Field trial of ADR scanner for finding subsurface hydrocarbons ahead of drilling

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September 2019
Overview

- Adrok introduction
- Project purpose
- Methodology
- Results
- Conclusions
- Future development
Adrok introduction
Who are Adrok?

- Adrok develops and uses advanced technology to supply geophysical services for locating, identifying and mapping subsurface natural resources (oil, gas, water and minerals)
- We provide our clients with measurements of the subsurface natural resources, rock types and rock sequences before drilling
- We call our technology Atomic Dielectric Resonance (ADR)
- We call our services Predrilling Virtual Logging ®
- We call our product a Virtual Borehole
What is ADR?

- ADR is a breakthrough survey tool used to map resources in the subsurface.

- It increases the effectiveness of identifying, classifying and mapping.

- Uses advanced pulsed radar technology to map geological layers and resources of interest for energy, materials, water industries.

- ADR transmission is low power and detects the modulated reflections returned from the subsurface structures.

- To aid material classification, ADR measures:
  - dielectric permittivity of material
  - spectral content of the returns to help classify materials (energy, frequency, phase)

- Adrok owns the I.P for ADR data acquisition and processing.
How does it work?

- Adrok uses a finite volume method to predict the propagation of full waveform EM waves
- 1D and 2D simulators based on Maxwell’s equations coupled to a ground model
- Incorporates conductivity ($\sigma$), permittivity ($\varepsilon$), permeability ($\mu$), polarisation ($P$) and Debye relaxation time ($\tau$)
- Can be matched to experimental data captured in the field
- Attenuation determined by conductivities and Debye parameter
How does it work?

Adrok deduced the following skin depth measurements:

- blue curve shows conductivity based on in-situ ADR measurement through limestone
- remaining curves represent other conductivity values taken from literature
- Bottom curve perhaps reasonable guess from a geophysicist used to classical EM
- The spectral shape changes initially but is then steady beyond 50m
- ADR centre frequency for deep penetration indicated by dotted line (3MHz)
Project purpose
Develop ADR as a viable tool for UK onshore for directly identifying subsurface hydrocarbons from ground level that can be launched as a commercial survey service to UK onshore oil companies.

Aim

- raise Adrok’s Technology Readiness Level (TRL) to 7 for onshore UK oil and gas surveys

Objectives

- collect and analyse data from client sites:
  - Cuadrilla in Lancashire
  - Transgas in Weald Basin

- deliver direct hydrocarbon indicator

- deliver Adrok Virtual Borehole logs

- integrate Adrok’s measurements with the clients’ earth model
Methodology
Adrok Workflows

1. Pre-survey field modelling
2. On-site survey
3. Training for geological signatures
4. Data processing & interpretation
5. Analysis & results delivery
6. Integration to other data sets

Adrok aims to provide useful subsurface measurements to help de-risk drilling programmes... Thus enhancing recovery of hydrocarbons, minerals & water!
Typecasting rocks

Adrok use a laboratory based instrument to help aid their understanding of different rock types:

- irradiate rock samples with pulsed RF energy
- build database of rocks interaction with ADR signal
- use database to find similarities and differences in rock types
- apply findings to field data to help interpret rock composition
Data acquisition

Locations of Data Collection
Data collected at the Weald and Lancashire basins.

Cuadrilla

Transgas

United Kingdom

Google Earth

100 km

Cuadrilla

Transgas

Data acquisition

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Data collected at the Weald and Lancashire basins.

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Google Earth

100 km

Cuadrilla

Transgas
This method uses several sources of processed data to identify distinct lithological zones in the V-Bore.

The following slides will display the results of the zonation for the stare data based on:

- Correlation Method
- Maximum Minimum Method
- Rank Matching Results
- Direct Hydrocarbon Indicators

Along with the above, a table will accompany the completed zonation that contains the log response for each of the graphs above in every zone.
This method uses several sources of processed data to identify distinct lithological zones in the V-Bore.

The following slides will display the results of the zonation for the stare data based on:

- Correlation Method
- Maximum Minimum Method
- Rank Matching Results
- Direct Hydrocarbon Indicators

Along with the above, a table will accompany the completed zonation that contains the log response for each of the graphs above in every zone.
Results:

Virtual boreholes

2D profiles

1. Cuadrilla

2. TransGas
Training Observations:

- Pendle Grit (carbonates and shale) shows large response in correlation 5-10MHz (Unit 7 ~6750ft).

- MaxMin Lines pick up the boundary between the upper and lower Bowland Shale (Unit 8 & 9 ~7250ft).

- Several large responses in correlation 5-10MHz within Hodder Mudstone; which could be due presence of hydrocarbons (Unit 11 ~9500ft).
Training Observations:

- Upper shale shows low saturation in Max Min Boxes and the presence of One Max Min lines (Unit 4 ~4250ft)

- Several large responses in correlation 5-10MHz within Bowland Shales (Unit 10 & 11 ~ 9500ft)

- MaxMin Lines pick up the boundary between the upper and lower Bowland Shale; which could be due presence of hydrocarbons (Unit10/11 ~ 10000ft)
Elswick

Blind test interpretation:

- Large response in correlation 5-10MHz similar to Pendle Grit (Carbonates and Shale) (~6500ft)
- MaxMin Lines pick up the boundary between the upper AND lower Bowland Shale (~9000ft)
- Several large responses in correlation 5-10MHz a single MaxMin Line similar to Hodder Limestone (~10250ft).
Repeatability: Becconsall

- The radial graph is fed by the table across, and offers insight into which parameter is best overall, as well as which parameters excel at picking up specific lithologies.

- Most lithologies show high identifiability across at least two sites for each of the parameters. 
  - *In the graph it can be seen that there is quite a lot of overlap around 2.*
  - MaxMin boxes is the overall best parameter, scoring the overall highest. 
  - *In the graph it can be seen because it covers the most area.*
  - The Sabden Shale and Pendle Grit are best identified by the Correlation Method 
  - *In the graph it can be seen because it spikes up towards it.*

<table>
<thead>
<tr>
<th>Lithology (Lancashire)</th>
<th>Correlation Method</th>
<th>Rank Matching</th>
<th>MaxMine Lines</th>
<th>MaxMin Boxes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sherwood Sandst.</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Manchester Marl</td>
<td>2</td>
<td>2</td>
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<td>3</td>
</tr>
<tr>
<td>Collyhurst Sandst.</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sabden Shale</td>
<td>3</td>
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<td>3</td>
</tr>
<tr>
<td>Pendle Grit</td>
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<tr>
<td>U. Bowland Shale</td>
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<tr>
<td>L. Bowland Shale</td>
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<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

ADR technology is able to identify lithologies in the subsurface in a repeatable manner using virtual boreholes.

MaxMin boxes appears to be the best lithology discriminator.
The four stares (Becc-100m to Becc400m) (first figure to the right) interpreted at the Becconsall site offer a great opportunity to investigate the repeatability of the ADR Zones and their consistency in laterally tracking similar features.
### Validation: Becconsall

#### ADR: Becc-100m

<table>
<thead>
<tr>
<th>System</th>
<th>Major Stratigraphic units</th>
<th>Lithostratigraphy</th>
<th>Driller top from ground in ft.</th>
<th>ADR Zone</th>
<th>ADR Zone top in ft.</th>
<th>Difference in ft.</th>
<th>Difference in %</th>
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</thead>
<tbody>
<tr>
<td><strong>Triassic</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Sherwood Sandstone</td>
<td>Mercia Mudstone</td>
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<td>0</td>
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<tr>
<td>Sherwood Sandstone</td>
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<td>1265</td>
<td>2</td>
<td>1265</td>
<td>806</td>
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<td>Kinnerton Sandstone</td>
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<td>3265</td>
<td>3476</td>
<td>211</td>
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<td><strong>Permian</strong></td>
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<td>4</td>
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<td>5312</td>
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<td>Sabden Shale Group</td>
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<td>7</td>
<td>6420</td>
<td>6783</td>
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<td>8</td>
<td>7005</td>
<td>7434</td>
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<tr>
<td>Worston Shale Group</td>
<td>Hodderense Limestone</td>
<td>7827</td>
<td>10</td>
<td>7827</td>
<td>8191</td>
<td>365</td>
<td>4.6</td>
</tr>
<tr>
<td>Hodder Mudstone</td>
<td></td>
<td>7846</td>
<td>11, 12, 13</td>
<td>7846</td>
<td>8421</td>
<td>574</td>
<td>7.2</td>
</tr>
</tbody>
</table>

**Legend:**
- Clay
- Sands
- Limestone/chalk
- Grey Clay
- Anhydrite
- Oil
- Silt
- Pyrite
- Coal

### Diagram Details:
- **ADR Becc-100m**
- **Becc - 1z Petrophysics**
- **ADR: Becc-100m**

### Notes:
- The table presents the stratigraphic units, their lithostratigraphy, and the differences in driller top from ground and ADR zone.
- The diagram illustrates the depth of each stratigraphic unit with color-coded layers indicating different rock types.
Training Observations:

- **Correlation Method**: large peaks in 5-10MHz found in the sandstones while the larger 1-5MHz peaks occur in the silts and chalk. The smallest peaks occur in the clays.

- **Rank Matching**: shifts to the left occur in the presence of the corresponding units. For example, a shift to the left in the total sandstones occur in both the Sherwood and Bridport Sandstone. In the presence of siltstones shifts to the left occur in both total clays and total sandstones.

- **Frequency and Energy harmonics**: lowest saturation across all three boxes is found in the chalk and clays. Sandstones correspond to some high saturation and these correlate with the largest peaks in 5-10MHz correlation. Carbonates and clays generally do not correspond to three lines. Sandstones and siltstones usually correspond to three lines throughout.

- **Dielectric Constant (Permittivity)**: DHIs occur in many different lithologies apart from the salt beds. Siltstones and sandstones see the presence of most DHIs clays and carbonates seen.
**Interpretation Conclusions:**

- **Correlation Method.** Presence of peaks in the 5-10MHz is used to identify the presence of sands. Larger peaks in 1-5MHz again are used to identify chalks/carbonates.

- **Rank Matching.** Chalk in the top 480m can be clearly identified by a shift to the left in the total carbonates. The Bridport Sandstone at ~1070m can also be identified by the rank matching as can the Sherwood Sandstone at approximately 1800m.

- **Frequency and Energy harmonics.** Unlike Creech three lines are common throughout the dataset. However, there are gaps where three lines do not occur and these could correspond to carbonates and clays based on the interpretation of the other parameters. Similarly, there is greater saturation in both the Max Summary and Total Summary Boxes than in Creech. However, areas of low saturation could still correlate with the sandstones. Low to moderate saturation is used to identify the siltstone and clays for example at 450-620m.

- **Dielectric Constant (Permittivity).** DHI's occur in many different lithologies apart from the salt beds. Siltstones and sandstones see the presence of most DHI's. DHI's are rare where the lithology has been identified as either clay or carbonates.

The interpretations confirm the presence of multiple sandstone layers and Adrok’s interpretation identifies both the Bridport Sandstone (Unit 8) and the Sherwood Sandstones (Unit 15) at Puddletown.
Broadstone

Interpretation Conclusions:

- **Correlation Method:** large peaks in 5-10MHz found in the sandstones while the larger 1-5MHz peaks occur in the silts and chalk. The smallest peaks occur in the clays.

- **Rank Matching:** shifts to the left occur in the presence of the corresponding units. For example, a shift to the left in the total sandstones occur in both the Sherwood and Bridport Sandstone. In the presence of siltstones, shifts to the left occur in both total clays and total sandstones.

- **Frequency and Energy harmonics:** lowest saturation across all three boxes is found in the chalk and clays. Sandstones correspond to some high saturation and these correlate with the largest peaks in 5-10MHz correlation. Sandstones and siltstones usually correspond to three lines throughout.

- **Dielectric Constant (Permittivity):** DHIs occur in many different lithologies apart from the salt beds. Siltstones and sandstones see the presence of most DHIs.

The interpretations confirm the presence of multiple sandstone layers and Adrok’s interpretation identifies both the Bridport Sandstone (Unit 6) and the Sherwood Sandstones (Unit 12/13) at Broadstone.
The radial graph is fed by the table below, and offers insight into which parameter is better overall, as well as which parameters excel at picking up specific lithologies.

Chalk is the lithology most identifiable by Adrok, with consistent characteristics across the three sites for each of the parameters. This can be seen when the 4 parameters are at their highest.

Correlation Method is the overall best parameter, scoring the highest. This is shown by the largest area covered in the graph.

Bridport Sandstone is best identified by the MaxMin Method. This can be seen by the spike up towards it in the graph.

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Correlation Method</th>
<th>Rank Matching</th>
<th>MaxMin Lines</th>
<th>MaxMin Boxes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sherwood Sandst.</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Chalk</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Bridport Sandst.</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Gault Clay</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Salfierous Beds</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Lower Greensand</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Ayelsbare Muds</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Sherwood Reservoir</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Ranking of the consistency of the parameters, amongst the 4 parameters. For each parameter, the amount of Sites with the same behaviour is counted.
1) Each site has different behaviour. 2) Two sites share behaviour. 3) All sites share the same behaviour.
To carry out the validation first Adrok translates the ADR Zones to relevant formations for Transgas.

- **Keuper and Lower Lias** are well delimited and exceptionally accurate.
- Greensands, Gault Clay and Mercia Mudstone are not as accurate. Differences in absolute meters and in % are largest.

Overall, thicknesses and depths are highly consistent between ADR Zones and the lithostratigraphic units.
Transgas Limited is very positive about Adrok technology. At ‘Target 1’, a conventional Oil target, the Atomic Dielectric Resonance (ADR) testing results led clearly to work Transgas Limited has carried out in conjunction with the Shell Geoscience Laboratory at Oxford University. Please see attached PDF. Adrok indicating the top of Target 1 at approximately 1040m, this is the same level as the contour depth of the 2019 reprocessed and reinterpreted seismic.

This work has given our company enough confidence to carry out further testing work on other Targets in other areas. It is helping us achieve our goal of eliminating the requirement for exploration wells and moving directly from ADR testing combined with seismic to production wells. Very substantial amounts of time and money are often spent drilling expensive exploration wells that are plugged and abandoned.

The advantages that Transgas Limited has identified by using ADR technology as an alternative to actual drilling i.e. creating a virtual well are:

- It requires only one day on site carrying out the test
- It requires no ground disturbance
- It produces no traffic problems
- It is silent in operation
- It is very low profile so no upsetting the local population
- It is not restricted by nearby housing
- It does not require a drilling rig
- It does not require planning permission
- It does not require environmental permits
- It has no environmental impact
- It creates no groundwater contamination problems

**Target 1 - Adrok Virtual Borehole**

**Correlation from a Standard Deviation**

**Rank Matching from Main Rock Types**

**Indication of Hydrocarbons**

**Adrok Interpretation of Rock Type and presence of Hydrocarbons**

The depth of the top of Target 1 in Adrok Virtual Borehole is the same as the contour depth from 2019 Reprocessed and Reinterpreted Seismic – approximately 1040m below surface.
Conclusions
## Conclusions

### Lithology
- Used ADR zonation method to interpret lithology from training sites and apply to blind test sites.
- High frequency correlation logs show consistent peaks in the hydrocarbon bearing shale units.
- Converted 1D measurements into 2D profile at Becconsall.
- Identified two reservoir sandstones (Bridgeport and Sherwood) across all 3 Transgas sites.

### Repeatability
- Repeatably sequence and identify distinct lithological units in the subsurface using Vbores.
- Converted 1D measurements into 2D profile at Becconsall.
- This is proven by the observation of consistent features across sections or by scanning the same site with several V-Bores.

### Validation
- Identify geological units and prognose their thicknesses and depths with accuracies between 0.3% (i.e. the Bridport Sandstone) and 9.2% (i.e. Lower Greensand).
- Provide precise depth indications for key horizon markers such as the Corallian or the Inferior Oolite.
- This is proven by quantitative comparisons between the blind sites collected by Adrok and the data made available after the interpretation.
What next?

- Marketing of results to onshore UK oil and gas operators
- Present results at UK technical conferences (e.g., Finding Petroleum, PETEX, DEVEX)
- Publication in a peer-reviewed journal
- Continue working with OGTC and partners to develop ADR onshore & offshore potential
Field trial of ADR scanner for finding subsurface hydrocarbons ahead of drilling

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September 2019