Simulation Model of typical geothermal play in Tenerife, The Canary Islands

Dr Kees van den Doel & Gordon Stove, Adrok

May 2024

The Solution

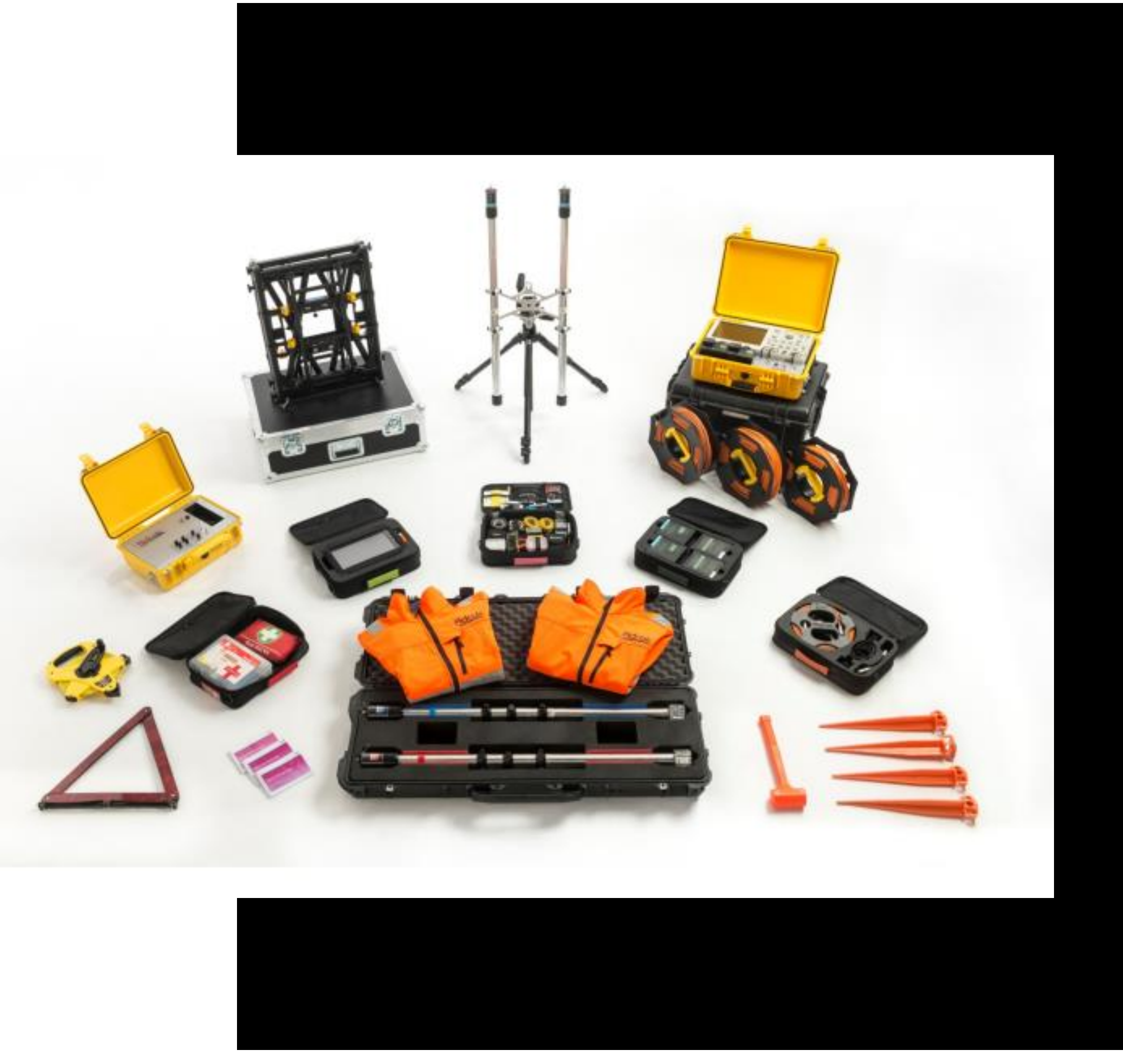
Predrilling Virtual Logging®

Using pulsed electromagnetic ADR Technology, we can now **Digitally Drill** to virtually determine the existence of subsurface natural resources, temperature and fluids without the need for invasive drilling

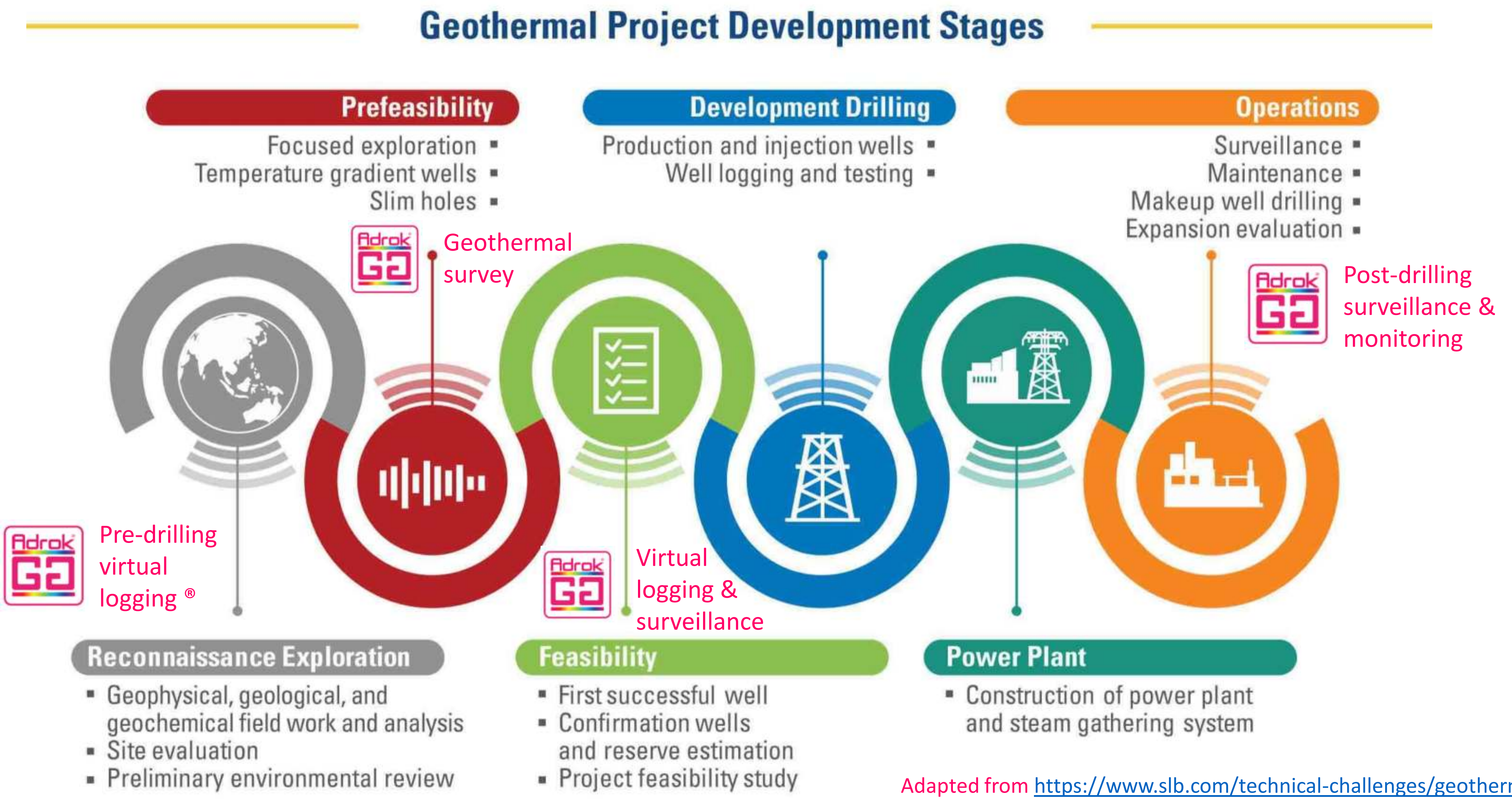
ADR allows the measurement of subsurface rock, mineral, fluid, temperature and gas conditions from the earth's surface, non-destructively

No need for extensive cable laying across fields compared to seismic & MT methods, as EM pulse is used

Our technology reduces the need for exploratory drilling and therefore reduces the expense and risks associated with it

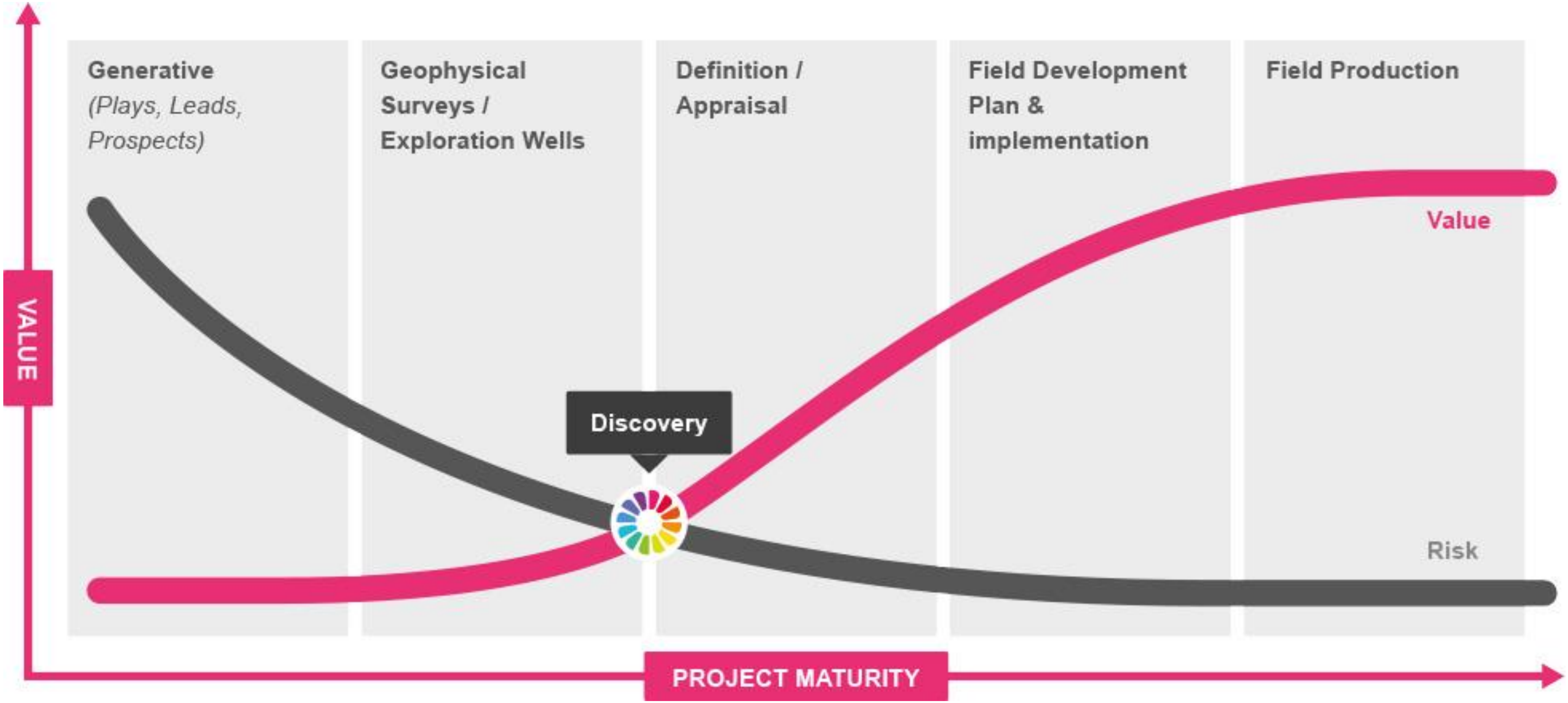


When to utilize an Adrok survey?

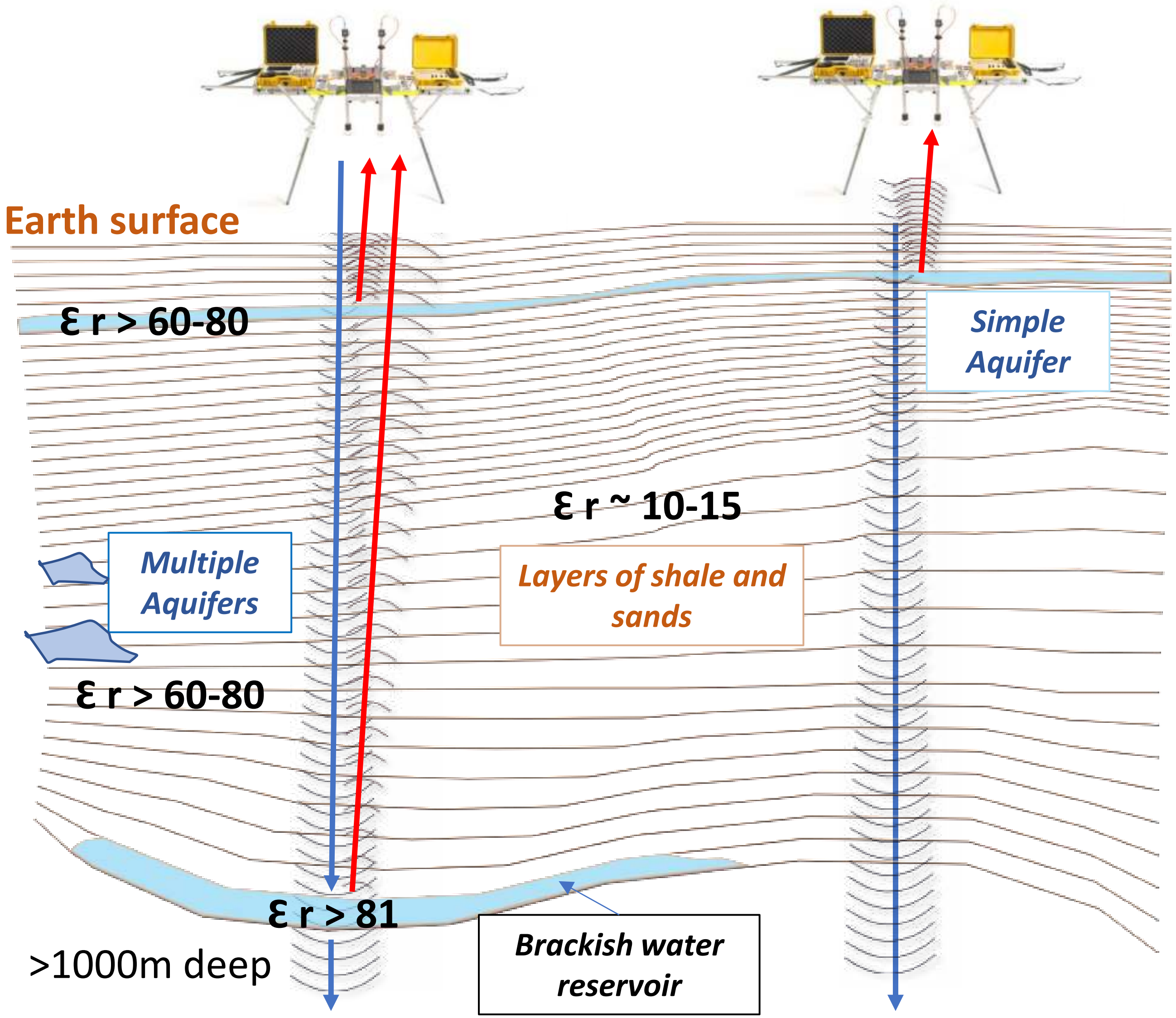


Adapted from https://www.slb.com/technical-challenges/geothermal

Deeper. Faster. Greener. Cheaper.



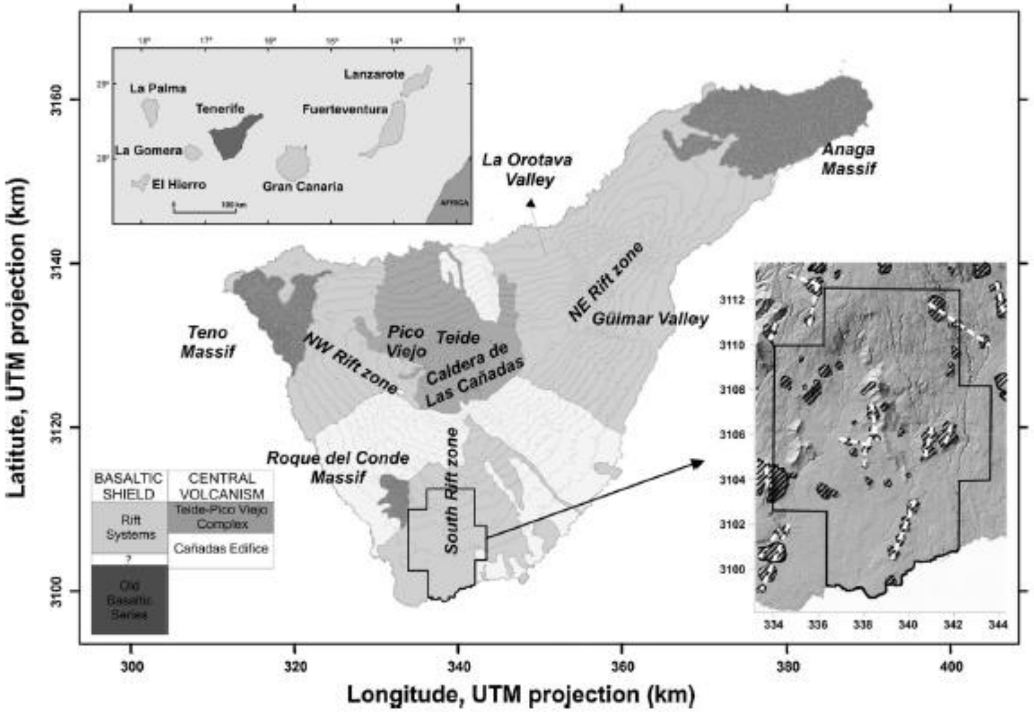
How the technology works



- Transmits broadband pulses of radio waves between **1 to 70 MHz** into the ground.
- Detects the modulated reflections returned from the subsurface structures.
- Measures dielectric permittivity (Ɛ r) and conductivity of material.
- Analyses spectral content of the returns to help classify materials (energy, frequency, phase).
- Time & frequency domain.
- Time ranges typically 20,000ns, 40,000ns & 100,000ns. This project used a 10,000ns range.
- High speed time domain sampling ~5GS/s
- Stack return signals for improved signal-to-noise 20,000, 100,000…..1million.

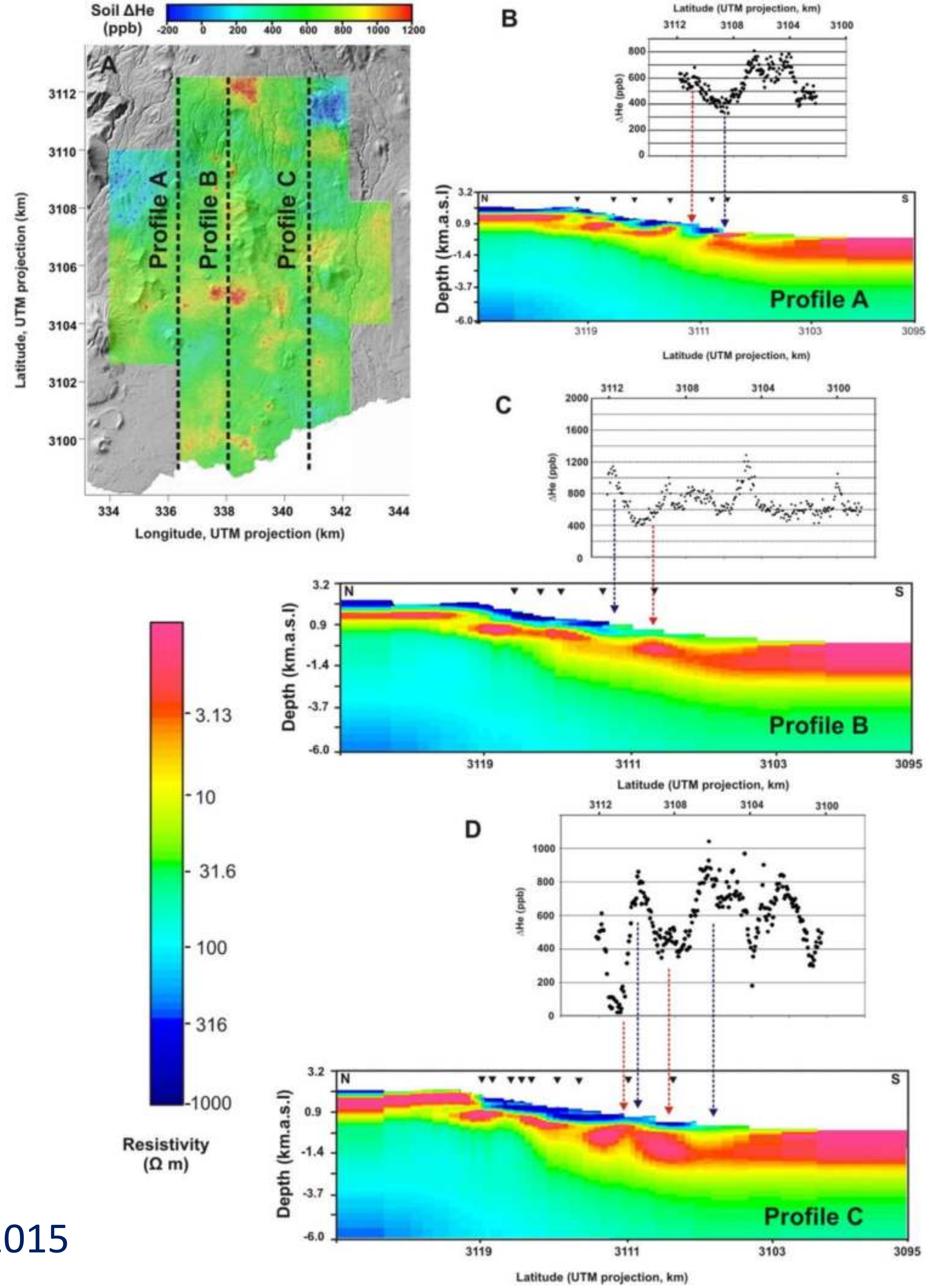
ADR Simulation Model input data

F. Rodríguez et al. / Geothermics 55 (2015) 195–206



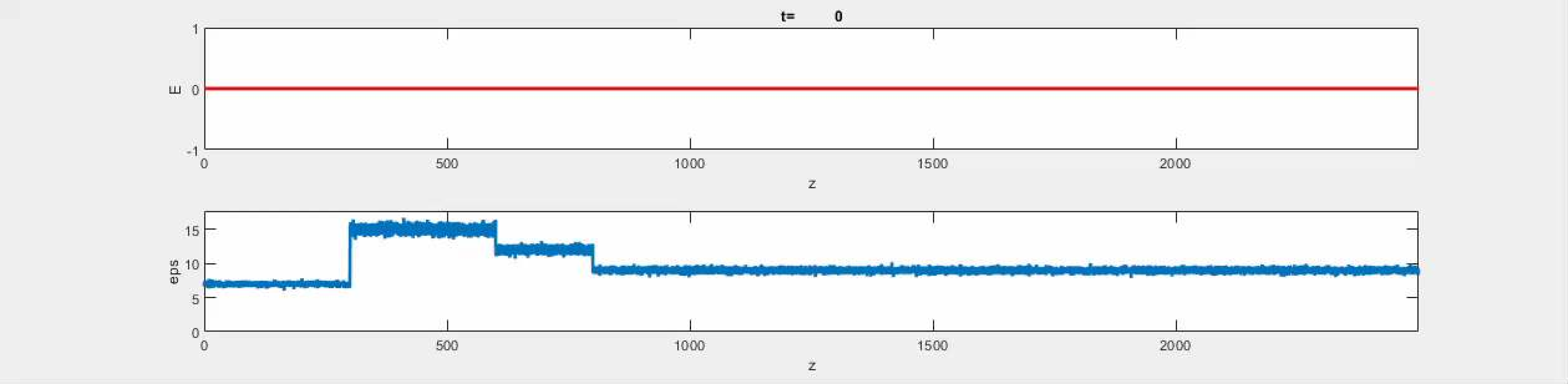
Depth bgl	Rock layer	Dielectrics	Resistivity Ω m
0m to 300m	Unaltered basaltic rocks	7	600
300m to 600m	Low resistivity central region interpreted as the clay cap of the geothermal system	15	3
600m to 800m	Basaltic rocks with higher temperature	12	60
800m to 2500m	A deeper structure associated to a hotter part of the geothermal system	9	300

- Geological data from Rodríguez et al., 2015, Surface geochemical and geophysical studies for geothermal exploration at the southern volcanic rift zone of Tenerife, Canary Islands, Spain, Geothermics, Volume 55, 2015,Pages 195-206, https://doi.org/10.1016/j.geothermics.2015.02.007(https://www.sciencedirect.com/science/article/pii/S0375650515000310)
- No drill hole data beyond 500m depth below ground level for corroboration. Resistivity and depths extracted from Figure 9C.
- Transmit ADR wave packet from transmitter (Tx) and record reflections from receiver (Rx).
- Dielectrics of the materials (DC) as indicated in table are theoretical, based on Adrok's experience of similar rock types.
- Reflection from dielectric interfaces will arrive at time.
- 2*(10sqrt(5) + d*sqrt(Er)) * 1e9/3e8, with d the thickness of each layer.



Rodríguez et al., 2015

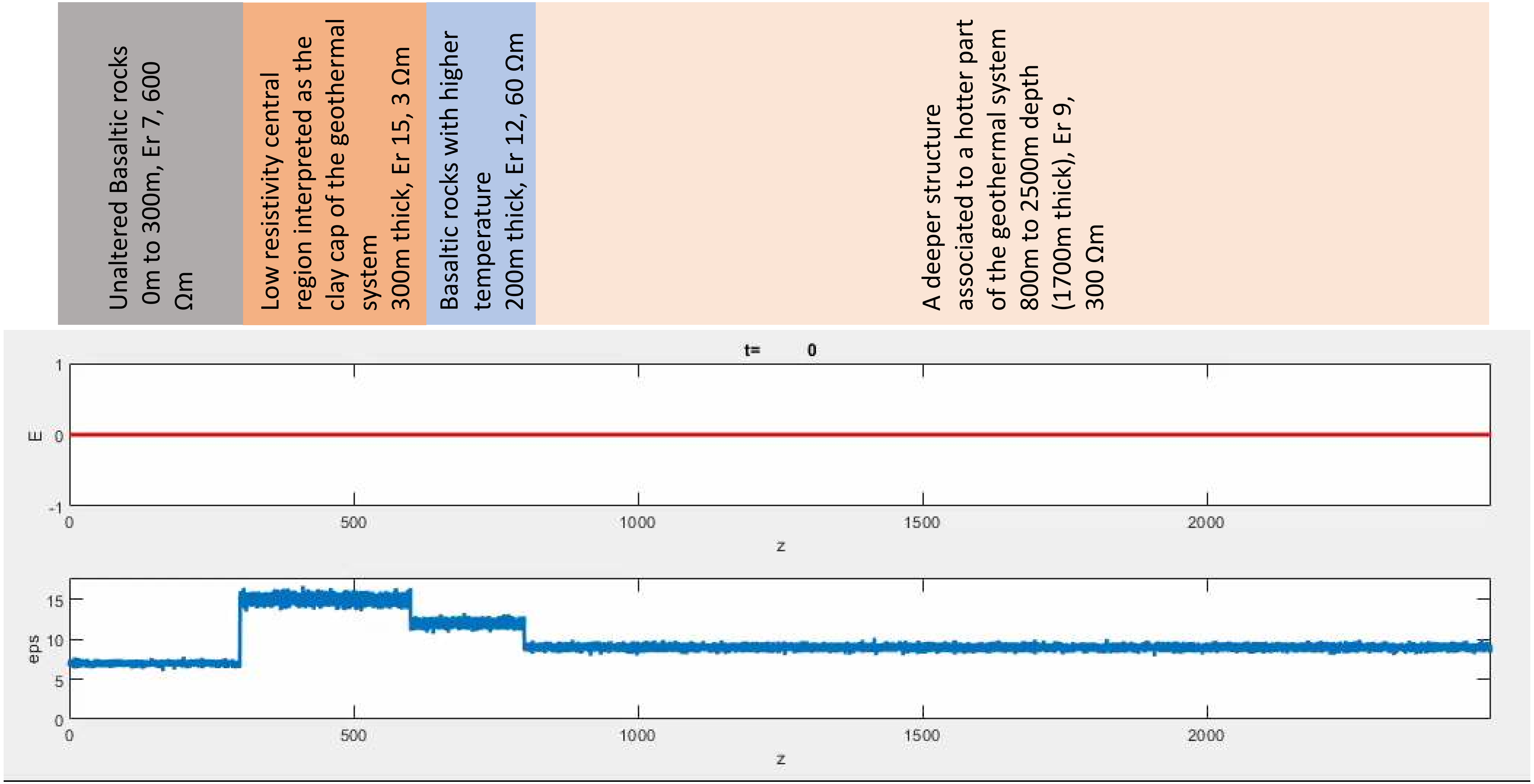
FDTD simulation of Maxwell's equations



ADR wave packet (top) travels from surface (left z=0) into the ground. At each change in dielectric (lower plot), corresponding to material interfaces, part of the wave packet is reflected back up to the surface where it is detected by the surface receiver (Rx). Homogeneous regions generate continuous backscatter (small wiggles traveling up (left)) caused by granularity of the material. This backscatter contains spectral information regarding material composition, whereas the timings of the interface reflections can be used to compute velocity and thereby dielectric.

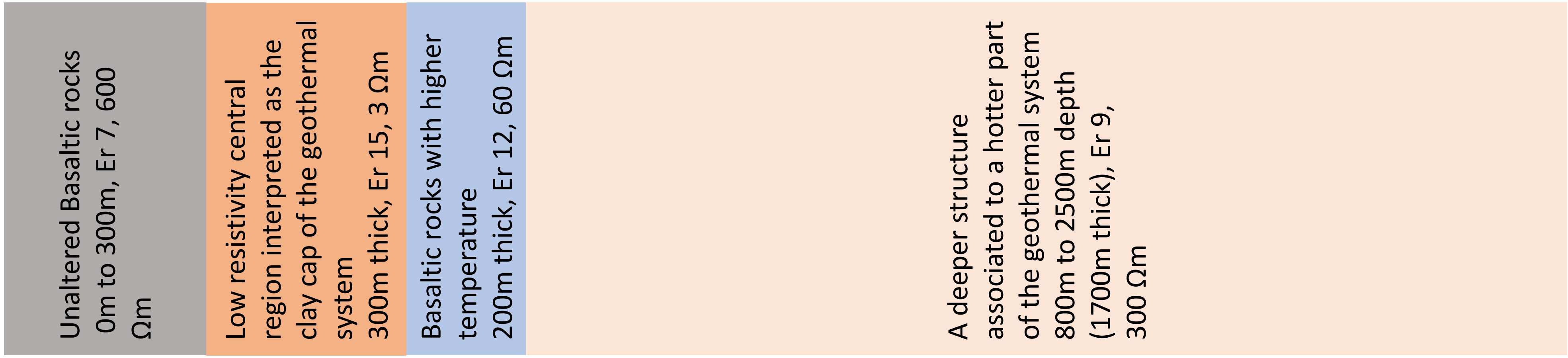
In this simulation, we see wave packet penetration to 2500m and beyond. Interestingly, we also see multiples from the 300m interface, you can see the reflection coming up, then bouncing off the ground/air interface and hitting the boundary for a second time. Something to keep in mind when analysing empirical field data in these types of rock formations.

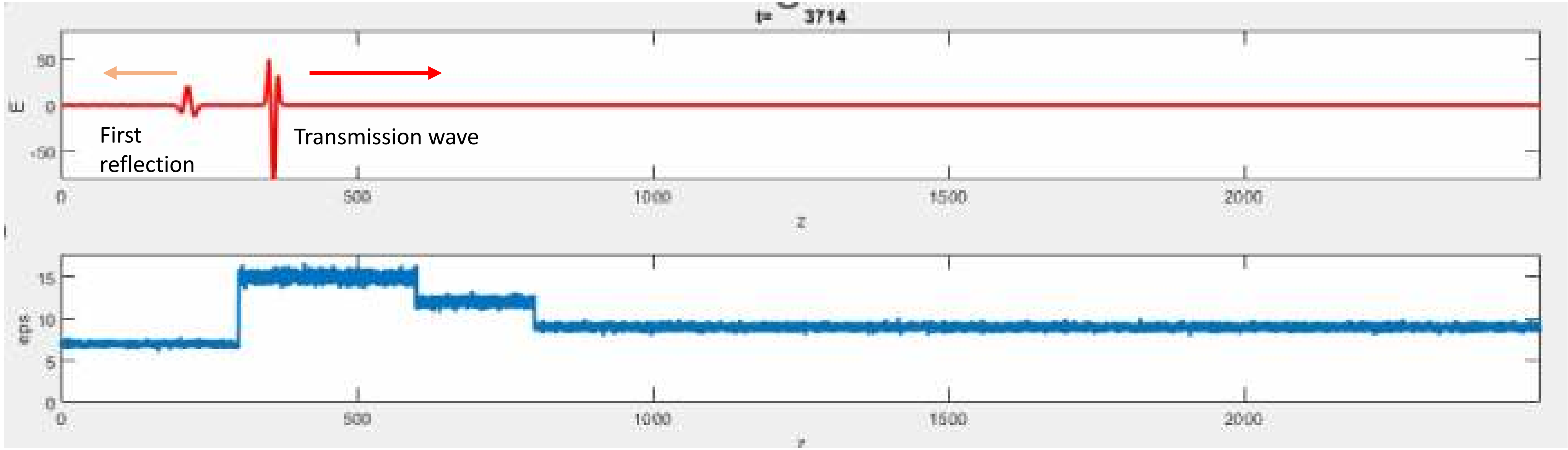
FDTD simulation showing two-way-travel of ADR signal in rock layers



Overlain rock layers from ground level (0m) through the subsurface to depths of 2500m using input data from page 2.

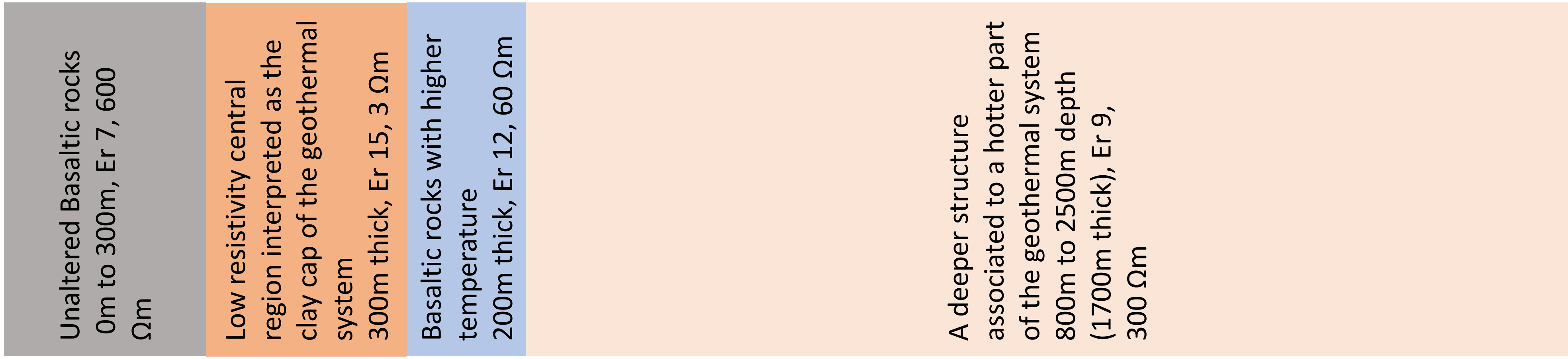
FDTD simulation showing two-way-travel of ADR signal in rock layers

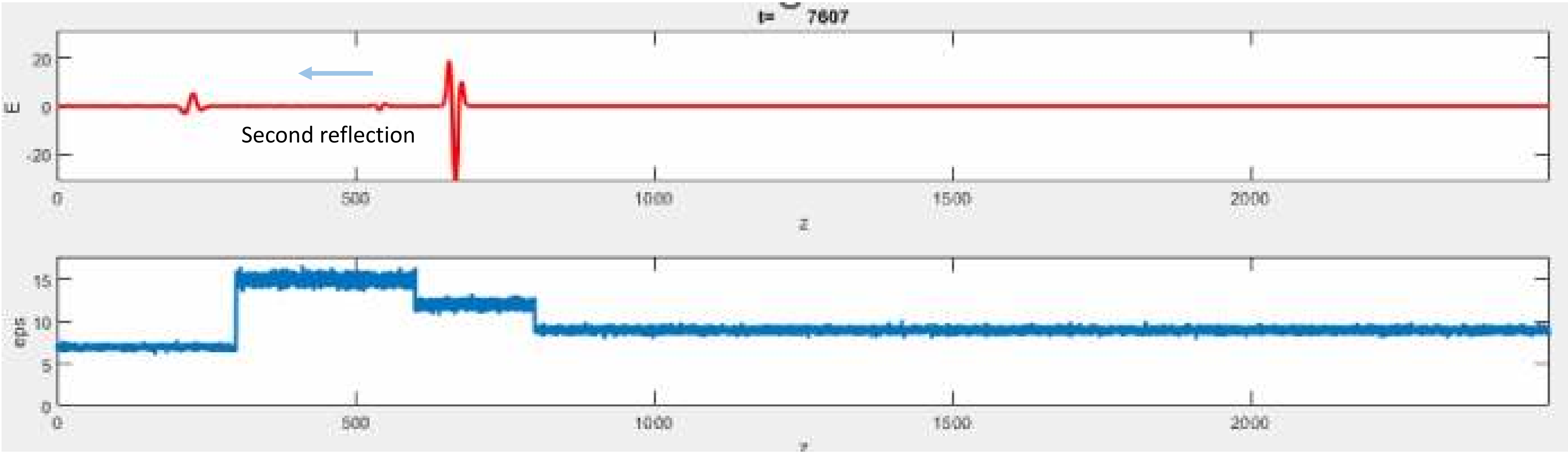




First reflection from the low resistivity central region returning to surface receiver antenna.

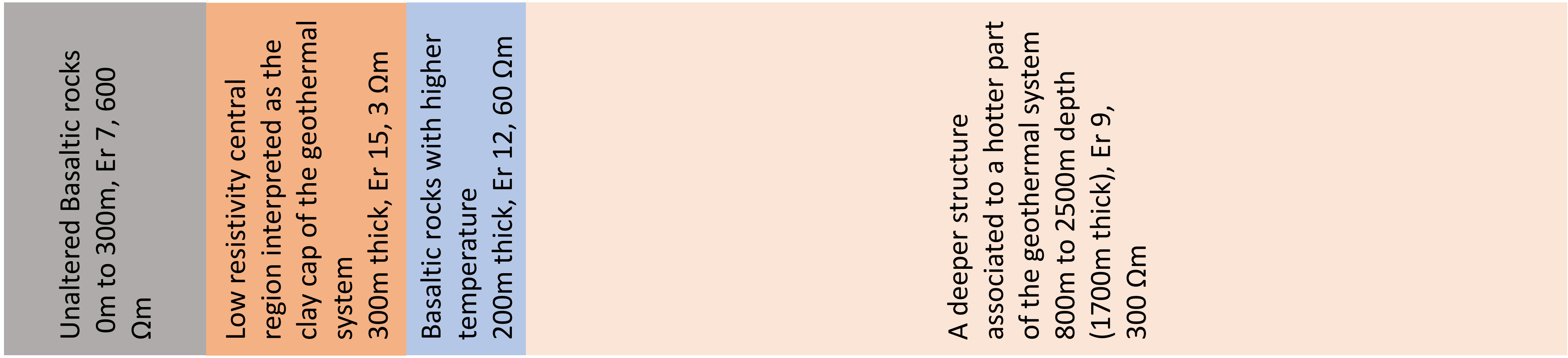
FDTD simulation showing two-way-travel of ADR signal in rock layers

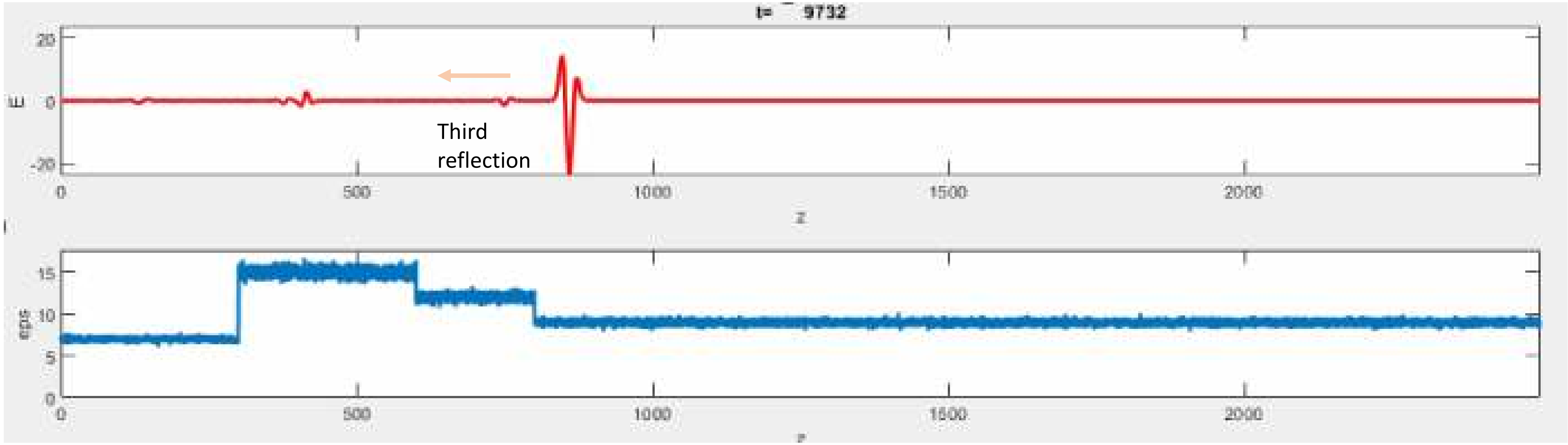




Second reflection from the basaltic rock layer returning to surface receiver antenna. This is a lower energy level return.

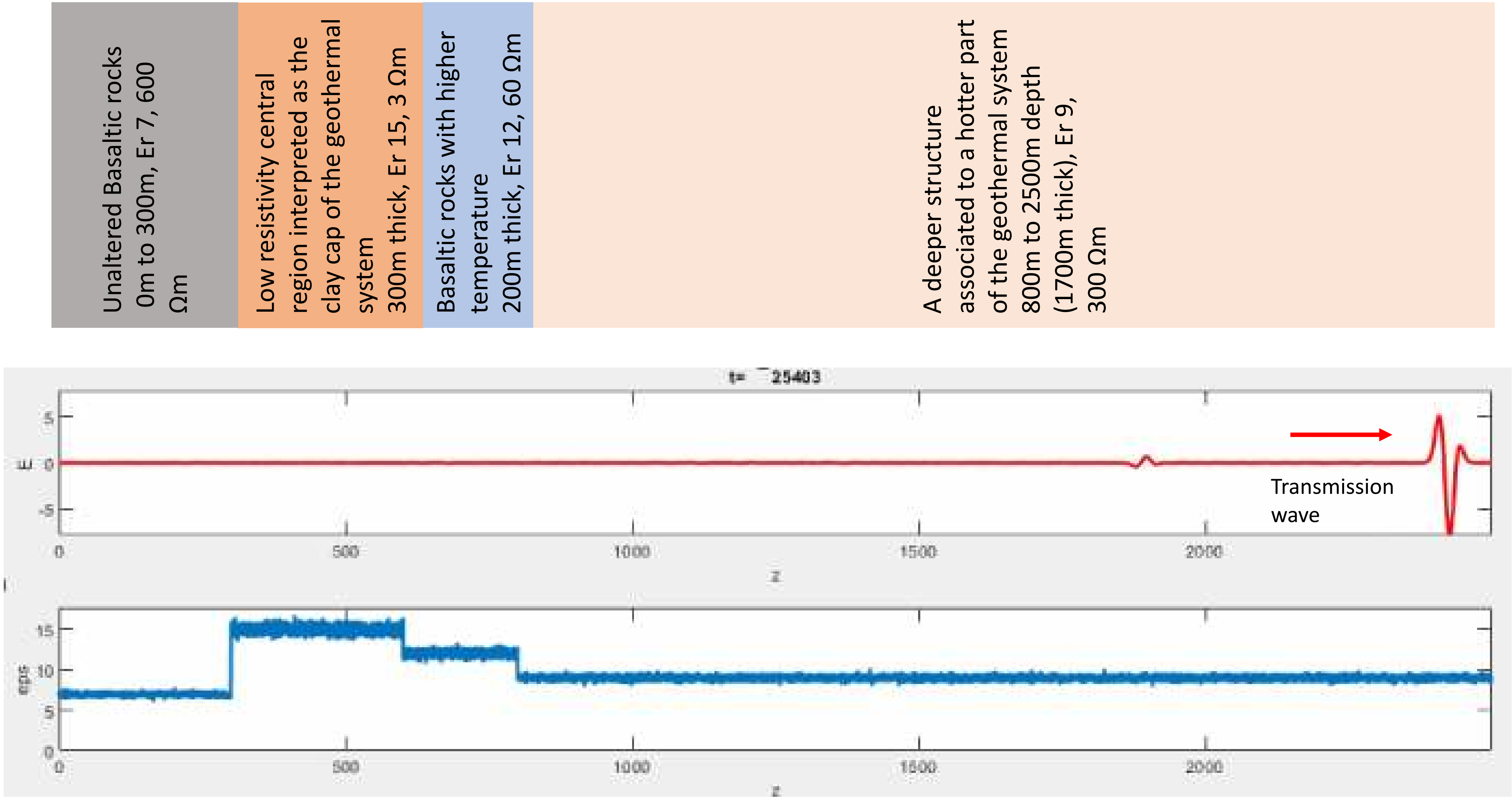
FDTD simulation showing two-way-travel of ADR signal in rock layers





Third reflection from the deeper structure layer returning to surface receiver antenna. This is a lower energy level return.

FDTD simulation showing two-way-travel of ADR signal in rock layers



Transmission wave still penetrating through the subsurface to depths of 2500m and potentially beyond.

Summary of geothermal applications

- Pulsed electromagnetic ADR waves can identify change in temperature using dielectrics, conductivity and energy reflections from return signals.
- Empirical Case Studies presented from onshore UK & New Zealand.
- Simulations presented for France, Denmark, Tenerife, Switzerland
- The field measurements show encouraging potential for the technology to be applied as a pre-drilling tool in onshore geothermal plays around the world, given the ease of survey deployment and low environmental footprint.

Measuring Temperature

The principal application for Adrok would be in the pre-drilling terrain- to prospect-scale thermal characterisation of the crust. Thermal maps could be easily generated which point towards the best target areas.

Adrok requires some calibration work before providing absolute values.

Measuring Water

Water has a high dielectric (>80). Due to this natural feature, the pulsed EM can measure peaks in relative dielectric values with depth.The identification of water-rich/aquifer layers at depth could be targeted in a similar way to the lithium brines in fracture hosted fluid pathways in Cornwall.

Monitoring temperature

Adrok can be used at key location around a geothermal borehole for example to monitor the change in temperature over time. If survey stations are established, ADR measurements could be made from the same station 12 months apart to provide a guide as to the annual change in temperature.This can, in turn, be used to better forecast the longevity of a geothermal field.

Useful in built up areas

Adrok is the only known technique that can directly target thermal anomalies in cities and towns where anthropogenic sources are often disruptive to other EM techniques for example.The ADR tool uses lower energy and several scans have been carried out in the middle of towns, on the sides of roads or even in the remote jungles! The portability and ease of manipulation of the equipment means it is very user friendly, cheap and non-invasive. NO SPECIAL PERMITS ARE REQUIRED!

Selected Publications

1. van den Doel, K., Jansen, J., Robinson, M., Stove, G.C. and Stove, G.D.C.,Ground penetrating abilities of broadband pulsed radar in the 1-70MHz range. In: SEG Technical Program Expanded Abstracts 2014, Denver. 1770–1774.
2. van den Doel, K. and Stove, G., Modeling and Simulation of Low Frequency Subsurface Radar Imaging in Permafrost. Computer Science and Information Technology, 2018 6(3), 40–45.
3. Stove, G. and van den Doel, K., Large depth exploration using pulsed radar. In: ASEG-PESA,Technical Program Expanded Abstracts 2015, Perth. 1–4.
4. Stove, G. D. C., Stove, G.C., and Robinson, M., 2018, New method for monitoring steam injection for Enhanced Oil Recovery (EOR) and for finding sources of geothermal heat. Australasian Exploration Geoscience Conference 2018 (AEGC), Sydney.
5. van den Doel, K. and Stove, G., Calculation of Optimal Noise Levels for the Detection of Conductive Lenses in Permafrost with Radar Scans, 81st EAGE Conference and Exhibition 2019 (1), 1-5.
6. van den Doel, K., Modeling and Simulation of a Deeply Penetrating Low Frequency Subsurface Radar System, 78th EAGE Conference and Exhibition 2016.
7. van den Doel, K. and Robinson, M., Numerical Simulation of Aquifer Detection Using Low Frequency Pulsed Radar, PIERS 2015, Prague.
8. Stove, G., 2018, Extending the reach of radio waves for subsurface water detection, CSEG Recorder,Vol. 43 No.06, pp 26-30
9. Stove, G., 2020, Helping De-Risk the Exploration for Suitable Geothermal Drill Targets, Geothermal Rising / Geothermal Resources Council (GRC) 2020 Annual Meeting
10. van den Doel, K, Robinson M, Stove C, Stove G., 2020, Subsurface Temperature Measurement Using Electromagnetic Waves and Machine Learning for Enhanced Oil Recovery, Conference Proceedings, 82nd EAGE Annual Conference & Exhibition, Volume 2020, p.1 – 5

Our Value Proposition becomes part of the solution

ECONOMICAL

We will be reducing exploration costs by up to 90%

CONVENIENT

Faster solution lessening the need for exploratory drilling

ENVIRONMENTALLY FRIENDLY

Harms the environment in no way

Gordon Stove
CEO & Co-founder

Adrok®

+44(0)131 555 6662

+44(0) 7939 051 829

gstove@adrokgroup.com

www.adrokgroup.com

Follow Us:

Adrok Ltd. Mitchell House, 5 Mitchell Street, Edinburgh, EH6 7BD, SCOTLAND, U.K.
Company reg. no. SC181158 | Predrilling Virtual Logging ® | Its Less Boring with Adrok ®

Our Value Proposition becomes part of the solution

ECONOMICAL

We will be reducing exploration costs by up to 90%

CONVENIENT

Faster solution lessening the need for exploratory drilling

ENVIRONMENTALLY FRIENDLY

Harms the environment in no way

Gordon Stove
CEO & Co-founder

+44(0)131 555 6662
+44(0) 7939 051 829
gstove@adrokgroup.com
www.adrokgroup.com

Follow Us:

Adrok Ltd. Mitchell House, 5 Mitchell Street, Edinburgh, EH6 7BD, SCOTLAND, U.K.
Company reg. no. SC181158 | Predrilling Virtual Logging ® | Its Less Boring with Adrok ®