

Seismic Geomorphology and Characterization of Deep Water Architectural Elements and its Applications in 3-D Modeling: A Case of Study, North Carnarvon Basin, Australia*

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Abstract

Analysis of a high resolution 3D seismic volume from Cenozoic strata in the offshore of North Carnarvon Basin, Australia has revealed fine details of deep water architectural elements, including their dimensions and position on the slope. Four main groups of architectural elements were identified and measured within eight stratigraphic sequences interpreted in the studied area: (1) erosive channel-fills, (2) channel-levee complexes, (3) mass transport deposits, and (4) sand fan lobes or sheets. Each depositional element exhibits a characteristic morphology and seismic response.

Although from offshore Australia, these Cretaceous-Miocene strata probably bear similarities to deep water strata in the southwestern deep water GOM (offshore Mexico). The high resolution seismic allowed placement of the architectural elements within a sequence stratigraphic framework. Falling stage systems tracts are characterized by development of small erosive channels in the upper slope, channel-levee complexes in the middle and lower slope, and sand fan lobes on the lower slope. Variations in the sediment composition are related to early development of large mass transport deposits. Lowstand systems tracts are characterized by the predominance of sand lobes on the lower slope and basin floor.

Analysis of slope gradients allowed comparison with other deep water sequences deposited on an ungraded-to-graded continuum of continental margins. The characterization of the stratigraphic grade of the margin showed the variations of the slope morphology and its consequences in the evolution of the margin from a *graded margin* to an *out-of-grade margin*.

Finally, the seismic attributes used as a guide in the seismic sequence stratigraphy interpretation were implemented in different approaches in order to build a 3-D geological interpretation. The interpreted horizons were included in the implementation of a simple methodology in order to construct probability maps for improving prediction of the distribution of architectural elements within a 3-D model.

Furthermore, measurements and spatial distribution of the mentioned elements identified in this study are used as inputs for the object-based model approach. However, it fails honoring data when well control and even constrains are included. Improved results are observed using a Sequential Indicator simulation approach constrained by three dimensional probability volumes calculated from geobody extractions using multiple seismic attributes.

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Seismic geomorphology and characterization of deep water architectural elements and its applications in 3D modeling. A case of study, North Carnarvon Basin, Australia

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ICE AAPG

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Outline

➤ Introduction

- Location - Data set
- Geology

➤ Methodology

➤ Seismic Sequence Stratigraphy

➤ Characterization of the stratigraphic grade for the coastal margin

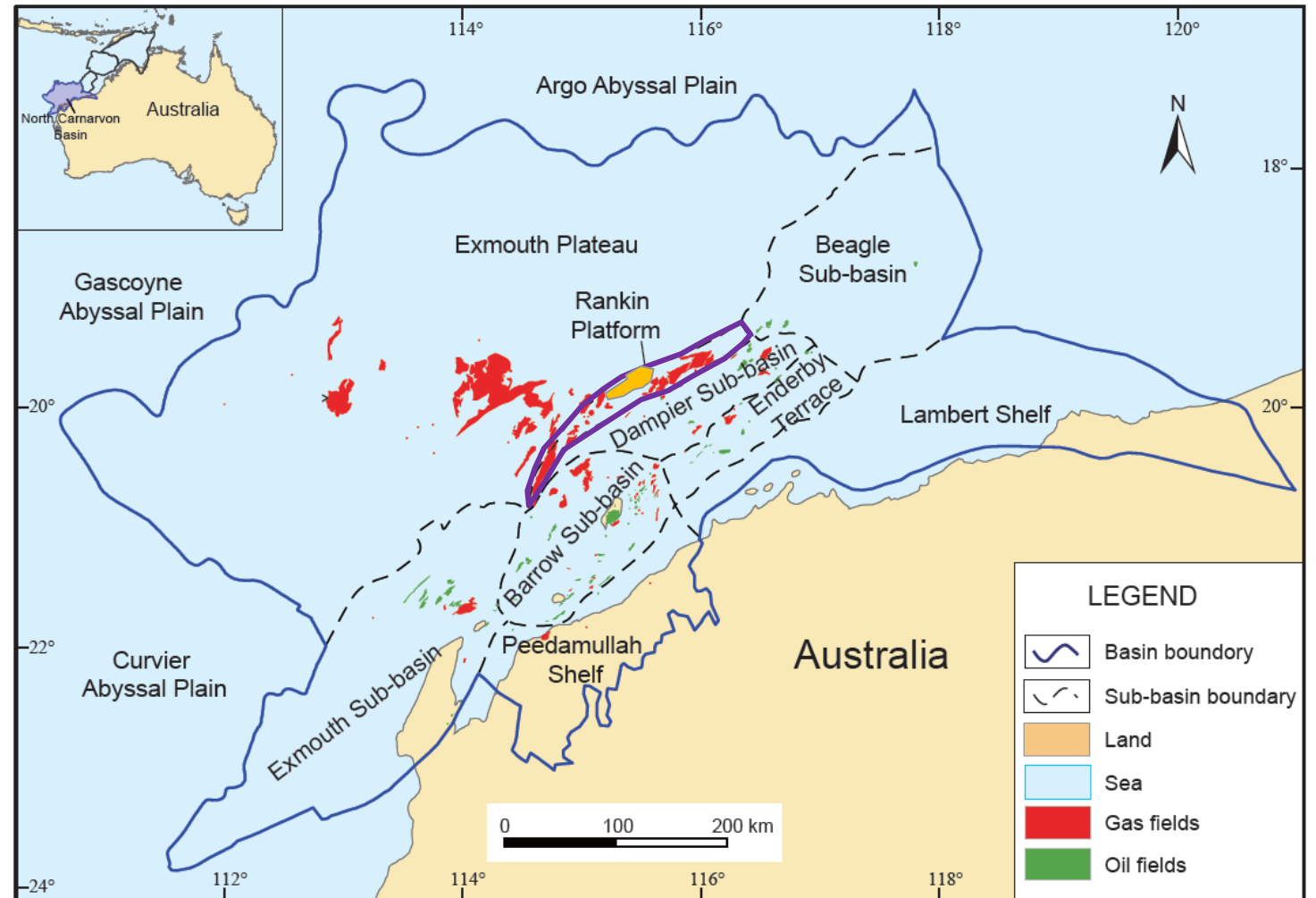
- Dip sections
- Compensation style deposition

➤ Seismic attributes and applications in 3D modeling

- Cell-based model
 - Object-based model
-

Location

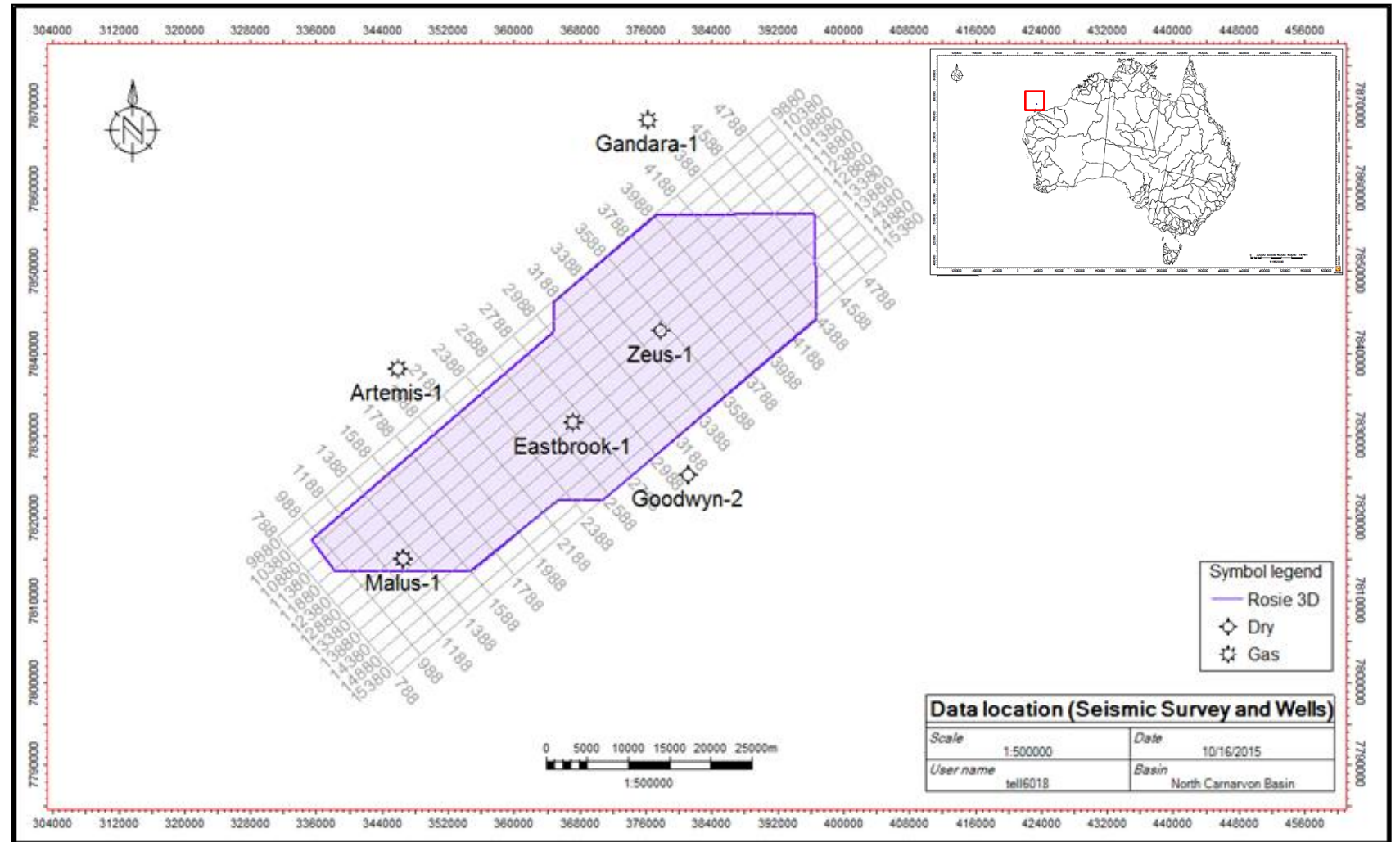
- North Carnarvon Basin is the most prolific Oil and Gas basin in Australia
- Area surrounded by hydrocarbon fields
Perseus 9.5 TCF
Jansz-lo 566 BCF
- Understand the configuration of deep water deposits
- Characterize geomorphology and dimensions of architectural elements
- Apply the results on three dimensional modeling



North Carnarvon Basin. Discovered fields for Oil and gas. Modified from Chongzhi, 2012

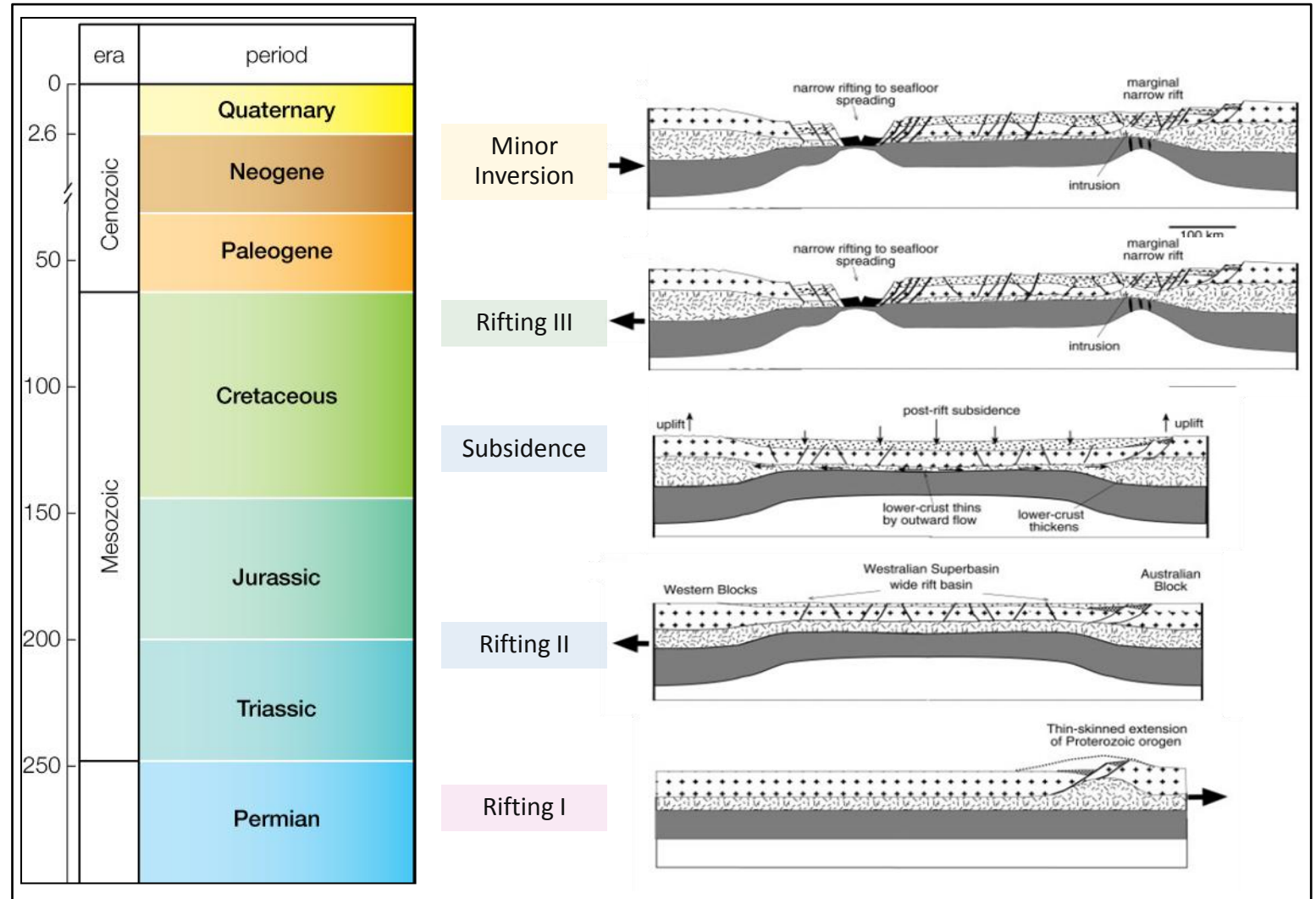
Data Set

- Rosie 3D Volume Post-stack
 - 45-55 hz Dominant frequency
 - 60 Km * 40 Km
 - Acquired in 1996
- Well logs from 6 hydrocarbon exploration wells(3 inside volume)
 - GR, Den, Sonic, PEF, LLD
- Biostratigraphy reports
- Check shots taken from previous studies in the area



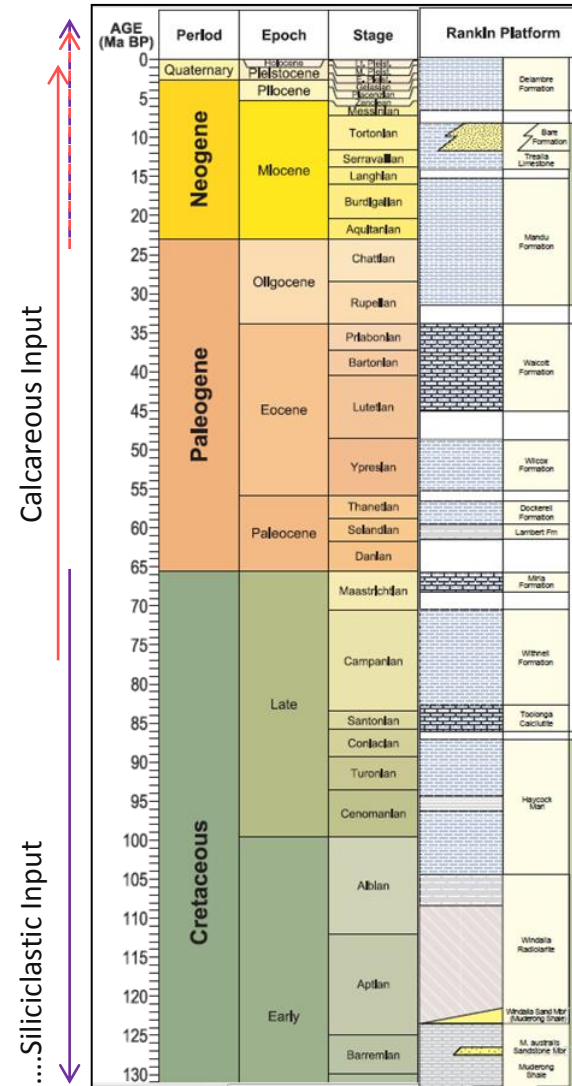
Geological overview

- North Carnarvon Basin is composed of Exmouth, Rankin Platform, Barrow, Dampier and Beagle Sub-basins
- Successive rifting events have undergone in the basin. Older rifting event was late Permian most recent Late Jurassic

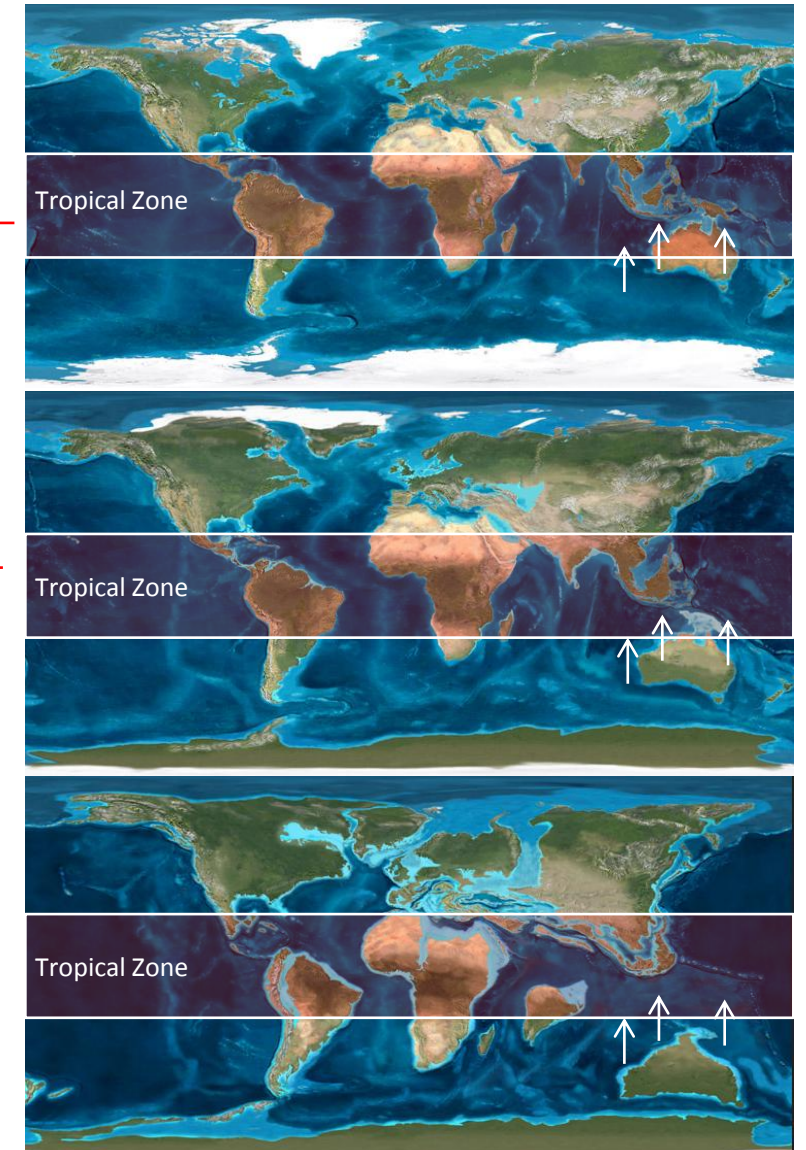


Geological overview

- Cenozoic sediments were influenced by the collision of the Banda Arc and Australia in the late Miocene (Baillie et al 1994)
- Change in the sediment type from siliciclastic during Mesozoic to mixed siliciclastic - carbonates in Cenozoic interpreted as result of the movement of the Australian plate since Cretaceous (Baillie et al 1994)



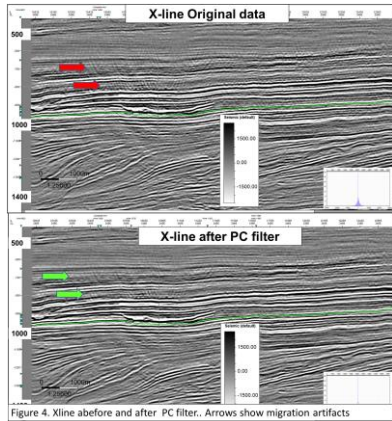
Modified from Nicoll et al., 2010



Modified from Blakey, 2015

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Methodology

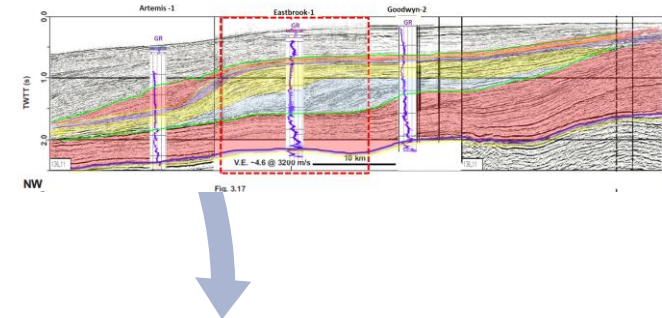
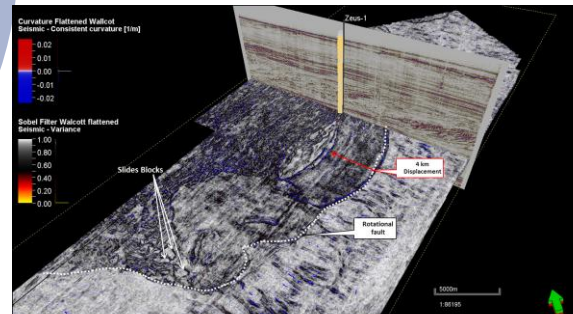


- 3D Rosie Seismic Volume Post-stack
- Principal Component Filter

Cleaning
information

Attribute
calculation

- Coherence
- Curvature
- Reflector Convergence
- Cos Phase
- Instantaneous Phase

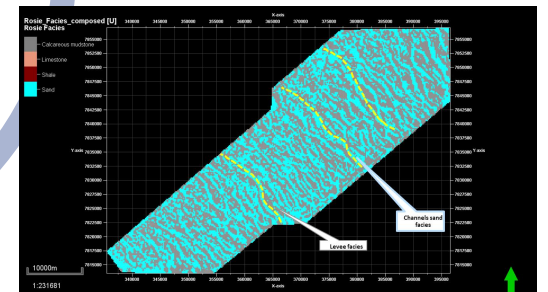


- Seismic stratigraphic In.
- Surface horizon flattening
- Characterization of the coastal margin
- Attribute co-rendering
- Measurements

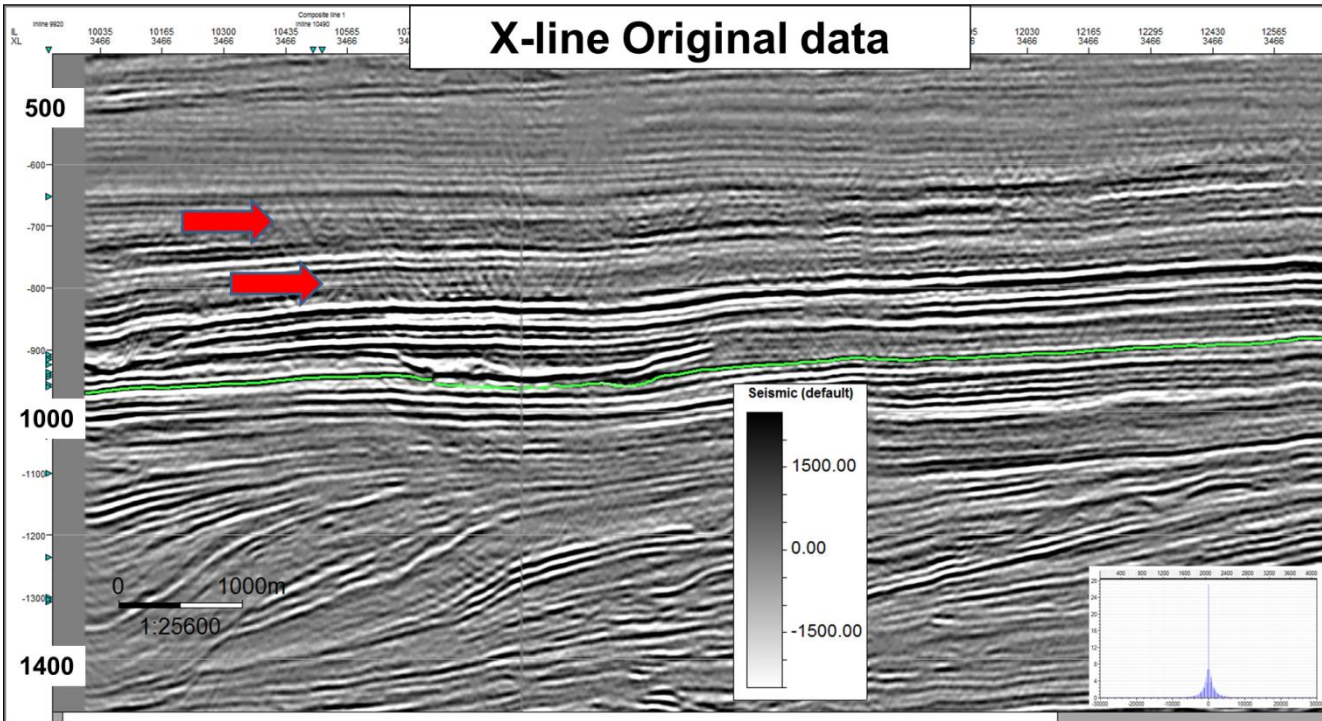
Seismic
Interpretation

3D modeling
Applications

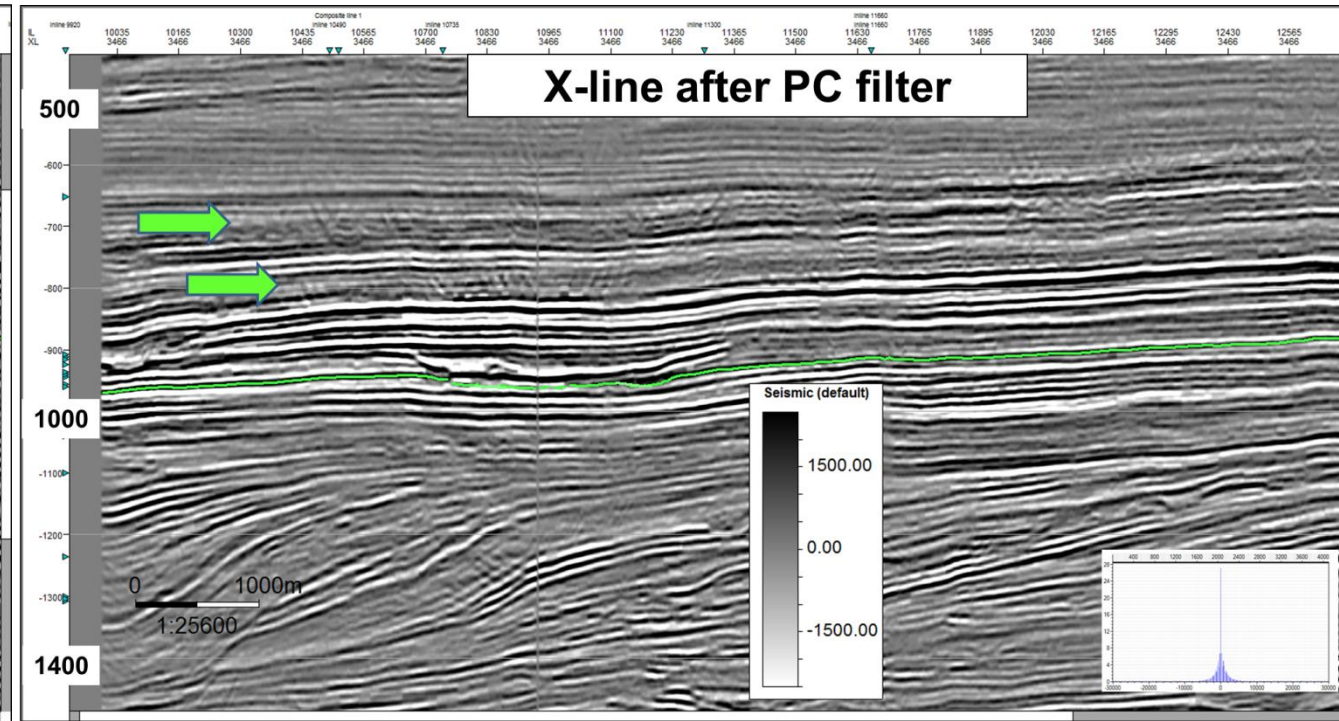
- SIS Probability Maps from seismic horizon extractions
- OBM using parameters measured in seismic sequences
- Probability volumes



Principal Component Filter

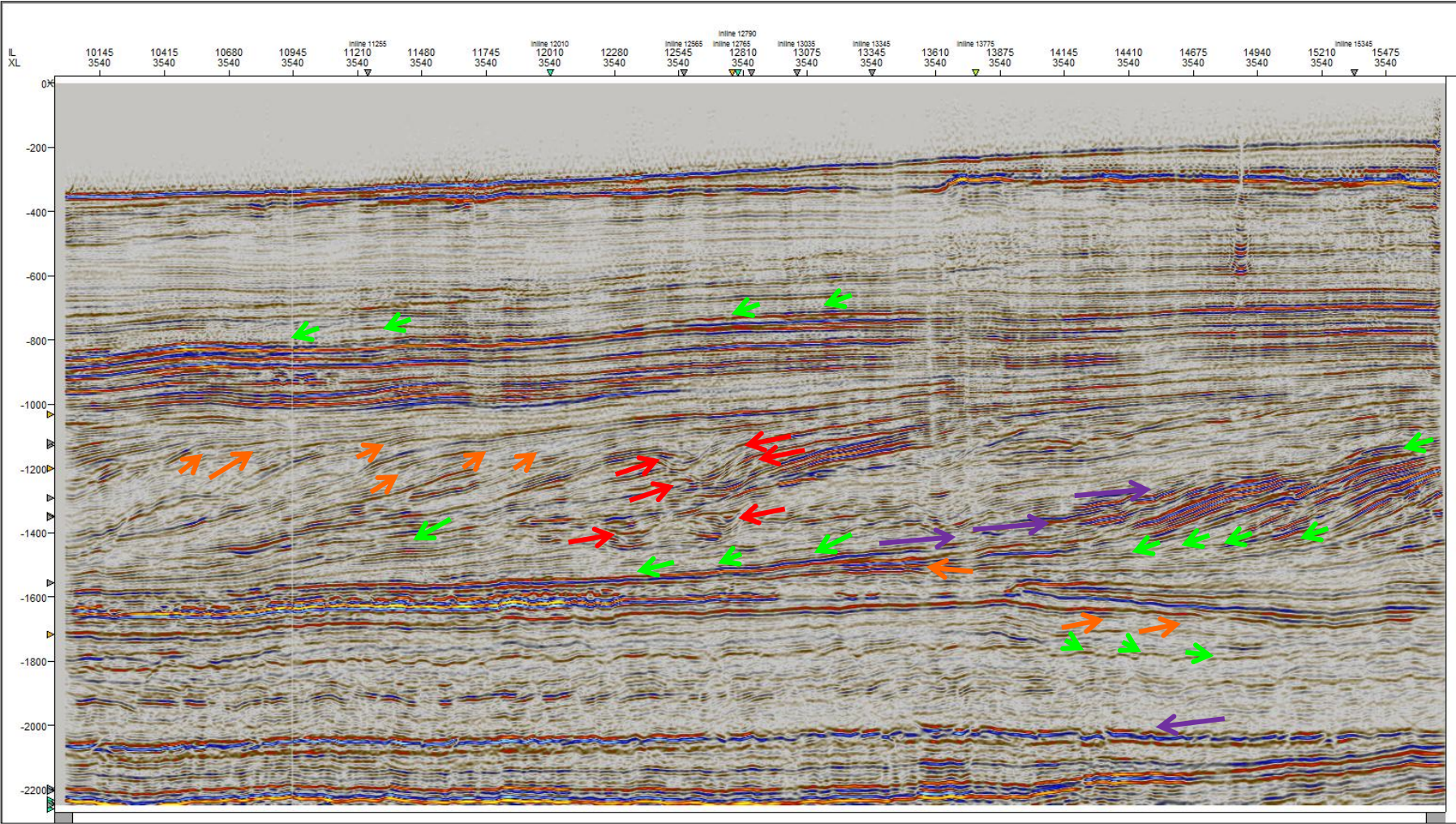
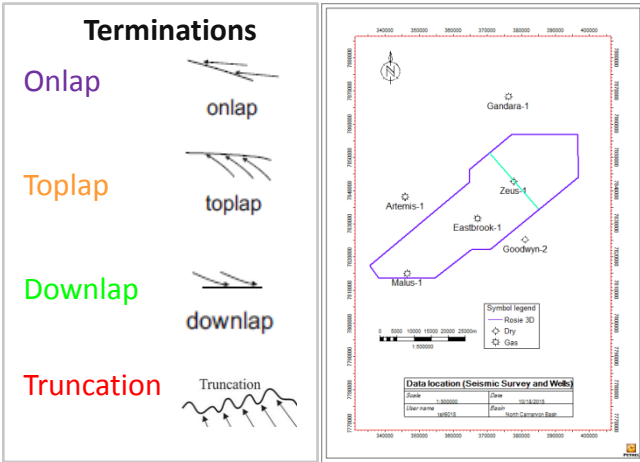
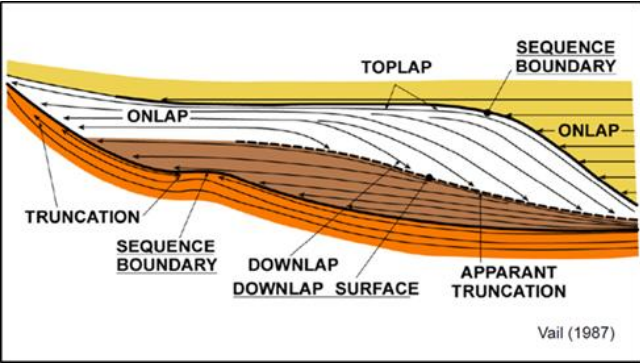


- Eliminates migration artifacts



- Improved image

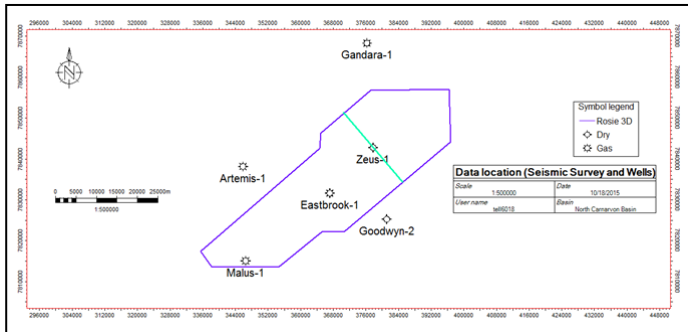
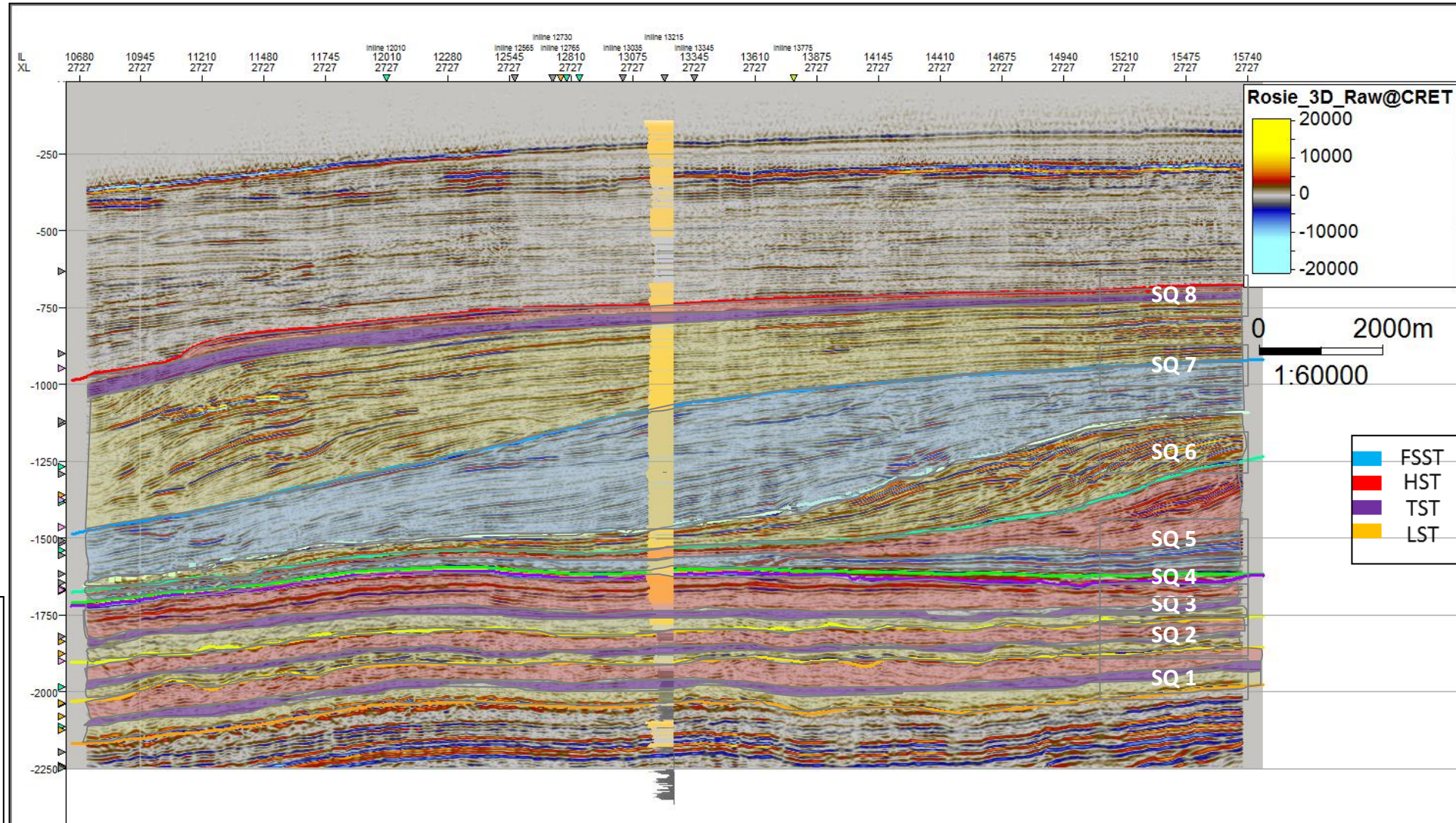
Seismic sequence stratigraphy



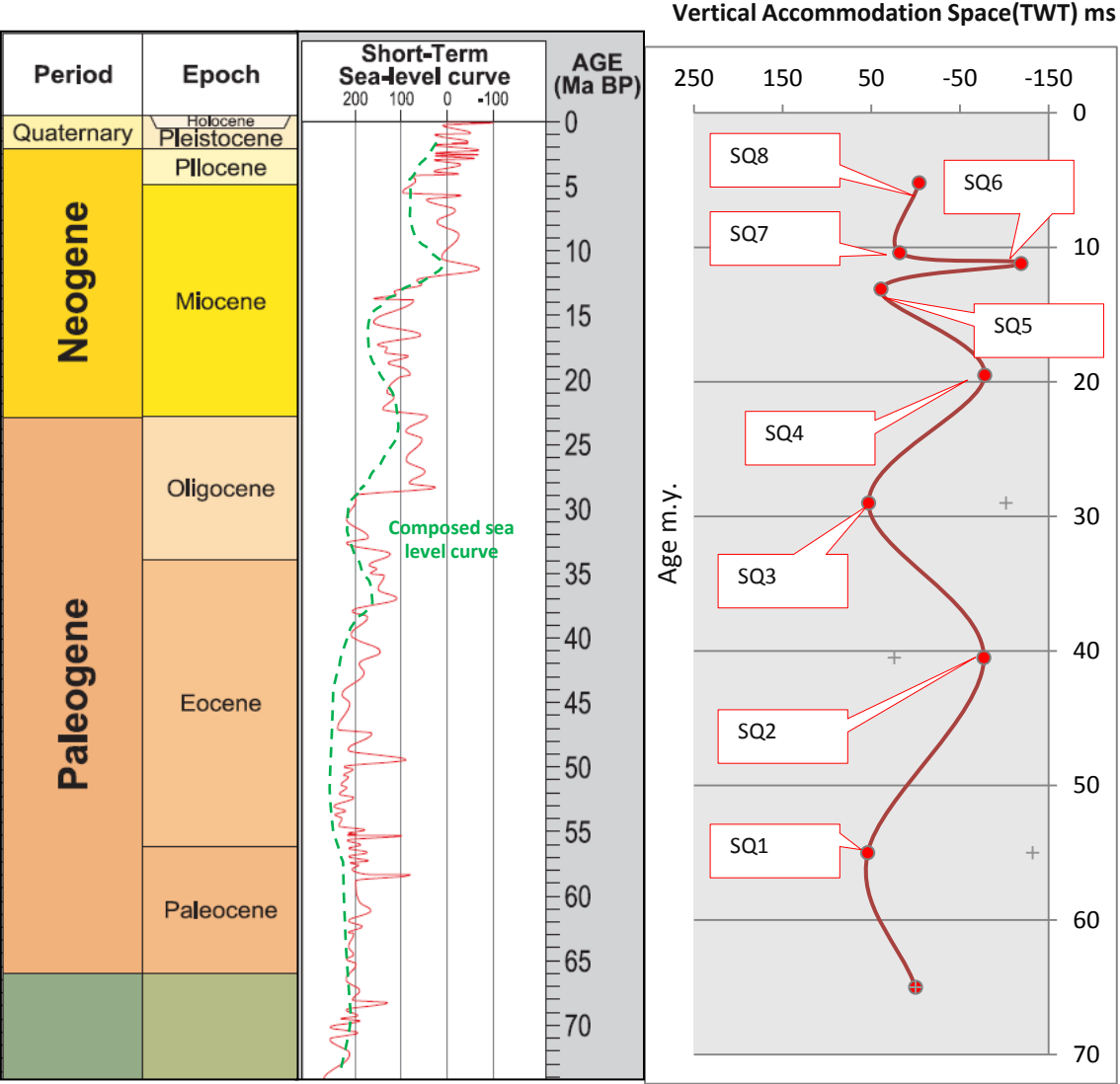
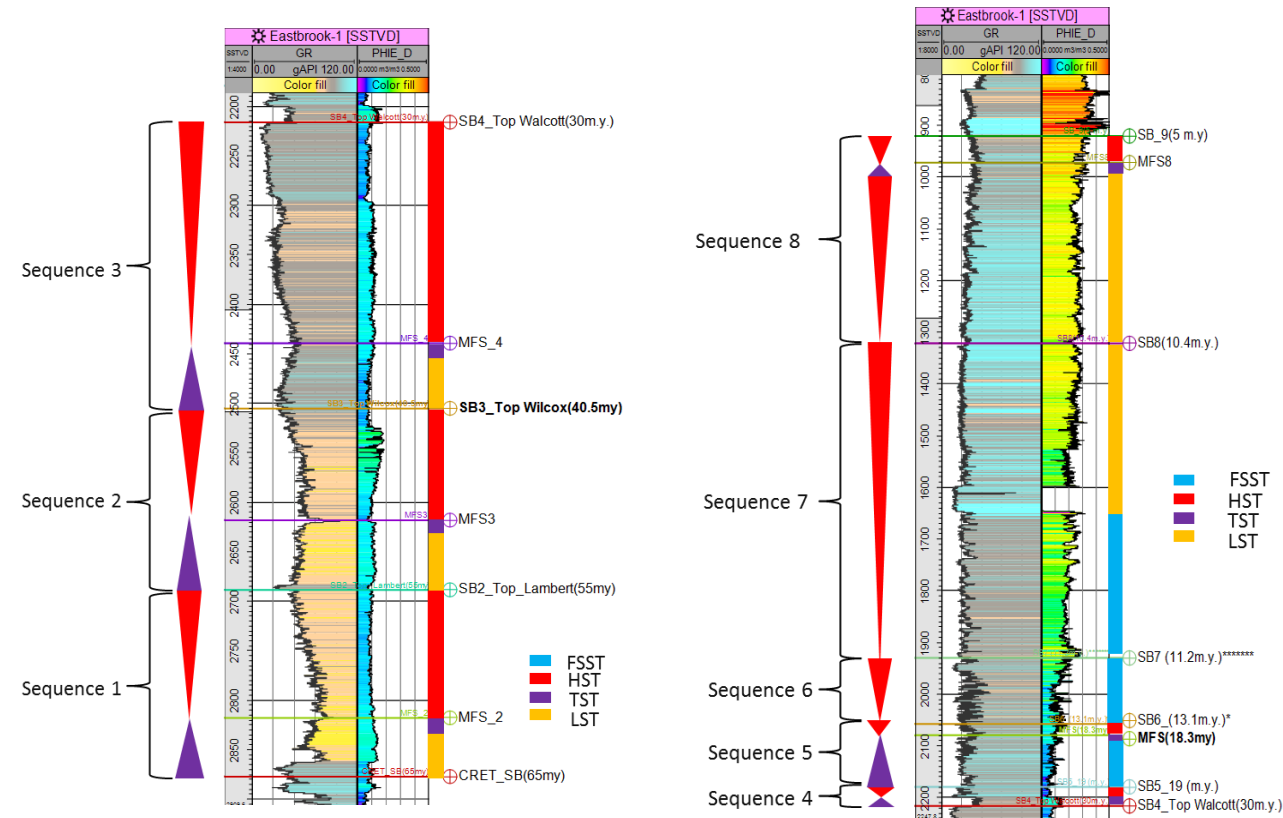
Seismic Sequence stratigraphy 3rd order

3rd order sequences

- Eight Sequences
- Sequence ages estimated by biostratigraphy reports(Moss, 2002)
- Lack of system tracts identified as result of high sedimentation rates during Miocene (10 – 20 m.y.)

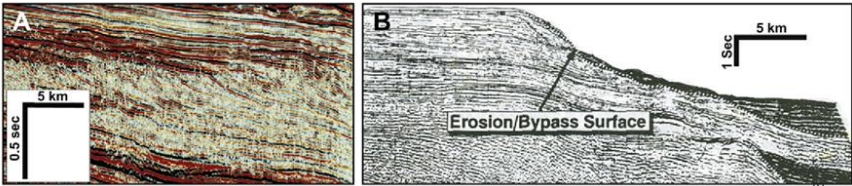


Sequence stratigraphy



Modified from Nicoll et al., 2010

Stratigraphic Grade of the Coastal Margin



Pyles et al., 2010

Graded

Progradational margins
Typical clinoforms geometry related

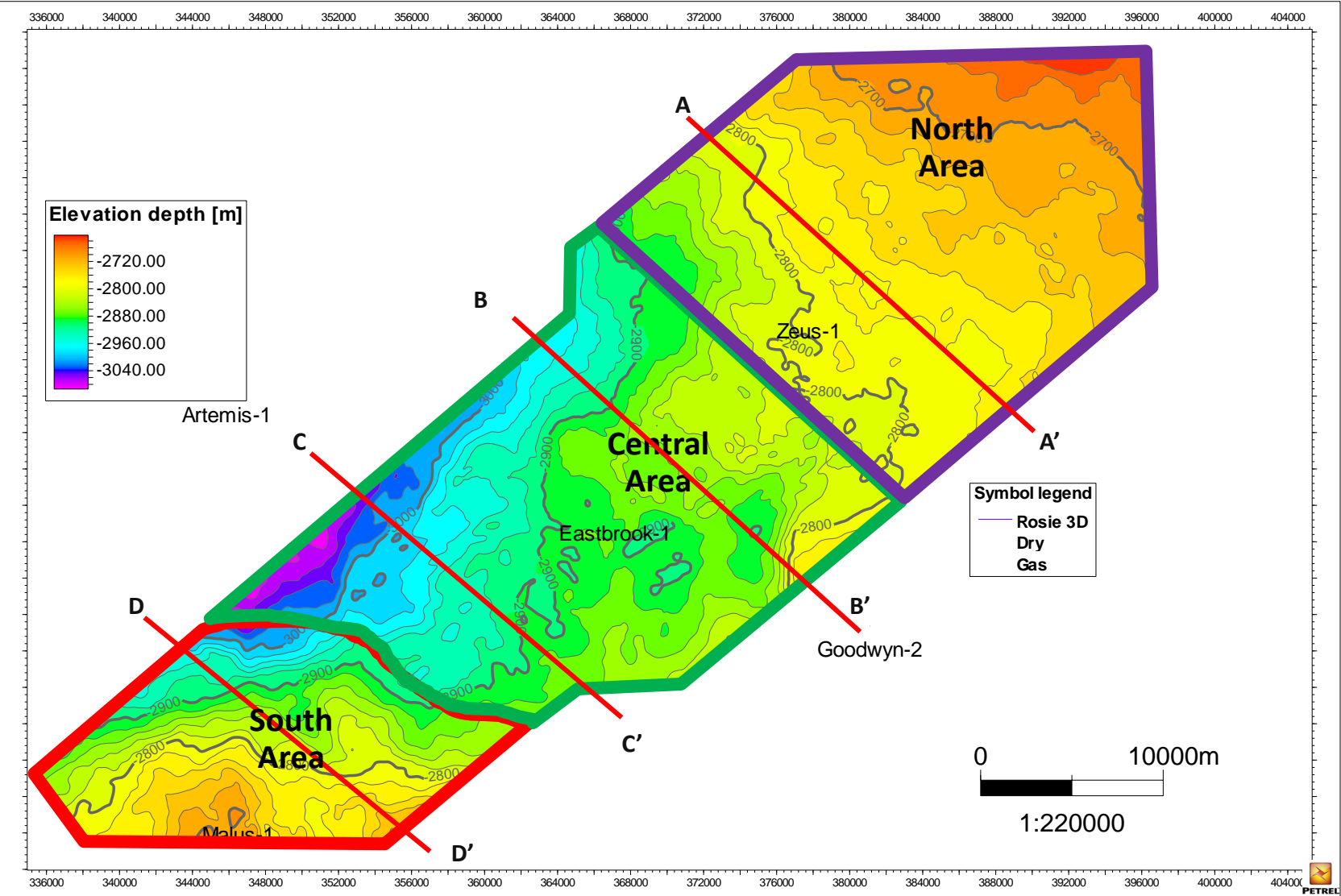
Shelf trajectory vs Depocenter trajectory **Parallel**

Control in architectural elements distribution

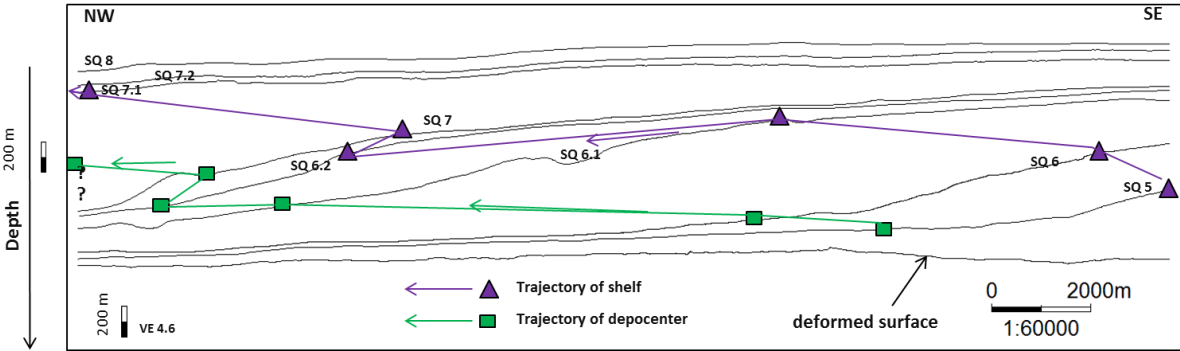
Out-of-Graded

Overstepped slope
Canyons in the Upper slope

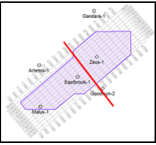
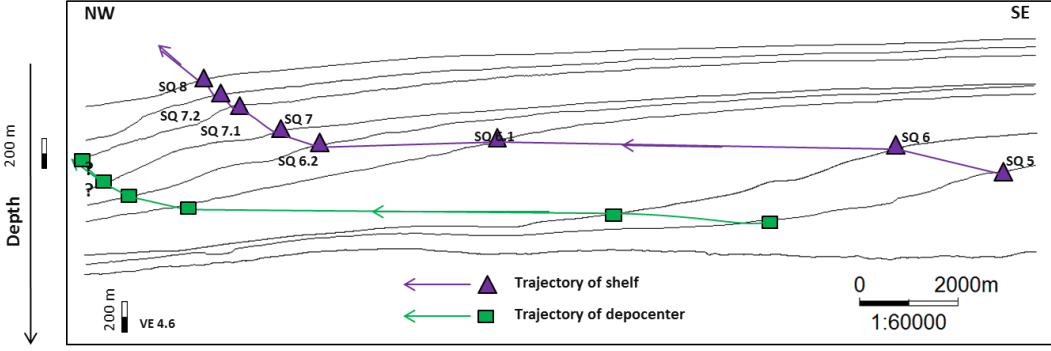
Shelf Trajectory vs Depocenter Trajectory **Divergent**



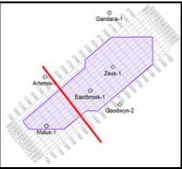
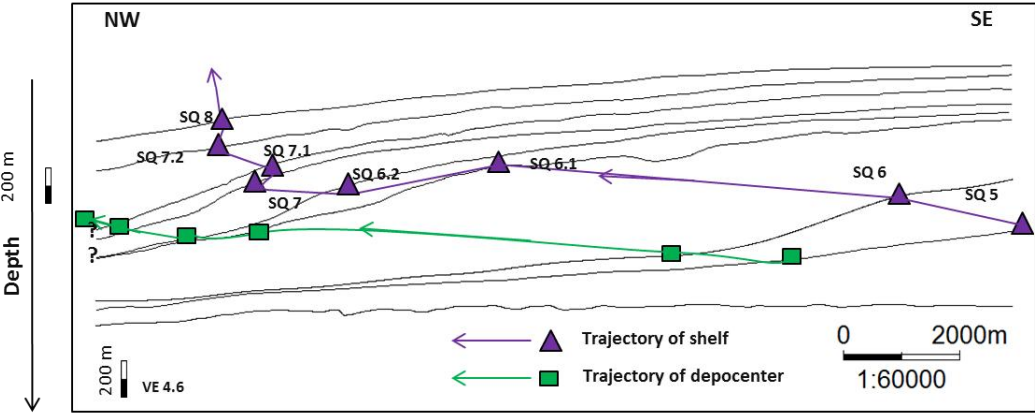
Stratigraphic Grade of the Coastal Margin



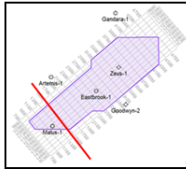
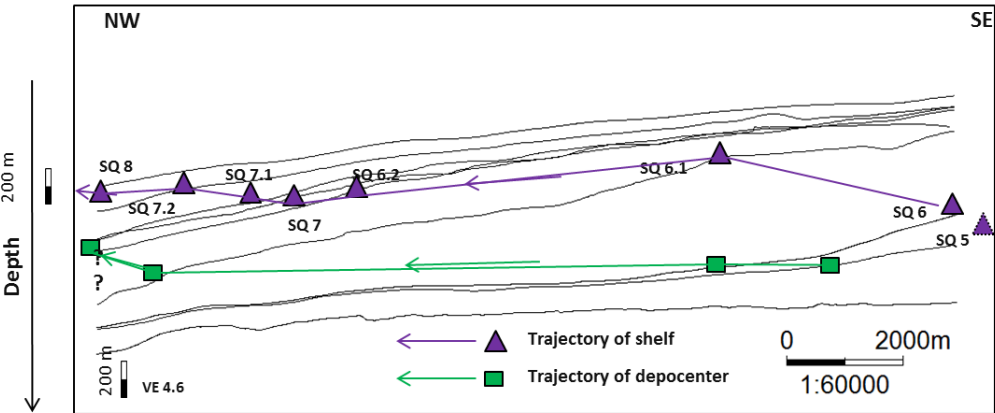
← Sediment transport direction



← Sediment transport direction

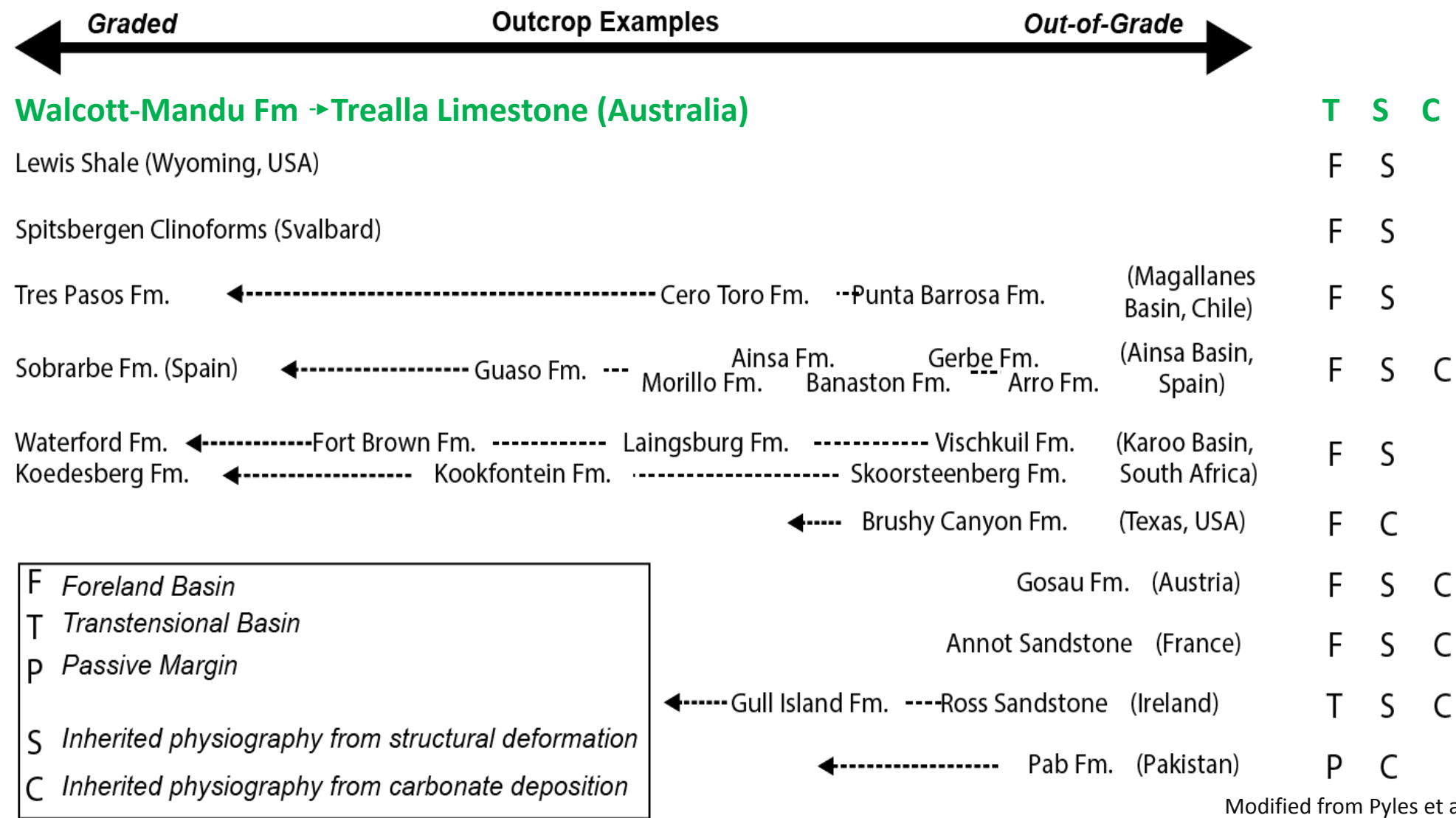


← Sediment transport direction

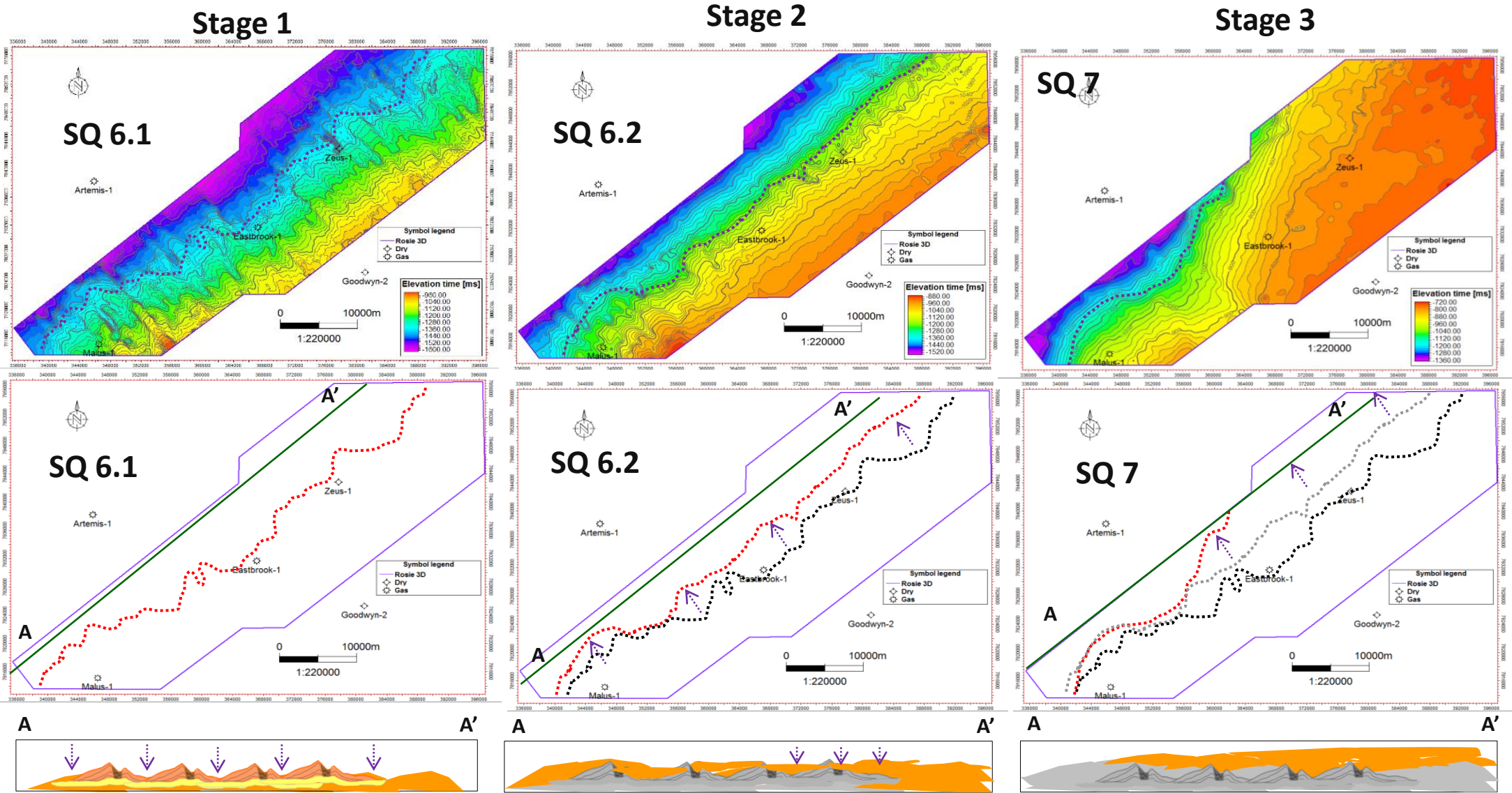


← Sediment transport direction

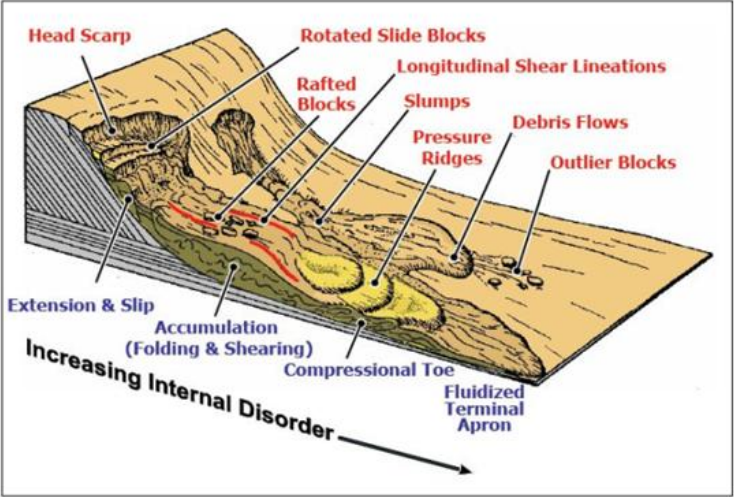
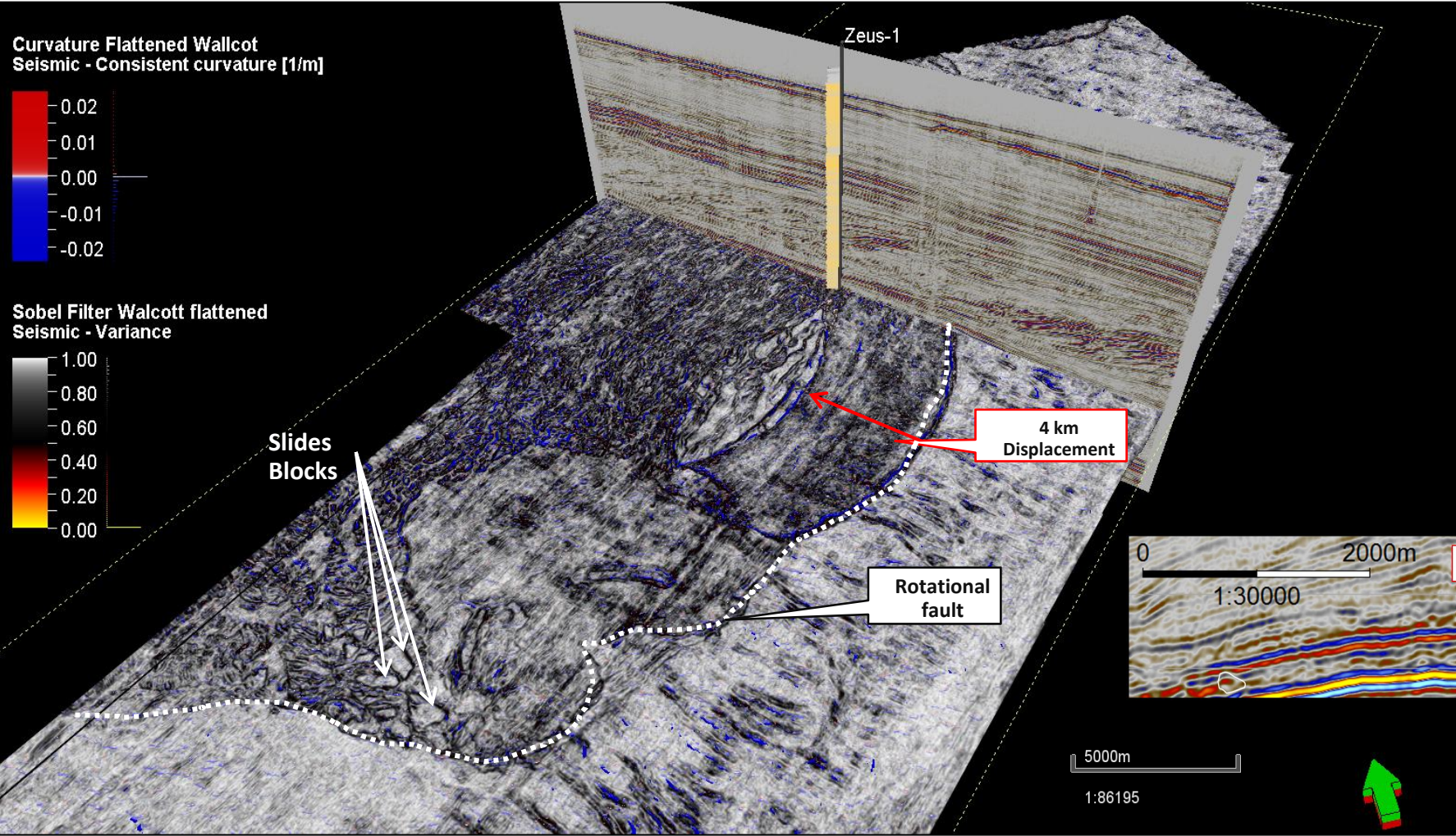
Stratigraphic Grade of the Coastal Margin



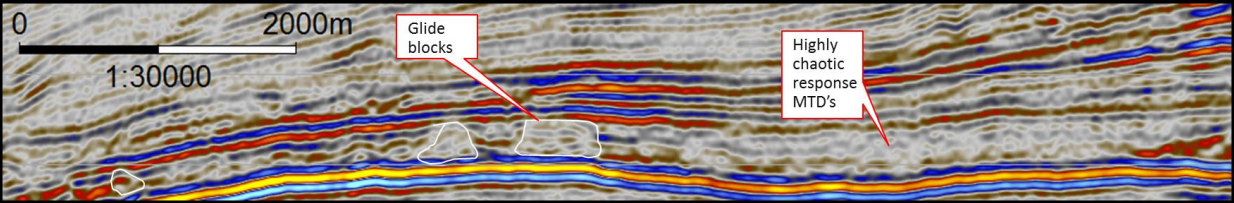
Compensational style deposition



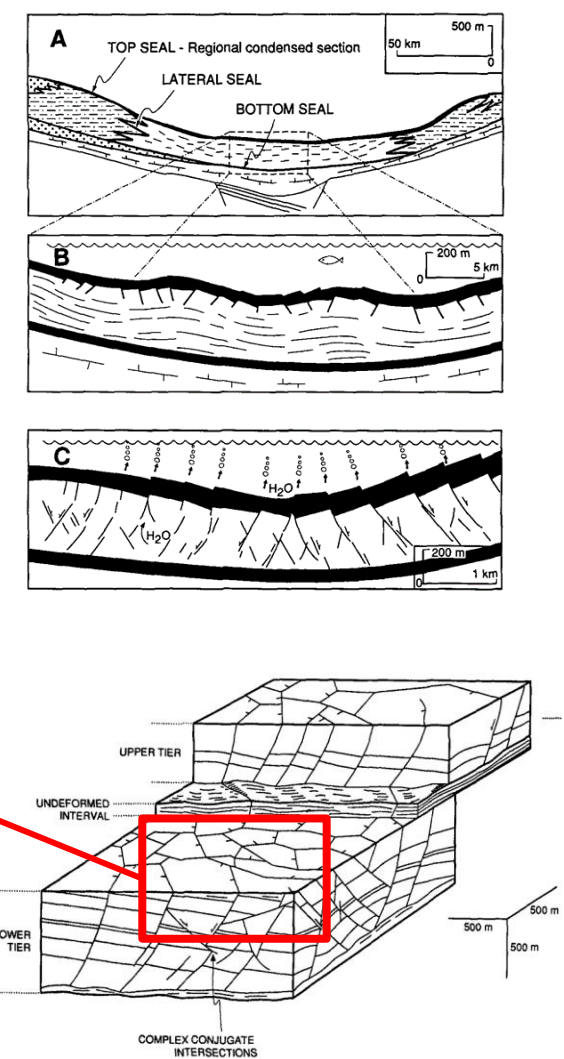
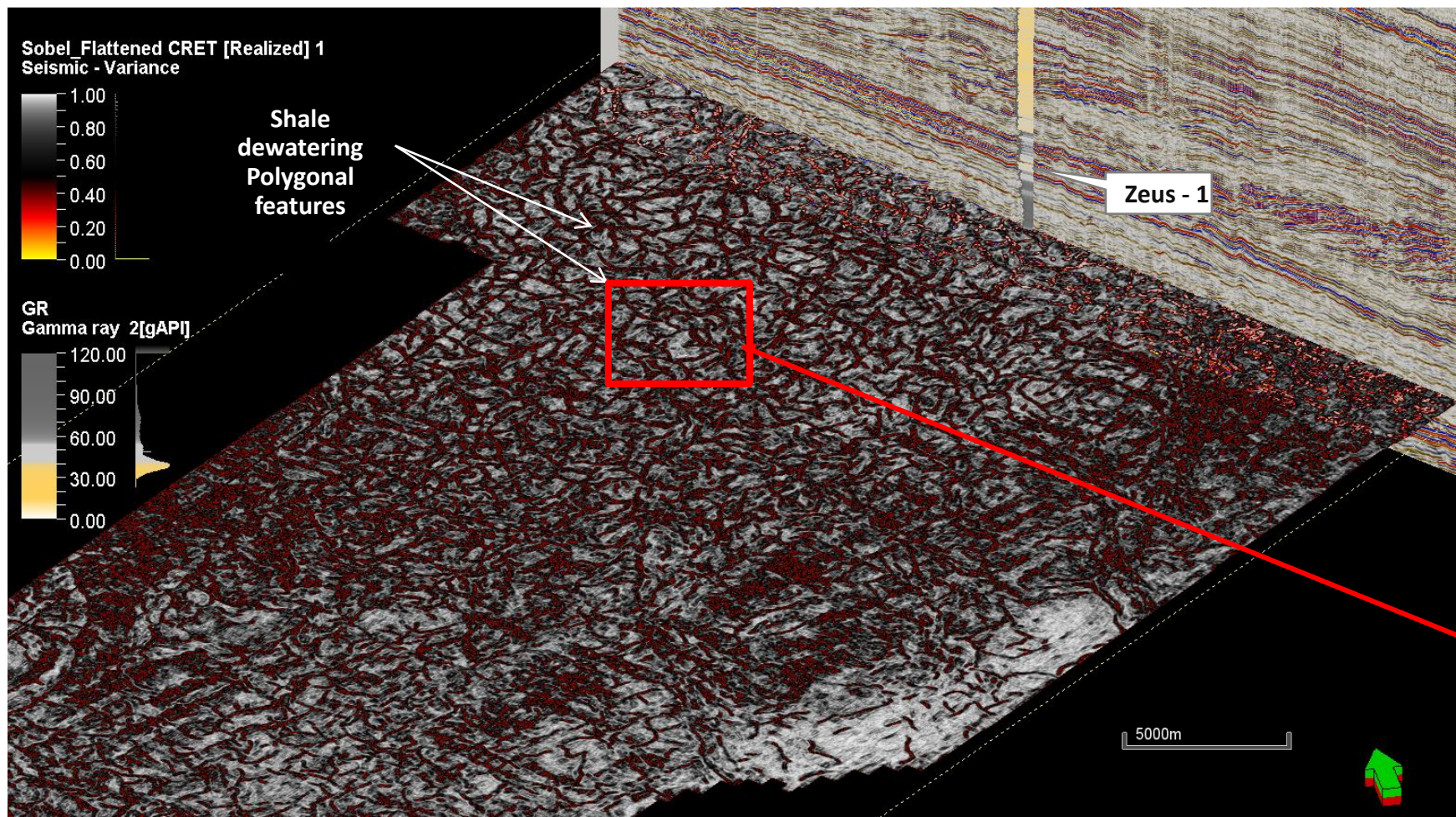
Seismic Attributes for interpretation- FSST Sequence 5



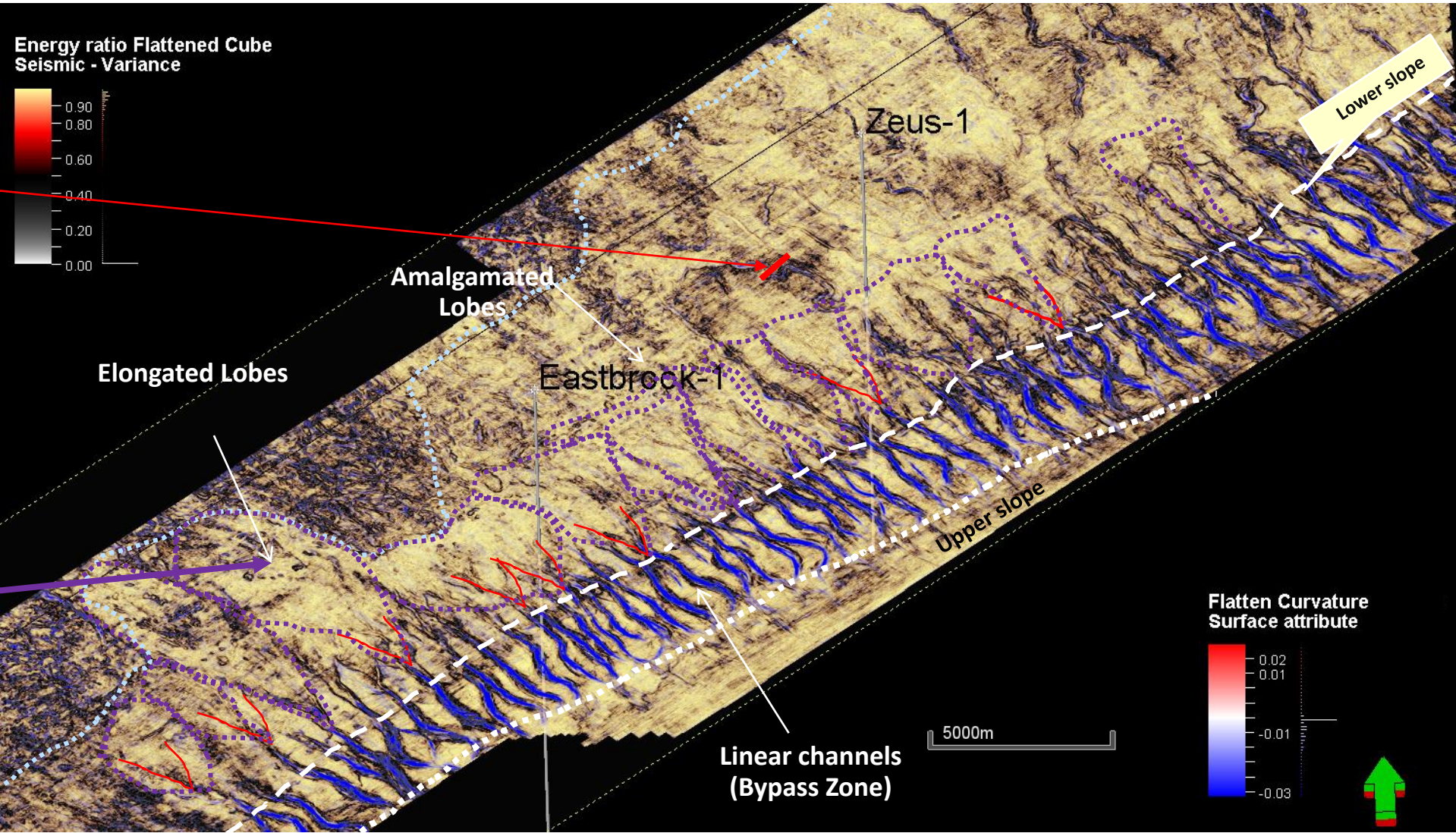
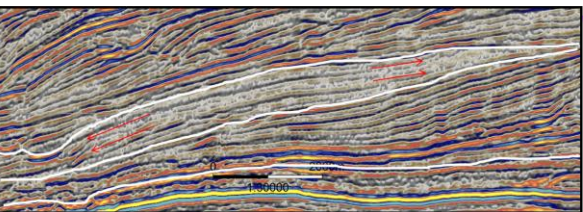
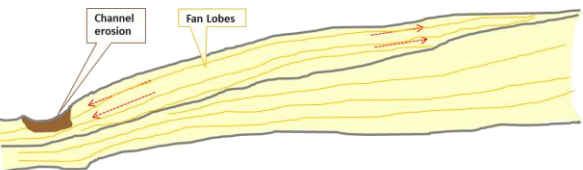
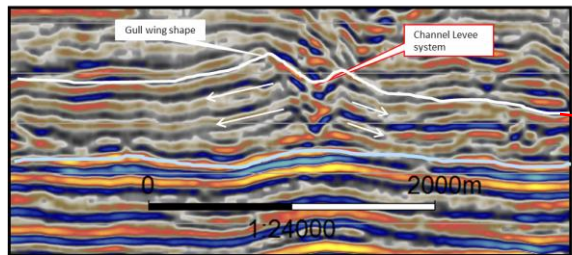
From Slatt, 2007



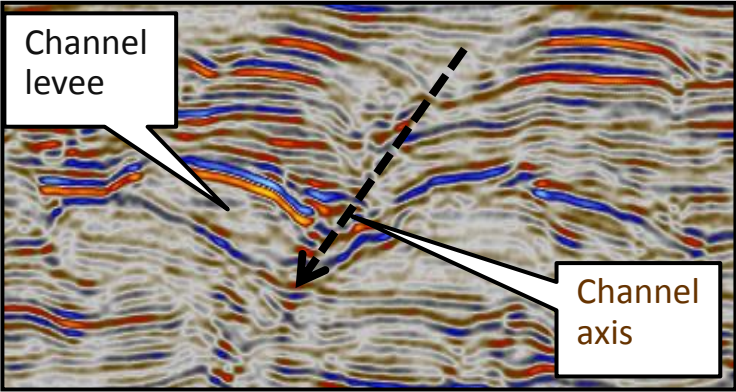
Seismic Attributes for interpretation – HST Sequence 2



Seismic Attributes for interpretation Sequence 6



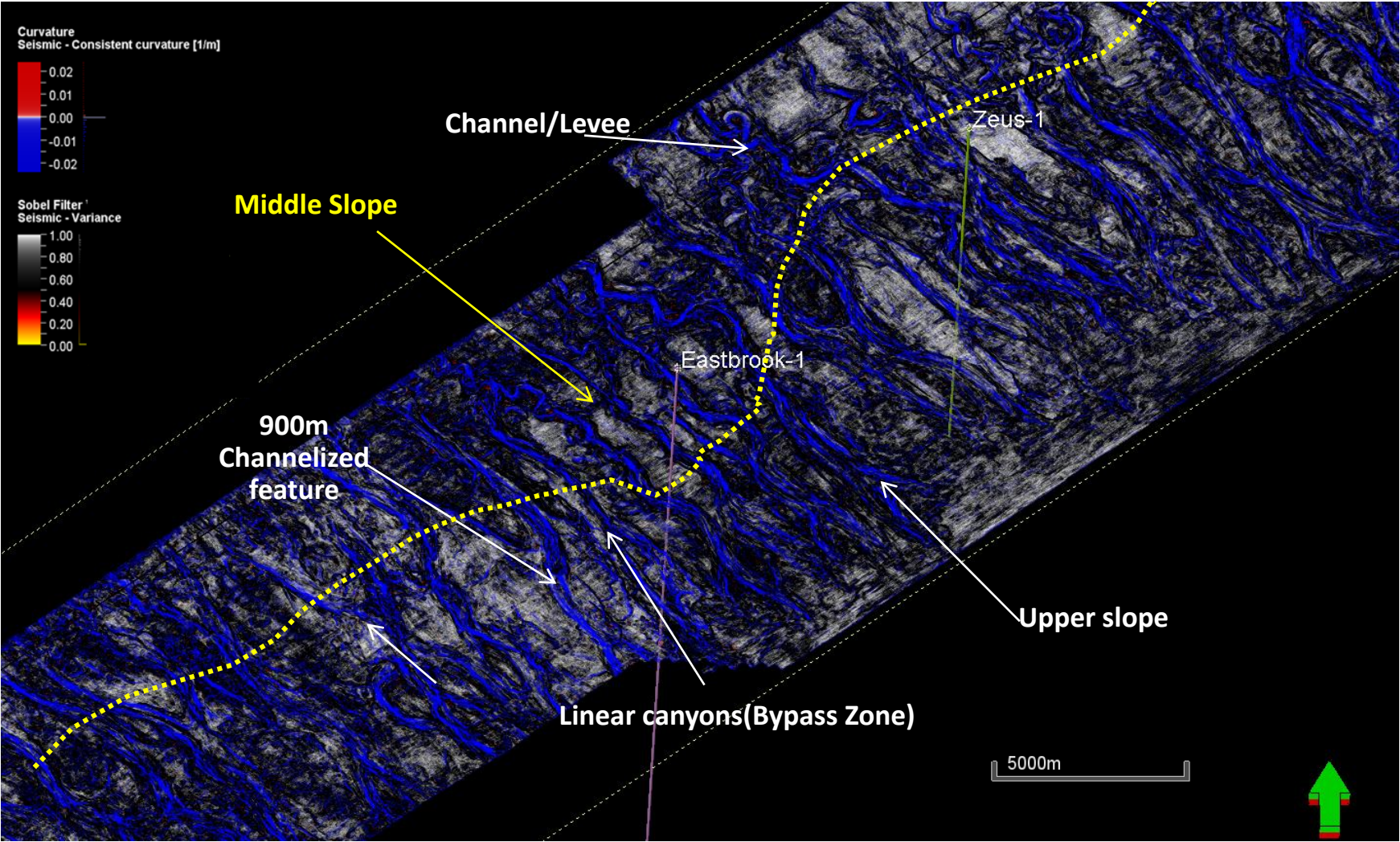
Seismic Attributes for interpretation Sequence 7



Channels sinuosity increase at lower slope

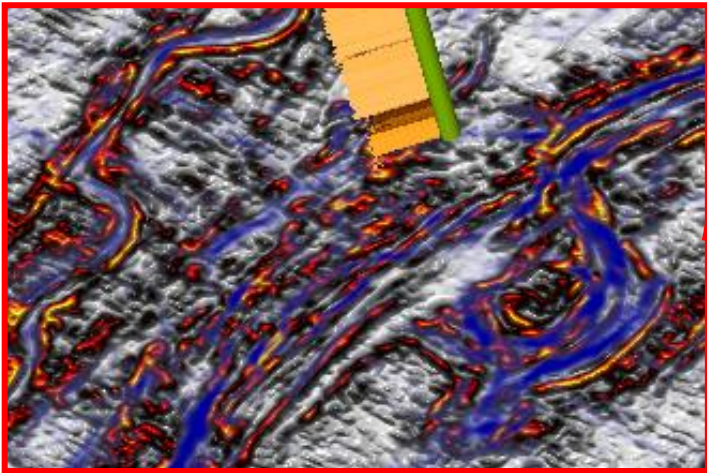
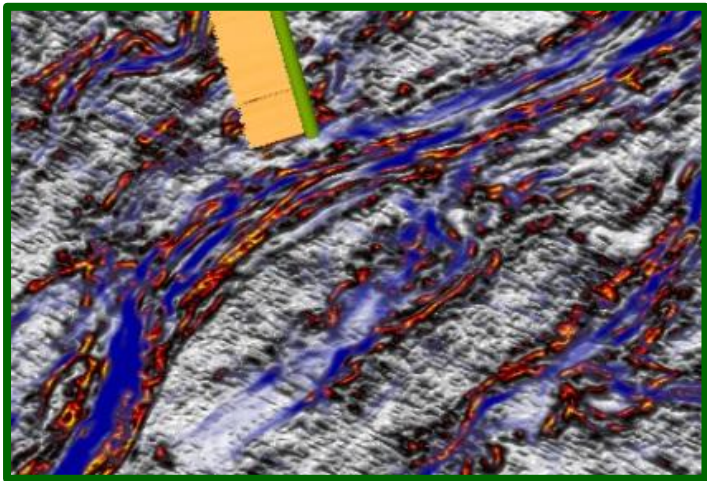
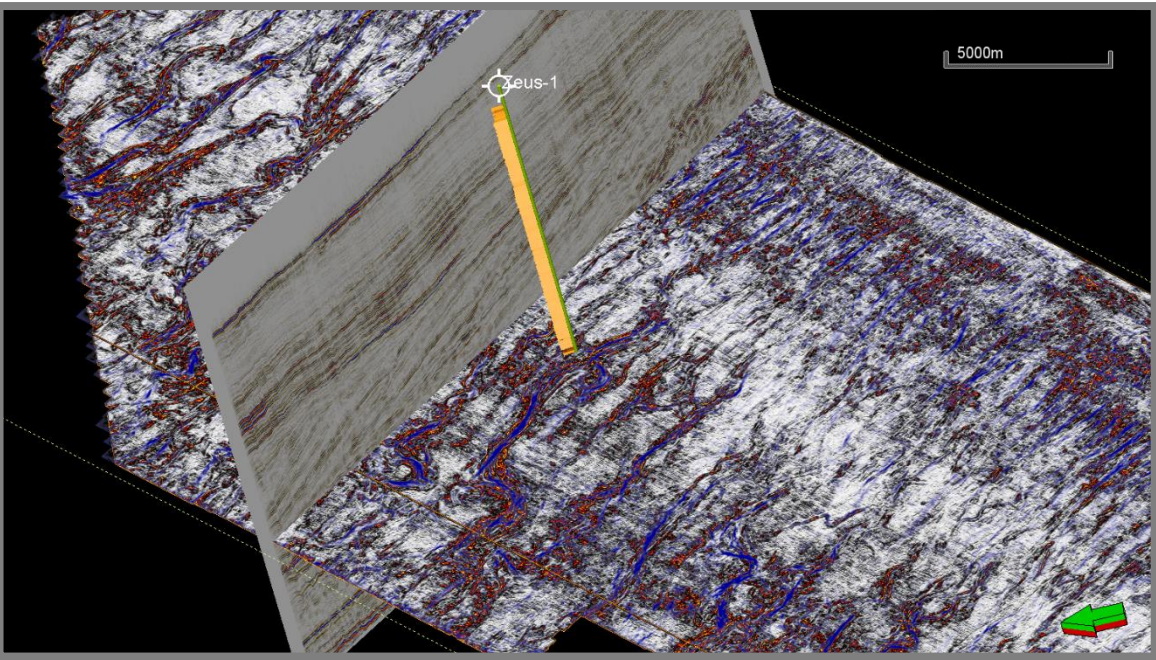
Straight channels carving the slope in the upper and middle position

Larger valley channels at upper slope(1000m)

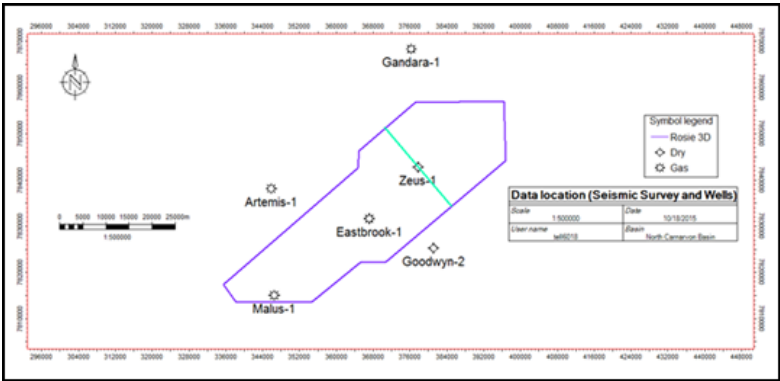
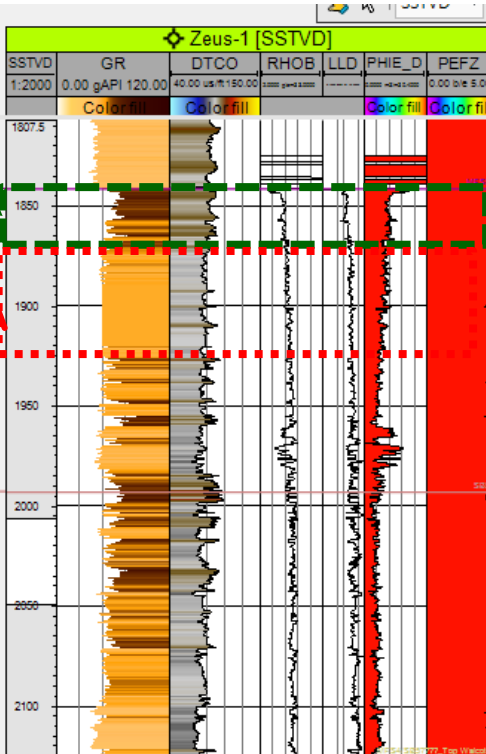


Flattened Volume -1264ms Curvature + Variance

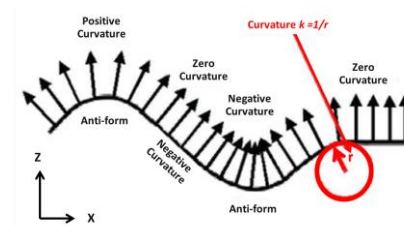
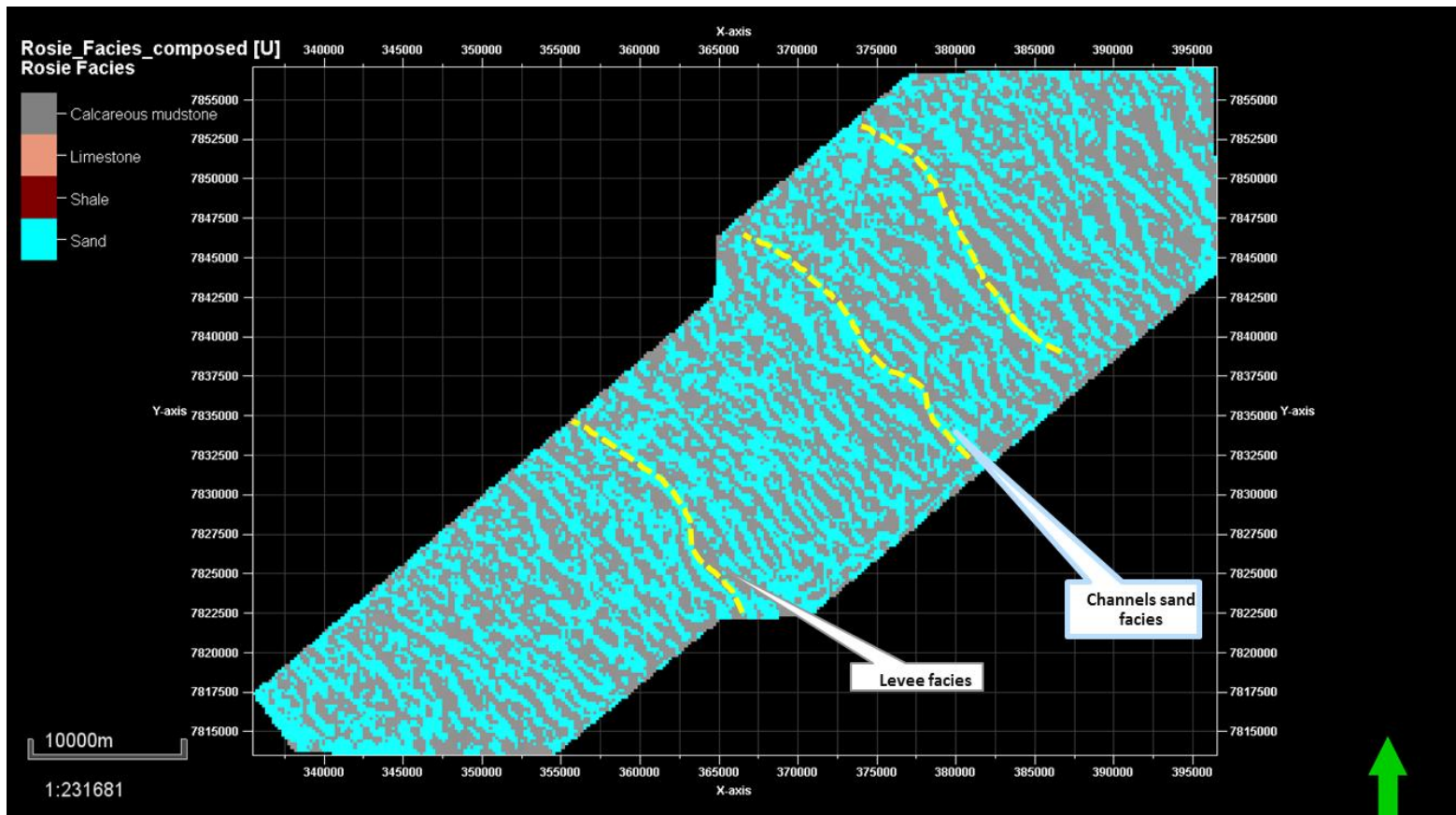
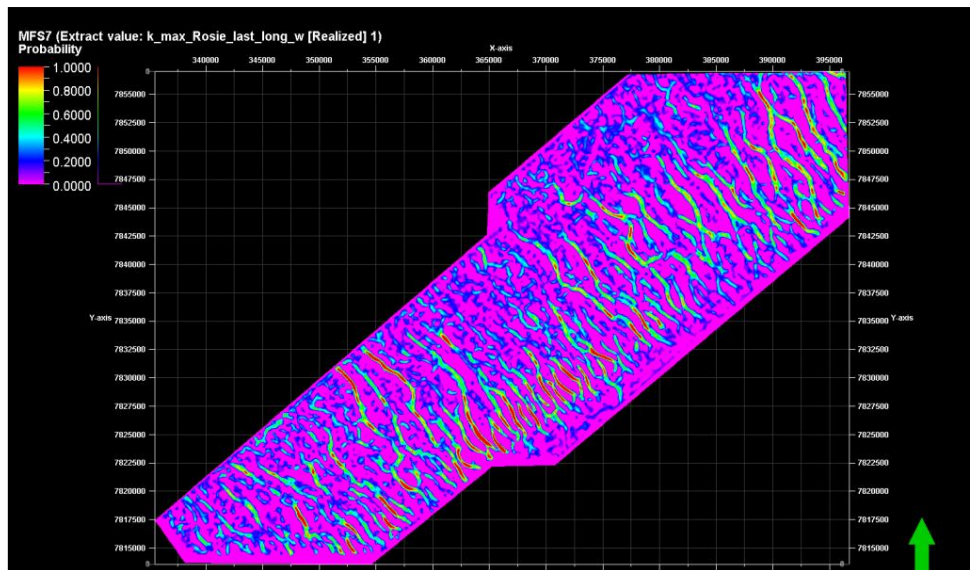
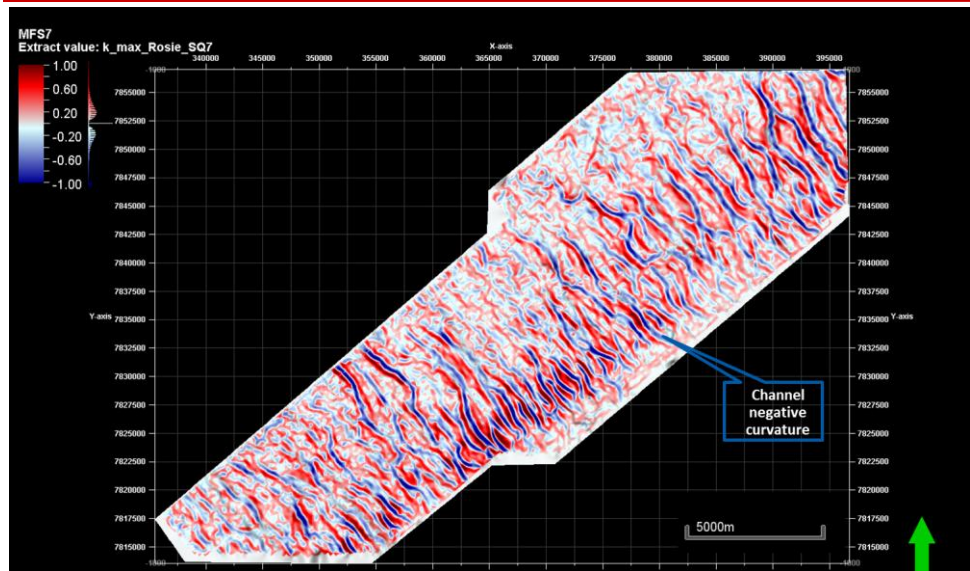
Seismic Attributes for interpretation Sequence 7



Trealla Fm. Channel Levee

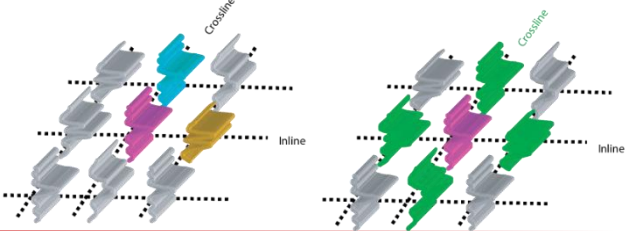
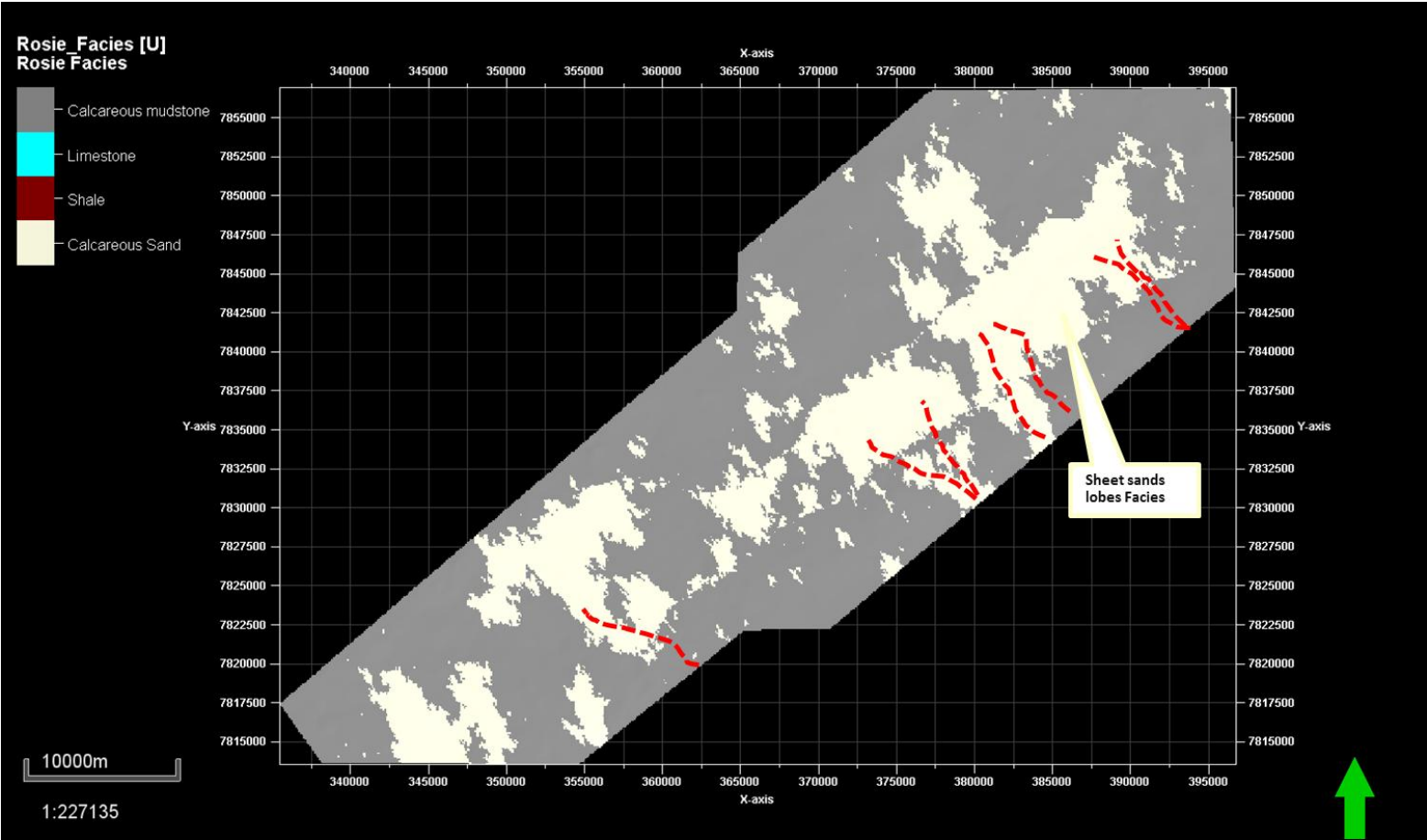
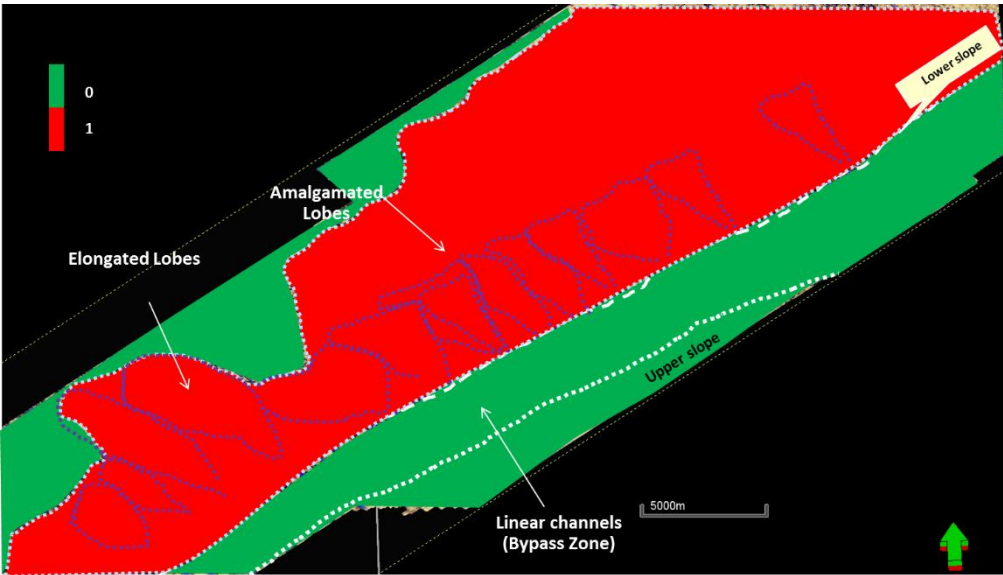
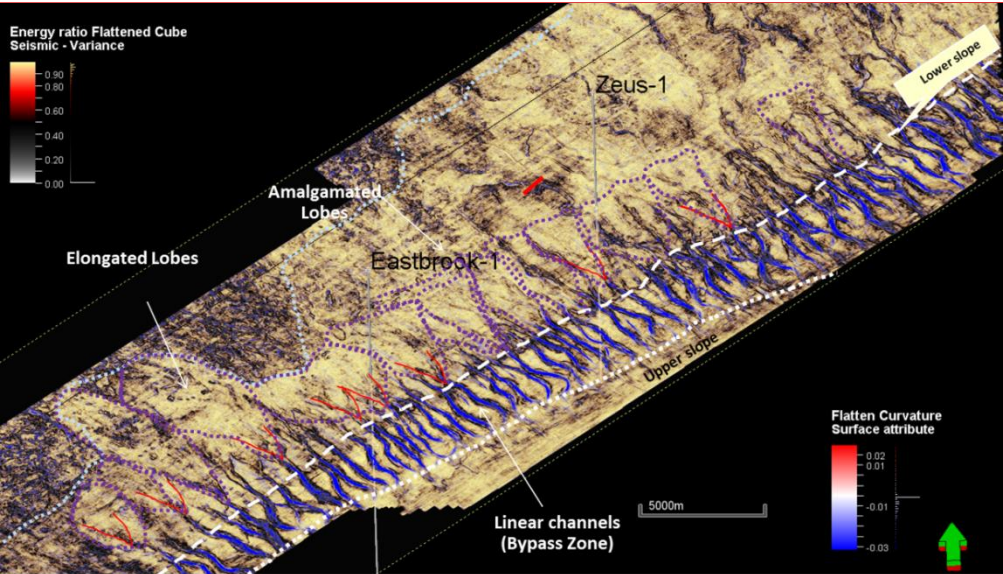


Attributes for 3D modeling - Probability maps from Curvature extraction - SIS






Modified from Roberts, 2001

Attributes for 3D modeling - Probability maps from attributes co-rendering - SIS

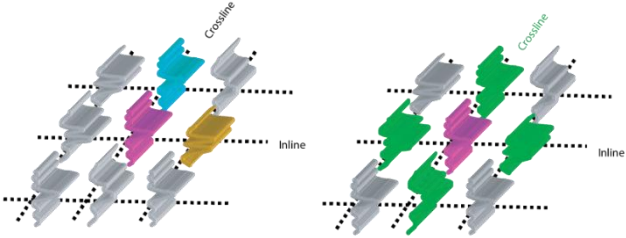
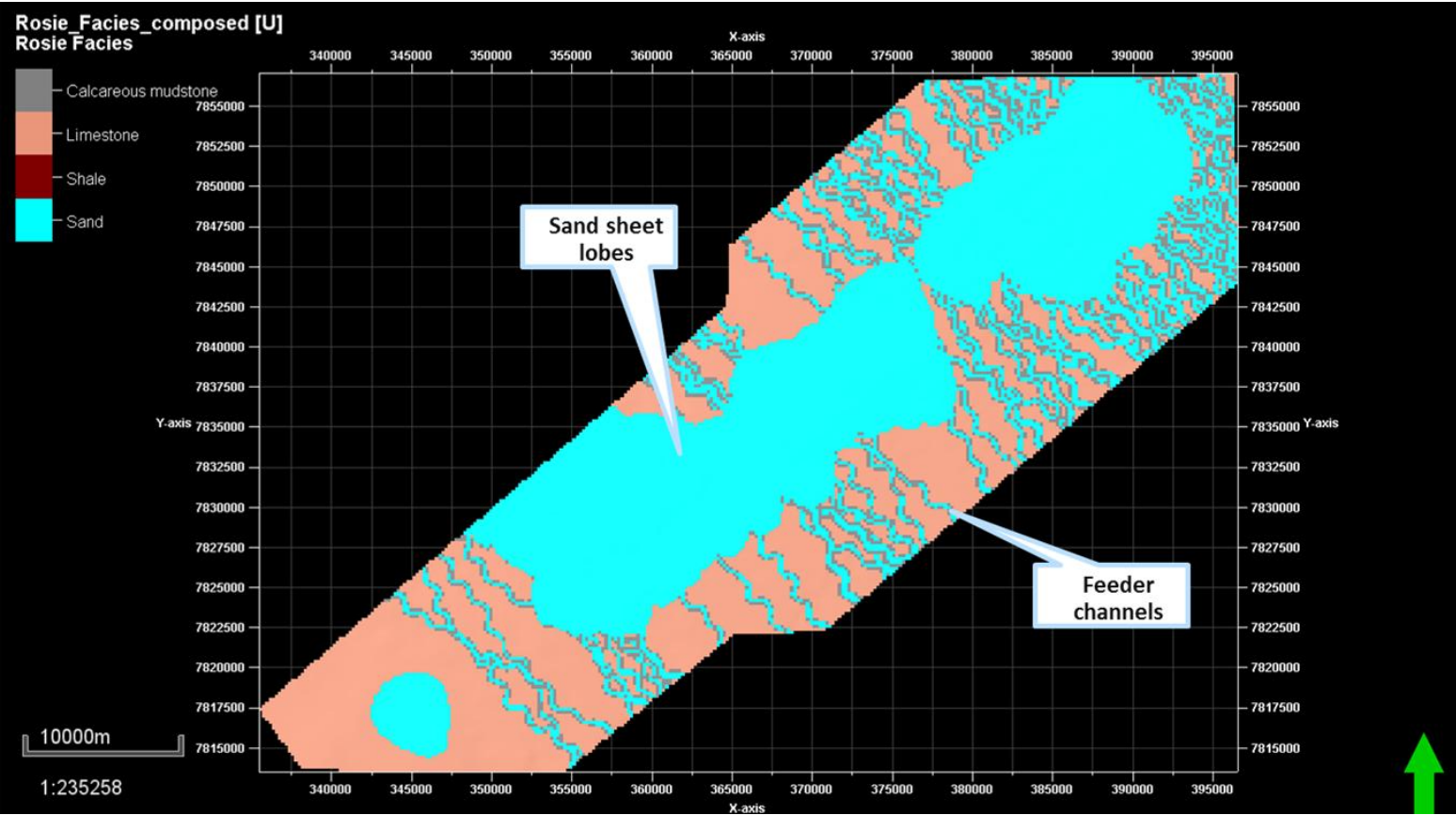
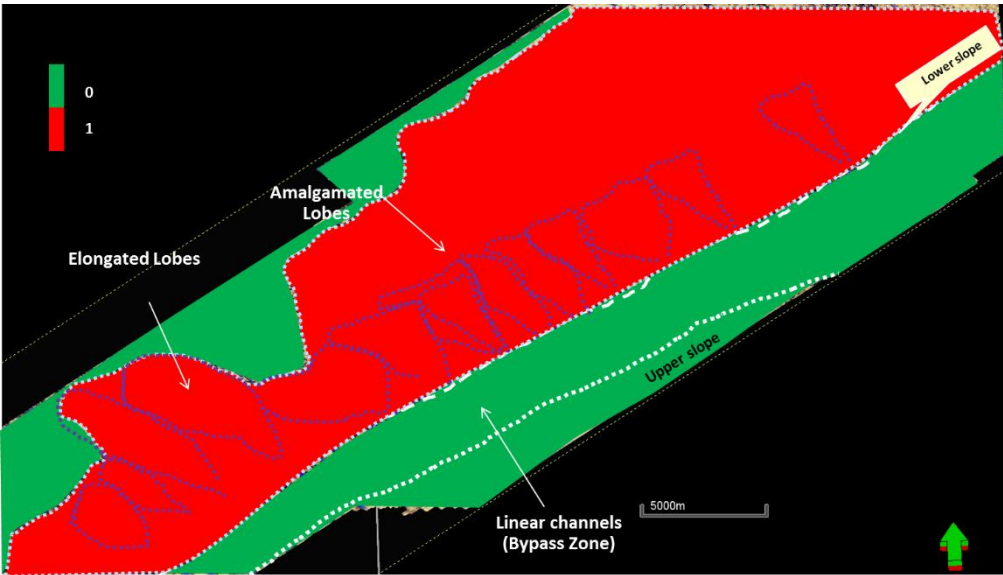
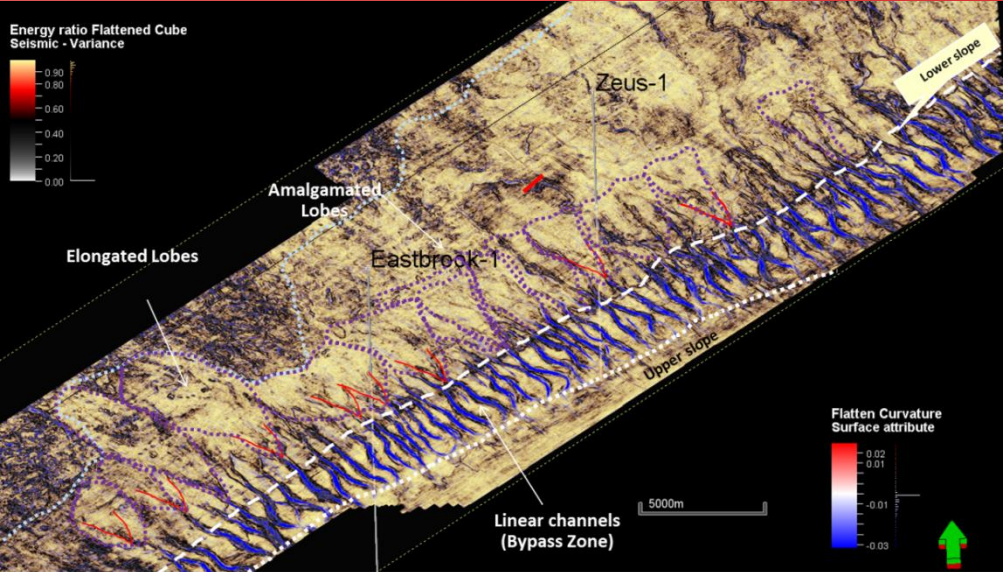


Chopra and Marfurt, 2007

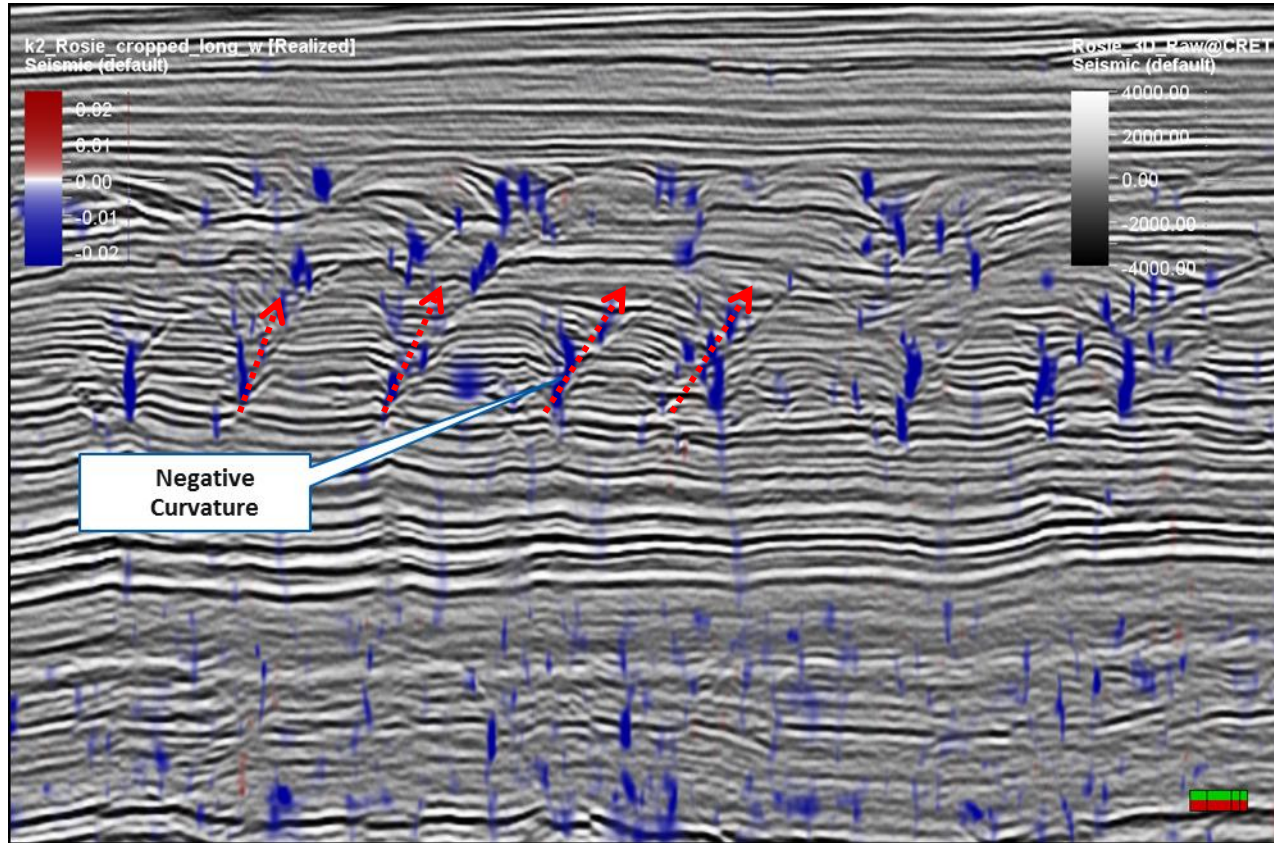
Architectural elements inventory

Stratigraphic sequence	Architectural element		Location	System Tract	Width (m)	Large (m)	W-length	Amplitude	Thickness (m)	Possible Lithology	Displacement (m)	Frequency (m)
							Synuosity (m)					
SQ 1	Shale dewatering	Fault	Basin Floor	FSST/LST	600	600	N/A		N/A	Silt	70	600
SQ 2	Shale dewatering	Fault	Basin Floor	FSST	600	600				Silt	70	600
SQ 3	Mass Transport deposit 	Slice	Slope	FSST	3000	500			150-350	Silt	2570	1000
SQ 4	Mass Transport deposit 	Debris	Basin Floor	FSST	2000	1500			120-150	Silt	2200	1500
SQ 5	Mass Transport deposit 	Slice	Slope	FSST	10350	16500			200-250	Carbonate blocks	4500	3500
	Mass Transport deposit 	Outrunner block	Lower slope	FSST	415	2000			120-150	Carbonate blocks	1300	250-300
	Channel 	Gullies	Upper Slope	FSST	114	4000	Straight		35-80	Silt and sand	N/A	300-350
SQ 6	Channel 	Feeder	Middle slope	FSST	240-300	3700	188	1900	50-70	Silt and sand		550
	Sheet sands 	Lobes	Lower Slope	FSST	2500	4800	N/A		150	Calcareous sandstone		100
SQ 7	Channels 	Valley	Upper Slope	LST	750	11500	Straight		180-250	Calcareous sandstone		600-1500
	Channels 	Channel Levee	Middle slope	LST	229	3950	1200	500	100-120	Calcareous sandstone/levee		800-1000
	Channels 	Distributary	Basin floor	LST	84	4990	1500	300	50-60	Calcareous sandstone		2500
SQ 8	Channels 	Distributary	Basin floor	LST	97	2450	1200	180	50-60	Calcareous sandstone		1250
	Sheet sands 	Lobes	Lower Slope	LST	3690	5600	N/A		150-200	Calcareous sandstone		3000

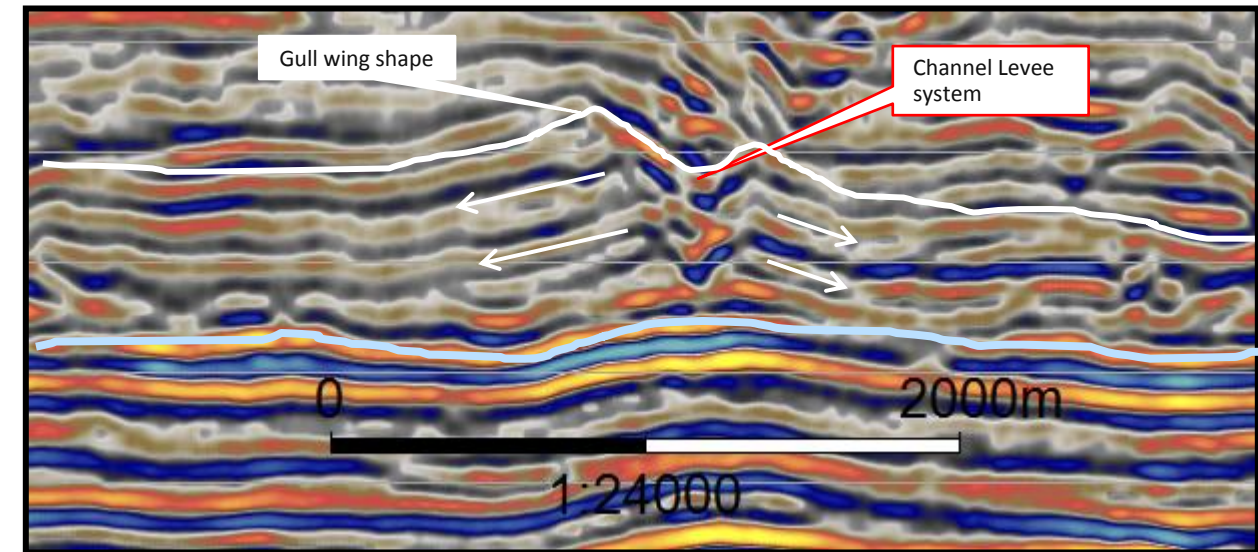
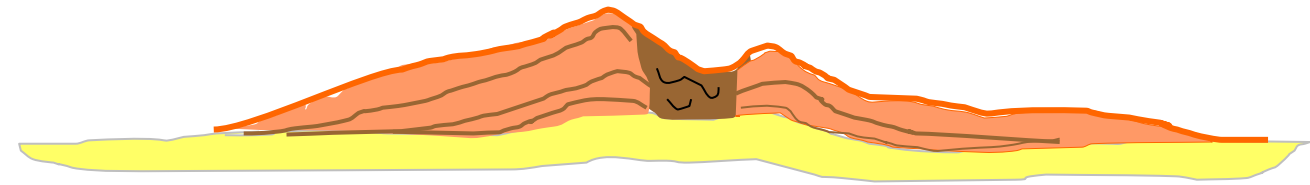
Attributes for 3D modeling - Probability maps from attributes co-rendering - OBM



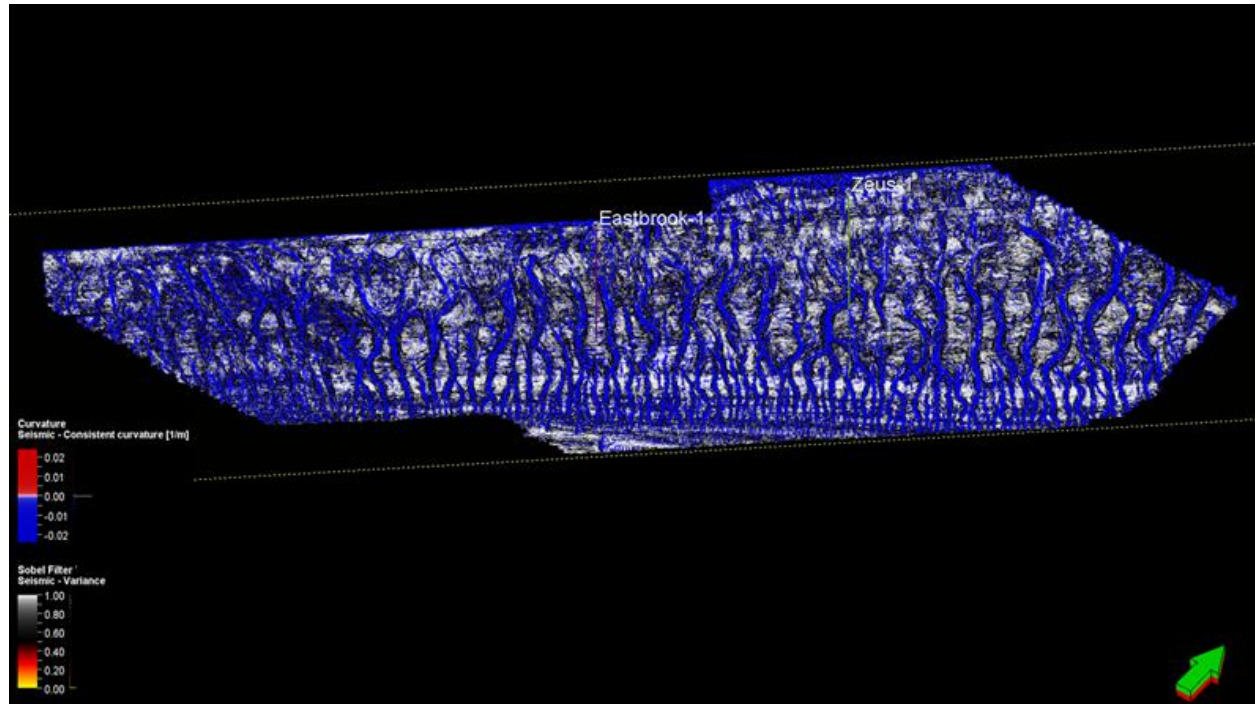
Attributes for 3D modeling - Probability Volumes from geobody extraction - SIS



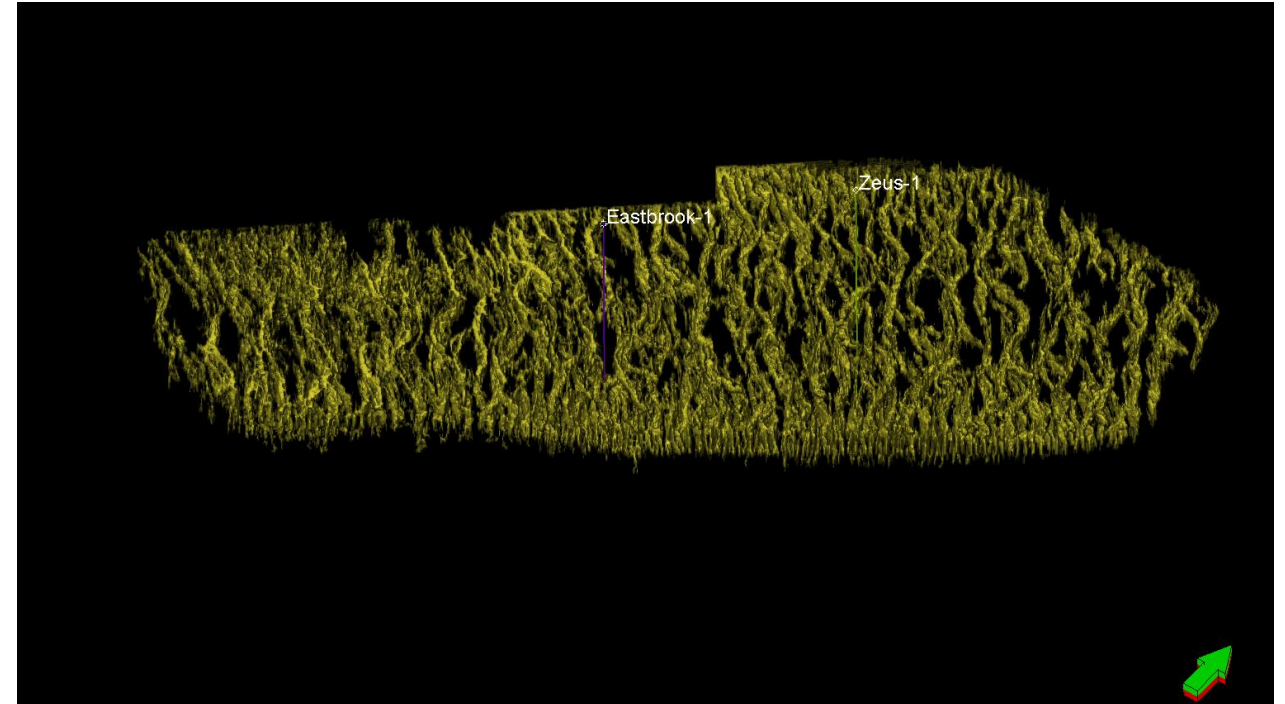
Seismic amplitude inline co-rendered with maximum curvature. Blue color highlight the negative curvature related to concave geometries of erosive channels. Multistory channels shows migration through horizons



Attributes for 3D modeling - Probability Volumes from geobody extraction - SIS

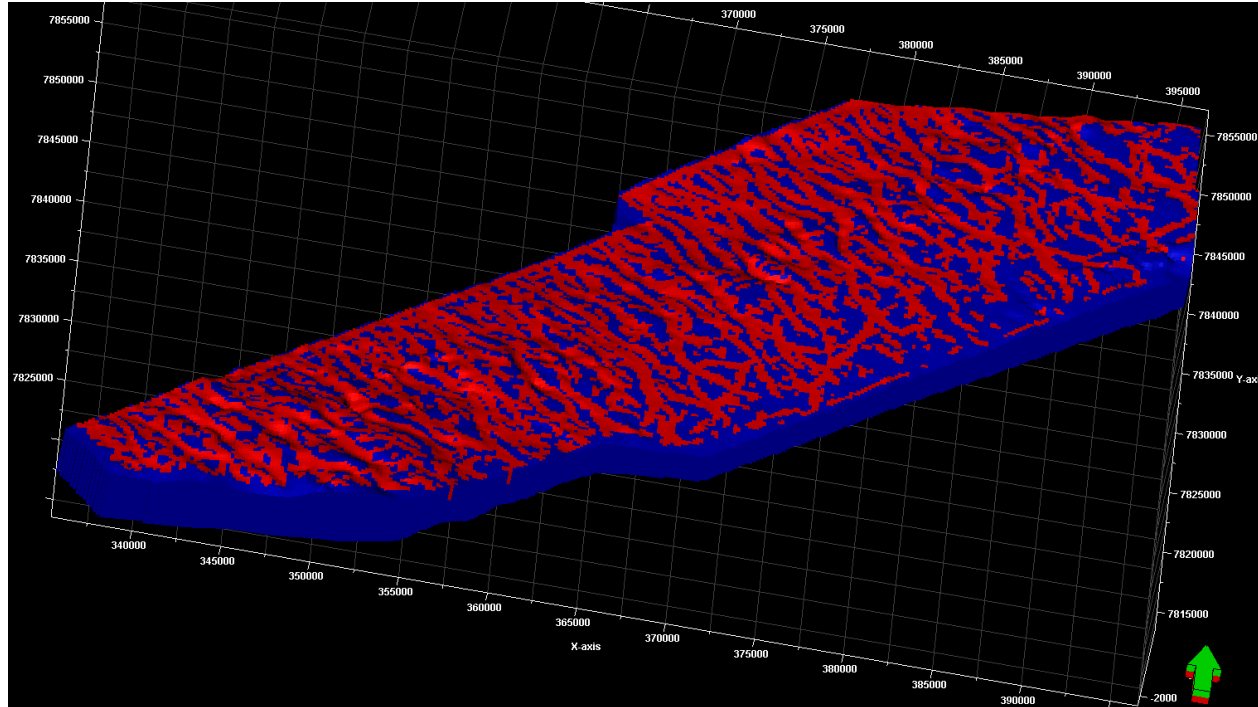


**Attribute co-rendering
Coherence + Curvature**

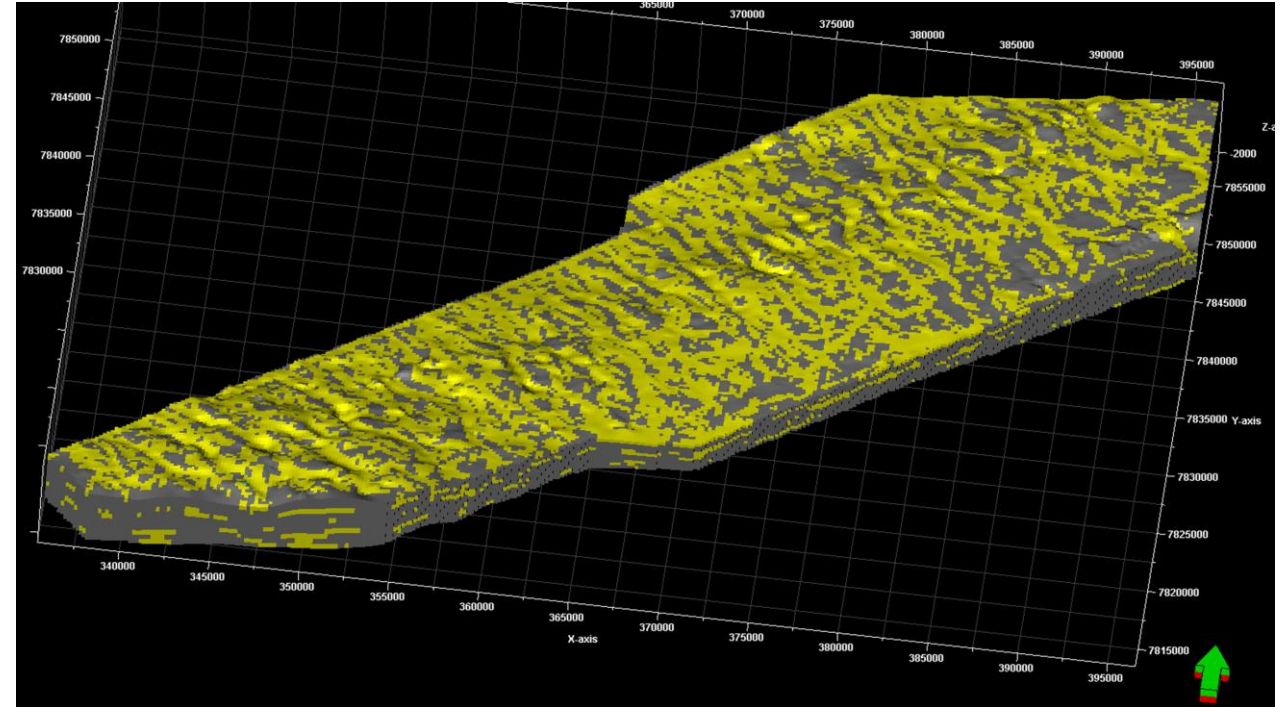


**Geobody extraction
for channel facies**

Attributes for 3D modeling - Probability Volumes from geobody extraction - SIS



**Points converted to Probability
Volume(Probability 1 red color Probability 0
Blue Color)**



**Populated zone with Probability volume as
constrain. (Yellow are Channel facies. Dark
gray Levee Facies)**

Conclusions

- The platform corresponds to a *graded* system evolving to an *out-of-grade* system.
 - The lateral variation of the interpreted sequences corresponds to changes in the compensated depositional style.
 - Distribution of architectural elements in the studied area was evaluated. Upper slope shows erosional channels. Middle slope exhibits channel levee complexes, and few sheet sands. Lower slope is dominated for deposition of sheet sand and distributary channels.
 - Architectural elements were identified with the combination of seismic attributes and a sequence stratigraphy interpretation
 - Seismic attributes extracted from horizon slices and geobodies extraction were integrated in 3D modeling as probability maps and volumes by a simple methodology. The use of those maps constrain facies distribution in three dimensional space.
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