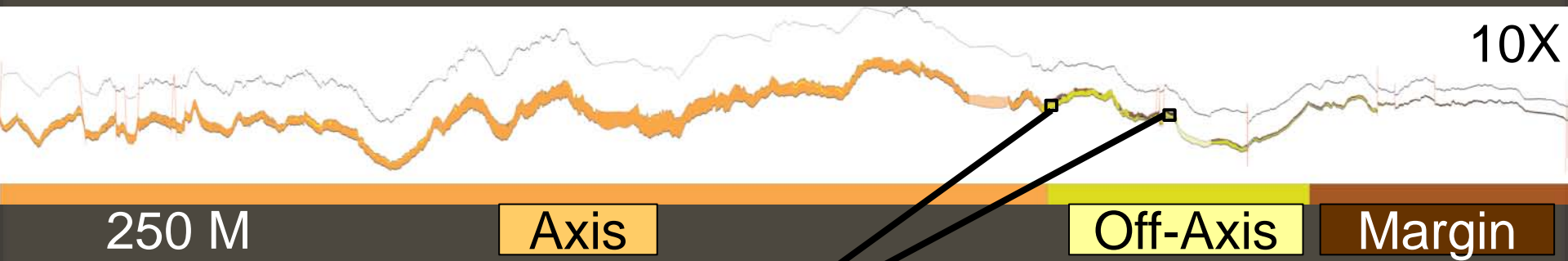
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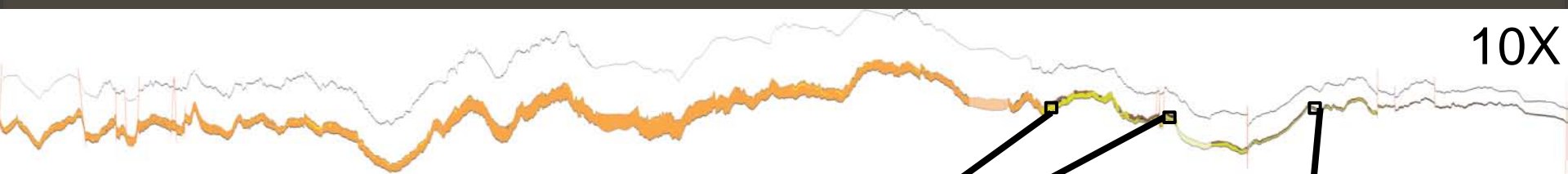
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Off-Axis Facies



Off-Axis Facies

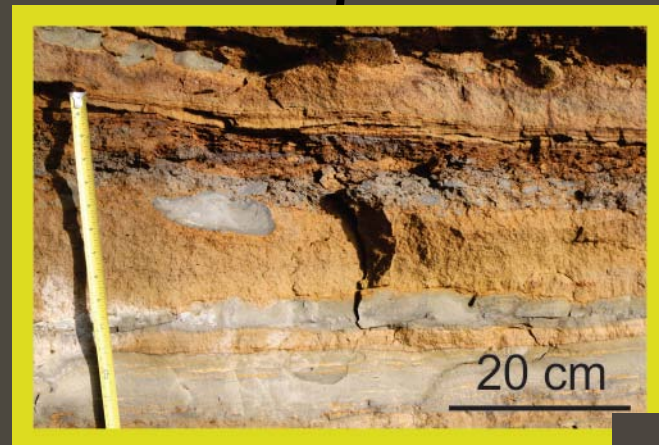
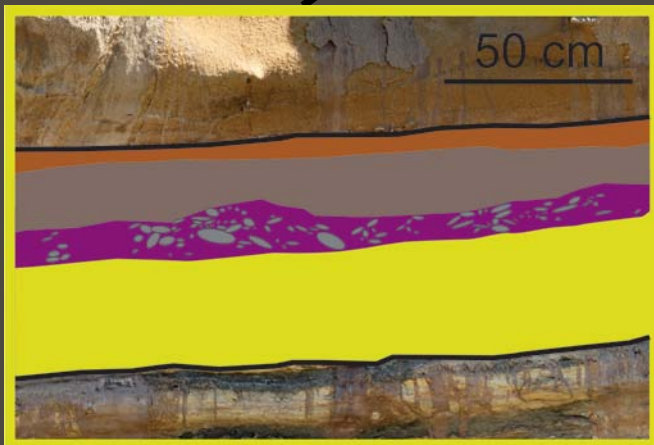
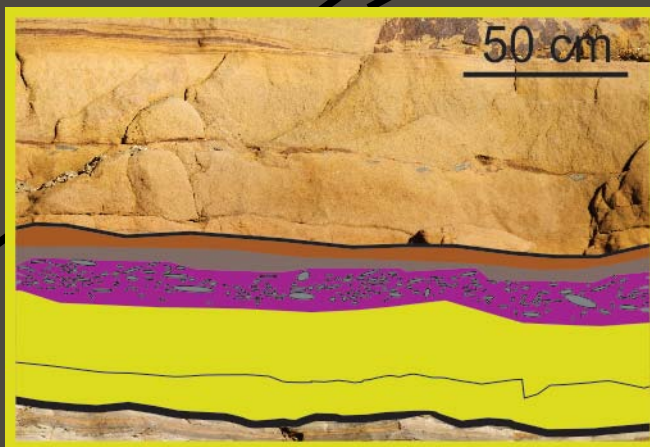


250 M

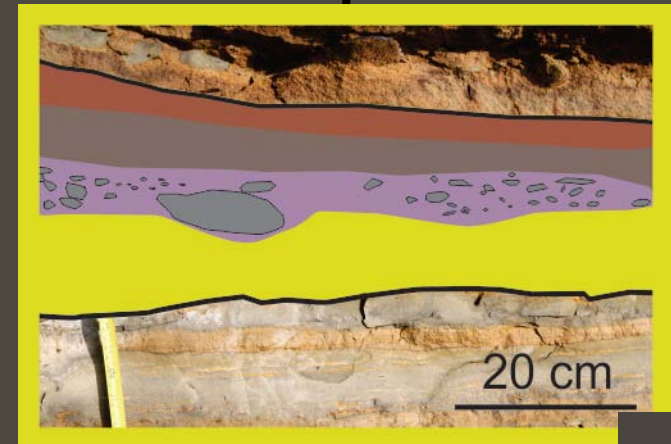
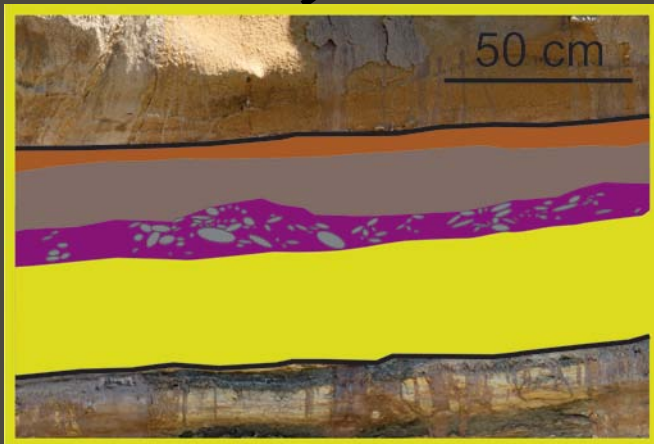
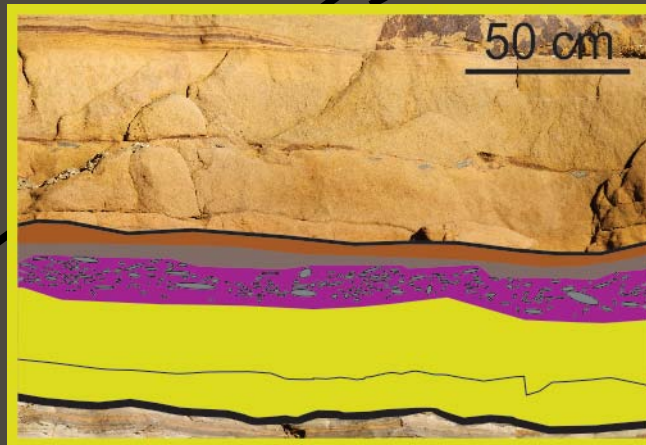
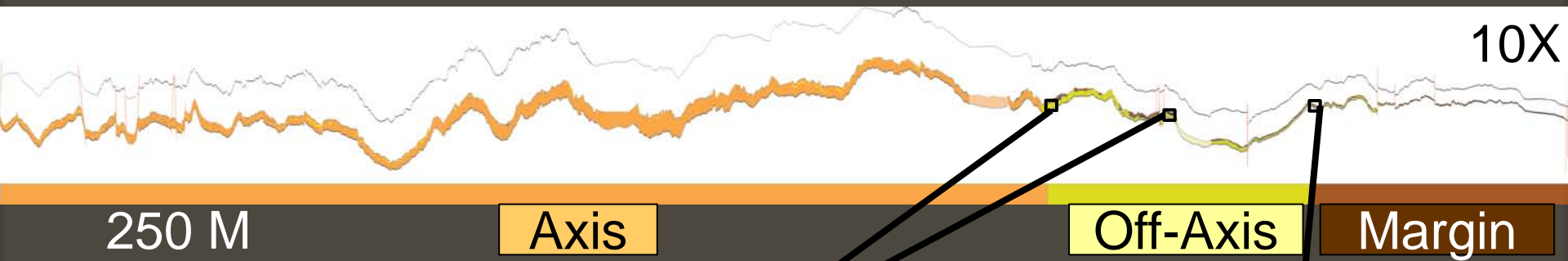
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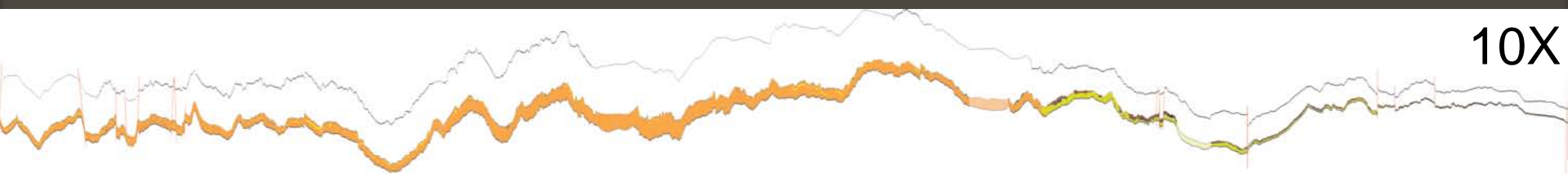
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Off-Axis Facies



Margin Facies



10X

250 M

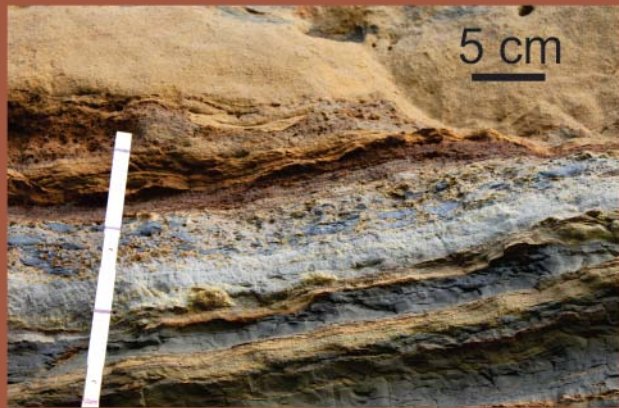
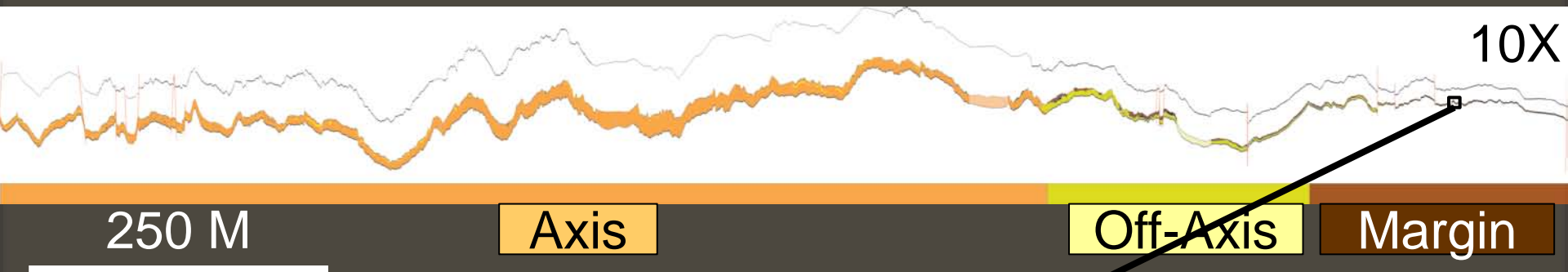
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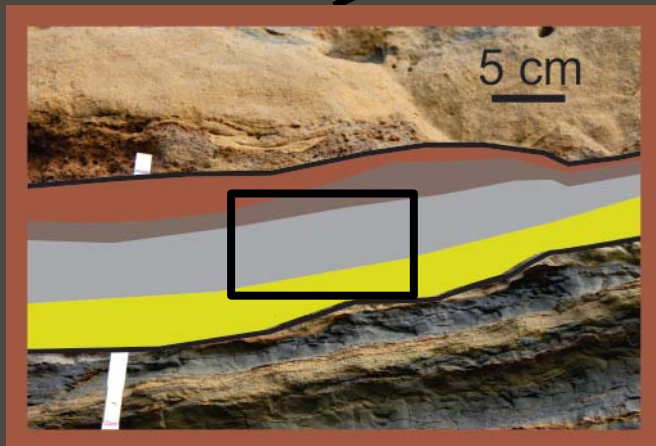
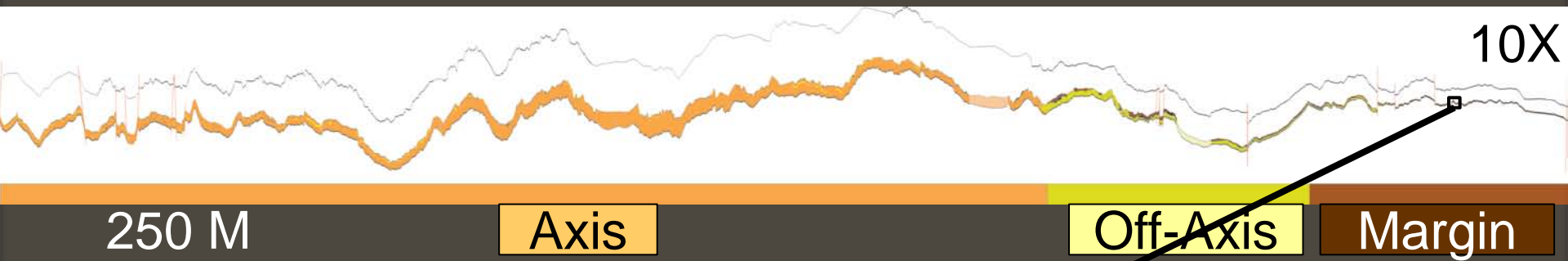
Margin

Clay- and organic-rich sand – clay to fine sand grain size

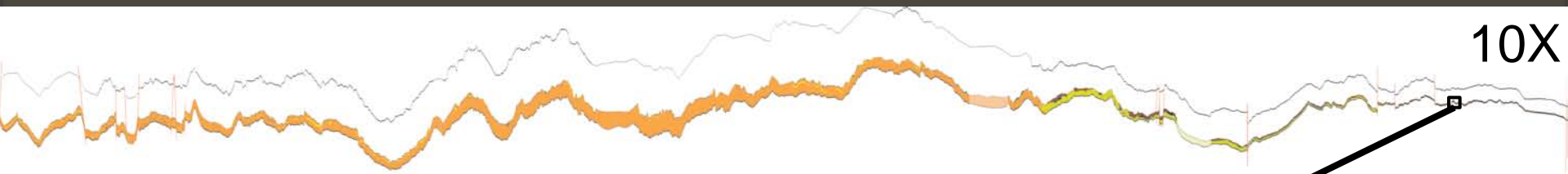
Margin Facies



Margin Facies



Margin Facies

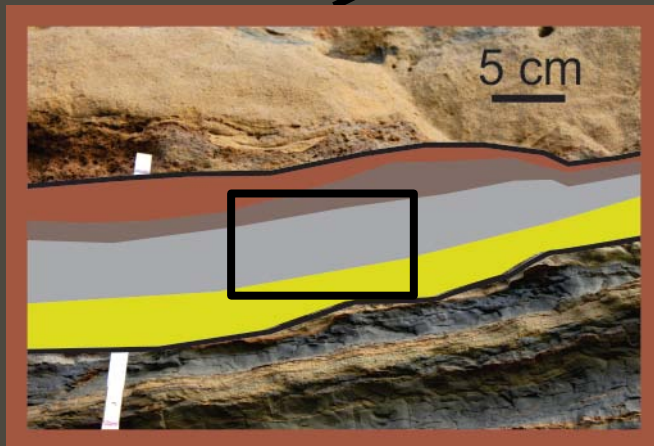
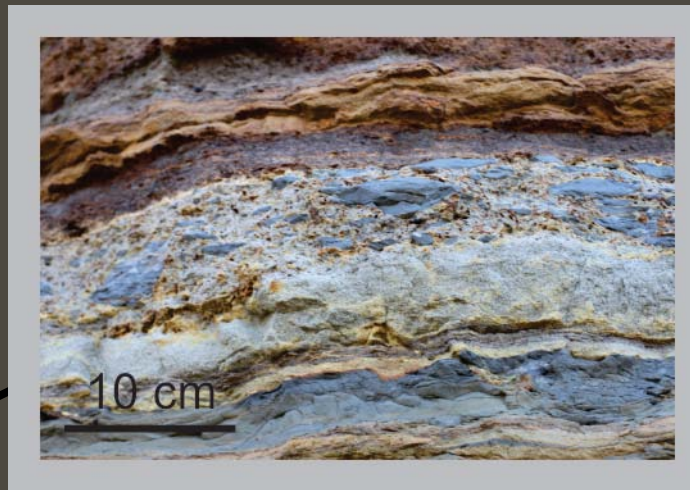


250 M

Axis

Off-Axis

Margin



Margin Facies

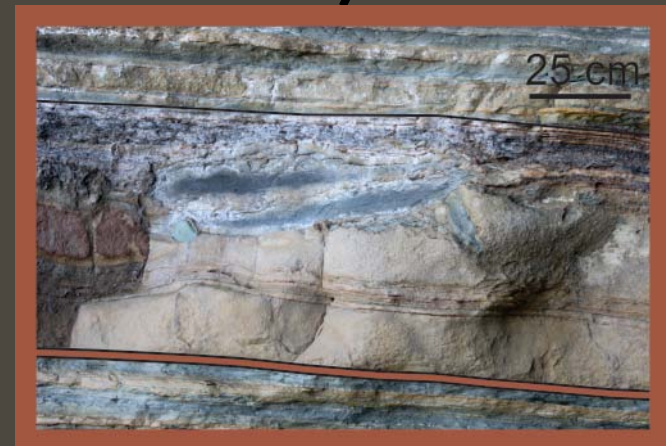
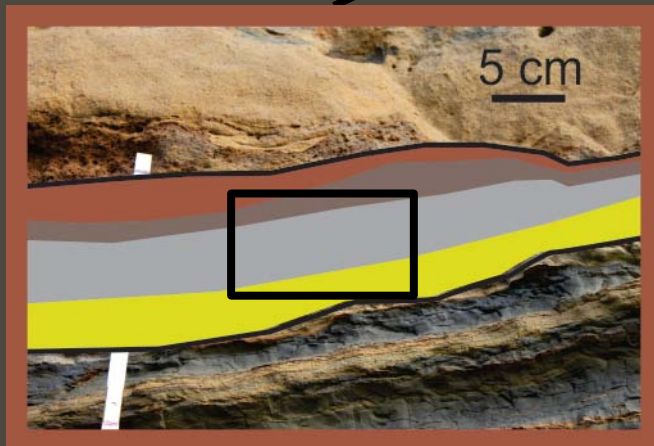
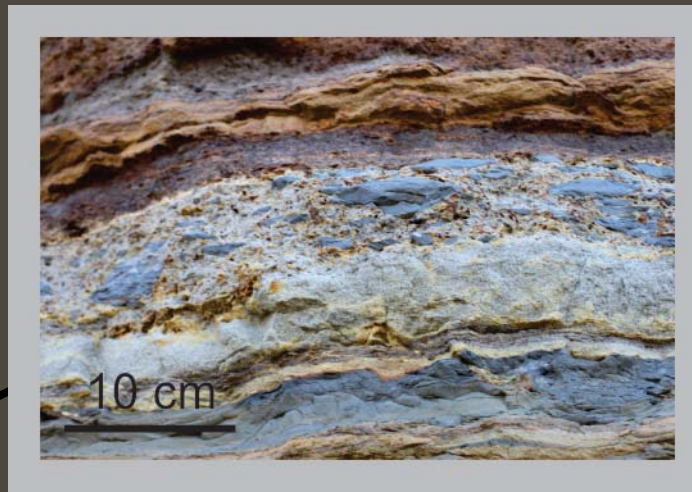


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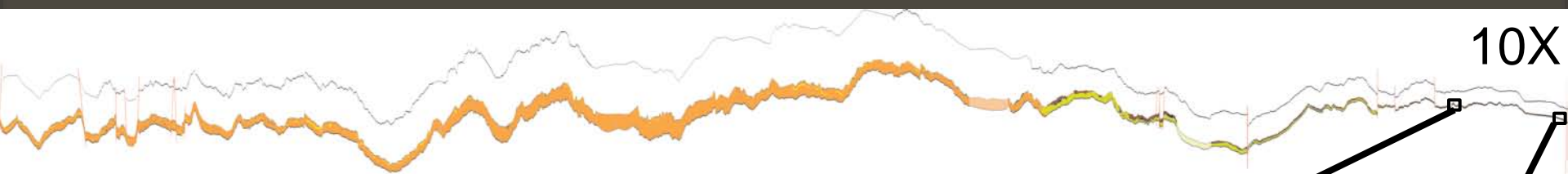
Axis

Off-Axis

Margin



Margin Facies

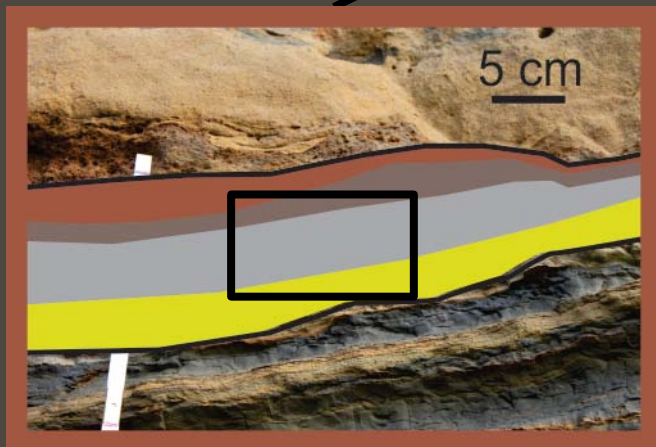
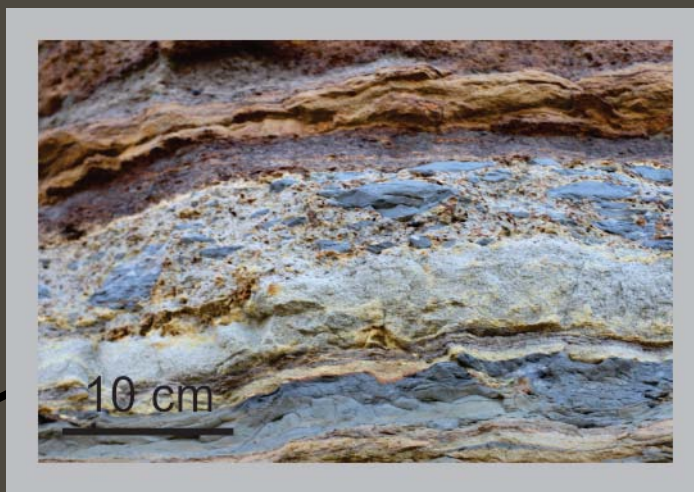


250 M

Axis

Off-Axis

Margin



Facies Proportions



10X

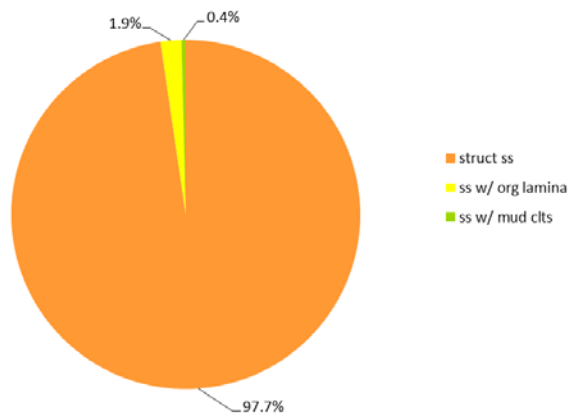
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Axis

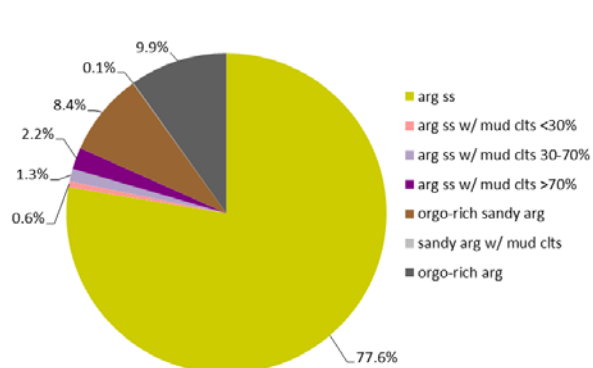
Off-Axis

Margin

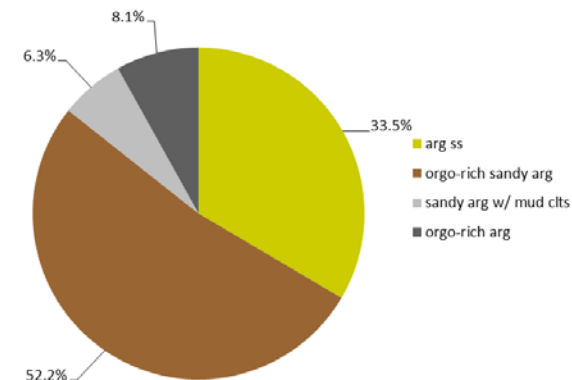
Goldie Bed - Facies Proportions
Axis



Goldie Bed - Facies Proportions
Off-Axis



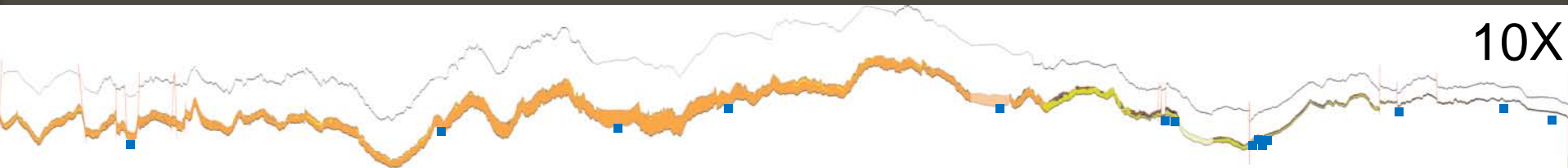
Goldie Bed - Facies Proportions
Margin



Mineralogy



10X

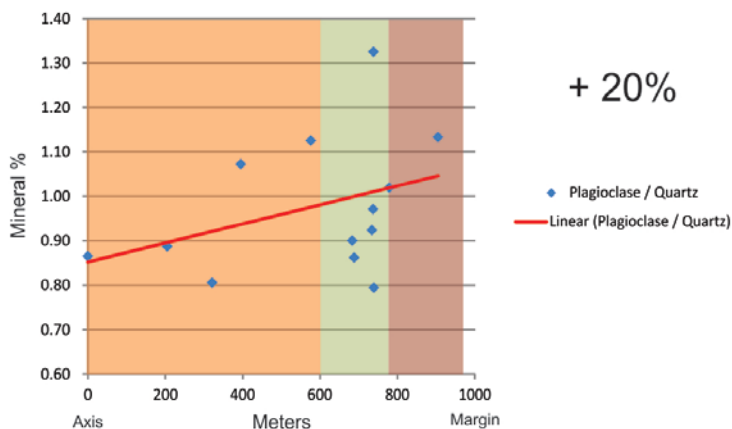


Axis

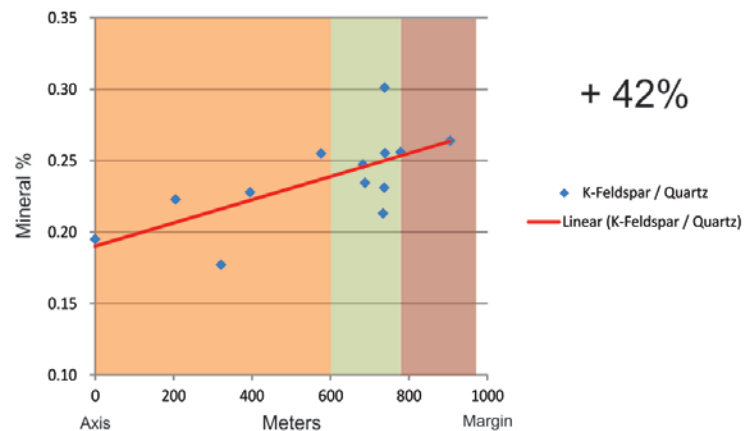
Off-Axis

Margin

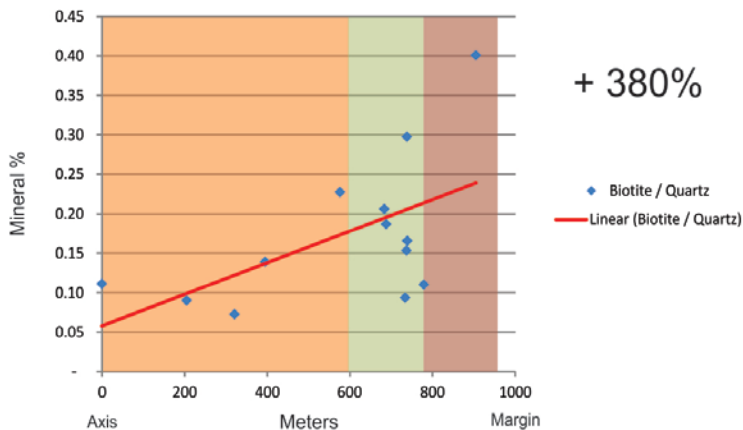
Plagioclase / Quartz



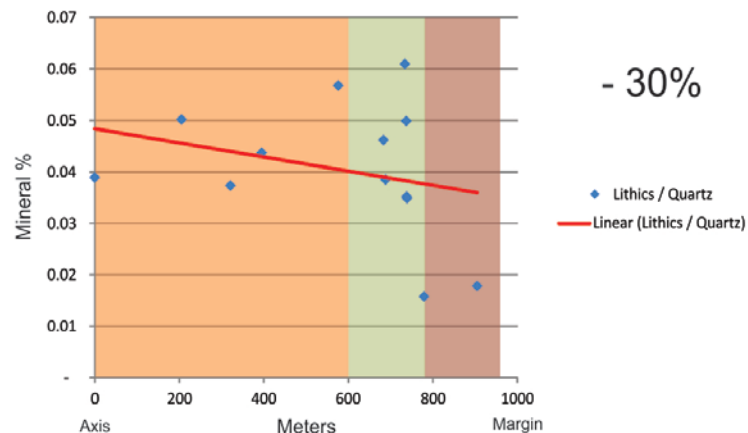
K-Feldspar / Quartz

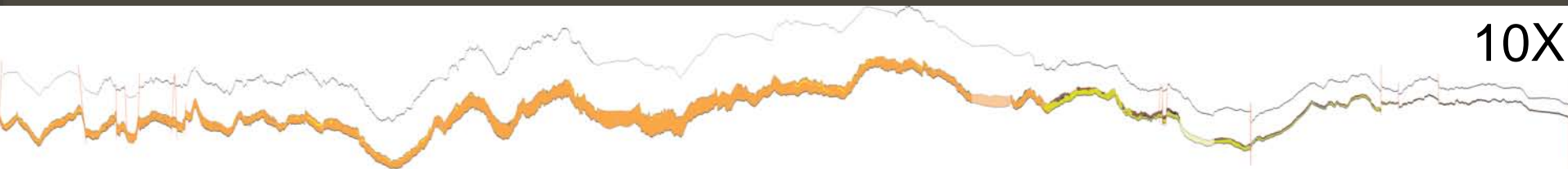


Biotite / Quartz



Pyroxene / Quartz





Axis

Off-Axis

Margin

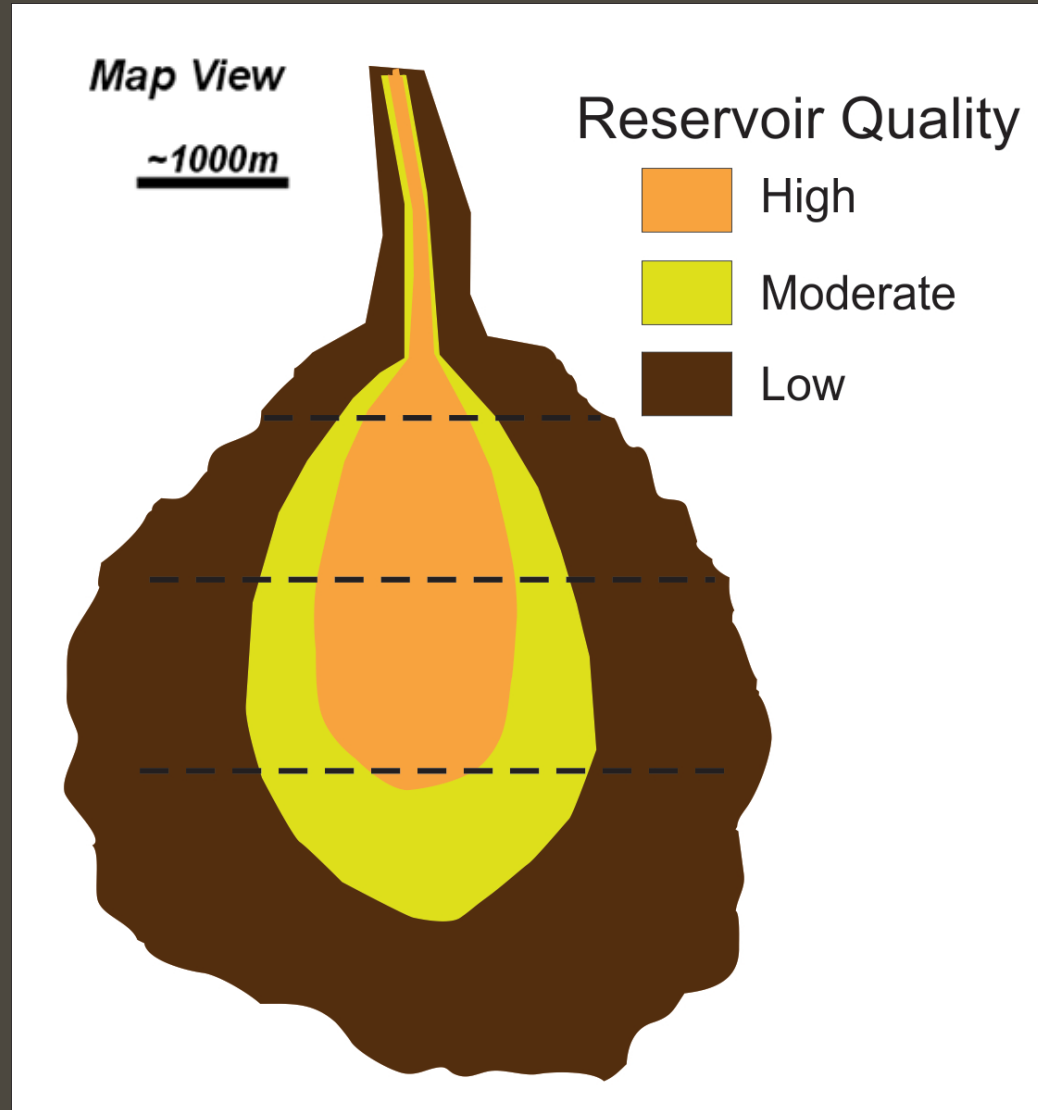
- Mineral proportions change laterally
- The data support fractionation of minerals by density and shape
- Future work will analyze the grain size distribution of each mineral with respect to shape and density

Summary

From axis to margin within a single bed:

Clean, structureless sand, amalgamated sand, grain size, quartz, pyroxene

Organic matter, mud and mud clasts, argillaceous sand, K-feldspar, plagioclase, biotite

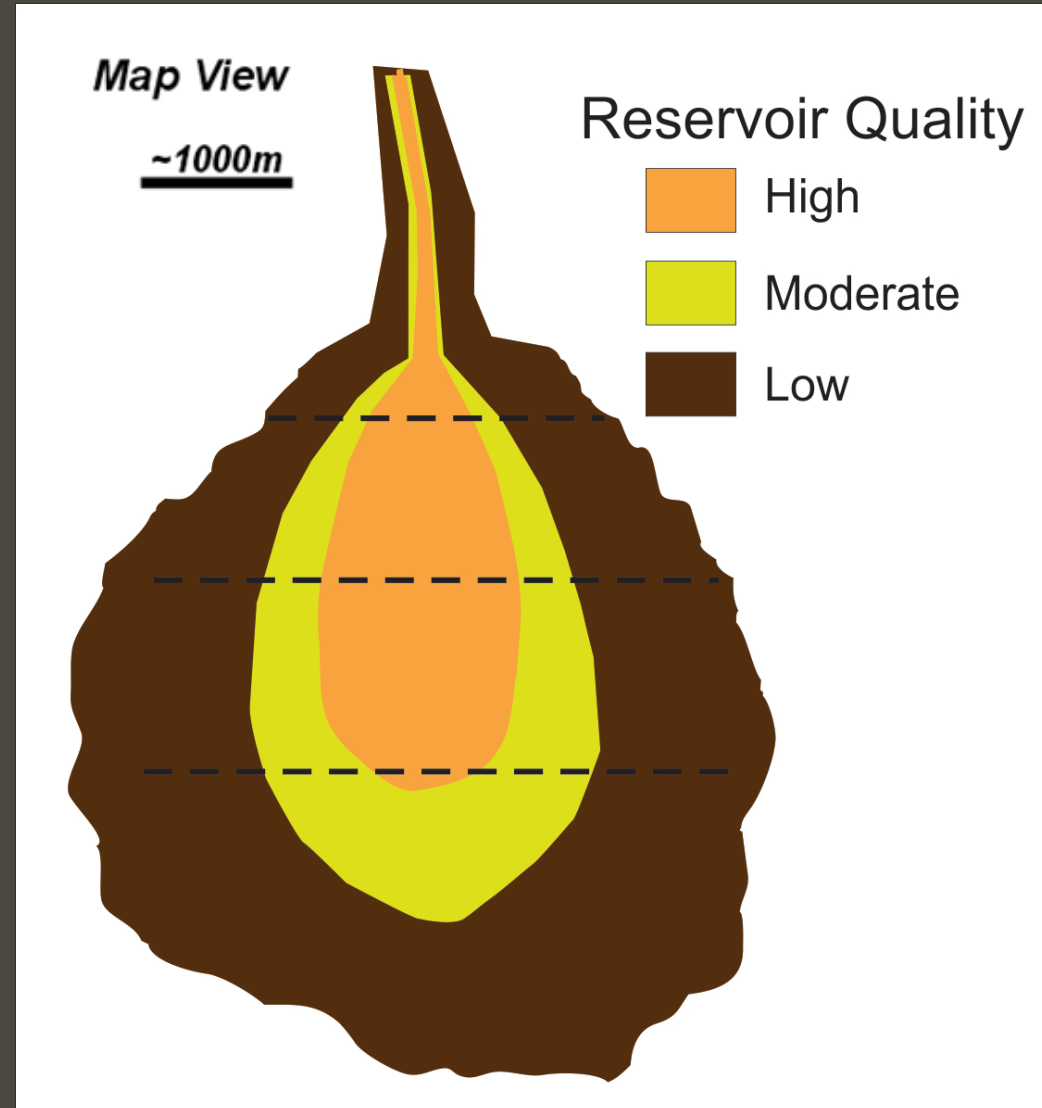


Summary

From axis to margin within a single bed:

Future work:

1. Hierarchical sampling – beds build elements that build lobes
2. Spatial sampling – lobes have proximal, medial, and distal locations
3. 3D tank experiment – testing fractionation of minerals by shape and density



Thank you

