Seismic Velocity Sensitivity Analysis: Gulf of Mexico Example, Pony Field*

Ryan Mann[1], Henry Zollinger[1], and Steve Checkles[1]

Search and Discovery Article #50479 (2011)
Posted September 30, 2011

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Houston, Texas, USA, April 10-13, 2011.

[1]E&P, Hess Corporation, Houston, TX. (hzollinger@hess.com)

Abstract

The Pony Discovery is a large subsalt 4-way dip closure with Middle and Lower Miocene reservoirs at depths near 30,000 feet. Five wells have penetrated the reservoir all clustered near the crest of the structure. The structure is relatively low relief therefore small changes in the migration velocity cause differences in the depth structure that translate to large changes in both the area of closure and the calculated reserves. A methodology is presented that integrates the well information and the surface seismic to estimate this structural uncertainty. Subsalt GOM seismic data yield a low frequency velocity model even with the latest wide azimuth acquisition methods and anisotropic imaging algorithms. This poor velocity resolution is due to the low signal to noise and small angle of incidence range subsalt. Velocity information from the five wells at Pony were analyzed utilizing sonic logs, seismic-to-well ties and VSPs. This analysis of the well data indicated substantial subsalt velocity variations that are not detectable from the surface seismic analysis. The velocity variations observed in the wells were used to create end member velocity estimates. These end member velocities were used to extrapolate the velocities away from the well control. Three different velocity structure scenarios were used in the extrapolation of the end member velocities: flat model; base of salt structure model and reservoir structure model. The most pessimistic structural scenario (low case) is the fastest velocities and flat structural extrapolation away from the well control. The most optimistic structural scenario (high case) is the slowest velocities and reservoir structure model. These high case and low case structural scenarios define the best estimate of the range of structural uncertainty of the reservoir. An analysis of the well derived velocities indicate that the reservoir structure model matches observed well velocities better than the flat velocity model or the base of salt structure model. Consequently, the best technical estimate (BTE) of the true subsalt structure is derived from an extrapolation of the average of the well derived velocities following the reservoir structure model away from the well control.

Seismic Velocity Sensitivity Analysis: Gulf of Mexico Example, Pony Field

Ryan Mann, Henry Zollinger, and Steve Checkles

April 6, 2011

Outline

Pony Field/Basin Overview

Seismic-to-Well Ties
- **Pony #1BP1**

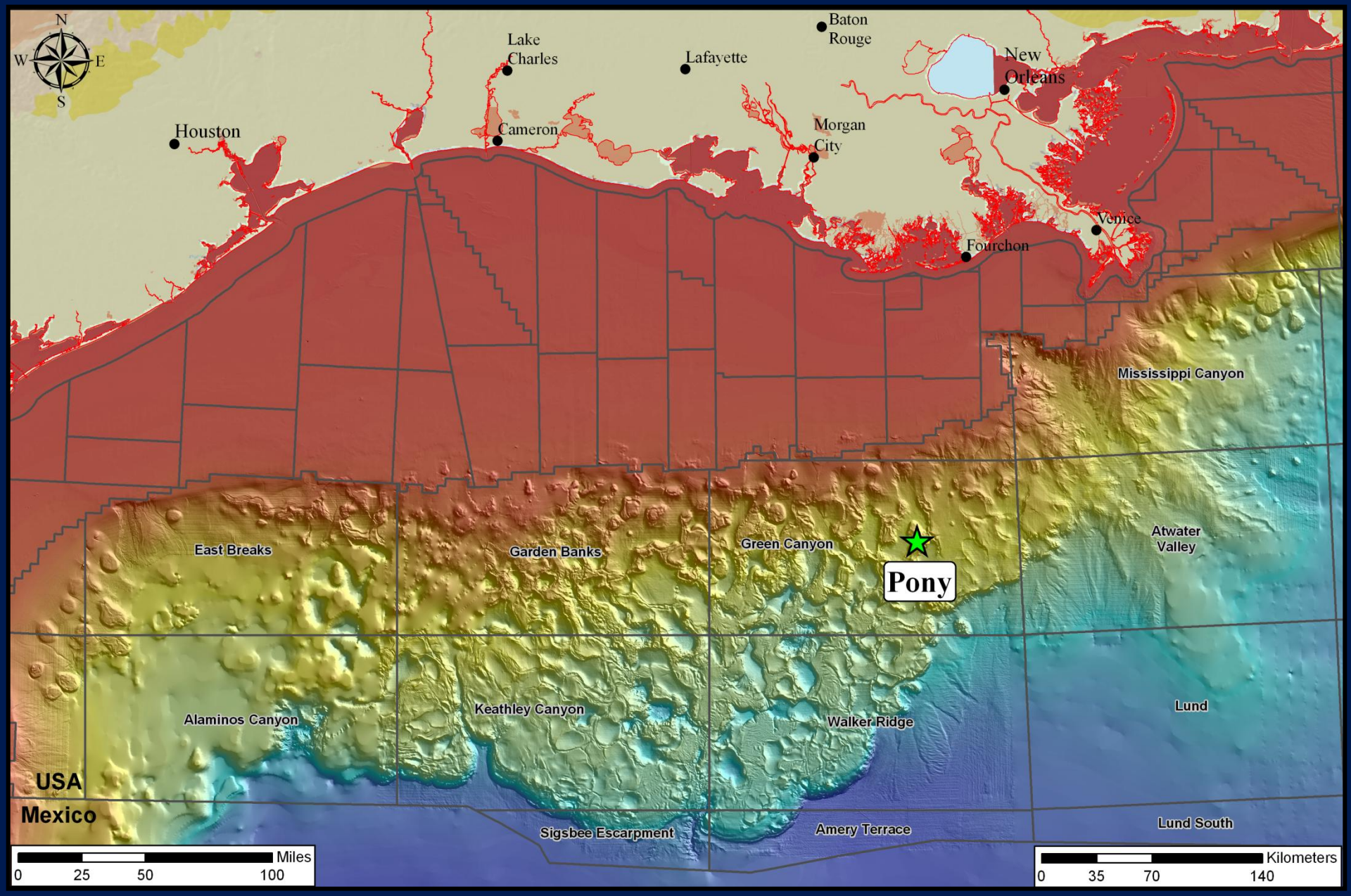
Velocity Range Determination
- ***Velocity trends from surface seismic***
- ***Velocity trends derived from sonic logs***
- ***Velocity trends derived from synthetic-to-seismic ties***

Extrapolation of Velocities away from Well Control
- ***Flat Velocity Model***
- ***BOS Structural Model***
- ***Reservoir Structural Model***

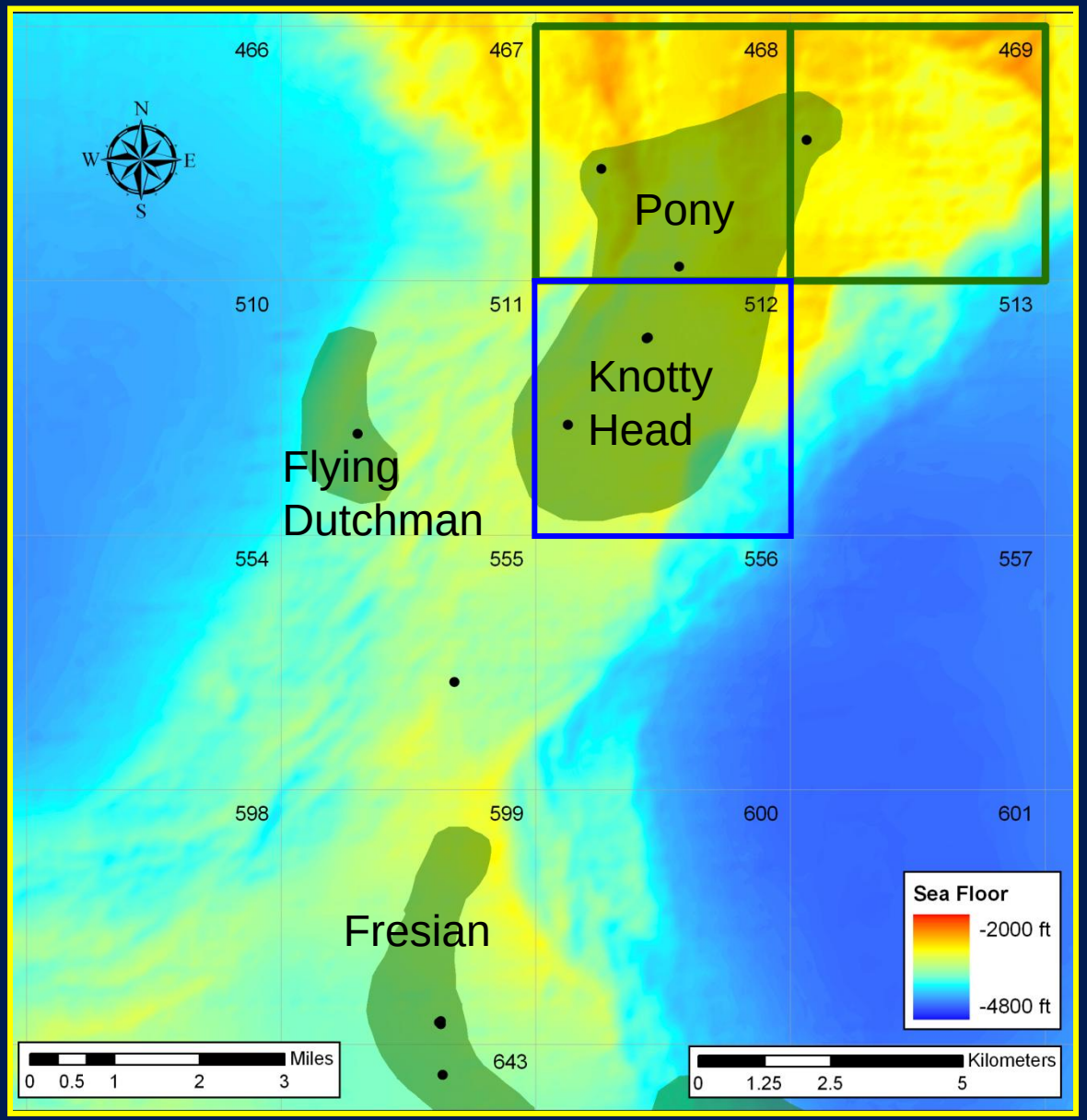
Velocity Range and Extrapolation Results
- ***Low, Mid, High Isotropic Velocity Cases***

Summary/Conclusions
- ***Results used as input for VTI processing***
- ***TTI Processing***

Location: Green Canyon, US Gulf of Mexico



Pony and Knotty Head fields are thought to share a common structure



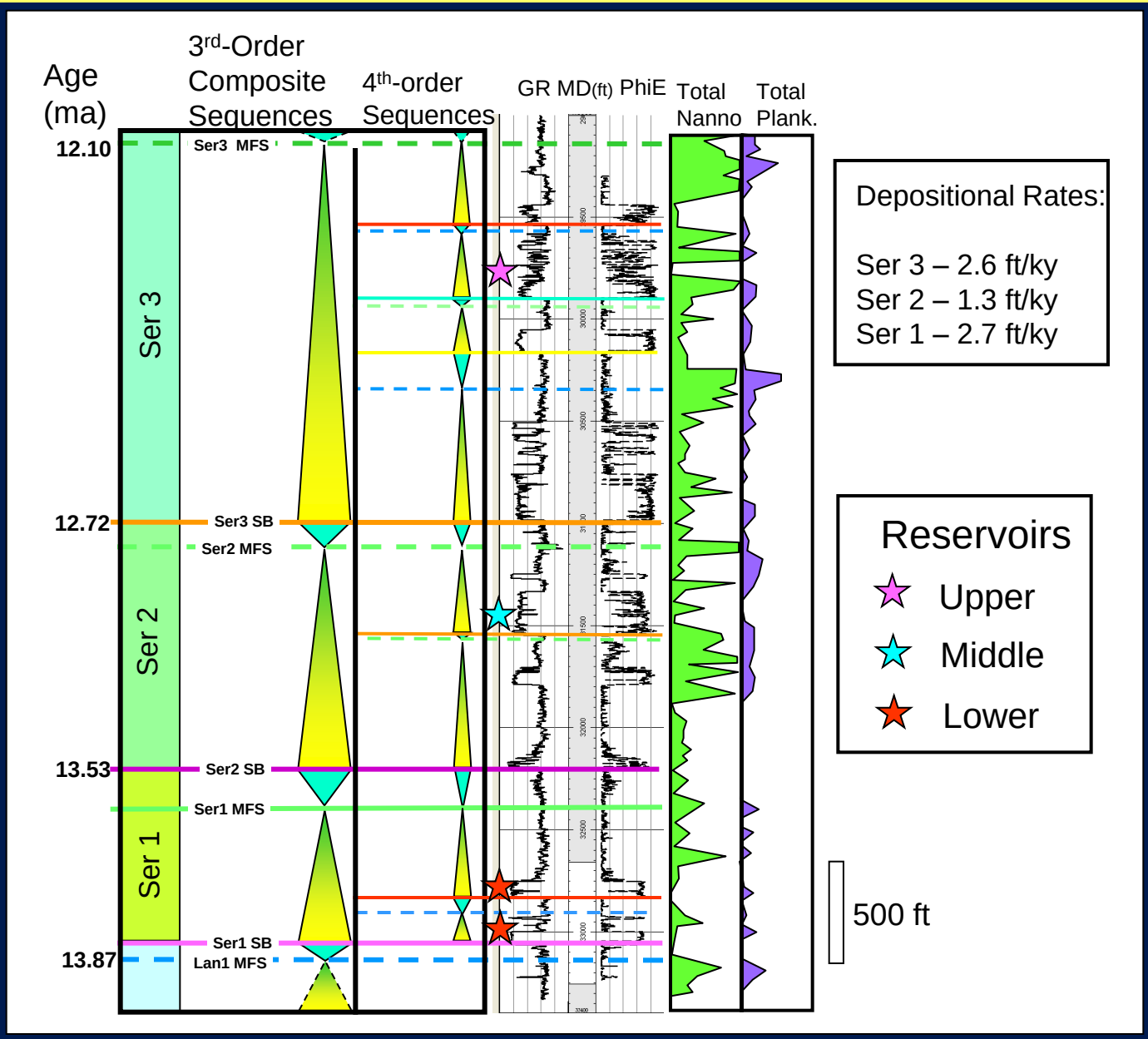
<u>Pony (GC 468 & GC469)</u>

- Equity: Hess (100%)
- Size: +/-200MMBOE *(WoodMac)*
- Water Depth: +/-3,500’
- Reservoir Depth: +/-30,000’
- Reservoir: Middle & Lower Miocene
- Structure: Subsalt 4-way

<u>Knotty Head (GC 512)</u>

- Equity:
  - Nexen (25%) Operator
  - BHP (25%)
  - Statoil (25%)
  - Chevron (25%)
- Size: +/-250MMBOE (WoodMac)
- Water Depth: +/-3,500’
- Reservoir Depth: +/-30,000’
- Reservoir: Middle & Lower Miocene
- Structure: Subsalt 4-way

Generalized Stratigraphic Column



Seismic Velocity Sensitivity Analysis: Key Issues

Objectives of Study

Predict the range of structural uncertainty at the Pony Field through analysis of surface and well velocity information.

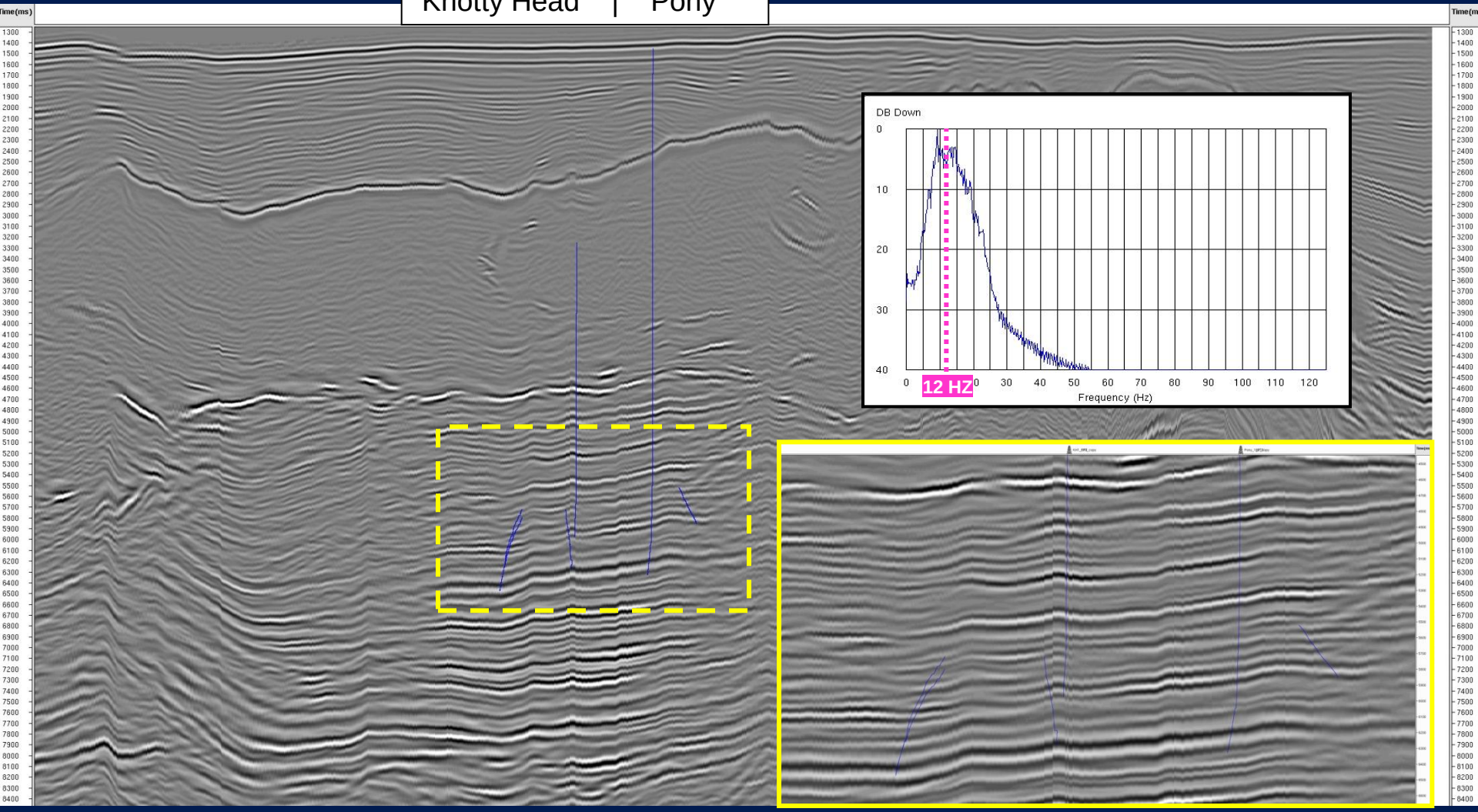
Key Issues to resolve

1. ***Predicting range of velocity uncertainty***

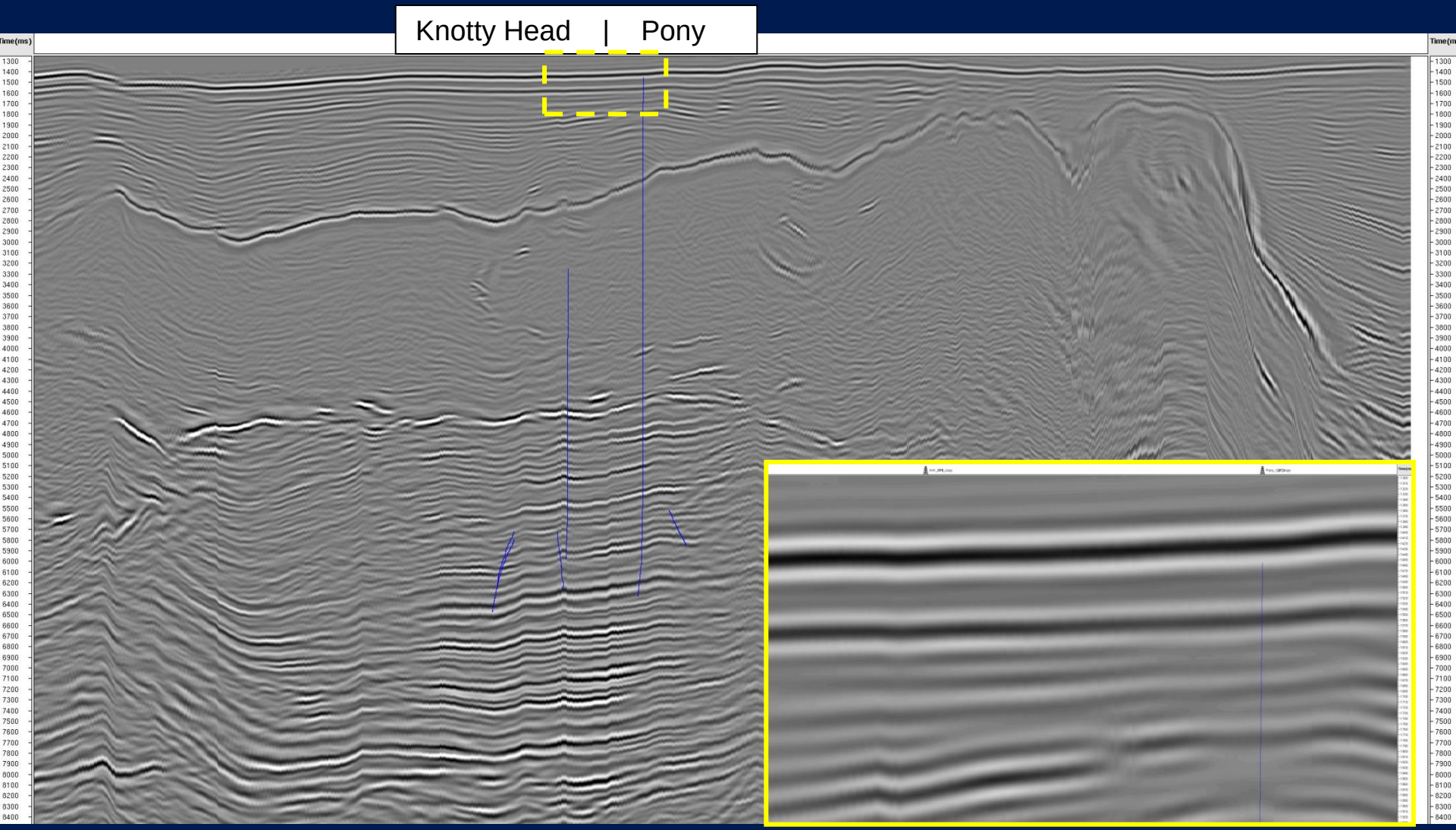
1. ***Extrapolating velocities from well control***

Phase and Frequency of Seismic Data

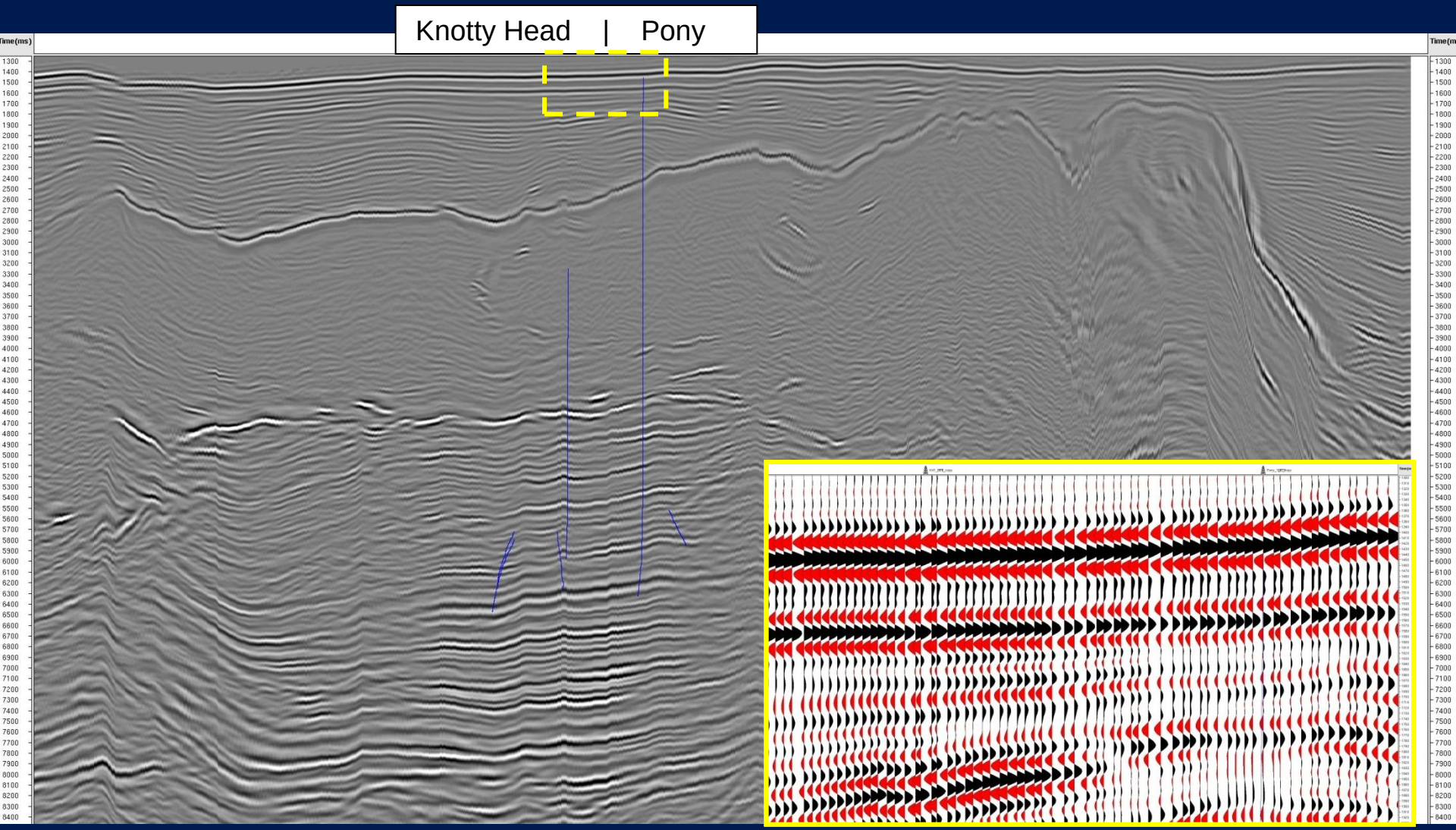
Knotty Head | Pony



Phase and Frequency of Seismic Data

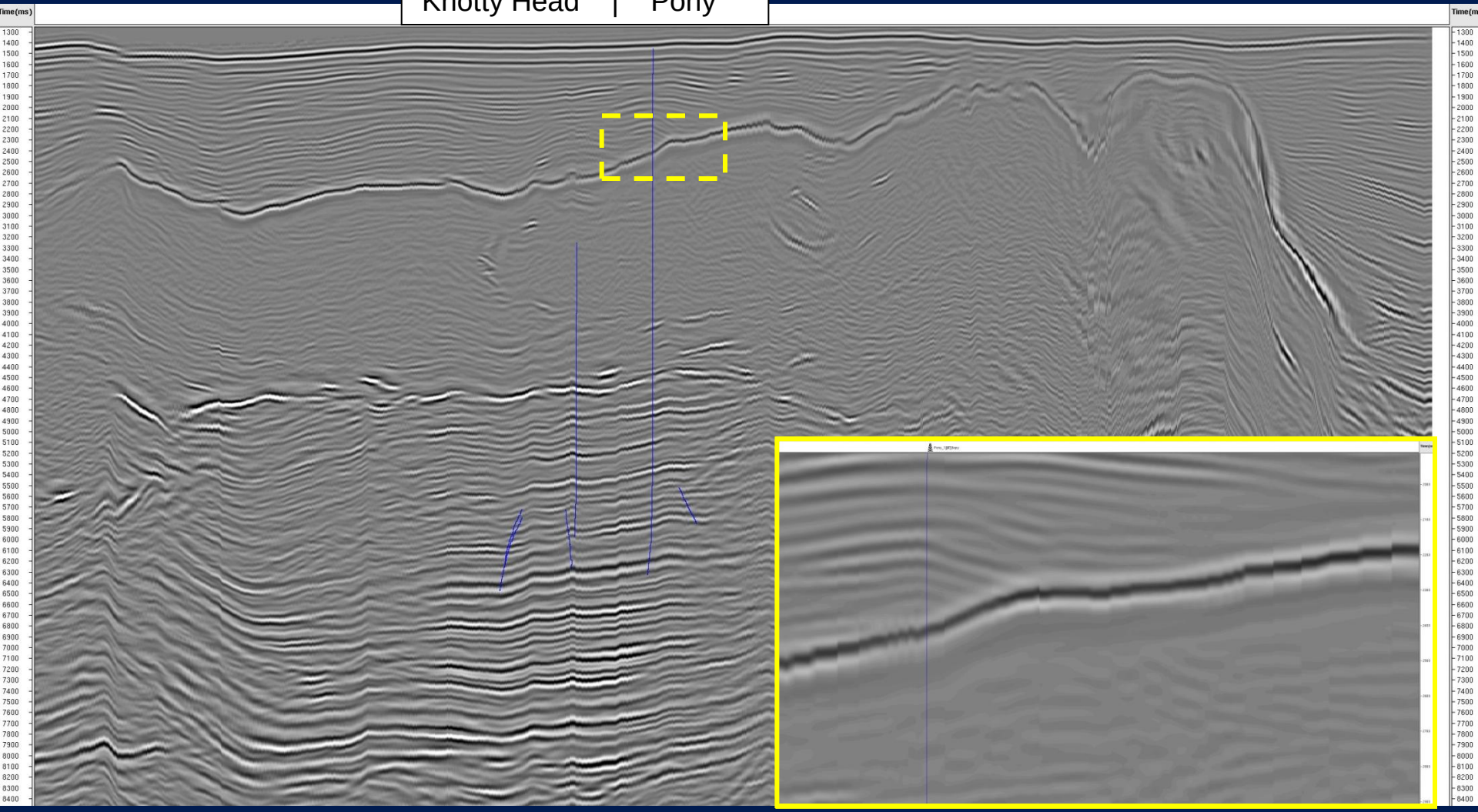


Phase and Frequency of Seismic Data



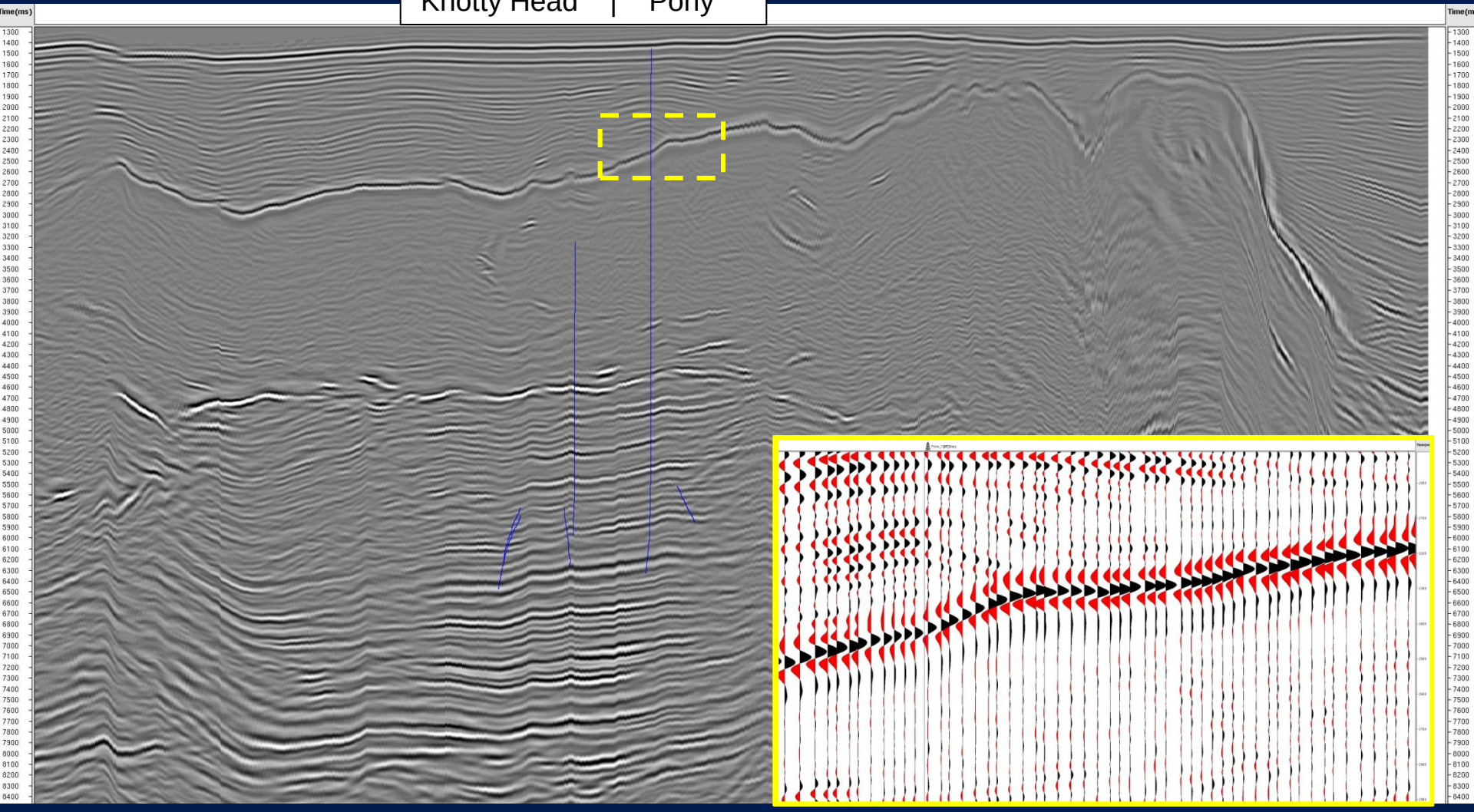
Phase and Frequency of Seismic Data

Knotty Head | Pony



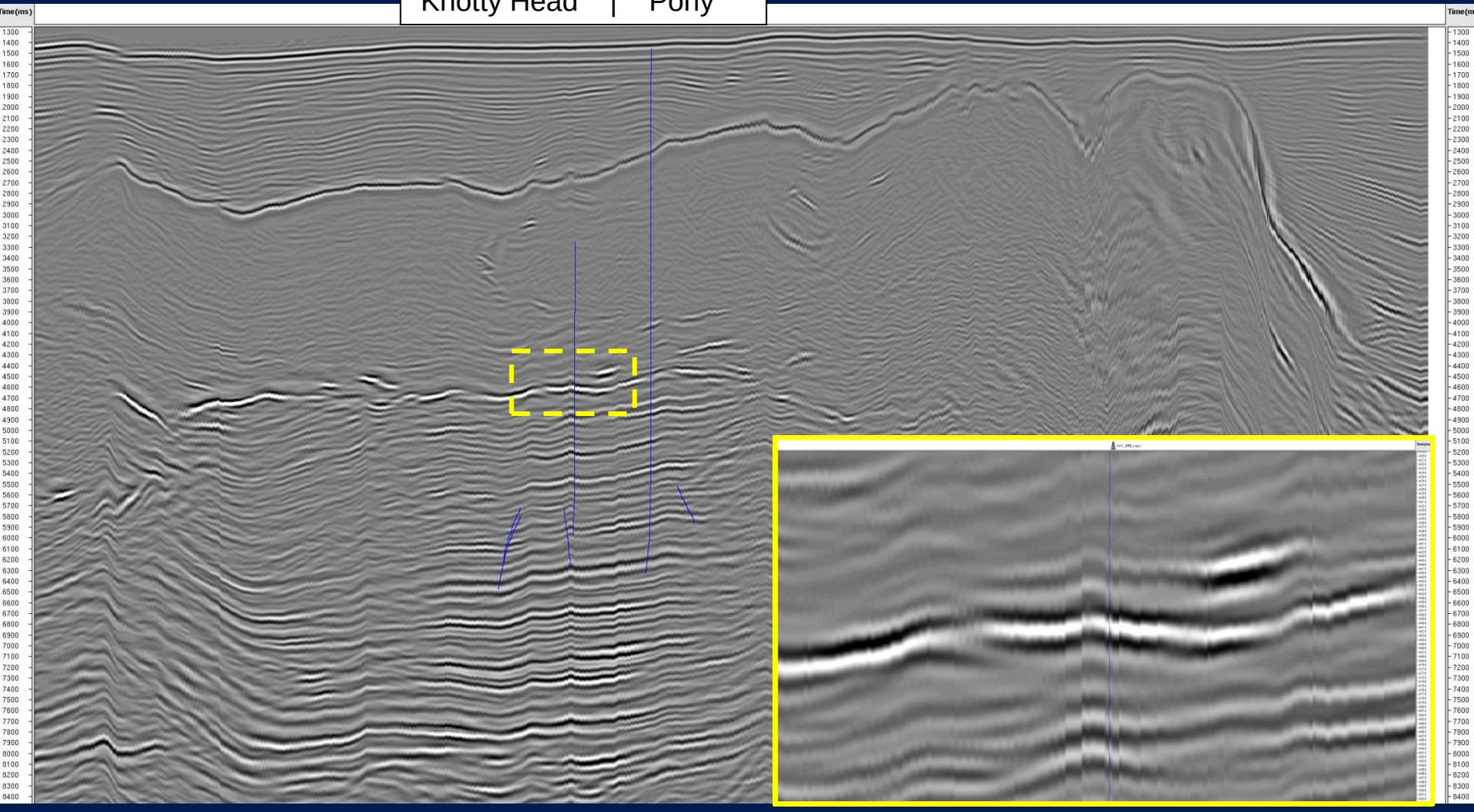
Phase and Frequency of Seismic Data

Knotty Head | Pony



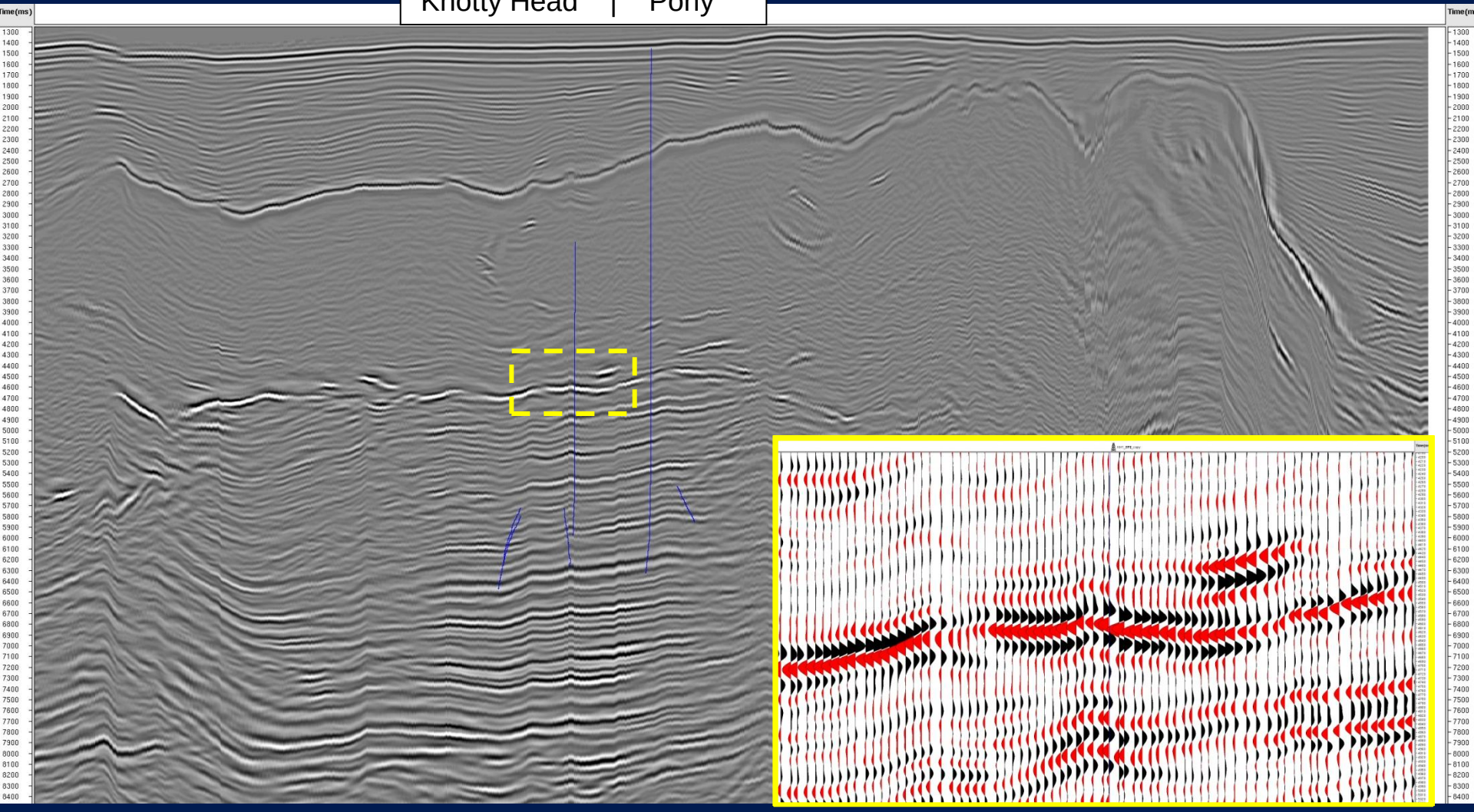
Phase and Frequency of Seismic Data

Knotty Head | Pony

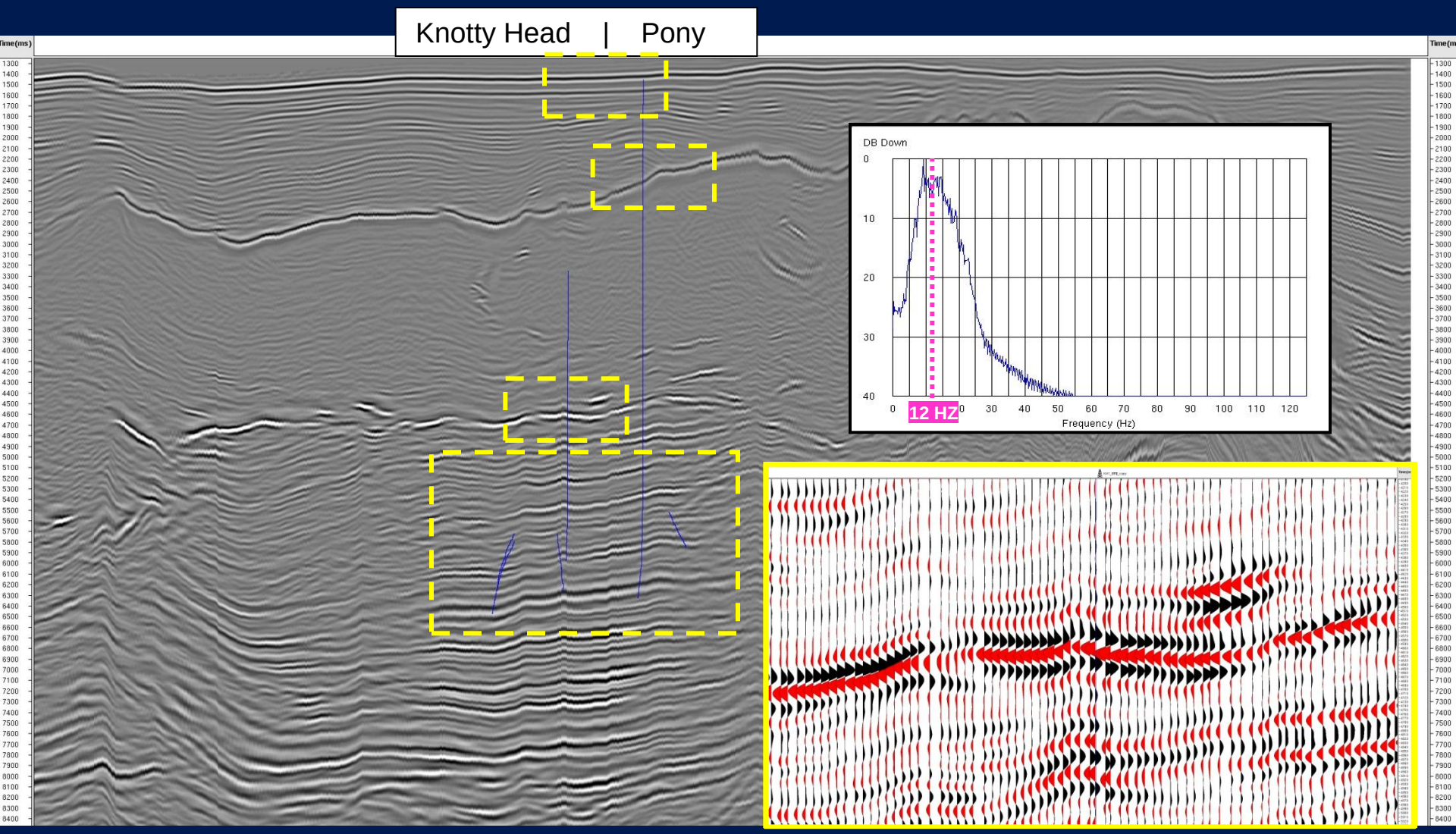


Phase and Frequency of Seismic Data

Knotty Head | Pony

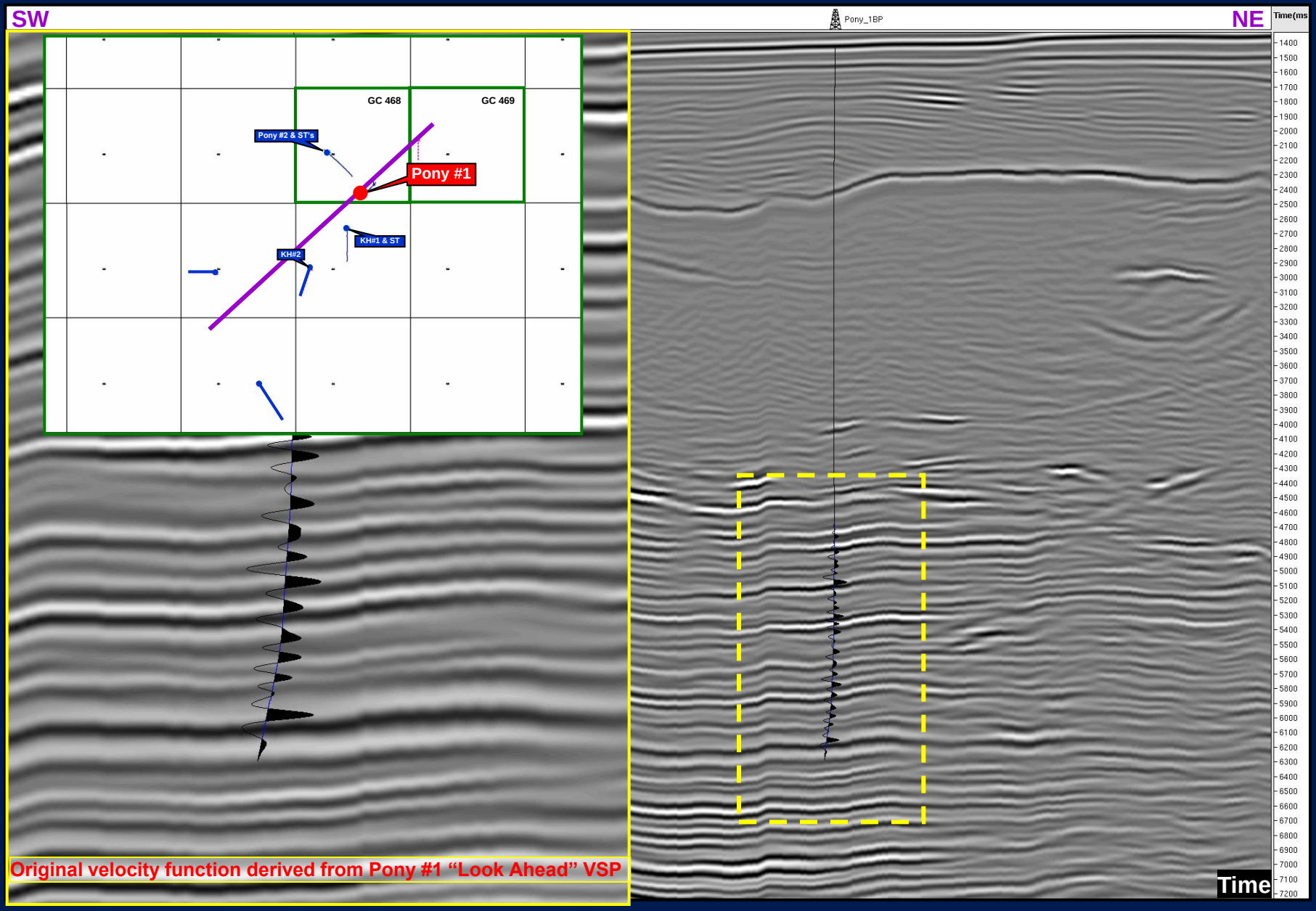


Phase and Frequency of Seismic Data

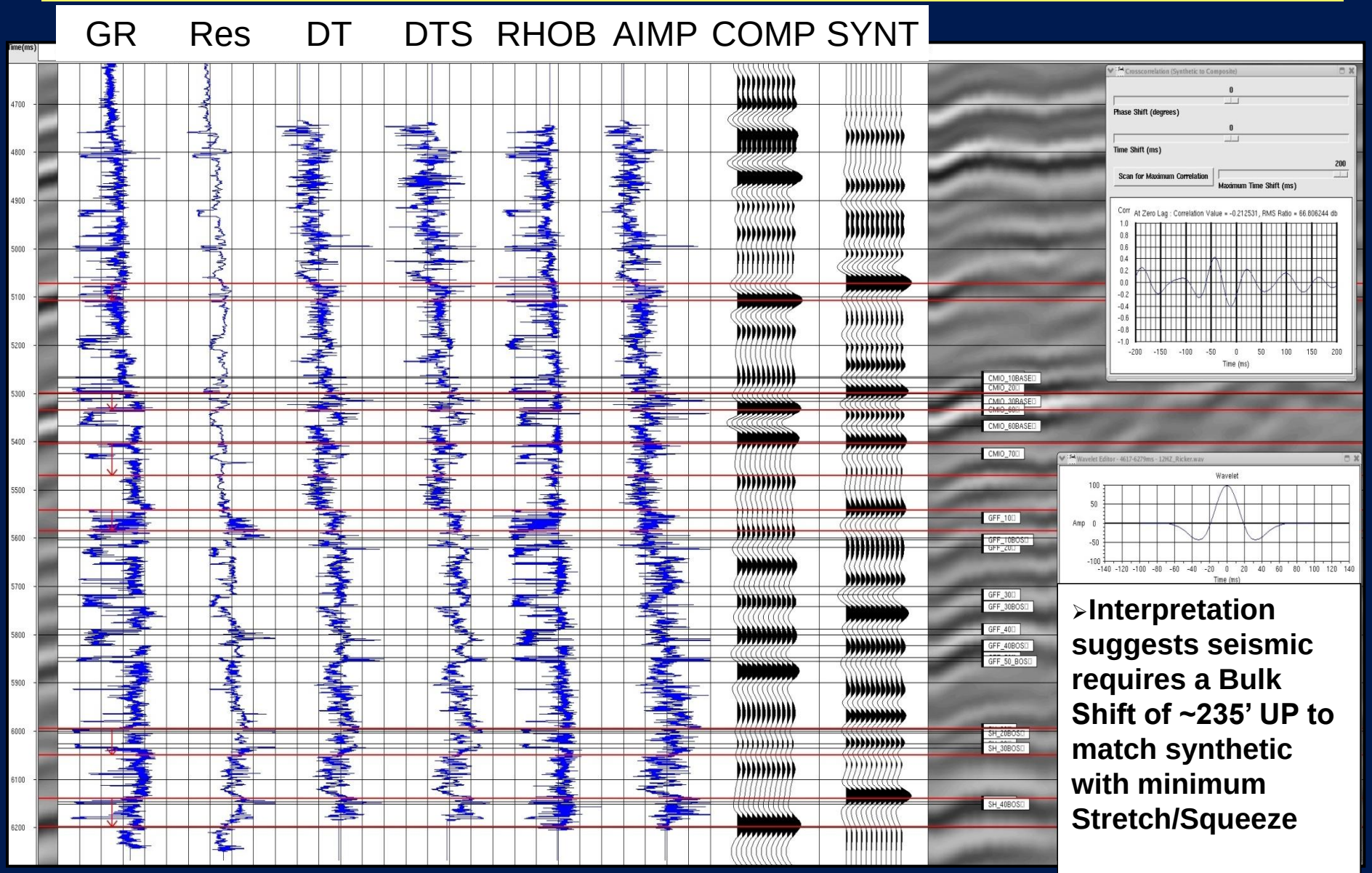


- Data is Zero Phase
- Subsalt Seismic Data Peak Frequency is 12 HZ

Pony #1: “Raw” Seismic to Synthetic Mistie

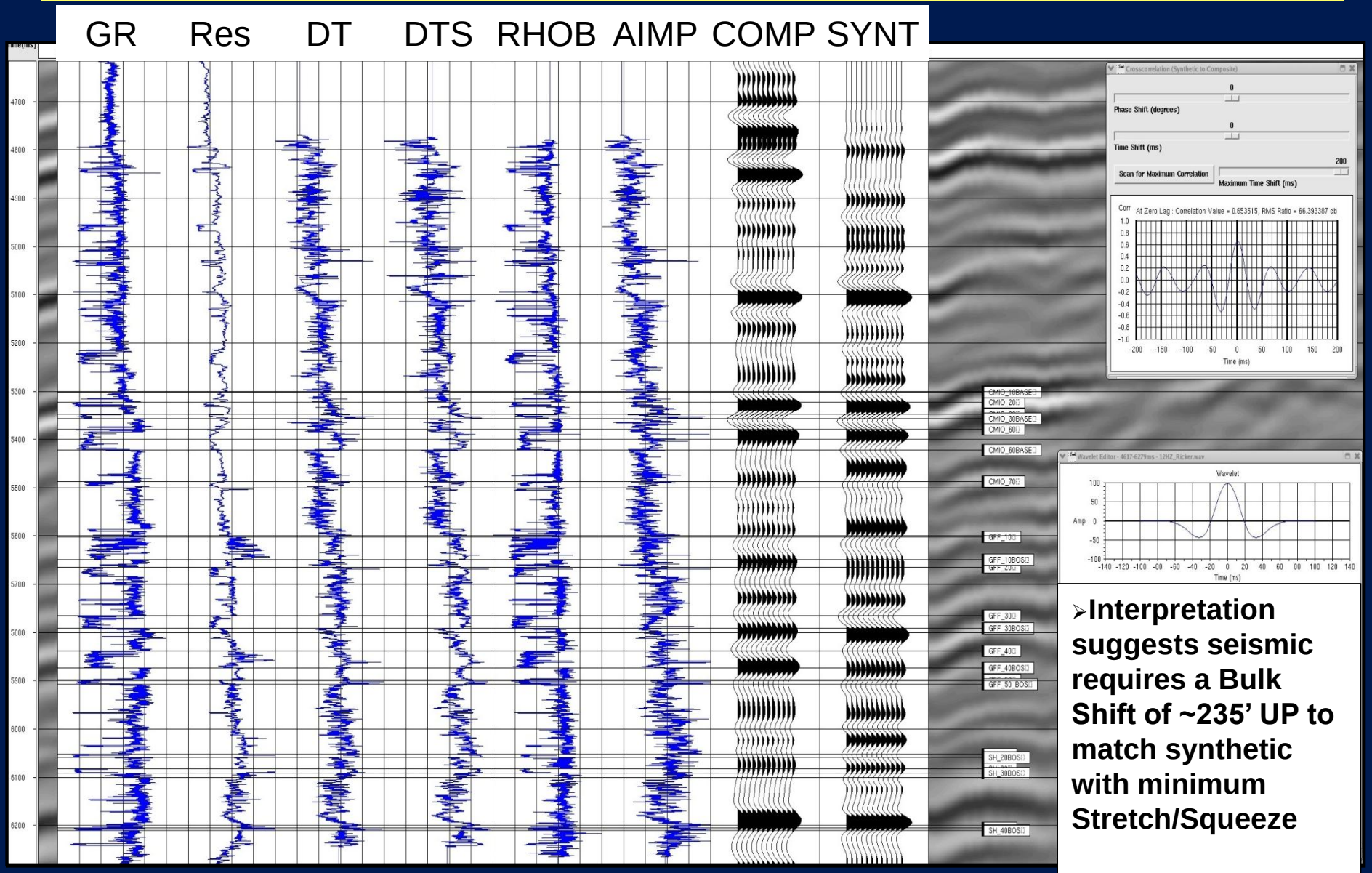


Pony #1: Synthetic w/ Logs vs. Seismic Composite



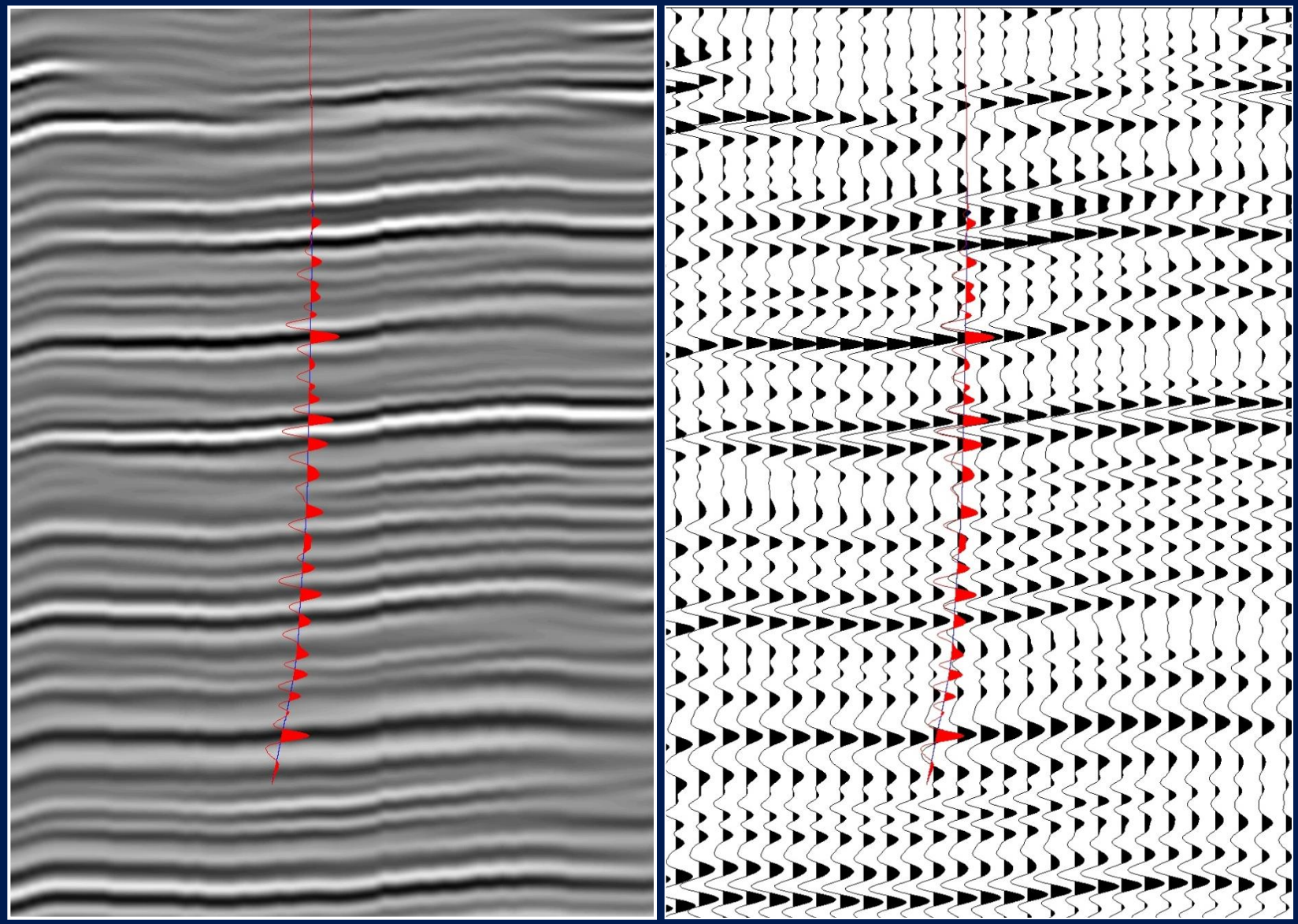
- **Interpretation suggests seismic requires a Bulk Shift of ~235’ UP to match synthetic with minimum Stretch/Squeeze**

Pony #1: Synthetic w/ Logs vs. Seismic Composite

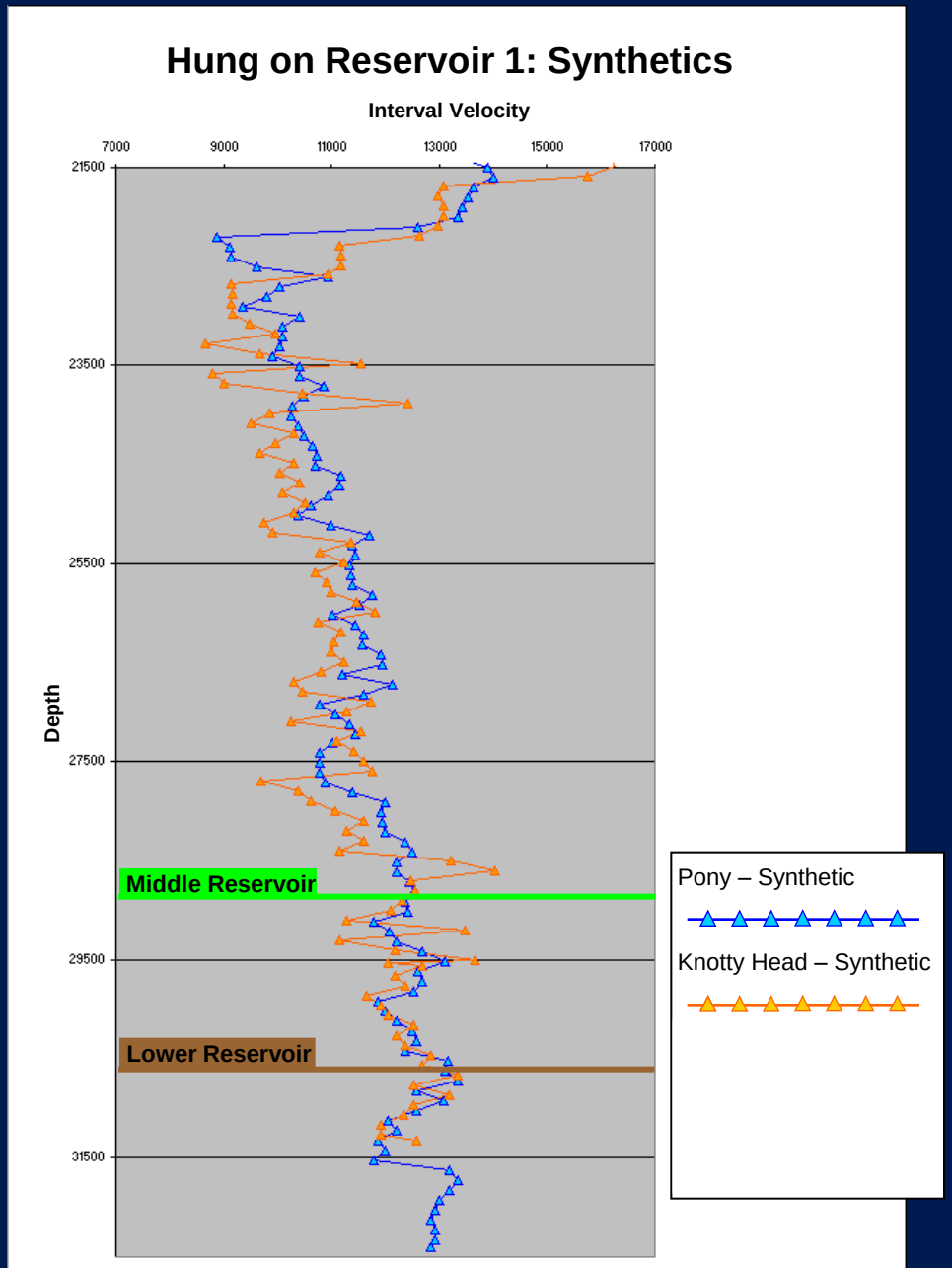


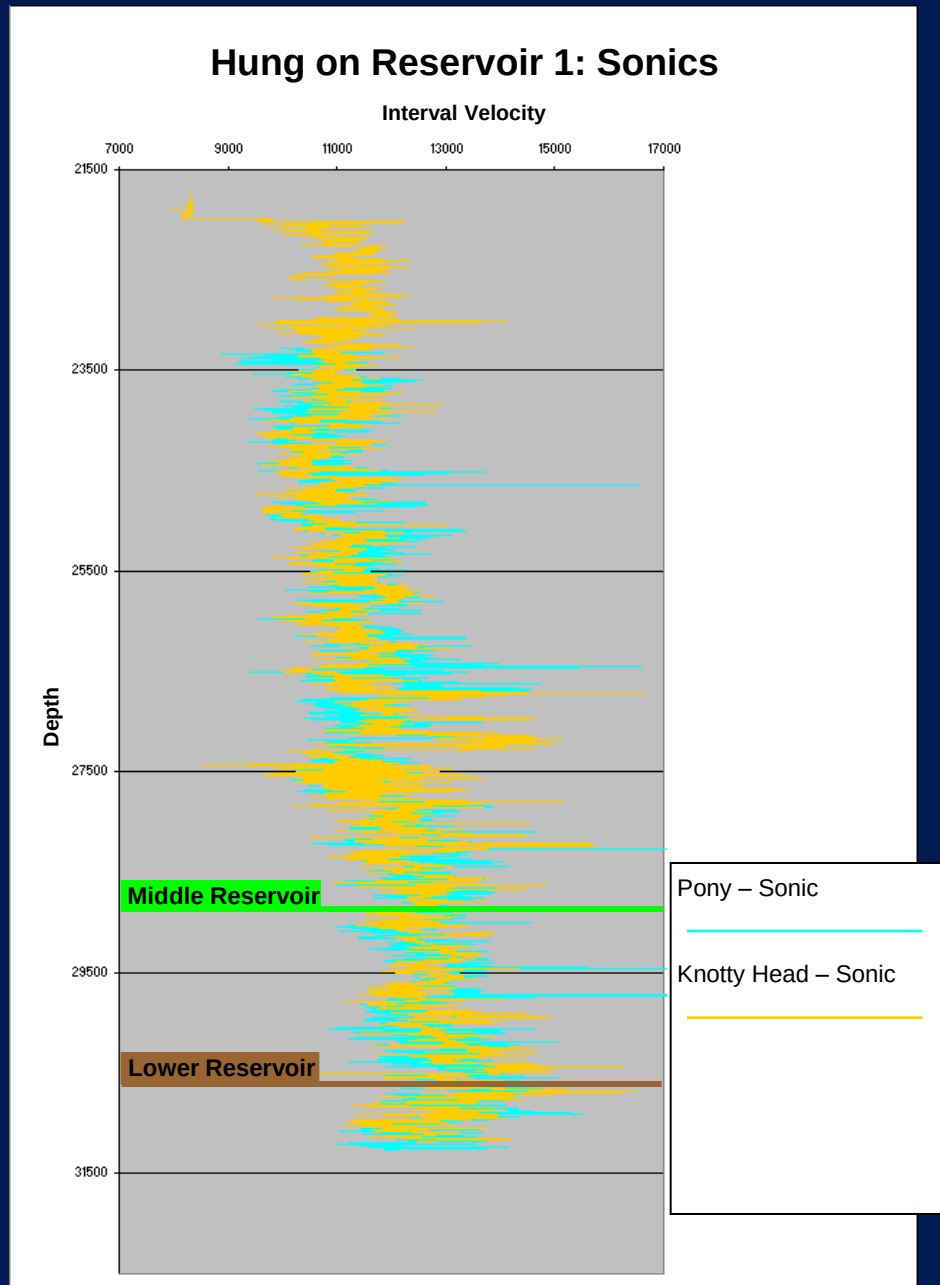
- **Interpretation suggests seismic requires a Bulk Shift of ~235’ UP to match synthetic with minimum Stretch/Squeeze**

Pony #1: Seismic to Synthetic Tie

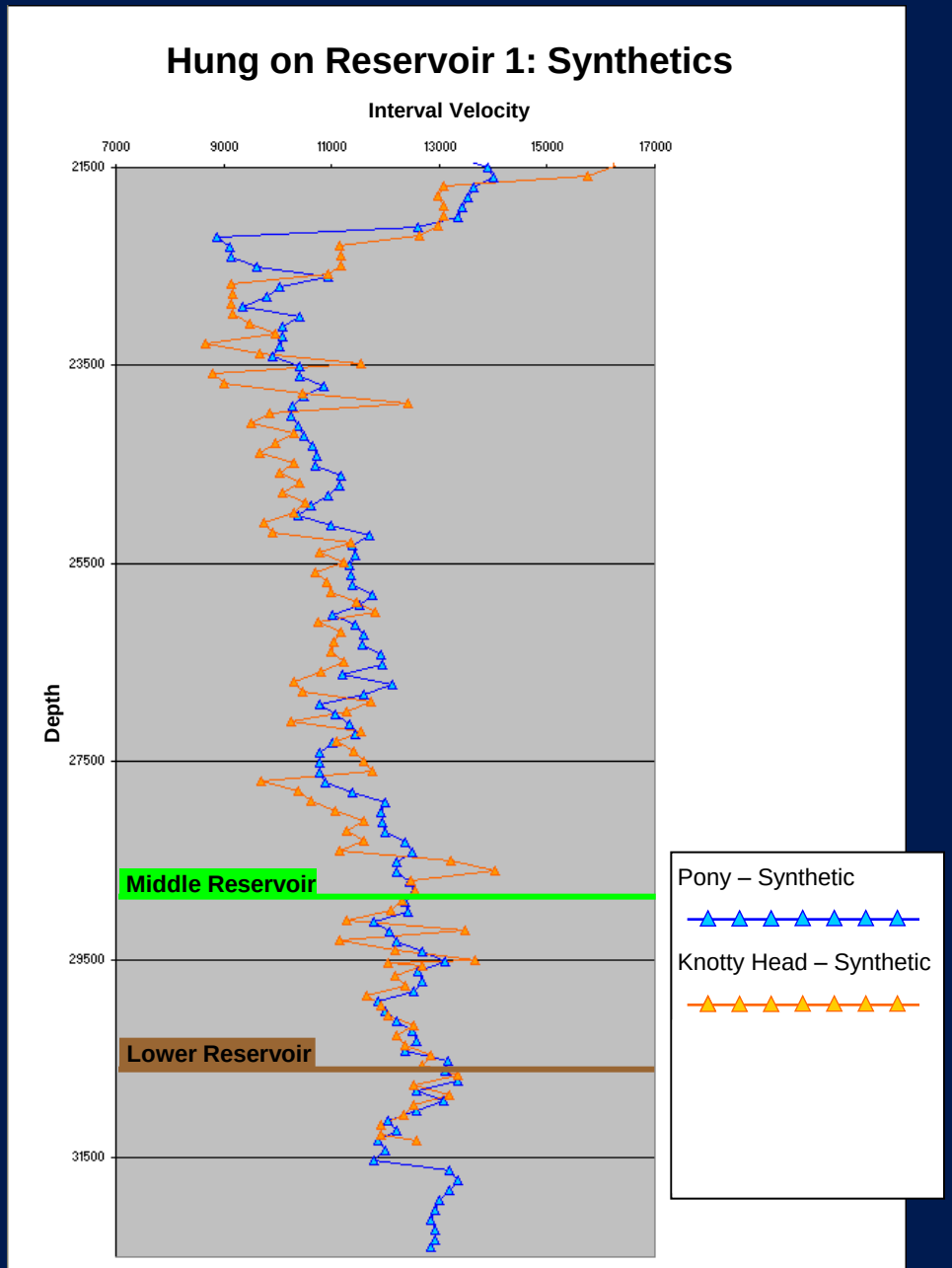


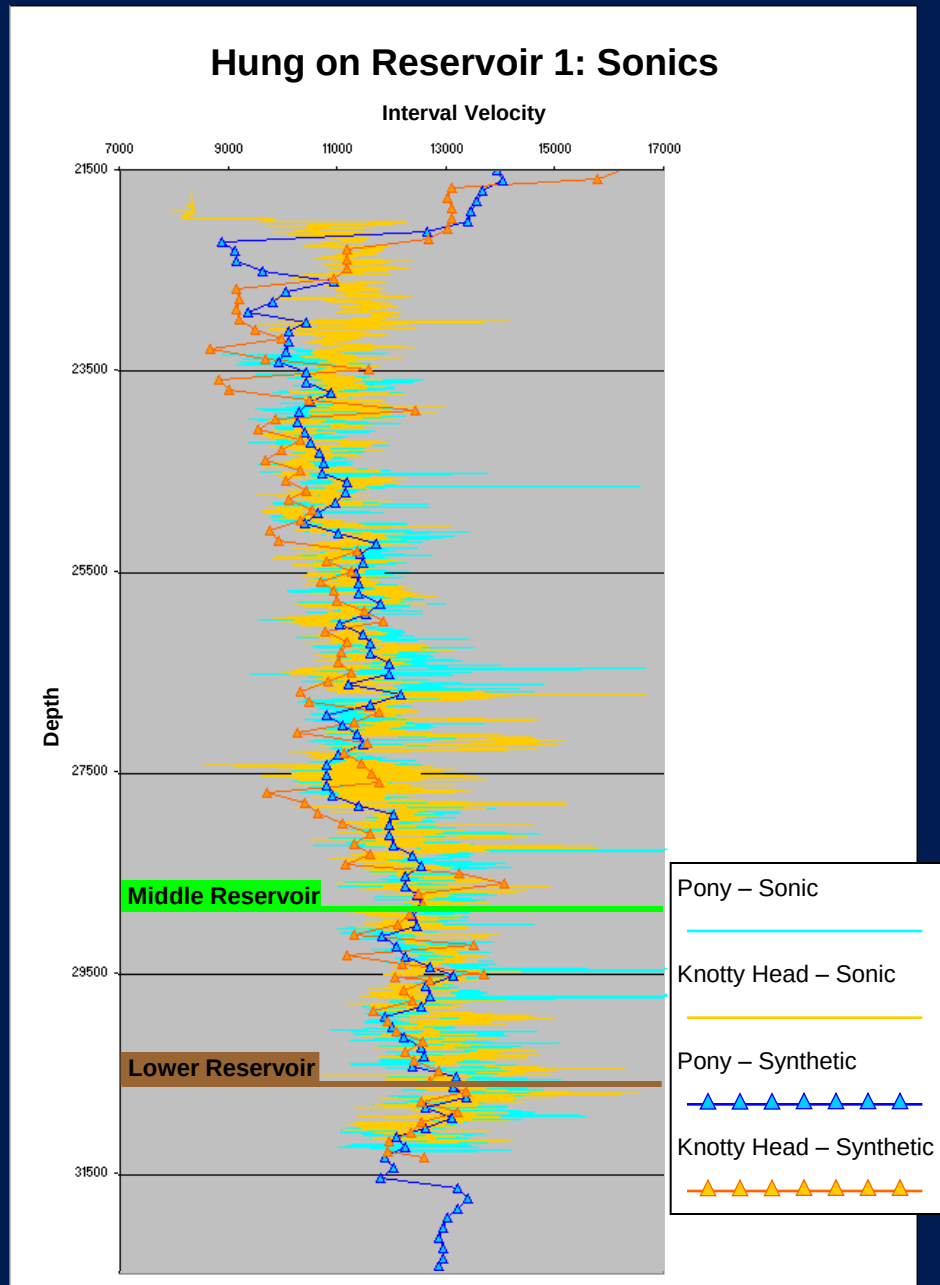
Interval Velocity vs. Depth: Sonics and Synthetics



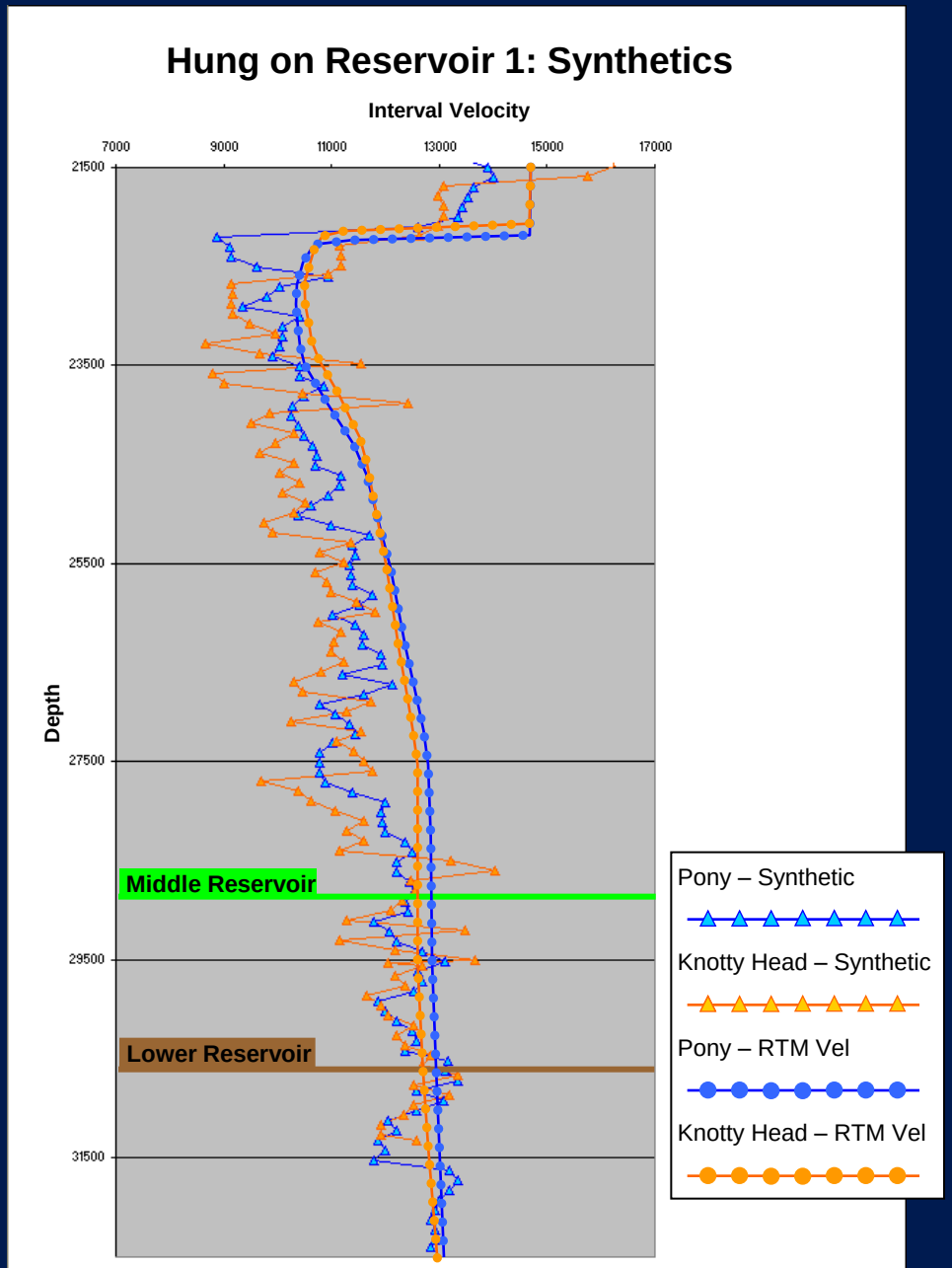


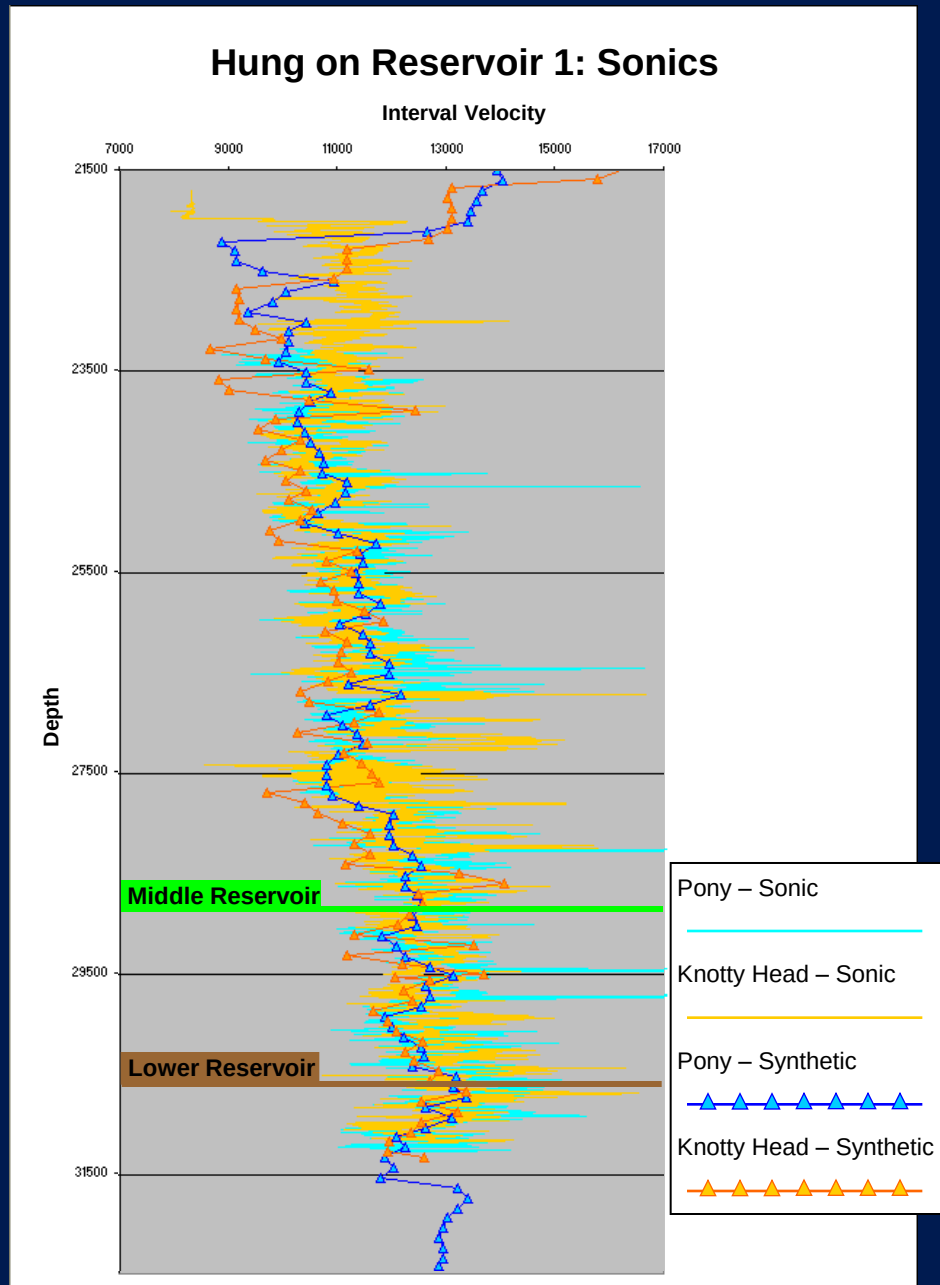
Interval Velocity vs. Depth: Sonics and Synthetics



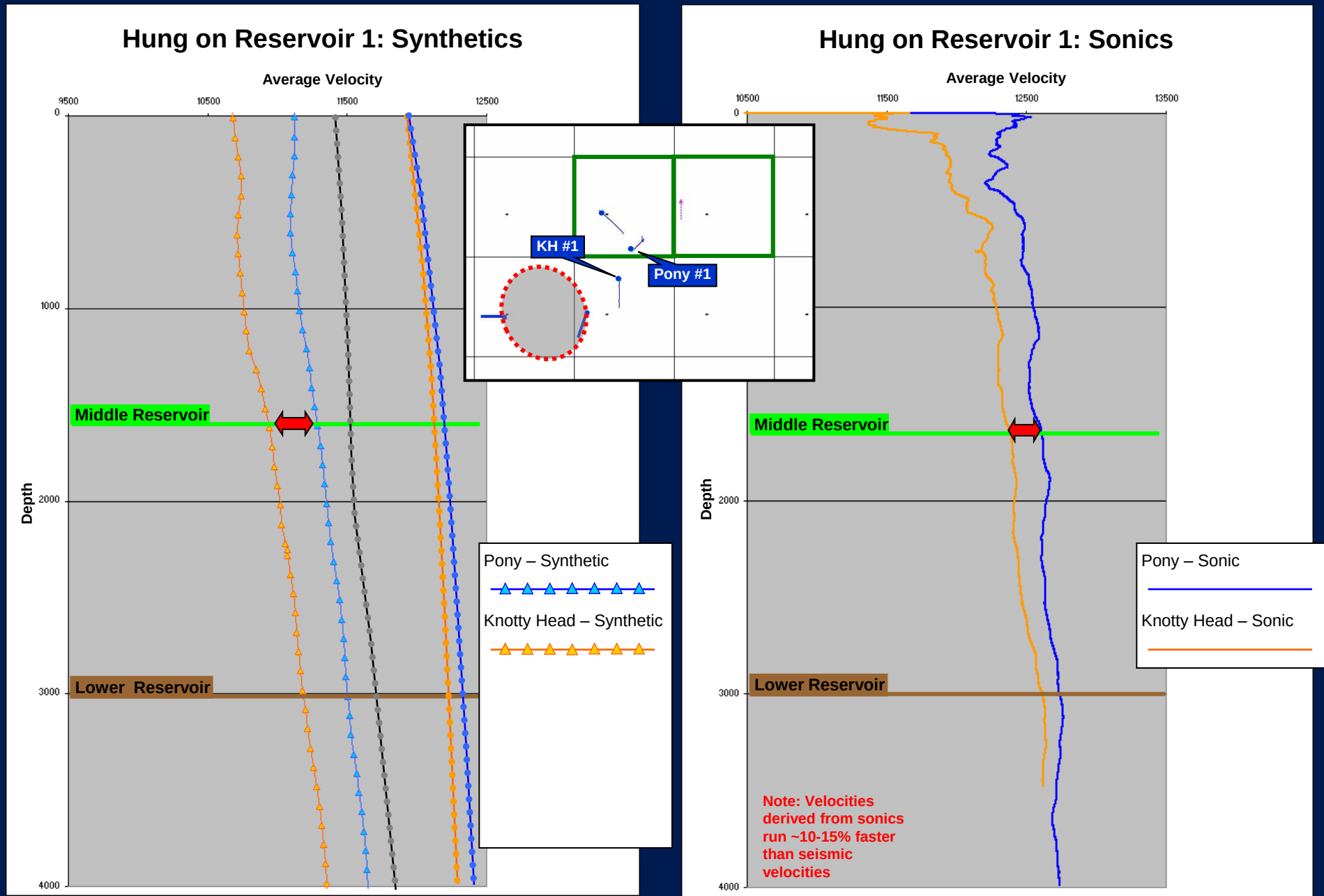


Interval Velocity vs. Depth: Sonics and Synthetics

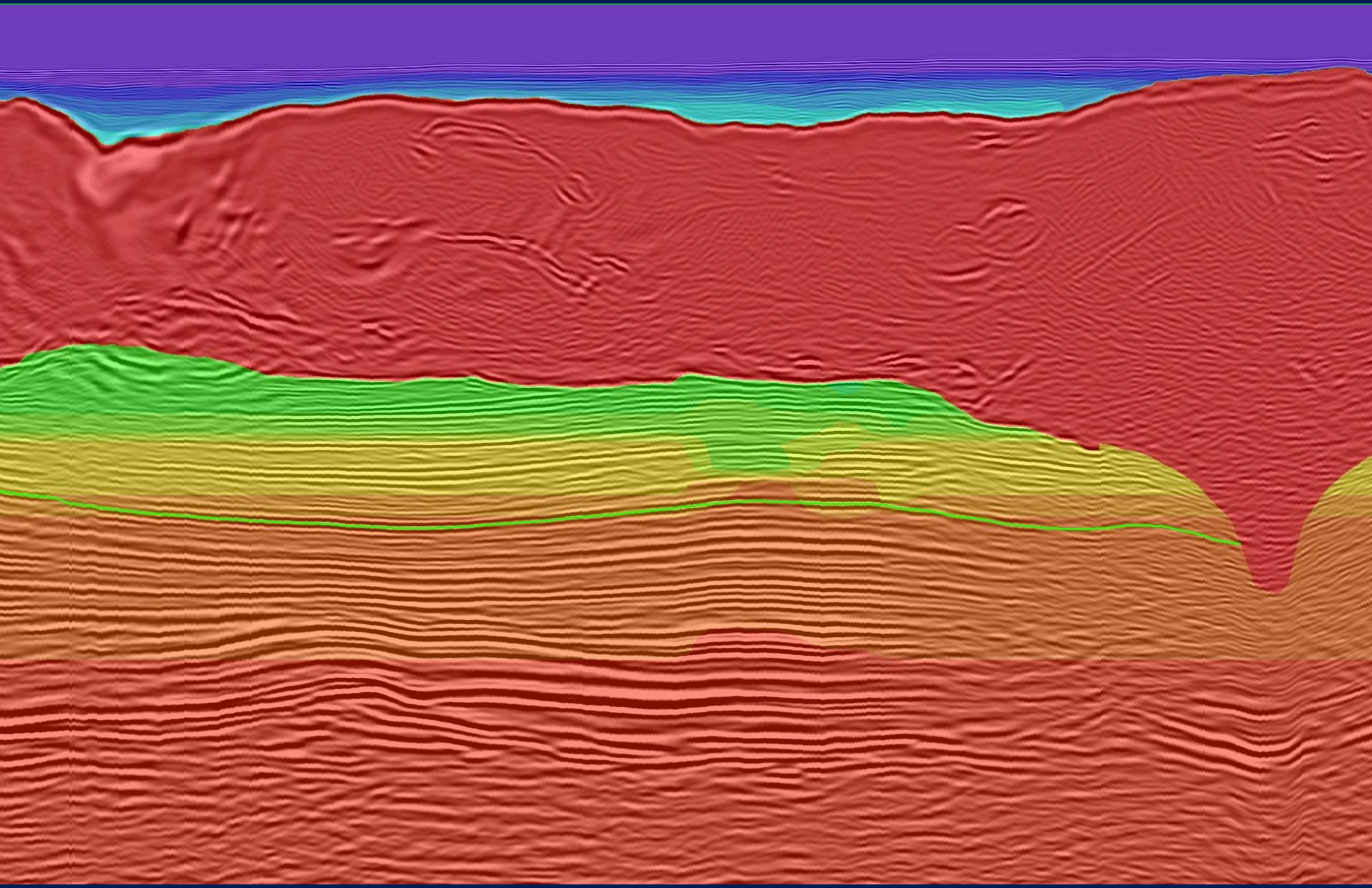




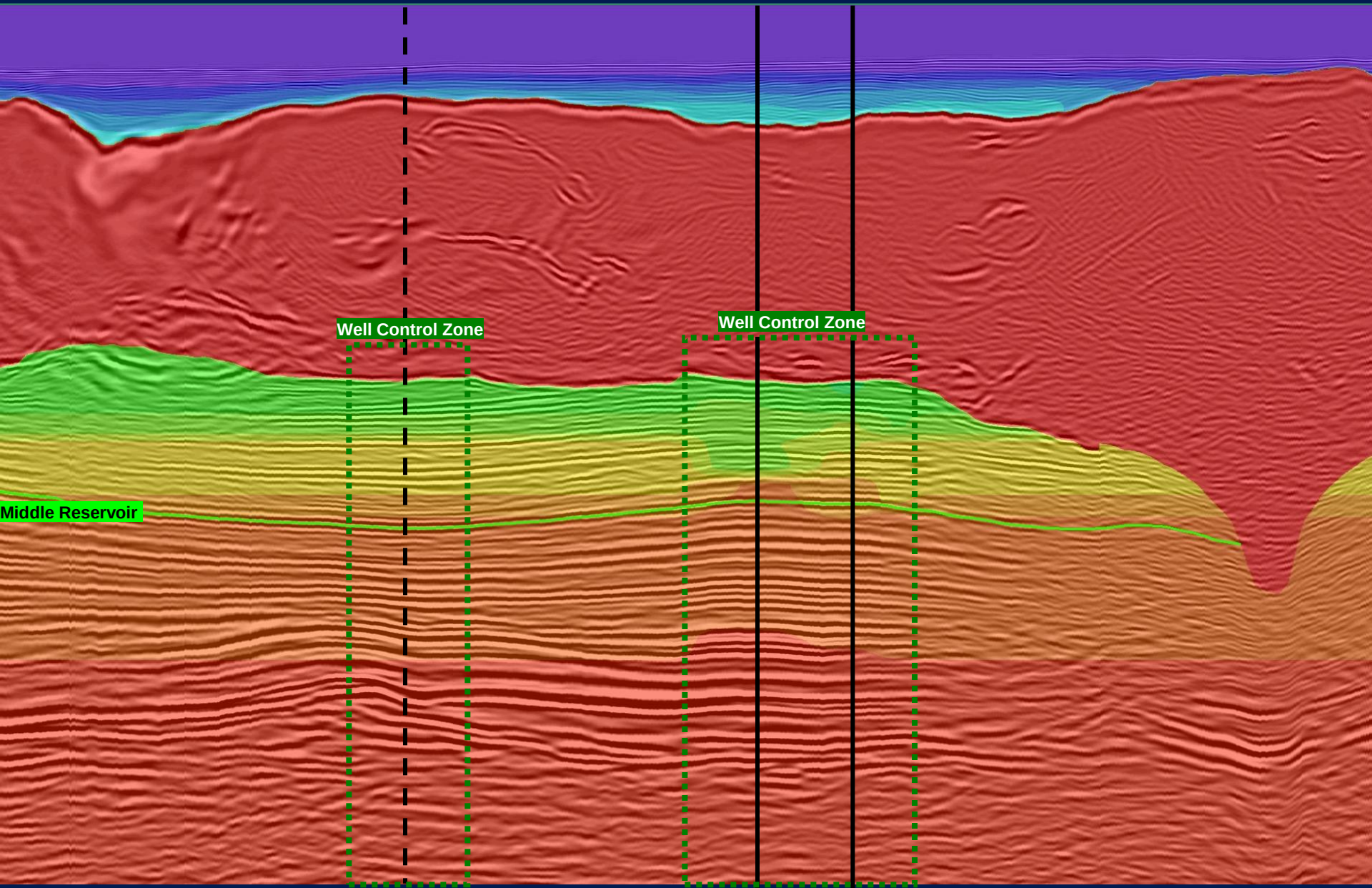
Average Velocity vs. Depth: Sonics and Synthetics



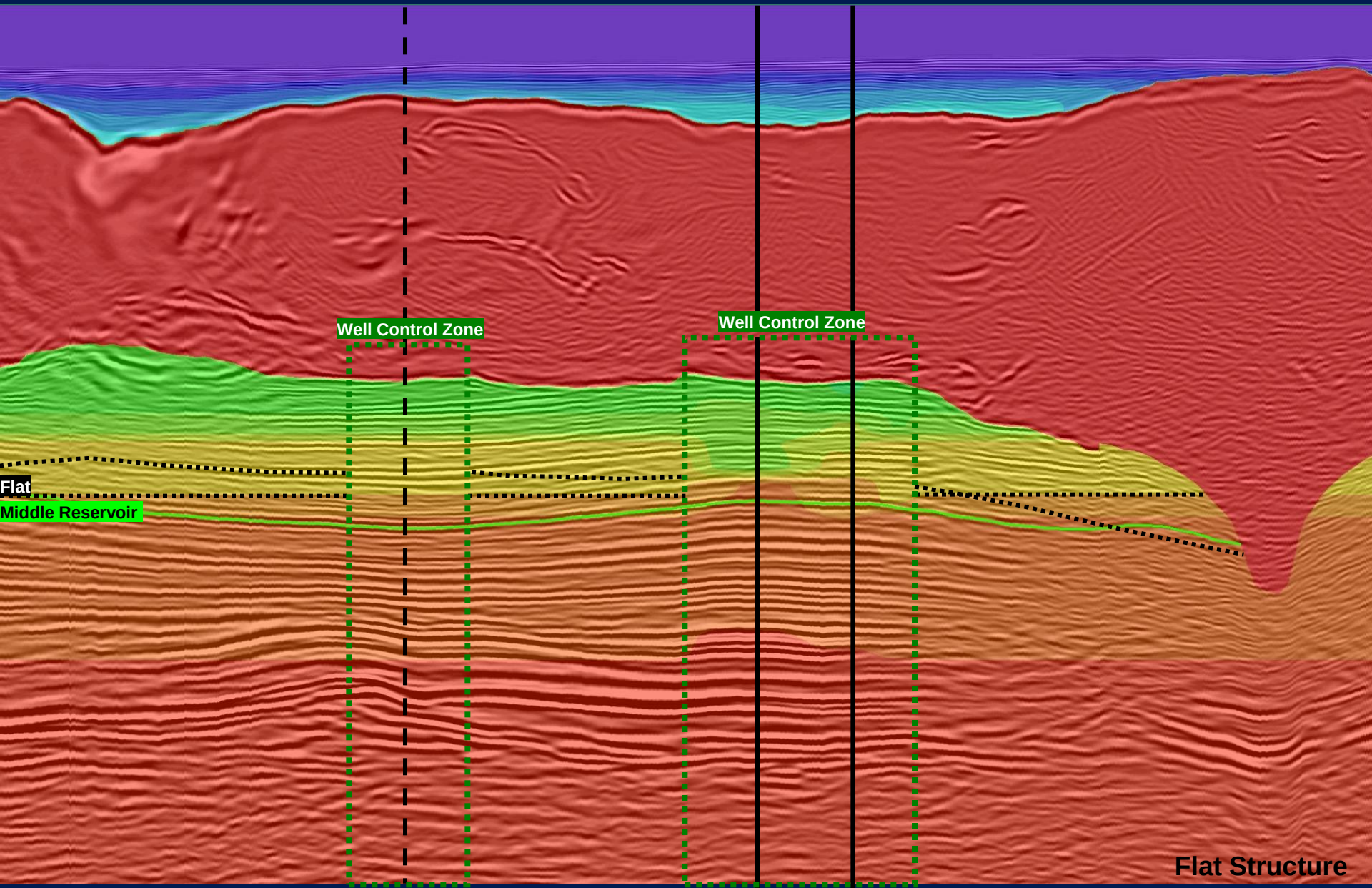
Methods to Extrapolate Velocities Away from Well Control



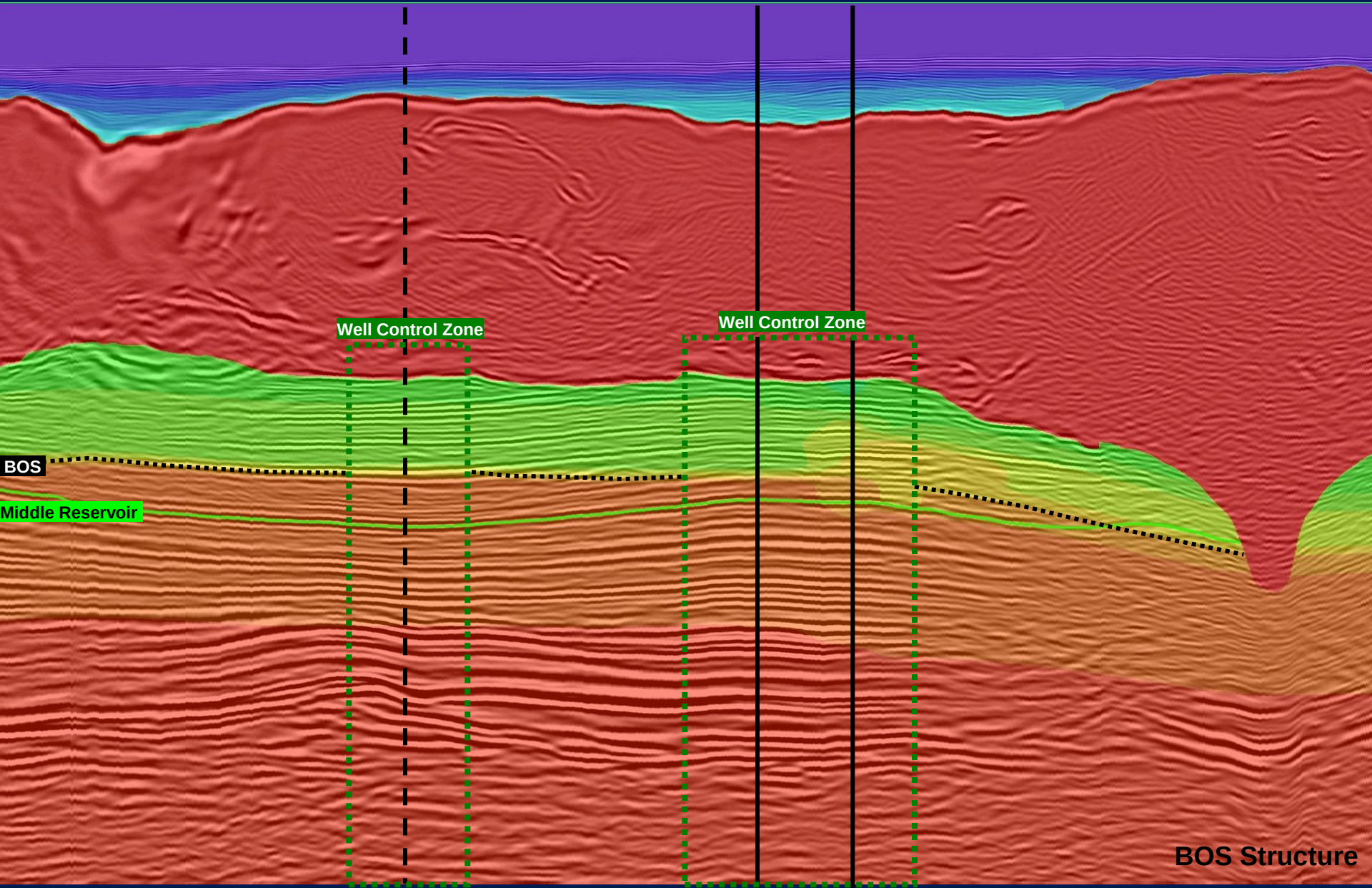
Methods to Extrapolate Velocities Away from Well Control



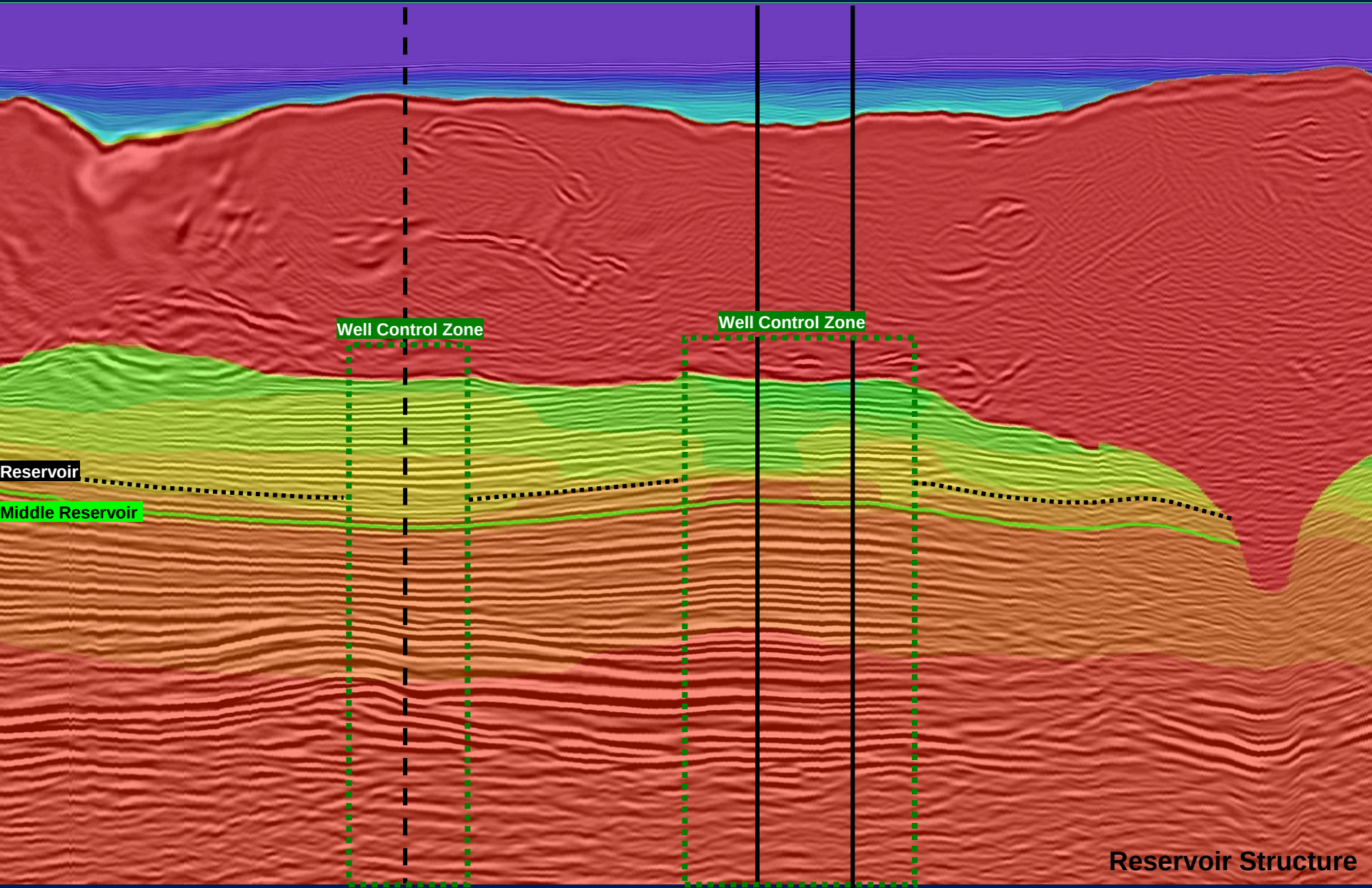
Methods to Extrapolate Velocities Away from Well Control



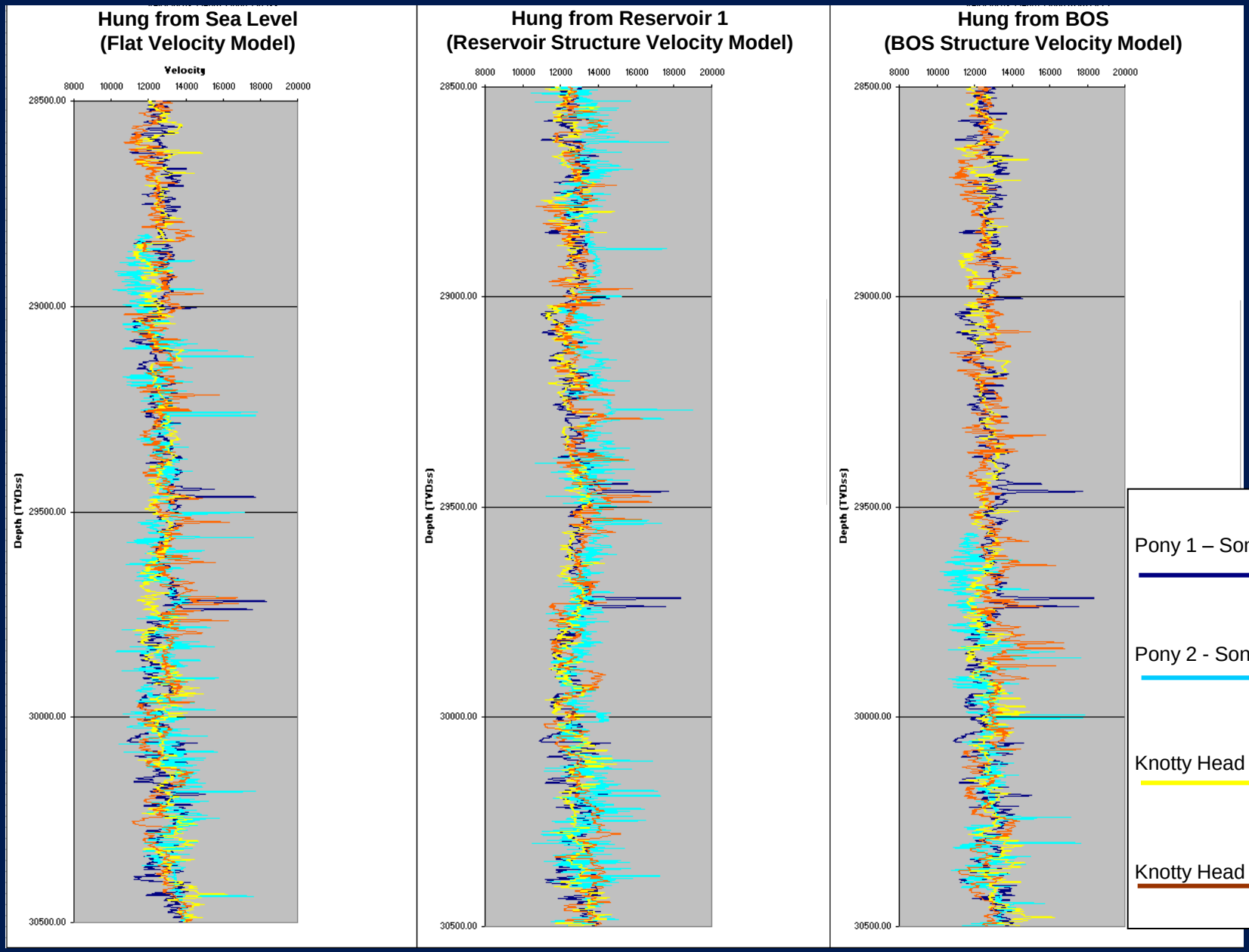
Methods to Extrapolate Velocities Away from Well Control



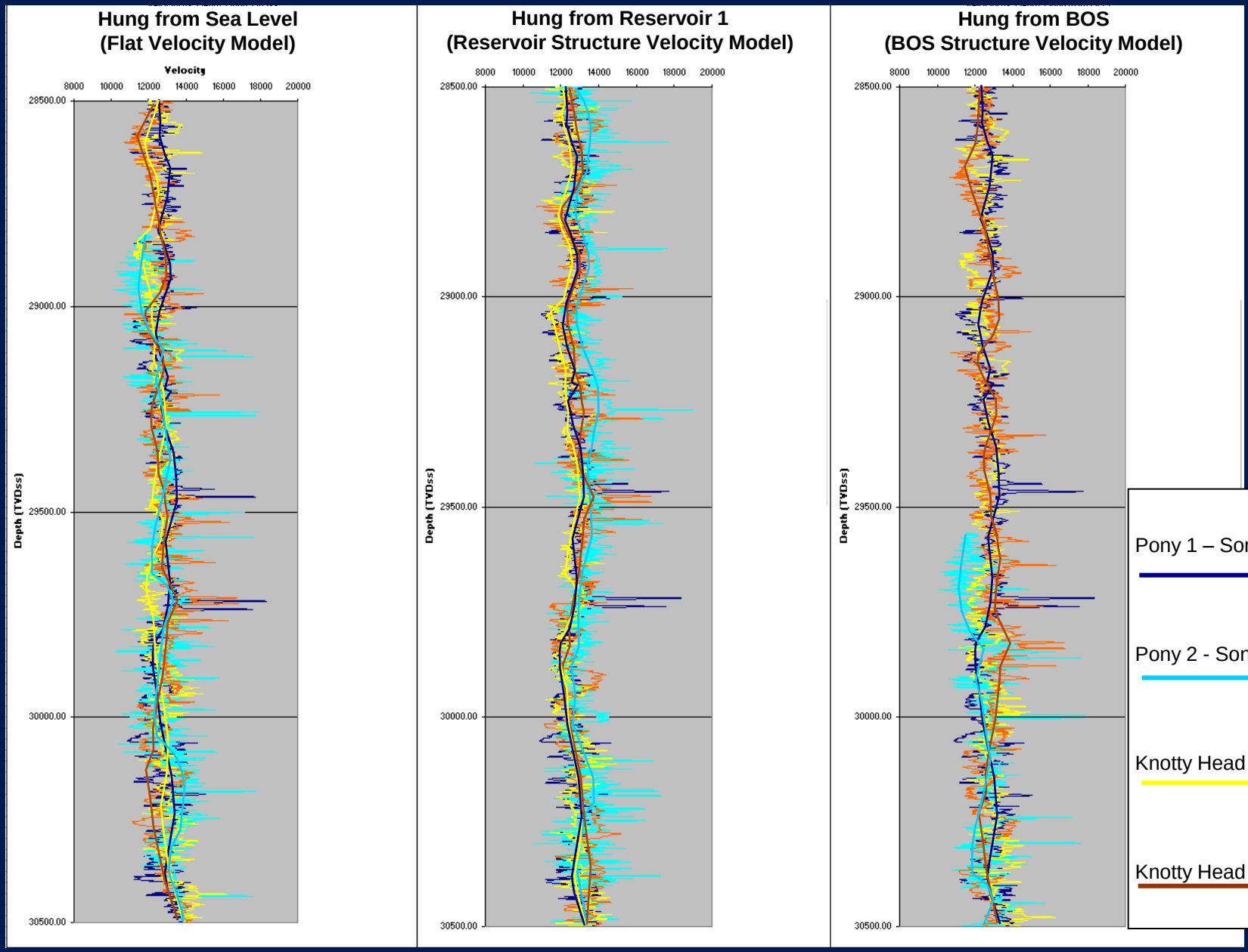
Methods to Extrapolate Velocities Away from Well Control



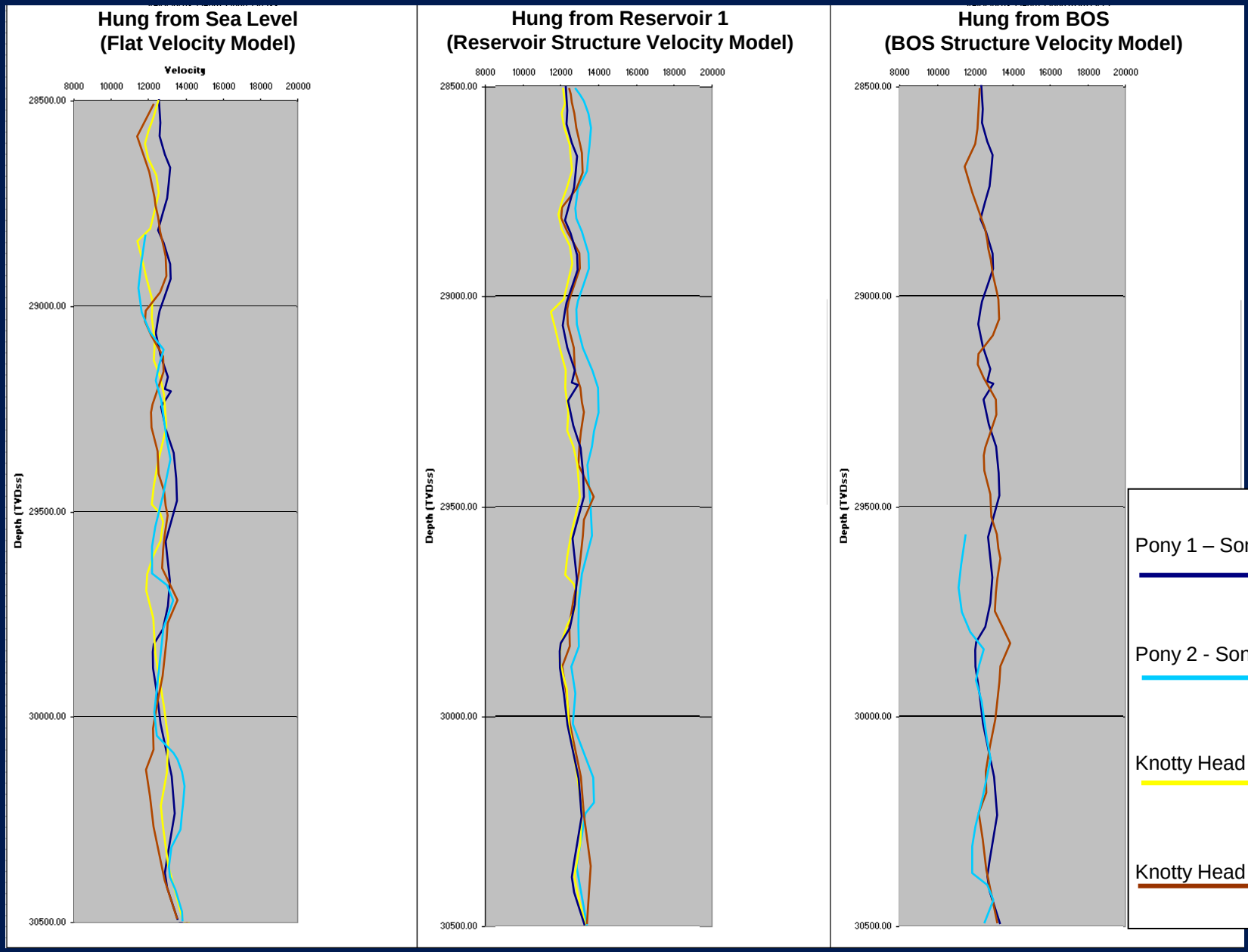
Sonic Velocity Trends by Well



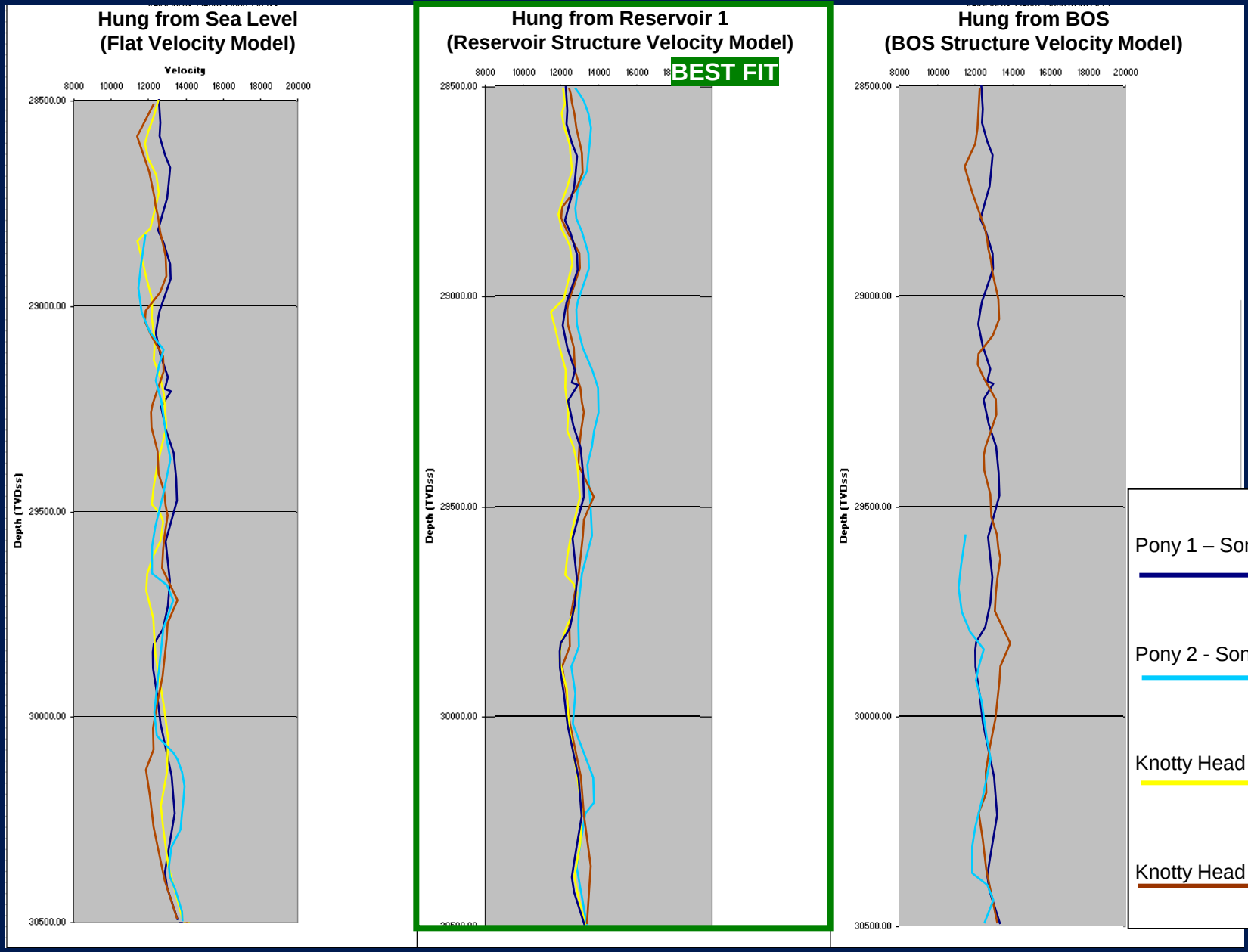
Sonic Velocity Trends by Well



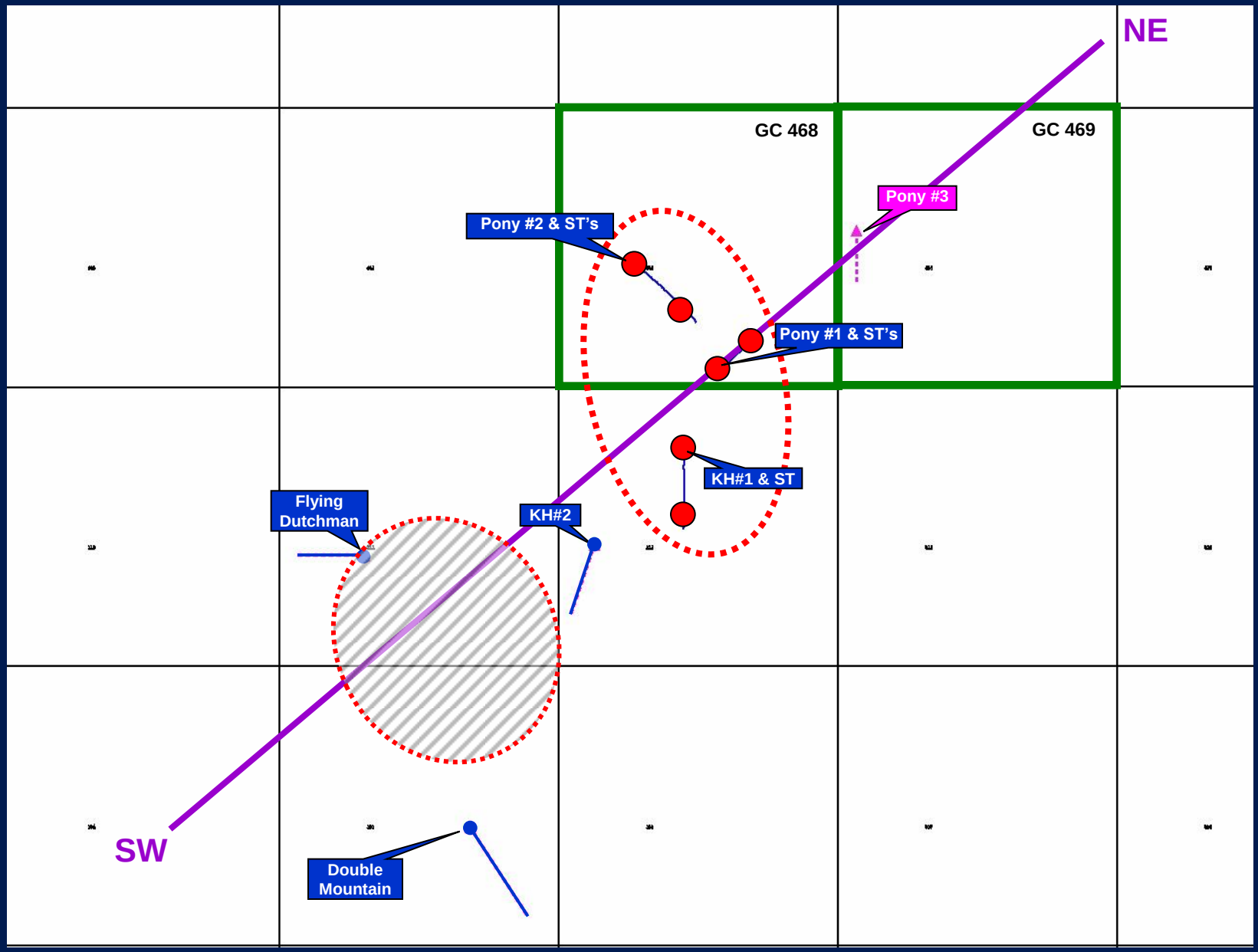
Sonic Velocity Trends by Well



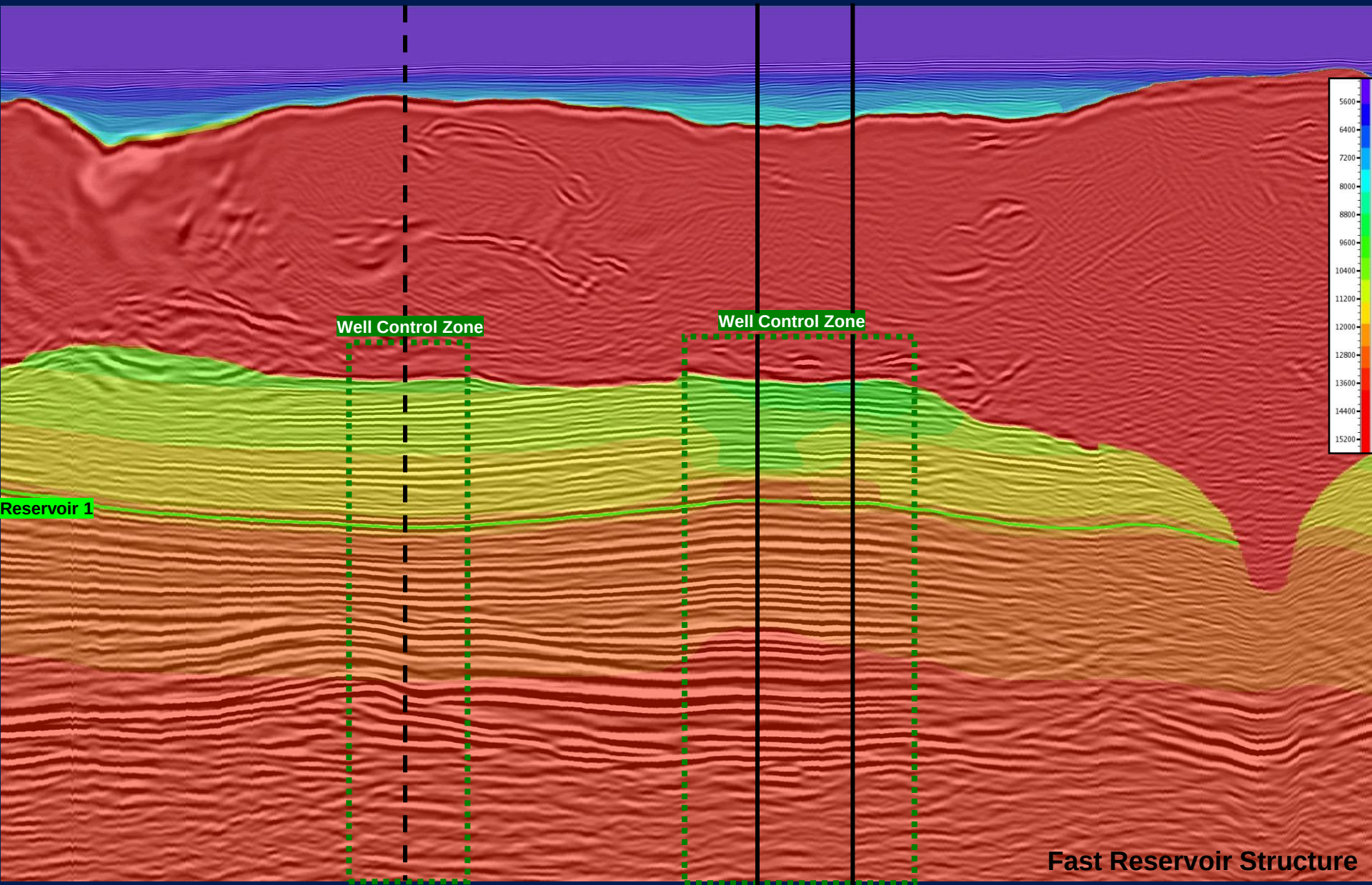
Sonic Velocity Trends by Well



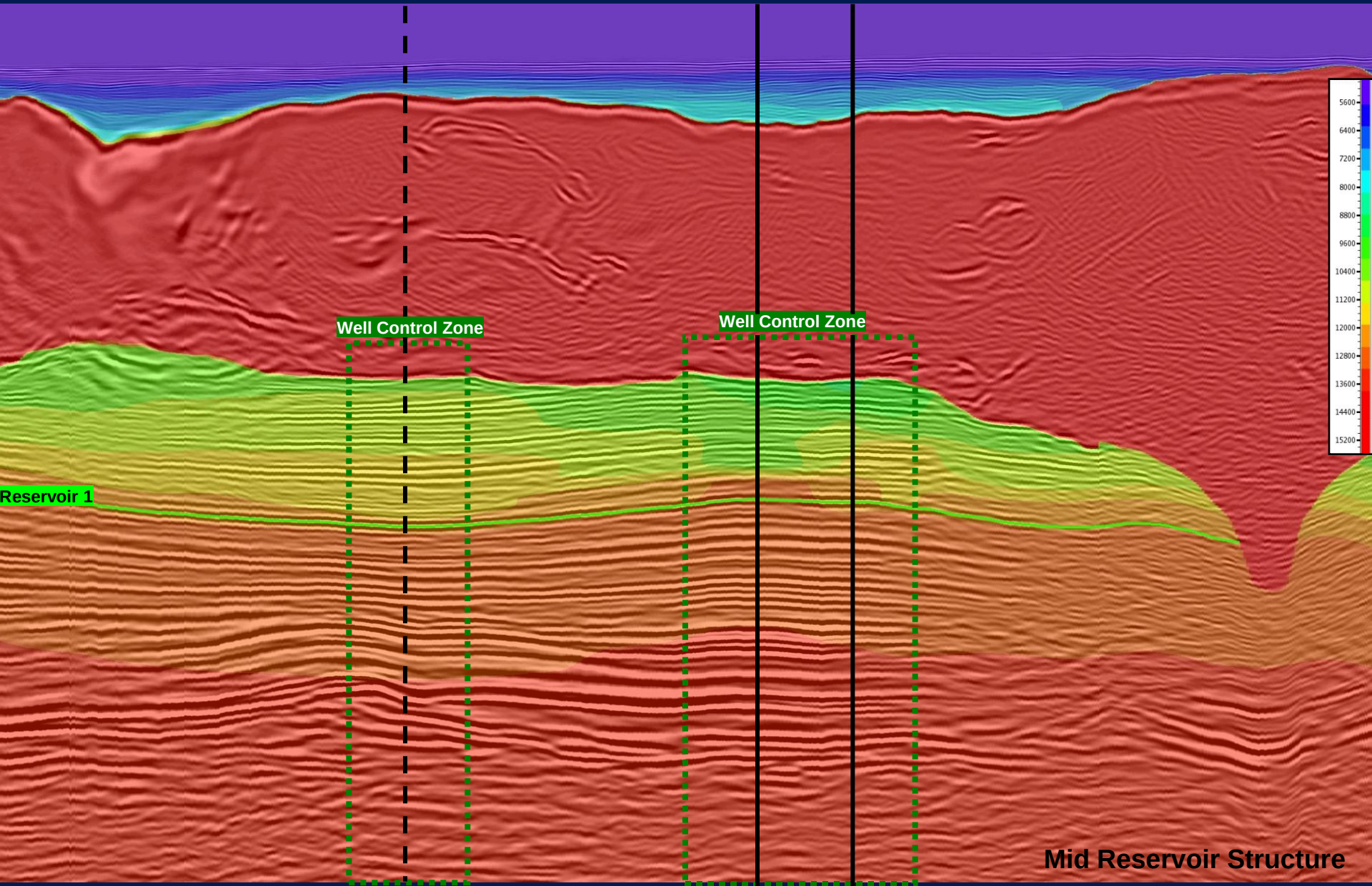
Basemap with Well Locations



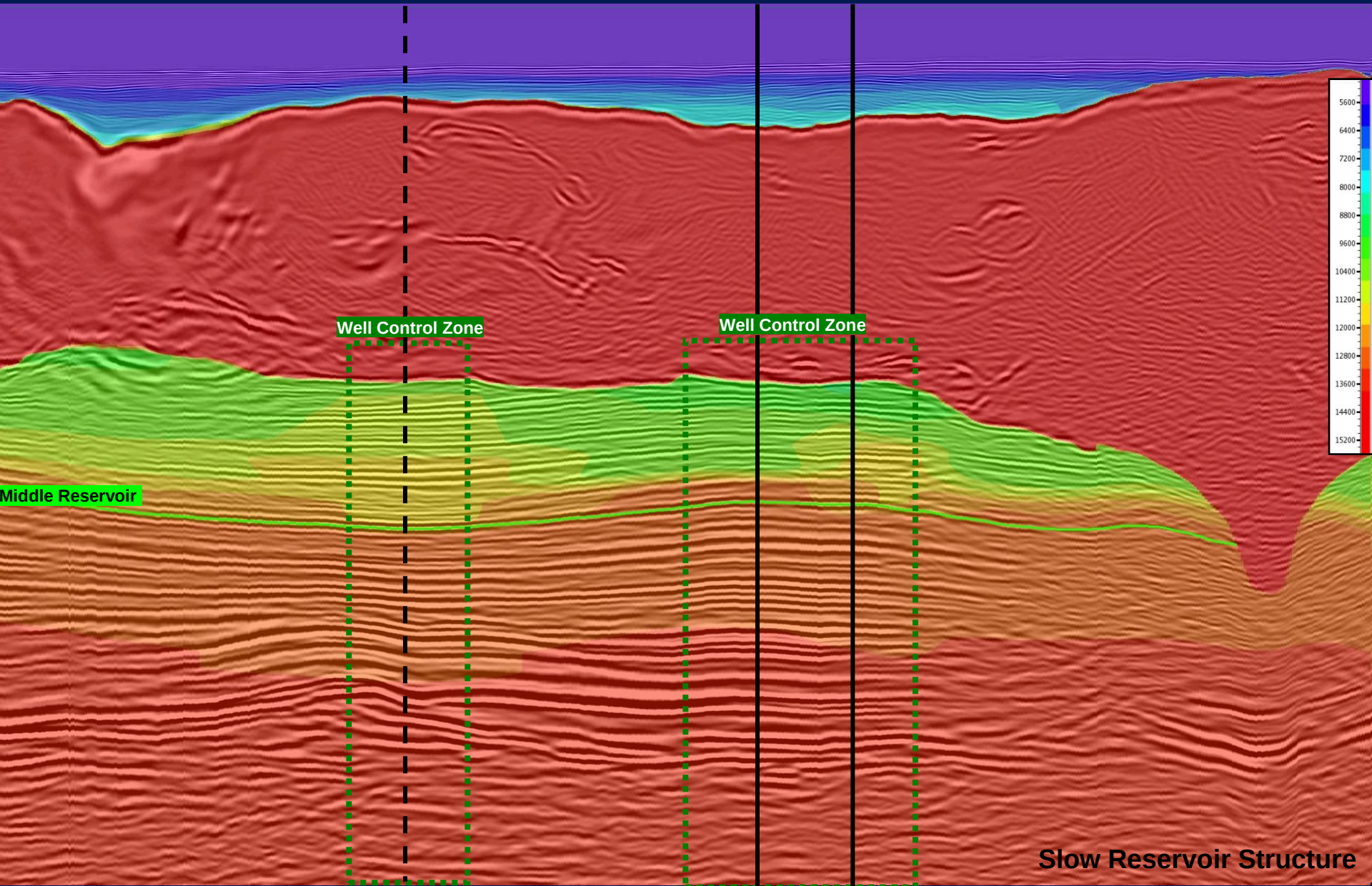
Extrapolating Velocities Away from Well Control



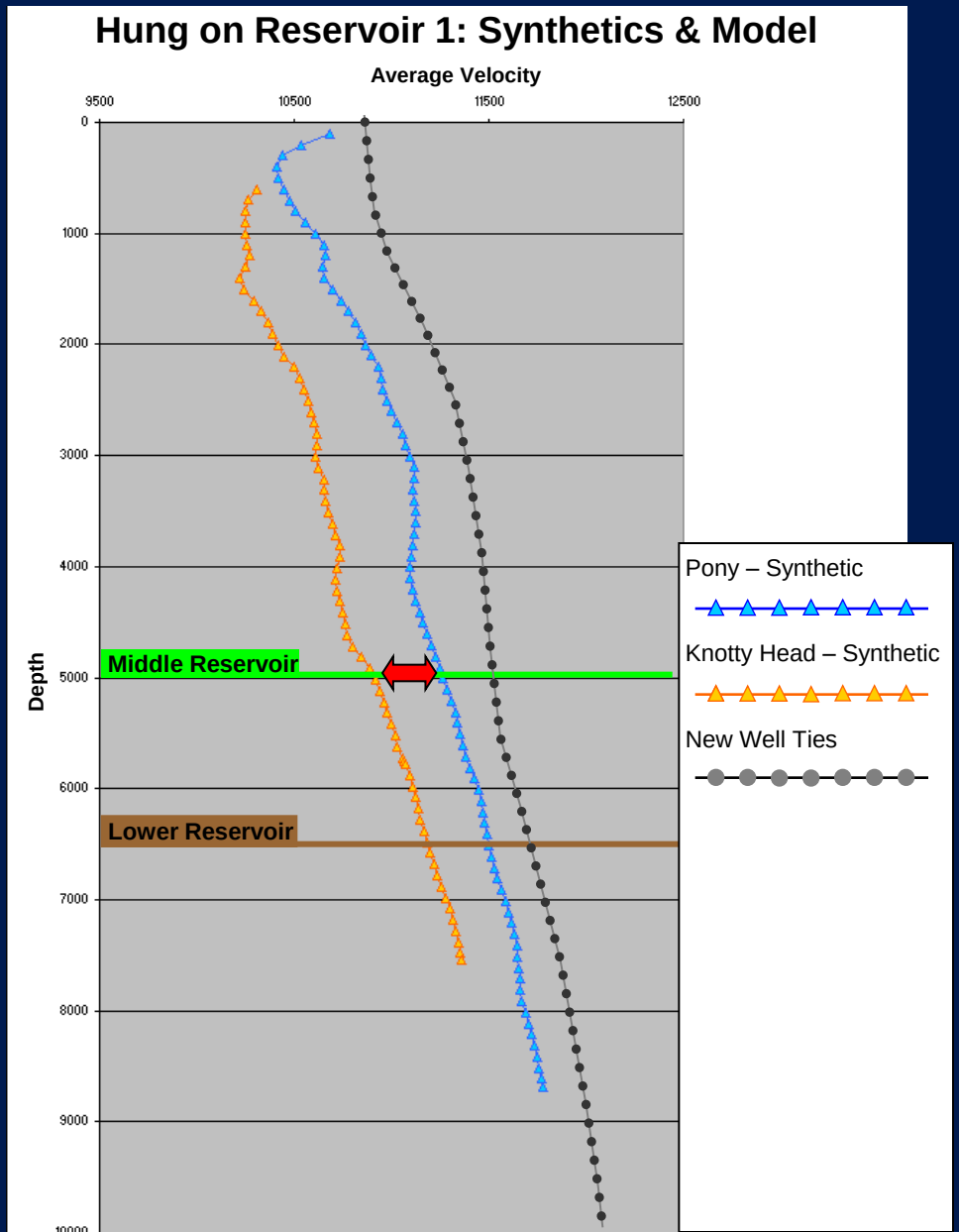
Extrapolating Velocities Away from Well Control

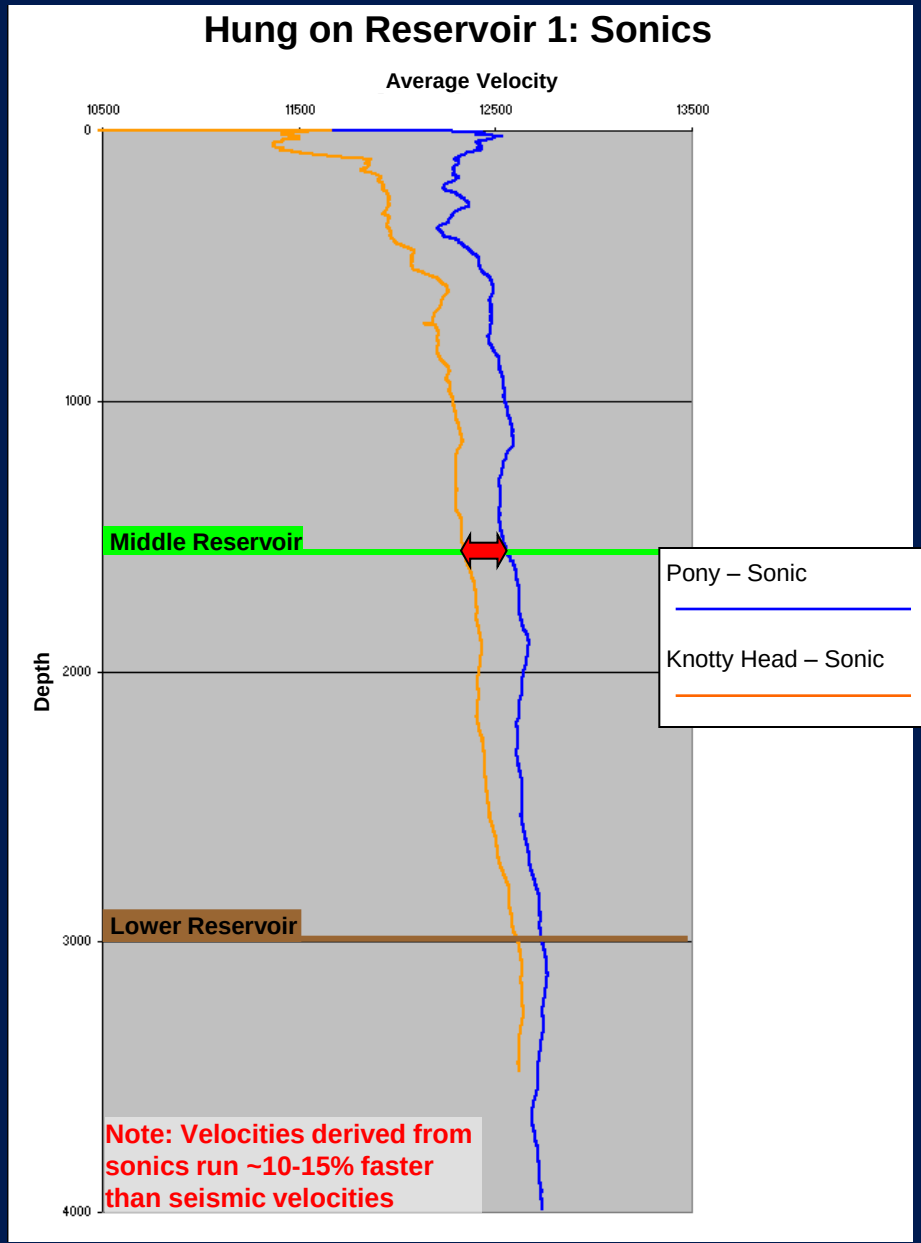


Extrapolating Velocities Away from Well Control

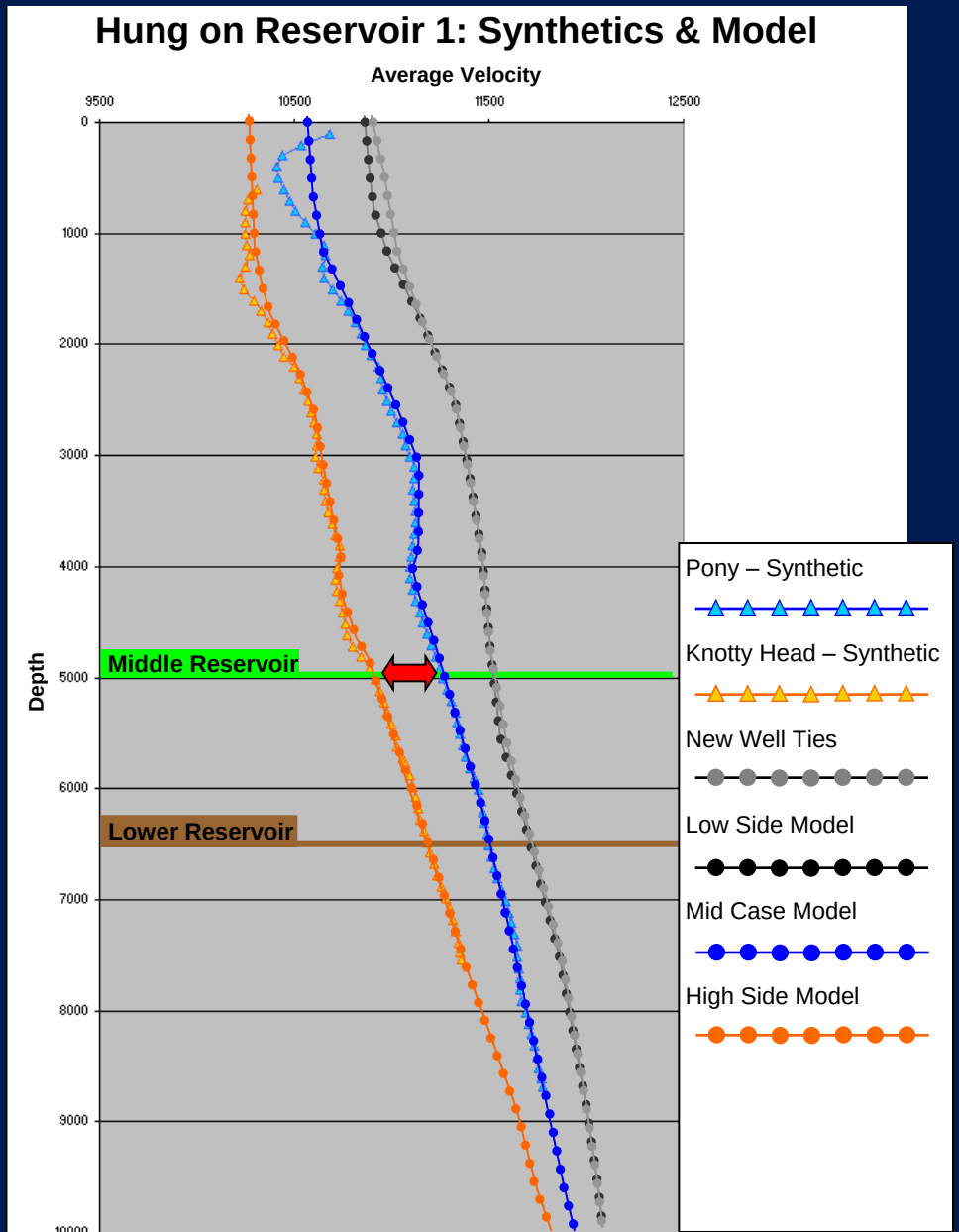


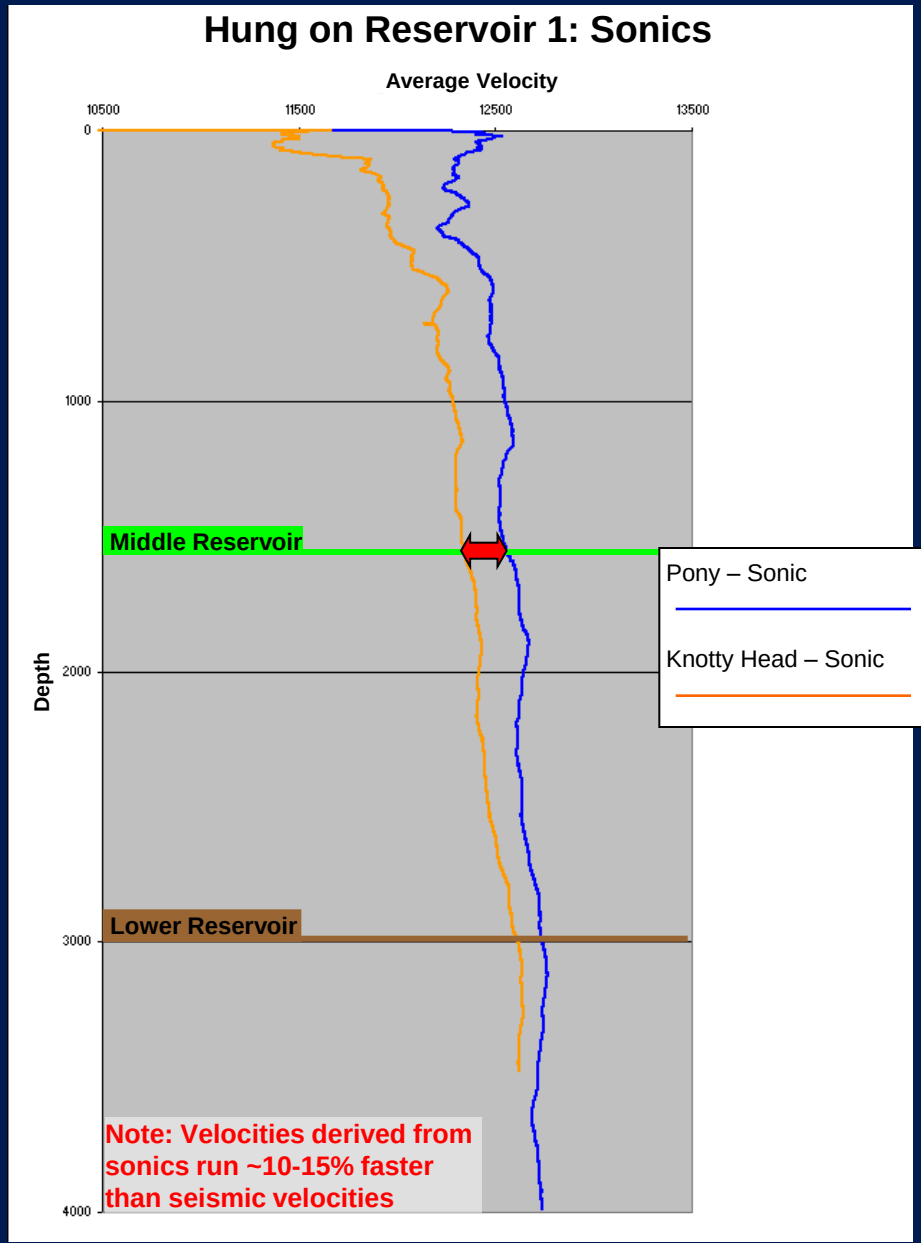
Average Velocity vs. Depth: Log and Velocity Model Comparison





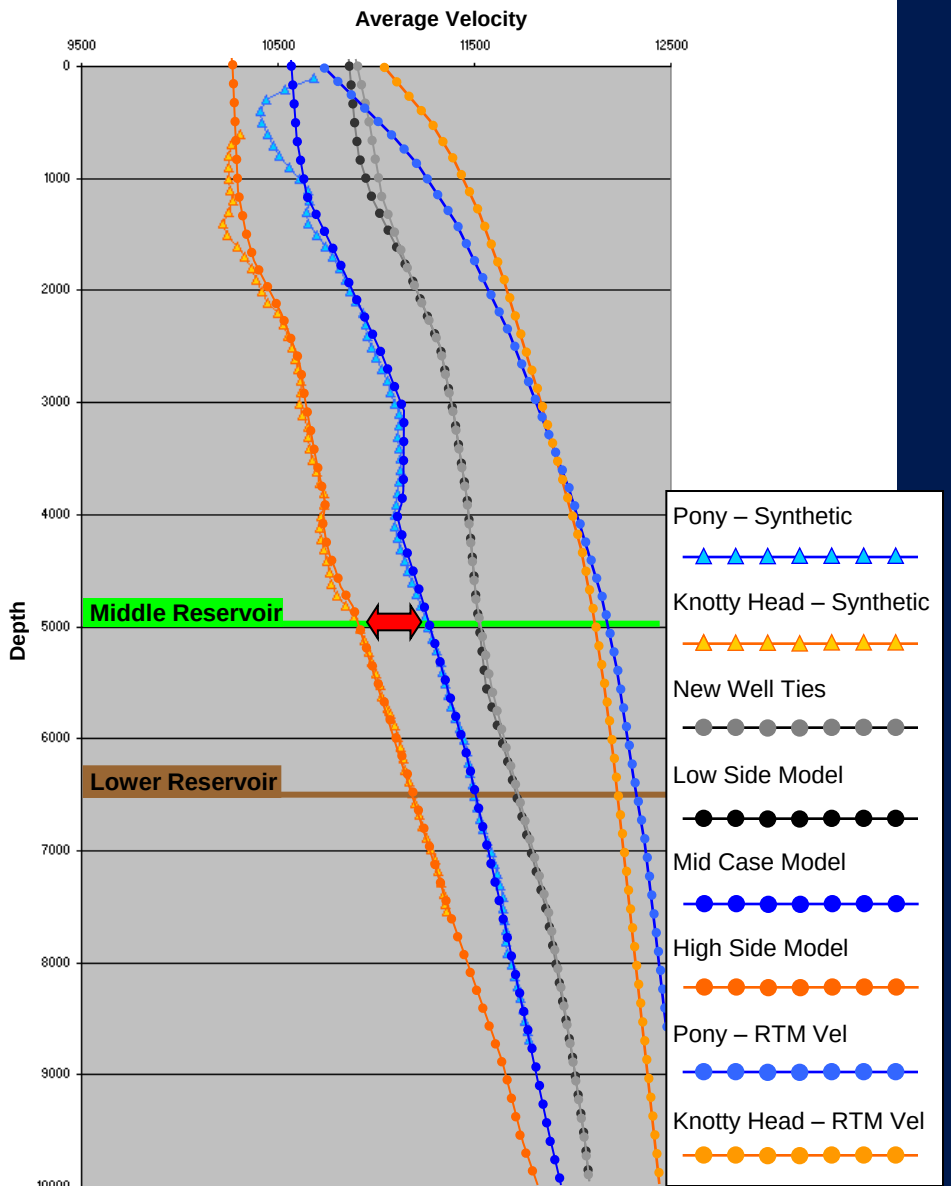
Average Velocity vs. Depth: Log and Velocity Model Comparison



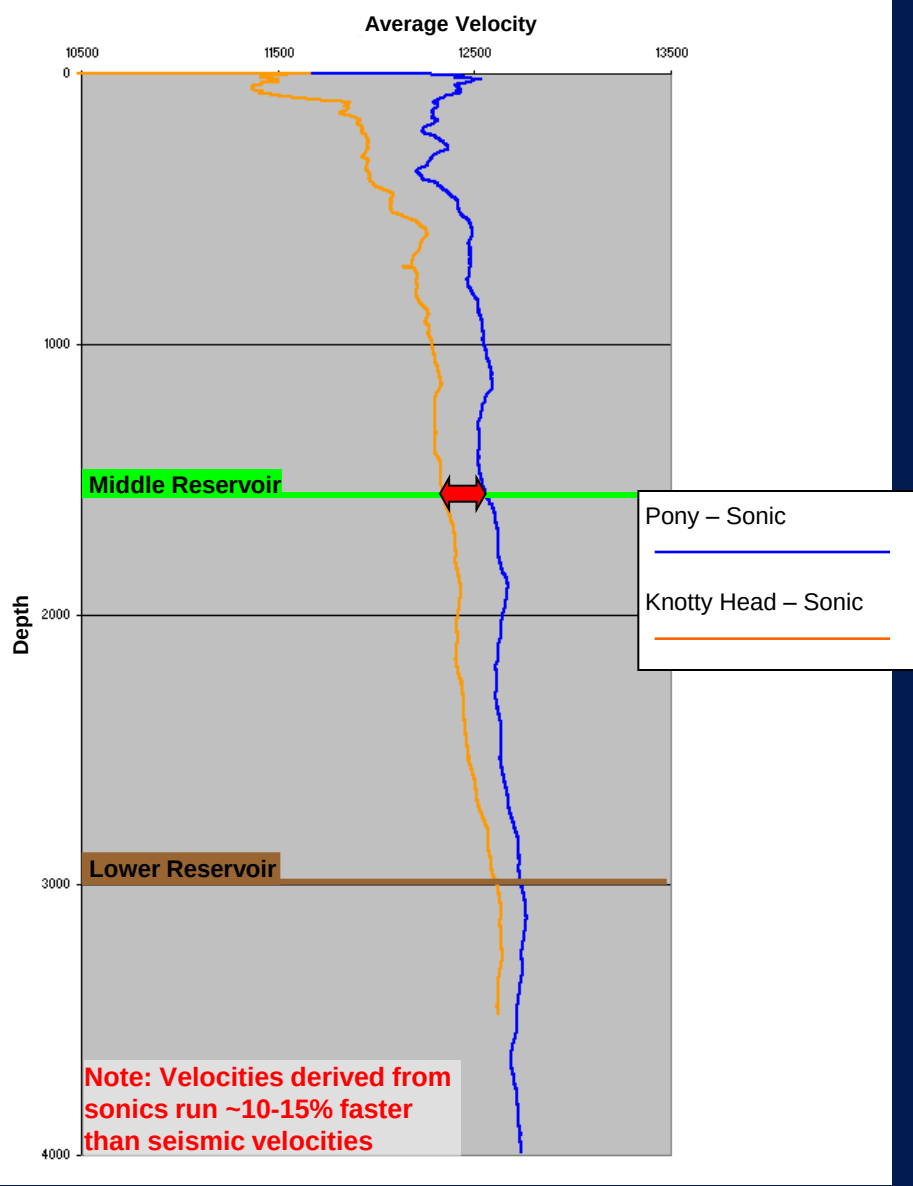


Average Velocity vs. Depth: Log and Velocity Model Comparison

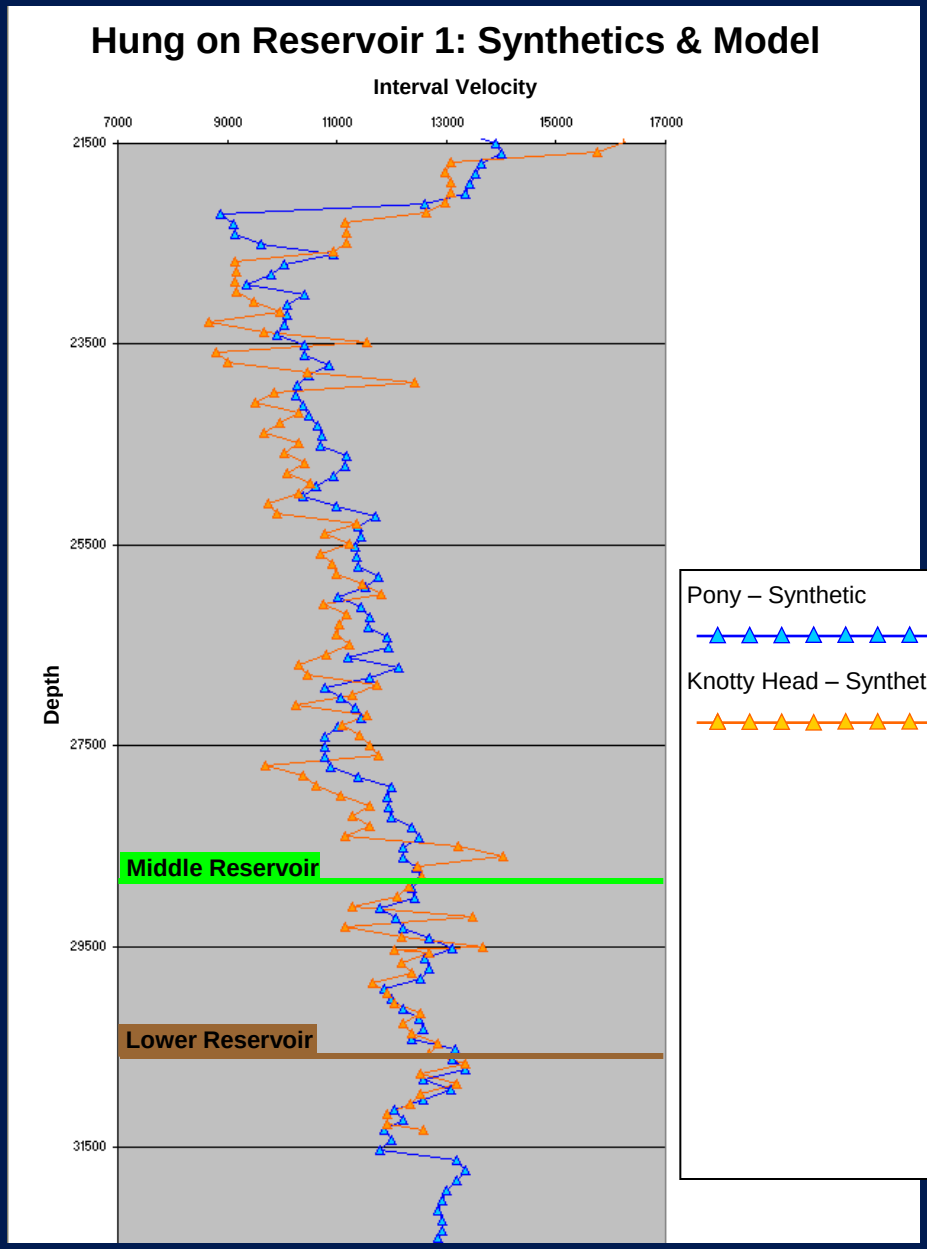
Hung on Reservoir 1: Synthetics & Model

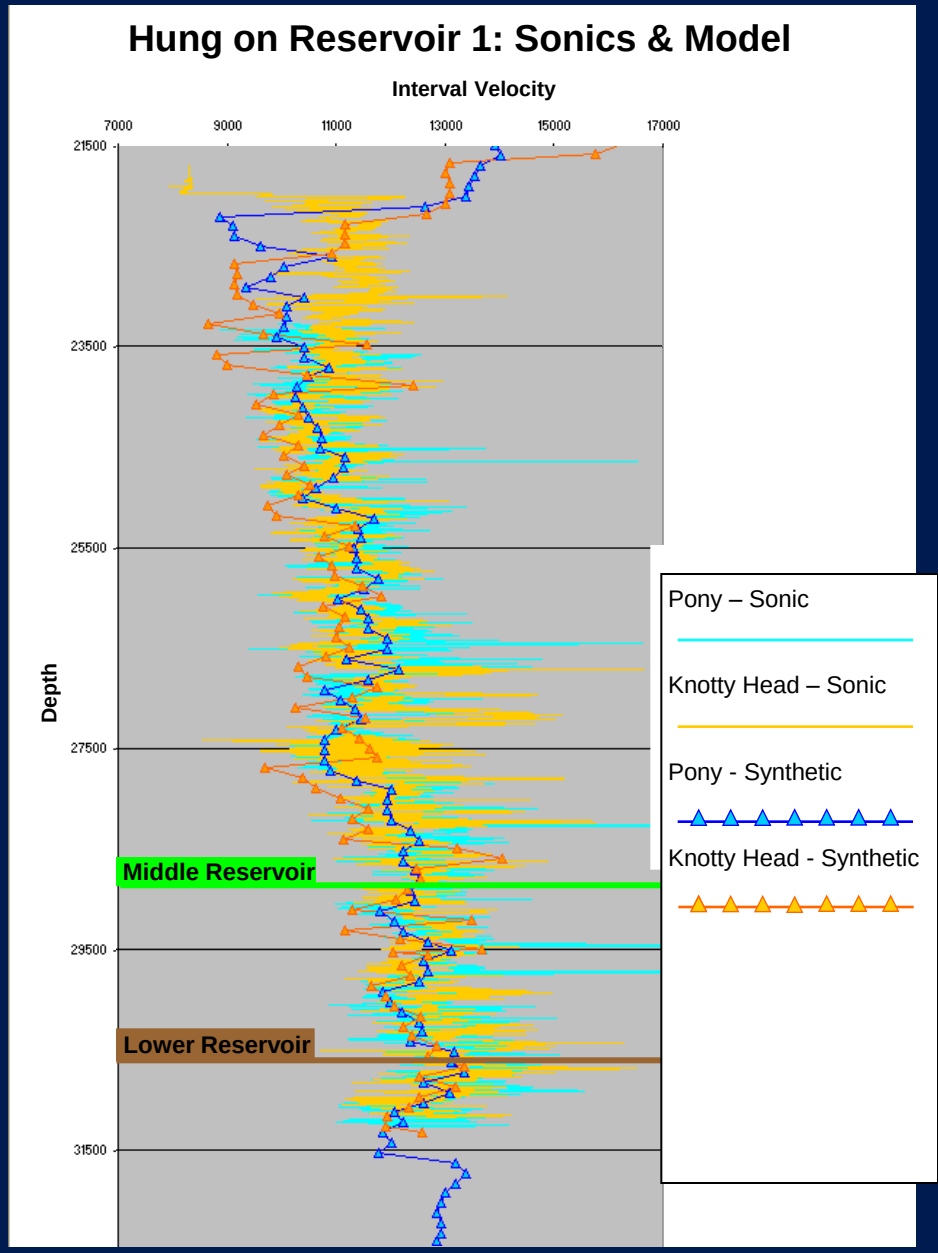


Hung on Reservoir 1: Sonics

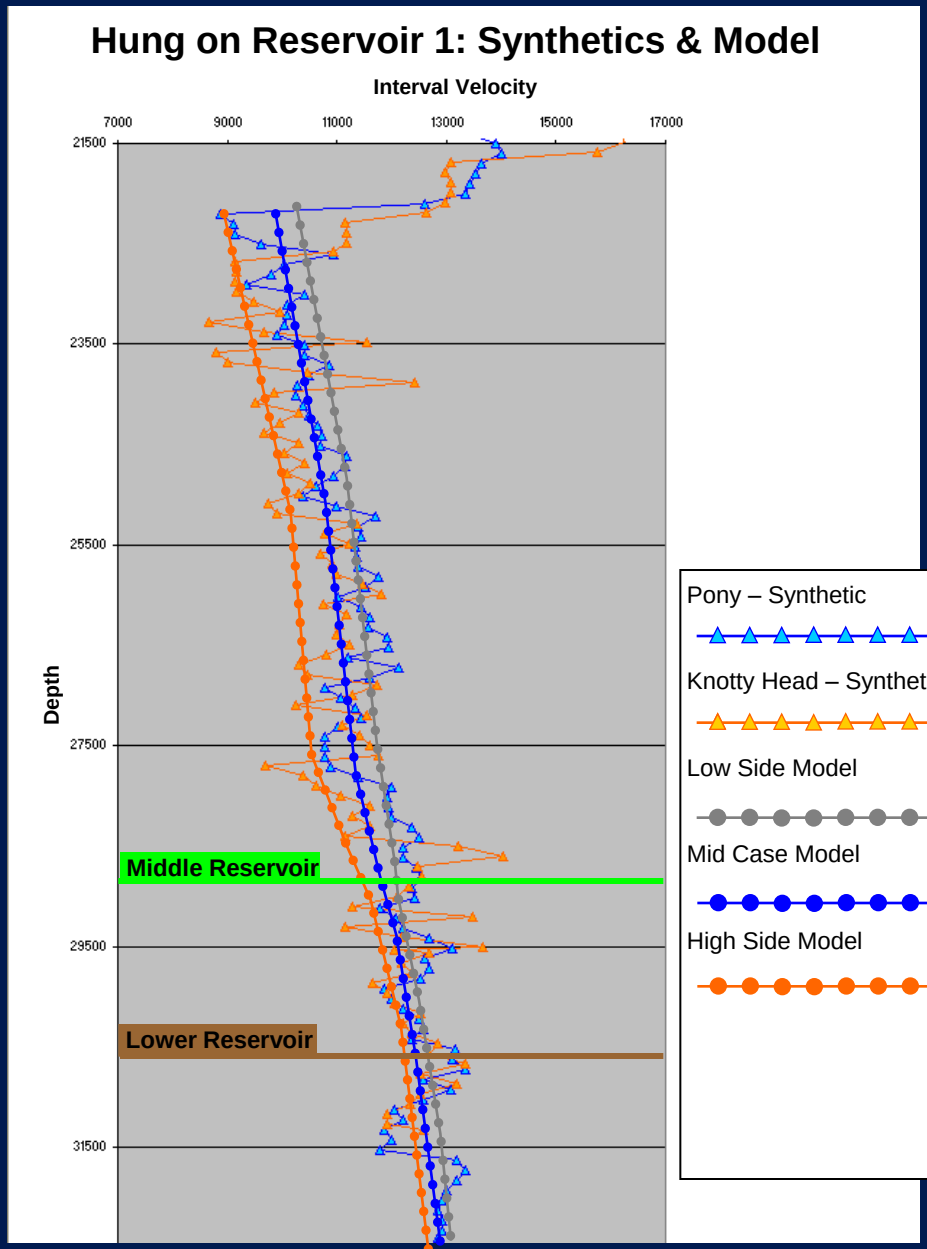


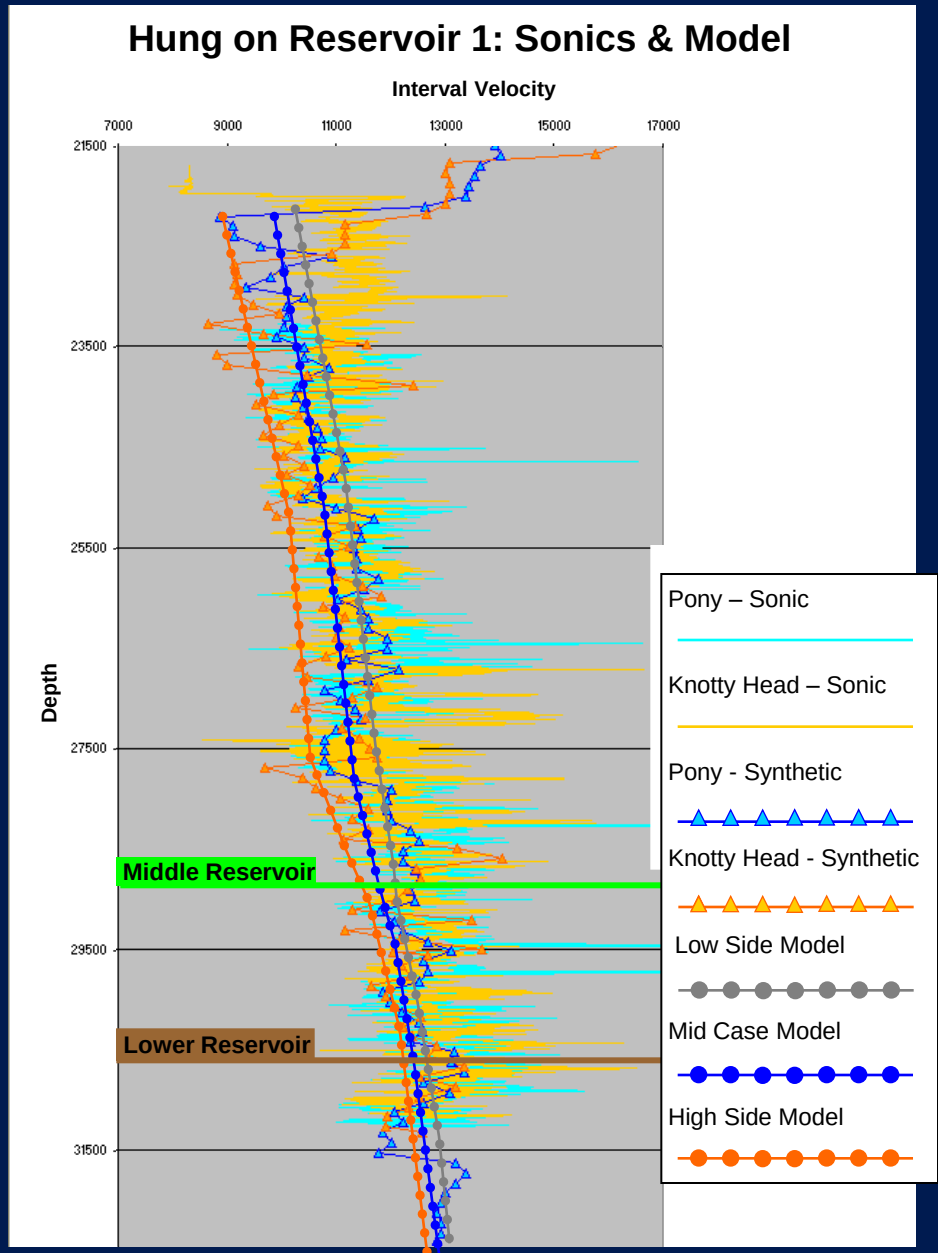
Interval Velocity vs. Depth: Log and Velocity Model Comparison



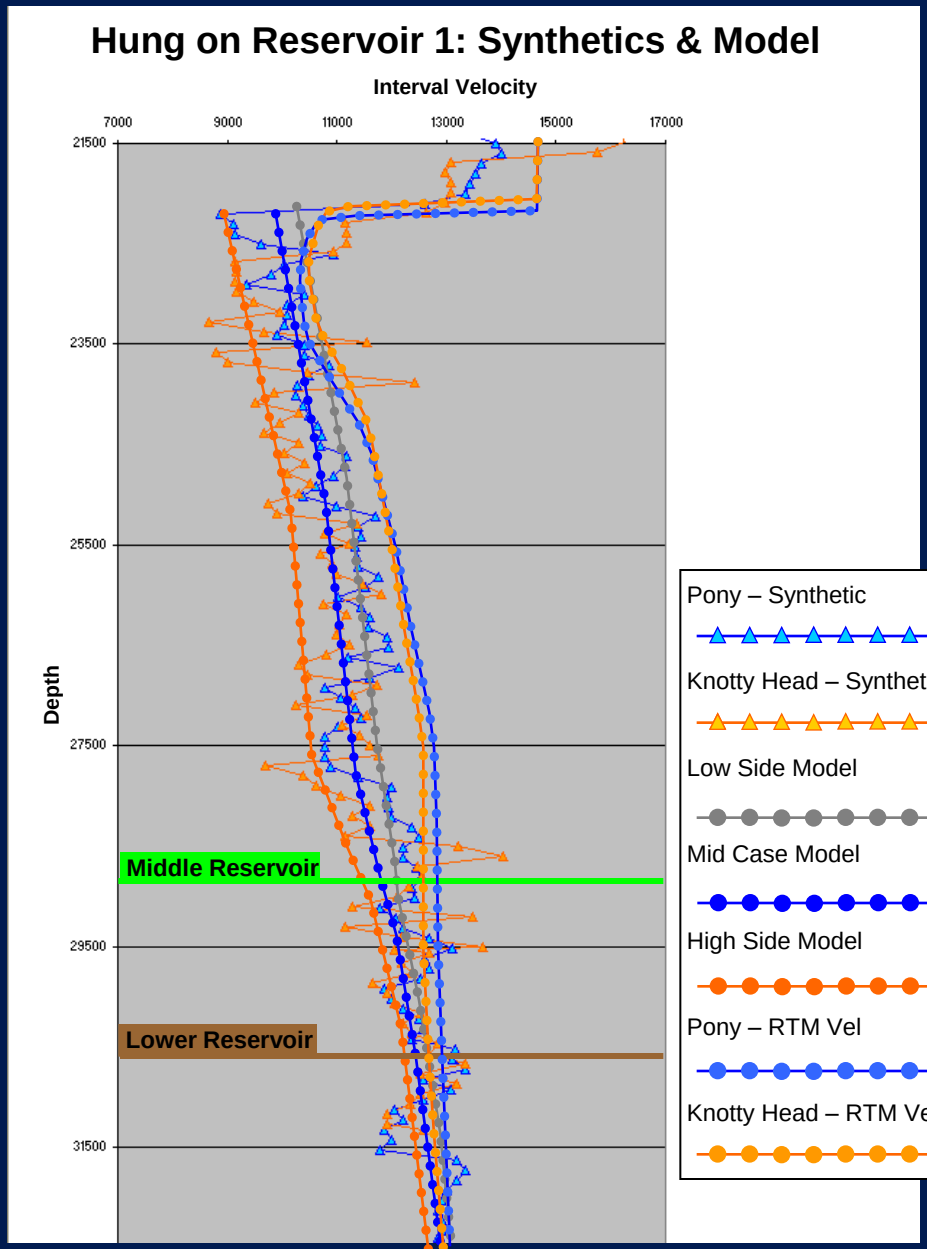


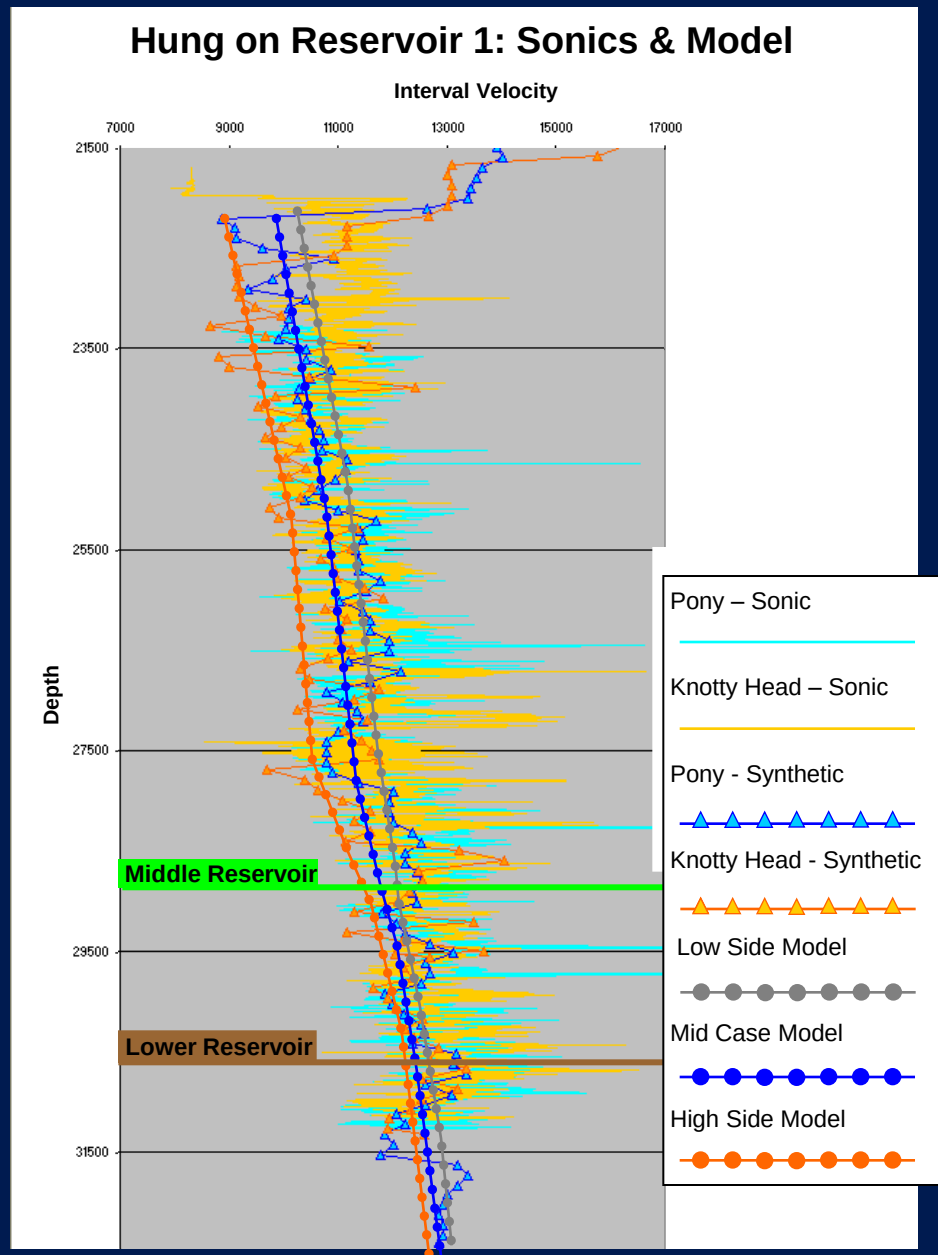
Interval Velocity vs. Depth: Log and Velocity Model Comparison



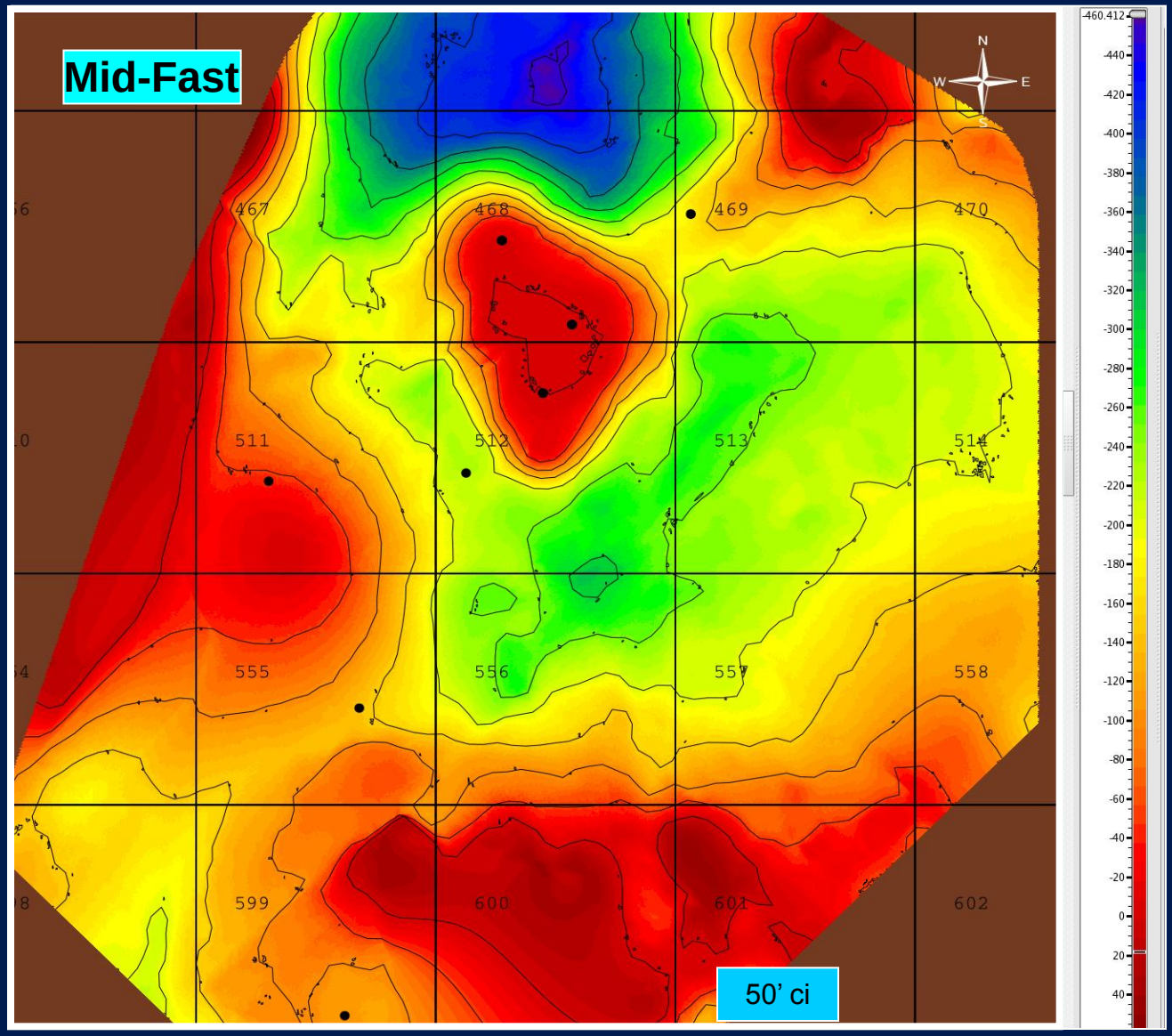


Interval Velocity vs. Depth: Log and Velocity Model Comparison

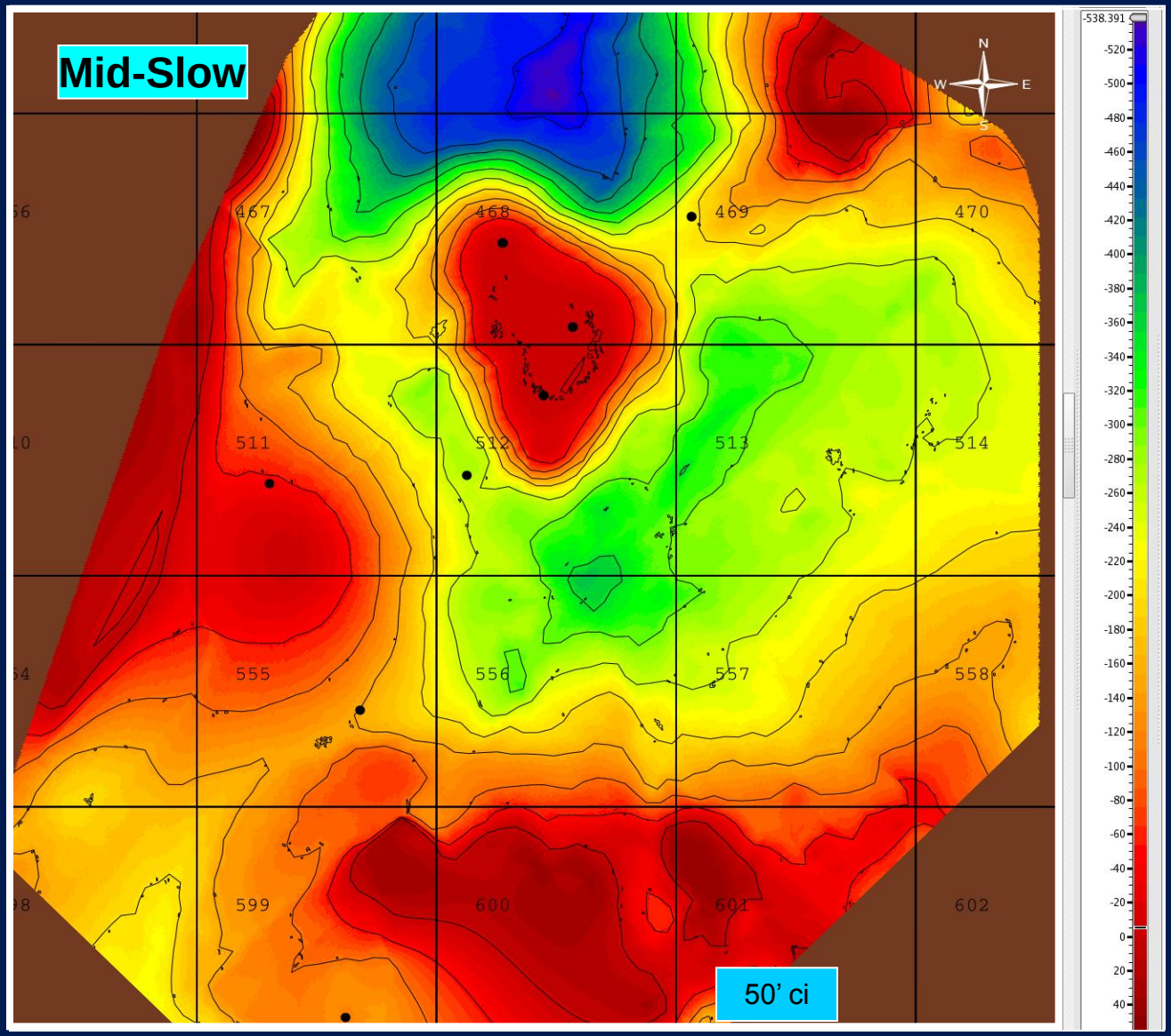




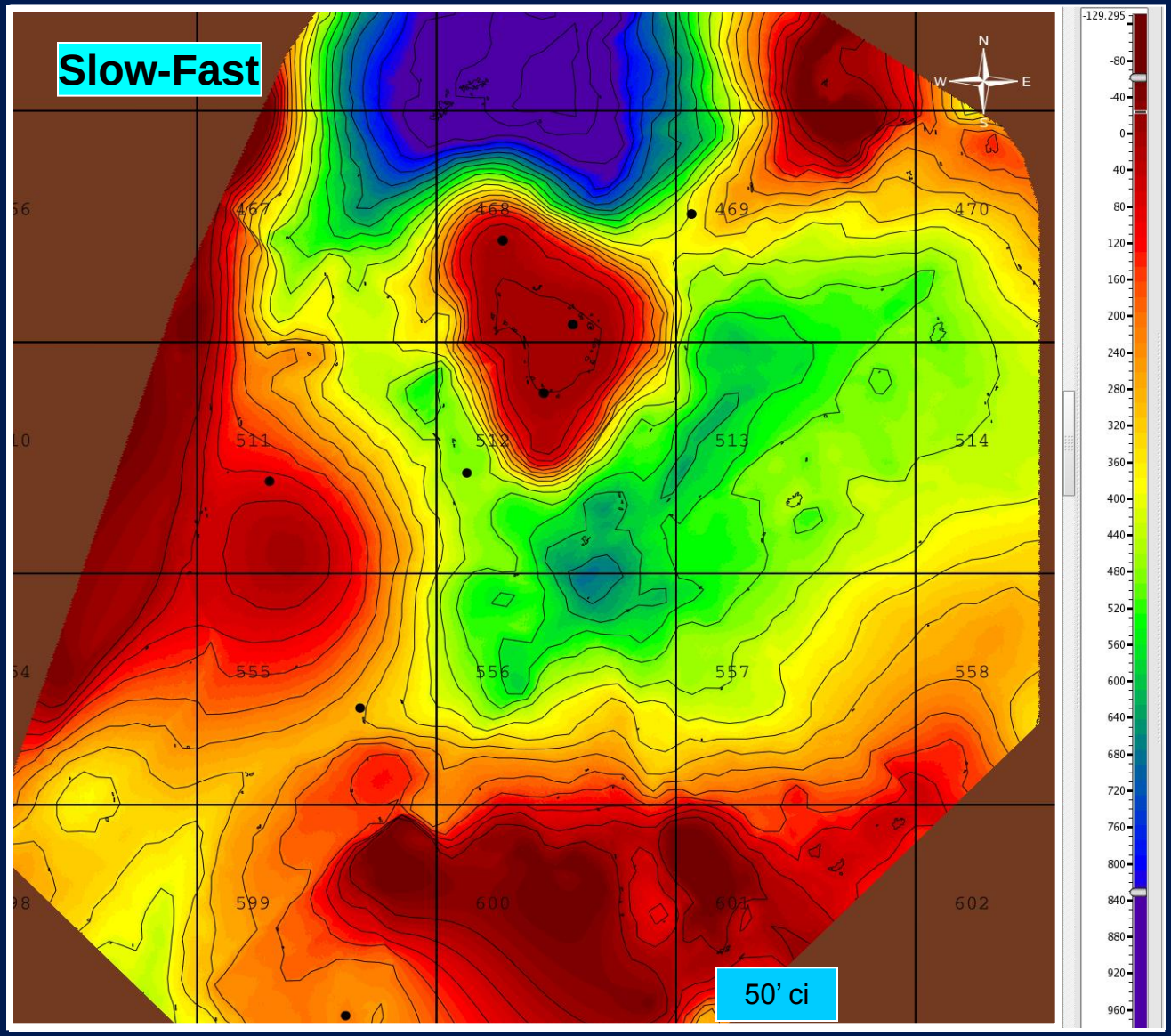
Differences between Velocity Models



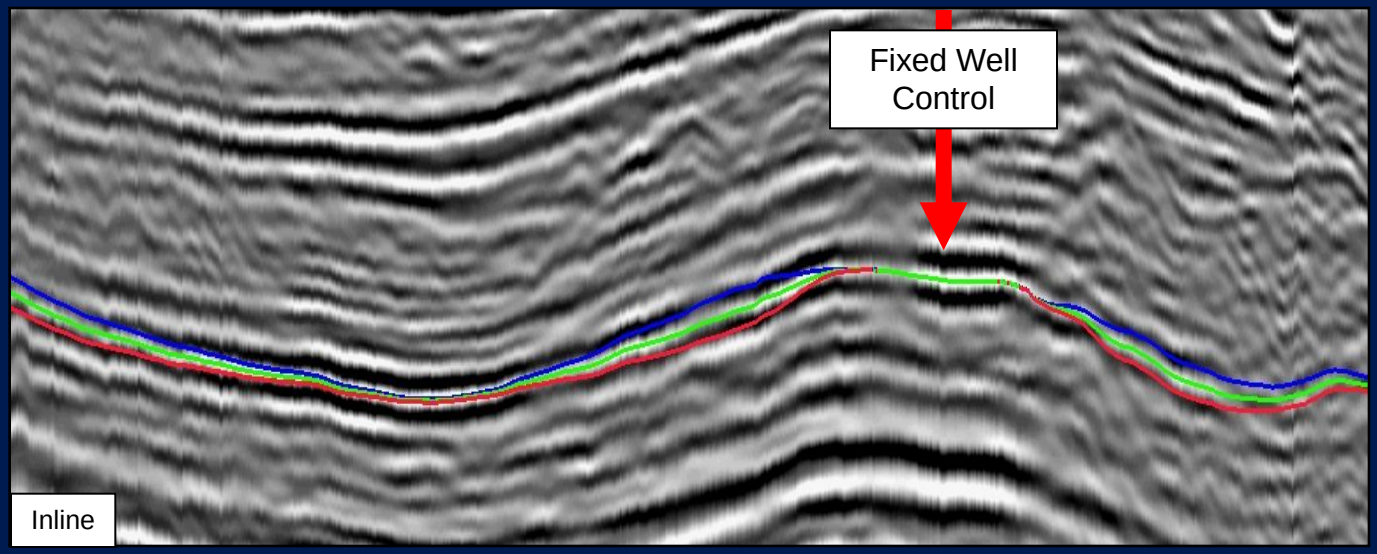
Differences between Velocity Models



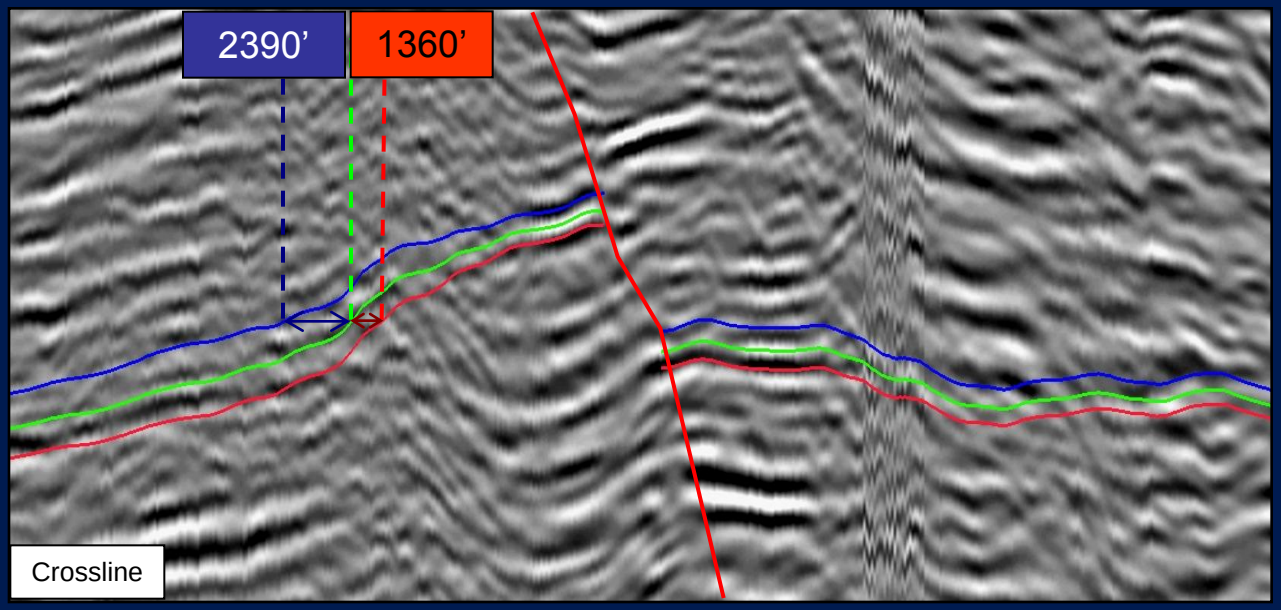
Differences between Velocity Models

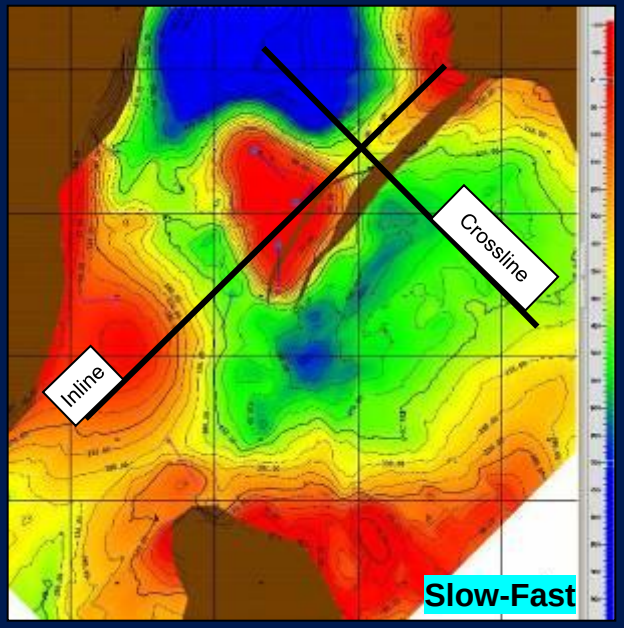


High-Mid-Low Isotropic Models vs. Seismic



High Case Model
Mid Case Model
Low Case Model





Conclusions

- At Pony Field, significant velocity variations were measured (as large as 250' between wells) even when the wells show consistent reservoir and intervening shale intervals.
- Predictions of depth structure away from the well control produces depth ranges up to 500' near the flanks of the structure.
- We concluded that there were two primary variables that have to be accounted for when predicting sub-salt depth structure:
  - *1. Predicting the range of velocity uncertainty. (Obviously, the more well control the better the prediction)*
  - *2. How to extrapolate velocities away from known well control. (e.g. flat velocities or following a specific structural pattern such as reservoir or base of salt structure).*
- The updated velocity models using the method described in this presentation can be used as input for advanced seismic reprocessing (e.g. VTI, TTI).
- This process of defining velocity uncertainty potentially can be used at all stages of prospect/field maturation from prospect identification to late stage field definition.