

Alder Flats 3D Data Impedance Inversion

Detection of an ECBM CO₂ Flood and Ardley Coal Characterization

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November 21, 2008**

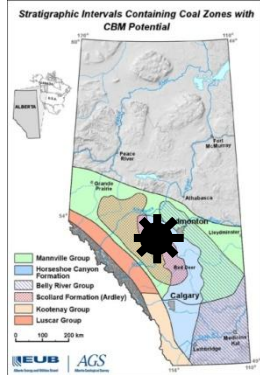
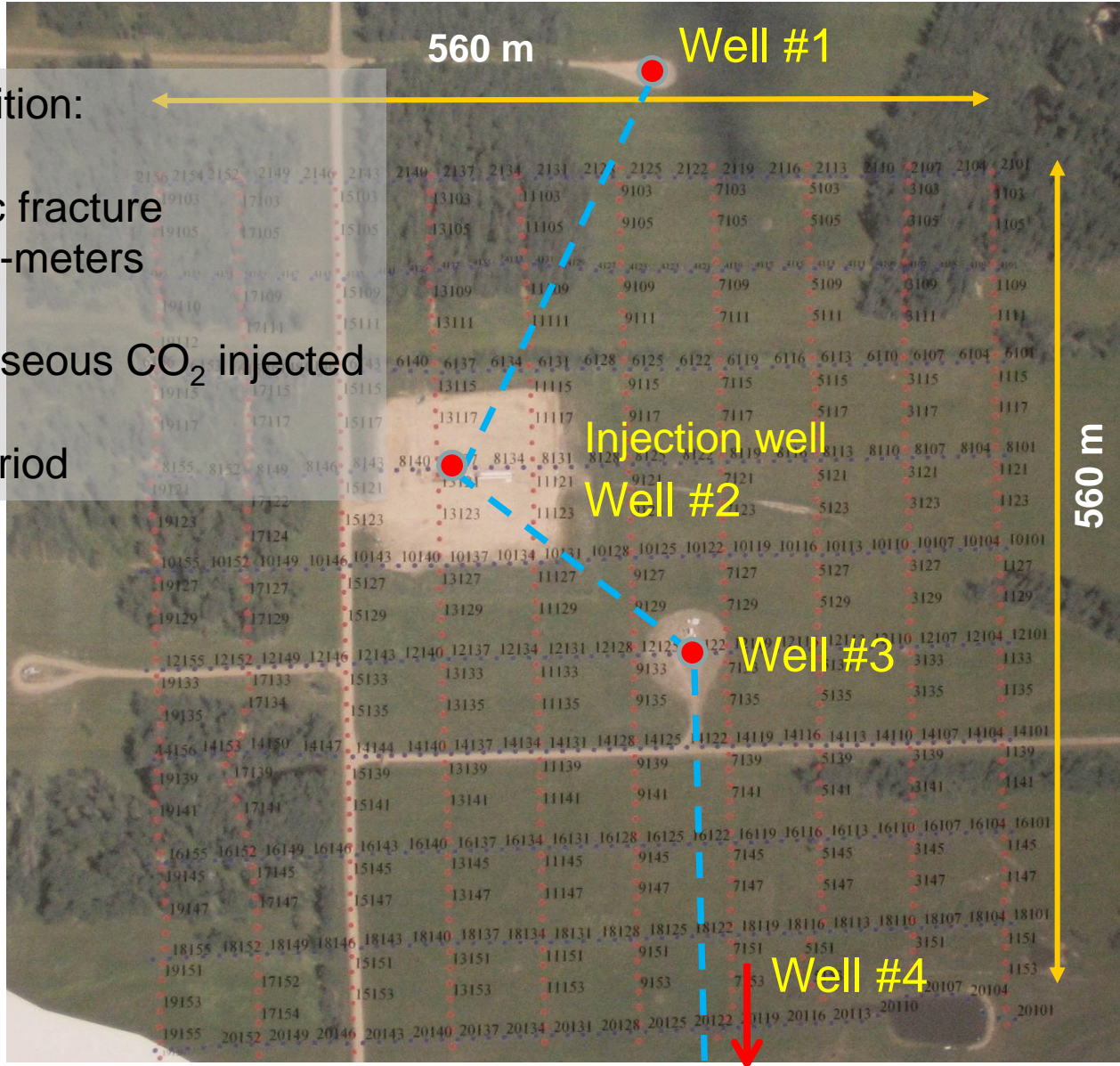


- Introduction to the Alder Flats project
- Deterministic acoustic impedance inversion
- Geostatistical inversion
- Conclusions

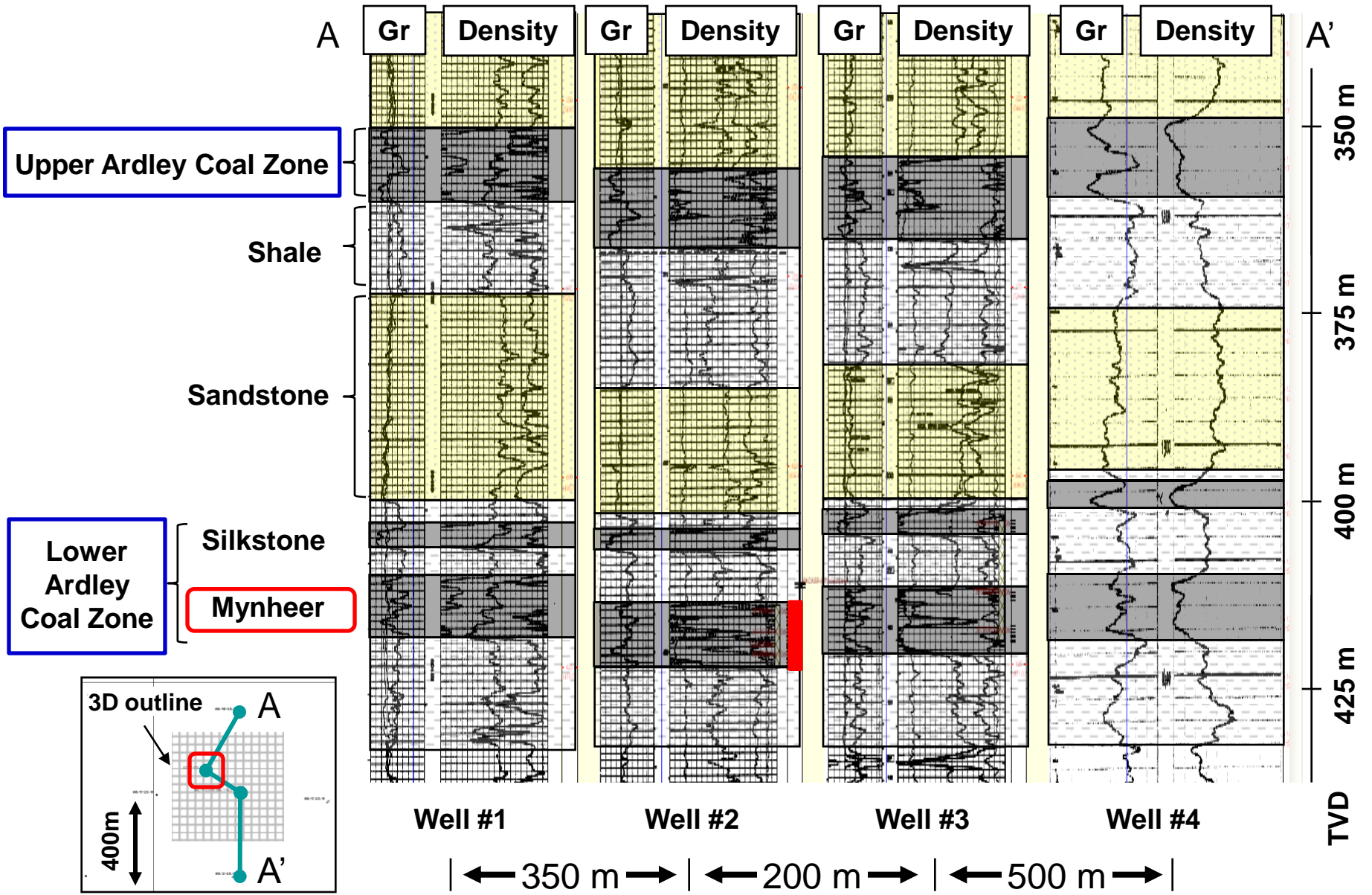
Alder Flats 3D Survey

Prior to 3D acquisition:

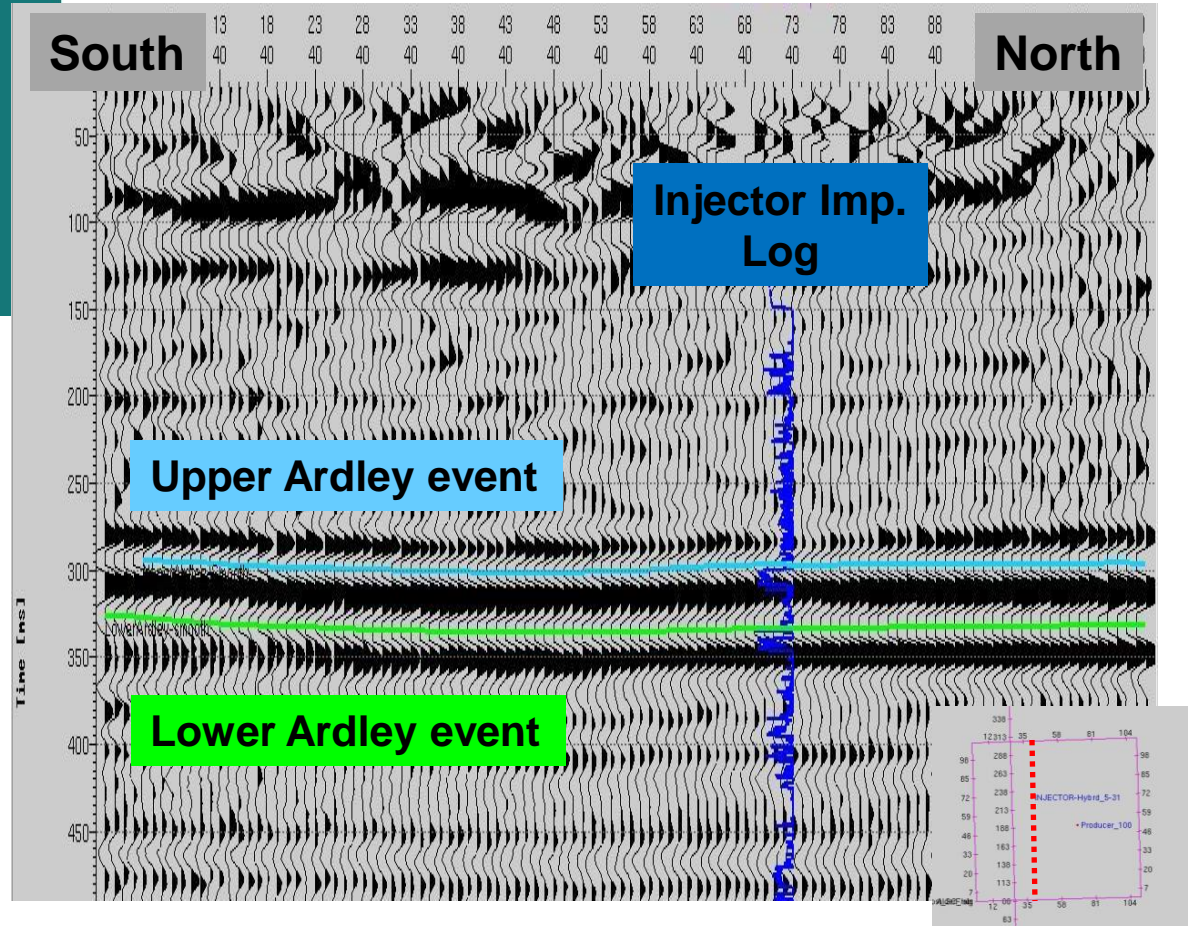
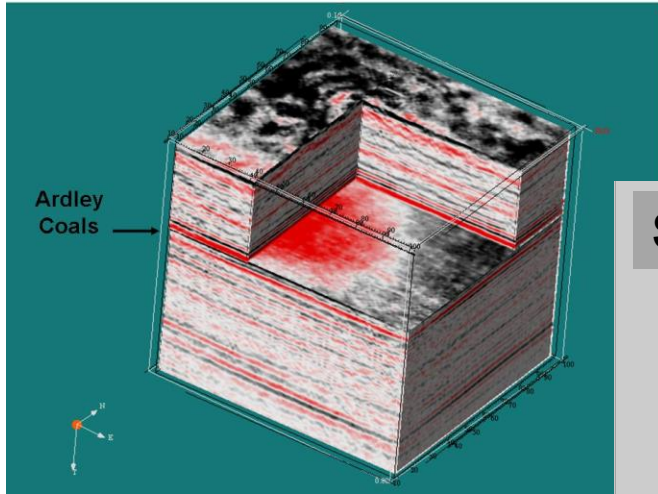
- SW-NE hydraulic fracture monitored with tilt-meters
- 180 tonnes of gaseous CO₂ injected
- 9 month soak period



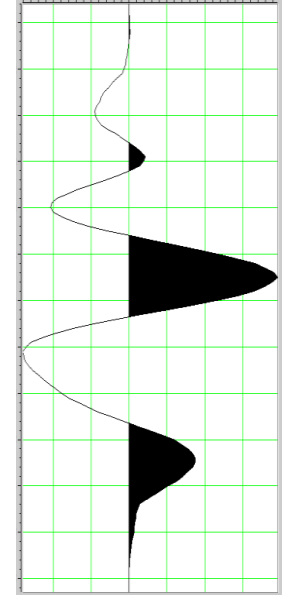
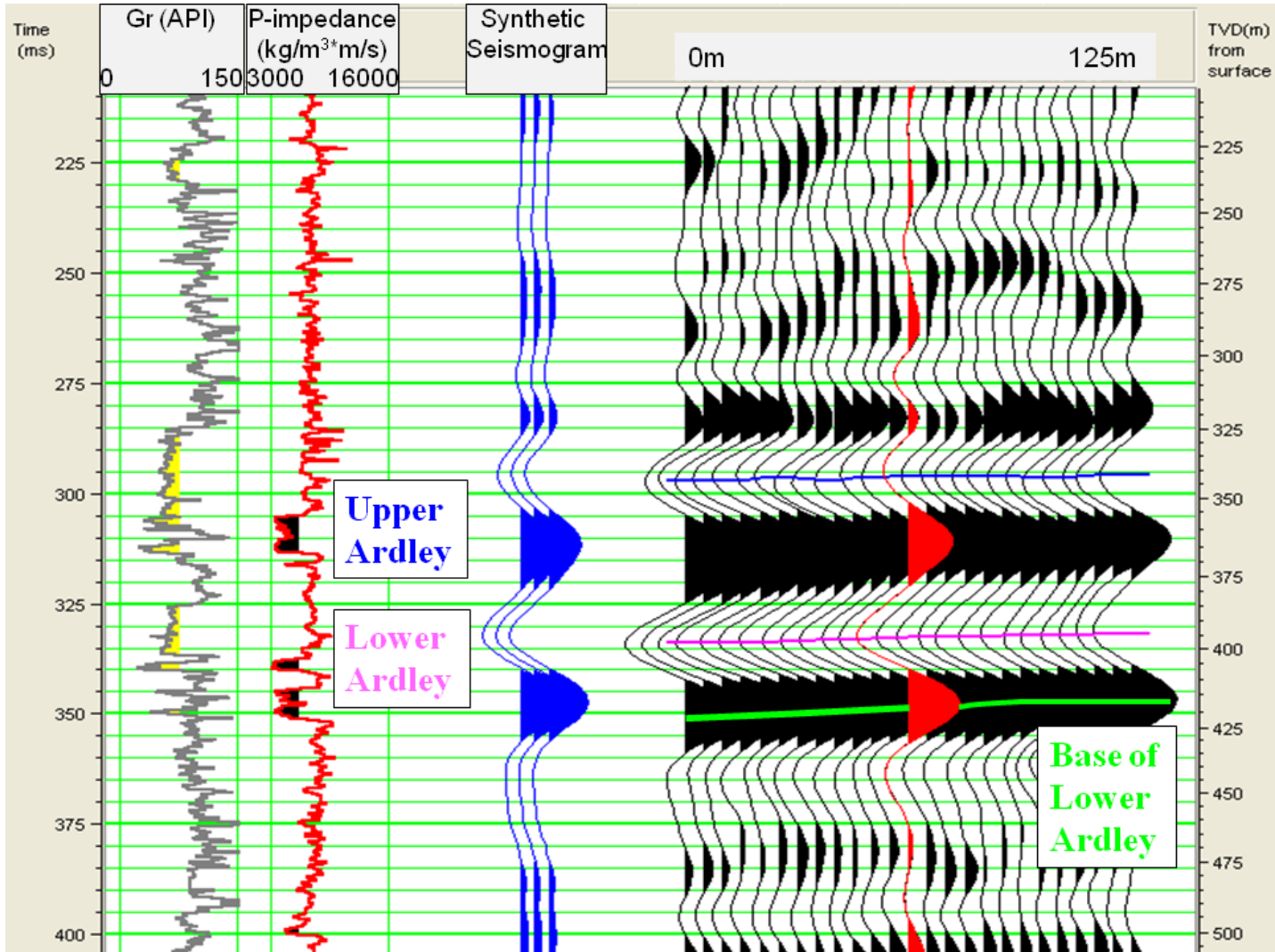
Study Area Cross-section ~1km



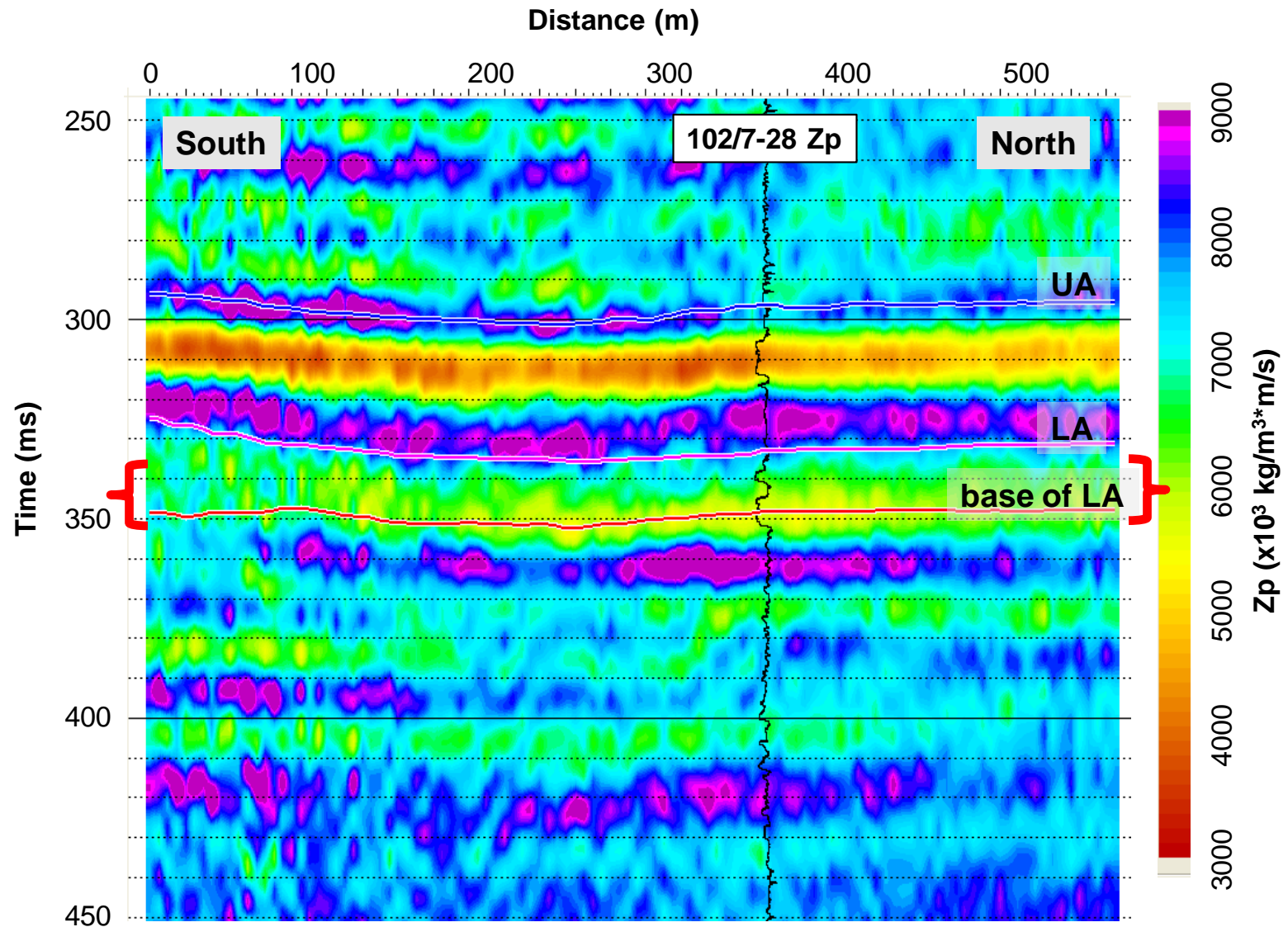
3D Data



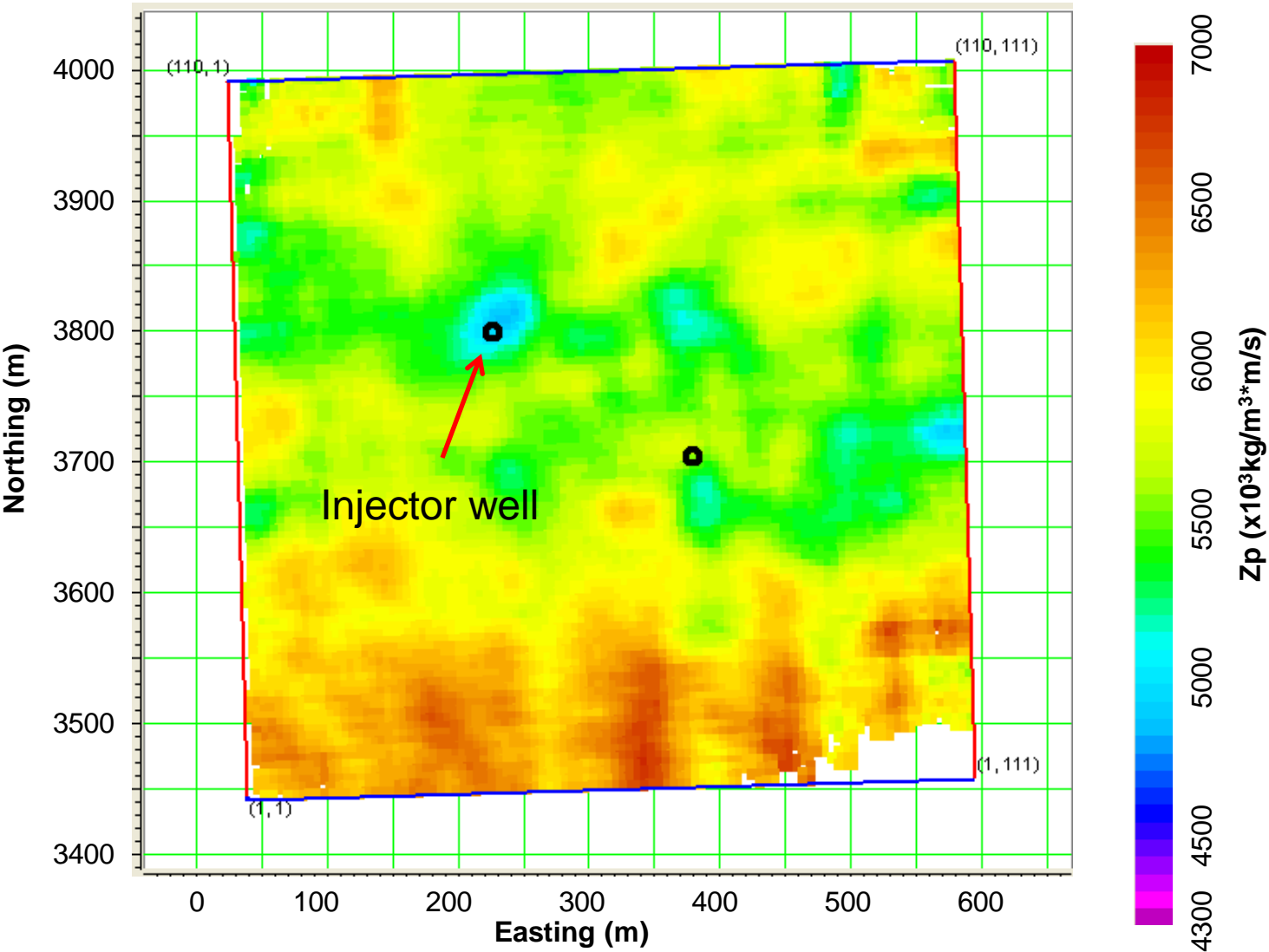
Thin Bed Tuning



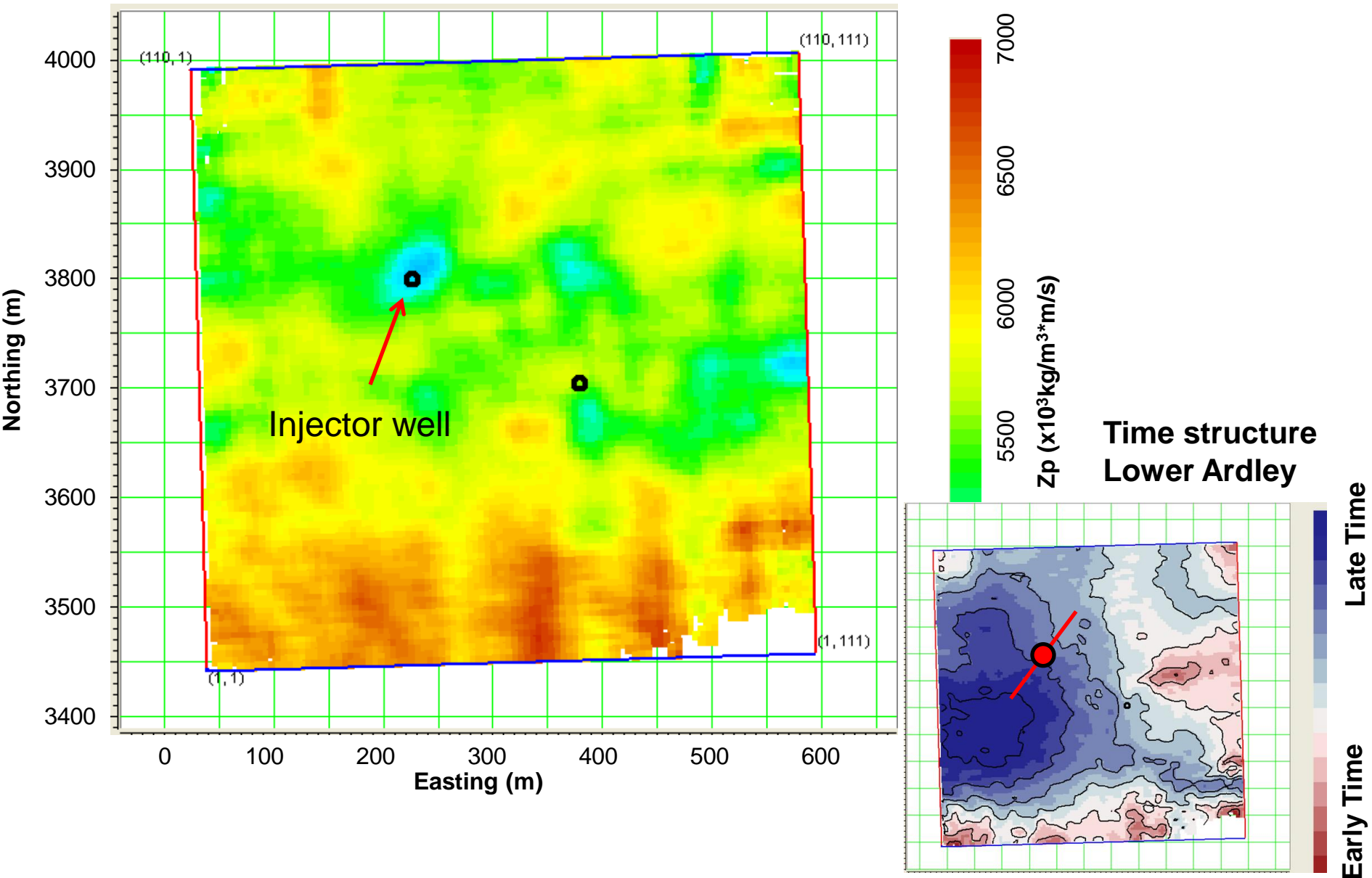
Acoustic Impedance Inversion



Mean Acoustic Impedance of the Lower Ardley



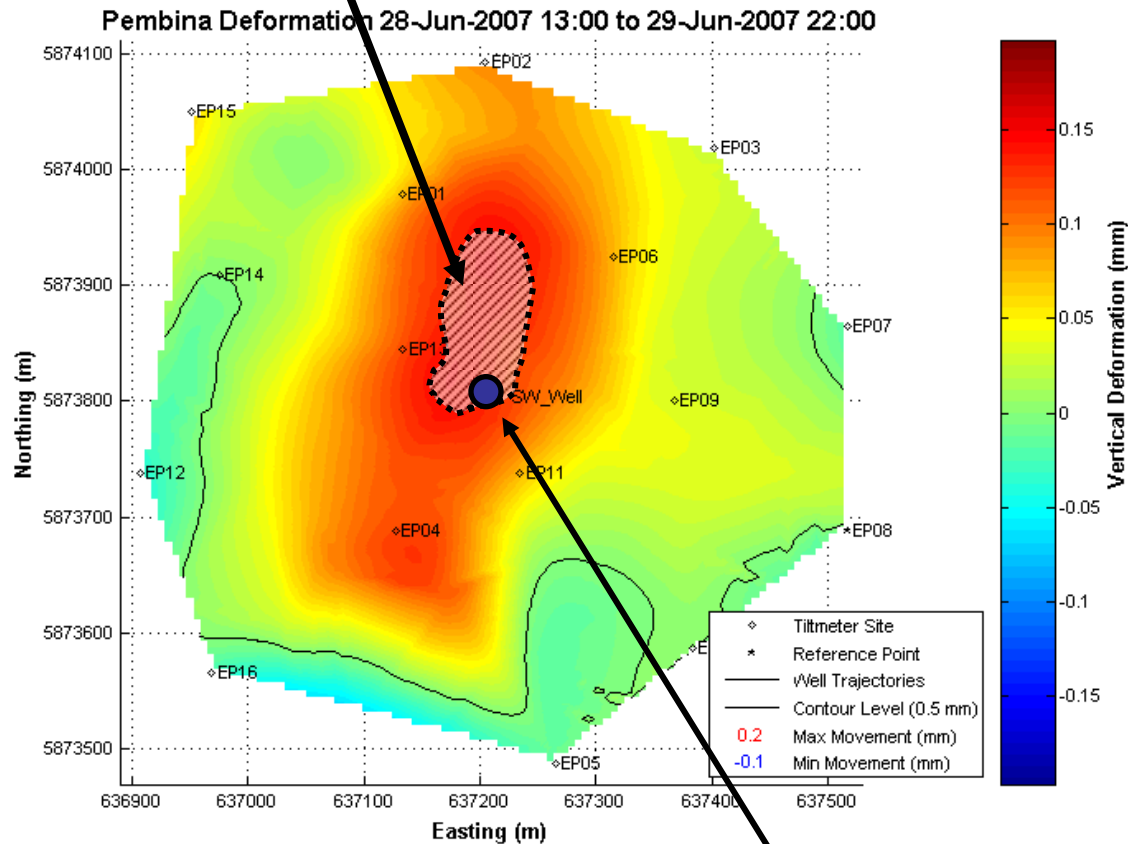
Mean Acoustic Impedance of the Lower Ardley



Comparison to Surface Tilt-meter Response

Mapped surface deformation during the second stage CO₂ injection - post seismic survey. Courtesy A.R.C.

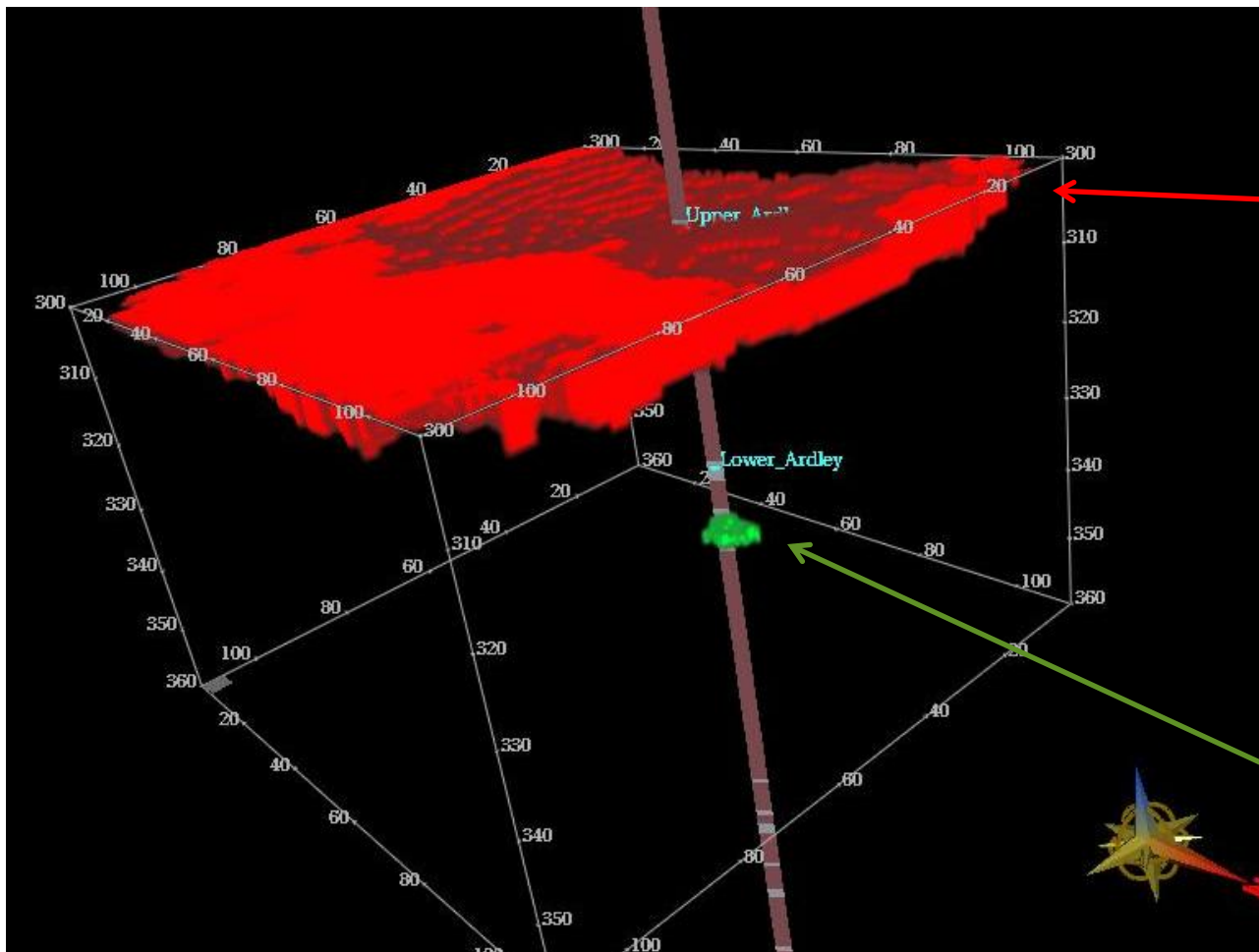
Max. Movement Zone



Injector well

3D View of the Low Z_p Voxels

Z_p voxels $< 5e^6 \text{ kg/m}^3 \cdot \text{m/s}$ and > 50 similar connections



Upper Ardley

Location, size and shape of the anomaly are as expected for the CO_2 flood

Anomaly of the Lower Ardley

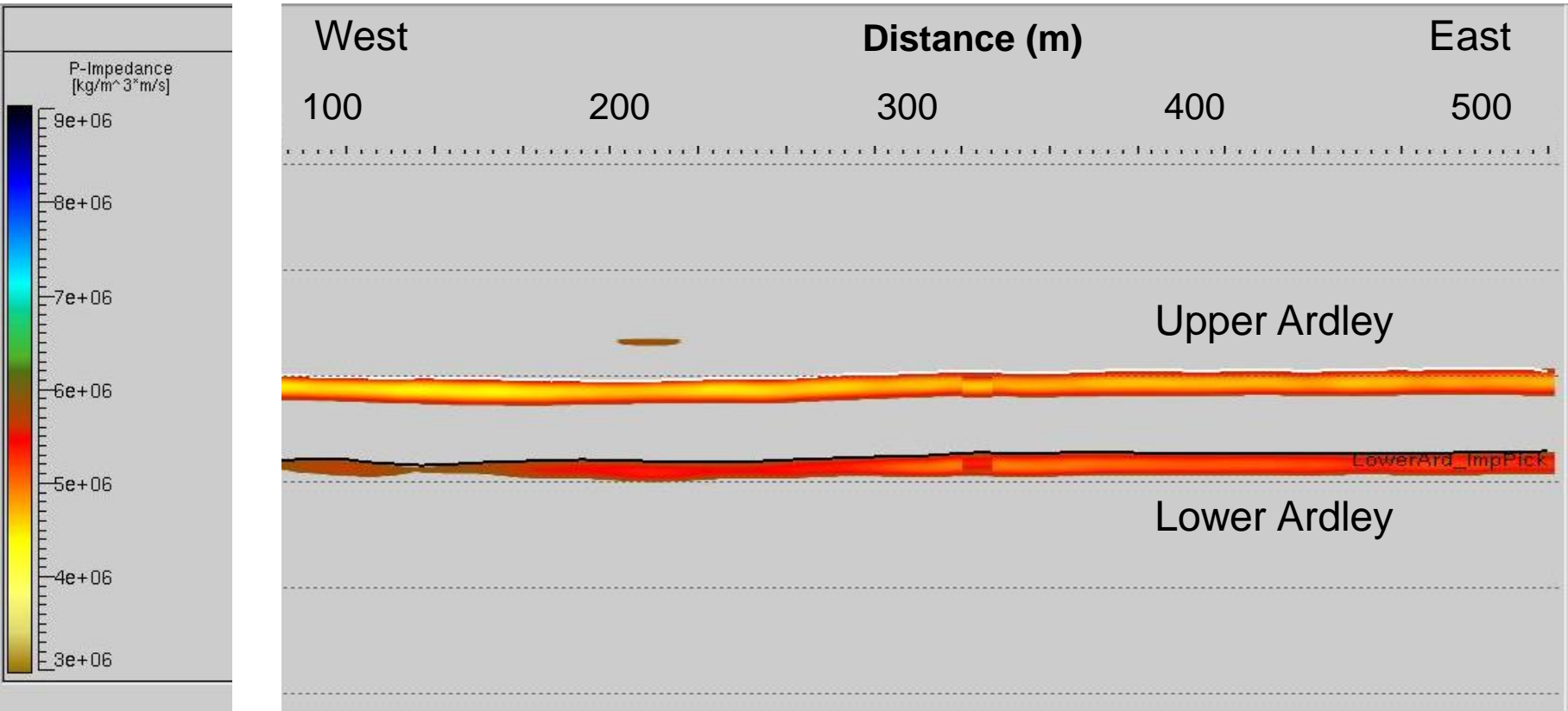
The Rock Physics

The anomaly shows a reduction in acoustic impedance of 10% or more.

- Coals have macro-porosity $\sim 0.5\%$. Gassmann fluid substitution predicts an $\sim 4\%$ reduction in acoustic impedance.
- Viète and Ranjith (2006) demonstrated coal matrix weakening in the laboratory with coal-CO₂ interaction - attributed to a change in the surface energy of the micro-porosity.
- Larson (2004) claims evidence that CO₂ acts as an organic solvent in coal and may plasticize the glassy solid matrix.

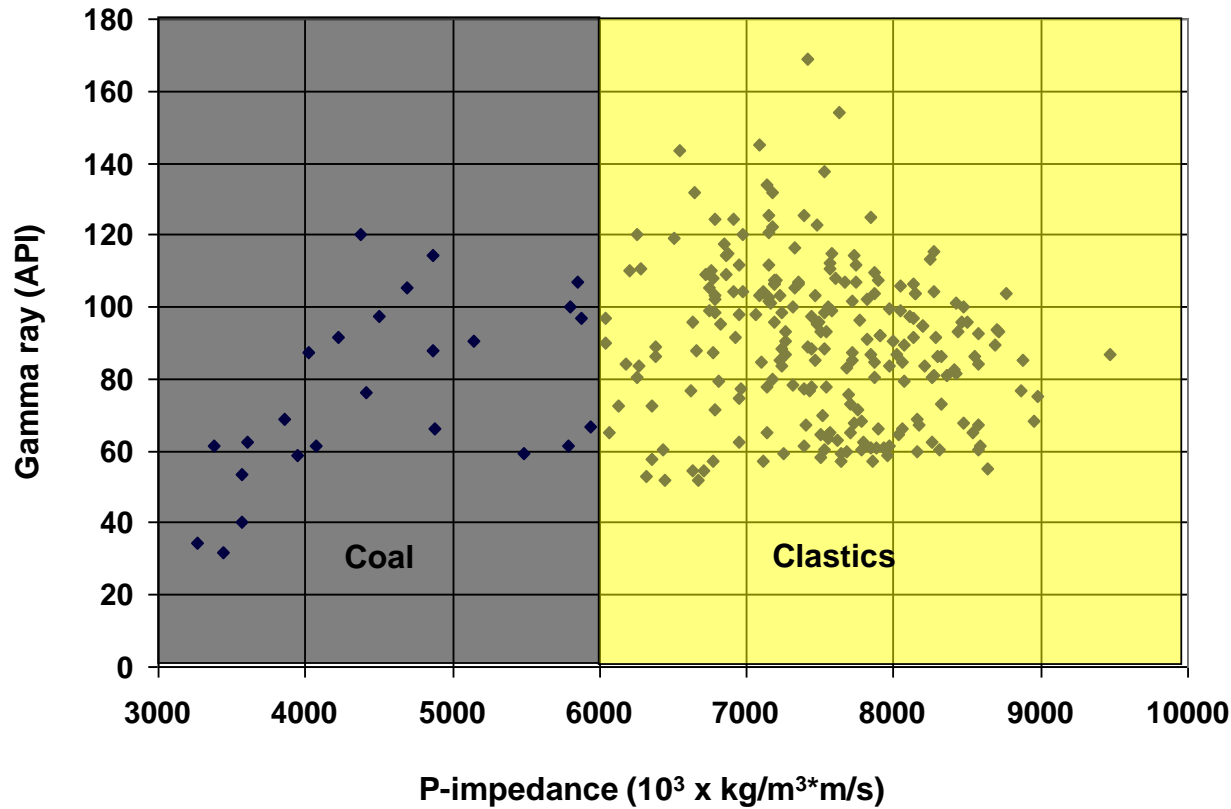
These results support an interpretation that CO₂ causes a net reduction in the coal matrix stiffness.

Resolution of the Inversion



Coals have $Z_p < 6e^6$ kg/m³*m/s

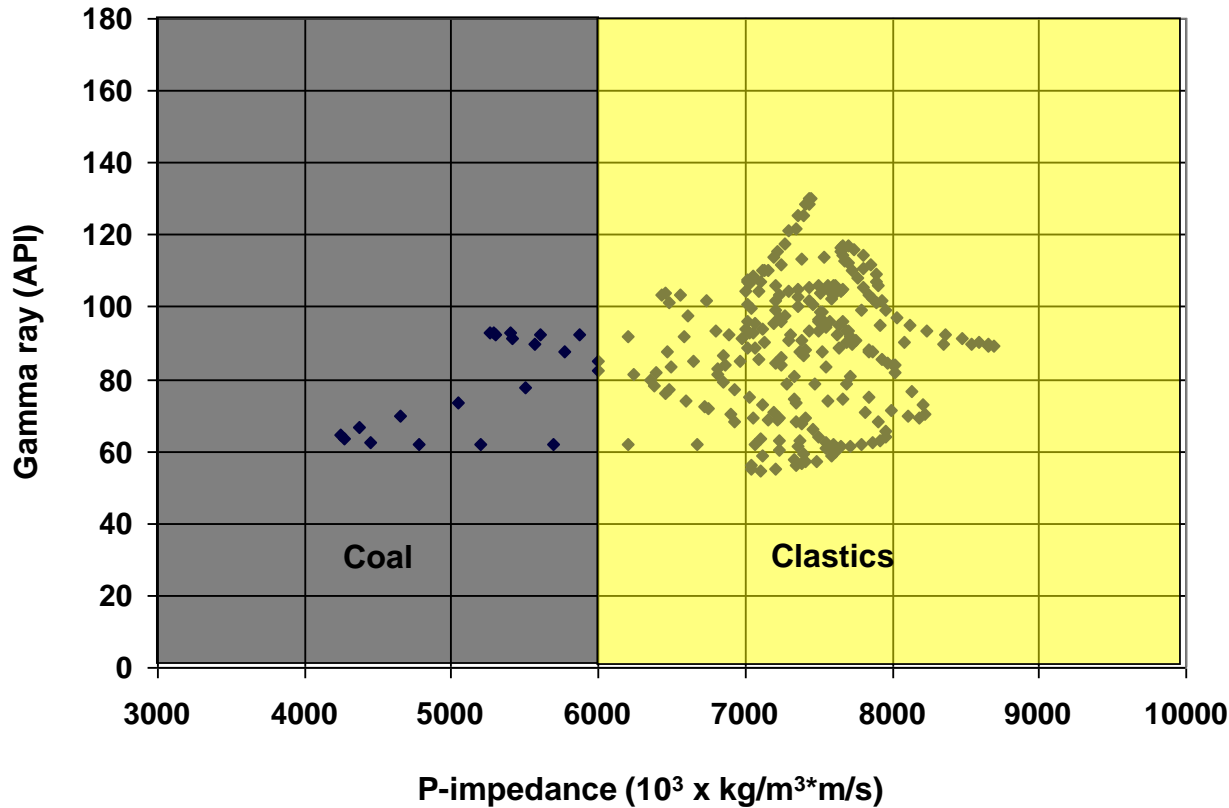
Well Data Cross-Plot: Logging Resolution



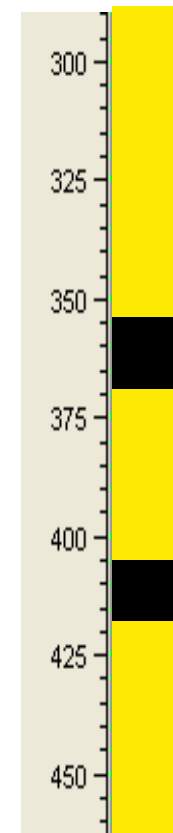
Lithology log



Well Data Cross-Plot: "Seismic" Resolution

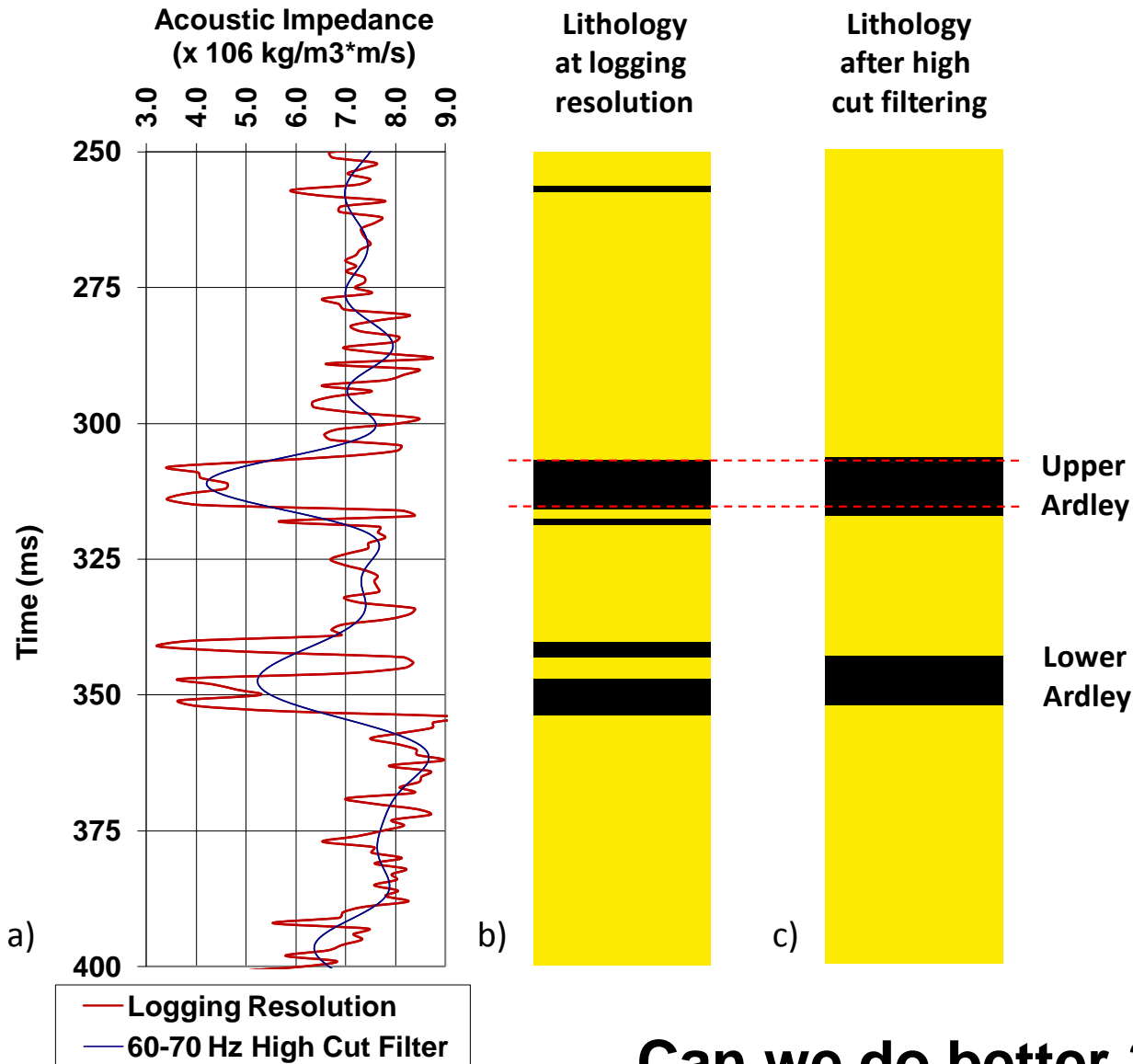


Lithology log



60 Hz high-cut filter applied to the well log data

Logs at “Logging” and “Seismic” Resolution



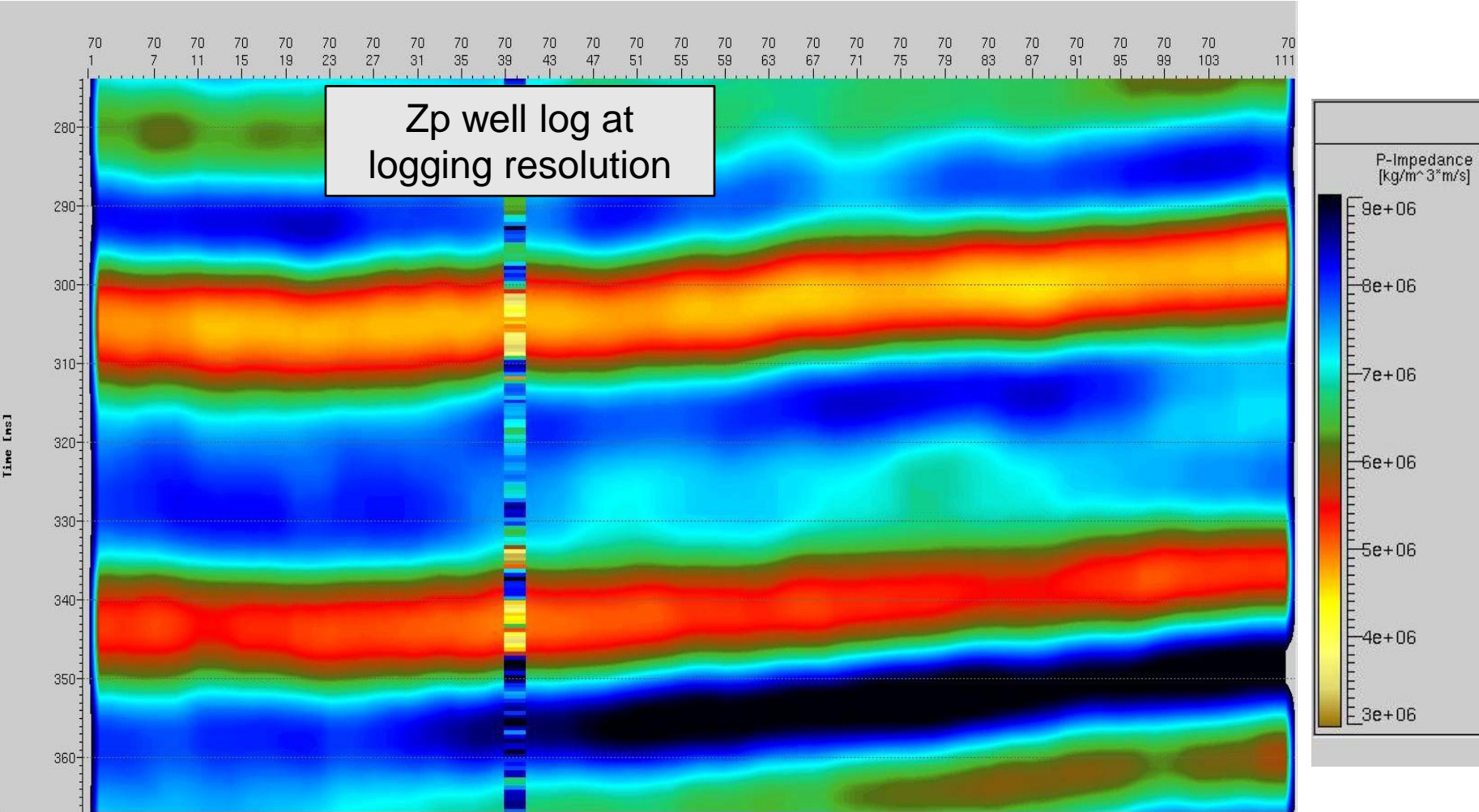
Three problems with the deterministic inversion results:

1. Thin beds not resolved
2. Coal zones too thick due to inversion “smearing”
3. Absolute Z_p values do not reflect the very low Z_p values in coal zones

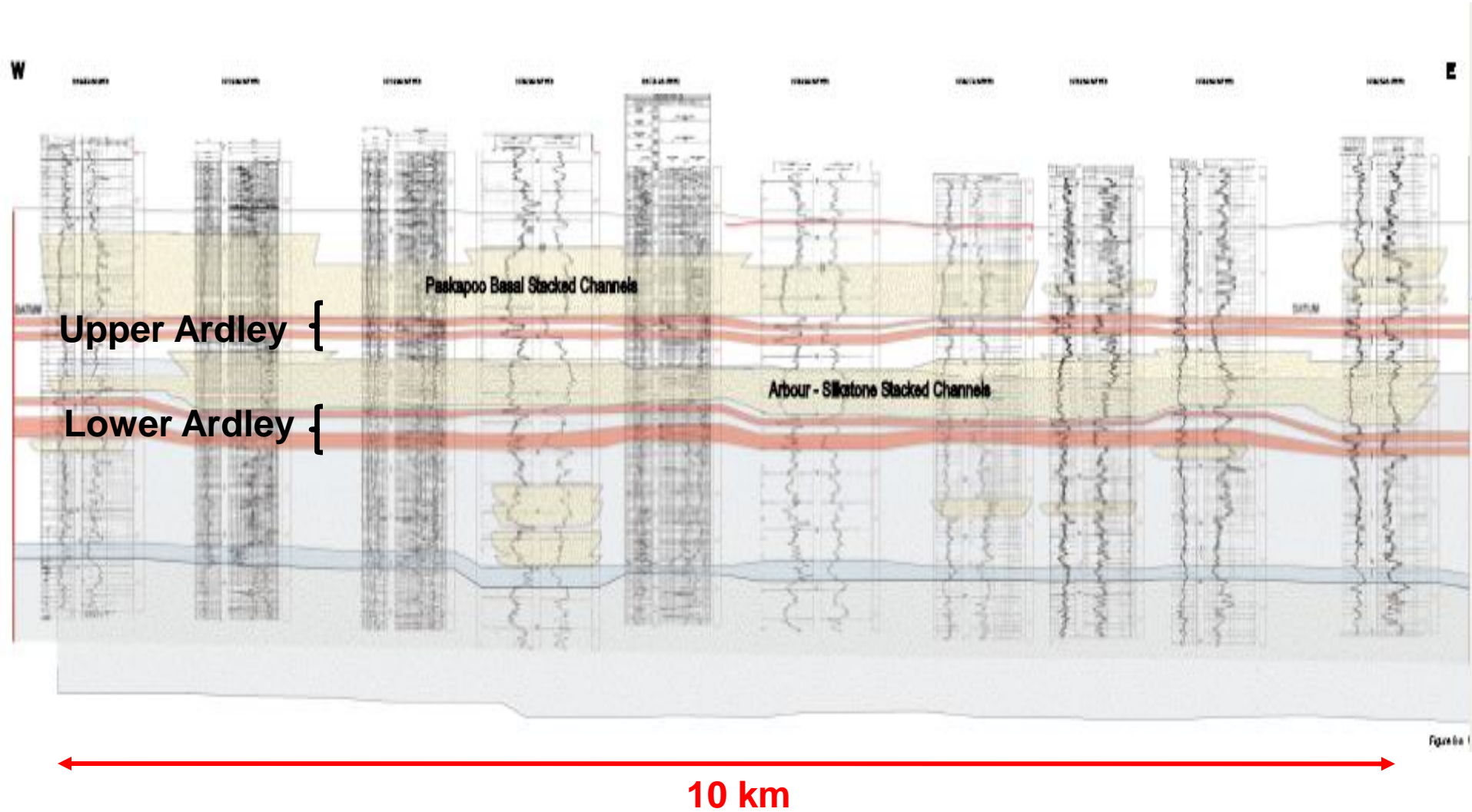
Can we do better ?

Yes

We Have High Resolution Log Data

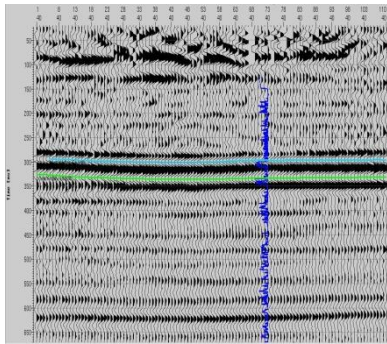


Regional Continuity of the Stratigraphy

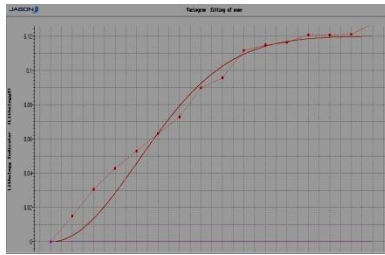


From the Pana (AGS), 2004

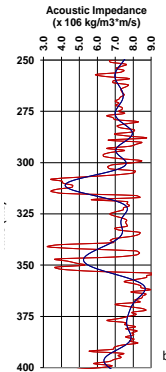
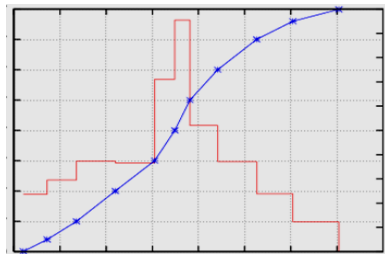
Geostatistical Inversion



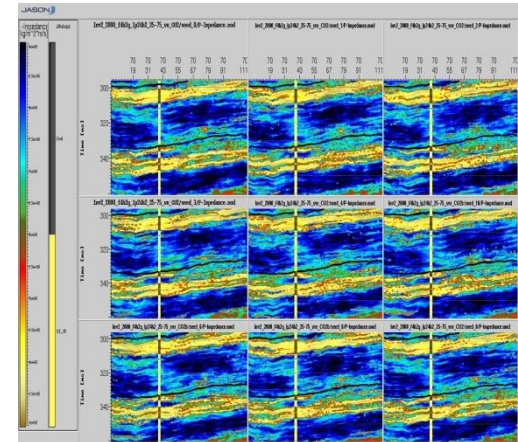
seismic



variograms & histograms



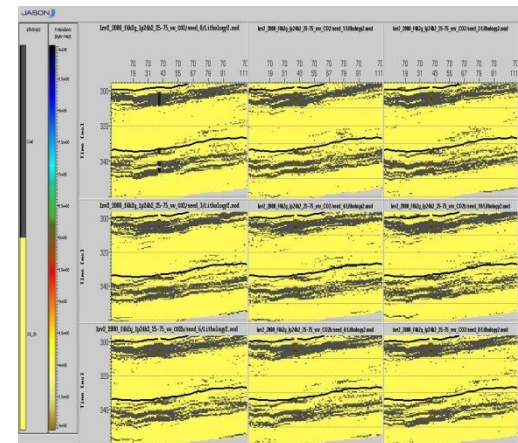
well data
constraint



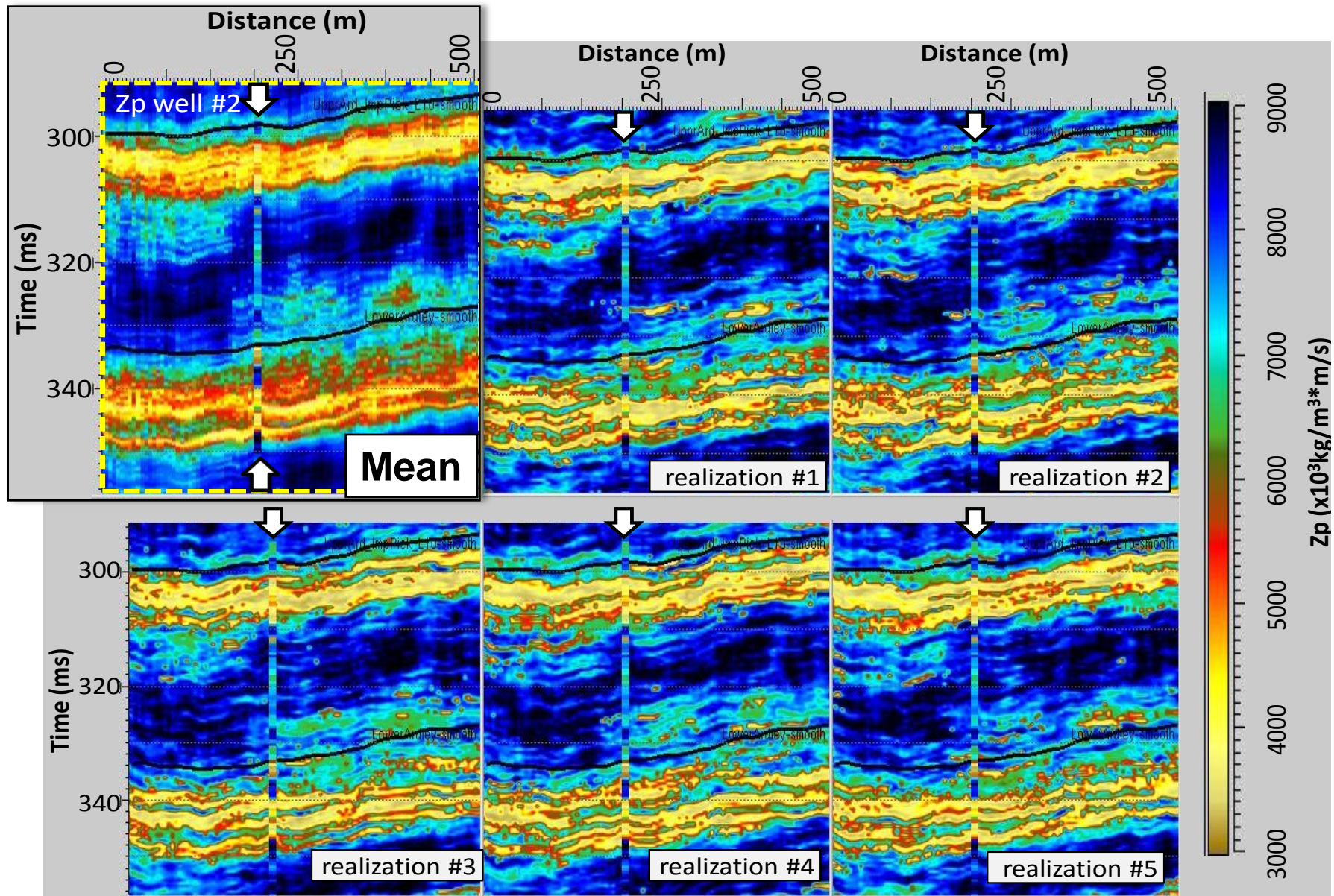
Zp

multiple model
realizations

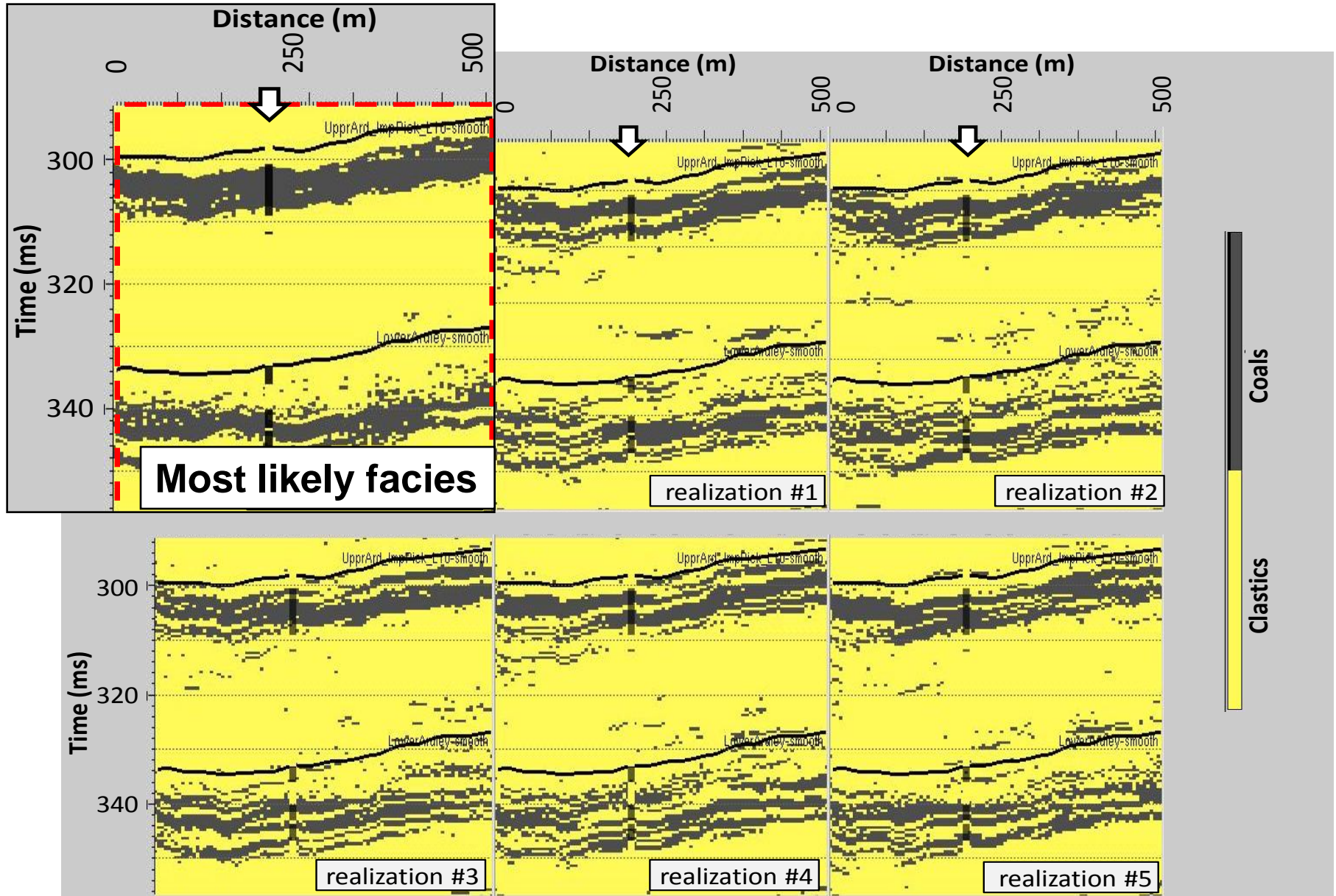
facies



Multiple Acoustic Impedance Realizations

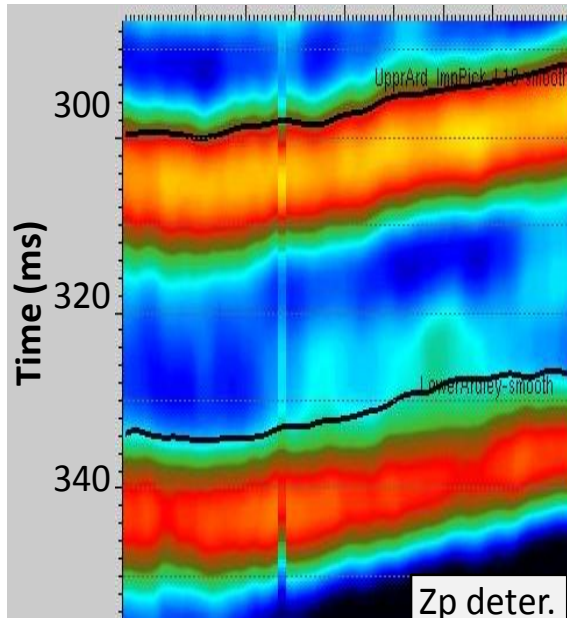


Multiple Predicted Facies Realizations

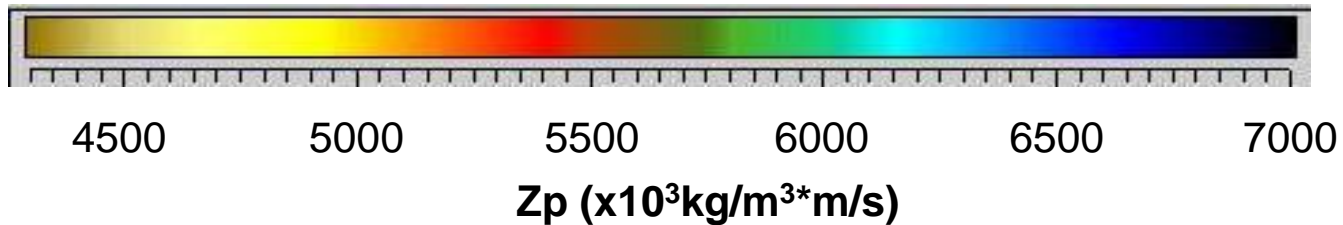
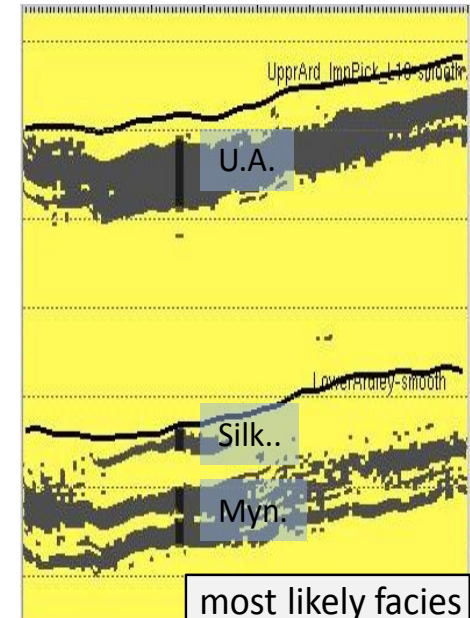
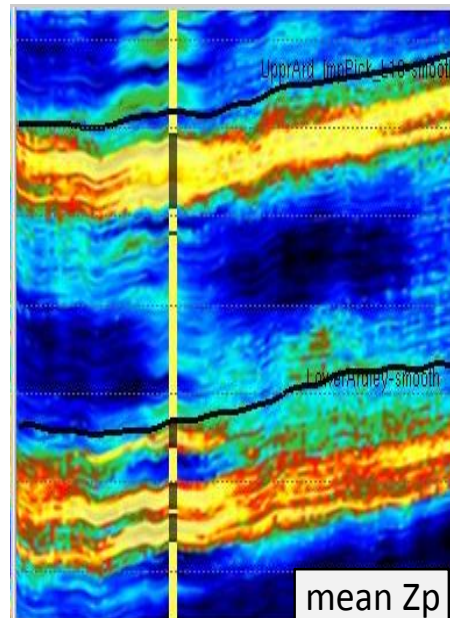


Comparison of the Inversion Methods

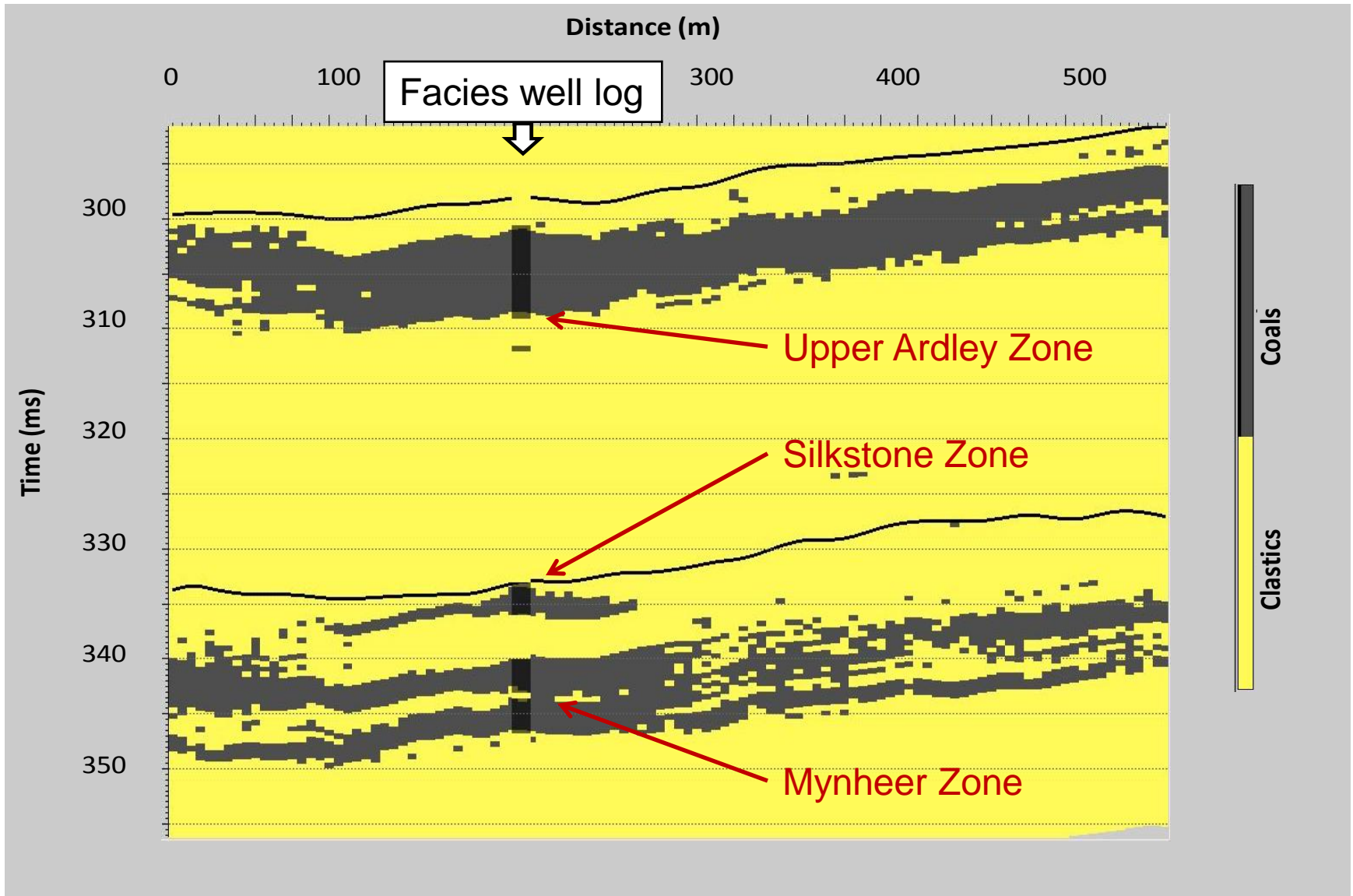
Deterministic Sparse Spike



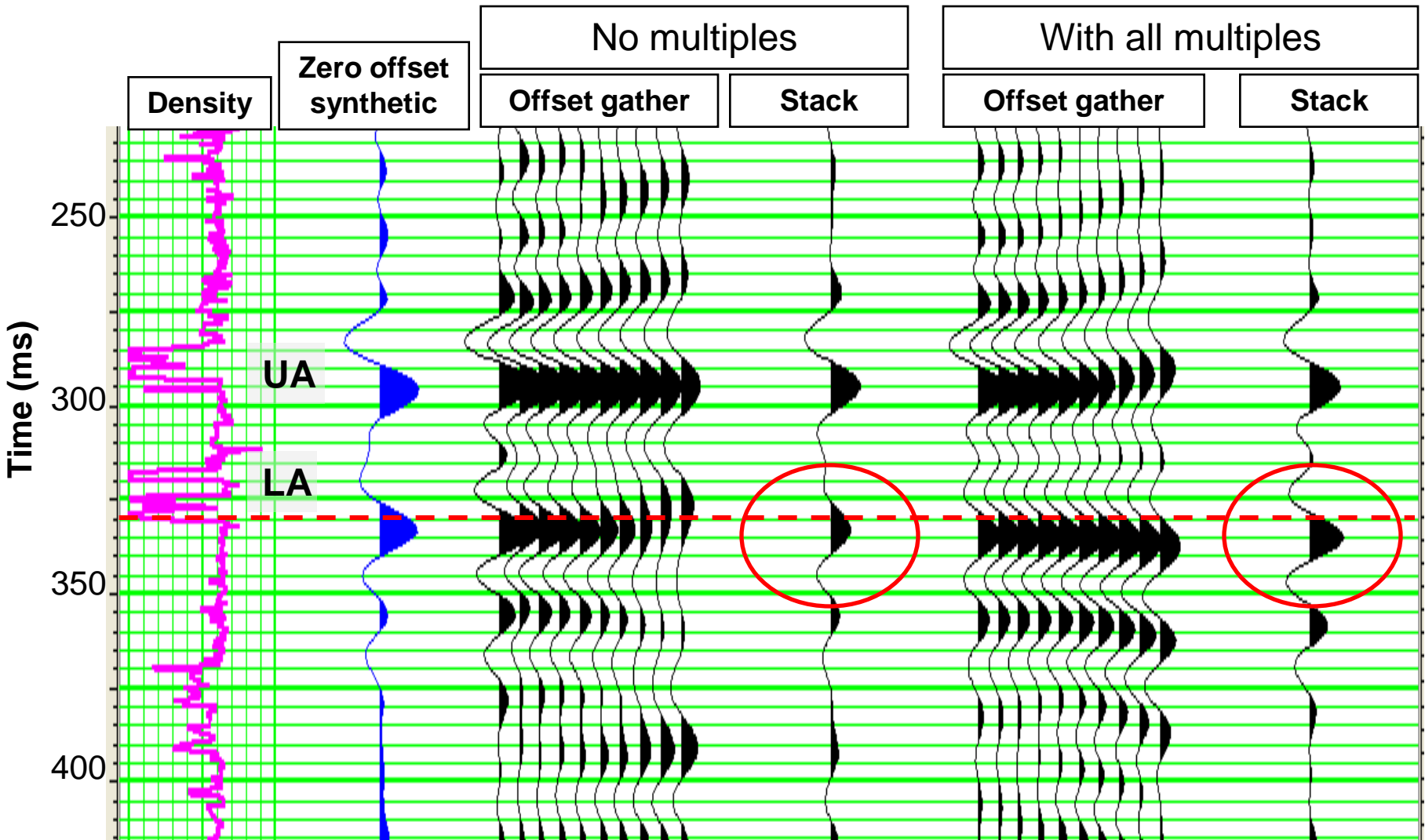
Geostatistical



Most Probable Facies Based on 10 Realizations



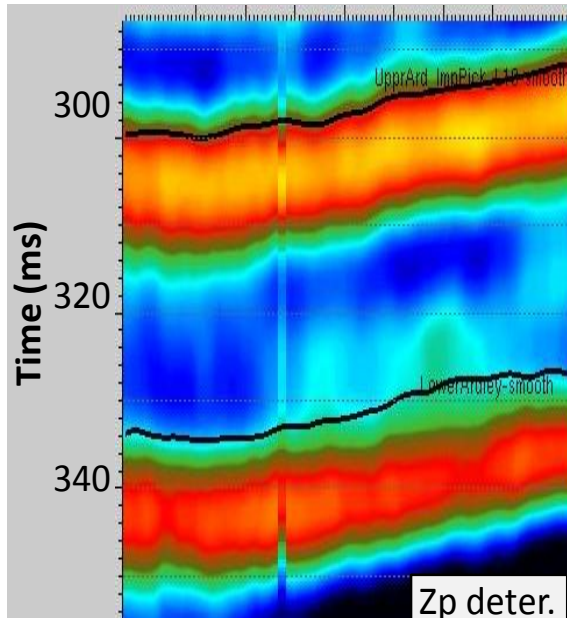
Multiples Cause a Lower Ardley Phase Delay



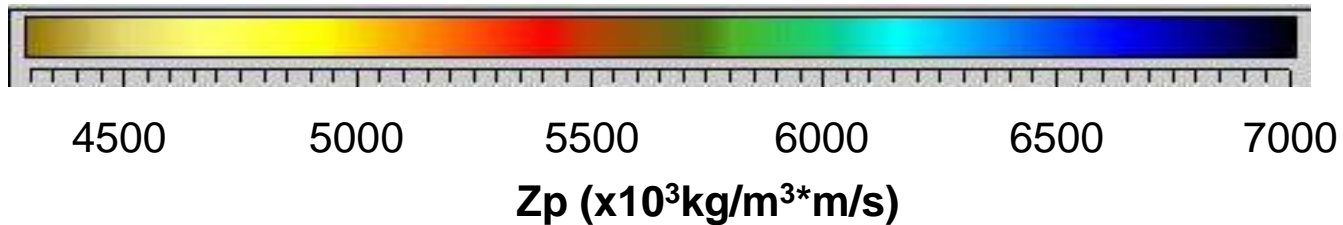
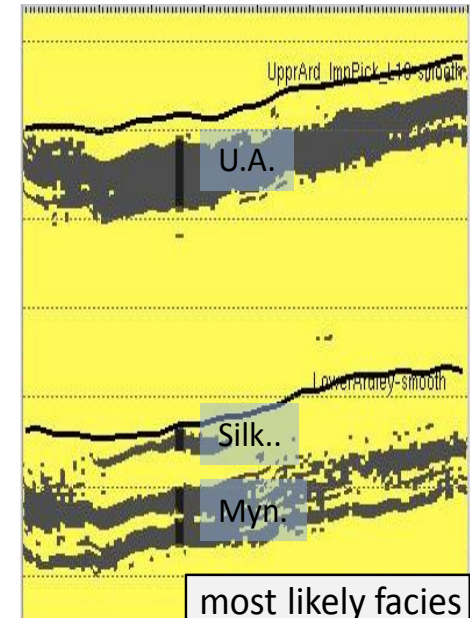
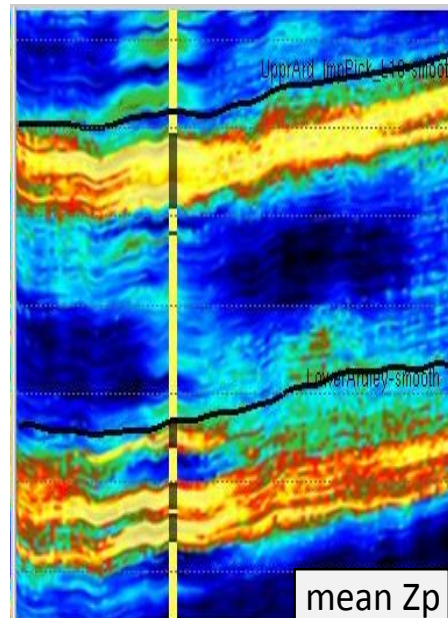
Synthetics created with a reflectivity model

Comparison of the Inversion Methods

Deterministic Sparse Spike



Geostatistical



- 180 tonnes of gaseous CO₂ is detectable.
- Model-based deterministic inversion shows the CO₂ flood as a low acoustic impedance anomaly around the injection well.
- Constraining the inversion with geostatistics can improve resolution and absolute impedance estimation.
- Geostatistical inversion can enable uncertainty analysis.

Acknowledgements



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