Quick start guide

Geoteric 2019.1 workflows

geoteric.com

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Overview

Our teams have the passion and experience to reveal the true value of your data. If you have a problem or query, our friendly Geoteric team will be more than happy to help.

Contact: support@geoteric.com

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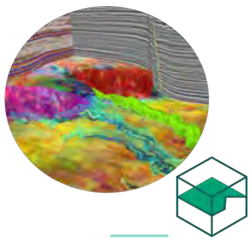
Contents

Our modules

The essential centrepiece of our suite of modules is Interpret, which enables full horizon, fault and geobody interpretation directly on colour blends. Our four additional modules can be accessed from Interpret, giving you powerful functionalities to solve the unique challenges you may face.

BASE MODULE



Interpret

Data management
- Internal data management
- Data import and export
- 3rd party links (Petrel, DSG)

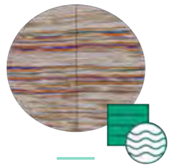
Visualisation
- Colour blend creation (RGB, CMY, HSV)
- Opacity blend creation
- 3D volume rendering

Seismic interpretation
- Automatic fault extraction
- Adaptive Faults ™
- Adaptive Horizons ™
- Adaptive Geobodies™

Utilities
- Volumetric calculator
- Horizon tools (flattening, cropping)

ADDITIONAL MODULE

Additional modules will only work if the base module, Interpret, has been installed.



Condition

Noise and spectral expression
- Noise attenuation
- Spectral whitening and bandpass filtering
- With easy to use parameter optimisation

Classify

Interactive Facies Classification (IFC)
- Multi-attribute and well based classification
- Uses Machine Learning algorithms

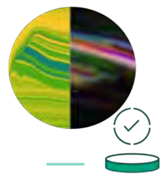
Reveal

High definition and standard frequency decomposition

Fault expression

Iso-proportional slicing

50+ seismic attributes & segmentation



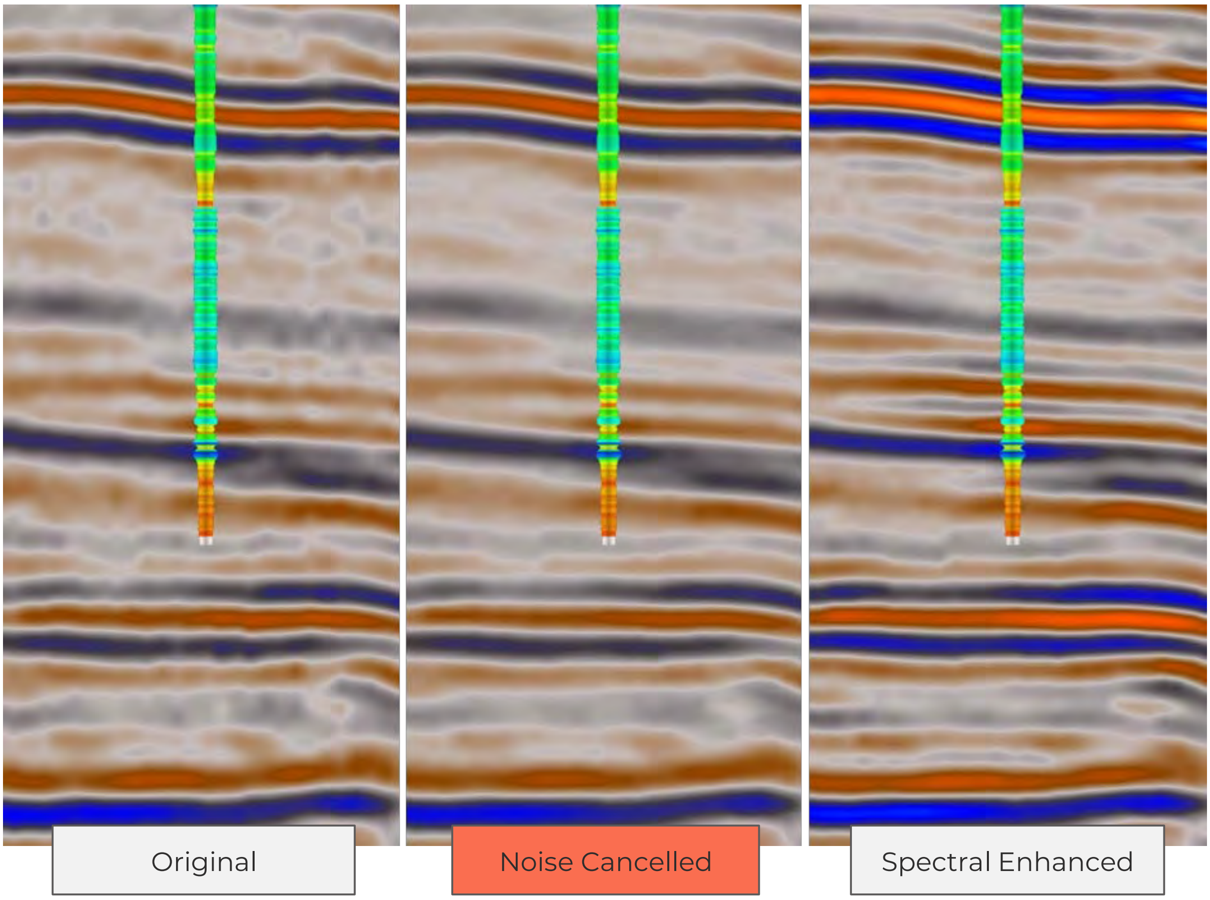
Validate

Forward modelling
- Model validation with synthetic seismic and RGB frequency blend
- Layer and wedge models
- Well log-based rock properties
- Fluid substitution

Condition

Noise expression

The noise expression tool was developed with the objective of optimising noise cancellation results. Its intuitive design allows you to see results of different levels of noise cancellation and the effect the noise filters have on your data, prior to full volume processing. A preview window displays an in-line, cross-line or time slice of your input seismic, providing live feedback as you optimise the filter parameters of the noise cancelling algorithms. Noise expression ensures you achieve the optimal results, by targeting different types of noise and preserving the structural integrity of your data. It improves interpretability and subsequent attribute analysis.



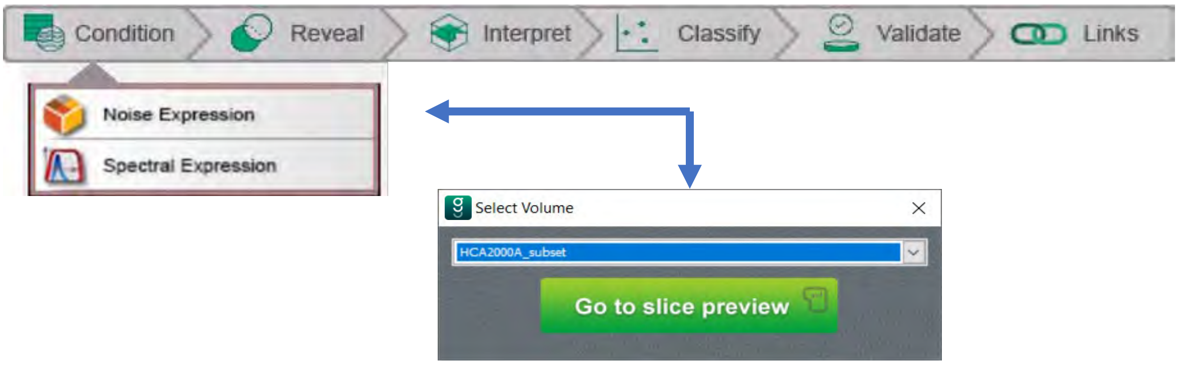
Improving the quality of your seismic image is of key importance to ensure you reveal the most from your data using Geoteric's Interpretation workflows.

This document will provide step-by-step recommendations for a typical noise expression workflow.

Tip: To save time you can crop a test volume to input into the Noise expression tool, optimise your results before processing and then generate 3D volumes over the entire 3D dataset.

Generating Noise Cancelled volume

1. Click Condition from the workflow icons toolbar (top right) and select Noise Expression. This will present you with a 'Select Volume' window. Select the volume you wish to process and press Go to slice preview



The noise expression tool will open and begin processing the default-settings over your selected input volume. You will be presented with an Example Driven interface of 9 preview swatches, which will enable you to effectively compare the results of the different noise filters in the tool, in a single view – without having to process each scenario to compare the output.

It is also possible to choose different in-lines, cross-lines and times slices to optimise your preview to ensure that your selected filter size works well in all parts of the dataset.

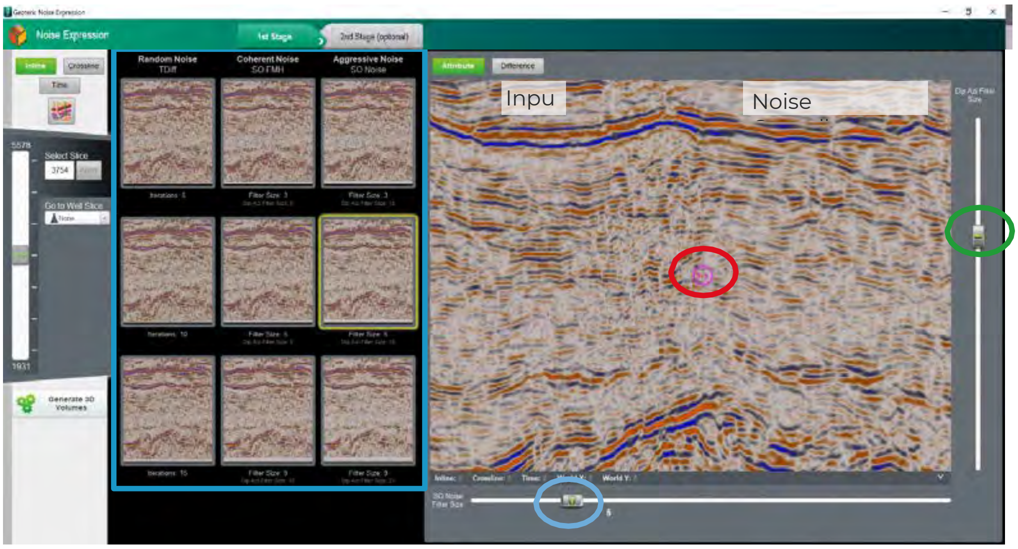
The next step will introduce each noise filter and guide you through the interface of the Noise Expression window.

Hint: Multiples cannot be efficiently attenuated using post stack noise cancellation processes, without severely comprising the quality and detail of your seismic data. However, with correctly optimised steering volumes and noise filters – their strength may be reduced.

2. The example driven interface (blue rectangle) is divided into 3 columns – each representing a different noise filter (TDiffusion, SOFMH & SO Noise). Each row defines the filter size/intensity of the noise filter, with the first row defaulting to small filter sizes (gentle attenuation) and the third row defaulting to larger filter sizes (more stubborn, cross cutting noise).

Tool features

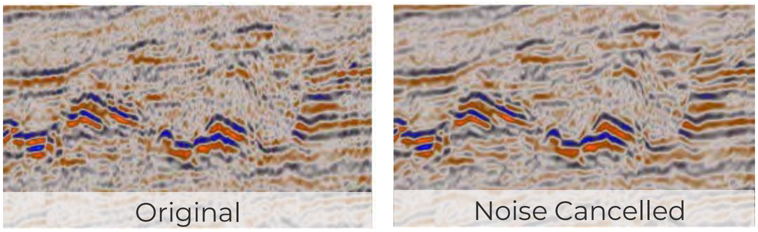
- QC Swipe (red circle) – this bar swipes left to right revealing the input seismic versus the noise cancelled preview. This enables you to be continually aware of how you are conditioning your data and to optimise your filters accordingly.
- Dip & Azi Filter (green circle) – this allows you to adjust the size of the steering volume that will drive the structurally orientated (SO) noise filters.
- Filter Size (blue circle) –enables you to adjust the footprint size of the chosen noise filter. A larger footprint will produce stronger noise attenuation results, while a smaller footprint will apply a less intensive iteration of the filter – preserving small scale fractures/stratigraphic features, for example.



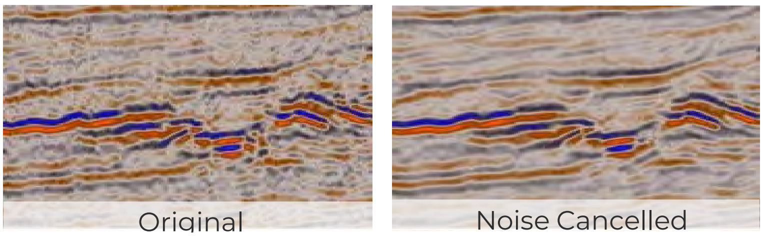
Example driven noise expression window

Attribute Information

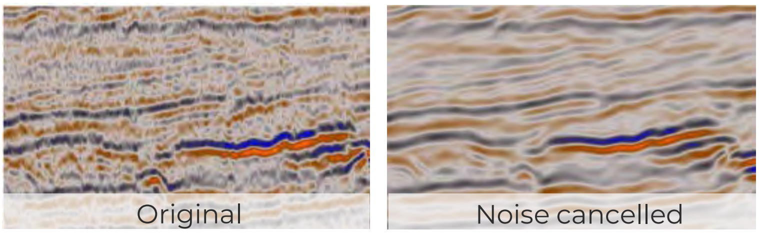
- TDiffusion – targets random noise (salt & pepper character).

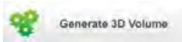


- SOFMH – targets coherent noise (minor acquisition footprint or migration noise).



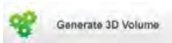
- SO Noise – targets aggressive noise (salt or basalt effects).



To generate a volume with a single noise filter applied, optimise your attribute filter size and DipAzi filter size and then click 

2nd Stage noise cancellation

Post stack seismic data will often contain various types of noise, meaning that no single filter may be able to attenuate all noise present. Noise Expression contains the functionality for you to apply a second iteration of the same or different noise filter before processing the results over the full 3D volume. This means you are able to optimise your noise cancelled volume by targeting different characters of noise in order to ensure your resulting volume is at its best for interpretation and subsequent attribute analysis.

1. After optimising your first noise attenuation filter, select the "2nd Stage (optional)" tab. The results from the 1st Stage will be the input for the 2nd Stage.
2. You can either then select the same noise filter and adjust the parameters or select a different noise attribute to target a different type of noise and adjust the parameters accordingly.
3. Once you're happy with the preview, you can change the preview slice to see the results in other areas and then 

What next?

This is only the beginning. With your newly conditioned volume you can progress to other workflows using Geoteric's suite of multi-attribute interpretation tools to see the geology in your data.

Analyse the frequency content in your seismic and improve the vertical resolution.

- Spectral Expression

Reveal and understand the geology in your data, before interpreting.

- Standard Frequency Decomposition (FD)
- Broadband High Definition Frequency Decomposition (HDFD)
- 3D fault delineation techniques such as Fault Expression, to better understand the structural elements in your data.

Interpret surfaces and faults from the seismic.

- Adaptive Horizons™
- Adaptive Faults™
- Adaptive Geobodies™

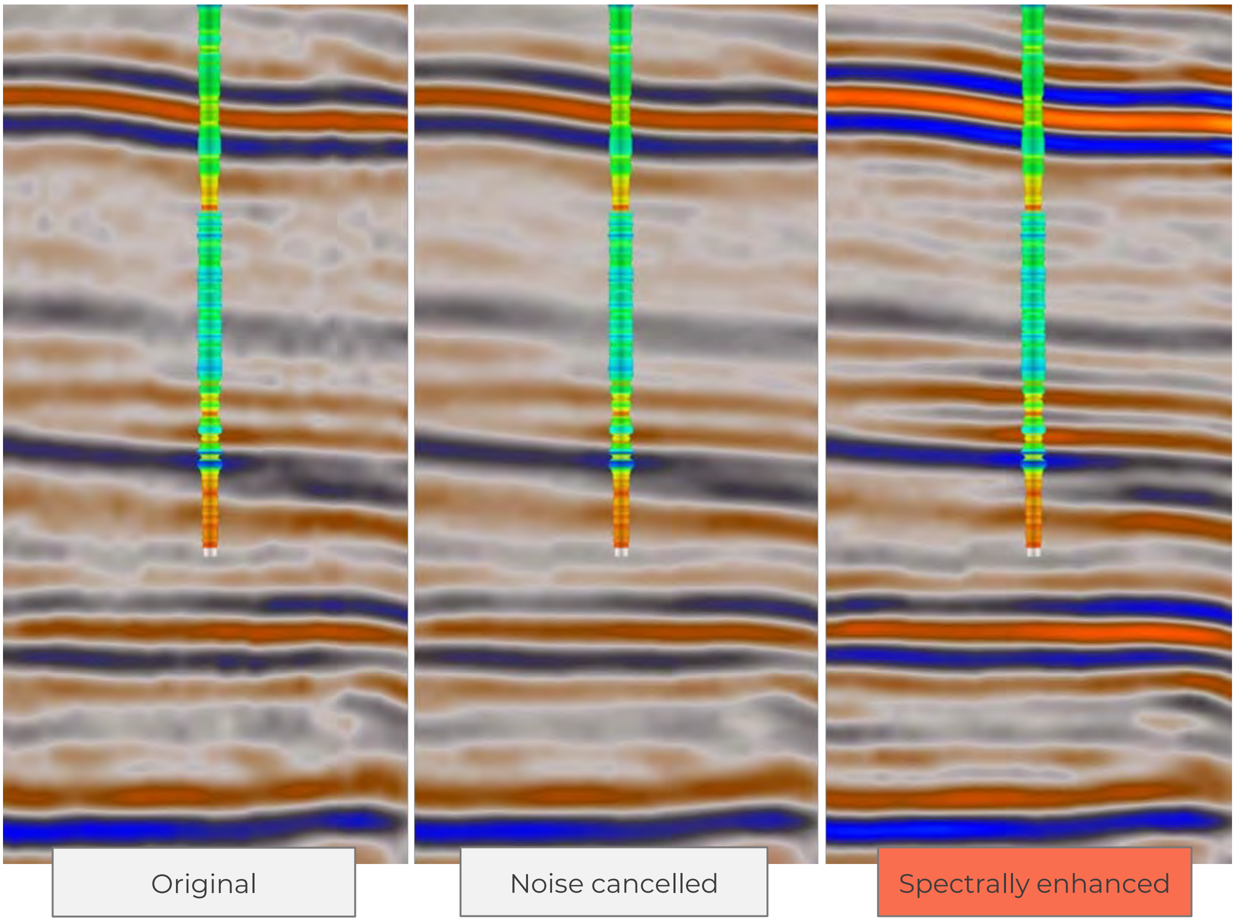
Interactive Facies Classification (IFC)

Model the seismic and RGB responses in Validate

Condition

Spectral expression

The Spectral expression tool was developed to provide an interactive method for spectral shaping to enable you to manually manipulate the frequency content of the data. The purpose of spectral shaping is to increase the contribution of the frequencies with a weaker signal – thus improving the resolution and frequency content of your data. Spectral enhancement allows you to see more information in your seismic image, carry out more detailed interpretation and input a more detailed seismic cube into subsequent Geoteric workflows.



Improving the quality of your seismic image is of key importance to ensure you reveal the most from your data using Geoteric's interpretation workflows.

This document will provide step-by-step recommendations for a typical spectral expression workflow.

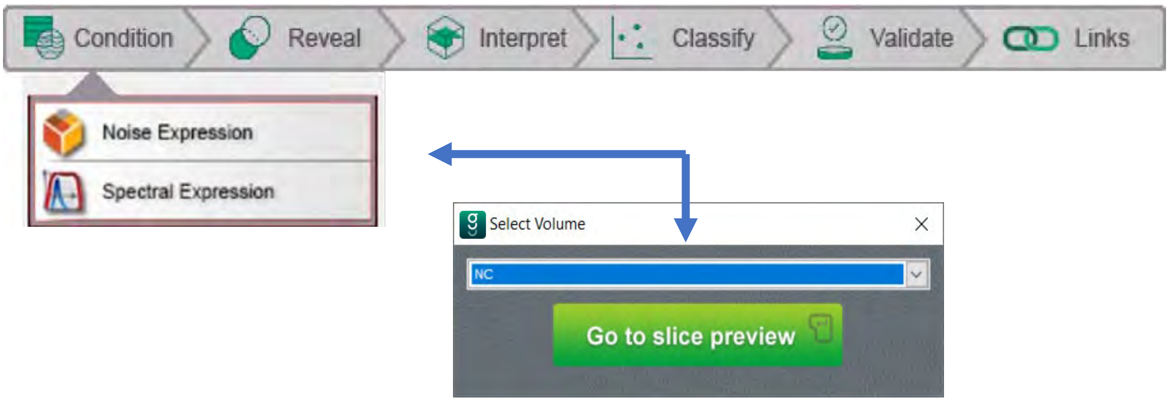
Tip: To save time you can crop a test volume to input into the spectral expression tool, optimise your results before processing and then generate 3D volumes over the entire 3D dataset.

Generating spectral enhanced volume

1. Click 

from the workflow icons toolbar (top right) and select Spectral Expression. This will present you with a 'Select Volume' window. Select the volume you wish to process and press 

2. **Hint: We recommend you run your volume through our noise expression tool to attenuate any noise remaining in your post-stack data. This will ensure unwanted signal is not boosted in the spectral expression workflow.**



The Spectral expression tool will open and begin processing the default-settings over your selected input volume. You will be presented with an example driven interface of 3 preview spectrums which will enable you to effectively compare the results of the different levels of enhancement, in a single view – without having to process each test before comparing the output.

It is also possible to choose different in-lines, cross-lines and times slices to optimise your preview to ensure that your selected attribute and footprint sizes work well in all parts of the dataset. You can turn on horizons to ensure your results calibrate to any previous interpretations/well picks.

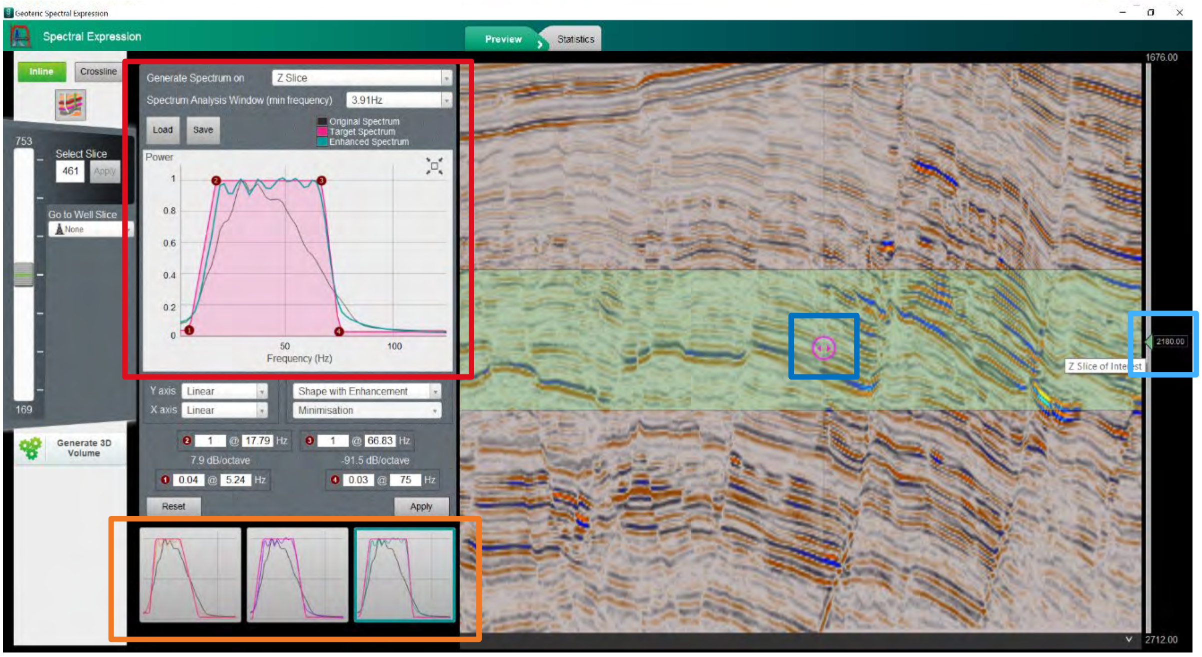
The next step will guide you through the interface of the spectral expression tool.

3. The example driven interface (orange rectangle) is divided into 3 windows – each representing a different level of spectral enhancement (low, medium & high).
4. Selecting one of these windows will show a preview of the spectral shaping results to the right, in the preview pane. Here you can also compare the results using the QC Swipe, with the input data.

Tool features

- Spectrum graph (red square) – this shows the original spectrum (black), the target spectrum (pink) and the enhanced spectrum (orange, pink or teal) along the selected time interval or horizon. The enhanced spectrum can be changed by moving the red circles labelled 1-4 or typing desired frequencies in the boxes below. Bandpass filtering can also be completed in this tool. Just select bandpass filtering under *shape with enhancement*.
- QC swipe (blue square) – this bar can be dragged from left to right to compare the enhanced results with the input seismic.

- Set interval (light blue square) – used to set the interval/z-slice of interest. The spectrum will be generated from the data that falls in this window.



Example driven spectral expression

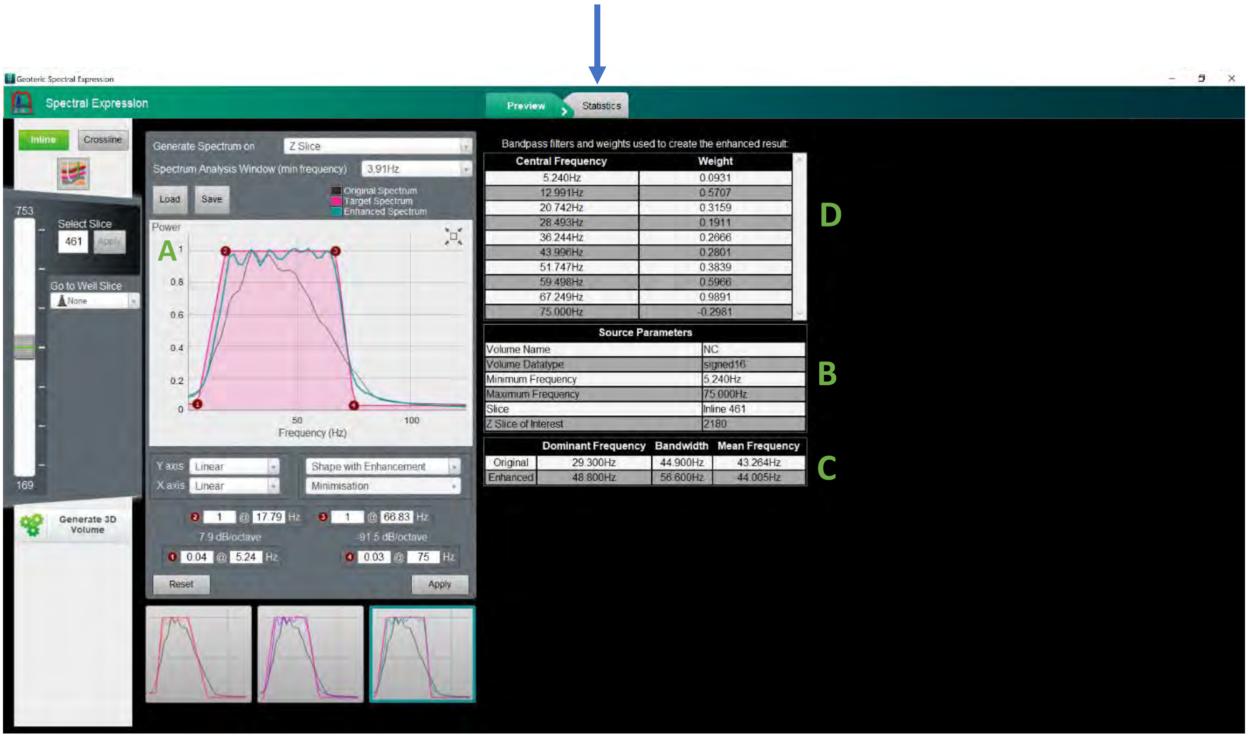
5. Select the time slice or input horizon that best represents your interval of interest. The spectrum information will be gathered from a window above and below this slice/horizon, so the results will be optimal for that interval. The *Go to well slice* will automatically go to the inline or crossline with that well for a more focused spectral shaping.
6. Use the pre-suggested levels of enhancement to compare the magnitudes of effect. This will enable you to decide if you should be applying a small amount of boosting, or a larger amount of boosting – without having to process multiple test volumes first.
7. Change the corner points of the trapezoidal filter by clicking and dragging in the spectrum graph or entering the desired frequencies and power values in the area below. This will allow you to manually interact with the spectrum to choose carefully which frequency you want to boost/reduce.
8. Each time you manipulate the spectrum, click Apply to apply it to the preview window.
9. The statistics tab (blue arrow) provides you with the relevant information required to understand what effects the spectral shaping is having on your data. You can also screengrab this for entry into your reports.
    a. Preview of graph and edited spectrum
    b. Summary of input volume, frequency range and interval/horizon of interest.

c. Effects of spectral shaping.

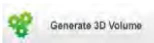
   i. Dominant frequency – recommended practice is to try and keep this unaltered (unless the intent is to distort your dominant frequency).

   ii. Bandwidth & mean frequency – increasing these should improve vertical resolution.

d. Bandpass filters and associated weights used to create the enhanced results.



Statistics window in spectral expression

10. You can change the inline/crossline preview to ensure your results are accurate across the whole interval of interest. Once you are happy with the results, click  to run over the full 3D seismic.

What next?

With your newly conditioned volume you can progress to other workflows using Geoteric's suite of multi-attribute Interpretation tools to see the geology in your data.

Reveal and understand the geology in your data, before interpreting.

- Standard Frequency Decomposition (FD)
- Broadband High Definition Frequency Decomposition (HDFD)
- 3D fault delineation techniques such as fault expression to better understand the structural elements in your data.

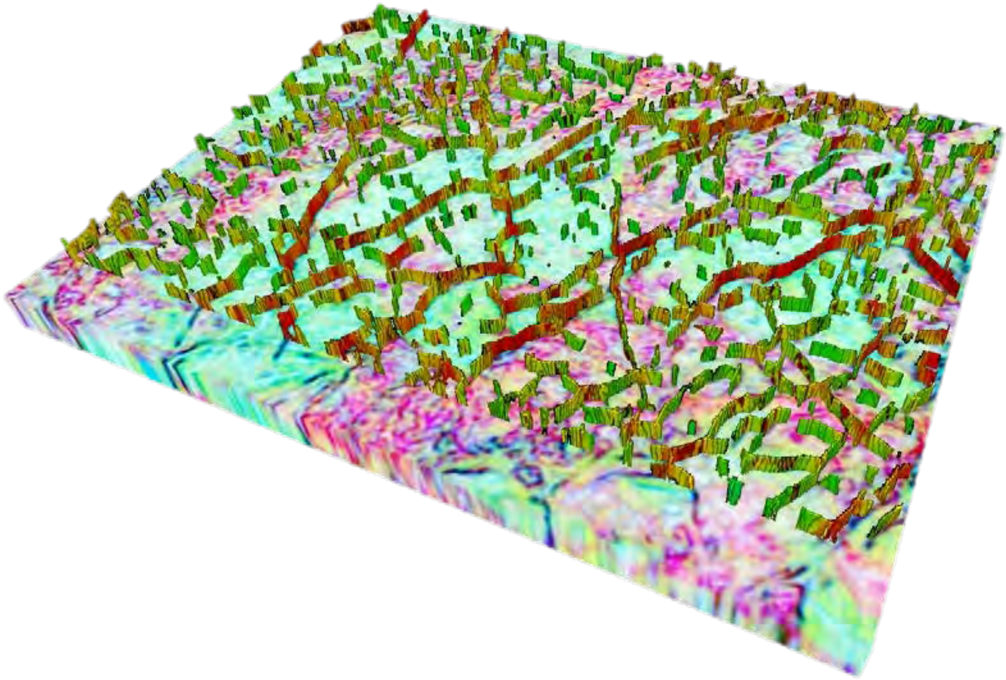
Interactive Facies Classification (IFC)

Model the seismic and RGB responses in Validate

Reveal

Fault expression

The Fault expression tool was developed with the objective of optimising fault interpretation and extraction. It utilises a powerful process to combine three attributes in one colour blend volume using a CMY colour scheme, allowing you to choose the attributes and associate each of them to a colour channel (cyan, magenta, yellow). Faults can have different seismic signatures and by using colour blends it is possible to combine these different responses. You can also generate a volume of detected faults based on the individual attributes or the CMY blend.

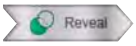


CMY (Cyan, Magenta, and Yellow) colour blend with fault detect rendered in 3D. Red represents high confidence faults.

This document will provide step-by-step recommendations for a typical fault expression workflow.

Tip: To save time you can crop a test volume to input into the fault expression tool, optimise your results before processing and then generate 3D volumes over the entire 3D dataset.

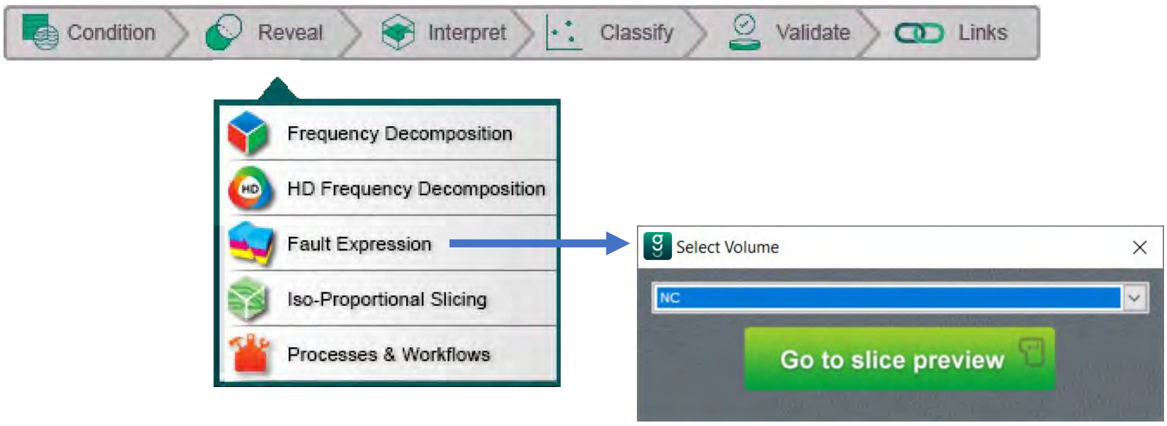
Generating attributes

1. Click 

from the workflow icons toolbar (top right) and select Fault Expression. This will present you with a 'select volume' window. Select the volume you wish to process and 

.

Hint: for optimal delineation of your faults – we recommend you use your data conditioned volume for this workflow.



The fault expression tool will open and begin processing the default-settings over your selected input volume. You will be presented with an example driven interface of 9 preview swatches which will enable you to effectively compare the results of the different attributes in the tool, in a single view – without having to process each test before comparing the output.

It is also possible to choose different inlines, crosslines and times slices to optimise your preview to ensure that your selected attribute and footprint sizes work well in all parts of the dataset.

The next step will introduce each attribute and guide you through the interface of the fault expression window.

2. The example driven interface (blue rectangle) is divided into 3 columns – each representing a different attribute (Tensor, SO Semblance & Dip). Each row defines the scale of investigation, with the first row defaulting to small filter sizes (for small scale, subtle features) and the third row defaulting to larger filter sizes (for extensive, more regional faulting).

Tool features

- Opacity bar (red circle) – slide this left and right to adjust the opacity of the resulting attribute volume for QC purposes so that you can always associate your results with the input seismic.
- Fault height (green circle) – slide this up and down to change the vertical extents of your filter size. Larger vertical footprint will more accurately capture vertically extensive faults.
- Fault width (blue circle) – slide this left and right to adjust the lateral extents of your filter size. Reducing this will better image steeply dipping faults, whereas increasing it will capture more shallowly dipping faults.

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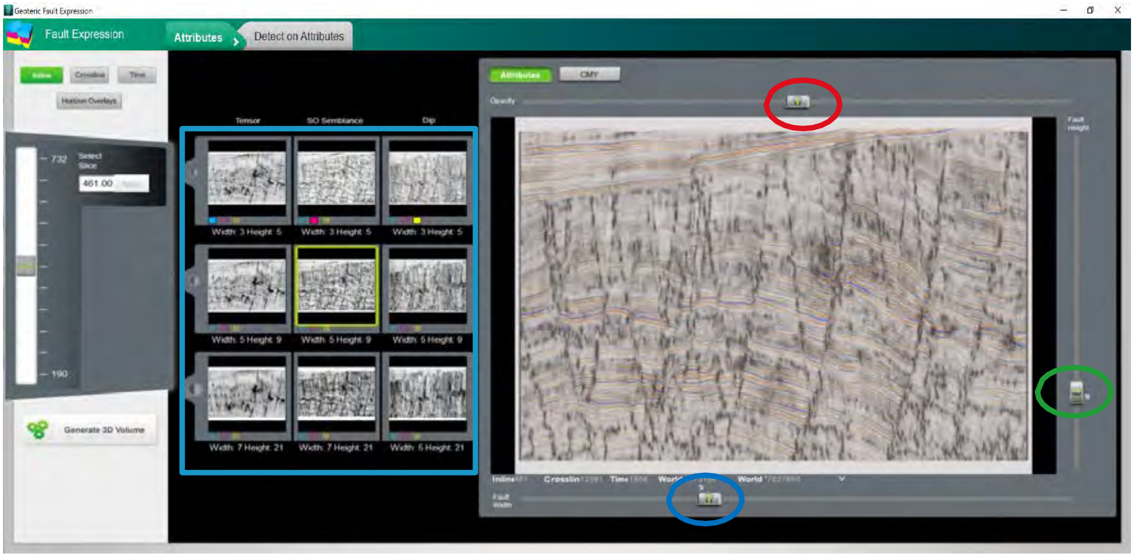
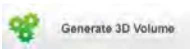
Attribute Information

- Tensor – detects changes in amplitude. If the fault is defined by a dimming or brightening of amplitude at its plane – then a high (dark) value will represent this in the attribute result.
- SO semblance – detects changes in phase. If the fault is characterised by a phase shift, either side of the plane, then dark grey values will indicate this point of change as the fault itself. This can highlight faults which offset the strata at either side of its location, for example.
- Dip – detects changes in orientation. Drag associated with the strata either side of the fault plane will be detected with high dip values.

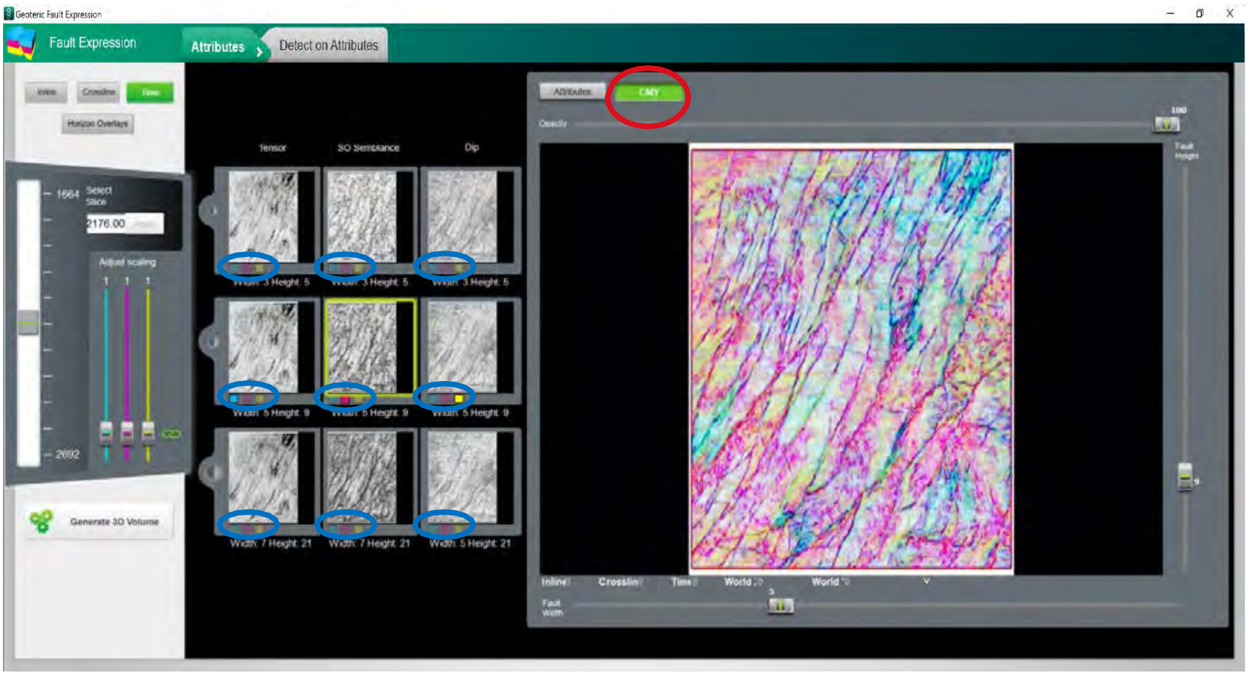


Fault expression window (single attribute)

To generate a single attribute – select the attribute and 

Generating CMY

1. To generate a CMY volume click on the CMY button (red circle). This colour blend can be composed of any three of the nine preview swatches. To choose the attribute that you want to preview in the resulting blend, click on the corresponding colour cubes under the desired swatch (blue circles).



Tip: you are not restricted to a single scale of investigation so you can optimise each attribute to the appropriate filter size and then combine as a CMY – for a more extensive and complete representation of the structure in your region. However, you can only select one swatch per colour channel.

2. When you're happy with your blend, click on 

which will process and output the three individual attributes and the CMY colour blend over the full extents of the selected input volume.

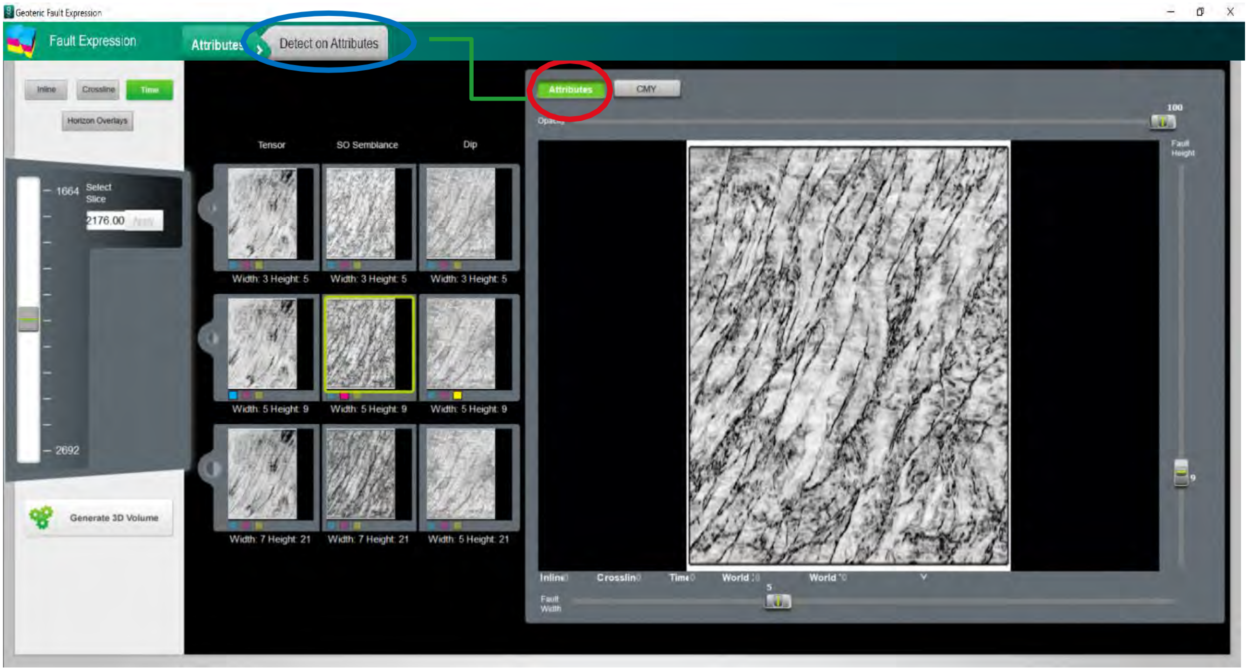
Tip: the attribute volumes will appear in the Volumes folder of your Project Tree in the main Geoteric window, and the CMY blend will appear in the Colour Blends folder.

Generating a fault detect volume

There are two ways to generate a full 3D fault network using fault expression: (1) using only a single attribute, or (2) a combination of attributes as a CMY colour blend. In both cases, the different swatches represent different fault enhancement filters which are run in the background to try to create a more continuous fault image to detect on. Use a swatch in the upper row to detect small scale faults or use the bottom row for larger scale regional fault detection.

1. Using single attribute

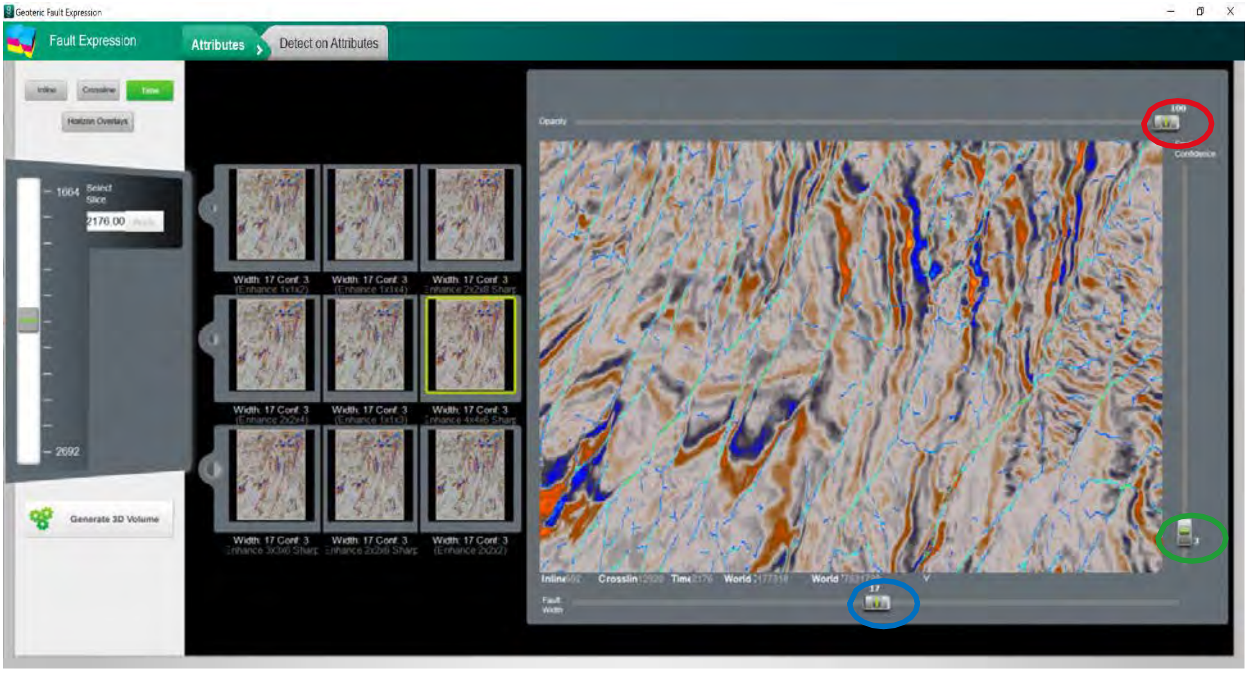
1. To create a fault volume using only one attribute, click on Attributes (red circle) and then on Detect on Attribute (blue circle) – as detailed in the following image



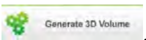
Fault expression window (single attribute)

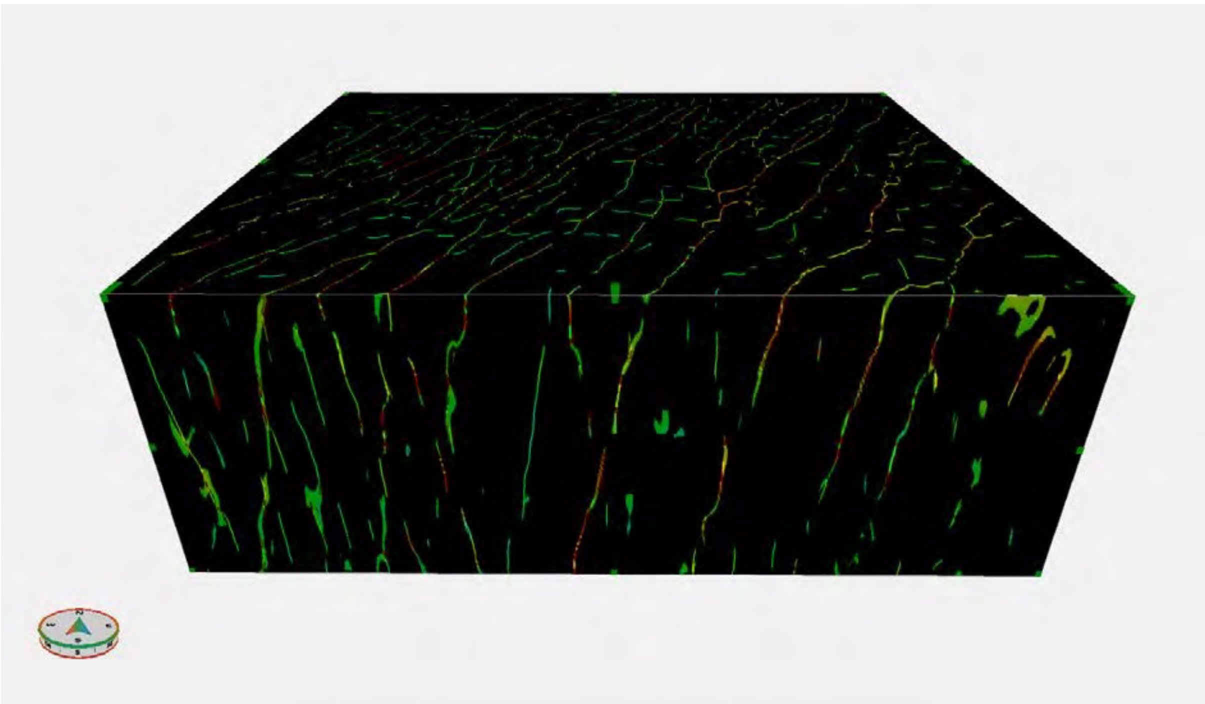
2. After this step you will see the window to edit the fault detection parameters.

- Opacity (red circle) – change the transparency of the detected faults so you can QC them against the input seismic.
- Fault confidence (green circle) – increasing this means only faults with a high likelihood of being faults (based on the input attribute) will be detected. This is good to decrease noise but can also be reduced to improve continuity and to detect subtlety.
- Fault width (blue circle) – adjusted to increase/decrease the search window of the detection algorithm.



Fault expression window (detect on attribute)

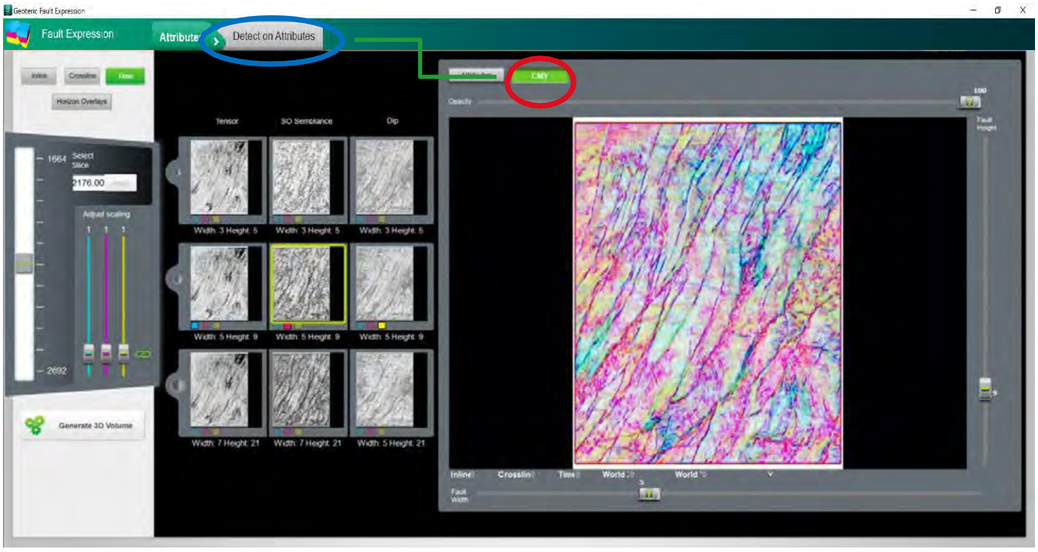
3. Click on  , select volume to process and the resulting volumes (one attribute and one Fault Detect) will be processed and output to the main Geoteric Project Tree → **Volumes**.



Fault detect volume (main Geoteric 3D viewer) and associated colour map

2. Using CMY colour blend

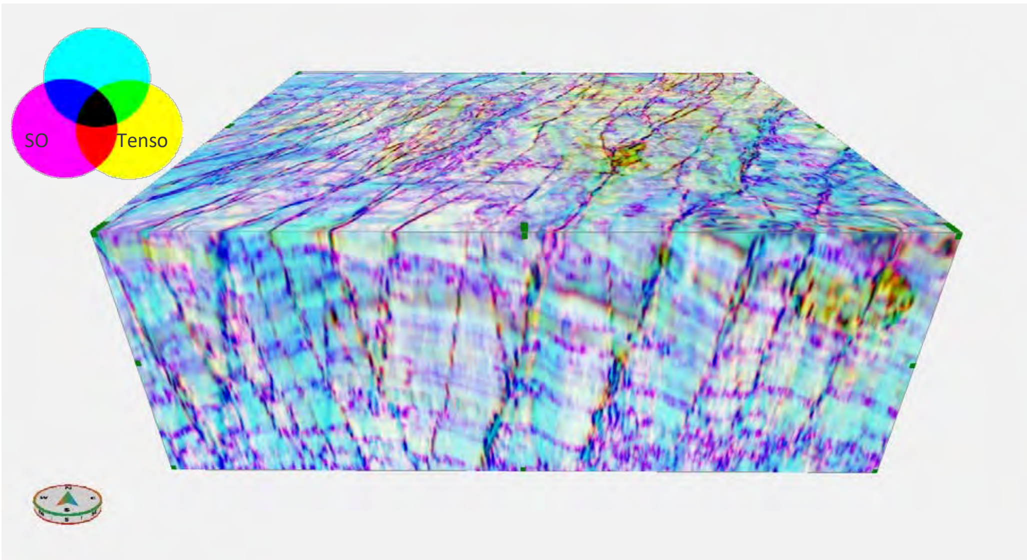
1. To generate a Fault Detect using a CMY the steps are very similar, instead click on **CMY** (red circle) and then **Detect on CMY** (blue circle) – as presented in the image below.



Fault expression window (attributes with CMY blending)

2. Follow Step 2 of "Using a Single Attribute" to optimise your Fault Detect volume and then Generate 3D Volume click to produce over the full extent of the selected volume.

Tip: you can use the volume output options to choose which outputs you would like produced over the full dataset. Attributes and Fault Detect will appear in the Volumes folder of the Geoteric Project Tree and the CMY Blend will appear in the Colour Blends folder.

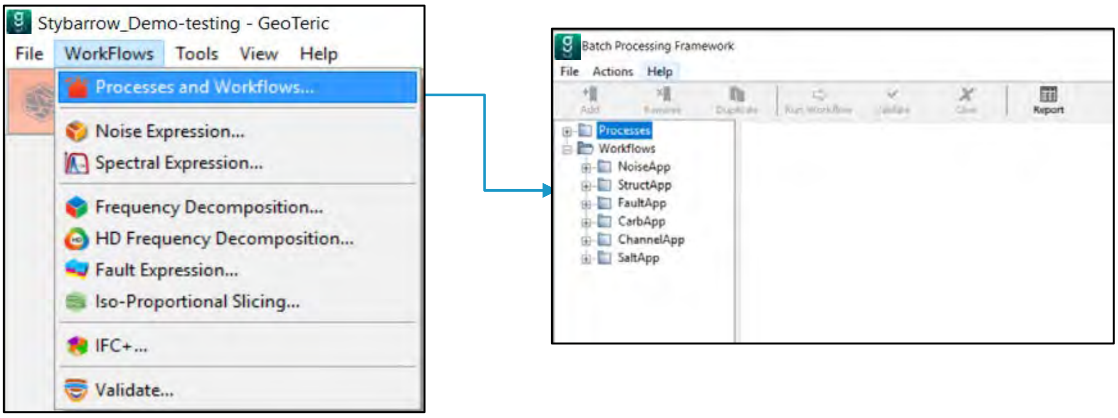


CMY Colour blend of Dip, SO Semblance (SOS) and Tensor (main Geoteric 3D viewer) and the associated colour map

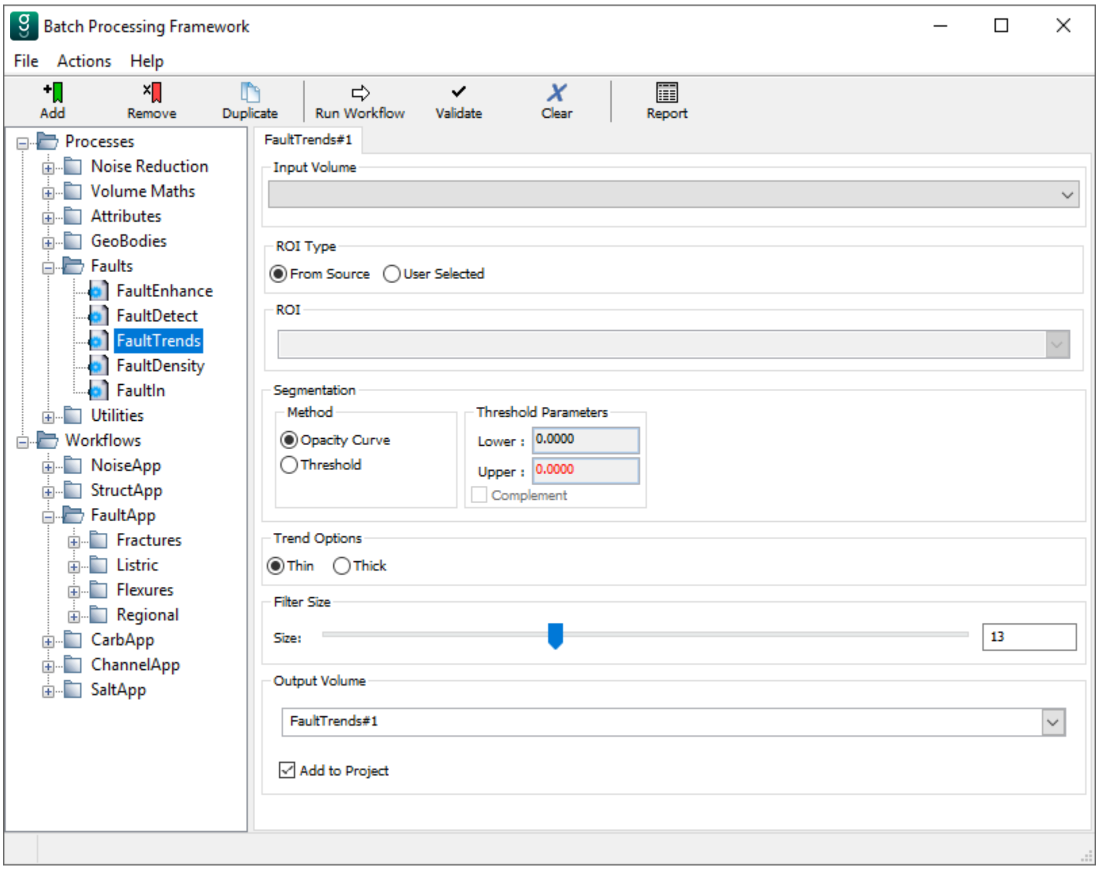
Classifying faults by orientation

Using the Fault Trend algorithm it is possible to sort faults according to their orientation/direction.

1. Go to Menus in the top left of the main Geoteric viewer and select Workflows → Processes & Workflows which will then open the Batch Processer (as pictured below).



2. Go to Processes → Faults → Fault Trends



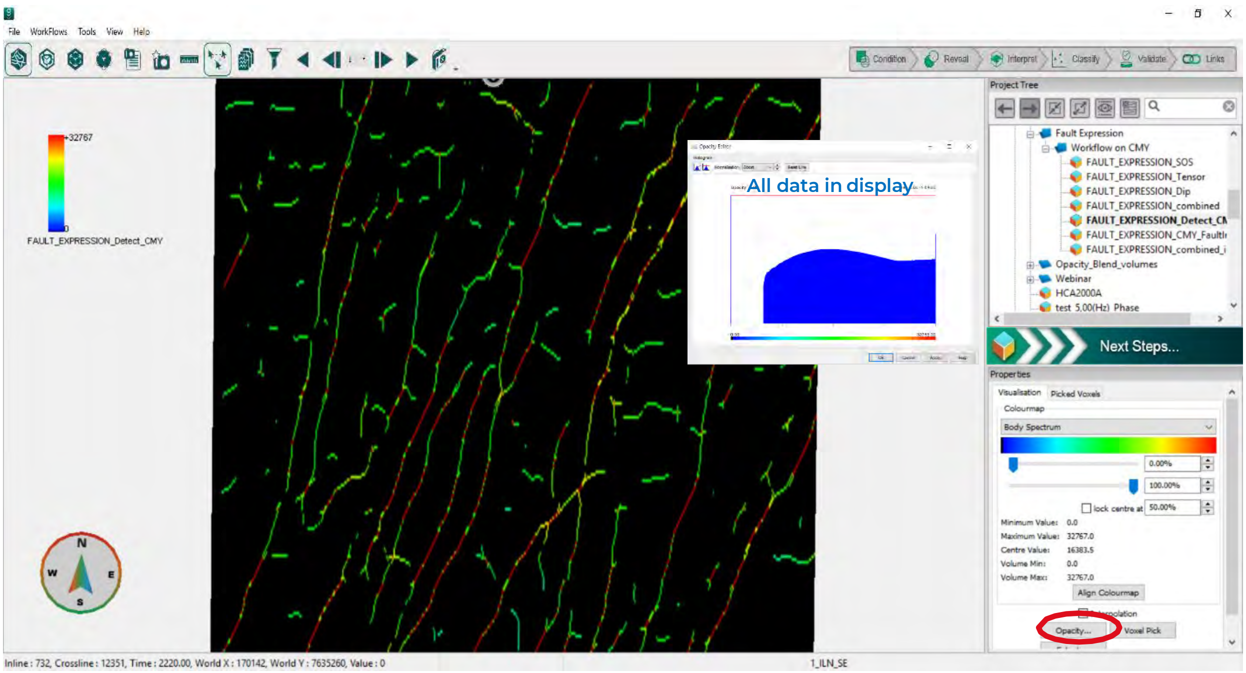
Batch processor showing fault trends options

3. The **Input Volume** must be the Fault Detect volume.
4. **Segmentation** - **Method** will decide which values from the input volume you want to include in this process. This can be set by **Threshold** or by **Opacity Curve**. Threshold will require you to manually enter the data range values you wish to be included in the fault trend process. Opacity curve will allow you to interactively determine the values you wish to include (see following steps and images).

Note: if you are using the opacity curve method for segmentation the fault detect volume and the opacity curve must be open and on display in order for it to link to the process.

5. In the main Geoteric project tree double click on the Fault Detect volume and then click on opacity (red circle) which will open the opacity window (**Opacity Editor**). The opacity curve can be manipulated using the mouse cursor – depicted in the following images.

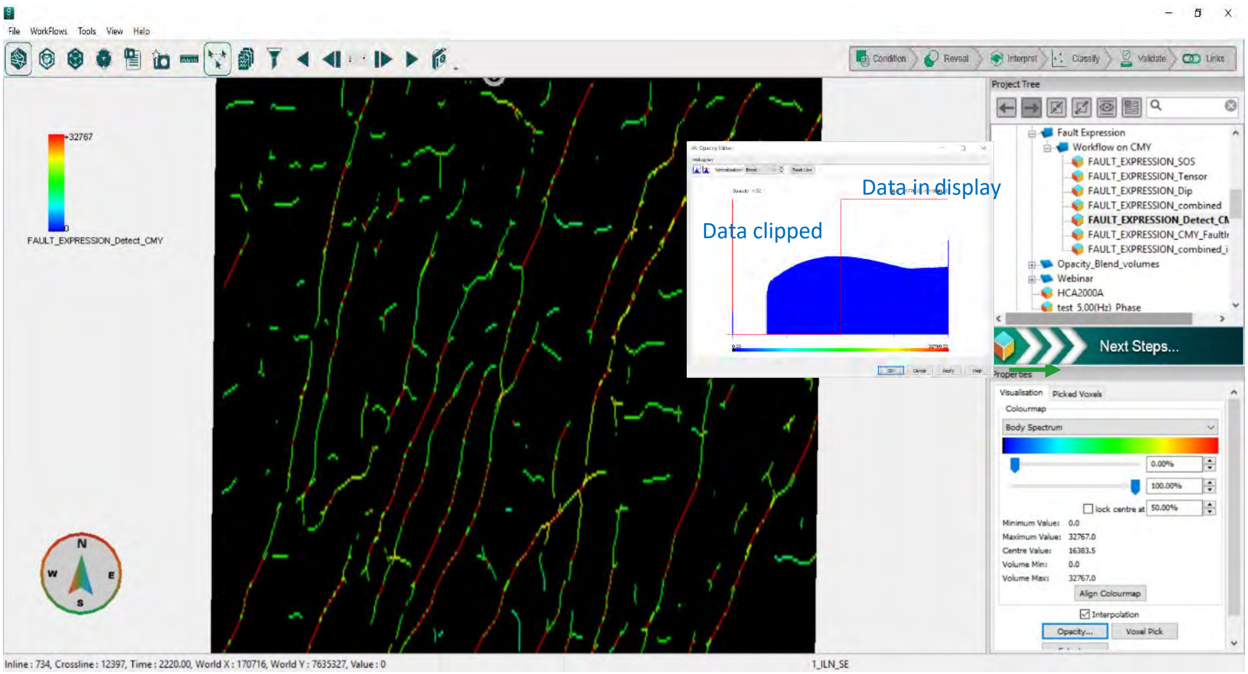
Tip: the Fault Detect volume defaults with the body spectrum colour bar, which associates colour with confidence. Red = higher confidence faults and Blue = lower confidence faults/noise. Segmentation will allow you to select only the faults you want to include in the fault trends analysis.



Fault detect in main 3D window with no segmentation to opacity editor

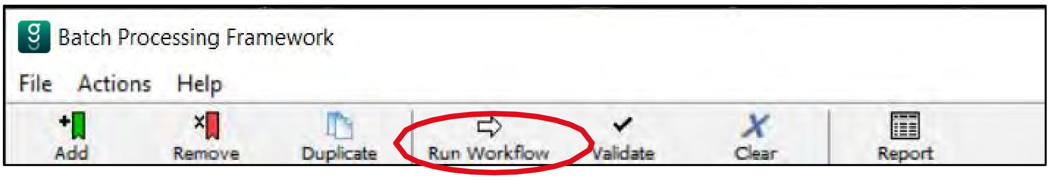
6. In the opacity editor, hover the cursor between the colour bar and the bottom axis of the histogram → hold down the left mouse button until a pencil appears and then drag to right to begin segmenting your data. Click apply to view segmentation in 3D viewer, all the faults to right of the red line (pictured below) will remain and all values to the left, will be removed.

NB: even if you are not segmenting particular fault values, you should always remove the zero (black) values as this just represents non-fault information which you don't want to include in the fault trends.

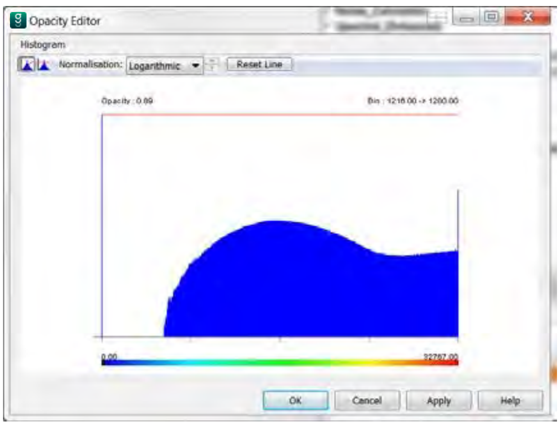


Fault detect in main 3D window with segmentation (note only the faults with higher confidence are left in display)

7. When you have only the chosen values (faults) on display, you can Run Workflow in the **Batch Processor**.

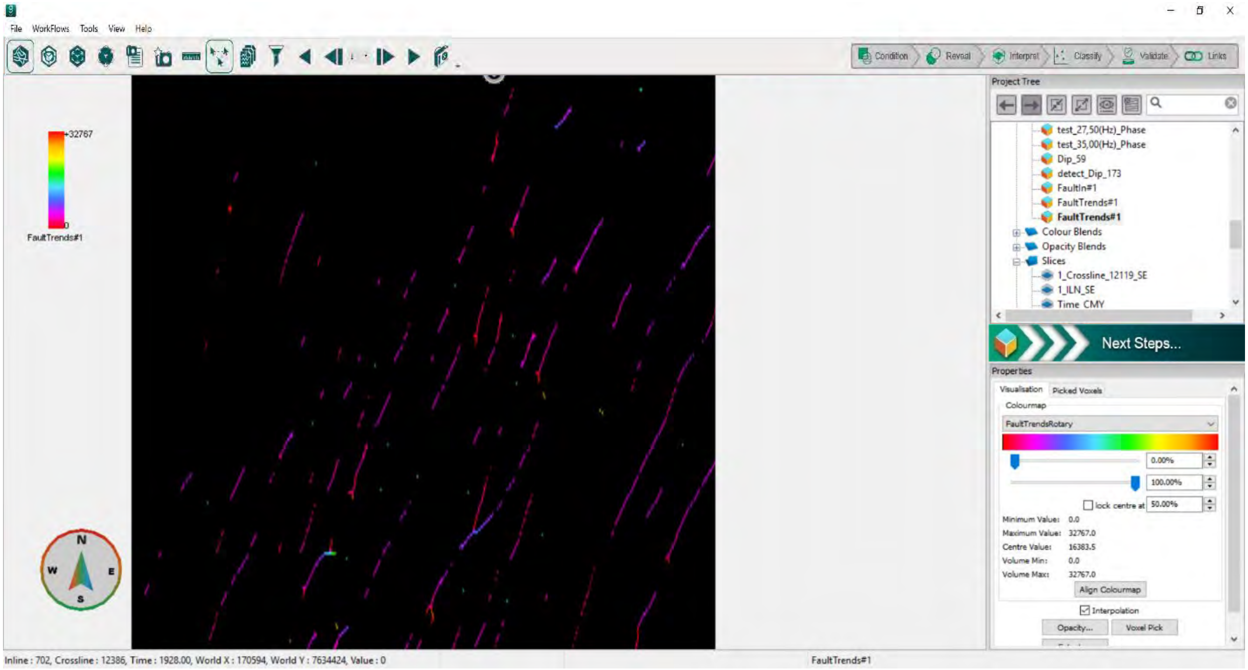


Tip: in the opacity editor you can change the normalisation type to logarithmic to see where the fault values fit on the colour bar histogram.



Opacity editor showing the distribution of fault detect values over the full colour bar

8. This will group your faults into their dominant orientation – which will be coded by colour. All faults that share the same colour will have the same orientation.



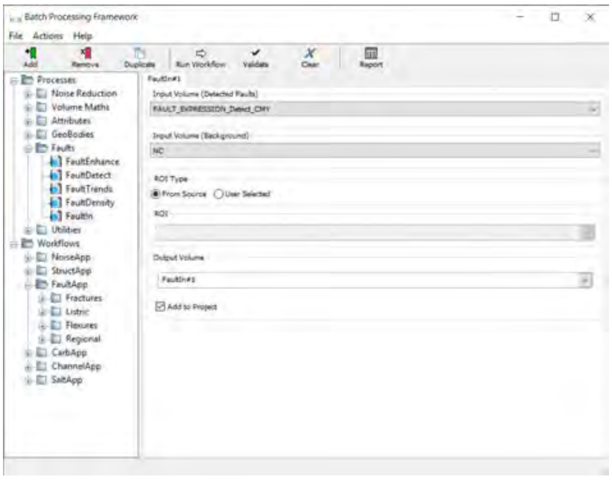
Fault trends volume (viewed in Z plane) in main Geoteric 3D viewer. Different colours represent different trends. This is the best way to reveal and understand the structural elements in your seismic without the need for any interpretation.

Tip: colour corresponds to direction, and the colour bar is aligned with north. This will enable you to determine which colours relate to which directions, giving you a more comprehensive understanding of the different structural regimes in your region without having to interpret first.

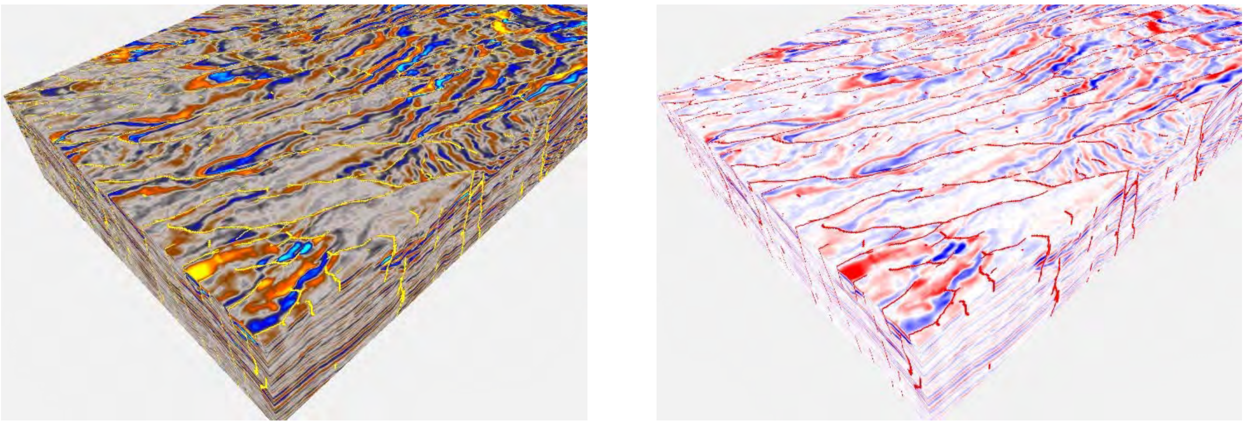
Inserting faults into seismic

You are also able to insert your detected faults into the seismic data to aid in structural interpretations and to better understand the relationship of faulting with the surrounding information.

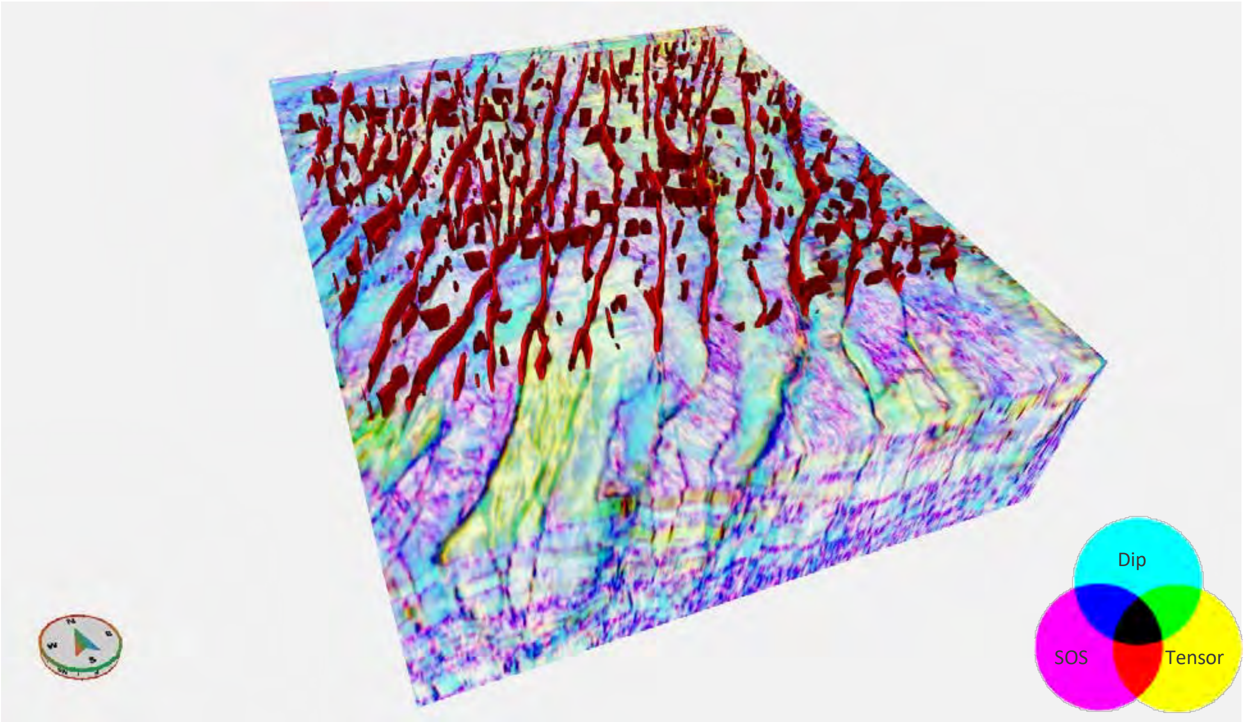
1. In the top left of the Geoteric window go to **Workflows** → **Processes & Workflows** → *Faults* → *FaultIn* *(depicted below).*



2. **Input volume (detected faults)** should be selected as the volume that resulted from your FaultIn or FaultTrends process and the **Input Volume (Background)** should be selected as your data conditioned seismic volume.
3. This process will assign the faults to have the maximum value of your dynamic range, so depending on which colour bar you are using to visualise your seismic – the faults may appear different.



Example of FaultIn volume displayed using two different colour bars. Faults appear in different colours, but values remain the same.



Example of fault network extracted using Fault Expression and then rendered in 3D with the CMY blend (Dip, SOS (SO Semblance) & Tensor) visualised.

What next?

Understanding the nature of the faulting in your data is of key importance in order to gain more insight as to how the faults interact with the reservoir.

Use Geoteric's stratigraphic workflows to better understand how faulting affects reservoir character

- Standard Frequency Decomposition (FD)
- Broadband High Definition Frequency Decomposition (HDFD)

This 3D fault network can be used to aid manual interpretations.

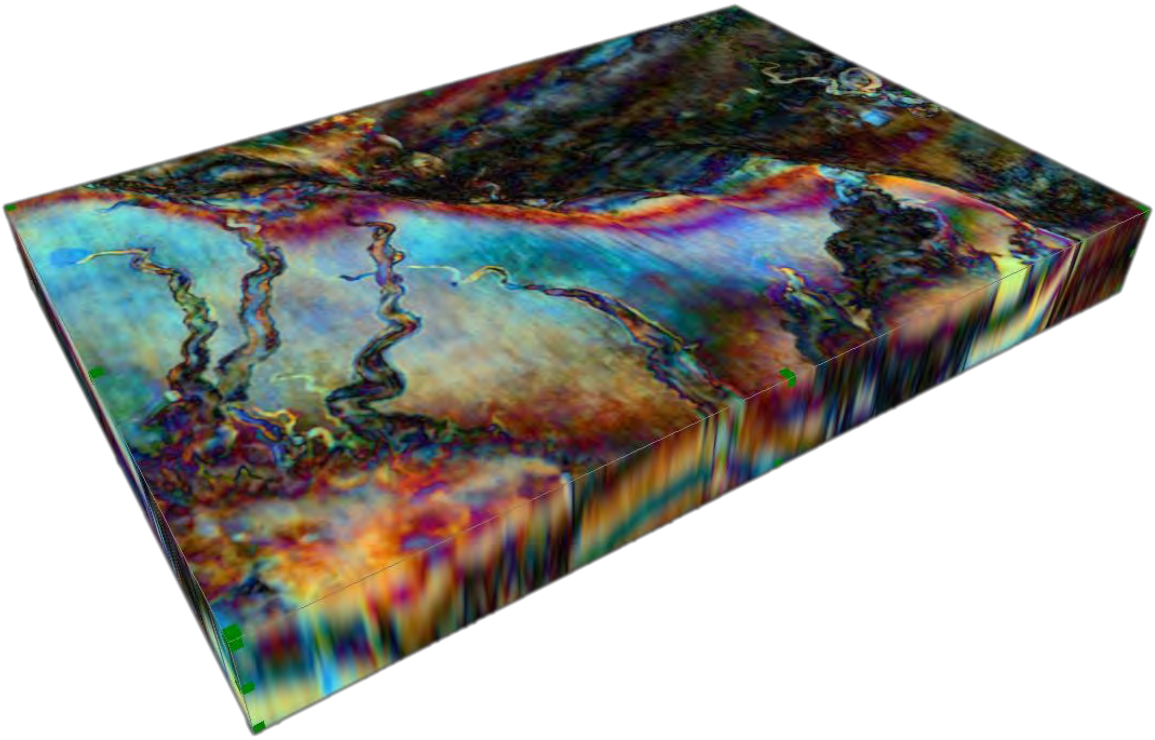
Interactive Facies Classification (IFC)

Model the seismic and RGB responses in Validate

Reveal

Fault decomposition

Frequency decomposition and RGB blending allow you to reveal the geology in your data prior to any interpretation, meaning you can make more informed decisions on your interpretation and understand reservoir heterogeneity with more confidence. Geoteric's HDFD provides the only method on the market for HD frequency decomposition on broadband seismic.



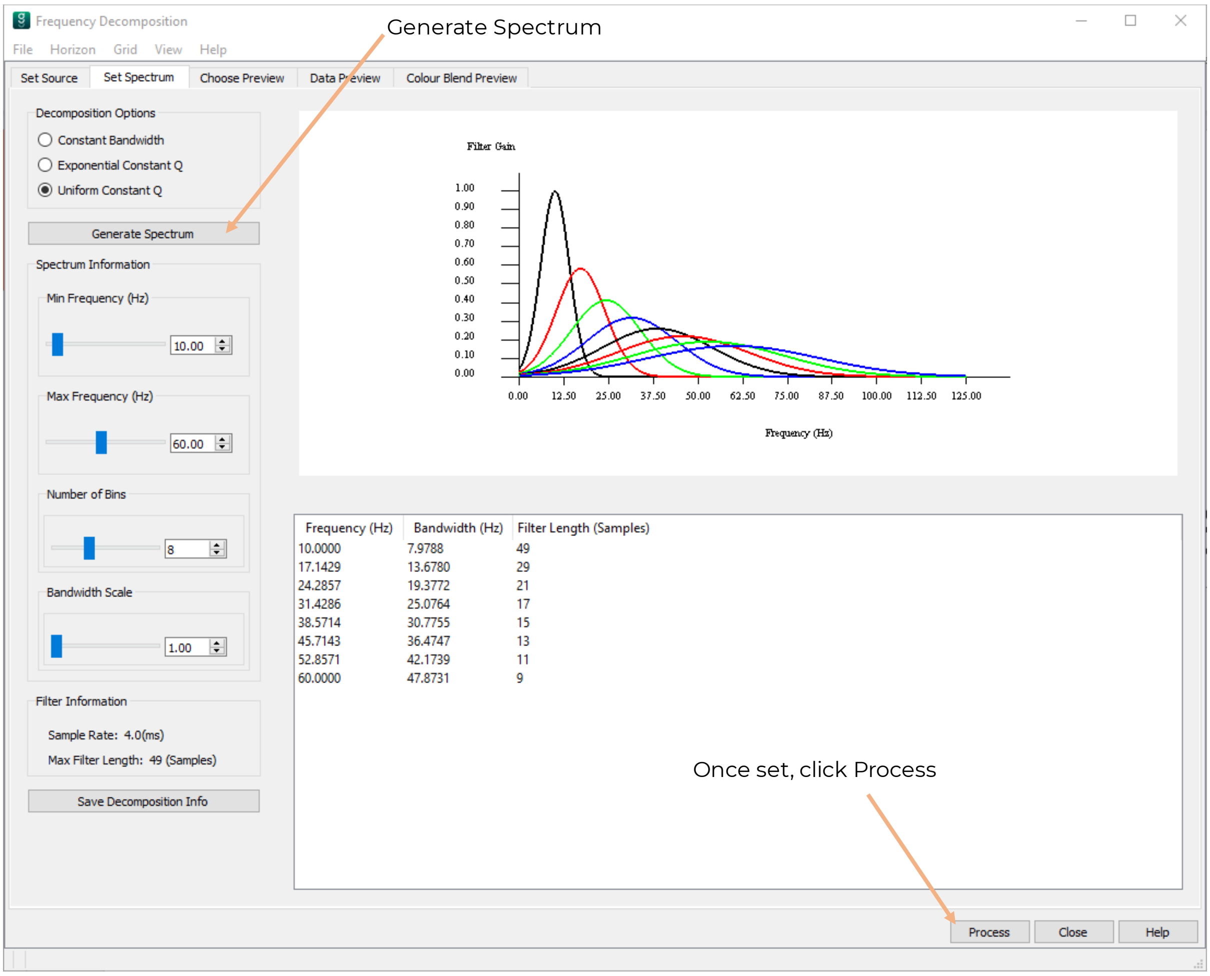
Geoteric's Frequency Decomposition provides you with a preview-based method for spectral decomposition and RGB Blending. This allows you to choose from a variety of decomposition options to suit your interpretation scenario and preview the RGB Blending of the resulting magnitude volumes at your chosen interval of interest.

This document will provide step-by-step recommendations for both a typical Standard Frequency Decomposition (Part 1) and HDFD (Part 2) workflow.

Tip: to save time you can crop a test volume to input into the HDFD tool, optimise your results before processing and then generate 3D volumes over the entire 3D dataset.

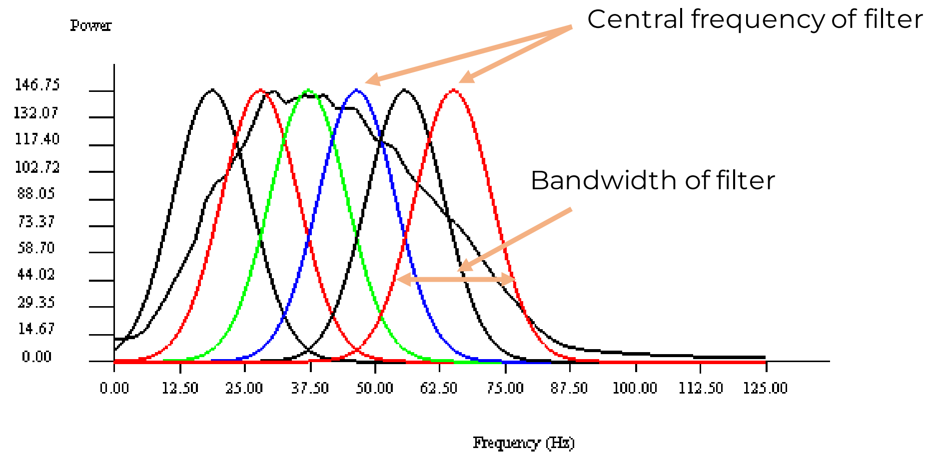
Part 1 - Standard frequency decomposition

1. Click Reveal from the workflow icons toolbar (top right) and select Frequency Decomposition. This will open the standard frequency decomposition tool. This tool comprises of 5 separate tabs: Set source, Set spectrum, Choose preview, Data preview and Colour blend preview.
2. Set source – select the time slice or horizon that you want to preview and optimise your results on.
3. Set spectrum
    a. Generate your spectrum, this will be created from the input data 32 samples above and 32 samples below the selected time slice/horizon.

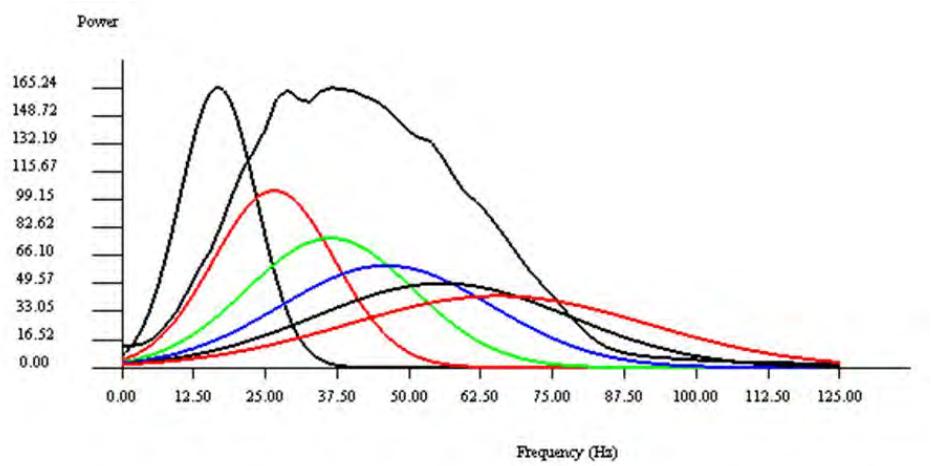


    b. The coloured curves in the graph represent the number of bins and the bandwidth associated with each. You can read these bandwidth values from the associated frequencies in the table below the graph. Selecting a curve on the graph will highlight its values in the table.
    c. There are three different decomposition options: Constant bandwidth, Exponential constant Q and Uniform constant Q:

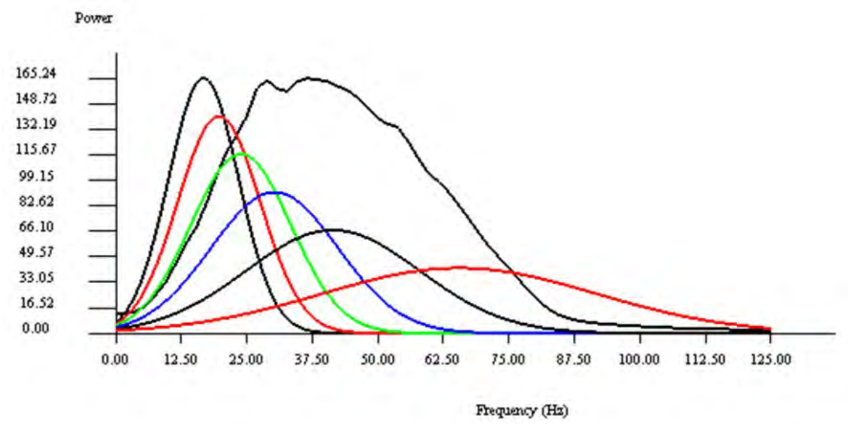
i. **Constant bandwidth** - used to differentiate between different geological elements, based on their bulk properties. Equal power in each band, the scale is kept constant and the frequency modulation varied – so the bandwidth of the filters is constant and independent of the central frequencies



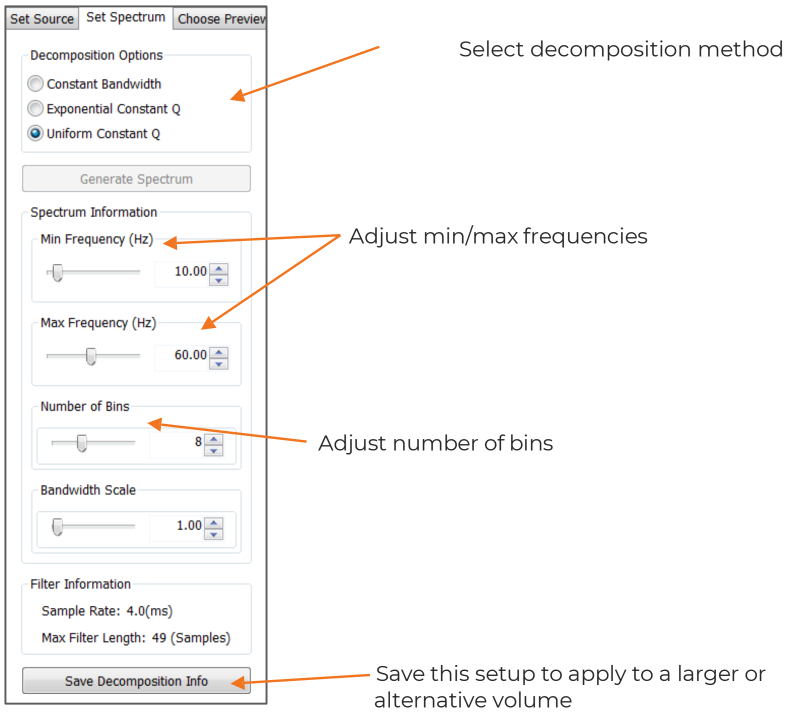
ii. **Uniform constant Q** – analysis is based on scale, so geological features will be separated on this basis. Frequencies modulation kept constant and the scale varied – the ratio between the frequency bandwidth and centre frequency is constant. Here, the central frequencies increase by a uniform amount.



iii. Exponential constant Q – analysis is also based on scale so the geological features will be separated on this basis but here the central frequencies increase exponentially.



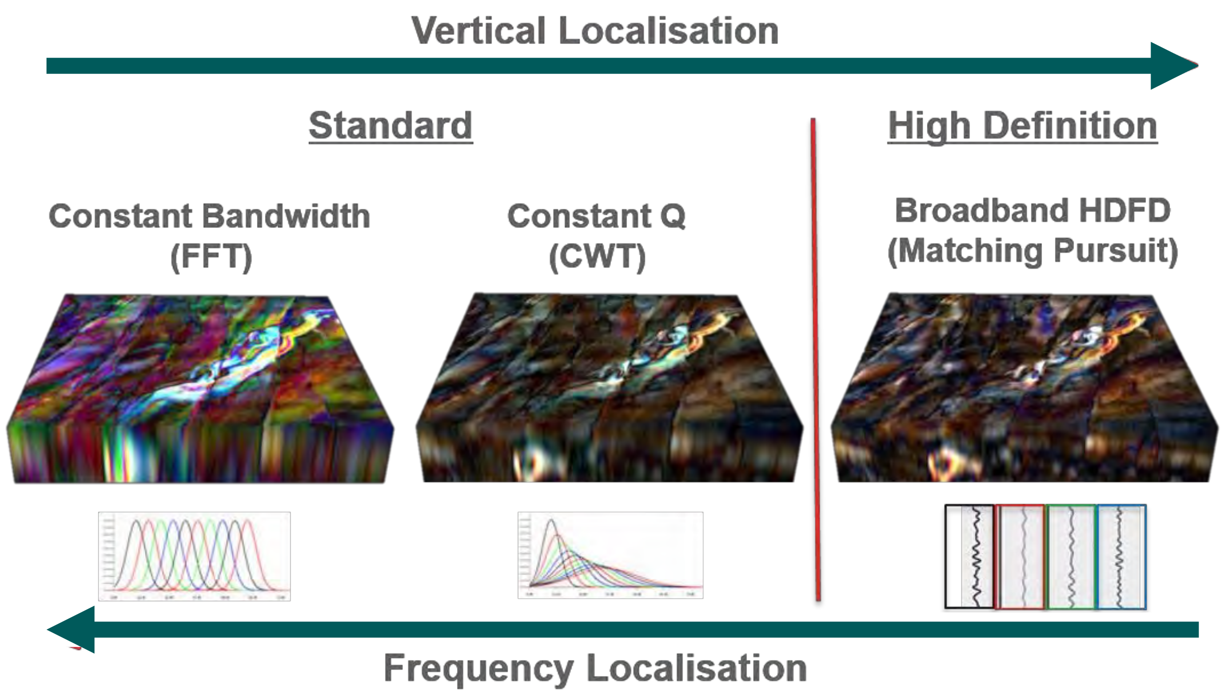
d. Once you have chosen your decomposition method you can determine the frequency range and number of bins. The min/max frequency will determine what range of the data will be decomposed and the number of bins will determine how many filters will be applied. Click 'Process' in the bottom right corner of the tool window to proceed to the next step.



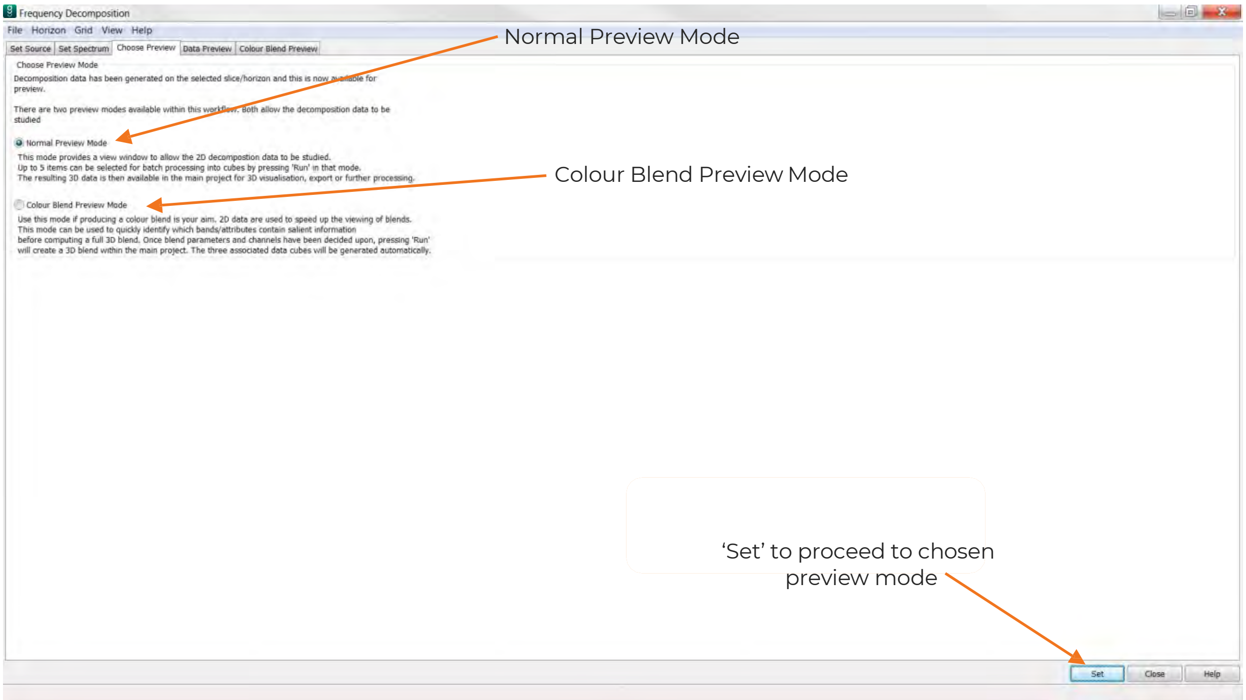
The diagram below shows the different types of frequency decomposition methods available in Geoteric.

- Constant bandwidth will deliver better frequency localisation, but slightly poorer vertical resolution.
- Whereas either of the Constant Q methods (constant or exponential) will deliver better vertical localisation.
- Of course, the best vertical resolution can be obtained using the Broadband HDFD tool, which is covered in the next section.

NB: increasing the number of bins will provide a more discrete separation of frequencies so that subtle variations in the geology can be revealed.

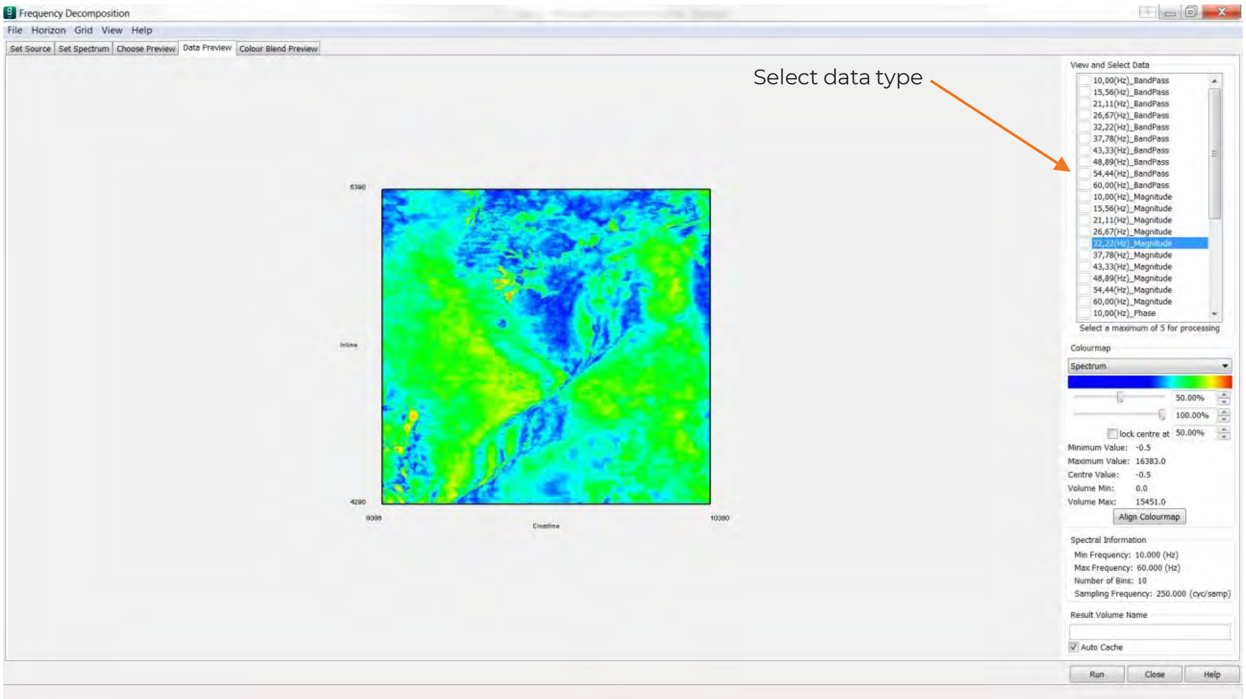


4. Choose Preview
    a. After clicking 'Process' the below window will appear. This is where you can select between 'Data Preview' and 'Colour Blend' Preview.
        i. Data Preview will allow you to see the individual responses at the specific frequency chosen in the preview tab. You will see options to preview Bandwidth, Magnitude and Phase.
        ii. Colour Blend Preview will allow you to select three Magnitude volumes and view their relationship in a colour blend on the time slice/horizon you selected in the first stage. This will allow you to optimise your colour blend prior to processing the full volume.

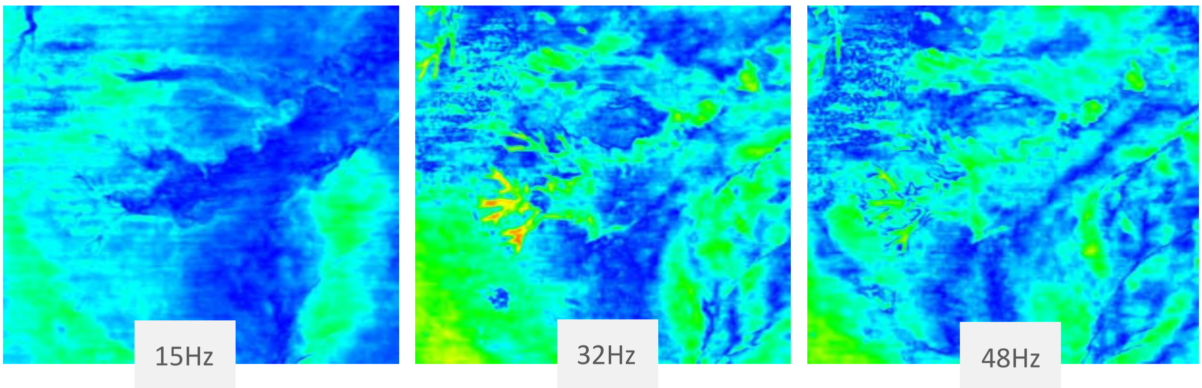


NB. you must return to this tab to select a different preview mode, and the click 'Set' again to proceed to new selection.

5. Normal Preview/Data Preview - this window is here so that you can understand the geology/frequencies of your data. It will help you isolate the frequencies that reveal your geology the best.



a. On the right side of the window you will see different options of data type to select. The number in each set will have been determined by the number of bins you selected in the 2nd stage. Below is a brief explanation of each, but for the purposes of this workflow we will just focus on the Magnitude volumes.
    i. Bandwidth is the full seismic response at each specific frequency (amplitude and phase).
    ii. Magnitude is the power of the amplitude at each specific frequency.
    iii. Phase is the phase response at each specific frequency.
b. Selecting the first magnitude volume and then using your arrow keys on your keyboard to scroll down, will allow you to see the different magnitudes of amplitude response at each specific frequency.



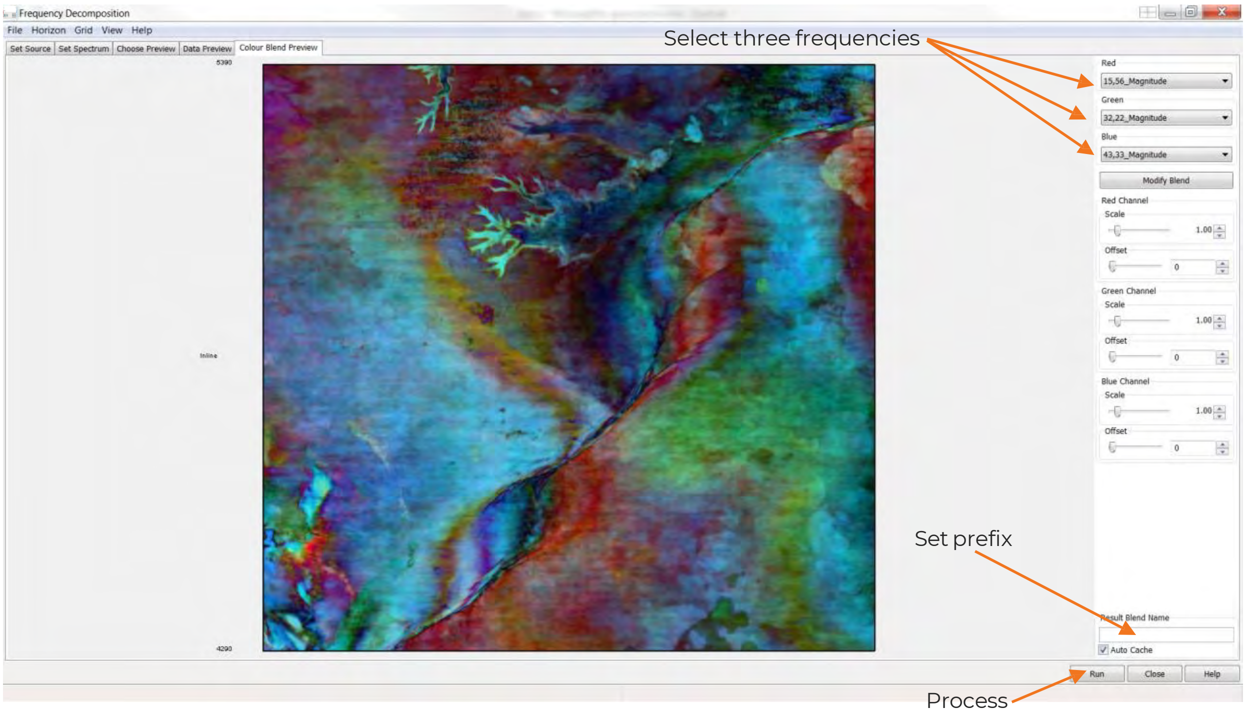
The example above show how each part of the channel is in fact only imaged in certain frequencies, so it is important to understand which frequencies are representing the geology most effectively.

c. You can select up to 5 volumes in the volume tree of this window, assign a prefix and export. However, it is more effective to now go ahead and see the relationship between these volumes within an RGB blend, before you process anything.
d. Return to the Data Preview tab, select 'Colour Blend Preview Mode' and click 'Set'.

6. Colour Blend Preview Mode

Here you will be able to select your chosen magnitude volumes in order to see which give you the best responses in your colour blend.

It will enable you to determine if you are seeing the right level of variability and contrast between the colours, which in turn represent geological/lithological changes.



a. Select your lowest frequency to be input in the red channel, your medium frequency to the green channel and the highest frequency into the blue channel (using the drop-down menus).

b. Adjusting the scale will increase the dominance of that particular colour. Remember in an RGB environment colour represent frequency, so if you adjust only a single colour then your results may be biased. Try to apply an even scale to all.

c. If you'd like to change the frequency inputs, then do so as previously and then click 'Set Blend' which will update the preview.

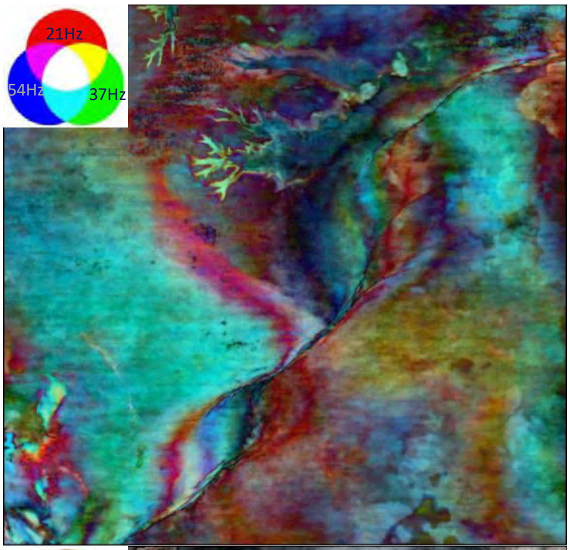
d. If you happy with your blend, set a prefix in the 'Name' box and then 'Run' the process.

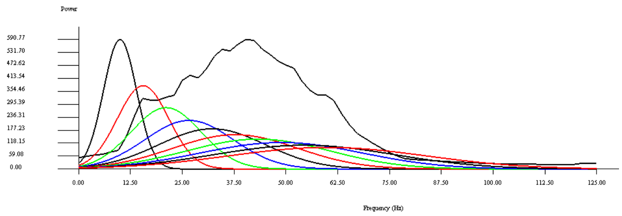
e. This will produce your RGB colour blend in 3D and the magnitude volumes that comprise it.

Tip: The following page will show some examples of the different variations in the results you can get using different frequency combinations.

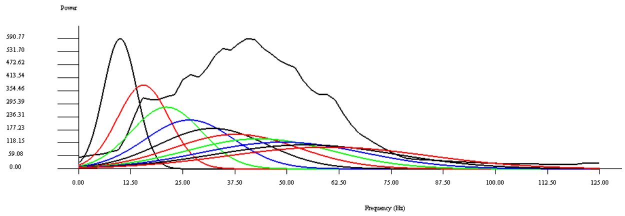
The contrast in colour you get will rely on the level of overlap of the bandpass filters for each corresponding frequency.

Large overlap will result in little variation and minimal/no overlap will result in strong contrast between red, green and blue – but very little transitional colours or combinations of frequency responses.

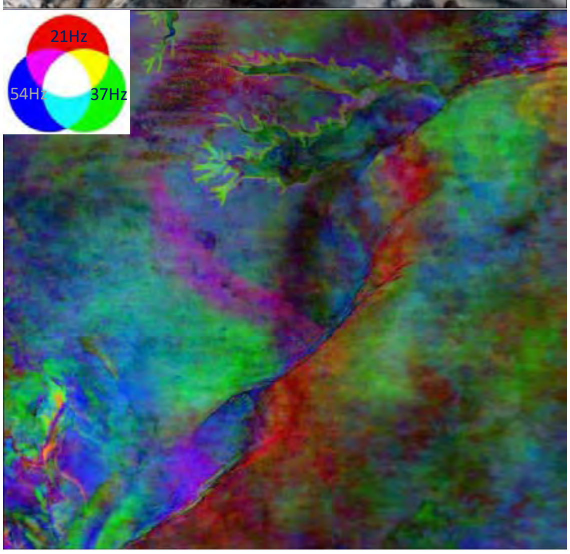


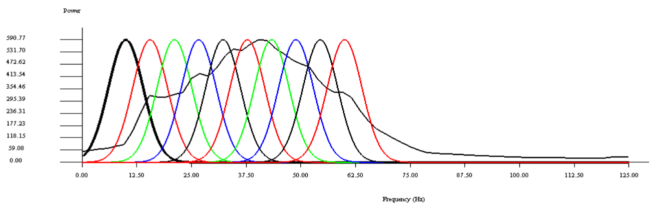


Using the Uniform Constant Q method, there is distinct separation between the frequencies but due to the increasing bandwidths there is also overlap. This means there are more 'transitional' colours in the blend – highlighting subtle variations and colour (frequency) combinations.



This is using the same decomposition parameters as above, however three frequencies have been selected from the higher end of the spectrum. Due to the high bandwidth of the filters in the higher frequencies there is a lot of overlap, which equals very little variation in colour.

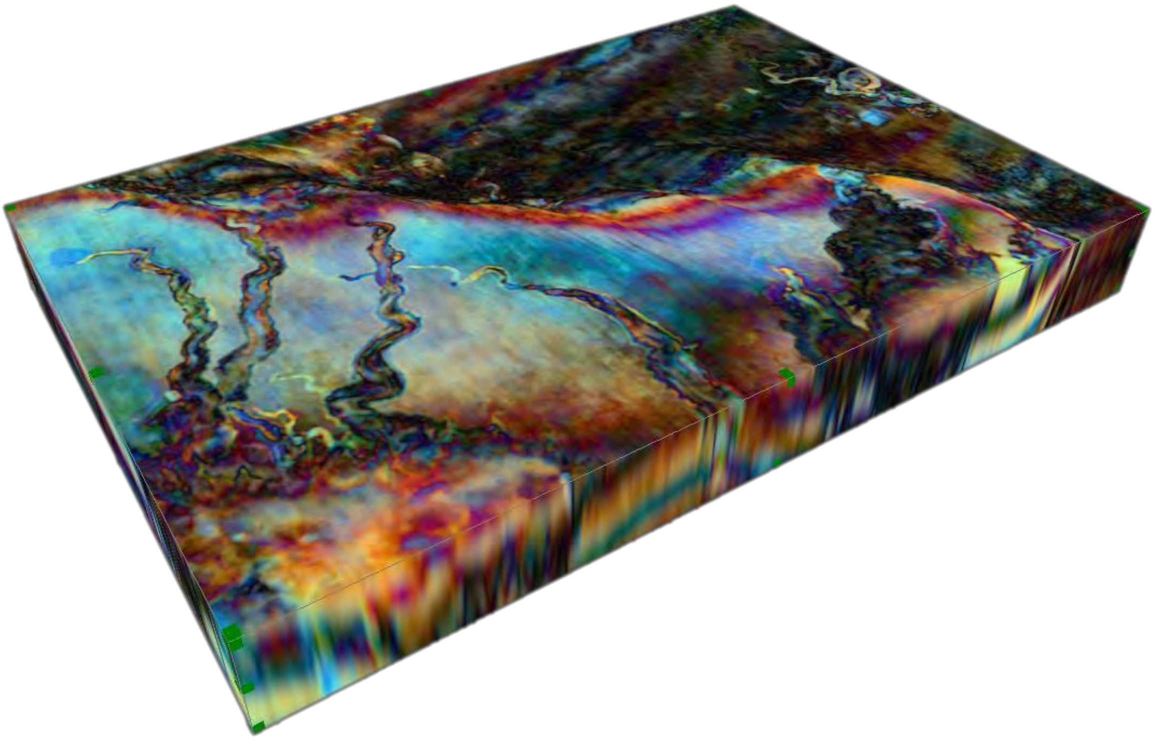




Using the Constant Bandwidth method you are able to separate frequencies more efficiently which means you can reduce the overlap of the filters. As you can see the blend is dominated by red, green, blue and less of transitional colours. This has proved useful for highlighting the edge character of the channel, not seen in the other two blends.

Part 2 - HDFD

Geoteric's HDFD provides the only method on the market for HD frequency decomposition on broadband seismic. HDFD provides you with an example driven method for spectral decomposition and RGB Blending. This allows you to use pre-suggested results to determine the best frequencies to generate a high definition RGB blend for optimum understanding of your reservoir heterogeneity.



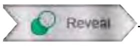
The objective of the HDFD is to obtain better vertical resolution in comparison to the standard methods of frequency decomposition. The process used is based on a Matching Pursuit Algorithm (Mallat & Zhang, 1993). The resolution of the HDFD method is very close to that of the original input seismic, allowing you to interpret on colour blends in vertical sections with more confidence, extract geological structures as geobodies and calculate volumetric properties using HD colour blends with accuracy. Even though the HDFD algorithms are a very complex process, for the Geoteric user it is a very simple user-friendly workflow.

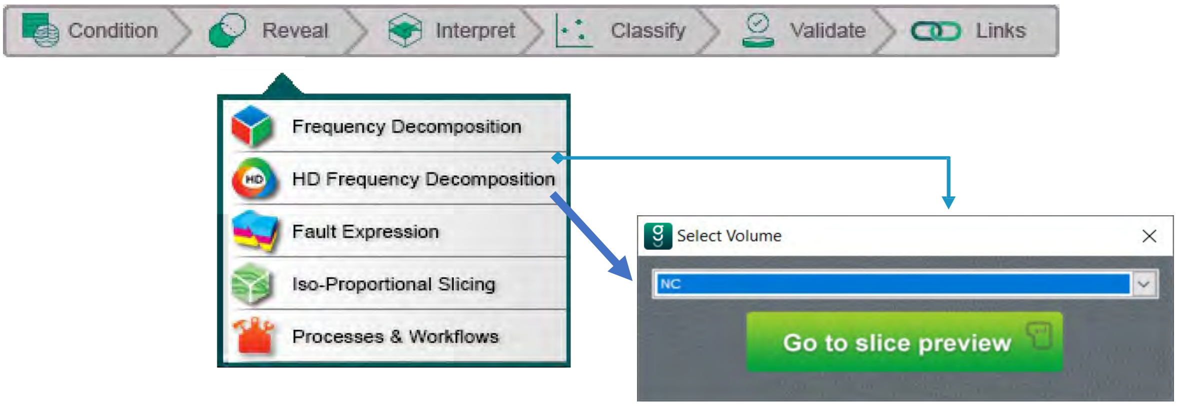
This section will guide you through the High Definition approach to frequency decomposition.

Your HDFD results can be optimised for frequency resolution or vertical resolution.

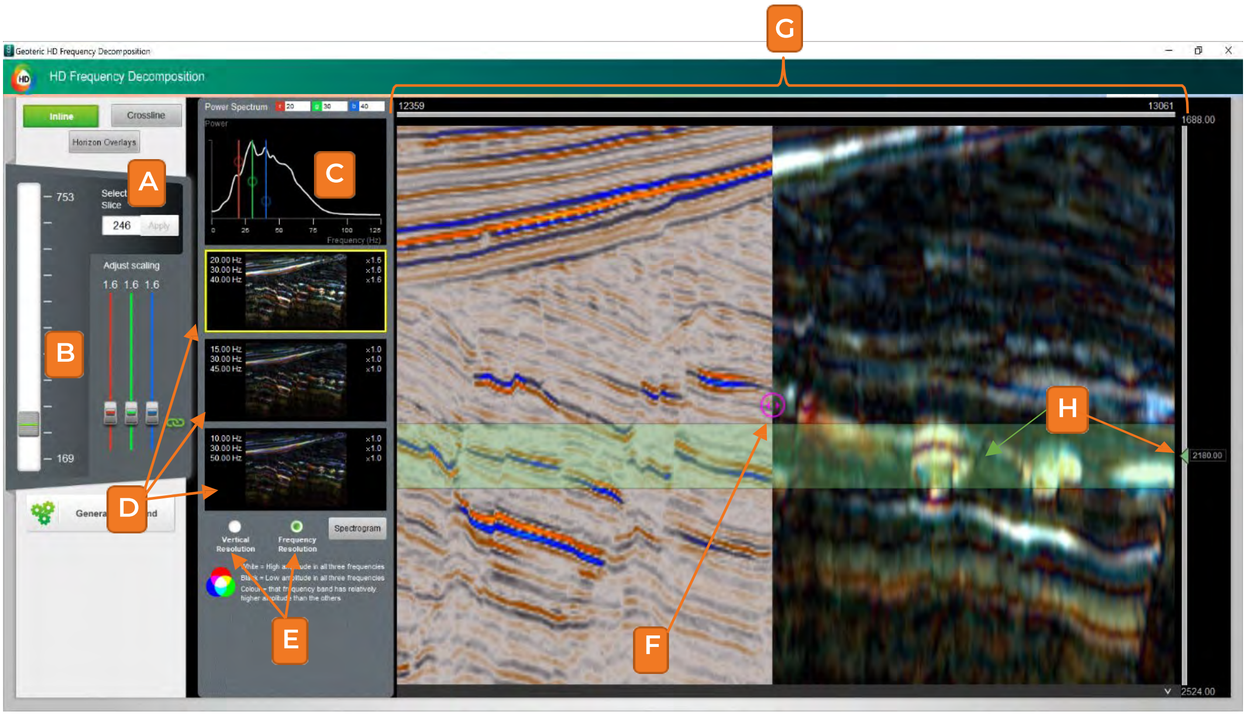
Tip: To save time you can crop a test volume to input into the HDFD tool, optimise your results before processing and then generate 3D volumes over the entire 3D dataset.

Optimising your HDFD Colour Blend – Frequency Resolution

7. Click  from the workflow icons toolbar and select HDFD. Select your input volume from the drop-down menu (we recommend you use your data conditioned volume) and click 'Go To Slice'.



8. This will open the HDFD tool (below).



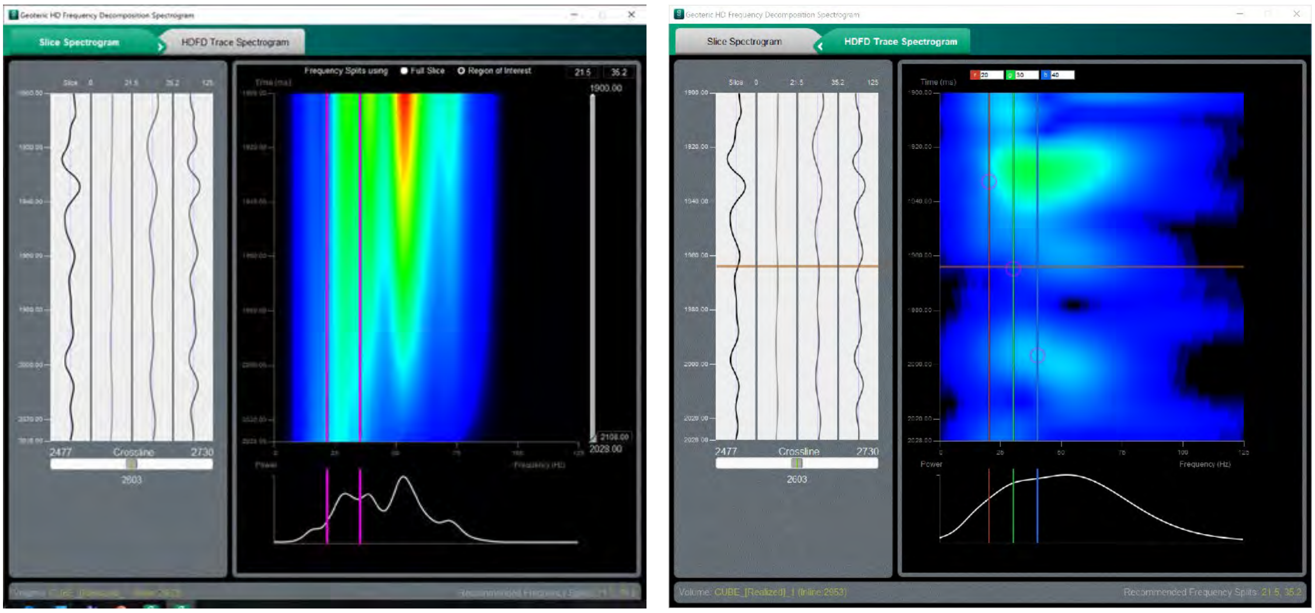
a. Select Preview Slice – select inline or crossline and display horizons.

b. Adjust Post Scale - adjusts contribution of each colour channel to the blend. Linking will ensure uniform adjustment to avoid misleading results.

c. Spectrum - generated from 32 voxels above and below selected time/depth (see 'h')

   i. Red, green & blue lines are for adjusting frequencies

   d. Example driven previews – suggested frequencies to combine as an RGB blend, based on a percentage of your maximum frequency.
      i. 1st- R= 8%, G=12%, B=16%
      ii. 2nd- R= 6%, G=12%, B=18%
      iii. 3rd – R=4%, G= 12%, B=20%
   e. Resolution – chose between better frequency resolution or better vertical resolution (both methods are still HD).
   f. QC Swipe – compare RGB blend with input seismic.
   g. Preview Window – preview of selected frequencies as an HDFD colour blend & input seismic for comparison.
   h. Z-slice – the spectrum is extracted along this interval (green window).
9. With the window now explained, you can optimise your settings before exporting the results as a 3D volume.
      i. Firstly, select your inline or crossline that you wish to preview your results on. This can be changed throughout the workflow to see how the results look in different sections of your interval of interest.
      ii. Use the Z-slice selection to move the arrow (green) up to you interval of interest.
      iii. Click between the three examples to see which are revealing the most information from your seismic.
      iv. Use the red, green & blue sliders on the spectrum to manually optimise your RGB blend to select which frequencies represent the geology most accurately.
      v. If the blend is looking quite dark, you can adjust the post scale.
10. The HDFD takes into account the spectral extremes present in Broadband data by applying frequency splits to the data. The user can either choose, no splits (Vertical Resolution) or 2 predefined splits (Frequency Resolution). Choose either Vertical Resolution or Frequency Resolution and press the Spectrum button.
      i. Vertical Resolution – By selecting the Vertical Resolution, there are no frequency splits, the Matching Pursuit Algorithm is applied to the full trace.



Vertical Resolution: Slice spectrogram on left, where there are no frequency splits and the Matching Pursuit algorithm is run on the entire trace. HDFD Trace Spectrogram on the right, which allows the user to select the area of interest to define the RGB frequency bands, by moving the horizontal line.

ii. Frequency Resolution – The data is split into 3 frequency bands, a low frequency, mid frequency and high frequency, prior to running Geoteric's Matching Pursuit algorithm. The underlying low frequency signal is matched to a dictionary of wavelets independently to the higher frequency events. The splits are calculated at 75% of the maximum power for the low end and high end, then averaged.

iii. On the Slice Spectrogram tab, one trace is selected and displayed, the trace can be changed and moved across the inline or x-line for QC purposes. For the Vertical Resolution, there will be no spits, but for the Frequency Resolution, the trace will be divided into low, mid and high frequency. The spectrogram is calculated using a Fourier transform over the entire selected slice on the HDFD main page.

iv. On the HDFD Trace Spectrogram tab, the user is able to focus in on a feature of interest, by moving the vertical line on the HDFD page, or entering in a trace number. Once the desired trace is visible, the horizontal line can be moved to the desired time/depth location, this enables the user to adjust the RGB bands to best highlight the feature of interest in a RGB Blend. The spectrogram is calculated using the HDFD algorithm on the selected trace only.

11. After the desired RGB is defined, press generate 3D Blend.

geoteric

What next?

Interpret and extract the information revealed in your high definition colour blend, to better understand the geology in your seismic.

- Adaptive Horizons™
- Adaptive Faults™
- Adaptive Geobodies™

Use interactive seismic classification techniques to better understand the reservoir heterogeneity

- Interactive Facies Classification (IFC)

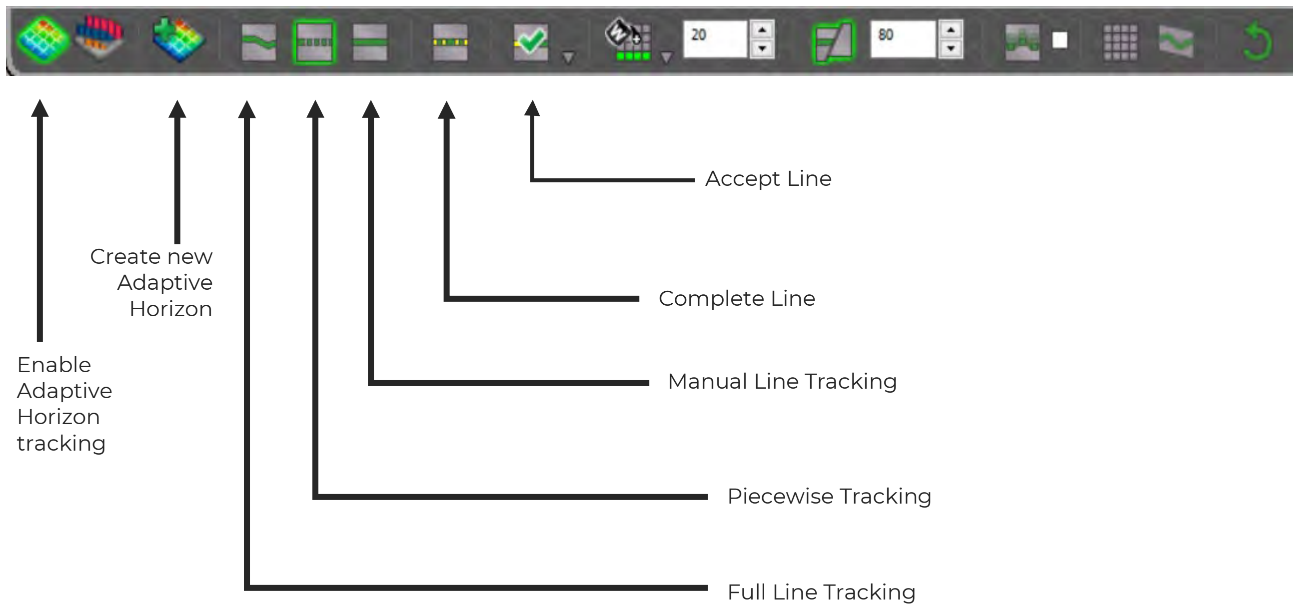
Model the seismic and RGB responses in Validate

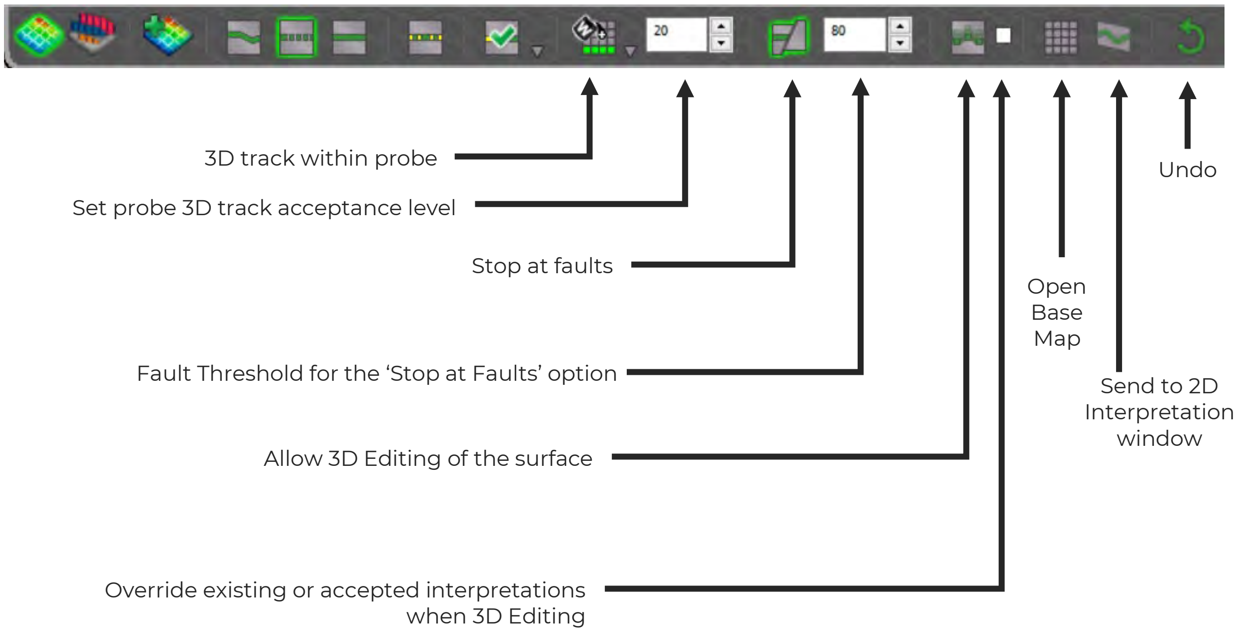
Interpret

Adaptive Interpretation

The Adaptive Interpretation system is a unified interpretation system for horizons and faults. It incorporates Region Structural Awareness through the use of Graph Theory. While most trackers rely on trace to trace correlation, Geoteric's Adaptive Interpretation correlates all the points on the slice to determine all the potential paths.

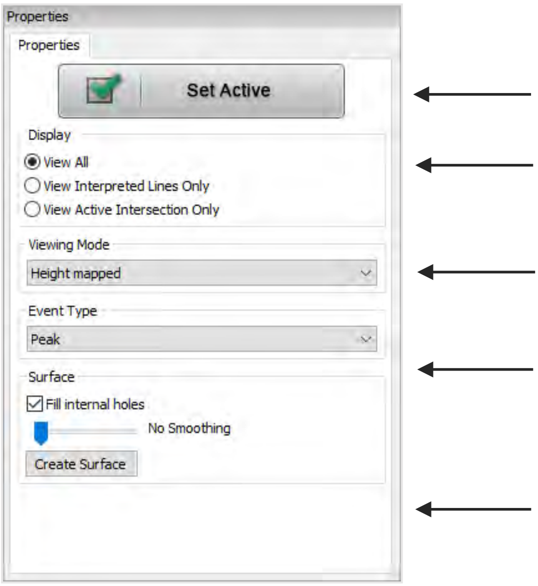
Adaptive Horizon Menus





To begin interpreting, create new horizon, select type of interpretation and click Shift+MB1

- Double-click to stop the interpretation
- To Delete – Shift+MB3. Release MB3 before Shift.



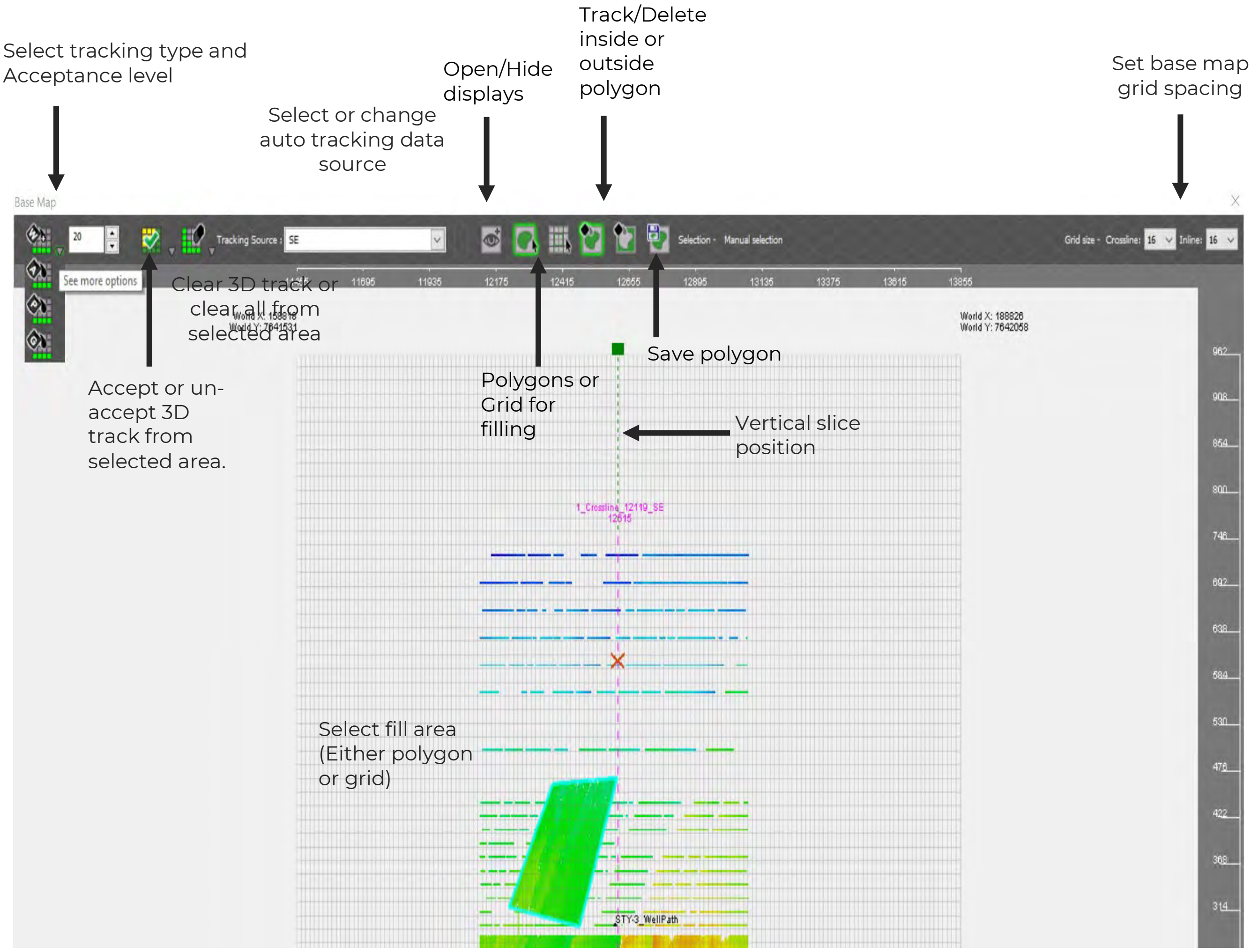
Set Horizon ‘Active’. Only one horizon can be active at a time.

Change display mode

Display either height values, a volume or colour blend on the horizon during interpretation.

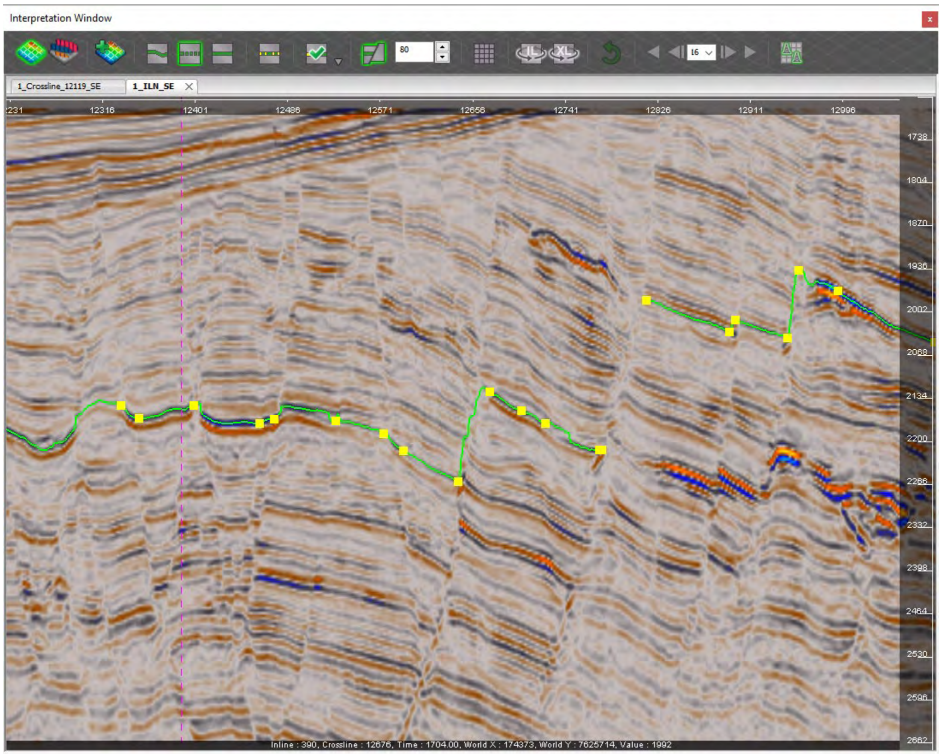
Select event type for horizon autotracking.

Generates Horizon surface from Adaptive Horizon Interpretation.


Select tracking type and Acceptance level
Select or change auto tracking data source
Open/Hide displays
Track/Delete inside or outside polygon
Set base map grid spacing
Base Map
Tracking Source
SE
Selection
Manual selection
Grid size
Crossline
Inline
See more options
Clear 3D track or clear all from selected area
Accept or un-accept 3D track from selected area.
Polygons or Grid for filling
Save polygon
Vertical slice position
Select fill area (Either polygon or grid)
STY-3_WellPath

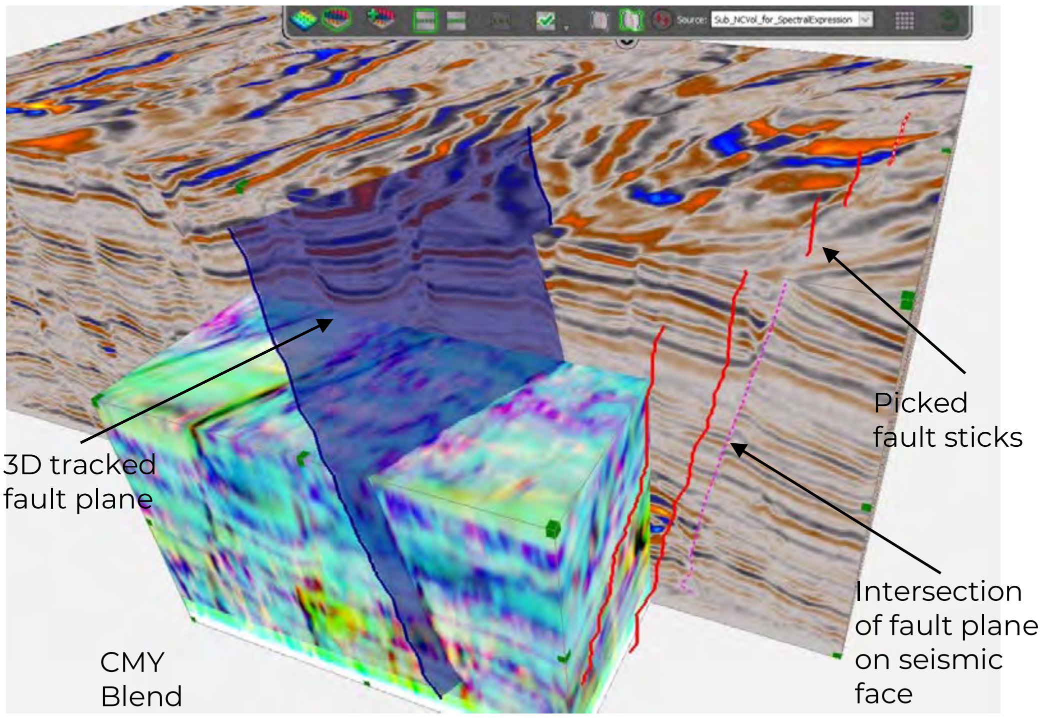
2D Interpretation Window

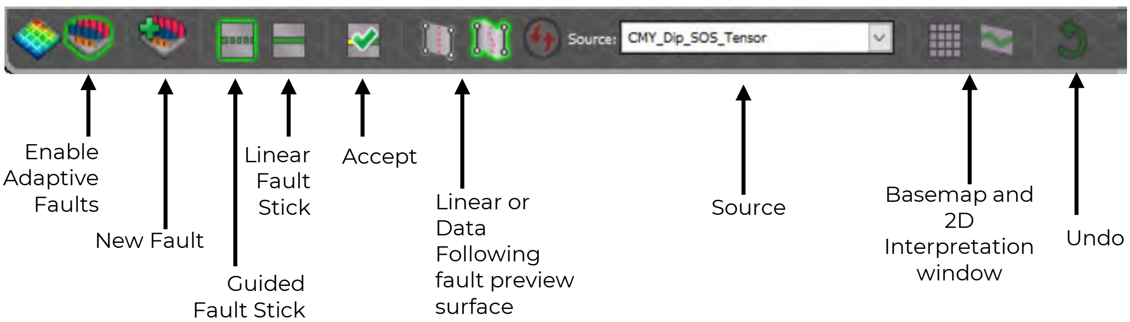
- Right click on a slice in the 3D scene and select ‘Send to Interpretation Window’.
- Pick both horizons and faults.
- Sending multiple slices will create additional tabs.
- Can be docked or allowed to float in a separate window.
- Linked with 3D scene – moving the slice in either will update the other.



Adaptive Faults™

- Faults can be tracked on any seismic volume, colour blend, or opacity blend.
- Faults are initially picked as sticks, with the fault surface interpolated linearly or by adaptively tracking on the seismic volumes themselves.
- In addition to picking, fault sticks can be automatically extracted from a fault detect volume and further grouped into individual fault-sets.





Once Adaptive Faults have been enabled, a focused toolbar (left) which contains all relevant filtering, grouping and editing functionality will be available. The toolbar can be moved around the screen and close to the area being interpreted.

Information below indicated the functionality and the shortcut keys in brackets.

Probe Mode: Move the inline, crossline, Z/Time slice or volumes (P)

Move Mode: Move, zoom or pan the window (H)

New Fault Stick Mode: Add new fault sticks to the active set (F)

Edit Fault Stick Mode: Select and edit existing fault sticks (E)

Select and activate a Fault-set: Activate a Fault-set (S)

Glue Mode: Join fault sticks together vertically (J)

Delete Mode: Delete individual fault sticks (D)

Cut Mode: Cut an existing fault stick into two individual fault sticks (R)

Paint Mode: Select sticks to move into active set (M)

Create a new fault-set: Creates & activates a new empty fault-set (V)

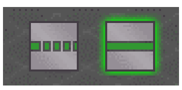
Fault Stick Editing

The need for the Shift key to start fault interpretation (versions prior to 2019.1) has been removed which makes interpretation much faster and easy to use. All interpretation tools, toolbar and actions are available in the interpretation window as they are in the 3D scene.

New Fault Stick Mode: All interpreted fault sticks will be collected into the active set. If no set has been activated, the default is the unassigned fault stick set.

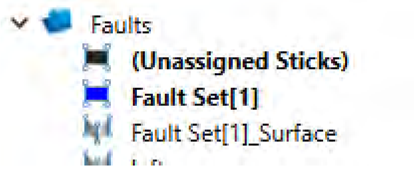
To create a new fault stick, click once on the seismic data to start, then continue to interpret until the last interpretation point, where a double click will end the fault stick.

The fault stick will be interpreted based on the seismic visualised in the 3D scene or interpretation window by default, or the seismic selected in the Source drop-down menu on the horizontal fault interpretation toolbar. The interpretation will use either the guided or linear interpretation as selected with one of the two icons across the top of the window.



Guided and Linear interpretation choice

Unassigned Fault Sticks: As a default, an 'Unassigned Sticks' fault-set will exist in your project. It is simply a catch-all folder for non-assigned fault sticks. Activate this set to quickly interpret multiple faults before later grouping them into individual fault-sets using the filtering and grouping tools.



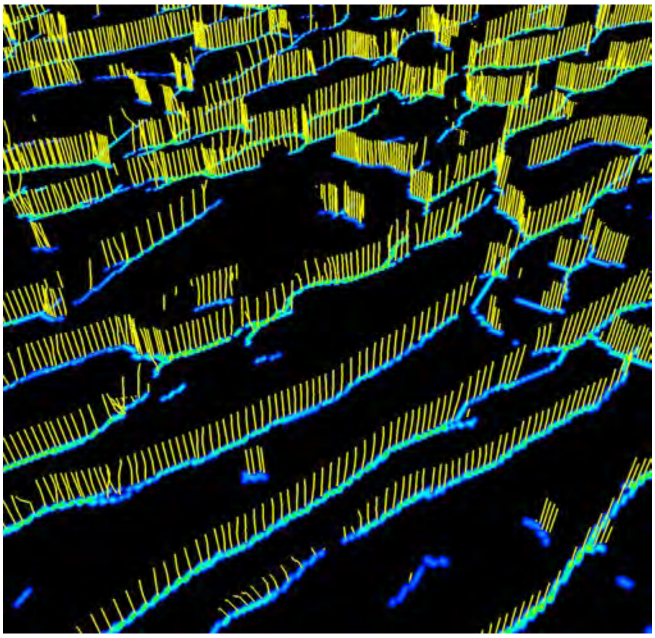
Unassigned Sticks Set in the project-tree

Fault Detect Stick Extraction

Fault Detect volumes are powerful for visualisation and determination of the presence and position of faults.

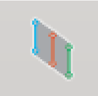
In Geoteric 2019.1, Fault Sticks can be automatically extracted from the Fault Detect volume or inline/crossline thereof. Z/Time slices cannot be used for fault stick extraction.

Note that any volume can be selected for stick extraction, but the result will most likely be un-usable, since the process is optimised for the fault detect volume only. It is recommended that only the fault detect volume is used.

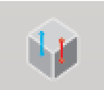


Clipped Fault Sticks extracted from a Fault Detect Volume. See below for more on fault clipping

Fault stick extraction is enabled either by a right-click on a slice, a volume or by selecting the relevant icons on the fault interpretation tool bar.



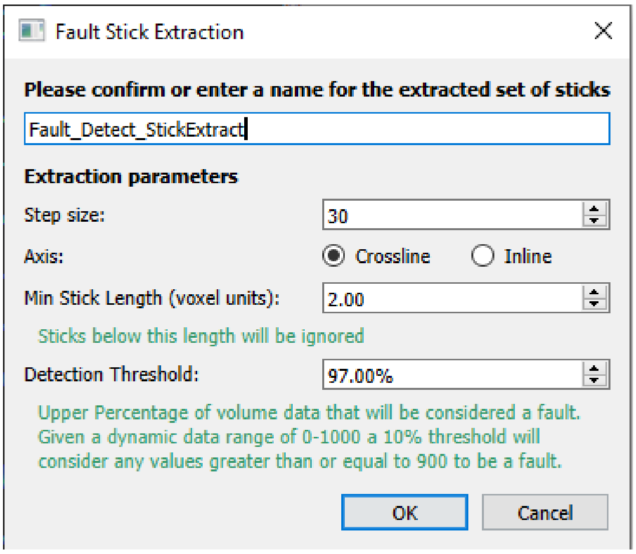
When selecting 'Extract Sticks for Slice icon from the fault interpretation toolbar, fault sticks will be extracted from only one slice. The slice chosen will be the active slice in the 3D scene be it inline or crossline. If no slice is available in the 3D scene a pop-up message will inform of this and ask you to visualise an appropriate dataset.



When selecting 'Extract Fault for the entire volume' icon from the fault interpretation toolbar, fault sticks will be extracted from the entire fault detect volume. The Fault Extraction Settings - parameter pop-up dialog will always be displayed to enable setting the parameters prior to running the process.

NB: When selecting the relevant icon from the fault interpretation toolbar, the Fault Extraction Settings - parameter pop-up dialog will not be displayed, and the extraction will be applied instantly. To set the parameters for fault stick extraction, go to the Tools drop-down menu and select the Fault Extraction Settings option.
With a right-click from an inline or crossline, the Fault Extraction Settings - parameter pop-up dialog will always be displayed.

Fault Extraction Settings



Give the new fault-set a name

Set IL or XL interval for extraction

Set minimum stick length

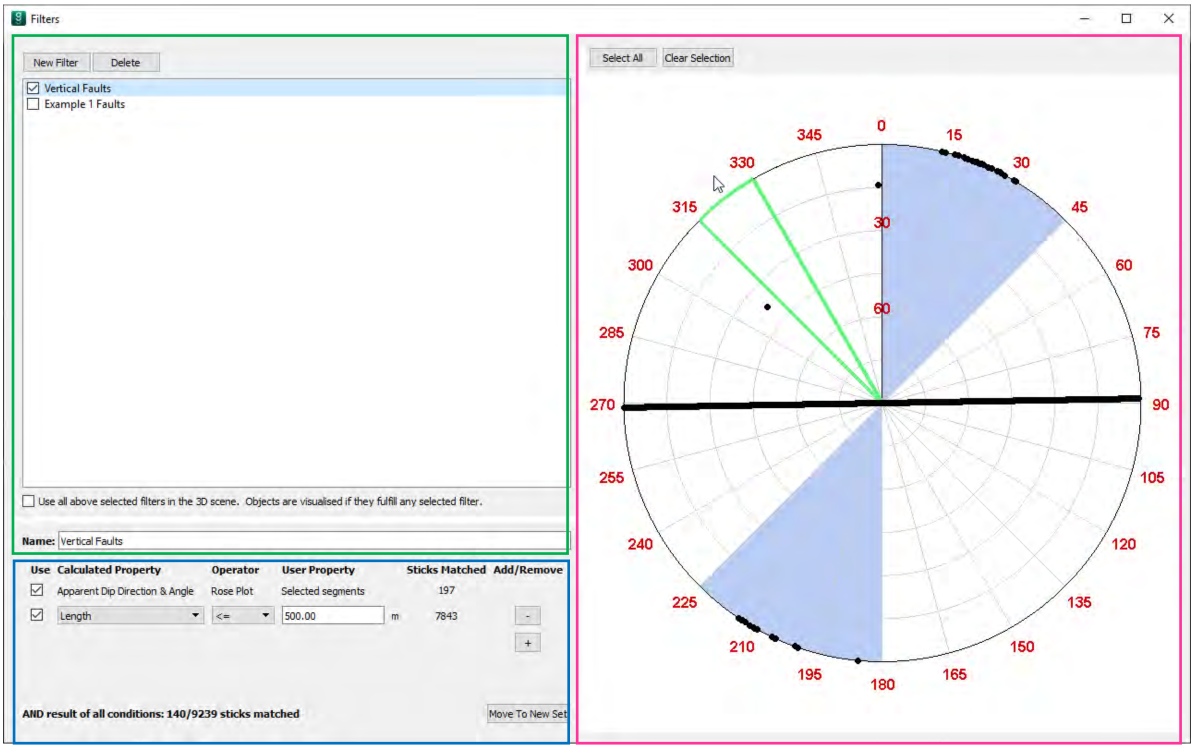
Set detection threshold. Smaller values will detect few, high confidence faults and higher values will detect many faults of varying confidence

Fault Stick Filtering

Automatic fault stick extraction creates large numbers of fault sticks. To make sense of all the fault stick data, statistical information regarding each individual fault stick itself is available for use in the fault stick visual filter.

Key parameters which can be used for filtering are the fault stick length, its vertical height, its apparent stick dip direction and apparent stick dip angle.

To open the filtering dialog box, select 'filtering' through the Tools dropdown menu or by right-clicking on a fault stick, or simply click the filter icon in the fault editing toolbar (this icon is green when a filter is applied, blue when no filter is applied).

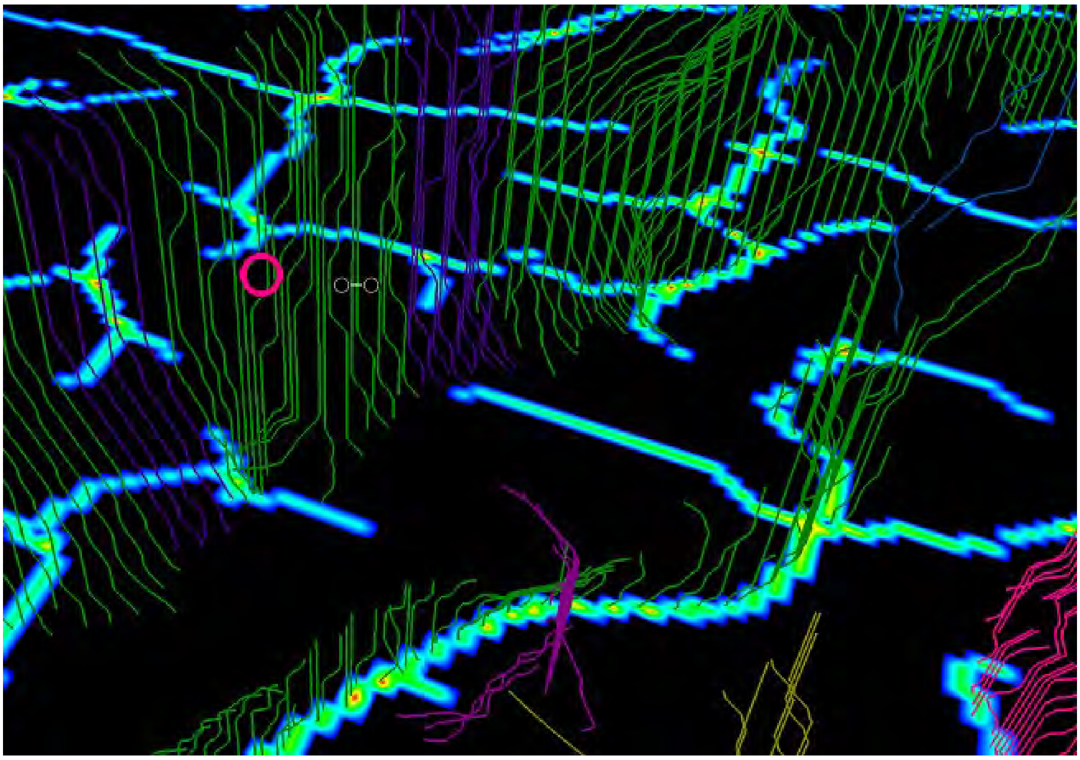


- Green box: Create or delete new filters and rename them. Toggle filters on and off and use filters to limit what sticks are visualised in 3D scene.
- Blue box: Add filter criteria for length, apparent dip and dip direction using basic mathematical limits. Move filtered sticks to a new set (CAUTION: this function will move all sticks in the project that satisfy the filter requirements not just those visualized in the 3D scene)
- Pink box: Use the stereonet plot to limit fault sticks based on apparent dip and dip direction. Click and drag to highlight areas of the plot for filtering.

Fault Stick grouping

Once automated extraction and fault stick picking, editing, and filtering are complete, unassigned or detected sticks can be quickly and easily grouped together using a combination of options available in the fault editing toolbar.

1. Fault Clipping (C) – toggle this feature on or off at any point to limit the visualisation of fault sticks to a single Z/time, inline, or crossline slice. Use the arrow next to the icon to change the clipping distance to optimise visualisation. This can be particularly useful in this workflow when a fault attribute is mapped onto a Z/time slice as shown above.
2. Create New Fault-set (V) – create an empty fault-set to move sticks into
3. Activate Fault-set (S) – use the eyedropper to activate the already existing fault-set you wish to move sticks into.
4. Move Fault Sticks (M) – use this function to click single sticks or swipe over multiple sticks to move them into the designated fault-set. When in this mode, the cursor will be a circle with the colour of the active fault-set.
5. Repeat steps 2-4 to continue moving sticks into separate fault-sets.

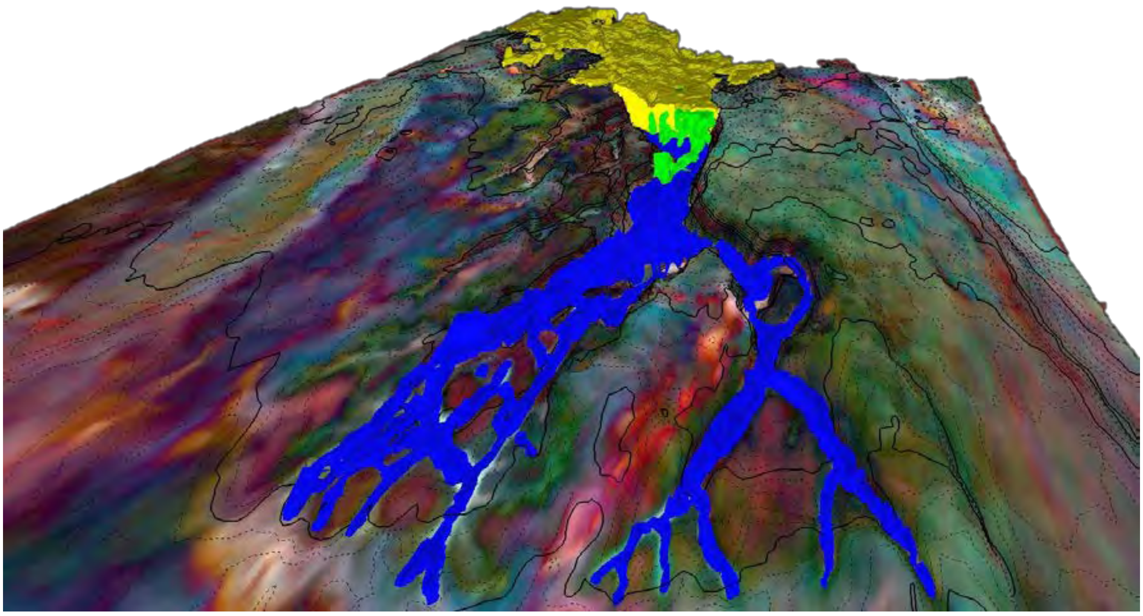


Moving green fault sticks into a new fault-set (once moved, the sticks will be pink, as indicated by the cursor)

Interpret

Adaptive Geobodies™

The Adaptive Geobodies tool allows for the extraction of geobodies in 3D, with a different approach to the classic method, which uses opacity or threshold as limits. Geoteric's Adaptive Geobodies allows you to extract the geology you have revealed using Geoteric's Interpretation workflow. The tool uses a Probability Density Function (PDF) which describes the value range that could/must be included in the geobodies neighbourhood and/or from clusters (seeds) used to begin the data inclusion. In Geoteric, Adaptive Geobodies can be used to extract features using any attributes or colour blend volumes, individually or simultaneously. Adaptive Geobodies are fully interactive and allow you as the interpreter to input your geological knowledge, in order to obtain the best interpretation possible.

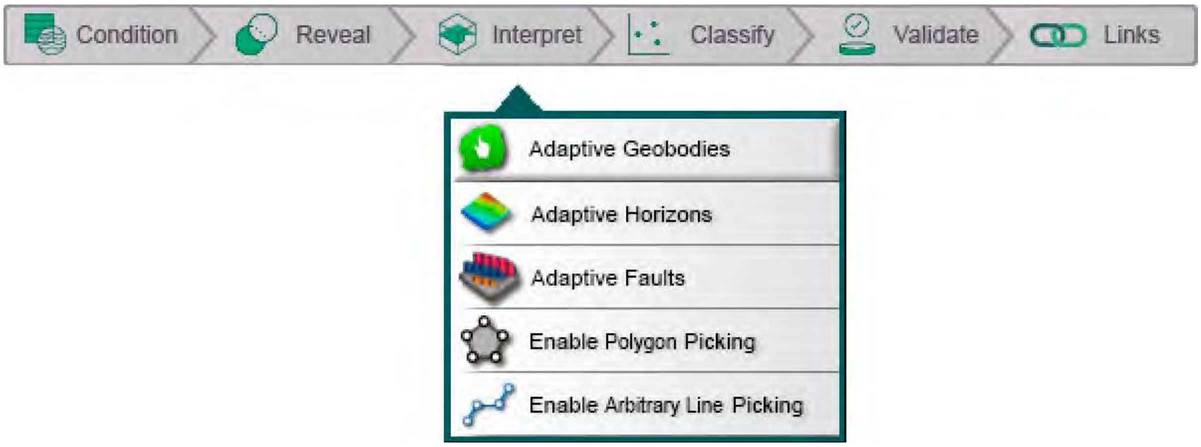


Part 1 will guide you through how to draw the clusters on your feature of interest and how to set up the geobody for optimum growth. Part 2 will then guide you through the manipulation and fine tuning of the geobody shape.

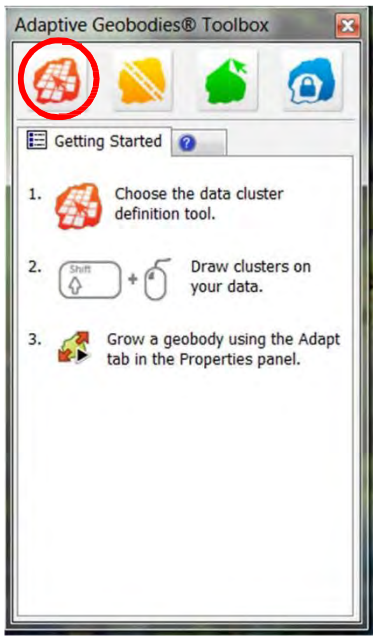
Part 1 – Growing your Geobody

Selecting Your Seeds/Clusters

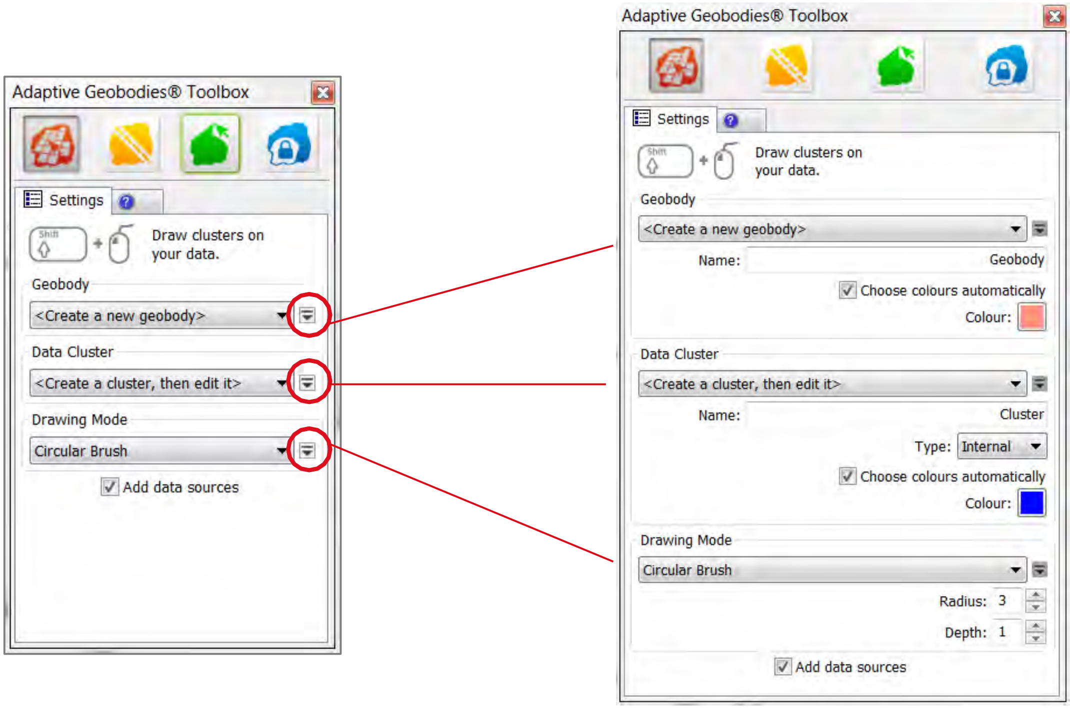
1. Open the Interpretation tab and click on Adaptive Geobodies.



The following window will open:



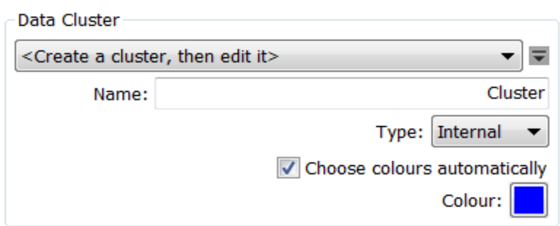
2. Click on the first red icon – Data Cluster Definition – and the following options will show. This is the tool for selecting the data of interest that you want to extract. Expanding each of the sections (as pictured below) will reveal more options.



Geobody section:

In this step you can either chose to 'Create a new geobody' or select an existing geobody (for re-editing, adding new clusters, re-adaption, etc.).

3. Data Cluster section:

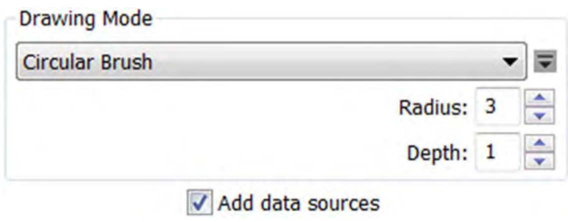


This is where you choose the cluster type: Internal or External.

- Internal clusters refer to the attribute values which will be included in the geobody.
- External clusters are the opposite: values not desired in the geobodies.
- Or choose existing clusters to add new data to.

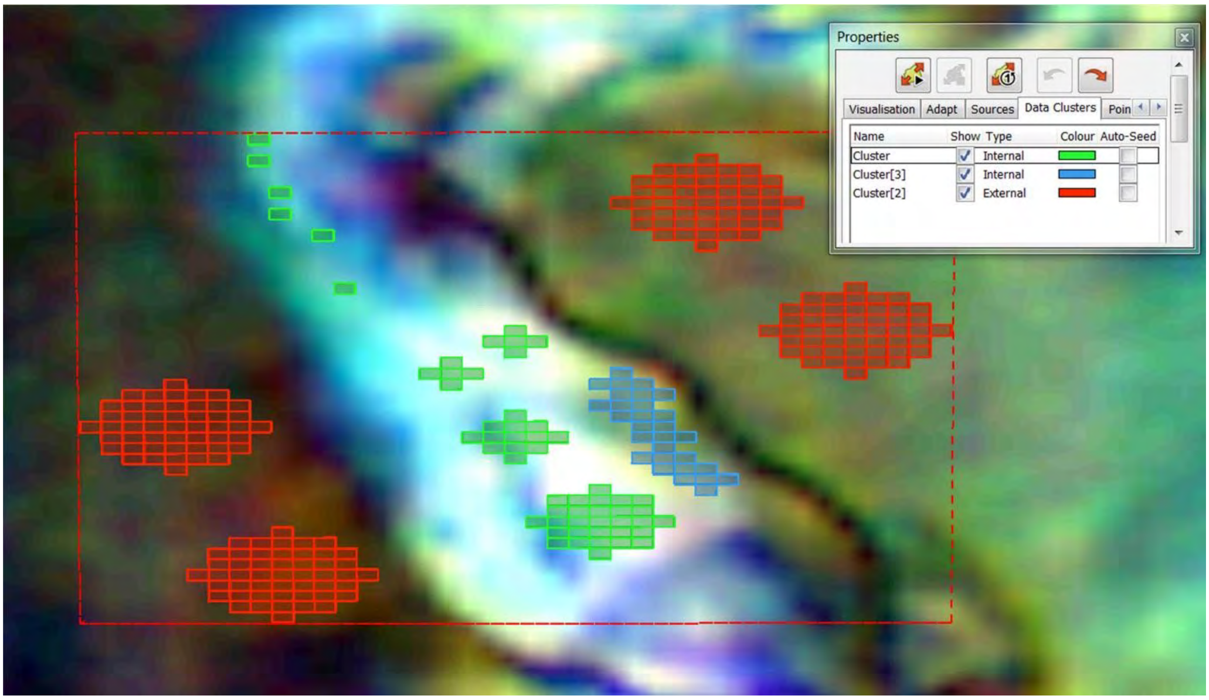
NB: a cluster is made up of a set of seeds. Seeds are 1x1x1 voxel in size. A geobody can contain one or more data clusters.

4. Drawing Mode section:



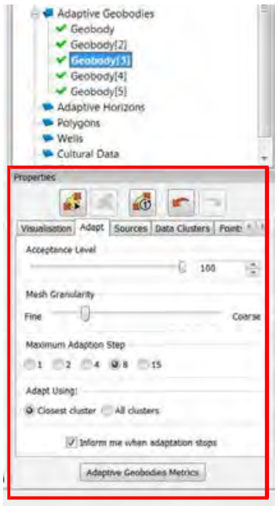
To add clusters, hold 'SHIFT + mouse button 1' and draw on part of the feature you want to extract. The added cluster will have the characteristics selected in the previous step (cluster type: internal or external, and size: radius and depth). To delete seeds from any cluster hold 'SHIFT + Right click' over the cluster.

NB: The clusters must contain the data that best characterises your feature. When the geobody begins to grow, it will adapt to areas that share similar values. How much variation it allows into its growth will depend on the acceptance Level (discussed in later steps).
NB: Clusters can be drawn on a time/depth slice, in-line, crossline or horizon or any exposed face of your 3D volume.



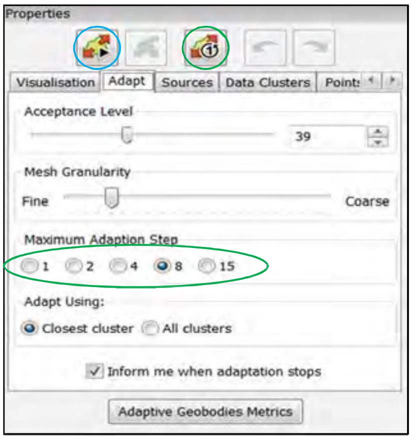
Three different clusters (red, green & blue). The red clusters have been set to define the exclusions zones (to help constrain geobody and the green and blue clusters define the variable character of the object.

Extracting Geological Features:



After drawing your first cluster, the Geobody will appear in the Project Tree of Geoteric's main window (as below). Make sure this is selected and the Adaptive Geobody 'Properties' box will open, which will give you access to the growth/adaptation/visualisation parameters.

1. Adapt Tab



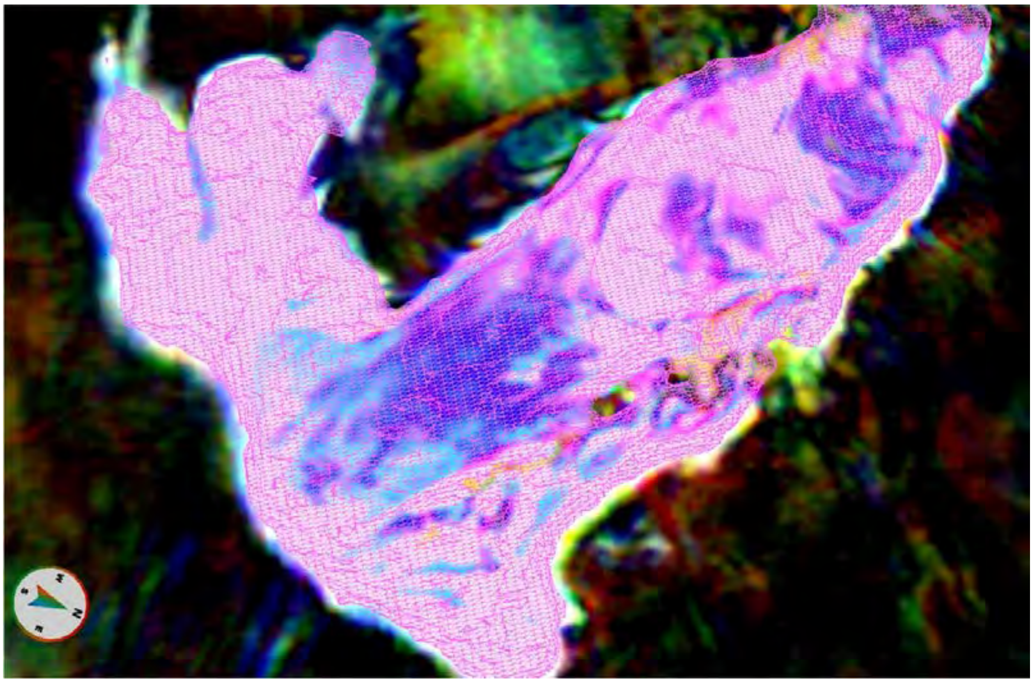
Acceptance Level

- Controls how the geobody will accept different values (chosen in the clusters) as similar values. So level 100 means that any attribute response is considered similar to the responses chosen within clusters. Zero means that there's no tolerance to discrepancies.

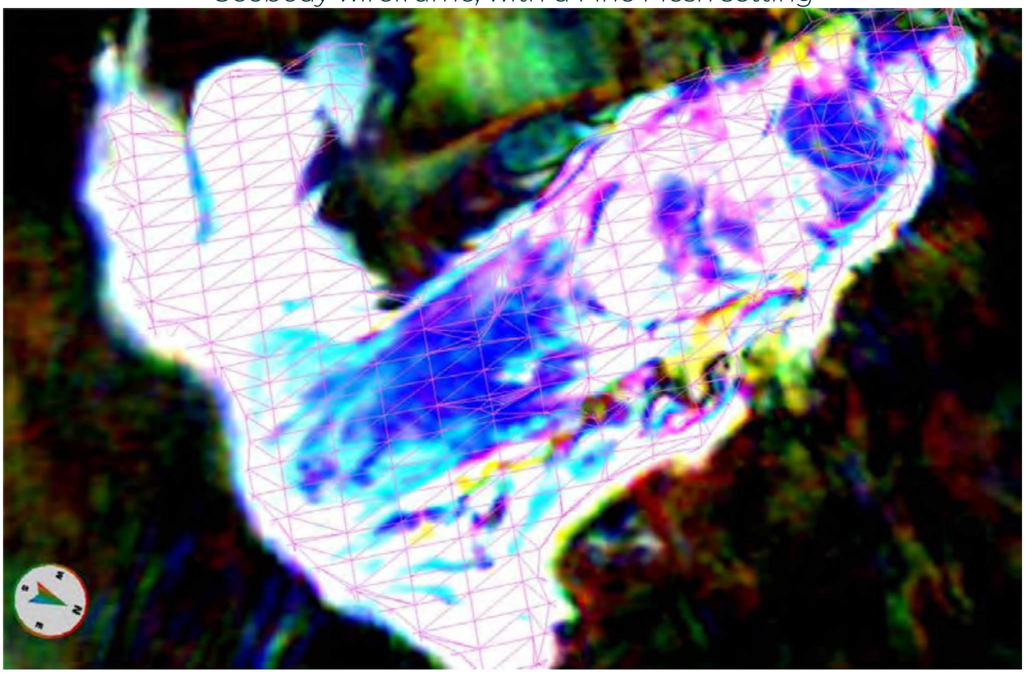
NB: Once you begin the growth of the geobody, the window below may appear. If this is the case and you still wish to grow the geobody more, click 'OK' and try increasing the acceptance level to allow more variability into the geobody's growth.

Mesh Granularity

- It is possible to adjust the granularity of your mesh wireframe. A fine mesh is recommended for smaller geobodies with a lot of detail and a coarse mesh is recommended for bigger geobodies (with less detail).



Geobody wireframe, with a Fine Mesh setting

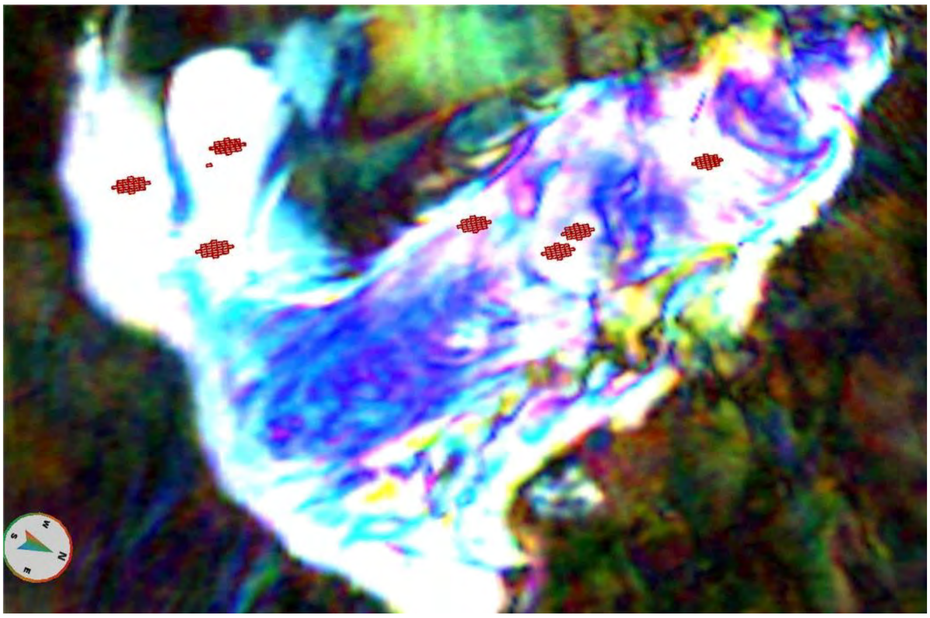


Geobody wireframe, with a Coarse Mesh setting

NB: The finer mesh has a truer representation of the actual geobody shape, but it can require more processing time.

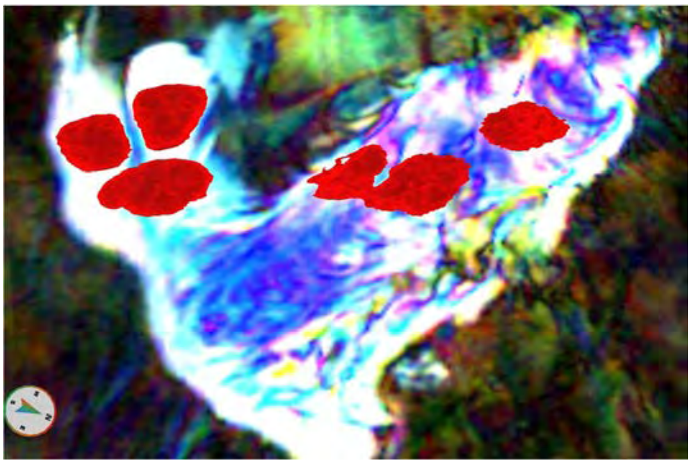
Growing Your Geobody

To start the growth, click on the Start Adapting  or Adapt Once  steps of 1, 2, 4, 8 or 15 voxels – according the settings defined by you.



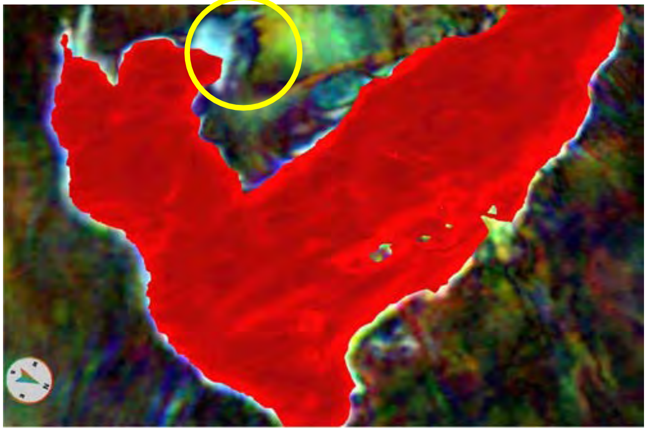
Clusters drawn in the region of interest on a colour blend of Near-Mid-Far stacks

After 4 clicks on the 'Adapt Once' button



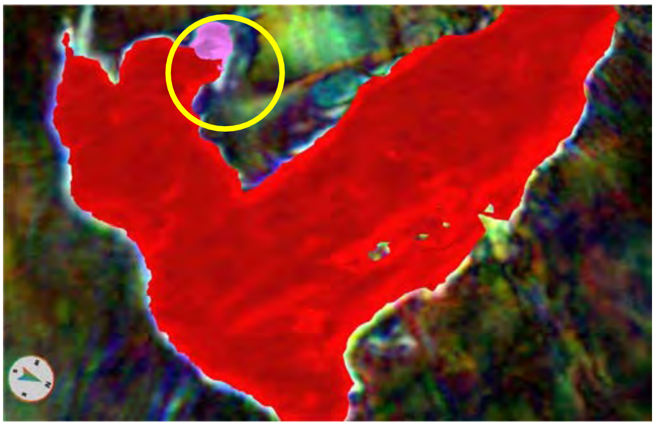
The geobody will start to adapt to all data values allowed in by the defined Acceptance Level.

'Start Adapting' will let the geobody takes its course based on the data selected and the parameters chosen. The growth of the geobody can be paused at any time, and you can 'Undo' previous adaptations or manipulations, if a mistake has been made.



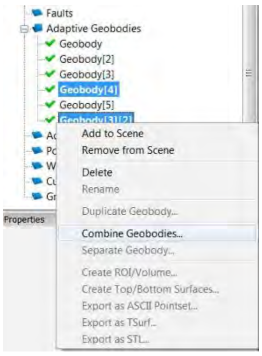
The geobody will start to adapt to all data values allowed in by the defined Acceptance Level.

Different regions of your feature may be characterised by a different character (yellow circle above). If a single geobody will not grow to include this area, a new cluster can be drawn (Create New Geobody) and this can be grown into a separate geobody (below).

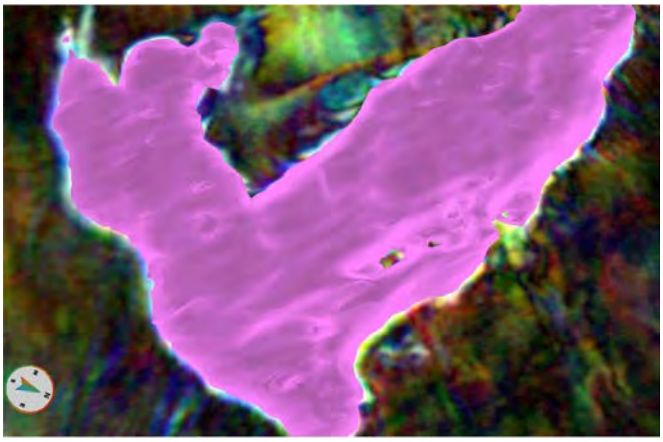


Two separate geobodies, representing different parts of the same feature.

Separate geobodies can be combined as one. Select the geobodies of interest from the Project Tree (main Geoteric window), right click and select the 'Combine Geobodies' option.

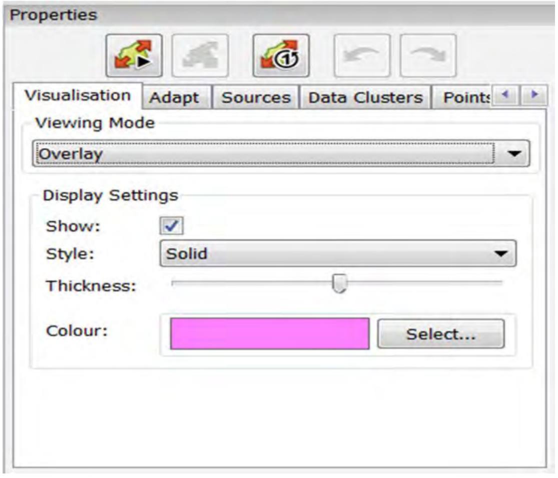


NB: You will need to select which geobody's properties will be inherited by the new body. This includes mesh granularity, colour, etc.



Combined geobodies using characteristics from second geobody (previous image)

Visualisation Tab



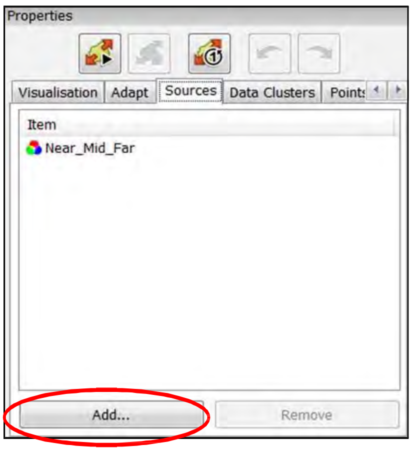
There are different types of visualisation that you can set for your geobody:

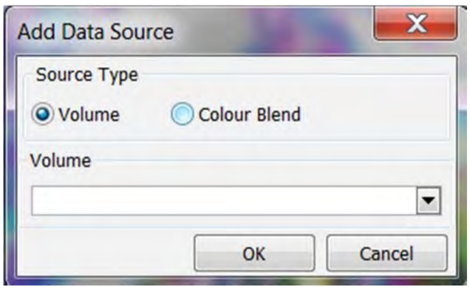
- Solid – by a single colour
- Wireframe – triangulated grid of the geobody
- Points – data points
- Data Mapped – select an attribute/colour blend to display on the surface of the geobody
- Overlay – marks the outline of the geobody on any volume/colour blend on display in the main window. This helps you QC the outer limits of your geobody and to check it fits the data. It will also help identify any holes/anomalous regions.

Sources Tab

This is where you can chose the source volumes and colour blends. These will be used for the geobody's growth, even if the volume is not in display. This enables you to include different data types into the growth of your geobody, particularly useful if more than one of your attribute results confirm the geological feature to have the same shape, size – thus giving more confidence in your interpretation.

You can include up to 10 attributes.



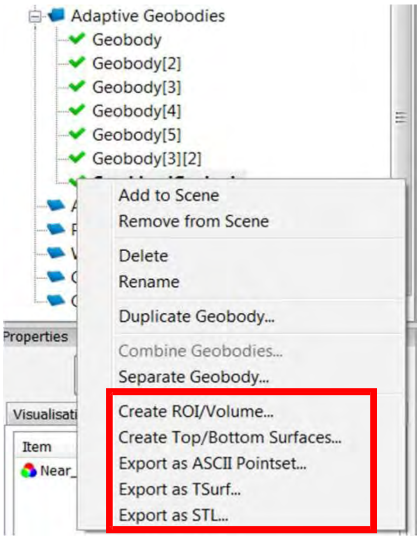


Exporting Your Geobodies

The generated geobodies can be exported in the following formats:

- Create ROI/Volume – creates a volume/ROI around the region of the geobody only
- Create Top/Bottom Surfaces – generates Top/Bottom surface to Horizons folder in Project Tree
- Export as ASCII Point Set – 3D point set
- Export as TSURF – top and bottom surface
- Export as STL – for 3D printing

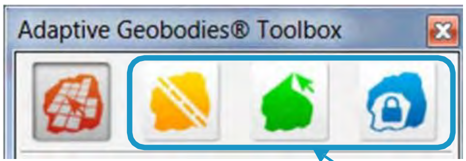
To export a geobody, locate it in your project tree and right click to reveal the options (as pictured below).



Part 2 – Editing your Geobody

After creating your geobodies in accordance to the first steps, you are now able to add the interpreters touch by manually editing the geobody to ensure you get the most accurate interpretation.

The editing tools are in the Adaptive Geobodies Toolbox, to the right of the Data Cluster Definition Icon. Make sure your geobody is selected in the main project tree before continuing.

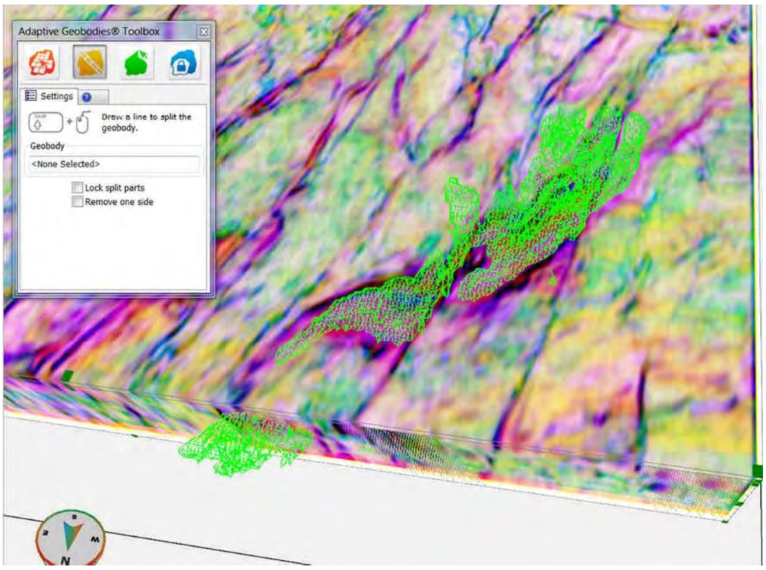


Manipulation Tools:

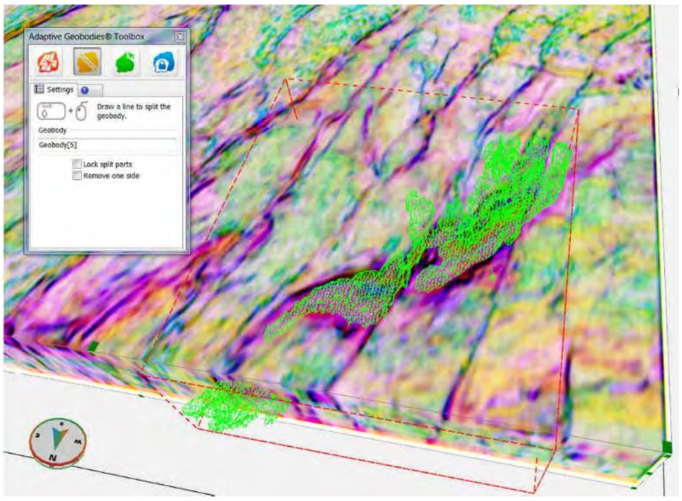
- Split geobody
- Manipulate geobody
- Lock geobody

Splitting

As you can see (below) the extracted geobody (displayed as a wireframe) is covering three fault blocks. While the geobody has clearly taken into account the presence or a change in character at the fault plane, it is also possible to split the geobody into several components – using the **Splitting Tool**. The splitting tool is a linear cutting/separating tool.



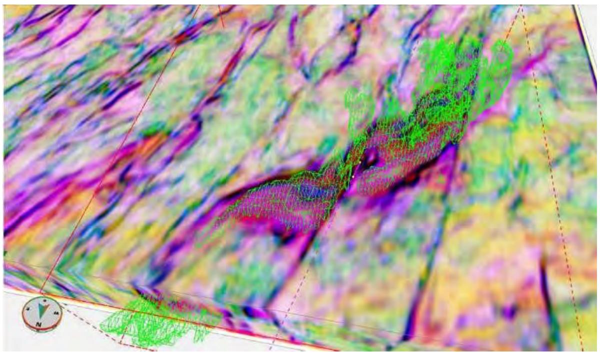
1. Ensure the geobody is selected (a red cube shape will appear around it as pictured below) and the Adaptive Geobodies Toolbox is open.



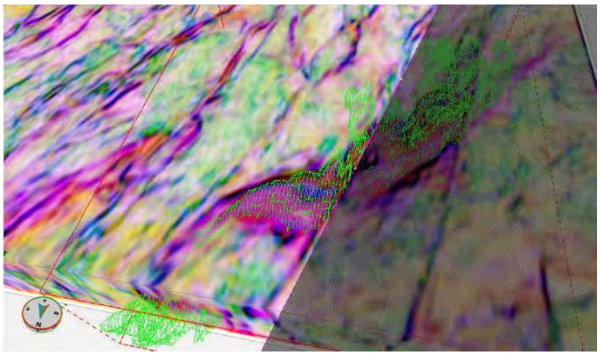
2. There are three different options to apply when using the Splitting Tool.

1. Split Parts (default)
2. Lock Split Parts – locking will be applied to the bodies contact area.
3. Remove One Side – one side will be removed/deleted.

To active the splitting tool press Shift + Left Mouse Button at the point of interest. A straight line will appear, centred at the point of where you clicked. To deselect the line click the Right Mouse Button or press Esc. To undo an action use the Undo button in the Adapt Tab (which is in the properties box under the main Project Tree).

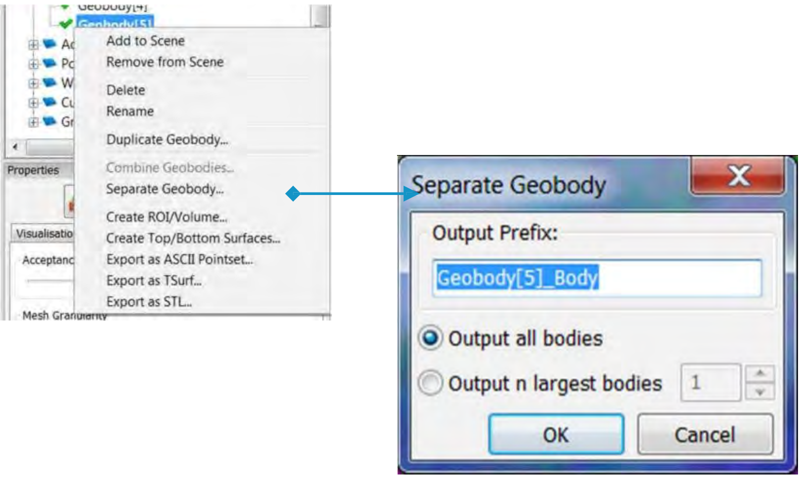


Splitting of geobodies – along the sectional plane (pink line) the geobodies will be separated.



Option Remove One Side – the shadowed side will be deleted.

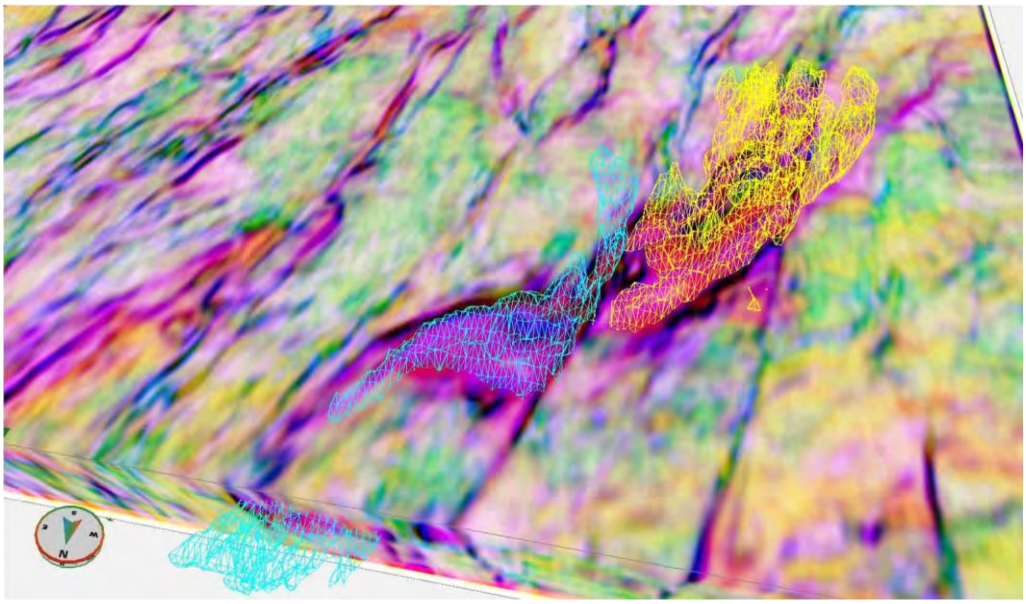
3. After splitting the geobodies using the interactive tool, you'll then be able to save out the geobodies as separate bodies. In the Project Tree, right mouse click on the relevant geobody and select the **Separate Geobody** option.



Output all bodies – to save all discrete geobodies.

Output n largest bodies – save n largest geobodies.

4. Separated geobodies are added to the Project Tree and can be renamed, manipulated and edited accordingly.



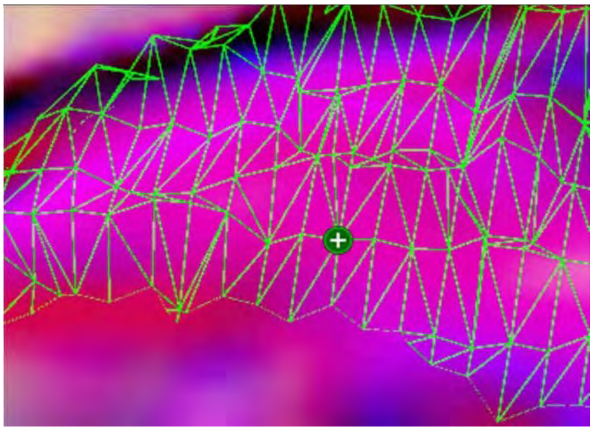
A single geobody split along the fault plane and then separated. Now displayed as two separate bodies.

NB: More complex cutting can be achieved using multiple iterations of the Splitting Tool, where the individual components can then be recombined using the Combine Geobodies option (left click mouse on geobody in Project Tree), as shown in Part 1.

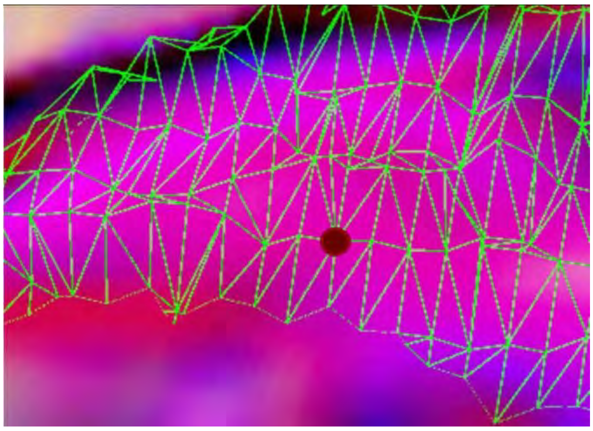
Manipulation

Splitting or cutting however, may not be required, but you may wish to add the interpreters touch by manipulating the geobody further according to your geological insight. The Manipulation tool allows geobody editing by stretching and moving nodes in the triangulated grid.

1. Select the geobody, as shown in previous steps, using the left mouse button.
2. Set the visualisation (shown in Part 1) to wireframe.
3. By pointing/hover the mouse to geobody grid, you will be able to see where the manipulator point can be added to the grid nodes (the point where grid lines meet) and where it cannot.

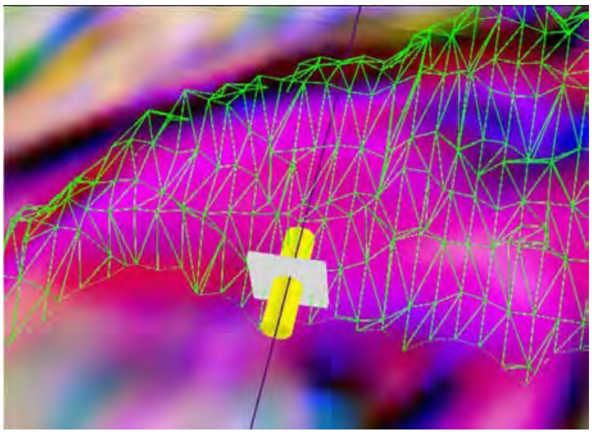


Node where it is possible to add manipulator point (green)

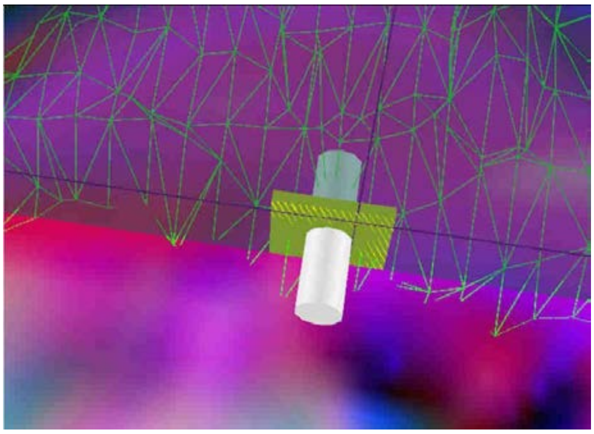


Node where it is **not** possible to add manipulator point (red)

4. Click the left mouse button and this will add the manipulator.



Using the mouse select the cylinder to define the movement of the grid along the cylinder axis

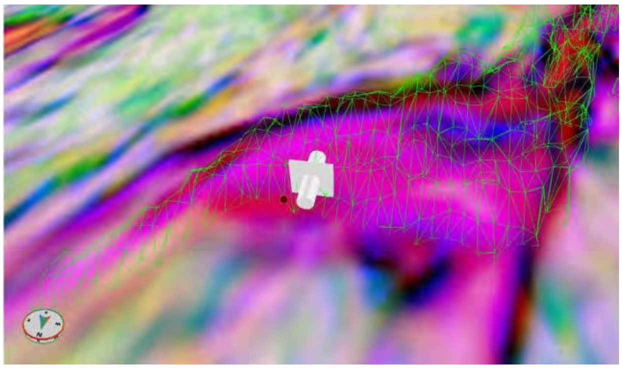


Select the handling plane to define movement along the plane.

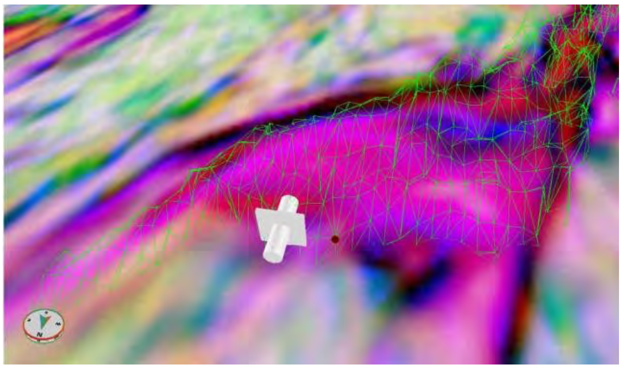
Press CTRL while holding over the manipulator to change its orientation between X Y & Z directions

5. There are two types of grid manipulations – **Stretch** and **Move**. These actions perform different types of modification to the triangulated grid within the defined amount of nodes (set in **Neighbourhood**).

This workflow allows you to add areas to the geobody that were not initially match by the probability density functions defined by the clusters (that you set in Part 1).



Geobody created only by including data within the acceptance



Adding additional area using the manipulation tool

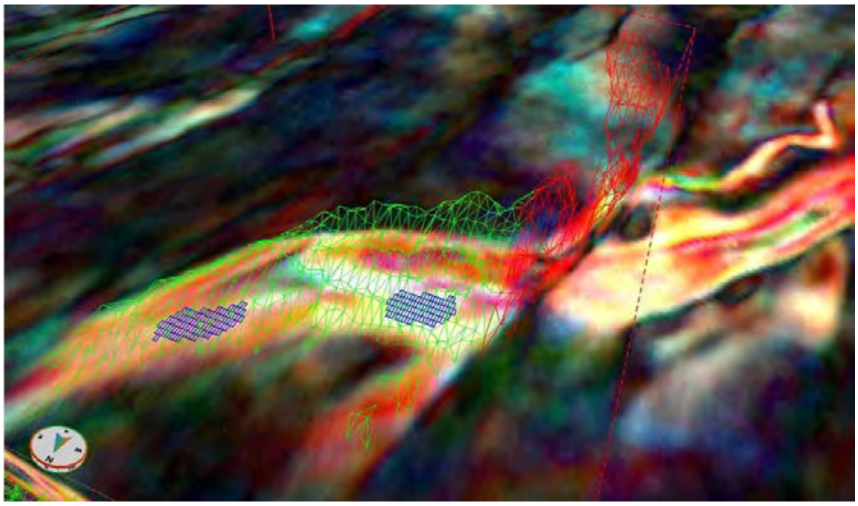
6. After you have manipulated the geobody, click a Single Adaptation (in the properties box under the Project Tree) to refit the distribution of clusters. To fully project manual changes or existing growth, it is necessary to use the Locking Tool.

Locking

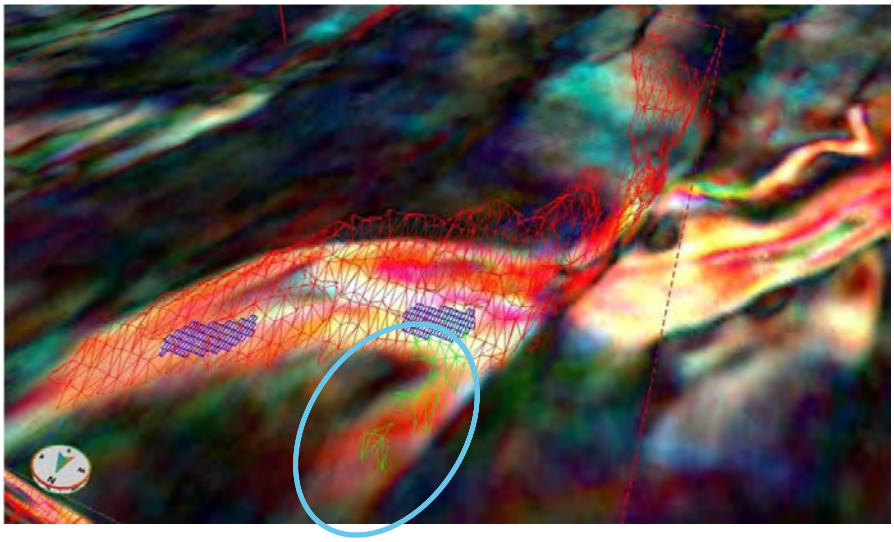
Locking the geobody preserves the shape of the geobody and limits its growth in determined regions. To use the tool, again make sure the geobody is selected.

1. Use Shift + Left Mouse Click to select the area to be locked. This is like a brush tool, so hold the button down as you draw over the area to lock. Set the Regional Brush size to adjust the size of the area selected. Or, use Lock and Unlock Whole Geobody to apply the status over the whole body.

2. Locking status – red represents locked sectors of the geobody and green represents the areas that remain unlocked.
3. The majority of your geobody would have honoured the statistics in the data. However, if there is a small region of the geobody you wish to change then it is easier to lock the whole geobody and then only unlock the areas you want to change or continue adapting.
4. To do this, Lock Whole Geobody and then use Shift + Right Mouse Button to unlock the desired region of the geobody. You can then continue the adaptation.



In this example the Lock was applied to section of the geobody adjacent to the fault plane. This prevents the geobody from adapting to the similar response of the feature on the opposite side of the fault.



Similarly, if you are happy with the majority of you geobody yet wish to continue the adaption on more complex sectors of the geology – you can Lock the whole geobody and unlock the regions you wish to continue growing (blue circle).

This workflow allows you to use higher Acceptance Levels in specific regions without compromising the growth in other regions.

What next?

The Adaptive Geobody guidelines has given you an oversight in selecting your data clusters and beginning the adaptation in order to extract your feature. It has also covered the manual manipulation of these bodies, showing they are truly data driven and interpreter guided.

With your defined geobodies it is now possible to use them in conjunction with other workflows in order to better understand the geology in your data.

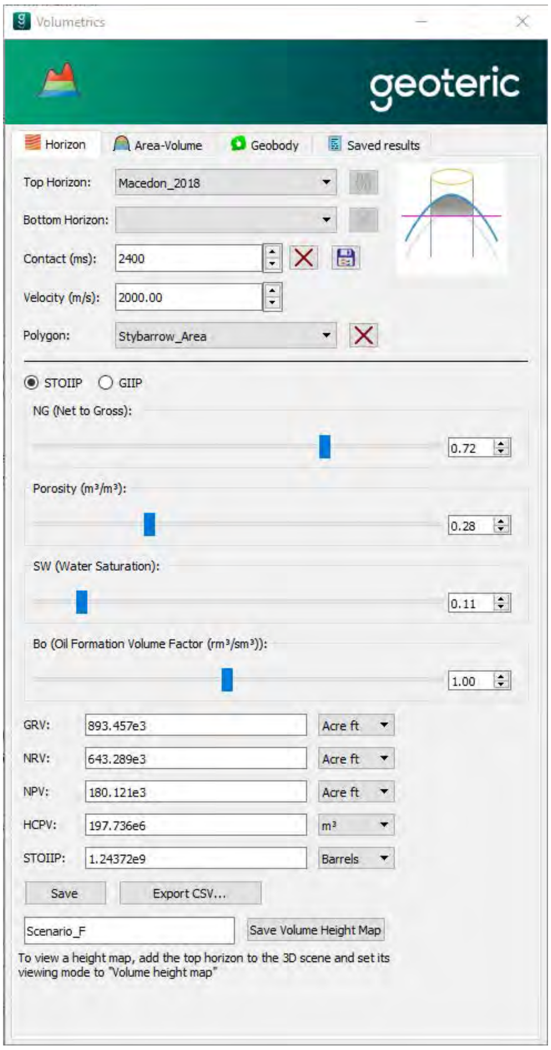
Use your generated geobody to constrain your reservoir characterisation in

- Interactive Facies Classification (IFC)
- Validate your interpretation with the RGB Colour Blends

Volumetrics

The 'Volumetrics' tool allows calculation of oil and gas resource estimates at any point during horizon or geobody interpretation and editing. The results can be saved within the project or into an external file which can be updated following further data acquisition and/or refinement of the interpretation.

1. Access the volumetrics tool by right clicking on a horizon or geobody and selecting 'Volumetrics'. Alternatively, go to Tools > Volumetrics
2. Choose between Horizon, Area-Volume, or Geobody calculations



- Horizon calculations can be performed on a single horizon or top and base horizons and limited by fluid contacts and polygons.
- Area-Volume calculations use a single horizon, and an optional polygon to compute Depth Area-Volume pairs at a given user defined interval. These can be exported and used in probabilistic reservoir geometry calculations.

- **Geobody** volumetrics uses only the volume of a selected geobody to define the reservoir container.

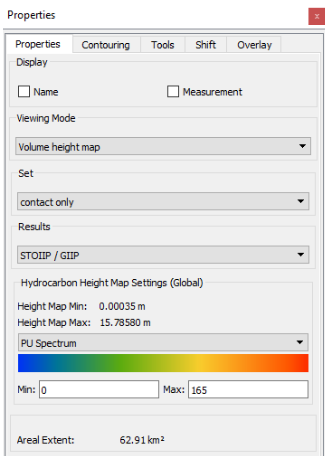
3. For the **Horizon** and **Geobody** tabs, once the reservoir geometry is defined, use the sliders or manually enter values for each element in the STOIIP equation. STOIIP or GIIP radio-buttons can be used to toggle between oil or gas calculations.
4. Gross rock volume, net rock volume, net pore volume, hydrocarbon pore volume, and STOIIP are automatically calculated. If desired, choose a unit of measurement for each output.
5. Click the **Save** button to save the results within the project. Once this is done, the **Saved results** tab can be accessed at any time to view the saved volumetrics calculation. The calculations can also be exported to a .csv file.

NB: If your project is in time, an interval velocity is required to perform the calculations. If using a geobody, the velocity can be viewed and edited by clicking the **Adaptive Geobody Metrics** tab.

Volume Height Maps

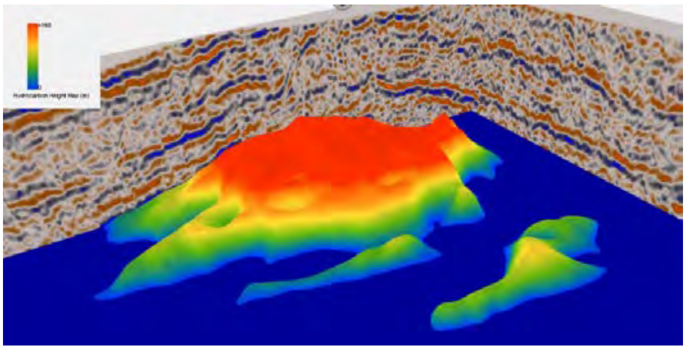
In the Horizon tab, a 'Volume Height Map' attribute can be saved to the input top reservoir horizon. Hydrocarbon Height Maps provide visual delineation of hydrocarbons and comparison between volumetric property parameters and their impacts on hydrocarbon distribution in different scenarios.

1. Once a horizon calculation has been performed. Enter a name into the Box at the bottom of the tab. The **Save Volume Height Map** button will become active. Click it.



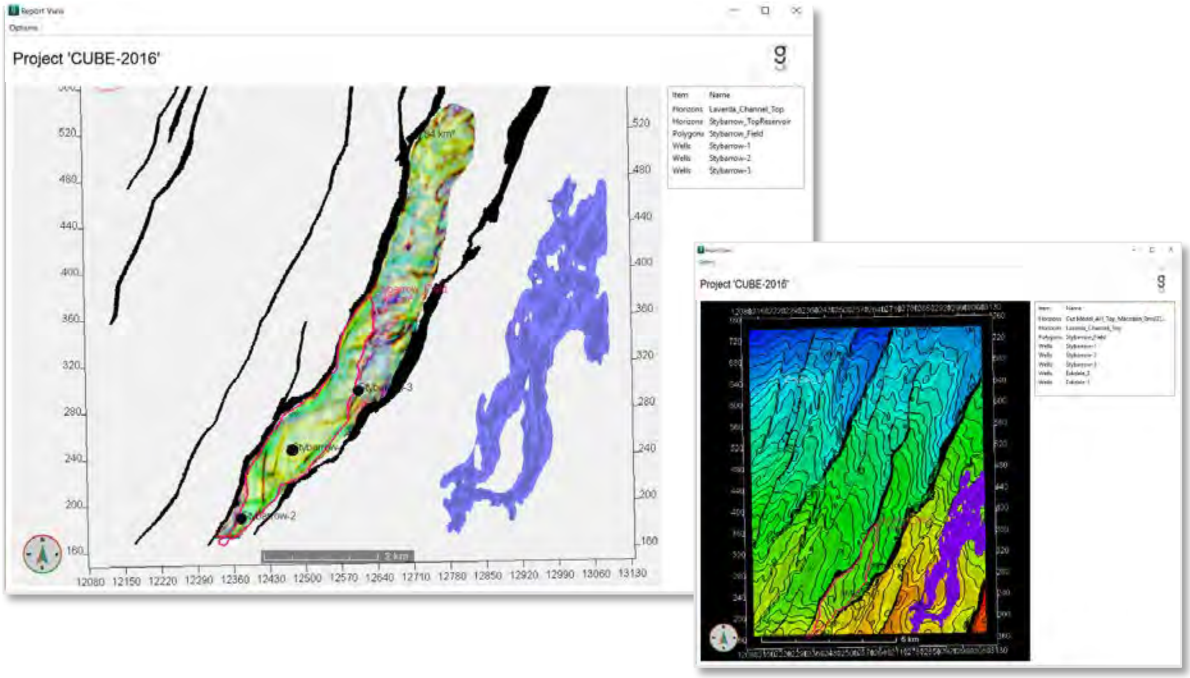
2. Add the top horizon to the scene in the 3D window. In the horizon properties tab, change the viewing mode to 'Volume height map'.

3. If multiple scenarios have been saved, choose a scenario for viewing in the **Set** dropdown box.
4. Choose the calculation to be visualized in the **Results** dropdown box. If desired the colour map can be changed and the min and max values of the colour map can be altered as well.



Example of a STOIIP Height Map together with a water contact shown in blue.

Report View

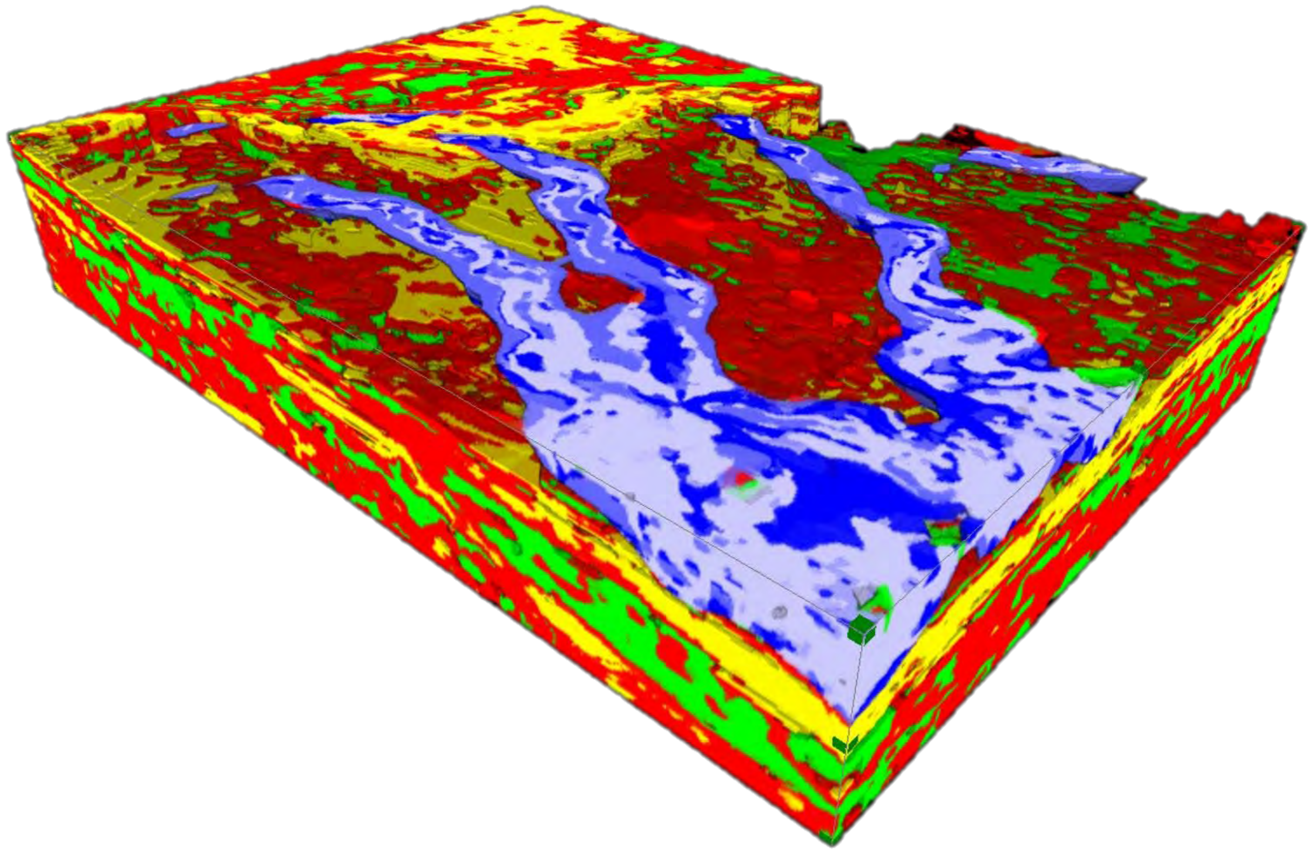


- Easy image capture
- Plan view of 3D scene
- Incorporates colour maps, scale bars and co-ordinate markers

Classify

IFC

Interactive Facies Classification (IFC) offers an easy method of seismic facies classification in an interactive environment. The IFC classification enables the classification of regions with different seismic responses using colour blends and up to 10 single volumes.



The IFC uses a data driven and interpreter guided approach combined with the ability to clearly visualise the geology using advanced multi-volume techniques.

It uses a sophisticated model of the attribute distribution using a probability density function, which provides you with the ability to detect subtle trends and to enable accurate differentiation of different classes of seismic facies.

Part 1 will guide you through the basic IFC workflow for classifying frequency decomposition RGB blends and constraining the results using geobodies.

Part 2 will include the use of well logs and scatter plots to add a quantitative approach to your interpretation and help you understand how the classification results calibrate to the geological data.

Part 1 - Classifying Your Volumes

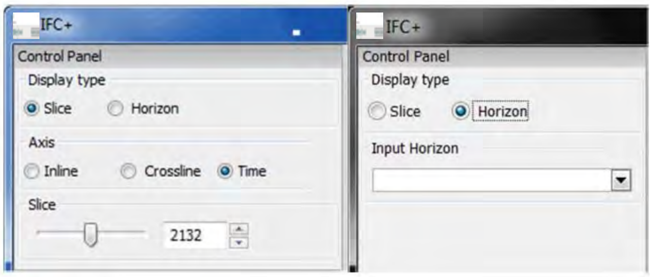
1. From the menu bar, select IFC (as shown below).

2. The IFC Interface

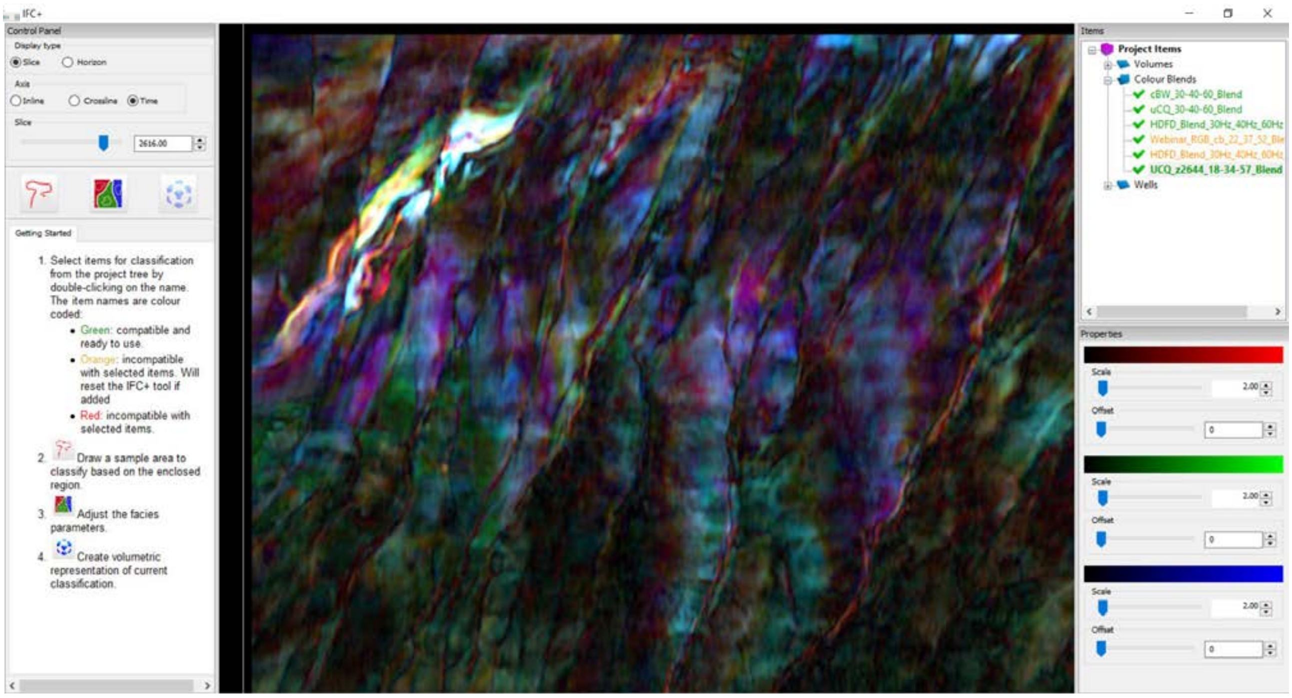
3. In the Items tab (Inventory) are all of the volumes, colour blends and wells available in your project. Initially, all volumes appear in green. After selecting the first volume (double click), volumes with different dimensions or ROI's (which cannot be combined with your initial selection – will appear in orange (as pictured below)).

Note: We recommend that the first volume you choose is the best volume for displaying facies variations. For example, a colour blend which best defines the variations within your reservoir interval. The opacity of subsequent volumes selected will be adjusted automatically so that you can see the response of each volume in display.

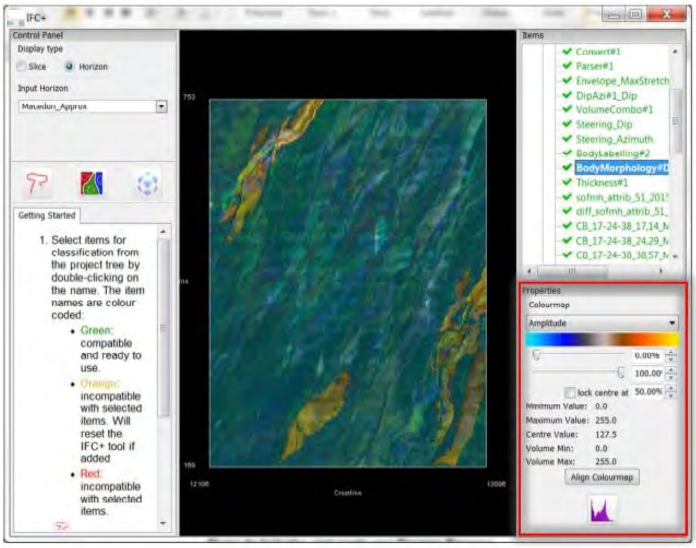
4. After selecting the first volume use the **Control Panel** to select the Inline, Crossline, Time/Depth Slice or horizon of interest – on which to display the colour blend or attribute results. This can be changed at any point of the classification and results of your first facies selection will be applied on the new line, slice or horizon.



5. Visualisation of the volume over selected line, slice/horizon.

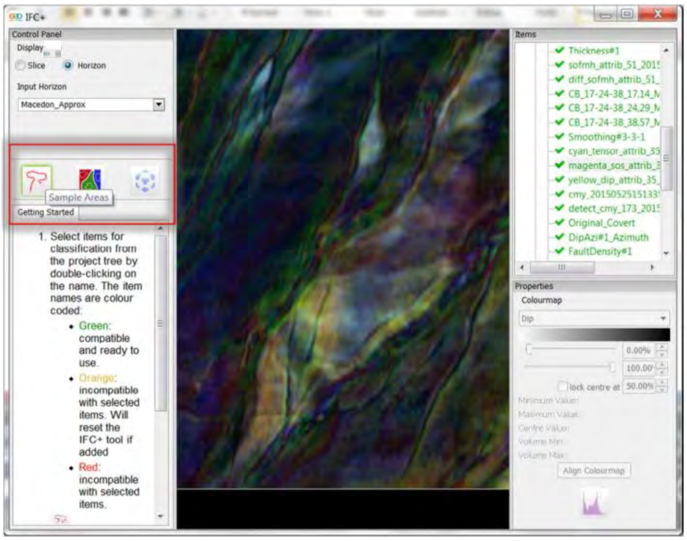


6. You can add up to 10 volumes in combination with a colour blend. The below example shows a geobody volume (created using **Geobodies** or **Adaptive Geobodies**) used as a mask on the area of interest, which allows you to limit the classification to a specific area (within the geobodies). You can also add additional attributes that reveal the stratigraphic and structural variations in your reservoir.

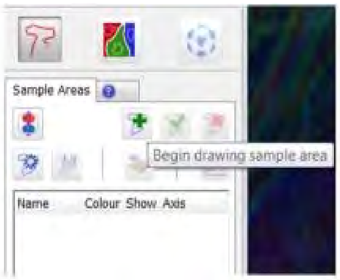


The opacity of the second and subsequent volume is automatically set to 30%. In **Properties**, it is possible to change the colour bars and opacity of the selected volume by clicking 

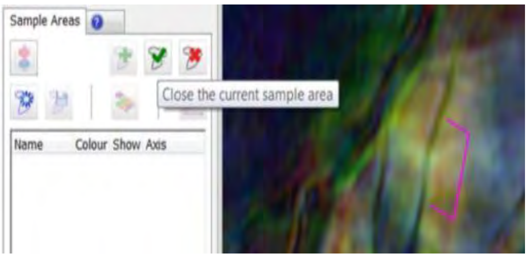
7. After you have selected your input data you can begin the facies classification. Define the different seismic facies by defining sample areas on the data that correspond to different facies. To start selecting the responses of interest (different facies), click the Sample Areas icon (as shown below).



8. In the Sample Area tab press **Begin drawing sample area**.

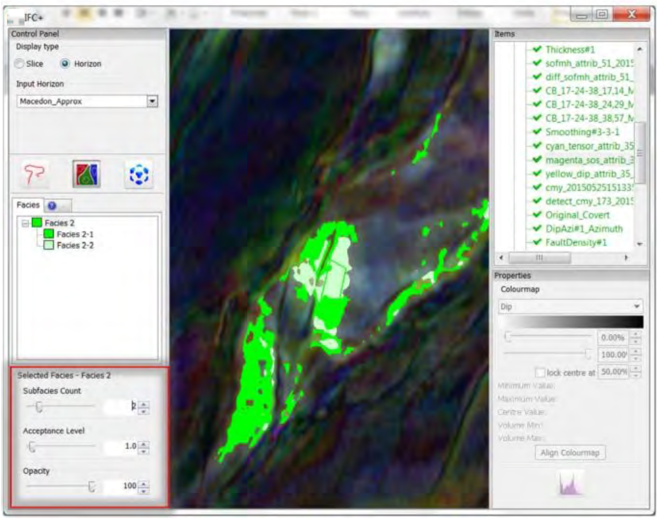


9. Using the Left Mouse Button to draw a polygon around part of the facies of interest. To close the polygon and complete the selection, use the **Close the current sample area** button. The polygon does not need to enclose the full area, just to sample the colour.



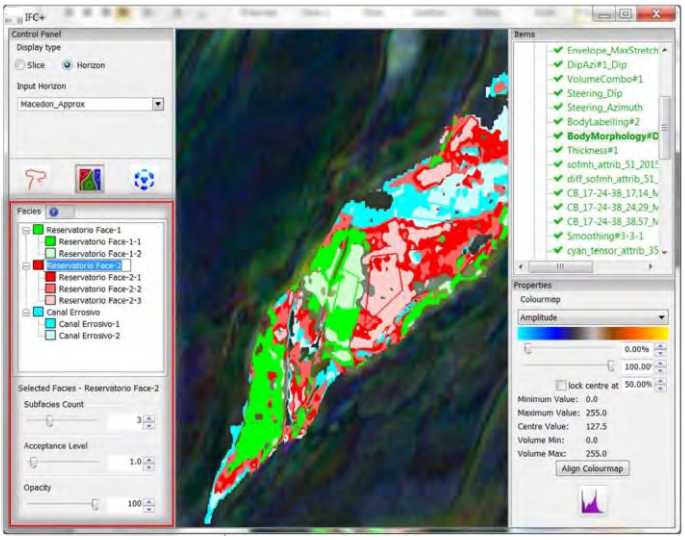
Note: The data distribution analysis will be slightly slower if a larger polygon is drawn. The smaller the polygon, the quicker the analysis, and the more detailed the result.

10. When the polygon is closed, a probability density function (PDF) of values within the polygon is created using the selected input volumes. Facies that satisfy the data distribution function and acceptance level will be matched over the whole ROI. Data values that fall within the acceptance level or the PDF will be classified. If within one PDF two distinct clusters are detected – then two or more subfacies will be generated (see image below).

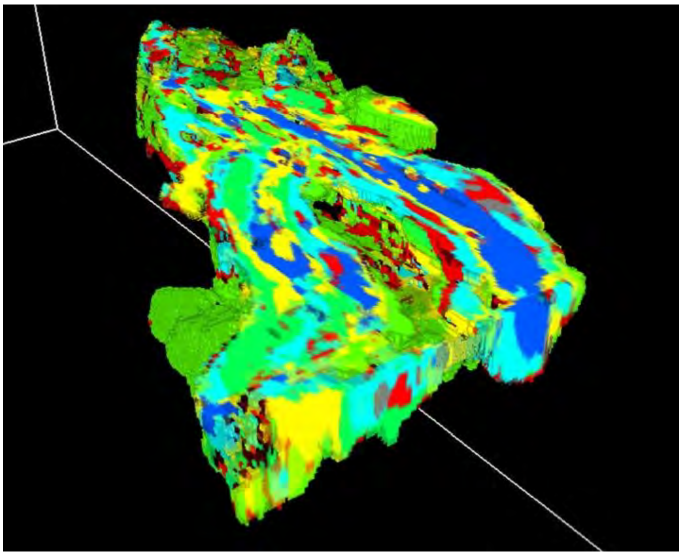


The acceptance level and number of subfacies can be adjusted in the **Selected Facies Panel** (highlighted in the picture above)

11. You can add new polygon selections, adjust the number of subfacies and level of acceptance to achieve the desired distribution. In the example below you can see that the use of **Geobodies volumes** as a mask is limiting the growth of the facies, to the area of interest (your reservoir). To facilitate your interpretation, you can rename the facies accordingly.



12. After optimising your classification, press Create Volume to generate a 3D seismic facies volume. This will be colour coded according to the colours used during the classification.



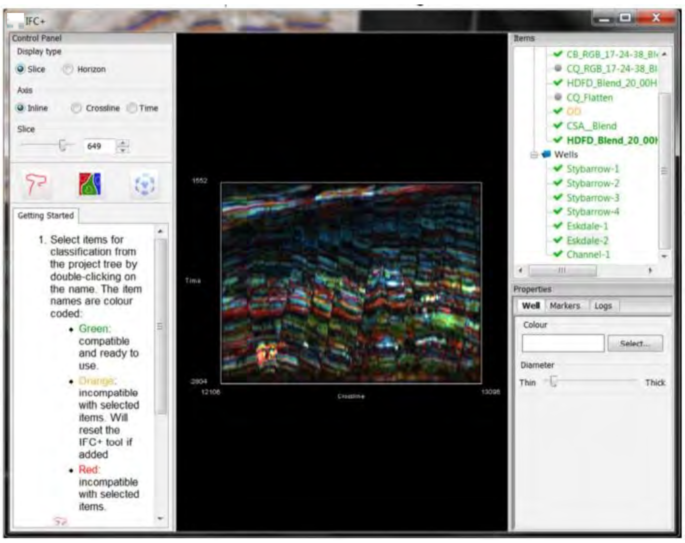
Example of facies classification using a discrete frequency colour blend and a geobody mask volume to limit the classification to within the reservoir. These results have been rendered in 3D.

Part 2

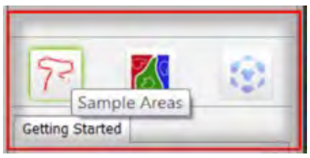
This section will show you how you can use wells and scatter plots to add a quantitative approach to your facies classification. It is possible to pick facies both manually, through polygon drawing, and between two assigned well markers – to calculate the distribution of that specific interval.

Facies classification using wells

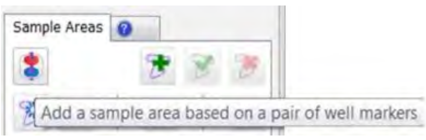
1. Follow steps 1-7 of **Part 1** of this workflow.
2. Now select an inline or crossline view that intersects your well.



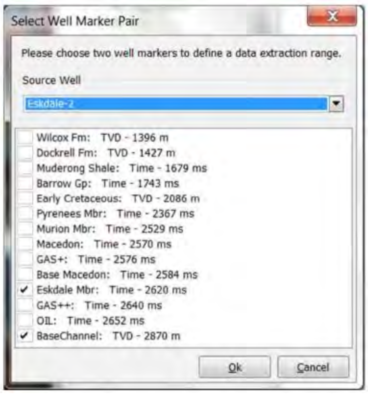
3. Selection of well(s) of interest. Here you are able to add your wells into the inline/xline display view. You can then display your markers so that you can pick your facies on the section view with reference to the well markers. You will also be able to use well markers to automatically classify the attribute responses that fall between any two of the markers selected.
4. To start the selection process (defining the area/response of interest), click the **Sample Areas** icon (as shown below).



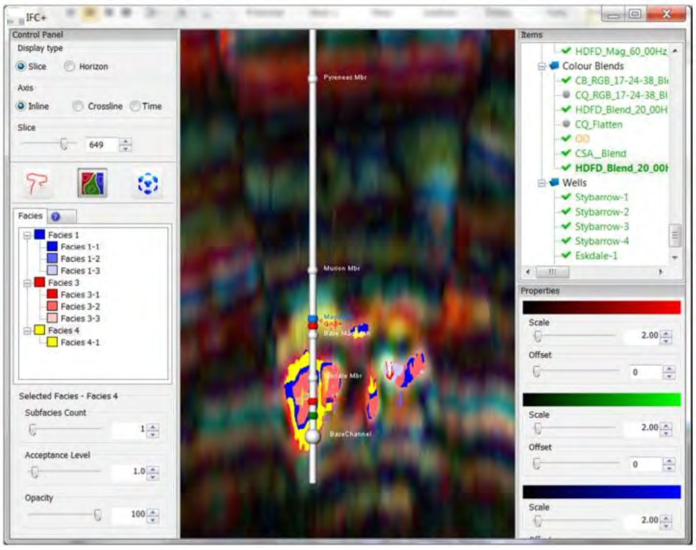
5. In the Sample Area tab, press Add a sample based on a pair of well markers.



6. Select the **Source Well** and the two well markers that will be used to constrain the interval of interest.



7. Press **OK** after making your marker selection. The facies classification will be automatically executed at this point, based on the selected volumes (**Items**).



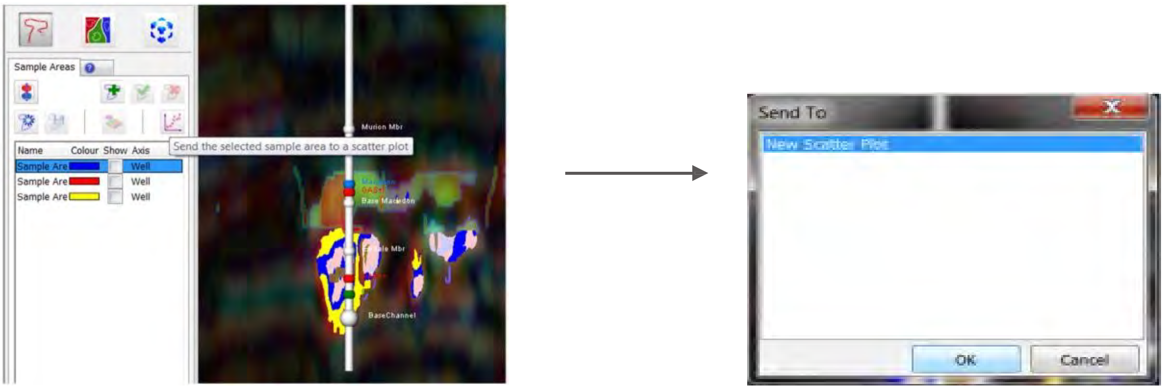
Note: It is also possible to view the facies distribution in Time/Depth slice and to scroll in inline/xline view. This is simply done by adjusting the Display Type (top left corner of IFC window).

8. After adjusting your facies and subfacies (**Subfacies Count, Acceptance Level and Colour**), you can create the full 3D seismic facies volume by pressing **Create Volume** .

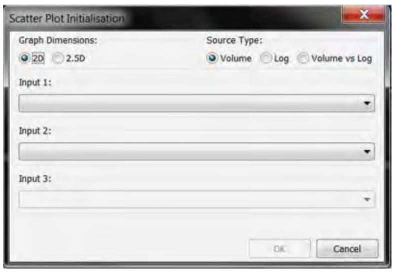
Generating Scatterplots for Quantitative Investigation

Don't close the IFC window yet, as you can now add your facies classes into a scatterplot to quantitatively investigate how accurate the separation of facies is, and how the facies relate to the geological data from your well logs. If necessary you can re-adjust your Acceptance Level and Subfacies count in order to fine tune your results, before generating a new 3D facies volume.

1. In the **Sample Areas** tab, select one of your Facies classes and then click on **Send the selected sample area to a scatter plot** (as pictured below). Then, select **New Scatter Plot**.



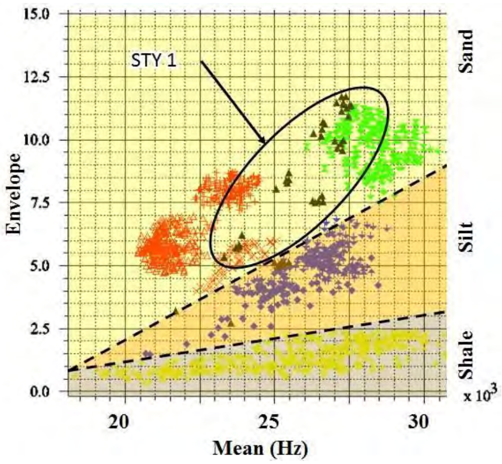
2. **Scatter Plot Initialisation** – it is possible to generate both **2D** and **2.5D** graphs. In the case of generating a 2.5D graph, **three** properties will need to be used. **Input 1** for the X axis, **Input 2 for** the Y axis and the coloured points on the graph will relate to **Input 3** (representing the Z axis).



3. It is possible to correlate the response of **Volumes**, **Logs** and **Volumes** vs **Logs**, within the marker interval or polygon area selected for your initial classification.

4. To add new facies to already existing scatterplots, select the desired facies (from the main IFC window) and click **Send the selected sample area to a scatter plot** and then select the scatterplot you wish to add it to (from the list of options).

Below is an example of a scatter plot showing a distinct facies separation between the individual classes. The volumes that are used in the scatter plot can be the same or different to those used in the initial classification. In this example the rock properties have been added by the interpreter using local and nearby well information. Using this calibration will allow you to effectively gain a better understanding of the facies classified using IFC.



What next?

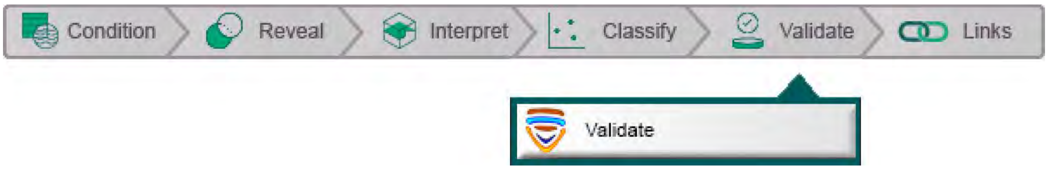
This workflow suggests the best practice approach for carrying out seismic facies classifications. Remember, the classification is not limited to colour blends only, and you can include additional attributes into your classification.

Model the seismic and RGB responses in Validate

Validate

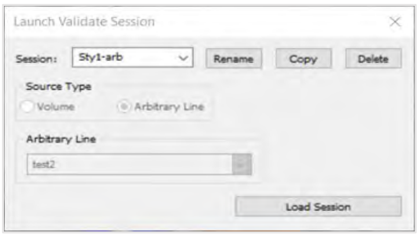
Forward modelling

Validate is a seismic forward modelling module, designed to allow interpreters to quickly and easily test how different geological and geophysical scenarios might affect the seismic response seen in the real data in terms of amplitude, phase, and frequency decomposition colour space.



Getting Started

1. Open the Validate module from the main menu.
2. Give your session a name.
3. Select either a volume or arbitrary line for modelling.



A. Determine inline/crossline to display if using a volume or choose Go to Well Slice.

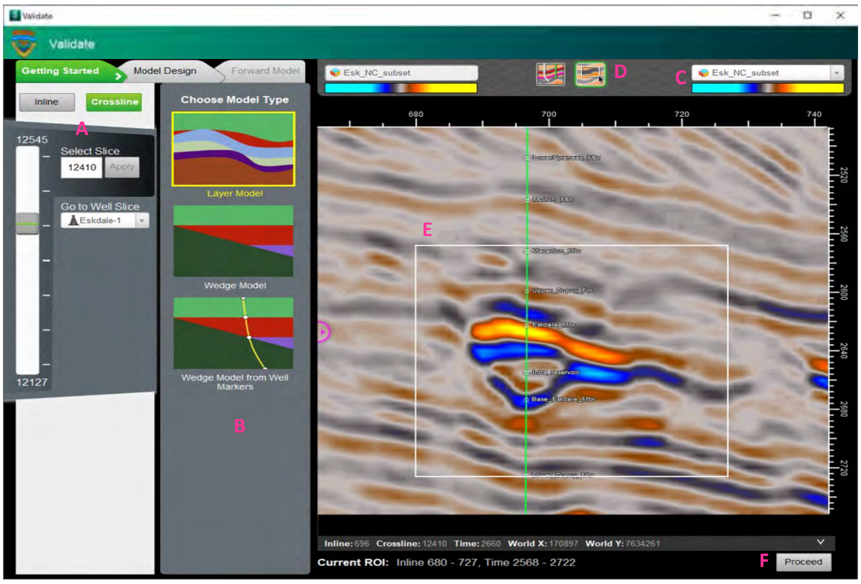
B. Determine type of model – Layer, Wedge or Wedge from Well Markers.

C. Select volume to display

D. Overlay horizons and wells.

E. If creating a Layer model – draw area of interest.

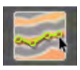
F. When area of interest for layer model is drawn or the wedge is set – Proceed to the Model Design tab.



Layer Model

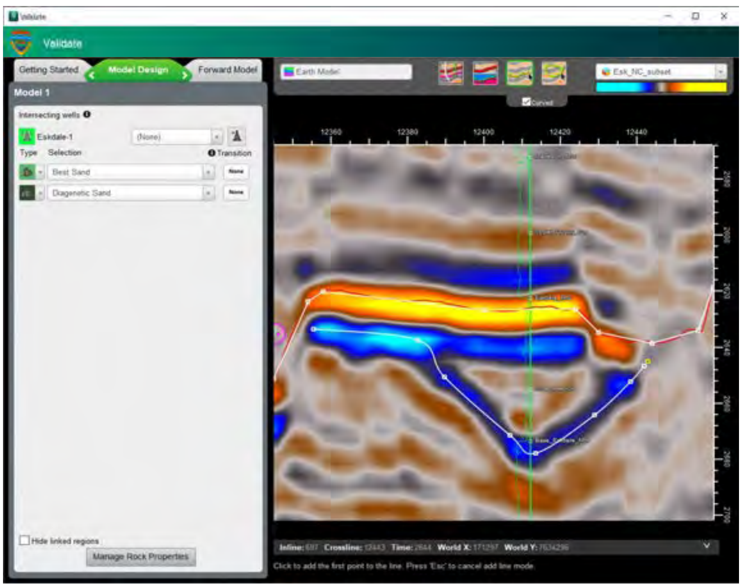
Layer models are used to test different scenarios in the seismic data. The user has the ability to draw layers from the seismic or use horizons to create layers. Each layer can be populated with different rock properties that are either entered in manually, calculated from the well logs, or extracted directly from intersecting wells. The rock properties can then be varied in the layer or in different models to test several hypothesis at once. Once the model is populated with rock properties, it is convolved with a wavelet to create a synthetic model. Then the Frequency Decomposition parameters from the project are applied to the synthetic model to create a synthetic RGB blend.


Create layers from horizons


Draw layers


Draw objects

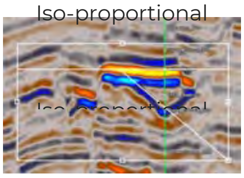

Overlay horizons and wells



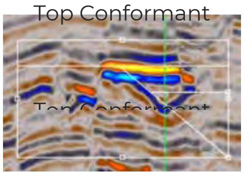
Wedge Model

Wedge models are used to correlate the thickness to RGB blend colours. The user can position a wedge manually or by using the well markers. Just like layer models, the wedges can be created from a volume slice or an arbitrary line. The layers are then populated with rock properties as above.

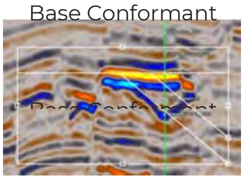
Iso-proportional

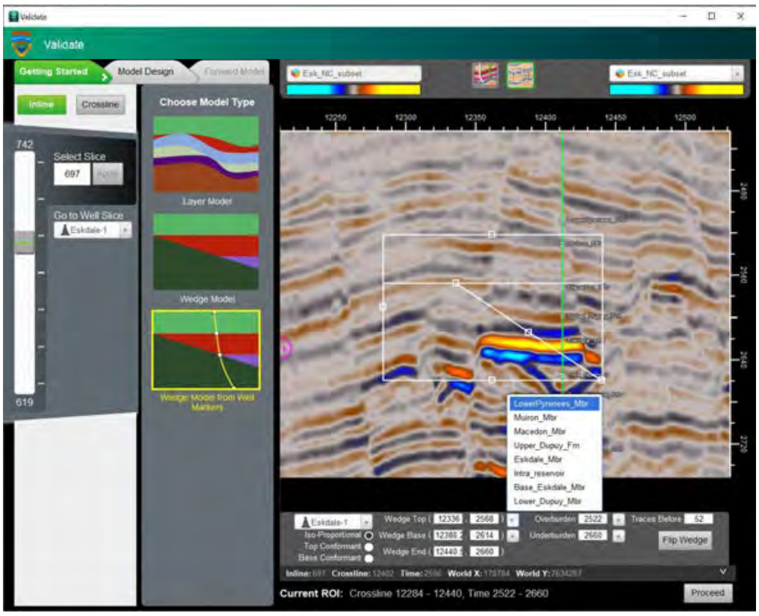


Top Conformant



Base Conformant





Rock Properties

There are several ways to enter the rock properties into the model

Manual rock

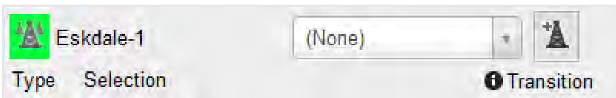
Well log set

Fluid Substitution set

Link layers

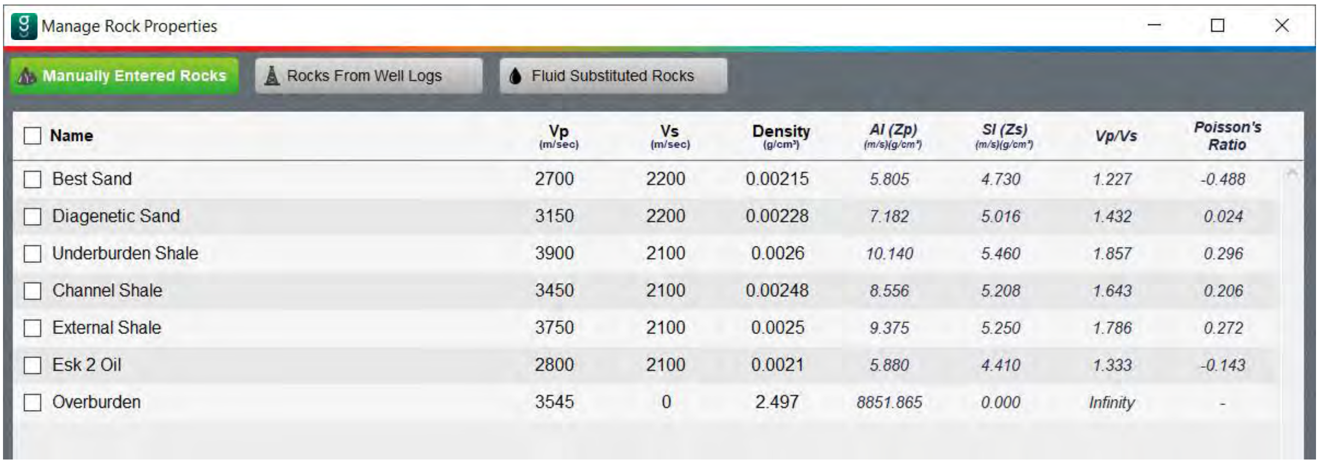
Well Group

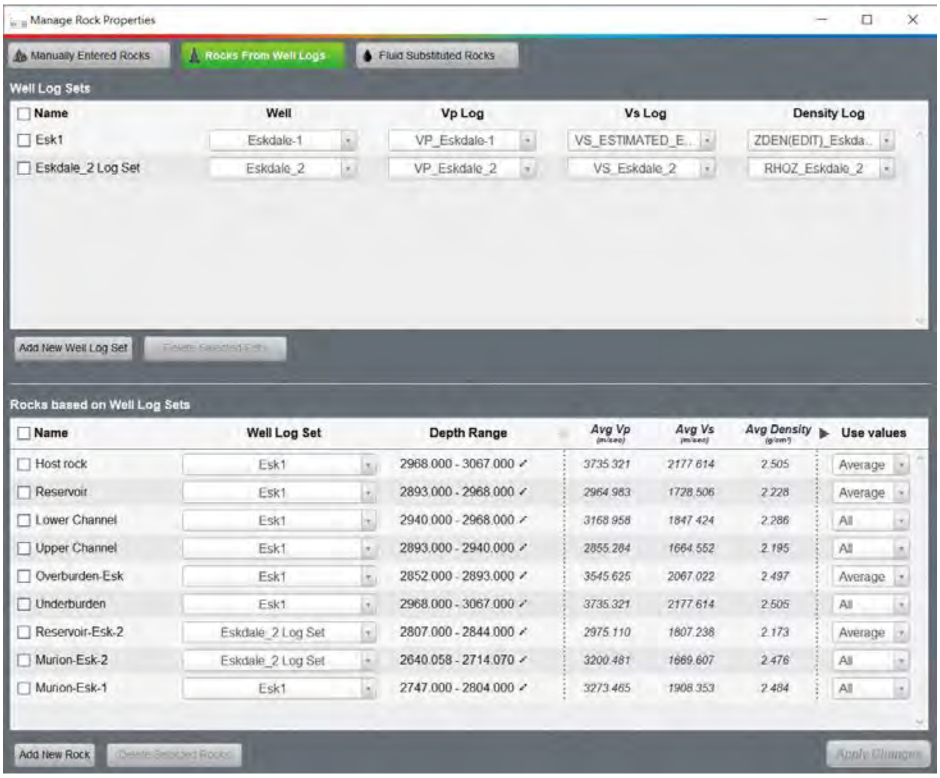
If a well intersects the inline or crossline displayed, the ‘Well Group’ option can be used to automatically extract properties from the well logs to the intersecting layers.



Manually entered rocks are defined from Vp, Vs and Density values in your area. Elastic properties will be computed from these inputs.

A default-set of generic rock properties based on values from Bourbie et al (1992) are provided, but it is suggested to enter in rocks based on your working area.





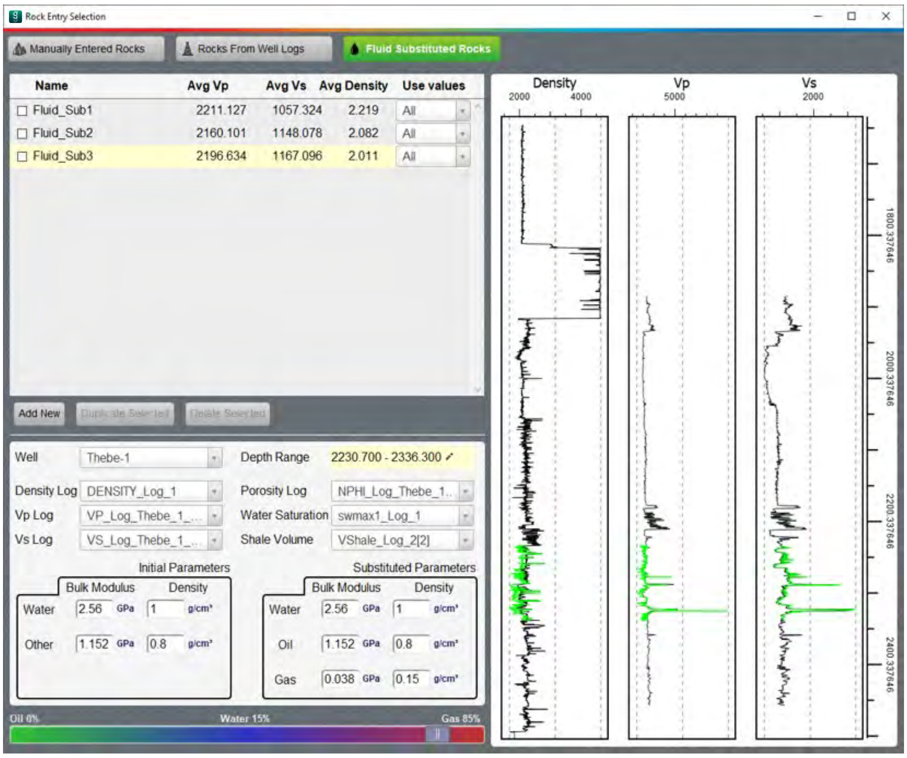
In the Rocks from Well Logs tab, Well Log Sets for each well can be created. Here the Vp, Vs and Density logs for each well will be set.

Below this, rocks from the Well Log Sets can be created.

- Add New Rock – name the new rock.
- Set which Well Log Set from which to take the parameters.
- Depth Range – this can be set from Well Markers in the project or from manually entering depth values.
- Choose either Average or All properties for that layer.

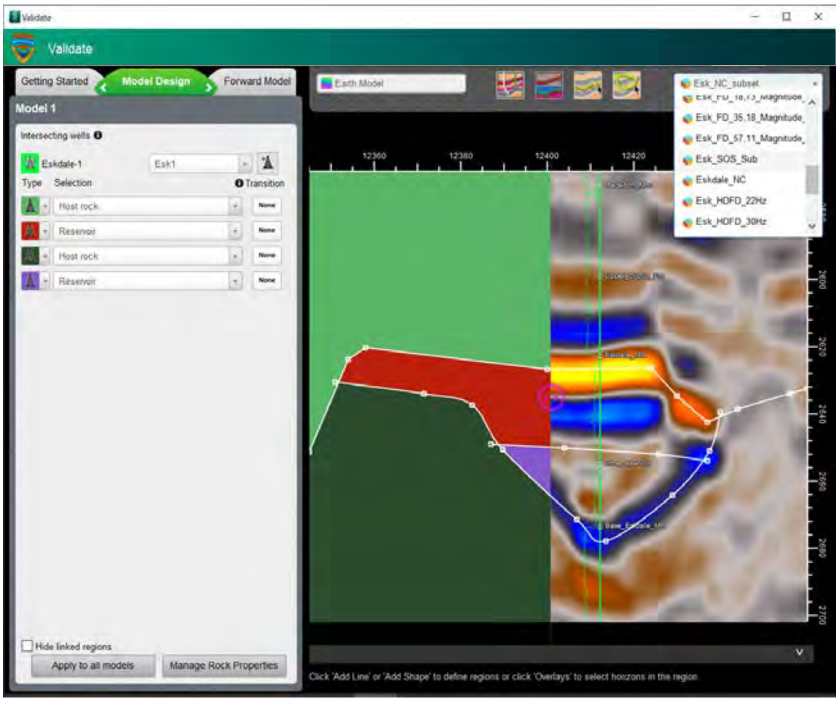
Fluid Substitution

- Fluid substitution can be done using a modified Gassmann equation (Simm, 2007).
- Additional logs needed – porosity, water saturation and Vshale
- Additional information – Bulk modulus and density of in-situ fluids and substituted fluids.
- In-situ logs – black
- Fluid subbed logs - green

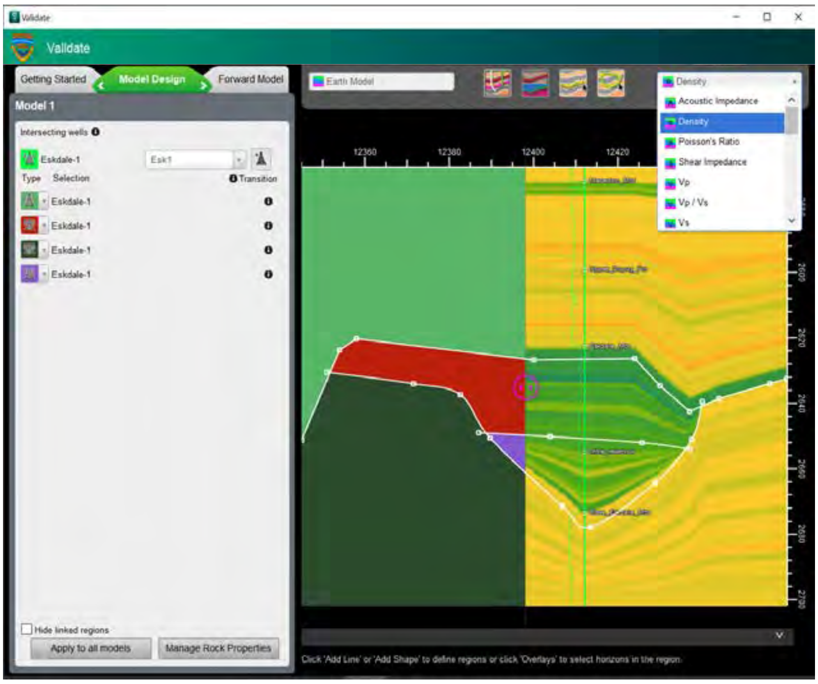


Views

- Once the layers are populated with rock properties, different views can be used to QC the model
- Any volume or blend in the project can be viewed.



You can also view the model properties; Vp, Vs, Density and Elastic properties

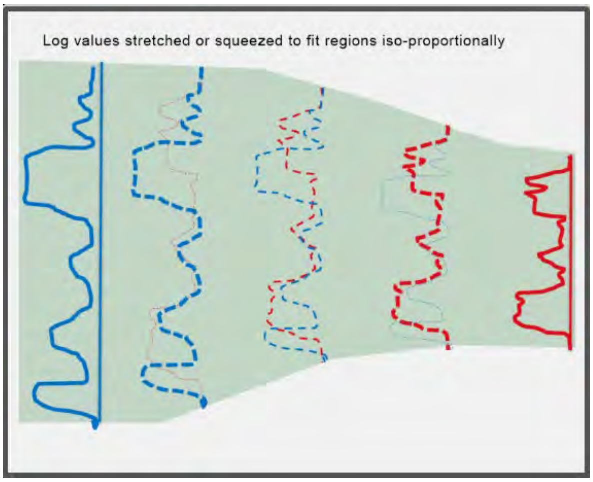


Transitioning Rock Properties

- If using Manual rocks or Rocks from Well logs
- Transition layers vertically or horizontally

Transitioning rock properties

- Well Group Information
- Log values stretched or squeezed to fit regions
- Weighted average taken for each log and used to create the variable density result



Forward Model

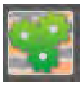
This is the stage when we convolve the reflection coefficients from the geological model (derived by use of Aki-Richards, 1980 equation) with a seismic wavelet at any single angle of incidence or range of angles to generate a synthetic seismic result.

Trace correlation – graphical display of the similarity between the synthetic and the real trace. Normalised value between -1 to 1.

Wiggle display – wiggle trace overlay for the synthetic seismic

Tuning graph (wedge model only)

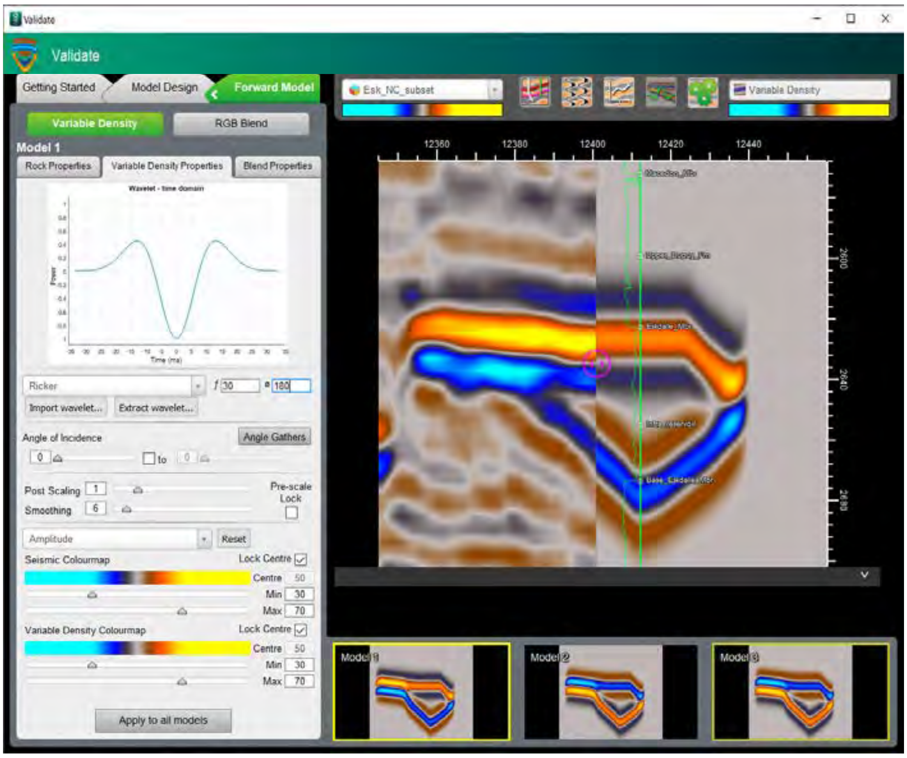
Wedge thickness (wedge model only). Supply a velocity for depth values.

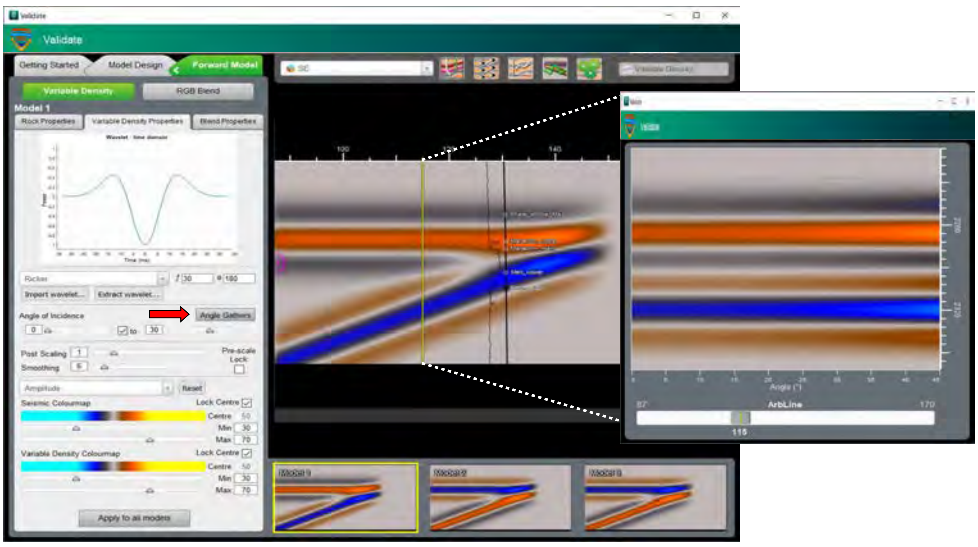


Send model results to the project – final step for visualising in the 3D scene

Variable Density

- Enter a wavelet – Ricker, imported or extract from the data
- Ricker wavelet set the frequency and phase
- Able to set the Ricker wavelet to have a specific angle of incidence
- Import wavelet – from Petrel or ascii file with the format of time:value
- Variable Density Post scaling – change the post scaling that is applied to the synthetic to better match the seismic input
- Pre-scale lock - When toggled on this will prevent the pre-scaling from automatically re-calculating should any adjustment be made to a model





Angle Gathers

This button enables a pop-up window which displays the angle gather for any trace within the model. Simply drag the yellow bar on the model or the slider at the bottom of the gather window to select the trace. The gather will display AVA behaviour from 0°to 45° for any reflecting interface along the trace.

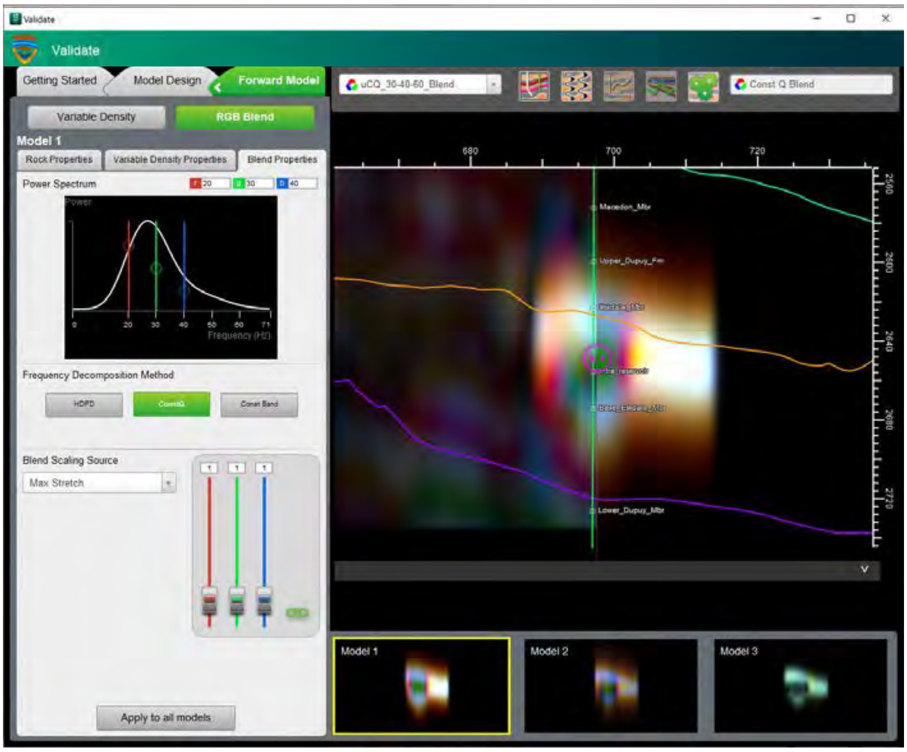
To test several scenarios, the rock properties, variable density and RGB properties can be changed between the 3 models

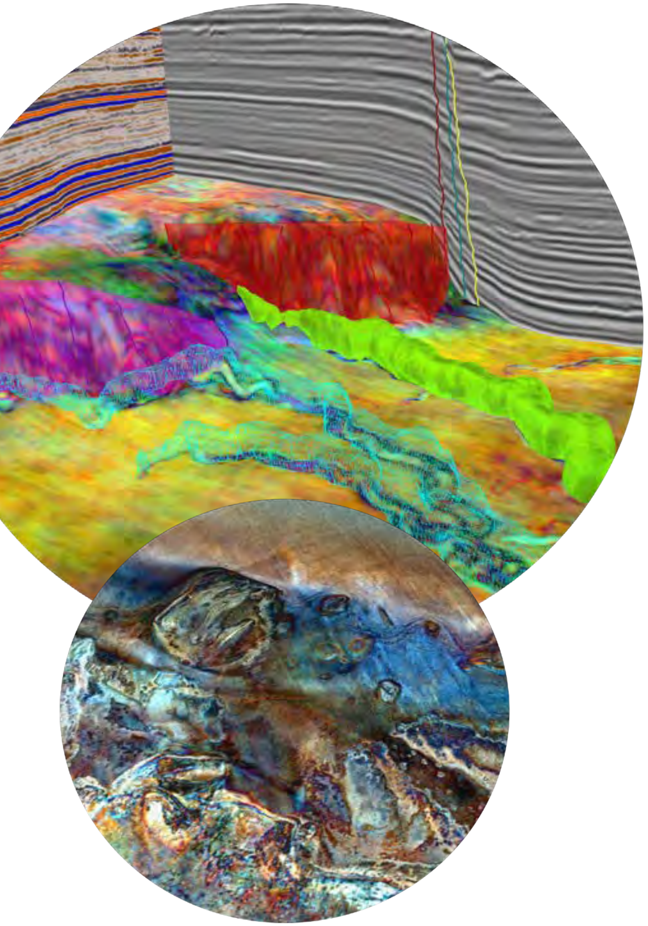
Or *Apply to all* models so that all 3 are the same

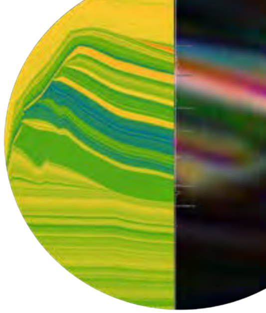
You can go back and change an option at any time

Frequency Decomposition RGB Blend

- Set the type of Frequency Decomposition – HDFD, Constant Q or Constant Bandwidth
- Set frequency bands used in the project
- Set Blend scale – it is recommended to start with max stretch
- Adjust Post Scale options







Hotkeys

Project

Ctrl + N	start a new project
Ctrl + O	continue an existing project
Ctrl + M	open project manager
Ctrl + Q	quit

Main 3D Window

Home	Z slice view along Z axis
Ctrl + R	reset ROI/extents enable/disable
Ctrl + G	orthographic camera
F4	full screen mode toggle
Ctrl + C	copy screenshot to clipboard
Ctrl + Alt + O	open opacity editor
Ctrl + P	toggle interactive or viewing mode
Ctrl + B	base map
Ctrl + I	2D interpretation window
Ctrl + W	report view
Alt + H	horizon interpretation
Alt + F	fault interpretation
Alt + G	Adaptive Geobodies™
Alt + A	arbitrary line picking
Alt + P	polygon picking
Alt + R	rulers
Ctrl + shift + F	search the project tree
Ctrl + F	open the filter window

Viewing Mode

Left mouse (hold)	over the volume to move the
Left mouse (hold)	current ROI
Alt + left mouse (hold)	over a ROI handle to resize the ROI
Alt + middle mouse (hold)	rotate the scene
Alt + left + middle mouse	translate the scene
(hold)	zoom in and out

Interactive Mode

Ctrl + Z	reset view
Left mouse (hold)	rotate the scene
Middle mouse (hold)	translate the scene
Shift + left mouse (hold)	translate the scene
Ctrl + left mouse (hold)	translate the scene
Left + middle mouse (hold)	zoom in or out
S	targeted zoom

Probe Controls

Ctrl + 1 or 3	increase/decrease ROI in X axis
Ctrl + 4 or 6	increase/decrease ROI in Y axis
Ctrl + 7 or 9	increase/decrease ROI in Z axis
1 or 3	move along X axis, steps of 1
4 or 6	move along Y axis, steps of 1
7 or 9	move along Z axis, steps of 1
Alt + 1 or 3	move along X axis, steps of 10
Alt + 4 or 6	move along Y axis, steps of 10
Alt + 7 or 9	move along Z axis, steps of 10

2D viewer

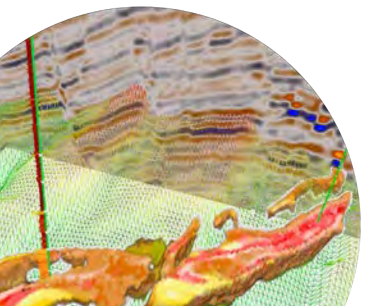
Left mouse (hold)	zoom in or out
Shift + left mouse (hold)	translate the slice
Ctrl + left mouse (hold)	translate the slice
Shift + middle mouse (hold)	translate the slice
Ctrl + middle mouse (hold)	rotate the slice

Adaptive Horizons™

Q	guided tracking
W	linear tracking
E	full line tracking
Shift + left mouse	to pick
Shift + right mouse	remove pick
L	complete a tracked line
Ctrl + D	delete all tracked points and interpreted points
D	clear tracked area
F	fill selected area
A	accept an interpretation

Adaptive Faults™

Q	guided tracking
W	linear tracking
Double left mouse	to end pick
A	accept interpretation overlay
P move the seismic slices	as a stick
H or Alt (hold)	move the scene
F	create new fault sticks
E	edit fault sticks
S	select to activate and extend
G	join two fault sticks together
D	delete fault sticks
R	cut fault sticks into two
M	move fault sticks active set
V	create new fault-set
L	stick extract on slice
O	stick extract on volume
C	toggle fault stick clipping
Z	linear surface mode
X	data following surface mode
F5	refresh preview surface
,	activate previous fault-set in the project tree
.	activate next fault-set in the project tree as a stick



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