Adrok Field Trial with OGTC

Introduction

Michael Robinson

CTO ADROK

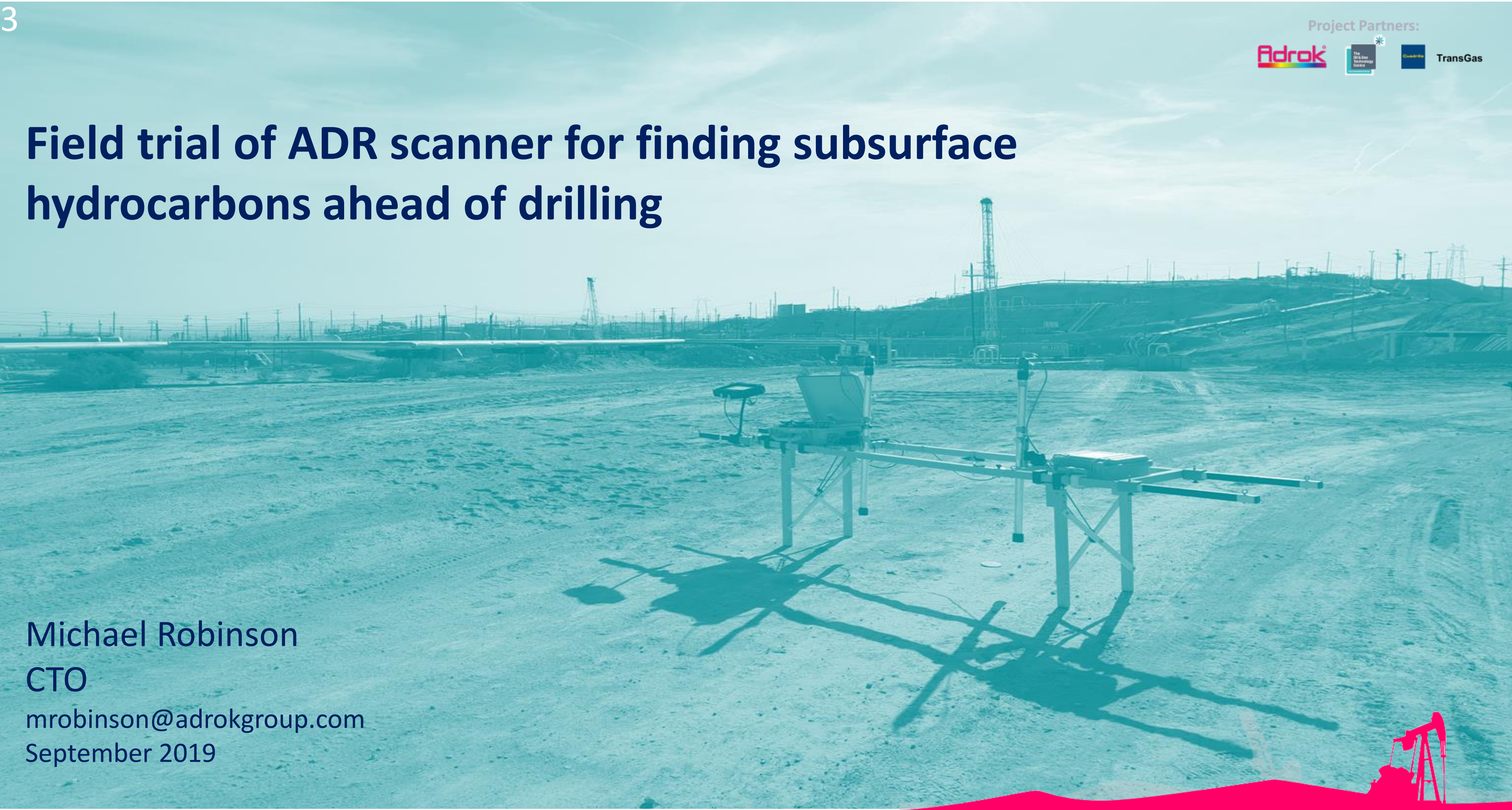
ADR scanner field trial

Adrok Group

Project Partners:

Adrok TransGas

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



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September 2019

Overview

Project Partners:

TransGas

- Adrok introduction
- Project purpose
- Methodology
- Results
- Conclusions
- Future development

Adrok introduction

Who are Adrok?

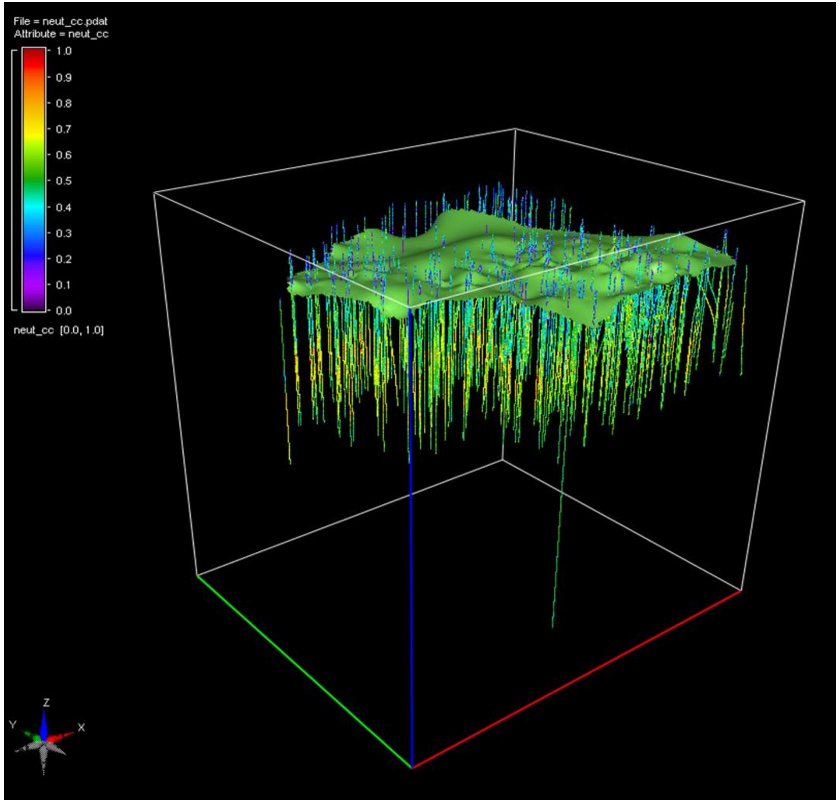
- Adrok develops and uses advanced technology to supply geophysical services for locating, identifying and mapping subsurface natural resources (oil, gas, water and minerals)

- 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*



3-d layout of Adrok's virtual boreholes

What is ADR?

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

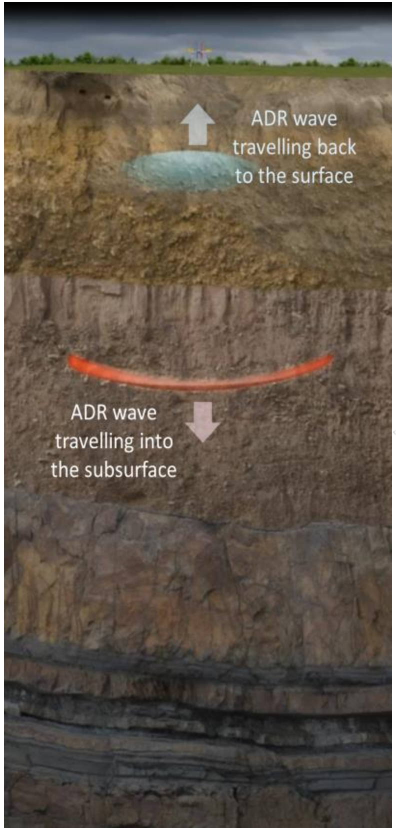
- It increases the effectiveness of identifying, classifying and mapping

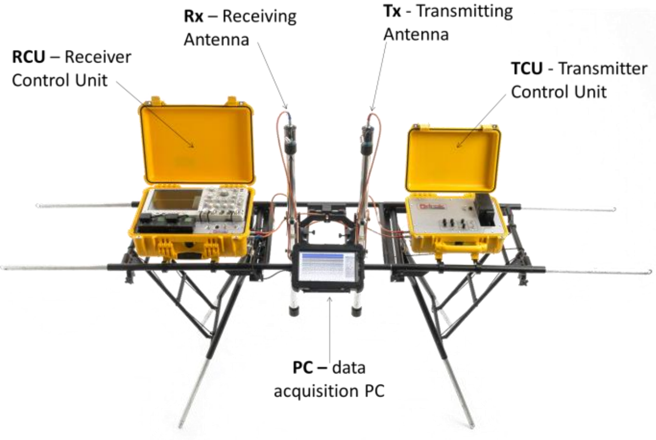
- Uses advanced pulsed radar technology to map geological layers and resources of interest for energy, materials, water industries

- 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





Adrok field scanner

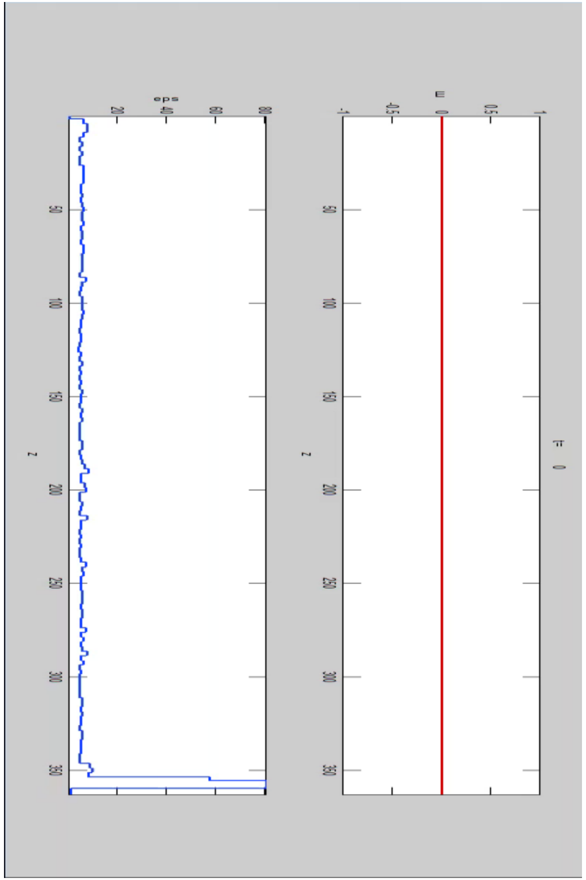
How does it work?

$$\epsilon_0 \frac{\partial^2 E(t,x)}{\partial t^2} + \sigma(x)\frac{\partial E(t,x)}{\partial t} + \frac{\partial^2 P(t,x)}{\partial t^2} - \frac{1}{\mu_0}\frac{\partial^2 E(t,x)}{\partial x^2} = 0, \quad (1)$$

$$\tau(x)\frac{\partial P(t,x)}{\partial t} + P(t,x) = \epsilon_0(\epsilon_r(x) - 1))E(t,x). \quad (2)$$

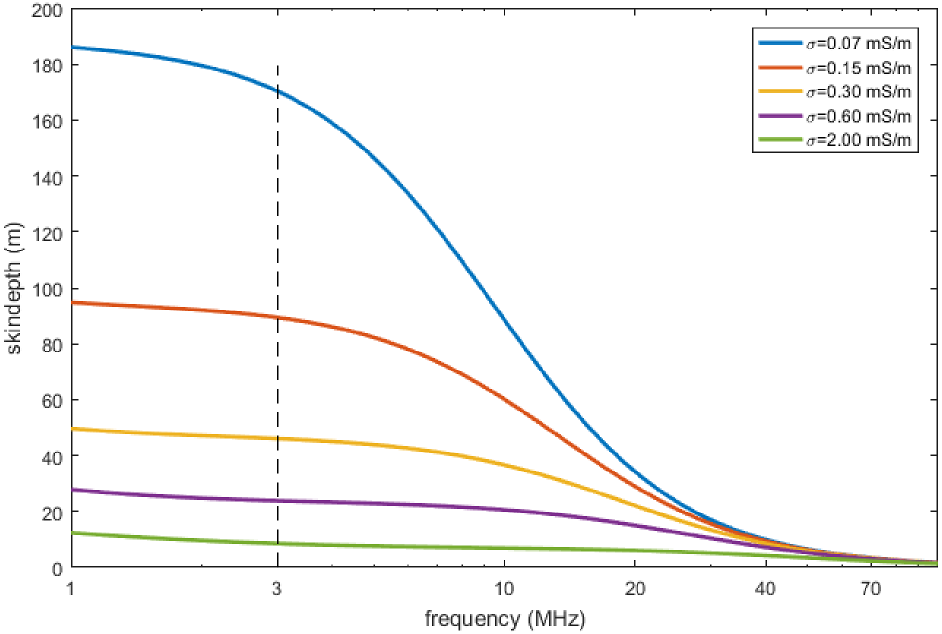
Adrok uses a finite volume method to predict the propagation of EM waves

- 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 (σ), permittivity (ε), permeability (μ), polarisation (P) and Debye relaxation time (τ)
- Can be matched to experimental data captured in the field
- Attenuation determined by conductivities and Debye parameter



How does it work?

SEG DENVER
26-31 OCTOBER 2014
Society of Exploration Geophysicists International Exposition and 84th Annual Meeting
Colorado Convention Center • Denver, Colorado USA • www.seg.org



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

Vision | Aim | Objectives

Vision

- 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

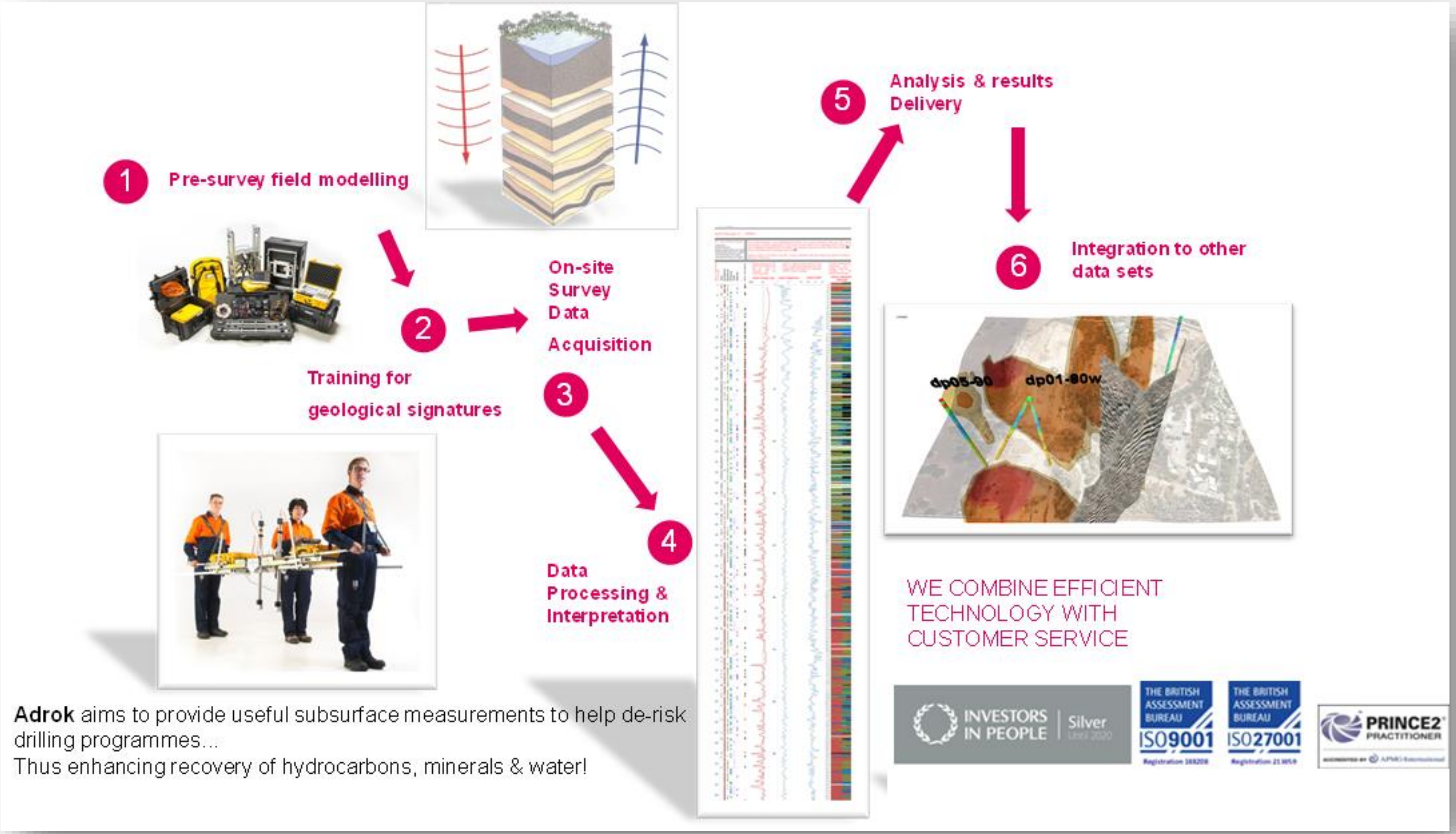
TRL	
9	Commercialized
8	Pre-production
7	Field Test
6	Prototype
5	Bench / Lab Testing
4	Detailed Design
3	Preliminary Design
2	Conceptual Design
1	Basic Concept

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

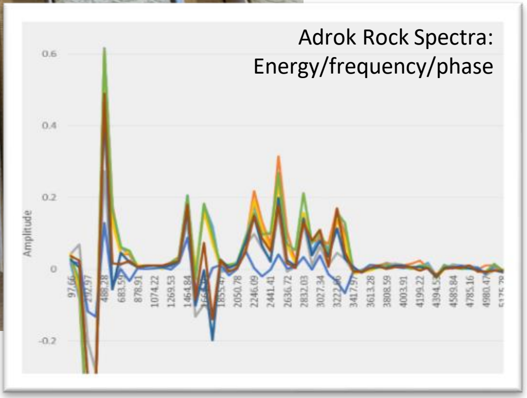
Methodology

Adrok Workflows



Typecasting rocks

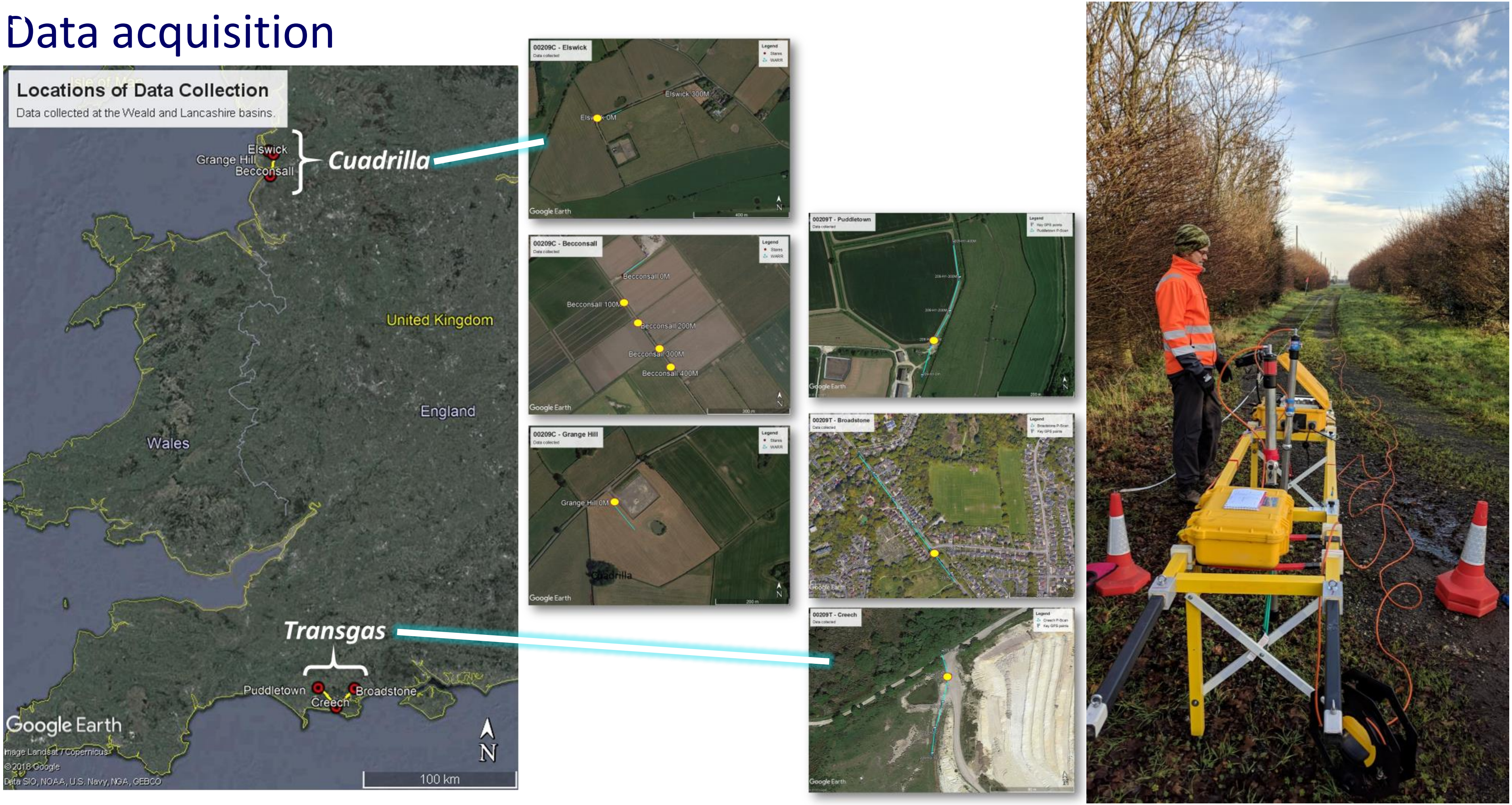
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL



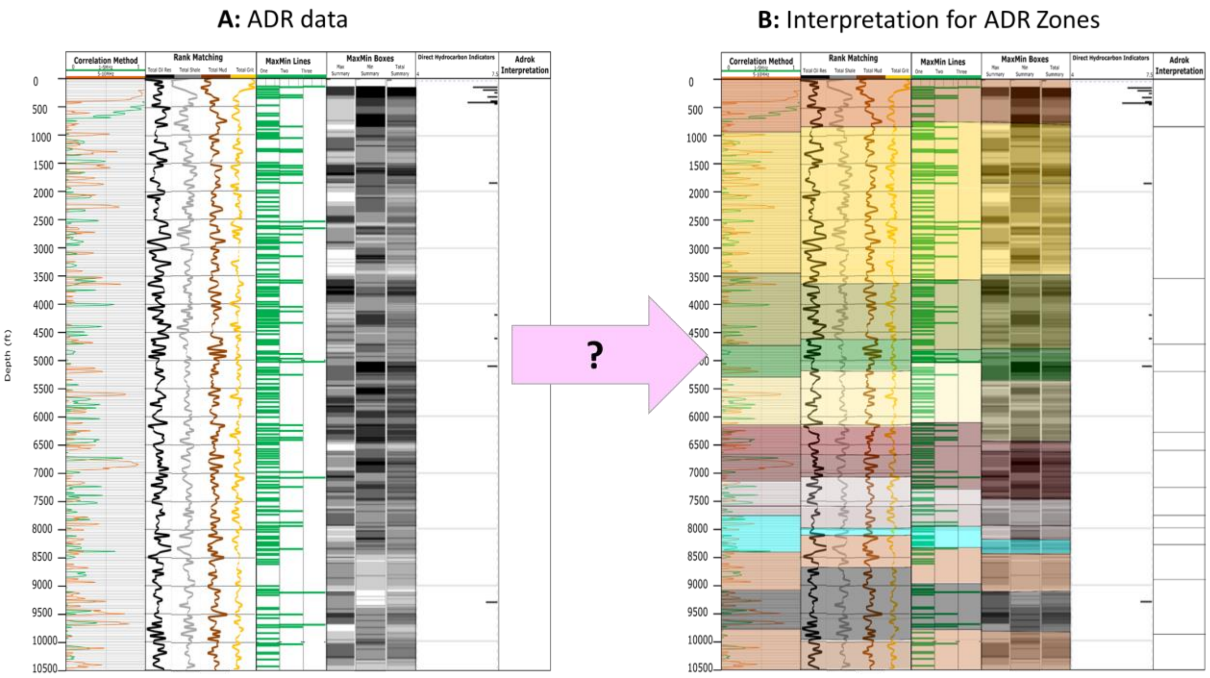
Adrok use a laboratory based instrument to help aid their understanding of different rock types:

- 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

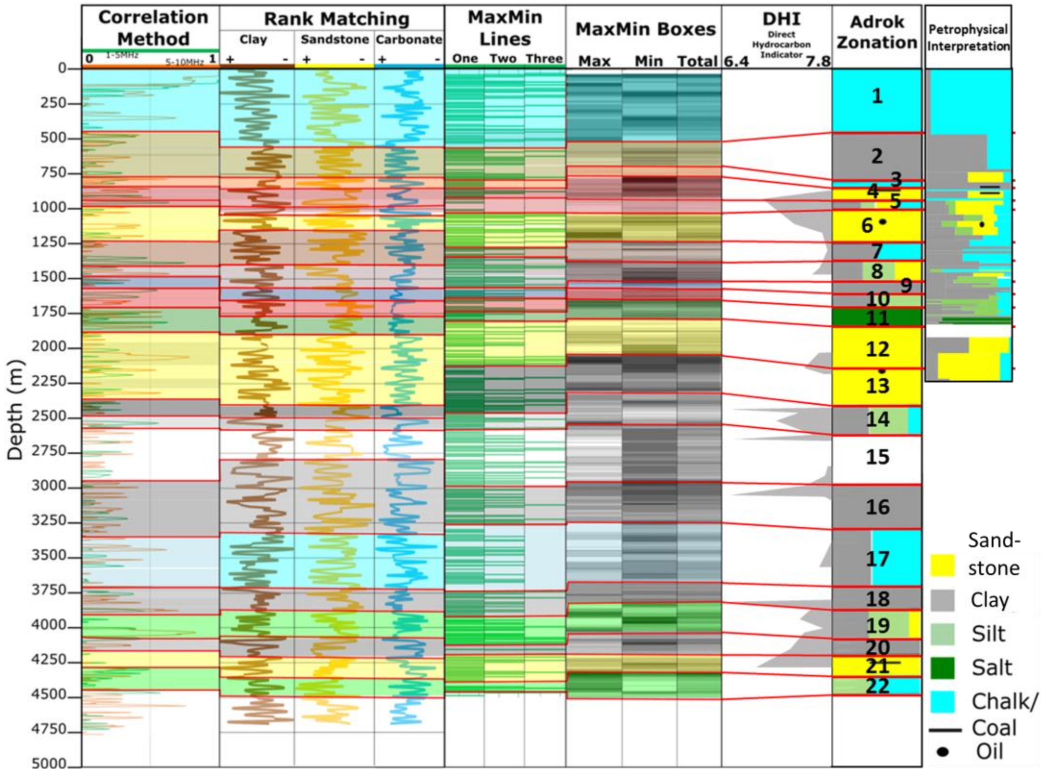


Data processing & interpretation



- 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.

Data processing & interpretation



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Results:

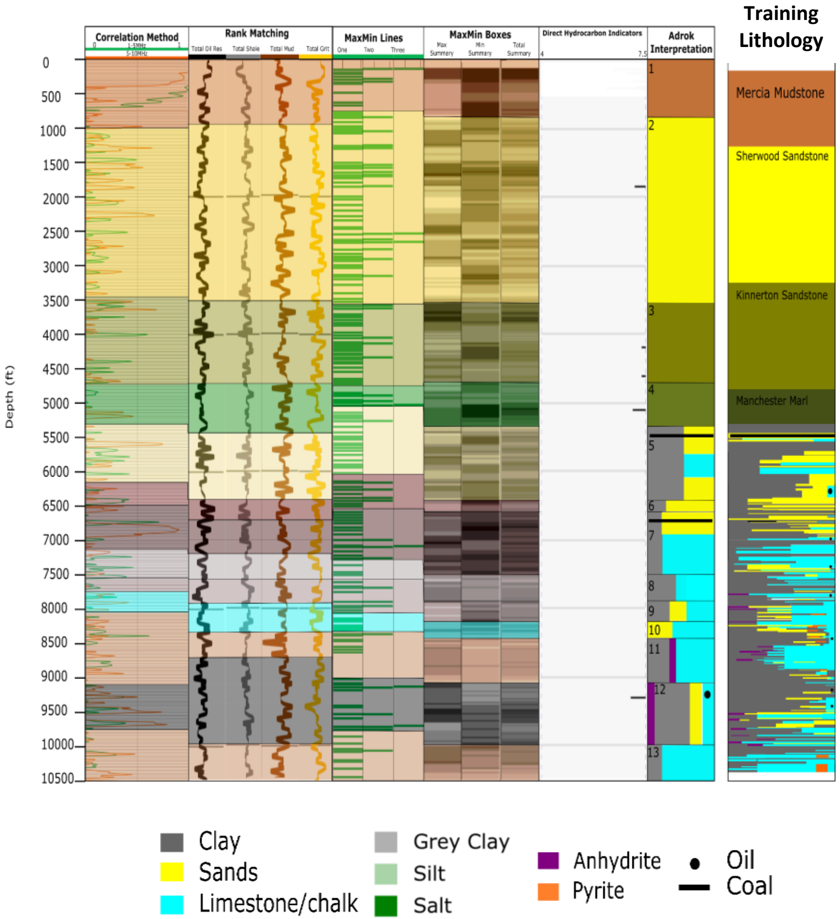
Virtual boreholes

2D profiles

1. Cuadrilla
2. TransGas

Cuadrilla

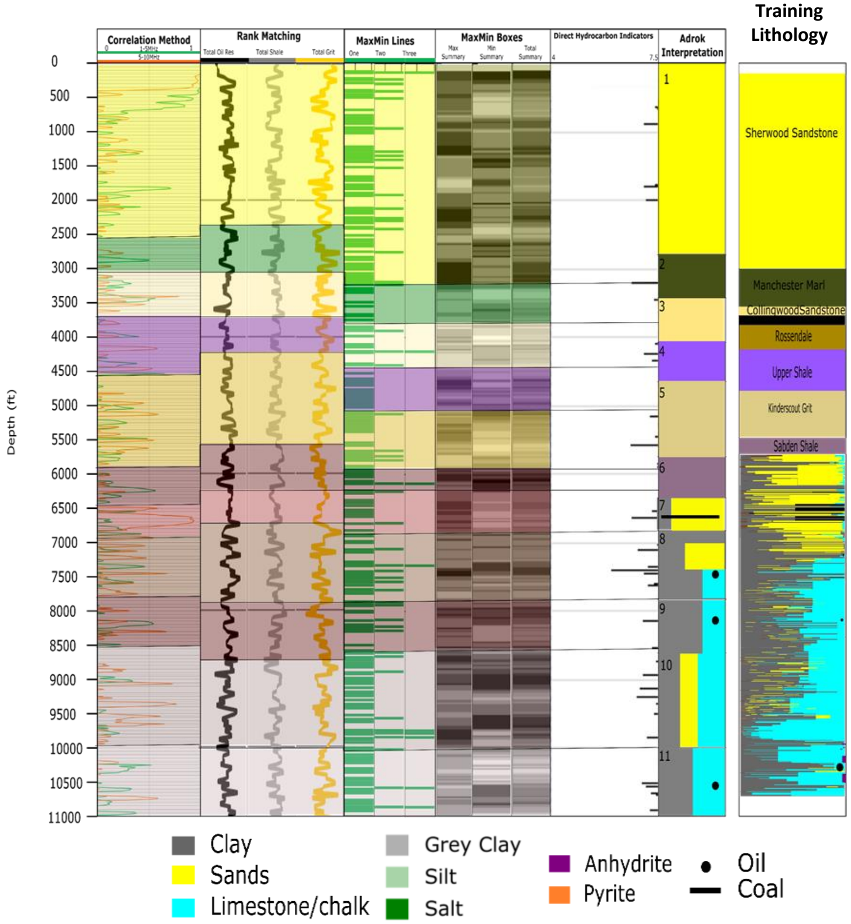
Becconsall



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).

Grange Hill 1z

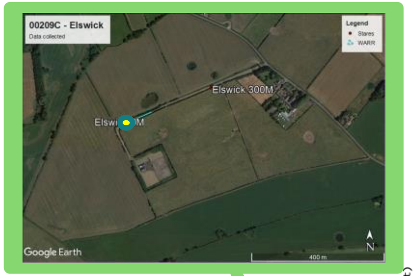


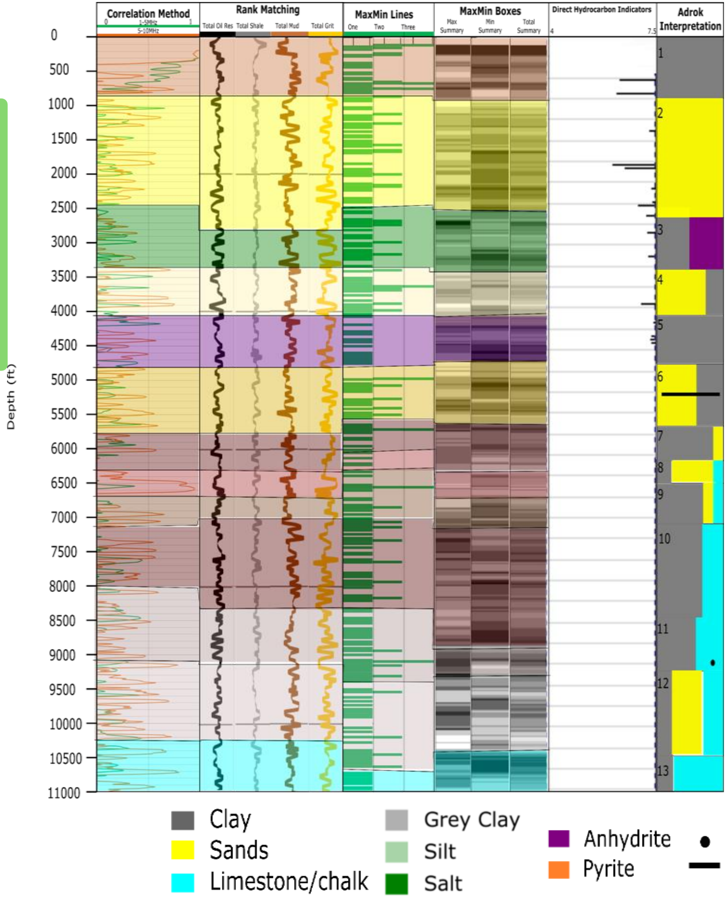
Training Observations:

- 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:





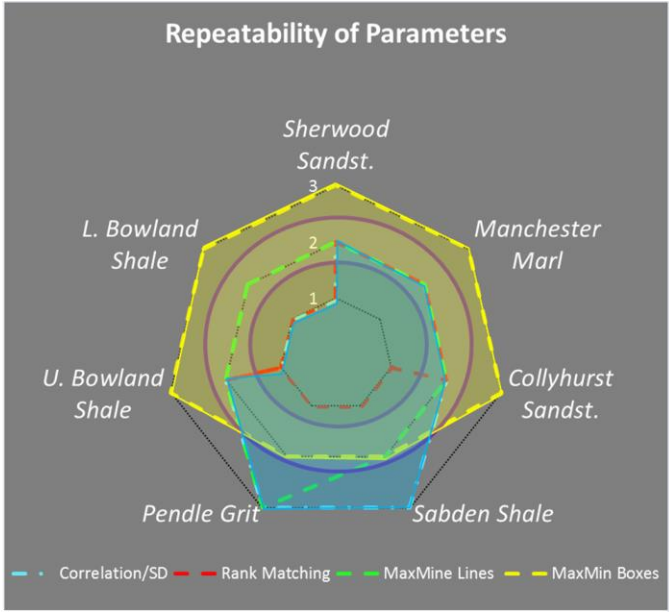
Unit	Unit Characteristics	Formation
1	Shale/Mud	Mercia Mudstone
2	Sandstone	Sherwood Sandstone
3	Shale	Manchester Marl
4	Shale/Sand	Collingwood Sandstone
5	Shale	Upper Shale
6	Sand Shale and possible coal	Kinderscout Grit
7	Shale with some sand	Sabden Shale
8	Sand with some shale and clay	Roeburndale
9	Carbonaceous slightly sandy shale	Brennard Grit
10	Carboantes and some shale	Pendle Grit
11	Carbonaceous slightly sandy shale	Upper Bowland Shale
12	Carbonaceous shale with some oil	Lower Bowland Shale
13	Limestone	Hodder Limestone

- 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.*



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

Ranking of the consistency of the parameters, amongst the 4 parameters. For each parameter, the amount of Sites with the same behaviour is counted.

Lithology (Lancashire)	Correlation Method	Rank Matching	MaxMine Lines	MaxMin Boxes
Sherwood Sandst.	2	2	2	3
Manchester Marl	2	2	2	3
Collyhurst Sandst.	2	2	2	3
Sabden Shale	3	1	2	2
Pendle Grit	3	1	3	2
U. Bowland Shale	2	2	2	3
L. Bowland Shale	1	1	2	3

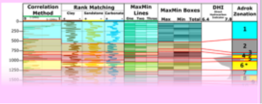
1) Each site has different behaviour. 2) Two sites share behaviour. 3) All sites share the same behaviour.

MaxMin boxes appears to be the best lithology discriminator

Repeatability: Becconsall

ADR Zones

- From Stares: Contrast and Interpretation between 5 ADR attributes.



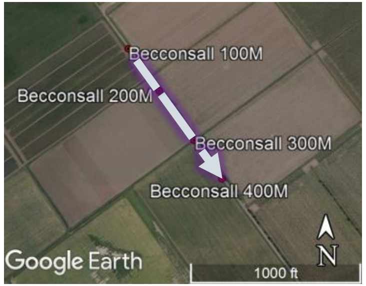
1. How consistent is each parameter at identifying lithologies?
2. Are there features in the data that can be horizontally followed throughout a section?
3. Which are the predictive ADR parameters for each lithology?

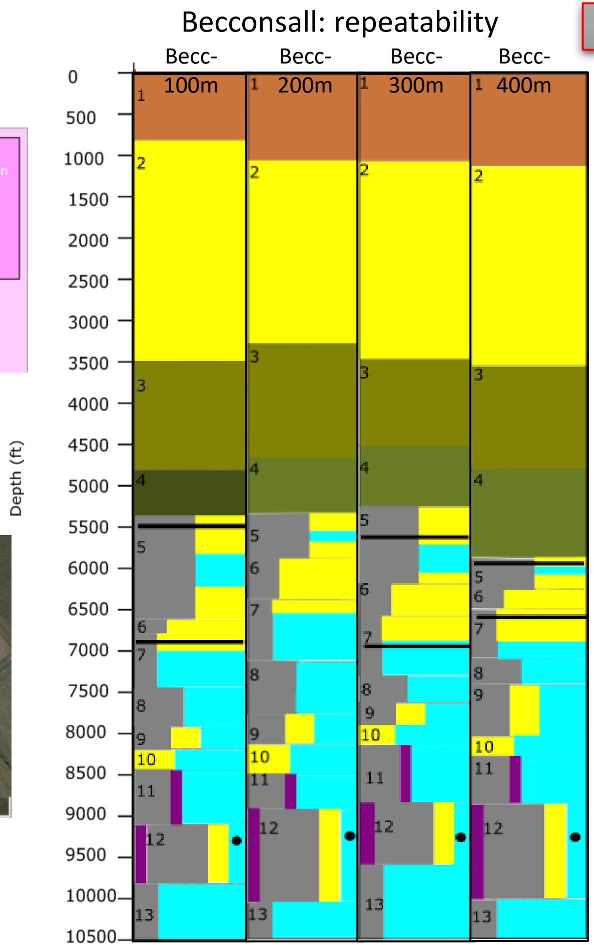
ADR Parameters

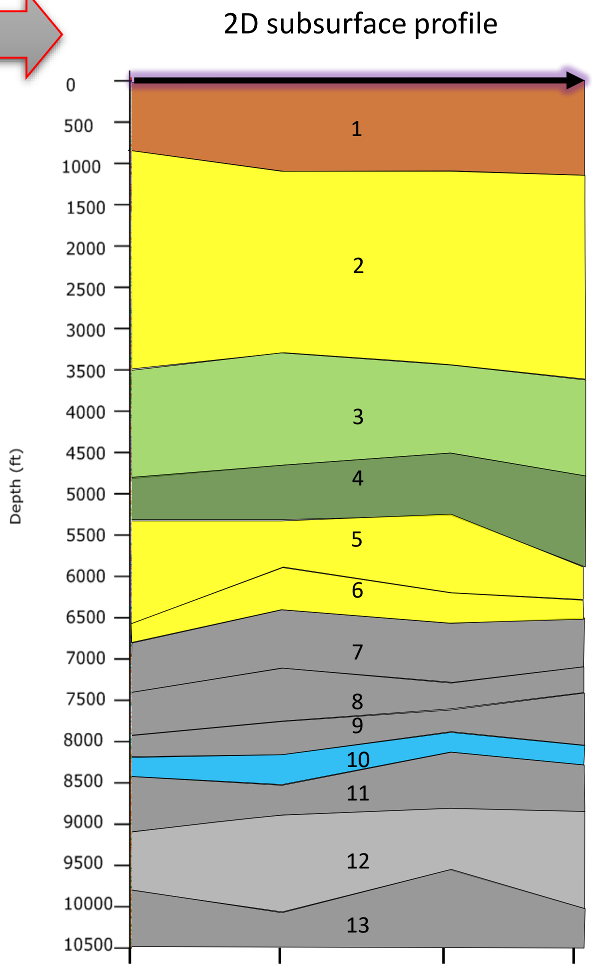
A study on the similarities between the ADR parameters that are prognosing similar lithologies or formations, all across the studied basins.

V-Bore VS V-Bore

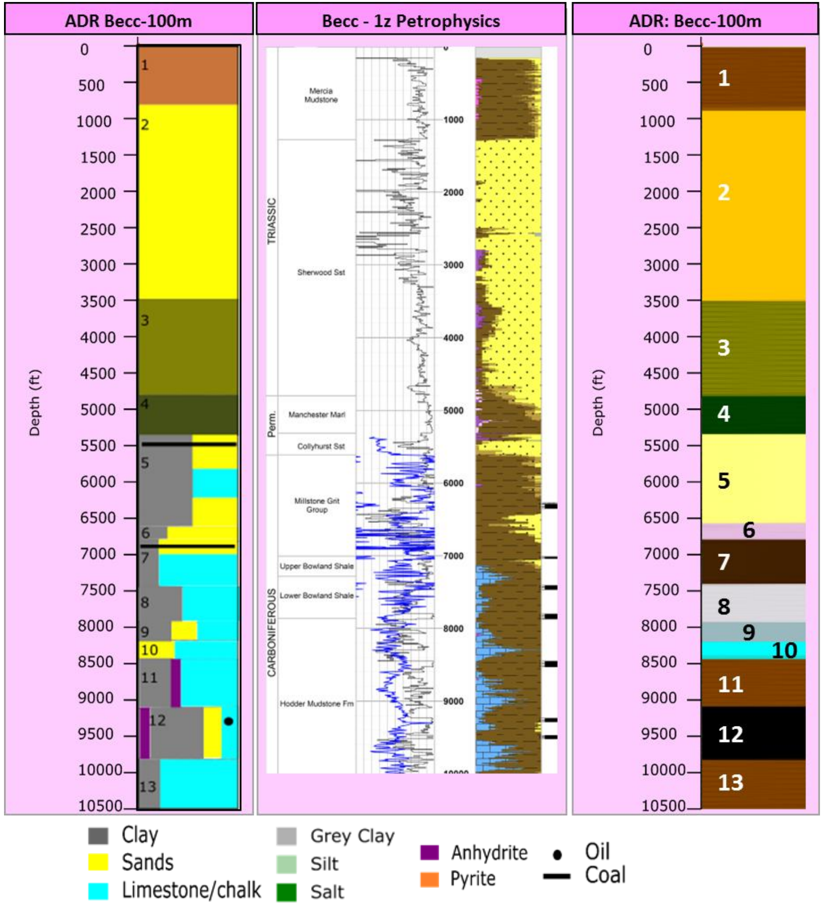
- The four stares (Becc-100m to Becc400m) (first figure to the right) interpreted at the Becconsall site offer a great opportunity to investigate the repeatability of the ADR Zones and their consistency in laterally tracking similar features.







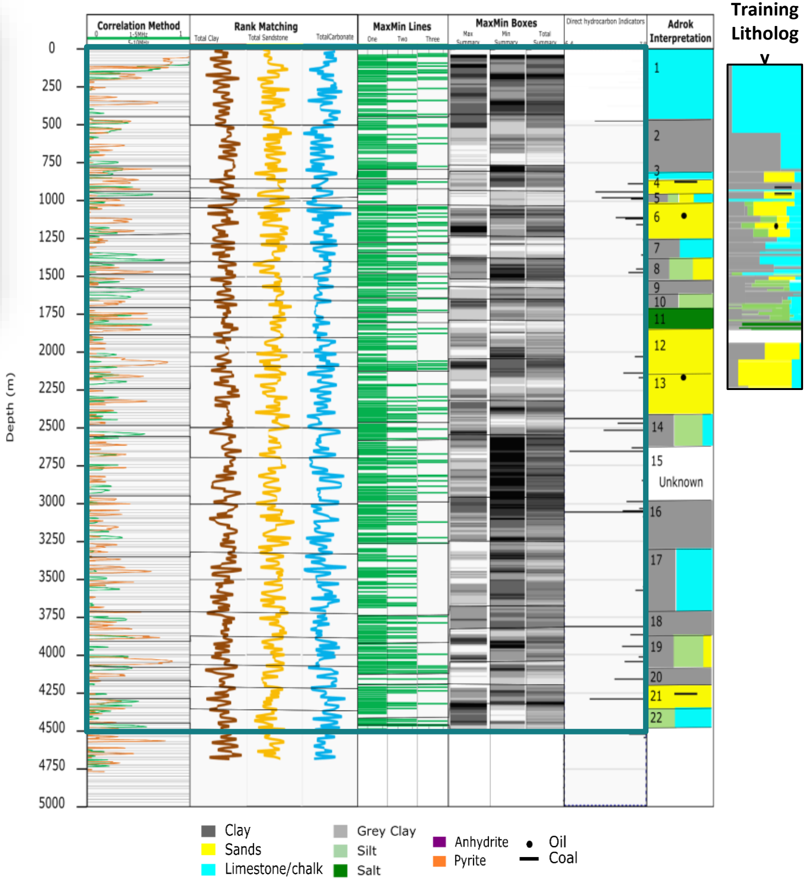
Validation: Becconsall



System	Major Stratigraphic units	Lithostratigraphy	Driller top from ground in ft.	ADR Zone	ADR Zone top in ft.	Difference in ft.	Difference in %
Triassic	Sherwood Sandstone	Mercia Mudstone	0	1	0		
		Sherwood Sandstone	1265	2	806	-458	-5.7%
		Kinnerton Sandstone	3265	3	3476	211	2.6%
Permian	Cumbria Coast Group	Manchester Marl	4800	4	4794	-5	-0.1%
	Appleby Group	Collyhurst Sandstone	5312	5	5346	34	0.4%
Pennsylvanian	Milstone Grit Group	Sabden Shale Group	6230	6	6608	378	4.7%
Mississipian		Pendle Grit Formation	6420	7	6783	363	4.5%
	N/A	Upper Bowland Shale	7005	8	7434	429	5.4%
	Worston Shale Group	Lower Bowland Shale	7283	9	7916	633	7.9%
		Hodderense Limestone	7827	10	8191	365	4.6%
		Hodder Mudstone	7846	11, 12, & 13	8421	574	7.2%

- Mercia Mudstone
- Sherwood Sandstone
- Kinnerton Sandstone
- Manchester Marl
- Collyhurst Sandstone
- Sabden Shale
- Pendle Grit
- U. Bowland Shale
- L. Bowland Shale
- Hodderense Limestone
- Hodder Mudstone (1)
- **Oil Reservoir**
- Hodder Mudstone (2)

Creech



Training Observations:

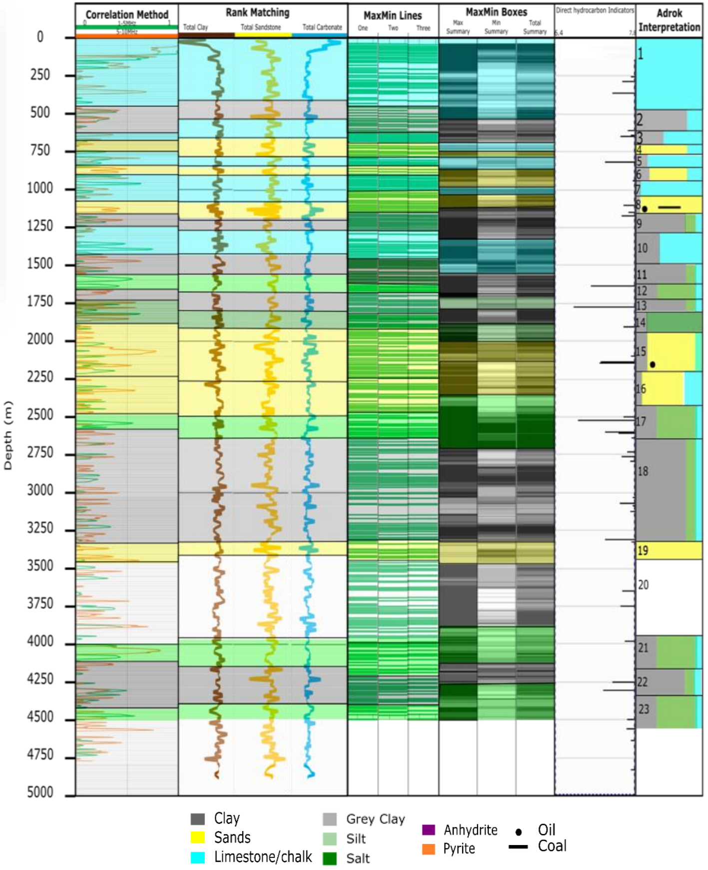
- Correlation Method: large peaks in 5-10MHz found in the sandstones while the larger 1-5Mhz peaks occur in the silts and chalk. The smallest peaks occur in the clays.

- 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

Puddletown

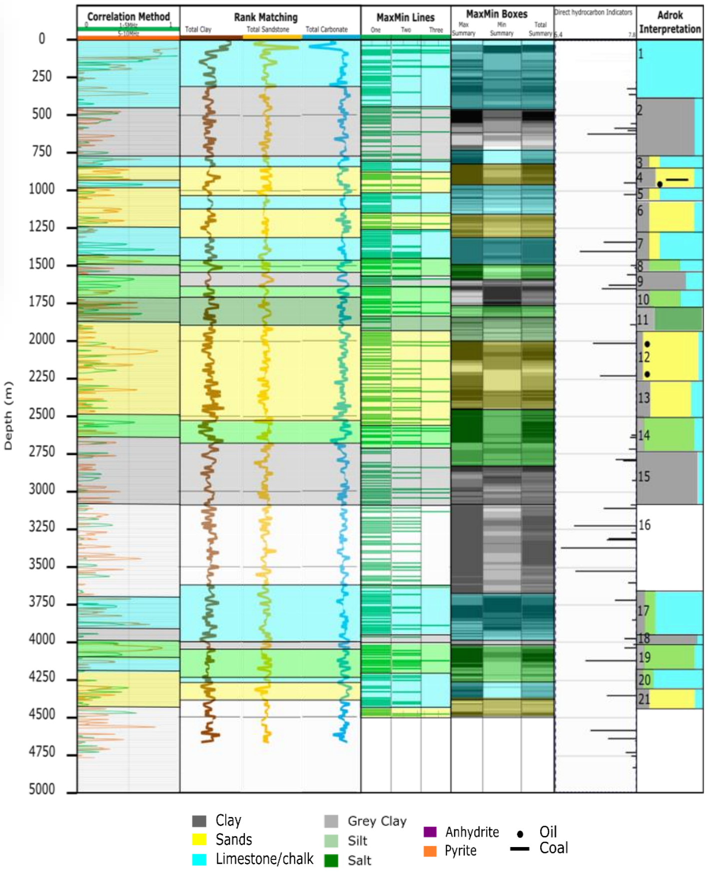


Interpretation Conclusions:

- 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) DHIs occur in many different lithologies apart from the salt beds. Siltstones and sandstones see the presence of most DHIs. 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

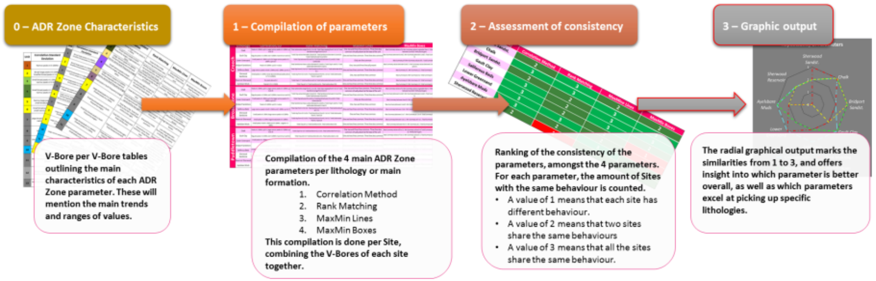


Interpretation Conclusions:

- 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.

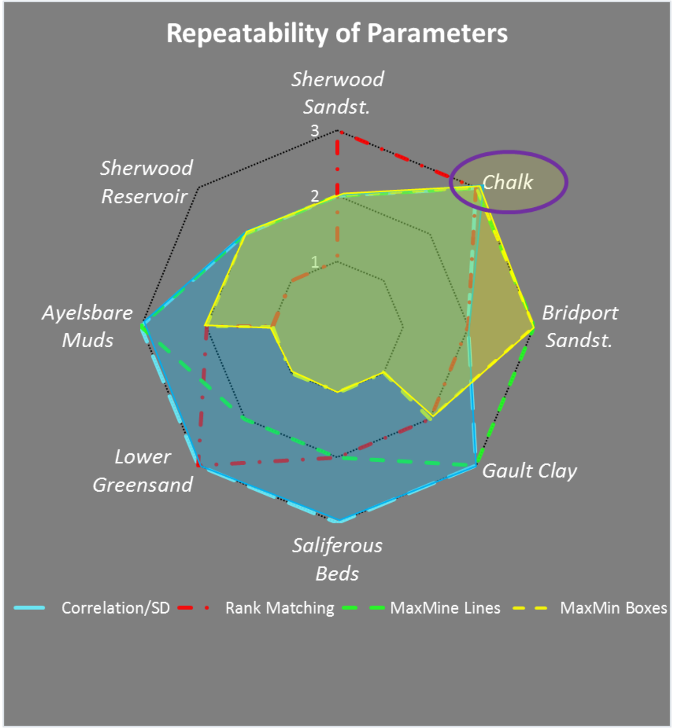
Repeatability: 3 sites



- 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.

Lithology (Weald)	Correlation Method	Rank Matching	MaxMine Lines	MaxMin Boxes
Sherwood Sandst.	2	3	2	2
Chalk	3	3	3	3
Bridport Sandst.	2	2	3	3
Gault Clay	3	2	3	2
Saliferous Beds	3	2	2	1
Lower Greensand	3	3	2	1
Ayelsbare Muds	3	2	3	2
Sherwood Reservoir	2	1	2	2

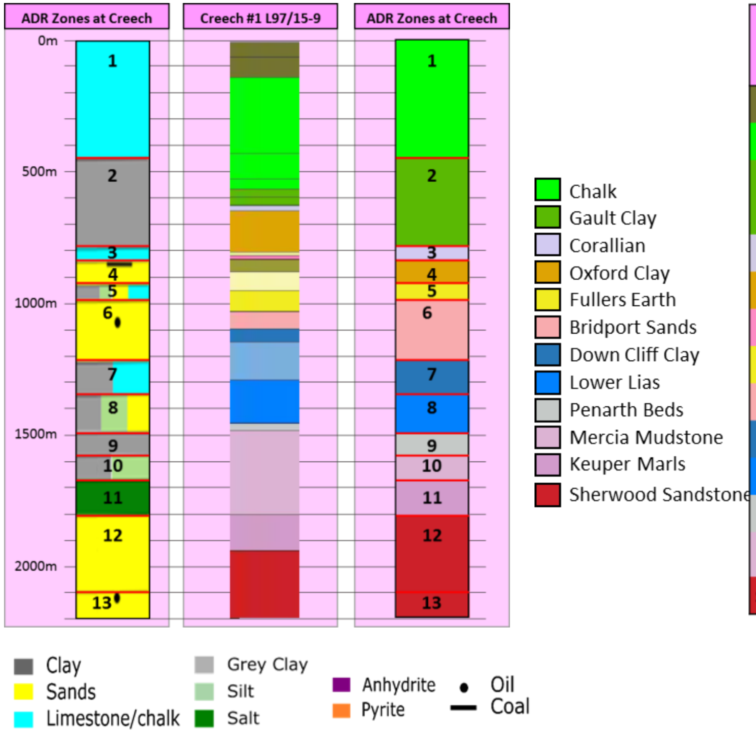
Ranking of the consistency of the parameters, amongst the 4 parameters. For each parameter, the amount of Sites with the same behaviour is counted.
1) Each site has different behaviour. 2) Two sites share behaviour. 3) All sites share the same behaviour.



- **ADR identified lithologies in the subsurface in a repeatably manner with the Stare Scans.**

Correlation Method is the best lithology discriminator for these sites

Validation: Creech



Lithostratigraphy from Creech #1 L97/15-9	TVDGL (m)	ADR Zone	ADR Zone top in m.	Difference in m	Difference in %
Tertiary	0	1	0		
Chalk	134				
U. Greensand + Gault	557	2	463	94	4.4%
L. Greensand	619	3	812	-193	-9.0%
Corallian	622				
Oxford Clay	641	4	860	-219	-10.2%
Cornbrash	812				
Frome Clay	874	5	957	-83	-3.9%
Inferior Oolite	1023	6	1016	8	0.4%
Down Cliff Clay	1141	7	1253	-112	-5.2%
Lower Lias	1305	8	1379	-74	-3.5%
Penarth	1451	9	1525	-74	-3.4%
Mercia Halite	1746	10 & 11	1613	132	6.2%
Sherwood Sandstone	1938	12 & 13	1848	90	4.2%

- 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.**

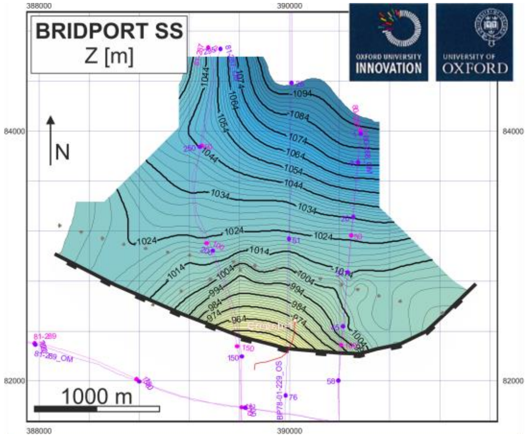
Transgas: feedback

Transgas Limited is very positive about Adrok technology. At 'Target 1', a conventional oil target, the Atomic Dielectric Resonance (ADR) testing results tied closely 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*



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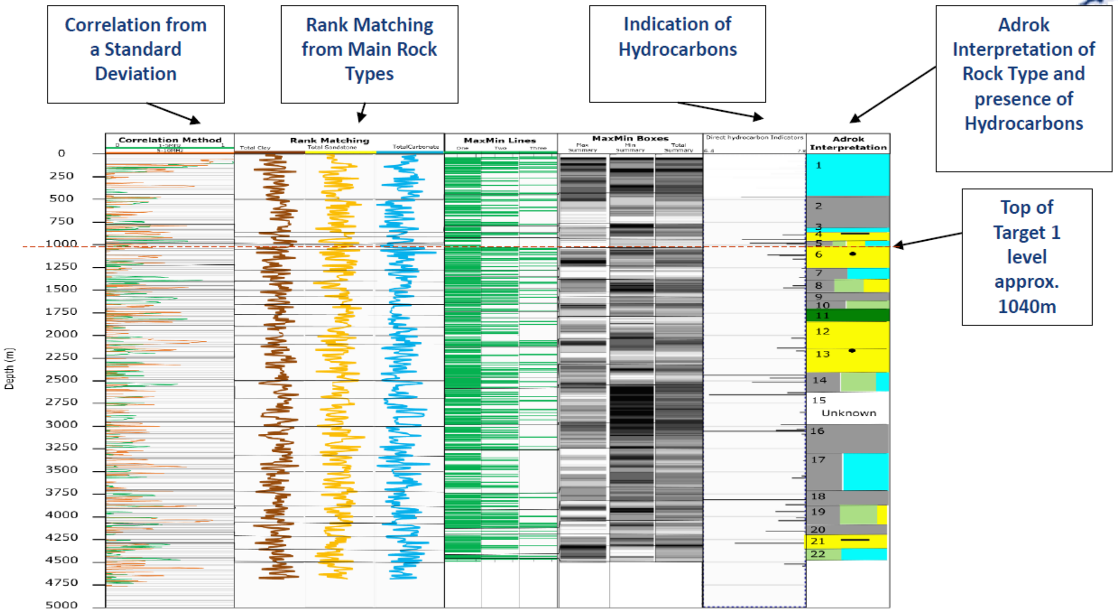
Target 1 - Adrok Virtual Borehole



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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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