A Strategy for Cooperative Inversion of Reservoir Data

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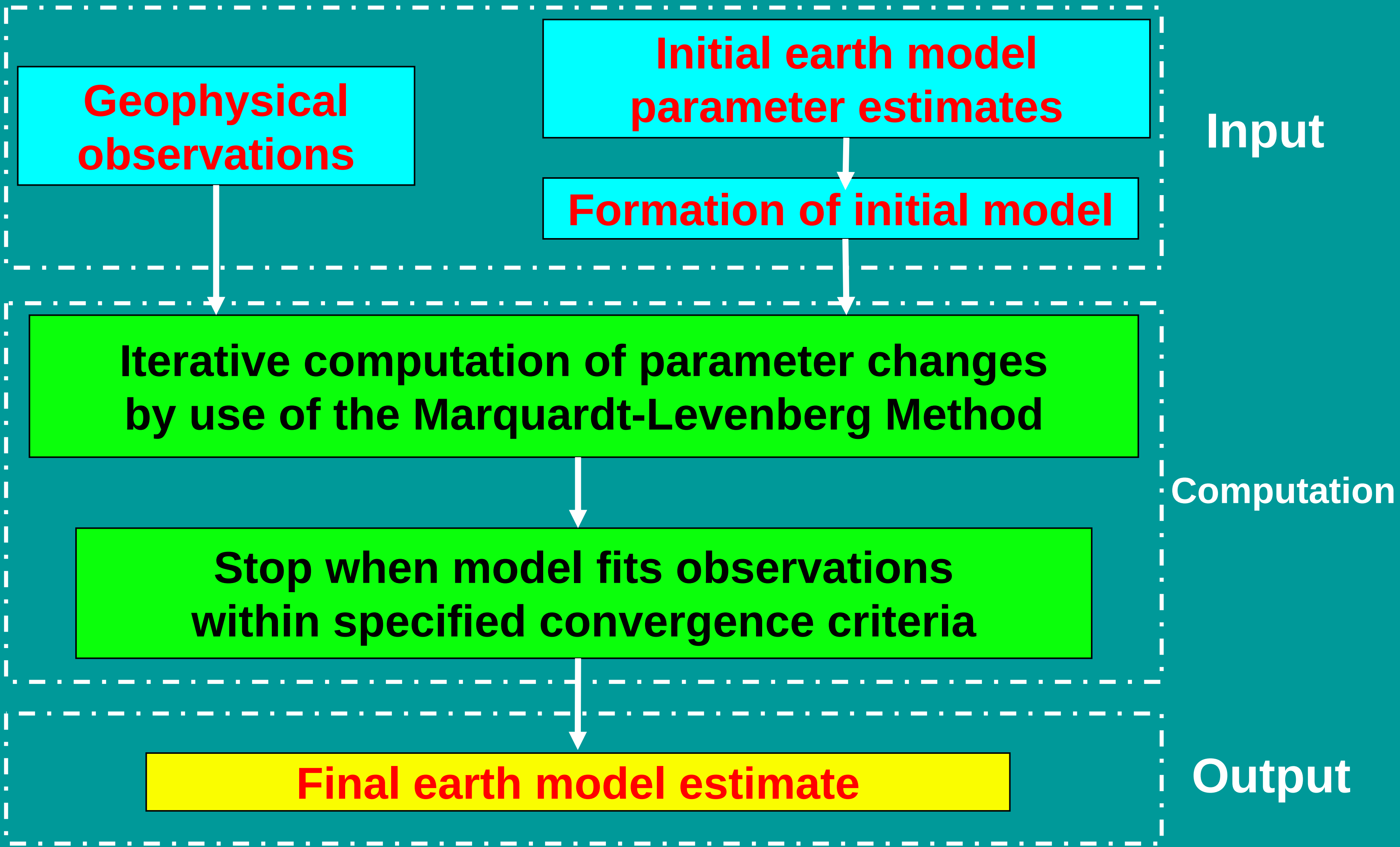
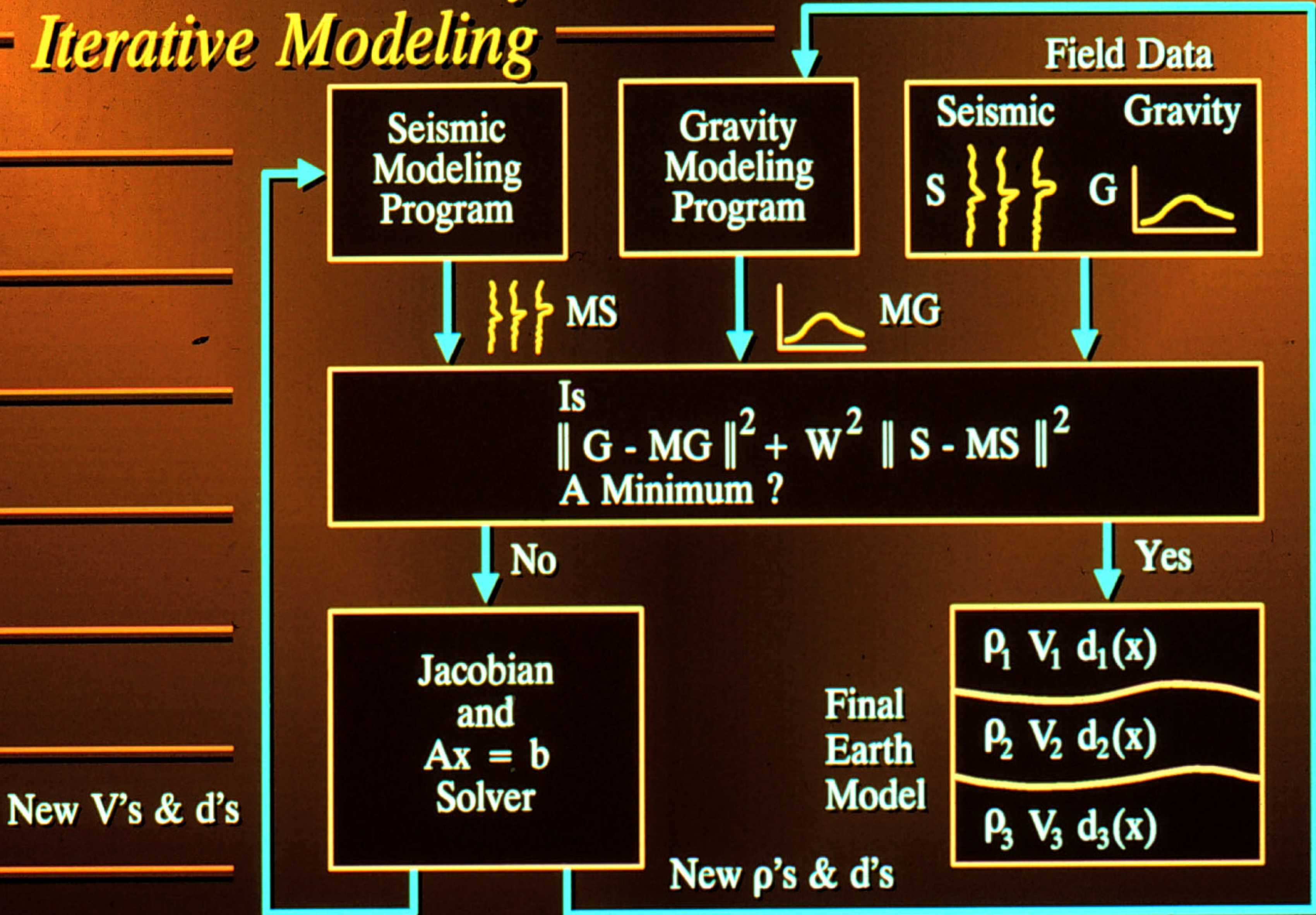
Principles of Cooperative Inversion

- We learn more about the Earth by fitting model responses to many different types of geo-data.
- Our goal is to find a model whose response matches all the types of data to within an acceptable error criterion.

Nonlinear regression by iterative Least Squares

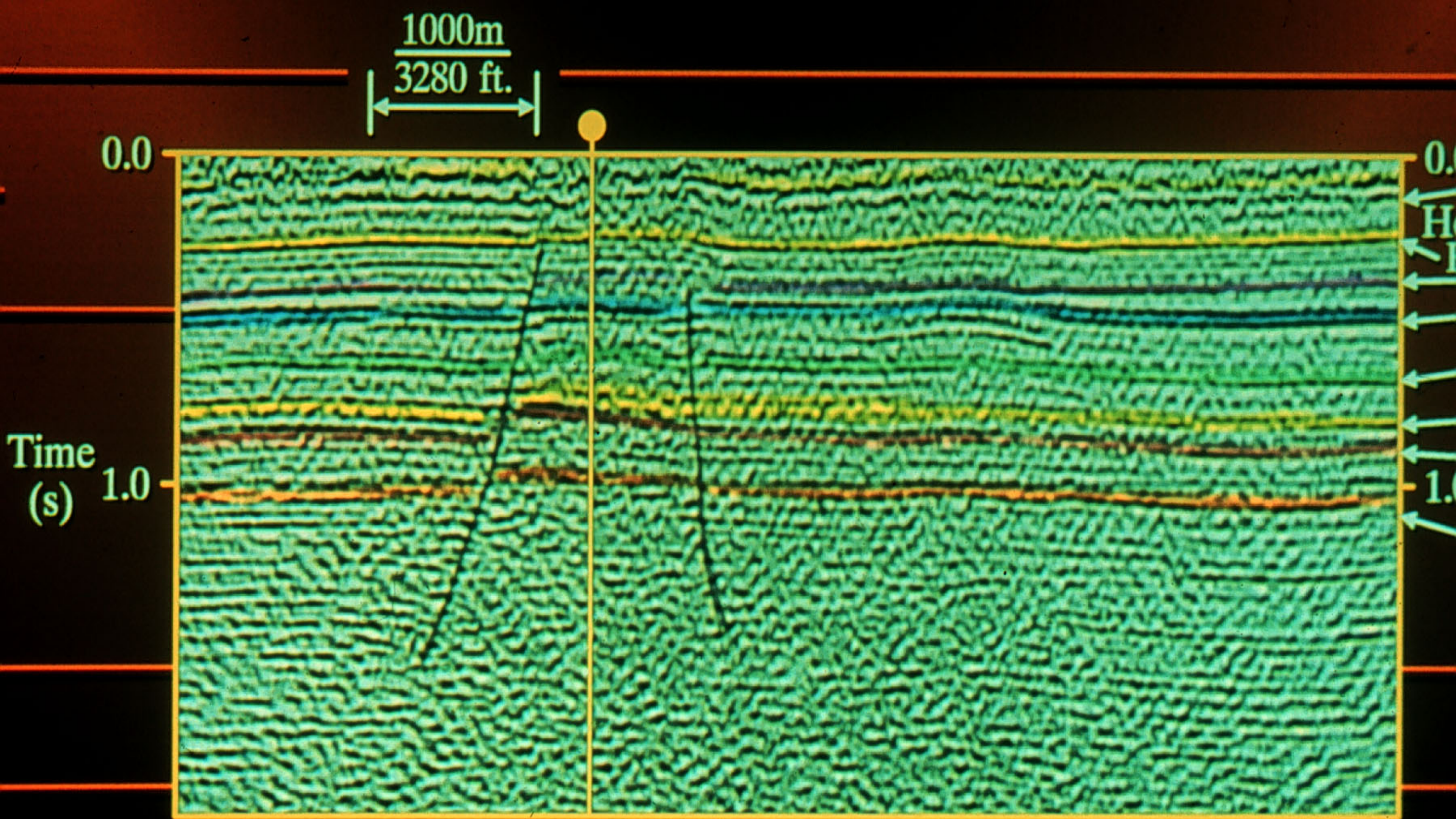


Joint Inversion By Iterative Modeling

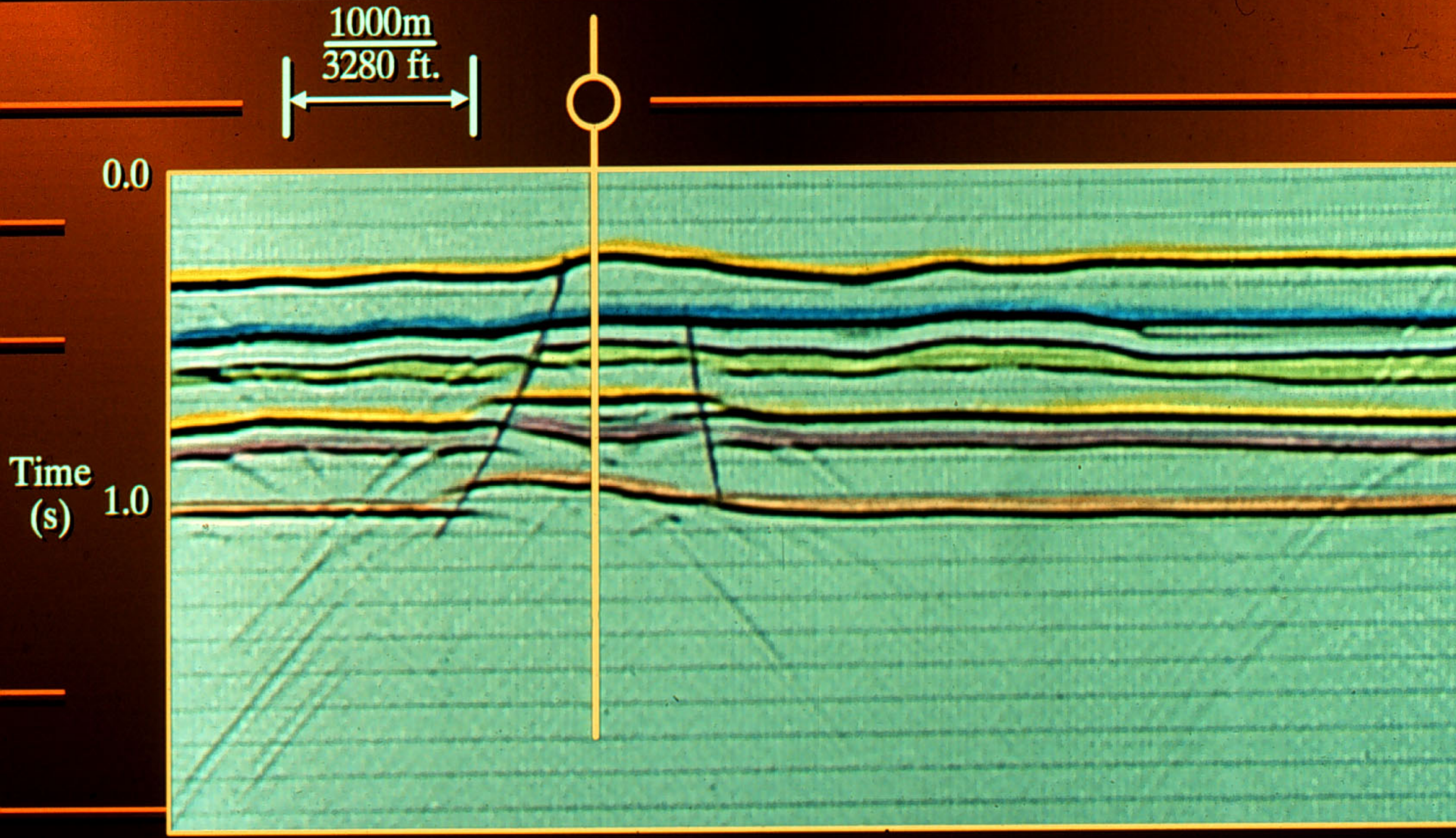


Lines et al. (1988)

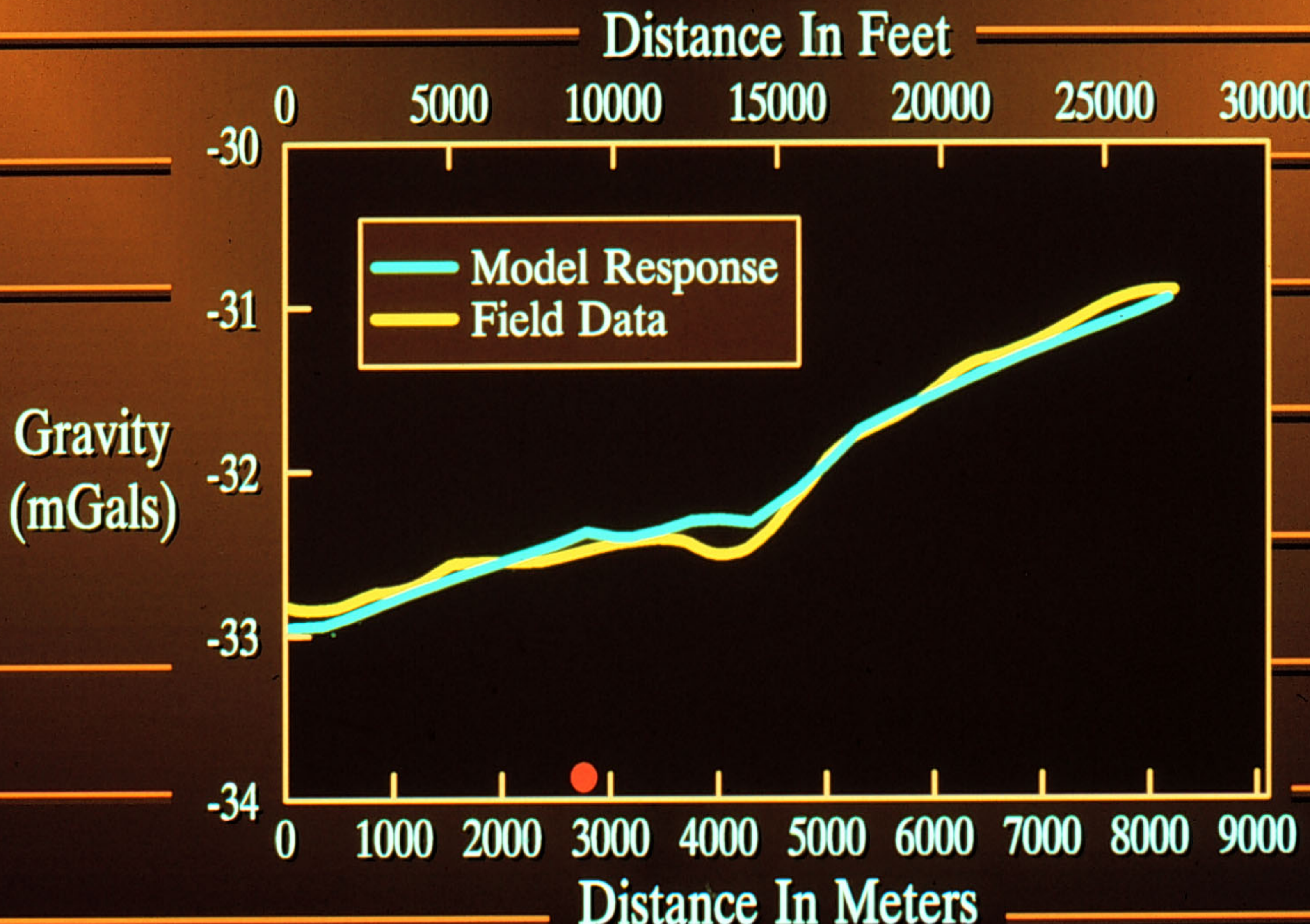
Seismic Line Used In Joint Inversion



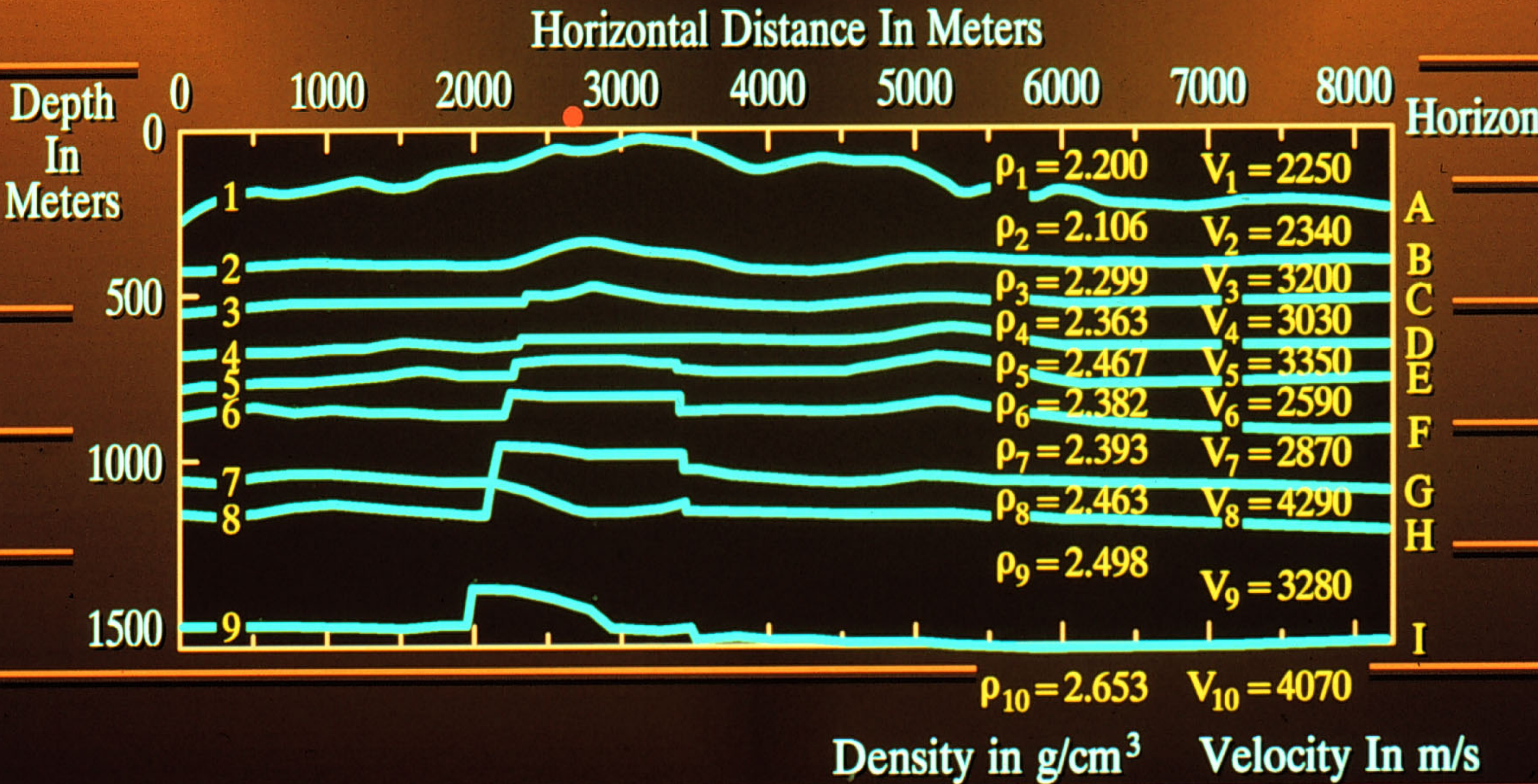
Finite Difference Synthetic Response



Surface Response After Manual Adjustment

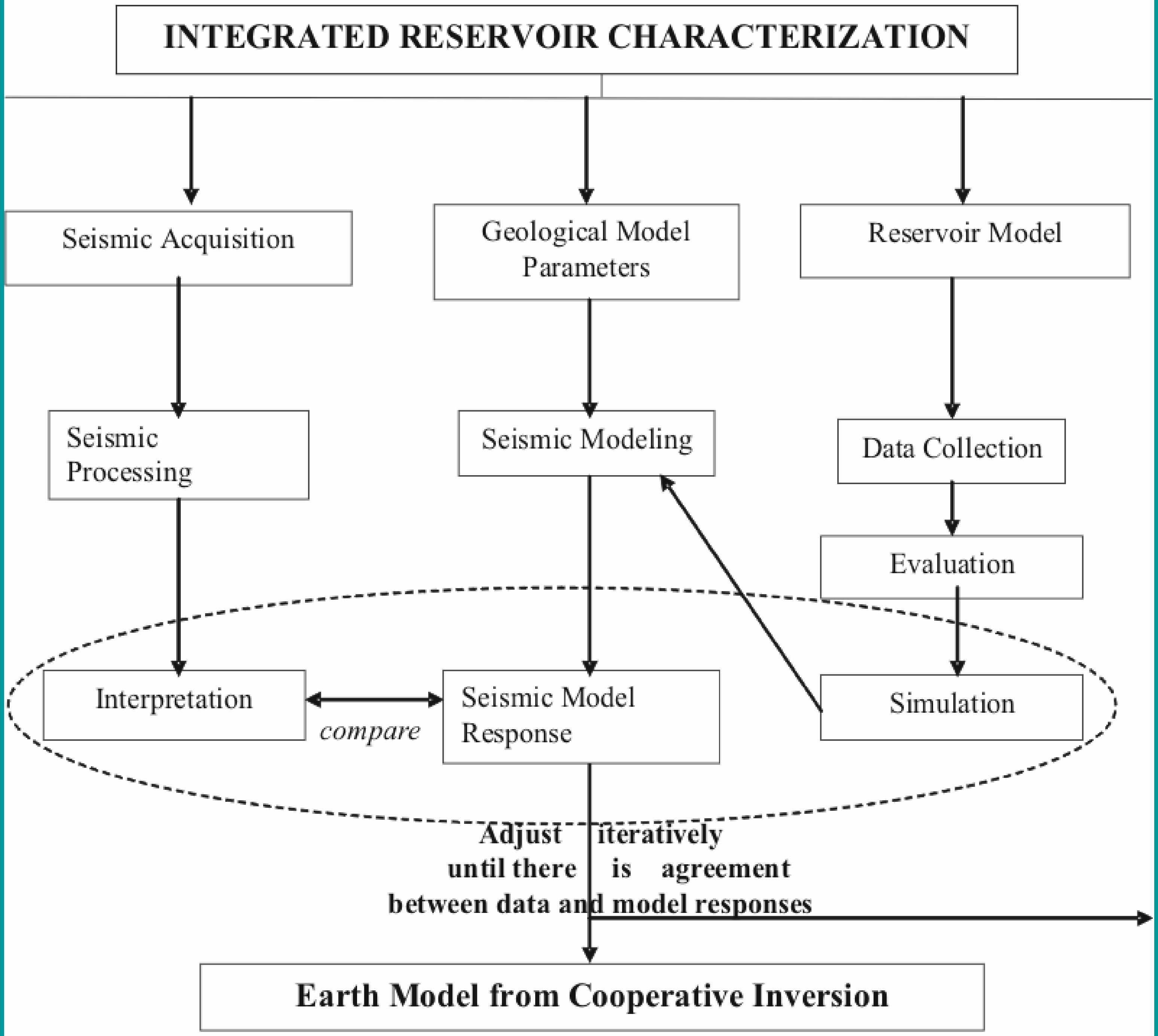


Final Seismic Model

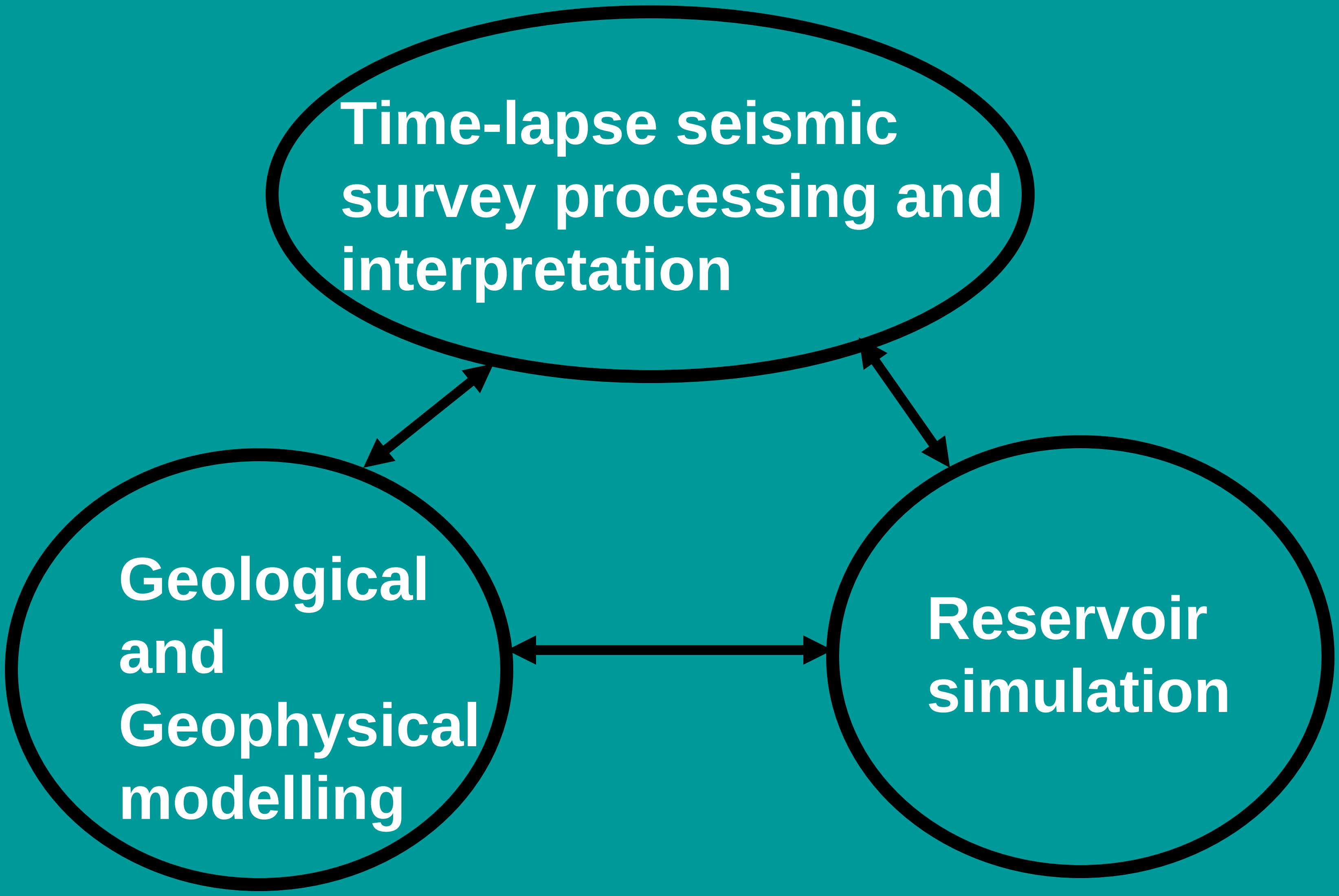


Reservoir Characterization – A Cooperative Inversion Project

- There is ambiguity in fitting both reservoir production data and geophysical data.
- Basic premise of this talk: The ambiguities of reservoir characterization can be reduced by using all available data (engineering, geological and geophysical).


INTEGRATED RESERVOIR CHARACTERIZATION
Seismic Acquisition
Geological Model Parameters
Reservoir Model
Seismic Processing
Seismic Modeling
Data Collection
Evaluation
Interpretation
compare
Seismic Model Response
Simulation
Adjust iteratively until there is agreement between data and model responses
Earth Model from Cooperative Inversion

Reservoir Characterization
(modified from Zou, 2005)



In seismic inversion, we model using an appropriate version of the wave equation.

For example, in its simplest form,

$$\nabla^2 u = \frac{1}{v^2}\frac{\partial^2 u}{\partial t^2}$$

FD Evaluation of Derivatives

- In computing solutions to the wave equation, second derivatives are evaluated by finite-differences. For example,

$$\frac{\partial^2 u}{\partial x^2} = \frac{1}{h^2}\left[u(x_0 + h) + u(x_0 - h) - 2u(x_0)\right]$$

Flow Equations for Oil Recovery Processes

- Basic equations are conservation of mass for three pseudo-components water, heavy oil and solution gas

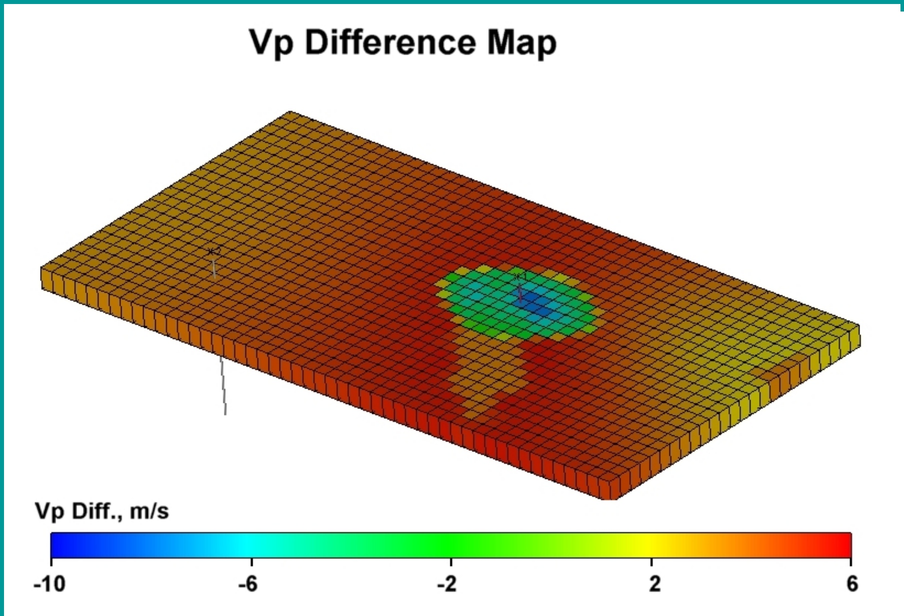
$$\frac{\partial m_L}{\partial t} + q_L = -\sum_L \nabla \cdot J_L \quad \text{for } L = W, O, G \text{ components}$$

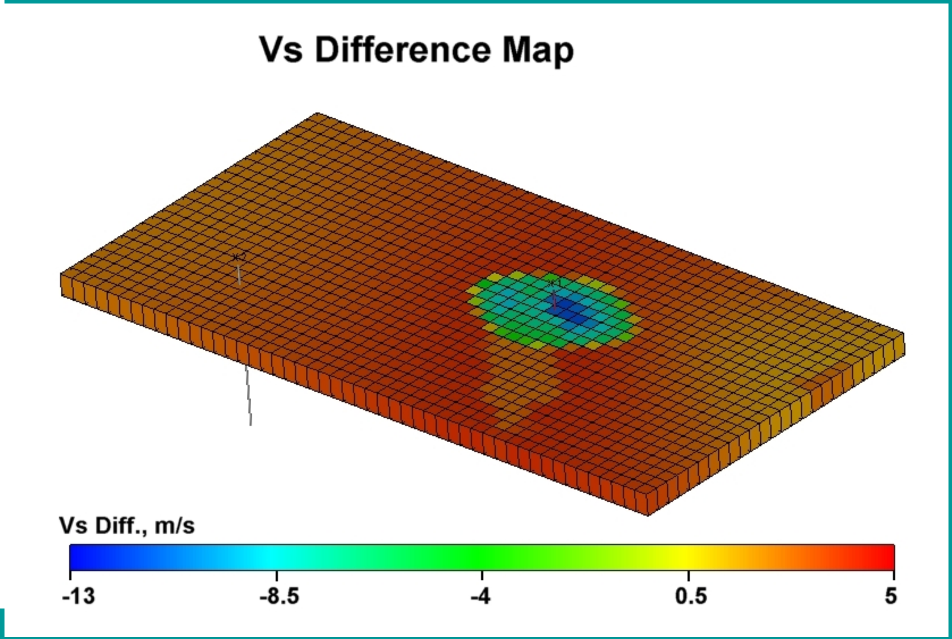
- Phase velocities are obtained from multiphase forms of Darcy's law

$$J_\ell = \frac{\rho_\ell k k_{r\ell}}{\mu_\ell}\left(\nabla p_\ell - \gamma_\ell \nabla z\right) \quad \text{for } \ell = w, o, g \text{ phases}$$

From Dennis Coombe

Reservoir Feasibility Tests



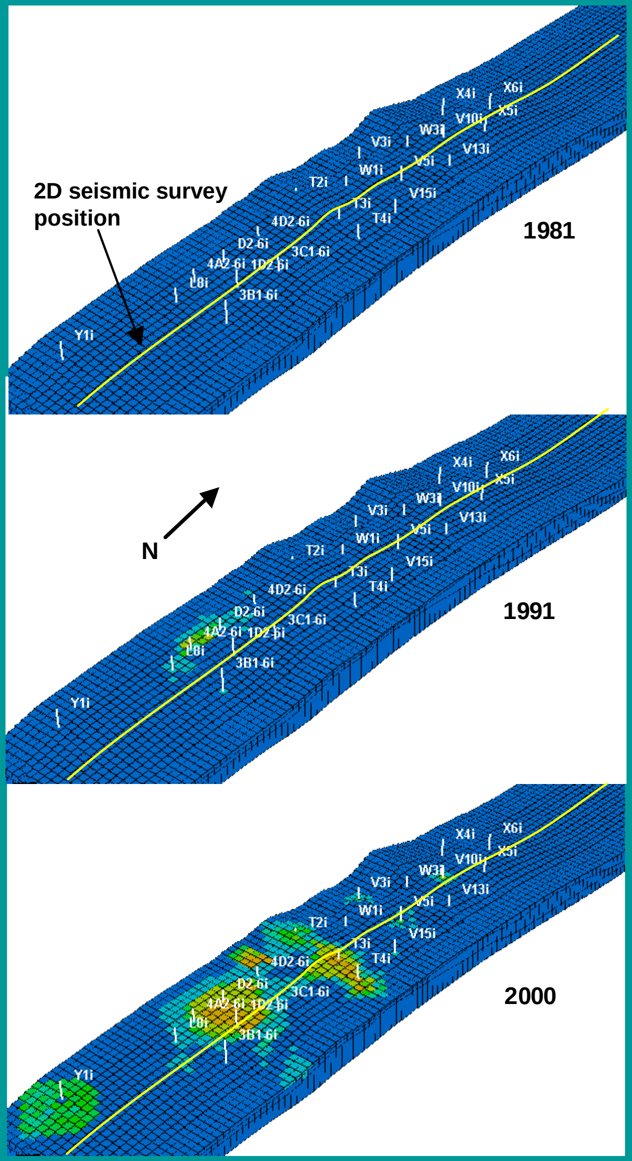


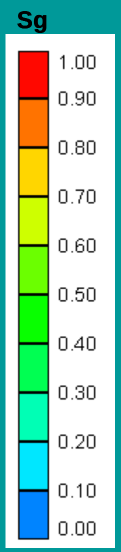
We need to to test the feasibility of reservoir characterization for each individual recovery process as in above water flooding example from Vasheghani and Riahi (2005).

Courtesy Fereidoon Vasheghani

Reservoir Models

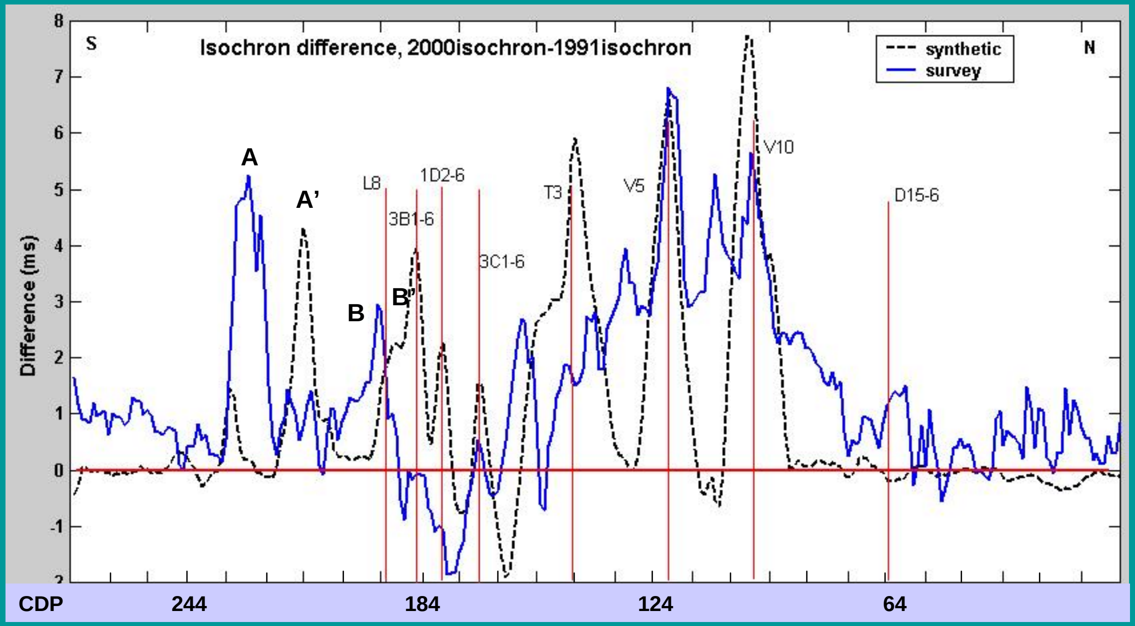
- Reservoir models for gas saturation (Zou et al., 2006)
- Can geological and geophysical data improve these models?





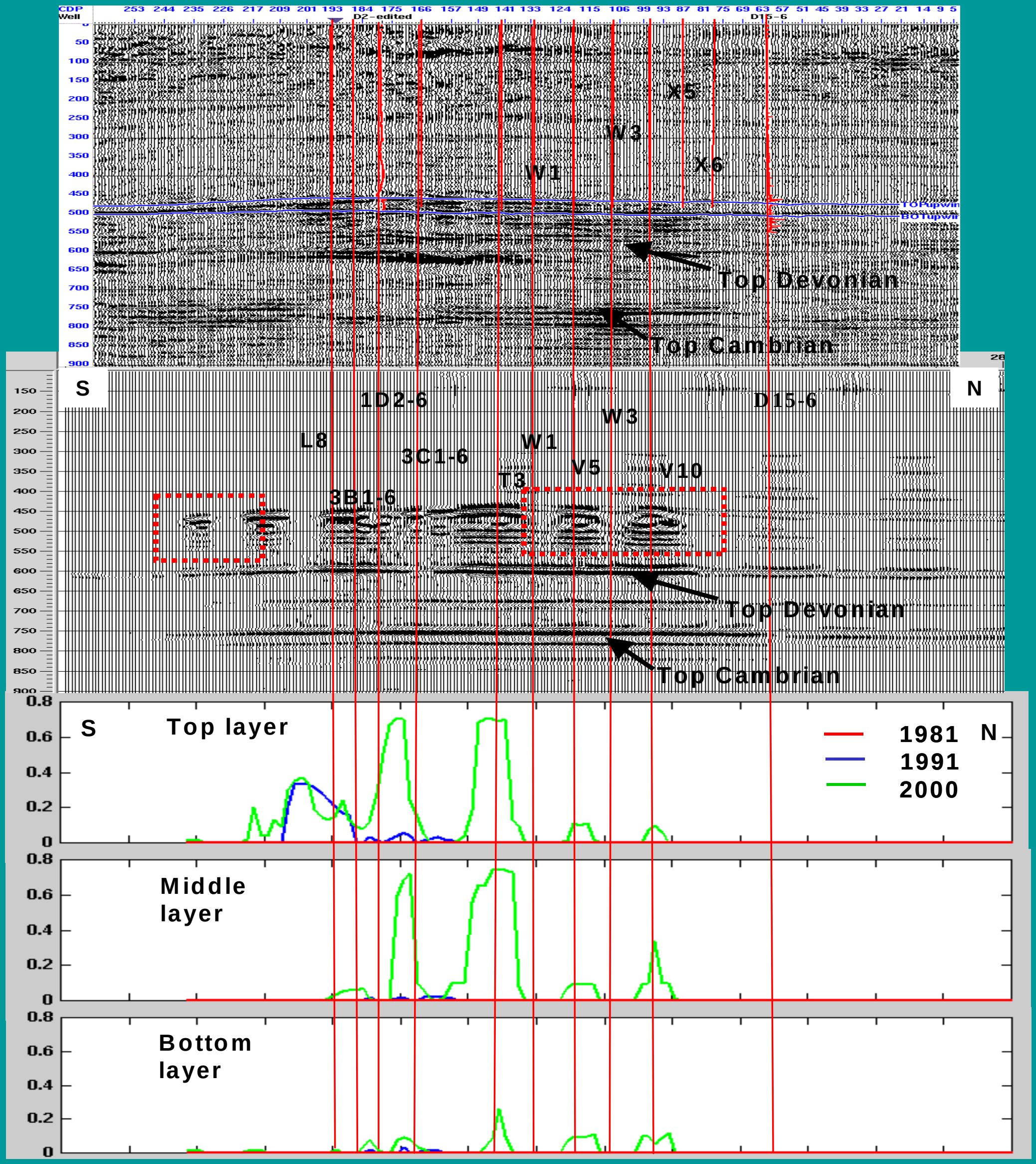
Updating reservoir models

- Time-lapse seismic data can be used to update reservoir models.
- (Zou et al., TLE, June 2006)



Reservoir Data and Model Responses

- Zou et al. (2006)



Reservoir Characterization – Quo Vadis?

- 1. Reservoir characterization will require an integrated interdisciplinary approach.
- 2. Important issues include:
  - a. Parameterization
  - b. Upscaling and downscaling of models
  - c. Combining information at different wavelengths
  - d. Passive and active seismic monitoring
  - e. Rock physics
  - f. Computational needs – parallel processing

Acknowledgements

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