

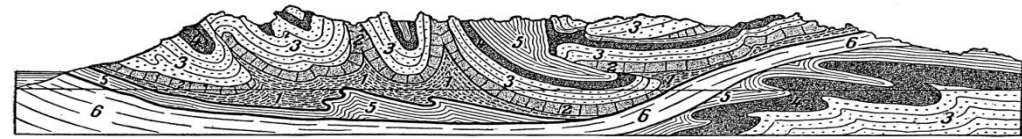
Multi-Attribute Seismic Wheeler Volume Workflows, Illuminating Stratigraphy, Geomorphology, and Prospectivity within a Mezardere Slope Fan Exploration Model, Thrace Basin, Turkey

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Introduction

This study outlines the use of multi-attribute seismic wheeler volume workflows as applied to the prograding delta front / prodelta deposits of the Oligocene Mezardere formation in the Thrace Basin of Turkey.

Traditional seismic interpretation methods focus on structure and amplitude mapping. More detailed seismic attribute analysis is often done afterwards to highlight stratigraphic details and patterns along key extracted time horizons or within narrow zones of interest. Visualizing seismic attributes across horizon surfaces can be very effective at identifying recognizable geological / geomorphological patterns.

If seismic events are relatively flat, animating/slicing seismic volumes up and down in time is very effective at revealing geomorphological patterns. *But, how do you harness the power of animation in time when chronostratigraphic seismic events are not flat?*

This work addresses this question in a setting where the seismic events are:

- Steeply dipping, faulted, and structurally deformed.
- Diverging and converging laterally within lobe shaped deposits.
- Potentially down-lapping, on-lapping and/or non-continuous/truncated.

As part of an ongoing exploration effort in the Thrace basin, detailed seismic stratigraphic interpretation work that aimed to overcome these challenges was initiated in early 2014.

Original Project Objectives:

1. Interpret and map individual clinoform deposits of the Mezardere formation.
2. Extract detailed seismic attribute data along regional chronostratigraphic horizon slices.
3. Evaluate individual clinoform deposits for hydrocarbon prospectivity.
4. Inform the development of a slope fan exploration model for the Mezardere formation.

The workflow that was developed to overcome these interpretation challenges and achieve the objectives of the project can be used as a model for how to integrate detailed seismic stratigraphic interpretation early and iteratively within the exploration process.

Model Workflow

Starting with (pre-stack) migrated volume and initial horizon interpretation.

DATA
CONDITIONING

Test and Run Dip Steering Data Volumes
Includes detailed and smoothed dip data volumes.

SEISMIC
ATTRIBUTES

Test Selected Seismic Attributes and Parameters

Generate Key Seismic Attribute Volumes
Utilize dip data as necessary.

HORIZON/FAULT
INTERPRETATION

Guide Horizon & Fault Interpretation

Interpret or refine key seismic stratigraphic boundary/guide horizons and fault planes, utilizing key attribute volumes and dip field data if useful.

Generate Horizon Sets

Test and generate continuous chronostratigraphic horizon sets between key guide horizons.

STRATIGRAPHIC
INTERPRETATION

Generate Wheeler Volumes

Essentially flatten the key seismic and attribute data volumes along the chronostratigraphic horizon sets to create geologic time volumes.

Visualize Wheeler Data

Animate key wheeler attribute volumes to identify significant stratigraphic features and key horizons.

ITERATION

VISUALIZATION

Visualize Extracted Horizons

Extract key horizons and visualize significant features in multi-attribute displays.

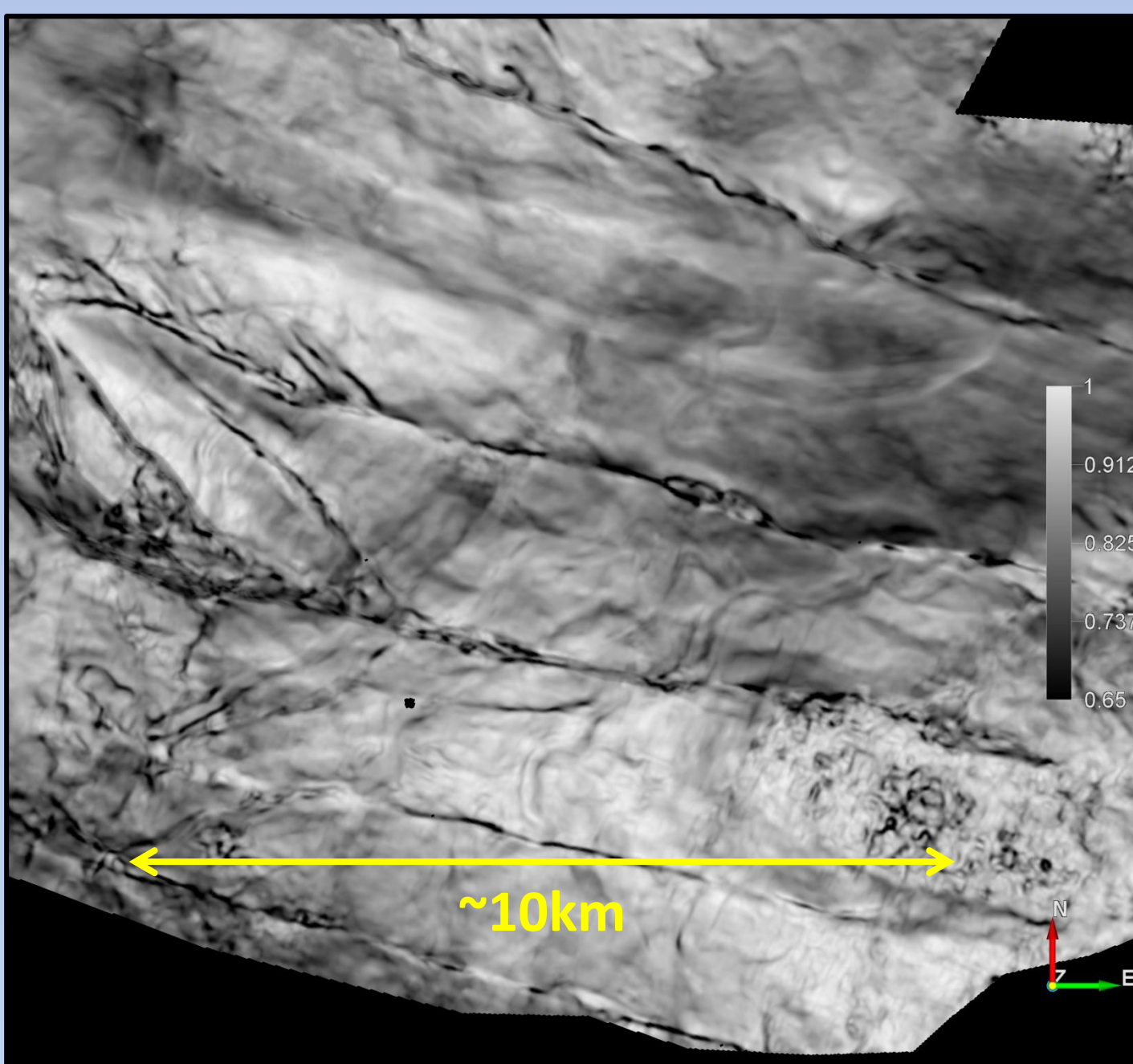
Key Seismic Attributes

Extensive testing of a wide variety of seismic attributes was undertaken at various stages and iterations of the workflow. These included but were not limited to, Similarity, Curvature, Spectral Decomposition, Energy, and Instantaneous Phase/Amplitude/Frequency.

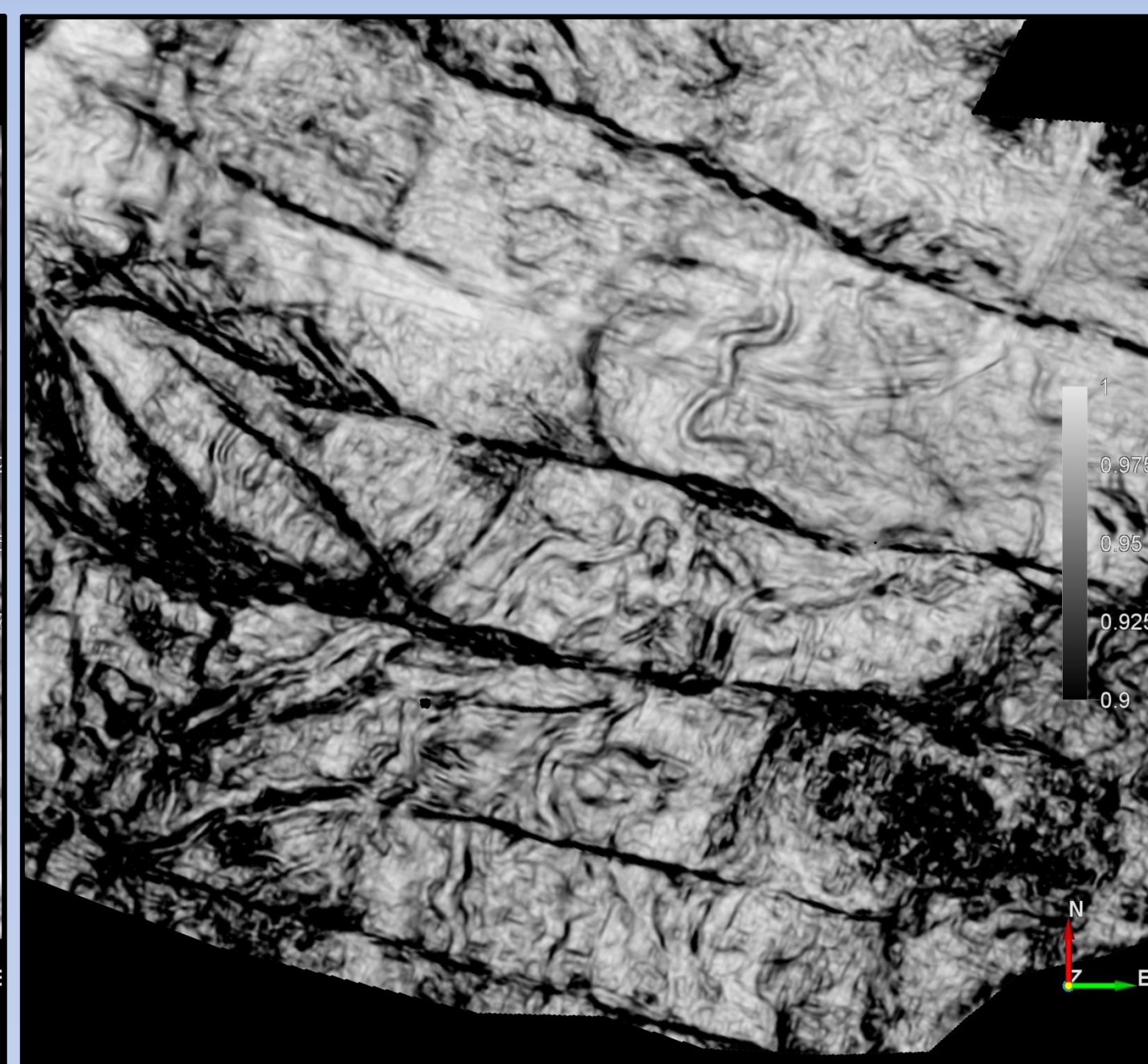
Rigorous testing of attribute parameters on smaller subsets of the data was the most time consuming and important aspect of this process. Parameter optimization is like focussing a lens on the part of the image you want to capture in most detail. Once parameters were optimized attributes were generated across the entire 3D volume.

In light of the project objectives to extract regional level detail along chronostratigraphic horizon surfaces, 3 key attributes were selected for visualization purposes: **Similarity, Energy, and Spectral Decomposition.** The images below show variations of each of these attributes over the same selected area of horizon 450 TekD4.

Similarity

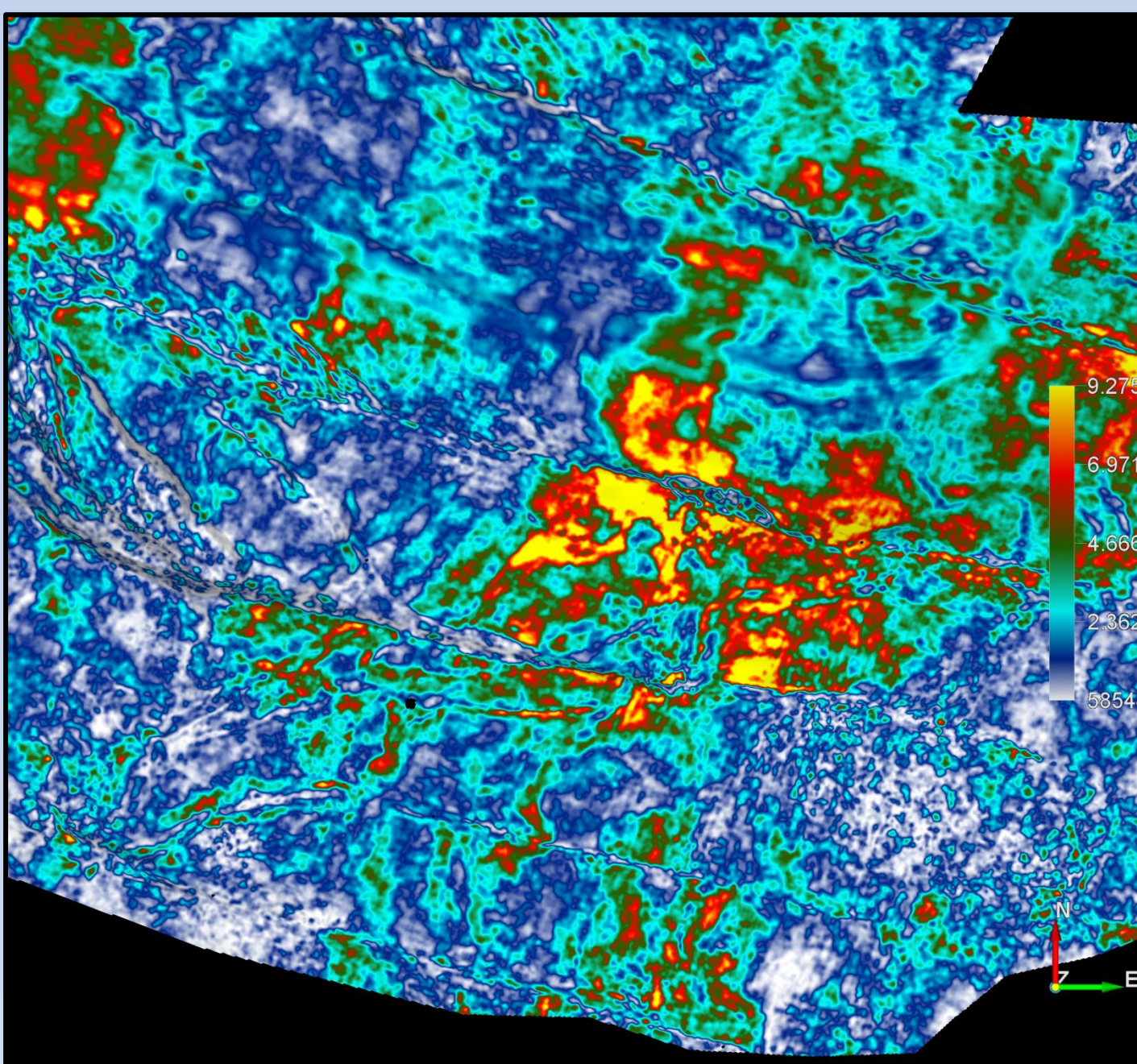


Dip Steered Similarity

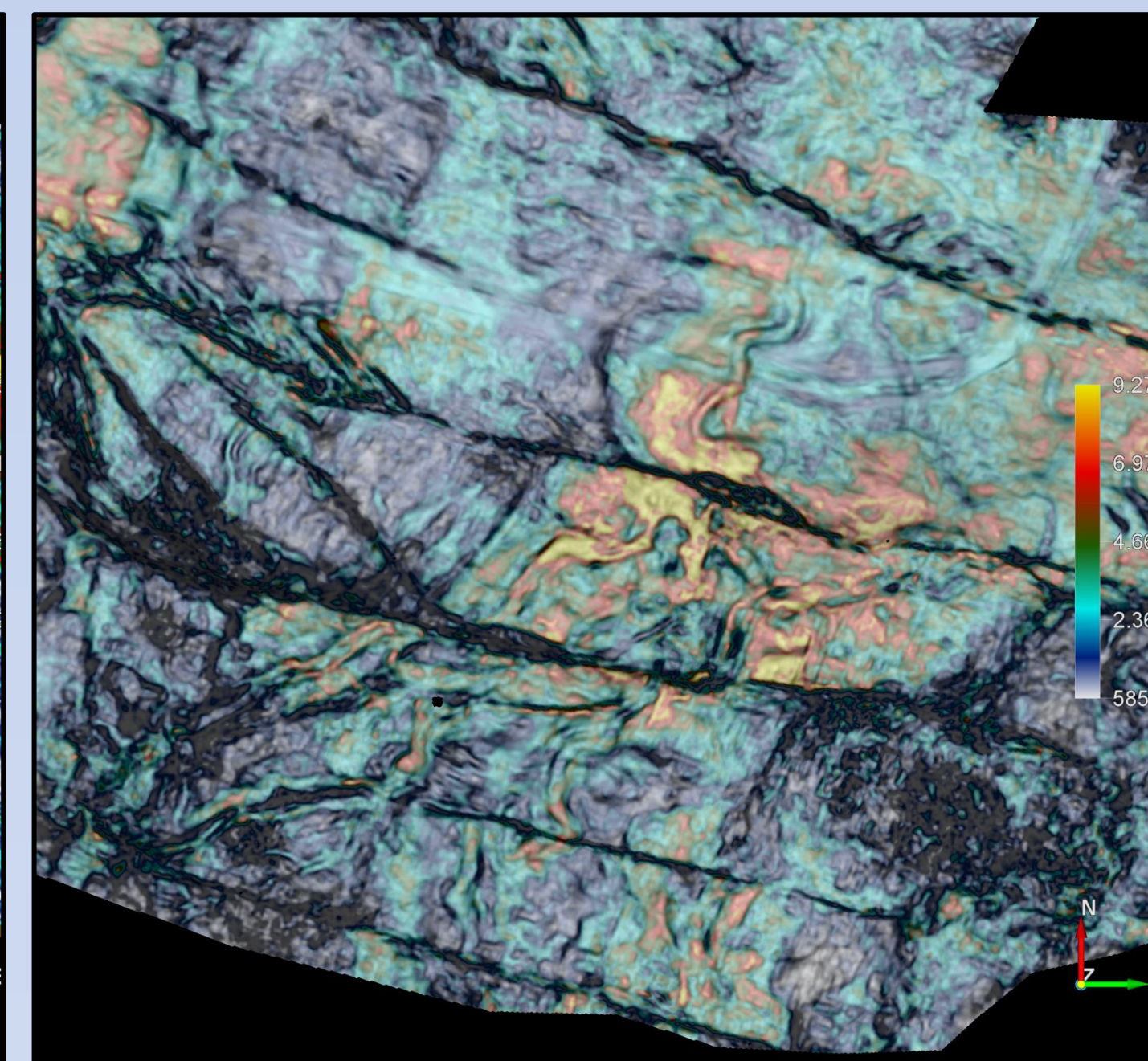


Utilizing dip volume data to generate the similarity (coherence) attribute resulted in significantly greater stratigraphic detail as shown in the images above. (Horizon 450 TekD4)

Energy

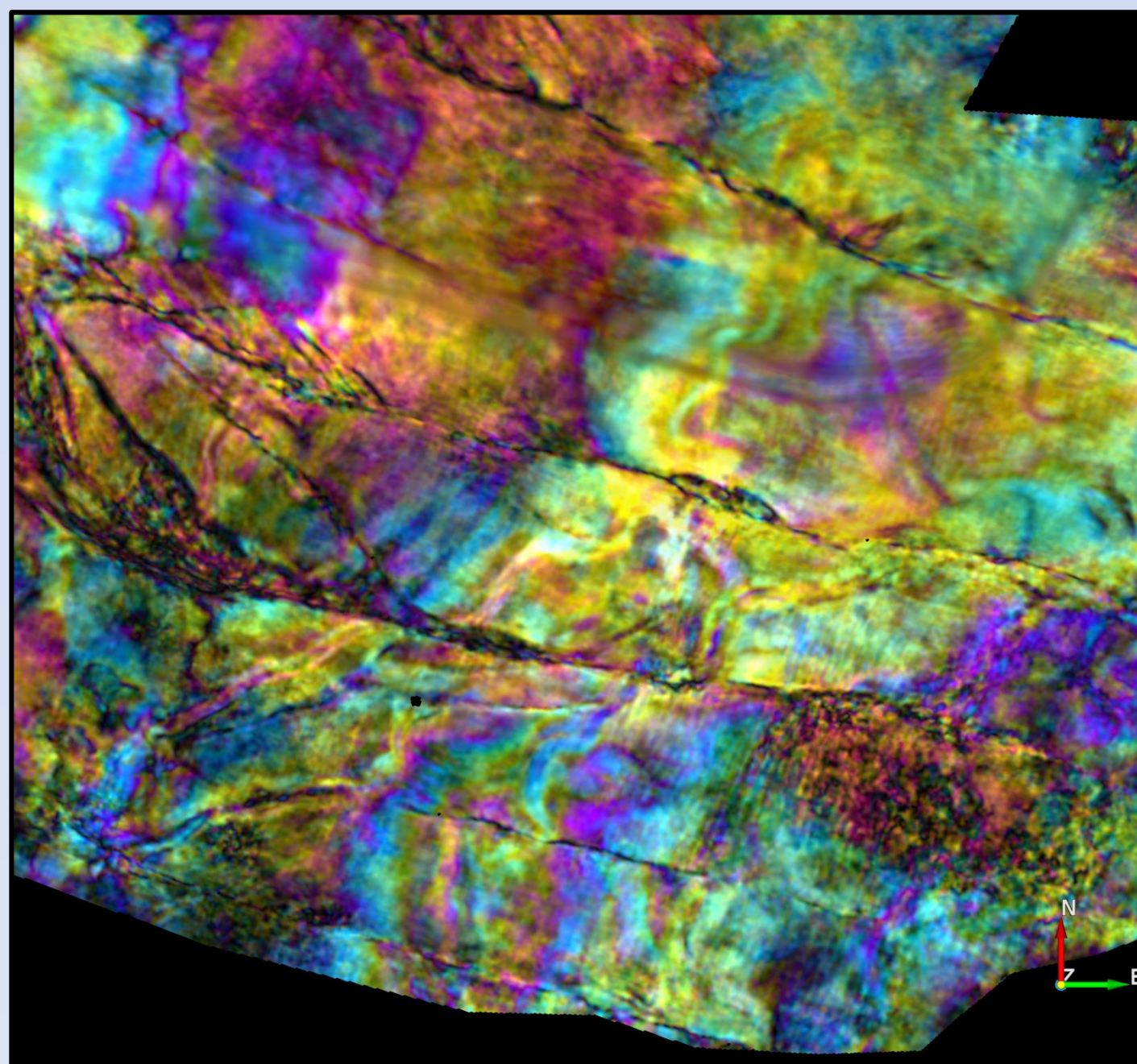


Energy and Similarity

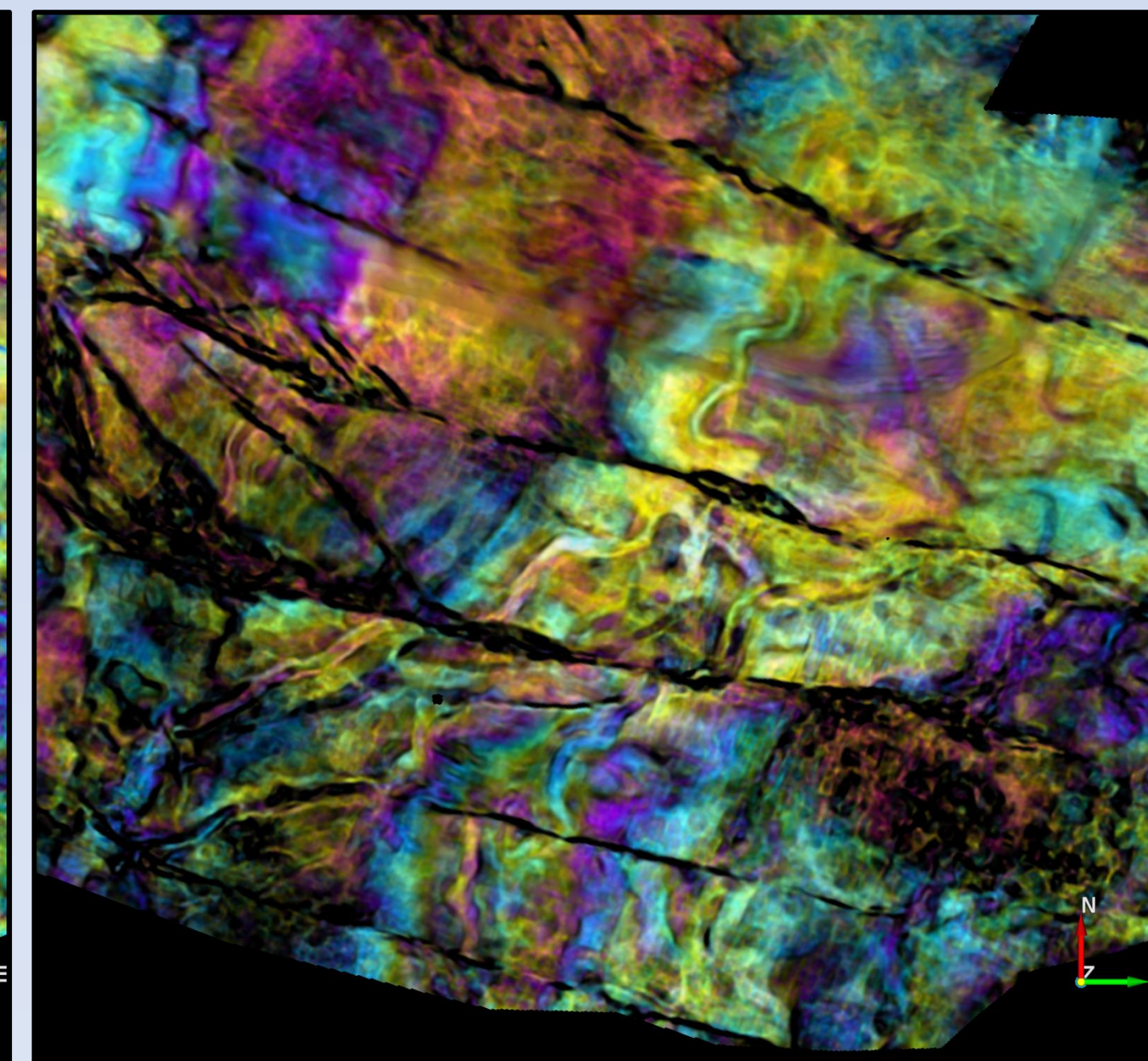


The Energy attribute was generated over a 30ms time window and provided a measure of absolute amplitudes. Co-rendering it with Similarity, helped to bring the Energy attribute into greater geological context. (Horizon 450 TekD4)

Spectral Decomposition



Spectral Decomposition and Similarity



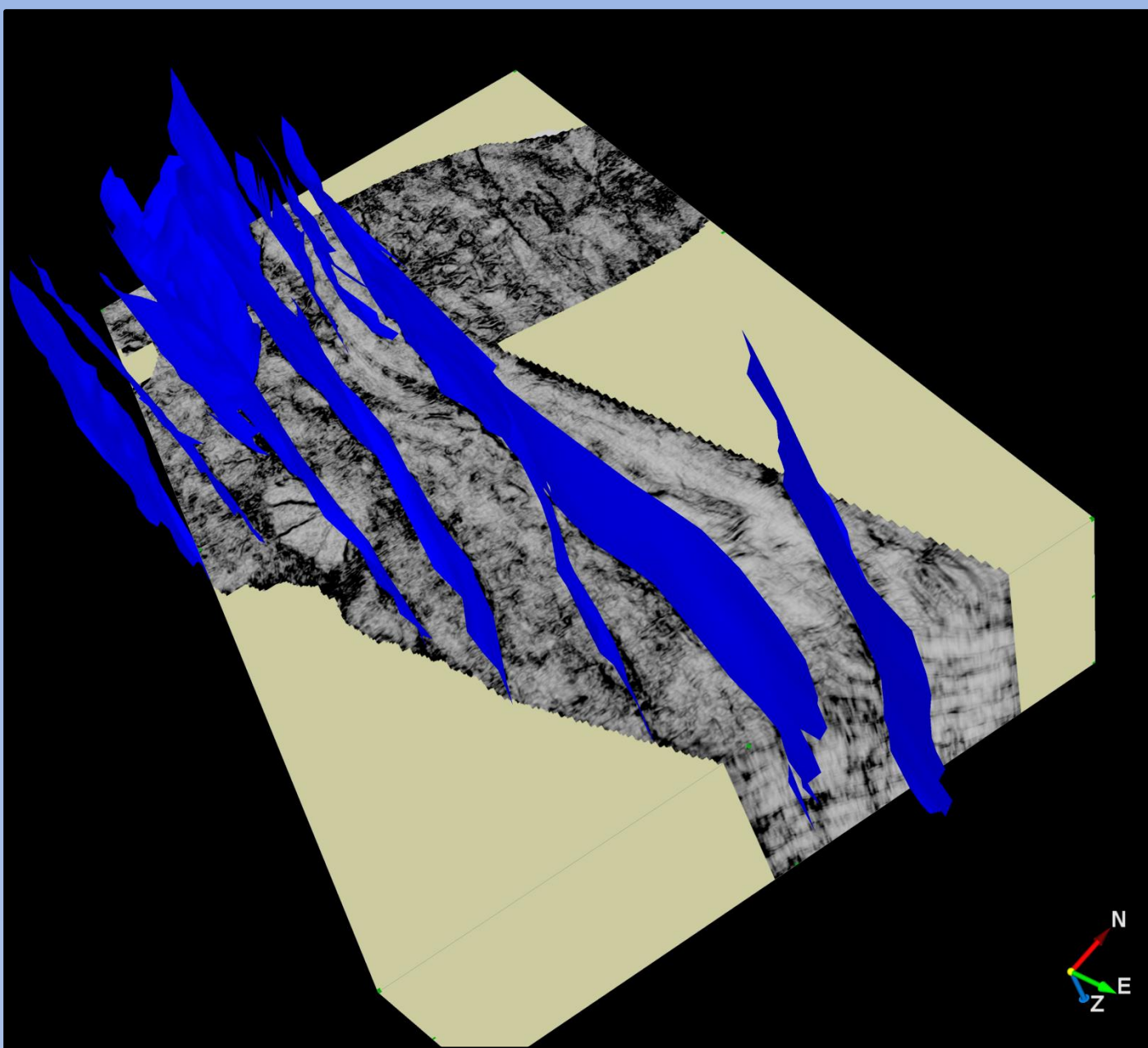
Using Spectral Decomposition to break down the seismic data into 15, 30, and 45Hz frequency bands and then displaying them on a color-blended horizon provided another level of detail / perspective of the geomorphological features. Co-blending with Similarity also helped to add more context. (Horizon 450 TekD4).

Fault Interpretation

Fault interpretation was an iterative process that was done by picking major fault systems on dip steered Similarity (coherence) volumes.

Initial picks were made on regular time slice intervals and then later refined as needed on vertical amplitude and similarity sections.

Image to right shows perspective view of dip steered similarity volume with key fault planes displayed.

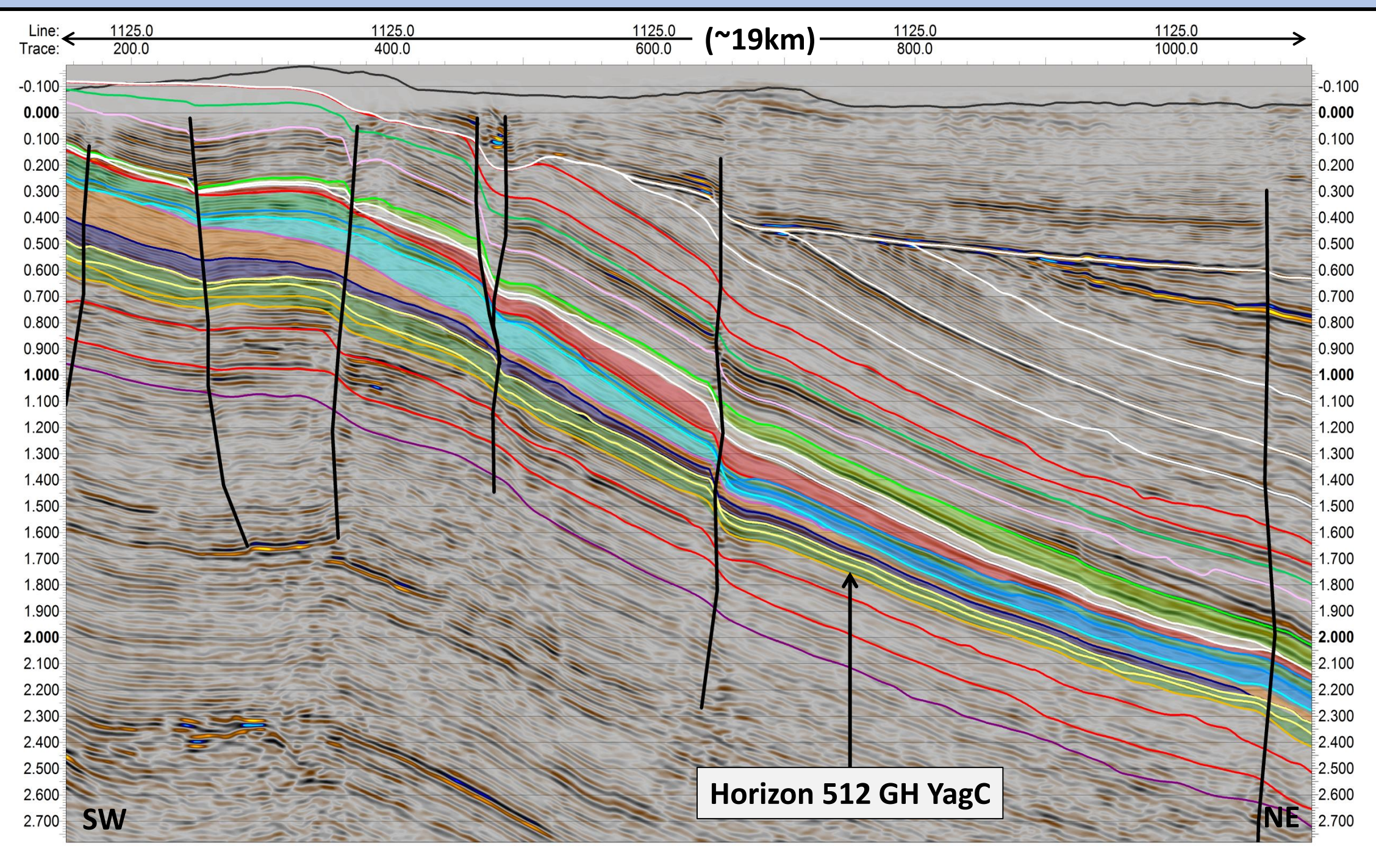


Horizon Interpretation

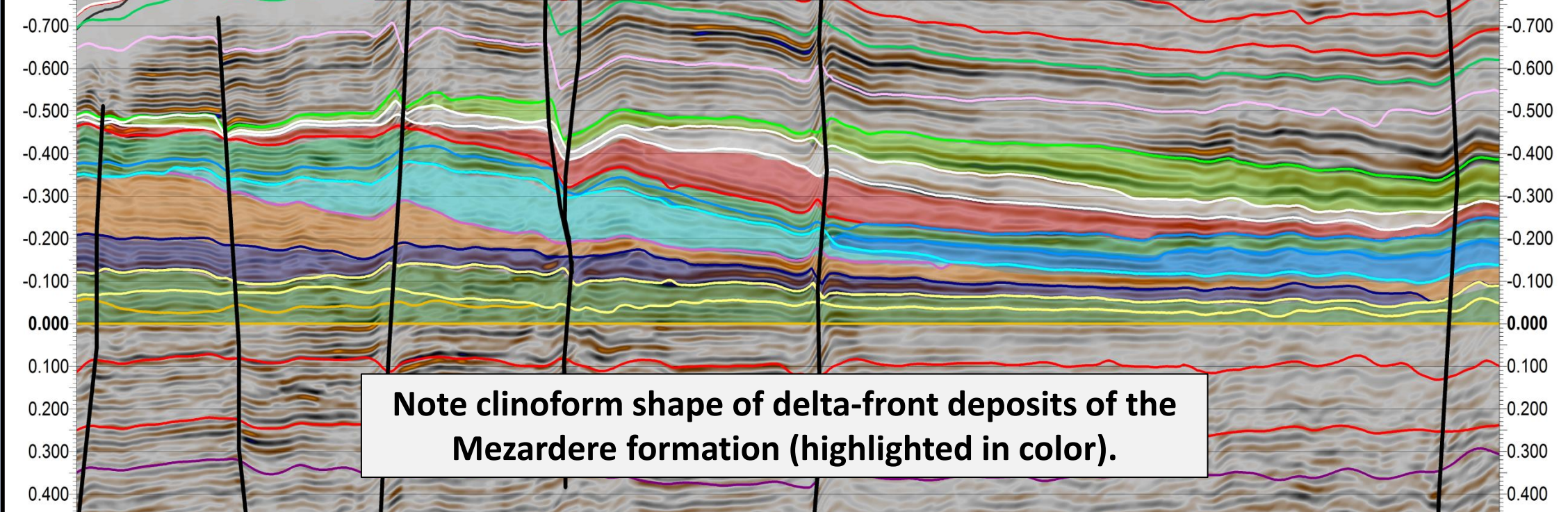
Horizon interpretation focussed on key seismically defined stratigraphic boundary events that separated prodelta slope fan deposits into distinct clinoform depositional lobes. These horizons are referred to as guide horizons.

Key challenges to horizon interpretation across the whole data volume included significant structure/faulting and strong events that eventually pinched out or merged laterally into other weaker events.

Seismic Dip Line (Inline 1125) with Guide Horizons Displayed



Above Dip Line Flattened on Horizon 512 GH YagC

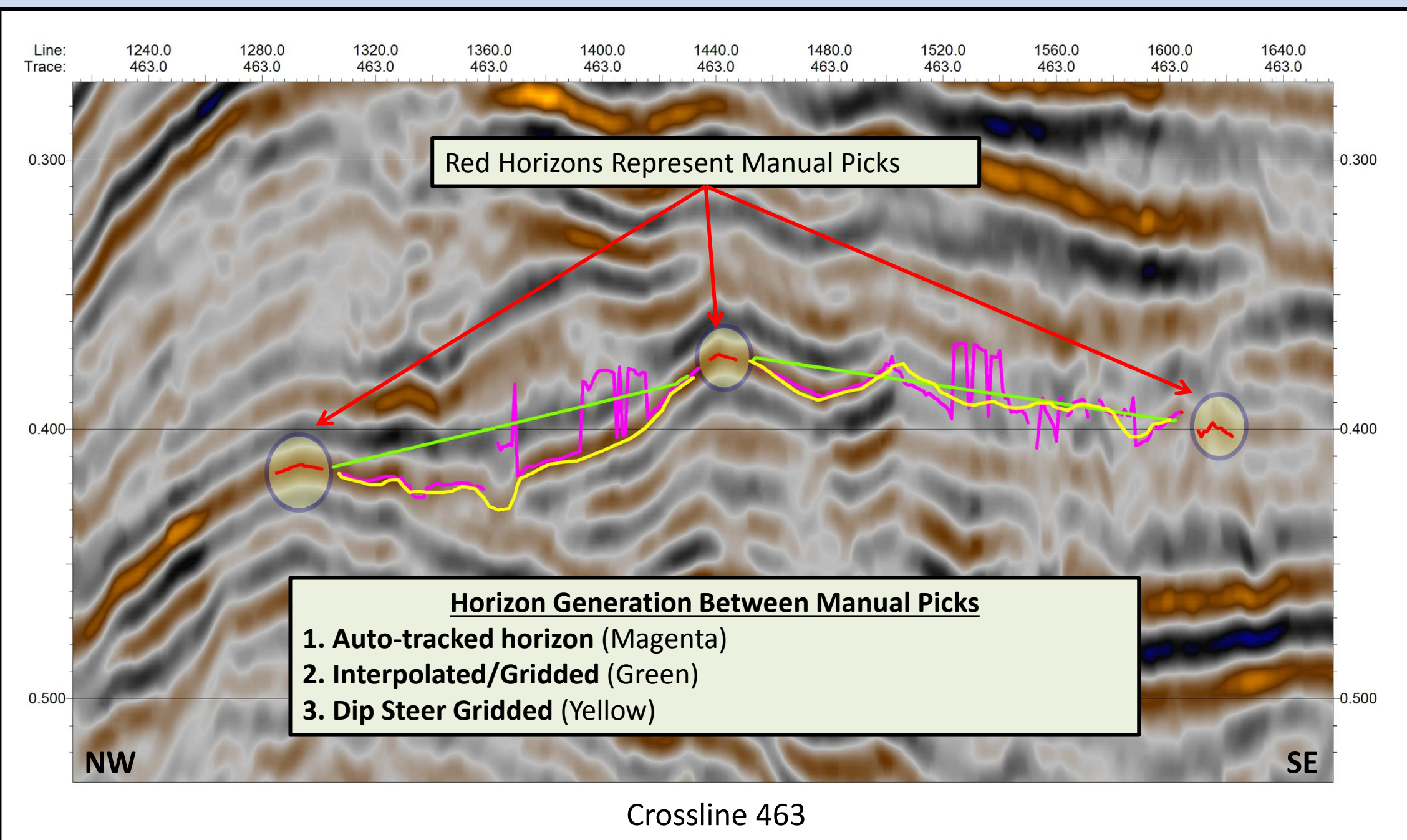


Manual interpretation of guide horizons were completed on a regular framework of approximately 40x40 to 20x20 inline/crossline spacing's.

Interpolation of horizons picks between manual picks were completed using a number of different processes.

1. 3D auto-tracking along selected peak/trough events.
2. Gridding/Interpolation between events, followed by smoothing.
3. Dip Steered gridding between events.

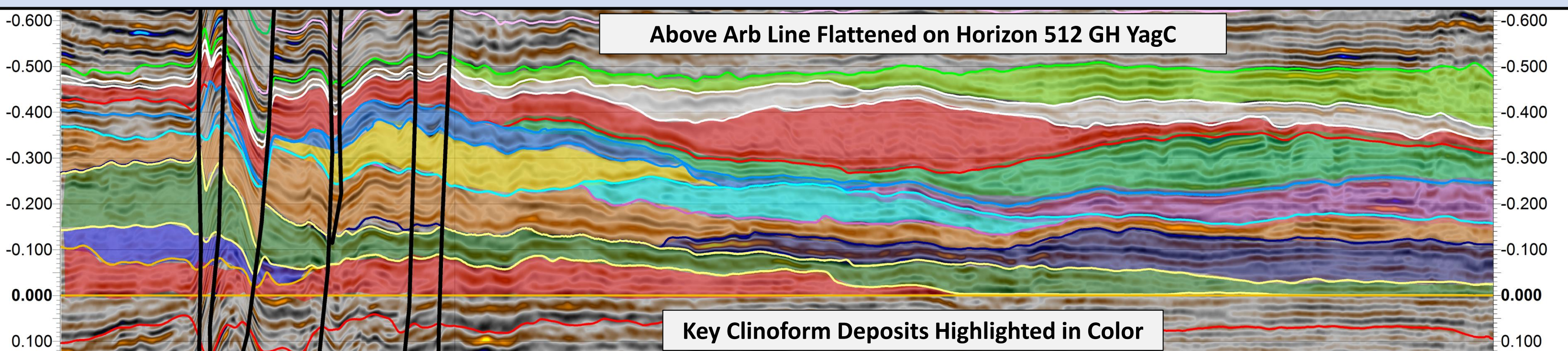
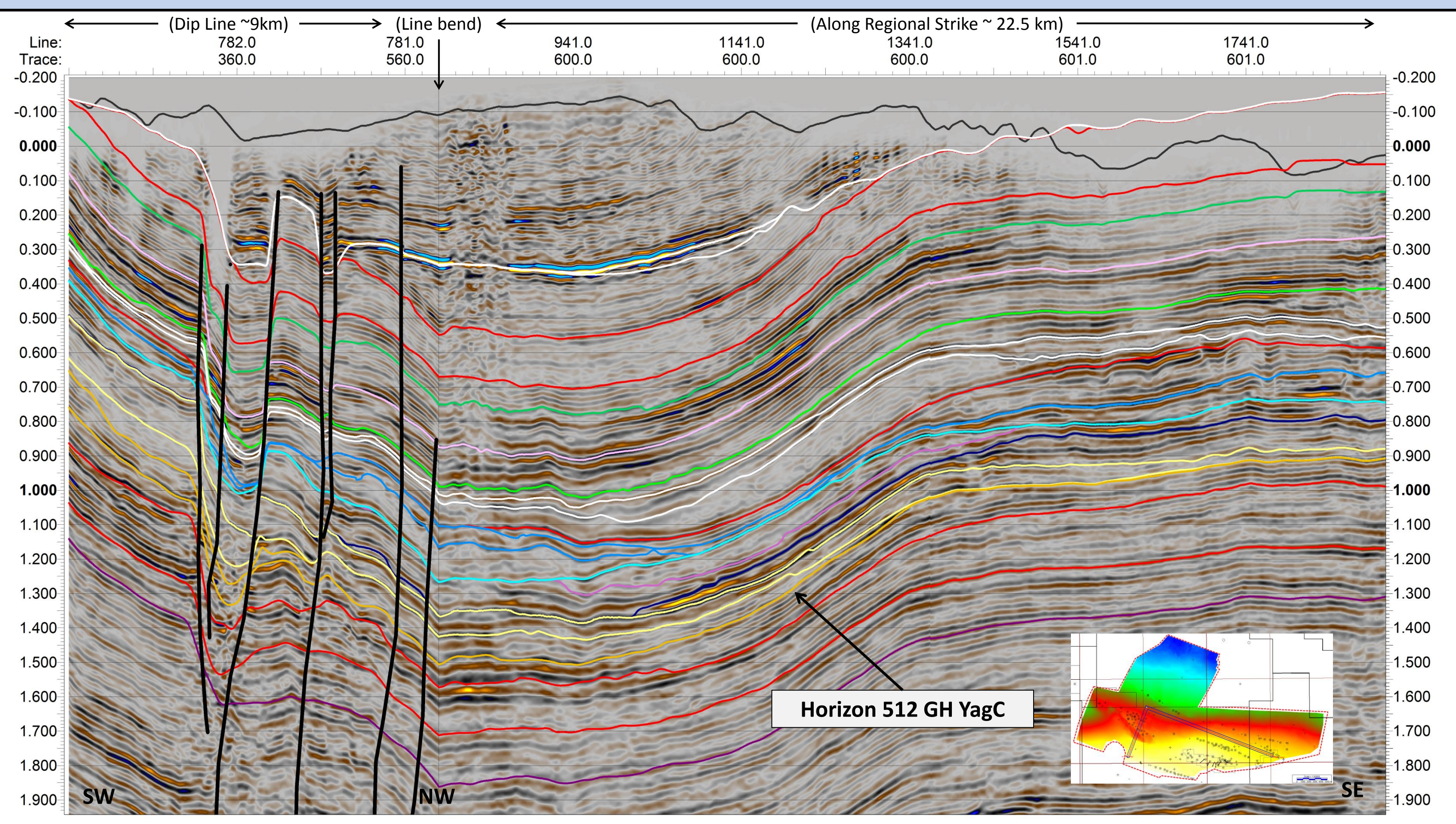
Each method had strengths and weaknesses which are illustrated in the image below.



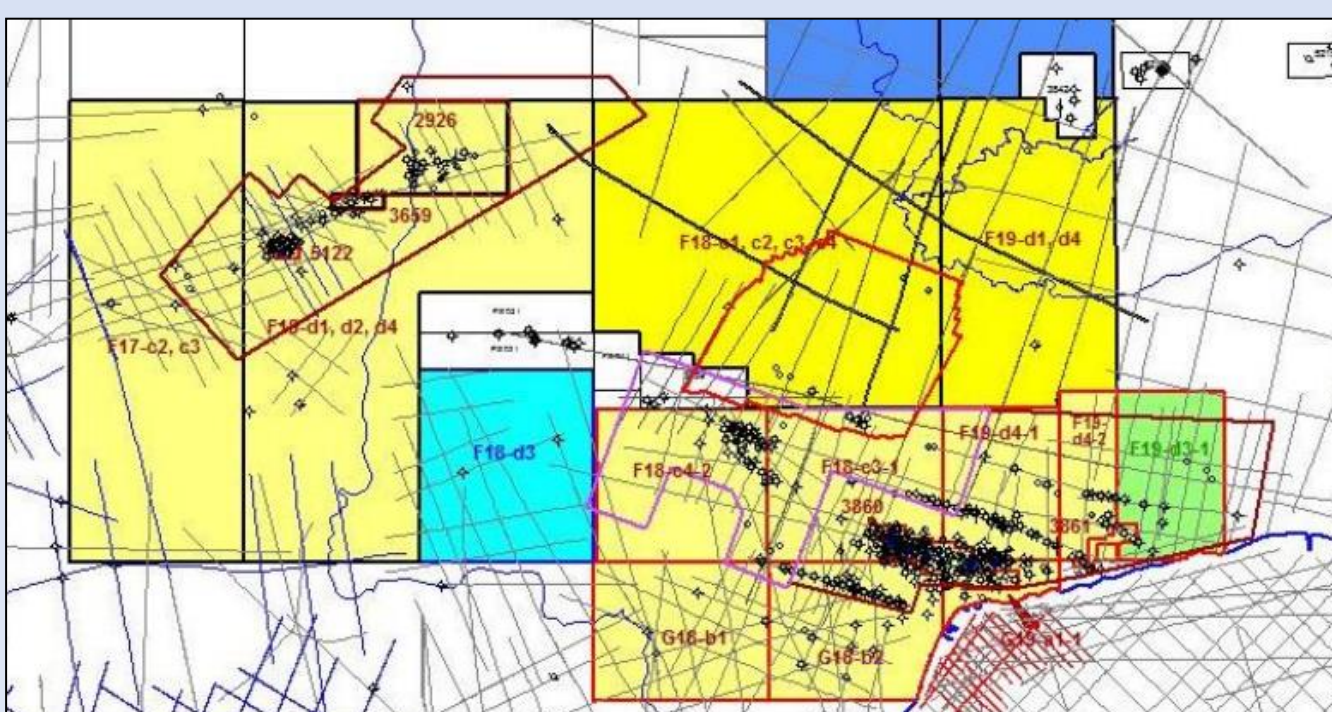
Auto-tracking honored events most accurately until events changed phase to doublets or pinched out causing the horizon to 'jump' events. **Gridding/Interpolation** was effective for quickly filling in small gaps, but did not honor events well over larger areas. **Dip steered horizon gridding** was most effective in that it tracked the overall dip of the seismic events between manual picks, but was not constrained to peak / trough parameter selection in the way that auto-tracking algorithms are.

Often all three horizon interpolation processes were implemented in an iterative fashion to achieve optimum results.

Seismic Data

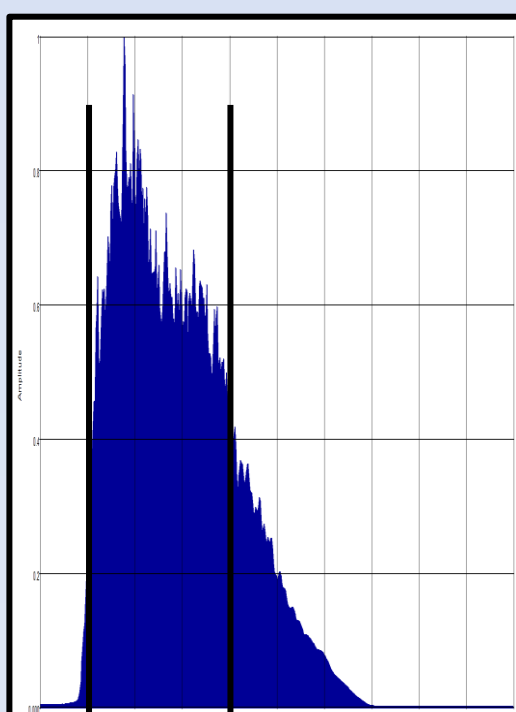


Seismic data utilized in this project included primarily ~800 km² of 3D seismic acquired in 4 separate programs from 2011-2015. Secondly, over 4000km of legacy 2D seismic data were also utilized as needed. Overlapping 3Ds were ultimately merged.



Average 3D seismic parameters:

- Source: Vibroseis, 6-98 Hz, 16 sec sweep
 - Bin Size: 20m x 20m
- In general, recovered frequencies on the final stacked (PSTM) data were relatively low with dominant frequencies between 15-40Hz. Also, variable near surface geology, and surface infrastructure led to degraded data quality in some areas.



Dip Steering / Data Conditioning

In order to run advanced seismic attributes and take advantage of dip steered horizon tracking, it was necessary to first run dip steered data volumes on the fully processed pre-stack migrated datasets.

Testing of dip steering parameters was undertaken on selected 2D profiles and evaluated by how well dip steered horizon tracking methods matched actual seismic events.

Once final parameters were selected, detailed and smoothed dip volumes were generated across the complete datasets.

By utilizing the calculated dip data to create a dip smoothed median filter it was possible to create a filtered version of the data that reduced random noise, and enhanced laterally continuous events, while preserving structural edges and faults. One drawback is that lateral amplitude variations were not as well preserved. This cleaner (DSMF) volume was used frequently in later stages of the workflow.

