# Stratigraphic Architecture of a Prograding Shelf-Margin Delta in Outcrop, Sobrarbe Formation, Ainsa Basin, Spain*

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## Abstract

The Sobrarbe Formation, Ainsa Basin, Spain, contains multiple, prograding, condensed-section bound, stratigraphic cycles of a linked, shelf-slope-basinal positioned system. The Sobrarbe is an outcrop analog to prograding, shallow-marine to deepwater systems such as the West Siberian Basin, NW slope Australia, and Sakhalin Island. Because of the extent of the exposure, the physiographic profile is apparent, as is the position of the delta at the shelf edge. The goal of this study is to:

- use observation in outcrop to reduce risk in subsurface interpretation and
- constrain the timing of deepwater sedimentation in prograding systems.

This study focuses on fluvial-deltaic strata from one condensed section bound cycle/parasequence. Data consists of measured sections, paleocurrents, strike and dips, mapped key surfaces and sand bodies and sand body dimensions.

Fluvial strata consists of high aspect ratio channel belts with associated crevasse splays and well developed paleosols with few wood fragments and no coal seams. Grain size inside the channels range from fine sand to cobbles, whereas outside channel strata is composed of clay and silt. The channel belts are offset and rarely cannibalize one another, except crevasse splays. Deltaic deposits are physiographically located at the shelf margin. These strata contain mouth-bar deposits consisting of inclined bedding of bioturbated, very-fine to fine-grained sand. These bars contain erosional surfaces lined by debrites. In the upper-slope system, there is a dense occurrence of highly-amalgamated, vertically-stacked, turbidite channels that downcut into mouth-bar foresets. Siltstone forms

background slope strata outside the channels, while the dominant grain size in the channels is very-coarse sand in association with mudclast conglomerate occurring locally at the base of channel stories.

The transition from entirely fluvial to entirely deltaic at the shelf break occurs over a distance of 3 km, reflecting the length of the very narrow shelf. Over the same distance, grain-size reduces from conglomerates in the fluvial point bars to dominantly very fine to fine sand in the mouth bars. The intra-mouth bar erosional surfaces are highly continuous within one parasequence and connect fluvial channels to coeval slope channels. These slope channels in turn feed base-of-slope fans. This relationship is interpreted to reflect coeval deposition across the physiographic profile as the parasequence prograded basinward.

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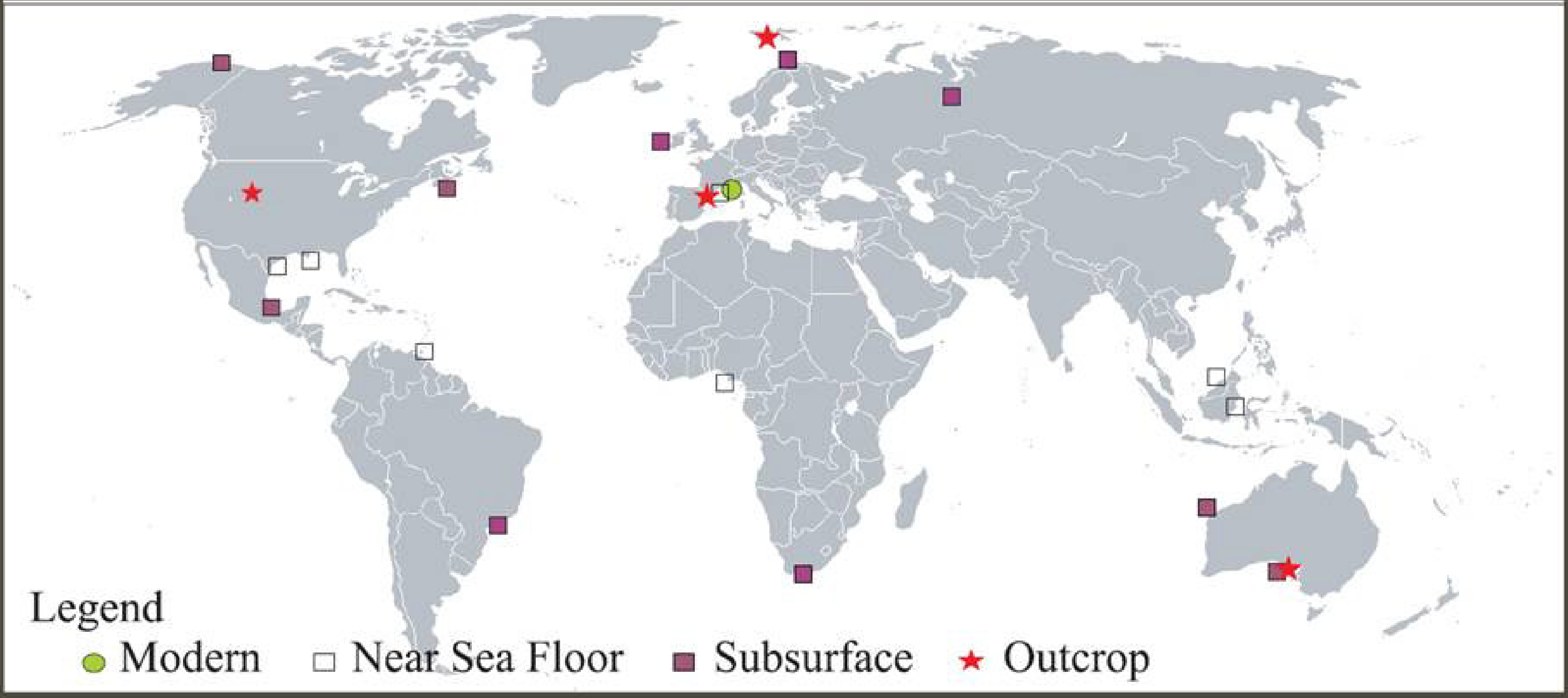
# Problem

- Significance:
  - Common reservoir
  - Limited database
  - Few outcrop analogs
- Problem:
  - -The internal architecture and facies distribution is unknown



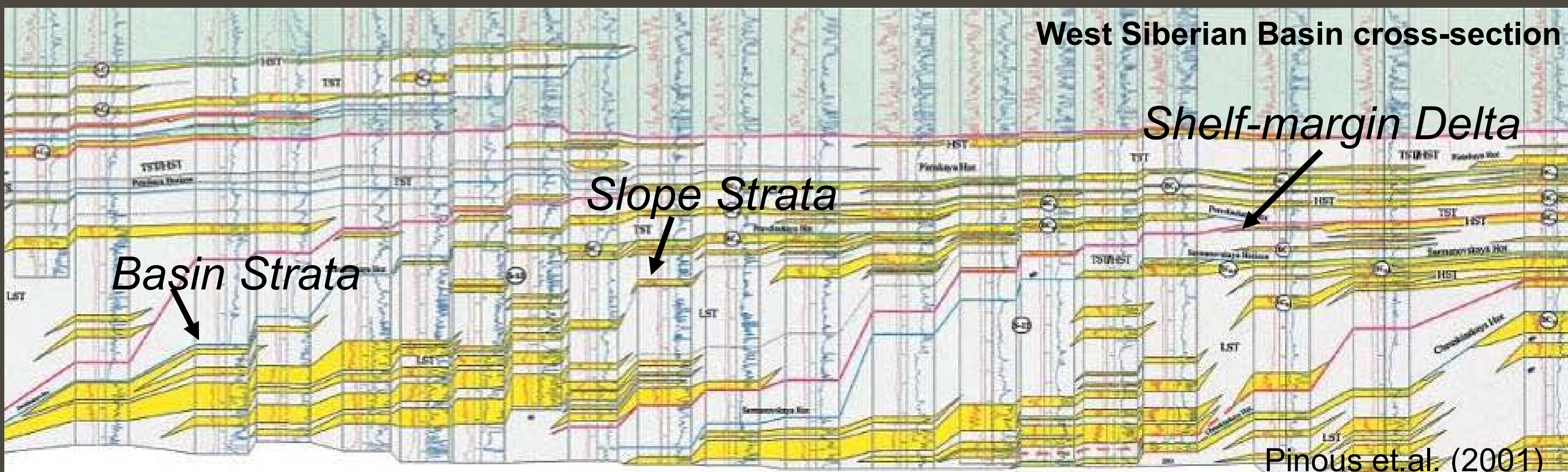


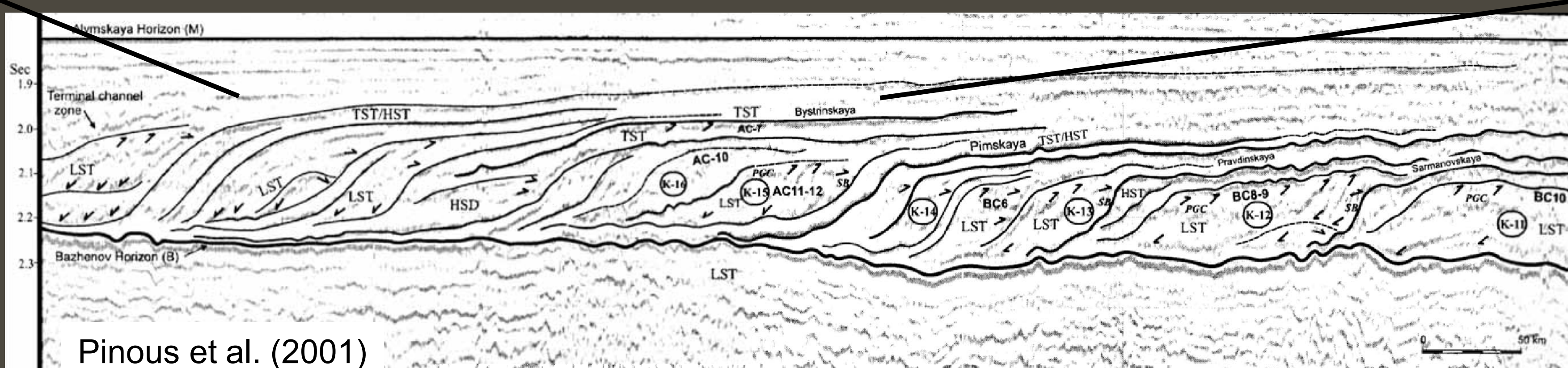

Notes by Presenter: How is risk reduced when exploring or producing from these systems?

# Problem

## West Siberian Basin

- Prograding, turbidite built clinoforms
- Coeval deposition from shelf margin to basin



# Objectives

What is the sub-seismic character of a prograding shelf-margin delta system?

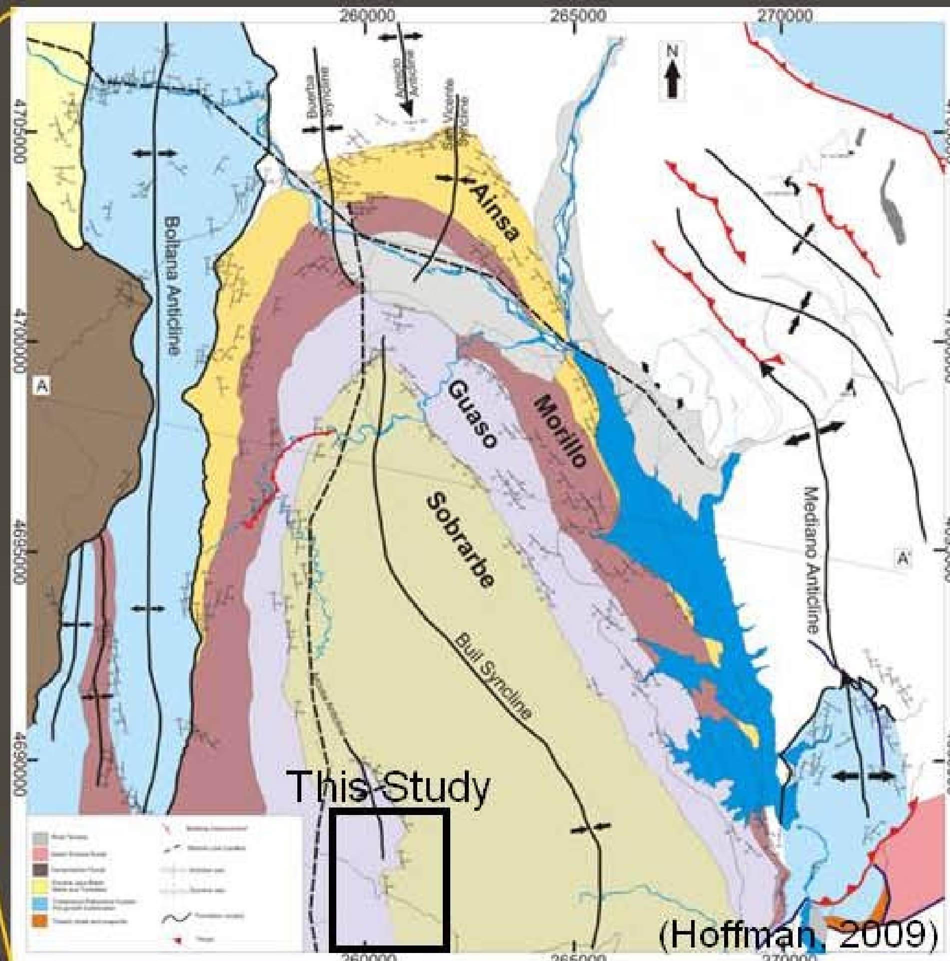
1) Regressive
2) Transgressive
3) Contrasting transgressive and regressive intervals
   - Architectural elements
   - Facies
   - Net to gross
   - Grain-size distribution
   - Channel Aspect Ratio



Notes by Presenter: An outcrop analog is used to understand subseismic attributes. My thesis also focuses on the timing and processes of delivering sediment to deepwater, but for the sake of time today I will focus on architectural elements and a few facies of shelf-margin deltas and then move up to large scale packaging and the timing of progradation of shelf deltas to the shelf margin.

# Introduction

## Sobrabre Fm., Ainsa Basin, Northern Spain

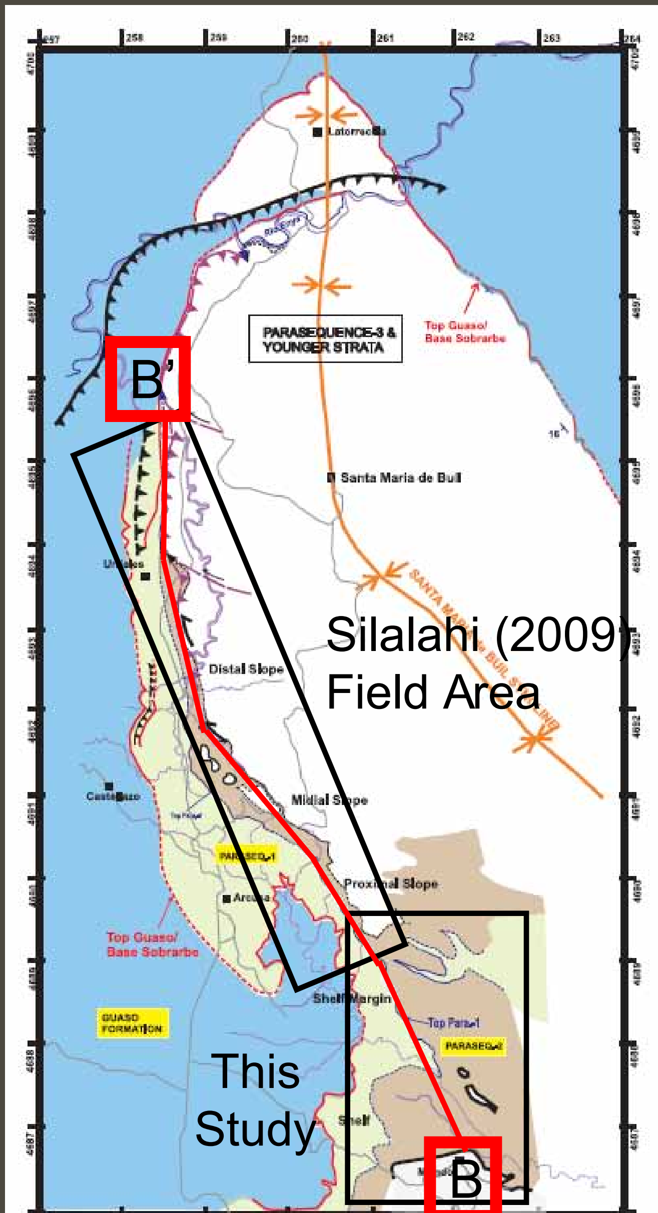




- The Eocene Sobrarbe delta prograded into the deepwater Ainsa Basin
- Coeval fluvial-deltaic to deepwater deposition

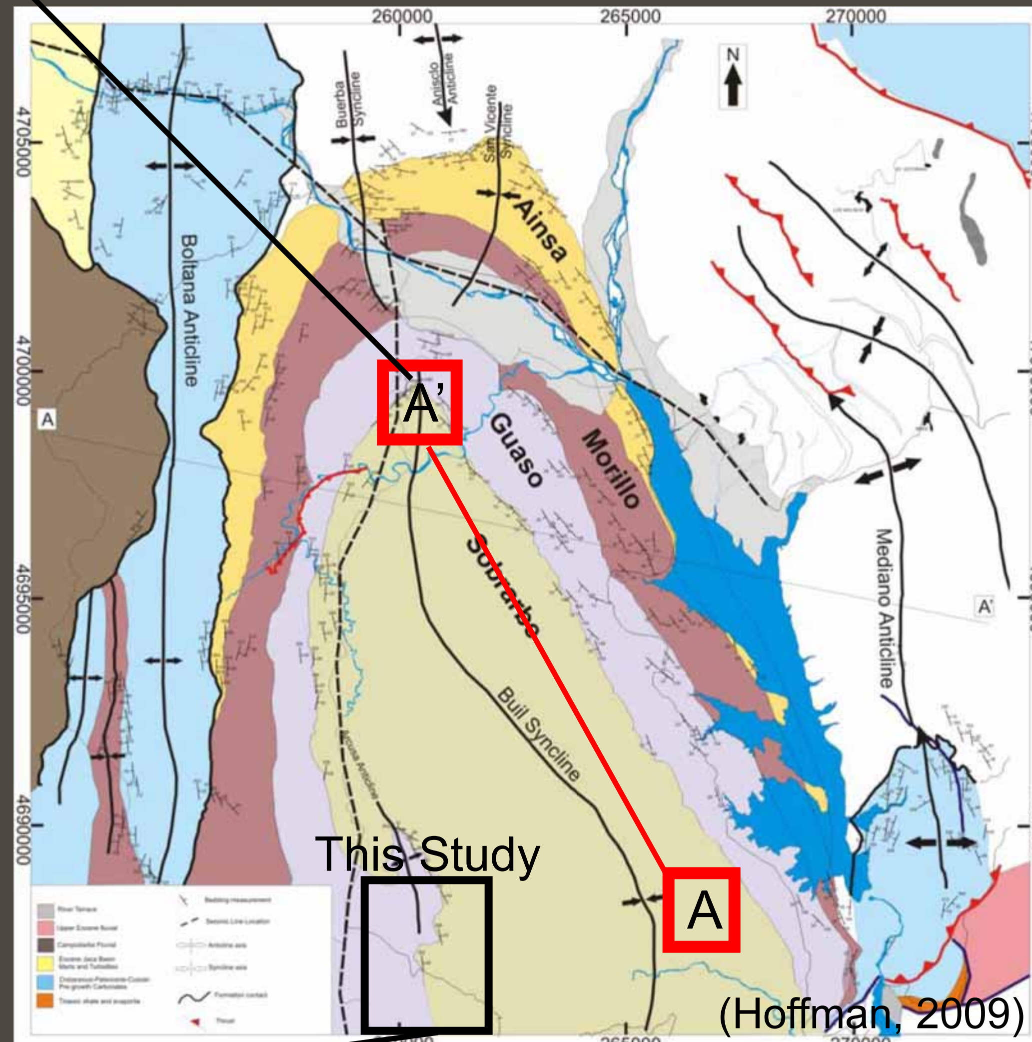


Notes by Presenter: Youngest Eocene fill
Shallow water deposition prograding over deepwater systems

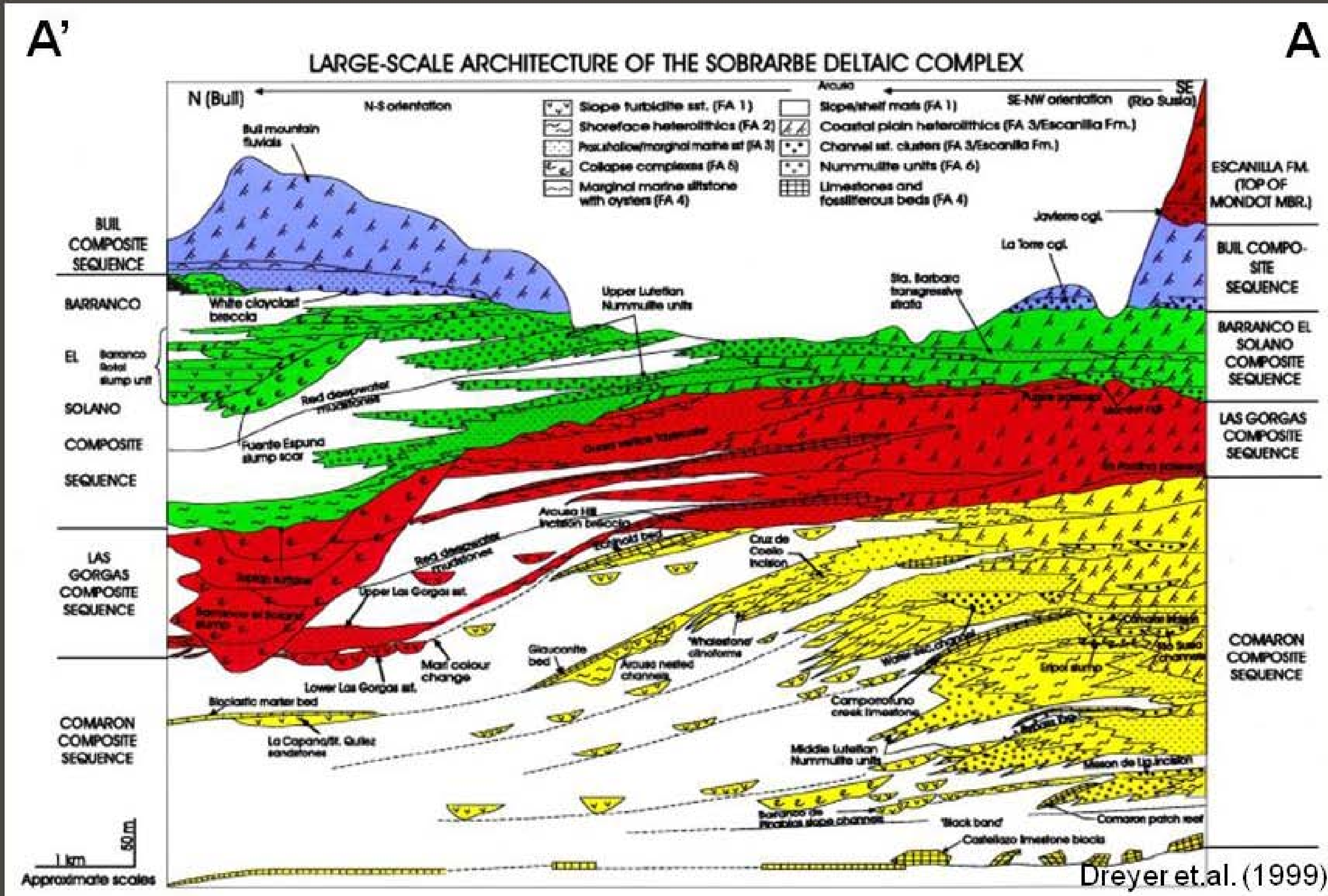
# Introduction




Moss-Russell (2009), Silalahi (2009)



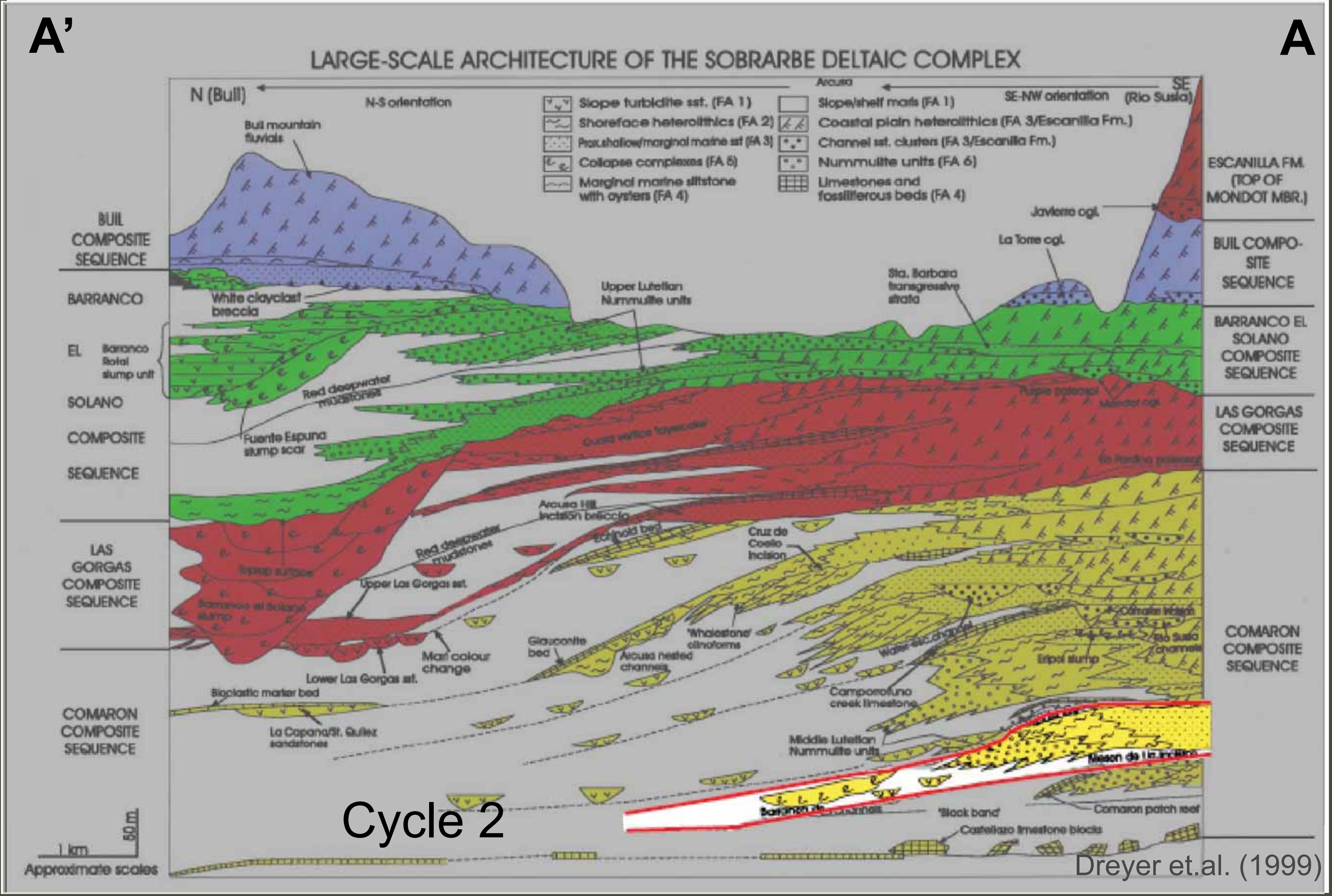
# Introduction



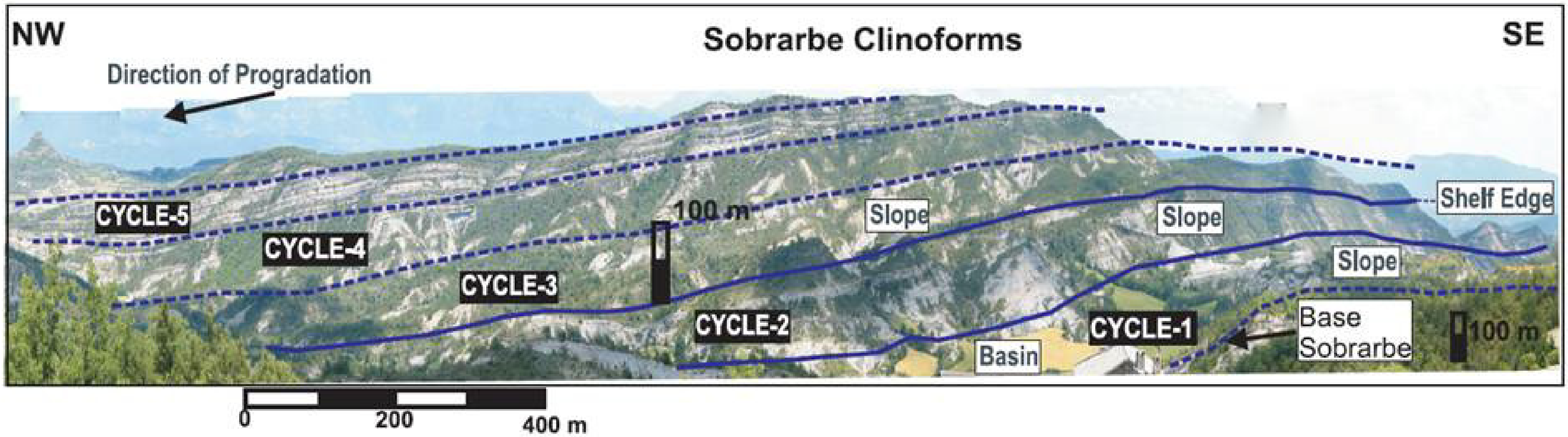


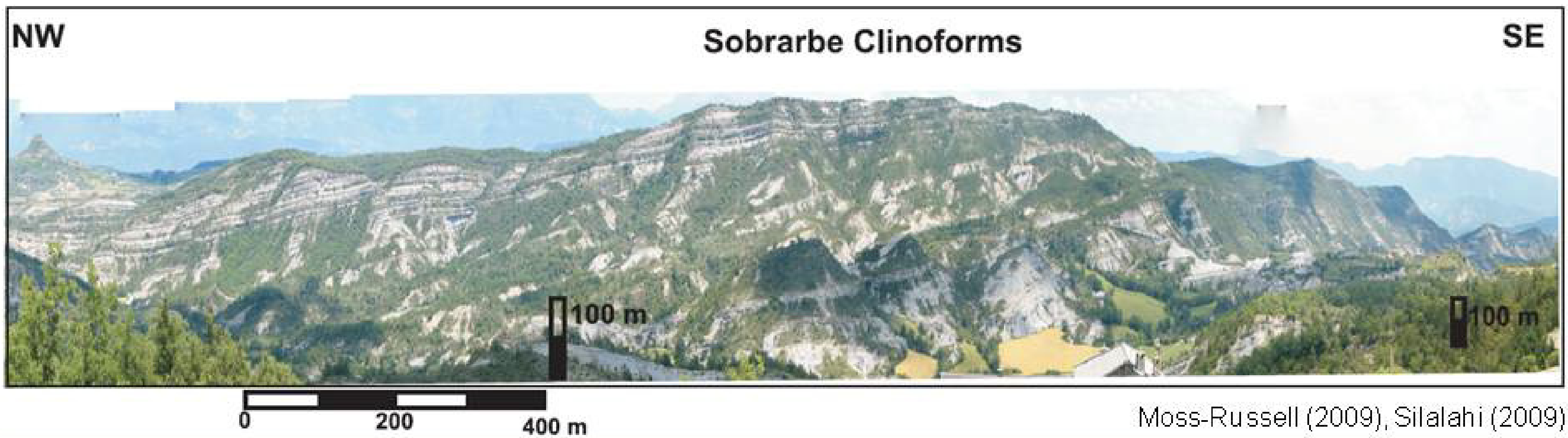

Notes by Presenter: From this cross-section cartoon of Dreyer et al (1999) you can see several prograding, condensed section bound cycles. This study and presentation focuses on the best exposed cycle, number 2.

# Introduction



# Introduction




Moss-Russell (2009), Silalahi (2009)



Notes by Presenter: Paleocurrents generally show a north direction meaning the exposure is almost a perfect dip panel.

# Introduction

Sobrarbe cycle 2

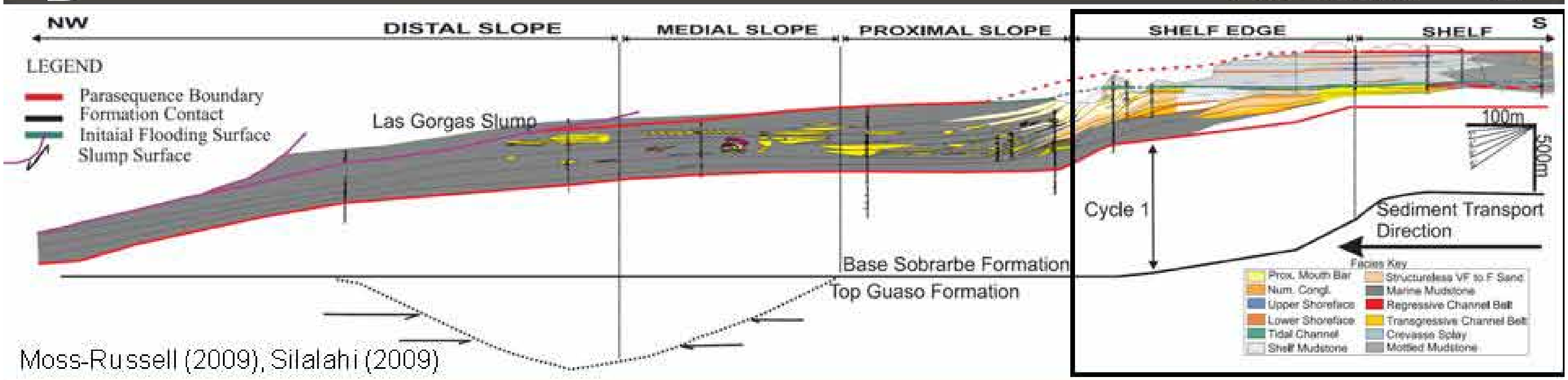
- Sediment transport to the left
- Demonstrates continuous outcrop
- Internal structure well exposed even on photo panels

N ← Direction of Progradation S

# Introduction

## Sobrarbe Cycle 2 Cross-Section

B' This Study B

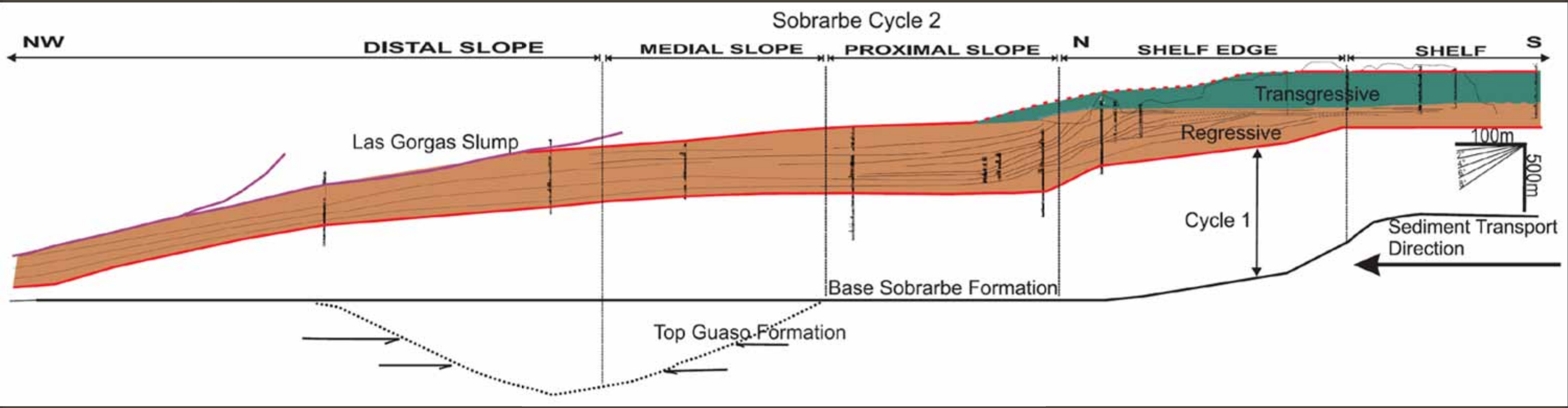





Notes by Presenter: Strike-view variation and system evolution. Continuous exposure. Water depth: about 288m (945 ft)

# Introduction

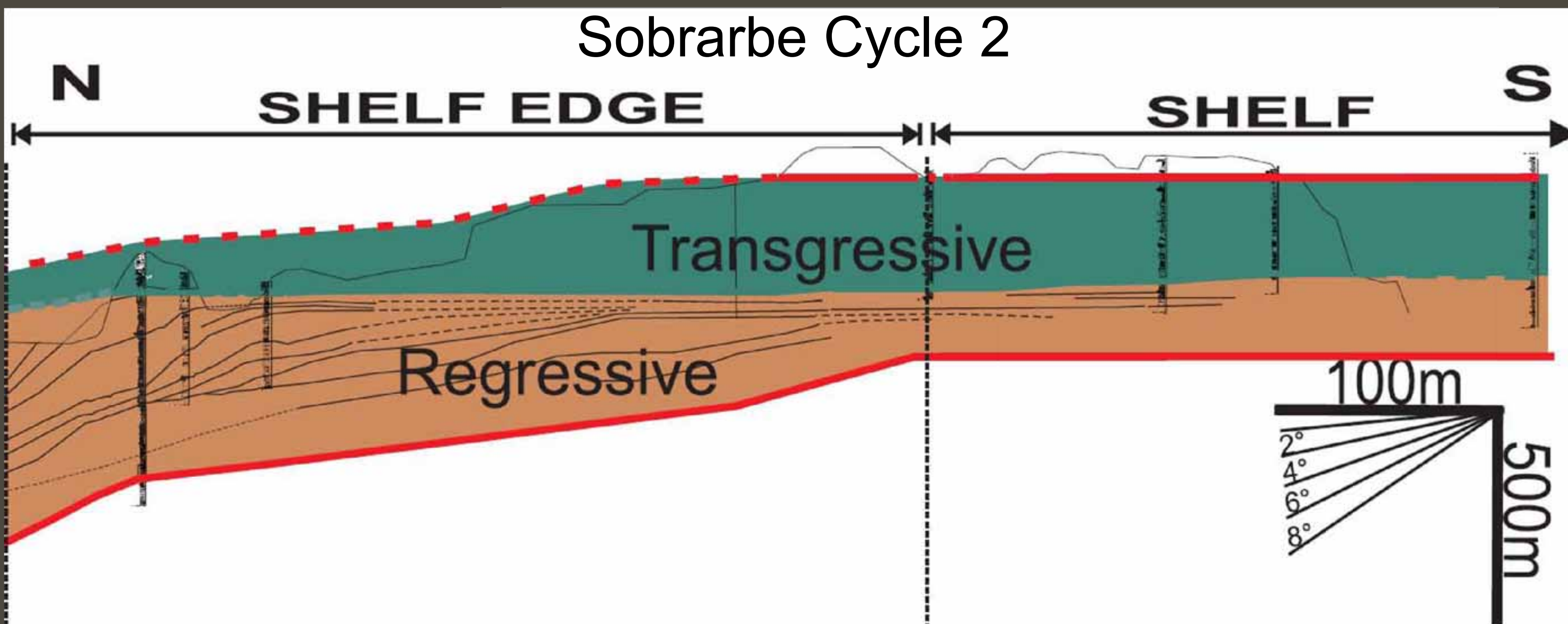
- Outcropping cycle 2 cross-sectional area
  - Transgressive 0.87 km$^2$ (18.4%)
  - Regressive 3.85 km$^2$ (81.6%)



# Introduction

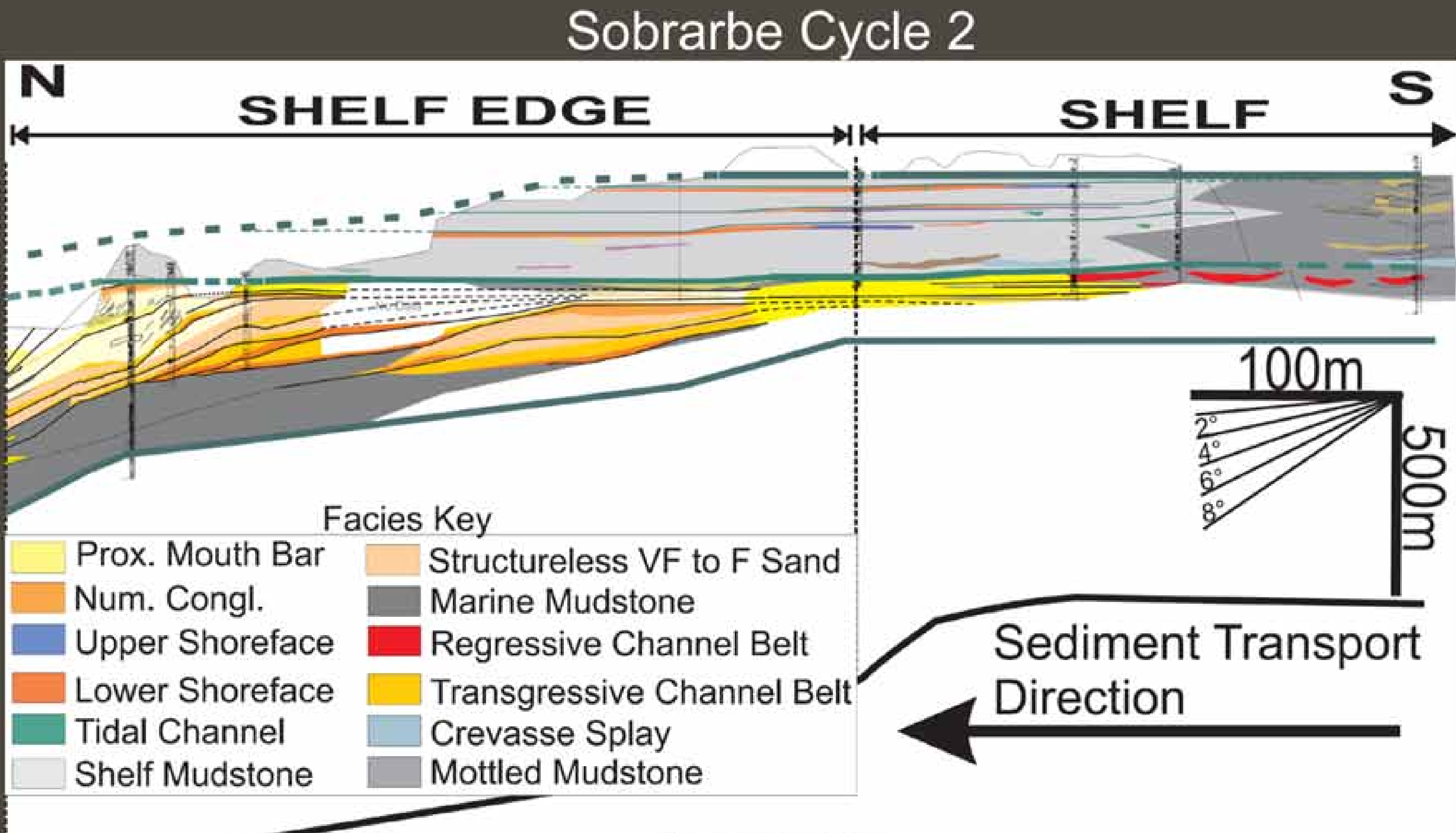
Comparative Volume

- Shelf margin to shelf cross-sectional area
  - Transgressive 0.82 km$^2$ (46.1%)
  - Regressive 0.96 km$^2$ (53.9 %)



# 1) Regressive

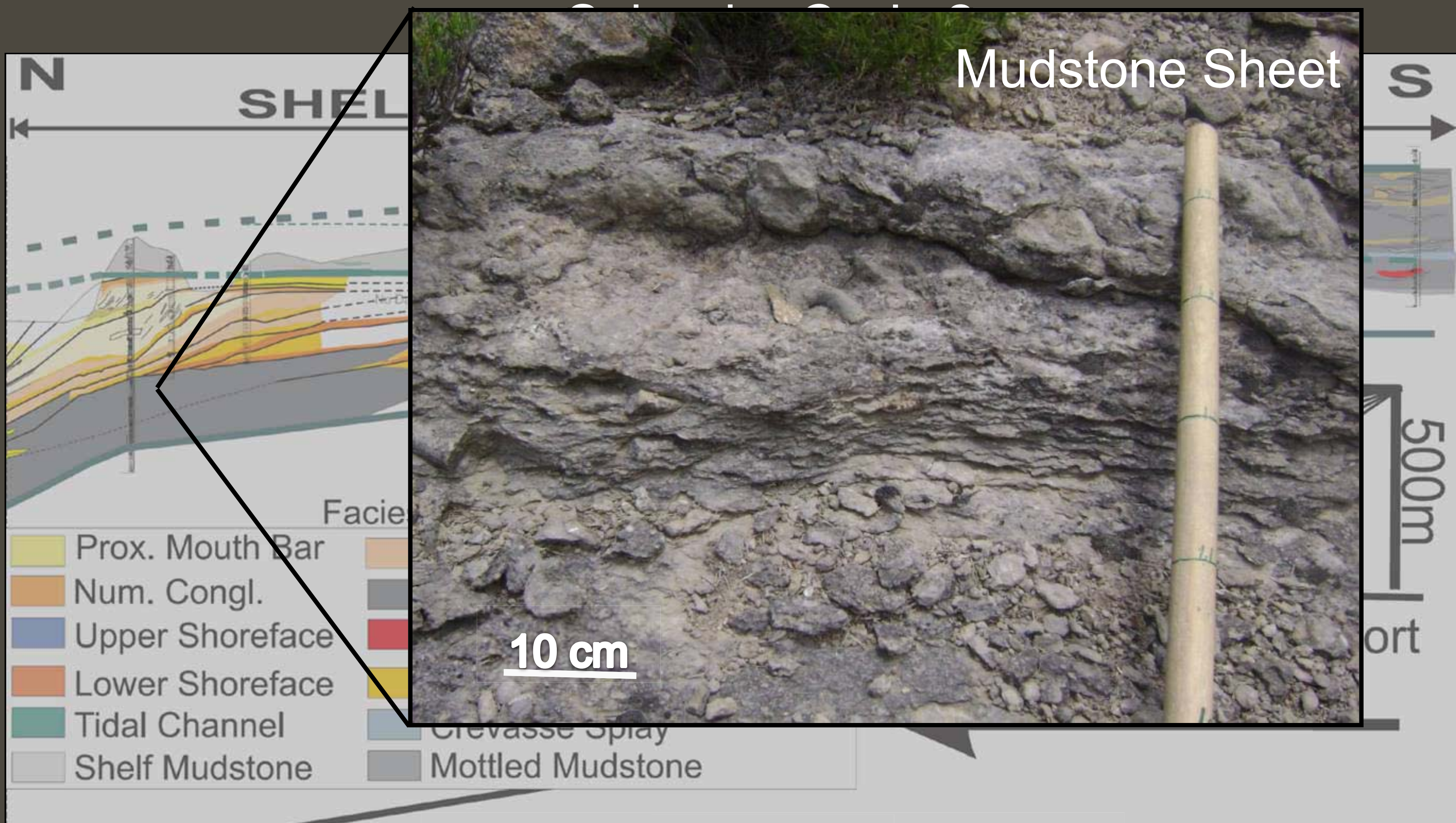
- Architectural Elements: distributary channel belts, mottled mudstones, mouth bars, and mudstone sheets




Notes by Presenter: Foreset steepening as delta builds to shelf edge.

# 1) Regressive

- Architectural Elements: distributary channel belts, mottled mudstones, mouth bars, and mudstone sheets



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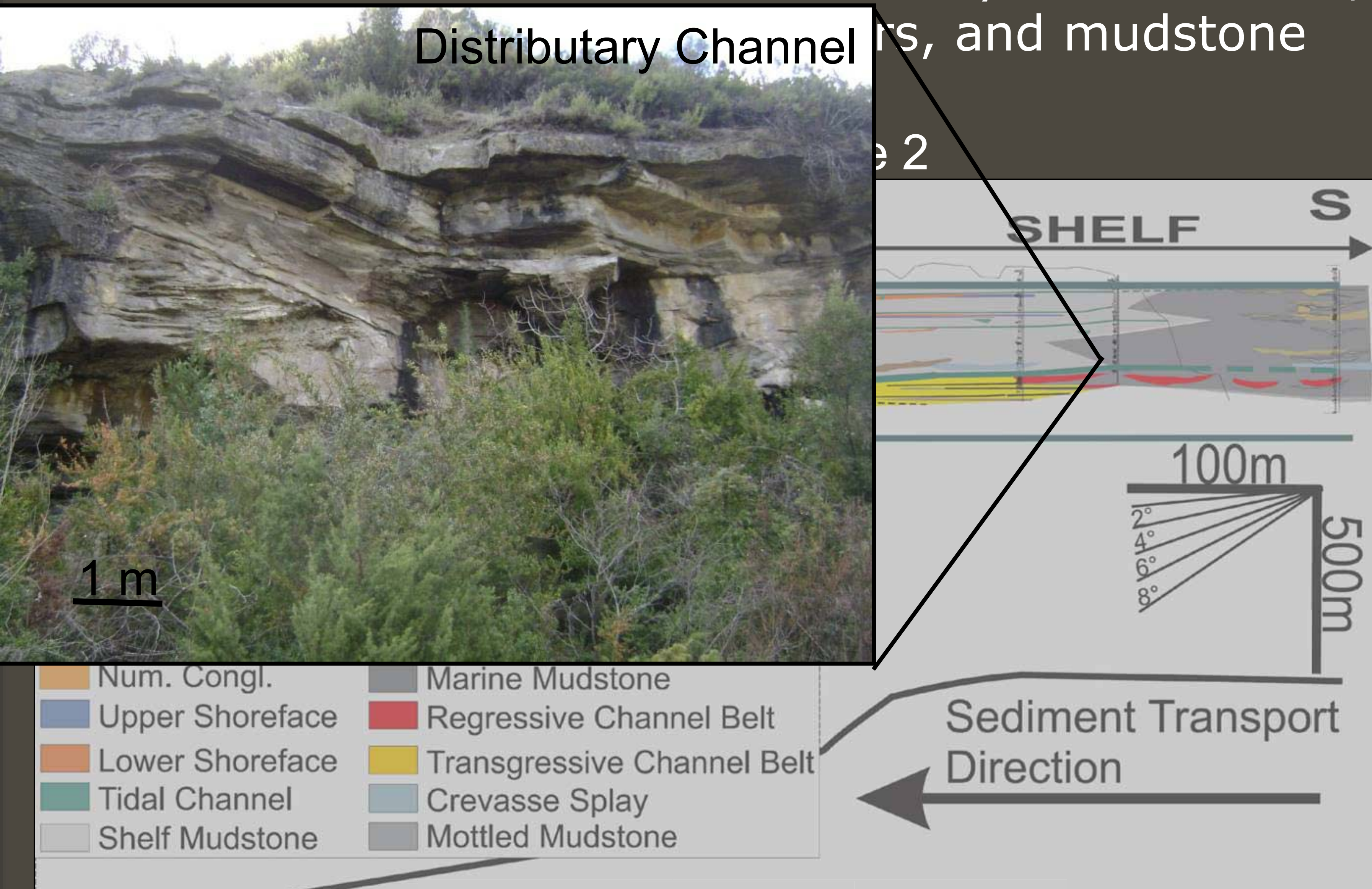
- Architectural Elements: distributary channel belts, ...rs, and mudstone

...e 2



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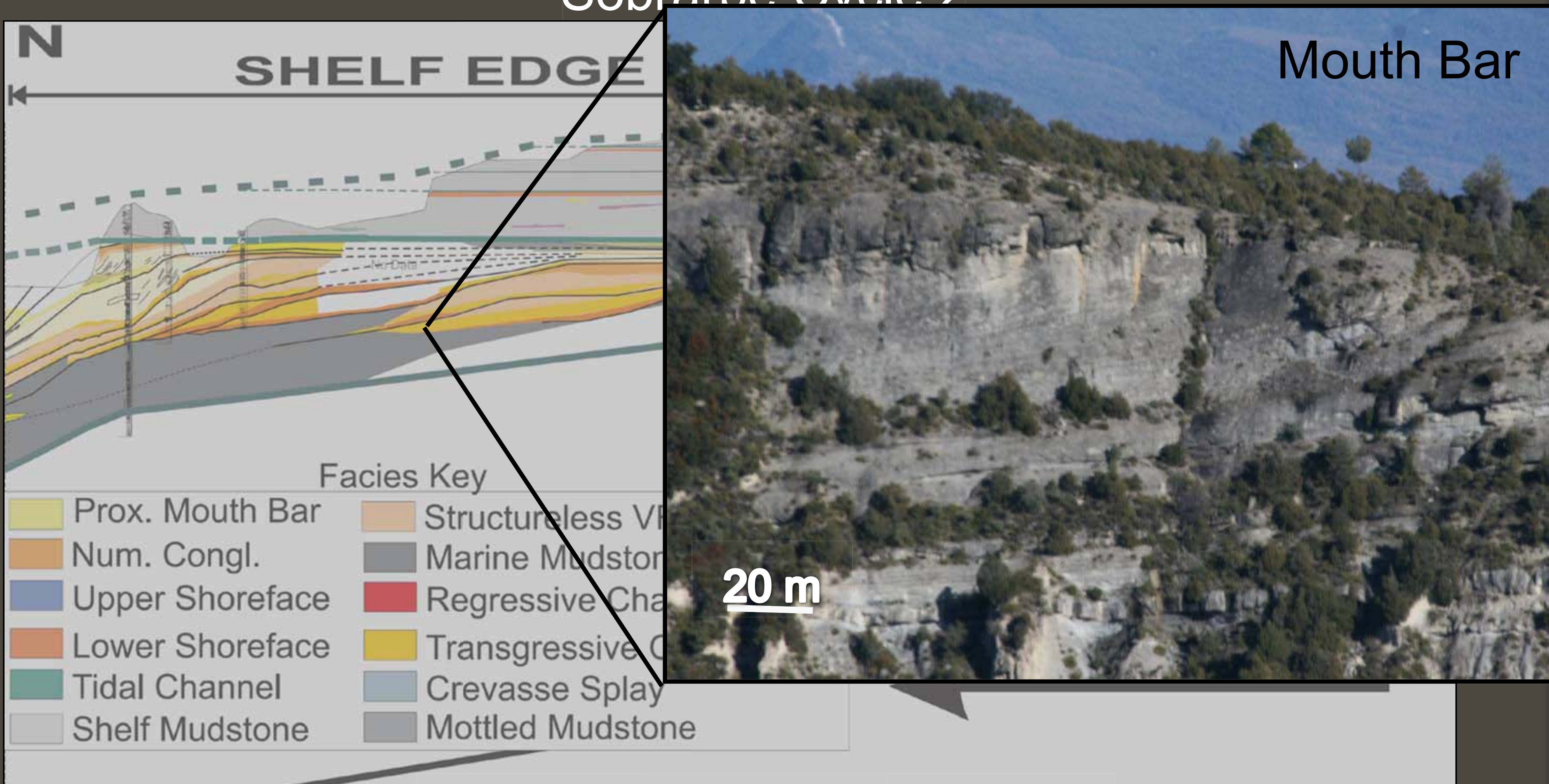
Sobrarbe Cycle 2



# 1) Regressive

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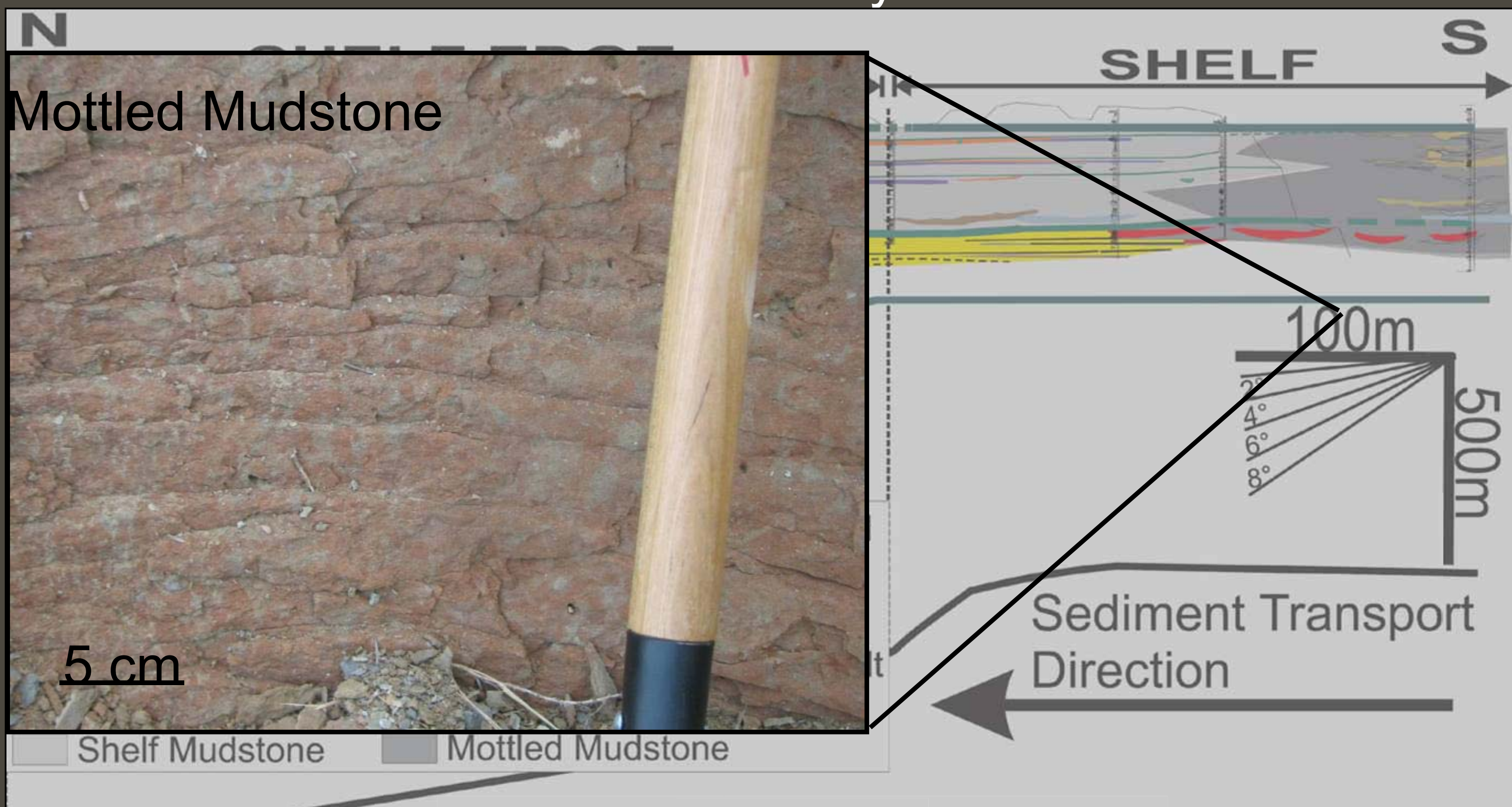
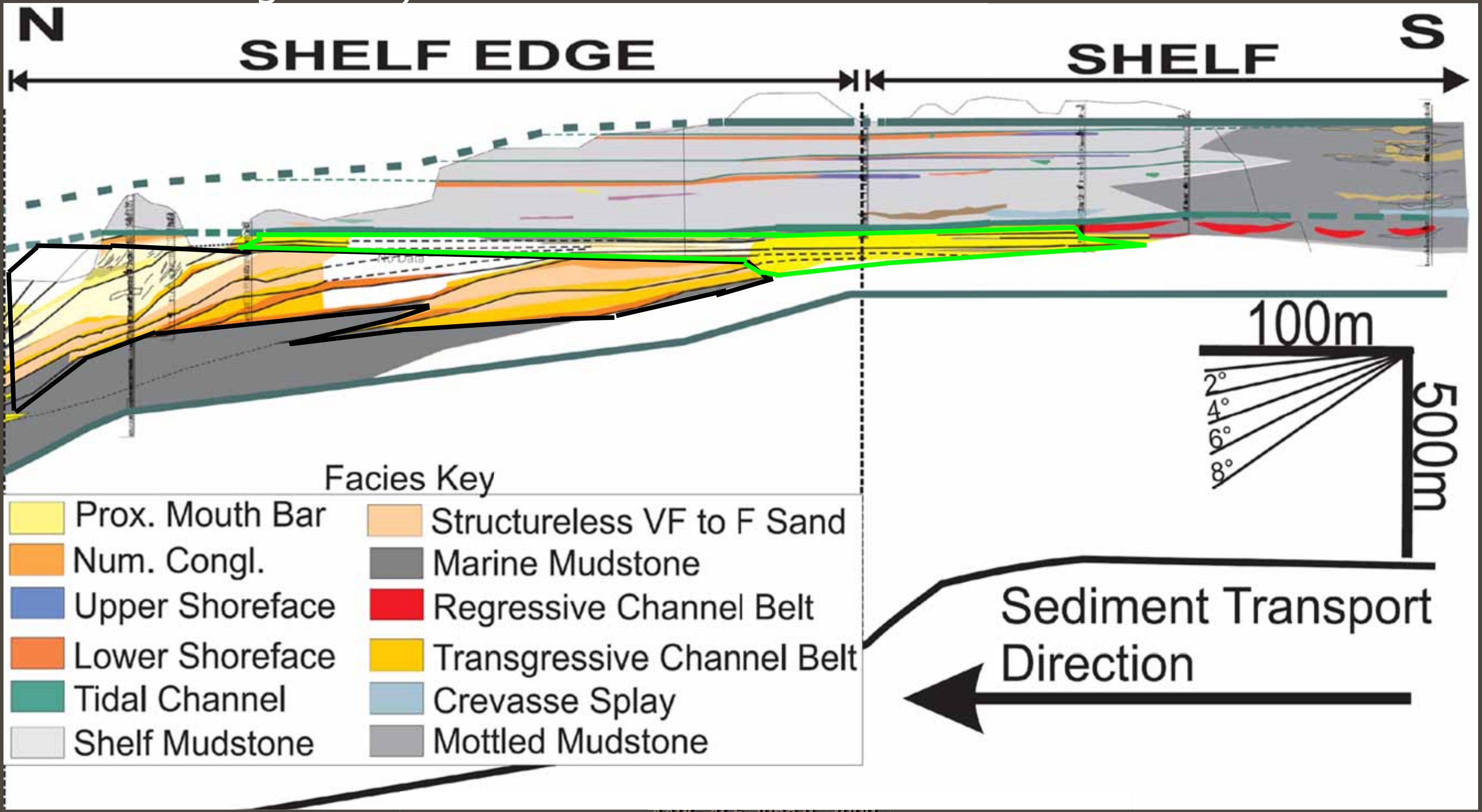
Sobrarbe Cycle 2



# 1) Regressive

- Facies
  - Proximal Mouth Bars= Traction deposition (trough and low-angle cross-stratification, planar beds, and ripples)
  - Distal Mouth Bars= Sediment gravity flows (structureless and graded)



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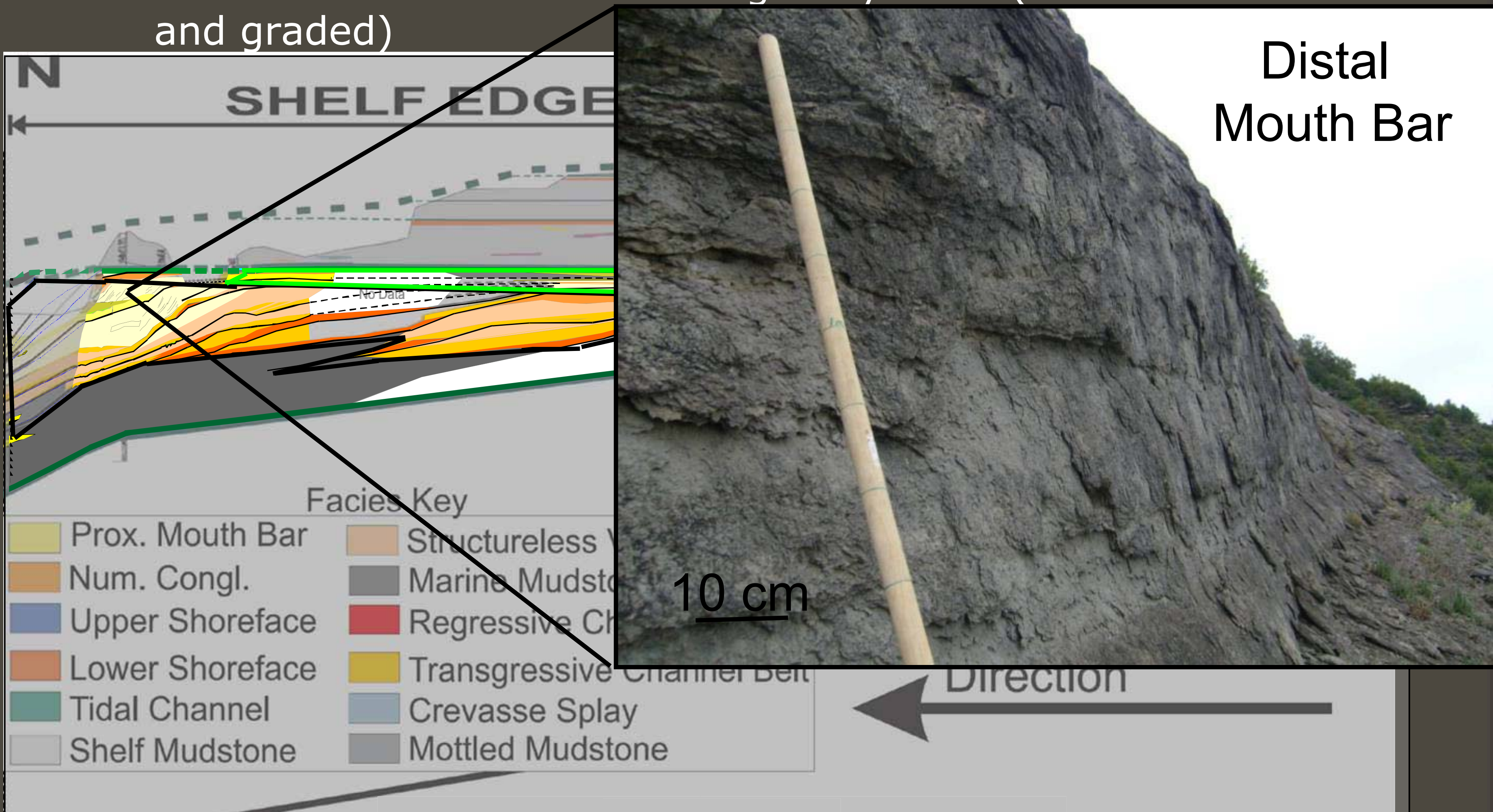

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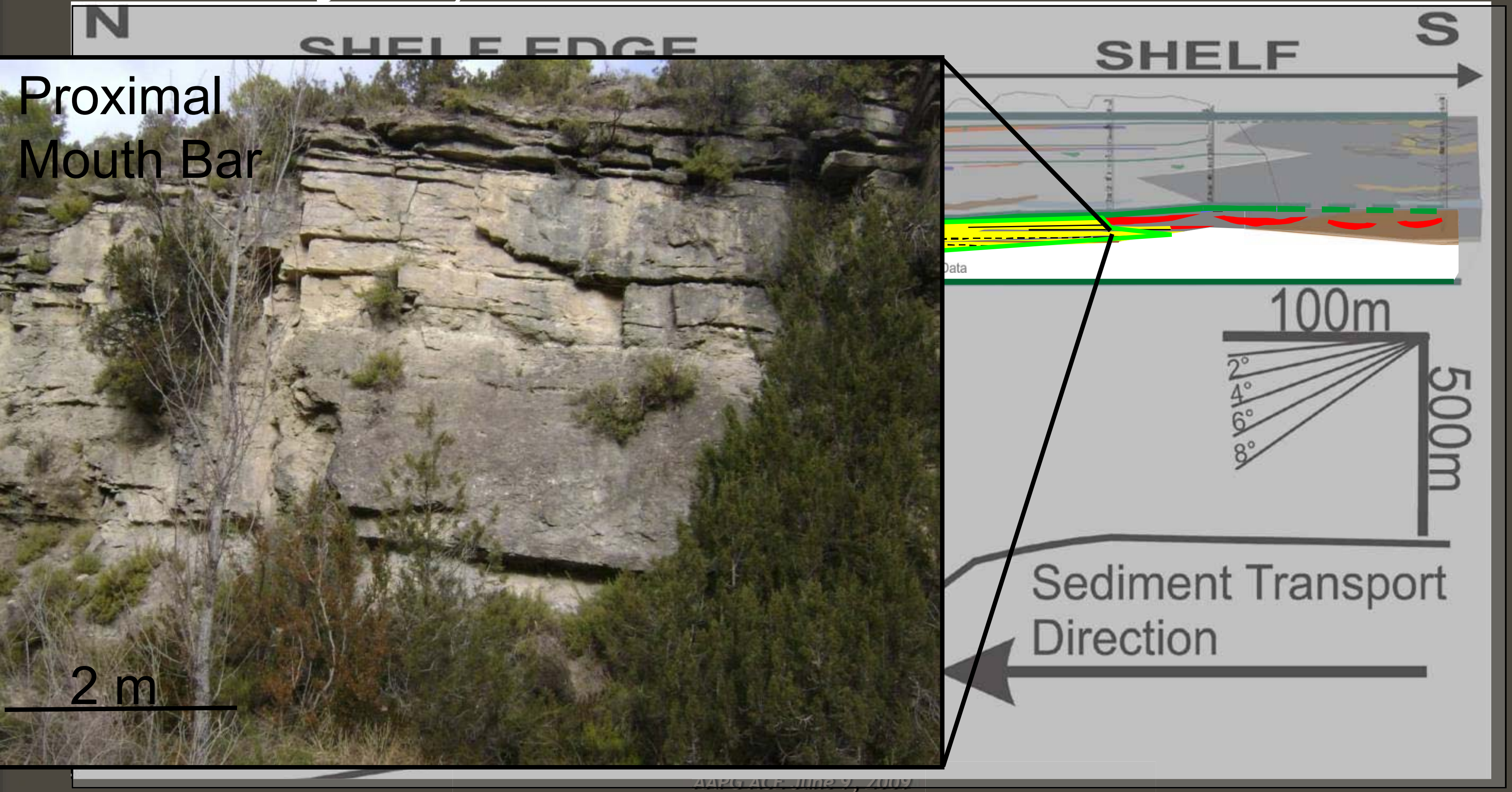
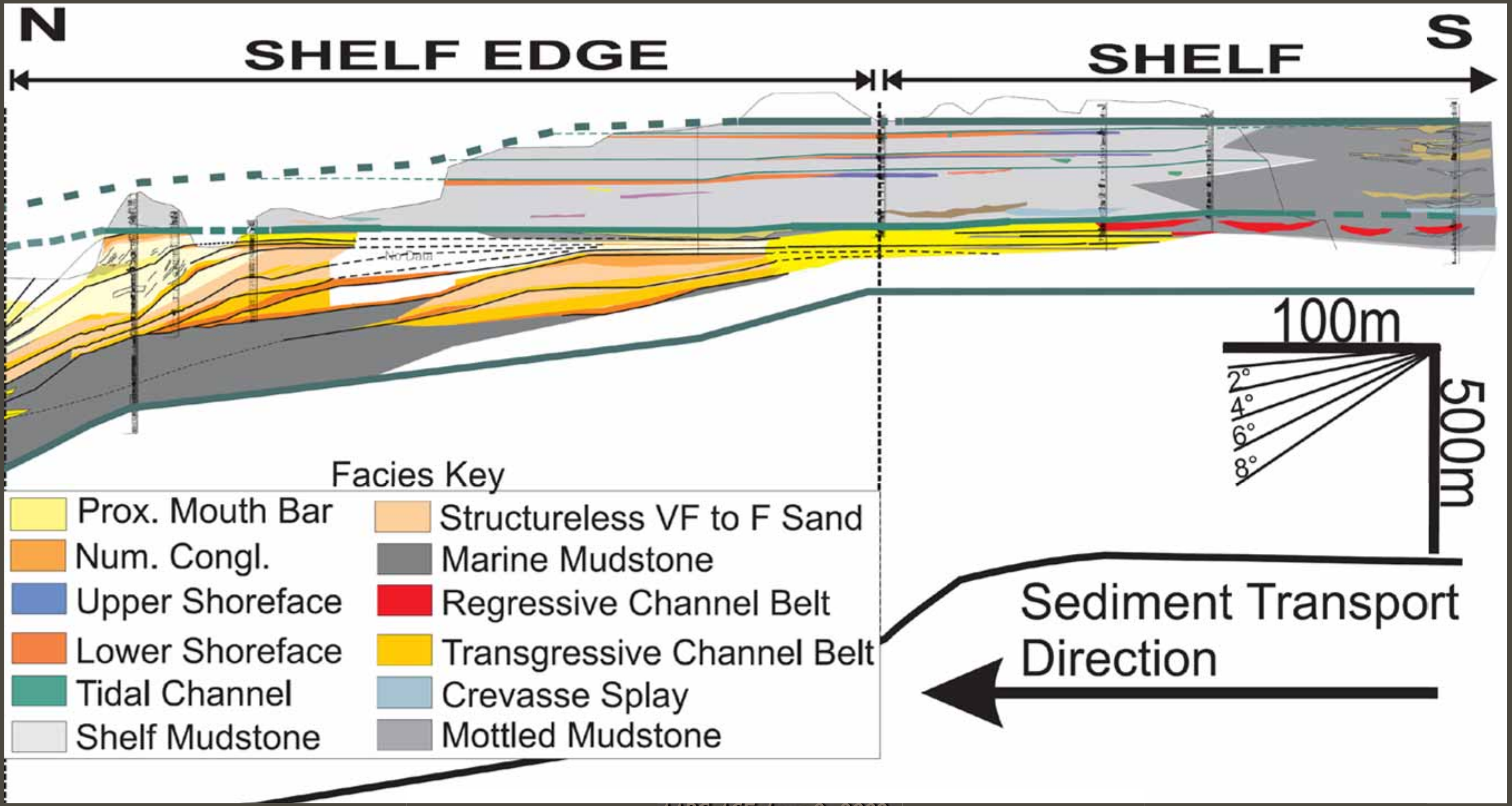


# 2) Transgressive

- Architectural Elements: tidal channels, shoreface, and shelf siltstones



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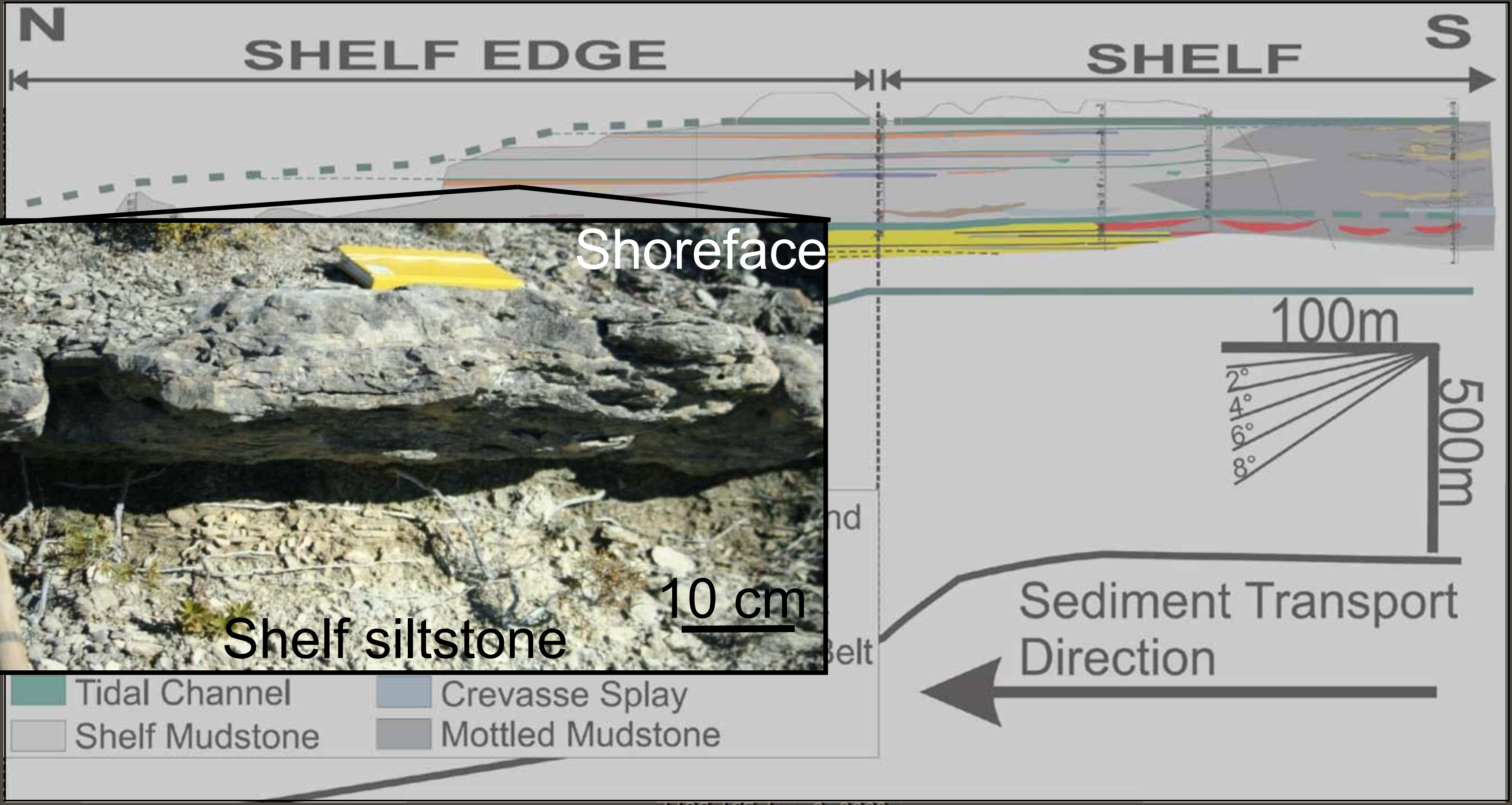

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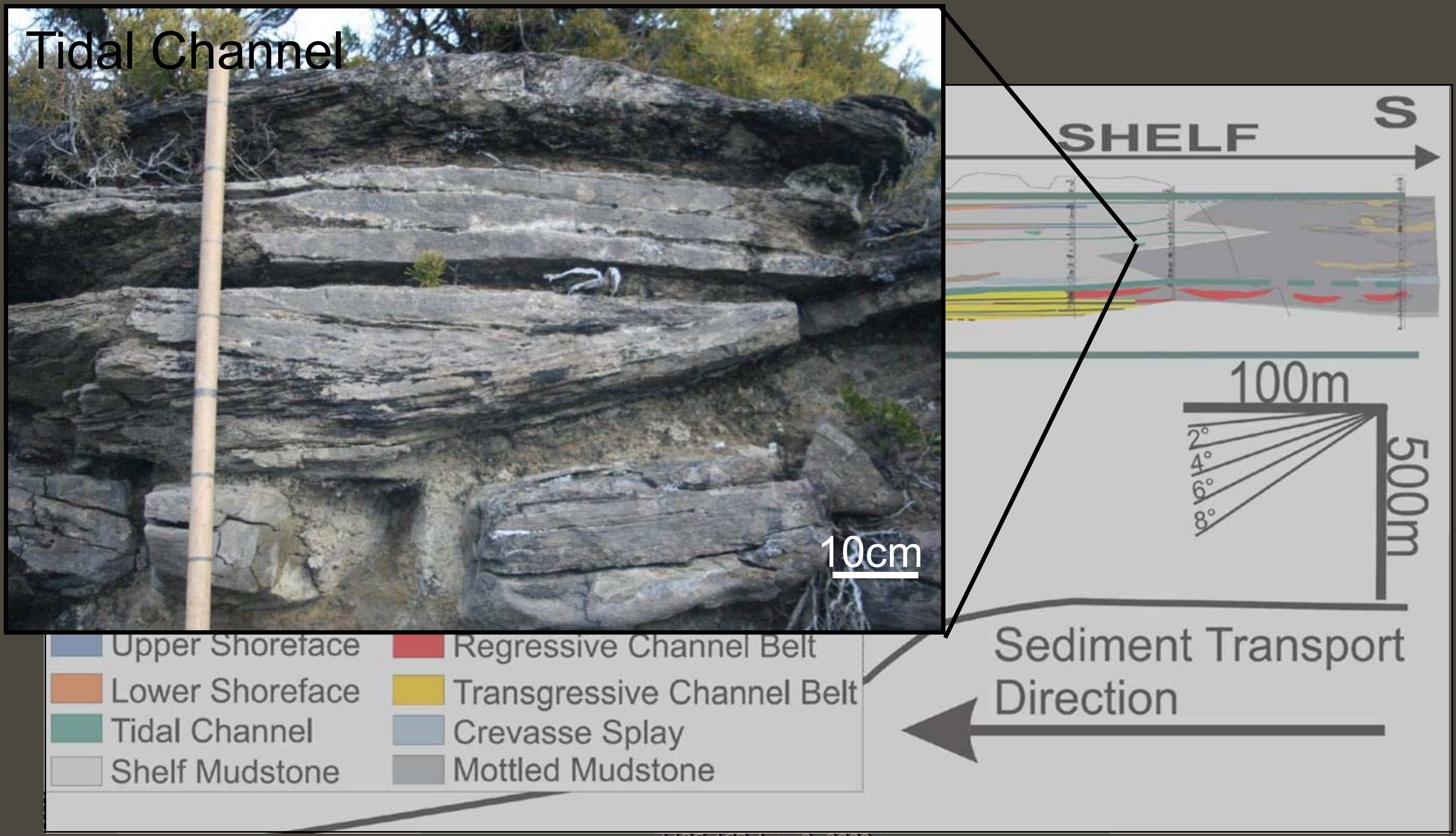

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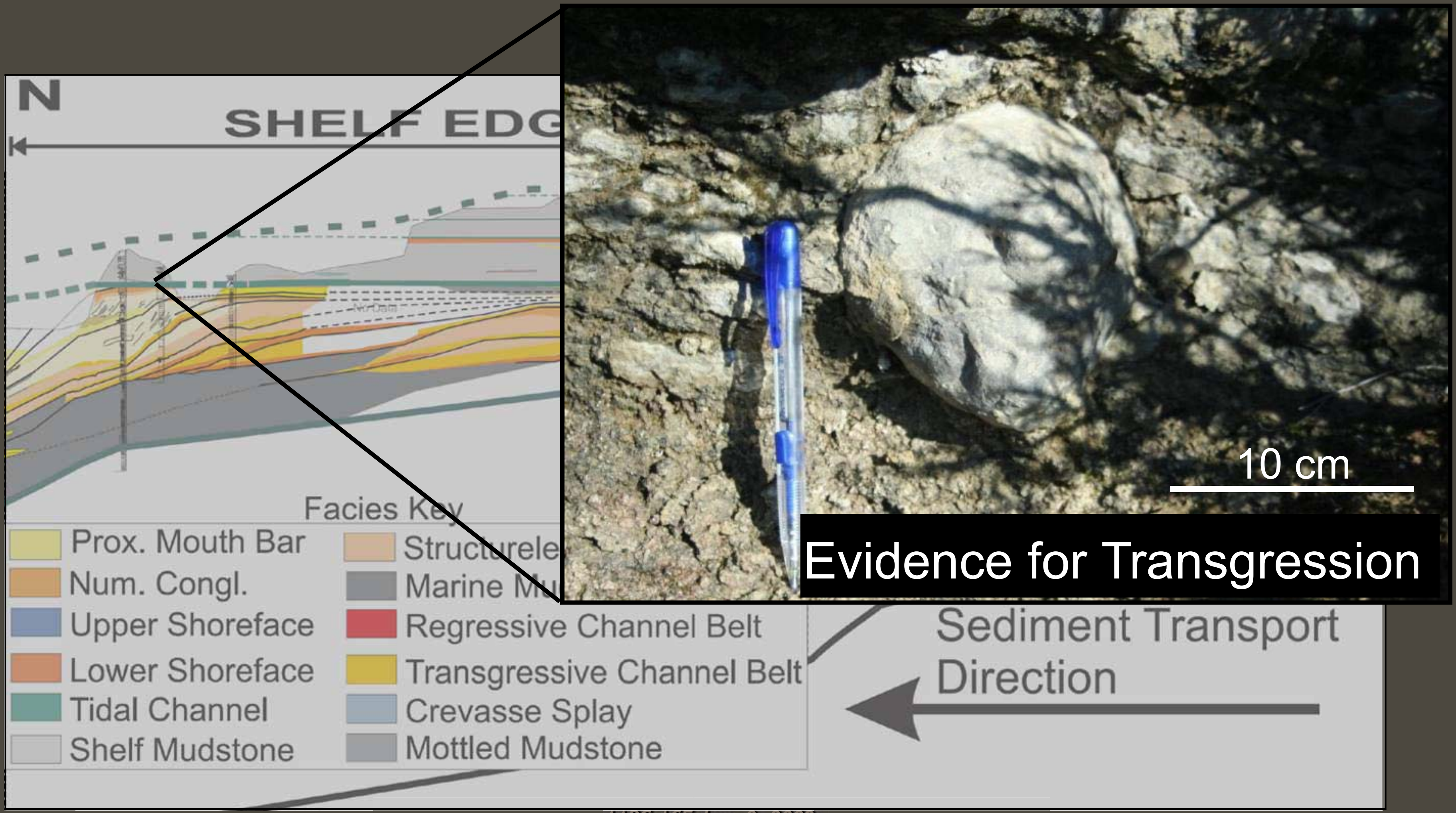

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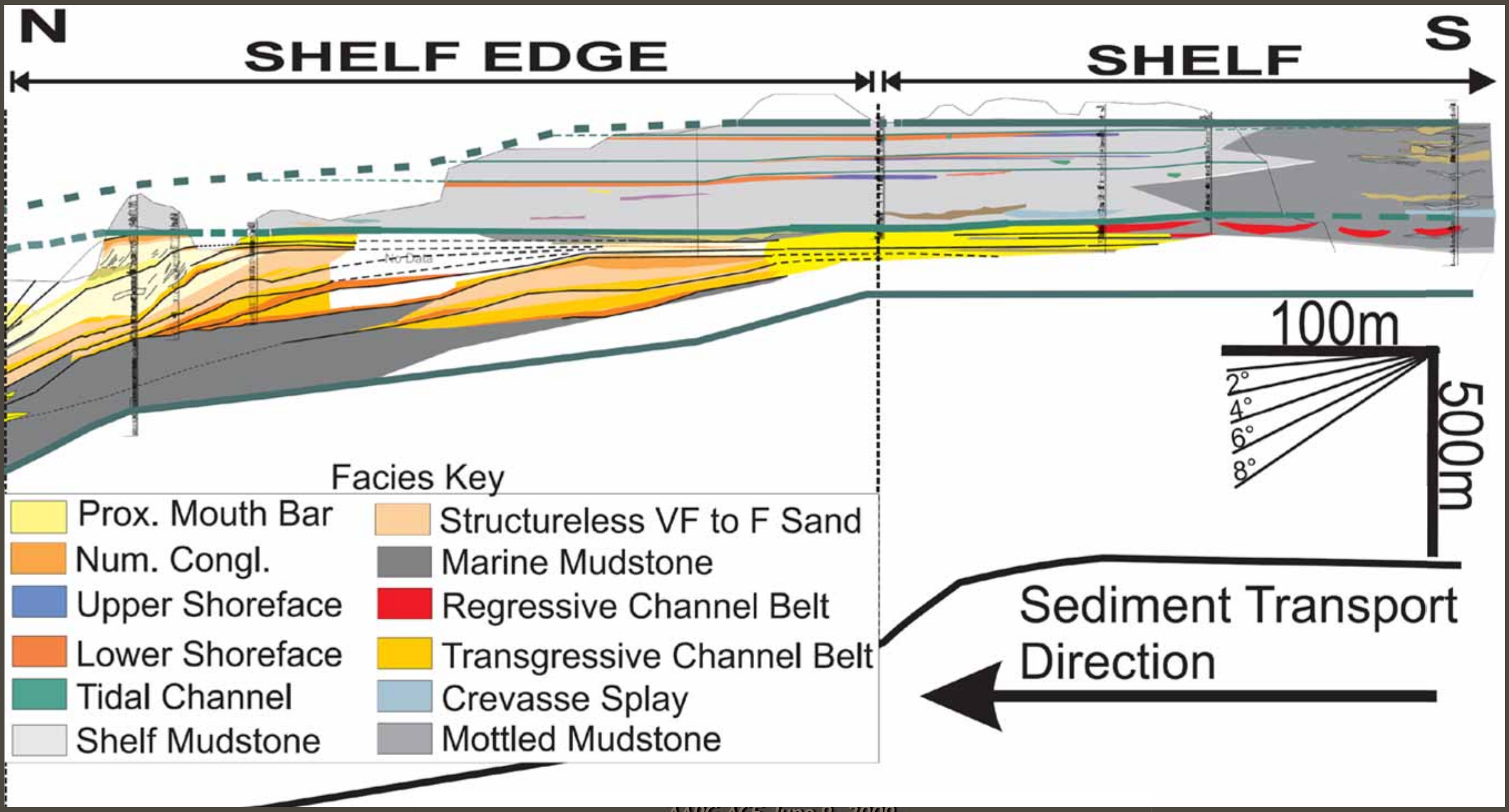

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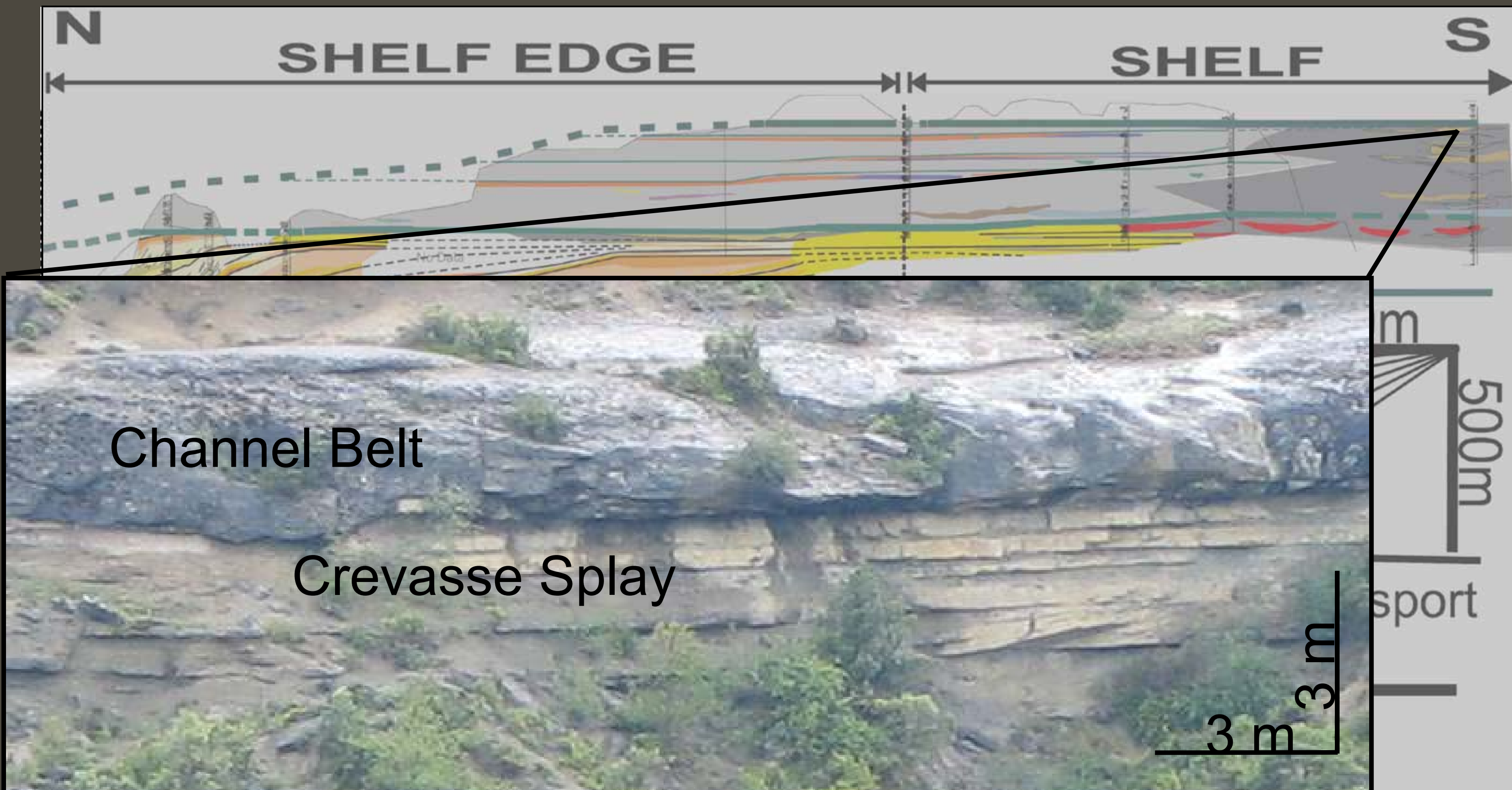

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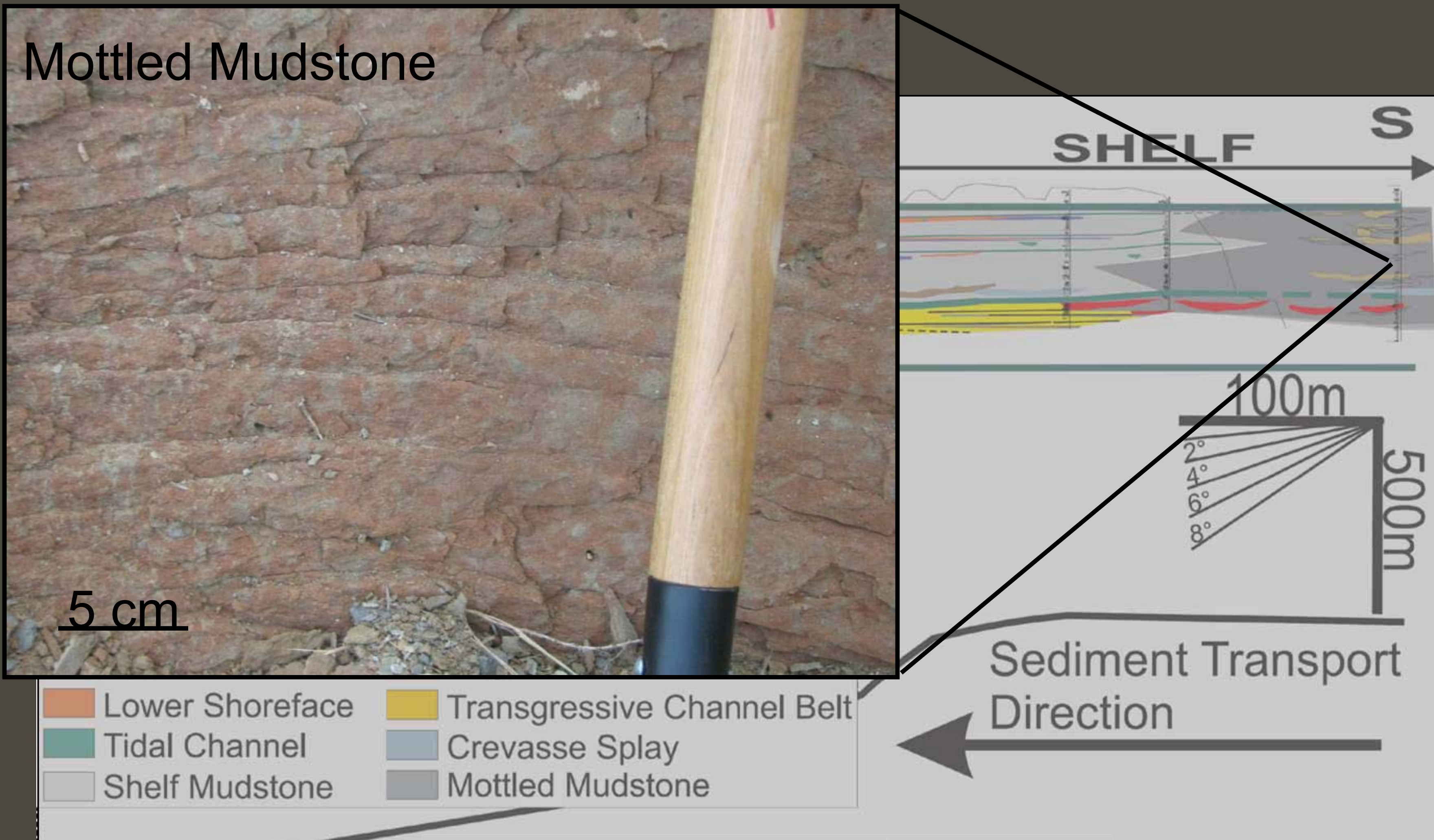
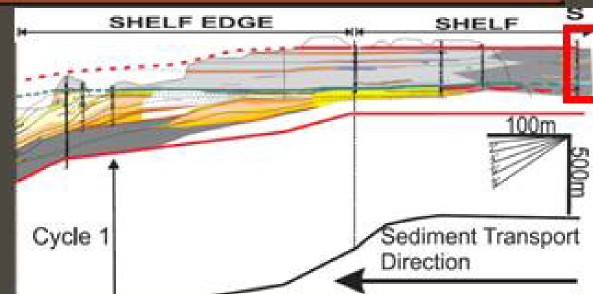
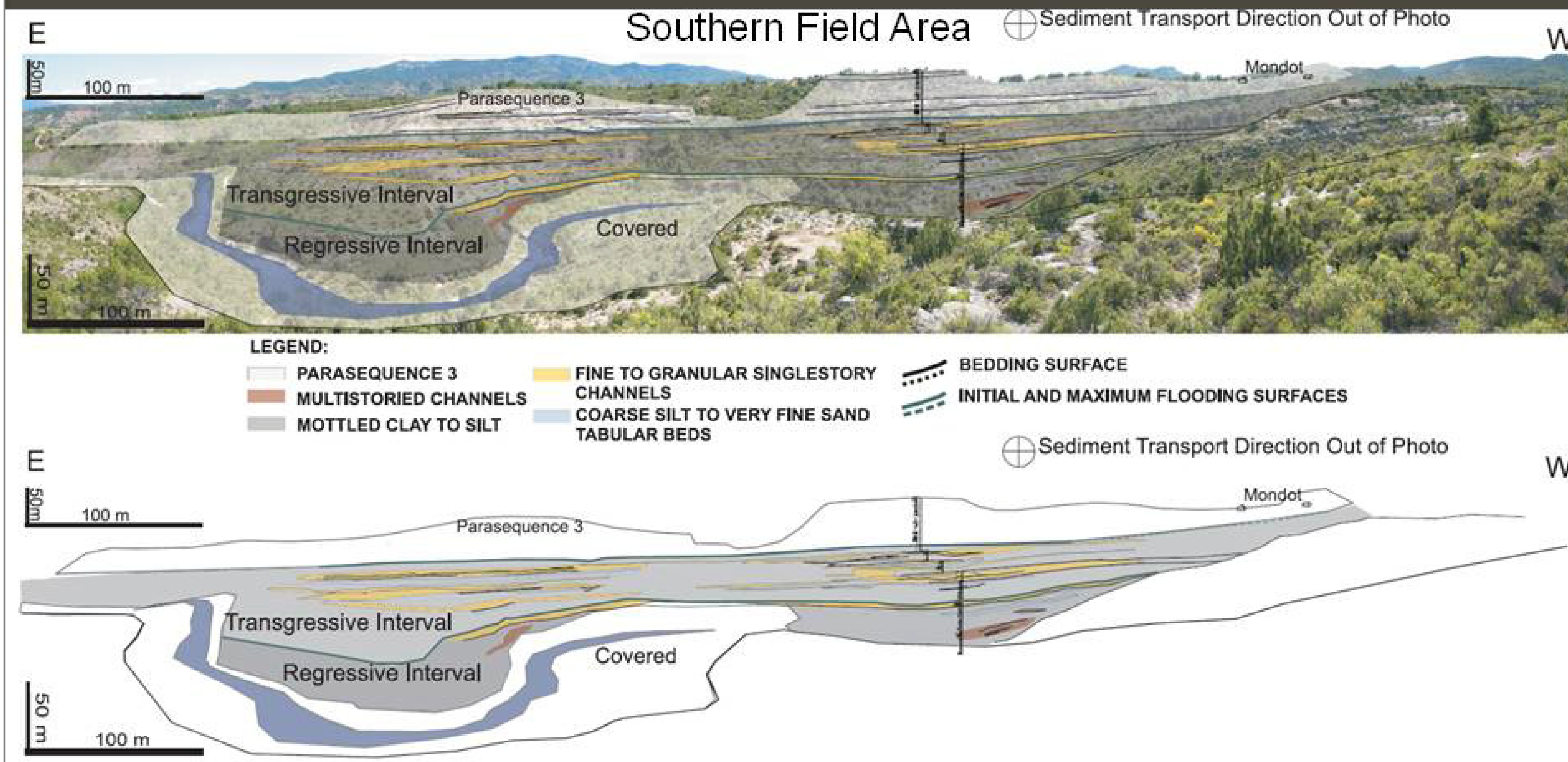


# 3) Transgressive vs. Regressive

## Aspect Ratio

- Transgressive channel belts (n=12) 63
- Regressive channel belts (n=3) 18



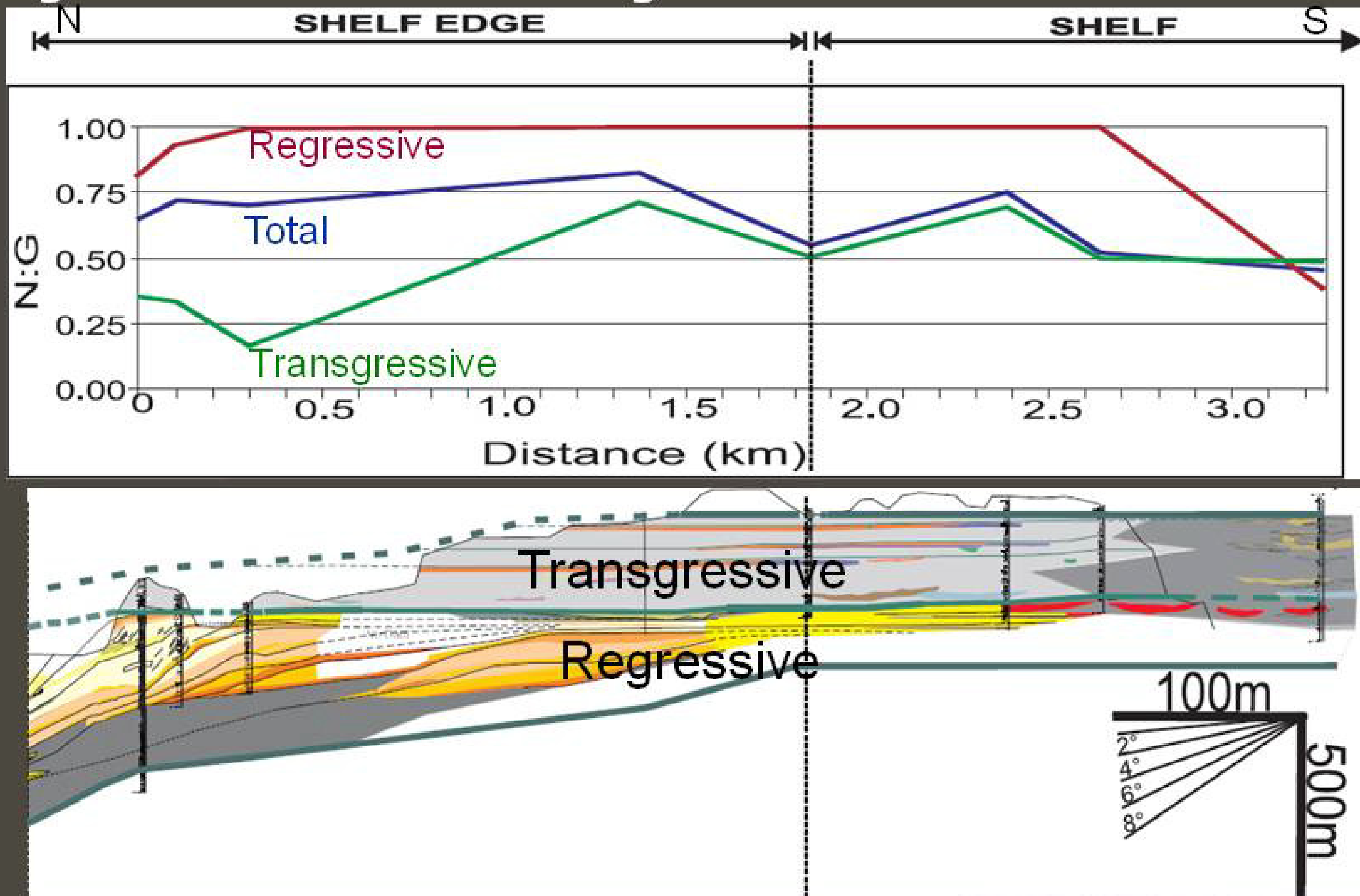






Notes by Presenter: Parallax of photo and recesses alters appearance of channels. There is no difference between top image and lower, photo is just removed to make the interpretation easier to see.

# 3) Transgressive vs. Regressive

- N:G highest at the shelf margin
- Regressive N:G > Transgressive N:G

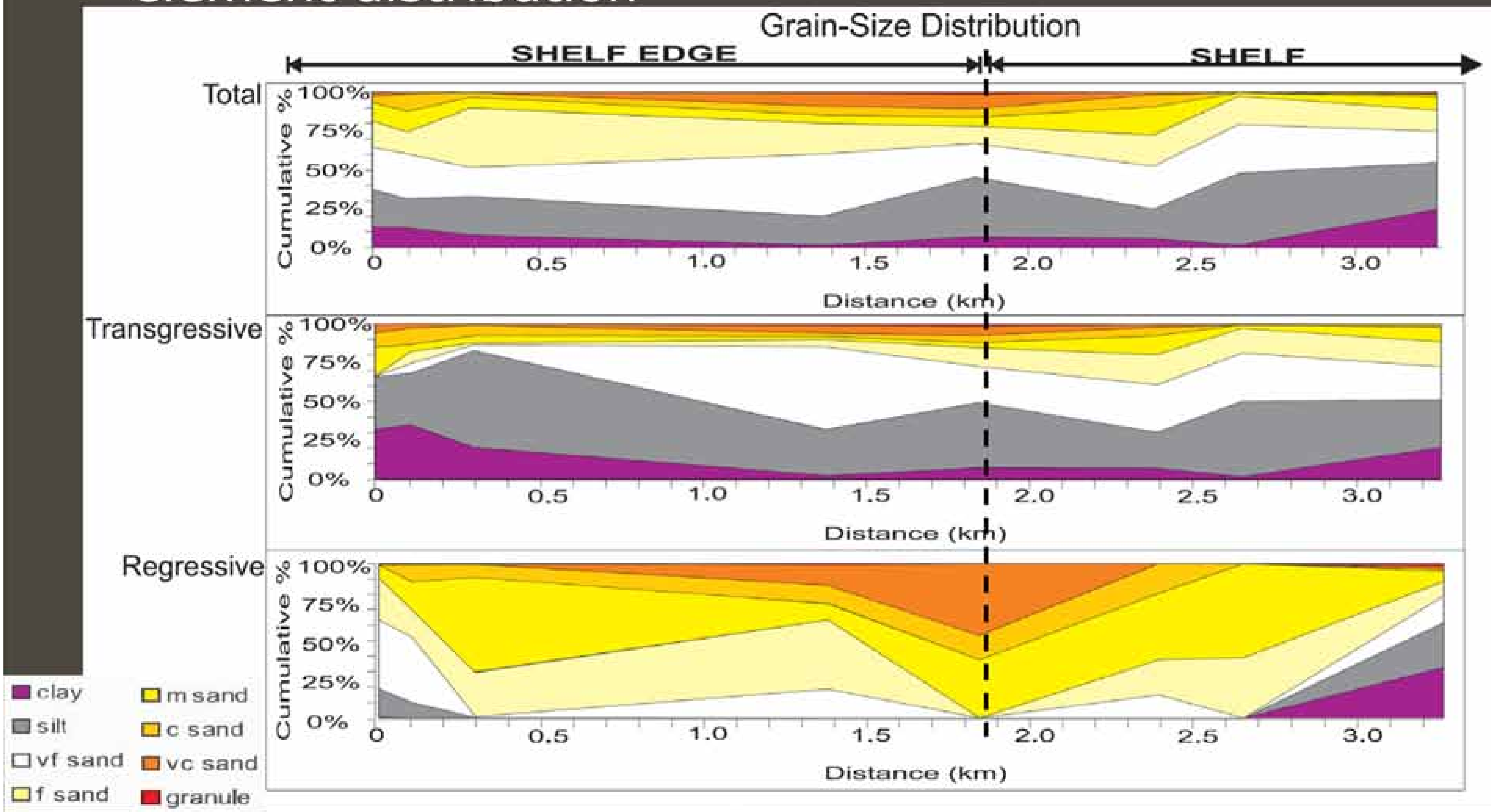





Notes by Presenter: But how much of this n:g is actually reservoir?

# 3) Transgressive vs. Regressive

- High facies diversity in transgressive interval
- Grain-size distribution controlled by architectural element distribution






Notes by Presenter: How much of that is reservoir? Location of reservoir depends on regressive vs. transgressive and location on physiographic profile.

# 3) Transgressive vs. Regressive

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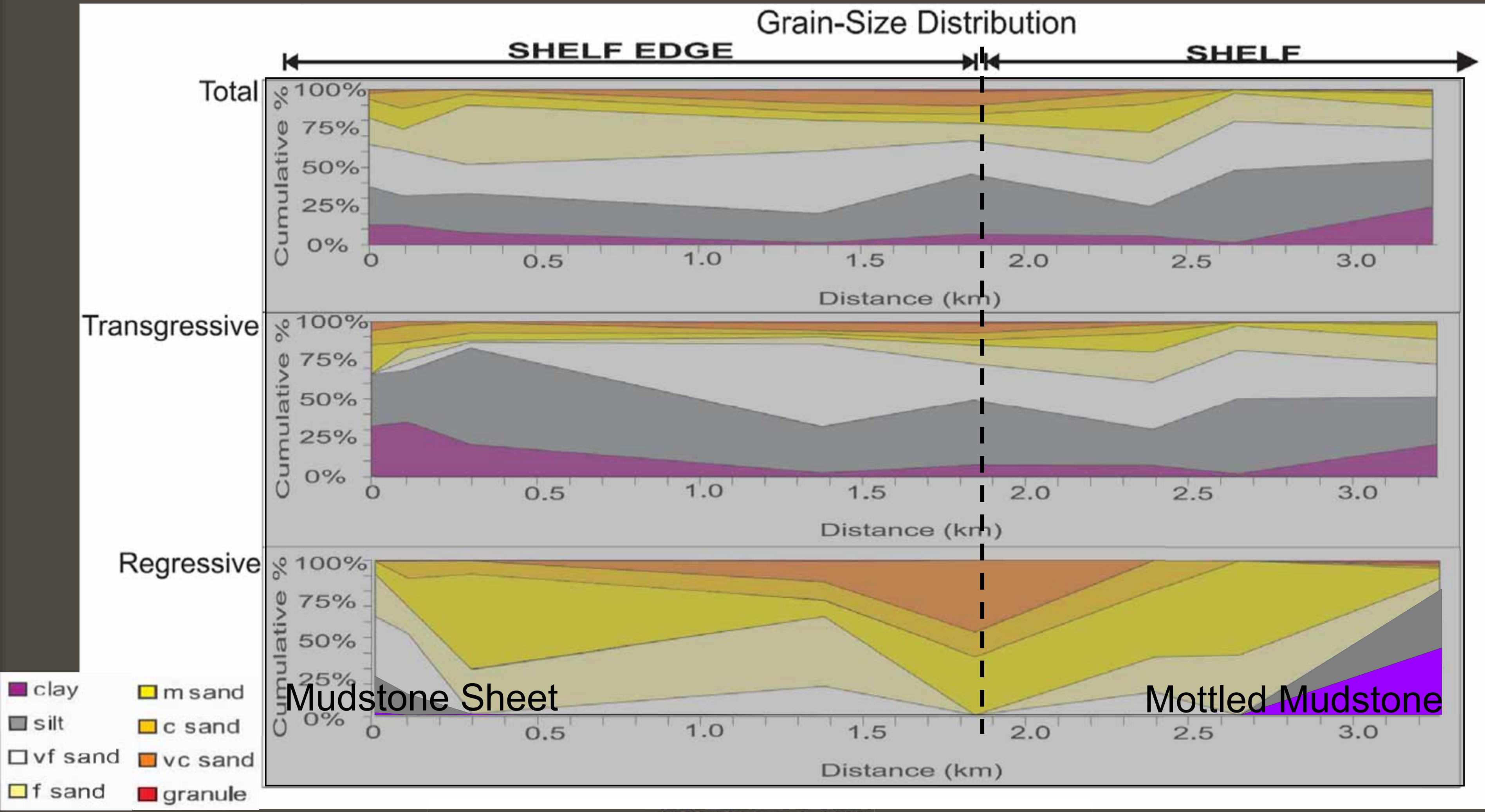

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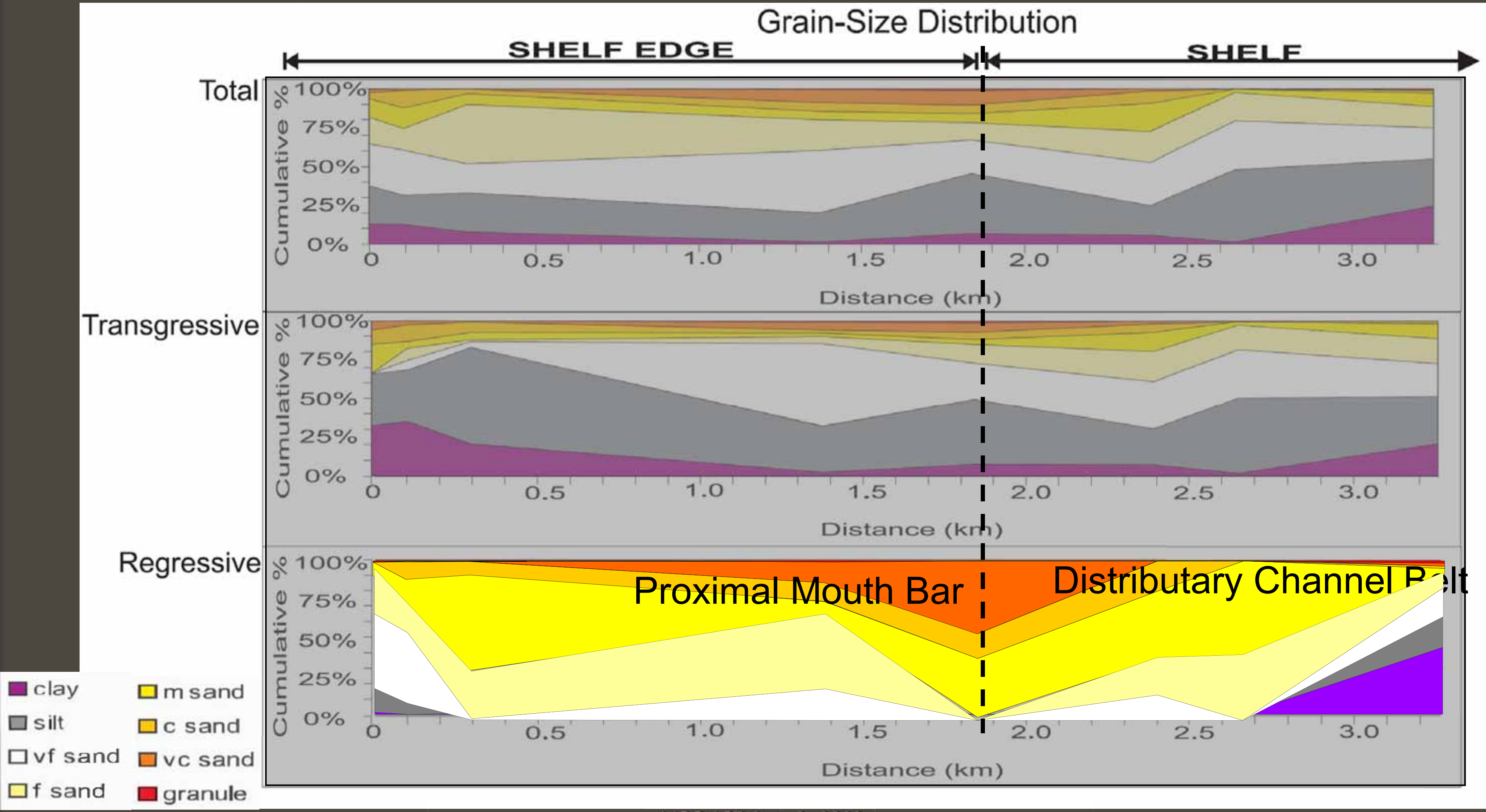

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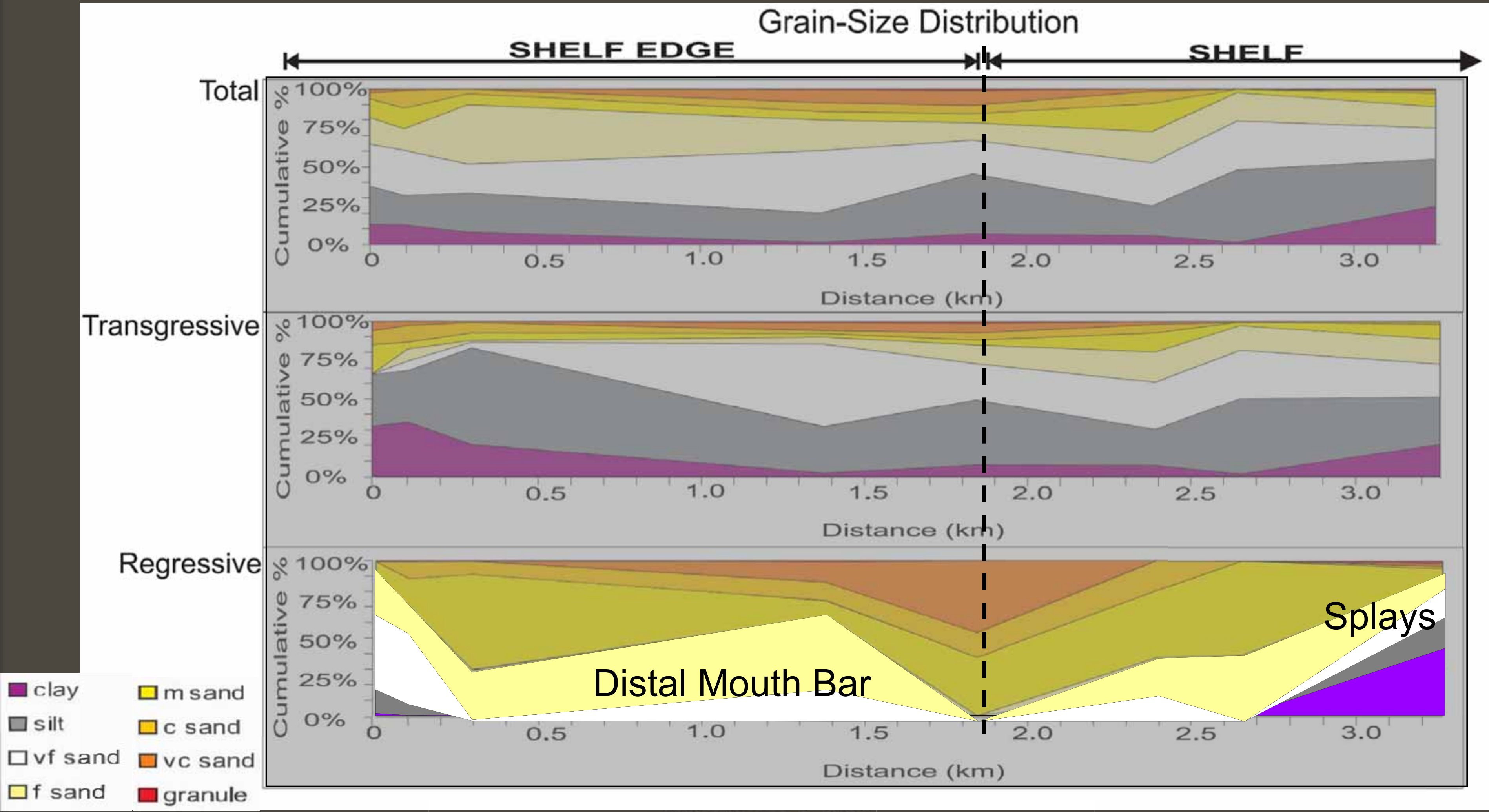
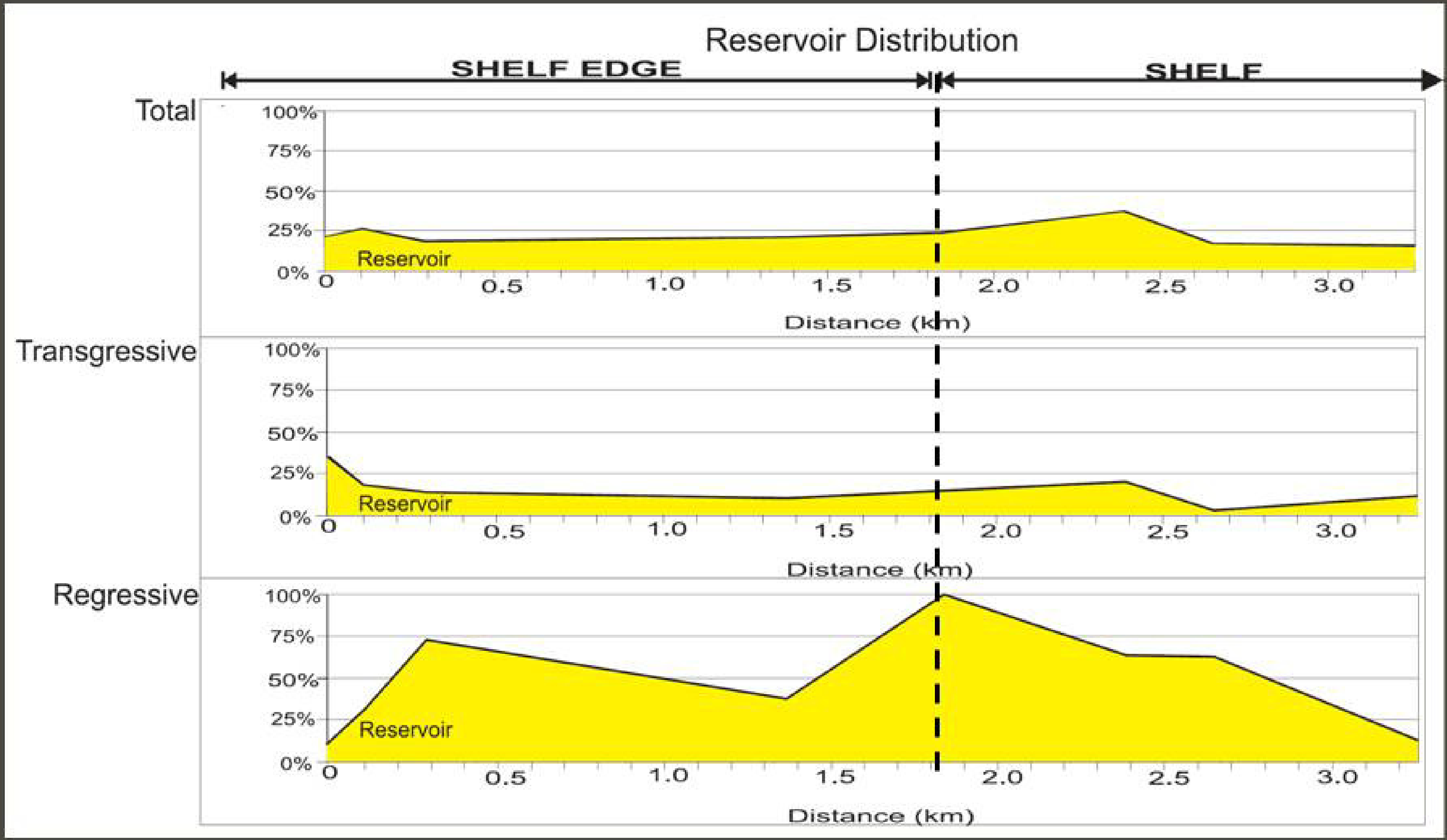


# 3) Transgressive vs. Regressive

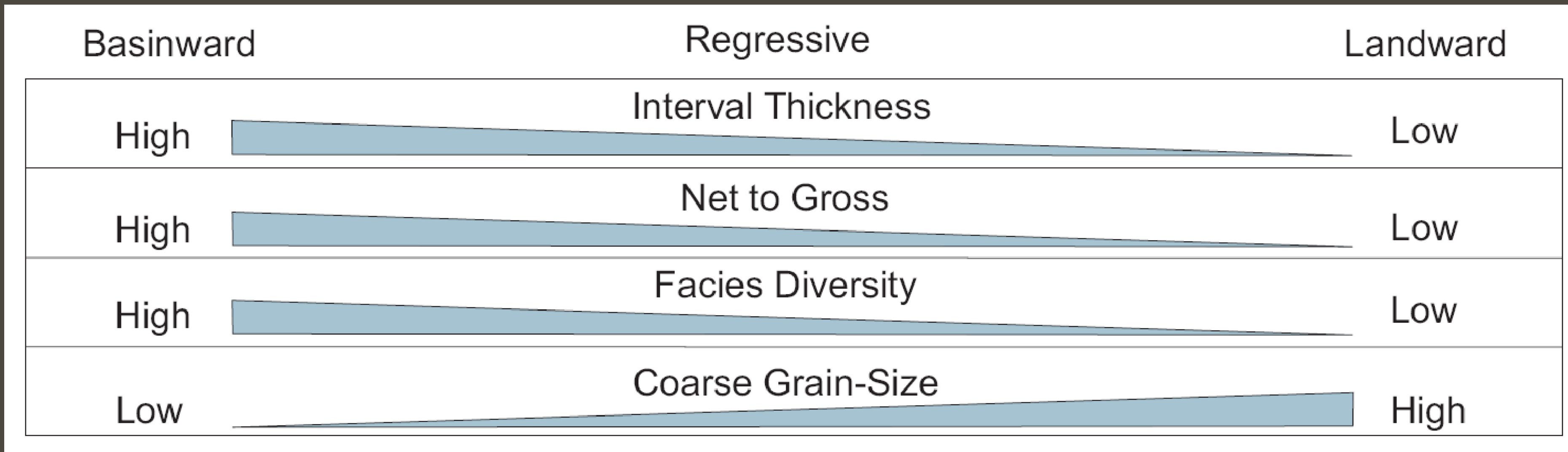
- Architectural element distribution is controlling the location of optimal reservoir

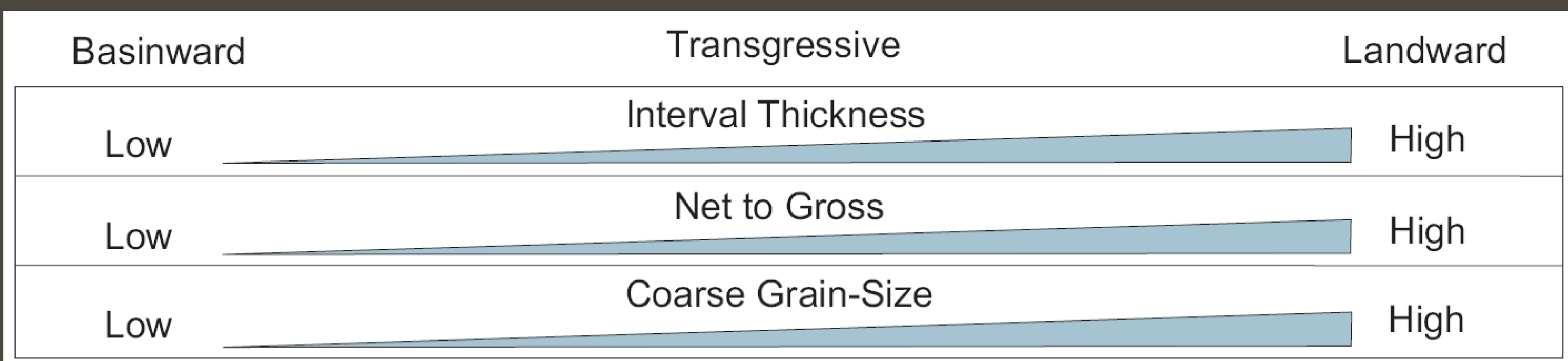





Notes by Presenter: How much of that is reservoir? Location of reservoir depends on regressive vs. transgressive and location on physiographic profile.

# Conclusions

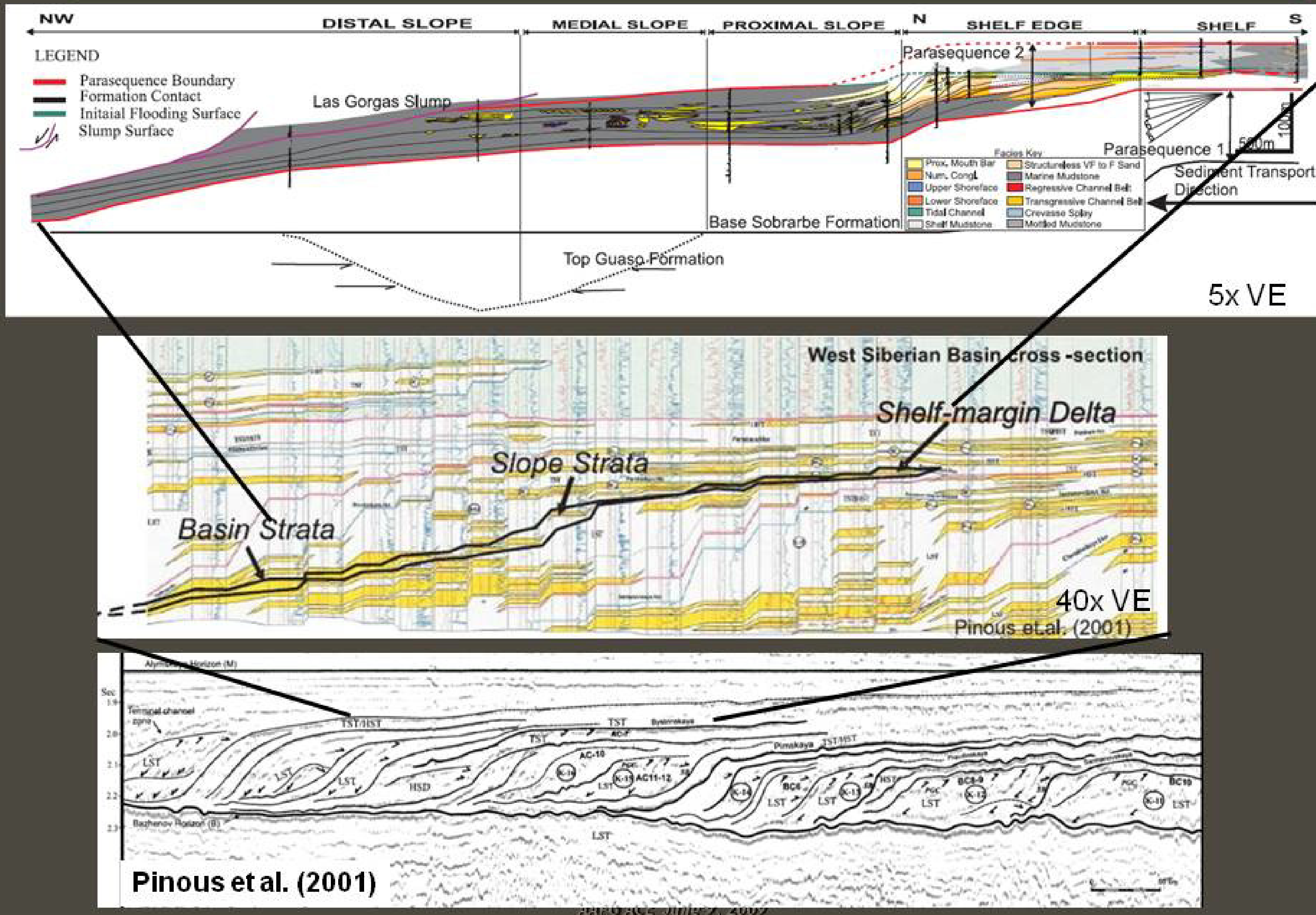


# Conclusions

| | Regressive | Transgressive |
|---|---|---|
| Increasing Interval Thickness | Basinward | Landward |
| Net to Gross | High | Low |
| Element Diversity | Low | High |
| Facies Diversity | Low | High |
| Channel Belt Aspect Ratio | Low | High |
| Channel Belt Element Thickness | High | Low |
| Occurrence Multi-storied Channel Belts | High | Low |
| Crevasse Splay Thickness | Low | High |
| Location of Highest Net to Gross | Shelf Edge | Shelf |
| Location of Coarsest Sediment | Shelf | Shelf |

# Conclusions




Notes by Presenter: Now for exploration or building facies models in prograding systems, we have an analog for stratigraphic architecture and reservoir quality.

# Acknowledgements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- Dr. Bryan Bracken, CVX
- Dr. Donna Anderson, CSM
- Dr. John Curtis, CSM
- Dr. Julian Clark, CVX
- Dr. Renaud Bouroullec, CSM
- Henri Silalahi, Matt Hoffman

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# Questions

## References


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