Geological Context - The Missing Element in the Interpretation Domain

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'It is our experience that the use of bench-marks, placed in a strong geologic context with specific examples, has been effective at stretching technical teams to consider alternatives and thereby develop a more objective characterization that leads to better business decisions and results.'

(Rudolph & Goulding, 2017, AAPG Bull.)
Set up

- **The Challenges and the Vision**
  - Segmented workspace and inadequate workflows
  - Geological age and stratigraphic organisation

- **Context examples for Cretaceous petroleum systems**
  - Large, global lithological and reservoir trends
  - Cretaceous sea level – a new synthesis
  - Linking exploration & production scales

- **Conclusions**

**Acknowledgements:** Dave Ray, Gareth Carroll, Andy Davies, Benjamin Greselle, Owen Sutcliffe, Mike Simmons
Challenges

- The End2End life cycle is segmented (tools, departments, disciplines, models)
- Consequences: loss of data access, time, insights, ‘old’ models, wrong analogs
Challenges

- Petroleum geological data interpretation deals with big variations in:
  - Scale (plug – seismic)
  - Density of information

  - Impact on:
    - Consistency
    - Accuracy
    - Bias
    - Risk evaluation
Hierarchical organisation of stratigraphic record

Predictive Stratigraphic Architecture

- Link between Exploration and and Production scales
- Improved prediction of petroleum system elements
- Improved prediction of reservoir characteristics
Geological age

- Geological age is the single most important factor to enable prediction, bring in context, and identify analogs
- Facilitate the access and visualisation of geological age in the interpretation domain (well log correlations, seismic)
- Make this process more efficient by applying machine learning techniques (Assisted Biostratigraphic Interpretation)

- Neftex global sequence stratigraphic time framework
Vision

- Provide readily accessible geological context for End2End interpretation workflow
  - Geological age as the enabler
  - Common, shared and labelled data
  - Create opportunities for Machine Learning and Data science
  - Game changer for new generation of interpreters

- Breakdown of artificial boundaries (e.g. exploration and production)
  - More effective use of data and insights, improved corporate communication

- Guide for software and database developments
Examples of geological context for cretaceous petroleum systems

- Global lithological trends

- Sea level and climatic control (foundation research)

- Global sequence stratigraphic patterns
Mesozoic lithological trends

- Neftex® Insights Database
- Globally applied sequence stratigraphic model
- Interrogation at 3rd order sequence level of geology and petroleum system elements

*1st order context*
Mesozoic lithological trends and reservoir distribution

- Neftex® Insights Database
- Globally applied sequence stratigraphic model
- Interrogation at 3rd order sequence level of geology and petroleum system elements

1st order context

- Transgression of new shelf areas
  - Expansion of carbonates
  - Peaks of clastics
- Pangea breakup
- Pangea supercontinent

Clastic vs. Carbonate Fields

Data base N= 8500
Cretaceous lithological trends

Lithological, Biotic & Oceanographic Events

2nd order context
Cretaceous lithological trends and reservoir distribution

Lithological, Biotic & Oceanographic Events

- **Abundant Chalk**
- **Anoxic Events**
- **Biotic Events**

Clastic vs. Carbonate Fields

2nd order context

- **Late Cretaceous**
  - Carbonate dominated
  - Higher order fluctuations
  - More variation in field trend

- **Early Cretaceous**
  - Clastic dominated
  - 2nd order fluctuations
  - Synchronous with field trend
Cretaceous eustatic sea-level curves compared

- remarkable difference in amplitude and frequency

<table>
<thead>
<tr>
<th>Maastrichtian</th>
<th>Campanian</th>
<th>Santonian</th>
<th>Coniacian</th>
<th>Turonian</th>
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<th>Albian</th>
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Haq 2014 - Global (minimal documentation)
Miller et al. 2004 - New Jersey Coastal Plain
Sahagian et al. 1996 - Russian Platform
Impact of sea level fluctuations on stratigraphic architecture

- Knowledge of amplitude and frequency of sea-level change is essential for correct prediction at exploration and production scales.

- Sea-level fluctuations

- Stratigraphic architecture

- Chronostratigraphy
Establishing realistic magnitudes – a literature survey

160 publications screened of which 37 represent unique and suitably detailed records:
- 800+ individual estimates of absolute sea-level rise and fall
- Focus on short-term change (<3 Ma) to exclude local tectonics

(in Ray et al., 2019)
Data evaluation – trends in amplitude variation

Max. amplitude range

Screening of database
- Geological screening
- Geostatistical analysis

Significant variations
- Max. amplitude 5 to >65m
- Stage level bins

4 Main trends
- Berriasian - Valanginian
- Hauterivian - Aptian
- Albian – Coniacian
- Santonian - Maastrichtian
Climate change

• Climate as a driver of sea level amplitude variations

• Impact on prediction of distribution and nature of reservoirs

• Geological context!

(Ray et al., 2019)
Climatic change

- Climate as a driver of sea level amplitude variations
- Impact on prediction of distribution and nature of reservoirs
- Geological context!

(Ray et al., 2019)
Cenomanian global sequence time framework

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<tr>
<th>Stages</th>
<th>Ammonites</th>
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- Globally age calibrated stratigraphic surfaces
- Insight in amplitude and frequency of sea-level fluctuations

Late Cenomanian Paleogeography and case study locations
Cenomanian carbonate reservoirs of the Arabian Plate

Regional seismic lines
intra-shelf basin morphology

Log, core and outcrop controlled facies model
- organic-rich intrashelf basins (SR)
- grainy, rudistic margins (reservoir)

2D & 3D outcrops displaying depositional geometries and stacking patterns

(e.g. Droste, 2010; van Buchem et al., 2002; Razin et al., 2010)
Cenomanian reference model

Stratigraphic architecture

- Predictable position petroleum system elements
- Importance of organic-rich intra-shelf basins

(van Buchem et al., 2011)

C-isotope reference curve and events

(K-120)

(K-130)

(K-140)

(K-150)

(ACBE)

(MCE)

(CTBE)

(Wohlwend et al., 2018)
Mid Cretaceous Seaway – US and Canada

Paleoceanography
- Connection of Mid Cretaceous Seaway re-established in Cenomanian

Prolific plays
- Eagle Ford ressource play
- Conventional clastic plays
  - Woodbine Gp. - East Texas
  - Tuscaloosa Fm. – Louisiana
  - Dunvegan Fm. – W. Canada

(Minisini et al., 2018)
Eagle Ford Group, W. Texas – carbonate/marl shelf

(Donovan et al., 2016)
Eagle Ford – paleoceanography

- Oceanographic control of depositional conditions
- Causing major facies changes

(Oldrett et al., 2015, 2017; Minisini et al., 2018)
Oceanographic control of depositional conditions
• Subtle expression of sequence boundaries in distal shelf setting
• Offset from facies changes

(Eldrett et al., 2015, 2017; Minisini et al., 2018)
Woodbine Group, E. Texas – siliciclastic margin and reservoir

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**X-section Eastern Margin of East Texas Field**

- East Texas Field produces from Dexter Reservoir unit since 1930

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(Denne et al., 2016)
Woodbine Group, E. Texas – re-interpretation of siliciclastic margin

- East Texas field reinterpreted as Incised Valley Complex – consistent with global pattern (K-130)!
- Significant implications for facies/reservoir relationships, well planning and in-place volumes
Chronostratigraphic scheme Texas- Louisiana Shelf

- Geological context helps to identify the main controlling factors
Cenomanian stratigraphic patterns – context at the global scale

- The local variation on the global theme
- Concepts and analogs
- Link between exploration and production scales
- Improved prediction of reservoir, seal and source rocks

• Context at the global scale – concepts and analogs
Workflow in 3 steps:

- Geological interpretation
- Conceptional model
  * in time and space
  * iterative, multi-proxy
  * integration
- Petroleum geological interpretation & models
  * for economic decision making
GEOLOGICAL CONTEXT

- Geological time
- Paleogeography
- Gross Depositional Environ.
- Sequence stacking patterns
- Local vs Global controls

- Promotes integrated work
- Improves corporate knowledge capture and communication
- Breaks down silos

STRATIGRAPHIC WORKSPACE

1. Geological interpretation tools
   - Seismic
   - Attribute analysis
   - Seismic geomorphology
   - Synthetic seismic space
   - Wells
   - Stratigraphy
   - Lithology & facies

2. Conceptual geological model
   - Depth and Time windows
   - Multi-proxy, iterative, integration process

3. Petroleum geological analysis
   - Drilling model
   - Rock mechanical model
   - Reservoir model
   - Exploration model
   - Basin model
   - Economic decisions

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