DecisionSpace® Geosciences: Fundamentals of Geophysics

Volume 2

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Creating Seismic Attributes for Reservoir Analysis

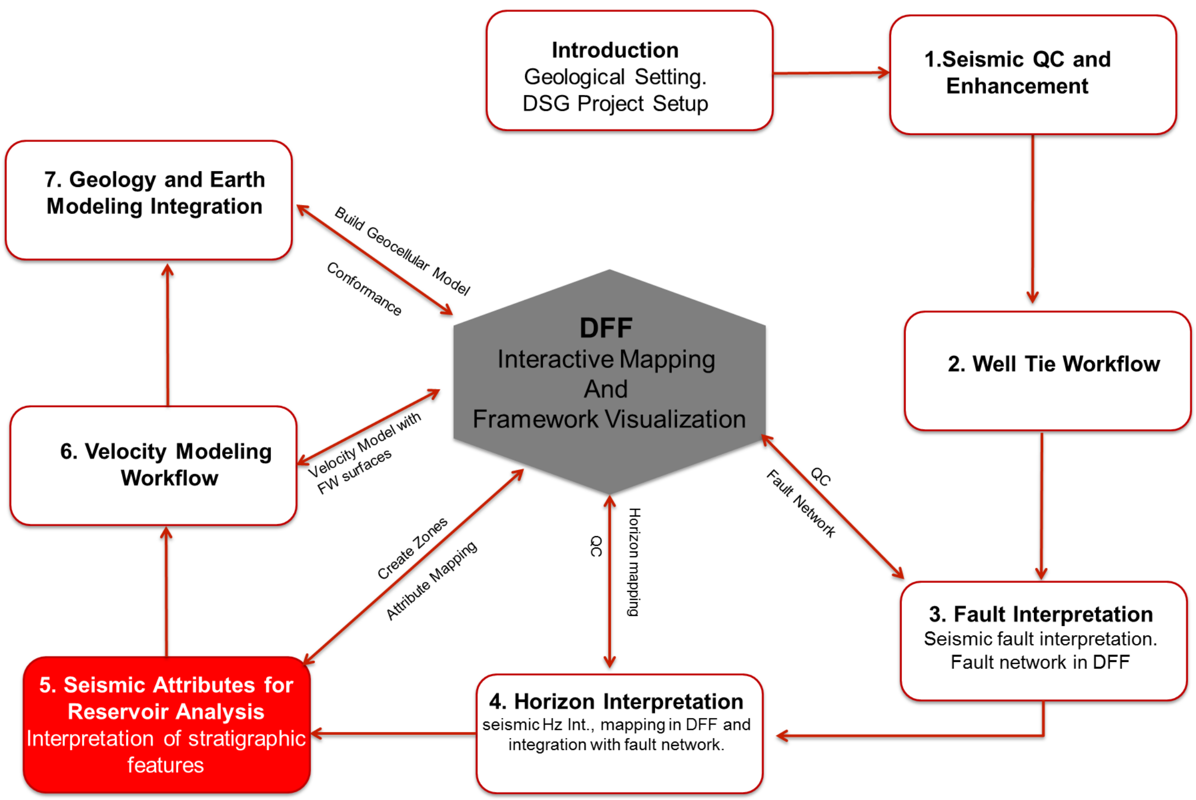
DecisionSpace Geosciences has the ability to create multiple seismic attributes for identifying significant characteristics of the reservoir. In this chapter you will learn to create and analyze attributes to identify bright spots, stratigraphic layers, differentiate lithologies, etc., using tools like Seismic Attribute Generator and Volume Math.

Overview

In this chapter, you will learn to:

- 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

Workflow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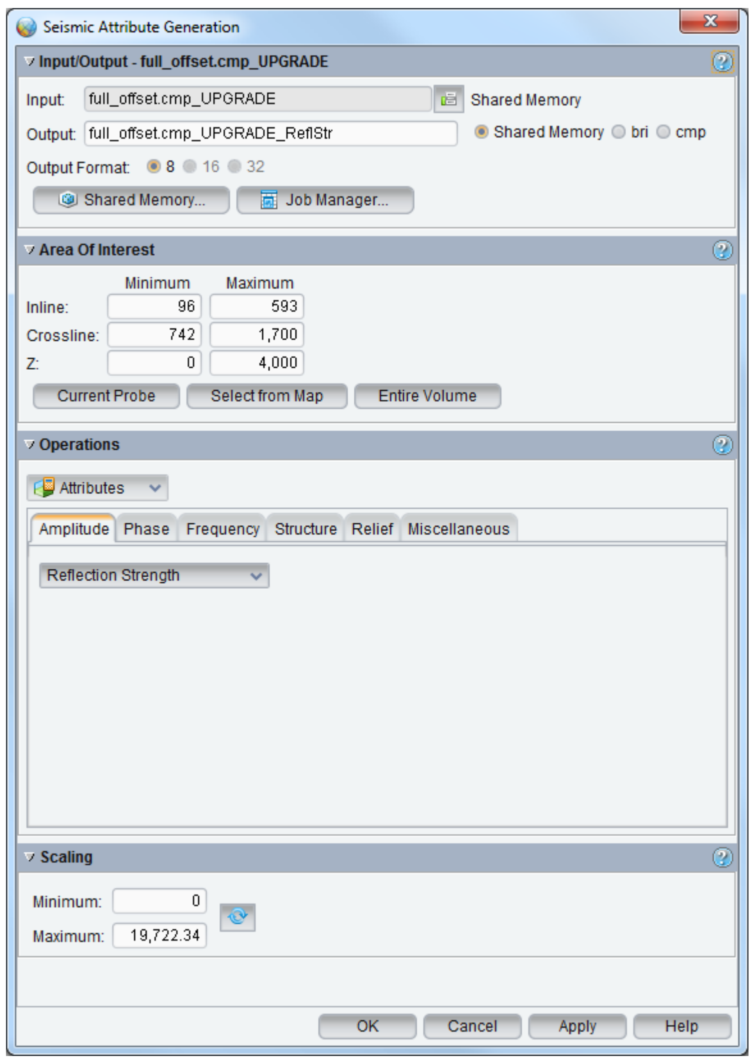
Enabling DecisionSpace Seismic Attributes

You must meet the following criteria to enable the DecisionSpace Seismic Attributes functionality:

- Seismic data must be loaded into your session.
- The DecisionSpace Geophysics module must be loaded into your session. If it is not loaded, the Seismic Attributes functionality will run, but the attributes will not display in the *Cube* view.

To access the attributes calculations, MB3 on a displayed seismic volume in *Section* and *Map* views, or on probes in the *Cube* view. The *Seismic Attribute Generation* dialog opens for you to select the desired attributes and parameters.

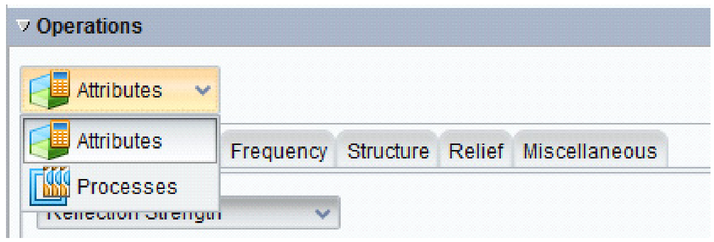


The attribute volumes created from shared memory or .vol are displayed as box probes. Attributes created from .3dv, .bri or .cmp data are displayed as inline probes.

Seismic attributes are always added to the inventory when calculations are complete.

The following two options are available under the *Operations* panel in the *Seismic Attribute Generation* dialog:

- Attributes
- Processes



The results of the calculations are added to the inventory of the DecisionSpace session.

You can generate the following types of attributes:

- Amplitude attributes
- Phase attributes
- Frequency attributes
- Structure attributes
- Relief attributes
- Miscellaneous attributes

All amplitude, phase, frequency, and miscellaneous attributes are 1D trace attributes that are computed down seismic traces. All structure attributes are 3D volume attributes computed across and down traces.

Structure attributes include two options for 3D coherency filtering or structure filtering. Seismic attributes are often improved by deriving them on coherency filtered seismic data rather than on the original seismic data.

Most seismic attributes are computed in an analysis window, the size of which can be adjusted, as it is the window size that controls the resolution of the attribute. Larger windows produce smoother attributes, which are of a lower resolution. Smaller windows produce attributes that are not as smooth and are of a higher resolution.

1D windows are along the time or depth axis. Samples measurement is given on the same axis. 3D windows have X, Y and Z axes and sample measurement is given on all three axes. X and Y should usually have the same window length.

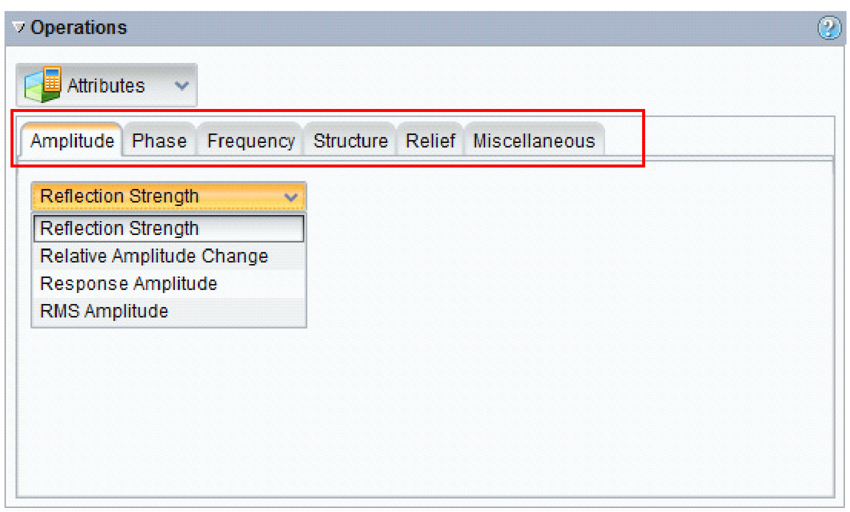
All seismic attribute computations are performed with 8, 16, and 32-bit floating point values. These values are converted to 8-bit values when output is stored to shared memory. The conversion is controlled either by minimum and maximum output values chosen by the user or by automatic re-scaling.

The defaults for the minimum and maximum output attribute values are suitable in most cases. Conversion factors are stored in the header of the shared memory output to permit display of the true attribute values in the DecisionSpace software.

You can run filter, gain, or apply various calculations to a seismic attribute volume or a seismic volume by enabling the Processes option on the *Operations* pane of the *Seismic Attribute Generation* dialog. These include structure filters with options to either preserve or smooth across faults.

Attributes in DecisionSpace

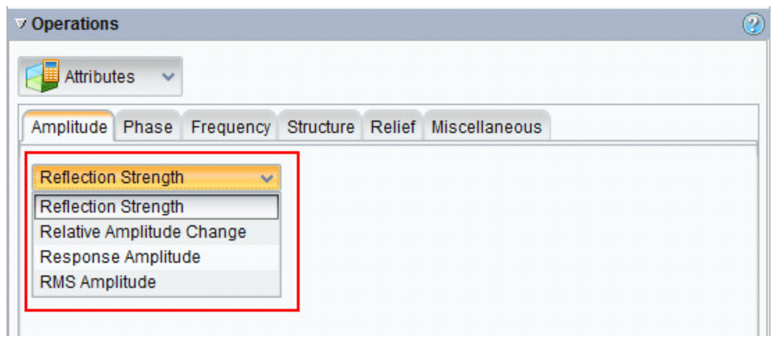
Attributes calculation has six tabs, as shown in the *Attributes* pane below. Start by calculating Amplitude Attributes.



Amplitude Attributes

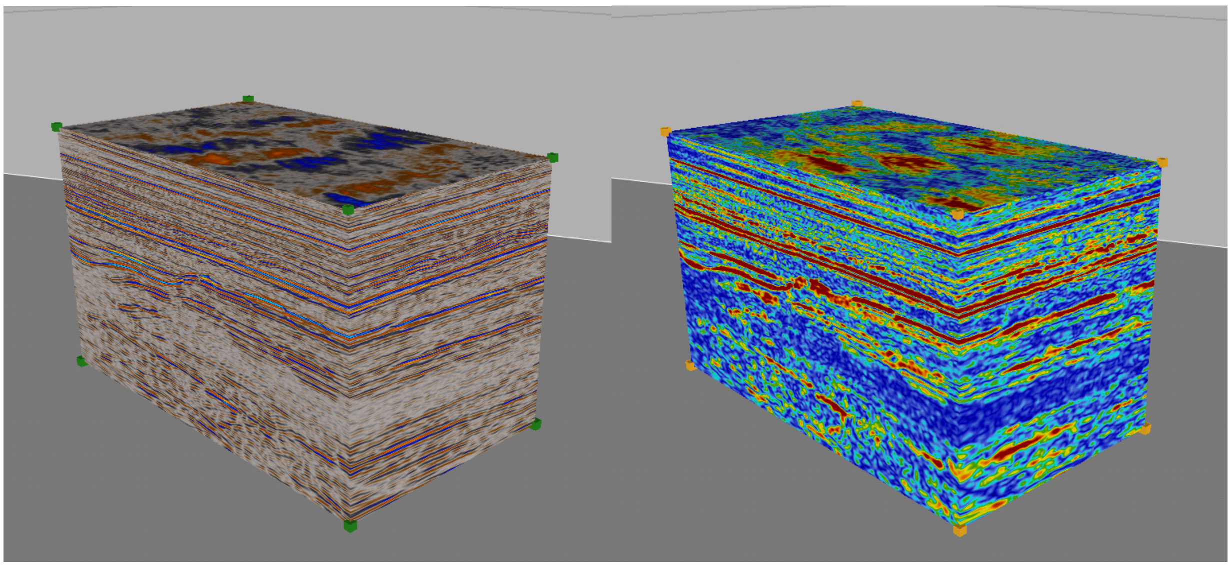
There are four Amplitude attribute calculations available in DecisionSpace Seismic Attributes:

- Reflection Strength
- Relative Amplitude Change
- Response Amplitude
- RMS Amplitude



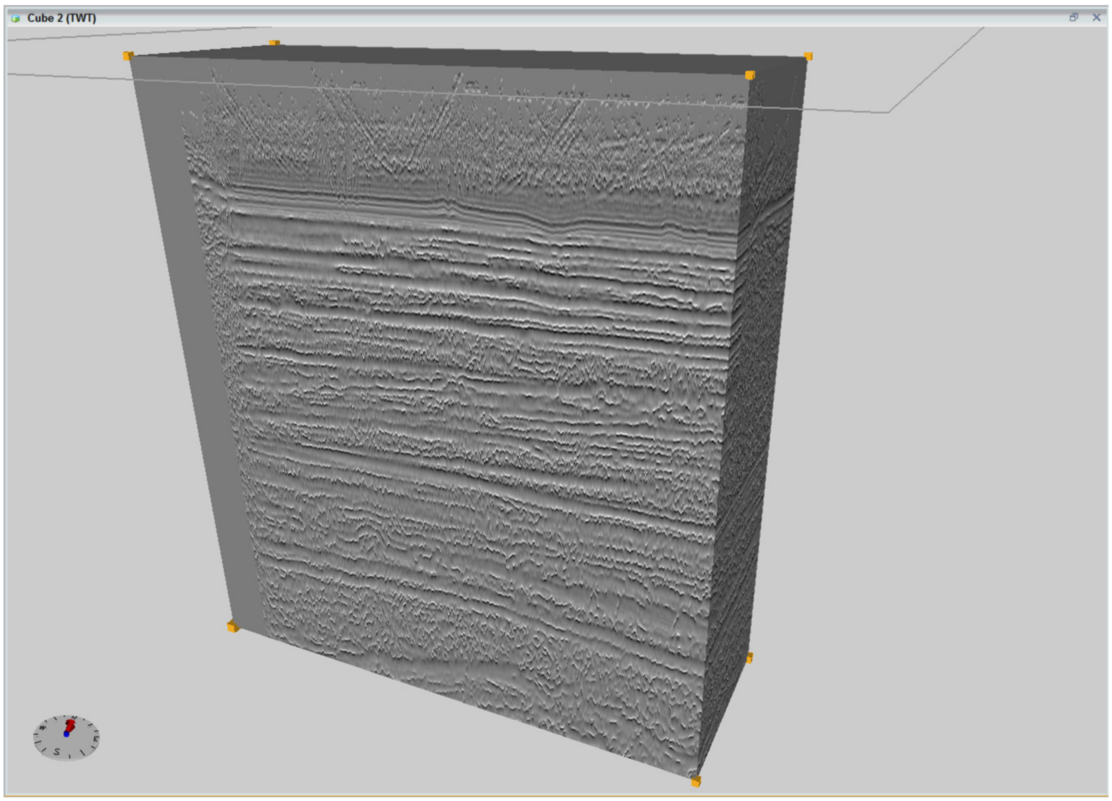
Reflection Strength Attributes

Reflection strength, also known as trace envelope or instantaneous amplitude, is the most popular trace attribute. It is used to identify bright spots, dim spots, and amplitude anomalies in general. Bright spots are important as they can indicate gas, especially in relatively young clastic sediments. The advantage of using reflection strength instead of the original seismic trace values is that it is independent of the phase or polarity of the seismic data, both of which affect the apparent brightness of a reflection.



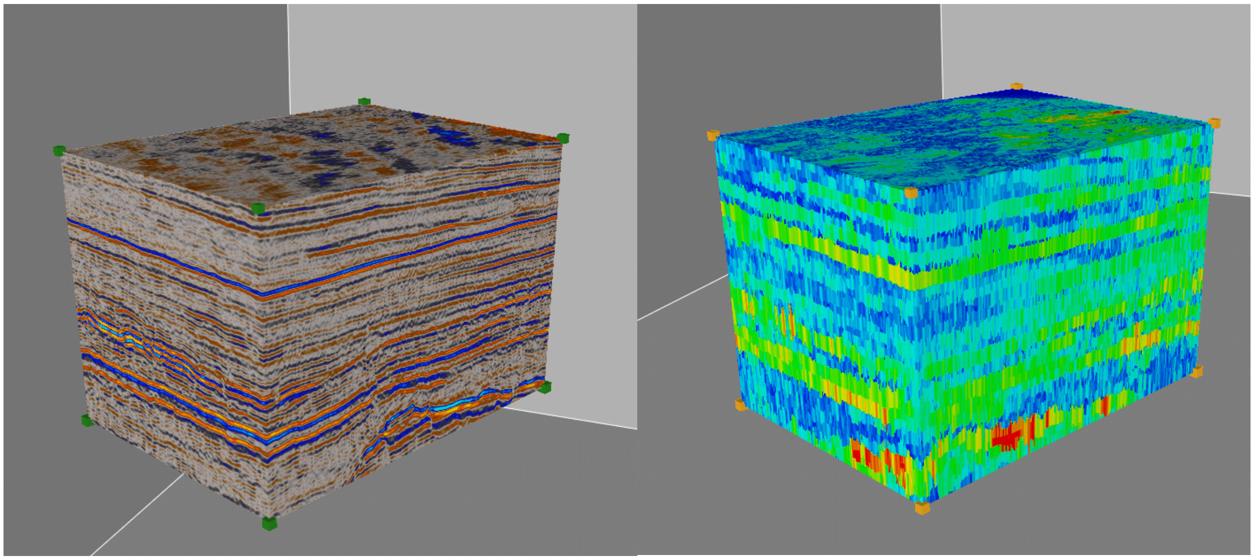
Relative Amplitude Change

The relative amplitude change reveals structural detail hidden in the amplitudes, and highlights zones of reflection interference, which occur at amplitude minima between reflections. It blends particularly well with *response phase* and *response frequency*, because these attributes have blocky output that change values at amplitude minima.



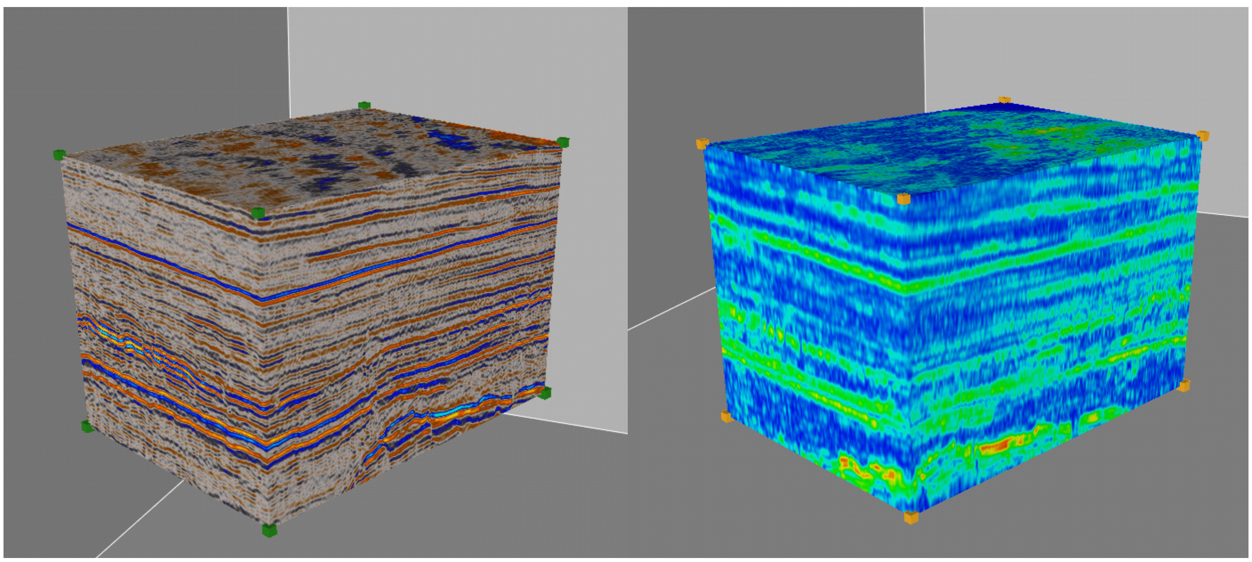
Response Amplitude

Response amplitude (also referred to as wavelet amplitude) is a nonlinear filtered version of the trace envelope (*reflection strength*). It equals the trace envelope measured at the envelope peaks and is held constant in each interval bounded by successive envelope troughs. Like all wavelet response attributes, it has a blocky appearance. Response amplitude is applied to track the reflection strength of the dominant reflections.



RMS Amplitude

RMS (Root-Mean-Square) amplitude resembles a smoother version of reflection strength. It is applied in the same way as reflection strength to reveal bright spots and amplitude anomalies in the seismic data. In contrast to reflection strength, you can set the resolution by changing the window length. Longer windows produce a smoother amplitude estimate. This is sometimes useful— for example, a sequence of closely spaced bright events, perhaps a stack of gas-charged channels, can sometimes be imaged or extracted as a single unit by using low resolution RMS amplitude.

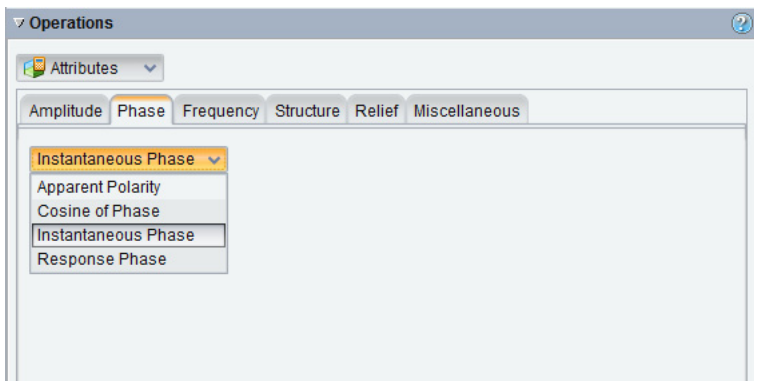


Phase Attributes

Phase attributes measure degrees. They are independent of the amplitudes and show continuity and discontinuity of events. Typically, they are very good at showing bedding.

There are four options under the *Phase* tab:

- Apparent Polarity
- Cosine of Phase
- Instantaneous Phase
- Response Phase

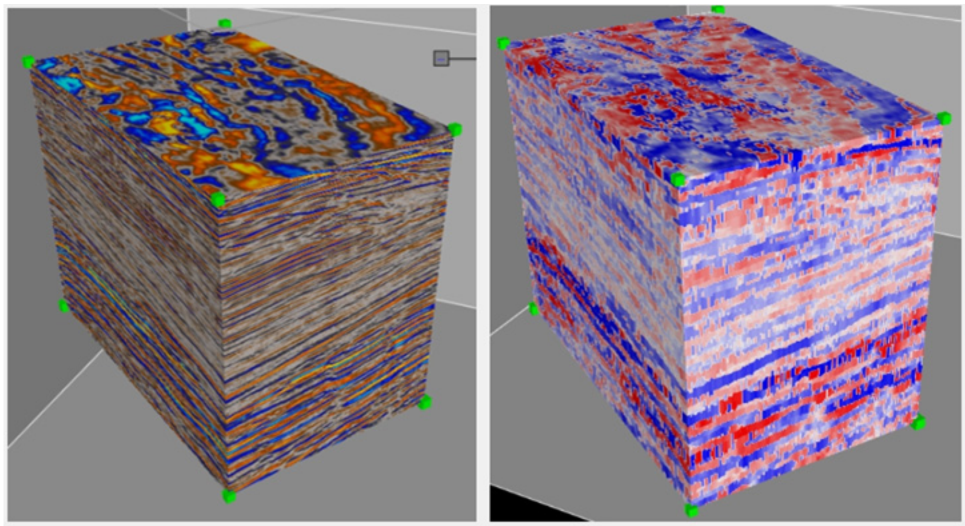


Apparent Polarity

Apparent polarity records the polarity of seismic data scaled by the reflection strength, which roughly approximates scaled reflection coefficients. It is a wavelet-response attribute like response phase and response frequency. In an interval on a seismic trace that is bounded by consecutive envelope troughs (reflection strength minima), the apparent polarity equals the sign of the seismic trace measured at the envelope peak multiplied by the value of the envelope peak, and held constant in the interval.

Apparent polarity is unreliable, as it is extremely sensitive to data quality. It correctly identifies the polarity of a seismic reflection only if noise is low, if the seismic wavelet has zero phase, and if the reflection is isolated and largely free of interference from neighboring reflections. Thin beds composed of equal but opposite polarity reflections cause apparent polarity to become unstable and to flip sign depending on small changes in the reflections.

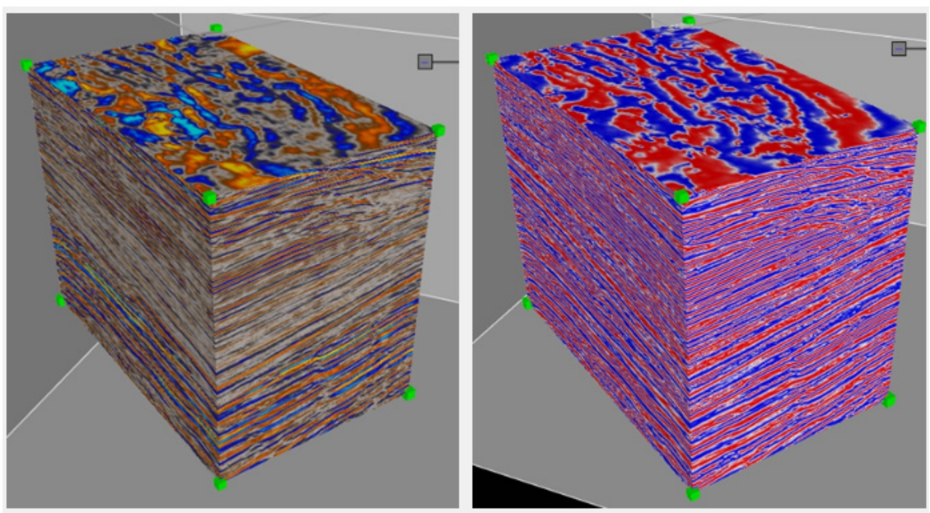
Apparent polarity finds modest use in identifying reflection polarity and for tracking reflections. If only the polarity is of interest, then response phase could prove a better choice because it does not have trouble with thin beds.



Cosine of Phase

Cosine of the instantaneous phase is a complex seismic trace attribute that equals the seismic data with all amplitude contrasts removed. Its values lie in the range of -1 to +1, and it has a flat envelope. Thus cosine of phase acts as the ultimate automatic gain control.

Like instantaneous phase, it makes the continuity of the seismic reflections more visible. Because it emphasizes reflection continuity, cosine of phase is helpful in revealing faults, pinchouts, angularities, channels, fans, and internal depositional geometries. Phase displays (such as cosine of phase) often reveal sedimentary layering patterns, and thus can help you identify seismic sequence boundaries. Cosine of phase is easier to deal with than instantaneous phase because its values are not wrapped, and it can be displayed like normal, though highly gained, seismic data. However, instantaneous phase better reveals tiny details in the data.



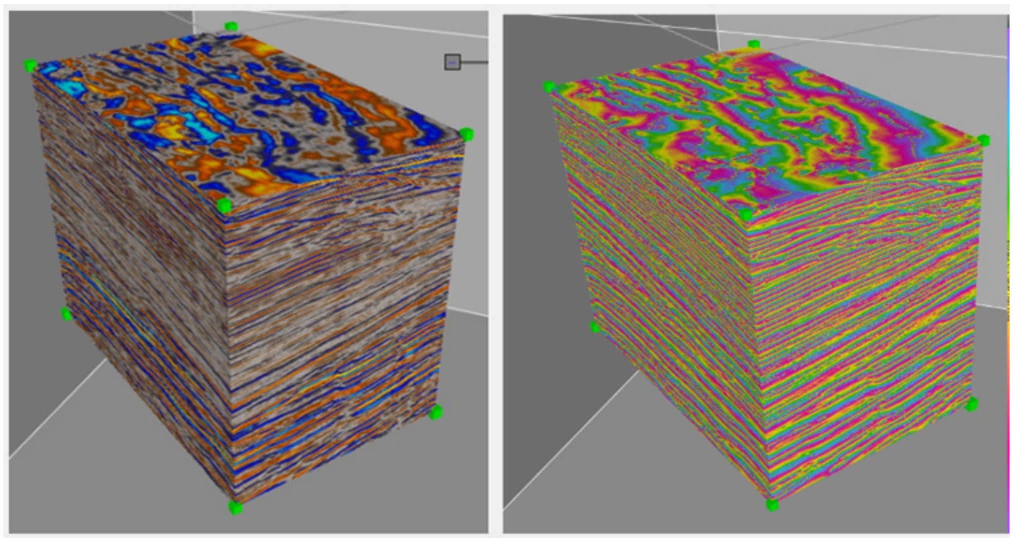
Instantaneous Phase

Instantaneous phase and reflection strength are the two fundamental complex trace attributes from which all others derive.

Instantaneous phase is a complex seismic trace attribute defined as the arctangent of the quadrature seismic trace (imaginary trace) divided by the original seismic trace (real trace). The mathematics for instantaneous phase is given in the background discussion of reflection strength.

Instantaneous phase removes all amplitude information from the seismic data. This makes the continuity of seismic reflections easier to follow, which is the chief application for instantaneous phase. Occasionally, instantaneous phase is also used to determine the phase of a reflection. For this purpose, response phase is a better choice.

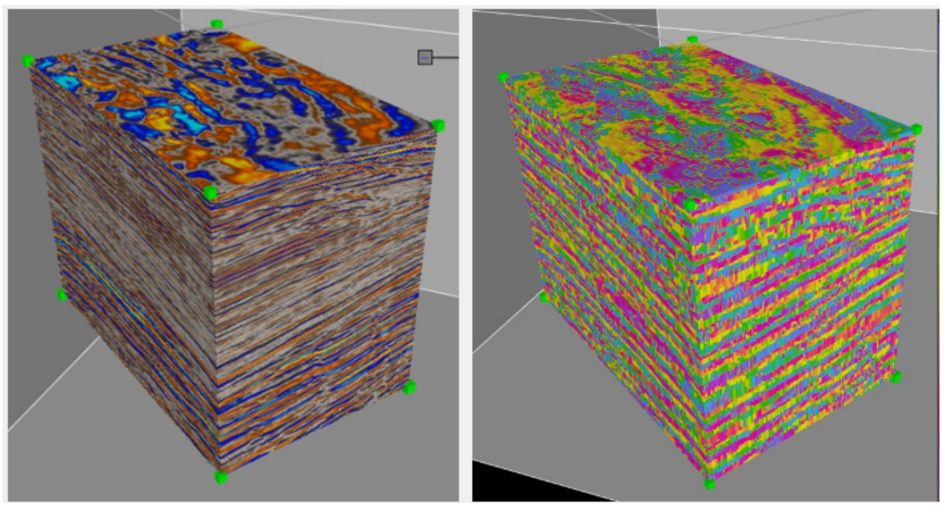
The convention followed by instantaneous phase is that peaks on a seismic trace have 0 degrees phase, troughs have 180 degrees, downgoing zero crossing have 90 degrees, and upgoing zero crossings have -90 degrees.



Response Phase

Response phase (also known as “wavelet phase” in the GeoProbe® software) is a nonlinearly filtered version of the instantaneous phase. It equals the value of the instantaneous phase measured at the envelope peaks and held constant in each interval bounded by successive envelope troughs.

In theory, response phase equals the phase of the seismic source wavelet. However, this is true only if the seismic reflections are not overly influenced by interference or noise, and the seismic wavelet has constant phase. In practice, seismic data always has noise and reflection interference is the rule, so response phase acts more like a stable (though blocky) version of the instantaneous phase.



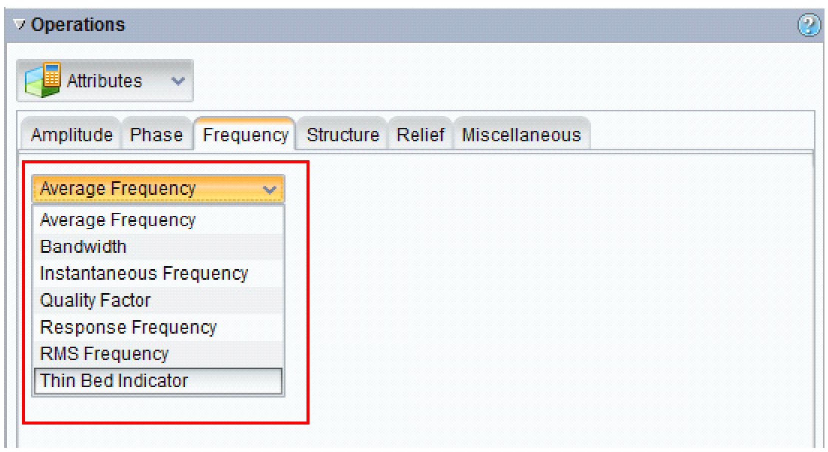
Frequency Attributes

Frequency refers to the number of sinusoidal cycles that occur along a waveform in a given time interval. Frequency attributes are inherently trace attributes of time data.

Frequency attributes are available in the *Frequency* tab of the *Operations* pane in the *Calculate Attributes* dialog when the Attributes option is selected.

There are seven frequency attributes available in DecisionSpace Seismic Attributes:

- Average frequency
- Bandwidth
- Instantaneous frequency
- Quality factor
- Response frequency
- RMS frequency
- Thin-bed indicator

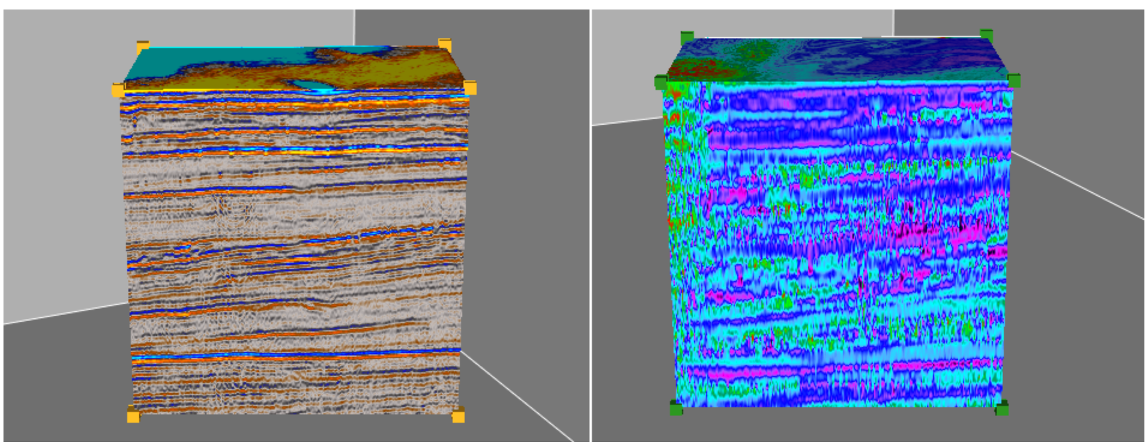


Frequency attributes are used to identify low-frequency shadows. Low-frequency shadows are distinct zones on seismic data that are characterized by anomalously low frequency content. They are caused by signal attenuation in a body, such as a gas sand, that is much stronger than in the surrounding rock. Seismic energy reflected from strata beneath the attenuating body lack high-frequency content relative to data elsewhere at the same reflection time. Shadows typically have lengths of several hundred milliseconds, and fade out gradually due to wave front healing.

Low-frequency anomalies can also be caused by statics problems or velocity problems that result in local mis-stacking or by poor signal penetration. As a result, frequency anomalies must be inspected carefully to see if they qualify as true shadows.

Average Frequency

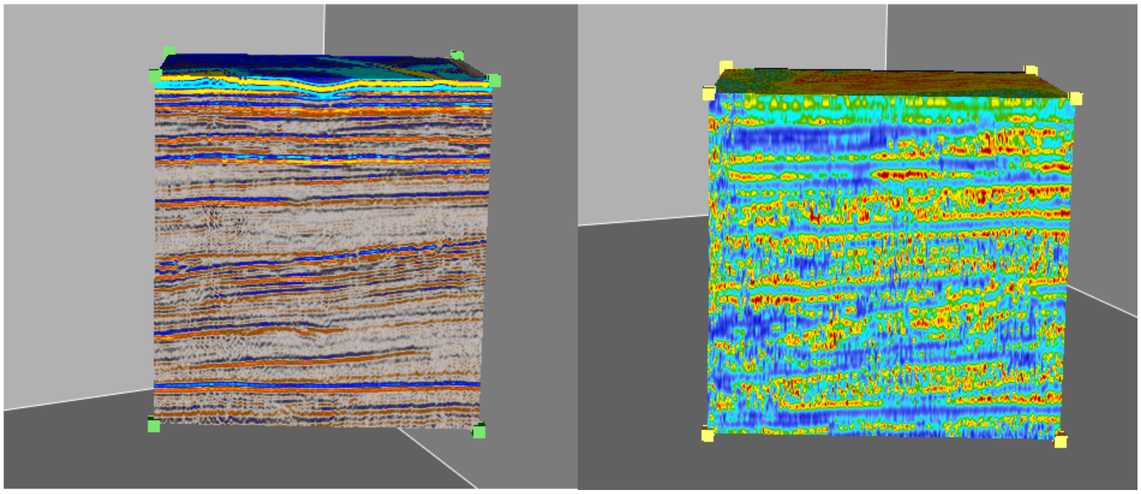
Average frequency is a stable and smooth version of instantaneous frequency. Because its values represent average Fourier spectral frequencies, they are constrained to the spectral bandwidth of the seismic data. This makes average frequency easier to understand and apply than instantaneous frequency. It is interpreted in the same way as instantaneous frequency to quantify reflection spacing and identify attenuation anomalies, such as low frequency shadows, which ideally could indicate gas reservoirs. In general applications, refer average frequency to instantaneous frequency or wavelet frequency.



Bandwidth

Bandwidth is interpreted much like average frequency. These two attributes are closely related and tend to change in tandem, so, in principle, attenuation anomalies that reduce the average frequency also reduce the bandwidth to a similar degree. Like average frequency, bandwidth finds application in stratigraphic analysis, and sometimes is highly effective in revealing channels and channel systems.

The resolution of the bandwidth attribute is determined by the length in time of the computation window. Use long windows for low resolution and short windows for high resolution.



Instantaneous Frequency

Instantaneous frequency can provide information about the frequency signature of events, the effects of absorption and fracturing, and depositional thickness. Instantaneous frequency also provides a means of detecting and calibrating thin-bed tuning effects, which may result from the constructive and destructive interference of reflector wavelets.

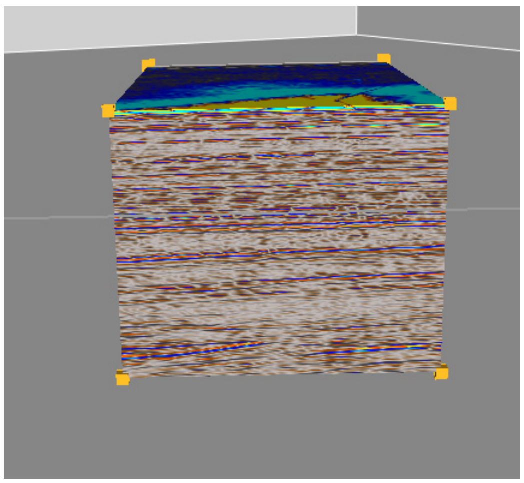
It also represents a value at a point rather than a value averaged over an interval. Instantaneous frequency reveals abrupt changes that otherwise would not appear in the averaging process. Such changes could indicate pinch-outs or the edges of hydrocarbon-water interfaces. Therefore, instantaneous frequency is a good check-and- balance to use in combination with other measurements.

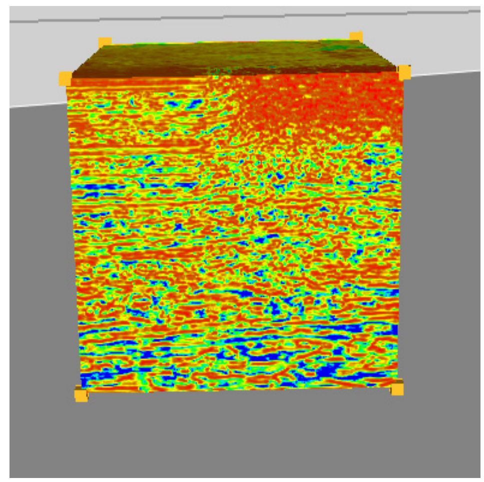
Quality Factor

Quality factor is a measure of overall spectral character that depends on the *average frequency* and *bandwidth* of the seismic signal. Zones where bandwidth and average frequency change separately are characterized either by relatively low or high quality factors. In theory, low values of quality factor identify zones of anomalous signal attenuation. Such zones should coincide with the tops of low-frequency shadows.

The connection of the quality factor attribute with rock property Q is tenuous, and it generally does not indicate attenuation. Instead, quality factor is applied as a qualitative measure that distinguishes spectral anomalies. Like both average frequency and bandwidth, it is applied in stratigraphic analysis.

The resolution of the Quality factor attribute is determined by the length in time of the *Computation* dialog. Use long windows for low resolution and short windows for high resolution.

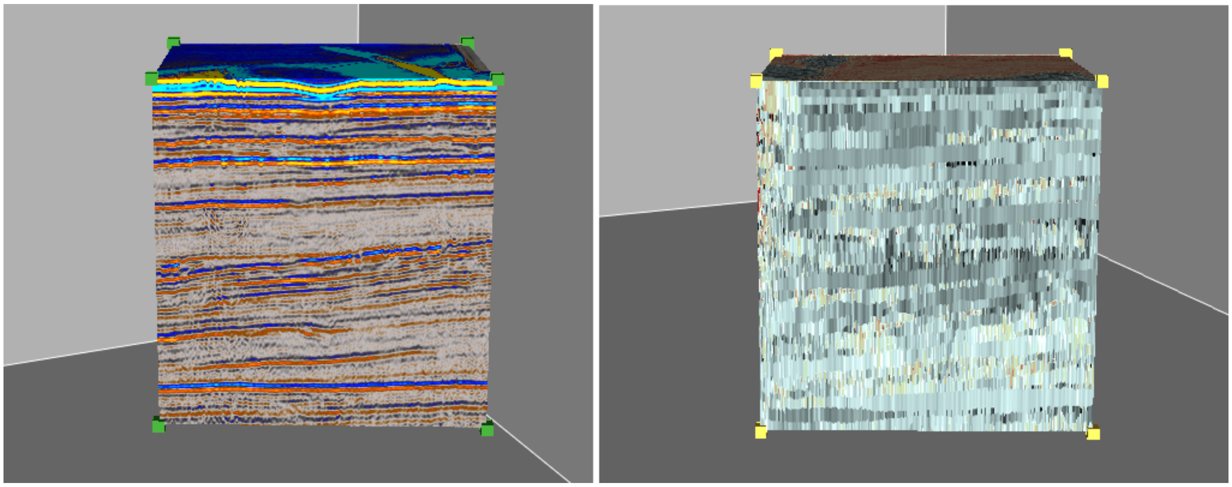




Response Frequency

Response frequency (also known as Wavelet Frequency in the GeoProbe software) is the instantaneous frequency measured at the envelope peaks, and held constant in each interval bounded by successive envelope troughs. It is used for tracking dominant reflections, and when looking for changes in the frequency content of the dominant reflections, which could reveal attenuation anomalies.

The images below are examples of the original .bri shared memory volume (left) and resultant response frequency attribute volume (right).



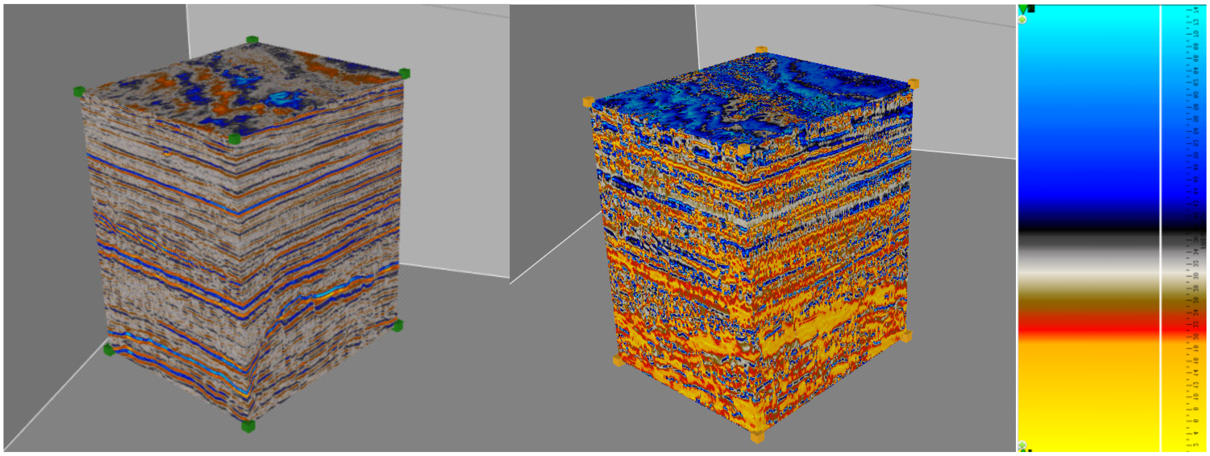
RMS Frequency

Instantaneous RMS (Root-Mean-Square) frequency (theory) is an estimate of the RMS spectral frequency at an instant in time. It is always positive and equal to or greater than instantaneous frequency. It is interpreted like instantaneous frequency, and may be a more sensitive measure for tracking reflection spacing and attenuation effects.

Note

The workflows are slightly different for 2D lines and 3D surveys.

The following figures are examples of the original .bri shared memory volume (left) and resultant RMS frequency attribute volume (right) calculated using the *Seismic Attribute Generation* dialog.

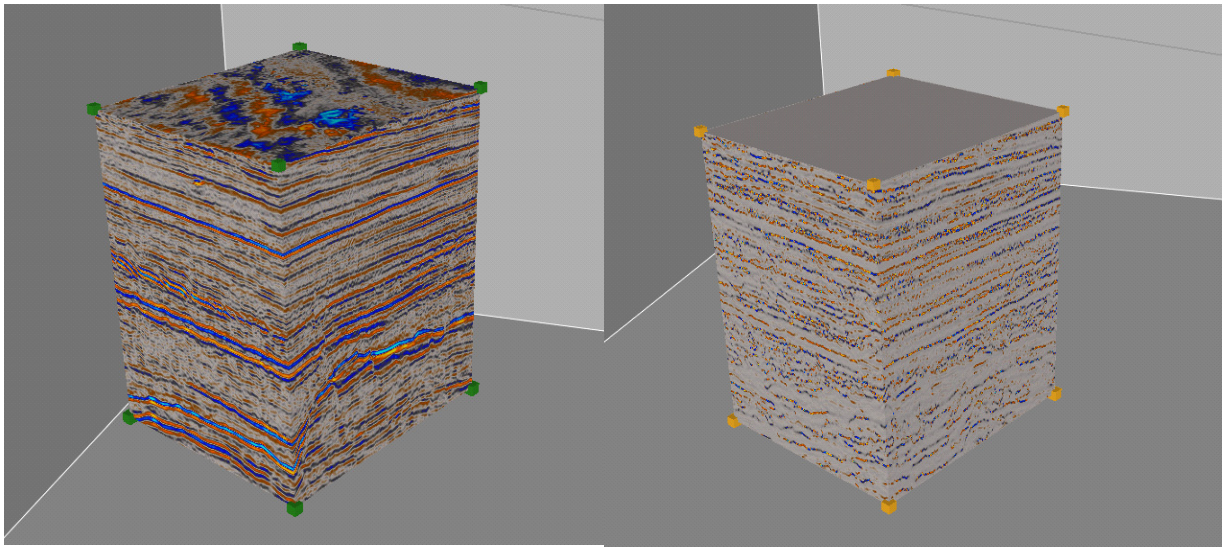


Thin-Bed Indicator

The thin-bed indicator identifies the points in seismic data that generate spikes in instantaneous frequency, either positive or negative. Frequency spikes occur where reflections interfere destructively and, to a lesser extent, at discontinuities.

The magnitudes and signs of the spikes have little interpretational value, but their locations identify zones of destructive reflection interference, and sometimes faults. Small changes in reflection spacing can cause big changes in the magnitudes of frequency spikes, or reverse their signs.

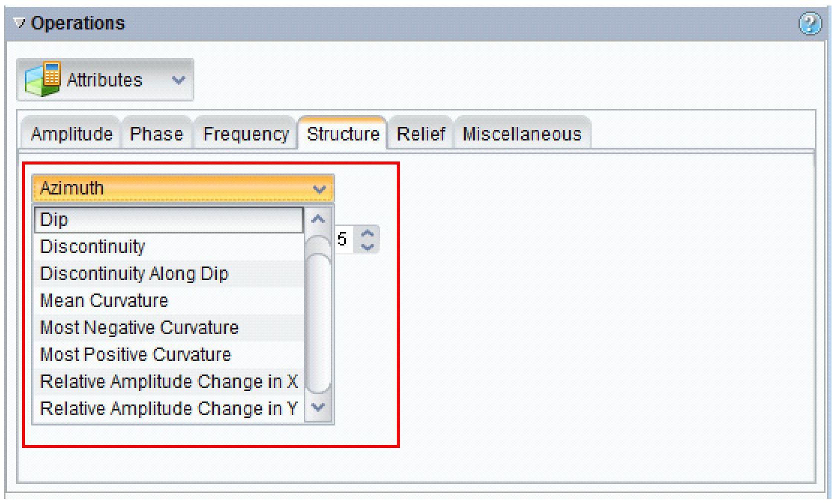
Because frequency spikes do not occur for bed thicknesses less than the tuning thickness, the thin-bed indicator cannot identify thin beds below seismic resolution. The thin-bed indicator finds modest employment in highlighting bedding patterns and thin zones of low reflectivity. It occurs between zones of stronger reflectivity, which could suggest a shale layer between two sand layers.



Structure Attributes

There are nine options under the *Structure* tab.

- Azimuth
- Dip
- Discontinuity
- Discontinuity Along Dip
- Mean Curvature
- Most Negative Curvature
- Most Positive Curvature
- Relative Amplitude Change In X
- Relative Amplitude Change In Y



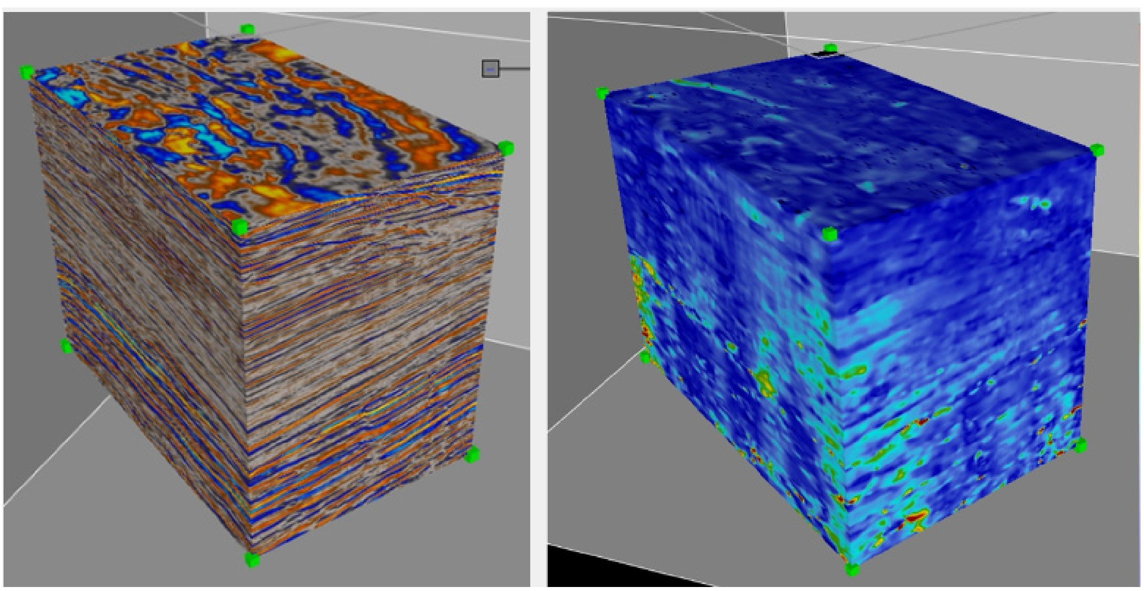
Azimuth

Volume azimuth is the down-dip direction of the seismic reflection in degrees from the y axis. Azimuth has the range of -180 to +180 degrees. When displayed with a circular monochrome color-bar, it resembles illuminated apparent topography, and is a good attribute for volume blending. Azimuth highlights broad structural patterns and reveals the flexure points of synclinal and anticlinal reflections.

Dip

Dip, in Seismic Attribute Generation, is recorded as a slope magnitude, with the direction given by the azimuth. The units are samples per trace scaled by 100, rather than units of degrees (which requires a velocity function for time-domain data). The inline and crossline spacings are taken to be 1; their true spacings are not used. In Seismic Attribute Generation, both dip and azimuth are computed through a gradient-squared tensor method.

Dip represents the magnitude of the maximum slope of the seismic reflections at a point, which is the slope measured in the direction of the reflection azimuth. Dip highlights structural trends, reflection bumps and sags, and faults. On vertical views, faults are sometimes easier to follow with dip than with the discontinuity attributes. Dip is a good background attribute for volume blending.

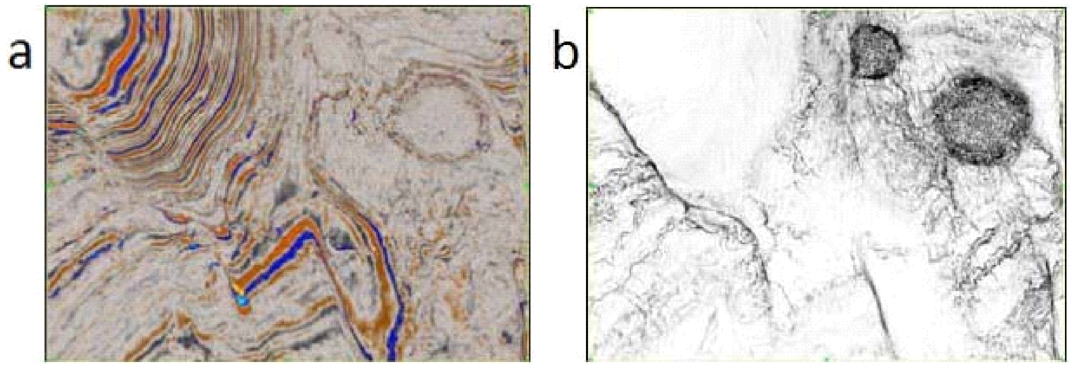


Discontinuity

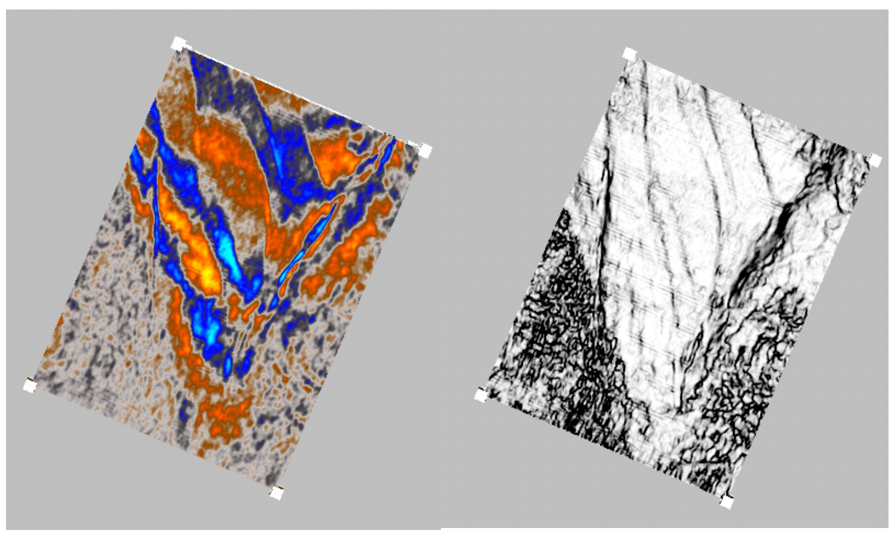
Discontinuity highlights faults, channels, diapirs, and other seismic discontinuities. It ranges from 0 to 100, where 0 indicates perfect continuity, and high values indicate discontinuities. Discontinuity is the same attribute as Structure Cube in the GeoProbe and PostStack software products.

The images below are a comparison of the original seismic and the discontinuity attributes along a time slice (1060 ms) through the data:

(a) original seismic data; (b) discontinuity attribute using default window size of three lines by three traces by 11 samples.



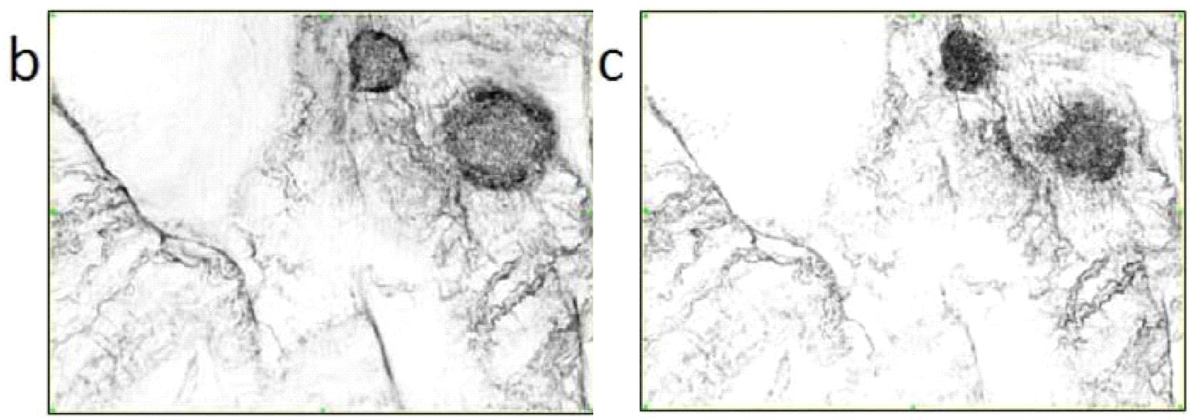
The images below are an example from the training data at slice 2284 ms. Note the faults-enhanced tracing.



Discontinuity Along Dip

Discontinuity Along Dip is a discontinuity attribute that accounts for reflection dip, and produces cleaner images than standard discontinuity, particularly in regions of strong dip. *Standard discontinuity* can be employed where reflection dips are negligible, but where they are moderate or steep, discontinuity along dip should be employed. Like standard discontinuity, discontinuity along dip highlights faults, channels, diapirs, and other seismic discontinuities, and is scaled from 0 to 100, where 0 implies perfect continuity, and high values indicate discontinuities.

The images below are a comparison of the two discontinuity attributes along a time 1060 ms slice (b) discontinuity attribute; (c) discontinuity along a dip attribute. Both discontinuity attributes were derived in the default window size of three lines by three traces by 11 samples.



Mean Curvature

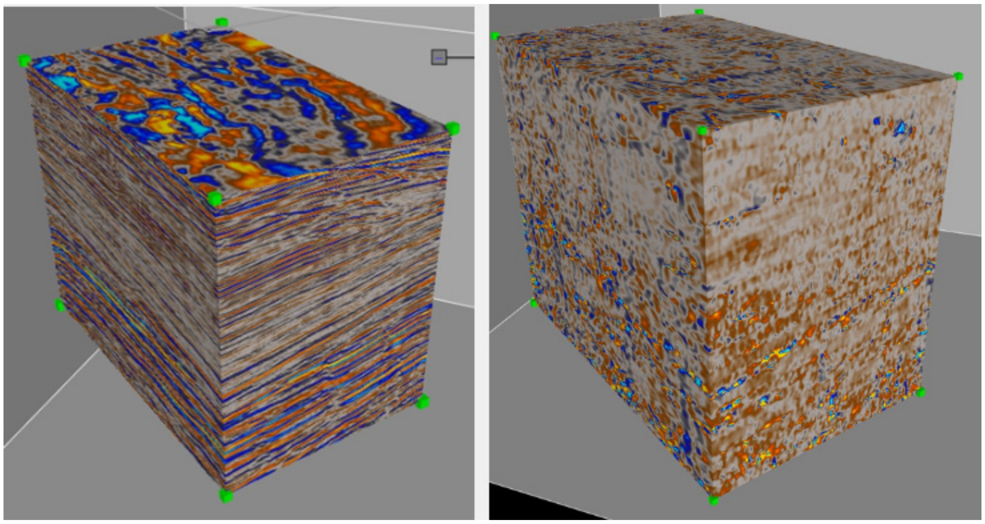
Mean curvature (K_{mean}) is the average of the most positive and most negative curvatures.

$$K_{mean} = \frac{K_{pos} + K_{neg}}{2}$$

It more accurately describes faults and channel boundaries, and sometimes provides better images than discontinuity. In terms of the curvature coefficients, mean curvature is defined by the following:

$$K_{mean} = C_{xx} + C_{yy}$$

Mean Curvature cannot be used with 2D data.



Curvature

Curvature refers to the rate of change of dip and azimuth along a seismic reflection surface. Dips and azimuths can vary differently in different directions, so curvature forms a complicated set of properties. For volume seismic attributes, only most positive and most negative curvatures have found much application. They complement discontinuity attributes to reveal structural details of faults and flexures. Because curvature attributes involve second derivatives, they tend to be noisy and often enhance acquisition footprints. For this reason, it is best to run curvature attributes on coherency-filtered seismic data.

DecisionSpace Seismic Attributes employs a gradient-squared tensor method to estimate reflection slopes, from which it derives the curvature coefficients. DecisionSpace Attributes calculates the following two curvature attributes:

- Most Positive Curvature
- Most Negative Curvature

Most Positive Curvature

Most Positive Curvature records the most positive rate of change of the reflection dip and azimuth. It highlights "frowns" in seismic reflections, or reflection bumps. It is closely related to *Most Negative Curvature*, which highlights "smiles," or reflection sags. Normal faults often exhibit positive curvature on the up-thrown side, and negative curvature on the down-thrown side. The sign convention employed for curvature attributes is illustrated below.

Most Negative Curvature

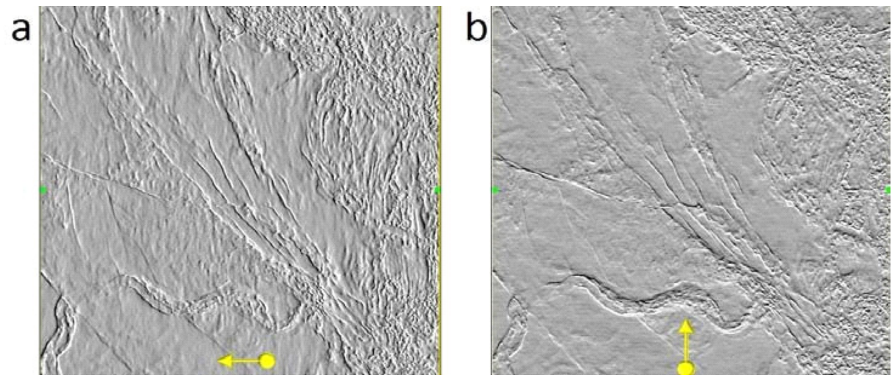
Most Negative Curvature records the most negative rate of change of the reflection dip and azimuth. It highlights "smiles" in the data, or reflection sags. It is closely related to *Most Positive Curvature*, which highlights "frowns," or reflection bumps. Reflection sags can indicate fluid-filled fractures that are below seismic resolution, but which cause velocity pull-down. Normal faults often exhibit negative curvature on the down-thrown side, and positive curvature on the up-thrown side. The sign convention employed for curvature attributes is illustrated below.

Relative Amplitude Change in X or Y

Relative amplitude change in the x or y direction serves as a directional high-resolution discontinuity attribute, revealing details in faults and channels viewed along time or depth slices. Because it is directional, it naturally looks illuminated when displayed in monochrome and achieves an effect similar to bump mapping, except the illumination direction cannot be changed arbitrarily in the display. To highlight all trends, relative amplitude change must be run in both the x and y directions. It is most effective where geologic structures are relatively uncomplicated.

The implementation of directional relative amplitude change in DecisionSpace Seismic Attributes scales the output to the convenient range of -100 to +100, regardless of true trace spacing. It incorporates a vertical median filter that reduces noise and reflection interference effects while leaving faults and channels untouched. By default, this filter is set to 7 samples. To turn the filter off, set the filter length to 1 sample. Selecting more samples in the filter increases the filter strength. Stronger filters can remove more noise, but risk removing geologic effects as well.

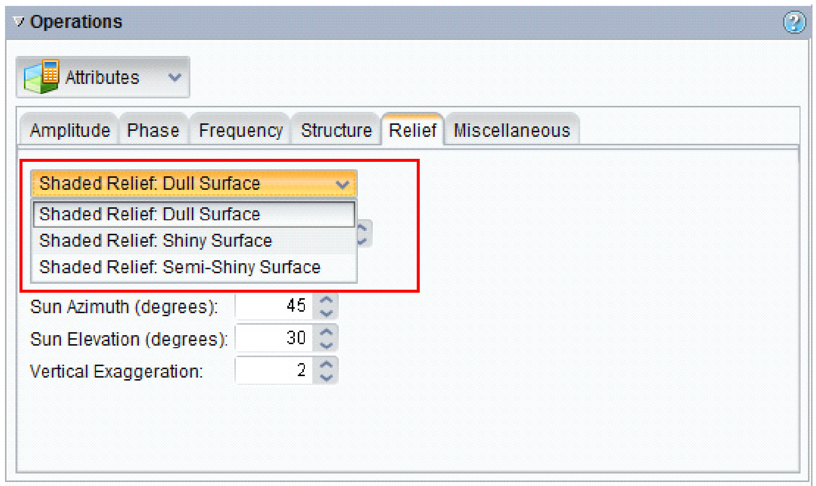
The images below are examples of horizontal relative amplitude change in the (a) inline direction and in the (b) crossline direction. The vertical operator length is seven samples in both cases. The yellow arrows indicate the direction of computation. As with any directional attribute, features that are perpendicular to the computation direction are revealed, while features parallel to that direction are hidden. Relative amplitude change is closely similar to discontinuity attributes.



Relief Attributes

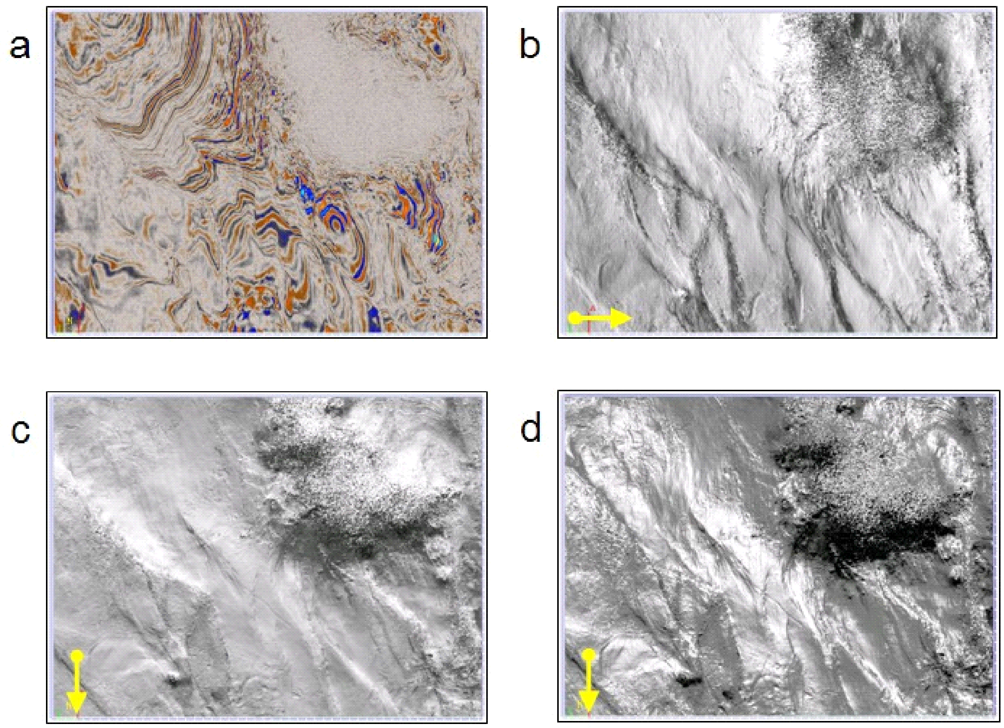
DecisionSpace Seismic Attributes provides three output options when creating shaded relief volumes, based on reflectance:

- Shaded Relief - Dull Surface
- Shaded Relief - Shiny Surface
- Shaded Relief - Semi-Shiny Surface



Seismic shaded relief attributes combine reflection dip and azimuth into a form that is more natural for interpretation. These attributes act like bump mapping, except they illuminate seismic reflection surfaces instead of amplitudes. They make time slices look like aerial photographs of topography, and vertical sections look like rugged canyon walls.

The images below show a seismic shaded relief along a time slice (1864 ms). Yellow arrows indicate direction of illumination. Original seismic data is shown in (a). Shaded relief for a dull surface is shown in (b). Shaded relief for a dull surface with illumination orthogonal to that of (b) is shown in (c). Shaded relief for a shiny surface the same illumination as in (c) is shown in (d). Varying the illumination direction highlights different features. Dull surfaces look more natural, but shiny surfaces can reveal more detail.

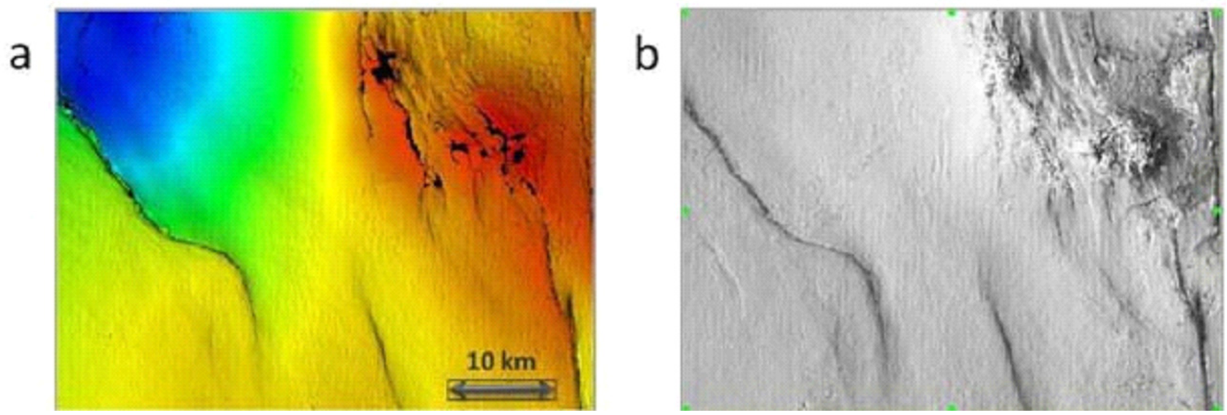


> **Note**
>
> Shaded relief attributes are not available for 2D seismic data.

Shaded relief is particularly useful for reconnaissance of geologic structure in advance of fault or horizon interpretation. The large-scale structure observed on a seismic shaded relief time slice resembles the structure seen on an intersecting interpreted horizon (see figure on the next page).

The correspondence is often close, even where geologic structures are fairly complicated. Seismic shaded relief also reveals details such as channels, but these match those seen on an interpreted horizon only where the horizon time is close to that of the shaded-relief time slice.

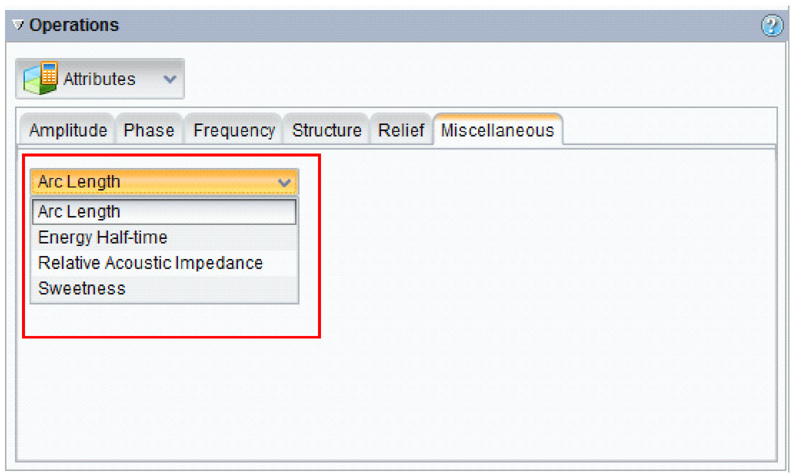
The images below show a seismic shaded relief time slice as on an intersecting interpreted horizon. In this example, the horizon spans 800 ms in time; 1354 ms at dark blue to 535 ms at bright red.



Miscellaneous Attributes

From the *Attributes* pane, select the *Miscellaneous* tab, then click the drop-down arrow to open the menu containing the following attributes:

- Arc Length
- Energy Half-time
- Relative Acoustic Impedance
- Sweetness

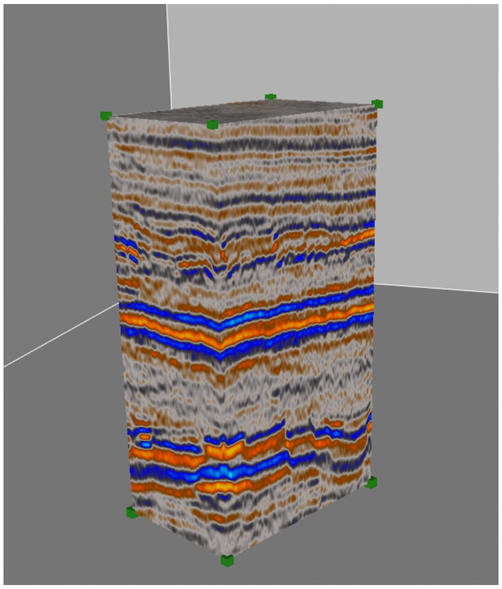


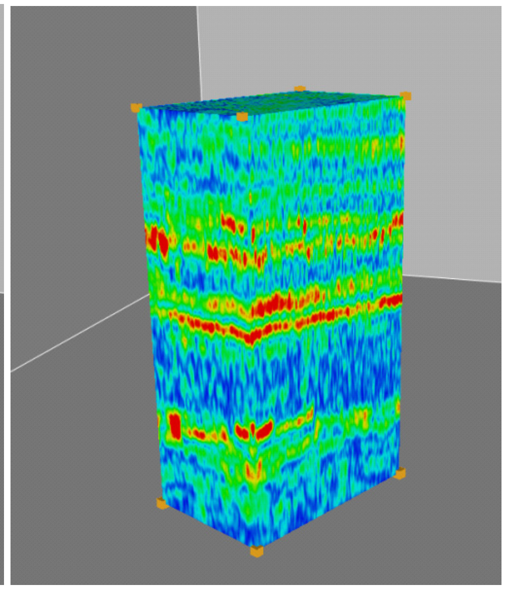
Arc Length

Arc length is defined as the length of the seismic waveform in a window measured along its wiggles, divided by the length of the window.

Arc length increases with both amplitude and frequency. Thus high arc length could indicate strongly reflecting, moderately spaced bedding or moderately reflecting, thinly spaced bedding. However, it tends to be driven more by amplitude than by frequency. Arc length sometimes reveals small channel systems better than other attributes. It should be applied empirically in conjunction with related attributes, such as *sweetness* and *reflection strength*.

The images below show a .bri shared memory volume (left) and a resultant arc length attribute volume (right) calculated using DecisionSpace Seismic Attributes.





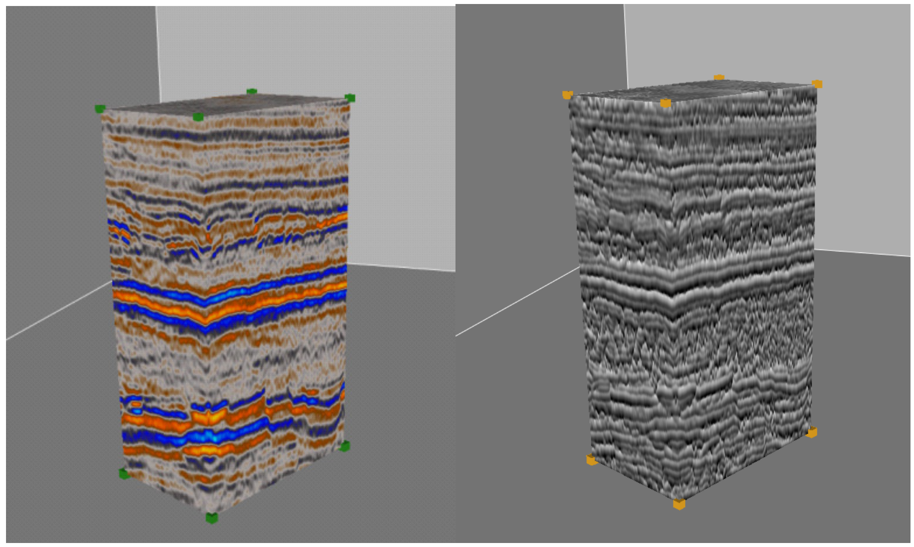
Energy Half-time

Energy half-time is a relative measure of where seismic energy in a time interval is concentrated.

In DecisionSpace Seismic Attributes, energy half-time is scaled to lie in the range of -100 to +100. A value of 0 indicates the data energy is centered at the window center, a negative value indicates it is centered in the upper half of the window, and a positive value indicates it is centered in the lower half of the window.

Energy half-time acts like a measure of average amplitude change within a window. Displayed in gray-scale, it tends to look 3D in a vertical view. Ridges in energy half-time appear illuminated and indicate either zones of low reflectivity between zones of stronger reflectivity, or non-vertical structural features, such as faults.

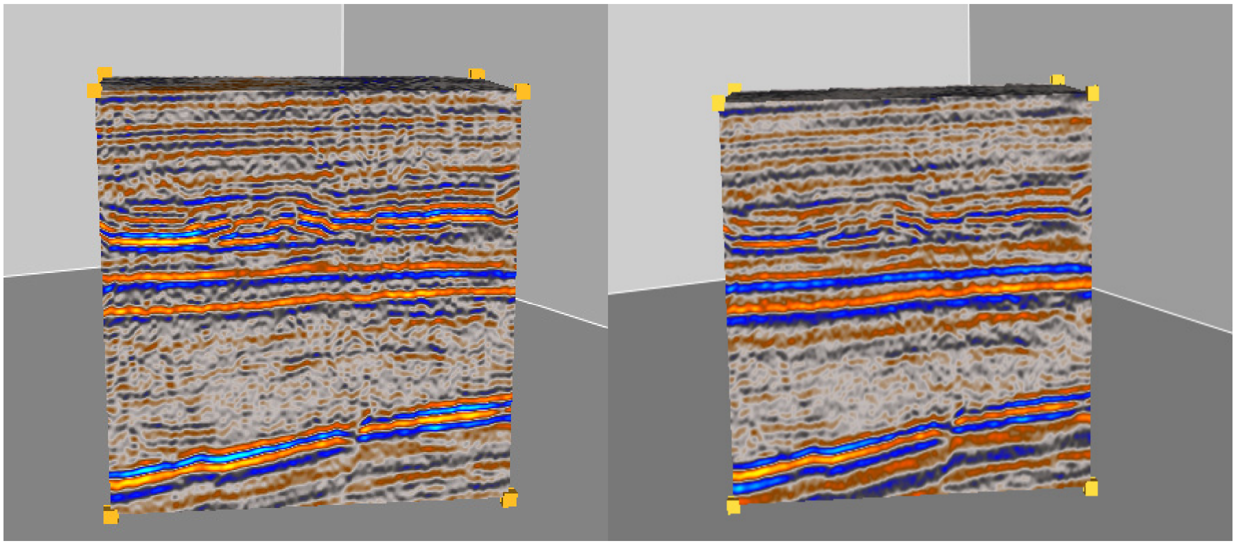
The following images show a .bri shared memory volume (left) and a resultant energy half-time attribute volume (right).



Relative Acoustic Impedance

Relative Acoustic Impedance is the only seismic impedance attribute that can be computed directly from conventional post-stack seismic data. Unlike the other seismic attributes in DecisionSpace Seismic Attributes, Relative Acoustic Impedance requires that the seismic data approximate a reflection coefficient series. When this is the case, and under favorable circumstances, Relative Acoustic Impedance indicates differences in porosity. This rough empirical relation is not always valid, and wherever possible, impedance results should be calibrated with porosity logs to establish the relation.

The images below show a .bri shared memory volume (left) and a resultant Relative Acoustic Impedance attribute volume (right).



Sweetness

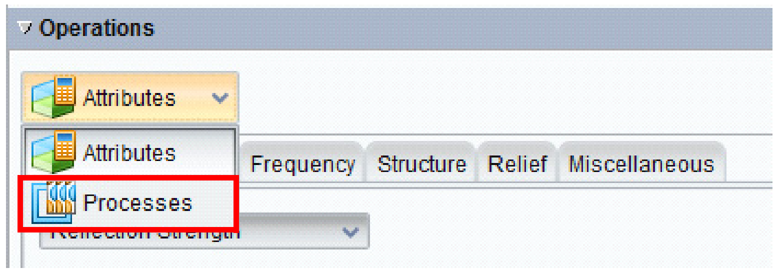
Sweetness is an empirical attribute designed to identify “sweet spots,” places that are oil and gas prone. The definition of sweetness is motivated by the observation that, in young clastic sedimentary basins, sweet spots imaged on seismic data tend to have strong amplitudes and low frequencies. High sweetness values are those that most likely indicate oil and gas. The definition of sweetness given here is a more stable and smoothly-varying measure. Sweetness in DecisionSpace Seismic Attribute is the same attribute as “average sweetness” in the GeoProbe software.

The Samples parameter (which specifies window length) affects only the computation of the average frequency, and rarely needs to be changed. Reducing it can enhance the character of the result, but also makes it look noisier.

Sweetness tends to be driven more by amplitude than by frequency and often closely resembles reflection strength. Sweetness anomalies of interest are therefore those that are more pronounced than the corresponding reflection strength anomalies and can be useful for channel detection.

Processes

Select the Processes option from the drop-down menu in the *Operations* pane of the *Seismic Attribute Generation* dialog to enable process selection.



There are five options under Processes.

- Filter
- Gain
- Enhance
- Spectral Shaping
- Utility

> **Note**
>
> The Process workflows are different for 2D lines and 3D surveys.

Filter

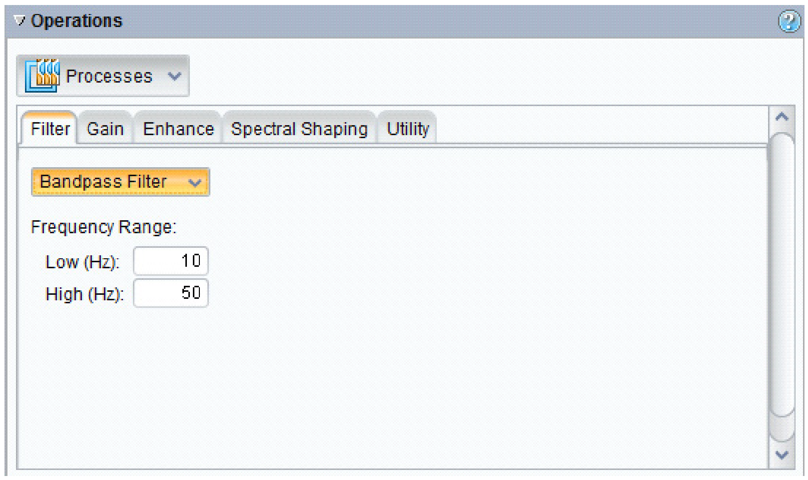
Six filters are available for attribute calculations. This section will describe the options available to set filter seismic attribute calculations.

Bandpass Filter

Bandpass Filter is a conventional trace filter that removes high-frequency and low-frequency noise to enhance the seismic signal. It is intended primarily for standard seismic data, but it is occasionally useful for seismic attributes as well.

You commonly apply the Bandpass Filter process to seismic data for the purpose of removing noise outside the bandwidth of the filter.

Another use of the Bandpass Filter process is in a workflow that approximates volume spectral decomposition. In this workflow, apply the Bandpass Filter process to create two or more narrow bandpass-filtered volumes, with at least one low-frequency volume and one high-frequency volume. Apply Reflection Strength to each filtered volume to create a set of "spectral response" volumes, which are then compared to identify differences in response.



Derivative Filter

The Derivative Filter returns the scaled derivative of the seismic trace, whether in time or in depth. It has the effect of applying a 90-degree phase rotation, boosting high frequencies, suppressing low frequencies, and removing the average value of the data (or DC component). As a result, the derivative of the seismic data often appears to have higher resolution and more noise than the original data.

In Seismic Attribute Generator, the Derivative Filter is scaled so as to leave the overall amplitude level unchanged or only slightly reduced. This scaling is achieved by setting the sample period to 1, regardless of its true value.

The derivative filter finds modest application in several workflows. Applied to standard seismic data, it is sometimes helpful in thin-bed analysis. Applied to acoustic impedance seismic data, it removes the background trend and returns standard seismic trace data with the correct polarity. Applied to relative acoustic impedance computed through recursive inversion, it returns the original seismic data with a slight time shift, which is caused by recursive inversion. Applied to a seismic attribute, such as amplitude, frequency or velocity, it returns the rate of change in time or depth of the attribute.

Laplacian Filter

The Laplacian filter is a standard image processing tool that is used to sharpen lines in blurry images. In seismic data analysis, the filter is applied to standard discontinuity attributes to sharpen fault and channel discontinuities and remove relatively flat background noise. It operates along time slices, so it improves lateral resolution but does not improve vertical resolution. It makes time slices look like line drawings.

> **Note**
>
> The workflows are slightly different for 2D lines and 3D surveys, as the results of 3D calculations are best viewed in a time slice. The results of Laplacian filtering using 2D data can only be calculated along a 2D line and viewed in the *Section* view along that line.

Laplacian filtering can also be applied usefully to other attributes that highlight discontinuities, such as dip or curvature. However, it is inappropriate and harmful for most seismic attributes and normal seismic data. The Laplacian filter employs a three trace by three line window.

Median Filter

Median Filter is a standard 1D median filter that operates on individual seismic traces in a running window. A median filter is a nonlinear filter that sorts all the data values in a window from the smallest to largest value, then selects the value in the center as the filter output. Median filters are effective for removing spikes and for preserving steps in the data values. In contrast, a standard smoothing filter spreads spikes around and smooths across data steps.

The window or filter length is set by the number of samples. Choose a longer window for low resolution, and a shorter window for higher resolution. The window employed here is a simple boxcar, and so it is not tapered. As a result, the output tends to look somewhat blocky in vertical view.

Apply the median filter to attributes that are plagued by spikes, such as instantaneous frequency. The median filter removes these spikes to produce a cleaner attribute that is easier to interpret. For instantaneous frequency, a filter length of 11 samples is effective. This approach to improving instantaneous frequency is sometimes preferable to computing average frequency, as it can produce sharper results.

Note

Do not apply this Median Filter to Relative Amplitude Change in X or Relative Amplitude Change in Y because a median filter is already built into those attributes. Also, do not apply the median filter to seismic data unless the data is noticeably disturbed by spikes.

Rotate Phase

The Rotate Phase attribute changes the phase of the seismic data by adding a constant phase angle through a convolutional filter. It does not alter the frequency spectrum of the seismic data. Phase Rotation is equivalent to Quadrature Filter when the phase angle is -90 degrees, and it is equivalent to Reverse Polarity when the phase angle is 180 degrees.

Apply phase rotation to correct the phase of a seismic data set to match the phase of another dataset.

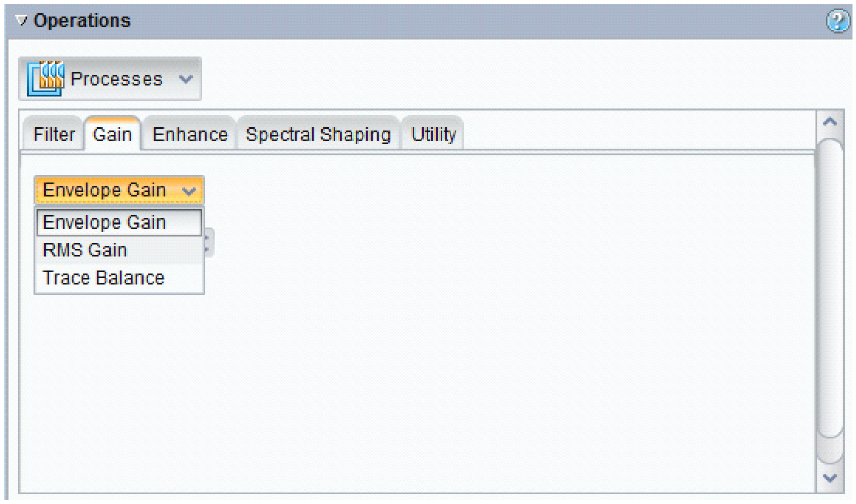
Quadrature Filter

Quadrature Filter, also known as a Hilbert Transformer, rotates the phase of the seismic data by -90 degrees. In complex seismic trace analysis, the quadrature filter is used to derive the imaginary seismic trace from the real seismic trace. Quadrature filter is identical to Phase Rotation with a phase angle of -90 degrees. Like phase rotation, the quadrature filter does not change the amplitude spectrum of the data.

This filter is applied to standard seismic data. It changes the apparent phase of thin-beds, which appear to be +90 or -90 degrees of phase, so that they look like zero-phase reflections. This arguably simplifies thin-bed interpretation in some cases.

Gain

Three gain calculations are available for attribute calculations. This section will describe the three options available to set gain seismic attribute calculations.



Envelope Gain

Envelope Gain is a common method for automatic gain control (AGC). It is derived by dividing the seismic trace by a smoothed version of its trace envelope, or reflection strength. Like all seismic AGC methods, the purpose is to reduce the amplitude contrasts in the data so as to make features with small amplitudes easier to see. Long windows apply less gain and have less effect. Short windows apply more gain and have more effect. Regardless of the magnitude of the input data values, this implementation of envelope gain scales the output values so that they fall roughly into the range of -100 to +100.

The results of envelope gain are similar to RMS gain. They tend to be a little cleaner than RMS gain, but the computation runs longer. RMS gain suffices for routine AGC.

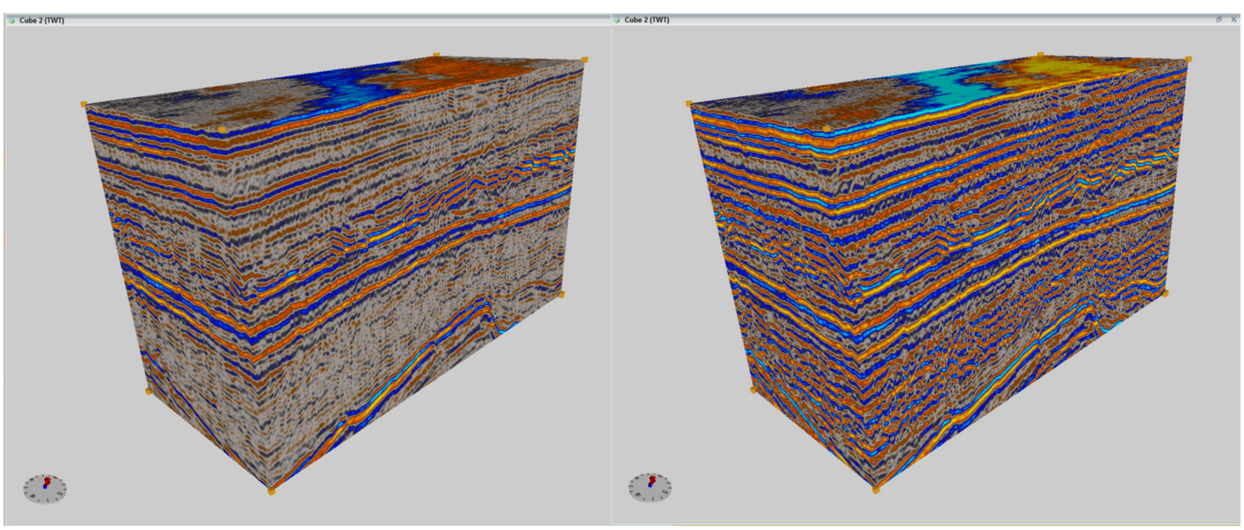
RMS Gain

RMS Gain is a standard method for automatic gain control (AGC). It is roughly the same as dividing the seismic trace by its RMS amplitude attribute. Like all seismic AGC methods, its purpose is to reduce the amplitude contrasts in the data so as to make features with small amplitudes easier to see. Long windows apply less gain and have less effect. Short windows apply more gain and have more effect. Regardless of the magnitudes of the input data values, this implementation of RMS Gain scales the output values so that they fall roughly into the range of -100 to +100. RMS gain also inherently balances all traces in a dataset to have the same average RMS amplitude.

Trace Balance

The Trace Balance process balances traces in a seismic dataset so that all traces have the same average amplitude. It does this by multiplying each trace by a unique scalar derived from its full trace RMS (root-mean-square) amplitude. Trace balancing removes only overall trace-to-trace changes in true amplitude data, and preserves the original vertical changes in amplitude. It has no effect on data that has already been gained by RMS Gain, which is a stronger gain process that inherently includes trace balancing. The minimum and maximum data values output by Trace Balance are roughly similar to those of the input dataset.

Apply trace balancing to seismic data that has lateral problems in trace scaling, such as those that might occur on true-amplitude land data with gaps in coverage. Trace balancing can be applied to amplitude attributes, but it makes little sense to apply it to phase, frequency, or structure attributes.

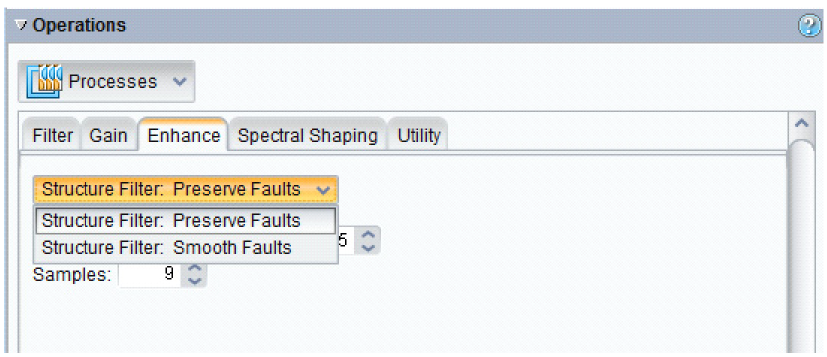


Enhance

Two enhancement calculations are available for attribute calculations. This section will describe the options available to set enhanced seismic attribute calculations.

Structure Filter: Preserve Faults

Structure Filter: Preserve Faults applies a coherency filter (or structurally oriented filter) that smooths seismic data along reflection dips while preserving faults and other sharp discontinuities. The averaging employs the “weighted majority with minimum range” (WMMR) nonlinear filter, a standard edge-preserving filter for image processing. This filter runs somewhat slower than the Smooth across Faults option. A characteristic of the WMMR filter is that it always discards a portion of the data, which it treats as “outliers,” in computing an average value, even where the data is clean. As a result, it does not produce quite as smooth a result as the simple averaging of the Structure Filter: Smooth across Faults option.

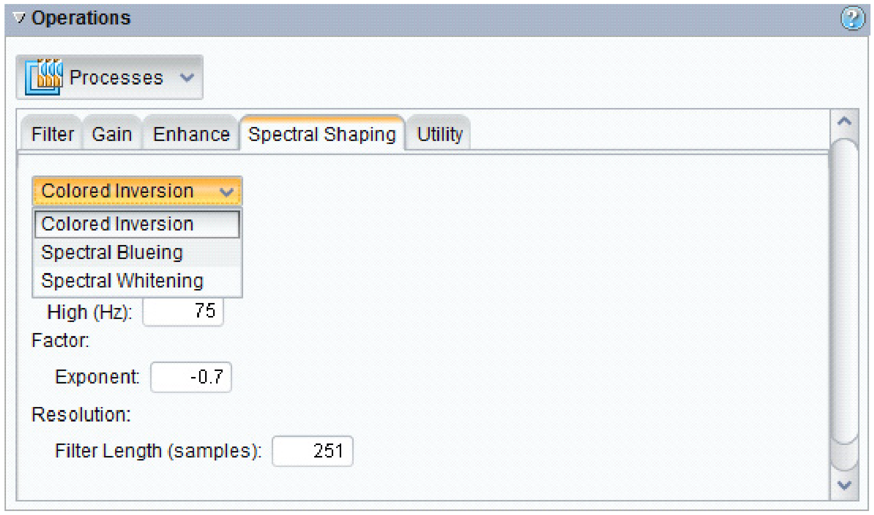


Structure Filter: Smooth Across Faults

Structure Filter: Smooth Across Faults applies a coherency filter (or structurally oriented filter) that smooths seismic data along reflection dips without regard for discontinuities, such as faults. It employs simple averaging, so it runs comparatively faster than the Preserve Faults option, which employs a nonlinear filter.

Spectral Shaping

Three spectral shaping calculations are available for attribute calculations. This section will describe the options available to set spectral shaping seismic attribute calculations.



Colored Inversion

Colored inversion is designed to make the average spectrum of inverted seismic data roughly match the average spectrum observed in impedance logs (Lancaster and Whitcombe, 2000; Neep, 2007). Because the Earth's reflectivity tends to be fractal, its amplitude spectrum $A_R(f)$ approximates a power law that favors high frequencies (see spectral bluing).

See the online help for more information on Colored Inversion.

Spectral Bluing

Spectral bluing (theory) is designed to make the average spectrum of seismic data roughly match the average spectrum observed in well logs (Neep, 2007). Because the Earth's reflectivity tends to be fractal, its amplitude spectrum $A_R(f)$ approximates a power law that favors high frequencies.

Spectral bluing is a key process for poststack seismic data enhancement. By broadening the spectrum of the seismic data and enhancing the high-frequency content, the resolution is enhanced so small features, such as pinchouts, minor faults, and small channels, become clearer. To be effective, the frequencies that are boosted must contain signal. Spectral bluing is ineffective on inherently noisy data.

Spectral blueing is often best run in a workflow with coherency filtering, offered in Seismic Attribute Generation as Structure Filter. Whether spectral blueing should be run before or after coherency filtering is debatable. In practice, both ways provide similar results, which differ only in their details.

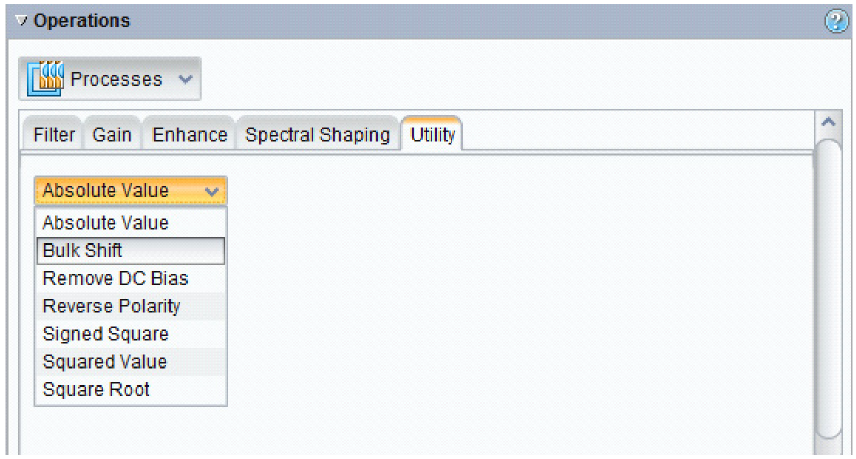
Spectral Whitening

Spectral whitening (theory) broadens the bandwidth of the seismic data by raising the amplitude spectrum to an exponent c with a value between 0 and 1. An exponent of 0 flattens the spectrum perfectly; an exponent of 1 leaves the spectrum unaltered; and an exponent between 0 and 1 flattens the spectrum while retaining some degree of spectral character. In theory, the whitened spectrum should retain some spectral character because the analysis windows are never long enough to justify the assumption that the overall reflectivity is white.

Spectral whitening is a key process for poststack seismic data enhancement. By broadening the spectrum of the seismic data, the resolution is enhanced so that small features, such as pinchouts, minor faults, and small channels, become clearer. To be effective, the low and high frequencies that are boosted must contain signal. Spectral whitening is ineffective on inherently noisy data.

Utility

Six utility calculations are available for attribute calculations. This section will describe the options available to set utility seismic attribute calculations.

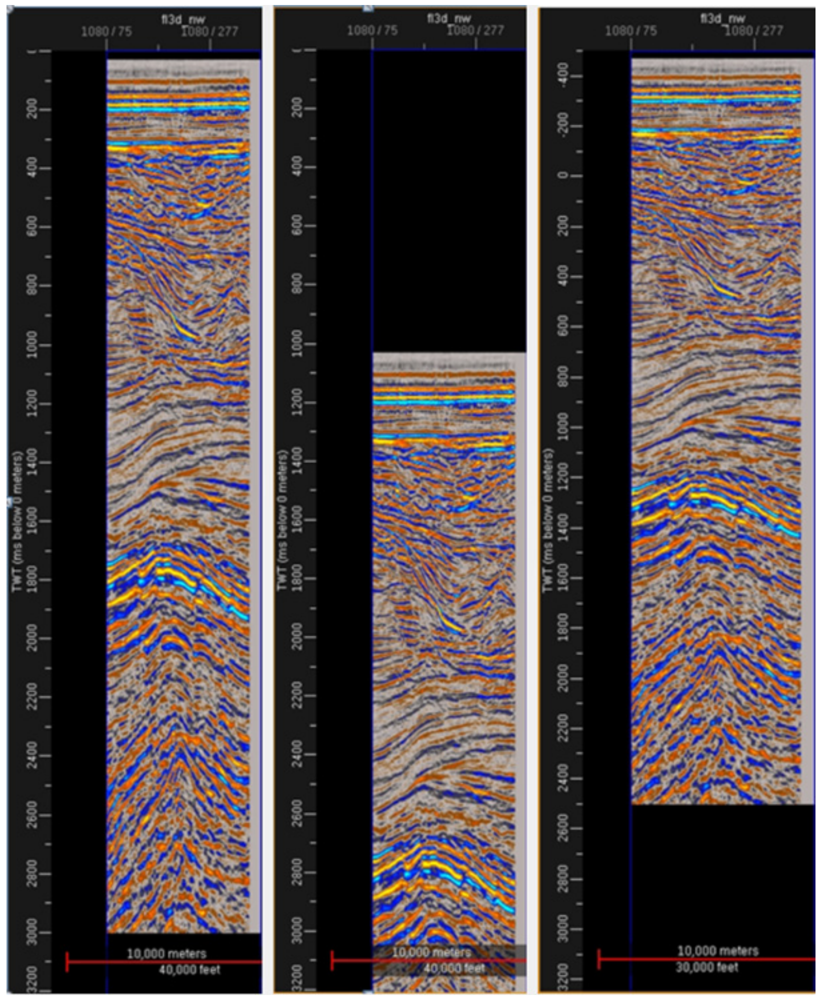


Absolute Value

This utility replaces each sample value with the absolute value of the original sample. Thus, it changes the sign of all negative data values to make them positive, but it has no effect on positive data values. This process is used whenever the magnitude of the data values is of interest, but not the sign. For example, applied to relative acoustic impedance, it helps identify those data zones that have the same difference from the background impedance (the low-frequency portion of the impedance that is inherently missing from relative acoustic impedance). Applied to the thin-bed indicator, this utility gives all "spikes" a positive value, which simplifies analysis.

Bulk Shift

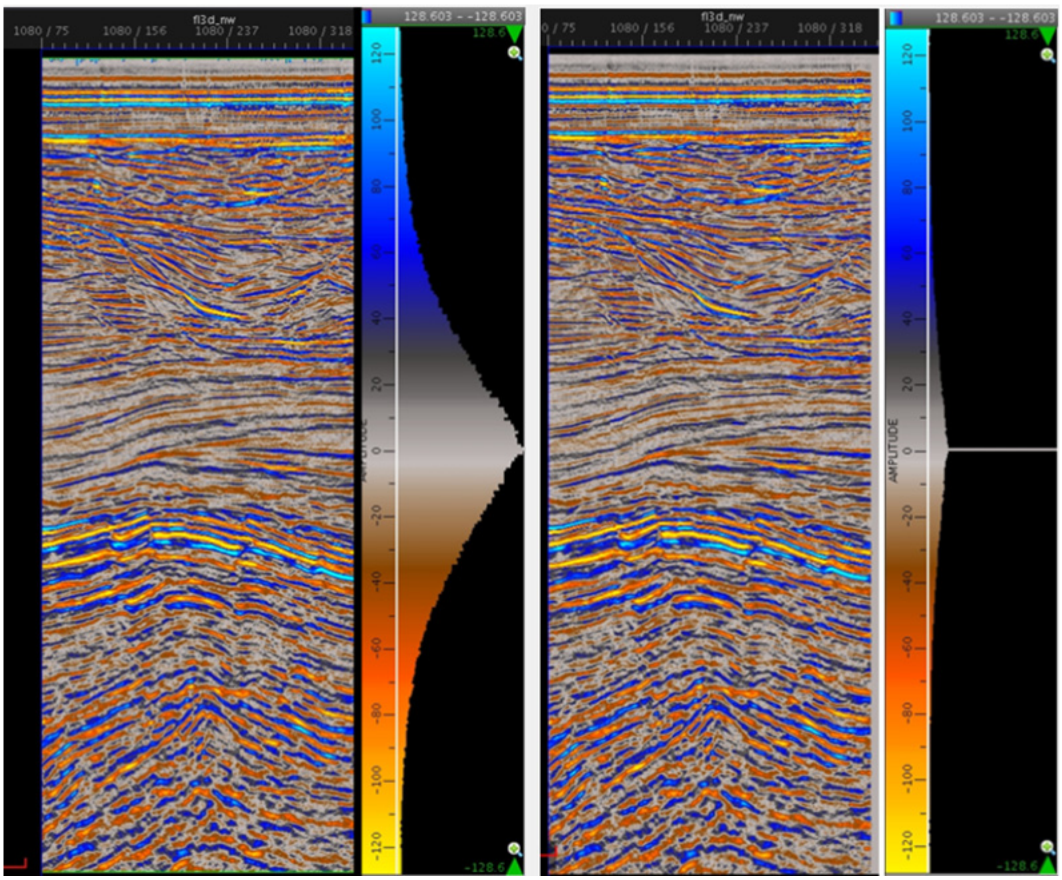
Bulk Shift applies a constant time shift (or depth shift) to the input seismic data set. A positive shift value moves the seismic data downward (deeper); a negative shift value moves the seismic upward (shallower).



Remove DC Bias

The Remove DC Bias utility removes the DC (or zero frequency) component of the seismic data. This is done by subtracting the average value, DC bias, from each seismic trace. It produces a zero-mean seismic trace, but does not otherwise affect the frequency content.

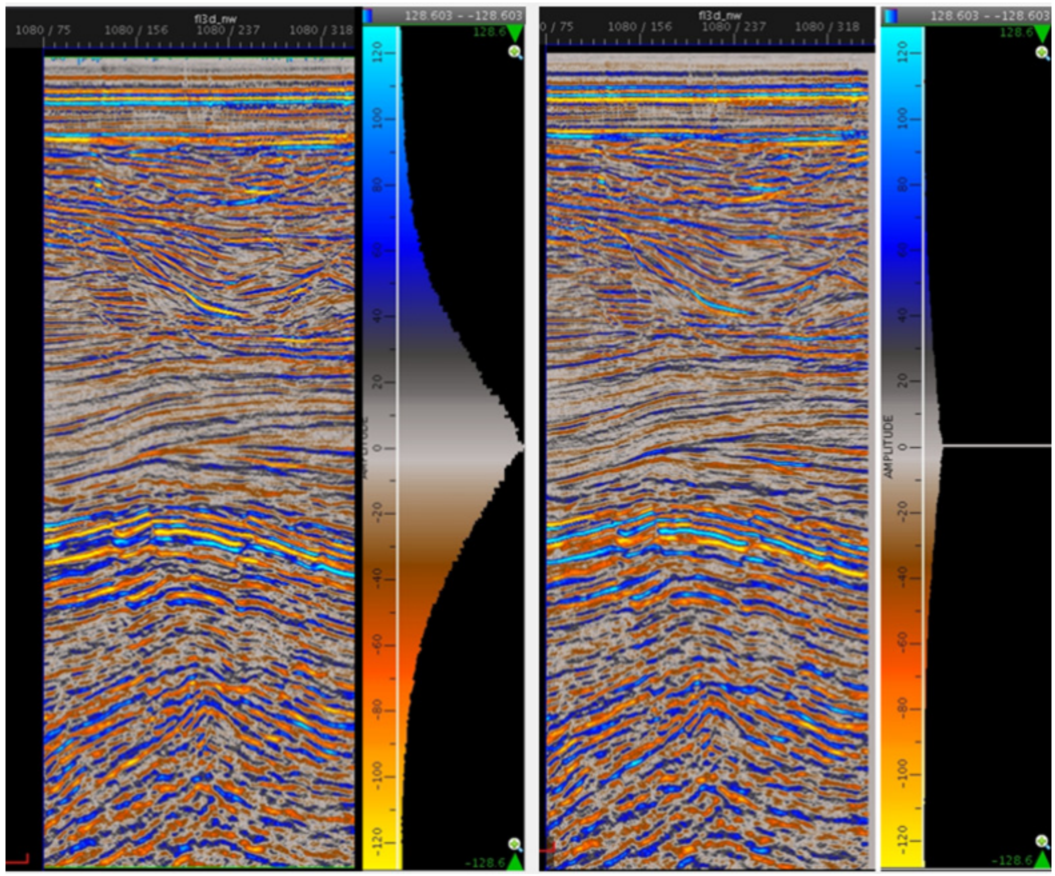
This process should be applied to seismic data to remove DC noise. Also apply it to seismic attributes when the variations in the attributes' values are small with respect to their average value, so as to make the variations easier to follow.



Reverse Polarity

The Reverse Polarity utility flips the polarity of the seismic data by multiplying all data values by -1. It is equivalent to applying a 180-degree phase rotation to the trace.

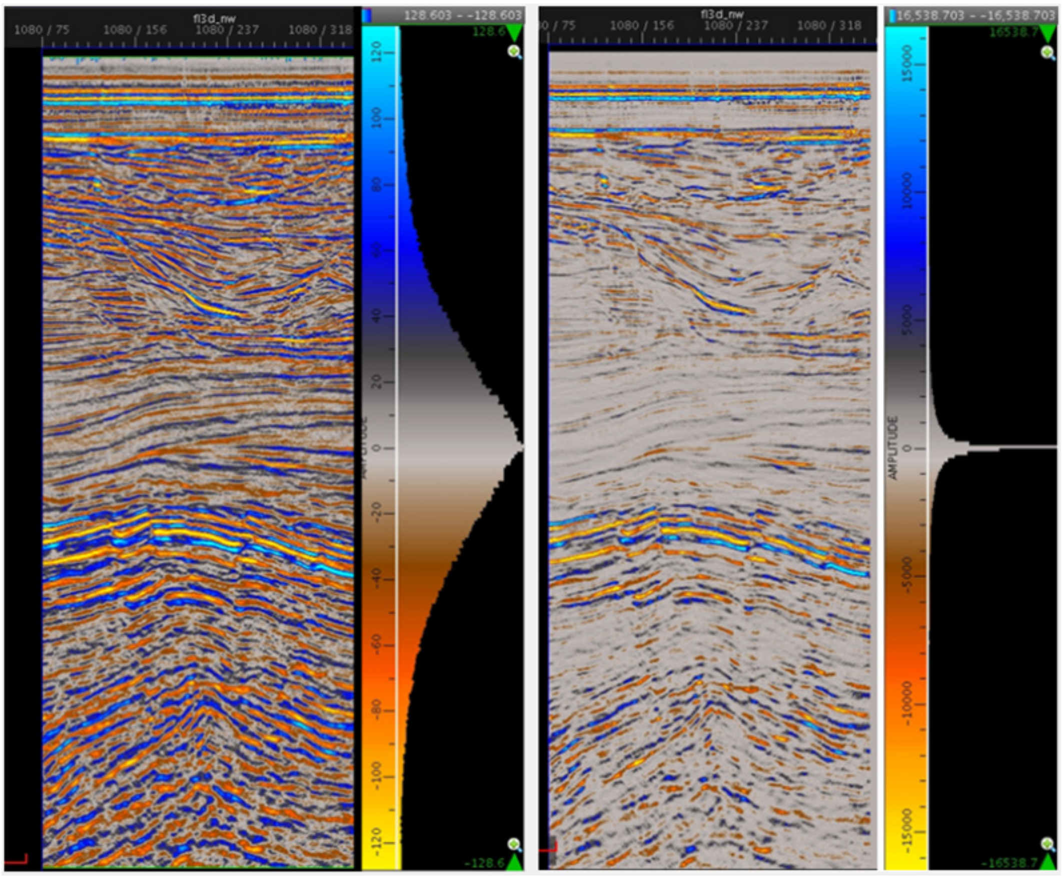
Apply this process to seismic data that has the wrong polarity.



Signed Square

The Signed Square utility squares each data sample, but retains its original sign. This moves the high amplitudes farther away from the low amplitudes.

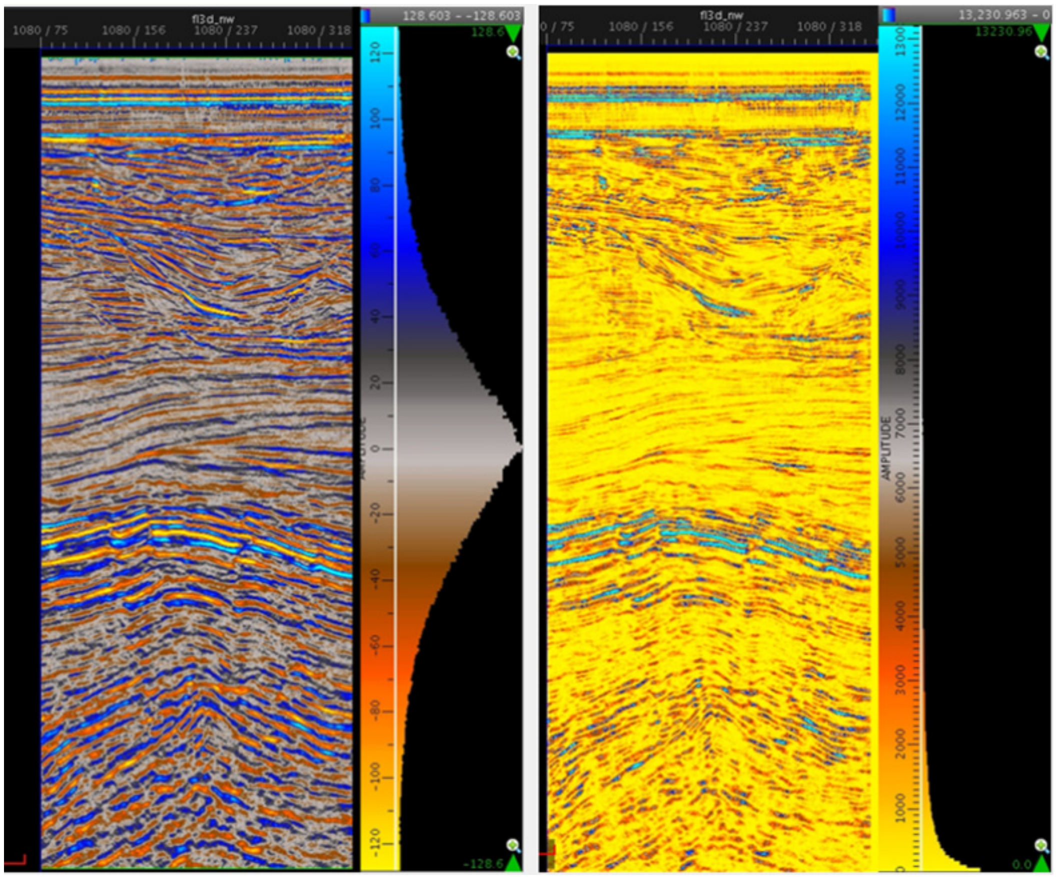
Apply this process to enhance amplitude contrasts while retaining the sign of the data.



Squared Value

The Squared Value utility squares each data sample; all values are positive afterwards. This moves high magnitude values farther away from the low magnitude values.

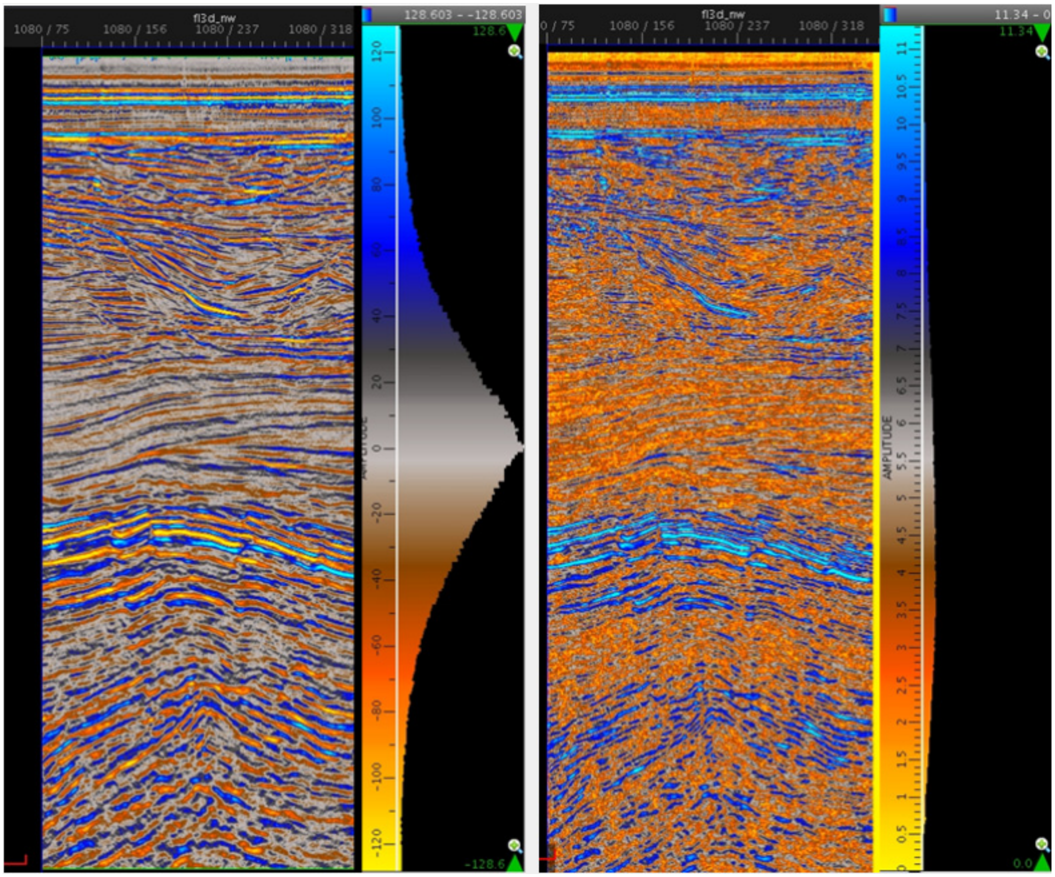
Apply this process to enhance magnitude contrasts.



Square Root

The Square Root utility takes the square root of each data sample; all values are positive afterwards. This moves the high amplitudes closer to the low amplitudes.

Apply this process to reduce amplitude contrasts.

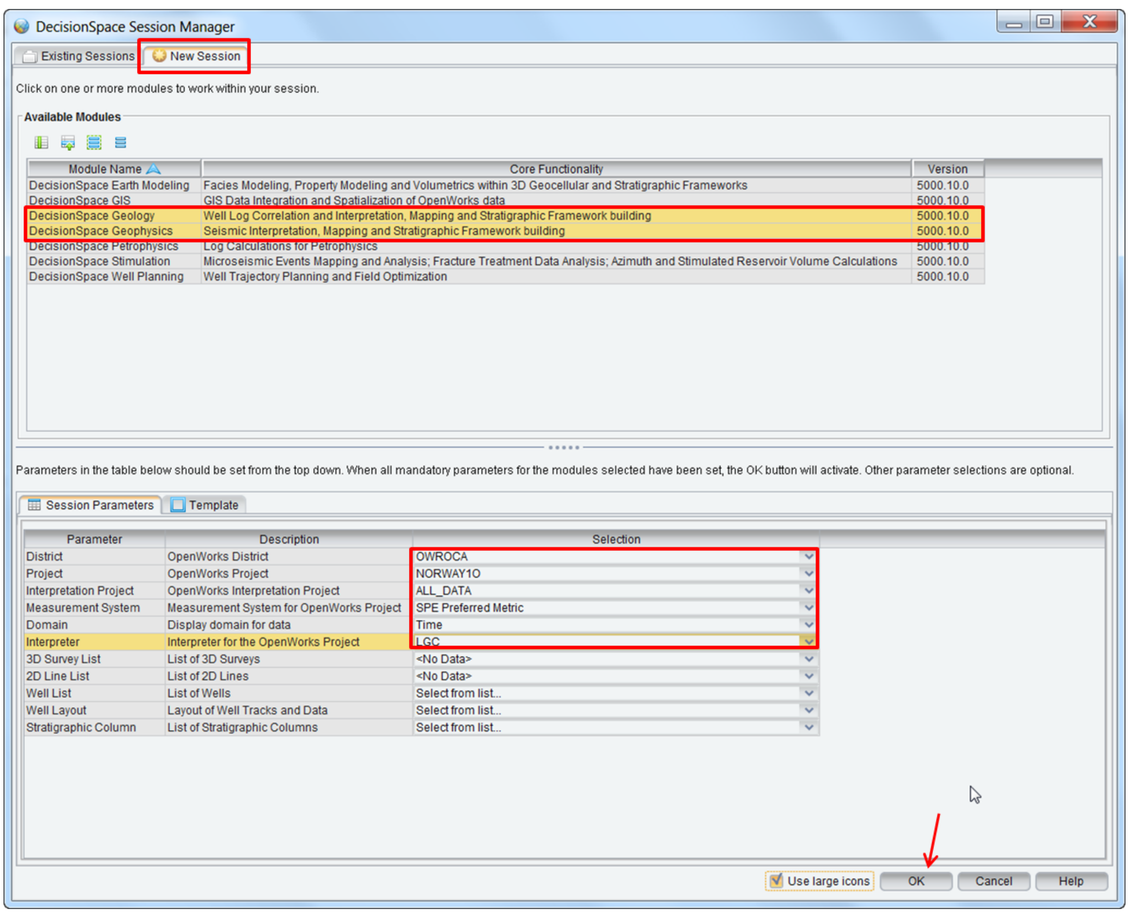


Exercise 5.1: Starting a New Session

1. Start a new session of DecisionSpace Geosciences. Select the **Geology** and **Geophysics** modules. Set the following parameters:

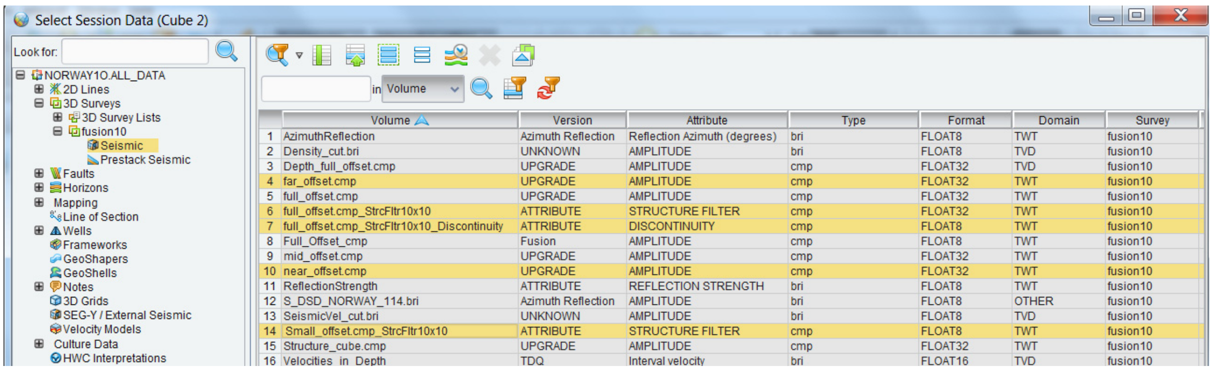
    - OpenWorks District: Ask your instructor
    - Project: **NORWAY10**
    - OpenWorks Interpretation Project: **ALL_DATA**
    - Measurement System: **SPE Preferred Metric**
    - Display domain of data: **Time**
    - Interpreter: **LGC**

    Use the default template **Triple Tile** and, if you wish, select the **Use large icons** check box.

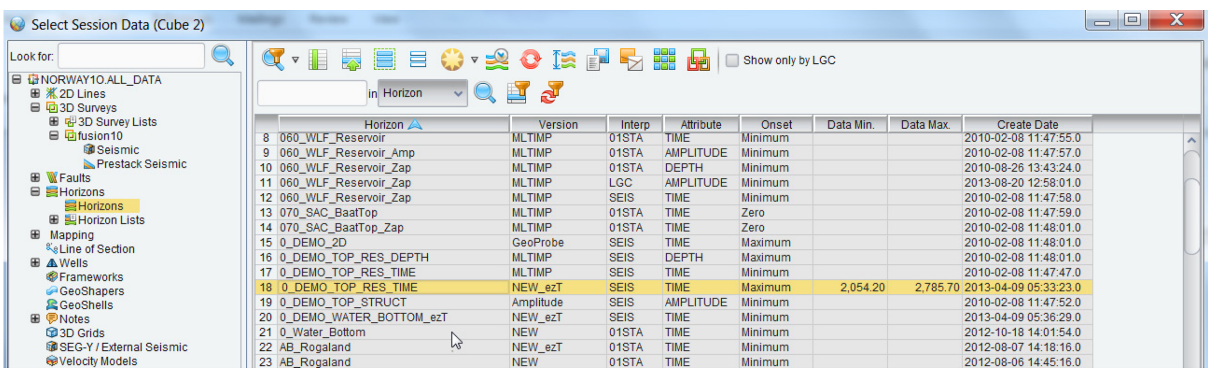


2. Maximize *Cube* view, then in the main toolbar go to **File > Select Session Data**.

3. Select **3D Surveys > fusion10 > Seismic** and **MB1+<Ctrl>** the following volumes: **far_offset.cmp**, **full_offset.cmp_StrcFltr10x10**, **full_offset.cmp_StrcFltr10x10_Discontinuity**, **near_offset.cmp**, and **Small_offset.cmp_StrcFltr10x10**. Click **Add data to session**.

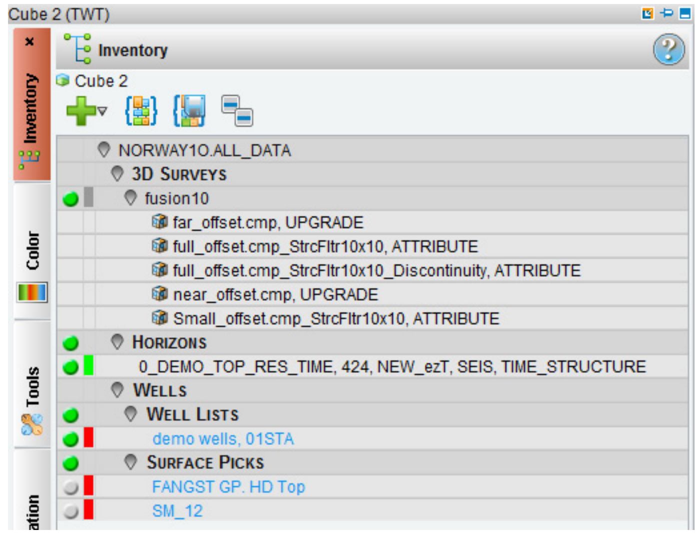


4. Select **Horizons > Horizon** and select **0_DEMO_TOP_RES_TIME, NEW_ezT**. If you wish, you can also select the horizon you previously interpreted (YOU_TOP_RES). Either one corresponds to the top of the reservoir. Click **Add data to session**.



5. Select **Wells > Well Lists > demo_wells** and click **Add data to session**. Select **Wells > Interpretation > Surface Picks > FANGST GP.HD Top** and **SM_12**. Click **Add data to session**, and then click **OK**.

Your Inventory task pane should look similar to the following picture:



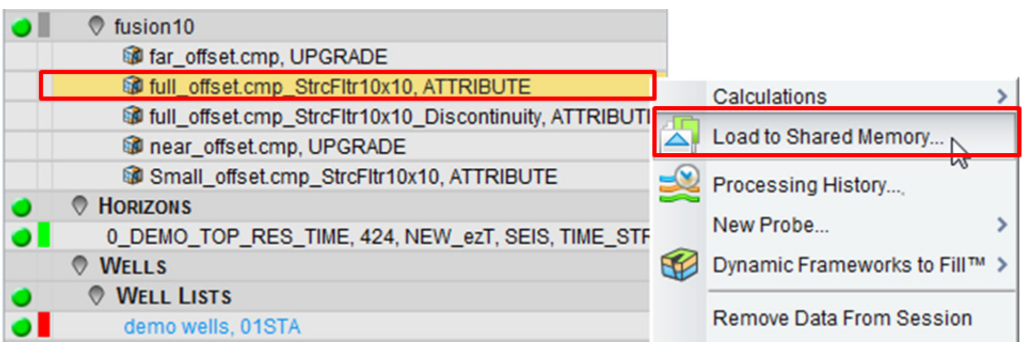
Exercise 5.2: Using Combo Mambo to Visualize Structure Filter and Discontinuity Volumes

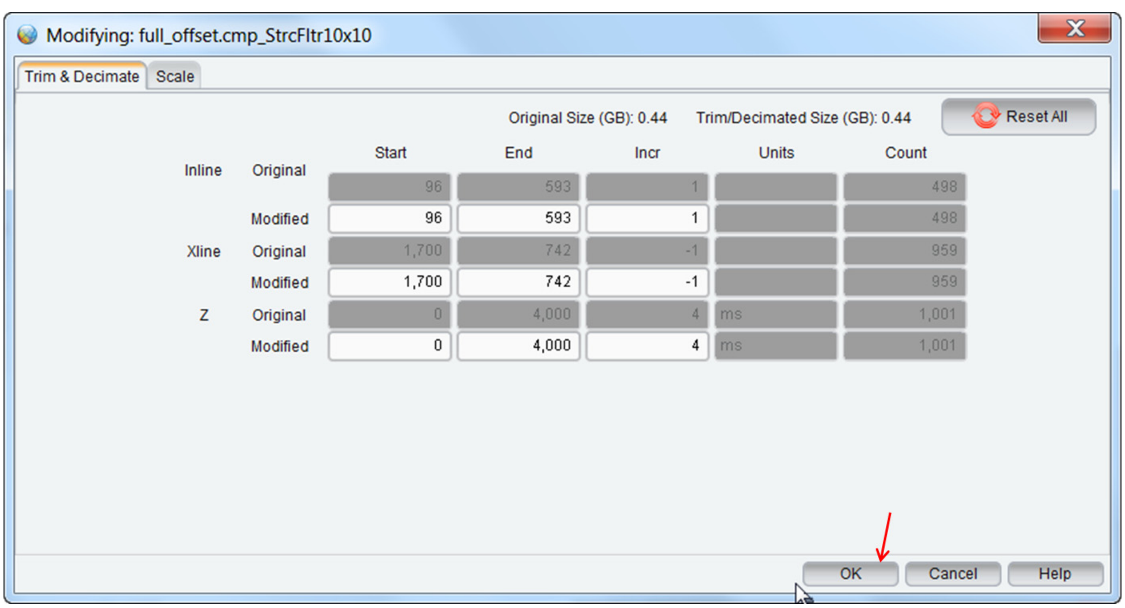
During previous exercises, you learned that Combo Mambo is a display property that uses one volume to create the effect of relief on another volume. You used this blended volume to aid in fault interpretation. Now, you will explore Combo Mambo further.

For blending to work, volumes must be loaded into shared memory.

1. From your *Inventory* task pane, **MB3** on the volumes **full_offset.cmp_StrcFltr10x10** and select **Load to Shared Memory...**.

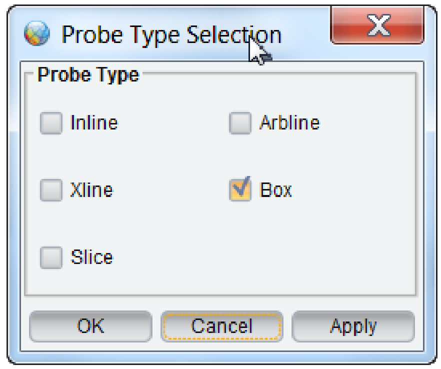
2. Accept the defaults by clicking **OK** in the *Modifying: full_offset.cmp_StrcFltr10x10* dialog.





3. Repeat this process to load the volumes **full_offset.cmp_StrcFltr10x10_Discontinuity** and **small_offset.cmp_StrcFltr10x10** into shared memory.

4. From the *Inventory* task pane, drag-and-drop the **full_offset.cmp_StrcFltr10x10** shared memory volume into *Cube* view. In the *Probe Type Selection* dialog, select to only display a **Box** and click **OK**.



5. In *Cube* view, in the *Inventory* task pane, toggle on horizon **0_DEMO_TOP_RES_TIME**. You will use the horizon as a reference to easily locate the top of the reservoir.

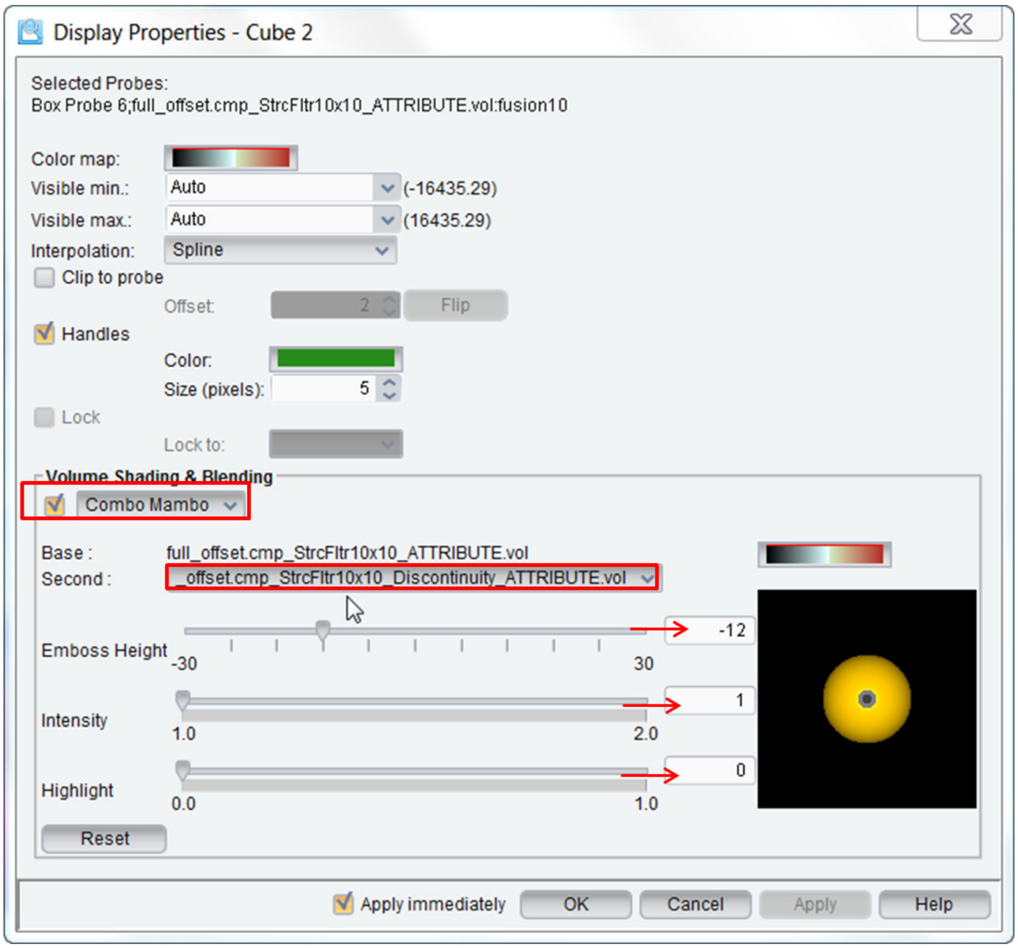
6. **MB3** on the **box probe** and select **Display Properties**.

7. In the *Volume Shading & Blending* section, select the check box next to the drop-down menu and select **Combo Mambo**.

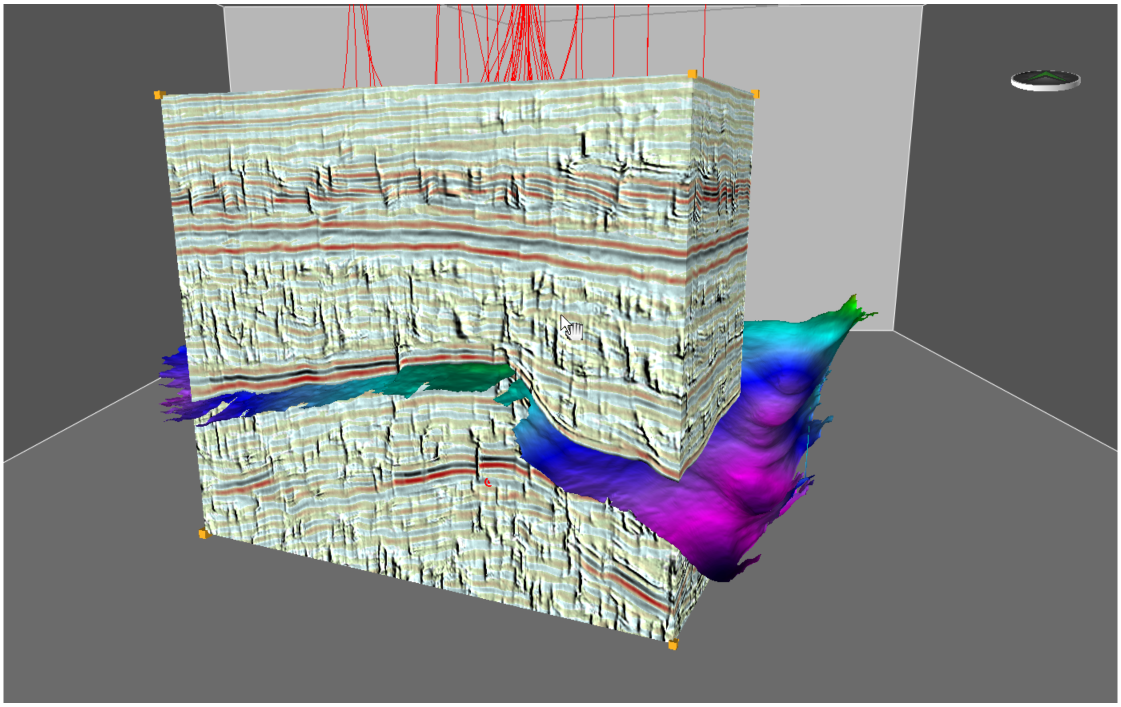
8. For the *Second* volume, use the drop-down menu to select the **full_offset.cmp_StrcFltr10x10_Discontinuity** volume.

   As you saw in the previous chapter, the discontinuity volume appears overlying the amplitude volume, giving the impression of high relief in your seismic.

9. Experiment by interactively moving the scroll bar corresponding to *Emboss Height*, *Intensity*, and *Highlight*. Notice the changes in your volume. After seeing the changes, manually type the values of "**-12**" for Emboss Height, "**1**" for Intensity and "**0**" for Highlight. Those values make a good view of the combo mambo shading. Click **OK** to close the *Display Properties* dialog.



10. Use **MB1+<Shift>** to animate every face in your volume to explore the Combo Mambo shading around your reservoir area.



Exercise 5.3: Generating and Visualizing Attribute Volumes

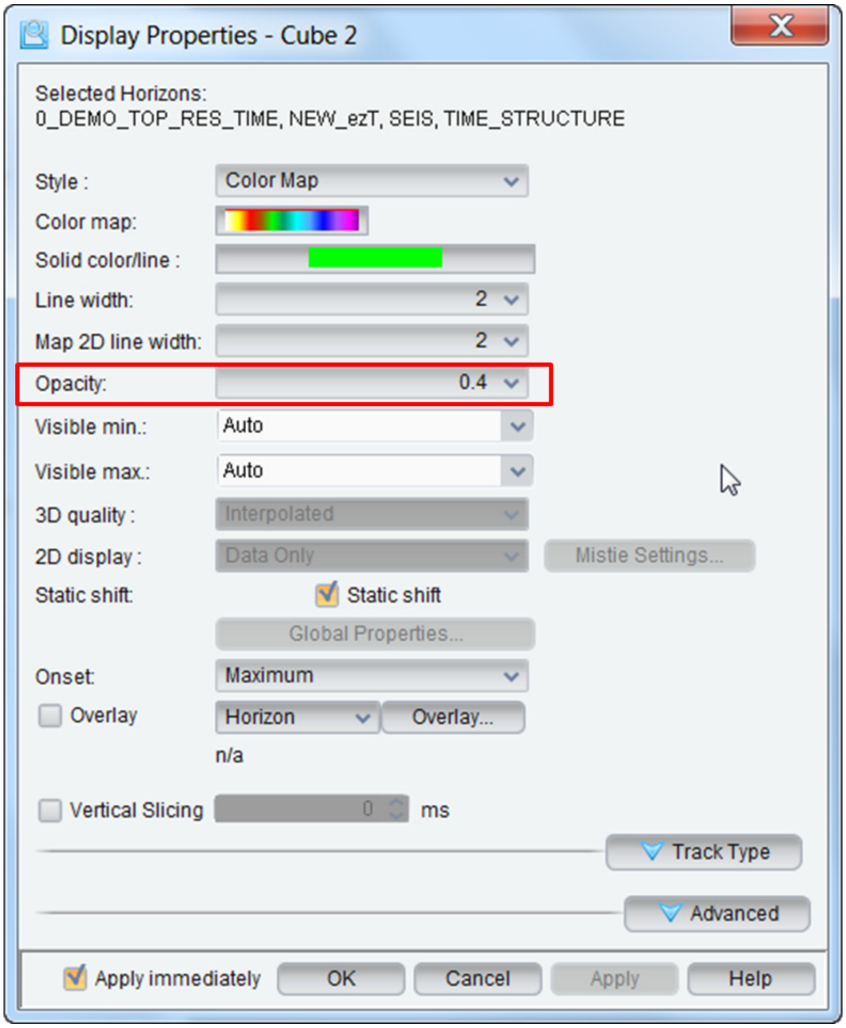
As you could tell in the previous exercise, by shifting the faces of the box probe, you can modify it so that its extension is reduced to only the reservoir area. A subset of the volume full_offset.cmp_StrcFltr10x10 was created for this exercise, named small_offset.cmp_StrcFltr10x10, that is defined by the extents of the reservoir. This volume is significantly smaller therefore reducing the time it takes to calculate seismic attributes during the class.

1. In your *Inventory* task pane, under *Seismic Probes*, **MB3** on **Box Probe n; Full_offset.cmp_StrcFltr10x10** and select **Remove Data from Session**.

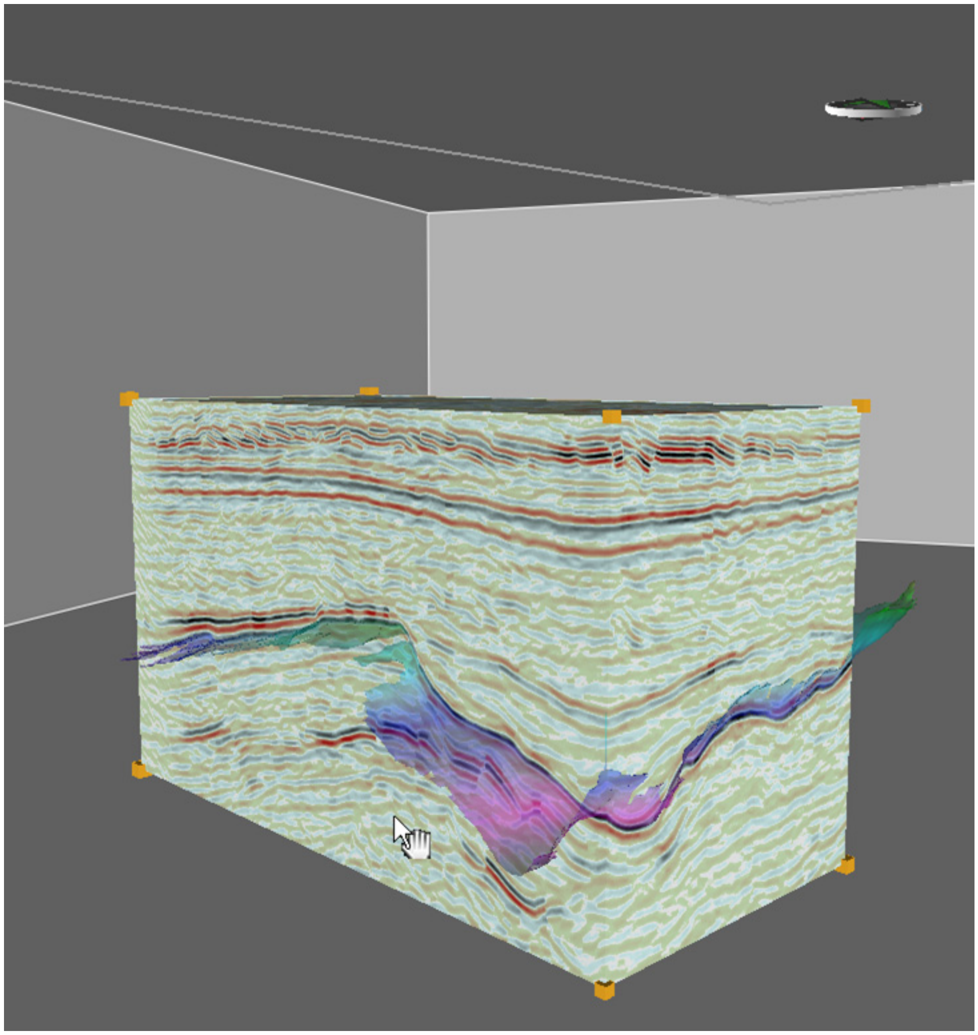
2. Drag-and-drop the shared memory volume **small_offset.cmp_StrcFltr10x10** from the *Inventory* into *Cube* view, and select **Box** from the *Probe Type Selection* dialog. With the cursor in the new box probe, click the hot key <**X**> to fully extend the volume.

   Notice one more time that this volume is a subset of the full one you were working with in previous exercises and that it perfectly covers the main reservoir area. The edges of the horizon are not covered by this probe due to the lower quality seismic in those areas which can affect the results of the attributes.

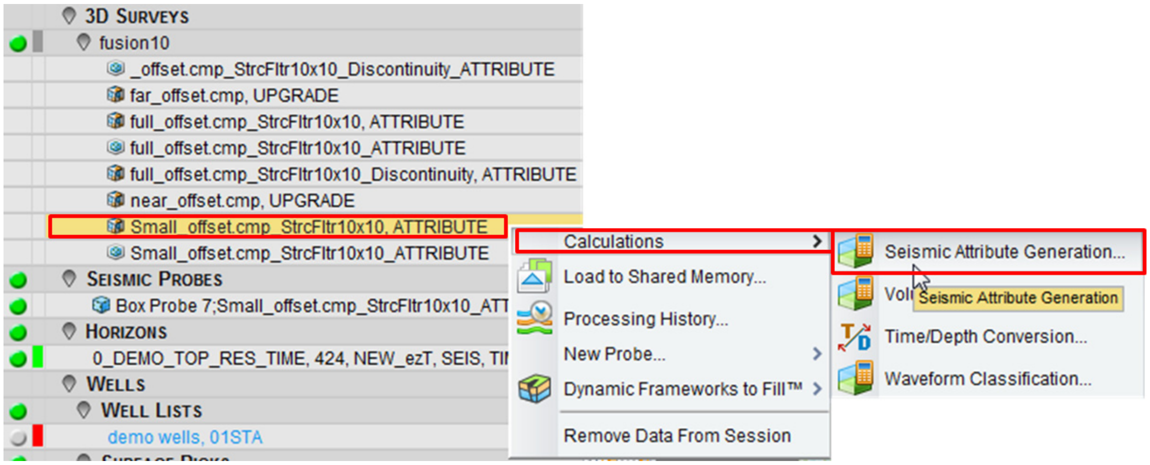
3. From the *Inventory* task pane, turn off **demo wells**. **MB3** on the **horizon 0_DEMO_TOP_RES_TIME** and select **Display Properties**. Using the *Opacity* drop-down menu, change the opacity to **0.4**. Click **OK** to close the *Display Properties* dialog.



Your *Cube* view should look like the picture below:



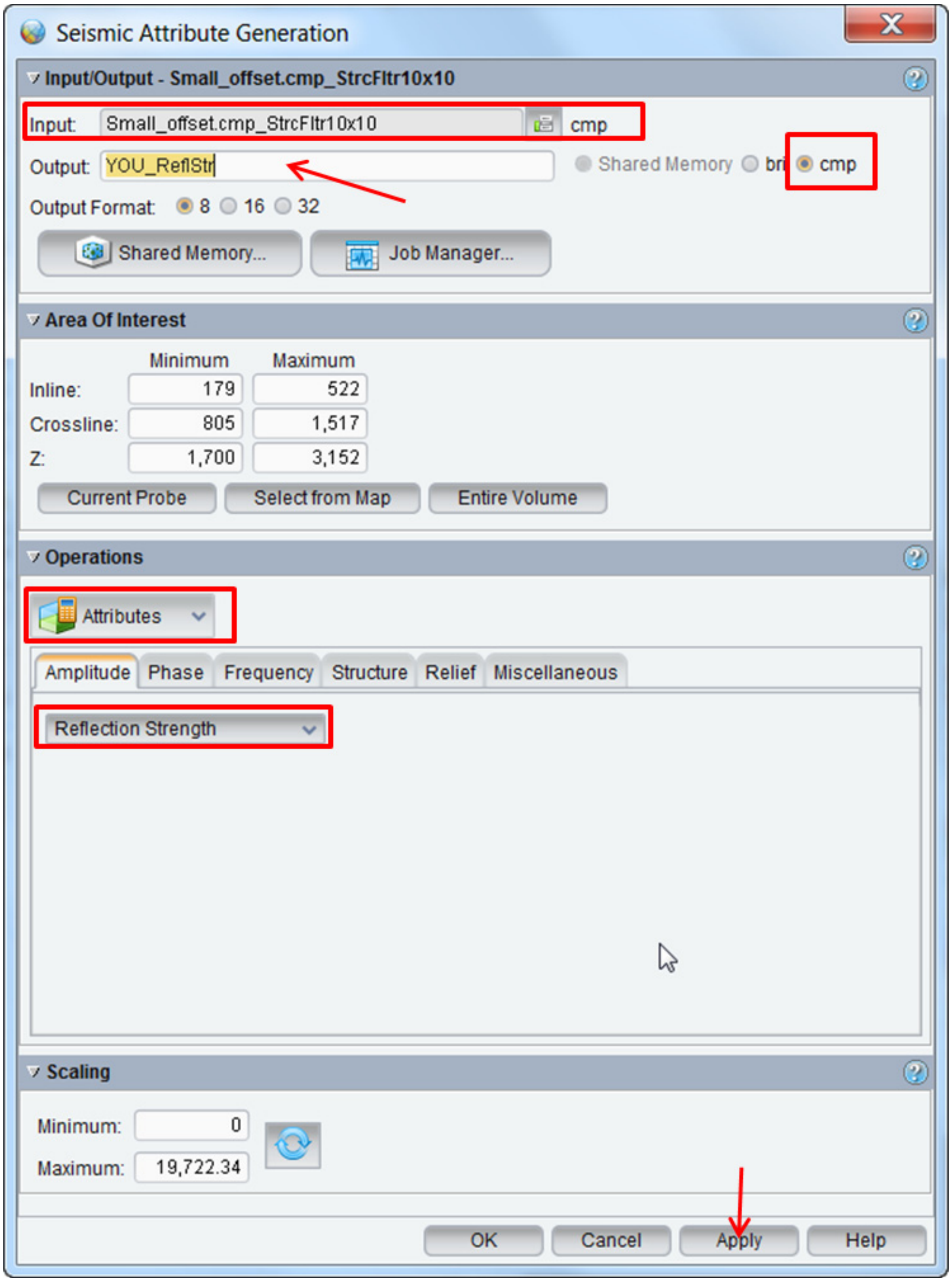
4. In the *Inventory* task pane, **MB3** on the cmp volume (not the shared memory) **Small_offset.cmp_StrcFltr10x10** and select **Calculations > Seismic Attribute Generation**.



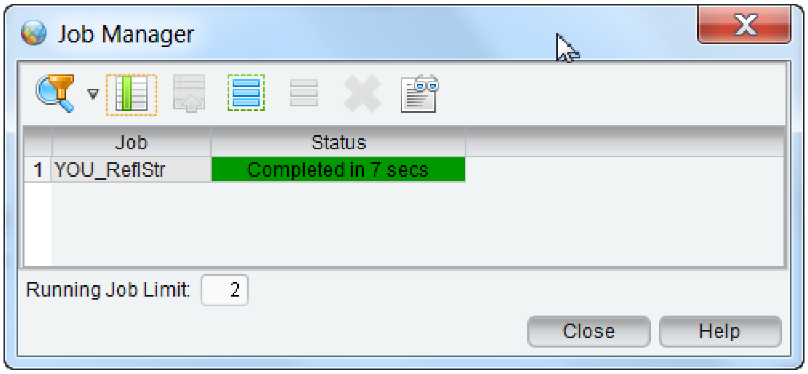
5. In the *Seismic Attributes Generation* dialog, make sure the input volume is set to **Small_offset.cmp_StrcFltr10x10 cmp**.

6. In the *Operations* panel, select **Attributes** from the drop-down menu. Select the *Amplitude* tab and then select **Reflection Strength** from the drop-down menu.

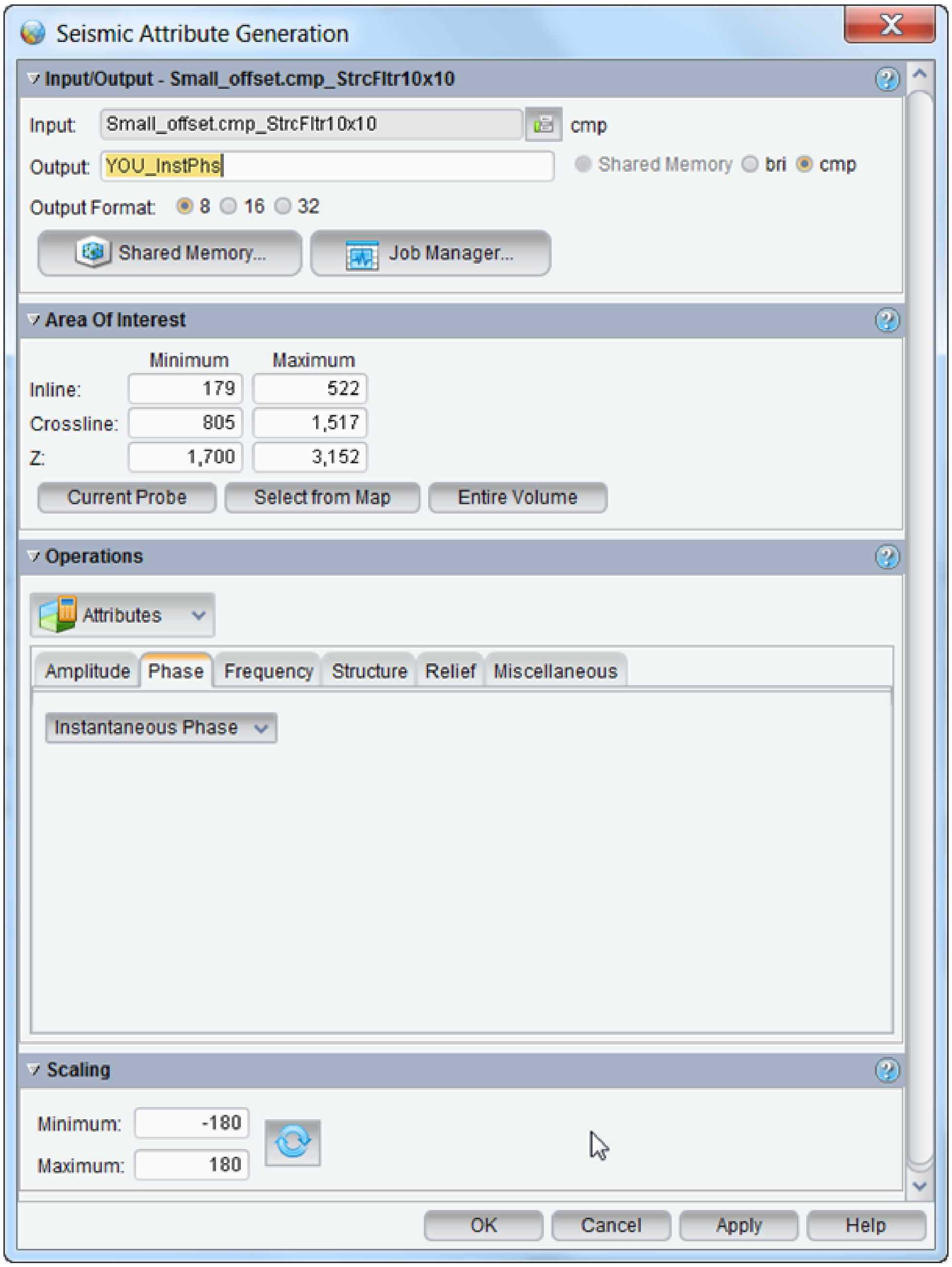
7. At the top of the dialog, select **cmp** as the output volume and **8** bit as the output format. Change the output name to “**YOU_ReflStr**.” Click **Apply**. Use the picture below as reference.



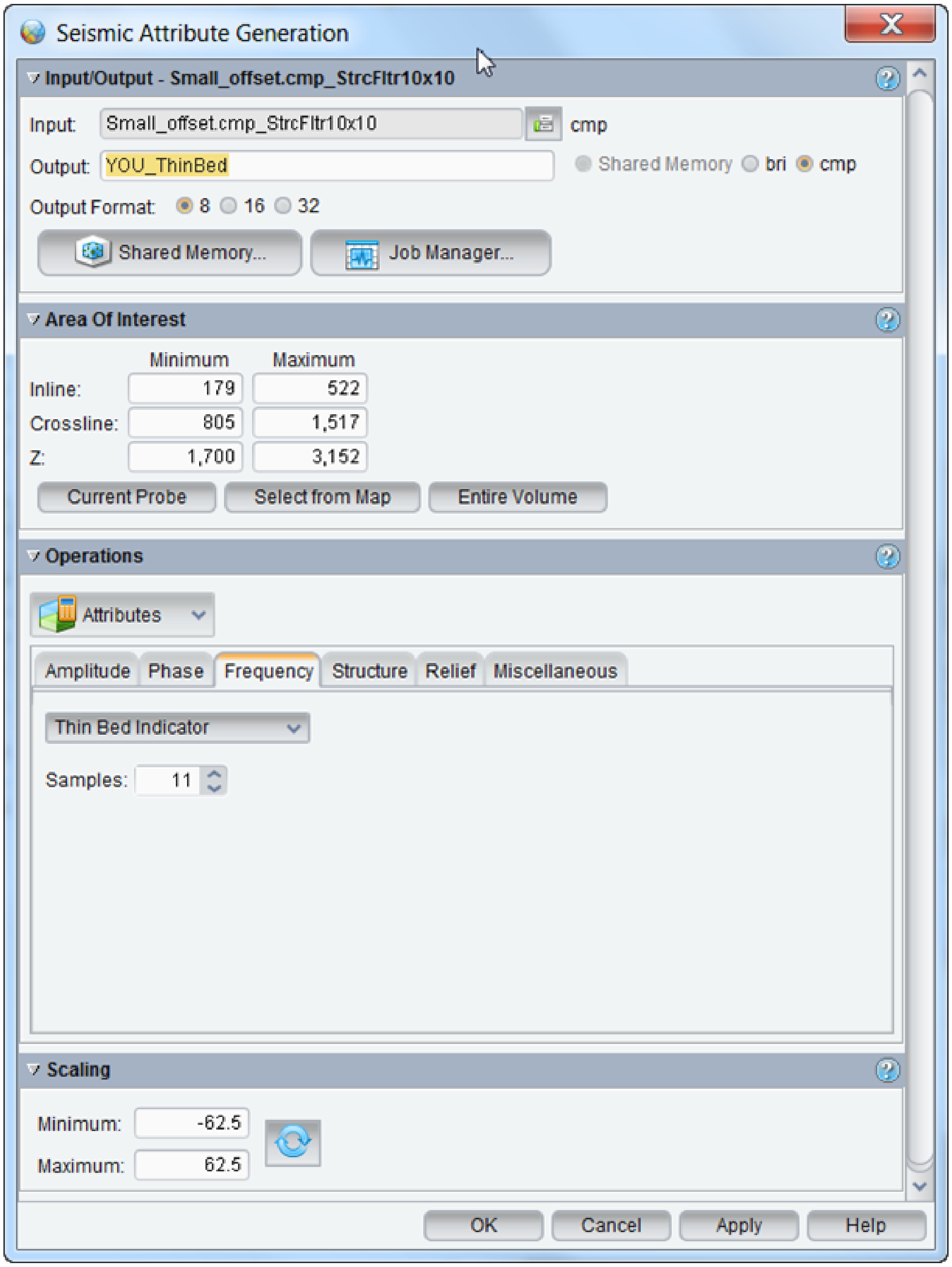
The *Job Manager* dialog opens showing the status.



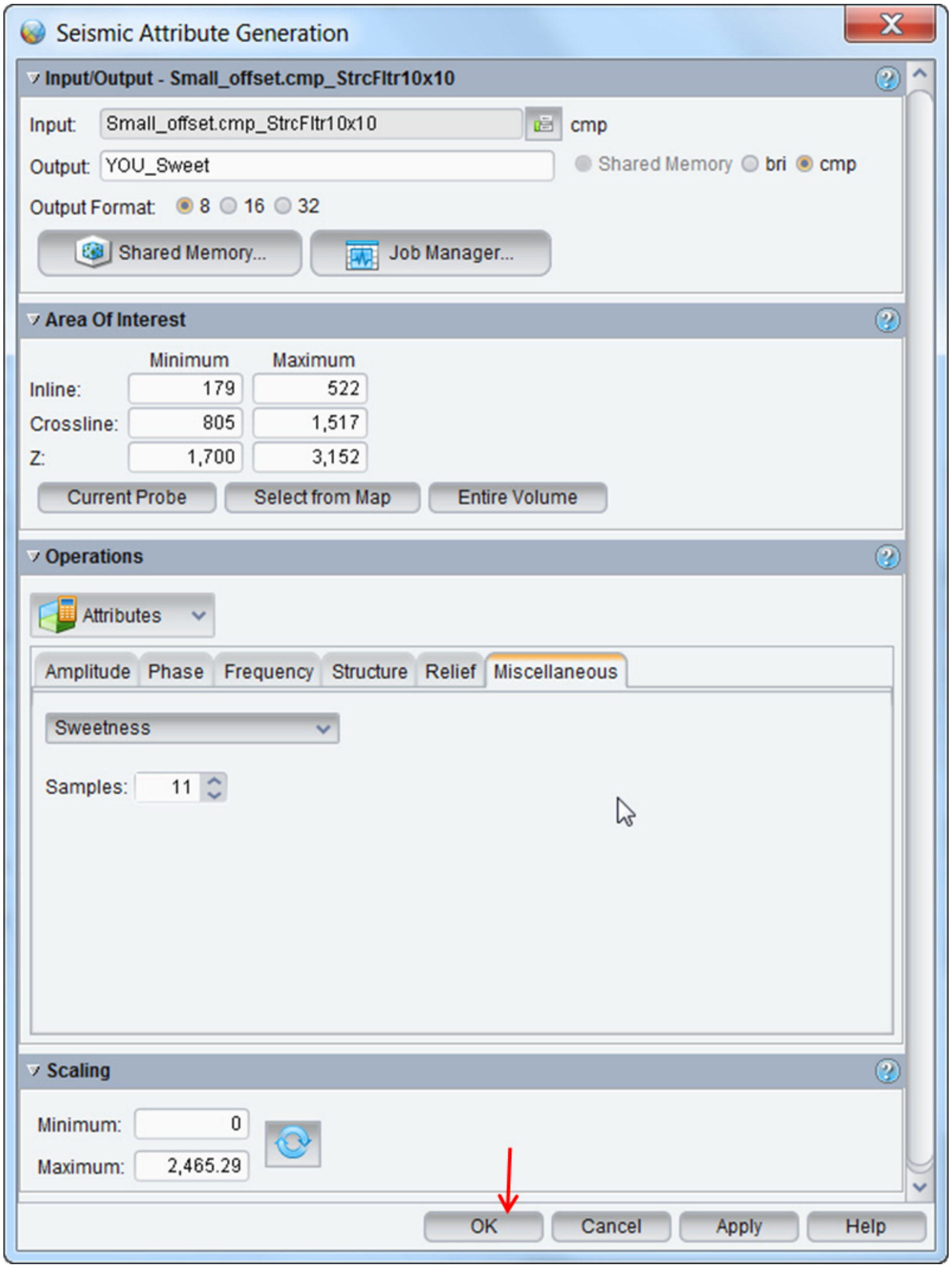
8. In the *Seismic Attribute Generation* dialog, select the *Phase* tab and select **Instantaneous Phase** from the drop-down menu. Change the output name to “**YOU_InstPhs**,” check that the other parameters haven't changed and click **Apply**.



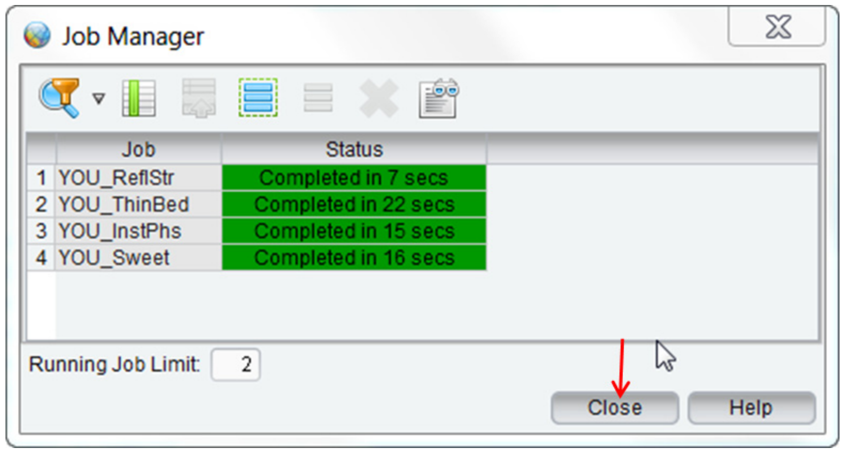
9. Once the *Job Status* dialog shows the process is finished, select the *Frequency* tab, select **Thin Bed Indicator**, change the output name to “**YOU_ThinBed**,” and click **Apply**.



10. Select the *Miscellaneous* tab and select **Sweetness** from the drop-down menu. Change the name to "**YOU_Sweet**." This time click **OK** to create the attribute and close the *Seismic Attribute Generation* dialog.



11. The *Job Manager* dialog should look similar the picture below, reflecting the four attributes you just calculated. Close the *Job Manager* dialog.

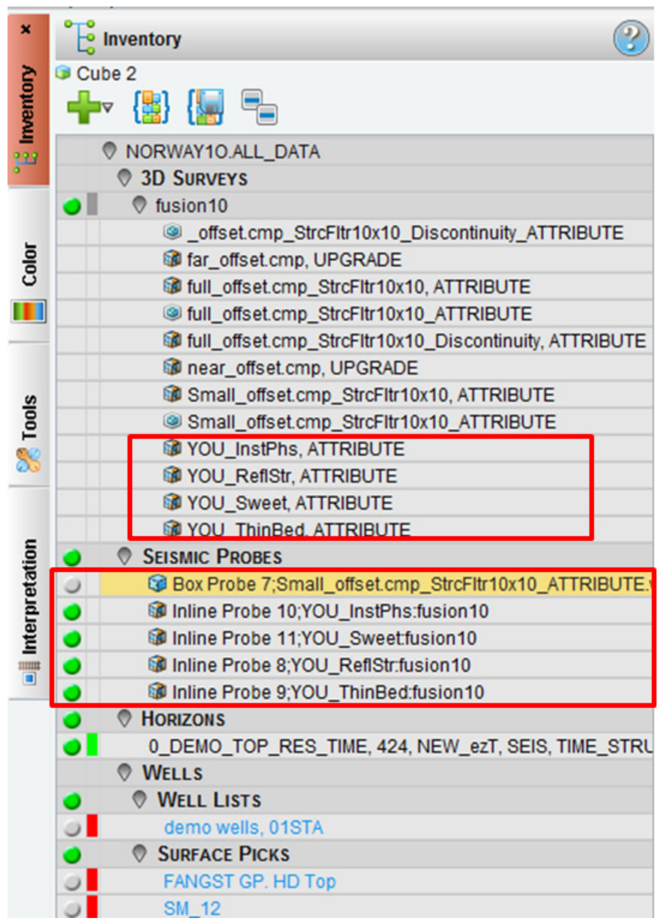


12. Save your session and name it “**YOU_CHAPTER5**.” (Hint: **File > Save Session As**.)

Your *Inventory* task pane should be reflecting the newly created volumes under **3D Surveys > fusion10**. Notice that by default, if you had the *Cube* view active at the time the volumes were generated, an inline probe of each one is listed under *Seismic Probes*.

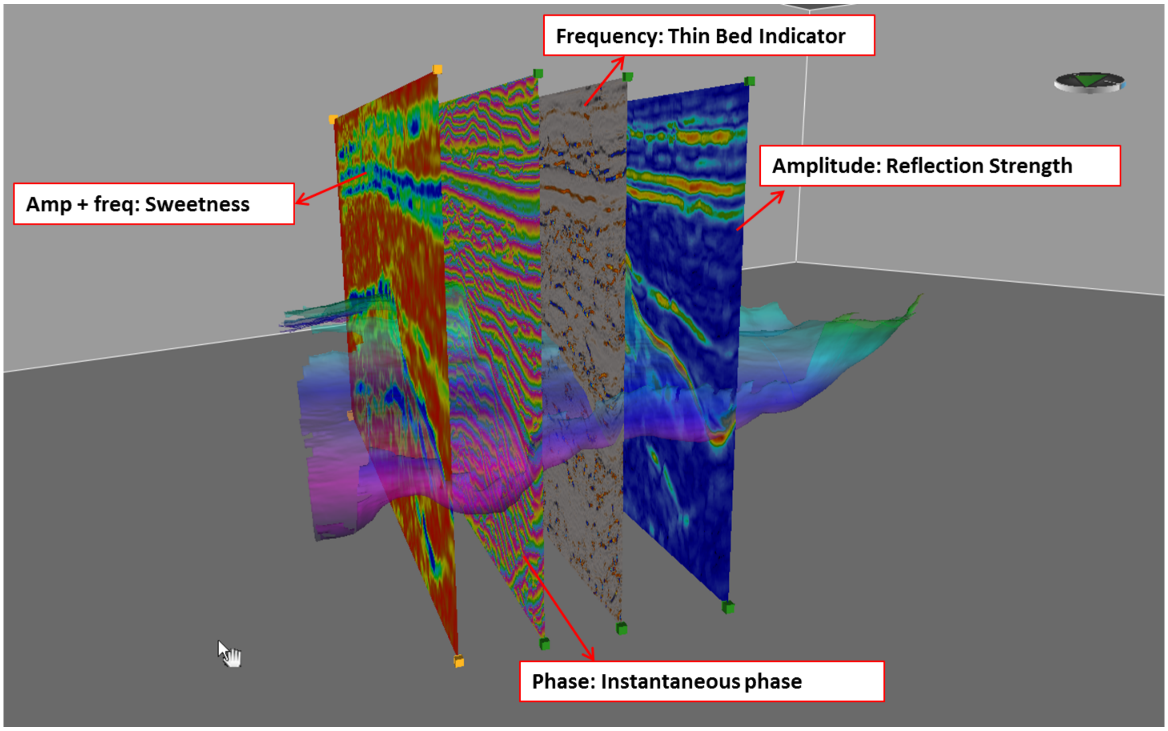
Note
If for whatever reason the inline probes are not there, you can create those by dragging the new volumes into *Cube* view and selecting **Inline**.

13. In the *Inventory* task pane, toggle off the **Box Probe** to better visualize the inline probes of the new volumes. Refer to the picture below.



14. In *Cube* view, the inline probes should be overlapping each other. Use **MB1 +<Shift>** to move every inline to a different position. Rotate the cube as desired to take a first look at your attributes.

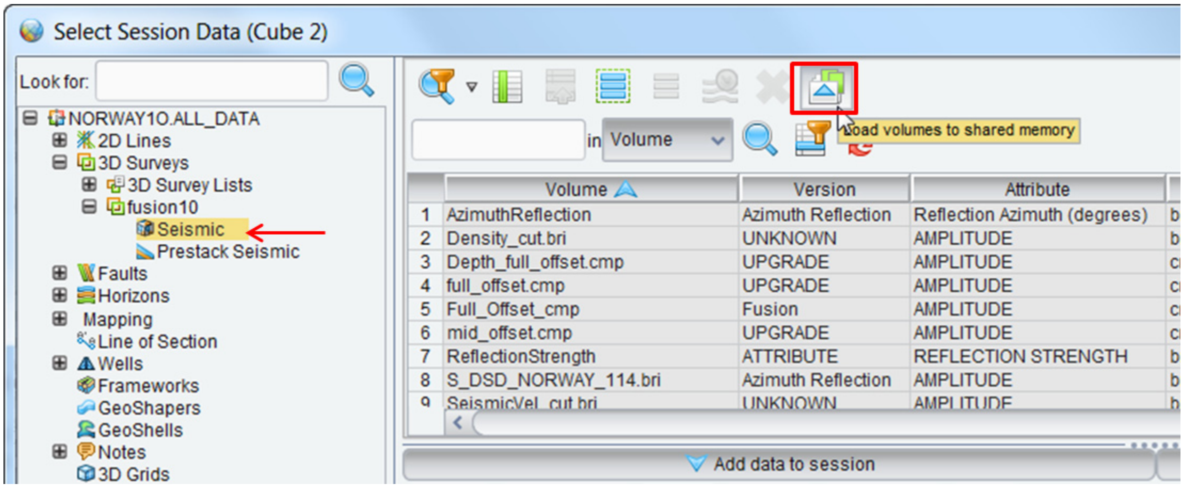
In the following steps, you will remove the automatically generated inline probes and you will render a box probe of each seismic attributes volume to better visualize the attributes. At this point, your *Cube* view should look similar to the picture below.



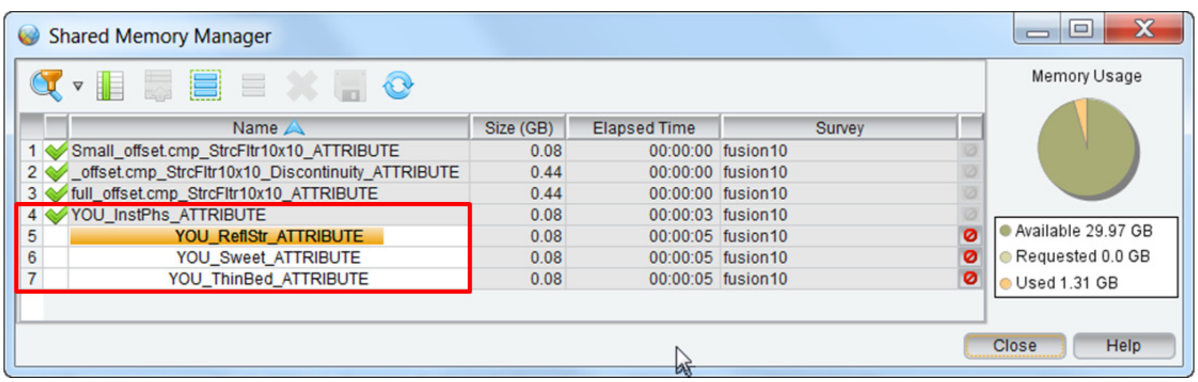
As described in the theory section at the beginning of this chapter, the attribute related to amplitude is Reflection Strength, which is used for highlighting bright spots. Notice how most of the bright spots are located near or at the top of the reservoir (use the horizon 0_DEMO_TOP_RES_TIME as reference). The attribute related to frequency is the Thin Bed Indicator, which is highlighting potential areas of thin shale layers. This reservoir has massive sandstone packages and identifying shale layers is useful to identify lithology intercalations. The phase attribute, Instantaneous Phase, is removing the effect of amplitude to let you visualize the continuity of all the layers at the reservoir level. Finally, the Sweetness attribute is mixing amplitudes and frequencies to identify sweet spots.

In the next steps, you will visualize every attribute individually using box probes and animating each face. First, you have to create shared memory volumes of all of the seismic attribute volumes.

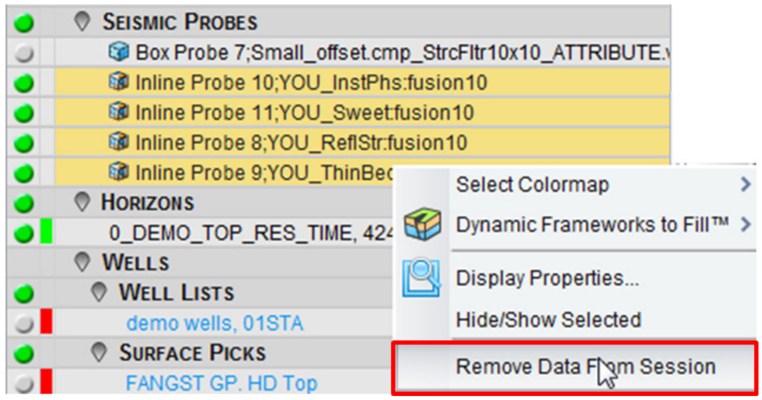
15. To create all the shared memory volumes simultaneously, go to **File > Select Session Data**. Navigate to **3D Surveys > fusion10 > seismic**, then in the main toolbar click the **Load volumes to shared memory** ( ) icon.



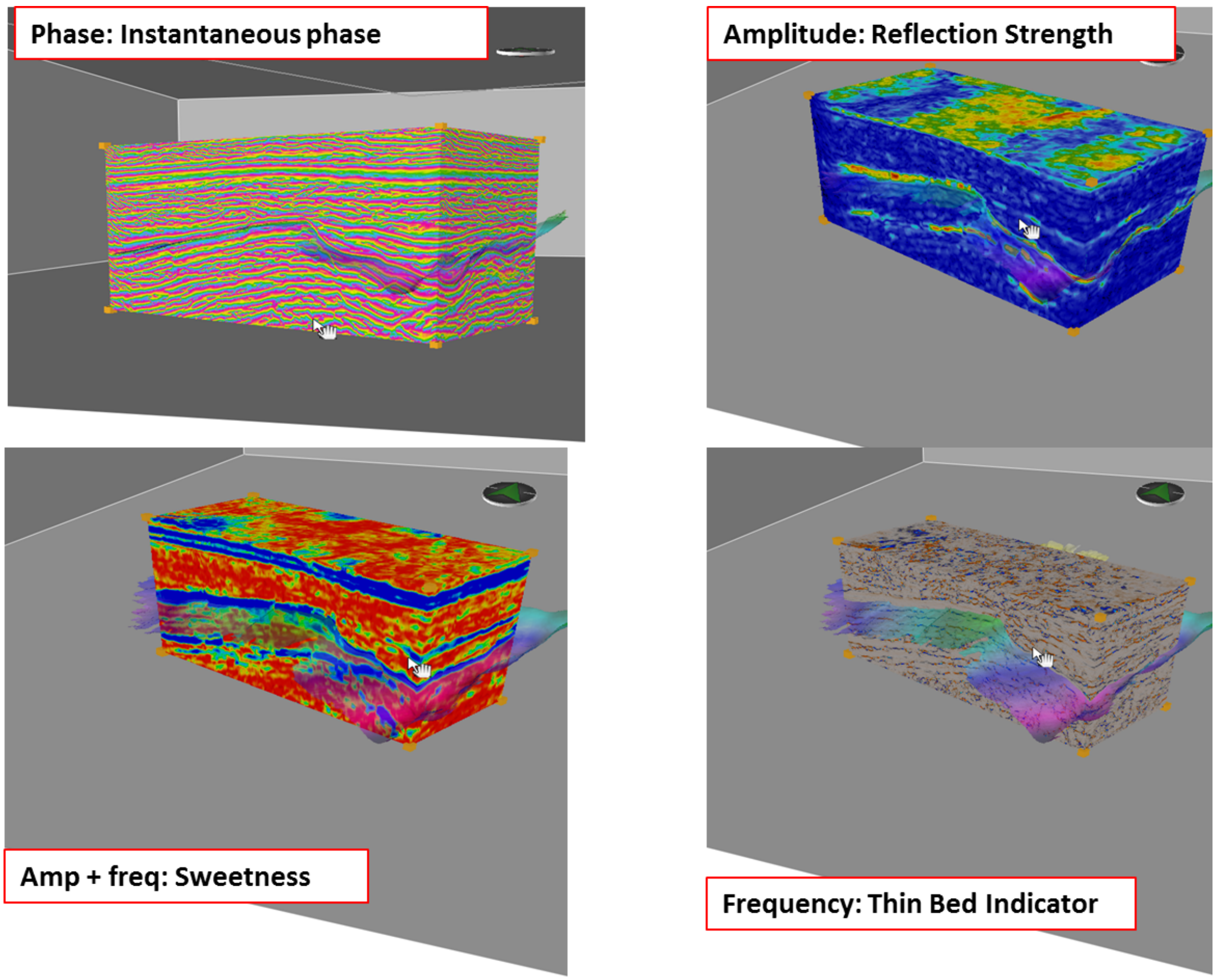
16. The *Shared Memory Manager* appears uploading your new four volumes. When finished, close both the *Shared Memory Manager* and *Select Session Data* dialogs.



17. Before visualizing the box probes, remove the inline probes from the session. In your *Inventory* task pane, **MB1+<Ctrl>** all the inline probes underneath the *Seismic Probes* section, **MB3** and then select **Remove Data from Session**. Also, make sure the box probe **Small_offset.cmp_StrcFltr10x10** is toggled off.



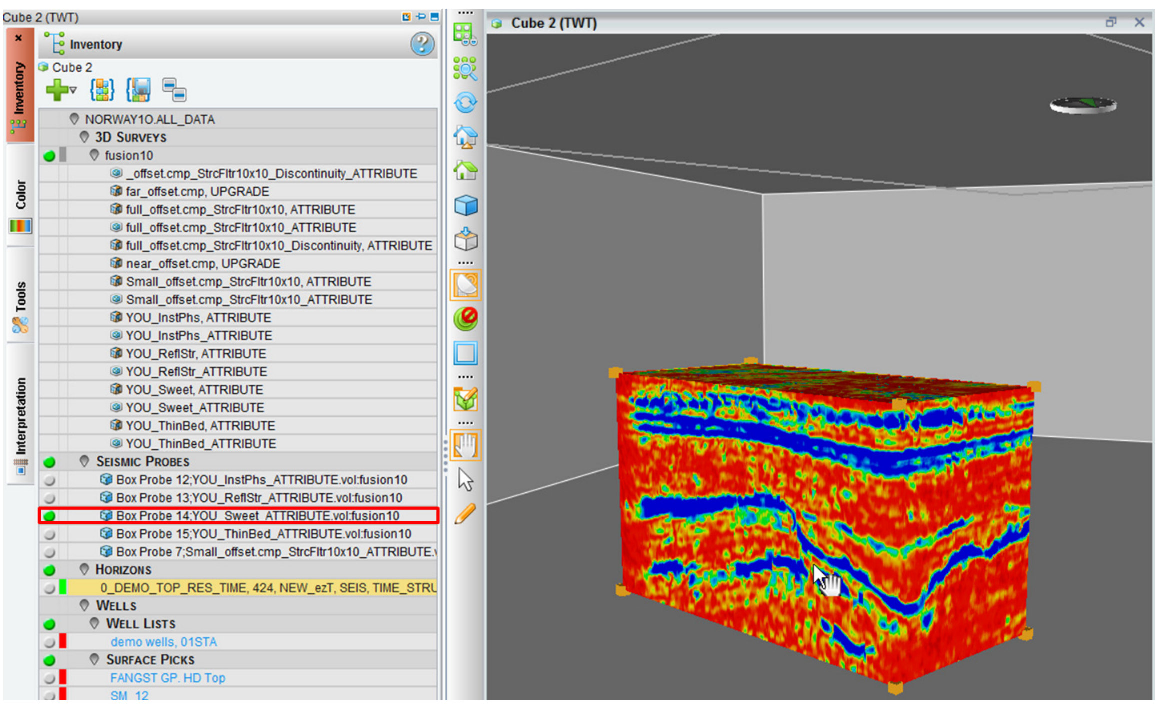
18. Drag-and-drop the shared memory volumes of the four seismic attributes you just created, one at a time, into the *Cube* view. Explore all of them individually by dragging its volume faces with **MB1+<Shift>**; remember that the hot key to full extend is <**X**>. When you finish exploring the first box probe, toggle it off in the *Inventory* task pane and add the next one. Do not remove any box probes from the session because they will be used in later exercises. The picture below shows a box probe of each attribute.



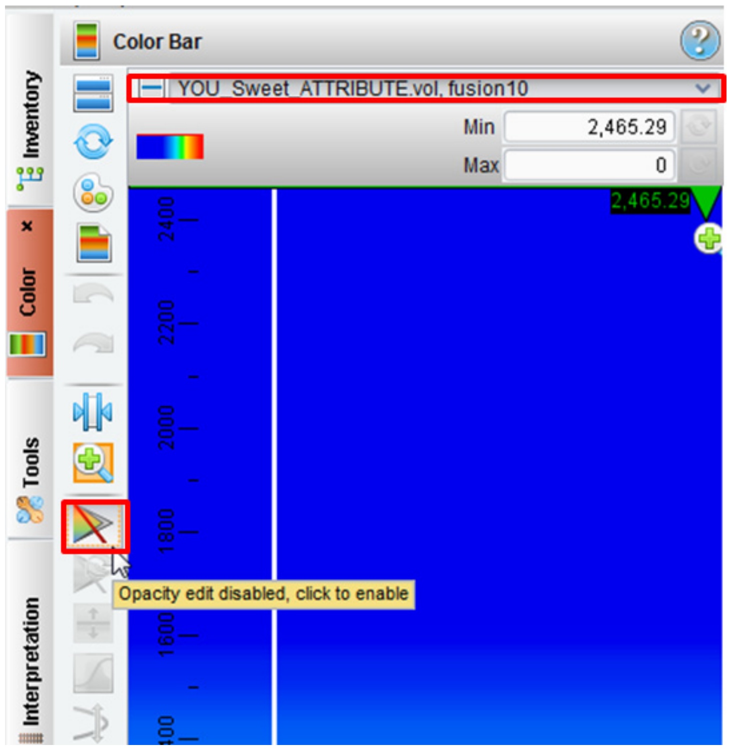
Exercise 5.4: Modifying Volume Opacity

Frequently, it is extremely helpful to modify the opacity when visualizing one attribute at a time. In the following exercise, you will modify the opacity of the Sweetness volume in order to highlight the highest values of the attribute which represent potential areas to drill.

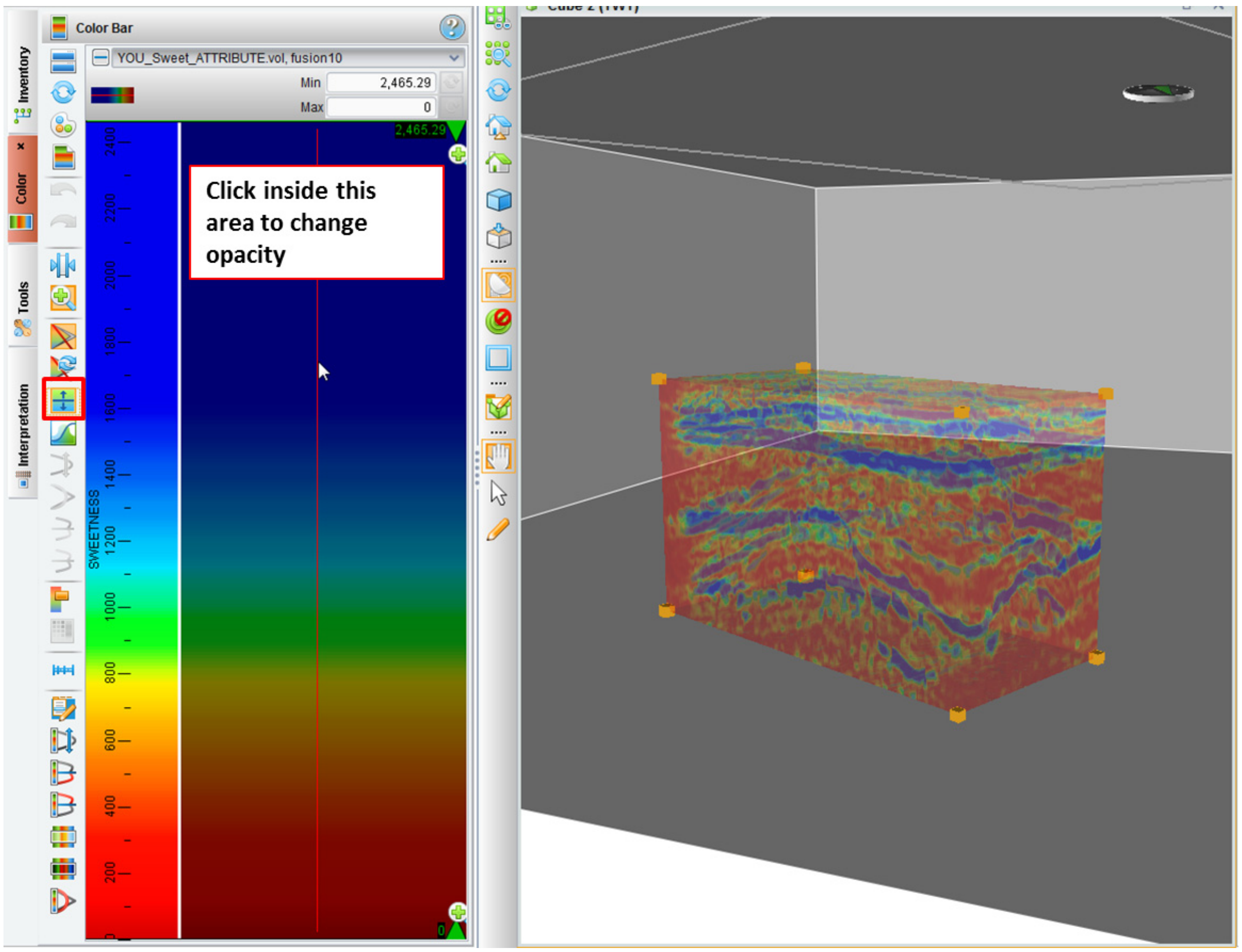
1. From the *Inventory* task pane, toggle off the horizon **0_DEMO_TOP_RES_TIME** and any other box probes you have on. Toggle on only the box probe **Box Probe N; YOU_Sweet_ATTRIBUTE**. Maximize the volume to its full extension.



2. In the *Color* task pane, select the volume **YOU_Sweet_ATTRIBUTE** from the drop-down menu. In the vertical toolbar, click the **Opacity edit** () icon to enable it.



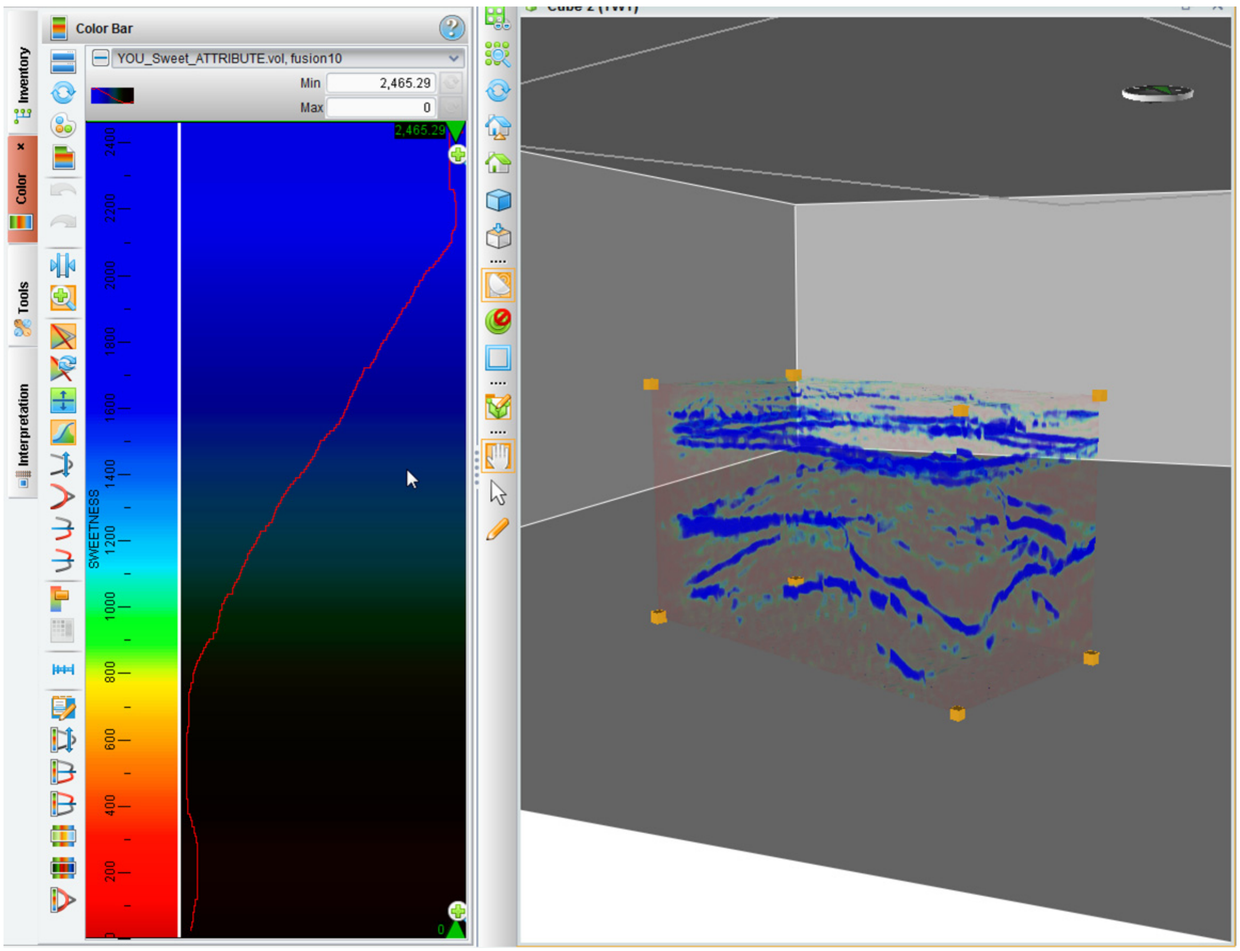
3. Click the **Uniform Opacity Edit Mode** ( ) icon to experiment changing the opacity uniformly in the entire volume. **MB1** inside the color section area at the right and drag the red line to define the opacity. This option is helpful if you are visualizing several volumes simultaneously or just want to see faults and horizons inside the volume. See the picture below.



4. Click the **Clear Opacity** ( ) icon to return the volume to its default opacity.

5. Now you will define what Sweetness values to display by changing the opacity to display specific amplitudes. Click the **Freehand Opacity Edit Mode** ( ) icon, and then in the color section area at the right of the *Color* task pane, hold **MB1** while dragging your mouse over the values of interest. Draw the opacity line using the picture below as a reference

In this example, you are going to visualize the highest sweetness values, which correspond to the blue color. Notice that your *Cube* view changes, displaying only the highest sweetness values.



6. After editing the opacity, animate every face of the box probe with **MB1+<Shift>**.

7. When you finish exploring the faces of your box probe, clear the opacity again ( ) to return to the original opacity mode. Alternatively, you can use the **Reset All** ( ) icon.

8. Save your session. **File > Save Session**.

Exercise 5.5: Color Blending

Up to this point, you have explored each of the volume attributes individually. In the following exercise, you will combine three seismic attributes simultaneously in one box probe. Additional to the Combo Mambo, DecisionSpace Geosciences offers two other ways to combine up to three volumes: Blending and RGB Blending.

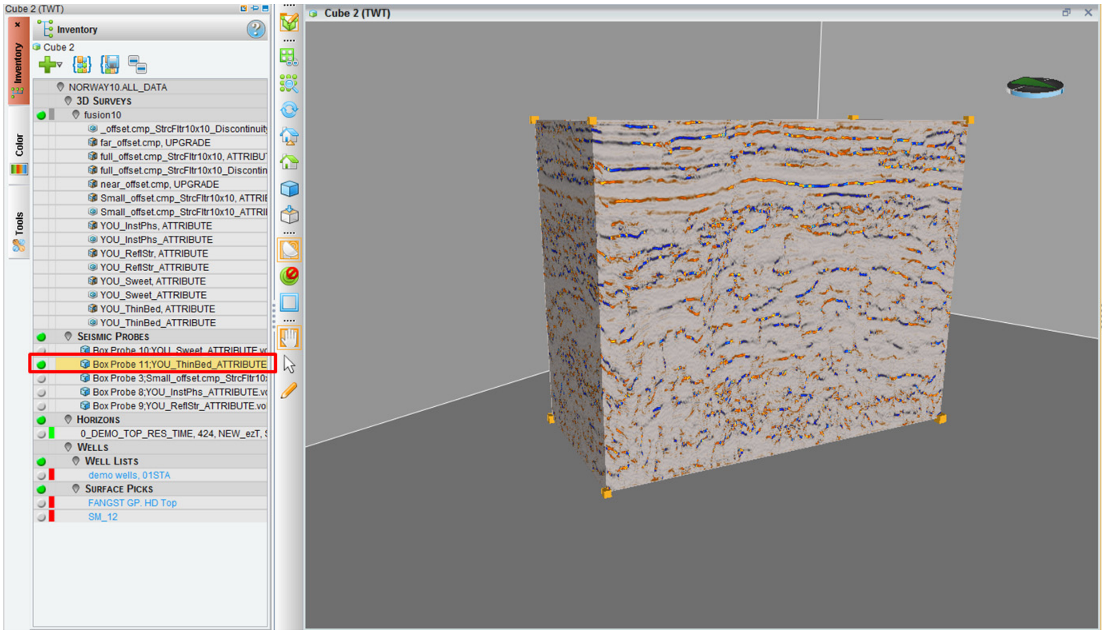
Note

The options for Combo Mambo, Blending and RGB Blending, are located in the *Display Properties* dialog of only the shared memory volumes.

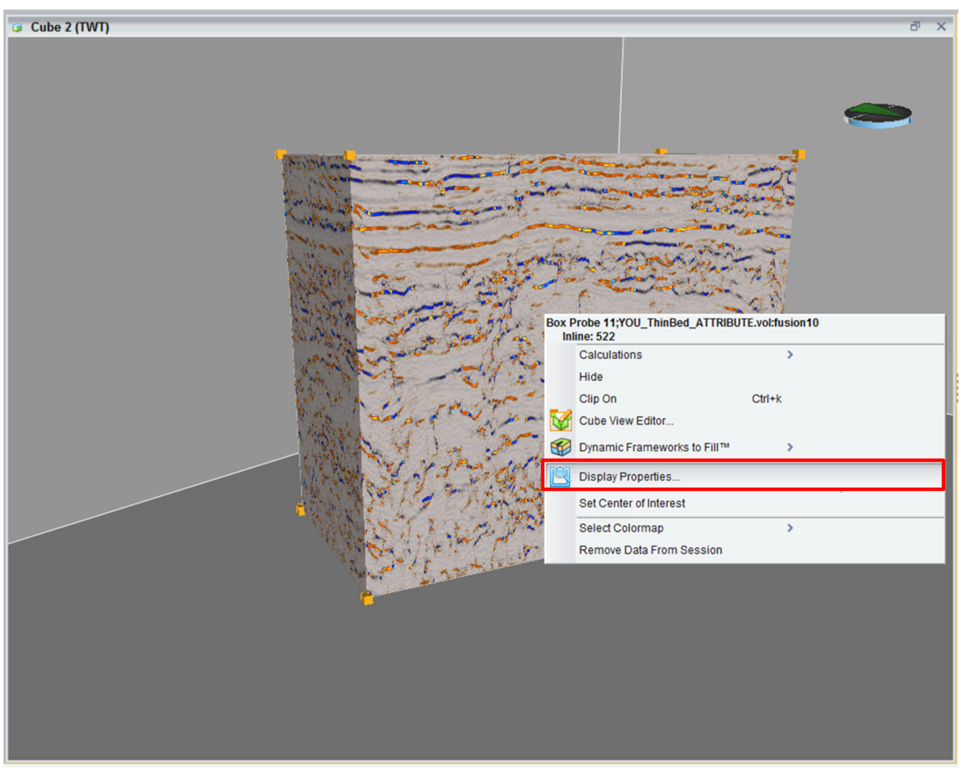
With Blending, you can select the preferred color palette and weight for the volumes individually. You can think of the weight as being similar to opacity. By default, the weight of every volume is 0.5, meaning you are able to distinguish each of the three volumes. Increasing the weight of one of the volumes will hide the other two. Similarly, reducing the weight will cause a decrease in opacity of that volume.

The second blending option, RGB Blending, is typically used to visualize amplitude volumes at different frequencies, for example spectral decomposition. If you load spectral decomposition volumes into DecisionSpace Geosciences, you can simultaneously explore amplitudes at lower, medium and high frequencies. RGB stands for Red, Green, and Blue, and as the name suggests, it is not possible to use color palettes in this option.

1. In the *Inventory* task pane, toggle off box probe **YOU_Sweet_ATTRIBUTE**. Toggle on the box probe **YOU_ThinBed_ATTRIBUTE** and maximize its extents. You are going to use this volume, showing the shale layers, as the base for the blending.

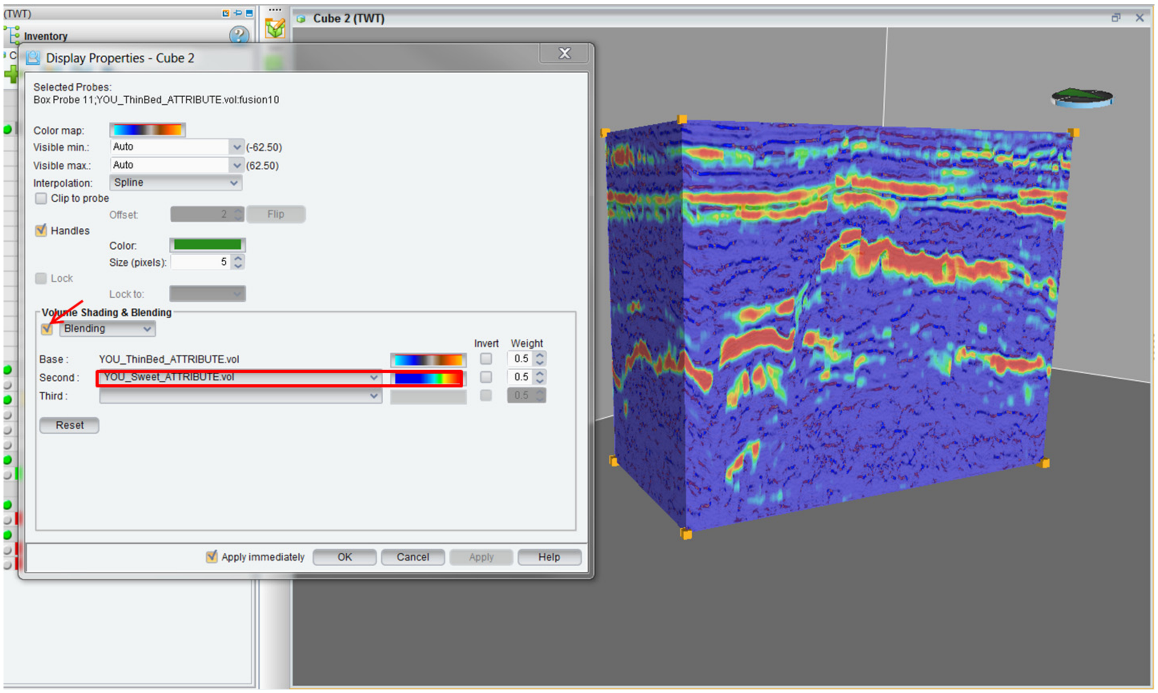


2. In *Cube* view, **MB3** on the volume and select **Display Properties**.



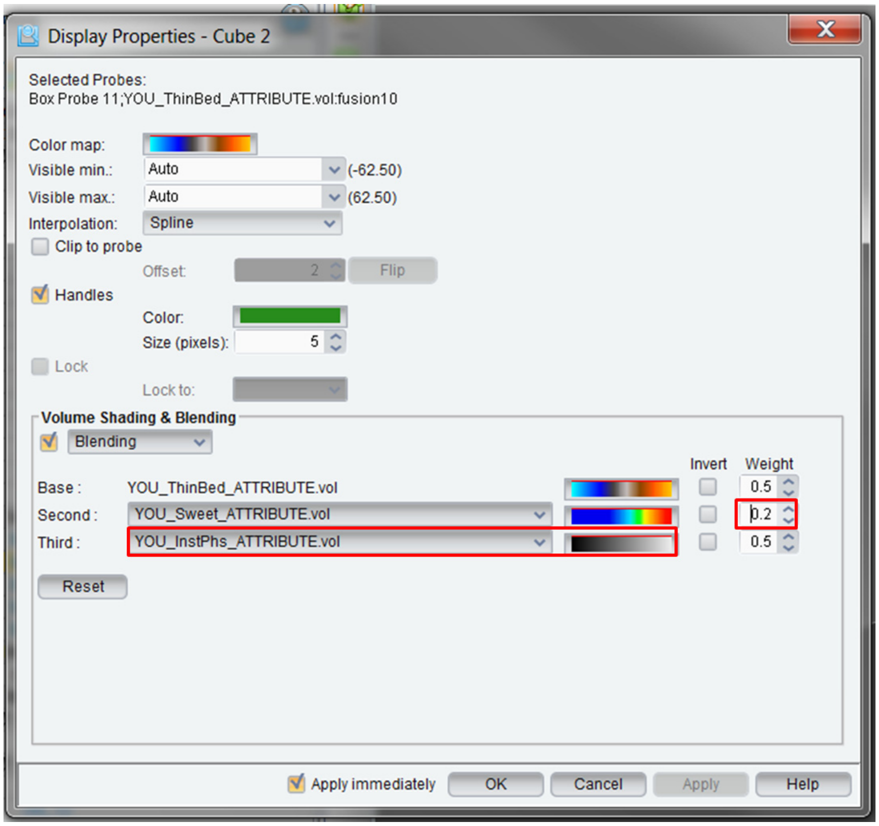
3. In the *Display Properties* dialog, select the check box in the *Volume Shading & Blending* section and select **Blending** from the drop-down menu. For the *Second* volume, select **YOU_Sweet_ATTRIBUTE** and make sure its color palette is set to **Geoprobe > Sweet**.

4. The results are automatically applied to the probe. Explore the results in *Cube* view, but leave the *Display Properties* dialog open.

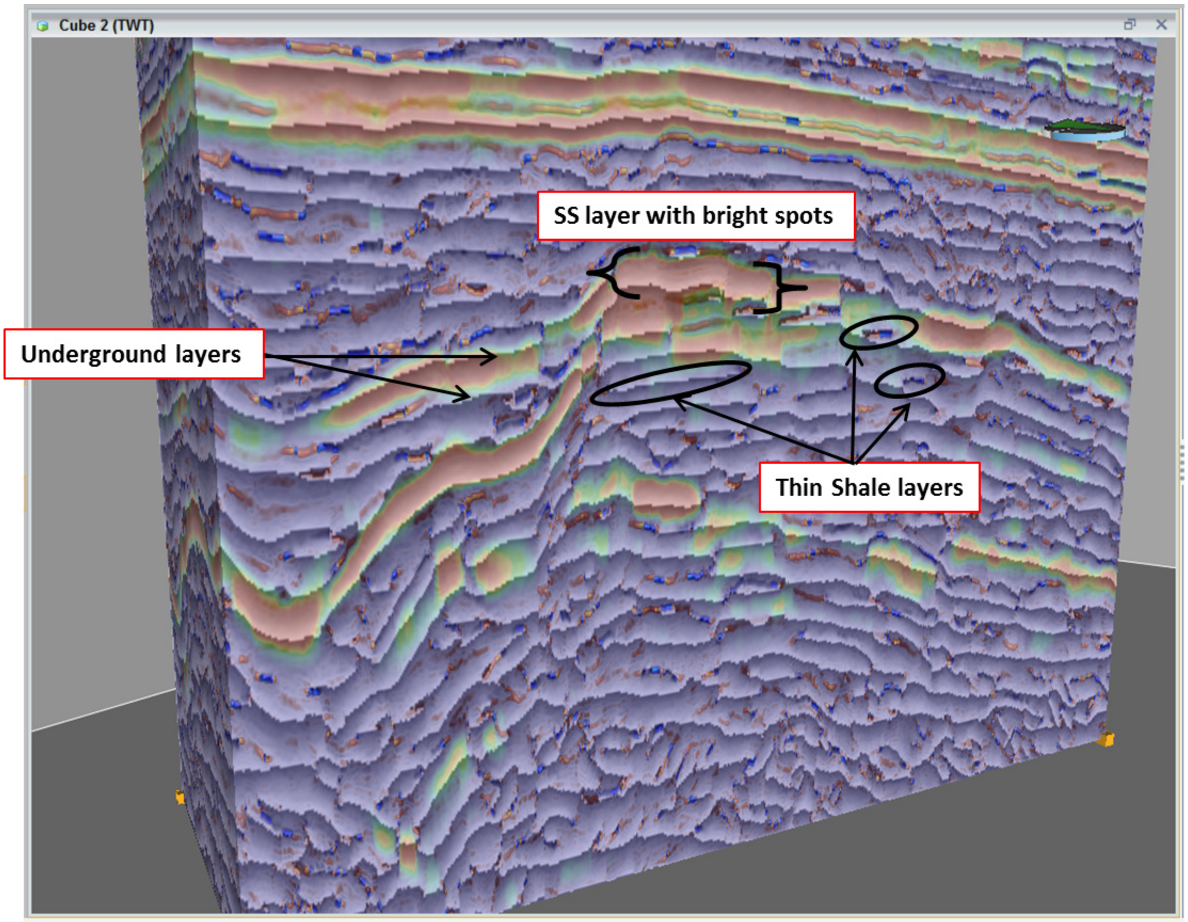


5. For the *Third* volume, select **YOU_InstPhs_ATTRIBUTE** and make sure its color palette is set to **System > Greyscale**.

6. Change Weight for the *Second* volume to **0.2**. Click **OK** to close the *Display Properties* dialog.



7. Explore the results in *Cube* view, moving all its faces.



The previous picture shows massive sandstone bodies that contain bright spot areas. Notice how the phase volume is delimiting every layer. The Thin Bed Indicator attribute is highlighting some shale intercalated in the sandstones bodies. Explore the volume as time permits.

Exercise 5.6: Volume Math: Analysis of AVO Effects

In chapter one, during the QC of the seismic with prestack data, you could tell that in some areas at the top of the reservoir some indications of AVO effects were evident (amplitude changes in prestack gathers for a single trace). In this exercise, you will use the Volume Math utility to manipulate the near offset and far offset volumes available in the project to quickly find the areas with AVO differences. It is important to note that you can use volume math to generate additional attributes if needed.

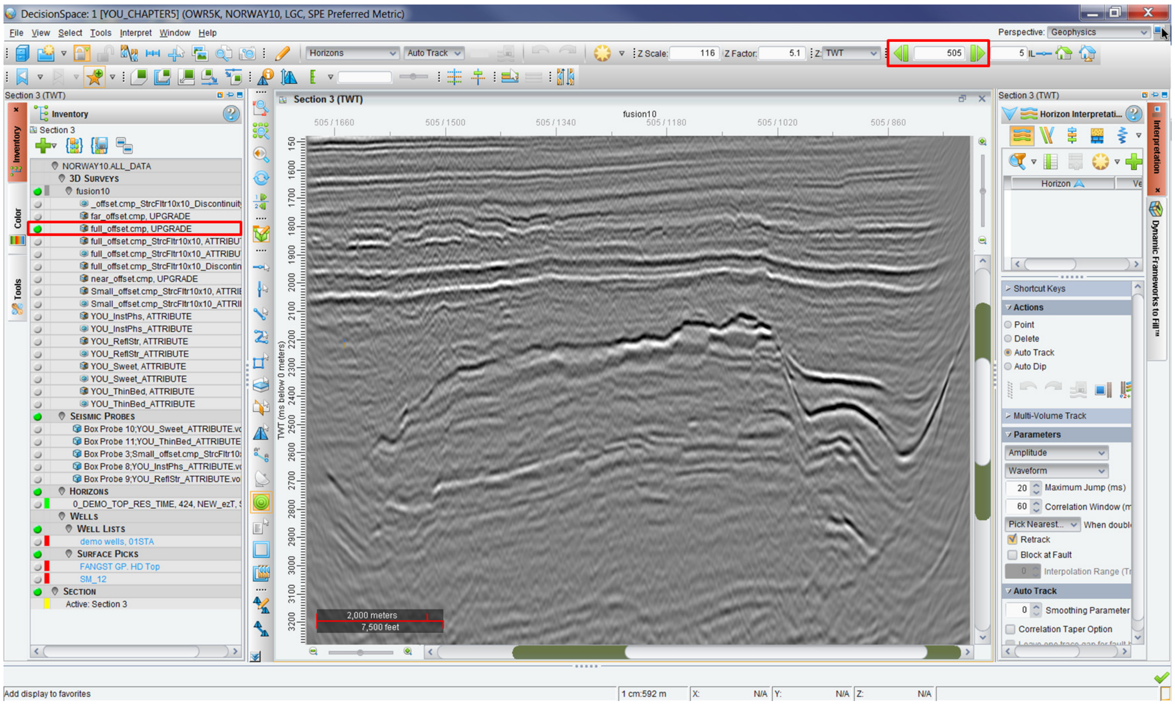
> **Note**
>
> AVO analysis is explored in more detail in the Well Seismic Fusion Software in the Landmark DecisionSpace Platform.

1. Load the original poststack volume **full_offset.cmp** into your session by clicking the **Select Session Data** () icon. Navigate to 3D **Surveys** > **fusion10** > **Seismic**. Highlight **full_offset.cmp** and click **Add data to session**. Click **OK**.

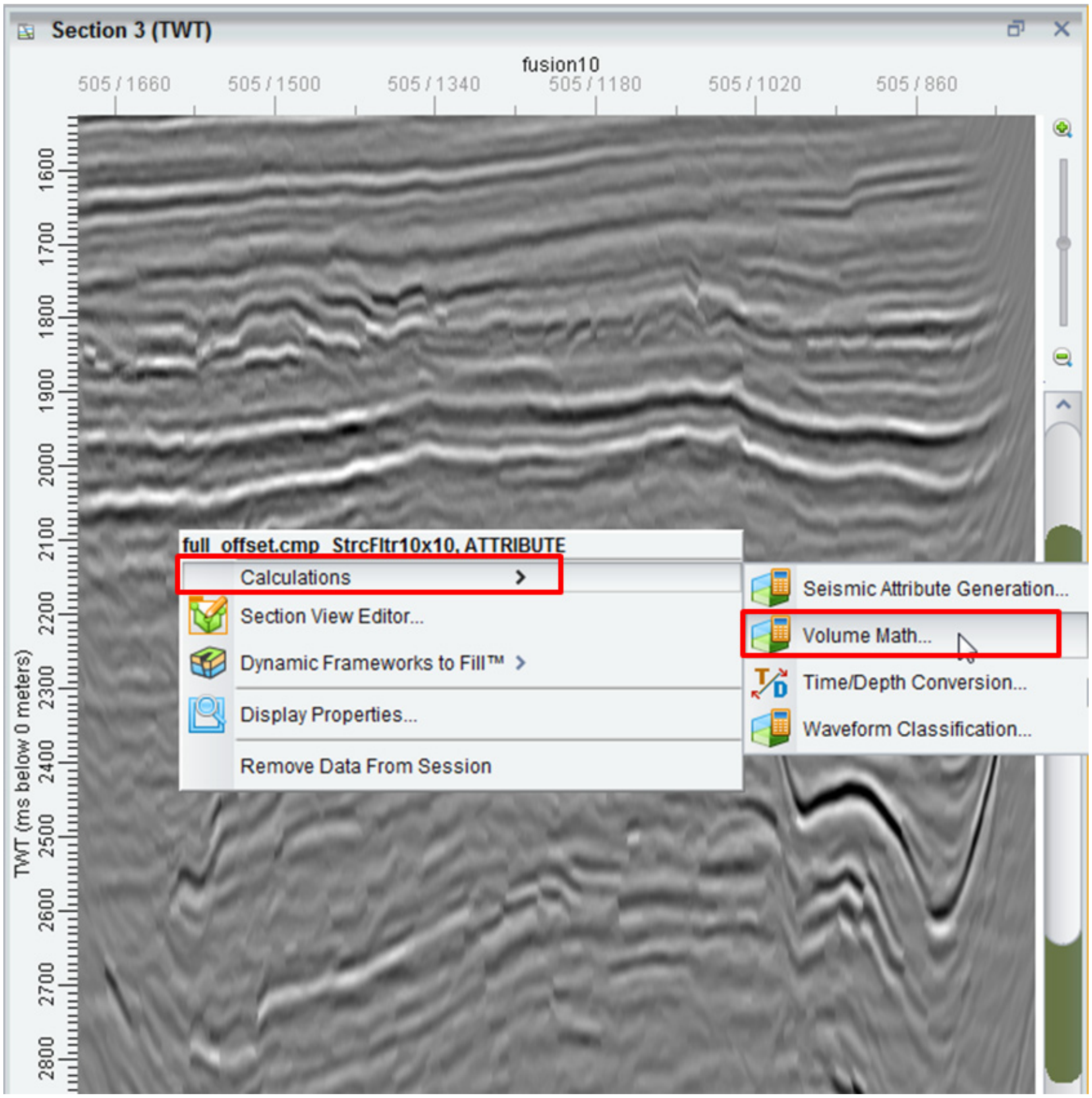
2. Activate and maximize *Section* view. Drag-and-drop **full_offset.cmp** into *Section* view and type "**505**" in the frame control.

3. **MB3** on the seismic and select **Display Properties** to change the *Color map* palette to **System > Greyscale**.

4. Zoom in to get a good perspective of the reservoir area. Your screen should look similar to the picture below.



5. **MB3** on the *Section* view and select **Calculations > Volume Math...**.

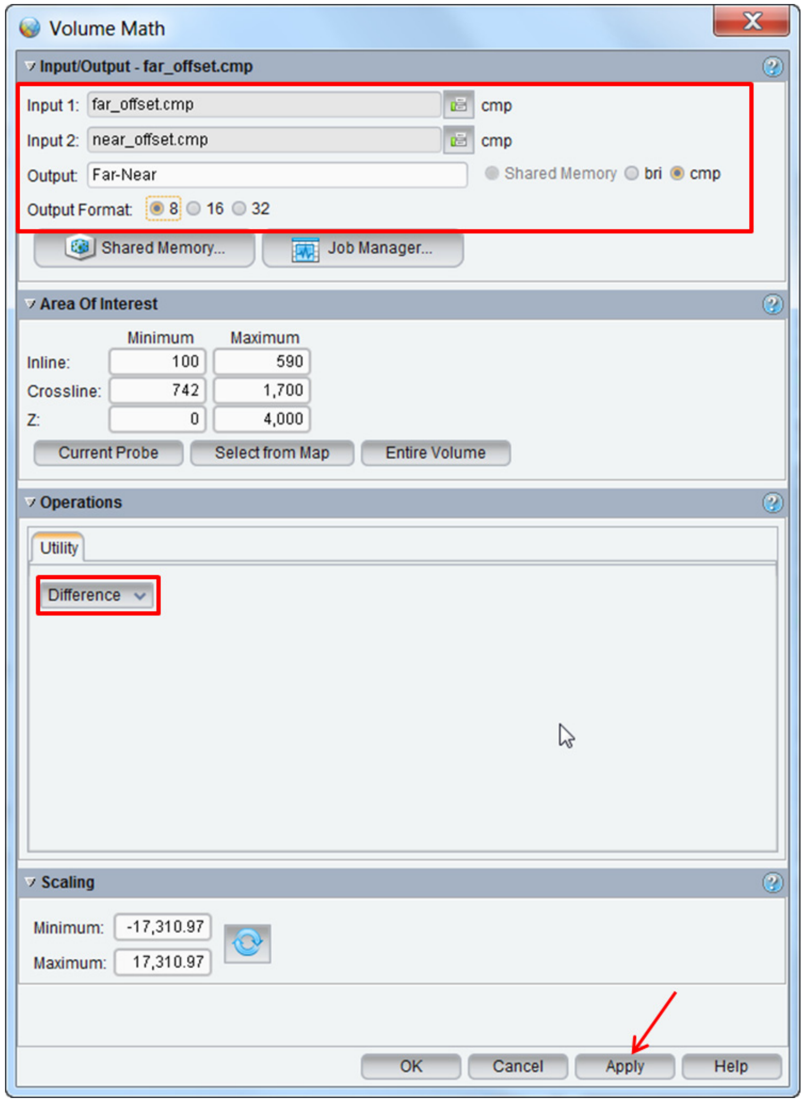


6. In the *Volume Math* dialog, in the *Input / Output* panel, select the volume **far_offset.cmp** for *Input 1*. For *Input 2*, select the volume **near_offset.cmp**.

7. In the *Operations* panel, select **Difference** from the drop-down menu.

8. In the *Input / Output* panel, name the *Output* volume "**Far-Near**," select **cmp**, and for *Output Format* select **8** bit.

9. Check that your *Volume Math* dialog looks like the picture below. Click **Apply** to create the Far-Near volume and leave the *Volume Math* dialog open.



10. The *Job Manager* dialog opens showing the status of the new generated volume. Once it is finished, close the *Job Manager* dialog.

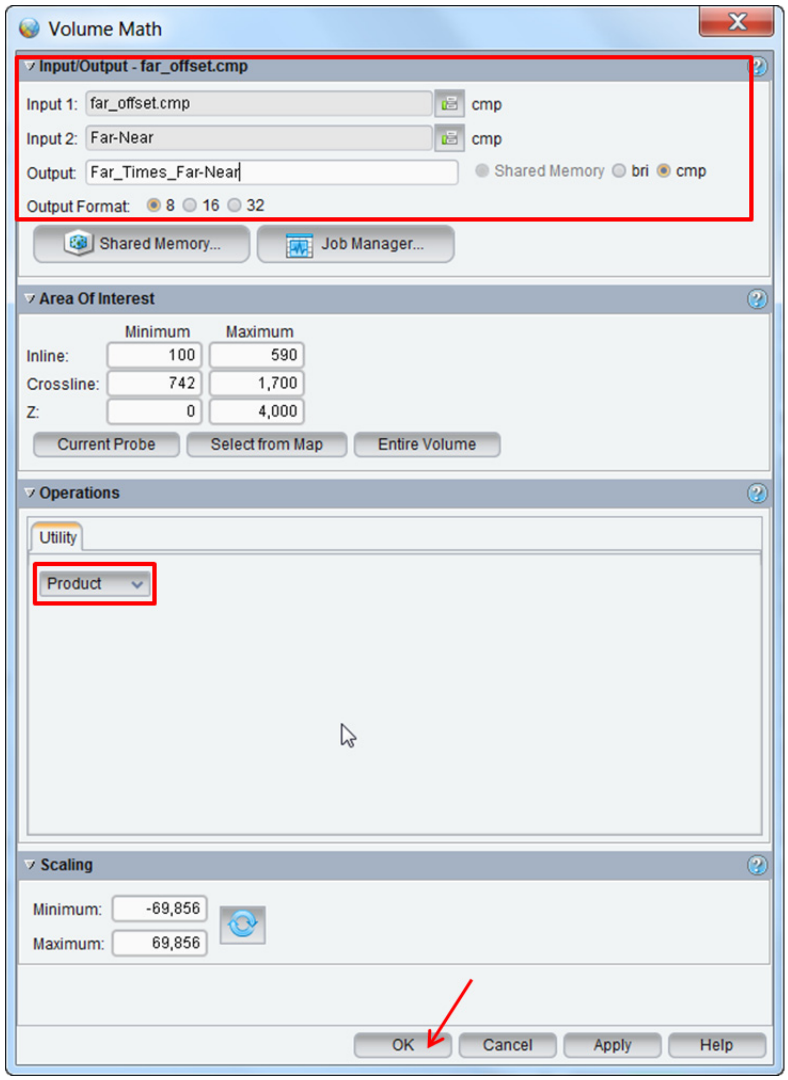
In the following steps, you will create a new volume that highlights the AVO anomalies by increasing the highest and lowest amplitude values (positive and negative), by multiplying the Far-Near volume and the Far_offset.cmp volume.

11. In the *Volume Math* dialog, change *Input 2* by selecting the **Far-Near** volume.

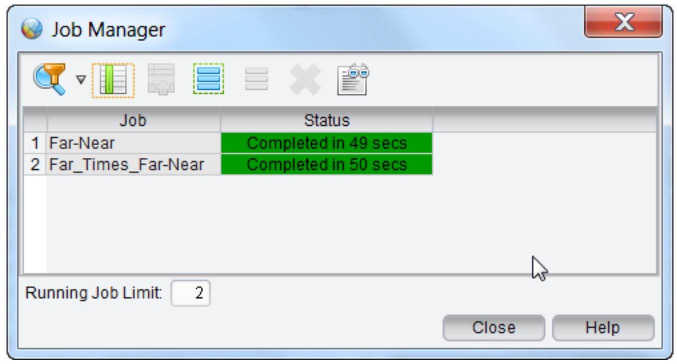
12. In the *Operations* panel, select **Product** from the drop-down menu.

13. In the *Input / Output* panel, change the *Output* name to "**Far_Times_far-Near**." Also, ensure **cmp** and **8** bit are still selected.

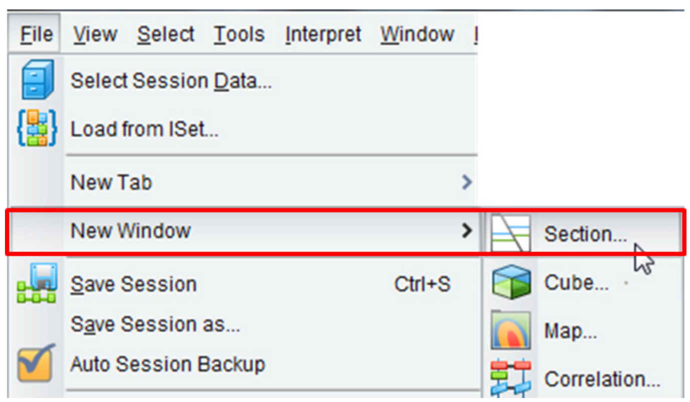
14. Check that your *Volume Math* dialog looks like the picture below. Click **OK** to generate the volume and close the *Volume Math* dialog.



15. Close the *Job Manager* dialog when the process is completed.



16. To visualize the results in *Section* view, open a new *Section* view window (**File > New Window > Section...**) and move it to the second monitor so you can compare two *Section* views simultaneously. If you only have one monitor, arrange the tabs so only two *Section* views are displayed.



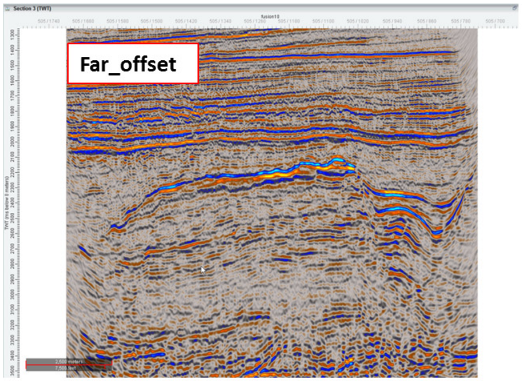
17. In the original *Section* view displaying the inline 505, toggle off the volume **full_offset.cmp** and toggle on only the volume **far_offset.cmp**.

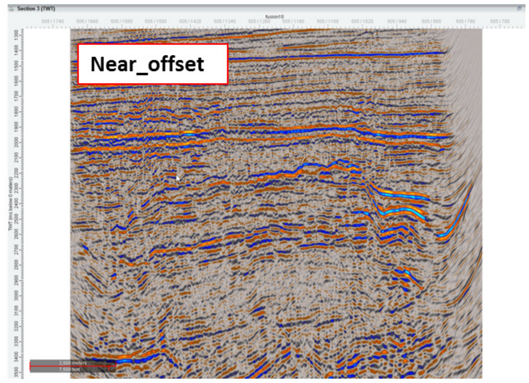
18. In the new *Section* view, toggle on only the **near_offset.cmp** volume. Compare both of them, noticing the differences in amplitudes.

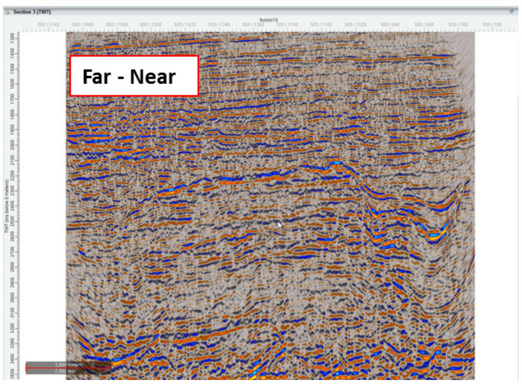
19. In one of the *Section* views, toggle off the seismic volume you are currently displaying and toggle on only the **Far-Near** volume.

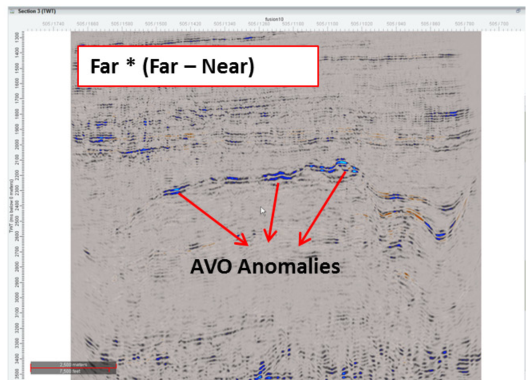
20. In the other *Section* view, toggle on only the **Far_Times_Far-Near** volume.

Notice how in the Far_Times_Far-Near volume, the bright events representing AVO anomalies are highlighted.









21. Close the secondary *Section* view window. Do not dock the view to other windows.

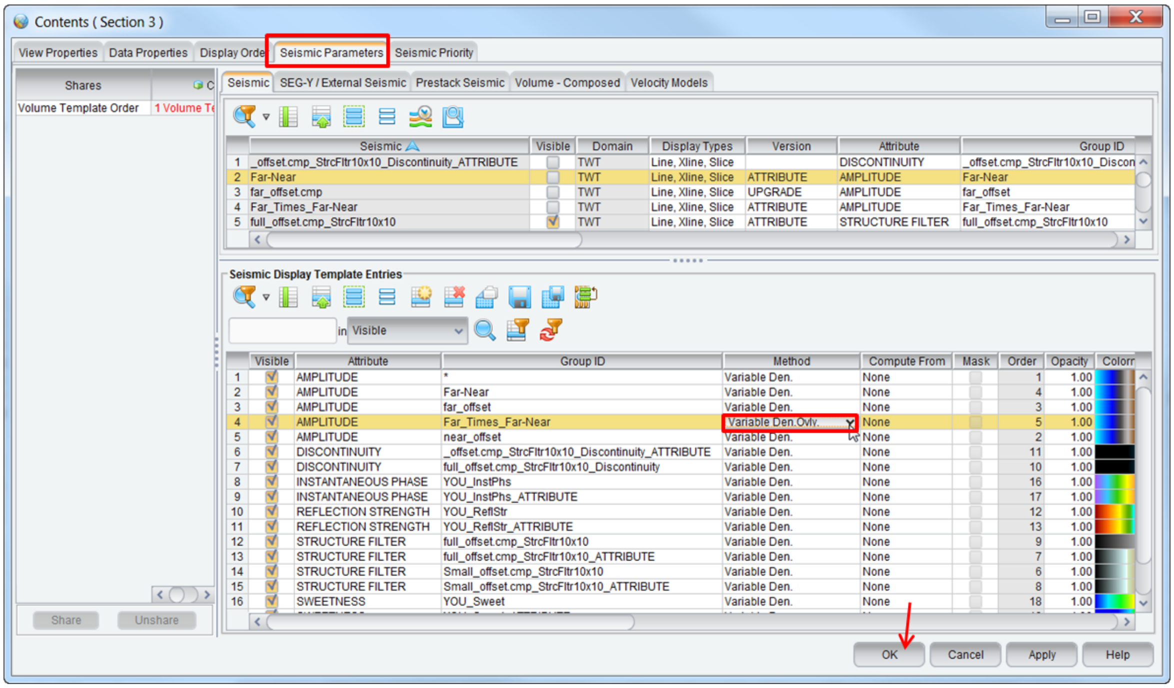
22. In the *Section* view of the main DecisionSpace Geosciences window, toggle off the displayed seismic and toggle on the **Full_offset.cmp** seismic.

In the following steps, you will modify the properties of the Far_Times_Far-Near volume and mask some of its values so you can visualize the AVO anomalies overlaying the structural amplitude volume.

23. Click the **Contents** ( ) icon in the vertical toolbar at the left side of *Section* view.

24. Click the **Seismic Parameters** tab and make sure the **Seismic** tab is selected.

25. In the *Seismic Display Template Entries* panel at the bottom, highlight the **Far_Times_Far-Near** volume. Click the *Method* drop-down menu and change the entry to **Variable Den. Ovly**. See picture below for reference. Click **OK** to apply the changes and close the dialog.



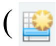
26. Go to **Tools > Seismic Mask Editor**.

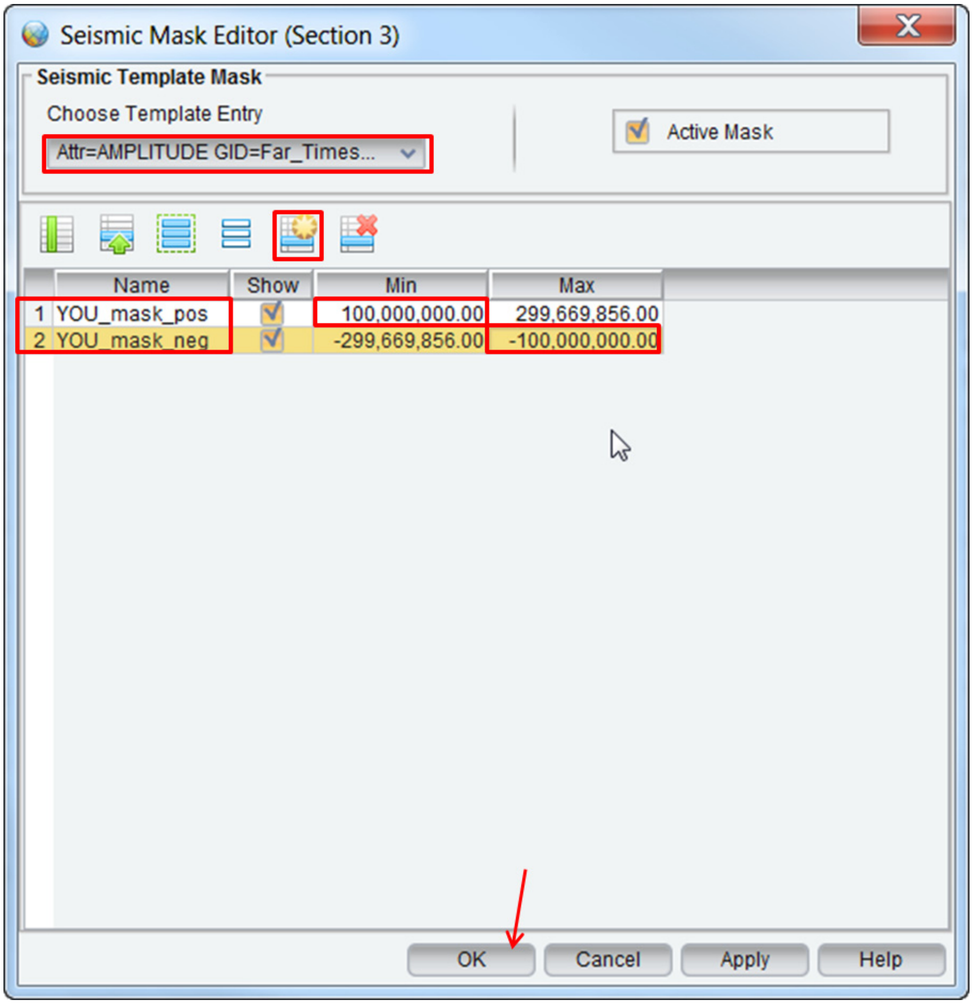
27. In the *Seismic Template Mask* panel, from the *Choose Template Entry* drop-down menu, select **New** to create a new mask.

28. From the *Velocity Mask Templates* tab, select the **Far_Times_Far-Near** seismic volume and click **OK**.

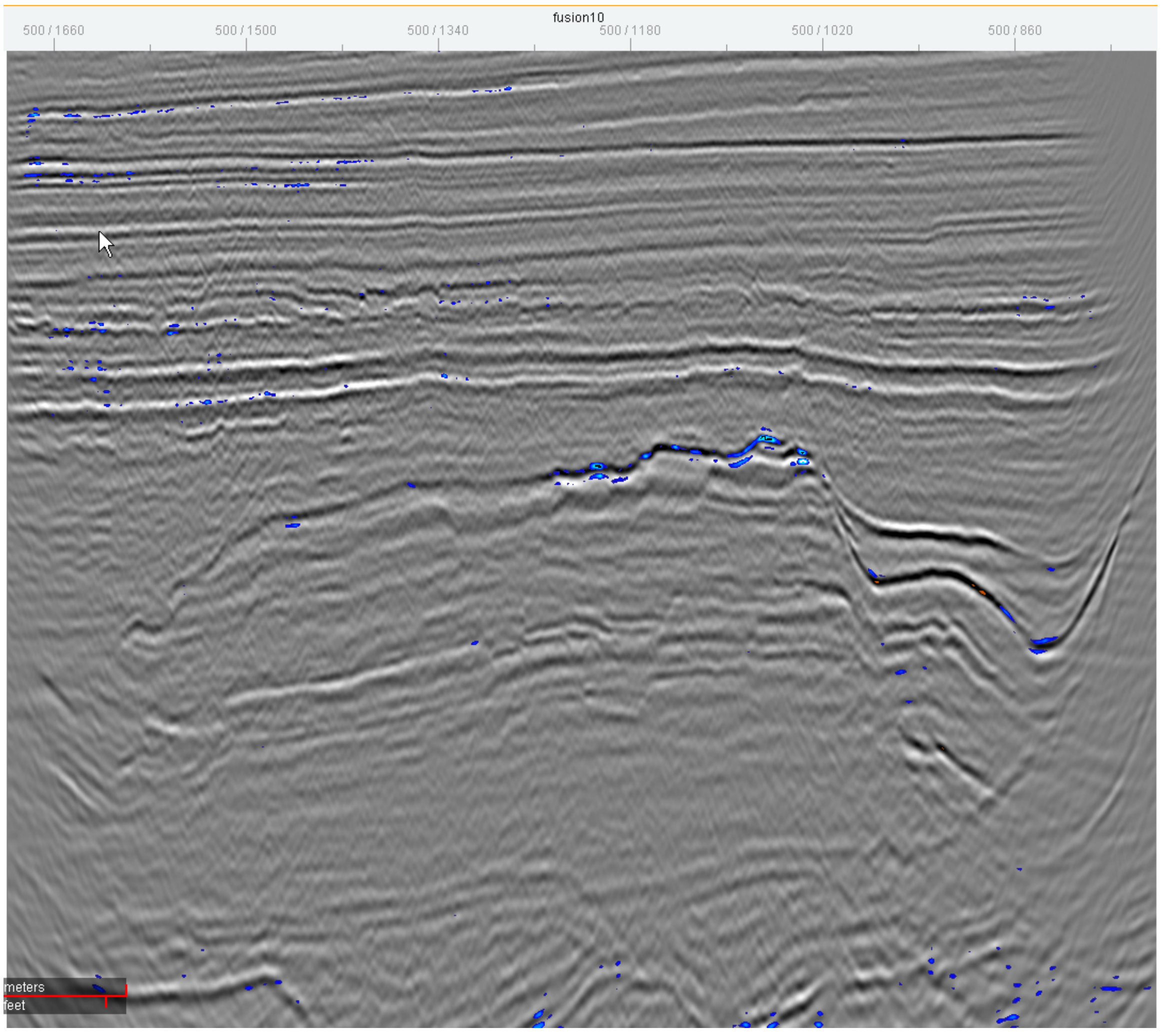
29. In the lower panel of the *Seismic Mask Editor* dialog, click the **Add new mask entry** () icon to add a new row.

30. In the *Name* field for the new entry, double-click and change the name to “**YOU_mask_pos**.” Change the *Min* value field to “**100,000,000**.”

31. Click the **Add new mask entry** () icon again. Give the new entry the name "**YOU_mask_neg**." Change the Max value field to "**-100,000,000**." Click **OK** to close the *Seismic Mask Editor* dialog.



32. In the *Inventory* task pane, toggle on the volume **Far_Times_Far-Near**, and make sure **full_offset.cmp** is still on. You should see the AVO anomalies overlying the structural filter volume as shown in the picture below.

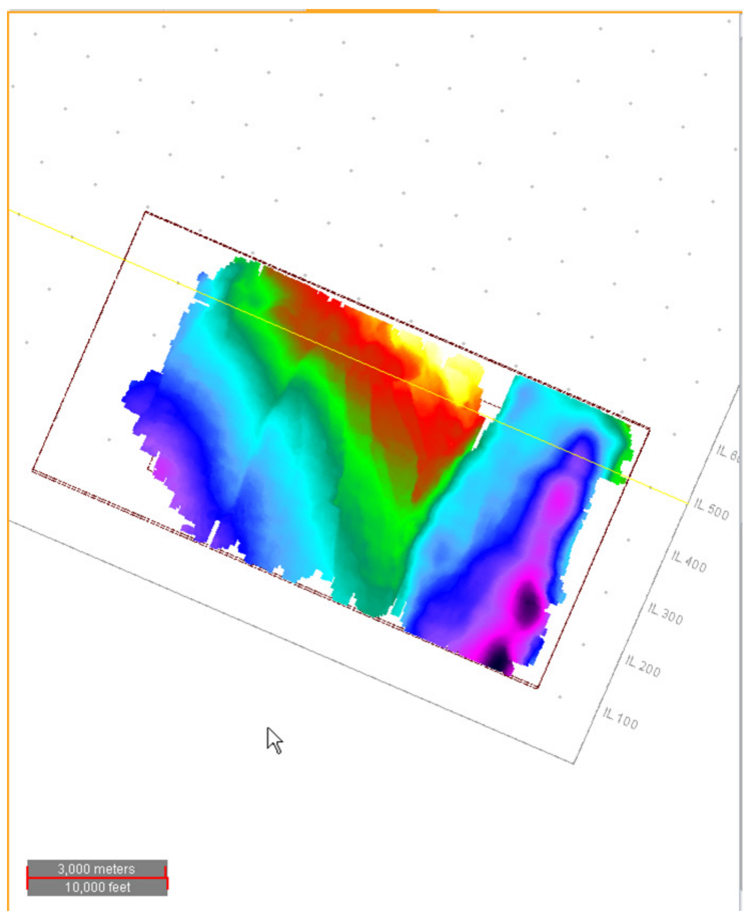


33. Save your session before proceeding with the next exercise.

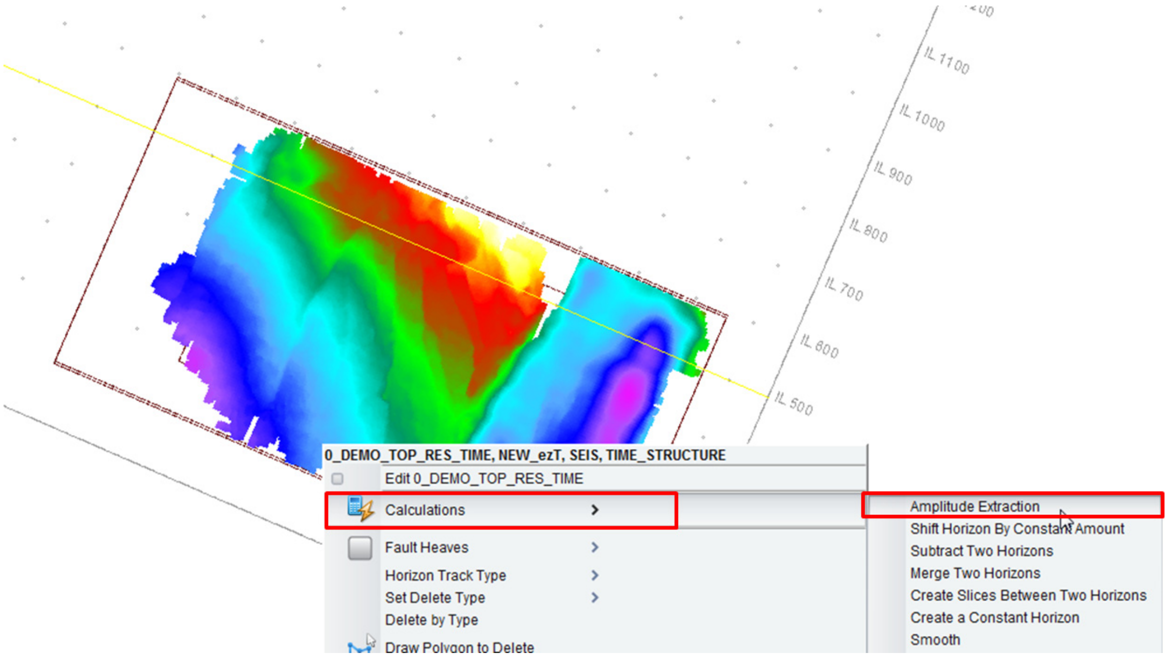
Exercise 5.7: Attribute Extraction Over Horizons and Crossplotting

Now that you have calculated several seismic attributes, in the following exercise, you will use the Amplitude Extraction tool inside DecisionSpace Geosciences to extract the calculated attributes in the horizons. By extracting the attributes at the horizon level, interpreters are able to identify sweet spots and more accurately limit the potential drilling areas. You will also learn to use the horizon slicing option, when a feature is identified in any of the attributes (e.g., AVO anomalies, channels, fractures, etc.) this option will let you analyze the direction the anomaly is migrating within the time or depth domain.

1. Maximize *Map* view and display only the horizon **0_DEMO_TOP_RES_TIME**. Zoom in to the horizon area for better visualization similar to the picture below.

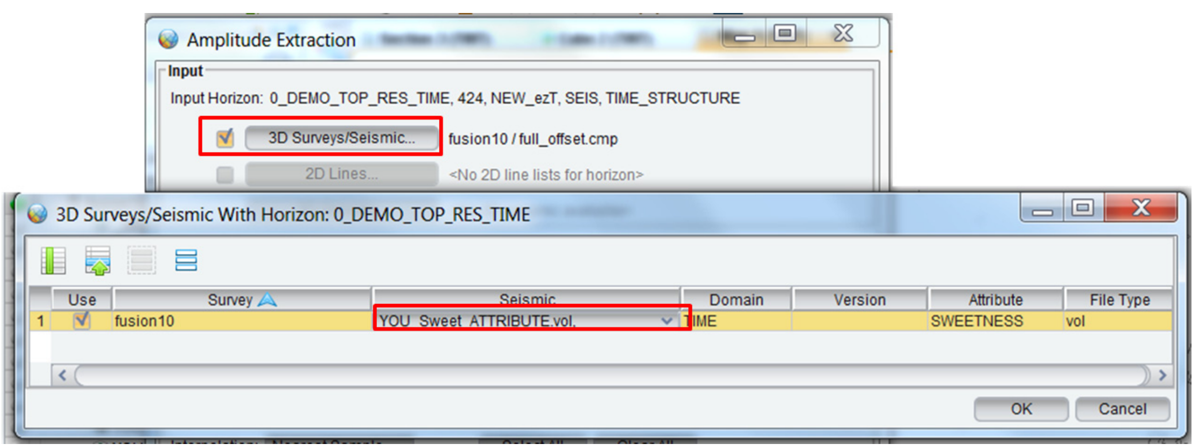


2. **MB3** on the horizon and select **Calculations > Amplitude Extraction**.



3. In the *Amplitude Extraction* dialog, under the *Input* panel, click the **3D Surveys/Seismic...** button.

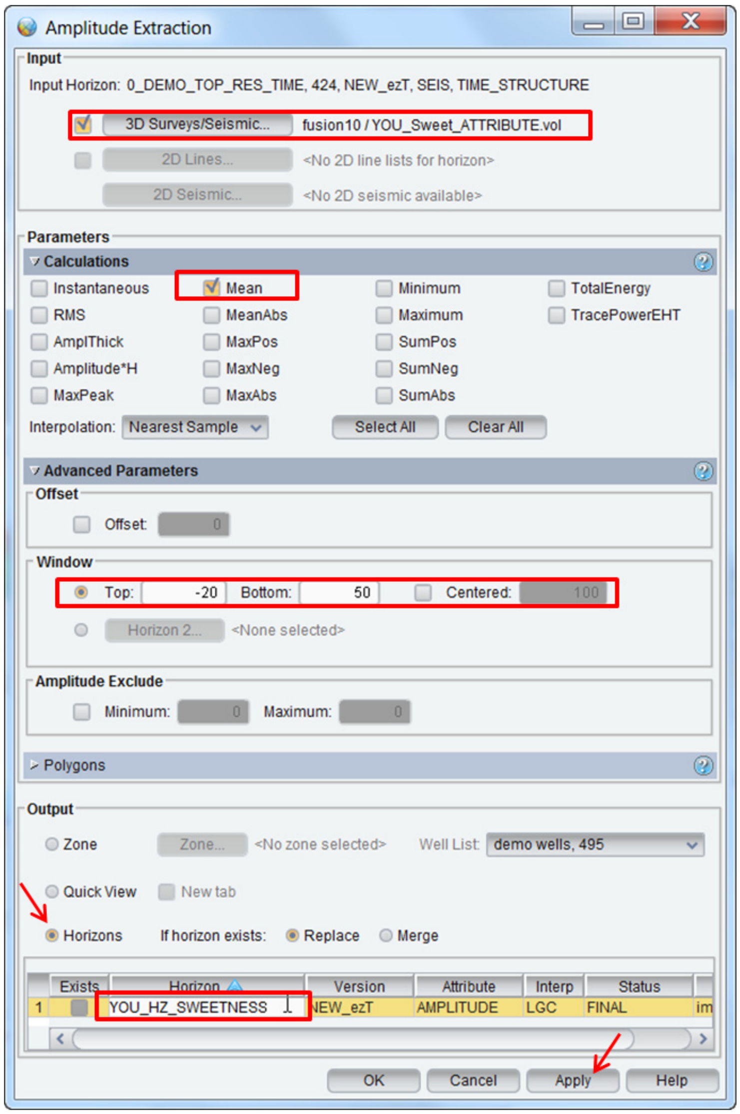
4. In the *3D Surveys/Seismic With Horizon: 0_DEMO_TOP_RES_TIME* dialog, select the volume attribute **YOU_Sweet_ATTRIBUTE.vol** from the *Seismic* drop-down field. Click **OK** to close the dialog.



5. In the *Calculations* panel of the *Amplitude Extraction* dialog, deselect **Instantaneous** (default) and select only **Mean**.

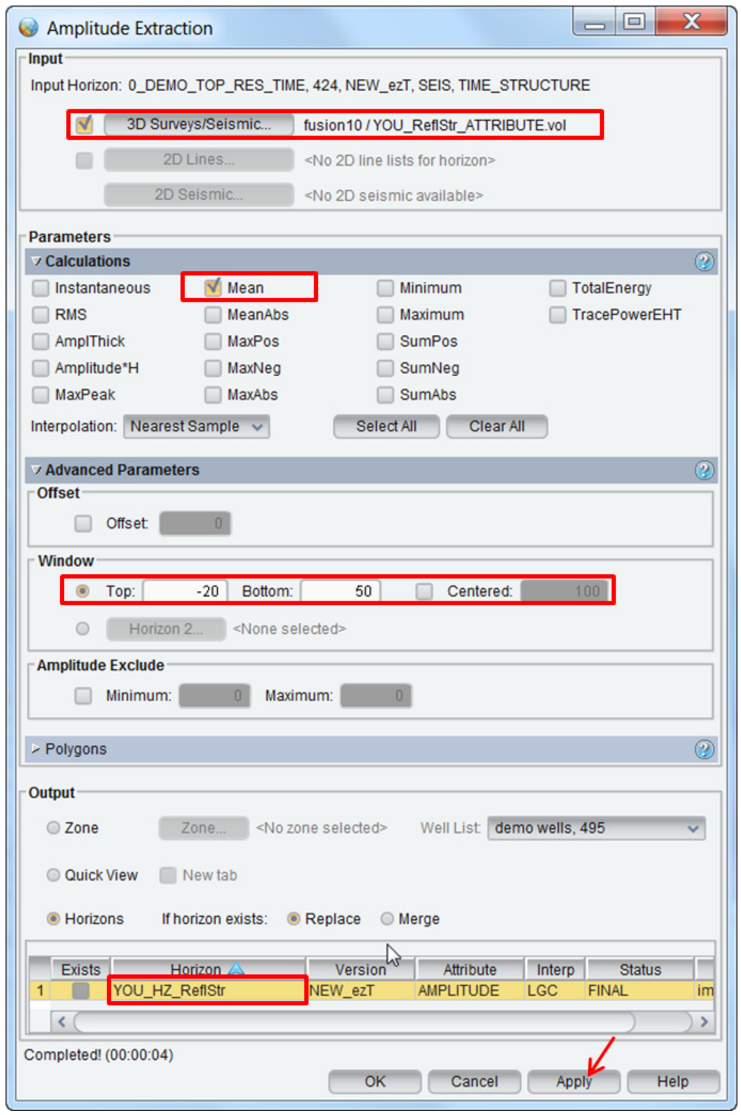
6. Under the *Advanced Parameters* panel, in the *Window* section, deselect **Centered** and modify the extraction window to be "**-20**" ms above the horizon (*Top*) and "**50**" ms below the horizon (*Bottom*).

7. In the *Output* section, select **Horizons**, then double-click to rename the horizon "**YOU_HZ_SWEETNESS**." Click **Apply** to generate the horizon and keep the dialog open to extract more attributes in the following steps.

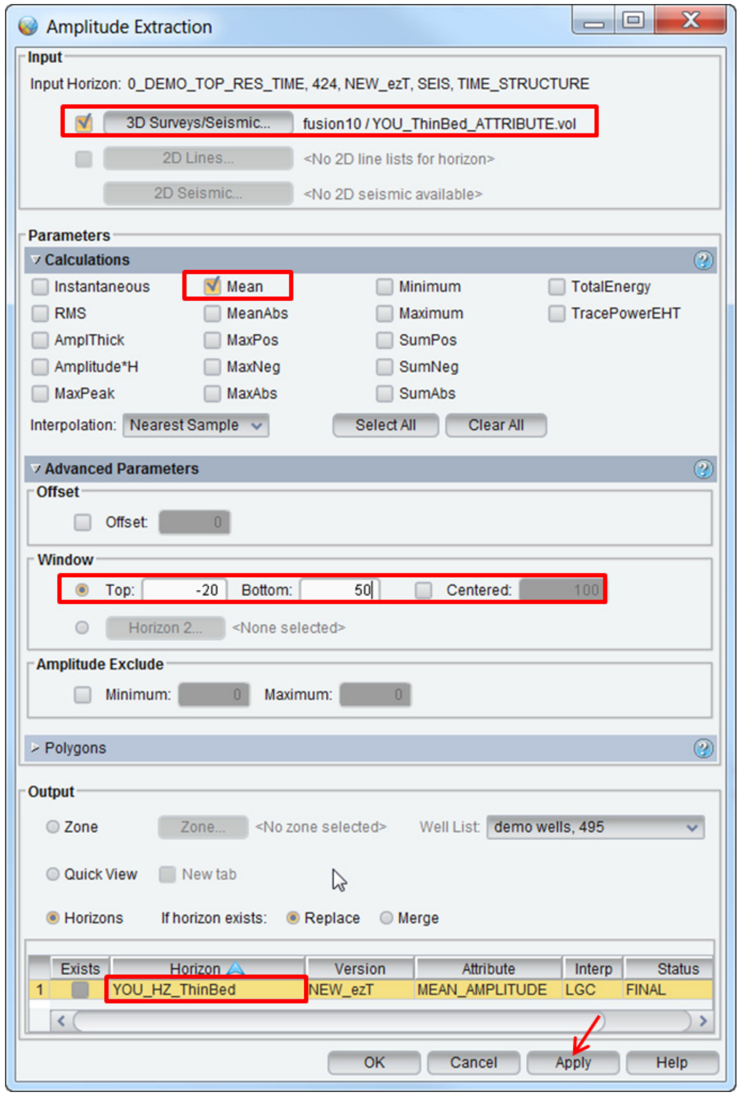


DecisionSpace Geosciences generates a new horizon every time you extract an attribute over a horizon. Use the previous picture as a reference.

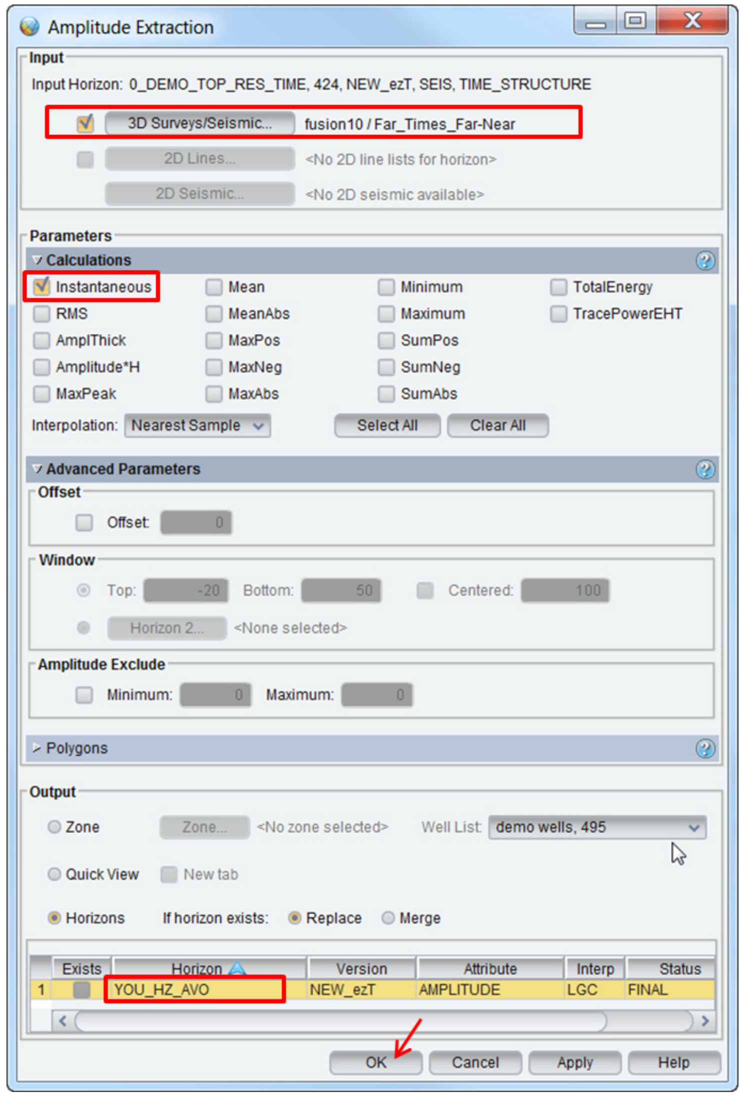
8. Repeat steps 3 and 4 to extract the reflection strength attribute. This time change *3D Surveys/Seismic...* to **YOU_ReflStr_ATTRIBUTE** and name the output horizon "**YOU_HZ_ReflStr**." Click **Apply**. Your *Amplitude Extraction* dialog should look like the picture below.



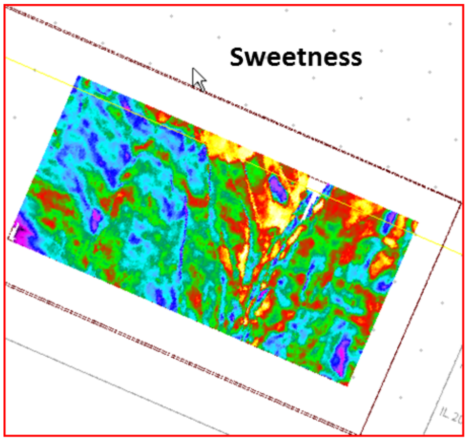
9. Repeat steps 3 and 4 to extract the frequency attribute. Change *3D Surveys/Seismic...* to **YOU_ThinBed_ATTRIBUTE** and rename the output horizon to "**YOU_HZ_ThinBed**." Click **Apply**. Your *Amplitude Extraction* dialog should look like the picture below.

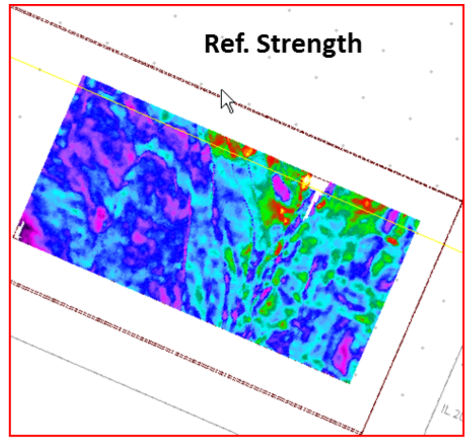


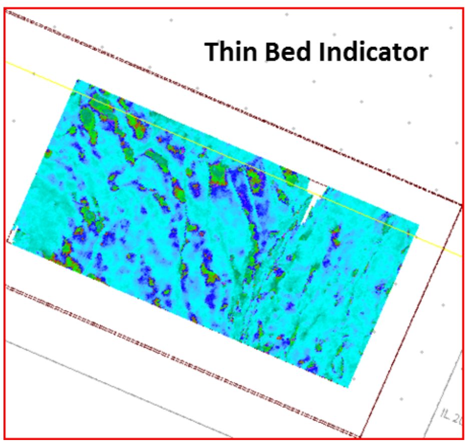
10. Repeat steps 3 and 4 to extract the AVO attribute. Change *3D Surveys/Seismic*... to **Far_Times_Far-Near**. This time, select the **Instantaneous** check box and deselect **Mean** (the *Window* section will grey out). Name the horizon "**YOU_HZ_AVO**." Click **OK** to create the horizon and close the *Amplitude Extraction* dialog. See image below.

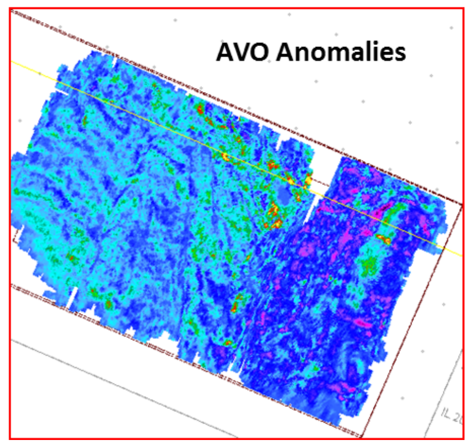


11. With *Map* view active, toggle on all of the new horizons one at the time and explore the results.





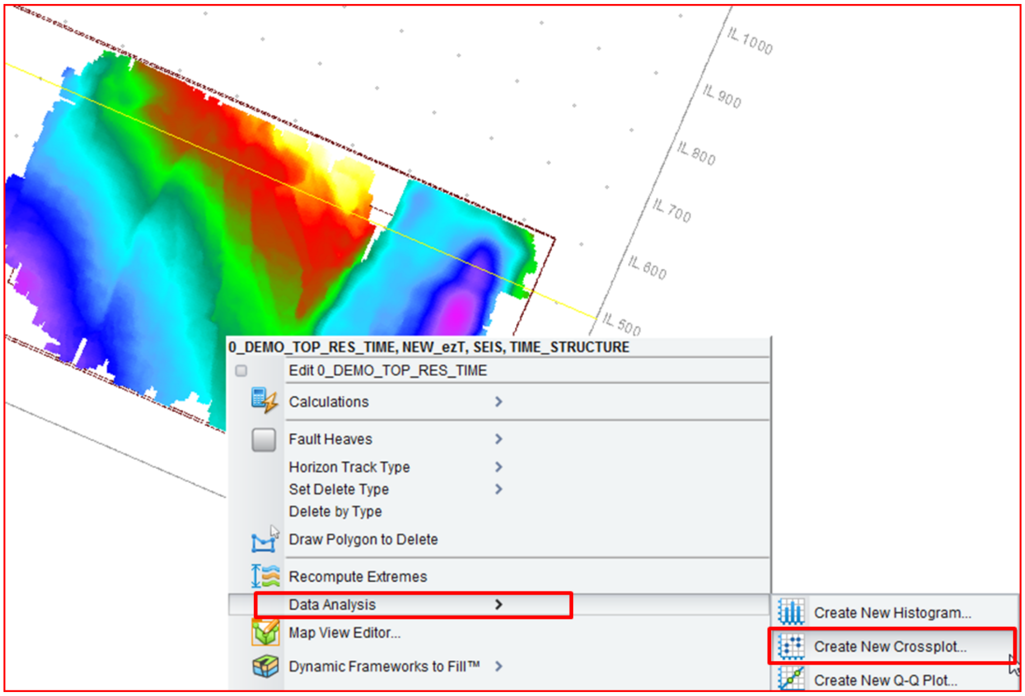




12. In *Map* view, after exploring the attributes extracted at the horizon, turn on only the horizon **0_DEMO_TOP_RES_TIME**.

In the following steps you will create crossplots of the attributes to highlight potential areas of interest.

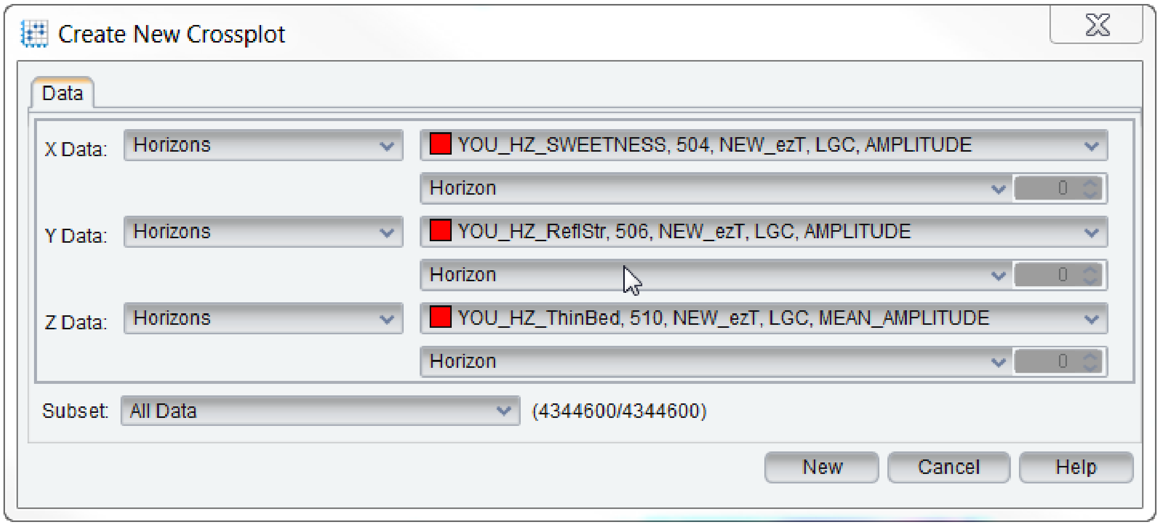
13. **MB3** on the horizon and select **Data Analysis > Create New Crossplot...**.



14. In the *Create New Crossplot* dialog, set the following parameters:

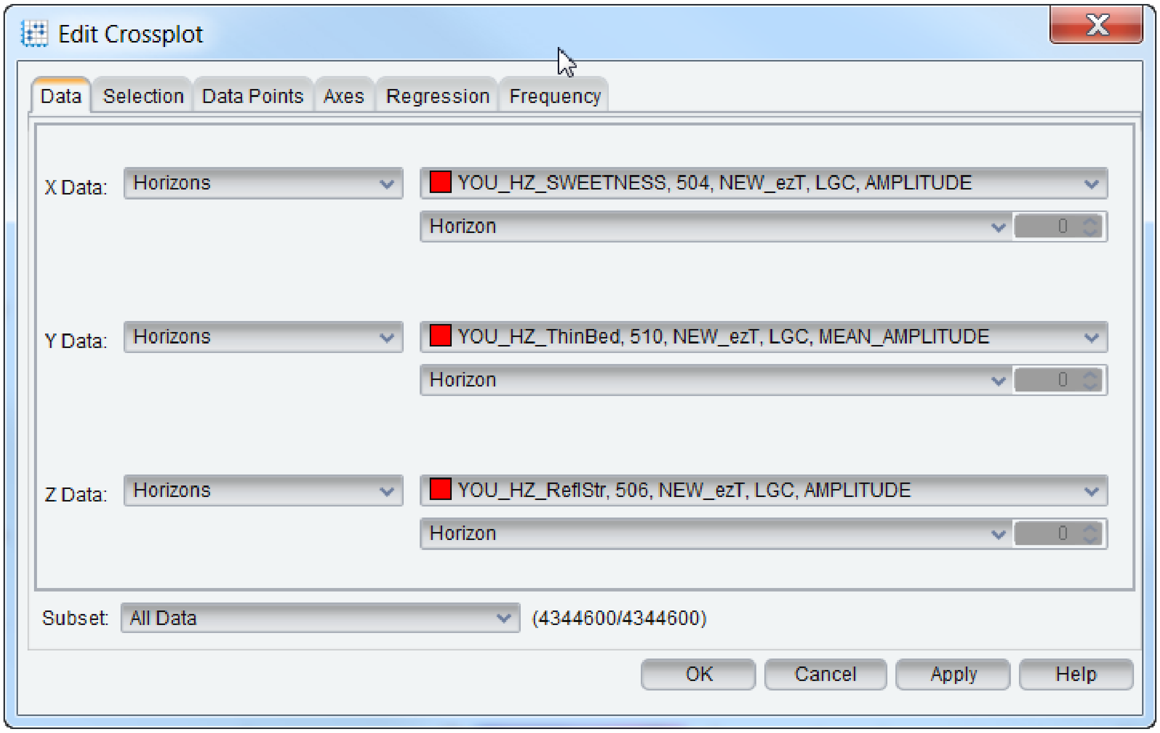
- X axis - *X Data*:
  — Horizon: **YOU_HZ_SWEETNESS**
  — Property: **Horizon**
- Y axis - *Y Data*:
  — Horizon: **YOU_HZ_ReflStr**
  — Property: **Horizon**
- Z axis - *Z Data* (represents colors):
  — Select One Data Type: **Horizons**
  — Horizon: **YOU_HZ_ThinBed**
  — Property: **Horizon**

15. Click **New** to create the crossplot. Your dialog should look similar to the photo below.

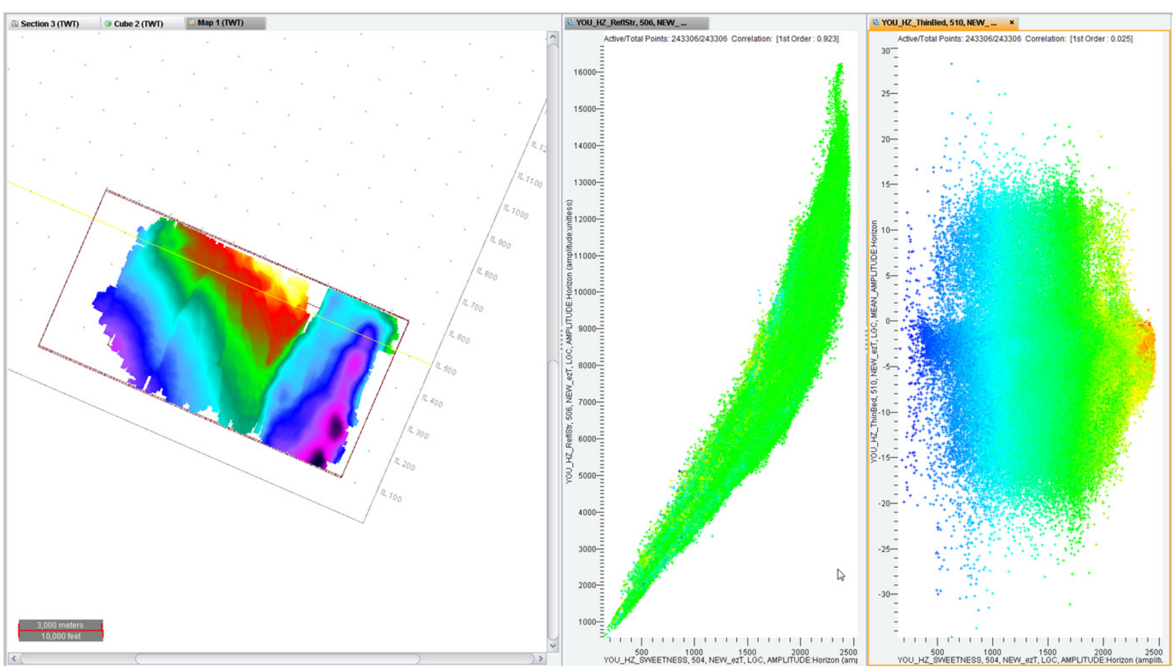


16. Drag the crossplot tab to a second monitor, or split your current view, so you can see both the map with the horizon and the crossplot.

17. Similar to steps 14-15, create a second crossplot window, this time showing in the X axis horizon **YOU_HZ_SWEETNESS**, in the Y axis horizon **YOU_HZ_ThinBed**, and in the Z axis horizon **YOU_HZ_ReflStr**.

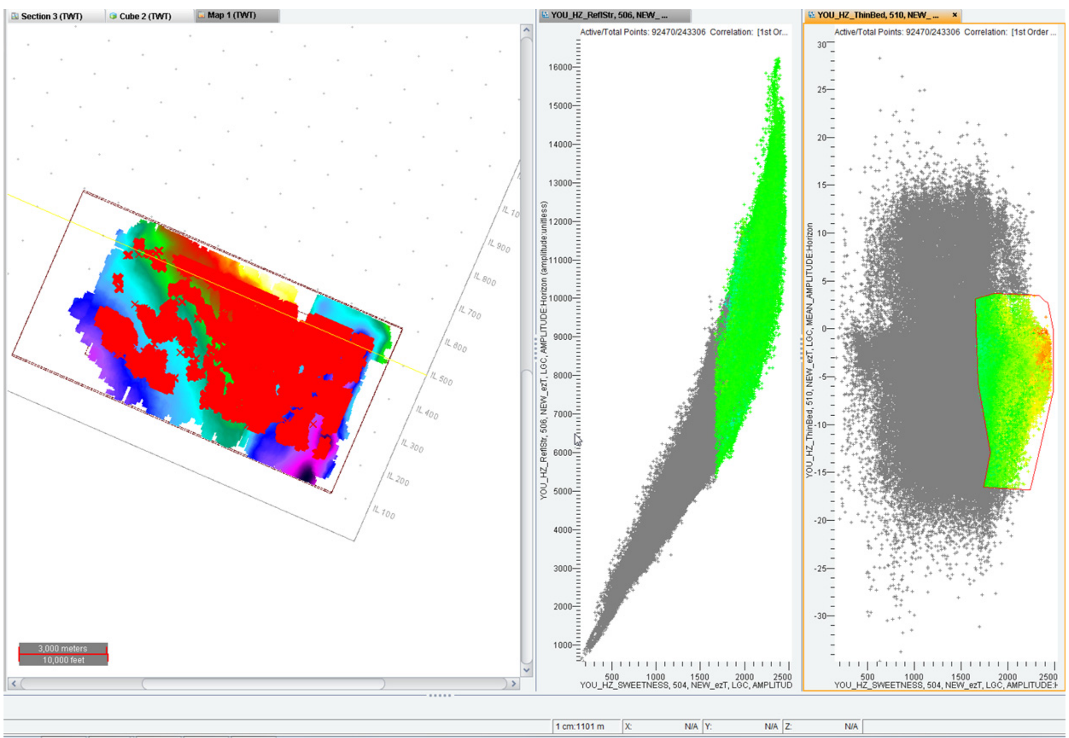


18. Arrange the tabs so you can see the three objects, *Map* view and the two crossplots, simultaneously.



As expected, the first crossplot is showing a normal positive relationship between the sweetness attribute and reflection strength. Both of these attributes are influenced by amplitudes. The highest values are an indicator of bright spots. The second crossplot is showing the frequency spectrum values in the Y axis. Thin shale layers are represented by high frequency values, and massive sandstones with potential hydrocarbons will attenuate the frequencies. Next, you will use the second crossplot (Sweetness vs Thin Bed) to draw a polygon around the area with low frequencies and highest sweetness - reflection strength values.

19. Activate the tab of the crossplot showing Sweetness vs Thin Bed layer. Click the **Draw Polygon(s)** () icon. Using a series of **MB1** clicks, define a polygon starting right underneath the value of **5** on the Y axis and between **1600** and **2500** values on the X axis. **MB2** to close the polygon. Use the picture below for reference.

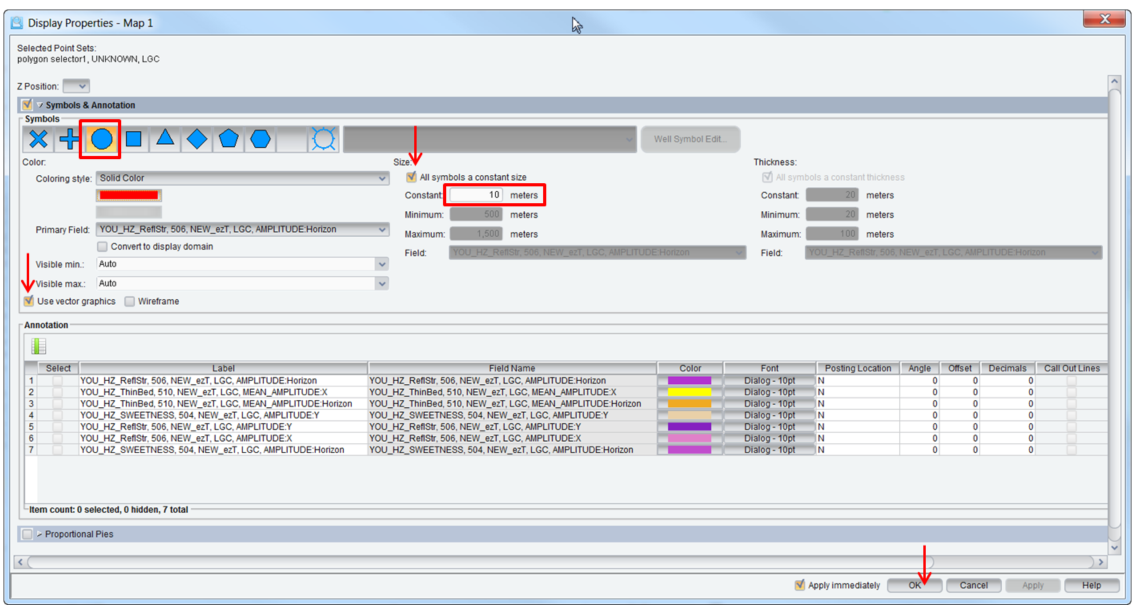


Notice that as soon as you close the polygon all the sample points inside the polygon are highlighted in all the open crossplots, and a series of Point Sets appear over your horizon showing the corresponding selected area.

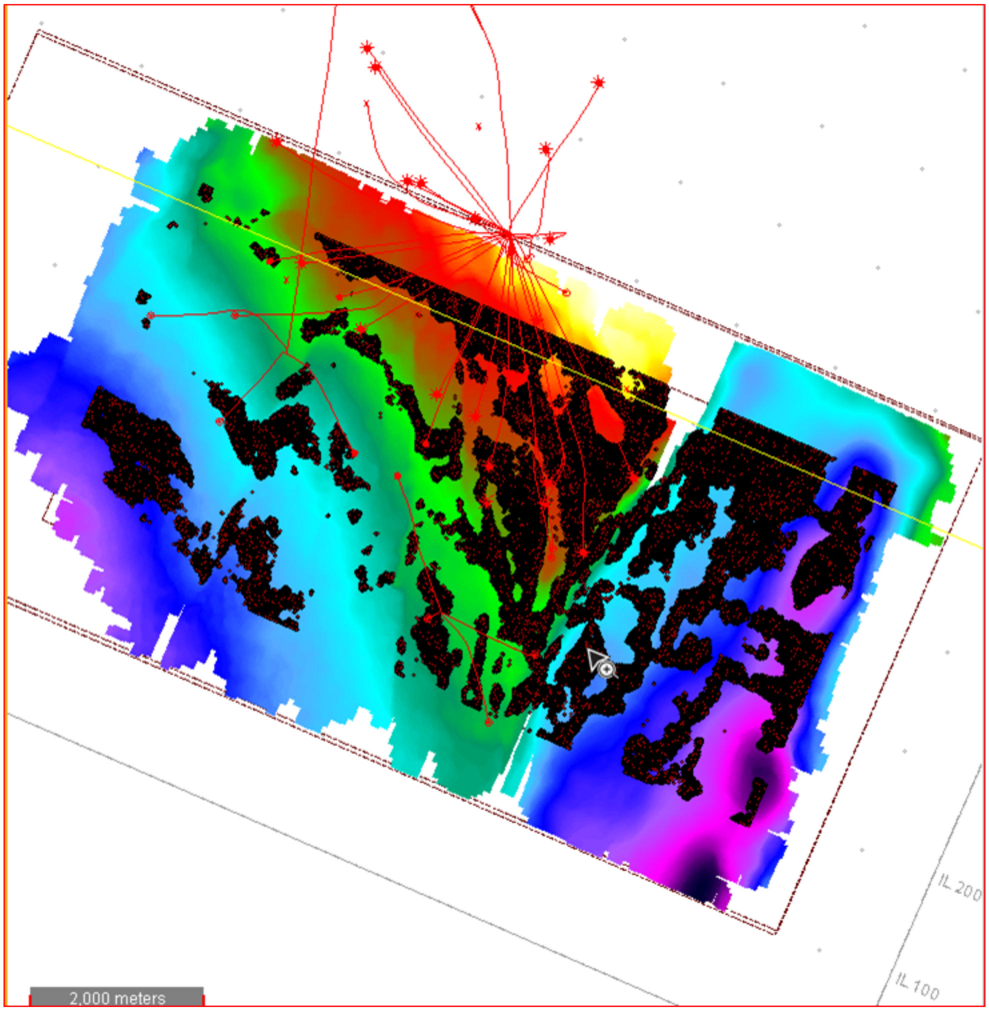
> **Note**
>
> Once the polygon is created, you can re-draw it if you wish. Start drawing the new polygon again with **MB1** and finish with **MB2**. All the samples will be reselected and the point set, which is still in memory, will be overwritten.

20. With *Map* view active, in the *Inventory* task pane, **MB3** on the point set polygon selector **1, UNKNOWN** and select **Display Properties**.

21. Expand the *Symbols & Annotation* panel, and then change the symbol to a **circle**. Select the **Use vector graphics** check box and the **All Symbols a constant size** check box, and then change the constant value to “**10**” meters. Click **OK**.



22. In *Map* view, turn on **demo wells**. Analyze in what area the majority of the producing wells are located, can you see any relation with the highlighted area? Other areas are not in favorable structural position such as the lower fault block in the Southeast portion of the structure.



23. Save your session.

Exercise 5.8: Attribute Extraction and Horizon Slicing

In DecisionSpace Geosciences, there is another way to extract attributes over the reservoir without having to create a new output horizon. An instant horizon overlay option from seismic attributes is available. This option is useful when you want to explore the continuity over time or depth of a specific attribute anomaly in the structure, or to quickly extract the attribute over the horizon for visualization without involving any statistical analysis. If you want to statistically analyze the behavior of the attributes over the reservoir, then you have to follow the steps of the previous exercise.

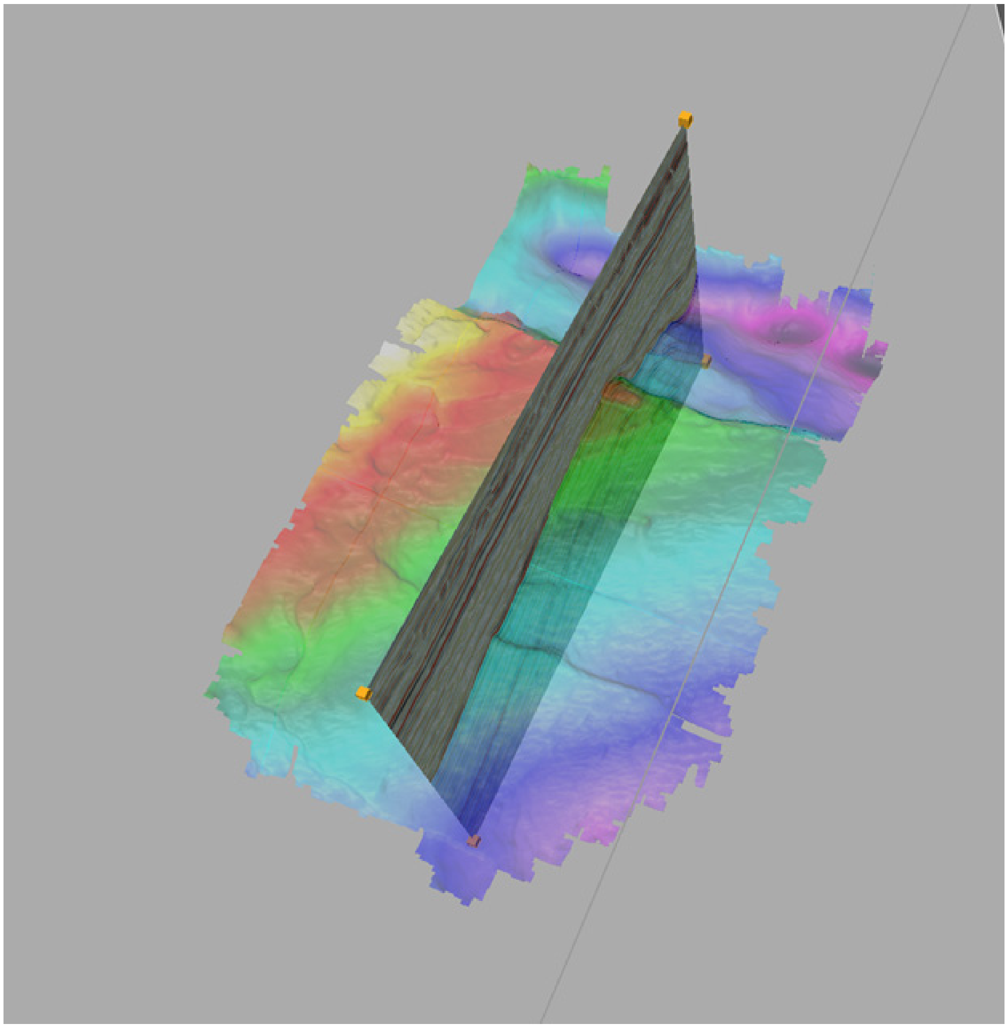
The instant volume attribute extraction is controlled directly in *Cube* view from the *Display Properties* dialog of any selected horizon. The volume(s) that you want to overlay over a horizon has to be in Shared Memory.

1. Load the volume **Far_Times_Far-Near** to shared memory. (**MB3** and select **Load to Shared Memory**.)

2. Activate and maximize *Cube* view, and toggle on only the horizon **0_DEMO_TOP_RES_TIME** and an inline probe of the **Small_offset.cmp_StrcFltr10x10** volume.

The horizon should have some opacity from previous exercises. You will remove the opacity in the following steps.

3. Adjust your *Cube* view so you can see the majority of the horizon and also some perspective of the inline. Your screen should look similar to the picture below.



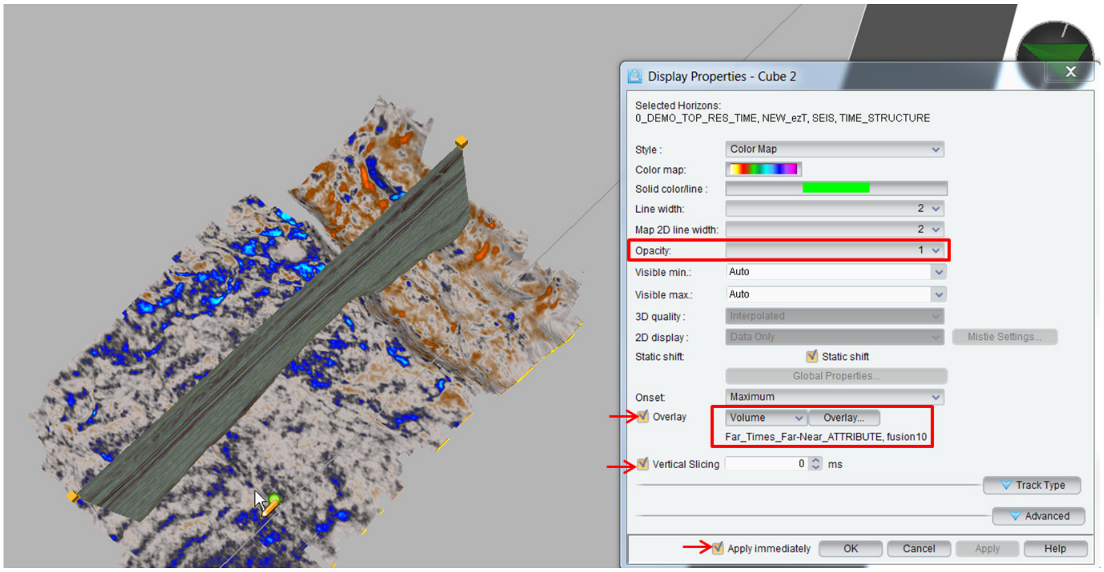
4. **MB3** on the horizon and select **Display Properties**.

5. In the *Display Properties* dialog, change *Opacity* to **1**.

6. Select the **Overlay** check box, select **Volume** from the drop-down menu, and then click the **Overlay...** button.

7. In the *Horizon Overlay Selection* dialog, go to the **Volume** tab and select the **FAR_Times_Far-Near_ATTRIBUTE** volume. Click the **Add** button and then click **OK** to close the dialog.

8. Select the **Vertical Slicing** check box. Make sure that the **Apply immediately** check box is also selected. Your *Display Properties* dialog and *Cube* view should look similar to the picture below.

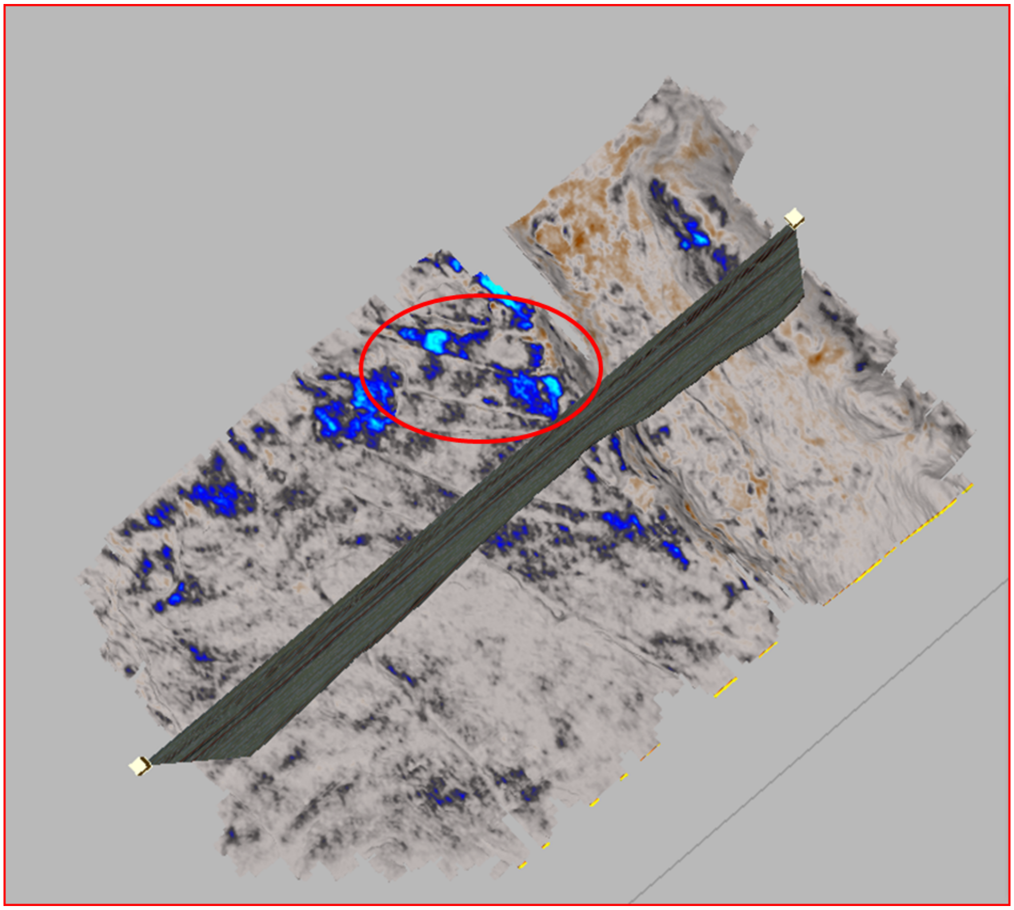


Note
In the previous picture, the bright blue colors are representing the AVO anomalies over the horizon.

9. In the *Display Properties* dialog, in the *Vertical Slicing* field, type in a value of “**20**” ms and press <**Enter**>. At this time value, you can see AVO anomalies between faults. Turn on your wells. Are wells crossing those anomalies? What else can you see at different times?

Note
You can also slice the horizon by clicking on the up and down arrows. Positive values slice the horizon downwards, negative number upwards. The arrows slice the horizon every 10 ms.

10. When you finish, deselect **Overlay** and **Vertical Slicing**. Close the *Display Properties* dialog.



11. Save your session.

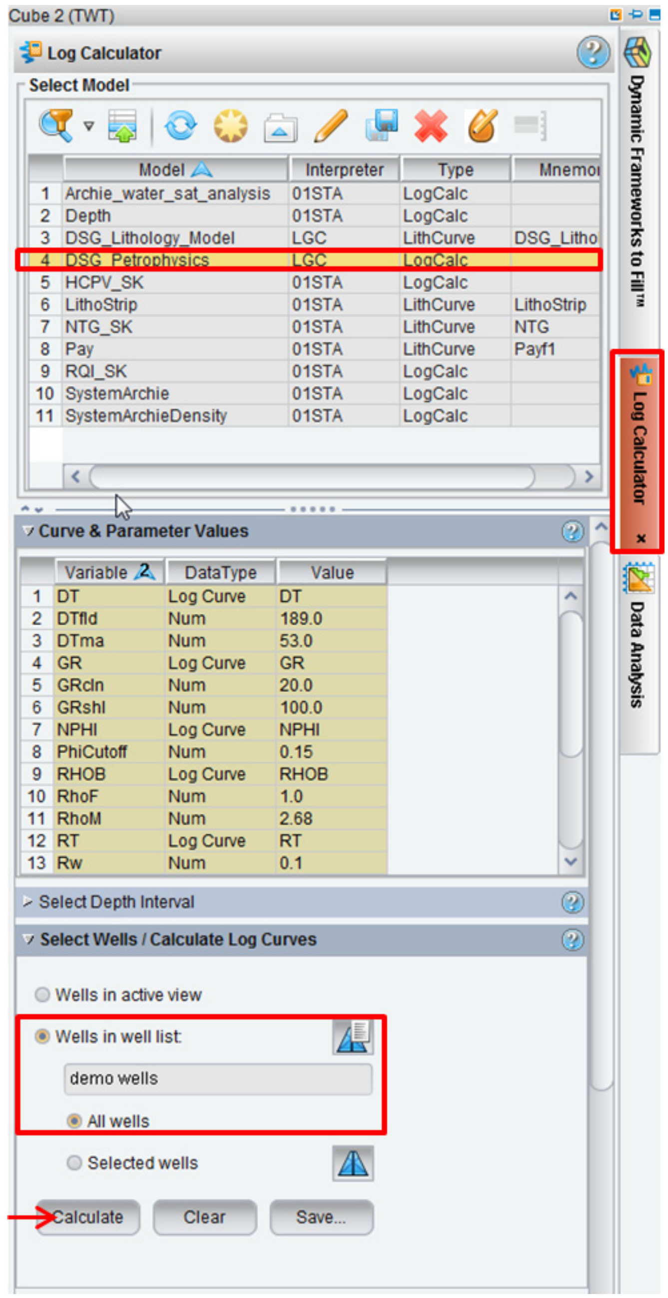
Exercise 5.9: Extracting Seismic Attributes at Well Locations

In this final exercise, you will extract the created seismic attribute at the well location using Zone Manager, and then you will compare the geophysical properties with some geological properties. For example, is there any relation between amplitudes, frequencies and porosities?

1. In the main toolbar, change the perspective to **Geology**.

2. In the *Log Calculator* task pane *Select Model* panel, highlight the petrophysical model **DSG_Petrophysics**.

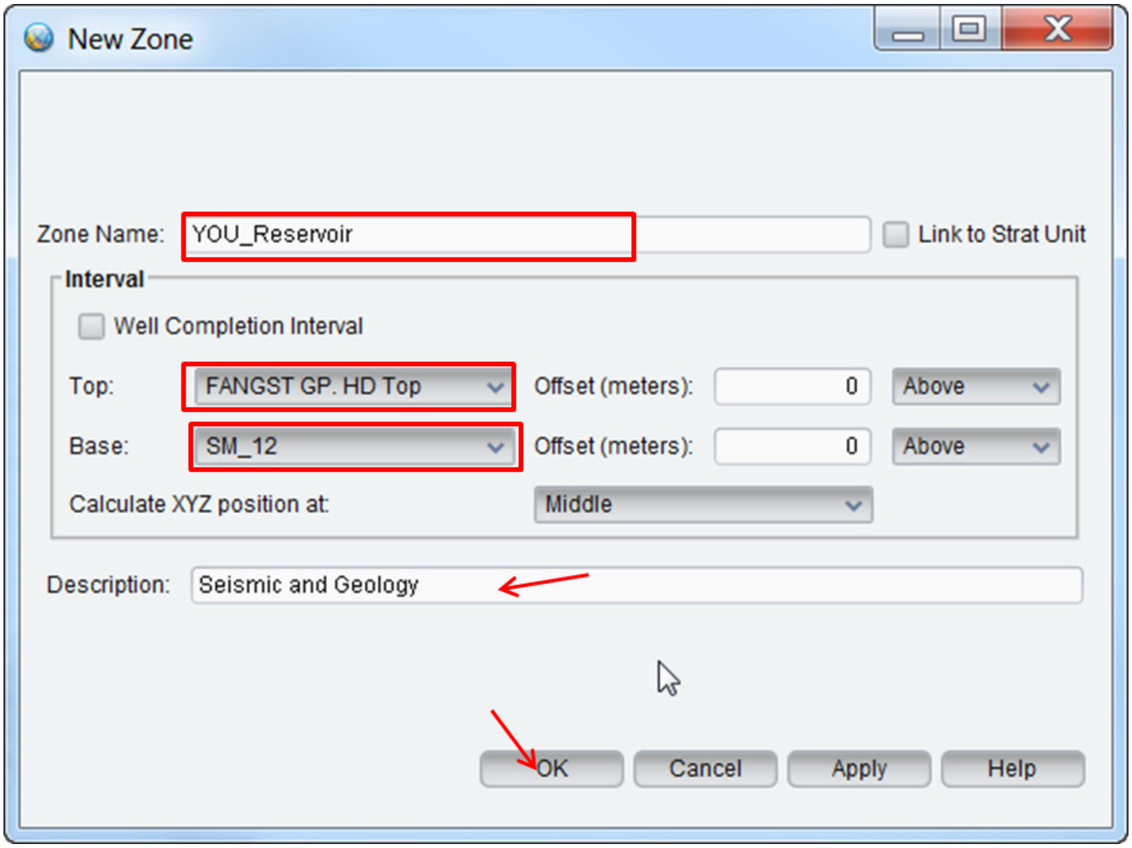
3. In the *Select Wells / Calculate Log Curves* panel, toggle on **Wells in well list** and select the well list **demo wells**. Make sure **All wells** is selected and click the **Calculate** button. See the picture below for reference.



4. Once the calculation is finished, in the main menu go to **Tools** > **Zone Manager**.

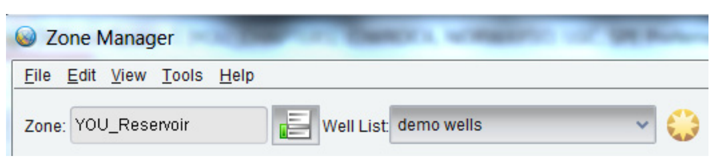
5. In the *Zone Manager* dialog, select **File** > **New Zone**.

6. In the *New Zone* dialog, give the *Zone Name* of "**YOU_Reservoir**." For *Top* select **FANGST GP. HD Top**, and for *Base* select **SM_12**. Click **OK**.



> **Note**
>
> You can also add a description of the zone.

7. At the top of the *Zone Manager* dialog, the **YOU_Reservoir** zone and the **demo wells** well list should be active. If not, manually select these options.



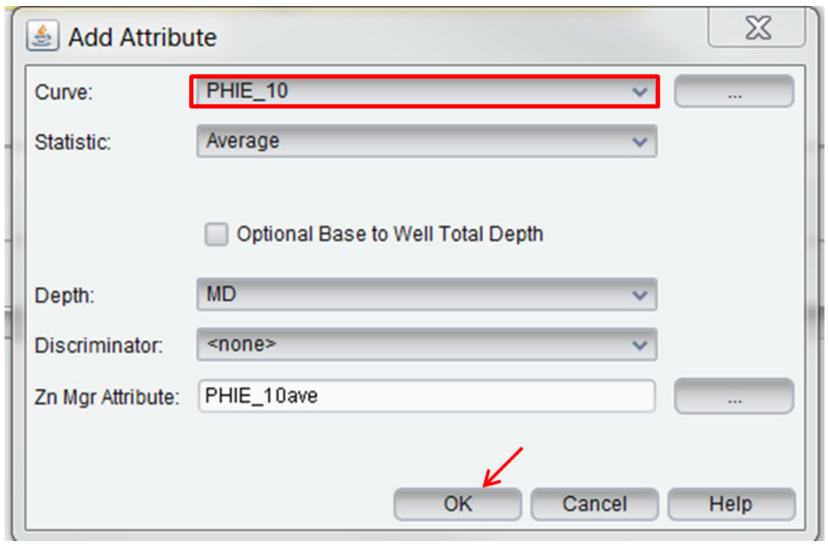
8. Click the **Calculate Zone XYZ data** ( ) icon to populate the coordinates and other information from your wells. Click **Yes** in the *XYZ Calculation Successful* dialog.

9. In the toolbar, click the **Curve Data Statistics** ( ) icon.

10. In the *Curve Data Statistics* dialog, the *Zone Definition* section should display **YOU_Reservoir**. If not, click the **Add Zone** ( ) icon to manually add **YOU_Reservoir Zone**.

11. In the *Attribute Definition* section, click the **Add Attribute** ( ) icon.

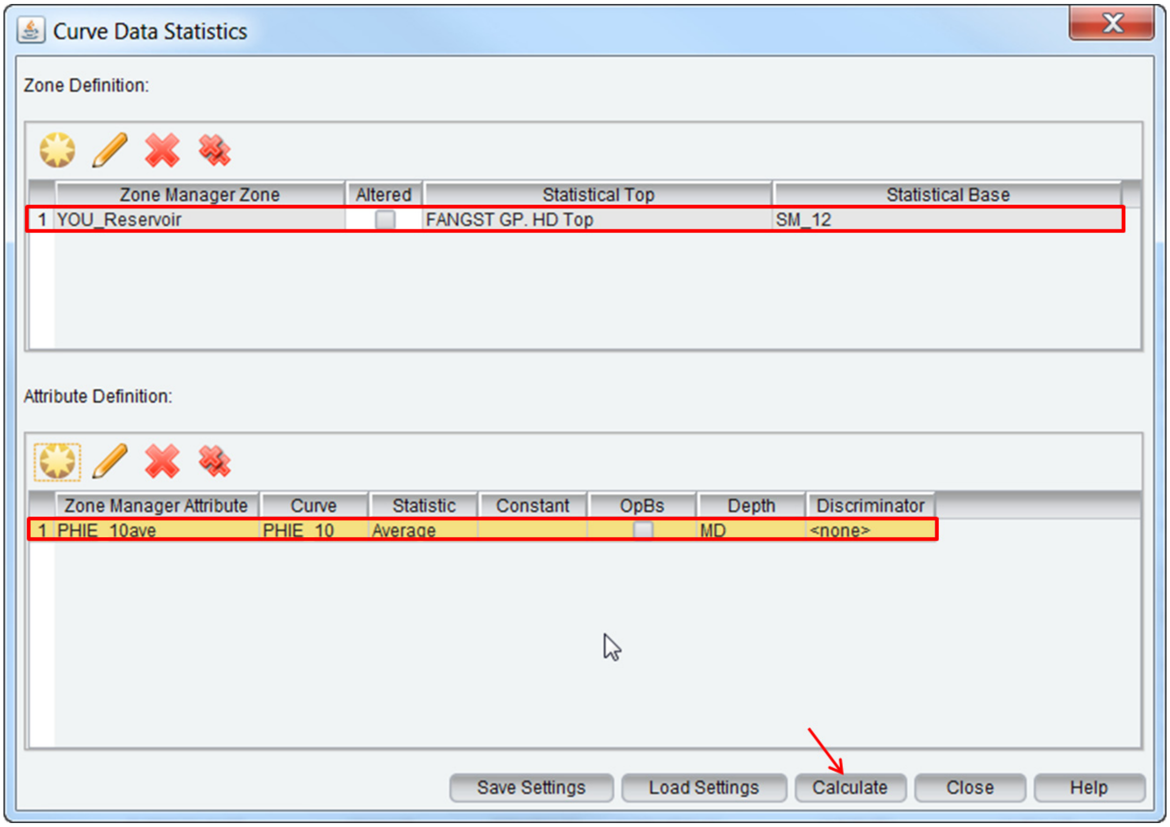
12. In the *Add Attribute* dialog, select the curve **PHIE_10** from the *Curve* drop-down menu and accept all the other defaults.



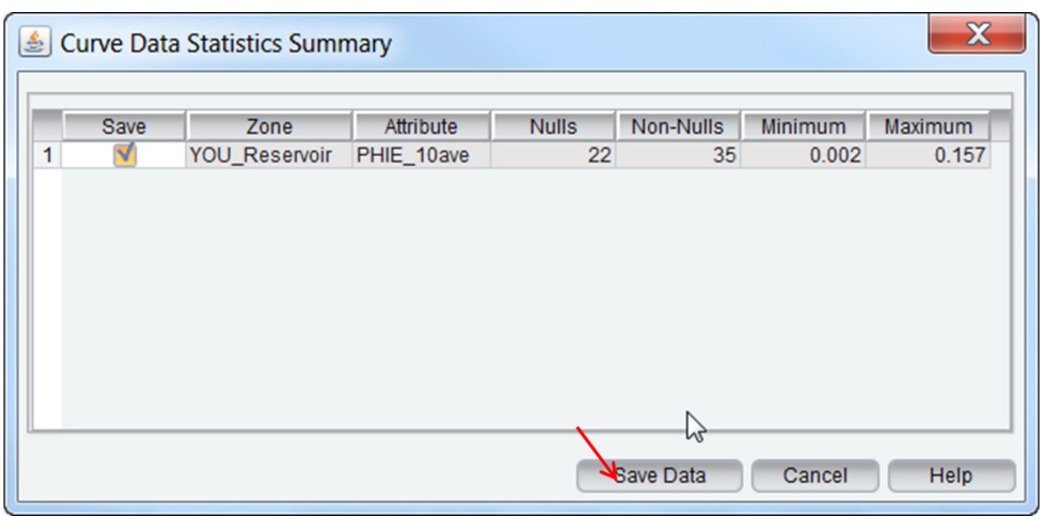
The PHIE_10 curve was one of the outputs from the petrophysical model calculation you previously ran. A new attribute will be automatically generated called PHIE_10ave.

13. Click **OK** to generate the attribute and click **Yes** to add the attribute to *Zone Manager*.

14. Your *Curve Data Statistics* dialog should look like the following picture. If it looks correct, click the **Calculate** button.



15. In the *Curve Data Statistics Summary* dialog click the **Save Data** button.



A new column should appear in *Zone Manager* showing the extracted porosity attribute along the reservoir zone. Leave *Zone Manager* open.

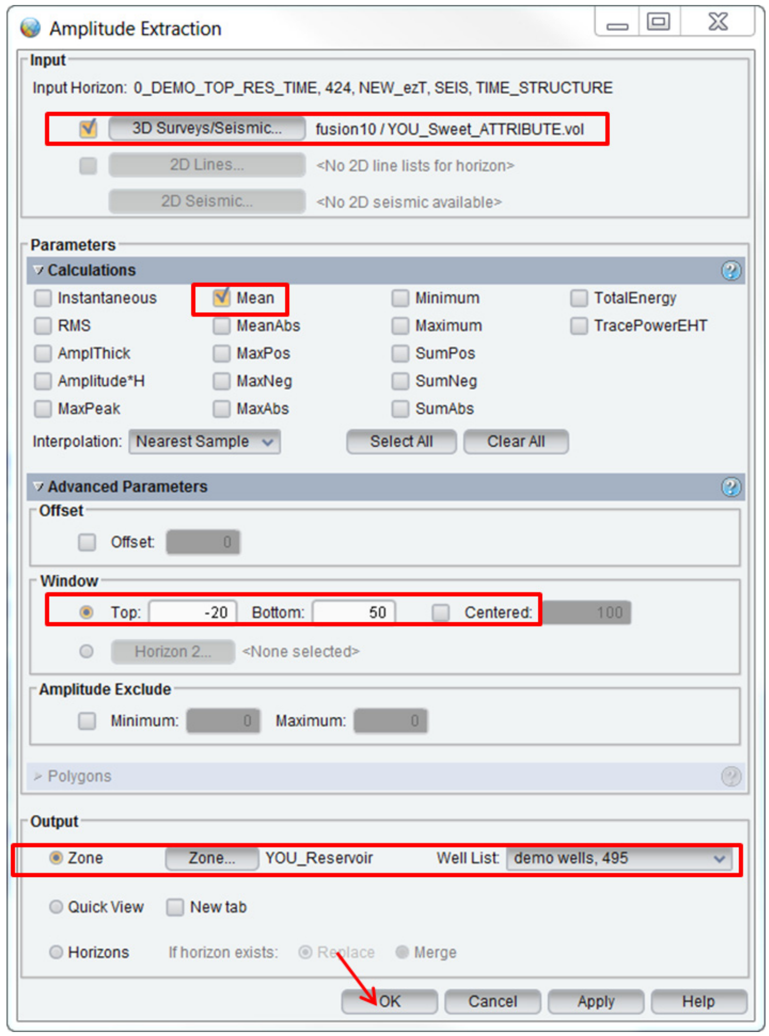
16. From the *Inventory* task pane, **MB3** on the horizon **0_DEMO_TOP_RES_TIME** and select **Calculations > Amplitude Extraction**.

17. As you have done in previous exercises, click the **3D Surveys / Seismic...** button to select the volume **YOU_Sweet_ATTRIBUTE**.

18. In the *Calculations* panel, select only **Mean**.

19. In the *Advanced Parameters* panel *Window* section, deselect the **Centered** check box and define a window with Top "**-20**" and Bottom "**50**."

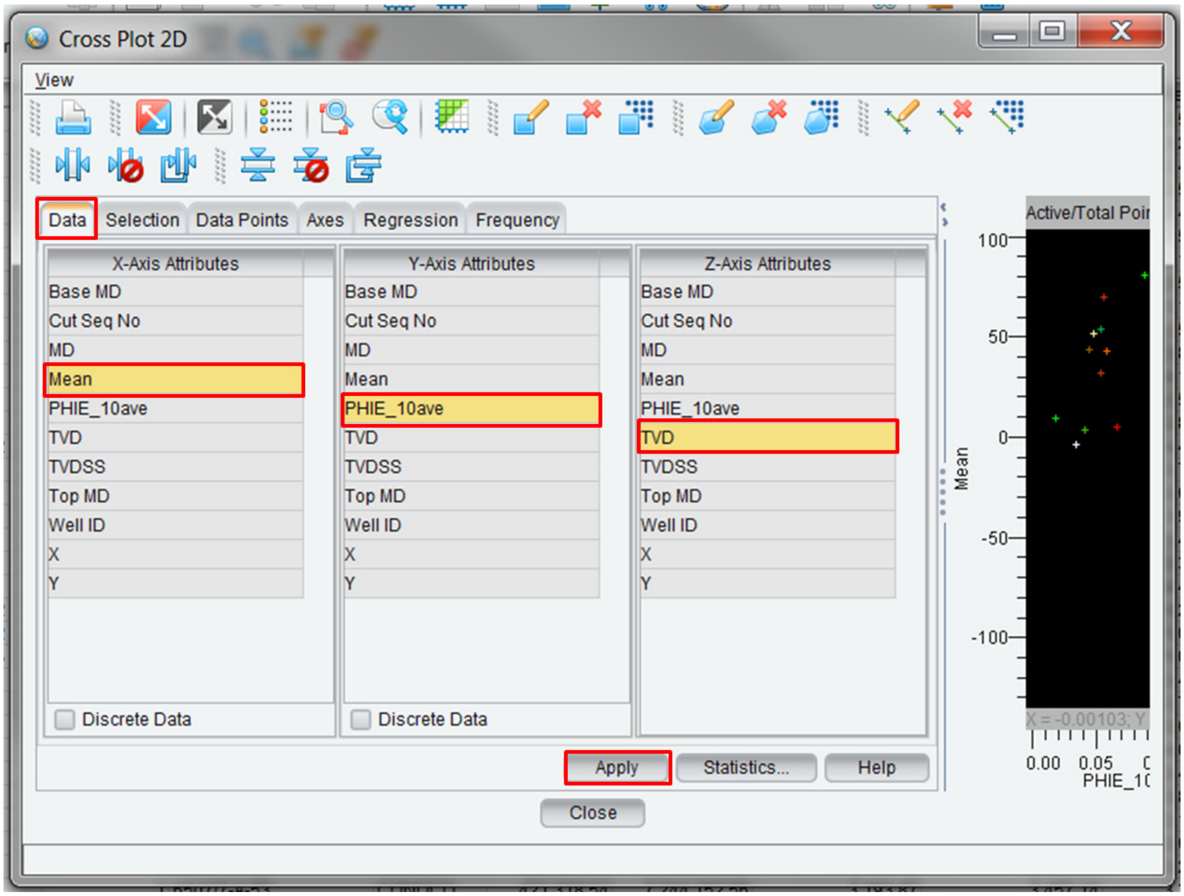
20. In the *Output* section, toggle on **Zone**, then click the **Zone...** button. In the *Select a Zone* dialog, select **YOU_Reservoir** and click **OK**. In the *Amplitude Extraction* dialog, click **OK** to extract the sweetness attribute in your wells through *Zone Manager*. Use the picture below as reference.



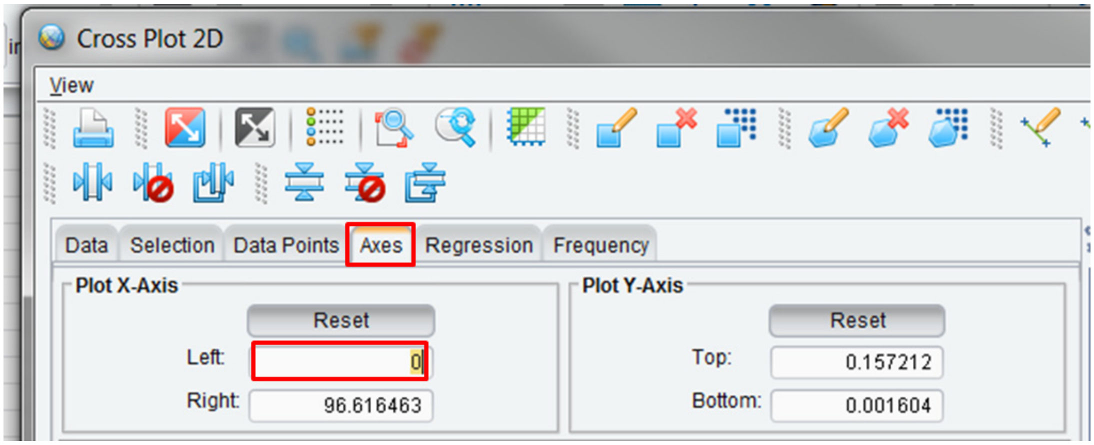
21. In the *Zone Manager* dialog, notice that there is a new column with the automatically generated name of Mean, which corresponds to the Mean Sweetness value over the reservoir window.

22. In the *Zone Manager* toolbar, click the **Crossplot 2D** ( ) icon, and set the following parameters:

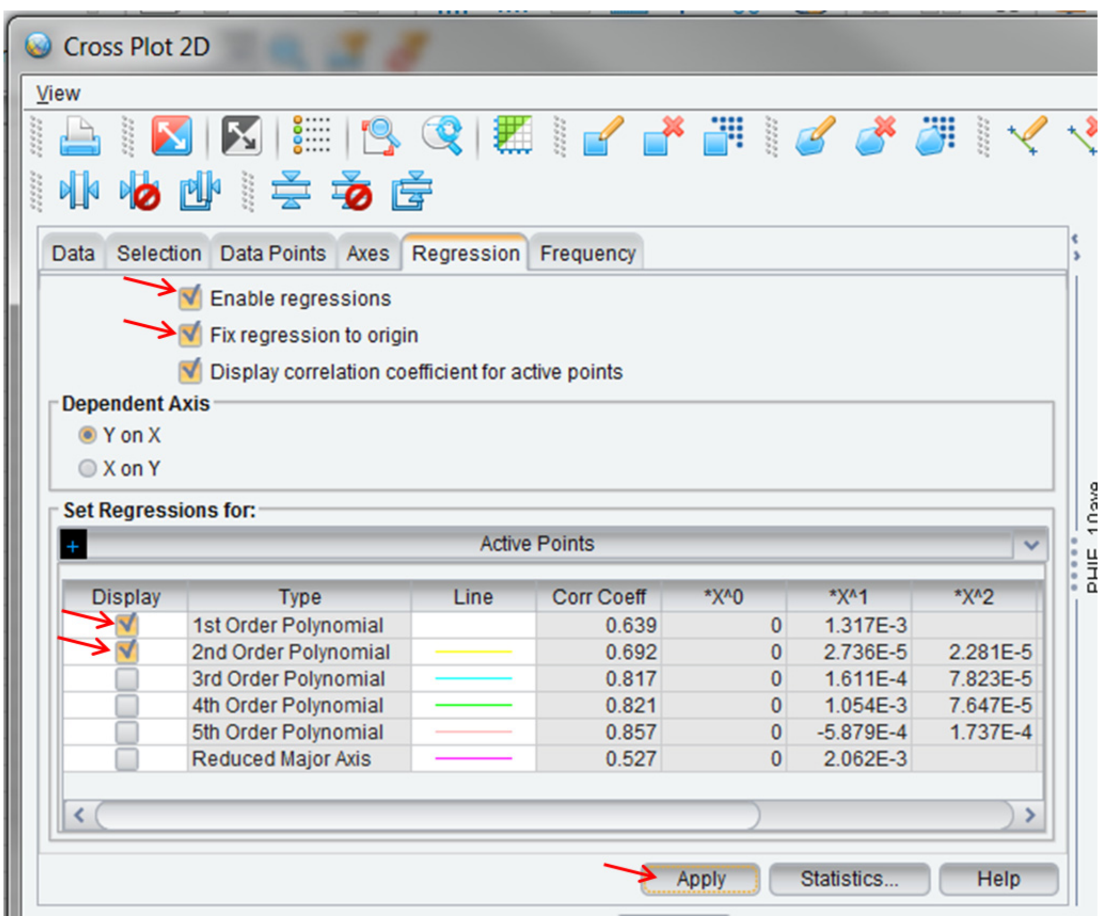
    - *Data* tab—Set X-Axis to **Mean**, Y-Axis to **PHIE_10ave**, and Z-Axis to **TVD**. Click **Apply**.



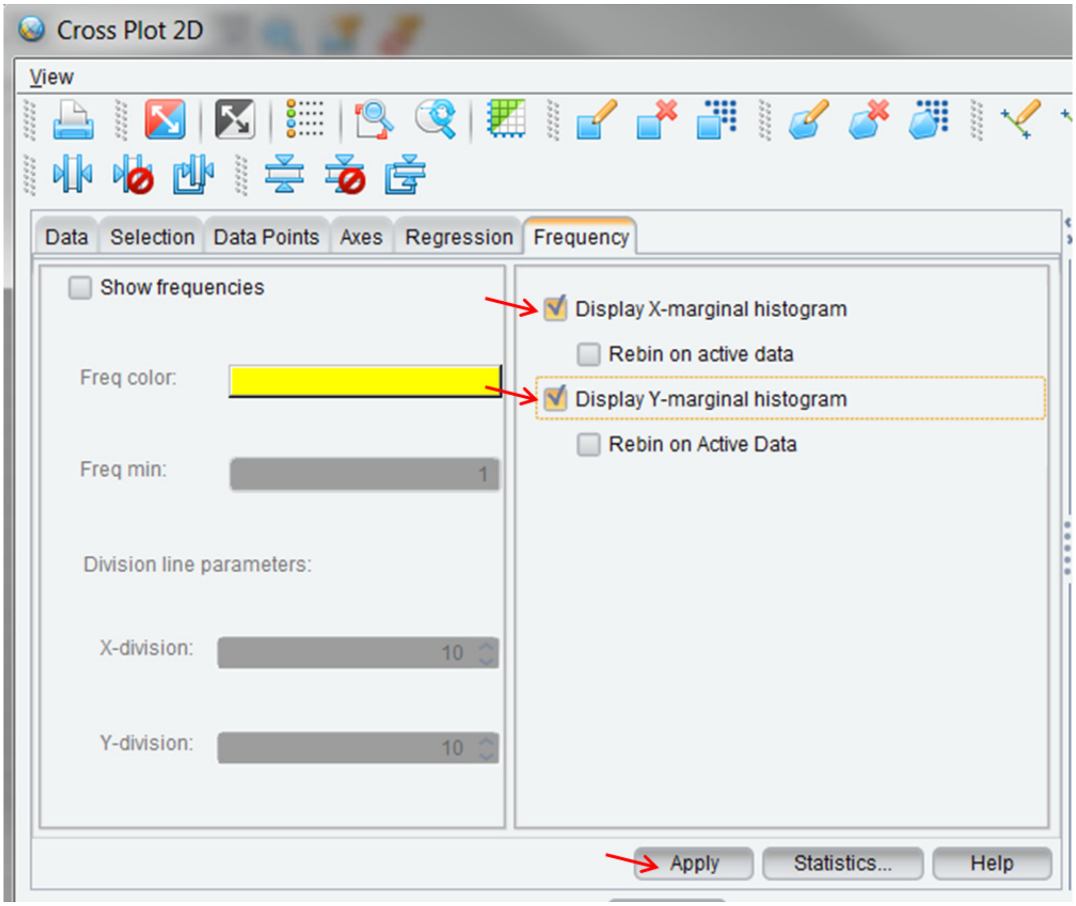
- *Axes* tab—Change the Plot X-Axis left scale to start at “**0**.” This way you will only consider positive sweetness values. Click **Apply**.



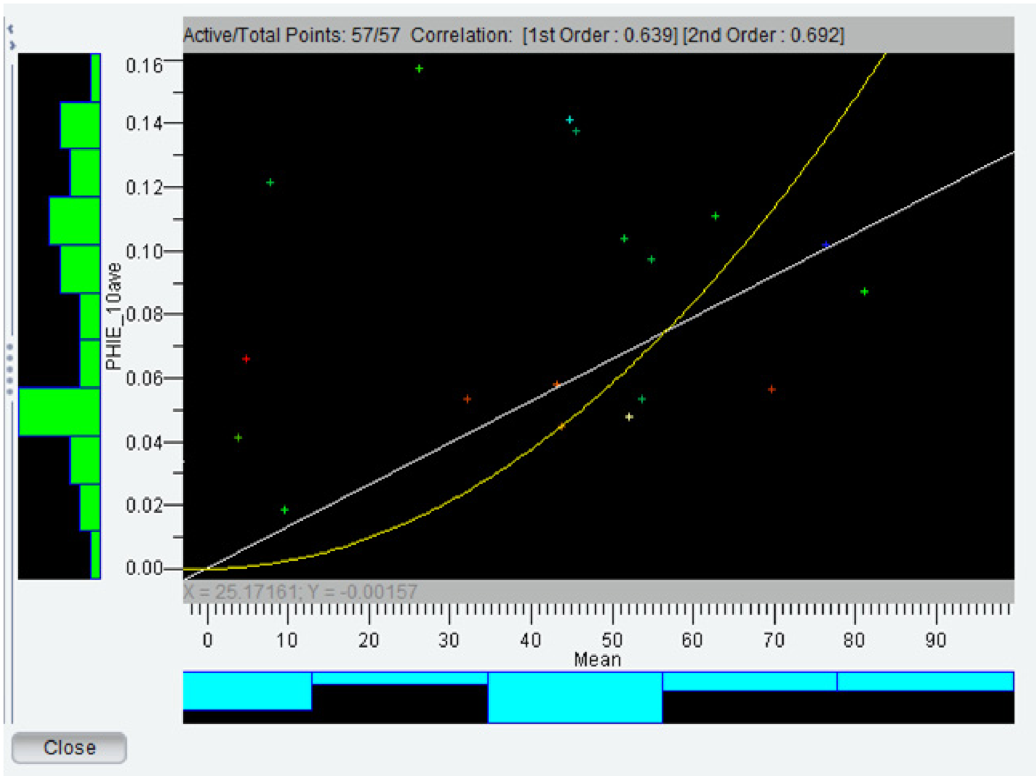
- *Regression* tab—Select all the three check boxes: **Enable regressions**, **Fix regression to origin**, and **Display Correlation coefficient for active points**. Select the check boxes next to **1st Order polynomial** and **2nd Order Polynomial**. Click **Apply**.



- *Frequency* tab—Select the **Display X-marginal histogram** and **Display Y-marginal histogram** check boxes. Click **Apply**.



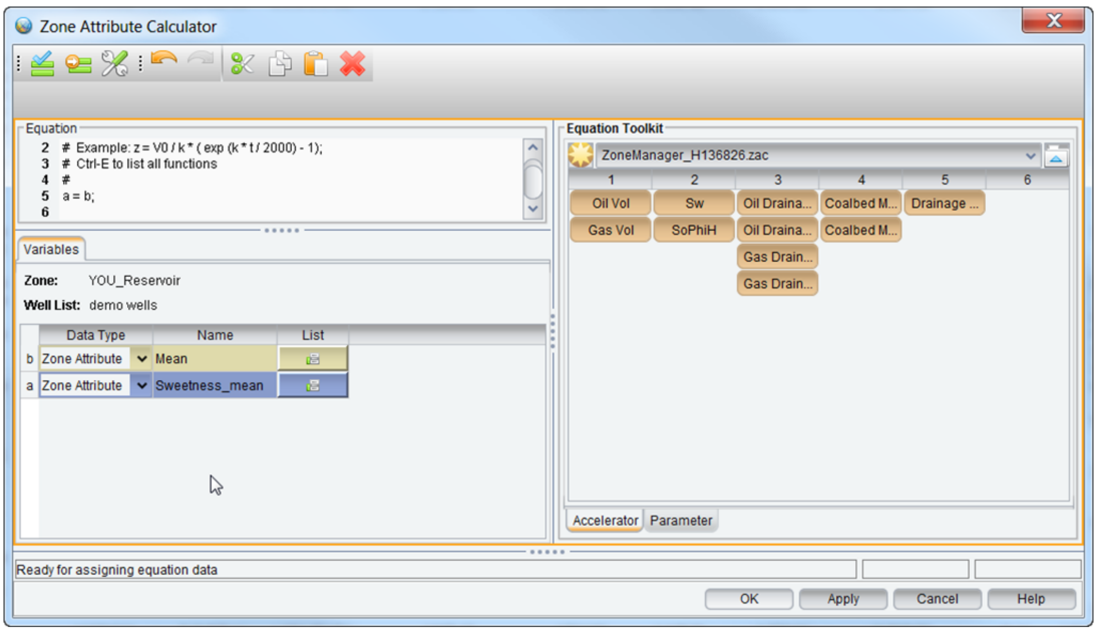
What relation are you seeing between Sweetness and effective porosity? If you have more time, experiment extracting any other petrophysical curve and any other seismic attribute.



Note

You can rename the attribute Mean in *Zone Manager* to another more distinctive name like Sweetness_Mean. To do this, do the following:

1. Click the **Zone Attribute Calculator** ( ) icon to open the *Zone Attribute Calculator* dialog.
2. Type the equation "**a = b;**".
3. Click the **Assign Equation Data** ( ) icon.
4. Define the attributes by clicking the **Definition** icon and selecting **Mean** for *a*, and type in "**Sweetness_mean**" for *b*.
5. Click **OK**.



This has to be done before extracting any other statistical Mean attribute from Amplitude Extraction; otherwise the attribute Mean will be overwritten.

In this chapter you have learned to:

- Create seismic attributes
- Analyze the seismic attributes individually in *Section*, *Map*, and *Cube* views.
- Blend different attributes in a single probe or single *Section* view.

- Use the Seismic Calculator to generate other attributes.
- Extract the attributes at the horizon level and statistically analyze them to identify sweet spots areas.
- Extract attributes directly from the volumes to study their behavior with the time or depth domain.
- Extract attributes at the well location to correlate geophysical related data with geological related data.

Chapter 6
Velocity Modeling Workflow

The *DecisionSpace Geosciences* software provides an effective approach to integrated prospect evaluation and development. The software enables you to efficiently analyze data and accurately map prospects by integrating a wide range of data and allowing you to focus on solutions that are defined by geology, geophysics, petrophysics, and reservoir models. Integrating geological and geophysical interpretation allows you to accurately map and analyze prospects, build sealed structural frameworks, reservoir models and plan wells in both traditional and unconventional scenarios.

A crucial component of this workflow is the Velocity Model, which enables you to employ a combination of geophysical data (in the time domain) and geological data (in the depth domain), in developing an accurate estimate of the geological depth structure.

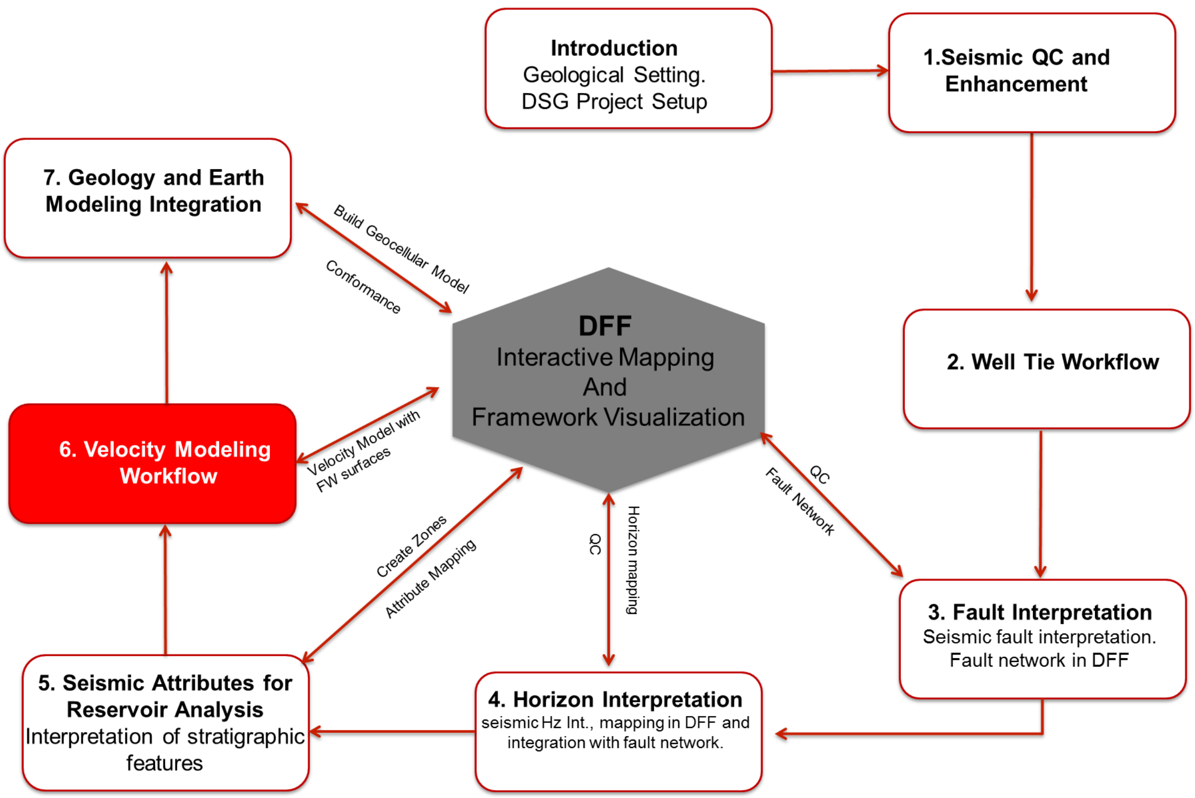
In the following chapter, you will edit Time-Depth tables and create a series of velocity models to ultimately make one comprehensive model for the structure of interest. You will be given TD curves, a seismic velocity volume, horizons with their associated picks, lithology and porosity information, and a framework of the structure. All of this data will contribute to the model and enhance the geologic accuracy. The menu on the application's left side will provide easy access to data and tools as you move through the steps.

Overview

In this chapter, you will learn to:

- ❑ 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

Workflow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QC
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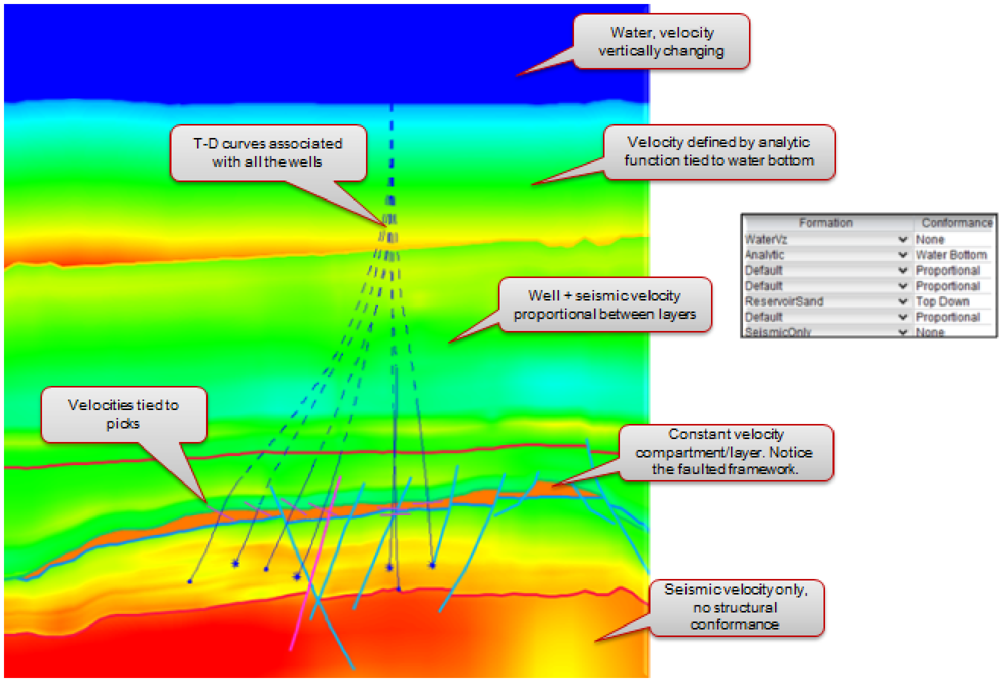
The Hybrid Velocity Model

DecisionSpace Velocity Modeling creates a Hybrid Model. The Hybrid Model format combines the advantages of variable resolutions, using both densely sampled grids and sealed topological frameworks. It is a volume data format that is ideally suited for large-scale projects with embedded complex structures. The Hybrid Model can be displayed and used for Time-Depth (T/D) conversion of horizons, faults, grids, seismic 2D and 3D data in DecisionSpace. Models generated by Velocity Modeling can also be used seamlessly within the SeisSpace® suite of processing tools. Note that a single Hybrid Model can store more than just velocity values. It can also include multiple complementary attributes, each at its own resolution within distinct structural compartments.

The Hybrid Model provides a powerful tool for creating and editing 3D velocity models. You can use the velocity modeling software to quickly build a geologically constrained velocity model for the purpose of TD domain conversion or seismic depth migration. Velocity modeling handles complex models, incorporating interpreted horizons or faulted frameworks to define the structure as well as multi-z salt bodies, allowing multiple top- and base-depth horizon input. Seismic velocities can also be incorporated into the model to define and guide the velocity trend.

The following illustration shows some of the data and model constraints that can be used in the velocity model.



Velocity Modeling Input Data

Name	Input Data Type
Structure	Interpreted horizons or Framework model (time or depth)
Formations	May be defined in the formation manager and can control velocity range, interpolation, and resolution/smoothing
Background trend	Seismic velocity
Analytic functions	$V_o + k*Z$ and other functions
Well data	TD functions and well picks

The velocity fitting works similar to the DepthTeam Express software, in which seismic velocities are used as the background trend. These are calibrated to well time/depth functions and then finally to well picks. Unlike DepthTeam Express, it uses a flexible grid that follows structure and can be defined with variable resolution between layers or in faulted framework compartments.

Velocity Modeling Output Data

The main output is a Hybrid Velocity Model, which is, by default, saved to memory. It can also be saved to OpenWorks. You can view and use the model within the DecisionSpace software. Moreover, you can also save the Hybrid Models to disk as OpenWorks bricks or shared memory volumes. You can also save the output in a SEGY file.

Apart from depth conversion and integrated geological and geophysical (G&G) interpretation, the velocity model can also be used for:

- Seismic imaging (pre and poststack time and depth migration)
- Seismic inversion
- Reservoir modeling
- Pore pressure prediction
- Fracture analysis
- AVO/AVA fluid analysis
- 4D analysis

Calibrating the Hybrid Velocity Model

Hybrid models are structural velocity models that combine the advantages of a structural framework with the dense resolution of a gridded model. The layers of the model can be parameterized separately. The DecisionSpace software can use velocity models for both static and dynamic domain conversion. The following describes how velocity models are actually constructed and calibrated.

- Define the resolution/grid cell size and the conformance of each layer or framework compartment.

> **Note**
>
> Any layers that share the same formation will have continuous velocities across the layer boundaries, while still using the internal boundaries for guiding the interpolation.

- Grid seismic velocities.

  All remaining calculations are performed on residual errors relative to this model.

- Divide the TD curves into delta velocity bins filled from the deepest to shallowest TD point, including delta velocity at all pick locations.

> **Note**
>
> Delta velocity represents the change in velocity between two stratified layers of different lithologies.

- Compute the delta velocity from the shallowest TD receiver to the surface.
- Iterate to update the delta velocity to tie each well pick.

> **Note**
>
> All extrapolation is conformal, using Shepard's reciprocal distance-squared weighting. Think of this conformal grid as many thin layers, each of which follows a conformal depth. The thickness of these thin layers is the vertical bin thickness. The spatial interpolation is continuous and shows no visible bin edges.

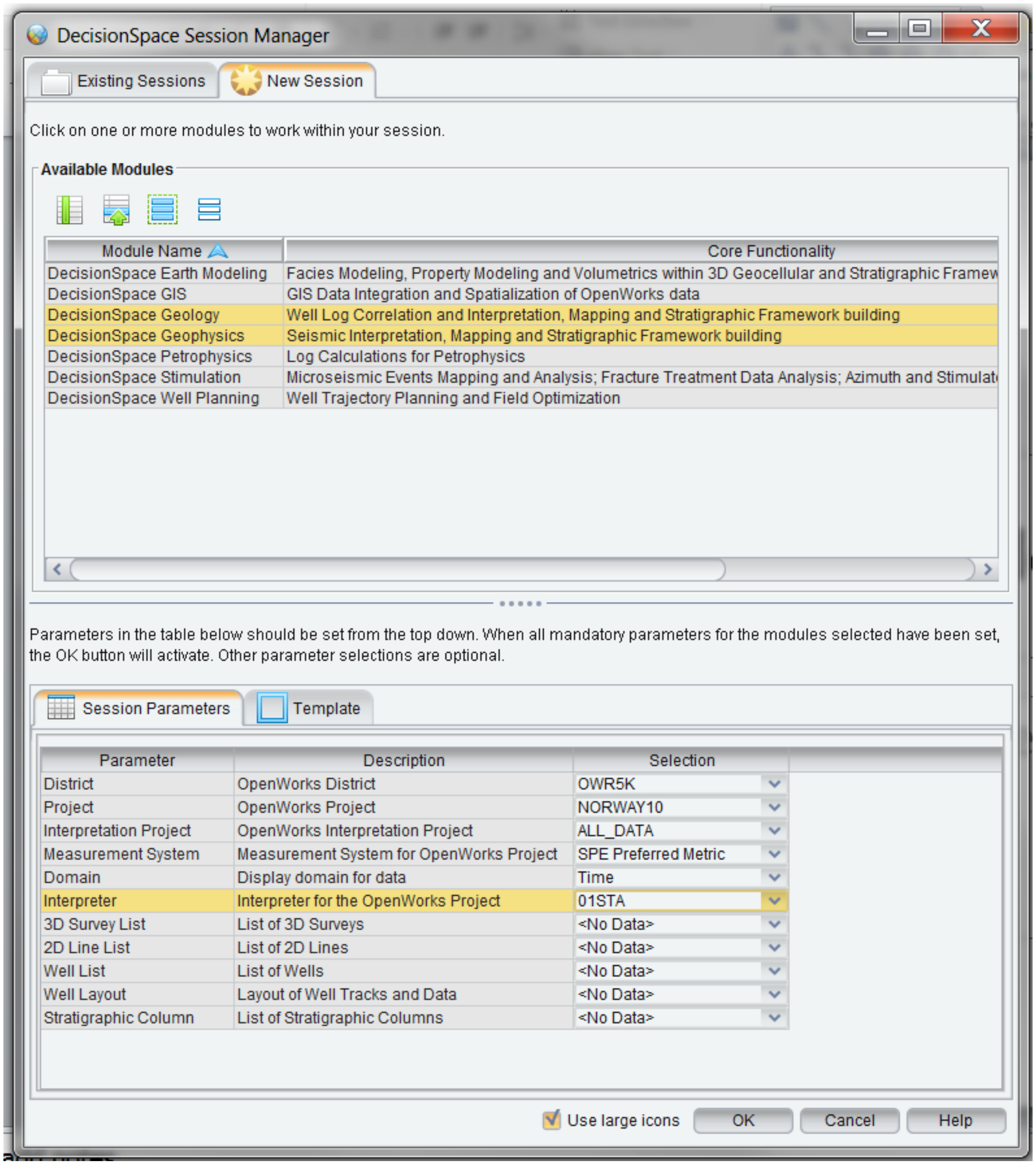
- Interpolate the delta velocities to all bin locations and apply the deltas to the background seismic velocity.
- Optionally, you can update the model with least-squares fitting.

Least-squares fitting adds no new features between wells, but distributes any errors between contradictory data. Least-squares fitting may be useful for smoothing errors around faults, salts, unconformities, and horizontal wells.

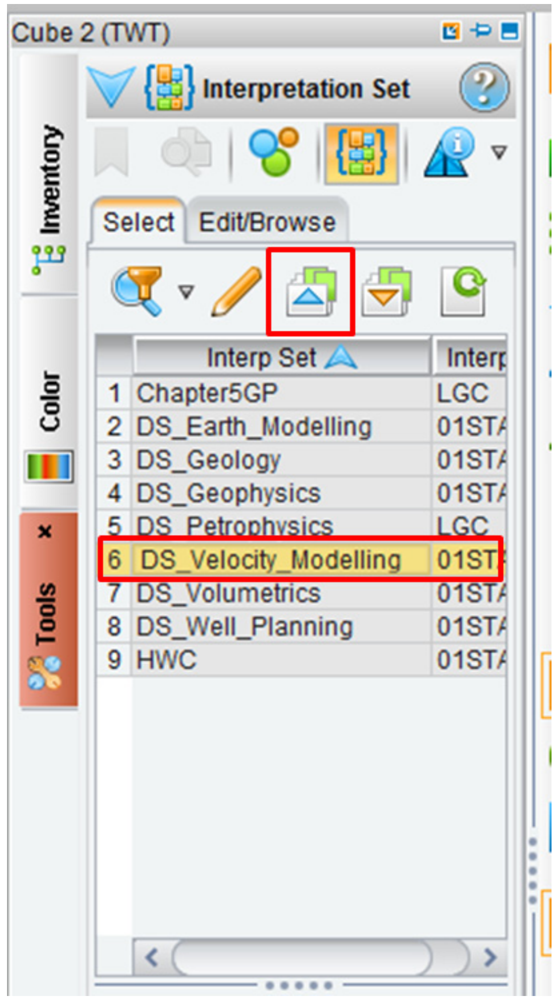
Exercise 6.1: Initializing the DecisionSpace Environment

After initializing the environment, you will be able to build many types of velocity models.

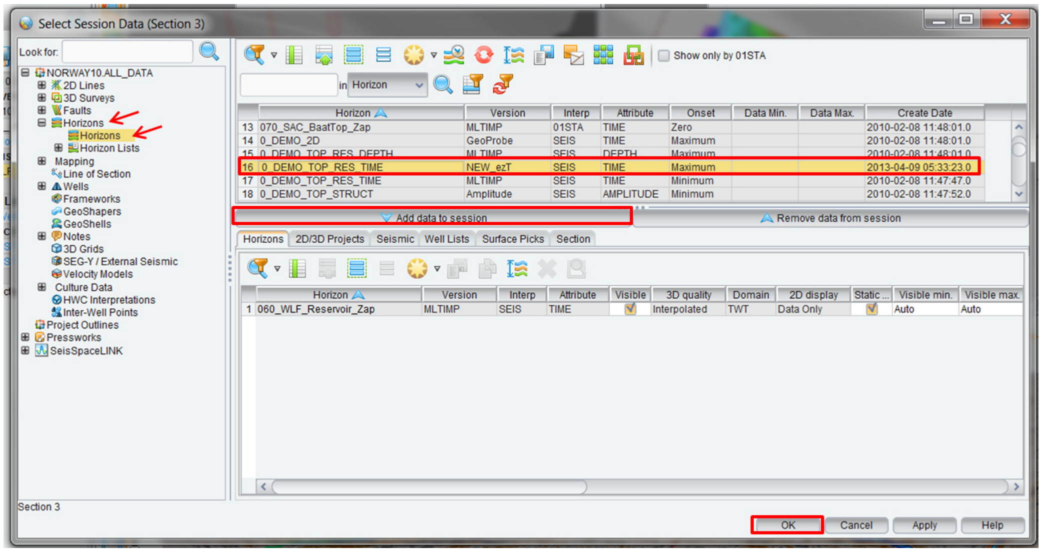
1. Start a new DecisionSpace session, select the **Geology** and **Geophysics** modules, and set up the parameters as shown in the picture below. Click **OK**.



2. Click the **Interpretation sets from tools taskbar** ( )icon. In the *Interpretation Set* task pane, select the **DS_Velocity_Modeling** ISet and click the **Load Data to Session** ( ) icon.



3. To add an additional horizon, click the **Select Session Data** () icon in the main toolbar. Navigate to **Horizons > Horizons** and select **0_DEMO_TOP_RES_TIME, NEW_ezT**. Click **Add data to session** and then click **OK**.



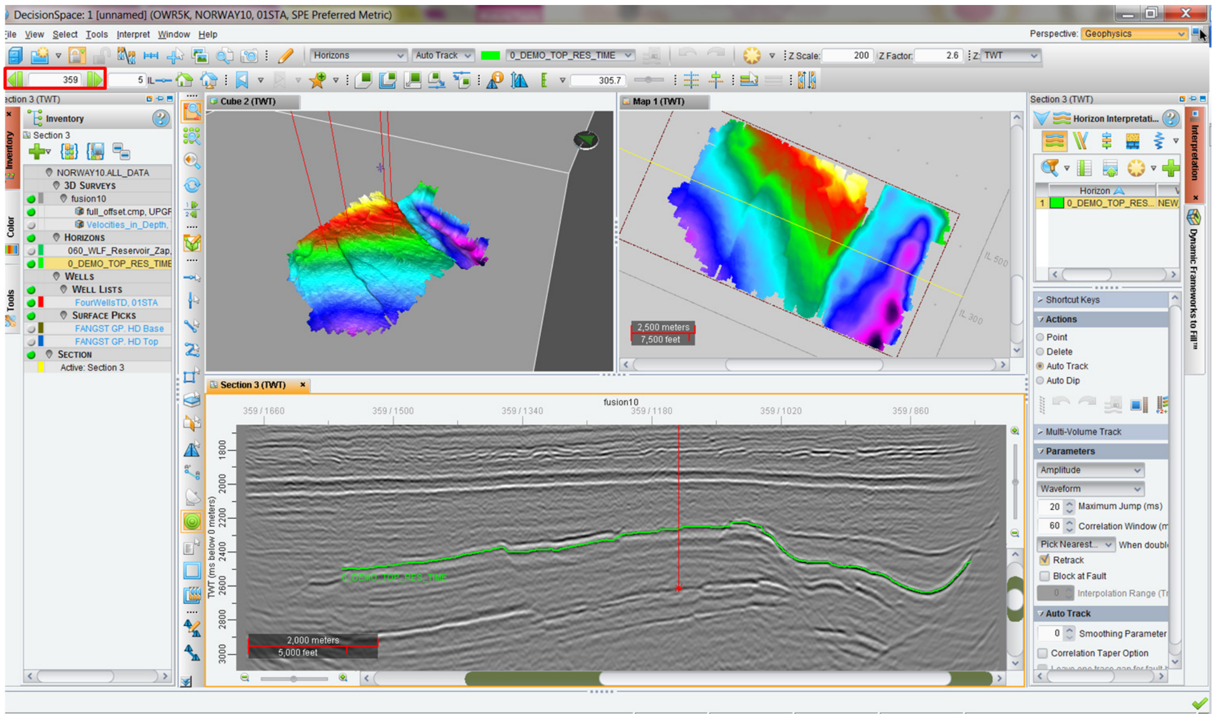
4. Set up your session by toggling on the following data items in your *Inventory* task pane:

- *Cube* view:
  — Horizon: **0_DEMO_TOP_RES_TIME**
  — Well List: **FourWellsTD**
- *Map* view:
  — Horizon: **0_DEMO_TOP_RES_TIME**
- *Section* view:
  — Seismic volume **full_offset.cmp**
  — Well List: **demo wells**
  — Horizon: **0_DEMO_TOP_RES_TIME**

> **Note**
>
> Alternatively, you can use the horizon that you created in Chapter 4, YOU_TOP_RES.

5. From the *Inventory* task pane highlight, and then drag-and-drop the **full_offset.cmp** into your *Section* view. Using *Display Properties*, change the color palette to **System > greyscale**. Using the frame control, navigate to **Inline 359**.

   Your session should look similar to the following image.

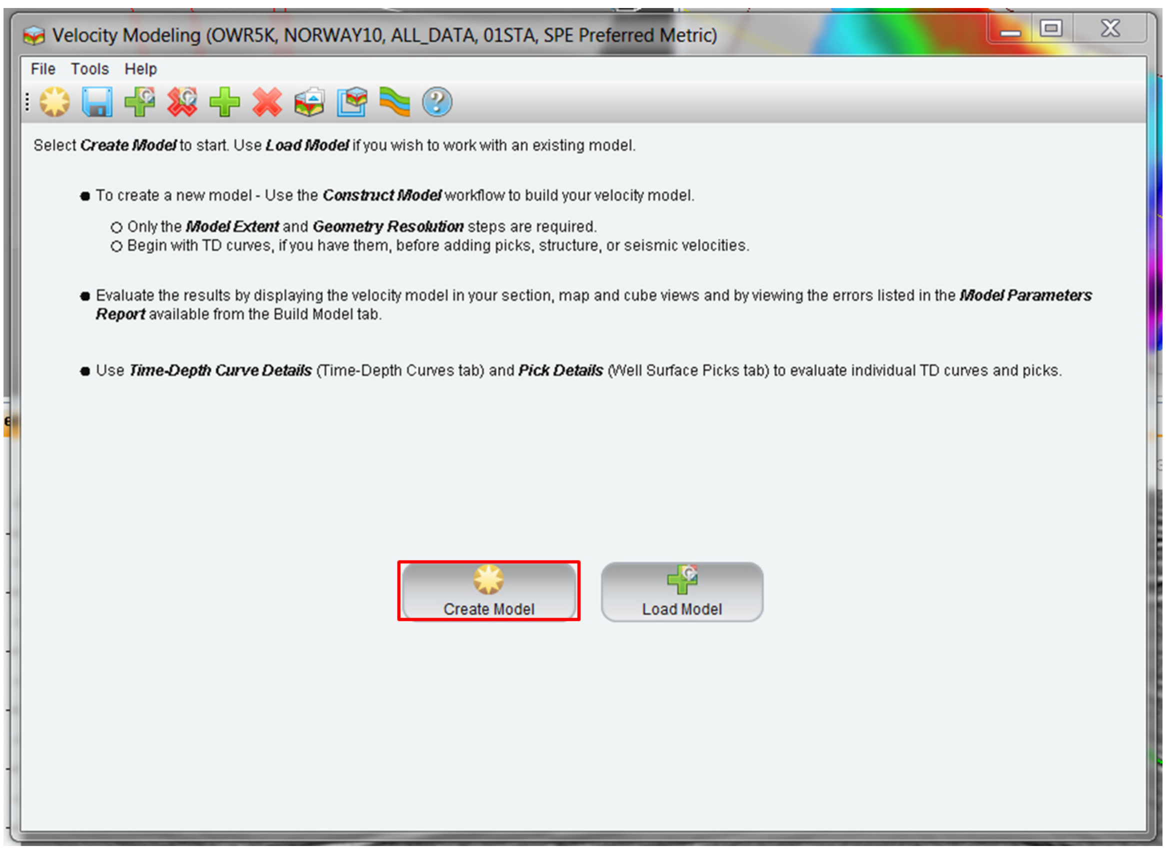


Exercise 6.2: Building and QCing a Quick Well T/D Velocity Model

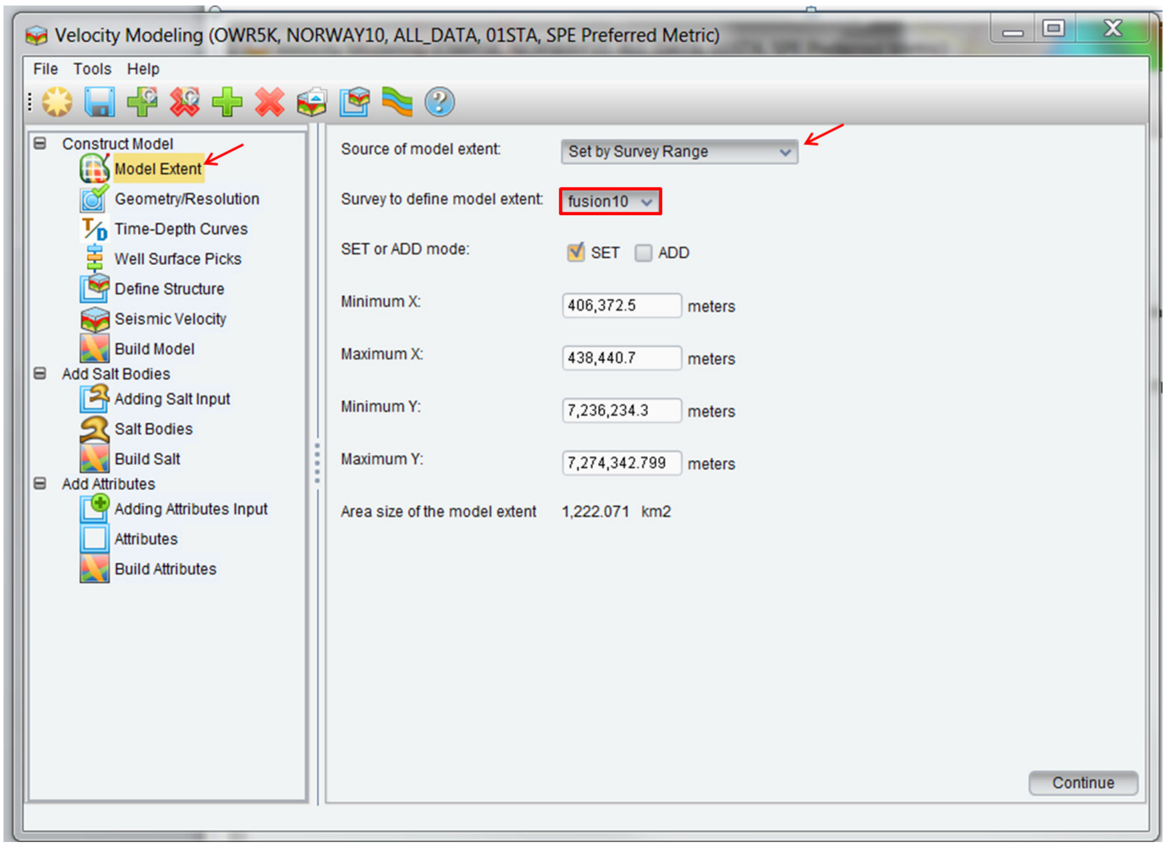
In this exercise, you will build and review a quick well T/D velocity model using the well with the optimal T/D function (e.g., a sonic log that is check-shot calibrated) and key structure layers. If the geology is consistent, the velocity model will be valid. This means it follows the structure and there is no bad data or velocity mistie from other wells with poor or noise T/D functions.

1. In the main menu, select **Tools > Velocity Modeling**.

2. In the *Velocity Modeling* dialog, click the **Create Model** button.

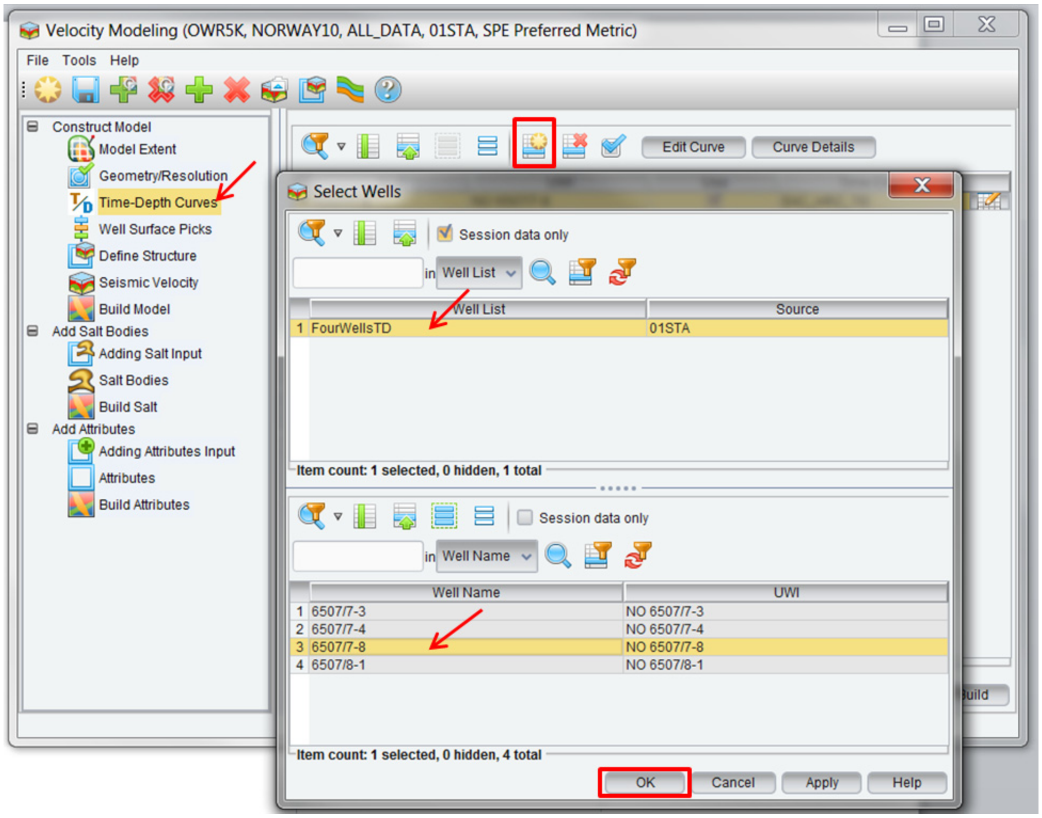


3. With *Model Extent* highlighted in the left pane, set *Source of model extent* to **Set by Survey Range**. Set *Survey to define model extent* to **fusion10**.

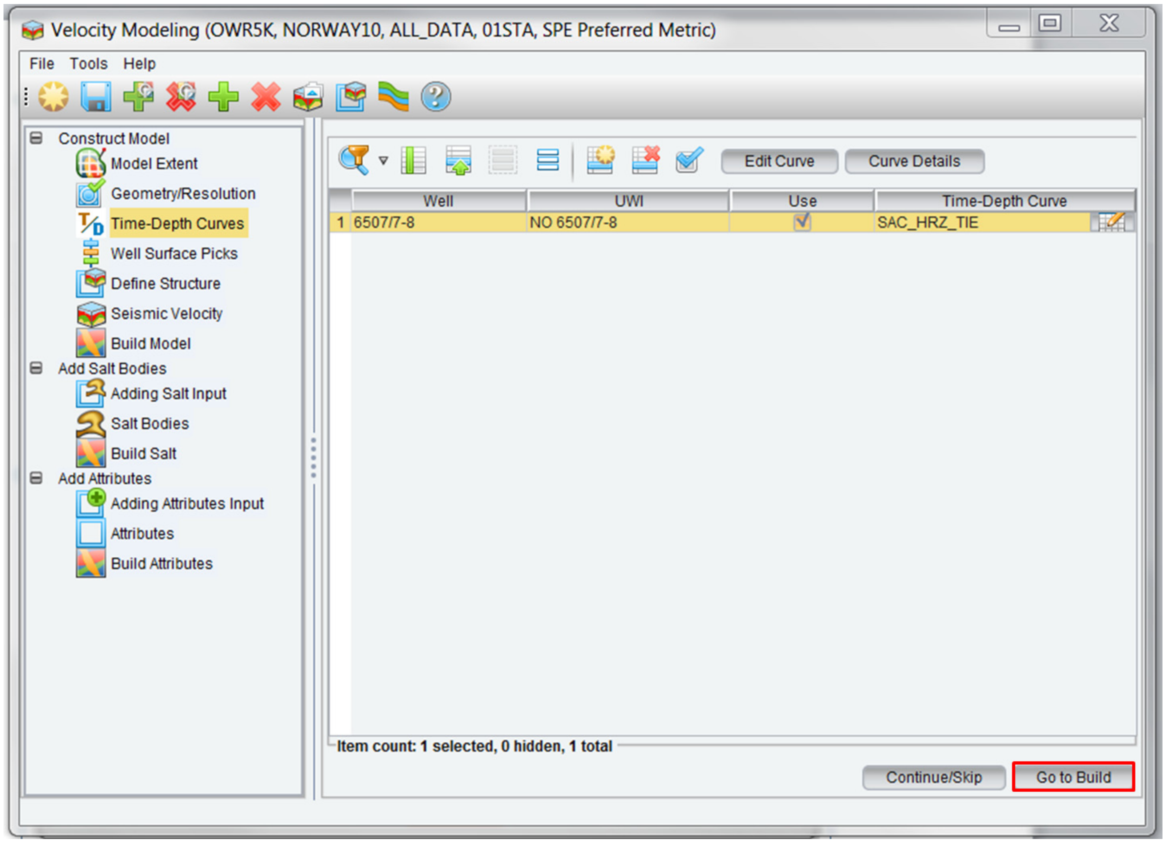


4. In the left panel, highlight **Time-Depth Curves** and then click the **Add Wells** () icon.

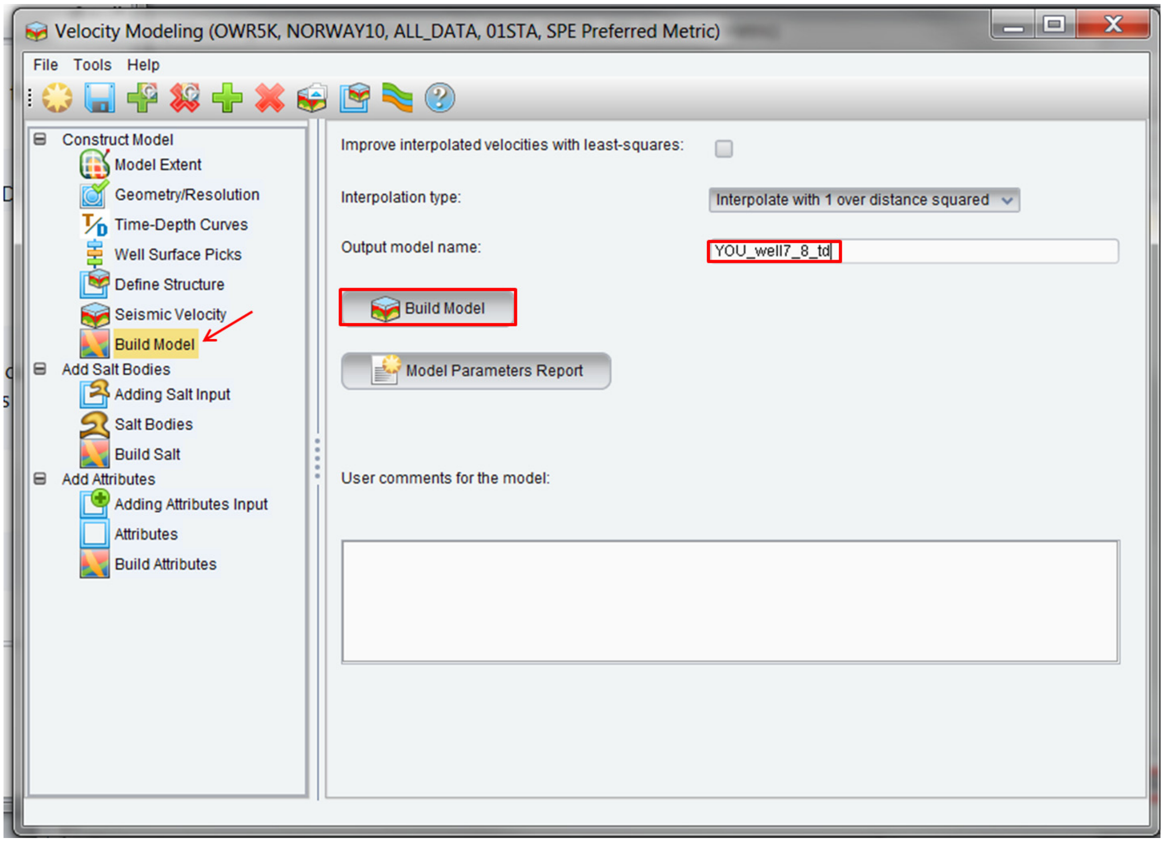
5. In the *Select Wells* dialog, highlight **FourWellsTD** in the top panel, and highlight *Well Name* **6507/7-8** in the bottom panel. Click **OK** to select the well and close the dialog.



6. At the bottom right of the *Velocity Modeling* dialog, click the **Go to Build** button.

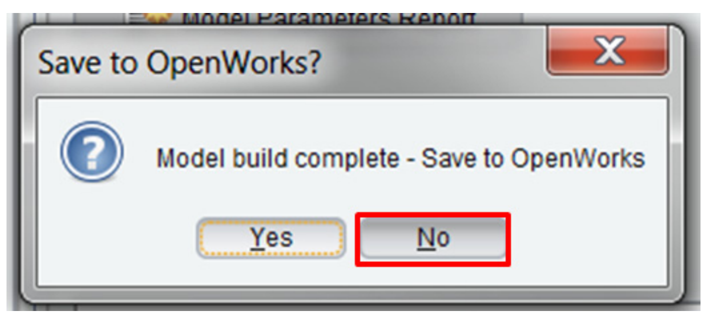


7. In the *Build Model* pane for *Output model name*, enter the "**YOU_well7_8_td**." Click the **Build Model** button.



A progress bar opens to display the status of the build.

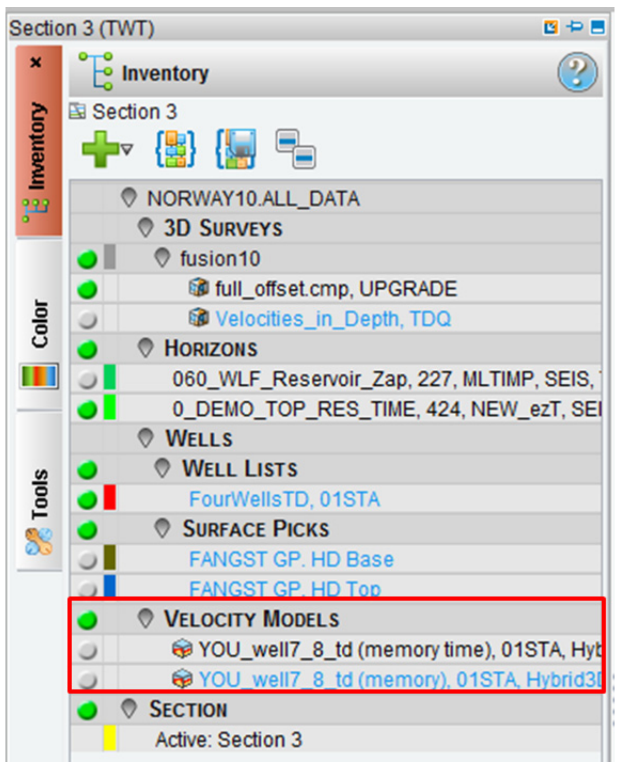
8. When the build is complete, the *Save to OpenWorks* dialog prompts you to save to OpenWorks. Click **No**.



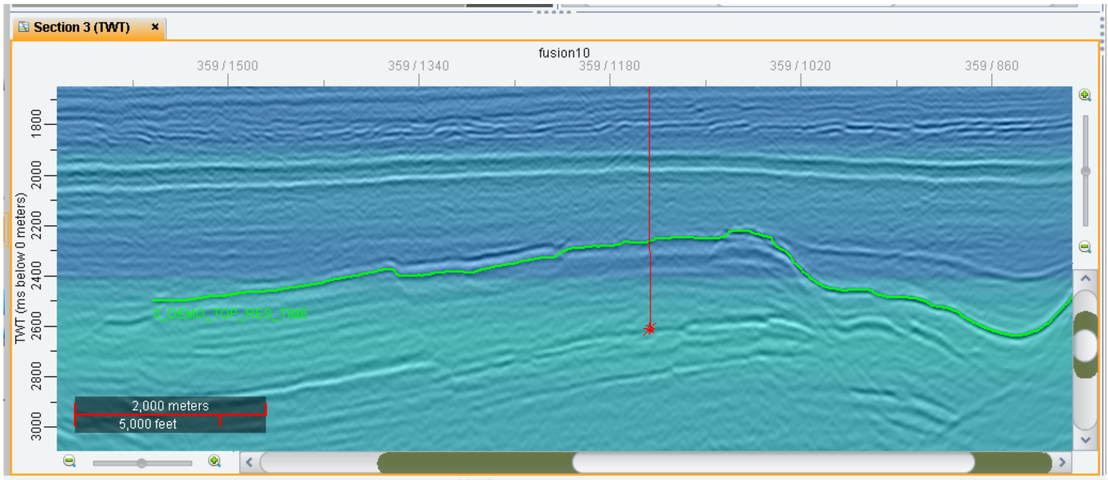
Note

By selecting No, you are able to review and work with your models available in RAM and later decide which ones, if any, you want to keep at the end of the session.

In the *Inventory* task pane there is a new header called *Velocity Models* with two new velocity models in the section. These models are the same exact model, however one is in time (black) and one is in depth (blue) so you can display the model in either domain. Both are labeled (memory) because they have not been saved to the database. Now you will overlay the velocity model on the seismic section.

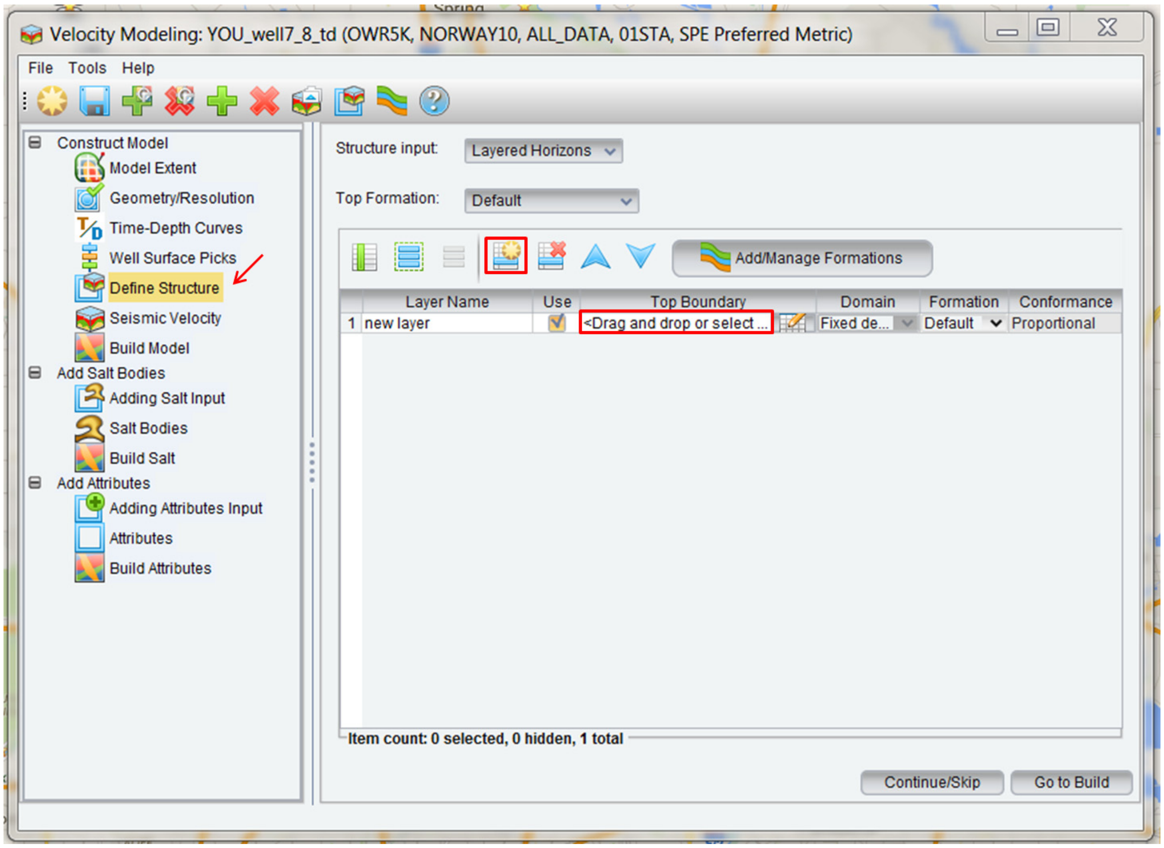


9. With *Section* view active, in the *Inventory* task pane, toggle on **YOU_well7_8_td (memory time)**.

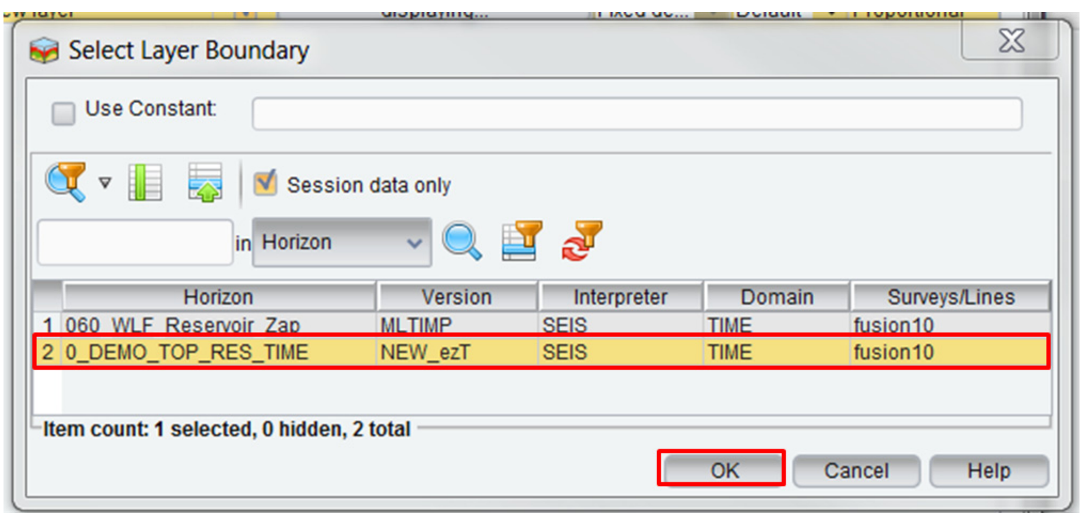


You can see that the velocity model is constant laterally because it is made from only one TD function. Although it is accurate at the well location, you can see that the 0_DEMO_TOP_RES_TIME horizon has some structure. Therefore, you will add that structure layer into the model.

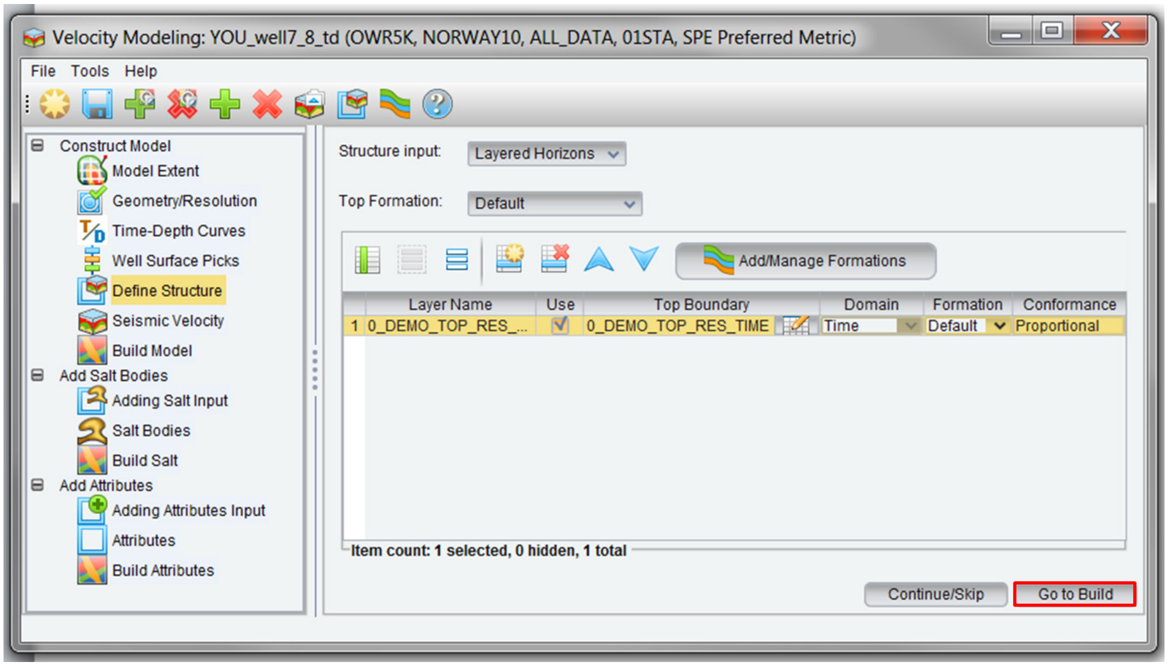
10. In the *Velocity Model* dialog, highlight **Define Structure** in the menu panel. Click the **Add Row** ( ) icon. Then double-click the **Top Boundary** field.



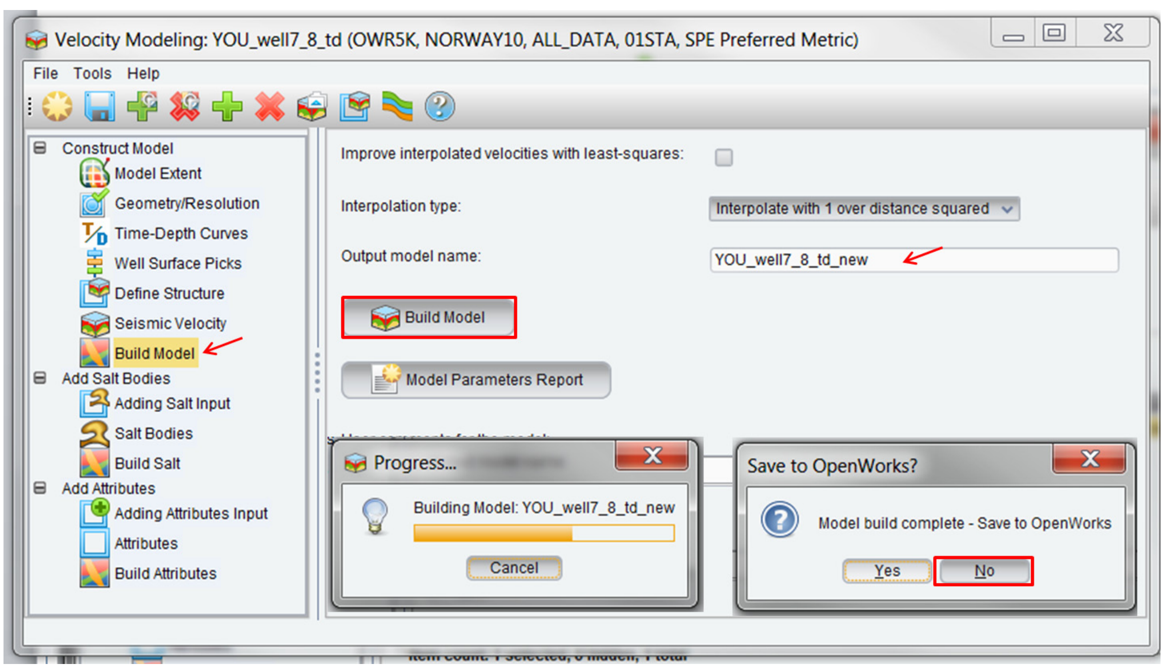
11. In the *Select Layer Boundary* dialog, select **0_DEMO_TOP_RES_TIME** and click **OK**.

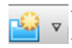


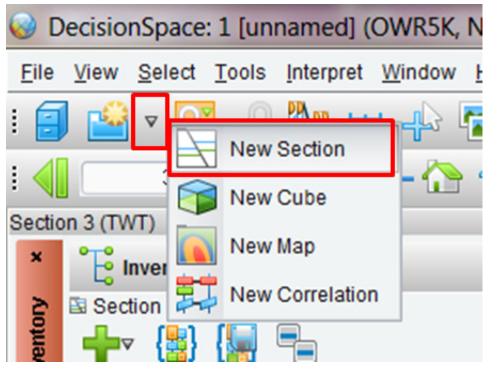
12. In the *Define Structure* panel, click **Go to Build**.



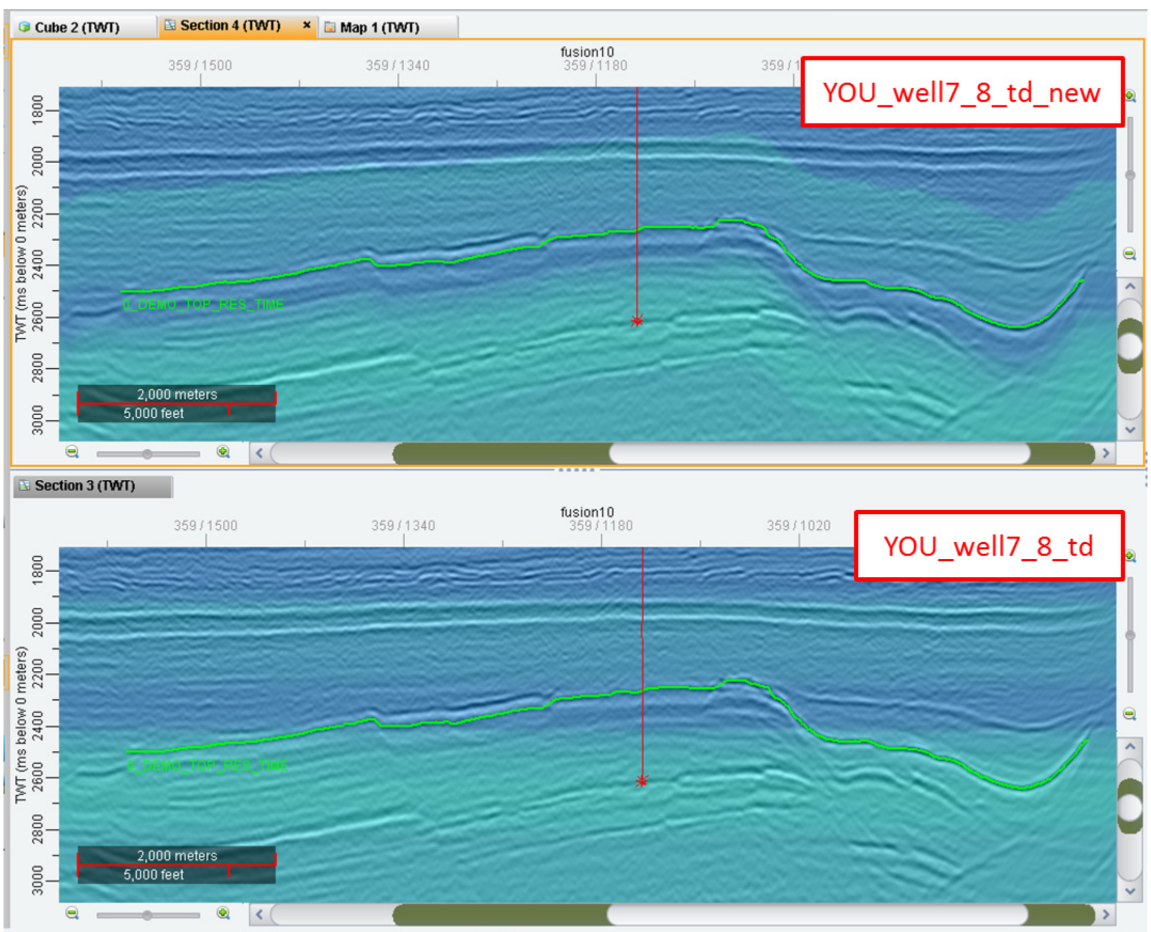
13. In the *Build Model* pane, rename the model to "**YOU_well7_8_td_new**." Click **Build Model**. The *Progress* dialog opens. When the build completes, select **No** in the *Save to OpenWorks* dialog.



14. To compare the two models, open a new *Section* view by selecting the arrow next to the New Tab () icon in the main toolbar and then selecting **New Section**.



15. Arrange the *Section* views as shown below. In the top *Section* view, toggle on **YOU_well7_8_td_new (memory time)** from the *Inventory* task pane.



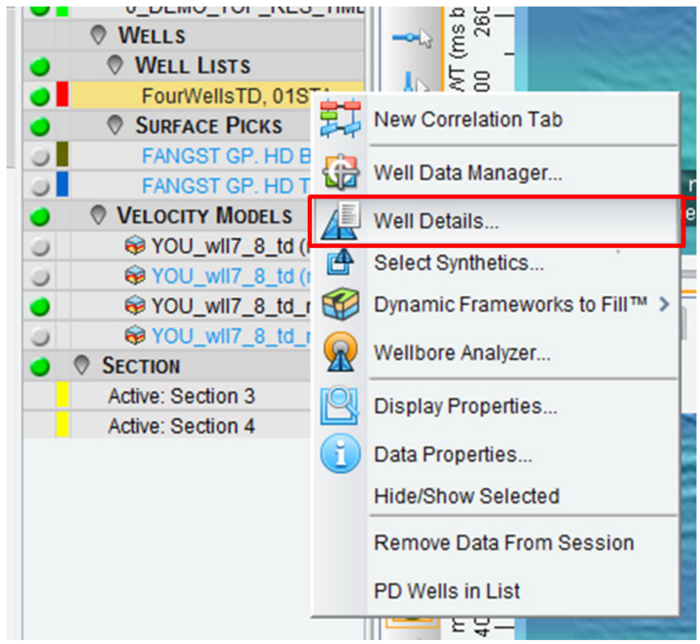
The low-velocity layer (light blue) accurately follows the reservoir top layer in the model with the single layer structure. However, it extends into the non-productive zone to the right of the major fault and into the lower structure water zone to the left. In addition, the velocity does not correctly follow the layer above the reservoir.

It is better and more realistic than the flat-layer model (which has no structure). However, more structure and velocity information is still needed to build a better model.

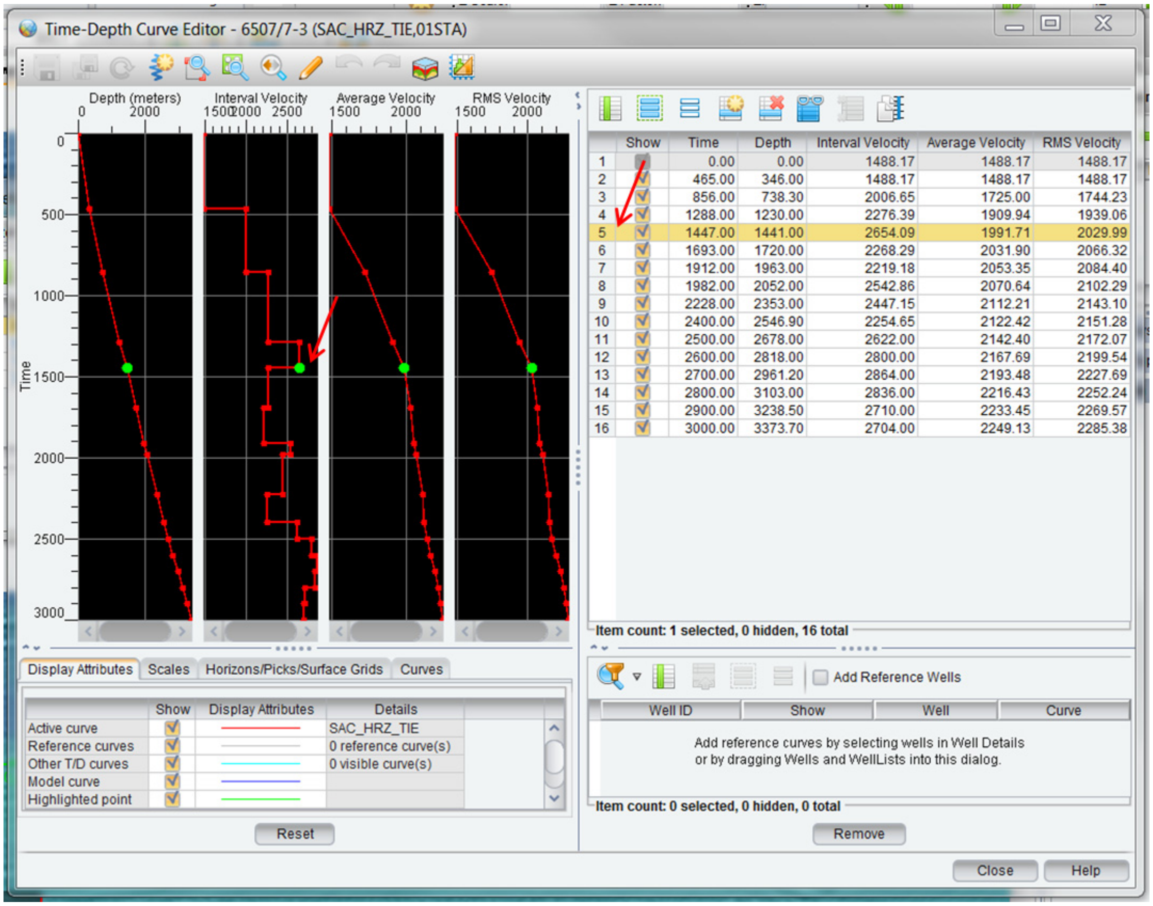
Exercise 6.3: QCing and Editing Time-Depth Tables

If the velocity varies between wells, you should include more than a single well in the velocity model. Before adding wells, it is best practice to QC the input well data.

1. In the *Inventory* task pane, **MB3** on **FourWellsTD** and select **Well Details...**.



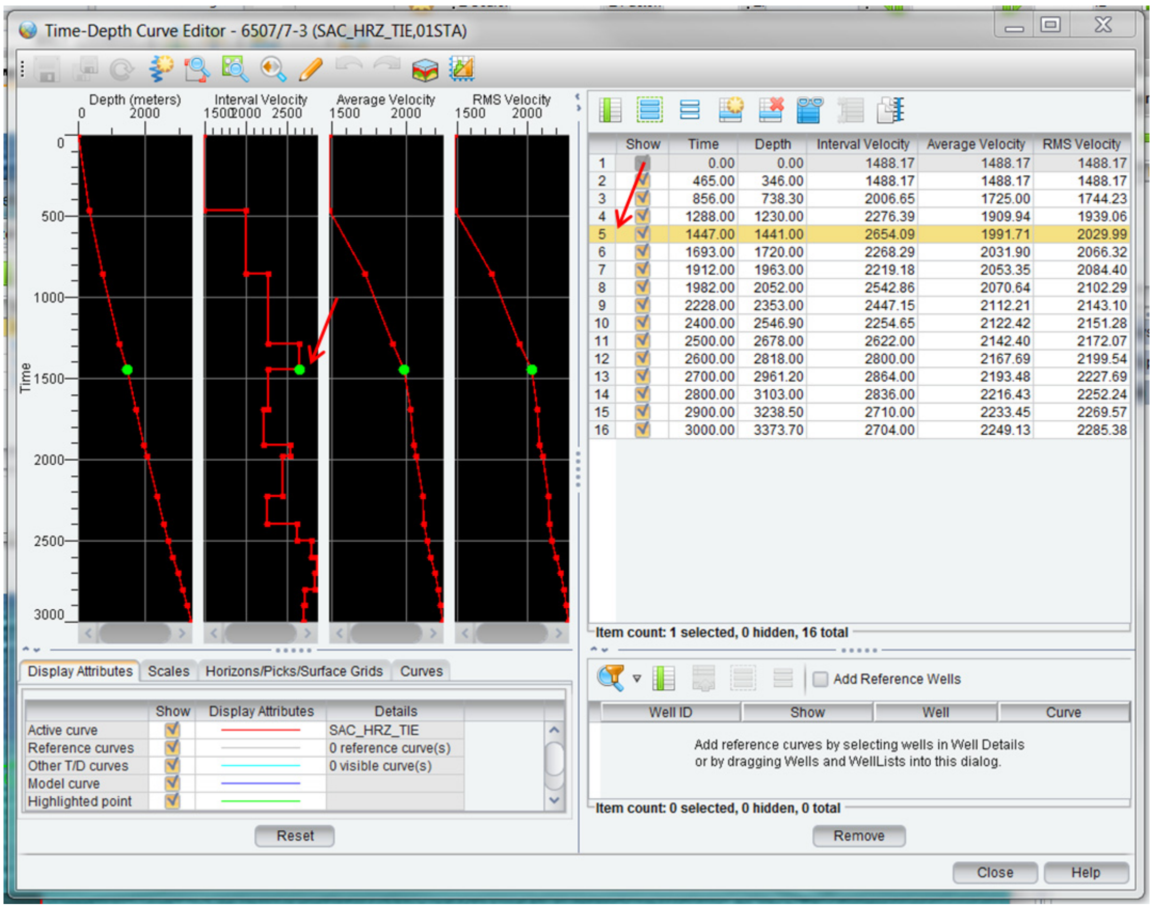
2. In the *Well Details* dialog, highlight well **6507/7-3** and click the **Time-Depth Curve Editor** ( ) icon.



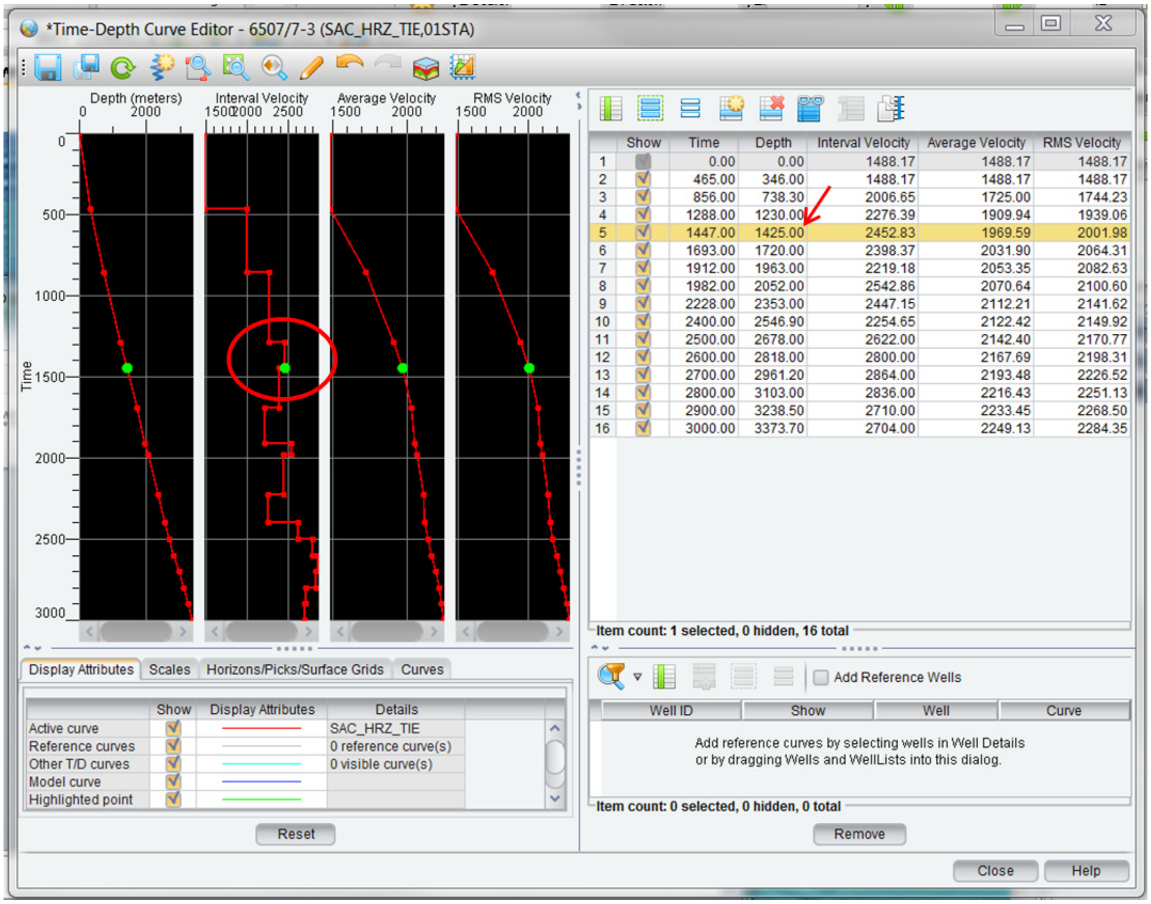
> **Note**
>
> The preferred TD should be set to SAC_HRZ_TIE. If not, click the **Preferred TD field** to access the drop-down menu and select **SAC_HRZ_TIE**.

The *Time-Depth Curve Editor* dialog opens with the Time Depth table displayed as Depth, Interval Velocity, Average Velocity, and RMS Velocity. You can display and edit the table in graphical and tabular mode.

To edit a velocity value, highlight the desired row in the *Time-Depth Curve Editor* dialog. A green dot shows in the graphic portion of the dialog. In the tabular part of the dialog, highlight the row you want to edit and then double-click the cell value in the table.



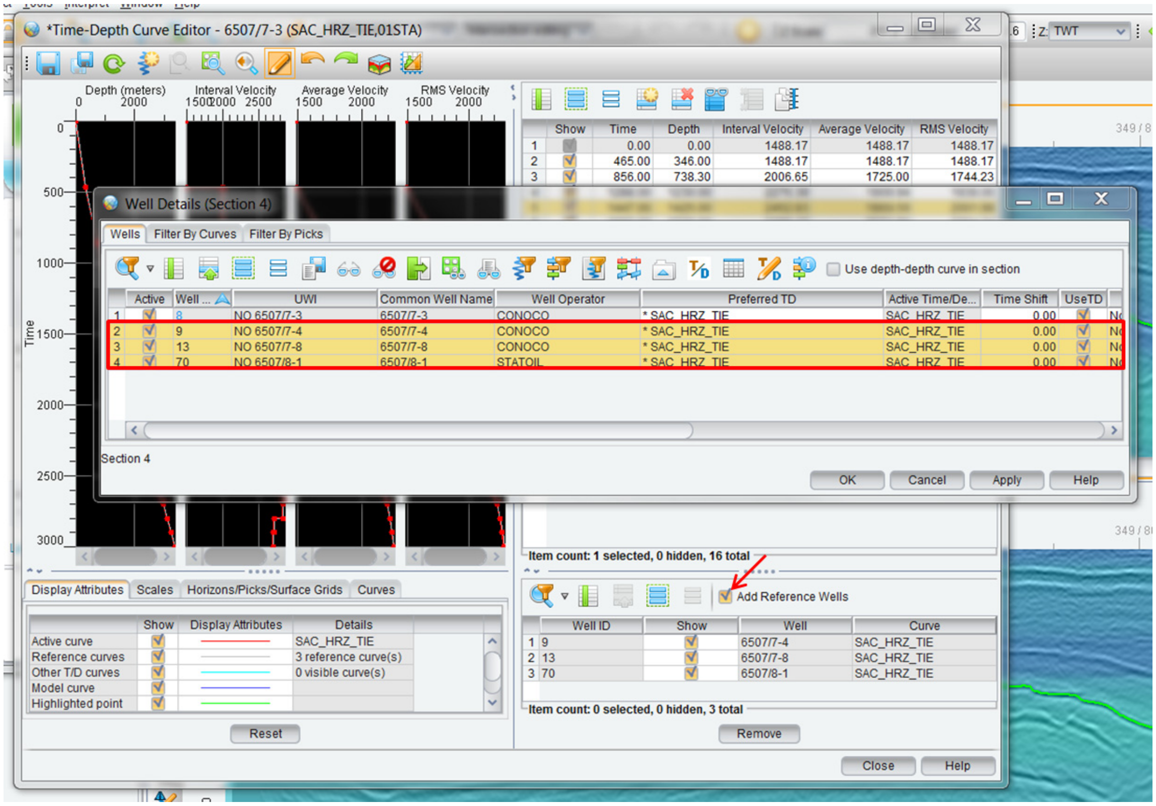
3. Highlight **Row 5**, then double-click the *Depth* cell and change the value to “**1425**” and then press <**Enter**>. Notice the change on the TD curve.



> **Note**
>
> To graphically edit the curve, click the Pencil ( ) icon in the toolbar and MB1-drag to move a node. To add a node, MB1 anywhere on the line. MB2 to delete nodes. Click the Undo ( ) icon to undo changes made and to restore the curve to the original value. The toolbar above the tabular section also contains editing tools. The Add and Delete Rows ( ) icons allow you to add new rows with values or delete whole rows. The Decimate Curve ( ) icon allows you to filter or reduce the number of tie points so only the most significant values are left. Also, at any point you can Reload ( ) the original curve.

4. Select the **Add Reference Wells** check box to display other curves as references for editing the current curve.

5. In the *Well Details* dialog, highlight the wells you want added as references.

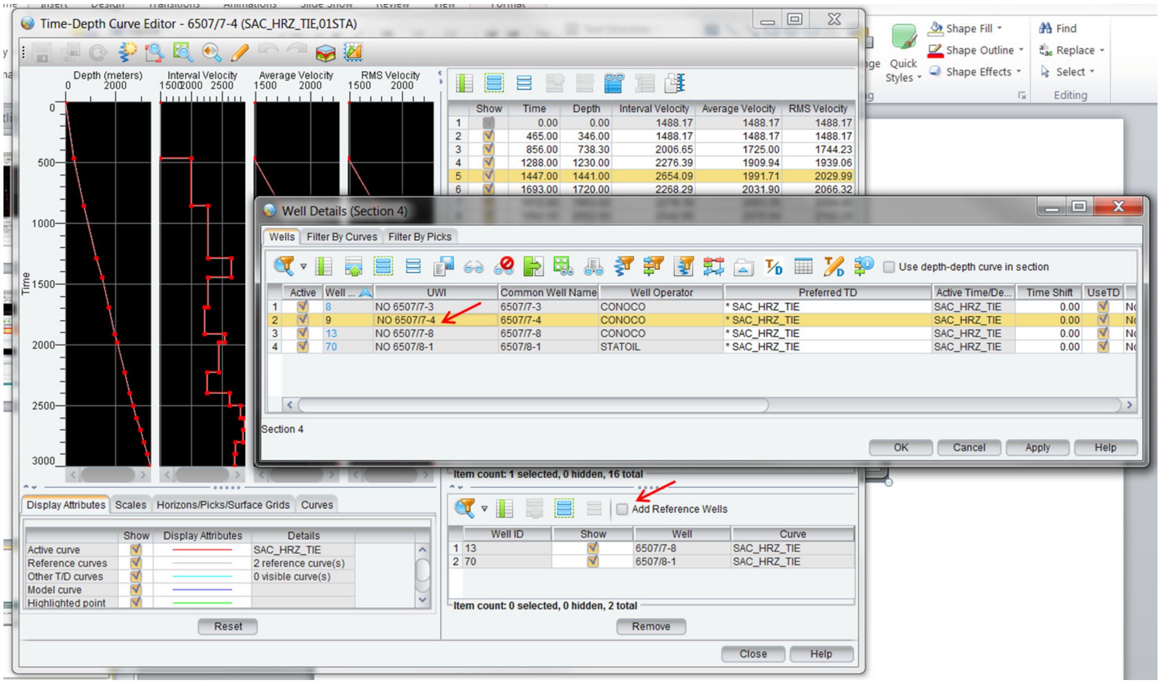


Once highlighted, the curves automatically appear in the *Reference Wells* portion in the tabular section of the *Time-Depth Curve Editor* dialog and in the graphic display. The active curve will appear red while the reference curves will be white.

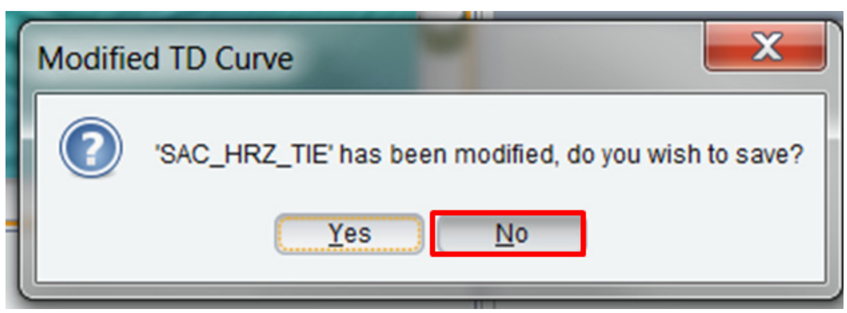
Note

If the wells form the *Well Details* dialog do not appear dynamically in the *Reference Wells* section of the *Time-Depth Curve Editor* dialog, clear the Active check boxes for the wells you want to use as a reference and then select them again. This should refresh the *Reference Wells* section and the selected wells will be displayed.

6. In the *Time-Depth Curve Editor* dialog, toggle off **Add Reference Wells**. In the *Well Details* dialog, highlight well **6507/7-4**.



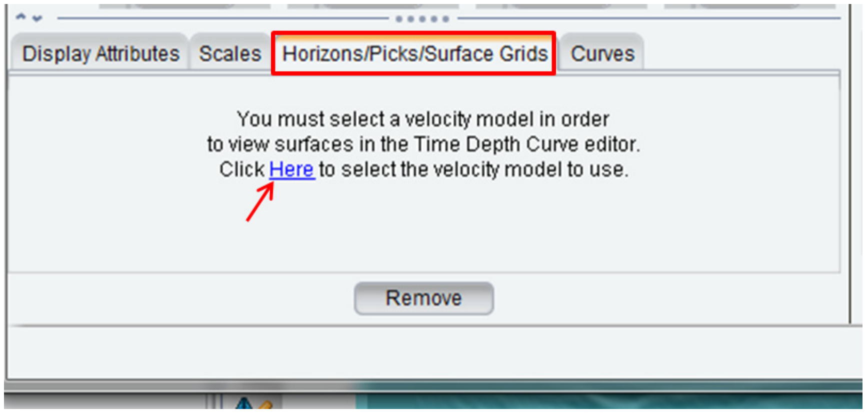
7. Click **No** in the *Modified TD Curve* dialog, so you do not save any changes to the curve.



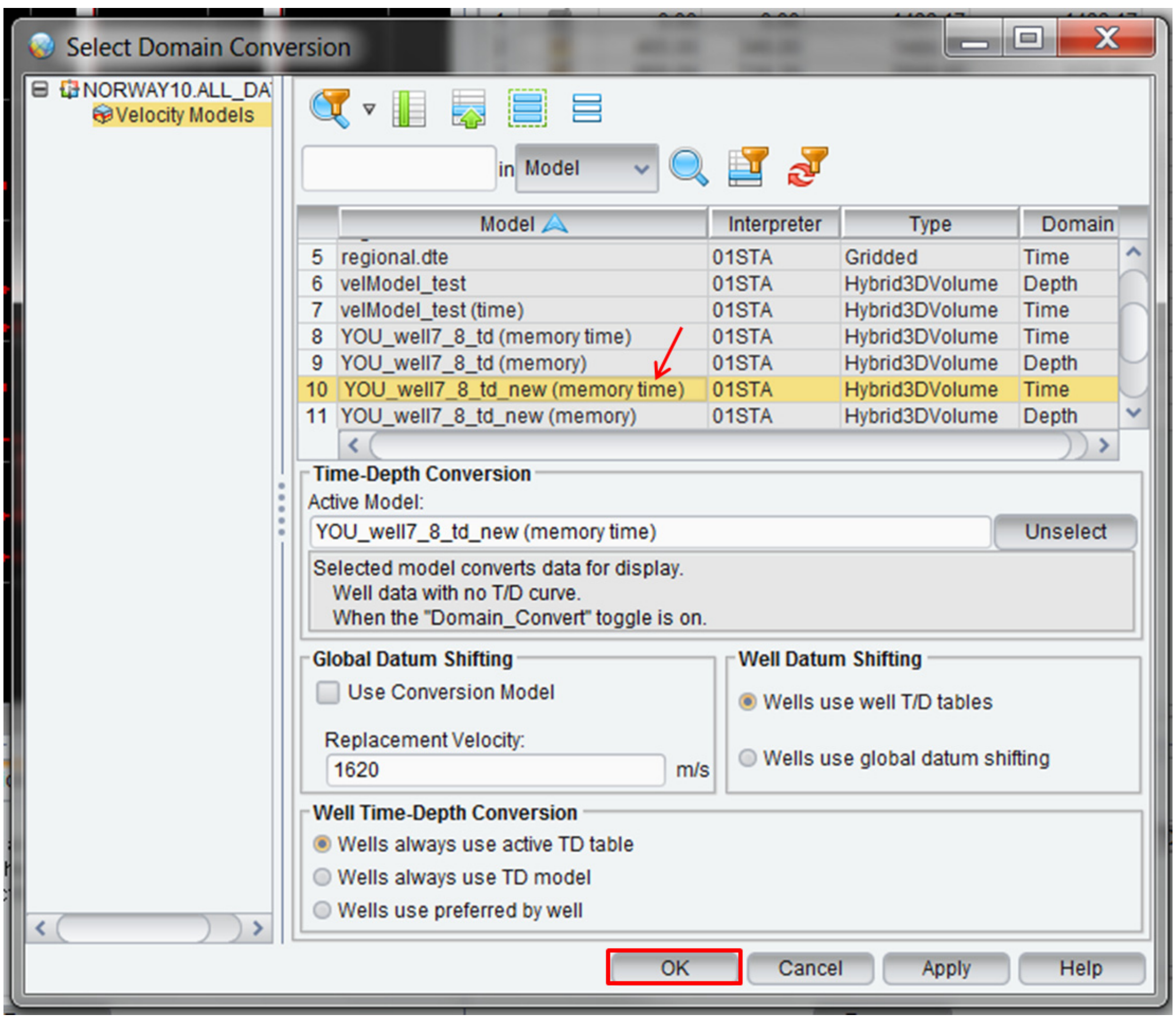
The active well for editing has now changed to 6507/7-4 and the display is updated to the newly selected well.

You are also able to add surface picks and horizons as a reference. The software uses the current velocity model to display the time horizons and depth picks at the correct intersection point for deviated wells. Currently, you do not have a velocity model set so you will have to set one before continuing.

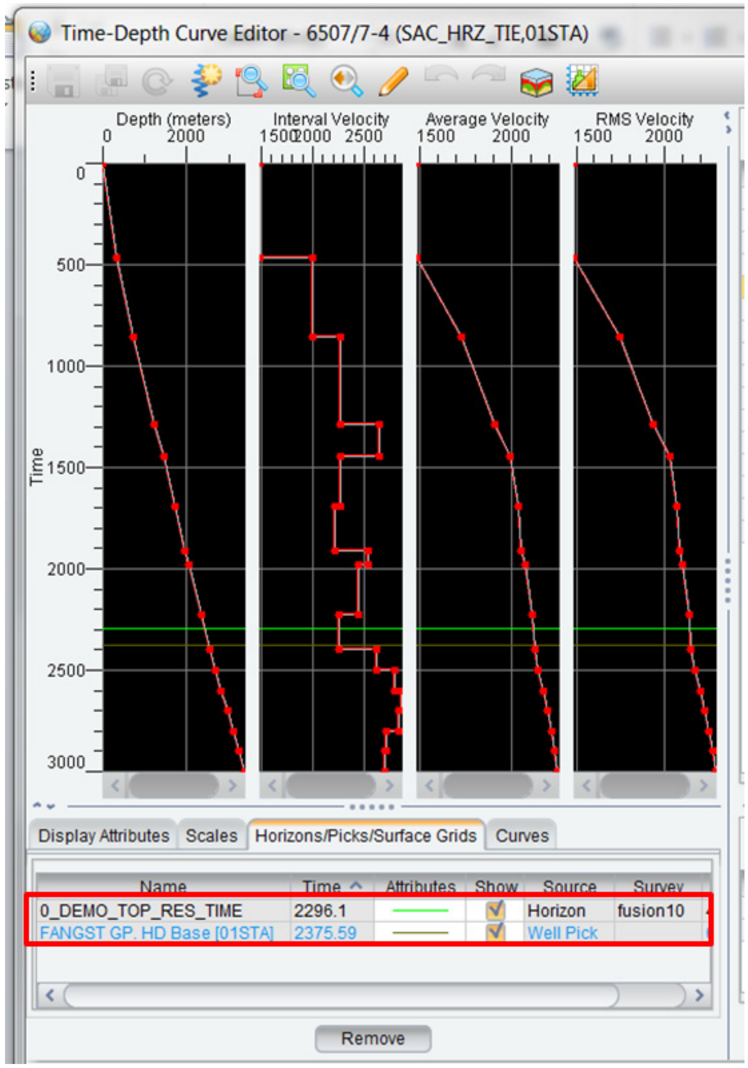
8. In the *Horizons/Picks/Surface Grids* tab, at the bottom left of the *Time-Depth Curve Editor* dialog, click the **Here** link to set a Velocity Model.



9. In the *Select Domain Conversion* dialog, select the model **YOU_well7_8_td_new** and click **OK**.



10. From the *Inventory* task pane, drag-and-drop surface pick **Fangst GP.HD Base** and horizon **0_DEMO_TOP_RES_TIME** into the *Horizons/Picks/Surface Grids* panel of the *Time-Depth Curve Editor* dialog.



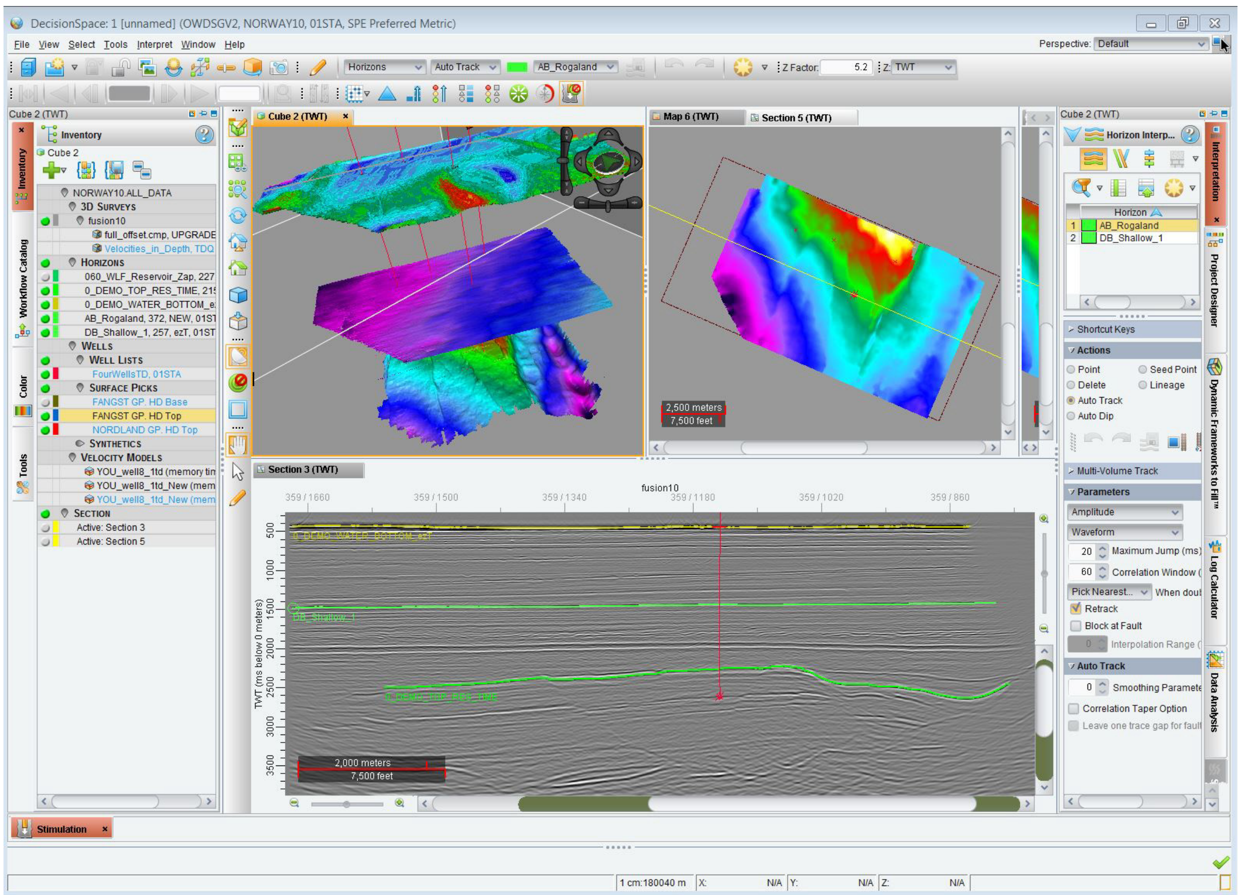
The surface pick and horizon will display graphically.

> **Note**
>
> You can change the display properties of the line by double-clicking the *Attributes* cell.

11. Close the *Time-Depth Curve Editor* dialog. Click **No** in the *Modified TD Curve* dialog. Close *Well Details*.

Exercise 6.4: Conditioning Four Input Horizons (Optional)

In this section, you will build a structural model with four layers and four well TD functions. The TD editor display helps you to understand the velocity profile and structural boundaries. To obtain a good depth conversion of the Top Reservoir, you must adequately define the overburden structure and major velocity interfaces. The 0_DEMO_TOP_RES_TIME, 0_DEMO_WATER_BOTTOM_ezT, AB_Rogaland, and DB_Shallow_1 horizons shown below should be adequate to control the velocity behavior between the wells.



It is recommended to QC the structure horizons against the Well TD tables. The goal of the QC is to determine if the structure layers coincide with the velocity breaks on the TD functions, and also that the structure interval does not become too small. A minimum thickness of 200 ms to 300 ms is a good guide. Thin intervals often cause velocity anomalies.

The class data TD functions have few points and are typical of check-shot data. Another option is to use calibrated sonic data, which will be more highly sampled (i.e., thousands of values). This will have higher resolution and will better define the vertical velocity profile. However, sonic logs can be more prone to noise. In either case, you will need to have previously done a synthetic well tie correlation to make sure that the TD correctly ties the well depth to the seismic time.

Typical problems with TD functions occur at the start of the log (i.e., the end of the logging or check-shot run) and at the bottom of the hole (i.e., the start of the logging or check-shot run). You can freely edit the bottom-hole anomalies, but you must use great care with top-hole anomalies.

Careful editing of the average velocity will often produce a reasonable and usable result in interval velocity. You may be able to create a water bottom break so the top of the model has a consistent TD function velocity. However, on some occasions, usually when the check shots are poor or not available, the correct TD relationship may have been obtained by introducing a large spike at the start of the TD function. In these cases the synthetic correlation will be correct but the TD function will produce a large, shallow velocity anomaly, which, if you edit out, will give you the wrong TD conversion. In this case a re-visit to the synthetics is required.

Note

Doing the synthetics correctly can be more work and trouble than building the velocity model. Another possible problem is that the check shots or VSP data could be loaded incorrectly or with the wrong datum. This will result in the velocity breaks not being at the structure layers and will produce velocity anomalies in the model. If you suspect this to be an issue, you may need to reload the TD functions.

The importance of the TD function data from sonic logs, check shots, and VSPs cannot be over stressed, as it is the only original data that comes directly from the actual geology. All other data used to make a velocity model is subject to interpretation or the vagaries of seismic acquisition and processing.

The input structure interpretation usually needs to be conditioned and smoothed. When QCing input horizons, look for non-geologic chatter and any edge anomalies. Typically, input is gridded to a 100 m or 200 m grid.

> **Note**
>
> It is good practice to take full advantage of the DecisionSpace interpretation environment to manually and batch edit the velocity controlling horizons. Manual options include paintbrush interpretation, interpolation and delete. Batch options include auto tracking and smoothing/filtering.

For velocity modeling, a 21 by 21 smoother is reasonable to get a more geologically correct guiding horizon. All data needs to be smoothed to some degree to optimize the resolution and it’s obvious from this example that the high frequency variation of the red horizon is not true resolution, but seismic noise or artifact.

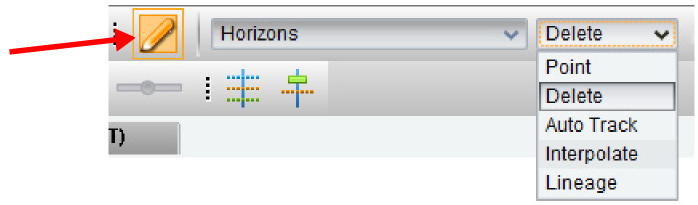
The Top Reservoir horizon (0_DEMO_TOP_RES_TIME) is already fairly smooth and you have to be careful not to over-smooth the structure layers, as this will reduce the highs and lows. However, the horizon will benefit from interpolation that can be easily done in the same manner as smoothing; i.e., by selecting the horizon in the *Inventory* panel of the *DecisionSpace* window or by putting your cursor MB3 on the *Map* view and selecting Calculation > Interpolation. In the upcoming exercise, you will learn how to smooth the remaining three horizons.

To condition four input horizons:

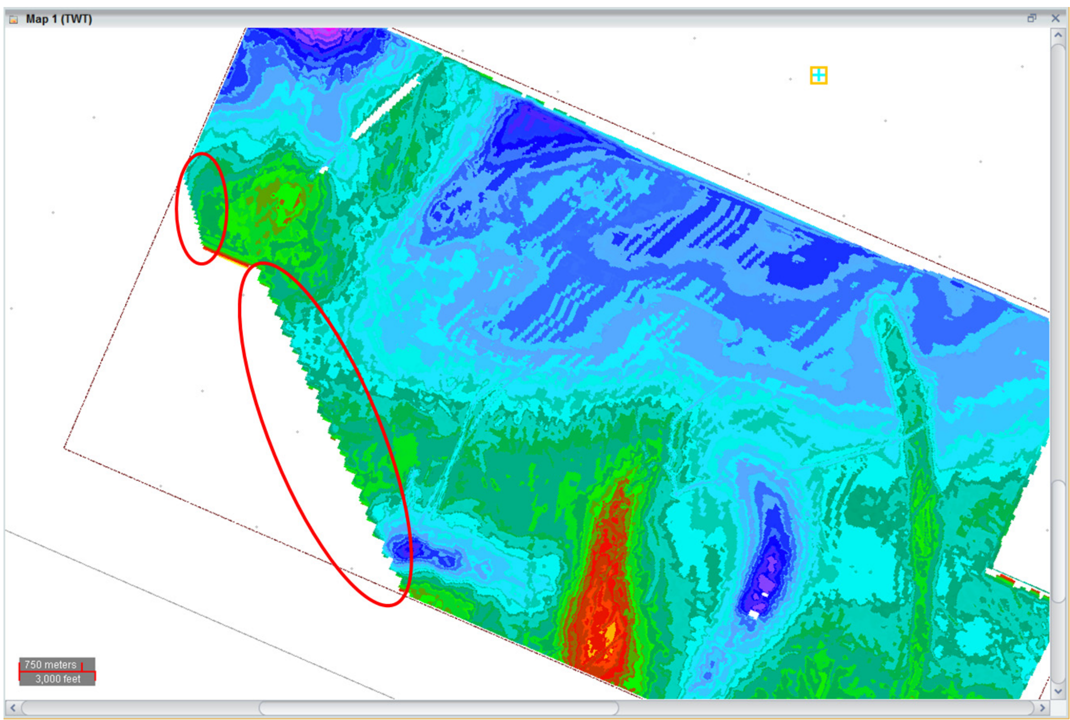
1. Additional horizons will be needed for this exercise. Click the **Select Session Data** () icon in the main toolbar. Navigate to **Horizons > Horizons** and select **0_DEMO_WATER_BOTTOM_ezT**, **AB_Rogaland (New_ezT)**, and **DB_shallow_1 (ezT, TIME)**. Click the **Add data to session** button, and click **OK** to close the dialog.

2. Change your current interpretation data type to **Horizons**.

3. Display the **0_DEMO_WATER_BOTTOM_ezT** horizon in the *Map* view and click the **Pencil** icon, select **Delete** from the drop-down menu.



4. **MB2+<Ctrl>** and drag to make the eraser box smaller or bigger, and erase rough edges or anomalous bumpy areas of the input horizons.



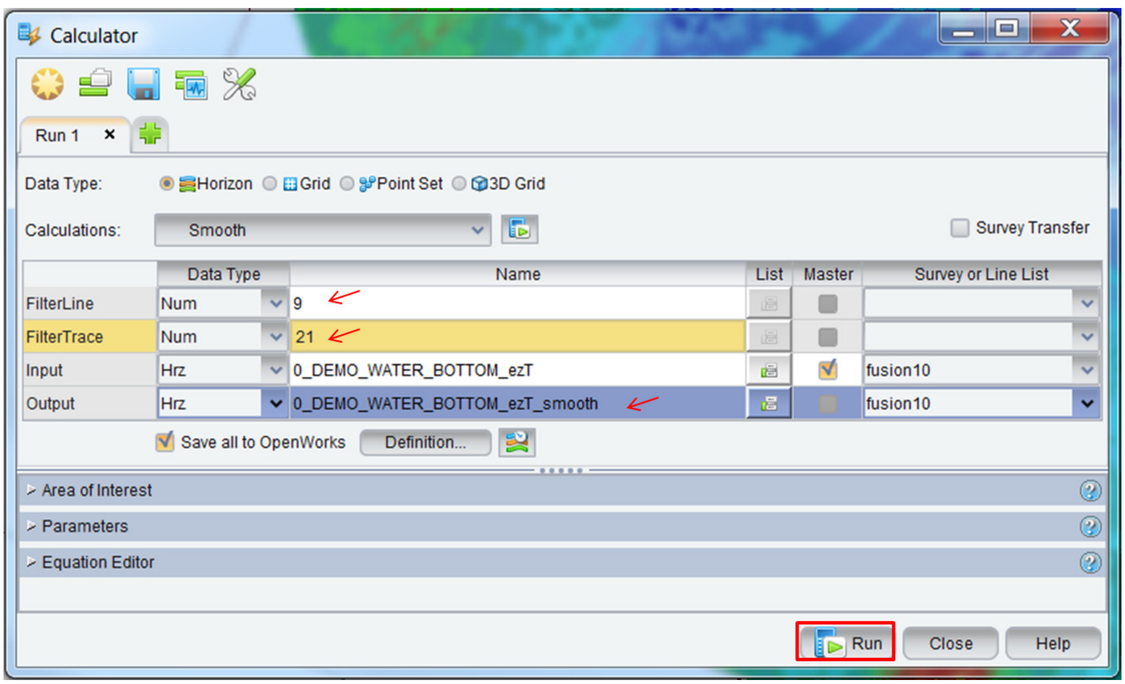
5. When done making changes to the horizon, in the *Interpretation* toolbar, click the **Save horizon changes to the database** icon.

> **Note**
>
> You can Undo or Redo an action, if you make a mistake. After manual editing, you can also smooth four input horizons.

6. In the *Inventory* panel or in the *Map* view, **MB3** on the **0_DEMO_WATER_BOTTOM_ezT** horizon and select **Calculations > Smooth**.

7. Change *FilterLine* to "**9**" and *FilterTrace* "**21**" and select the **Save all to OpenWorks** check box.

8. For *Output,* select the output horizon name which contains **_smooth** from the field and then click **Run**.



9. Note the horizon smoothness change in *Map* and *Section* views.

10. Follow the above mentioned instructions for the remaining input horizons, with exception of the Top reservoir horizon, 0_DEMO_TOP_RES_TIME, for which Interpolation is applied.

Exercise 6.5: Building a Multi Time-Depth Function Structure Model Using Framework Surfaces

In this exercise, you will build a velocity model with four well TD functions and four structural layers. You will use the framework surfaces as structural component for velocity model.

A common misunderstanding about using a DecisionSpace framework for the velocity model is that the interpretation focus is usually on the reservoir model, and that the DecisionSpace Dynamics Frameworks to Fill (DFF) model is used to QC the interpretation and build a sealed framework that is then populated with petrophysical data to create a reservoir model.

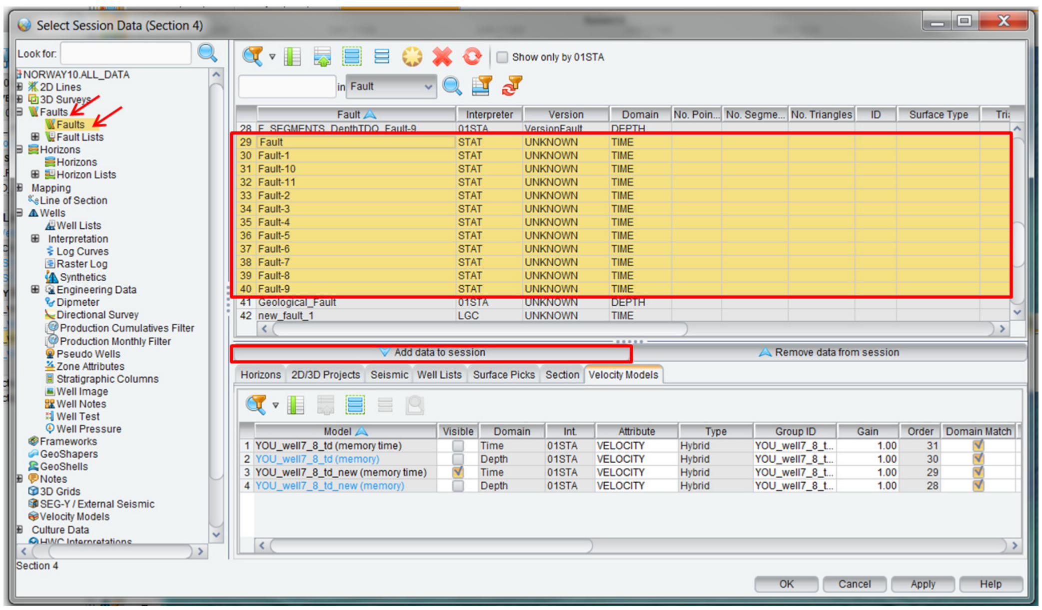
The reservoir framework model does not support the framework for the velocity model. First, it has no overburden structure. Second, the reservoir is likely to be relatively thin (10s or 100s of meters). Sampling and calculating velocity over small intervals leads to noisy and erratic velocity. To obtain a smoother and more reasonable velocity you need to sample it over larger intervals, typically at least 200-300 ms. You may define a constant or analytic velocity over a small interval, but sampling it from seismic velocities, well TD functions, or calculating pseudo velocity from depth picks and seismic time, leads to velocity anomalies that detract from rather than improve the model.

Another possible problem in using a faulted framework is (apart from the possibility of small faulted compartments that are subject to the same problems as discussed for thin layer above) that sharp faults may cause depth conversion artifacts below them. Bear in mind we are building a model. In the real Earth a fault is a diffraction point and below it, the seismic wave energy spreads and heals so you don't get a sudden discontinuity on the imaging of the layers. With a velocity model and vertical depth conversion, sharp faults can create discontinuity artifacts on the layer below that do not actually exist in the real geology. Hence, as we discussed earlier in the course, there is a need to smooth all data to some extent. So, defining faults may be a good thing with respect to structure, but the faults may also produce unwanted artifacts. Of course, if you grid a structure horizon with fault polygons, you are including the structure effect of the fault without having to use a framework, plus you have more control over the smoothing.

Thus, there are advantages to using a framework model, but the model should be one that has been built for velocity modeling without small intervals or compartments. Also it should contain an adequate overburden structure.

Although DecisionSpace Velocity accepts both time and depth domain structures, you will work on time domain framework because it is the native domain of structural interpretation. Create a time domain framework for building velocity model using the following horizons and faults.

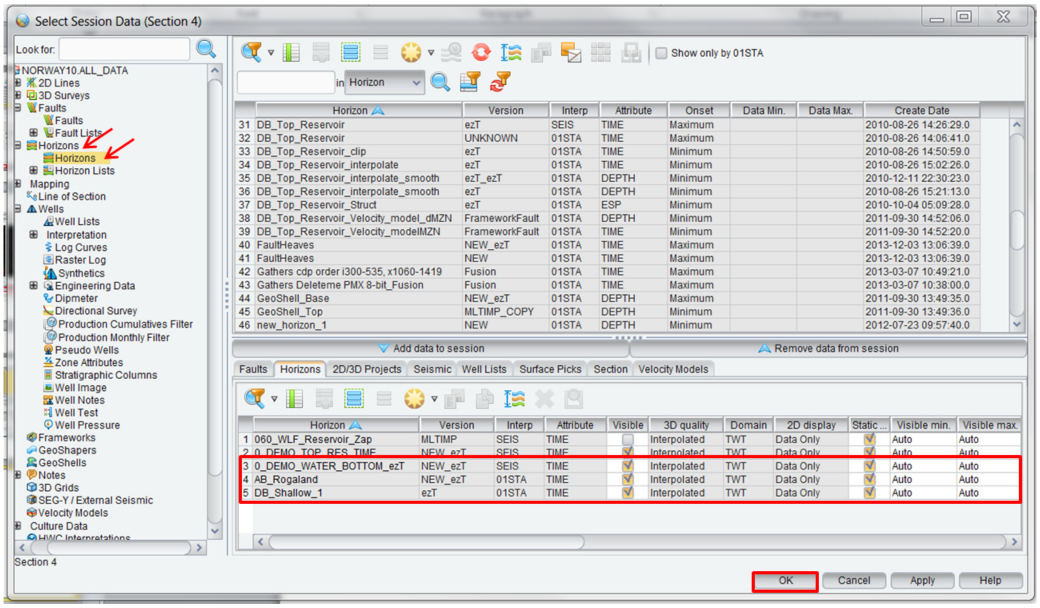
1. From the toolbar, click the **Select Session Data** ( ) icon. In the *Select Session Data* dialog, navigate to **Faults** > **Faults** and **MB1+<Shift>** to highlight **Fault** through **Fault-11**. Click **Add data to session**.



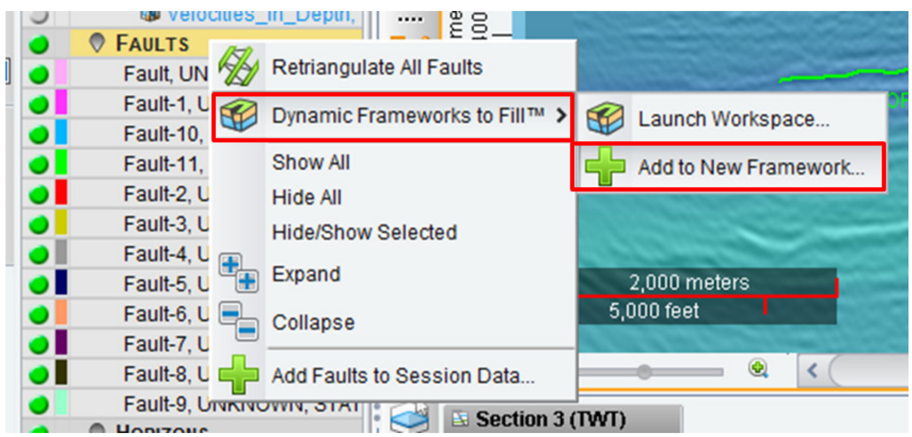
2. Navigate to **Horizons** > **Horizons** and **MB1+<Ctrl>** the following horizons:

   - **0_DEMO_WATER_BOTTOM_ezT**
   - AB_Rogaland, **NEW_ezT**
   - **DB_Shallow_1 (TIME)**

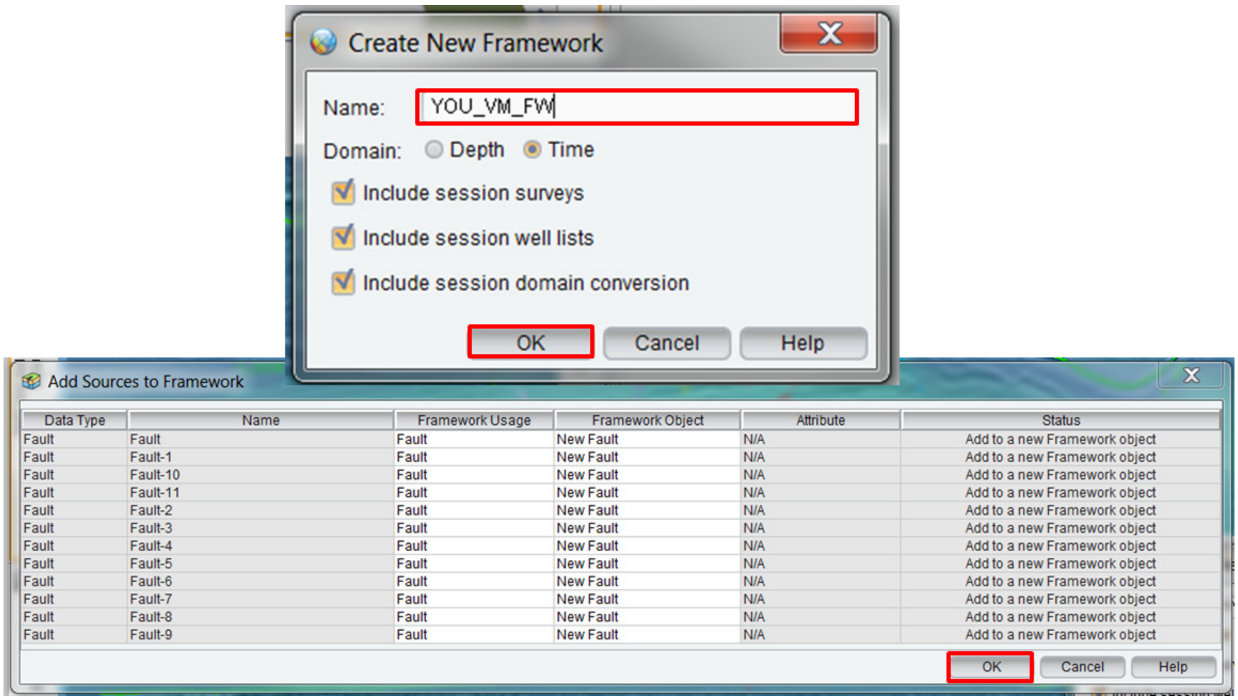
3. Click **Add data to session**. Click **OK**.



4. In the *Inventory* task pane, highlight and **MB3** on the **Faults** data category and then select **Dynamic Frameworks to Fill** > **Add to New Framework**.

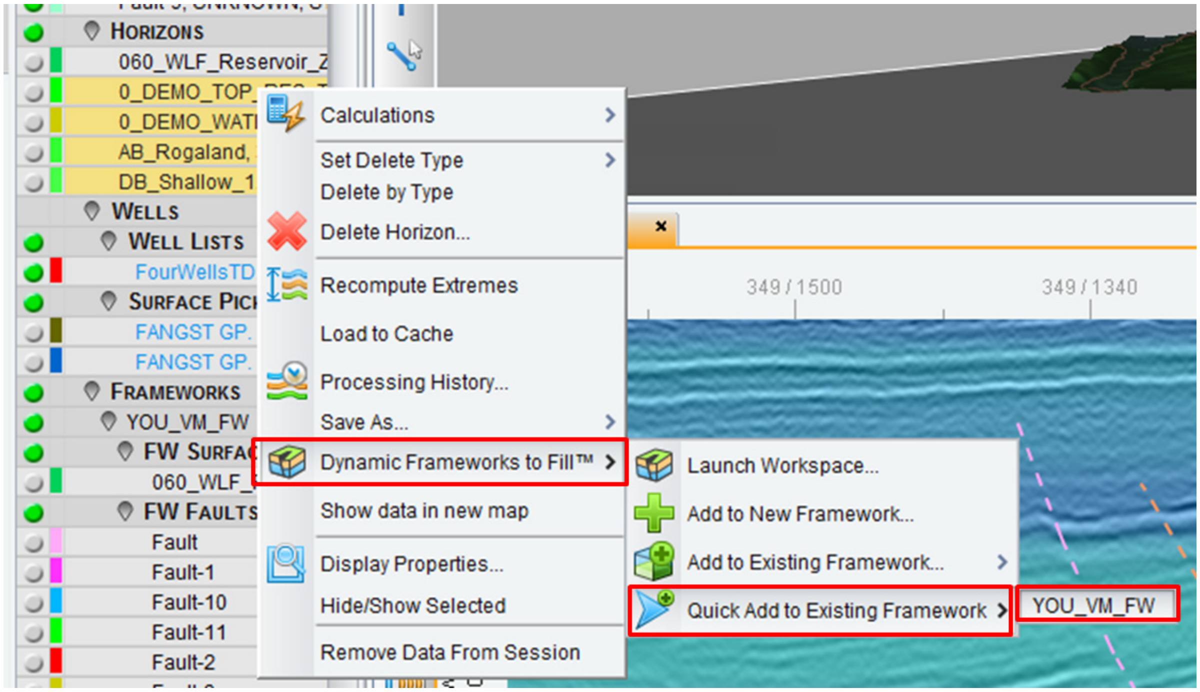


5. In the *Create New Framework* dialog, enter “**YOU_VM_FW**” in the *Name* field. Click **OK** and then click **OK** in the *Add Sources to Framework* dialog.



As you have seen in previous exercises, the framework now appears in the *Inventory* task pane with the category *FW Faults* listed below. Next, you will add in the horizons to create FW Surfaces.

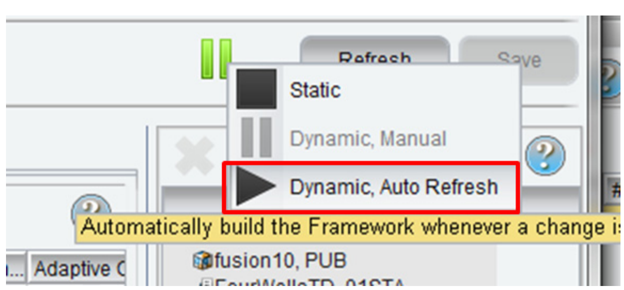
6. In the *Inventory* task pane, highlight the horizons **0_DEMO_TOP_RES_TIME**, **0_DEMO_WATER_BOTTOM_ezT**, **AB_Rogaland**, and **DB_Shallow_1**, **MB3**, and then select **Dynamic Frameworks to Fill > Quick Add to Existing Framework > YOU_VM_FW**.



The horizons are added as new surface objects and will be gridded as framework surfaces. You must refresh your framework to see the changes. Also, before you can use the framework as an input into your velocity model, the faults must be networked and the gridding of the surfaces needs to be matched to create a sealed structural model.

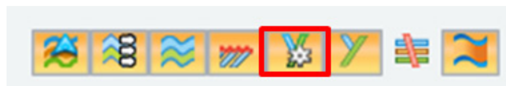
7. In the *Dynamic Frameworks to Fill* task pane, click the **Launch Framework Workspace Window** ( ) icon.

8. At the top, right of the *Dynamic Frameworks to Fill Workspace*, change the state of the framework to **Dynamic, Auto Refresh**.

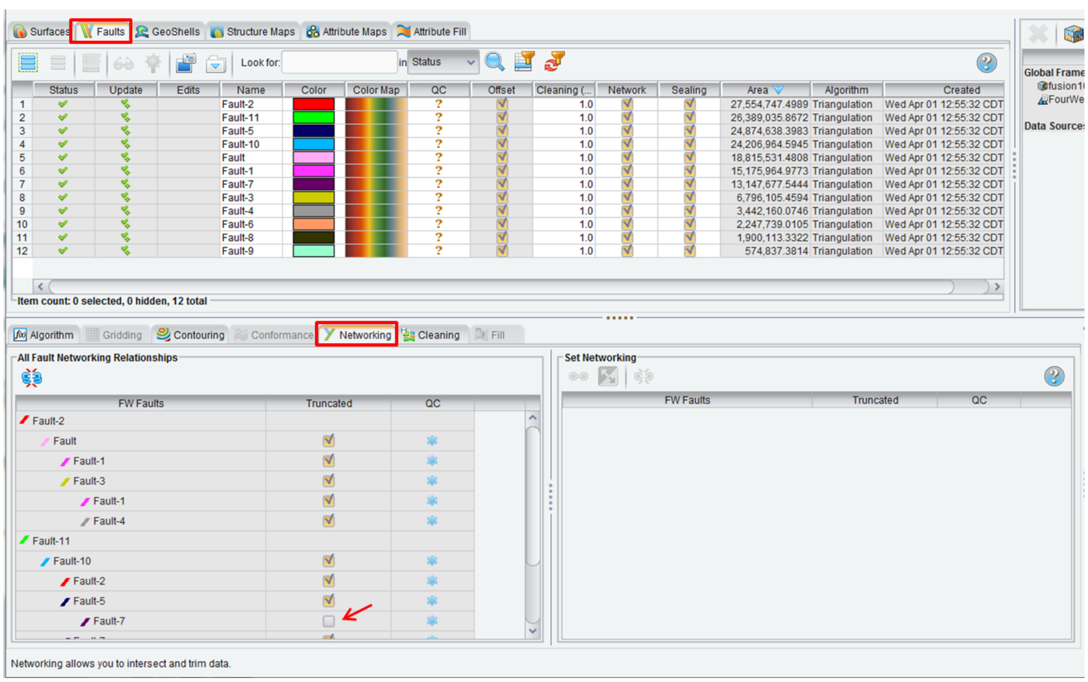


> **Note**
>
> Having your framework in Dynamic Auto Refresh will cause the framework to update when any change is made. If many changes need to be made at once you can leave your framework in Dynamic, Manual and make the changes when necessary.

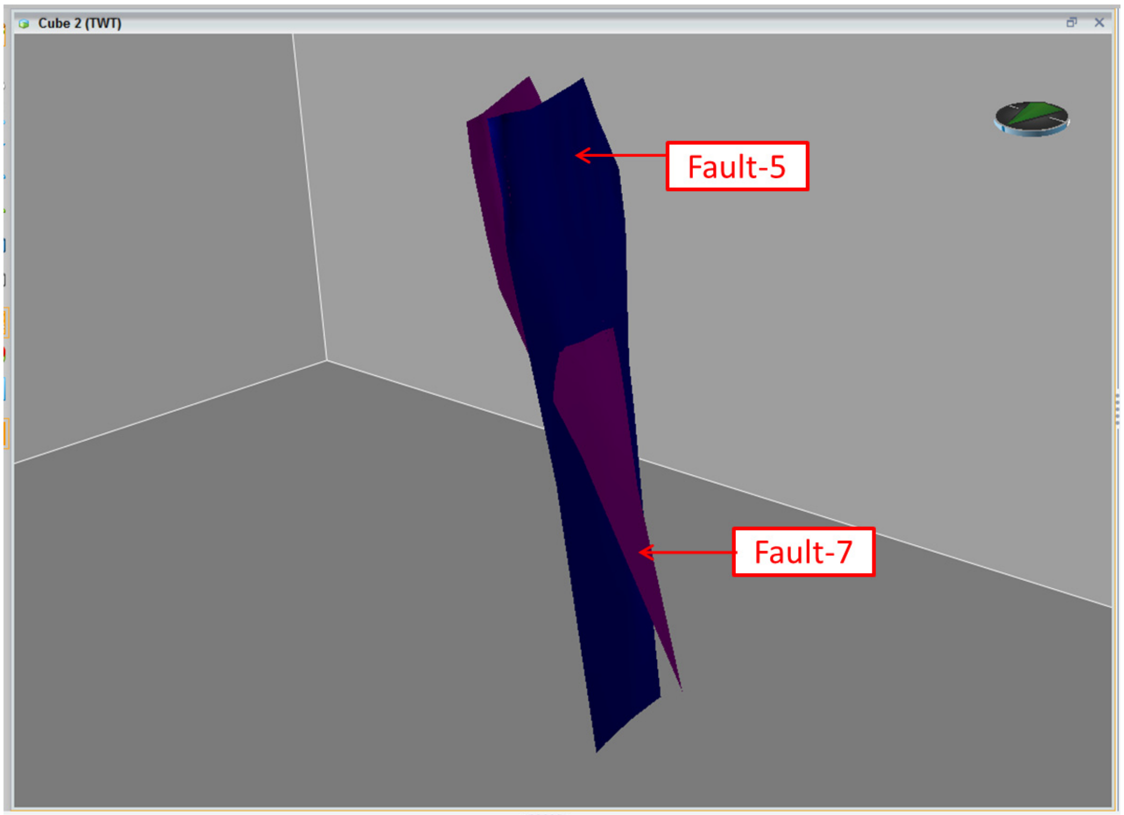
9. In the global icons toolbar at the top of the workspace, turn on the **AutoNetwork Faults** () icon. The framework will automatically refresh.



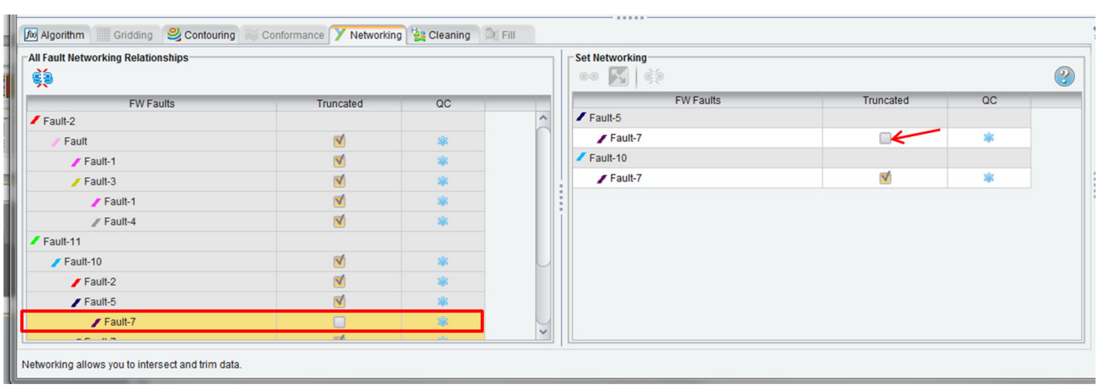
10. To review the fault network, select the **Faults** object tab and then select the **Networking** actions tab.



You may have to scroll down to notice that Fault-7 is not being truncated against Fault-5. Using *Cube* view, you can view this relationship to determine that Fault-7 is crossing Fault-5 because more than 25% of its area is crossing. You will manually truncate Fault-7.



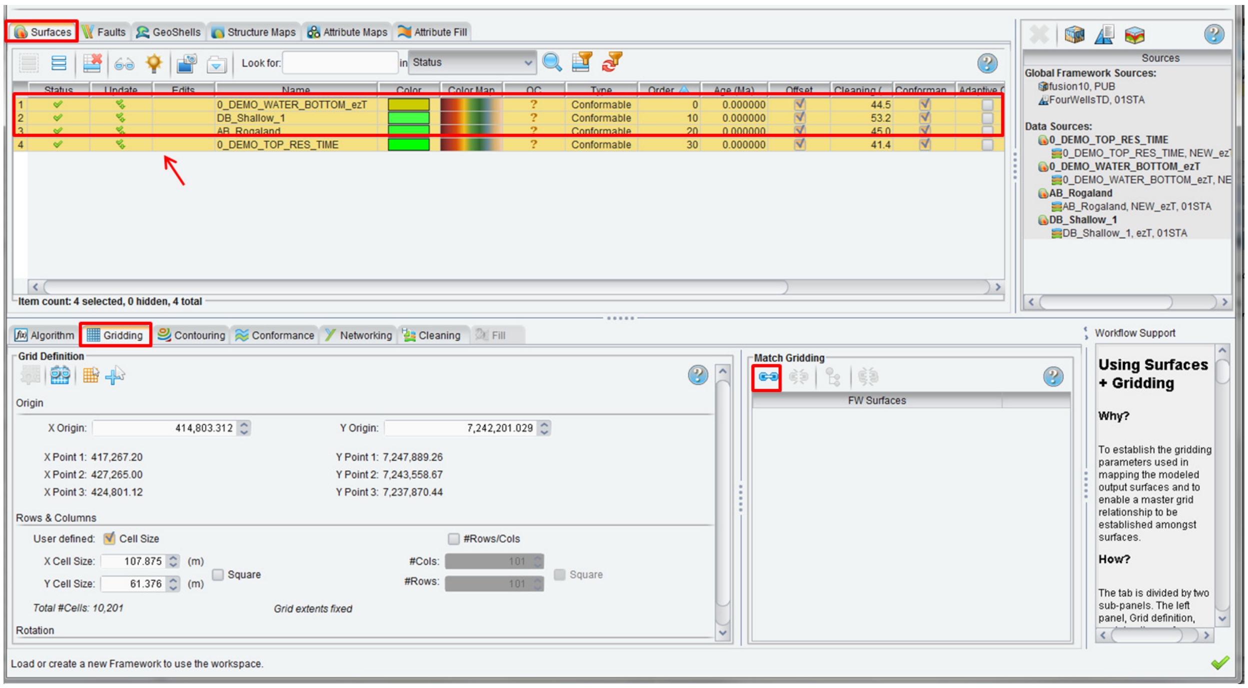
11. From the *All Fault Networking Relationships* panel, highlight **Fault-7**. From the *Set Networking* panel, select the **Fault-7** check box indicating it will be truncated by Fault-5.



The framework refreshes and the fault network is complete. Next, you will make 0_DEMO_TOP_RES_TIME the master surface, so that all the other surfaces have the same gridding. This ensures the resolution of the surfaces match when you add them as structure layers into the velocity model.

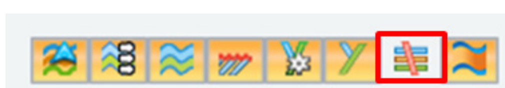
12. Select the **Surfaces** object tab and the **Gridding** actions tab. Select **0_DEMO_TOP_RES_TIME** and then **MB1+<Ctrl>** each of the other surfaces until all are selected. (Order matters for match gridding because the first surface selected will be the master for gridding.)

13. In the *Match Gridding* panel, click the **Link** ( ) icon.



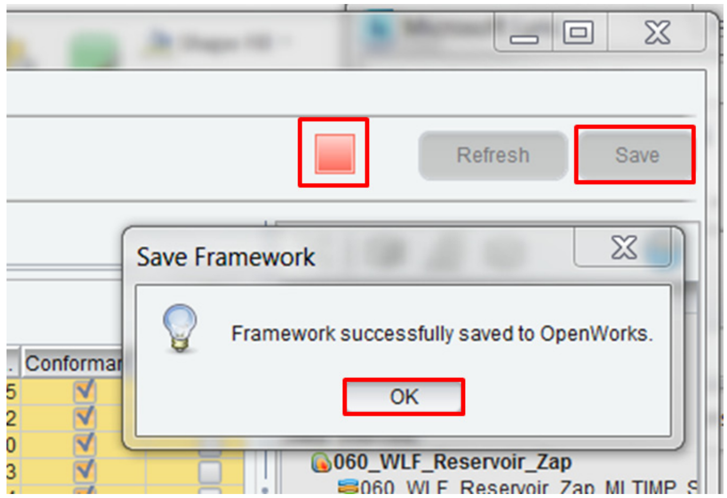
The last step to complete the sealed structural framework, before saving it to be added into the velocity model, is to turn on fault offsetting.

14. In the global icons toolbar, turn on the **Fault Offsetting** ( ) icon.

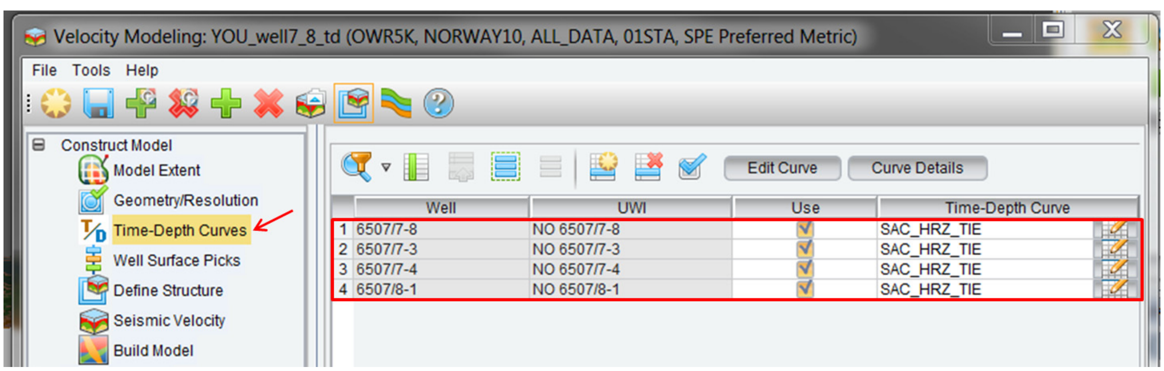


To use the framework as input to your velocity model, the framework must be saved in a Static state.

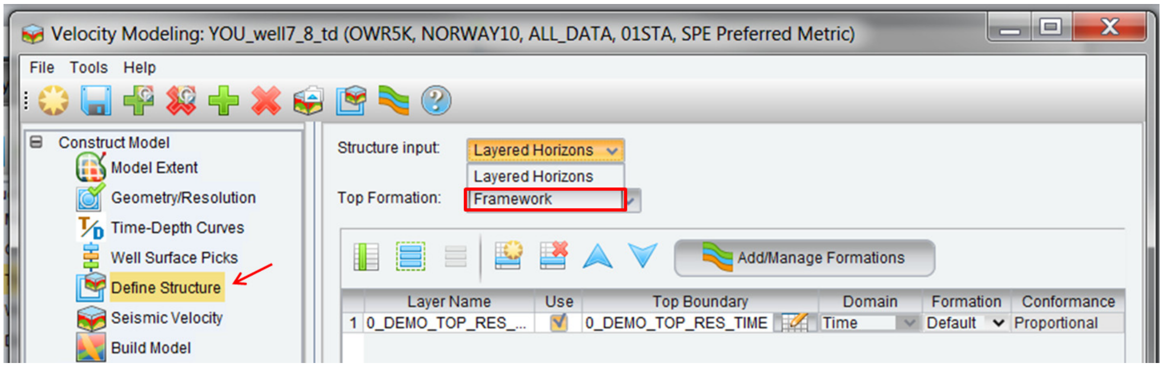
15. In the *Dynamic Frameworks to Fill Workspace*, change the state of the framework to **Static**. Click the **Save** button. Click **OK** in the *Save Framework* dialog.



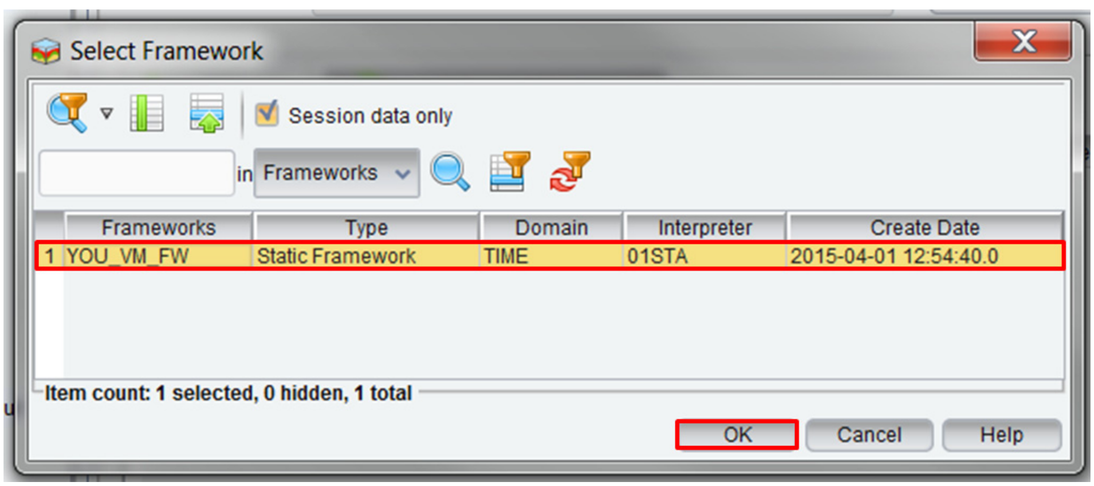
16. In the *Velocity Modeling* dialog, select **Time-Depth Curves** from the menu at the left. Add the remaining wells from the well list **Four Wells** by dragging-and-dropping the list from the *Inventory* task pane.



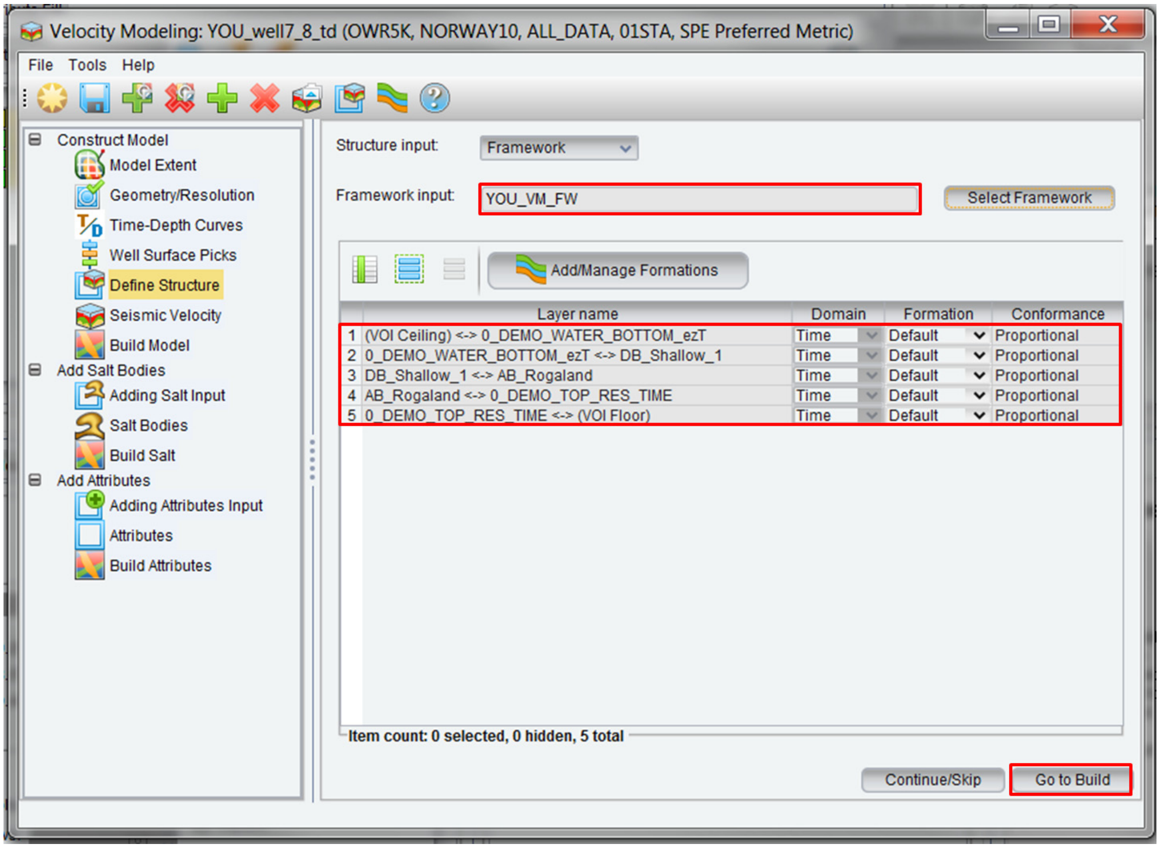
17. Select **Define Structure** from the menu at the left. Select **Framework** from the *Structure input* drop-down menu. Click the **Select Framework** button to select a framework for the *Framework input* field.



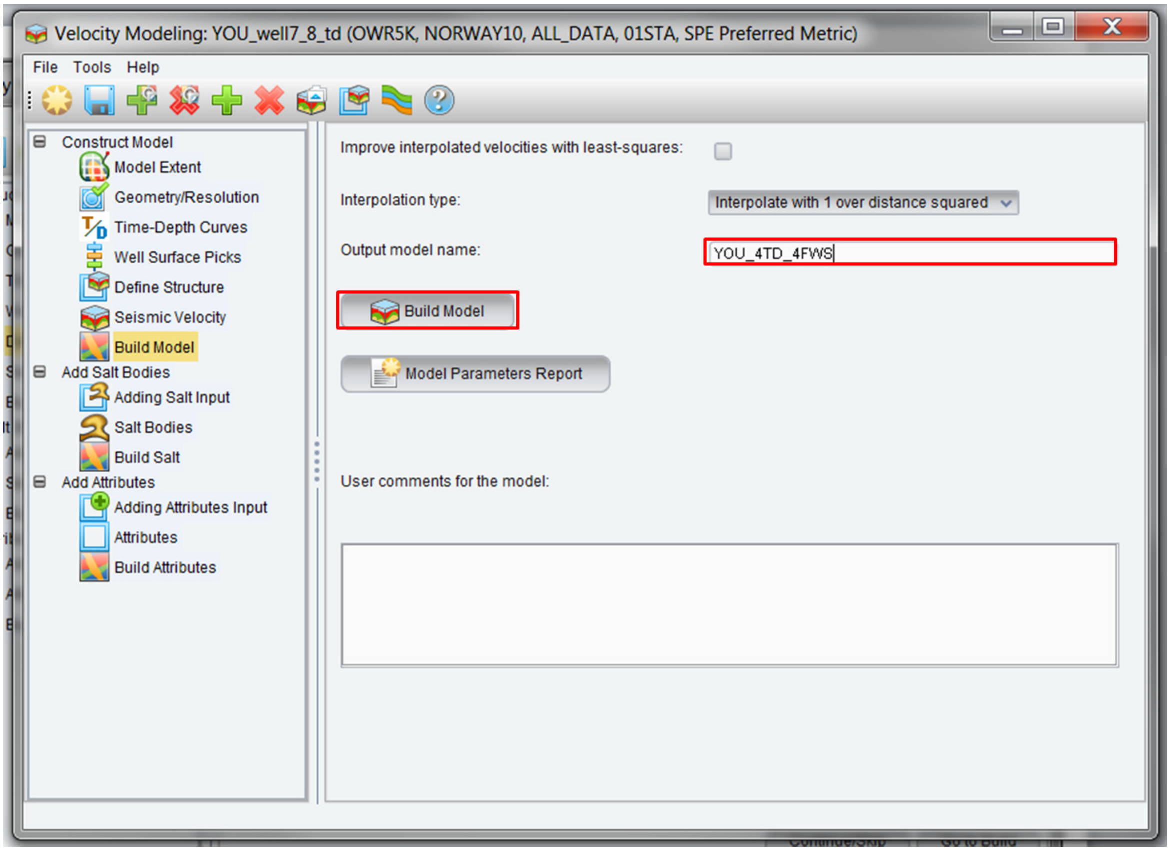
18. In the *Select Framework* dialog, highlight **YOU_VM_FW** and click **OK**.



19. Once the framework surfaces have loaded, click the **Go to Build** button.



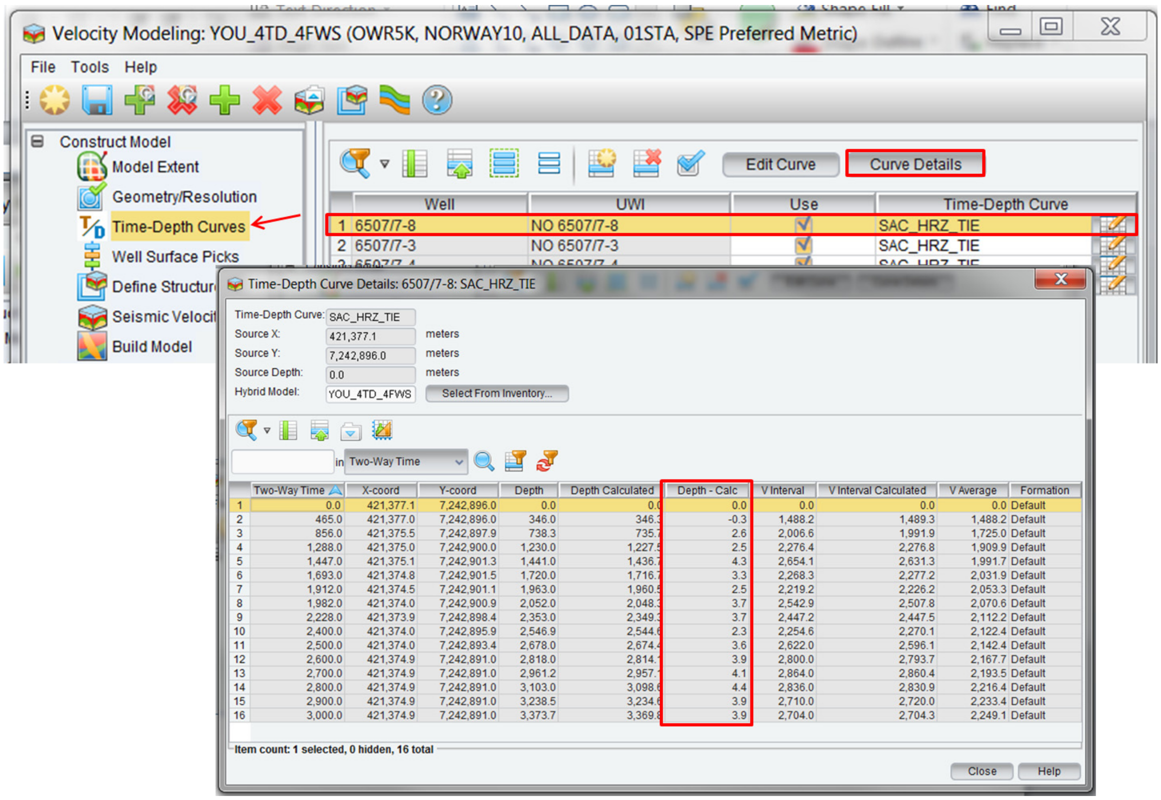
20. Rename the model "**YOU_4TD_4FWS**." Click **Build Model** and select **No** when prompted to save the model to OpenWorks.



Note

In the *Build Model*, you can click the **Model Parameters Report** button to view an Input Summary, Input Details, and an Error Report.

21. Click **Time-Depth Curve** from the menu at the left. Highlight well **6507/7-8** and click the **Curve Details** button.

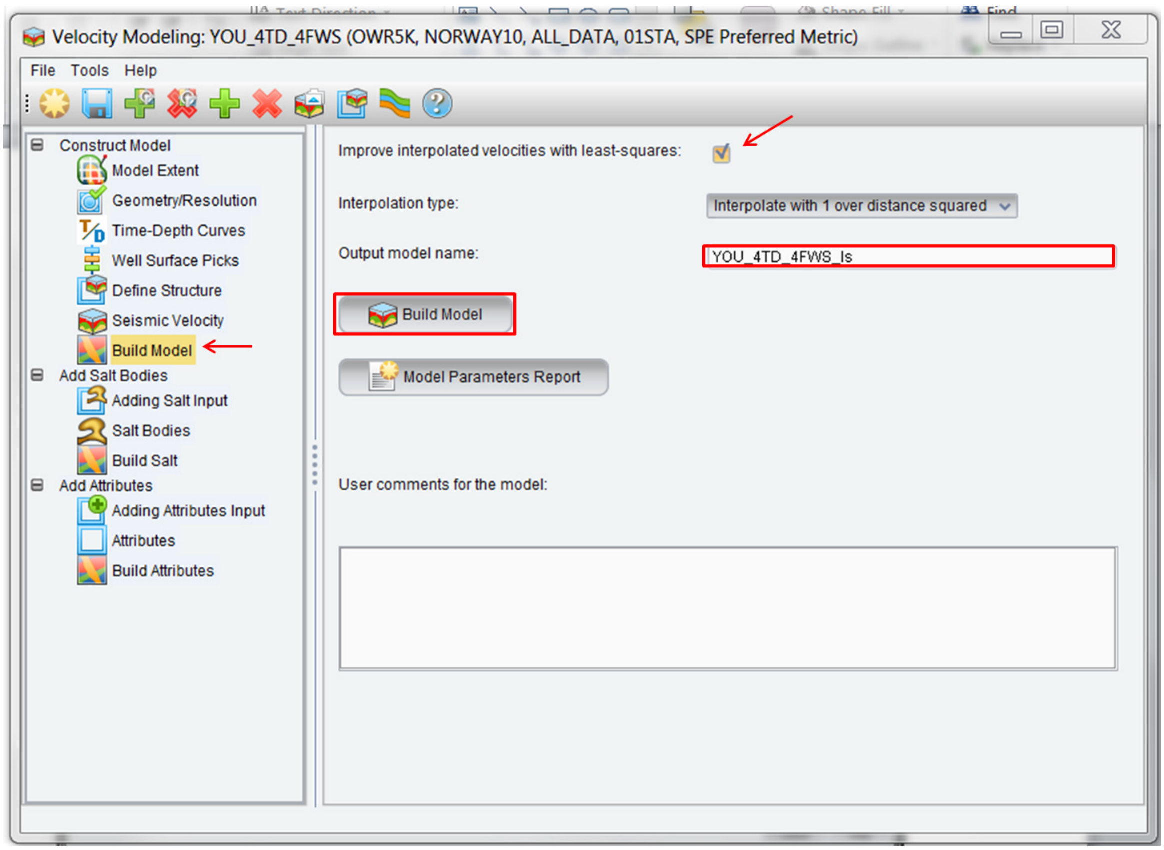


In the *Time-Depth Curve Details* dialog, notice the values in the *Depth - Calc* column. These values show you how much the calculated depths used in the model differ from the original depths from the TD curves.

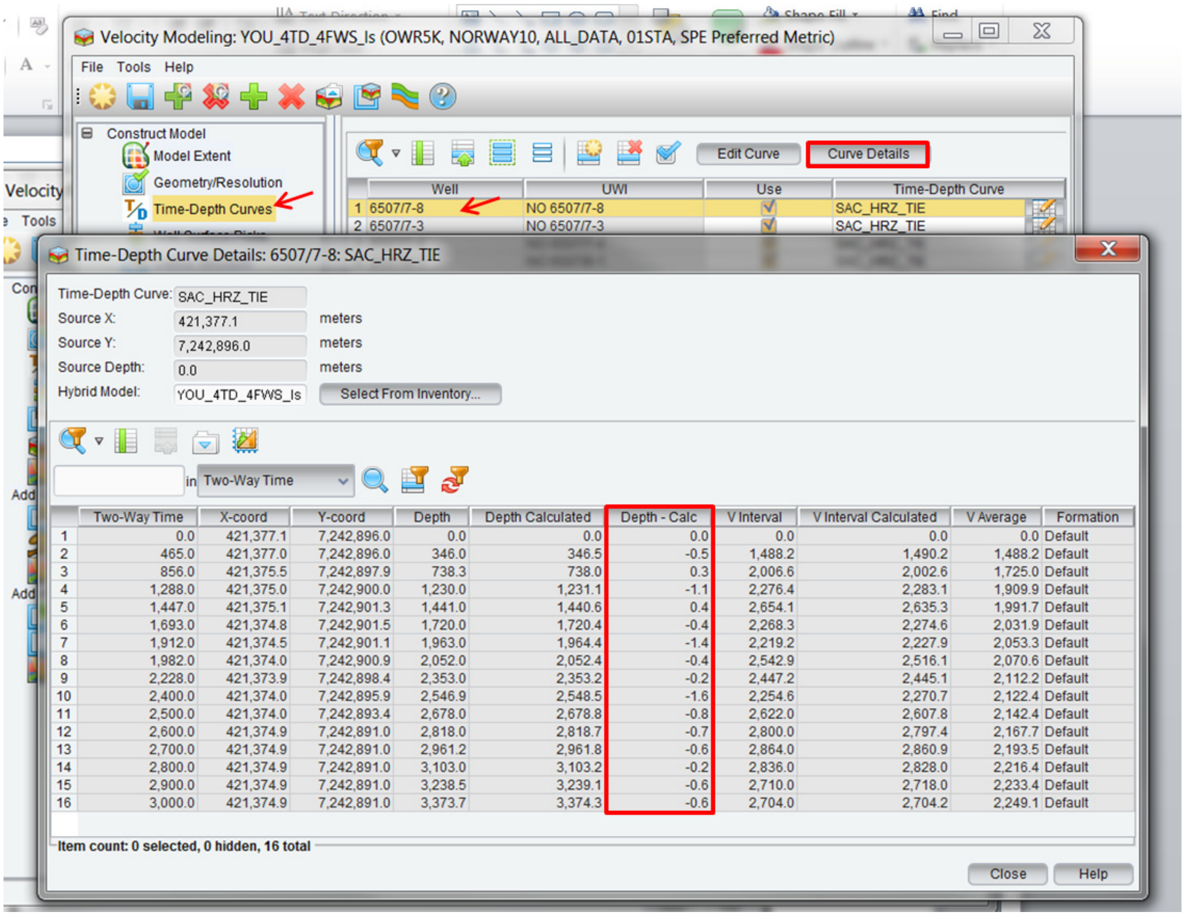
22. Close the *Time-Depth Curve Details* dialog.

You will re-build the same model, but this time you will use the Least-squares fitting option. This will perform a final pass on the model to better fit it to the data (FourWell TD functions in this case) and reduce the residual mis-ties. If the mis-ties are due to bad data, the least-squares fitting option will better fit the bad data and possibly give velocity anomalies in your model.

23. Select **Build Model** from the menu at the left. Select the **Improve interpolated velocities with least-squares** check box. Rename the model "**YOU_4TD_4FWS_ls**." Click **Build Model**. Select **No** when prompted to save to OpenWorks.



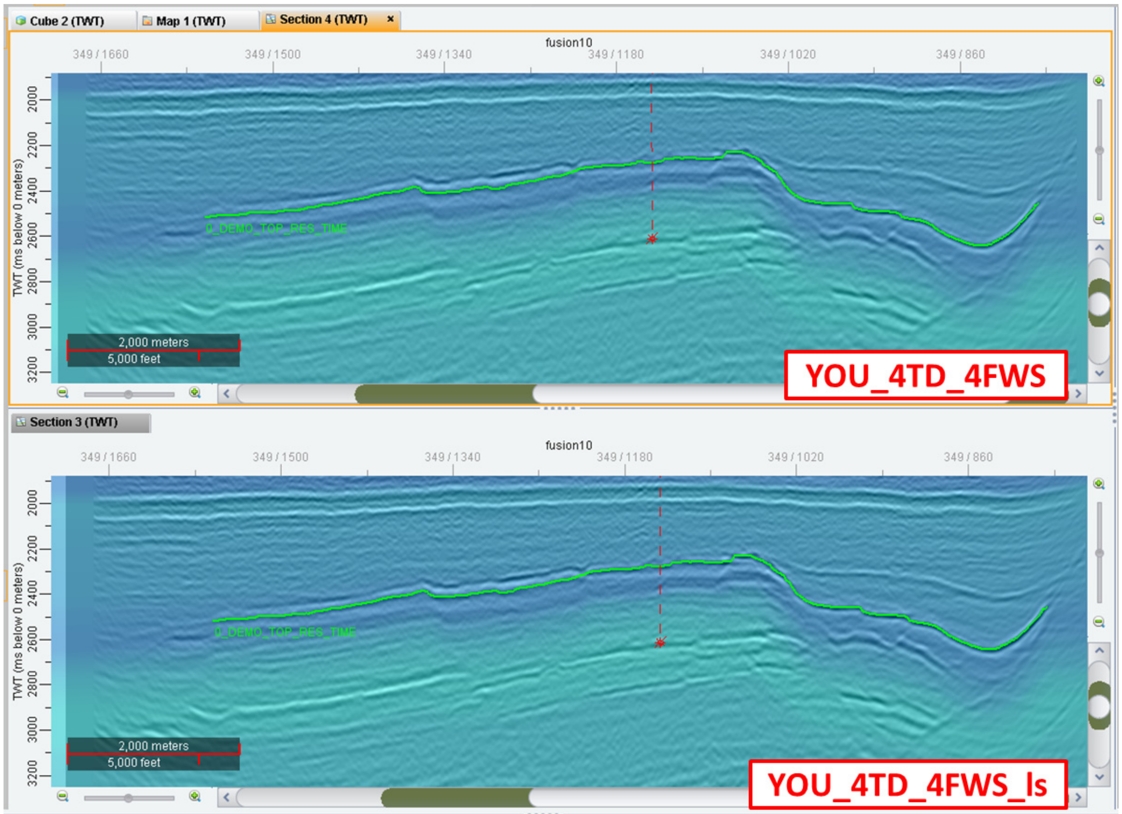
24. Select **Time-Depth Curve** from the menu at the left. Highlight well **6507/7-8** and click the **Curve Details** button.



Observe how the *Depth - Calc* column has changed with the additional least-squares fitting. Most of the wells are now tied to less than 1 meter of accuracy.

25. Close the *Time-Depth Curve Details* dialog, but leave the *Velocity Modeling* dialog open.

26. In the *Section* view at the top of the main window, from the *Inventory* task pane, toggle on **YOU_4TD_4FWS (memory time)**. In the *Section* view below, toggle on **YOU_4TD_4FWS_ls (memory time)**.



The model using four well TD functions and four structure layers looks much better than the initial one with one well TD function and one layer model. As expected, there is no visual difference from using the least-squares option, except it is a better fit to the original TD function data, by a few meters.

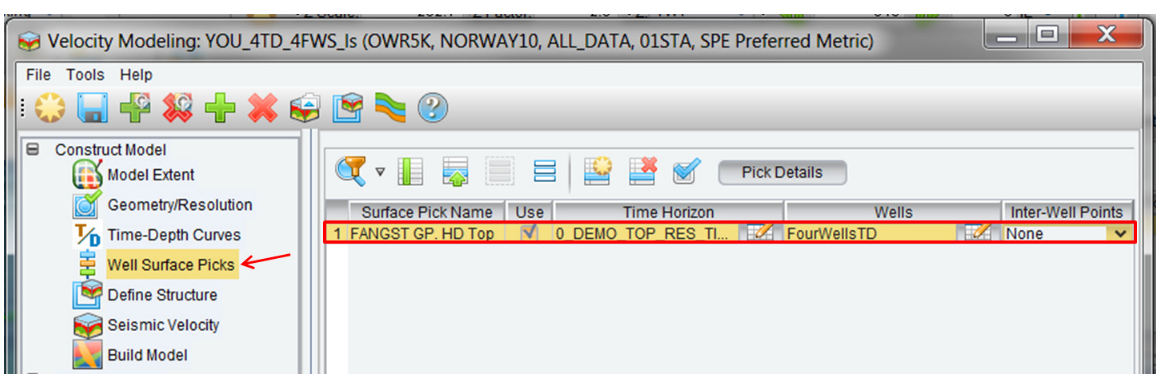
Exercise 6.6: Calibrating the Velocity Model to Well Picks

In this exercise, you will calibrate the velocity model to well surface picks and their associated horizons to create a more accurate model that ties to the well picks. The term “more accurate” could be problematic because, as we have discussed previously, the well TD function data is original absolute data (although it is still subject to data errors), whereas the well surface picks are interpreted data, which of course makes it subject to misinterpretation (this can be due to poor data or a difference of opinion between competing geologists).

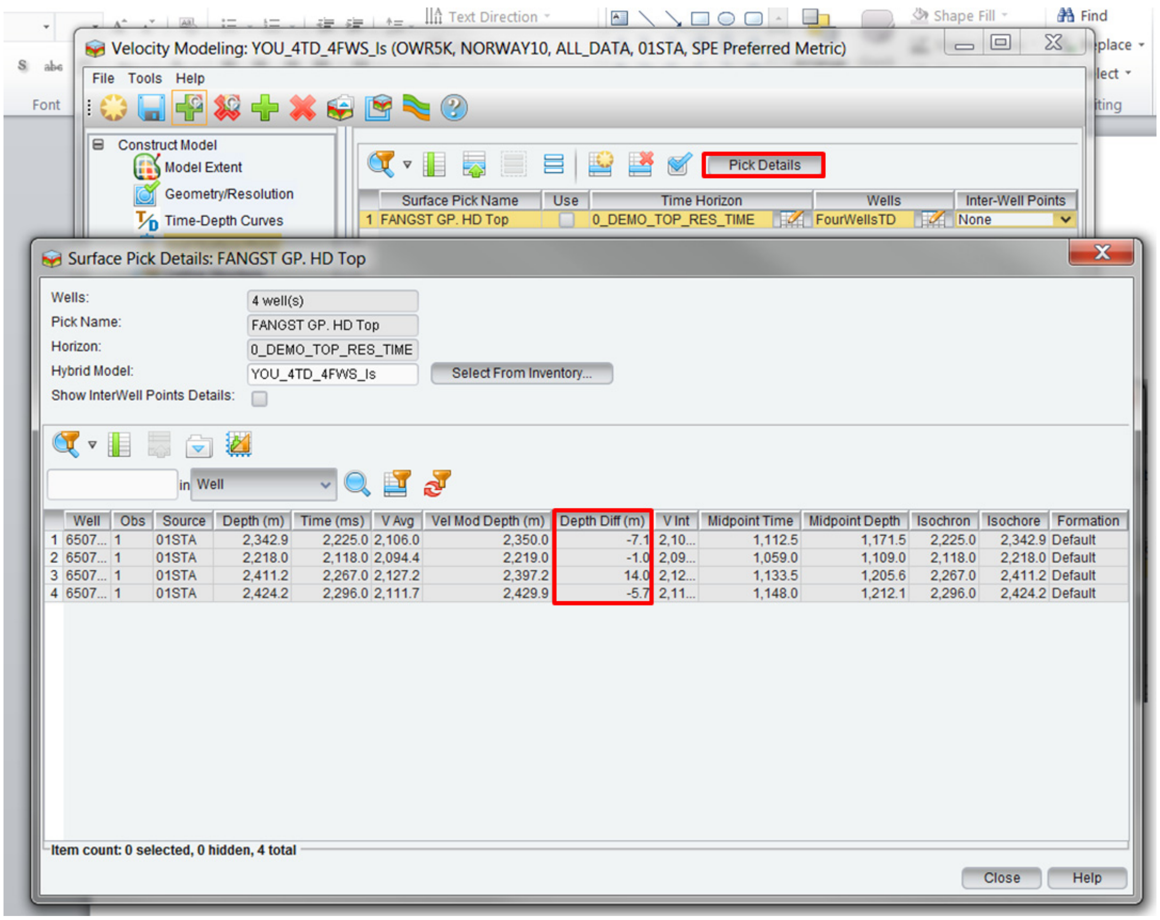
Most explorationists want a reservoir model that ties to their well tops. Moreover, velocity modeling is a sensitive tool and any misinterpretation of either logs or seismic will usually result in a velocity anomaly. To make a smooth velocity model, the process of calibrating to picks may serve as an interpretation QC that will enable us to question and possibly correct anomalous seismic and well interpretation data.

1. In the *Velocity Modeling* dialog, from the left menu select **Well Surface Picks**. From the *Inventory* task pane, drag-and-drop the surface pick **Fangst GP.HD Top** into the *Well Surface Pick* panel.

2. From the *Inventory* task pane, drag-and-drop the horizon **0_DEMO_TOP_RES_TIME** and the well list **FourWellsTD** into the associated *Time Horizon* and *Wells* cells of the *Well Surface Pick* panel.

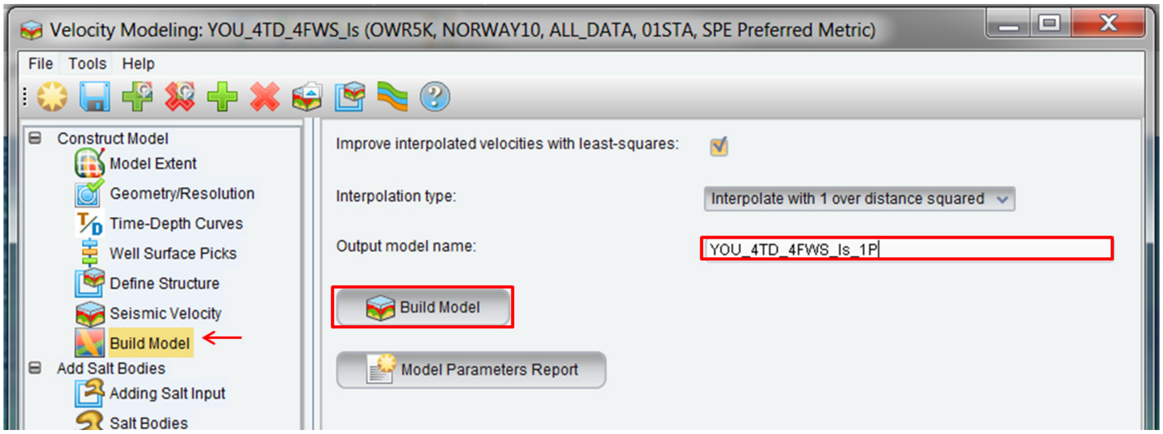


3. Highlight **FANGST GP.HD Top** and click the **Pick Details** button, to QC the pick.

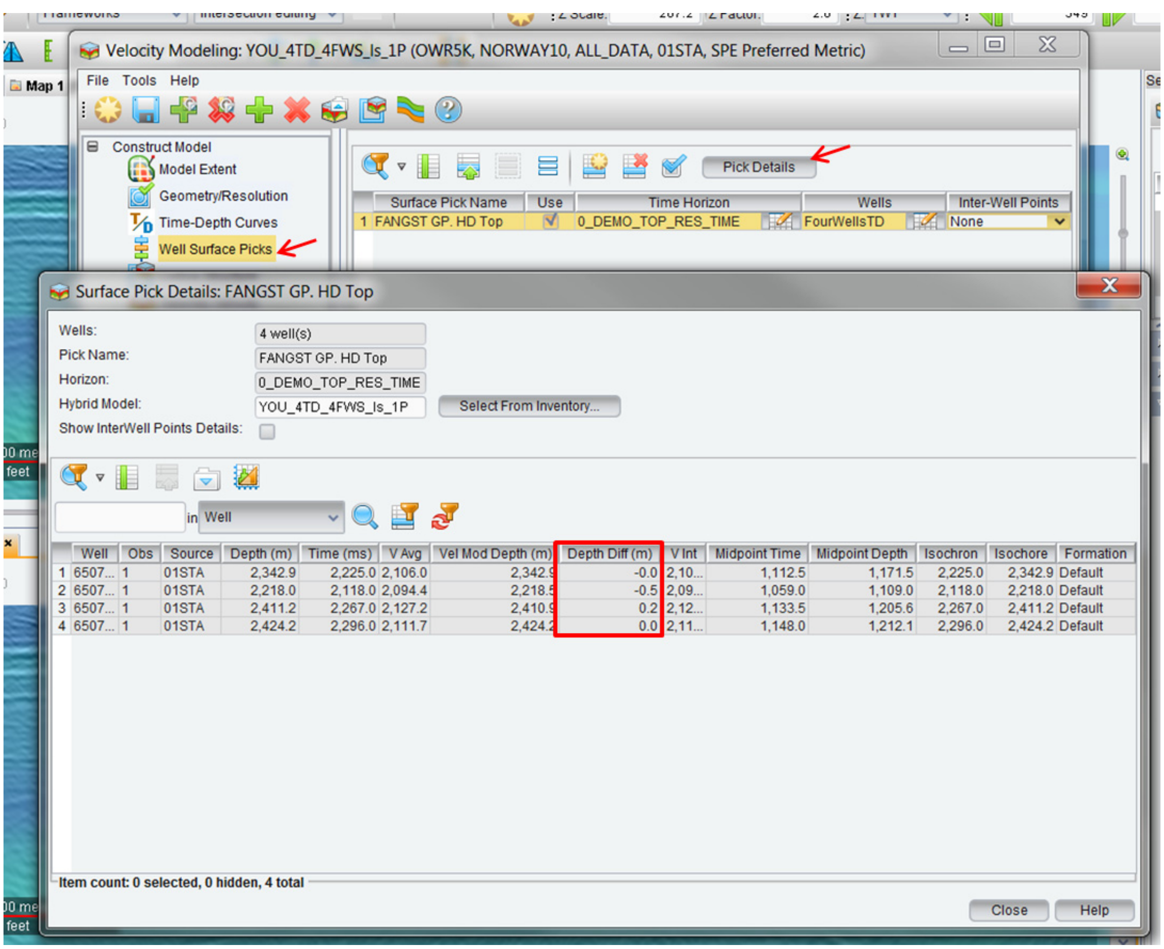


The *Surface Pick Details* dialog opens and displays information about the location of your picks. The numbers in the *Depth Diff* column gives the residual between the pick depth and the model depth at a point where the well path intersects the associated structure surface. Notice the Depth Diff residuals.

4. Close the *Surface Pick Details* dialog. Select **Build Model** in the left menu panel. Rename the model “**YOU_4TD_4FWS_ls_1P**” and click **Build Model**. Click **Yes** when prompted to save the model to OpenWorks.



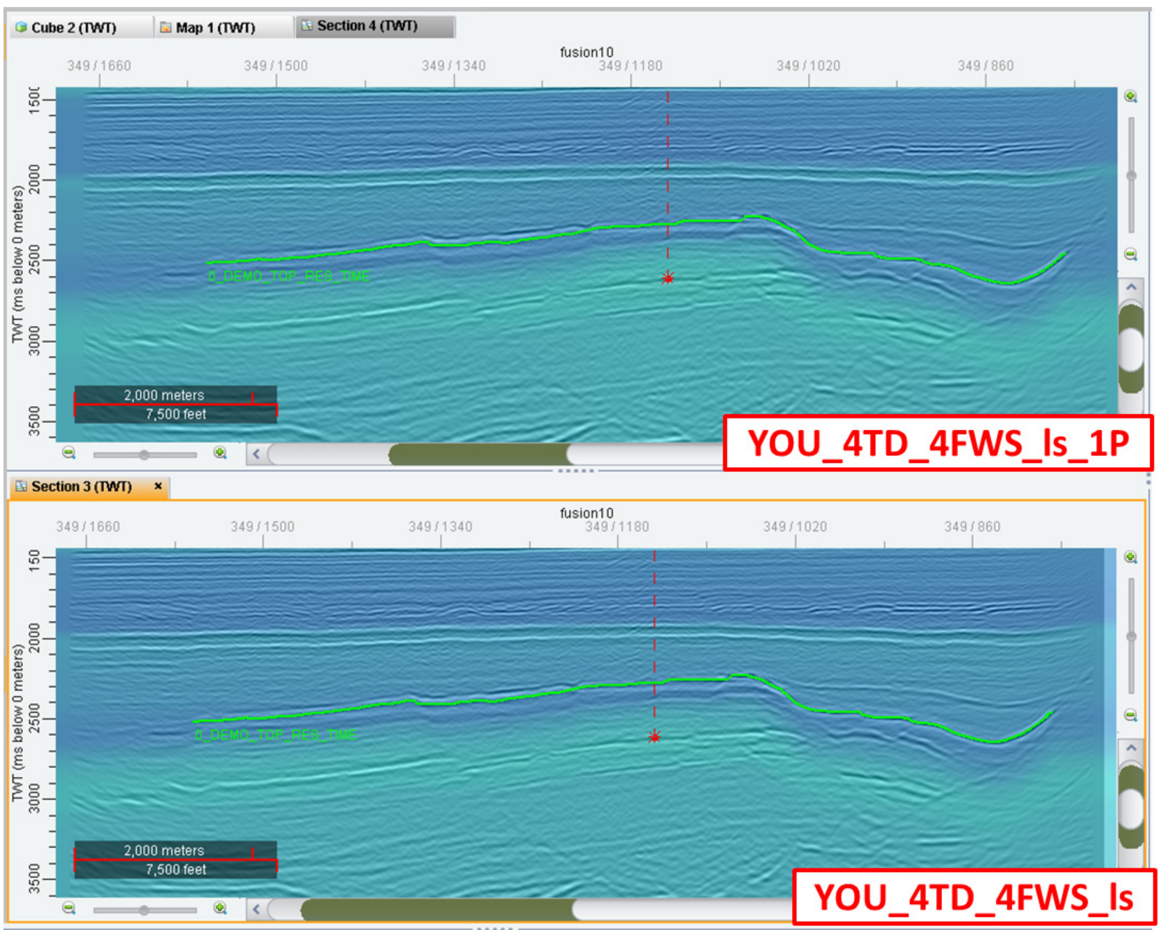
5. Select **Well Surface Picks** from the left menu panel, highlight **FANGST GP.HD Top** and click the **Pick Details** button.



Check the *Depth Diff* column to review the residual mis-tie of the model depths to the Pick depths. The column values change to almost zero. Since the residuals were small and fairly consistent, the minor distortion of the model that has been performed by the least-squares fitting is probably acceptable to obtain a more accurate model that better ties to the pick depths. As discussed previously for the TD functions, if there had been one erroneous pick with a large mis-tie, the least-squares fitting may have imposed an unacceptable distortion (and hence produced a velocity anomaly) on the model in order to fit it. The least-square fitting option works on both the TD functions and the Picks.

6. Close the *Surface Pick Details* dialog.

7. In the *Section* view at the top, toggle off the velocity model **YOU_4TD_4FWS (memory time)** and toggle on the new velocity model **YOU_4TD_4FWS_ls_1P (memory time)**. The *Section* view below should still have **YOU_4TD_4FWS_ls** toggled on.



Note

For this data, there are no anomalous picks. However, anomalous picks commonly cause distortions in the velocity mode. Some techniques for finding anomalous picks in DecisionSpace Velocity Modeling are:

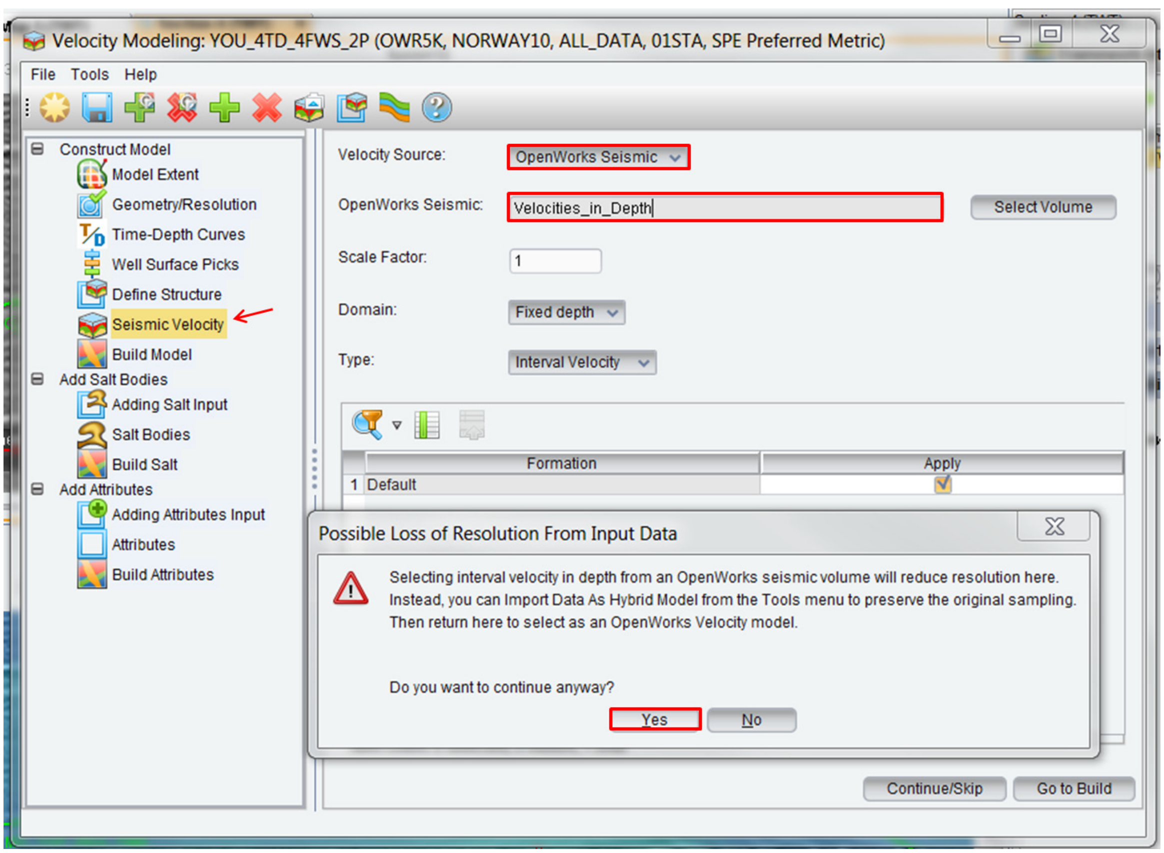
- Build a Pick-only Velocity Model.
- Overlay the velocity model along a well-to-well arbitrary seismic line with the horizons and picks used in the model displayed.

Exercise 6.7: QC Seismic Velocities

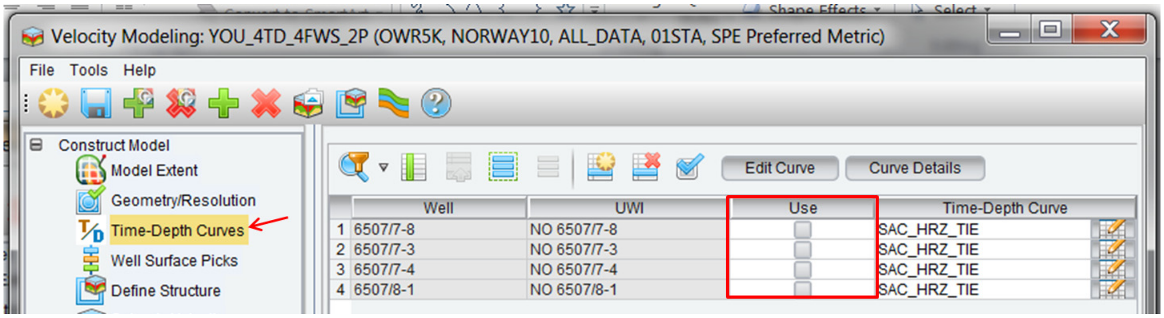
In this exercise, you will incorporate seismic velocities. Seismic velocities are not pure or geological velocities, as they may include anomalies and distortions that relate to problems in the seismic data. In fact, a better term for these might be seismic stacking factor rather than seismic stacking velocity. However, after suitable smoothing they do provide the velocity trend.

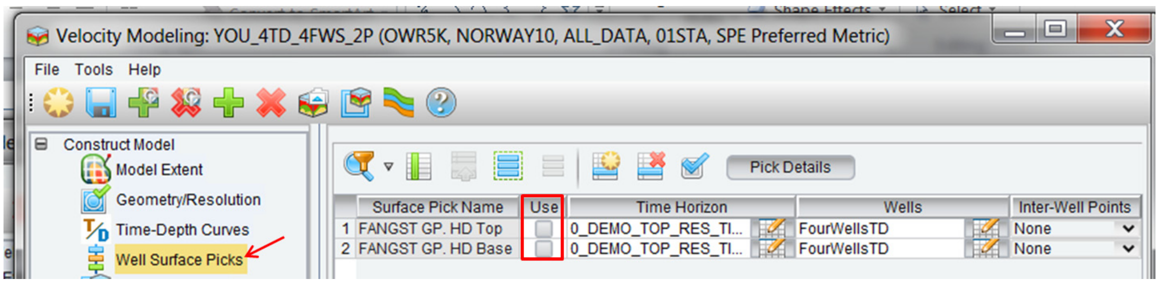
1. In the left panel of the *Velocity Modeling* dialog, select **Seismic Velocity**. Select **OpenWorks Seismic** from the *Velocity Source* drop-down menu.

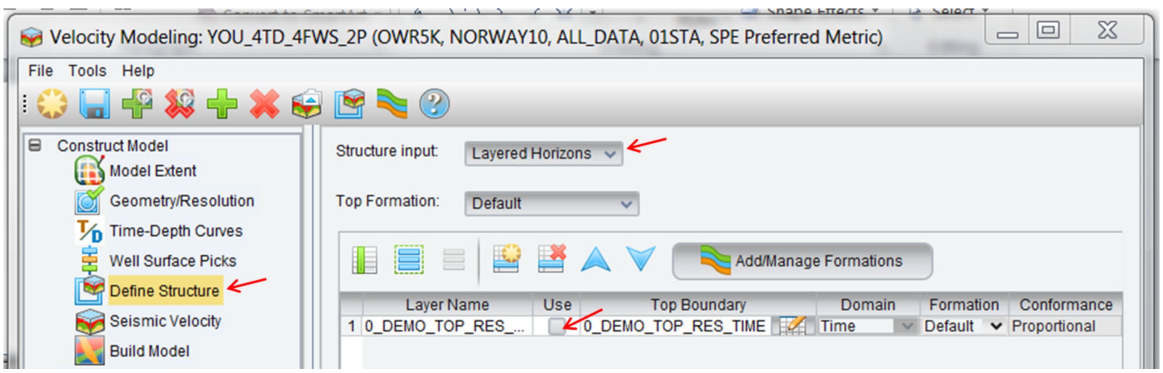
2. From the *Inventory* task pane, drag-and-drop the seismic volume **Velocities_in_Depth** into the *OpenWorks Seismic* cell. Click **Yes** in the *Possible Loss of Resolution From Input Data* dialog.



3. Navigate to the other data menus and toggle off all the TD functions, surface picks, and structure data in the model.

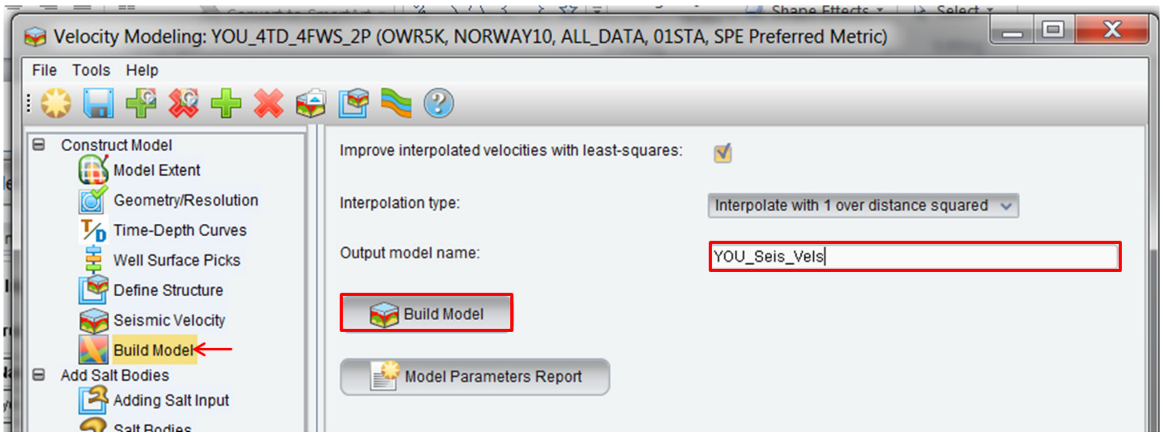






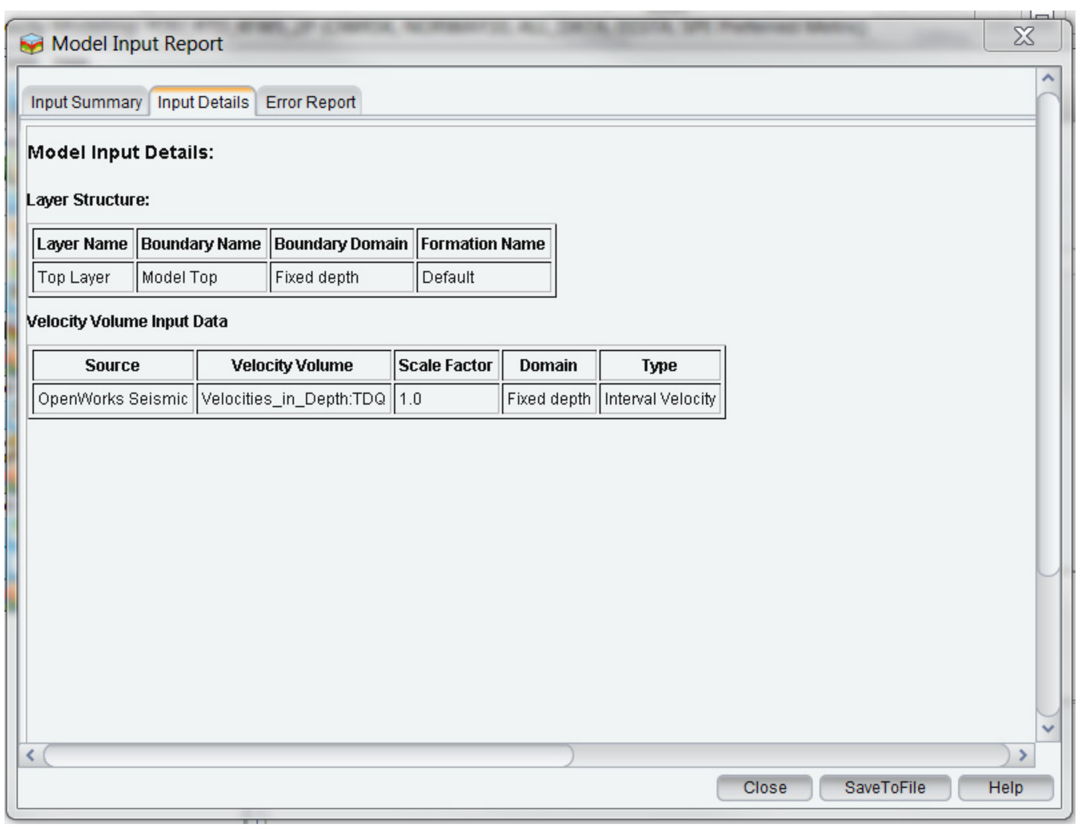
> **Note**
>
> To toggle off the structure layers, you must change the *Structure Input* to **Layered Horizons**. Then deselect the **Use** check box for the horizon.

4. In the left menu panel, select **Build Model** and change *Output model name* to *"***YOU_Seis_Vels***"* and click **Build Model**. Click **No** when prompted to save the model to OpenWorks. Click **OK**.

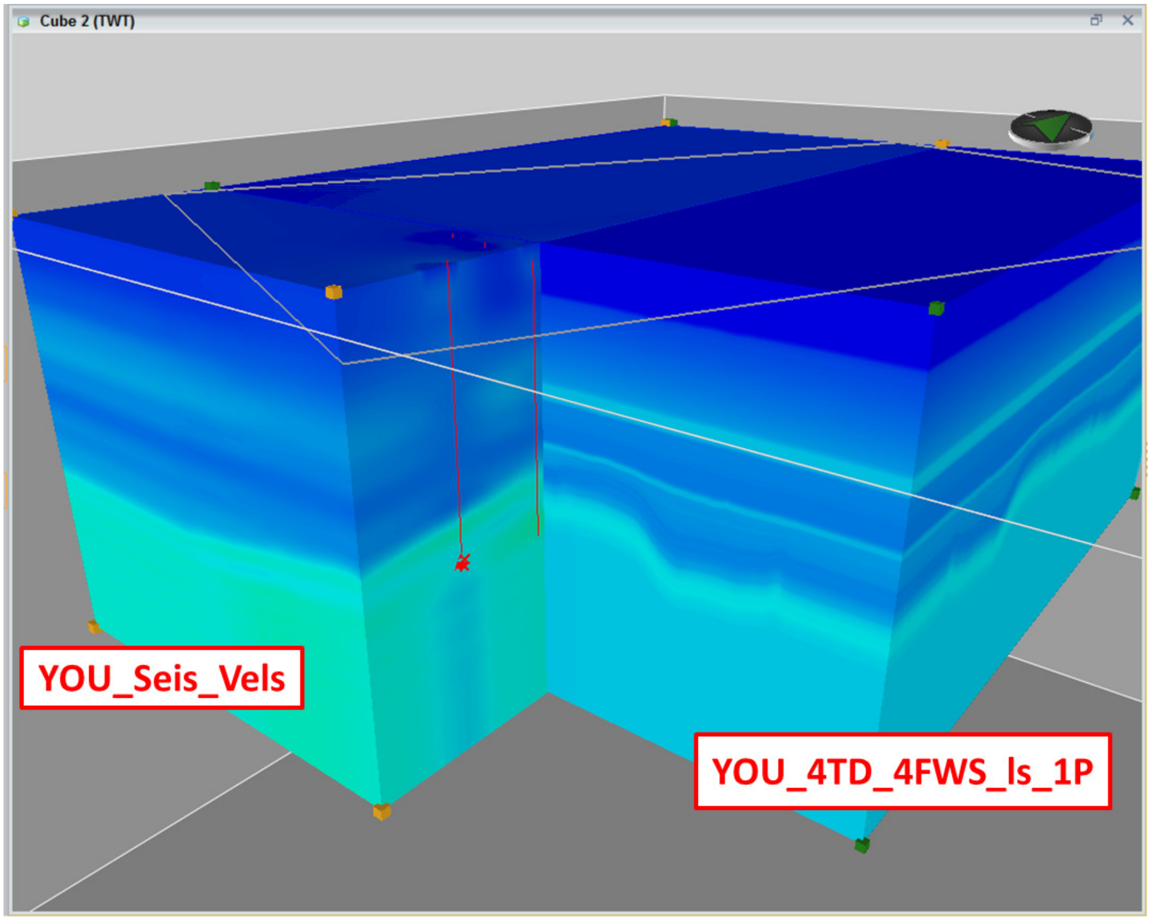


Note

You can double check to make sure the seismic velocities are the only input by clicking the **Model Parameters Report** button and selecting the **Input Details** tab.



5. Activate and maximize *Cube* view. From the *Inventory* task pane, drag-and-drop the velocity models **YOU_Seis_Vels** and **YOU_4TD_4FWS_ls_1P** into the view and select **Box** in the *Probe Selection* dialog. Arrange the box probes as shown below to compare the two.



Usually, the seismic velocities need to be smoothed. To validate seismic velocity variations, you need to smooth using the spread length. However, most prospects are reasonably shallow and the seismic shot record mute, limiting the data to about half the spread length. Hence, if you run smoothing tests you will probably find that the best result is around 2 - 3 km smoothing. A typical smoothing for 3D data would be 2000 m x 2000 m x 100 ms. It would be much greater for 2D data (5 - 10 km), depending on the line spacing.

Original seismic velocities are stacking velocities that can be quite noisy. These are typically smoothed and reduced to create migration velocities. Original seismic velocity functions may be spaced every 250m (for 3D data) and have around 10 picked X Y T V values in six seconds of data. However, these may have been interpolated during processing and exported either as an ASCII or SEG Y file. These files often have the excessive amount of interpolated data (e.g., 10 m x 10 m x 4 ms). Using this interpolated data for velocity modeling can cause problems because of the amount of data and quality control and editing of original data.

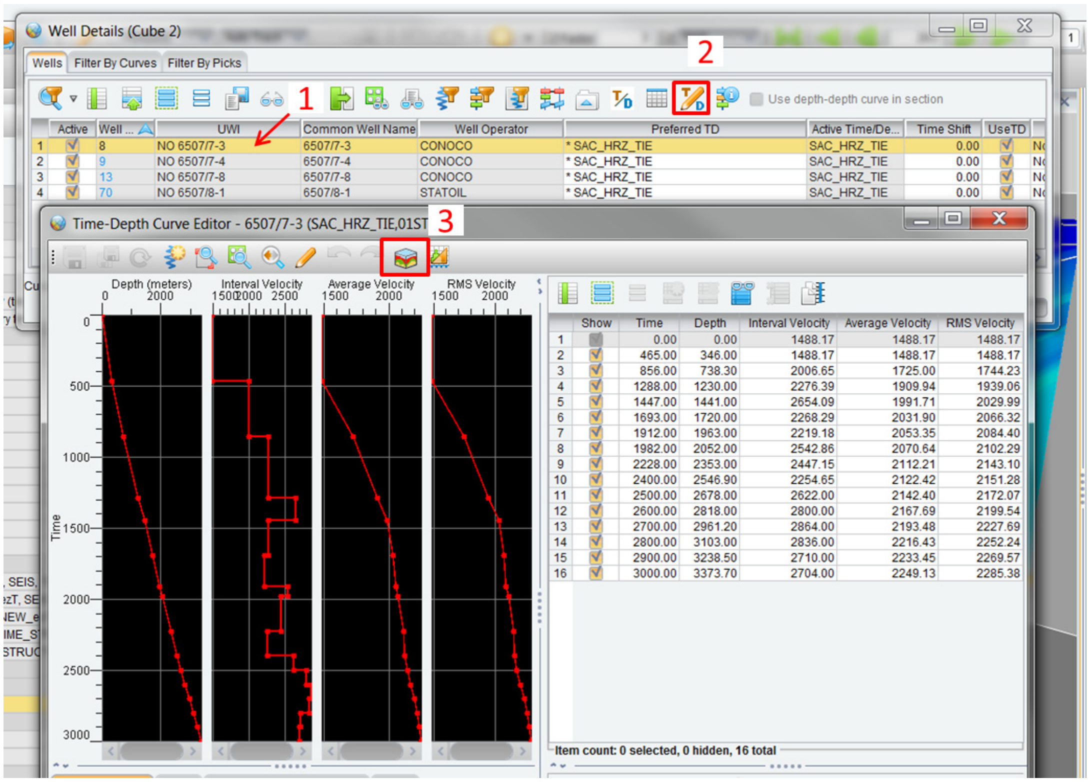
Since you have to smooth the data about 2 km, decimating interpolated data is the recommended option. The supplied seismic velocities have already been processed and calibrated to the well velocities. Furthermore, original seismic stacking or migration velocity are considered as RMS velocity and need to be converted to interval velocity before use in the velocity model.

In this exercise, you will use the already smoothed seismic interval velocity in depth.

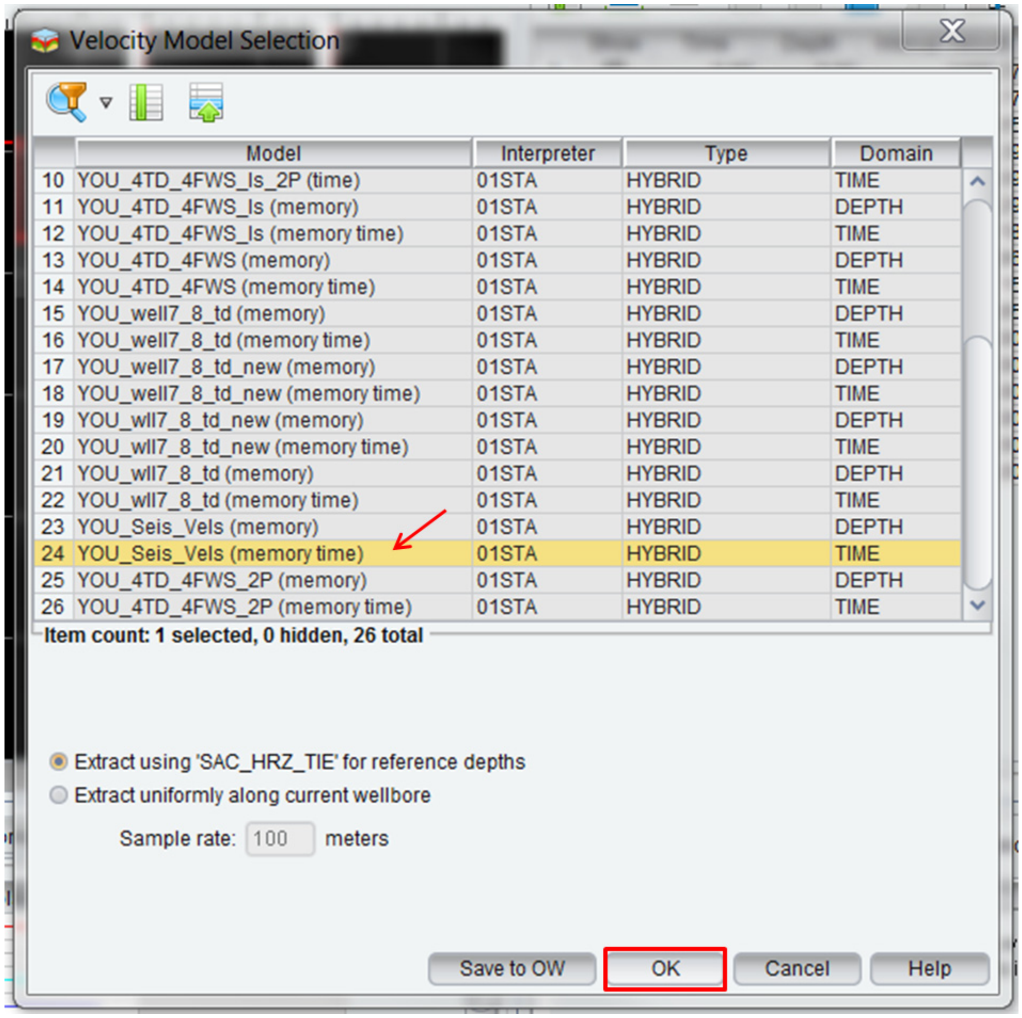
Extracting a TD curve from the seismic velocity cube at a well location and comparing it to the well TD function is a good way to QC the seismic velocity.

6. In the *Inventory* task pane, highlight the well list **FourWellsTD**. **MB3** and select **Well Details**.

7. In *Well Details*, highlight **6507/7-3** and click the **Time-Depth Curve Editor** ( ) icon. From the *Time-Depth Curve Editor* toolbar, select the **Extract TD curve at active well location** ( ) icon.



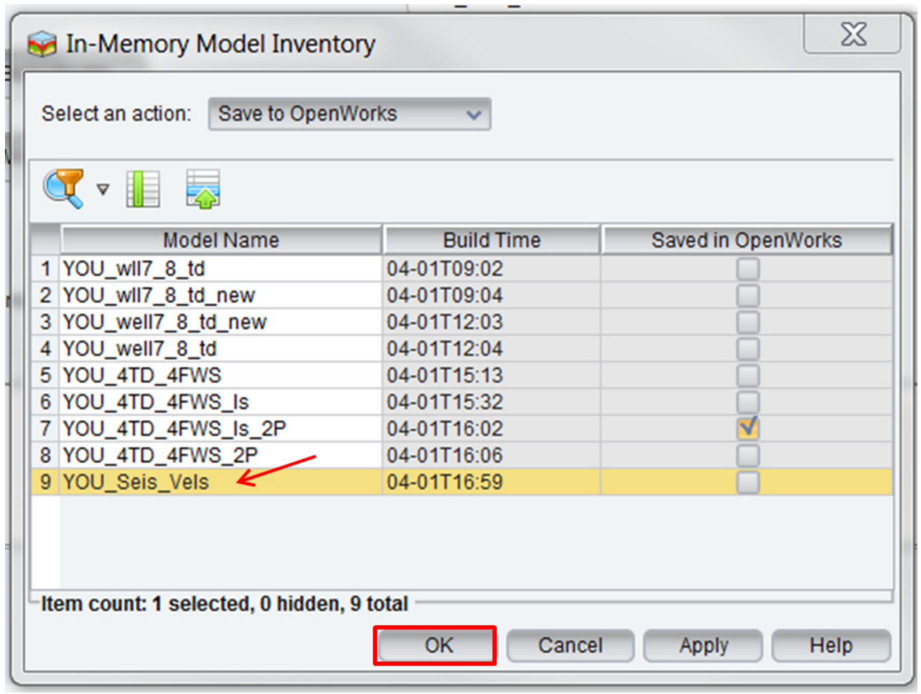
8. From the *Velocity Model Selection* dialog, select **YOU_Seis_Vels (memory time)** and click **OK**.



The extracted seismic velocity appears in blue and resembles the well TD function because they have similar values. Use this process to QC the seismic velocities in other wells by selecting them in the *Well Details* dialog.

9. Close the *Time-Depth Curve Editor* dialog and the *Well Details* dialog.

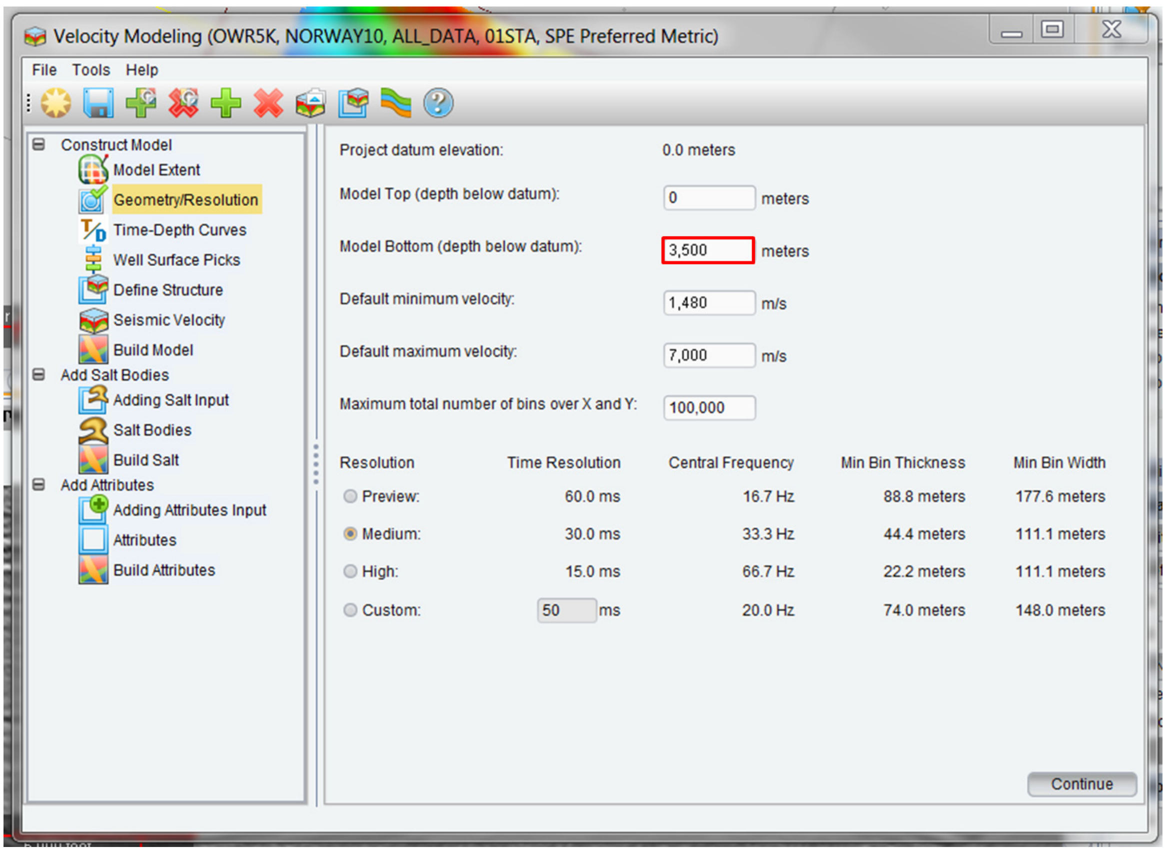
10. In the *Velocity Modeling* menu bar, select **File** > **Save**. In the *In-Memory Model Inventory* dialog, highlight **YOU_Seis_Vels** and click **OK**. Select **Yes** to save to the database and click **OK** to confirm.



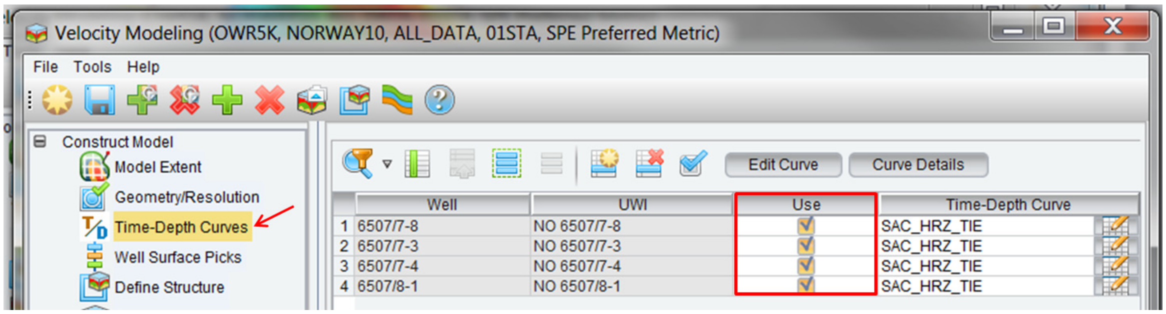
Exercise 6.8: Building the Final Velocity Model

In this exercise, you will review Velocity Model building menus to make sure that you are using the correct conditioned data and parameters for the final model.

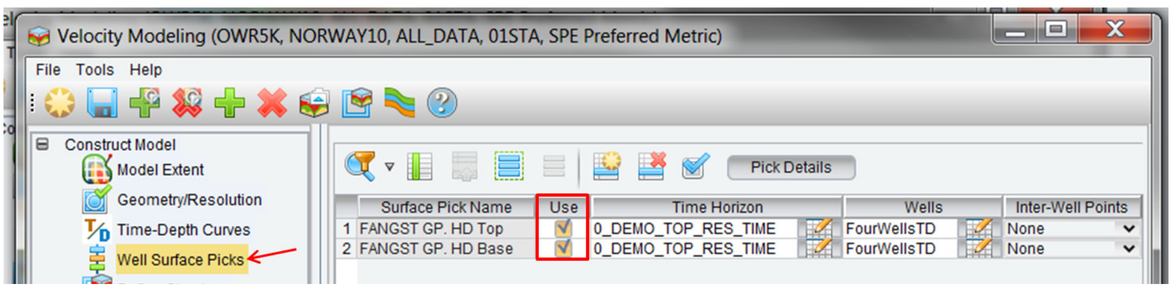
1. In the *Velocity Modeling* dialog, in the left panel menu, select **Geometry and Resolution** and change *Model Bottom (depth below datum)* to “**3500**” m.



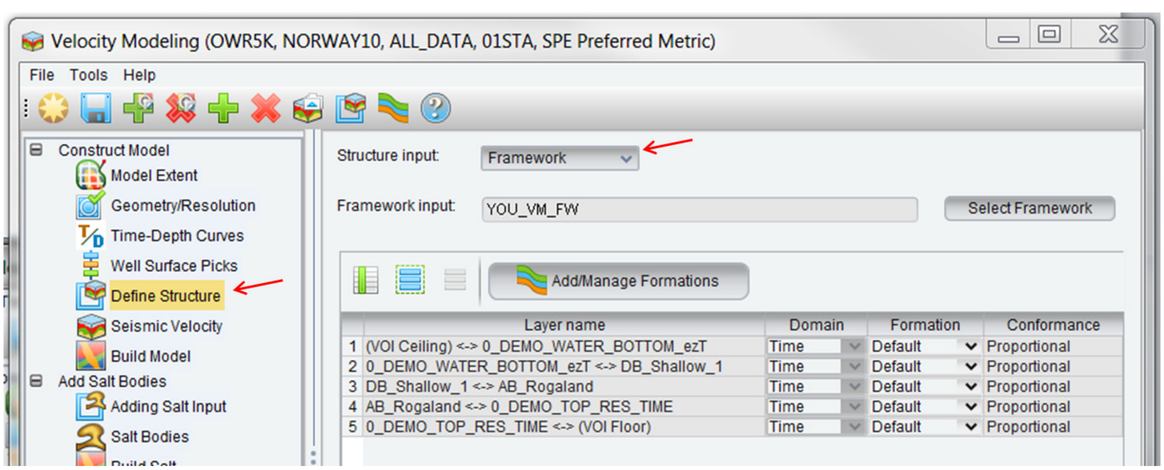
2. Select **Time-Depth Curves** from the left panel, and select the **Use** check boxes associated with the four well TD functions which have been quality controlled and edited.



3. Select the **Well Surface Picks** from the left panel and select the **Use** check boxes associated with the two picks.

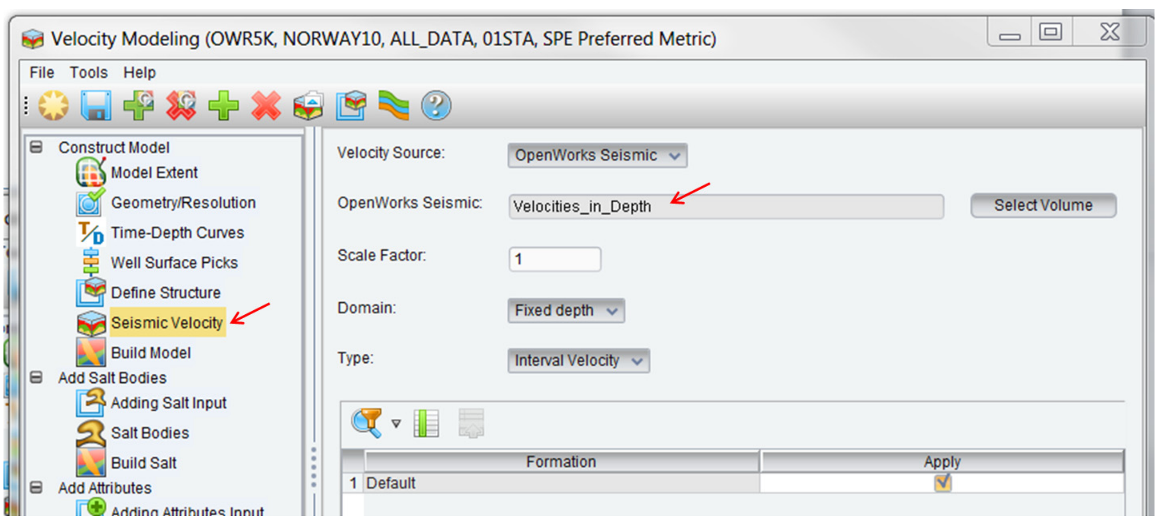


4. From the left panel, select **Define Structure** and select **Framework** from the *Structure input* drop-down menu. Ensure **YOU_VM_FW** is the *Framework input*.



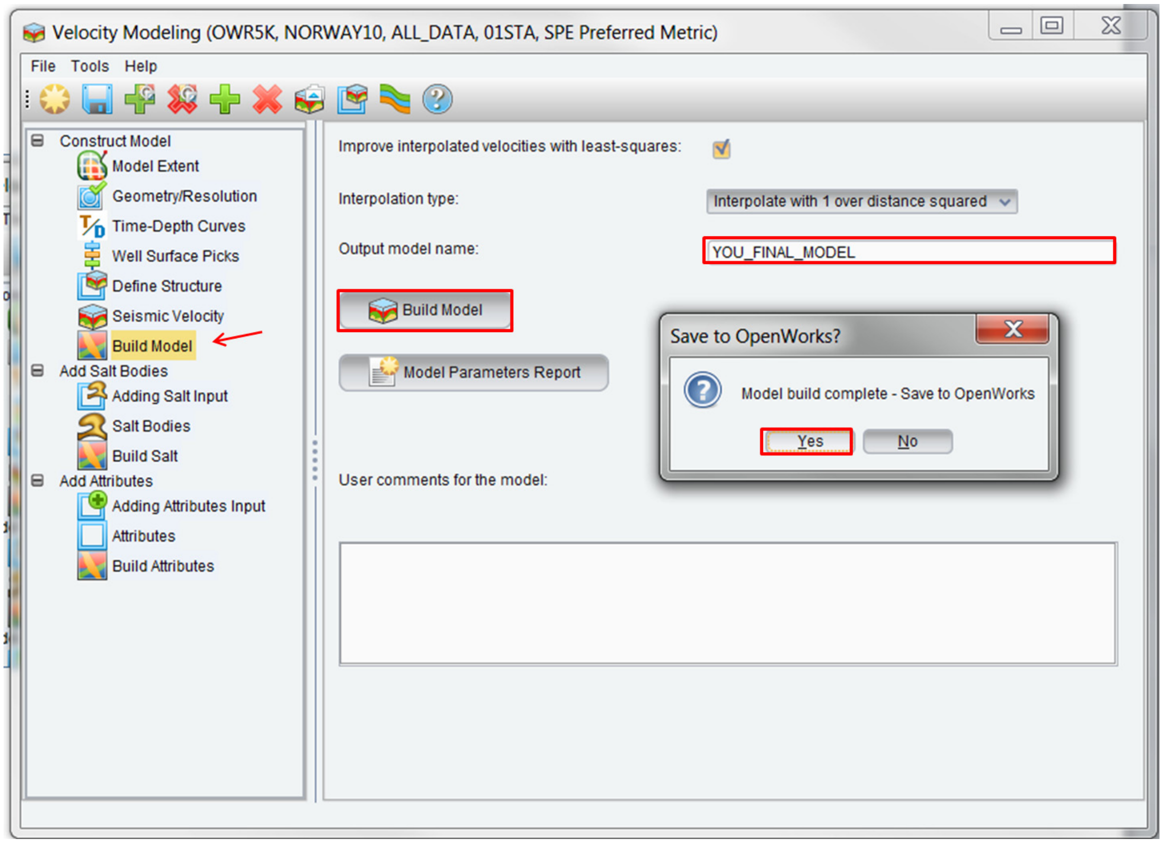
> **Note**
>
> In the Formation Manager (under the Add/Manage Formations button), you can define formations, set or limit the velocity using constant or analytic functions, and paste a velocity from another hybrid model. The conformance may be set, the interpolation limited, and each formation can have a different bin cell size.
>
> Furthermore, in the Formation Manager, properties such as Porosity, Pressure, Density, Anisotropy, and so forth may be set in a similar way. These attributes have no bearing on the model at present and do not affect the depth conversion process. They may be useful for future reference and applications, particularly if the model is used in your processing system.

5. Select **Seismic Velocity** from the left menu panel. Ensure **Velocities_in_Depth** is selected for *OpenWorks Seismic*.



> **Note**
>
> The seismic velocity will apply over the default formation which, in this case, is the whole model. The seismic velocity will be used as a background trend for the well TD functions and pick data interpolation and fitting.
>
> In addition to the seismic interval velocity in depth that is being used in this exercise, you can also import seismic velocity as ASCII X Y TV data, or from another hybrid model. Furthermore, if you define specific formations, you can pick and select what data is used in each formation.

6. Select **Build Model** from the left menu panel. Ensure the **Improve interpolated velocities with least-squares** check box is selected. For *Output model name*, enter "**YOU_FINAL_MODEL**." Click **Build Model**. When the *Save to OpenWorks* dialog opens, select **Yes**. Click **OK**.



Note

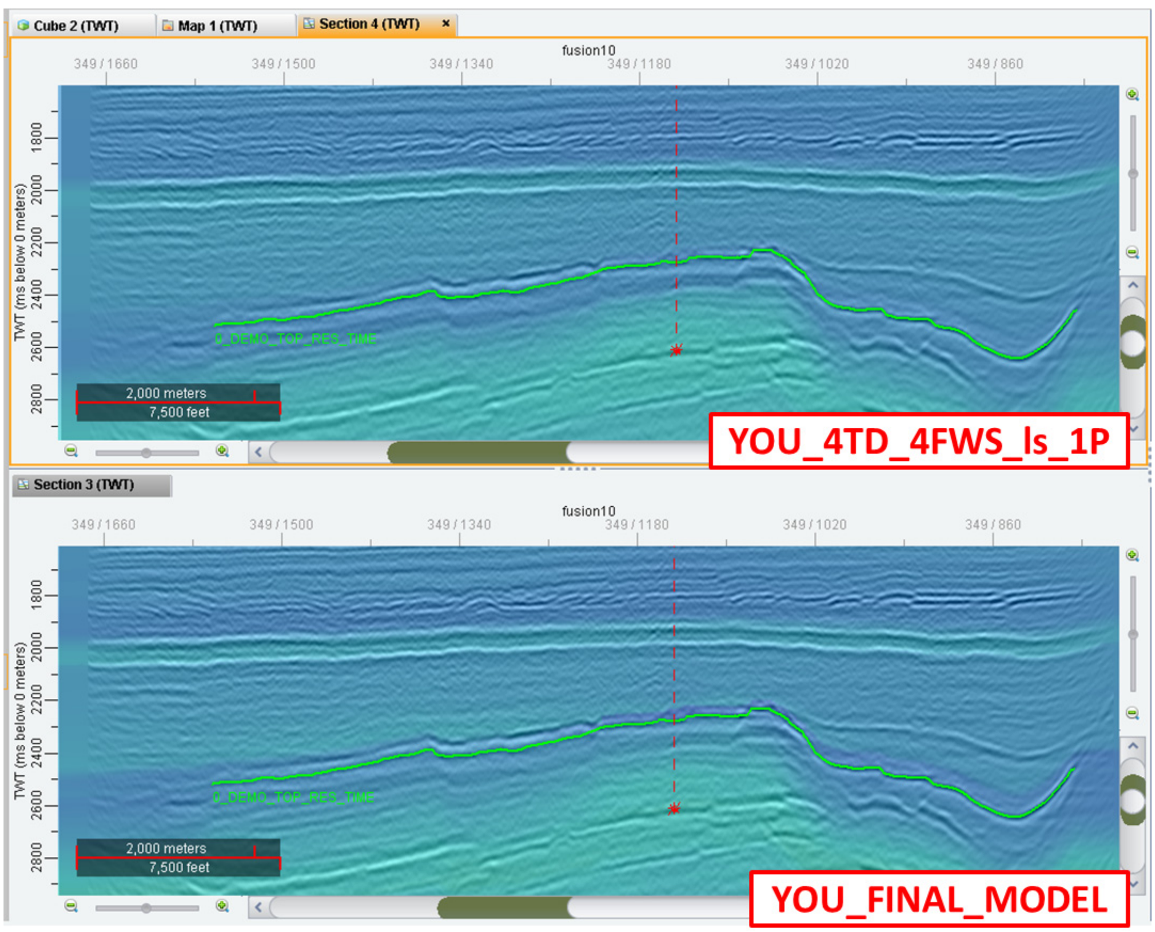
Just as in previous steps, you can QC the model by going to the *Curve Details* in the *Time-Depth Curves* panel and checking the *Depth-Calc* column, and also going to *Pick Details* in the *Surface Picks* panel and checking the *Depth-Diff* column. Also, you can go to the Model Parameters Report to check the input summary, input details, and error report. Once the model is built with well-QCd and well-conditioned data, the generated reports should be satisfactory.

Exercise 6.9: Quality Control and Depth Conversion with the Final Velocity Model (Optional)

In this exercise, you will learn about basic Velocity Model QC workflows in DecisionSpace Geosciences.

You can compare the model with and without seismic velocity.

1. Minimize *Cube* view, and make the two *Section* views visible. In the top *Section* view, toggle off the active Velocity Model and toggle on **YOU_4TD_4FWS_ls_1P**. In the lower *Section* view, toggle off the active Velocity Model and toggle on **YOU_FINAL_MODEL**.

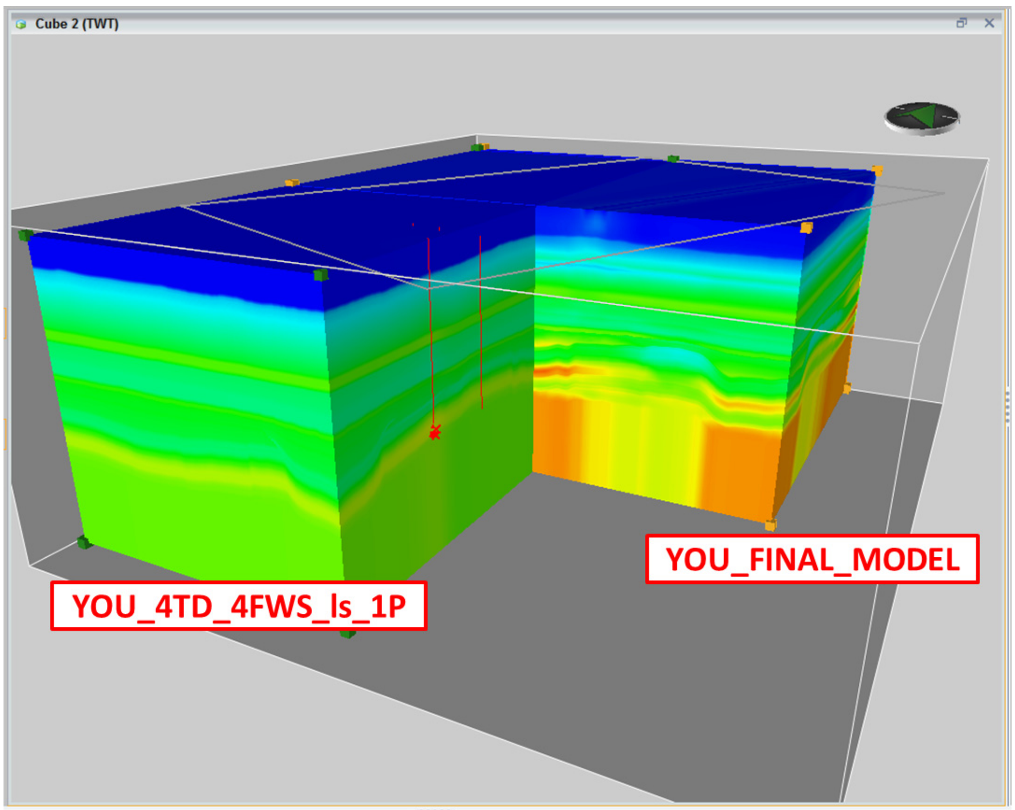


Note the contribution of the seismic velocity below the well extent.

Similarly, QC the velocity model without the seismic velocity and with the seismic velocity in the *Cube* view.

2. Activate and maximize *Cube* view. In the *Inventory* task pane, toggle off the box probe of **YOU_Seis_Vels**.

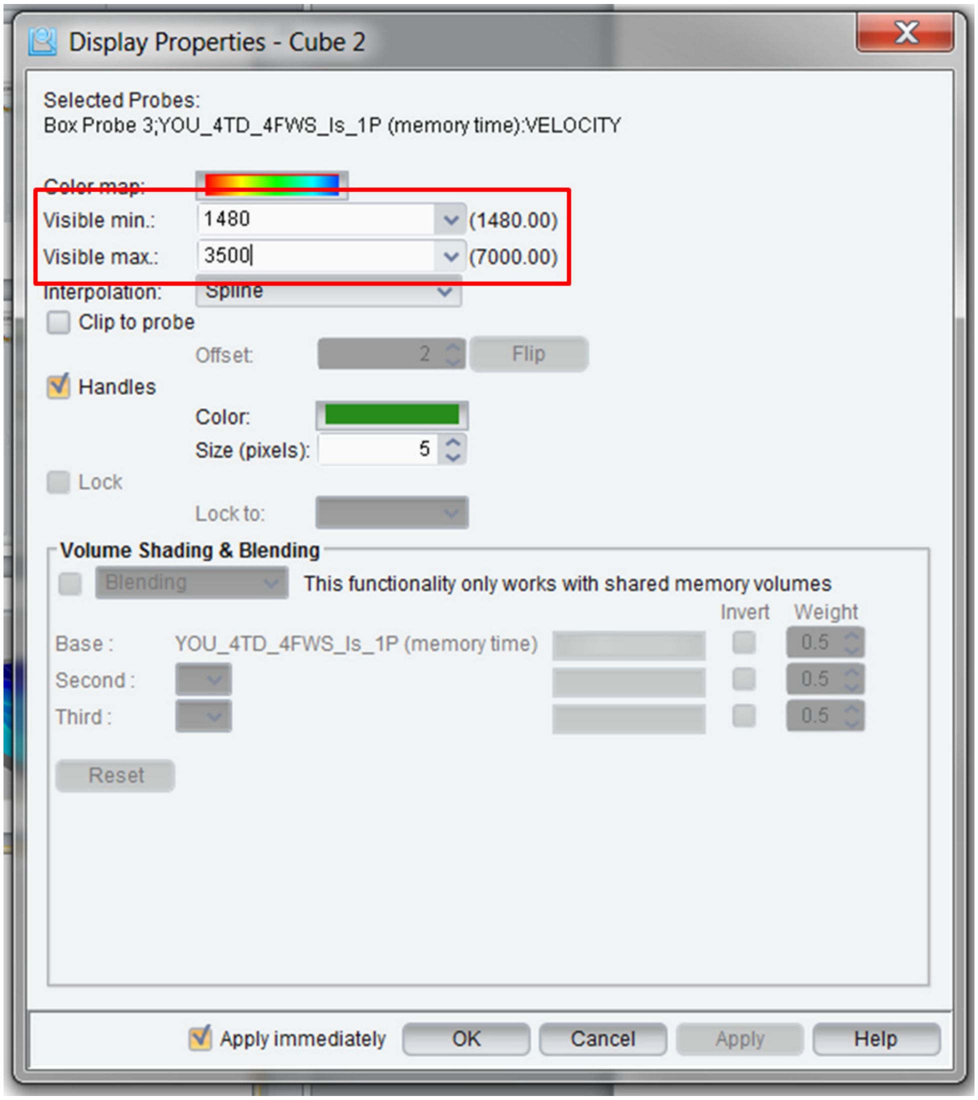
3. From the *Inventory* task pane, drag-and-drop the velocity model **YOU_FINAL_MODEL (time)** in to the view and select **Box** in the *Probe Type Selection* dialog. Also, ensure **FourWellsTD** is toggled on in your *Inventory* task pane. Arrange the box probes similar to the picture below.



4. **MB1+<Shift>** to move the probes faces and note the contribution of the seismic velocity between and away from the well data.

Note

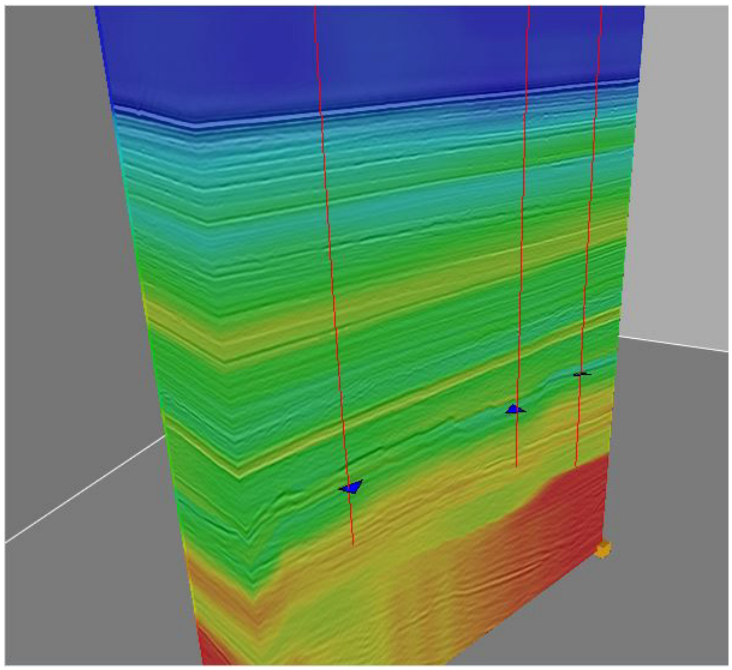
You can change the color spectrum to visualize the changes in velocity in more detail. In the Display Properties for each volume, change the Visible Min/Max values to 1480/3500.



Note

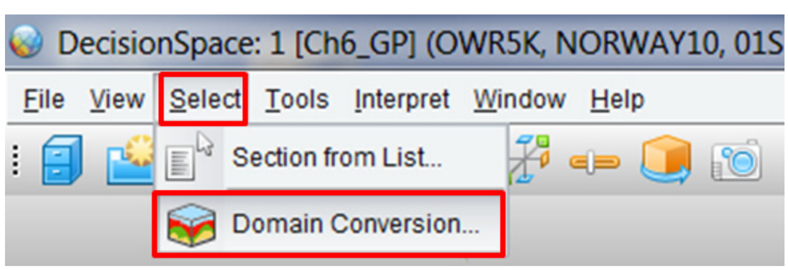
Another effective way to view and QC the velocity model is to use the Blending option available in the *Display Properties* menu. First you must use the Volume Exporter to save the velocity model as an OpenWorks seismic volume and then load both the OpenWorks seismic and velocity volumes to shared memory. The volume exporter is located in the *Velocity Modeling* dialog under **Tools > Volume**.

The following image shows a velocity model blended into a seismic volume.

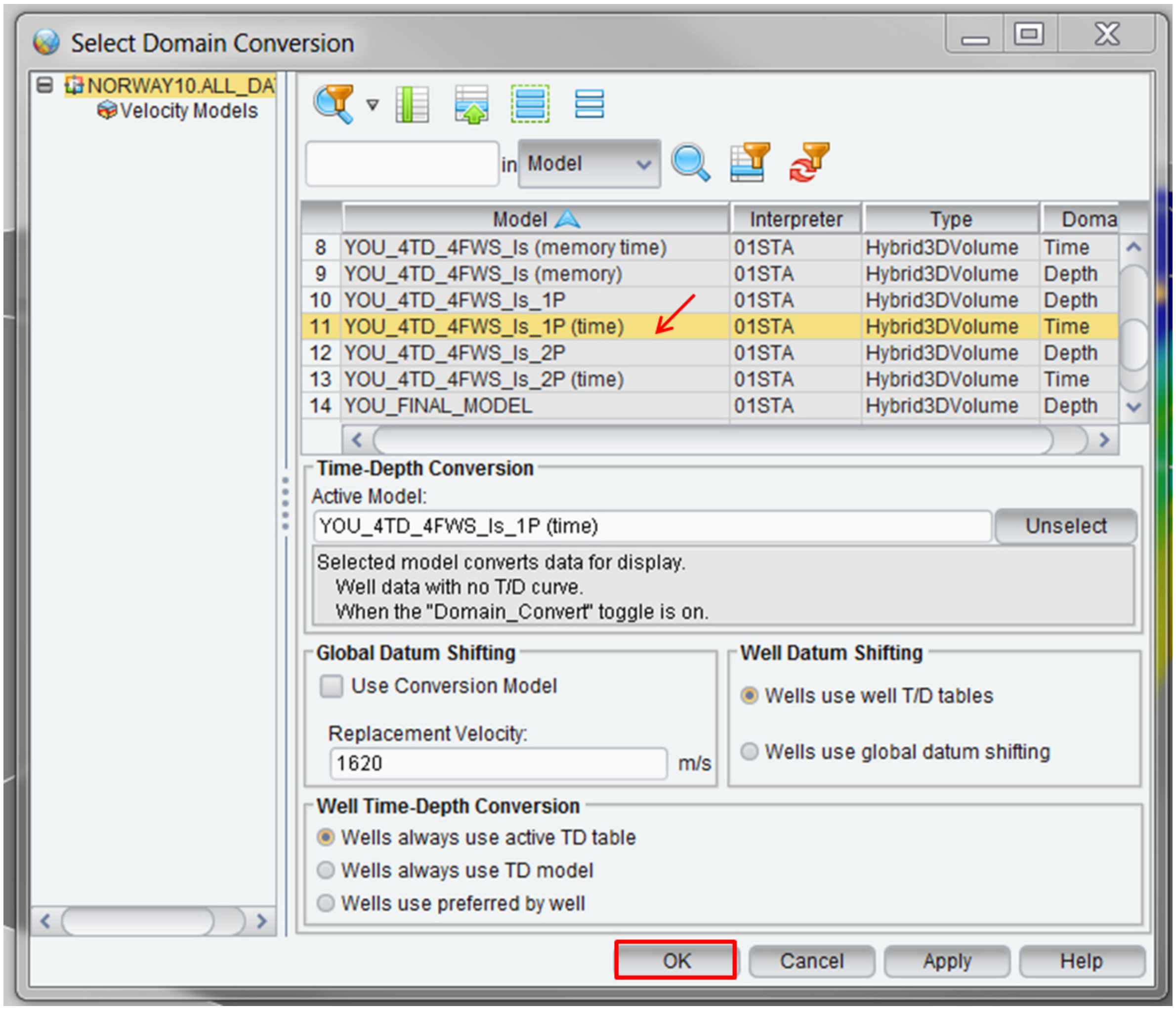


The true effect of incorporating the seismic velocity trend is available in the depth conversion. You will now use both models (with and without seismic velocities) to depth convert the Top Reservoir horizon and display the results on an arbitrary line going through the four wells and a difference map.

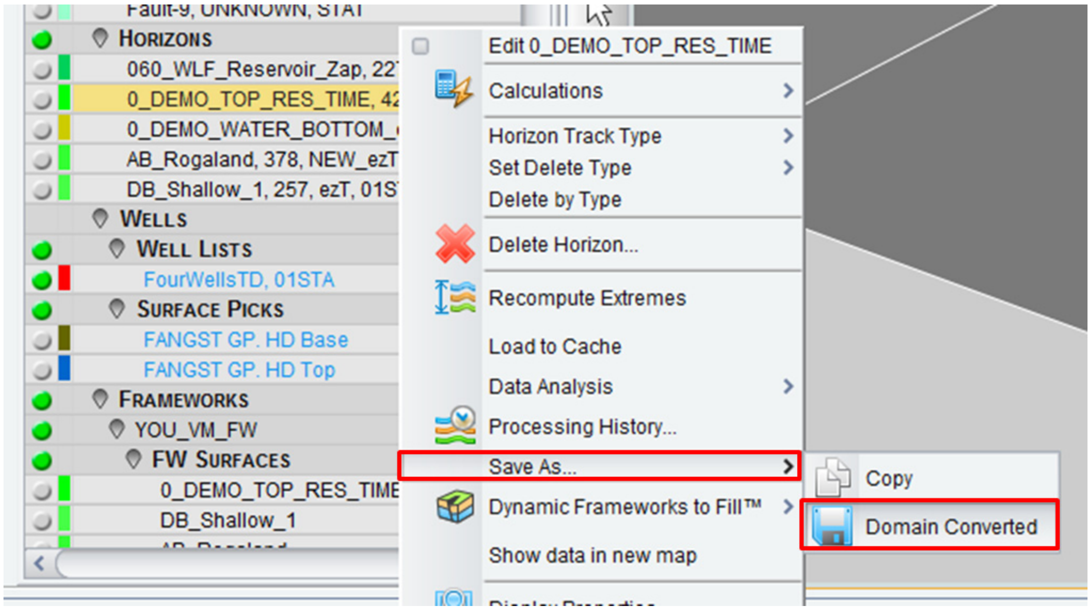
5. From the main menu bar select **Select > Domain Conversion...**.



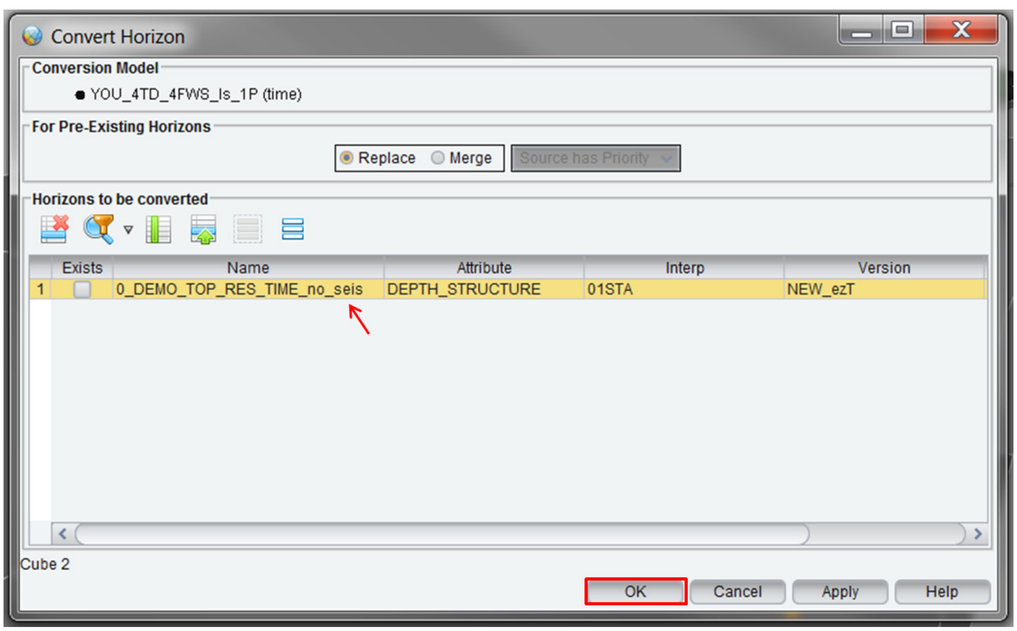
6. In the *Select Domain Conversion* dialog, highlight **YOU_4TD_4FWS_ls_1P** and click **OK** to set this as the active velocity model.



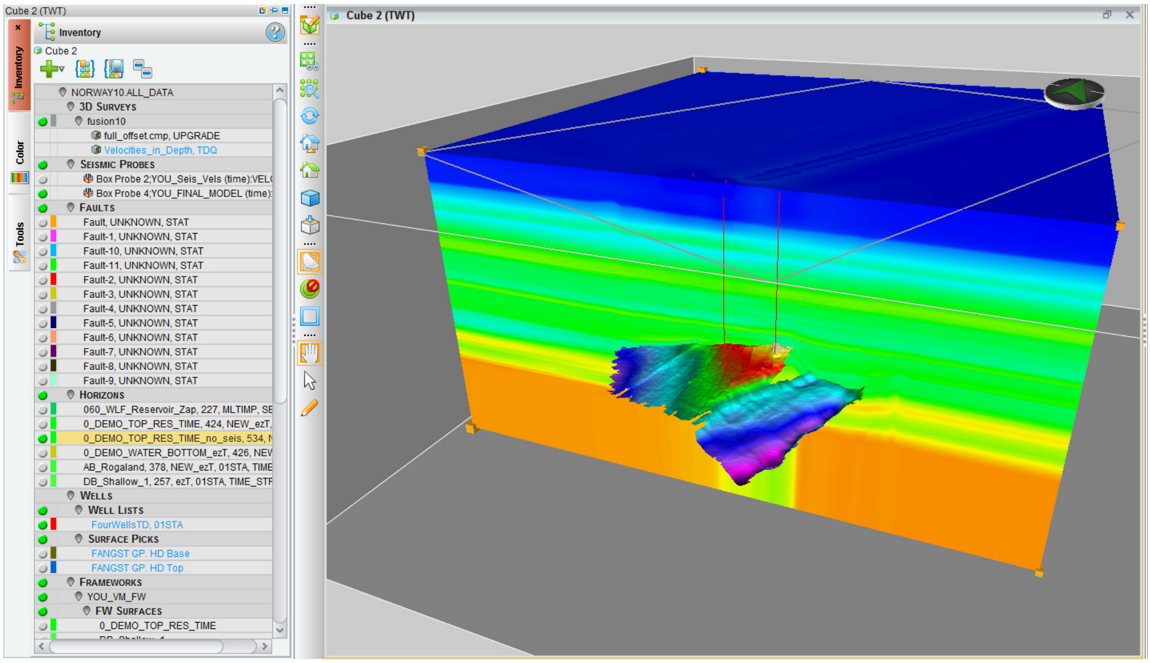
7. In the *Inventory* task pane, highlight and **MB3** on the horizon **0_DEMO_TOP_RES_TIME** and then select **Save as... > Domain Converted** to convert the time horizon to a depth horizon.



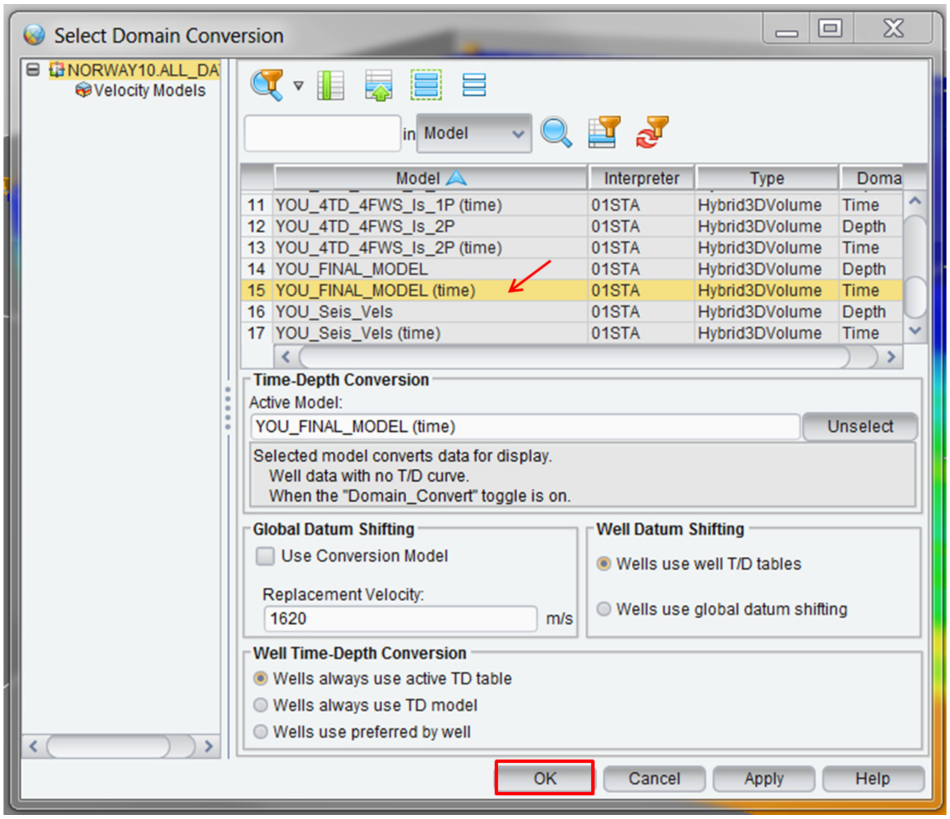
8. Append the name with "**_no_seis**" in the *Convert Horizon* dialog. Click **OK** to add the depth horizon to the *Inventory* task pane. Depth data objects appear in blue font.

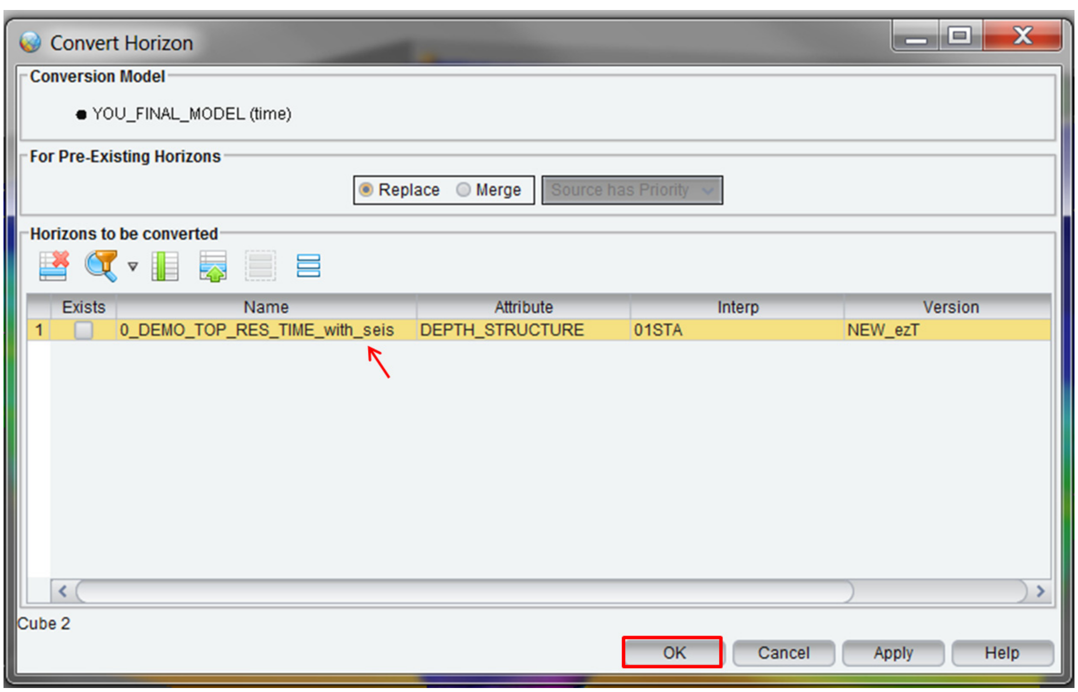


The horizon will automatically appear in your active *Cube* view. You will be able to view the depth horizon while the view is set to a time domain, because the session has been domain converted.



9. Repeat Steps 4 - 7. This time, in the *Select Domain Conversion* dialog, highlight **YOU_FINAL_MODEL (time)**. In the *Convert Horizon* dialog, add *"***_with_seis***"* to the horizon name.





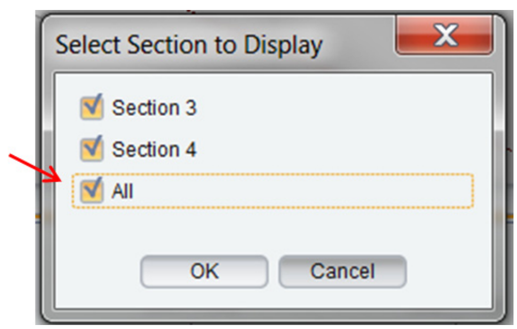
In the Inventory task pane, two depth versions of the 0_DEMO_TOP_RES_TIME horizon are available. Now you will display both versions to visualize the differences between the two depth conversions.

10. Activate *Map* view, and in the *Inventory* task pane toggle on **FourWellsTD** and toggle off the horizon **0_DEMO_TOP_RES_TIME**.

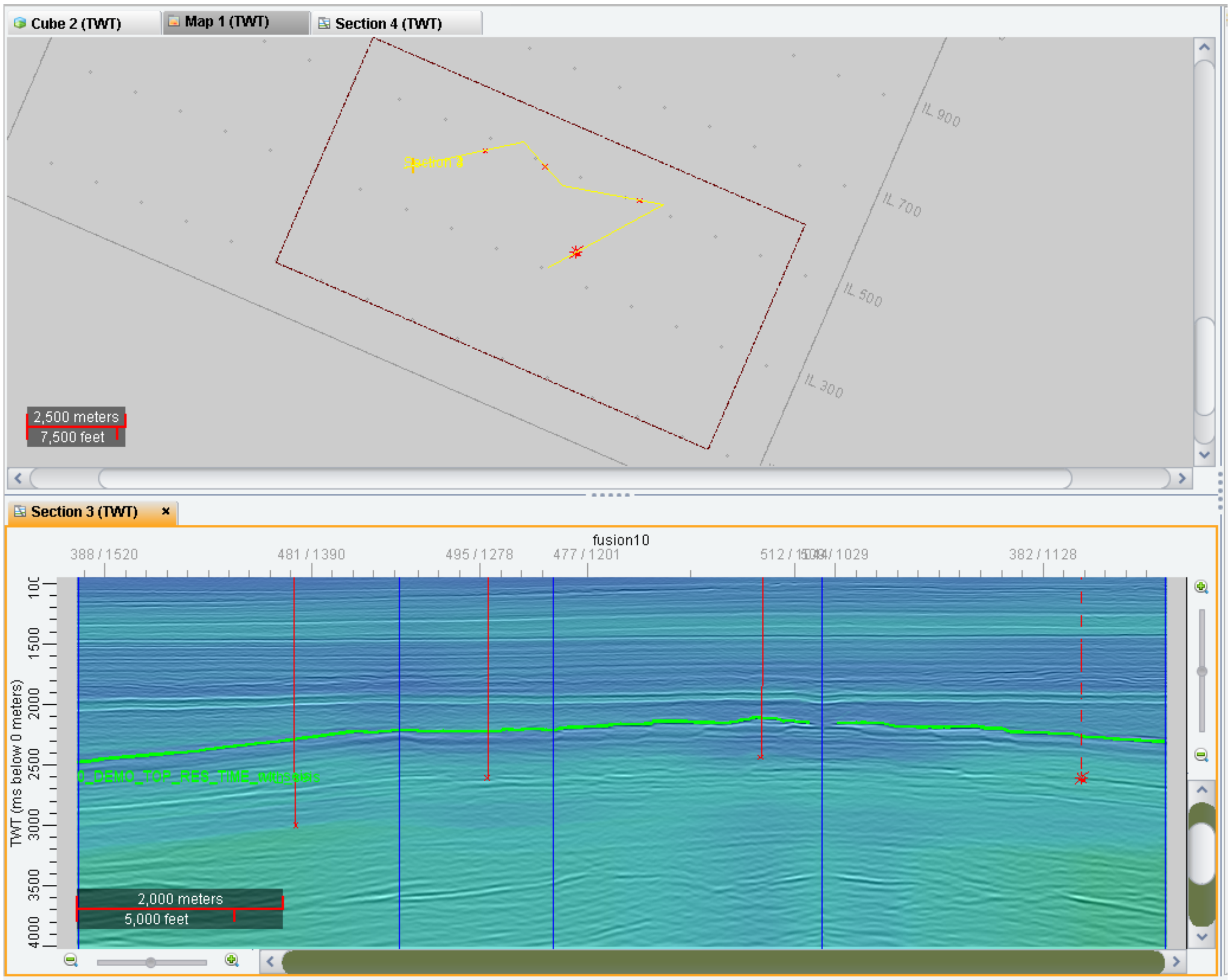
11. Click the **Select Point to Point** ( ) icon and click **MB1** to digitize an arbitrary line that goes through all four wells similar to the photo below. **MB2** to broadcast the arbitrary line to your *Section* views.

> **Note**
>
> Holding <**Ctrl**> and clicking on any of the wells will cause the section to go directly through the well.

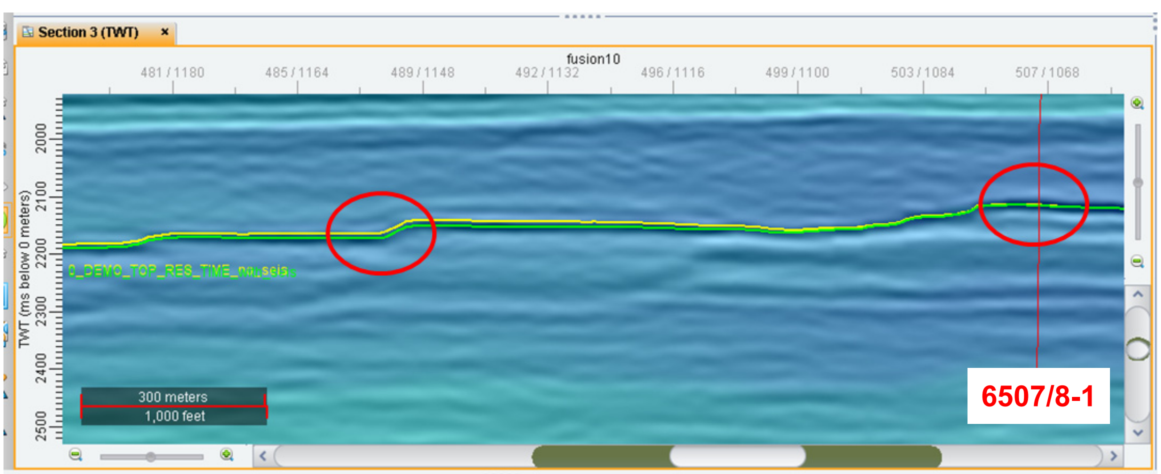
12. In the *Select Section to Display* dialog, select **All** and click **OK**.



13. In the active *Section* view, from the *Inventory* task pane, toggle off the time horizon **0_DEMO_TOP_RES_TIME** and toggle on both of the depth converted versions.



14. Use the **Area Zoom** icon to zoom in around a well.



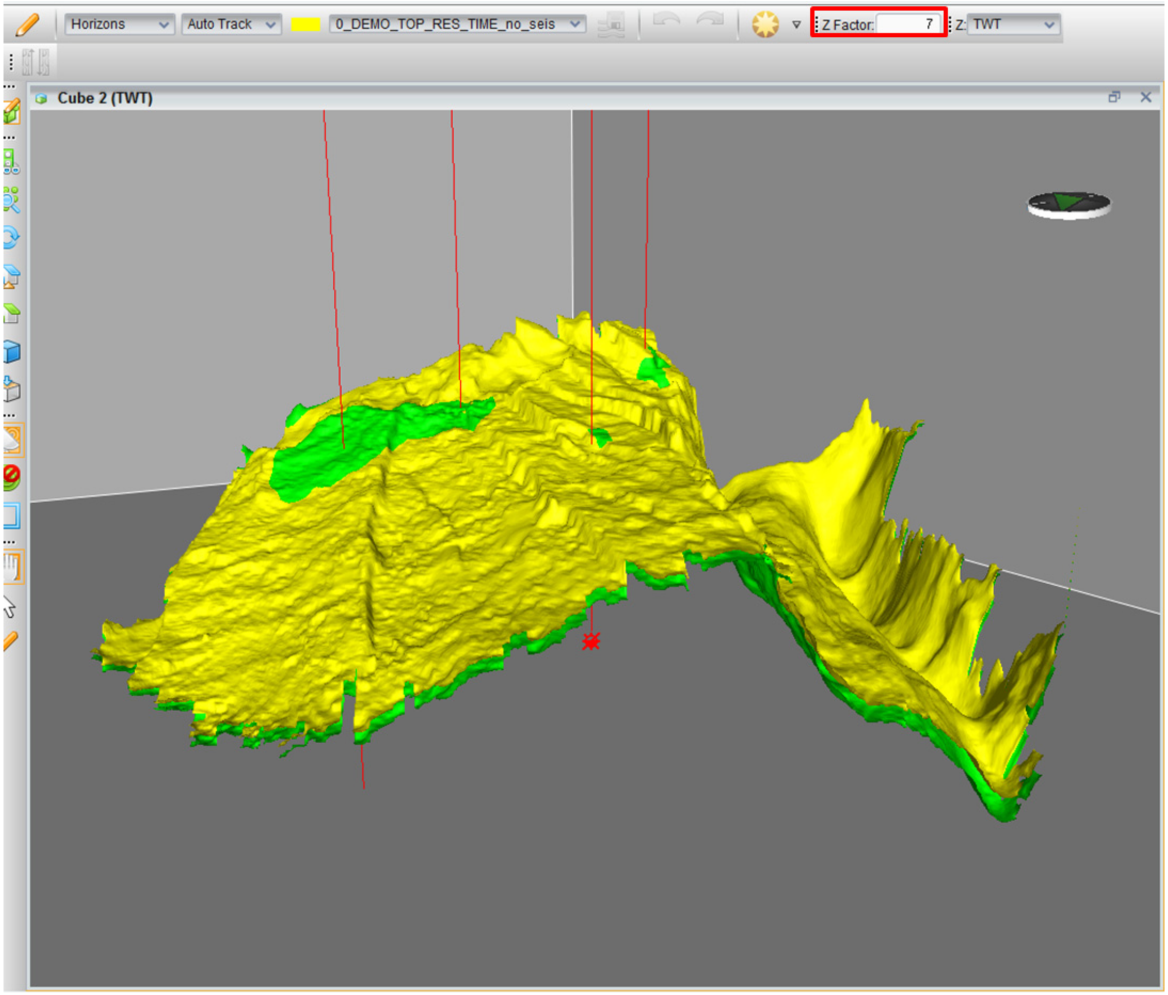
In the above picture, the no_seis horizon is in yellow. Observe that in the wells both depth conversions are the same because they are both tied to Picks, but between and away from the wells you can see the effect of the seismic trend velocity.

> **Note**
>
> By default, the horizons are the same color. Change the color of one of the horizons by clicking **MB3** on the horizon and then selecting **Display Properties** in order to better visualize the differences between the two.

It is also helpful to visualize the differences in the *Cube* view where you can change the z-value to exaggerate the areas where the depth conversions are not similar.

15. Activate and maximize *Cube* view. In the *Inventory* task pane toggle on the two depth horizons **0_DEMO_TOP_RES_TIME_no_seis** and **0_DEMO_TOP_RES_TIME_with_seis**, and ensure **FourWellsTD** is also toggled on. Toggle off any probes.

16. Change *Z Factor* in the toolbar to “**7**.”

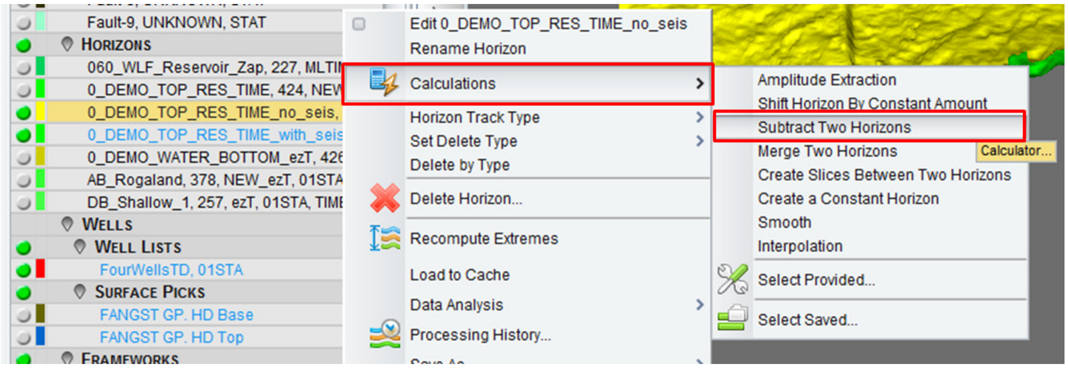


Notice that the two horizons have slight differences, but near the well locations they are overlapping.

> **Note**
>
> If it is easier to visualize, change the color of the horizons by using the *Display Properties* menu and changing the *Style* to **Solid Color**.

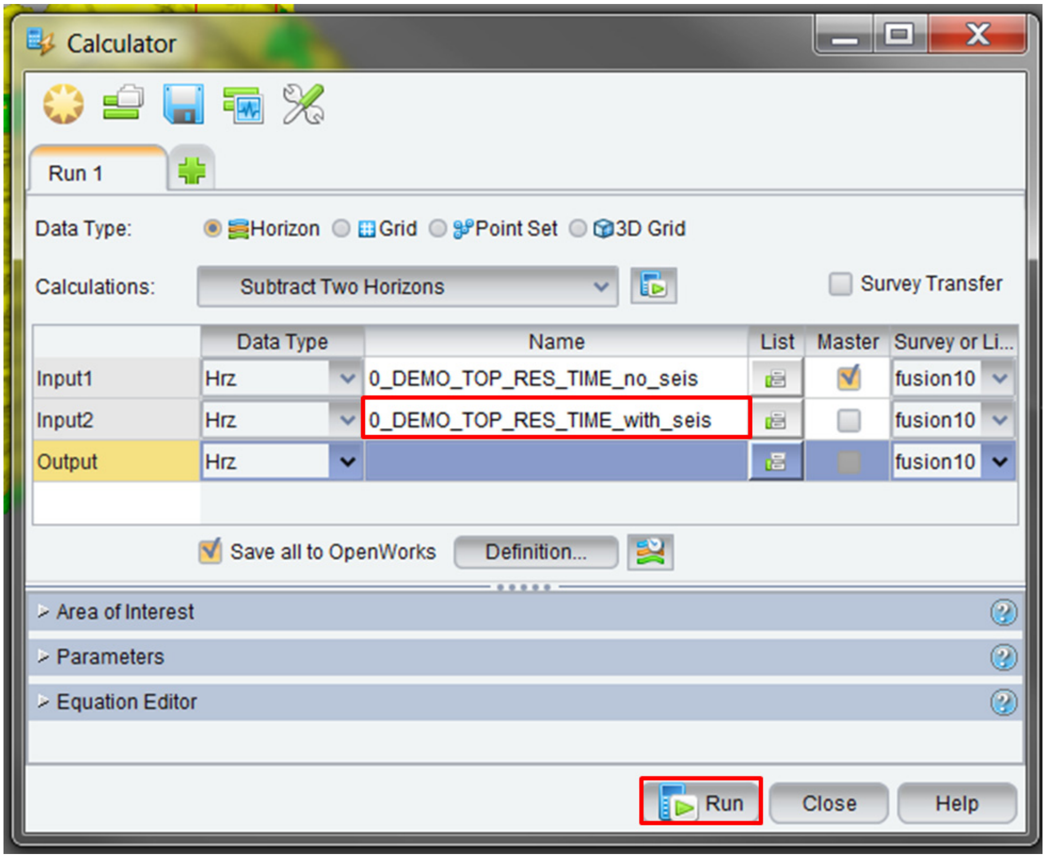
Along with the calculations you learned in Chapter 4, you can use the seismic calculator to visualize the difference map between the two depth conversions by subtracting one horizon from the other.

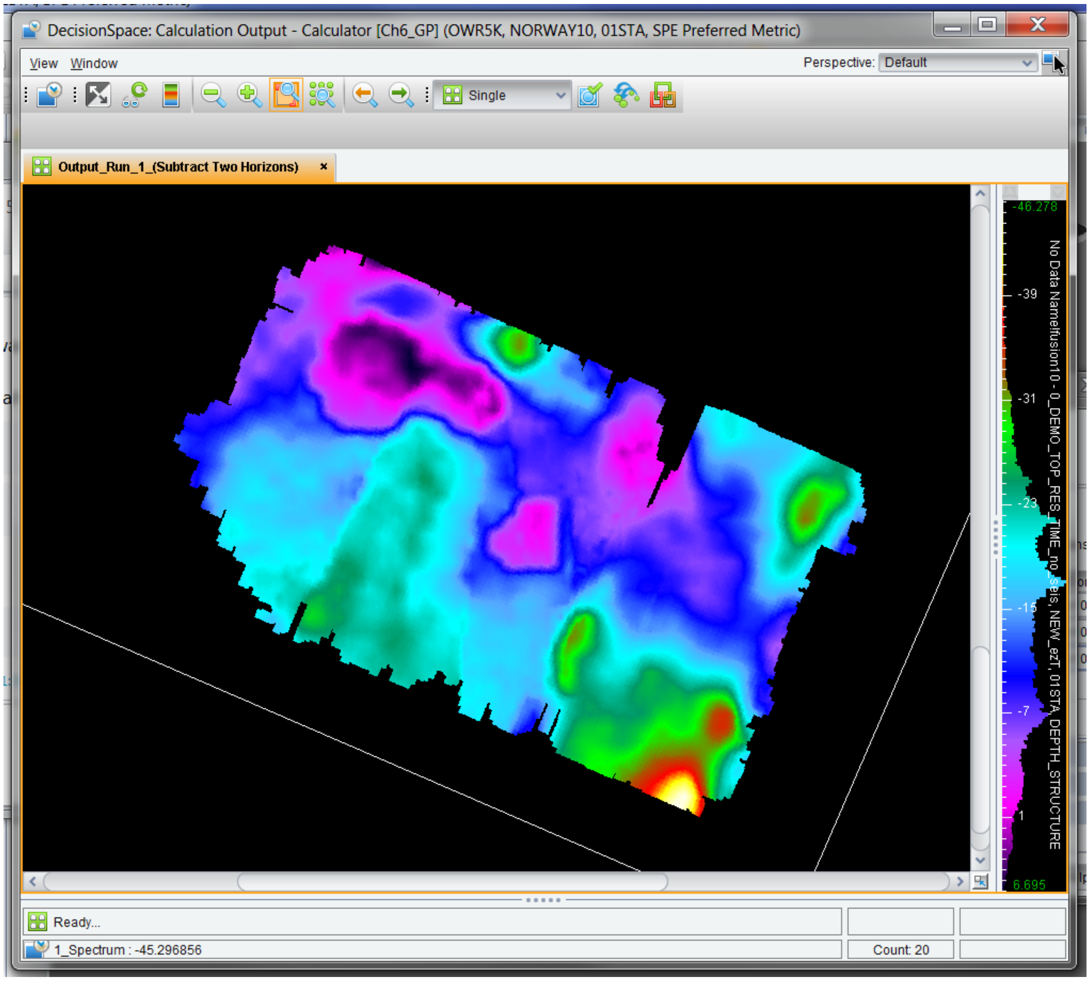
17. In the *Inventory* task pane, highlight and **MB3** on the horizon **0_DEMO_TOP_RES_TIME_no_seis** and then select **Calculations > Subtract Two Horizons**.



In the *Calculator* dialog, *Input1* will be populated with the _no_seis horizon.

18. From the *Inventory* task pane, drag-and-drop the **0_DEMO_TOP_RES_TIME_with_seis** horizon into the *Input2* field. Clear the output field. (This will automatically send the output to the Quickview dialog where you can review the results before saving.) Click **Run**.





We can see that apart from the well positions where the two depth conversions tie (purple areas), the with_seismic result is generally 10-30 m deeper (light and dark blue areas).

19. Close the *Quickview* and *Calculator* dialogs. Close the *Velocity Modeling* dialog if it is still open. Click **Yes** to confirm the exit.

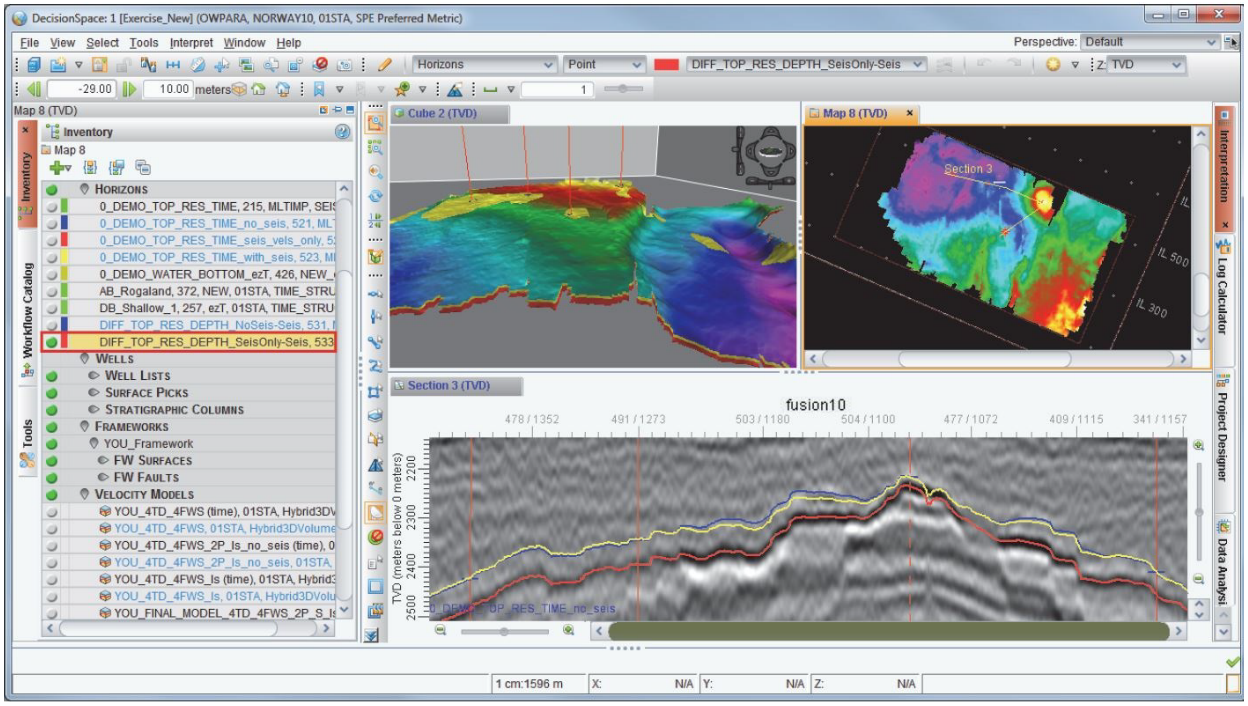
You can see that the effect of including the seismic data in the model is to push the Top Reservoir 10 m-40 m deeper. This may not be the result that you want, but you have to decide whether you want to honor the seismic or not. In this case, the seismic velocities appear from another model, because they were interval velocities in depth. Therefore, it is recommended if you can obtain the original seismic stacking or migration velocities to see if (after smoothing) they will give a similar result. This will increase your confidence in the final model. Furthermore, more wells, better TD functions (a calibrated sonic rather than the sparse checkshot data that you are using), and more picks at more layers will increase your confidence and reduce uncertainty in the model.

To complete your understanding of the contribution that the seismic velocity is making to your model, you can convert time to depth domain using only the seismic velocities and comparing results in the same way as before.

You can see that using only the faster seismic velocities produces a 40 m - 100 m deeper result which, does not tie to picks. However, the 80 - 100 m deeper area (red/yellow on the difference map) occurs south and west of the wells which is where the inclusion of the seismic velocities in the final model produces a 20 m - 40 m deepening (light and dark blue area). It is clear that your final model, which does tie to picks, is correctly using the seismic velocity trend and not just reverting to the actual seismic velocities.

Top Reservoir Depth

- Final Model with seismic velocities = yellow
- Final Model without seismic velocities = spectrum or green
- Model using seismic velocities only = red



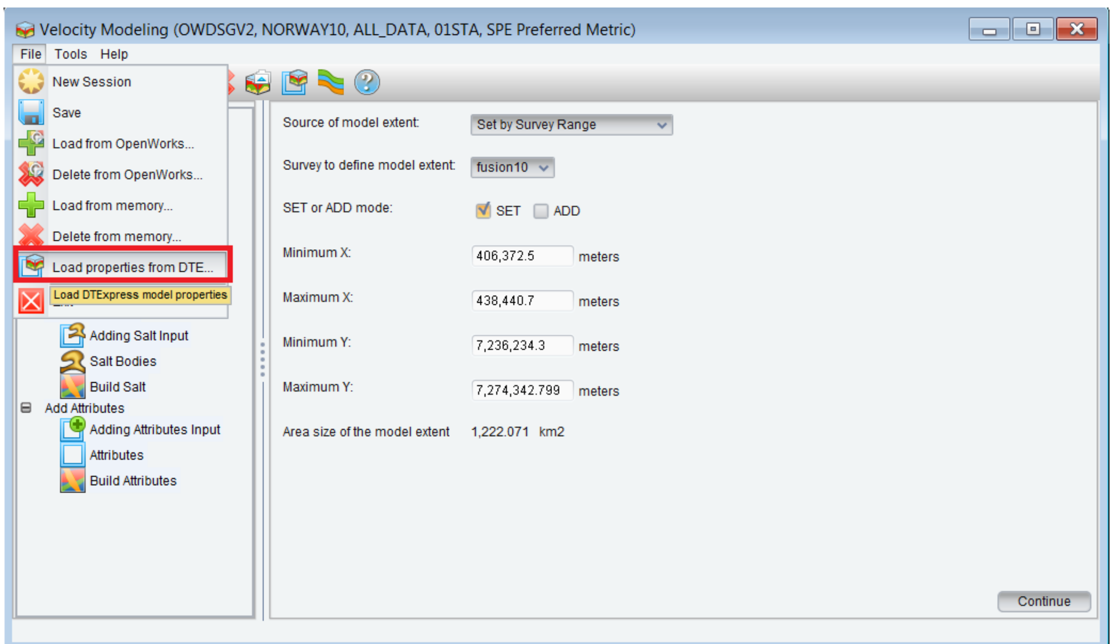
Although there is only one final model, as you analyze the data you can see that choices and different models can be constructed. For example, with or without seismic velocity, how much you smoothed the seismic velocity, how the data is interpolated, least squares fitting or not, including or excluding possibly anomalous TD or Pick data, and so forth. Although there is always a best model and depth conversion, a measure of uncertainty may be attained by creating other possible models and depth conversions. The benefit of this kind of uncertainty analysis is that it focuses on where the actual uncertainties exist in the data.

Additional Workflows

Workflow 1: Using a DepthTeam Express Velocity Model as an Input

You can start a DS Velocity model by imputing a DepthTeam Express model. This will read in all of the well TD function and Pick data that was used in the DepthTeam Express model and also offer the completed DepthTeam Express model cube as a seismic trend volume.

A DecisionSpace velocity model is always NS-EW, whereas a DepthTeam Express model may be defined as NS-EW or Inline/Xline. Hence, you will have to set Model Extent range yourself.



> **Note**
>
> Ensure that the DepthTeam Express plugin is installed on your machine before starting this workflow.

Workflow 2: Adding Floating Bodies (Salt) to the Velocity Model

As was discussed under frameworks, you can create complex free floating bodies in GeoProbe by interpreting the parts of the body that can be seen on the seismic. Geoprobe has a number of innovative ways to best make the interpretation [for example, horizons (SW and easy), faults (SW and easy), geobodies, and geoanomalies]. All of the interpretation, from whatever source, can be converted to normal horizon data and shrink-wrapped to create a complex-geometry geoshell of salt or overthrust bodies.

Geoshells can be viewed and added to framework models in DecisionSpace.

For simpler bodies, if you have interpreted the intersecting top and bottom of the body, you can add the top and bottom horizons directly in Velocity Modelling under "Salt Bodies."

They will be truncated automatically at the intersection points to create a sealed body. However, if you use this method the data does need to be heavily sampled especially around the top and base intersections.

If you want to make a salt or sand body, interpret the top and bottom separately (above the Top Reservoir) on every 10th line. Grid them in Grid and Contour using a hulled surface around the data points. Convert back to a horizon. Make sure that they intersect and overlap then select the final velocity model and add them into it under Salt Bodies.

Note

The salt horizons have to be in depth, so you need to interpret them on depth seismic, or simply **MB3 > Save as…> Domain Converted**, using the active final model. Use the formation manager to set a constant velocity. If you choose the salt formation, it has a default high velocity of 4572 m/s. This should give a significant push down of the Top Reservoir depth depending on how big and thick you have made the salt body.

Chapter 7
Geology and Earth Modeling Integration

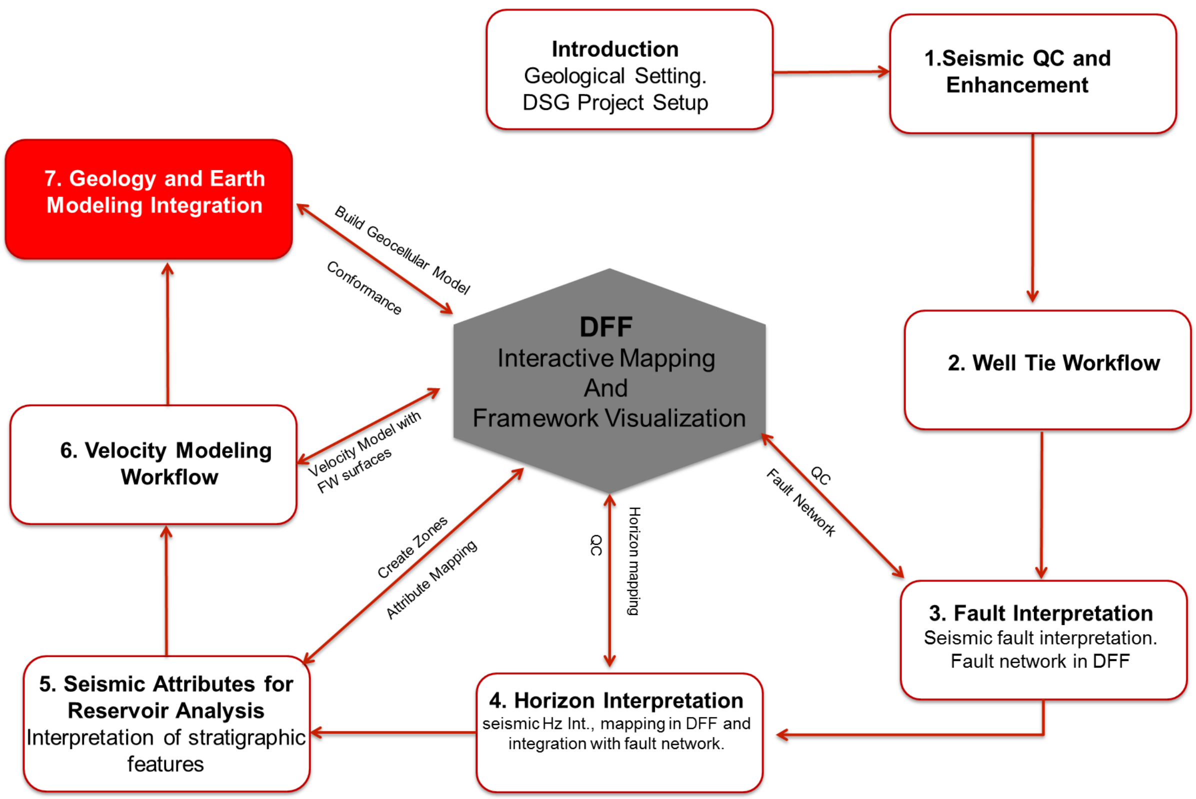
The DecisionSpace® Geosciences software provides an elegant approach to integrated prospect evaluation and development. The goal of the DecisionSpace Geosciences software is to help the average interpreter quickly and accurately map hydrocarbon-related anomalies. The software accomplishes this by integrating a wide range of data types to a narrow range of probable solutions constrained by geology, geophysics, petrophysics, and reservoir models. Integrating geological and geophysical interpretation allows you to accurately map and analyze prospects, build sealed structural frameworks and reservoir models, and plan wells in both traditional and unconventional scenarios.

Overview

In this chapter, you will learn to:

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

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.

Geology Integration with Framework

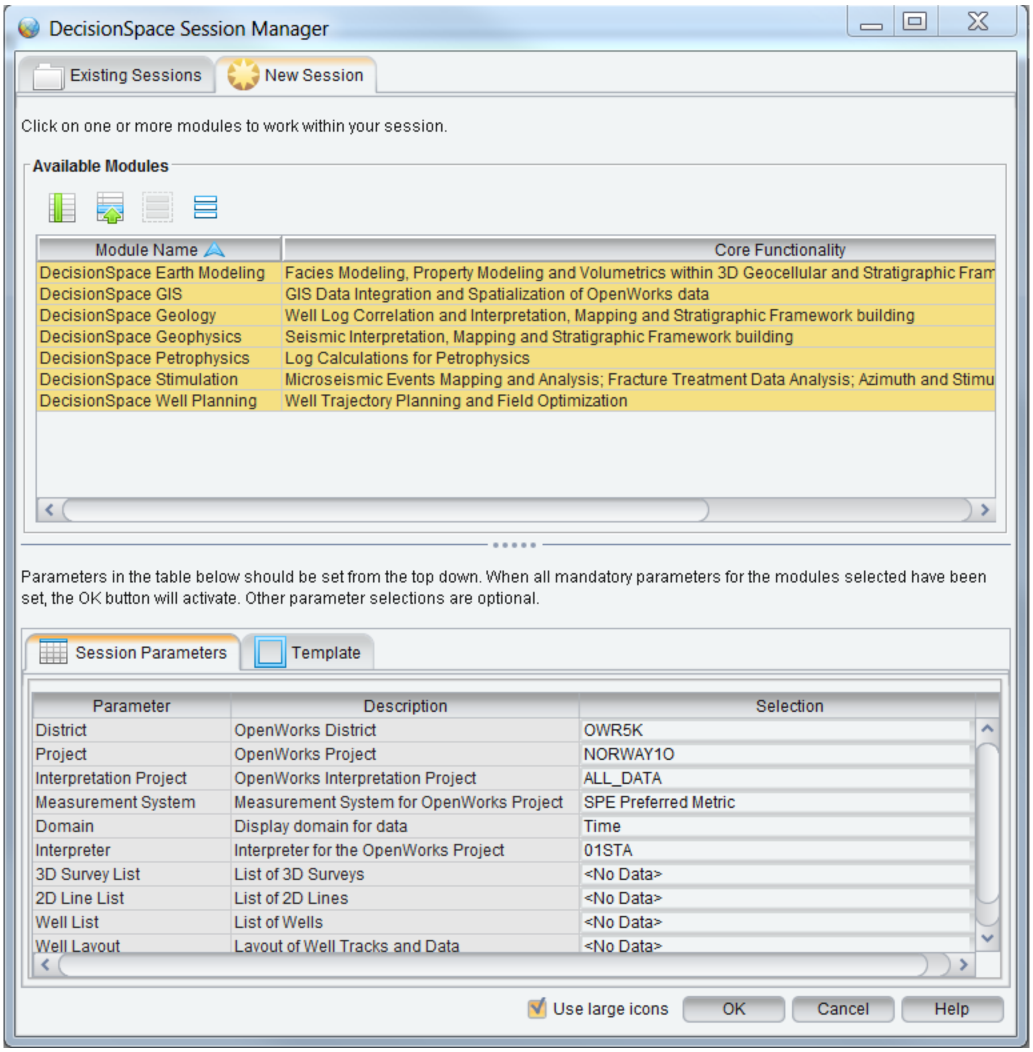
Dynamic Frameworks to Fill (DFF) provides construction of multiple-surface frameworks. These frameworks honor surface-to-surface thickness relationships and properly truncate structural surfaces against faults and unconformities. By establishing the age relationships and defining fault hierarchies, geologists can trim and seal intersecting surfaces topologically. This topologically correct DFF enables exploration geologists to quickly generate more accurate structure, isopach, and net/gross maps of their prospects.

With DecisionSpace Geosciences and DFF, interpretation and mapping go hand in hand as DFF can integrate the shape of seismic surfaces to guide the mapping of well-top surfaces. Geoscientists can quickly build very high-resolution structural frameworks by integrating the horizontal resolution of seismic horizons with the very high vertical resolution of well log data.

Because you cannot correlate FANGST GP.HD Base and FANGST GP.HD Top surfaces on every wellbore, DFF offers a tool of conformance relationships. Conformance leverages a classic concept in geology, which asserts that in the vast majority of cases, formation thicknesses tend to vary very slowly as compared to structural variability. When this assumption is believed to be valid, you can use surfaces that are well-sampled horizontally (e.g., seismic surfaces) to guide the mapping of surfaces with poor horizontal sampling (e.g., well top surfaces). For scenarios where you have a seismic surface and a well top at a deeper (or shallower) level that you want to map, conformance provides a means for mapping the well top surface.

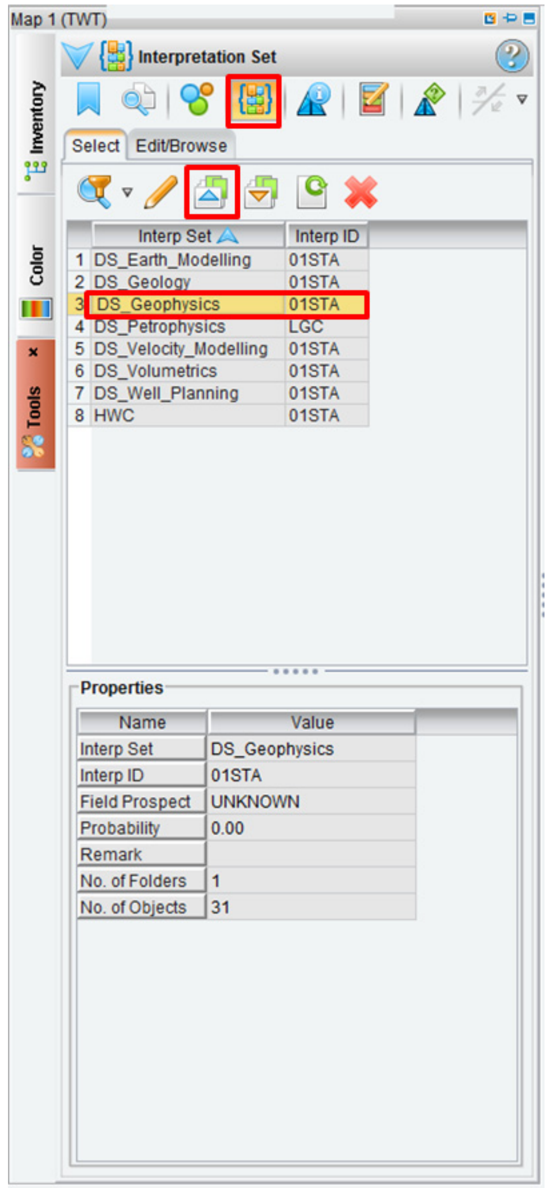
Exercise 7.1: Geological and Geophysical Integration

1. Start a New Session with the parameters in the picture below, and then click **OK**.



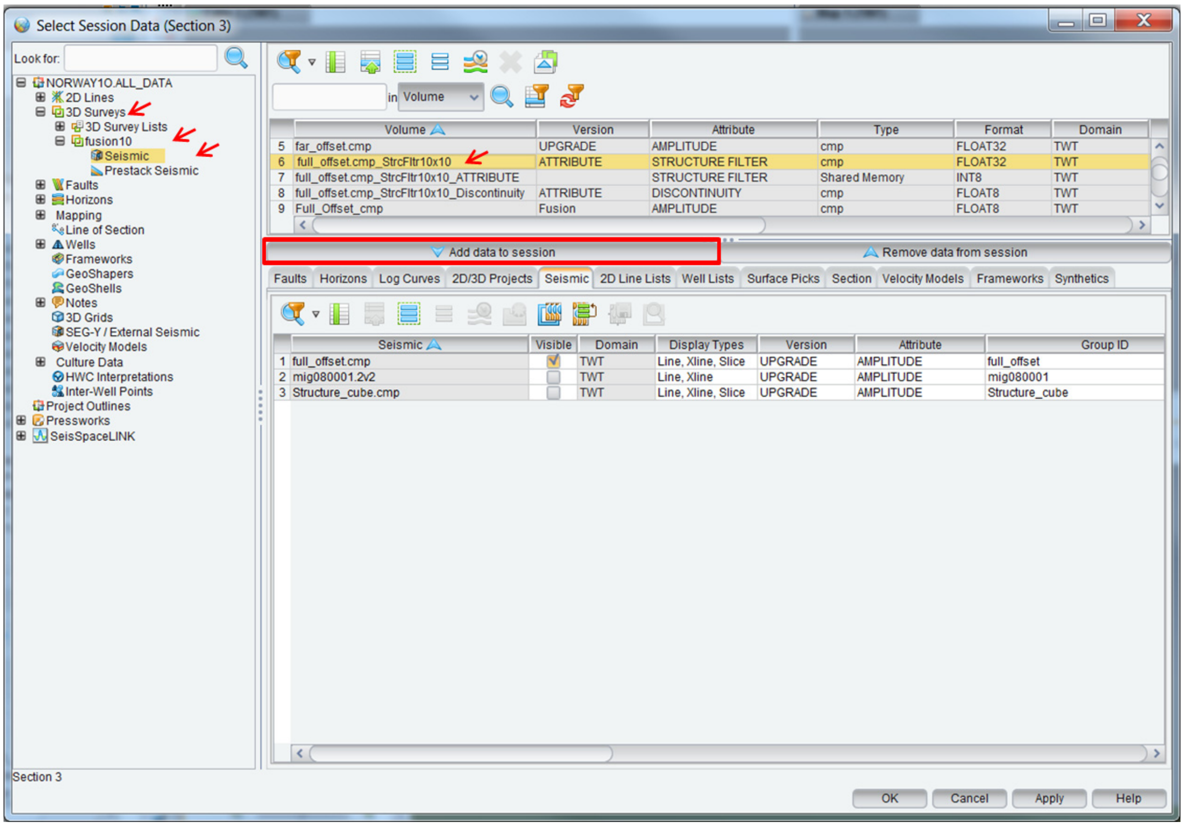
2. From the *Tools* task pane select the **Interpretation Set** icon, and in the resulting task pane select the **DS_Geophysics** ISet.

3. Click the **Load Data to Session** () icon.



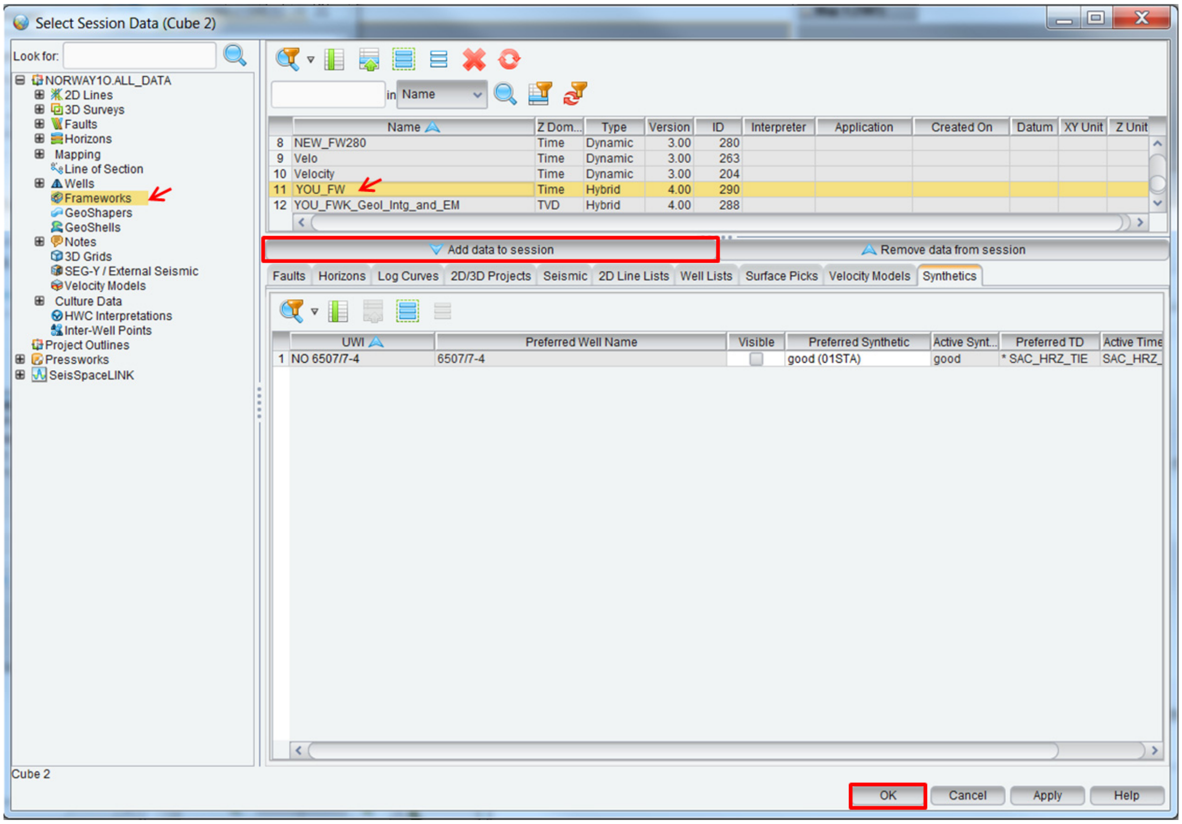
The volume used in all of the previous exercises is not included in the ISet and needs to be added to the session in order to continue the comparison.

4. Click the **Select Session Data** ( ) icon. In the left panel of the *Select Session Data* dialog, select **3D Surveys > fusion10 > Seismic**, and then select **full_offset.cmp_StrcFltr10x10**. Click **Add data to session**, but do not click OK.



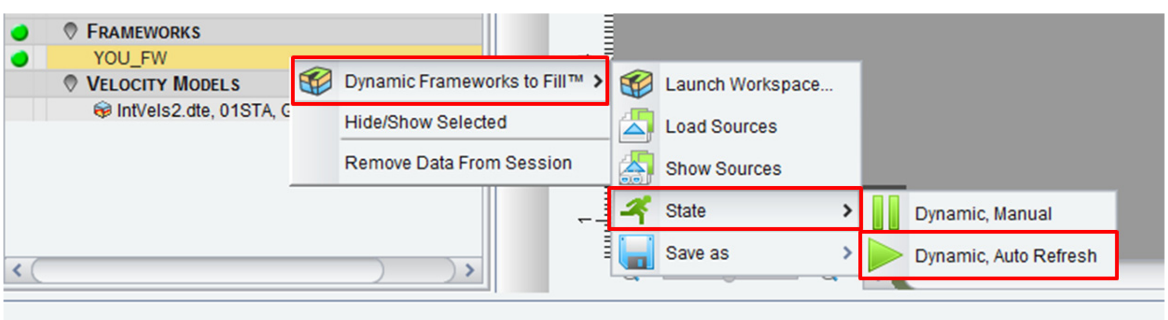
In previous chapters, you have built the YOU_FW to contain both seismic faults and horizons. In the following steps, you will add surface picks that would typically be received from the geologist to fully integrate the two disciplines with each other.

5. In the left panel of the *Select Session Data* dialog, select **Frameworks**, select **YOU_FW**, and then click **Add data to session**. Click **OK** to close the dialog.



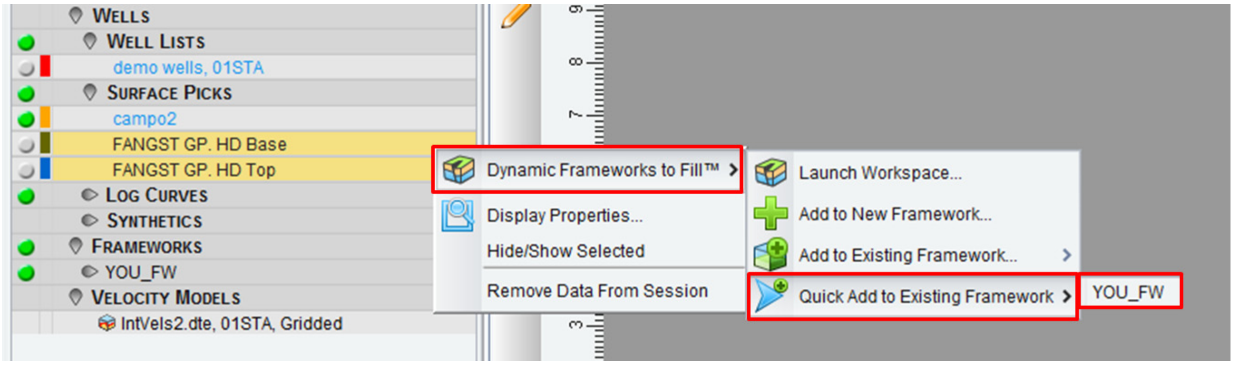
When existing frameworks are brought in to a session, they are brought in as static. To be able to make any changes to your framework, the state needs to be changed to Dynamic, Manual or Auto Refresh.

6. In the *Inventory* task pane **MB3** on **YOU_FW** and select **Dynamic Frameworks to Fill > State > Dynamic, Auto Refresh**.

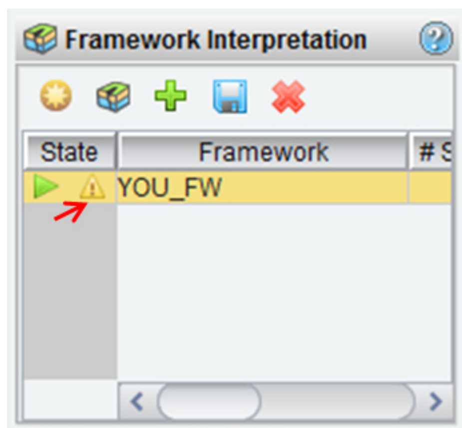


You will incorporate the geological aspect of your project into your framework.

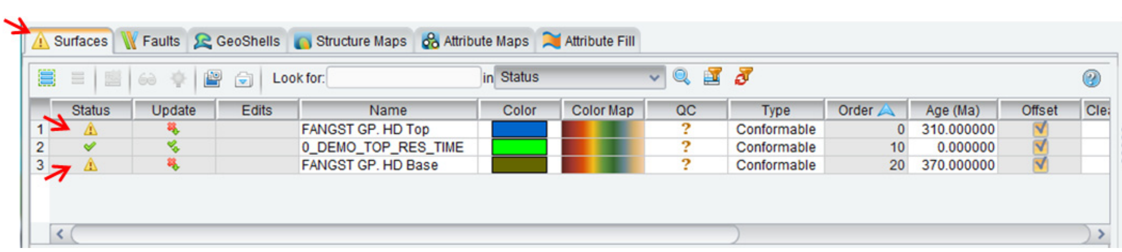
7. In the *Inventory* task pane, select the **FANGST GP. HD Base** and **FANGST GP. HD** Top surface picks, **MB3**, and then select **Dynamic Frameworks to Fill > Quick Add to Existing Framework > YOU_FW**. This will bypass the *Add Objects to Framework* dialog, and add the surface picks automatically as FW Surfaces.



In the Dynamic Frameworks to Fill task pane notice that there is a warning triangle next to YOU_FW.



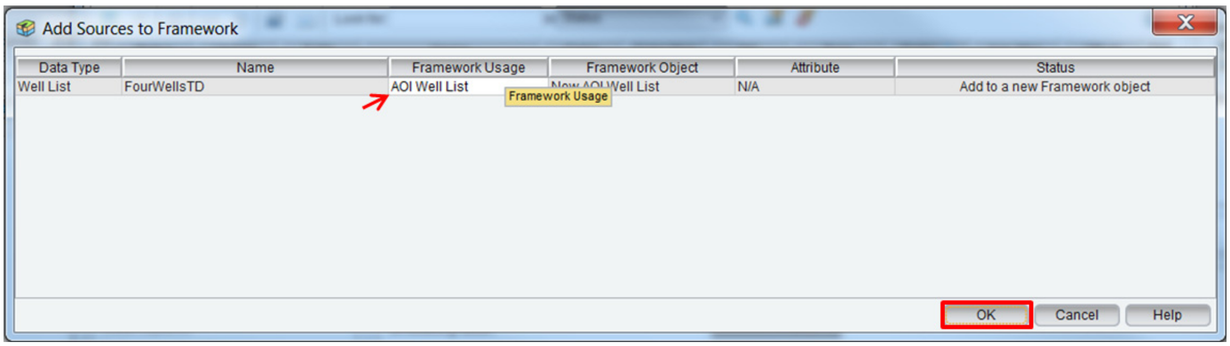
8. Click the **Launch Framework Workspace Window** ( ) icon. Notice that the *Surfaces* tab displays the warning triangle. This is because you have added objects that are associated with well lists, but there is no well list associated with the framework.



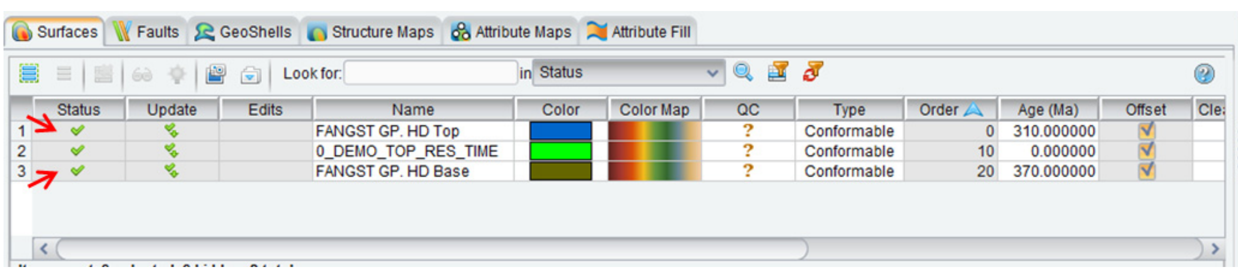
9. Open **Select Session Data**, and navigate to **Well Lists** (**Wells > Well Lists**). From the right panel, select **FourWellsTD** and then click **Add data to session**. Click **OK** to close the dialog.

10. From the *Inventory* task pane, drag-and-drop the **FourWellsTD** well list into the *Dynamic Frameworks to Fill Workspace*.

11. The *Add Sources to Framework* dialog opens, indicating that the FourWellsTD well list will be added as an AOI Well List. Click **OK** to accept the default.



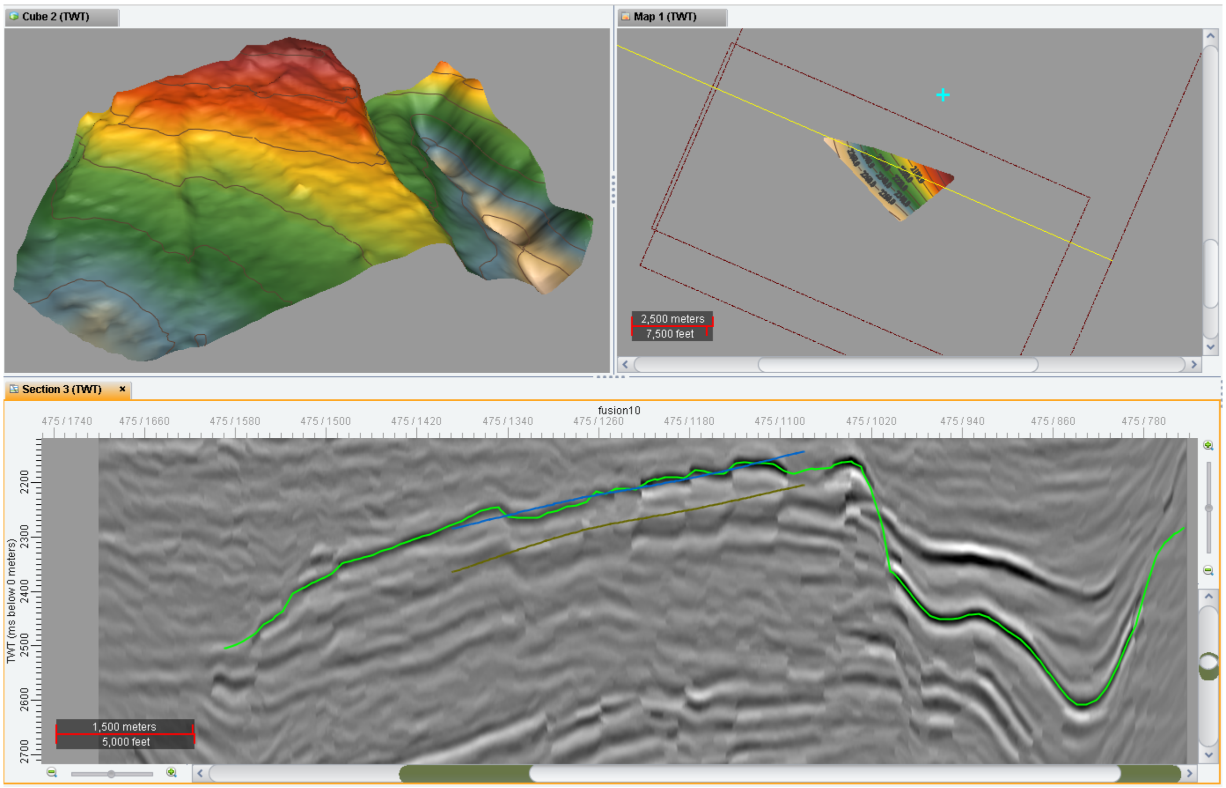
When the FourWellsTD well list is added in to the framework, the two surfaces, FANGST GP. HD Base and FANGST GP. HD Top, automatically build and all warning messages go away.



12. In the *Inventory* task pane for *Cube* view, toggle off everything except for the **0_DEMO_TOP_RES_TIME** FW Surface.

13. In the *Inventory* task pane for *Map* view, toggle on the **FANGST GP. HD Top** FW Surface.

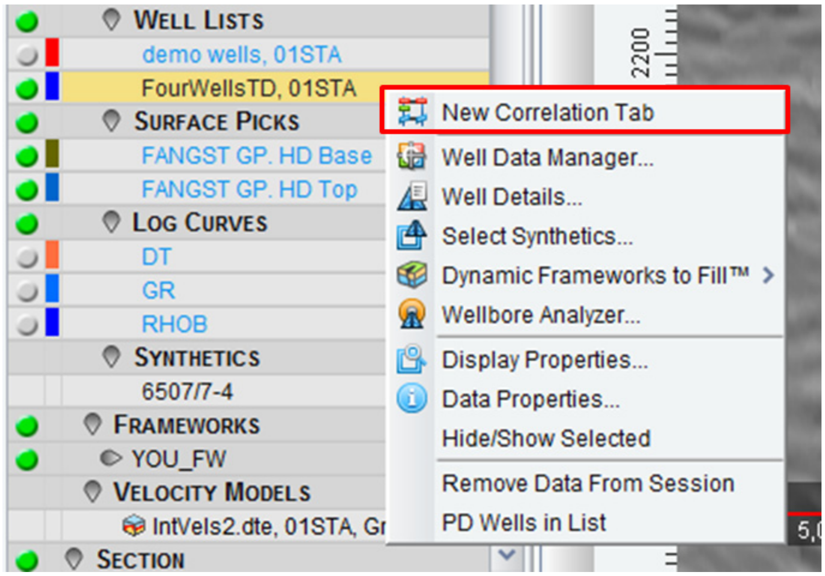
14. In *Section* view, display **full_offset.cmp_StrcFltr10x10** at **IL 475**, by dragging-and-dropping the volume into *Section* view and using the frame control to navigate to the correct IL. Also, toggle on all three FW Surfaces from the *Inventory* task pane.



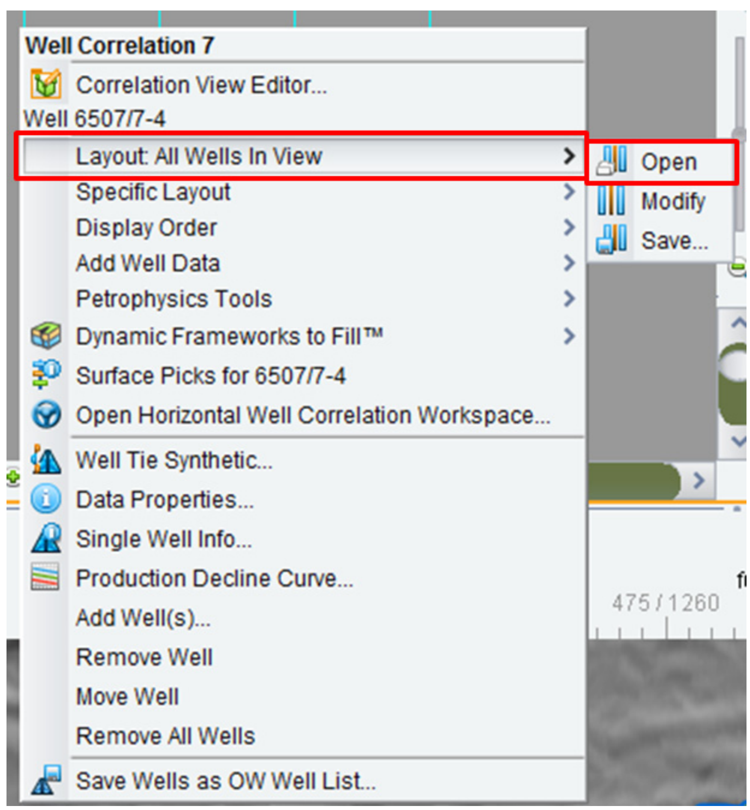
There are a couple of things to notice in your views. First, notice the difference in the shapes of the two framework surfaces. The 0_DEMO_TOP_RES_TIME surface in *Cube* view is the shape of the survey in which it was created, whereas the shape of FANGST GP. HD Top in *Map* view is due to the layout of the wells that contain the FANGST GP. HD Top pick within it. The difference in shape is also apparent in *Section* view. The FW Surface made from the seismic horizon goes along the entire reflector, as opposed to the two FW Surfaces made with the surface picks, which only cover a small portion of the Inline.

The advantage of having surface picks integrated into your structural model is the amount of vertical resolution provided from hard data from the well bores. With the higher vertical resolution comes a lack of horizontal resolution, due to the fact that wells are spaced out from each other, and only supply single points of data. This is why it is key to integrate the horizons from the geophysicists and the well top picks from the geologists, so you can leverage the resolution from both disciplines to get the best structural model possible.

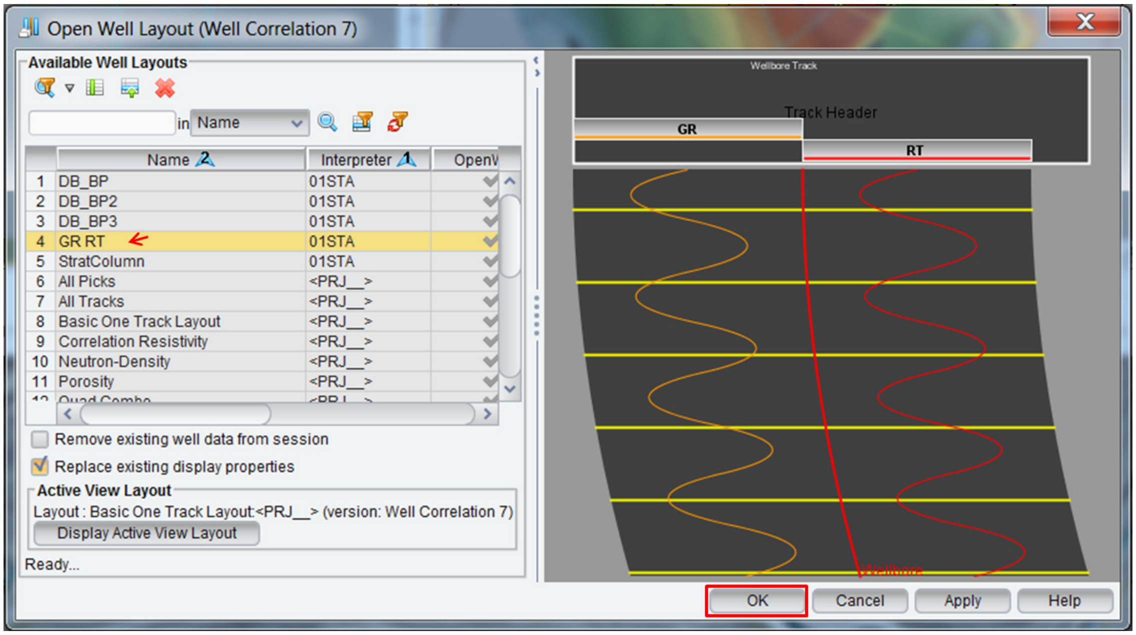
15. From the *Inventory* task pane, **MB3** on **FourWellsTD** and select **New Correlation Tab**.



16. A new *Well Correlation* view opens in the same space of whichever view was active. **MB3** on one of the well bores and then select **Layout All Wells in View > Open**.



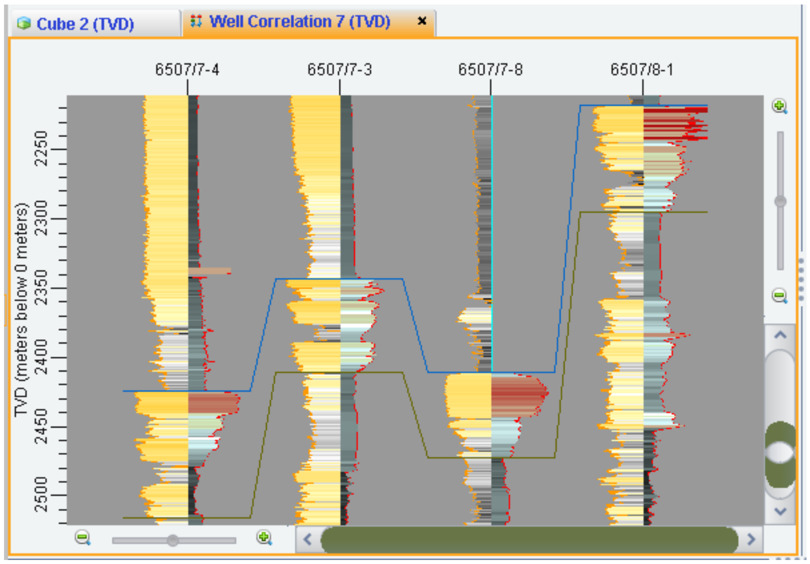
17. Select the **GR RT** well layout, and click **OK**. This will toggle on the GR and RT curves as well as the FANGST GP.HD Top and FANGST GP.HD Base surface picks.



Note
If you select a well layout that contains objects that are not currently in your session, they will automatically be brought in to your session when the well layout is applied.

18. In your *Well Correlation* view, zoom in to see the detail in the well logs better. Run your cursor on one of your wells and you will see a marker in *Section* view showing you where you are.

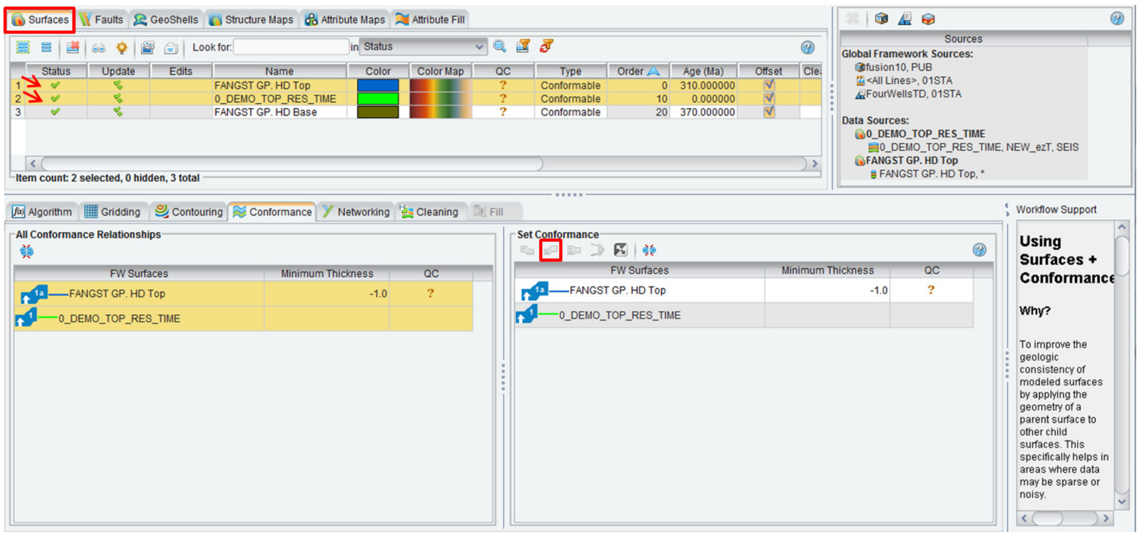
Notice the amount of detail that is shown in the well logs, as opposed to the seismic. As previously mentioned, you get a significantly higher vertical resolution within the well logs, but you are only getting the detailed information in a small point within a large survey.



19. Close the *Well Correlation* view, you do not need it for the remainder of the exercise.

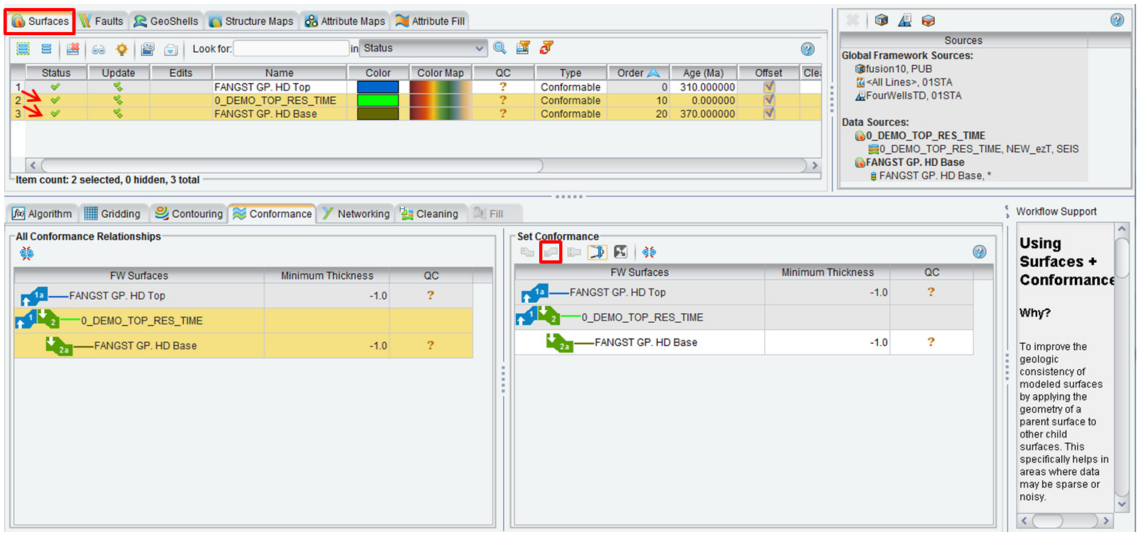
In the following steps, you will use the conformance technology available in Dynamic Frameworks to Fill to apply the higher horizontal resolution of the surface created from the seismic horizon to the two surfaces created from the surface picks.

20. In the *Dynamic Frameworks to Fill Workspace*, select the **FANGST GP. HD Top** and **0_DEMO_TOP_RES_TIME**, from the *Surfaces* object tab. With the surfaces highlighted, navigate to the *Conformance* actions tab, and click the **Conform surfaces bottom up** () icon in the *Set Conformance* panel.



> **Note**
>
> You can change the order of your surfaces within the *Surfaces* object tab by going to *Settings* and deselecting the *AutoSort Surfaces* check box. This allows you to change the values within the *Order* column.

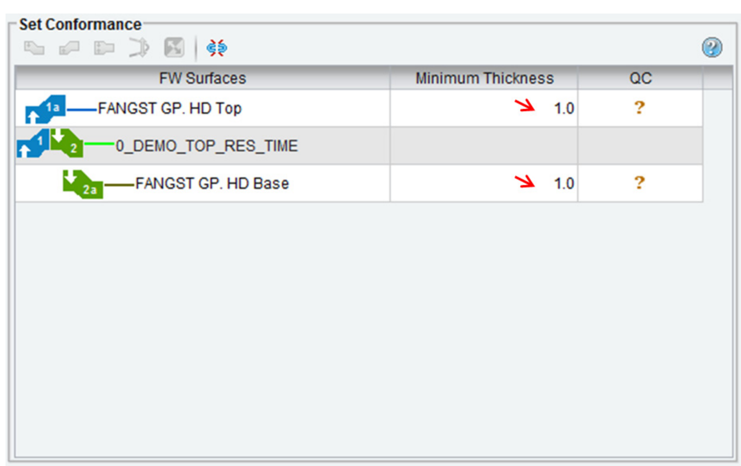
21. In the *Surfaces* object tab, select **FANGST GP. HD Base** and **0_DEMO_TOP_RES_TIME**, and in the *Conformance* actions tab select the **Conform surfaces top down** ( ) icon.



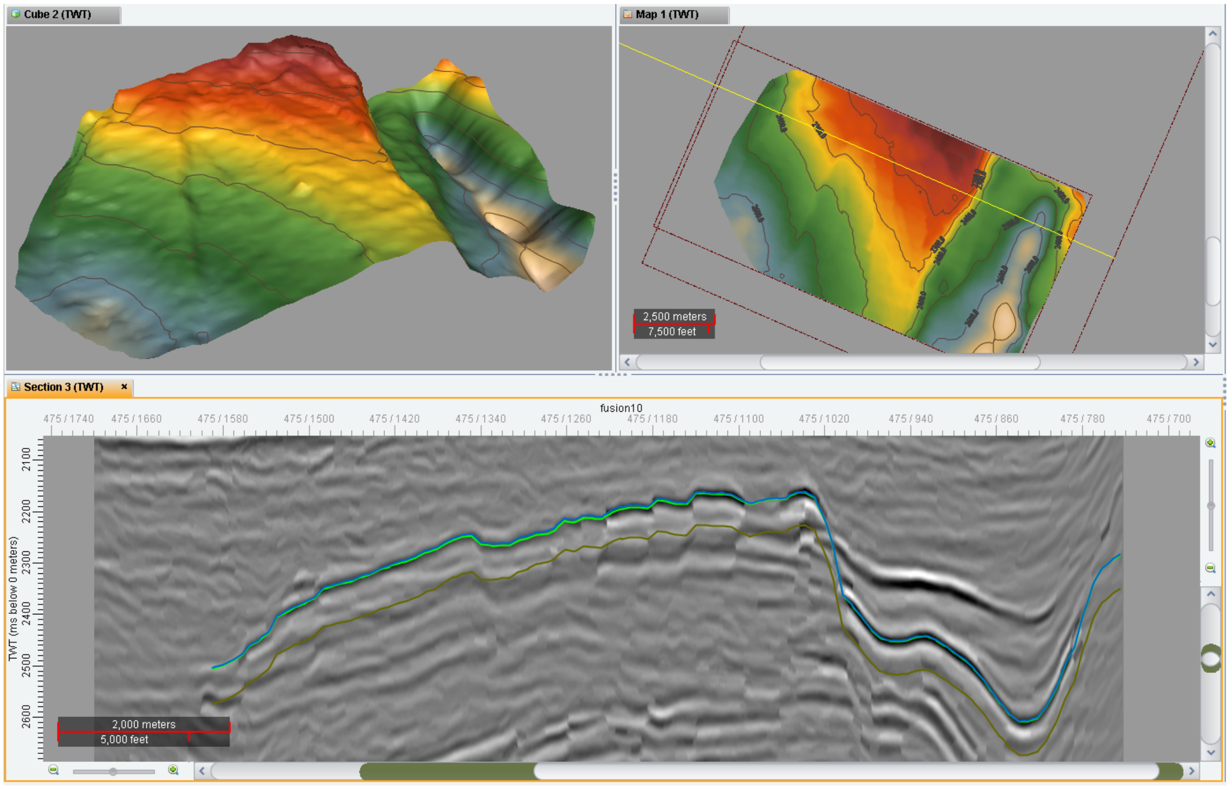
Note

If you get an error with one of your surfaces after setting the conformance relationships, it is due to the crossing of your surfaces. In many areas, the surfaces are interpreted very close to one another and can cause some crossing.

It is a best practice to review the original interpreted data of your horizons to ensure that the framework surfaces are made from the best data possible. If you are satisfied with your interpretation, use the option in the *Conformance* action tab to set a Minimum Thickness for each surface. This forces the software to maintain a distance of at least that designated amount between surfaces.



22. After Conformance is set, minimize the workspace and observe how the FANGST GP. HD Top and FANGST GP. HD Base have changed. They now fill the entire survey, and follow the general shape of the 0_DEMO_TOP_RES_TIME, while still considering the hard data from the surface picks.



Note

It is also possible to perform volumetrics in Dynamic Frameworks to Fill, but this functionality is only available with a framework that has been created in depth. For more details you may take the **Integrated Interpretation and Mapping using Dynamic Frameworks to Fill** class.

Exercise 7.2: Creating a Geocellular Model

In this section, you will convert your framework into a Stratigraphic Geocellular Model that can be used in the Earth Modeling module of DecisionSpace Geosciences. During this class, you have been introduced to powerful tools for dynamically mapping and creating frameworks by means of tightly integrated geological and geophysical workflows of the DecisionSpace Geosciences software. Traditionally, Geocellular Models are not tied to the interpretation data. By extending the reach of the Dynamic Frameworks to Fill feature into Earth Modeling workflows, the DecisionSpace Geosciences software is starting to close this gap and eventually will fully connect Geocellular Models with raw interpretation data.

For Earth Modeling, it is necessary to have a framework that is in depth. There is a framework available in your dataset that contains similar data to the framework you have created throughout the class. You will need to add this framework into your session.

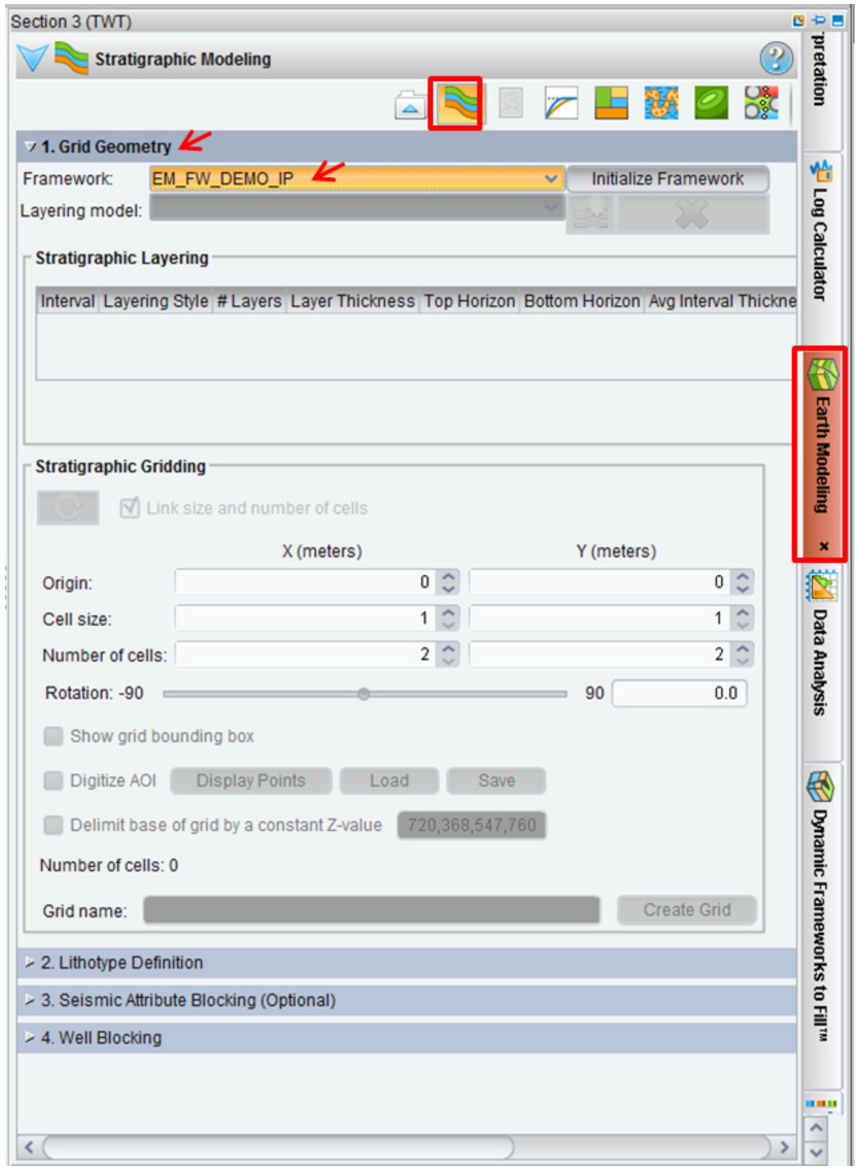
1. Open **Select Session Data** and in the right panel, select **Frameworks**. Select the **EM_FW_DEMO_IP**, and then click **Add data to session**. Click **OK** to close the dialog.

2. Maximize *Cube* view, and change the Domain to **TVD**. Toggle on the **0_DEMO_TOP_RES_TIME**.

3. Launch the *Earth Modeling* task pane and from the *Earth Modeling* toolbar icons, select **Stratigraphic Modeling** and open the *Grid Geometry* panel.

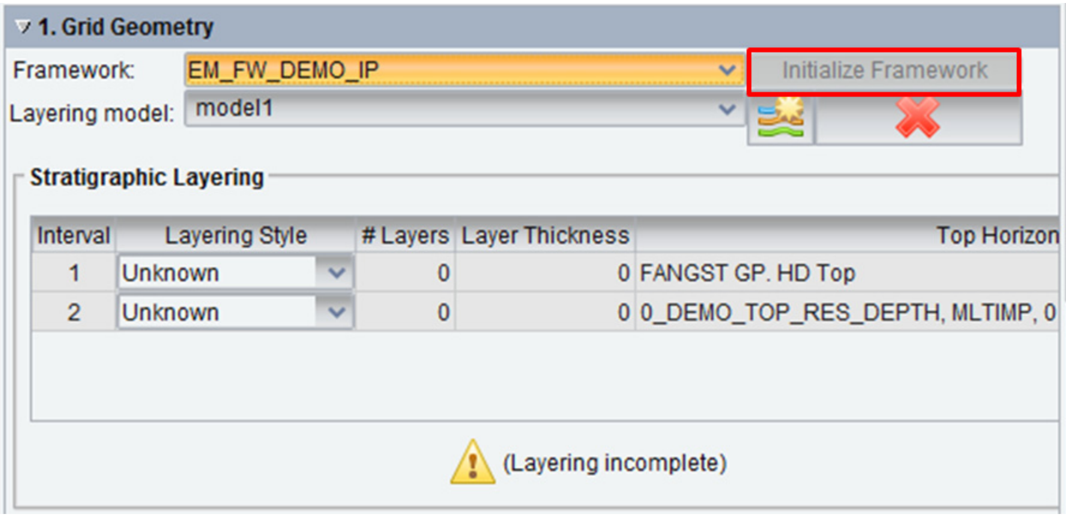
> **Note**
>
> If you do not see the *Earth Modeling* task pane, it may be due to the Perspective you have selected in the top right of your DecisionSpace window.

The **EM_FW_DEMO_IP** Framework appears in the drop-down menu.



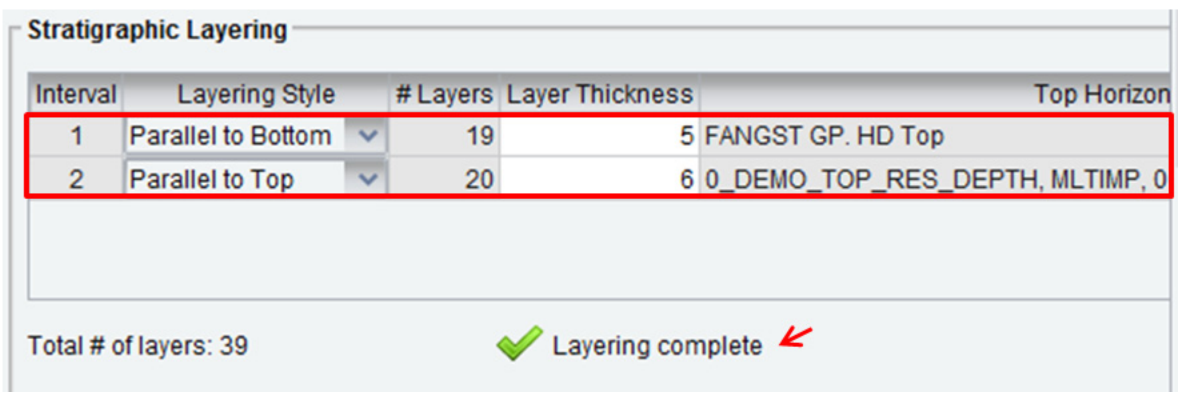
The *Grid Geometry* panel gives you the option to select a framework with its embedded layering scheme. You can specify layering style, number of layers and thickness within each interval, and finally, create a geocellular grid.

4. Click the **Initialize Framework** button.



The system detects the number of layers in the framework. In this example, two intervals are found.

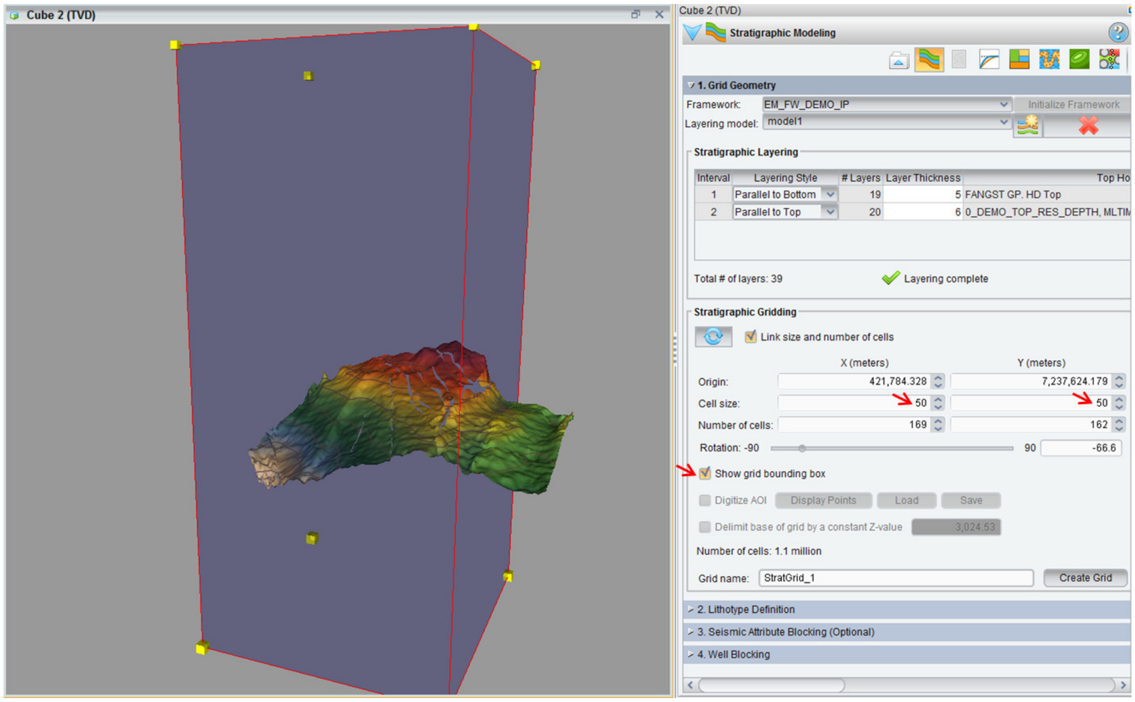
5. Set the layering style as shown in the image below. Adjust *Layer Thickness* for each interval to result in as close to 20 layers as possible. To reduce the number of layers per interval, increase *Layer Thickness*, and vice versa.



6. In the *Stratigraphic Gridding* section, ensure that the cell size is **50** meters x **50** meters. Select the **Show grid bounding box**.

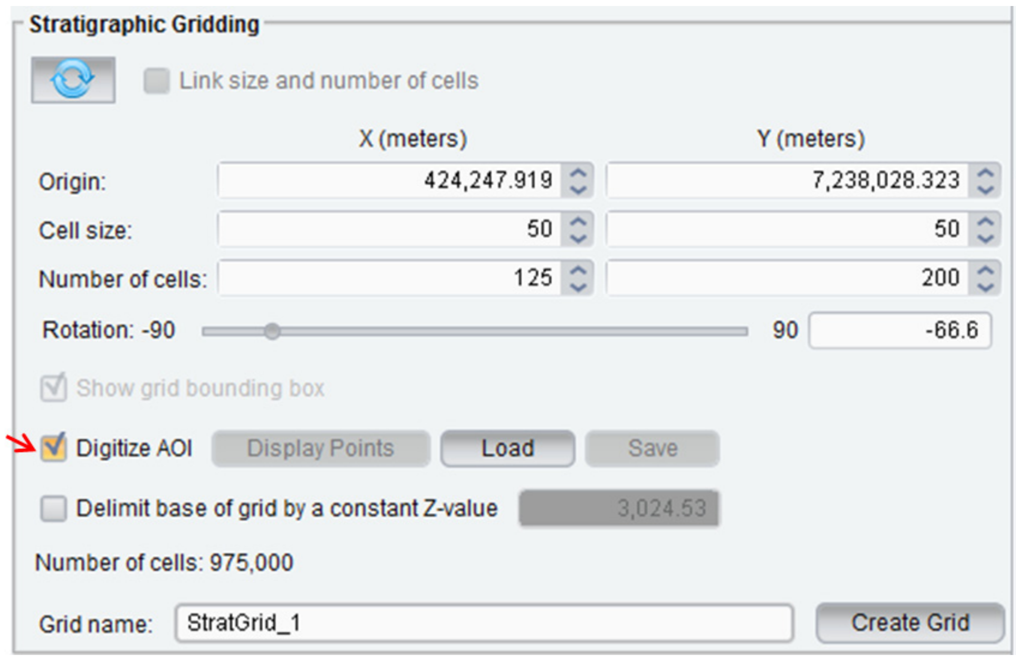
   The bounding box displays as a blue box framed in red in your *Cube* view.

7. You can subset the framework prior to making the geocellular grid, by selecting and dragging the handles while in *Select/Drag* mode.

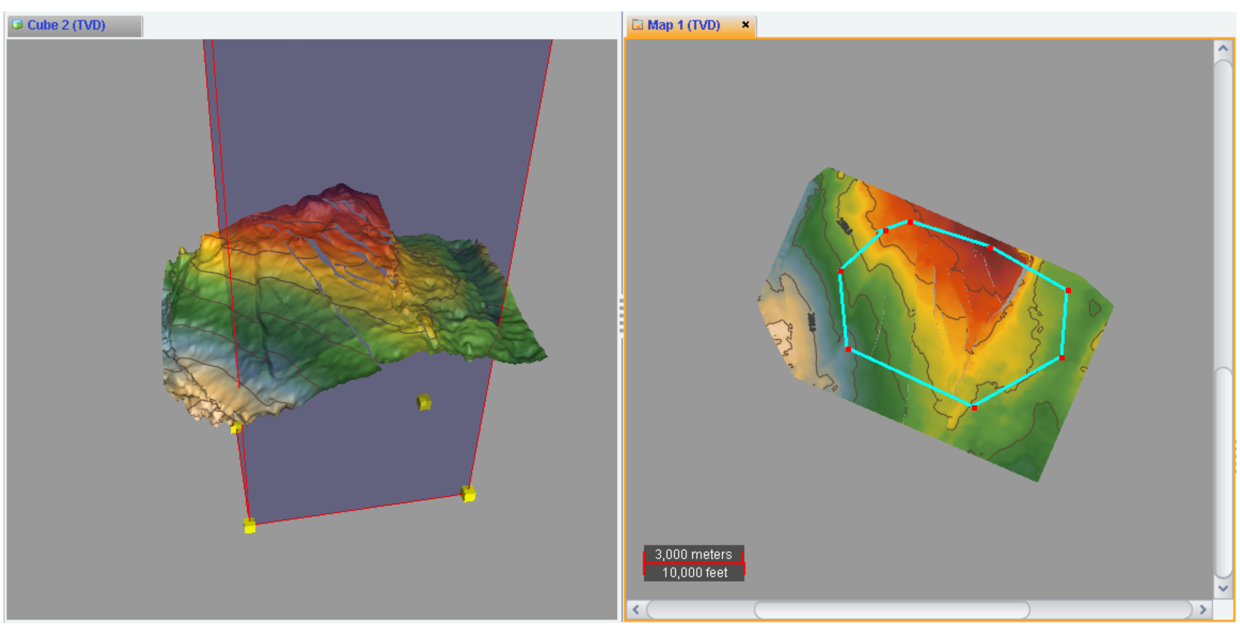


8. Activate *Map* view, and change the domain to TVD to create an AOI of irregular shape.

9. Switch to the *Map* view. From the *Inventory* task pane toggle on only the **0_DEMO_TOP_RES_DEPTH** FW Surface. In the *Stratigraphic Gridding* sub-panel, select the **Digitize AOI** check box.



10. In *Map* view, digitize an AOI bounding polygon. Click with **MB1** to define the polygon, and **MB2** to close it. Note the updated bounding box in the *Cube* view when you close the polygon.



11. Deselect the **Digitize AOI** check box to create a grid of the entire area.

12. Enter "**YOU_Geocellular**" in the *Grid name* field and click **Create Grid**.

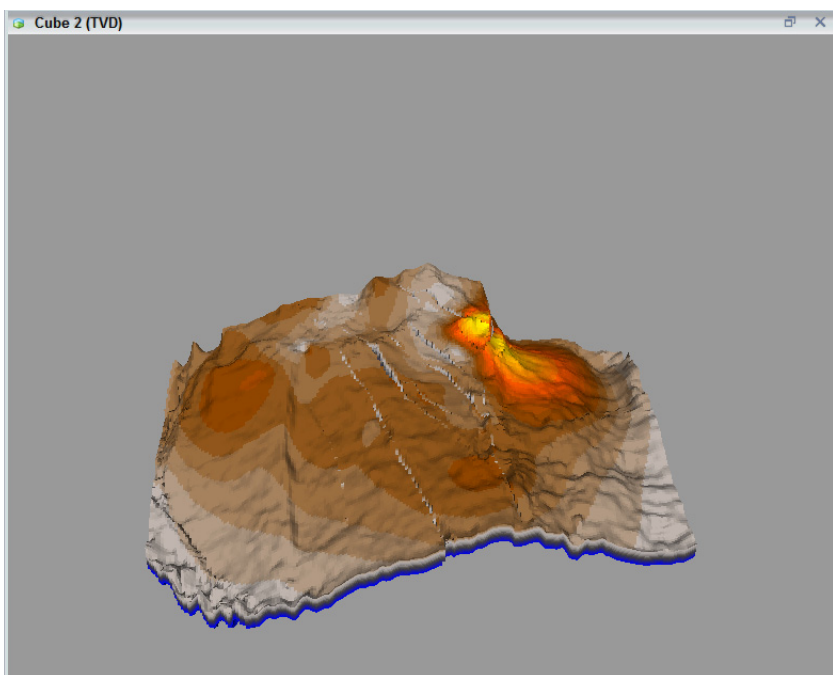
> **Note**
>
> With the number of cells at roughly one million, the conversion will run quickly. Some models are now approaching up to a billion cells. It would take some time for the software to build a model of that size, perhaps several hours or overnight.

13. Click **OK**.

    The *Inventory* panel adds 3D GRIDS as a new data type with an automatically created Probe.

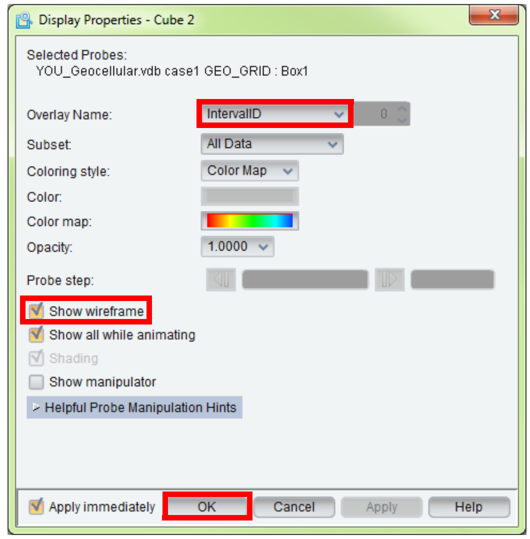
14. Activate and maximize *Cube* view. If the bounding box is still displayed, deselect the **Show grid bounding box** check box in the task pane. Also, toggle off all the frameworks components.

15. Select **Box1: KLayer** probe, under *3D GRIDS* in the *Inventory* panel.

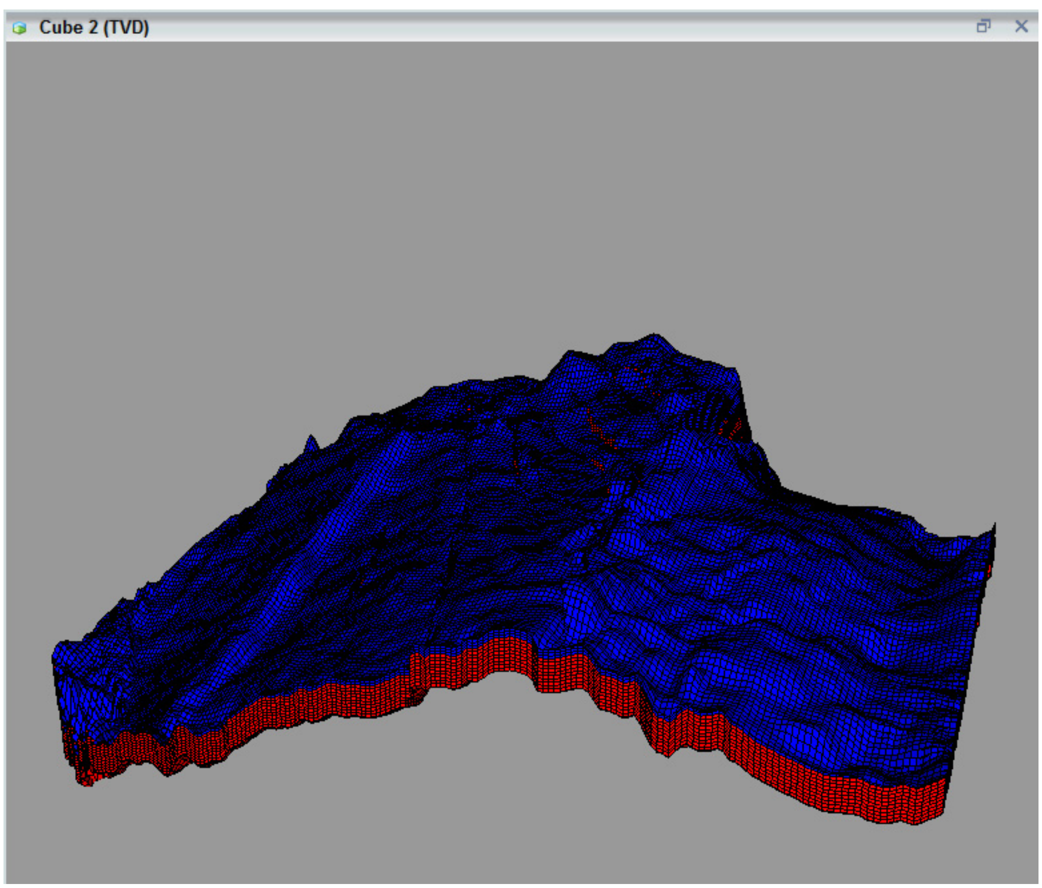


16. **MB3** on the 3D grid probe object and select **Display Properties**.

17. In the *Display Properties* dialog, select the **Show Wireframe** option. Select **Interval ID** from the *Overlay Name* drop-down menu to view the intervals present in the grid. Click **OK** to close the dialog.



Your display should look similar to the one shown below.



Appendix A
Integration with GeoProbe

DecisionSpace® Geosciences has the ability to interact with the GeoProbe software. It works like an undocked window. This allows users the flexibility to use the GeoProbe software 3D visualization and interpretation functionality while using DecisionSpace to act as a 2D view of seismic faces and a *Map* view. Drag-and-drop capability between the applications allows the user to see any data updated or interpreted in DecisionSpace displayed in the GeoProbe software and vice versa.

Overview

In this appendix, you will learn to:

- ❑ 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

Data Display – GeoProbe Integration

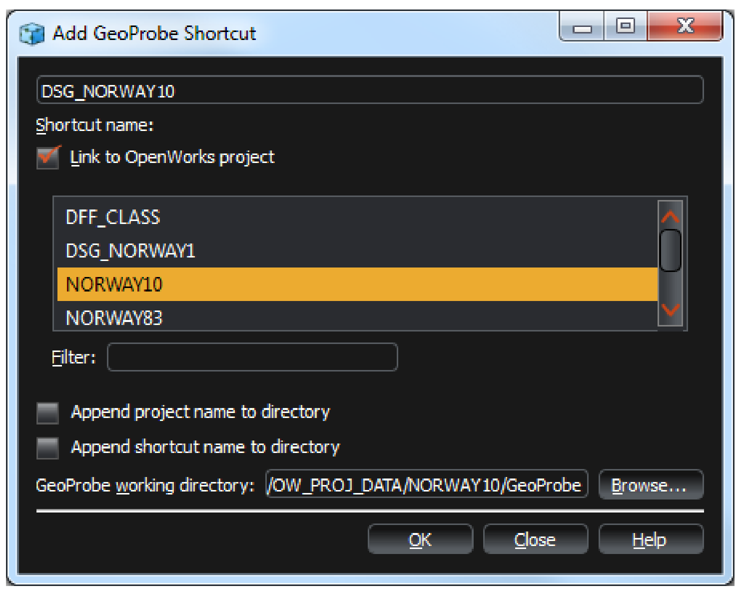
Connecting GeoProbe Software with DecisionSpace Geosciences

When the GeoProbe software has been launched, you need to ensure that the applications can communicate with each other. Toggle the PD connect in the GeoProbe software or the equivalent icon in DecisionSpace.

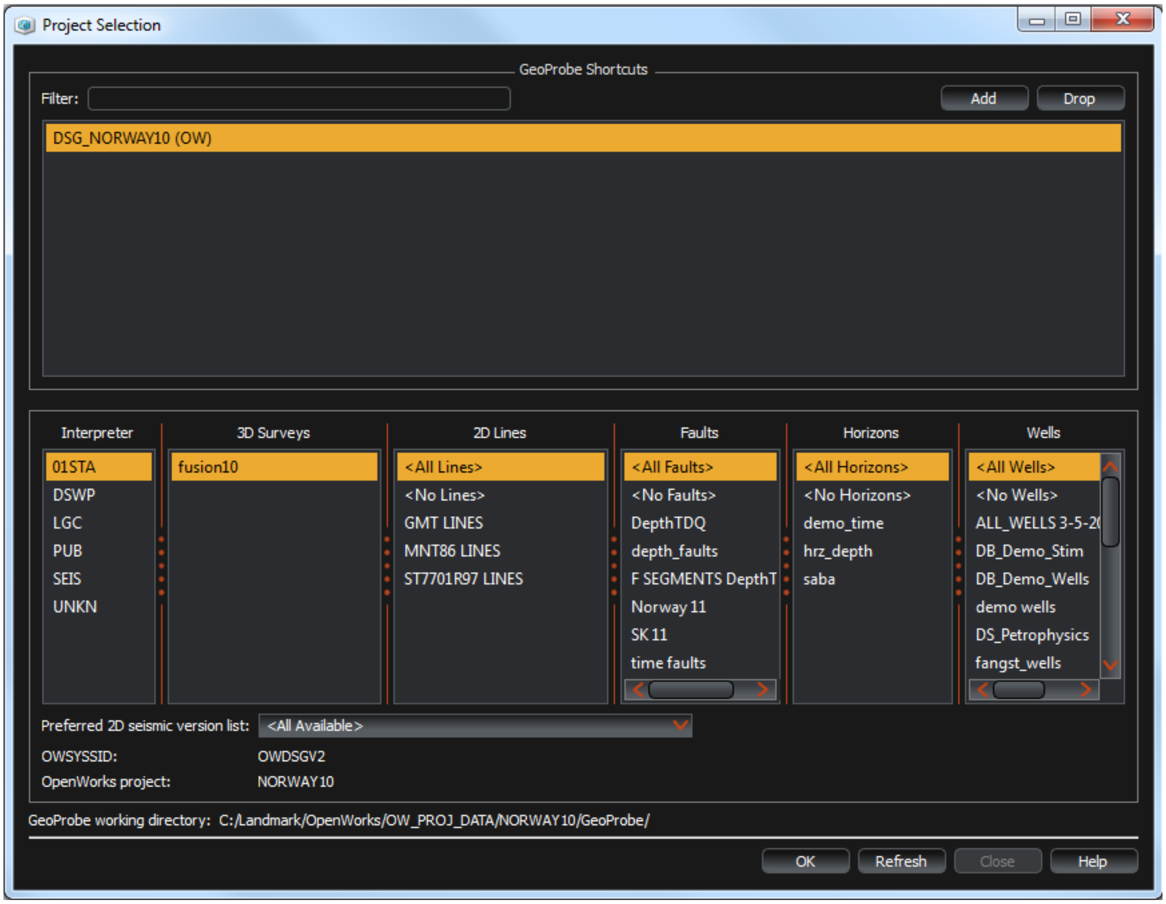
1. To launch the GeoProbe software click **OpenWorks Launcher > Applications > GeoProbe**.

2. In the *Project Selection* dialog, click **Add**.

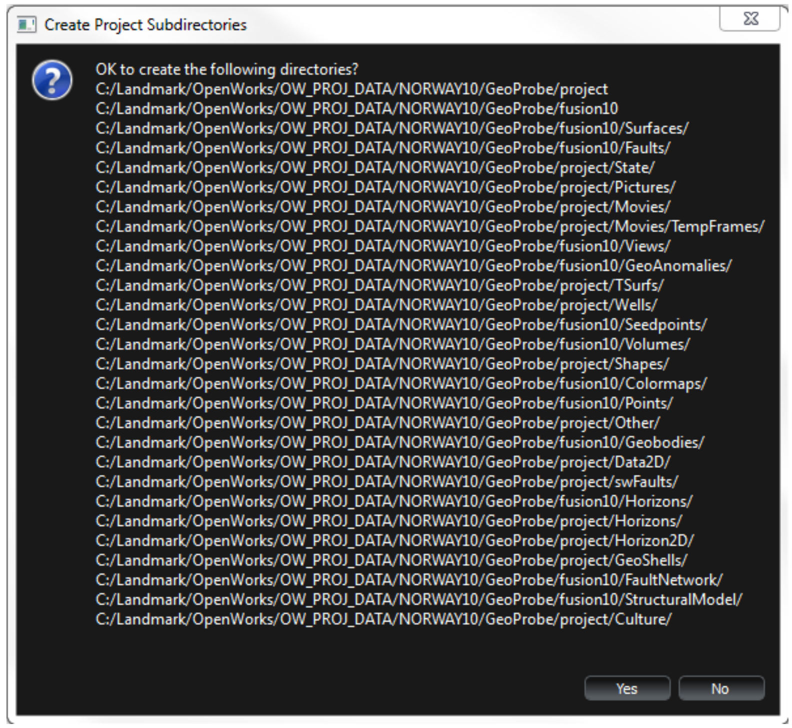
3. In the *Add GeoProbe Shortcut* dialog, type the shortcut name "**DSG_NORWAY10**," click **Link to OpenWorks** project, highlight the **NORWAY10** project, and then click **OK**.



4. Verify that your selections are the same as shown below, and click **OK**.

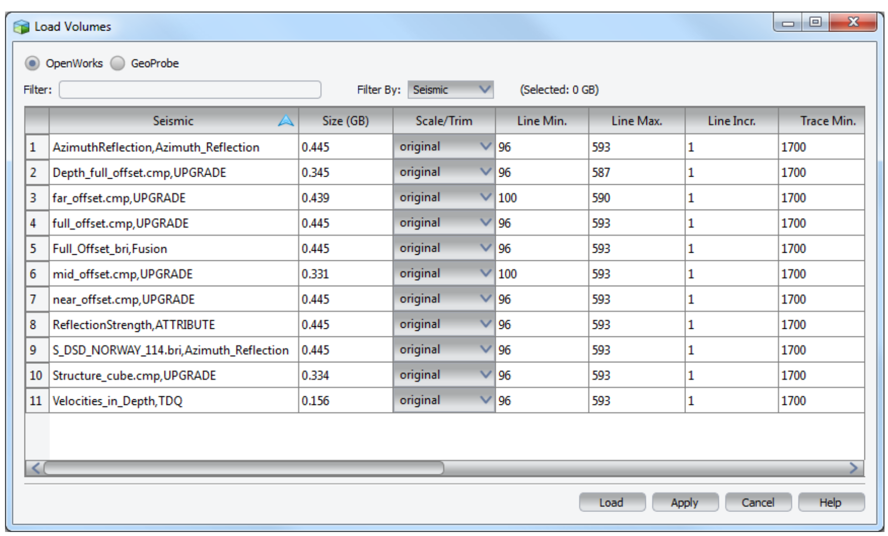


If the *Create Project Subdirectories* dialog appears, click **Yes** and continue.

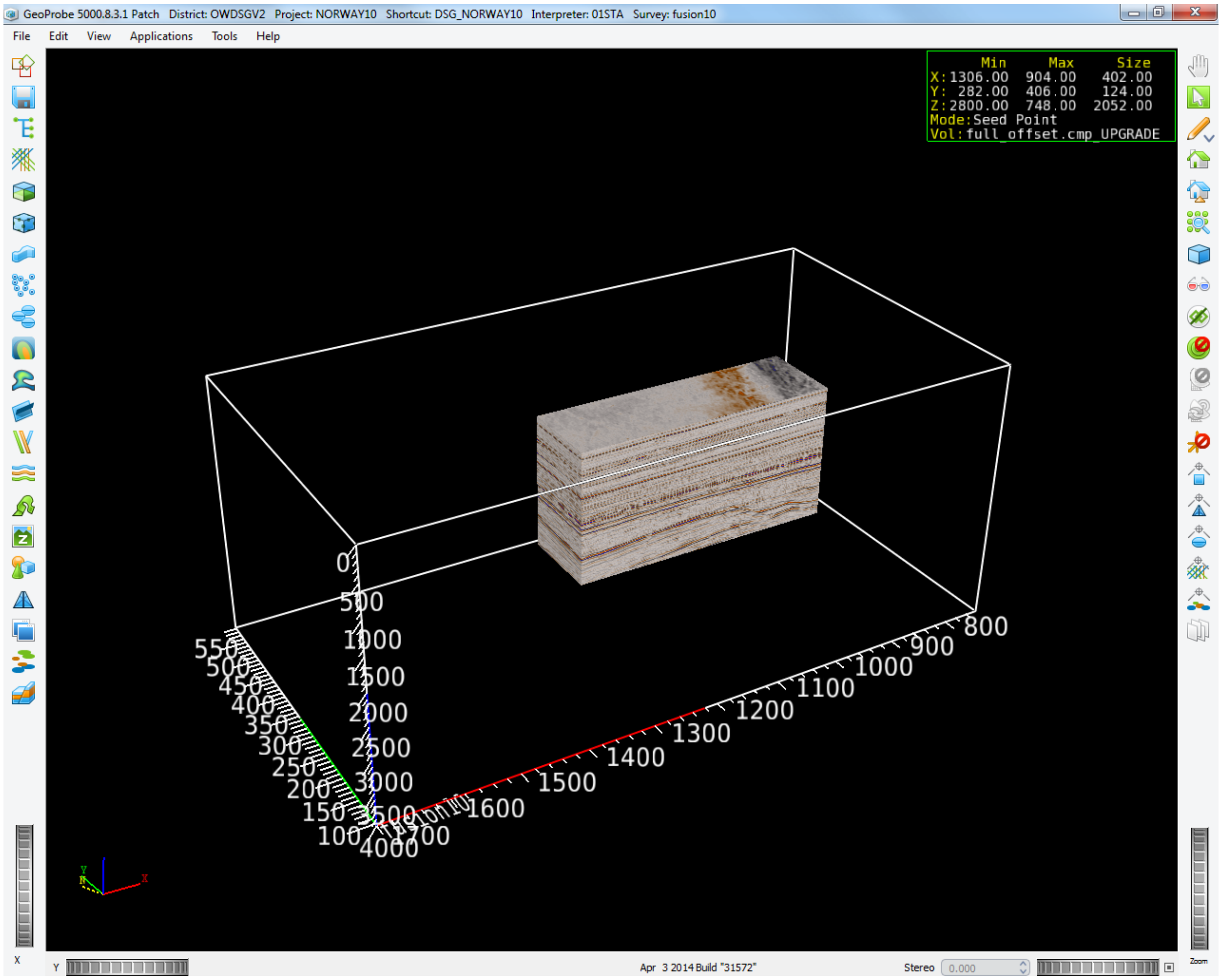


5. In the *Object Manager* dialog, ensure that **Volumes** is selected. Click the **Load** icon and select the **From OpenWorks** option.

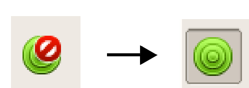
6. Select **full_offset_cmp_UPGRADE.vol** and click **Load**.



TheGeoProbe main window should appear as shown below.

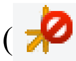


7. In the *GeoProbe* window, toggle on the **PD connect** icon.

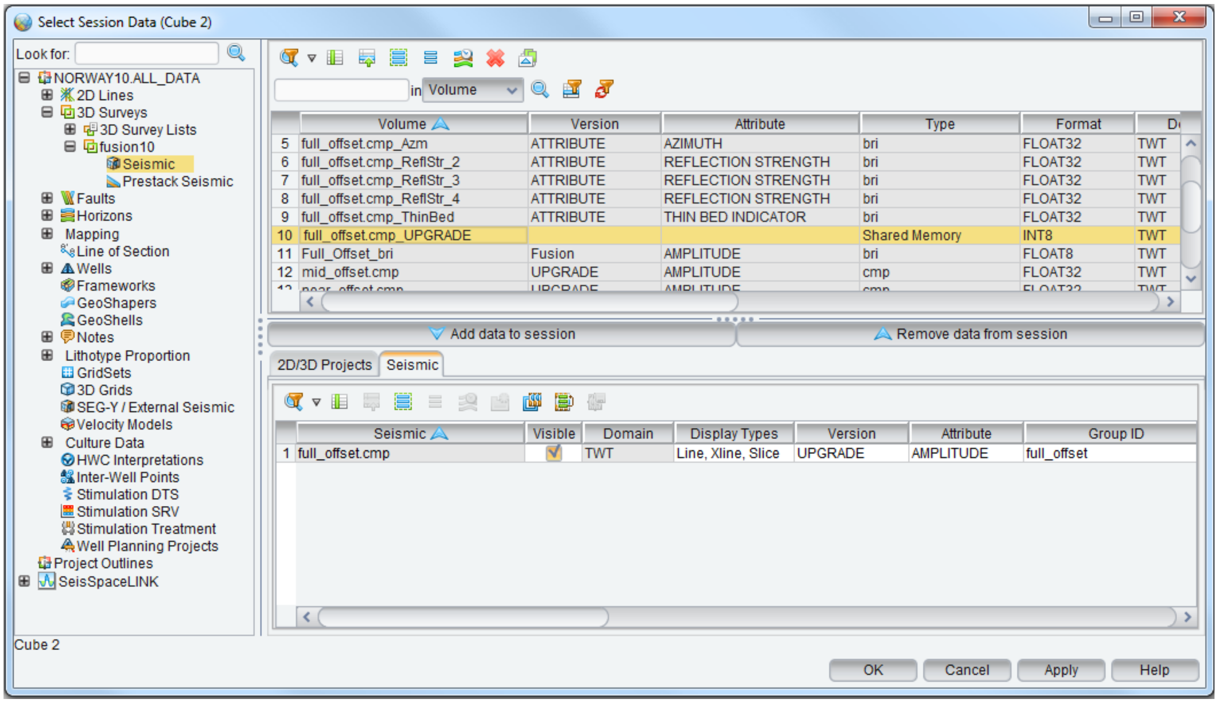


8. Toggle on the **Live Update** icon.

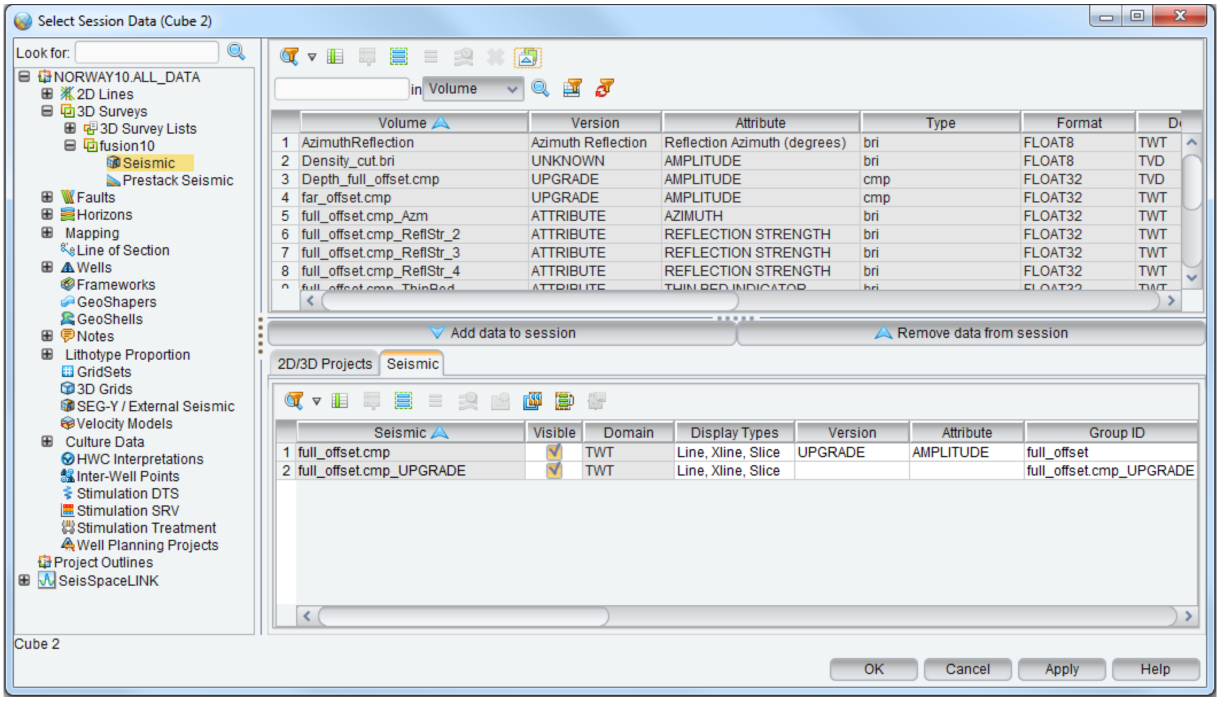
> **Note**
>
> The **Live Update** icon remains grayed out until PD connect is turned on.

Optionally, toggle on the **3D cursor** icon ( > ) to enable cursor tracking between the GeoProbe software and DecisionSpace.

9. In *DecisionSpace*, ensure that you are using the same shared memory volume. Go to **Select Session Data** and select the GeoProbe shared memory volume, **full_offset.vol**.

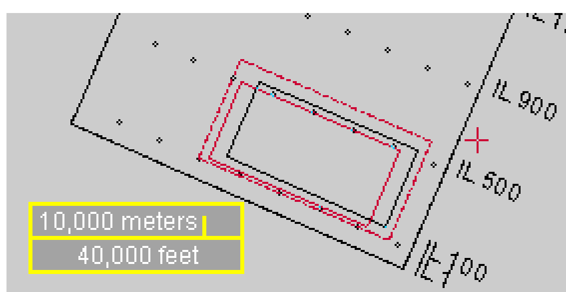


10. Click **Add data to session**, then click **OK**.

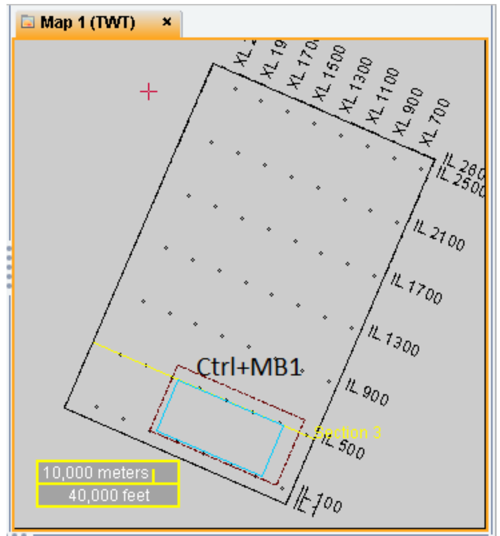


11. Click the **Listening** icon ( ) in DecisionSpace to enable communication with the GeoProbe software.

12. Select or animate the probe in the GeoProbe software. This should draw a yellow outline in DecisionSpace *Map* view. The black square marks the previous position of the probe.



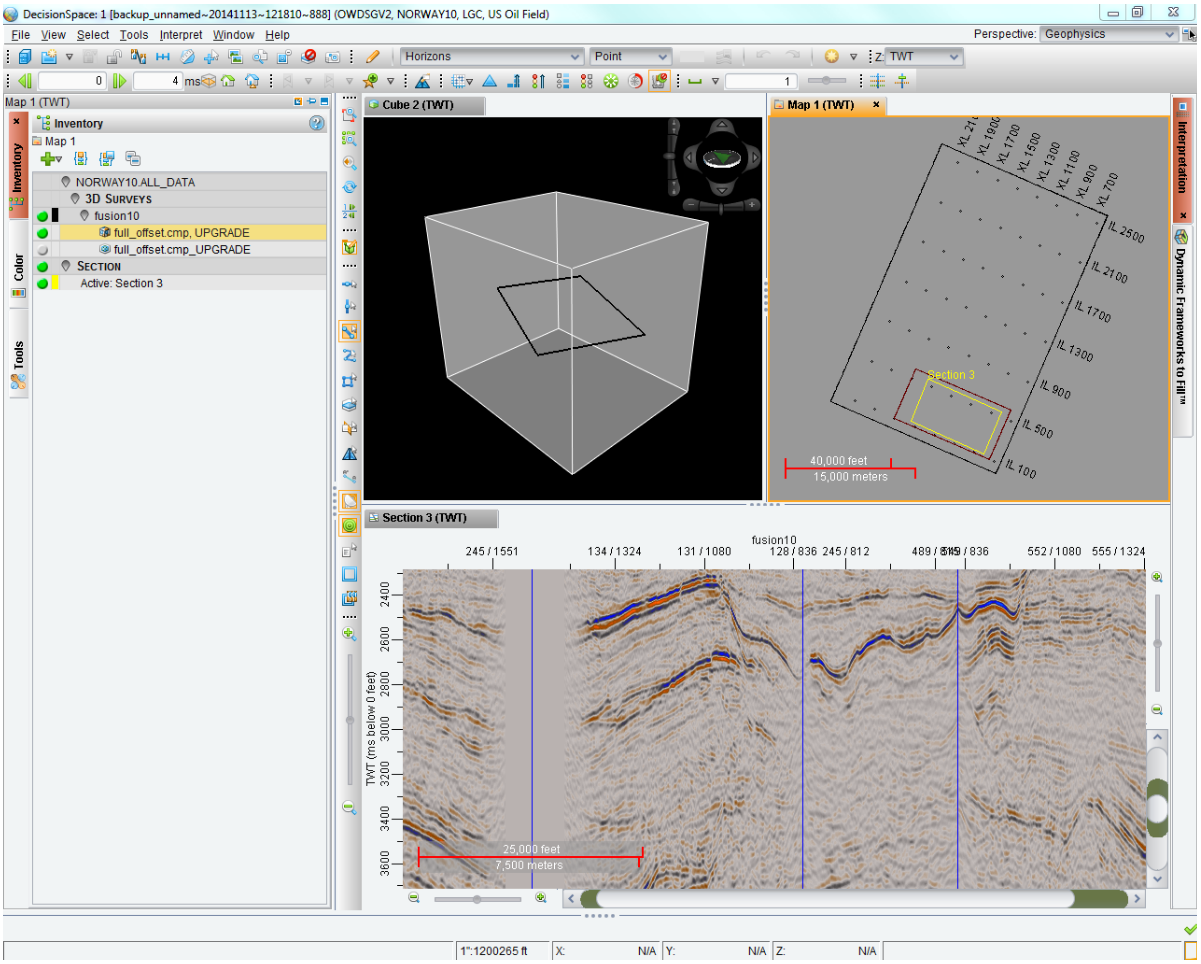
13. On the *Map* view, click the **Select Point to Point / ZigZag** () icon.



14. Select one of the faces of the outlined probe using **MB1+<Ctrl>**, then **MB2**. This will display the seismic in *Section* view and tie it to the GeoProbe probe.

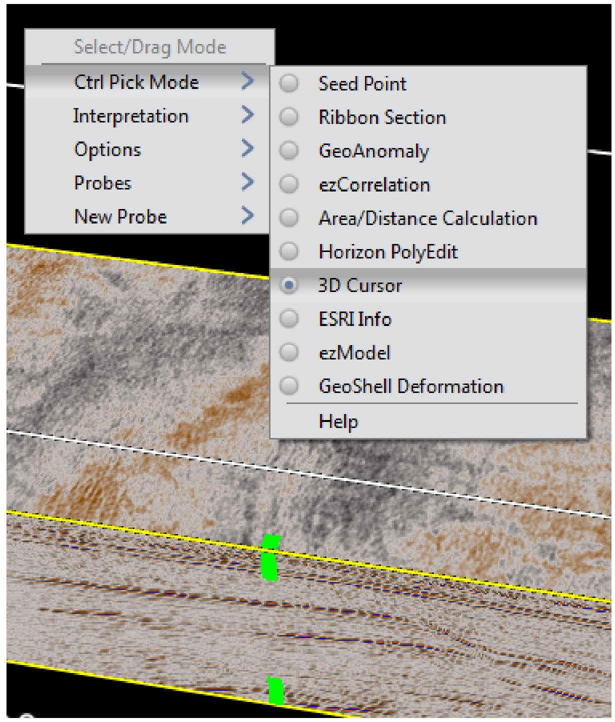
15. Move or resize the probe in the GeoProbe software.

The *Section* view content (line/trace location and probe outline) will change, tied to the new location of the GeoProbe probe.



The section will be tied until the Listening icon is turned off.

16. The GeoProbe software automatically tracks from DecisionSpace. To get DecisionSpace to track the cursor location from the GeoProbe software, **MB3** and then select Ctr**l Pick Mode > 3D Cursor**, then use **MB1+<Ctrl>** to track inside of the GeoProbe software.

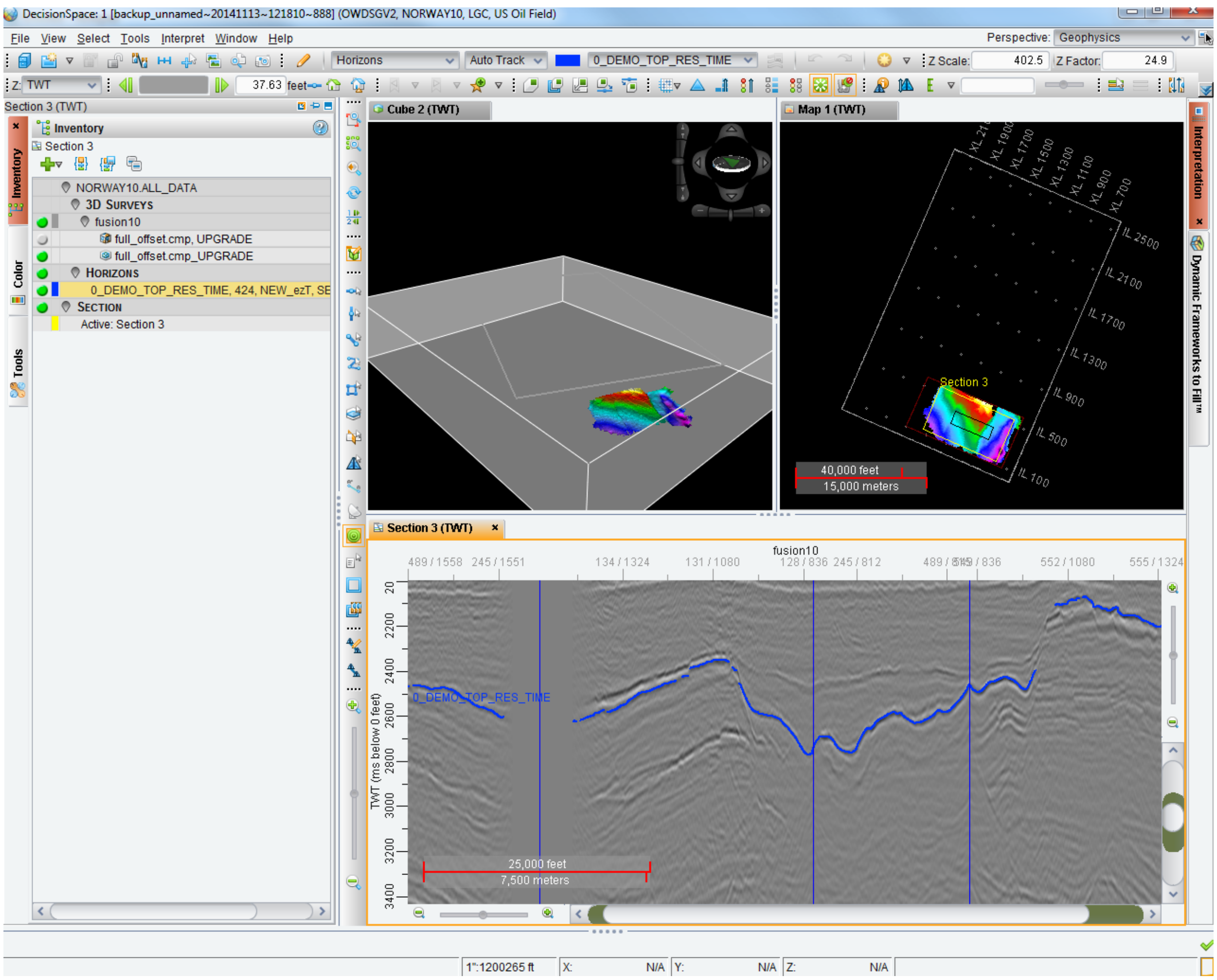


17. Now **MB1+<Ctrl>** and move the cursor in GeoProbe and you will be able to see its location inside DecisionSpace.

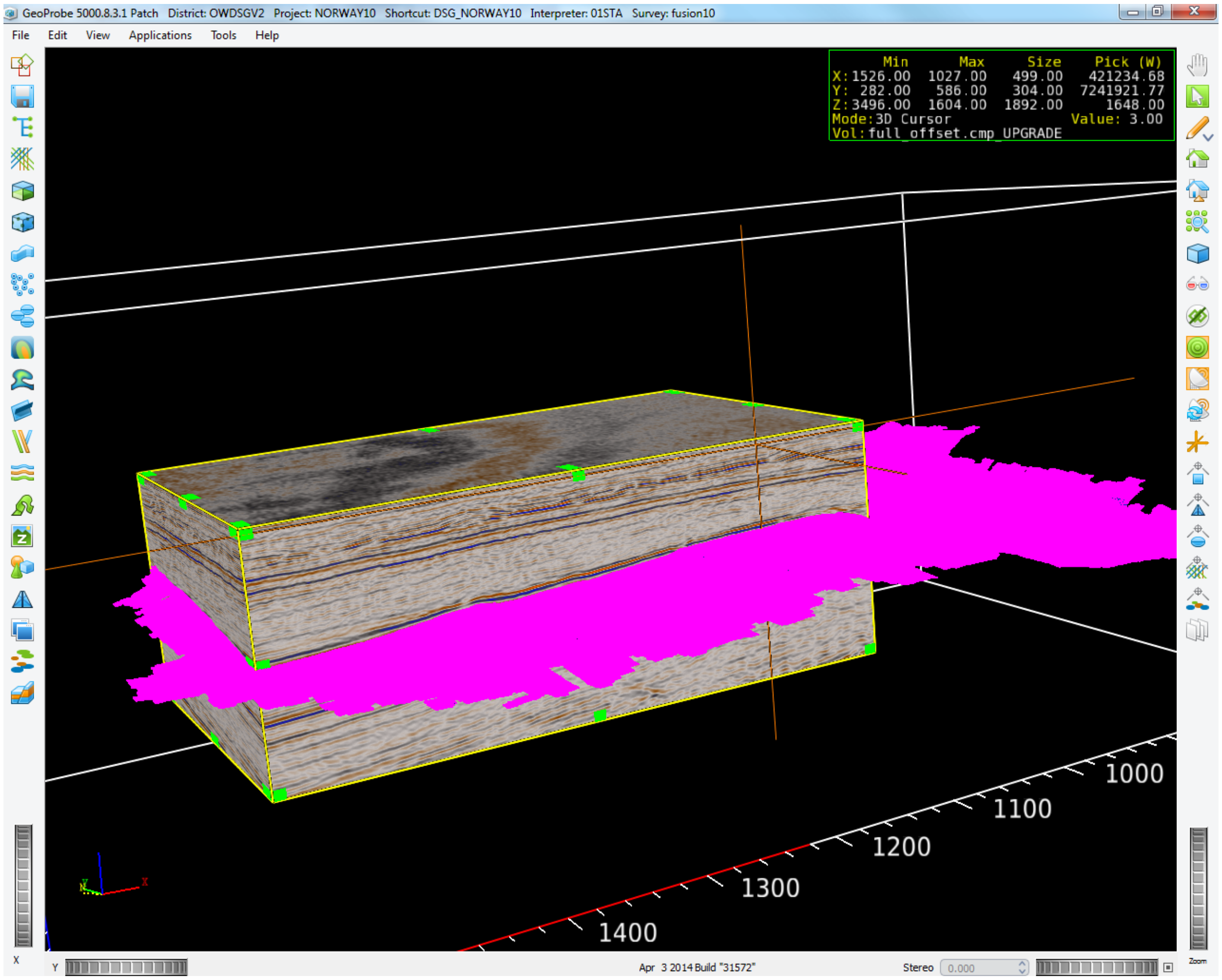
Editing Horizon Data in DecisionSpace

To view your DecisionSpace-generated horizon in the GeoProbe software, ensure you have Live Update toggled on. This allows you to see any dynamic changes between the applications.

1. Drag-and-drop the **0_DEMO_TOP_RES_TIME** horizon from your DecisionSpace *Inventory* to the GeoProbe main window.

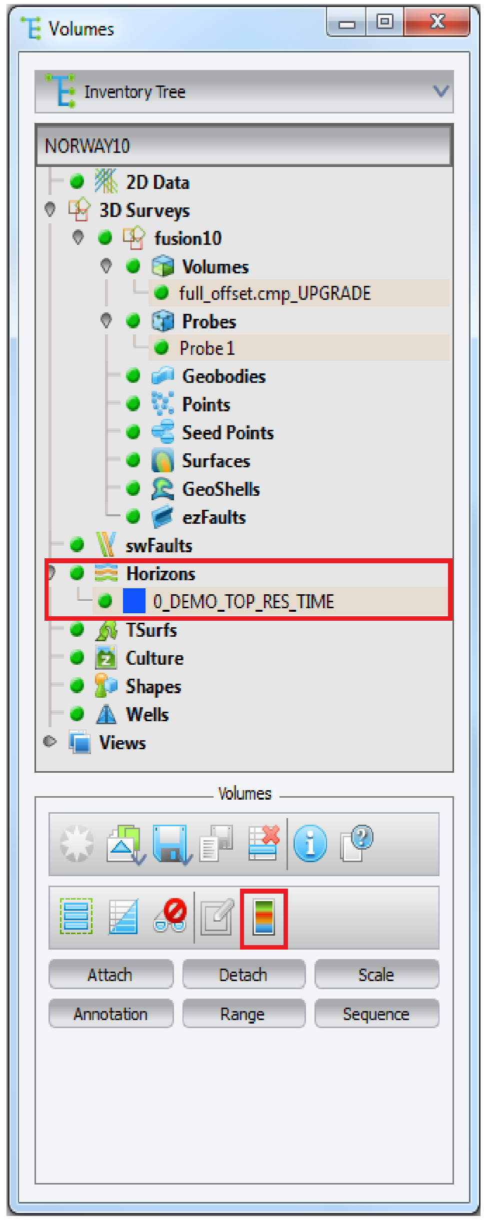


The horizon is now in your GeoProbe window and is available for viewing and editing.

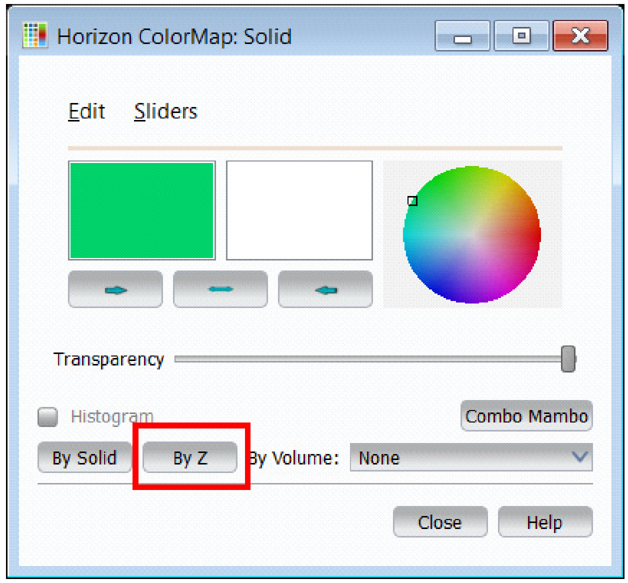


You may want to change the color map of the horizon.

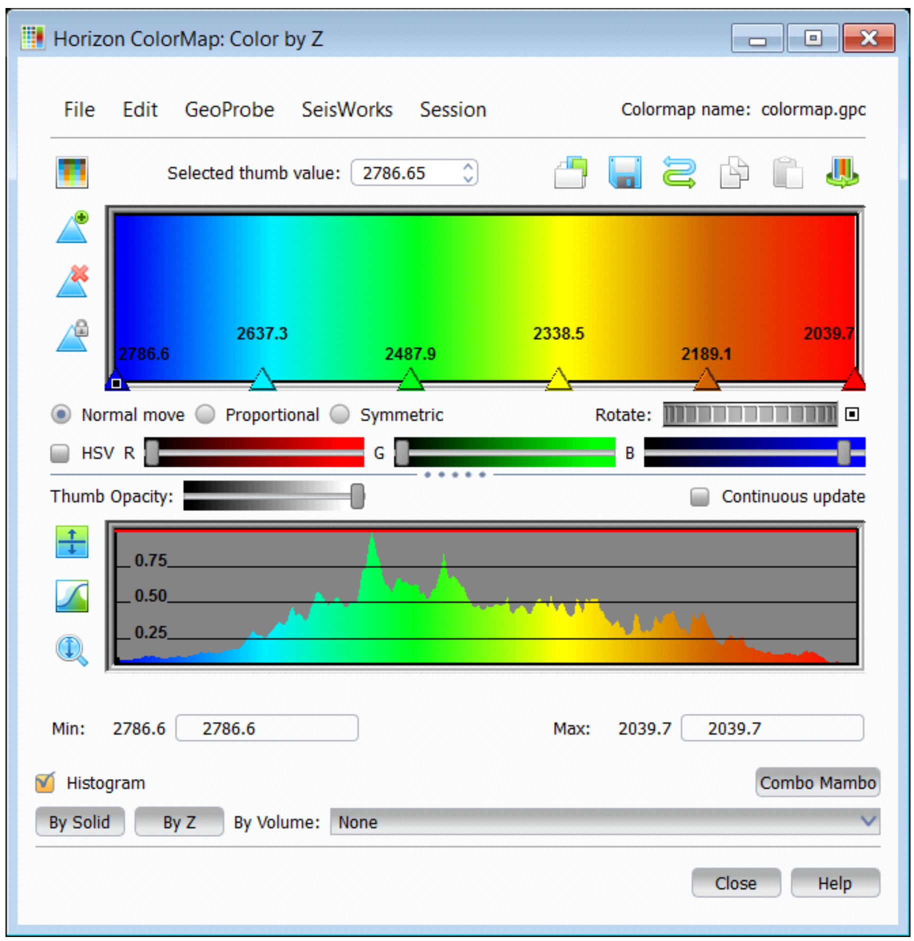
2. Go to **Object Manager > Horizons**. You will see the **0_DEMO_TOP_RES_TIME** horizon. Highlight it and click the **ColorMap** icon.



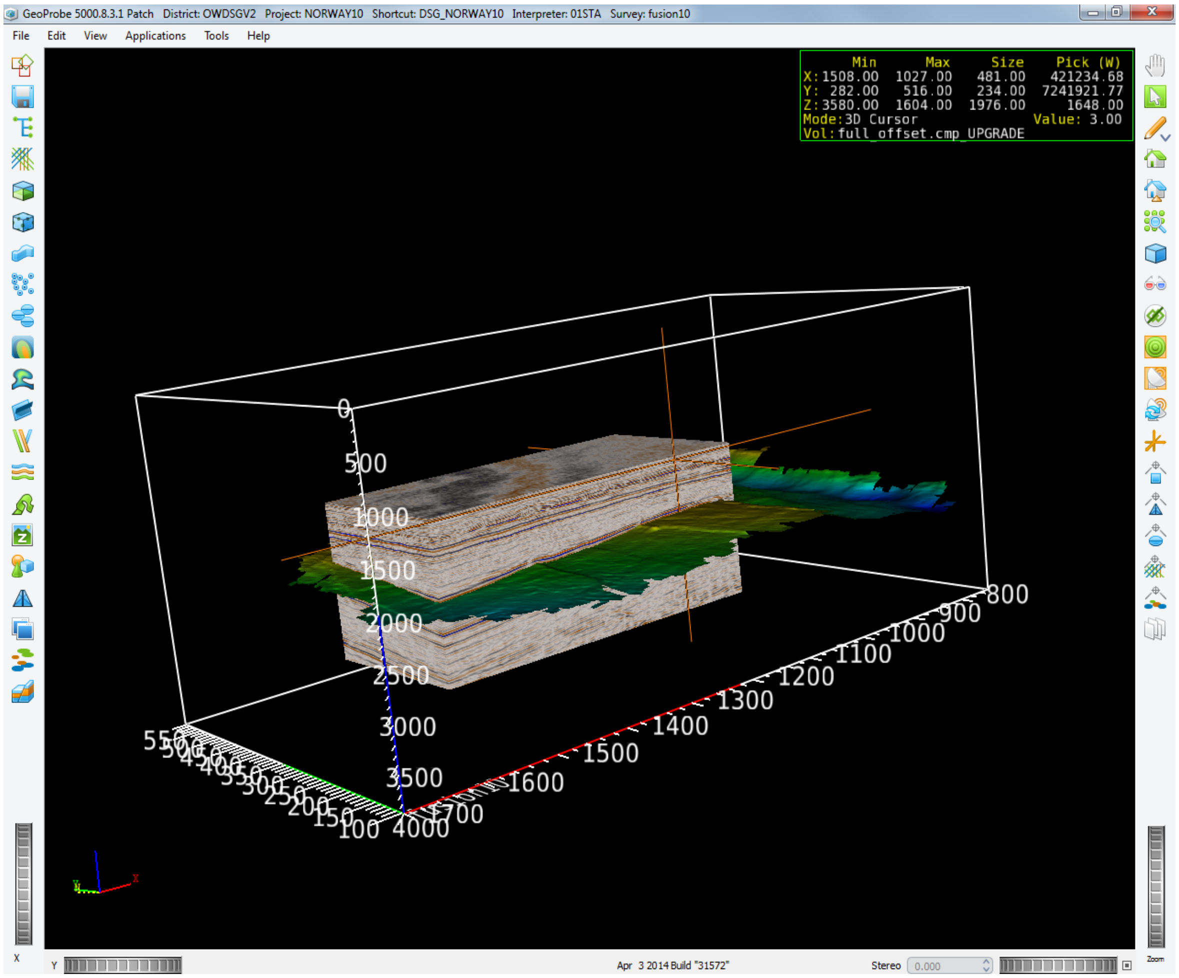
3. Change to color **By Z**.



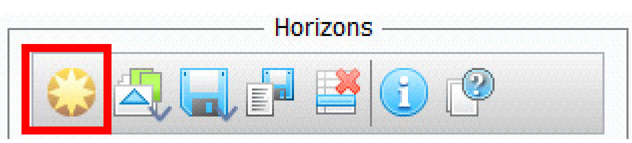
The *Horizon ColorMap* dialog changes to the following.



Your display should look like the following:

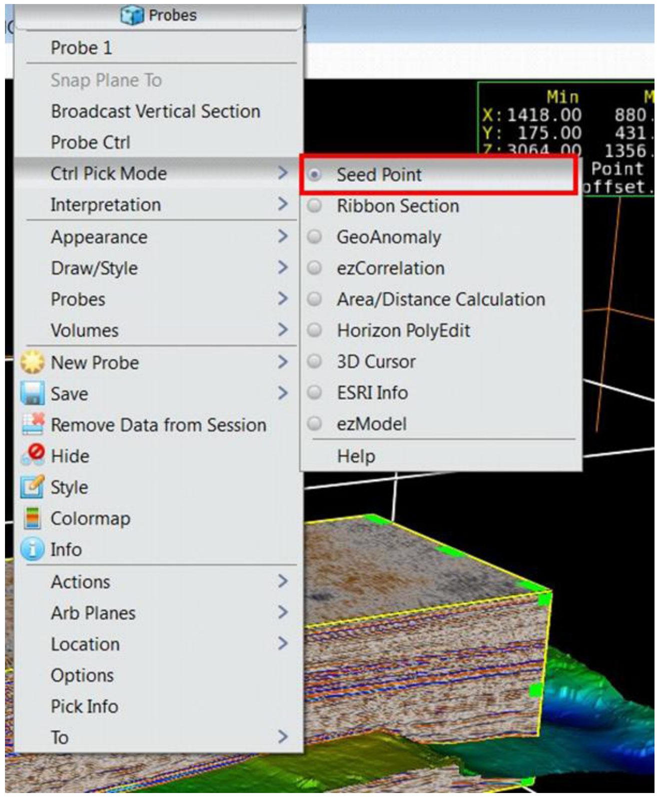


4. From the *Object Manager* (Horizons), create a new horizon using the **New Horizon** icon.



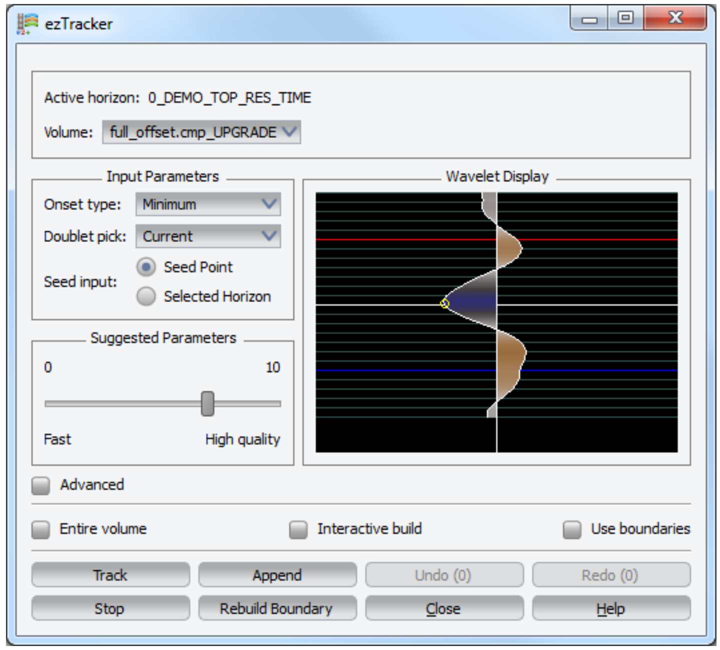
5. Click **ezTracker**.

6. With your cursor in pick mode (arrow), **MB3** and then select **Ctrl Pick Mode > Seed Point**.



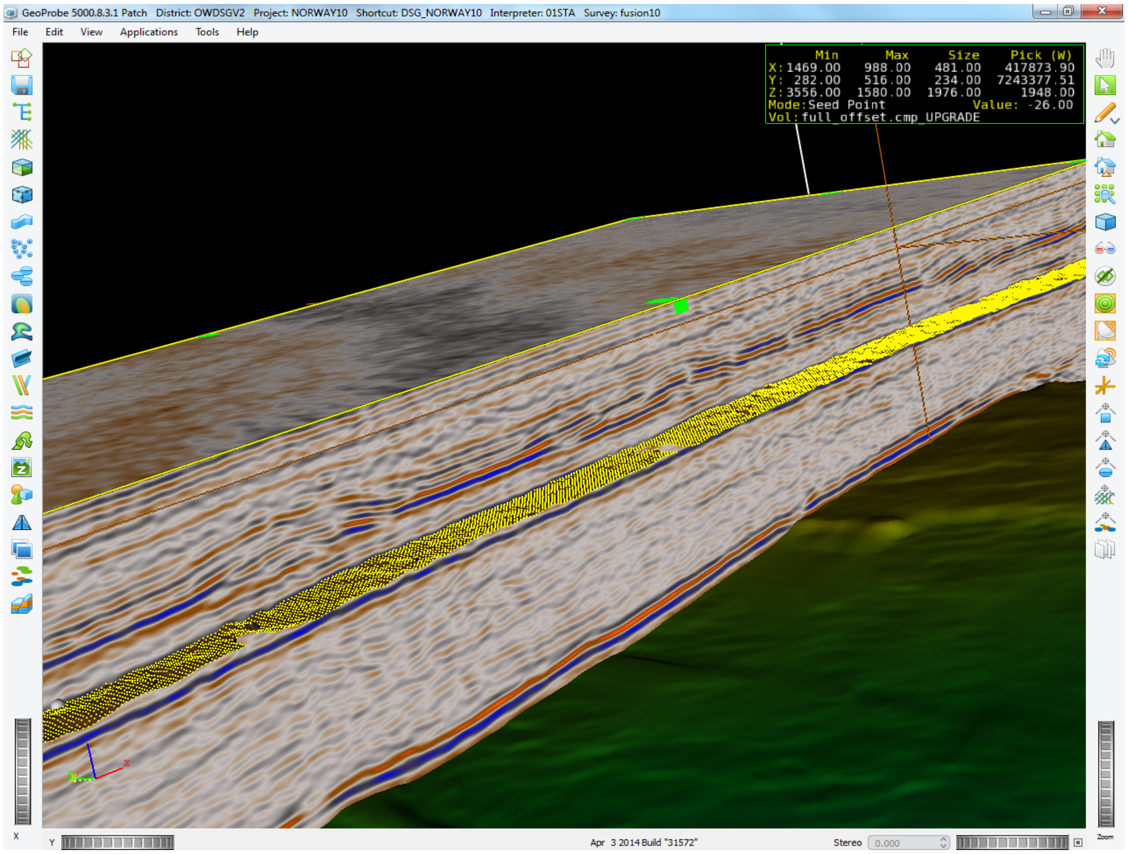
7. Select a seed point on the seismic probe using **MB1+<Ctrl>**. (Use the **Page Up**/**Page Down** keys to make the point larger or smaller.)

8. Set the parameters as shown and click **Track**.



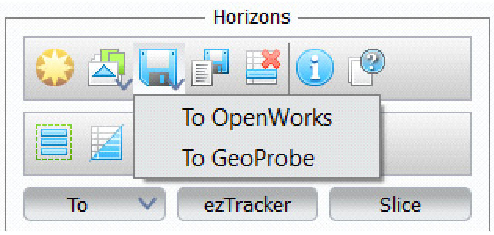
9. Your horizon should track based on the extents of the probe (if you selected interactive build).

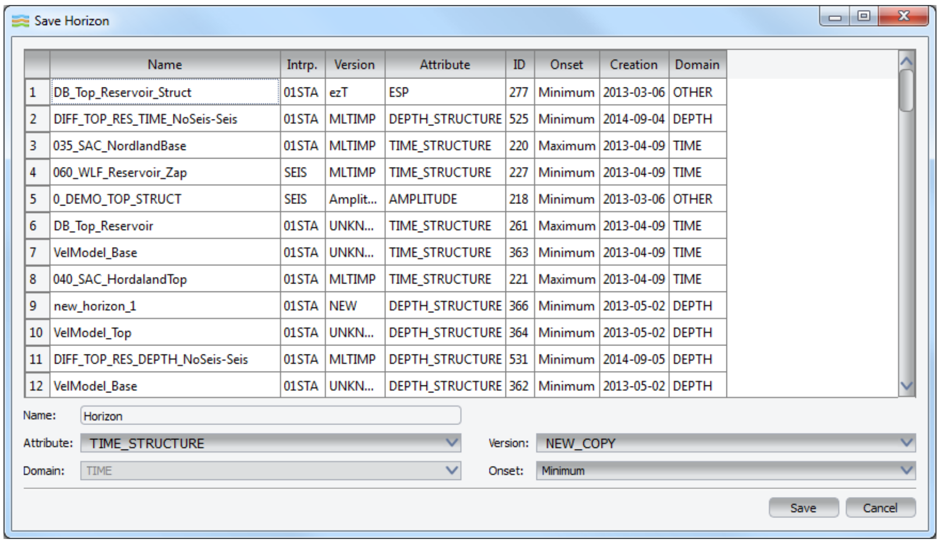
As you drag the probe, the horizon will continue to build.



Currently, this horizon is stored in memory. For DecisionSpace to see this horizon, it needs to exist as a name in the OpenWorks software.

10. From the *Object Manager*, click the **Save** icon, select **To OpenWorks**, and give the horizon a name.





11. You can now drag-and-drop this horizon from your *Object Manager* to either DecisionSpace *Inventory* or a view.

    These horizons are now linked, and any updates you do in GeoProbe will be seen in DecisionSpace (and vice versa).

    You may want to experiment using paintbrush in DecisionSpace to see the effect in GeoProbe, or continue appending to your horizon in GeoProbe **ezTracker** to see the result in DecisionSpace.

To see the changes made to the horizon in DecisionSpace, save the horizon changes to the database (database icon in the *Interpretation* panel). If changes made in GeoProbe do not appear instantly in DecisionSpace, select **View > Reload > Horizon**.