

# **3-D Architecture of Cretaceous Channel Systems in the Northern Orange Basin, Offshore South Africa\***

**Lynise J. Esterhuizen<sup>1</sup>, Jonathan Salomo<sup>1</sup>, Chantell Van Bloemenstein<sup>1</sup>, and Anthony Fielies<sup>1</sup>**

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## **Abstract**

The integration of seismic, well and core data provided the basis for characterizing the depositional framework and geomorphology of Cretaceous fluvial and marine channel systems offshore the northern Orange Basin. In this study, the morphologies of the depositional systems were investigated using time, variance, and RMS amplitude seismic attributes on high-resolution 3D seismic. Lithological information and depositional environments were obtained from well logs and core data of exploration wells drilled on the shelf. These environments range from braided and fluvial-meandering channel systems to fluvio-deltaic systems from the Aptian to Cenomanian.

The depositional geometries identified within the systems include flood plains, splays, point bars, levees, and cut bank deposits. Channel widths vary between 50m to 2km. In the Aptian-Albian interval in the northeastern part of the Orange Basin, channels are controlled by curvilinear faults dipping towards the southwest. Dominant faults visible within this sequence dissipate towards the west. Wider channel systems within the Cenomanian sequence are intersected by extensive northwest-southeast trending faults. These faults disrupted channel deposition and would compartmentalize potential reservoir sands if they are sealing. Distinct thin sinuous channels occur throughout the Cretaceous and are laterally extensive from north to south. Channel system patterns in the Aptian-Albian sequence are disorganized while those in the Cenomanian are organized. The fill ratios of the channel systems are higher in the Aptian-Albian than in the Cenomanian.

The paleocurrent direction during the mid-Aptian through Early Albian switched between east and southeast. During the Cenomanian the paleocurrent direction shifted between the northeast and southeast. This suggests a strong influence by the paleotopography. Further offshore, these systems progress from a slope environment with large scale marine channels into a deep marine environment with basin and slope floor fan features recognized on seismic.

Potential reservoirs include pro-delta/sheet-like turbidites, deltaic and fluvial sands, slope channel complexes, and basin floor fan systems. Source rocks charging these Cretaceous reservoirs include the proven Barremian-Aptian restricted marine oil and gas prone source as well as a postulated Cenomanian-Turonian aged source rock.

### **Selected References**

Jungslager, H.A., 1998, Petroleum Habitats of the Atlantic Margin of South Africa: Petroleum Agency SA Internal Report.

Neal, J., and V. Abreu, 2009, Sequence Stratigraphy Hierarchy and the Accommodation Succession Method: *Geology*, v. 37/9, p. 779-782

Nobel, R., 1987, A-F1 Geological Well Completion Report: Soekor.

Vail, P.R., and W.W. Wornardt, 1991, An Integrated Approach to Exploration and Development in the 90's: Well Log–Seismic Sequence Stratigraphic Analysis: *Gulf Coast Association of Geological Societies Transactions*, v. 41, p. 430-650.

### **Websites Cited**

[www.scotese.com](http://www.scotese.com). Website accessed December 2018.

[https://www.petroleumagency.com/images/pdfs/Pet\\_expl\\_opp\\_broch\\_2017bw1.pdf](https://www.petroleumagency.com/images/pdfs/Pet_expl_opp_broch_2017bw1.pdf). Website accessed December 2018.

# **3D Architecture of Cretaceous Channel Systems in the Northern Orange Basin, offshore South Africa**

AAPG ICE, November 2018

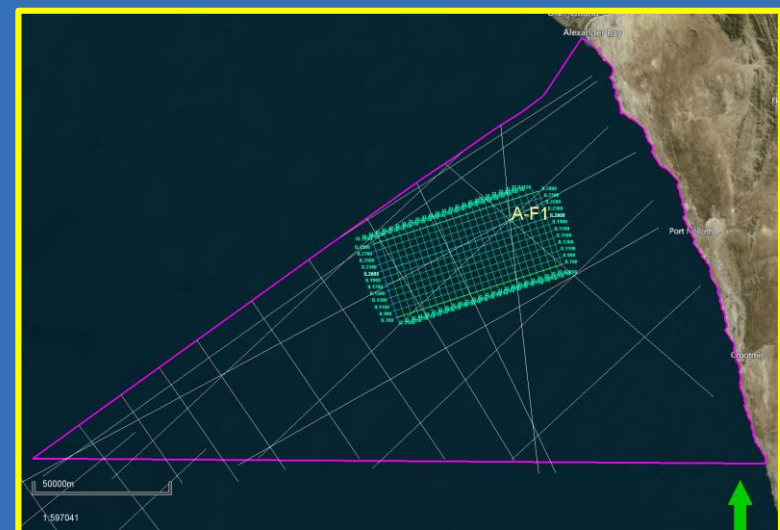
L. Esterhuizen, J. Salomo, C. Van Bloemenstein, A. Fielies

# Content

- Introduction
- Regional Geology
- Workflow
- Channel Architecture
  - Attribute analysis -Depositional geometries
  - Characteristics
    - Paleo current direction, sinuosity, channel width, fill-ratio
  - Channel systems – Regional overview
- Potential Reservoirs
- Conclusion

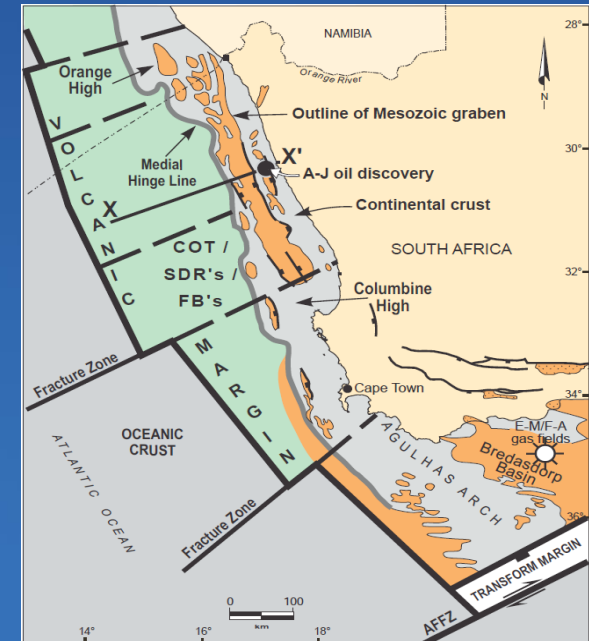
# Introduction

- The focus of this study was to look at the 3D architecture of Cretaceous channel systems in the Northern Orange Basin (Block1)
- Seismic attributes (variance and RMS), gamma ray log and core photographs were analysed and compared.
- 1500km<sup>2</sup> 3D survey with water depths ranging between 150 -175m.

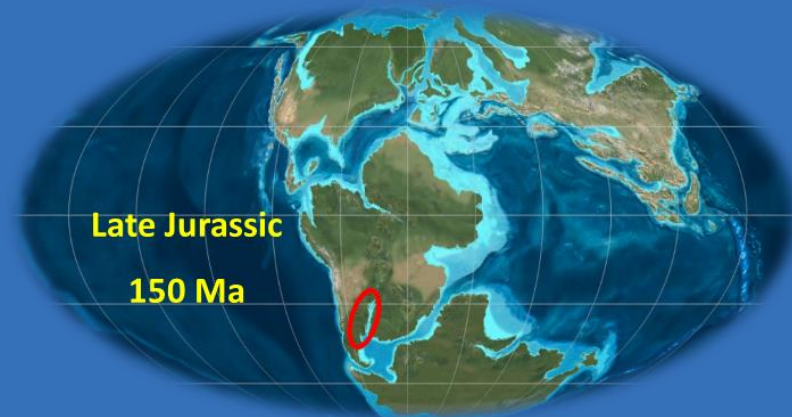


# Regional Geology

- The Orange Basin is situated off the west coast of South Africa and Southern Namibia
- It covers an area of 160 000 km<sup>2</sup>
- Formed as a result of the break up of Africa and South America during the Late Jurassic
- Major structural features:
  - Half grabens filled with synrift sediments
  - Large perpendicular trending fractures zones
  - NW-SE trending basement high (marginal ridge)

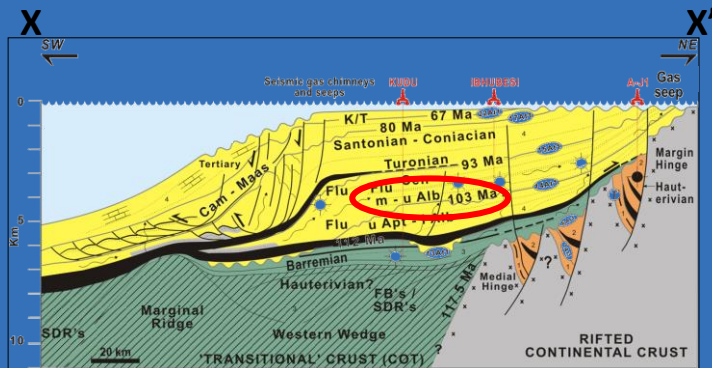


Jungslager, 1998

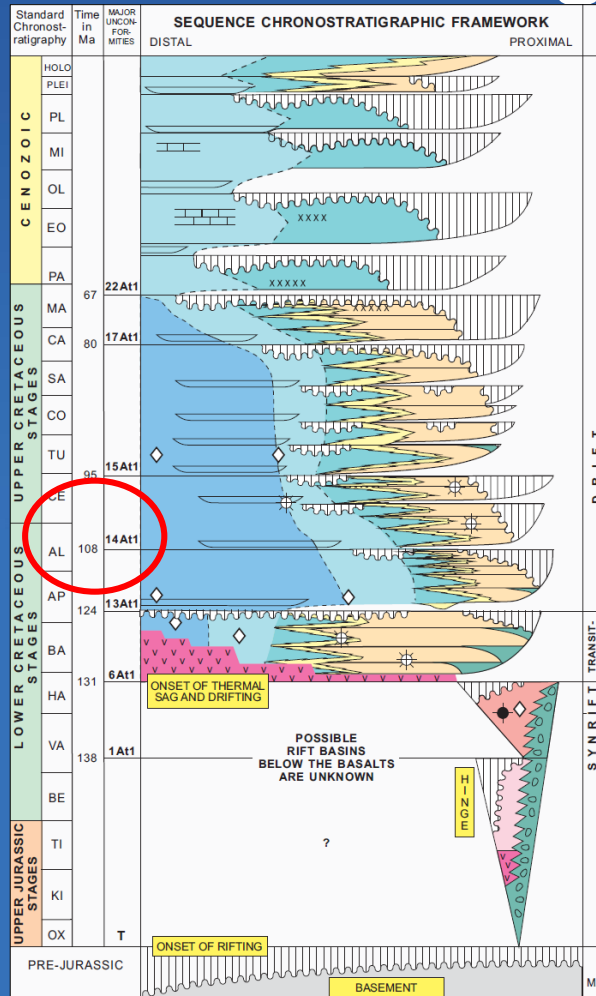


# Regional Geology

- Two-fold subdivision: an older synrift unit, overlain by a younger post-rift unit
- Rifted plate margin that is underlain by pre-rift and synrift grabens, covered by post-rift sediments.
- Four main tectono-stratigraphic sequences represent the major phases: **Synrift**, **Post-Rift** (Transitional), **Drift** and **Post-Drift** (Cretaceous and Tertiary)



Jungslager, 1998



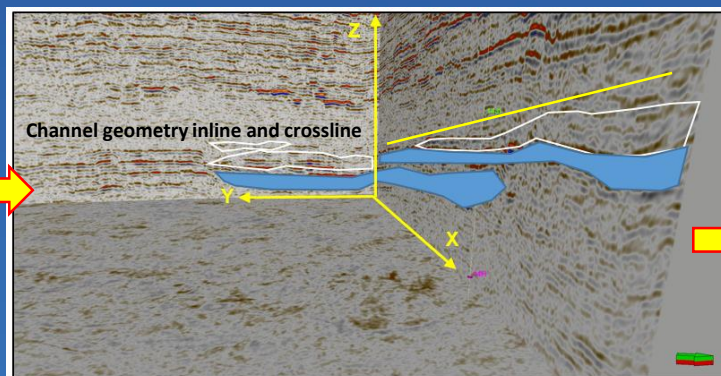
- Westward depocentre migration
- Episodic uplift
- Development of decollement
- Gravity faulting, slumping, major slides
- End of main fluvial input
- Major Uplift
- Fully open Atlantic
- Thermal subsidence, Ibhuesi (gas play) fluvial channel sands
- Regional Drowning, Aptian Source rock
- First Marine incursion
- Synrift grabens sediments, Oil discovery

# Workflow

**Step 1:** Initial view

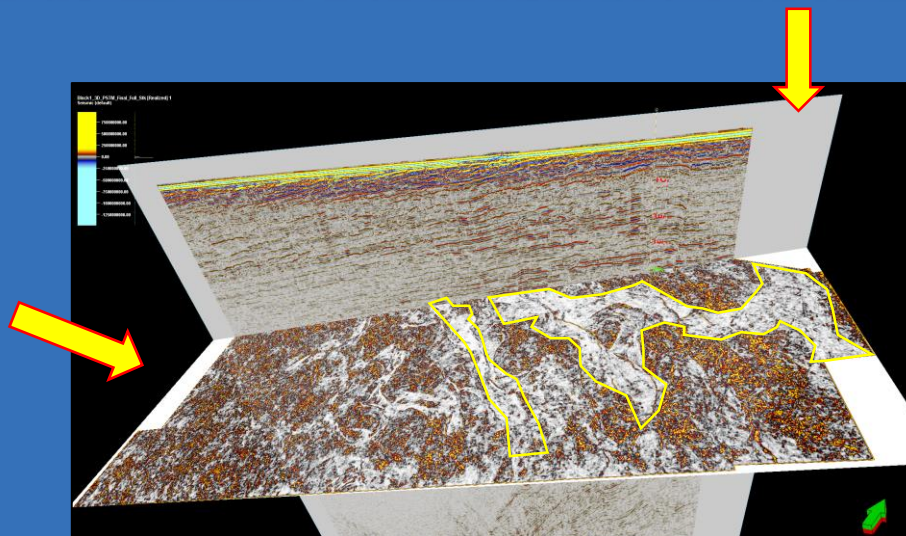
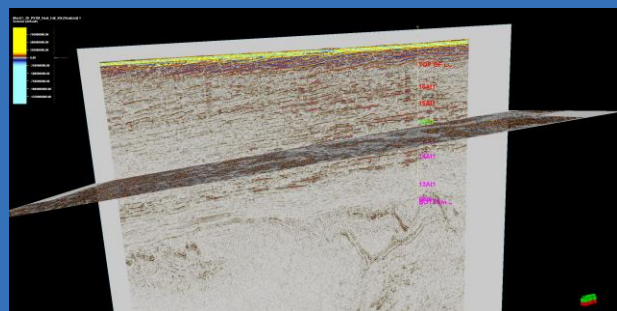


**Step 2:** Orientated the time slice to the dip of bedding



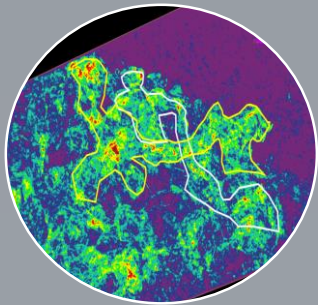
*View with from Inline, crossline and time-slice*

**Step 3:** Run seismic attribute on the volume



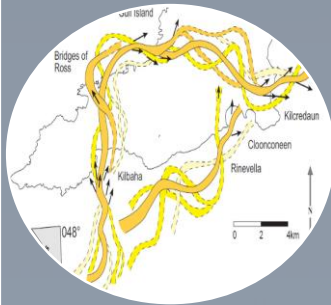
**RESULT:**  
Stratal slice

# Workflow

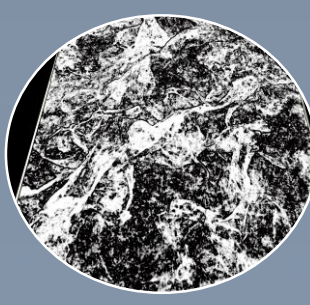


Define  
depositional  
geometries using  
seismic attributes

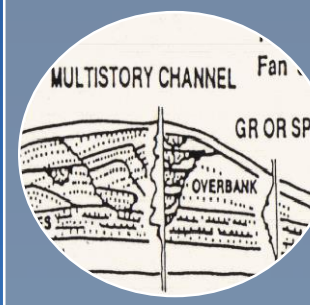
Seismic  
interpretation of  
faults, top and  
base horizons



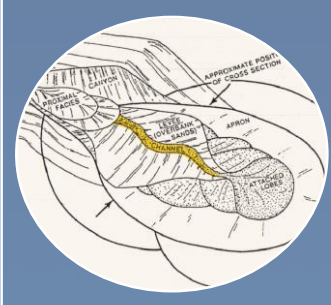
Identify the switch  
in paleo-direction



Determine  
channel widths,  
fill ratio and  
sinuosity of the  
various channel  
geometries



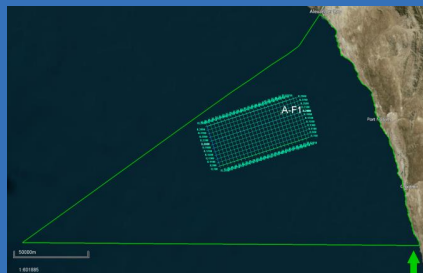
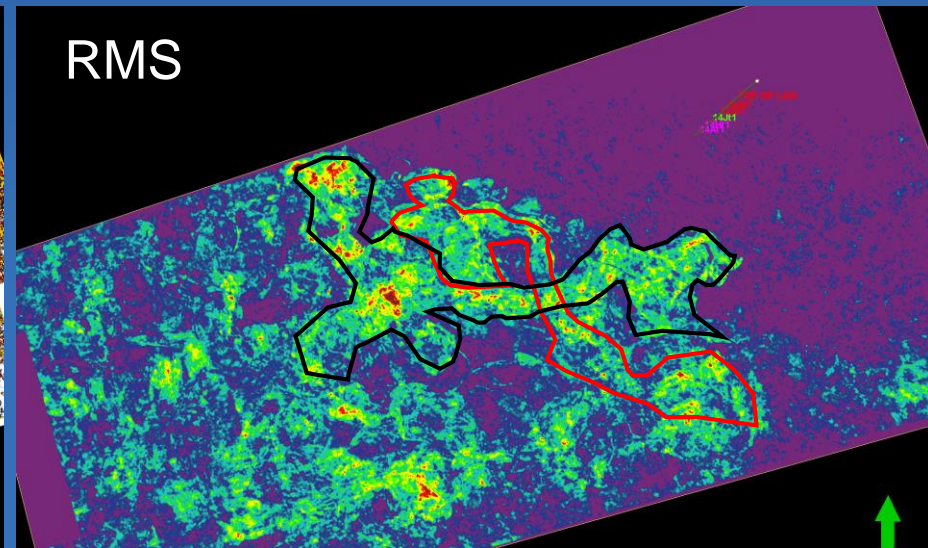
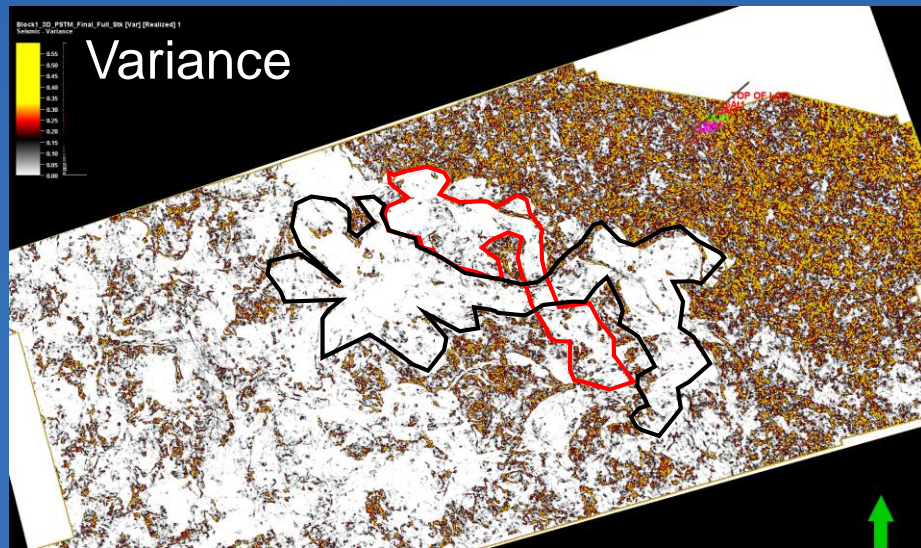
Compare seismic  
interpretation with  
well logs and core  
to substantiate  
depositional  
environments



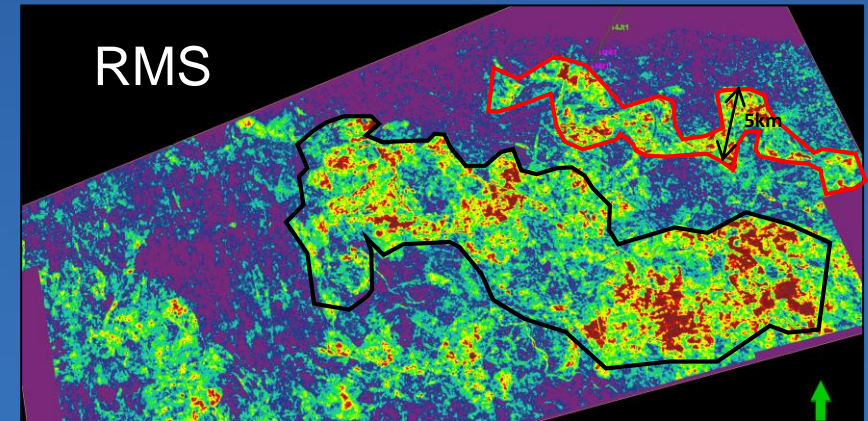
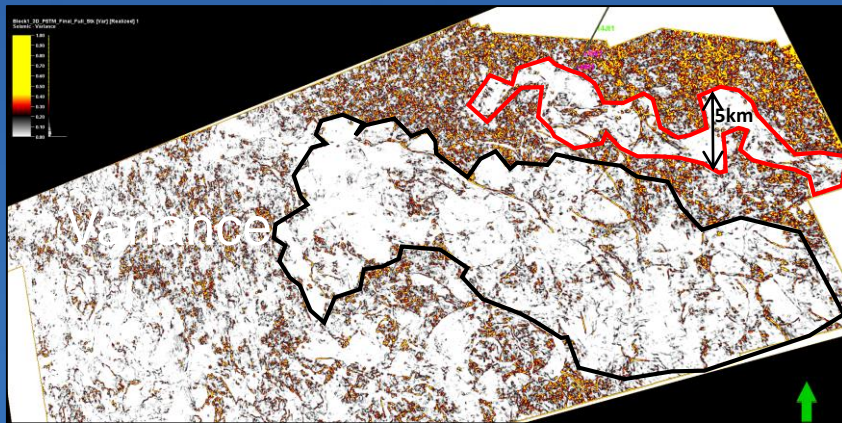
Identify possible  
reservoirs



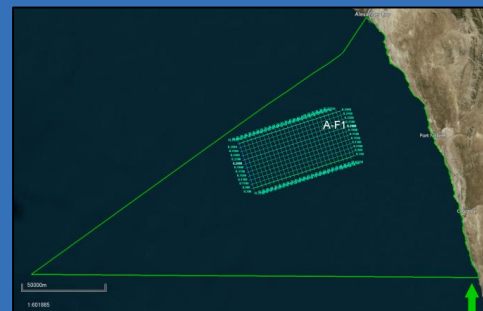
# Attributes Analysis: Albian-Aptian Lower level



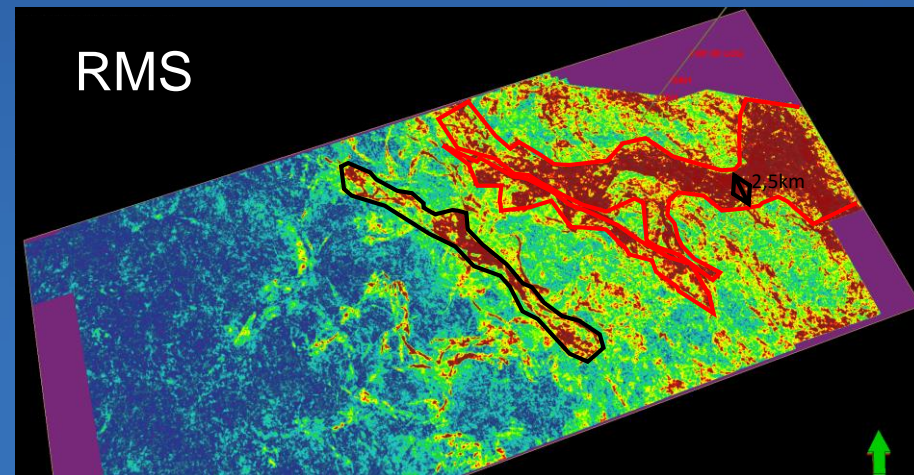
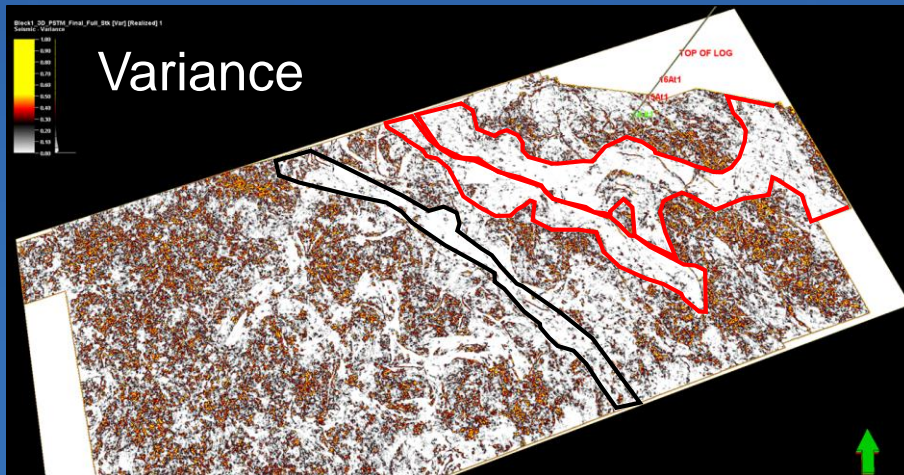
# Albian-Aptian Upper level



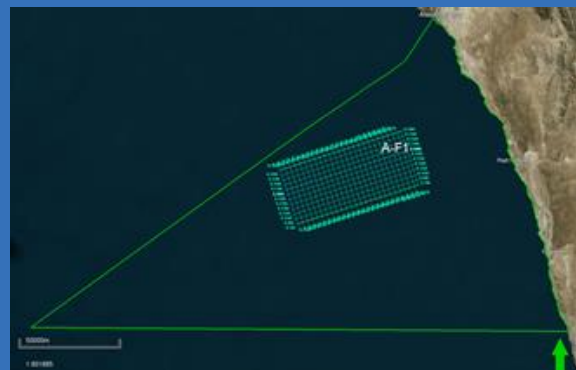
Channel width range: 50m - 2,5km



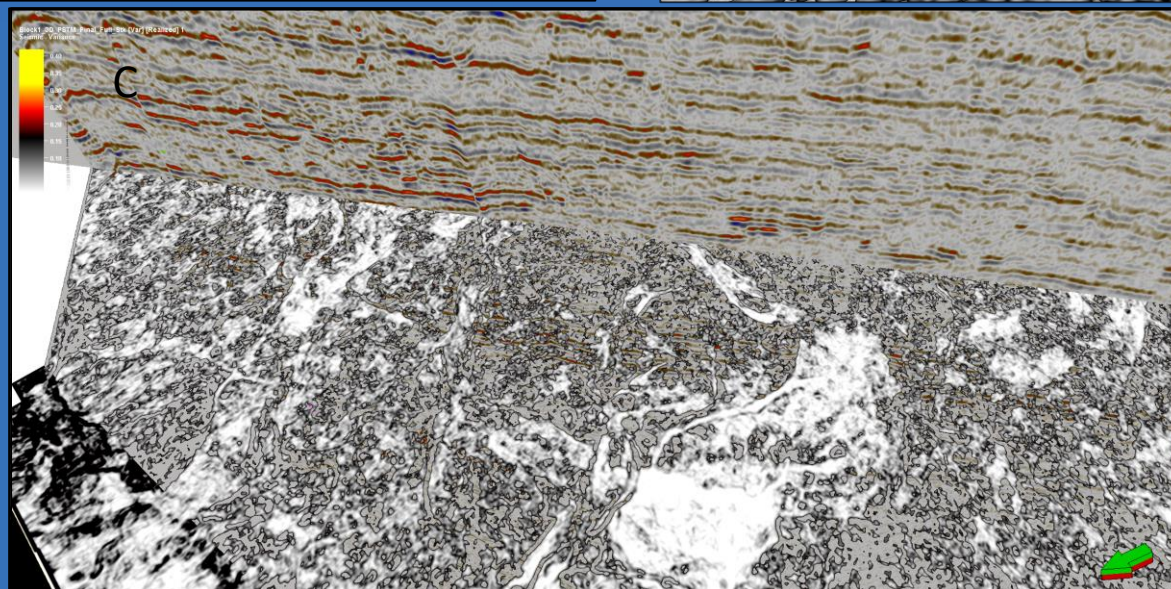
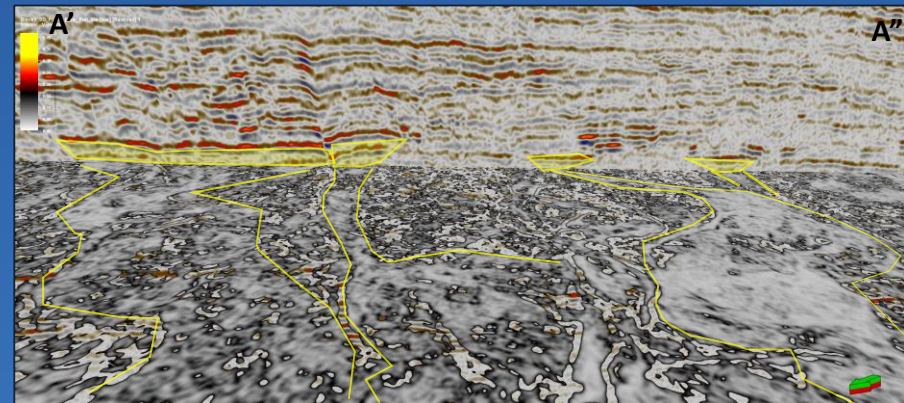
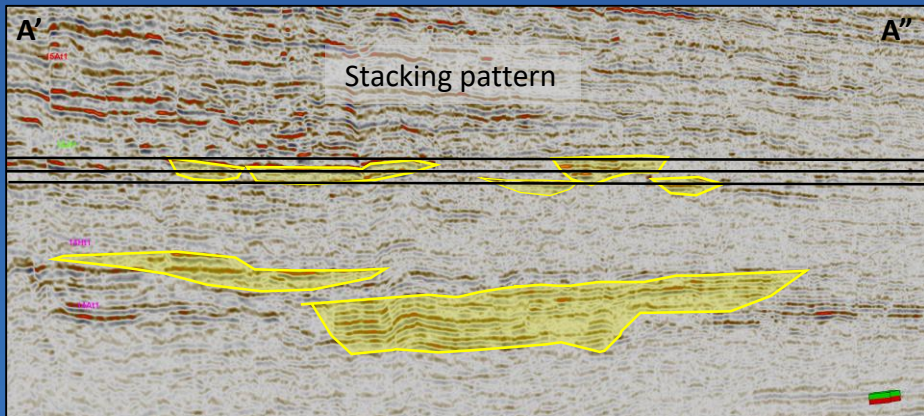
# Attributes Analysis: Cenomanian



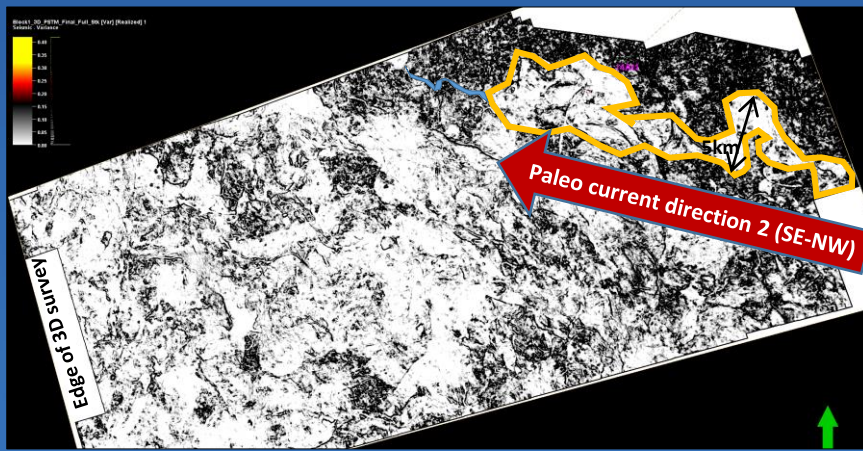
Channel width range: 50m - 2,5 km



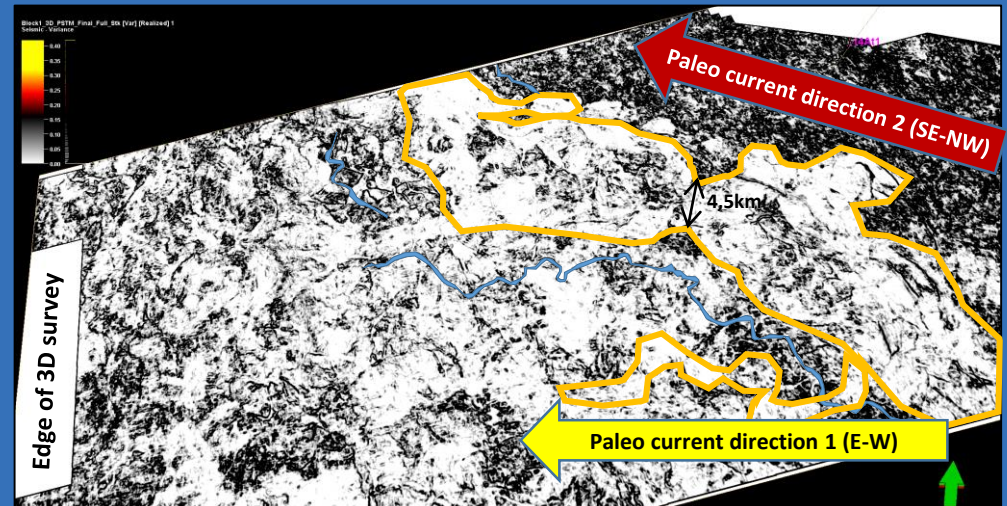
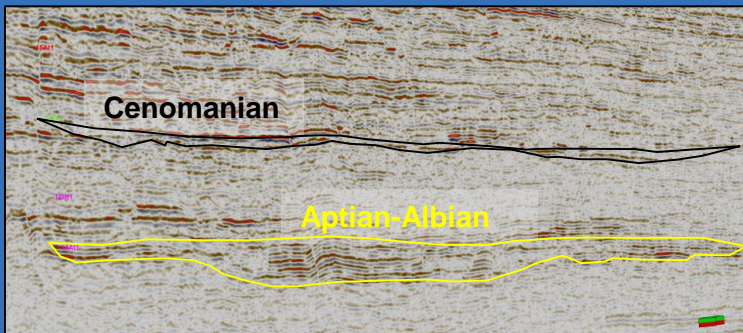
# Interpretation of channels on stratal slice



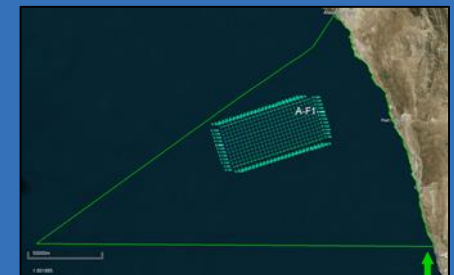
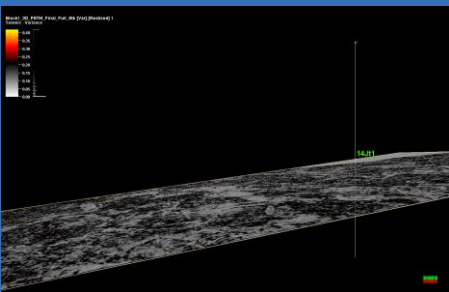
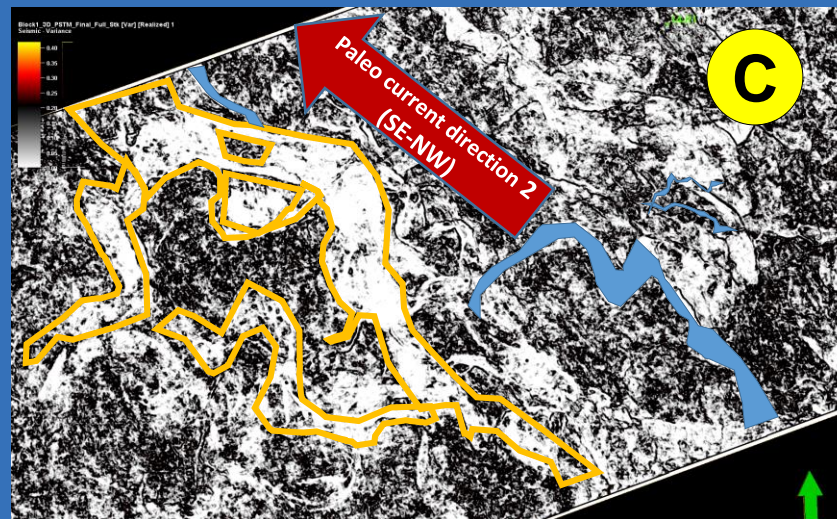
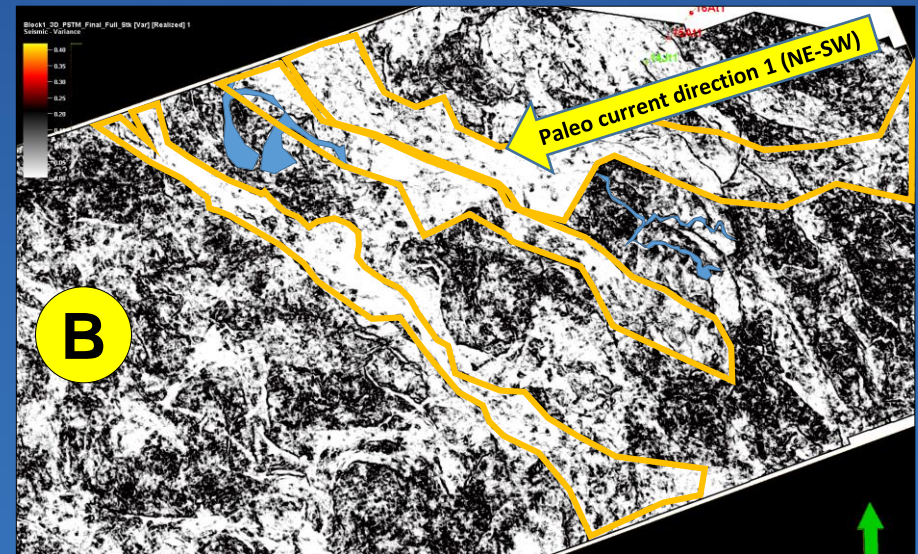
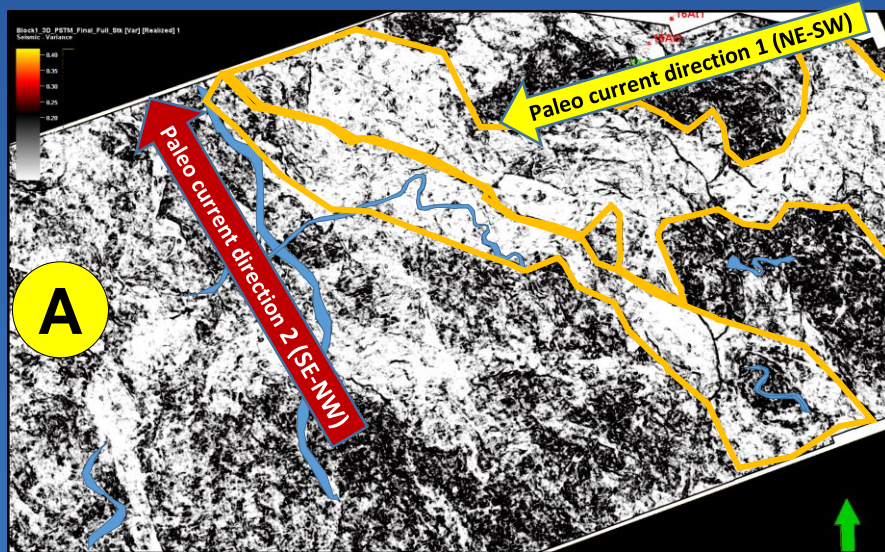
# Aptian-Albian: Paleo-current direction switches, channel widths, sinuosity and fill ratios



Difference in fill ratio

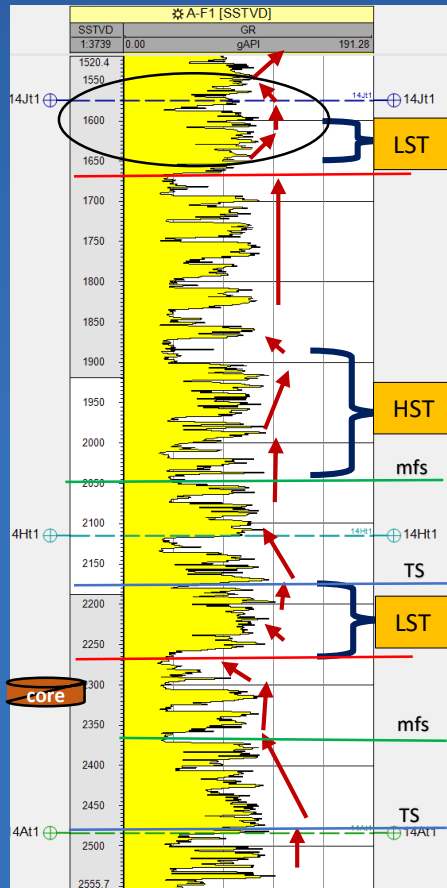


# Cenomanian Channels: Paleo-current direction switches, channel widths and sinuosity

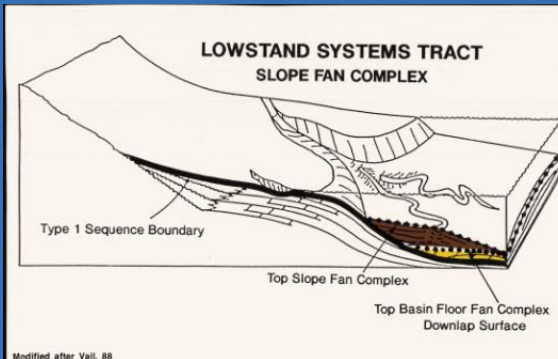
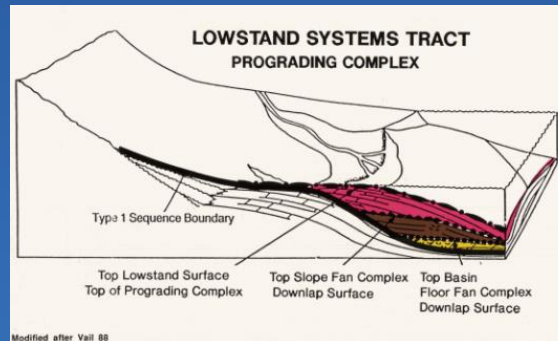


# Depositional environments: Cenomanian

## GR log



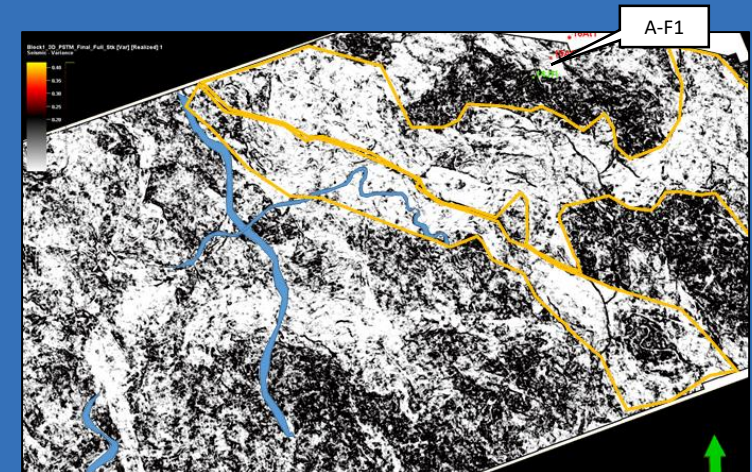
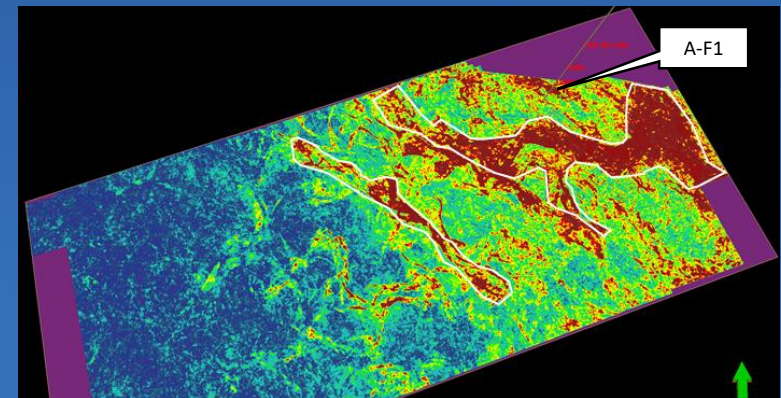
## What to expect?



Modified after Vail, 1988

No core was intersected at the depth of interest (1600m)

## Results from attribute analysis and mapping

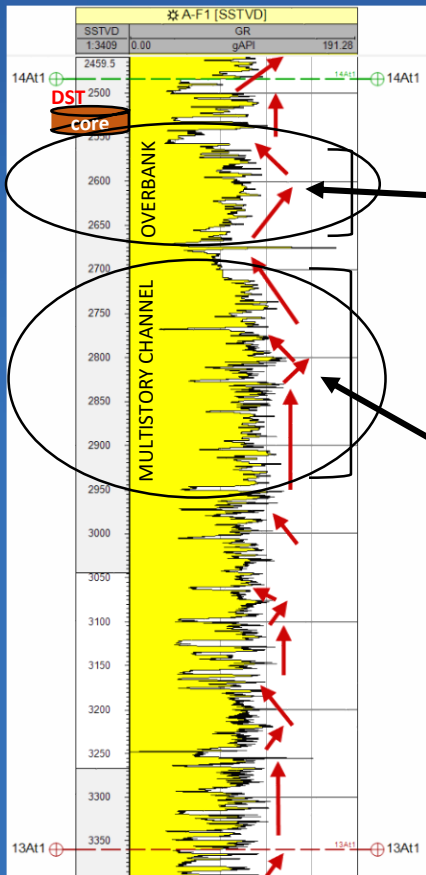


Sw: 73-94%, Porosity: 4 to 27% and permeability: 0,02-367md

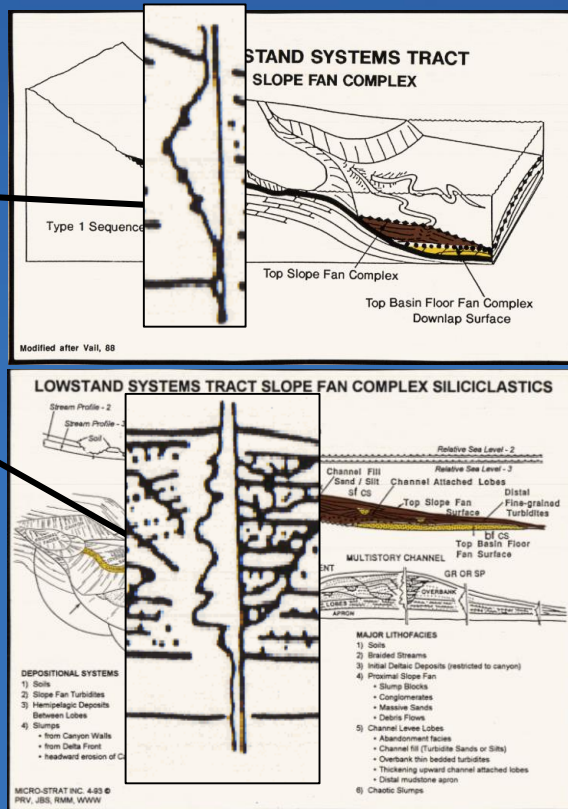
# Depositional environments: Aptian-Albian



## GR log

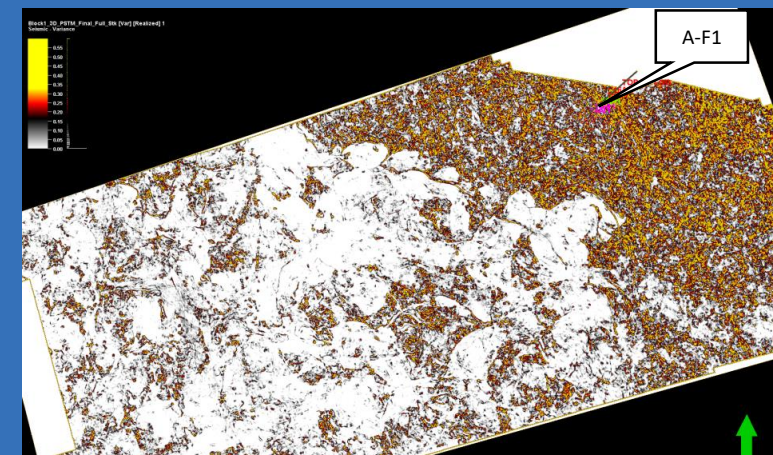
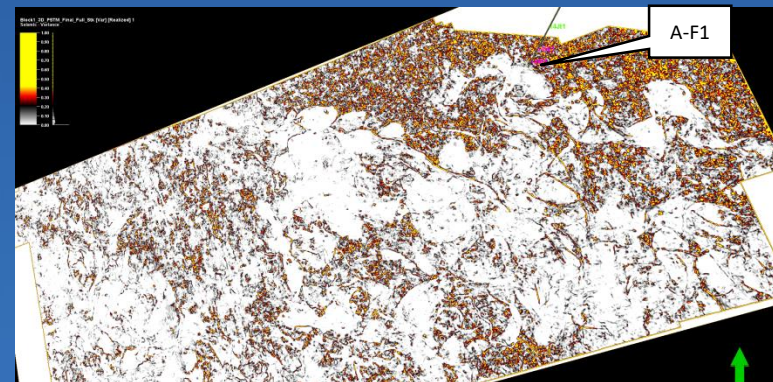


## What to expect?



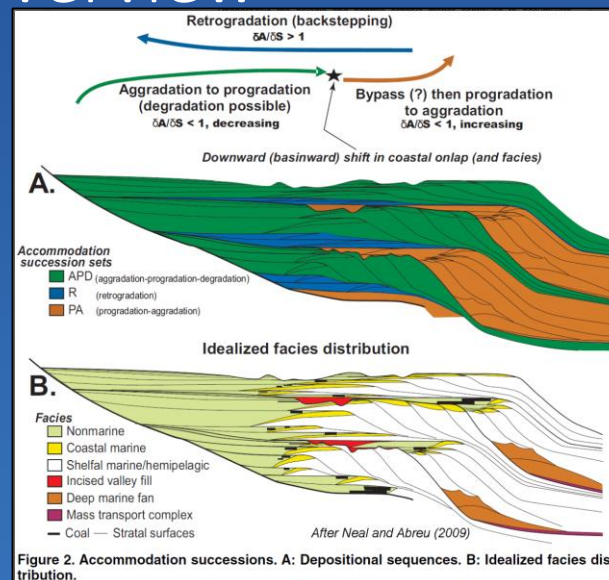
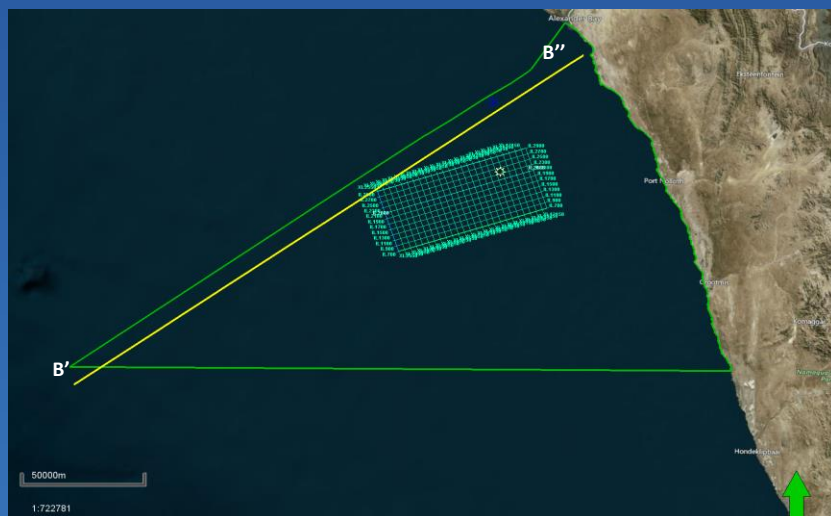
Modified after Vail, 1988

## Results from attribute analysis and mapping

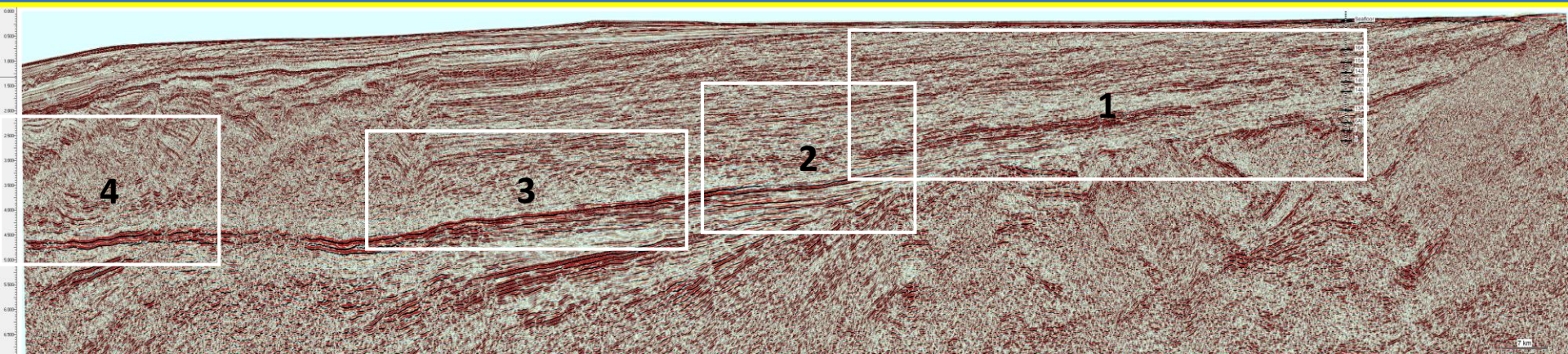


Intersected 13m gas bearing sandstone (channel sequence). Sat 5-8m thin and isolated Sw: 52-81%, Porosity: 22-25 % and permeability: 0,02-324md

# Channel Systems - Regional Overview



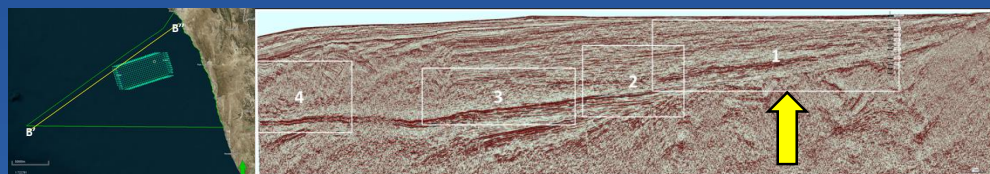
After Neal and Abreu (2009)



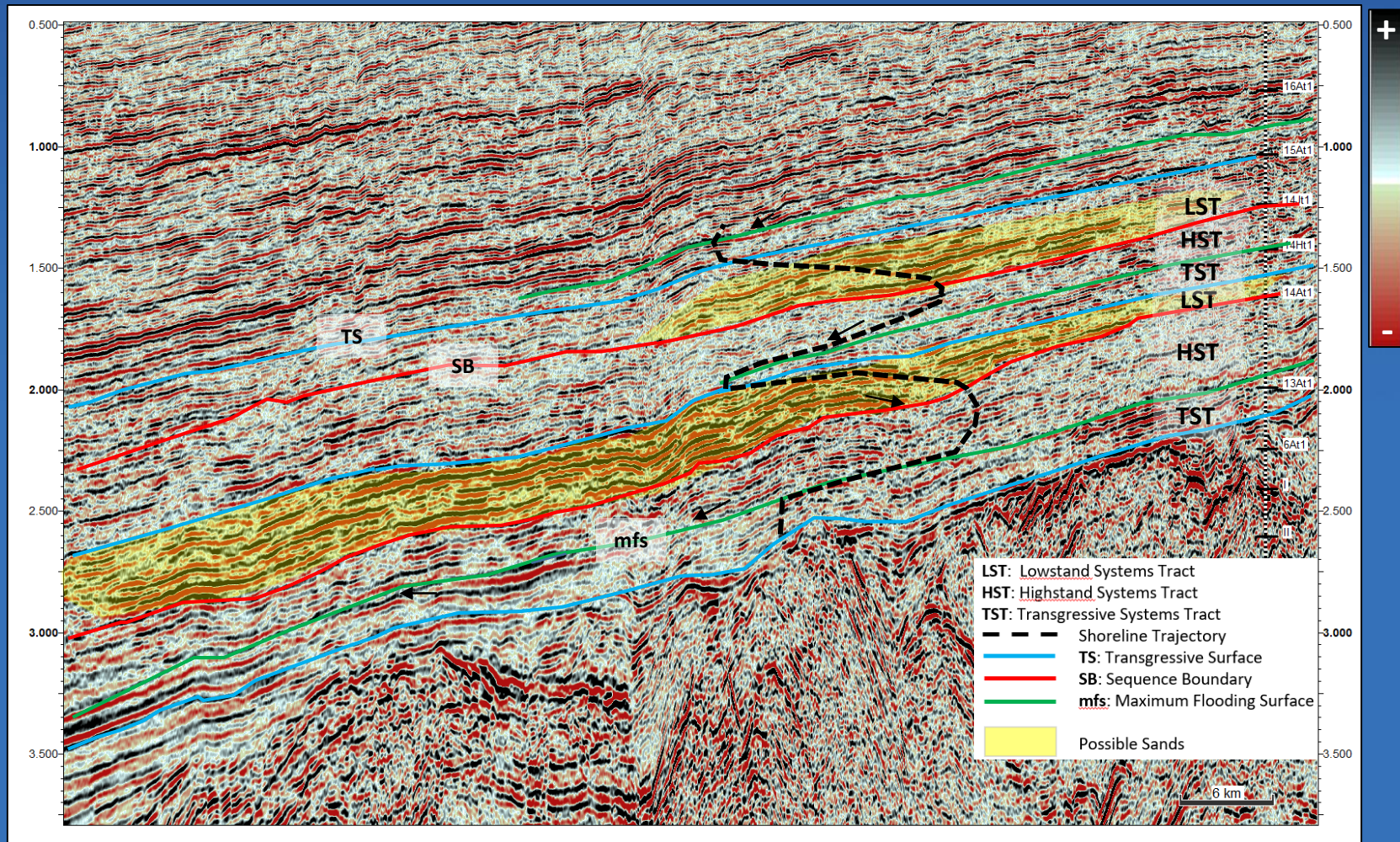
243Km

# Section 1

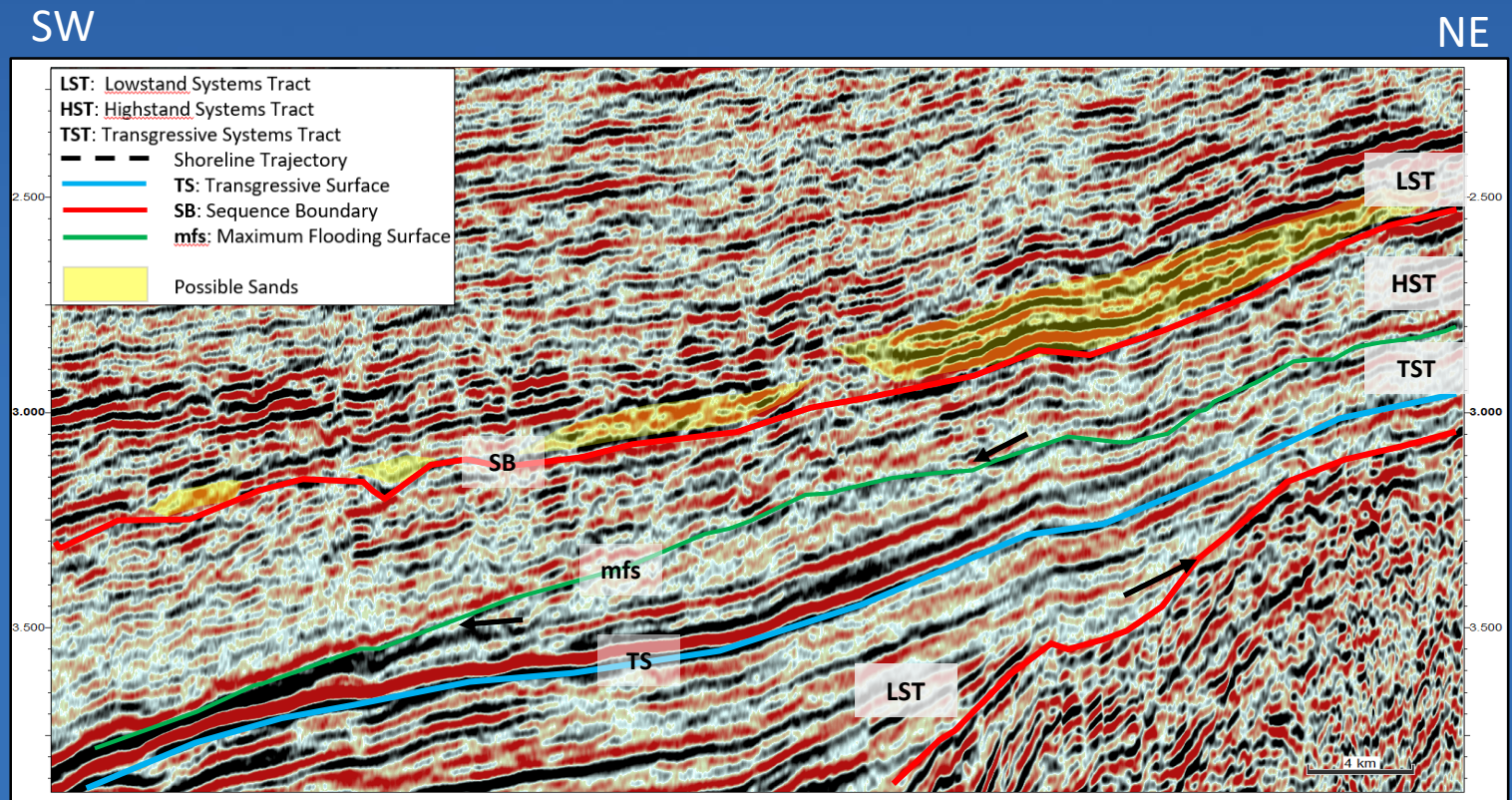
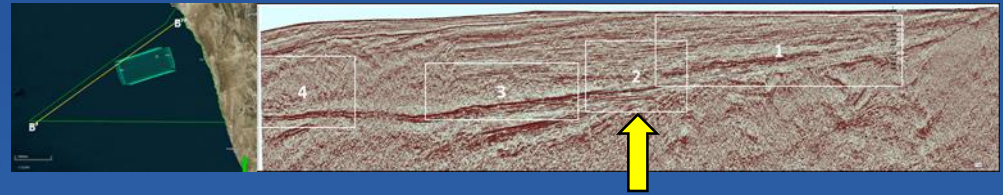
SW



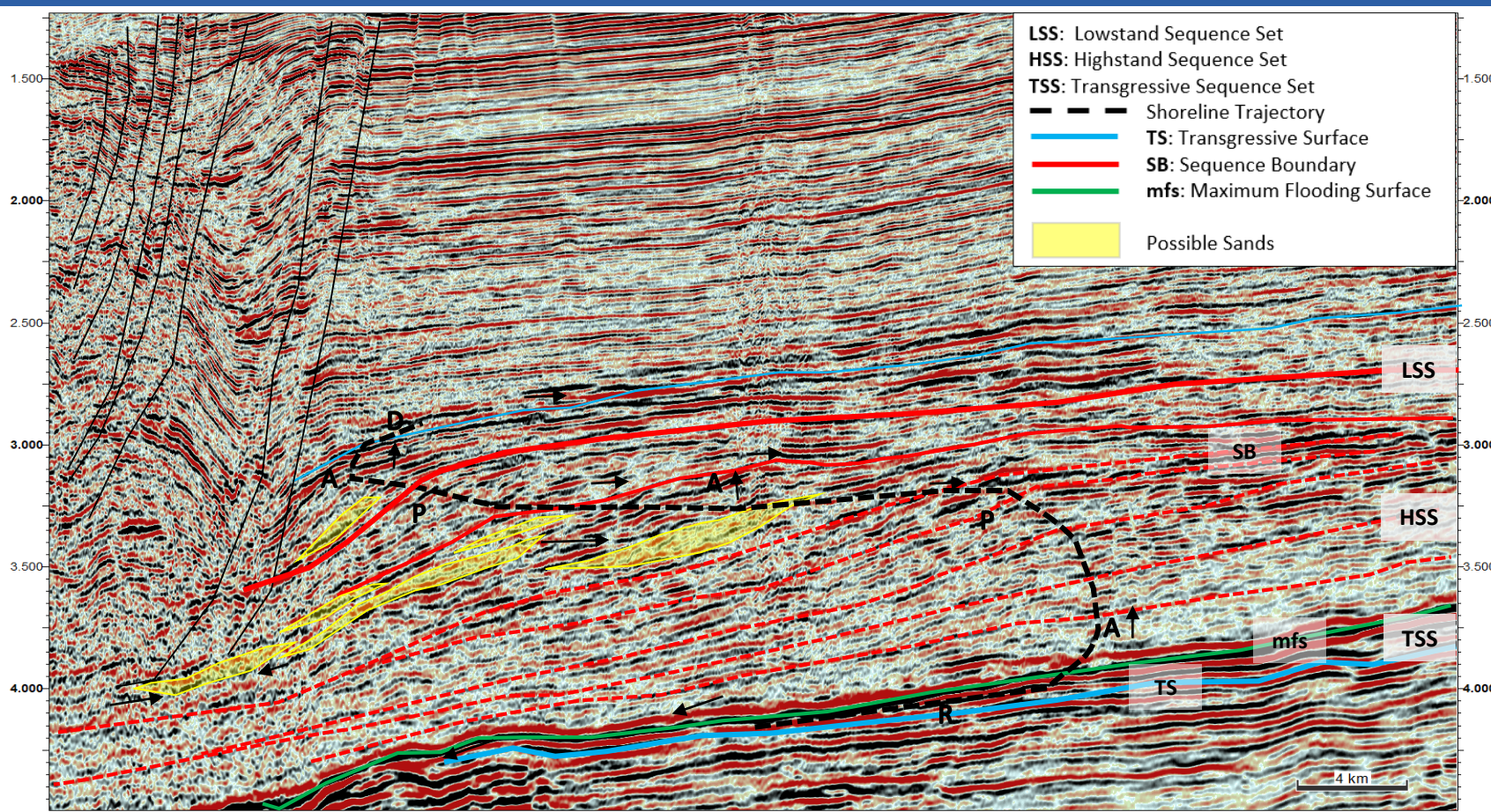
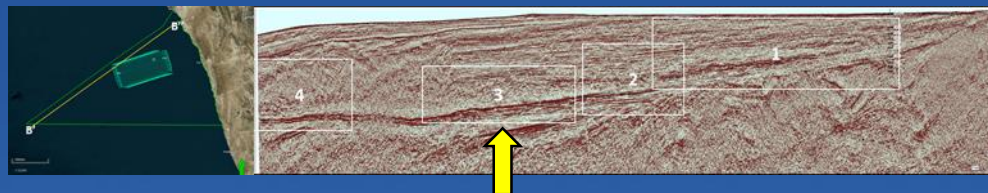
NE



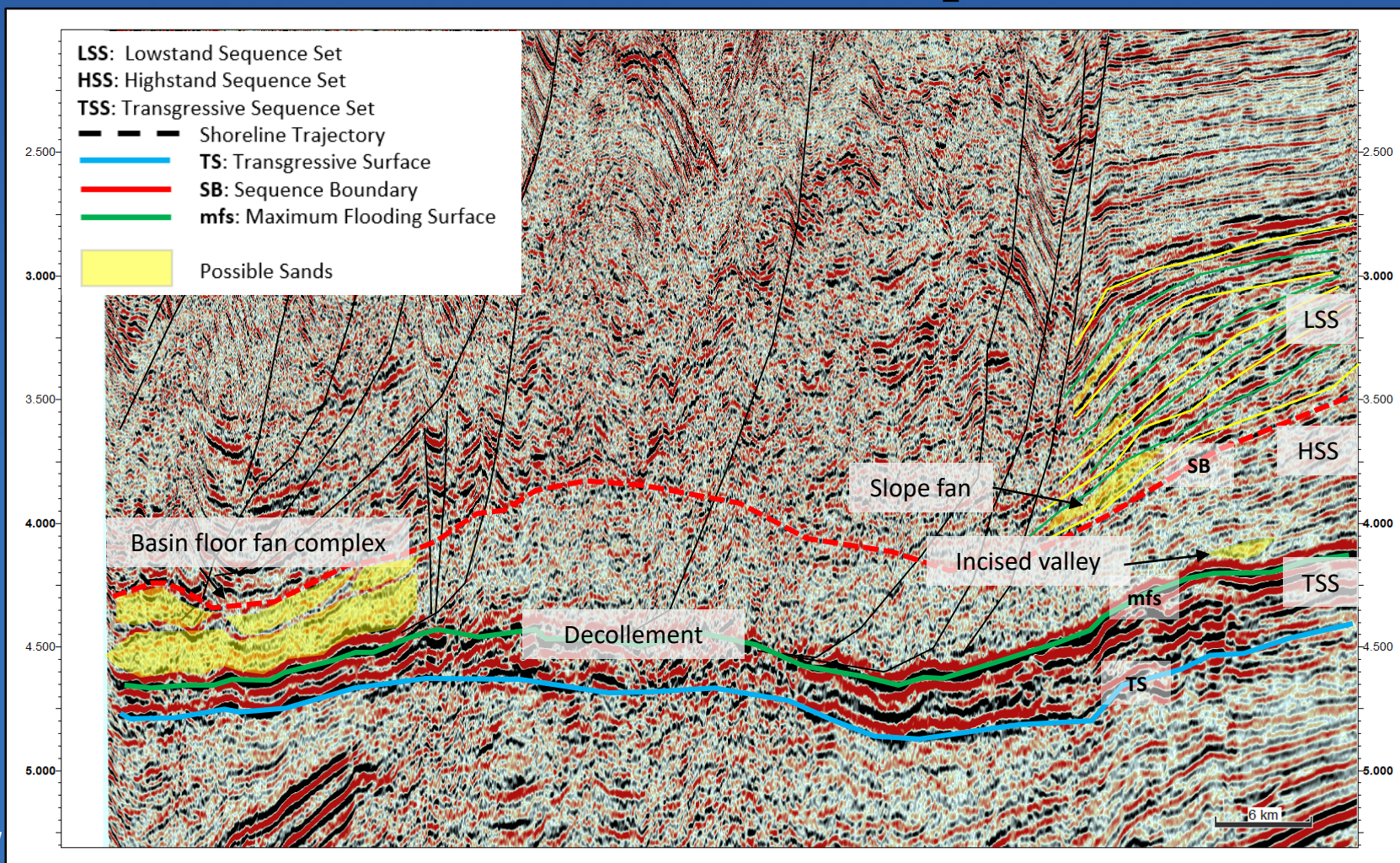
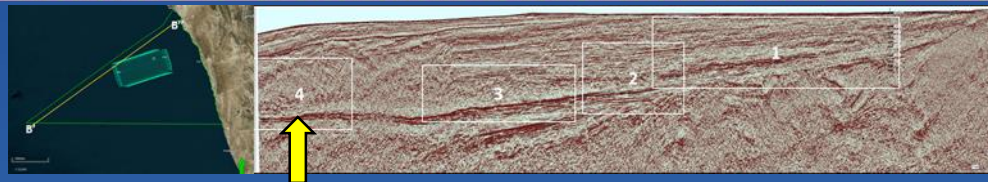
# Section 2



# Section 3



# Section 4



# Potential Reservoirs

Aptian-Albian

A-F1

Thick meandering channel

Channel complex

A-F1

Incised channel

Cenomanian

A-F1

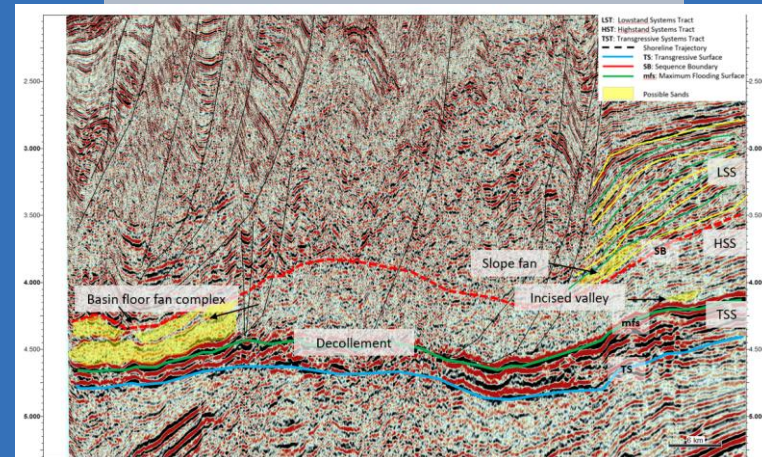
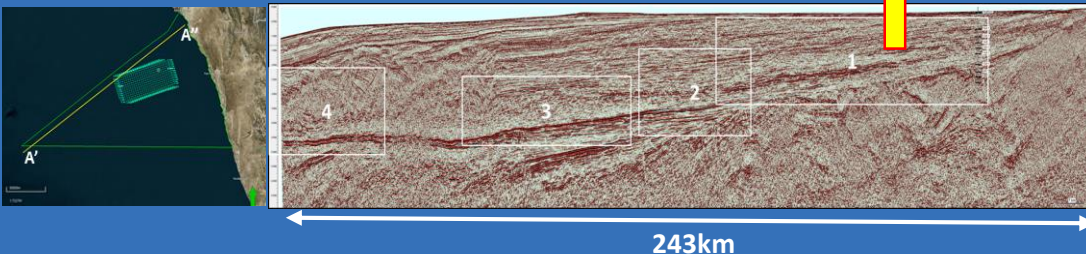
Levee (overbank sands)

Meandering channels

Oxbow lakes

## Deepwater reservoirs Section 4

- **Potential reservoirs:** include pro-delta/sheet-like turbidites, deltaic and fluvial sands, slope channel complexes and basin floor fan systems.
- **Source rocks:** charging these Cretaceous reservoirs include the proven Barremian-Aptian restricted marine oil and gas prone source as well as a postulated Cenomanian-Turonian aged source rock.
- **Migration path:** Faults and laterally up-dip through interbedded sands
- **Trap:** Stratigraphic traps or sealing faults
- **Seal:** Regional interbedded shales or clays



# Conclusion

- **The depositional geometries:** multi-storey channels, levees, splays, points bars, cut bank deposits, slope fans, incised valleys and basin floor fans.
- **Channel widths:** 50m to 2km; **Channel systems fill ratio:** higher in the Aptian than in the Cenomanian
- **Aptian-Albian** channels controlled by south-westerly dipping curvilinear faults.
- Dominant faults dissipate towards the west.
- Wider channel systems within the **Cenomanian** sequence intersected by extensive northwest-southeast trending faults.
- **Paleo current** switches are evident. The Aptian-Albian current changes direction from east to southeast, while the Cenomanian shifts from northeast to southeast.
- **Potential reservoirs:** pro-delta/sheet-like turbidites, deltaic and fluvial sands, slope channel complexes and basin floor fan systems.
- **Source rocks:** The **proven Barremian-Aptian** restricted marine oil and gas prone source and a **postulated Cenomanian-Turonian** aged source rock.
- The **A-F1** well drilled just outside the main channel systems in the shale dominated part of the system.

## Reference List

- [www.scotese.com](http://www.scotese.com)
- Jungslager, H. A., 1998. Petroleum Habitats of the Atlantic Margin of South Africa. Petroleum Agency SA Internal Report.
- Neal, J. Abreu, V., 2009, Sequence stratigraphy hierarchy and the accommodation succession method. *Geology*, pp. 77-782
- R Nobel, 1987, A-F1 Geological Well Completion Report, Soekor
- Vail, P. R., Wornardt, W. W., 1993, Sequence stratigraphy concepts and applications, Micro-Strat Inc.
- [https://www.petroleumagencyrsa.com/images/pdfs/Pet\\_expl\\_opp\\_broch\\_2017bw1.pdf](https://www.petroleumagencyrsa.com/images/pdfs/Pet_expl_opp_broch_2017bw1.pdf)