Reducing Geologic Uncertainty in Seismic Interpretation*

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Abstract

When working with seismic and petrophysical data, both data types may pose a number of unique challenges to the interpreter. Although 3D seismic data provides wide data coverage, the information often lacks granularity and is not a direct measurement of the reservoir properties we are typically interested in obtaining. Petrophysical log data is quite nearly the opposite; in that, we may discern minor changes in reservoir properties along a well bore, but these measurements do not extend more than a few meters away from the logging tool. Combining the best of both data types, geologic models capable of filling in the gaps between seismic and petrophysical data sets have become exceeding valuable. This presentation will examine a number of uncertainty reducing workflows associated with both forward and inverse modeling techniques. Geophysical forward modeling techniques calculate a specific geophysical response given a well-defined physical property model. In the case of 2D seismic modeling, the physical property model can be taken directly from petrophysical log data, sonic and density logs that have been adequately tied to an existing seismic survey. Using both available log data combined with geologically reasonable model constraints, geo-modelers may construct a number of modeled seismic responses that can be used to help validate or invalidate various working geologic models. In contrast, geophysical inverse modeling techniques attempt to construct a physical property model based off a geophysical response. In the case of seismic inversion, impedance values are calculated from an existing seismic data set. The largest challenge associated with inverse modeling is that there are multiple solutions available given an individual seismic data set. By using a simulated annealing (SA) inversion algorithm, geoscientists are able to greatly reduce the total number of possible solutions that are available by leveraging both a background model combined with efficient wavelet estimation for optimal tuning parameters.

Reducing Geologic Uncertainty in Seismic Interpretation

AAPG Pacific/Rocky Mountain Section

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Agenda

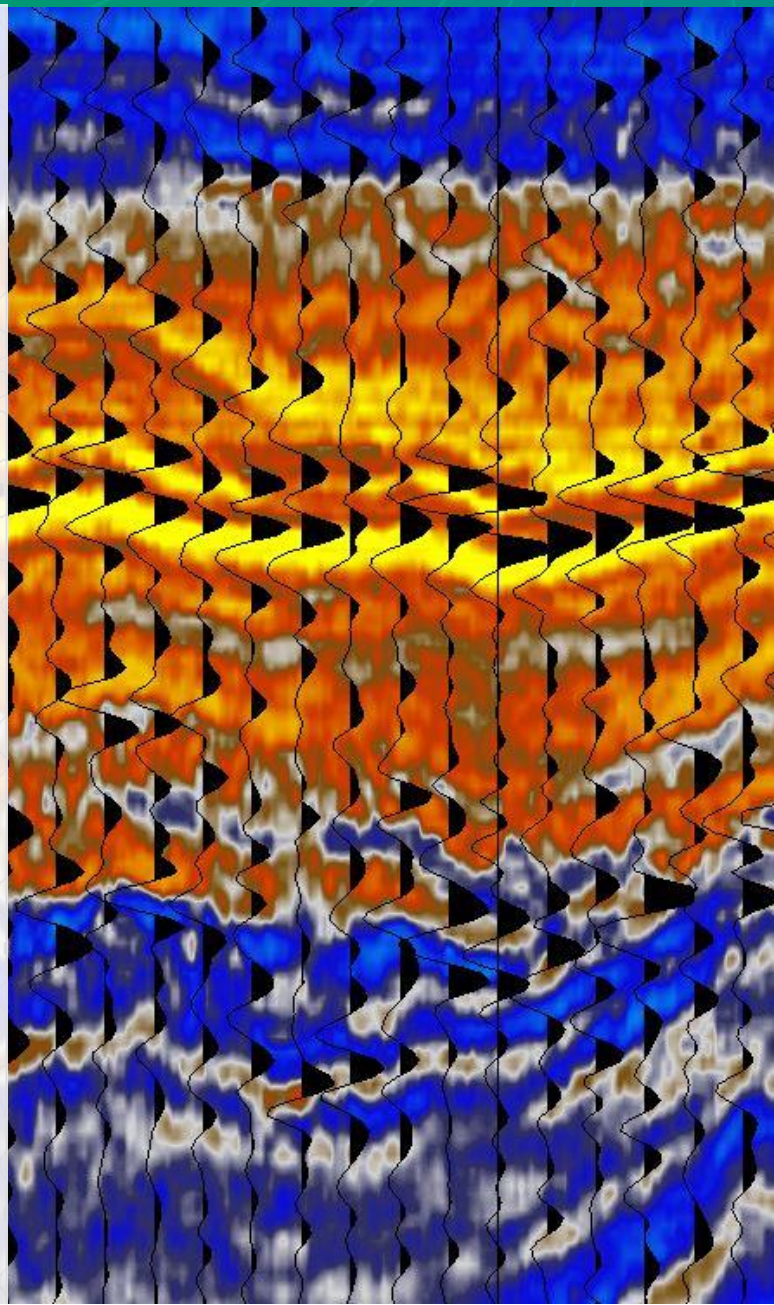
Data and Uncertainty

Geologic Models and Non-Uniqueness

Model Constraints/Boundaries

Modeling Examples

Summary



Data and Uncertainty

Well Data

- **High Level of Detail**
- **Limited Data Coverage**

Seismic Data

- **Low Level of Detail**
- **Extensive Data Coverage**

The need for Geologic Models

Data Gaps

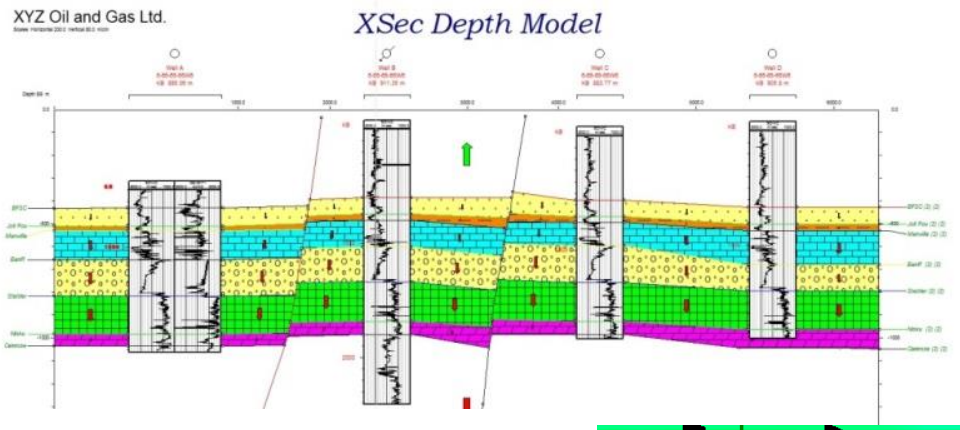
Geophysical Ambiguity

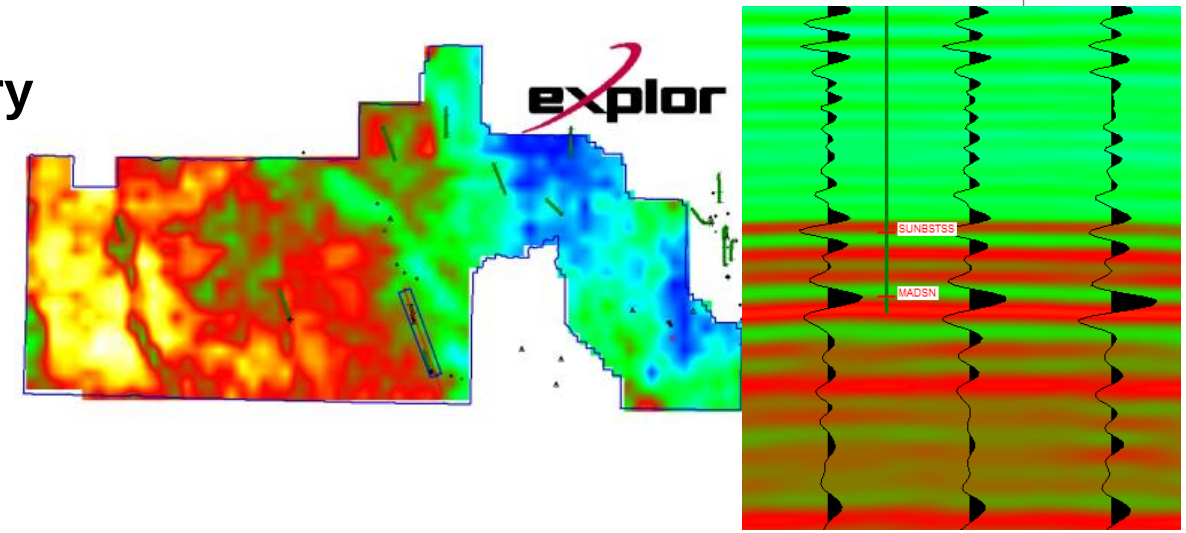
Verification of Interpretation

Predicting Rock Behavior

Optimize Survey Geometry Layouts

Mitigate Risk and Reduce Uncertainty

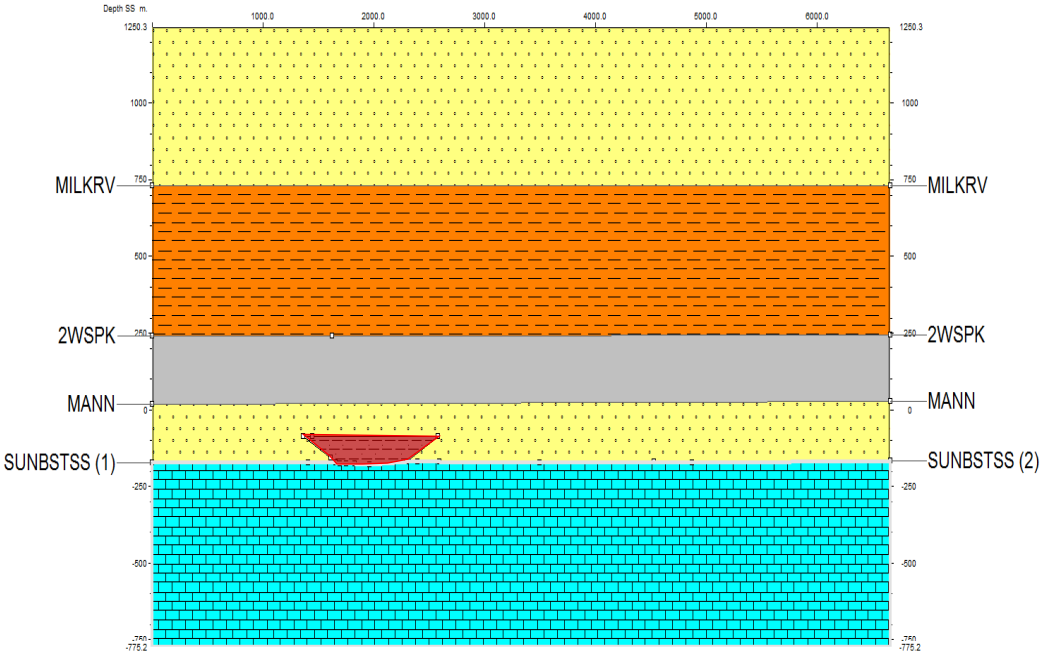




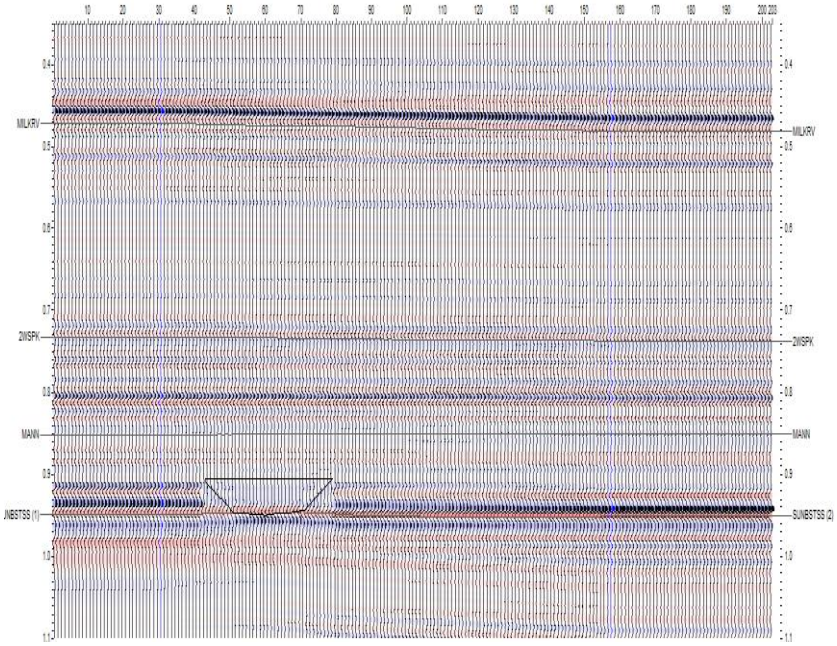
Types of Geologic Modeling

Forward

Earth Model → **Geophysical Response**



Lithology Model

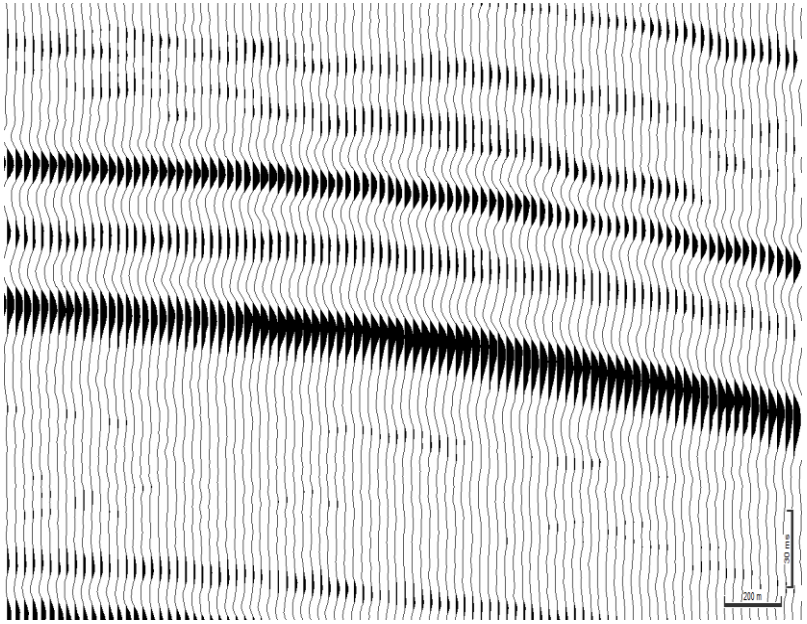


Seismic Amplitude

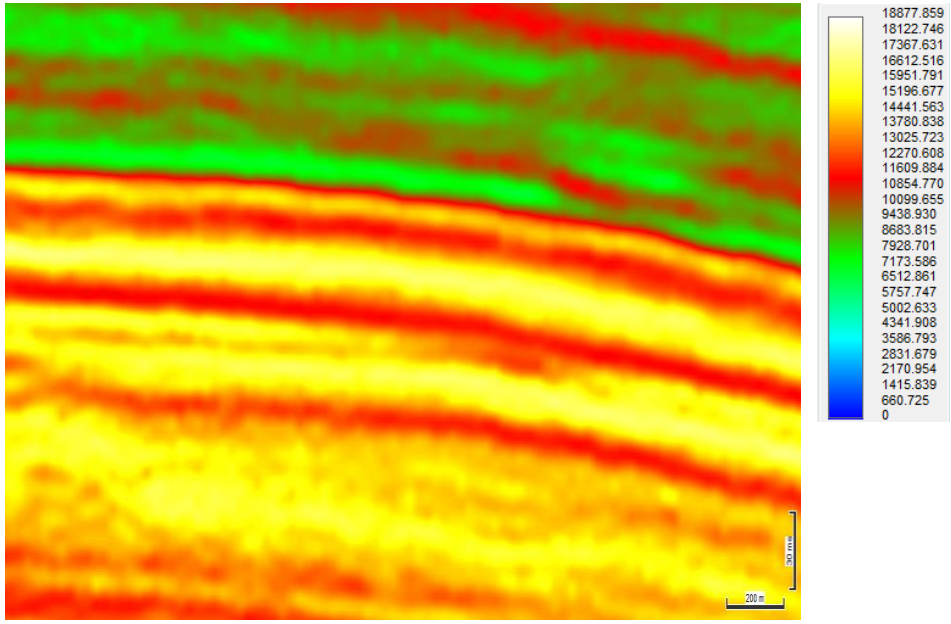
Types of Geologic Modeling

Inverse

Geophysical Response → **Earth Model**



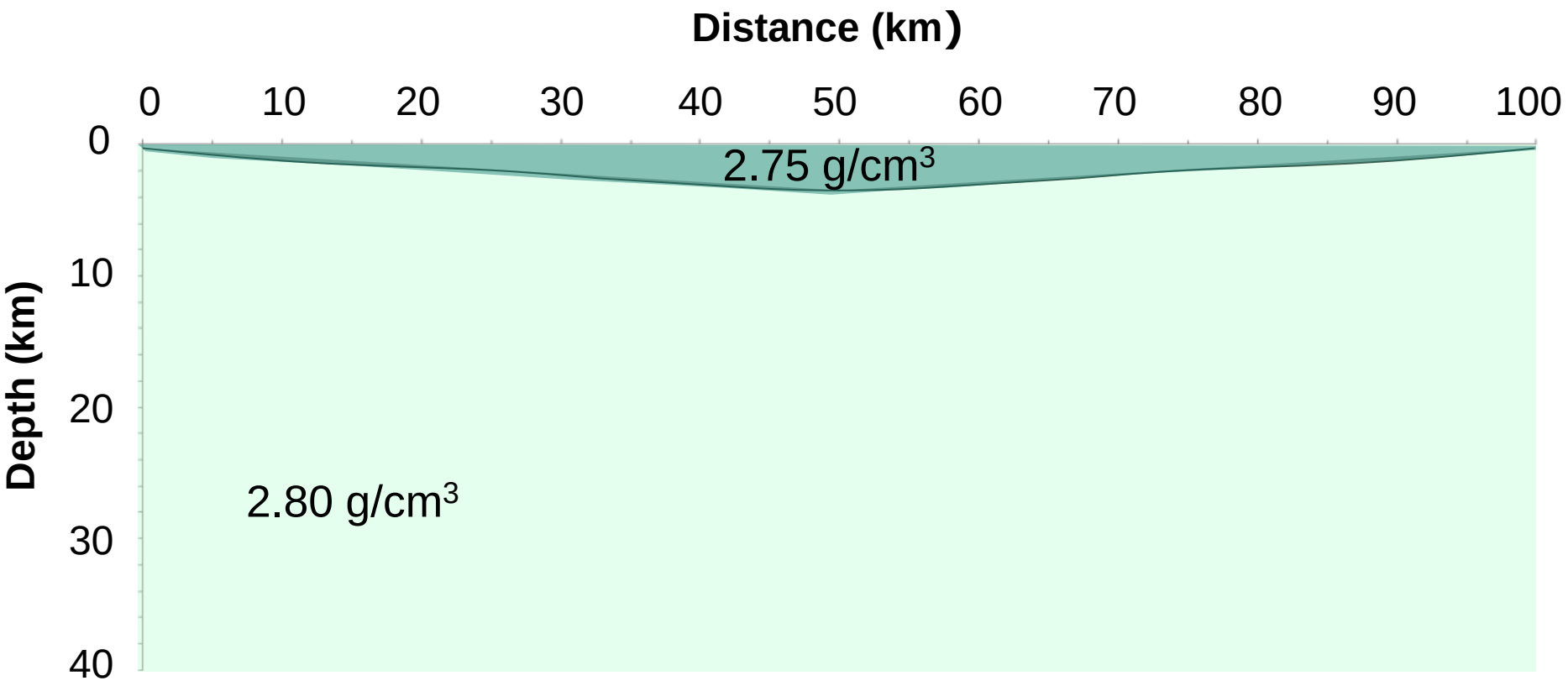
Seismic Amplitude



Absolute Impedance

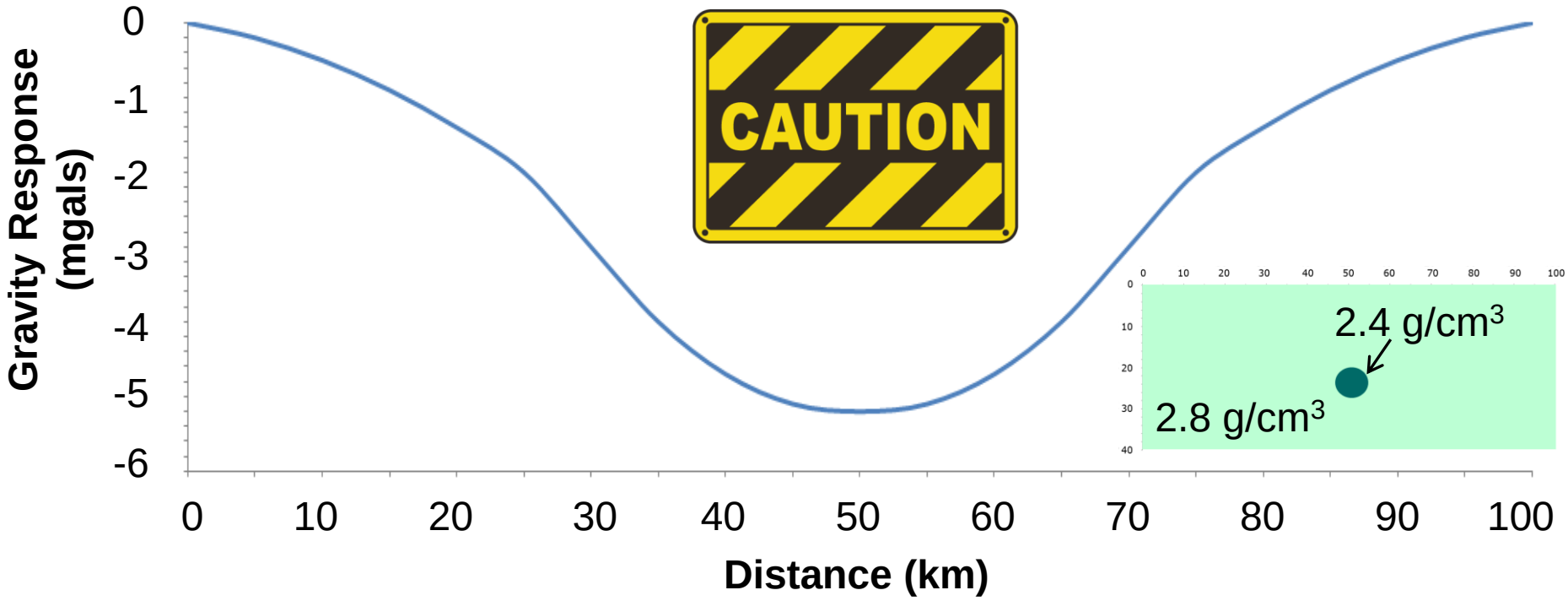
Forward Modeling

Input: Earth Model



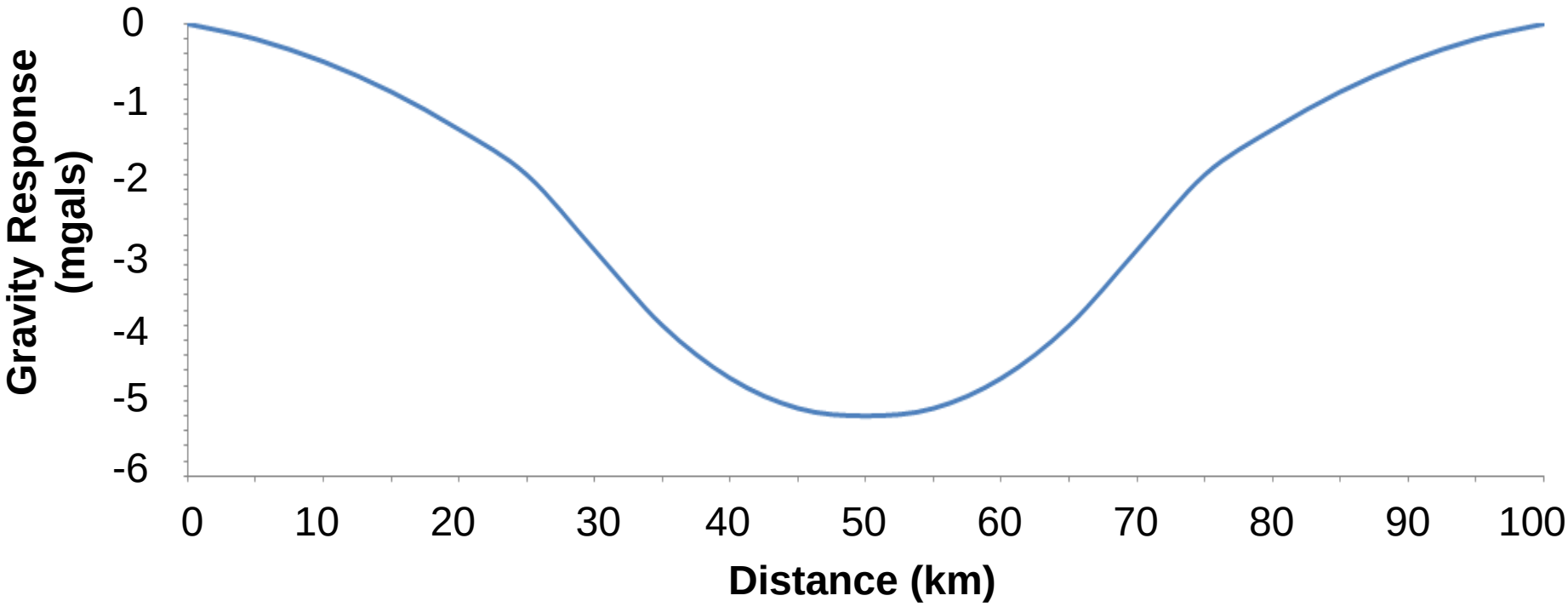
Forward Modeling

Output: Geophysical Response



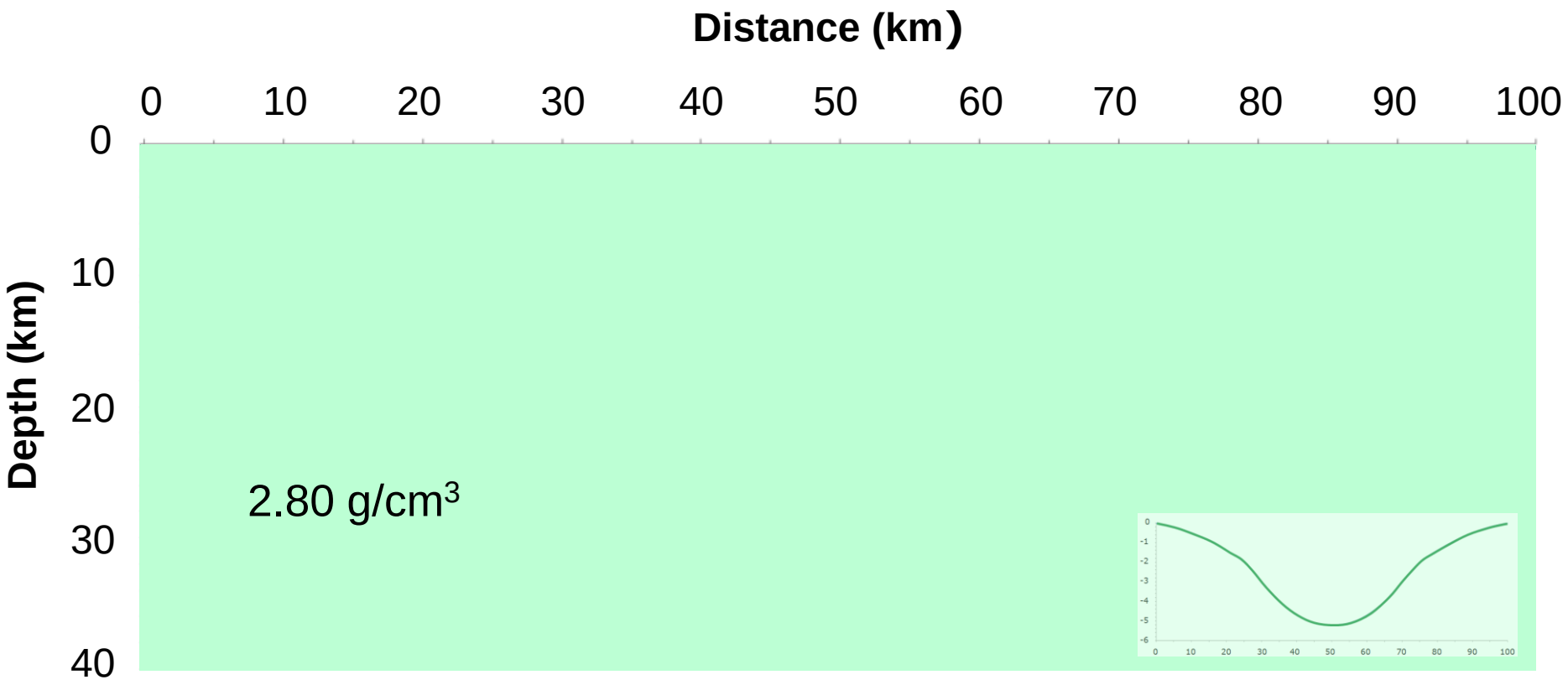
Inverse Modeling

Input: Geophysical Response

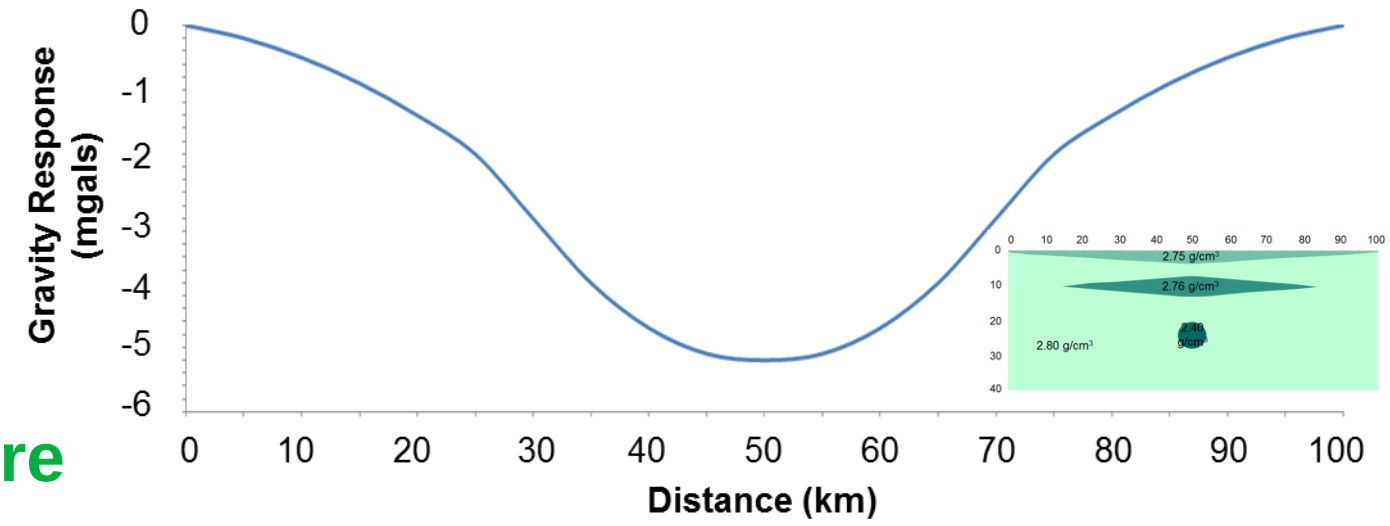


Inverse Modeling

Output: Earth Model

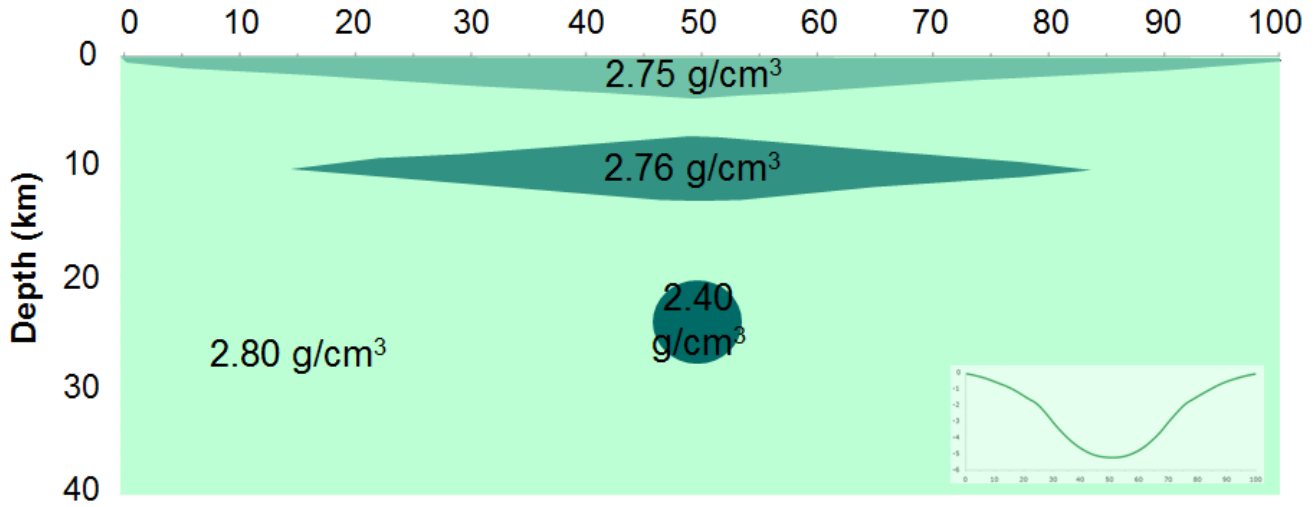


Forward Model



Earth Models are Non-Unique!

Inverse Model



Dealing with Non-Uniqueness

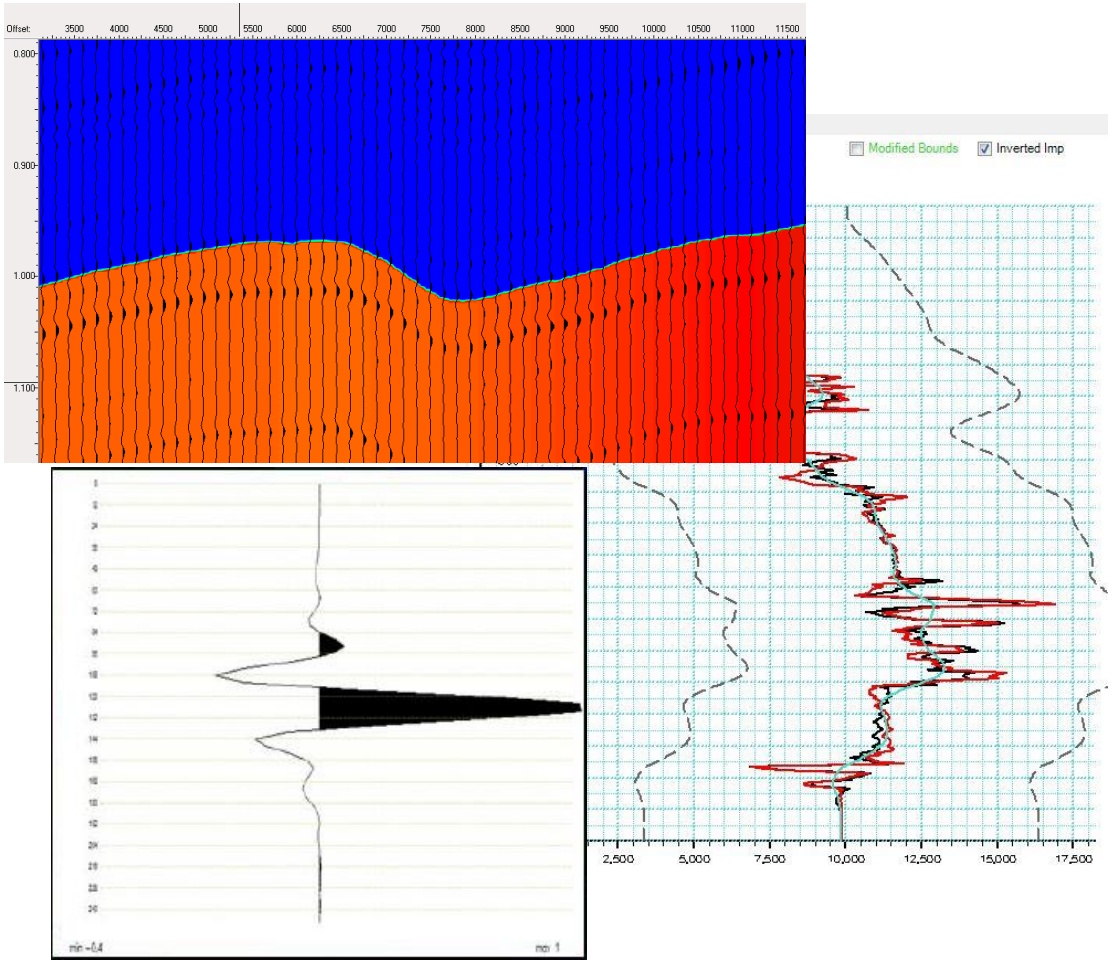
You need to set Boundaries

Background Model

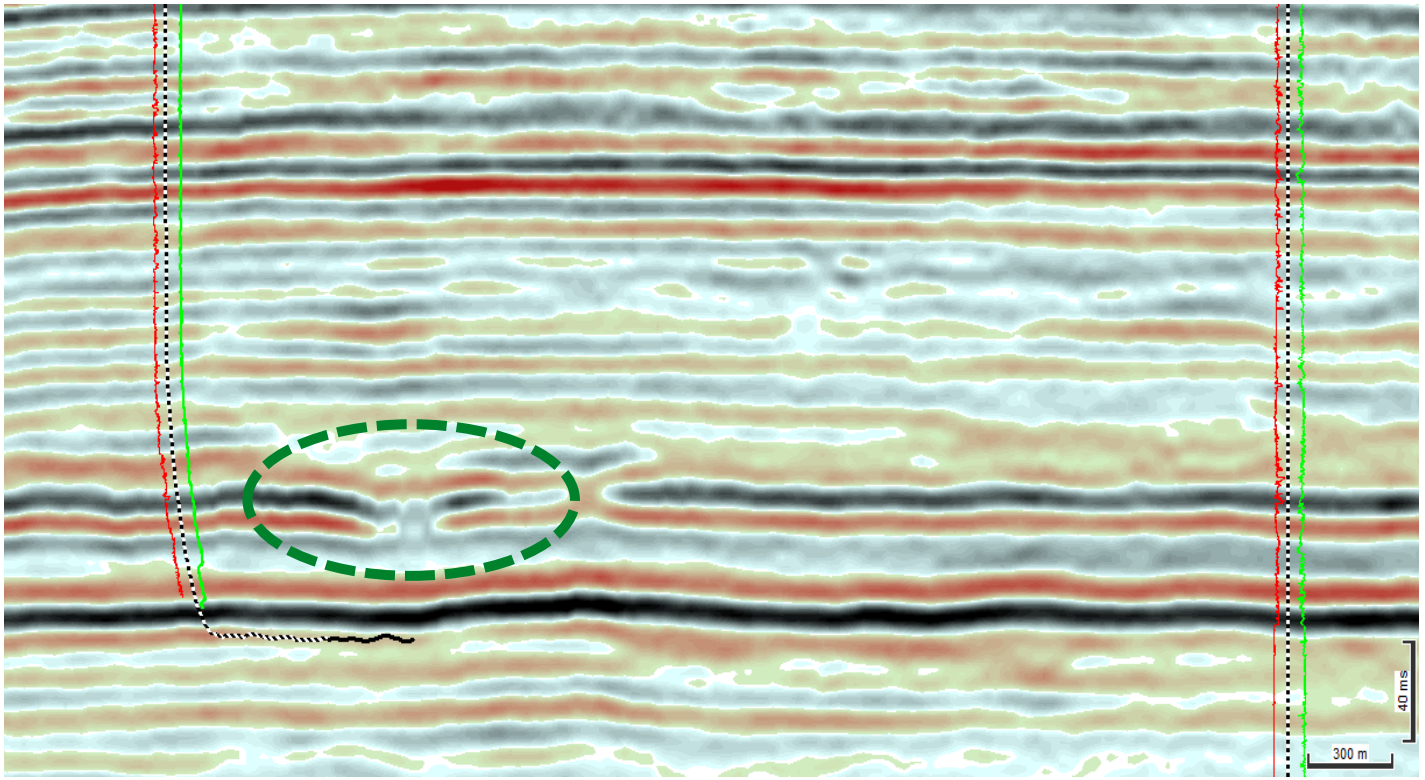
- **Velocity Volume**
- **Log and Well Data**
- **Seismic Wavelet**

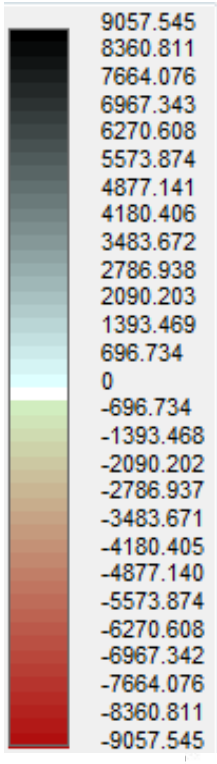
Additional Geologic Information

- **Formation properties**



Forward Modeling of Lower Mannville Channels in Southern Alberta





Depositional Environment

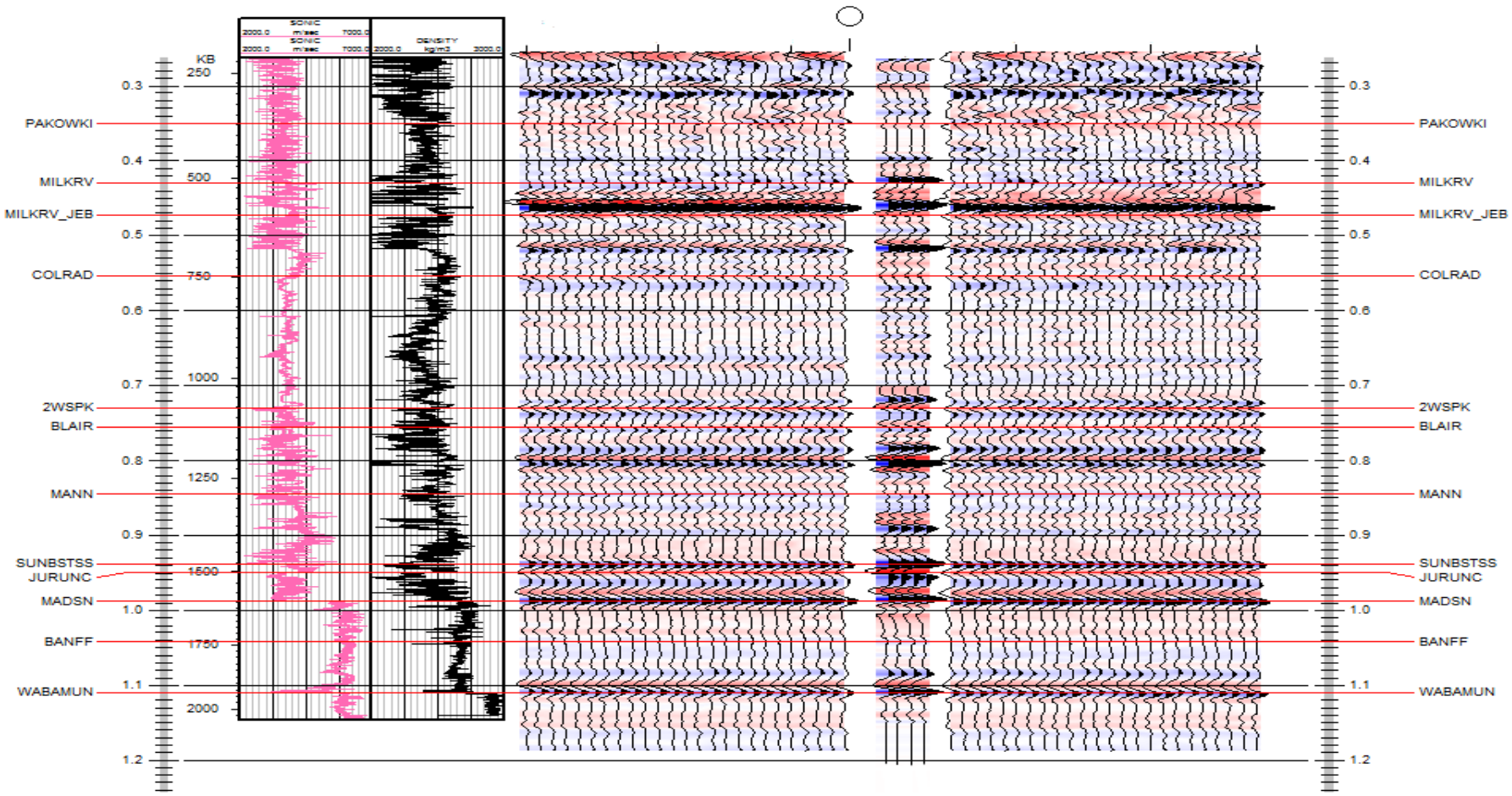
Lower Mannville:

- Lower Cretaceous : 145 – 99.6 MYA
- Non-Marine Clastics Sourced from Up-Thrust Sedimentary Rocks from West
- Deposited along South to North Trending Drainage Pattern
- Drainage controlled by Paleotopography of Pre-Cretaceous Unconformity

Map Credit: Ron Blakey, Colorado Plateau Geosystems, Arizona, USA.

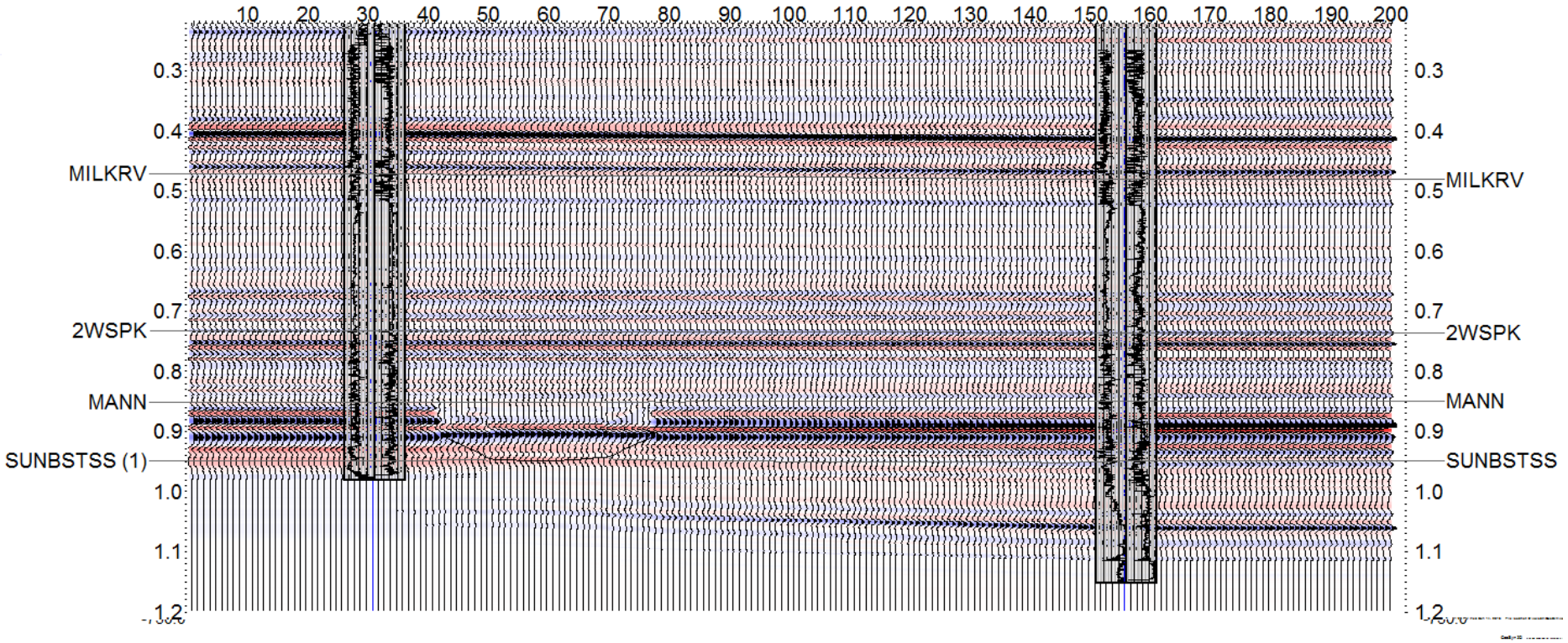
2D Forward Modeling Workflow

Tie Seismic to Log Data at Key Well Locations



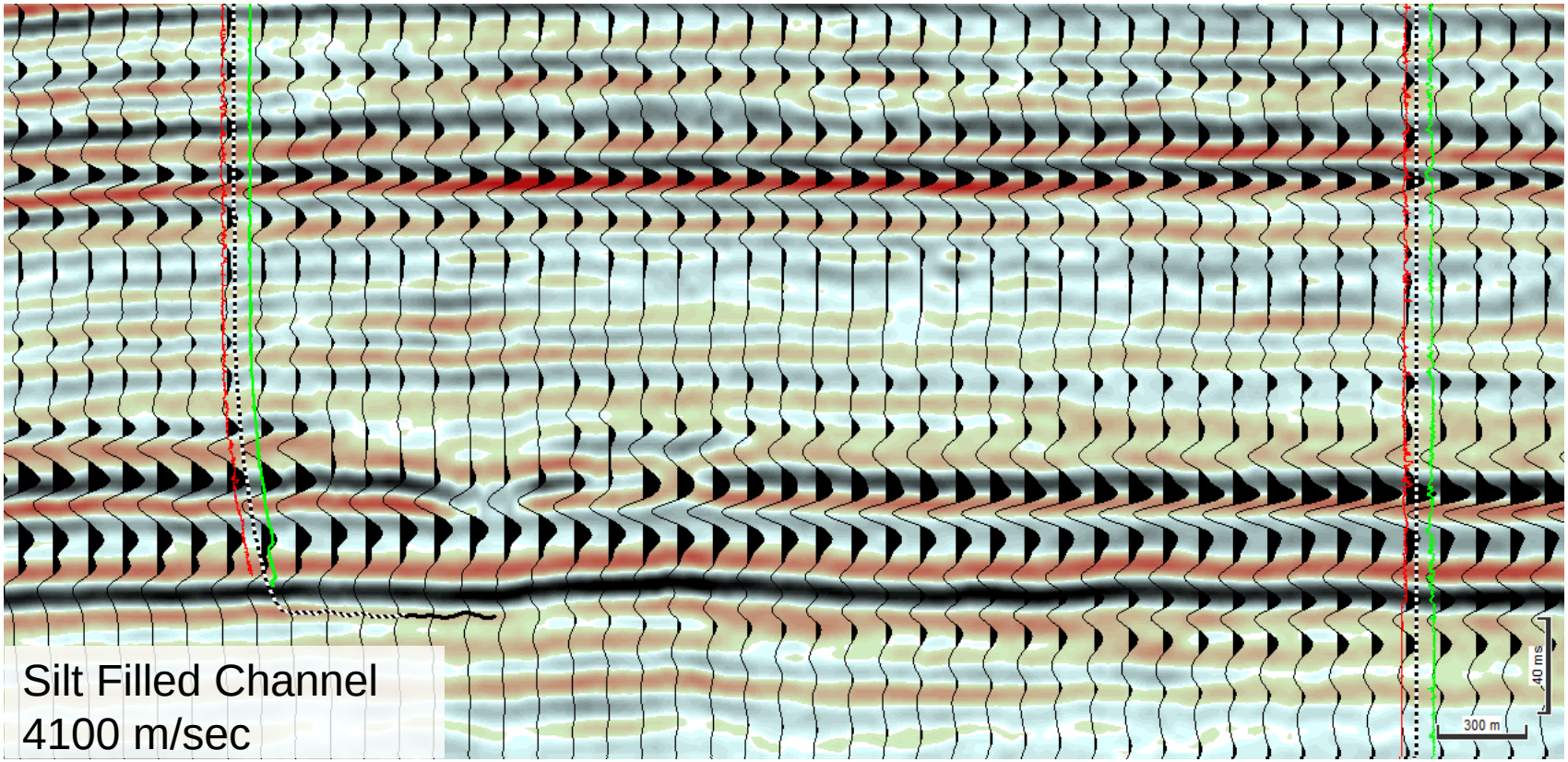
2D Forward Modeling Workflow

Construct and Modify 2D Model

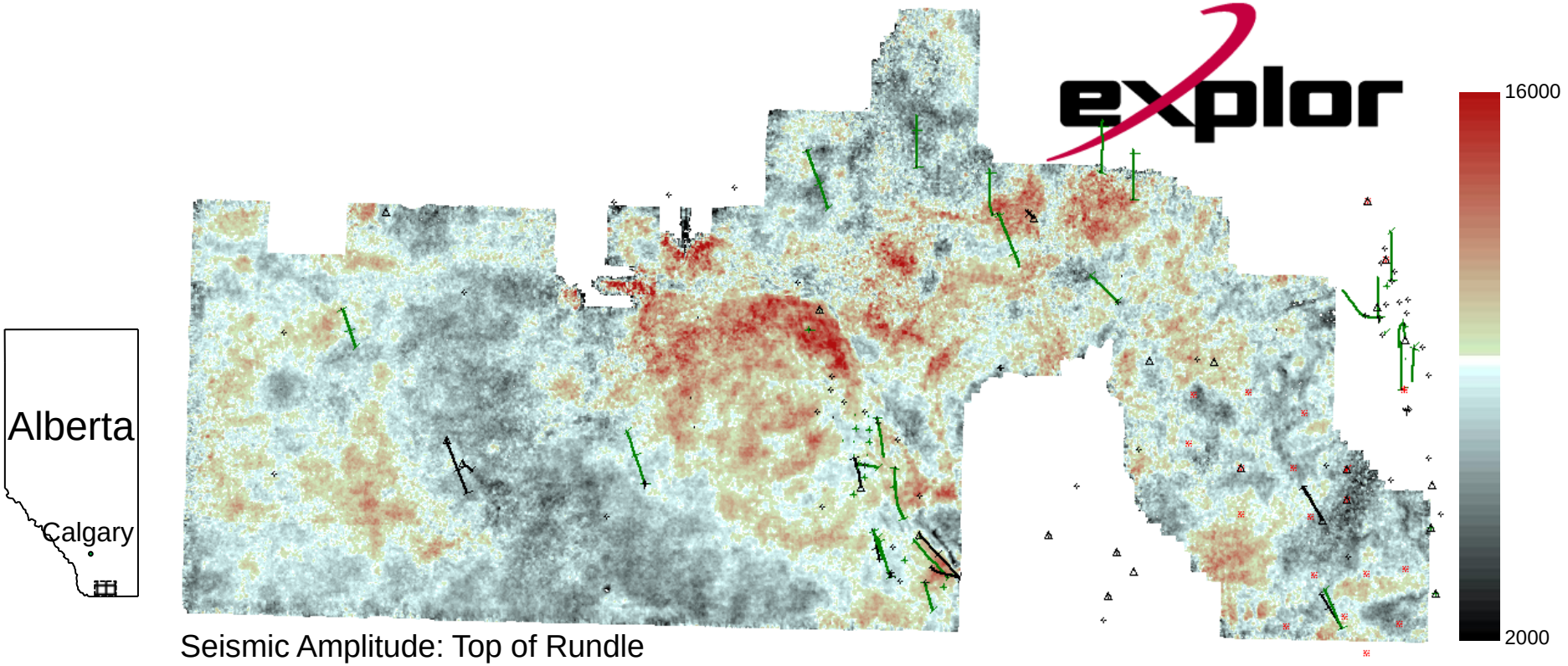


2D Modeling Results

Model Validation/Invalidation



Inverse Modeling of the Rundle Group in Southern Alberta

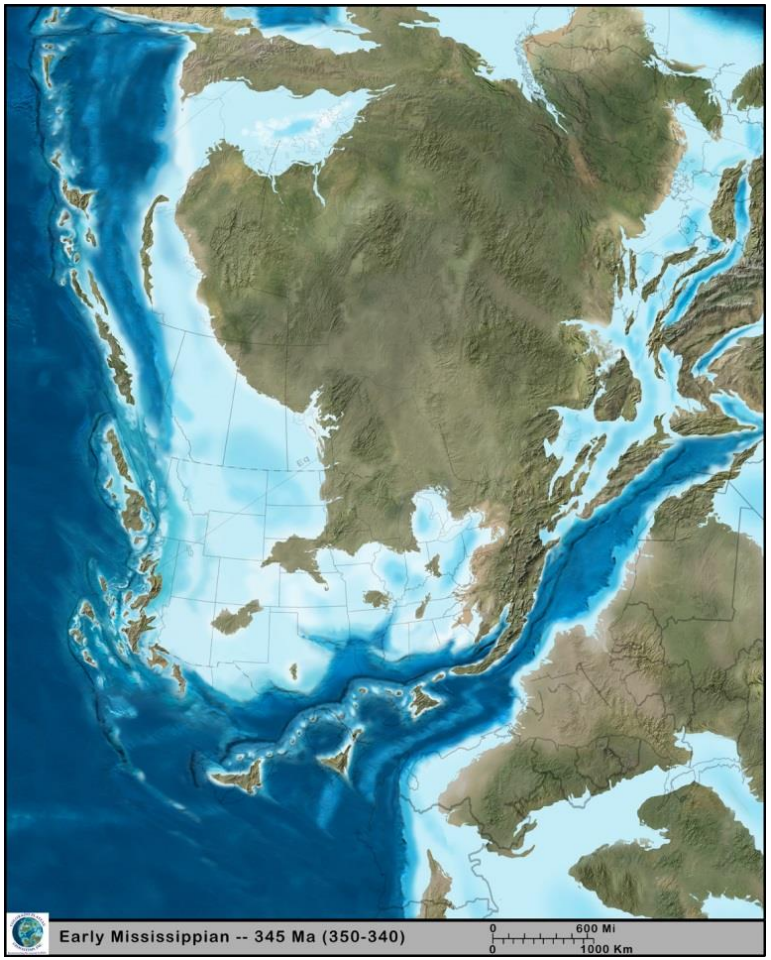


Seismic Amplitude: Top of Rundle

Depositional Environment

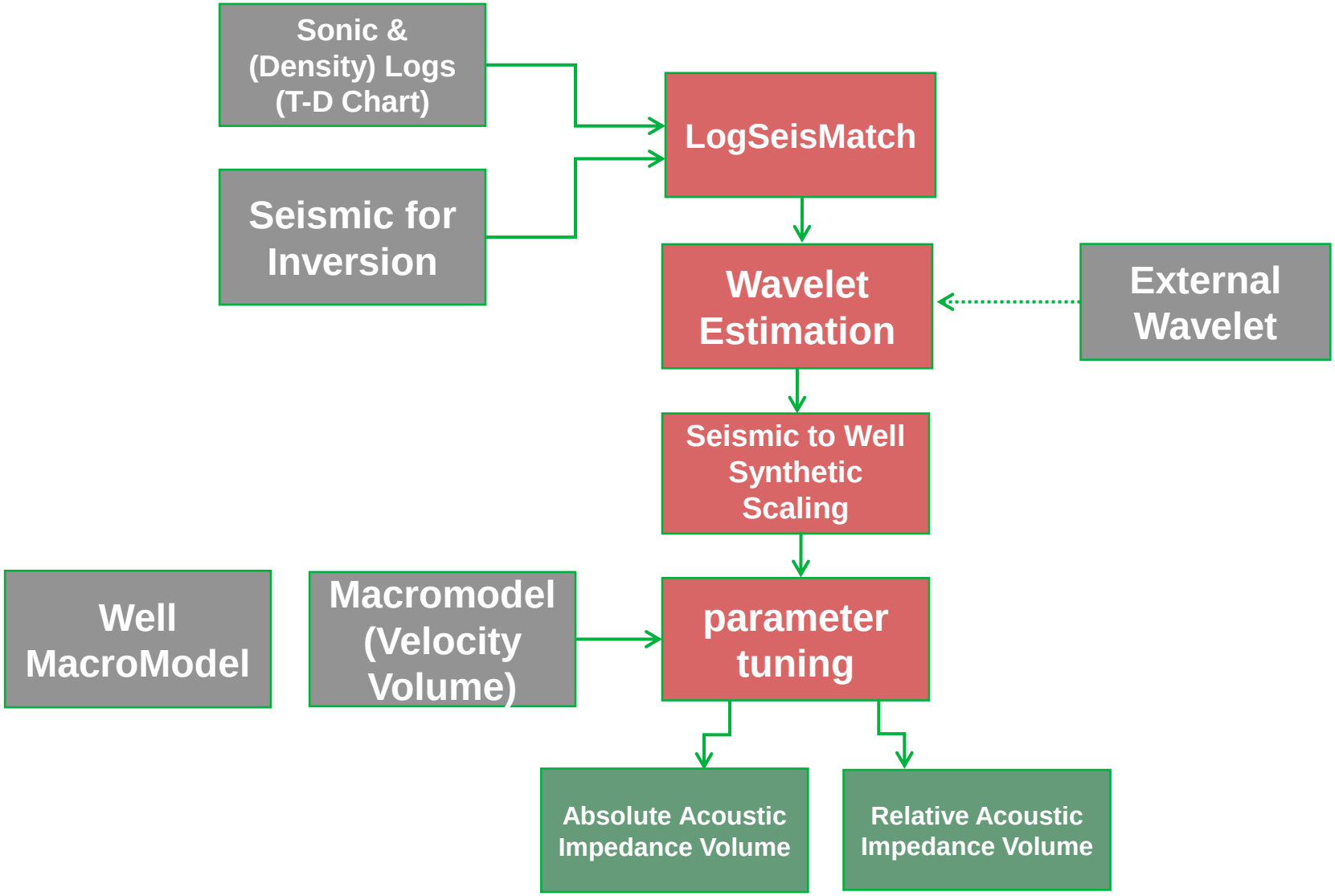
Rundle Group:

- Middle to Late Mississippian: 345.3 – 318.1 MYA
- Tropical /Shallow Marine Environment
- Carbonate Platform and Ramp Lithofacies
- Bounded at the top by an Unconformity



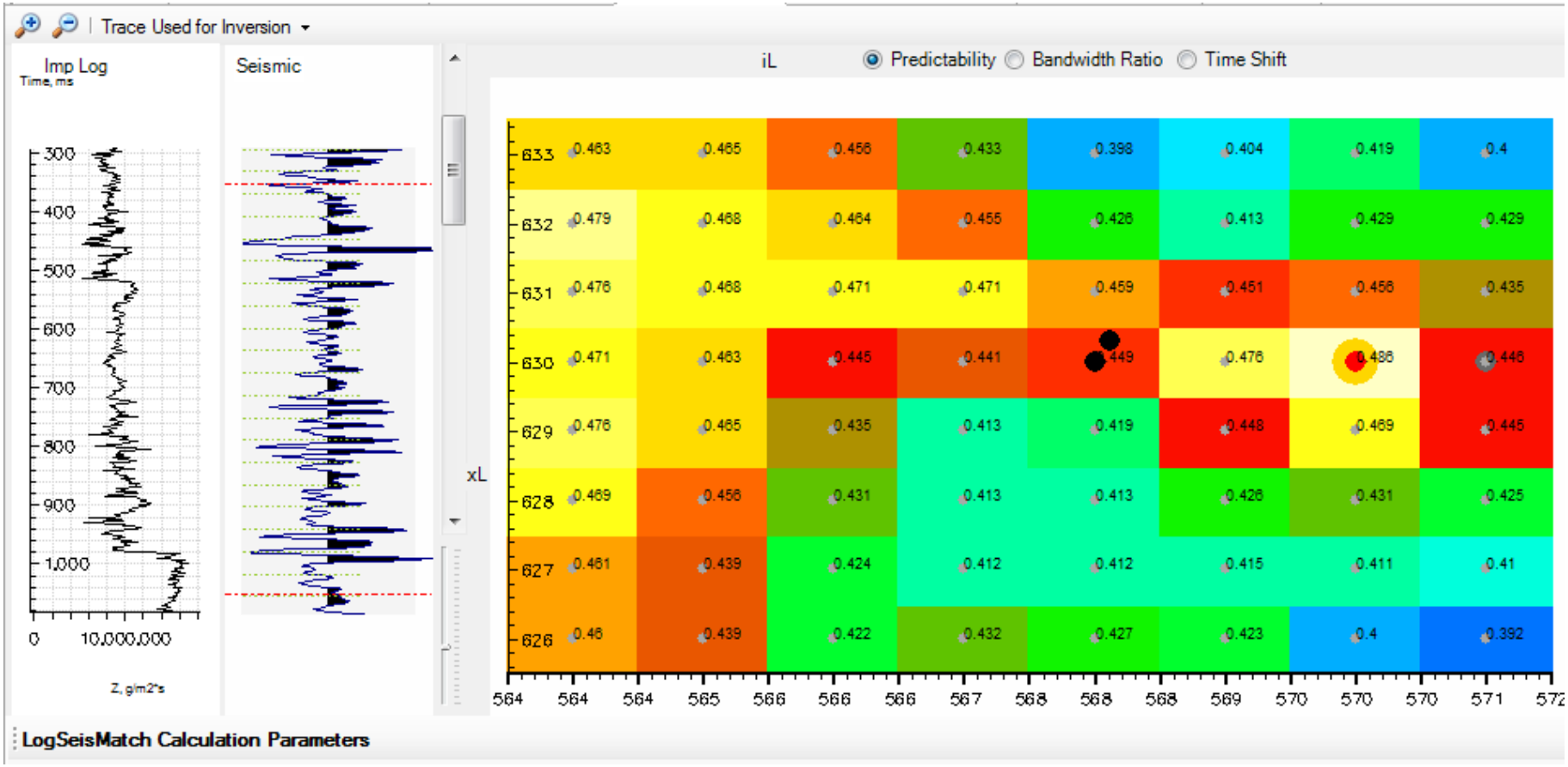
Map Credit: Ron Blakey, Colorado Plateau Geosystems, Arizona, USA.

SA Inversion Workflow



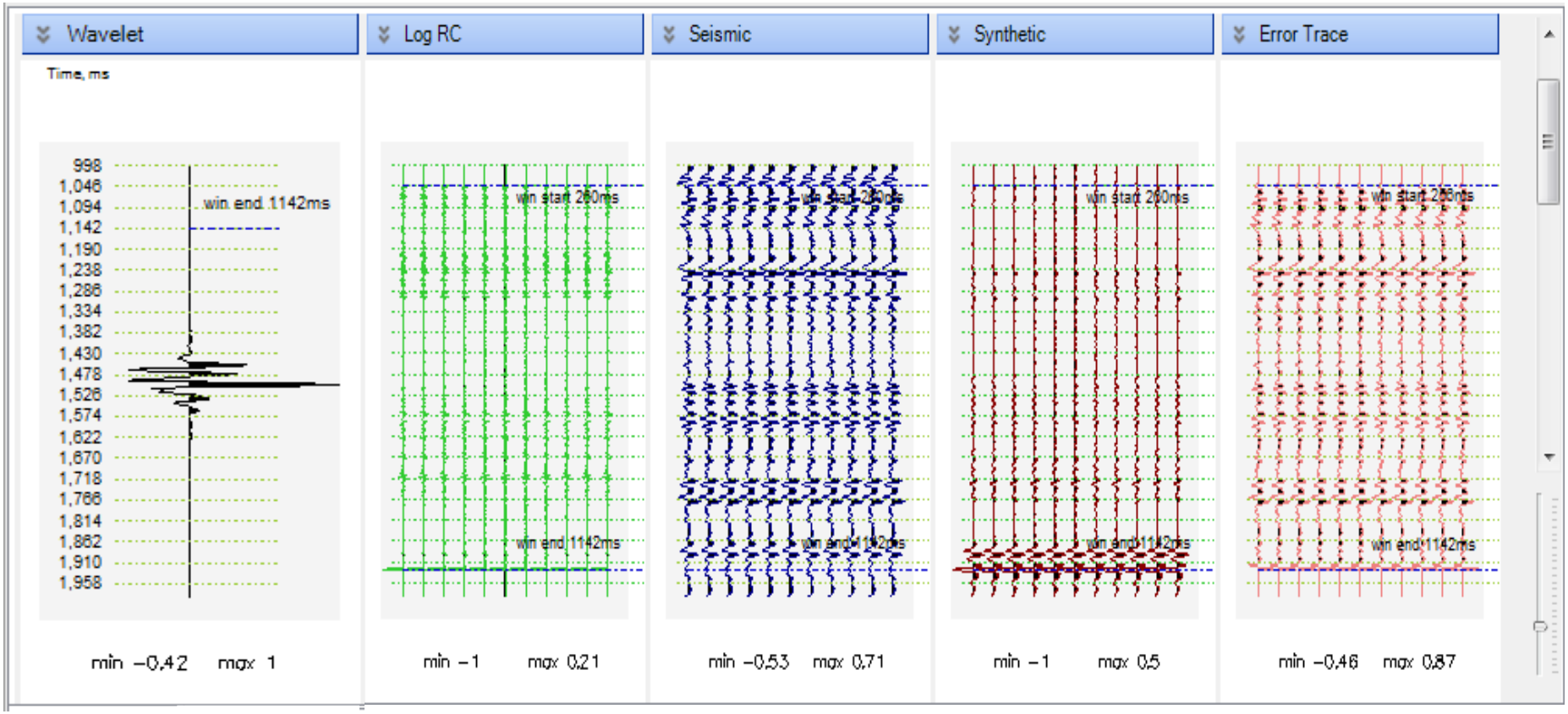
SA Inversion Workflow

LogSeis Match



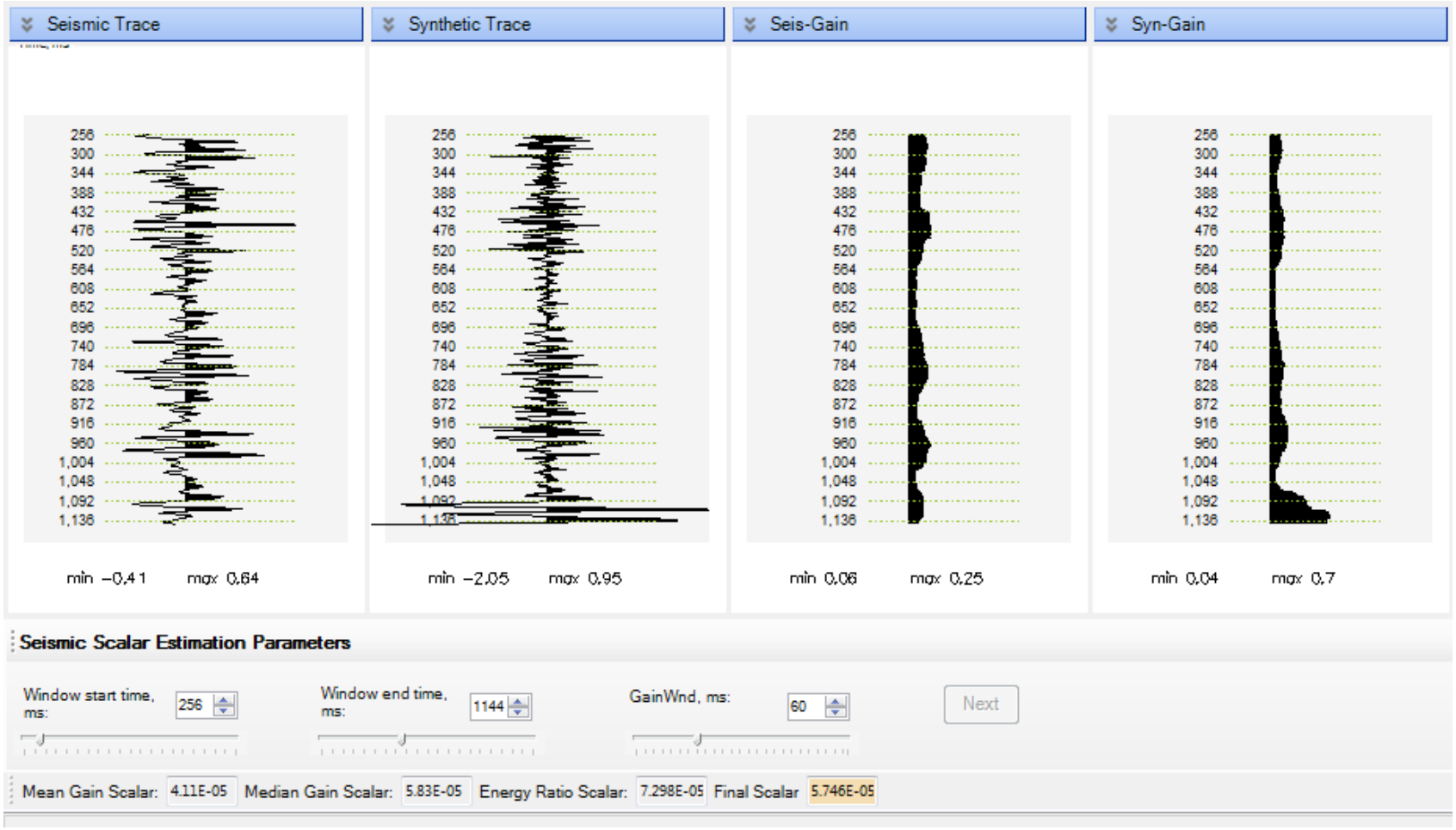
SA Inversion Workflow

Wavelet Estimation



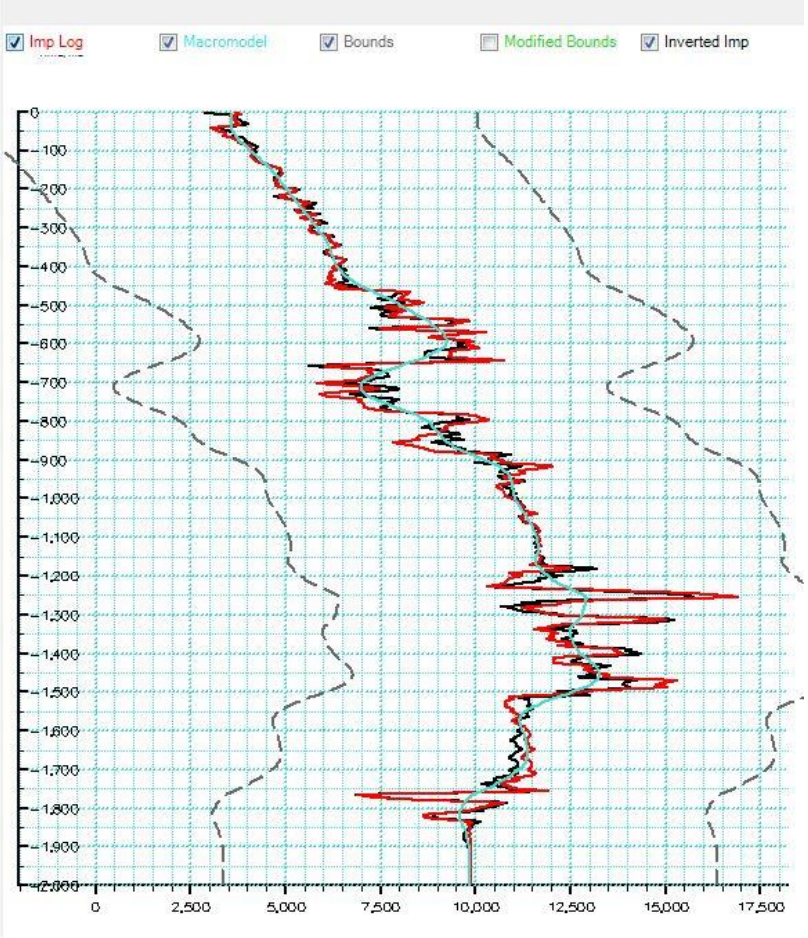
SA Inversion Workflow

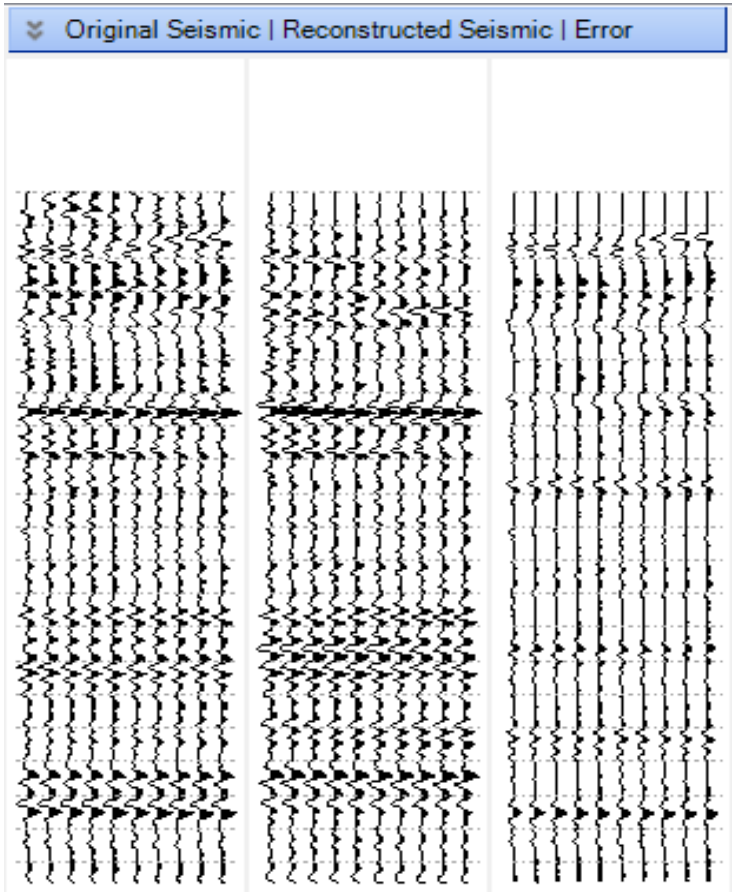
Seismic to Well Synthetic Scaling



SA Inversion Workflow

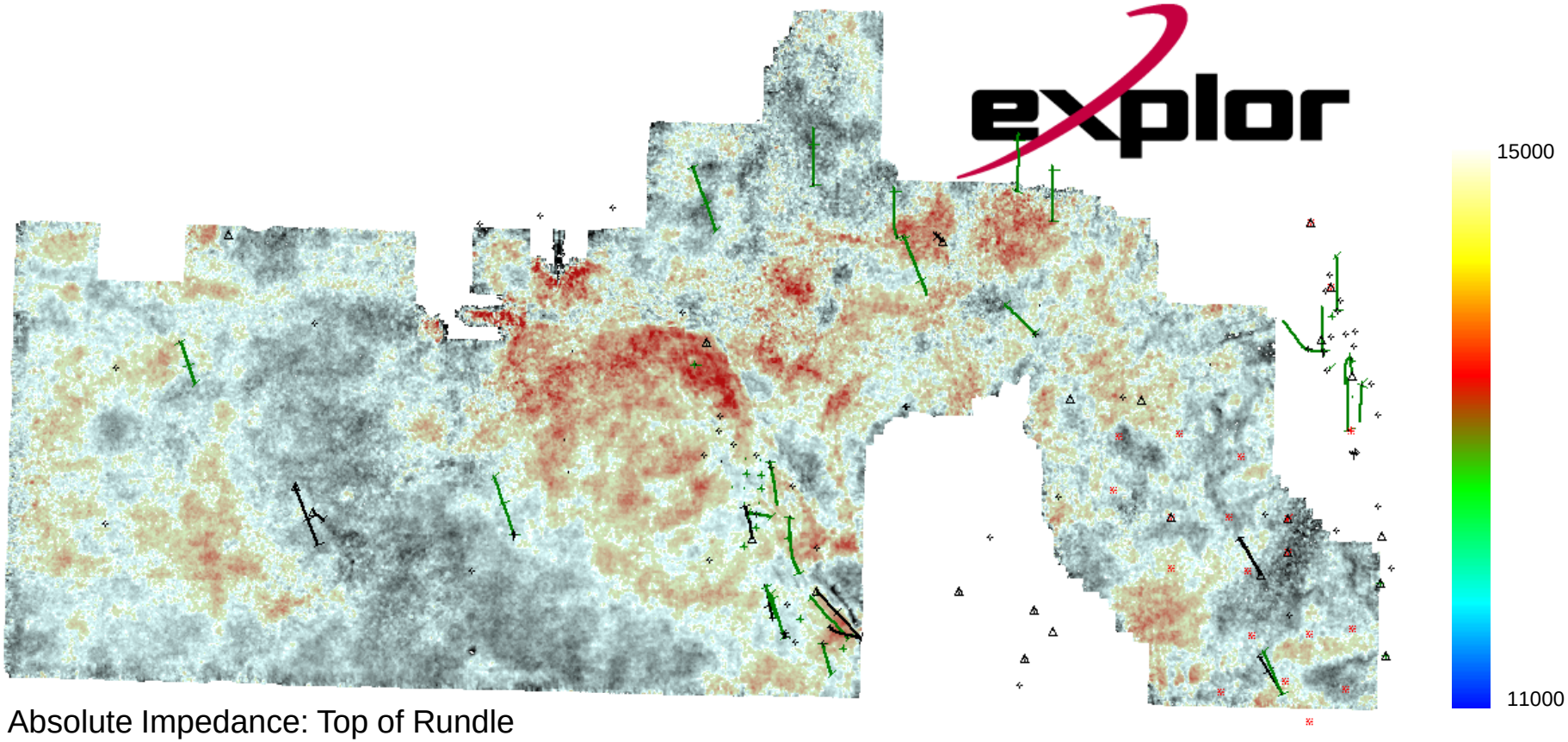
Parameter Tuning





SA Inversion Results

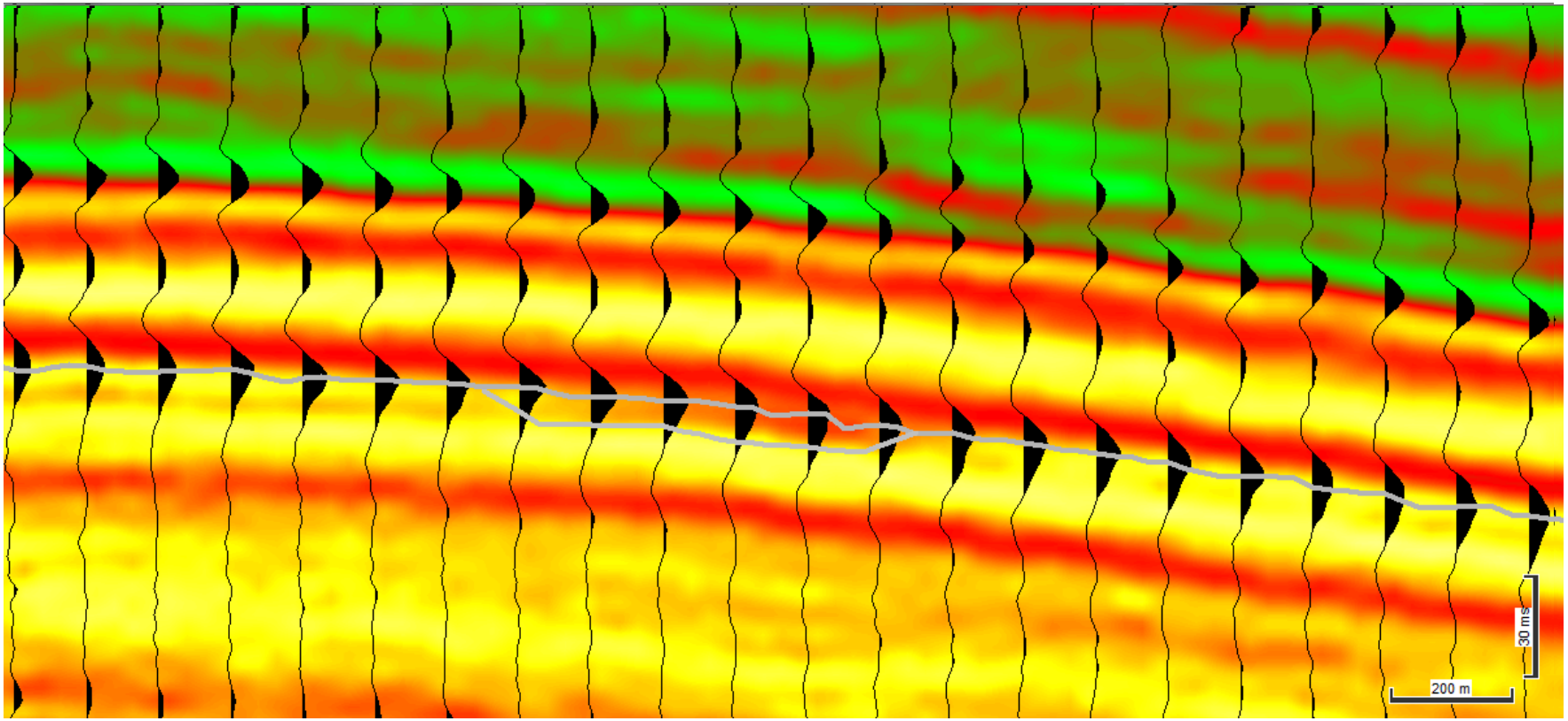
Increased Resolution over Amplitude Data



Absolute Impedance: Top of Rundle

SA Inversion Results

Increased Resolution over Amplitude Data



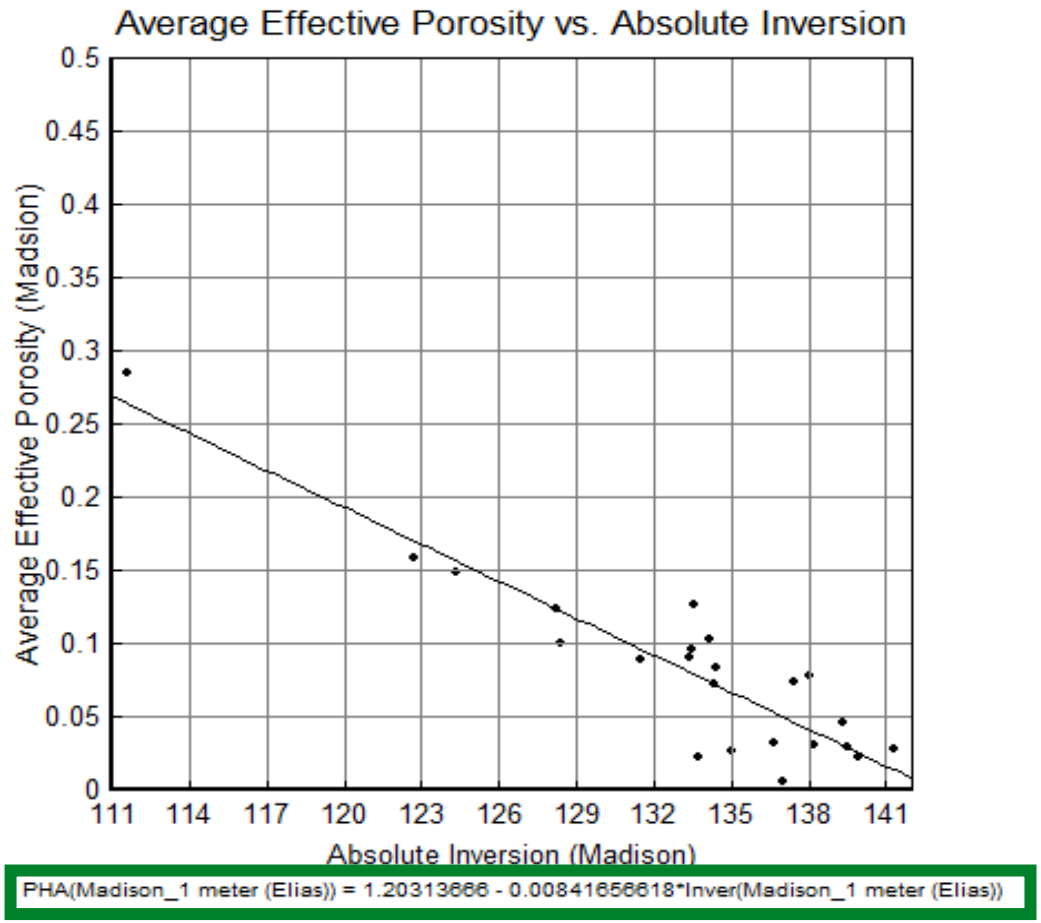
Taking your Interpretation Further…….

Rock Layers not Rock Boundaries

Better tie with Well Logs Reservoir Properties (Porosity, Permeability, etc.)

Calculation of Reservoir Properties using Regression Analysis

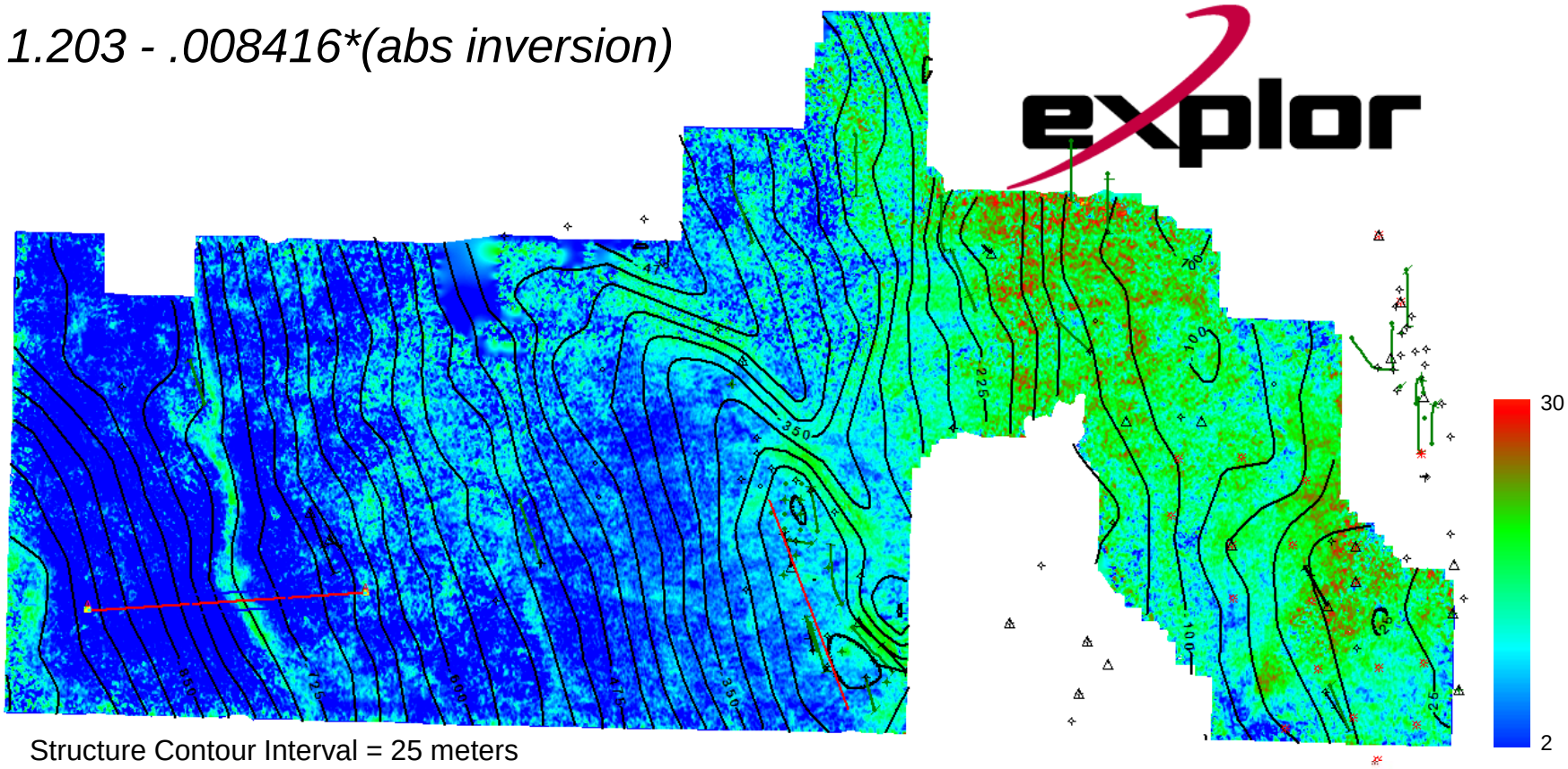
Average Effective Porosity vs. Absolute Inversion



Regression Calculated Reservoir Properties

Inversion Porosity

1.203 - .008416(abs inversion)*



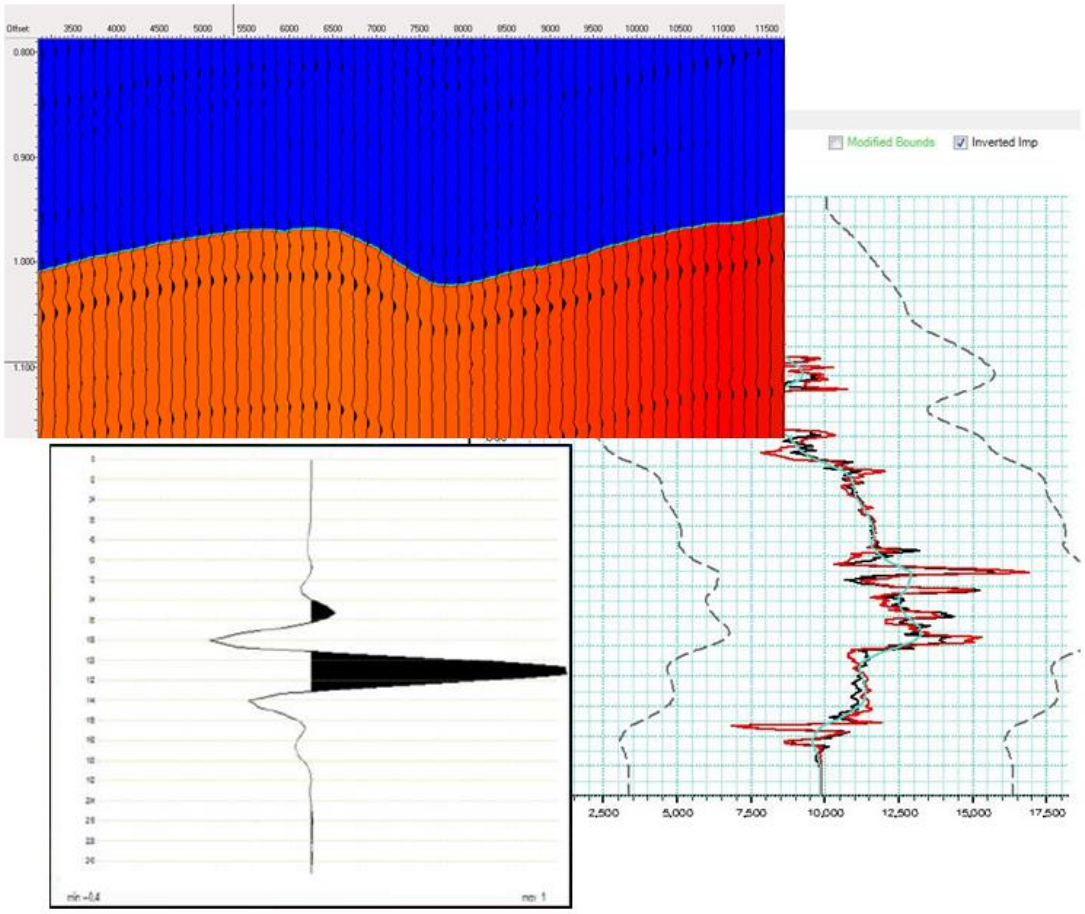
Structure Contour Interval = 25 meters

Geologic Modeling Summary

Addressing Non-Uniqueness

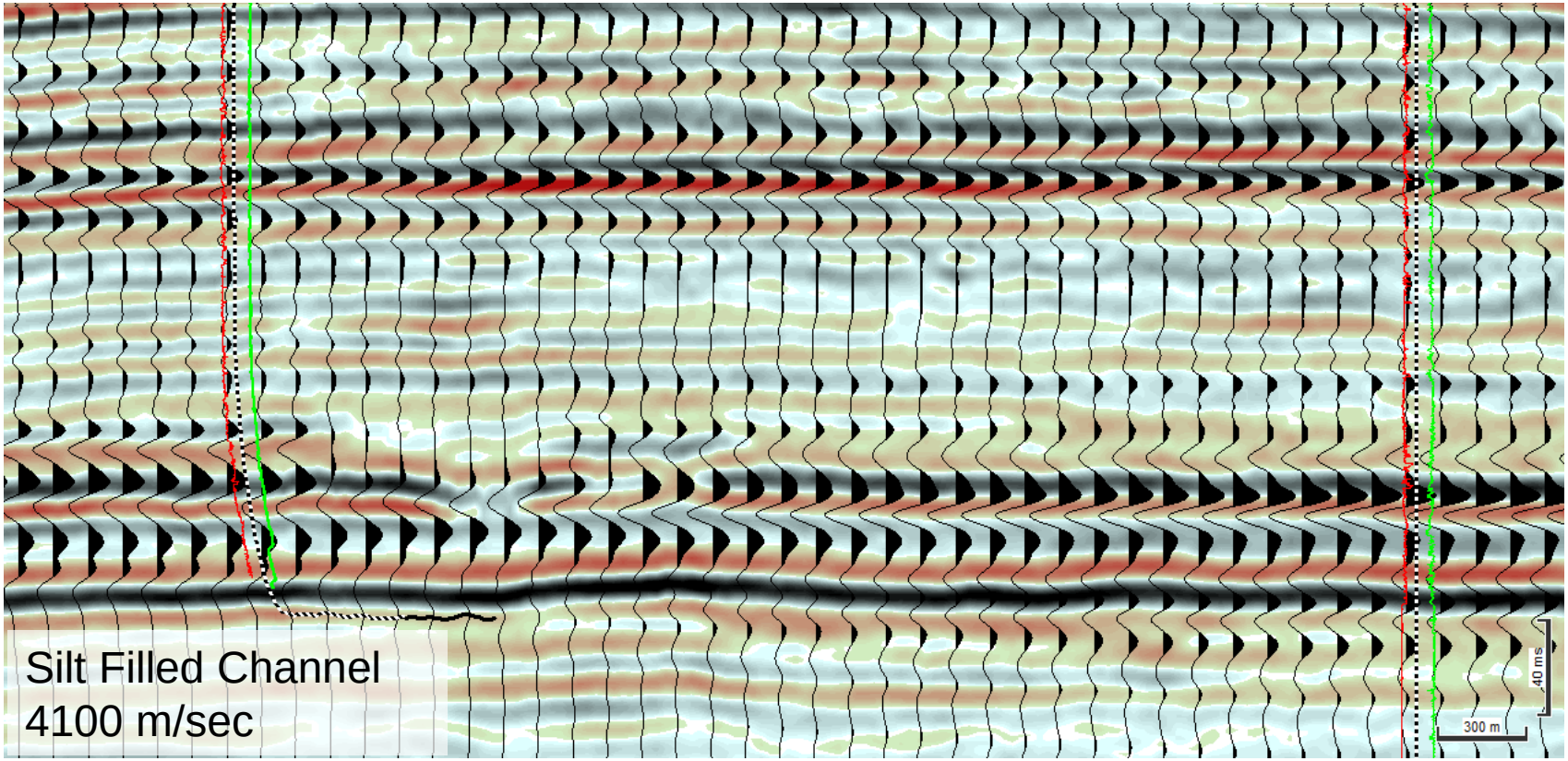
Background Model

Additional Geologic Information

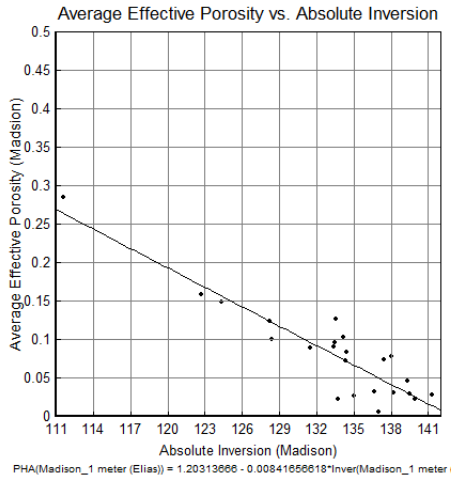


Geologic Modeling Summary

Mitigate Risk and Reduce Uncertainty



Geologic Modeling Summary



Additional Insight with Proper Calibration

Final Thoughts……

“All models are wrong, but some are useful”
George Box

“The truth…..is much too complicated to allow anything but approximations”
John Von Neuman

Acknowledgements

Thank You…….

Questions?

Jim Bock, Senior Technical Advisor

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