DecisionSpace® Geosciences: Fundamentals of Geophysics

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Halliburton | Landmark
10200 Bellaire Blvd., Houston, Texas 77072-5206, USA
P.O. Box 42810, Houston, Texas 77242-2810, USA
Phone: 281.575.3000, Fax: 713.839.2015
Internet: https://www.landmarksoftware.com

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Table of Contents

Preface
Fundamentals of Geophysics

The DecisionSpace® Geosciences software provides an elegant approach to integrated prospect evaluation and development. The goal of DecisionSpace Geosciences is to help interpreters quickly and accurately map oil and gas plays, prospects, and fields. The software accomplishes this by integrating a wide range of data types with a narrow range of probable solutions, constrained by geology, geophysics, petrophysics, and reservoir models. Integrating geological and geophysical interpretations allows you to map and analyze your projects accurately, build sealed structural frameworks and reservoir models, and plan wells in both traditional and unconventional scenarios.

Overview of DecisionSpace Geosciences Courses

The following are available as DecisionSpace Geosciences courses:

- DecisionSpace Geosciences: Getting Started (one day)
- DecisionSpace Geosciences: Integrated Interpretation and Mapping using Dynamic Frameworks to Fill (three days)
- DecisionSpace Geosciences: Fundamentals of Geophysics (two days)
- DecisionSpace Geosciences: Fundamentals of Geology (two days)
- DecisionSpace Geosciences: Practical Velocity Modeling (three days)
- DecisionSpace Well Planning: Onshore Methods (three days)
- DecisionSpace Offshore Well Planning (three days)
- Stochastic Modeling and Geostatistics for Reservoirs, Principles and Methods (three days)
- DecisionSpace Geosciences: Stimulation (one day)

- DecisionSpace Geosciences: Well Tie Workflow (one day)
- Decision Space Geosciences: Interpreting Lithology and Petrophysics by Zones with DFF (one day)

This manual accompanies the instruction provided in the *DecisionSpace Geosciences: Fundamentals of Geophysics* course, revision 5000.10.01. The manual is both a teaching tool and a practical, hands-on reference. Because DecisionSpace Geosciences is very extensive and flexible, it is not possible to cover all features, functions, and courses of any particular course in a single manual. Therefore, we provide key examples and descriptions, with exercises that are directed toward common Geosciences workflows.

After you have worked your way through the course, you will find the manual is a quick and easy-to-use reference for investigating topics of interest.

Leveraging Data with DecisionSpace Geosciences and Dynamic Frameworks to Fill

DecisionSpace Geosciences is a unified workspace, wherein geoscientists and engineers can leverage their skills in a collaborative environment to discover and evaluate assets.

Within this collaboration space, you can access and manage geoscientific and engineering data by leveraging database connectivity and multi-user interpretation tools across the DecisionSpace platform (i.e., OpenWorks, EDM, and corporate data stores).

Well-tie and velocity modeling tools enable on-the-fly conversion of time to depth (and vice versa), ensuring that all data can be interpreted and used in a common domain.

The co-location of seismic data, interpreted horizons and faults, well picks, fault picks, and log curves accelerates cross-domain interpretation. Cross-domain data integration provides essential cross-validation of the overall interpretation, mapped surfaces, and property maps.

The DecisionSpace Geosciences platform possesses several particularly powerful strengths.

Close integration between geological and geophysical interpretation tools — tied directly to dynamically updateable framework-based mapping tools — provides an order-of-magnitude increase in core exploration and development workflows.

Our goal is to enable you to develop your skills through hands-on training to a level that will give you sufficient experience, with supporting materials, to achieve substantial productivity gains. You will achieve breakthrough changes in efficiency and accuracy through cross-domain data visualization and new paradigms in integrated interpretation and mapping capabilities. This new approach to integrated interpretation and mapping is incorporated in Dynamic Frameworks to Fill.

Using Dynamic Frameworks to Fill

The Dynamic Frameworks to Fill functionality provides you with integrated geological and geophysical interpretation tools that leverage framework surfaces in their respective workflows. For example you will have the ability to create and edit fault picks from ‘predicted’ seismic faults in *Correlation* view, which then triggers an update of DFF. In DFF you will have the following advanced technologies at your disposal:

- An advanced topology engine that properly grids surface data in the context of fault blocks (with an associated ability to digitize fault polygons), unconformity-bounded regions, and AOI polygons.
- It provides Conformance technology that models surface picks, guided by seismic horizons.
- It provides an advanced topology engine that properly extracts zone properties for wells with incomplete penetrations that will also handle multiple traversals of the same zone for horizontal wells.
- It provides Multi-surface framework and property map updates tied to changes in data or edits to existing interpretation. This is enabled by the ability to:
    - Associate multiple data sources (e.g. picks, seismic horizons, pointsets for structural surfaces, raw and calculated log curve data for property maps) with a given surface or property map.
    - Update all surfaces and property maps when input data are changed by data import (i.e., new wells are drilled and additional surface pick and log curve data are available) or interpretations are changed (e.g., horizon or surface picks, and raw or calculated log curves for property maps).
    - Update all dependent surfaces when primary surfaces (e.g., parent surfaces in conformance relationships, or fault planes cutting a surface) are altered in a multi-surface framework.

Design Background of Dynamic Frameworks to Fill

The direct tie between data, interpretations, and mapping is the key theme in the design of DFF. The DecisionSpace Geosciences environment facilitated the design of DFF as an integrated interpretation and mapping system tied directly to a next generation, framework-based mapping system. As a result, DFF ties directly back to raw interpretive data such as horizons, surface picks, and log curves.

By contrast, other framework or earth model construction systems emphasize the use of static grids (and point sets) as their starting point for model building. This reflects an increasingly outdated manner of thinking about framework construction, which assumes that interpretation is the realm of interpreters and framework building is the realm of (earth) model builders. Given the historical bias toward separating interpretation and framework (model) construction, many competitive products designed their framework building tools with a strong emphasis on the use of static grids and point sets, two input types that possess no ability to update according to changes made to the original data that the interpretation was based upon. Many model builders who use these competitive products accept the fact that interpreters will supply interpretations in the form of point sets or static grids. Consequently, these products have tools to manipulate static grids to make the model look correct. In other words, they have tools to locally warp grids to make indentations or bumps. The grids only update where they are pushed or pulled by the modeler, rather than the latest interpretation. There is no way to update the entire trend of a surface based on changes to source data.

Dynamic Frameworks to Fill supports the proposition that the industry would prefer that edits to a framework model are based on changes to the original interpretation. The key point is that DFF takes a data centered approach to the framework construction process that fully involves the professional interpreter. The benefit of this approach is that the framework QC process can compare framework surface geometries directly to original seismic, horizon, and top data to verify its accuracy.

The Structure and Content of the Fundamentals of Geophysics Course

This three-day course will give you a practical introduction to the Fundamentals of Geophysics for DecisionSpace Geosciences. This section provides a high-level summary of the chapters and exercises.

Preface: Introduction

Chapter 1: Seismic QC and Enhancement

- Display and manipulate prestack data
- Generate a structural filter volume
- Generate a discontinuity volume
- Use the bulk shift functionality

Chapter 2: Well Tie Workflow

- Launch the well tie workflow
- Use the well tie workflow wizard to select parameters for creating synthetics
- Tie synthetics to seismic data
- Export and save a wavelet in openworks and as an ASCII file
- Apply the family concept to compare wavelets
- Apply thickness edits to all loaded logs
- Save synthetics, time-depth curves, and check shots to the OpenWorks database
- Display synthetics in *Section* view

Chapter 3: Fault Interpretation

- Interpret faults in *Section*, *Map*, and *Cube* views
- Refine and enhance fault interpretations
- Use Fault QC to interpret multiple fault segments
- Create fault networks using the Dynamic Frameworks to Fill (DFF) platform

Chapter 4: Interpreting Horizons

- Create horizons and horizon lists
- Interpret horizons on the basis of synthetic
- Interpret horizons in *Section* view
- Use horizon correlation polygons (Correlation Tool)
- Visualize horizon interpretation in DFF
- Interpret horizons in the *Cube* view
- Track areas using Area Track
- Track horizons using ezTracker Plus
- Interpret horizons in *Map* view
- Create Fault Polygons in DFF
- Calculate fault heaves and polygons (Conventionally)
- Use ezValidator to unfault/unfold stratigraphy
- Use the Seismic Calculator to perform operations on horizons

Chapter 5: Creating Seismic Attributes for Reservoir Analysis

- Render volumes using volume shading
- Calculating seismic attributes

- Visualize the seismic attributes
- Blend multiple seismic attributes
- Use volume math
- Extract seismic attributes along horizons
- Crossplot attributes
- Extract attributes at well locations

Chapter 6: Velocity Modeling Workflow

- Build and QC a quick well T/D velocity model
- Edit time-depth tables
- Condition input horizons
- Build a velocity model using a multi-surface structural framework
- Calibrate a velocity model to well picks
- Incorporate seismic velocity into the model

Chapter 7: Geology Integration and Earth Modeling Integration

- Integrate geological information into a time domain framework
- Conform geological picks with geophysical surface
- Integrate framework in earth modeling

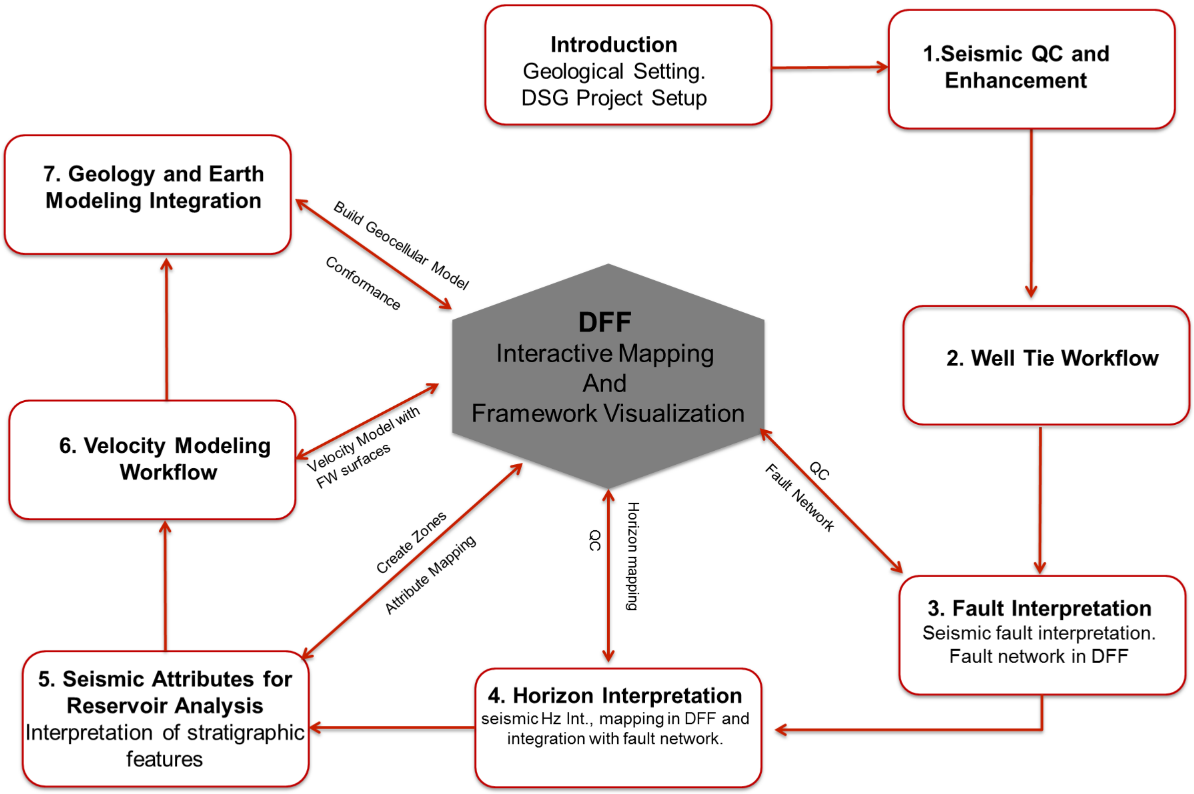
Appendix A: Integration with GeoProbe

- Connect the GeoProbe software to DecisionSpace
- Display the probe face as a seismic section in DecisionSpace
- Navigate through the data in the GeoProbe software, updating the seismic in DecisionSpace

- Interpret in DecisionSpace and see updates in the GeoProbe software
- Edit data in the GeoProbe software and see updates in DecisionSpace

Course Workflow

The following diagram reflects the workflow that you are going to follow in this class:



Chapter 1 Seismic QC and Enhancement provides information about the manipulation of prestack data and QC of seismic volumes before starting your interpretation. You will learn about shifting 2D lines and 3D seismic volumes by a defined time using Bulk shift functionality, creating an enhanced structural and discontinuity volumes from an existing amplitude volume to highlight the structures effectively during fault/horizon interpretation.

Chapter 2 Well Tie Workflow provides guidelines for tying the well control to the seismic data. You will learn about creating a well synthetic and manipulating a TD curve (that relates the seismic time to well depth), improving the well tie workflow analysis by using the Family Concepts feature and applying thickness edits to logs across families. It is important to run the Well Tie Workflow (WTW) before horizon interpretation, so that you know about the reflector that is the equivalent to the geological feature that you want to interpret.

Chapter 3 Fault Interpretation provides information about interpreting faults. Additionally, this chapter also provides information about Dynamic Frameworks to Fill (DFF) feature of the DecisionSpace Geosciences software, which is used to QC fault planes and build fault networks. It is important to build fault networks in the early stages of the interpretation process, as it gives you an idea of the relationship between them, and general structure.

Chapter 4 Horizon Interpretation provides information about all the tools available for interpreting horizons. These include semi-automated horizon tracking tools such as Polygon/Area track and ezTracker. In this chapter, you will also learn about visualizing horizons dynamically and building fault polygons on the fly. You will see how DFF links your source data like surfaces or faults with framework surfaces as source data changes, the frameworks surfaces update as well.

Chapter 5 Creating Seismic Attributes for Reservoir Analysis provides guidance in how to create and analyze seismic attributes to identify bright spots, stratigraphic layers, differentiate lithologies, etc. Next, the generated seismic attributes will be extracted to the surfaces interpreted in the previous chapter. Additionally, you will also learn how to extract attribute values in Zone Manager. Zone Manager allows you to integrate seismic attributes with geological and petrophysical attributes to help identify a relations between them.

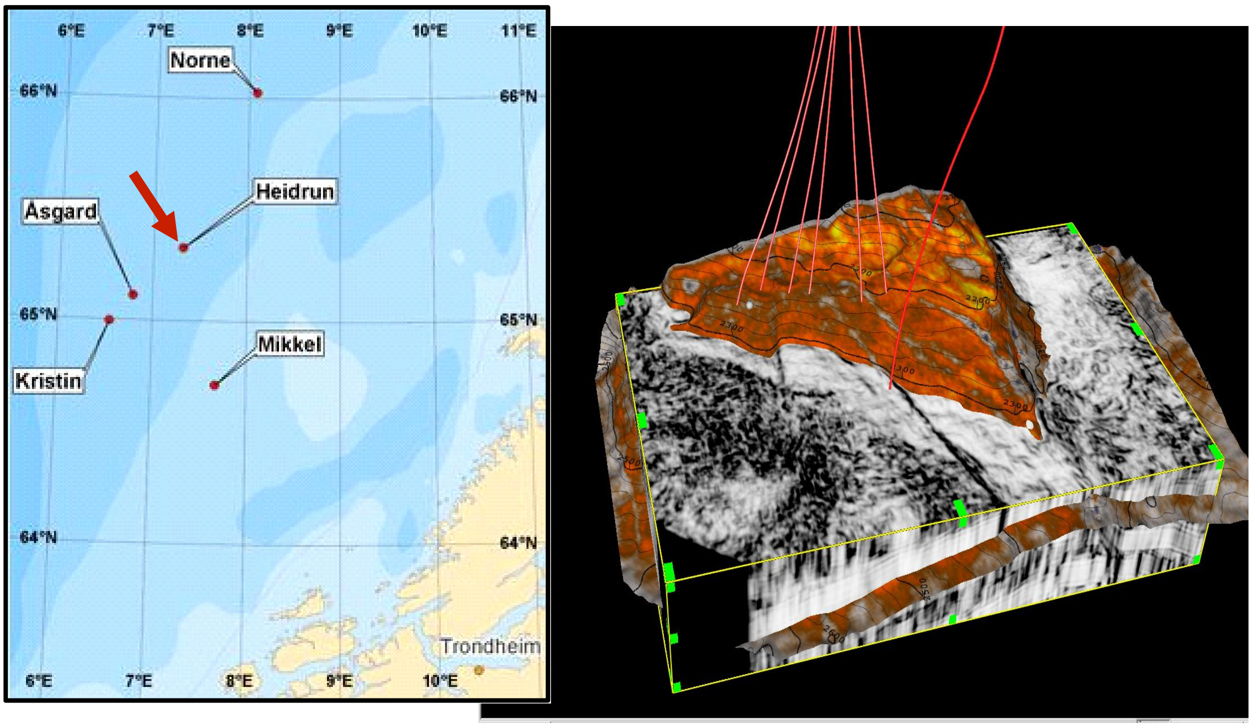
Chapter 6 Velocity Modeling Workflow provides information about building a velocity model by using a framework from previously interpreted faults and horizons. A velocity model in DSG uses frameworks to guide you about the construction of a model from a structural perspective.

Chapter 7 Geology and Earth Modeling Integration provides information about ways to integrate your seismic interpretation with geological interpretation. DSG enables seamless collaboration between different asset members. You will also learn how to include geological tops in the model and establish conformable relationships. Information provided in this chapter also describes how to create a geocellular model from your final framework interpretation.

Geological Setting

The Dataset for this Class: Heidrun Field

Heidrun in the Norwegian Sea (map below) has been producing oil and gas since October 1995.



The Heidrun field is located on Haltenbanken in the Norwegian Sea in water depth of about 350 meters. The field was developed with a floating concrete tension-leg platform, installed over a subsea template with 56 well slots. The northern part of the field is developed with subsea facilities. This heavily faulted reservoir comprises Lower and Middle Jurassic sandstones. The recovery strategy for the field is pressure maintenance using water injection and injection of excess gas.

The Heidrun field has yielded some 660 million barrels of oil since it came on stream, with a current flow of about 150,000 barrels per day. At its peak it produced over 300,000 barrels per day from the Fangst group.

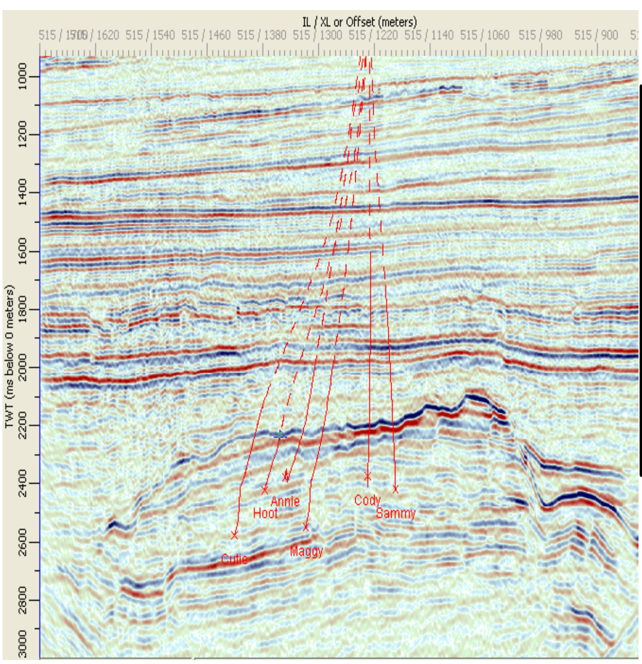
Its annual gas output totals roughly 1.3 billion cubic meters. Purposeful efforts to improve oil recovery have boosted estimated oil reserves in the field to about 1,130 million (1.13 billion) barrels.

Original discovery was on a high-amplitude-gas bright spot, but most of the production is from non-bright seismic signatures of the oil leg, which makes up about 80% of the total production.

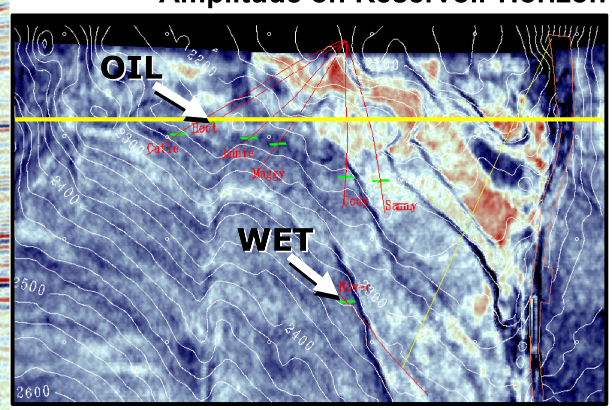
The Heidrun structure is a large southwest-plunging horst block on the southwest flank of the Nordland ridge and was formed during the Cimmerian extensional tectonic phase in the Late Jurassic-Early Cretaceous. The Heidrun reservoirs are severely truncated at the northern edge of the structure and are sealed by Cretaceous shales.

The Heidrun Jurassic reservoir rocks, the Fangst Group, and the Tilje and Are formations were deposited on the southeastern flank of the developing northeast Atlantic rift domain. Despite an over-all transgressive regime, the interval was characterized by a high, coarse, clastic influx from the elevated rift shoulders. The shallow depth of burial (less than 2500 m) has limited compaction effects. Reservoir quality in the clean Fangst sands is somewhat enhanced by dissolution, and the sands exhibit maximum permeabilities higher than 10 Darcys and porosities in excess of 30%.

Seismic-stack signature does not change much from oil pay to non-pay, as seen in the amplitude map on the pay horizon (below).



Amplitude on Reservoir Horizon

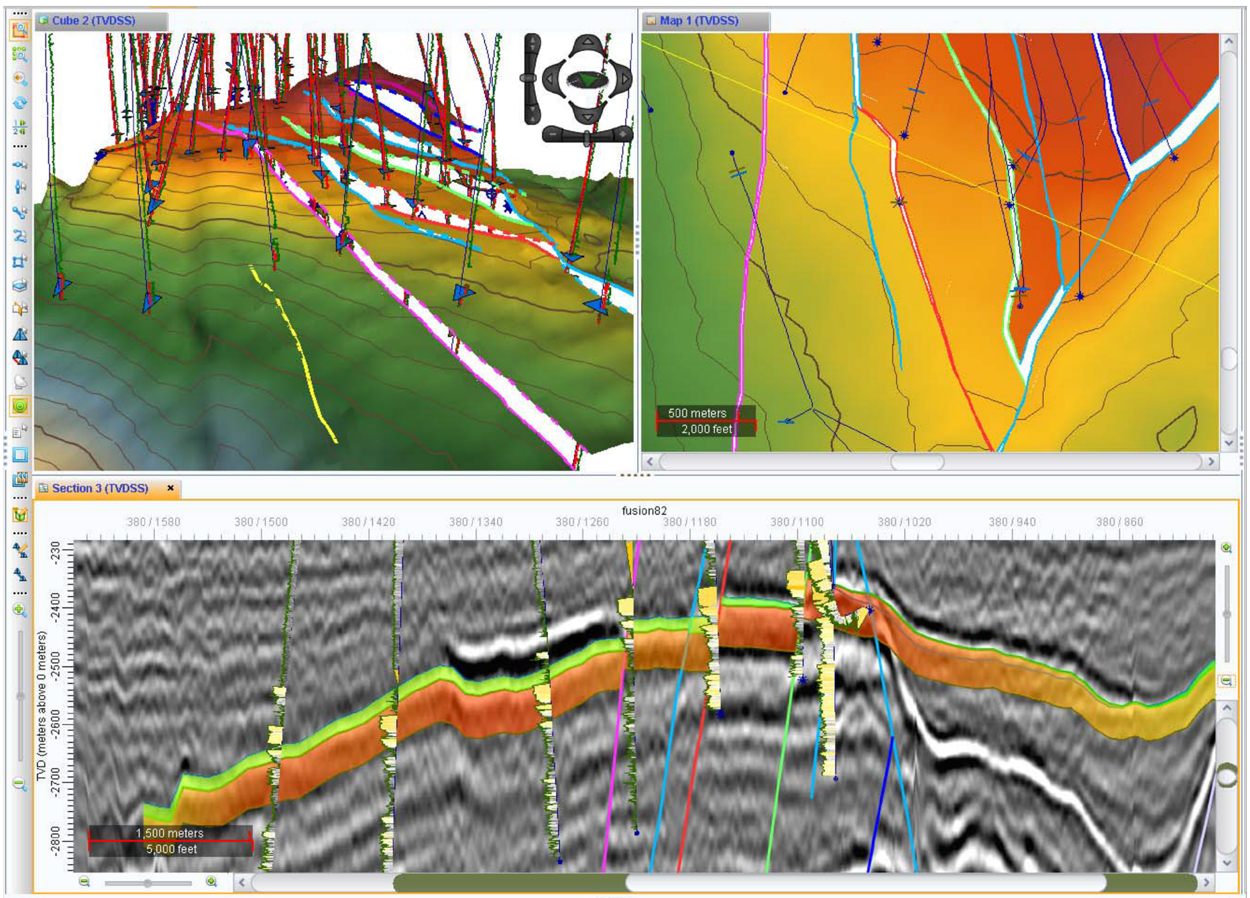


Shows location of gas cap, but not oil pay

Red = high amplitude
Blue = low amplitude

Geological Interpretation and Mapping with DFF

Rather than using a number of independent tools to create a series of maps, in this course you will experience and learn how to use Dynamic Frameworks to Fill, a tightly integrated interpretation and mapping system, to create your maps. This integrated system enables geologists and geophysicists to construct and automatically update multi-surface structural frameworks (i.e. structure maps) and property maps in a straightforward manner. This will be useful for Geosciences interpreters and model-building specialists alike. You will see that the workflow-based approach detailed in this manual automates much of the complex model-building process, and brings advanced structure mapping into the mainstream.



Chapter Organization and Conventions of this Manual

The chapters that compose this manual examine key workflows within DecisionSpace Geosciences.

General Organization of Chapters

Chapters in this training manual conform to the following organizational structure. Topic introductions are useful quick references.

- **Introduction**: The focus and learning goals of the course are defined and exercise topics are introduced. Moreover, diagrams and descriptions define the workflow you will perform
- **Overview**: Overview sections are intended to call attention to the theory and functionality related to the chapter topic. Though some dialogs are displayed, these overview sections are not written as step-by-step exercises. Your instructor may demonstrate the overview material, or may simply ask you to use DecisionSpace to explore the overview topics
- **Exercises**: Exercises are the core of the manual. Most of the manual comprises the detailed steps that are necessary to achieve learning goals. To guide your learning, you will find diagrams and screen captures in abundance. The exercises may include current topic descriptions of varying length, with accompanying notes

Exercises that contain **bold** font require your interaction (with keyboard and mouse). Overviews are for reading.

Note on Exercises

Each exercise comprises a series of steps that build a workflow, helps you select parameters, executes the flow, or analyzes the results. Many of the steps provide detailed explanations of how to correctly select parameters and make good use of the functionality of interactive processes.

The numbered paragraphs are steps that will guide you through the command path. As you proceed through the exercises, note the options that you find on the dialogs, but stay near the prescribed workflow. This will enable you to complete the exercise in the allotted time and produce results similar to those shown in the accompanying figures.

DecisionSpace Geosciences is a sophisticated application with a user-friendly interface. When you work with DecisionSpace Geosciences you will often note that it provides multiple interpretation paths. For the sake of clarity and to keep you moving through the course, only one path, or method, is described in each exercise. The authors hope that after this class you will return to your workplace and explore the solution paths that are easiest and most intuitive for you. To enable you to effectively cover course material we ask that you follow the instructions in the manual and use the solution paths described herein.

As you progress through the exercises, familiar parameters and obvious instructions may not be shown in workflow steps. For instance, in many workflows the instruction to click the OK button after parameter selection is sometimes implied by the context. In these cases we often omit that instruction, to avoid monotony.

The screen captures you will see throughout this manual are chosen to best illustrate the point at hand. Because of variations in path and session state that occurred during the writing of the exercises, screen captures may not always match the image on your monitor. Window size, display scale, colorbar content and limits, interpretation display characteristics, and so forth, can easily be changed. Header text in the main viewer can vary, as the manual uses a few incremental releases of the application.

Personalized Output

In this course you may need to personalize and identify your work. You will save certain data with your initials as part of the output name. This could be a horizon you interpreted, an attribute volume you generated, or a session file. For example, if your name is Aaron Buster Chapman, you might save some of your data by naming it ABC. The creators of this manual don’t know your name, so we use the letters “YOU” to refer to your initials. When you see the letters “YOU,” substitute your initials.

Interpretation ID automatically generates data versions in OpenWorks. The use of five alpha-numeric characters in data-version nomenclature is mandatory at the start of your session. For this manual, it is 01STA. Do not assume that by adding your initials, or interpretation ID, to the name of an entity you define the data as yours. Including your initials in the data name only assists you in the selection of data, not in defining ownership. Ownership is defined through the interpretation, also known as interpreter.

By using your initials you make your saved sessions easy to identify. In addition, your horizons and other interpretations will be easy to find among the other files that are saved in this project.

The session (saved-state) files are very helpful if you go astray in one of the exercises or encounter a hardware or software problem. If either of those circumstances occurs you can restart your session at your previous saved point.

The manual uses the following common conventions in describing how to access and use various features of DecisionSpace Geosciences. You are probably familiar with most of them.

Conventions of this Manual

Windows, dialogs, and boxes	DecisionSpace Geosciences has user interfaces that appear as windows on your workstation. The terms ‘window’ and ‘dialog’ are often used interchangeably, but the term dialog is usually reserved for windows that require user interaction in the form of parameter selection or information input. ‘Box’ is usually a smaller window, such as a warning box or message box. ‘Box’ can also be an area inside a window that is defined by a rectangular line.
Dialog Names	The titles of windows, dialogs, some tabs, and occasional boxes are *italicized* when they appear in text. Typically, dialog names appear in a bar at the top of a window (this is also known as the window title).

Mouse Buttons **MB1**, **MB2**, **MB3**	The manual does not instruct you to press mouse buttons. Instead, you will see instructions to click or use MB1, MB2, or MB3, where MB1 is mouse button 1, and so forth. Mouse buttons are numbered from left to right. **MB1** means click the left mouse button, **MB2** means click the middle mouse button, **MB3** means click the right mouse button. If your computer is set up for a left-handed mouse, the mouse buttons are reversed in direction. Mouse buttons may not work properly if Caps Lock or Num Lock are on. **MB1** is used for most selections.
Menu Options	Menu options and push-button names are bold when they appear in a step (an instruction for an action). For example, when you see the instruction "**Close** the dialog," it is an instruction to click the Close button.
Type or enter	Type all terms that appear in quotes and bold. For example, when you see the expression, *Enter "***2300***" in XYZ field,* you should type 2300 in the prescribed place. Context will often suggest that you need to change an instruction. For example, when you read "**YOURINITIALS**" or "**YOU**", you are expected to type your initials.
<**key**>	Press the indicated key on the keyboard. For example, <**Enter**> is an instruction to press the Enter key.
Select, Click, Choose, or Highlight	Move the cursor to the specified option or object and press, then release, the mouse button. Unless otherwise specified, use **MB1**.
Click and drag	Press the mouse button and hold it down while moving the cursor. Then release the button. This is also called press and drag, or **MB1-drag**.
Shift and drag	Hold the shift key while pressing the mouse button. Hold the mouse button down while moving the cursor around the option you want, then release the button.
Double-click	Click the button twice, rapidly, without moving the mouse. The first click highlights the option or object beneath the cursor; the second click is equivalent to pressing the **OK** button to accept the selection.
Conditions for bold font	We use bold font to make the exercises easier to follow. Bold text means the text is an instruction that requires user action, such as an instruction to click a button or an icon, enter text, highlight list items, and so forth.

Chapter **1**

Seismic QC and Enhancement

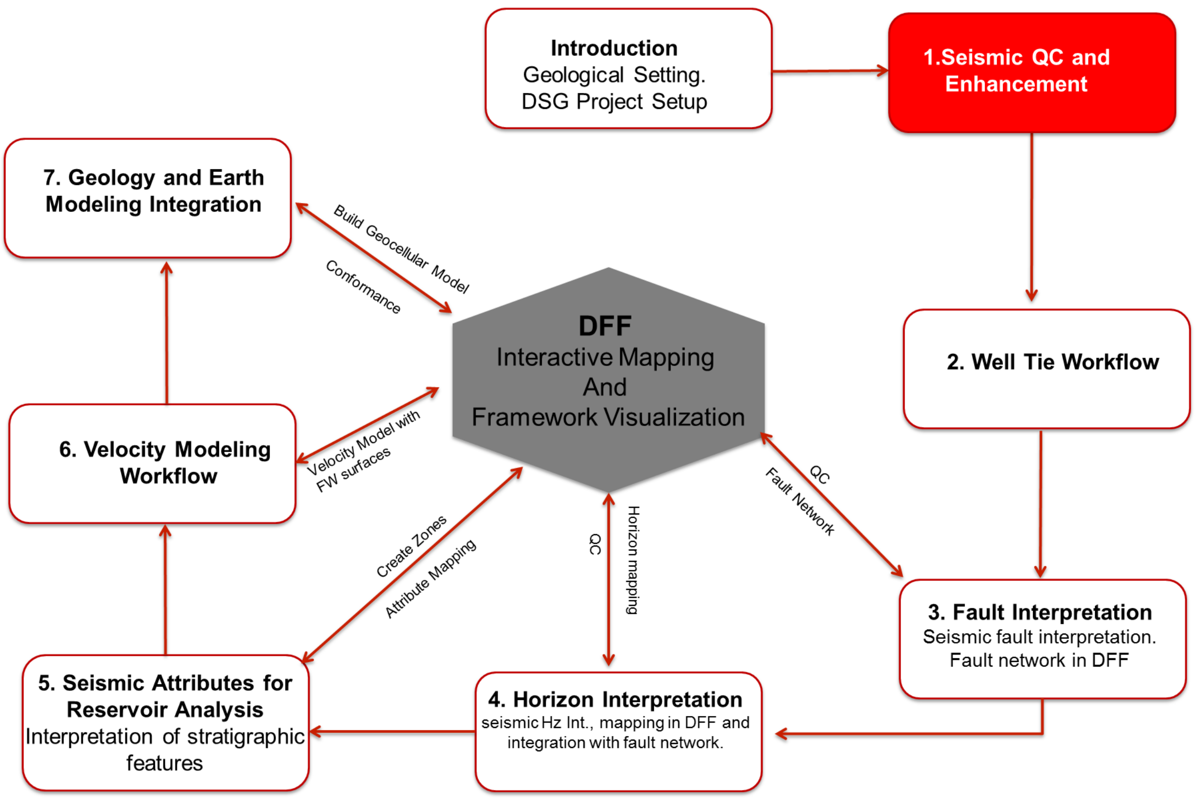
The main focus of this chapter is to expose seismic interpreters to some of the tools available in DecisionSpace Geosciences to QC the stacked seismic data before starting their interpretation. Detecting anomalies in the seismic data in the early stages can save enormous amounts of time for the interpreters. Once the stacked seismic data has been validated, the second goal is to show how the interpreter can improve the quality of the seismic before starting the structural interpretation. This is done by improving the quality of the seismic, which allows horizons and faults to be highlighted more. Also, generating seismic attributes on the improved volume will reveal anomalies, stratigraphic changes, geobodies, etc., clearer than performing them on the original volume. Finally, you will learn how to QC 2D seismic lines using 3D seismic as reference and apply a bulk shift to the 2D lines.

Overview

In this chapter, you will learn to:

- Display and manipulate prestack data
- Generate a structural filter volume
- Generate a discontinuity volume
- Use the Mistie Correction - Bulk Shift functionality

Workflow


Introduction
Geological Setting.
DSG Project Setup
1.Seismic QC and Enhancement
2. Well Tie Workflow
3. Fault Interpretation
Seismic fault interpretation.
Fault network in DFF
4. Horizon Interpretation
seismic Hz Int., mapping in DFF and integration with fault network.
5. Seismic Attributes for Reservoir Analysis
Interpretation of stratigraphic features
6. Velocity Modeling Workflow
7. Geology and Earth Modeling Integration
DFF
Interactive Mapping
And
Framework Visualization
Build Geocellular Model
Conformance
Velocity Model with FW surfaces
Create Zones
Attribute Mapping
QC
Horizon mapping
QC
Fault Network

Using Prestack Seismic Gathers for QC and Inspection of Amplitudes

The use of prestack seismic data is becoming more popular with seismic interpreters. Many problems related to data and processing are hidden in the stack volume. Prestack data lets the interpreters validate things like:

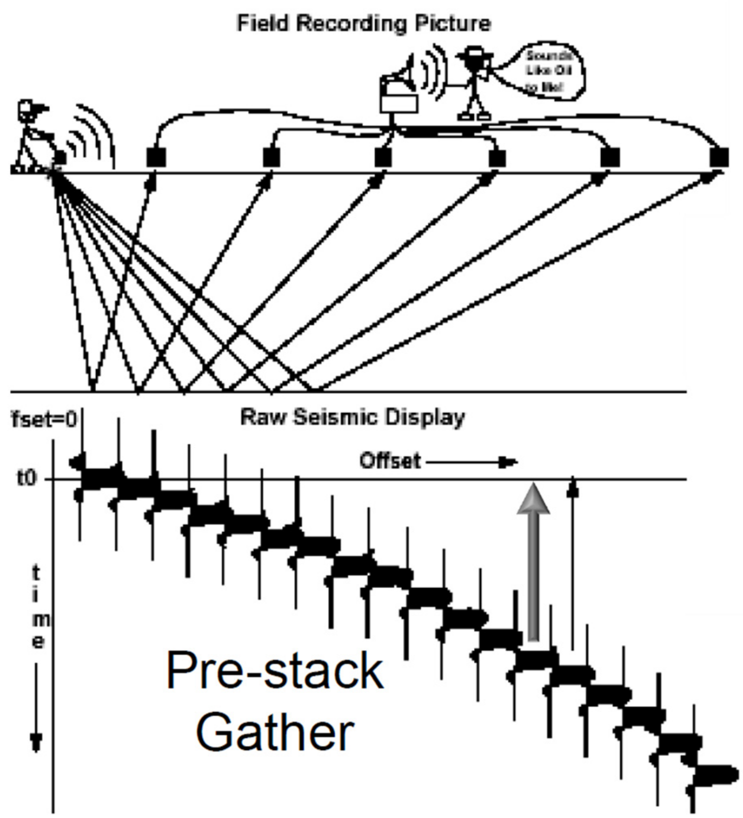
- Was NMO/RMO stretch properly applied?
- Does the seismic have good offset coverage?
- Was the noise properly handled? How severe was the mute?
- Is there any AVO relations?

If there are wells in the area, then the interpreter can check prestack gathers around them to start understanding fluid or lithological changes.

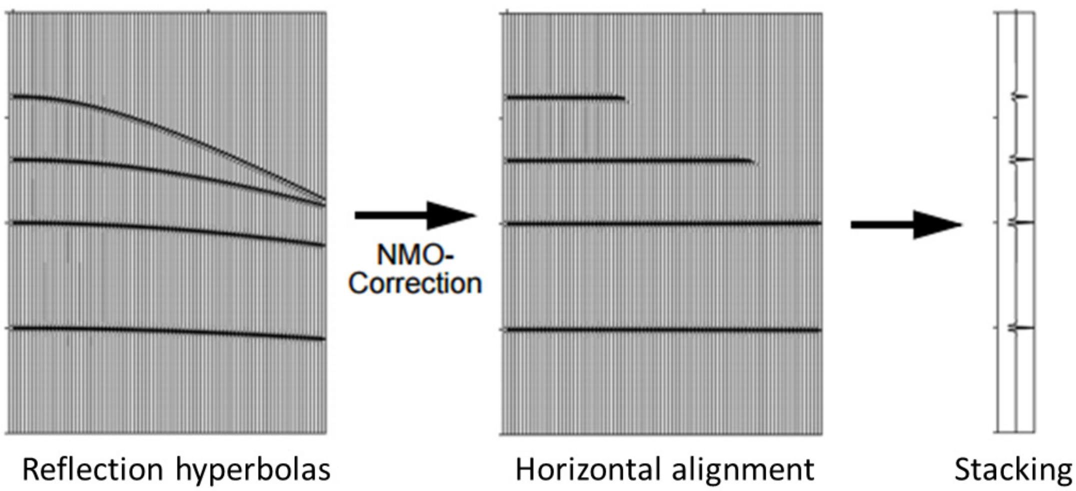
The seismic interpreter does not necessarily have to be an expert in prestack workflows like AVO, AVA, Fluid Substitution Analysis, etc., but a basic understanding can help to detect if the stack seismic is in good shape to use for interpretation, especially at the reservoir level. DecisionSpace Geosciences makes it simple for the interpreter to bring the prestack gathers in their same interpretation environment.

> **Note**
>
> In this section, you will use prestack seismic data only for QC purposes. If you are interested in a detailed class about prestack concepts and software, we recommend the Landmark class: *Well Seismic Fusion: Introduction to Lithology and Fluid Prediction*.

The picture below represents how the waves are being reflected over the same horizon and arriving to the different receptors. The difference in offset and travel time is the reason why the gathers representing the horizon are not flat, but rather hyperbolic.



Velocity analyses are necessary to align the reflectors. The picture below shows the principle of Normal-Moveout (NMO) correction. The reflections are aligned using the correct velocity, so that the events are horizontal. Then, all the separate traces are summed together (stacked).



Van der Kruk, J. (2001). Reflection seismics 1. Institut fur Geophysik, Zurich, CH, 61 pp

The travel time curve of the reflections for different offset between source and receiver is calculated by the formula:

$$t^2 = t_0^2 + \frac{x^2}{v^2_{stack}}$$

The NMO correction can be derived and is giving by:

$$\Delta t = t_0^2 - t(x)$$

with:

$$t(x) = \sqrt{t_0^2 + \frac{x^2}{v^2_{stack}}}$$

The Moveout ΔT is the difference in travel time for a receiver at a distance x from the source and the travel time t_0 for zero-offset distance.

When doing quality control on your seismic after applying a NMO correction, if your reflection curves upwards, the velocity was too low. On the other hand, if the reflection curves downwards, the velocity was too high, either case causes an improper correction to the seismic. If the interpreter detects something like this in the reservoir area, then it is a sign the seismic has to be sent back to the seismic processor. Once the issue is corrected, it is safe to start the interpretation process.

The concept of Residual Moveout (RMO) corrections is similar to those of NMO. One cause for RMO is if there was a NMO correction that did not properly adjust for non-hyperbolic moveouts or anisotropy.

The assumptions made for a RMO correction are valid in circumstances of a constant velocity earth and a migration velocity that is not far off. There are several common situations that need to be considered that may cause errors when applying an RMO correction, like: a layered earth with varying vertical velocities, encountering anisotropic material, and spatial velocity changes (e.g., statics and buried velocity lenses).

RMO corrections are most effective after time or depth migrations have been performed on the prestack data.

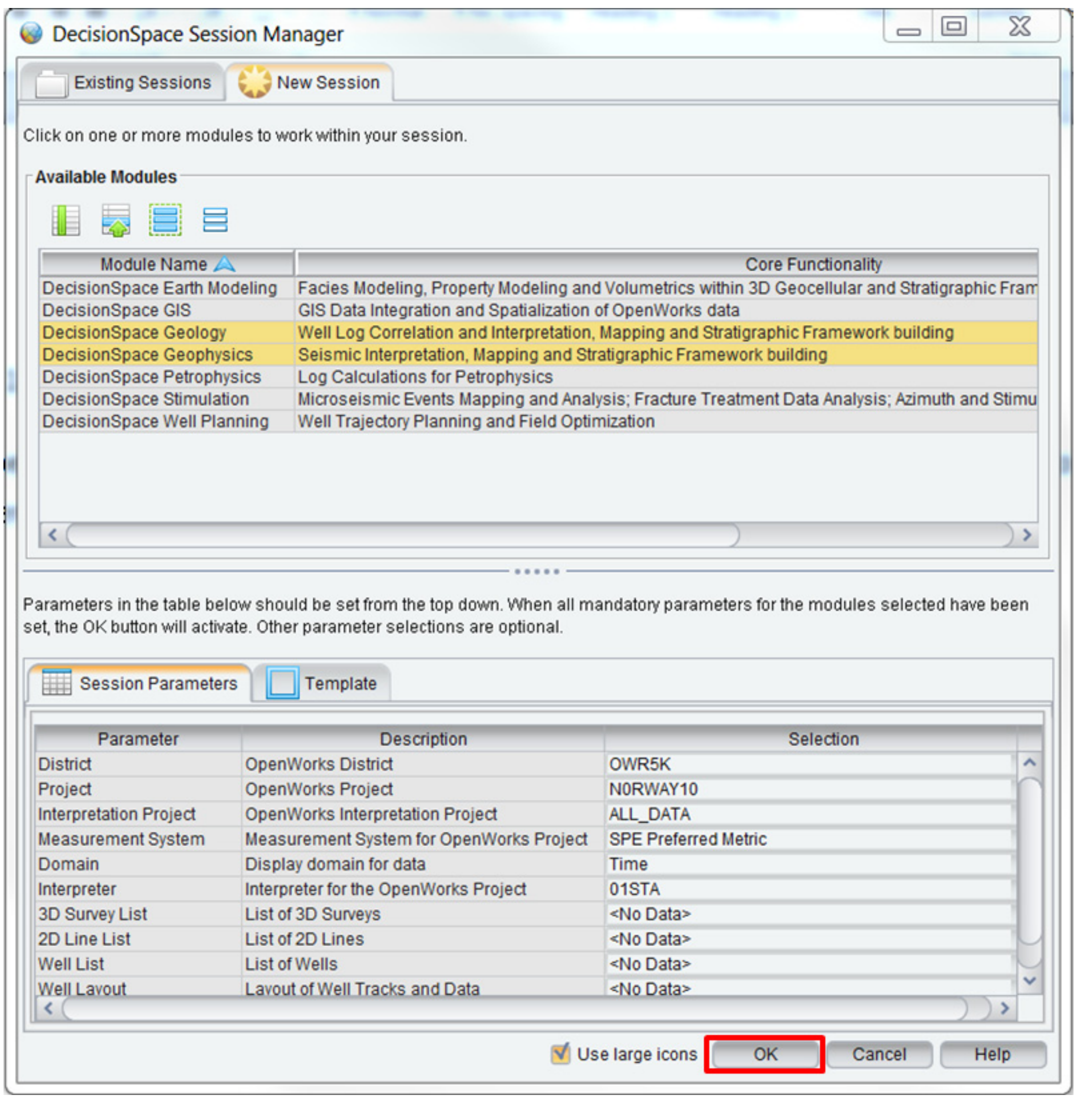
Mute is the process in which part of the prestack data is zeroed to account for unnecessary data. It is important to consider the amount of mute that is applied to the prestack data to ensure that the poststack data has been processed properly.

Mute is used in several different cases, for instance, to remove noise caused from the early arriving surface waves, as well as to remove the stretched data from applying an NMO stretch. Typically, muting is directed towards both lower frequency and long-offset traces.

Exercise 1.1: Manipulating and Displaying Prestack Data

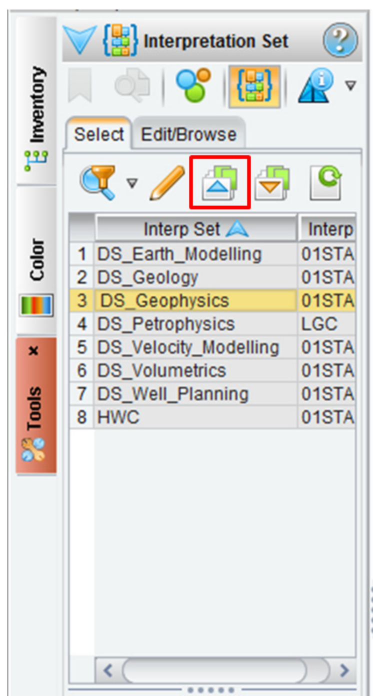
Being able to view your prestack data has many advantages including: ensuring that the seismic volumes that you will make all of your interpretation on are correct and being able to recognize potential areas of hydrocarbons. In the following exercise, you will learn the steps to view your prestack seismic data in DecisionSpace Geoscience.

1. Open the *DecisionSpace Session Manager* and select the modules and session parameters identified in the following image, and click **OK** to start your session.

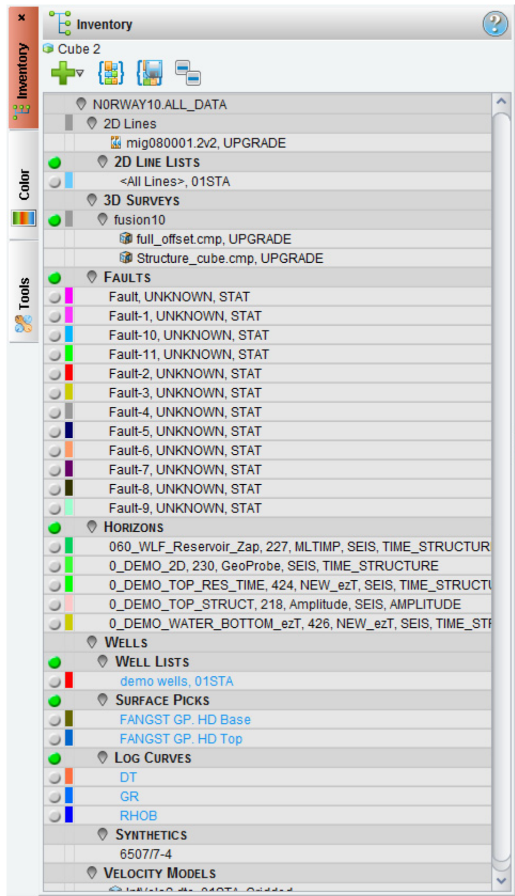


2. Once your session opens, click the **Interpretation sets from Tools taskbar** ( ) icon at the top of your *Inventory*. This opens the *Tools* task pane.

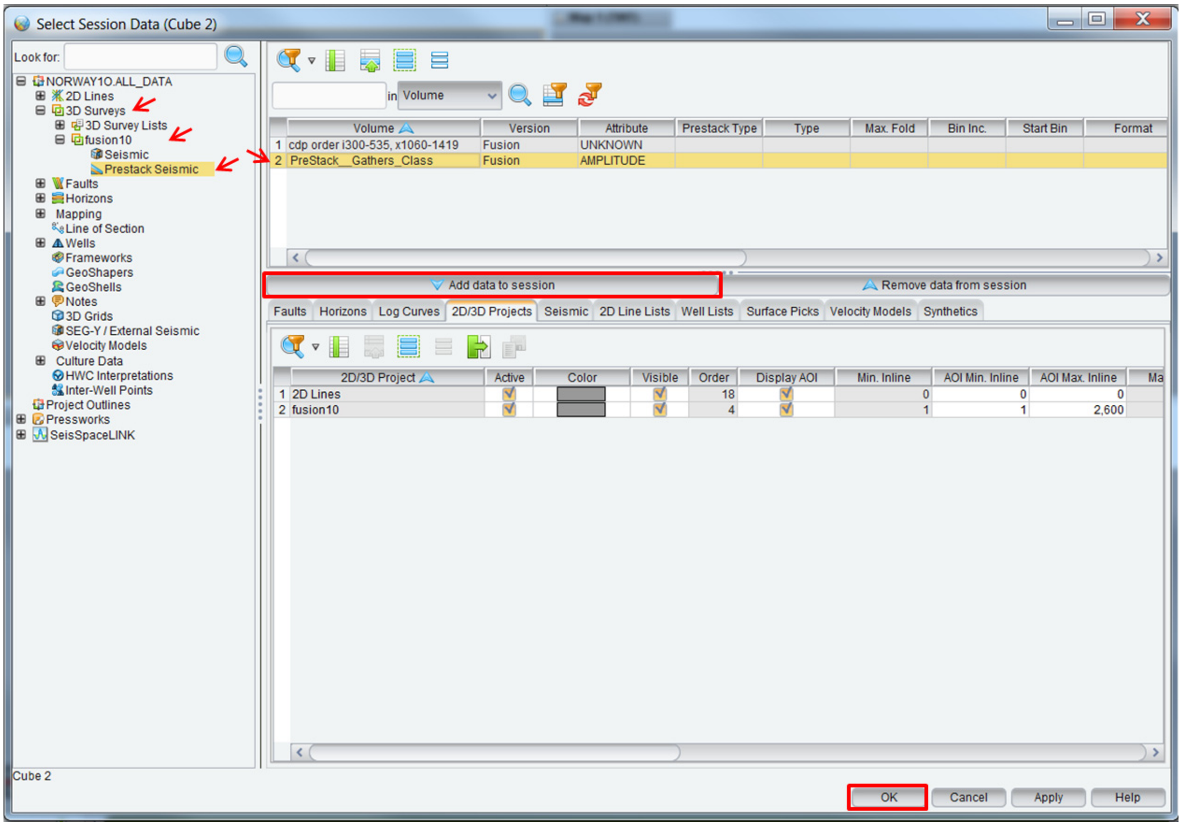
3. Select the **DS_Geophysics** ISet, and click the **Load Data To Session** ( ) icon.



Loading data into your session from an ISet is helpful for a quick start up when opening a new session. The ISet contains a list of the majority of the data objects you will need for the following exercise.



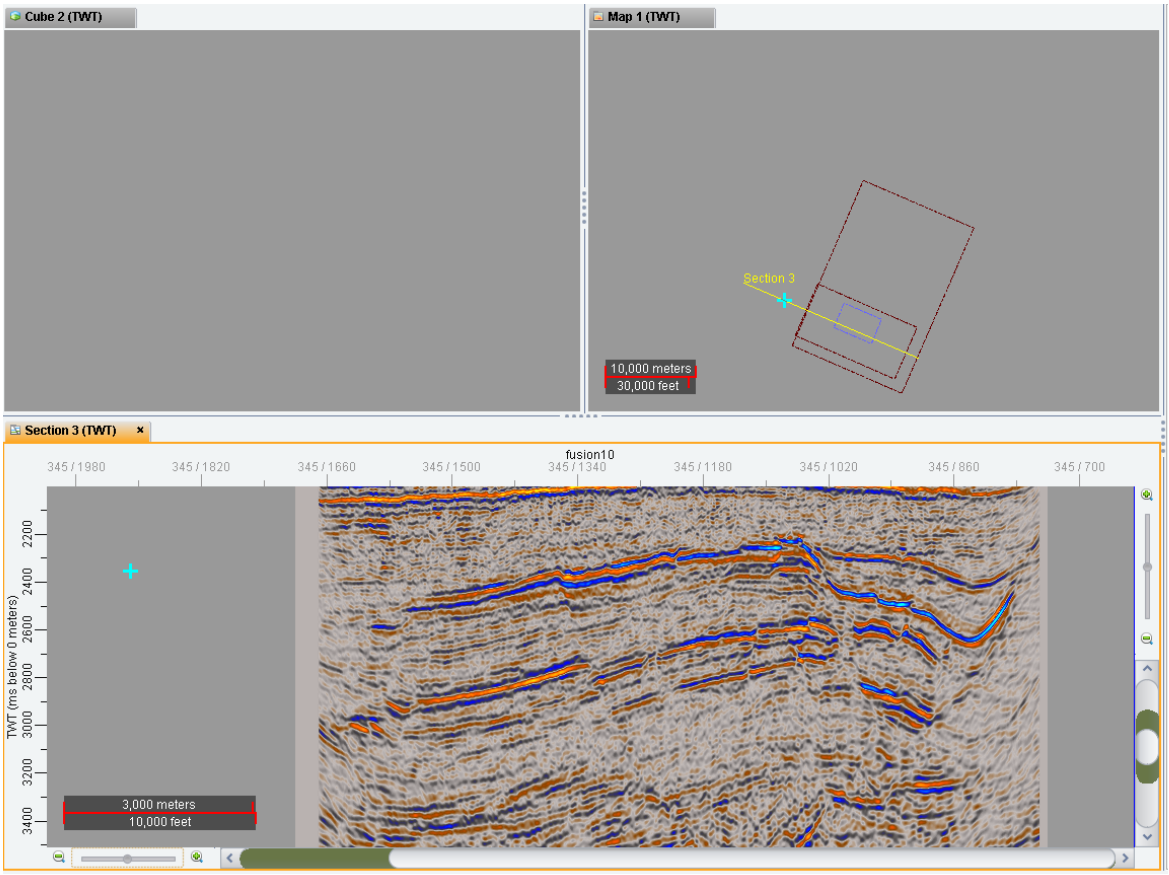
4. Click the **Select Session Data** ( ) icon in the main toolbar. In the *Select Session Data* dialog, select **3D Surveys > fusion10 > Prestack Seismic**. Select **PreStack_Gathers_Class** and click **Add data to session**. Click **OK** to close the dialog.



> **Note**
>
> If your gathers aren't found you may have to manually point OpenWorks to where your gathers are located. Ask your instructor for help on the file location.

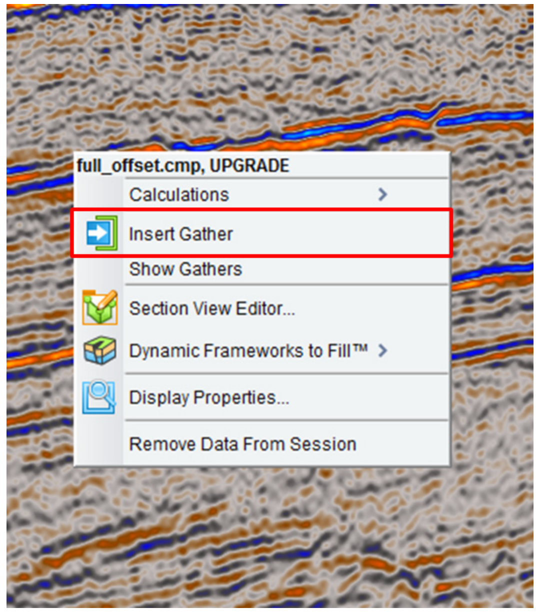
5. Activate your *Section* view. In the *Inventory* task pane, select the **full_offset.cmp** seismic volume, and drag-and-drop it in to your active *Section* view.

Dragging and dropping a seismic volume in to *Section* view automatically displays the IL at the center of the survey, as you can see in *Map* view.



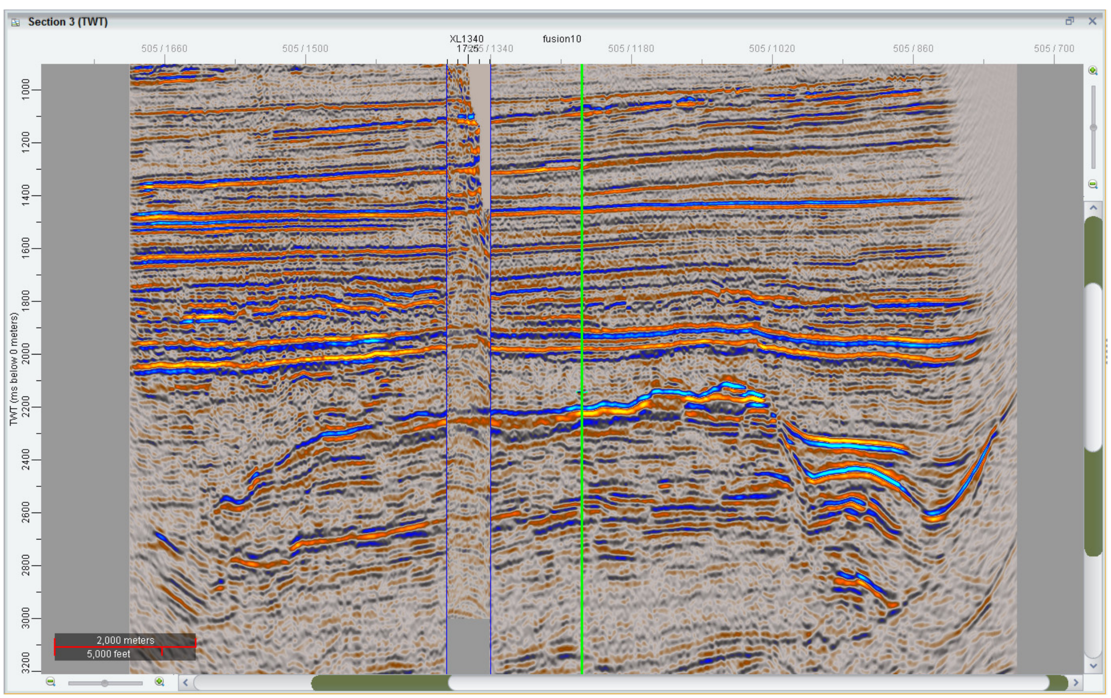
6. Maximize *Section* view by double-clicking the tab, and from the *Frame Control* toolbar change the *Current Inline* field to show **IL 505**.

7. To view the prestack gathers that make up the full_offset.cmp volume, in the section **MB3** and select **Insert Gather**.



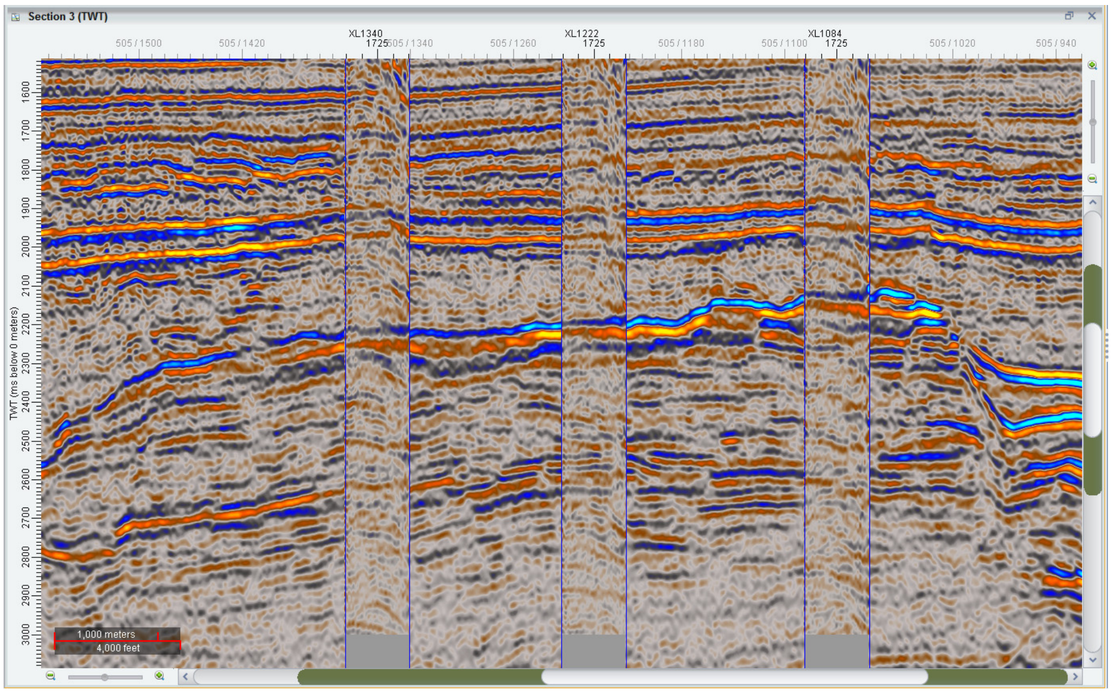
A gather will appear where you clicked MB3 in *Section* view.

8. If the gather is not placed in the right location, you can move it by clicking **MB1** and dragging.



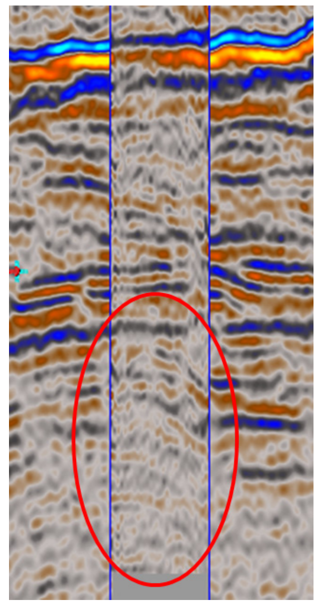
A green line appears on the XL or IL that the gather will be displayed for after it is moved, as seen in the picture above. The gather you see is the prestack data that was combined to make one trace for a specific IL or XL. As you can see with the currently displayed gather, the information located in the header shows that this is the prestack gather for XL 1340.

9. Compare several other gathers to your seismic volume by clicking **MB3** and selecting **Insert Gather**. This will not remove the previous gather, but add another one.

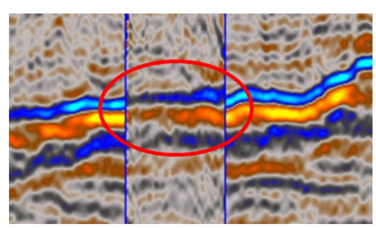


It is very important to make sure that the prestack gathers match well in your area of interest. If the gathers show a mismatch with the reservoir, then it is likely that you need to have your seismic volume reprocessed before beginning interpretation. If you make your interpretation on badly migrated seismic, your interpretation will be flawed.

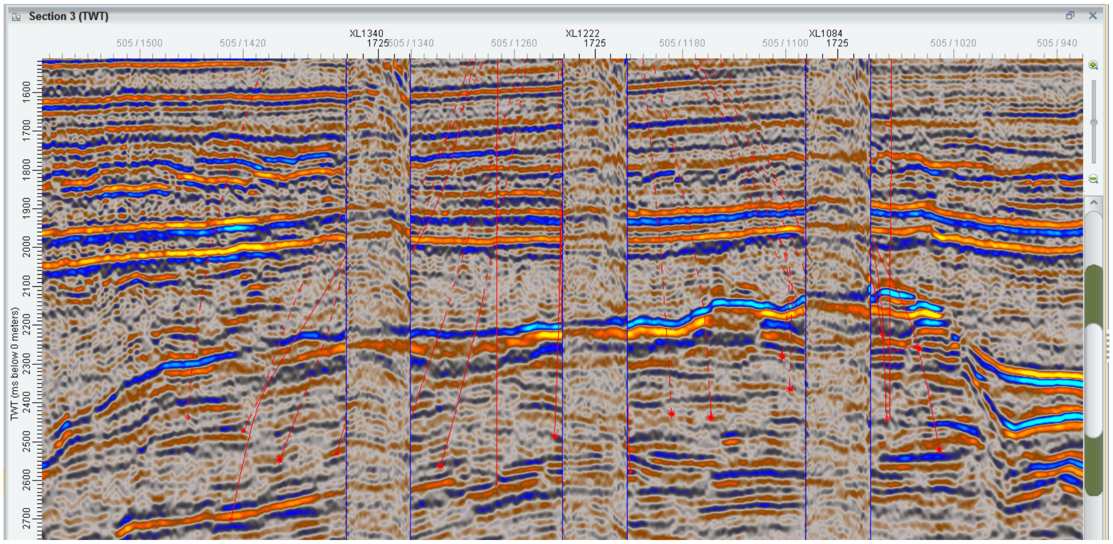
Notice in the area below the reservoir the far offset gathers are much lower than the near offset gathers. This dipping down is potentially an indication of a bad migration, probably due to a bad NMO correction in that area. If this were to be the area of interest, you would need to send your seismic back to be reprocessed. Since the seismic within the reservoir area has been correctly processed it is fine to continue with the seismic volume you have.



The gather for XL 1222 exhibits a typical characteristic found with AVO analysis. Typically, when looking at prestack seismic you expect to see diminishing amplitudes with an increase in offset, but in the case of the gather for XL 1222, the far offset is showing higher amplitude than that found in the near offset suggesting an AVO effect within that area.

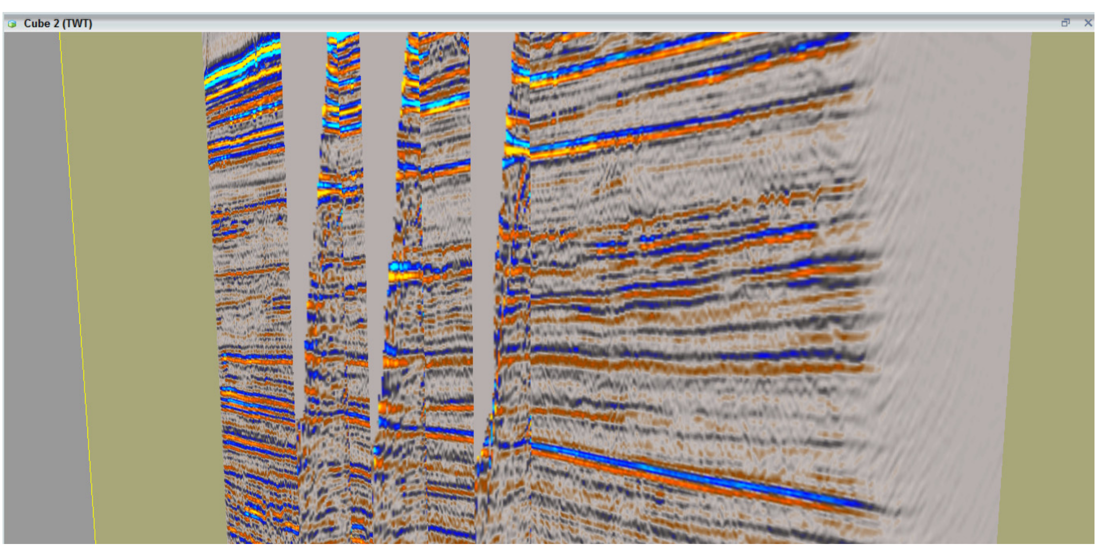


10. If you turn on the wells in the area, you will see a correlation between those wells that have produced and the areas that are exhibiting what looks to be an AVO effect. Go to the *Inventory* task pane and toggle on the **demo wells** well list.

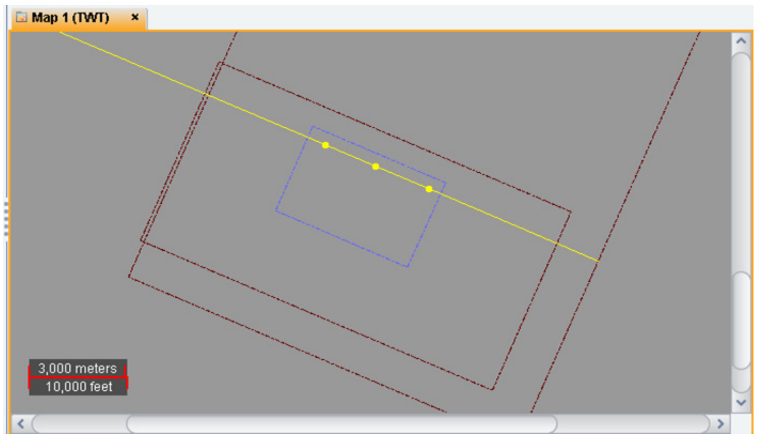


You will explore this in more detail by generating attributes and performing volume math in one of the following chapters. Also, as mentioned in the Introduction you can also take the class, **Well Seismic Fusion: Introduction to Lithology and Fluid Prediction**.

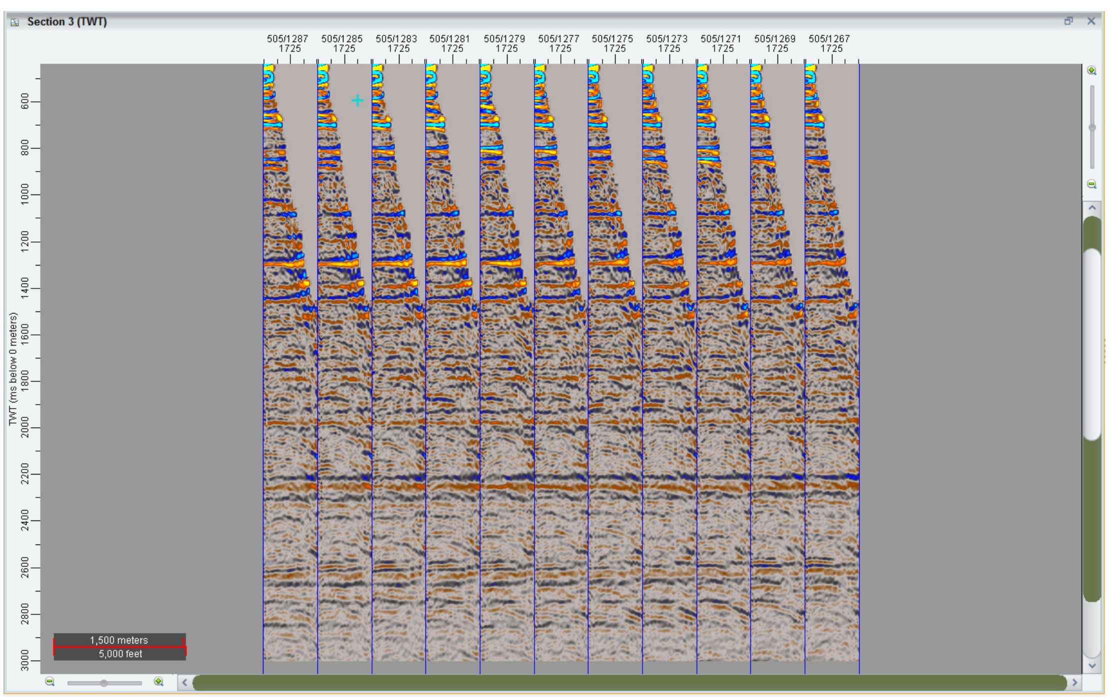
11. You can display your section and the gathers in 3D as well. Activate *Cube* view and from the *Inventory* task pane, toggle on **Active Section**.



12. Experiment with adding more gathers and moving them around in *Section* view. You will notice that the *Cube* view displaying the active section automatically updates as well.

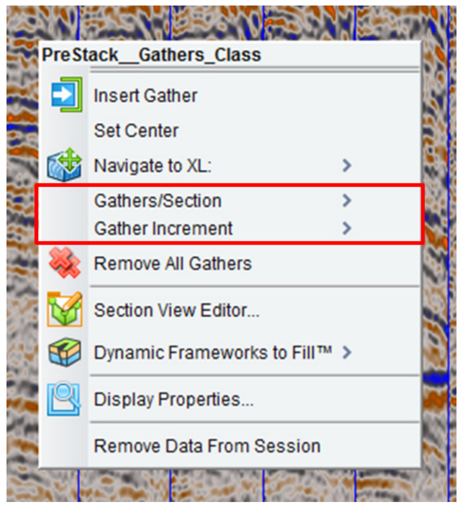
> **Note**
>
> You can also see the update of the gathers in *Map* view if the Active Section is displayed there as well.
>
> 
>

13. You also have the ability to display all of the gathers at once. Activate and maximize *Section* view, **MB3** on the seismic and select **Show Gathers**.

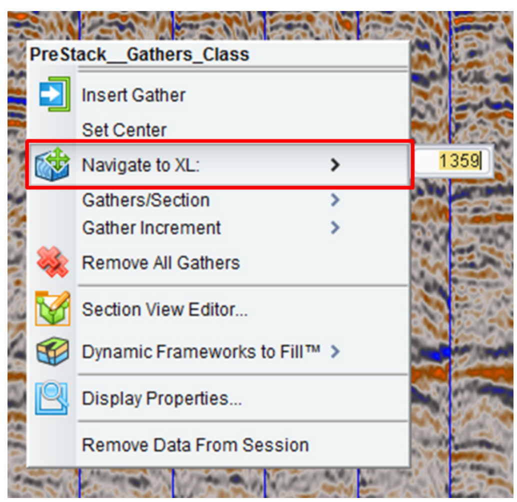


If you **MB3** on the gathers, you can designate multiple viewing parameters for them, including:

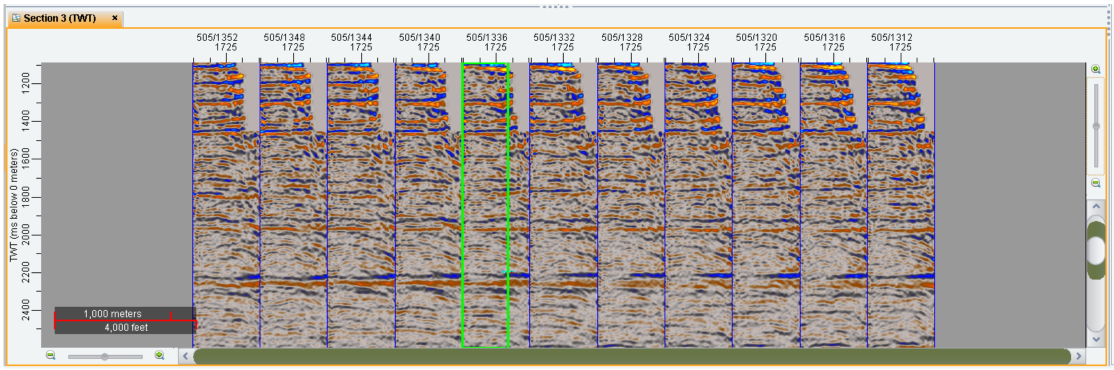
- Gathers/Section—Changes the number of gathers you want to display in *Section* view.
- Gather Increment—Changes how often you want to display a gather. The default setting is 2. For example, you can set the Gather Increment to 10 and cover a larger area than if you were to use the default.



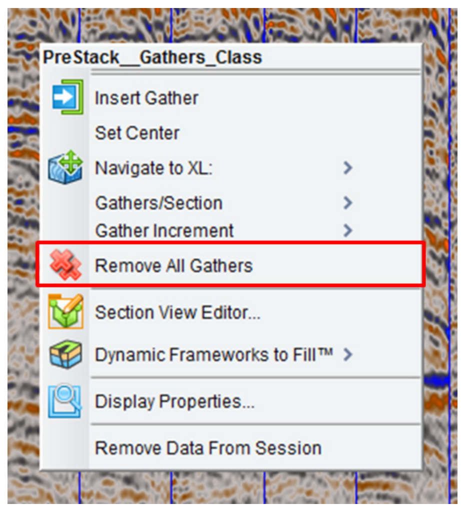
If you **MB3** on the gathers and select **Navigate to XL**, you can type in the specific XL you wish for that gather to be. You can also do this to the single gathers that you displayed on the seismic earlier.



14. Place the cursor at the edge of the track and **MB1-drag** to adjust the width to change the width of the gather track.



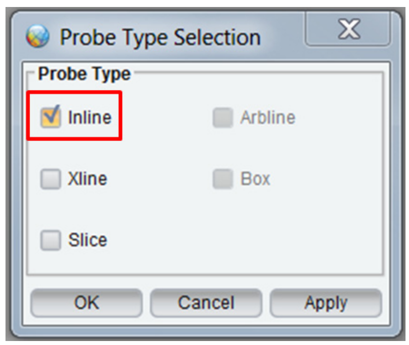
15. Before continuing to the next exercise, you need to clean up your view. **MB3** and select **Remove All Gathers**.



Exercise 1.2: Attribute Generation for Interpretation Enhancement

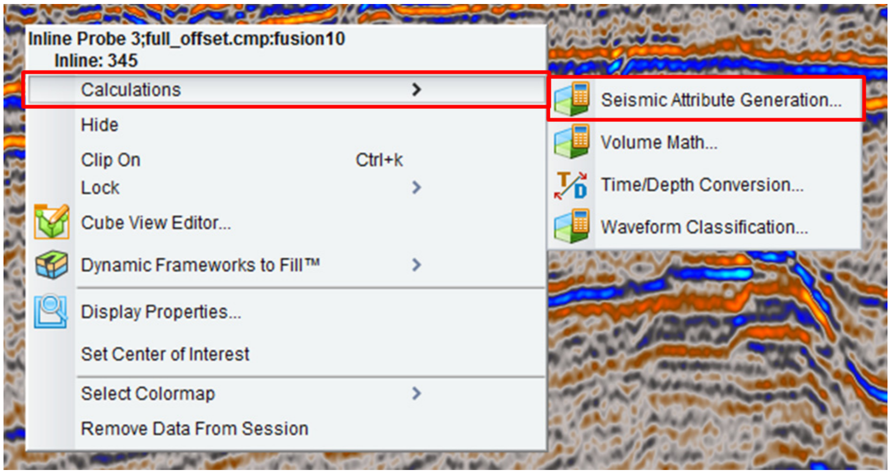
In the previous exercise, you performed a QC of the full_offset.cmp volume by looking at the raw data (prestack gathers) that make it up. Now that you have ensured that the seismic in the reservoir area is correct, you may want to reduce the noise within the volume to aid in your interpretation. This can be done by using a structural filter to smooth out the volume and make the structural features more clear within the seismic. In the following exercise, you will learn how to create an enhanced seismic volume, and observe the differences made when using the enhanced volume.

1. Activate and maximize *Cube* view. In the *Inventory* task pane, toggle off the **Active Section**, then select the **full_offset.cmp** volume and drag-and-drop it into your *Cube* view. In the *Probe Type Selection* dialog, select only **Inline**. Click **OK**.



You will use this inline as a reference for comparing the improvements made by running a structural filter on the volume.

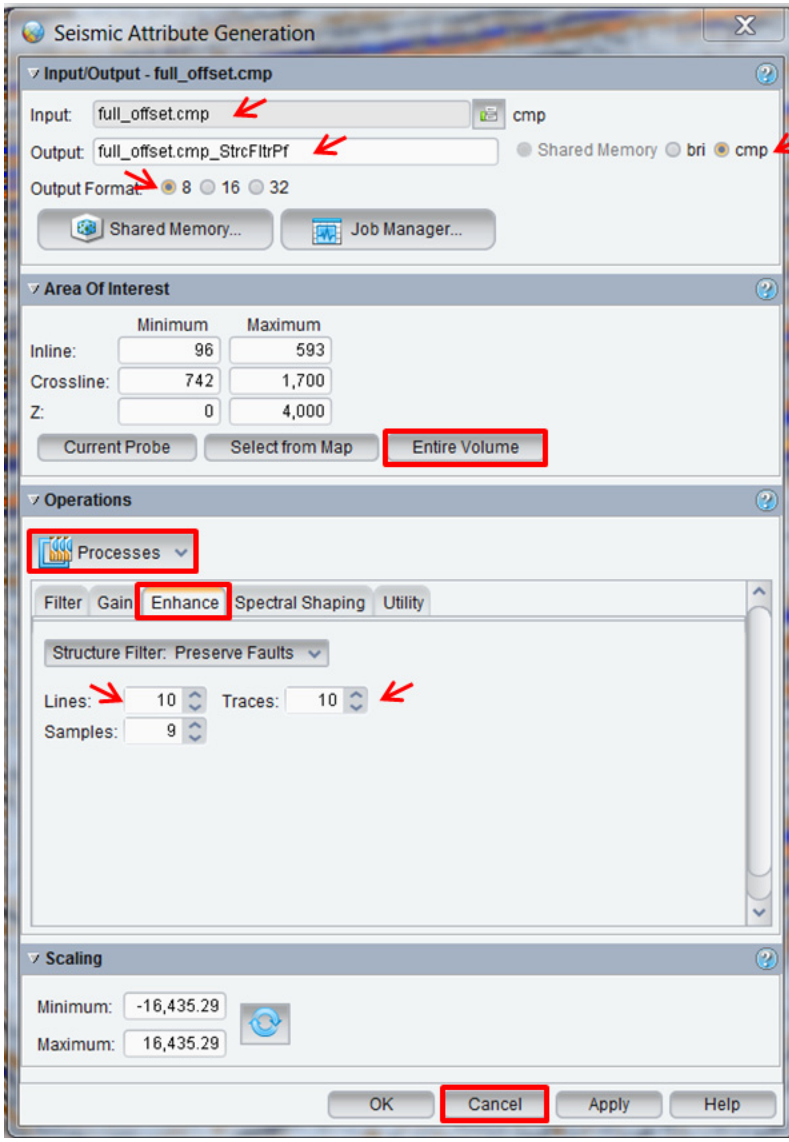
2. **MB3** on the inline and select **Calculations > Seismic Attribute Generation**.



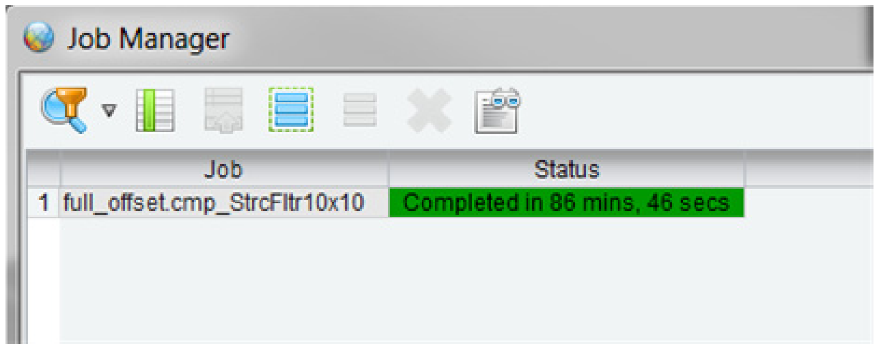
3. In the *Input/Output* panel of the *Seismic Attribute Generation* dialog, ensure that the **full_offset.cmp** volume is selected as the *Input*, and change the name of the *Output* volume to "**full_offset.cmp_StrcFltr10x10**". Change the type to **cmp**, to ensure that the volume does not take up too much memory, and for the same reason choose the *Output Format* of **8** bit.

4. In the *Area of Interest* panel click the **Entire Volume** button to set the minimum and maximum faces to match the extent of the volume, and therefore perform the filter on all of the seismic.

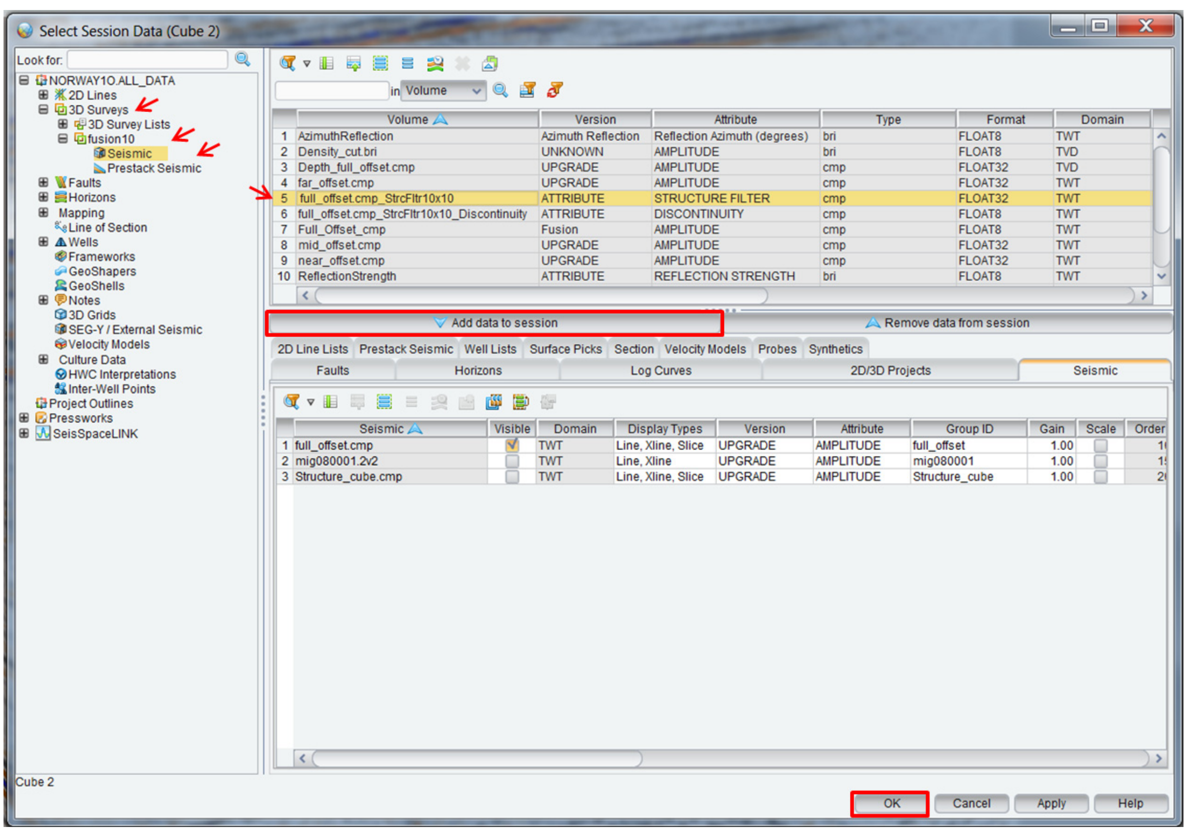
5. In the *Operations* panel, select **Processes** from the drop-down menu, and then select the **Enhance** tab. From the drop-down menu, select **Structure Filter: Preserve Faults**. This will run the structural filter on the volume while making sure to not smooth over discontinuities in the reflectors that show displacement. For the *Lines* and *Traces* fields, input “**10**” for both.



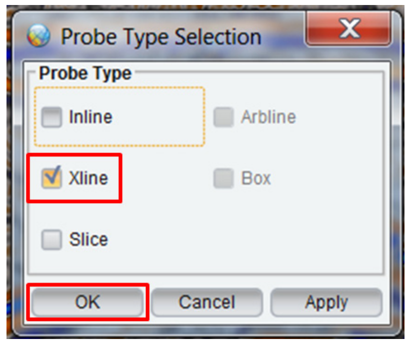
6. **Do not click OK**. When you have filled out all of the parameters click **Cancel**, these steps are here only to show you the process of how the structural filter is created. If you were to click OK, the *Job Manager* dialog would appear showing the process' status, and the total run time to create the attribute as shown in the picture below. As you can see, running this attribute on the entire volume took nearly an hour and a half to create. For time management purposes, the full_offset.cmp_StrcFltr10x10 has already been created and included in the project dataset.



7. Open **Select Session Data**, select **3D Surveys > fusion 10 > Seismic > full_offset.cmp_StrcFltr10x10**, and click **Add data to session**. Click **OK** to close the *Select Session Data* dialog.

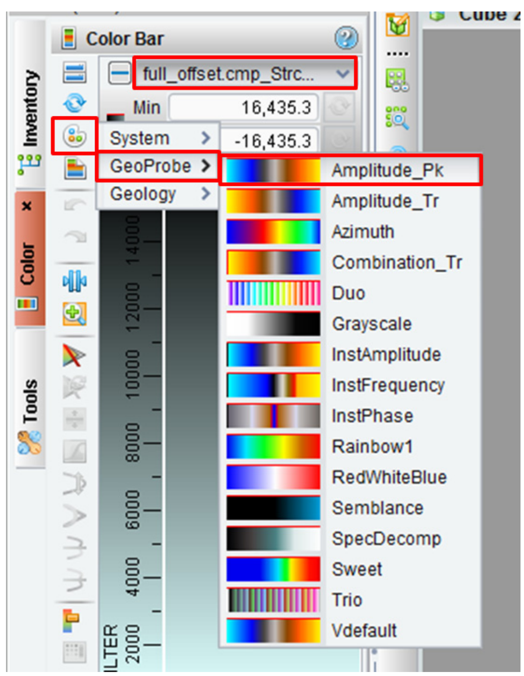


8. Highlight the **full_offset.cmp_StrcFltr10x10** in your *Inventory* task pane, and drag-and-drop it in to your *Cube* view. In the *Probe Type Selection* dialog choose to create an **Xline** probe and deselect the option to create an Inline probe. Click **OK** to create the probe and close the dialog.

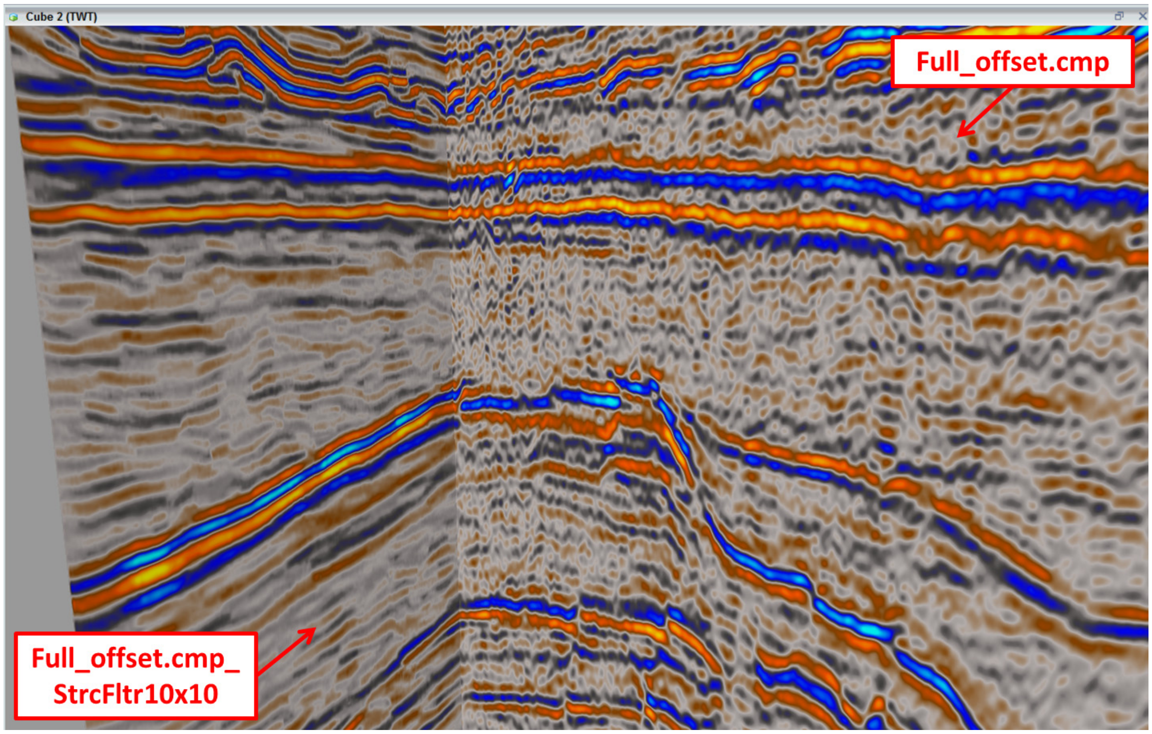


The default color map of the full_offset.cmp_StrcFltr10x10 is different from the full_offset.cmp, and should be changed so you can compare the two volumes to each other easily.

9. Navigate to the *Color* task pane, select **full_offset.cmp_StrcFltr10x10** from the drop-down menu, and then click the **Select Color Map** ( ) icon. From the pop-up menu, select **GeoProbe > Amplitude_Pk**.



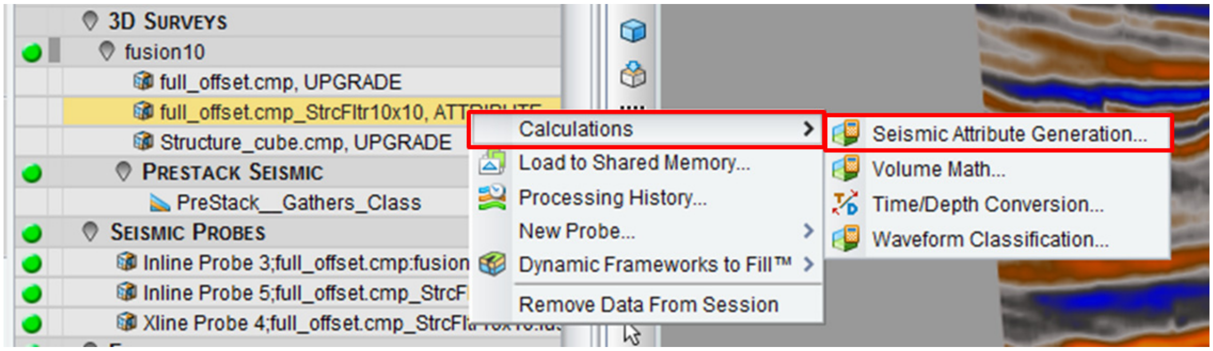
Notice the differences between the two volumes. The full_offset.cmp_StrcFltr10x10 is significantly smoother, and it is much clearer where there are definite breaks in the seismic.



10. Move both of the probe faces around to continue to compare the differences between the two volumes. If you have time, you can create other probes as comparison as well.

Now that you have created an enhanced seismic volume, it will not only make interpretation on this horizon easier, but any attributes that you create from it should also be clearer. In the following steps, you will create a discontinuity attribute from the full_offset.cmp_StrcFltr10x10 volume.

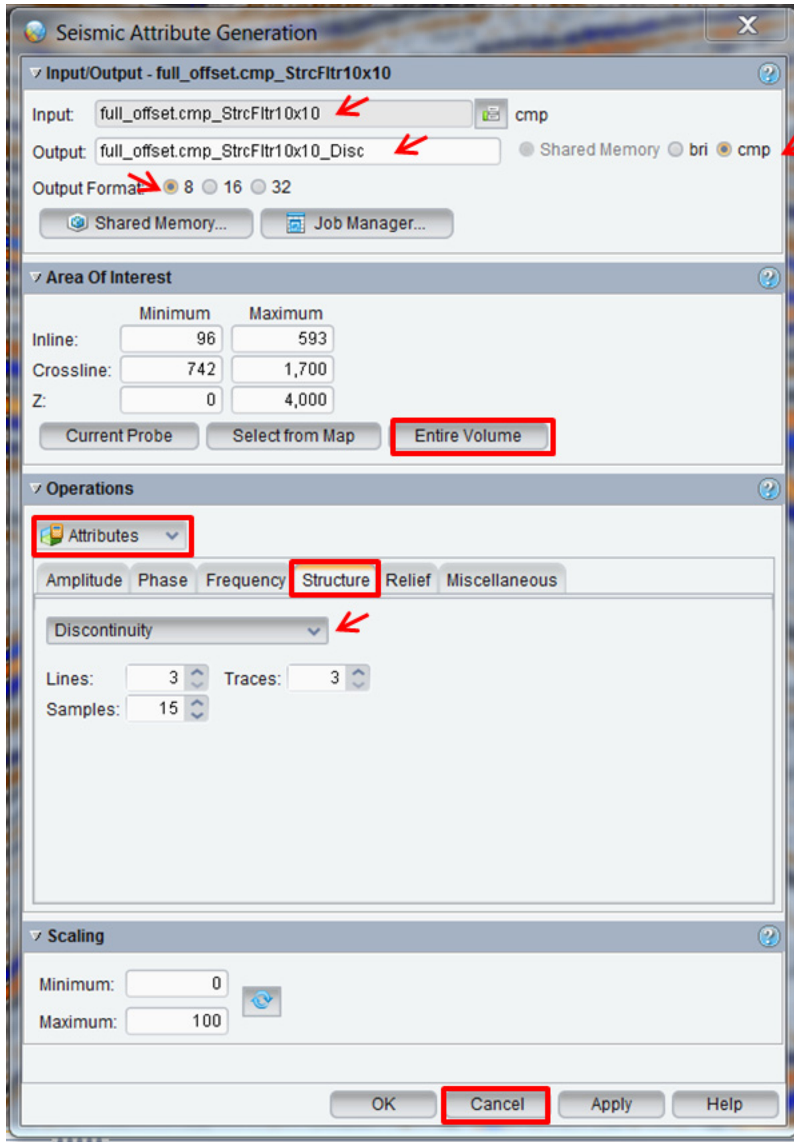
11. From the *Inventory* task pane, select **full_offset.cmp_StrcFltr10x10**, **MB3** and select **Calculations** > **Seismic Attribute Generation...**.



12. In the *Seismic Attribute Generation* dialog, ensure that **full_offset.cmp_StrcFltr10x10** is designated as the *Input* volume, and accept the default *Output* name. Like the previous attribute, make sure you are generating a **cmp** with an *Output Format* of **8** bit.

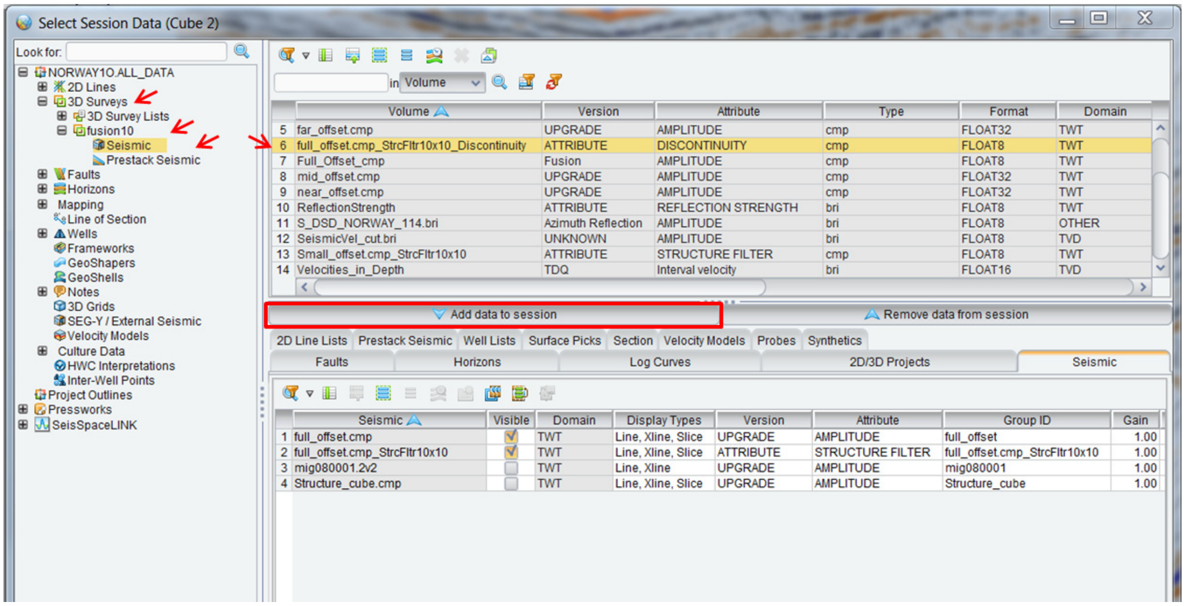
13. In the *Area of Interest* panel, click the **Entire Volume** button to produce the discontinuity volume over the entire extent of the seismic.

14. In the *Operations* panel, select **Attributes** from the drop-down menu, if not already selected, and the **Structure** tab. From the drop-down menu select **Discontinuity**.

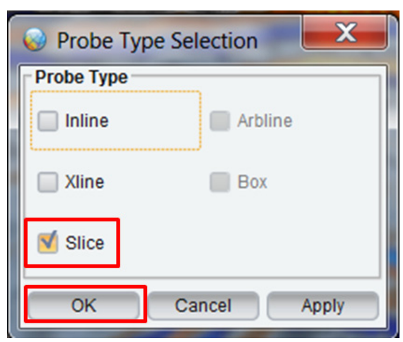


15. **Do not click OK**, like the full_offset.cmp_StrcFltr10x10. When you are done with setting the parameters click **Cancel**. The discontinuity volume took 6 minutes and 33 seconds to create. Although not as long, this volume has also been created for you and included in the project dataset.

16. Go to *Select Session Data* and in the dialog select **3D Surveys > fusion 10 > Seismic > full_offset.cmp_StrcFltr10x10_Discontinuity**. Click **Add data to session**, and click **OK** to close the dialog.

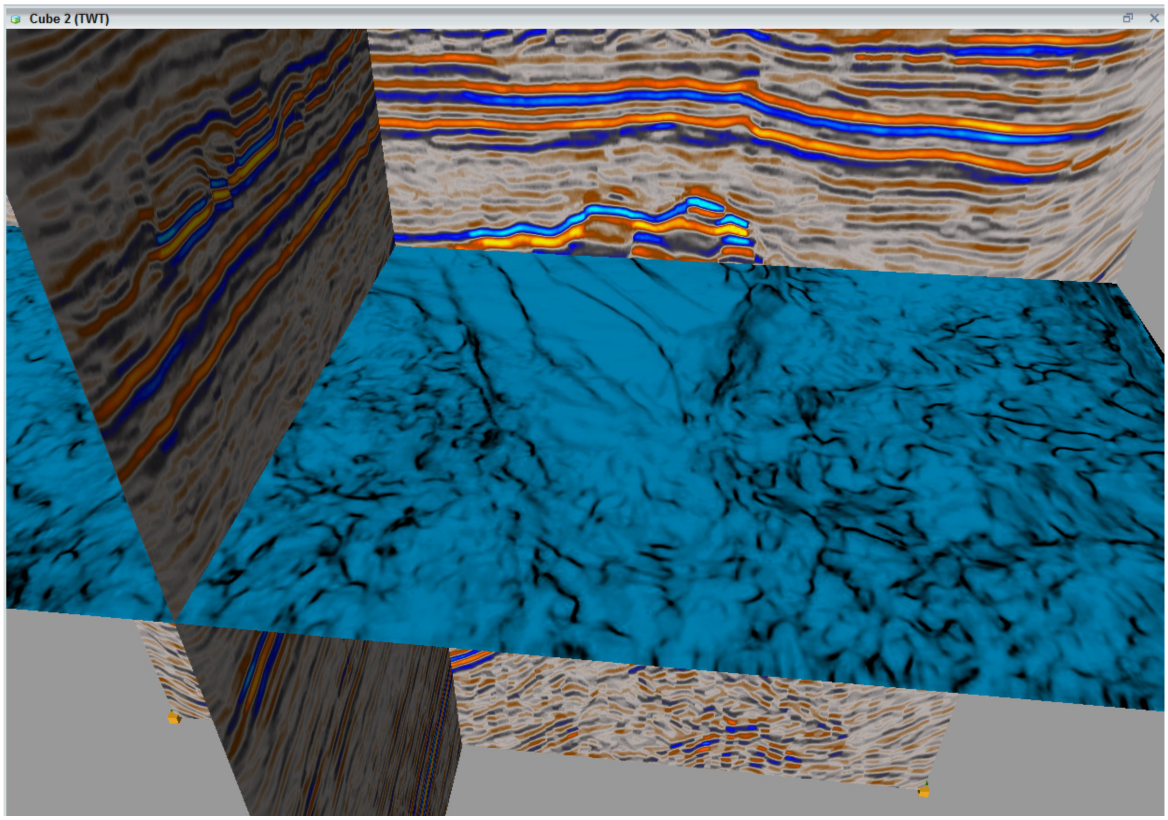


17. In the *Inventory* task pane, select **full_offset.cmp_StrcFltr10x10_Discontinuity** and drag-and-drop it in to *Cube* view. Select to create only a **Slice** in the *Probe Type Selection* dialog, and click **OK**.



18. Move the discontinuity slice down to the reservoir area, by holding **MB1+<Shift>** and pushing the down arrow.

The breaks within the seismic are represented by black, as shown in the picture below. Moving the slice down to the reservoir level shows how well the discontinuities (faults) line up with the faults within the full_offset.cmp_StrcFltr10x10 volume. At this level the faults stand out significantly. This is also due to the fact that performing the attribute generation on the smooth seismic volume eliminated much of the noise that was present in the regular full_offset.cmp, which would therefore make the discontinuity volume slightly harder to read.



Note

Both the inline and xline in the picture above are from the full_offset.cmp_StrcFltr10x10 volume.

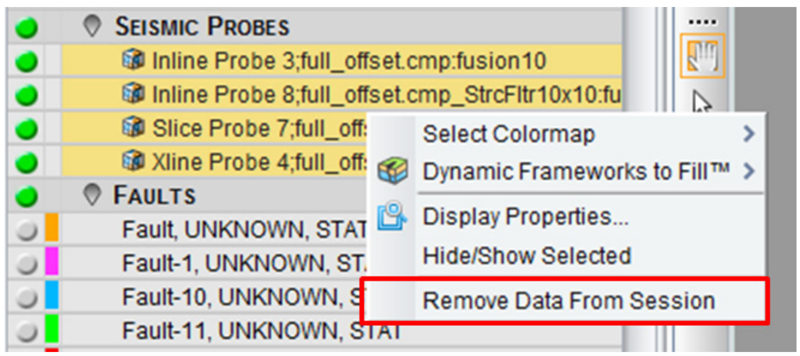
You will use the two volumes you have created in your interpretation of both faults and horizons in later chapters.

In the following exercise, you will continue with the QC of the data in your project. For projects that also have 2D seismic lines it is very important to make sure that they correspond with your 3D seismic volumes. You will learn how to perform a bulk shift of an entire 2D line, as well as perform a mistie correction.

Exercise 1.3: 2D Seismic Balancing

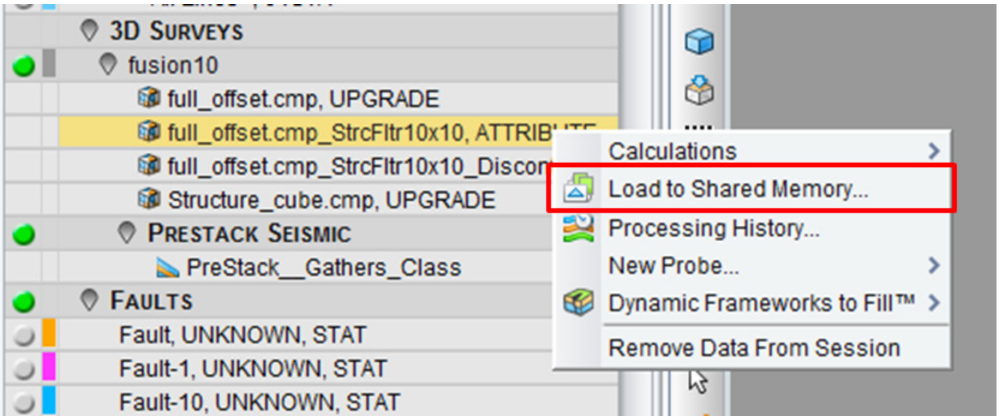
It is important to ensure that all of the data within your project is corresponding properly with each other, so you must make sure your 2D seismic lines link with your 3D seismic volume. The processing is often more extensive with 3D seismic, so it is best practice to bulk shift your 2D seismic lines to be in line with your 3D data. In the following exercise, you will compare the 2D lines to the 3D volume, and adjust the 2D lines as needed by applying a bulk shift.

1. In the *Inventory* task pane of your *Cube* view, highlight all of the probes currently in your session, **MB3,** and then select **Remove Data From Session**.

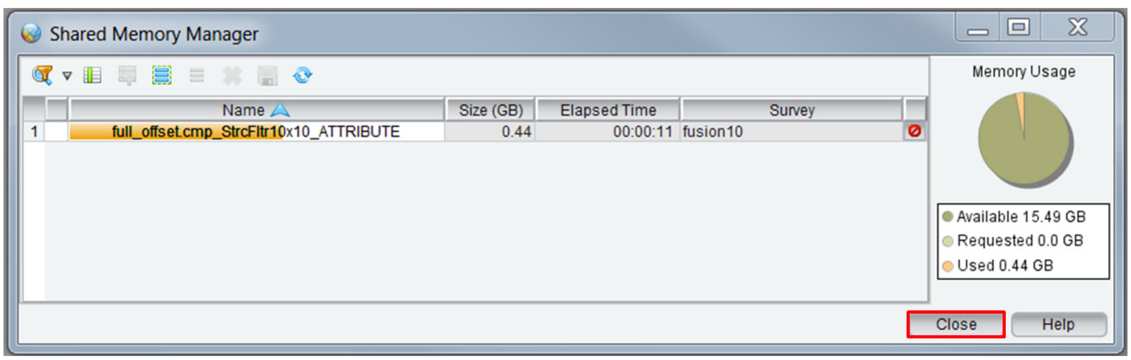


You will need to create a box probe of your seismic volume in order to easily compare the 2D lines. Box probes can only be created from a volume loaded to shared memory. Loading volumes in to shared memory allows for faster rendering of the volume.

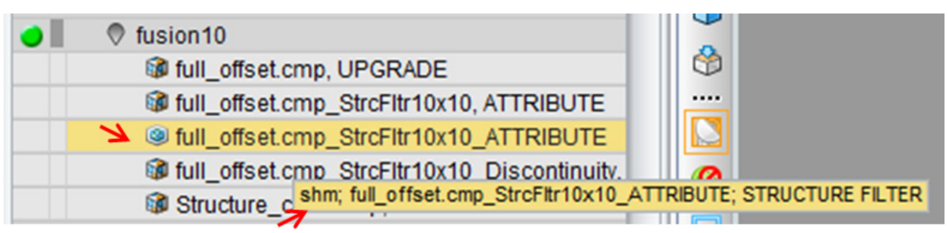
2. Still in the *Inventory* task pane, highlight the **full_offset.cmp_StrcFltr10x10** volume, **MB3**, and then select **Load to Shared Memory...**.



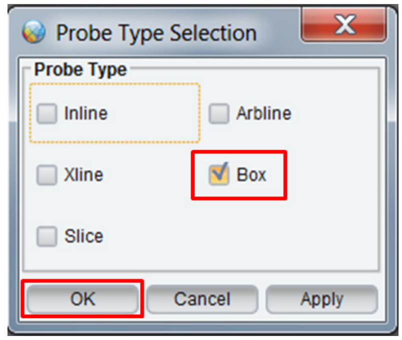
3. Accept the defaults in the resulting *Modifying: full_offset.cmp_StrcFltr10x10* dialog and click **OK**. The *Shared Memory Manager* dialog opens showing the status of the volume being loaded, and when it is done click **Close**.



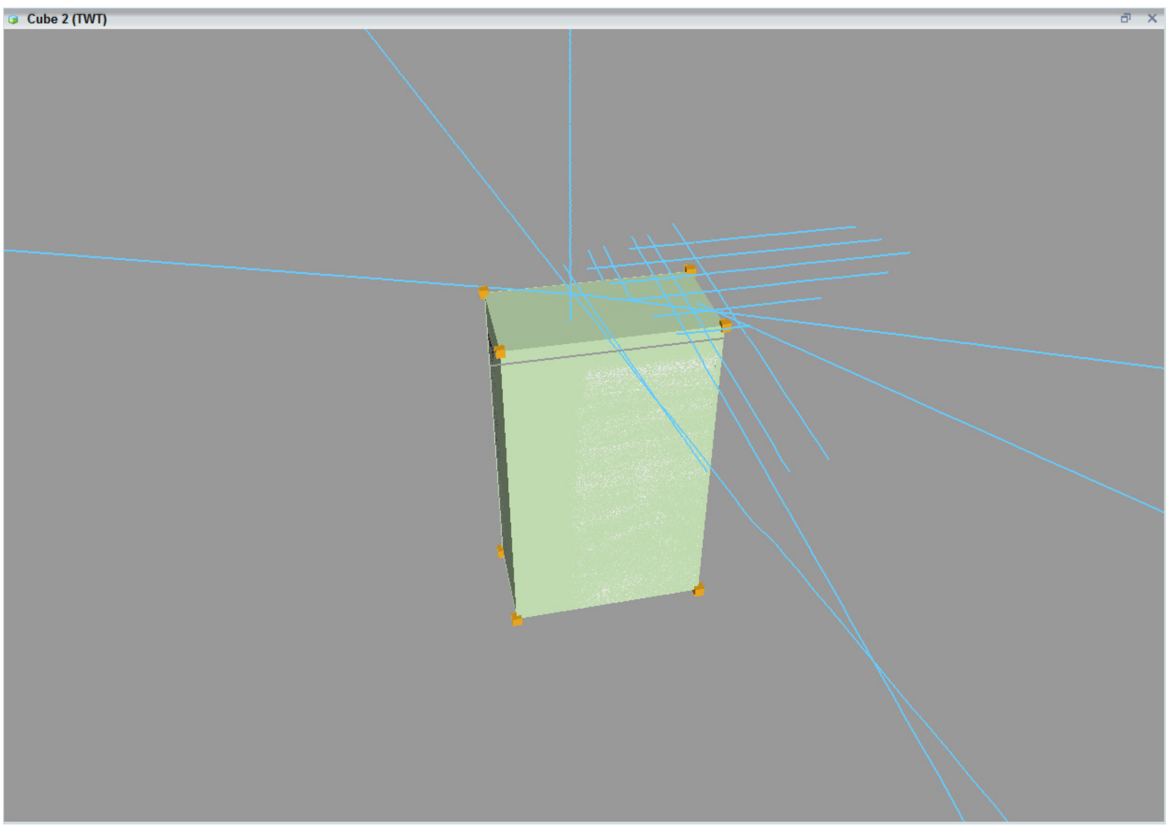
A new volume appears in the *Inventory* task pane with the same full_offset.cmp_StrcFltr10x10 name, but it has a different icon next to it. Also, if you hover over the new volume you see the name appended with "shm."



4. Highlight the shared memory **full_offset.cmp_StrcFltr10x10** in the *Inventory* task pane, and drag-and-drop it in to *Cube* view. In the *Probe Type Selection* dialog, choose to only create a **Box**, and click **OK**.



5. In the *Inventory* task pane toggle on **<All Lines>, 01STA** under *2D Line Lists*.

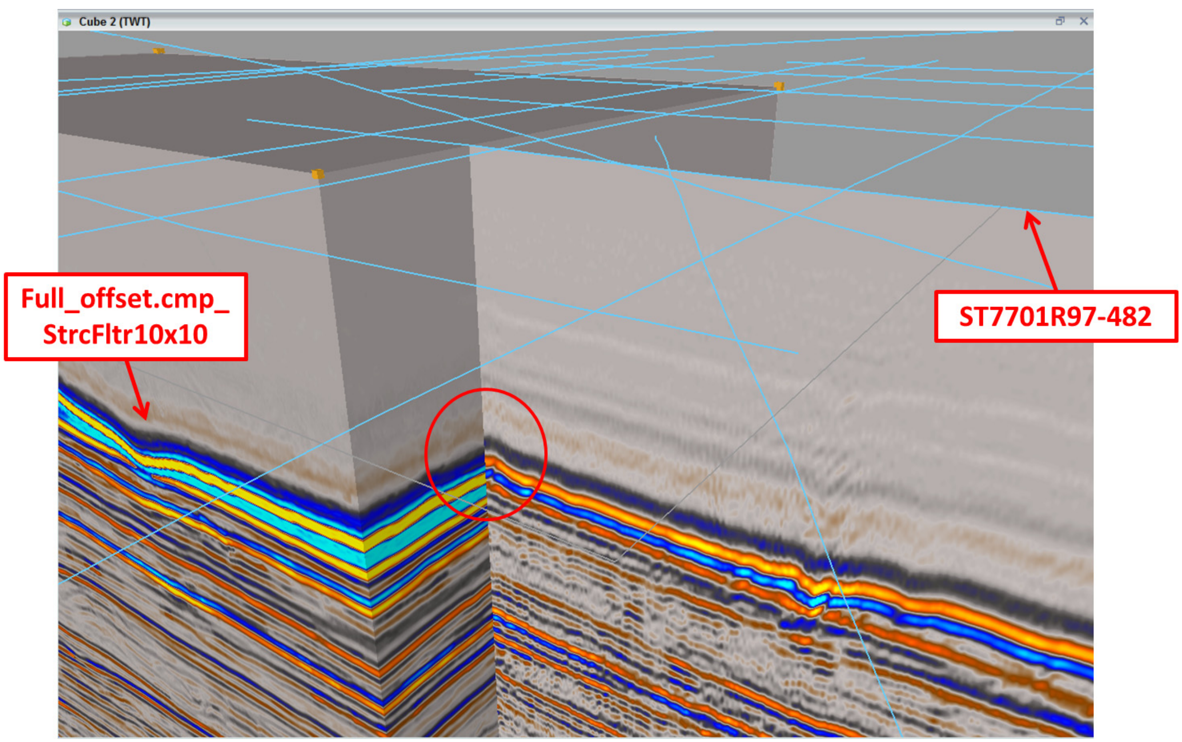


> **Note**
>
> To expand the volume to the full extent press the hot key <x>.

6. To make the comparison easier, **MB3** on the seismic volume and select **Display Properties**. In the *Display Properties* dialog, change the *Color Map* to **GeoProbe > Amplitude_Pk**.

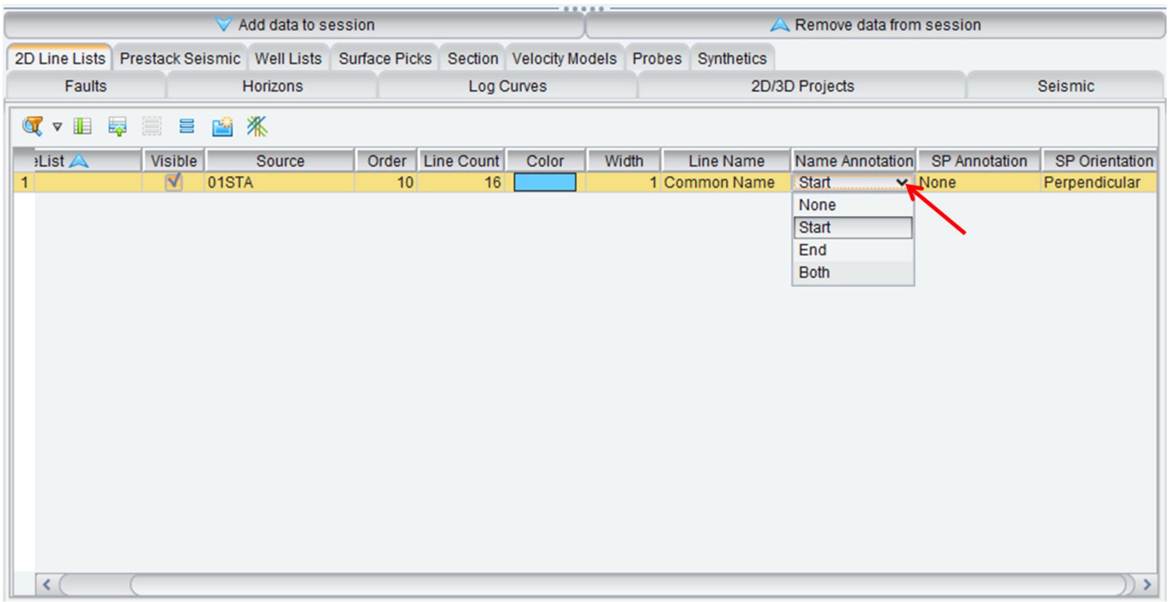
7. In *Cube* view, find the 2D line **ST7701R97-482** by hovering over it, and then click **MB2** to display it.

8. Arrange the box probe faces and the *Cube* view so you can clearly see the intersection between the 3D seismic volume and the 2D line. The mistie is apparent at the reflector for the sea bottom, marked by the circle in the picture below.



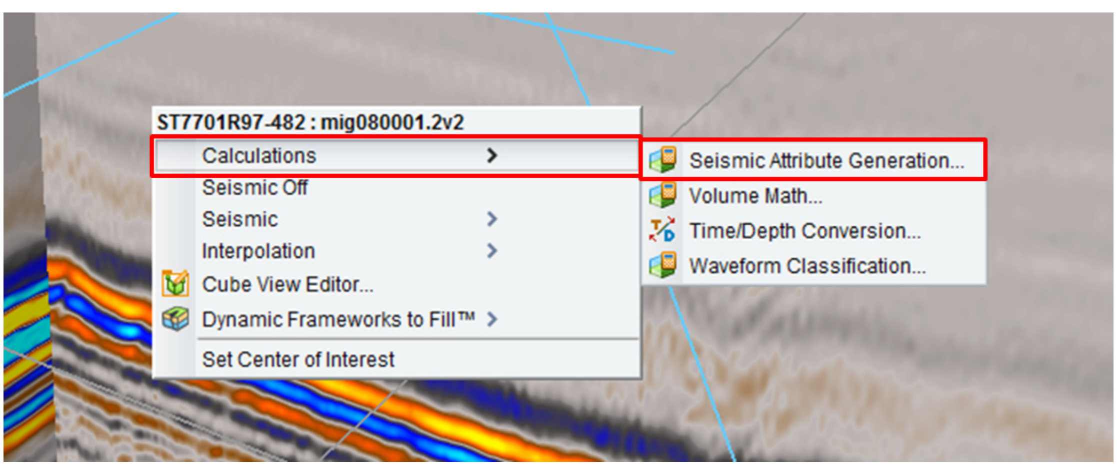
Note

You can also add annotation to the 2D lines from in the *Select Session Data* dialog in the *Name Annotation* column in the *2D Line Lists* tab.



Since there is a mismatch between the 2D line and 3D volume, as seen in the previous picture, a bulk shift is needed to link the two together. This bulk shift is very important. In a later chapter you use both 2D and 3D seismic to help with the interpretation of a horizon.

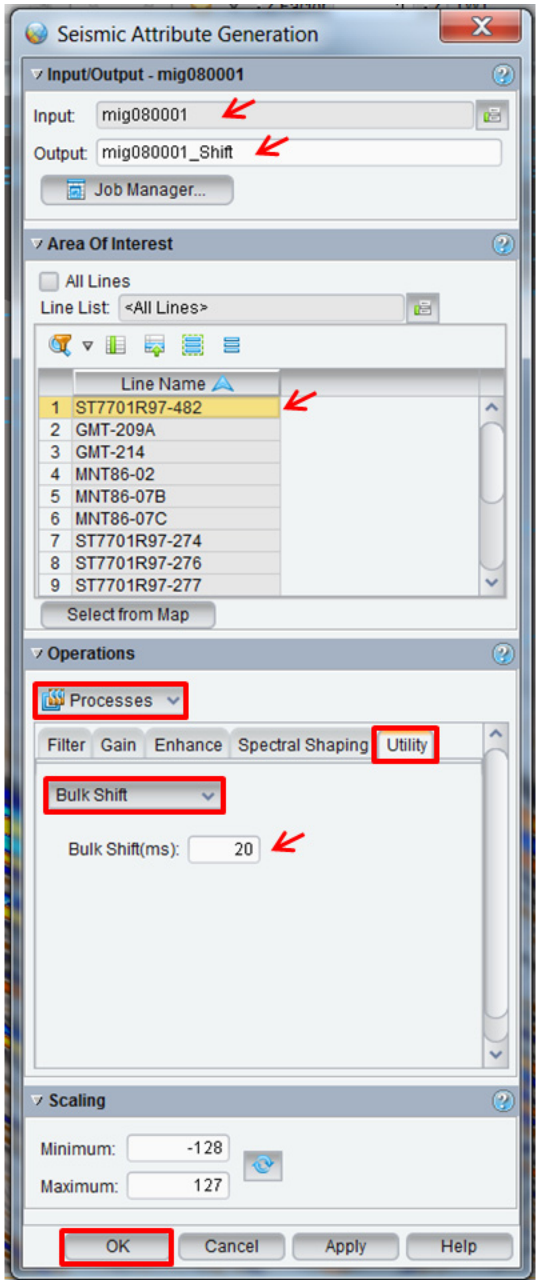
9. In *Cube* view **MB3** on **ST7701R97-482** and select **Calculations > Seismic Attribute Generation...**.



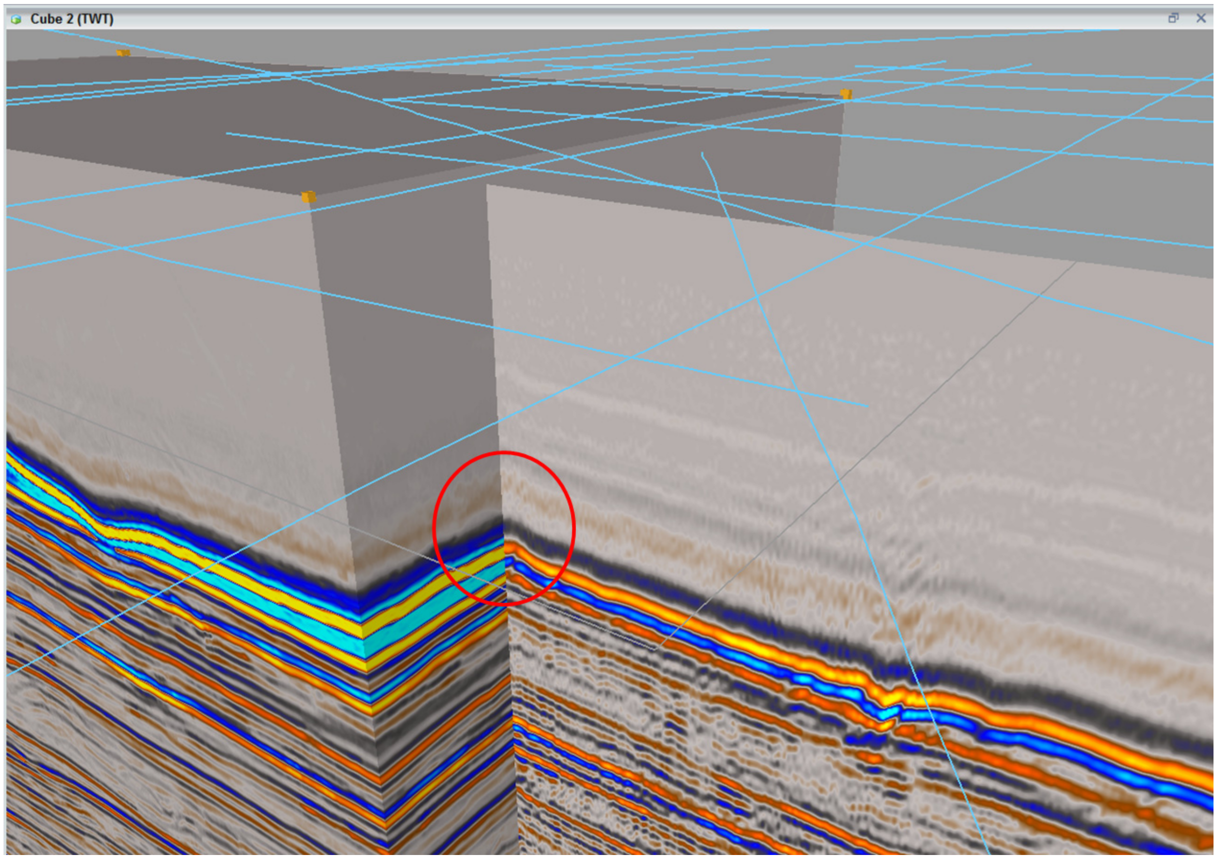
10. In the *Input/Output* panel of the *Seismic Attribute Generation* dialog, make sure that **mig08001** is selected for the *Input* and name the *Output* "**mig08001_Shift**."

11. For *Area of Interest*, select **ST7701R97-482** from the *List Name* column.

12. In the *Operations* panel, select **Processes** from the drop-down menu, select the **Utility** tab. Select **Bulk Shift** from the drop-down menu, enter a *Bulk Shift* of "**20**" ms, and click **OK**.



13. The *Job Manager* dialog opens, when it is done close it. The bulk shift moved the entire line down 20 ms. Notice how the bottom seabed reflector now corresponds with the 3D volume.



Note

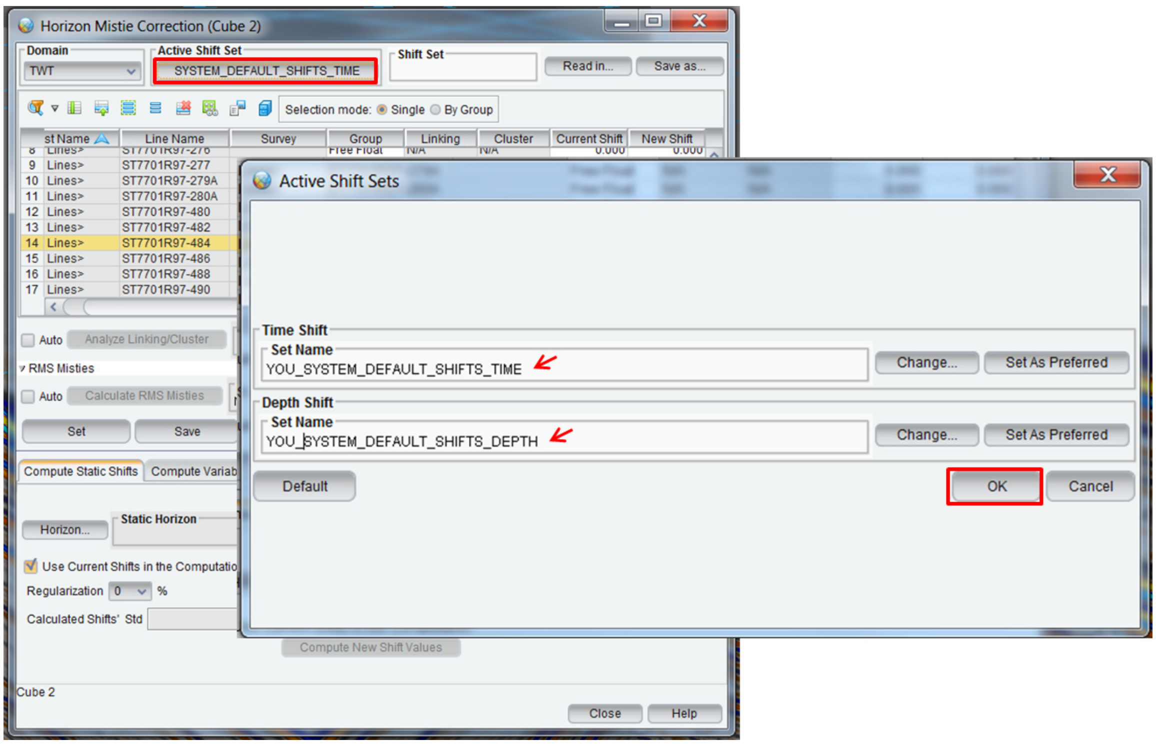
All of the attributes created in the previous exercise on the 3D seismic volume can be generated on the 2D seismic lines.

If you do not know the specific amount that you need to move the 2D lines you can do it graphically in both *Cube* and *Section* view. Note, this will also move the actual seismic as opposed to creating an attribute with a shift.

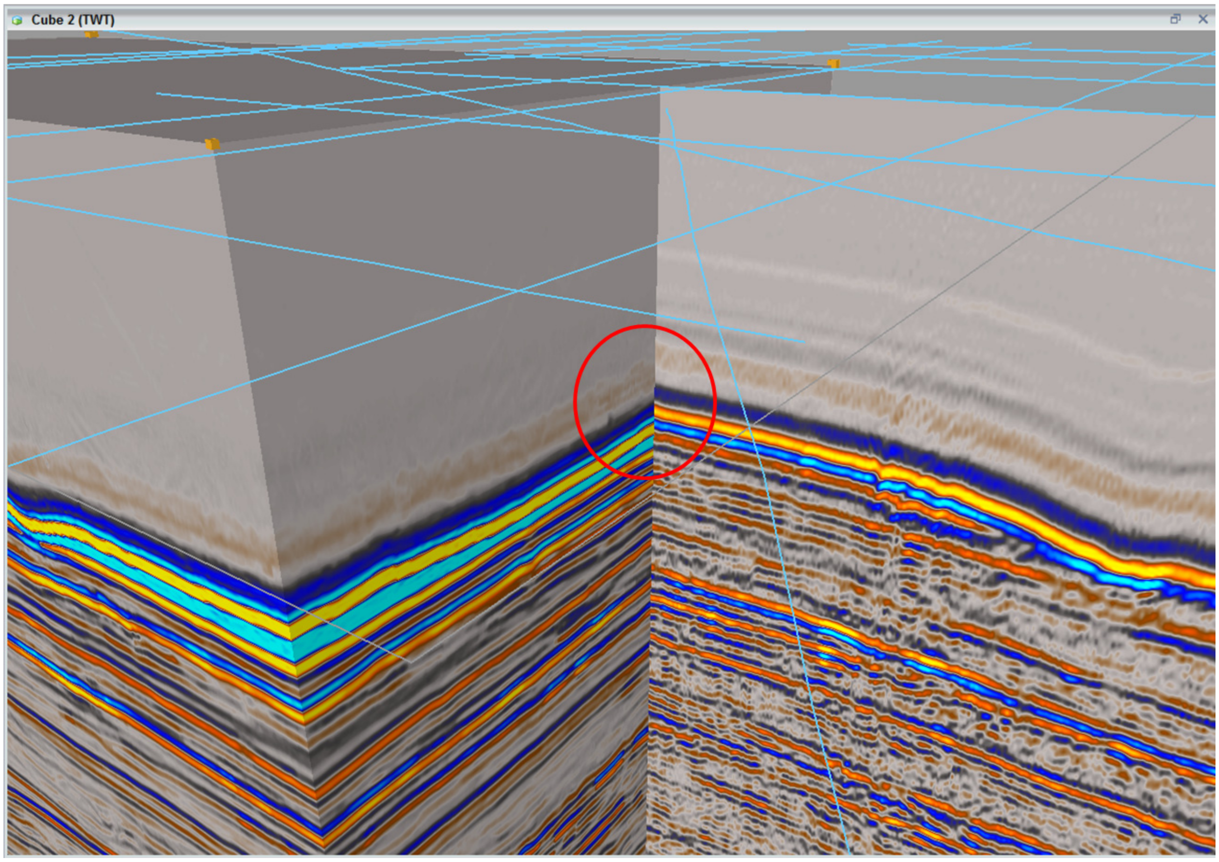
14. In the main toolbar select **Tools > Mistie Correction**. This opens the *Horizon Mistie Correction* dialog.

It is necessary to change the Active Shift Set to a personal shift set rather than the default shift set, unless the seismic shifts are intended for anyone with access to the project.

15. Click the **Active Shift Set** button, and change both the *Time* and *Depth Shift* set names to include "**YOU**" before the default. Click **OK** to set these as the current Shift Set. This allows you to make shifts to the seismic without changing the seismic that other people are using.



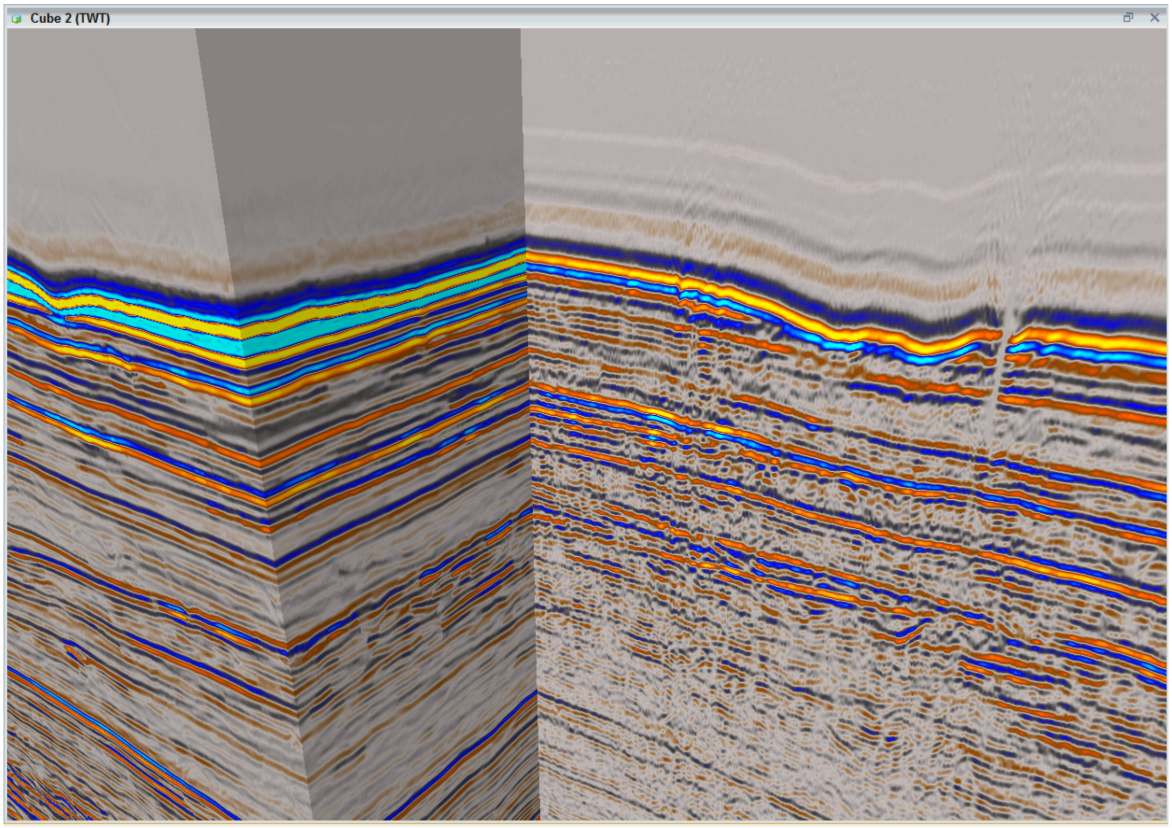
16. In *Cube* view, **MB2** on the displayed **ST7701R97-482** to turn it off, and **MB2** on **ST7701R97-484** to display it. Arrange your *Cube* view, so you can see the intersection between it and the 3D volume.



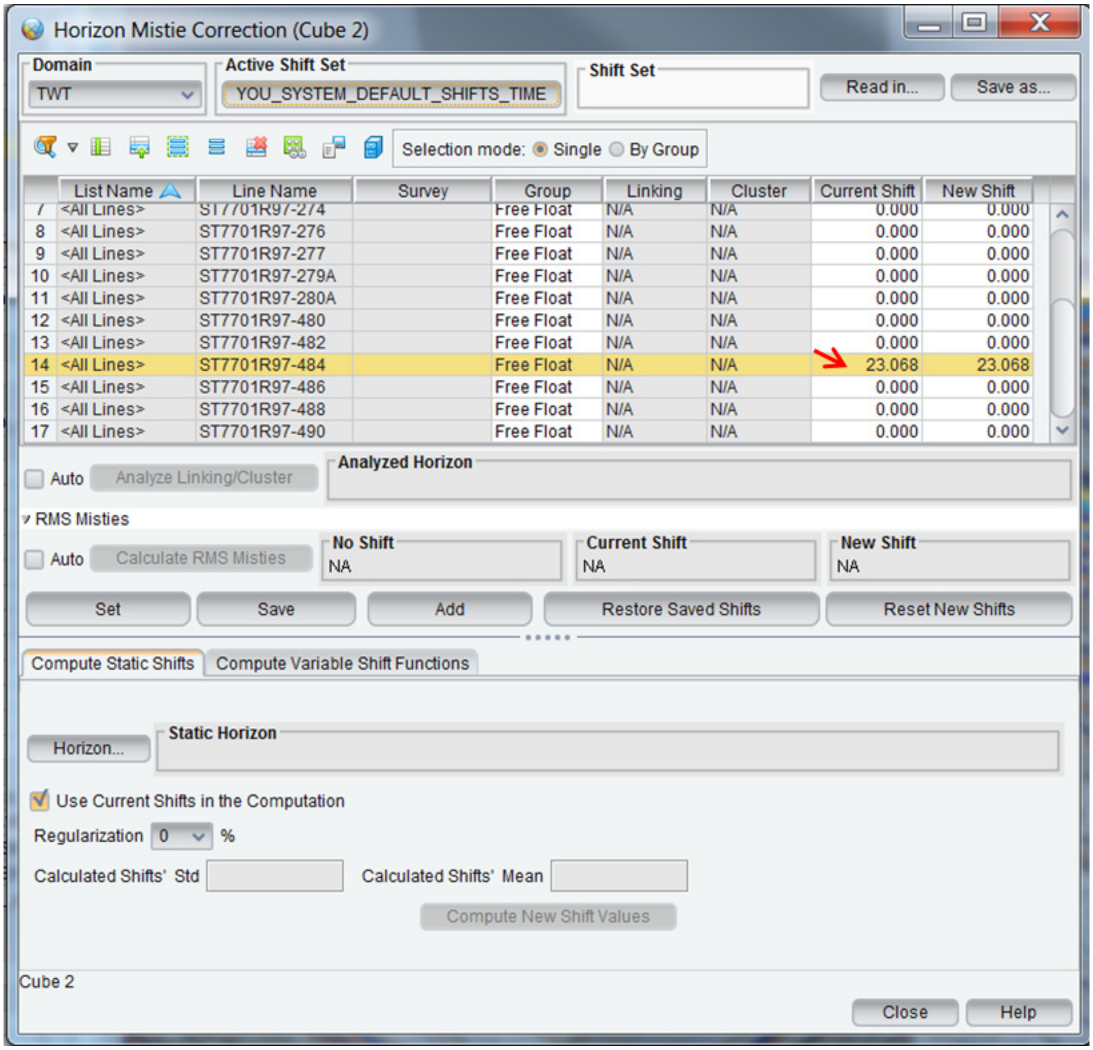
Like the previous 2D line, this line needs to be shifted as well.

17. From the *Shift Seismic* toolbar, click the **Shift 2D Seismic** () icon, which enables you to graphically move the 2D lines up and down to correspond with the 3D seismic.

18. With the Shift 2D Seismic icon active, **MB1** on **ST7701R97-484** and shift it to match the reflector in the 3D volume.



19. Once you are satisfied with the shift of ST7701R97-484, navigate back to the *Horizon Mistie Correction* dialog. In both the *Current Shift* and *New Shift* columns you will see the exact amount of (ms) you have shifted the 2D line.



20. If you have time, practice adjusting more of the 2D lines in your project that you think may need some adjustment.

In this chapter you have learned several different techniques to perform quality control on the data in your project. In the following chapter, you will learn how to create a Well Tie Synthetic, to further ensure that your geophysical interpretation will correspond with your geological interpretation.

Chapter 2
Well Tie Workflow

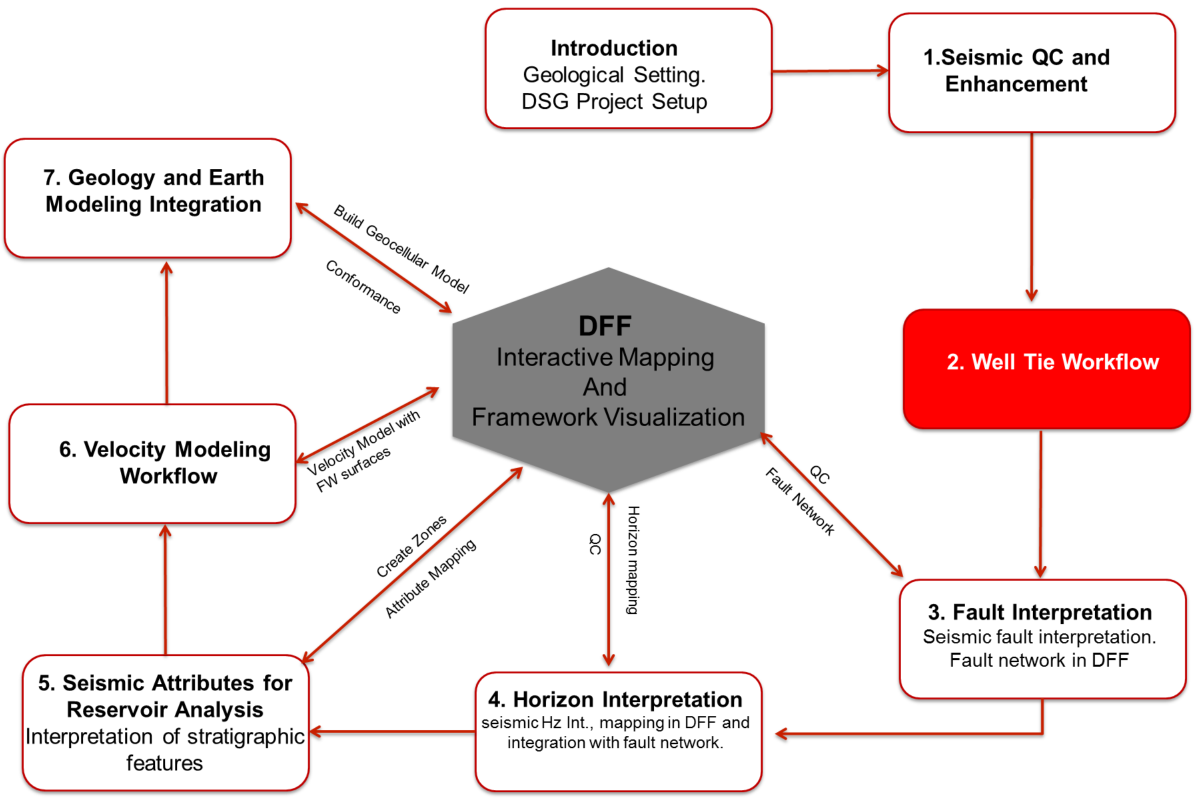
The DecisionSpace Geosciences software provides a useful link to the Well Tie Workflow wizard, which allows you to create a successful tie. In this chapter, you will select input log data, estimate wavelets, and generate a synthetic trace. Using the tools available in the wizard, you will tie your synthetic to the seismic data, and save a Time-Depth curve that you will use later to display well picks and build a robust velocity model.

Overview

In this chapter, you will learn to:

- ❑ Launch the Well Tie workflow
- ❑ Use the Well Tie Workflow wizard to select parameters for creating synthetics
- ❑ Tie synthetics to seismic data
- ❑ Export and save a wavelet in OpenWorks and as an ASCII file
- ❑ Apply the Family concept to compare wavelets
- ❑ Apply thickness edits to all loaded logs
- ❑ Save synthetics, time-depth curves, and check shots to the OpenWorks database
- ❑ Display synthetics in *Section* view

Workflow


Introduction
Geological Setting.
DSG Project Setup
1.Seismic QC and Enhancement
7. Geology and Earth Modeling Integration
Build Geocellular Model
Conformance
DFF
Interactive Mapping
And
Framework Visualization
2. Well Tie Workflow
6. Velocity Modeling Workflow
Velocity Model with FW surfaces
QC
Fault Network
Create Zones
Attribute Mapping
QC
Horizon mapping
3. Fault Interpretation
Seismic fault interpretation.
Fault network in DFF
5. Seismic Attributes for Reservoir Analysis
Interpretation of stratigraphic features
4. Horizon Interpretation
seismic Hz Int., mapping in DFF and integration with fault network.

Overview: Well Tie Workflow

A crucial step in true geological and geophysical integration is the well tie. When the seismic interpreter and the geologist know how the seismic reflectors relate to the geologic section in their project area, a ground truth is added to the maps around the wells.

The Well Tie Workflow plays an essential role in the early stages of interpretation. Time-Depth curves are the basis of building a correct velocity model as these are the hard data from well tie. Well tie is necessary for any well-seismic analysis on real data because it allows you to properly calibrate your time seismic data using depth data from the well. As a result, you will be able to correctly identify reflectors that correspond to the geological feature you want to interpret. Another product of well tie is a proper wavelet which is useful for deconvolution.

Background Theory

About Acoustic Impedance and Reflection Coefficients

This section provides a review of geophysical theory to show how the DecisionSpace Geosciences software creates synthetics.

A reflection is produced at interfaces between rocks with different velocities (V) or different densities (ρ). The magnitude of the reflection is given by the reflection coefficient.

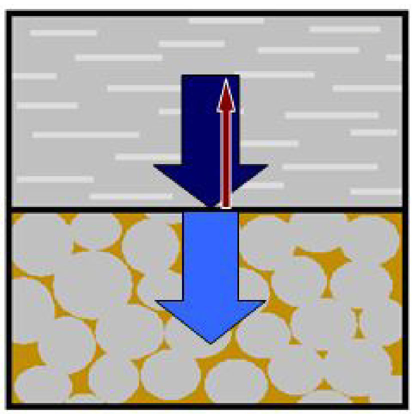
Reflection Coefficient = $(\rho_2 V_2 - \rho_1 V_1) / (\rho_2 V_2 + \rho_1 V_1)$

where V = p-wave velocity
ρ = density

Acoustic Impedance (I) = ρV

Therefore, Reflection Coefficient = $(I_2 - I_1) / (I_2 + I_1)$

The image below shows a two-layer earth model.



The model shows an arrow that represents the downward seismic energy striking the interface. The upward (red) arrow represents the reflected energy. Most of the energy continues downward, as shown by the slightly smaller downward arrow.

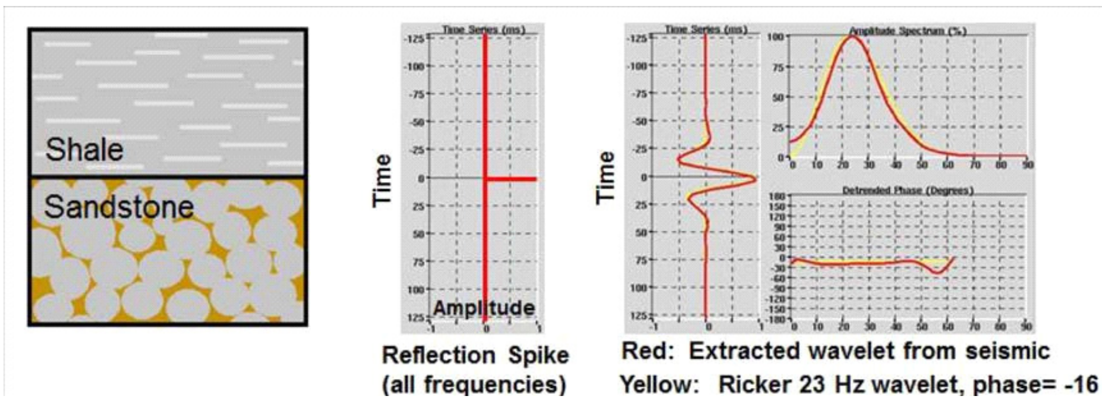
The image represents sound striking the interface at 90 degrees. If the sound energy reflects at some other angle, more complicated Zoeppretz equations are needed to calculate the reflection amplitude.

This amplitude, which varies with angle of incidence, is the basis of AVO analysis.

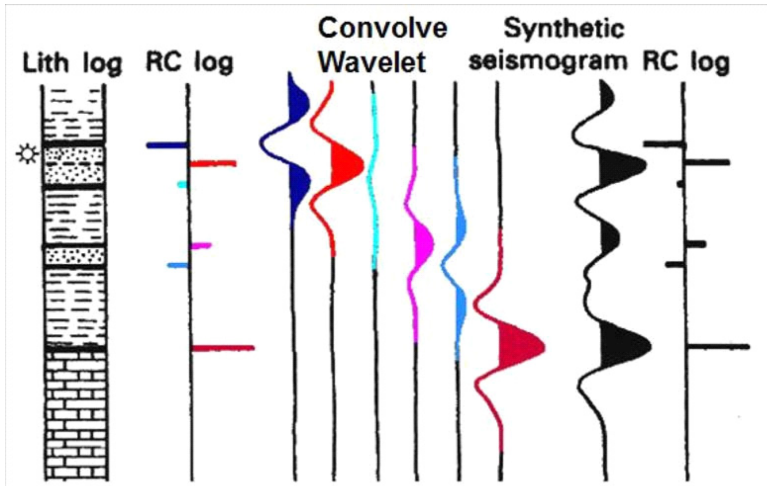
Since the sonic and density logs for wells in your project area are usually present, acoustic impedance changes can be calculated in depth. As noted above, where there is a change in acoustic impedance, there is a reflection.

About Reflections, Wavelets, and Convolution

A reflection occurs at an interface, where the seismic energy is recorded as seismic data. If it was possible to produce, transmit, and record all frequencies, the reflection would be a spike at the two-way time taken to travel down and back to the reflector. In the figure below, the interface and the reflection spike at the reflection time are illustrated. Seismic data is limited in frequency and typically ranges between 4 and 80 Hertz (higher frequencies are possible in shallow surveys). Therefore, the seismic reflections are not spikes, but band-limited wavelets, as shown in the figure below.



The following figure starts with a lithologic log, where each layer has constant velocity and density. The reflection coefficients are shown at each interface (RC log). Each spike is replaced by a wavelet (a process called convolution). The wavelets are then summed to produce the synthetic – the seismic response that would be expected from those layers of rock.



This type of convolution is performed by the DecisionSpace Geosciences software to create the synthetic. Instead of a lithologic log, it uses acoustic impedance changes calculated from sonic and density logs.

While reservoir properties are layer properties, seismic data is created by interface properties. That is, to see a geologic top or base, there has to be a large enough change in the velocity and density at the boundary to generate a reflection that can be detected over background noise.

The synthetic that you generate from sonic and density logs can be compared to your seismic data. They should match (the peaks and troughs of the synthetic should match similar characteristics of seismic data). This is called a seismic tie because it ties a depth in the well (derived from the well log) to a time in the seismic data. This well tie correlates the geology to the seismic at well locations. Tracking seismic changes can indicate how the geology changes away from well locations. From the well tie, you obtain depth and time. Therefore, you have the velocity between well depth and seismic time at the well location. You will use these velocities when you create your velocity model.

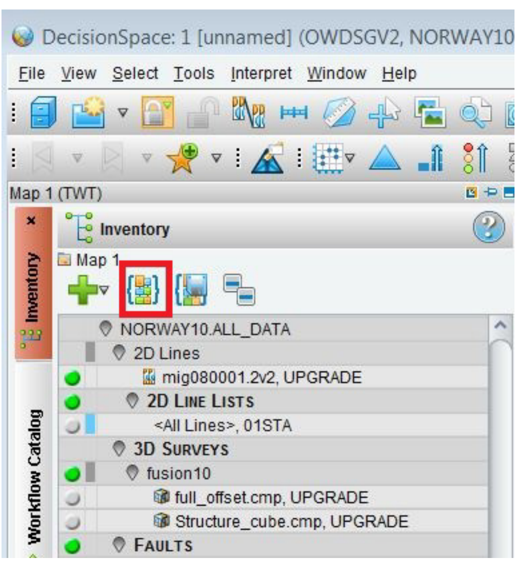
Exercise 2.1: Selecting Data for Use in Synthetic Generation

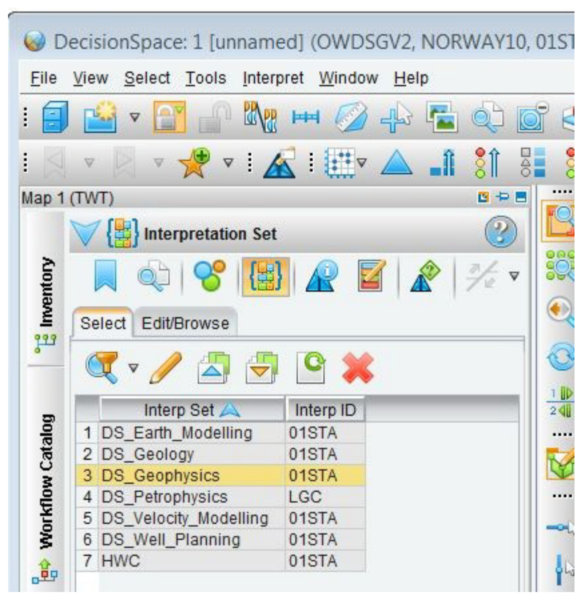
The DecisionSpace Geosciences Well Tie workflow is a tool that enables communication with Well Seismic Fusion as part of the geophysical functionality in the DecisionSpace software. It generates synthetics through a basic GUI-guided workflow.

In this exercise, you will launch the *Well Tie Workflow* wizard to generate a synthetic for well 6507/8-1.

To set up session data:

1. Ensure you have added the **DecisionSpace Geophysics ISet** to your session. From the *Select Session Data* dialog, select **Wells > Well Lists > FourWellsTD**, click the **Add data to session** button, and then click **OK**.





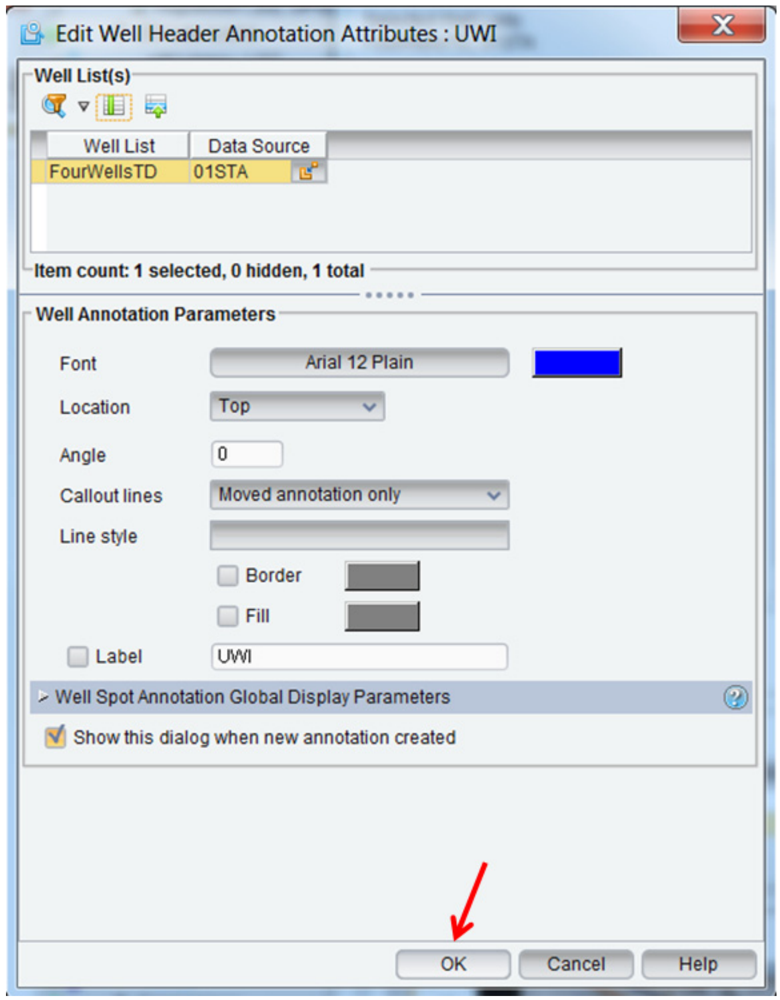
2. Display the **full_offset.cmp** volume and **inline 505** in the *Section* view with the **FourWellsTD** well list and the **GR** and **DT** logs. If the well list is not loaded, you can add it from the *Select Session Data* dialog.

3. Double-click the *Map 1 (TWT)* tab to enlarge the *Map* view and to display the well names in the *Map* view.

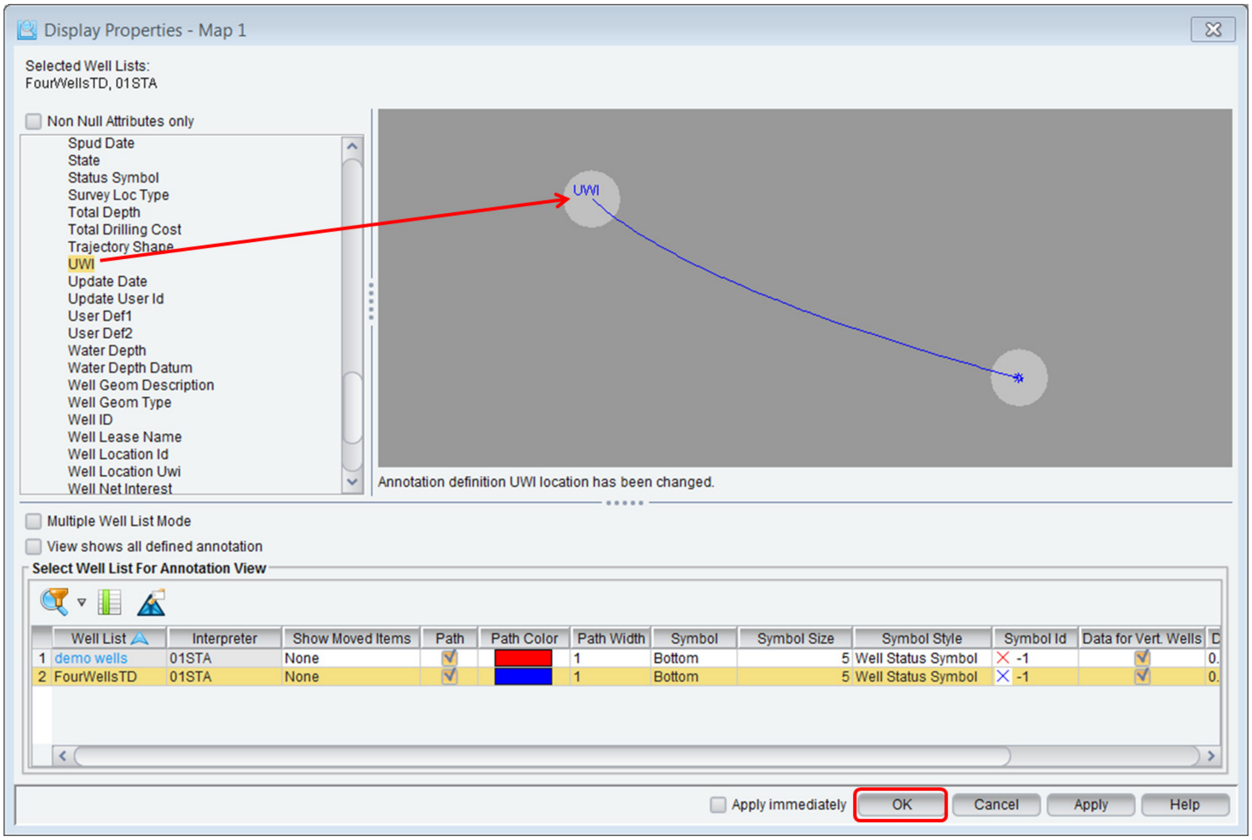
4. Toggle on the **FourWellsTD, 01STA** in your *Inventory*.

5. **MB3** on **FourWellsTD, 01STA** and select **Display Properties**.

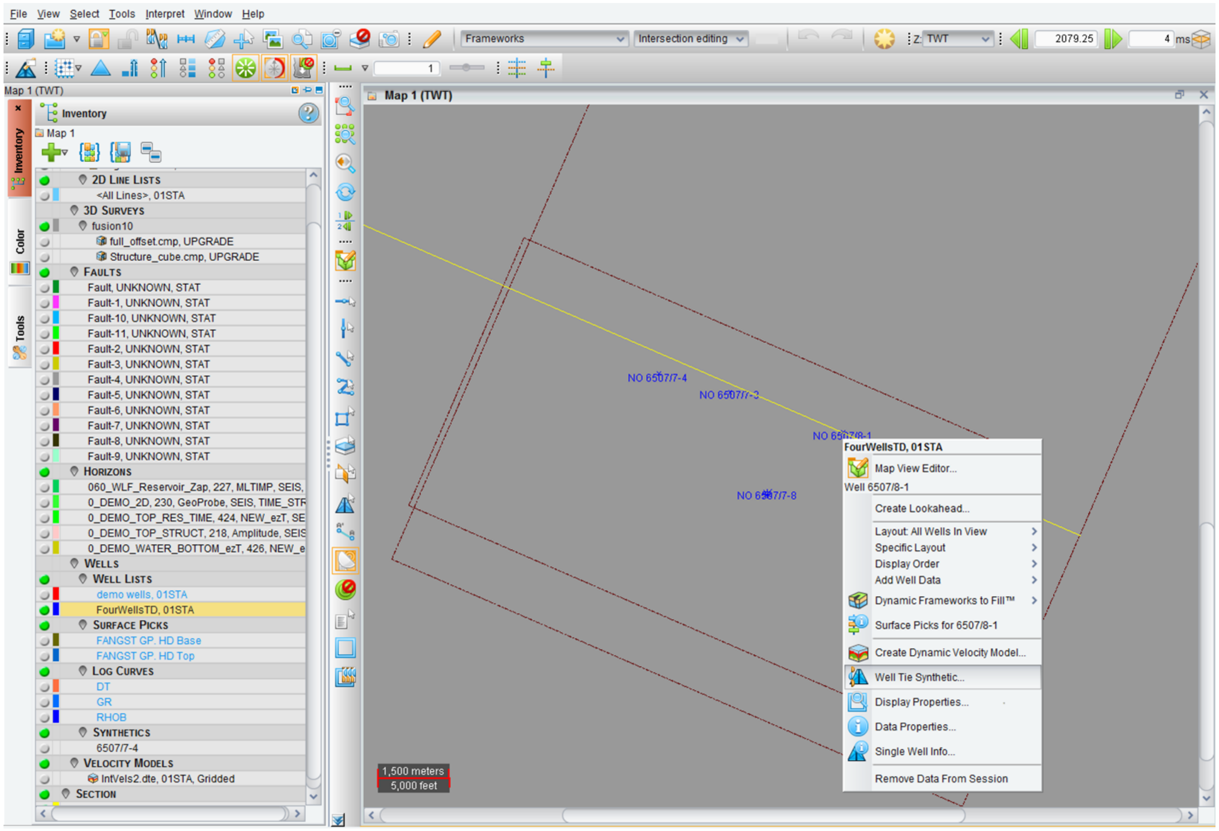
6. In the *Display Properties* dialog, expand *Well Header* and drag-and-drop **UWI** to the surface location. The *Edit Well Header Annotation Attributes: UWI* dialog opens. Click **OK** to accept the default value.



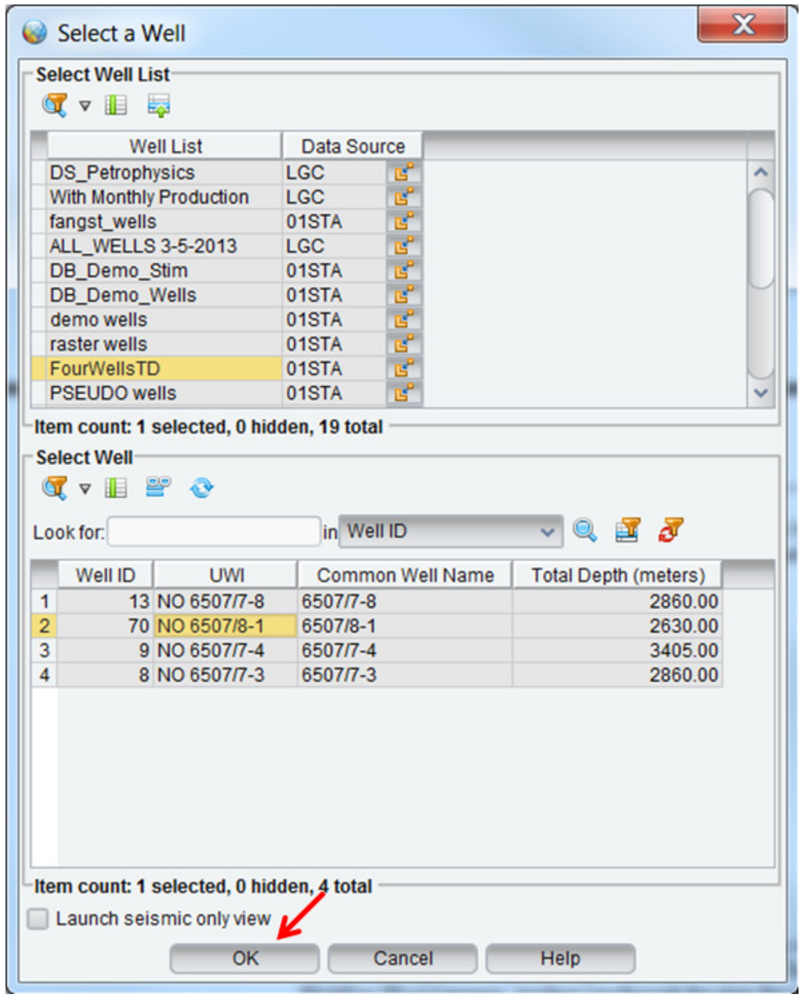
7. Click **OK** to view the four wells on the map.



8. In *Map* view, hold your cursor over the **6507/8-1** well, **MB3** and then select **Well Tie Synthetic...**.

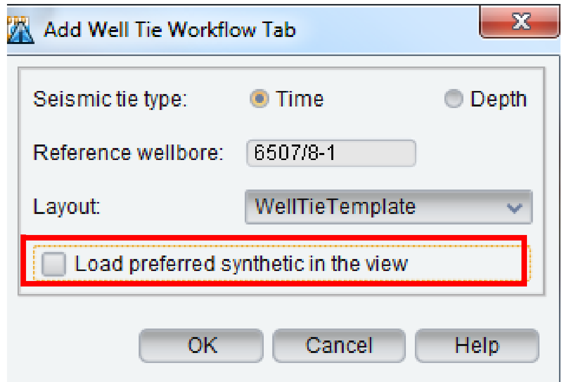


Alternatively, start the Well Tie Workflow by selecting **Tools > Well Tie Synthetic**, the well of interest from the well list, and then click **Select**.



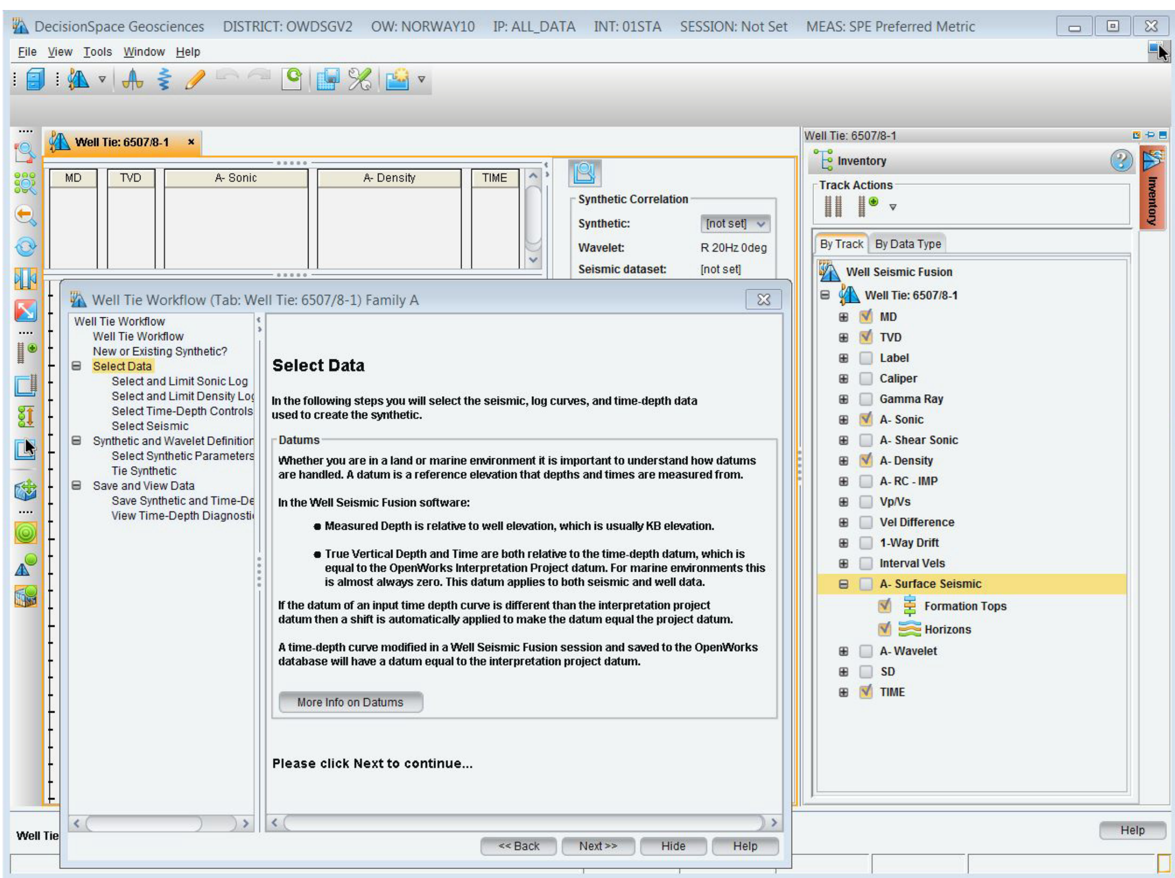
9. The *Add Well Tie Workflow* tab appears, prompting you to select a seismic tie type (Time, Depth, or Layout). Select **Time** to create a time-depth synthetic.

10. Deselect the **Load preferred synthetic in the view** check box. When this check box is selected, the preferred synthetic and all associated data in the new *Well Tie* tab view will display.



11. Click **OK**.

    This launches a new session of Well Seismic Fusion set up with the related data required for generating a synthetic. The *Well Tie Workflow Wizard* appears, guiding you through the steps for synthetic generation.



If the **Skip information pages** check box is selected, the menu tree expands and hides the informational steps of *Select Data*, *Select Synthetic and Wavelet*, and *Save and View Data*. The check box is not selected in this example.

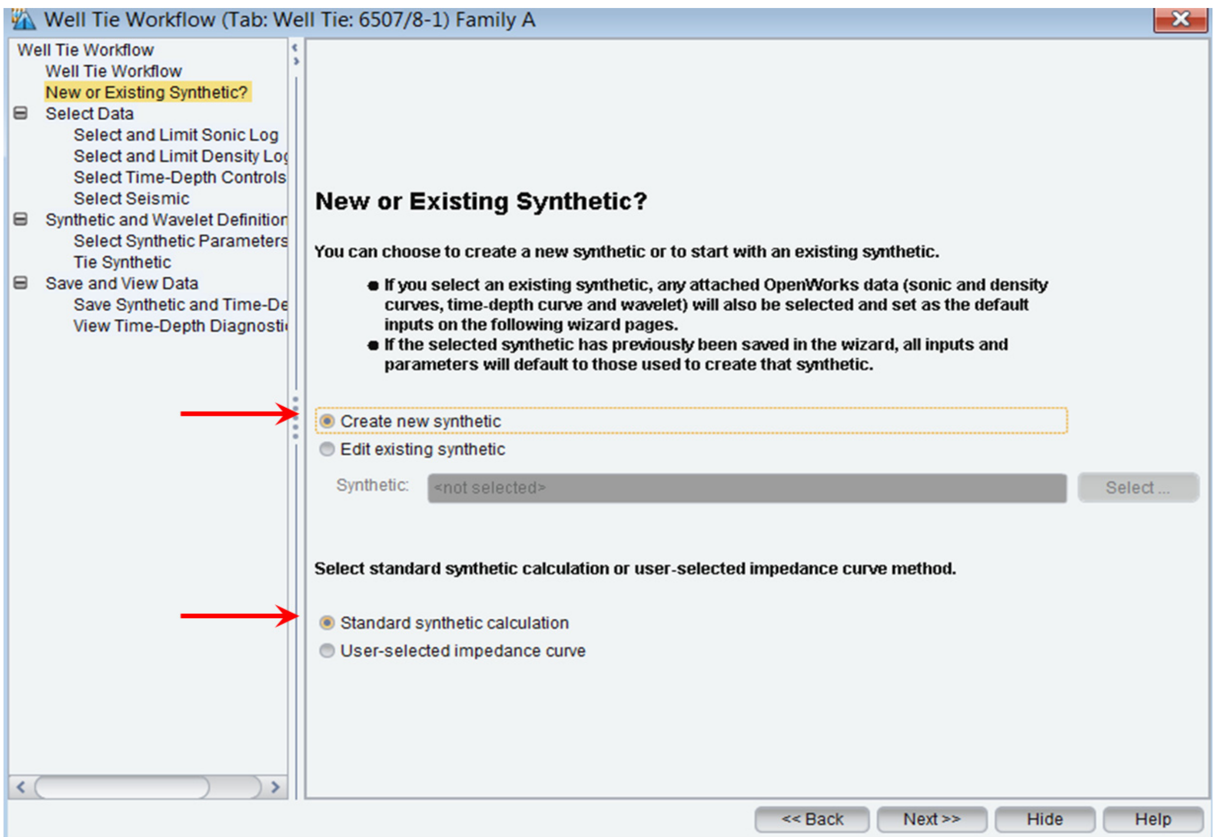
Exercise 2.2: Using the Well Tie Workflow Wizard

In this exercise, you will use the Well Tie Workflow Wizard for adding and selecting data to generate a synthetic.

1. In the *Well Tie Workflow Wizard* window, select **New or Existing Synthetic?** from the left pane.

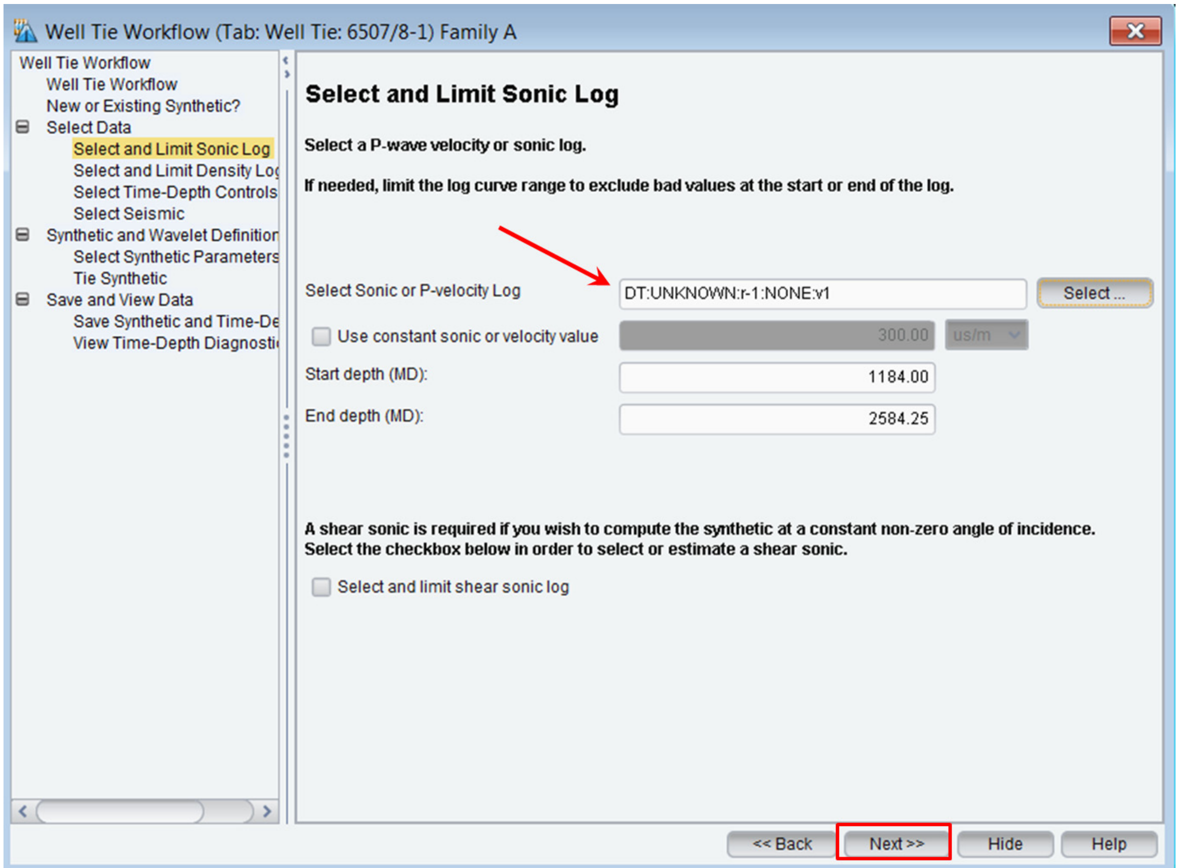
2. Review the information and select the **Create new synthetic** option and then click **Next**.

   For this exercise, you will calculate a synthetic using sonic or velocity and density logs.



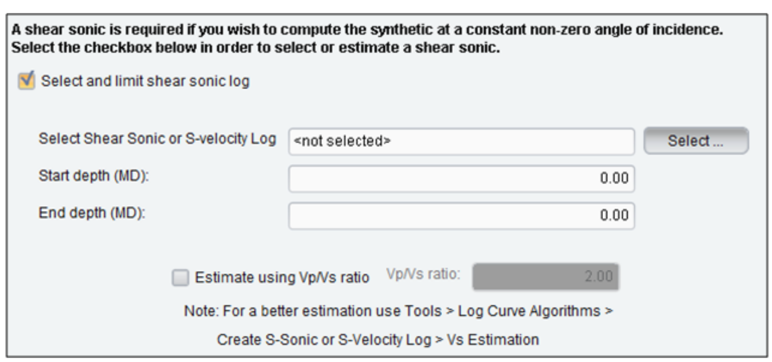
3. Read the information in the *Select Data* section on Datums and then click **Next**.

4. In the *Select and Limit Sonic Log* dialog, select **DT** for the **Select Sonic or P-Velocity Log** field. and then click **Next**.

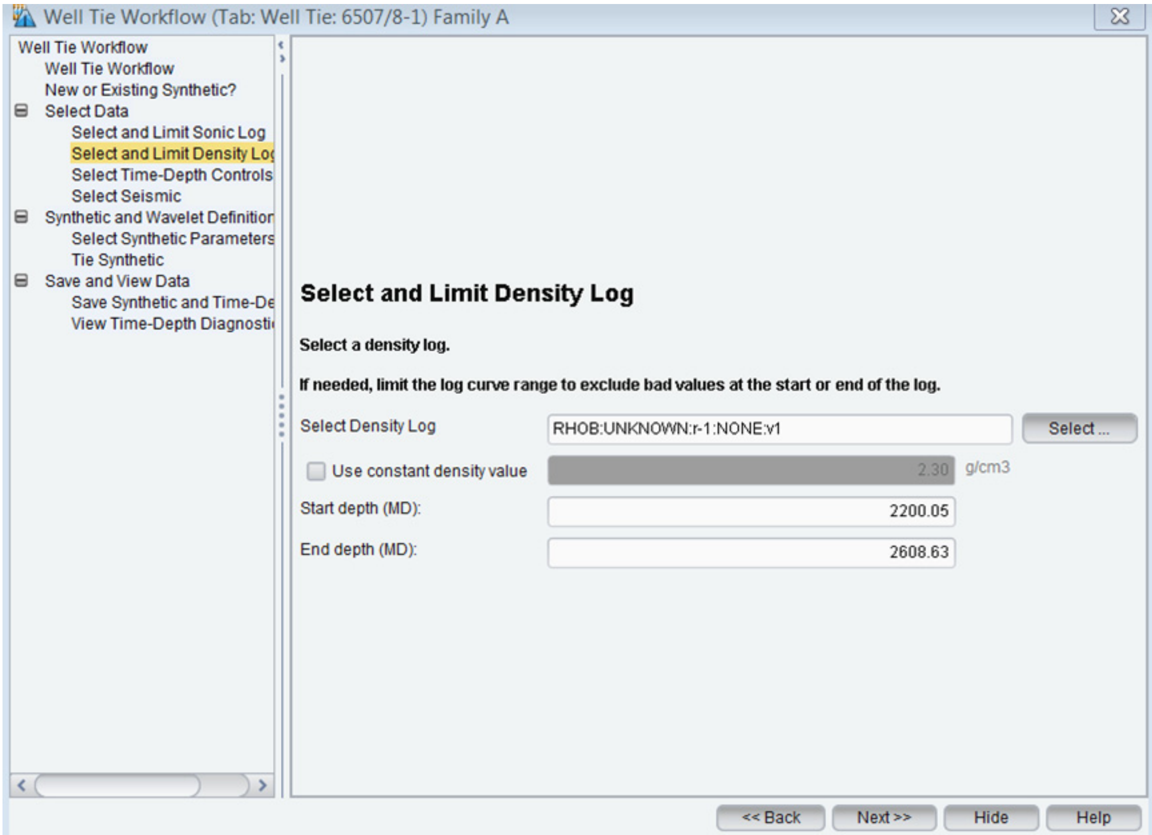


Note

An enhancement in DSG 5000.10 is the consolidation of P-Sonic and Shear Sonic steps on Well Tie workflow.

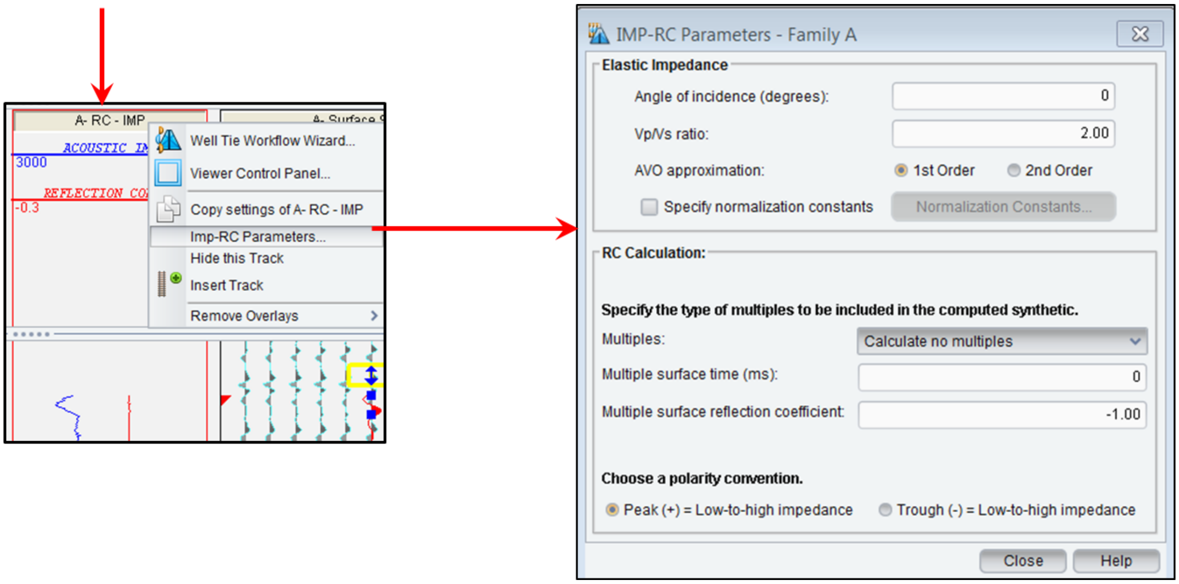


5. In the *Select and Limit Density Log* dialog, select the **RHOB** density log, and then click **Next**.



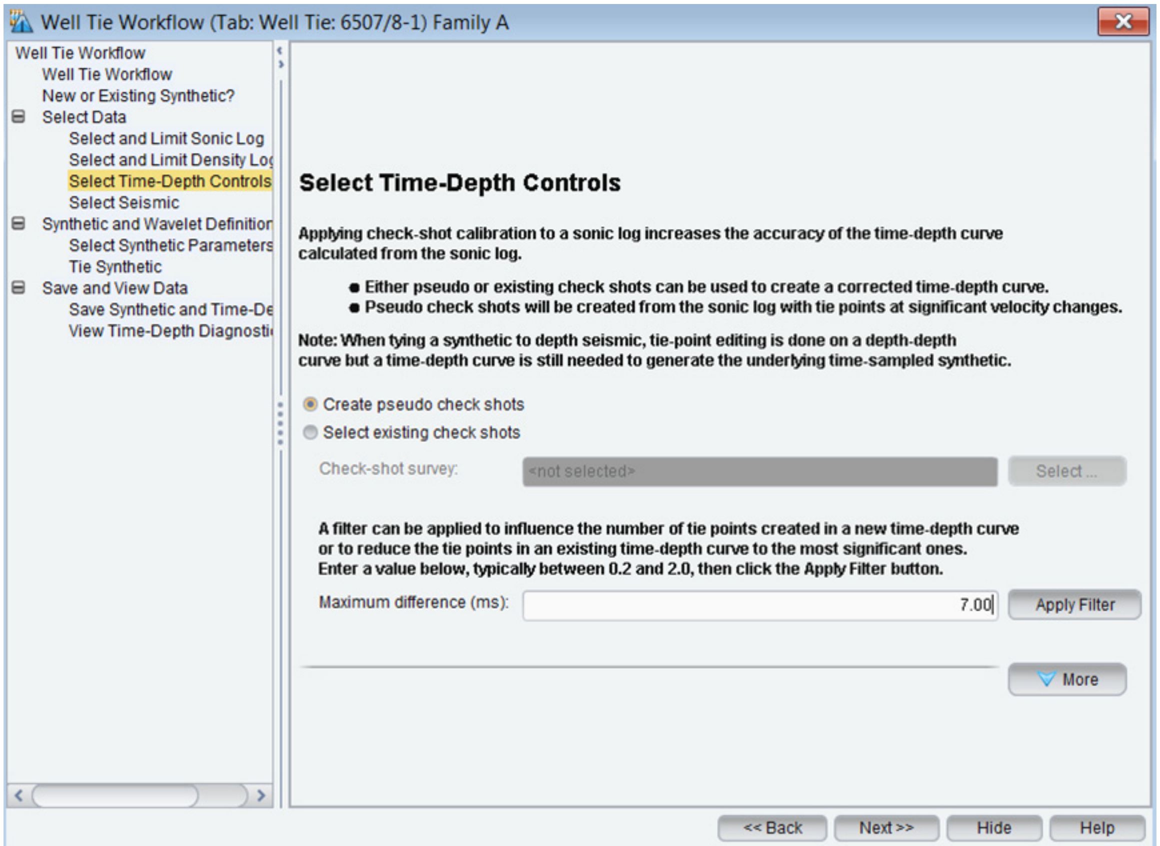
Note

The Elastic Impedance portion is attached to the IMP-RC Parameters and can be selected by using **MB3** on the Family **A- RC – IMP** track header. Do not make any selection here and return to the *Well Tie Workflow* wizard.



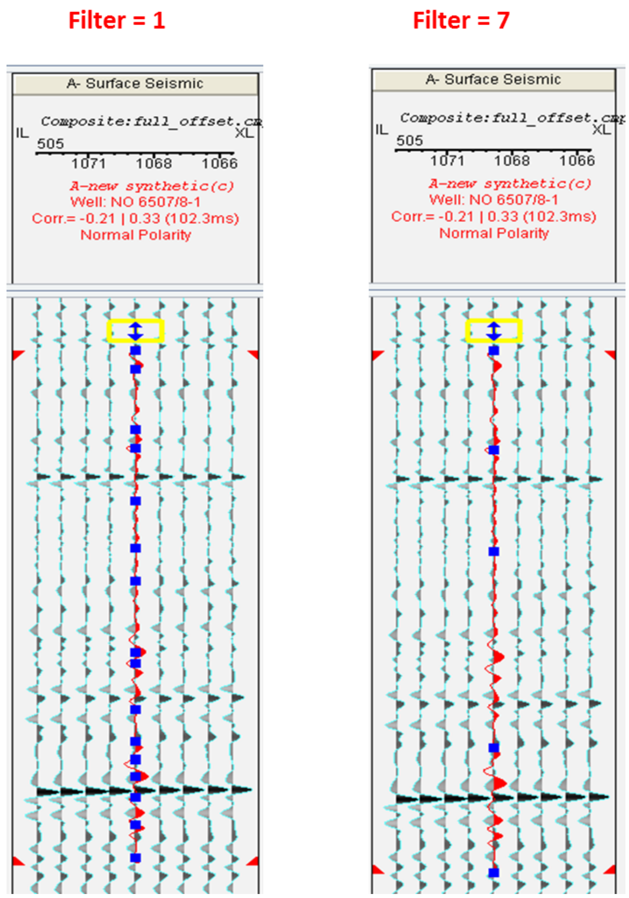
6. In the *Select Time-Depth Controls* dialog, toggle on **Create pseudo check shots**. The pseudo shots will be created from the sonic log with tie points at significant velocity changes.

7. Enter "**7**" in the *Maximum difference (ms)* field and then click the **Apply Filter** button.



Note

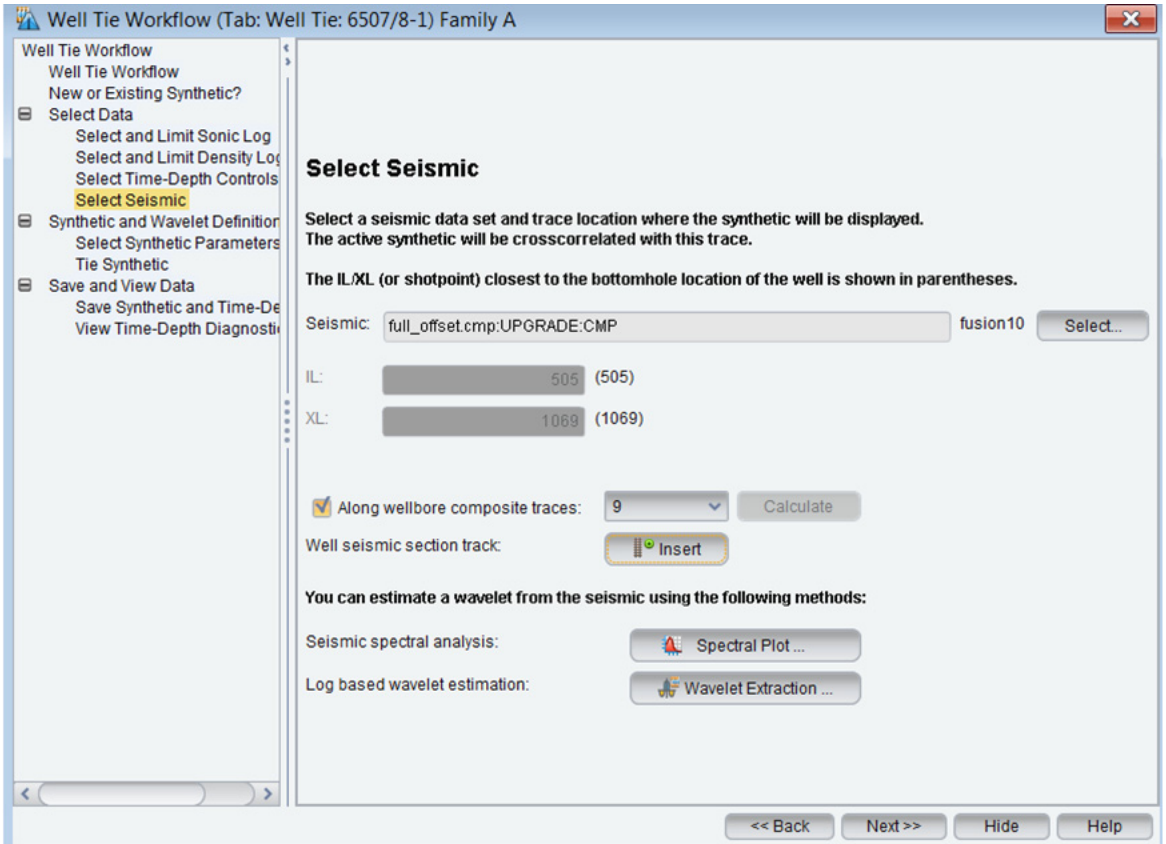
The number of tie points (blue points) in the synthetic track are reduced when we apply the filter. The remaining points are the most significant changes of velocity in the sonic log. You will use them in the calibration with the seismic data.



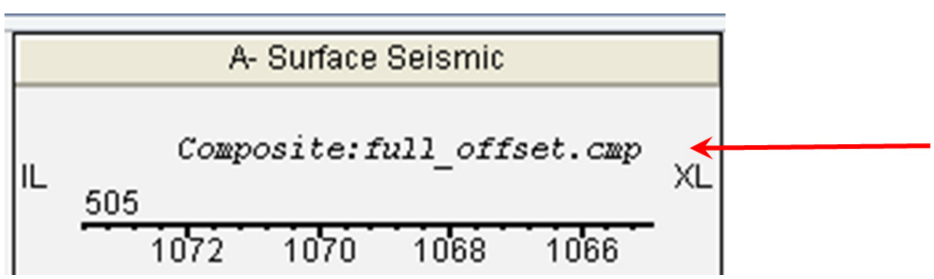
8. In the *Select Seismic* dialog, select the seismic **full_offset.cmp**.

9. Select the **Along wellbore composite traces** option.

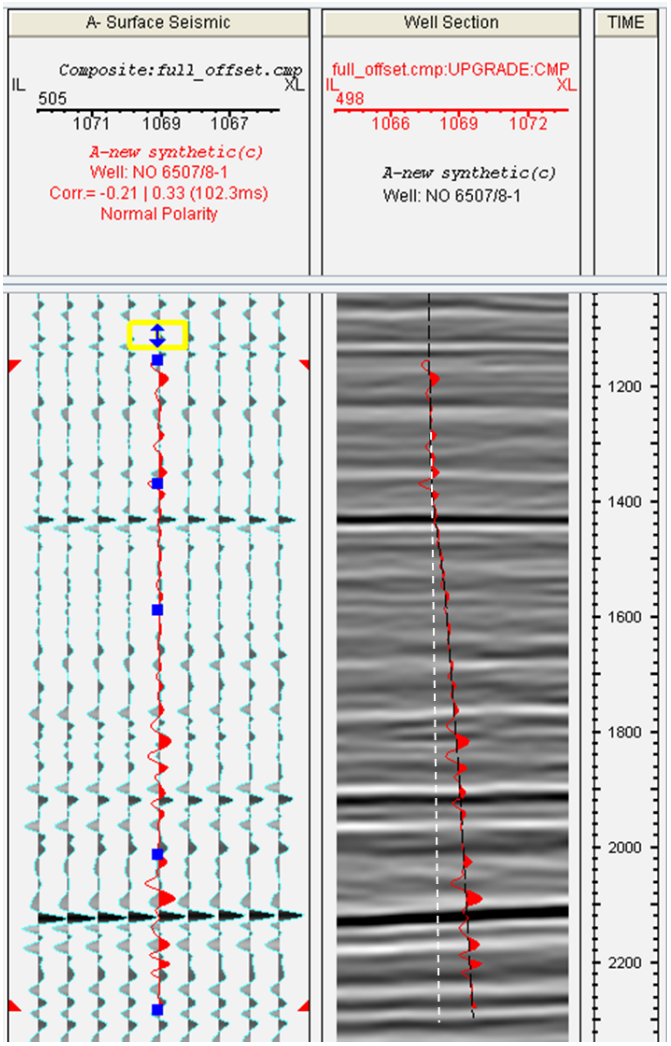
10. Select **9** from the drop-down menu and click the **Calculate** button.



11. Go to the Well Tie session and see how the traces in the *A-Surface Seismic* track have changed and the header of the seismic is **Composite:full_offset.cmp**.



12. Click the **Insert** button to add a track with a well seismic section to display seismic and synthetic along a deviated wellbore.



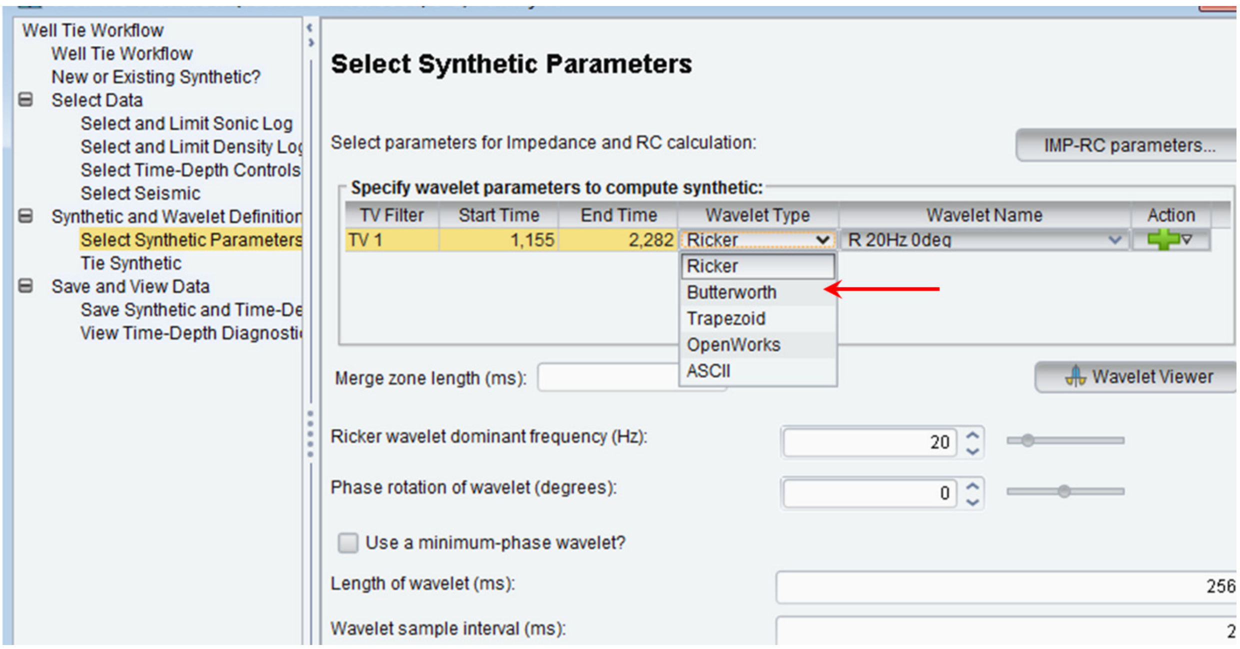
Composite Traces are extracted traces from a 3D stacked seismic data set along the wellbore of a directional well. All points that define the wellbore coordinates are used in the computations. The wellbore coordinates of the bottomhole location are used for the X, Y position below the bottom of the wellbore. Composite traces are used to compute Correlation Coefficient.

Well Section Track displays the 3D stacked seismic data and the synthetics along the directional well.

> **Note**
>
> The dashed vertical line in the *Well Section* track is just an illustration to see the well deviation. It may not appear in your session.

13. Continue clicking **Next** until the *Select Synthetic Parameters* dialog opens.

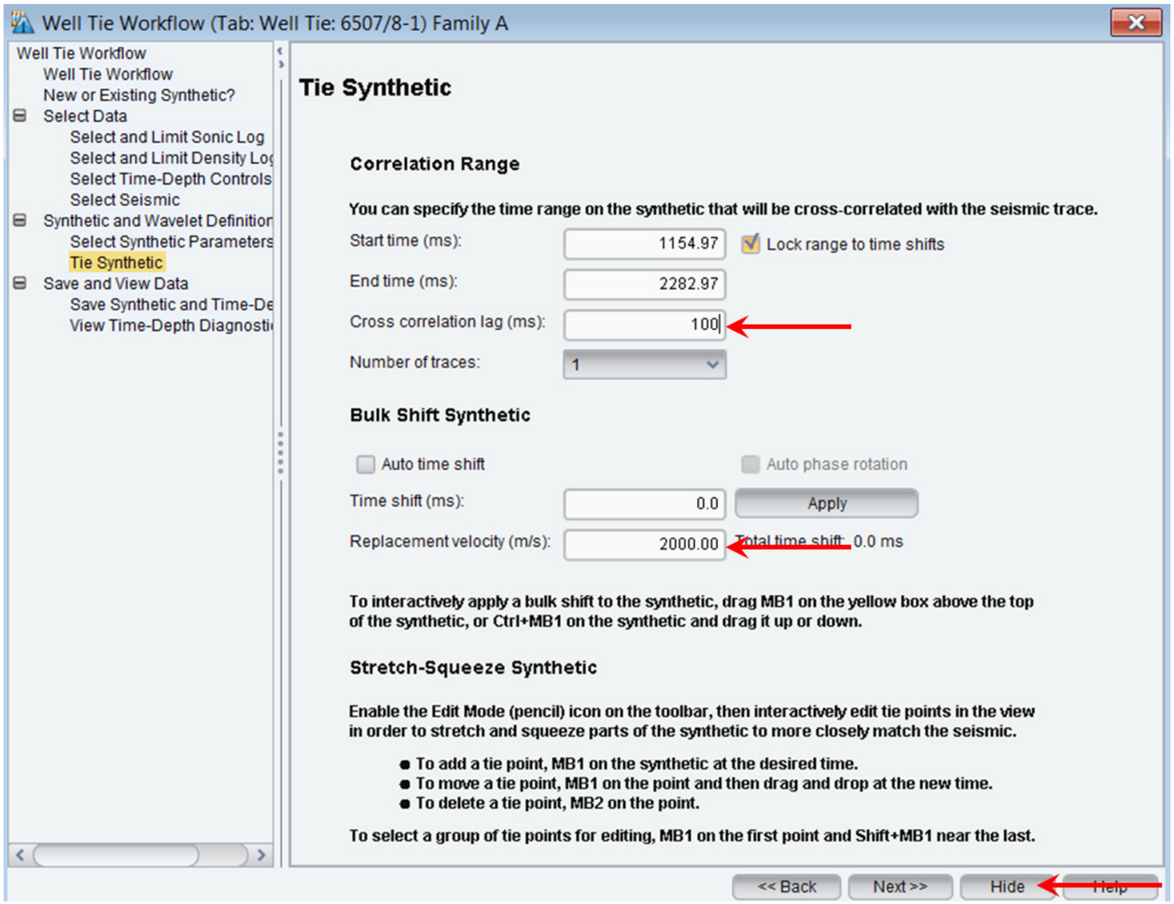
14. In the *Select Synthetic Parameters* dialog, select **Ricker** from the *Wavelet Type* drop-down menu and **R 20Hz 0deg** from the *Wavelet Name* drop-down menu. Note that you have new options available; Butterworth, ASCII, and Trapezoid (called Bandpass in R5000.8.3.1).



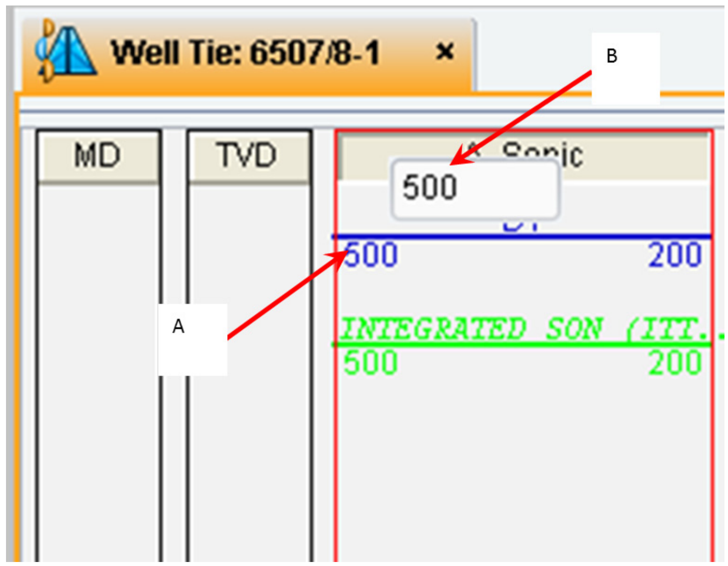
15. Click **Next**.

16. In the *Tie Synthetic* dialog, enter "**100**" in the *Cross correlation lag (ms)* field.

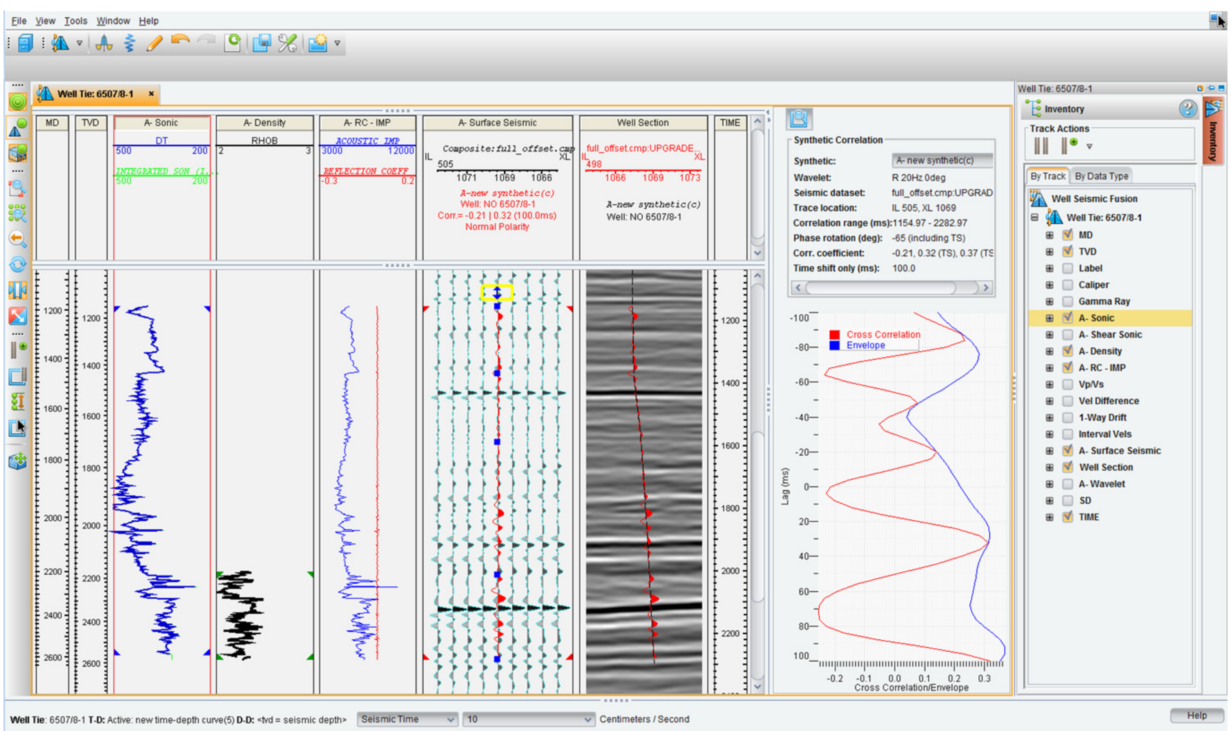
17. Enter "**2000**" in the *Replacement velocity (m/s)* field.



18. Click the **Hide** button to close the *Well Tie Workflow Wizard*. If necessary, adjust the scale of the **DT** and **INTEGRATED SON (ITT CORR)** curves in the *A-Sonic* track. Both curves should have the same scale (500 – 200). You can do this by **MB1** on the **Scale value**, enter the value and press the <**Enter**> key.



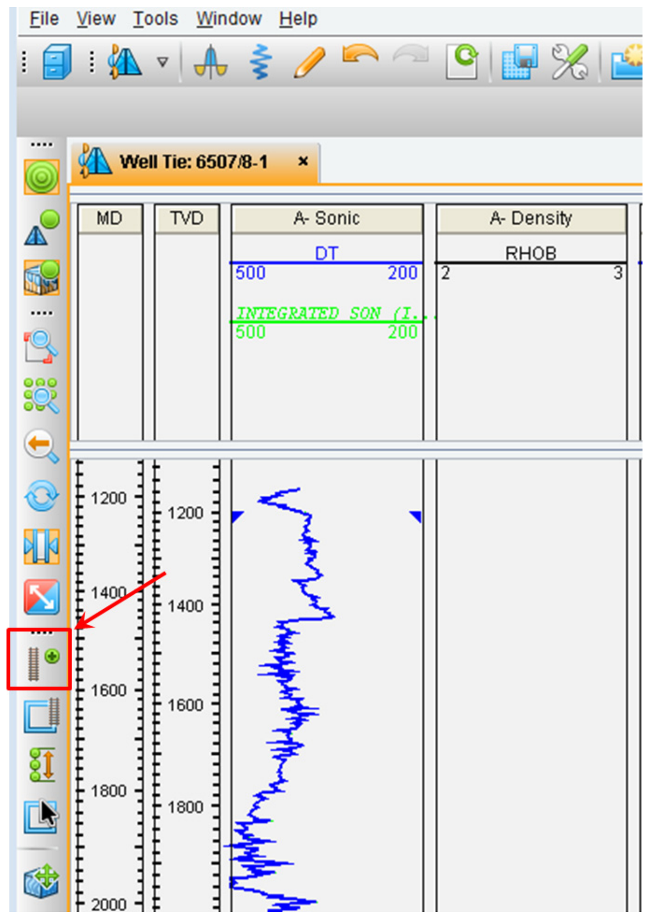
You should now have a synthetic seismogram as displayed in the image below:



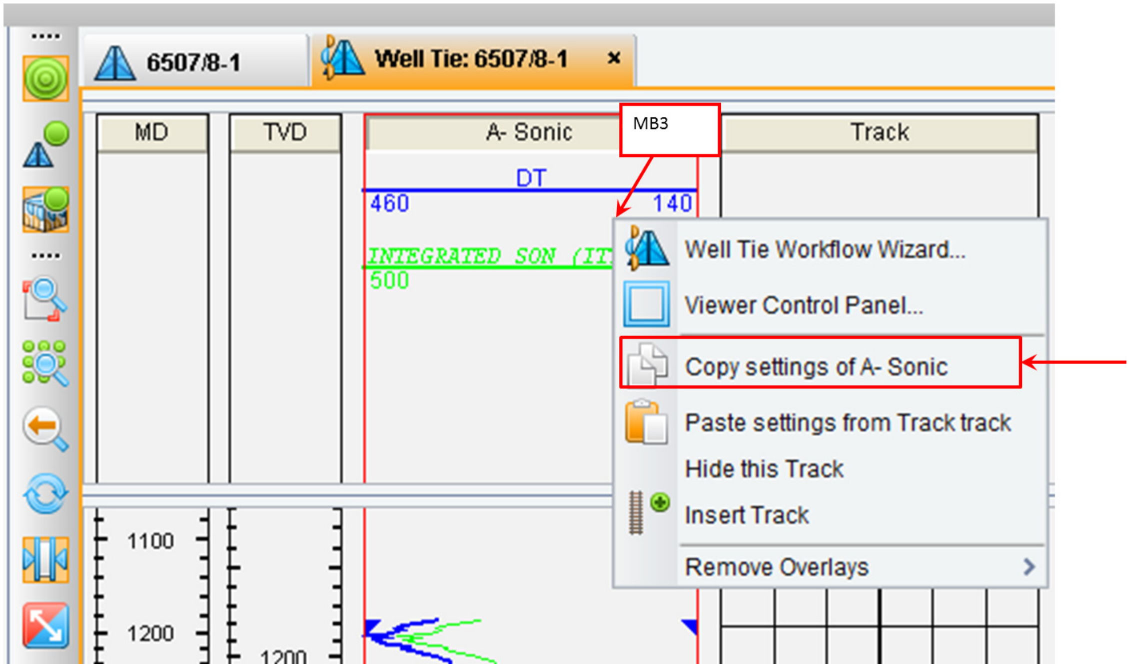
Exercise 2.3: Customizing the Work Session

New functionality has been added to DSG 5000.10 for customizing the display and arranging the data in the Well Tie Workflow. These improvements increase workflow efficiency. In this exercise, you will learn how to add new tracks, insert data into existing tracks, and copy settings and synthetics to different tracks. You will also become familiar with how to use the inventory panel to customize the data that is displayed in the session.

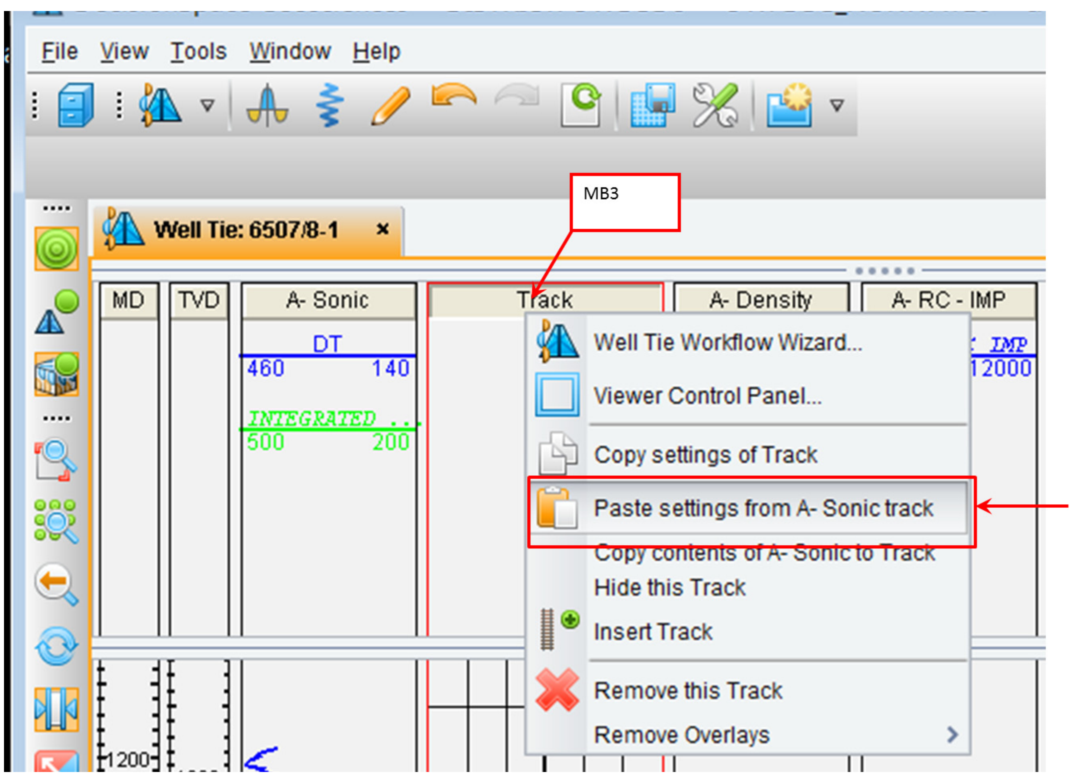
1. Click the **Insert New Track** icon in the vertical tool bar.



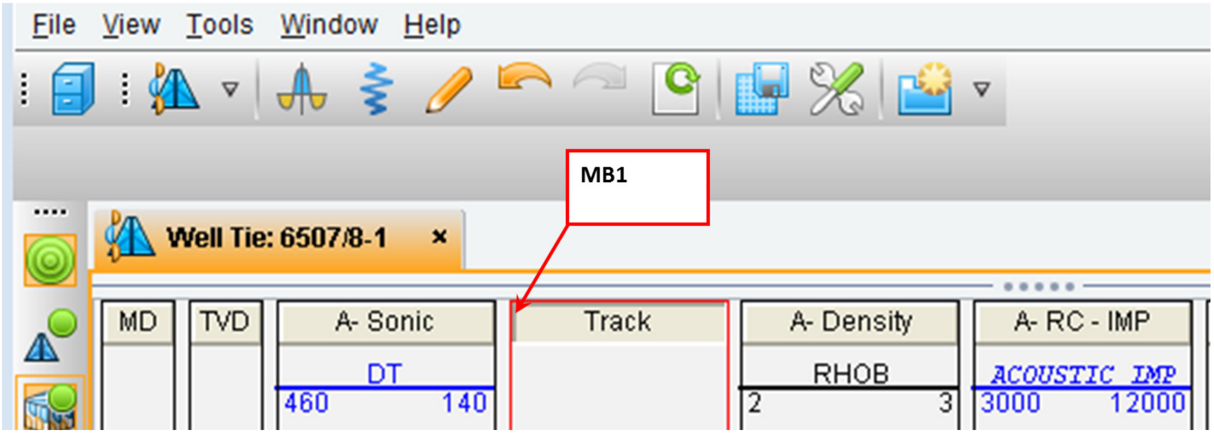
2. **MB3** on the *A-Sonic* track name and select **Copy settings of A-Sonic**.



3. **MB3** on the new track header and select **Paste settings from A-Sonic track**.



4. Display the log data in this new track. **MB1** on top of **Track** to select it.

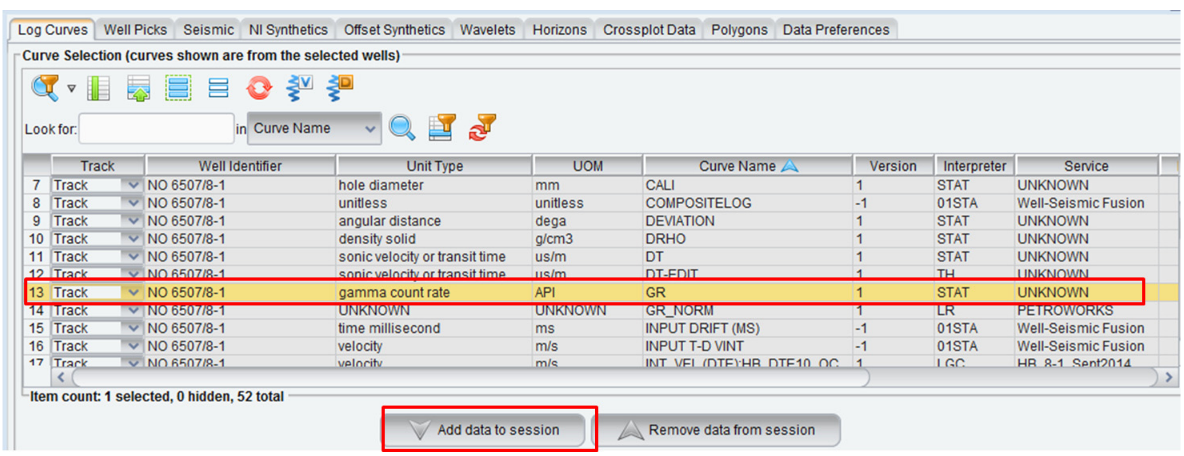


5. Click the **Select Session Data** ( ) icon.

   The *Select Session Data* dialog appears.

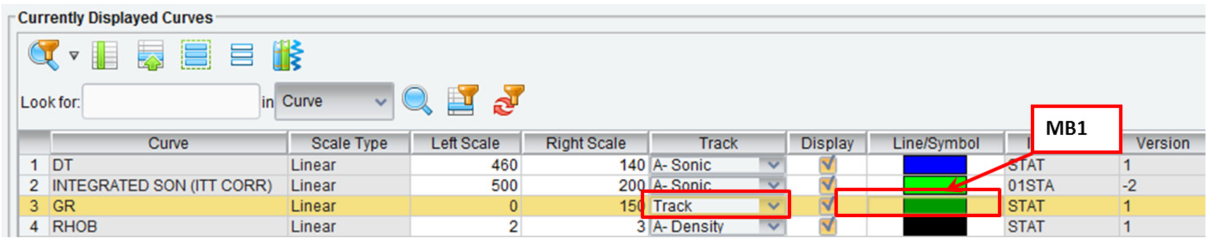
6. Select the *Log Curves* tab.

7. Select the **GR** curve and then click the **Add data to session** button.



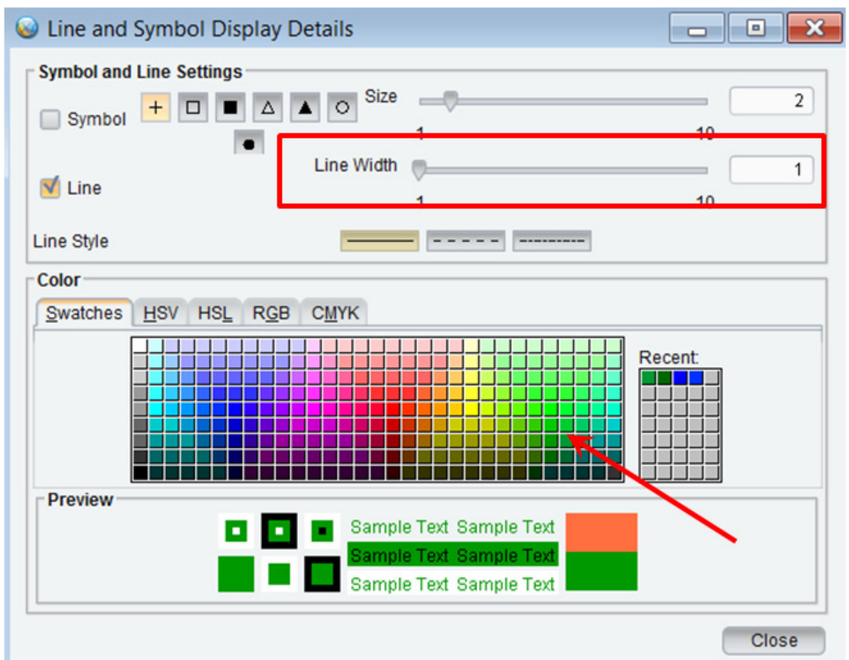
8. If necessary, select **Track** from the **Track** drop-down menu to assign the **GR** log to the new track.

9. Click the color in the **Line/Symbol** column to change the display properties.



The *Line and Symbol Display Details* dialog appears.

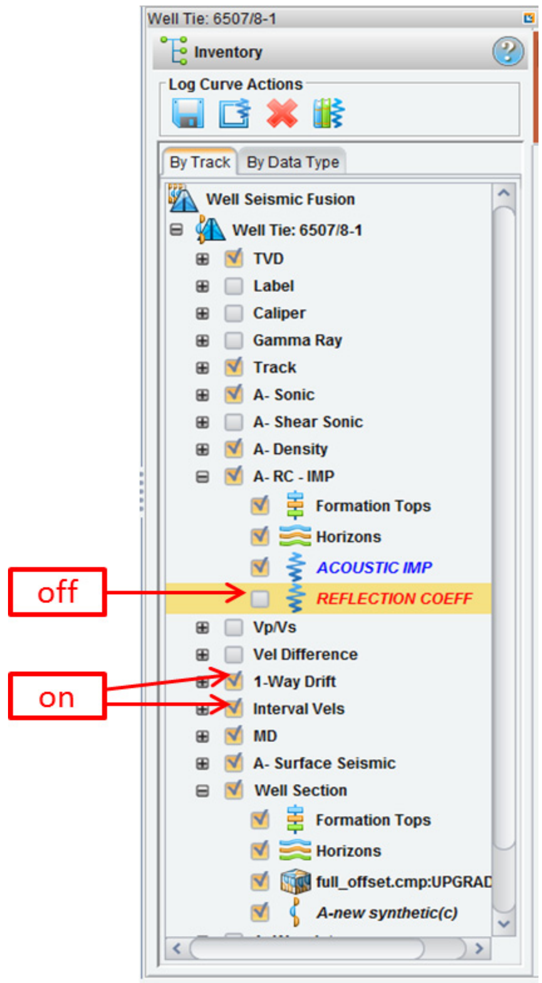
10. Change the *Line Width* to **1** and color to **Dark Green**.



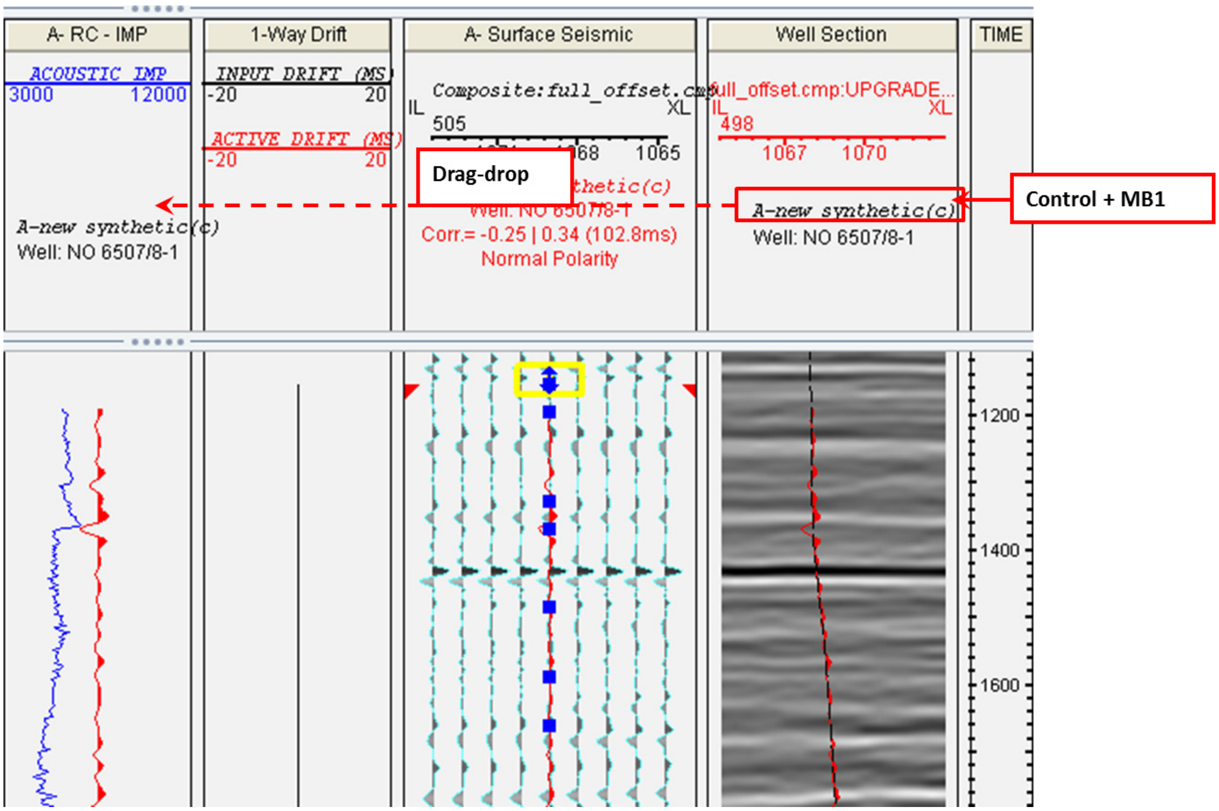
11. Click **Close** to apply the settings and exit the *Line and Symbol Display Details* dialog. In the *Select Session Data* dialog, click **OK** to exit.

12. Deselect the **REFLECTION COEFF** check box under the *A-RC-IMP* track in the *Inventory* panel.

13. Select the **1-Way Drift** and **Interval Vels** check boxes.



14. In the *Well Section* track, **MB1+<Ctrl>** on **A-new synthetic** and drag-and-drop the curve to the *A-RC-IMP* track.



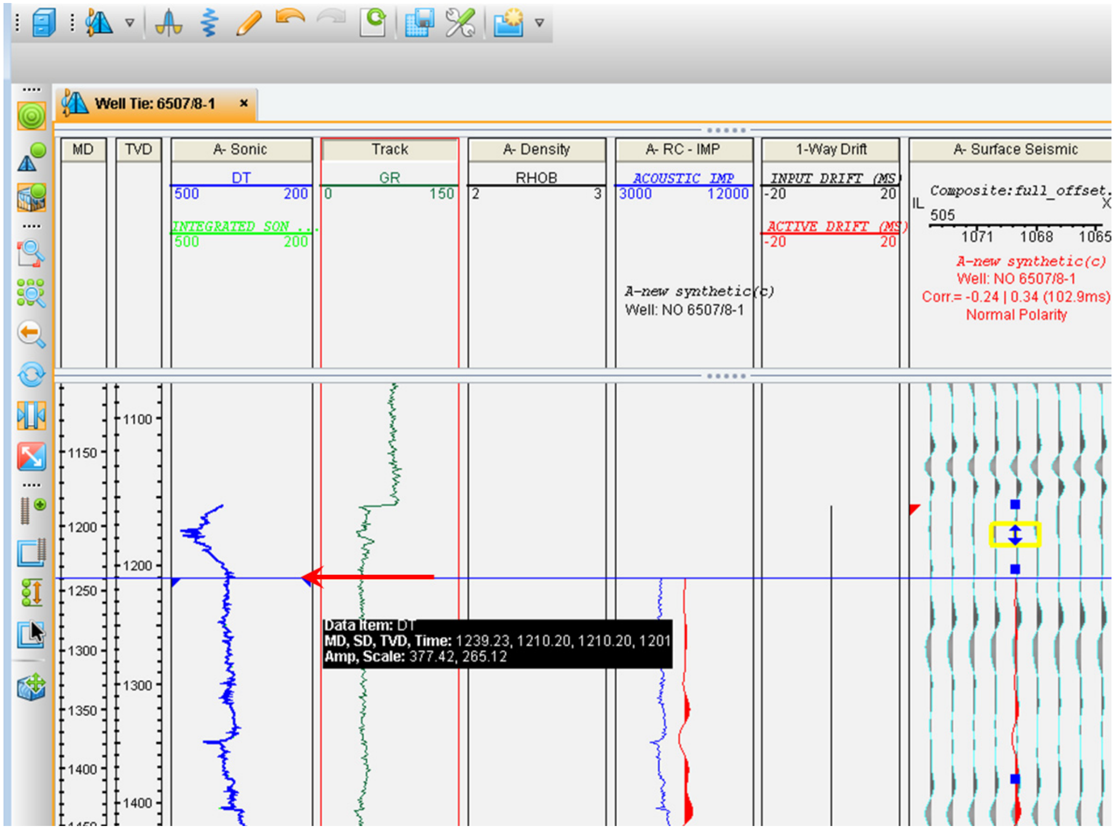
Note that a better way to see the relationship between the Acoustic Impedance curve and synthetic seismogram is when they are both in the same track.

Before starting calibration, we usually use other logs that are less affected by environmental effects (i.e. GR, Resistivity, etc.) to identify possible artificial effects that may exist in the sonic log.

In this particular well, the beginning of the sonic log could be affected because we can't see a similar change in the GR log at the same depth. We will consider the sonic log from TVD value of 1210m.

15. Ensure that the **Interpretation Mode (** ✎ **)** is off.

16. **MB1** on the blue triangles in the *A-Sonic* track and drag downwards until **1210 m TVD**.



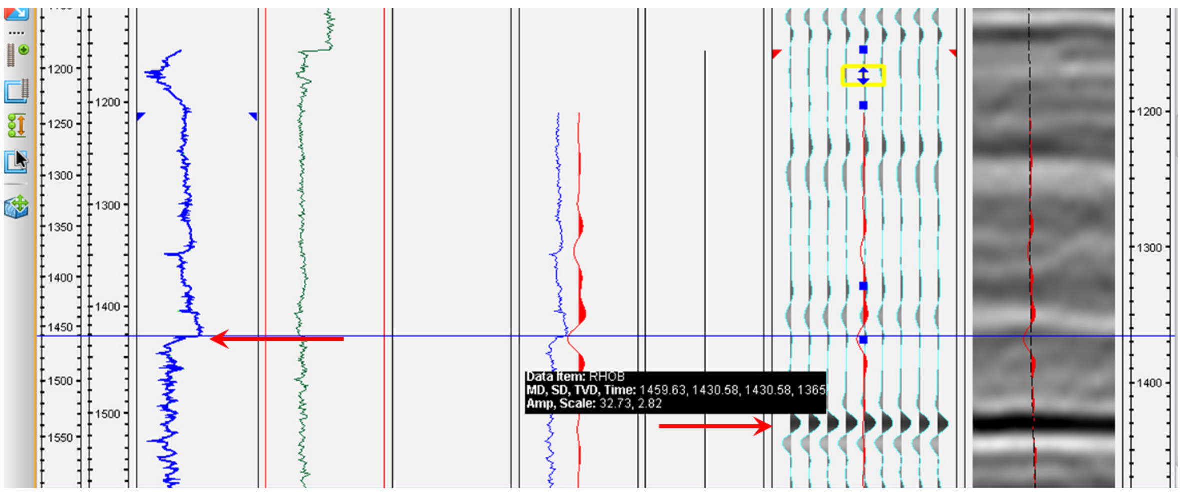
Note that the big reflection in our synthetic seismogram is removed.

> **Note**
>
> Use the <**r**> hot key to toggle **MD**, **TVD**, and **TIME** values on any track. Use the <**q**> hot key to cycle through cursor line options across the Well Tie, and <**w**> to rotate through cursor line colors.

Exercise 2.4: Tying Synthetic to Seismic

In the previous exercise, you customized your work session to better visualize the data. Next, you will begin to tie your synthetic to the seismic by changing parameters, editing tie points, and changing the frequency of your wavelet.

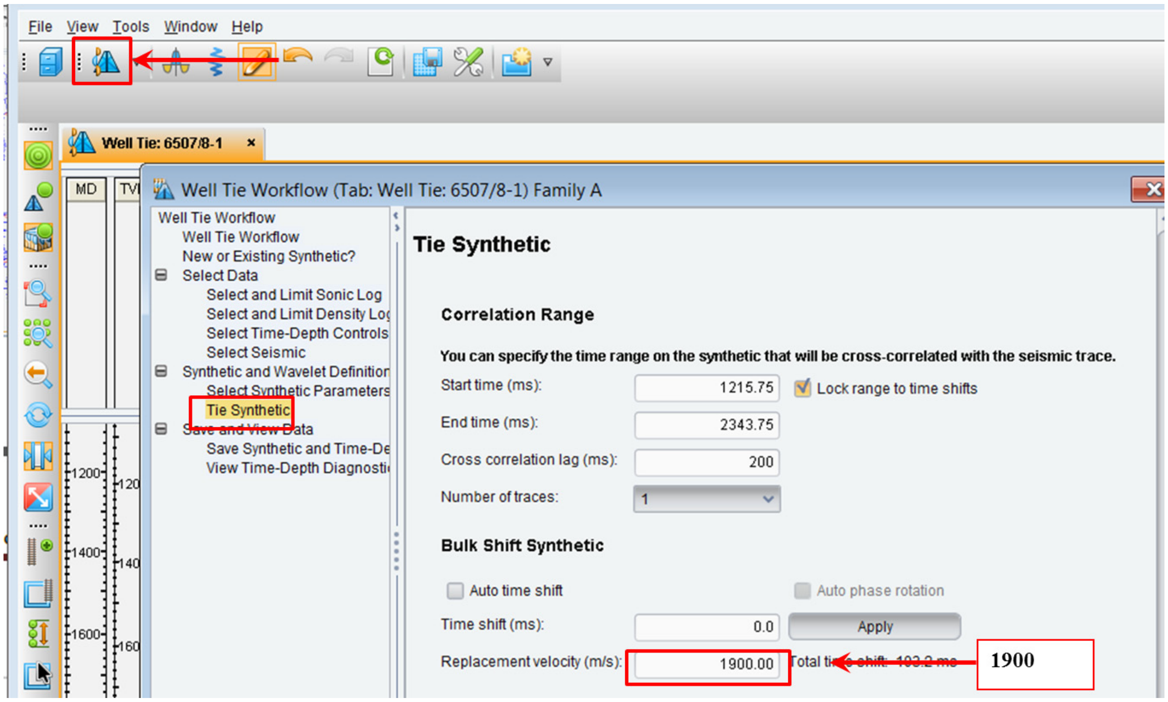
Big changes of velocity in the sonic log mostly correspond with principal seismic reflectors. Look at the first big change (around 1430 m TVD) in the sonic log. Can you see a strong reflector below this change (around 1430 ms)? You may need to use the Graphical Rescale tool to stretch the curve.



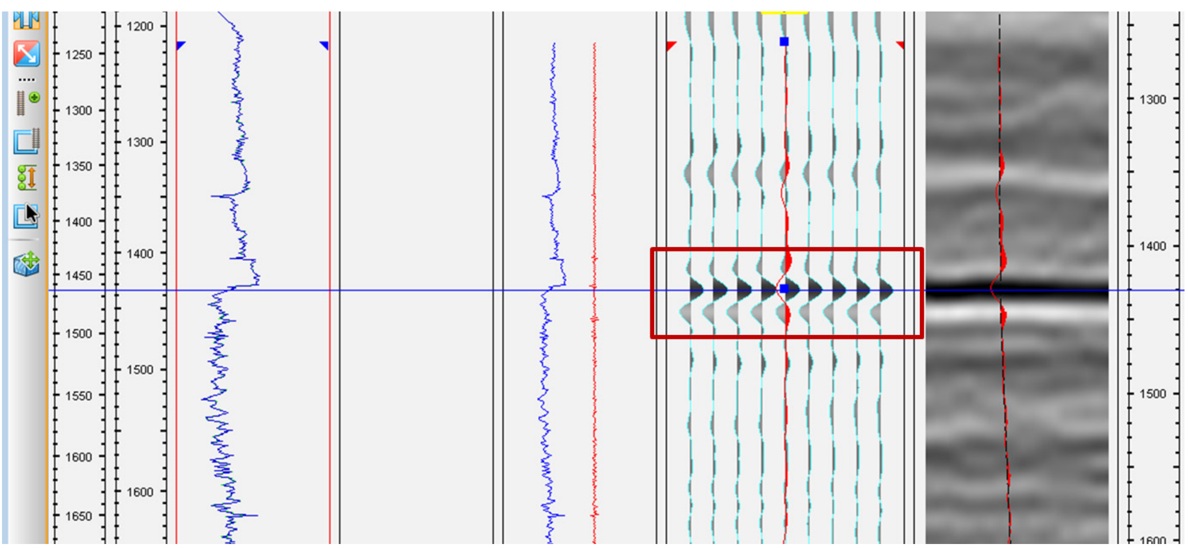
Note

Ask the instructor for help if you do not have a similar display.

1. Open the *Well Tie Workflow Wizard* and change the *Replacement velocity* to “**1900**” m/s. Press <**Enter**> or click elsewhere to see the change.

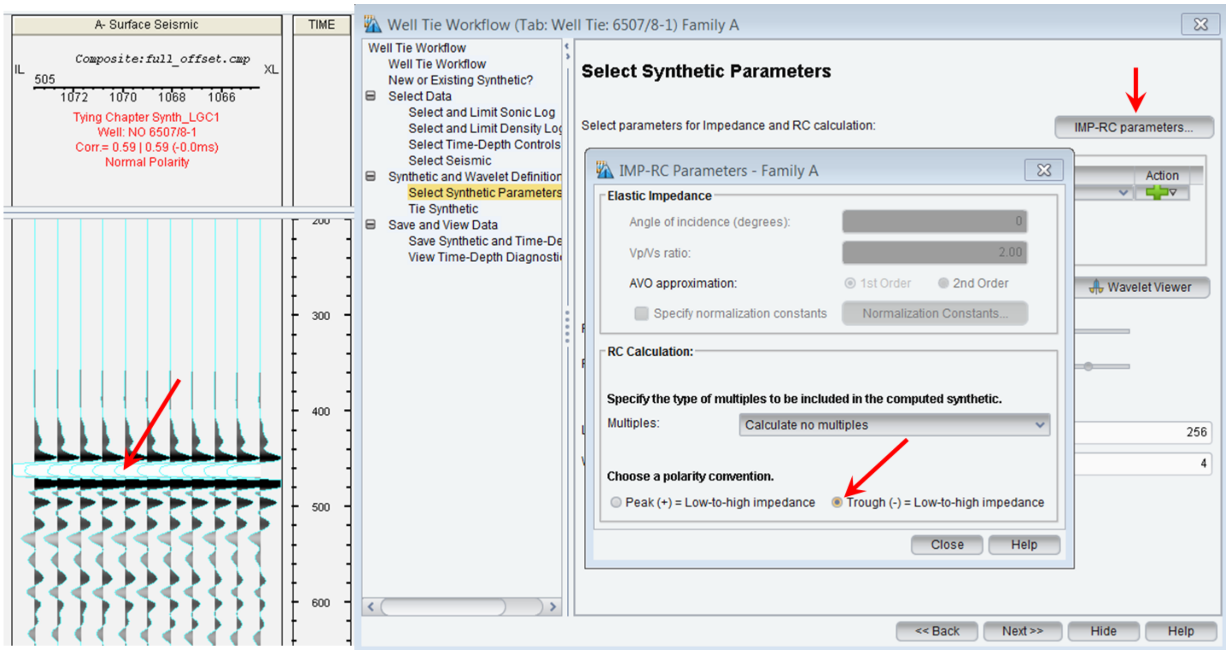


Note the polarity of this strong reflection is reversed. This is because we are using the Norway data set which follows a European polarity convention.



2. Double-check the water bottom reflection. It shows a trough response. Switch to the *Select Synthetic Parameters* dialog, and click the **IMP-RC Parameters** icon.

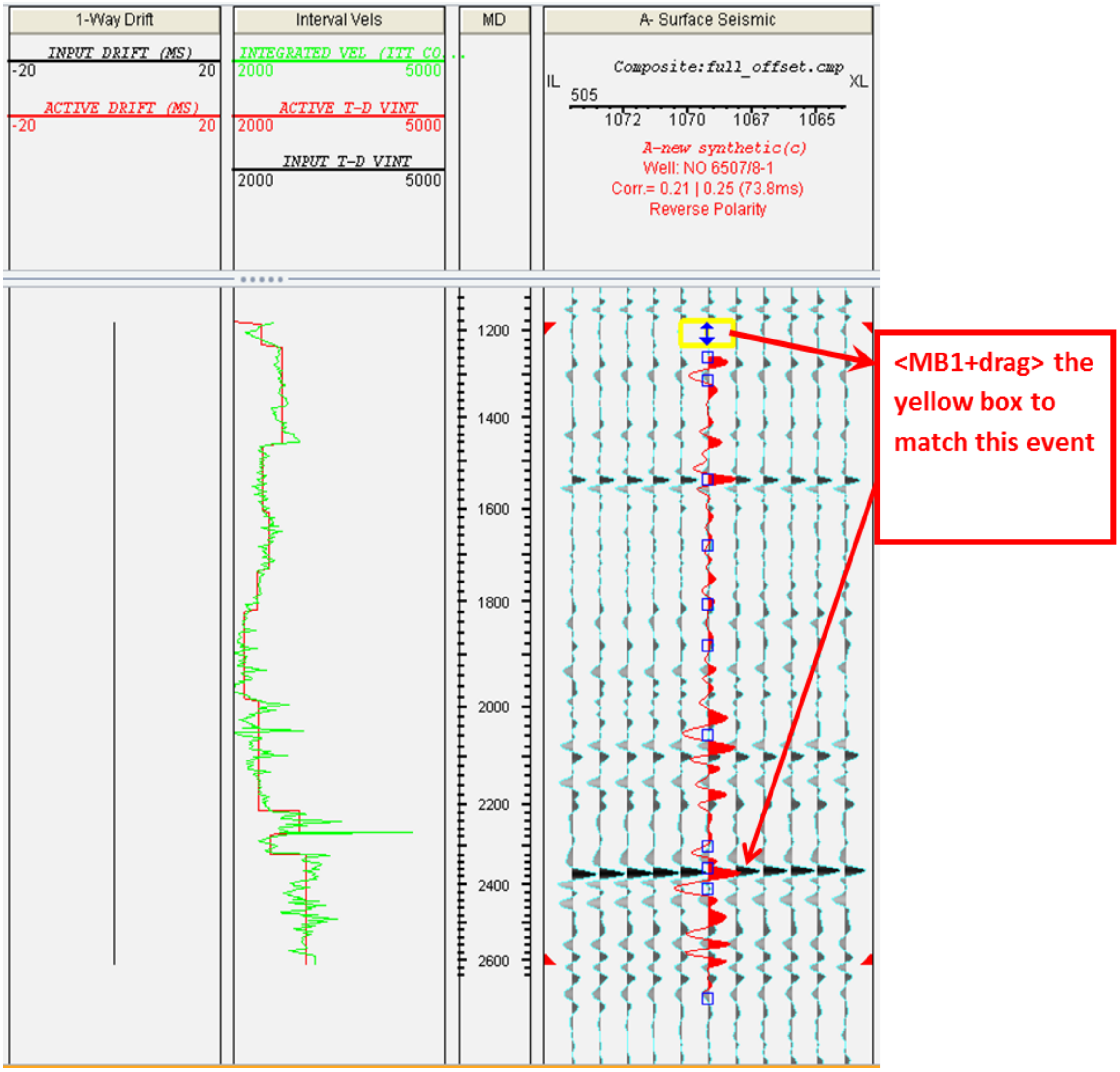
3. In the *IMP-RC Parameters* dialog, select the **Trough (-)** option.



Note that the major reflector in the synthetic now matches the seismic data. Getting the Replacement Velocity and Phase to identify where the first point to the Sonic is placed is very important.

4. Click the **Edit Tie Point mode** () icon.

5. **MB1-drag** the yellow box to bulk shift the most prominent peak in the synthetic (at about **2320 m MD**) to match the seismic peak (at about **2120 ms TIME**).



It is a good practice to have the *MD* (Measured Depth) track next to the synthetic as you stretch and squeeze. The tracks in the *Well Tie* display are flexible and can be easily rearranged. To change the track order, click the top label and drag it to the desired position. A red triangle will indicate where it will be placed when you release MB1.

6. Move the *MD* track by dragging-and-dropping its top label to place it to the left of the *A-Surface Seismic* panel.

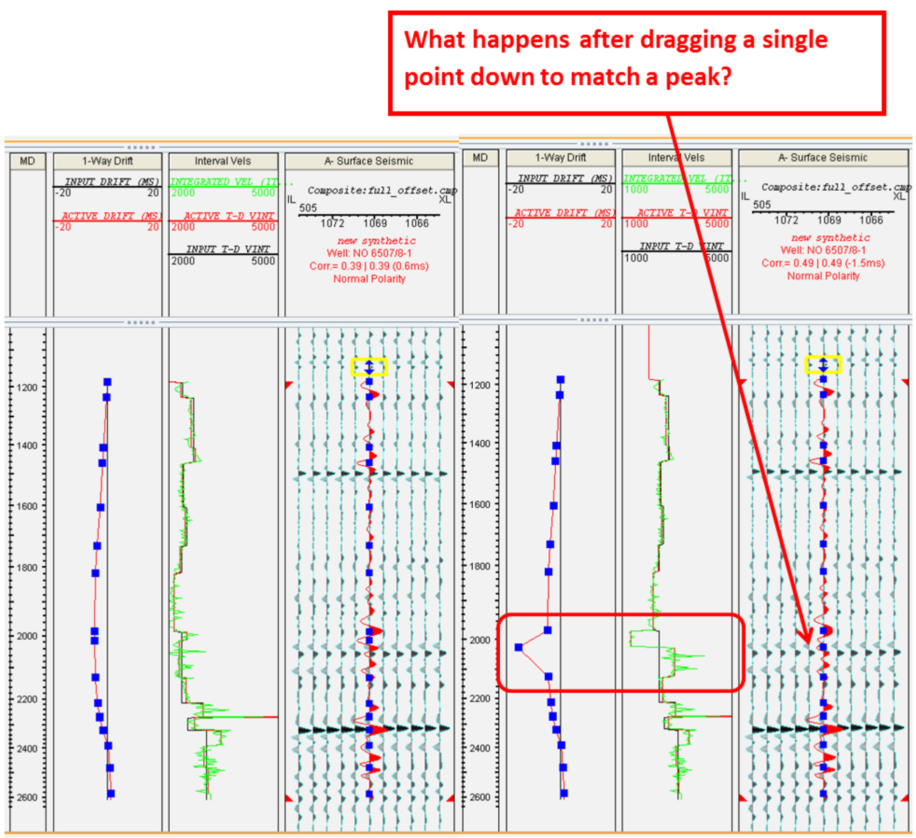
7. If necessary, **MB1-drag** the sash between the tracks to widen the *Synthetic Correlation* panel so you can see all parameters in the *Synthetic Correlation* box. You can move the *1-Way Drift* and *Interval Velocities* track next to the *MD* track.

8. Press <**q**> to display a marker and move your marker on the seismic section. You can review the **Time**, **TVD**, **amplitude**, and other information at the bottom of the main window. (You can also use the <**r**> hot key).

9. Use the <**Z**> hot key to view the details and find the misregistration at about **2080 m MD**.

10. After you locate the misregistration, click the **Edit Tie Point Mode** ( ) icon. **MB1-drag** a single point at about **2020 m MD** down to match the seismic peak at about **1920 ms TIME**.

11. Check the drift curve and interval velocities. Are they geologically reasonable?

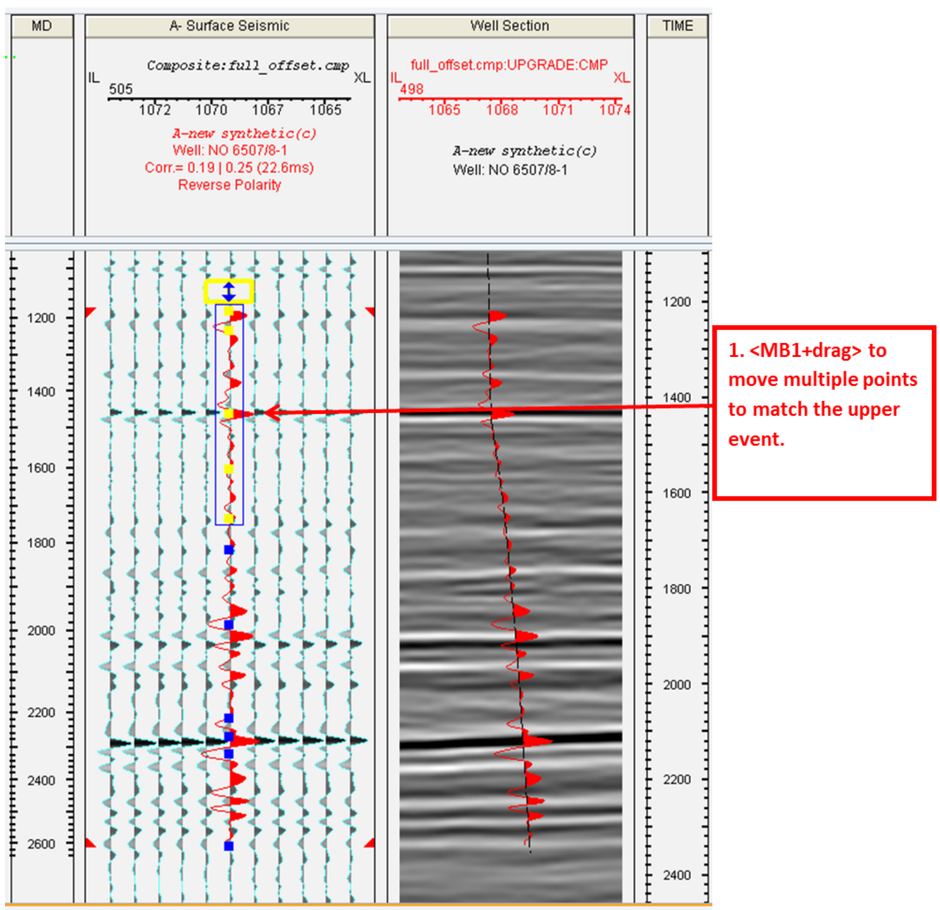


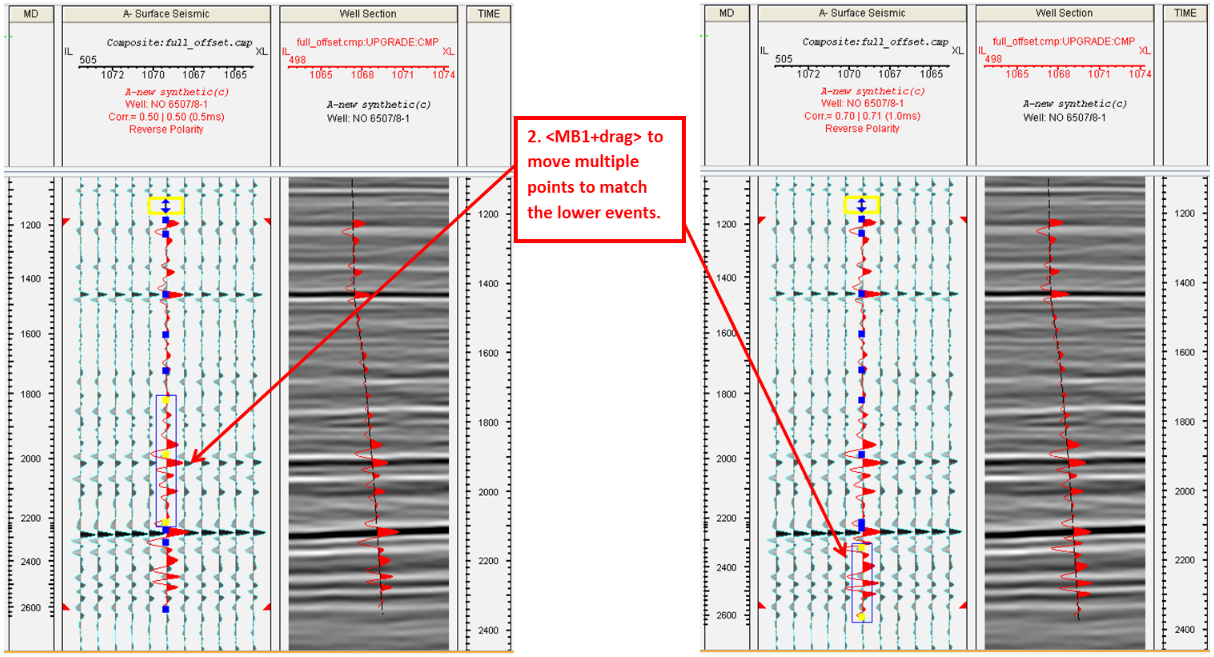
Note the anomalies in the drift curve and T-D curve caused by dragging a single point down to match a peak. In most cases, it is geologically unreasonable. Usually, you can avoid doing so by shifting a certain range of tie points. That is why you should always use drift curve and interval velocity curve as QC tools.

12. Undo the single point modification by pressing <**Ctrl + Z**> or clicking the **Undo Tie Point Edit** icon.

13. With the <**Shift**> key pressed, select a range of points in the upper part of the Synthetic trace (as shown in the image below). Note that the selected tie points are now in a group. **MB1-drag** the group down to match the seismic peak at about **1430 ms TIME**. Group the tie points in the lower part of the synthetic trace.

14. **MB1-drag** the group down to match the seismic peaks at about **1920 ms** and **2120 ms TIME**.





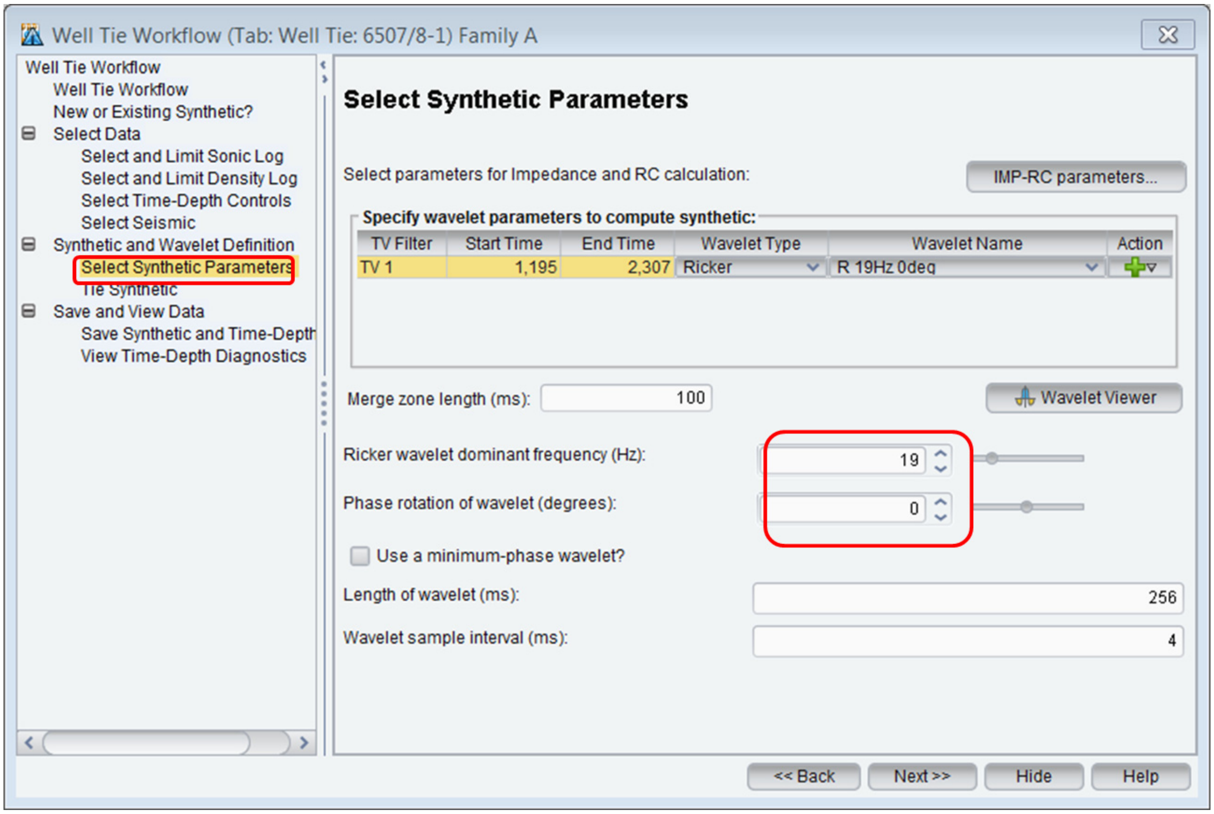
> **Note**
>
> Be careful while stretching and squeezing synthetic traces to fit the seismic, specially when you are using an accurate time-depth control.

15. Check the frequency and phase rotation of your wavelet. You can modify them in the *Select Synthetic Parameters* dialog.

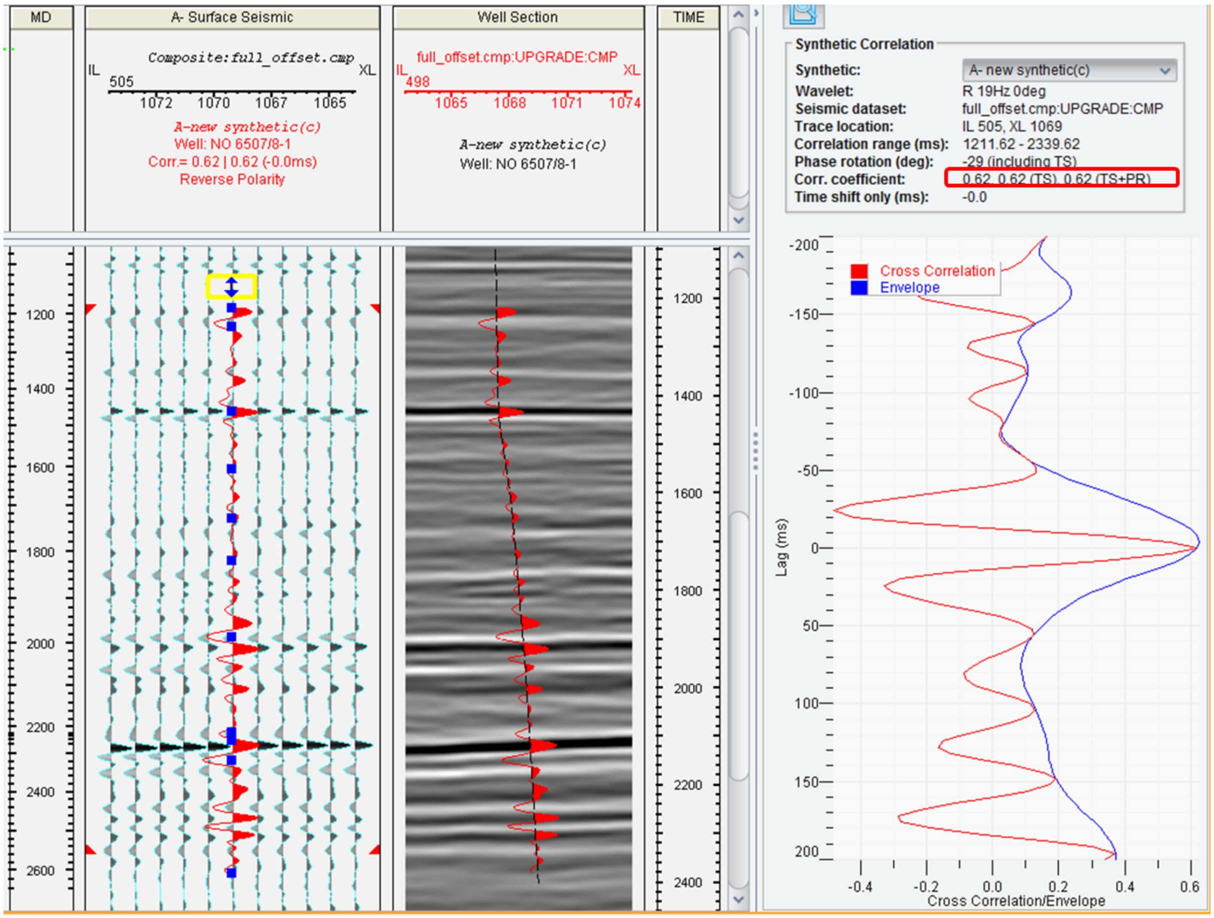
16. To get a rough estimation of the dominant frequency of your seismic data, count the number of peaks or troughs within 1 second. In this case, the count is 19. You can experiment with other dominant frequencies to find the maximum correlation.

17. In the *Select Synthetic Parameters* dialog, select **Ricker** from the *Wavelet Type* drop-down menu. Most seismic data, including this class data set, is processed to zero phase.

18. Ensure the **Use a minimum-phase wavelet?** check box is not selected.



19. Check your correlation coefficients again. Have they increased? Your coefficients may differ from others but try to keep the time shift specified coefficient **(TS)** above **0.5** by shifting a range of points, and make sure the major reflectors in seismic match those in the synthetic trace.



Wavelet Extraction

In this section, you will learn about wavelet analysis enhancements. A Butterworth wavelet is created in the Frequency domain. The characteristics of the amplitude spectrum are:

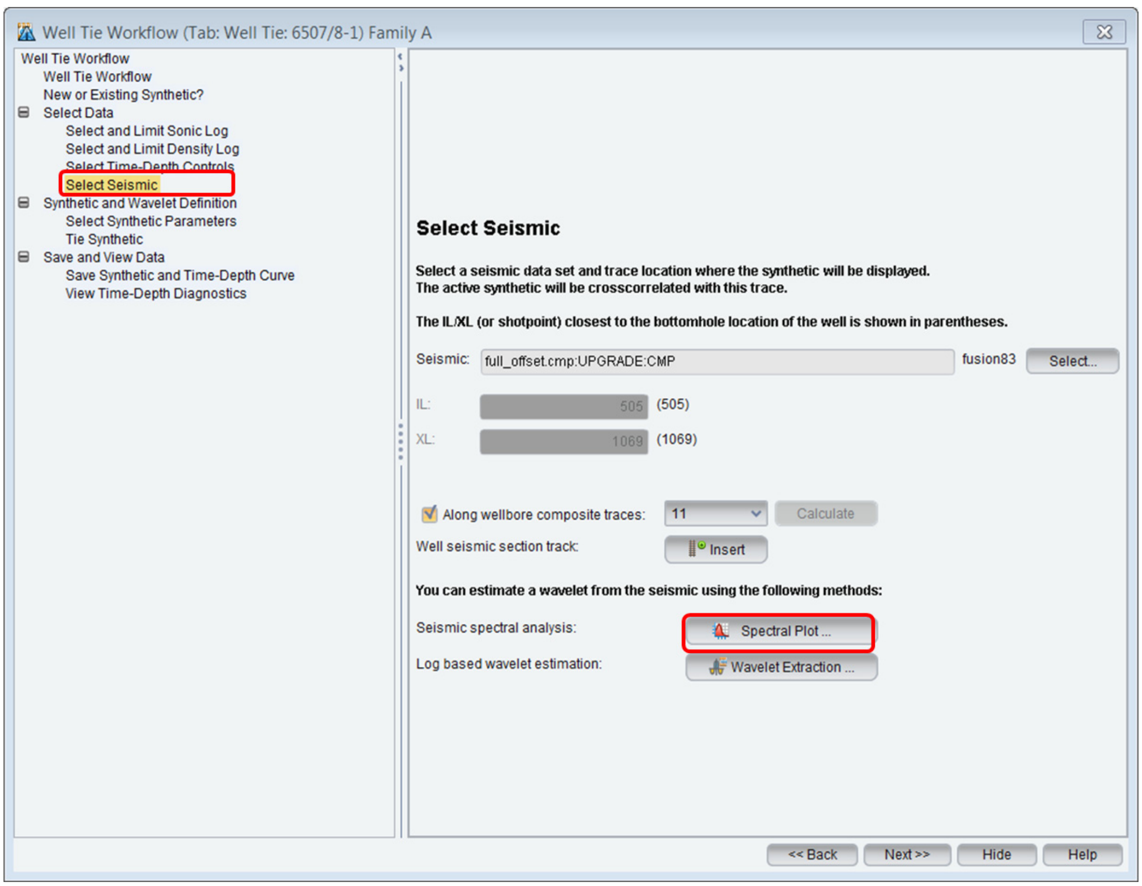
- Flat pass band.
- Smooth exponential decay of amplitude on both low-cut and high-cut sides. The amplitude decay is asymptotically straight when plotted on a dB versus octave scale.

Exercise 2.5: Wavelet Analysis

The Well Tie Workflow provides two basic tools to estimate a wavelet from processed seismic data:

- Seismic spectral analysis (spectral plot)
- Log based wavelet estimation (wavelet extraction)

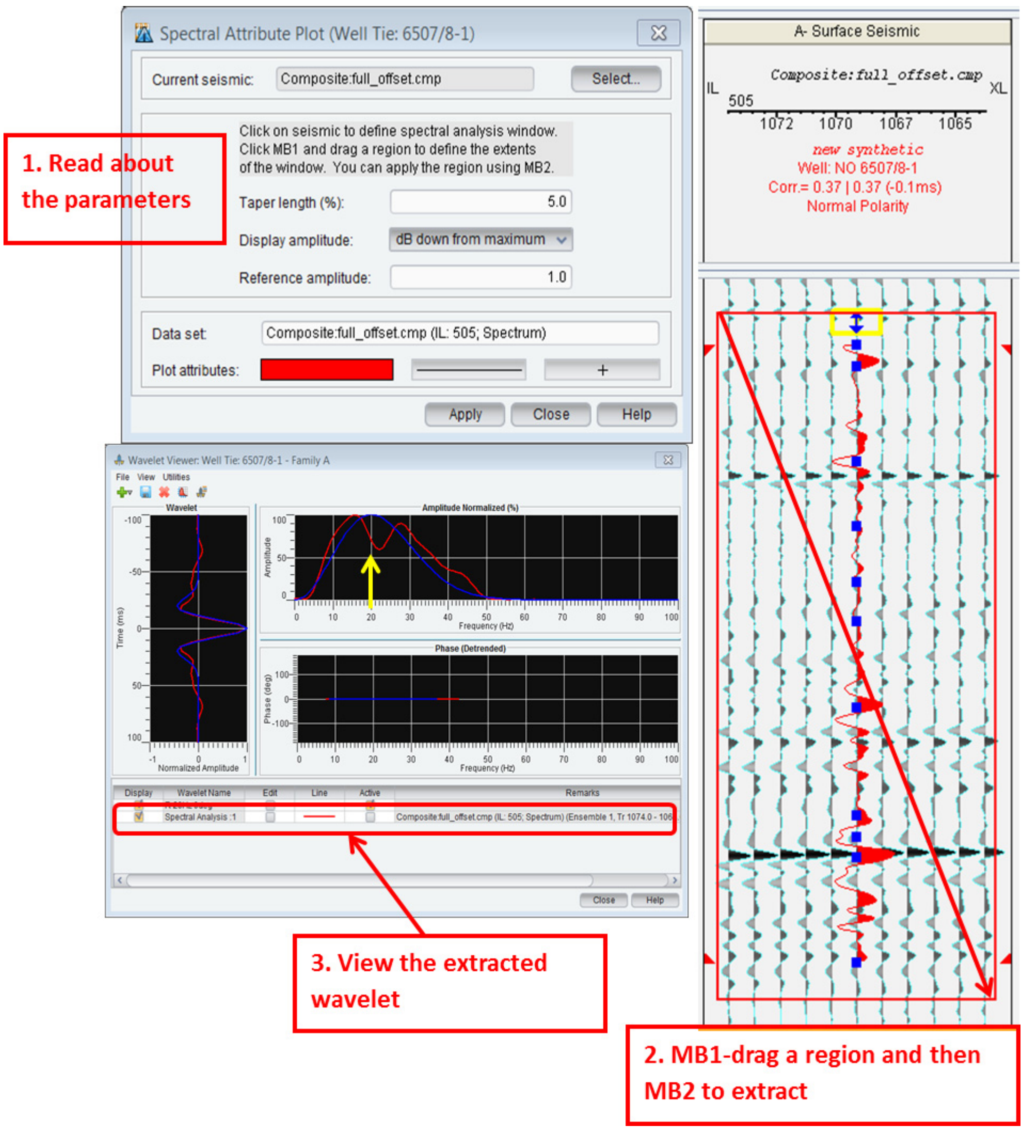
1. Open the *Well Tie Workflow Wizard*, expand the *Select Seismic* panel.
2. Click the **Spectral Plot...** button.



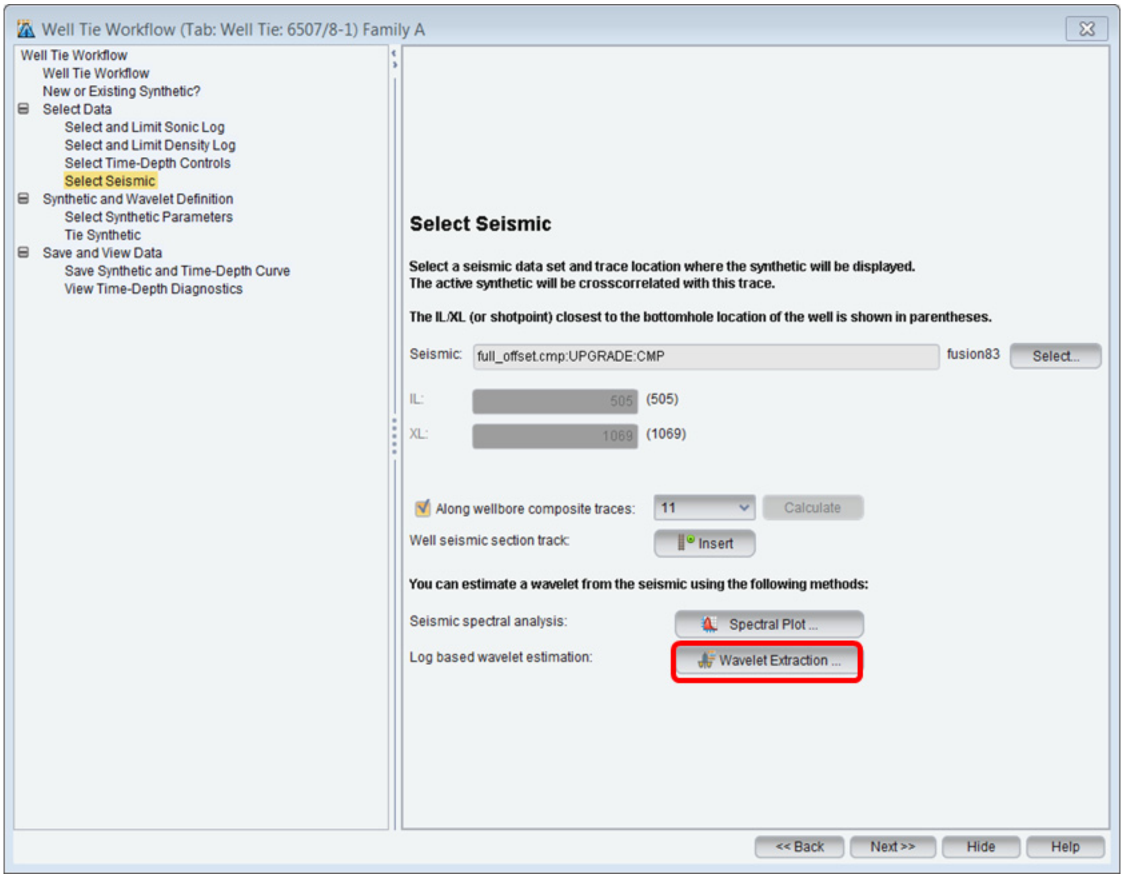
3. Review the message in *Spectral Attribute Plot* dialog. In the *A-Surface Seismic* track, hold **MB1** and drag a region to define the wavelet extraction window as shown in the picture below. **MB2** to apply. The *Wavelet Viewer* opens. The extracted wavelet is shown as Spectral Analysis: 1. (In this way, the wavelet is generated based on the frequency of your seismic data).

4. The *Wavelet Viewer* should be displaying the Ricker wavelet (R 20Hz 0deg, from previous exercise) and the extracted Spectral Analysis: 1 wavelet; compare both of them. (If necessary, toggle on both wavelets in the *Display* column). Experiment changing the active wavelet and notice the changes in your synthetics log and correlation coefficient.

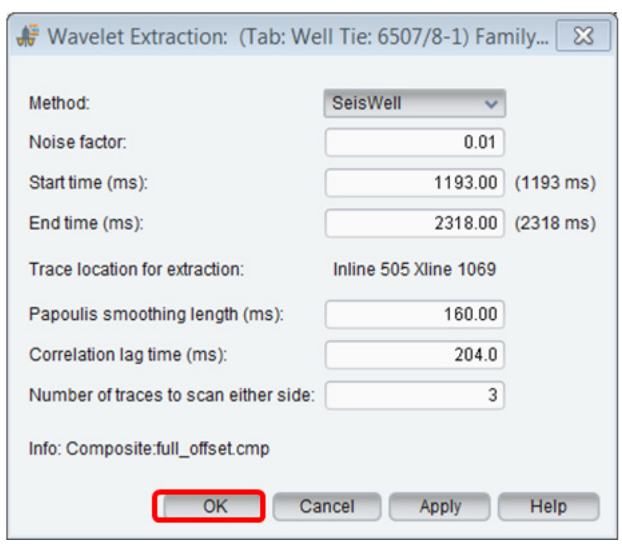
5. In the *Wavelet Viewer*, look at the Amplitude versus Frequency plot and select a mid frequency of the spectrum: _______ Hz. (You will probably select near 20 Hertz).



6. In the *Select Seismic* panel, click the **Wavelet Extraction...** button.



7. In the *Wavelet Extraction* dialog, accept the parameters by clicking **OK**.

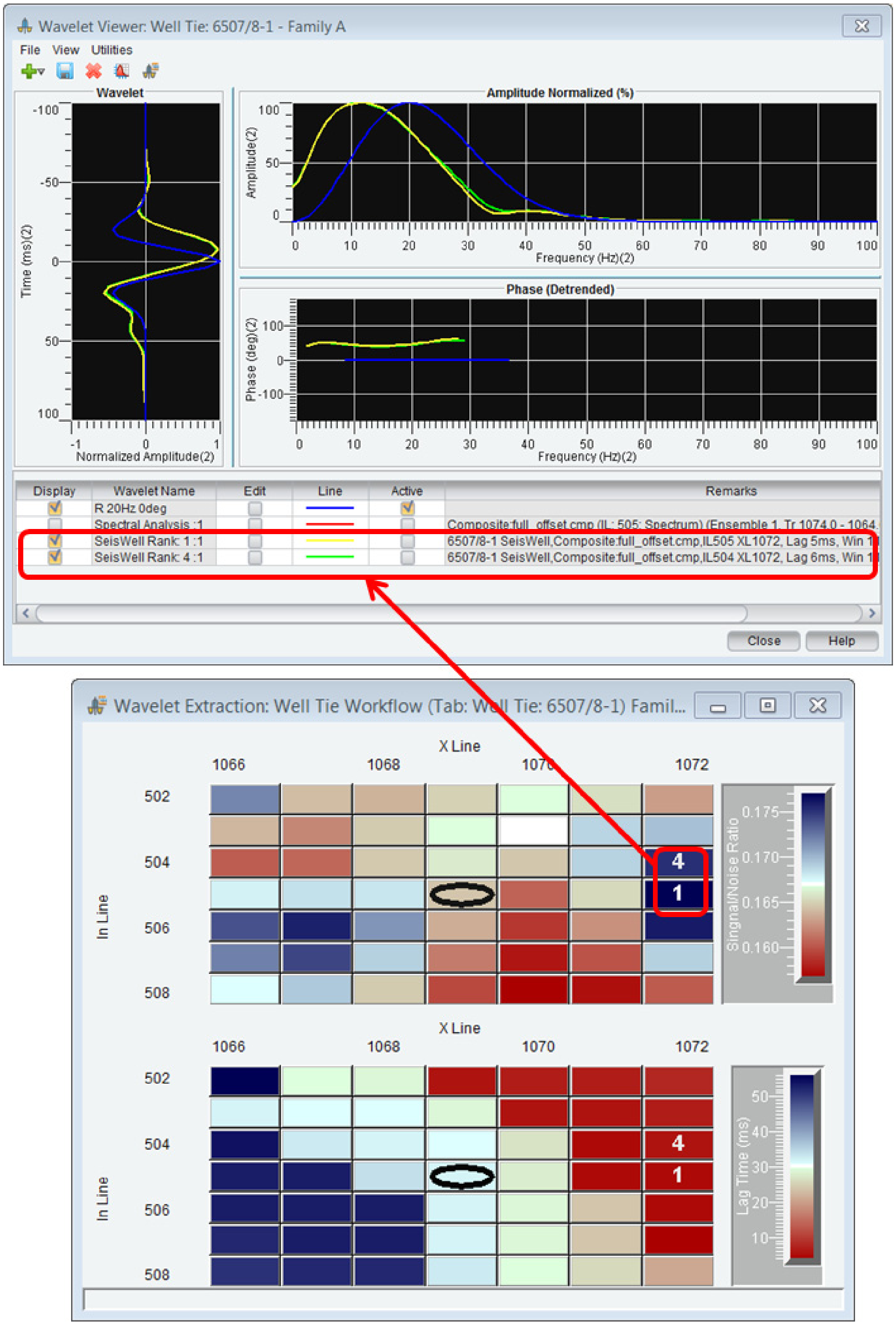


Definitions for two of the parameters are as follows:

- Noise Factor—Enter a value to control stability. The default value is 0.01, which is equivalent to 1%.

- Papoulis smoothing length—The Papoulis smoothing length has a significant influence on the general appearance of extracted wavelets. The Papoulis filter is a moving bandpass used for spectral averaging, or smoothing of the input series spectra. The narrower the bandpass, the lesser the smoothing. A narrow bandpass in the frequency domain corresponds to a longer window length in the time domain. To reduce the smoothing, specify a longer Papoulis window length. Similarly, specify a shorter Papoulis window length to increase the smoothing. The Papoulis smoothing length should at least be as long as the wavelet dominated portions of the cross-correlations between the trace and the reflection series. The central envelope lobe represents the wavelet dominated portion of the cross-correlation. The Papoulis smoothing window length approximates the window length of which the final extracted wavelet will contain significant data.

8. In the cell plot of wavelet extraction, click two cells as shown in the image below (the well location is indicated by a black oval). View the two extracted wavelets in *Wavelet Viewer*.



The upper plot is a *Signal/Noise Ratio* plot. The lighter color indicates a higher S/N ratio, and the coordinates of each box are Inline and Xline numbers. Signal/Noise Ratio is a measure of goodness-of-fit between the filtered RC series and the seismic trace. A value of 1.0 means that exactly half the power of the input seismic trace was predicted by filtering the RC series with the estimated wavelet.

The lower plot is a *Lag Time* plot. The lighter color indicates a larger lag time, and the coordinates of each box are Inline and Xline numbers. The lag diagram is important because it indicates the consistency of the time at which the best match occurs over a group of traces.

Best Matching Wavelet

The default best matching wavelet is a wavelet that has the highest Signal/Noise Ratio within the scan range (the trace which produced the best overall match is flagged with 1). That does not necessarily mean it has the best values for the other diagnostic statistics. It may also be unacceptably far from the well location.

The S/N plot is the best place to see how stably the match is moving away from the well. If the geology is laterally varying, one would expect that to be evident on the *S/N Map* view. In this view, the S/N is fairly stable, although it might be worthwhile to look at the best wavelet from the lobe of blue cells in the lower left quadrant of the view. Interestingly, this lobe has a very different lag time to best match than the actual best match. This could simply be caused by a geologic dip, but it could also be caused by cycle jumps or significant seismic character changes.

The black oval indicates the location of your synthetic trace. The trace which produced the best overall match is flagged with 1 (meaning it has the highest Signal/Noise Ratio).

Note

The tab number on each cell is a ranking number of signal/noise ratios among all the shown subareas. Higher ranking gives a higher signal/noise ratio. You may get a different tab number for your extracted wavelet in this exercise, (e.g. 2 or 3 instead of 4).

Available Wavelet Types

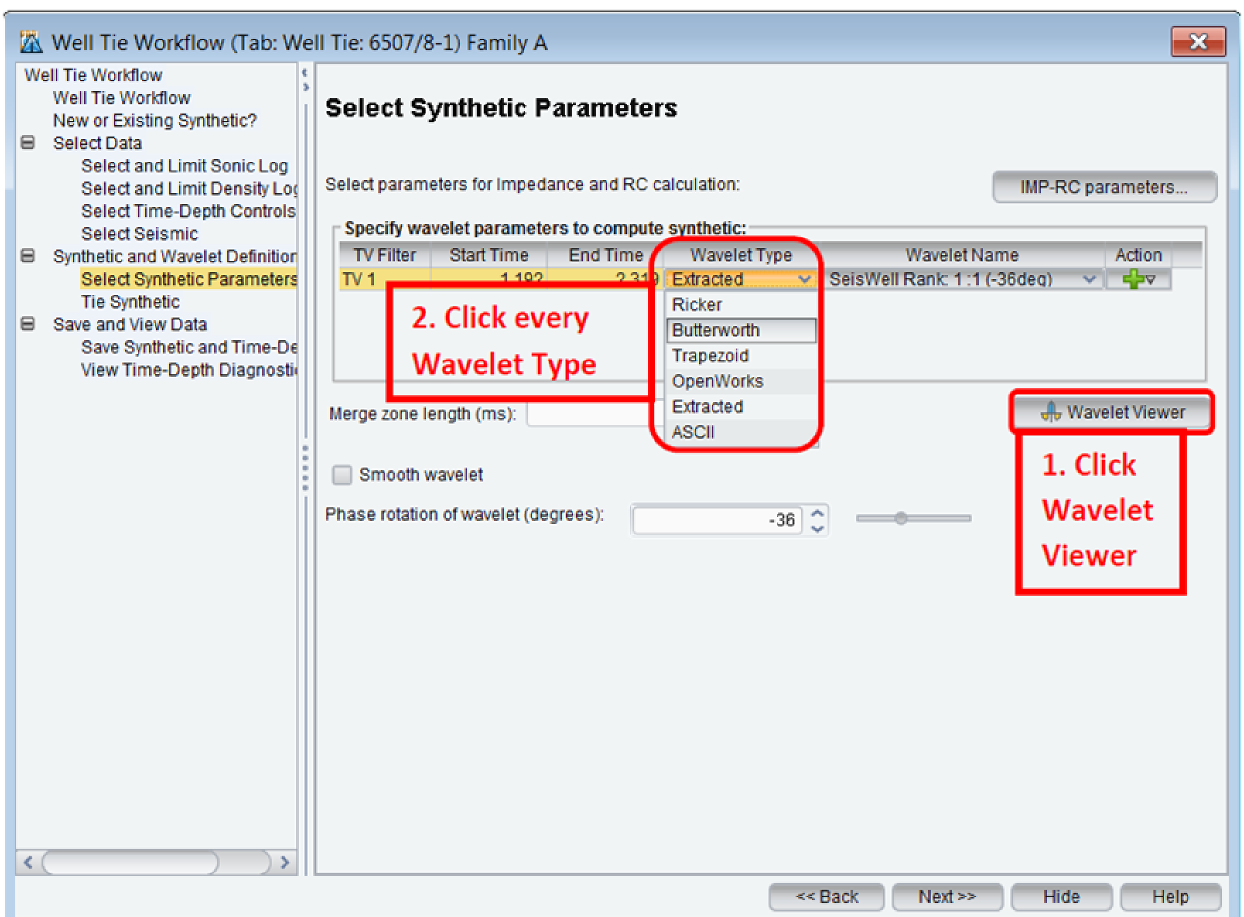
For each synthetic seismogram, geophysicists must choose one type of wavelet that will be used and then the specific parameters needed to define the wavelet.

Making a choice about different wavelets becomes easier with a thorough understanding of the differences and similarities, and how changing the parameters changes the wavelets.

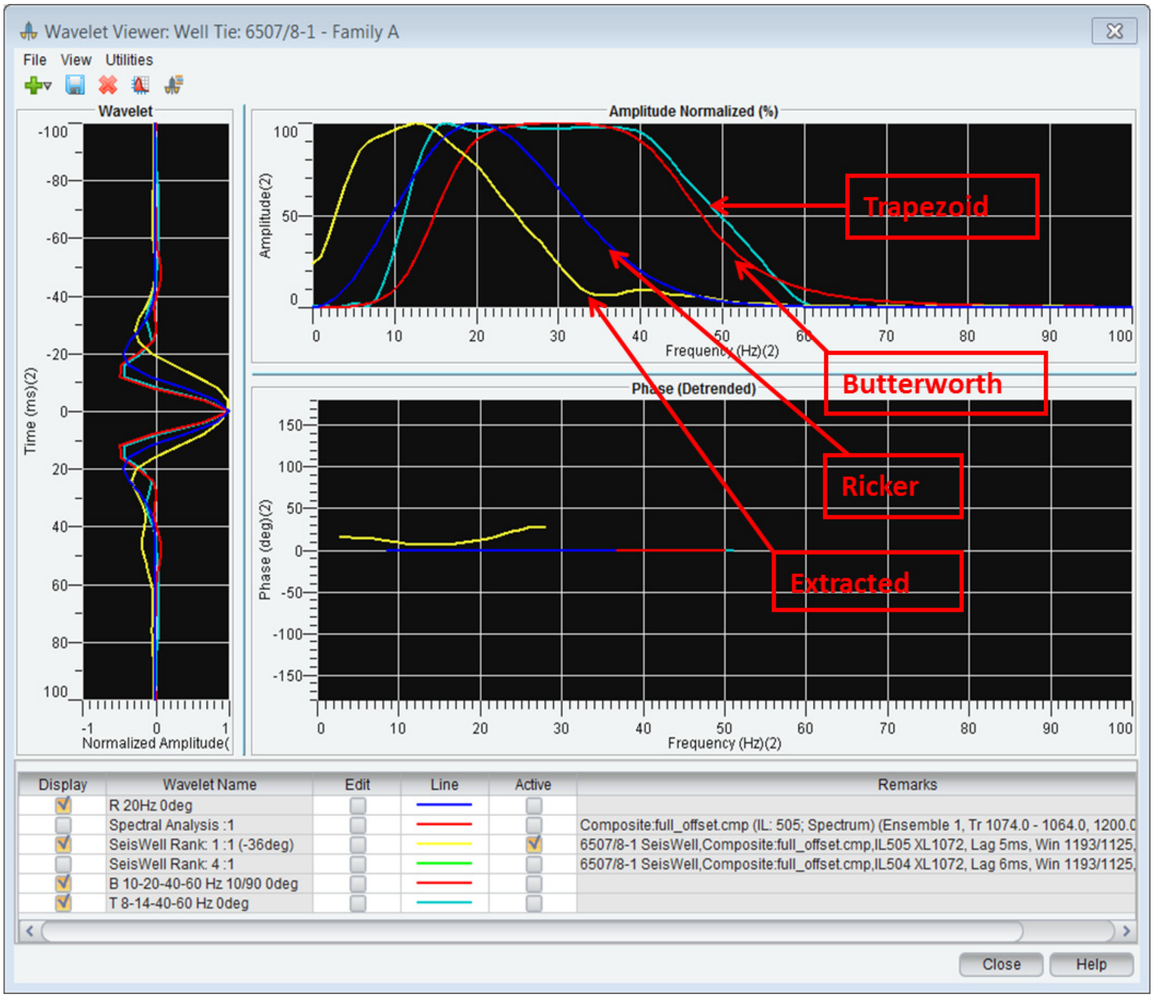
9. Leave the *Wavelet Viewer* and *Well Tie Workflow Wizard* open, close any other window related to wavelet extraction.

10. In the *Well Tie Workflow Wizard*, go to the *Select Synthetic Parameters* panel and click the drop-down menu under **Wavelet Type**.

11. Select the **Ricker**, **Butterworth** and **Trapezoid** options individually to display them together in the *Wavelet Viewer*.



12. In the *Wavelet Viewer*, display only **Trapezoid**, **Butterworth**, **Ricker** and any of the extracted wavelets, to better visualize the differences between all of them.



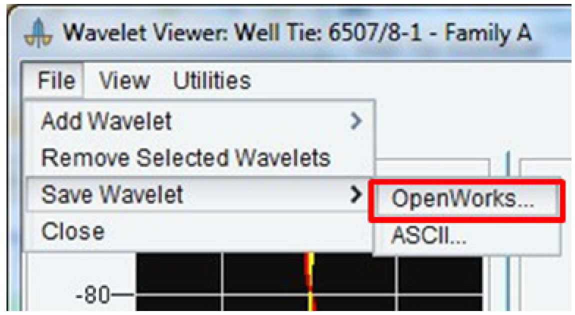
Typically, you will choose a wavelet according to the source of seismic signal. The sources used on land are mostly dynamite and vibroseis, and the most frequently used source in a marine survey is air gun (mostly airgun or dynamite data is minimum phase, while vibroseis data is either 0 or 90 degree phase).

According to different sources, good approximations in general are:

- Ricker wavelets—Used when the synthetic seismogram is to match **dynamite** or **air gun** data.
- Butterworth wavelets or Trapezoid wavelets—Used when the synthetic seismogram is to match **Vibroseis** data.

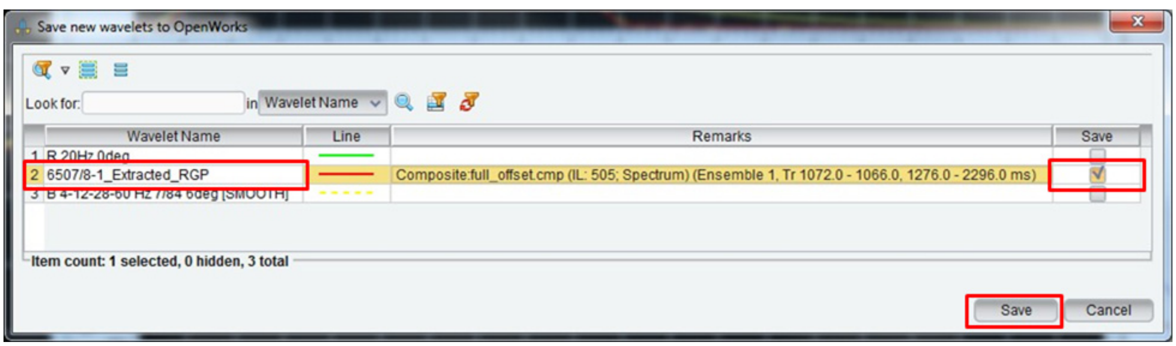
Saving the Wavelet to OpenWorks

13. Ensure that the *Wavelet Viewer* is open. Select the **Spectral Analysis:1** wavelet. Select **File > Save Wavelet > OpenWorks...**.



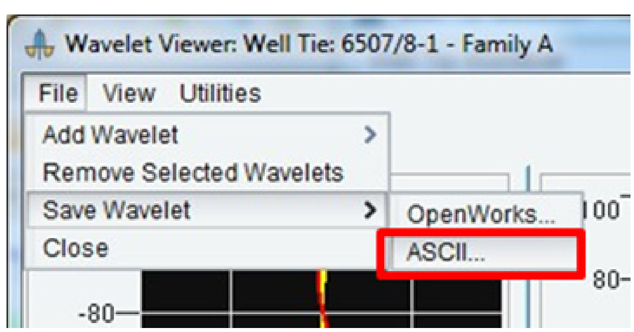
14. Change the extracted *Wavelet Name* and make sure the **Save** option is toggled on for this wavelet.

    Saved wavelets for all wells are in the same location in the database. Specify a name that is easy to remember. Include the well's name and interpreter (**6507/8-1_Extracted_YOU**).

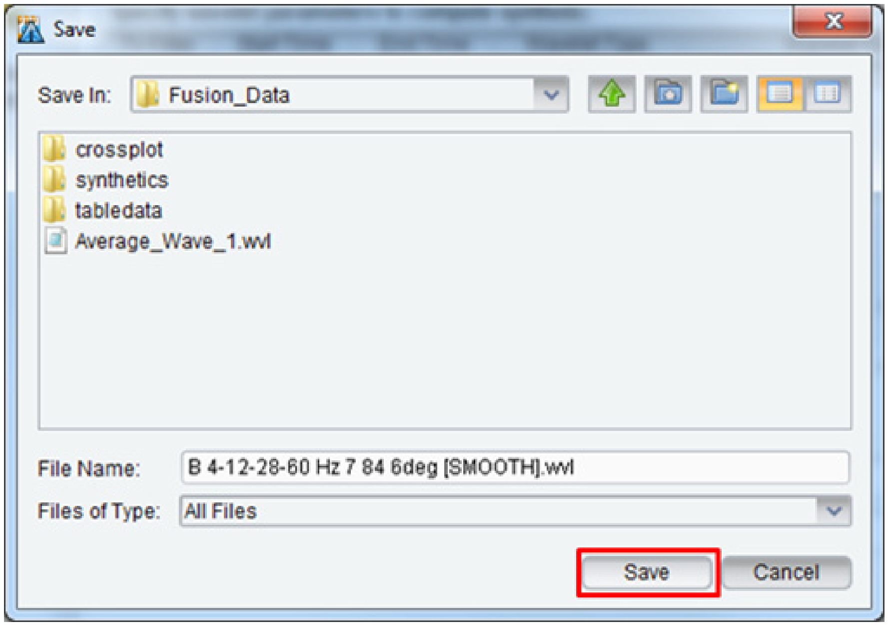


Saving the Wavelet as an ASCII File

15. Select the **Butterworth** wavelet and save it as an ASCII file by selecting **File > Save Wavelet > ASCII...** from the menu bar.



16. You can choose your preferred path where the wavelet will be saved and change the name, if required. In this particular case, keep the default path and name and then click **Save**. Click **OK** in the *Save ASCII Wavelet* dialog.



17. Click the **Interpretation** ( ) icon of the *Well Tie Session* window to turn off the interpretation mode.

Family Concept - Multiple Synthetics

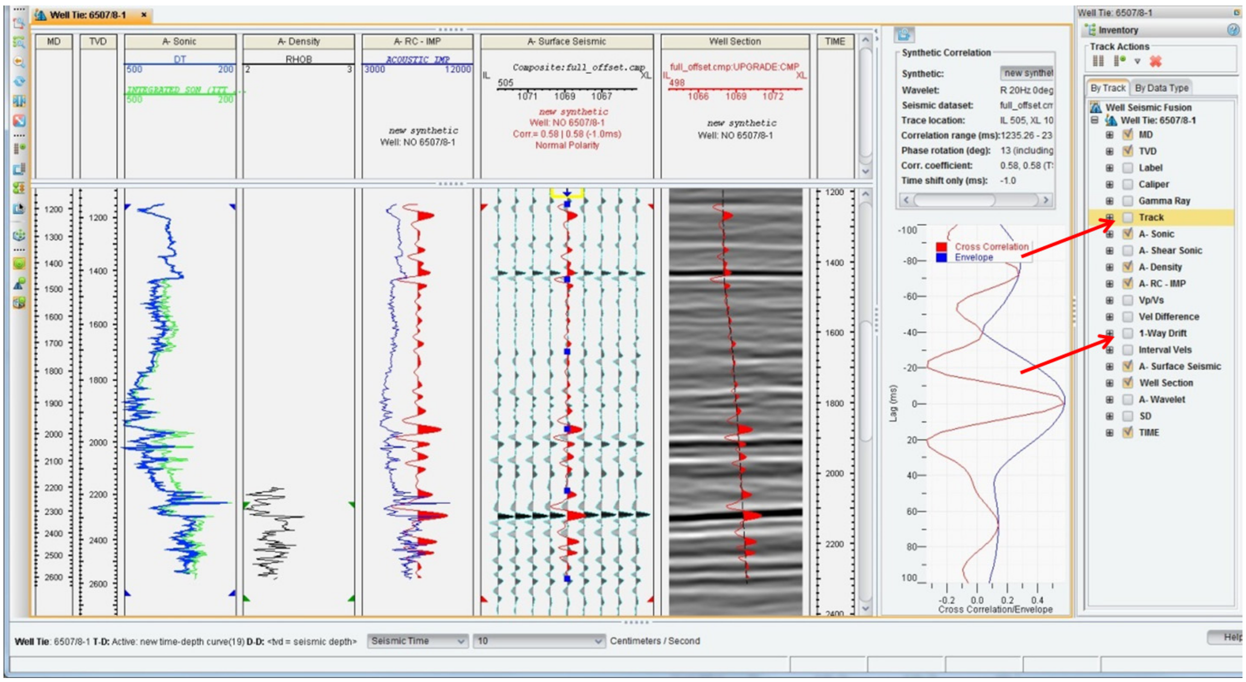
An important step in the construction of synthetic seismograms is to compare different wavelets to find the best match with the seismic data. A new feature in the DecisionSpace Geosciences software, called Family Concept, gives you the ability to have different synthetics in the same session of the Well Tie workflow.

You will create three families in the next steps to display the Ricker Wavelet, the spectral analysis wavelet saved in OpenWorks, and the Butterworth wavelet you saved as an ASCII file. Arranging the synthetics created by each wavelet will allow you to compare the correlation coefficients and determine which best fits the data.

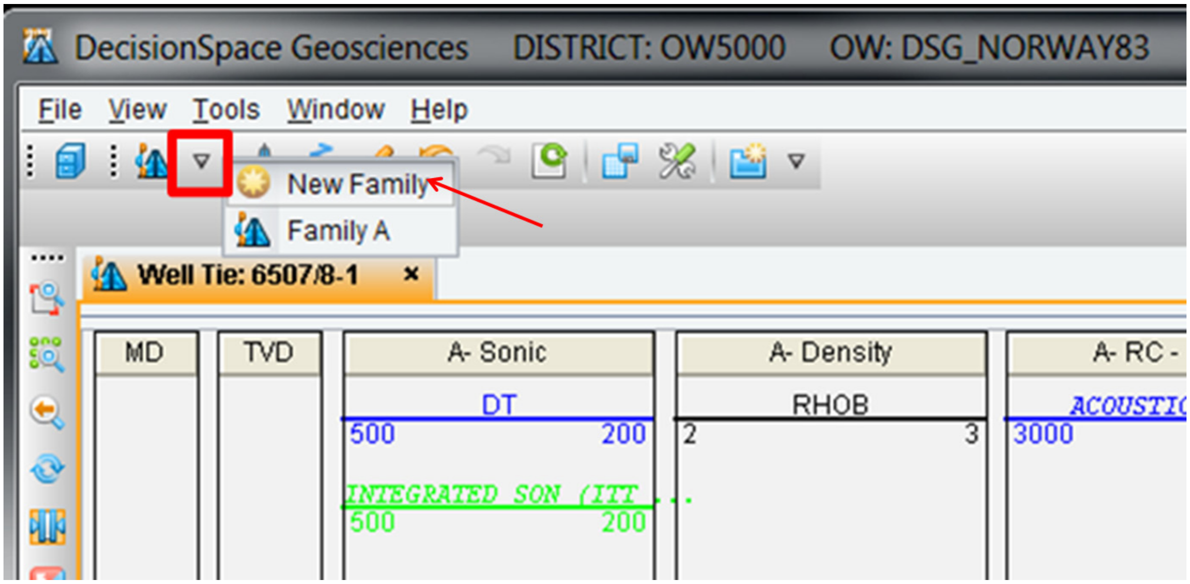
Exercise 2.6: Multiple Synthetics for Different Wavelets

To use multiple synthetics for different wavelets:

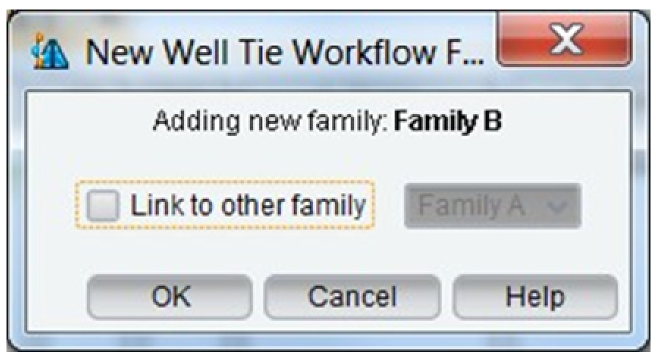
1. From the *Inventory* pane, toggle off the track with the **GR** log, **Interval vels** track, and the **1-Way Drift** track.



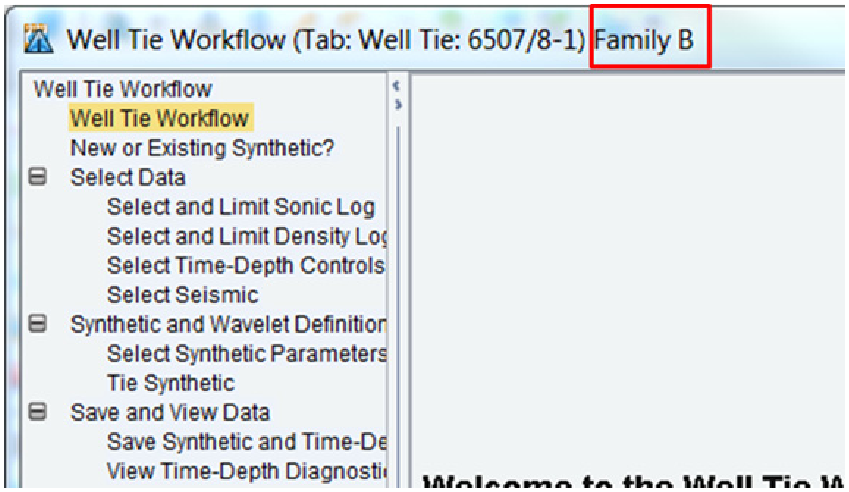
2. To create a new family, click the down arrow next to the **Well Tie Workflow wizard** icon, and select the **New Family** option.



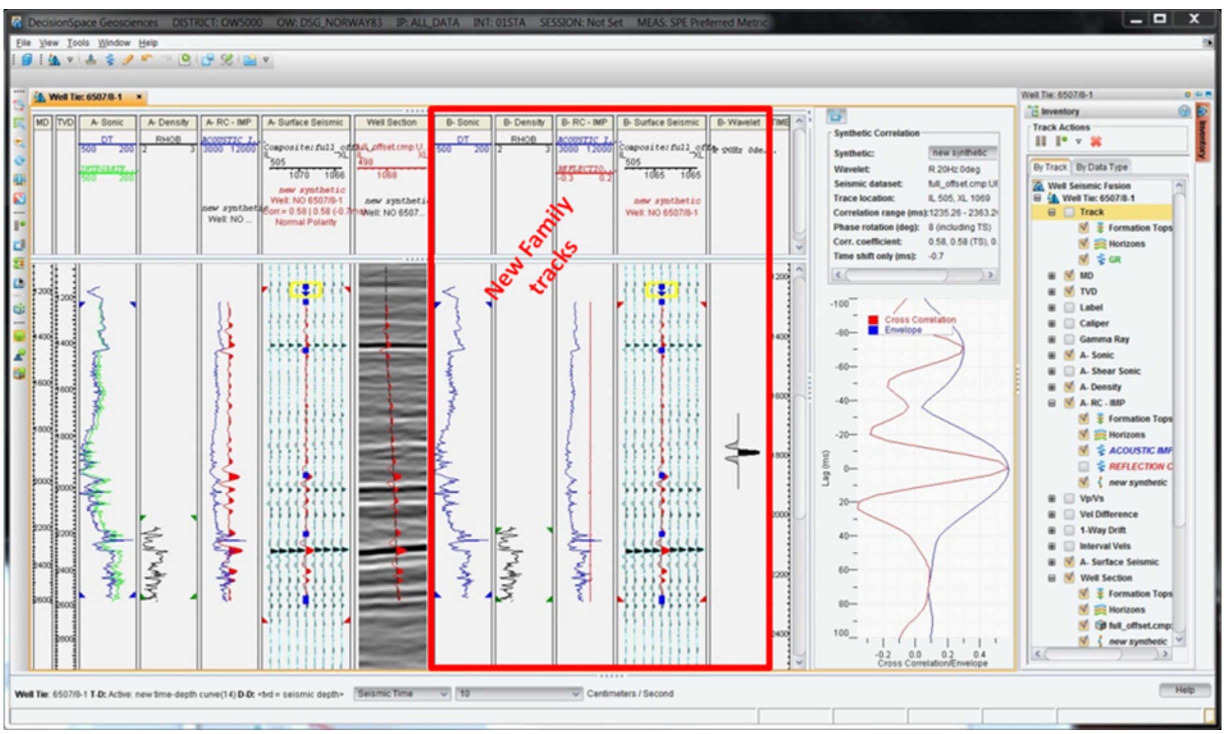
3. Deselect the **Link to other family** check box and click **OK**.



A new *Well Tie Workflow Wizard* dialog appears. Note that *Family B* appears at the top of the dialog.

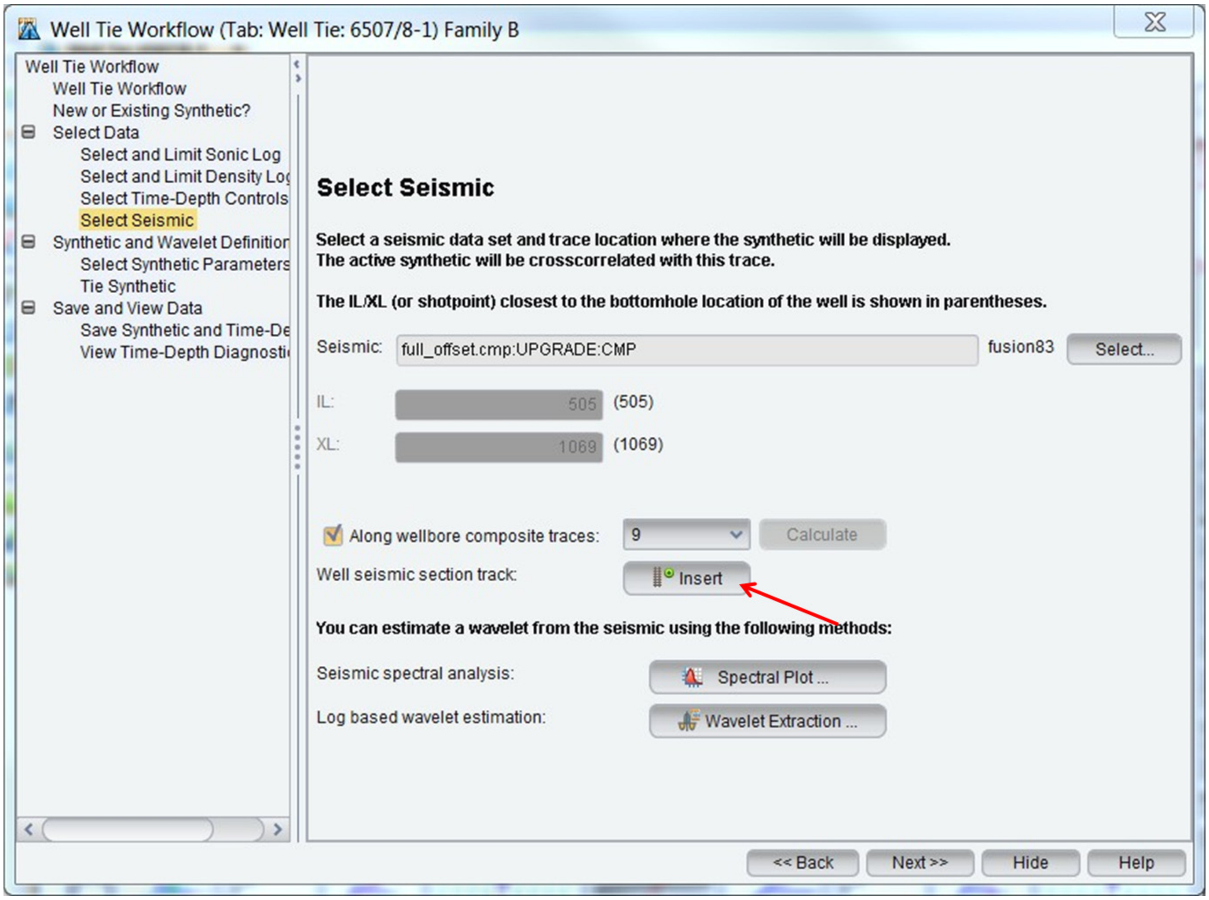


4. All of the data (logs and wavelet) for *Family A* are automatically selected for *Family B*. Go back to the Well Tie session and look at the new tracks.



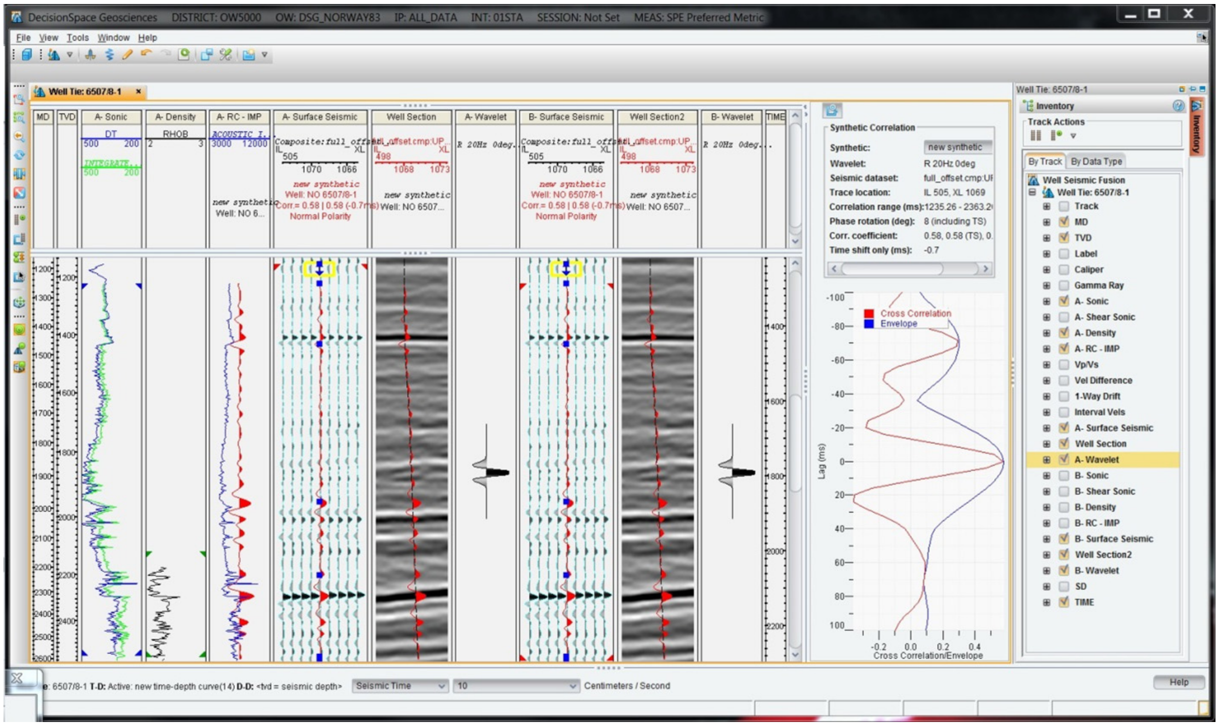
Note that with the new wizard, you can select different input logs to create a different synthetic for the same well. Keep the same input logs and we will explore a basic advantage of having several families in one session.

5. In the *Well Tie Workflow Family B* dialog, click **Insert** to insert a well section for the new family. Click **OK** in the *Well Selection* dialog.



6. From the *Inventory* panel, deselect the **B-Sonic**, **B-Density**, and **B-RC-IMP** check boxes.

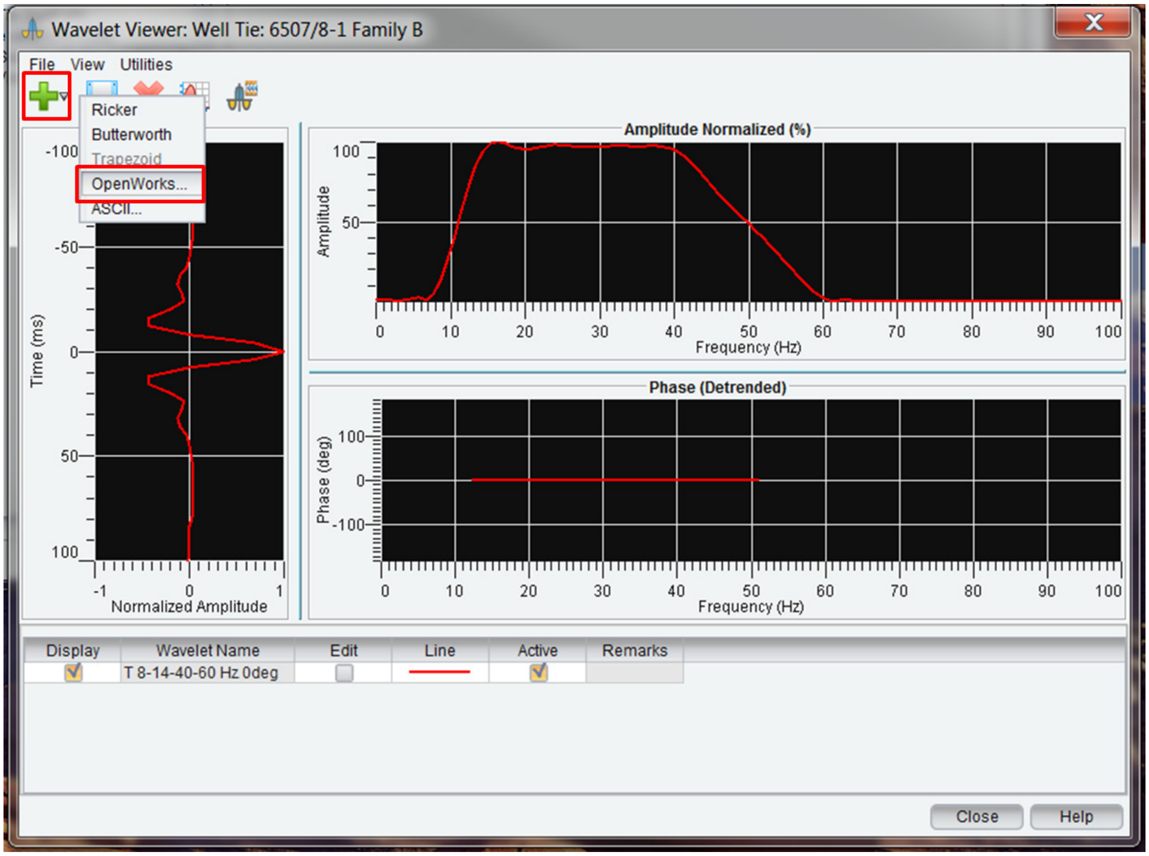
7. Select the **A-Wavelet** and **B-Wavelet** check boxes.



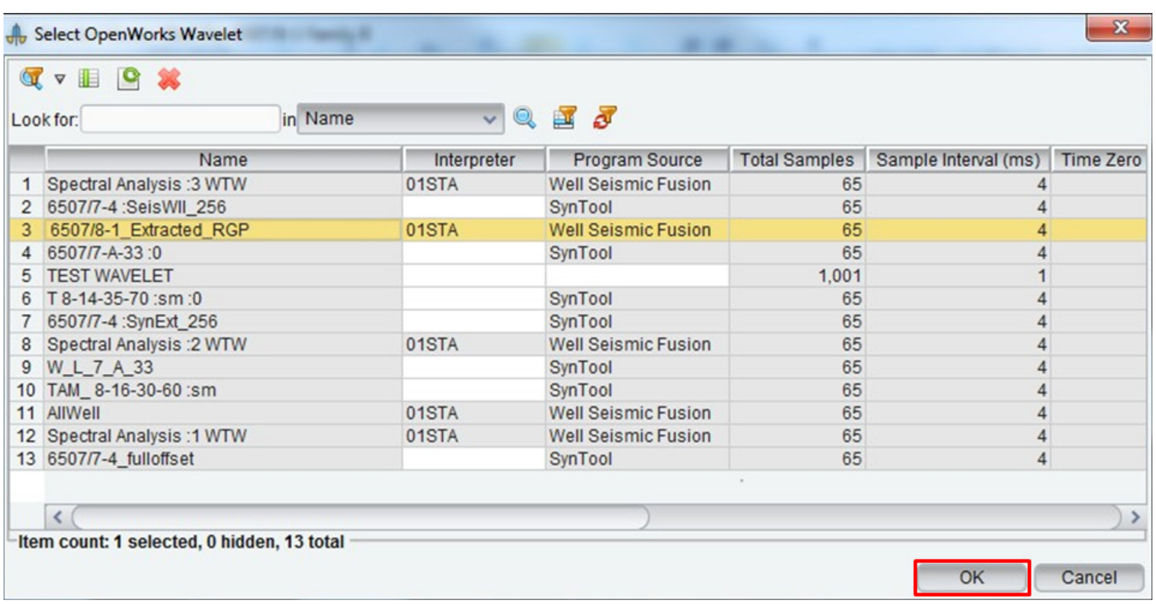
You should now have a session with two independent synthetics.

8. On the *Select Synthetic Parameters* dialog, click the **Wavelet Viewer** icon.

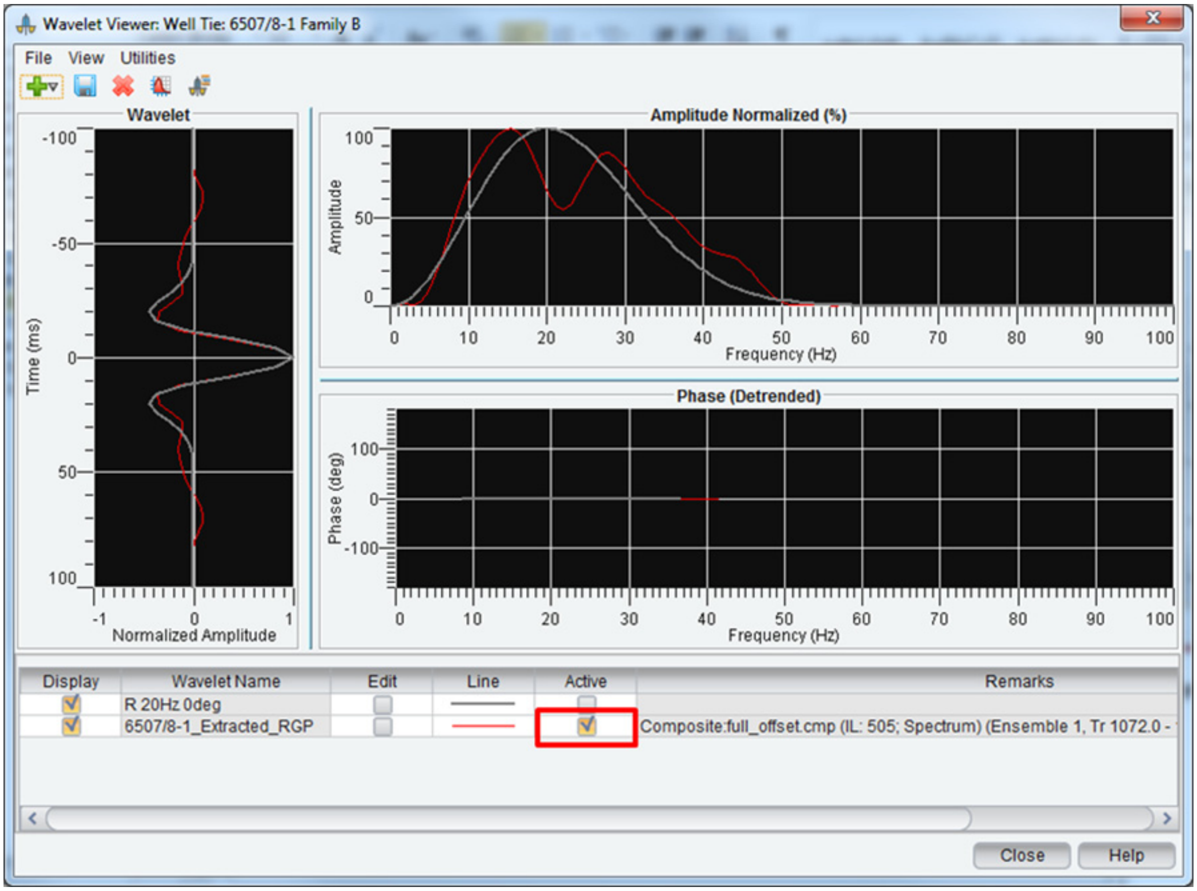
9. In the *Wavelet Viewer* dialog, click the **Add Wavelet** icon and select **OpenWorks**.



10. Select the wavelet that was saved previously (**6507/8-1_Extracted_YOU**) and click **OK**.

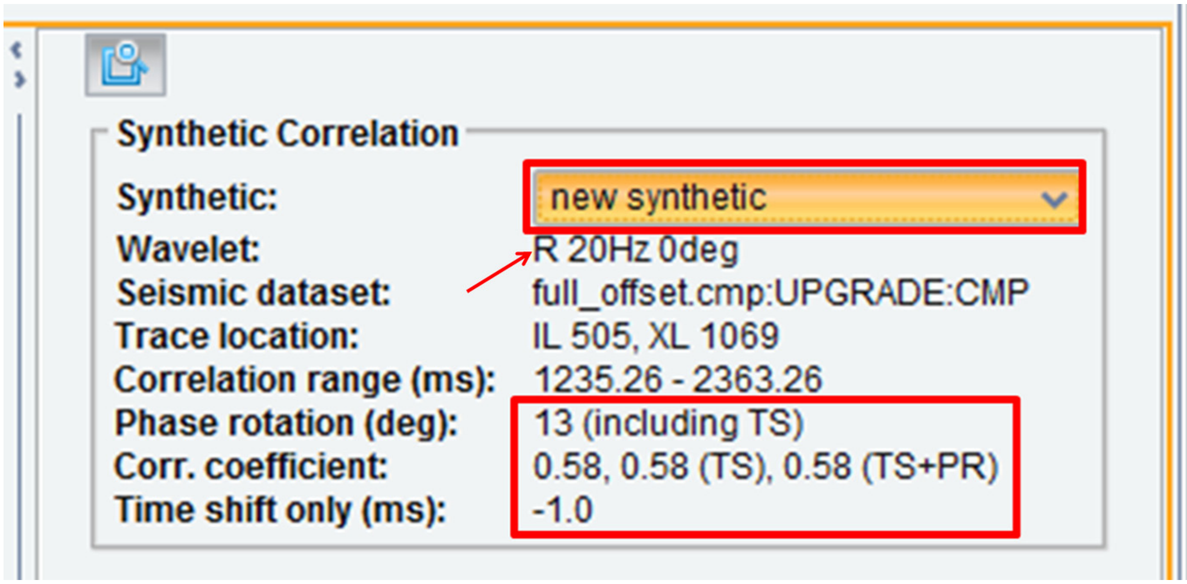


11. Ensure that the **6507/8-1_Extracted_YOU** wavelet is **Active**. You can activate it from *Wavelet Viewer*.

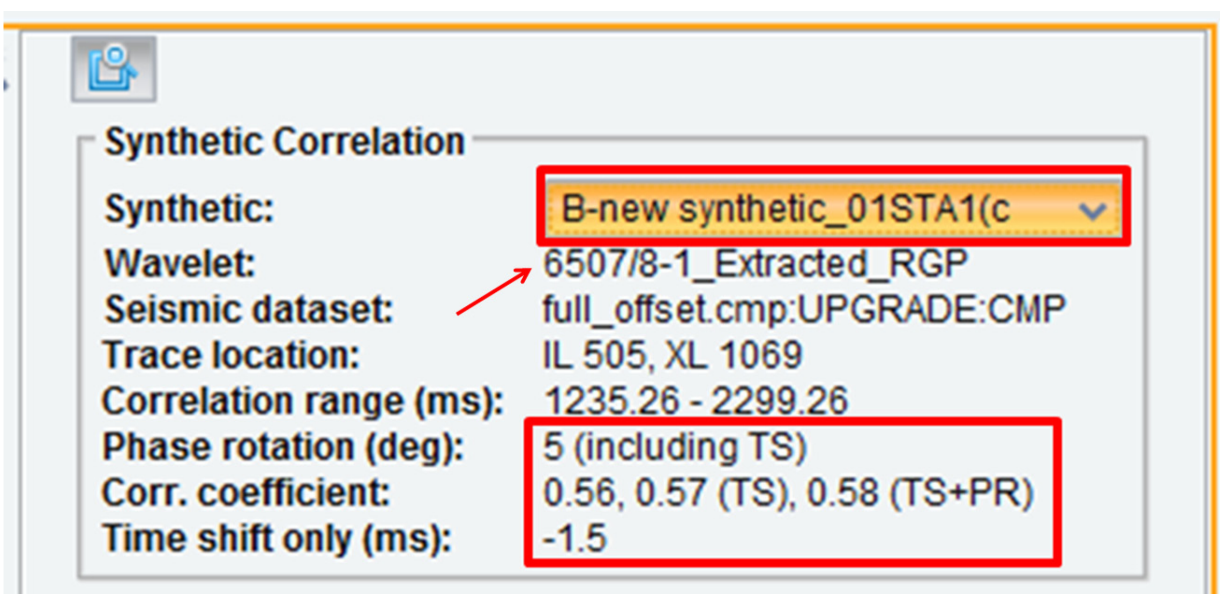


In the *Synthetic Correlation* panel, you can now compare the correlation coefficients for *Family A* and *Family B* synthetics.

12. In the *Synthetic Correlation* panel, review the coefficients for *Family A* (new synthetic). The correlation value should be around **0.6**.

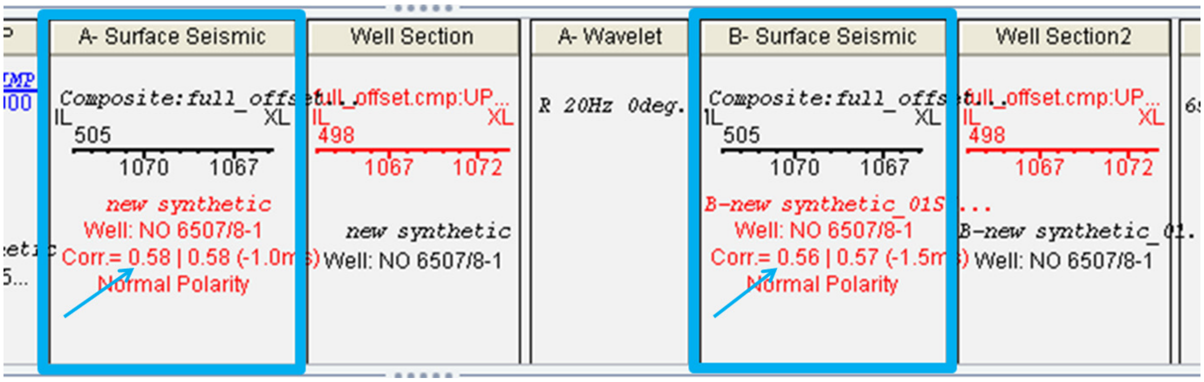


13. Select **B-new synthetic_01STA1** (synthetic for Family B) from the **Synthetic** drop-down menu.

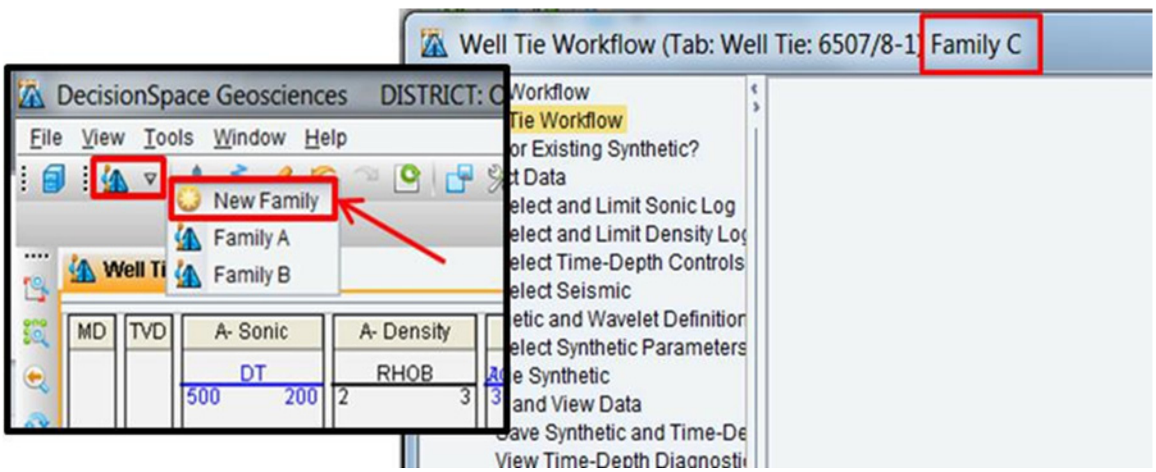


The Coefficient for *Family B* is lower than *Family A*. The correlation suggests very small changes in the phase and time shift to reach the same correlation coefficient as *Family A* (you may get different values here due to the tying steps).

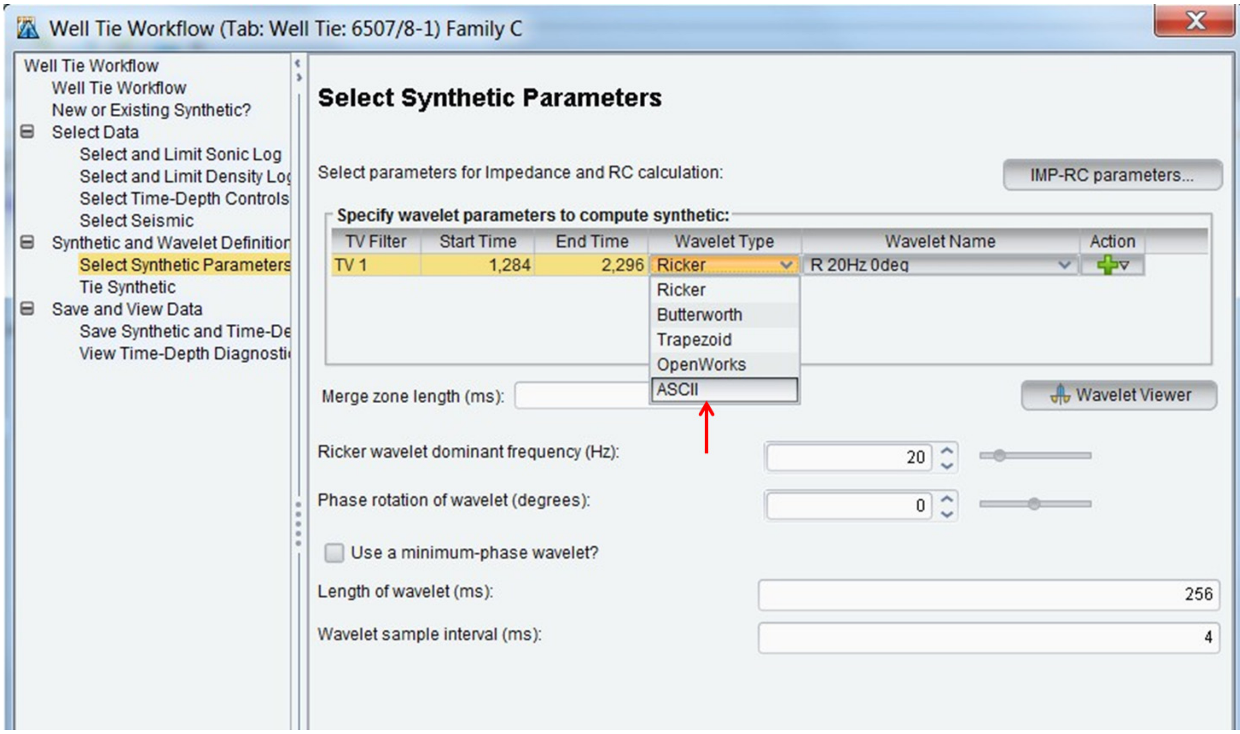
Note that you can also see the Correlation Coefficient in the *Synthetic* header on the *Surface Seismic* track.



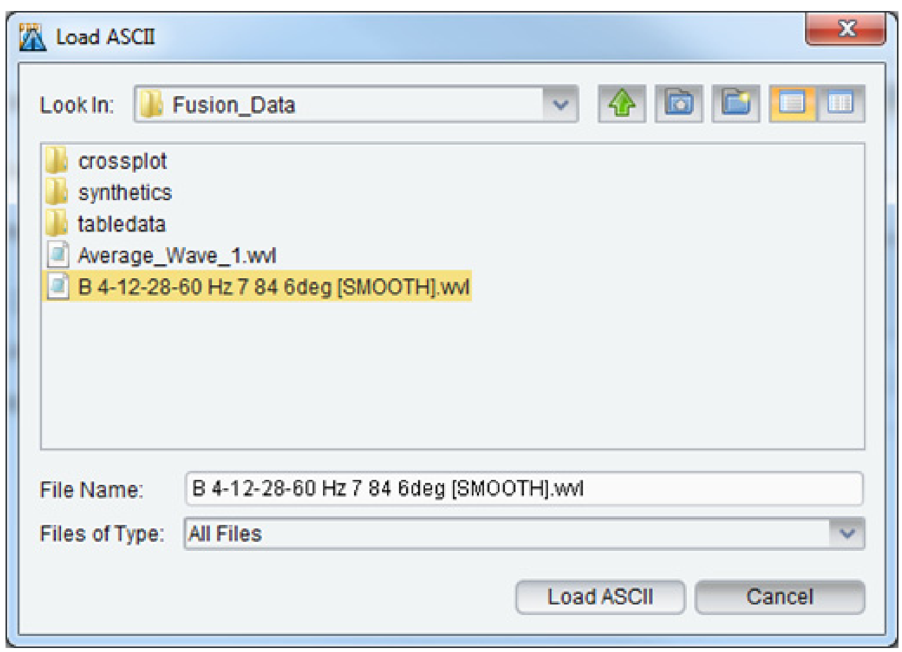
14. Repeat steps to add another family (*Family C)*.



15. In the *Select Synthetic Parameters* dialog, select **ASCII** from the *Wavelet Type* drop-down menu.



16. Select the previously saved ASCII wavelet (Butterworth wavelet).

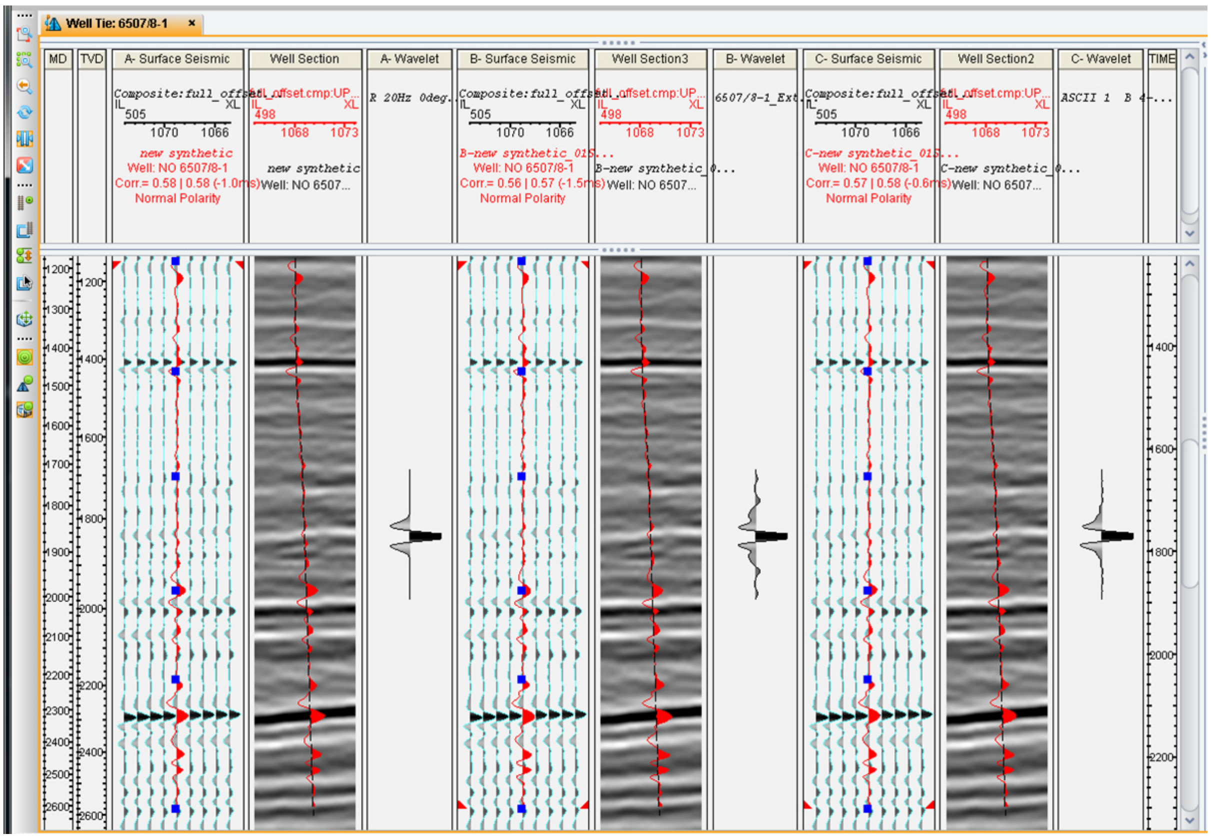


17. In the *Select Seismic* step for the *Well Tie Workflow for Family C,* insert a *Well seismic section* track.

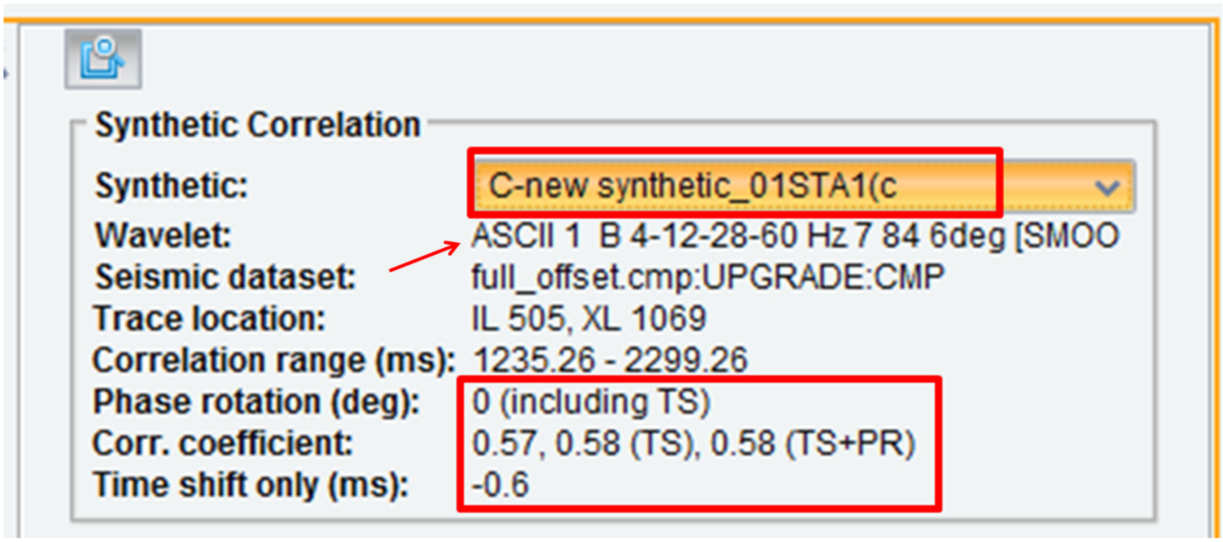
18. From the *Inventory* pane, display the **Surface Seismic**, **Well Section**, and **Wavelet** tracks for each family.

> **Note**
>
> **MB3** unnecessary tracks, and select the **Hide this track** option to hide the unwanted tracks.

Your session should look like the following:

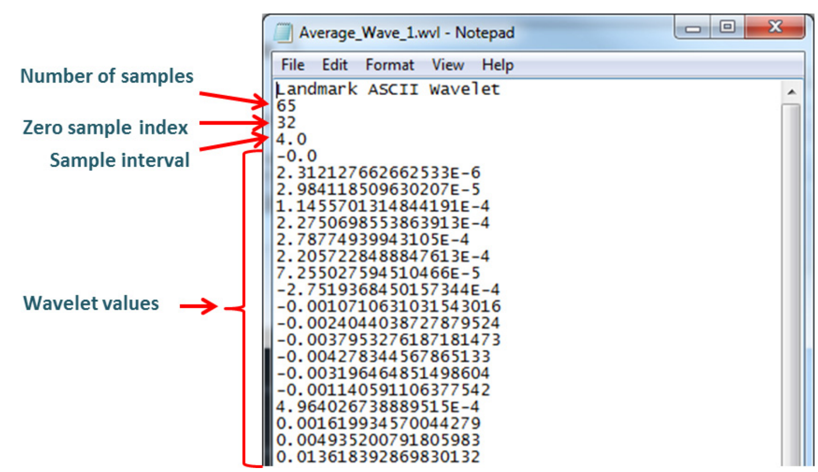


19. Review the Correlation Coefficient value for *Family C*. You may get different coefficients than the one in the image. Choose the wavelet that is best suited to your needs.



Note

The Import ASCII wavelets functionality supports the Landmark Syntool® wavelet format. By default, the extension of the wavelet file is .wvl. However, any properly formatted text file can also be imported.

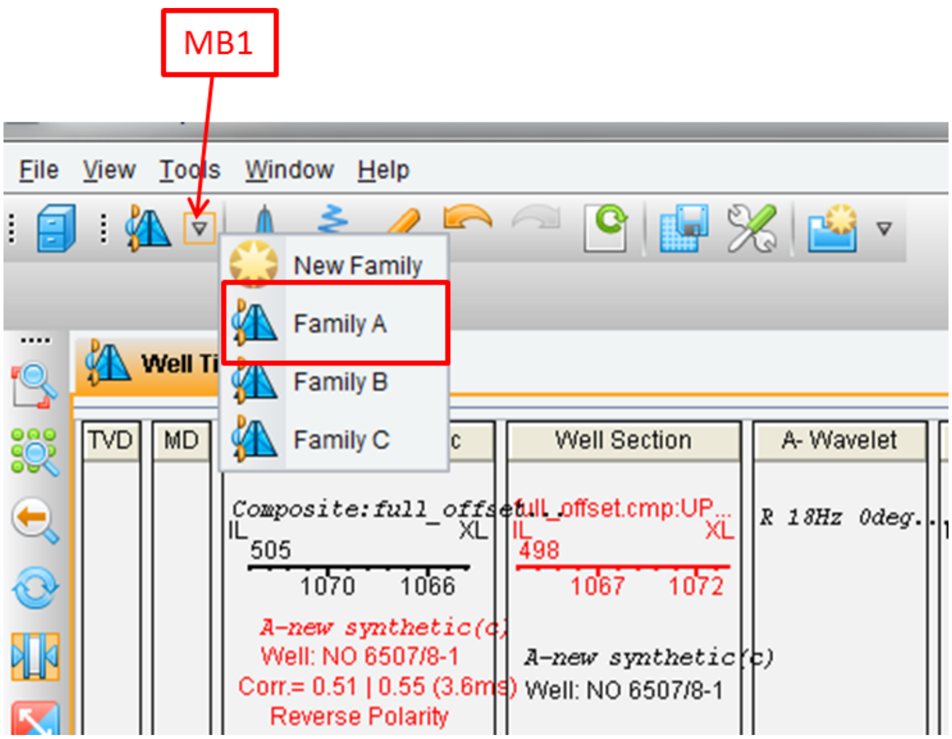


Exercise 2.7: Saving and Displaying Synthetics and Time-Depth Curves

In the next steps, you will save your synthetic and Time-Depth Curve to the OpenWorks database. In chapter 4, you will use the synthetic to correlate the geological data in the wellbore to help you decide which seismic reflection you should interpret.

To save and display synthetics and time-depth curves:

1. The synthetic and Time-Depth Curve displayed in Family A provide the best match to the data and you will save them to the database. Hide the *Well Tie Workflow* wizard for **Family C**. Click the *Well Tie Workflow Wizard* drop-down, and select **Family A**.



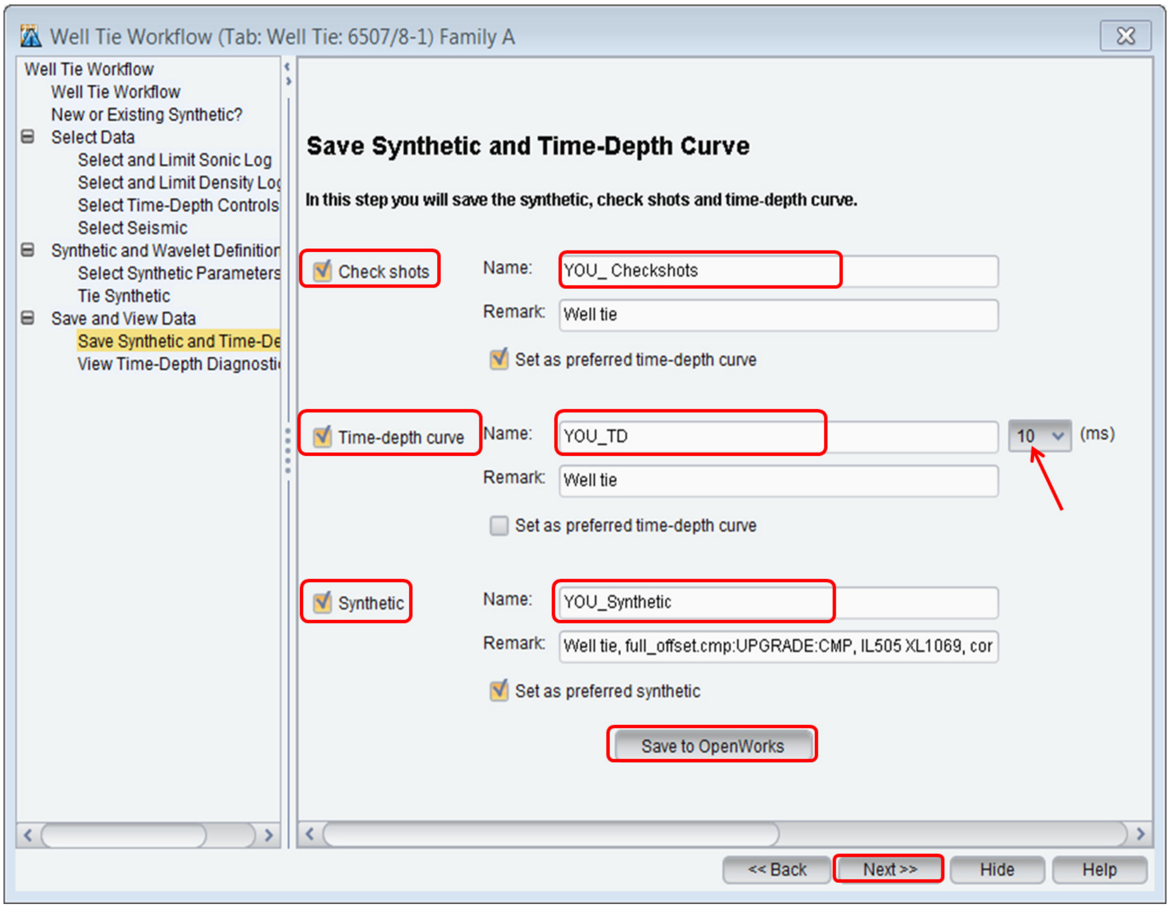
2. Select the **Save Synthetic and Time-Depth Curve** option.

3. You may choose to save check shots, time-depth curve, and synthetic for future use. Toggle on **Check shots**, **Time-depth curve**, and **Synthetic**.

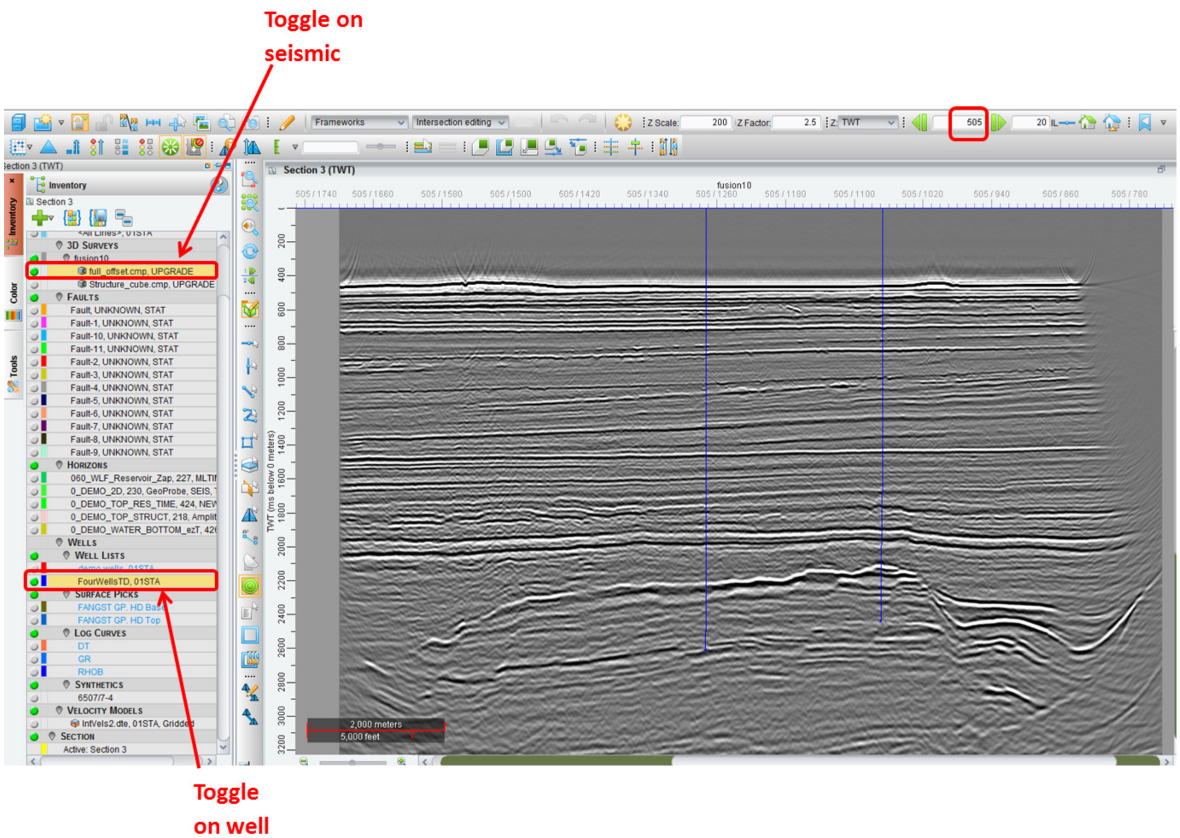
4. Edit the names as "**YOU_Checkshots**," "**YOU_TD**," and "**YOU_Synthetic**" respectively.

5. Click the **Save to OpenWorks** button. Accept all the defaults in the *Data Save* dialog.

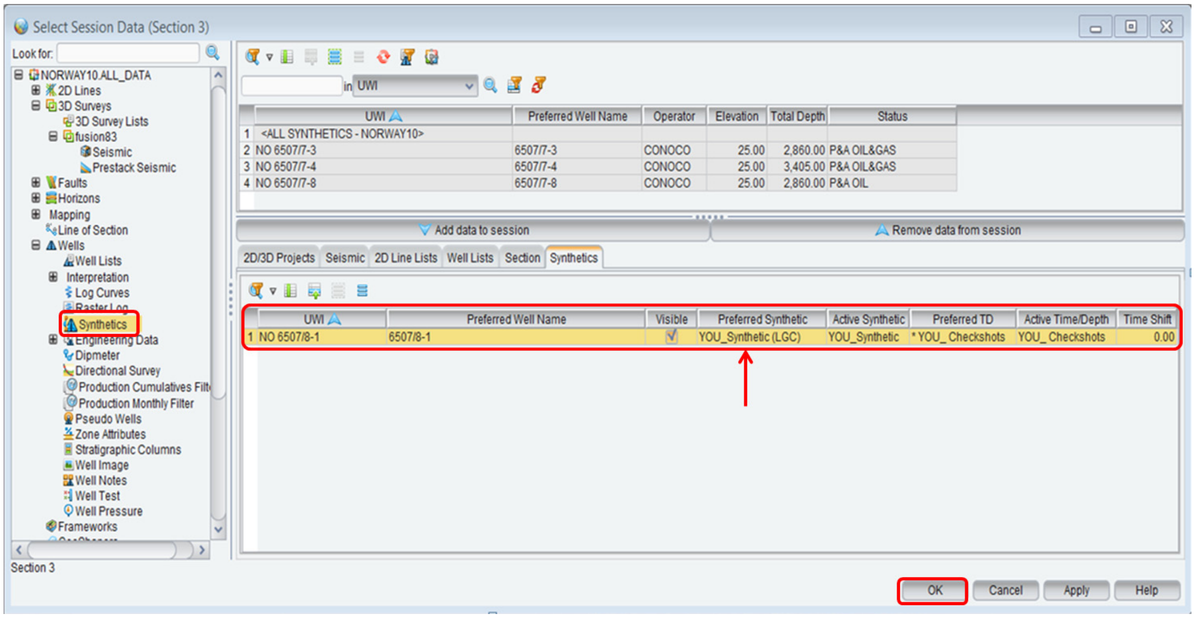
6. Save your session as "**6507/8-1_Session_1**." You have an option to choose the interval in milliseconds to save in the time-depth table.



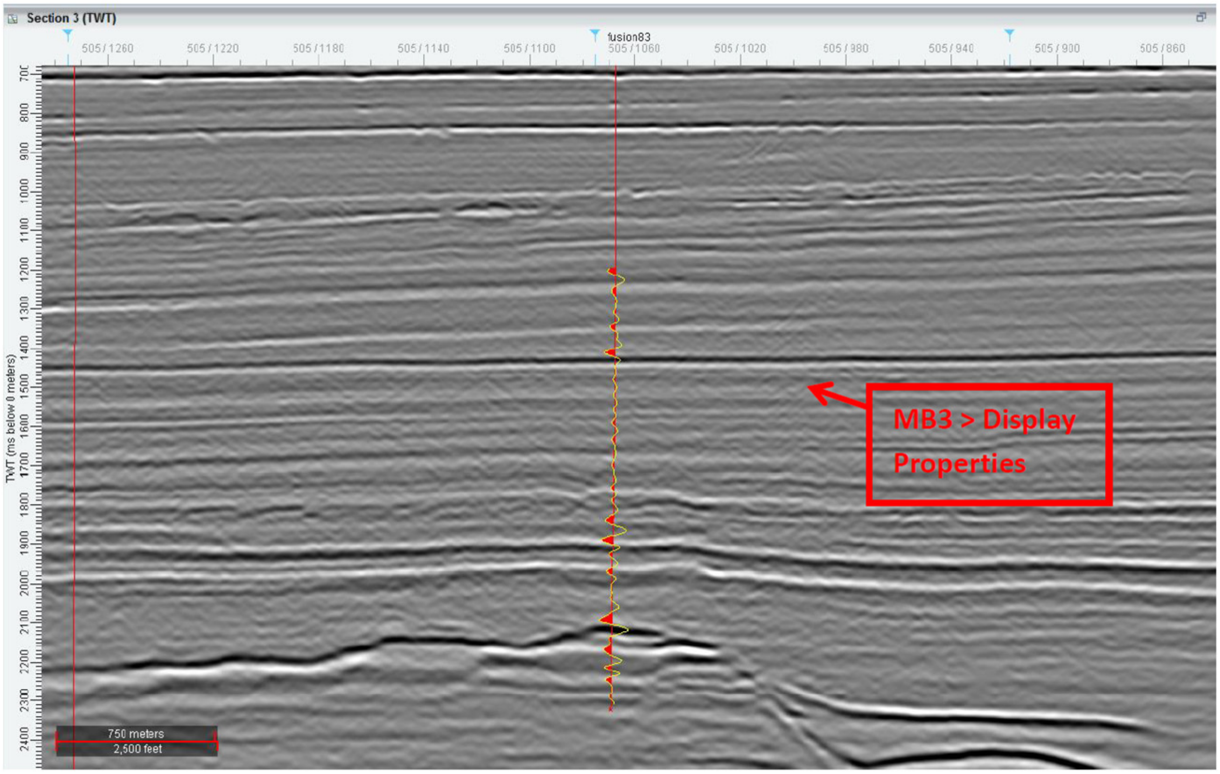
7. Double-click in *Section* view to enlarge it, make sure the seismic **full_offset.cmp** and the Well list **FourWells TD** are toggled on in the *Inventory*. Check that you are in the inline number is **505**.



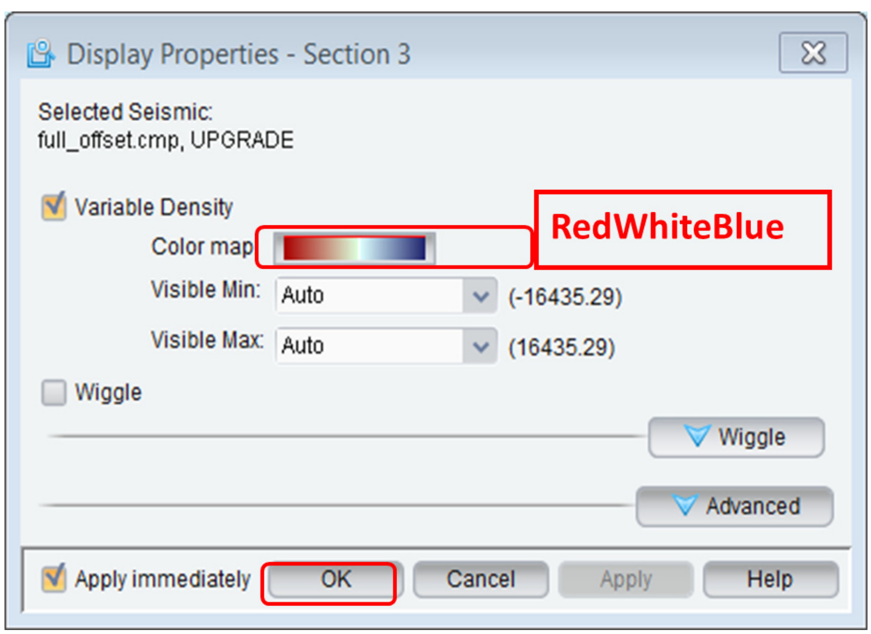
8. Click the **Select Session Data** ( ) icon and then add your synthetic for **Well 6507/8-1** to the session. You may need to specify your new synthetic as the preferred synthetic. Click **OK**.



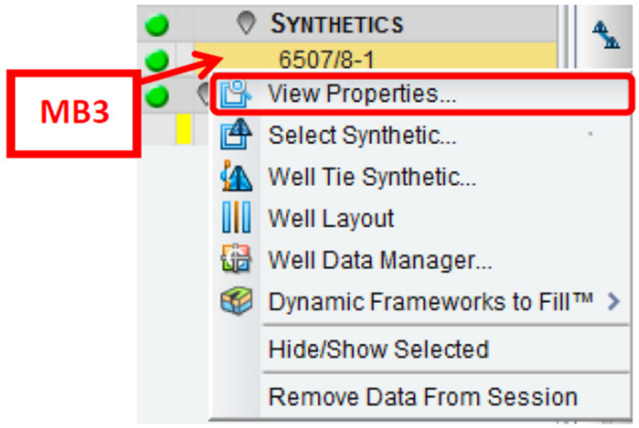
9. The *Section* view now shows the synthetic you just added. Verify that your synthetic is used (make sure your section stays at Inline 505). **MB3** on the seismic section and select **Display Properties...**.



10. Change *Color map* to **RedWhiteBlue**, and then click **OK**.



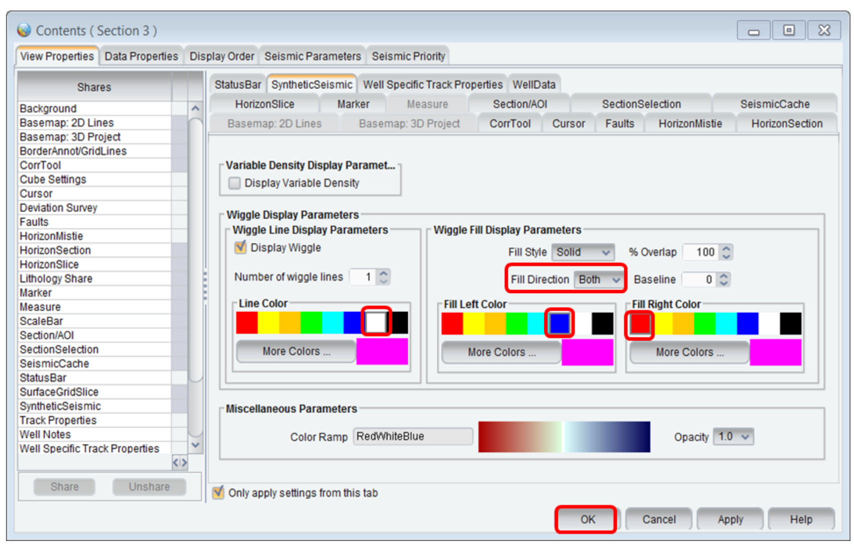
11. Under *SYNTHETICS* in the *Inventory* panel, **MB3** on **6507/8-1** and then select **View Properties**.



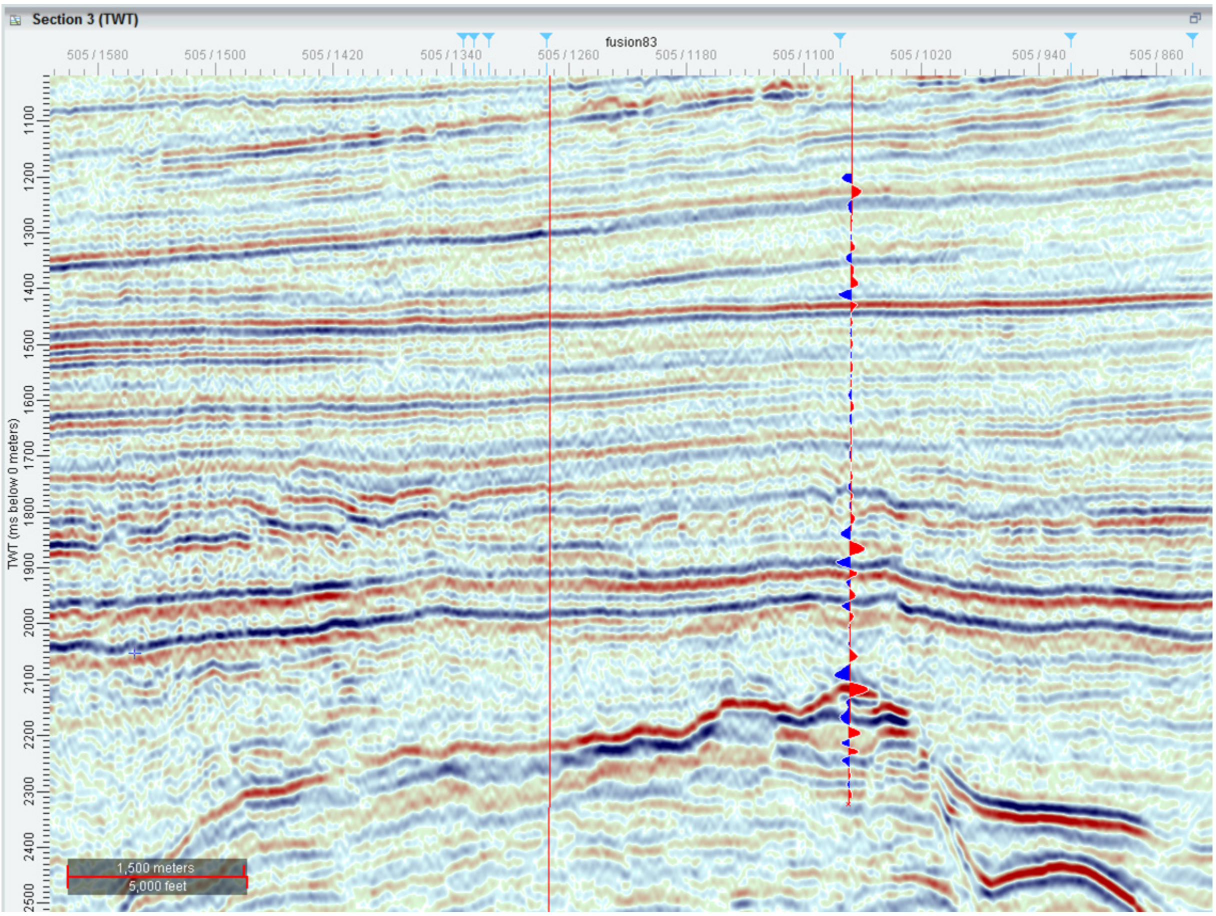
12. In the *Contents* dialog, select **Both** from the *Fill Direction* drop-down menu.

13. Select **White** as the *Line Color*.

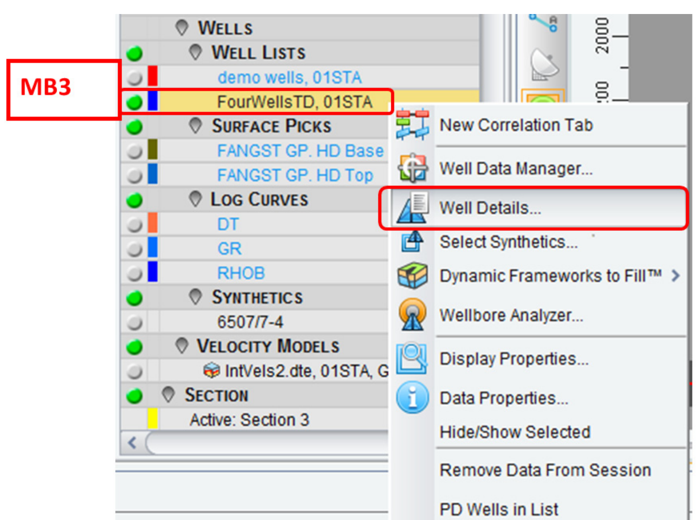
14. Select **Red** as the *Fill Right Color*, and click **OK**.



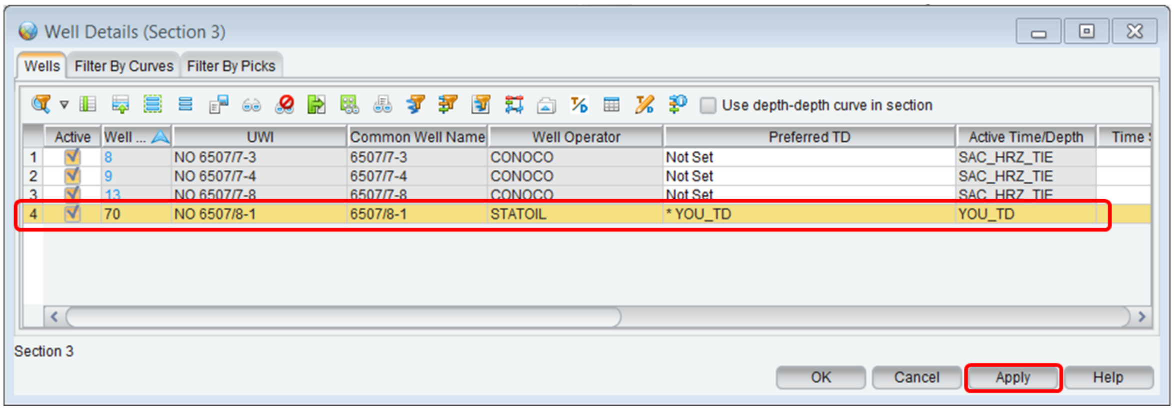
15. Return to the *Section* view. Focus on major reflectors to observe how the synthetic is tied to the seismic.



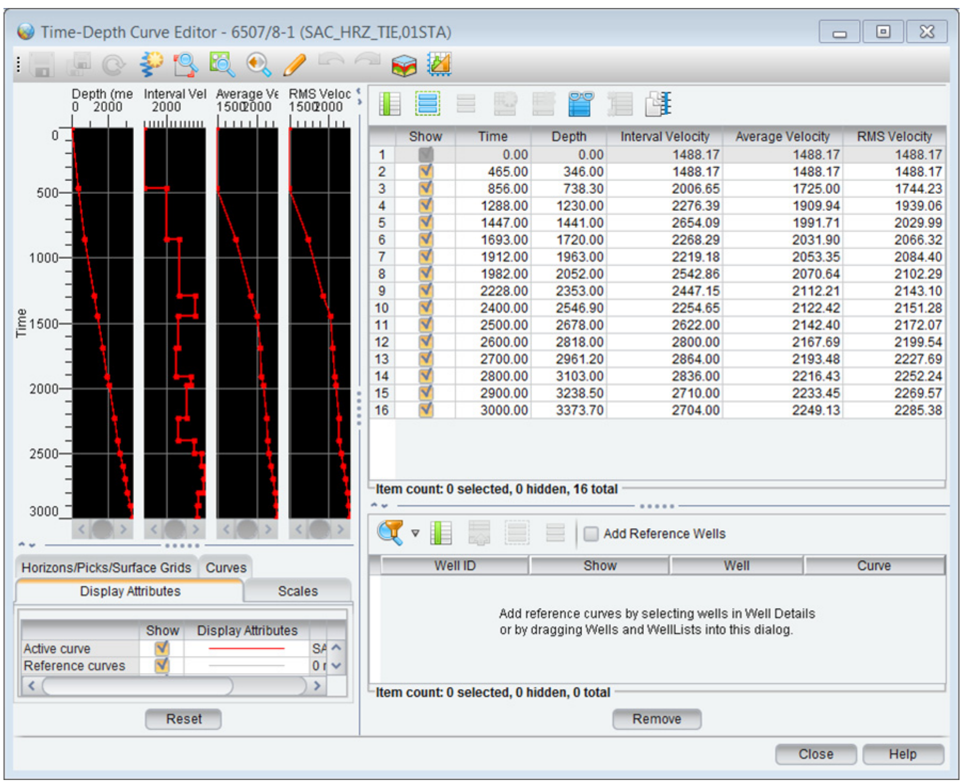
16. In the *Inventory* pane, **MB3** on the current well list (**FourWellsTD**) and select **Well Details...**.



17. In the *Well Details* dialog, select **YOU_TD** from the *Preferred TD* and *Active Time/Depth* drop-down menus, and then click **Apply**.



18. Keep the well **6507/8-1** selected in *Well Details* dialog, and click the **Time-Depth Curve Editor** () icon to display the T-D curve.



Exercise 2.8: Applying Thickness Edits to Loaded Logs Across All Families

Tuning effect is an important consideration when dealing with thin beds. Tuning thickness is the bed thickness at which two events become indistinguishable in the seismic. It equals ¼ of the wavelength and is determined by interval velocity and seismic frequency.

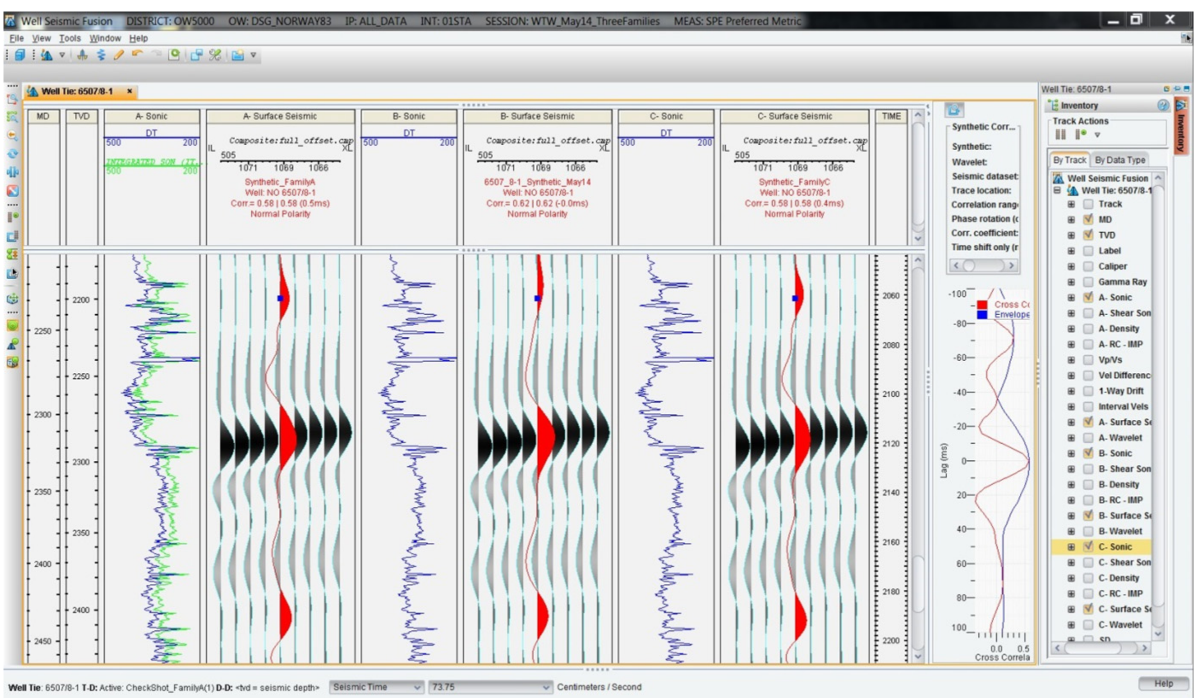
Thickness edit provides seismic interpreters a handy tool to study thin reservoirs, by applying the thickness change to all the curves and synthetic traces. You will be able to examine the tuning effects on synthetics and conduct detailed analysis of thin beds as well as effects of AVO/Fluid Substitution.

1. In the *Well Tie Workflow* window, hide the **Well Section** and **Wavelet** tracks for all families from the *Inventory* pane.

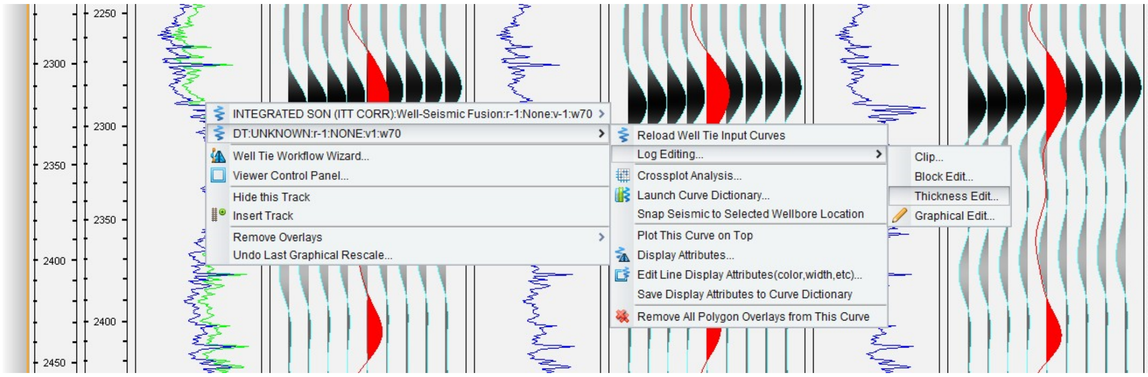
2. Select the **Sonic** check boxes for all families.

3. Zoom in between **2050 ms** and **2200 ms**.

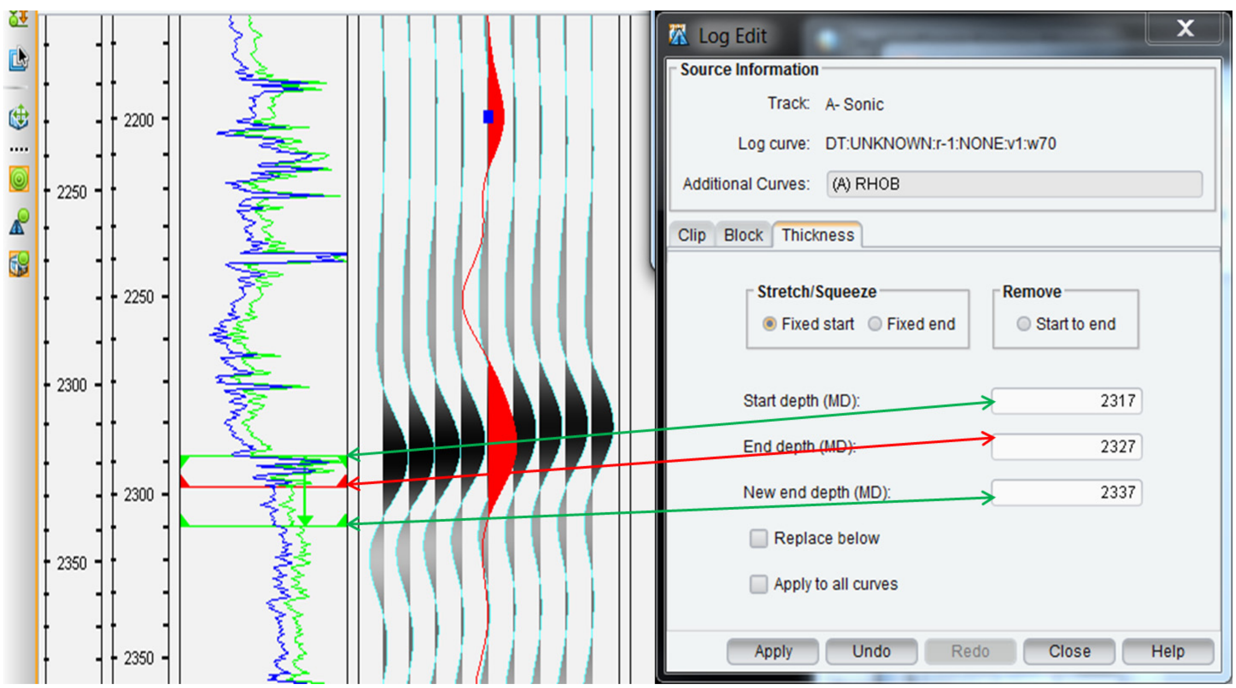
   You should have a session like the one in the image below.



4. **MB3** on the **DT** log (A-Sonic Track) and select **DT > Log Editing > Thickness Edit...**.



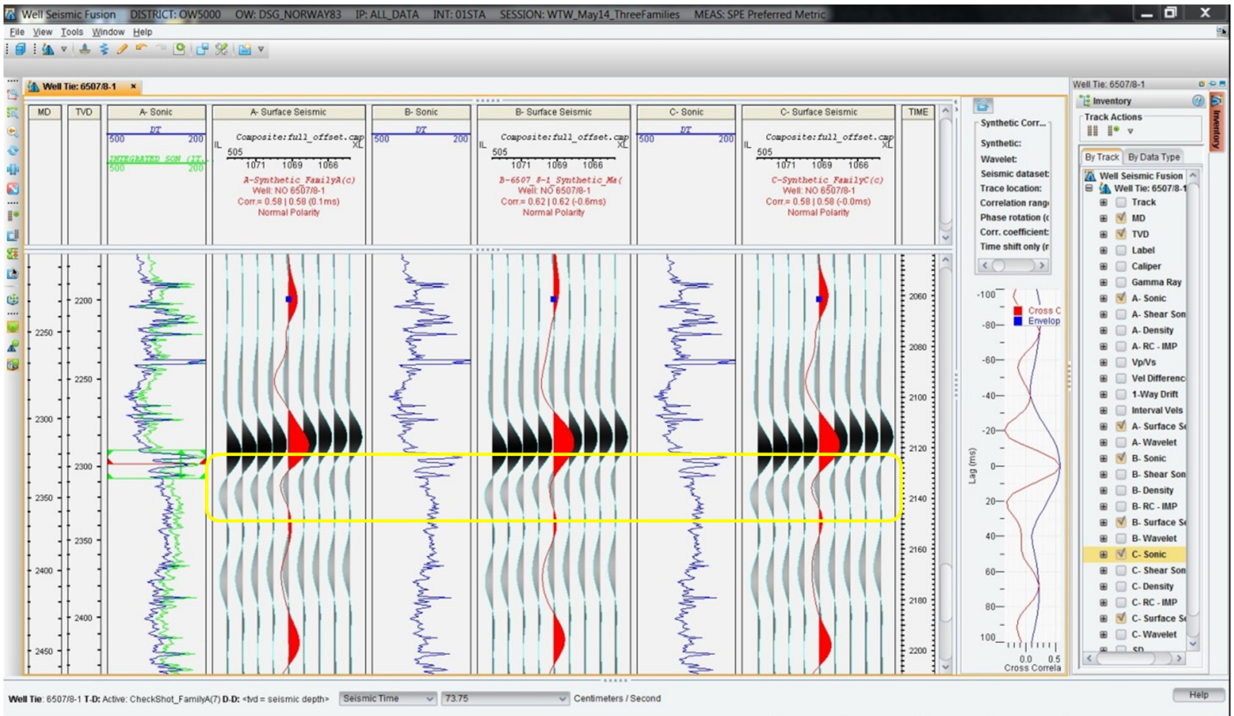
5. On the *DT* log (*A-Sonic* Track), **MB1** to select the ***Start depth*** at **2317 MD**, ***End depth*** at **2327 MD**, and ***New end depth*** at **2337 MD**. You can also enter these values in the *Log Edit* dialog.



6. Select the **Apply to all curves** check box.

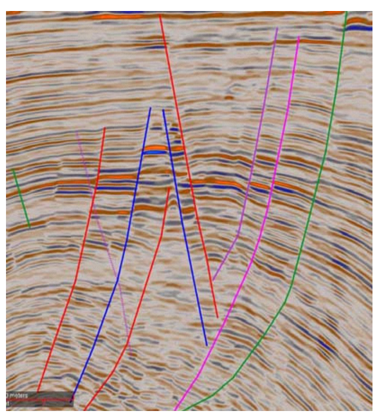
7. Click **Apply**.

Note that change in the thickness of the layers is going to impact the synthetic seismic trace (You may need to take a closer look to find the differences).



Chapter 3
Fault Interpretation

The DecisionSpace Geosciences software allows interpretation of new and existing faults. Seismic faults are interpreted in *Section*, *Map*, and *Cube* views and that interpretation can be refined by several manipulation options. The use of QC Display for fault sticks helps speed up the process of fault interpretation in a semi-automated manner. The DecisionSpace Geosciences software also provides the functionality to predict faults in areas of poor data constraints. The Dynamic Frameworks to Fill (DFF) platform of the DecisionSpace Geosiences software facilitates fault plane quality control as you are interpreting since it lets you visualize the fault planes being created on the fly as your interpretation proceeds. Dynamic Frameworks to Fill also enables an automated and/or user controlled fault networking to aid in identifying crosscutting and truncating relationships in the early stages of the interpretation. In other words, you don't have to wait until you finish your fault interpretation process to create fault planes or fault networks. By enabling these options at the beginning of your interpretation you can detect discrepancies in the early stages of your interpretation, optimizing time and efficiency.

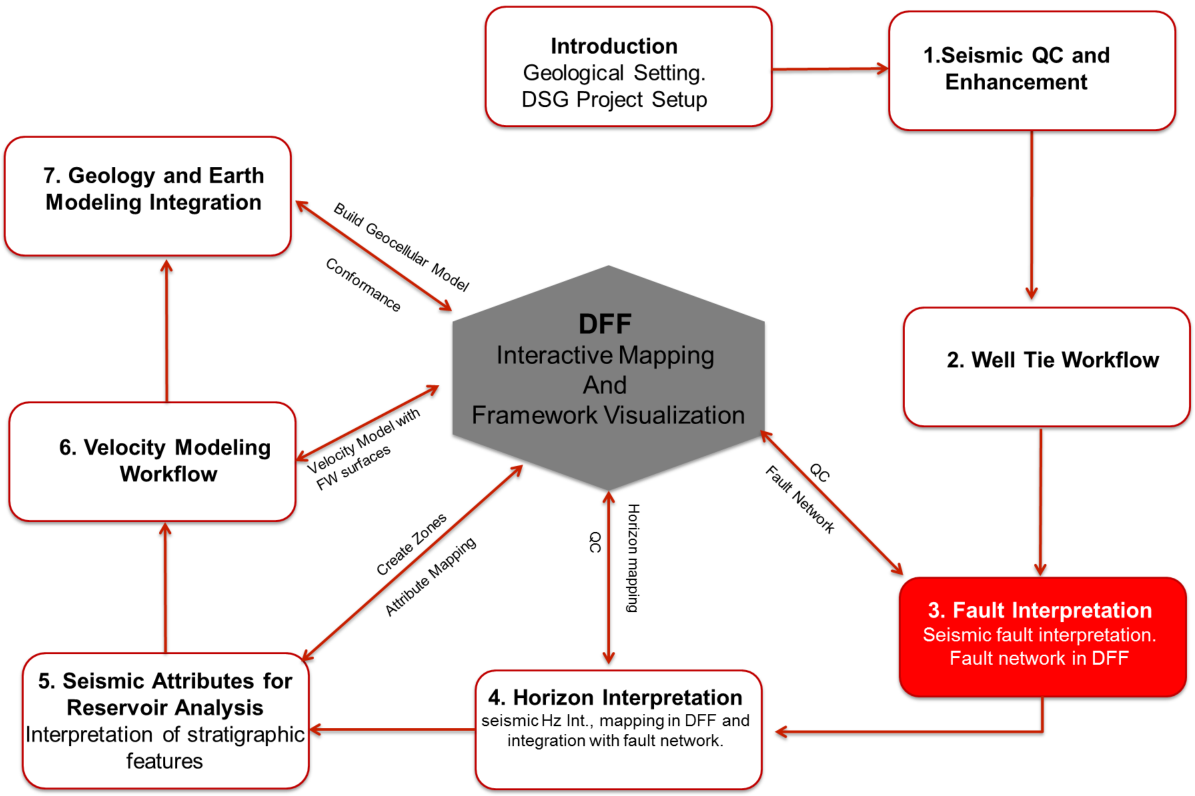


Overview

In this chapter, you will learn to:

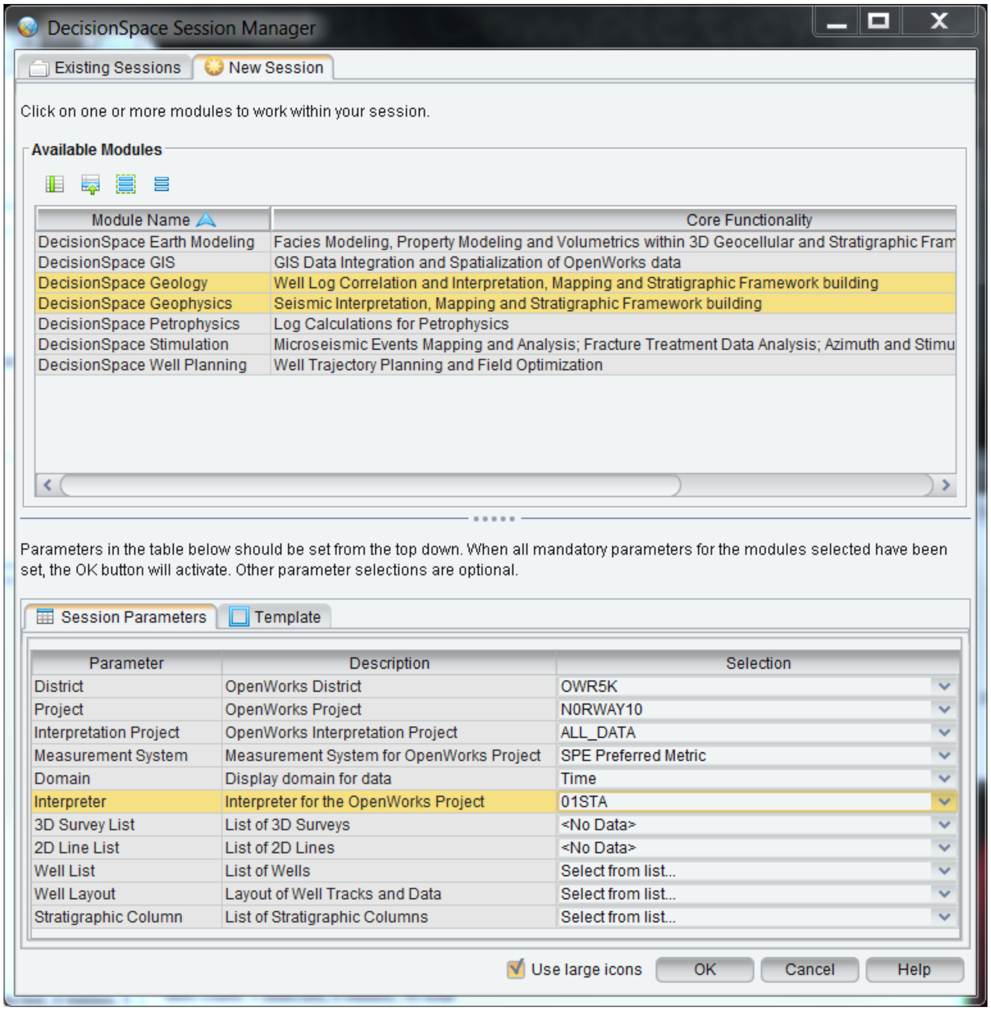
- ❑ Interpret faults in *Section*, *Map*, and *Cube* views
- ❑ Refine and enhance fault interpretations
- ❑ Use Fault QC to interpret multiple fault segments
- ❑ Create fault networks using the Dynamic Frameworks to Fill (DFF) platform

Workflow


Introduction
Geological Setting.
DSG Project Setup
1.Seismic QC and Enhancement
2. Well Tie Workflow
3. Fault Interpretation
Seismic fault interpretation.
Fault network in DFF
4. Horizon Interpretation
seismic Hz Int., mapping in DFF and integration with fault network.
5. Seismic Attributes for Reservoir Analysis
Interpretation of stratigraphic features
6. Velocity Modeling Workflow
7. Geology and Earth Modeling Integration
DFF
Interactive Mapping
And
Framework Visualization
Build Geocellular Model
Conformance
Velocity Model with FW surfaces
Create Zones
Attribute Mapping
QC
Horizon mapping
QC
Fault Network

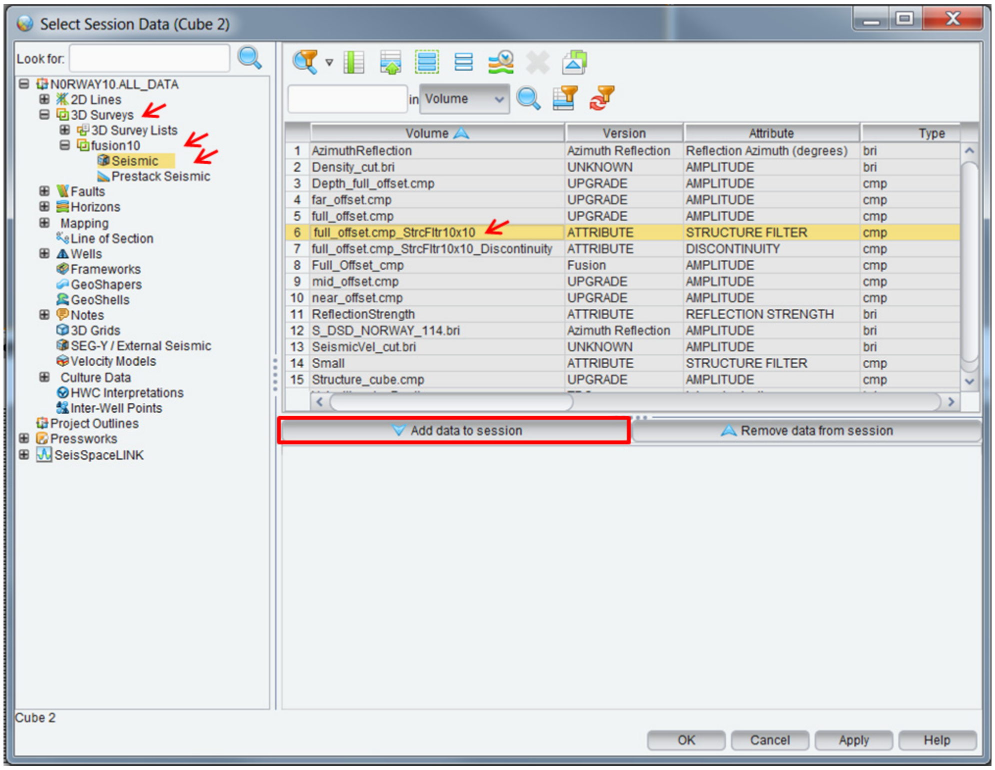
Exercise 3.1: Fault Interpretation in *Section* View

1. Start a new session with the parameters in the picture below, and click **OK**.

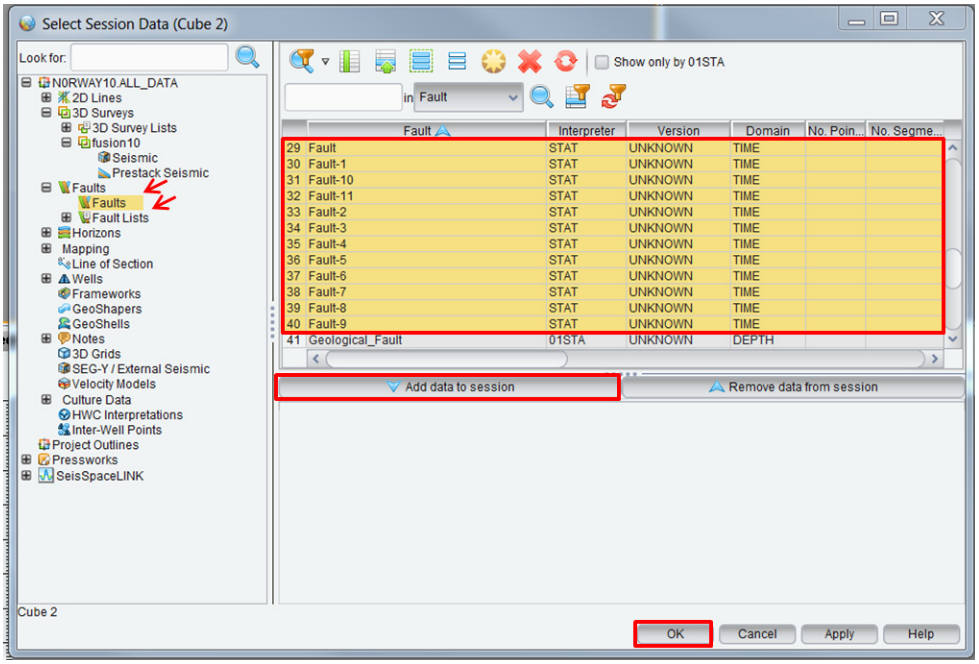


2. Once your new session starts click the **Select Session Data** () icon. In the *Select Session Data* dialog, select **3D Surveys > fusion10 > Seismic** and then in the right panel, select **full_offset.cmp_StrcFltr10x10**. Click **Add data to session**.

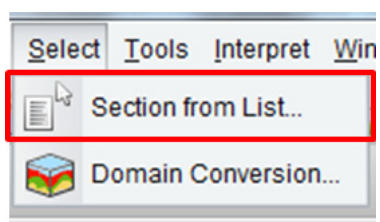
Full_offset.cmp_StrcFltr10x10 is the smoother volume you learned how to create in Chapter 1. You will be using this volume to make the majority of your interpretations, because the structural filter applied to the original seismic allows you to easily see the key features within your area.



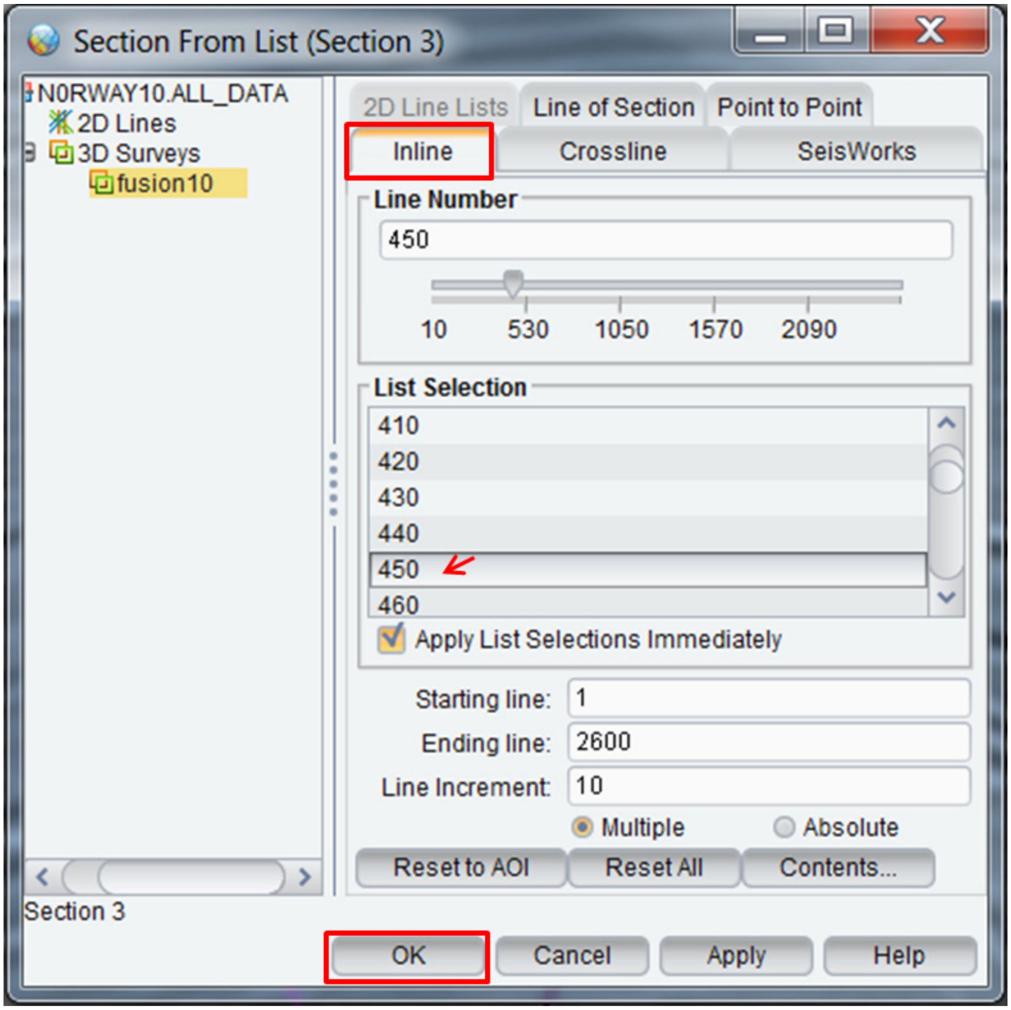
3. In the *Select Session Data* dialog, select **Faults** > **Faults** and then in the right panel, select **Fault** and **Fault-1** through **Fault-11**, make sure they are in **TIME**, and then click **Add data to session**. Click **OK**.



4. Activate and maximize your *Section* view, and in the *Main Toolbar* select **Select > Section from List...**.



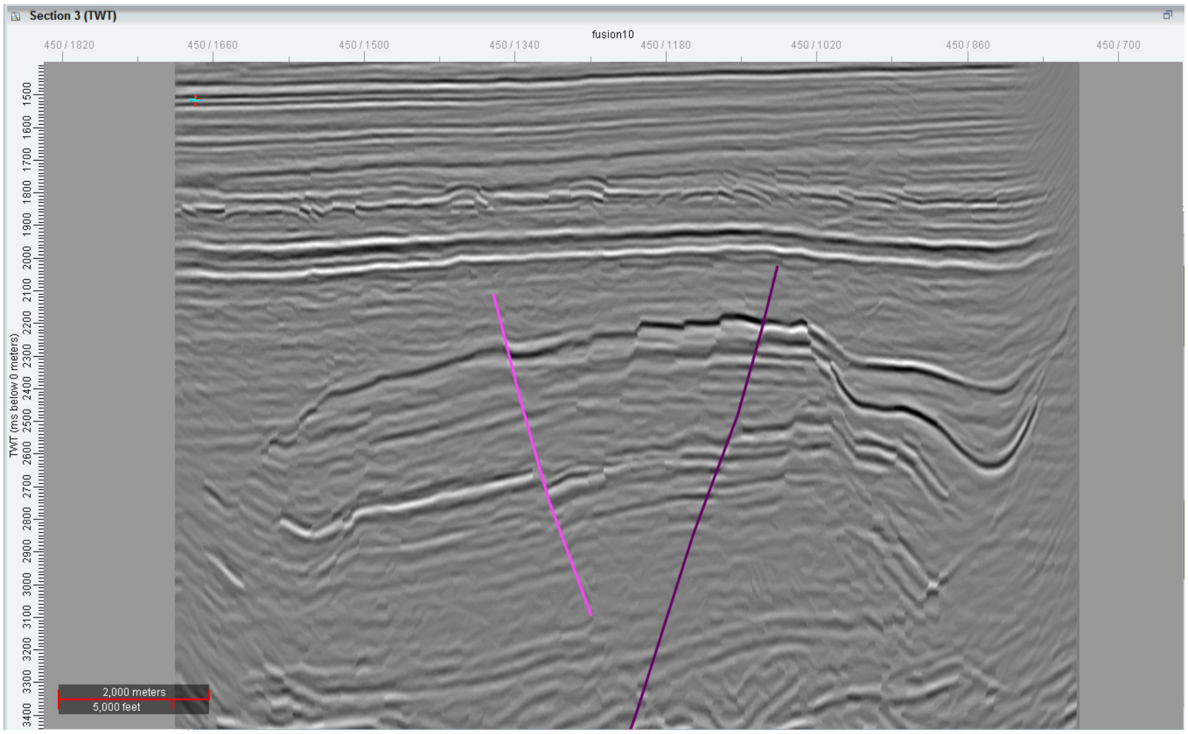
5. In the *Section From List* dialog, select the **Inline** tab, select **450** from *List Selection*, and click **OK**.



Note

You can also type the value of the specific Inline you want into the *Line Number* field, or use the sliding bar as alternative ways to select your Inlines and Crosslines.

6. In the *Inventory* task pane, make sure that **full_offset.cmp_StrcFltr10x10** is toggled on, and then toggle on **Fault** and **Fault-7**. You will use these two faults as references for your own interpretation.



> **Note**
>
> The area has been zoomed in to our area of interest, and the seismic has been changed to greyscale for manual purposes. If you wish to also view your seismic in greyscale you may do so by changing the *Color map* in *Display Properties* under **Color map > System > Greyscale**.

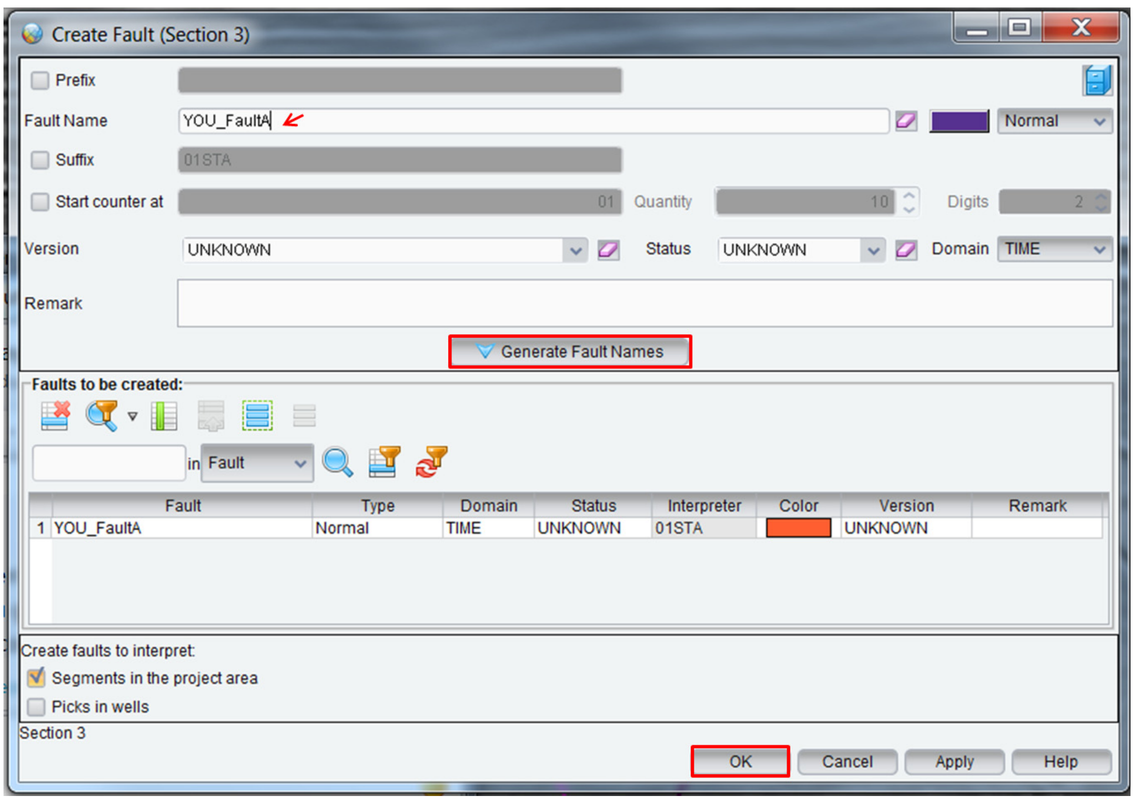
7. In the *Interpretation* task pane, click the **Fault Interpretation** () icon.

   The two faults currently being displayed will be available to edit. You will be making a new fault for interpretation.

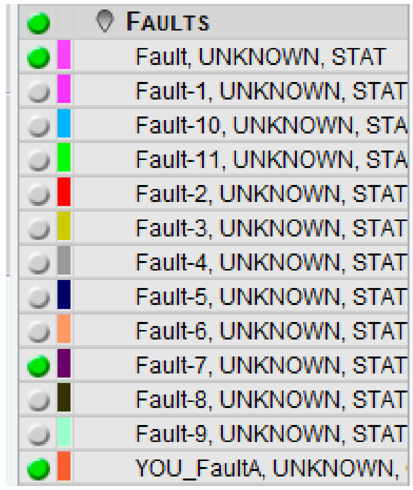
8. Selecting Fault Interpretation in the *Interpretation* task pane will automatically change the interpretation data type to Faults in the *Interpretation* toolbar as well. In the *Interpretation* toolbar click the **Launch Create Faults dialog** ( ) icon.

The *Create Fault* dialog allows you to create more than one fault at a time, as well as control the specific colors and other parameters of the fault.

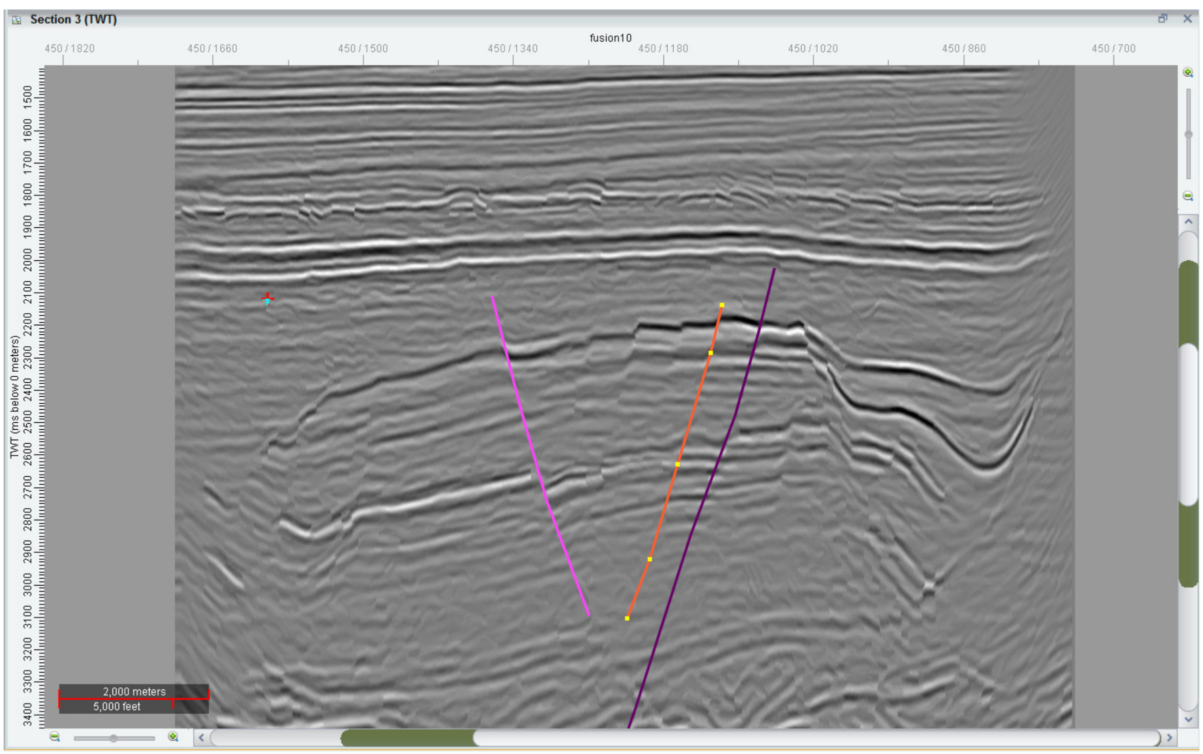
9. In the *Create Fault* dialog name the fault "**YOU_FaultA**," choose the color of your liking, click the **Generate Fault Names** button, and then click **OK**.



Your newly created fault will appear in the *Inventory* task pane.

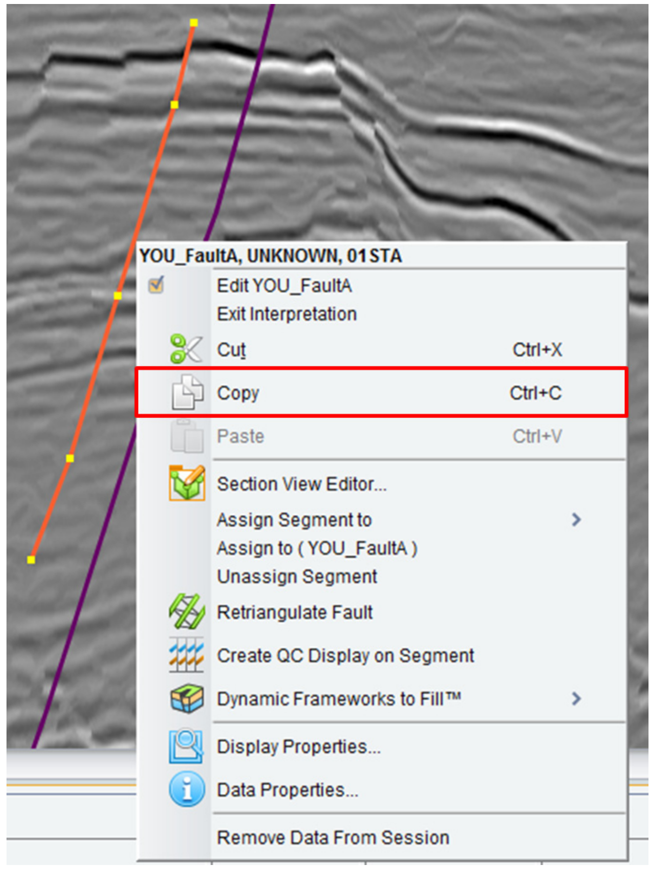


10. You will be interpreting the fault directly to the right of Fault-7. In your active *Section* view, click the **Interpretation Mode** ( ) icon. **MB1** to begin your interpretation, and when you are satisfied with your fault segment click **MB2** to end your interpretation.



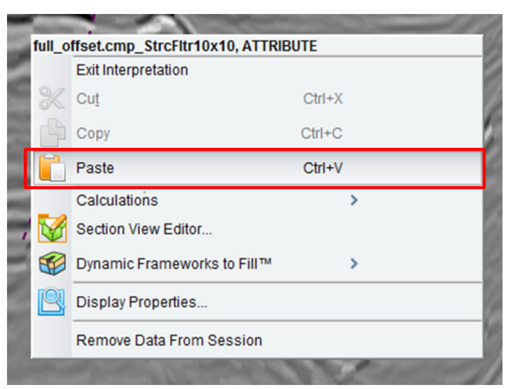
Another way to continue the interpretation is to copy the segment from one IL and paste it within another so you only have to make minor changes.

11. To copy a fault segment **MB3** on the **You_FaultA** segment and select **Copy**.

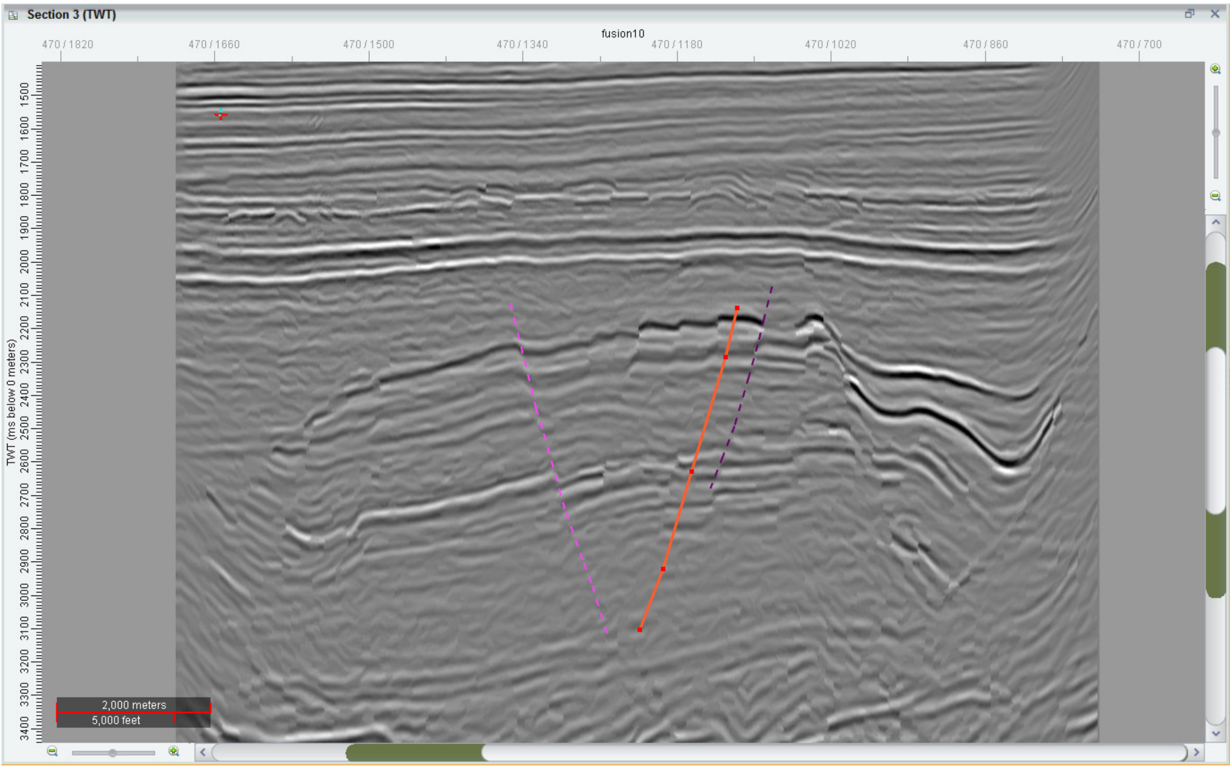


12. In the *Frame Control* toolbar enter a value of “**20**” for the amount of IL to skip, and then click the **Skip Forward** ( ) icon.

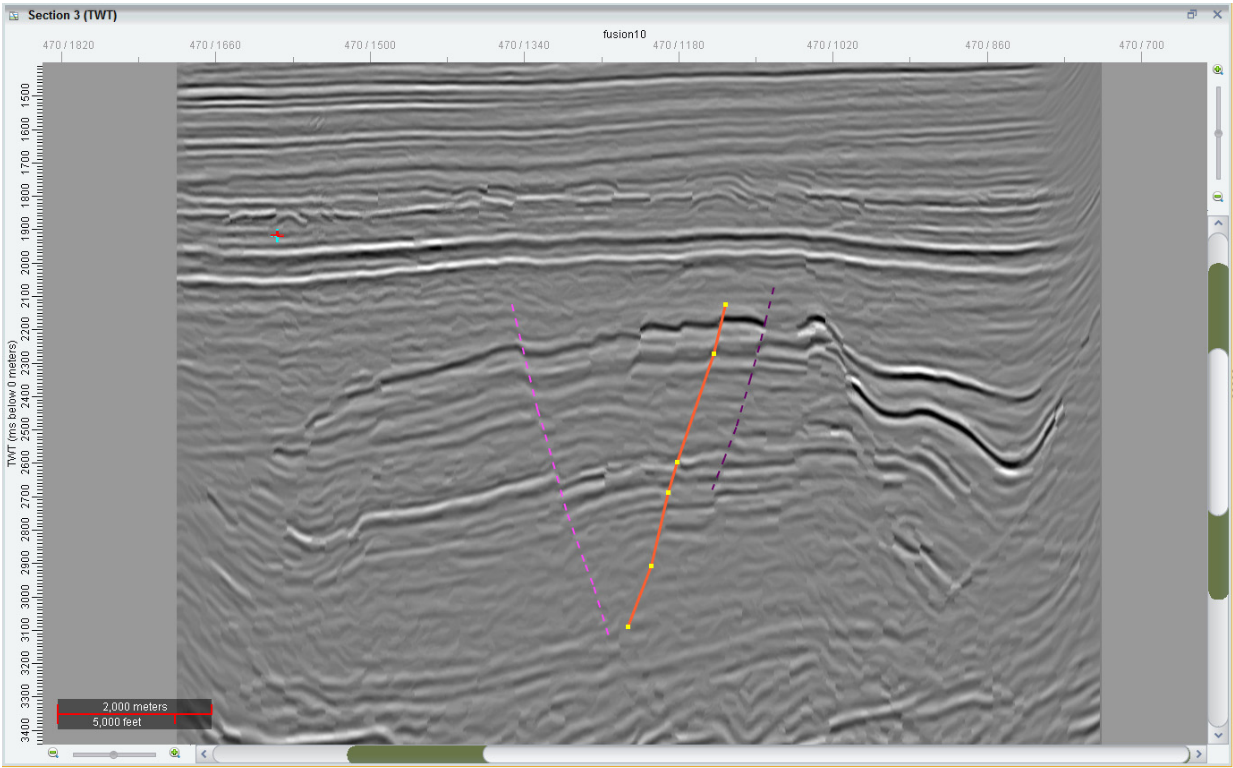
13. In *Section* view, **MB3** and select **Paste**.



The copied fault segment appears in the section. Notice that the segment is not quite where the fault should be interpreted. It is possible to move the entire segment, as well as edit specific nodes of the segment.

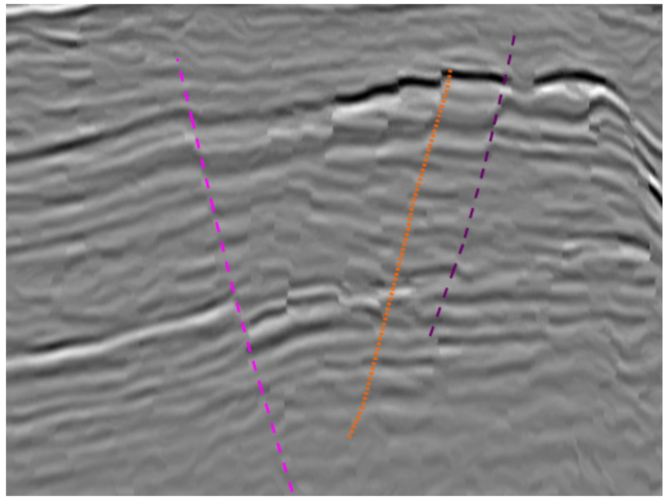


14. To move the entire segment at one time, hold down **MB1+<Shift>** on the fault segment and drag to the correct location. To edit the individual nodes, **MB1** on the specific node you wish to move. To add a node, **MB1** on the segment where you want it to appear. To delete any extra nodes, **MB2** specifically on that node. Adjust the segment, and when you are satisfied click **MB2**.



> **Note**
>
> Nodes that appear yellow in your display are currently active and available to edit. If the nodes appear red *Interpretation Mode* is on, but that particular segment is not active.

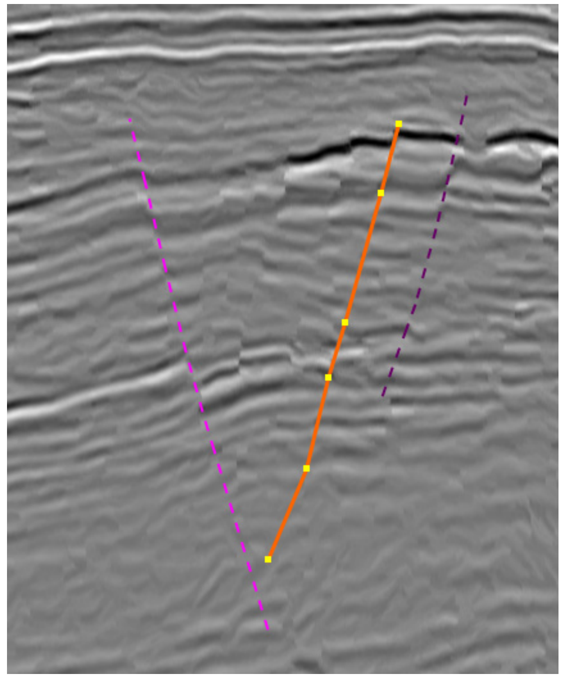
15. Click the **Skip Forward** ( ) icon again and interpret your fault segment on both 490 and 510 inlines.



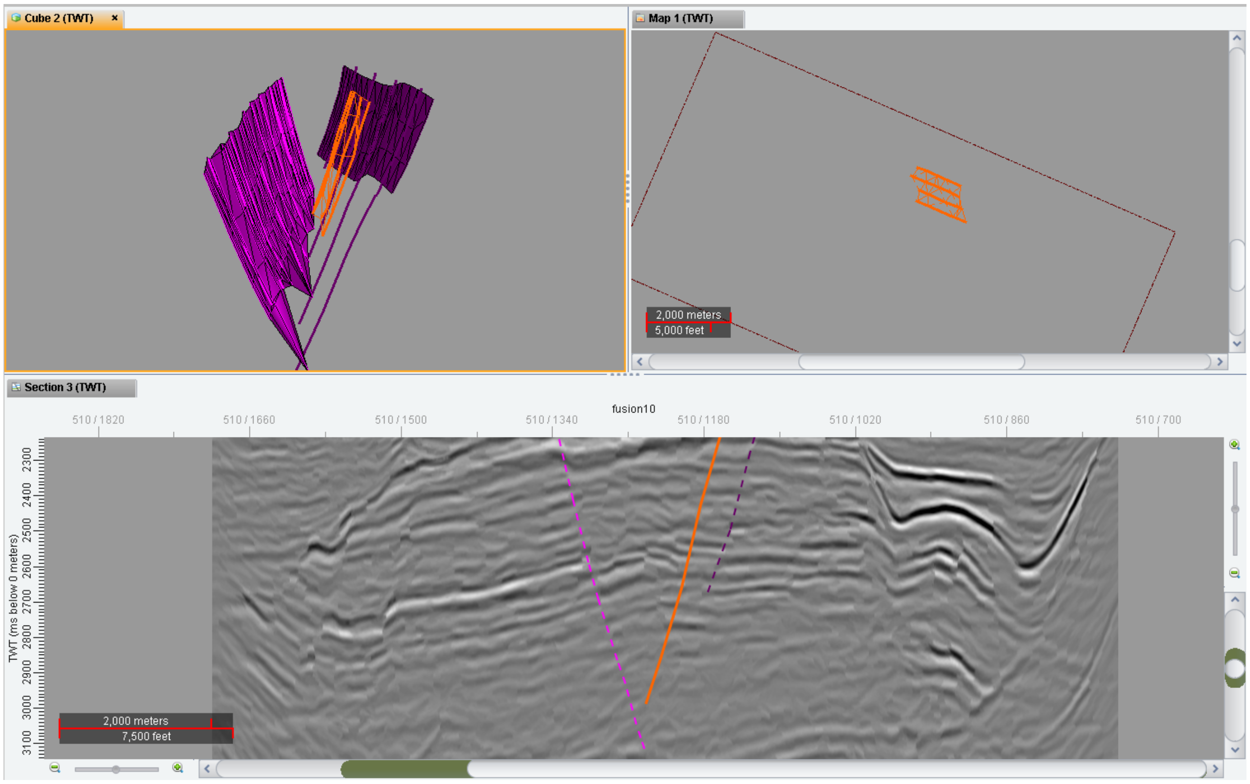
Note

The dotted line depicts the position in which the software is calculating the fault plane to intersect the section, due to the triangulation of the plane from the already interpreted fault segments. You can choose to convert this line into a fault segment, by hovering over the segment and pressing <**s**>, or click **MB3** and select **Convert to Segment**.

16. In your *Section* view hover over your projected fault segment and press <**s**>. This should make the fault segment real and editable. Make any changes to the segment that are necessary for the best interpretation.



17. Minimize your *Section* view and in your *Cube* view, toggle on **Fault**, **Fault-7**, and **YOU_FaultA**. In your *Map* view, toggle on only **YOU_FaultA**.

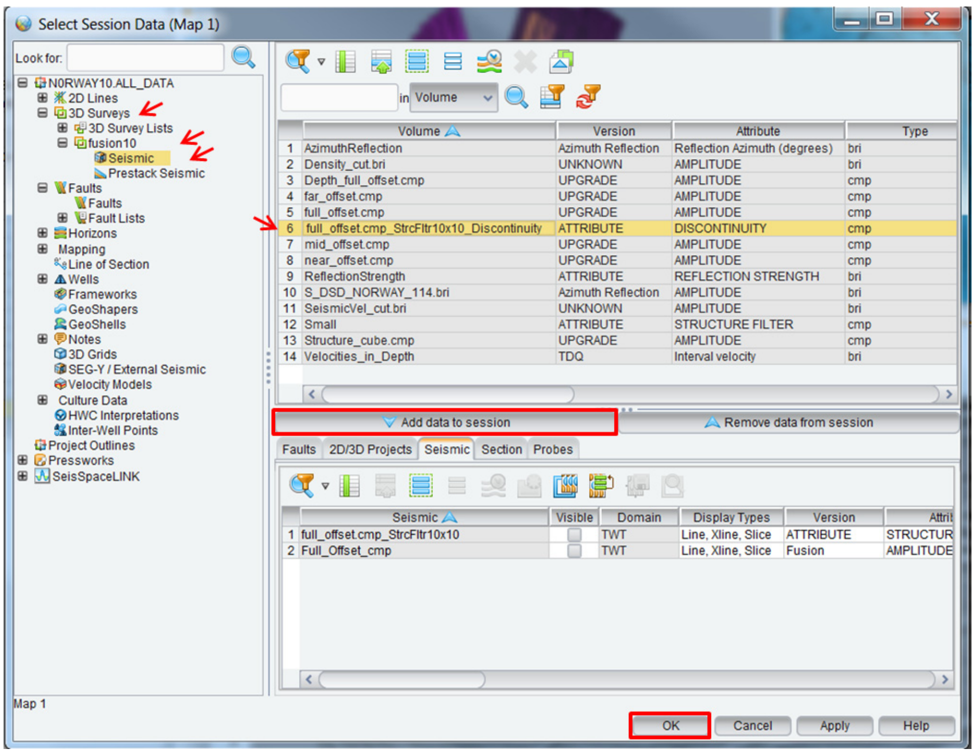


Until now, you have been making your interpretation only in *Section* view. In the following exercise, you will continue your interpretation in *Map* view, using a discontinuity map.

Exercise 3.2: Interpreting in *Map* View

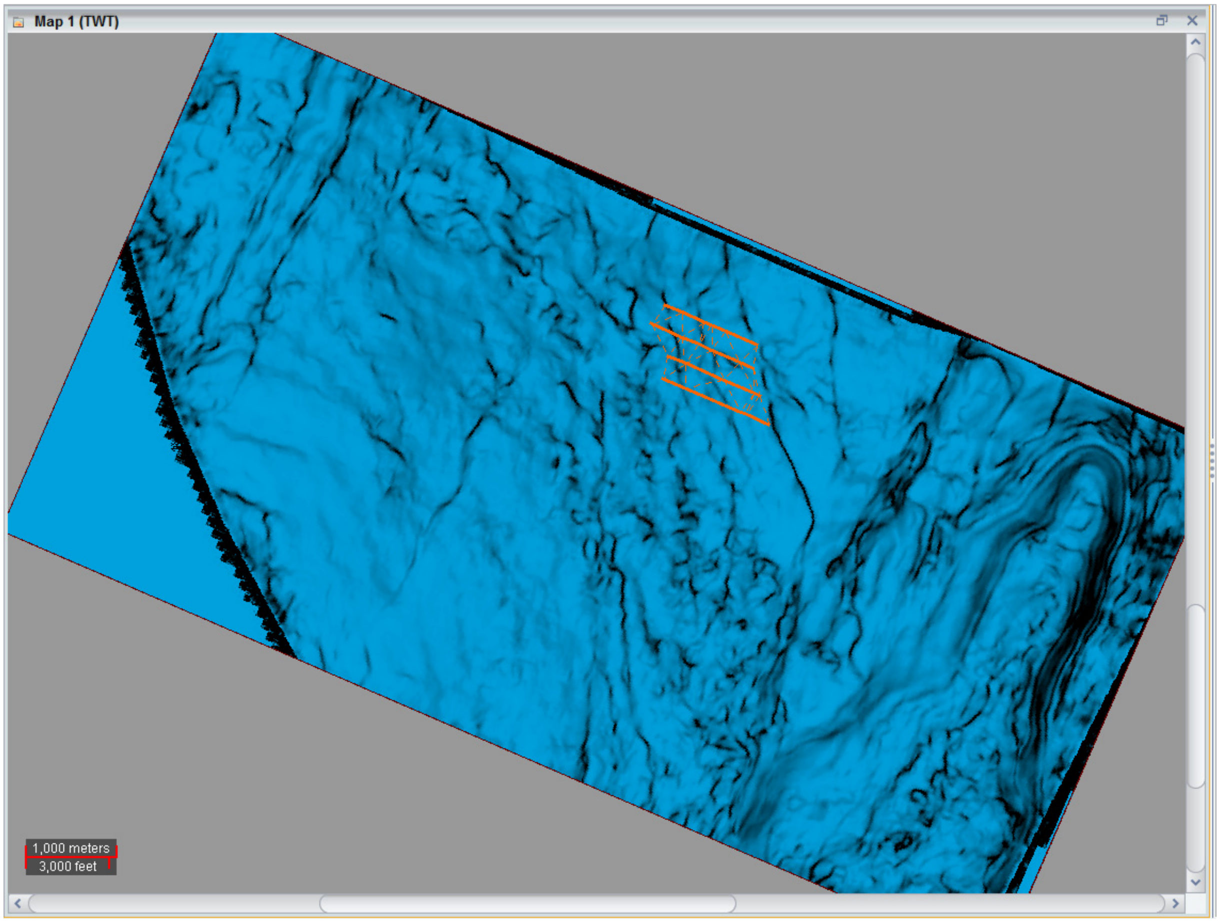
In the following steps, you will use the discontinuity attribute calculated in Chapter 1 to make your fault interpretation. Displaying a discontinuity slice in *Map* view allows you to have a better idea of the lateral extent of your faults. You can interpret a fault segment along the discontinuities, which will not only modify the fault plane in that area, but help guide your interpretation in other views.

1. Click the **Select Session Data** ( ) icon. In the *Select Section Data* dialog select **3D Surveys > fusion10 > Seismic** and in the right panel select **full_offset.cmp_StrcFltr10x10_Discontinuity**. Click **Add data to session** and then click **OK**.



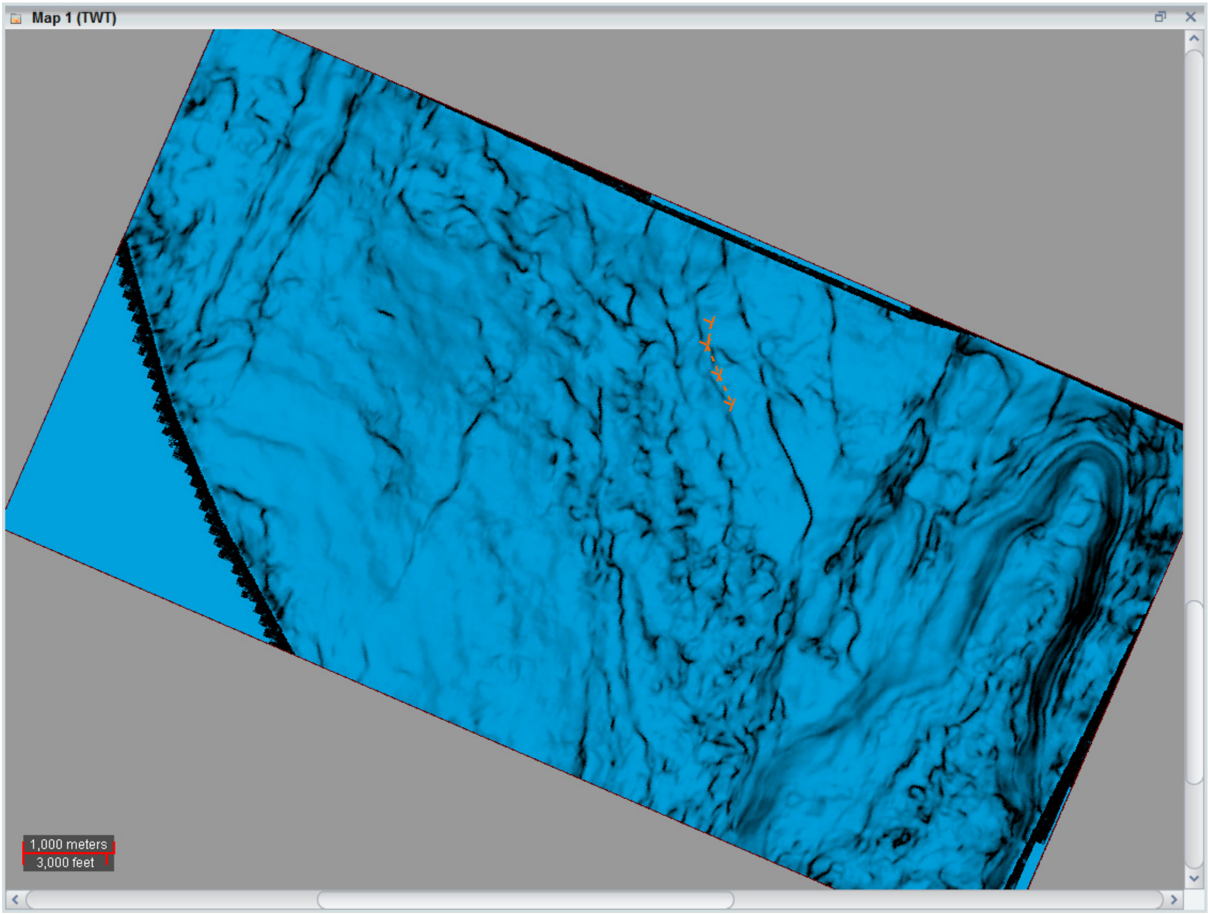
2. Activate and maximize your *Map* view. Toggle on the **full_offset.cmp_StrcFltr10x10_Discontinuity**, and in the *Frame Control* toolbar navigate to **slice 2540**.

Right now it is hard to determine which discontinuity the segments are corresponding to. By entering into *Map Intersection* view you will only see the portions of the fault that intersect with the slice you have displayed.

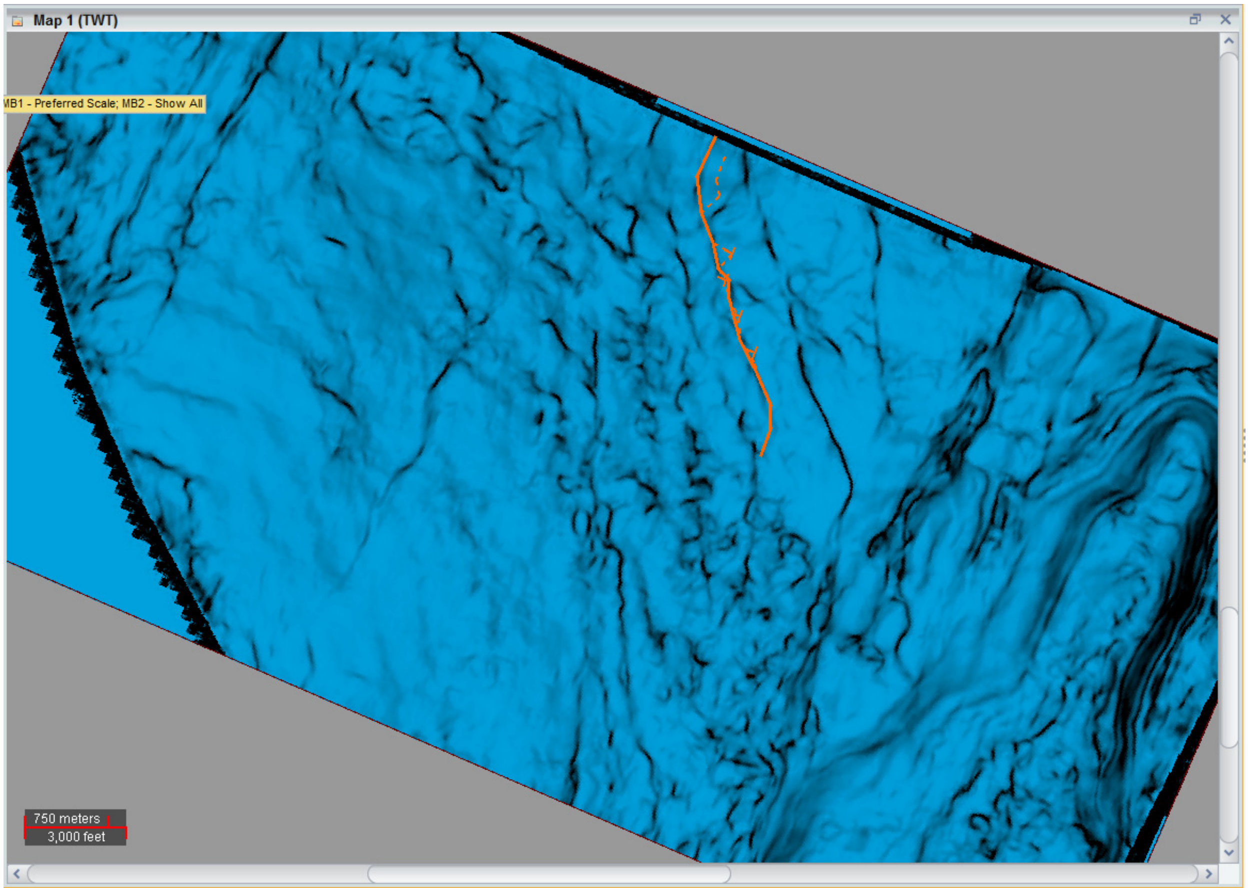


3. In the main toolbar select the **Map Intersection View** ( ) icon.

Entering *Map Intersection* view makes it much easier to determine which discontinuity depicts the lateral extent of YOU_FaultA.

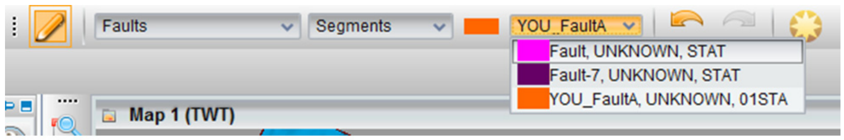


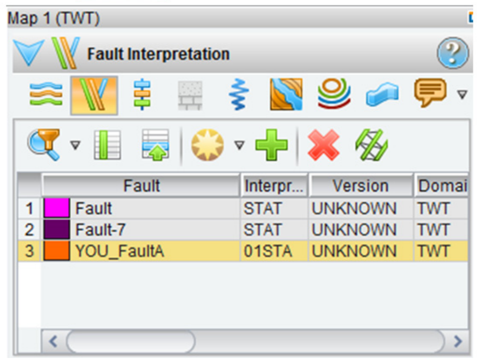
4. In *Map* view, make sure that the **Interpretation Mode** is on, and **Faults** are designated as the *Data Type*. **MB1** on the discontinuity that corresponds to **YOU_FaultA**. **MB2** when you are satisfied with your interpretation.



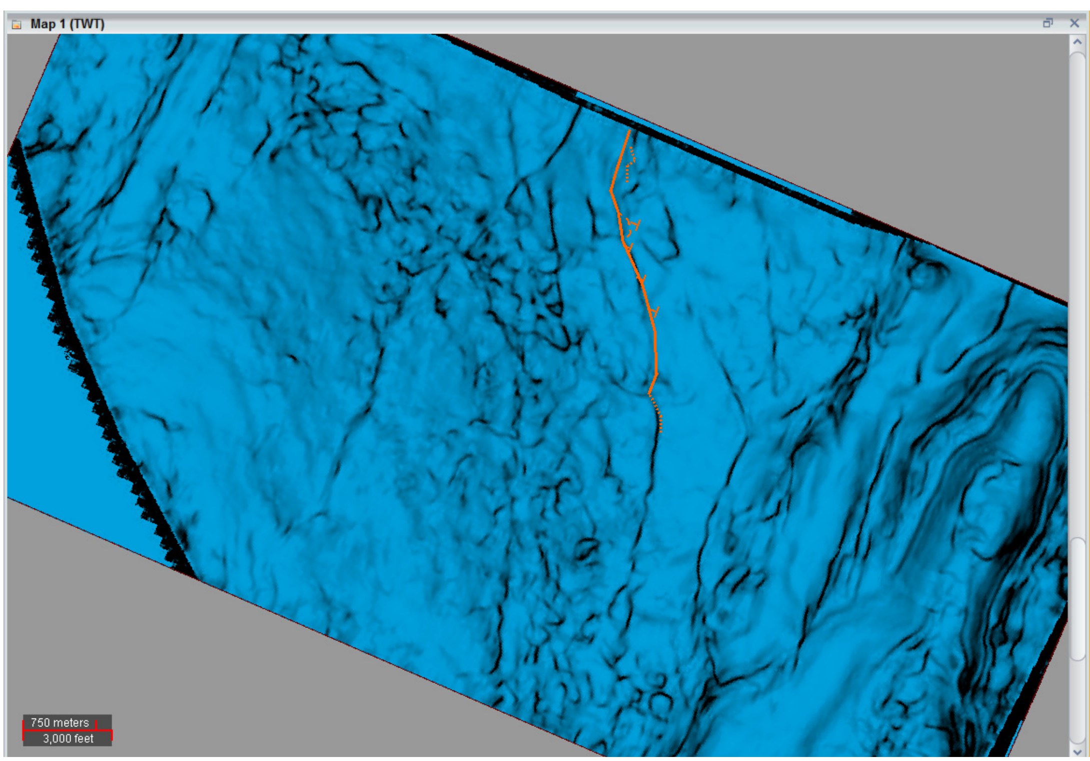
Note

Objects are only available to interpret when toggled on. To switch between objects you can select them from the drop-down menu in the *Interpretation* toolbar, or in the *Interpretation* task pane.



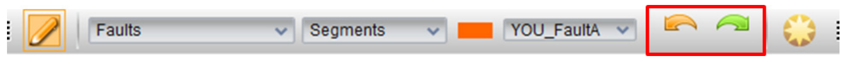


5. Change the skip increment to “**50**,” and then skip forward to interpret on the **2590** slice.



Note

You can remove an entire segment by pressing <**Ctrl+ z**> or by clicking the **Undo** icon. You can also replace your segment in this way by clicking the **Redo** icon.

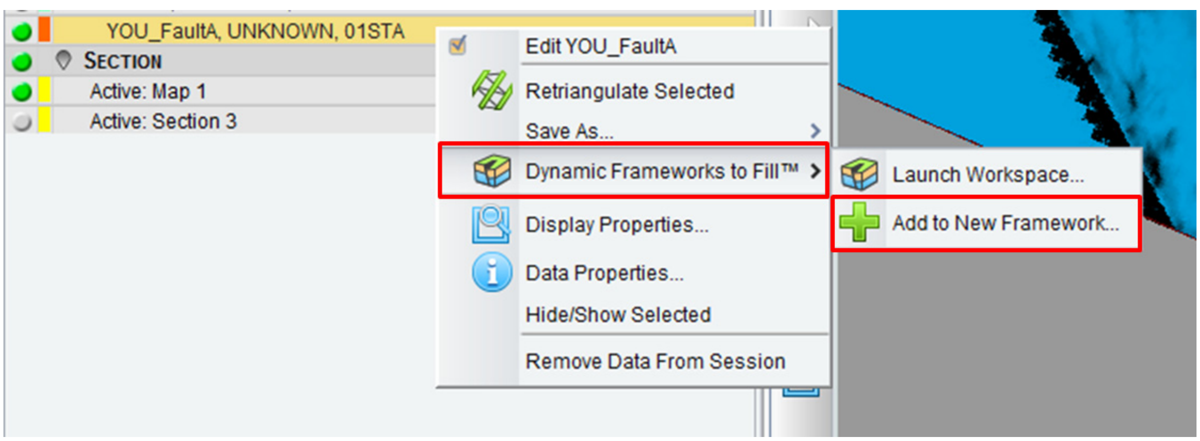


Exercise 3.3: Using Fault QC Display

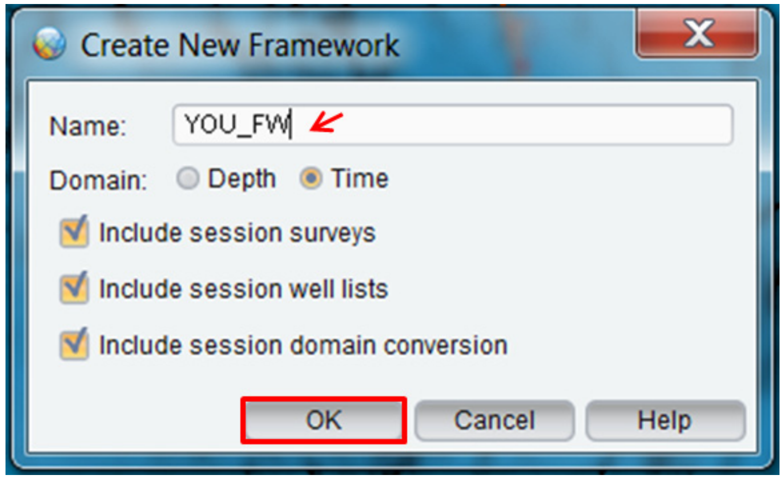
So far you have interpreted your fault in both *Section* and *Map* views, by skipping through the volume and interpreting the fault segments. Using the QC Display allows you to see multiple sections, taken perpendicular to the selected fault segment. This allows you to best see the faults and therefore make a better interpretation.

The QC Display will give you a more efficient way to interpret your fault segments. Using Dynamic Frameworks to Fill gives you a way to quickly create a fault plane to be used in your structural model. As you make your interpretations the fault segments will be saved to OpenWorks. Dynamic Frameworks to Fill is directly connected to the OpenWorks database, and will update every time you make a change to your fault. In the following steps, you will add your fault to a framework, and continue your interpretation in a QC Display, to see how quickly a fault plane can be created.

1. In the *Inventory* task pane, **MB3** on the **YOU_FaultA** and select **Dynamic Frameworks to Fill > Add to New Framework...**.



2. In the *Create New Framework* dialog, name the framework "**YOU_FW**," and click **OK**.

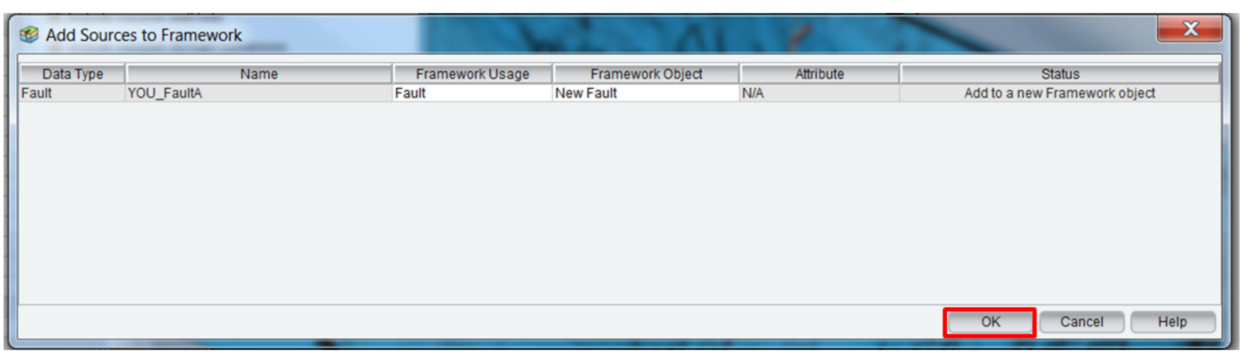


Note

The default domain, when creating a new framework, is the domain in which your session was opened.

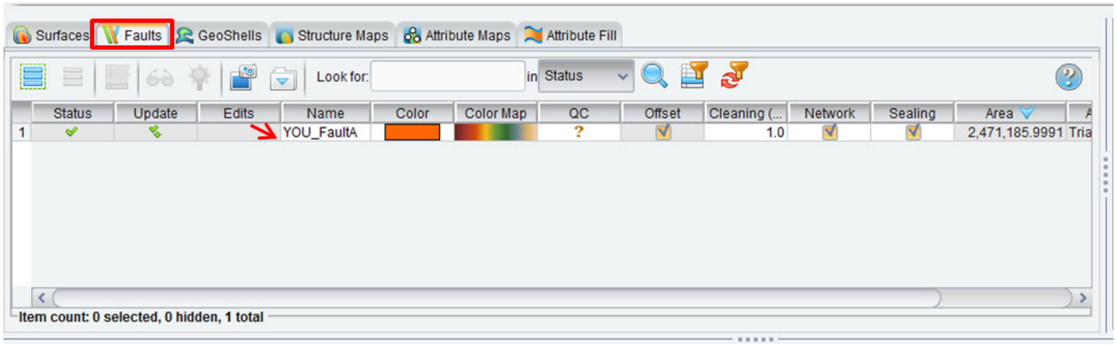
The three checkboxes are to include the surveys, well lists, and the velocity model that are currently included in the session. If you do not have any of these in your session, they will not be included at that time. If you have them in your session, but don't wish to include them, you can deselect the check boxes. You can add any of these items to the framework after it is created.

3. In the *Add Source to Framework* dialog, accept all of the defaults, and click **OK**. You will have the chance to experiment with other options in this box in a later chapter.

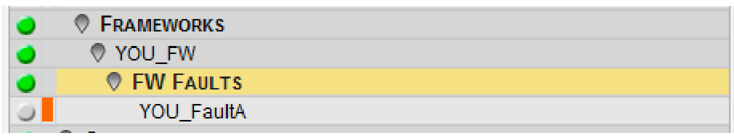


4. Navigate to the *Dynamic Frameworks to Fill* task pane, and click the **Launch Framework Workspace** () icon.

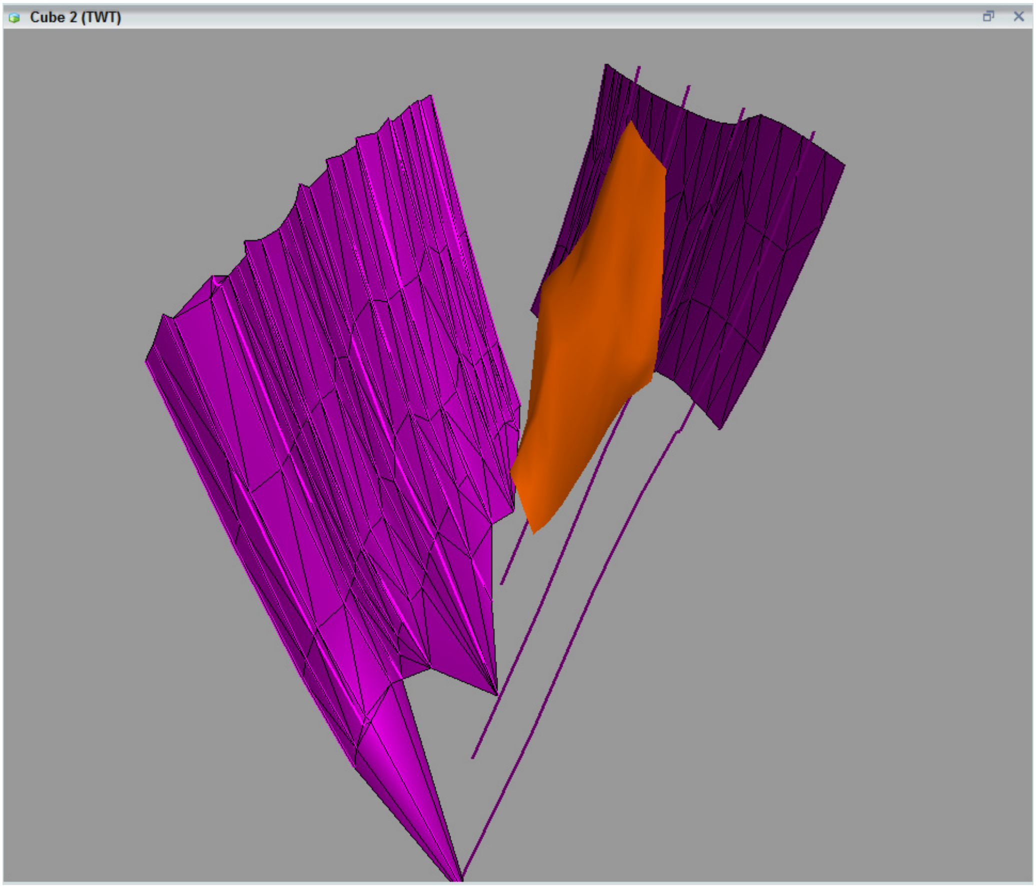
5. In the *Dynamic Frameworks to Fill Workspace*, click the **Faults** objects tab. You will see that YOU_FaultA has been added to your framework.



There is also a new category in your *Inventory*, **Frameworks > YOU_FW > FW Faults**.



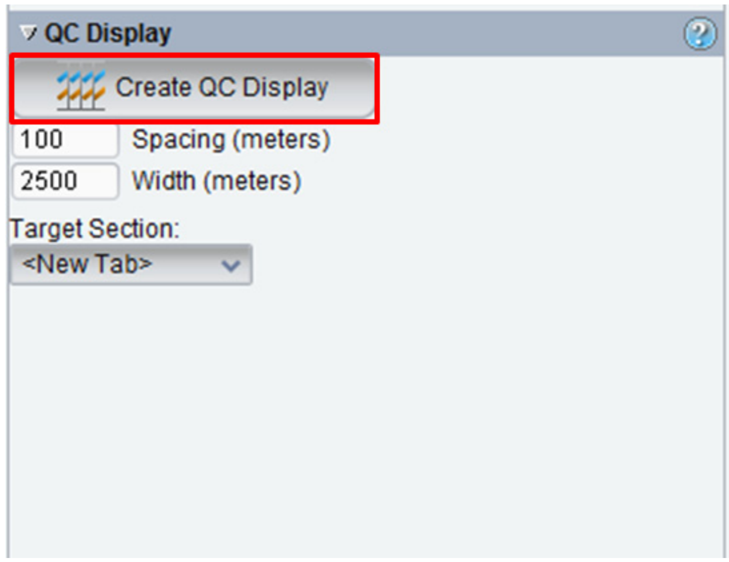
6. In *Cube* view, display your **FW Fault**, and turn off the **YOU_FaultA** original seismic fault.



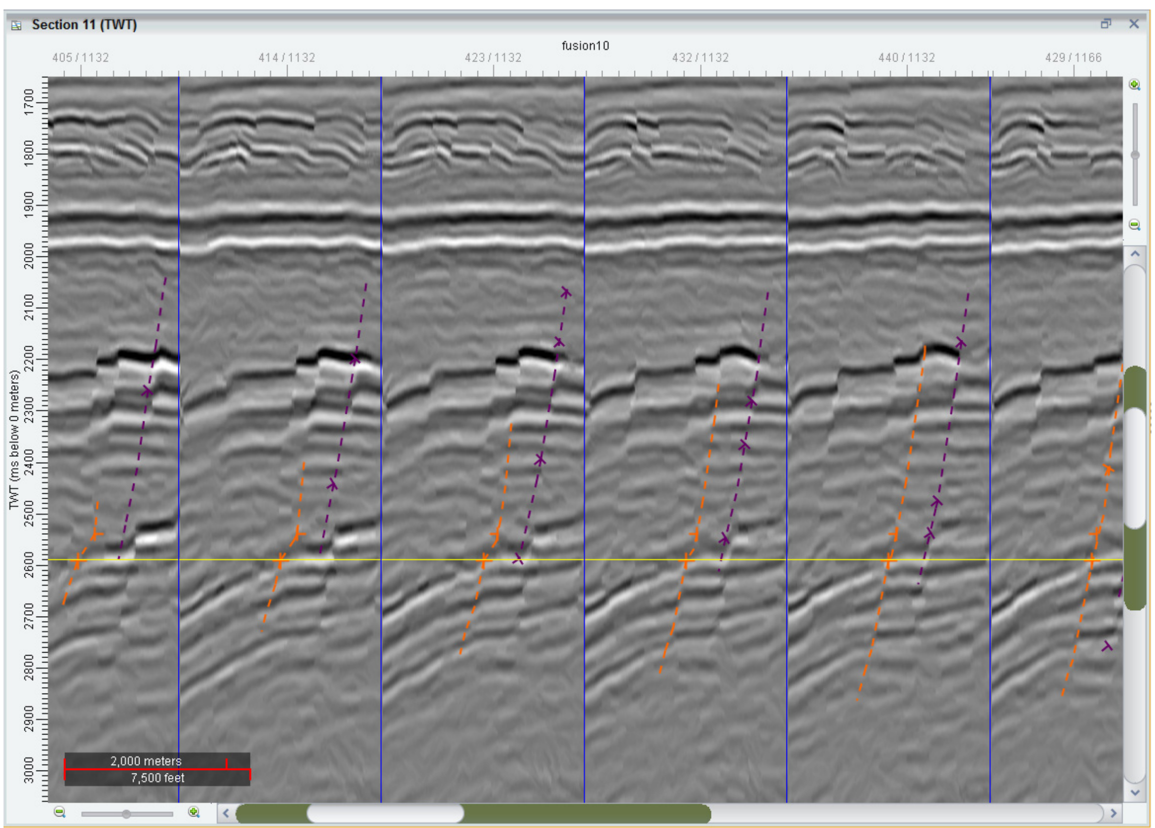
Now that you have added your fault to a framework, you will create a QC Display to continue your interpretation of the seismic YOU_FaultA fault.

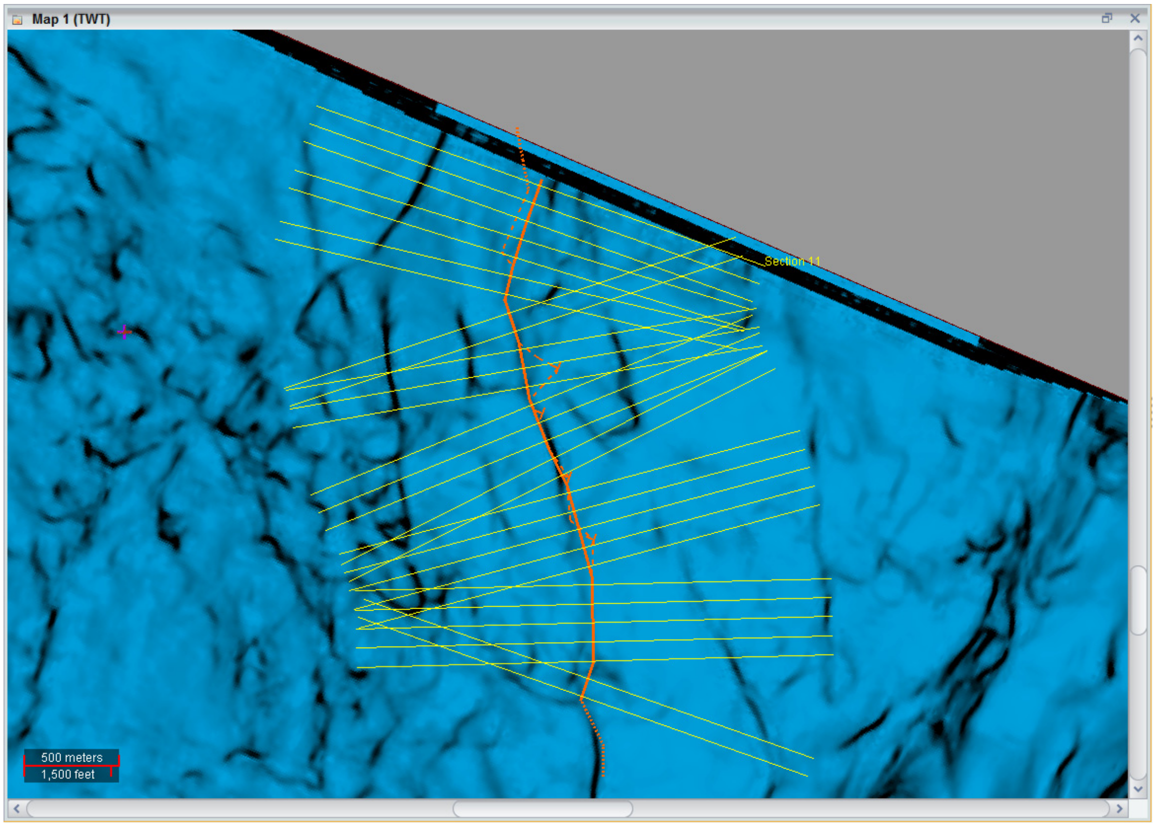
7. With *Map* view active, activate the **YOU_FaultA** fault segment. You may have to switch your interpretation data type back to **Faults** to select the fault segment.

8. In the *Interpretation* task pane, expand the *QC Display* panel, accept all defaults in the panel, and click **Create QC Display**.

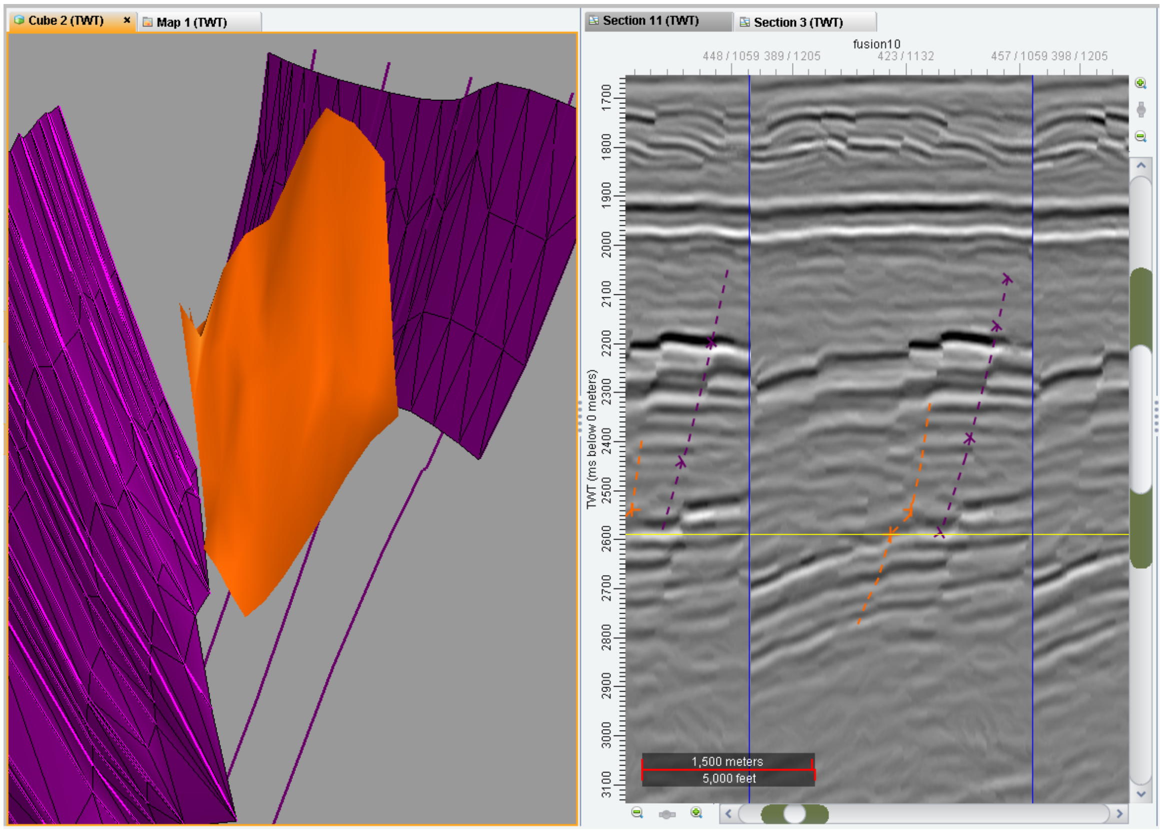


A new *Section* view opens showing all of the QC panels that were created. Also, in *Map* view you can see the panels that were created and how they relate to the extent of the fault segment.



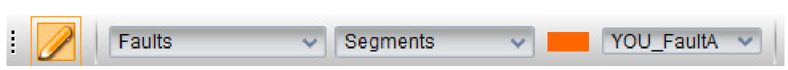

Map 1 (TWT)
Section 11
500 meters
1,500 feet

9. Arrange your tabs so that your *Cube* view is in the left half and your new *QC Section* view is in the right half of the screen.

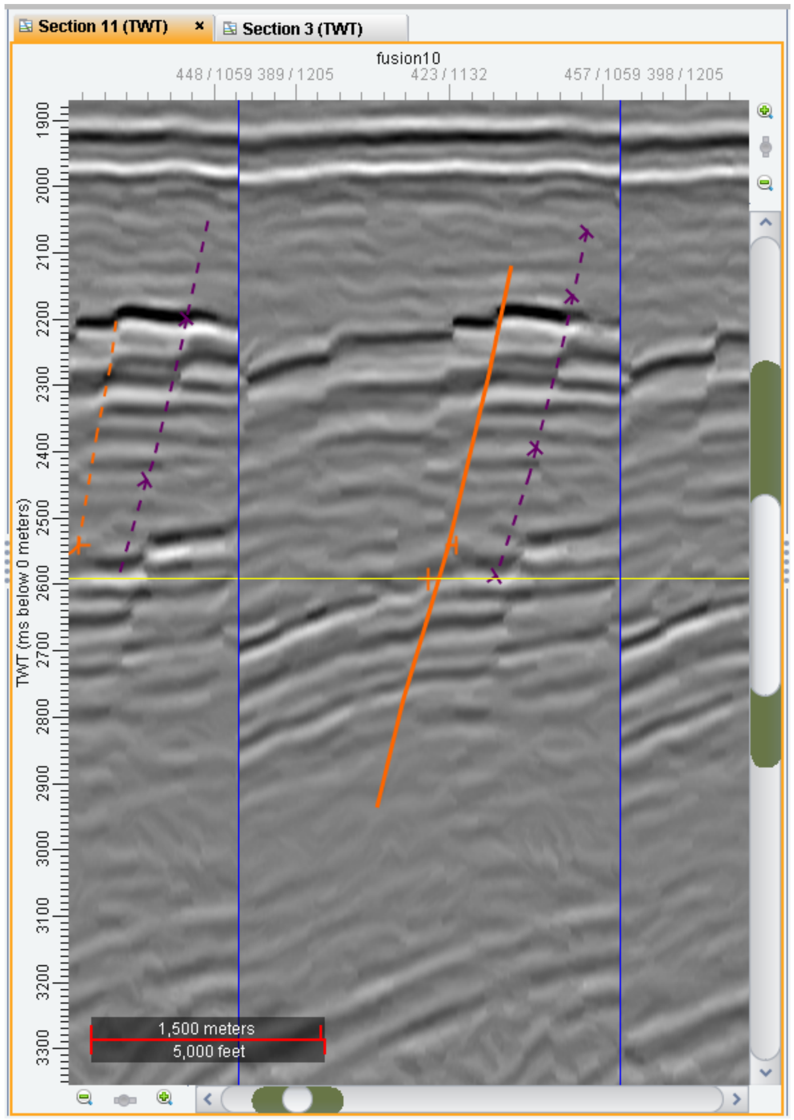


10. In your *Section* view, zoom as needed, to begin your interpretation of the YOU_FaultA fault.

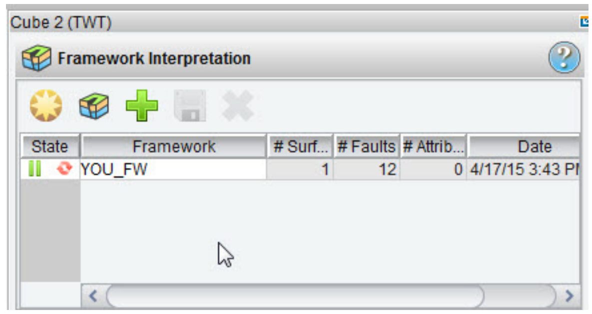
11. Make sure **Interpretation mode** is on, that the *Interpretation Data Type* is set to **Faults**, and that **YOU_FaultA** is selected for interpretation.



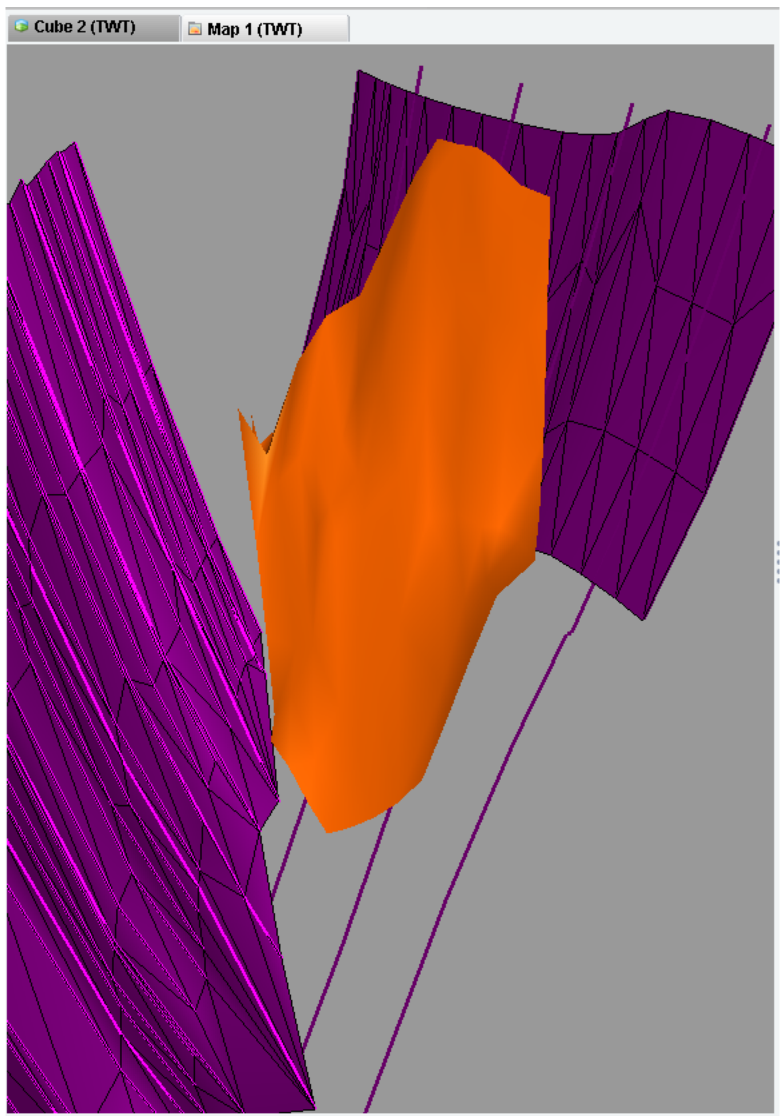
12. In any of the panels, begin your interpretation by clicking **MB1** to add nodes to your fault segment, and clicking **MB2** to end your interpretation.



13. When you finish your interpretation a refresh symbol appears next to your framework in the *Framework Interpretation* task pane. Click the **Refresh** () symbol to update your framework, and add the segment to your framework fault.



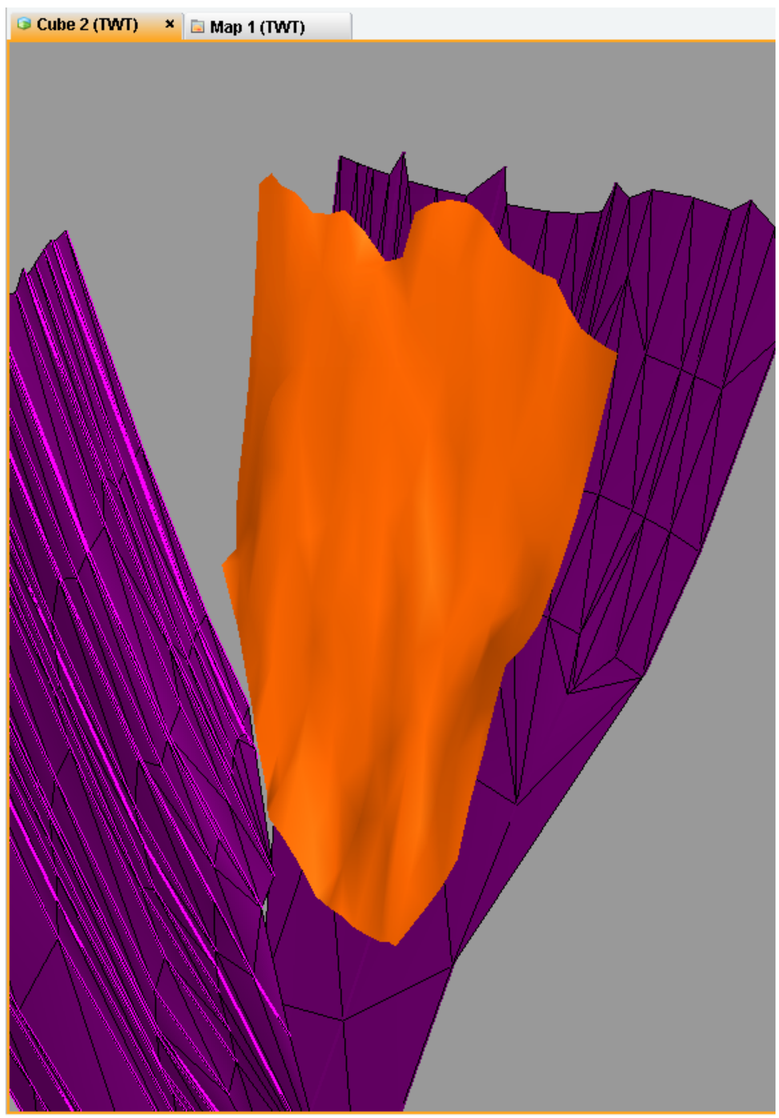
Notice the update to your YOU_FaultA FW Fault in *Cube* view.



14. Before continuing your interpretation, change your framework to **Dynamic, Auto Refresh** ( ), so you can see the changes to your fault plane happen automatically.

15. Continue your interpretation on the other panels in your QC Display. As you continue your interpretation the projected placement of your fault will change. If you like a segment you can quickly make it a real segment as opposed to performing manual interpretation.

    Once your interpretation is complete your fault plane should look similar to the one below.



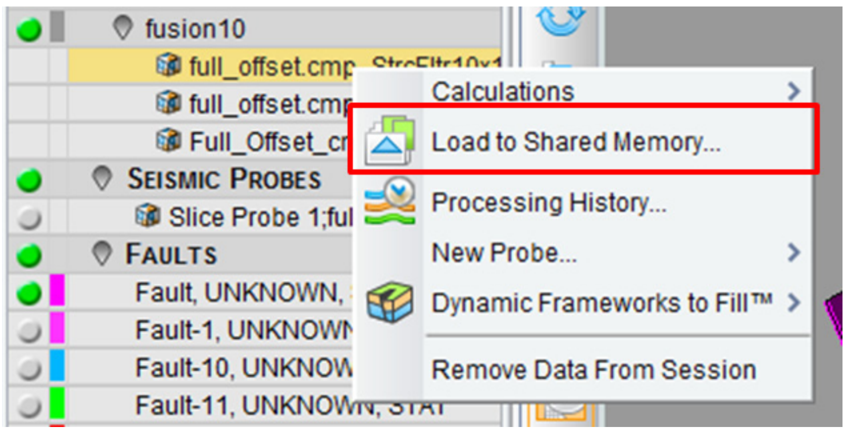
In the following exercise you will use *Cube* view to continue interpretation on your faults.

Exercise 3.4: Interpreting in *Cube* View

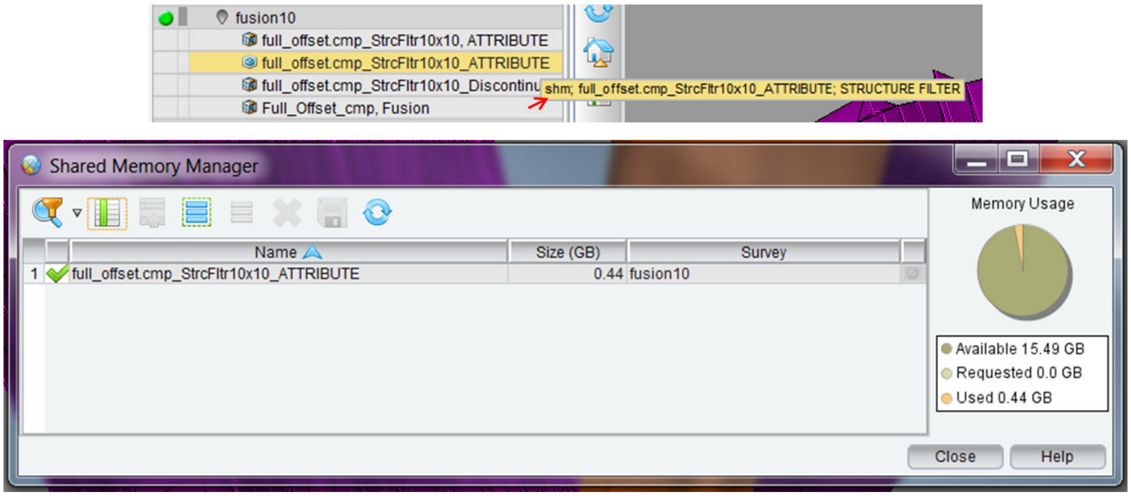
In DecisionSpace, you have the ability to make interpretations in your *Cube* view. This allows you to have a 3D view of the development of the fault plane as you make interpretation, as opposed to *Map* and *Section* view where you are viewing the fault in 2D.

1. Activate and maximize your *Cube* view.

2. In the *Inventory* task pane, **MB3** on **full_offset.cmp_StrcFltr10x10** and select **Load to Shared Memory...**.



3. Accept the defaults in the *Modifying full_offset.cmp_StrcFltr10x10* dialog, and click **OK**. The *Shared Memory Manager* displays with the status of the volume being loaded to shared memory. When it is complete a check mark appears next to the volume in the *Manager*, and a new object appears in the *Inventory*.

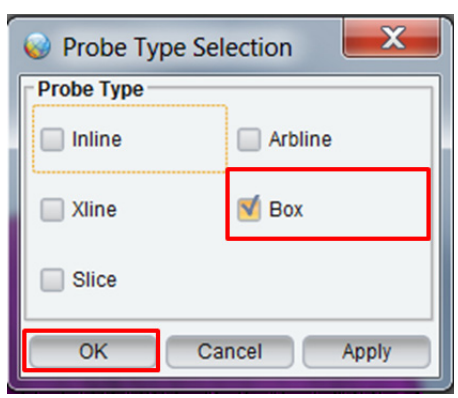


Note
The volume that is in shared memory will have a different icon, as well as be prefixed with “shm” when hovered over in the *Inventory* task pane.

4. Close the *Shared Memory Manager*.

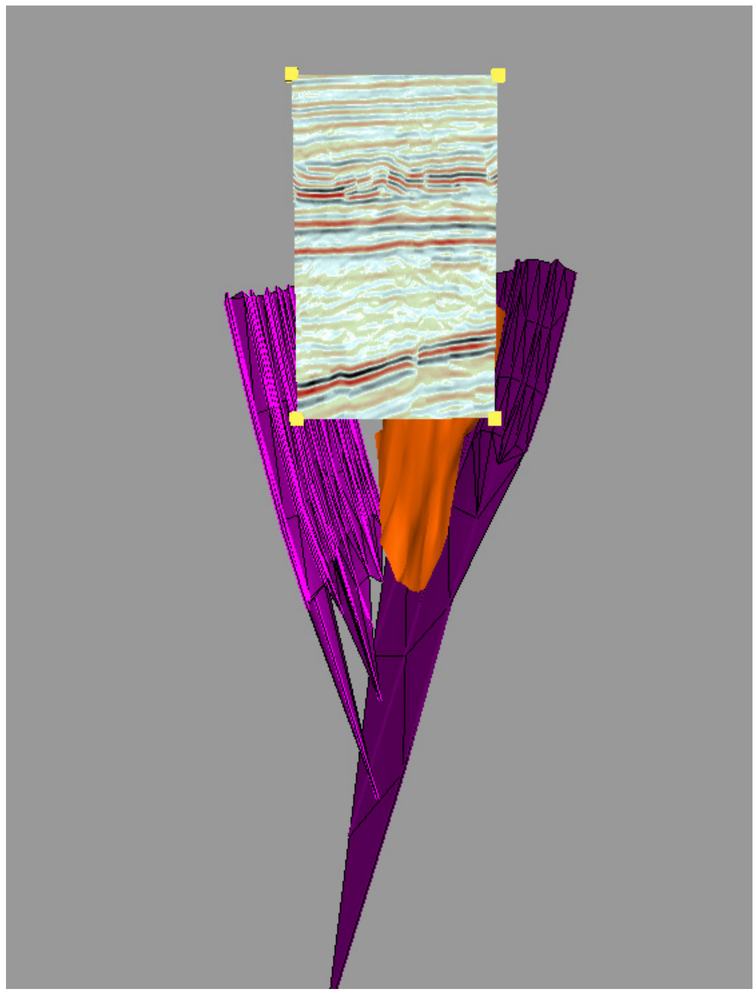
5. In the *Inventory* task pane, **MB1** on the **shared memory full_offset.cmp_StrcFltr10x10** volume and drag it in to *Cube* view.

6. In the *Probe Type Selection* dialog, select **Box** and click **OK**.

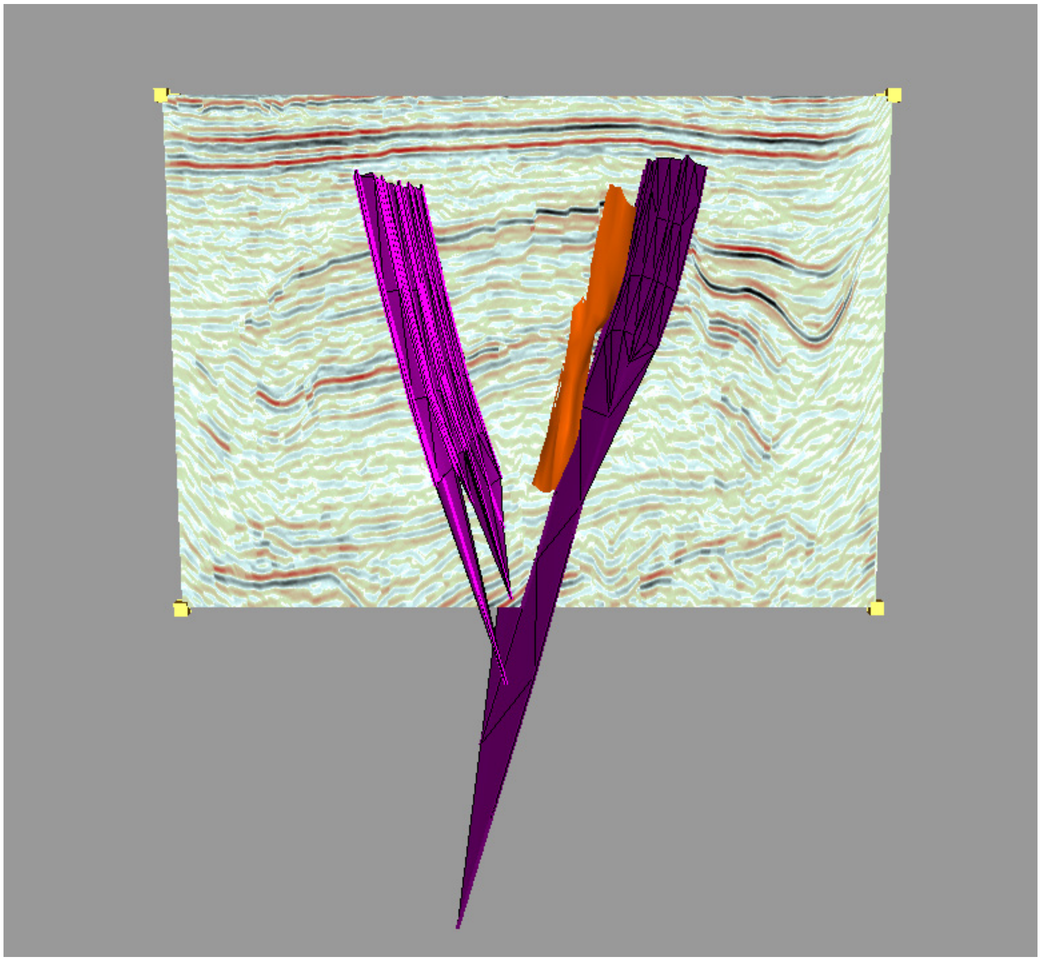


Note

The option for a Box Probe is only available if your volume is in Shared Memory.



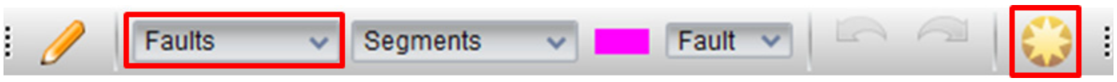
7. Move the faces of the probe in *Cube* view to display only an area containing the reservoir, and the majority of the fault extents. **MB1+<Shift>** on any of the faces of the probe to move through the volume.



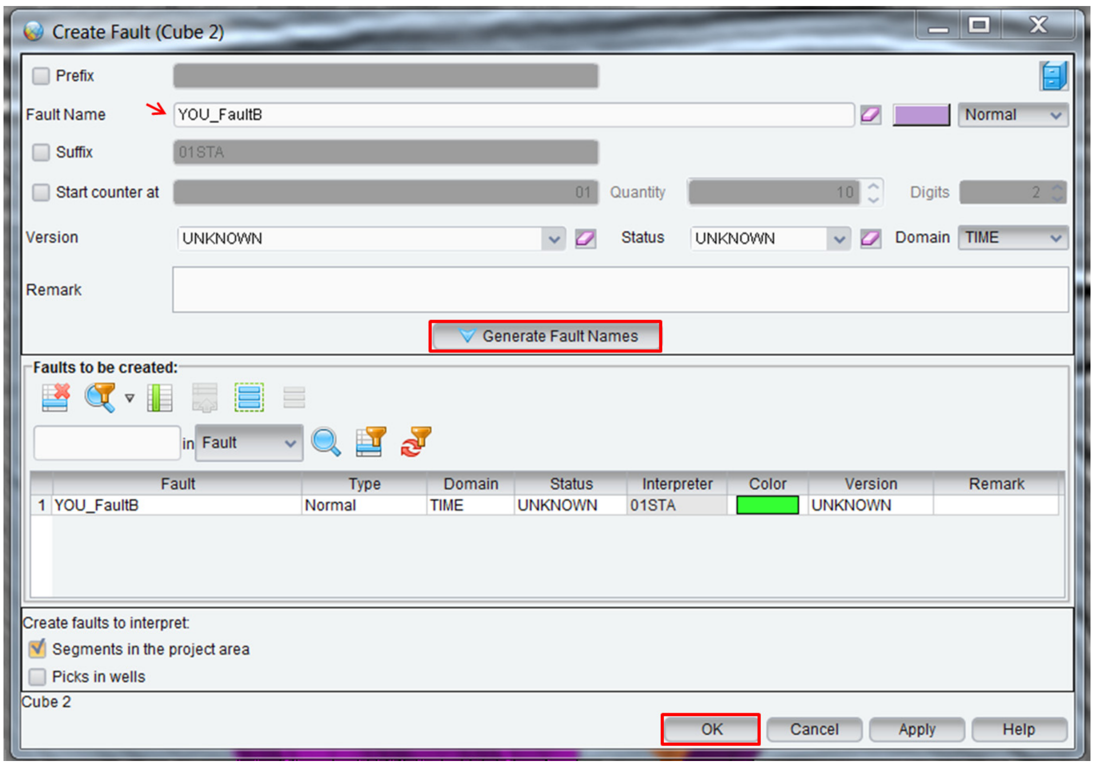
> **Note**
>
> For the remainder of the exercise the volume will be in grey scale. You can change the color of your volume by clicking **MB3** on the volume and selecting **Display Properties**.

Now that you have displayed a volume in your *Cube* view you will create a new fault, and use the volume to make an interpretation of that newly created fault.

8. In the *Interpretation* tool bar, set the *Interpretation Data Type* to **Faults**, and then click the **Launch Create Faults dialog** ( ) icon.



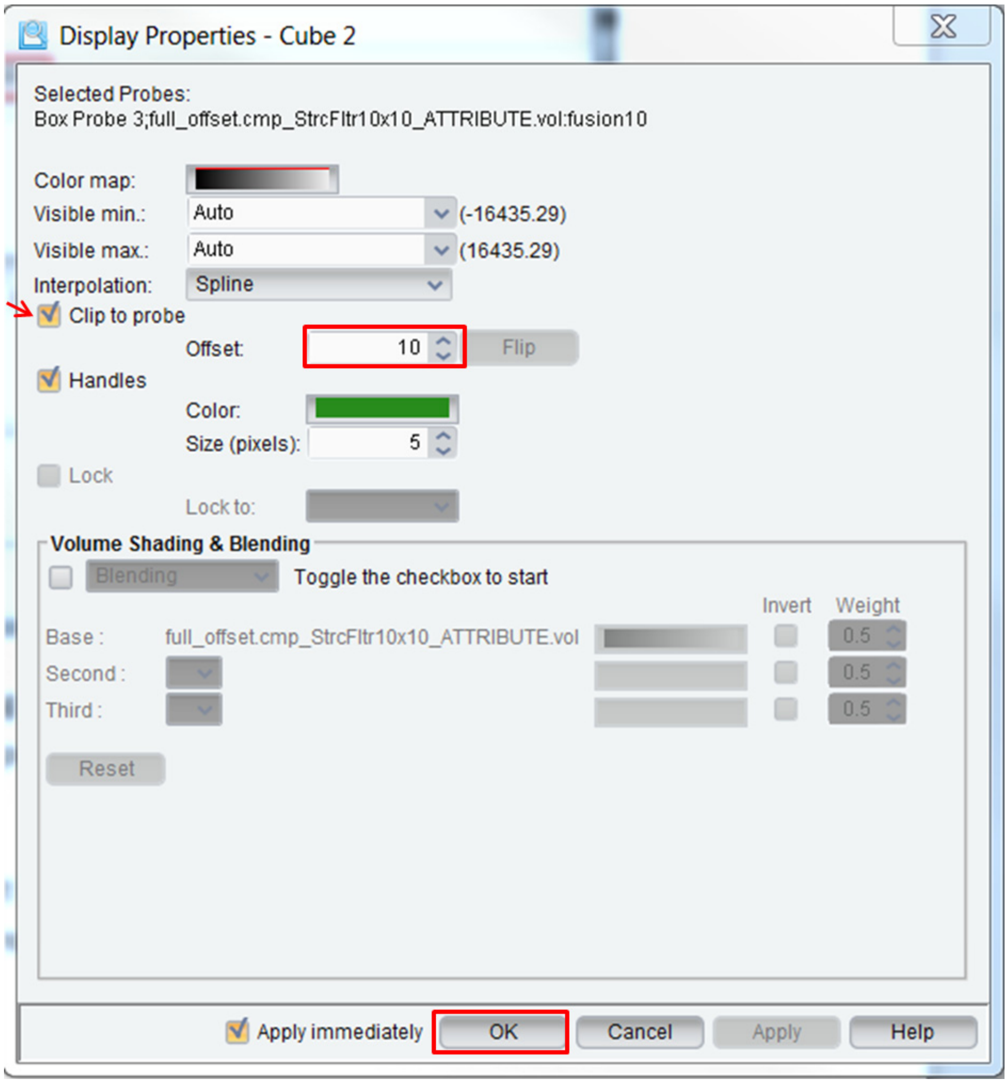
9. In the *Create Fault* dialog, name the new fault "**YOU_FaultB**," and click the **Generate Fault Names** button. Once the fault is created click **OK**.



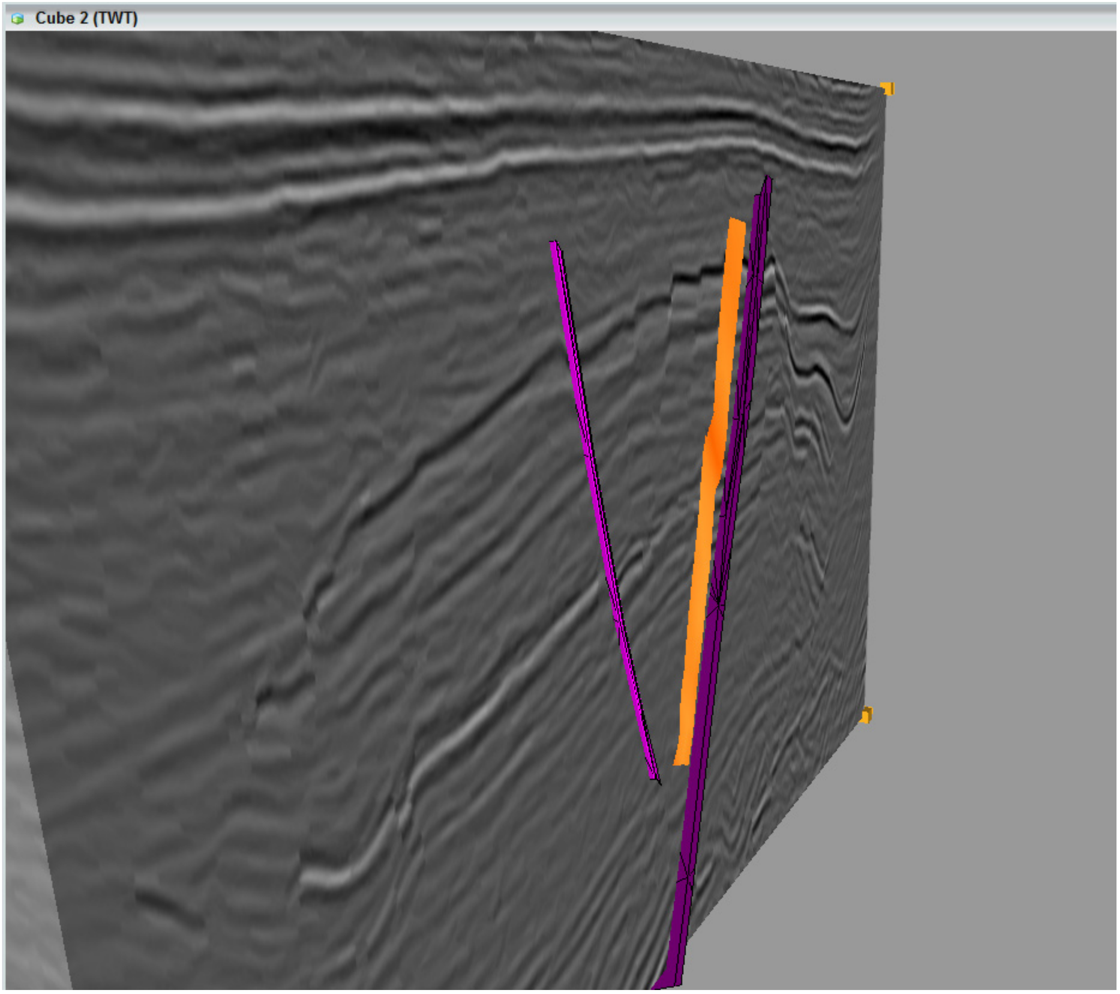
While trying to make interpretation in *Cube* view, being able to see the entire extent of all of your objects can become overwhelming. In *Display Properties*, you have the option to clip your objects to control the extent of the object displayed beyond the probe face.

10. In *Cube* view, **MB3** on the box probe and select **Display Properties**.

11. In the *Display Properties* dialog, select the **Clip to probe** check box, and make the offset “**10**.” Click **OK**.



Notice that now all of the faults are only showing past the volume a specific distance and this stays the same as you move throughout the volume.

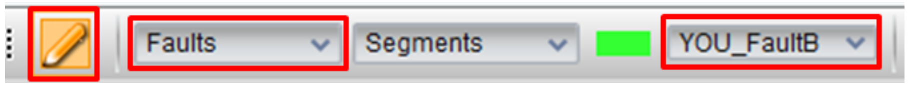


Note

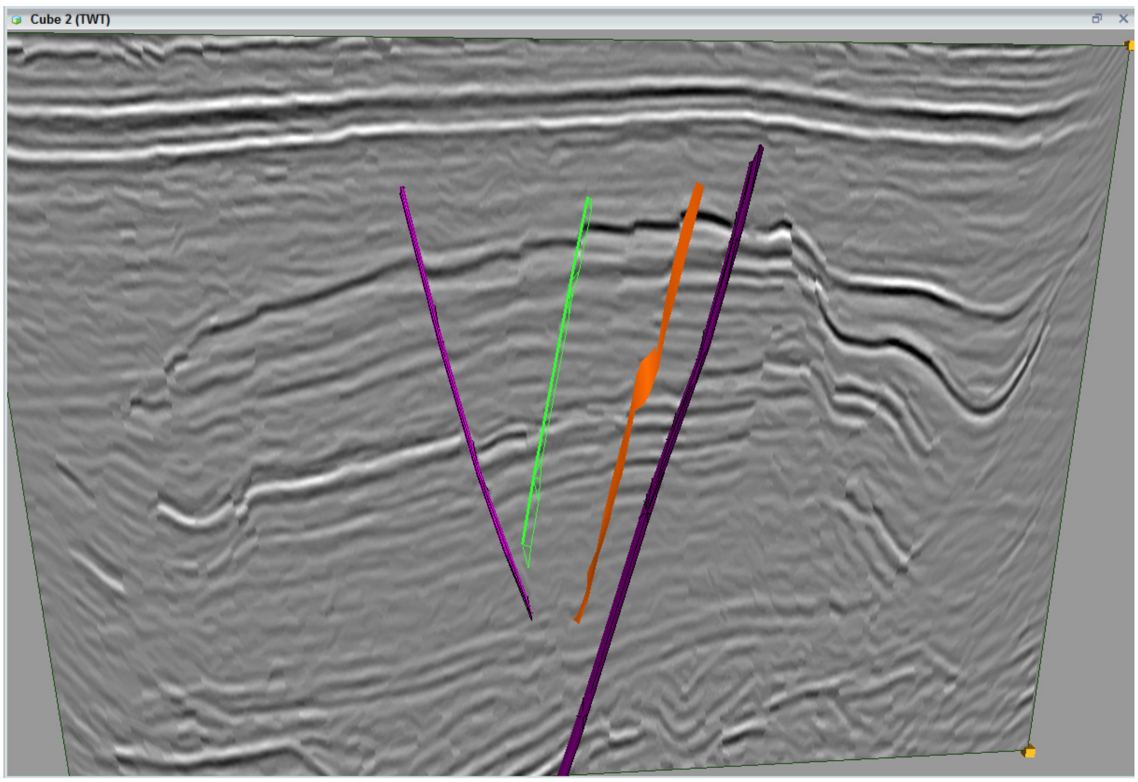
To increase and decrease the offset of the objects you can press the <+> or <-> buttons on your keyboard.

In the following steps you will begin to interpret your new YOU_FaultB fault in *Cube* view.

12. In the *Interpretation* tool bar, make sure **Faults** is selected as the *Interpretation Data Type*, and select **YOU_FaultB** as the Fault for interpretation. Activate **Interpretation Mode**.



13. In your *Cube* view, begin your interpretation, like in *Map* and *Section* view, by clicking **MB1** to start your fault segment, and **MB2** to end it. Continue interpreting by holding down **MB1+<Shift>** and dragging the probe face towards you.

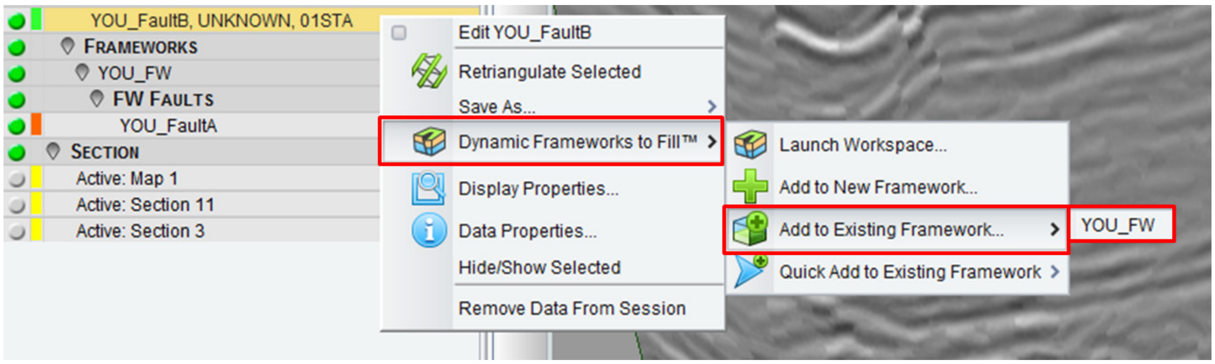


Note

The picture above shows a segment of YOU_FaultB displaying triangulation. The segment is connected to another interpreted segment that has been clipped, prohibiting the view of that adjacent segment.

Now that you have made several interpretations, you will add that fault into your existing Framework. This will allow you to see the development of the framework fault plane that you will be using in your structural model.

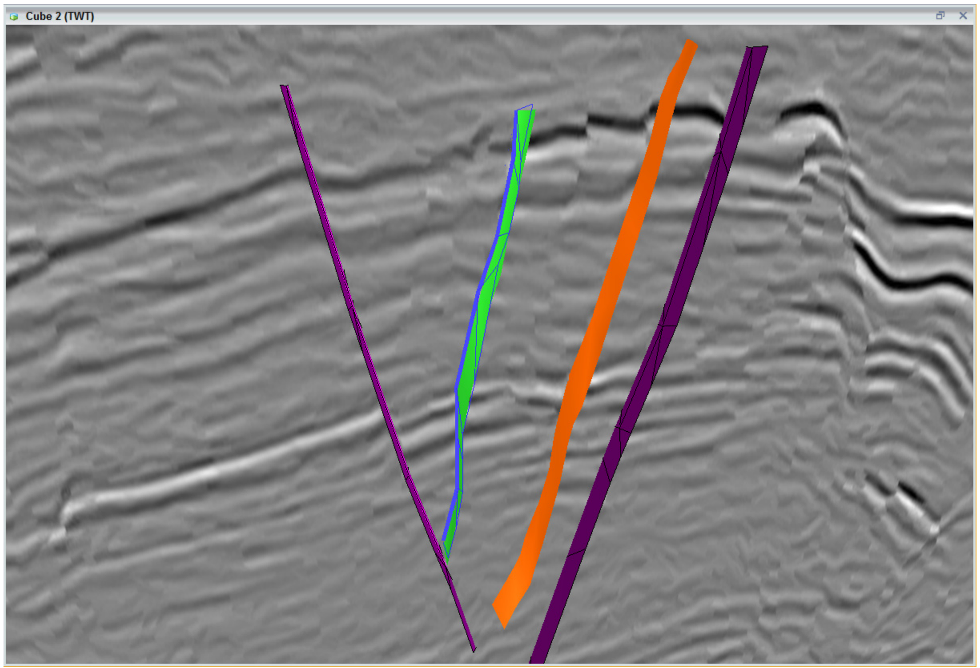
14. In the *Inventory* task pane, **MB3** on **YOU_FaultB** and select **Dynamic Frameworks to Fill > Add to Existing Framework > YOU_FW**.



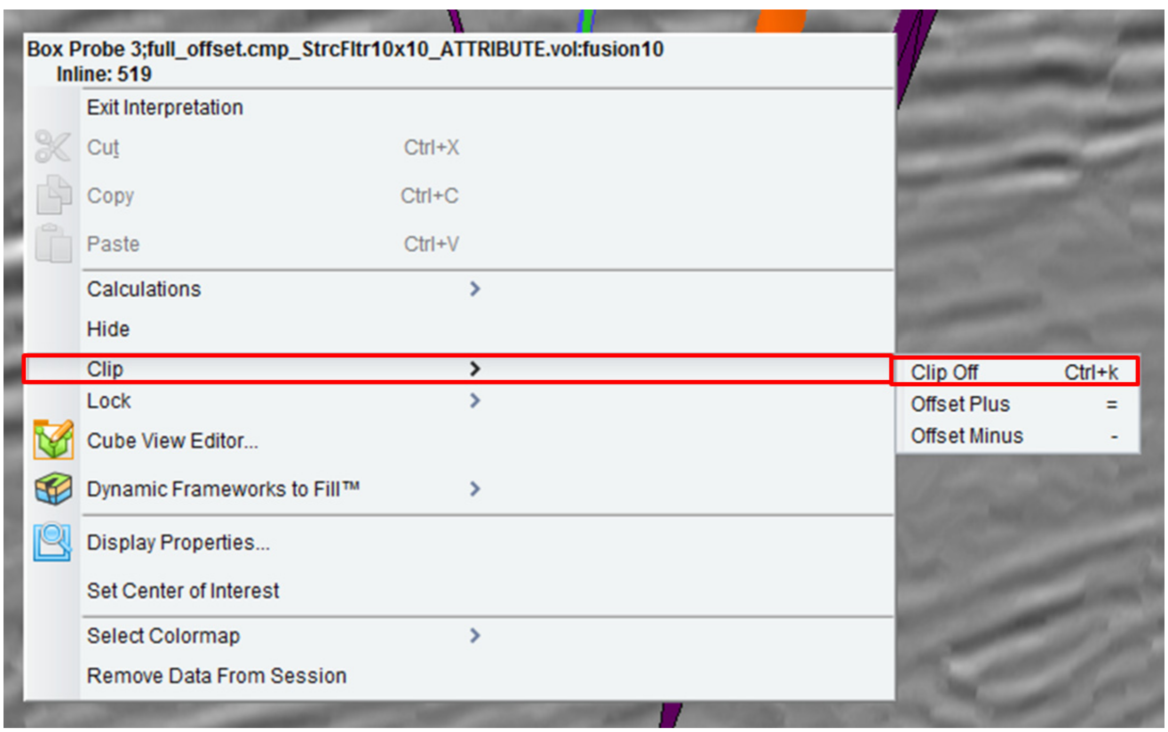
15. Accept the defaults in the *Add sources to Framework* dialog, and click **OK**.

16. To see the difference between the seismic fault and the framework fault, change the color of the seismic fault. Click **MB3** on **YOU_FaultB** in the *Inventory* task pane and select **Display Properties**, and change the color in the resulting dialog.

17. Push the probe face away from you and continue to make your interpretation of the **YOU_FaultB**.

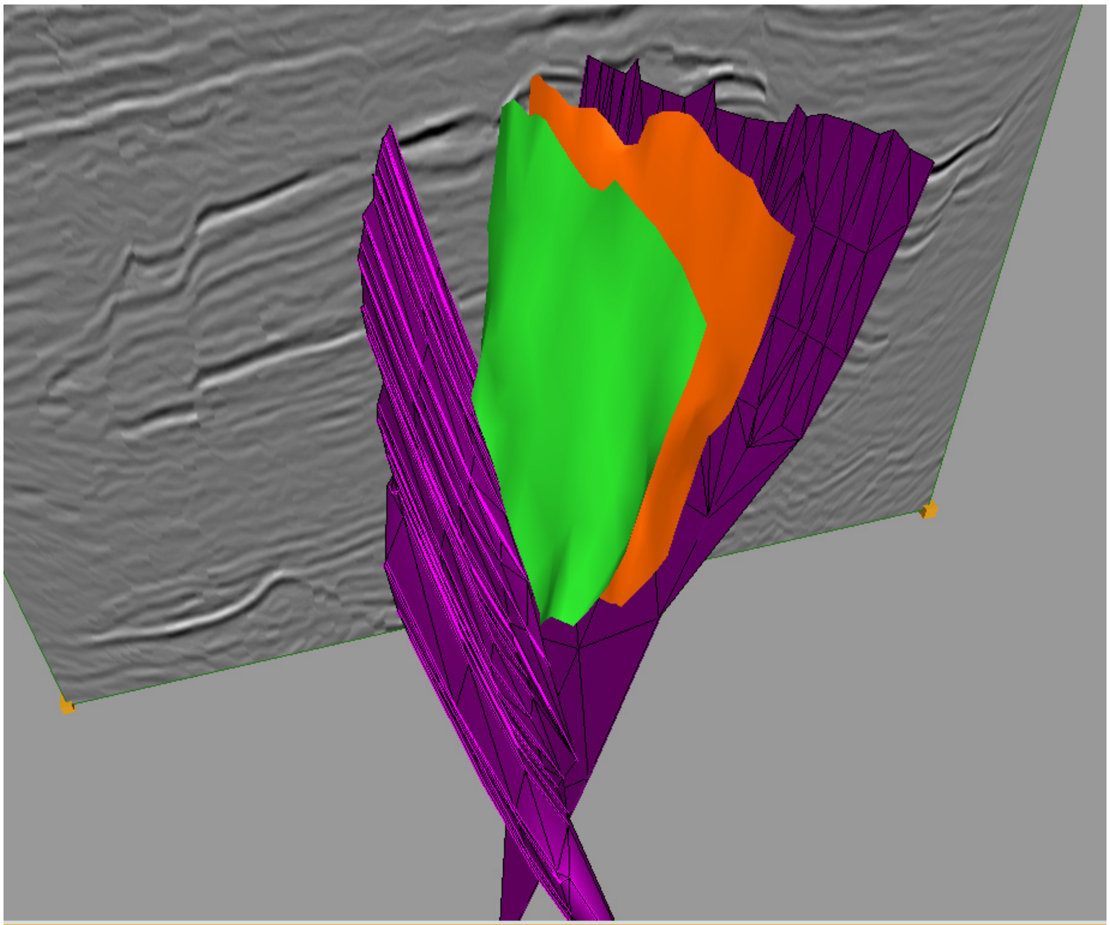


18. When you are satisfied with your interpretation **MB3** on the probe and select **Clip > Clip Off**.



19. Turn off **Interpretation Mode**, and toggle off the **YOU_FaultB** seismic fault.

You can see the entire framework fault plane as you have interpreted it. Your view should look similar to the one below.



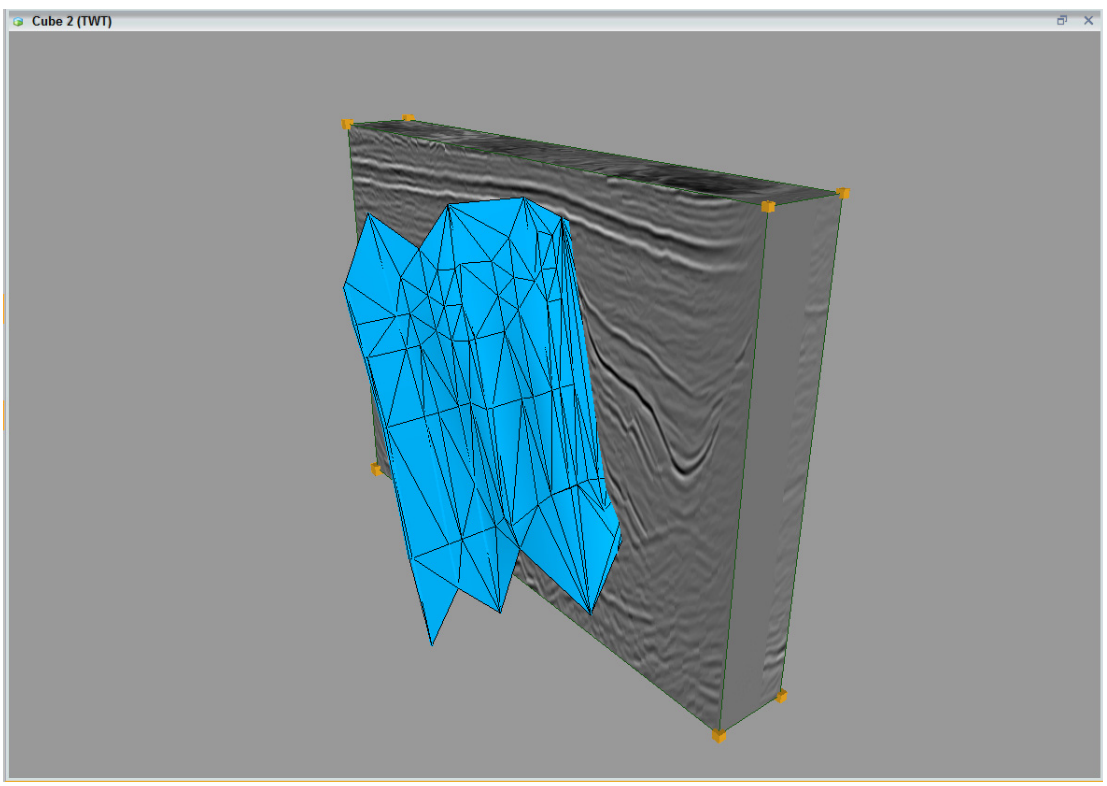
Exercise 3.5: Advanced Display Options

Once your are done with the general interpretation of your faults it is likely that some fine tuning of those faults will be needed. There are several display options available to you in *Cube* view to aid in determining if there needs to be any adjustments made to your interpretation.

In *Display Properties* you can overlay your seismic volumes onto your faults in order to see what the volume looks like along your fault. For example, you can display your discontinuity volume along your fault to make sure that it generally corresponds to those identified discontinuities. This allows you to see where there may be some inconsistencies, and potentially point out areas where interpretation may need to be changed. In the following steps, you will learn how to overlay your Discontinuity Volume along a fault.

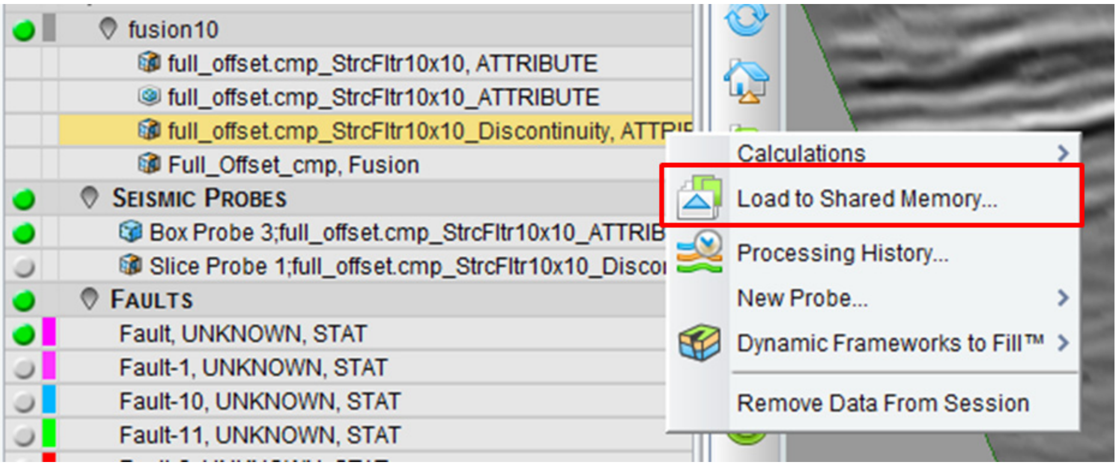
1. Activate and maximize your *Cube* view.

2. In the *Inventory* task pane, only display **Fault-10** and the **full_offset.cmp_StrcFltr10x10 Box Probe**.

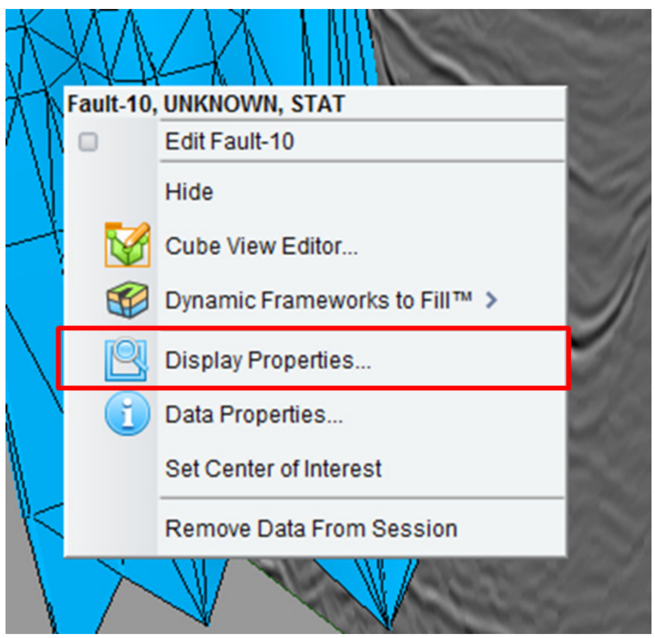


To display a seismic volume as an overlay, it has to be in shared memory.

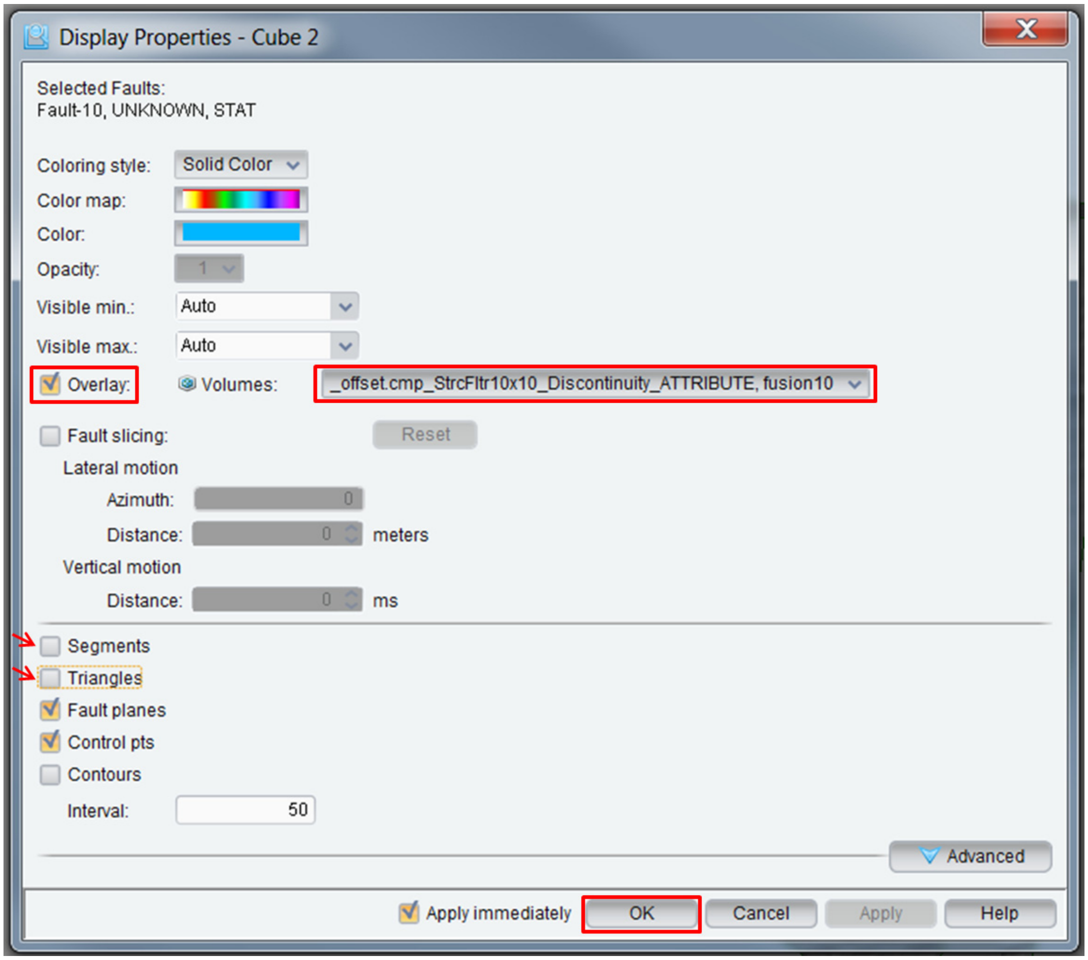
3. In the *Inventory* task pane, **MB3** on the **full_offset.cmp_StrcFltr10x10_Discontinuity** Attribute and select **Load to Shared Memory...**.



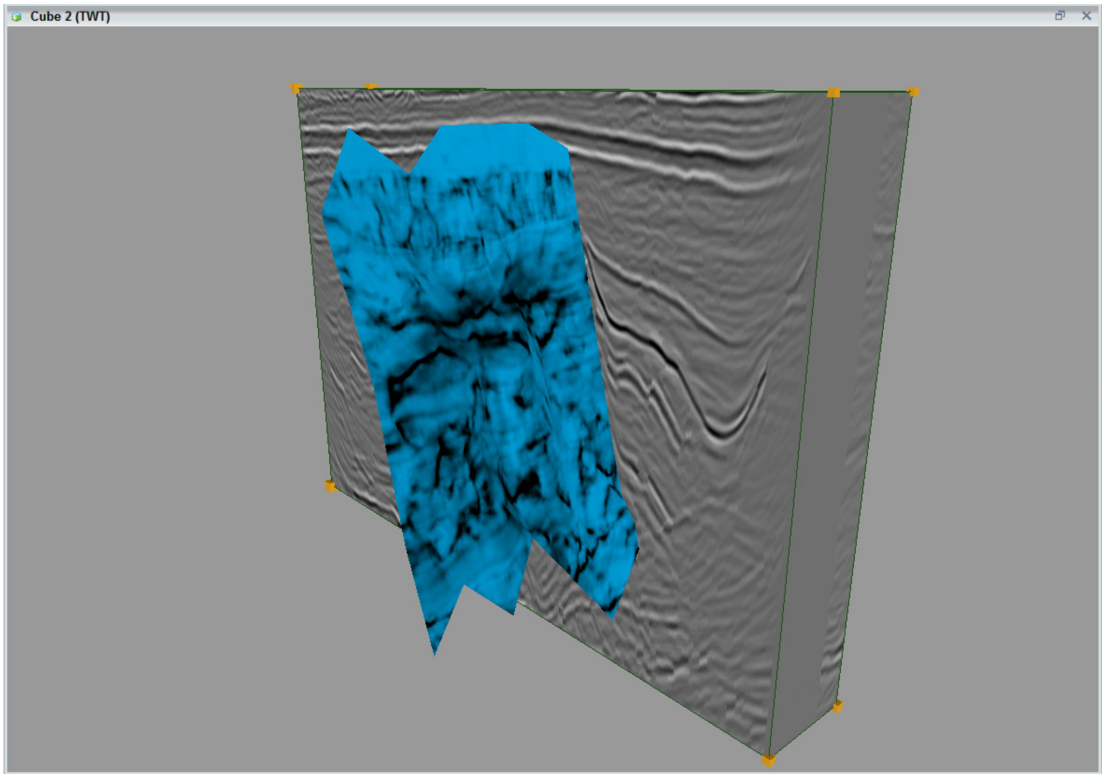
4. In *Cube* view, **MB3** on **Fault-10** and select **Display Properties...**.



5. In the *Display Properties* dialog, select the **Overlay** box, and from the drop-down menu select **full_offset.cmp_StrcFltr10x10_Discontinuity**. Also deselect the boxes for both **Segments** and **Triangles**, so you can clearly see the overlay on your fault.

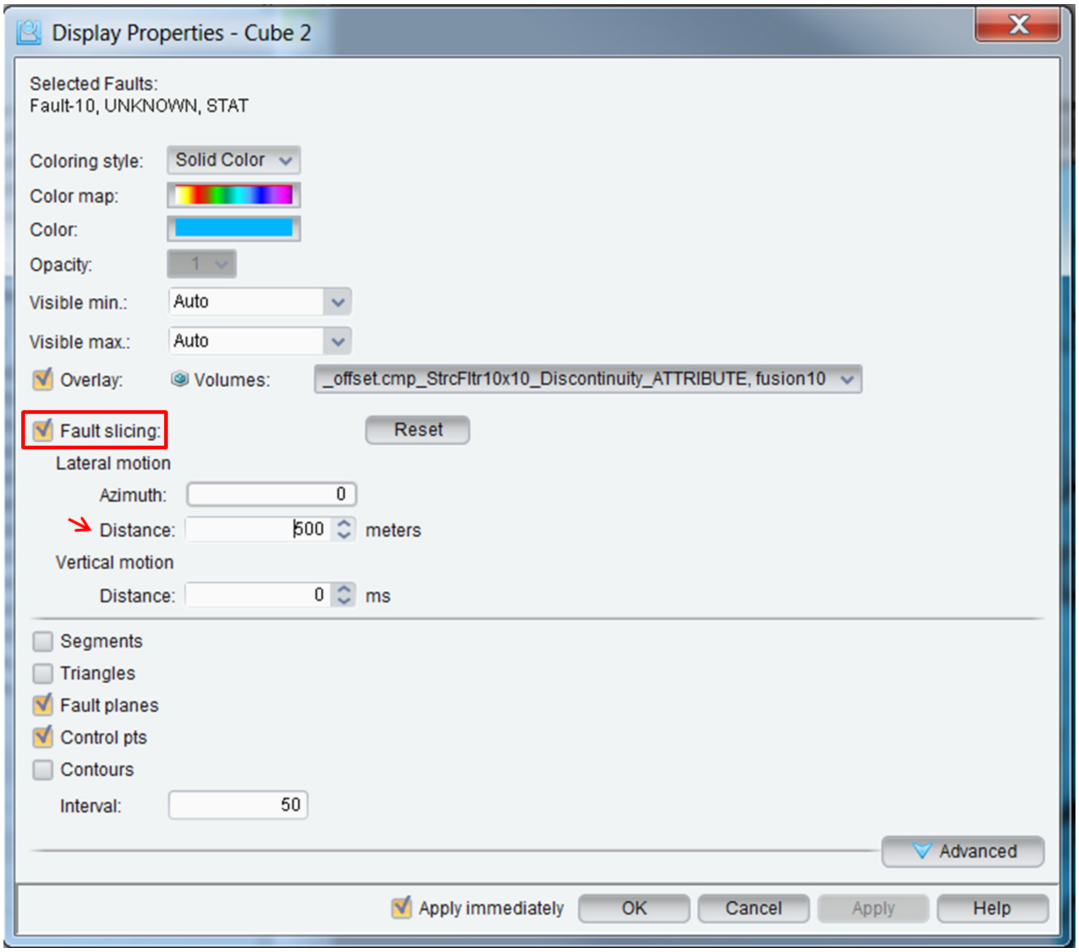


Notice that the discontinuity volume shows that the majority of the faults correspond to the disconnections within the seismic, but notice at the top of the fault there seems to be an area that consistently shows a blue color. This blue color signifies that the fault is not going through any discontinuities. Situations like this are signs that you need to look closer at your original interpretation.

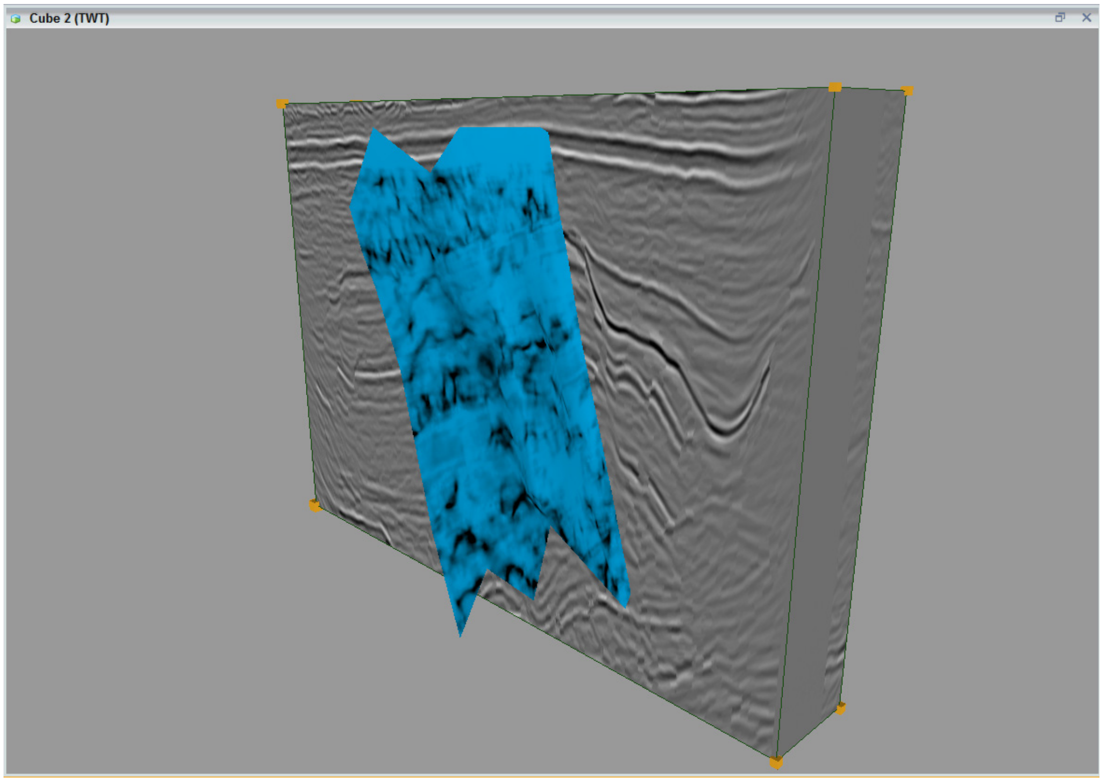


In *Display Properties* there is an option to manipulate the fault without changing the interpretation. This is useful in a situation where you think moving the entire fault may improve the overall interpretation. For example, when the discontinuity overlay is showing a consistent mismatch you can shift your fault to see if there may be a better fit.

6. Open the *Display Properties* dialog for Fault-10 again if you have closed it. Select the **Fault slicing** check box, and change the *Lateral motion Distance* to “**500**.”



Your view should look similar to the one below.



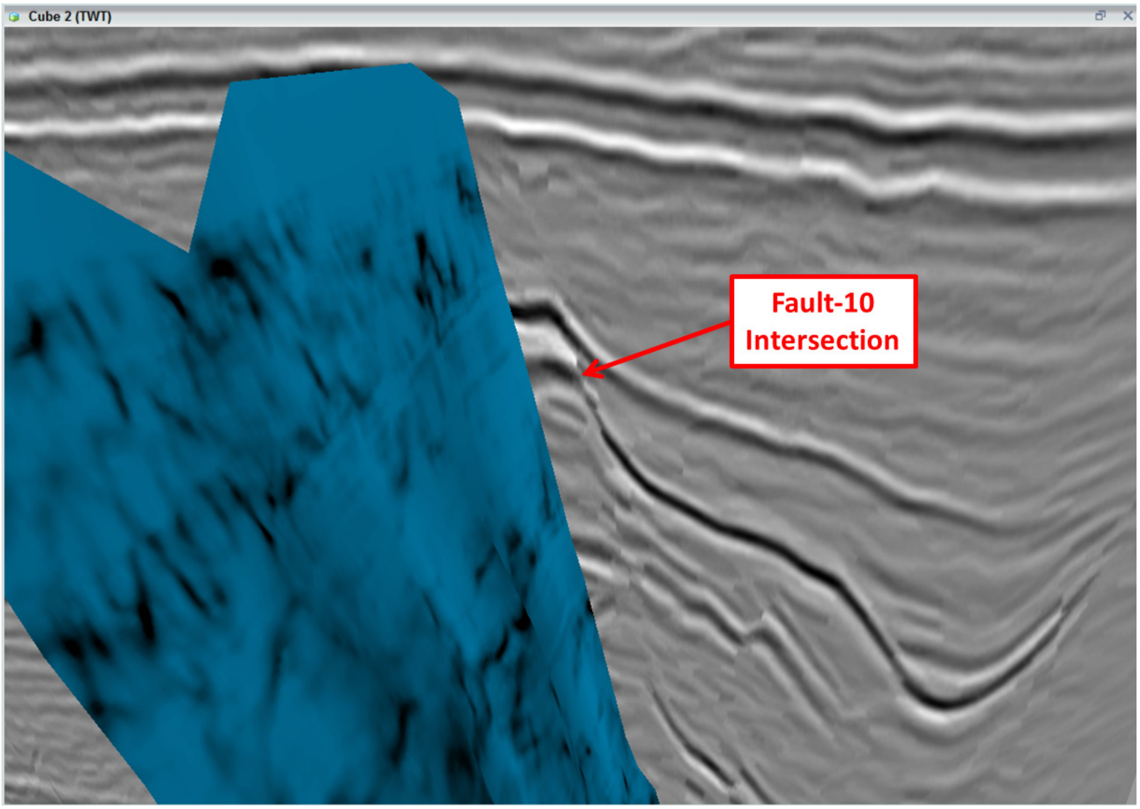
The entire fault has been shifted to the left 500 XLs. Notice how there is not only a significant drop in the amount of black shown in the overlay, but there is no improvement in the top portion of the fault. This means that the movement made by the fault slicing did not create a better fit with the discontinuity volume.

7. Experiment with the other fields of fault slicing, and when you are done click the **Reset** button, to restore the fault to its original position.

> **Note**
>
> Applying Fault Slicing will not change any of the original data, it only changes the display of the fault.

8. Zoom in to where the upper portion of the fault intersects the volume and inspect the interpretation of the fault to the seismic.

The picture below shows another advantage of fault slicing. Not only does it allow you to see the results of a bulk shift of your fault, but it allows you to see the actual intersection of the fault with the seismic without having to turn off the fault.



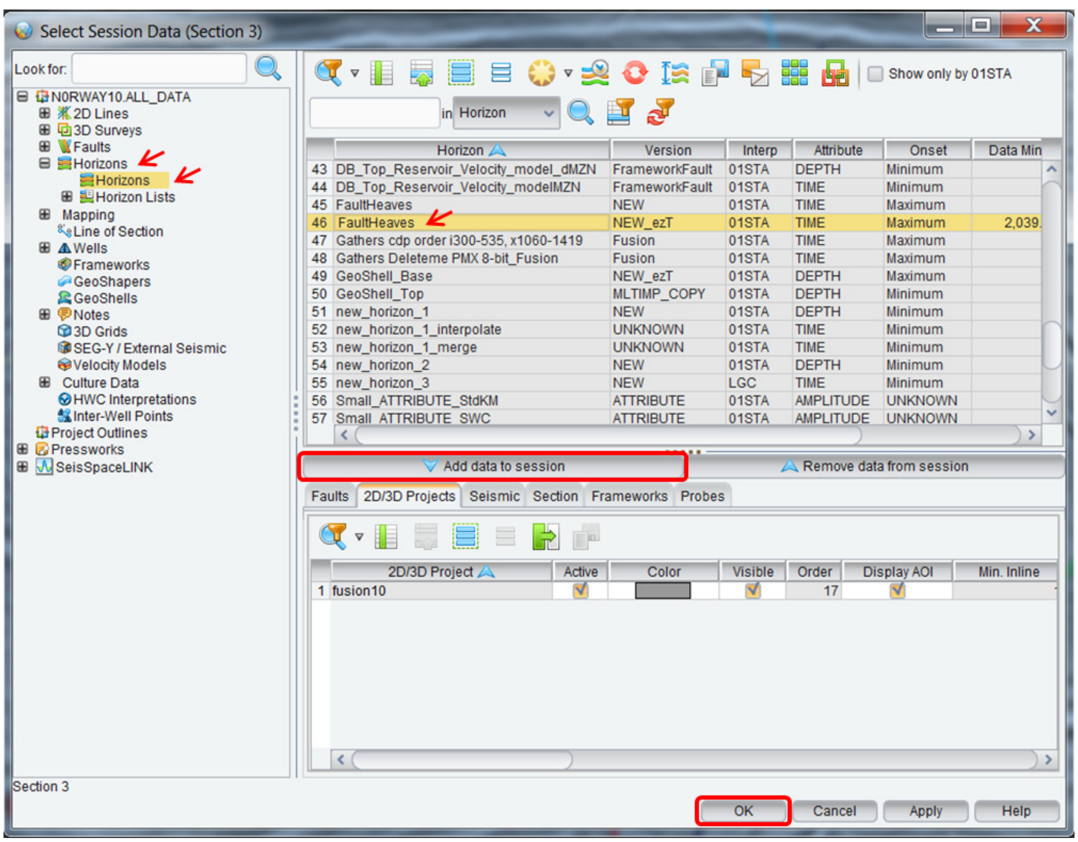
Looking at the portion of the seismic that corresponds with solid blue part of the fault you can tell that according to the seismic the fault plane does not extend up that far. To fix this, the original interpretation will have to be modified.

Exercise 3.6: Fault Prediction (Optional)

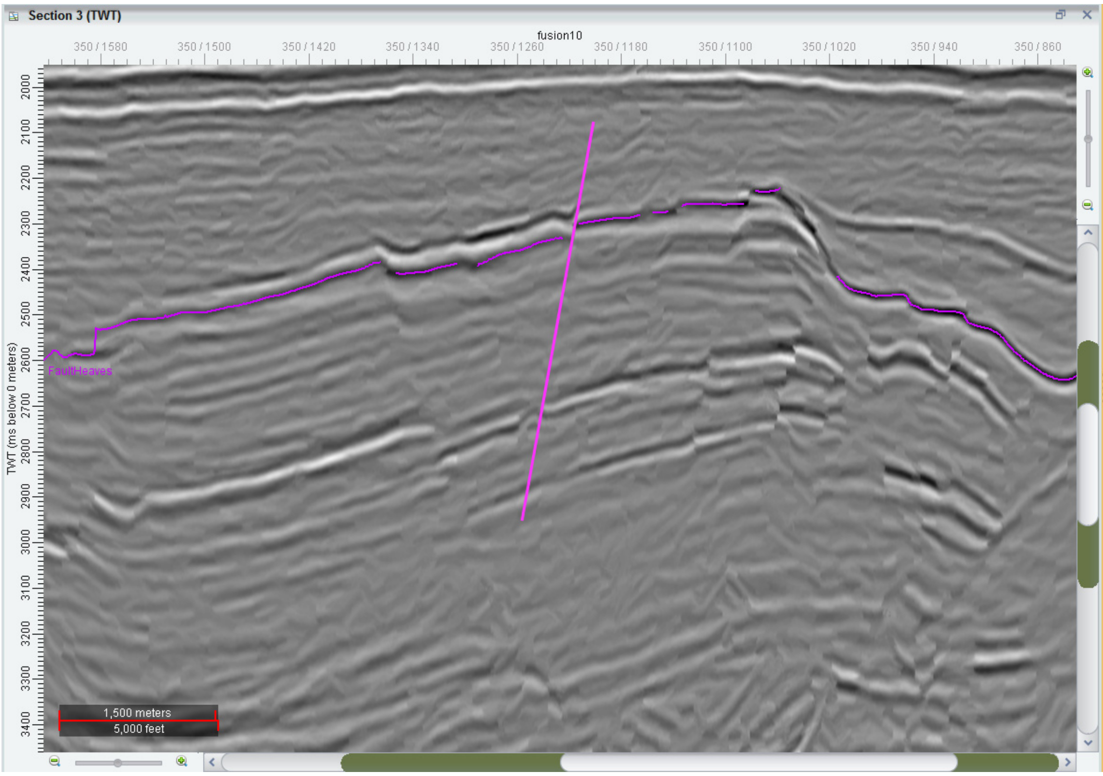
The Fault Prediction interpretation mode restores adjacent rocks to a pre-faulted regime in areas with poor data constraint, typically in deeper areas that are insufficiently resolved. The prediction is based primarily on the geometry of the hanging wall fold, and produces a fault geometry that will best restore the horizons to a pre-faulted configuration.

In the following steps, you will use Fault Prediction as a QC of your already interpreted faults. In order for the Fault Prediction to work, there needs to be breaks within your horizon interpretation where a fault is thought to be. A horizon has already been made in your project with the correct breaks necessary to perform fault prediction, so you will need to bring this in to the session.

1. Activate *Section* view and in the main tool bar click the **Select Session Data** ( ) icon. In the *Select Session Data* dialog, in the left panel, select **Horizons > Horizons**, and in the top panel select the horizon **FaultHeaves, NEW_ezT**. Click **Add data to session**, and then click **OK** to close the dialog.

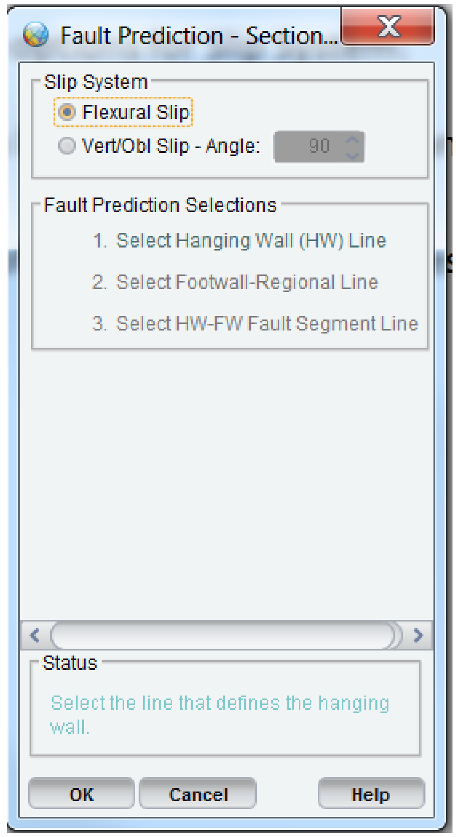


2. With *Section* view still active toggle off all of your faults, both seismic and framework, except for the **Fault 1** seismic fault. This should leave only the FaultHeaves horizon and the Fault-1 fault displayed.



3. In the *Interpretation* tool bar turn on **Interpretation Mode** ( ) and from the **Actions** drop-down select **Fault Prediction**. **Fault-1** should be the object for interpretation, because it is the only fault turned on.

The *Fault Prediction* dialog automatically opens.

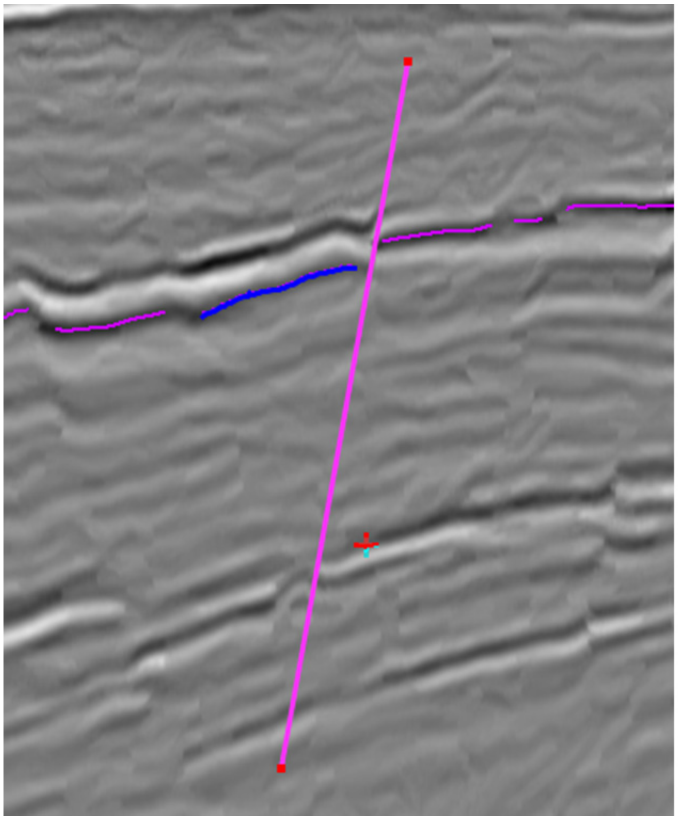


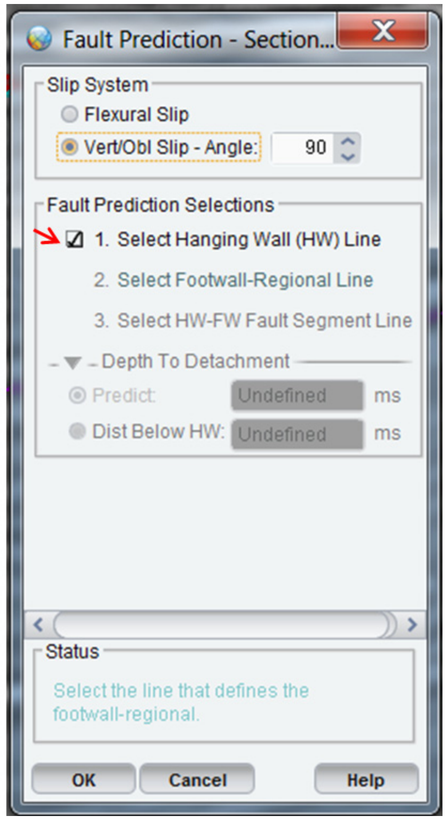
There are two options for Slip System:

- Flexural Slip—used for compressional settings and when layer dips are greater than 30 degrees
- Vert/Obl Slip—used for extensional settings or analysis of compressional structures where bedding dips are less than 30 degrees

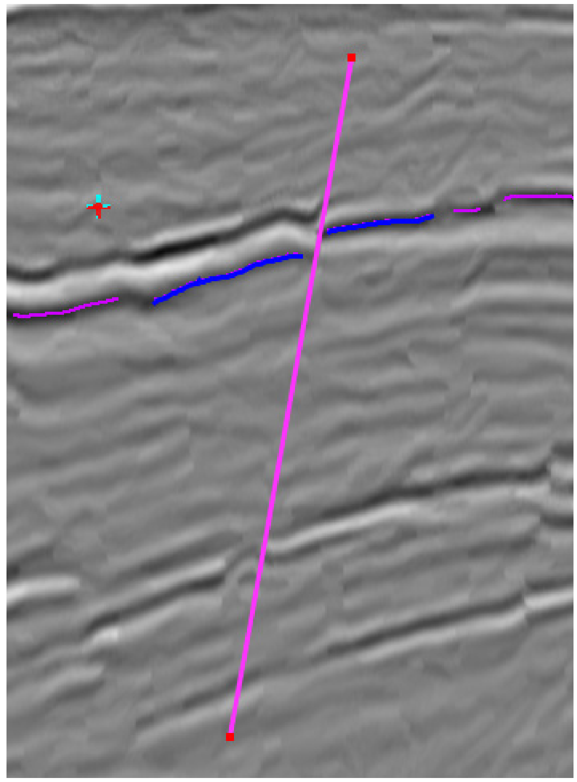
4. Fault-1 has been created in an extensional environment, select the **Vert/Obl Slip** option.

5. Hover over the segment of the FaultHeave horizon within the hanging wall of Fault-1, and the color changes to red. **MB1** to select this segment, which changes the color to blue, and satisfies the first criteria in the *Fault Prediction* dialog.



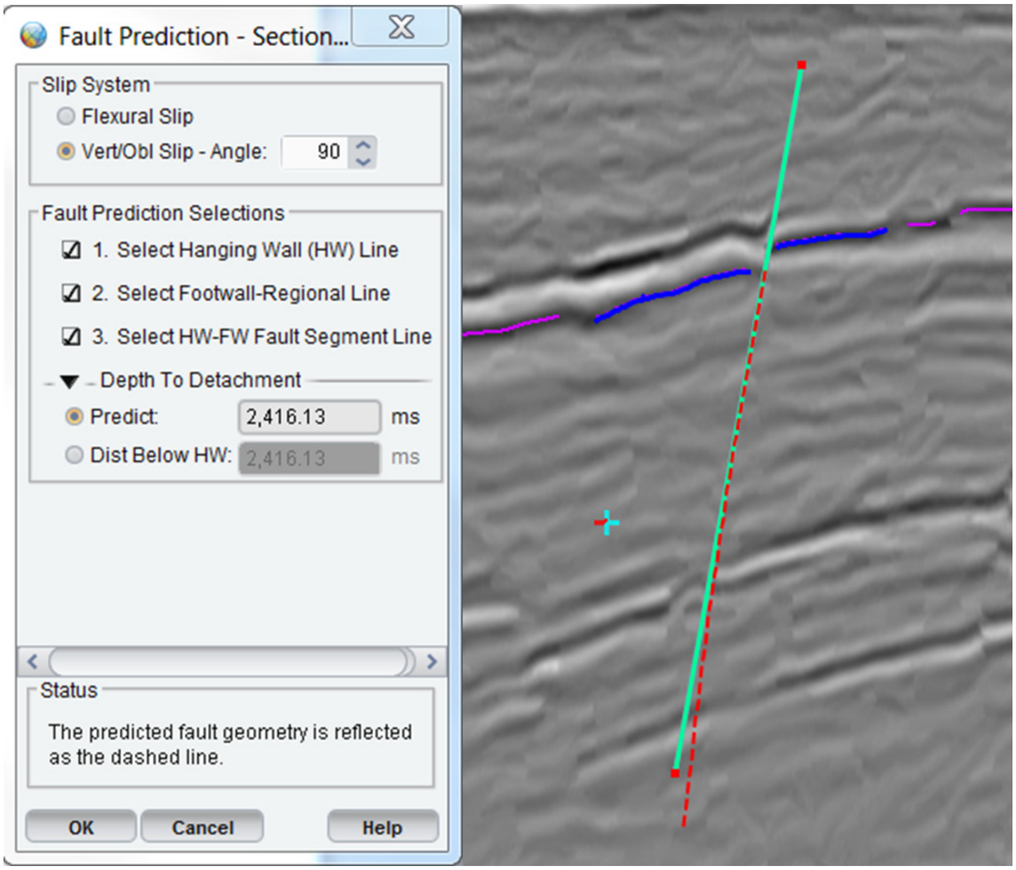


6. Select the segment of the FaultHeave within the footwall of Fault-1to satisfy the second criteria in the *Fault Prediction* dialog.



7. Finally, select the **Fault-1** segment to fulfill the last criteria for fault prediction.

A dashed line appears in *Section* view showing where the fault should be to restore the horizon to horizontal with the currently set parameters.



> **Note**
>
> If you know what depth you have detachment, you can change this in the Depth to Detachment portion of the *Fault Prediction* dialog. This should only be used for normal faults.

8. Click **OK** to change your fault to correspond with the fault prediction. A warning dialog opens asking if you really want to change your fault interpretation. For this exercise click **No**.

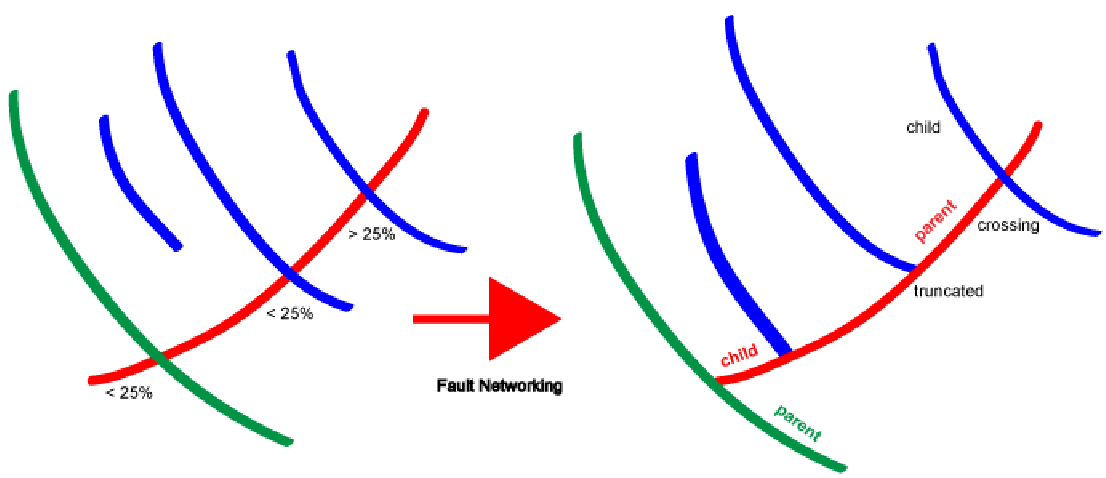
Now that you have finished fault interpretation you will learn how to network those faults in Dynamic Frameworks to Fill.

Fault Networking

Fault Networking identifies a fault hierarchy and determines crosscutting and truncating relationships between the faults in the area. This is an important part in creating a completely sealed structural model. The relationships can be generated both manually and automatically. These relationships can then be edited in the Dynamic Frameworks to Fill Workspace, to ensure that they correspond as closely as possible to the subsurface geology of the area.

Automatically generated fault networking determines the relationships based on total area of the fault planes in consideration. At each fault intersection, the fault with the larger area is classified as the parent fault and the fault with the smaller area is considered the child fault. The parent fault automatically truncates the child, unless more than 25% of the child fault would be lost upon truncation. In this case, the relationship is considered a crossing relationship.

Different parent-child relationships are illustrated in the picture below.

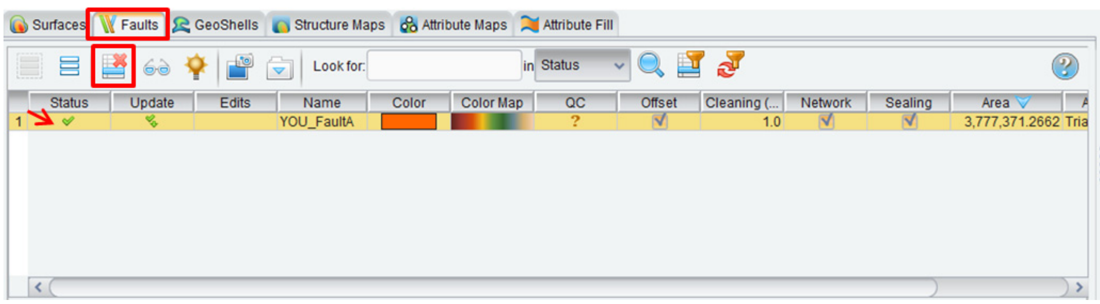


Exercise 3.7: Creating a Fault Network

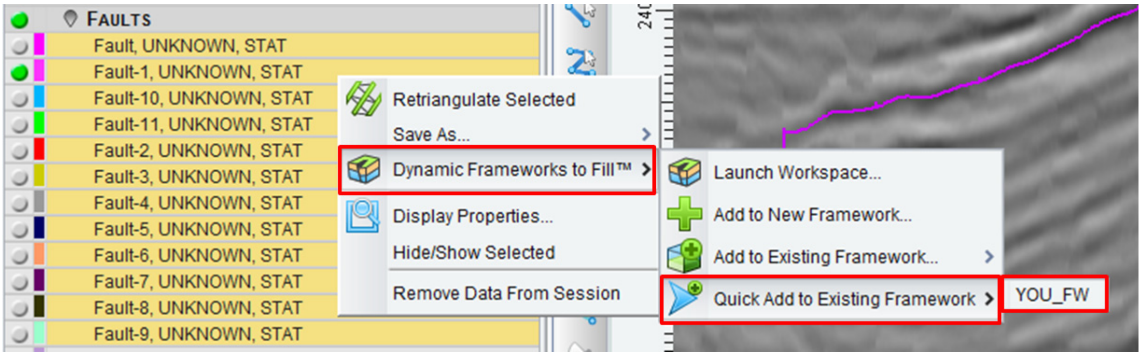
Once all of the faults within your area have been interpreted, there are certain geological relationships that need to be established to continue to build your sealed structural model. With Dynamic Frameworks to Fill you can establish an extensive fault network between all the faults you have placed into your framework. In the following exercise, you will learn how to create a fault network using Dynamic Frameworks to Fill.

Currently the faults (Fault - Fault-11) makeup the majority of the faults within the area, this includes a fully interpreted version of the YOU_FaultA that you were interpreting in previous exercises. So, before adding faults to your framework you need to remove the YOU_FaultA from the framework.

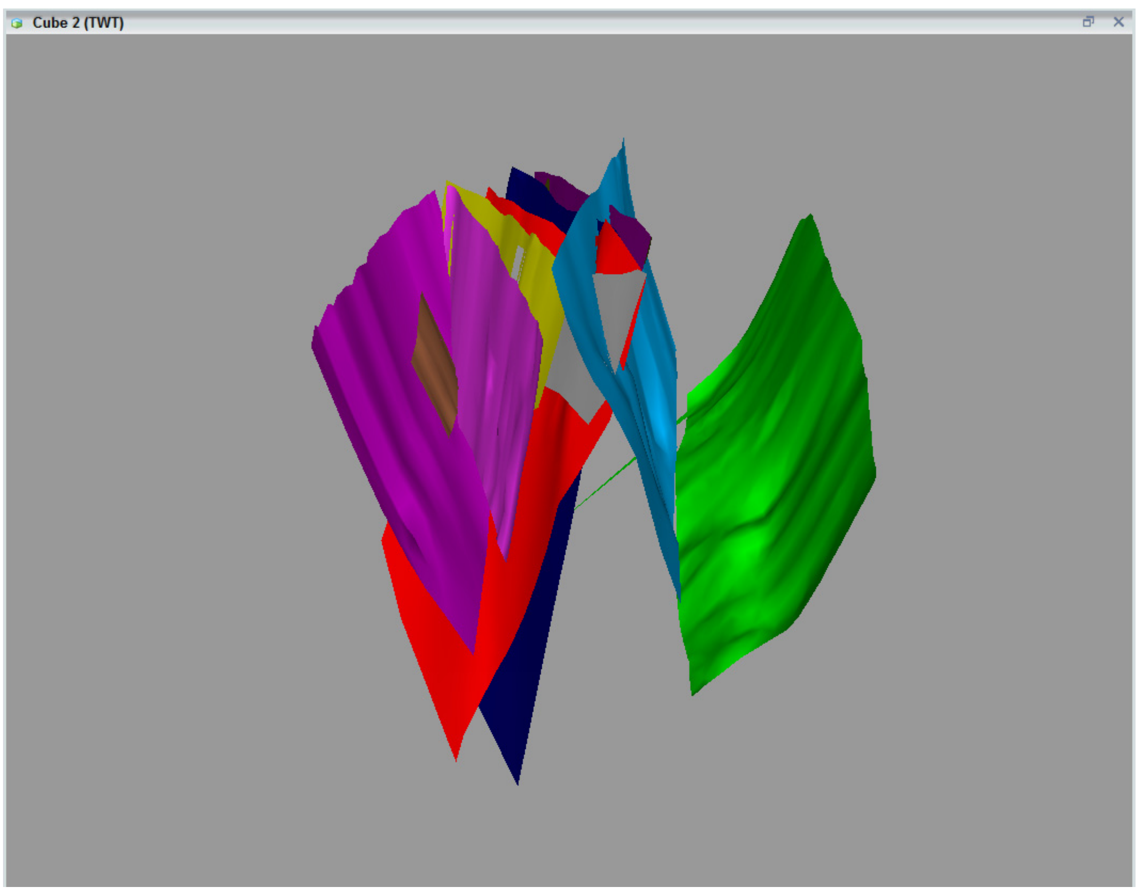
1. In the *Dynamic Frameworks to Fill* task pane, click the **Launch Framework Workspace Window** ( ) icon. In the *Dynamic Frameworks to Fill Workspace*, navigate to the *Faults* objects tab and select **YOU_FaultA**. With YOU_FaultA highlighted click the **Remove the selected model entry/entries** ( ) icon.



2. In the *Inventory* task pane, select **Fault** through **Fault-11**, **MB3** and then select **Dynamic Frameworks to Fill > Quick Add to Existing Framework > YOU_FW**. This adds all of the highlighted faults into the framework as faults, and does not open the *Add Sources to Framework* dialog.

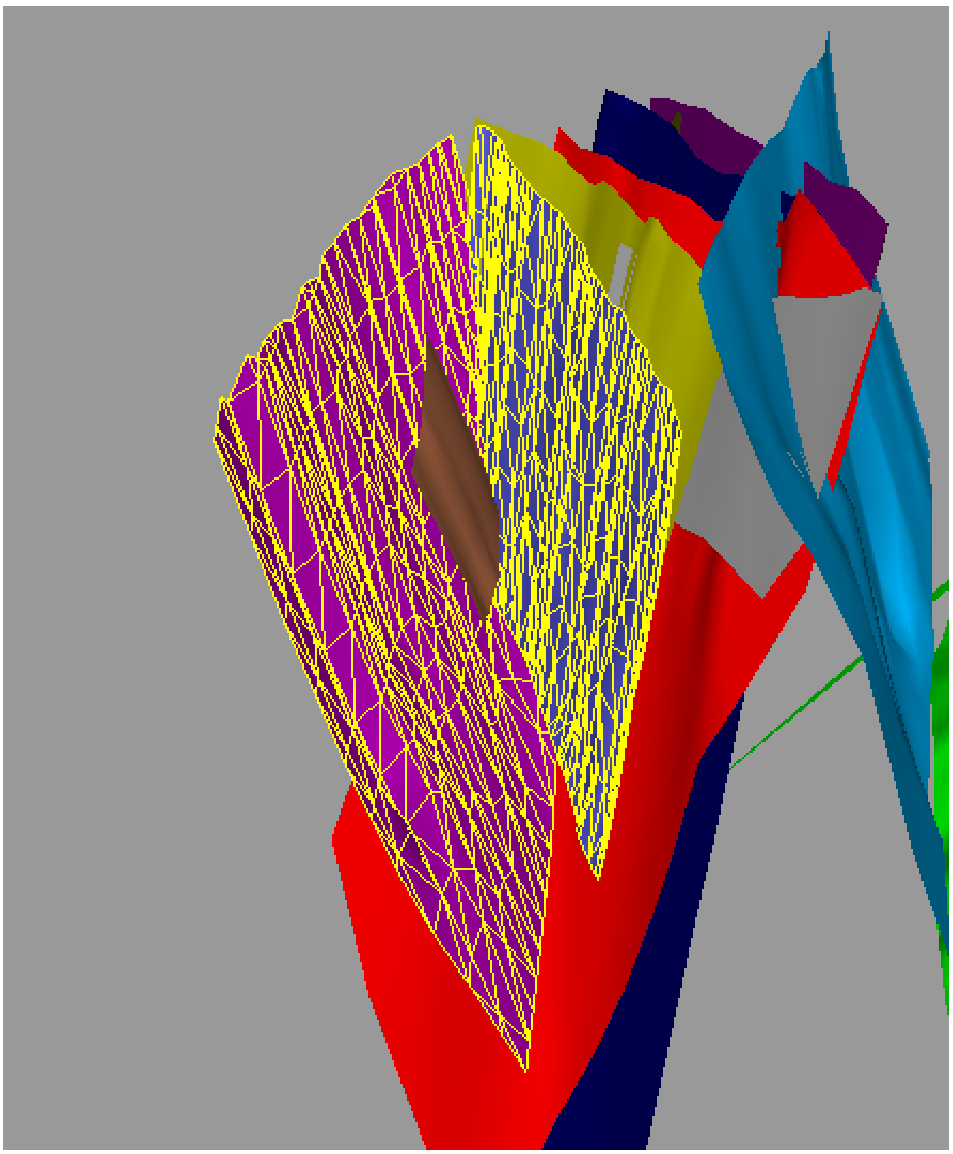


3. Activate and maximize *Cube* view, and display only your newly created **FW FAULTS**.



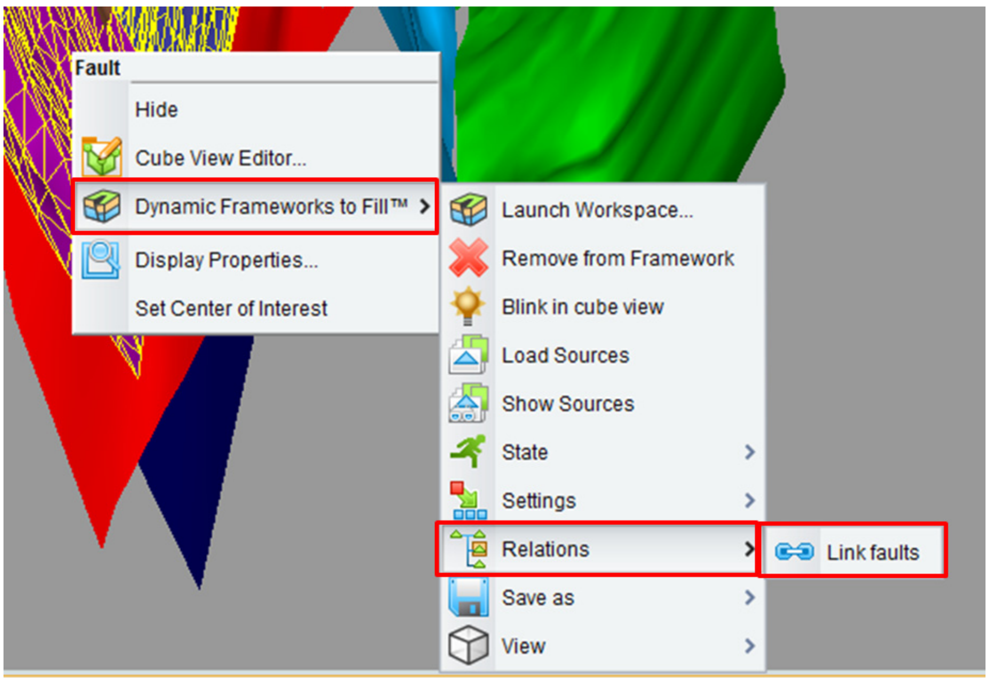
Notice the relationships between the faults currently in your framework, and how they are all crossing through each other. Geologically we know these aren't reasonable relationships. In the following steps, you will learn how to manually set up networking relationships between your faults.

4. Change your arrow to **Select/Drag Mode**, and then **MB1** on **Fault** to select it, and **MB1+<Ctrl>** to select **Fault-1**.

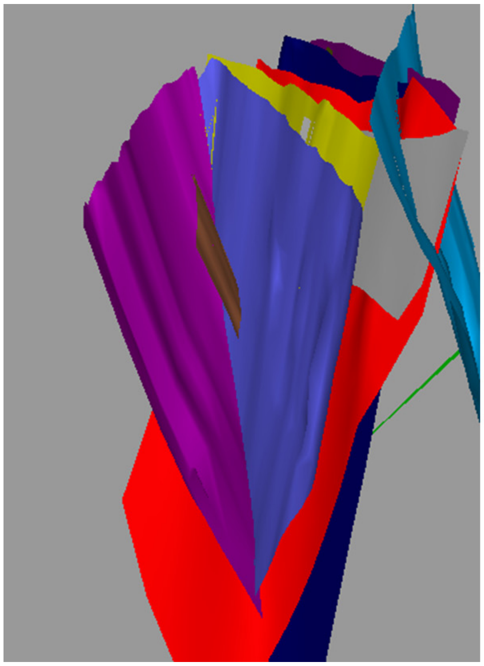


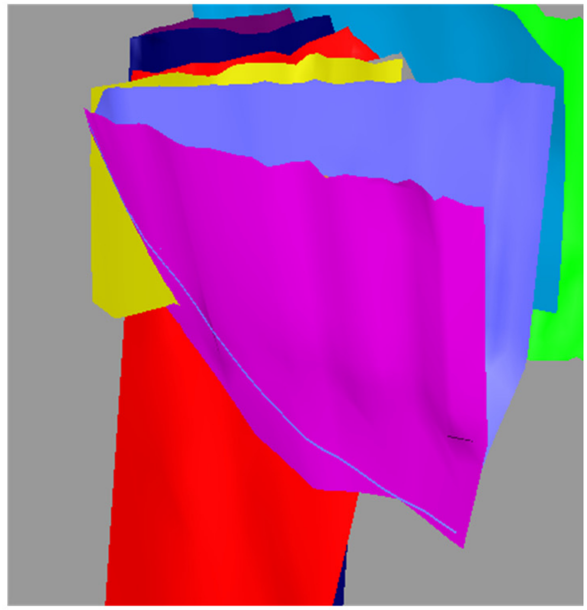
> **Note**
>
> The color of Fault-1 was changed for ease of viewing. The default color for the faults should be the same as the original object. To change the color of the FW FAULT you must change it from the Dynamic Frameworks to Fill Workspace, in the *Faults* object tab.

5. **MB3** on one of the selected faults and select **Dynamic Frameworks to Fill** > **Relations** > **Link faults**.



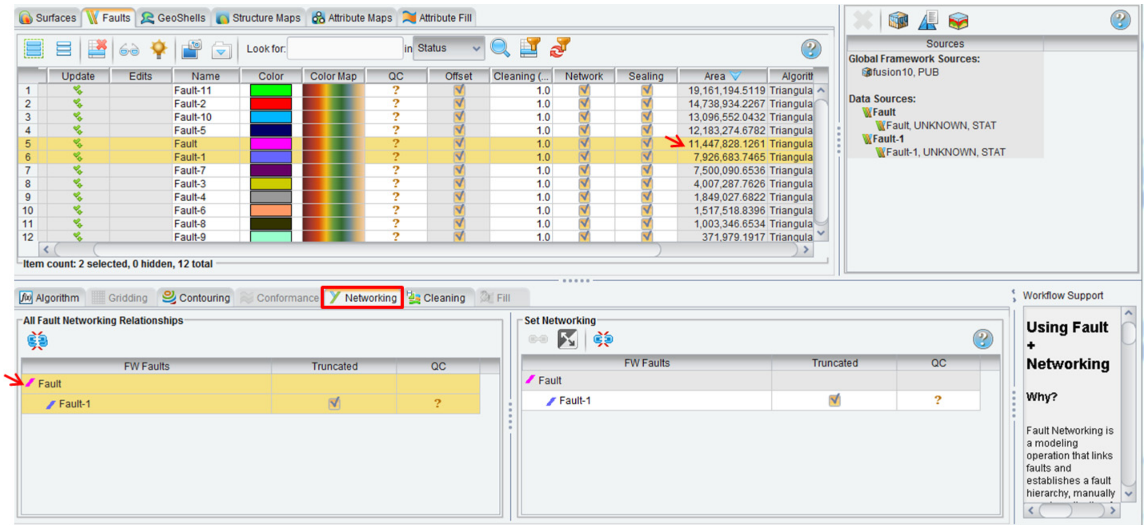
Linking the faults cause the fault planes to be both extended as well as truncated, as shown in the pictures below.





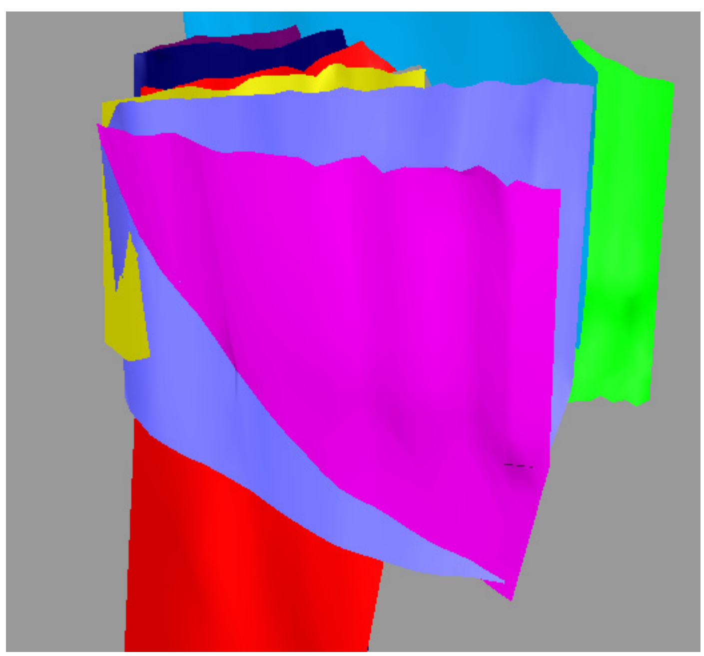
Relationships, as mentioned in the background theory, are determined by the size of the fault planes. The parent fault in this case is Fault, due to its larger size. Also, Fault-1 is truncated, because less than 25% of its area is affected by truncation. You can see these relationships, and the area of each fault plane in the *Dynamic Frameworks to Fill Workspace*.

6. Navigate back to the *Dynamic Frameworks to Fill Workspace* in the *Faults* object tab you can see the size of the fault plane in the *Area* column. With the *Faults* object tab still selected, navigate to the **Networking** actions tab, where you can see all of the networking relationships in your framework.

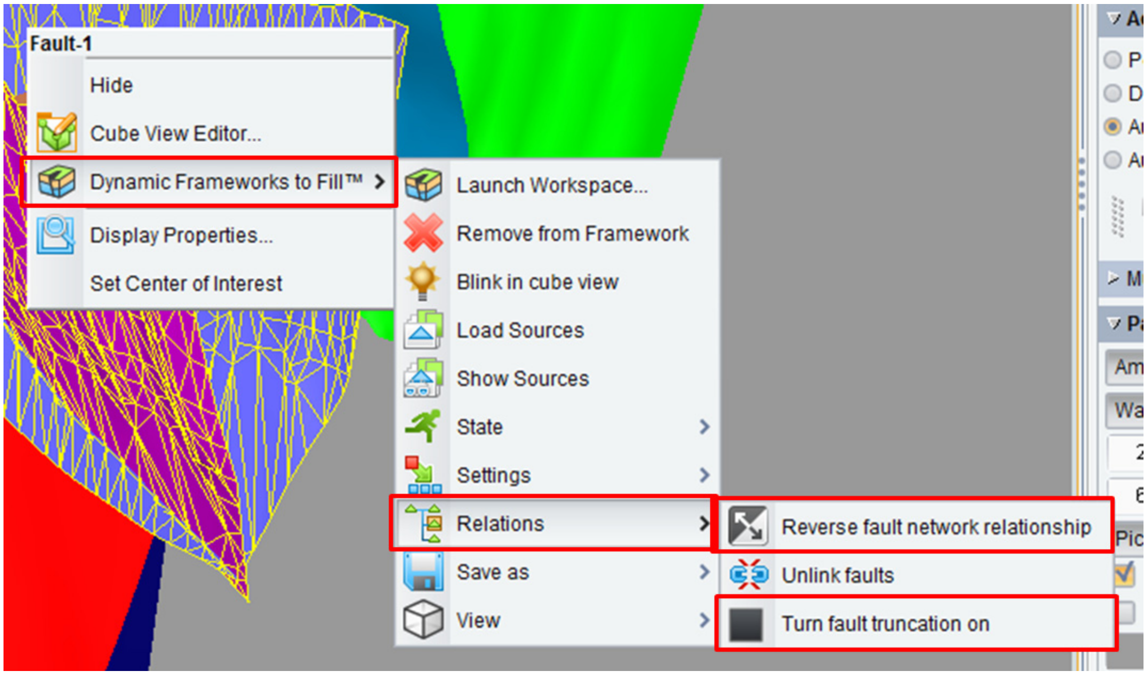


If you are not satisfied with the relationships you can modify them in the *Networking* actions tab, or from the MB3 menu.

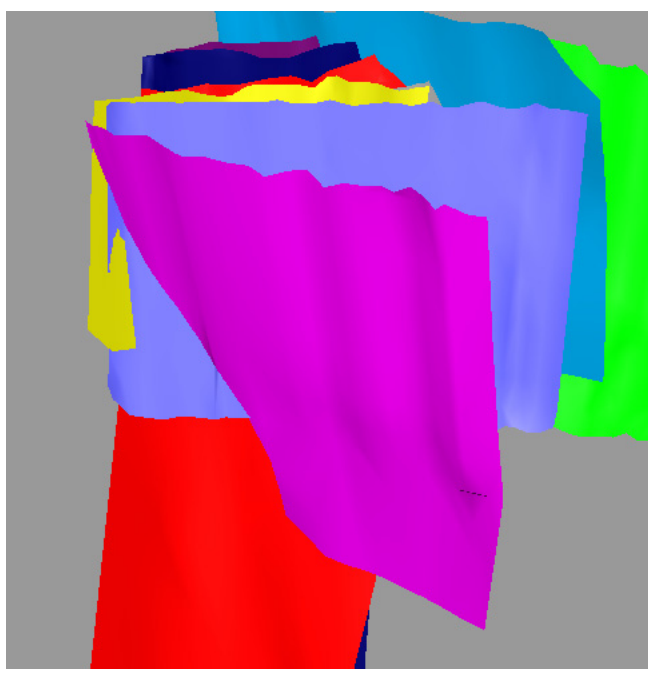
7. In the *Set Networking* panel, click the check box in the *Truncated* column. This keeps the parent-child relationship that was created between the two faults, but breaks the truncation relationship between them.



8. In *Cube* view, select both **Fault** and **Fault-1** again, **MB3** and then select **Dynamic Frameworks to Fill > Relations**, and then select **Turn Fault Truncation on** and **Reverse fault network relationships**.

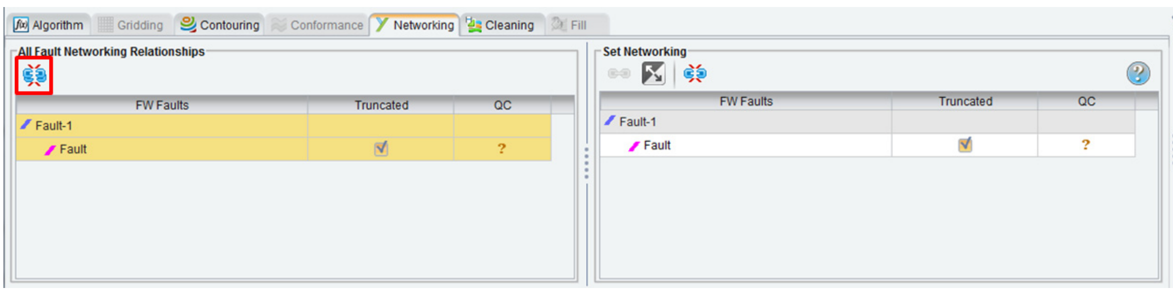


Fault is now the child, and truncated against Fault-1, as shown in the picture below.



In Dynamic Frameworks to Fill, there is the ability to have the faults within your framework automatically networked. This is incredibly useful when you have a large number of faults within your framework that would take a considerable amount of time to manually network. In the following steps, you will learn how to create an automatic fault network with all of your framework faults.

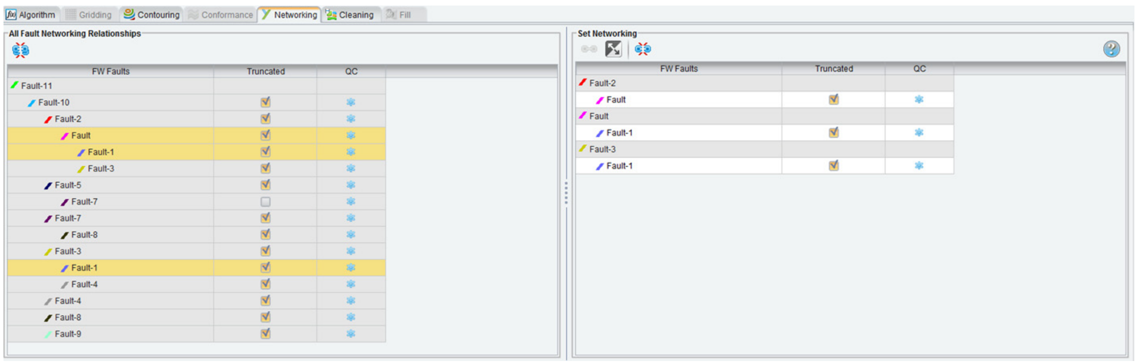
9. In the *All Fault Networking Relationships* panel of the *Networking* actions tab of the *Dynamic Frameworks to Fill Workspace*, click the **Unlink all shown relationships** ( ) icon. A warning dialog opens asking if you are sure you wish to unlink all shown relationships, click **Yes**. This icon unlinks all of the relationships within your framework.



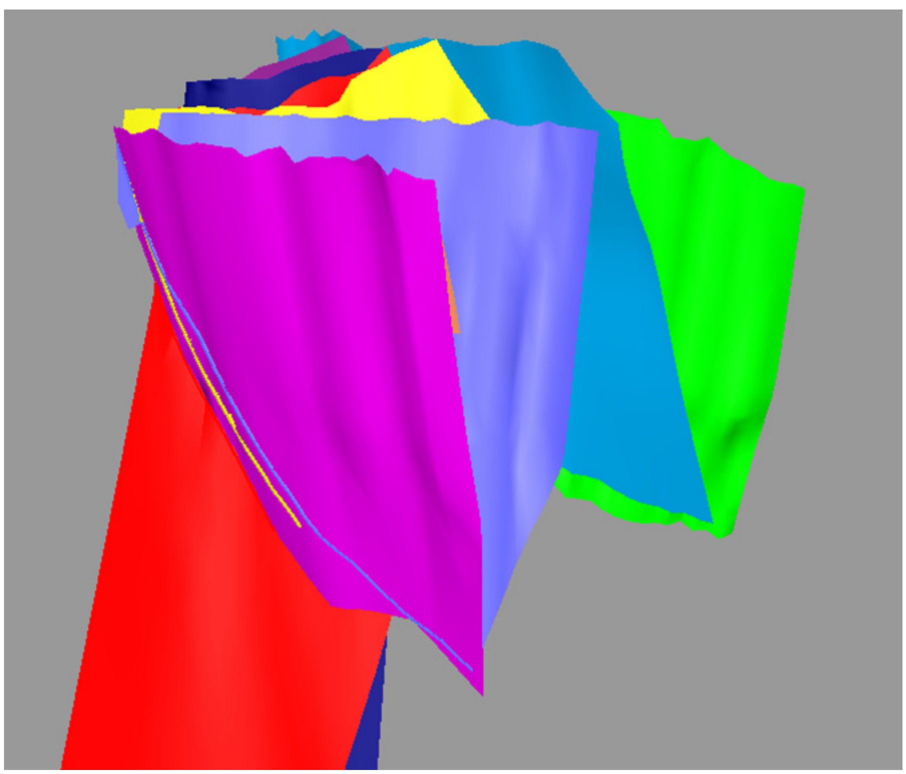
> **Note**
>
> If you want to only unlink the relationships between specific faults click the **Unlink** icon in the *Set Networking* panel as opposed to the one in the *All Fault Networking Relationships* panel.

10. At the top of the *Dynamic Frameworks to Fill Workspace* there are multiple settings icons. Click the **AutoNetwork Faults** ( ) icon. Your framework will automatically update with all of the relationships shown in the *Networking* actions tab, as well as in *Cube* view.

The picture below shows all of the relationships that were established within frameworks from AutoNetworking. As mentioned earlier, all relationships within the framework are shown in the left panel, whereas the relationships that involve only the selected faults are shown in the right panel. In the case below, Fault and Fault-1 are selected in the *Faults* object tab.



The image below shows the *Cube* view after AutoNetworking was applied. You can see the intersections of multiple faults into Fault.



11. In the *Dynamic Frameworks to Fill Workspace*, select **File > Save Framework**, and then close your session.

In this chapter, you learned how to interpret faults, and then create geological relationships between them to enhance your structural model. In the following chapter, you will learn how to create horizons, and then add those in to your framework in order to continue to build that model.

Chapter 4
Horizon Interpretation

In this chapter, you will learn how to use the tools available in DecisionSpace Geosciences to interpret horizons. Previously, in Chapter 2, you worked through the Well Tie Workflow to produce a synthetic in order to tie your well data to the seismic. That synthetic will help to determine the reflector that should be interpreted for the following exercises. Horizon interpretation will begin in *Section* view, where you will use auto-picking to manually interpret on multiple inlines and xlines. Continuing in *Cube* view, additions to the interpretation can be made using a probe to visualize the horizon in 3D.

Other than the manual picking tools, DecisionSpace Geosciences also contains two auto tracking tools, Area Track! and ezTracker Plus, to help complete horizon interpretation. Area Track! is used to quickly track over small areas of the horizon, and ezTracker Plus is a customizable tracking tool used to track a horizon over an entire survey.

Once interpretation has begun, horizons can be added into a framework as a gridded surface to be used both for QC during interpretation and as a key component in your sealed structural model. With your surface in your framework, you can use Dynamic Frameworks to Fill to auto generate both fault offset and fault polygons. This is done by using the intersections of your surface with the faults in your framework.

There are several QC tools available to help aid in interpretation throughout the process, such as ezValidator and the Correlation Polygon. ezValidator allows you to unfault and unfold a section, and Correlation Polygon helps correlate events located in separate fault blocks. After interpretation is complete, Seismic Calculator offers operations to quickly and easily edit or refine multiple horizons.

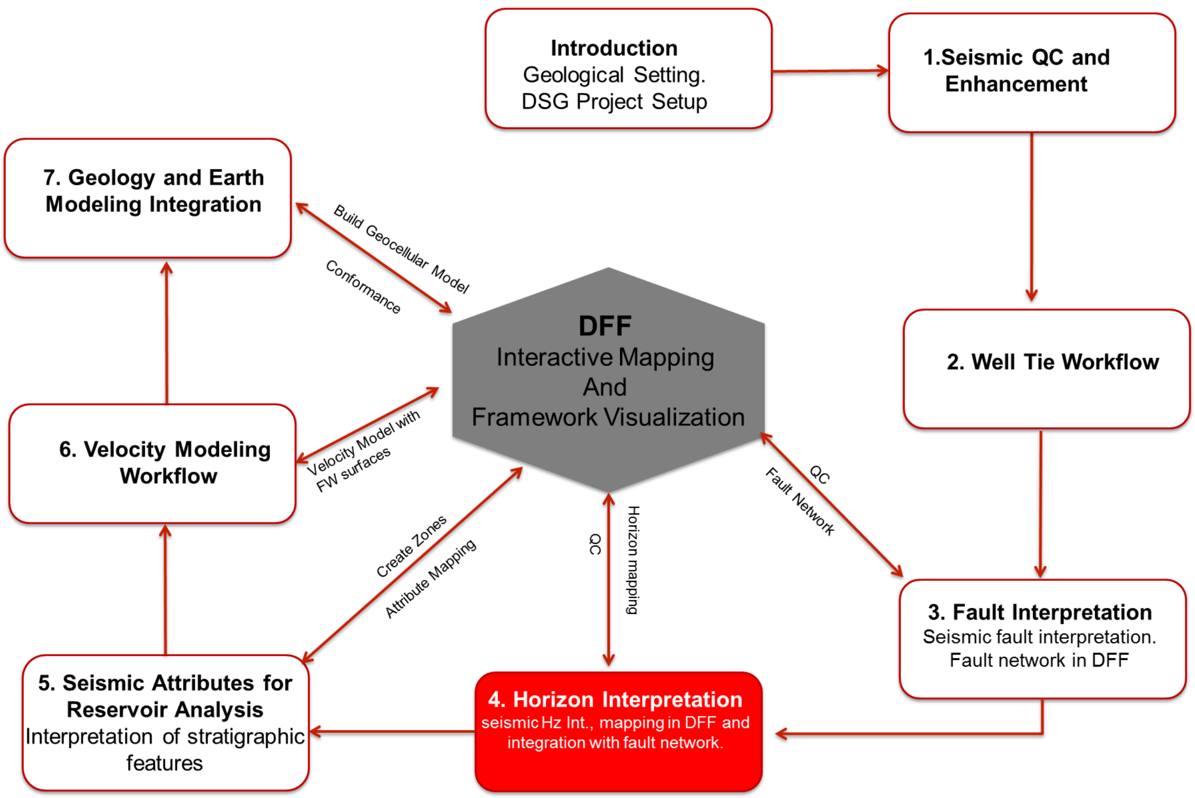
Overview

In this chapter, you will learn to:

- ❑ Create horizons and horizon lists
- ❑ Interpret horizons on the basis of Synthetic
- ❑ Interpret horizons in *Section* view
- ❑ Use horizon correlation polygons (Correlation Tool)
- ❑ Visualize horizon interpretation in Dynamic Frameworks to Fill

- ❑ Interpret horizons in the *Cube* view
- ❑ Track areas using Area Track!
- ❑ Track horizons using ezTracker Plus
- ❑ Interpret horizons in *Map* view
- ❑ Create Fault Polygons in DFF
- ❑ Calculate fault heaves and polygons (Conventionally)
- ❑ Use ezValidator to unfault / unfold stratigraphy
- ❑ Use the Seismic Calculator to perform operations on horizons

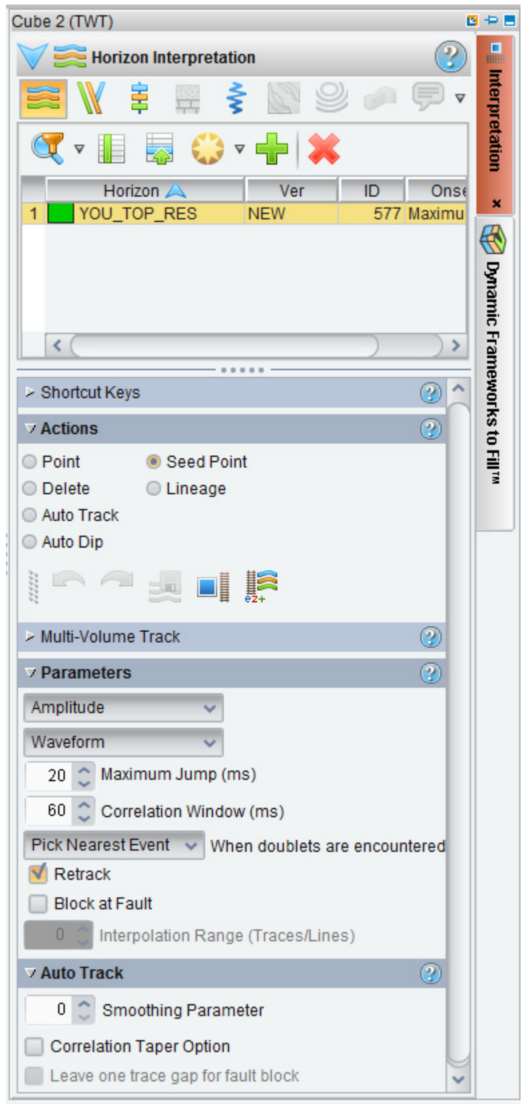
Workflow



Introduction
Geological Setting.
DSG Project Setup
1.Seismic QC and Enhancement
2. Well Tie Workflow
3. Fault Interpretation
Seismic fault interpretation.
Fault network in DFF
4. Horizon Interpretation
seismic Hz Int., mapping in DFF and integration with fault network.
5. Seismic Attributes for Reservoir Analysis
Interpretation of stratigraphic features
6. Velocity Modeling Workflow
7. Geology and Earth Modeling Integration
DFF
Interactive Mapping
And
Framework Visualization
Build Geocellular Model
Conformance
Velocity Model with FW surfaces
Create Zones
Attribute Mapping
QC
Horizon mapping
QC
Fault Network

Interpreting in ***Section***, ***Map*** and ***Cube*** Views

Information in this section covers the items you will commonly use in the *Horizon Interpretation* task pane:



Horizon Interpretation mode in *Section*, *Map* and *Cube* view involves auto-picking, where the user manually clicks a trace to set a seed point. The software then moves the seed point to an inflection that matches the specified onset type within a specific window above and below the user's set point. While in Horizon Interpretation mode, you have the ability to pick horizons based on three different attributes: amplitude, value, and phase. This exercise (and the following information) involves tracking the amplitude of the traces. The onset types tracked on amplitudes include minimum, maximum, or zero crossings.

Depending on the method of auto-picking, the software will handle the movement of the seed point from trace to trace differently. There are three methods available for amplitude tracking (found in the *Parameters* panel):

- Waveform—This is the default mode. Data is compared to the original trace at all times during your interpretation. The process looks at a range of data above and below the seed point and scans within a search window on nearby traces to identify a similar waveform.

- Cross Correlation—This is a classic method for statistically comparing data to determine if there is a match. The correlation process looks at a user-specified range of data above and below the seed point and scans within a search window on nearby traces to see if it can identify a similar set of data. If it finds a match, it will track the horizon to those traces. This also tracks a waveform.

- Peak-to-peak—Data is selected on peaks. The software searches between inflection points for the onset type specified and moves the seed point to that location. The seed point is then transferred to the next trace at the same time value as the previous point. This process is repeated every time the user clicks MB1.

The *Actions* panel is where you select the action you would like to use for picking a horizon. The actions available for interpretation depend on the currently active view. Below is a list of the actions and how they behave:

- Point—Manual tracking mode. MB1 to digitize and MB2 to end the rubber band.

- Delete—Erases an area of the horizon either by MB1 points to start and end deletion or by using a box like paintbrush.

- Auto-track—Default horizon interpretation mode. Follows the direction and length specified by the user, but determines the dip using an algorithm.

- Auto-dip—Follows the direction, length, and dip specified by the user. This mode is best used when traveling along geometry and structure, where phase can be ignored because it is non-constant.

- Interpolation (*Map* only)—Fills in gaps in the horizon by performing an interpolation between known points in the X and Y direction.

- Seed Point (*Cube* only)—Tracks the amplitude using an Auto Tracker at specified seed point placed on a probe.

- Lineage (*Map* and *Cube* only)—Shows ancestors and descendants at a point on the tracked horizon.

You may also specify other criteria in the *Parameters* panel that determine how the horizon will be tracked:

- Maximum Jump—Use Maximum Jump to specify the maximum value for jumps between traces in an auto tracked horizon.

- Correlation Window—Specifies a range in which the tracker searches above and below the seed point when trying to match a similar set of data.

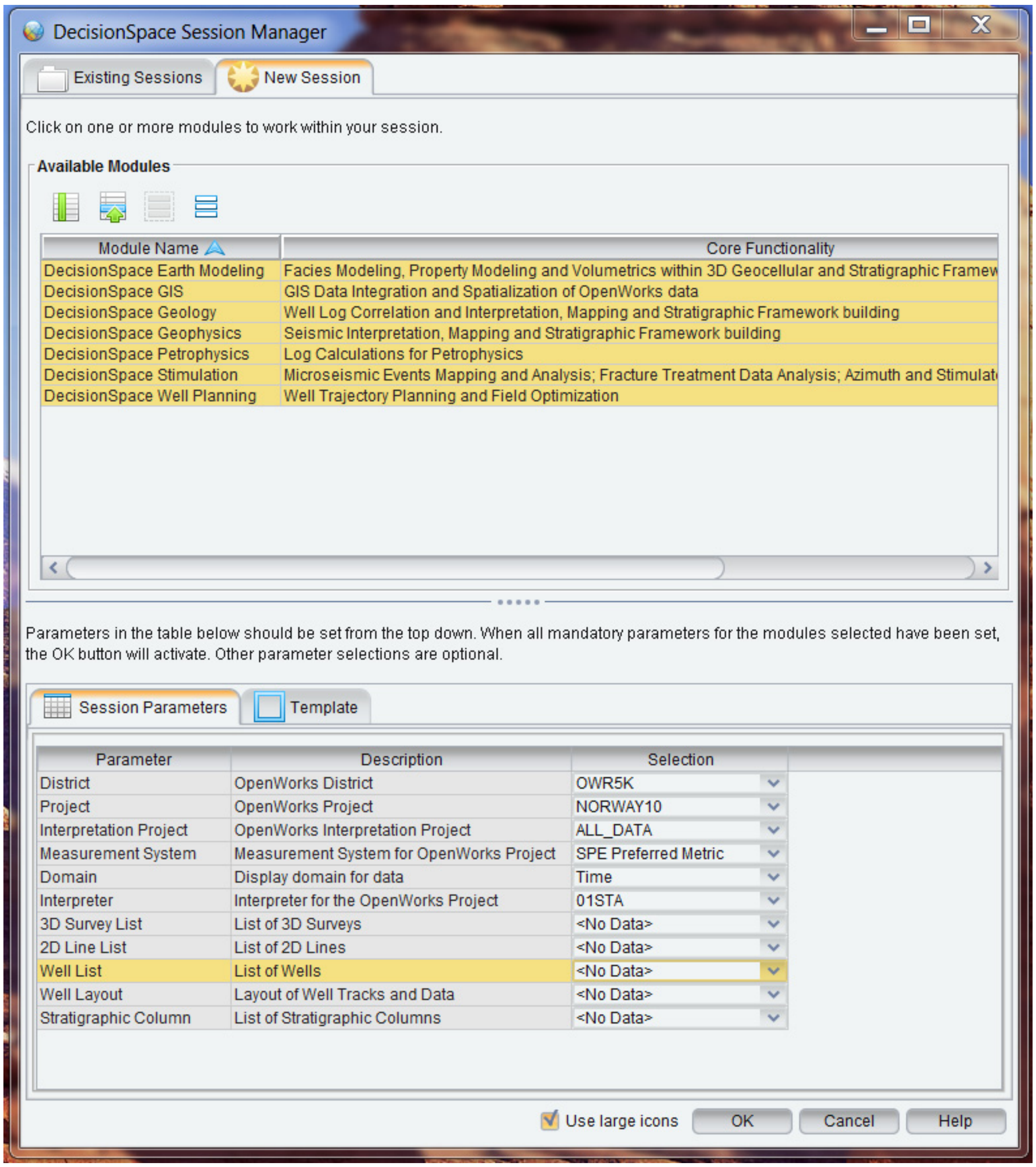
- Block at Faults—The Block at Fault option provides accurate horizon tracking near a fault plane by preventing the auto tracker from tracking consecutive traces that are separated by a fault plane.

For further information regarding Horizon Interpretation actions and parameters, see the Help page associated with the *Horizon Interpretation* task pane.

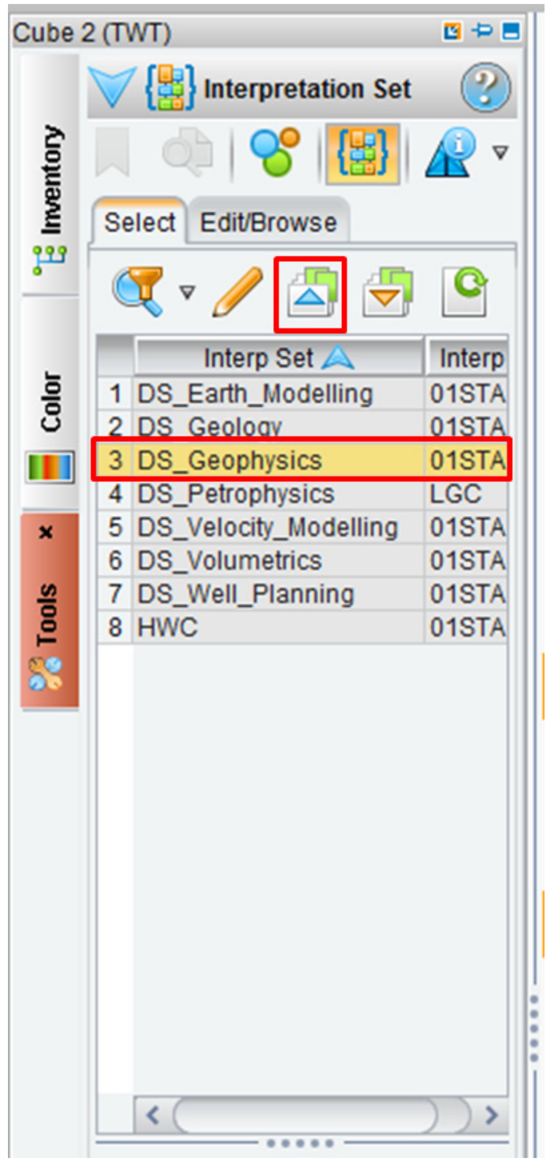
Exercise 4.1: Interpreting Horizons in *Section* View

In the following exercise, you will learn how to create a new horizon and begin interpretation in your *Section* view.

1. Start a new session with the parameters in the picture below, and click **OK**.

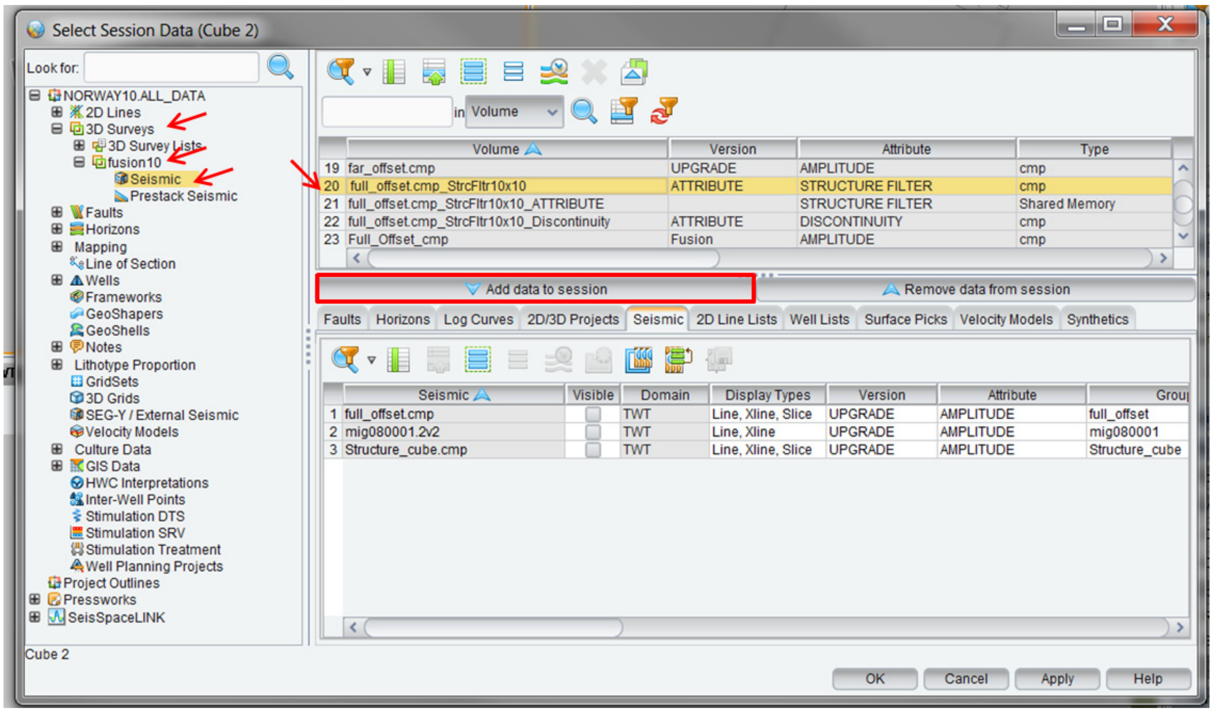


2. When your new session starts, go to the *Tools* task pane, select the **DS_Geophysics** ISet and click **Load Data To Session** (). Your *Inventory* should now be populated with data objects.

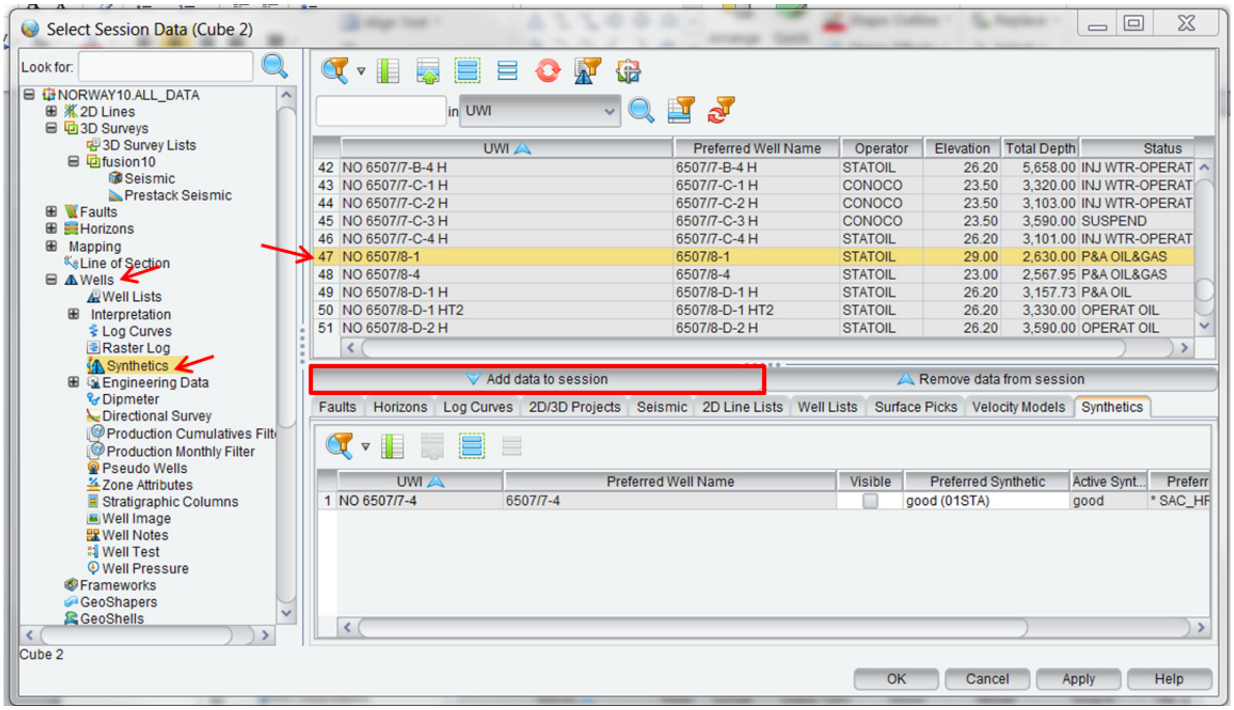


Note
Interpretation Sets are lists of specific project data items. They allow you to organize your project by including only the items you may need for a particular workflow or scenario. You can easily load or unload data items in an ISet through the *Interpretation Set* task bar.

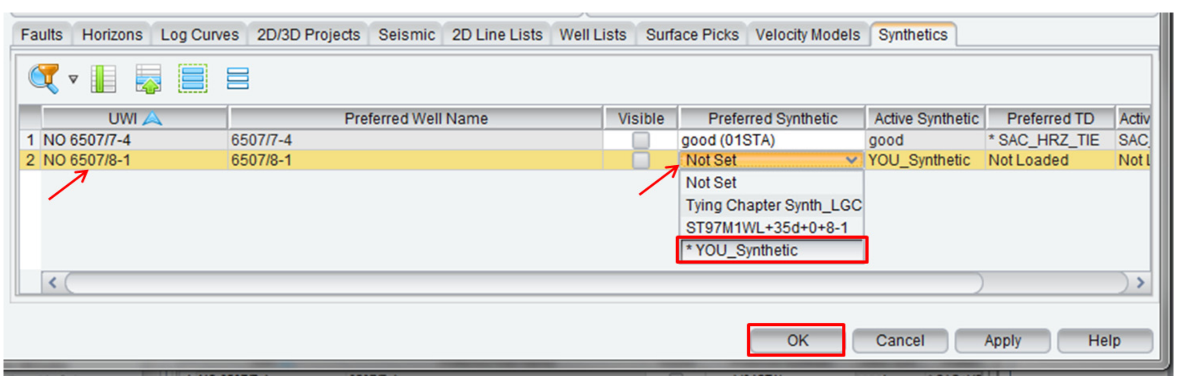
3. You will also need to load the full_offset.cmp_StrcFltr10x10 volume and the synthetic you created in a previous chapter to your session by going to **Select Session Data** ( ). In the *Select Session Data* dialog, select **3D Surveys > fusion10 > Seismic**, and then in the right panel, select **full_offset.cmp_StrcFltr10x10**. Click **Add data to session**.



4. Still in the *Select Session Data* dialog, in the left panel, select **Wells > Synthetics** and then highlight **NO 6507/8-1** in the upper right panel. Click **Add data to session**.

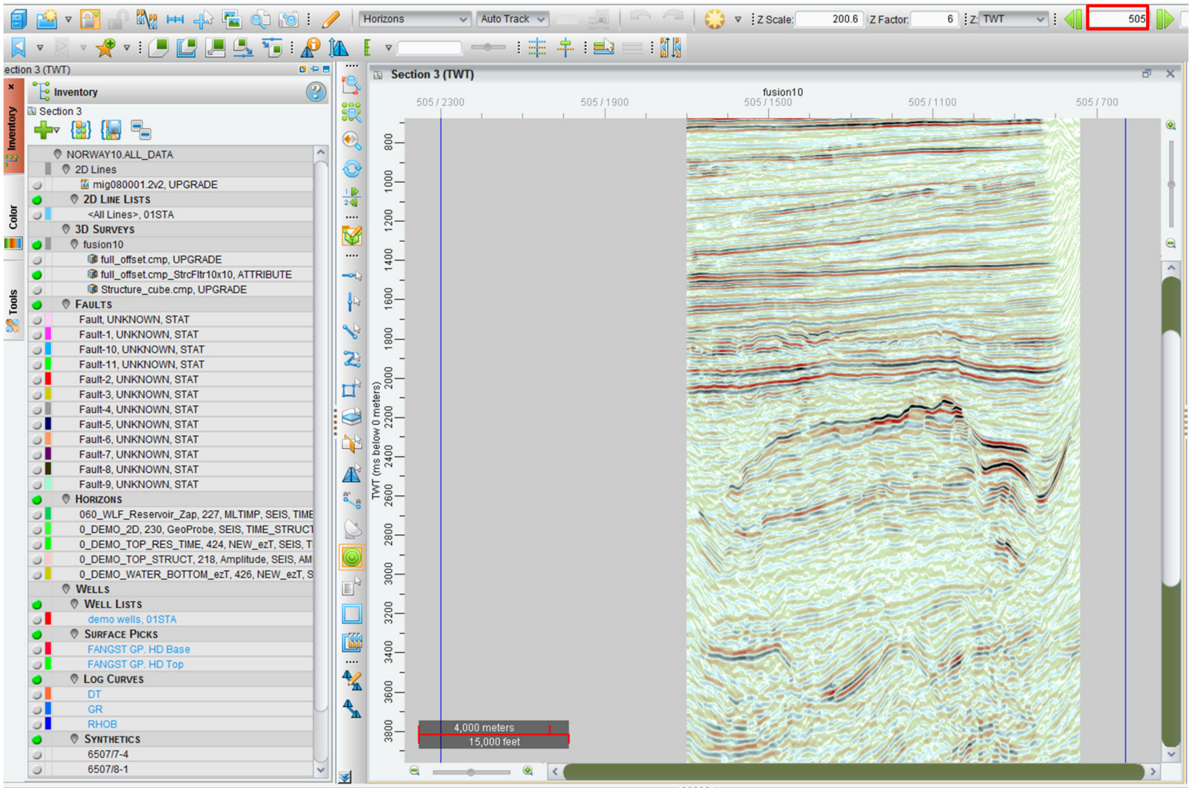


5. In the lower panel, check to see that **YOU_Synthetic** is set as the *Preferred Synthetic* for the well **NO 6507/8-1**. If not, click the drop-down menu for *Preferred Synthetic* and select it. Click **OK** to close the *Select Session Data* dialog.

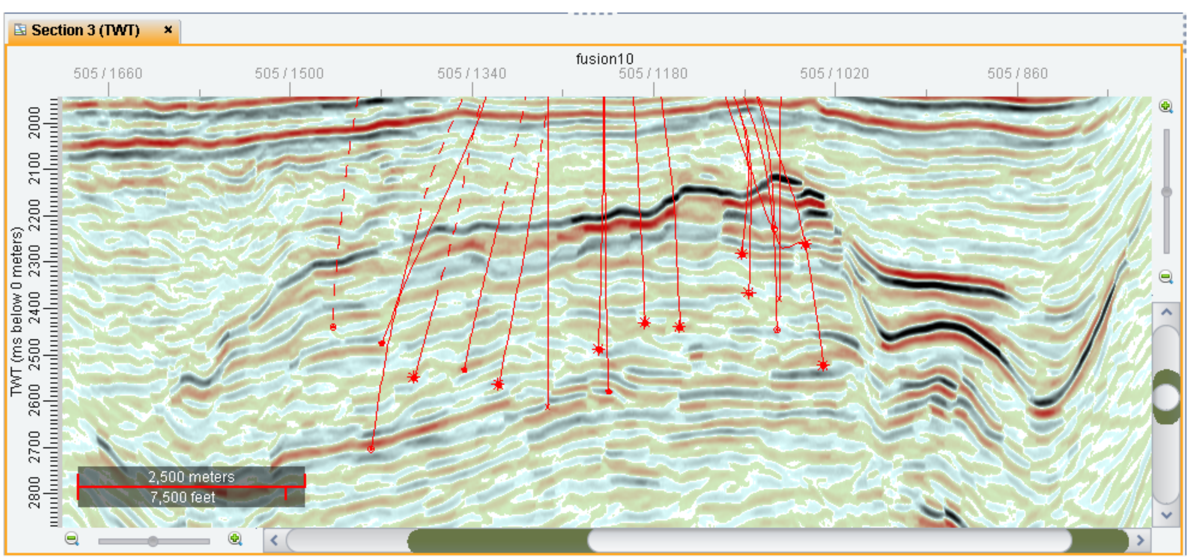


> **Note**
>
> If you don't have YOU_Synthetic or you are not satisfied with the results from the exercise, you can use the *Tying Chapter Synth_LGC* synthetic that is already in your dataset.

6. From the *Inventory* task pane, drag-and-drop the **full_offset.cmp_StrcFltr10x10** volume into *Section* view, and then, in the frame control panel, navigate to **IL 505**.



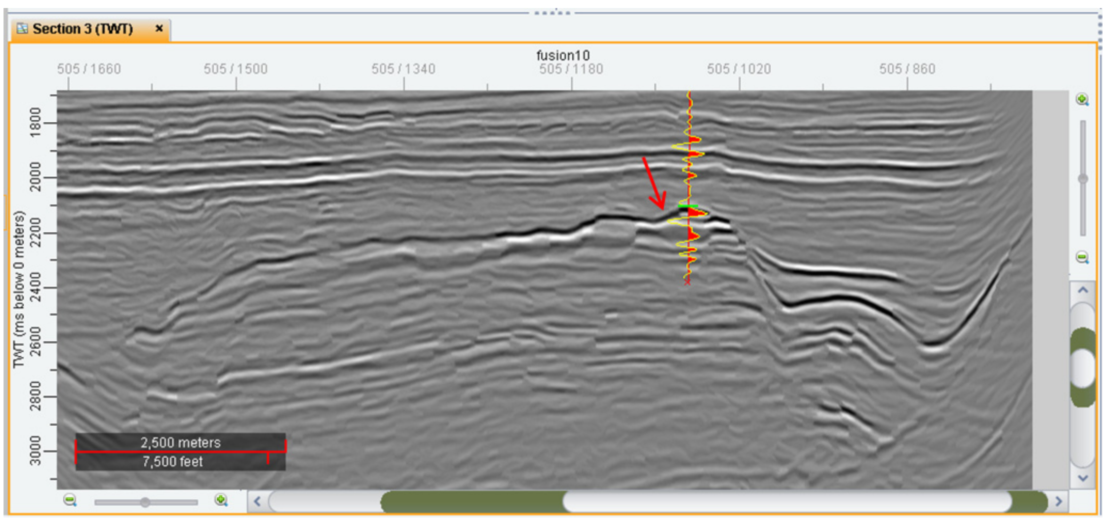
7. Still in the *Inventory* task pane, toggle on the **demo wells** well list, and zoom in so you have a good view of the reservoir.



In a previous chapter you created a synthetic for the well 6507/8-1. Displaying this synthetic in your *Section* view will allow you to tie the well data to the seismic and help you decide which reflectors correspond to specific well tops. In the following steps, you will use the synthetic to determine which reflector matches best with the FANGST GP.HD Top surface pick, and make a new horizon interpretation on that reflector.

8. With *Section* view active, in your *Inventory* task pane toggle on synthetic **6507/8-1** and surface pick **FANGST GP. HD Top**.

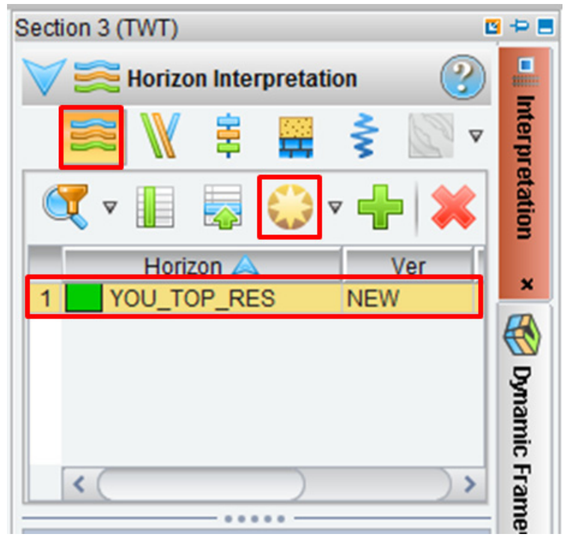
> **Note**
>
> The picture below shows a simplified view. If you feel a view is too crowded with wells, you can **MB3** on the well list and select **Well Details**. From there you can make only the wells you wish to see visible.



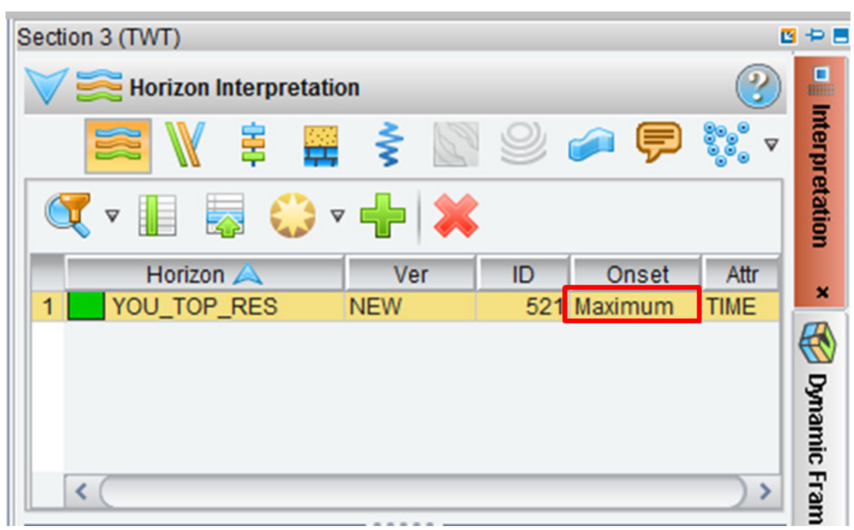
The peak in the synthetic, as well as the FANGST GP.HD Top surface pick, is associated with a maximum reflection event, at the top of the reservoir. You will create a new horizon and make your interpretation along this event.

> **Note**
>
> Seismic in *Section* view will be in greyscale in the manual for display purposes. If you wish to have a similar display, go to *Display Properties* and change the color map to **System > greyscale**.

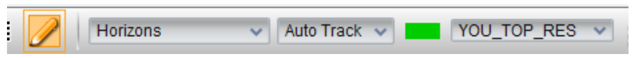
9. In the *Interpretation* task pane, click the **Horizon Interpretation** ( ) icon. To create a new horizon, click the **Create New Horizon** ( ) icon. A new horizon will be created in the *Horizon Interpretation* task pane with a default name. Double-click the name and change it to “**YOU_TOP_RES**.”

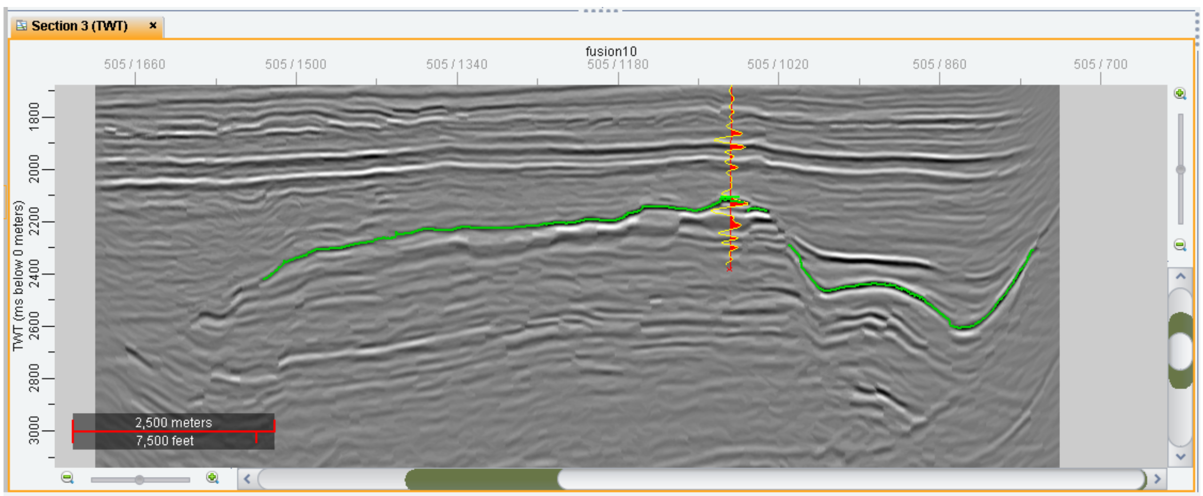


10. The default onset for horizon interpretation is a minimum, but the event you will be interpreting is a maximum. Expand the *Interpretation* task pane, click the **Onset** cell to change it to **Maximum**.



11. In your active *Section* view, make sure **Interpretation Mode** ( ) is on, and **YOU_TOP_RES** is selected as the object for interpretation in the *Interpretation* toolbar at the top of the window. To make your interpretation, click **MB1**, and when you are satisfied end your interpretation by clicking **MB2**.

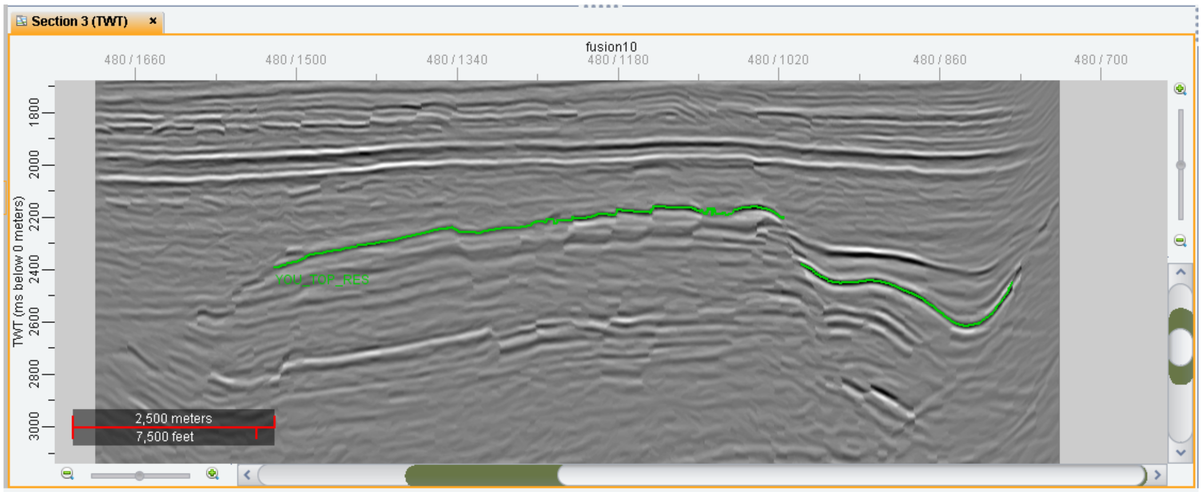




You may have to try a combination of interpretation modes. For example, with events that are steeply dipping, you may need to switch the mode to Auto Dip which works better for traveling along geometry/structure.

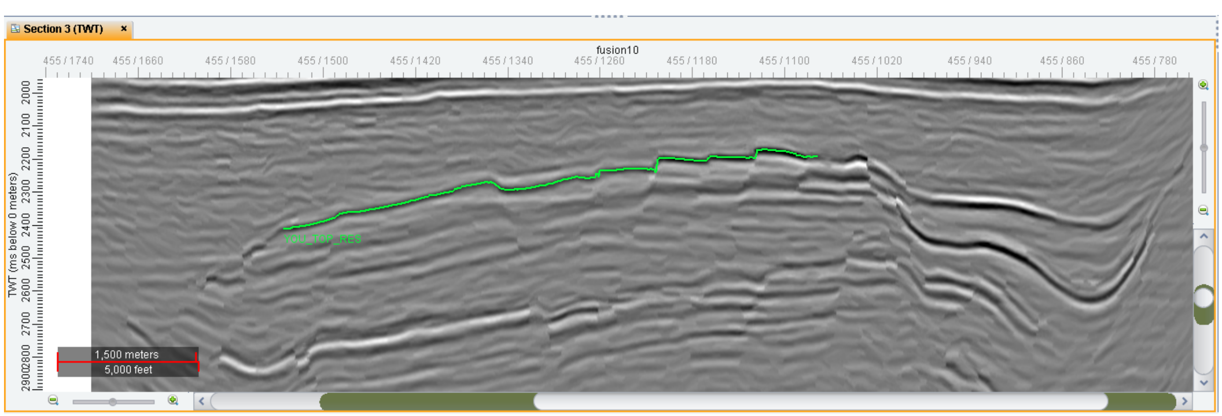
12. Skip 25 IL backwards by setting a current skip increment of **25** and then clicking the **Skip Backwards** ( ) icon. Interpret the same event on **IL 480**.

When you are done with your interpretation, your view should look similar to the one below.

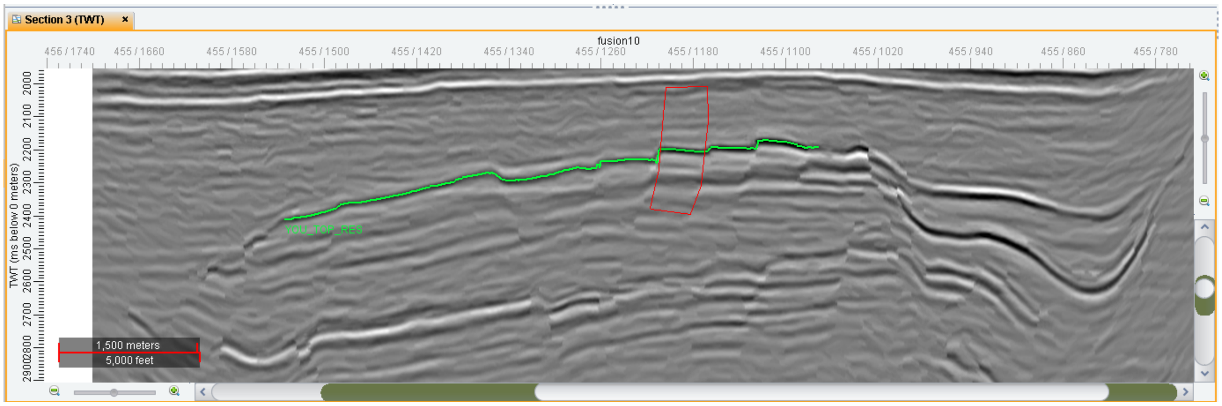


The Correlation Tool is extremely useful in highly faulted areas, by giving you the ability to compare seismic on one side of a fault to the seismic on the other side. It allows this by taking a snapshot of your seismic within a defined polygon that you can then move around in your *Section* view. In the next few steps, you will use the Correlation Tool to help make your interpretation of YOU_TOP_RES across several faults.

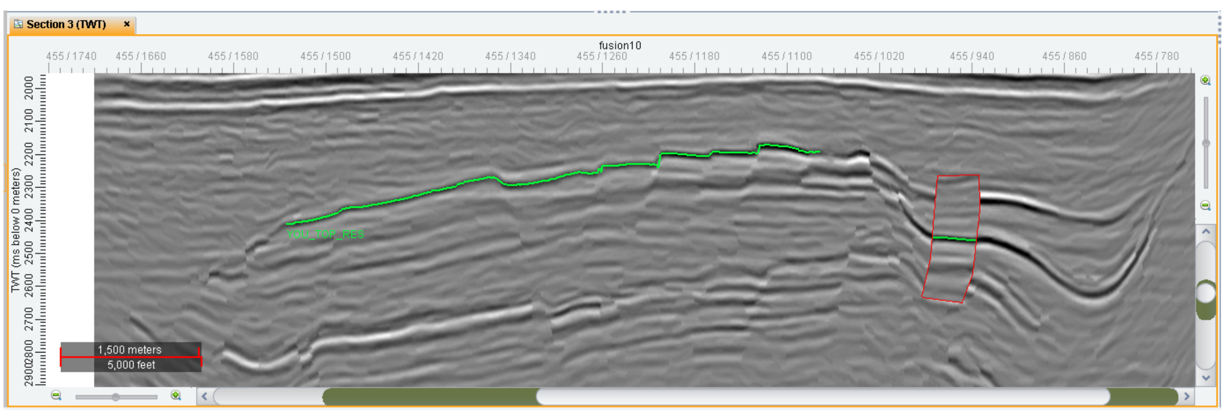
13. Step back another **25 IL** (you should be on IL 455) and begin your interpretation on the left side of the major fault, like the picture below.



14. You will use the interpretation you made on one side of the fault to aid in the interpretation of the same event on the other side. Click the **Correlation Tool** () icon from the main toolbar, and using **MB1** draw a polygon containing the seismic you wish to use for correlation. **MB2** to close and finish the correlation polygon.



15. Hover your mouse over the polygon, the cursor will change to a four-sided arrow. To move the polygon, **MB1-drag** the polygon to a new location and release. Use the correlation polygon to aid in the interpretation of the event on the right side of the fault.

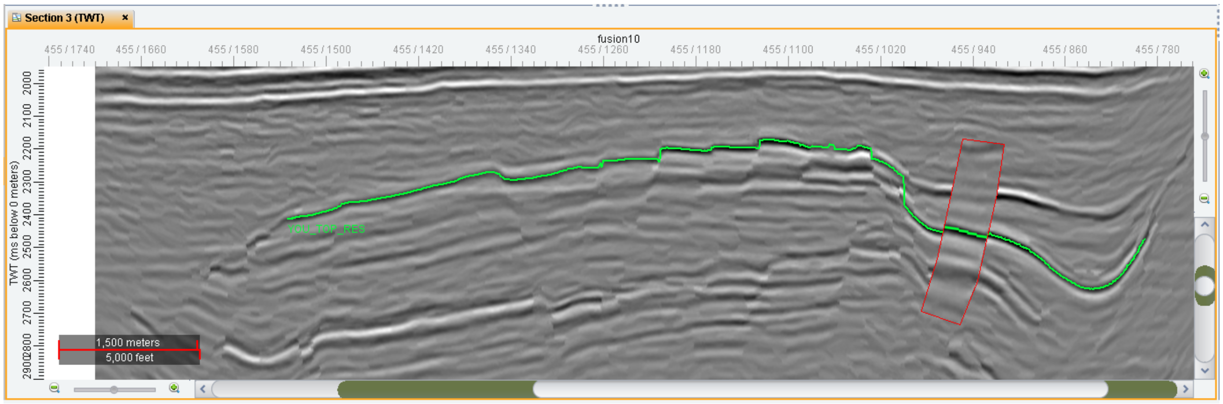


Note

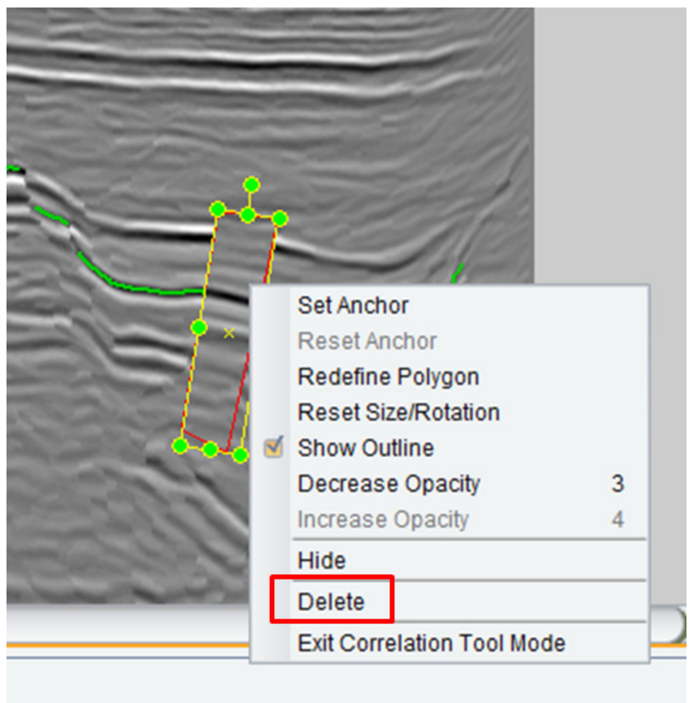
Other functions that can be performed with the bounding box include:

- Stretch and Squeeze—**MB1** inside the polygon and green nodes will appear along the bounding box which can then be dragged for resizing.
- Rotation—**MB1-drag** the topmost node of the bounding box.
- Display properties—**MB3** inside the polygon to change the opacity and set an anchor so the polygon does not move.

Your view should look similar to the one below.



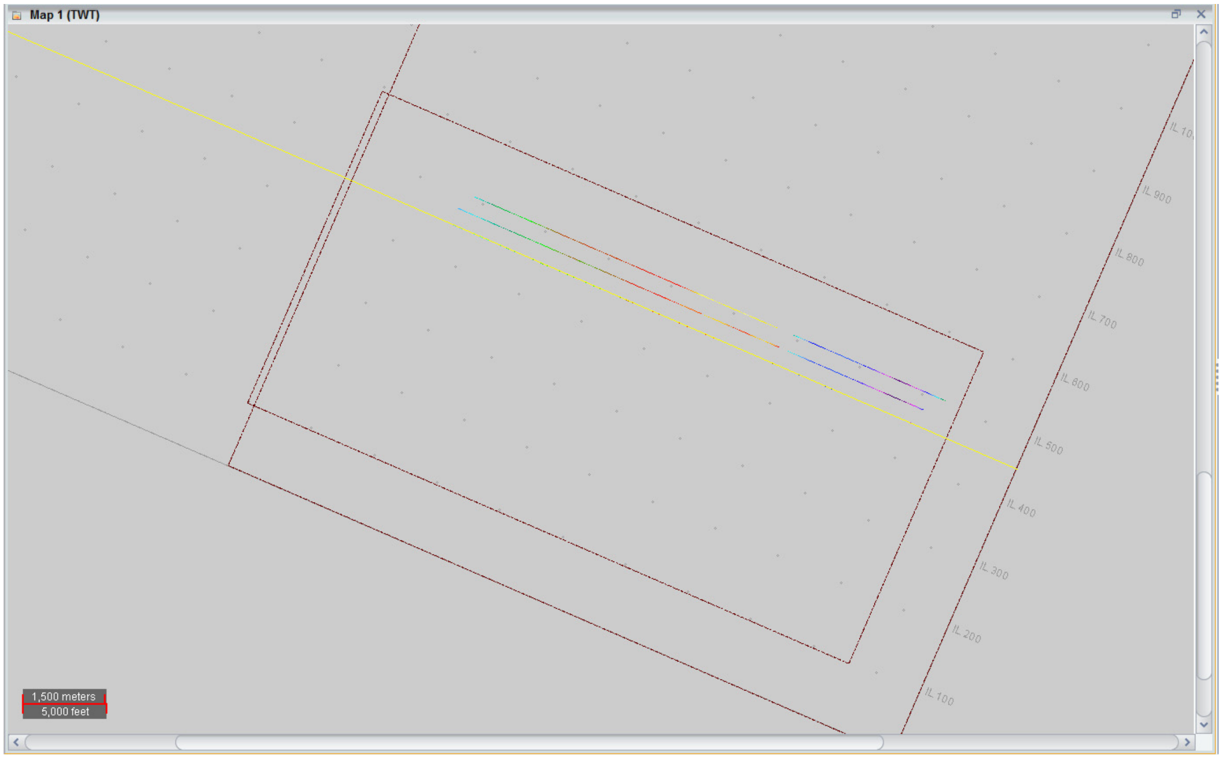
16. When you are done with the polygon, **MB3** and then select **Delete**.



Note

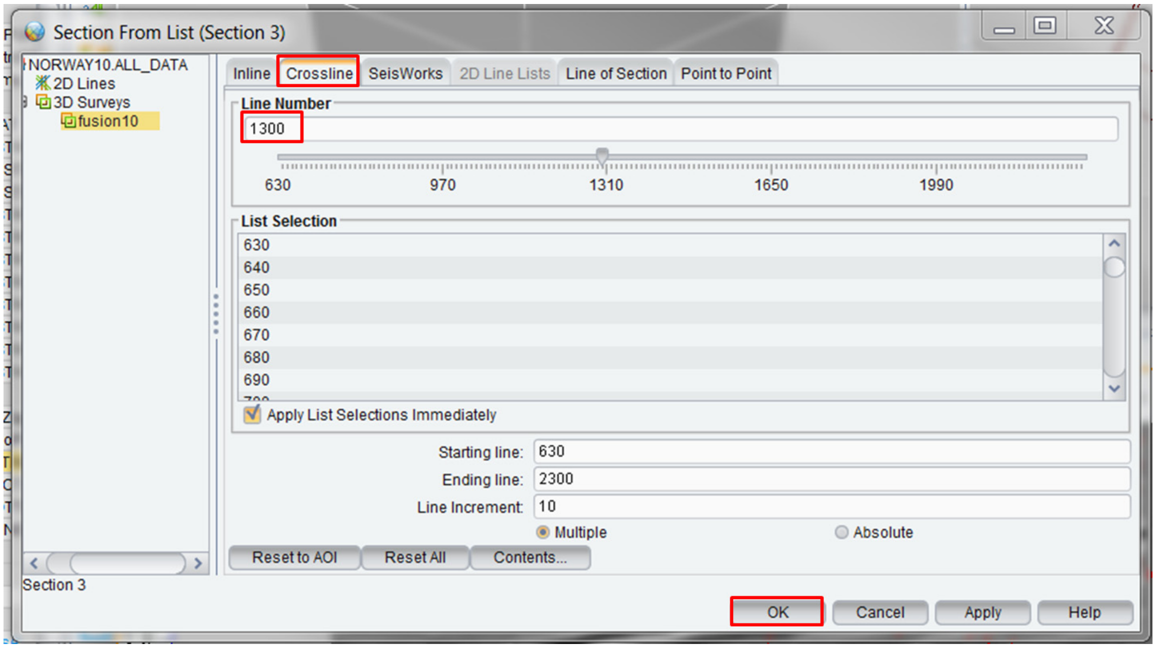
Correlation polygons become a new data object in your inventory under *CorrTool*. You can toggle the polygon on and off, and even use the polygon in other *Section* views. In the *Select Session Data* dialog, parameters such as opacity, horizontal and vertical stretch, rotation and line style can be changed. If you modify the polygon in your session, these items will be reflected in *Select Session Data*.

17. Make the *Map* view active, and toggle on **YOU_TOP_RES** in order to see your interpretation updating for the rest of the exercise.

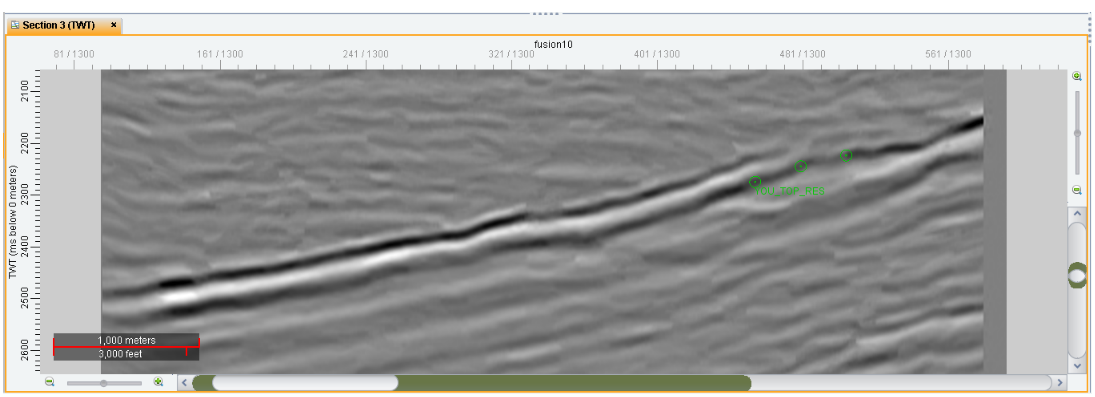


Next, you will continue your interpretation on a crossline perpendicular to your current view.

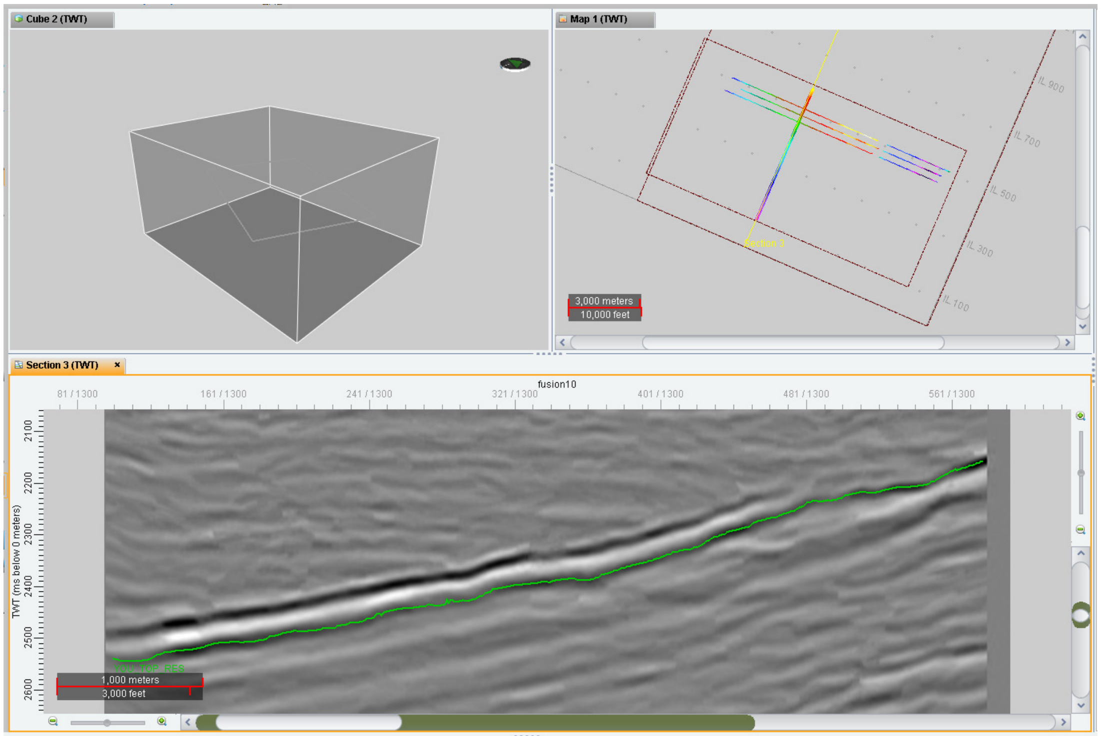
18. Activate *Section* view and from the main menu select **Select > Section from List...** in the main toolbar. In the *Section From List* dialog, ensure **fusion10** is selected in the left panel and select the **Crossline** tab. Type "**1300**" for *Line Number*, and click **OK**.



The North end of the crossline shows three intersection points from the previous interpretations made on the inlines. Use these points to help guide your interpretation, and ensure that you are making your interpretation on the correct reflector. These points can also act as QC to show you where previous interpretations may not necessarily match up with what you are currently seeing in your specific *Section* view.

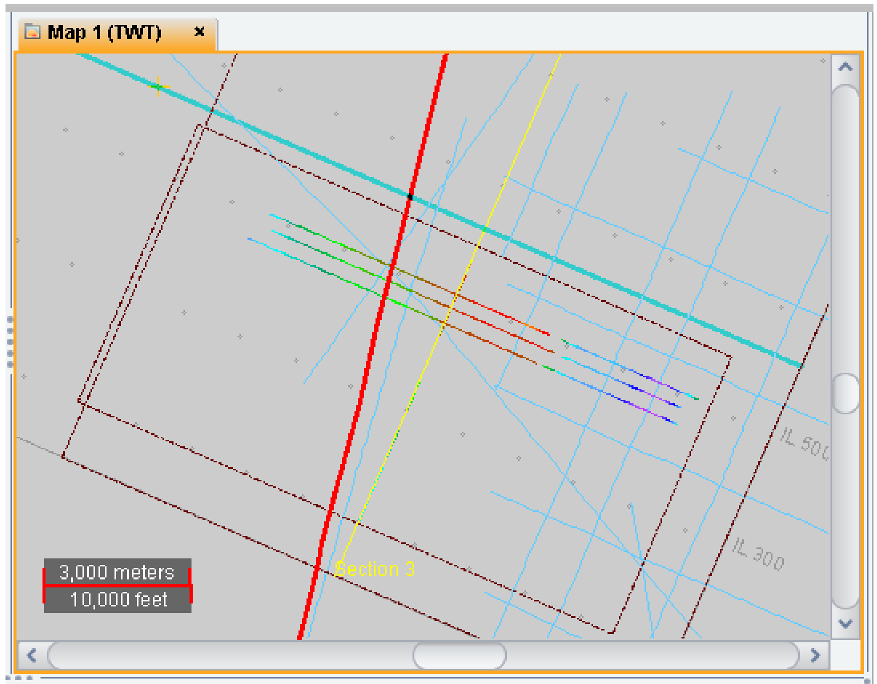


19. Turn **Interpretation Mode** () on, and use the intersection points as a guide to interpret **YOU_TOP_RES** on XL 1300. Notice *Map* view will update with the new interpreted line.



Many projects may not have 3D seismic data for an area, and may only have 2D seismic lines. You have the ability to display those 2D lines in to *Section* view as well. In areas where 2D and 3D seismic is included, it may be useful to use the 2D lines to assist in your interpretation, especially in areas where there may have been bad processing. The next few steps demonstrate how you can broadcast a 2D line into *Section* view.

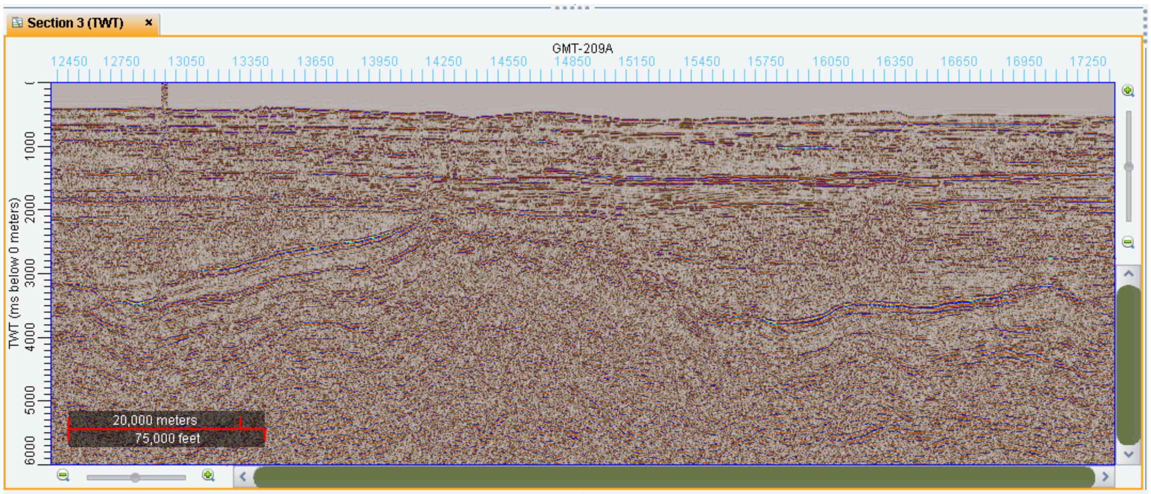
20. Activate *Map* view and toggle on **2D Line Lists** > **All Lines** in the inventory. Click the **Select Inline/2D Line** ( ) icon from the vertical toolbar. **MB1** on the 2D Line **GMT-209A** and **MB2** to broadcast it to *Section* view.



Note

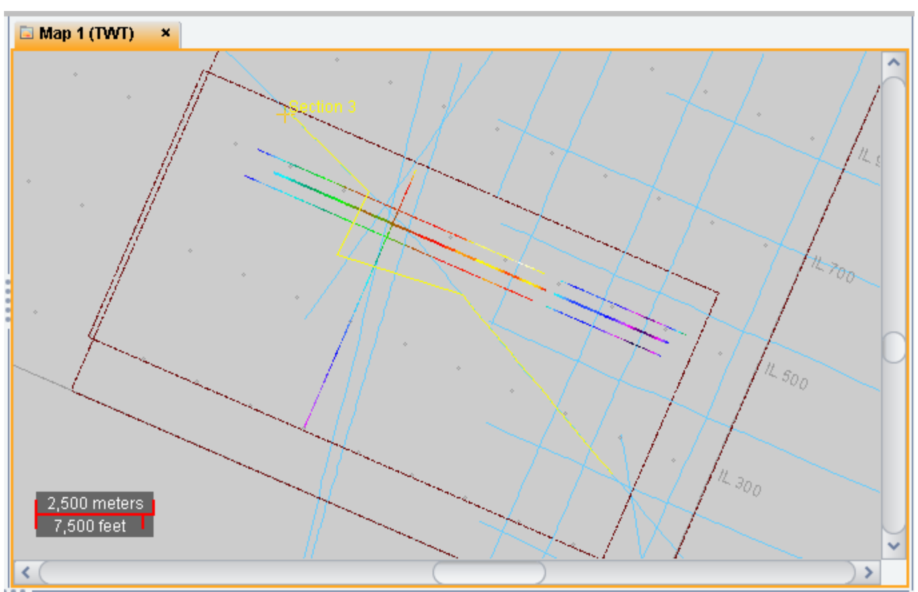
To select the 2D lines, the 2D seismic needs to be active for selection. To switch between seismic data, press the <**spacebar**>. A dialog will appear briefly designating the seismic that is currently active.

21. Activate *Section* view, and ensure that **mig080001.2v2**, under *2D Lines*, is toggled on in your *Inventory*. **MB2** the **Preferred Scale** ( ) icon, in the vertical toolbar, to view the entire line.

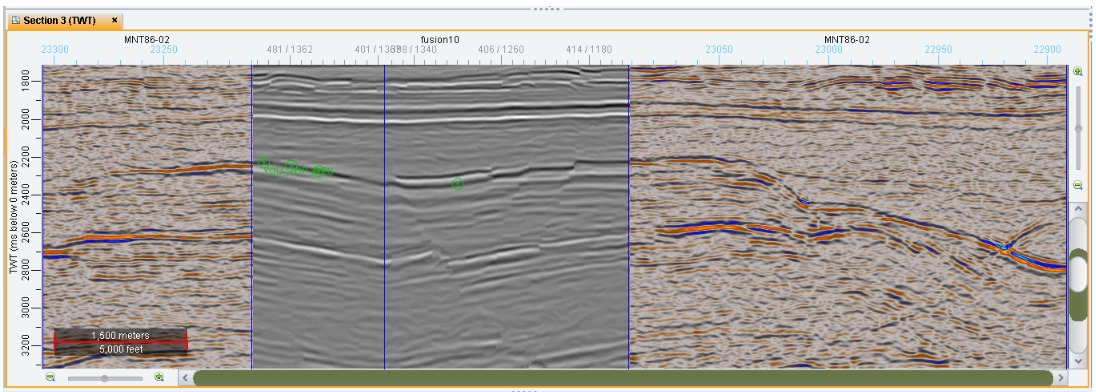


In this project, the majority of the 2D lines are not within the area of interest. You can create an arbline containing 2D and 3D seismic within the key area to utilize the information from both data types.

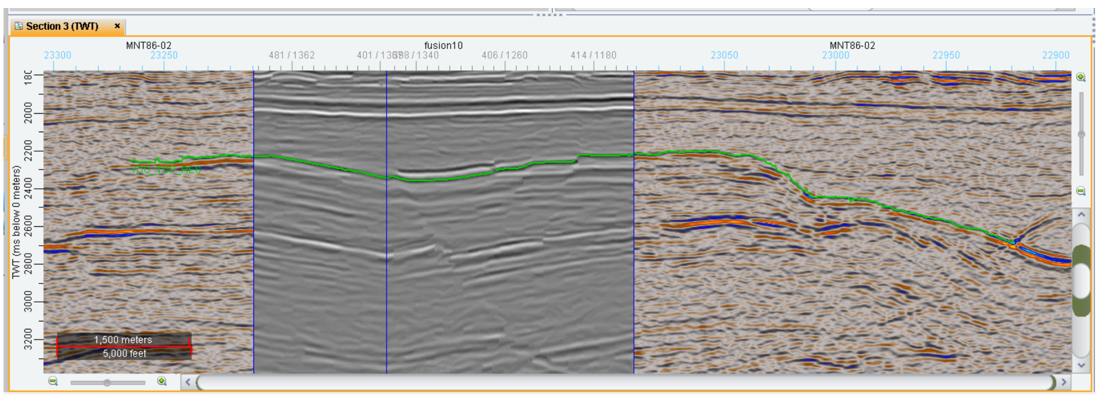
22. With *Map* view active, click the **Select Point-to-Point** ( ) icon. Digitize a line similar to the one shown in the image below by clicking **MB1** and then clicking **MB2** to finish and broadcast the line. Ensure that parts of the segment are along the 2D line MNT-86-02.



Section view will now display four panels. The two greyscale panels, from the 3D seismic volume, show points of intersection from the interpretation already made on YOU_TOP_RES.



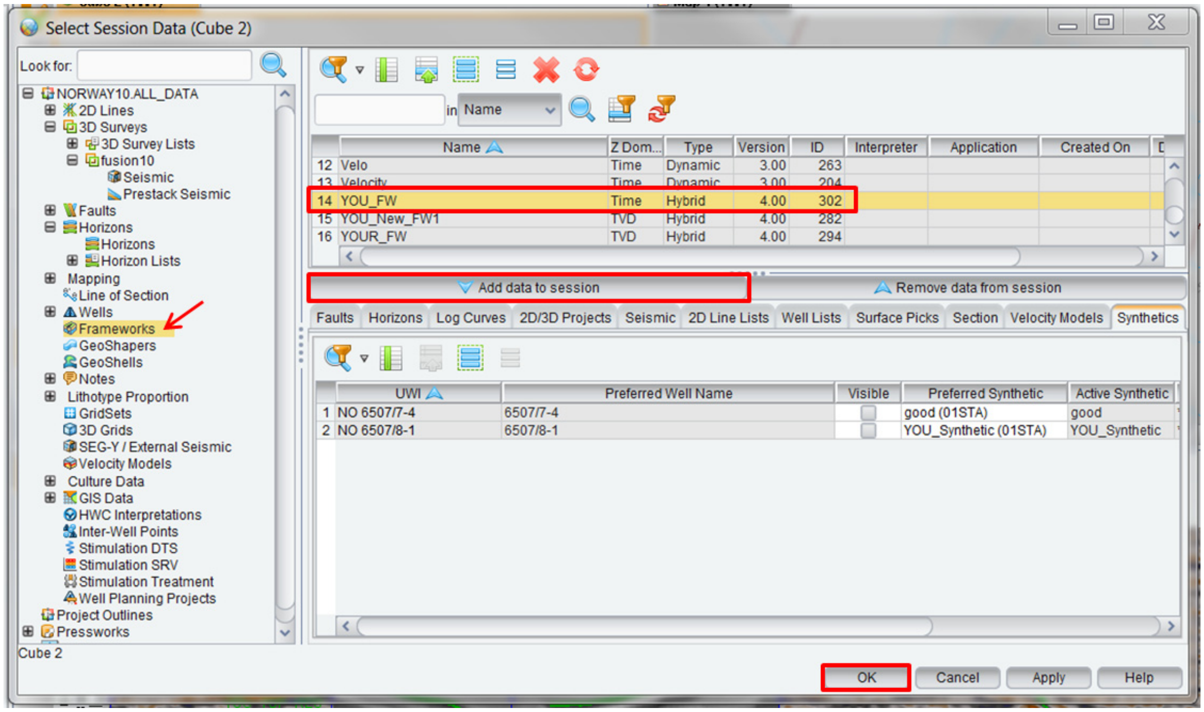
23. Interpret **YOU_TOP_RES** on the arbitrary line.



As previously done with fault interpretation, you are able to add your horizon into a framework after you have made just a few lines of interpretation. The software uses these points to grid a surface over the area containing interpretation, which can then be displayed in any of your views. This allows for both quick surface generation, as well as a way to QC your interpretation as it is being made.

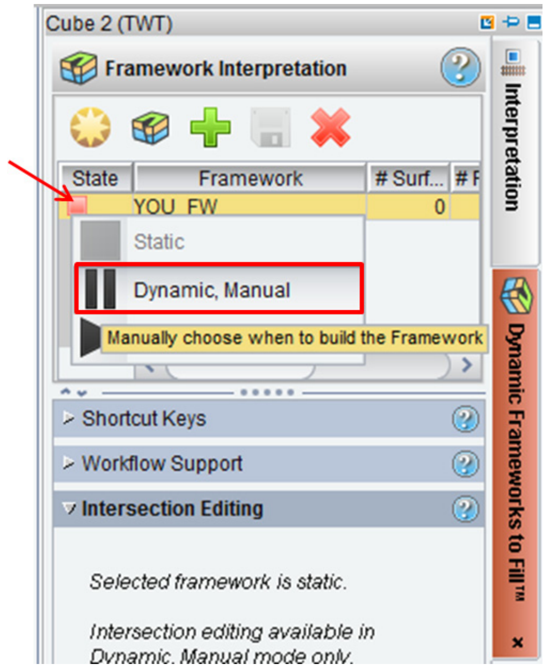
You will need to add your framework from the previous chapter into this session.

24. Go to **Select Session Data** ( ), and in the resulting dialog select **Frameworks > YOU_FW**. Click **Add data to session**, and then click **OK** to close the dialog.

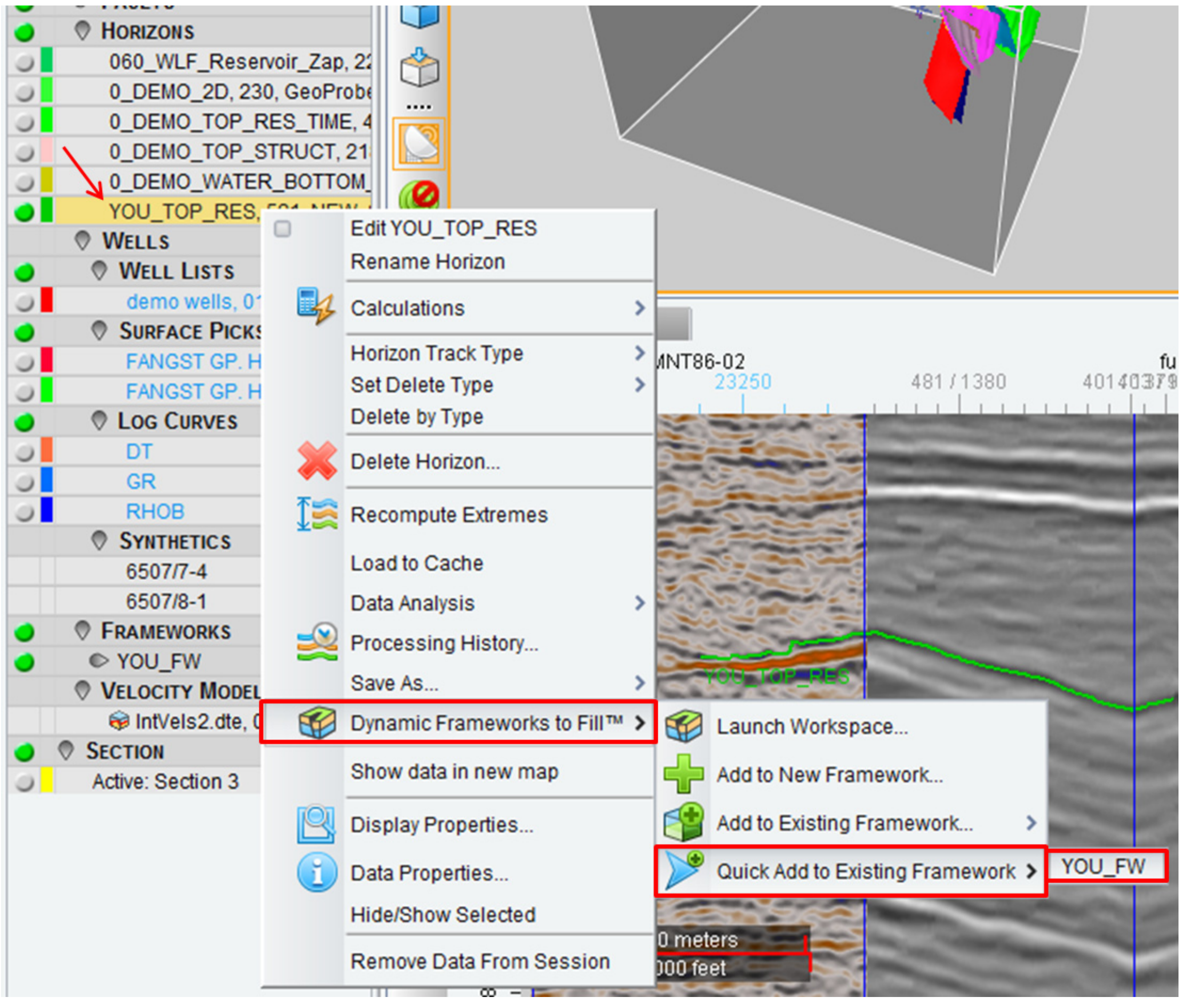


When a framework is added to a session, it is in Static mode, and therefore will not be communicating with the database. To add the horizon to your framework you will need to change the mode to either Dynamic, Manual or Dynamic, Auto Refresh.

25. In the *Dynamic Frameworks to Fill* task pane, click the red square under *State* to open a drop-down list and select **Dynamic, Manual**.

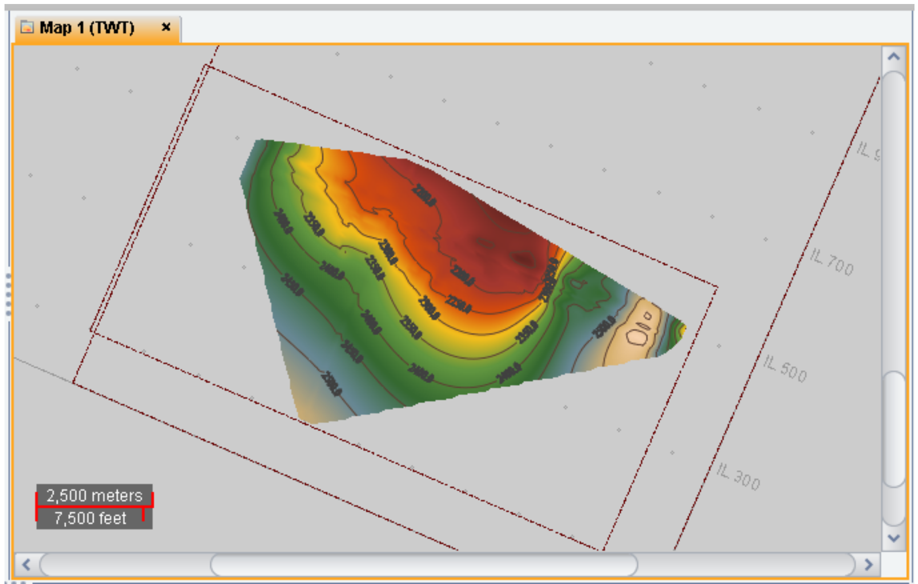


26. In your *Inventory*, **MB3** on **YOU_TOP_RES** and select **Dynamic Frameworks to Fill > Quick Add to Existing Framework > YOU_FW**.



Selecting Quick Add to Existing Framework does not give you the option to change how that object is used within your framework, and brings it in as the default. In the case of horizons, this default is a new surface.

27. When any changes are made to the framework while it is in Dynamic, Manual, an icon will appear to notify you that the framework needs to be refreshed. In the *Dynamic Frameworks to Fill* task pane click the **Refresh** ( ) icon. Display the new **YOU_TOP_RES** framework surface in *Map* view, and toggle off all other items.

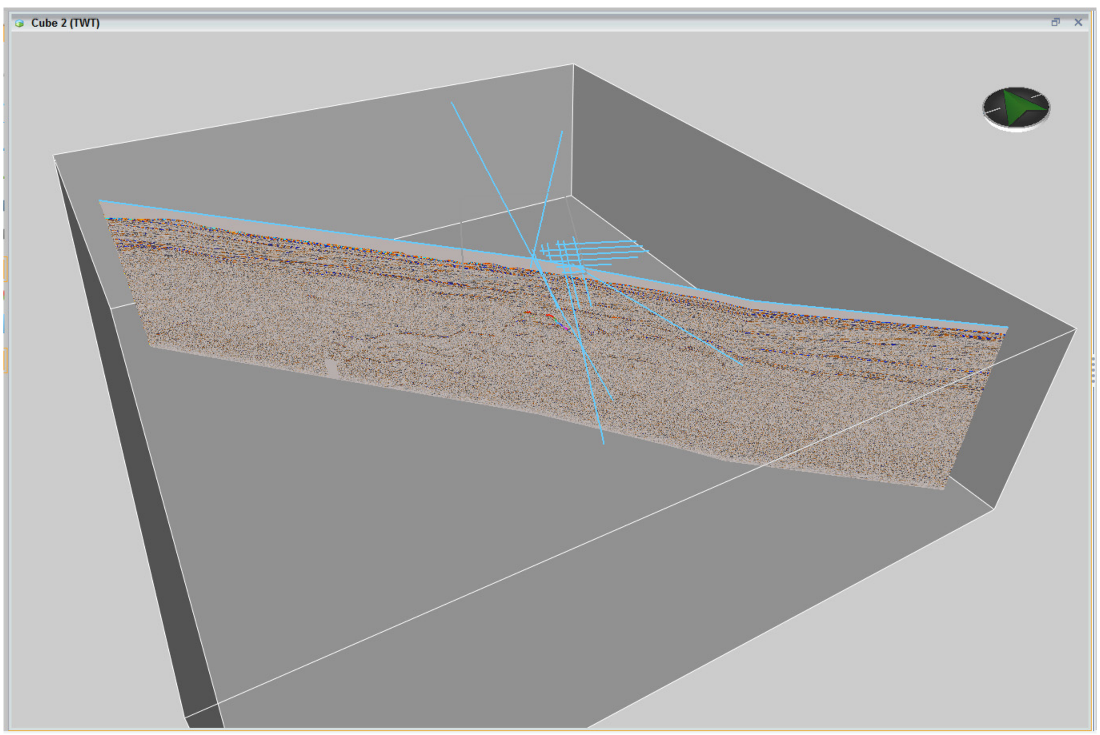


In this exercise, you have started interpretation of your horizon in *Section* view, using 2D seismic as well as Dynamic Frameworks to Fill to begin to QC the surface. In the next exercise, you will use the 2D lines that you have made interpretation along as a reference to continue your horizon interpretation in *Cube* view.

Exercise 4.2: Interpreting Horizons in *Cube* View

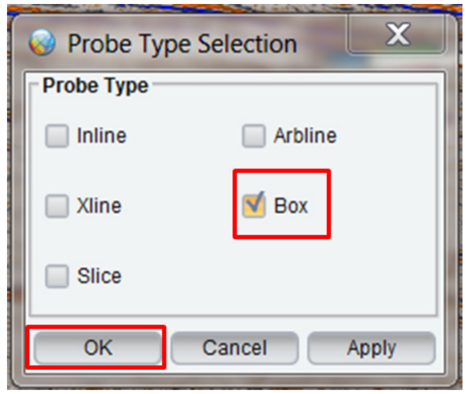
In the previous exercise, you began interpreting a new horizon on a maximum event and then loaded that horizon into your framework. Next, you will continue interpretation on a box probe in *Cube* view using the 2D line that contains your interpretation as a reference. As you add to your horizon, you will be able to watch your framework surface update in *Map* view.

1. Activate and maximize *Cube* view. In the *Inventory* task pane, toggle on horizon **YOU_TOP_RES** and the **2D Lines**. Locate 2D Line **MNT-86-02** and **MB2** to display.

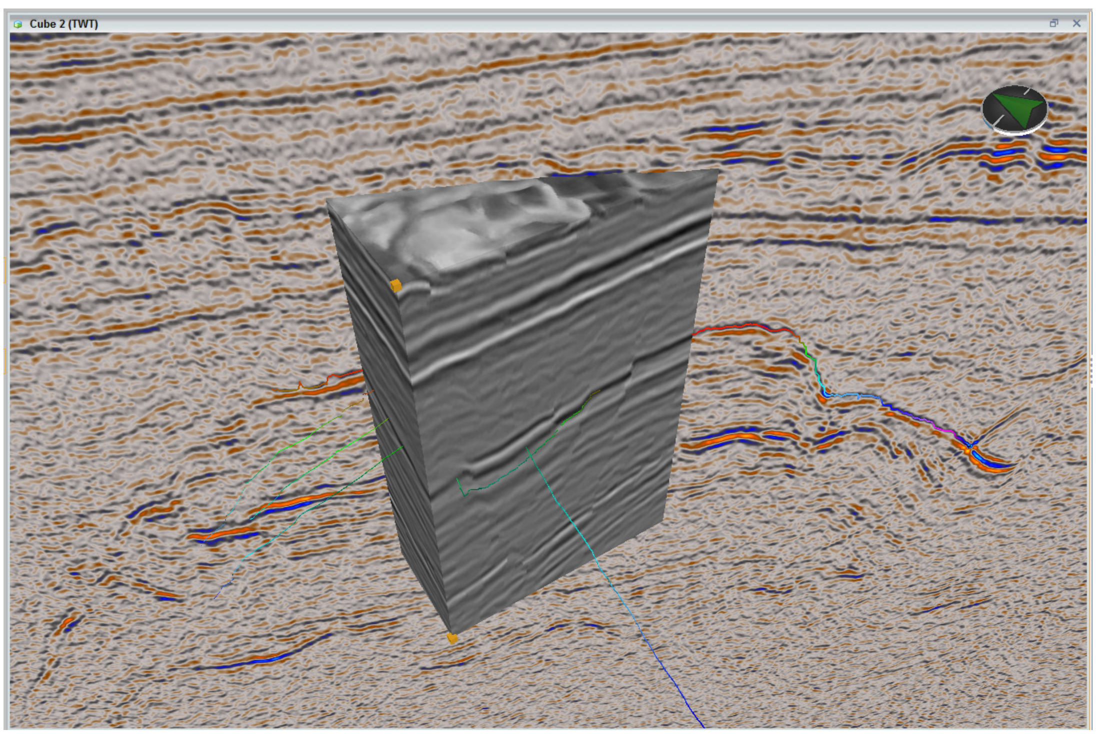


2. Load your seismic volume **full_offset.cmp_StrcFltr10x10** into shared memory by clicking **MB3** and then selecting **Load to Shared Memory...**. Click **OK** when the dialog opens. Close the *Shared Memory Manager* dialog when loading is complete.

3. Drag-and-drop the shared memory volume into *Cube* view, and select only **Box** in the *Probe Type Selection* dialog. Click **OK**.



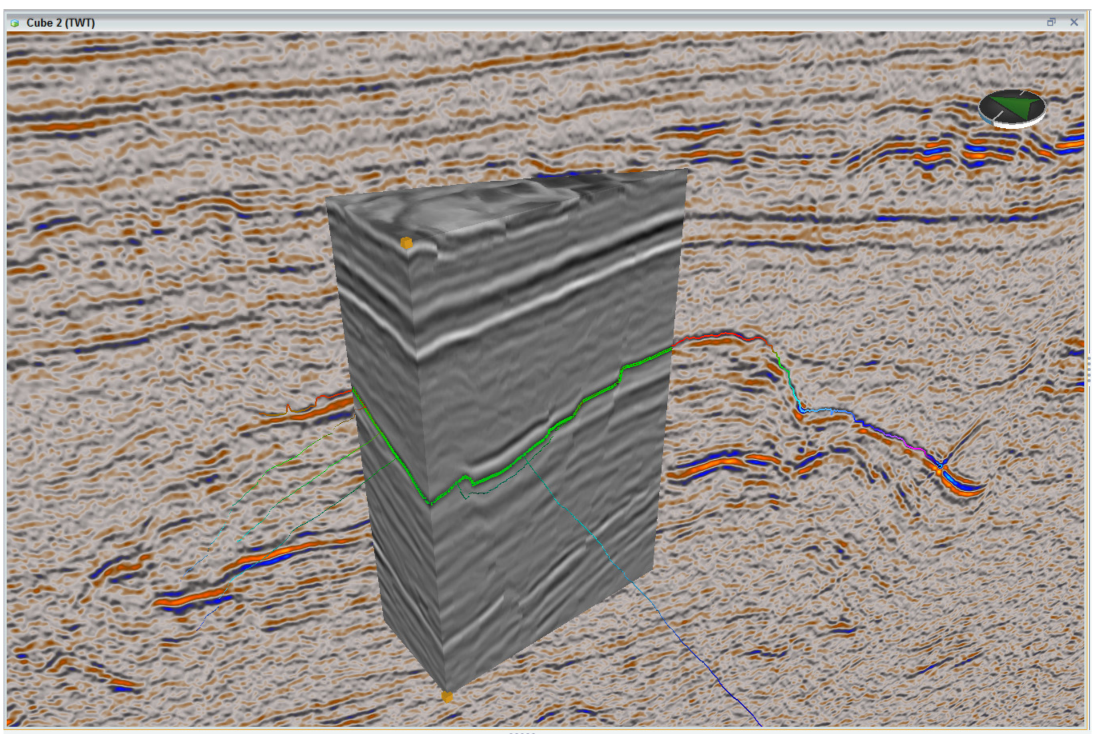
4. Press the expert key <**x**> to expand the probe to its full extents. Arrange your *Cube* view so that the probe is intersecting the 2D line. You can then use the interpretation of YOU_TOP_RES on the 2D line as reference for your interpretation on the 3D volume.



> **Note**
>
> The box probe will be in greyscale through this exercise so it is easier to visualize the interpreted lines. To change the color map of your probe, **MB3** and select **Display Properties**, and click the color map drop-down menu to select **System > Greyscale**.

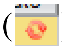
The process of interpretation on a probe face in *Cube* view functions the same as it does in *Section* view. In the following steps, you will begin your interpretation along the 3D volume.

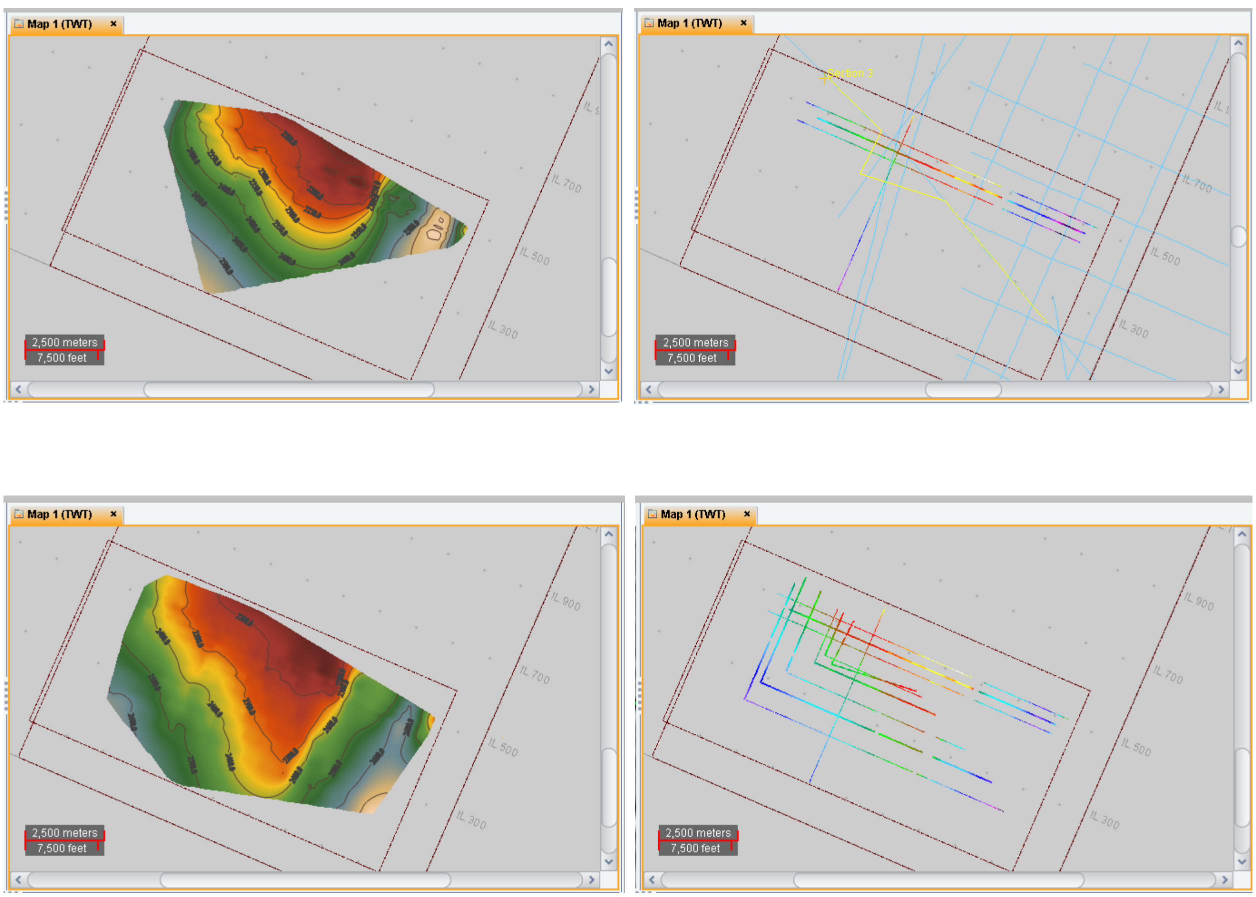
5. In the *Interpretation* toolbar, turn on **Interpretation Mode** (), ensure that the data type is designated as Horizons, and the object is YOU_TOP_RES. Use the segments on the 2D line as a guide to continue interpreting horizon **YOU_TOP_RES** on the faces of the probe. Interpret around the edges of the probe. You can rotate the probe by holding down **ALT**.



6. Move the probe faces towards you by holding **MB1+<Shift>** and drag. Do this several more times to continue the interpretation.

> **Note**
>
> You can also hold down <**z**> while in interpretation mode which will allow you to use the Select/Drag mode to move the entire probe manually. When you let go of <**z**>, the cursor will return to interpretation mode.

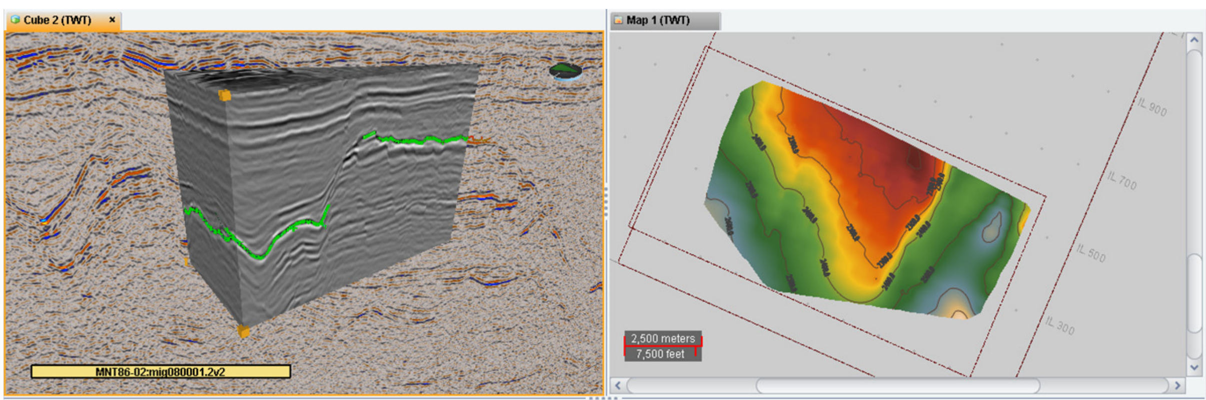
7. Minimize the *Cube* view so that you can see *Map* view again. In the *Dynamic Frameworks to Fill* task pane, click the **Refresh** () icon for your framework. Refreshing your framework incorporates the changes that have been made to your horizon, and will re-grid the framework surface to reflect those changes.



The previous picture shows a before (from exercise 4.1) and after of the framework surface after several additions of interpretation on the probe in *Cube* view. The horizon interpretation associated with the framework surface is also displayed for reference.

> **Note**
>
> If the framework does not show that it can be refreshed, go to the *Horizon Interpretation* task pane and click the **Save horizon changes to the database** () icon. You must save the changes, before the framework can find the edits and incorporate the changes.

8. Rotate your *Cube* view so you are viewing the opposite side of the 2D line, and continue making the interpretation on that side of the box probe. Once you are satisfied with your interpretation click the **Refresh** icon for your framework to update your surface.



The framework surface is a representation of the segments you have interpreted in *Section* and *Cube* views. In the following exercise, you will use those segments to track small areas of the horizon using the Area Track! tool.

Using Area Track! and ezTracker Plus

Once the horizon interpretation is complete and seed points are created, you can auto track the horizon to quickly interpret across a selected area.

Area Track! automatically extends your interpretation of an active horizon for a specified area. Typically, Area Track! is used as a quick way to look at a specific region of your horizon or to test the tracking parameters prior to using ezTracker Plus, which is used to track the entire survey area. The basic workflow is to interpret on a single line and track forward and backward from that line for a specified number of lines. Review the output in *Map* view, then move to the edge of the tracked area, and track again. If there is a problem with the tracked horizon (for instance, no data in a new fault block, or tracking jumped a loop), you can reinterpret in *Section* view, and then retrack using the corrected interpretation as input. Although the typical workflow is to use a segment of the horizon for input in to Area Track!, it is also possible to use a seed point on a probe in *Cube* view.

ezTracker Plus is the DecisionSpace Geosciences' customizable auto-tracking tool that, as previously mentioned, is used to track a horizon within the entire survey. This tool is more versatile than Area Track!, allowing you to change the seismic survey you want to track on, block the tracking across certain objects or amplitudes, and produce output horizons detailing the tracking process.

When tracking a horizon with the auto tracking tools, certain specifications need to be determined for the way in which the software picks traces. The slider available in both Area Track! and ezTracker Plus (found in the Tracking tab) considers the parameters necessary to track the horizon at a high quality or in a faster time. Sliding to either end of the spectrum will change the Tile Size and Score.

In the tracking dialog, beginning and end tile sizes are specified, and then the software uses those parameters to iteratively track the horizon with the different tile sizes. The tracker begins with the Starting Tile Size, and uses the trace at the center of the tile to perform a cross correlation calculation with every other trace within that tile. The cross correlation is normalized to a number between 0 and 100, which will then be compared to the specified score. If the correlation is larger than the score, the score is met, and the tracker will move to the next trace. The area of that tile will be tracked once the score has been met for every trace in the tile. It is important to take in to account that if even one comparison fails, the *entire* tile will not be tracked. After the tracker has attempted to track the specified region using that tile size, the next iteration starts with a tile size 2 less than the previous size. This process continues until the Ending Tile Size is reached.

The closer you move the slider to Fast, the smaller the tiles sizes and the lower the score. Use these values for strong reflectors and less faulted data. High quality starts tracking with larger tiles and a higher score. Use these values for discontinuous reflectors and heavily faulted seismic data. The parameter definitions are as follows:

- Tile Size—The tile size is specified by a number of lines and traces. For example, a tile size of 11 would be a square of 11 lines by 11 traces. The minimum tile size is 3x3.

- Starting and Ending tile size—As you move the slider, these values change dynamically, but it is possible to specify them manually. The tracker performs iterative tracking by beginning with the Starting Tile Size and reducing the size by 2 until it reaches the Ending Tile Size.

- Score—This option defines how aggressively the tool tracks the data. The tracker performs a cross correlation and compares that to the score. A match is made if the score is met. A higher score is more difficult to meet, and means the tracker is more selective in what it tracks.

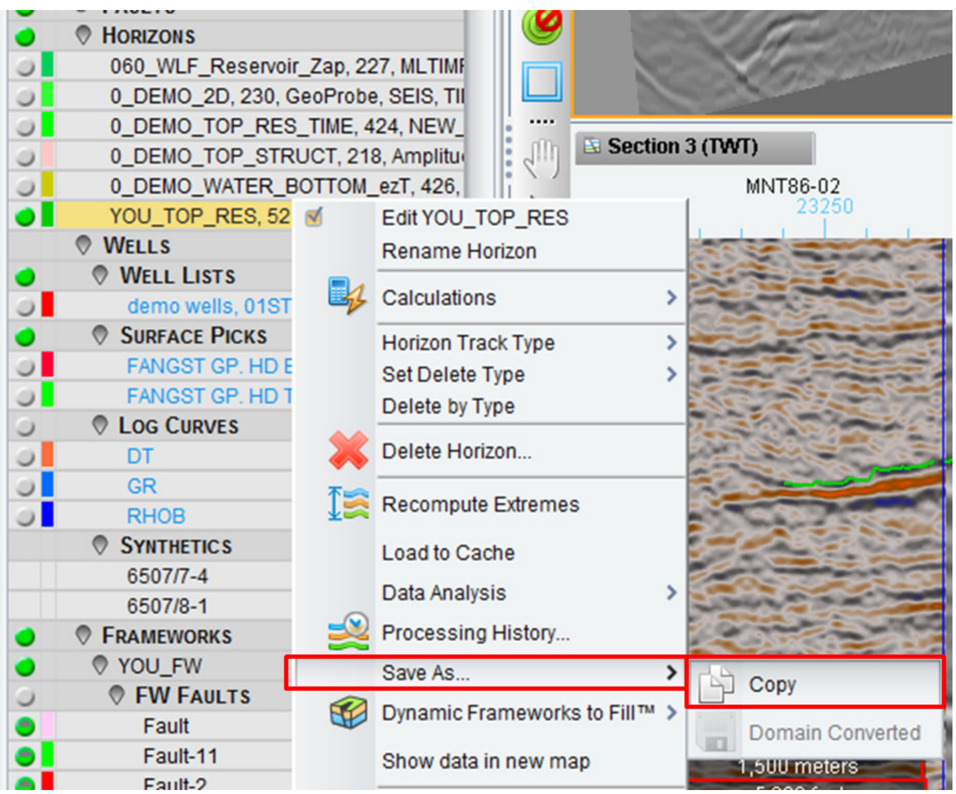
Details regarding maximum jump, correlation window, doublets and block at faults is also included in the background information before Exercise 4.1. For more detailed information on any of the topics here, see the Help pages associated with each auto tracking tool.

Exercise 4.3: Area Track!

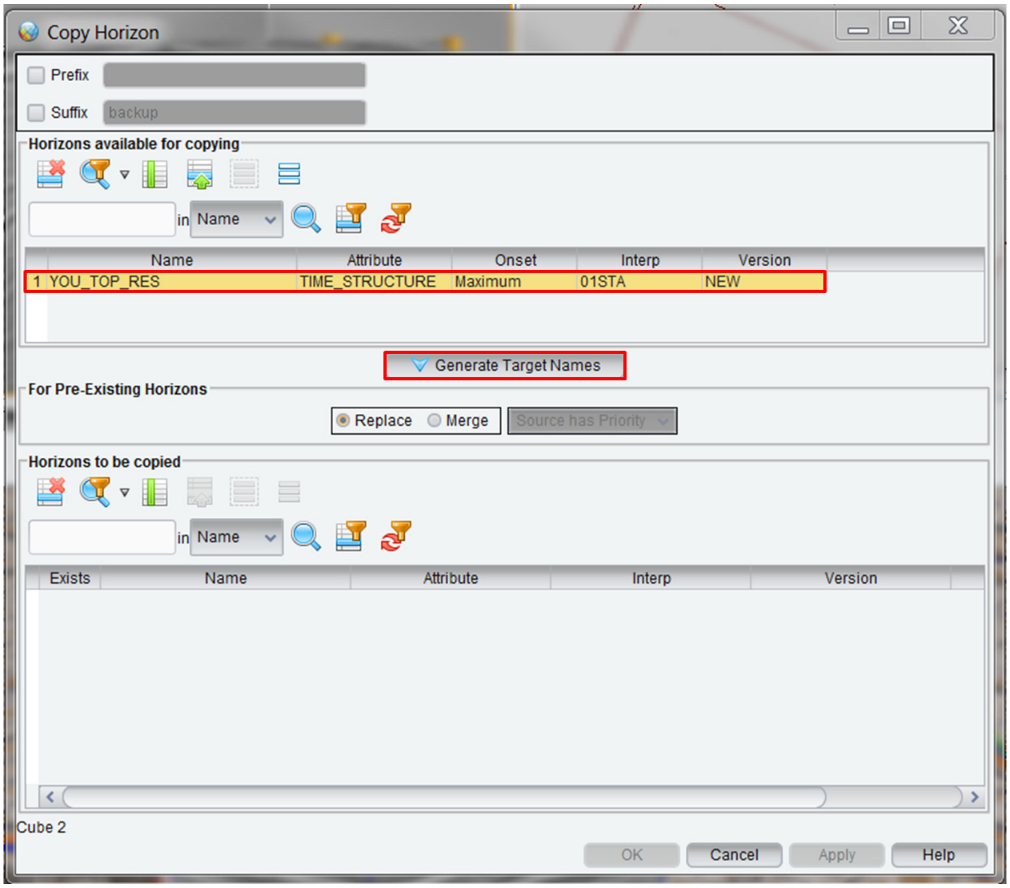
In previous exercises, you learned to interpret a few segments of a horizon in both *Section* and *Cube* view. There are several actions in *Horizon Interpretation* that allow you to track your horizon within small, specific areas. In this exercise, you will learn how to use the Area Track! and Polygon Track!, which are very useful when you need to get an idea of how your horizon appears in a specific region of the survey. It can also be used as a predecessor to determine the parameters to be used in ezTracker Plus.

When using the auto tracking tools, the output default is to override the input horizon. A good practice is to make a copy of your seed horizon before using the auto tracking tools. This will preserve your original interpretation and be a safeguard in the event of you forgetting to change the output selection in the *Area Track* dialog.

1. In the *Inventory* task pane, **MB3** on the horizon **YOU_TOP_RES** and select **Save as... > Copy**.

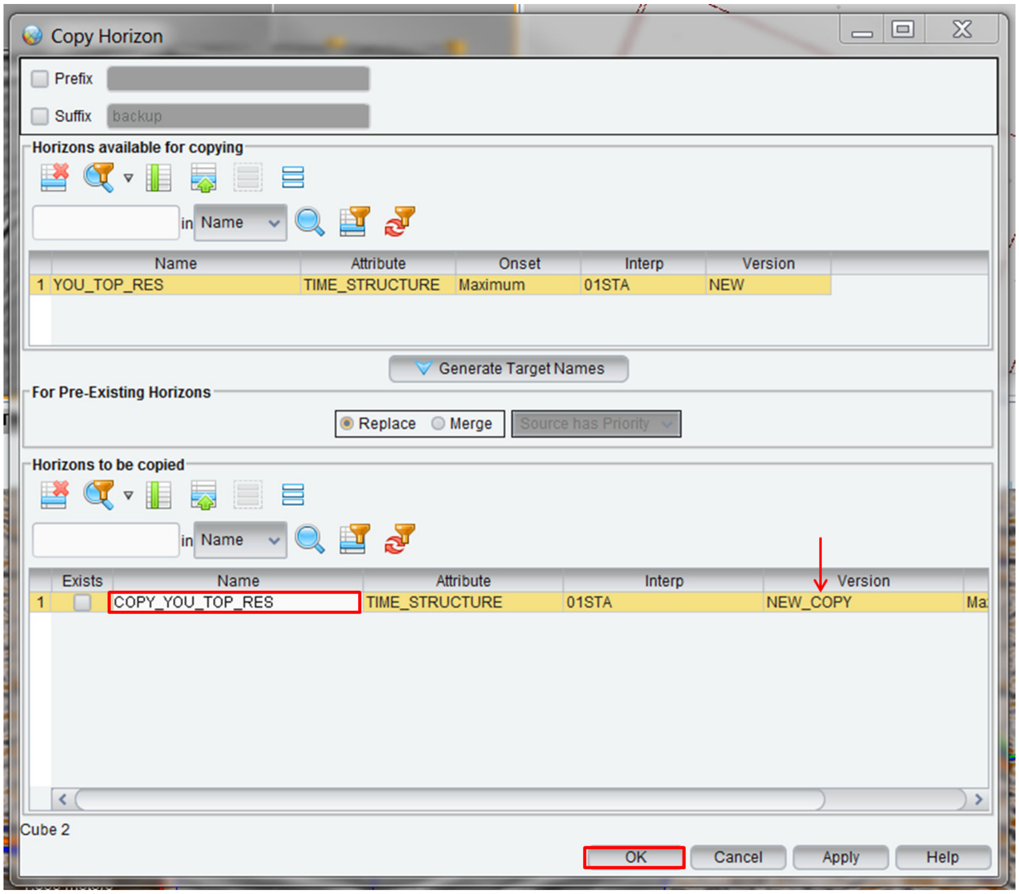


2. In the *Copy Horizon* dialog, select **YOU_TOP_RES** in the upper panel and then click **Generate Target Names**.



Once you click Generate Target Names, a copy of the horizon appears in the lower panel. You are now able to edit the name and version. In the *Version* column, notice that the horizon is appended to say "NEW_COPY," however the *Name* column has the identical name of the original horizon. You will change the name as well to make sure the two horizons are easily distinguishable in the *Inventory*.

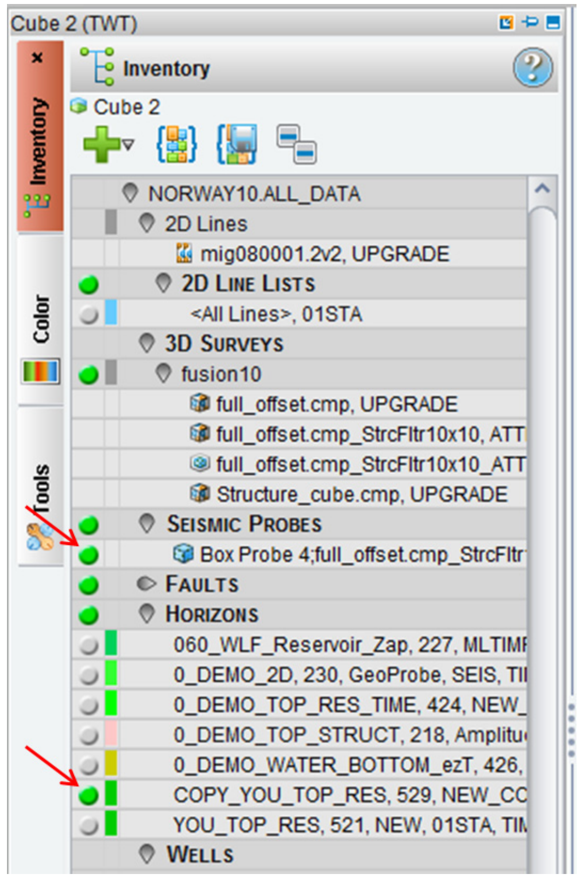
3. In the lower panel in the *Name* column, double-click **YOU_TOP_RES**, and change the name to "**COPY_YOU_TOP_RES**." Click **OK** to create the new horizon.



You will use COPY_YOU_TOP_RES as the active horizon for Area Track! to preserve your original interpreted seed horizon. In the last exercise, you began interpreting your horizon in *Cube* view using auto line pickers. Seed point is another interpretation mode available in *Cube* view. With this mode active, you can place a point on a probe face at a specific reflector to be used as an input for Area Track!.

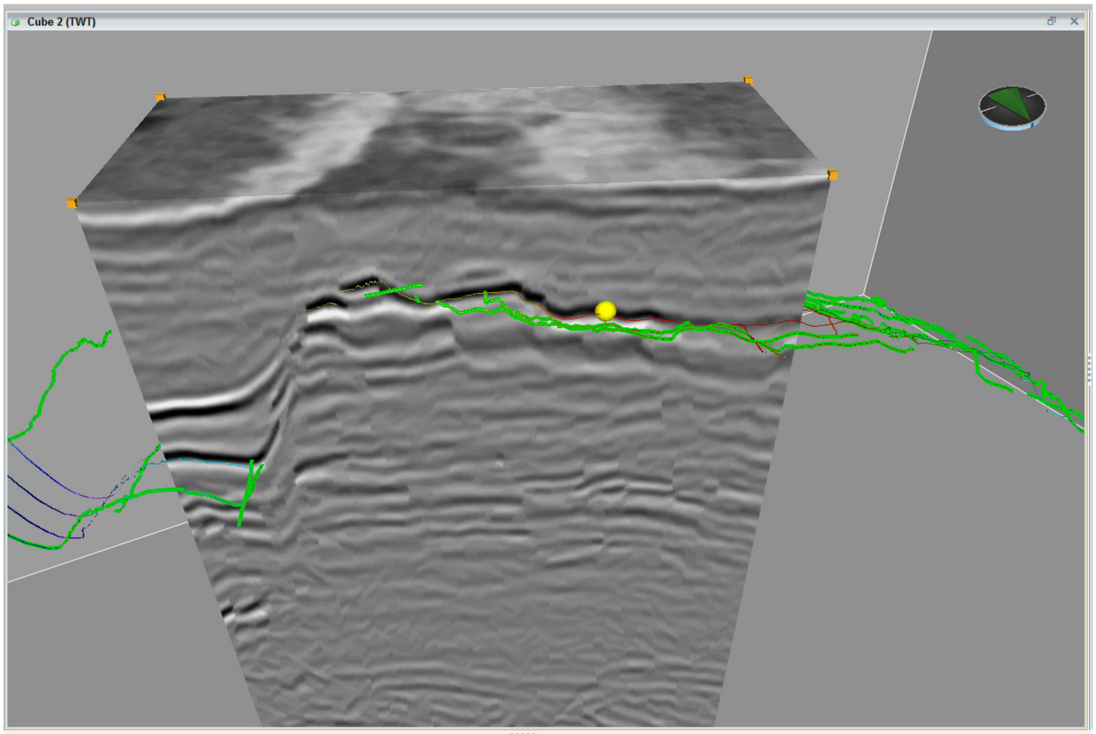
In the next few steps, you will place a seed point and then experiment with different tracking parameters to determine which is be best for your project.

4. With your *Cube* view active, toggle off **YOU_TOP_RES** and the 2D Lines in the *Inventory*, and ensure **COPY_YOU_TOP_RES** and **Box Probe** are toggled on.



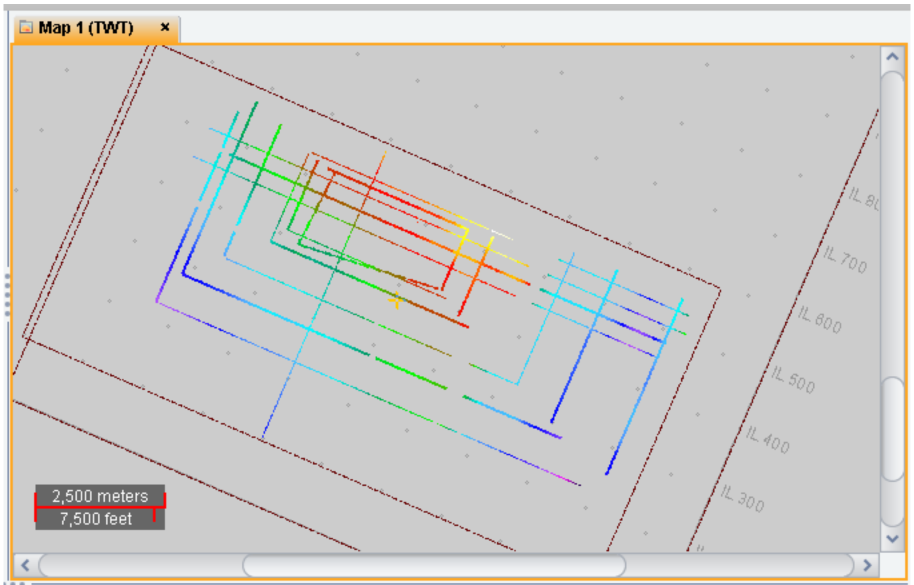
5. In the *Interpretation* toolbar, turn on **Interpretation Mode**, and change the action to **Seed Point**.

6. Move your box probe face to display **IL 500** and **MB1+<Ctrl>** to add a seed point on the reflector in a spot similar to the picture below.

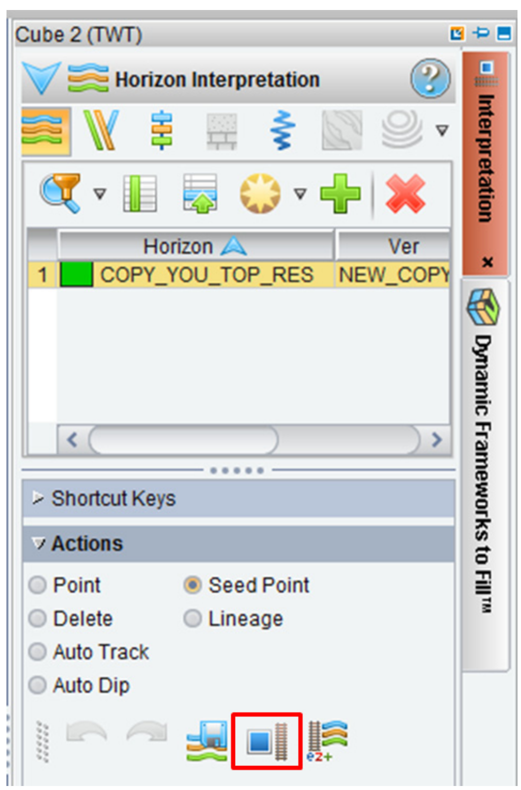


7. Activate *Map* view, toggle off the FW Surface and YOU_TOP_RES, if they are on, and toggle on the **COPY_YOU_TOP_RES** horizon in your *Inventory* task pane.

8. Area Track! shows a preview of the area that will be tracked in your *Map* view. Zoom in to have a better view of your survey area.



9. Activate *Cube* view and in the *Horizon Interpretation* task pane, **COPY_YOU_TOP_RES** should be the active horizon. In the *Actions* panel click the **Area Track!** ( ) icon.



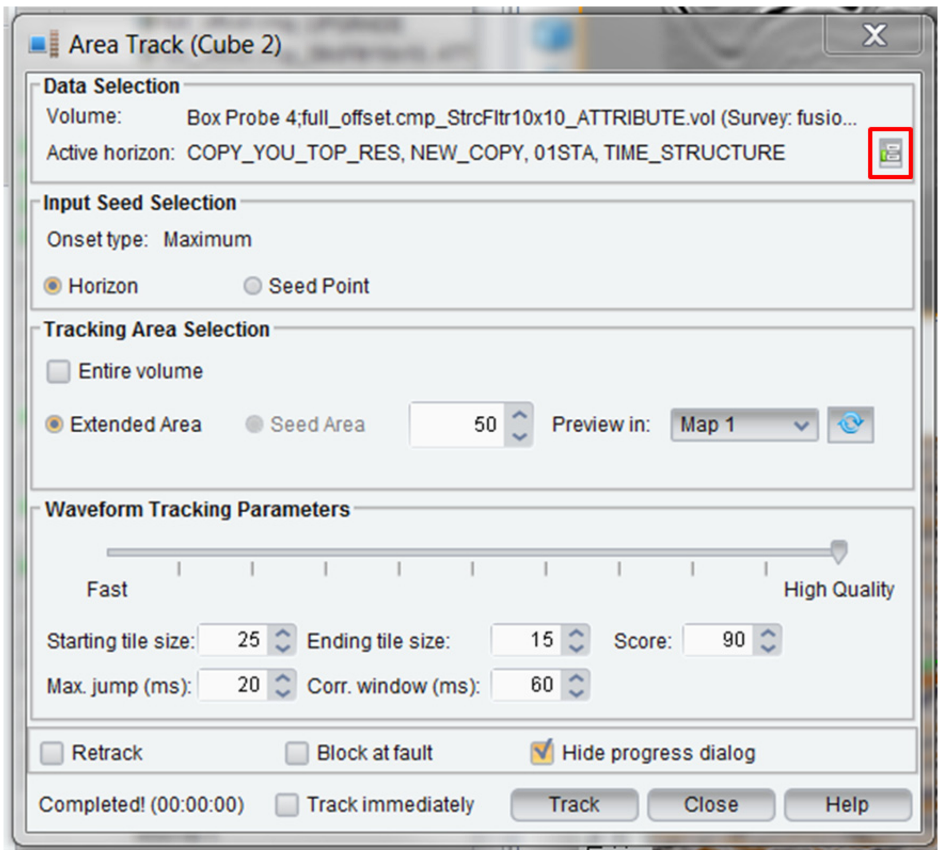
The Area Track! default parameters for the *Data Selection* panel are:

- Volume—The seismic volume associated with the probe active in your *Cube* view.

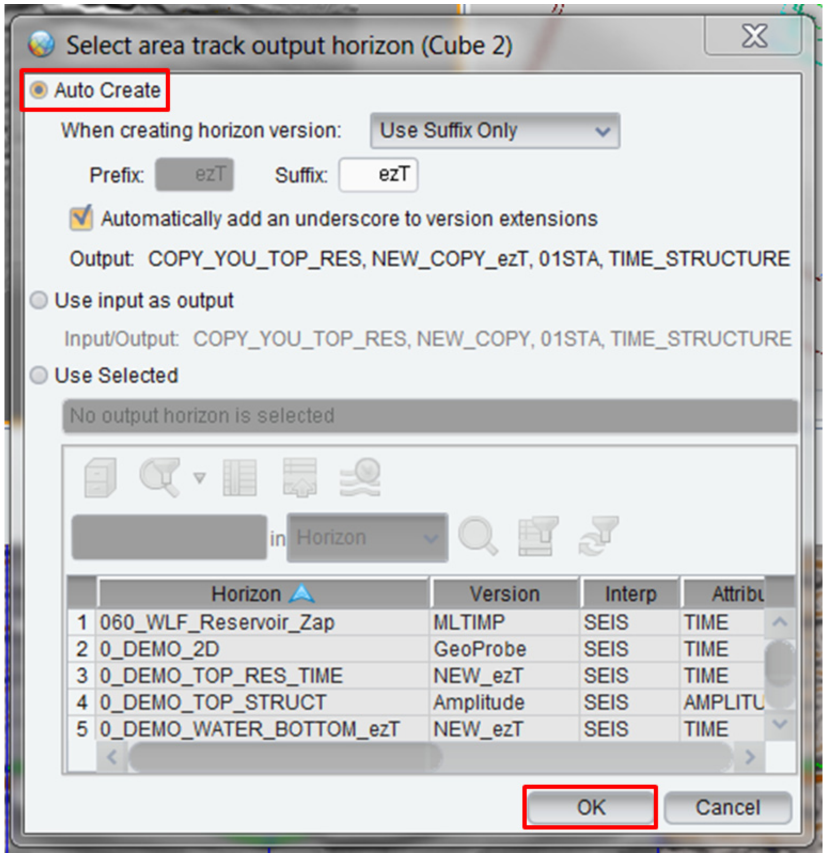
- Active Horizon—The horizon highlighted in the *Horizons Interpretation* task pane when you opened Area Track!.

As mentioned earlier, the default output horizon for Area Track! will be your input horizon, so you will be tracking over the original input.

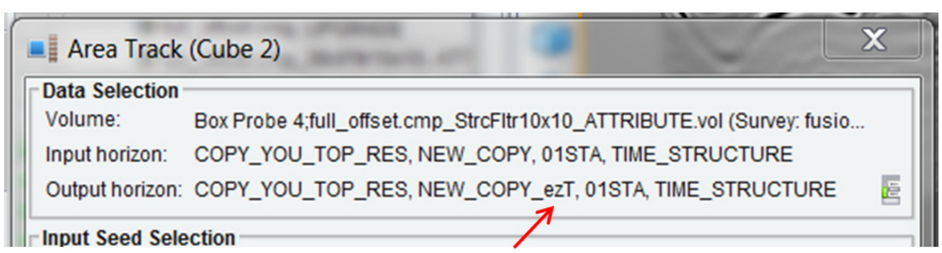
10. To change the output horizon, you need to click the **Select output horizon** ( ) icon to the right of the horizon name.



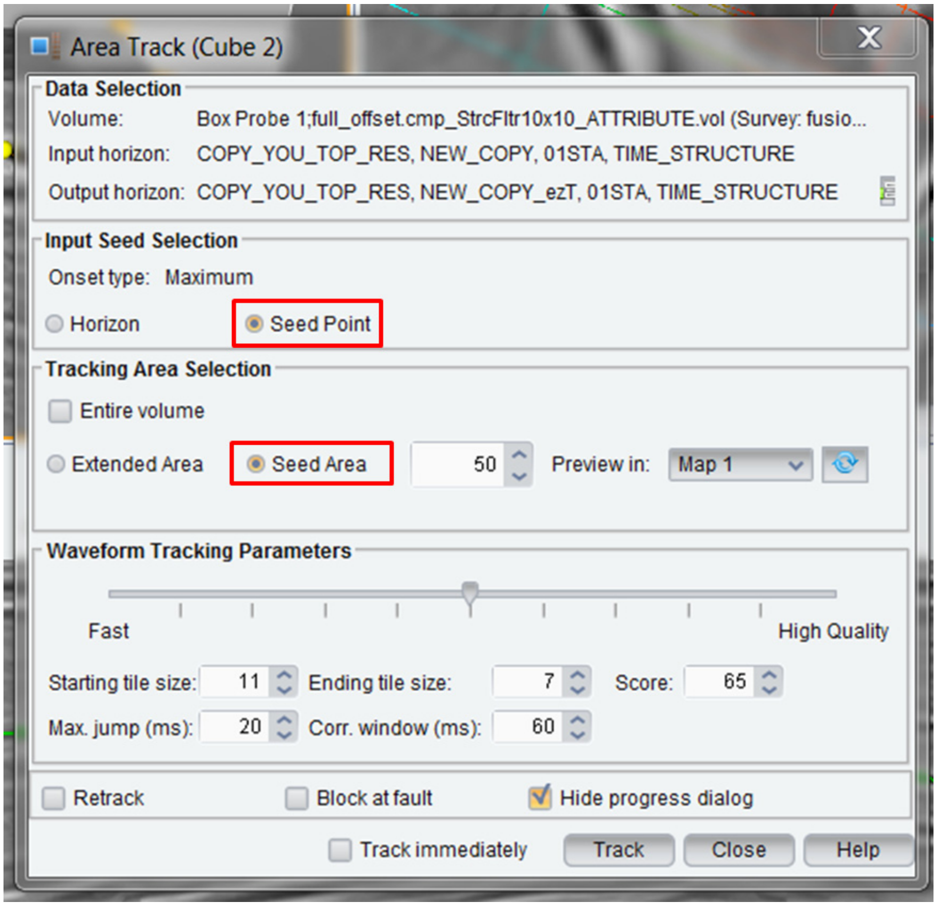
11. In the *Select area track output horizon* dialog, select **Auto Create** to have the software create a new horizon as the output with the suffix ezT appended to the version name. Click **OK** to return to the *Area Track* dialog.



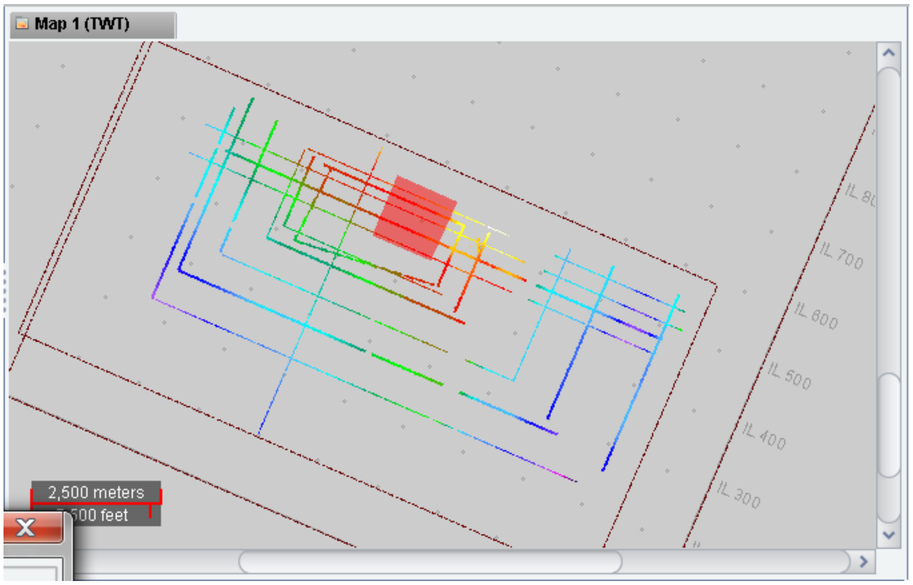
The *Data Selection* panel is now updated to show an *Output horizon* with the appended ezT.



12. In the *Input Seed Selection* panel, select **Seed Point**. The *Onset type* is taken from your input horizon details. In the *Tracking Area Selection* panel, select **Seed Area**. This allows the software to track a specific distance centered on and around your seed point. Keep the default distance of 50 m.



In your *Map* view, you will see a preview of what area will be tracked. Your preview should be similar to the one in the picture below.

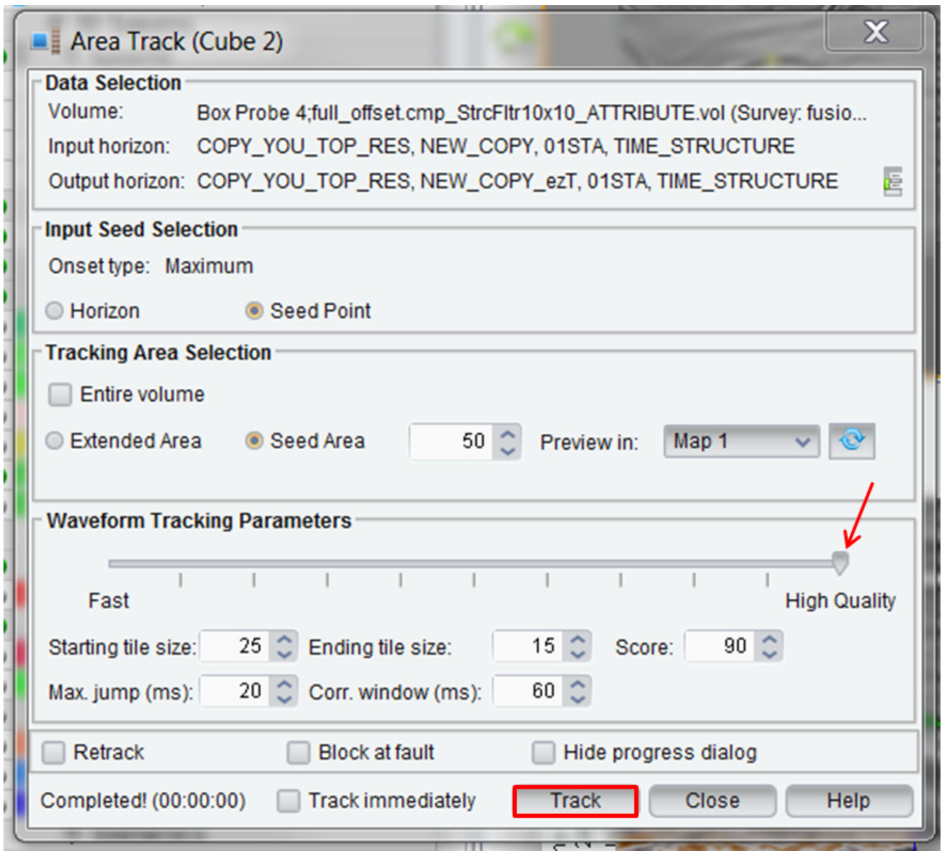


> **Note**
>
> If you do not see a red box indicating the preview area, you may need to click the **Refresh Map view highlight** ( ) button in the *Tracking Area Selection* panel of the *Area Track* dialog.

As mentioned in the background theory before the exercise, the *Waveform Tracking Parameters* panel of the *Area Track* dialog defines the tracking parameters you will use to track the horizon. There is a slider bar that you can move between tracking High Quality or Fast. Moving the slider towards High Quality will increase the tile size and score necessary to track a specific area, while moving it towards Fast will decrease those parameters. A higher score will result in more selective tracking meaning noisy, highly faulted, or poor quality data is less likely to be tracked. This may lead to a horizon you have more confidence in, but it may also be poorly resolved. Conversely, having a low tracking score will decrease the standards in which points are being selected but likely allow for the entire extent of the area of interest to be tracked. Due to the lower standards of tracking it is important to QC the output in order to ensure that all points chosen represent the horizon accurately.

In the next few steps, you will experiment with both options to determine which parameters best fit your horizon. Often, you will try different combinations of tile size and score to reach a fit that falls somewhere between High Quality and Fast on the slider bar.

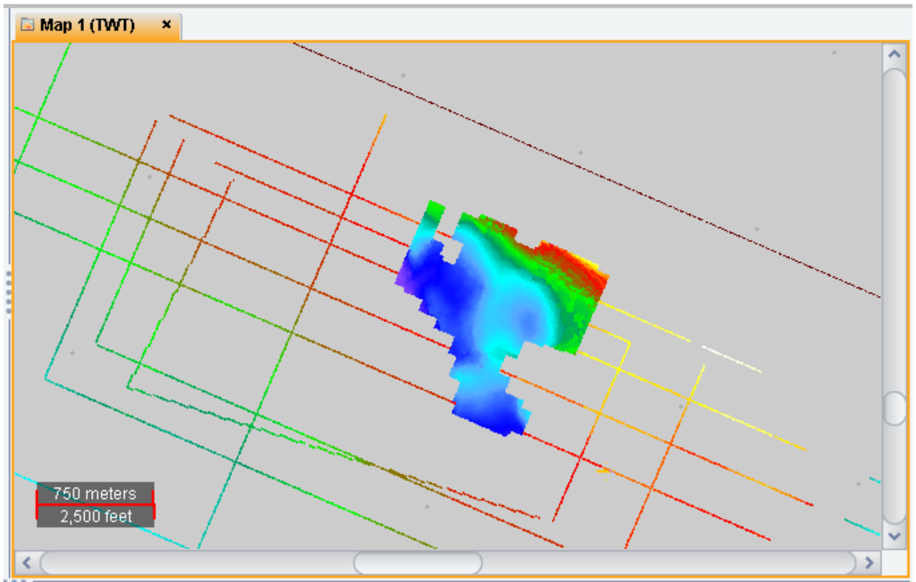
13. Move the slider all the way to the right so it is set at **High Quality**. Accept all of the defaults, noting that the tile sizes and score are large, and the starting and ending tile sizes are different. The software will perform multiple iterations of tracking starting with a size of 25 and ending at 15. Click **Track**.



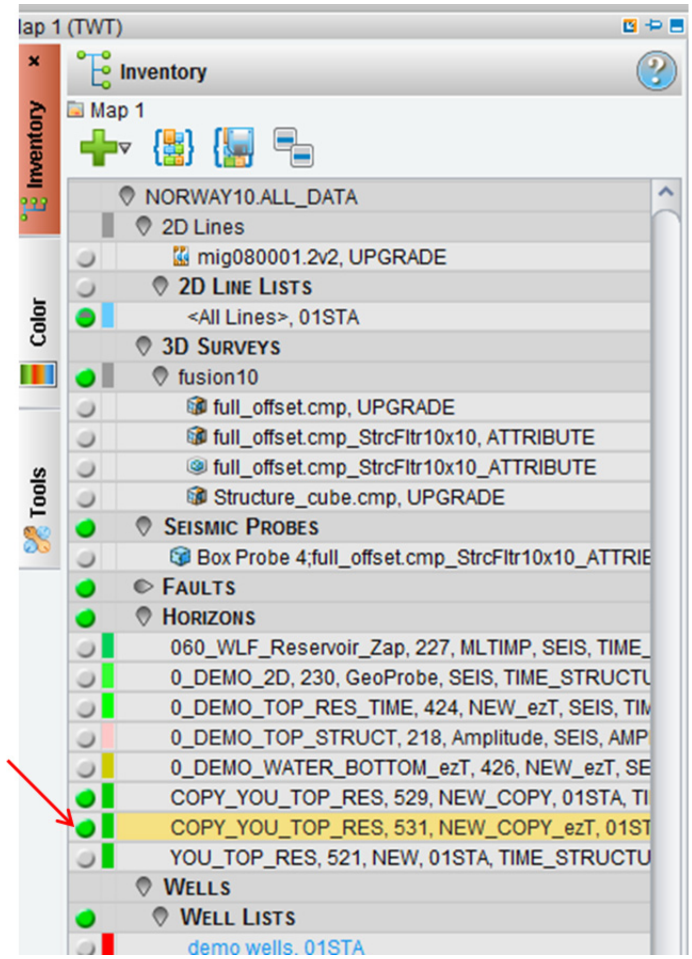
> **Note**
>
> If the Track button is greyed out, Interpretation Mode needs to be turned on in *Cube* view.

The *Area/Polygon Track Progress* dialog opens, and the tracked area of the horizon appears in your *Map* and *Cube* views.

14. When tracking is done, observe that there are areas of the box that were not tracked. Most likely, this is a faulted region of the seismic data, and the score could not be met in order for tracking to be completed, which resulted in no tracking.



There will also be a new horizon in your *Inventory* called COPY_YOU_TOP_RES, NEW_COPY_ezT.

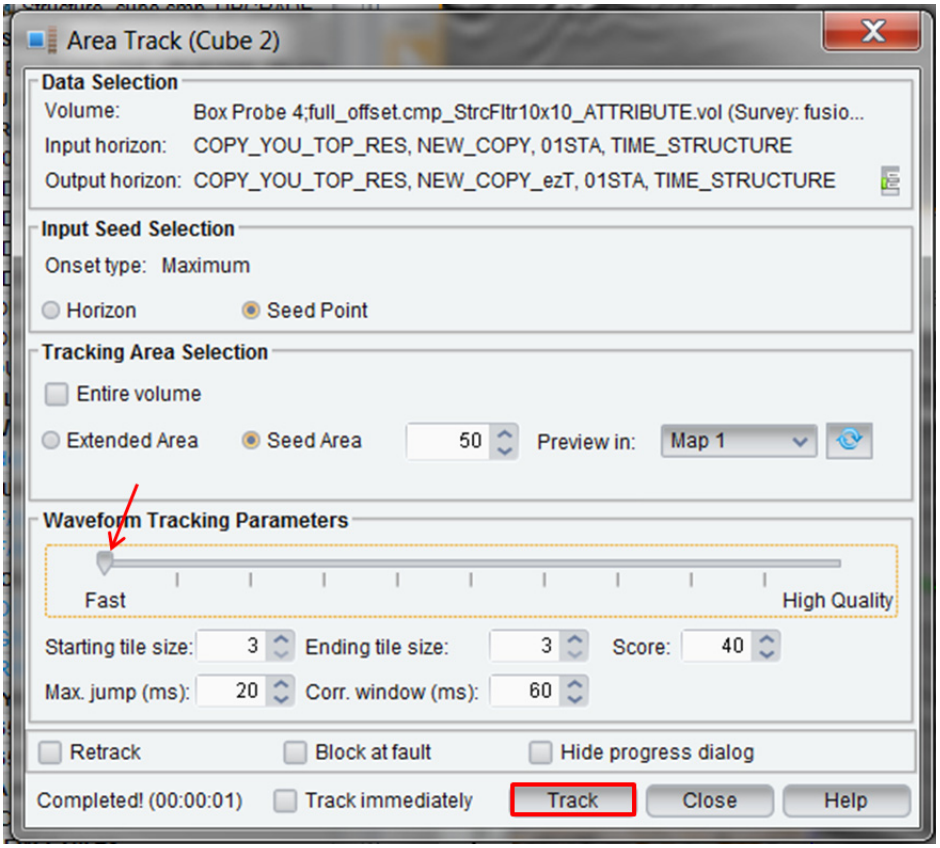


You will now track the same area using different parameters.

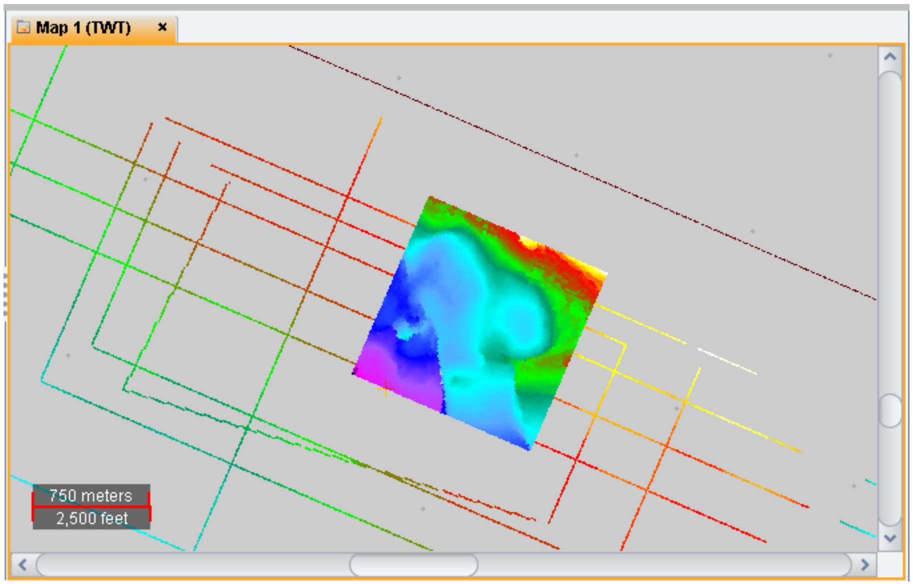
15. In the *Interpretation* task pane, in the *Actions* panel, click the **Undo** ( ) button.

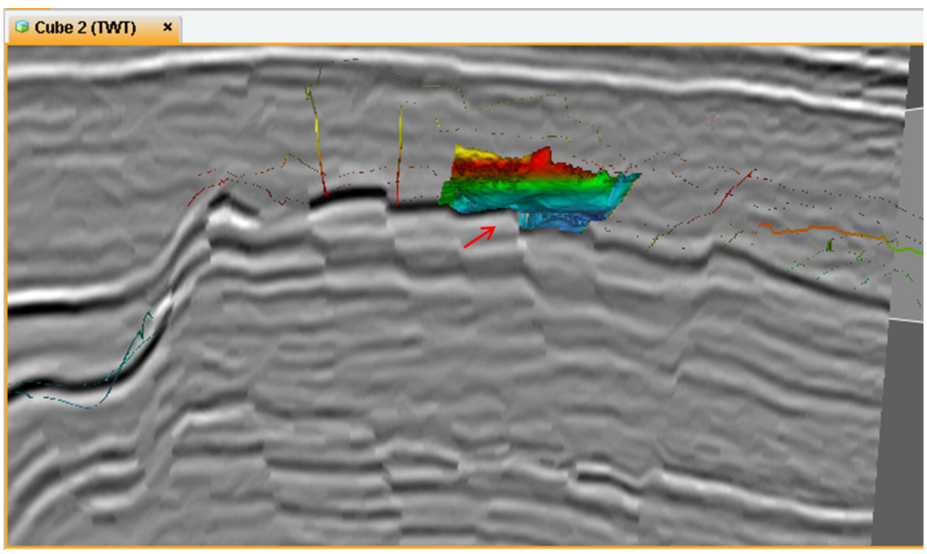
> **Note**
>
> The undo action is unavailable if the horizon changes are saved. Horizon changes are saved when you click the **Save horizon changes to the database** icon, you wait longer than 10 minutes, or you switch out of that specific horizon interpretation.

16. In the *Area Track* dialog, move the slider bar to **Fast**. The increase in tracking speed is due to the fact that multiple iterations of the calculation will not be performed. This is because the starting and ending tile sizes are the same. Also, note the change to a smaller tile size and lower score, which will result in more extensive coverage due to less strict criteria. Click **Track**.



17. Observe the results of the Fast Area Track! in *Map* view and notice that the entire area has been tracked with no gaps. Comparing your seismic volume in *Cube* view to your output shows a faulted area has been tracked over. Therefore, in this particular case you cannot be confident with the output of this particular area track. This shows the importance of being familiar with the geology in your project.

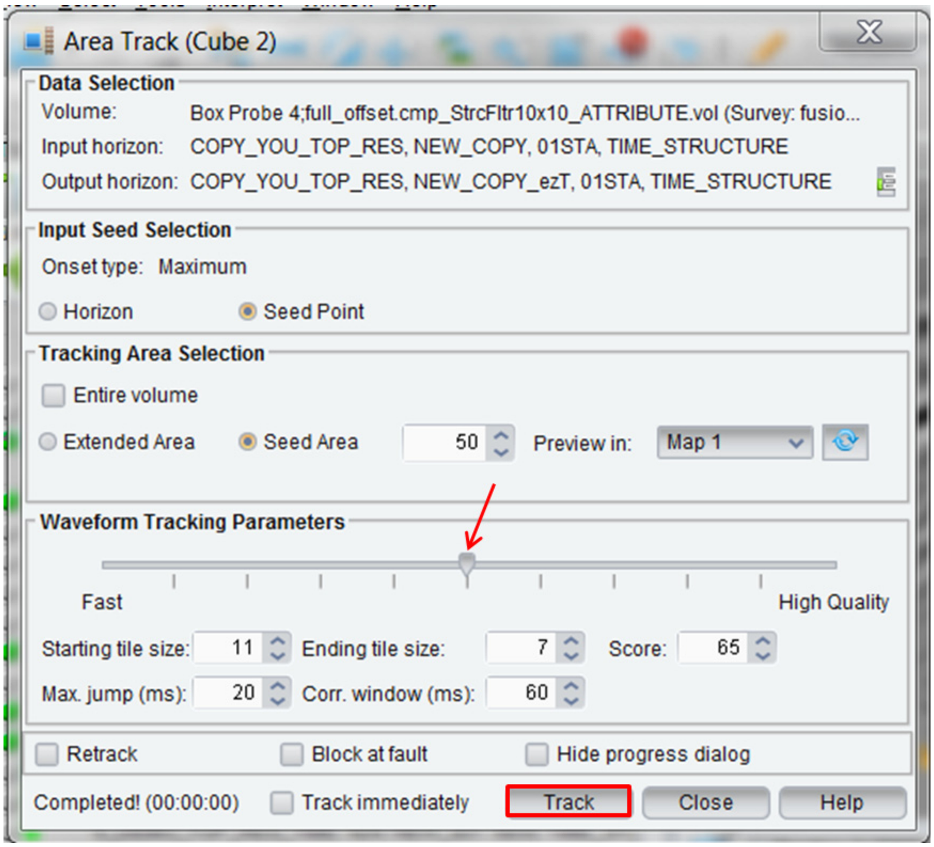




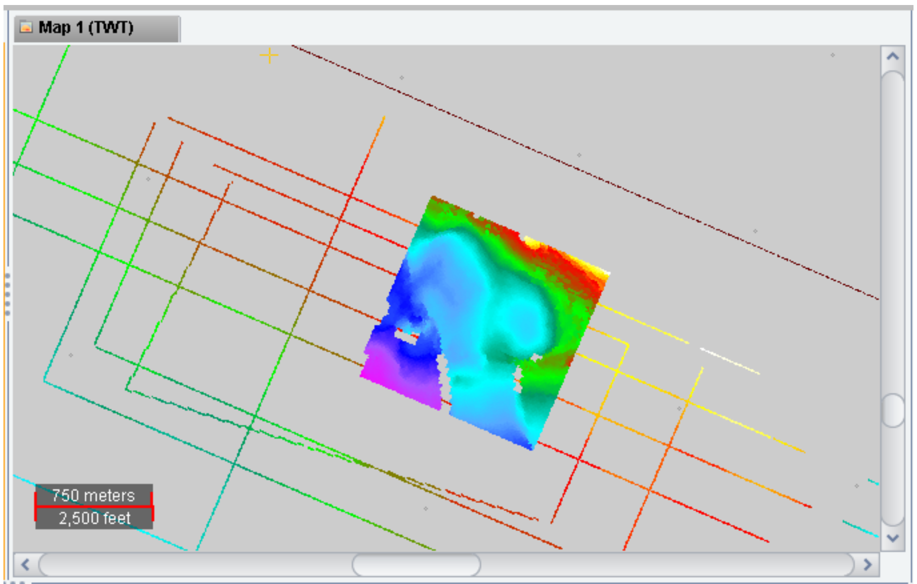
18. Click the **Undo** ( ) button again in the *Area Track* dialog.

You will now run the tracking with the default parameters.

19. Move the slider bar to the middle. Tile sizes have decreased from the High Quality setting, but still allow for multiple iterations. The score also falls at a middle point, between the two end-members. Click **Track**.



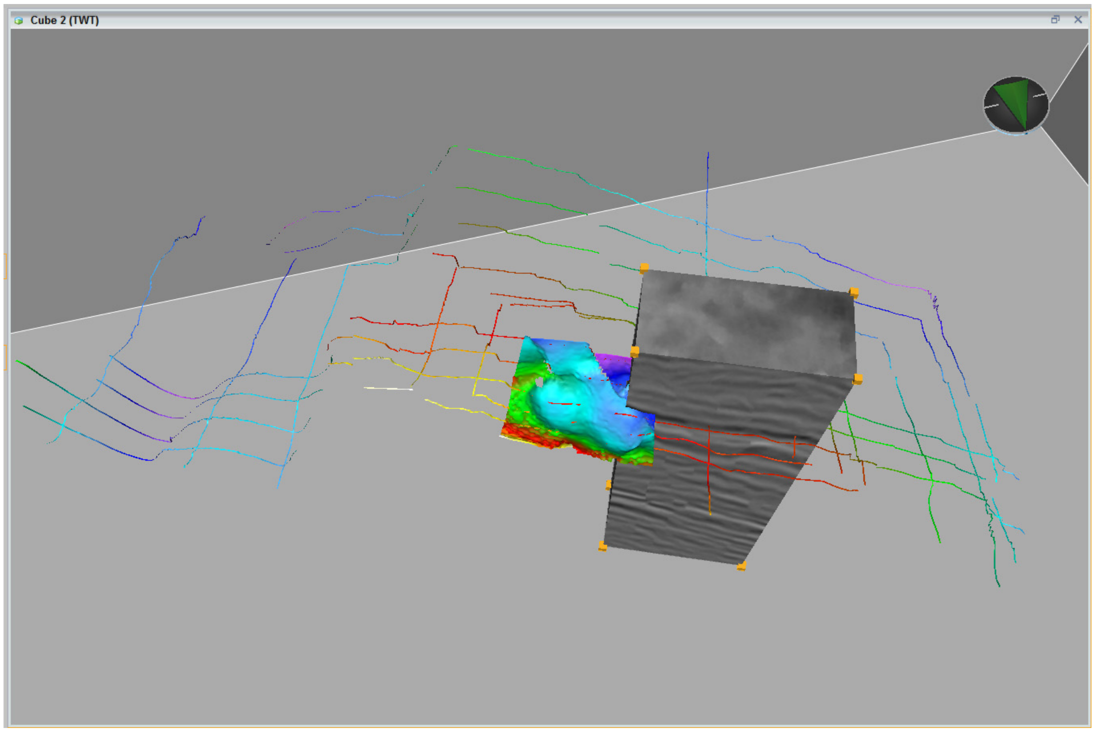
20. Finally, observe the output from the default parameters in your *Map* view. The changes are subtle, but there are some gaps to account for the discontinuities on the seismic. The fact that the software ran multiple iterations with different tile sizes gives you the ability to be more confident with the output over the one achieved with the Fast parameters, while still allowing for some freedom for variance in the seismic.



The previous steps have helped you determine that the most fitting parameters are those designated by the defaults. You will continue the rest of the exercise using these parameters.

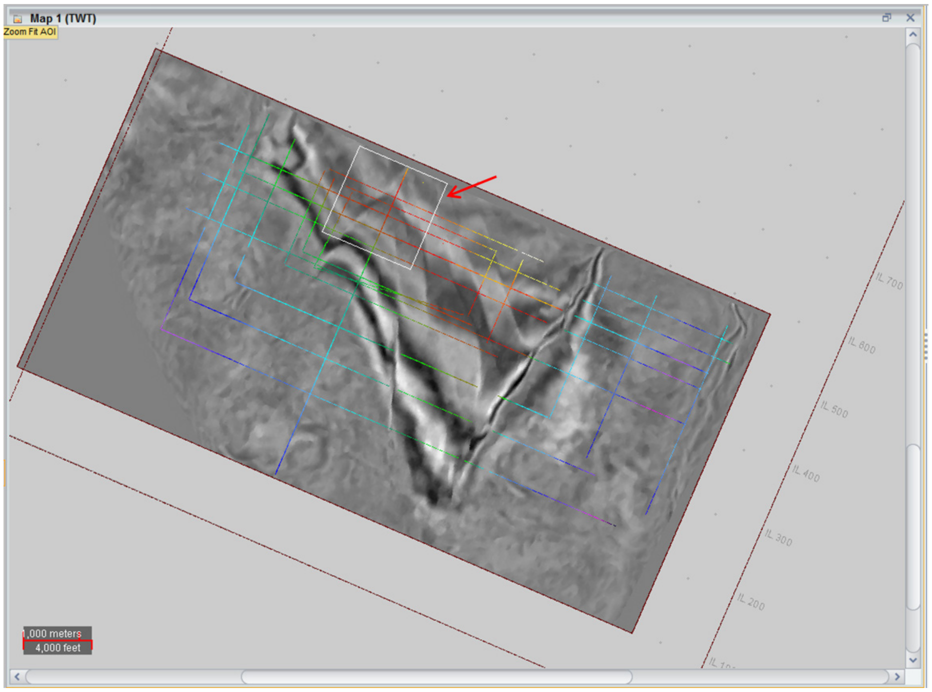
Rather than being limited to a consistent perimeter around a seed point, you can specify the extent of the tracking area using an active probe. You are then able to move the faces of the probe, or the probe itself, to continue tracking automatically in multiple areas.

21. Adjust your probe so that it covers only a small area of the survey similar to the picture below. Make sure the probe overlaps segments of your interpreted horizon because the horizon will be your seed input for Area Track! in the following steps.

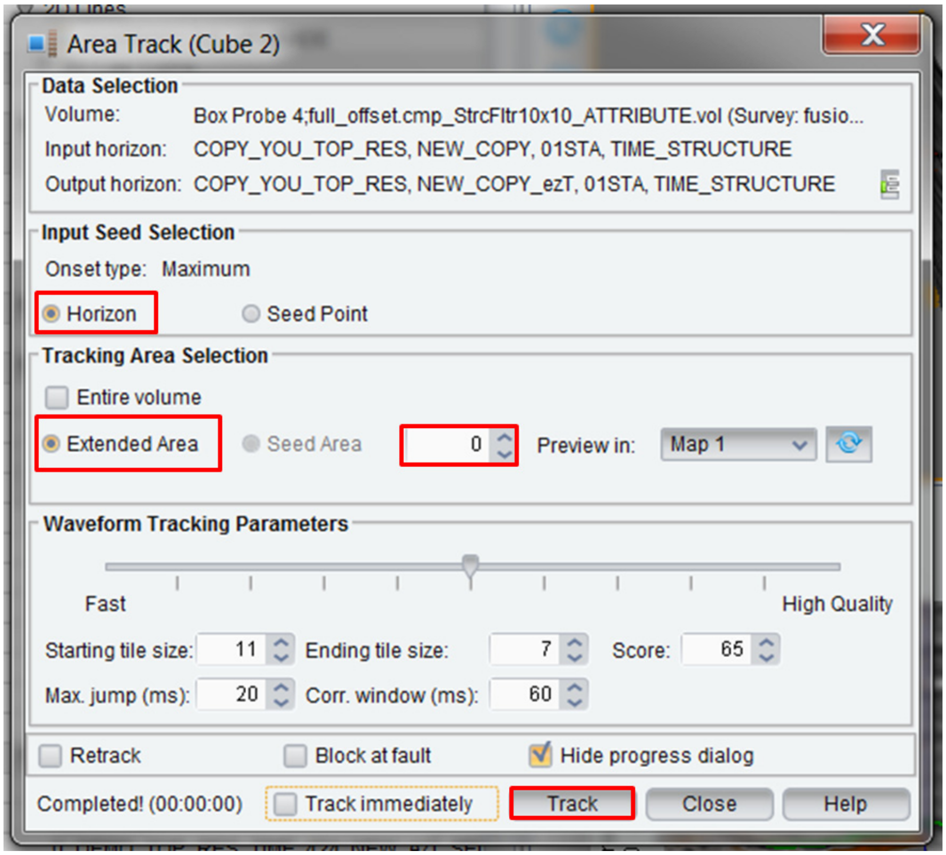


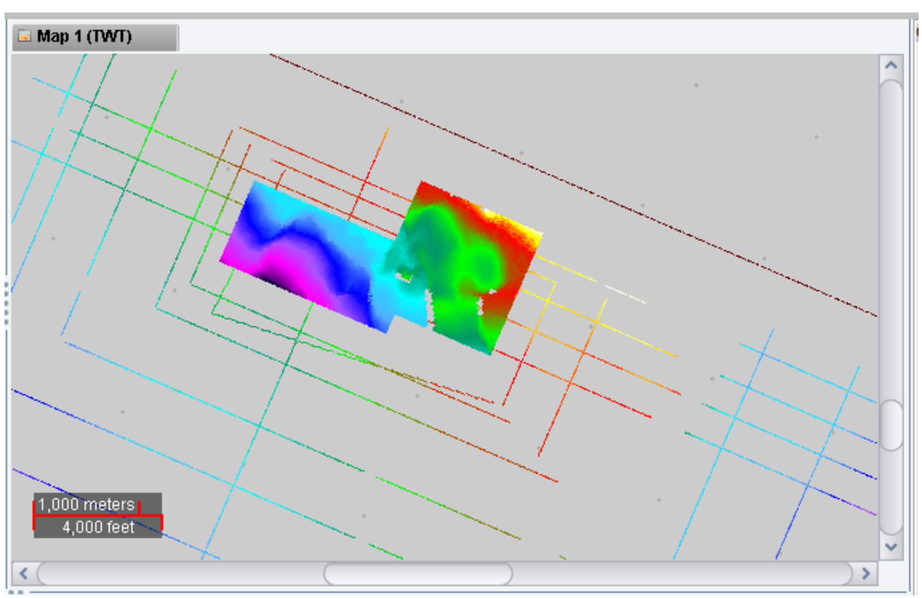
Note

By toggling on your Box Probe while your *Map* view is active, you can visualize an outline of the probe. This will make it easier to see the location of your probe. To change the color of the outline, **MB3** on the probe in the *Inventory* and select **Display Properties**. Click the box next to the property **Color**.



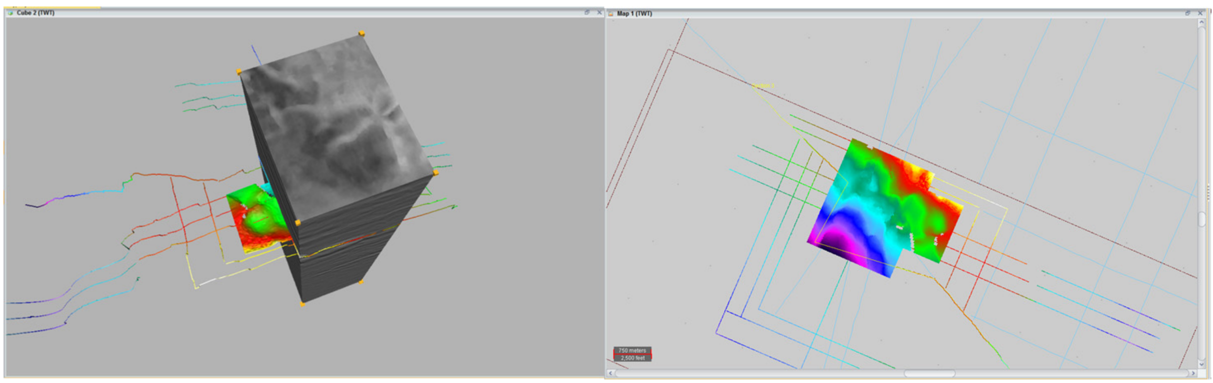
22. In the *Area Track* dialog, change the *Input Seed Selection* to **Horizon** and the *Tracking Area Selection* to **Extended Area**. Change the extended area amount to **0**, meaning it will not track outside of the probe, and accept the defaults for the *Waveform Tracking Parameters*. Click **Track**.





Map view will update with the newly tracked area of the horizon. Notice that the region tracked in the previous steps using the seed point changes color to correspond to the added horizon interpretation. The first area is considered a high point in relation to the newly tracked horizon.

23. In the *Area Track* dialog, select the **Track Immediately** check box. In your *Cube* view, **MB1+<Shift>** to move a probe face and watch the area being tracked automatically.



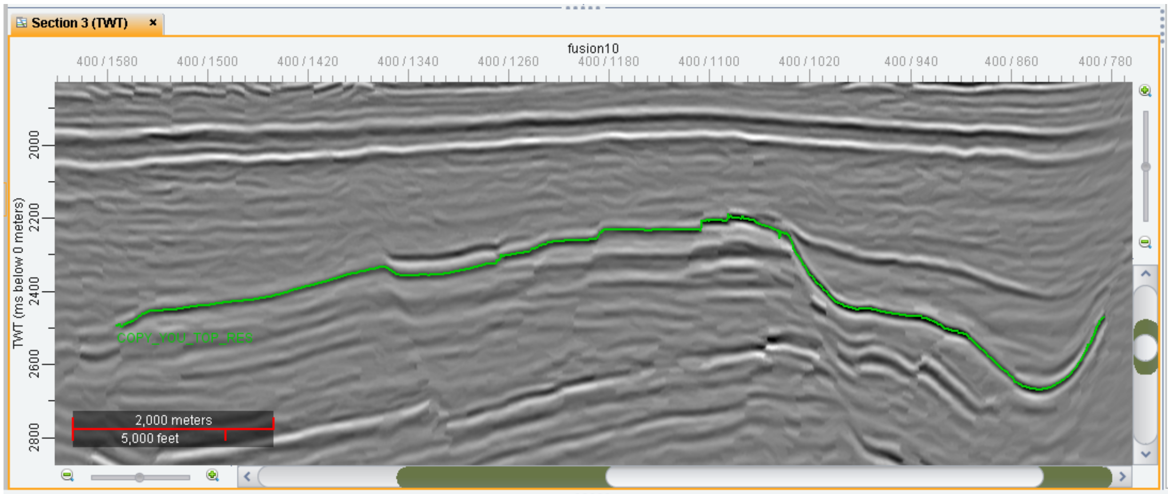
> **Note**
>
> You can also track immediately moving the entire probe by selecting the **Select / Drag** ( ) icon from the vertical toolbar.

24. Turn off **Track Immediately** in the *Area Track* dialog when you are done using the probe to track. Leaving Track Immediately turned on even when you close the dialog will cause the software to continue to track using the probe.

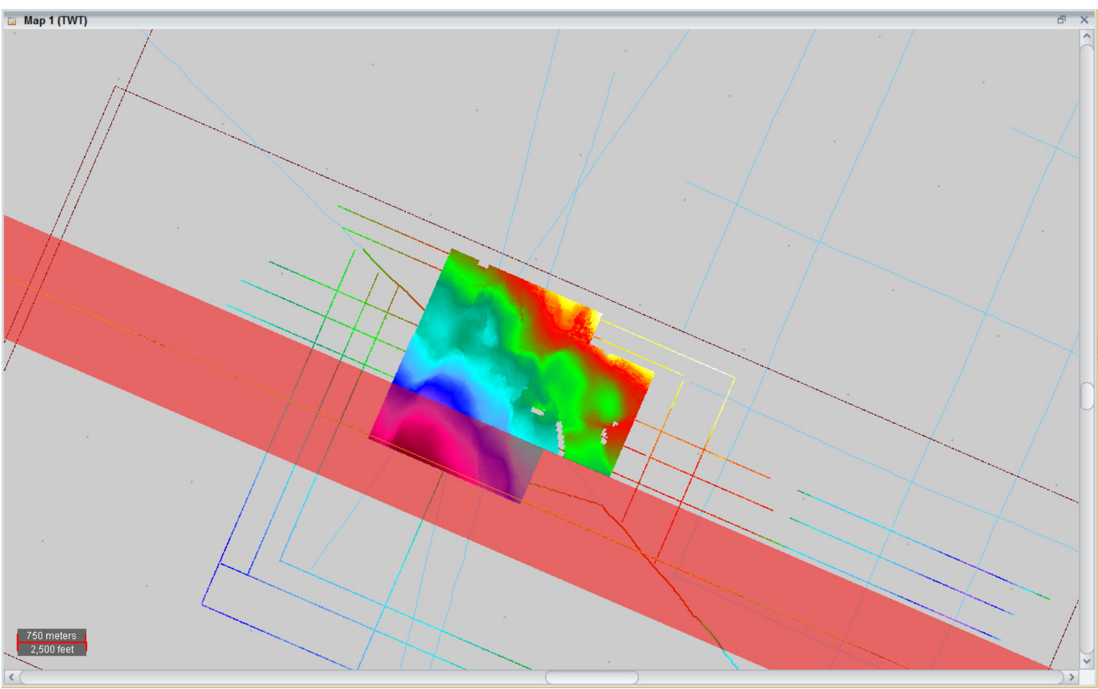
You can also use Area Track! interpreting in *Section* view. The input will be the horizon segment you have interpreted in that section. Like with the probe, you can track an extended area on both sides of the section. The section used for tracking can be an inline, crossline, or arbline.

25. Close the *Area Track* dialog for *Cube* view. Activate your *Section* view and navigate to **IL 400** by either selecting from the *Map* or using **Select > Section From List > Inline 400**.

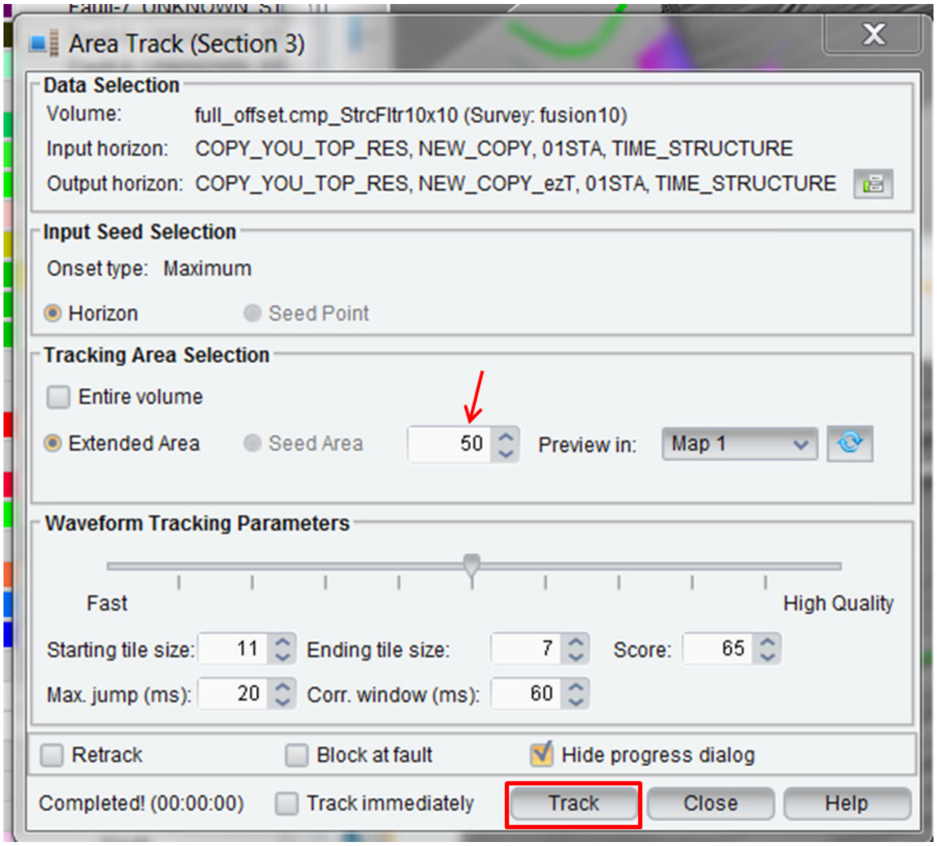
26. Toggle off **YOU_TOP_RES**, and toggle on **COPY_YOU_TOP_RES, NEW_COPY**. In the *Interpretation* task pane, make sure the **COPY_YOU_TOP_RES, NEW_COPY** is selected and **Interpretation Mode** is on. Make an interpretation on the inline to have an input seed.



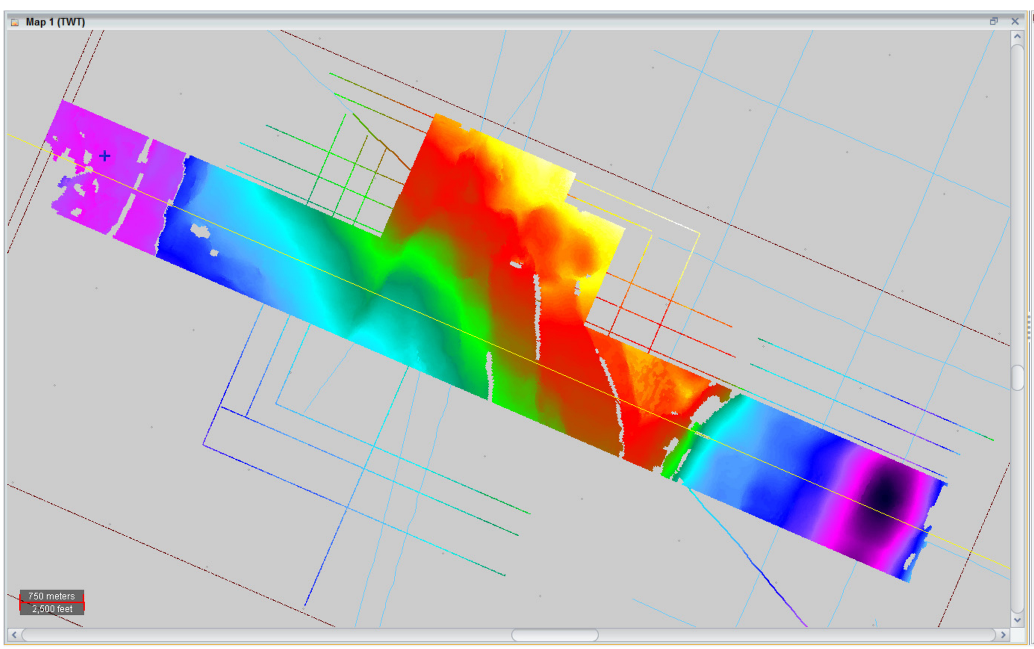
27. After making the new interpretation in *Section* view, in the *Horizon Interpretation* task pane, in the *Actions* panel, click the **Area Track!** ( ) icon. In the *Area Track* dialog, click the **Refresh** ( ) icon to see the preview in *Map* view.



28. The default extended area that will be tracked is 50 m to either side of the section line. Accept the other defaults and click **Track**. View the output in *Map* view and then close the *Area Track* dialog.



29. View the output of the tracking in *Map* view.



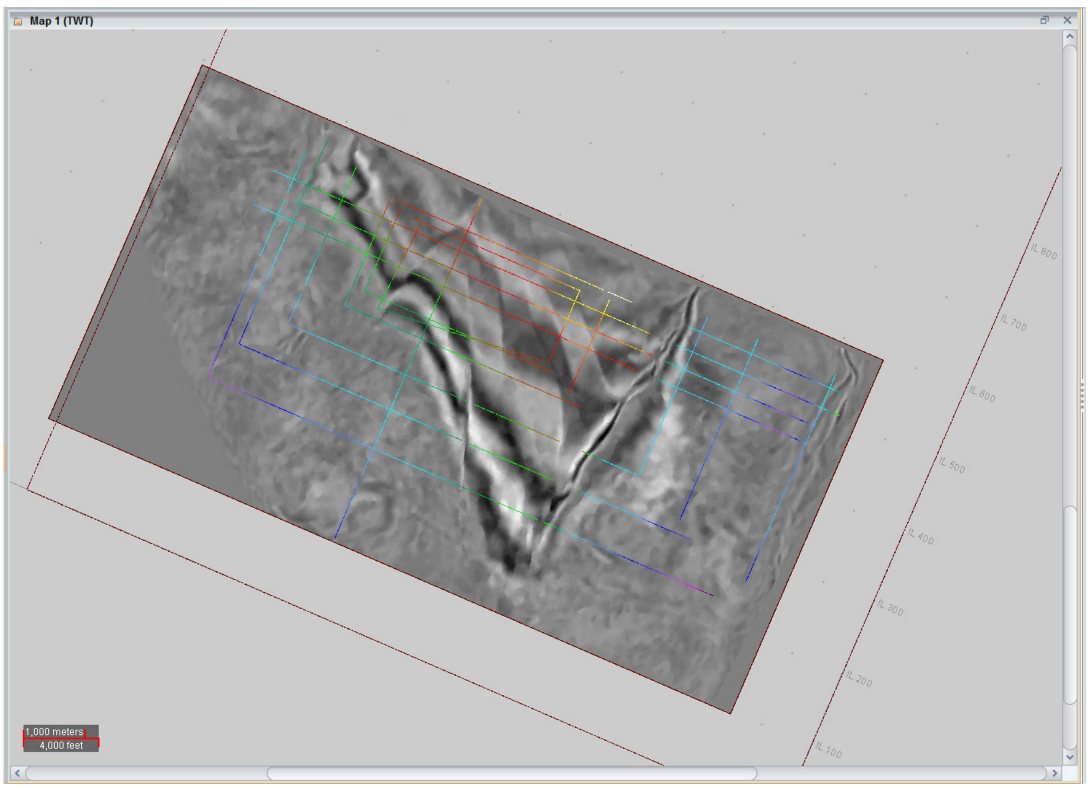
You have now determined the parameters that work best for your horizon by tracking small areas. In the following exercise, you will use these parameters to track your horizon across the entire survey.

Exercise 4.4: ezTracker Plus

In the previous exercise, you tracked small areas of the horizon, and were able to use those areas to determine the best parameters for autotracking in this project. Now, you will use ezTracker Plus to track the horizon across the entire survey.

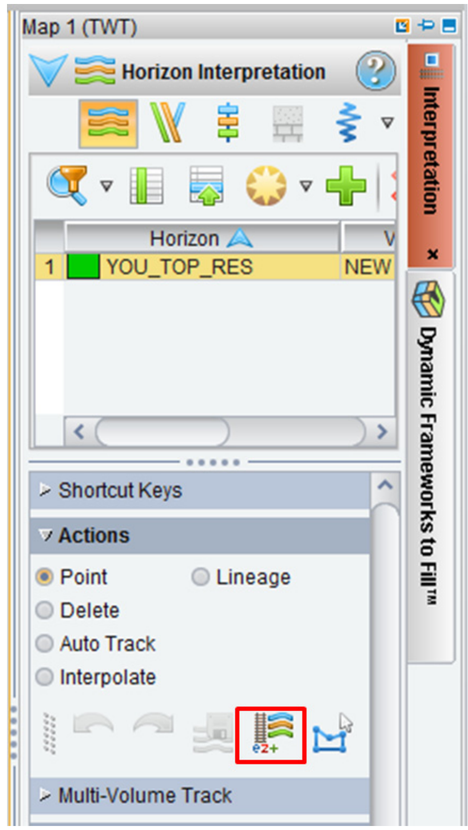
ezTracker Plus is the DecisionSpace Geoscience's customizable autotracking tool. This tool emphasizes multiple iterations and lets you track amplitudes on waveform, peak to peak, and cross correlation.

1. Activate and maximize *Map* view, toggle on **YOU_TOP_RES** and the **full_offset_cmp_StrCFltr10x10** volume in shared memory, and then toggle off all other items.



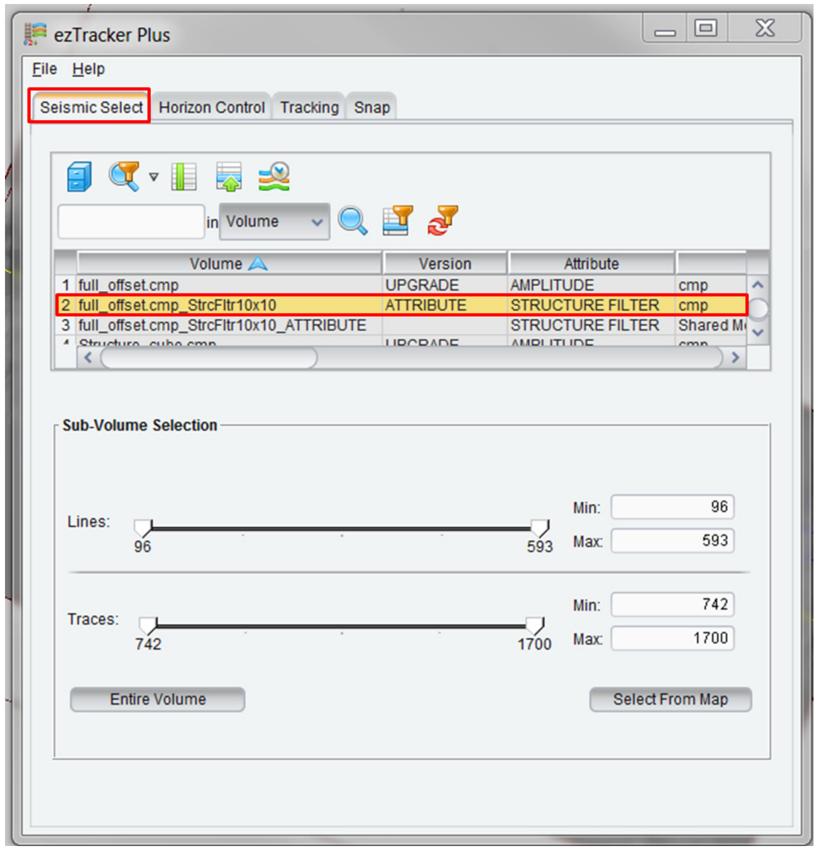
> **Note**
>
> The picture above is displaying a slice at 2300.

2. In the *Horizon Interpretation* task pane, in the *Actions* panel, click the **ezTracker Plus** ( ) icon.

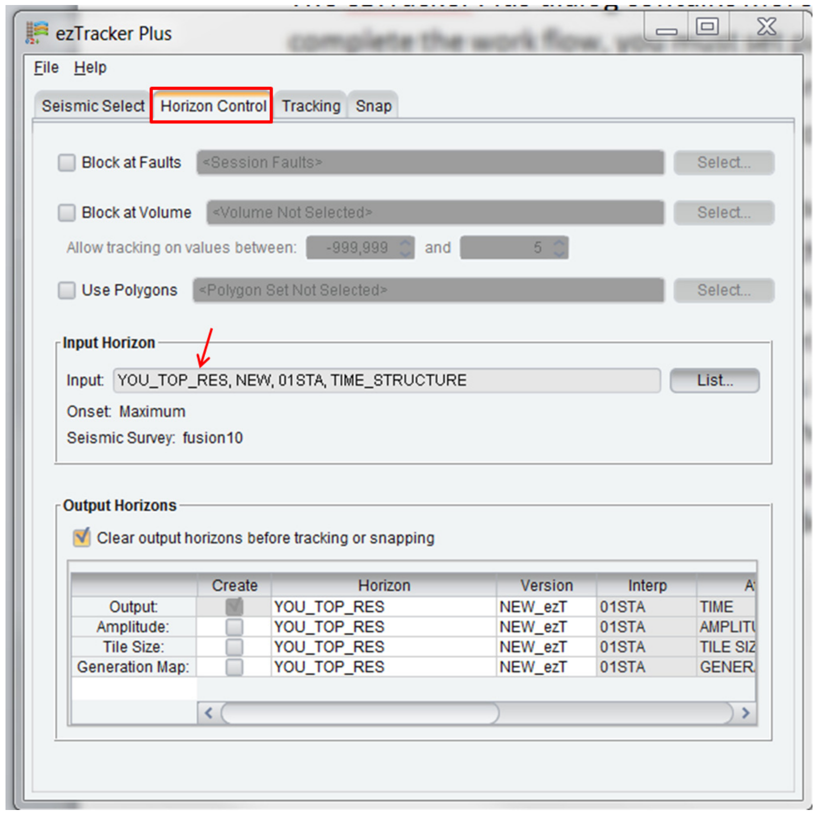


The *ezTracker Plus* dialog contains more options than the *Area Track* dialog. To successfully complete the work flow, you must set parameters in three tabs: Seismic Select, Horizon Control, and Tracking. These tabs contain many more options for tracking your horizon than will be used for this exercise. You can reference the background theory if you have any questions about these parameters.

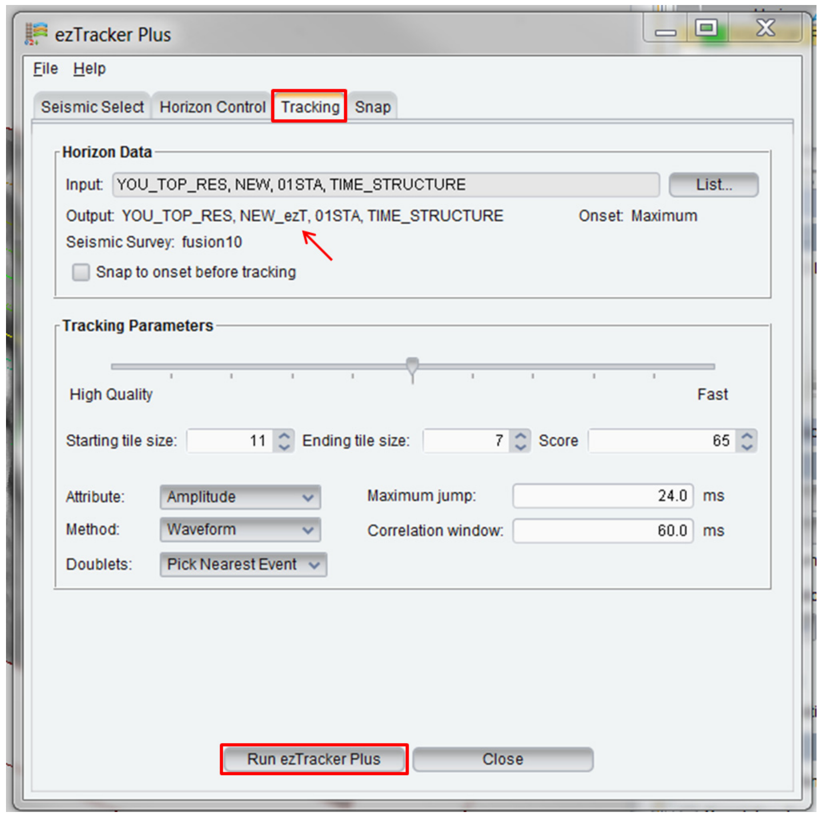
3. In the *Seismic Select* tab, select the seismic survey **full_offset.cmp_StrcFltr10x10**. You will track the entire volume, so accept the defaults for *Sub-Volume Selection*.



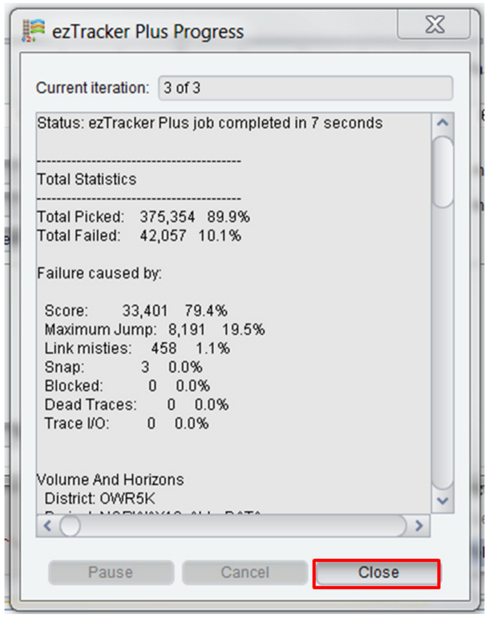
4. Click the *Horizon Control* tab. This panel is where you have the option to change what horizon you input. By default, the input horizon is the one active in interpretation mode when you opened ezTracker Plus, and should be YOU_TOP_RES, NEW. Accept the defaults in this tab.

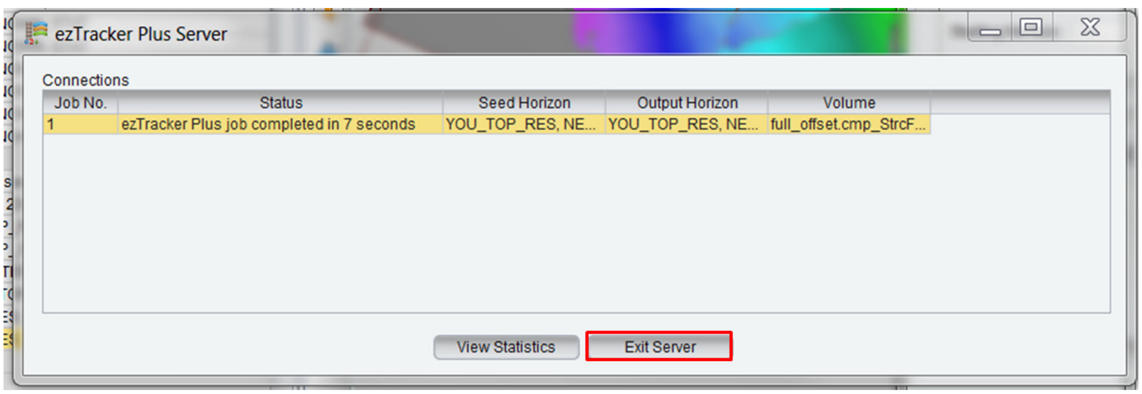


5. Click the *Tracking* tab, note that the output horizon name is identical to the selected horizon, but "ezT" is appended to the version name. You established in the previous exercise, that the default parameters work best for autotracking in this project. Therefore accept the defaults in this tab and click **Run ezTracker Plus**.



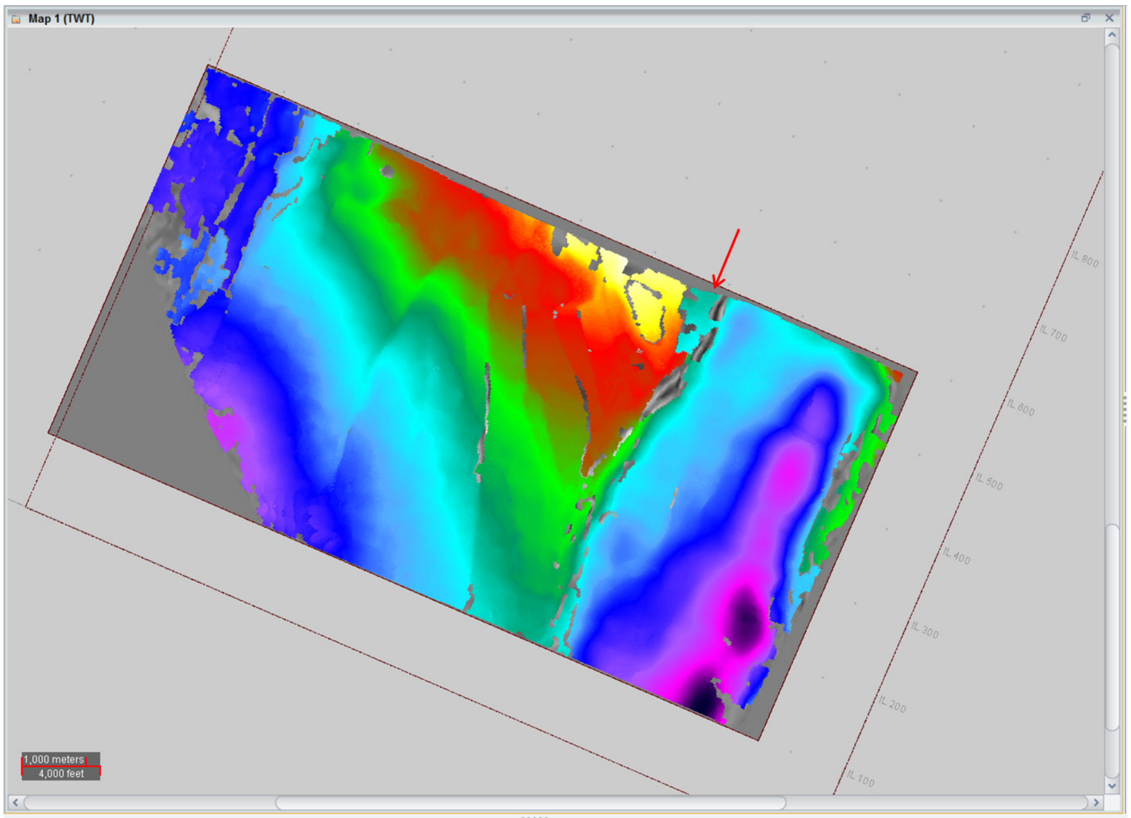
The *ezTracker Plus Progress* dialog opens as well as the *ezTracker Plus Server* dialog. You may close the dialogs when tracking is complete.



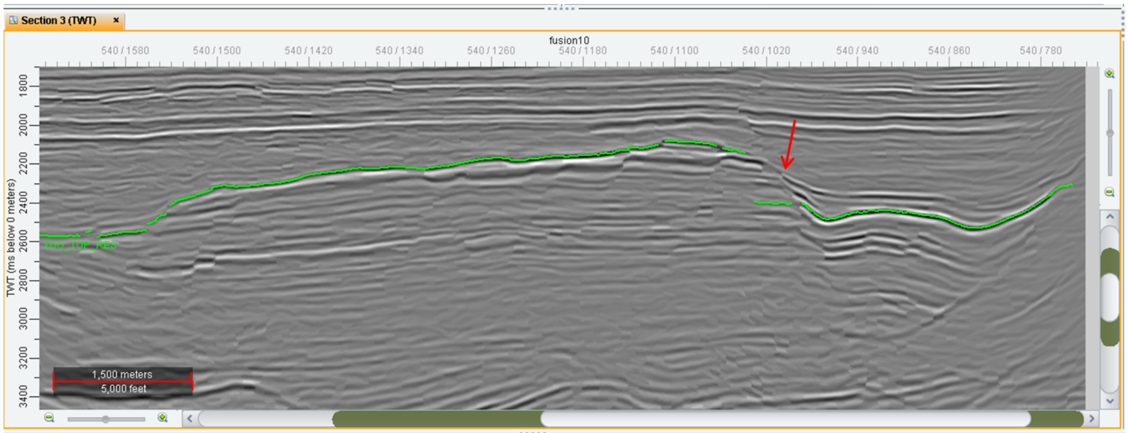


6. With *Map* view active, in your *Inventory*, toggle on **YOU_TOP_RES, NEW_ezT** to view the tracked horizon.

You will notice that portions of the horizon were not tracked. This may be due to the discontinuities in the seismic caused by faulting, but may also occur because your seed interpretation was not well resolved in this region. You should always QC the output when using an auto picking tool to ensure the results are geologically sound. For example, the northeast portion of the horizon, shown in the picture below, needs to be looked at in closer detail. In the following steps you will use *Section* view to perform QC on your ezTracked horizon.

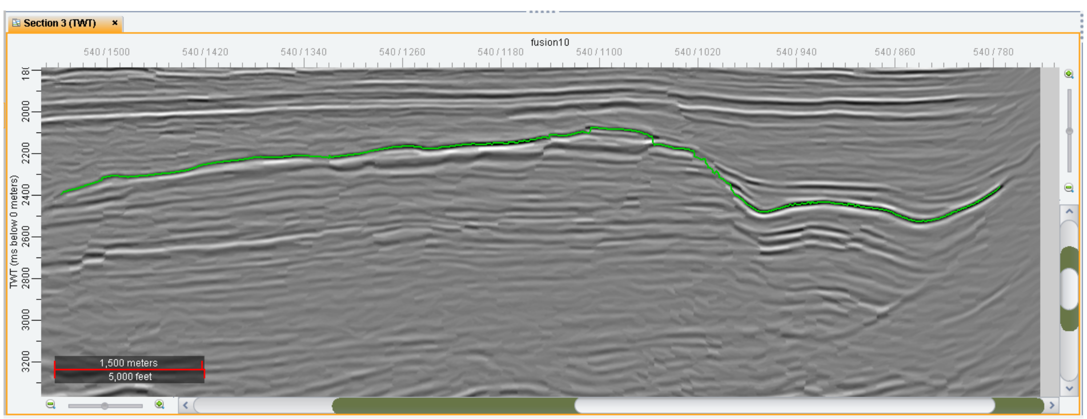


7. Activate *Section* view, toggle on **YOU_TOP_RES, NEW_ezT** and navigate to **IL 540**.



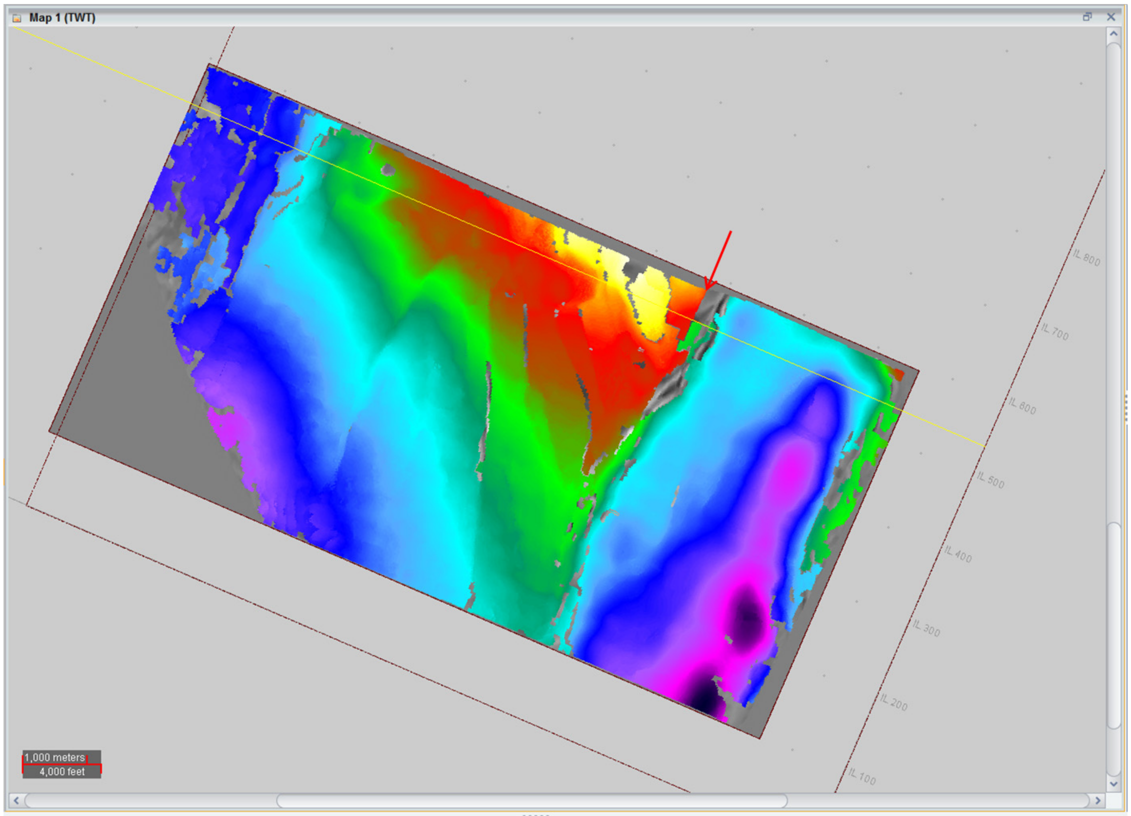
Notice that the horizon interpretation jumps to the incorrect event. This may be due to poor resolution in this area of the seismic from your original seed interpretation. Best practice is to go back and fix your original interpretation, which will ensure that the software has sufficient data to make accurate interpretations.

8. Toggle off **YOU_TOP_RES, NEW_ezT** and toggle on the original **YOU_TOP_RES** horizon. Turn on **Interpretation Mode** ( ) and interpret the horizon on this inline.



9. In the *ezTracker Plus* dialog, click **Run ezTracker Plus** again. This will rerun ezTracker and overwrite YOU_TOP_RES, NEW_ezT as the output.

10. When tracking is complete, activate *Map* view and ensure **YOU_TOP_RES, NEW_ezT** is displayed. Notice the changes made to the horizon specifically in the region where you added interpretation.



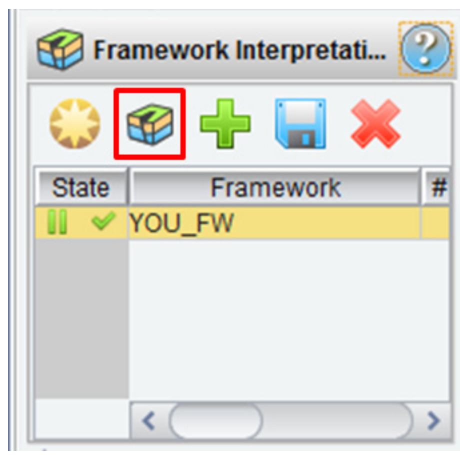
In the next exercise, you will use the interpretation modes in *Map* view to further refine the horizon.

Exercise 4.5: Interpreting in *Map* View

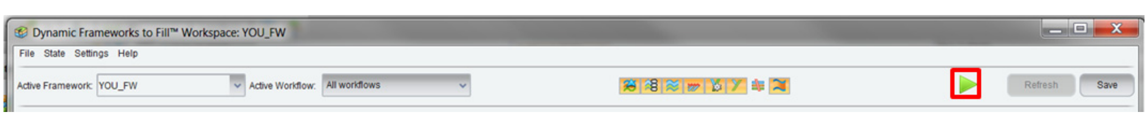
In the previous exercise, you tracked your horizon across the entire survey using ezTracker Plus, but the horizon contains a few gaps where the auto tracker was unable to track the horizon. Interpretation mode in *Map* view offers two actions to help fill in those gaps: Auto Track and Interpolate.

In this exercise, you will perform your interpretation in *Map* view and watch your Framework surface dynamically update as those changes are made. Currently your Framework surface is created by the untracked horizon from earlier exercises, not the newly ezTracked horizon from the last exercise. First, you will need to delete the untracked horizon from your framework and replace it with the ezTracked horizon.

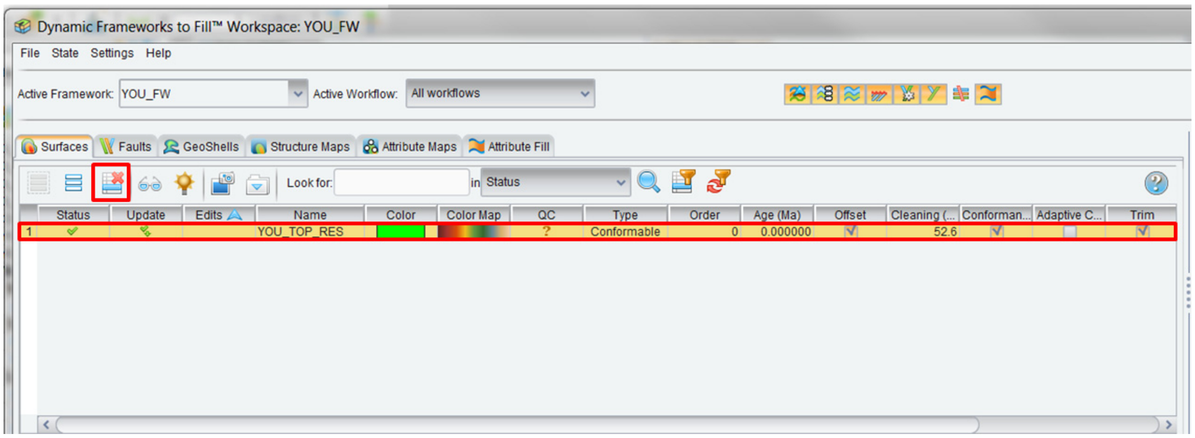
1. In the *Dynamic Frameworks to Fill* task pane, click the **Launch Framework Workspace Window** ( ) icon.



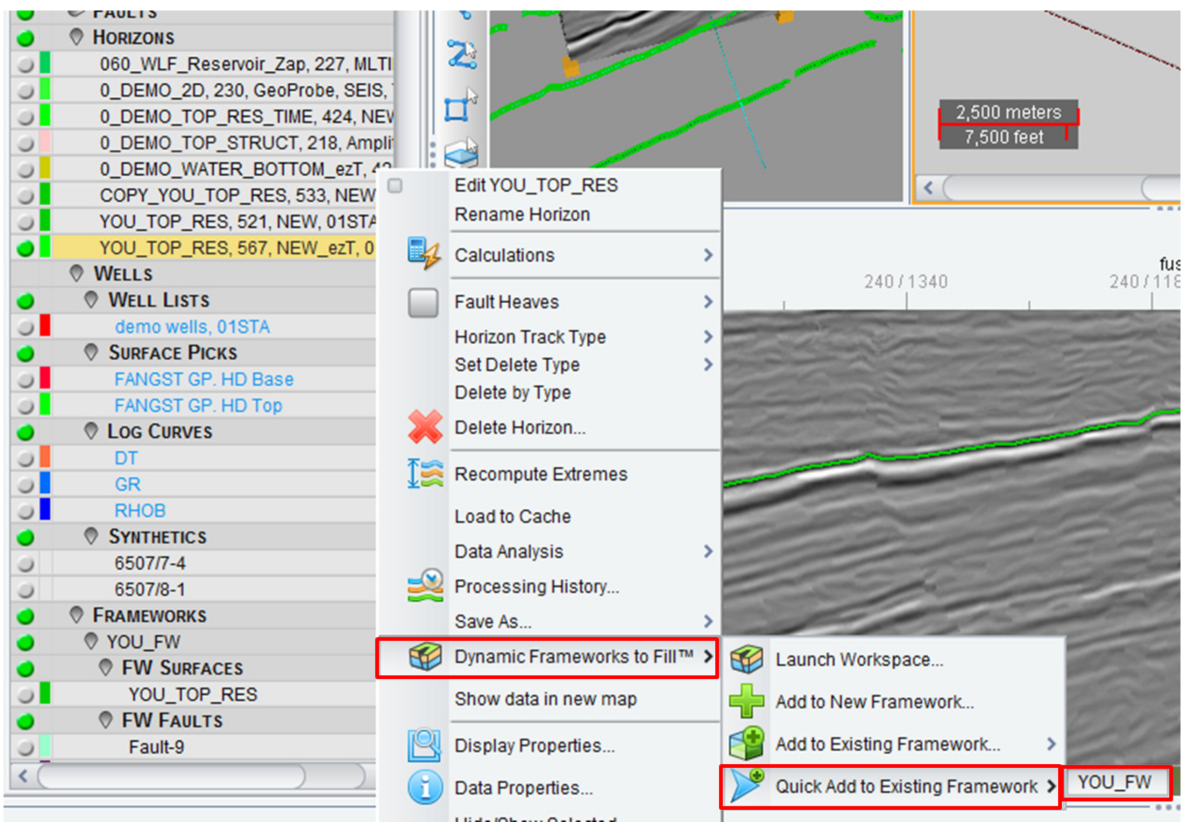
2. In the *Dynamic Frameworks to Fill Workspace*, change the framework to **Dynamic Auto Refresh** ( ) to make sure that all changes made are automatically reflected in your view.



3. In the *Surfaces* objects tab, highlight **YOU_TOP_RES** and click the **Remove the selected model entry/entries** ( ) icon to remove the surface from the framework.

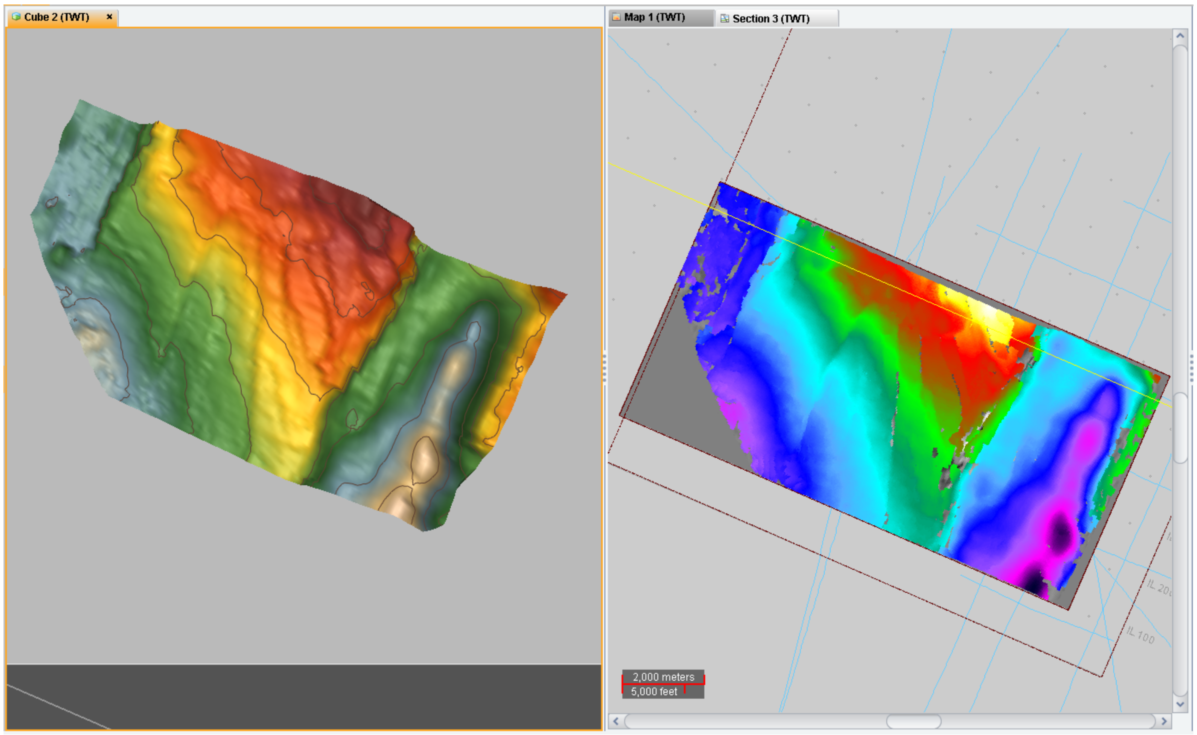


4. In the *Inventory* task pane, **MB3** on the **YOU_TOP_RES, NEW_ezT** horizon and select **Dynamic Frameworks to Fill > Quick Add to Existing Framework > YOU_FW**. The Quick Add option allows you to bypass the *Add Sources to Framework* dialog, automatically adding the horizon as a new surface.



When the surface has been added, the framework will automatically update reflecting the changes made to it.

5. Arrange your views as shown below, only showing the *Cube* and *Map* view. In *Cube* view display the **YOU_TOP_RES** framework surface, and in *Map* view show only the **YOU_TOP_RES, NEW_ezT** seismic horizon.

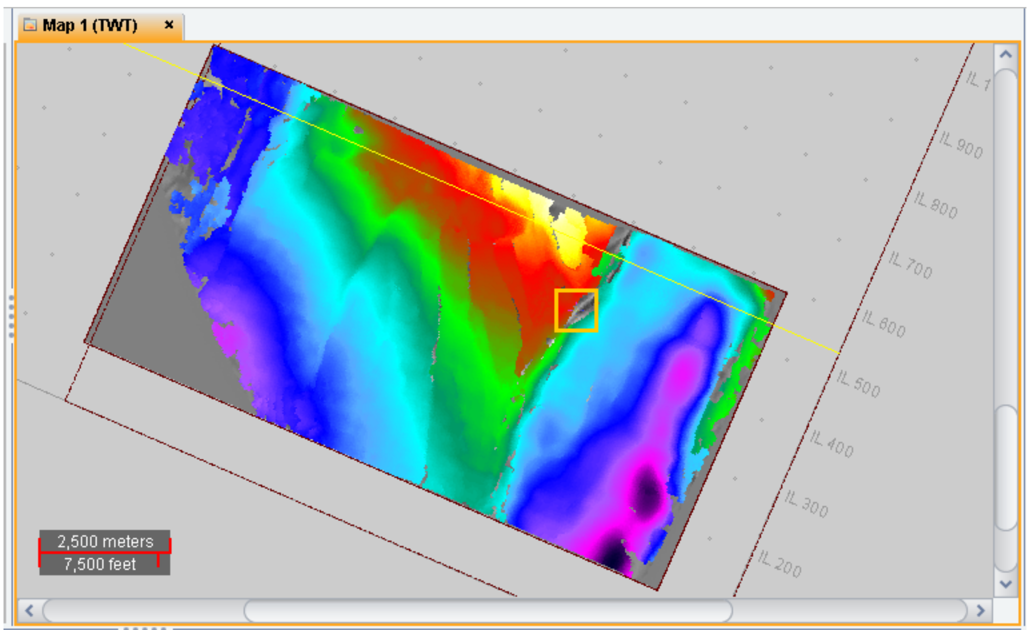


> **Note**
>
> In *Cube* view, use the **View From Top** ( ) icon after orienting your FW surface and horizon in the same direction if you want your view to be the same as the manual.

You will now refine your interpretation using the *Map* view Interpretation Mode options Auto Track, Delete, and Interpolate. As you make interpretation edits and save the changes, your framework will automatically refresh in your *Cube* view.

6. With *Map* view active, from the *Interpretation* toolbar, toggle on **Interpretation Mode** and select **Horizons** as the data type and **Auto Track** from the *Actions* drop-down menu.

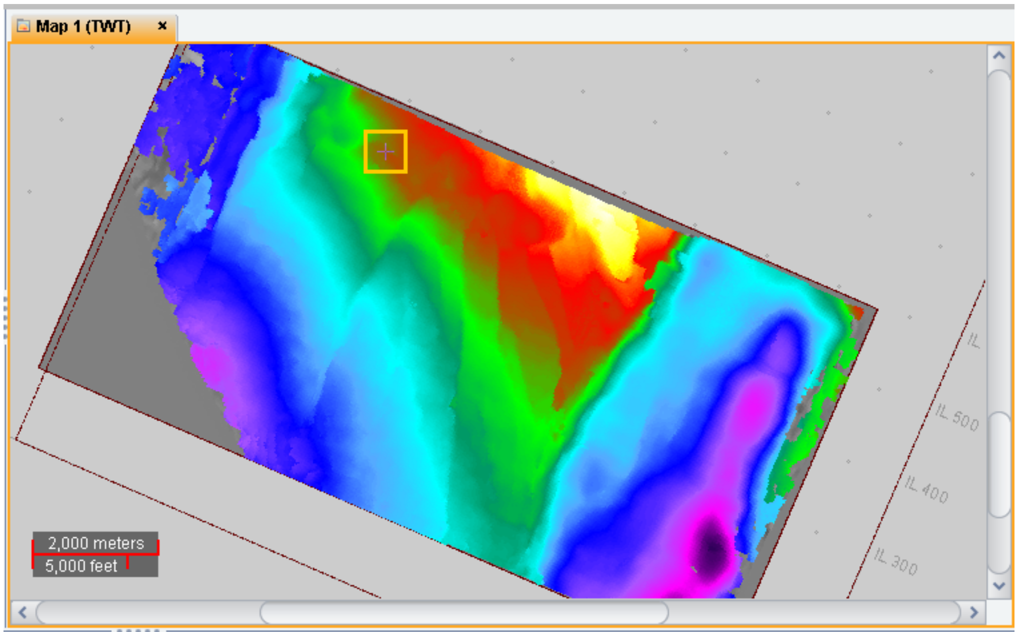
7. The cursor becomes a box. Place the cursor in some of the holes remaining in the horizon from ezTracker Plus and **MB1** to track within those gaps.



8. Change the interpretation mode to **Interpolate** using the *Actions* drop-down of the *Horizon Interpretation* toolbar.

Interpolation, unlike auto tracker, fills in the gaps by creating points between known points as opposed to selecting existing traces. It does this by performing a linear interpolation in both the X and Y directions.

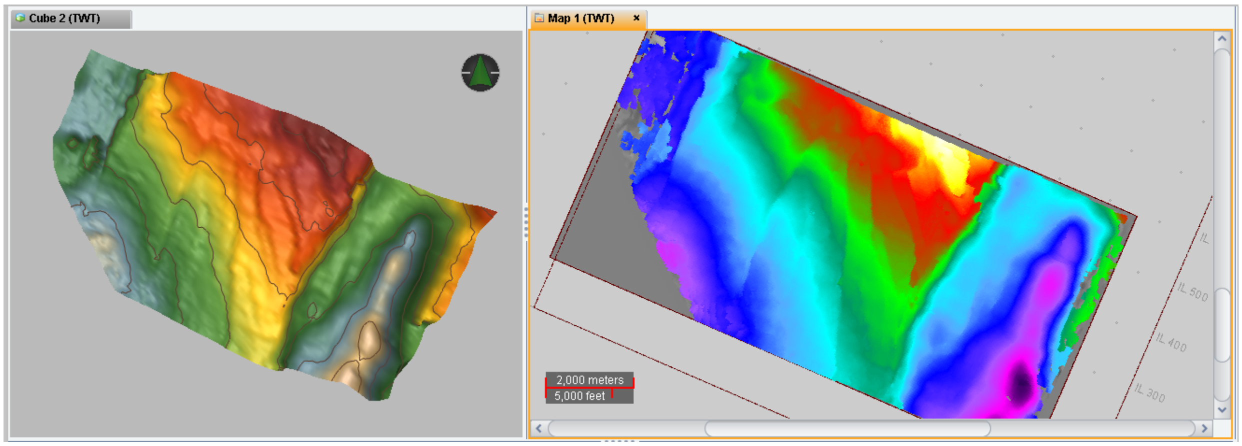
9. As shown in the picture below, **MB1** to interpolate in the regions with larger gaps.



> **Note**
>
> For the exact interpolation equation used by the software, select the Help bubble in the *Actions* panel of the *Horizon Interpretation* task bar.

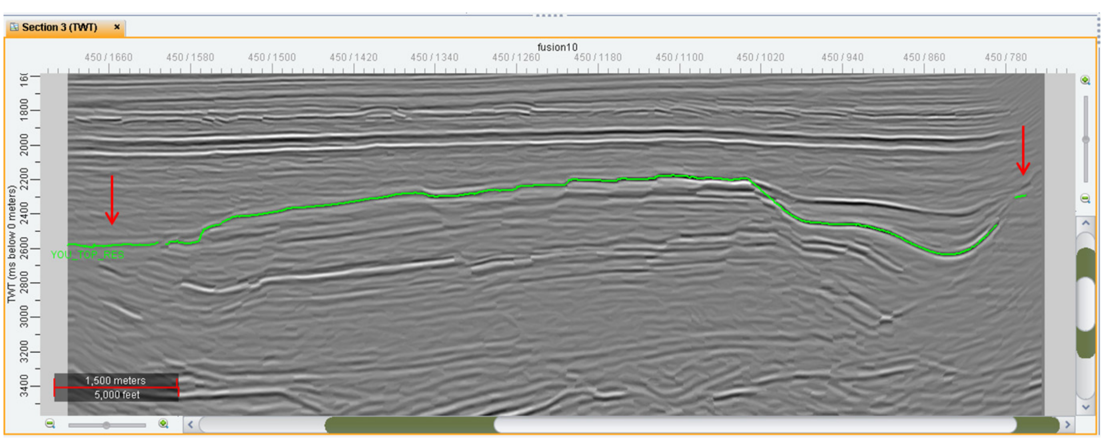
Changes to the horizon need to be saved to the database before they will be reflected within the framework surface.

10. Click the **Save horizon changes to the database** ( ) icon, which prompts frameworks to account for the changes to the horizon, and regrid the surface. Observe the changes made to the FW surface in *Cube* view.



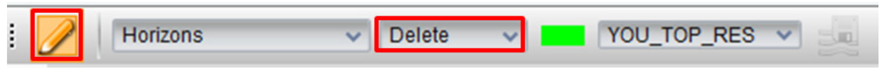
The edges of the data contain seismic that is difficult to resolve. Therefore, the interpretation created with ezTracker Plus in these particular regions is not necessarily very accurate. This can be seen by looking at an inline. In the following steps you will use the Delete action to clean up the interpretation around the edges of the survey.

11. Activate *Section* view and using the frame controls, navigate to **IL 450**. Display only the **YOU_TOP_RES, NEW_ezT** in the *Inventory* task pane. Notice that at the ends of the data, as mentioned before, ezTracker Plus has tracked the horizon into regions of the seismic that cannot be easily determined.

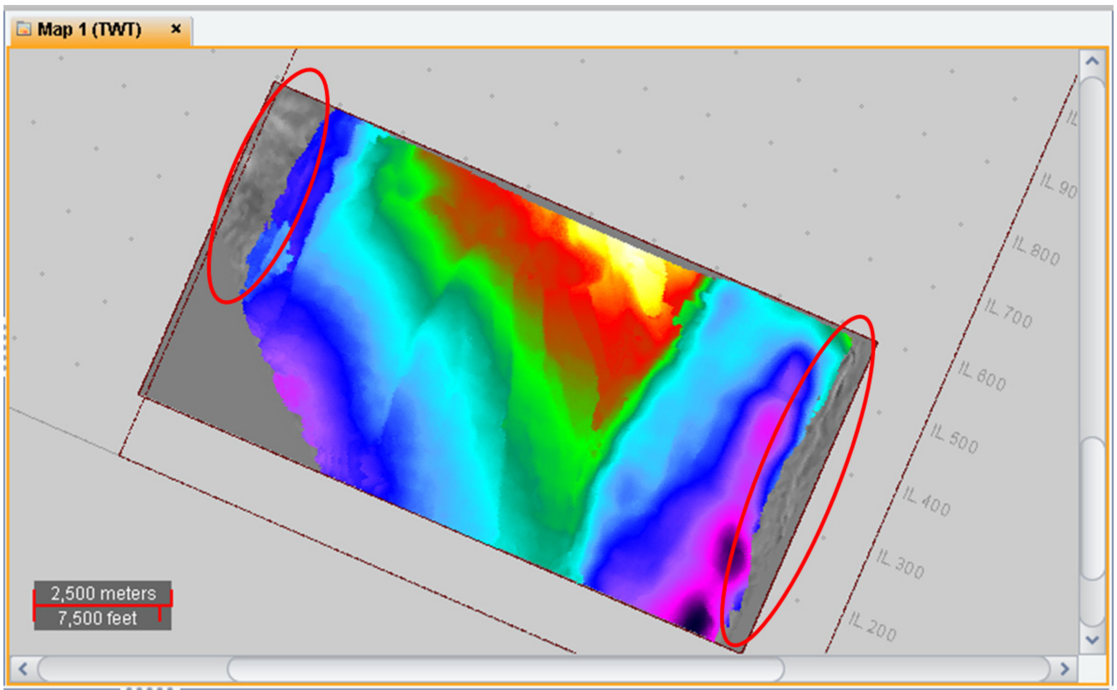


Editing your horizon from *Section* view, although effective is not necessarily the most efficient way to modify large areas that have the same issue. In *Map* view, you can fully modify the horizon quickly.

12. Activate *Map* view again, make sure that **Interpretation Mode** is on and change the interpretation mode to **Delete** from the *Actions* drop-down.



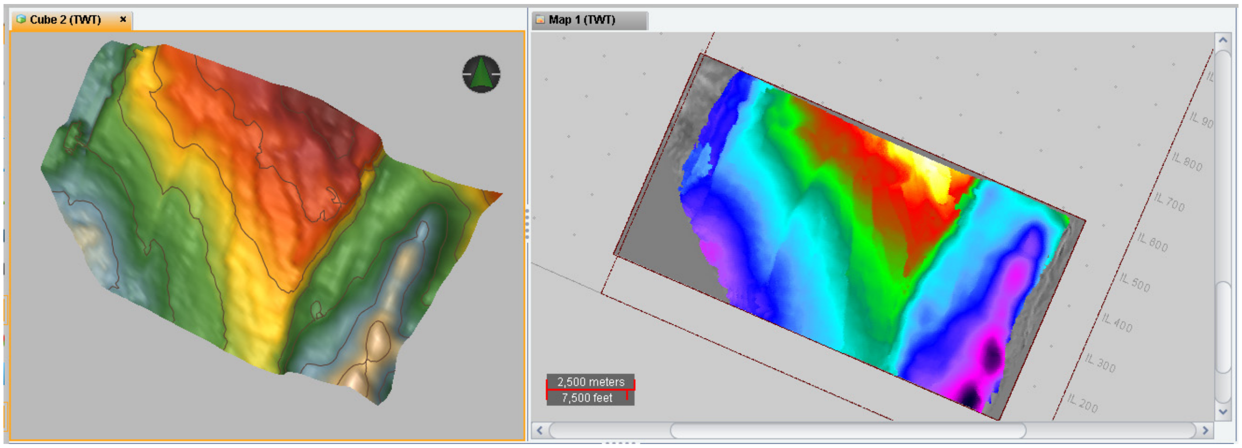
13. Now use the Delete paintbrush box to delete a small portion of the horizon around the East and West edges as shown in the picture below. **MB2+<Ctrl>** to resize the box if necessary.



Note

The **Draw Polygon to Delete** ( ) icon in the *Actions* panel of the *Horizon Interpretation* task pane allows you to delete interpretation within a specific polygon.

14. In the *Interpretation* toolbar, click the **Save horizon changes to the database** ( ) icon and turn off **Interpretation Mode**. Watch the edges of your FW surface update in *Cube* view.

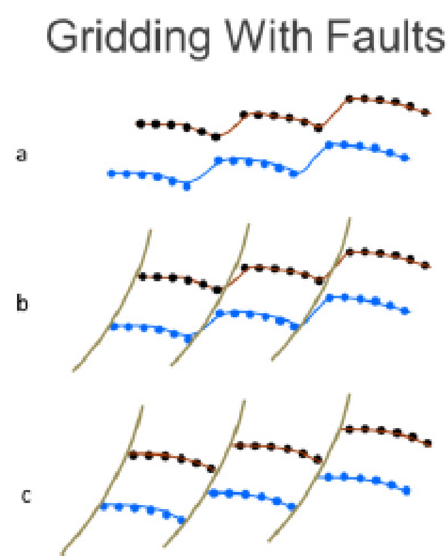


With the modifications made to the ezTracked horizon, you have a significantly refined surface that can now be related to the faults within your framework. In the next exercise, you will learn how to create fault polygons from the intersections of the fault planes with the framework surfaces, within Dynamic Frameworks to Fill.

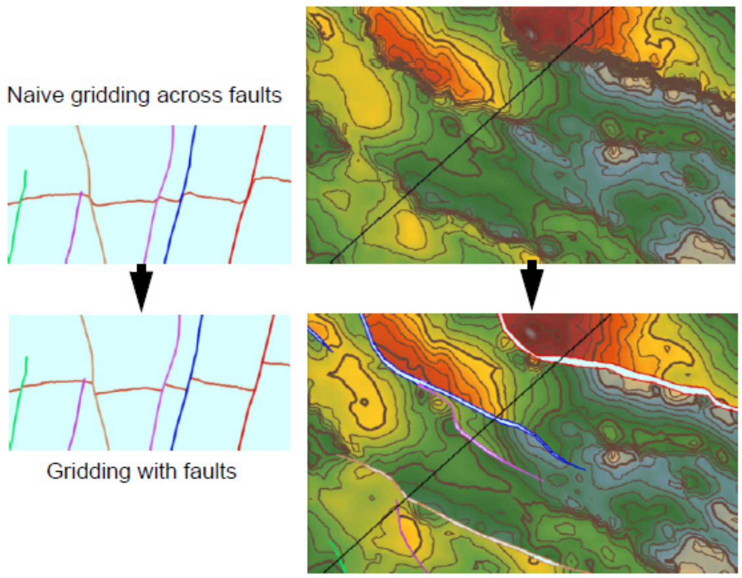
Exercise 4.6: Generating Fault Polygons Using Dynamic Frameworks to Fill

Framework mapping algorithms can grid surface data that bisect fault planes. This differs from traditional mapping algorithms that use fault centerlines or hand-drawn fault polygons to denote the location of faults in gridding algorithms. Dynamic Frameworks to Fill uses fault plane data to segregate surface data, and then grids the data on a fault-block by fault-block basis.

In the figure below, you can see horizon surface data gridded initially without a fault interpretation (a). In (b), faults have been added, and in (c), you can see the results of incorporating the fault planes in the gridding process. Effectively, the fault planes segregate and grid the surface data by fault block, and then project the surfaces into the fault-block bounding faults where they are truncated.



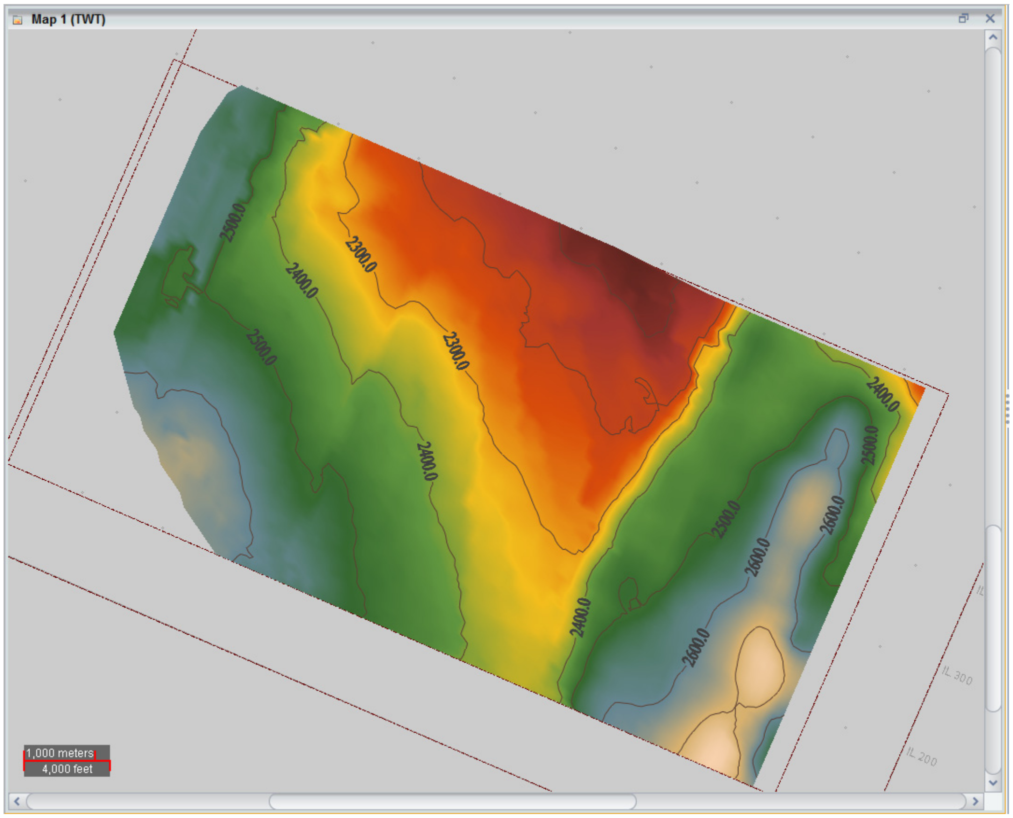
The figures below show the results of naïve gridding, without considering the faults, and of gridding by fault block. The latter creates fault polygons as the natural intersection of fault planes with truncated structural surfaces. In this exercise, you will pick several lines of your horizons, and then refresh your framework. The surfaces will immediately be updated and you can watch as your fault polygons develop in *Map* view.



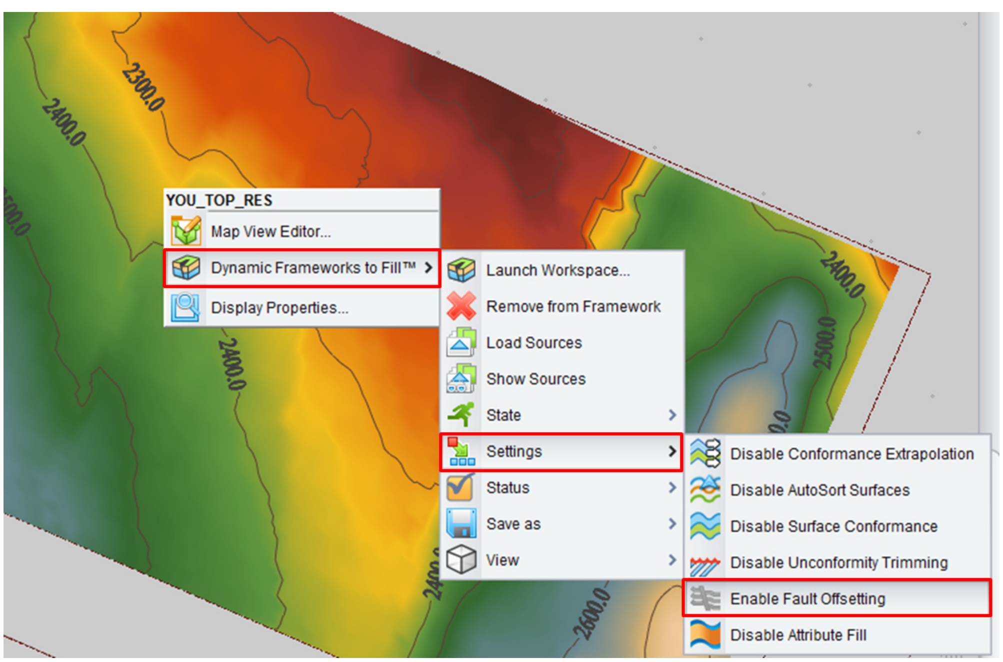
In Chapter 3, you created a basic framework containing a fault network, and in previous exercises you also added your interpreted horizon into this framework to create a gridded surface. Although the framework objects intersect each other, the software is considering them as independent objects until they are referenced to each other. As mentioned in the background theory, you are able to use Dynamic Frameworks to Fill to grid the surface while also incorporating the information on the intersection of the faults with that surface. The software will use a cleaning distance around each fault to segregate the surface data into fault blocks, project the surface back out to the fault, and then regrid the surface using a projection of the fault throw. During this process, fault polygons will be created automatically that can be viewed on your surface.

In the following exercise, you will learn how to create relationships between your surfaces and fault networks in Dynamic Frameworks to Fill. These relationships will result in fault polygons that can later be saved out as OpenWorks Fault Polygons.

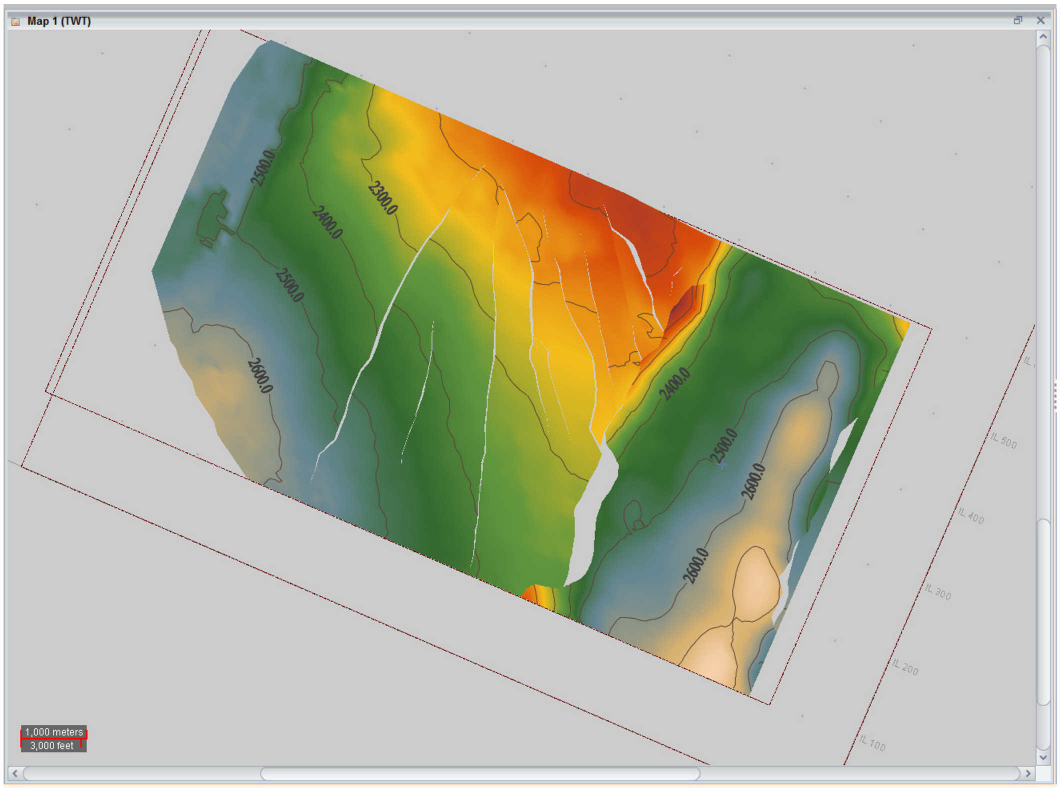
1. With *Map* view active, from the *Inventory* task pane display only the FW surface **YOU_TOP_RES**.



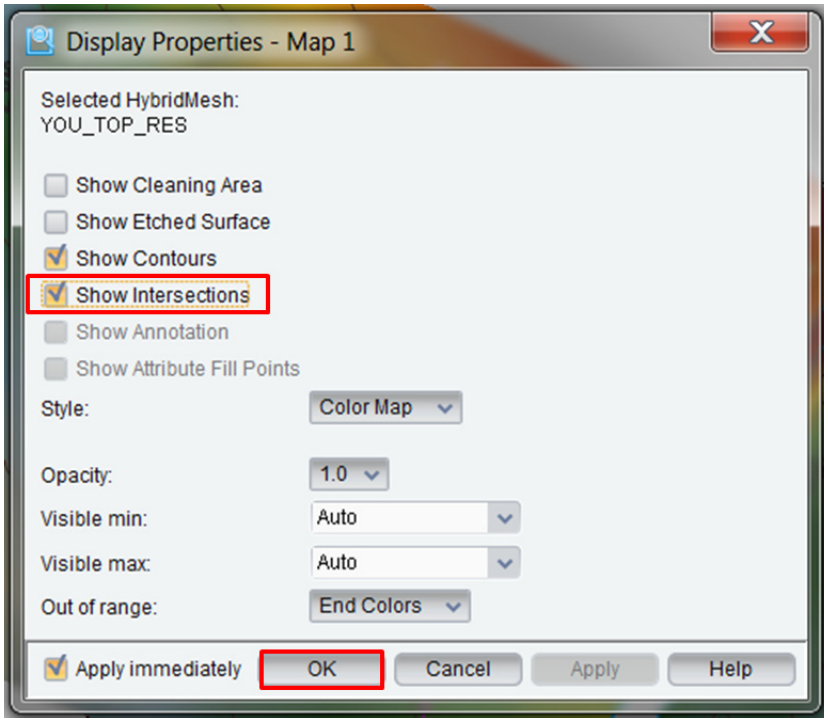
2. **MB3** on the FW Surface and select **Dynamic Frameworks to Fill > Settings > Enable Fault Offsetting**.



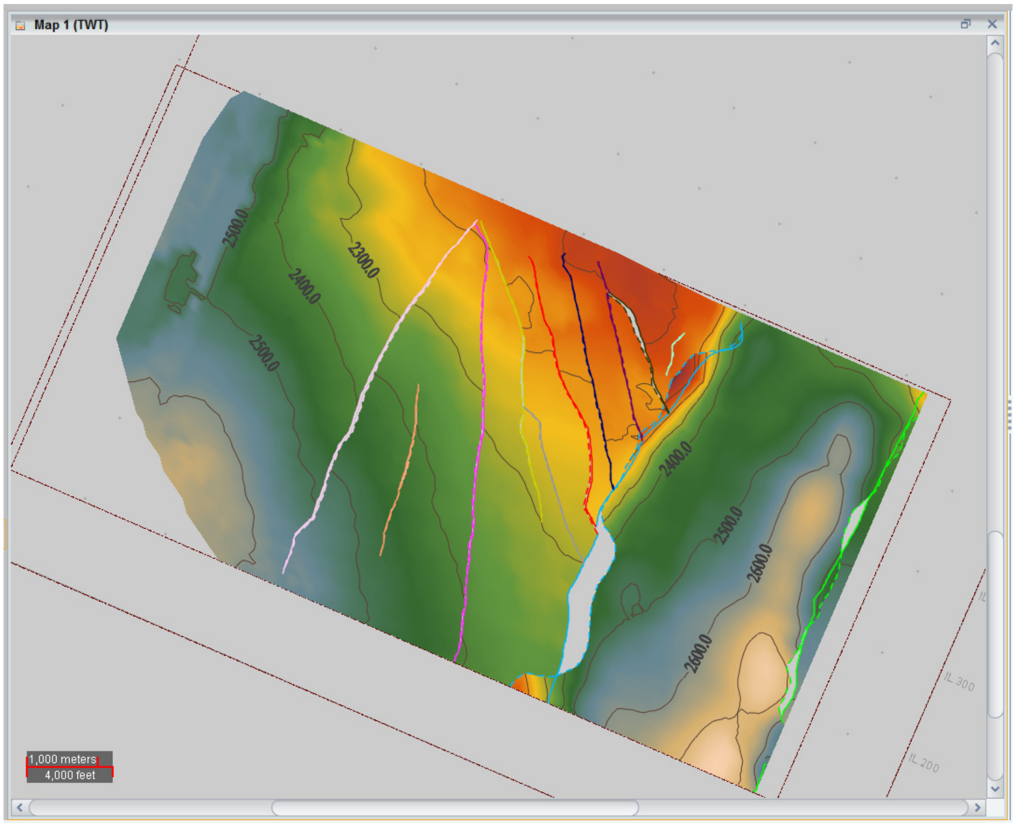
The state of your framework should be currently set to a Dynamic, Auto Refresh, so the calculations for Fault Offsetting will be performed automatically and your surface will update to display the offset. As mentioned in the background theory, the offset is caused by the vertical displacement of the horizon along the fault plane.



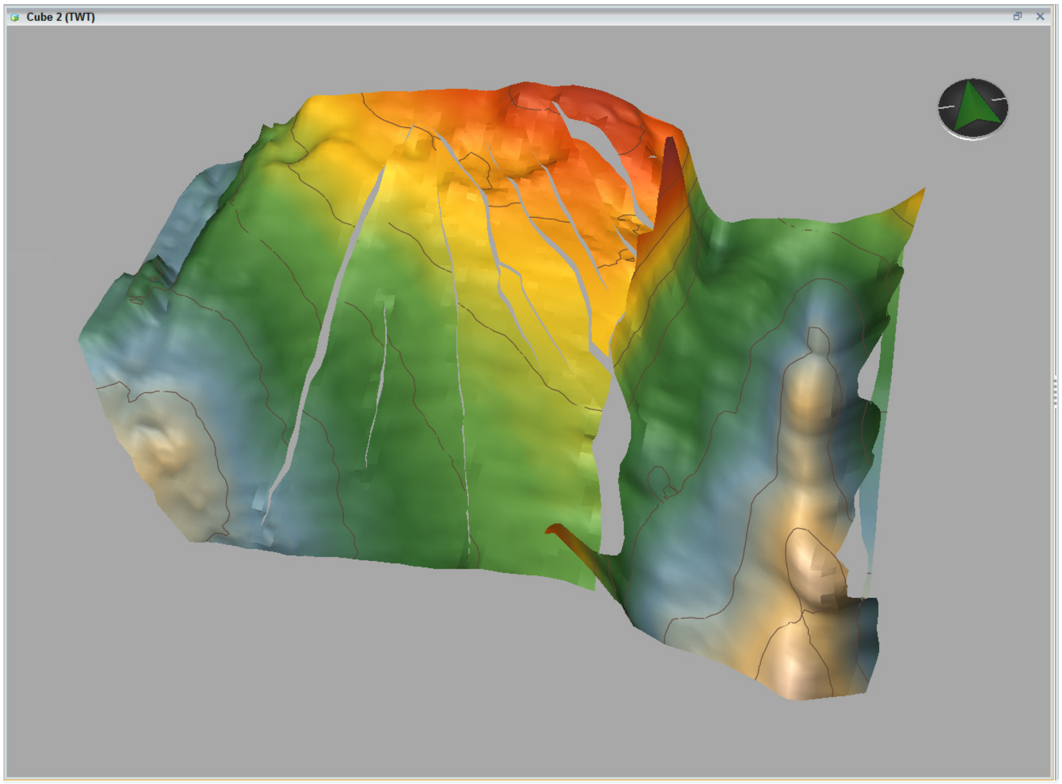
3. To see the intersections with the colors of the corresponding fault, **MB3** on the surface and select **Display Properties**. In the *Display Properties* dialog, select the **Show Intersections** check box and click **OK** to close the dialog.



Your *Cube* view should now look similar to the one below, showing the colors of the corresponding faults around the fault polygons.



4. To view the offsetting of the surface, activate *Cube* view and observe the fault offsetting applied to **YOU_TOP_RES**.



> **Note**
>
> You also have the ability to save the fault polygons created using Dynamic Frameworks to Fill to the database as mapping polygons in OpenWorks. To do this, **MB3** on the horizon and then select **Dynamic Frameworks to Fill > Save as > save intersections as mapping polygons**. The resulting polygons are identical to the intersections, so the intersection lines that do not close will also not be completely closed polygons.

Dynamic Frameworks to Fill provides ways to edit the intersections and polygons if you are not satisfied. You can either edit the intersections within the framework prior to saving them to OpenWorks, or you can edit the polygons themselves while in polygon interpretation mode. Note that changing the intersections within the framework will cause the framework surface to be regridded.

Exercise 4.7: Calculating Fault Heaves (optional)

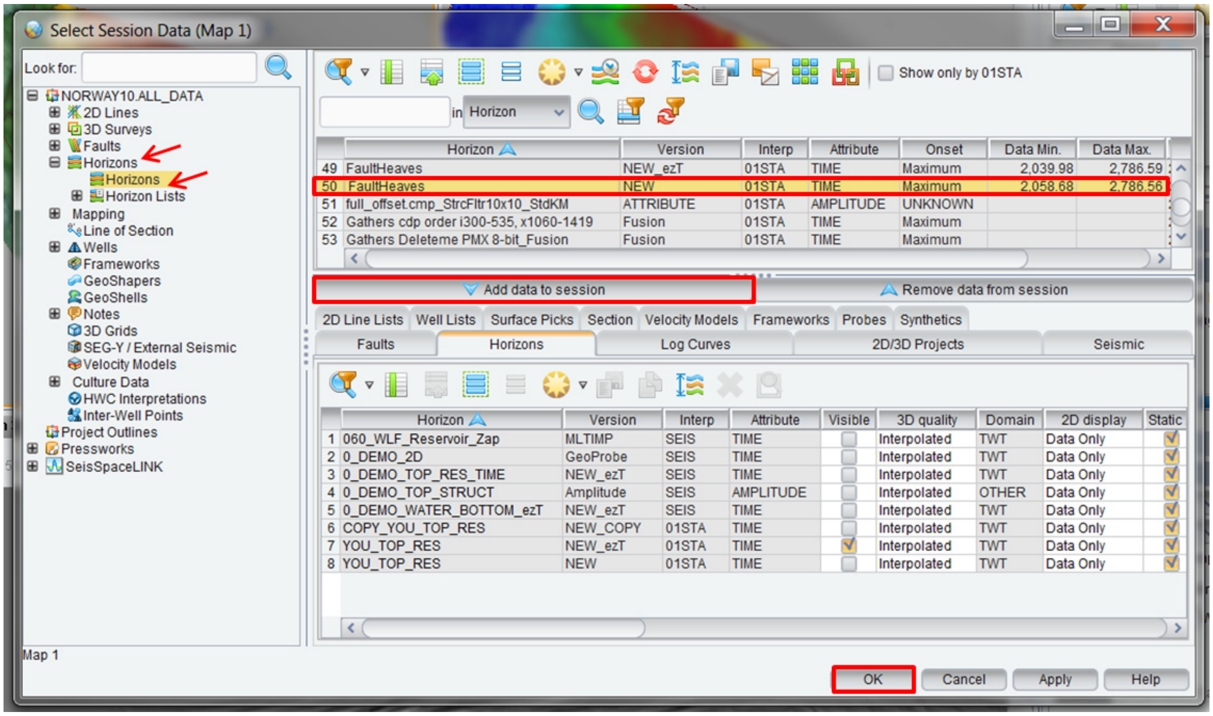
The following exercise teaches you the conventional method used in DecisionSpace Geosciences for calculating fault heaves and creating fault polygons. Fault heaves are the representation of the horizontal gap within a horizon caused by the displacement of the fault. Fault polygons are then created as the graphical representation of the fault heaves, which are then used for identifying trends in the area.

For the software to perform the fault heave calculations, certain rules must be followed during interpretation:

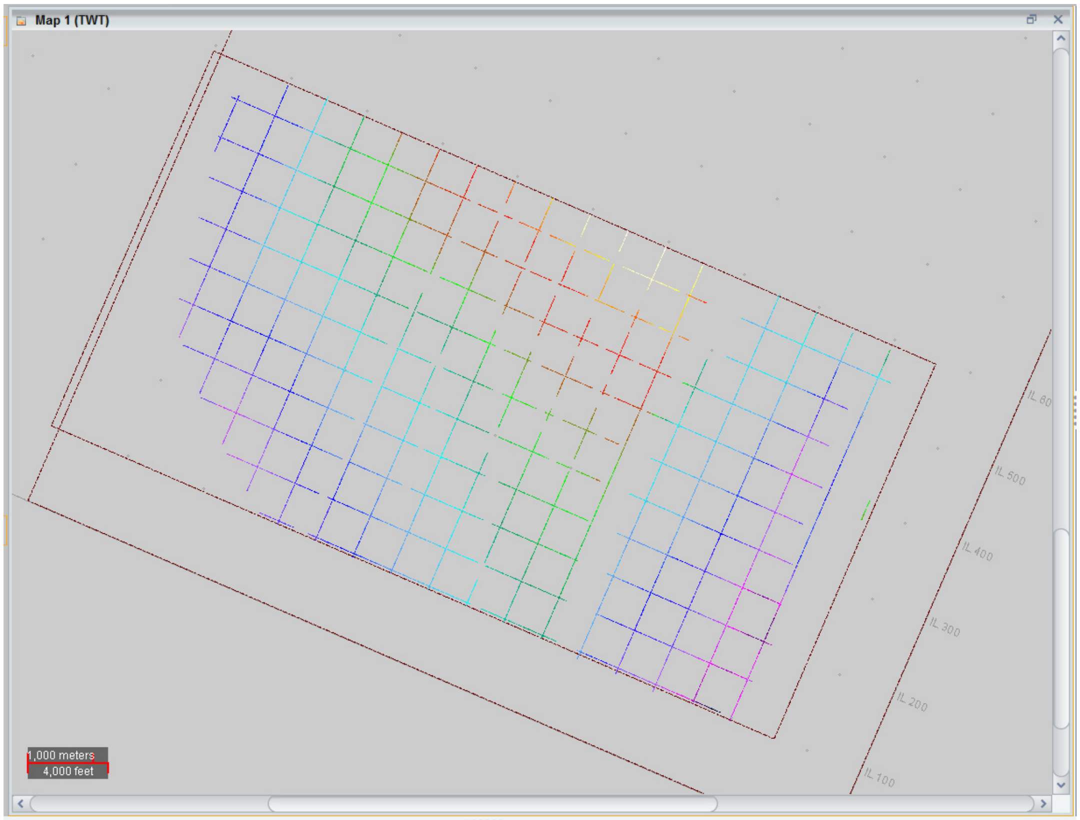
- Heaves only work with Fault Segments, not triangulations
- Horizon must not cross over faults
- Horizon must exist on both sides of the fault

The horizon you have previously interpreted crosses over faults in multiple places, therefore you will add a preexisting horizon into your session that already conforms to all of the above rules. You will then use this horizon to calculate fault heaves.

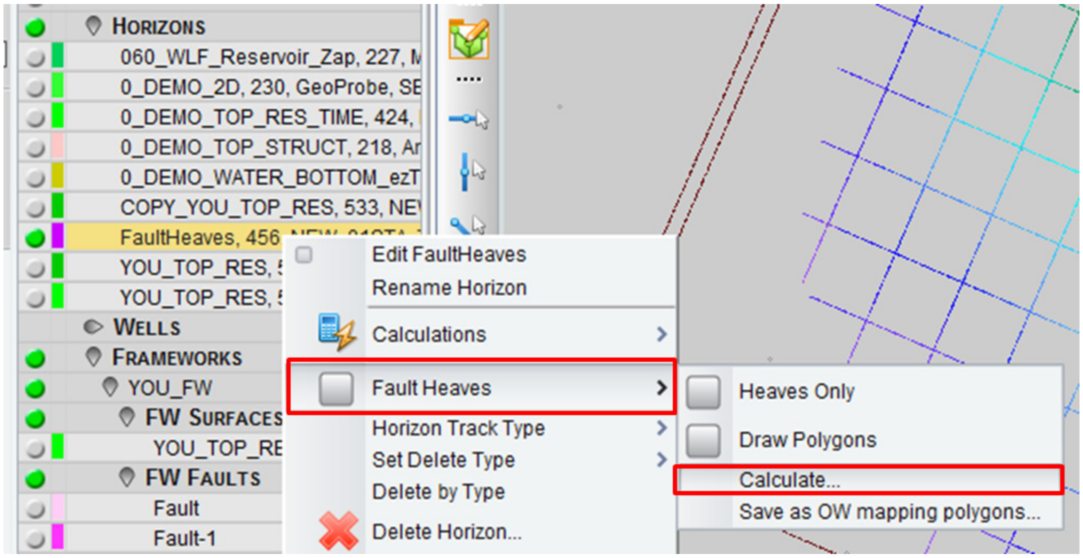
1. Go to **Select Session Data** ( ) and select **Horizons** > **Horizons**. In the upper right panel, select **FaultHeaves, NEW** and then click **Add data to session**. Click **OK** to close the dialog.

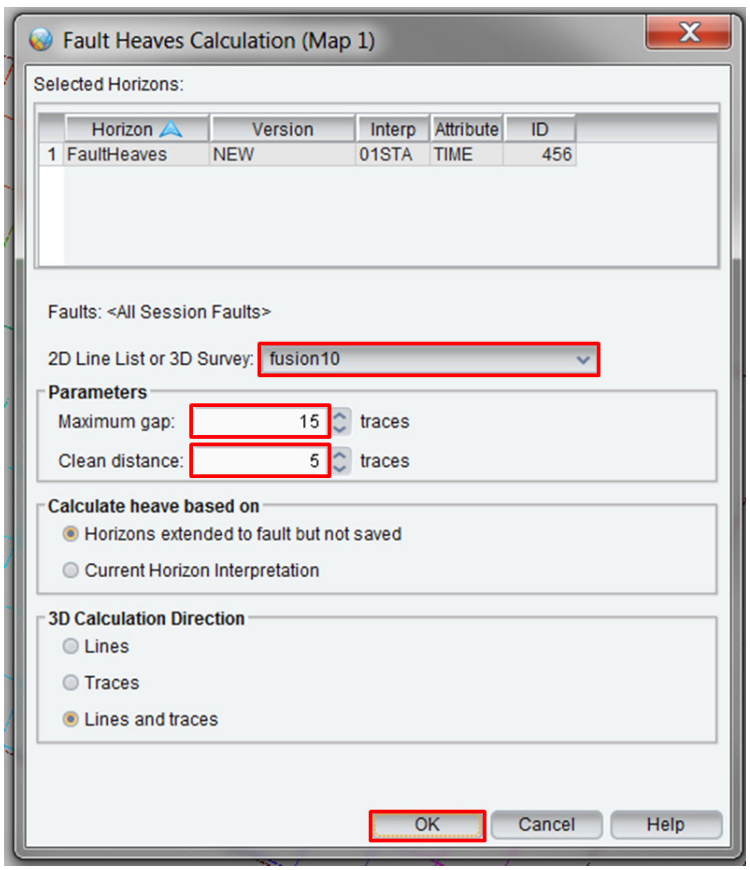


2. Activate and maximize *Map* view, and in the *Inventory* task pane, display only the horizon **FaultHeaves**.



3. In the *Inventory*, select and **MB3** on **FaultHeaves** and then select **Fault Heaves > Calculate...**. In the *Fault Heaves Calculation* dialog, select the parameters as shown below.

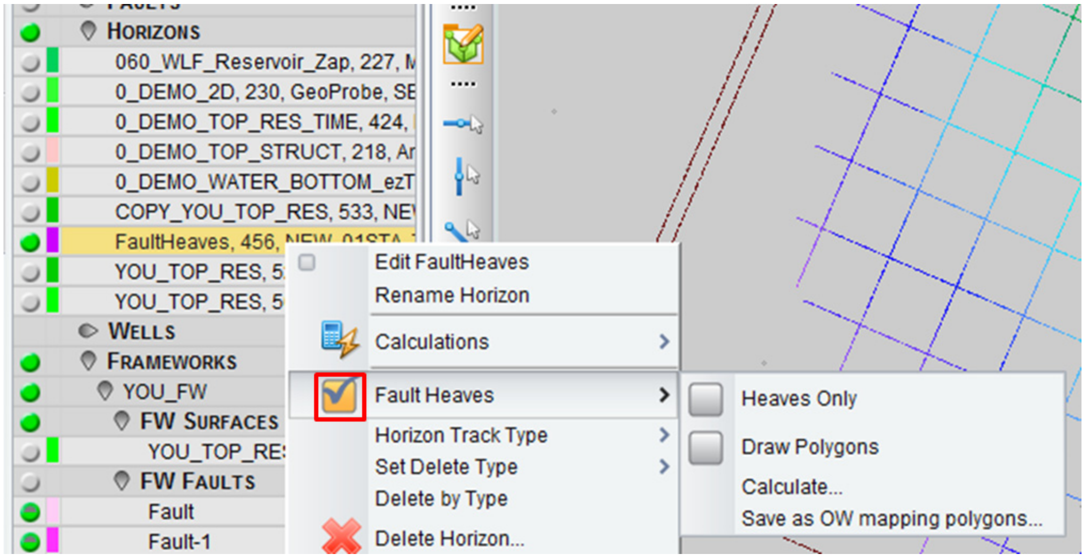


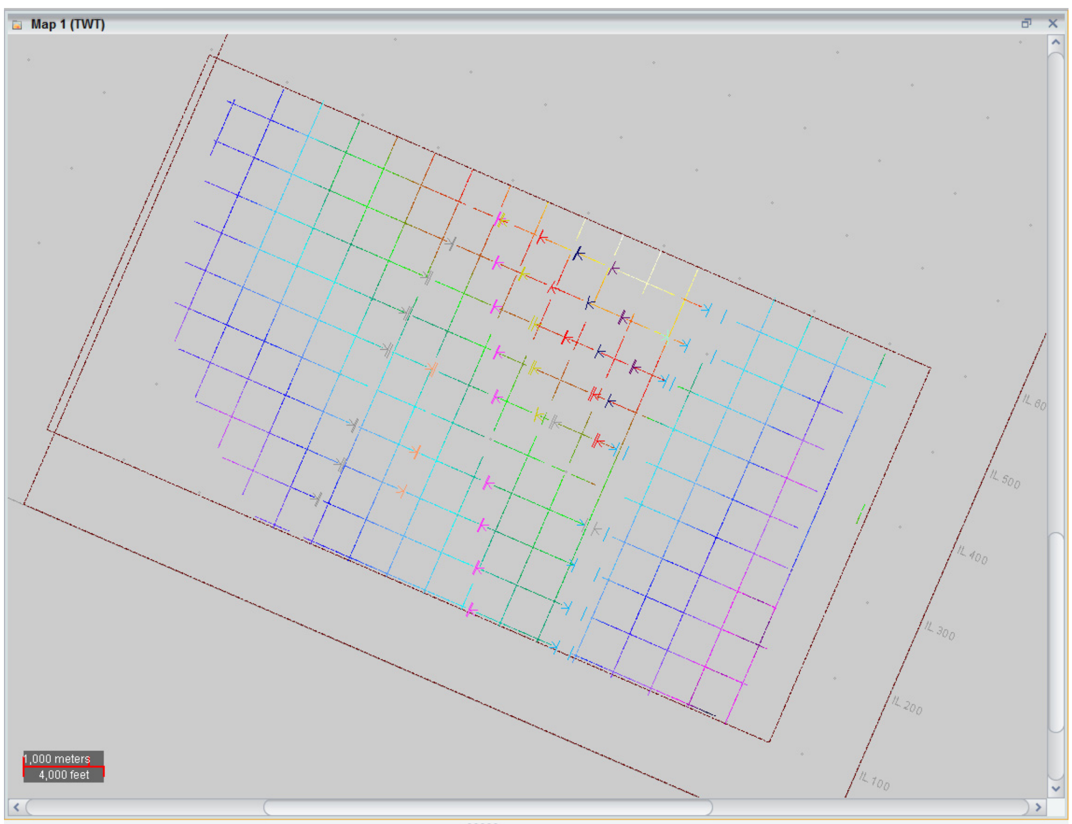


Maximum gap is the number of traces the software will search outwards of the fault to find a horizon segment. The value should be large enough for the software to find horizon segments on either side of the fault. There are no disadvantages for using too large of a number.

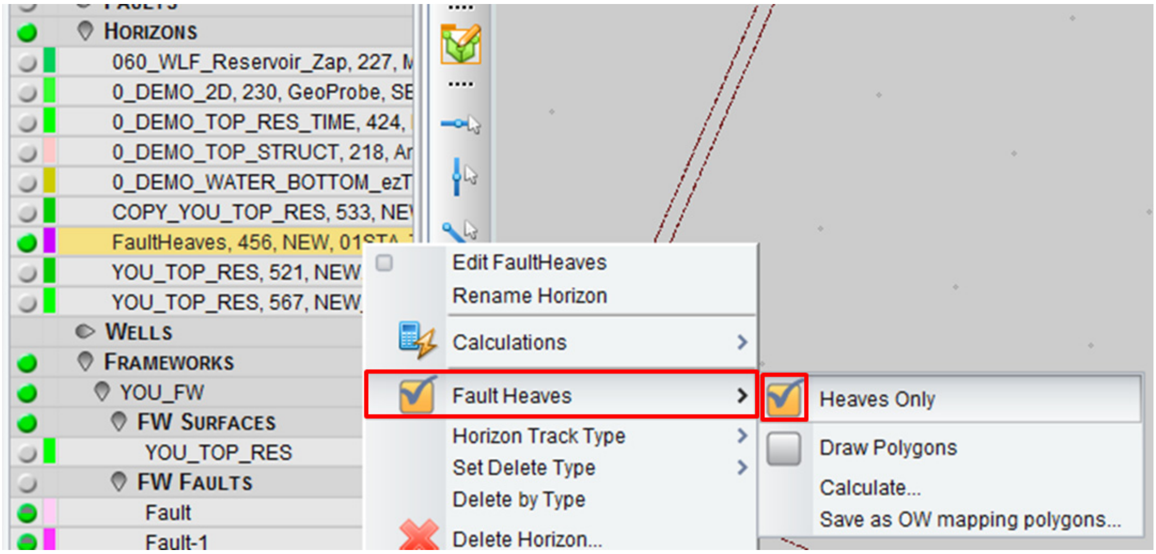
Cleaning distance defines the distance around the fault in which the software will not consider horizon data while calculating fault heaves. Applying cleaning distance, as well as selecting *Horizons extended to fault but not saved*, will clean the traces around the fault and then extrapolate the horizon to the fault before calculating. The original interpretation will not be changed.

4. To view the heaves in *Map* view with the horizon, **MB3** on the **FaultHeaves** horizon and select the **Fault Heaves** check box.

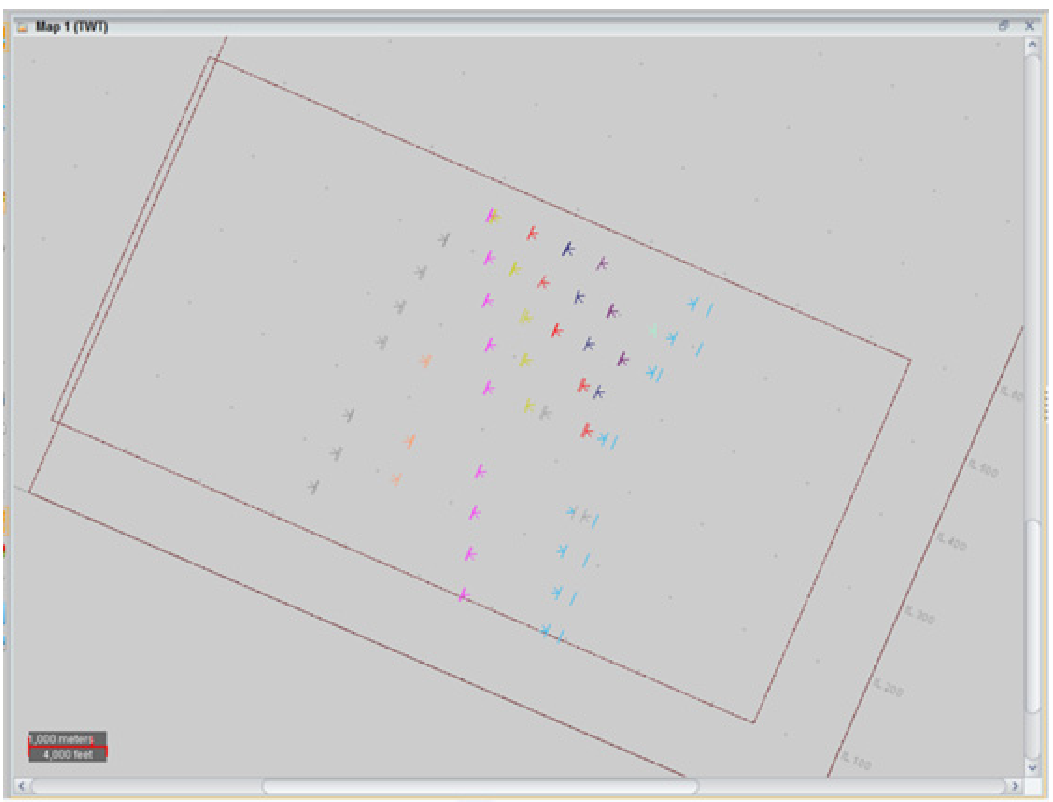




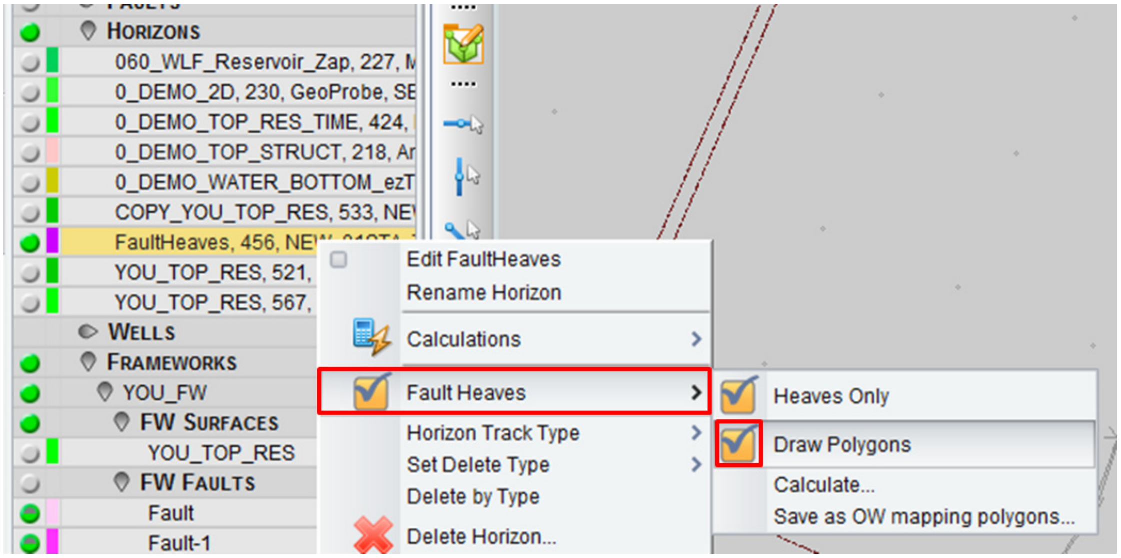
5. You may also view only the fault heaves, without the horizon interpretation, **MB3** on **Fault Heaves** and select the **Heaves Only** check box.



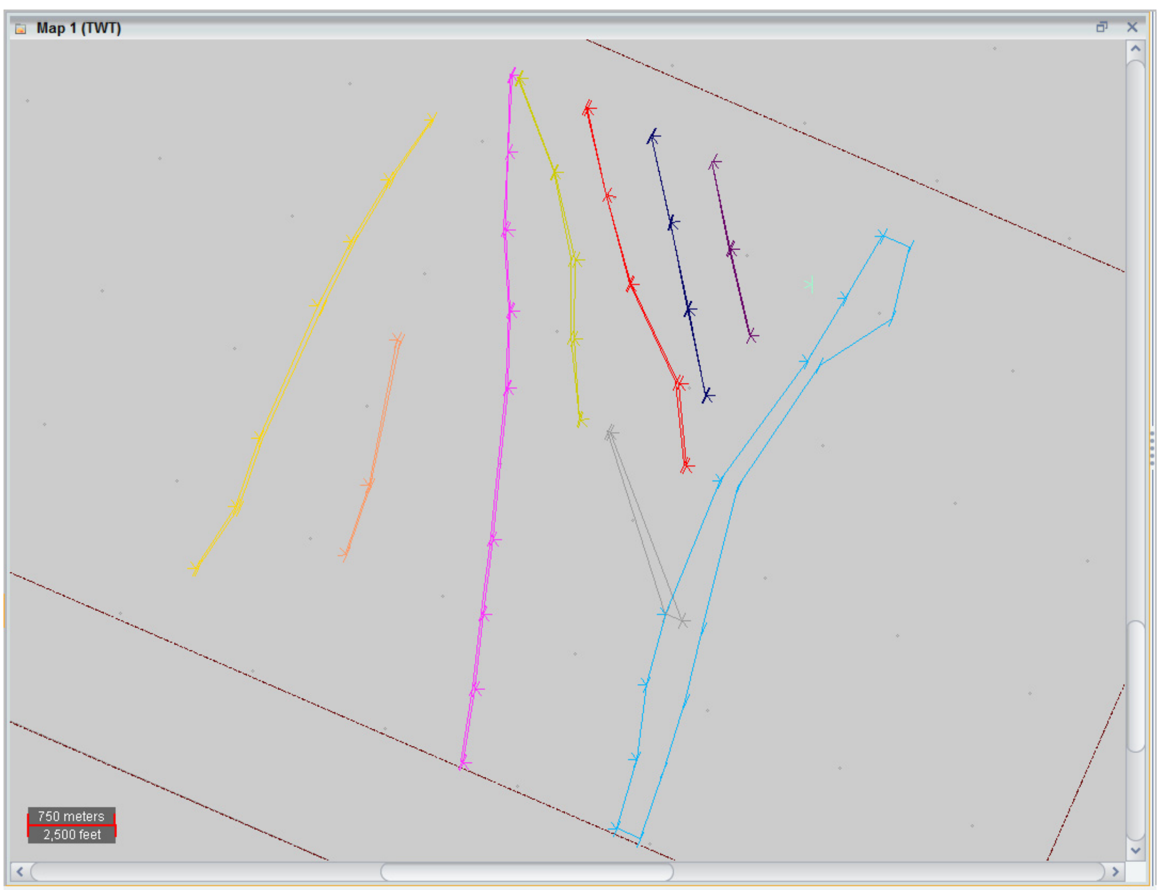
Your *Map* view should look similar to the one pictured below.



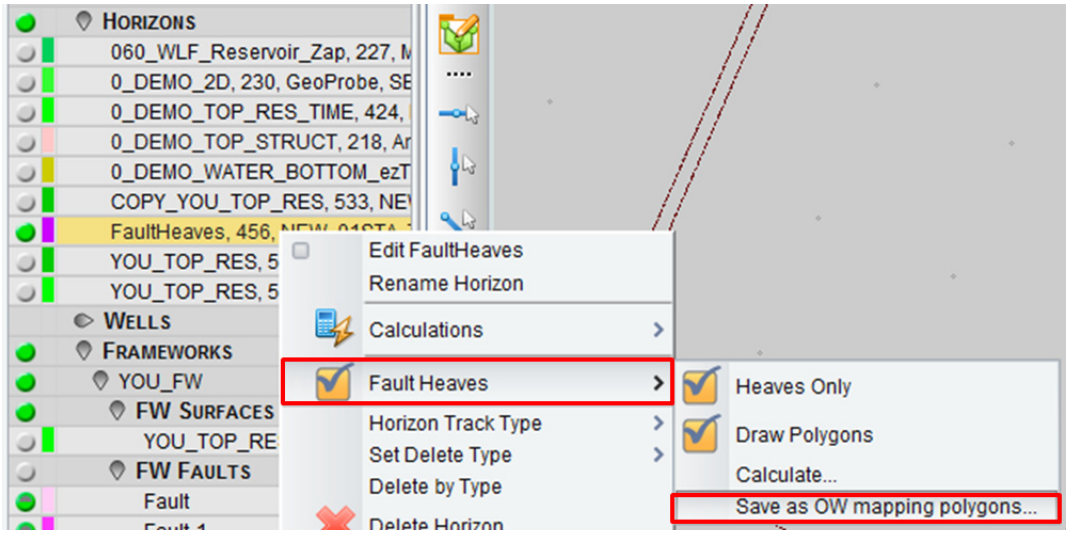
6. To create the fault polygons around the fault heaves, **MB3** on the **Fault Heaves** horizon and then select **Fault Heaves** > **Draw Polygons** check box.



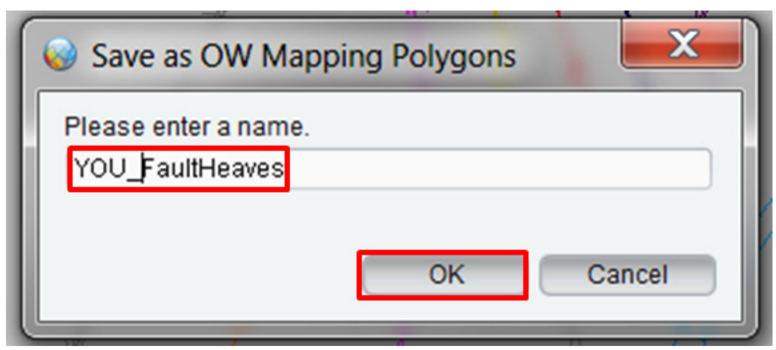
Your view should look similar to the one below.



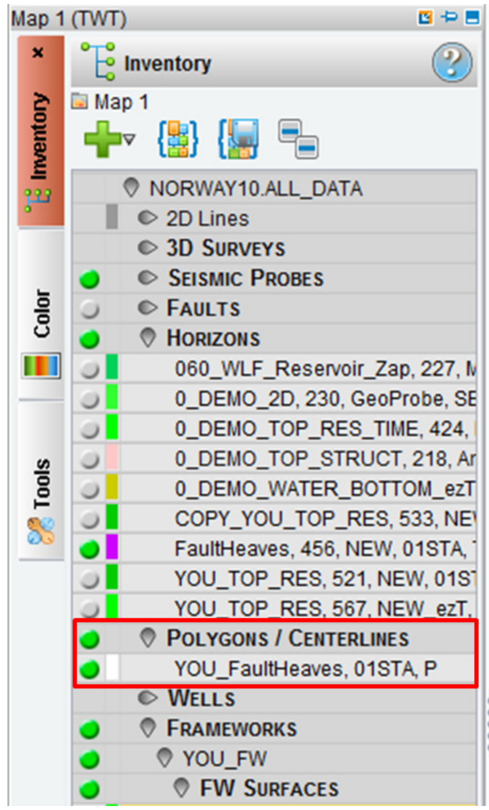
7. You have the ability to save the polygons as OpenWorks Mapping Polygons. To do this, **MB3** on the **Fault Heaves** horizon in the *Inventory* task pane and select **Fault Heaves > Save as OW mapping polygons...**.



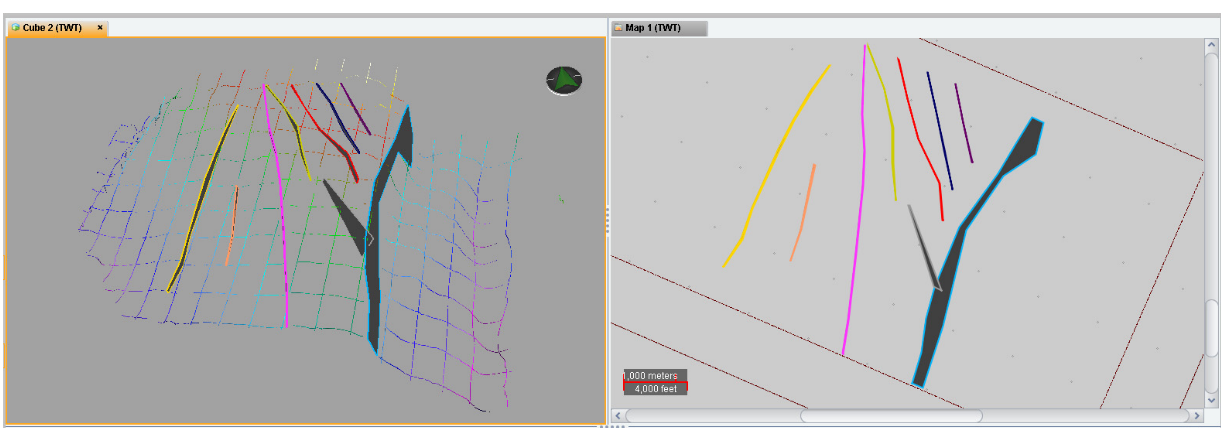
8. In the *Save as OW Mapping Polygons* dialog, type the name "**YOU_FaultHeaves**" and click **OK**.



The polygons now appear as a new data item under *Polygons/Centerlines* in your *Inventory* that can be toggled on in both *Map* and *Cube* view.



9. With *Cube* view active, toggle off the FW Surface **YOU_TOP_RES**, and toggle on the horizon **FaultHeaves** and the polygons **YOU_FaultHeaves**.



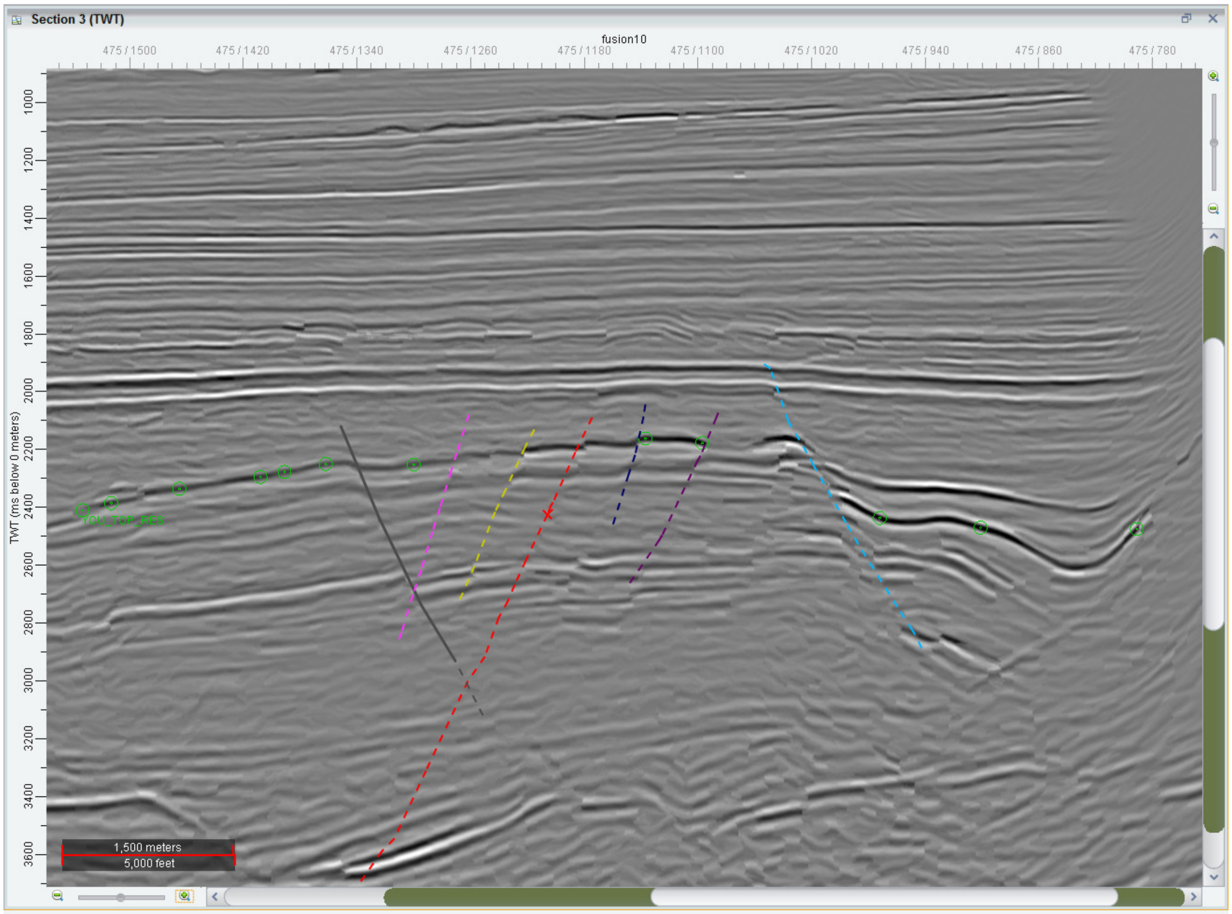
Exercise 4.8: ezValidator (optional)

ezValidator is a tool used for verifying and refining horizon interpretation in deformed regions by removing fault throw or unfolding horizons. Unfaulting the section allows you to view the seismic character and stratigraphy in a continuous manner. This allows you to easily correlate your surfaces across faults, and therefore validate your overall structural interpretation. Whereas, unfolding horizons helps to reveal depositional changes that occurred within the basin prior to deformation.

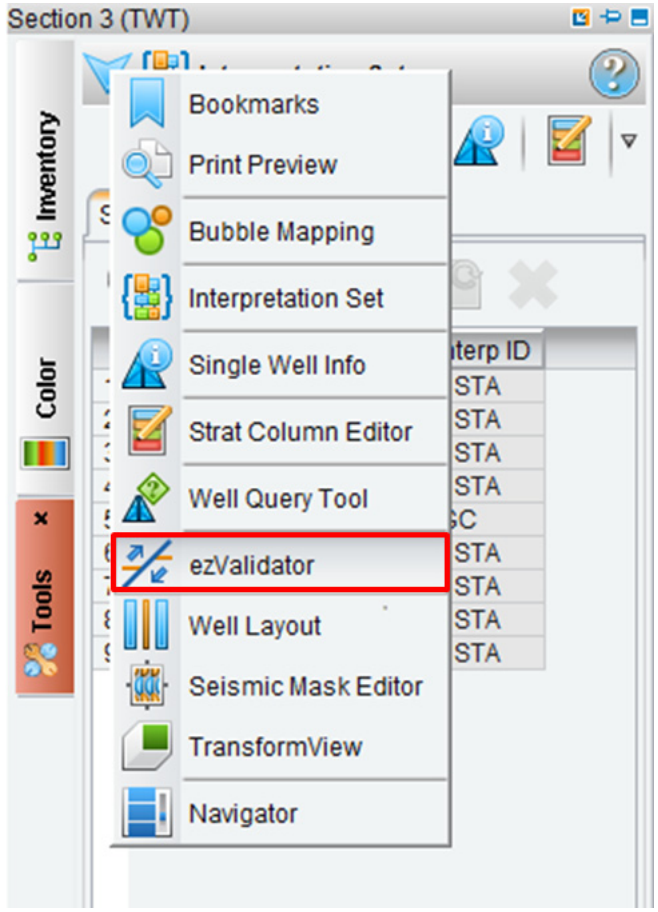
You will use ezValidator to unfault a section to correlate across a series of faults, and therefore more easily interpret your horizon. You will then unfold the horizon to view it as it was originally deposited. While ezValidator can be used in either the depth or time domain, it can only be used while in *Section* view.

1. Activate and maximize *Section* view, and using the frame controls navigate to **IL 475**. In the *Inventory* task pane, toggle on the horizon **YOU_TOP_RES, NEW**, as well as faults **Fault** and **Fault-1**, **Fault-10**, **Fault-2**, **Fault-3**, **Fault-5**, **Fault-7**.

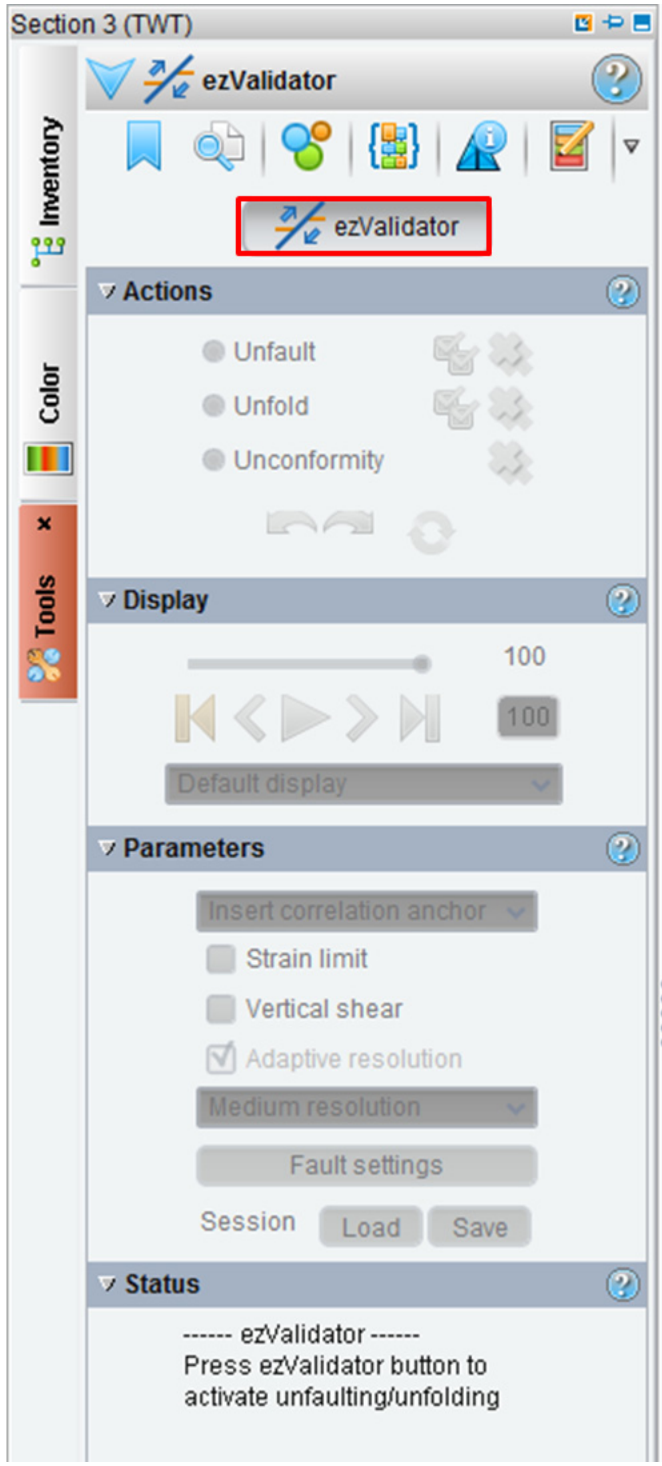
Your *Section* view should look like the one below.



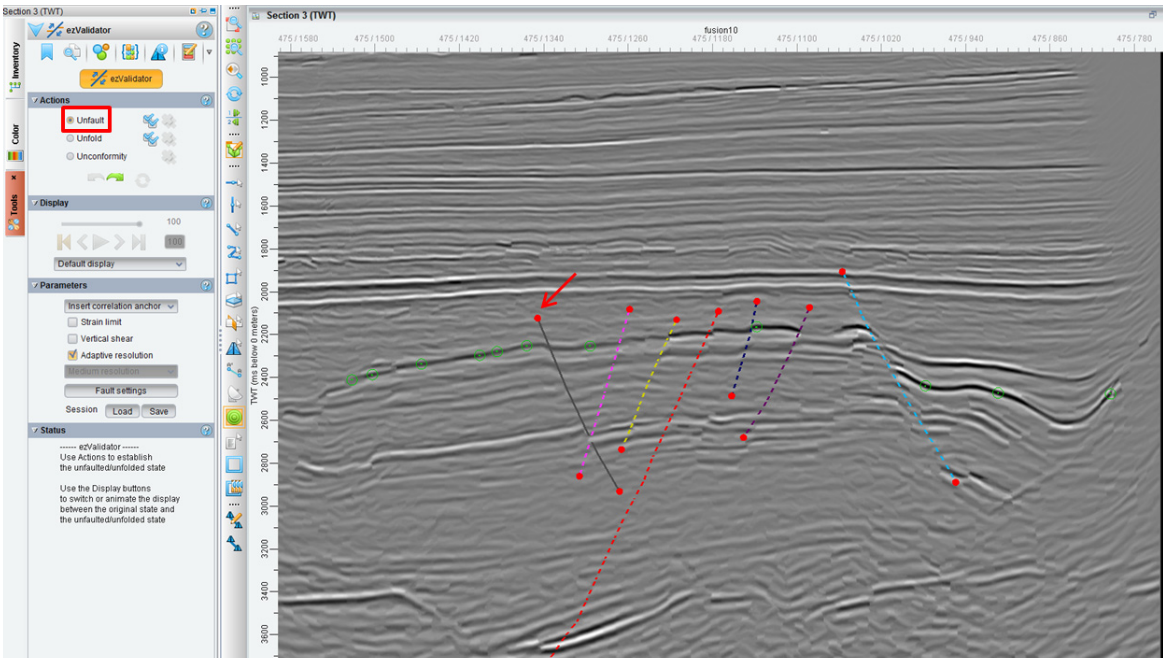
2. Navigate to the *Tools* task pane, click the drop-down ( ) icon at the top left and select **ezValidator**.



3. In the *ezValidator* task pane, click the **ezValidator** button to begin.

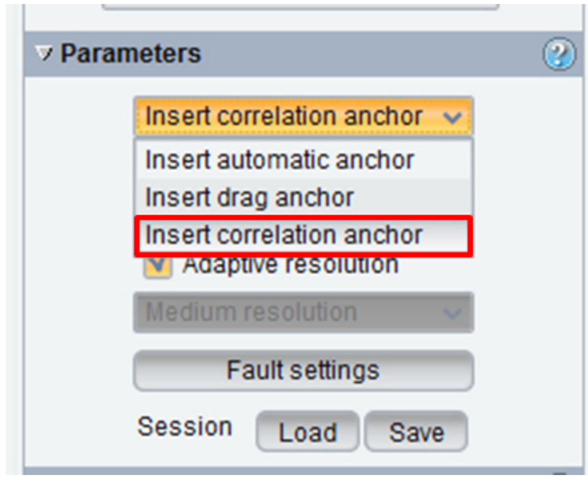


4. In the *Actions* panel, choose the option to **Unfault** your section. Active fault tip anchors will appear in red at the ends of all of the faults in your view.



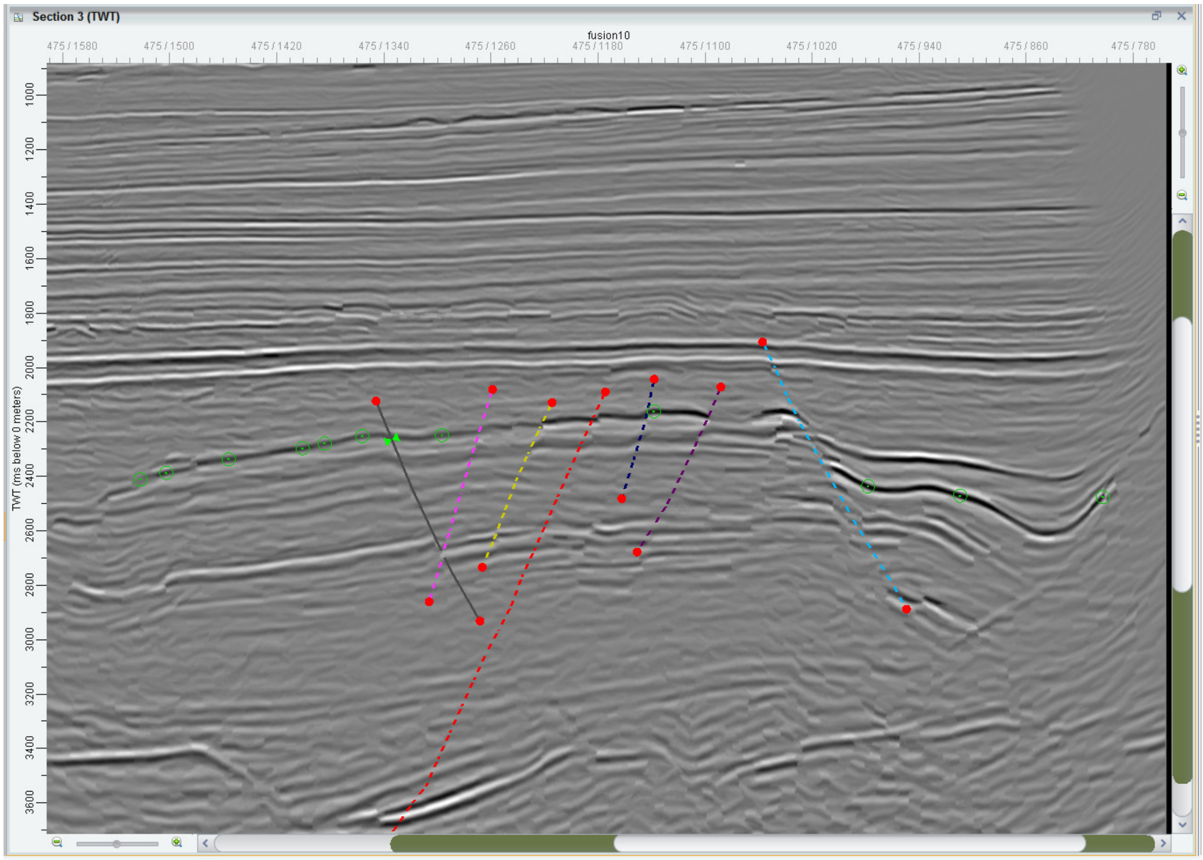
> **Note**
>
> The seismic will not be shifted beyond the fault tip anchors while you are performing any unfaulting. If you would like movement to occur beyond the end of the fault, **MB2** on the anchors causing them to be inactive, indicated by the white hollow circles.

5. In the *Parameters* panel, click the drop-down menu to select **Insert correlation anchor**.



To begin the unfaulting process you need to indicate a surface that exists on both sides of the faults. You will place anchors on a specific reflector, which the software will use to remove the total offset of the horizon caused by that fault.

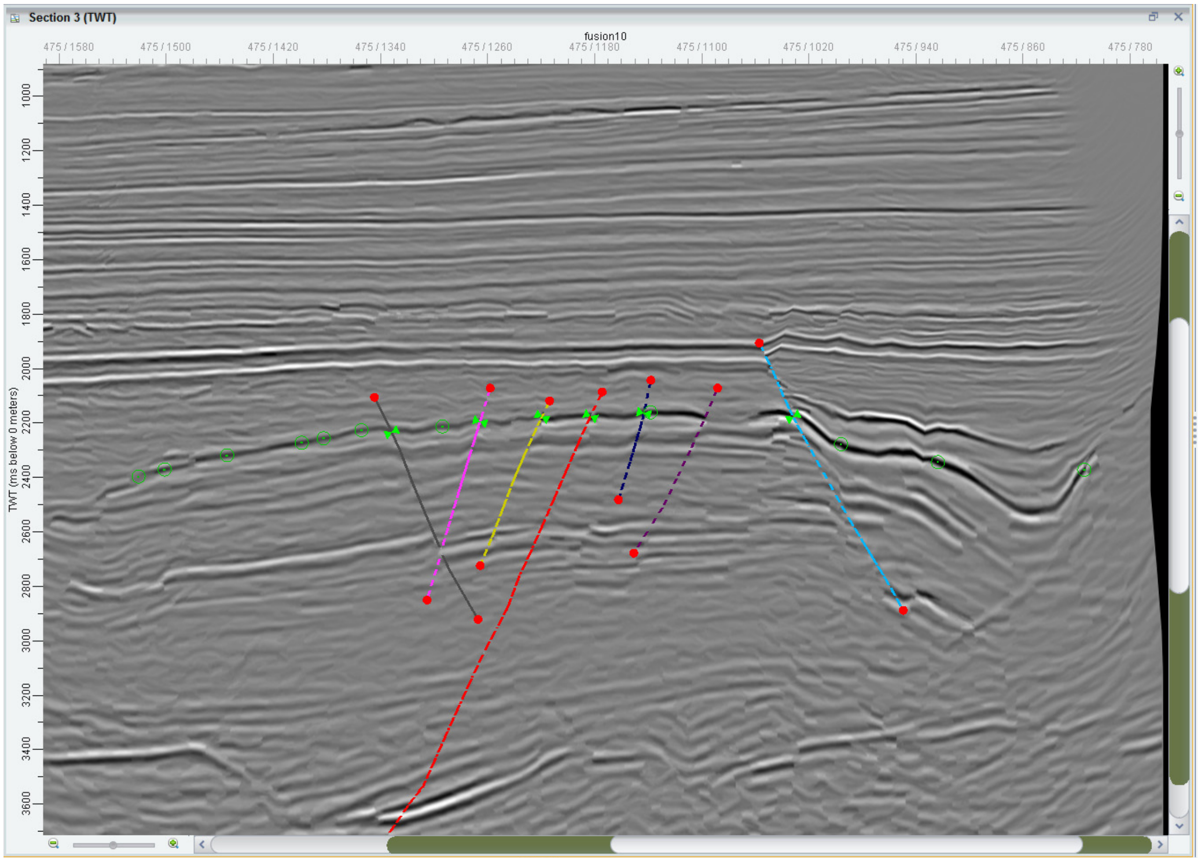
6. **MB1** on the reflector for **YOU_TOP_RES, NEW** on one side of **Fault**. A yellow arrow will appear to mark the location. **MB1** on the same reflector on the other side of **Fault** and the seismic will unfault to remove the offset.



> **Note**
>
> After unfaulting is performed, green drag anchors will appear marking the location of the reflector along the fault. You can **MB1** on the anchors to move the seismic on one side of the fault up and down in order to adjust the correlation.

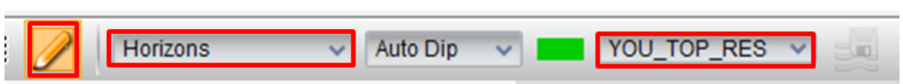
7. Repeat step 6 for the other faults until the seismic is unfaulted along the entire reflector.

Your view should look similar to the one below after you have completed the unfaulting.

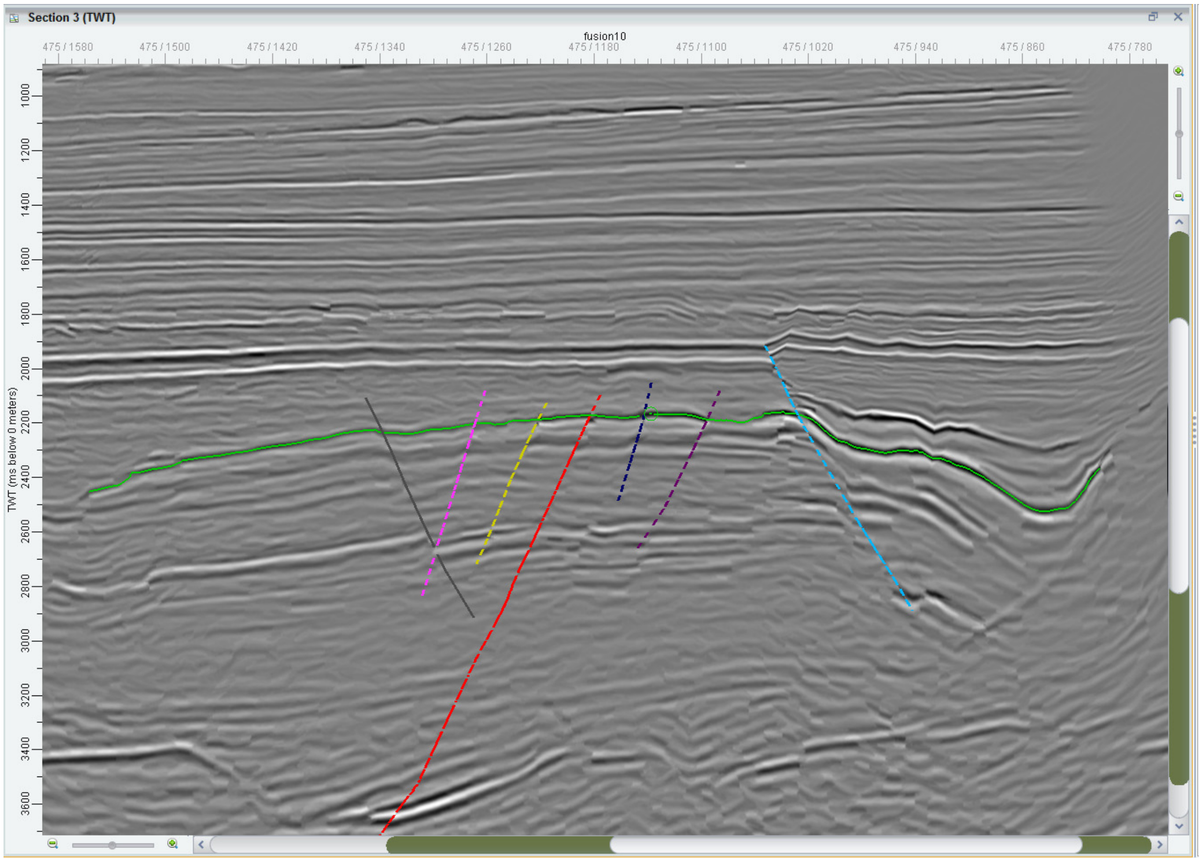


Note
You can delete anchors by clicking **MB2**.

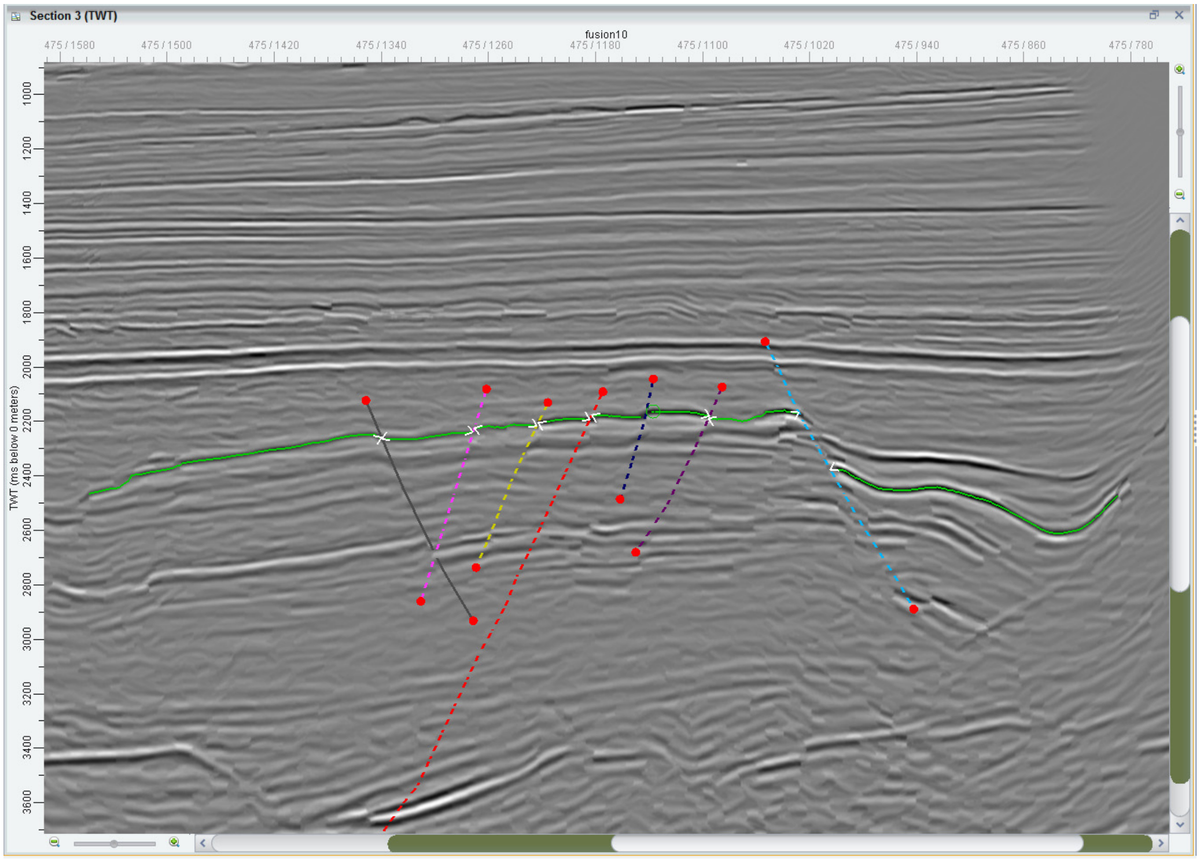
8. When you are satisfied with the unfaulting, activate **Interpretation Mode** from the *Interpretation* toolbar. Select **Horizons** from the *Data Type* drop-down and make sure **YOU_TOP_RES, NEW** is the active horizon.



9. Interpret **YOU_TOP_RES, NEW** across the section by clicking **MB1** to begin the interpretation and clicking **MB2** to finish your interpretation. When you are satisfied turn off **Interpretation Mode**.

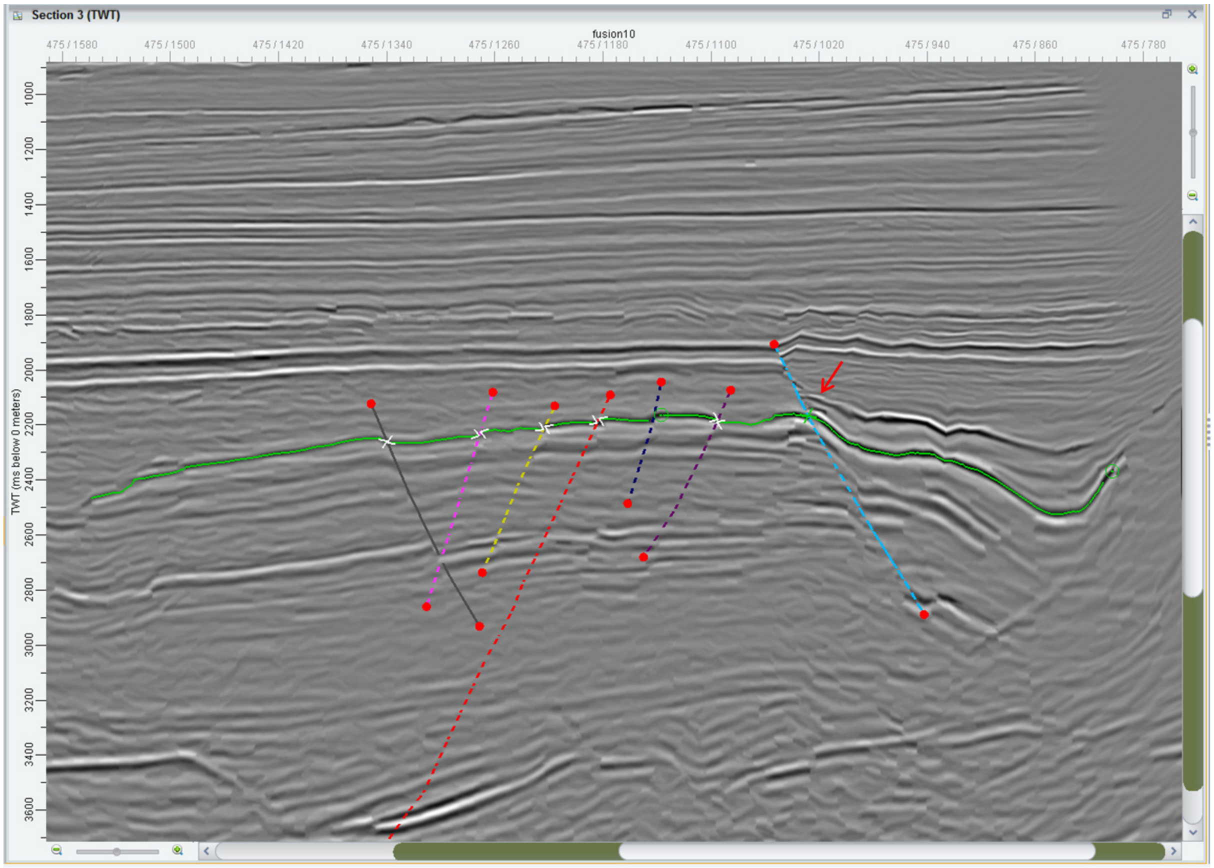


10. Click the **Unfault reset** ( ) icon in the *Actions* panel to return the horizon to its original offset position.



The drag anchors are now replaced with horizon anchors, which mark the horizon on either side of the fault. The anchors shown in the picture above are white indicating that they are inactive. Active anchors are displayed in the same color as the horizon they correspond to. In the next steps, you will activate the anchors.

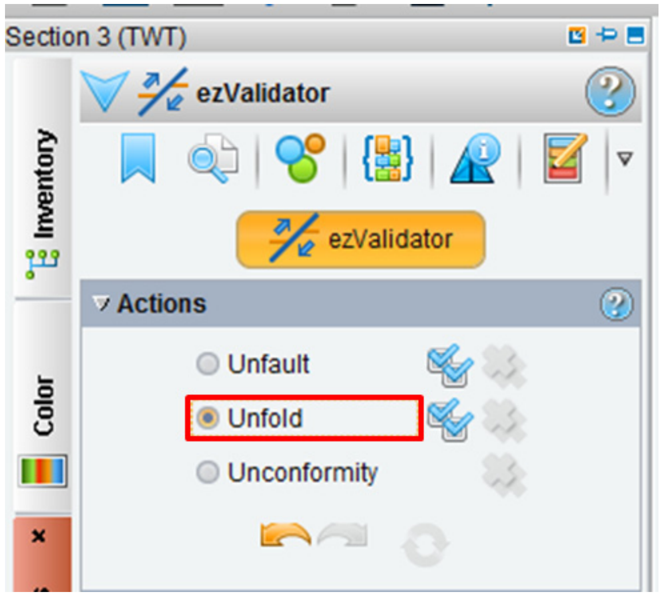
11. **MB1** on a horizon anchor associated with **Fault-10**, indicated by the arrow in the picture below (furthest to the right).

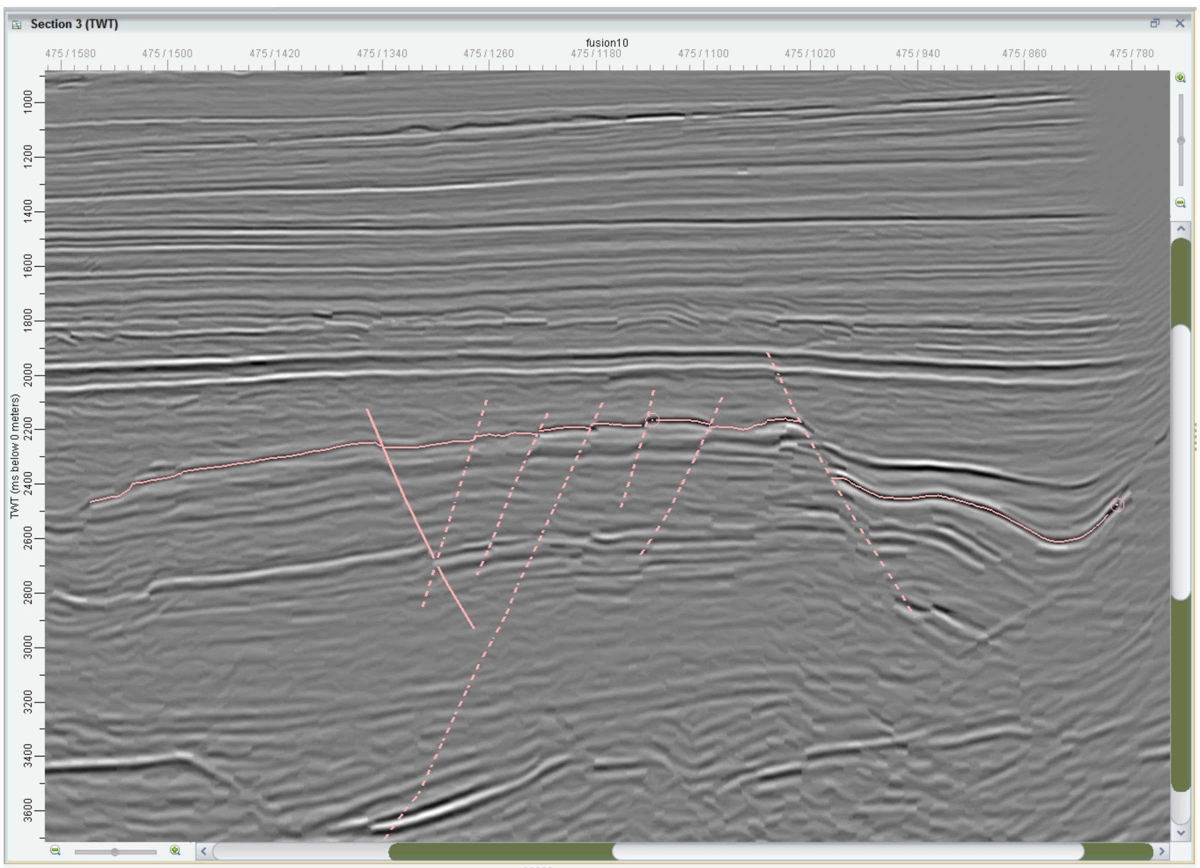


By clicking on the anchor, you have removed the offset caused by the fault. Notice the anchors on Fault-10 are active and match the color of the horizon.

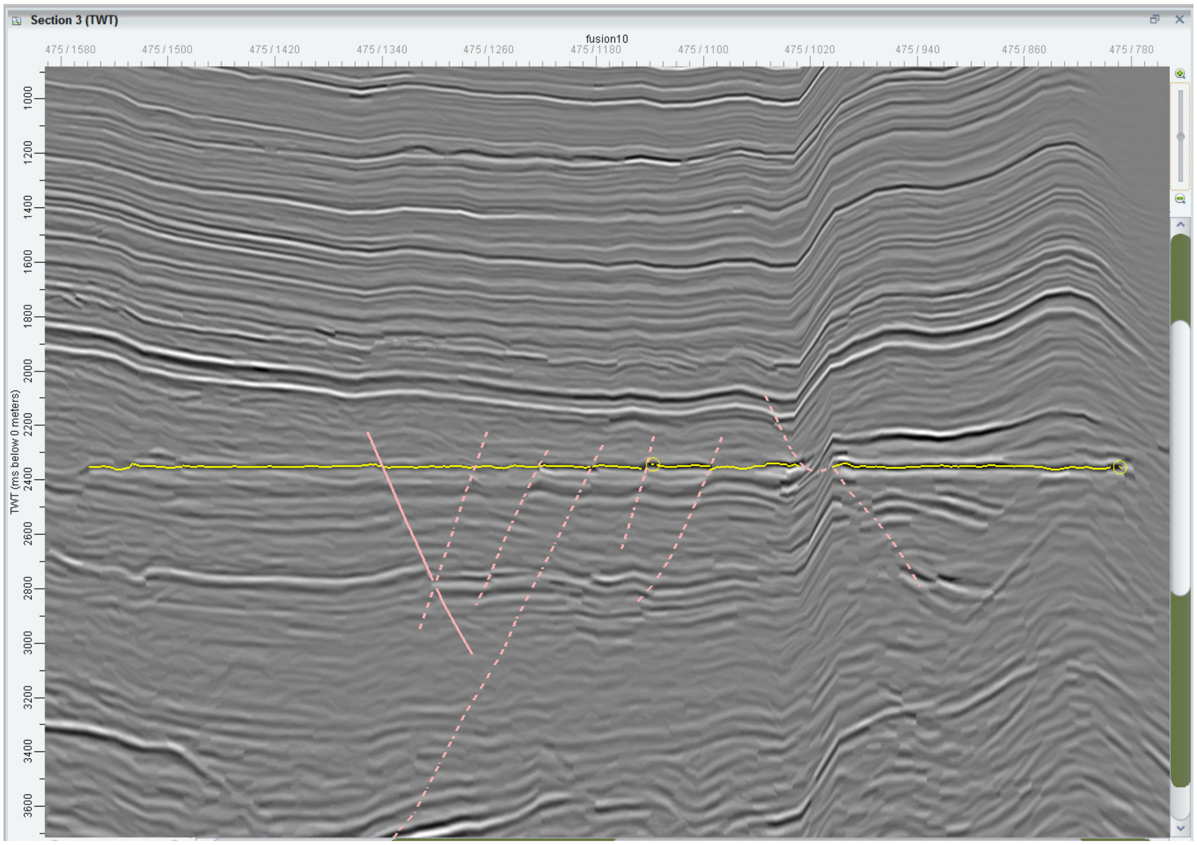
12. Return to the original fault offset by clicking **MB2** on the anchors.

13. In the *Actions* panel, toggle on the option to **Unfold**. All of the faults and the horizon changes to a light pink color.





14. **MB1** on the horizon to unfold it.



Notice that although the horizon is being restored to a flattened state, the remaining seismic area has become deformed to accommodate this change. This is partly due to an existing unconformity above the horizon that has not been accounted for, therefore causing the region above to be deformed as the entire seismic is shifted. There are also a few minor faults that have not been unfaulted which can also cause deformation in the seismic.

Note
More information on the limitations to unfolding is found in the Help page.

15. Click the **ezValidator** button to turn off the ezValidator tool and return the section back to its original state.

Exercise 4.9: Seismic Calculator

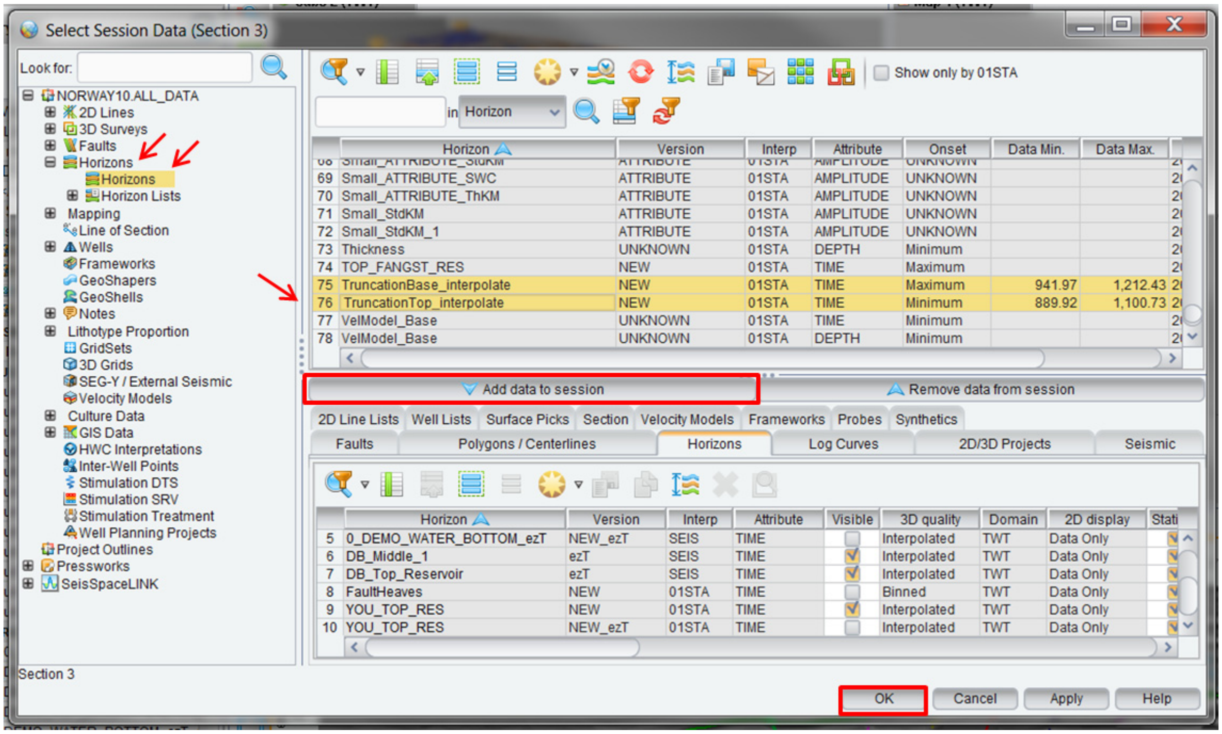
Seismic Calculator is a tool available in DecisionSpace Geosciences that contains preloaded algorithms to help you perform common calculations. Along with the preexisting algorithms you can create your own or edit the preloaded ones to fit your needs. The calculator provides a quick way to merge or delete portions of horizons as well as create new ones. For this exercise, you will learn how to perform the following calculations that specifically deal with horizons:

- Merging two horizons
- Creating proportional slices between two horizons
- Truncating one horizon against another
- Decimating a horizon

These operations will be performed on horizons that are already available in the dataset, some of which have been created specifically to demonstrate these calculations. You have a few of the horizons already loaded in your *Inventory*, but you must add the others into your session.

1. Go to **Select Session Data** ( ). In the dialog, select **Horizons > Horizons** and **MB1+<Ctrl>** the following horizons:
    - **DB_TOP_RESERVOIR, ezT**
    - **DB_Middle_1 (TIME)**
    - **TruncationBase_interpolate**
    - **TruncationTop_interpolate**

2. Click **Add data to session** and click **OK** to close the dialog.

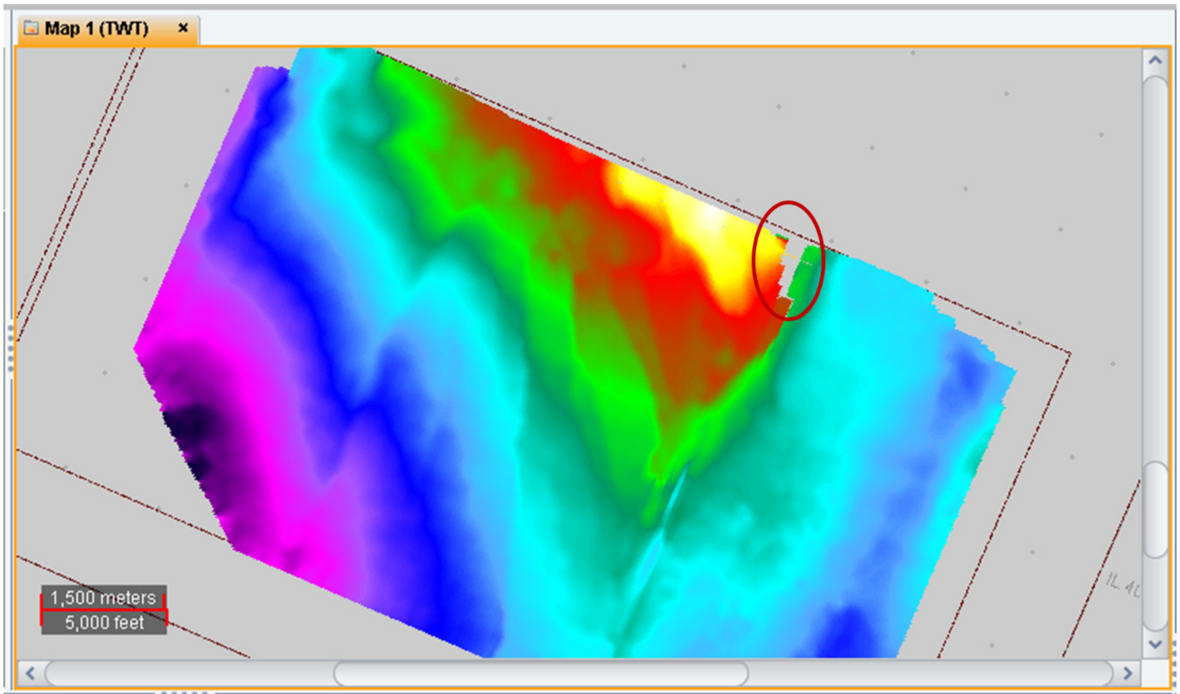


Merging Two Horizons

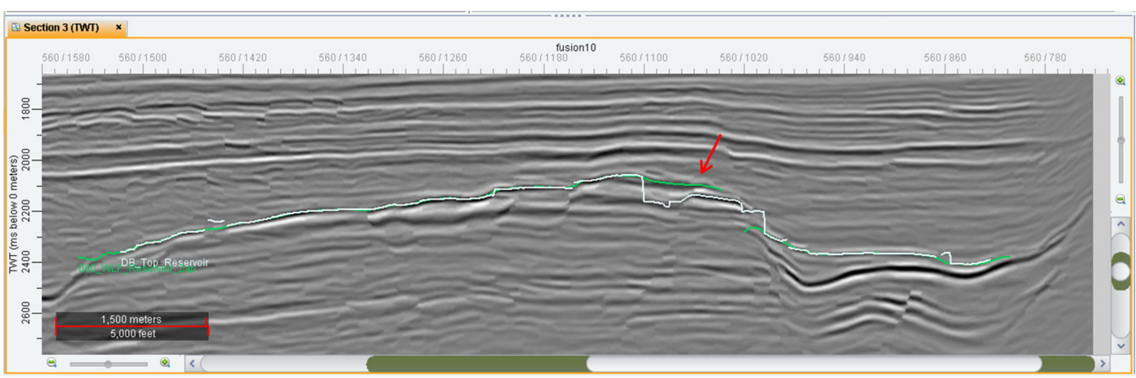
In the following steps, you will learn how to merge two horizons. This is useful when you have two overlapping horizons each with valid information to incorporate into one all-encompassing surface. It can also be used to connect horizons from different surveys. In the following steps you will use the merging functionality to fill the gaps of one horizon with the information from another.

3. In *Section* view, navigate to **inline 560** by entering “**560**” in the *Current Inline Input* field in the *Frame Control*.

4. Activate *Map* view and display only the horizon **060_WFL_Reservoir_Zap**. Zoom in and note the gap in the horizon shown circled in the picture below.

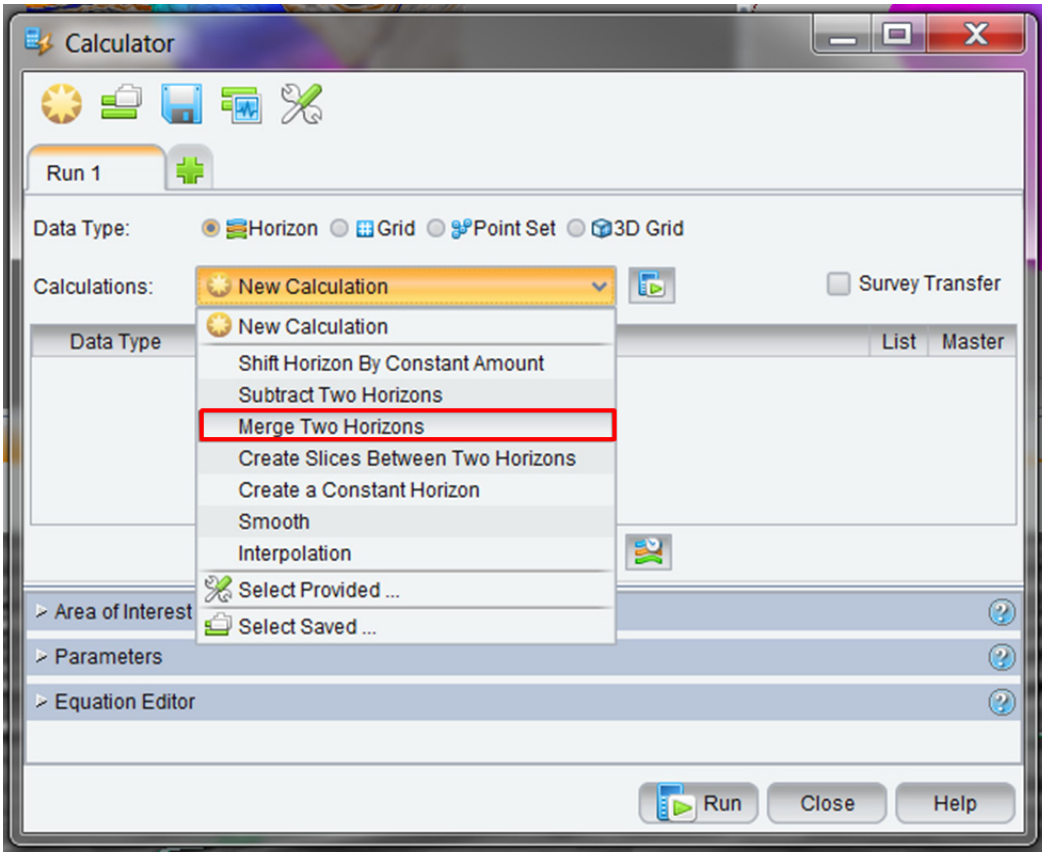


5. Activate *Section* view, and in the *Inventory*, display only the horizons **060_WFL_Reservoir_Zap** and **DB_TOP_Reservoir**, as well as the **full_offset.cmpStrcFltr10x10** seismic volume. Notice that the DB_TOP_Reservoir contains the data missing from 060_WFL_Reservoir_Zap. Merging these two horizons will be useful for creating a fully resolved horizon.

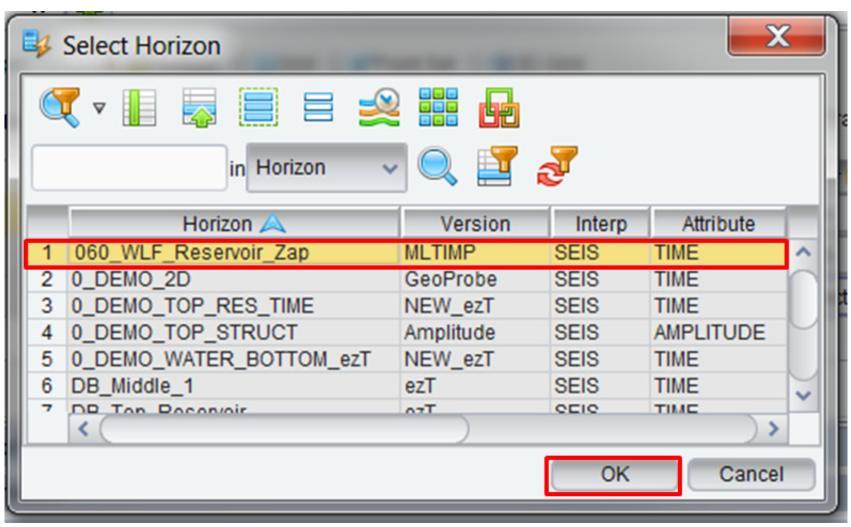


6. From the main menu bar, select **Tools > Calculator** to open the *Calculator*.

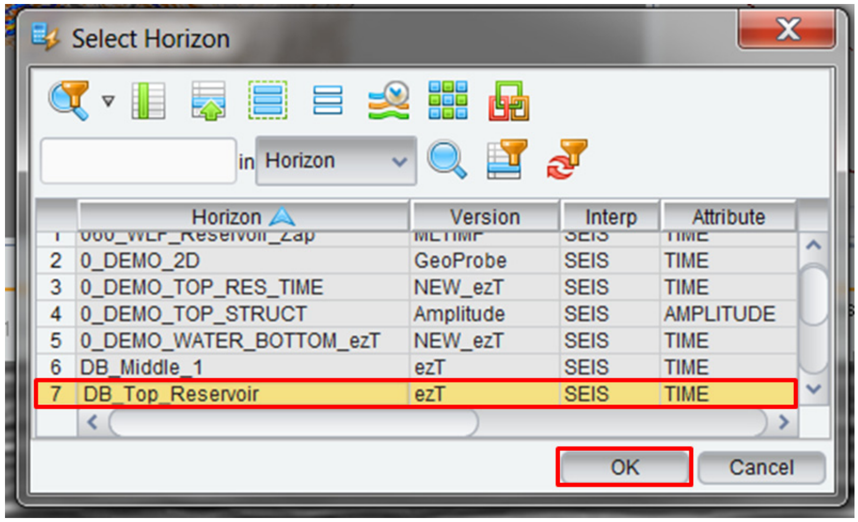
7. In the *Calculator* dialog, from the *Calculations* drop-down menu, select **Merge Two Horizons**.



8. For Input 1, click the **List** ( ) icon. In the *Select Horizon* dialog, select **060_WLF_Reservoir_Zap** and click **OK**.

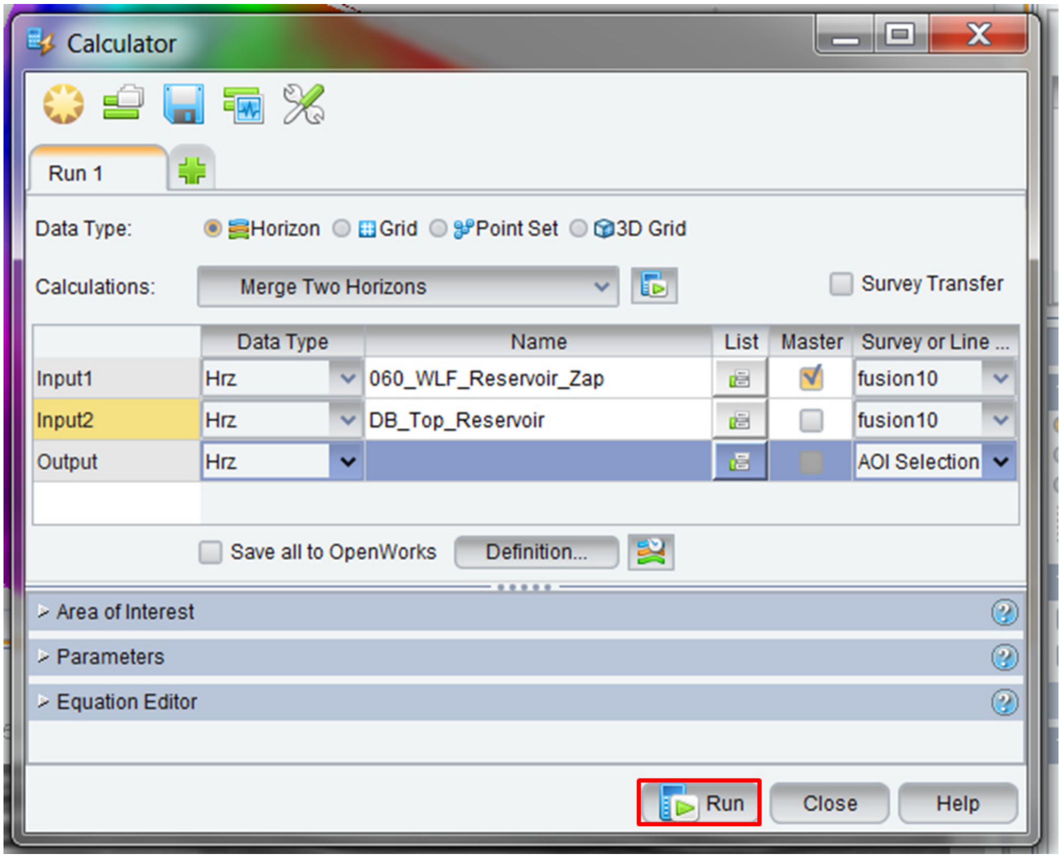


9. For Input 2, click the **List** ( ) icon. In the *Select Horizon* dialog, select **DB_TOP_Reservoir** and click **OK**.

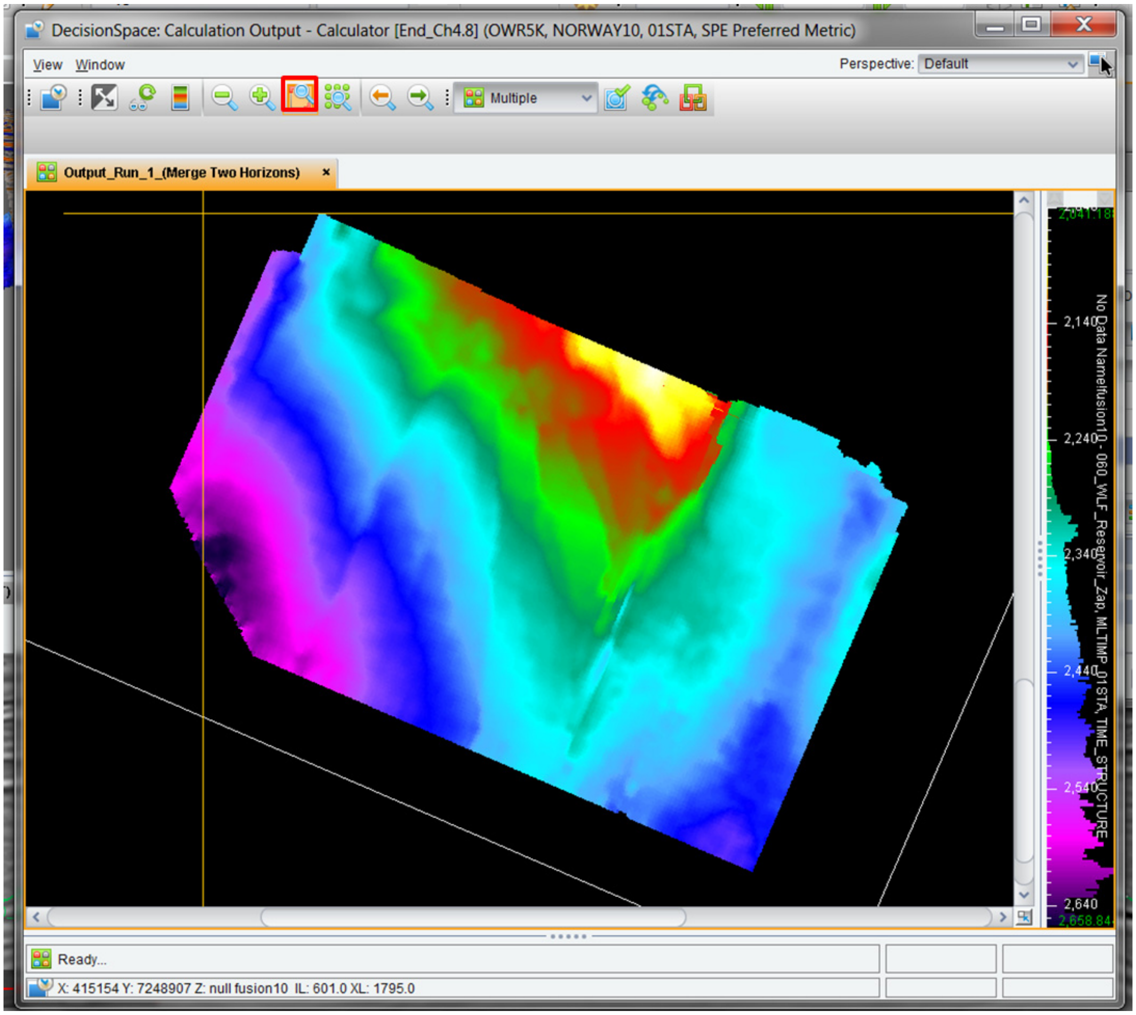


> **Note**
>
> You can also drag-and-drop the horizons from your *Inventory* into the *Name* fields.

10. In the *Calculator* dialog, leave the *Output Name* field blank. Click the **Run** button.



11. In the *Calculation Output* dialog, click the **Area Zoom In** ( ) icon and zoom in to view an image similar to the one below. Notice that the gap you saw present in 060_WLF_Reservoir_Zap is not present in the merged horizon.



Note

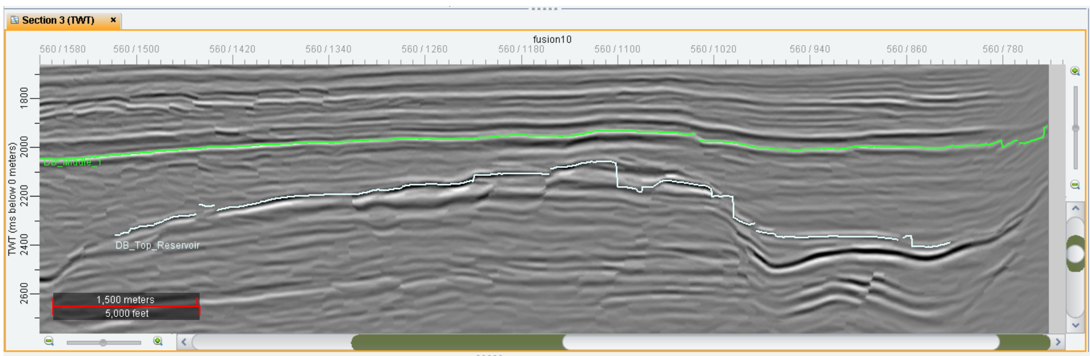
To save the output horizon, **MB3** and then select **Save**. In the *Save* dialog, enter a name and click **OK**.

12. Close the *Calculation Output* dialog. Leave the *Calculator* dialog open.

Creating Proportional Slices Between Two Horizons

In the following steps, you will learn how to create proportional slices within an interval between two horizons. The output will be a specified number of horizons with a shape that is intermediate to the bounding horizons. This function is useful when needing to quickly create intervals to be used for extracting attributes in particular zones of interest. You can then save those slices to the database as additional horizons.

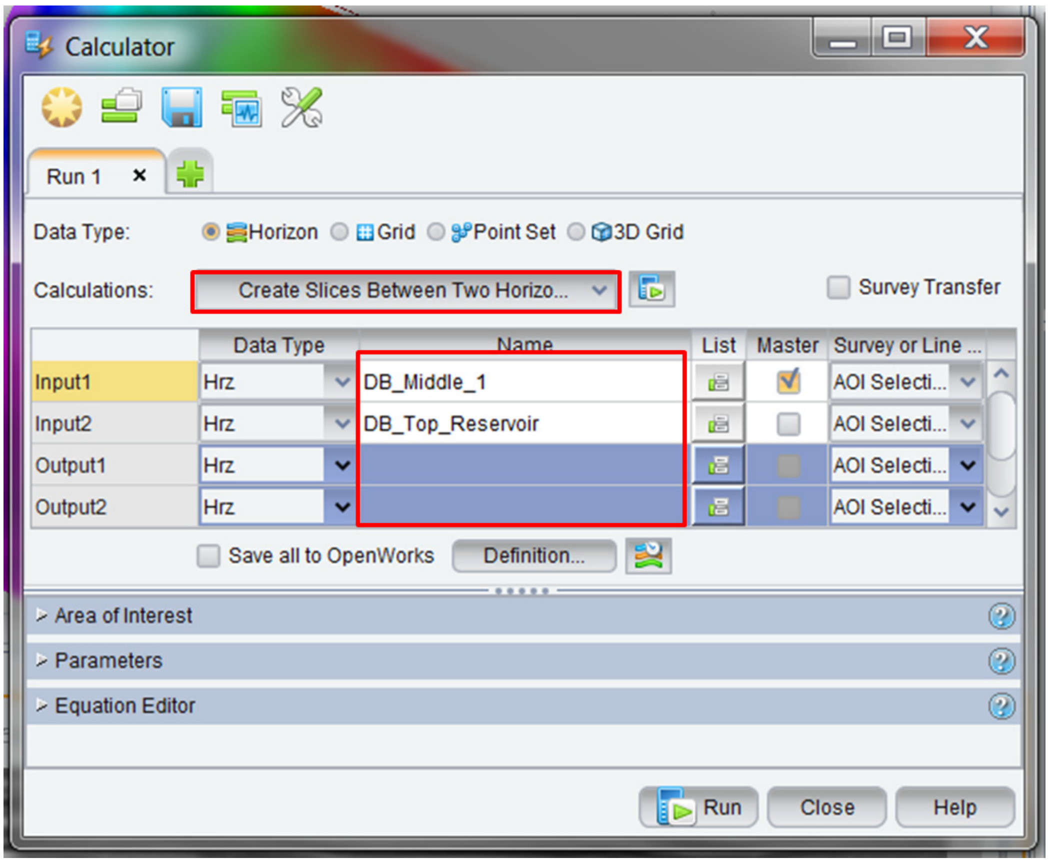
13. Activate *Section* view, and in the *Inventory*, toggle off **060_WLF_Reservoir_Zap**. Toggle on the horizon **DB_Middle_1**.



14. In the *Calculator* dialog, use the *Calculations* drop-down and select **Create Slices Between Two Horizons**.

15. Change the following parameters to match the picture below:

    - Input1: **DB_Middle_1**
    - Input2: **DB_Top_Reservoir**
    - Output1 and Output2: blank

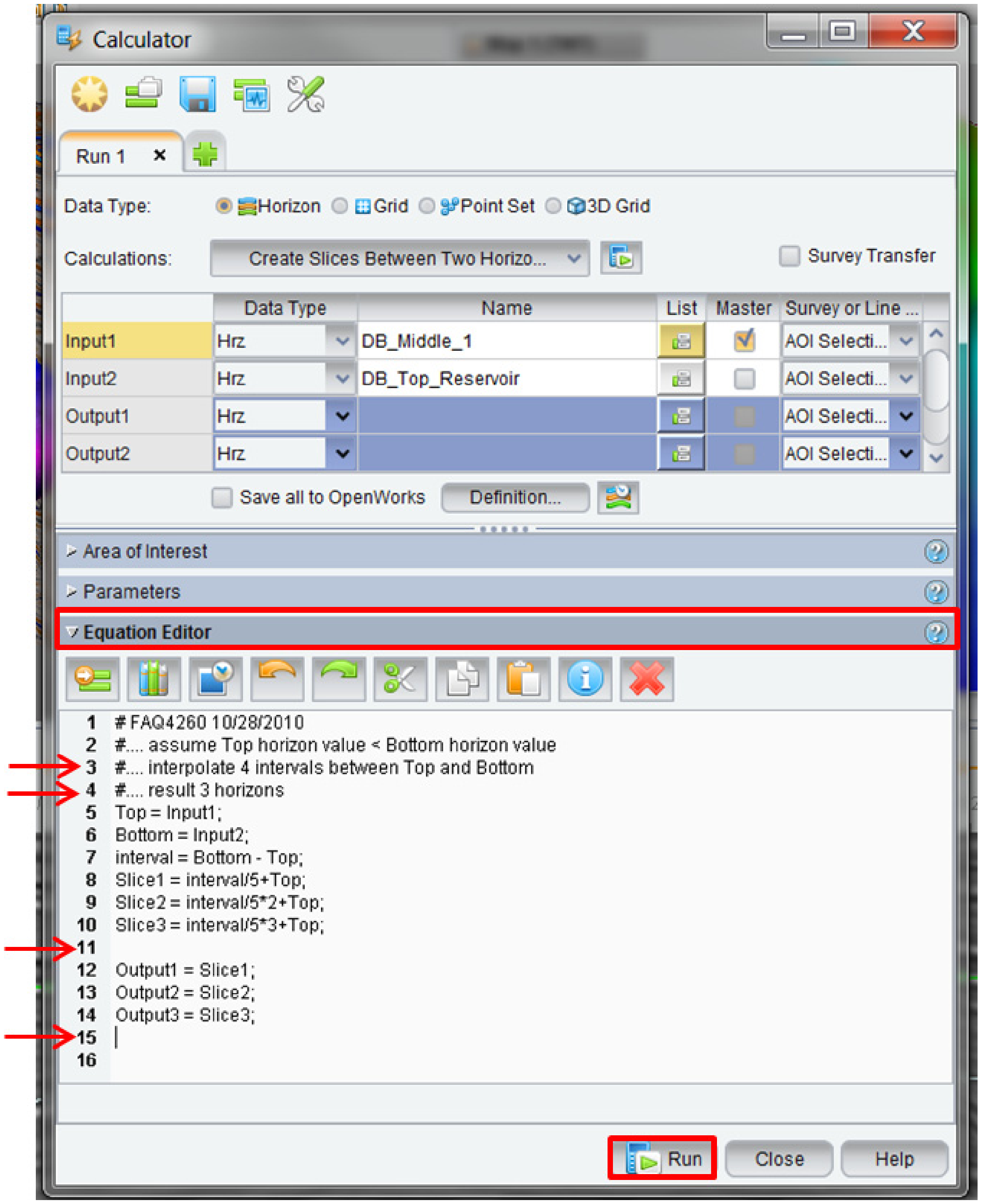


The formula is currently set up to produce four horizons. In the following steps, you will learn how to edit the syntax of the equation so only three horizons are produced when running the calculations.

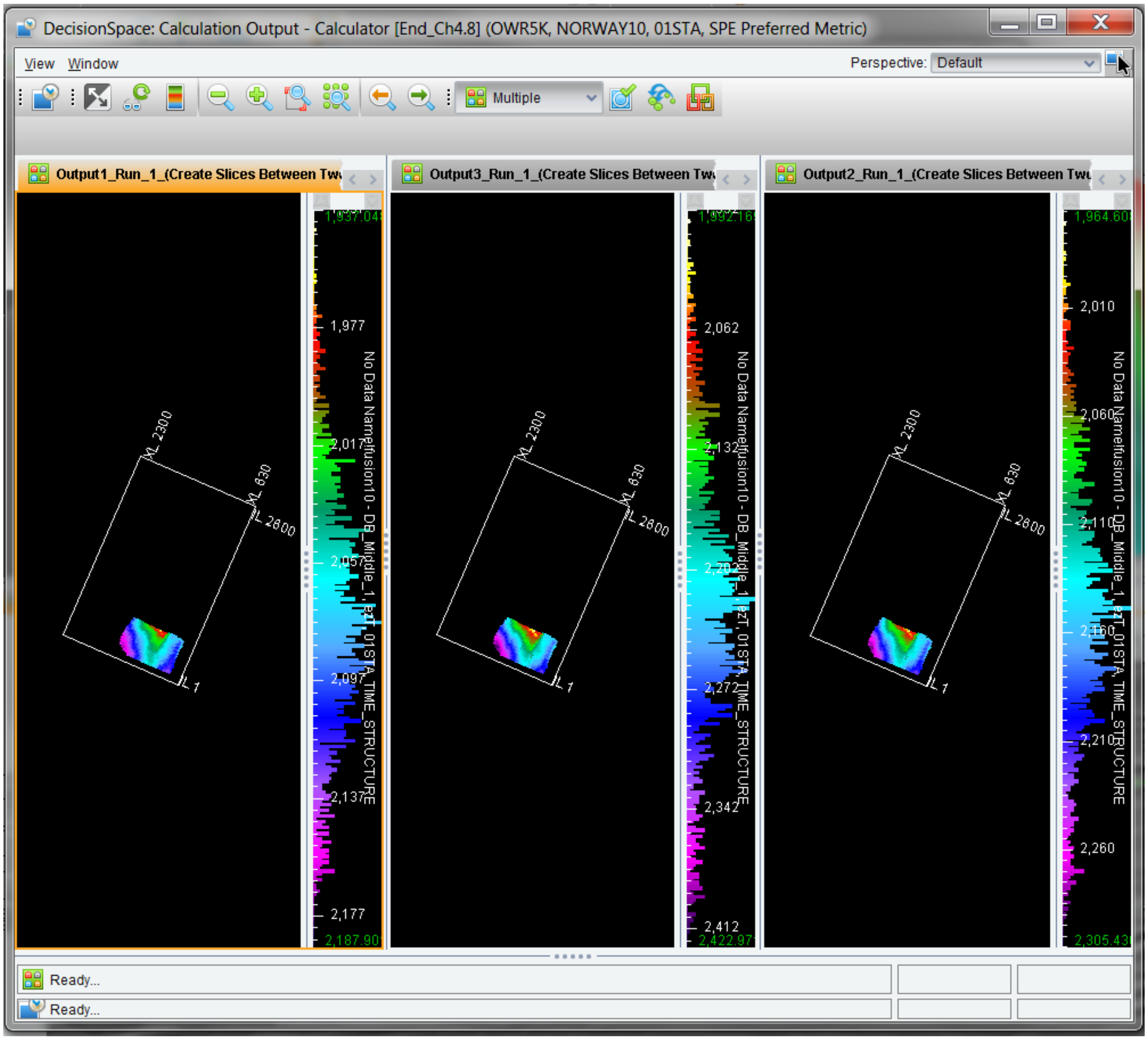
16. Expand the *Equation Editor* panel and make the following changes to the algorithm syntax:

    - Line 3: Replace 5 with "**4**"
    - Line 4: Replace 4 with "**3**"
    - Delete the line for Slice 4.
    - Delete the line for Output4.

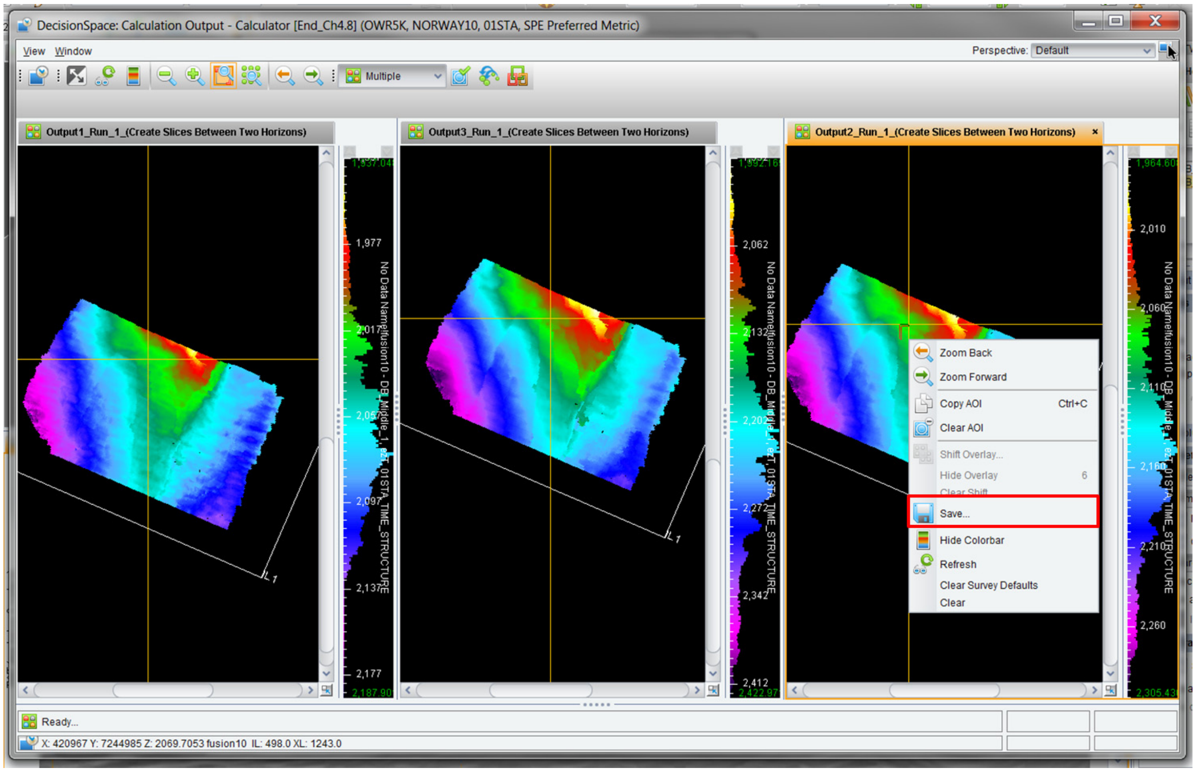
17. Click the **Run** button to view the three horizons in the *Calculations Output* dialog.



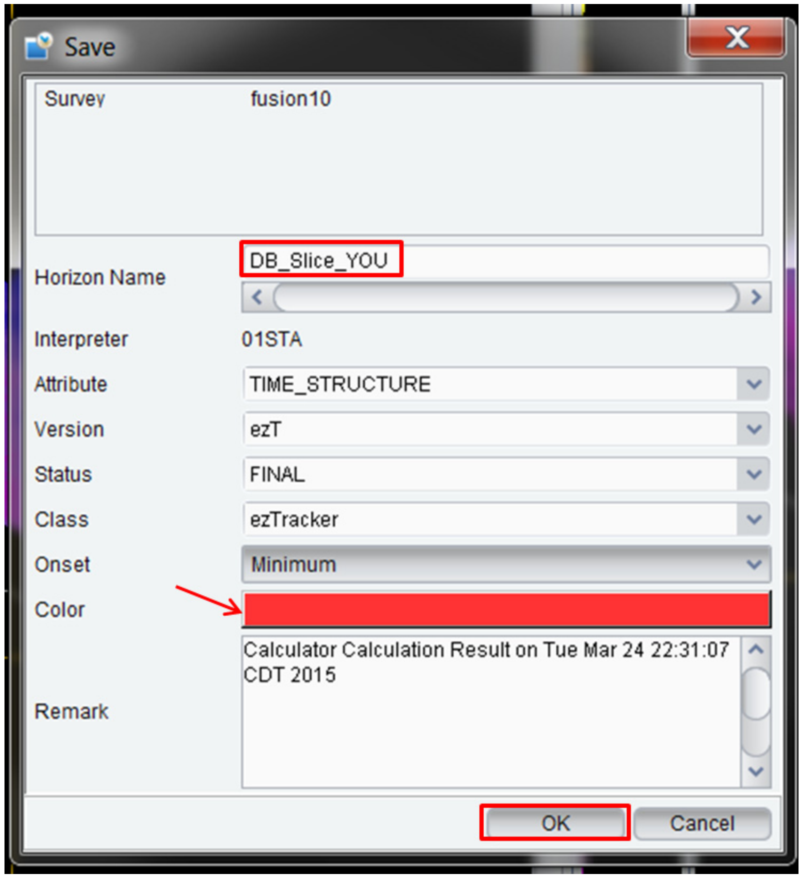
Your display should look similar to the following:



18. **MB3** on the **Output2_Run_1** horizon and then select **Save...**.

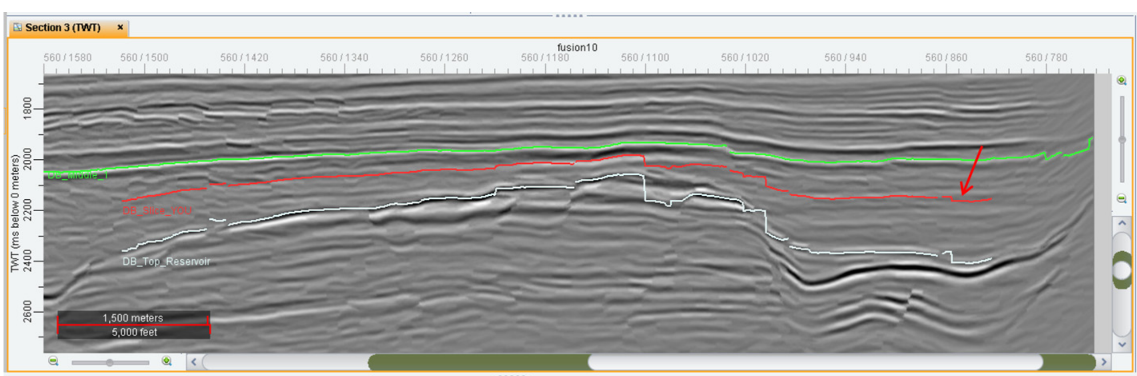


19. In the *Save* dialog, enter “**DB_Slice_YOU**” in the *Horizon Name* field and change the color to something different from the currently displayed horizons. Click **OK**.



20. Close the *Calculations Output* dialog and the *Calculator* dialog.

21. In your active *Section* view, toggle on **DB_Slice_YOU**. Note that the new horizon is between DB_Middle_1 and DB_Top_Reservoir.



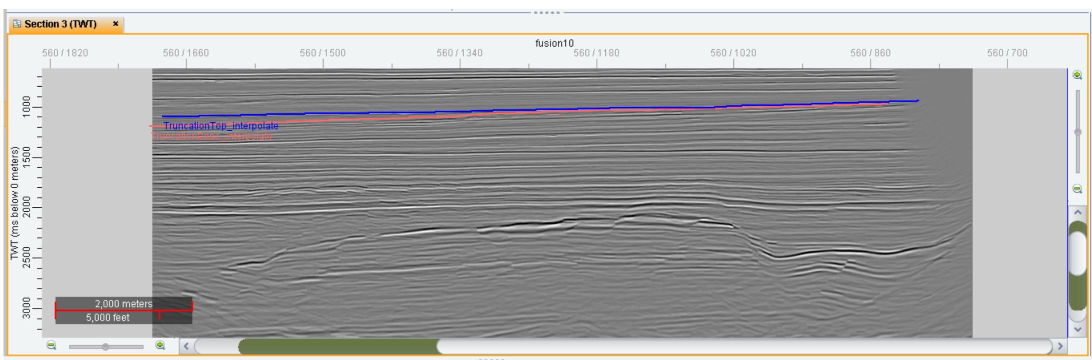
Truncating One Horizon Against Another

In the next steps, you will learn how to truncate one horizon against another. This is very useful in depositional environments with lapout and unconformities. In the following example, the base surface is truncated by the top surface, in order to create a sealing intersection between the two surfaces, a truncation needs to be performed.

22. With *Section* view active, toggle off **DB_Middle_1**, **DB_Slice_YOU**, and **DB_Top_Reservoir**. Toggle on **TruncationBase_interpolate** and **TruncationTop_interpolate**.

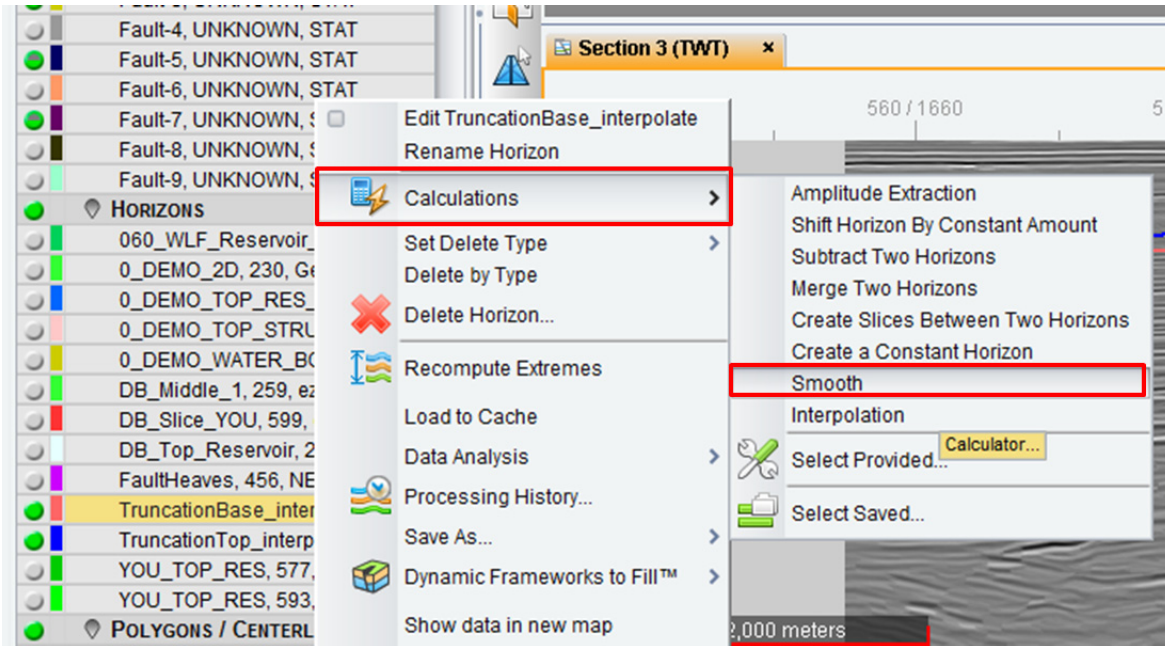
> **Note**
>
> You may have to zoom out to see the horizons; they are located near the top of the section above the reservoir.

In your *Section* view notice that the TruncationBase_interpolate horizon is being truncated by the TruncationTop_interpolate. Note the dip of the base horizon in *Section* view, and that it should terminate on the right where it meets the top horizon.



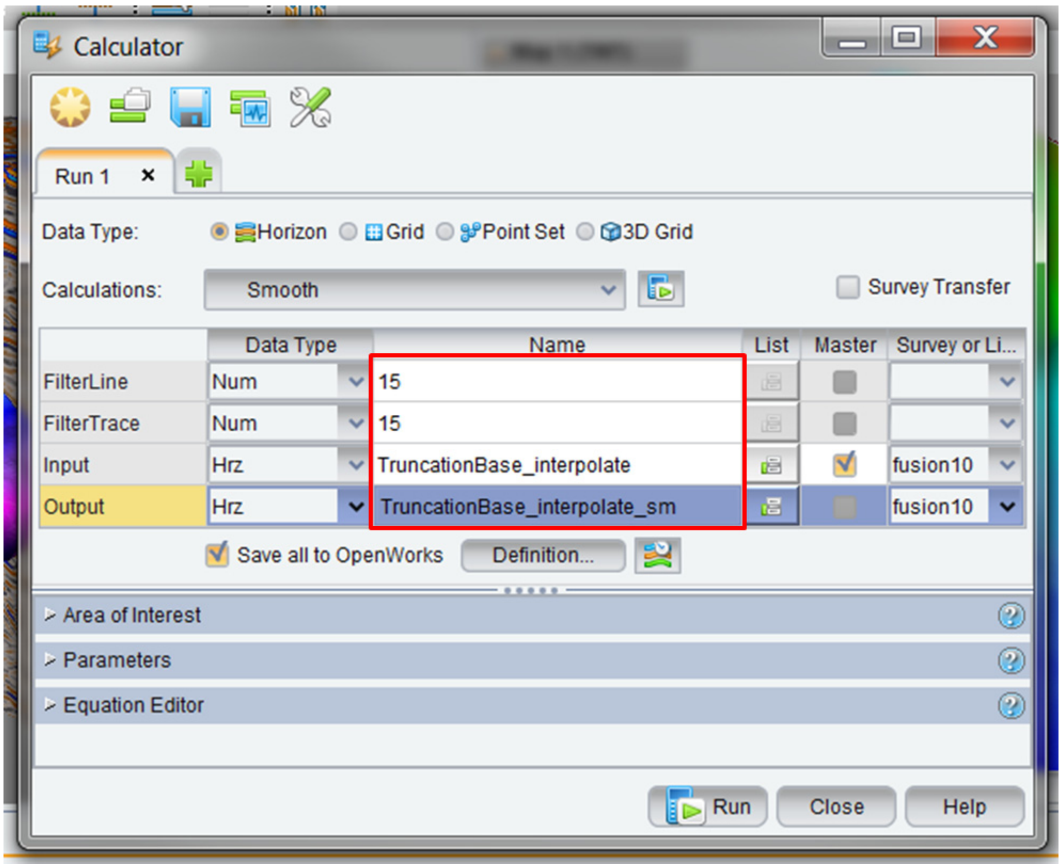
It is best practice to smooth your horizon before performing the truncation. Smoothing your horizon ensures that any spikes in the horizon will not interfere with where the horizon should truly be truncated.

23. In the *Inventory* task pane, select the horizon **TruncationBase_interpolate**, **MB3** and select **Calculations > Smooth**.



24. In the *Calculator* dialog, ensure the following parameters are set:

- FilterLine: **15**
- FilterTrace: **15**
- Input: **TruncationBase_interpolate**
- Output: **TruncationBase_interpolate_sm**



Note

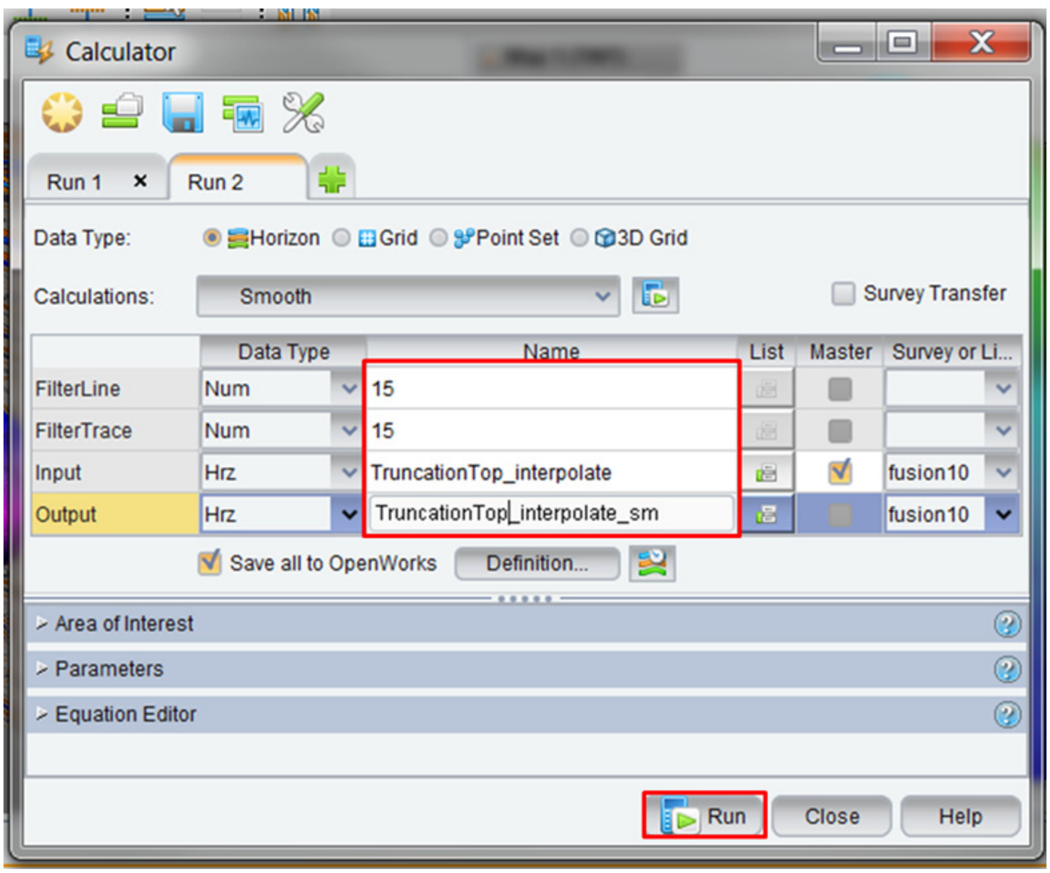
The smoothing filter works by creating a grid of rectangles with dimensions defined by the FilterLine and FilterTrace parameters. In each rectangle, the amplitude is calculated for each point and then averaged to produce an output value that is placed at the center of the rectangle. The output values of each rectangle make up the data points which compose the final smoothed output horizon.

With the Multiple Runs option, it is possible to calculate the same operation for different inputs, so you are able to smooth both horizons at one time.

25. To perform the same operation on the TruncationTop_interpolate horizon, add a new run by clicking on the **Add Run** ( ) icon next to the *Run 1* tab and set the following parameters:

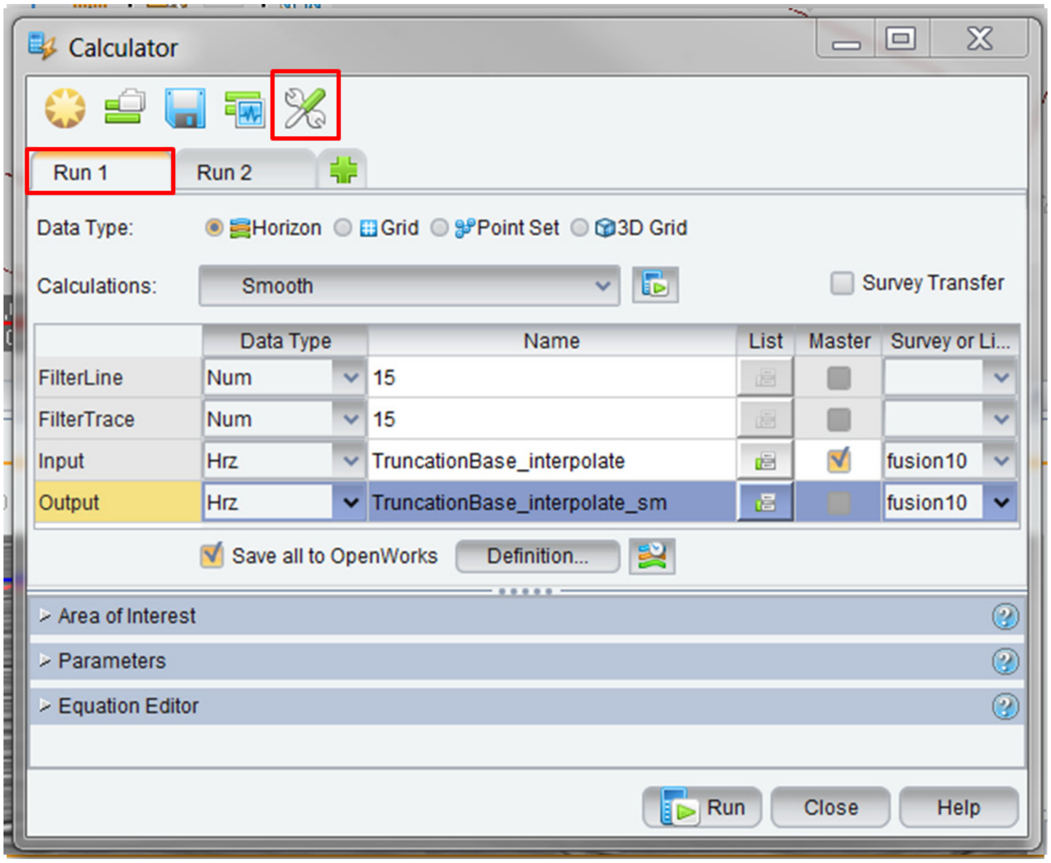
    - FilterLine: **15**
    - FilterTrace: **15**
    - Input: **TruncationTop_interpolate**
    - Output: **TruncationTop_interpolate_sm**

26. Click **Run** to produce the two smoothed horizons.

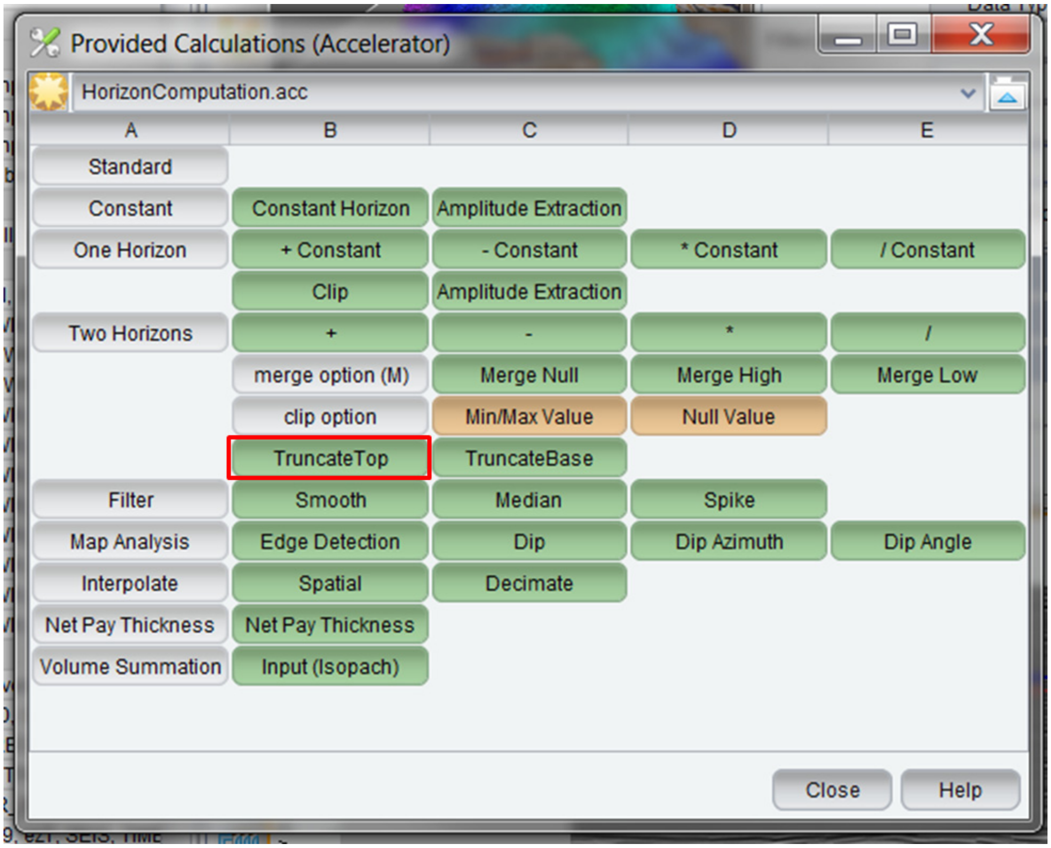


The smoothed horizons appear in your inventory. You will now use the smoothed horizons as inputs to the truncation calculation.

27. Select the *Run 1* tab, and click the **Select Provided Calculations** () icon in the top menu.



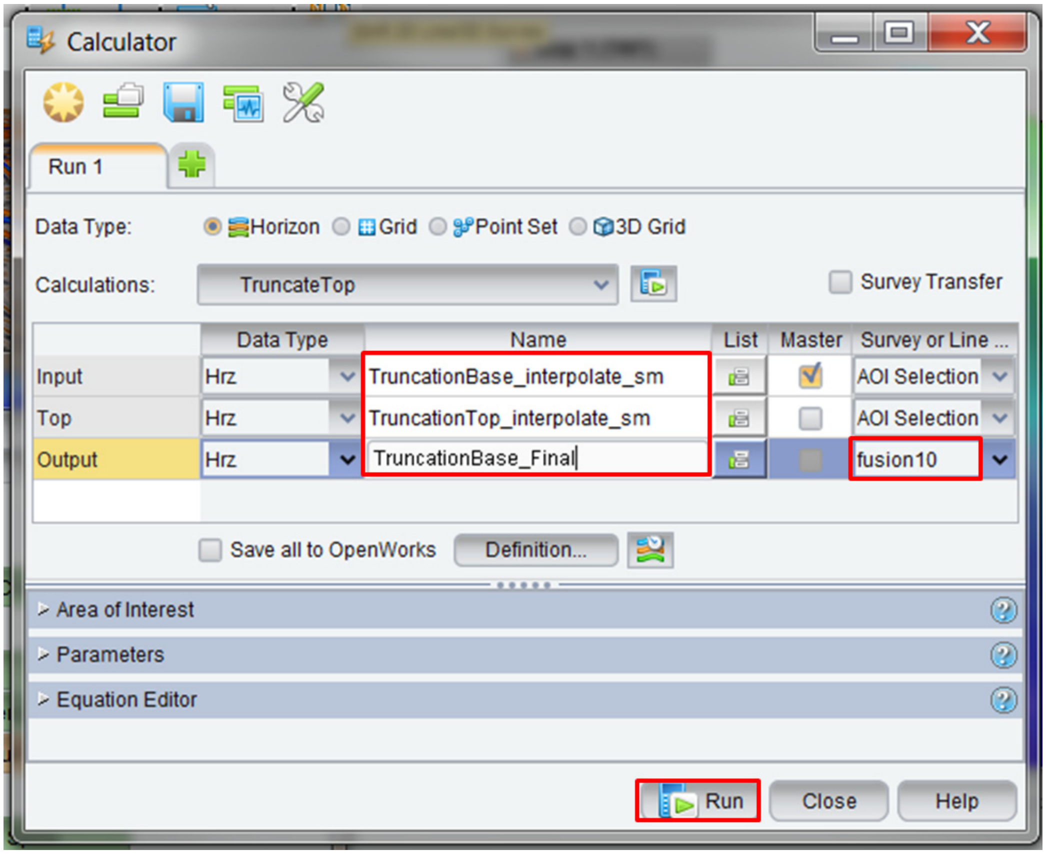
28. In the *Accelerator* dialog, click the **TruncateTop** button.



29. In the *Calculator* dialog, use the following parameters:

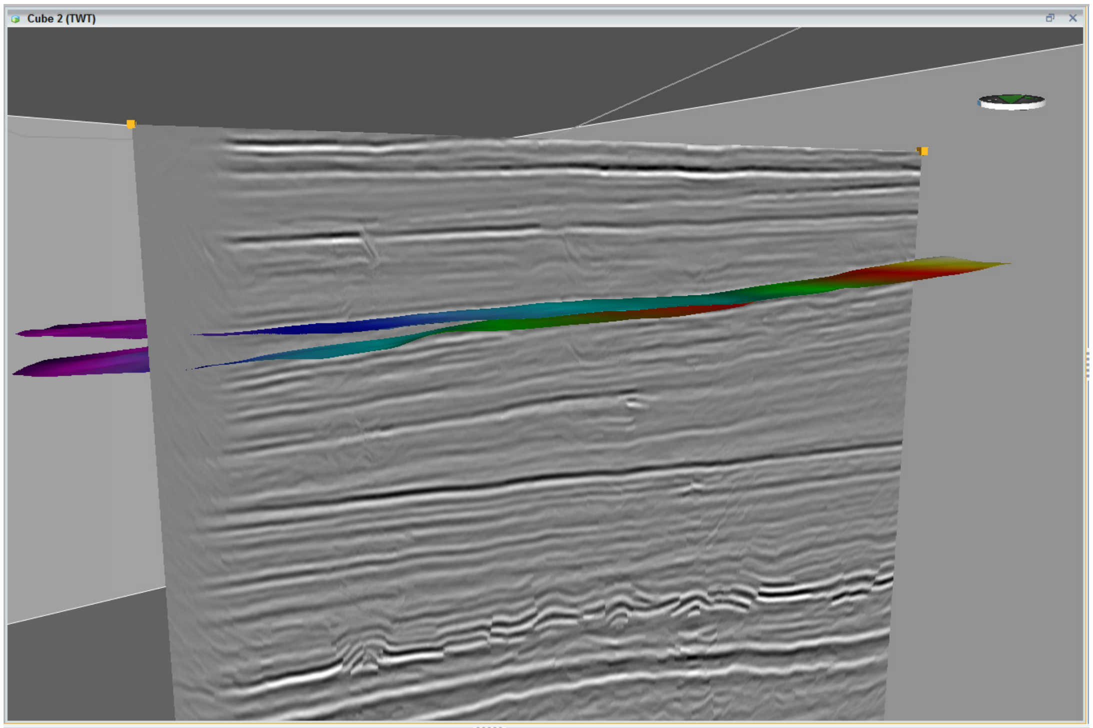
- Input: **TruncationBase_interpolate_sm**
- Top: **TruncationTop_interpolate_sm**
- Output: **TruncationBase_Final**
- Survey or Line List: **fusion10**

30. Click **Run**.



All previous calculations have been shown in 2D. You can also visualize the results of your calculations in 3D. The truncation of the horizon is easier to visualize in 3D.

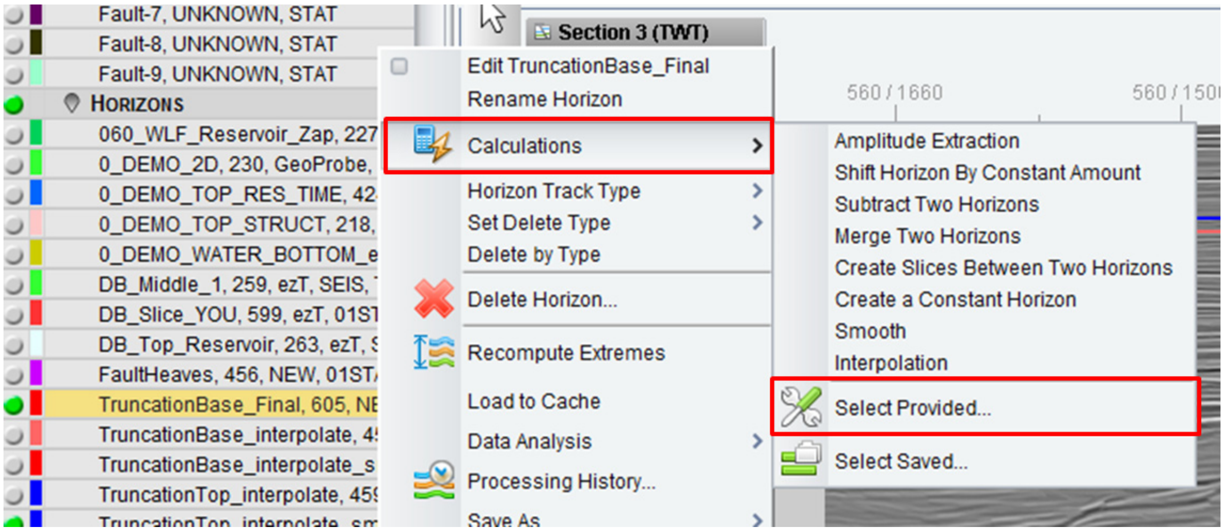
31. When the operation is complete, close the *Accelerator* and *Calculator* dialogs, and activate *Cube* view. Toggle on the **box probe n; full_offset.cmp_StrcFltr10x10_ATTRIBUTE** and the horizons **TruncationTop_interpolate_sm** and **TruncationBase_Final** to view the results of the calculation.



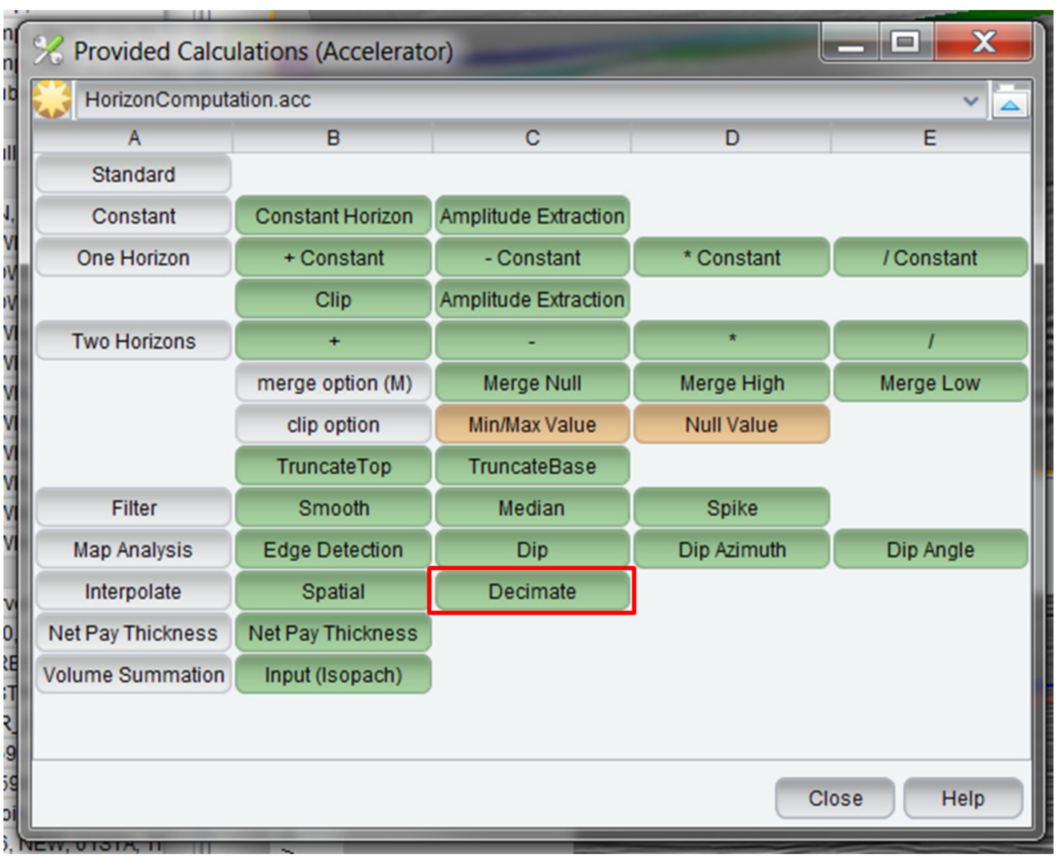
Decimating a Horizon

Lastly, you will learn how to decimate horizons. This calculation will allow you to decimate in one or two directions, starting from a specific inline / xline position. Decimation is useful in circumstances where you need to reduce the size of your data object. You may also decimate specific lines, which allows you to remove lines you have misinterpreted.

32. From the *Inventory* task pane, select the horizon **TruncationBase_Final**, **MB3** and select **Calculations** > **Select Provided...** to open the *Accelerator* dialog.



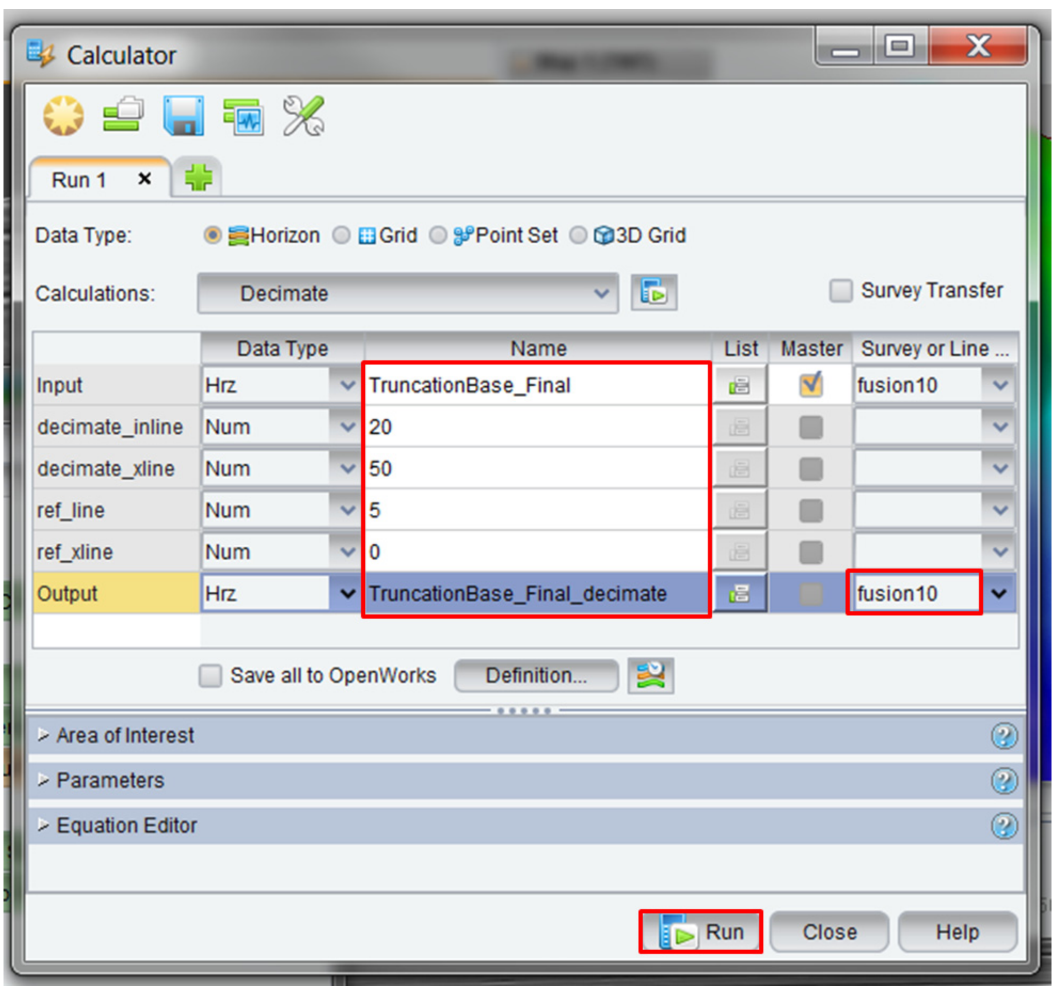
33. In the *Accelerator* dialog, click the **Decimate** button.



34. When the *Calculator* dialog opens, set the following parameters:

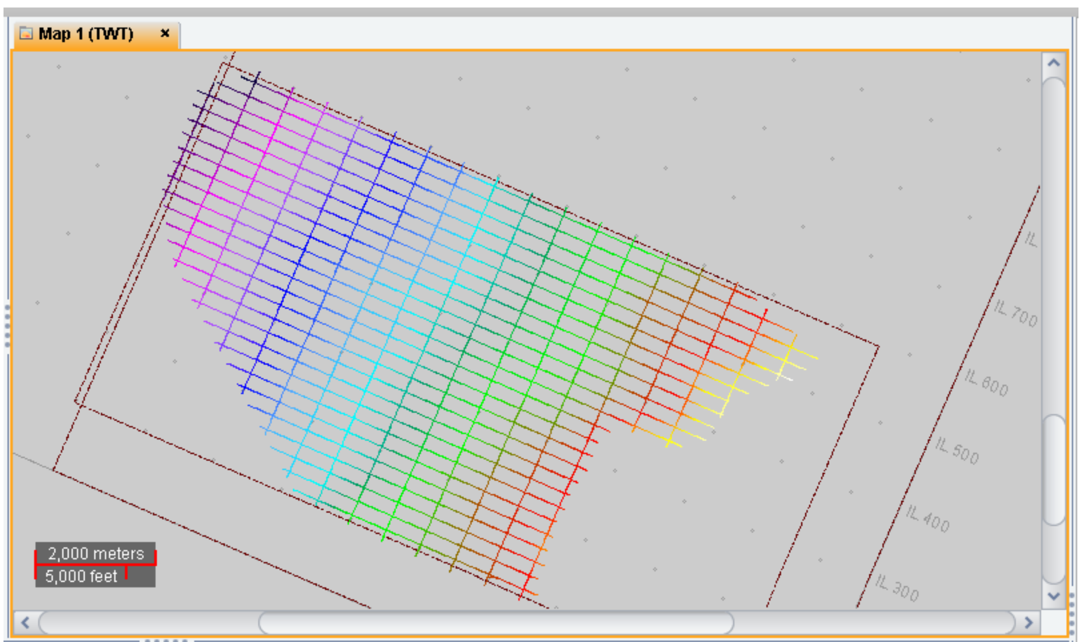
    - Input: **TruncationBase_Final**
    - decimate_inline: **20**
    - decimate_xline: **50**
    - ref_line: **5**
    - ref_xline: **0**
    - Output: **TruncationBase_Final_decimate**
    - Survey or Line List: **fusion10**

35. Click **Run**, and when the operation is complete close the *Accelerator* and *Calculator* dialogs.



> **Note**
>
> The decimation will delete values based on the increment denoted by the decimate_inline or decimate_xline field. For example, a decimate_inline value of 20 tells the software to keep every 20 inlines and delete everything in between those lines. The ref_line and ref_xline tell the software which line to begin decimating on. If the value is 0, the calculation will start on the minimum line number.

36. Activate *Map* view, toggle on only **TruncationBase_Final_decimate**.



In this chapter, you learned how to interpret horizons in each view, use the auto tracking tools available in DecisionSpace Geosciences to track entire horizons, and how to incorporate the horizons into a structural framework. You also learned how to use QC tools such as ezValidator, and how to perform calculations on horizons using the Seismic Calculator. In the following chapter, you will learn how to create attribute volumes and extract attributes from your interpreted horizon.