Architectural Hierarchy and Anatomy of an Exhumed Submarine Slope Channel Complex*

Jorge P. Figueiredo[1], David M. Hodgson[2], and Stephen S. Flint[2]

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[1]Exploration, Petrobras, Rio de Janeiro, Brazil (jorgepicanco@uol.com.br)
[2]School of Environmental Sciences, University of Liverpool, Liverpool, United Kingdom

Abstract

A well exposed upper slope channel complex set in Unit F, Fort Brown Formation (Permian) SW Karoo Basin, South Africa, allows the identification of a hierarchy of erosion surfaces overlain by characteristic architectural elements and lithofacies associations. Outcrop constraints and palaeocurrent measurements indicate that the channel complex set is 1.1 km wide, greater than 60 m thick, oriented WNW-ESE (flow to ESE) and is partially confined by adjacent external levee deposits. One channel complex was studied in detail, where two scales of erosion surface are identified. The larger is a composite surface greater than 300 m in width and 35 m in depth. Three smaller-scale surfaces, less than 200 m wide and shallower than 25 m, are nested within the larger cut. Sedimentary facies in the channel-fills show an overall fining- and thinning-upward distribution. At the deepest part of the main composite erosion surface, the channel fill is composed of contorted fine-grained deposits interpreted as slumps. These are overlain by mudstone clast conglomerates, interpreted as lag deposits formed during a period of sediment bypass. The conglomerates are overlain by fine-grained structureless and amalgamated sandstones, which pass laterally into channel margin thin-bedded siltstones. The contact between beds and bedsets in this oldest channel-fill is usually erosive. The magnitude of erosion decreases upward in the successive channel fills. Each erosion surface and related depositional succession represents the cut-bypass-and-fill of a single channel. Four single channels were identified that form a laterally offset stacking pattern. This set of channels is interpreted as a channel complex that formed during a period of waxing-to-waning energy, possibly related to a high frequency allocyclic control.

The scales of the single channel-fills and the channel complex revealed in this study shows that channel complexes can easily be imaged in 3D seismic data; nevertheless, it is not always true for single channels. Hence, it is likely that most of the features interpreted in 3D seismic data as single channels are in fact channel complexes, which has a serious consequence for the analysis of

the internal heterogeneities in these reservoir types. High resolution outcrop-based studies such this presented here complement seismic interpretation and resolve the internal anatomy of the elements that cannot be imaged even in the high quality 3D seismic data.

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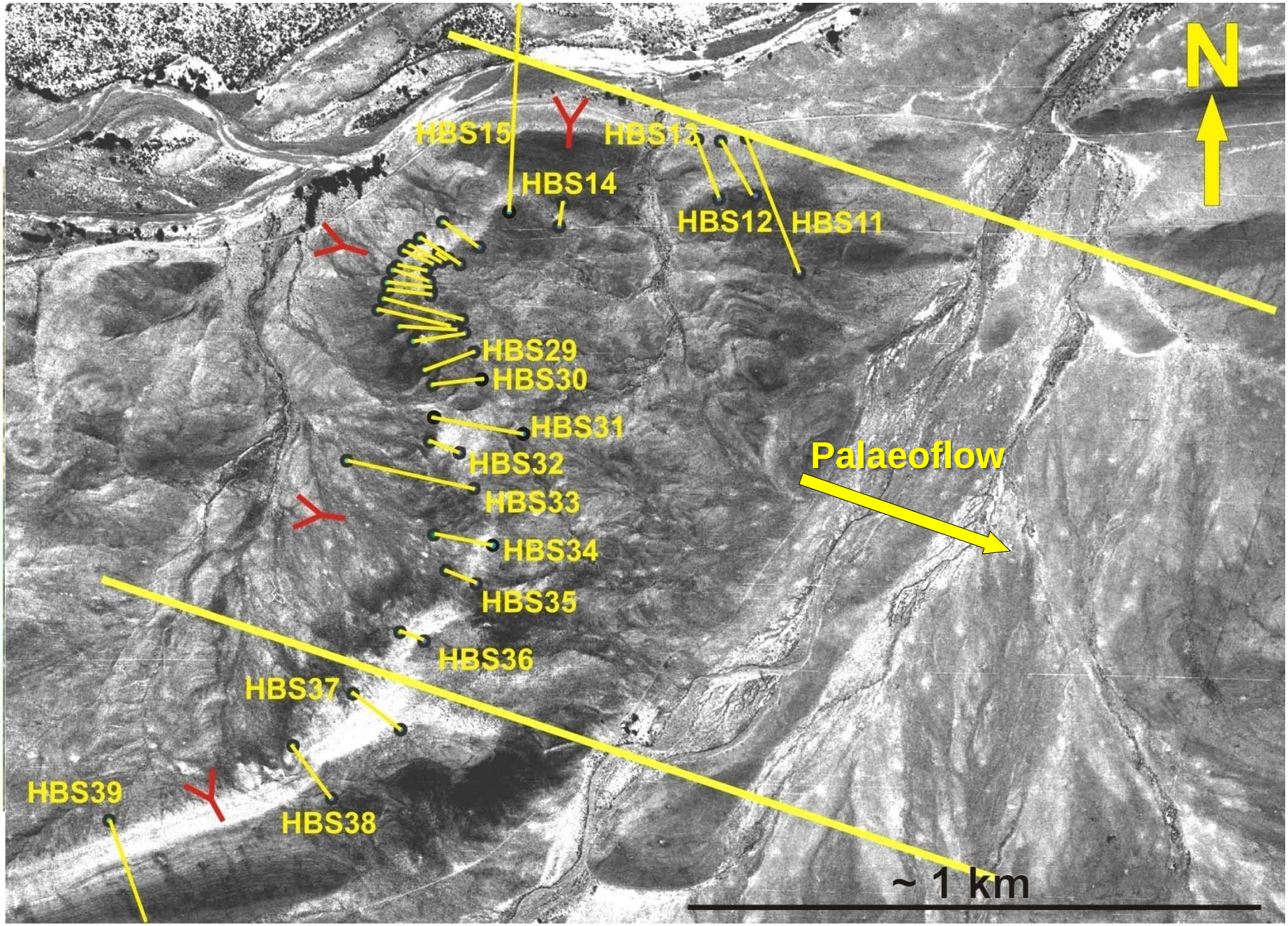
Architectural hierarchy and anatomy of an exhumed submarine slope channel complex

Dr. Jorge J. P. Figueiredo
Dr. David M. Hodgson
Prof. Stephen S. Flint

UNIVERSITY OF LIVERPOOL

Talk outline

- ✓ **Study area** (***Geographic location and stratigraphic/sedimentological context***)
- ✓ **Erosion surfaces observed at the case study**
- ✓ **Sedimentary facies distribution in the case study**
- ✓ **Architectural elements of the case study**
- ✓ **Model for upper slope channels and channel Complexes development)**
- ✓ **Final Remarks**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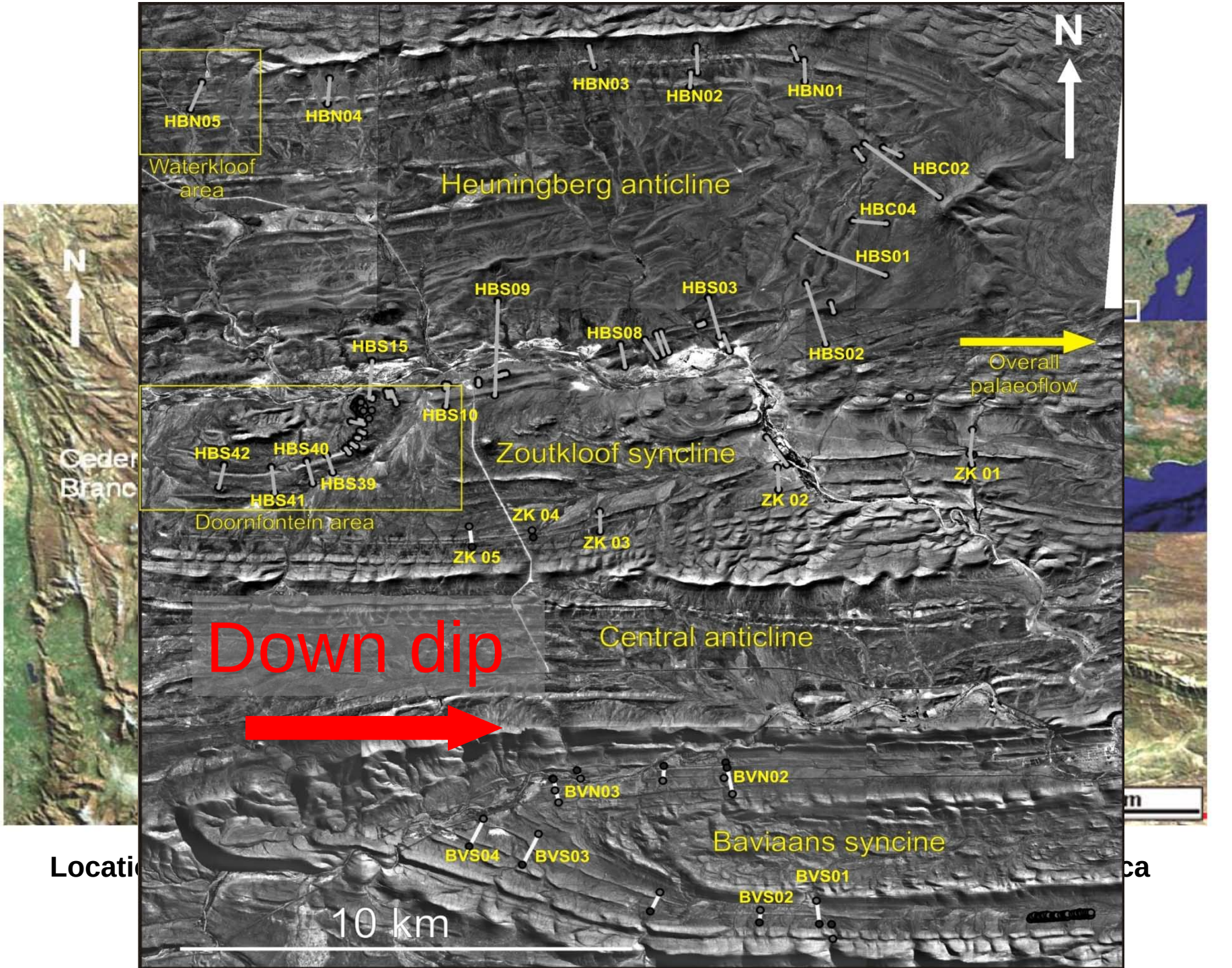
Palaeoflow
~ 1 km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HBN02
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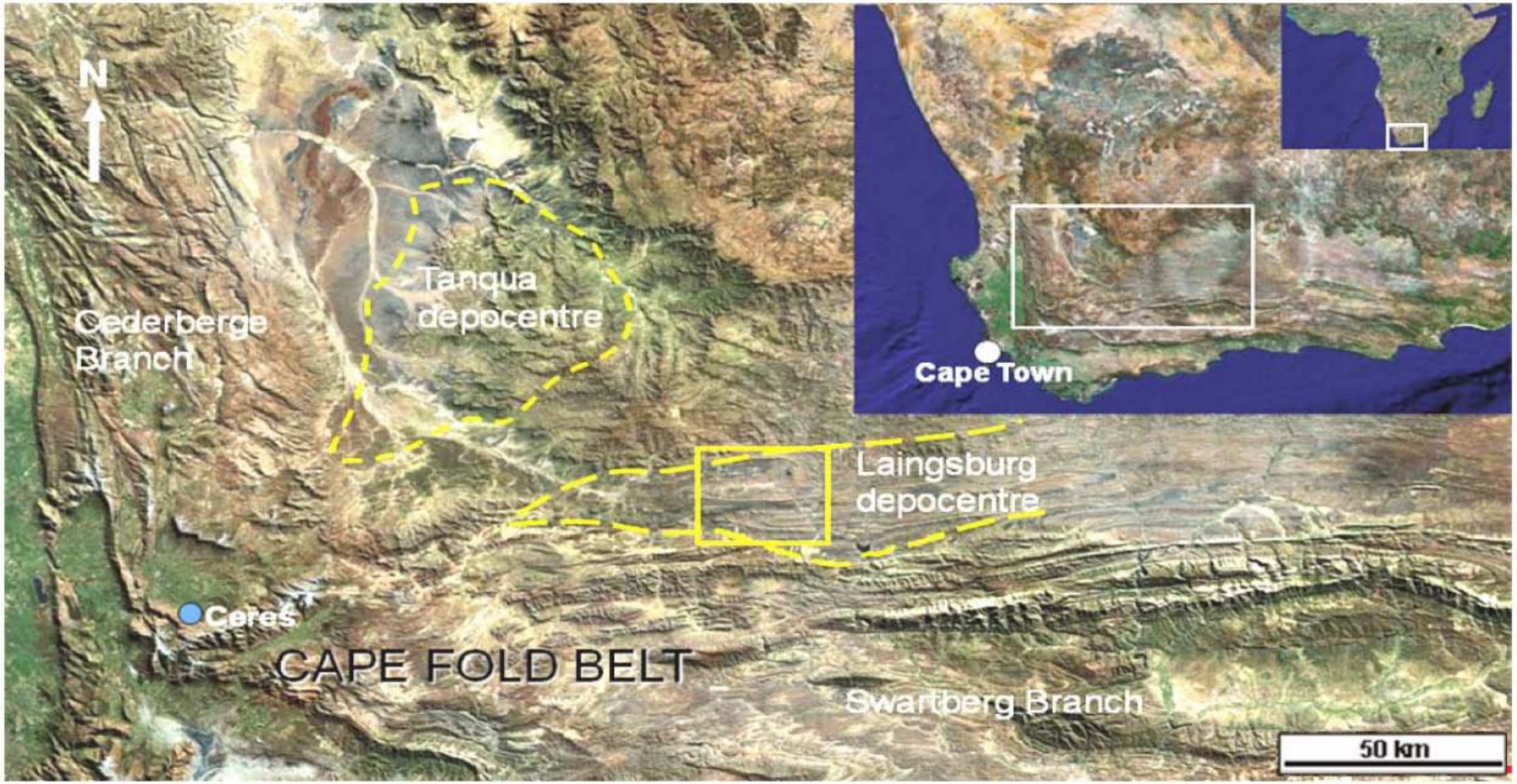
Waterkloof area
Heuningberg anticline
HBC02
HBC04
HBS01
HBS09
HBS03
HBS08
HBS15
HBS02
Overall palaeoflow
HBS10
HBS42
HBS40
HBS39
HBS41
Doornfontein area
Zoutkloof syncline
ZK 01
ZK 02
ZK 04
ZK 03
ZK 05
Down dip
Central anticline
BVN02
BVN03
BVS04
BVS03
Baviaans syncine
BVS01
BVS02
10 km

Locati ca

Study area

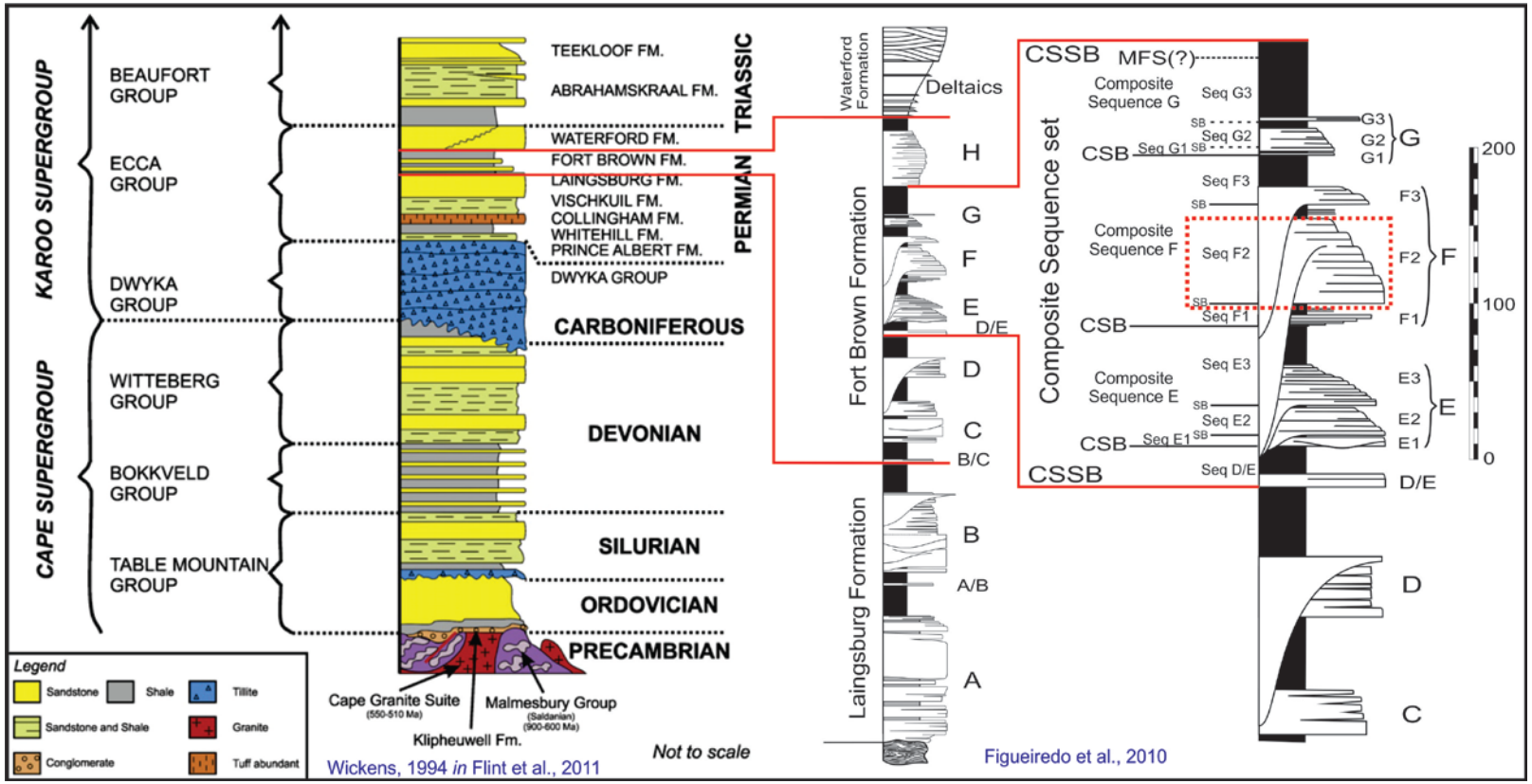
Geographic location

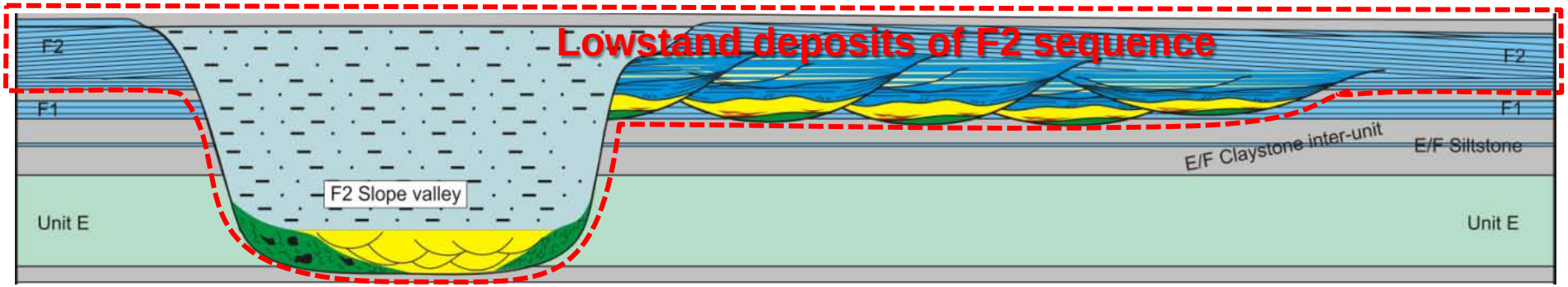


Location map of the Laingsburg depocentre in the SW Karoo Basin, South Africa

Study area

Stratigraphic and sedimentogical context: UPPER SUBMARINE SLOPE





Study area

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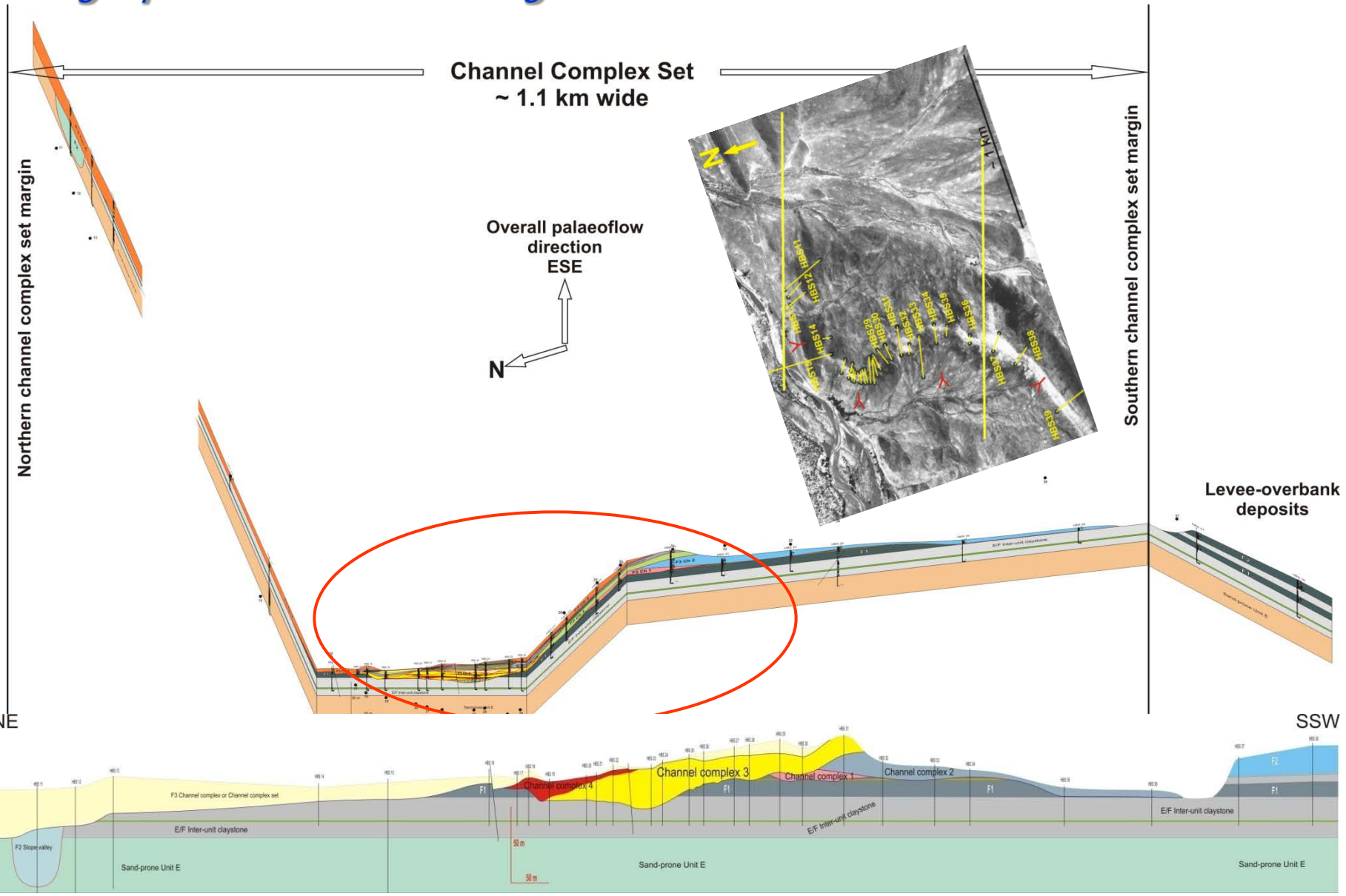
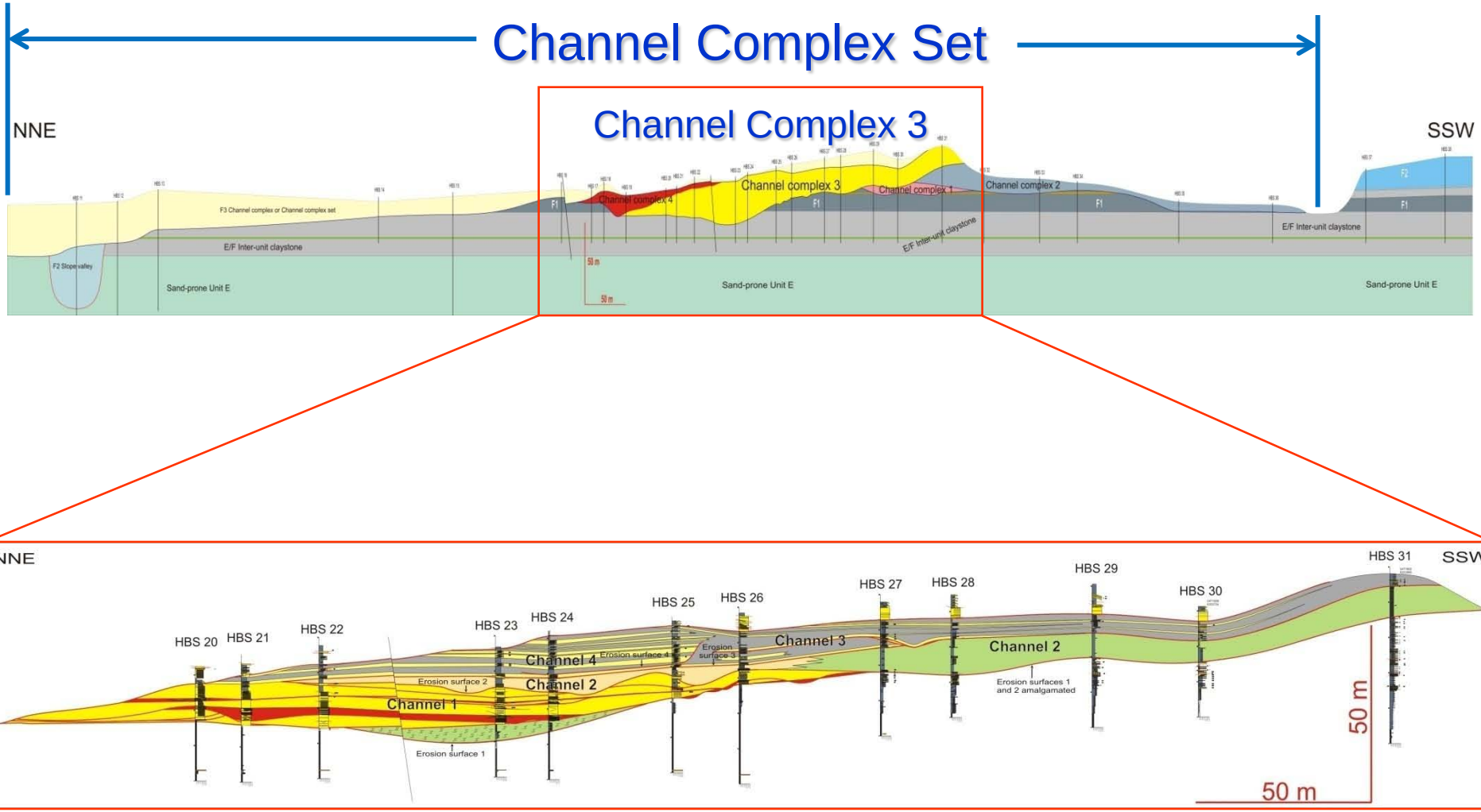


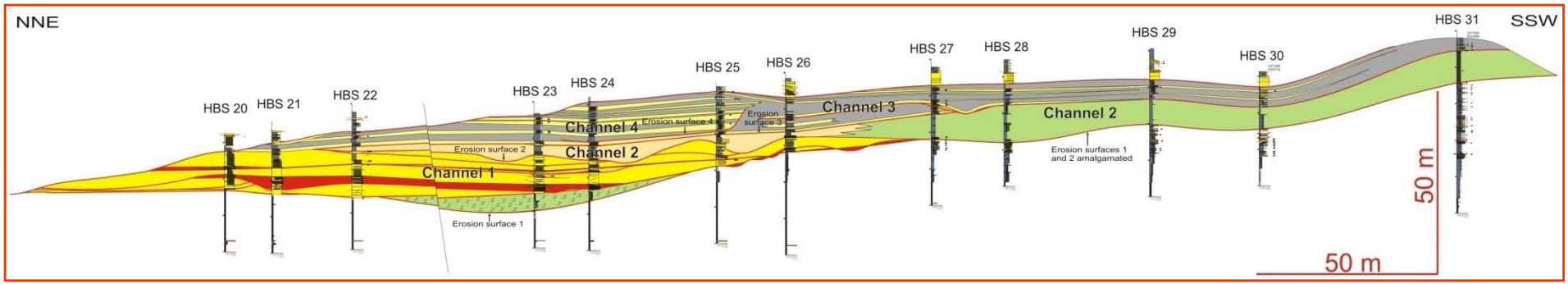
Erosion surfaces and sedimentary facies distribution

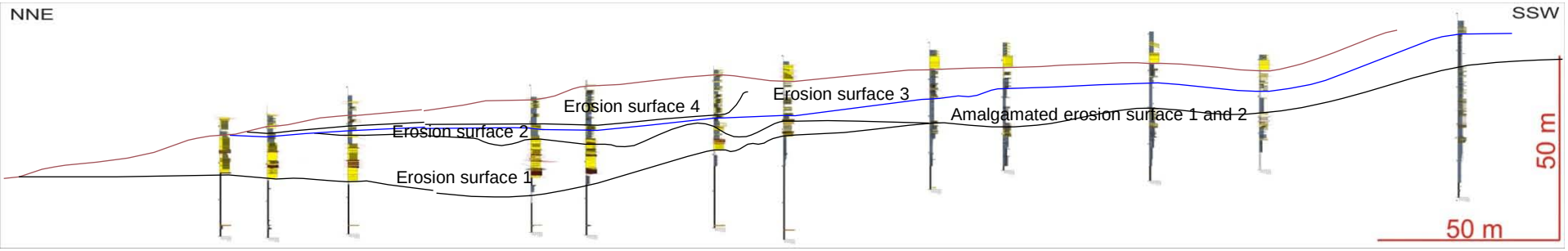
Upper slope channel complex



Erosion surfaces

Upper slope channel complex

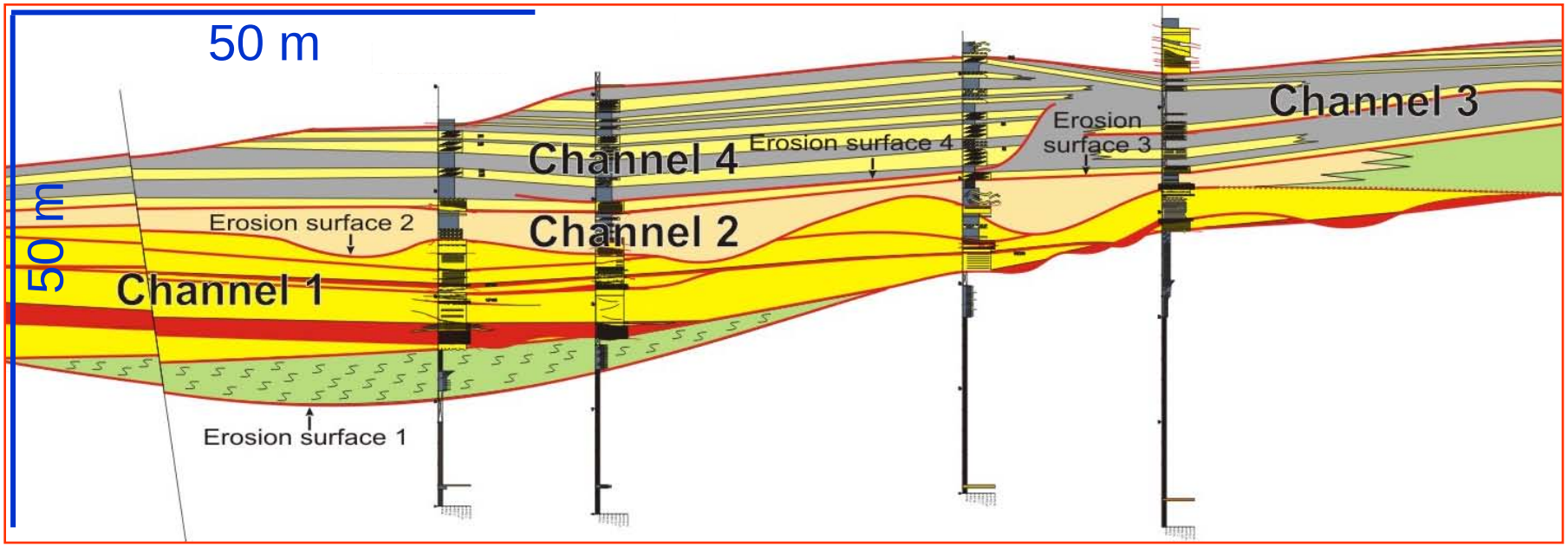


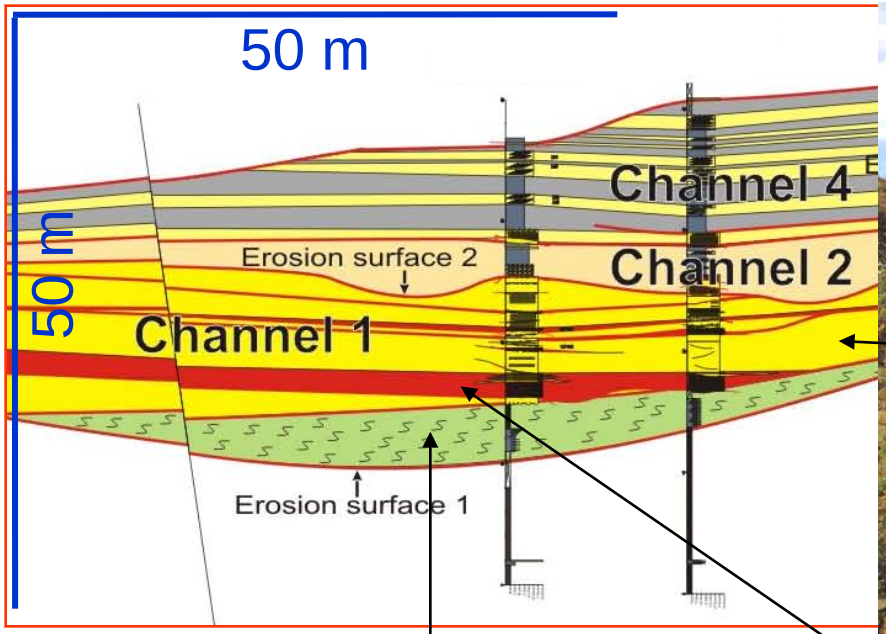


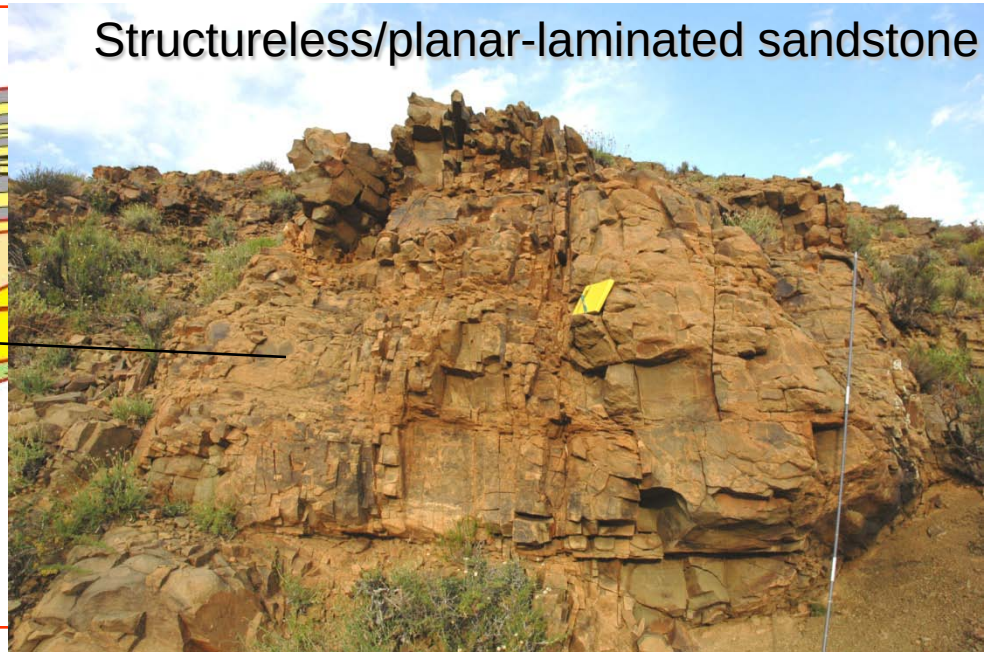
The basal erosion surface = Erosion surface 1 (deepest)

Erosion surfaces 2, 3 and 4 show a shallowing* upward profile
(*considering how deep is the erosion)

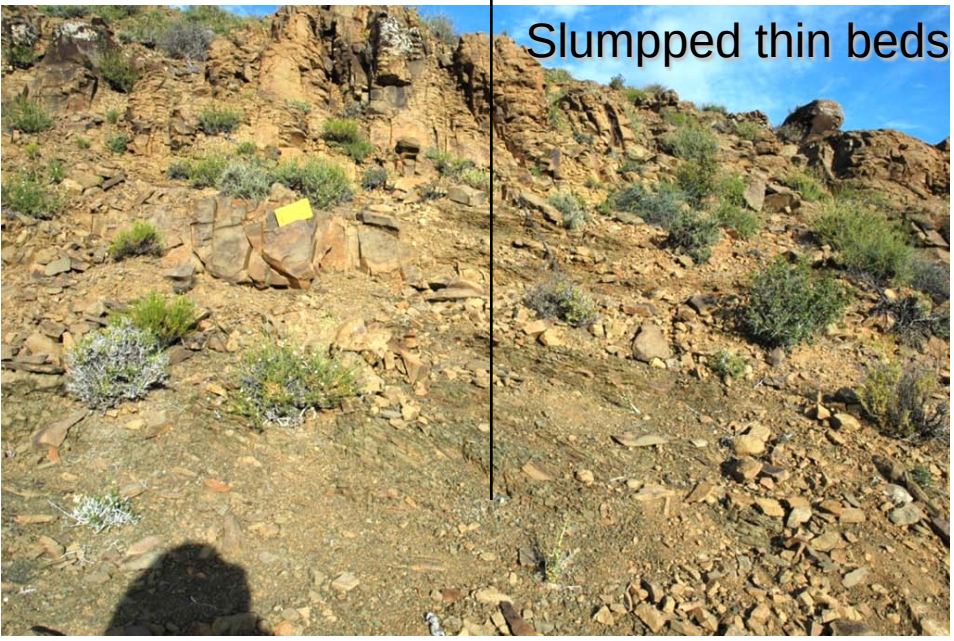
Sedimentary facies distribution

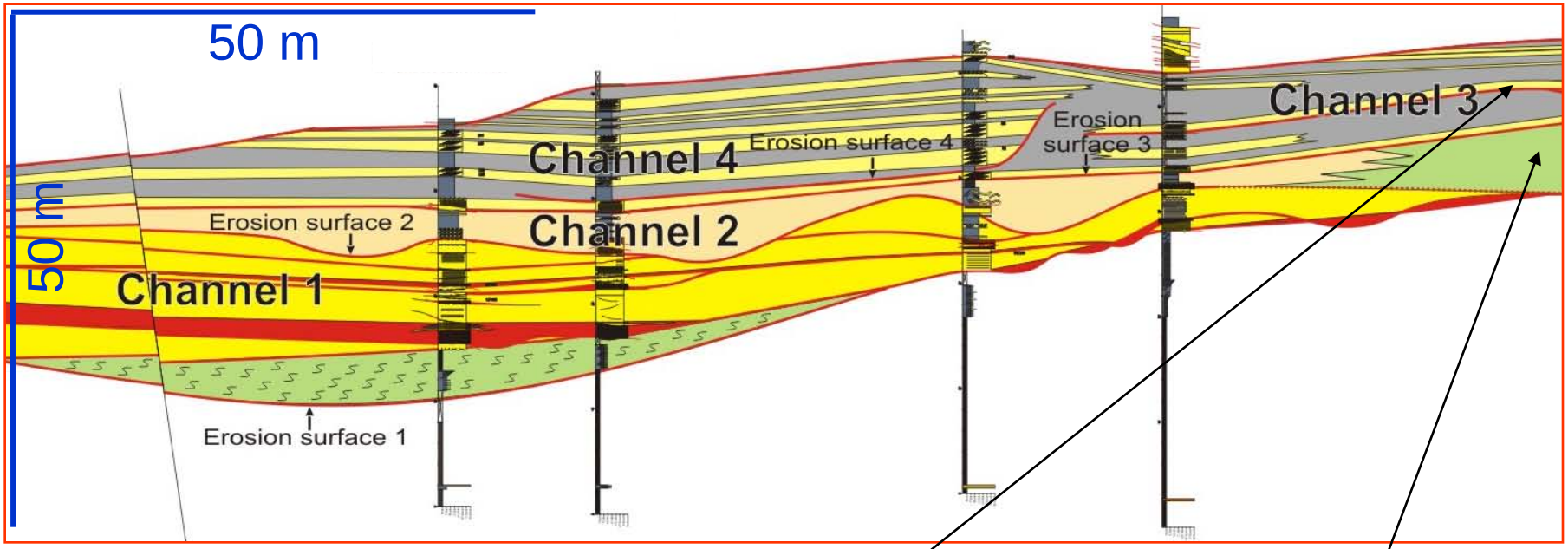




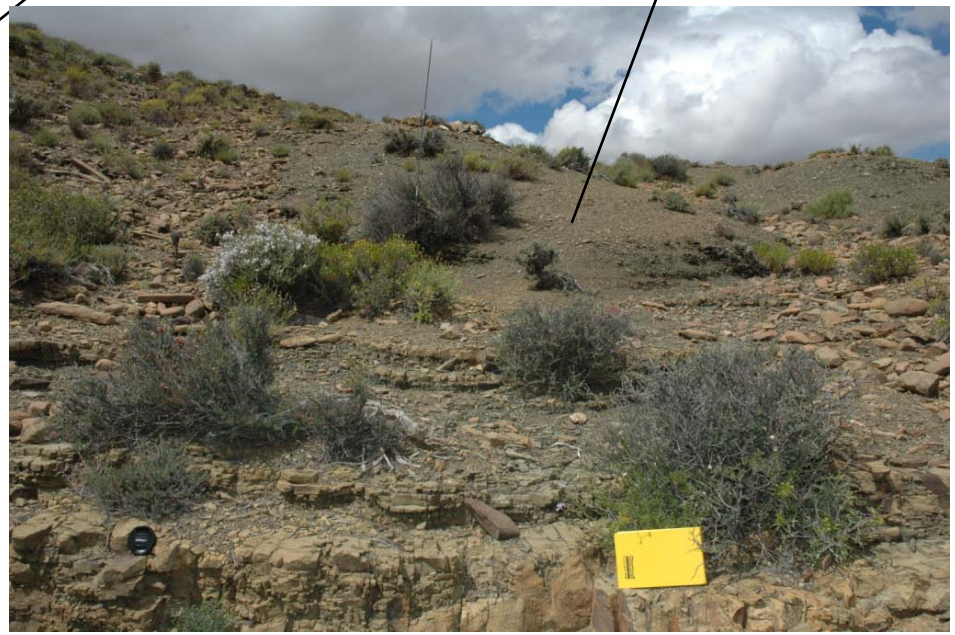


Channel axis lithofacies details



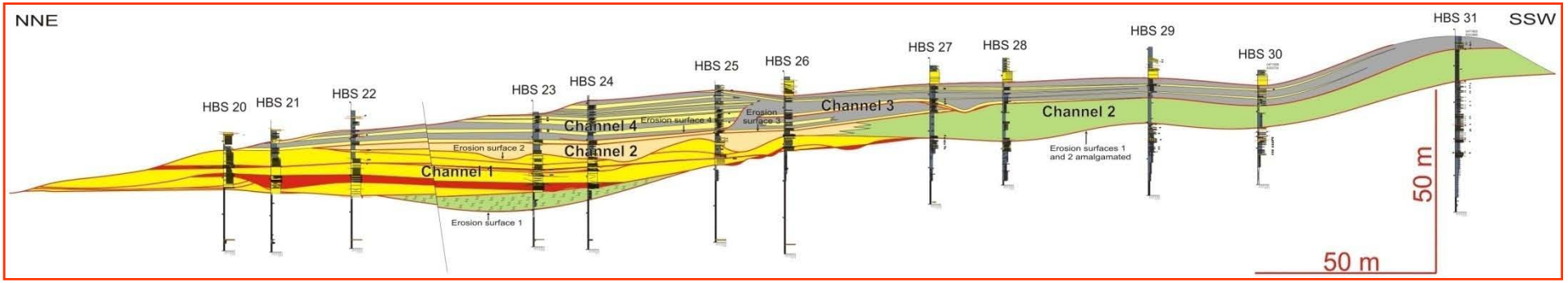


Planar-laminated/rippled sandstone



Sedimentary facies distribution

Upper slope channel complex

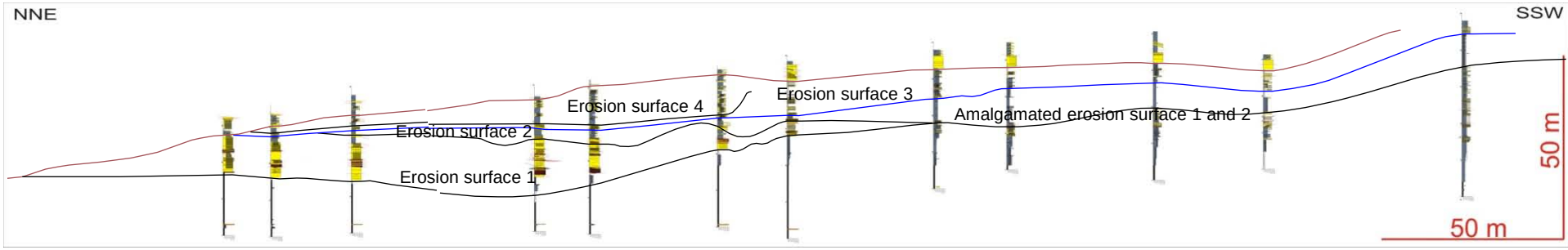


Keys for sedimentary facies distribution

- Slumps, siltstones and rippled laminated sandstones.
- Structureless/planar-laminated fine sandstones
- Mudstone clast comglomerates *Lag deposits*
- Slumps and/or Slides
- Siltstones
- Siltstones intercalated with thinly bedded very fine sandstone
- Planar and/or climbing rippled very fine sandstones

The sedimentary fill of the erosion surfaces shows that, the younger the erosion surface, the the finer and thinner is the lithological content. This leads to the interpretation of an overall decreasing in the energy of the erosional/depositional processess

Architectural elements



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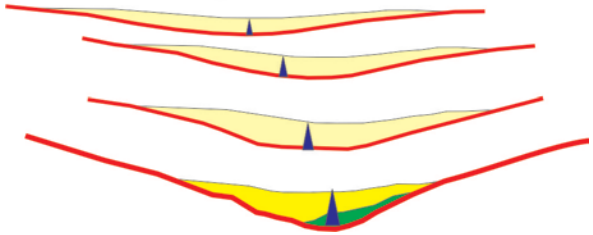
- Planar and/or climbing rippled very fine sandstones

Data integration from erosion surfaces geometry and sedimentary facies distribution leads to interpret two orders of architectural elements in the example showed in this work



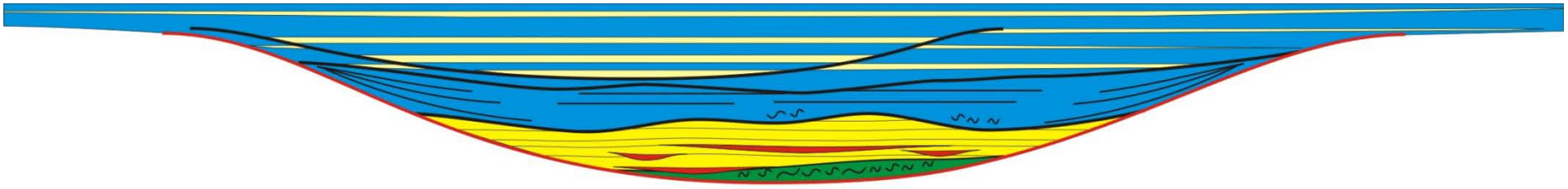
Single channels subvertically stacked

Channel complex

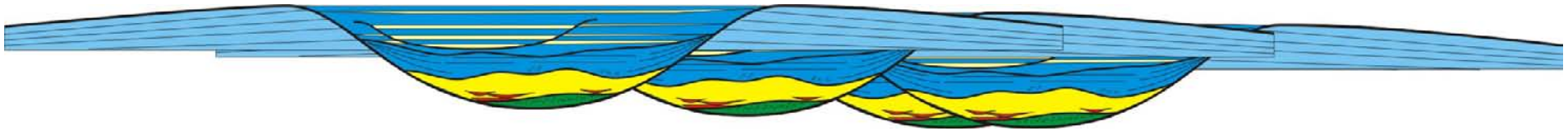
Architectural elements - *Hierarchy/scale*

Upper slope channel complex

Channel Complex

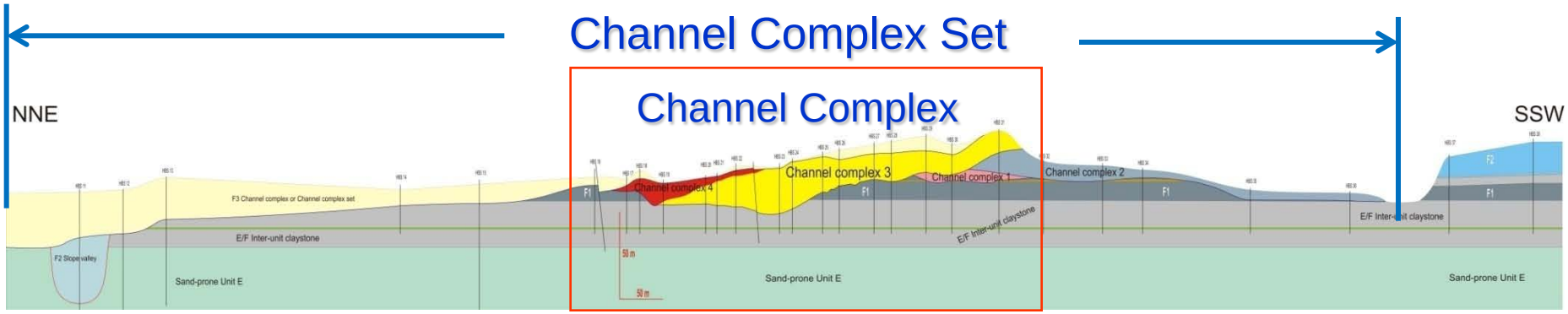


Channel Complex Set



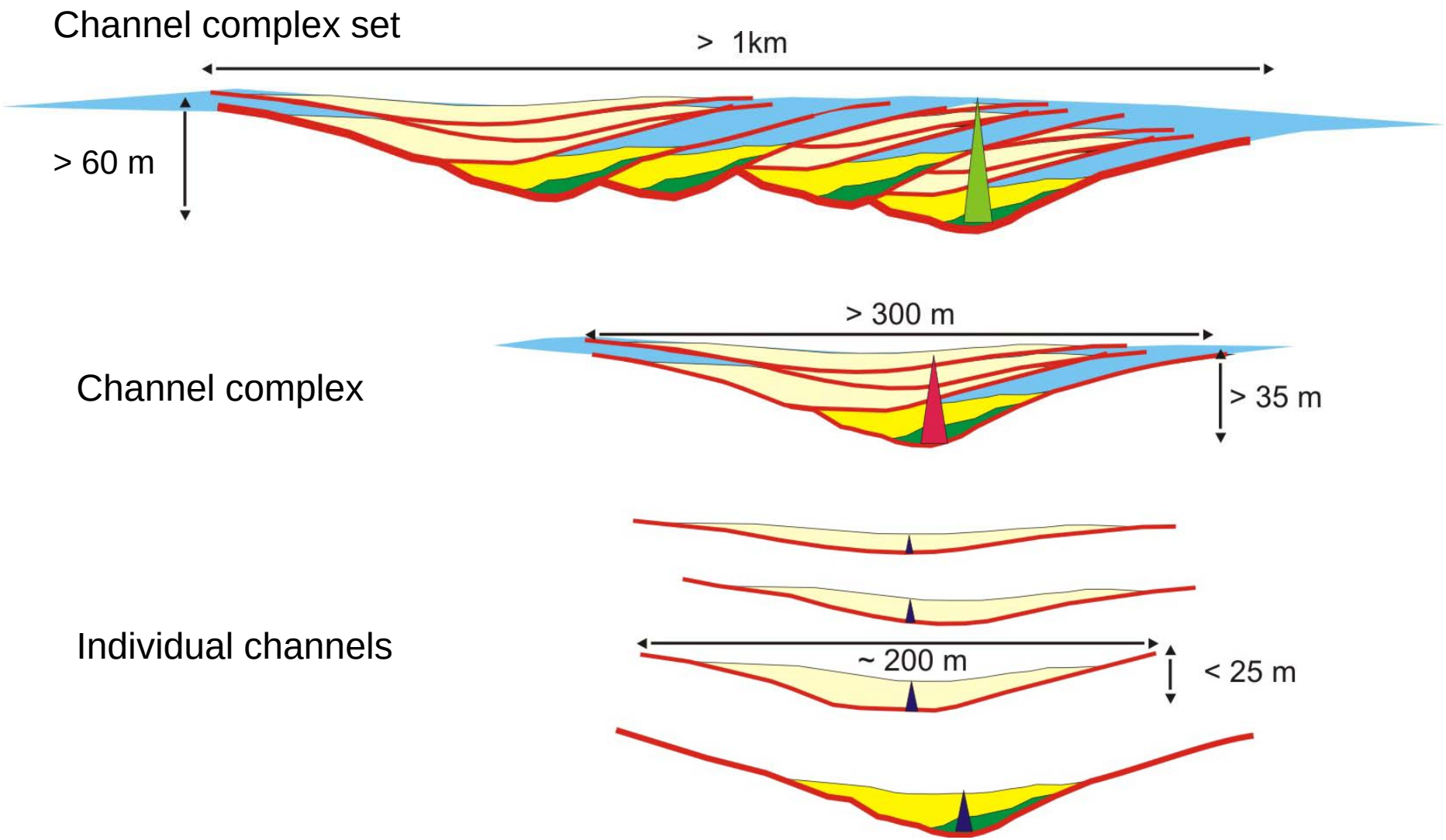
Channel Complex Set

Channel Complex



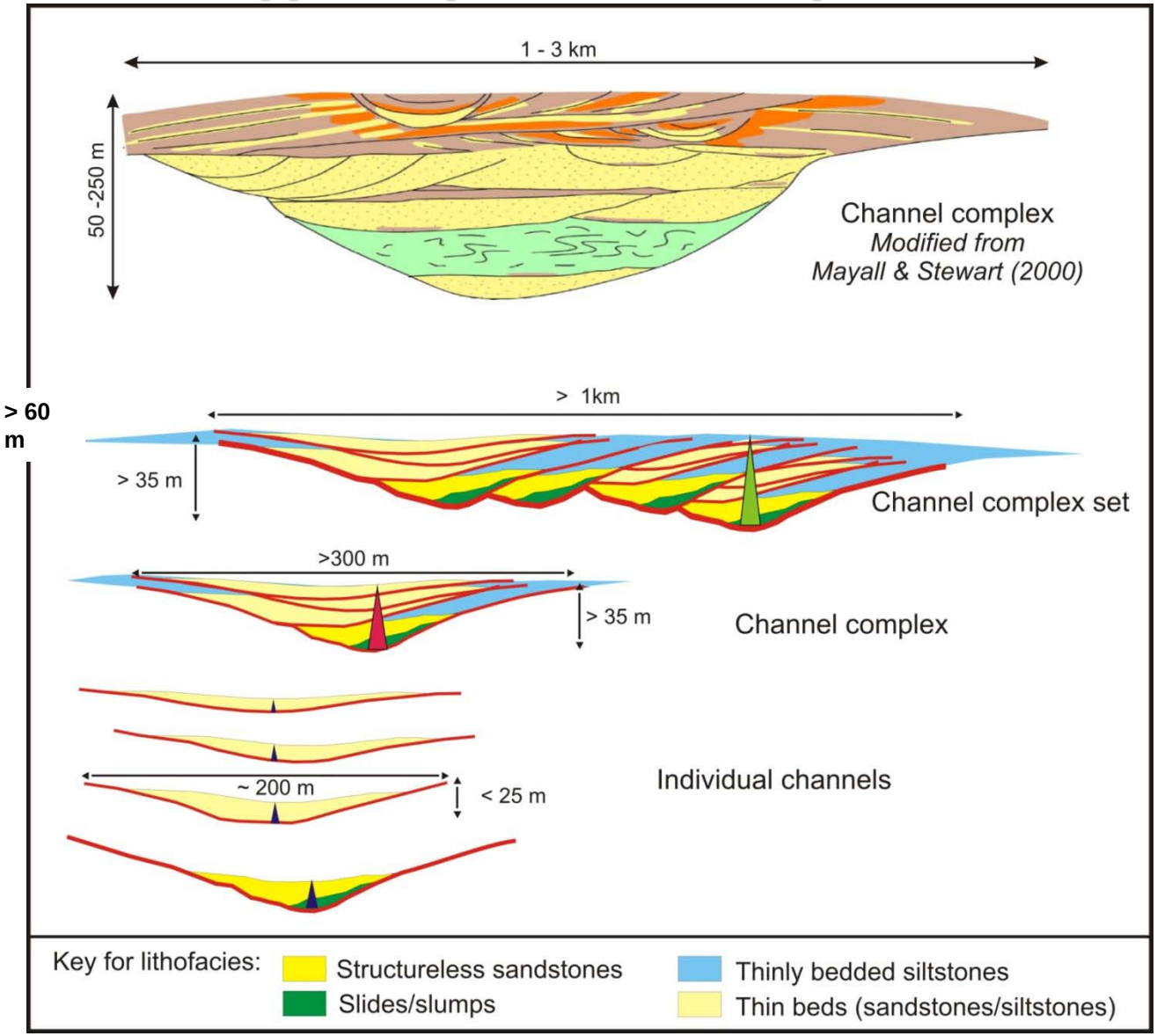
Architectural elements - *Hierarchy/scale*

Upper slope channel complex



Architectural elements - *Hierarchy/scale*

Upper slope channel complex



Remarks

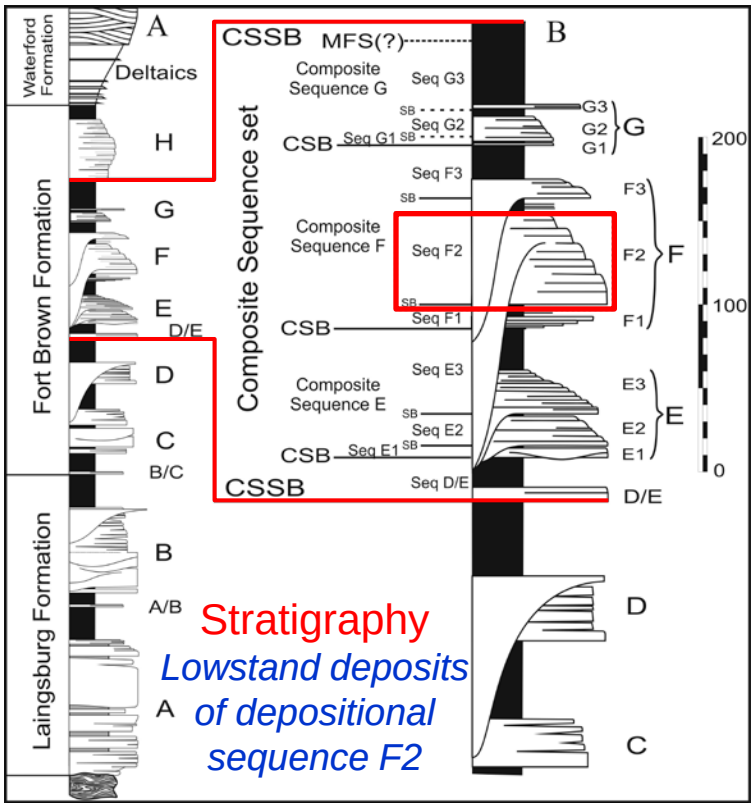
When compared to seismic-based models, the case study shows a difference in scale by an order of magnitude. It reveals that what is interpreted as a single channel from seismic is more likely a channel complex.

Implication

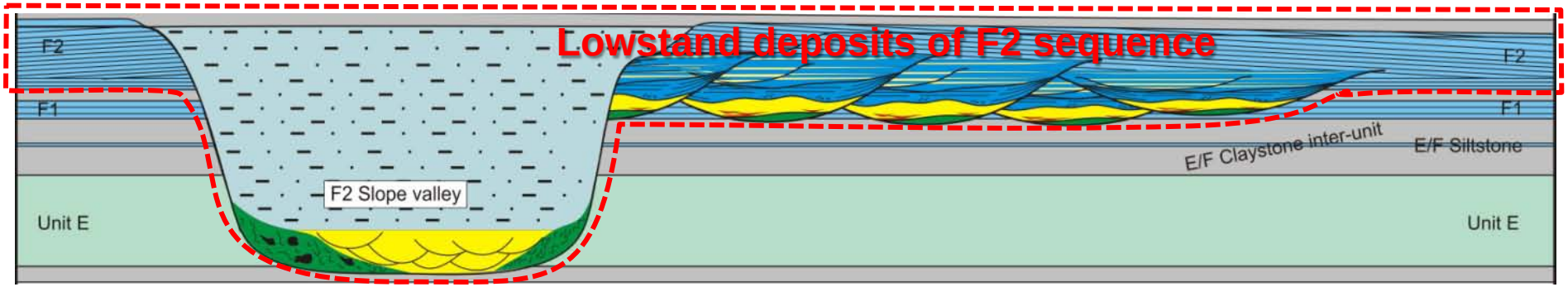
The misinterpretation of the erosional/depositional elements scale can lead to the misinterpretation of the internal heterogeneities of the channel/channel complex fills. This can affect the quality of reservoir as predicted based only on seismic dataset.

High resolution outcrop based studies help to resolve the internal anatomy of the channel/channel complex elements in order to complement seismic interpretation.

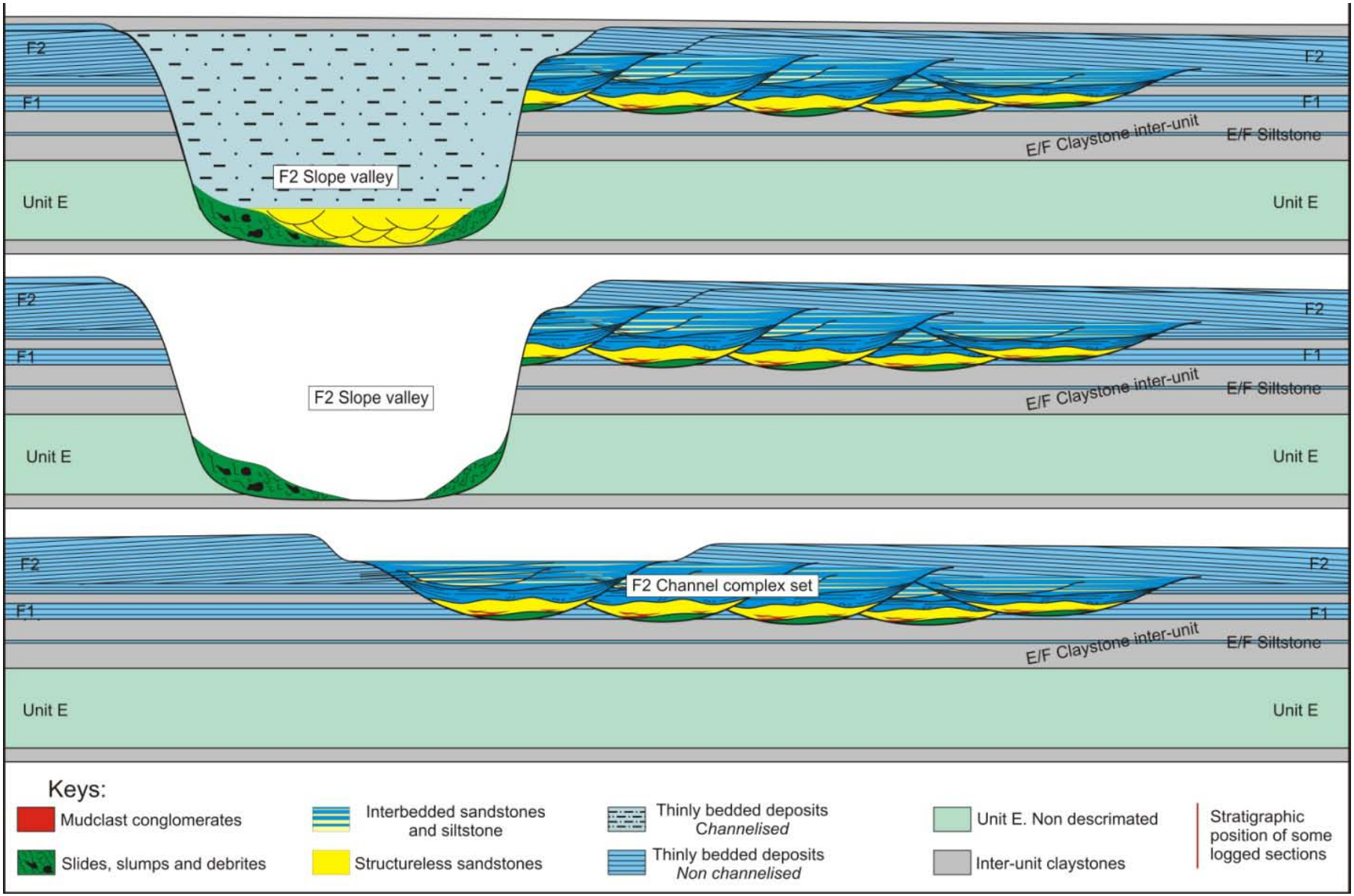
Model for channel complex and channel complex set evolution – Stratigraphic timing



What is the sequence of the events?

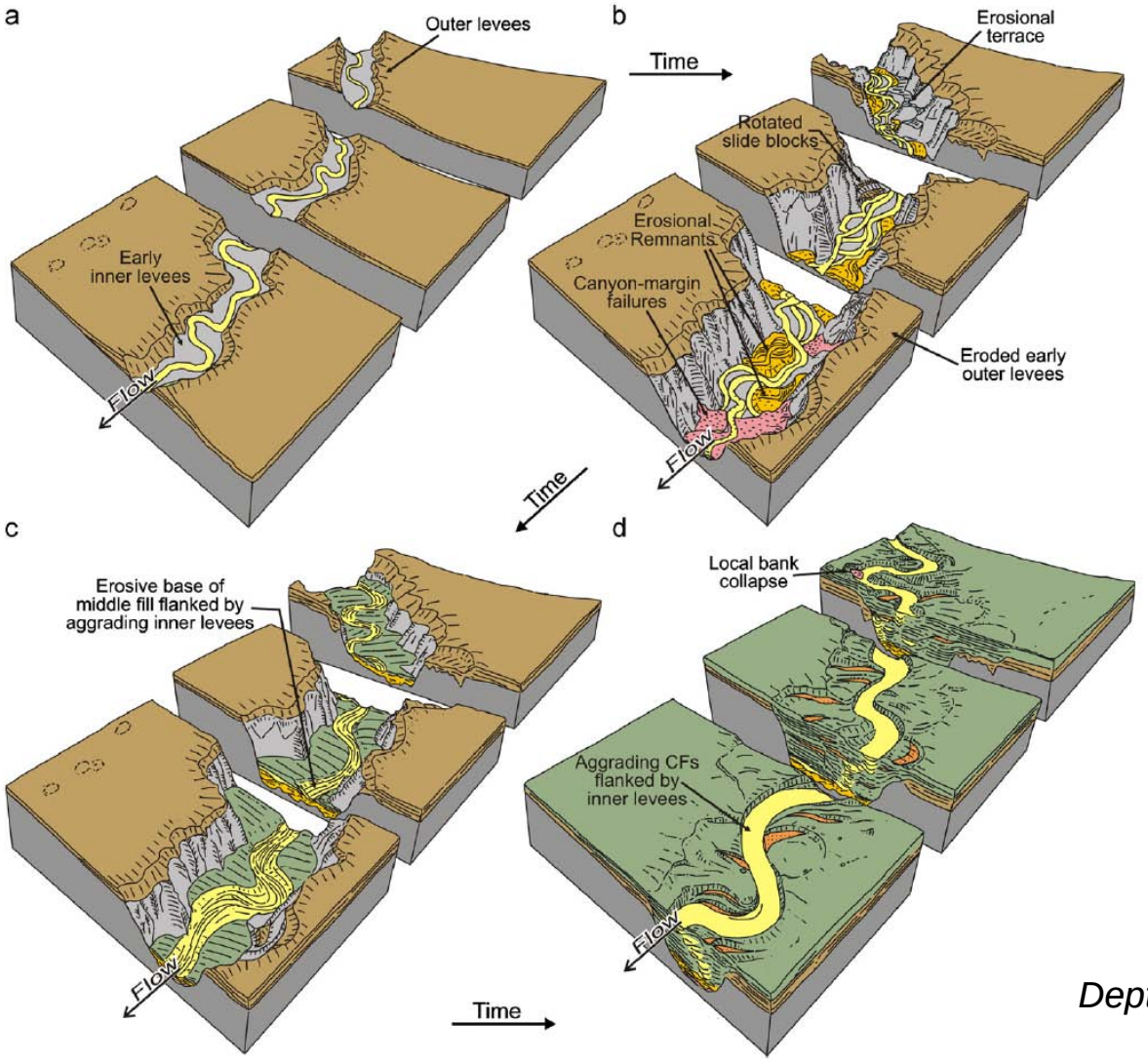


Model for channel complex and channel complex set evolution – Stratigraphic timing



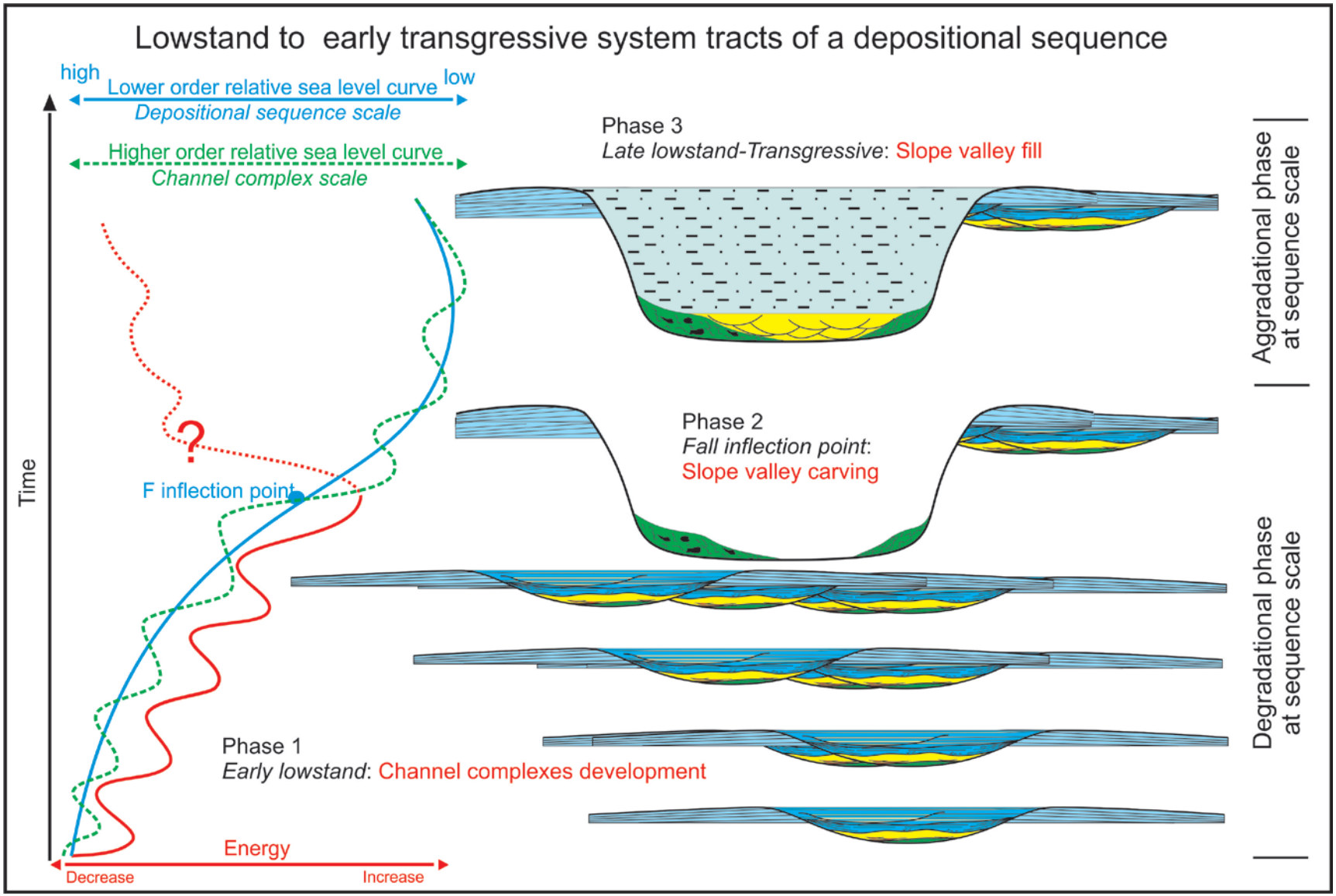
Model for channel complex and channel complex set evolution – Stratigraphic timing

Analogous

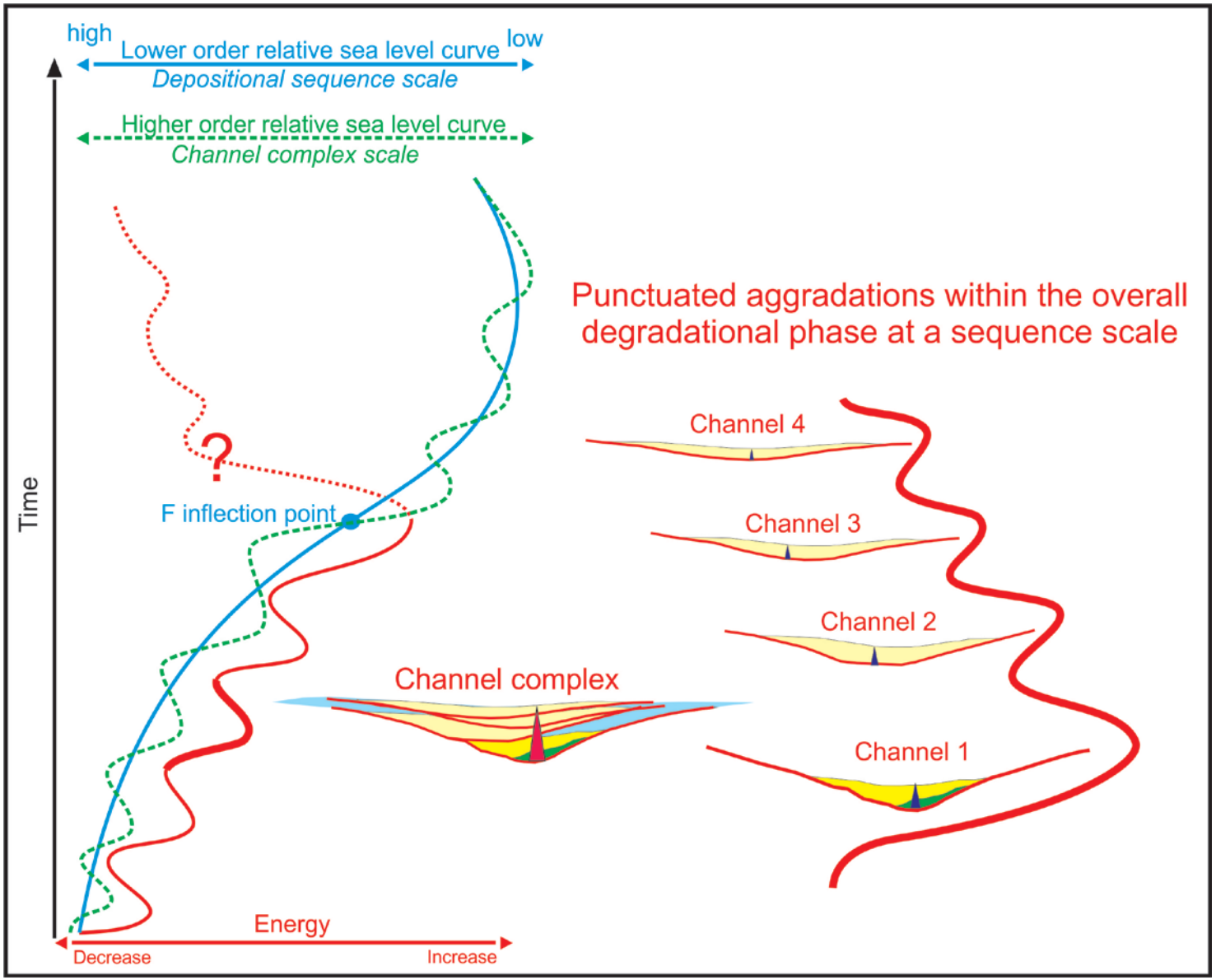


Deptuk et al., 2007

Model for channel complex and channel complex set evolution – Stratigraphic timing



Model for channel complex and channel complex set evolution – Stratigraphic timing



Final Remarks

In contrast to longstanding interpretations that consider upper submarine slope settings as zones dominated by sediment bypass, this work shows that it is also possible to find high net-to-gross deposits, with potential as hydrocarbon reservoirs in these settings.

A predictive scheme for their presence can be developed once the hierarchy of the erosional-depositional elements and/or the chronostratigraphy of the analyzed succession are known, and from this study it is inferred that reservoirs in the upper submarine slope may develop preferentially during the degradational phase at a sequence scale.

Channel complex set and its constituent channel complexes formed early in the degradation phase at the scale of depositional sequence. However, the development of the channel complex set was only possible due to punctuation of the waxing energy phase by waning energy periods allowing localized aggradation and development of the channel complexes with high net-to-gross content.

Thank you

Acknowledgment

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Jorge thanks OGX for the support to attend this conference.