Simulation Model of typical geothermal plays

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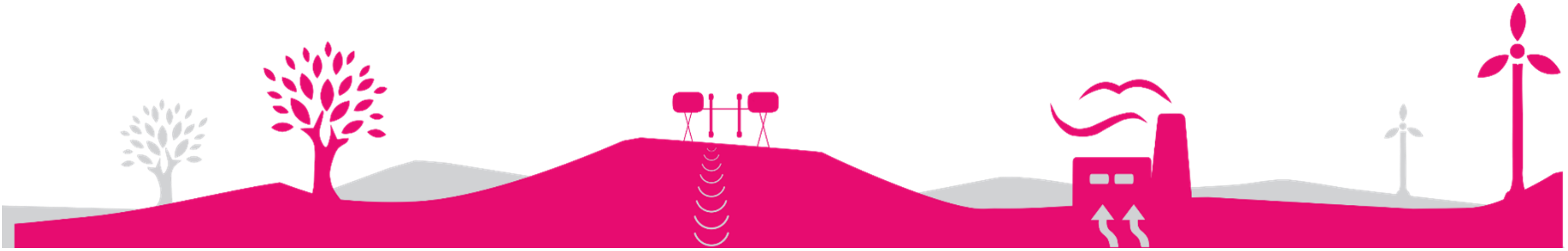


The Solution

Atomic Dielectric Resonance (ADR)

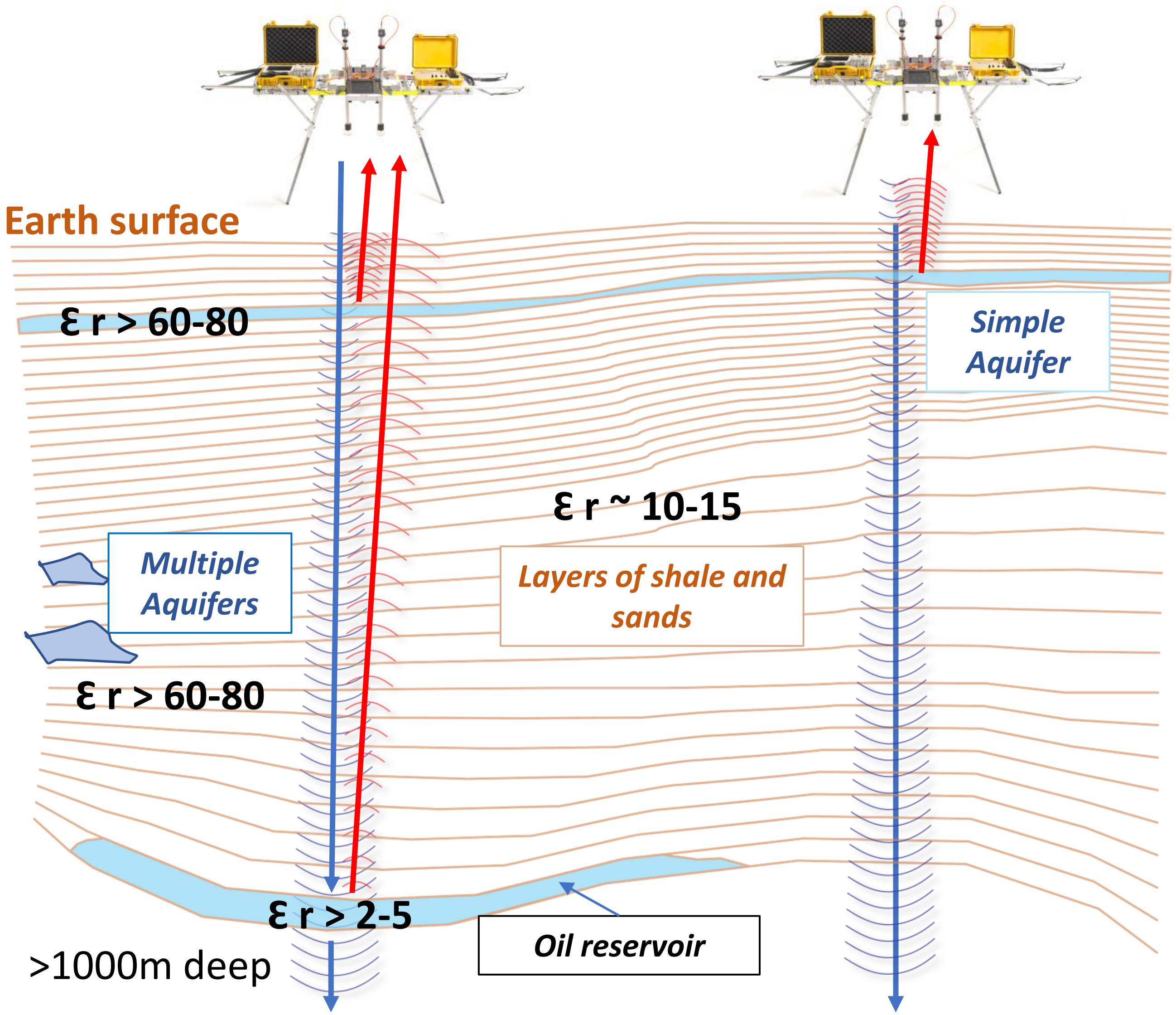
Using low impact, pulsed electromagnetic ADR Technology, we can now determine the existence of subsurface natural resources, movements and fluids without the need for invasive drilling

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

No need for extensive cable laying across fields compared to seismic & MT, AMT electrical methods, as EM pulse is used to investigate conductivity of rock mass

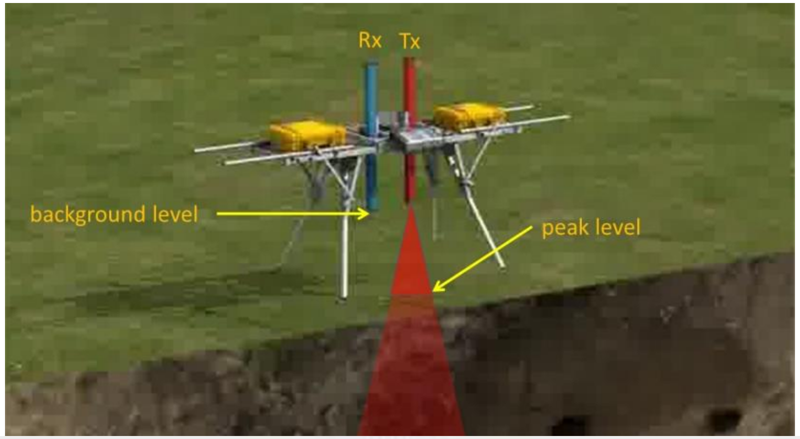
Our technology eliminates the need for drilling and therefore reduces the expense and risks associated with it

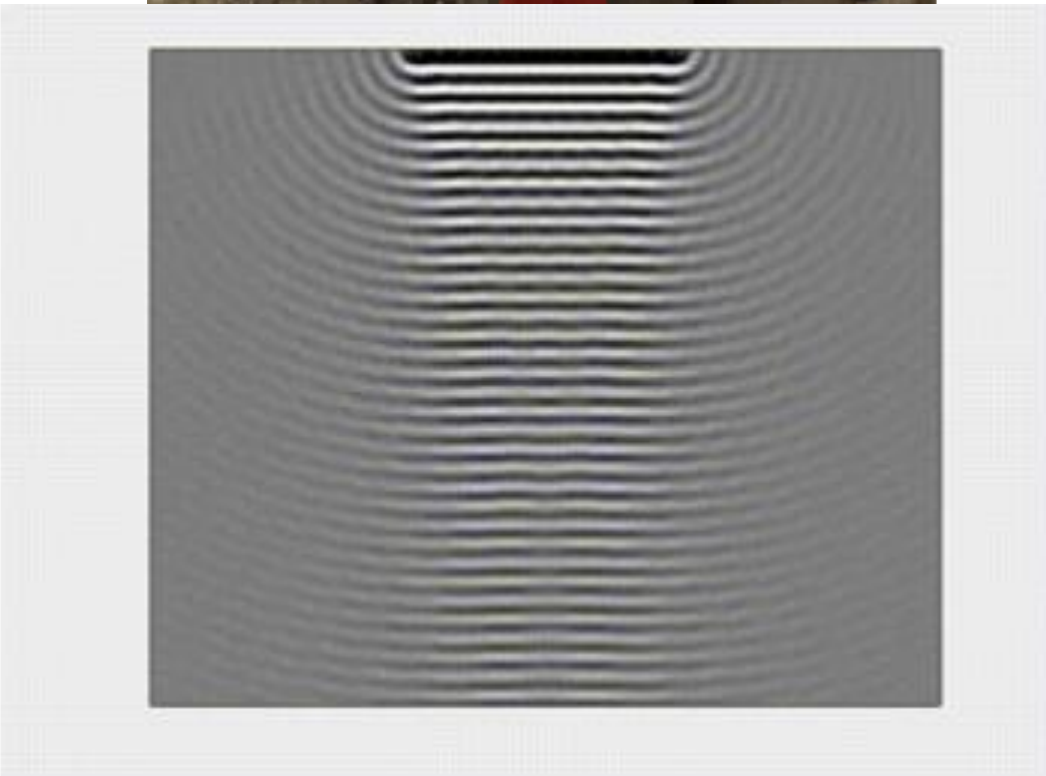
How the technology works



- 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.

Wave propagation

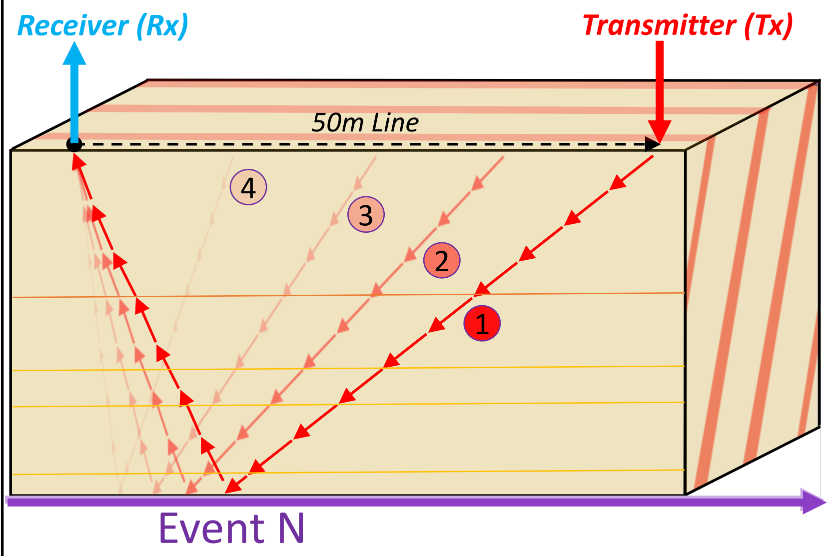




- Line of transmitters in Wide Angled Reflection & Refraction (WARR) mode creates beam (Synthetic Aperture Radar, SAR based phased array)
- A fuller technical explanation is available at:

https://www.adrokgroup.com/technology/how-it-works

Depth conversion



Two way time from Tx at a given length of the line to Rx at 0 after event N reflection.

1 *TwT for Tx at 50m*
2 *TwT for Tx at 32.50m*
3 *TwT for Tx at 25m*
4 *TwT for Tx at 12.5m*

- WARR stands for Wide Angle Reflection and Refraction. These are 50m long lines that serve as Time-Depth calibration for our Stares, and are taken along the trend of the geology. An operator moves the Transmitter Antenna along a straight line and away from the Receiver Antenna, from, for example, 0m to 50m. Longer lines can be used to obtain deeper penetration.

- After that, and by analysing the Two Way Time (TwT) from common points, we can solve a depth-time equation. This is based on principles of Ray Tracing, solving the problem by repeatedly advancing idealized narrow beams called rays through the medium by discrete amounts. Simple problems can be analysed by propagating a few rays using simple mathematics.

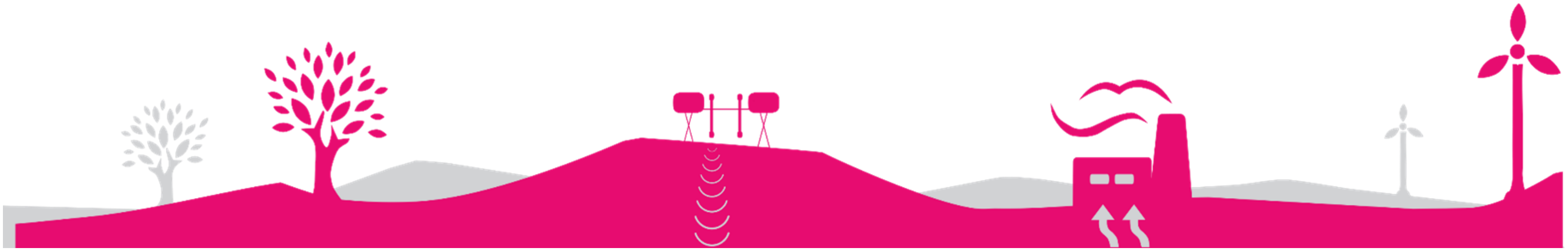
Resolution:

- ✓ We are using a resolution in which we analyse the TWT every 0.5 metres.
- ✓ Rock layer resolution of approximately 30 to 40m.
- ✓ Vertical depth accuracy is approximately +/- 10m.
- ✓ Our analysis checks for the events every 3.3m along the line (that is 15 columns in X) and every 0.5m vertically (for a total of 400 lines in Y). The values acquired take into account the surrounding, averaging from the previous point.
- ✓ Therefore, every WARR is computed based on 6000 points.

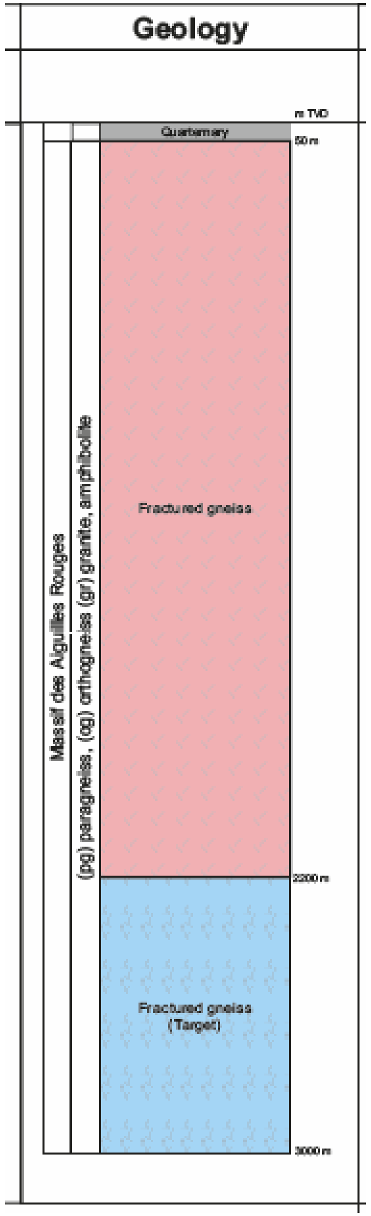
Limitations:

- ➢ The manual process can involve intrinsic errors of around 2 to 5%.
- ➢ Strong changes in velocity can alter the depth-conversion significantly in unknown geological settings.
- ➢ Steeply dipping horizons challenge certain mathematical assumptions of the calculations, decreasing overall precision.
- ➢ Therefore, while the order of events will always be correct, the precise depth of the targets or boundaries may be metres away.

Switzerland
Lavey-1 well simulation 1



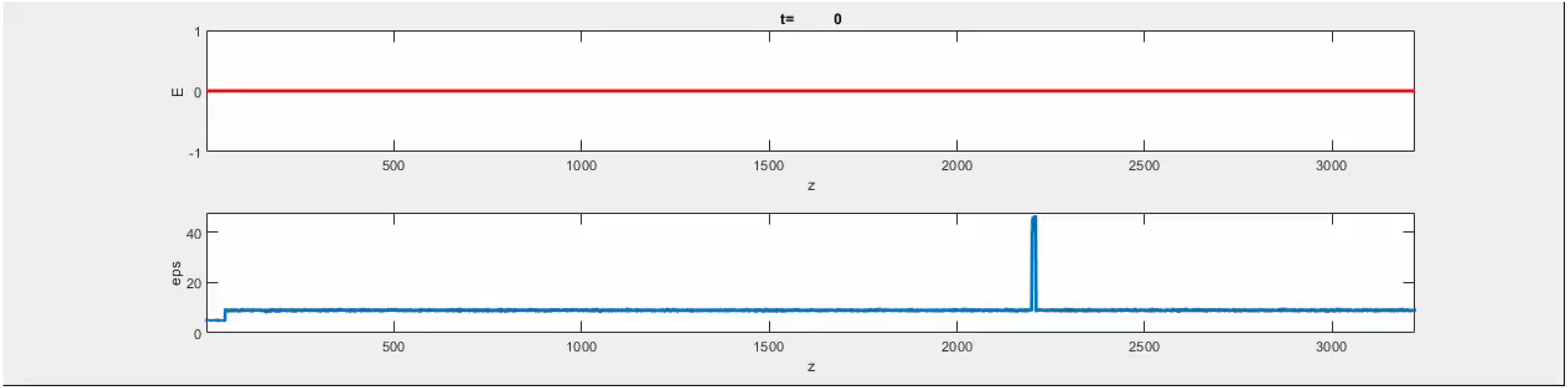
ADR Simulation Model input data for Swiss geothermal site



Depth bgl	Rock layer	Dielectrics
0m to 50m	Quaternary	5
50m to 2200m	Fracture gneiss dry	9
2200m to 2210m	Fine fractures grouped in fracture gneiss (water filled)	44
2210m to 3220m	Fracture gneiss dry	9

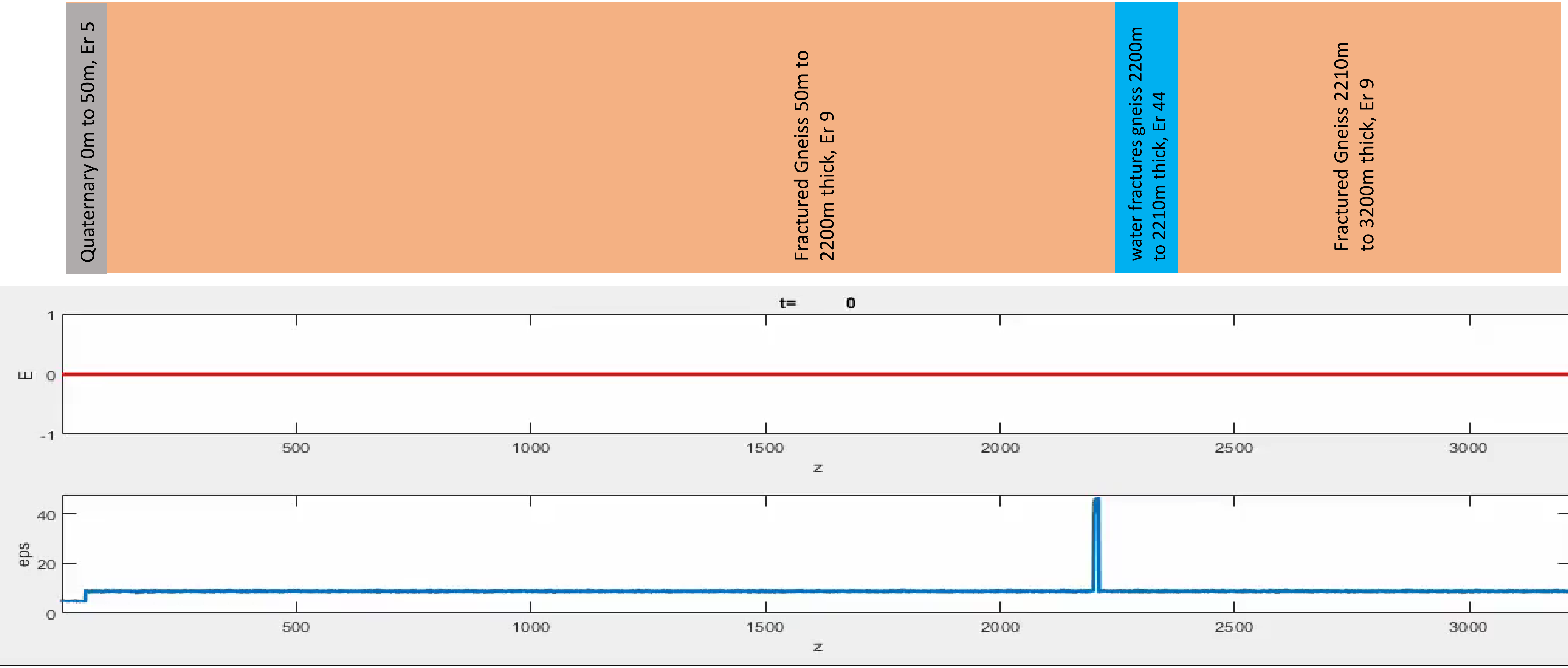
- Geological data provided for AGEPP geothermal setting example (Lavey-1).
- Transmit ADR wave packet from transmitter (Tx) and record reflections from receiver (Rx).
- Dielectrics of the materials (DC) as indicated in table are theoretical, based on Adrok's experience of similar rock types.
- Reflection 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 (click on video under graph)



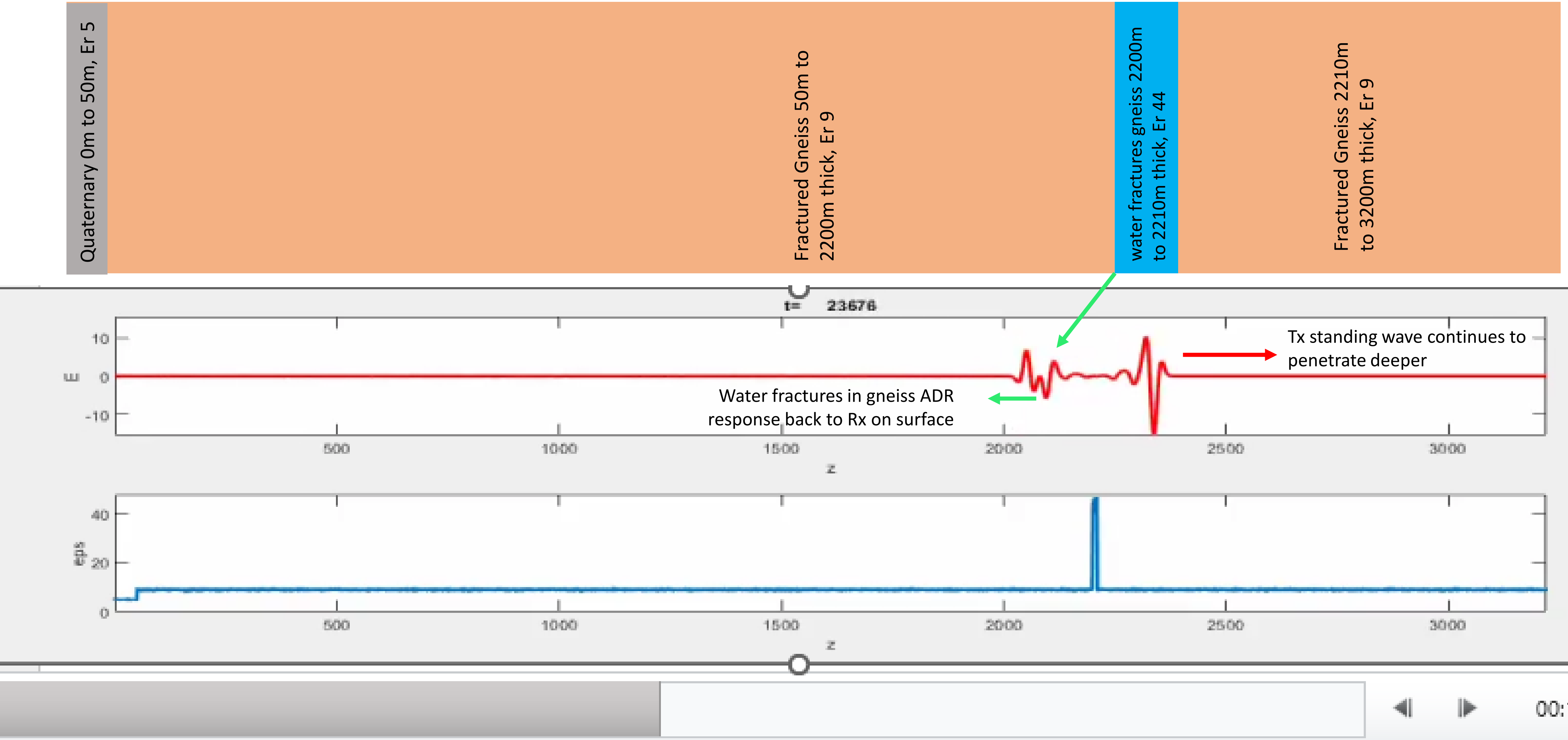
ADR wave packet (top) travels from surface (left z=0) into the ground. At each change in dielectric (lower plot), corresponding to material interfaces, part of the wave packet is reflected back up to the surface where it is detected by the surface receiver (Rx). Homogeneous regions generate continuous 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.

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

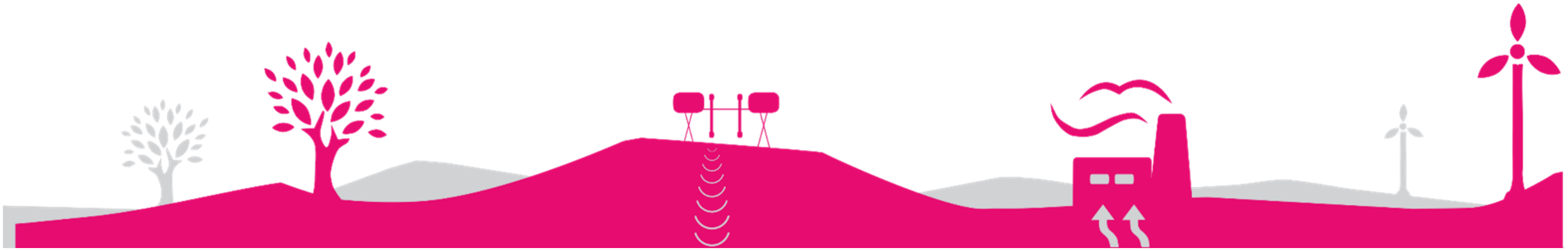


Overlain rock layers from ground level (0m) through the subsurface to depths of 3200m using input data from page 7.

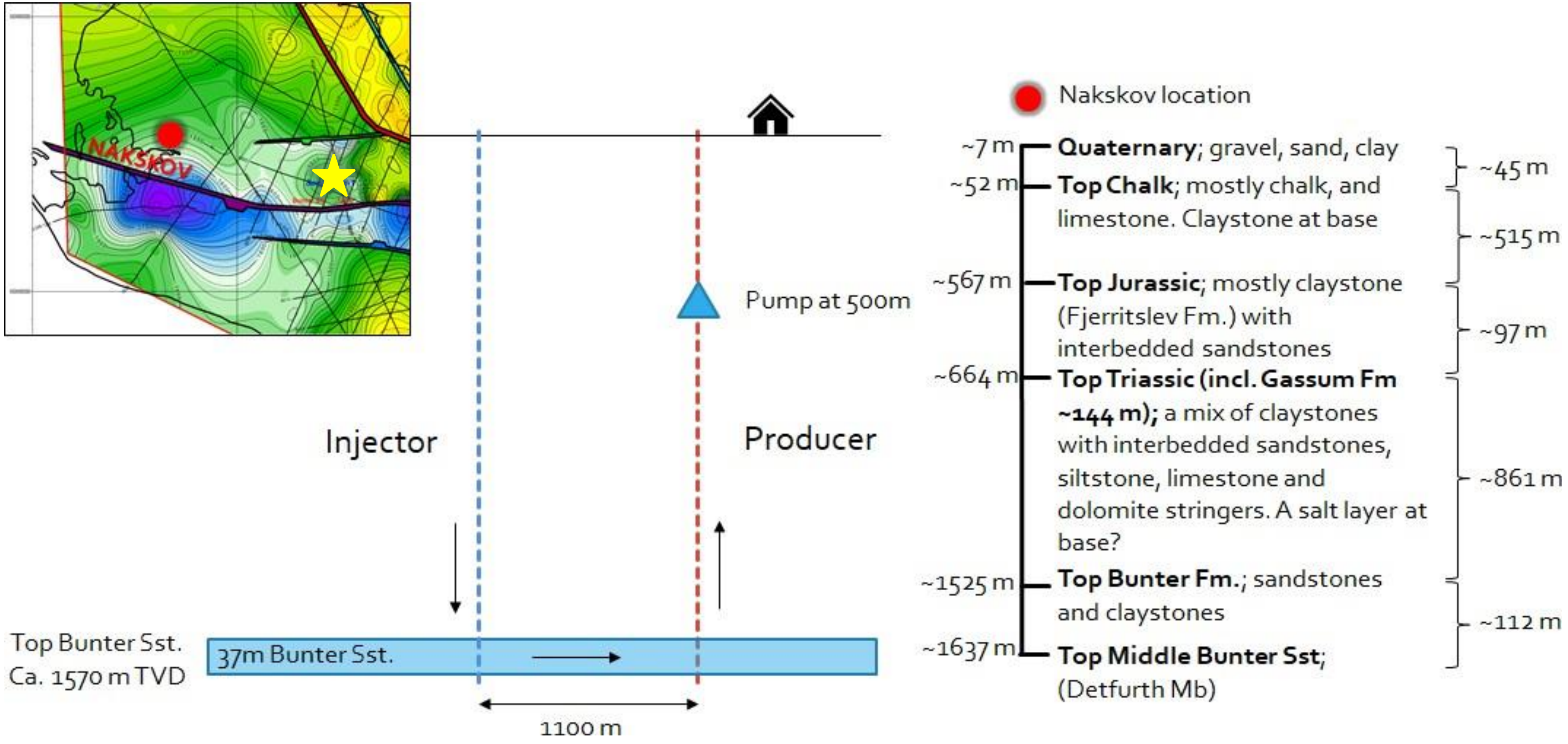
FDTD simulation showing two-way-travel of ADR signal in rock layers



Denmark
Søllested-1 simulation 1



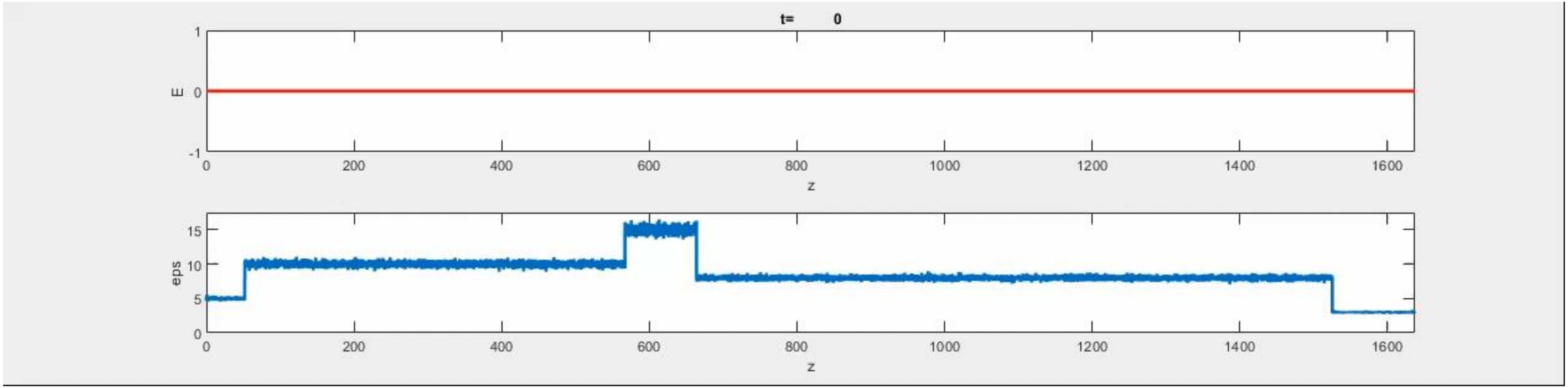
ADR Simulation Model 1 input data (Søllested-1)



Rock layer	Dielectrics
Quaternary	5
Top Chalk	10
Top Jurassic	15
Top Triassic	8
Top Bunter Fm	4
Top Middle Bunter Sst	3

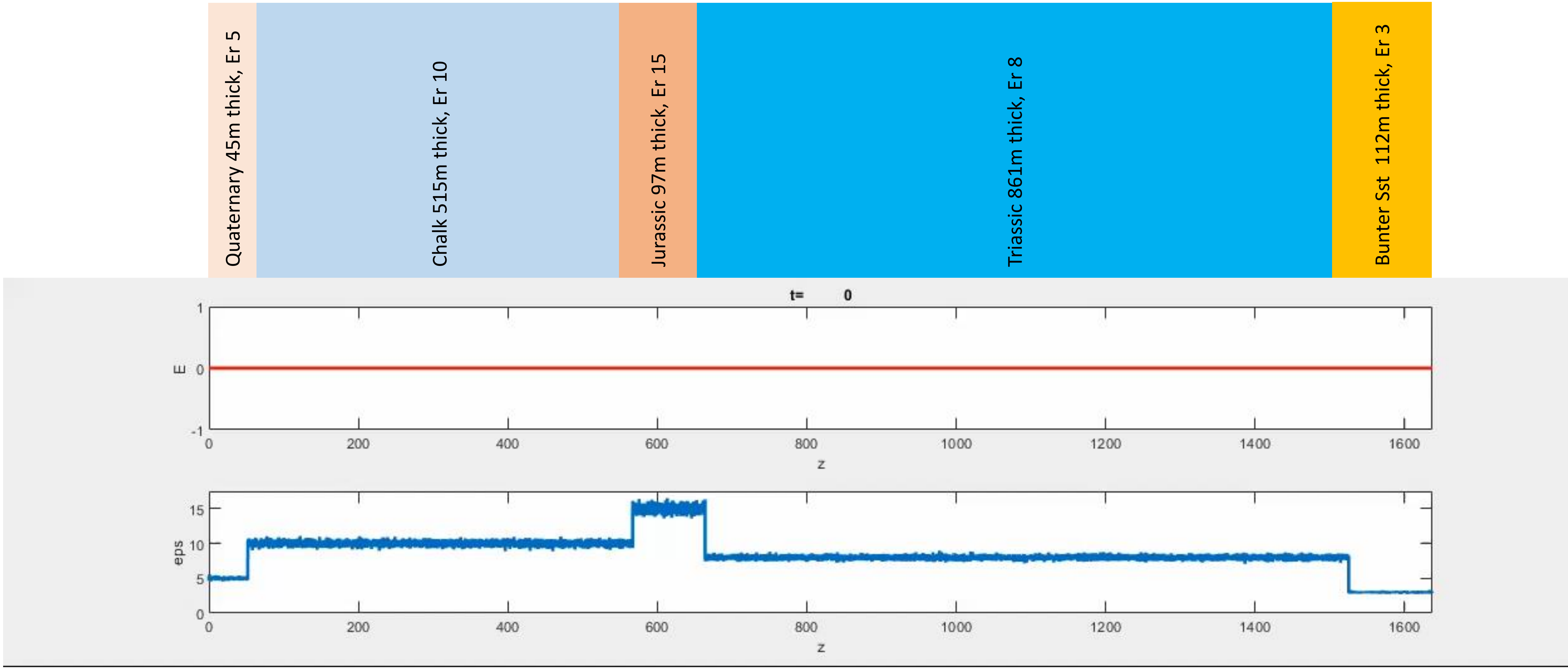
- Geological data provided for Denmark geothermal setting example.
- Transmit ADR wave packet from transmitter (Tx) and record reflections from receiver (Rx).
- Dielectrics of the materials (DC) as indicated in table are theoretical, based on Adrok's experience of similar rock types.
- Reflection from 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 (Søllested-1)



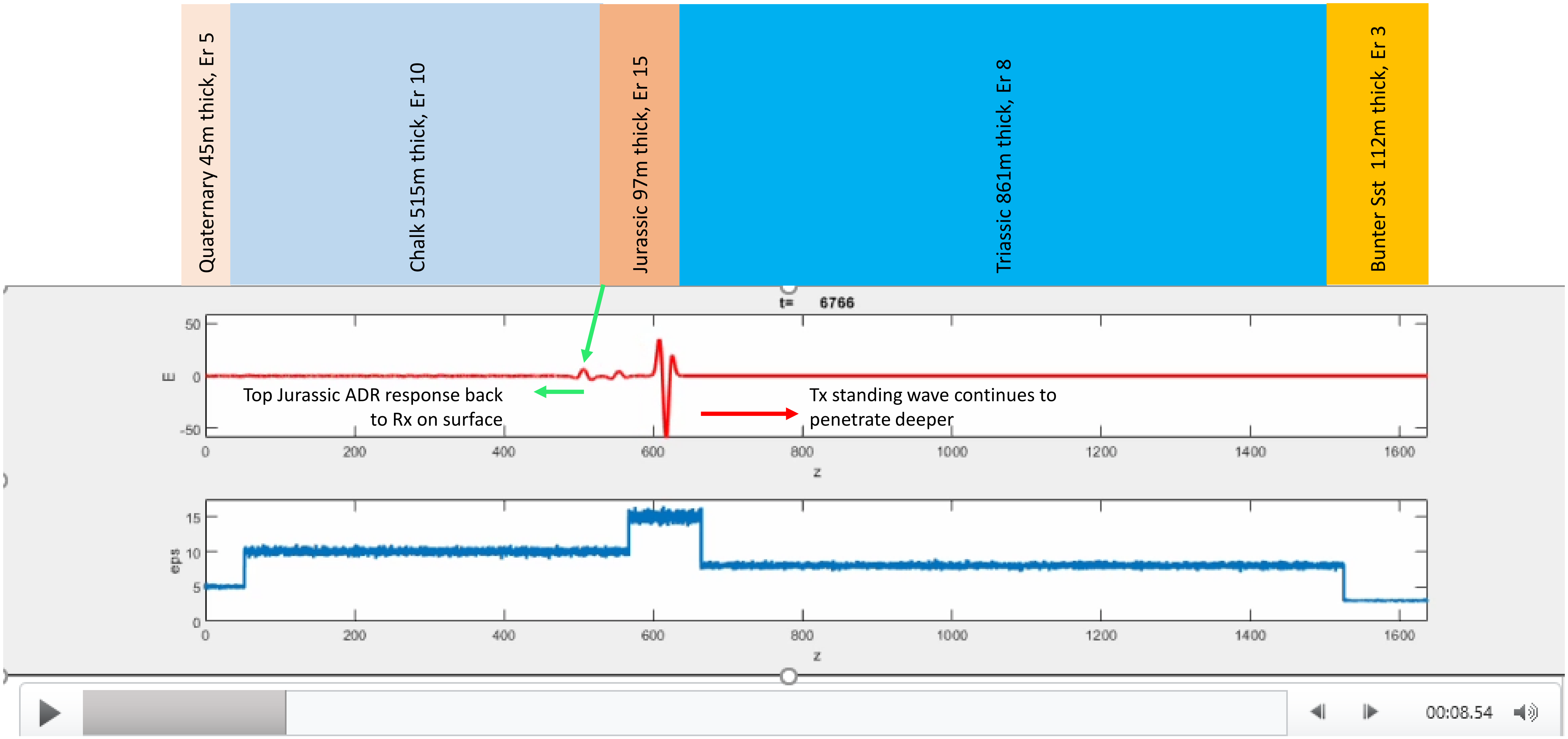
ADR wave packet (top) travels from surface (left z=0) into the ground. At each change in dielectric (lower plot), corresponding to material interfaces, part of the wave packet is reflected back up to the surface where it is detected by the surface receiver (Rx). Homogeneous regions generate continuous 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.

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

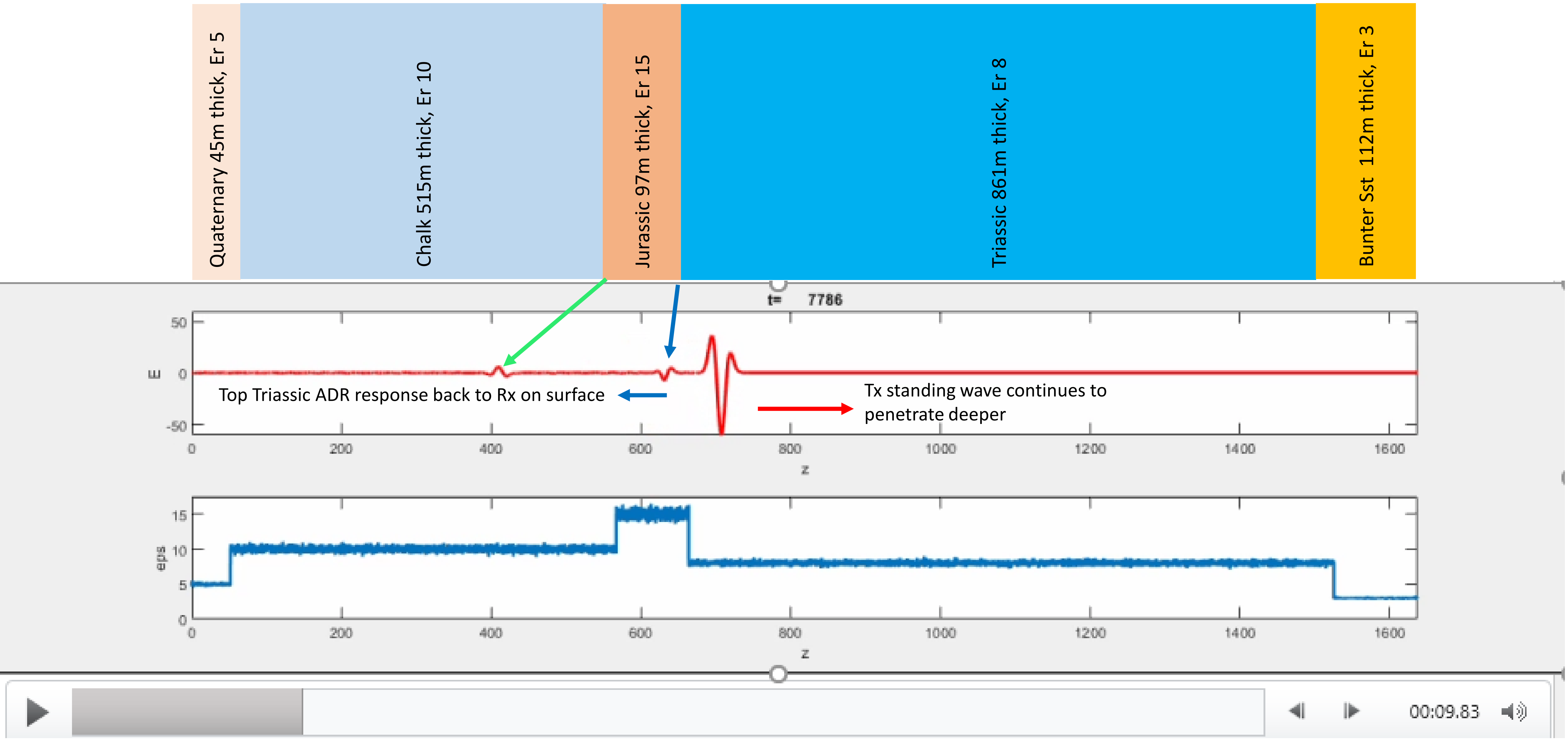


Overlain rock layers from ground level (0m) through the subsurface to depths of 1637m using input data from page 7.

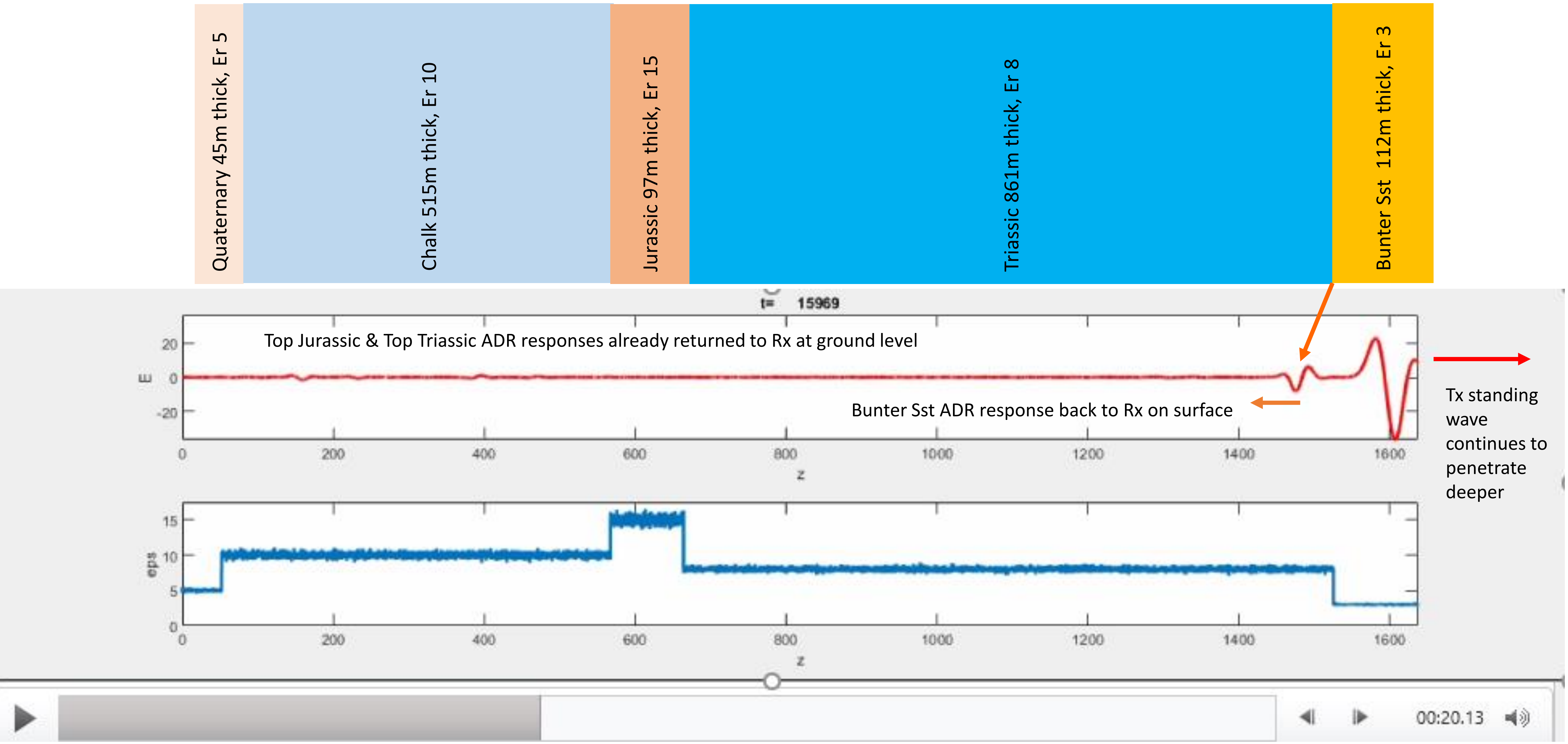
Top Jurassic response ADR signal shown by green arrow (screenshot)



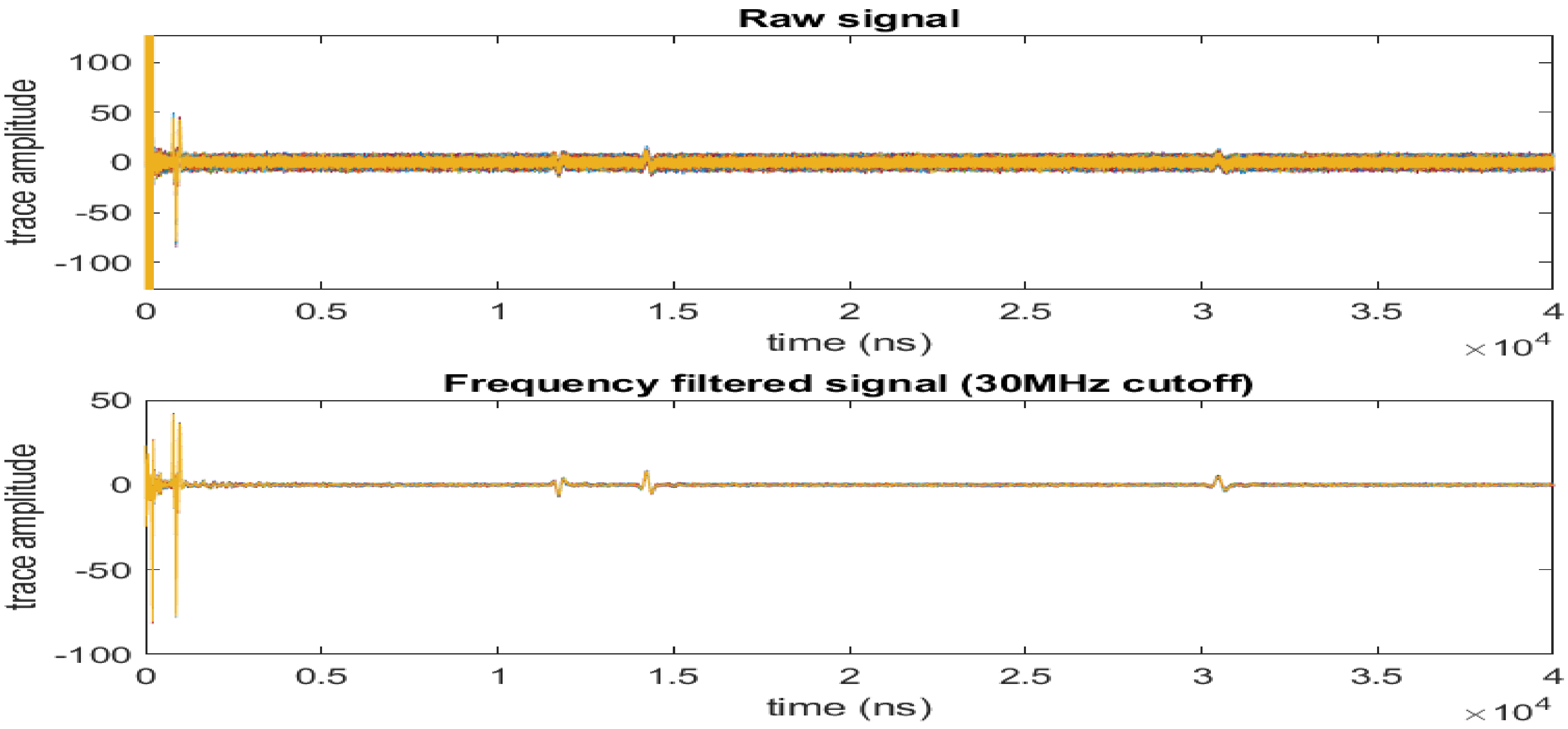
Top Triassic response ADR signal shown by blue arrow (screenshot)



Bunter Sst response ADR signal shown by orange arrow (screenshot)

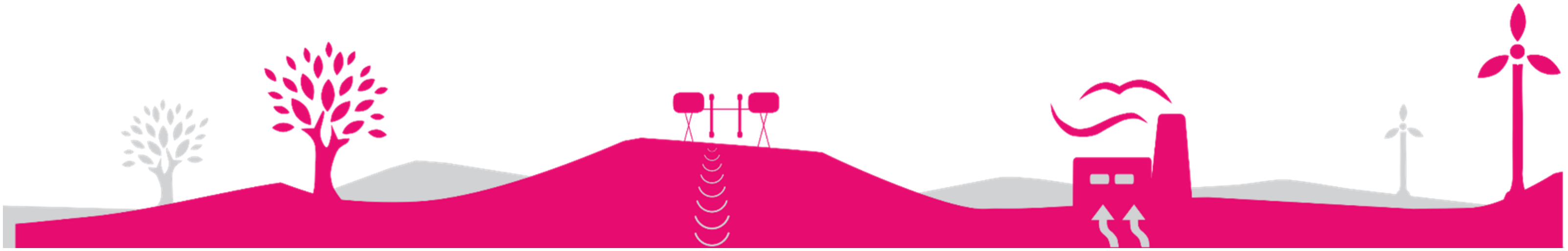


Simulated received surface data



Simple plot of received surface signal versus time. The thick line is the backscatter data and the “blips” are the interface reflections. This is the data going into our various signal processing methods to determine physical features, including Adrok’s E-gamma (energy reflections tool) which is closely related to temperature.

Denmark
Stenlille-19 simulation 1



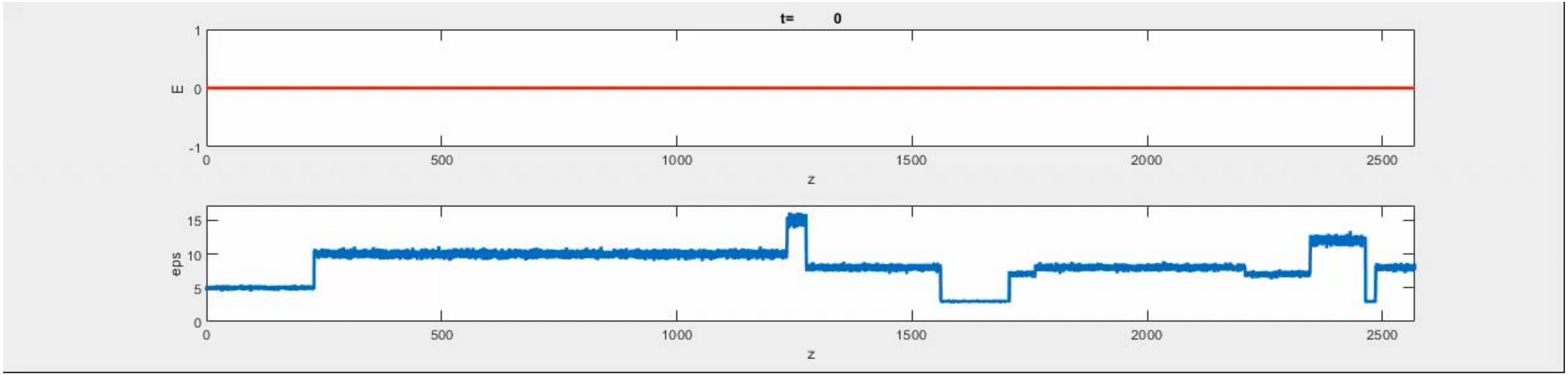
ADR Simulation Model 2 input data (Stenlille-19)

Stenlille-19			metres	metres	GS 29/06/2022
Chronostrategrapy	Formation	Lithology	Top Depth	Bottom Depth	Di-electrics**
Cenozoic	Un-differentiated	sand/shale mixture	0	229	5
Late Cretaceous	Chalk Group	chalk/limestone	229	1234	10
	Rødby	claystone	1234	1241	15
	Vedsted	claystone	1241	1275.5	15
Jurrasic	F-II Mb.	shale	1275.5	1417	8
	Karlebo Mb.	claystoen w. stringers of sand	1417	1561	8
Triassic	**Gassum Sandstone**	**Sandstone w. gas in upper section***	**1561**	**1706.5**	**3**
	Vinding	shaly sandstone	1706.5	1762	7
	Oddesund	claystone w. shaly intervals	1762	2058.57	8
	Tønder	Claystone w. sand intervals	2058.57	2208	8
	Falster	shale w. sandy intervals	2208	2346	7
	Ørslev	claystone	2346	2464	12
	Bunter Sst (Solling Mb.)	**sandstone**	**2464**	**2486**	**3**
	Hardegsen Mb.	shale	2486	2535	8
	Volpriehausen Mb.	shale	2535	2570.07	8

* Due to gas injection - see saturation track in log plot. Stenlille-19 is located in a gas storage facility

** leave that to you to fill in. GS completed 29/06/2022

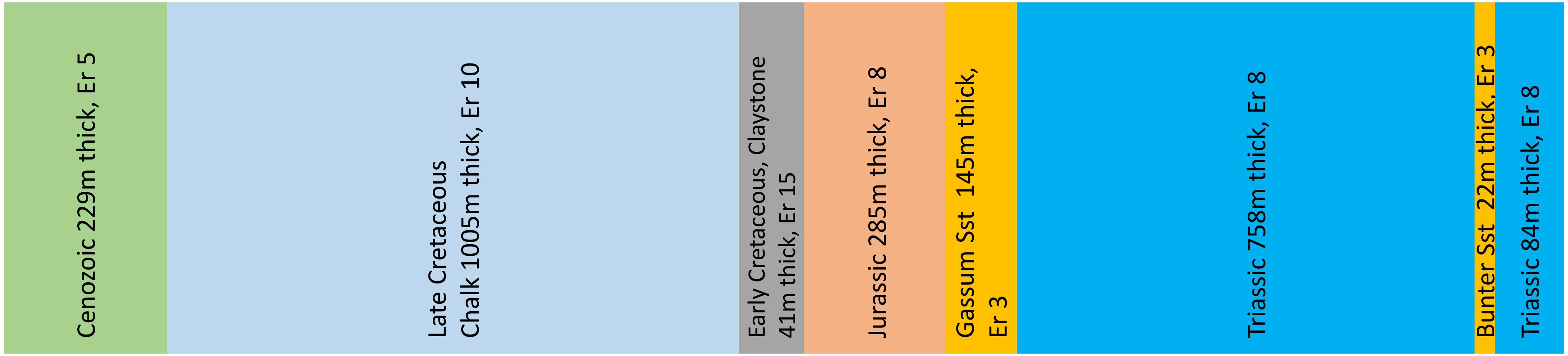
FDTD simulation of Maxwell's equations (Stenlille-19)

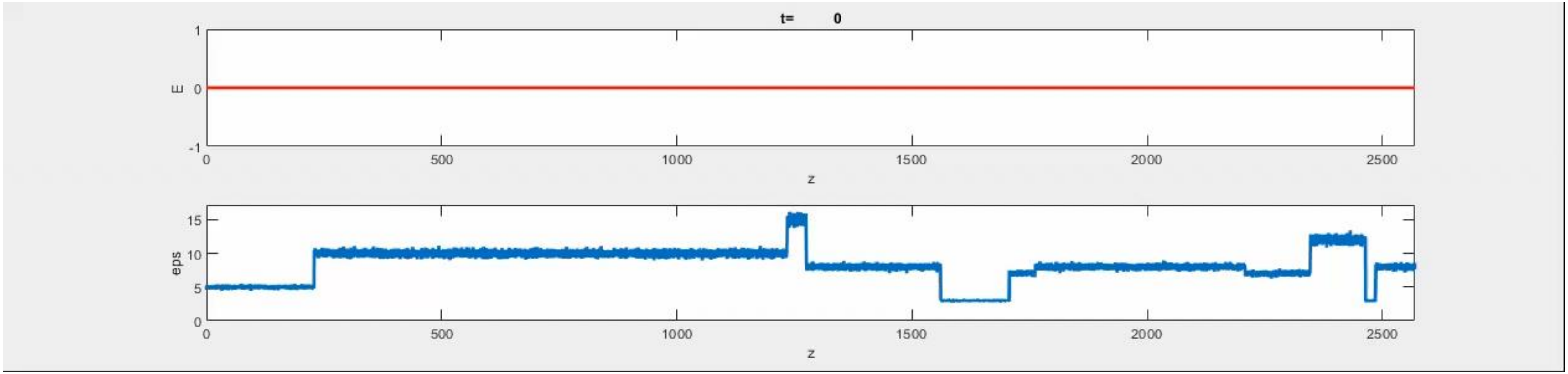


ADR wave packet (top) travels from surface (left z=0) into the ground. At each change in dielectric (lower plot), corresponding to material interfaces, part of the wave packet is reflected back up to the surface where it is detected by the surface receiver (Rx). Homogeneous regions generate continuous 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.

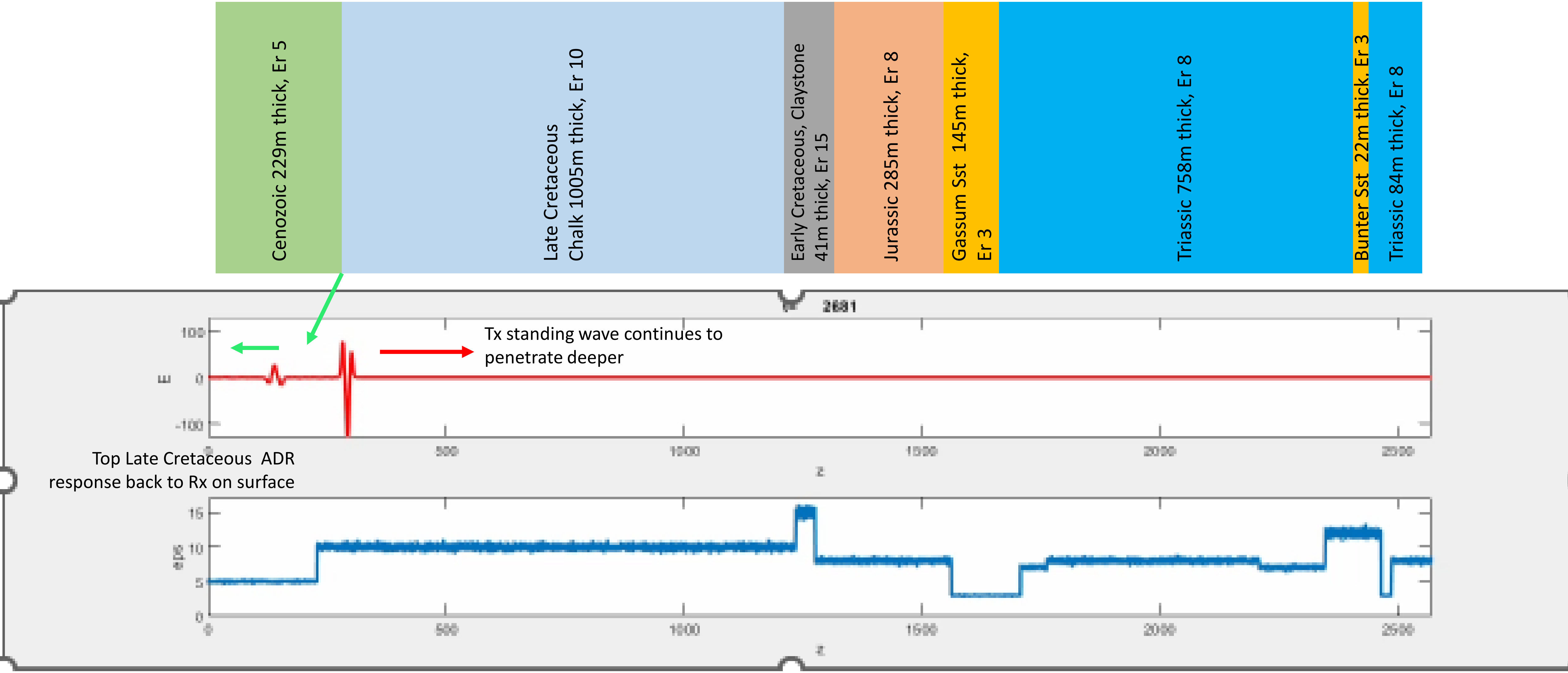
Reflections from the various interfaces can be seen to propagate back up to the surface detector (Tx) as can be seen in the video.

FDTD simulation of Maxwell's equations

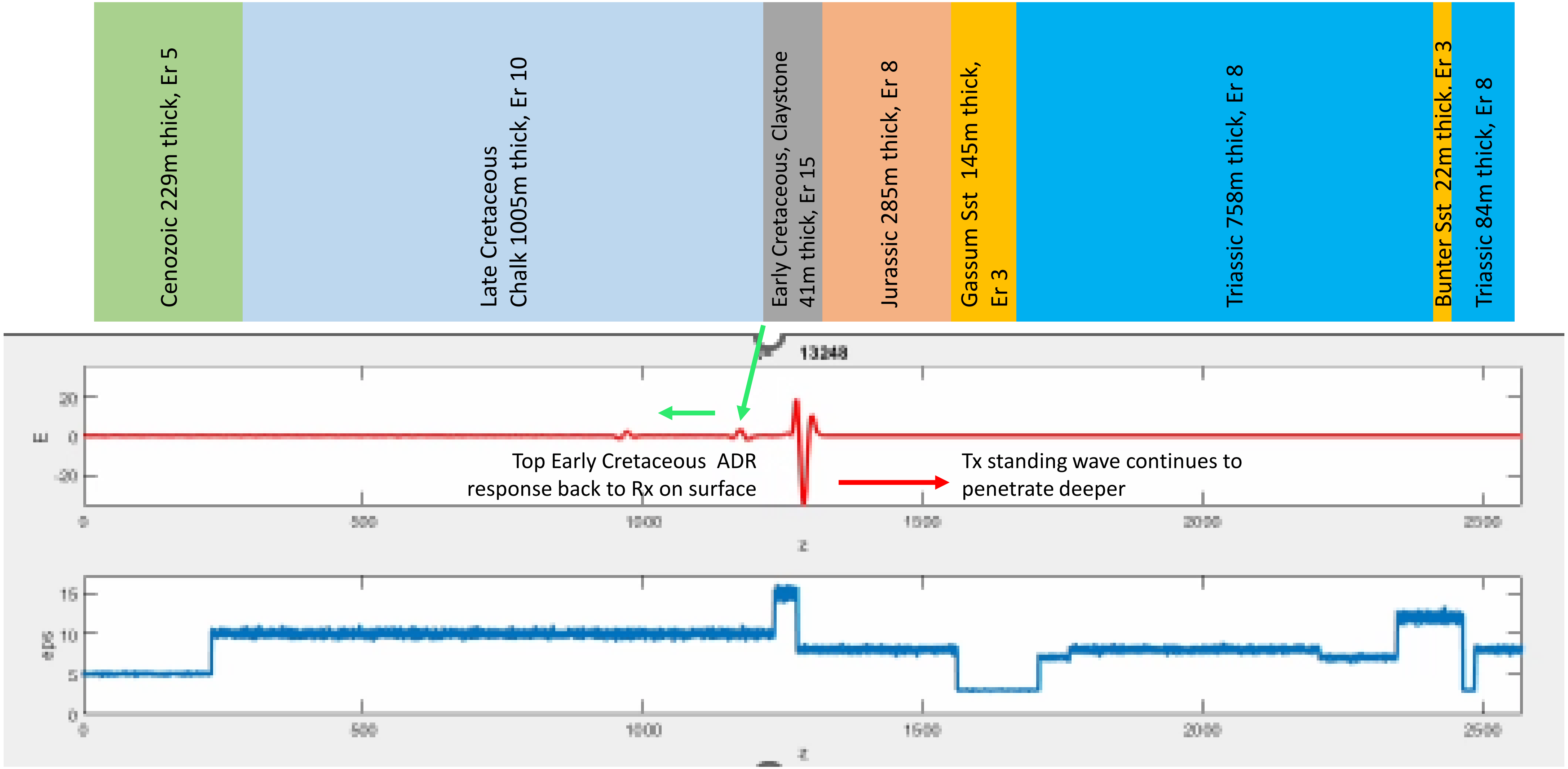




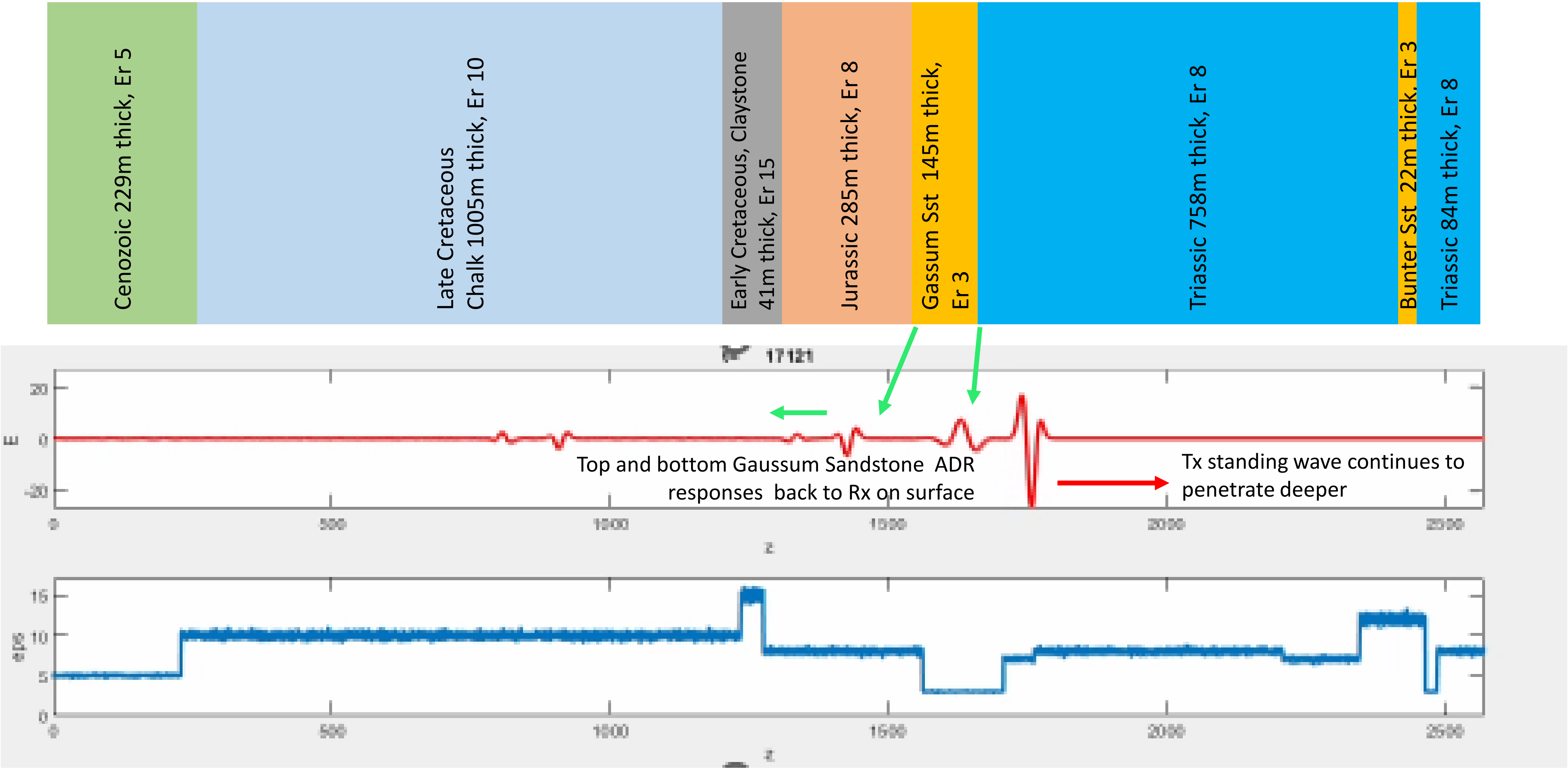
FDTD simulation of Maxwell's equations (Chalk response)



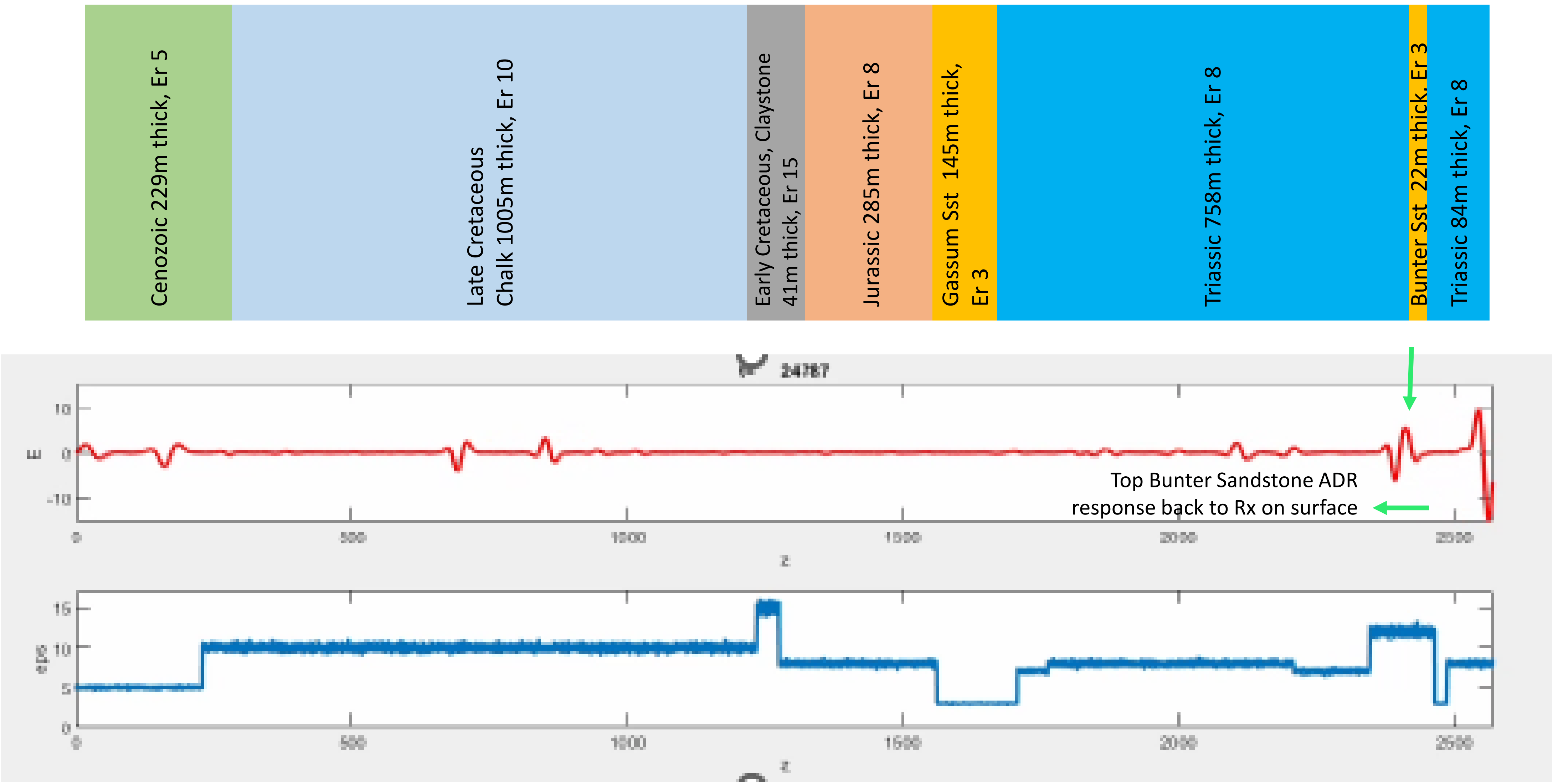
FDTD simulation of Maxwell's equations (claystone response)



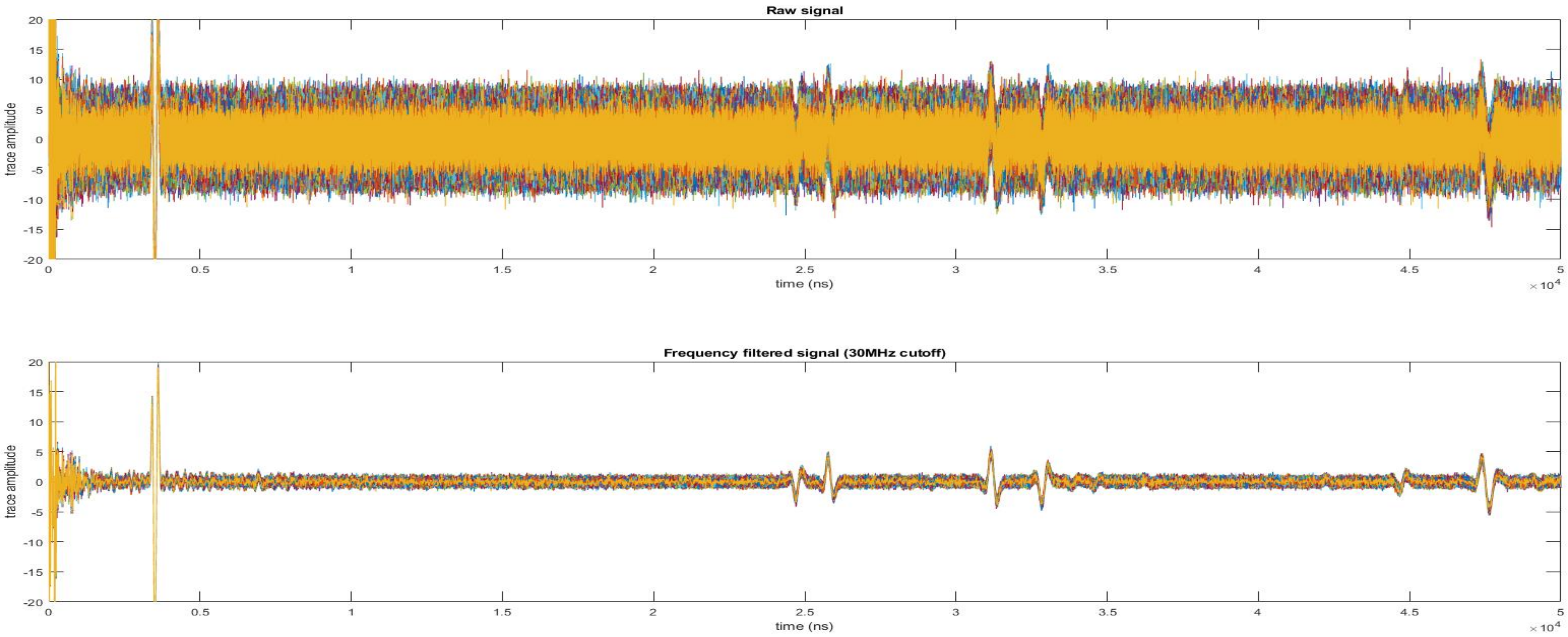
FDTD simulation of Maxwell's equations (Gassum sst response)



FDTD simulation of Maxwell's equations (Bunter sst response)

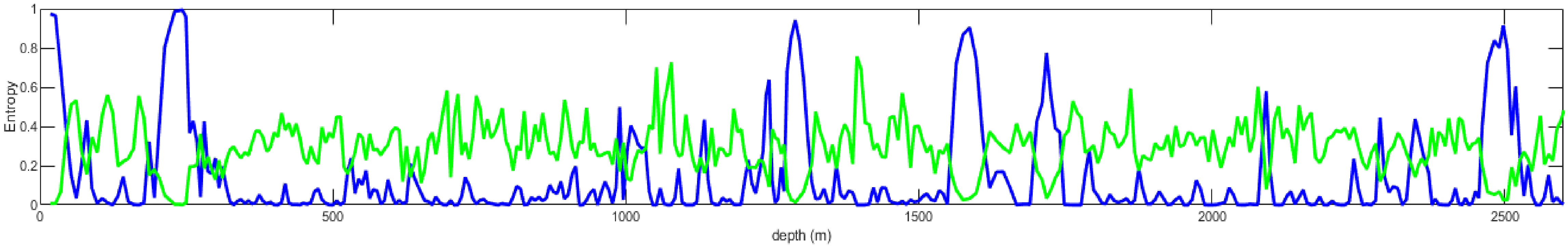


Simulated received surface data



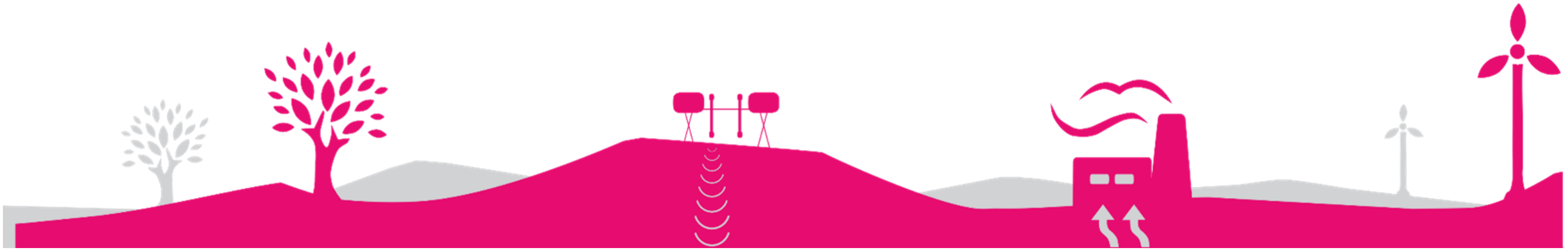
Simple plot of received surface signal versus time. The thick line is the backscatter data and the “blips” are the interface reflections. This is the data going into our various signal processing methods to determine physical features. Bottom graph shows result after some basic denoising. The reflected wavepackets (“blips”) are the reflections from the various interfaces between different materials. Biggest blips are from the sandstone as it has the highest contrast.

Simulated received surface data sample analysis

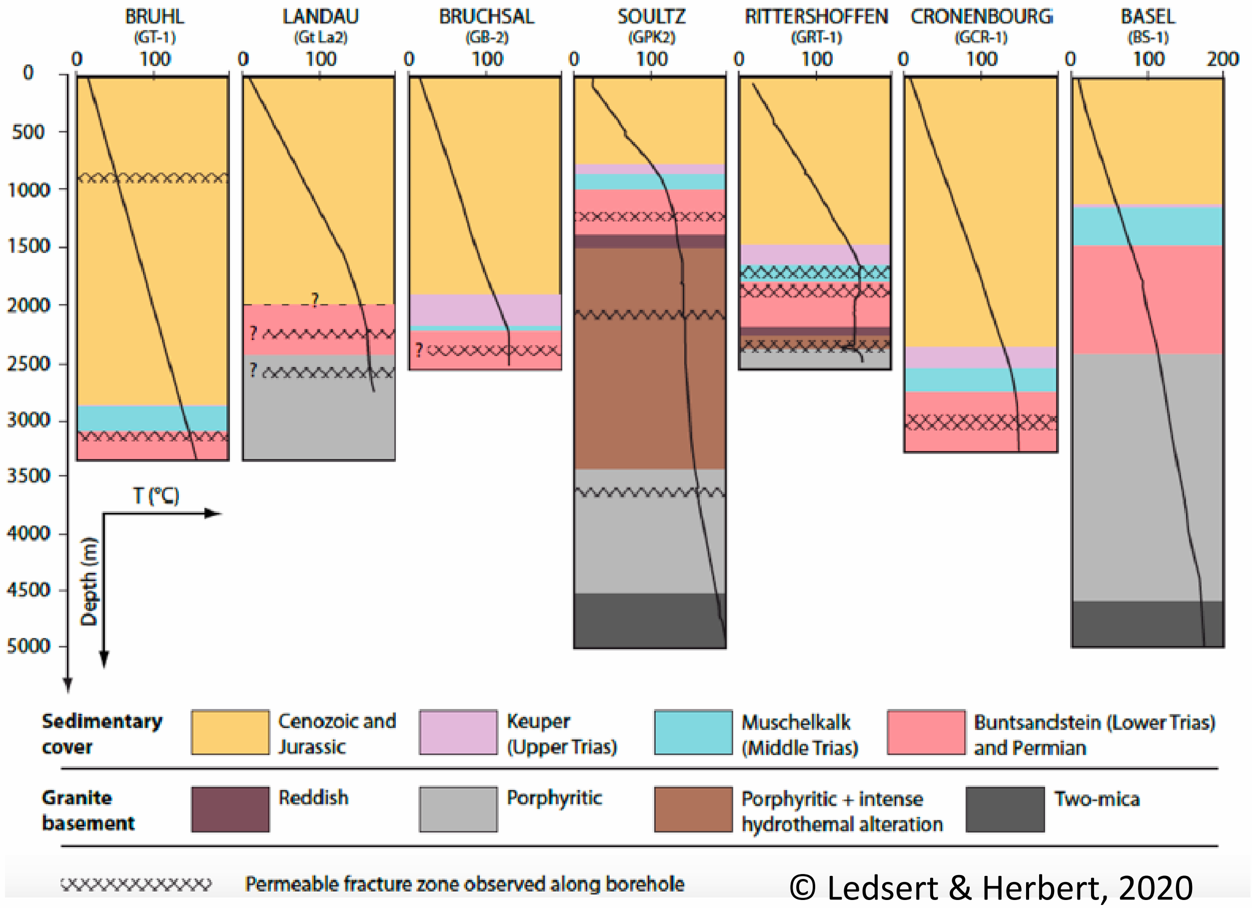


Example of data analysis using the entropy feature detection. Blue peaks above the background (green curve) indicate significant anomalies, interfaces in this case. Conversion from time to depth done using a DCO file generated from the model. In practice this velocity model is derived from WARR data or from known geology.

France
Soultz, Upper Rhine Graben, simulation 1



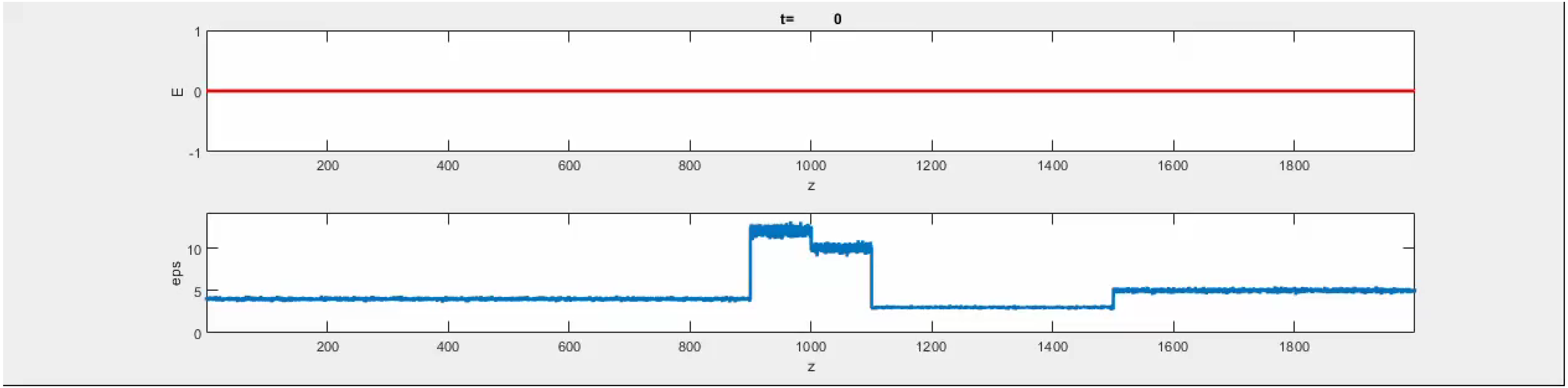
ADR Simulation Model 1 input data (Soultz, Upper Rhine Graben)



Chronostrategrapy	Formation	Lithology	Top Depth (metres)	Bottom Depth (metres)	Adrok Dielectrics
Cenozoic and Jurassic	Sedimentary cover	Sand/Shale mixture	0	900	4
Triassic (upper)	Keuper	Dolomites, Shales or Claystones	900	1000	12
Triassic (middle)	Muschelkalk	Shell-bearing Limestone	1000	1100	10
Lower Triasic & Permian	Bruntsandstein (Bunter Standstone)	Sandstone	1100	1500	3
Granite Basement	Granites	Granites with porphyritic and intense hydrothermal alteration	1500	2000	5

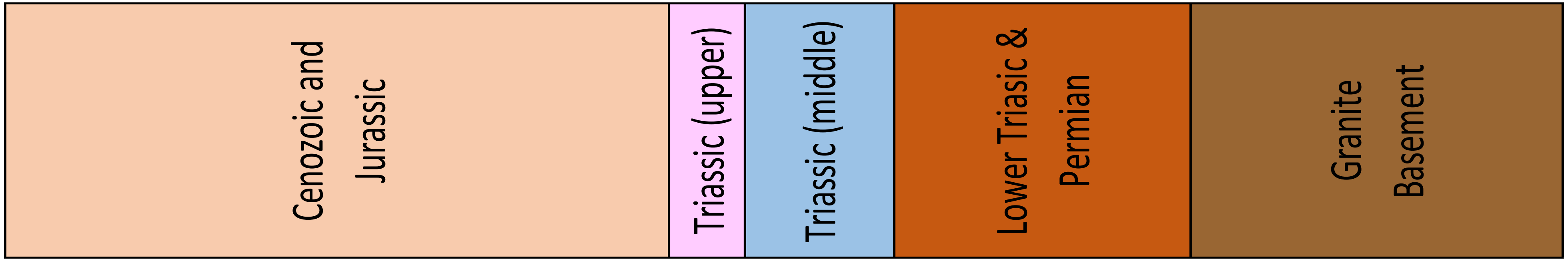
- Geological data based on Ledsert & Herbert (2020) https://www.mdpi.com/2076-3263/10/11/459
- Transmit ADR wave packet from transmitter (Tx) and record reflections from receiver (Rx).
- Dielectrics of the materials (DC) as indicated in table are theoretical, based on Adrok's experience of similar rock types.
- Reflection from dielectric interfaces will arrive at time.
- 2*(10sqrt(5) + d*sqrt(Er)) * 1e9/3e8, with d the thickness of each layer.

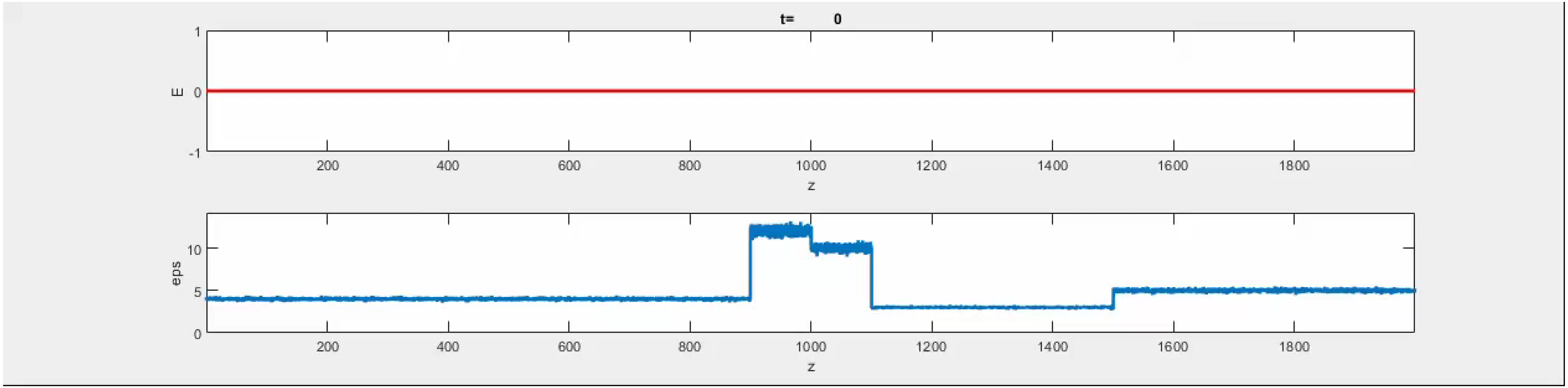
FDTD simulation of Maxwell's equations (Soultz, URG)



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.

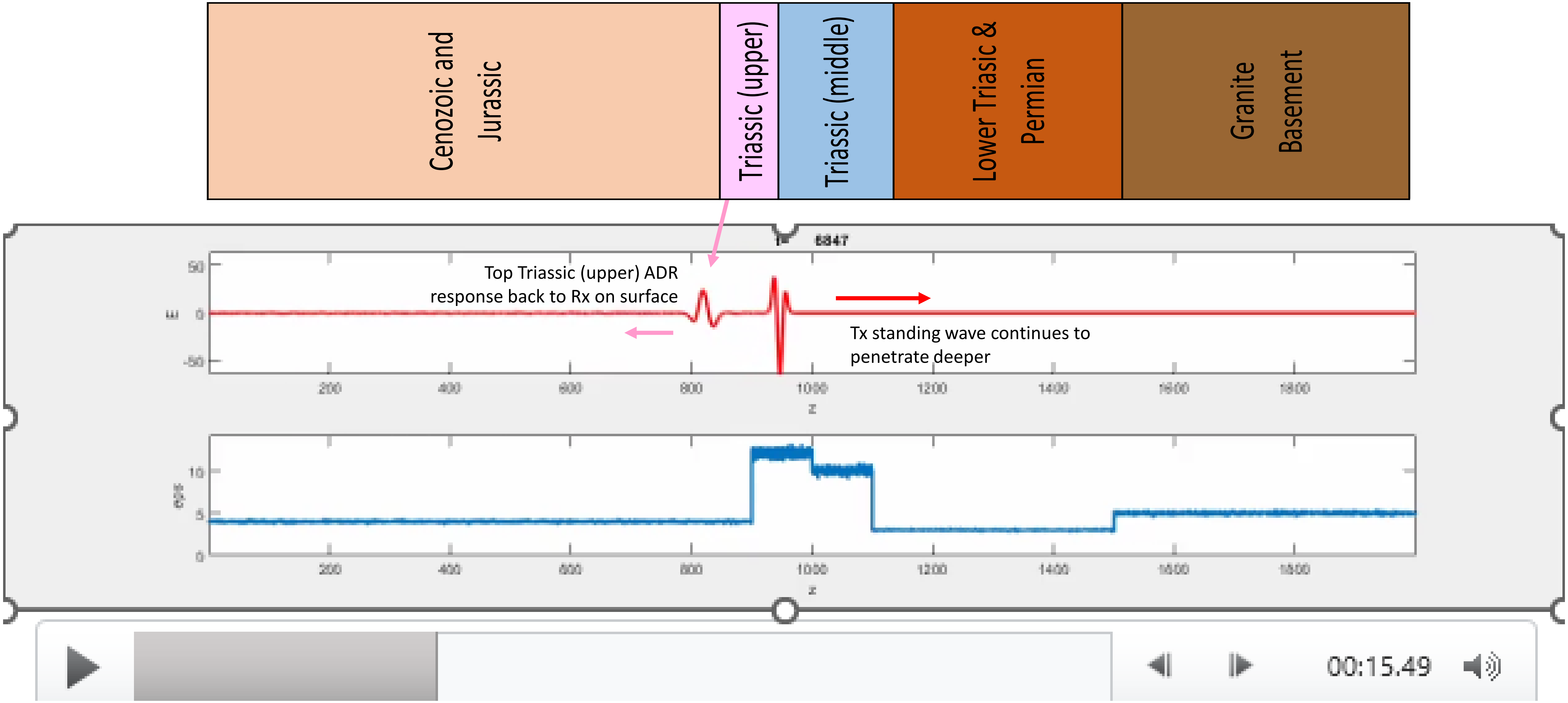
FDTD simulation showing two-way-travel of ADR signal in rock layers



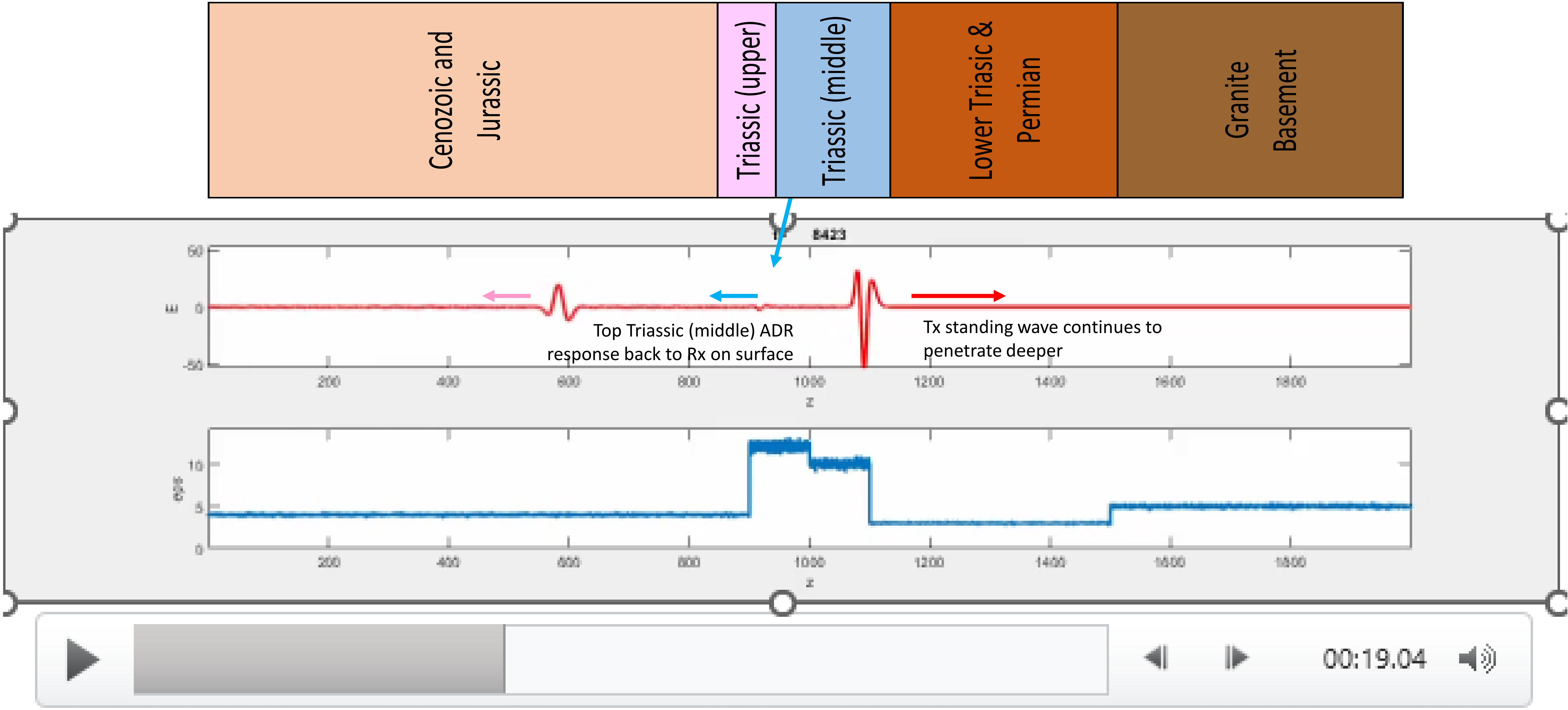


Overlain rock layers from ground level (0m) through the subsurface to depths of 2000m using input data from page 7.

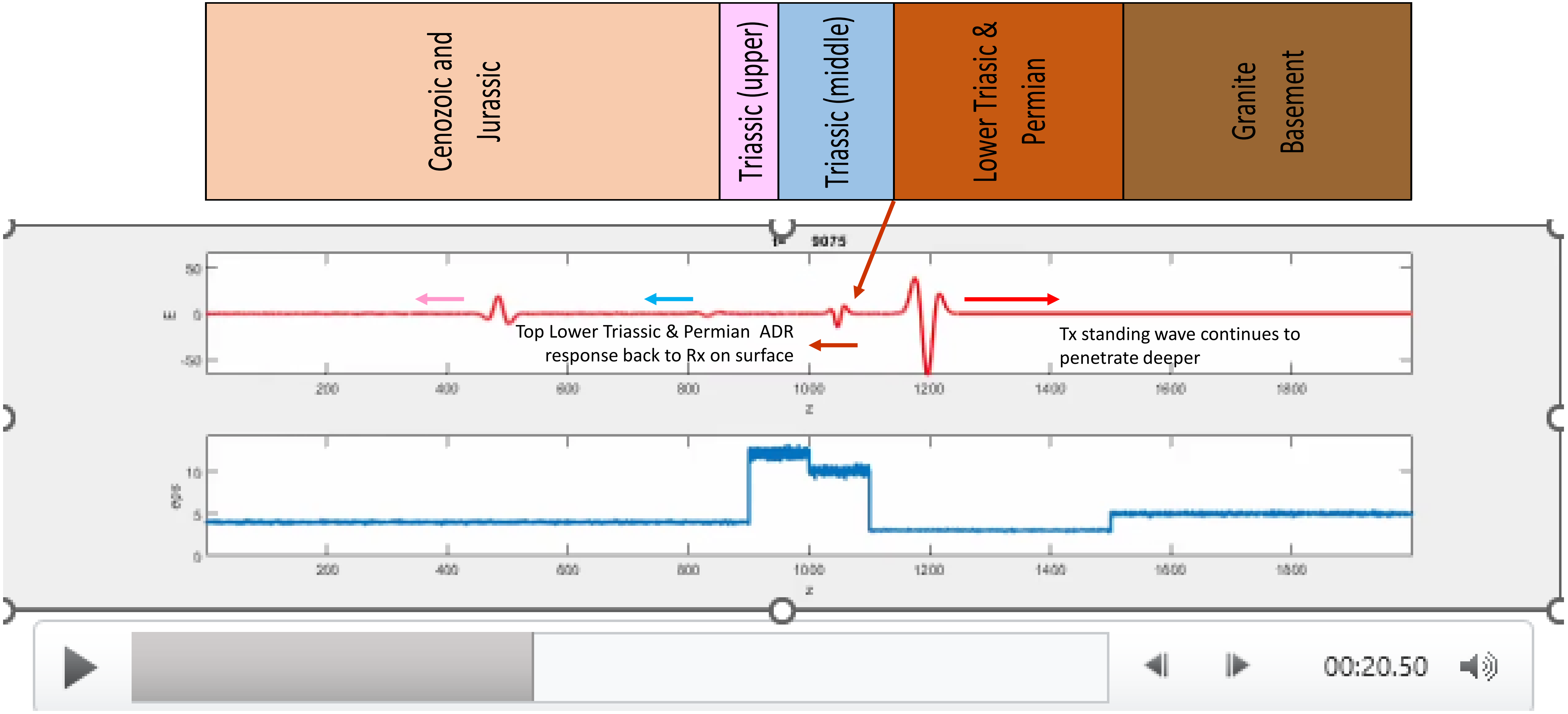
Top Triassic (upper) response ADR signal shown by pink arrow



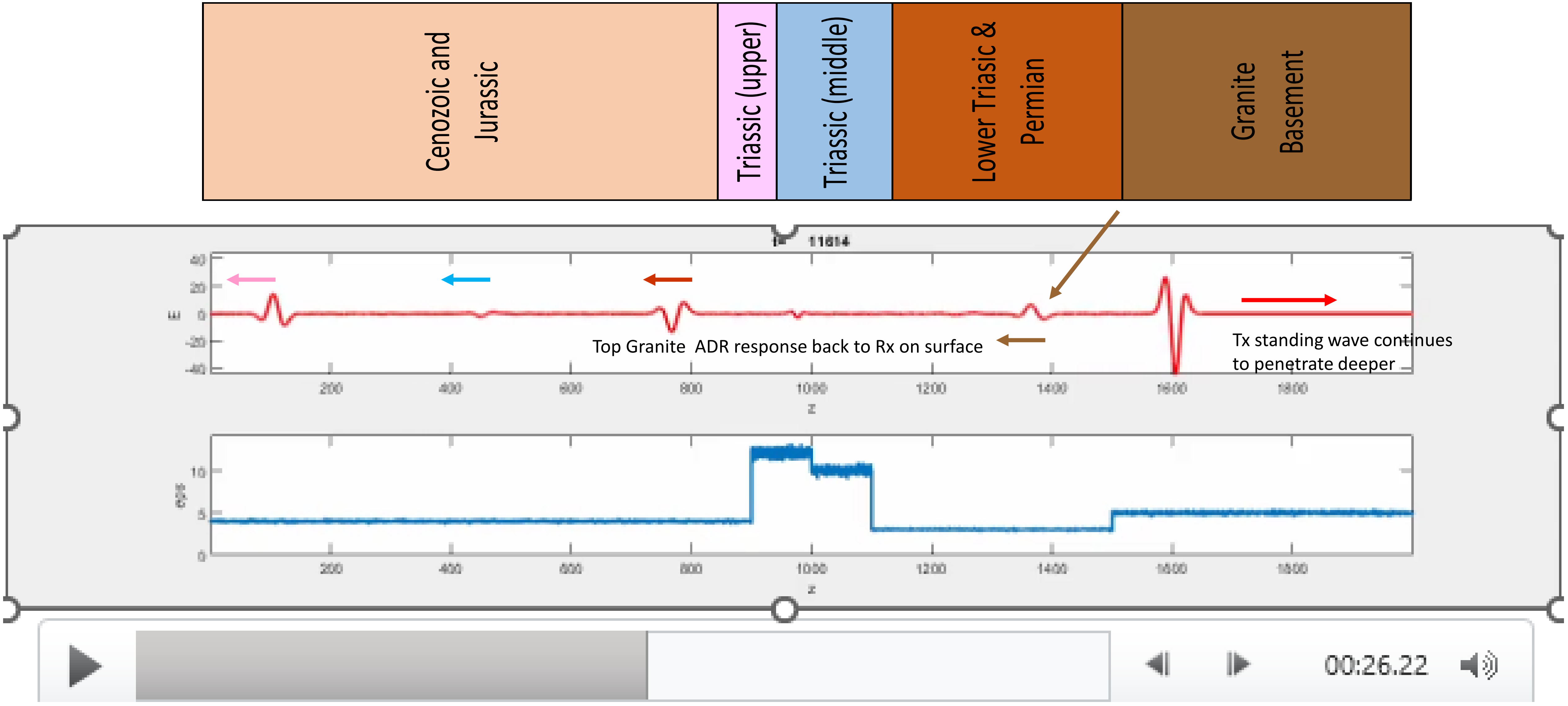
Top Triassic (middle) response ADR signal shown by blue arrow



Lower Triassic & Permian response ADR signal shown by orange arrow



Granite Basement response ADR signal shown by orange arrow



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CEO & Co-founder

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