Invisible light imaging and classification of subsurface rocks and rock sequences

Innovative Technologies and Approaches I
European Association of Geoscientists & Engineers (EAGE)

Oral Presentation Z033

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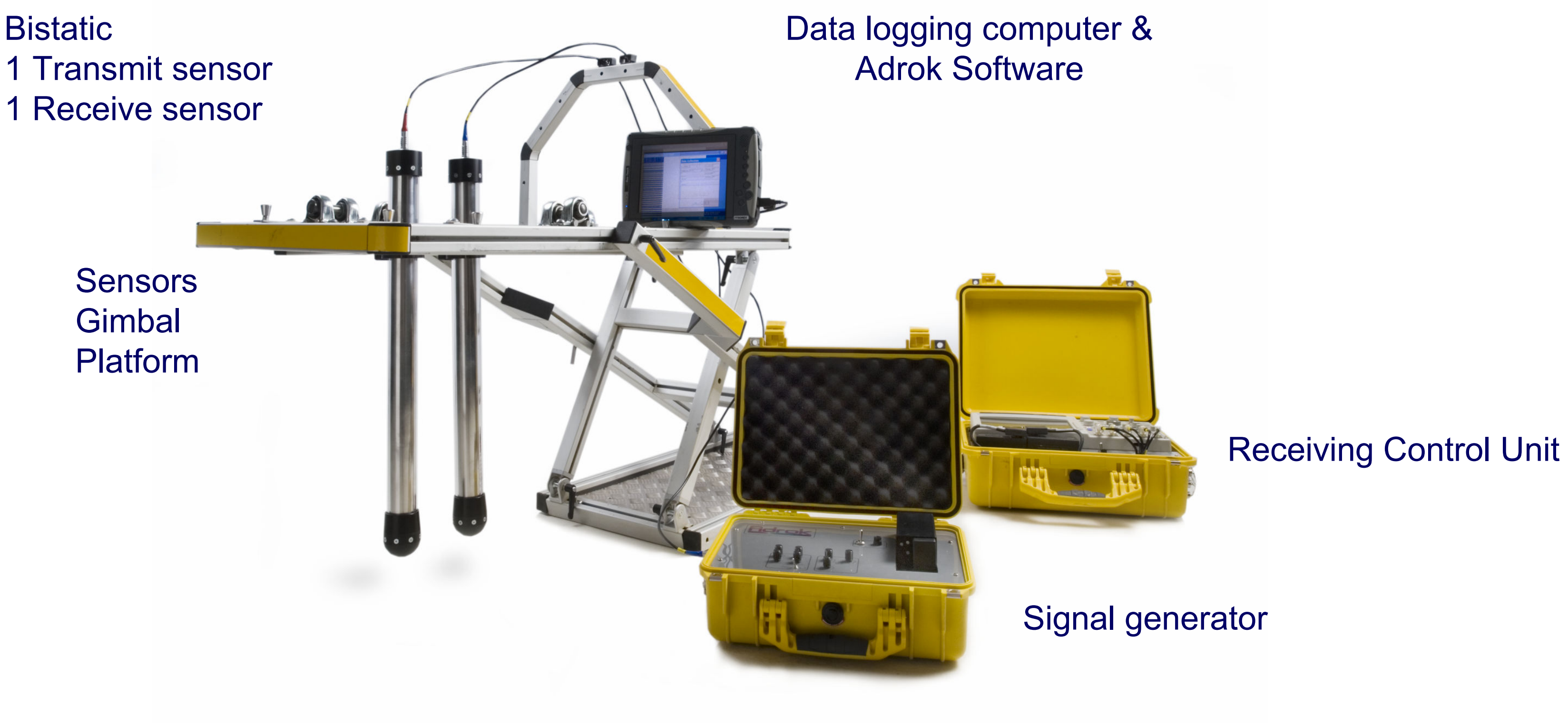
Objectives

- Introduce new geophysical technology - Adrok® Scanner
- Describe technical principles
- Present 2 case histories as field proof
  - Onshore, Scotland (sedimentary tests)
  - Onshore, North Africa (new gas discovery)
- Summary and conclusions

Adrok Scanner

- What is it?
  - New entrant in the subsurface imaging market for oil, gas and minerals E&A
- What is its purpose?
  - To help map, locate & identify oil, gas, water & minerals from the surface & therefore help reduce drilling dry holes
- What does it deliver?
  - Generates "Virtual Borehole" logs of subsurface geology from surface



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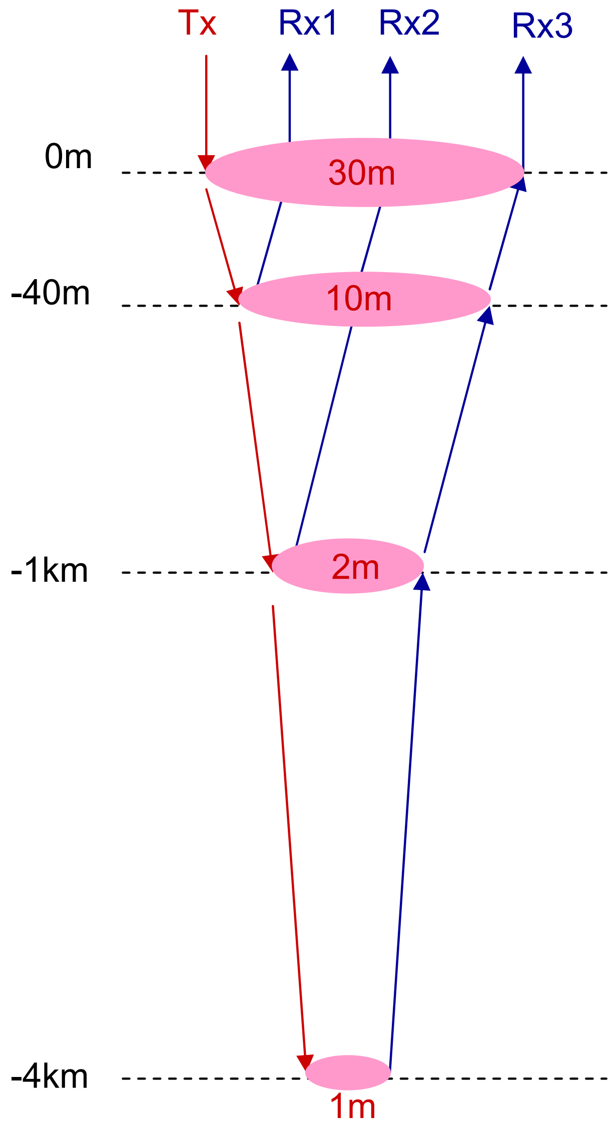
Adrok

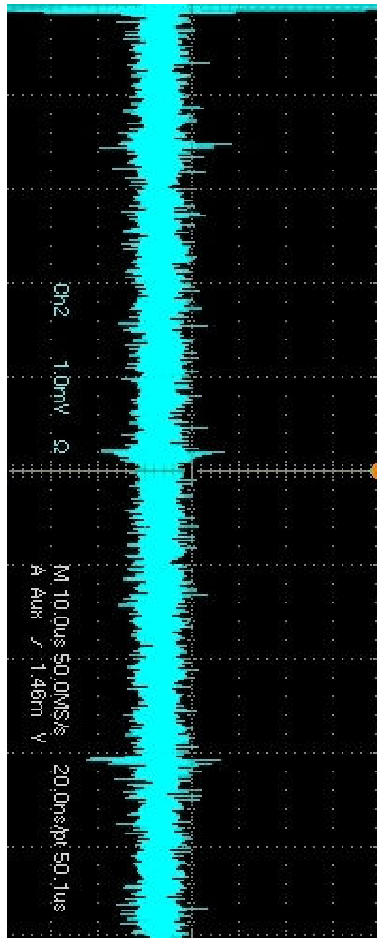
Field Deployment

Adrok Subsurface Scanning Process

- Adrok Scanner Illuminates the ground by Transmitting & Receiving Invisible Lased Light beams of Electromagnetic energy
  - Pulsed
  - Coherent (over a narrow band of frequencies)
  - Collimated (cylindrical shape)
  - Radiowaves, Microwaves
  - Resonant frequencies
  - Minimal beam dispersion

- Penetrates from ground surface to proven depths of up to 4km





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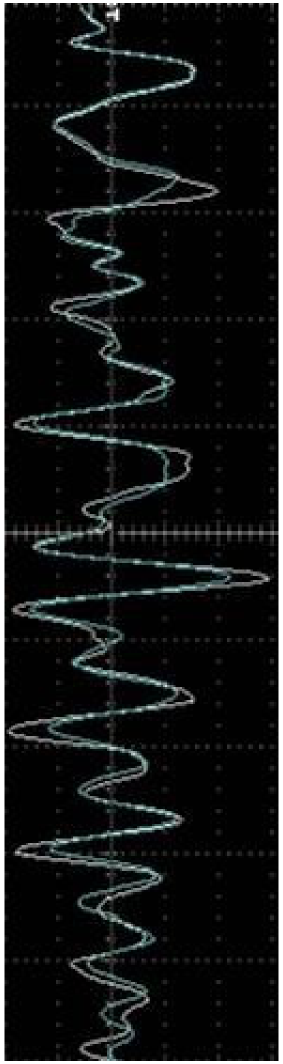
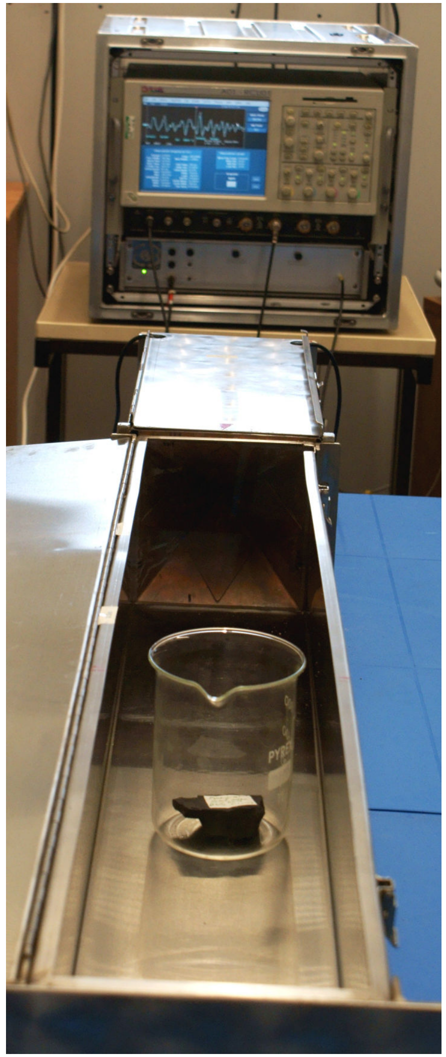
“5R” Technical Process

- Adrok has developed five complimentary sets of procedures for subsurface measurements of:
  - Rock properties
  - Range
  - Resonance
  - Reflectivity
  - Recognition

Rock Properties

- Adrok Scanner measures the dielectric permittivity of rocks:
  - in the ground in situ
  - or in laboratory / core store
- From the dielectric measurements, we produce velocities, dielectric constants, and depth measurements from the surface and between subsurface layers.
- Moisture content of rocks
- Hydrocarbon concentrations in rocks
- Grain size indices
  - E.g., fine grained sandstone produces more resonant frequencies than coarse grained sandstone





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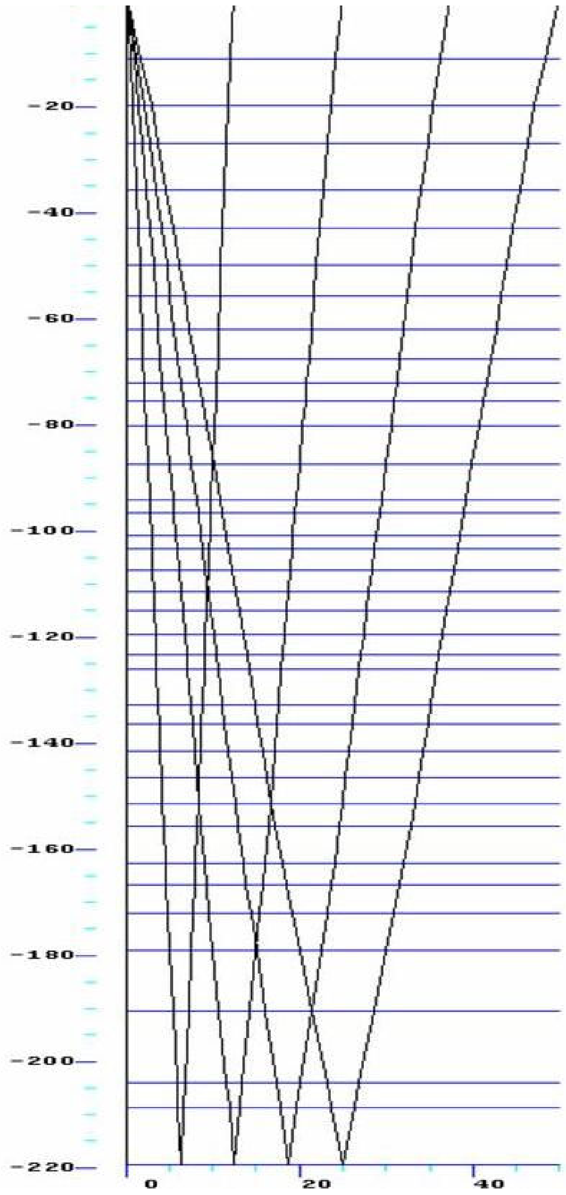
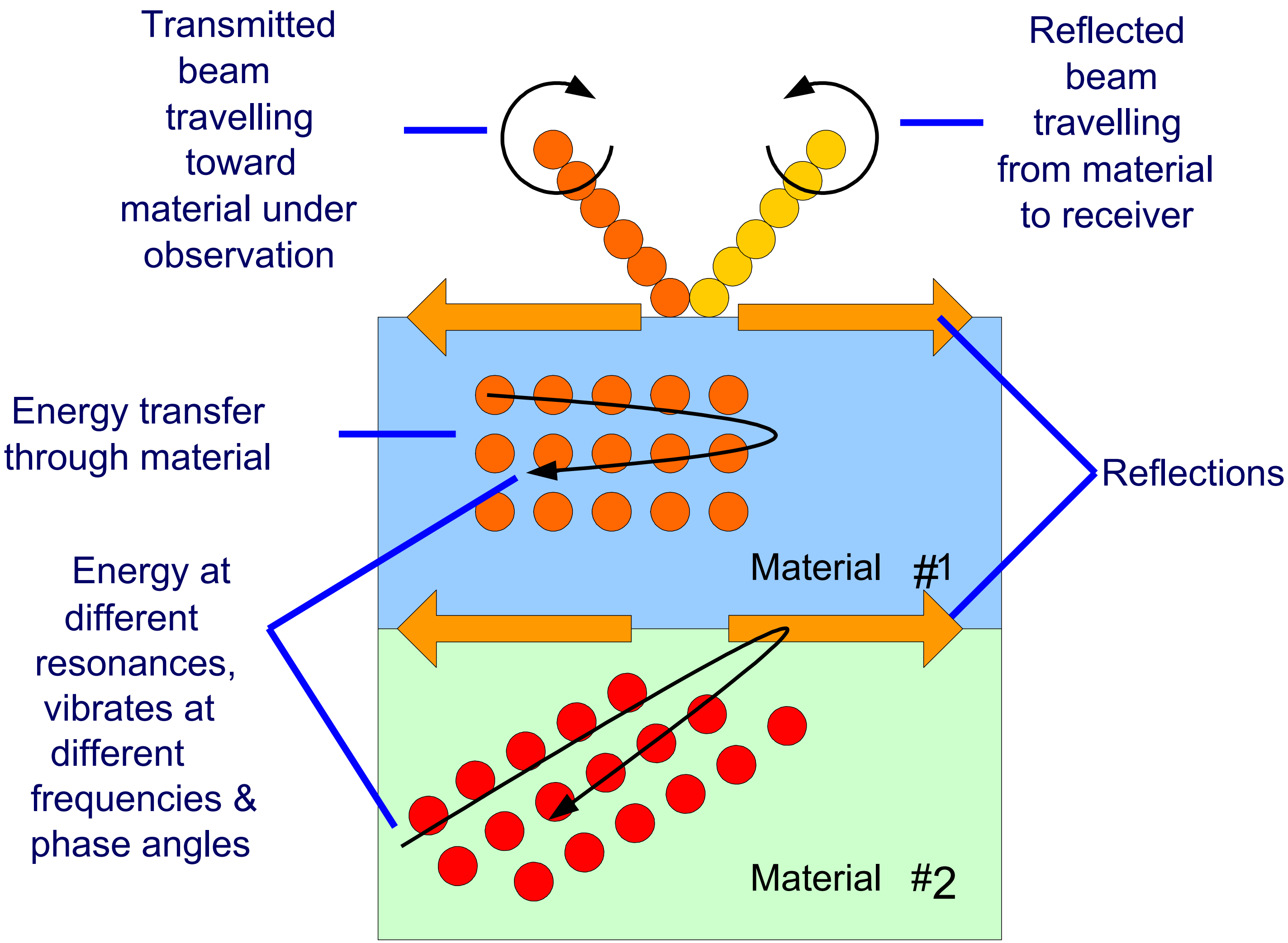
Range

- Accurate depth measurement
  - Subsurface responses are referenced to 3 time stamped levels in z-depth plane
    1. Transmitter datum from sensor aperture
    2. Surface level datum
    3. Direct Wave datum (between TX & RX) for any given separation.
  - Nanosecond time range
    - Interlayer Velocities of beam through media are related back to speed of light
- Deep penetration
  - Standing waves of energy sent into the ground
  - Minimal attenuation & dispersion
    - Because beam is lased & operates over a limited range of frequencies
- Directional beam
  - Beam can be controlled to look obliquely through ground



Resonance

- Beam sent into the ground is resonating (the signal rings in the ground), this has two effects:
  1. It can help beam propagation (Ranging)
  2. Resonance within layers of uniform dielectrics helps illuminate boundaries



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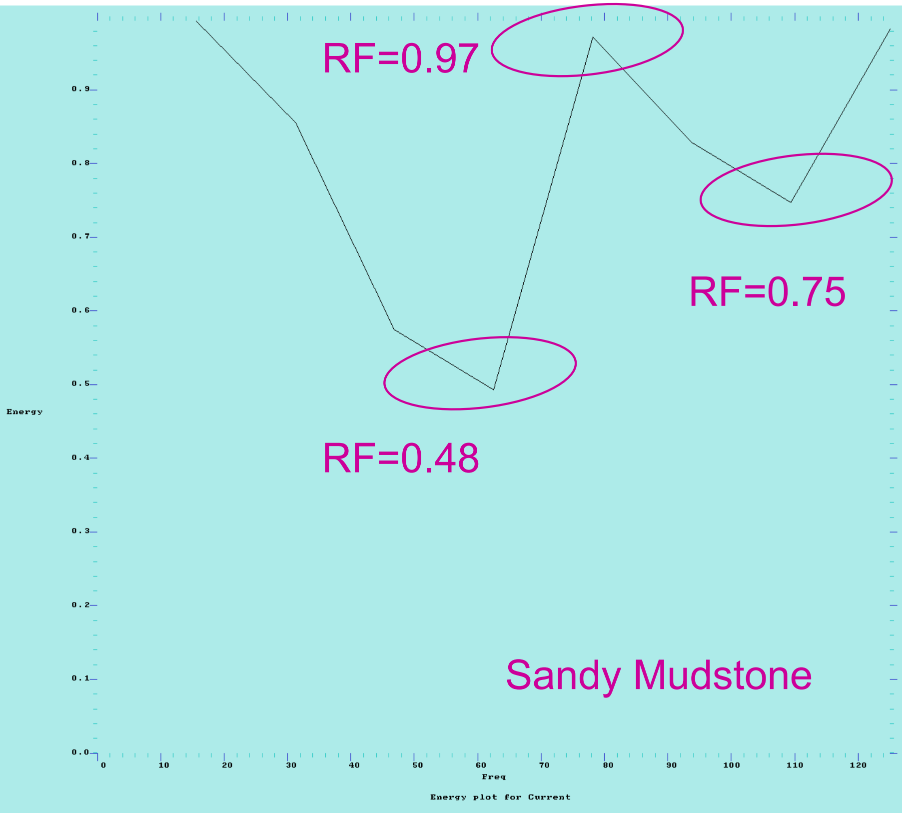
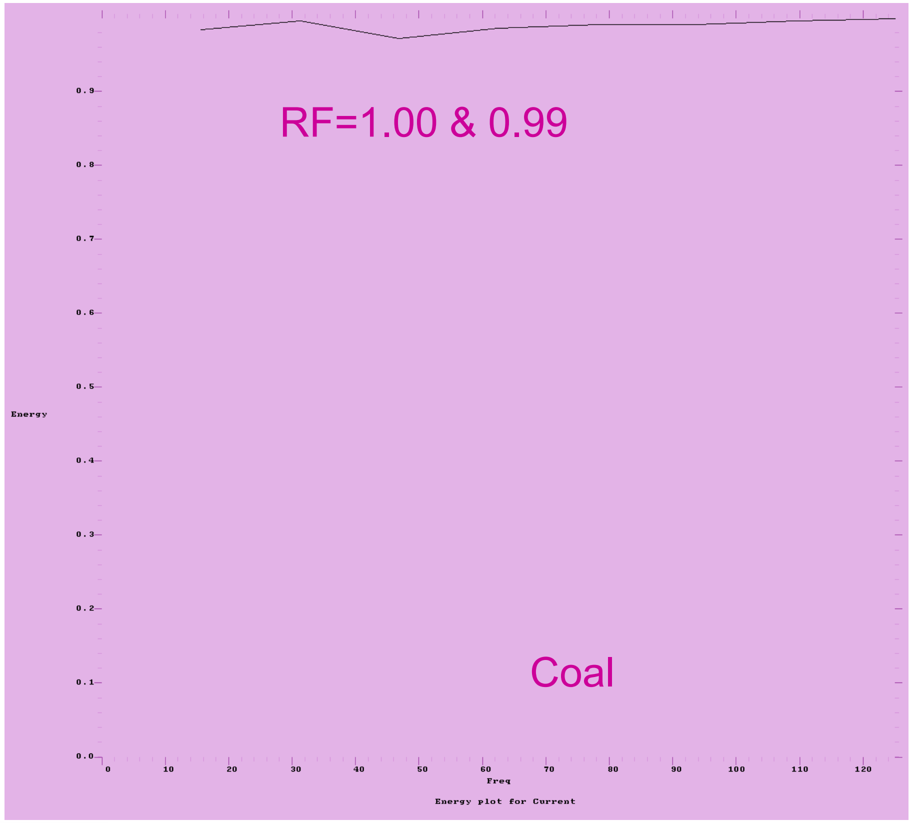
Reflectivity

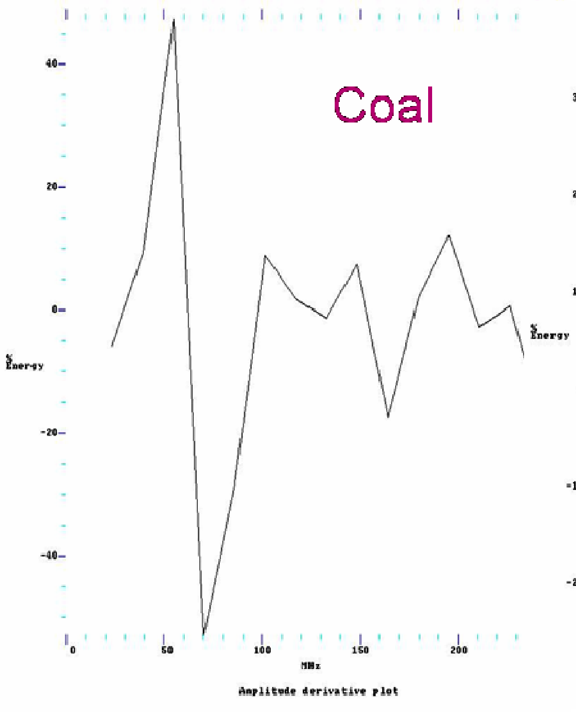
- Reflectivity measurements helps identify subsurface boundaries & one rock type from another
- At dielectric boundaries in the ground, Reflectivity Coefficients are calculated from the amplitude response of the beam
- Different reflectivity responses for different rock types:
  - Fine grained rocks give more reflectivity response than coarse grained rocks
  - Pure Mudstone is highly reflective, but Sandy Mudstone has absorption & reflection peaks

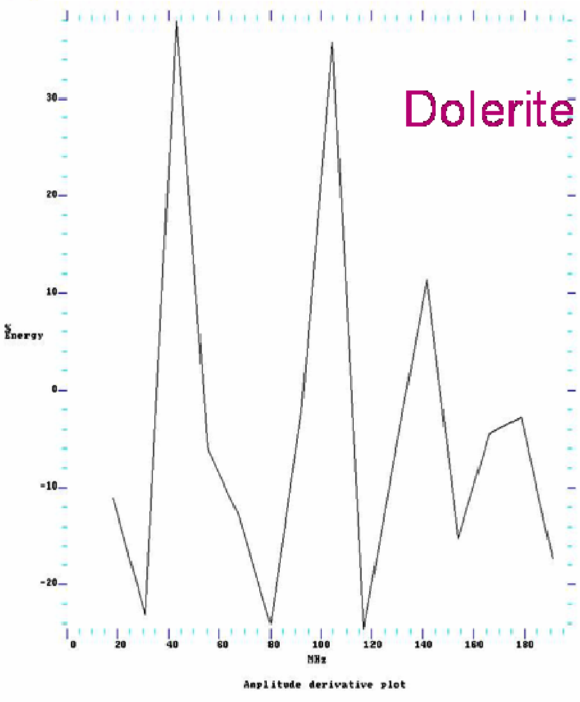


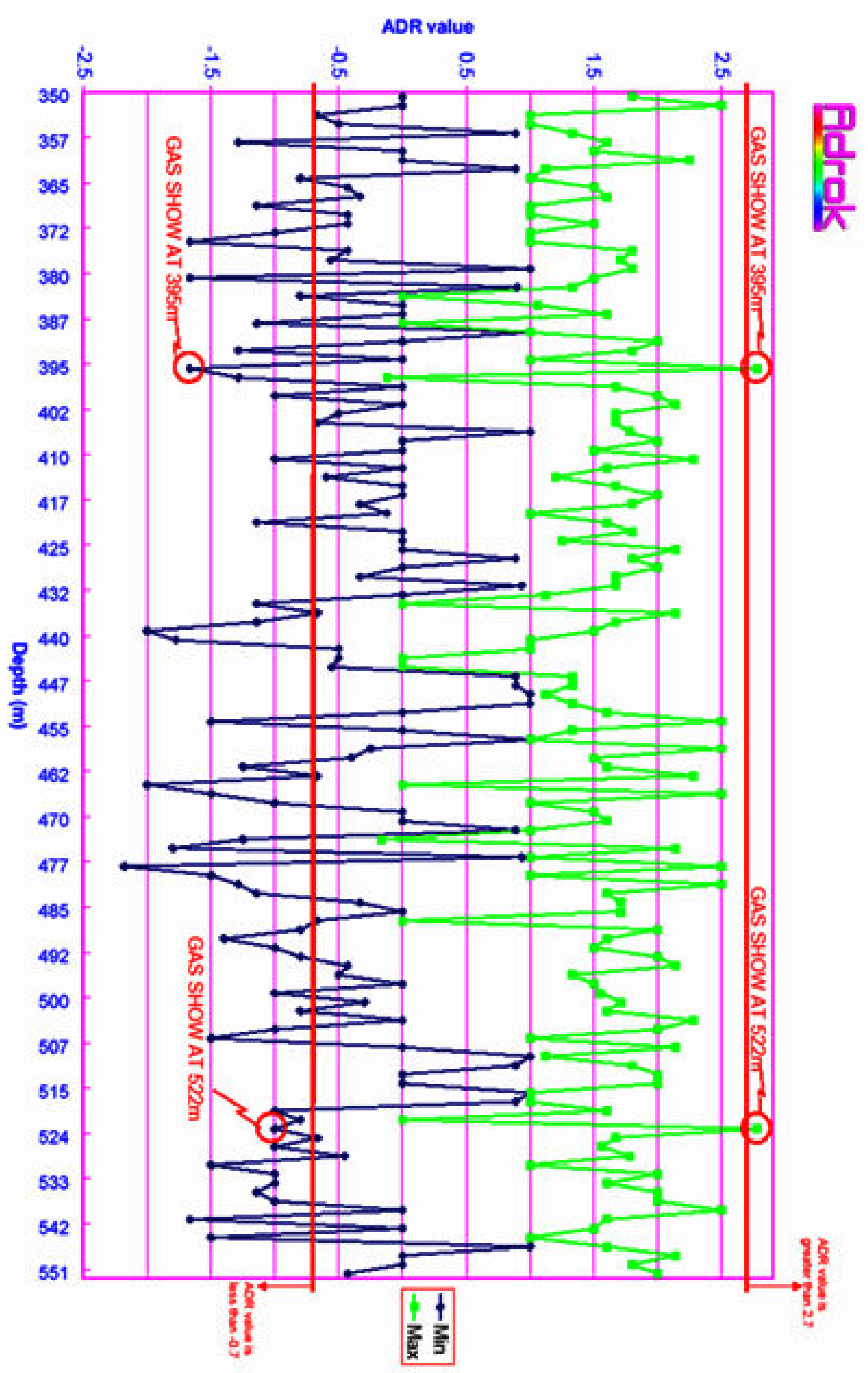


Recognition

- Adrok Scanner is an imaging spectrometer
- Reference databases of Adrok signatures developed by Spectral Analysis (energy, frequency)
- Expert Systems developed to help classify material signatures by different statistical methods:
  - Principal Components Analysis
  - Maximum Likelihood Analysis
  - Multivariate Classification
  - Harmonic Analysis



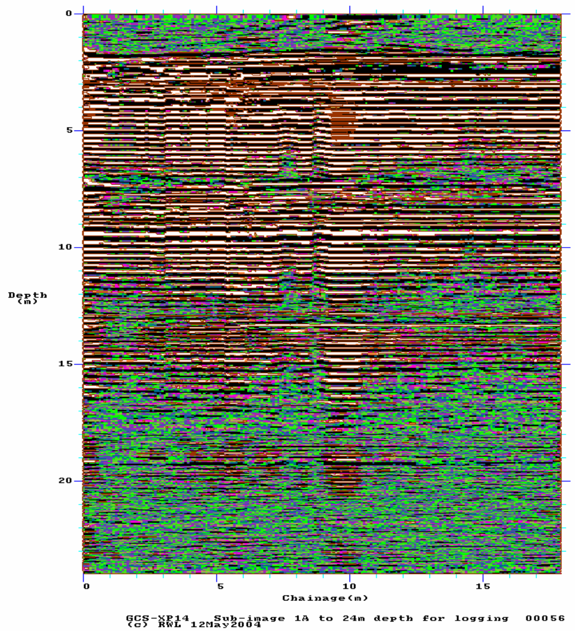




Case History 1
Coal Beds in Central Scotland

- Technical Due Diligence Exercise
- Independently corroborated by Professors from University of St. Andrews, Scotland
- Two blind tests (1) Can Adrok Scanner penetrate beyond conventional GPR depths?
  (2) Can Adrok Scanner correctly identify the principal rock types?
- Adrok Scanner accurately imaged & classified subsurface stratigraphy at 3 separate onshore sites & 1 offshore site
- Results of Cults Hill site in Fife, Scotland are presented here

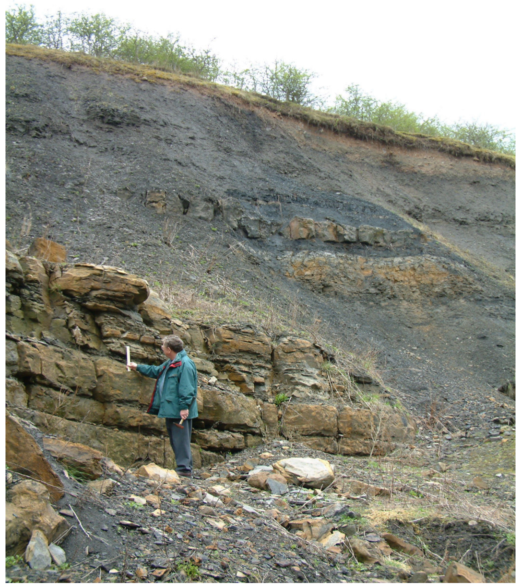
Adrok Image output



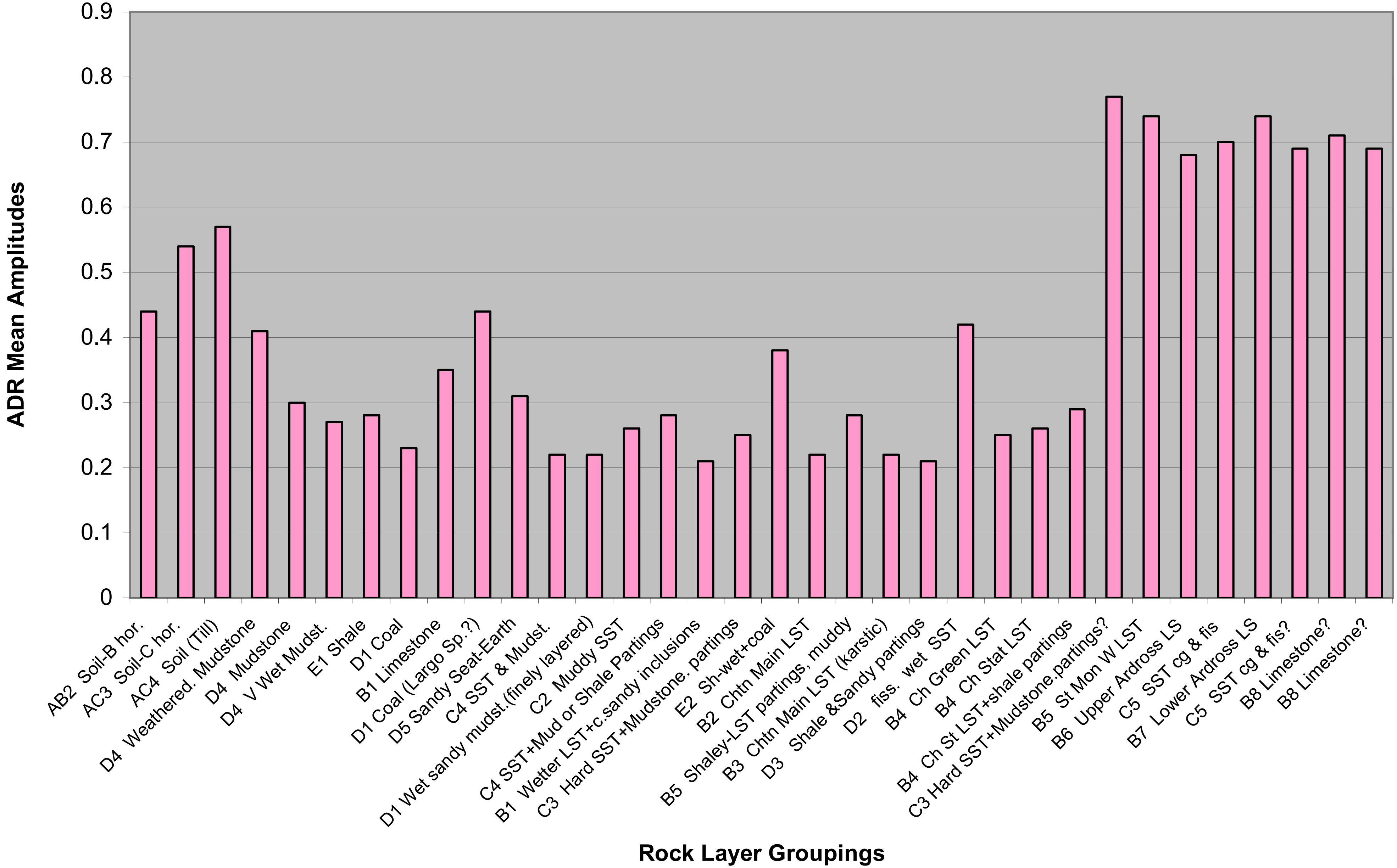
Adrok Sub-layer Classification

Horizon	Thickness (m)	Dielectric Constant	Base Depth (m)	ADR Scanner Prognosis - Code and Possible Rock Type
1	0.21	6.6	0.21	AA1 Topsoil
2	0.54	7.85	0.75	AB2 Soil-B horizon
3	0.38	11.15	1.12	AC3 Soil-C horizon (Till)
4	0.64	9.56	1.76	AC4 Soil C weathered parent material (Till)
5	0.42	9.86	2.18	D4 Weathered Mudstone
6	0.65	3.09	2.83	D4 Mudstone
7	0.2	20.43	3.03	D4 Very Wet Mudstone
8	0.63	8.13	3.66	E1 Shale
9	0.35	4.35	4.01	D4 Mudstone
10	0.44	9.91	4.44	D4 Mudstone
11	0.85	7.94	5.29	D4 Mudstone
12	0.96	9.67	6.26	D1 Coal
13	0.76	10.01	7.02	B1 Limestone
14	0.64	5.02	7.66	D1 Coal (Largoward Splint?)
15	0.48	10.68	8.14	D5 Sandy Seat-earth
16	0.59	7.05	8.72	C4 Sandstone with Mudstone
17	0.34	16.04	9.07	D1 Wet sandy mudstone (finely layered)
18	0.67	3.22	9.74	C2 Muddy sandstone
19	0.65	7.11	10.39	C4 SST + Mudstone or shale partings?
20	0.55	11.63	10.93	B4 Wetter LST+ coarser sandy inclusions
21	0.53	5.59	11.46	C3 Muddy sandstone
22	0.63	5.67	12.09	C3 Hard SST+ mudstone partings
23	0.51	10.08	12.6	B2 Sandy Mudstone?
24	0.36	23.31	12.96	E2 Shale-wet + coal
25	0.6	8.99	13.56	B2 Charlestown Main Limestone (LST)
26	0.49	18.58	14.05	B5 Shaley-LST partings, muddy
27	0.43	13.34	14.48	B2 Charlestown Main LST (Massive LST)
28	0.6	5.8	15.08	B2 Charlestown Main LST
29	0.62	6.41	15.69	B2 Charlestown Main LST
30	0.49	4.91	16.18	B3 Charlestown Main LST (karstic surface) textural
31	0.49	4.95	16.66	B2 Charlestown Main LST
32	0.25	15.11	16.91	B3 Charlestown Main LST (karstic surface) textural
33	0.66	5.99	17.57	B2 Charlestown Main LST
34	0.42	4	17.99	B2 Charlestown Main LST
35	0.2	25.58	18.19	B3 Charlestown Main LST (karstic surface) textural
36	0.47	17.89	18.66	B2 Charlestown Main LST (Massive LST)
37	0.31	35.53	18.97	B3 Charlestown Main LST (karstic surface) textural
38	0.36	4.59	19.34	B2 Charlestown Main LST (base of exposed section)
39	0.28	19.61	19.62	D3 Shale and sandy partings
40	0.43	22.23	20.05	D3 Shale and sandy partings
42	0.39	22.95	20.81	D2 fissured wet SST
43	0.31	29.94	21.12	D2 fissured very wet SST
45	0.48	8.19	22.09	B4 Charlestown Green Limestone

Quarry checked by geologist



Cults Rock Classifications based on Mean Amplitudes



Case History 1 Conclusions

Principal rock types typecast in Cults Quarry classified by ADR weighted mean frequency (WMF) analysis

Selected Horizons	Horizon Typecast and Classified	Mean Er	Mean Amplitude	Mean FRQ (MHz)	Weighted Mean FRQ(MHz)
30,32,35,37	B2 Chtn Main Limestone	20.28	0.22	358.47	133.35
39,40	D3 Shale & sandy partings	20.92	0.21	353.16	128.15
42,43,61,64	D2 fissured wet SST	32.86	0.42	336.12	280.25
45	B4 Chtn Green LST	8.19	0.25	341.33	161.9
51,52,54,57	B4 Chtn Station LST	12.55	0.26	341.29	234.09
55,56,58	B4 Chtn Stat LST+sh. Partngs	8.66	0.29	345.32	245.22
67	B5 St Min W.LST	5.14	0.74	320.36	317.57
70	B6 Upper Ardross LST	7.58	0.68	314.76	313.45
73,74	C5 SST c.g & fissured	16.22	0.7	321.54	325.23
80	B7 Lower Ardross LST	9.31	0.74	319.9	323.97

10 sample horizons from the 80 rock layers identified by the Adrok Scanner in the quarry were analysed further by Spectral Analysis.

The correlation between Mean Amplitude and Weighted Mean Frequency is +0.89, which is a positive correlation and significant at the 99.9% confidence level for 8 degrees of freedom.

Adrok Scanner clearly demonstrated that it had successfully identified the principal rock types at this site, as well as achieving much deeper penetration than would have been possible by conventional GPR systems.

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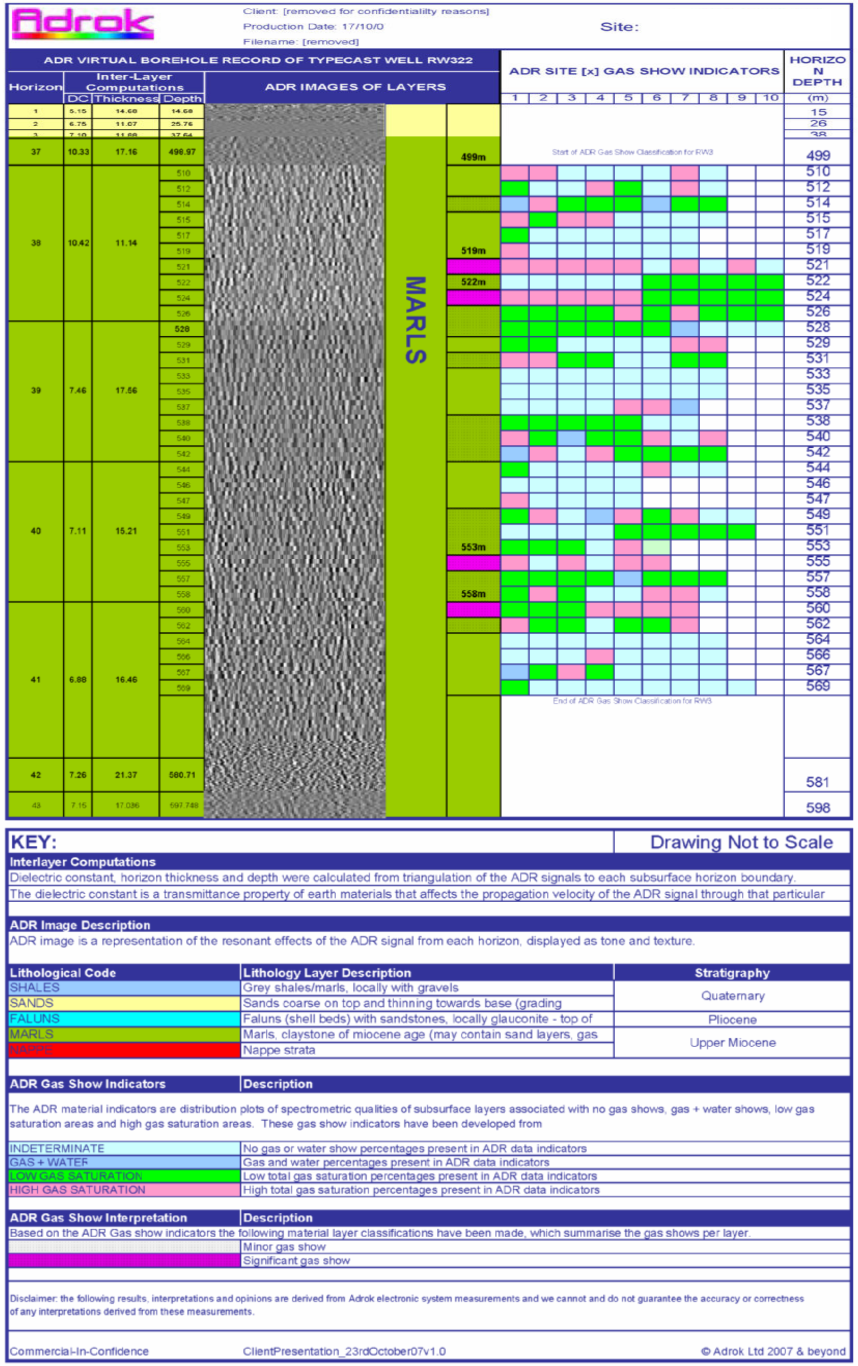
Case History 2
Onshore N. Africa, thin gas horizons

- Survey Area located in North Africa
- Adrok trained on 3 drilled well locations (for gas & sedimentary rock layer signatures)
- Surface terrain comprised low lying hills and scrubland
- Tortonian sand reservoirs
- Gas horizons were very thin (less than 1m thick).
- Prospect site was 42km offset from training well location
- The results of the Adrok survey were compared to the actual drilling results (Adrok presented results before drilling commenced).
- Adrok produced Virtual borehole log charts
- No HSE accidents



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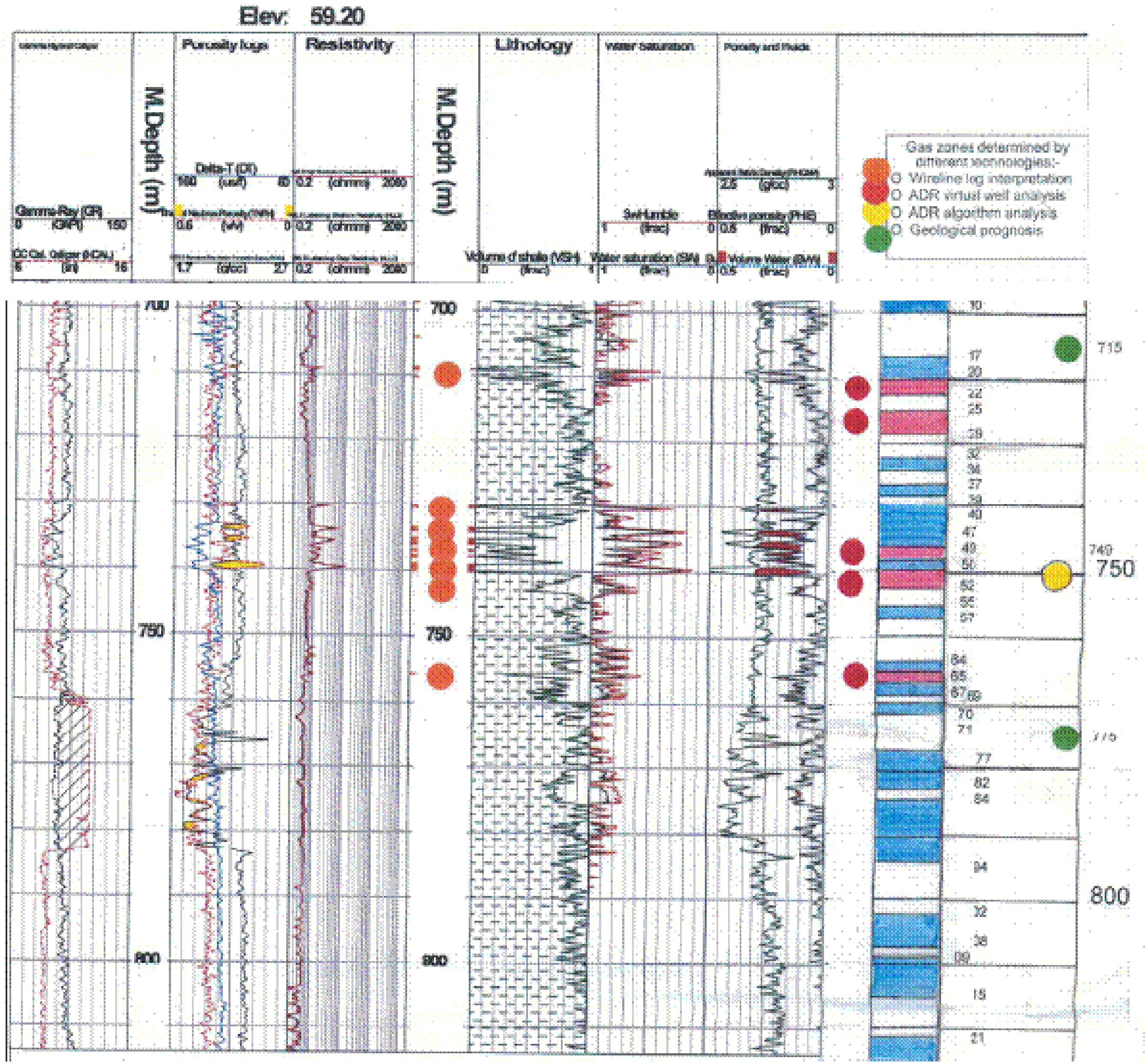

Composite Log comparing ADR Scanner results with Seismic AVO, & down-hole tools showed that ADR gas layer findings (red dots) were more accurately identified than AVO (green dots).

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Case History 2
Client Conclusions

Interpretation and Conclusions

From Log Plot A, at DNO-1, depths of gas sands predicted by pre-drilling ADR analysis and those determined by wireline log analysis are shown to be similar to within a few metres. This provides good evidence that ADR is a successful predictive technology in gas exploration.

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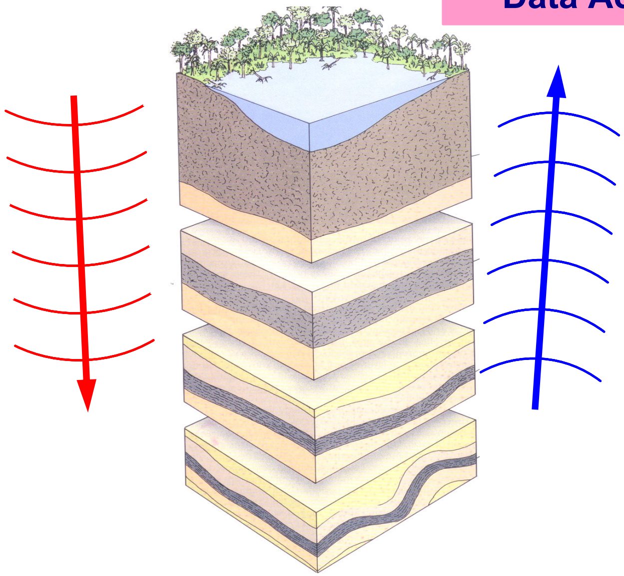
Adrok Survey Process

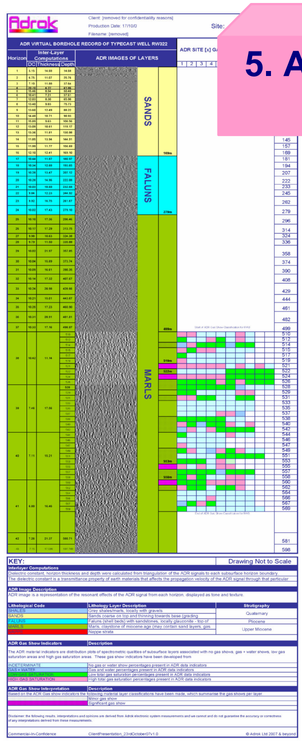
1. Pre-survey field modeling

2. Training for geological signatures

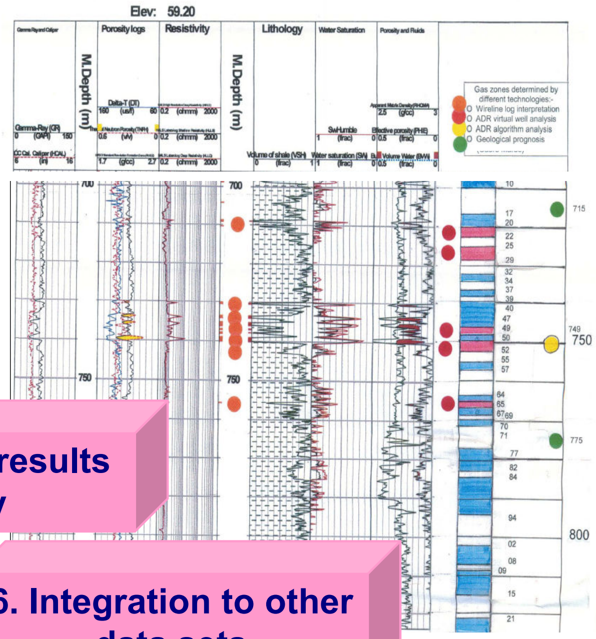
3. On-site Survey Data Acquisition



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

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Summary & Conclusions

- **Adrok Scanner**
  - Field proven innovative geophysical system
  - Based on 5 strong sets of scientific procedures (“5Rs”)
  - Helps map, locate & identify oil, gas, water & minerals from the surface with precision & confidence
  - … therefore helps reduce drilling dry holes

- **Adrok Survey Services**
  – onshore & offshore Virtual Borehole logs
  - Appraisal
  - Field delineation and gross volumetrics
  - Infill drilling location identification and confirmation
  - 2D structural surveying
  - Small scale exploration

Thank You

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