Improved Flow Zone Definition of the Scott Field Reservoir using a Quantitative Electrofacies Approach
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• Large oilfield discovered in 1983
• Structurally complex field with several fault-bounded pressure compartments
• Two main reservoir units of Upper Jurassic age:
  • Piper Formation
  • Scott Member (Sgiath Formation)
• Field property ranges
  • N:G ~ 0.85 - 0.90
  • Average Ø ~ 10% - 20%
  • Permeability ~ up to 8D
Introduction – Controls on Reservoir Quality

**Sedimentary Facies**
- Excellent quality clean coarse sands
- Poor quality shaley sands

**Diagenesis**

**Tar Mat Presence**
- Tar Mat In Core
- No Tar Mat In Core

**Small Scale Faulting**

Large range of permeabilities for a given porosity, depending mainly on clay content, grain size and quartz cementation.
Scott Field (Block II) Modelling Approach

- Aim of modelling work: to identify areas of unproduced oil poorly accessed by current well-stock
- Single structural model selected dynamically from a large range of possibilities
- Variable geological inputs include
  - Fault seal capacity, Electrofacies vs FZI, Facies variogram ranges, Tar mat presence/absence and permeability modifiers, Free-water level
- Selection of geological models using quality of match to the dynamic for subsequent history matching.

Dynamic screening of realisations allows us to test the efficacy of facies modelling approaches.
Facies Analysis

- Sedimentary facies (Lithofacies)
  - Subjective characterisation based upon lithology and sedimentary structures
  - Core dependent – large amount of error in defining facies in uncored wells
  - Facies often described in terms of interpreted depositional processes
  - Diagenesis not usually incorporated into classification
  - Categories not usually optimised for flow unit definition (although there is usually some relationship)

Approach to Block II

- Trial analysis indicated the logged core lithofacies had a relatively poor match to wireline log values
- Unable to objectively populate facies throughout the geomodel
- High degree of scatter on PoroPerm plots for different lithofacies indicated reduced utility for populating Geomodel facies

DECIDED NOT TO APPLY SEDIMENTARY FACIES TO POPULATE GEOMODEL
Approach to Facies Definition for Geomodelling

- Facies Analysis
  - Flow Zone Indicators (FZI’s)
    - A theoretical method to define distinct rock types with similar fluid-flow characteristics
    - Should be related to rock texture, grain size, mineralogy, sedimentary structures and petrophysical properties
    - Based upon the relationship between porosity and permeability
    - FZI rock types classified using equations:
      - \( RQI = 0.0314 \times \sqrt{\frac{\text{Permeability}}{\text{Porosity}}} \)
      - \( FZI = \frac{RQI}{\text{NormPorosity}} \)
    - Relationships between FZI and wireline log data to predict FZI rock types in uncored wells

- Approach to Block II
  - Defined different FZI rock types using core analysis data
  - Log data showed few reliable predictive relationships with FZI rock types
  - Petrophysically derived porosity and permeability values used to classify FZI rock types in uncored wells

APPLIED FZI ROCK TYPING APPROACH TO POPULATE GEOMODEL
Approach to Facies Definition for Geomodelling

• Facies Analysis
  • Electrofacies
    • Facies description based upon measured log parameters
    • Objective classification using statistical, machine learning or artificial Intelligence
    • Core used to calibrate poroperm relationships
    • Can be used for wells without core
    • Categories are based upon physical and chemical rock characteristics and a strong link to reservoir properties is common

• Approach to Block II
  • Quantitative approach
  • Calibrated with data from 14 cored wells
  • Trial analysis indicated the identified electrofacies could be predicted from wireline log values
  • Provided a means to populate facies throughout the geomodel
  • Relatively tight scatter of core plug data on PoroPerm plots for different electrofacies indicated good utility for populating Geomodel facies

APPLIED ELECTROFACIES FACIES APPROACH TO POPULATE GEOMODEL
Electrofacies Definition in the Scott Field

- Cluster Analysis
  - Used heavily in biology, ecology, palaeontology, geochemistry and quantitative finance
  - Objectively groups samples based upon multiple measured parameters

- Discriminant Function Analysis
  - Used heavily in biology, ecology, palaeontology, geochemistry and quantitative finance
  - Objectively groups samples into pre-defined categories based upon multiple measured parameters

- Two techniques can be used together to objectively identify different rock types using **cluster analysis** (available core can be used to define poroperm characteristics) then applied to uncored wells using **discriminant function analysis**
Electrofacies Definition in the Scott Field

- Cluster Analysis – Used to define Electrofacies in cored wells

**Cluster analysis** is a data exploration (mining) tool for dividing a multivariate dataset into “natural” clusters (groups).

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Cluster Analysis can classify large numbers of samples with many variables.
Discriminant function analysis is a statistical analysis to predict a categorical dependent variable (called a grouping variable) by one or more continuous or binary independent variables (called predictor variables).

- Class A
- Class B

Discriminant Function Analysis can use many variables for classification
• **Discriminant function analysis** is a statistical analysis to predict a categorical dependent variable (called a grouping variable) by one or more continuous or binary independent variables (called predictor variables).

![Discriminant Function Analysis Diagram](image)

- **Class A**
- **Class B**
- **New unknown sample**

**Electrofacies Definition in the Scott Field**

Discriminant Function Analysis can use many variables for classification.
Electrofacies Definition in the Scott Field

• Workflow Summary

- Objectively identify electrofacies from wireline log data using Cluster Analysis on cored wells
- Ensure identified clusters have distinct poroperm and flow unit character
- Ensure identified clusters look geological
- Define discriminant functions using cored well training set
- Use discriminant functions to define facies in uncored wells from wireline log data
- Understand Geological Significance of Clusters
- Model Facies in Geomodel
- Truth Test with Quality of Dynamic Matches (Objective Functions)
Cluster Analysis Results – Electrofacies Groups

Predominantly Non-Net Electrofacies

Predominantly Net Electrofacies

Net Electrofacies Class Centroids

<table>
<thead>
<tr>
<th>CLASS</th>
<th>DENSITY</th>
<th>GAMMA</th>
<th>NEUTRON</th>
<th>SONIC</th>
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<tbody>
<tr>
<td>3</td>
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<td>19.266</td>
<td>0.052</td>
<td>60.326</td>
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</table>
**Electrofacies Definition in the Scott Field**

- Net Rock Electrofacies Porosity vs Permeability from Core

<table>
<thead>
<tr>
<th>Electrofacies</th>
<th>Porosity vs Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrofacies 3</td>
<td><img src="image1.png" alt="Image" /></td>
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<tr>
<td>Electrofacies 4</td>
<td><img src="image2.png" alt="Image" /></td>
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<tr>
<td>Electrofacies 8</td>
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<tr>
<td>Electrofacies 10</td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>Electrofacies 11</td>
<td><img src="image5.png" alt="Image" /></td>
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</tbody>
</table>

Tightened scatter than lithofacies

Can be identified with 86% success from log data

Can be populated through geomodel
Density of sample points suggest further cluster subdivision possible but would need to be geologically based.
Electrofacies Definition in the Scott Field

Lower permeability grouping is strongly stratigraphically constrained: **Highlighted points Lower Scott C**

Allows further refinement of poro-perm groups for modelling

- Electrofacies 3
- Electrofacies 4
- Electrofacies 8
- Electrofacies 10
- Electrofacies 11

Lower K population stratigraphically restricted
Electrofacies Definition in the Scott Field

Lower permeability grouping is strongly stratigraphically constrained: **Highlighted points Lower Scott C**

Allows further refinement of poroperm groups for modelling.
Electrofacies Definition in the Scott Field – Populated Geomodel

• Electrofacies distribution appears geological
• 15 of the 17 stochastic realisations taken to history matching were populated with Electrofacies rather than FZI rock indicating that they provided a better match to the subsurface ‘plumbing’
• Block II of the Scott Field has been stochastically modelled using variable Geological inputs
• Sedimentary facies were considered but not used in the Scott Block II model
• Both Flow Zone Indicators (FZI's) and Electrofacies have been used as alternatives for facies modelling
• Electrofacies have been defined using ‘Cluster Analysis’
• Core analysis data was used to define PoroPerm character
• Discriminant Function Analysis was trained using the Cluster Electrofacies groupings and applied to uncored wells
• An important stratigraphically constrained difference in PoroPerm character has been identified in the Lower Scott C reservoir zone significantly improving permeability prediction in this and the overlying reservoir zones
• 90% of the successfully screened model realisations were constructed using the Electrofacies approach
• High quality of dynamically screened realisations significantly reduced Reservoir Engineer patching