Charaterizing Facies Architecture and Intermediate-scale Reservoir Heterogeneity in the Dahomey Basin

A.E. JONATHAN, O.OLADIPO, B. JIBRIN, A. OKUBOYEJO, C.F. GEORGE & M. OGUNLEYE

Presentation Outline

- Introduction
- Objectives
- Hierarchies of heterogeneities
- Methodology
- Sequence Hierarchies and Reservoir Zonation
- Regional Sequence Stratigraphic Framework
- Regional 3D Framework
- Depositional Environments and Genetic Units
- 3D Reconstruction of Stratigraphic Architectures
- Reservoir Property Characterization
- Conclusion

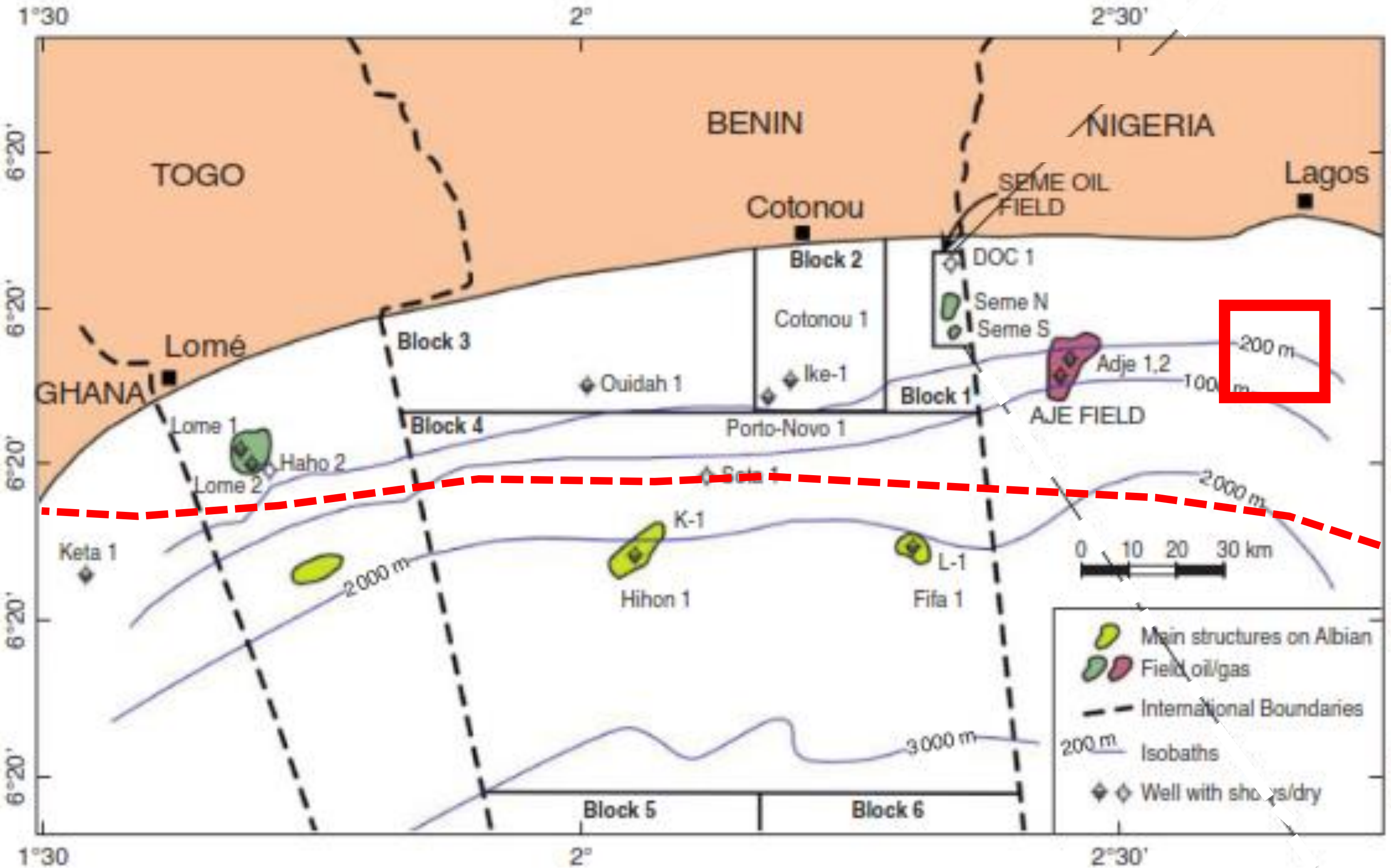
Introduction

- Located shallow offshore Dahomey Basin; Rifted basin (half-graben), part of WARS
- Structural style: normal and strike-slip faults
- 3 Fields discovered – Seme, Aje and Ogo

Stratigraphy

- Benin/Ijebu Fm
- Afowo Fm
- Oshosun Fm
- Imo Fm
- Araromi Fm
- Awgu Fm
- Abeokuta
- Albian Sandstone
- Ise Fm

(Franck d'Almeida, 2016)



Post-Rift Shallow marine & Syn-Rift Lacustrine Delta Play

Post-Rift Turbidite Play & Syn-Rift Lacustrine Delta Play

Objectives

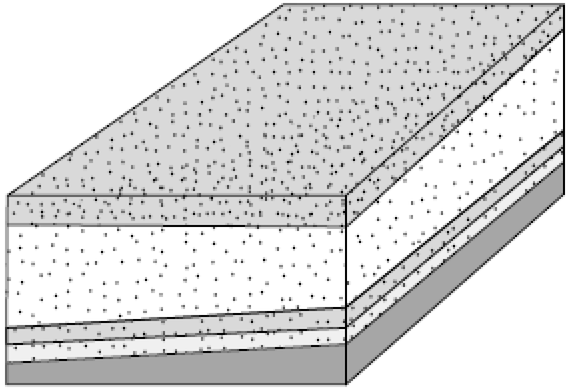
LEKOIL

- Interpret depositional genetic units and facies
- Quantify basin-wide flooding events and (potential) barriers to fluid flow
- Produce 2D stratigraphic model of Field X and Dahomey Basin
- **Controls on Reservoir Quality Distribution**
- Construct a 3D predictive model of reservoir stratigraphic architecture

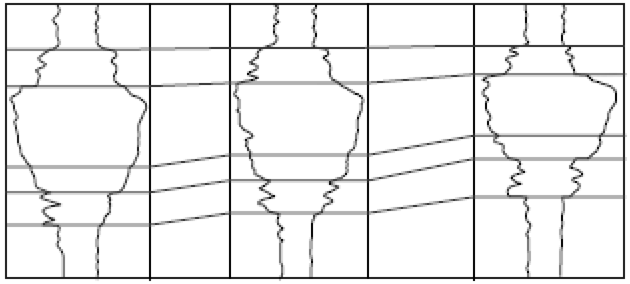
LEKOIL

Heterogeneity increases Model Complexity

Layer-Cake

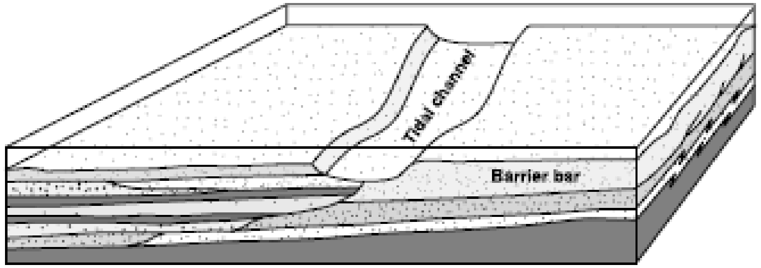


Layers represent sands deposited in the same environment of deposition.

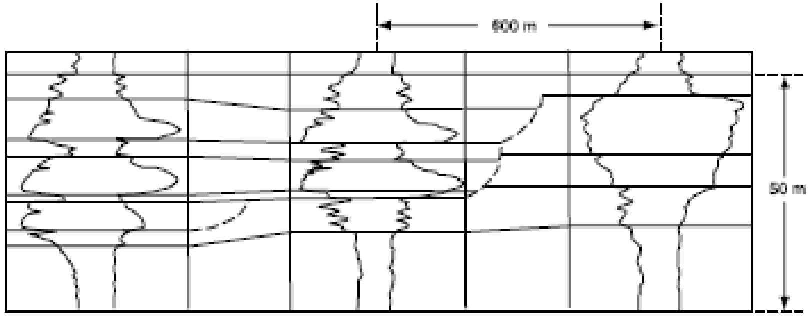


Excellent log correlation showing gradual lateral changes in thickness and properties.

Jigsaw Puzzle

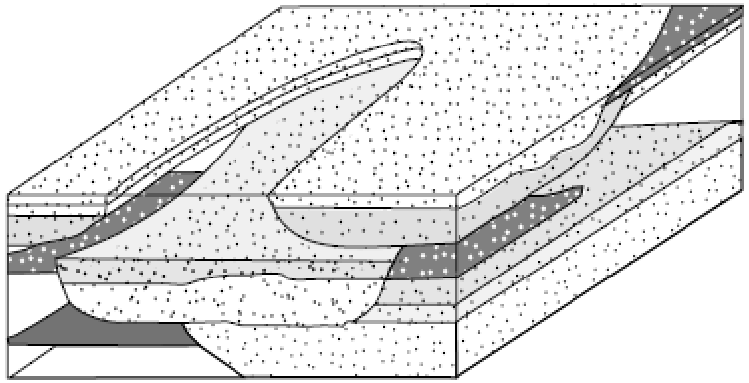


Reservoir architecture determination requires a detailed sedimentological analysis.

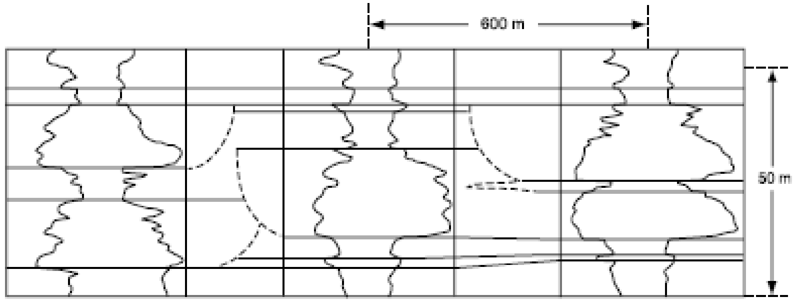


Although the sand/shale ratio is high, correlation may be difficult without a detailed facies interpretation.

Labyrinth



In 3-D, interconnections exist locally but in part only via thin low-permeable sheet sands.

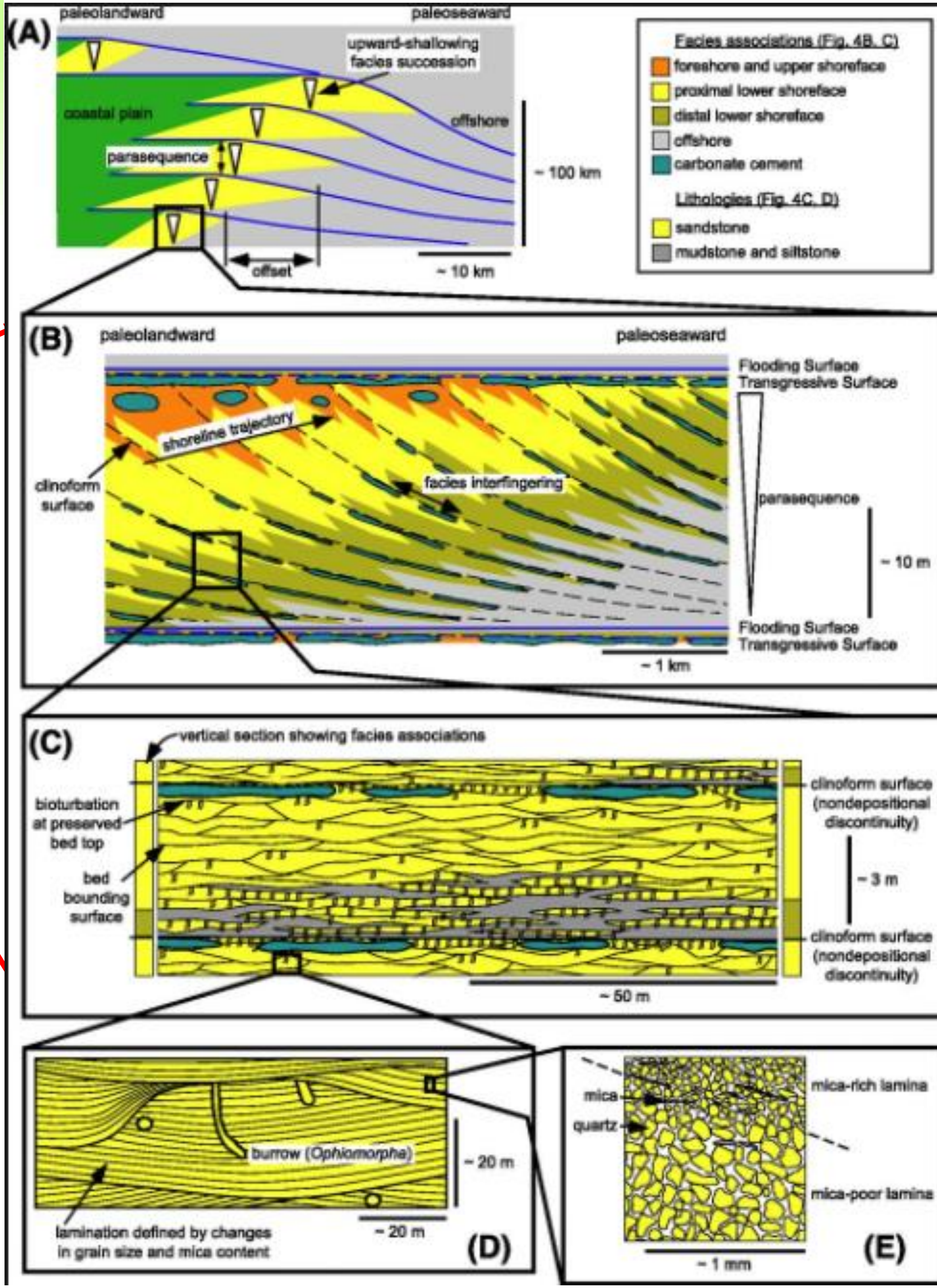


Difficult log correlation even when the well spacing is 400 to 600 m.

(Weber and van Geuns, 1990)

Hierarchy of heterogeneities in shoreface-shelf reservoirs

- Parasequence stacking patterns
- Intra-parasequence facies architecture
- Carbonate cement distribution
- Shale lengths and distributions
- Bioturbation type and intensity
- Cross-stratification
- Laminae and mica distribution
- Grain size and sorting



Courtesy G.J.Hampson and J.A. Howell, 2017

Sequence Stratigraphic Framework, Genetic Units and Hierarchy of Well-X, Dahomey Basin

LEKOIL

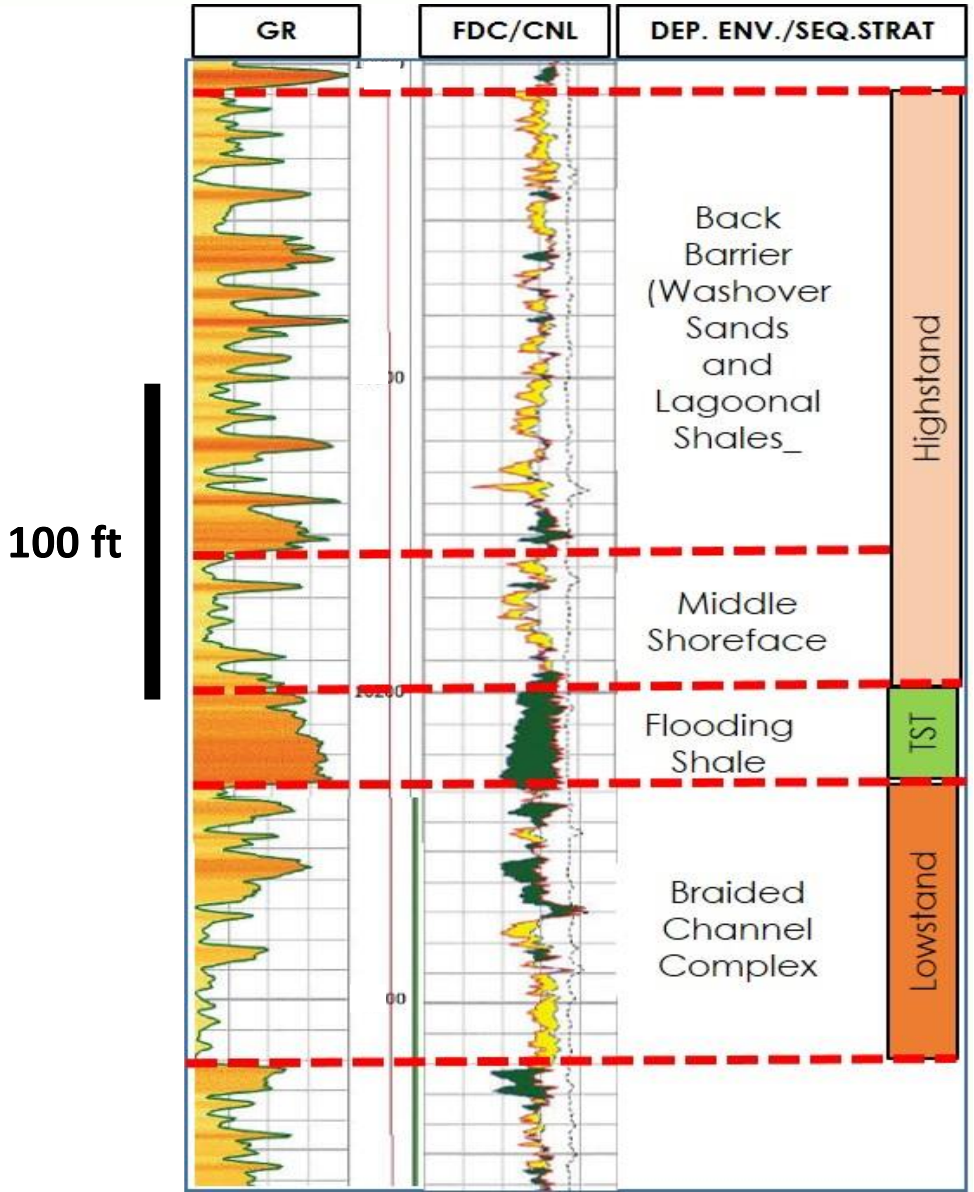
Data

- High Resolution 3D Seismic data
- Composite wireline logs
- Side-wall cores and ditch cuttings
- Analogues

Method

- Multi-well log analysis
  - Log shape
  - Genetic Units and Facies Interpretation
- Stacking patterns
- Sequence Analyses and Depositional Environment Reconstruction
- Correlation

Sequence Interpretation



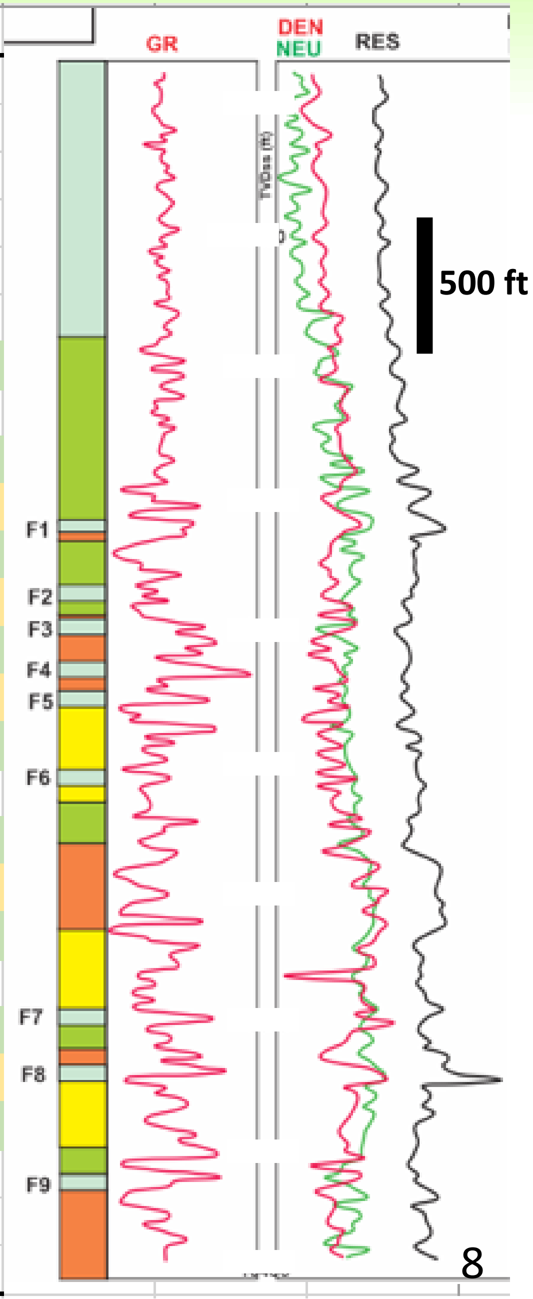
Sequence Hierarchies and Reservoir Zonation

- **Key surfaces and flooding events correlated across basin**
- **Improved stratigtraphic zonation from lithostratigraphic subdivisions**

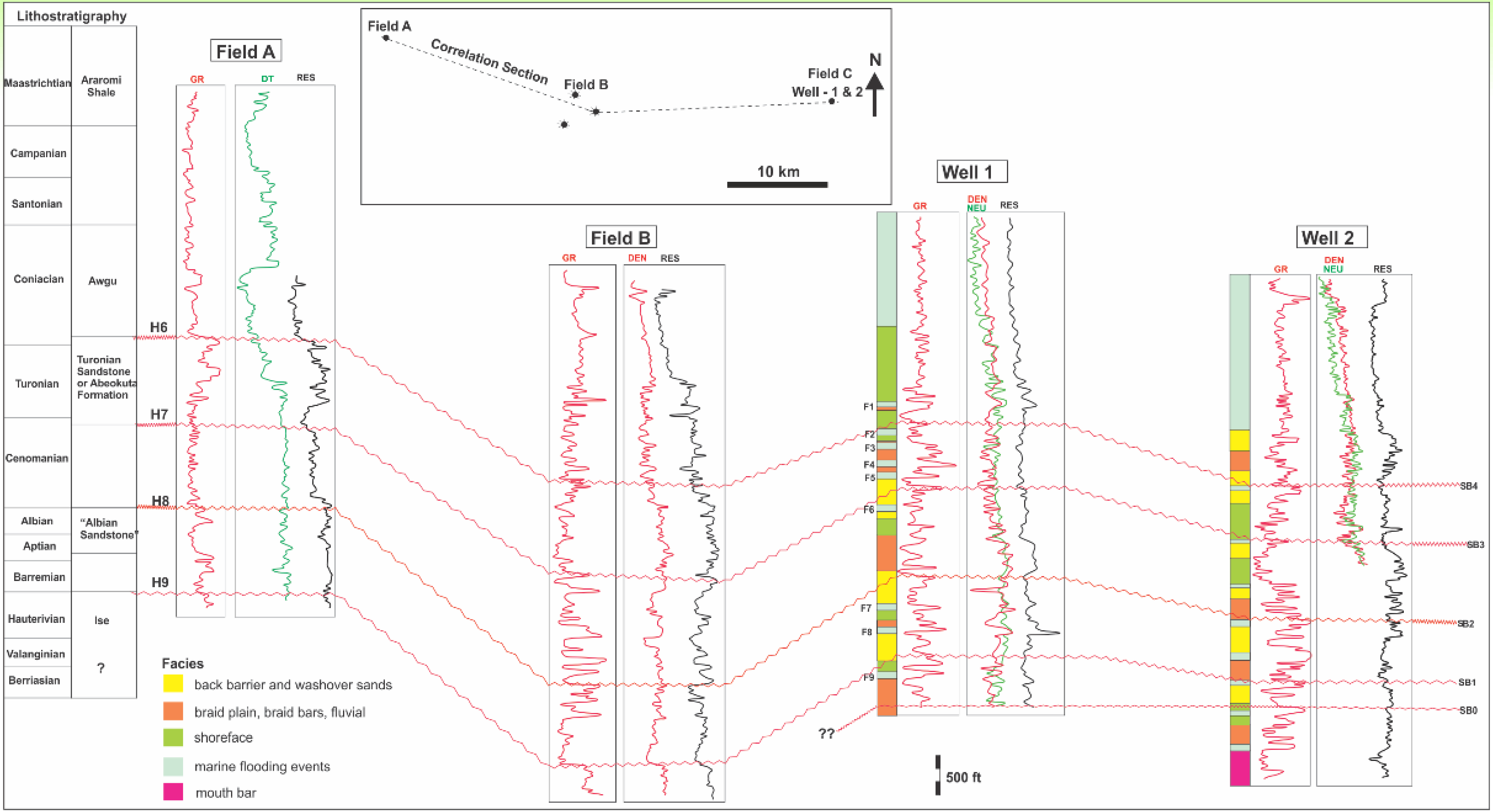
- **Reservoir Flow Units are separated from major flooding events and SBs**
  - Flooding Shales are 9 – 36 ft thick
  - SBs defined by multi-well logs breaks and seismic terminations

- **Characterization of Genetic Units is based on**
  - Higher order GUs (4th Order)
  - & Petrophysical properties

Kaki et. al. (2013)	This Study	Name
H2		Mid-Miocene Unconformity
H3		Base Miocene Unconformity
Intra-Imo FM		Eocene Unconformity
H4		Top Araromi Fm
Intra-Araromi FM		Mid-Maastrichtian Unconformity
H5		Maastrichtian Unconformity
	F1	Flooding Event
H6	SB4	Top Abeokuta Sandstone
	F2	Flooding Event
		Flow Unit
	F3	Flooding Event
		Flow Unit
	F4	Flooding Event
		Flow Unit
	F5	Flooding Event
H7	SB3	Early Cenomanian Sandstone
	F6	Flooding Event
		Flow Unit
	F7	Flooding Event
H8	SB2	Mid-Albian Unconformity
	F8	Flooding Event
		Flow Unit
	F9	Flooding Event
H9	SB1	Mid Cretaceous Unconformity
?	SB0	?
Deep Marker		Base of syn-rift Ise (?)

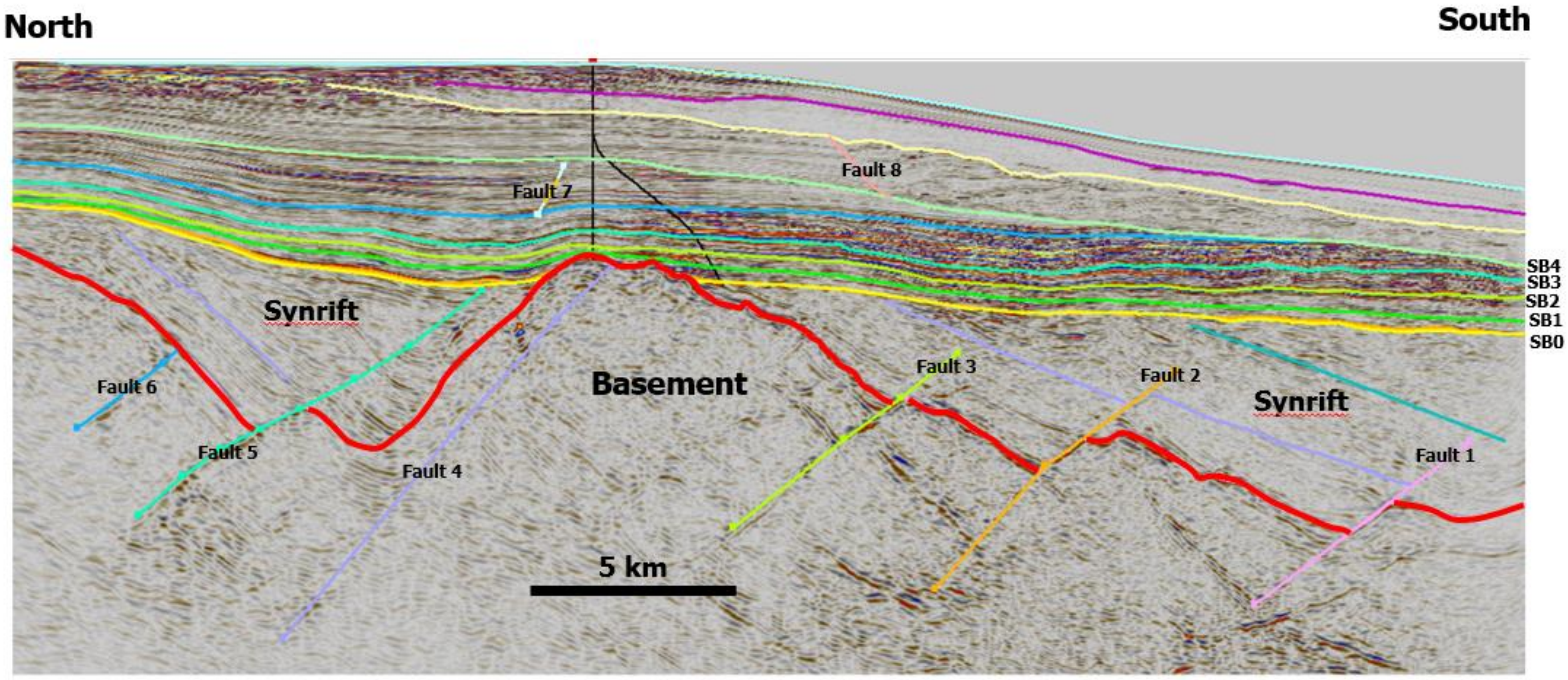


Regional Sequence Strategraphic Framework



Regional Mapping (3D framework)

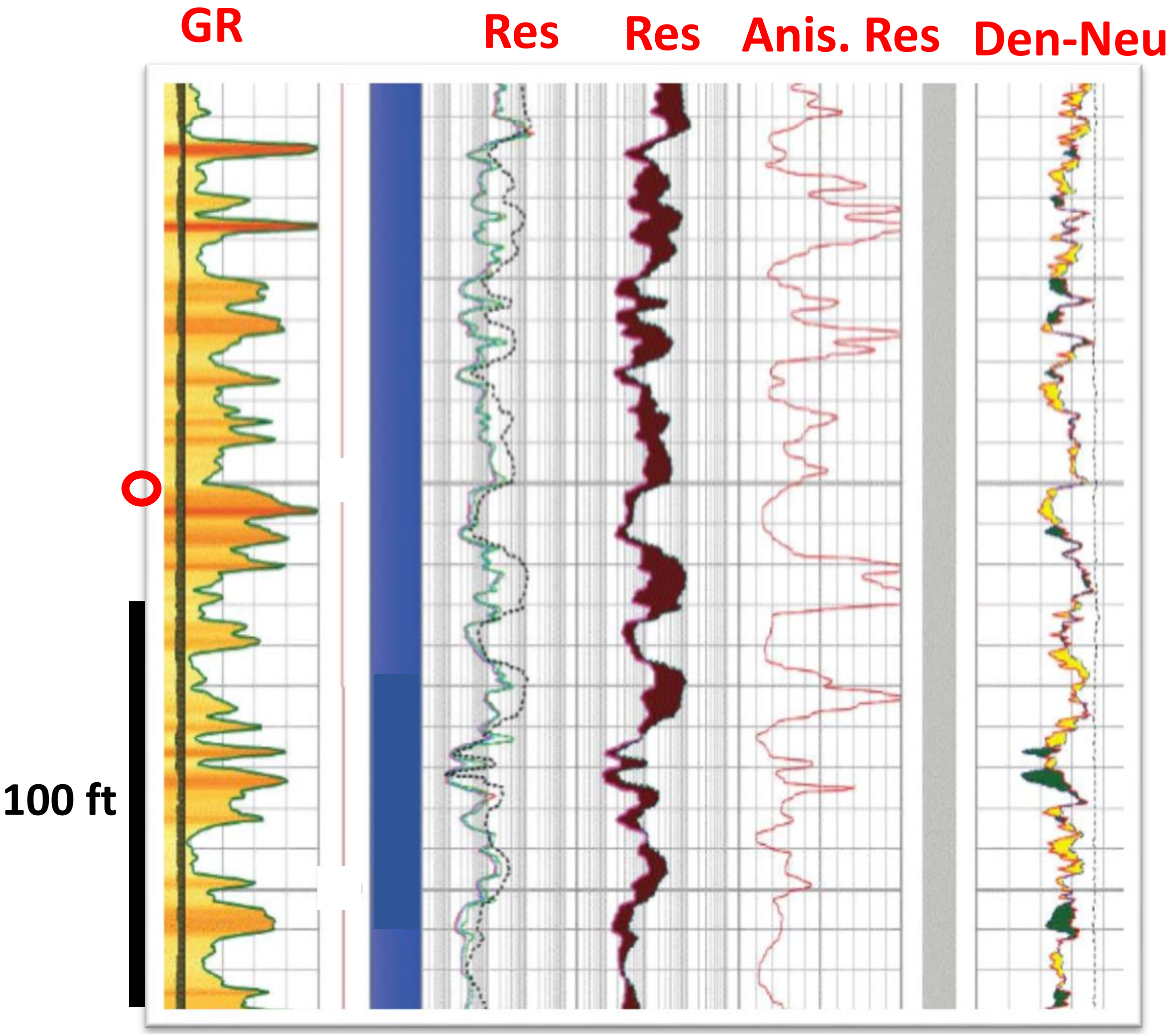
- Mapped surfaces from 3D seismic
- Five interpreted regional events equivalent to the sequence boundaries in the post-rift
- Basement-involved normal faults and off-lapping cycles in the L. Cretaceous syn-rift

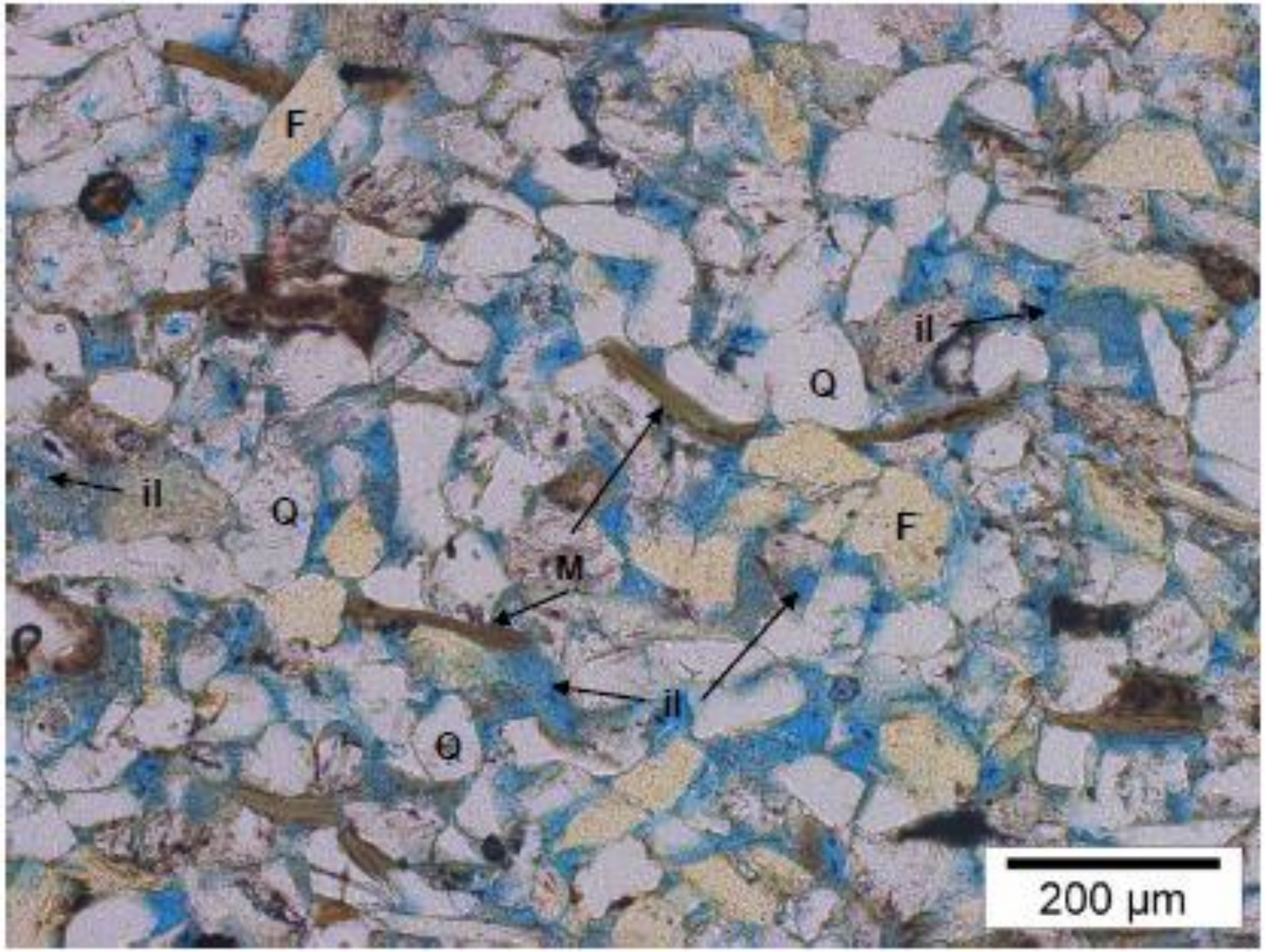


Depositional Environments and Genetic Units from Logs and Rock Facies

LEKOIL

SHOREFACE

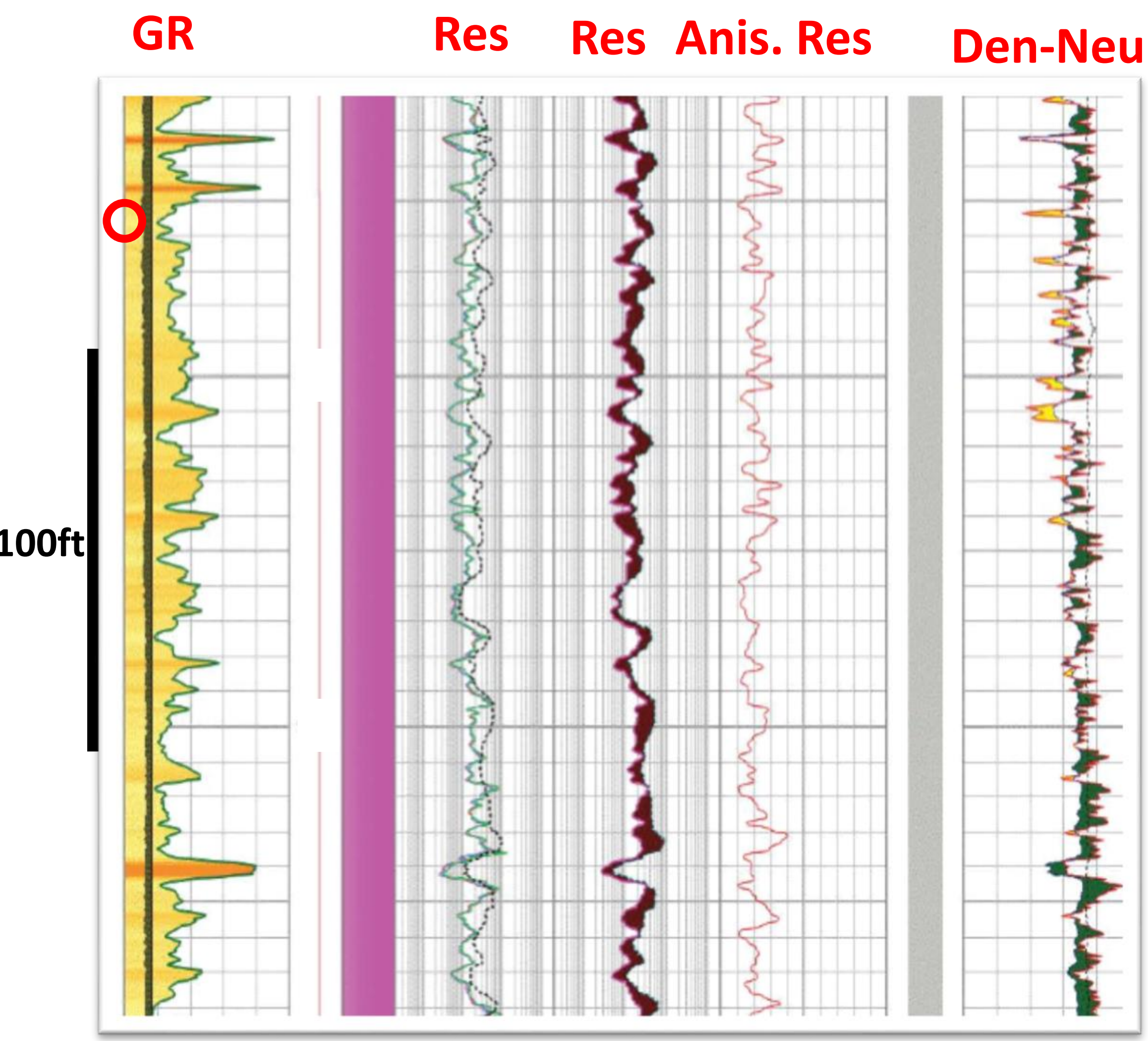


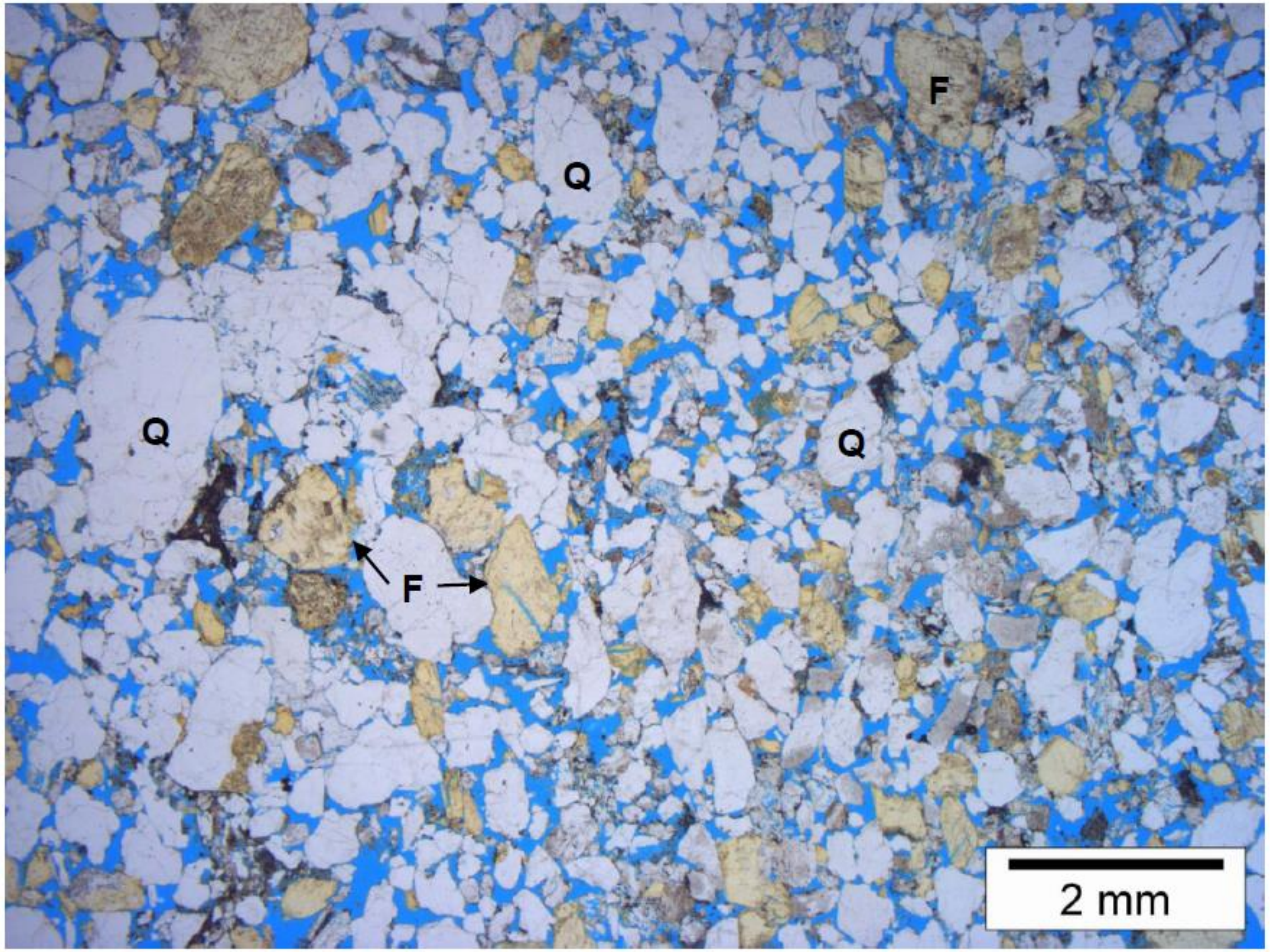


Q = Quartz; F = Feldspar; M = Mica; il = ilmenite

Depositional Environments and Genetic Units from Logs and Rock Facies

BRAID BARS, BRAIDPLAIN



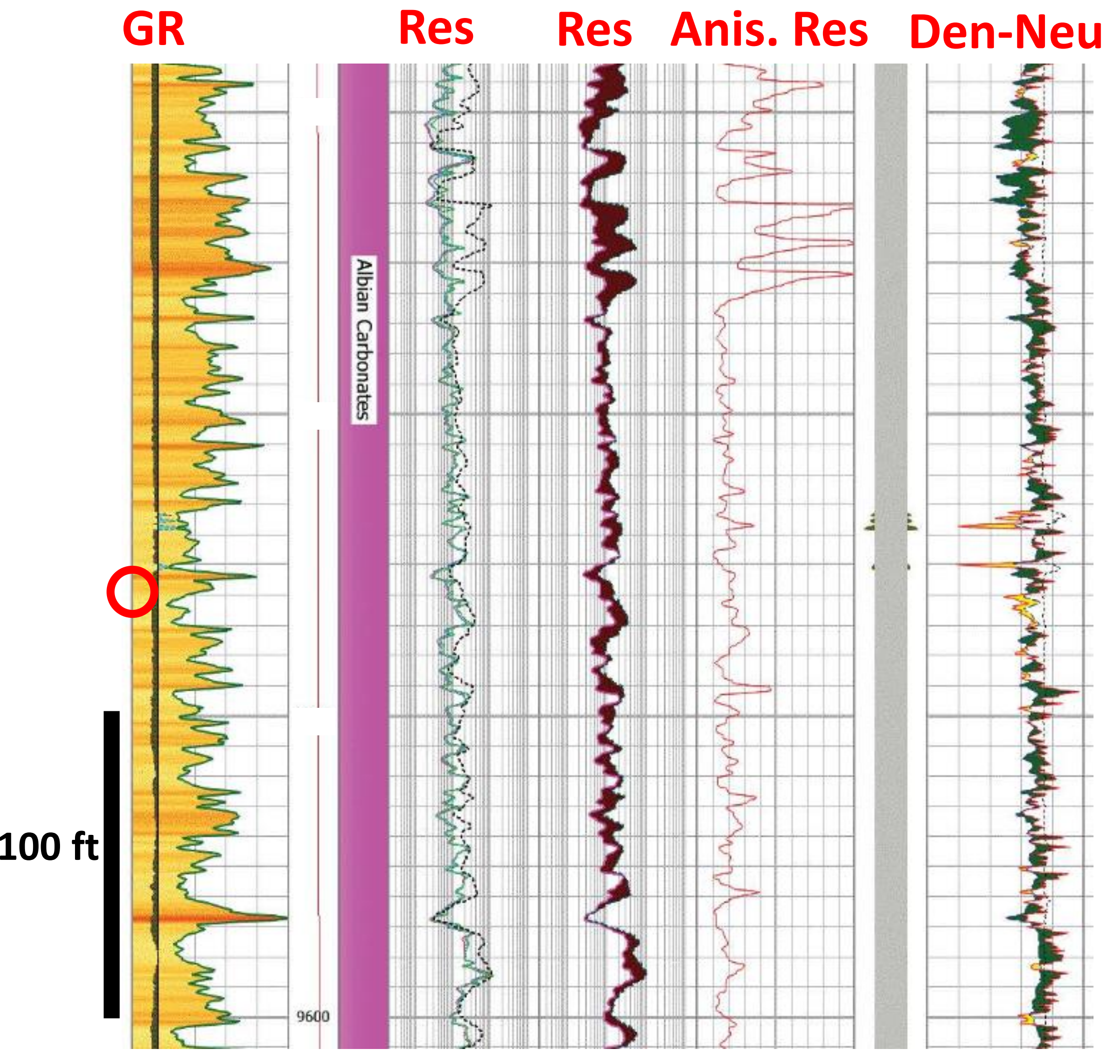


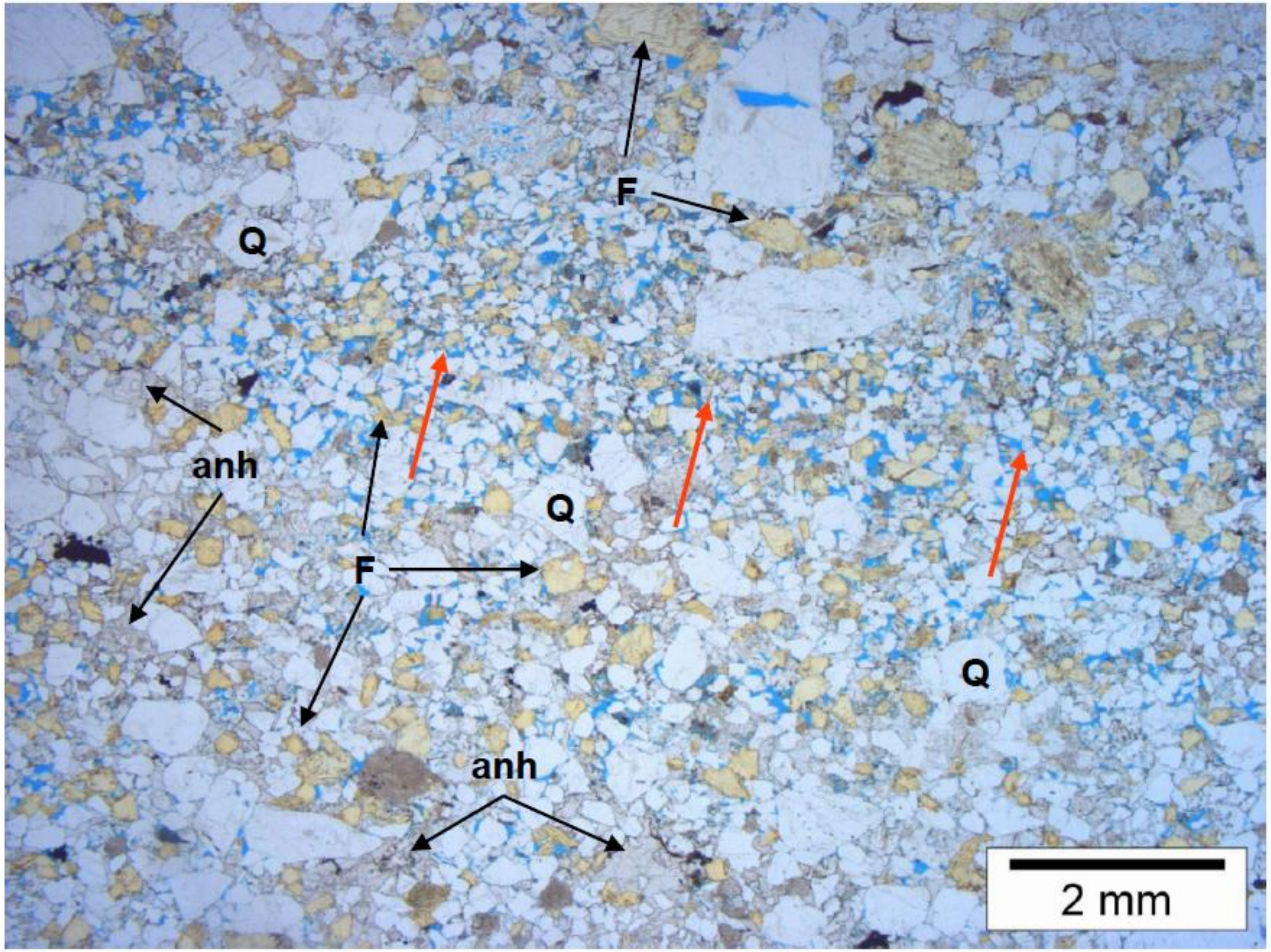
Q = Quartz; F = Feldspar

Depositional Environments and Genetic Units from Logs and Rock Facies

LEKOIL

Lagoon/Back Barrier Washover



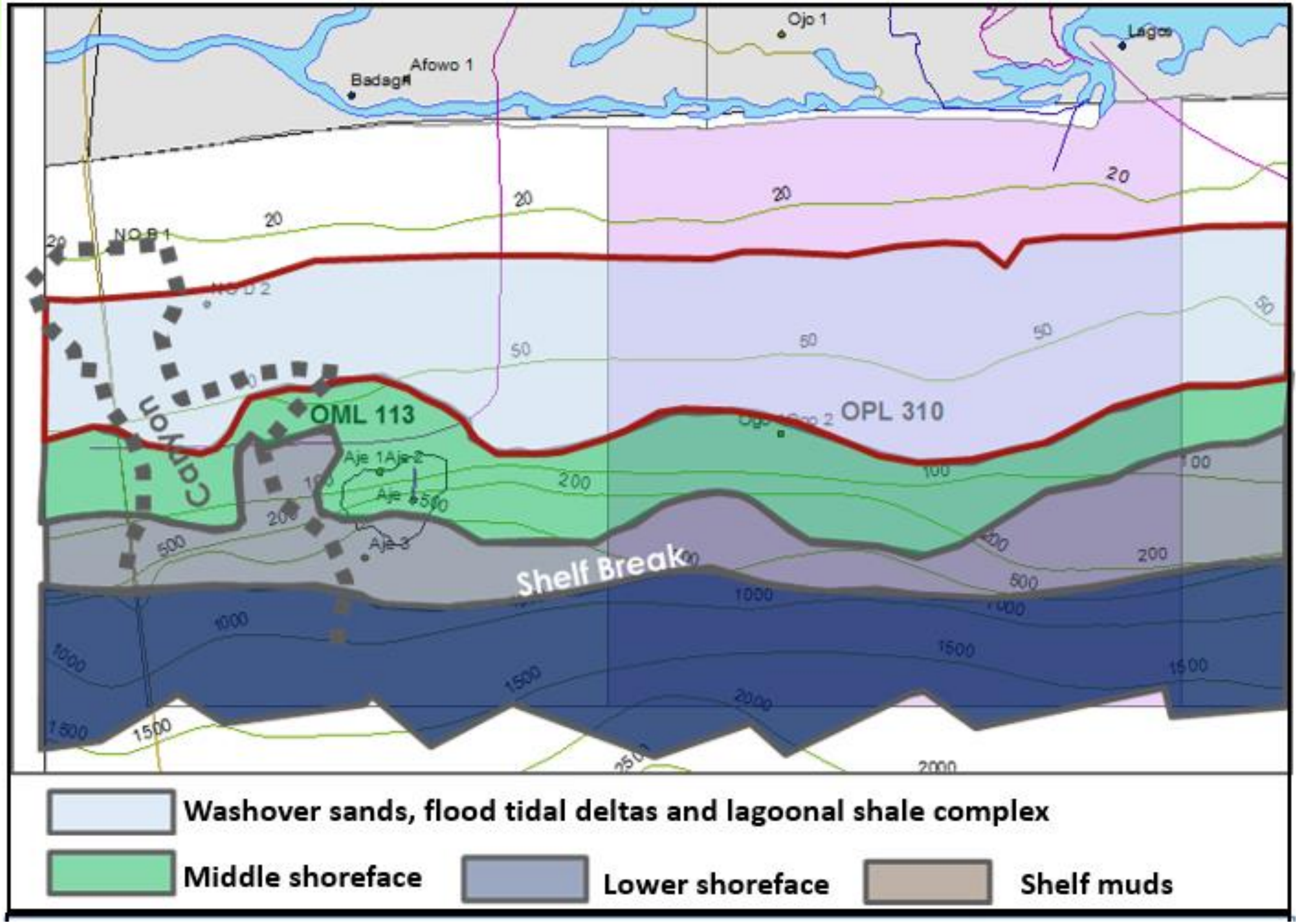


Q = Quartz; F = Feldspar; anh = anhydrite; red arrow = intergranular porosity

Depositional Environments Reconstruction and Facies Belts

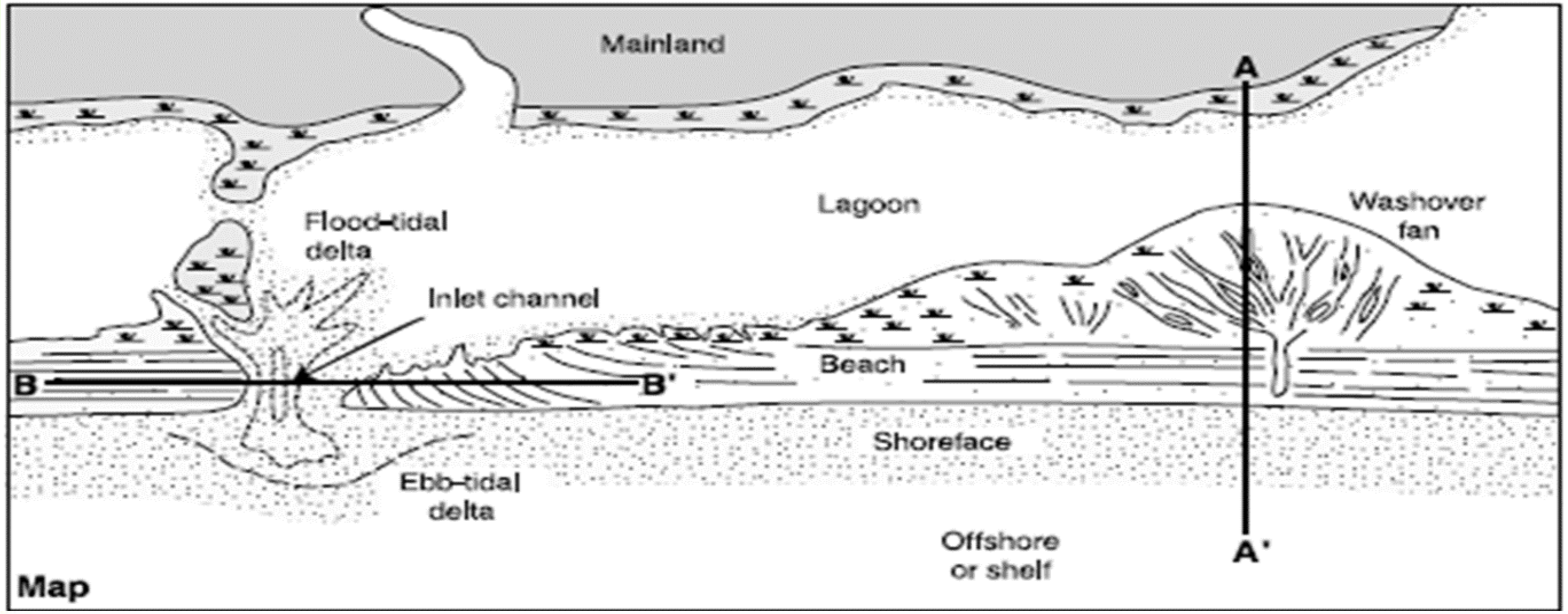
LEKOIL

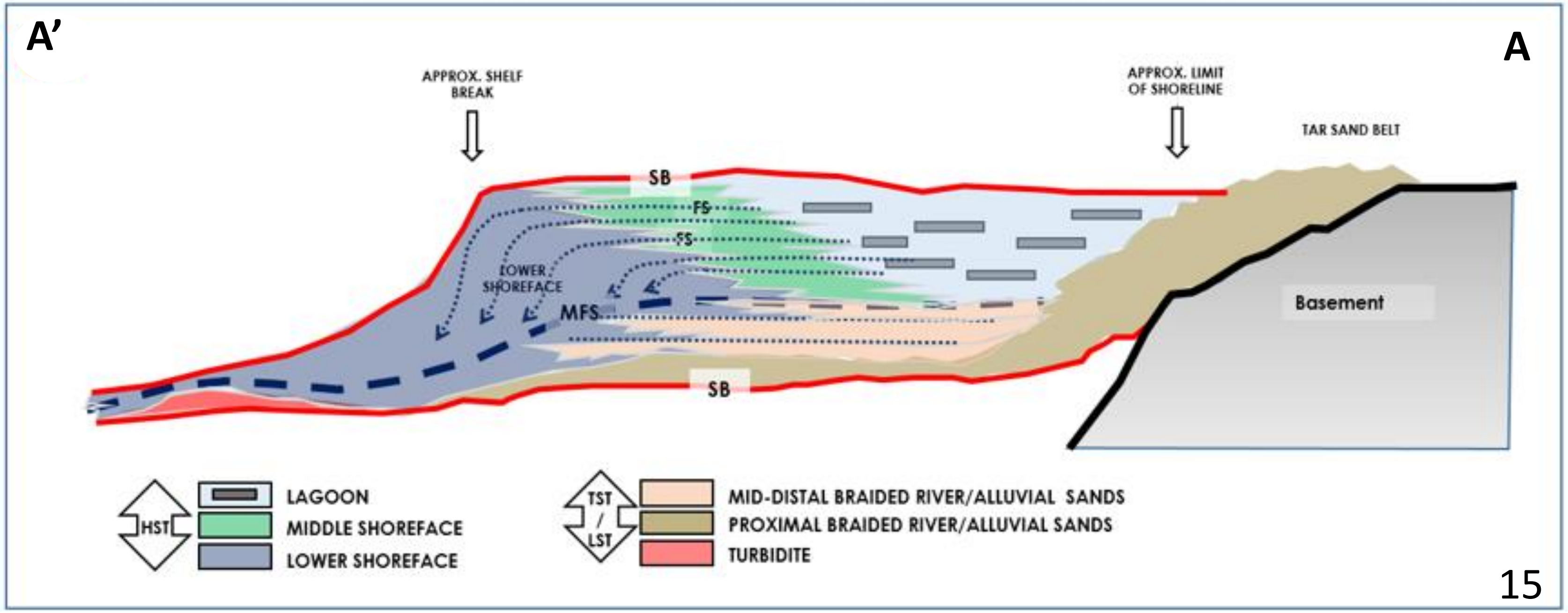
- **Coastal to shoreface**
  - Back barrier
  - Washover sands
  - Lagoons
  - Tidal deltas
  - Mouth bar
  - Braidplain and braid bars
- **E – W Palaeo-shoreline**
- **Controls on DE and RQ**
  - Sea level variations
  - Distance from
  - palaeo-shoreline



Depositional Analogue and Architecture of Genetic Units

- **Facies belts are parallel to paleo-shoreline**
- **Facies Associations and Genetic Units reflects position and distance from the paleo-shoreline**
- **Reservoir quality changes basin ward of the shoreline i.e. increase authigenic carbonate cements**





Depo. Environment from Biostratigraphic Data

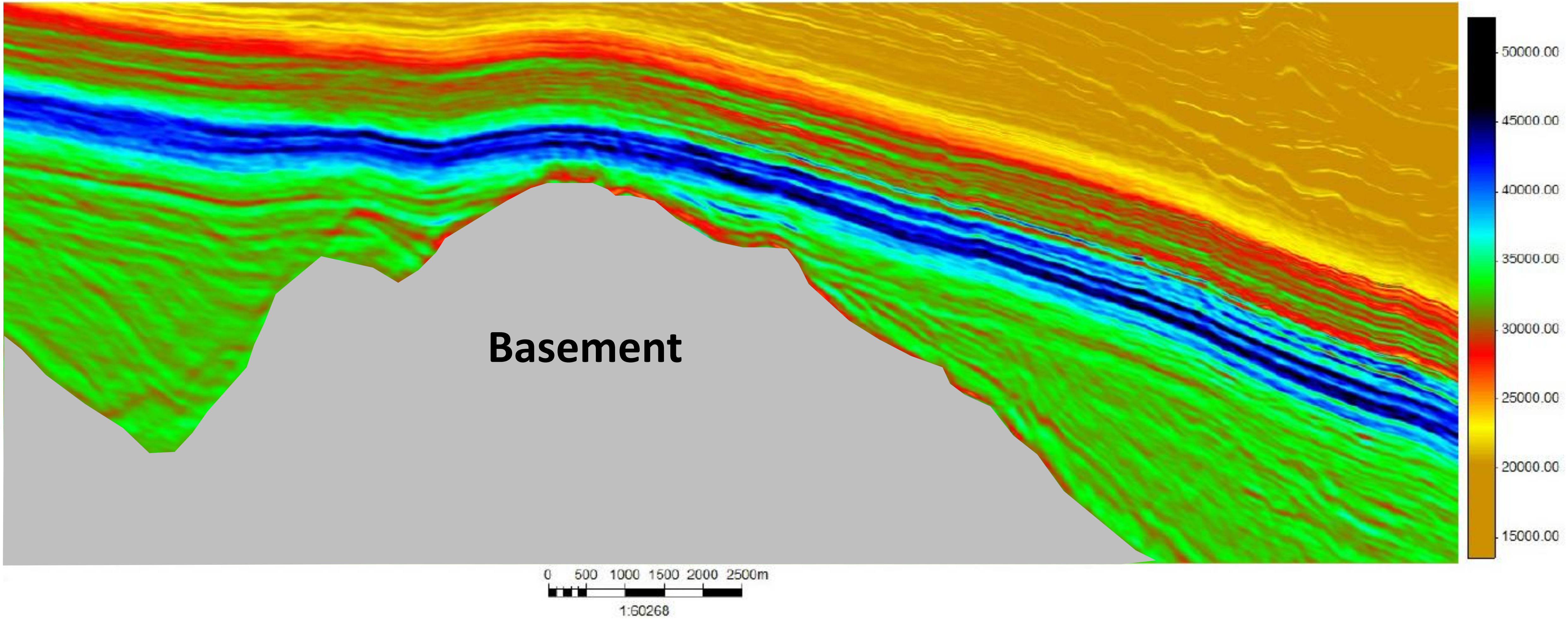
- 453 ditch cutting samples taken **between 1,620 and 10,678 ft** at 20ft interval

- Interval 7,640 – 7,920ft recorded ***Haplophragmoides sp***., ***Eponides africana***, ***Calcareous indeterminate*** and rare planktic species. Calcareous Nannofossils is generally barren within this interval. This suggests deposition in **Inner Neritic setting**.

- Intervals 8,020-8,880ft recorded ***Haplophragmoides sp***., ***Trochammina sp Eponides africana*** and ***Arenaceous indeterminate***. This suggests deposition in a predominantly **Coastal Deltaic** with occasional deepening to shallow **Inner Neritic setting**.

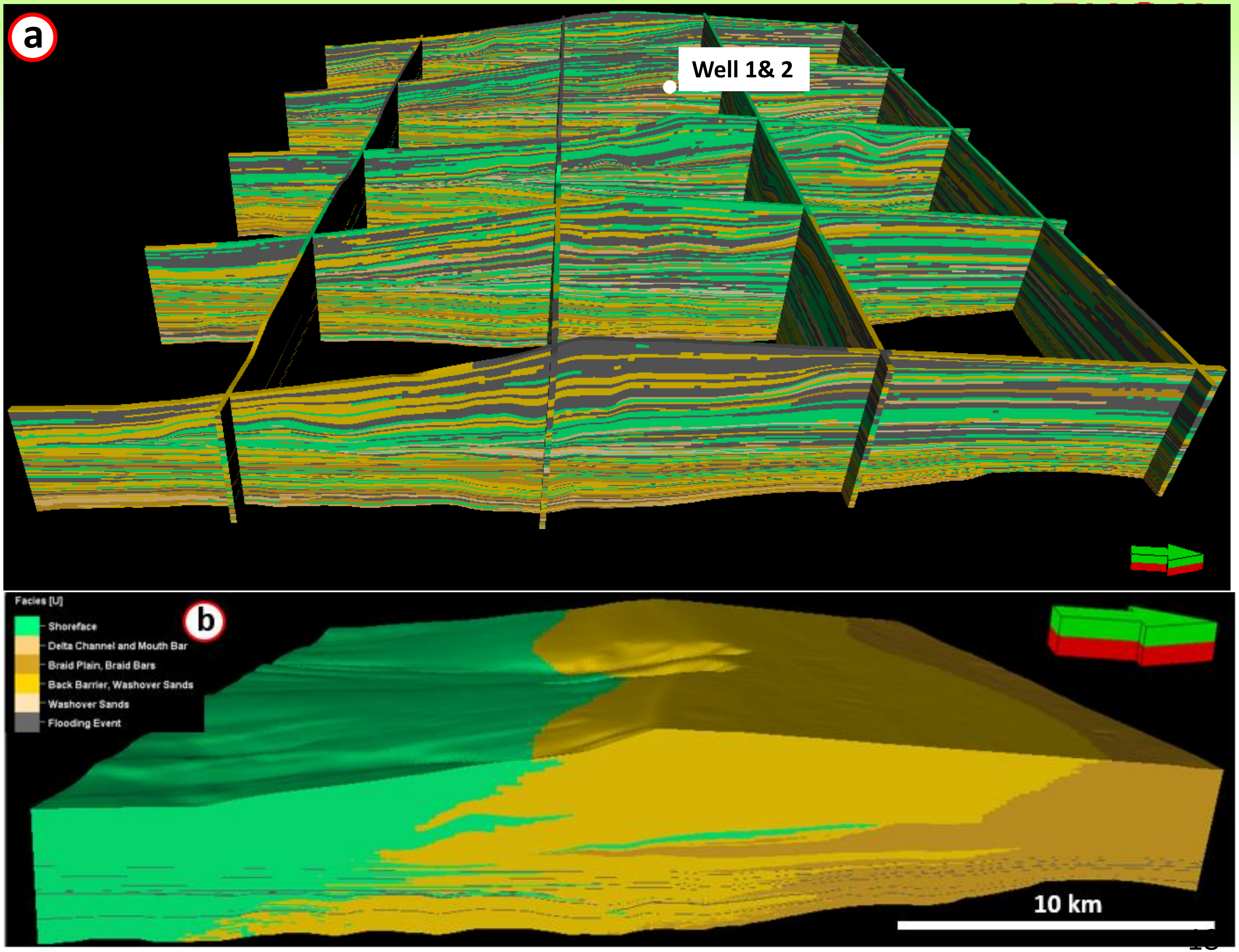
3D Reservoir Architecture and Gross Rock Property Characterization

- Low acoustic impedance (AI) indicates high porosity
- Low porosity most likely indicates either tight sand or shale



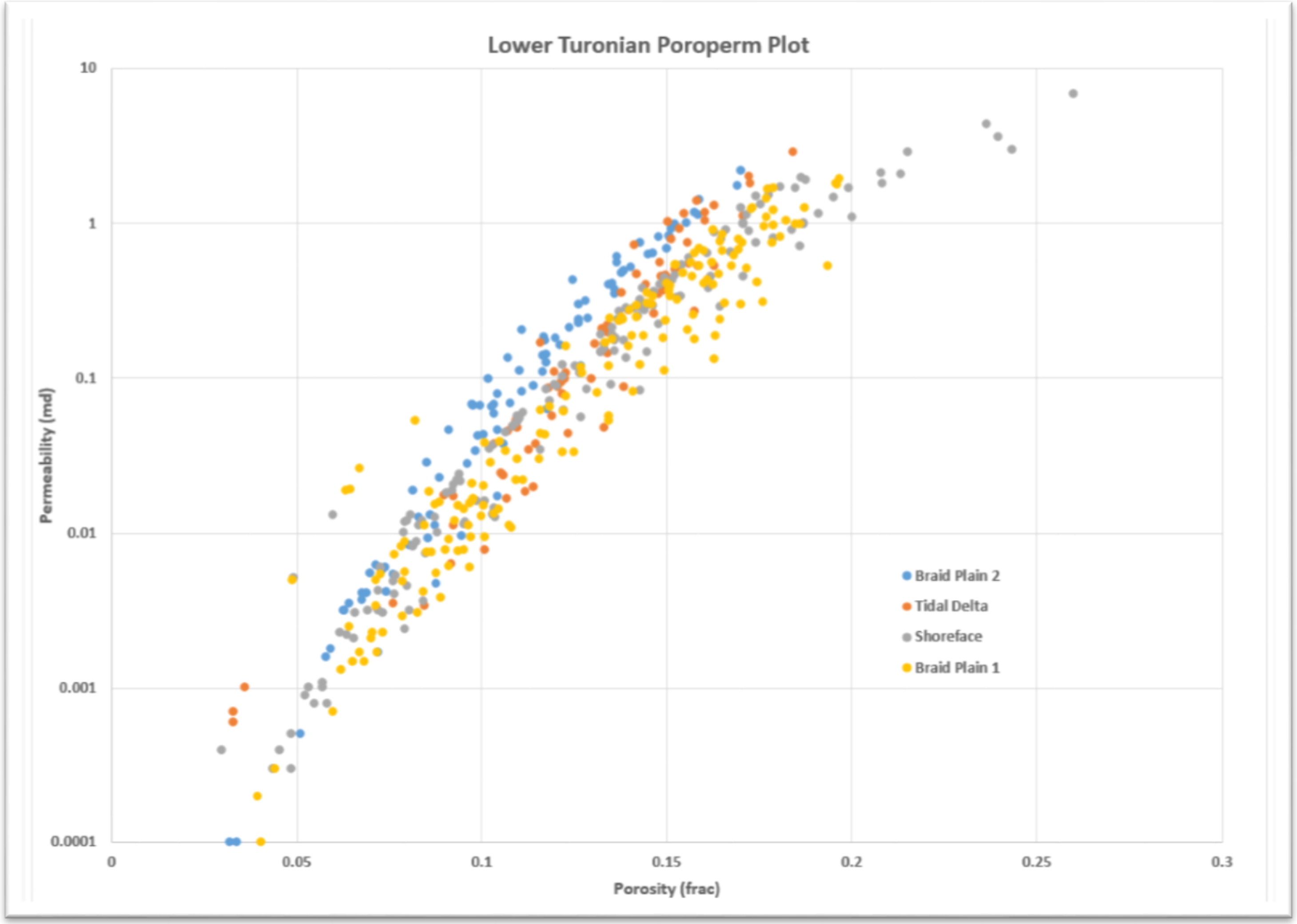
3D Reconstruction of Stratigraphic Architectures (Static Modelling)

- Key surfaces of 2nd and 3rd Order Sequences integrated with seismic horizons, and GU to generate facies models
- (a) honours facies proportions along wells; (b) accounts for facies transitions



Reservoir Property Characterization of Flow Units

- **Flow units defined between successive flooding events**
- **However cross-plot of Poroperm data may be used to subdivide reservoir sands, i.e. individual GUs)**
  - Possible implications for higher order heterogeneities (sandbody connectivity and baffles) and simulation
- **Petrophysical character of Gus are distinct from the X-Plot**
- **Braid Plain 1 and 2 flow units correspond to distinct levels in the stratigraphic succession**



Conclusion

LEKOIL

- **Sequence Stratigraphic Interpretation and hierarchical subdivision and regional correlation of the Upper Cretaceous in the Dahomey Basin**
- **Interpretation of the genetic Units and depositional environments of the Upper Cretaceous**
- **Nine 4th Oder cycles recognised separated by distinct and widespread marine flooding events and SBs**
- **Improved understanding on the primary controls Reservoir Quality**
  - Sea level cycles
  - Distance from palaeo-shoreline
- **3D framework of reservoir flow units have been defined, to serve as basis for rock property distribution and upscaling**

Acknowledgement

LEKOIL

OPTIMUM PETROLEUM

NIGERIAN ASSOCIATION OF PETROLEUM EXPLORATIONISTS

SINCE 1975