Simulation Model of typical geothermal play in Italy by Adrok

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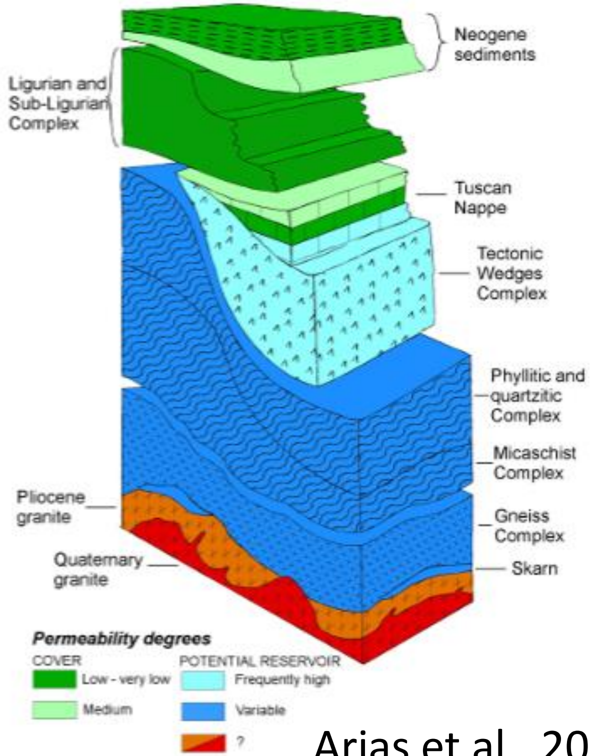
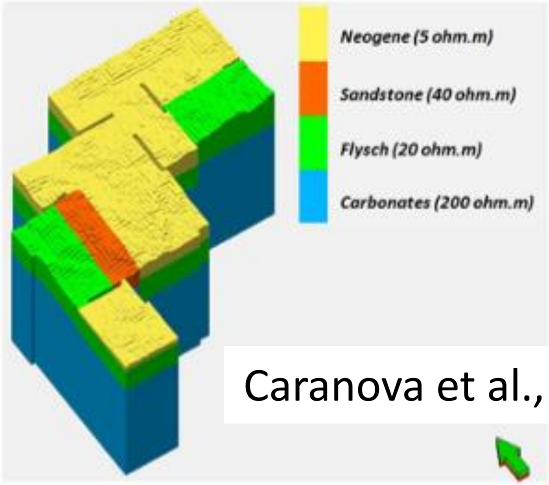
ADR Simulation Model input data



Arias et al., 2010

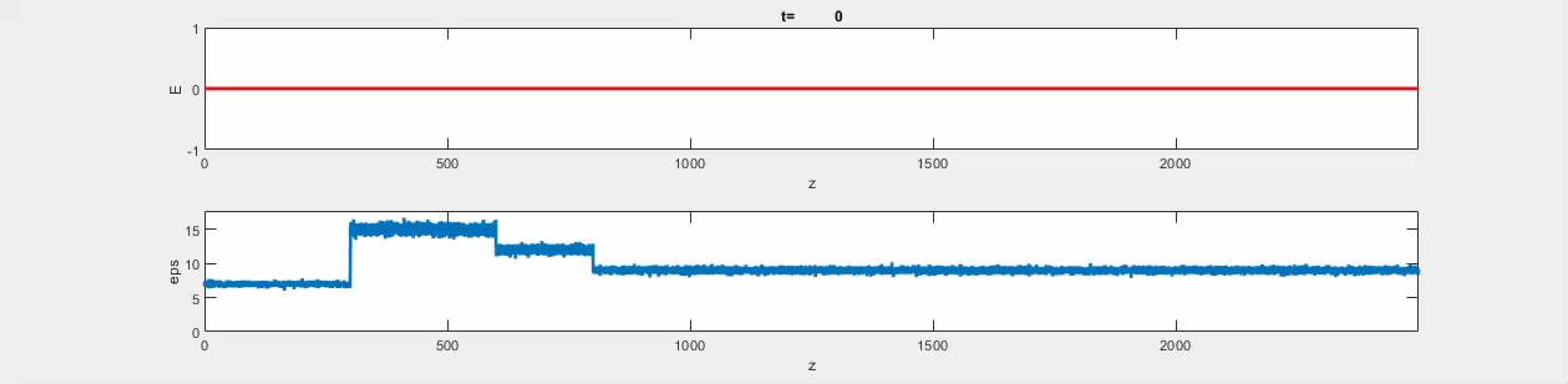


Caranova et al., 2015

Depth bgl	Rock layer	Dielectrics	Resistivity Ω m
0m to 400m	Low permeability Sediments (Jurassic-Oligocene)	4	5
400m to 1000m	Sandstones (Upper Trias – Oligocene)	7	40
1000m to 3000m	A deeper structure associated to a hotter part of the geothermal system (metamorphic complex)	11	200

- Geological data from Arias et al., 2010,
- Resistivity adapted from Carnova et al., 2015
- 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.

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.

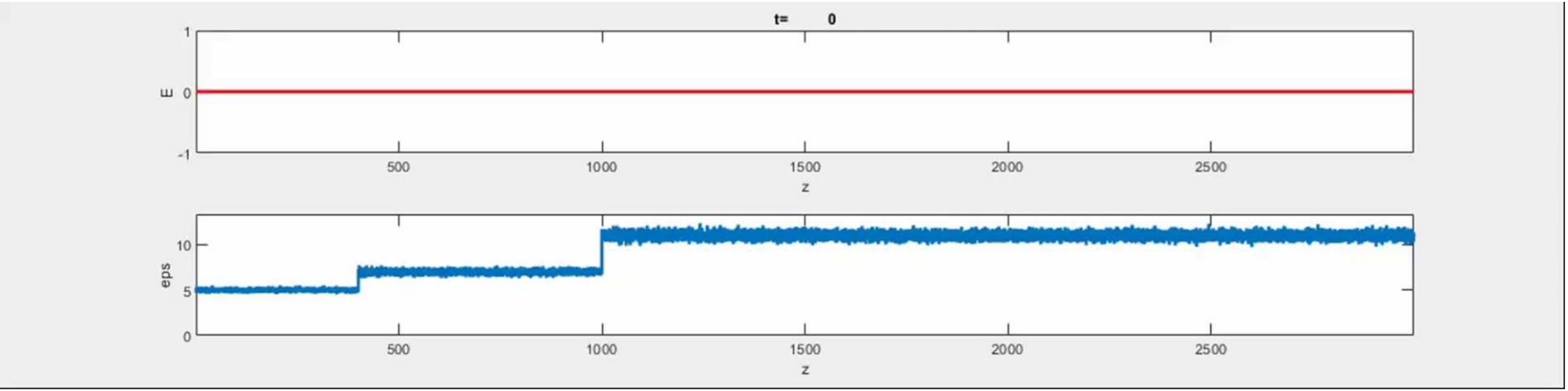
In this simulation, we see wave packet penetration to 2500m and beyond. Interestingly, we also see multiples from the 300m interface, you can see the reflection coming up, then bouncing off the ground/air interface and hitting the boundary for a second time. Something to keep in mind when analysing empirical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

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

Low permeability Sediments (Jurassic-Oligocene)
0m to 400m, Er 4, 5 Ωm

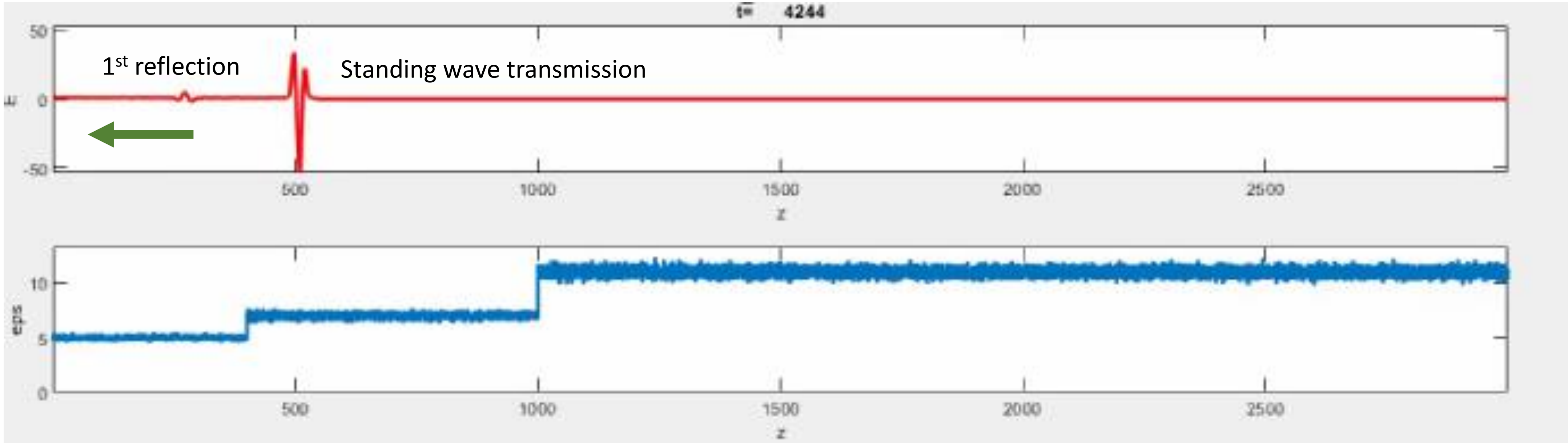
Sandstones (Upper Trias – Oligocene)
600m thick, Er 7, 40 Ωm

A deeper structure associated to a hotter part of the geothermal system (metamorphic complex)
2000m thick, Er 11, 200 Ωm



Overlain rock layers from ground level (0m) through the subsurface to depths of 2000m 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

Low permeability Sediments (Jurassic-Oligocene)
0m to 400m, Er 4, 5 Ωm

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A deeper structure associated to a hotter part of the geothermal system (metamorphic complex)
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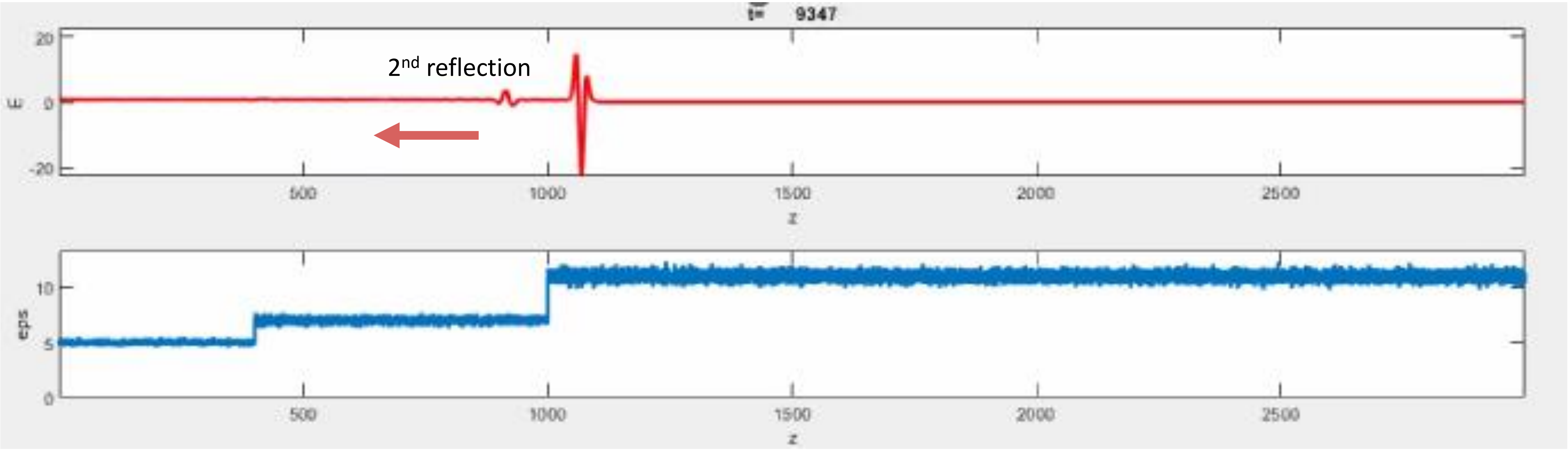
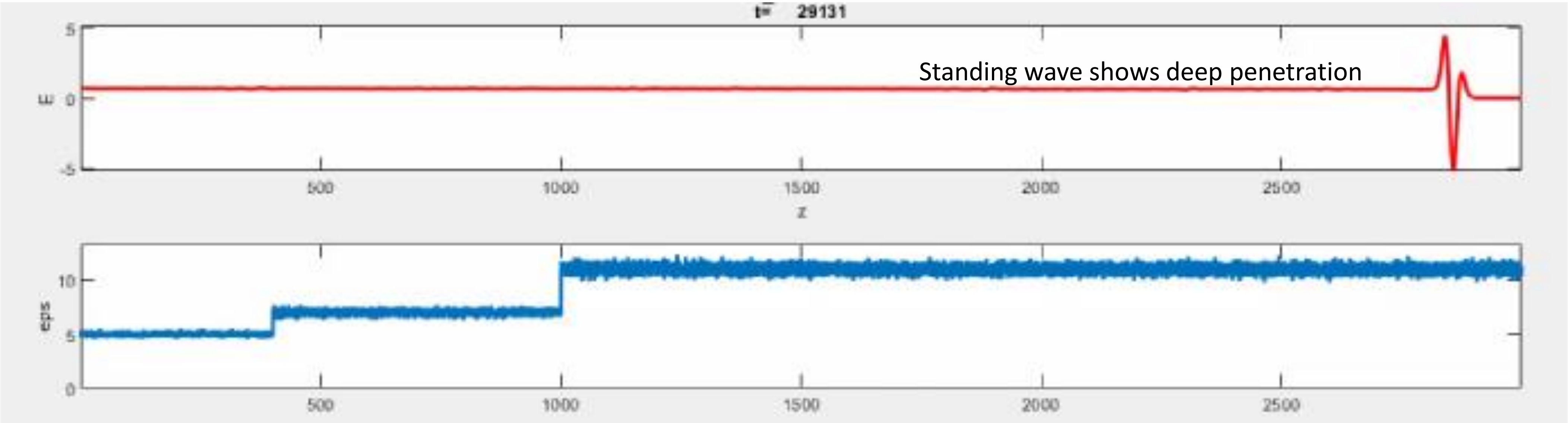


Second reflection from the higher resistivity metamorphic layer returning to surface receiver antenna.

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



Standing wave transmission is penetrating all the way down to 3000m and has kept its shape and properties.

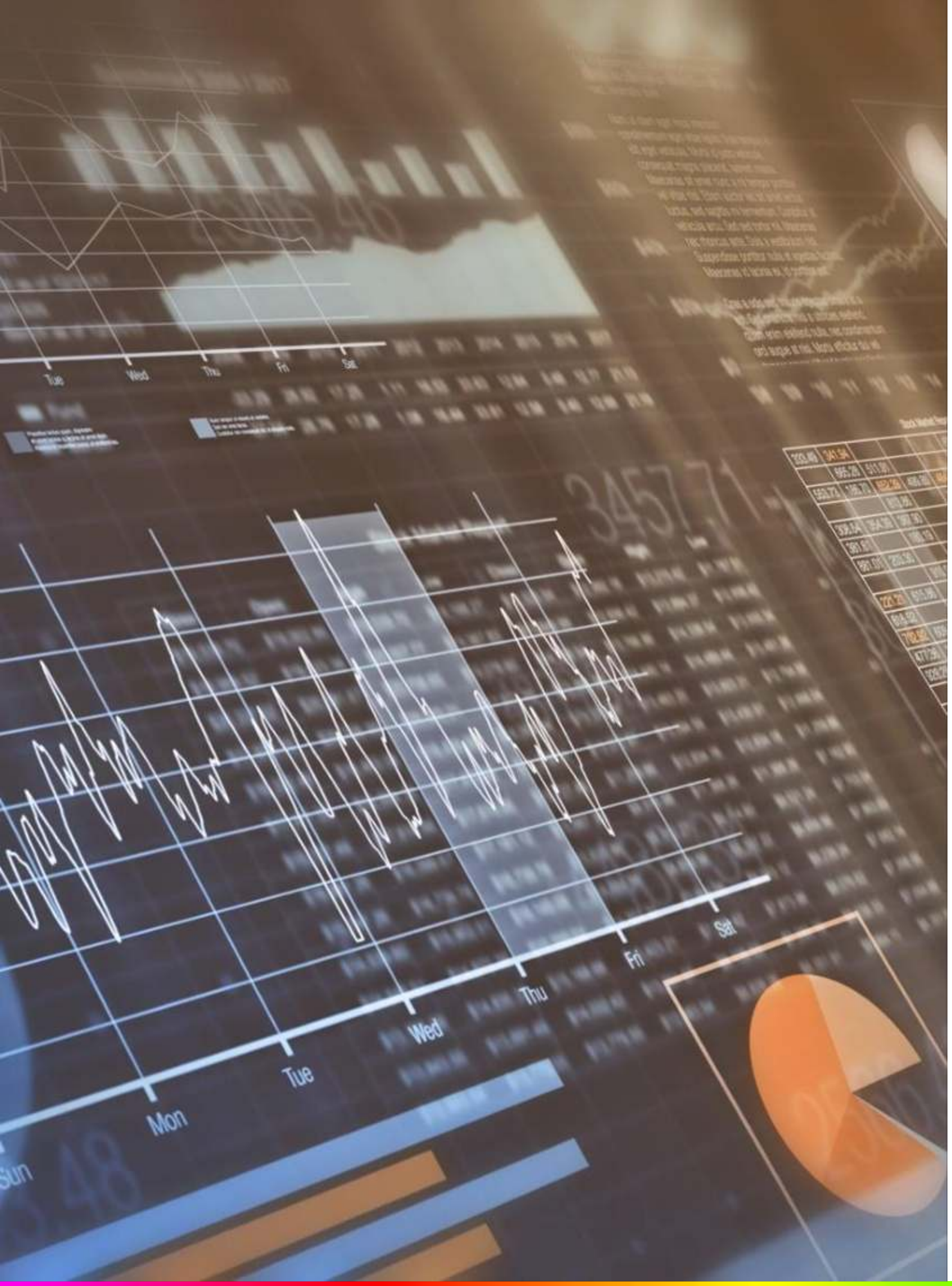
Summary of geothermal applications

- Pulsed electromagnetic ADR waves can identify change in temperature using dielectrics, conductivity and energy reflections from return signals.
- Adrok now has Case Studies onshore Australia, Canary Islands, Denmark, Italy, New Zealand and the UK at depths ranging from 1km to 5km.
- 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.
- Adrok's method looks like it is picking up changes in temperature and changes in water, based on dielectrics and conductivity.
- We do not (and cannot) claim to fully understand why it works at this stage, but the case studies we have worked on have shown consistent matches to reality. Further research is needed for geothermal applications. We are currently seeking partners for collaboration.

Selected Publications

https://www.adrokgroup.com/news/published-papers

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



Technology Summary

- High-definition ***m* scale resolution at *km* scale depth** with or without wells or seismic
- **Predrilling Virtual Logging®** for actionable client decisions
- Results give intelligence more akin to **downhole petrophysics** than seismic
- ADR can be applied to measuring subsurface **temperature**
- ADR can be applied to measuring subsurface **fluids**
- **Digitally drilling** into the subsurface is the future of exploration

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

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