Dragging Onshore and Offshore Exploration into the Quantum Age: using novel electromagnetic technology

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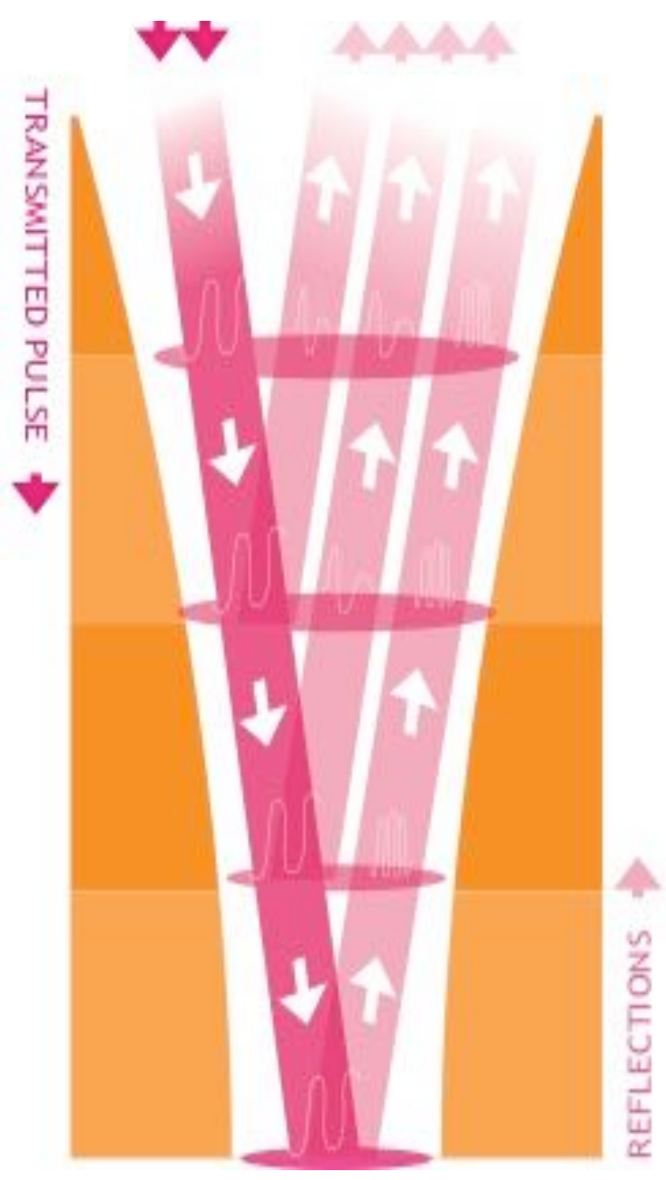
1. Introduction

Although available to the market for over four years, Atomic Dielectric Resonance (ADR) technology is viewed with scepticism by industry geophysicists, many of whom erroneously dispute the systems depth penetration based on an incorrect application of the skin depth concept derived from Maxwell's equations for planar waves in a conductor. Because the geophysical profession is looking for analytical as well as empirical results, the presentation of positive field-results has unfortunately not appreciably resulted in new business for Adrok in the Oil Industry, in particular. (Adrok has grown rapidly in the Mining Industry, by contrast, over the past few years.) Notwithstanding, Adrok has performed a number of onshore Exploration and Appraisal projects for a number of different Oil Companies.

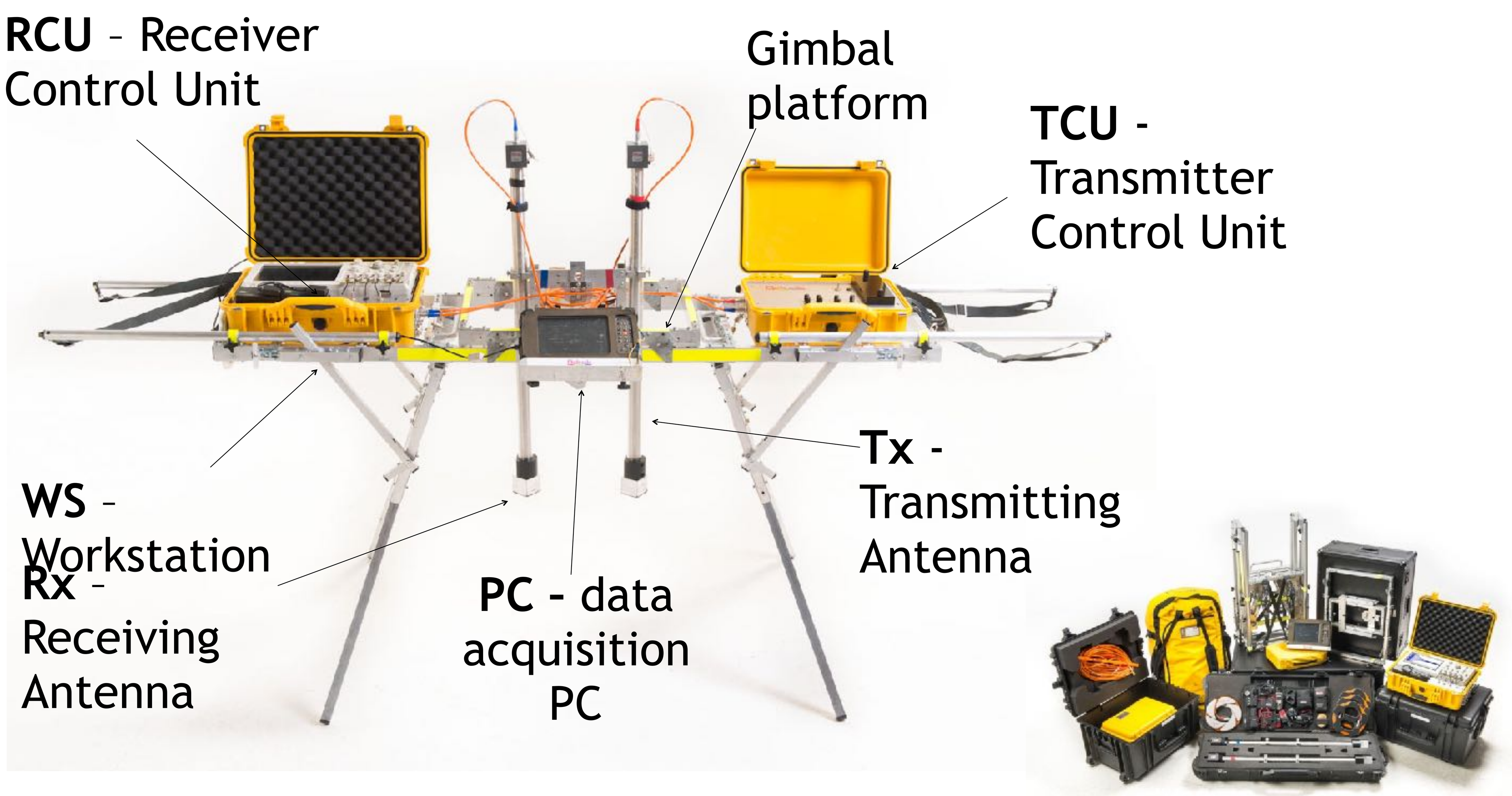
This publication discusses the technology in more detail as well as present a number of case studies by way of empirical evidence of the technology's efficacy in Exploration and Appraisal activities.

2. The Technology: Atomic Dielectric Resonance (ADR)

- RAdio Detection And Ranging in visually opaque materials
- Transmit pulsed broadband of radiowaves and microwaves
- Depending on depth of investigation transmit between 100kHz to 1GHz
- For large depth mining exploration typically transmit between 1MHz to 100MHz
- ADR sends broadband pulses into the ground and detects the modulated reflections returned from the subsurface structures
- ADR measures dielectric permittivity of material
- ADR also uses spectral content of the returns to help classify materials (energy, frequency, phase)

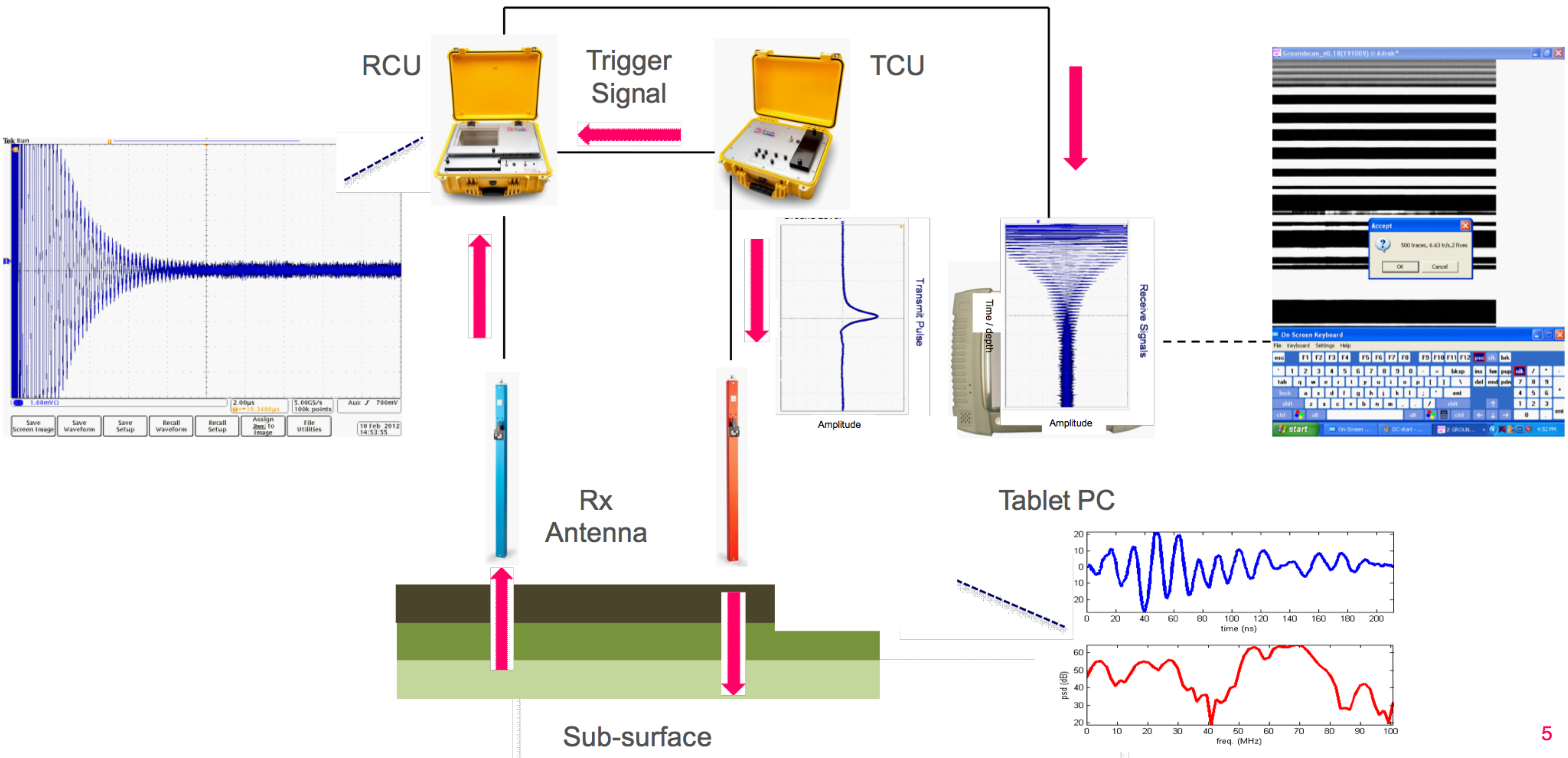


2.1 Field ADR Scanner



2.2 Laboratory ADR Scanner

2.3 System Diagram



2.4 Specifications

ADR Setting	Typical Range
Tx frequency maximum	12.5MHz-10GHz
Tx frequency minimum	100kHz-1GHz
Time Range	2ns to 250,000ns
Number of pixels per trace	40 to 4000
Pulse Repetition Frequency (PRF)	10-100kHz
Pulse Width	0.1ns to 10ns
Power supply	4 off 24Vdc Li-Ion batteries
Power consumption	150W for ADR equipment *plus* 100W for tablet PC
Power transmission	< 5 miliwatts (mW)

2.5 Simulation & Forward Modelling

- Maxwell equations coupled to ground model
  - Propagate pulse straight down and back
  - Collect voltage at virtual detector point
  - Spatially variable ground parameters:
    - Relative permittivity
    - Conductivity
    - Debye relaxation time
  - 8th order finite-difference time-domain (FDTD) numerical simulation
  - Perfectly matched layers (PML) at simulation boundaries
  - Add Gaussian noise to simulation output
- All model parameters calibrated to experiments
- Ground model: permittivity, conductivity and polarization (P)
- E electric field, σ conductivity, τ Debye relaxation time, εr dielectric
- Resulting system of partial differential equations:

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

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

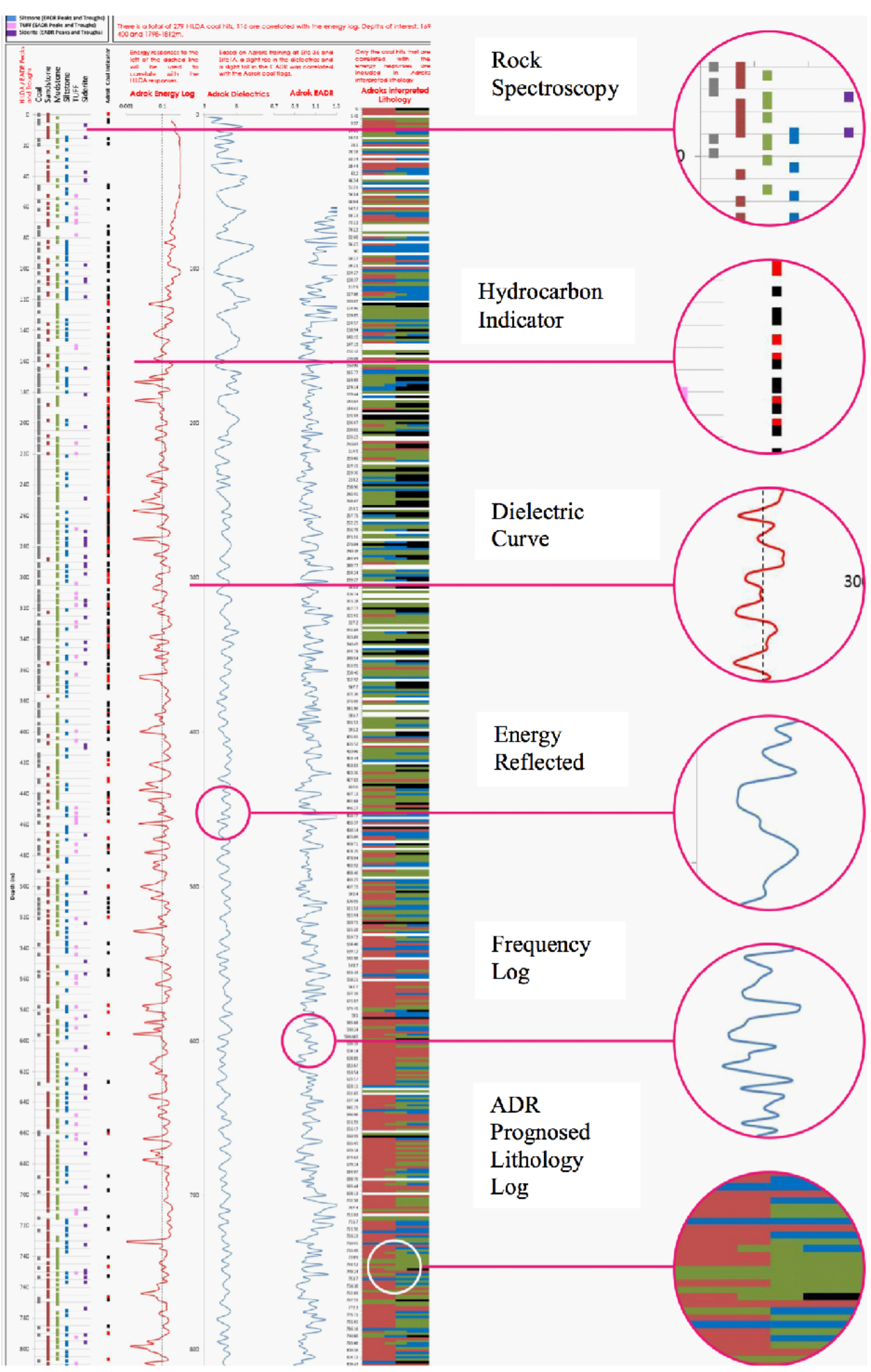
3. Virtual Lithological Logs

In the field, four main types of field survey are conducted WARR Scan, P-Scan, WARR stares and stare scans. The tracked WARR files are used to rectify depths along the survey section these can be used to rectify the stares. These Scans exist in a TIME domain but by using proprietary software the image can be rectified into a SPACE domain. FFT analysis can be carried out in both domains yielding energy, frequency and phase results but it is important to realise that frequency on a time domain image is measured in cycles per second (Hz) whereas frequency on a space domain image is measured in cycles/ m. The time domain image is used to produce spectral lines and other spectral statistics such as range and reflectivity, all of which help to classify/ identify lithological units or mineral and rock types. The space domain image can provide useful spectral statistics for identifying structural features such as faults, fractures and fissures.

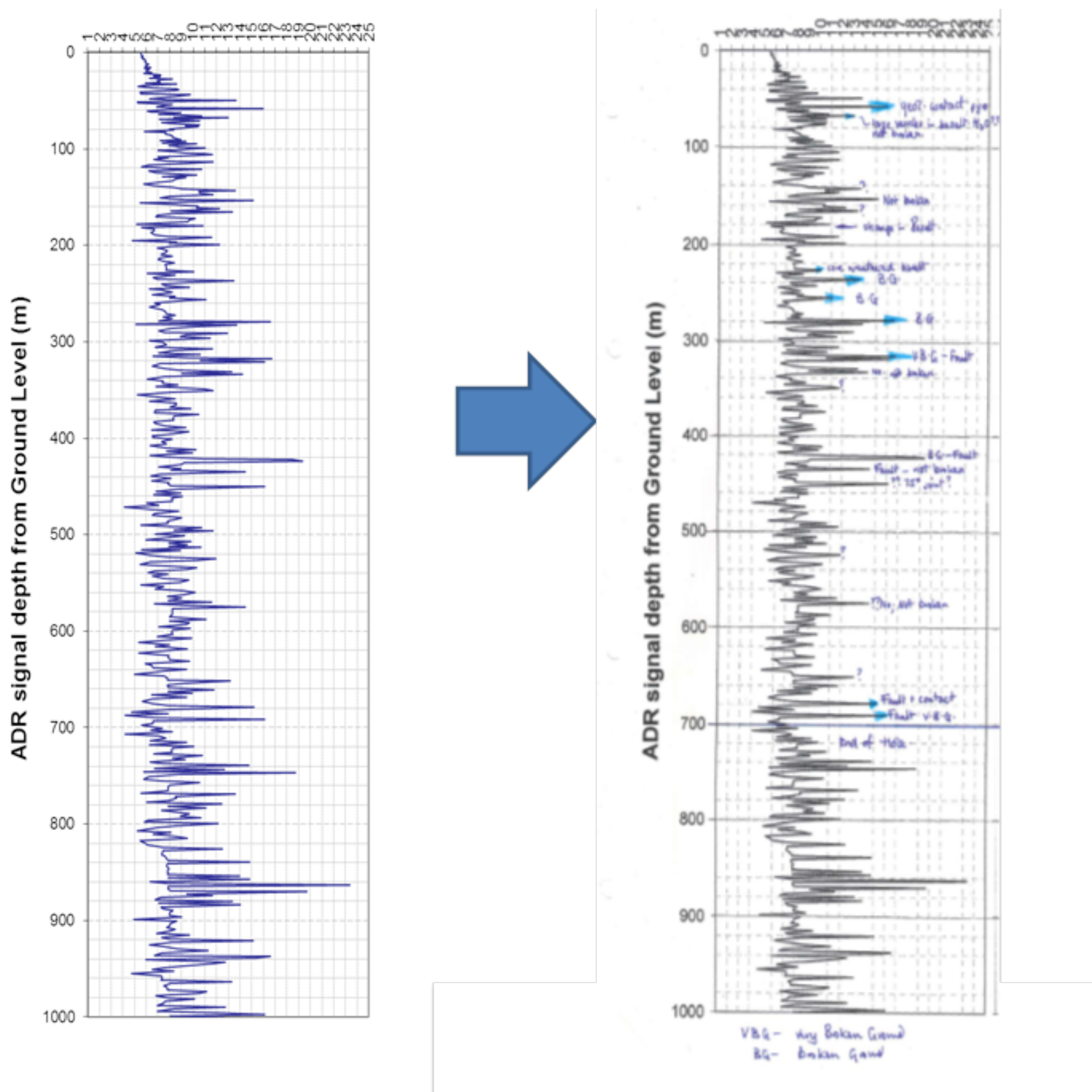
A variety of measurements can be made, which when taken together should give a specific signature for the material under investigation (“Spectroscopy”). Spectral lines are produced at the atomic scale, and can be used to identify the material composition of any medium capable of transmitting a beam of light (in this case a lased ADR beam of radiowaves and microwaves). They result from the interaction at the quantum scale between radiowave and microwave photons in this coherent beam and atoms or molecules of rock layer materials. Such measurements include Spectral Line analysis, ADR Resonant Energy Ratio and the ADR Energy Gamma method.

The outputs from the processing gives information in a lithological form showing Energy Log, Dielectrics and Energy ADR. Furthermore, two-dimensional images can also be collected by continuously scanning.

3.1 Adrok Virtual Lithological Log



3.2 Dielectrics picking faulting

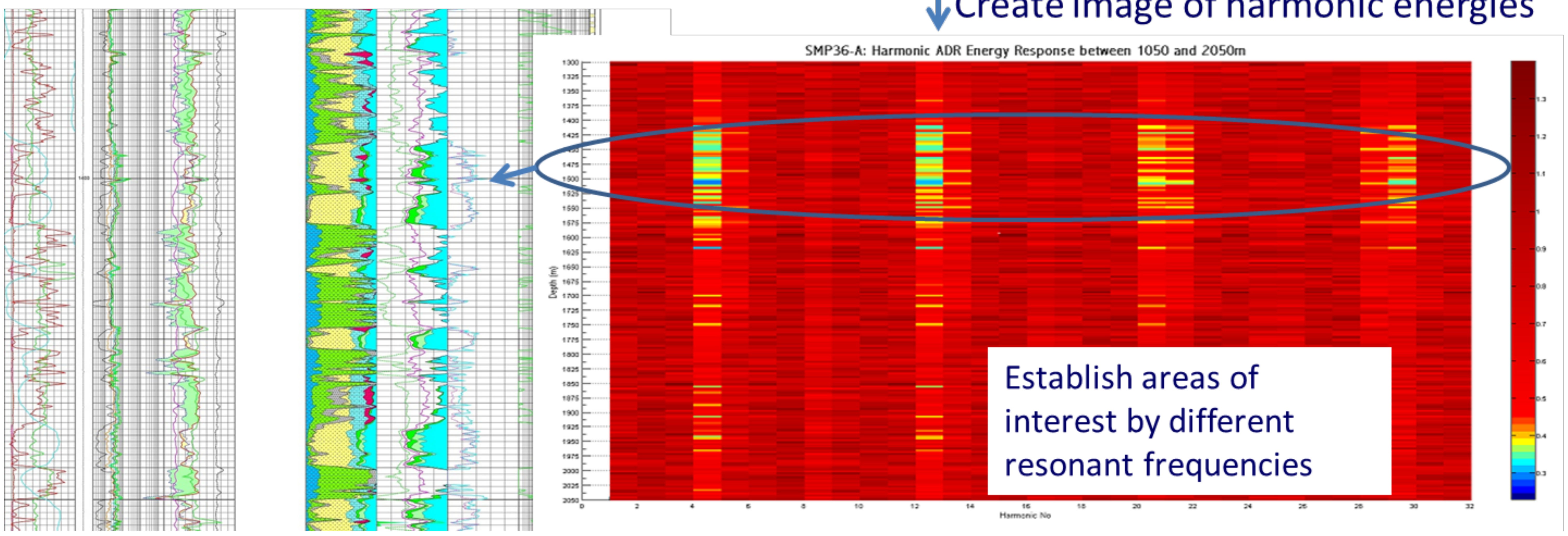


3.3 Frequency harmonics

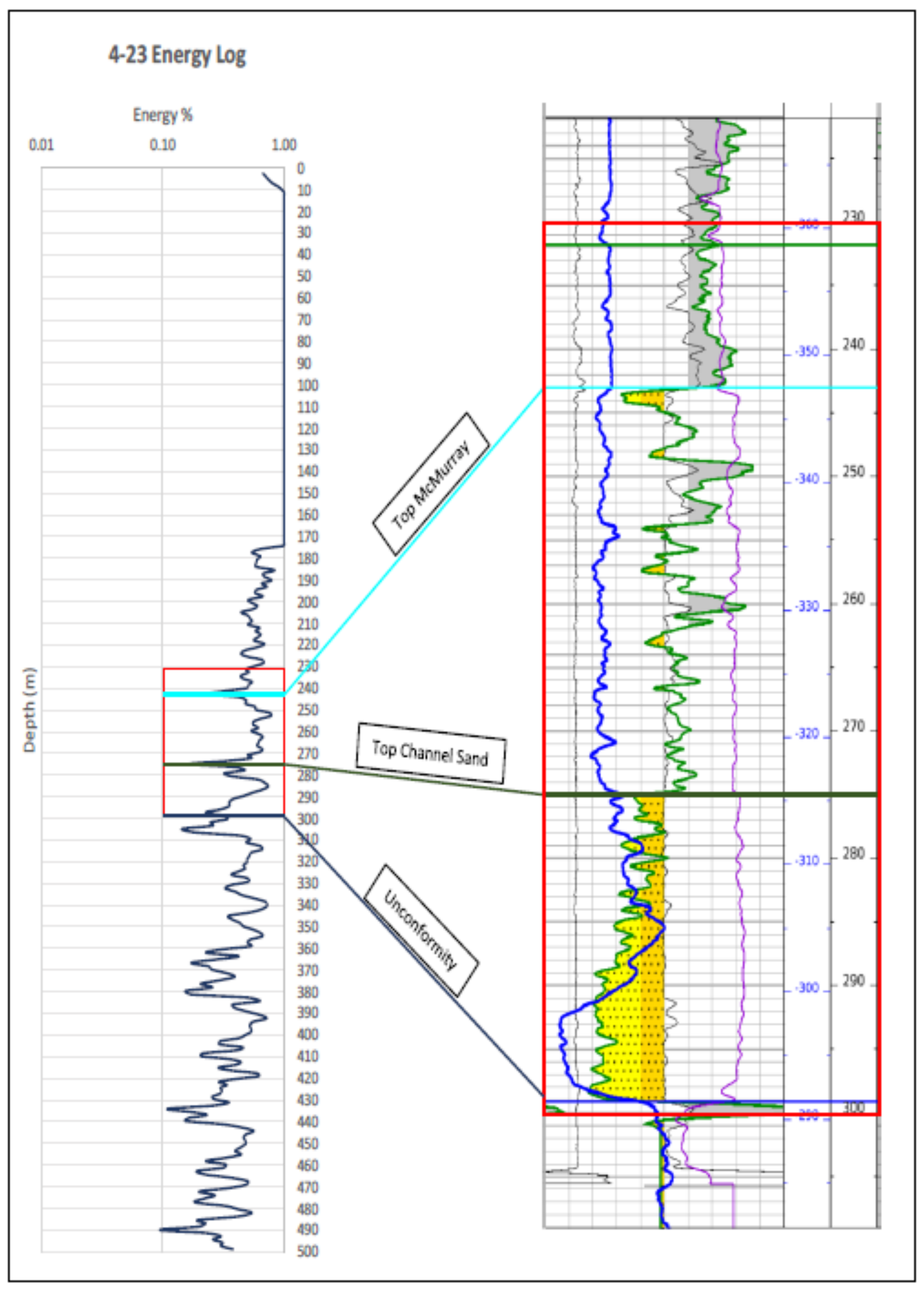
Time (ns)	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16
51	100	59.2	22.9	77.4	89.5	71.5	31.9	8.1	20.1	28.1	30.3	27.7	13.9	11.2	4.9	10.3
102	100	52.1	22	25.5	21.8	14.3	8.4	10.6	14	14.5	12	8.3	6.6	6	5.3	3.7
153	100	46.2	34.9	29.2	26.5	22.3	15	7.5	3.4	3.8	6.4	8.9	9.6	8.4	6.3	4.7
204	100	13.4	20.4	16.2	21.3	13.9	7.8	18.9	11.8	4	7.4	2.1	7.1	5.7	6.3	6.5
255	11.4	34.2	52	91.4	100	22	51.1	22.9	21.8	15.1	6	21.7	17	11.1	24	24
306	100	53.6	30	36.3	59.3	40.7	34.4	29.7	27.3	15.5	8.4	14.1	25.9	29.7	24.4	16
357	100	71.5	36.1	22	21.1	20.4	9.6	14.5	13.5	9.1	8	11.9	7	6.4	7.7	6.9
408	100	92.5	63.2	37.4	6.4	30.3	29.8	19.1	6.3	12.7	15.9	12.6	10.1	4.7	8.9	12.3
459	64.2	100	93.3	81.2	72.4	53.1	29.6	18.3	8.9	8.7	13.3	23.4	27.7	21.8	17.4	14.2

Time (ns)	H17	H18	H19	H20	H21	H22	H23	H24	H25	H26	H27	H28	H29	H30	H31	H32
51	15	6.8	1.6	2.5	1.4	1.7	1.4	4.1	3	3	3.1	1.2	0.7	0.4	0.8	0.8
102	1.4	1.2	2.2	2.2	1.8	1.3	1.5	1.8	1.3	0.6	0.3	0.6	0.7	0.5	0.3	0.6
153	3.8	3.5	3.3	2.8	2	1.3	1.3	1.5	1.6	1.6	1.4	1.2	0.9	0.8	0.8	0.9
204	4.6	5.2	3	3.2	2.9	3.2	4.3	3.5	3.5	2.5	1.6	1.6	1.3	2	1.5	1.7
255	15.2	2	2.8	8.1	5.8	3.5	8.9	21.3	8.9	6.4	9.4	9.5	4.6	1.9	2.1	3.1
306	23.8	18.2	5	12.2	16.6	13.9	11.6	13.5	16.2	9.6	3.9	6.9	5.9	3.8	7.7	8.7
357	4.6	5.1	5.3	3.8	4	3.9	4.5	2.9	3.9	4.1	3.6	3.1	4	3.5	2.6	3.3
408	10.2	3.8	5.3	9.7	7.4	4.9	3.6	4.9	6.7	5.7	3.8	2.7	5.6	5.6	3.9	2.3
459	10.4	7.4	5.4	10.4	11.7	11.2	11.6	10.8	9.4	7.2	5.3	5.3	5.2	6.4	7.4	7.3

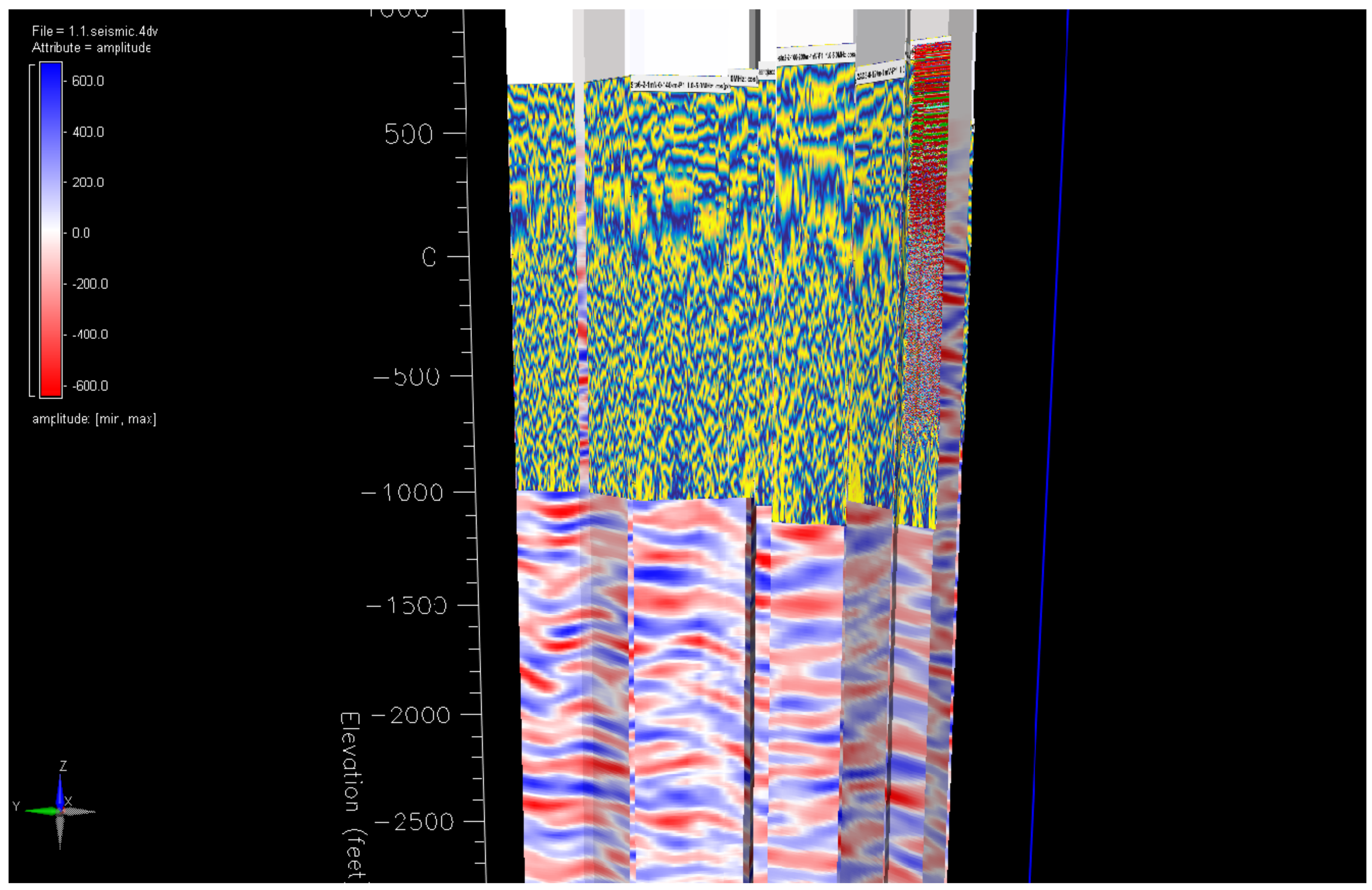
Create image of harmonic energies



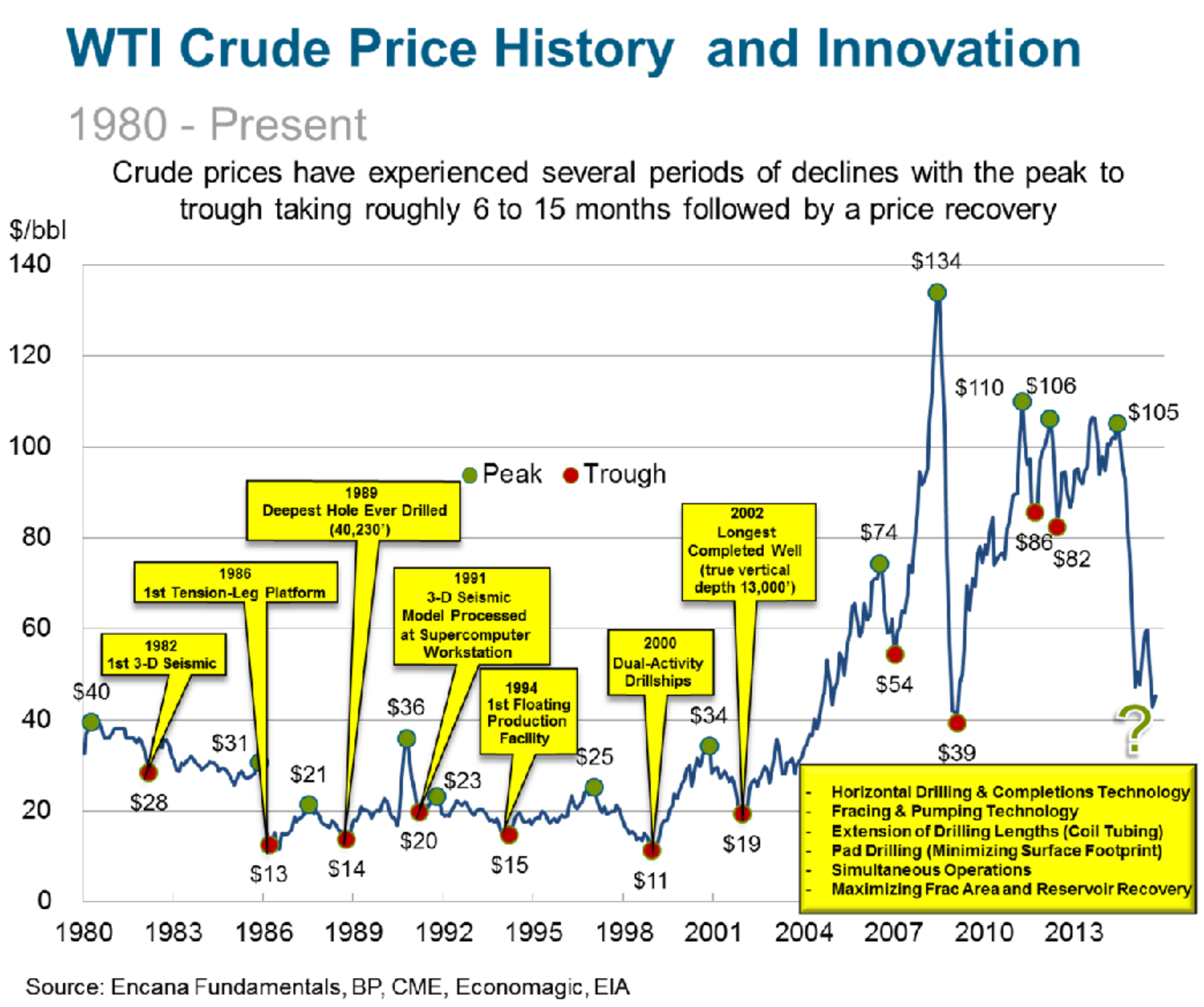
3.4 ADR Energy Log v Gamma ray



3.5 ADR 2D Imagery enhancing Seismic



4. Applications of ADR coming soon….



Innovate UK

IGas Energy

Adrok

Energy Catalyst - Early Stage Feasibility - Round 3

Feasibility study for innovative remote sensing to increase onshore UK gas production (kicked-off October 2016)

Subsea ADR deployed from ROV launched May 2016