MPSI™: Plugin to OpendTect

Manual (Version 1.4)

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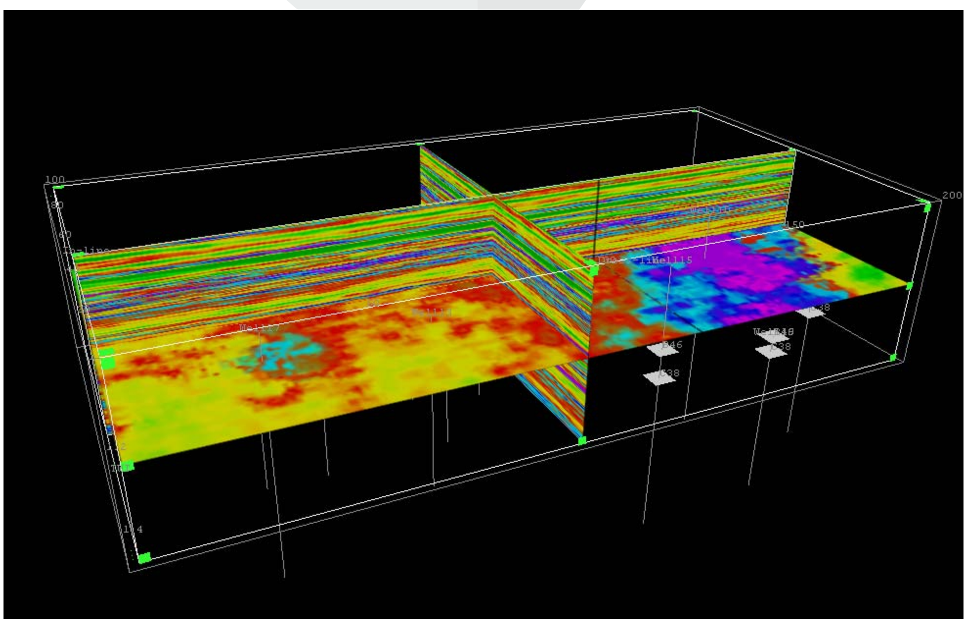


CONTENTS

1. GETTING STARTED

1.1 Introduction

The Earthworks OpendTect plugins are collectively called MPSI™ and include deterministic and UltraFast stochastic seismic inversion. Whether deterministic or stochastic the inversion procedure is model-based. A 3D broad-band impedance model of the sub-surface is constructed using well and picked seismic horizon data. Geostatistical gridding (kriging) is constrained by 3D anisotropic variograms. In addition, the user specifies a 2D error grid which is used to provide spatial variation in the constraints used in the subsequent seismic inversion. The error grid is a geostatistical standard deviation map based on the wells. The user can specify the relative importance of the seismic data and the model in the inversion, allowing the model to take priority close to the wells (where the impedance is known) and to relax the model constraint and use more seismic information away from the wells.

Using a 3D impedance model and error grid, subsequent inversion can be either deterministic or stochastic. In a deterministic inversion the objective is to estimate the unique mean or average impedance, based on least squares linear inversion. In a stochastic inversion the goal is to estimate a set of realisations of impedance representing the uncertainty in the seismic inversion. The impedance realisations from stochastic inversion can then be used to estimate the uncertainty in reservoir properties such as lithology or porosity in the form of probability maps and volumetric uncertainty. The stochastic realisations can be used to estimate reservoir connectivity and associated connected or swept volume uncertainty. It is possible also to output Net to Gross or Net Thickness maps from stochastic realisations. The stochastic inversion menu provides a comprehensive suite of utilities to allow the user to analyse the realisations in this way.

1.1.1 Workflow

The 3D Model Builder provides access to the screens allowing you to create your 3D model which provides the starting point. Prior to running the tools, the user should ensure that the relevant data such as Wells, Horizons, Wavelets and Seismic volumes reside within the OpendTect environment. Therefore, as the first step to running the application, the user should perform the following activities.

1. Set up your survey to contain the relevant seismic volumes, wells, wavelet and horizons that you intend to use. Note that the Earthworks plug-ins assumes that the wells are tied and the horizon picks are clean, final picks. Also, for deterministic or stochastic inversion a wavelet is required and should be loaded using the OpendTect wavelet import option or derived using the OpendTect Well to Seismic Tie module.

2. Define the 3D Model details you intend to use by creating a EW3DModel attribute

3. Define the spatial constraints you intend to use by creating the relevant attribute type for example EW2DErrorGrid attribute for defining your 2D error grid details.

4. Define the specific inversion details by creating the relevant attribute for the type of inversion you require: either EWDeterministicInversion for a

deterministic inversion or EWStochasticInversion for a geostatistical inversion.

5. Perform the inversion through the selection of the attribute you have created within the previous four steps.

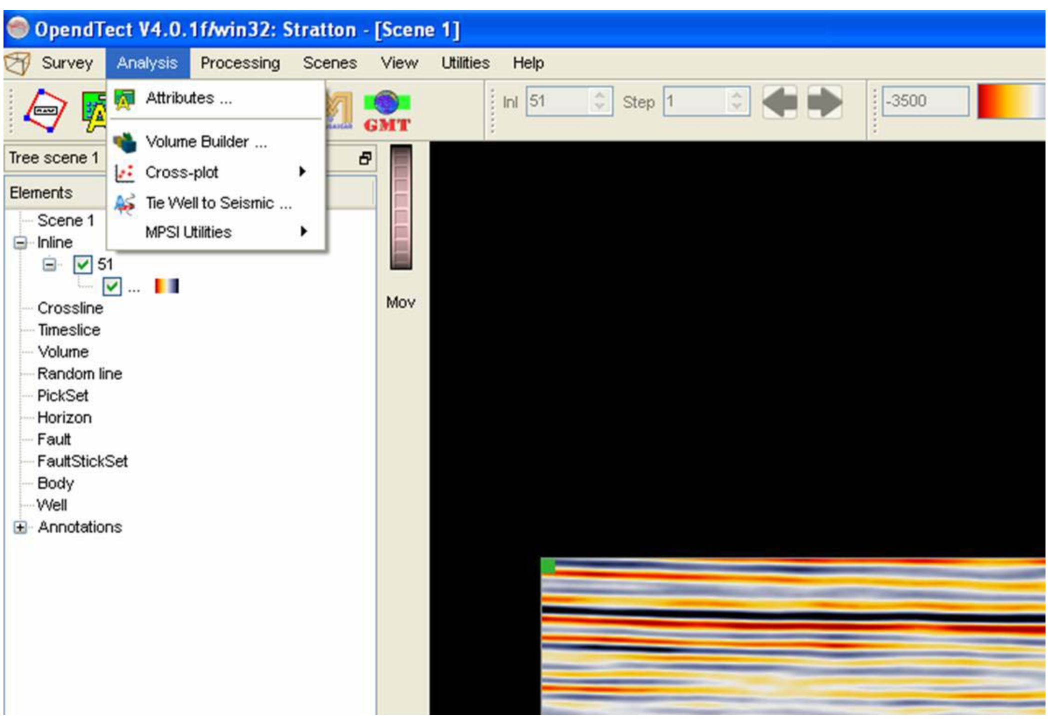
OpendTect is an Attribute based engine. Attributes are saved in an Attribute Set and can be accessed via the Attribute-set Window. We will recommend any new OpendTect user to read the main OpendTect User Documentation to get familiar with OpendTect system. An OpendTect Attribute can be seen as a parameter set containing the basic settings to compute or derive a Seismic Attribute. The real computation can be done on-the-fly (on in-lines, cross-lines or time slices) or in batch. The main difference between the 2 options is that on-the-fly computation doesn't store the output in the database (Attributes are kept in memory). On-the-fly computation is very useful to evaluate parameters before processing the whole cube in batch. Attribute Processing is done on a trace by trace basis. MPSI OpendTect plug-ins uses the same architecture except for the Connections™ and Net to Gross modules that takes their input data from pre-process cubes and the Stochastic Inversion pre-processing. The Stochastic Inversion pre-processing is done in full 3D using the boundary defined in the OpendTect Work area (View->Work area) and trace spacing and time range defined in the OpendTect Survey.

A worked example is provided below in section 10.

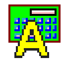
1.1.2 Attributes options

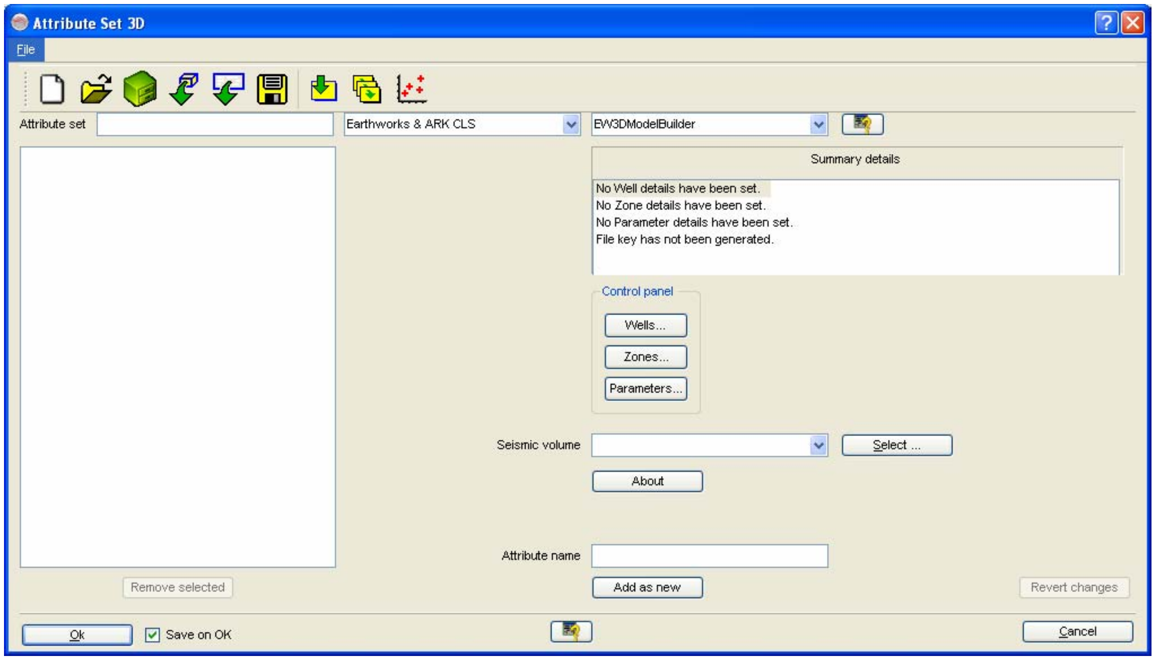
The Attributes are accessible through the pull-down menu `Processing` along the top of the window

- **Click `Analysis`**



➢ **Select `Attributes`…**

Alternatively, click the attribute icon  on the tool bar



A generic part of the 3D attribute set involves a range of buttons along the top of the window:

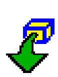
The attribute set toolbar contains icons to open, save and apply attribute sets.

 or *File - New set* clears the window to create a new attribute set. The attribute set name can be specified when you save the set (press *OK*, or select *File - Save set* menu option).

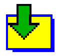
 or *File - Open set* opens a previously saved set in the current project (from the directory Attribs/).

 or *File - Save set* saves the "active" attribute set in the Attribs/ directory of the current project.

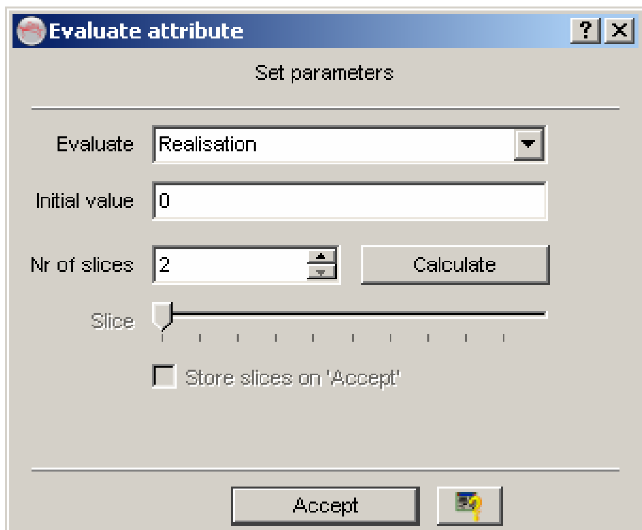
 opens a default attribute set. Filenames for input data must be re-specified.

 imports an attribute set from another project. Filenames for input data must be re-specified.

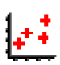
 reconstructs set from job file.

 *Swift* icon for direct display of the selected attributes with the current attribute parameters. The selected attribute is applied to the active display element (shown in reverse video in the tree). The main graphic interaction buttons and options remain active while the Attribute Set window is open, so you can change the active element.

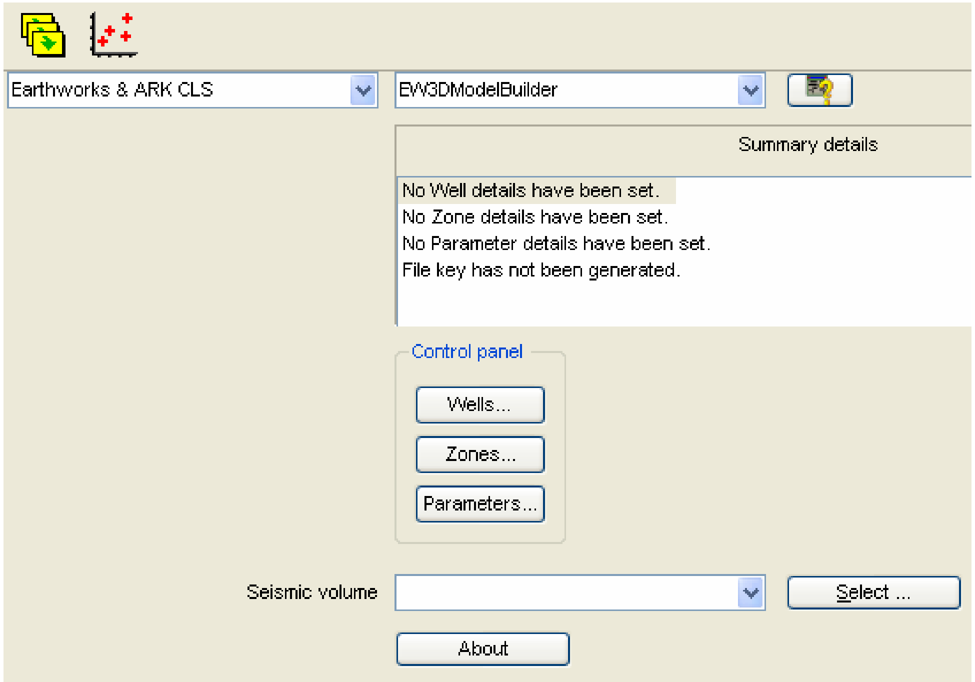
 Automatic variation and evaluation of attributes and attribute parameters. If you have an "active" attribute and the current display element is a slice (inline, crossline or time slice) or a horizon, a new window will pop up in which you can specify how to vary the parameters of the displayed attribute.



Here the realisation can be evaluated by setting the initial value to be 0 (first realisation) and the number of slices (realisations). Once the calculate button is clicked OpendTect calculates the realisations and then the slider can be used to instantly move through all the slices.

Crossplot Attributes. On pressing this button, you can choose attributes to crossplot. Multiple attributes can be selected. The attribute values are extracted at picked locations. Once attribute values are calculated, the crossplotting table opens.

- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EW3DModelBuilder`**



The items below are available for selection under the pull-down menu in the attribute set. Those options available may be restricted to the Earthworks plugin by using the first pull-down menu and selecting `Earthworks & ARK CLS`. The items below are described within the sections that follow.

- 3D Model builder (Wells and Zones)
- 2D Error grid
- Deterministic Inversion
- Stochastic Inversion
- Post-inversion Utilities
- Volumetrics and Connectivity
- Net to Gross Module

1.2 3D Model Builder

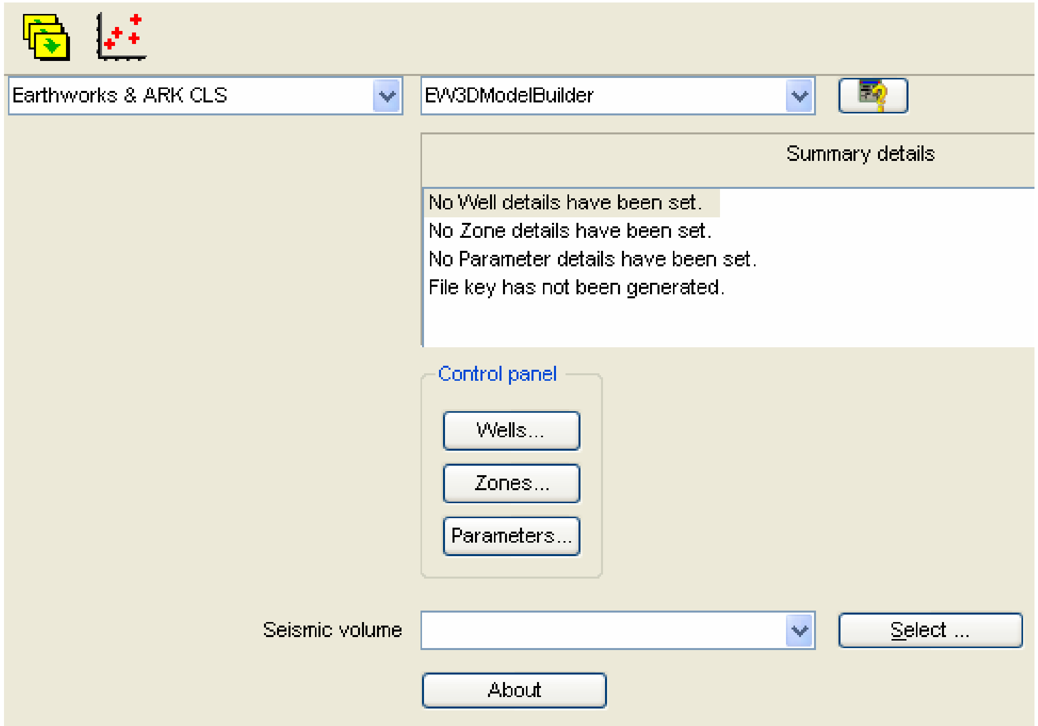
This is the first stage for running Earthworks inversion applications and must be completed before the other components.

The 3D Model builder allows you to customize your inversion process and create the Inversion attribute tailored to your needs. This attribute is created in the standard OpendTect Attribute Set Window which is launched from the `Analysis` pull-down menu (as described above).

Once the Earthworks 3D Model Builder attribute has been selected the user is provided with a window for including information about the wells, zones and parameters that are accessed from the EW Control panel.

- **Click `Analysis`**
- **Select `Attributes`...**
- **Change `All` to `Earthworks & ARK CLS`**

- **Select `EW3DModelBuilder`**

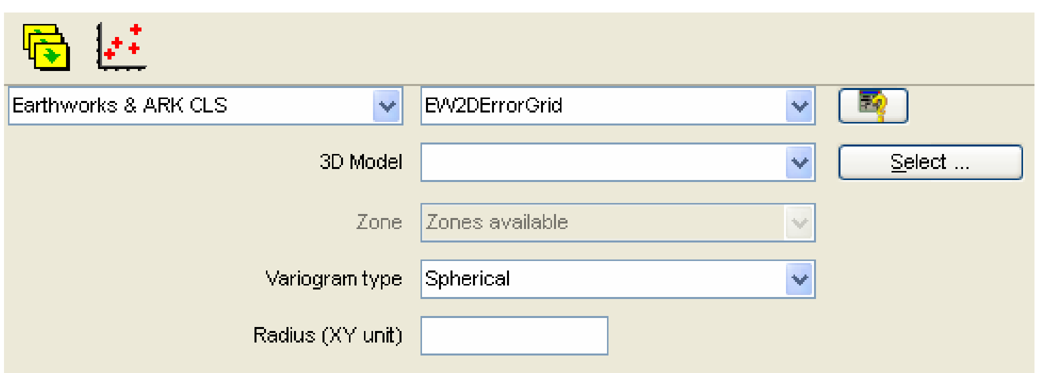


Each option will launch a window to obtain from the user the specific input values that are required to construct the model. Each window must be visited in order to confirm the exact details to be used within the 3D model being created. Thus, there are three stages in setting up the model.

1.3 2D Error grid

This menu option enables the definition of the 2D error grid it requires the user to select the 3D model, select the zone as appropriate, choose a model of spatial correlation (variogram type) and the radius of influence (range of the variogram).

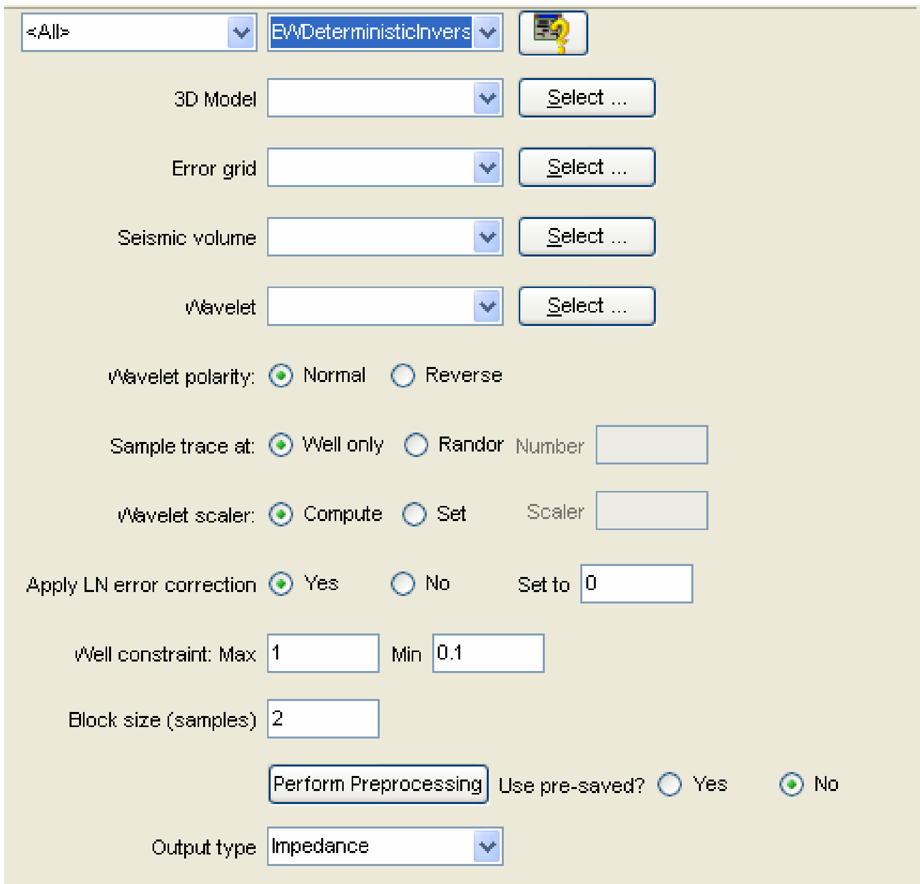
- **Click `Analysis`**
- **Select `Attributes`…**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EW2DErrorGrid`**



1.4 Deterministic Inversion

This selection requires the user to select the 3D model, the error grid, seismic volume and the wavelet and to choose the block size, the maximum constraint at each well and the maximum constraint far from each well.

- **Click `Analysis`**
- **Select `Attributes`…**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EWDeterministicInversion`**

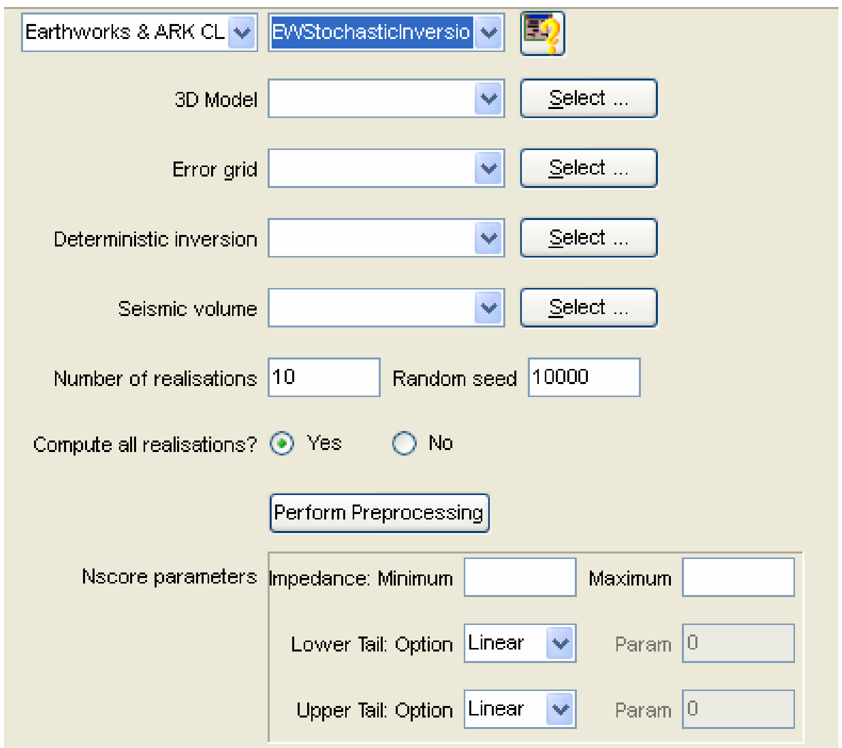


The user is given the option to compute the seismic and model scalars at the well location only. If the user selects `No` they are required to include the number of traces to sample. Similarly the user is given the option to automatically compute the wavelet scalar. If the user selects `No` they are required to include the wavelet scaling used in the computation. The user is also given the option of whether to apply the LN error correction or not. Options to output impedance, synthetic seismic or residual error traces are available. Options set in the Deterministic inversion panel also affect the stochastic inversion module.

1.5 Stochastic Inversion

As above, this selection requires the user to select the 3D model, the error grid and the seismic volume. In addition, the user is required to include the deterministic inversion. The user is required to enter the number of realisations and to decide whether to compute all of them. A random seed is entered to initiate the Monte Carlo process. A number of the inversion parameters required by the stochastic inversion are automatically obtained from the selected Deterministic Inversion attribute set.

- **Click `Analysis`**
- **Select `Attributes`…**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EWStochasticInversion`**

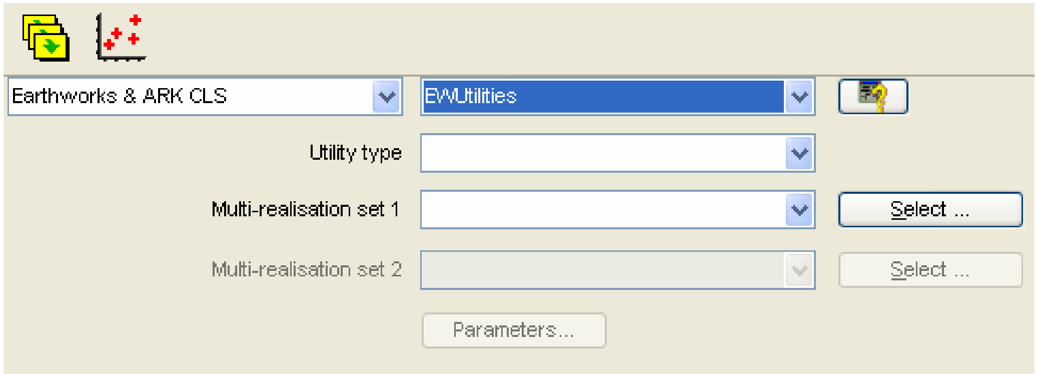


The stochastic inversion requires knowledge of the normal score transformation applied to the data: min and max values and lower and upper tail options.

1.6 Utilities

This selection calculates various outputs than can be generated from a set or two sets (joint) stochastic inversion realisation.

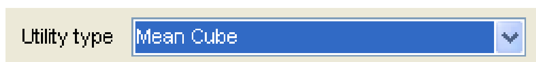
- **Click `Analysis`**
- **Select `Attributes`…**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EWUtilities`**



1.6.1 Mean Cube

This selection calculates the mean of the realisations previously calculated during the stochastic inversion.

- **Select `Mean Cube`**



1.6.2 Std Cube (Standard Deviation)

This selection calculates the standard deviation of the realisations previously calculated during the stochastic inversion.

- **Select `Std Cube`**

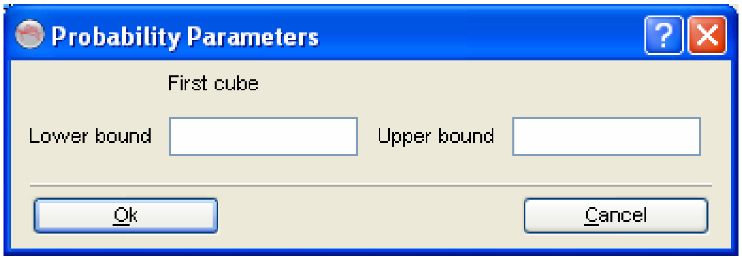
1.6.3 Probability cube

This selection requires the set of realisations from the stochastic inversion for use in the calculation of a probability cube between lower and upper bounds.

- **Select `Probability`**

- **Click on `Parameters…`**

Specify the probability range.



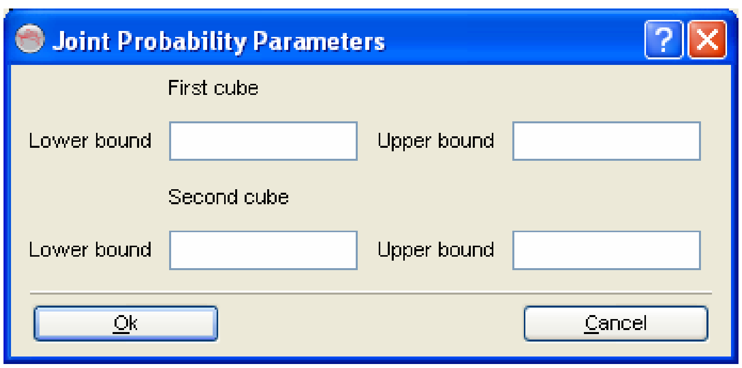
1.6.3.1 Probability cube joint

In this selection the set of realisations from one stochastic inversion are combined between lower and upper bounds with those of a second set of realisations between lower and upper bounds in the calculation of a probability cube.

- **Select `Joint Probability`**

- **Click on `Parameters`…**

Specify the probability range.



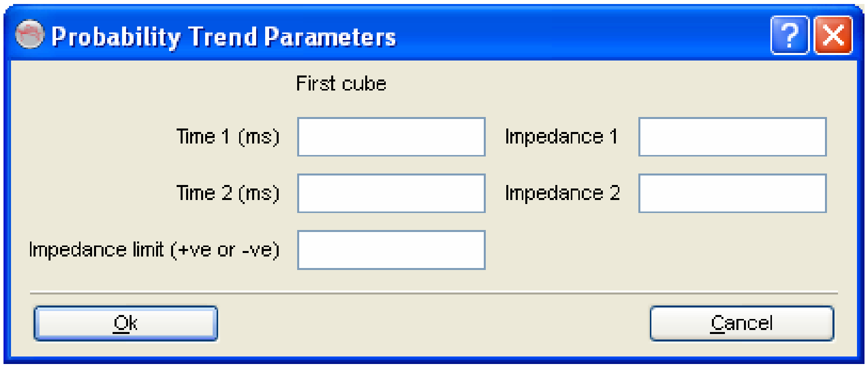
1.6.3.2 Probability cube trend

This selection also requires the set of realisations from the stochastic inversion for use in the calculation of a probability cube but instead of being between fixed upper and lower bounds the probability is calculated for a given trend in time and impedance.

- **Select `Probability Trend`**

- **Click on `Parameters`…**

Specify the probability range.



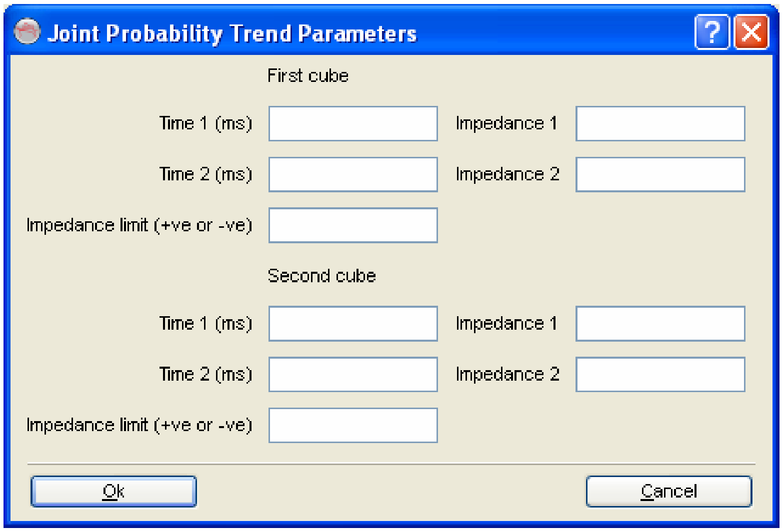
1.6.3.3 Probability cube joint trend

The final combination of options for the probability cube available to the user is the calculation of the joint trend. The set of realisations from one stochastic inversion are combined for a given trend in time and impedance with those of a second set of realisations for a given trend in time and impedance in the calculation of a probability cube.

- **Select `Joint Probability Trend`**

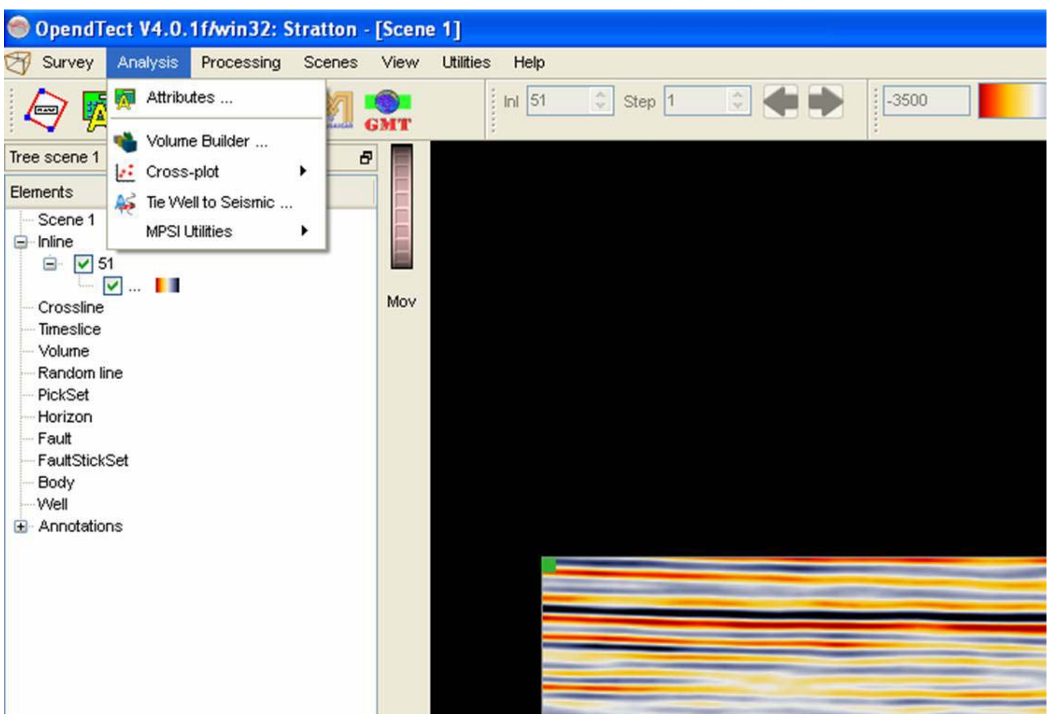
- **Click on `Parameters`…**

Specify the probability range.



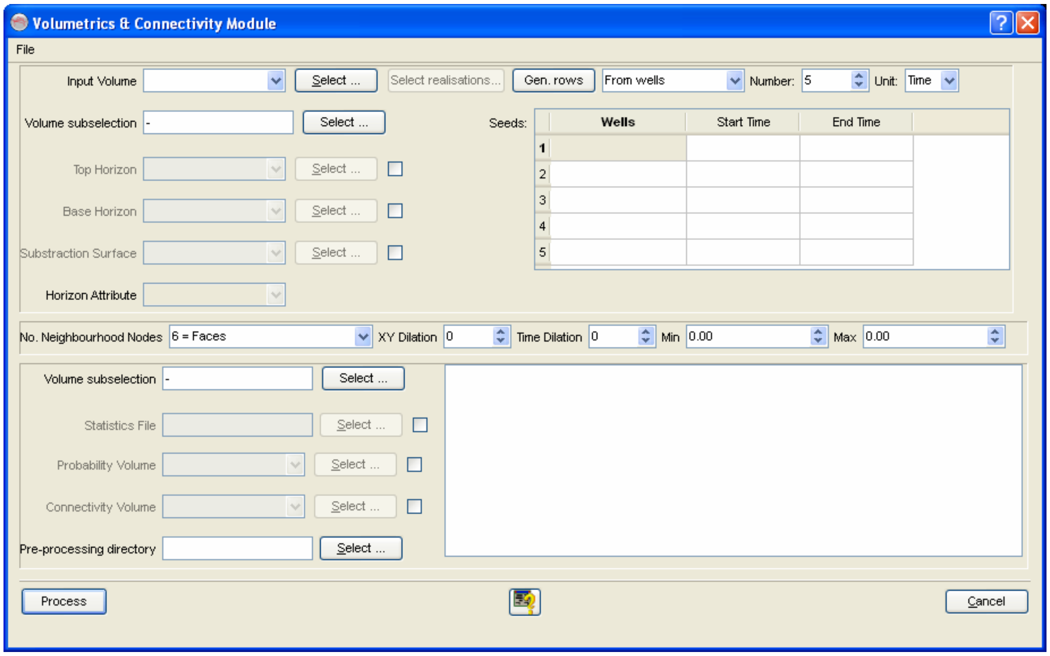
1.7 Connections™ Geobody Connectivity and Volumetrics

This plug-in is not configured as an attribute set (working trace by trace) but instead operates on complete seismic volumes using pre-saved realisations or inversion results. These volumes will have been processed and saved to disk using the OpendTect Analysis computational engine. The Connections™ module is therefore accessed from the OpendTect main menu and not as an Attribute set.



- **Click** `Analysis`
- **Click** `MPSI Utilities`

➢ **Select Volumetrics…**

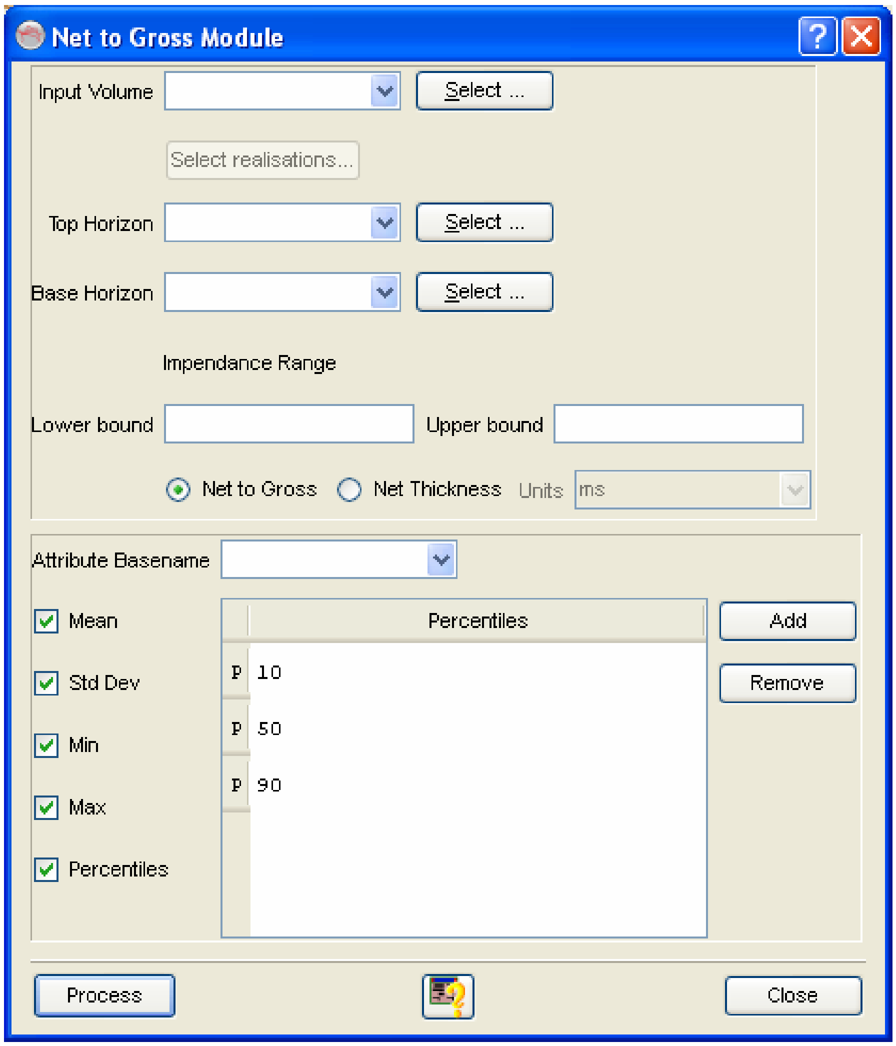


The algorithm will scan each realisation from a set of one or more seeds, and flag all nodes that are connected to these seeds for which the impedance is within the user-specified impedance range. . The output from this analysis could be any of:

- Probability cube (the probability of the nodes to be connected given a data range)
- 3D connected geobodies
- Reporting of the geobody statistics including
  - Per realisation:
    - Number of distinct geobodies
    - Total Connected Cells (volume)
  - Per geo-body:
    - The Total Connected Cells (volume)
    - Total XY Cells (area)
    - Maximum Time Thickness
    - Mean Time Thickness

1.8 Net to Gross Module

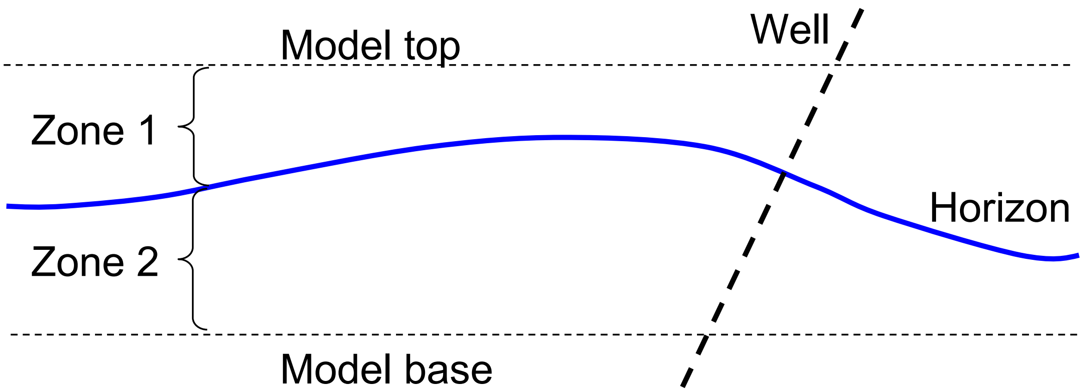
This plug-in is not an attribute set but instead operates on complete seismic volumes using pre-saved realisations or inversion results. These volumes will have been processed and saved to disk using the OpendTect Analysis computational engine. The Net to Gross module is therefore accessed from the OpendTect main menu and not as an Attribute set.



- **Click `Analysis`**
- **Click `MPSI Utilities`**
- **Select `Net to Gross…`**

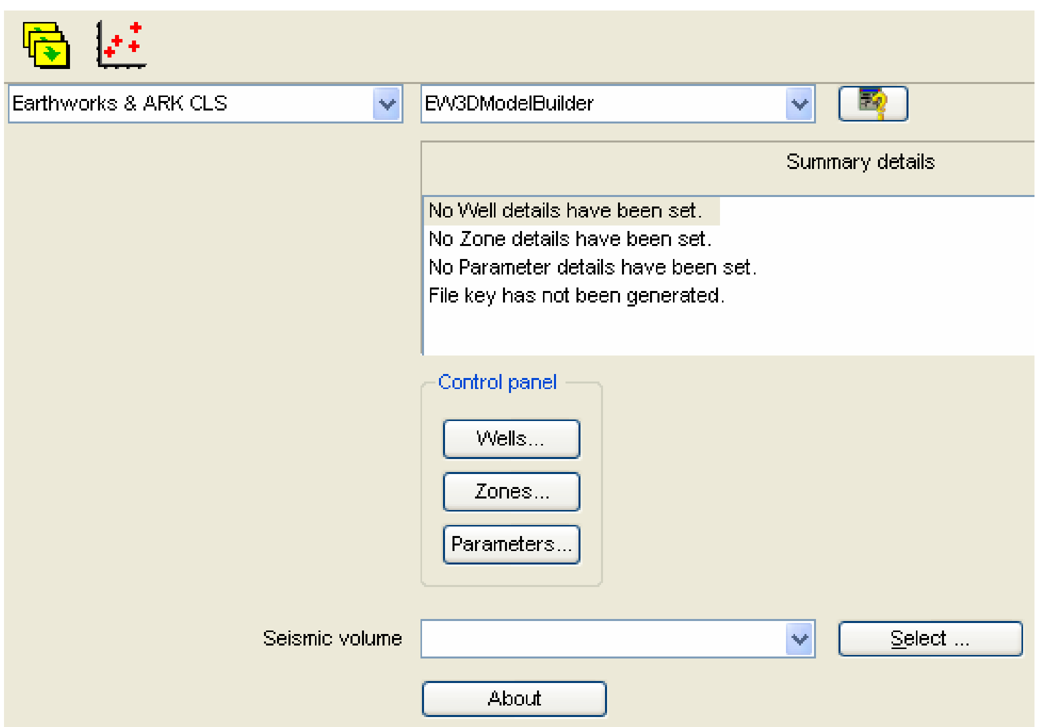
2. MODEL BUILDER 3D

The workflow to create an inversion impedance attribute is created in the standard OpendTect Attribute Set Window which is launched from the `Analysis` pull-down menu. The first step is to create a 3D impedance model. The 3DModelBuilder requires the user to select well data and to create stratigraphic zones for the model.



The Earthworks 3D Model Builder displays a Control Panel where the wells, zones and other parameters are selected.

- **Click `Analysis`**
- **Select `Attributes`…**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EW3DModelBuilder`**



Each control panel option will launch a window to obtain from the user the specific input values that are required to construct the model. Each window must be visited in order to confirm the exact details to be used within the 3D model being created. Thus, there are three stages in setting up the model.

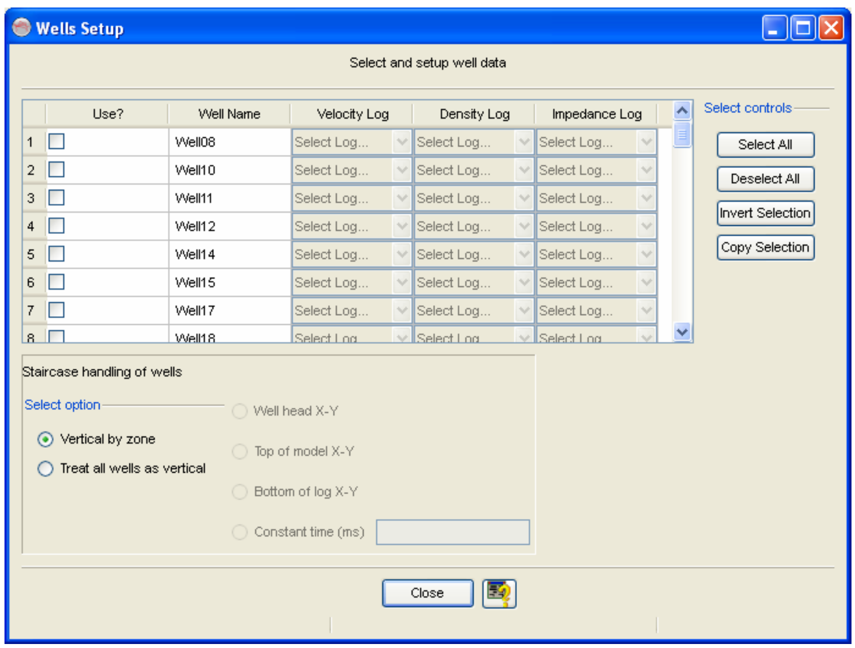
2.1 Selecting well data

Prior to setting any well data, you must ensure that

- All well data, deviation data, time-depth data and logs that you are intending to use for the model have been loaded to OpendTect

- Wells are correctly positioned in the time domain and properly calibrated and tied to the seismic data using the wavelet you want to use for the inversion

- **EW Control Panel**
- **Click `Wells`**

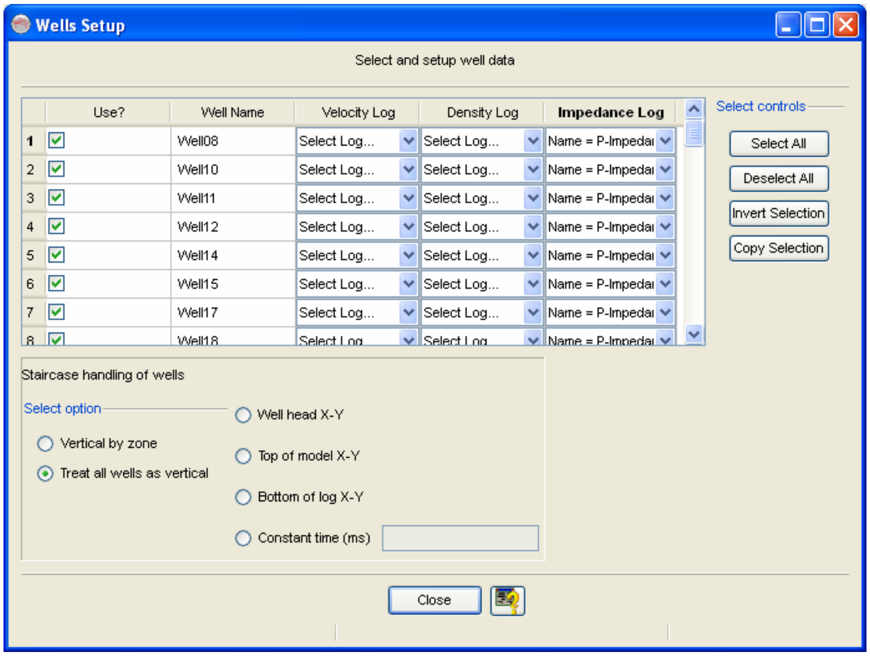


The Wells Setup panel lists all wells present in the database. Select the well details that are to be used for the 3D model being built. Wells are available for selection individually by selecting the checkbox in the first column or may be selected or deselected globally using the panel buttons on the right hand side. Once a well has been selected, any logs that have been loaded for that well will appear within the drop down menu items for that table entry. For convenience, once a well log is selected in a given column the selection can be applied automatically to the entire column by selecting the `Copy Selection` button on the right hand side, providing a log of the same name exists for other wells.

<u>*Either*</u> a single impedance log <u>*or*</u>, a velocity and density log pair must be provided for each selected well within this table. Once `Ok` has been selected well logs that contain null values will be identified and the user will be prompted to decide if he wishes to continue using the log or not.

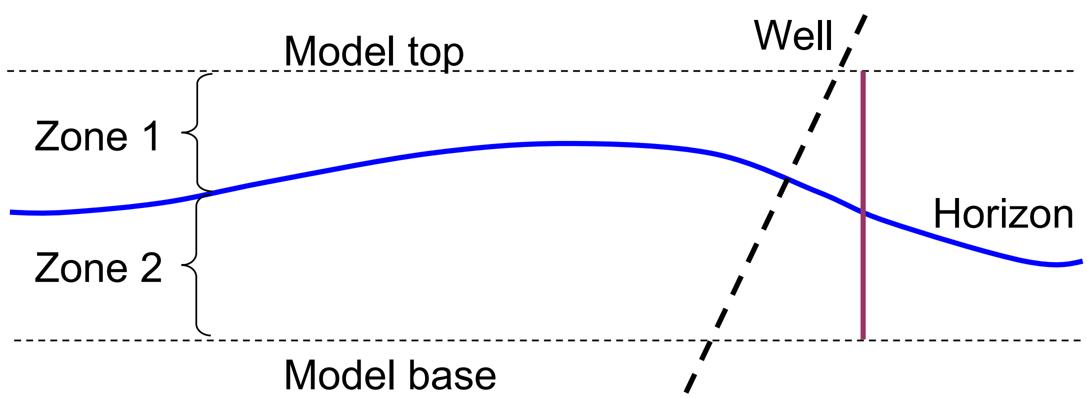
2.1.1 Well Deviation Handling & Staircase Options

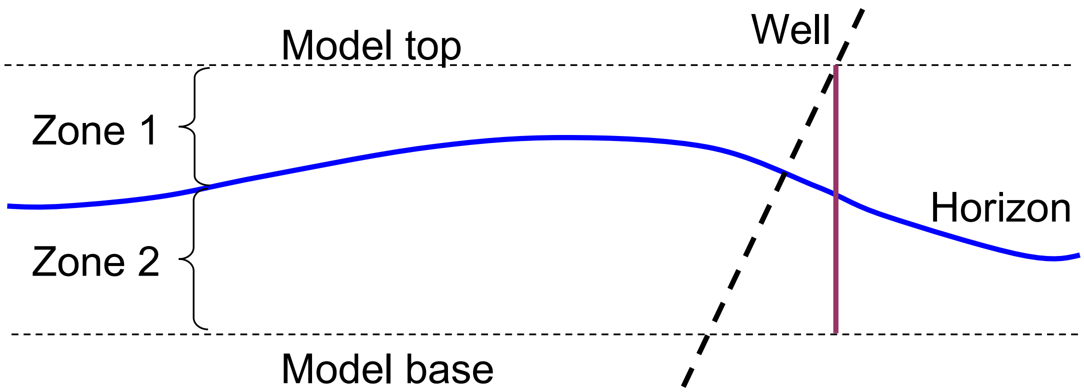
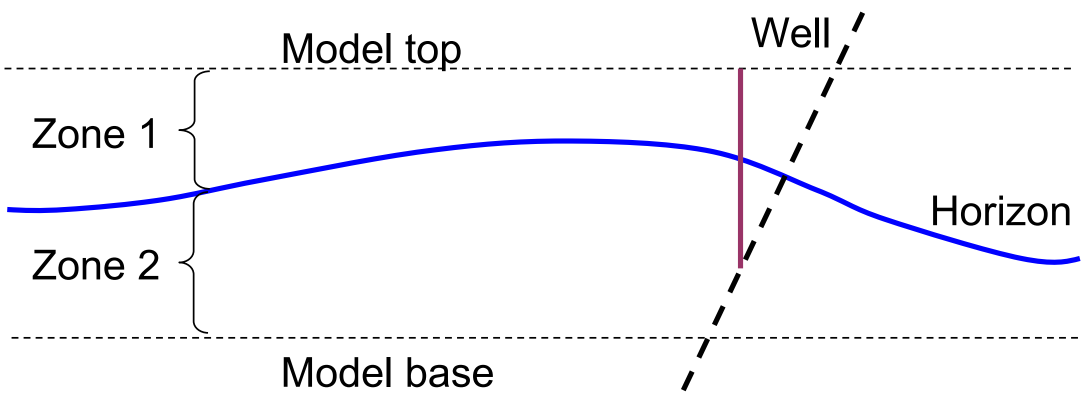
Staircase refers to the manner in which deviated wells are segmented during the construction of a 3D model. If the user accepts the default setting of `Vertical by Zone` wells will be divided into segments by zone and each segment will be treated as a vertical well within the zone (this is explained in detail below in section 2.2 Creating zone data).



If the user decides to `Treat all wells as vertical` the wells will be transformed to vertical continuously across the zones. This option requires the user to make a choice to determine the associated X-Y location for the wells:

Selected Item	Meaning	Effects
Well Head X-Y	Use the well head position	*If selected*, the software will assume the well is vertical within the model domain below the Well Head X-Y coordinates



<table>
<tr><td>Top of Model X-Y</td><td>Use the top of model position</td><td>If selected, the software will assume the well is vertical and positioned at the location of the intercept of the deviated well path with the top of the model.
Note that the top of the model is only defined when the model attribute is computed.</td></tr>
<tr><td colspan="3">
</td></tr>
<tr><td>Bottom of Log X-Y</td><td>Use the end of log position</td><td>If selected, the software will assume the well is vertical and positioned at the X-Y location of the last log sample. The figure below shows that this may be neither the model base nor the well base.</td></tr>
<tr><td colspan="3">
</td></tr>
<tr><td>Constant Time</td><td>Use the position at a constant two-way time</td><td>If selected, the software will assume the well is vertical and positioned at the location of the intercept of the deviated well path with a constant time slice across the model.</td></tr>
</table>

On successful selection of your wells and their corresponding well logs, a return to the main 3D Model builder screen will update the summary details.

2.2 Creating zone data

The second stage for setting up the 3D Model requires the creation of zones that define the region to which your 3D Model data applies. A zone is an interval within the model bounded by two picked seismic horizons or by one picked seismic horizon and the top or base of the model. A zone is used as a stratigraphic interval for the purpose of interpolating well logs laterally to create a 3D impedance model.

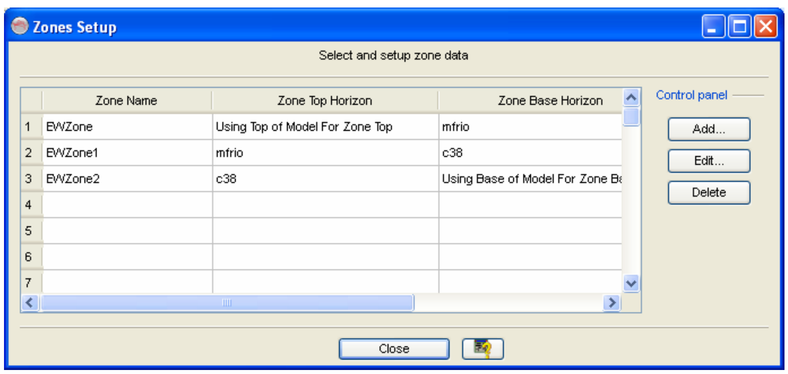
Prior to defining the zones you must ensure:

- All necessary seismic horizons required in the model are defined and prepared within OpendTect. Horizons should be continuous across the model area, have no pick errors and should not cross each other.

- You should have in mind the order of zones and the necessary horizons that are required to build these zones. You will be required to define the zones in order from the top to the base of the model.

The zones selection window is launched from the main 3D Model builder window

- ➢ **EW Control Panel**
- ➢ **Click `Zones`**



The 3D Model must have at least 2 zones created whose boundary regions are defined by seismic horizons already loaded.

There are three stages to the definition of zones:

1. Define the region boundaries by selecting a top and base component.

2. Define how the well staircase (verticalisation) is to be handled

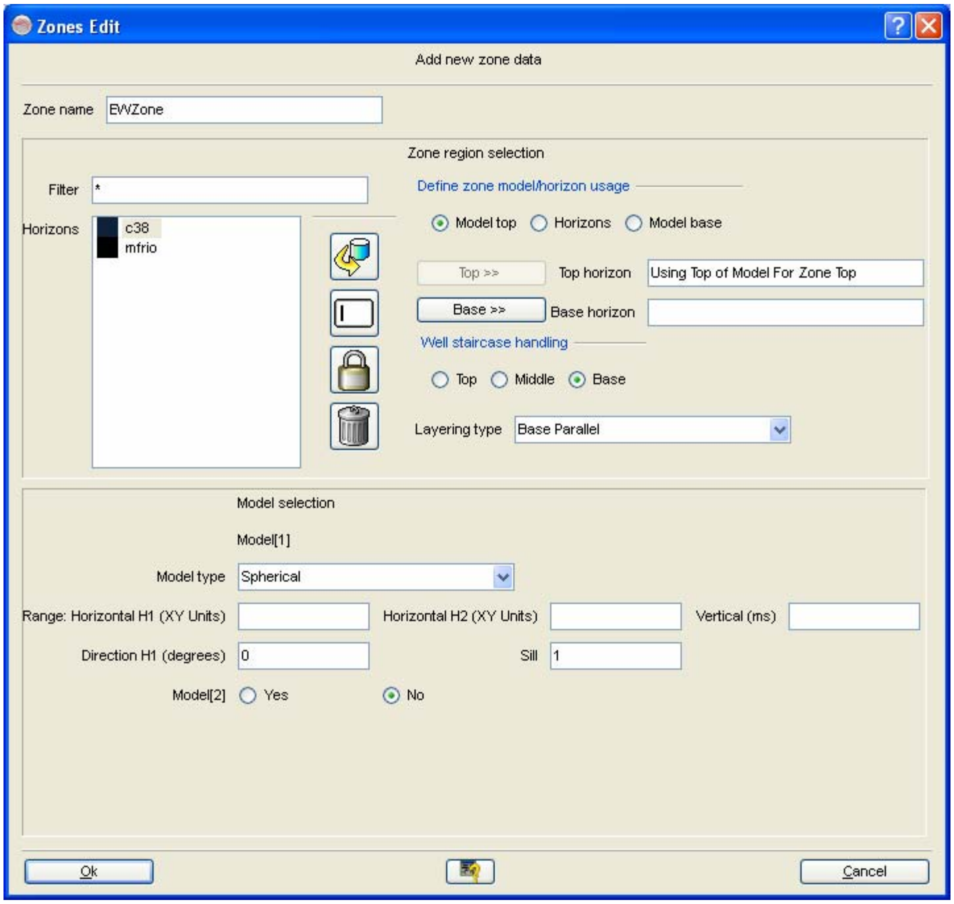
3. Define what the stratigraphic layering type is for this zone

2.2.1 Adding zone data

A zone may be added by defining its specific region boundaries and associated values. For the first zone only, the top of the model is used as the top of the zone instead of a horizon and similarly, the last zone will use the model base as the bottom of the zone. To add a zone, click the `Add` button from the control panel on the right hand side of the window.

- ➢ **EW Control Panel**
- ➢ **Click `Add`**

This will launch the Add New Zone screen as shown below where e.g., there are two horizons available for use as a zone boundary.



At the top left of the dialog window the `Zone Name` is provided with a default name `EWZone` which is incremented as more zones are added. The user may change the zone name to refer to particular geological intervals.

The first step in adding a zone is to define the region of the zone by setting the top and base boundaries. This is completed in the right hand side group box entitled `Define Zone Model/Horizon Usage`. The Model Top selection is only available for the first zone. The Model Base selection will be used for the final zone created. The table below provides a description of the options available.

Selected Item(s)	Meaning	Effects
Model Top	Use the top of the model as the top of the zone.	• If selected, the software will use the top of the model for the data values within the various computation algorithms and calculations. • Only the first zone can use the Model Top option and cannot use the Model Base. • Note that the top of the model is only defined when the model attribute is computed. • Top of the model is a constant time

Horizons	Define the zone using two picked seismic horizons	If selected, the software will use the selected horizons for its data values within the various computation algorithms and calculations
Model Base	Use the base of the model as the base of the zone	• If selected, the software will use the base of the model for the data values within the various computation algorithms and calculations. • If a zone has been selected to use the Model Base then this must be the last zone being created for this model. • Note that the base of the model is only defined when the model attribute is computed. • Base of the model is a constant time

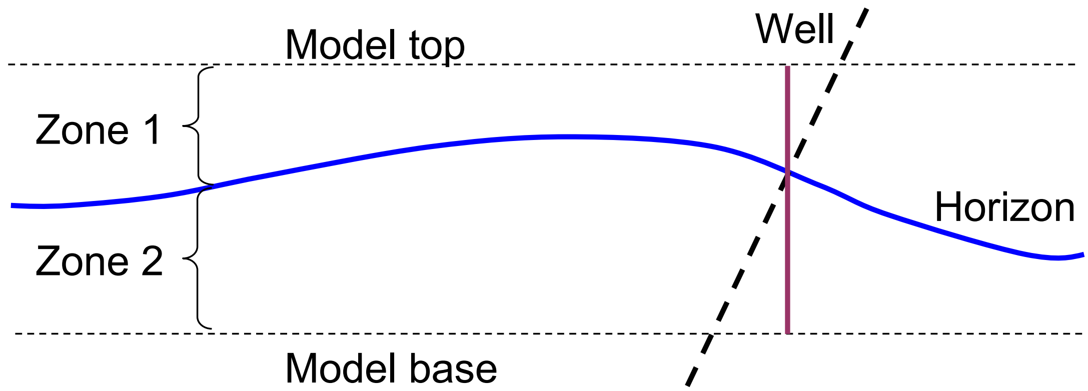
2.2.2 Well Deviation Handling & Staircase Options

Staircase refers to the manner in which deviated wells are segmented during the construction of a 3D model. If you selected the "Vertical by Zone" option on the Wells panel then the wells will be divided into segments by zone and each segment will be treated as a vertical well within the zone, with options controlling the positioning of the wells then.

Selected Item(s)	Meaning	Effects
Top	Use the top of zone X-Y position to locate the well segment	• If selected, the software will position the verticalised well segment for this zone at the X-Y location obtained from the intercept of the deviated well path with the top of the zone. • Note that if this option is used for the first zone, the top of the zone will be defined as the top of the model. The top of the model is only defined when the model attribute is computed. • Top would be the usual choice for the last zone in the model.
Middle	Use the middle of zone X-Y position to locate the well segment	If selected, the software will verticalise the well at the X-Y position found from the intersection of the deviated well path midpoint time position between the top and base horizons selected for this zone.
Base	Use the base of zone X-Y position to locate the well segment	• If selected, the software will position the verticalised well segment for this zone at the X-Y location obtained from the intercept of the deviated well path with the base of the zone. • Note that if this option is used for the last zone, the base of the zone will be defined as the base of the model. The base of the model is only defined when the model attribute is computed. It may not be possible to build a valid model when using this option for the last zone. • Base would be the usual choice for the first

		zone in the model.

The figure below shows an example for two zones where zone 1 has a verticalised well which uses the location where the deviated well coincides with the base of the zone. The verticalised well in zone 2 uses a location where the deviated well coincides with the top of the zone. In this case the verticalised well by zone removes the affect of the well deviation through the zones.



The algorithm must be quite sophisticated to account for these user options. The length of the well passing through the zone will not remain the same after it has been verticalised by zone. Consequently, once the user has specified a type of behaviour the model must identify the location of the vertical well origin and then calculate the time length that the vertical well must have to intercept the zone edge.

2.2.3 Layering type selections

The layering type refers to the type of stratigraphy to be used in the interpolation of impedance values from the values across the 3D model.

Selected Item(s)	Meaning	Effects
Proportional	Use proportional layering for this zone	• If selected, the software will construct a proportional layering scheme between the top and base of the zone. • This option is not recommended for the first or last zones in the model as the horizontal upper or lower boundary respectively is unlikely to be geologically plausible as the basis for a proportional layered stratigraphic sequence.
Top Parallel	Use layering parallel to the top of the zone for this interval	• If selected, the software will construct a layering scheme parallel to the top of the zone. • Note that if this option is used for the first zone, the top of the zone will be defined as the top of the model. The top of the model is only defined when the model attribute is computed. It may not be possible to build a valid model when using this option for the first zone.

		• Top Parallel would be the usual choice for the last zone in the model.
Base Parallel	Use layering parallel to the base of the zone for this interval	• If selected, the software will construct a layering scheme parallel to the base of the zone. • Note that if this option is used for the last zone, the base of the zone will be defined as the base of the model. The base of the model is only defined when the model attribute is computed. It may not be possible to build a valid model when using this option for the last zone. • Base Parallel would be the usual choice for the first zone in the model.

2.2.4 Variogram model selections

A geostatistical (kriging) method is used to estimate impedance values across the model by interpolation. Kriging requires the user to specify a model of spatial correlation (variogram) for each zone within the 3D impedance model. The same variogram parameters from the zones of the model will be used to determine spatial uncertainty if the stochastic inversion is used.

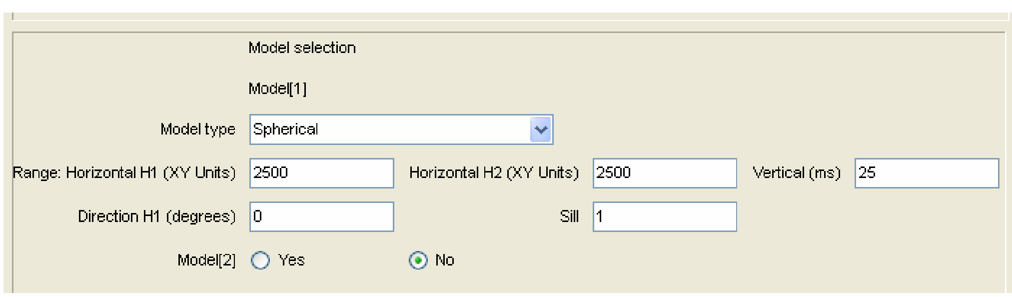
There are four stages to the spatial correlation model selection:

1. Select which model type is applicable for this zone

2. Provide values for each range

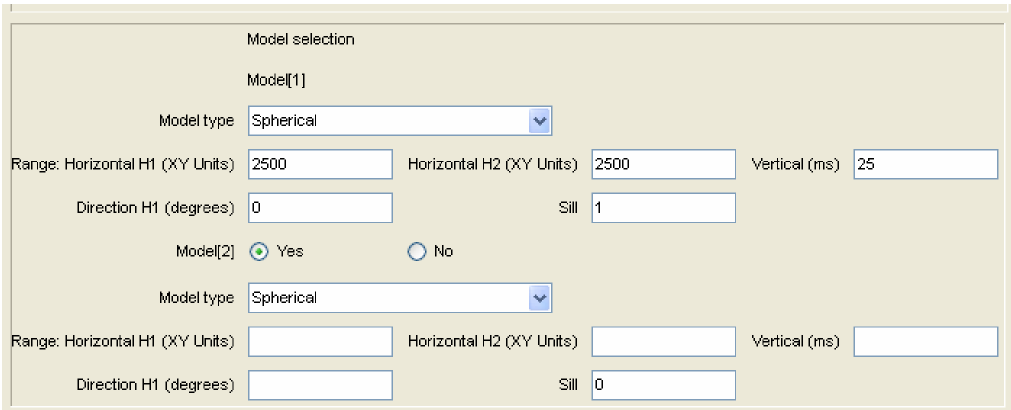
3. If the model is horizontally anisotropic, provide orientation and anisotropic range values for the horizontal direction H1

4. Decide if a second (nested or combination) model is to be used and provide the details for this



The variogram type may be chosen from a list of the three main types. The variogram model is 3D and can be specified as a fully anisotropic spatial correlation function by changing the range of the model (distance of spatial correlation). The vertical direction of the variogram is always true vertical (parallel to the time axis of the model). The horizontal plane of the variogram is always parallel to the layering scheme defined within the zone. Hence the only orientation information required for the 3D variogram model is the rotation of the horizontal anisotropy within the layer relative to North direction. The sill of the variogram model is standardized to a value of 1.0. If two model components are combined the software will automatically standardize the proportions to sum to a total sill of 1.0. In addition, note that a nugget component is not supported as a variogram model option by this software. This is deliberate as a nugget option (measurement error or noise term) is not required in the construction of impedance models for seismic inversion.

Currently the software supports a maximum of two nested models for the variogram specification. If two nested models are used then the sill of each model is the proportion of that model in the total model.



A description of each option and the consequence of their incorporation into the model is described below.

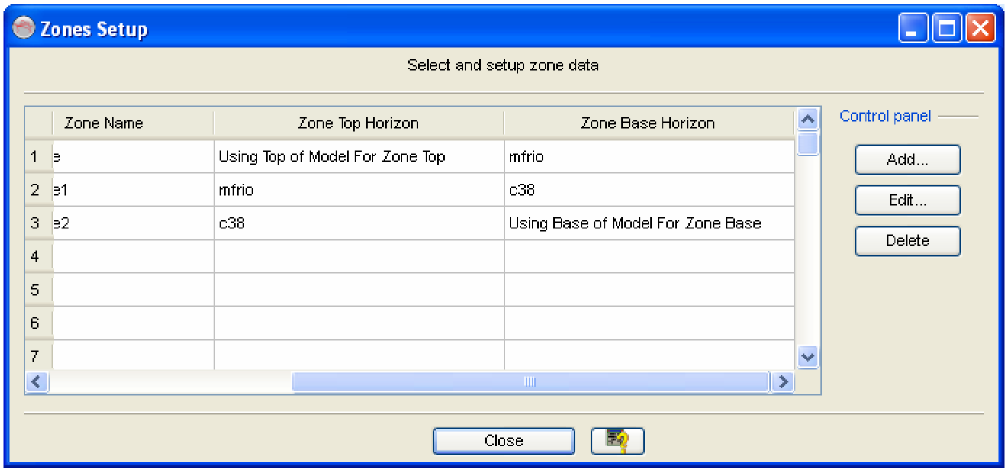
Selected Item(s)	Meaning	Effects
Model Type	Select spatial correlation function type	If the **exponential** option is selected the software will use an exponential variogram model. This is a common function type observed in variograms from well logs and represents a rough/rugose spatial behaviour. If the **spherical** option is chosen the software will use a spherical variogram model. This is a good general default model to use; being slightly less rough/rugose than an exponential model. If the **Gaussian** option is selected the software will use a Gaussian variogram model. This spatial correlation function is extremely smooth and is generally inappropriate for geological properties and is not recommended in most cases. Select this option with care.
Vertical Range	The vertical variogram range for this model, in ms or s	This value is used to determine the maximum vertical influence of the samples. Typical values of the vertical range for a clastic interval are from 5.0 – 50.0 ms. The range should be determined from vertical variogram analysis.
Horizontal Range H1	The horizontal variogram range for this model in direction H1, in survey X-Y units	• The horizontal variogram range determines the maximum horizontal influence of the samples. Typical values of the horizontal range for a clastic interval are from 500 – 5,000 m (1,500 – 15,000 ft). The range should be determined from horizontal variogram

		analysis. The vertical range of the variogram is usually much less than the horizontal ranges H1 and H2. The variogram is therefore anisotropic between the vertical and horizontal planes. • The anisotropy ratio of horizontal to vertical directions (in the same measurement units) is typically 20:1 up to 200:1 or more. Note that the vertical range is specified in z ms or s (depending on the survey settings) and the horizontal range in metres or feet, so conversion of units may be required to calculate the anisotropy ratio.
Horizontal Range H2	The horizontal variogram range for this model in direction H2, orthogonal to direction H1, in survey X-Y units	• The horizontal variogram range determines the horizontal influence of the samples typically in the direction orthogonal to H1. Typical values of the horizontal range for a clastic interval are from 500 – 5,000 m (1,500 – 15,000 ft). The range should be determined from horizontal variogram analysis. • If range H2 is equal to range H1 then the variogram is isotropic in the horizontal plane. If range H2 is greater or less then H1 then the variogram is anisotropic in the horizontal plane.

Direction H1	The orientation from North of horizontal variogram direction H1.	This value is used to set the horizontal variogram orientation. Units are compass degrees from North. If the range H1 = H2 then the variogram is horizontally isotropic and this parameter will have no effect.
Sill	The scaling of the variogram sill Default = 1	• This value is used to set the maximum variance of the variogram model. Because the models are standardized, this will always revert to a value of 1 if only one model is used for a zone. • If two models in combination are used for a zone then this parameter controls the proportion of variance of each model in the total model for the zone. The software automatically standardizes the proportions to sum to 1.
Model[2]	This allows the option to use a second model.	If selected the screen is updated to allow the values listed above for the second model to be used. If two models are used for a zone then the sill parameter controls the relative proportion of variance of each model in the total model for the zone. The software automatically standardizes the proportions to sum to 1.

This process should be repeated for each zone to add at least one more zone before the 3D model can be processed. This procedure requires a repeat of the above activities, the only difference encountered will be the restricted use of the Model Top/Base as the zone boundary that was described earlier.

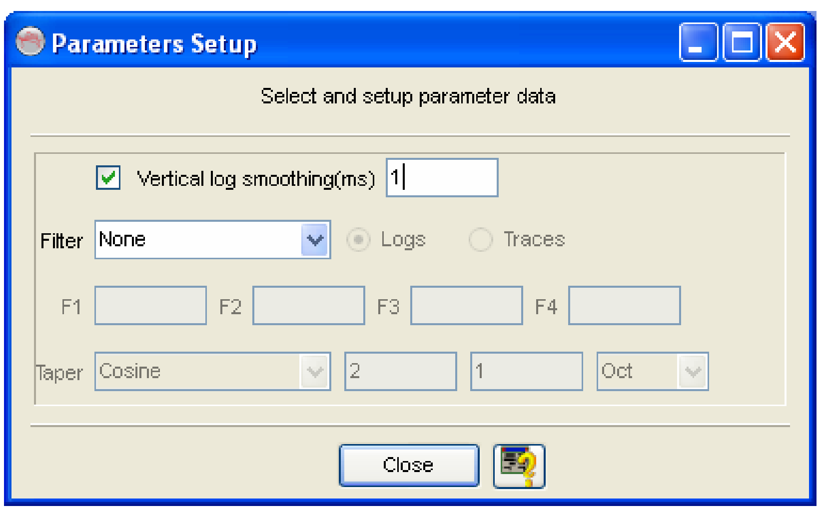
An example is given below of a three zone model



2.3 Parameters

The remaining parameters to build a 3D model concern the amount of smoothing or filtering required on the well impedance log. If no filtering is specified then the program will only apply any necessary anti-alias filters when resampling the well logs to the sample rate of the impedance model.

- **EW Control Panel**
- **Click `Parameters`**



Several options are available to the user: vertical log smoothing of the well logs (i.e. a moving average with the window specified in ms) and filtering in the frequency domain of either the well logs or of the final 3D model trace

When using the Vertical log smoothing option it is recommended that the vertical smoothing is related to the block size of the intended inversion model output. *Increasing* the vertical log smoothing will result in the creation of a smoother model.

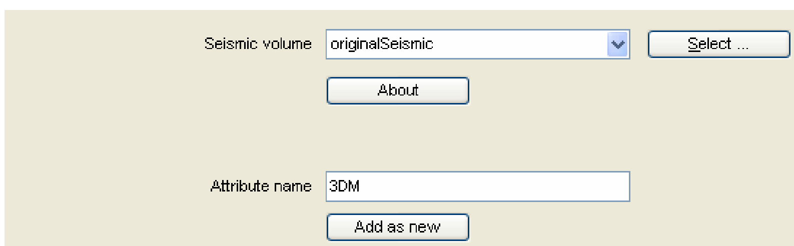
Four frequency domain filter types are available:

Low-pass
High-pass
Band-pass
Trapezoidal

Frequencies are in Hertz and tapers are specified in either Hertz or in octaves. An octave is a doubling of the frequency. Tapers may be linear or cosine. If filtering is required it is generally recommended to use a lowpass filter or, for any other filter choice, to ensure the lower frequency is set to 0 Hz to keep as much low frequency content as possible. Other filters settings are generally intended for special circumstances such as QC or testing. For a deterministic inversion it is not recommended to allow the upper frequency of the filter to extend beyond the highest frequency of the wavelet used in the inversion.

Clicking Close will return the user to the attribute set.

The user can now select the stored seismic volume which will define the geometry, give the attribute set a name and Add as New to the OpendTect attribute set.



3. SPATIAL CONSTRAINTS

3.1 Error grid (2D)

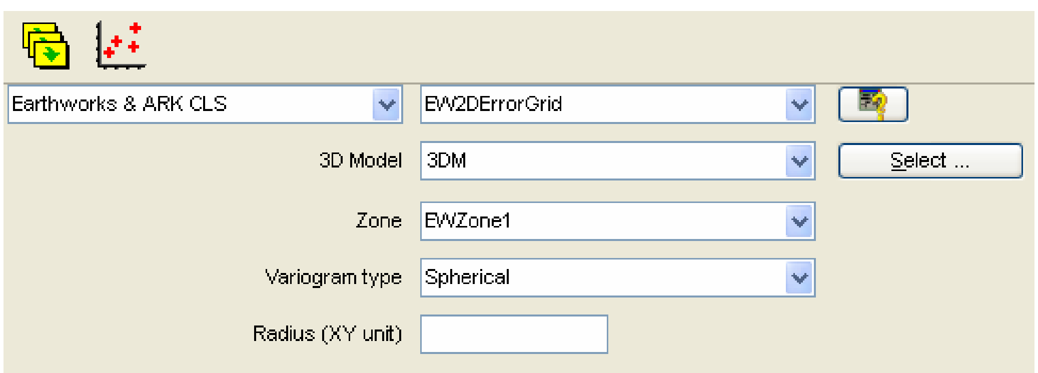
A 2D Error Grid is used to provide a spatial constraint for a subsequent deterministic or stochastic inversion. The 2D error grid is a standard deviation map obtained by a simple kriging of the well locations. The variogram model used for this process is standardised to a sill of 1.0. This results in a map with values of zero at the well locations, which increases to a maximum of 1.0 at distances greater than the radius of influence (variogram range) around wells.

In the deterministic or stochastic inversion this 2D error grid is used to provide a spatially varying control of the inversion convergence criteria. The error grid scheme in Earthworks inversion software ensures the impedance result is conditioned to the wells when close to a well and allows the user to increase the seismic contribution away from the wells, where the initial impedance model is less reliable.

The model constraint will be usually set to be strong (and therefore the seismic constraint weak) close to the well locations (error grid values small) and conversely allow weak model constraints (and therefore a strong seismic constraint) away from the well locations (error grid values large). The relative model and seismic constraints are thus controlled by the error grid.

The selection of EW2DErrorGrid from the pull-down menu will reveal a window where input values are required for creating the attribute.

- **Click `Analysis`**
- **Select `Attributes`…**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EW2DErrorGrid`**



The user begins by selecting the 3D Model definition to use for the 2D Error Grid. If valid, the zone selection menu will be populated with the zones that have been defined within the selected 3D Model attribute loaded by using the Select… button. The user selects the zone which will be used to define the X-Y locations of the well segments to calculate the error grid. The X-Y positions of the zone are determined by the settings in the 3D model. If the well staircase option for deviated wells is being used then the well X-Y values will correspond to the top, middle or base of the zone as selected by the user in the zone parameters for the 3D Model.

The effects of selecting each option are described below.

Selected Item	Meaning	Effects
EW 3D Model	This is the 3D Model attribute created before this step	Selection of this item will mean that the values defined from the 3D Model will become input for this attribute. The zones that this model contains will become the selectable items within the next dialog item.
EW Zone	The zone to use in this error grid	Selection of a zone will mean that the well X-Y position information as defined in the 3D model for this zone will be used for the error grid calculations. Only wells with data in the selected zone will be used in the calculation of the error grid.
Variogram function Type	Provides the options for the type of variogram function to apply. Options available are: • Spherical • Exponential • Gaussian	• Determines the shape of the variogram function used in the calculation of the error grid. • The choice of variogram function type is not critical for the error grid. The user may prefer to use the same variogram type and parameters as defined for the zone itself. • Alternatively a good default to use would be a spherical variogram type.
Radius of influence around the wells	Range of the variogram model and distance from a well at which the error grid reaches a maximum value of 1. In survey X-Y units (metres or feet)	• The radius of influence determines at what radius around a well the error grid reaches a maximum value of 1. • The user may prefer to use the same distance as the variogram model defined for the selected zone. • In the case of an unbound or transitive model (e.g., Gaussian and exponential) a convention is applied depending on the model type (e.g., exponential model: the effective range is one third of the theoretical range; 95% of the sill variance). • Choosing a larger value for this parameter will extend the relative importance of the model in a subsequent inversion over a greater distance around each well.

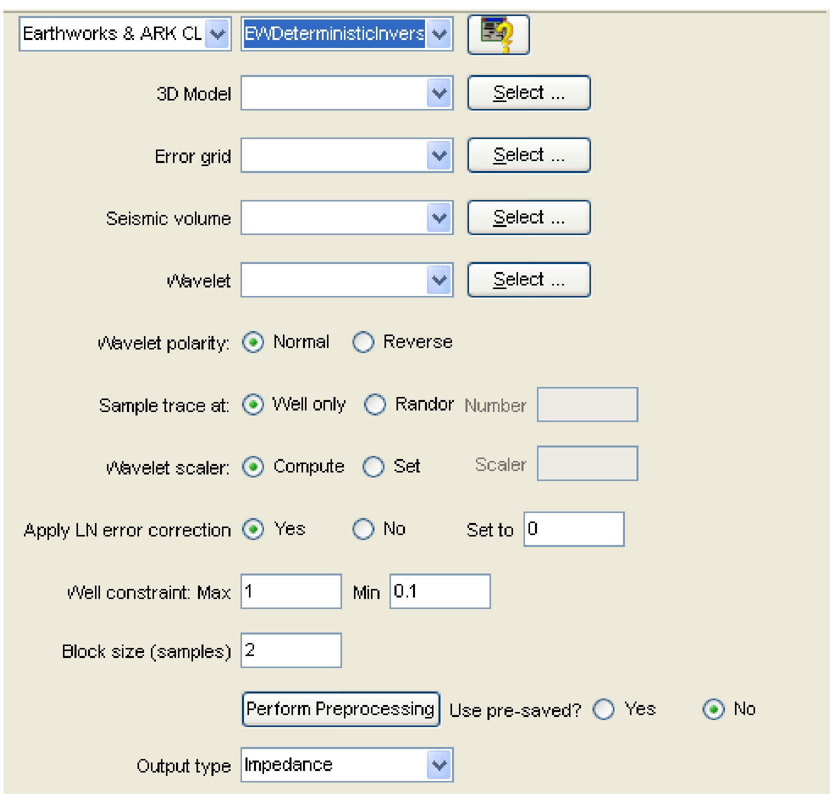
4. DETERMINISTIC INVERSION

The deterministic inversion scheme is model-based. Unlike other model-based schemes the inversion is a direct (linear) solution without iterations. Its other distinctive feature is the use of a 2D Error Grid. The error grid controls the relative importance of the initial impedance and the seismic trace information when inverting each trace. The inversion is spatially controlled with more influence being placed on the model at traces close to well locations. This model constraint is relaxed away from the wells to increase the influence of the seismic trace information in the final inversion.

Model-based inversion uses a broad-band impedance as the starting point for the inversion. During the inversion, the model is updated using the inverted seismic trace information within the seismic bandwidth. The model is not altered outside of the seismic bandwidth. It is therefore recommended that the model should not contain high frequencies above the seismic bandwidth. These can be filtered from the well impedances used in the model construction on the model parameters menu.

The inversion requires input from a 3D model and a 2D error grid. Therefore, prior to conducting the inversion the user must ensure that there is available a 3D Model and a suitable error grid.

- **Click `Analysis`**
- **Select `Attributes`…**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EWDeterministicInversion`**



4.1 Main parameter options

The selections that the user must make and options available are described below.

Selection	Meaning	Effects
EW 3D Model	This is the 3D Model attribute created before this step	Selection of this item will mean that the values defined from the 3D Model will become the input for this attribute.
Error grid	This is the Error Grid attribute created before this step	Selection of this item will mean that the values defined from this Error Grid will become the input for this attribute.
Seismic volume	This is the input seismic volume to be inverted	
Wavelet	This is the wavelet to be used for the inversion	
Wavelet Polarity	Override the loaded wavelet polarity	Allows the user to flip the wavelet polarity if necessary
Sample trace at	Decision to compute scalars at well locations only or randomly selected trace locations	*Well Only* – the scalars for the seismic data and the model are computed at well locations only. *Random* – the user must enter the number of traces to use for the scalar calculation. The well traces are always used first. Additional traces are selected at random from the survey.
Wavelet scalar	Decision to autocompute or set wavelet scalar	*Compute* – the scalar for the wavelet is computed. The value calculated is displayed in the OpendTect log file (Utilities->Show log file…) *Set* – the user must enter the scalar for the wavelet. A default can be found by running once allowing the program to compute and then take the value from the log file as a starting point for testing the best scalar.
Apply LN error correction	Decision to apply a natural logarithm (Ln) correction	*Yes* – the Ln correction is applied. *No* – the Ln correction is not applied This option corrects for the exponential relation between impedance and reflectivity. Because inversion minimizes the error symmetrically with respect to the seismic amplitudes (reflectivity), the errors associated with the resulting impedance are not symmetrical in conventional inversion. This option corrects both the error distribution and the mean impedance for this problem. If the scalar is set to any value greater than 0 then MPSI uses the user defined value. If the value is set to 0 MPSI will compute the scalar and the value is displayed in the OpendTect OpendTect log file (Utilities->Show log file…). A good default can be found by running once allowing the program to compute and then take the value from the log file as a starting point for testing the best LN correction factor.

Well Constraint: Max.	The maximum model constraint to be used close to the well Range 0.0 – 1.0	• The constraint is scaled using the error grid. A typical value for a model constraint close to the well would be 0.9. • Note that when testing inversion parameters it is recommended to relax this constraint to be the same as the minimum constraint far from the well. This allows the user to judge how well the seismic inversion is able to reproduce the well data. • When the minimum constraint far from a well has been determined, the user can then test the effect of increasing the model constraint at the well.
Well Constraint: Min.	The minimum model constraint to be used far from the well Range 0.0 – 1.0	• The constraint is scaled using the error grid. A typical value for a model constraint far from a well would be 0.1.
Block size	The required block size for the inversion, in number of samples	• The block size for the inversion will usually be selected after a series of tests. • The block size is a function of the seismic frequency content and bandwidth. Generally the higher the frequency content of the seismic the smaller the choice of block size. • A typical block size could be in the range 2 – 6 ms, depending on seismic frequency content. • Any multiple of the seismic sample rate may be used
Perform Pre-processing	Strategy for managing large inversion matrices in memory	• With long time gates and high sample rates the matrix size in the seismic inversion may be very large. Additionally, unlike other algorithms, the software must re-compute the matrix inversion each time the error grid value changes • These conditions may result in large matrices and corresponding long run times. When displaying a test in the OpendTect window it may be helpful to pre-compute the matrices and then read the pre-computed matrices from disk, which will shorten the wait when re-displaying an inversion test. • User Tip: Setting the near and far constraints to the same value will improve the runtime performance significantly as matrix inversion is only performed when the error grid value changes.
Output Type	Output type to be	• Selecting **Impedance** corresponds to the

	computed. Options available are: • Impedance • Synthetic • Residual	inverted impedance trace • Selecting **Synthetic** will result in the synthetic seismic trace being output • Selecting **Residual** will result in the residual (difference) between the synthetic and seismic trace being output It is not possible to output the 3 properties simultaneously from a single attribute. It is recommended that the synthetic and residual computation options are used interactively as a QC on an inline and/or x-line basis, perhaps using the evaluate option

5. STOCHASTIC INVERSION

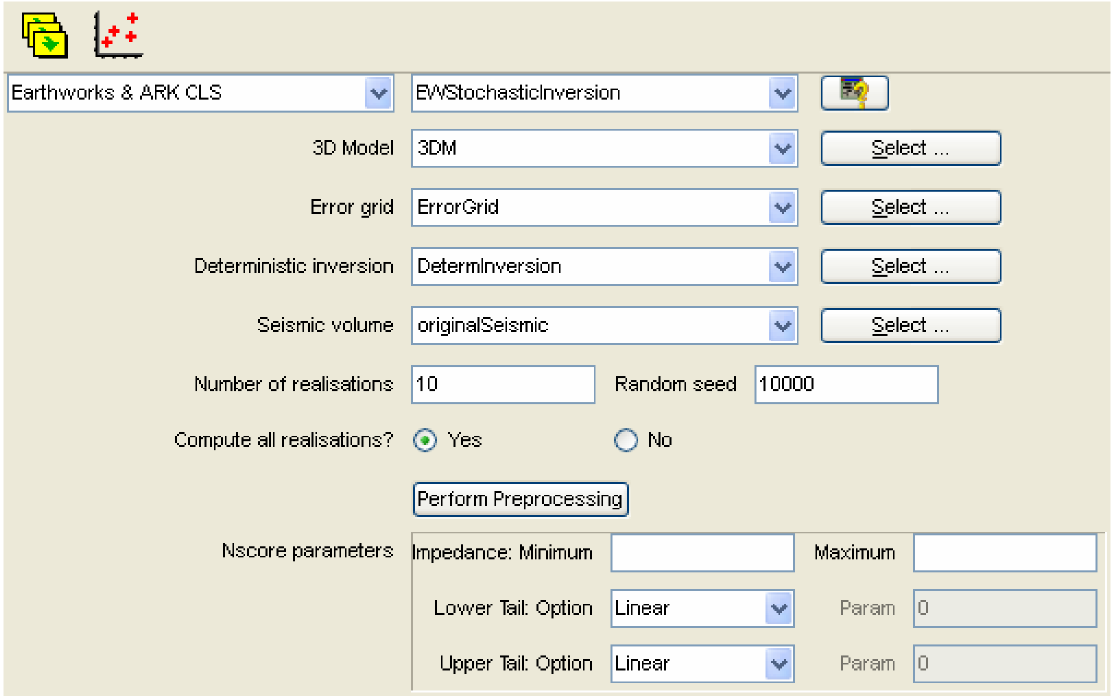
Stochastic inversion is complementary to deterministic inversion. Stochastic inversion is used to understand the uncertainty in seismic inversion and via the stochastic inversion utilities it allows the user to explore the impact of this geophysical uncertainty on the lithology, porosity or reservoir volumes over the inverted 3D seismic volume. For thin intervals a stochastic inversion is particularly appropriate for understanding uncertainty and reservoir volume and connectivity. The stochastic inversion enables the user to improve the estimation obtained from a deterministic inversion as the mean of many realisations (calculated using the utilities).

The stochastic inversion scheme used in MPSI™ is considered the fastest stochastic seismic inversion scheme currently available. The method uses a prime factor Fast Fourier Transform (FFT) scheme to generate the stochastic realisations in the frequency domain. Because of its speed, the stochastic inversion can compute rapidly the large numbers of realisations necessary to capture the full range of uncertainty. A typical stochastic inversion run will compute 100+ realisations for subsequent uncertainty analysis.

The stochastic inversion requires input from a 3D model, associated 2D error grid and from a deterministic inversion. Therefore, prior to conducting the inversion the user must ensure that these components are available.

The Earthworks Stochastic Inversion is available as follows.

- **Click `Analysis`**
- **Select `Attributes…`**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EWStochasticInversion`**



5.1 Main parameter options

The selections that the user must make and options available are described below.

Selected Item	Meaning	Effects
EW 3D Model	This is the 3D Model attribute created before this step	Selection of this item will mean that the values defined from the 3D Model will become input for this attribute.
Error grid	This is the Error Grid attribute created before this step	Selection of this item will mean that the values defined from this Error Grid will become input for this attribute.
Deterministic inversion	This is the deterministic inversion attribute created before this step	Selection of this item will mean that the values defined from this deterministic inversion will become input for this attribute. Note that this includes parameters such as wavelet scalar, log normal correction, well constraints, block size. Importantly also note that the option to output inverted, synthetic or residual traces is also passed through to the stochastic inversion from the deterministic inversion parameters.
Seismic volume	This is the input seismic volume to be inverted	
Number of Realisations	The number of realisations to be computed	• For a test just 1 or a few realisations should be requested. • For a final stochastic inversion run to determine the uncertainty a typical 100

		realisations would be generated. • The realisations are stored as multi-components within an OpendTect attribute
Random Seed	Large odd integer to initialise the random number generator	Changing the seed will give a different set of stochastic inversion realisations.
Compute all realisations	Decision to compute all realisations	This option allows the user to override the number of realisations during OpendTect display. This is because OpendTect only displays the first attribute (realisation) of a multi-attribute (multi-realisation) set. To view a series of test realisations set this to Yes and use the Evaluate tool described below.
Perform pre-processing	The pre-processing must be performed at least once and repeated whenever the 3D model parameters change. The pre-processing performs essential processing that cannot be handled by the OpendTect trace-based processor. The pre-processing is done in full 3D using the boundary defined in user defined OpendTect Work area (View->Work area) and trace spacing and time range defined in the OpendTect Survey.	

5.2 Gaussian transformation (NScore)

Before undertaking the stochastic inversion process the impedance values at the well locations are transformed from their natural probability density function (PDF) to a standard normal (Gaussian) PDF using a normal score transform. The stochastic inversion then takes place in the frequency domain using this Gaussian transformed data. After stochastic inversion the results are still in a Gaussian transform space and must be back transformed into the original impedance units. This is achieved by using the inverse normal score (NScore) transform.

The effects of selecting each option are described below

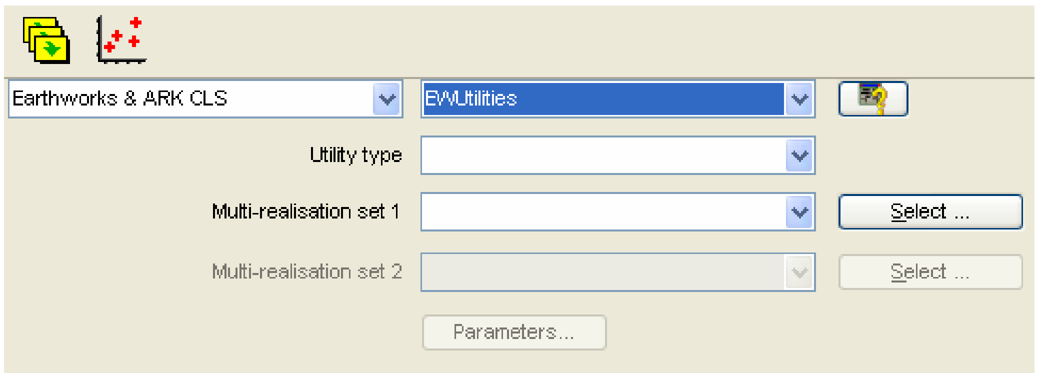
Selected Item	Meaning	Effects
Min/Max Value	The value of the minimum and maximum impedances allowed in the final inversion result	• The minimum and maximum impedances allowed should be set slightly larger than the impedance range of the well logs (ideally, after smoothing/band limitation is applied). • The stochastic inversion will have a significantly larger dynamic range of impedance values compared to a deterministic inversion. • Any impedance values after back transform which exceed the min/max limits will be set to the value of the min or max limit. • Restricting the min/max limits too much will create a local spike in the impedance histogram at the min or max value.

		• Guide values for the min max values are output in the OpendTect log file (Utilities->Show log file…).
Lower Tail option	Option for interpolation of low impedance values down to the minimum value in the back transform	• *If Linear* is selected then linear interpolation will be used. This is the recommended default option. • *If Power* is selected then a power law function will be used for the interpolation. This requires the next parameter to be set.
Lower Tail parameter	Only applicable to the Power selection	Coefficient to be used in the lower tail Power function definition.
Lower Tail option	Option for interpolation of high impedance values up to the maximum value in the back transform	• *If Linear* is selected then linear interpolation will be used. This is the recommended default option. • *If Power* is selected then a power law function will be used for the interpolation. This requires the next parameter to be set. • *If Hyperbolic* is selected then a hyperbolic function will be used for the interpolation. This requires the next parameter to be set.
Upper Tail option	Only applicable to the Power and Hyperbolic selections	Coefficient to be used in the lower tail Power or Hyperbolic function definition.

6. POST-INVERSION UTILITIES

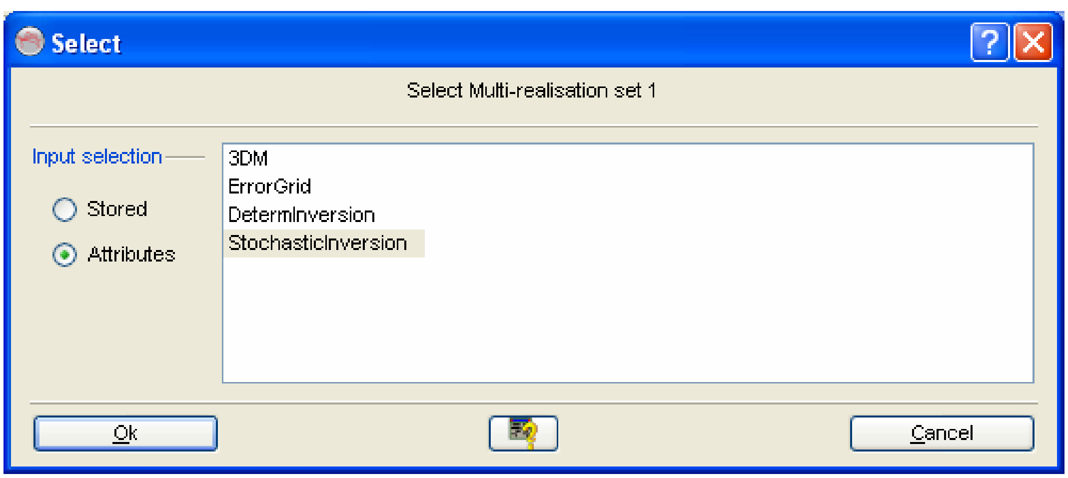
There are several utilities intended for analysis of attributes containing multiple realisations from the stochastic inversion process:

- Mean and Standard Deviation cubes
- Probability cube
- Probability Trend cube
- Joint Probability cube
- Joint Probability Trend cube

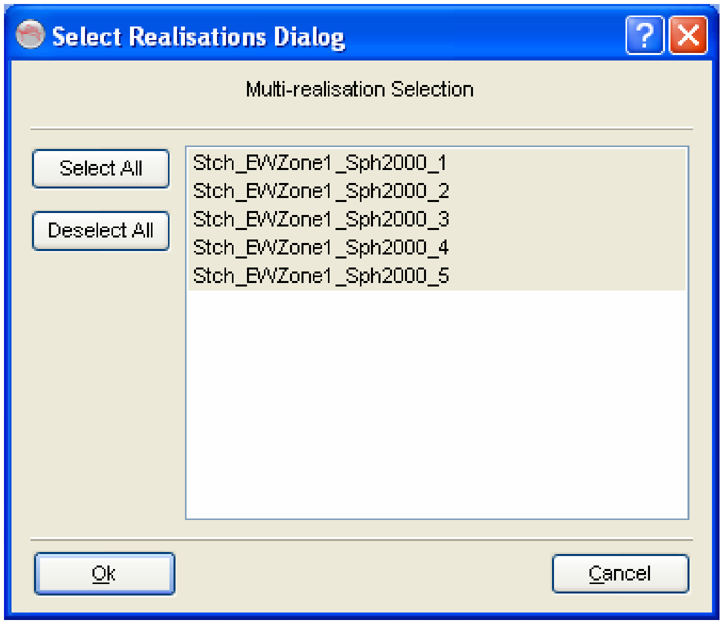


With the exception of the mean and standard deviation utilities, all of the utilities can also be used to classify single-attribute data such as the output from a deterministic inversion.

In all cases the multi-realisation set must be selected and provides the following screen:



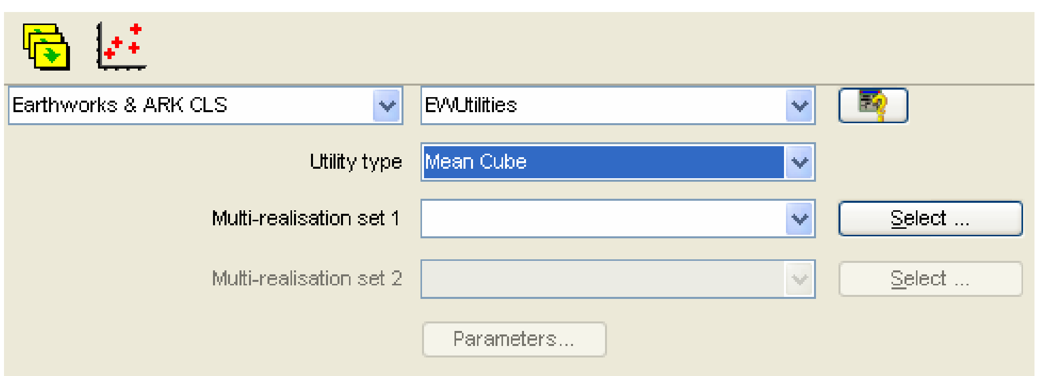
After selecting the file the following window appears where the user is required to select the realisations for processing



6.1 Mean Cube

This selection calculates the mean of the set of realisations previously calculated during the stochastic inversion.

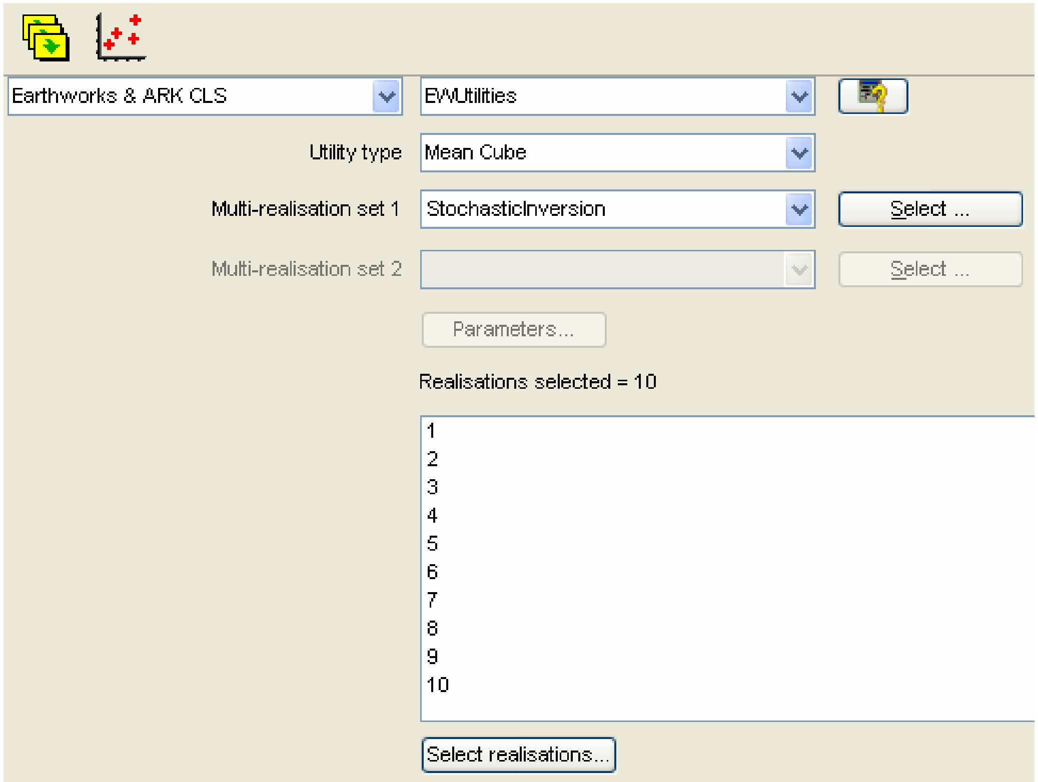
- **Click `Analysis`**
- **Select `Attributes`…**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EWUtilities`**
- **Select `Mean Cube`**



The effects of selecting each option are described below

Selected Item	Meaning	Effects
Multi realisation set	The set of stochastic impedance realisations to be processed	

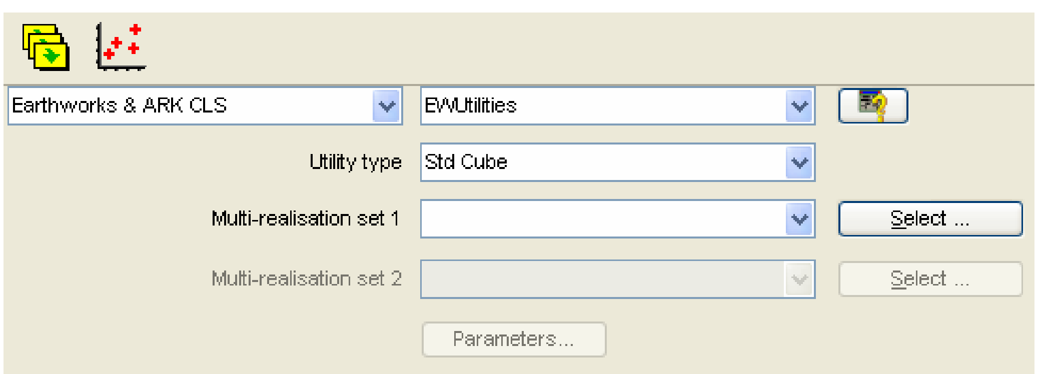
The window below shows the final output options



6.2 Std Cube (Standard Deviation)

This selection calculates the mean of the set of realisations previously calculated during the stochastic inversion.

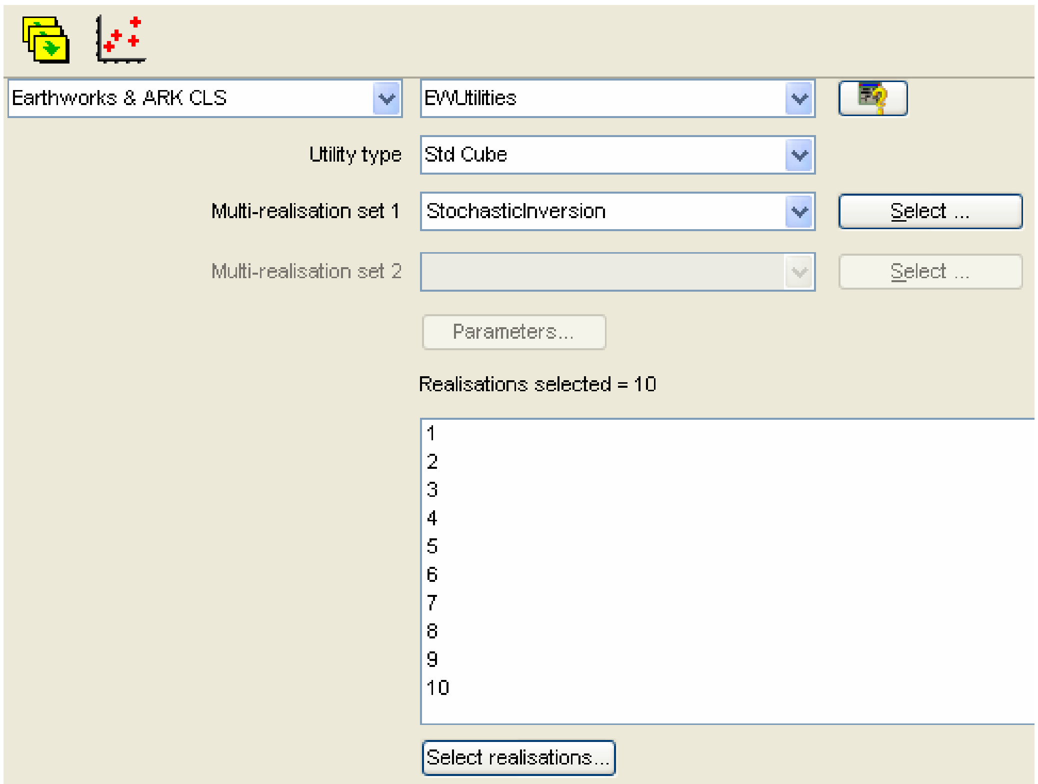
- **Click `Analysis`**
- **Select `Attributes`...**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EWUtilities`**
- **Select `Std Cube`**



The effects of selecting each option are described below

Selected Item	Meaning	Effects
Multi realisation set	The set of stochastic impedance realisations to be processed	

The window below shows the final output options

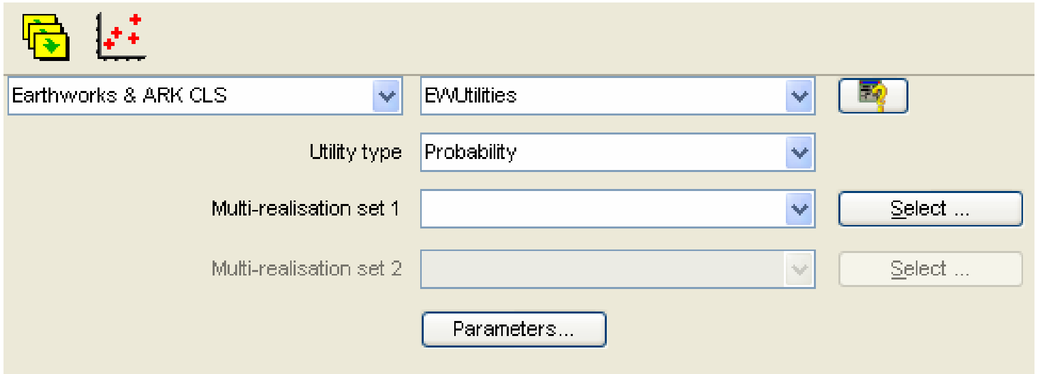


6.3 Probability cube (Probcube)

The probability cube (Probcube) utilities are designed to calculate a probability at each seismic sample based on the frequency with which each realisation gives an impedance value within a specified range. This impedance range is chosen to represent some reservoir or petrophysical criteria.

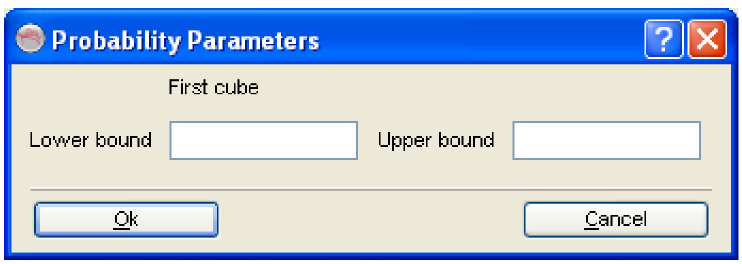
This utility is launched by

- **Click `Analysis`**
- **Select `Attributes`…**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EWUtilities`**
- **Select `Probability`**



The probability range need next to be defined.

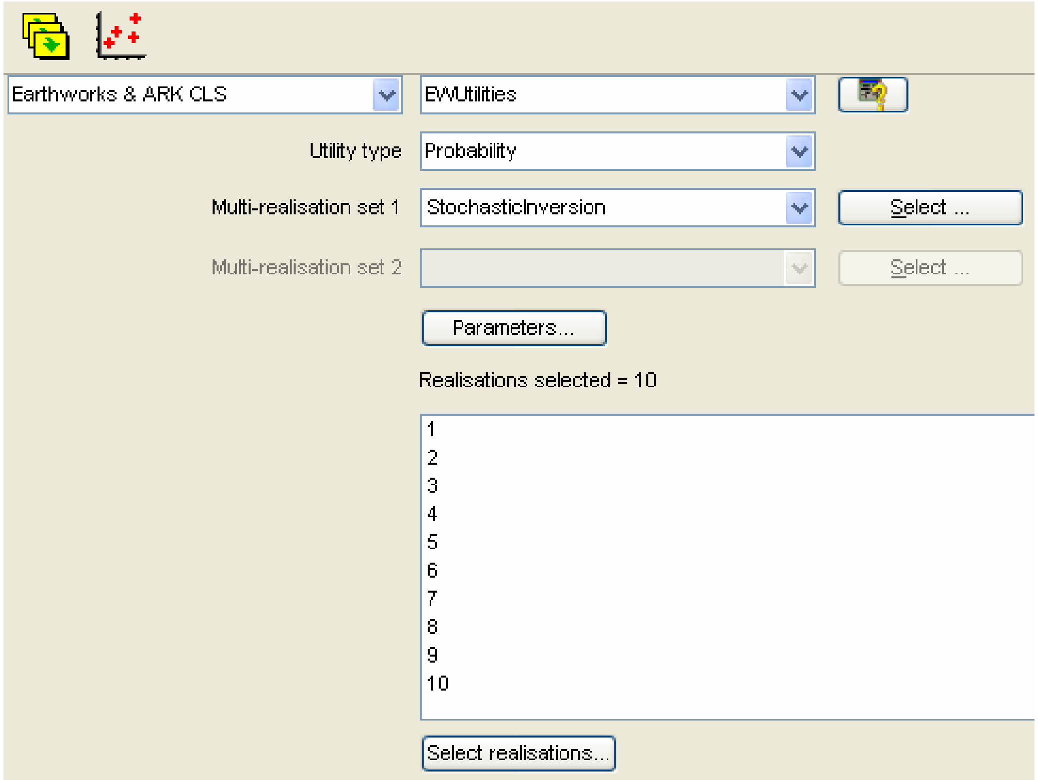
➢ **Click `Parameters`…**



The effects of selecting each option are described below

Selected Item	Meaning	Effects
Multi realisation set	The set of stochastic impedance realisations to be processed	
Lower bound	Minimum impedance value to be included in the probability classification	Only impedance values greater than the *Lower Bound* and less than the *Upper Bound* will be counted towards the probability cube computation
Upper bound	Maximum impedance value to be included in the probability classification	Only impedance values greater than the *Lower Bound* and less than the *Upper Bound* will be counted towards the probability cube computation

The window below shows the final output options



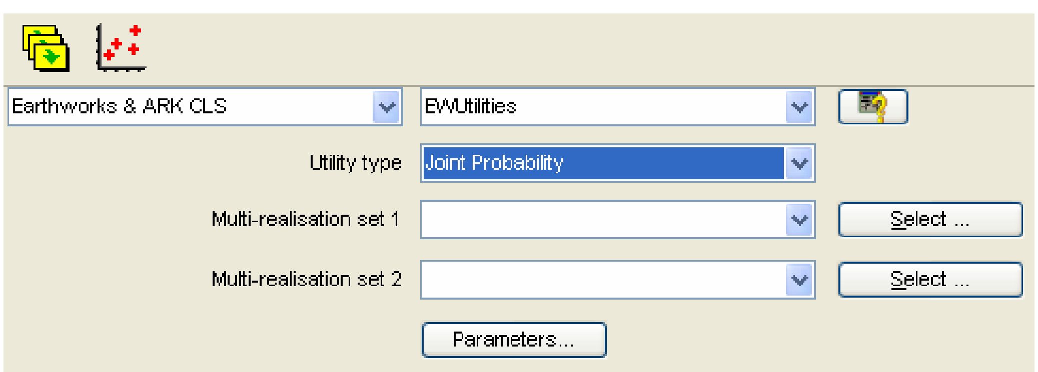
6.4 Joint probability cube

This joint option allow two sets of multi-attributes (such as from simultaneous inversion) to calculate a probability at each seismic sample.

NB. The two sets should have the same number and same selections of realisations in each

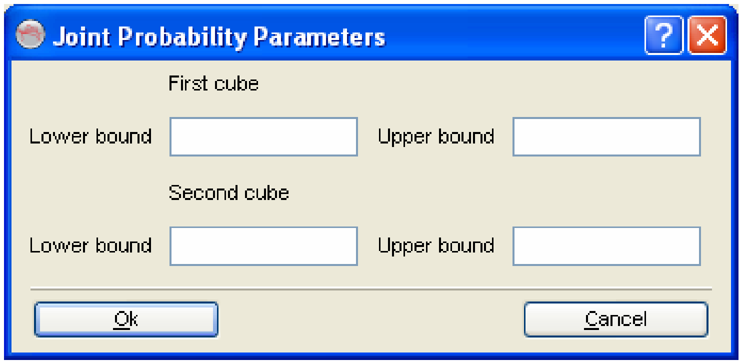
This utility is launched by

- **Click `Analysis`**
- **Select `Attributes`…**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EWUtilities`**
- **Select `Joint Probability`**



The probability range need next to be defined.

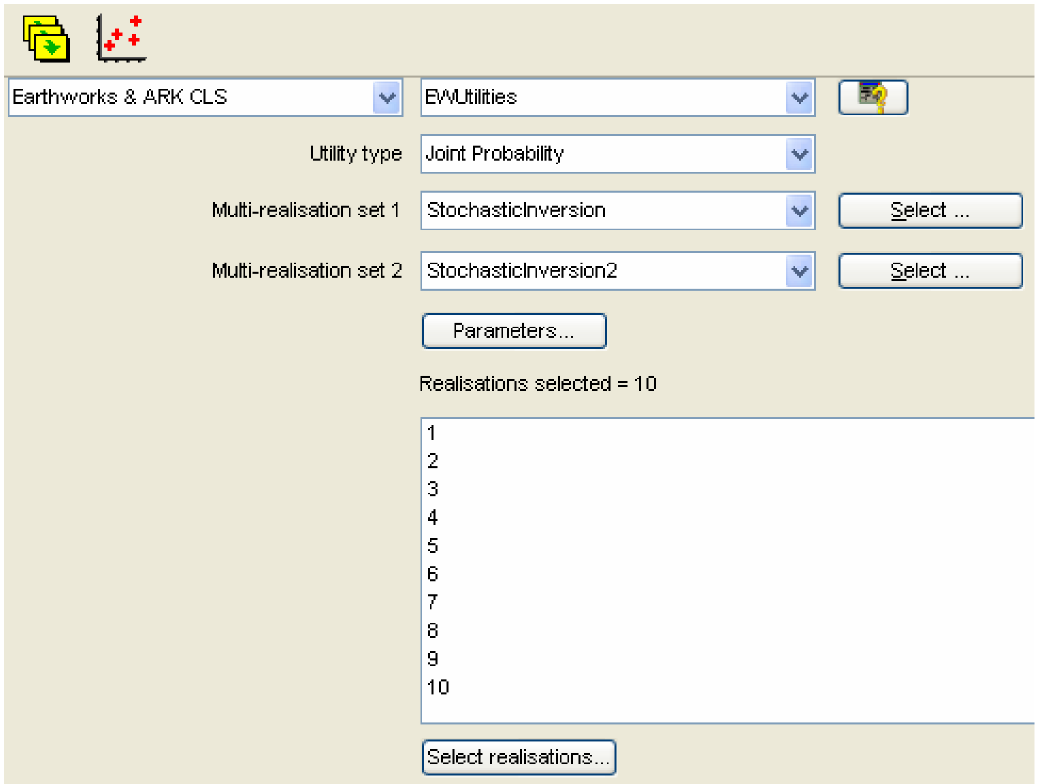
➢ **Click `Parameters`…**



The effects of selecting each option are described below

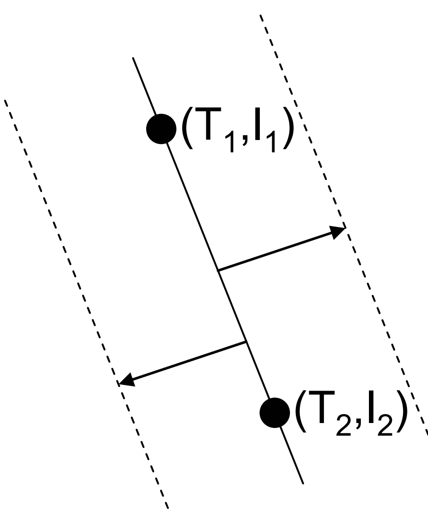
Selected Item	Meaning	Effects
Multi realisation set	The first of a pair of sets of stochastic impedance realisations to be processed	For a simultaneous inversion output, this might be the IP (P-Impedance) set
Lower bound	Minimum impedance value to be included in the probability classification from the first multi-realisation set	Only impedance values greater than the respective *Lower Bound* and less the respective *Upper Bound* for both realisation sets will be counted towards the probability cube computation
Upper bound	Maximum impedance value to be included in the probability classification from the first multi-realisation set	Only impedance values greater than the respective *Lower Bound* and less than the respective *Upper Bound* for both realisation sets will be counted towards the probability cube computation
Multi realisation set 2	The second of a pair of sets of stochastic impedance realisations to be processed	For a simultaneous inversion output, this might be the Is (S-Impedance) set.
Lower bound	Minimum impedance value to be included in the probability classification from the second multi-realisation set	Only impedance values greater than the respective *Lower Bound* and less than the respective *Upper Bound* for both realisation sets will be counted towards the probability cube computation
Upper bound	Maximum impedance value to be included in the probability classification from the second multi-realisation set	Only impedance values greater than the respective *Lower Bound* and less than the respective *Upper Bound* for both realisation sets will be counted towards the probability cube computation

The window below shows the final output options



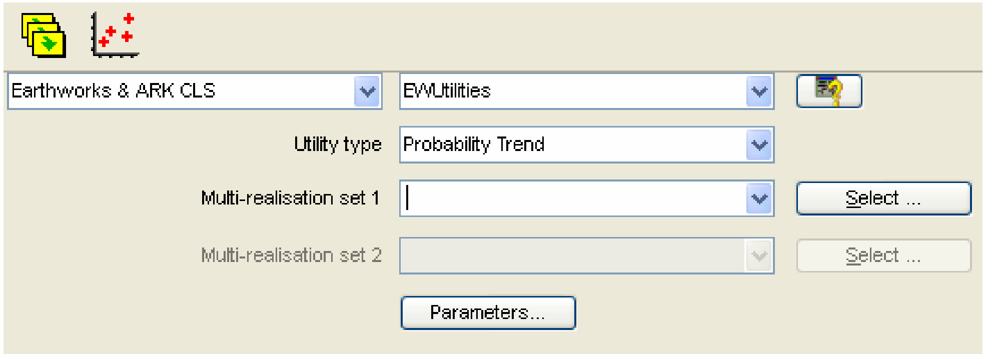
6.5 Probability cube trend

This trend option allows the classification criteria to vary with time during the calculation of probability at each seismic sample. The trend is a linear function with time which gives either the upper or lower impedance limit for the classification criteria. An impedance limit either greater or less than this provides the classification.



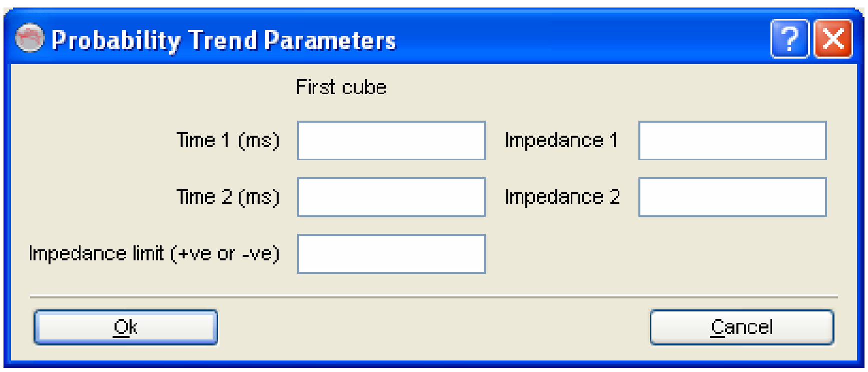
This utility is launched by

- **Click `Analysis`**
- **Select `Attributes`...**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EWUtilities`**
- **Select `Probability Trend`**



The probability range need next to be defined.

➢ **Click `Parameters`…**

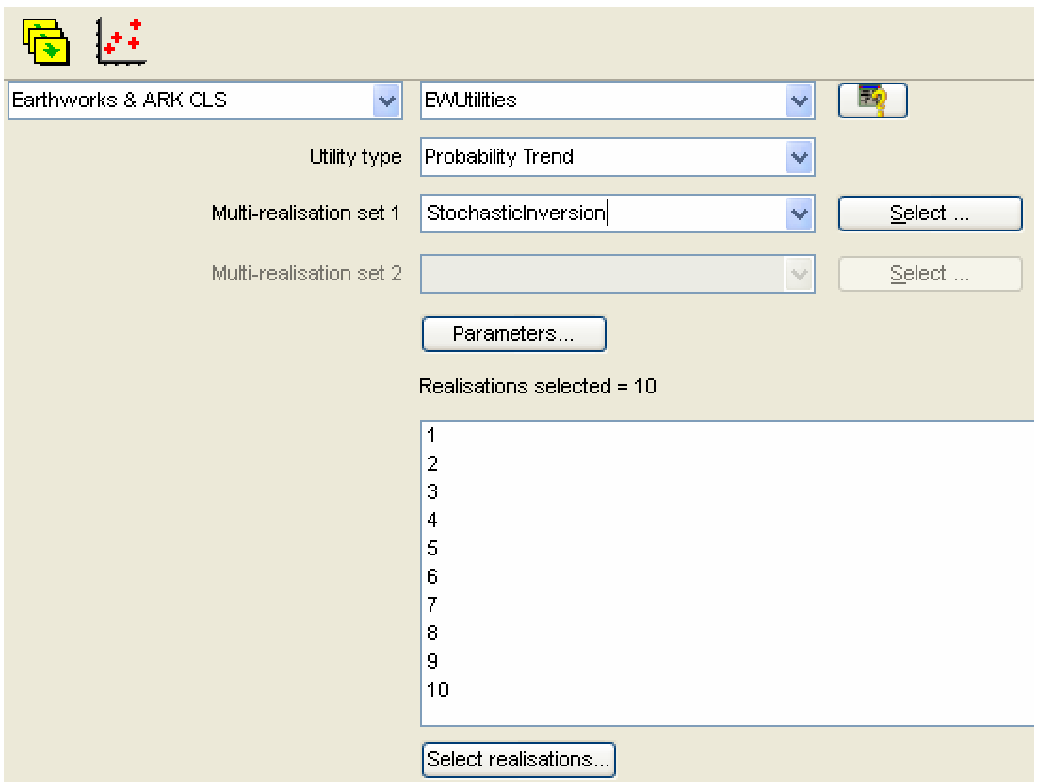


The effects of selecting each option are described below

Selected Item	Meaning	Effects
Multi realisation set	The set of stochastic impedance realisations to be processed	
Time 1	First time position for definition of linear impedance trend	A linear impedance trend will be constructed defined by values of *Impedance 1* at *Time 1* and *Impedance 2* at *Time 2*
Impedance 1	Impedance value at position *Time 1* for definition of linear impedance trend	A linear impedance trend will be constructed defined by values of *Impedance 1* at *Time 1* and *Impedance 2* at *Time 2*
Time 2	Second time position for definition of linear impedance trend	A linear impedance trend will be constructed defined by values of *Impedance 1* at *Time 1* and *Impedance 2* at *Time 2*
Impedance 2	Impedance value at position *Time 2* for definition of linear impedance trend	A linear impedance trend will be constructed defined by values of *Impedance 1* at *Time 1* and *Impedance 2* at *Time 2*

Impedance limit	Limit of impedance values relative to the impedance trend to be included in the probability calculation	• The impedance limit defines the upper or lower impedance boundary for inclusion in the probability calculation. • If this value is *positive* then the impedance range included in the probability calculation at any time sample will be from the impedance calculated from the trend line and *greater* up to this impedance limit • If this value is *negative* then the impedance range included in the probability calculation at any time sample will be from the impedance calculated from the trend line and *less* down to this impedance limit

The window below shows the final output options

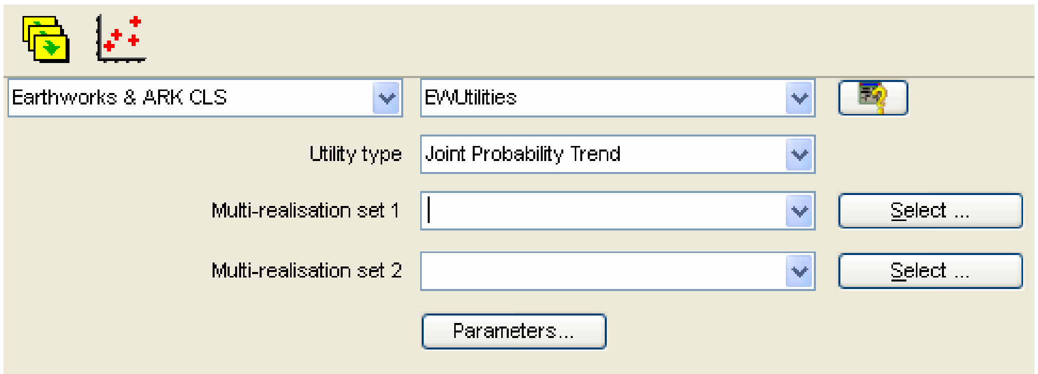


6.6 Probability cube joint trend

This utility is similar to that of the joint probability cube and probability trend. As with the first of those utilities this one requires two sets of the realisations which are the same selections. The utility is launched by

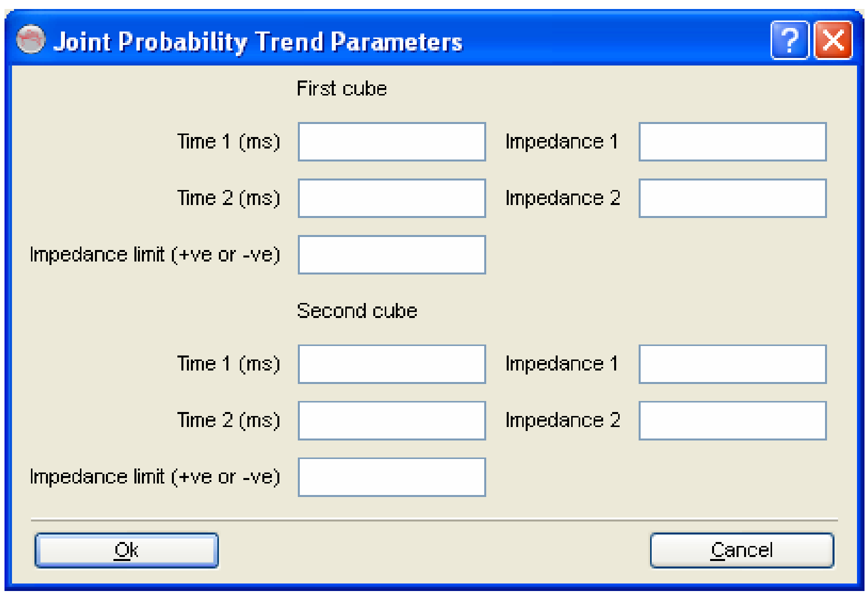
- **Click `Analysis`**
- **Select `Attributes`…**

- Change **`All`** to **`Earthworks & ARK CLS`**
- Select **`EWUtilities`**
- Select **`Joint Probability Trend`**



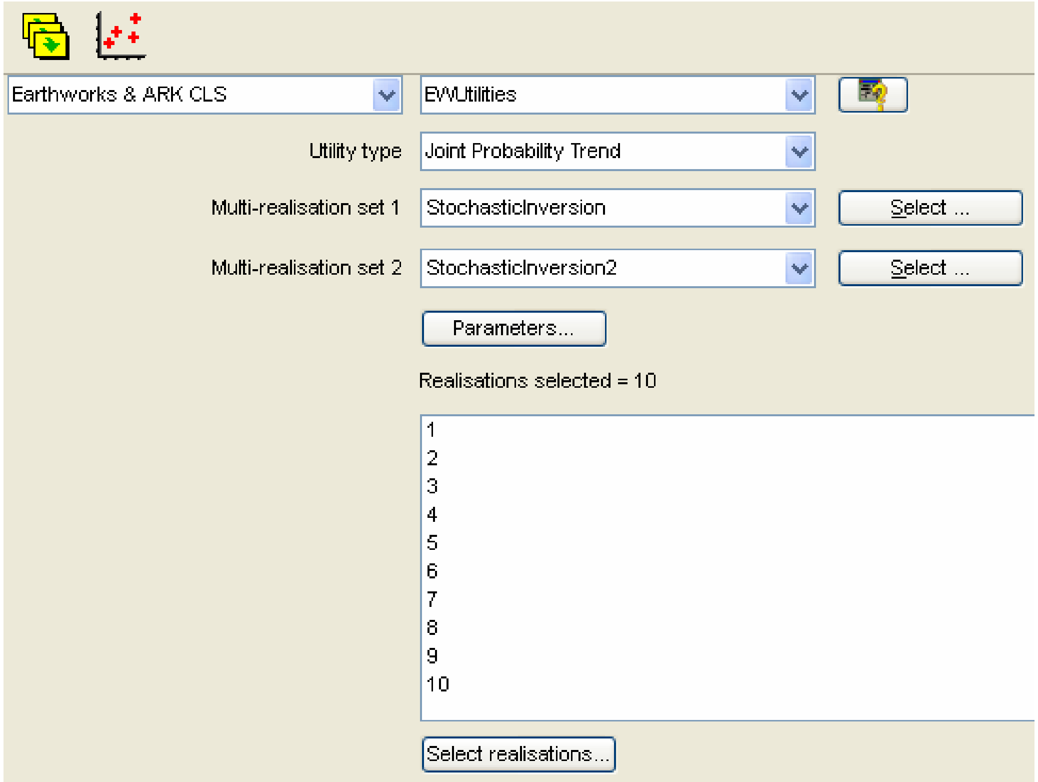
The probability range need next to be defined.

- **Click `Parameters`…**



The effects of selecting each option are described above (ProbcubeTrend) and the user is required to enter information about both.

The window below shows the final output options


Earthworks & ARK CLS
EWUtilities
Utility type
Joint Probability Trend
Multi-realisation set 1
StochasticInversion
Select ...
Multi-realisation set 2
StochasticInversion2
Select ...
Parameters...
Realisations selected = 10
1
2
3
4
5
6
7
8
9
10
Select realisations...

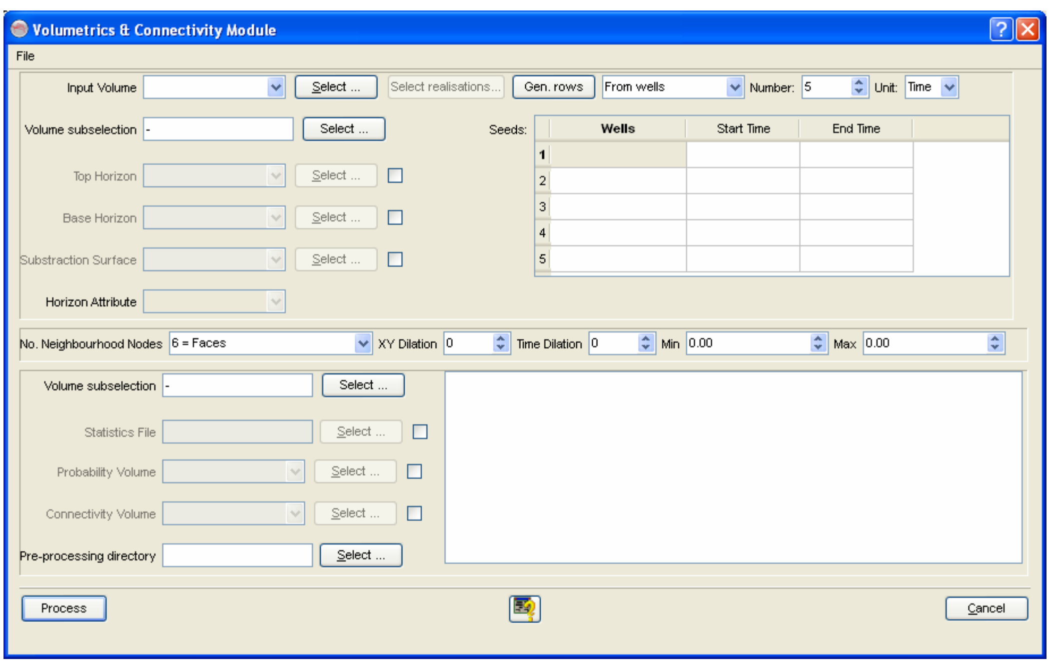
7. CONNECTIONS™ GEOBODY CONNECTIVITY AND VOLUMETRICS

The Connections™ module is designed to compute geobodies from a seismic volume using either one or multiple seed points. The geobody connectivity is calculated by determining if adjacent nodes (seismic samples) are within the specified impedance range. If they are, they are marked as connected and then used as further seed points. In this way the algorithm "walks out" from the initial seeds to create the geobody. If multiple initial seed points are specified then multiple geobodies may be detected. Geobodies intersecting more than one initial seed point are merged to give a single geobody. All geobodies found are numbered and the associated volumetrics associated with each can be optionally output.

Connections™ can be run on a single seismic volume such as the output from a deterministic inversion or it can be run on a multiple realisation set, processing results for each realisation and then allowing computation of a connected probability volume. The output from Connections can be used to estimate reservoir connectivity and associated connected or swept volume uncertainty.

The Earthworks' Connections™ module is available as follows:

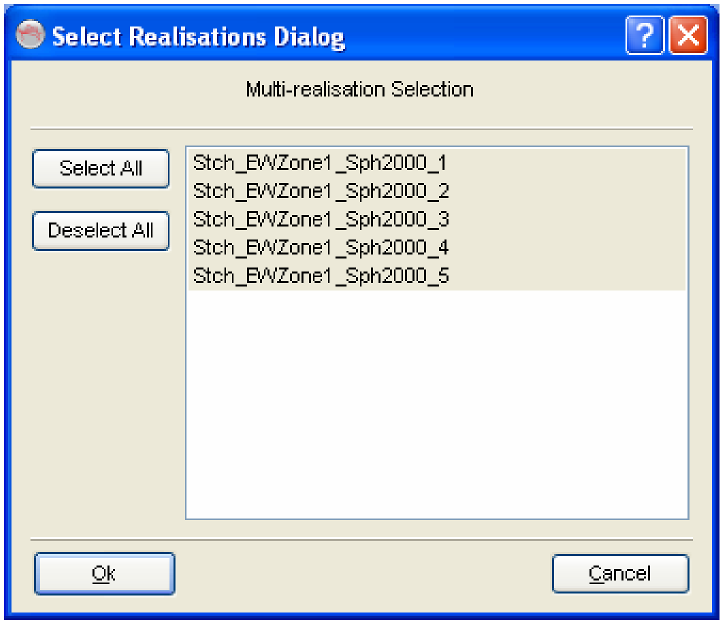
- **Click `Utilities`**
- **Click `MPSI Utilities`**
- **`Select Volumetrics…`**



This module works using pre-saved cubes that have either been saved to disc using the OpendTect processing engine or imported as seismic volumes. It does not follow the OpendTect Attribute pattern as the job is not run on a trace by trace basis but by scanning the volume from a current location or node to its neighbouring nodes.

The Input Volume may be a multi-realisations set but can also be a single-attribute data volume such as the output from a deterministic inversion.

If the Input Volume is a multi-realisation set the following window appears where the user is required to select the realisations for processing.



The algorithm will scan from a set of seeds, marking all nodes (seismic samples) that are connected to these seeds given a connectivity cut-off defined by minimum and maximum amplitude (usually impedance) values. The output could be any of:

- Probability cube (the probability of the nodes to be connected within the specified impedance range)
- 3D connected geobodies with unique identification numbers
- Statistical file reporting the geobody statistics
    - Per realisation:
        - Number of distinct geobodies
        - Total Connected Cells (volume)
    - Per geobody:
        - The Total Connected Cells (volume)
        - Total XY Cells (area)
        - Maximum Time Thickness
        - Mean Time Thickness

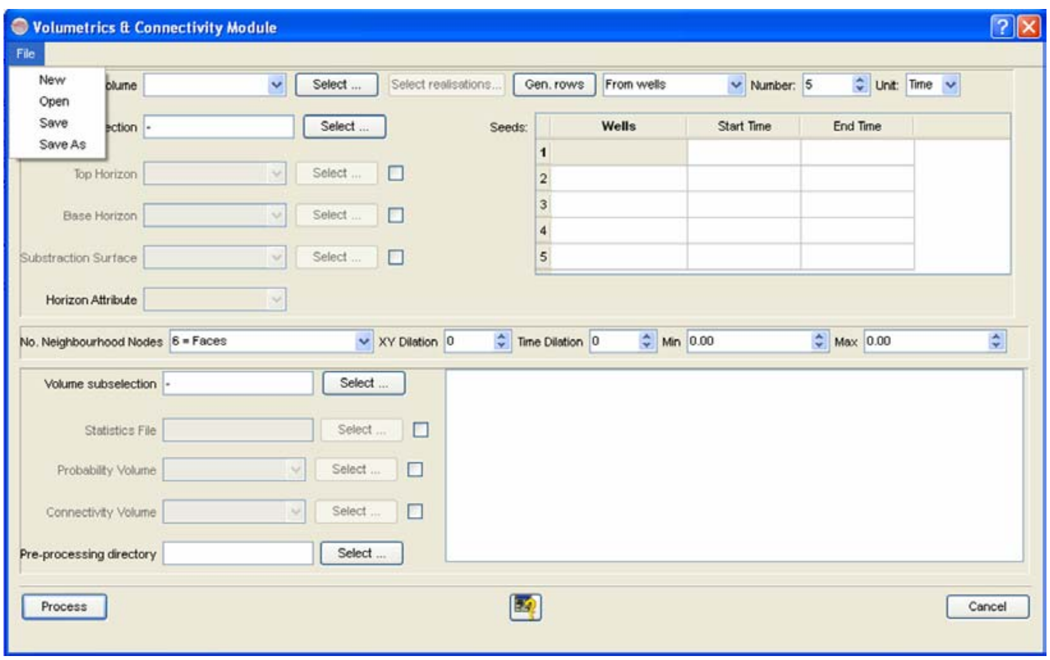
7.1 Main parameter options

The selections that the user must make and options available are described below.

Selection	Meaning	Effects
Input Volume	The set of stochastic impedance realisations to be processed	▪ Needs to be a saved cube in the OpendTect's database. ▪ Can be a multi-realisation or a single attribute data
Volume Subselection	Option to define the scan volume	A scan sub-volume (if smaller than the input volume) can be defined here in term of in-lines, x-lines and times ranges
Top Horizon	Top horizon that will act as a upper boundary by the search engine	
Base Horizon	Base horizon that will act as a lower boundary by the search engine	
Subtraction Surface & Attribute	Option to subtract a lateral impedance trend	Lateral non-stationary impedance trend which can be used as reference impedance value to compute connectivity cut-off. Subtracts an impedance value (one per trace location) from every trace sample at this trace location. Impedance range is then defined relative to this trend
Seed Table	Seed Definition	Seeds can be user defined (a set of nodes defined by inline, x-line, time) or from well logs intervals (in Time or Measured Depth) by setting the interval in term of Time or MD range
Gen. Row, Type & Number	Generate N rows of a given type -User defined or From Wells- in the seed table, N being defined by number field	
Unit	If "From wells" is selected the interval unit can be set to Time or MD (Measure Depth)	
No. Neighbourhood Nodes	Define how the neighbouring nodes of the current node are defined. Nodes are considered as cubes in which case connectivity is defined as: 6 nodes means test for connection by faces only 18 nodes means test for connection by faces and edges 26 nodes means test for connection by faces, edges and corners	
XY Dilation	Option to dilate the seed in X and Y direction (0 means 1 node, 1 means 5 nodes, 2 means 9 nodes… so Number of Nodes = 1 + XY Dilation*4)	
Time Dilation	Option to dilate the seed in time direction (0 means1 nodes, 1 means 3 nodes, 1 means 5 nodes… Number of Nodes = 1 + Time Dilation*2)	
Min	The minimum connectivity cut-off in the same amplitude units as the input volume. Will retain every sample greater or equal to min.	
Max	The maximum connectivity cut-off in the same amplitude units as the input volume. Will retain every sample less or equal to max	
Volume Subselection	The output volume if different from the scan volume (always less than or equal to the scan volume)	

Statistic File	User defined file where the statistics are output per realisation and geobody. Output includes: For each realisation: ▪ Number of distinct geo-bodies ▪ Total Connected Cells (volume) For each geo-body: ▪ Total Connected Cells (volume) ▪ Total XY Cells (area) ▪ Maximum Time Thickness ▪ Mean Time Thickness
Probability Volume	Output probability cube, the probability of the nodes to be connected given the user defined threshold
Connectivity Volume	Output 3D connected geo-bodies cube (one per realisation). Geo-bodies cubes contain one different number per geo-body with 0 been the background matrix
Pre-processing directory	Specify the directory where MPSI temporary processing files will be stored. It is necessary to create a directory where MPSI will store its temporary connectivity files. Make sure this directory is readable and the disk big enough to contain the data
Reporting Area	The statistic file will be displayed here at the end of the processing

It is possible to save the Volumetrics and Connectivity settings into an .xml file. This file can then be reloaded for later usage. To access the save and restore functionalities click the File menu.



Options are:

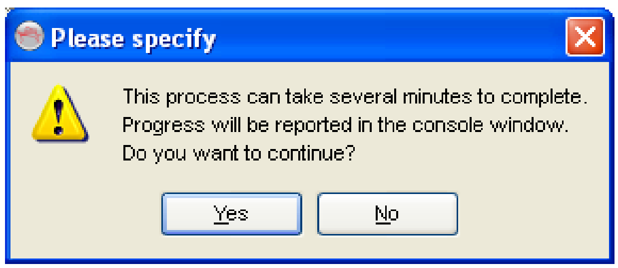
- New: To enter new settings. Will clear the display
- Open: To open a pre-saved settings (.xml) file
- Save: To save the current settings to the current xml file
- Save as: To save the current settings to a new .xml file

MPSI connectivity computation is split into 3 parts:

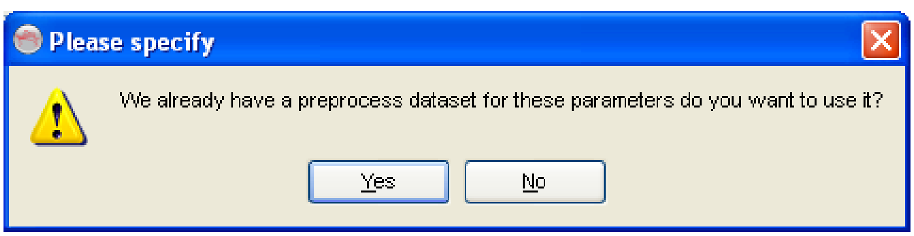
- Pre-processing scans the input cube and saves temporary files on disc.
- Processing does the connectivity computation
- Output data are then save to the database

Before each steps the user is asked to continue or not.

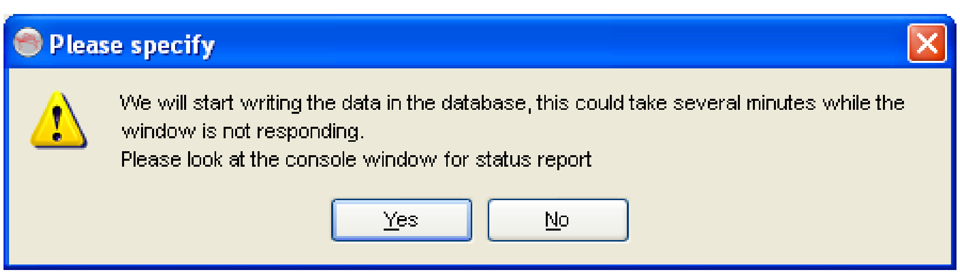
The following dialog appears before starting the pre-processing. The user can check that the parameters are corrected before clicking `Yes`.



The following dialog appears if the pre-processing doesn't need to be re-run. The user can decide to re-run the pre-processing if need be by clicking `No`.

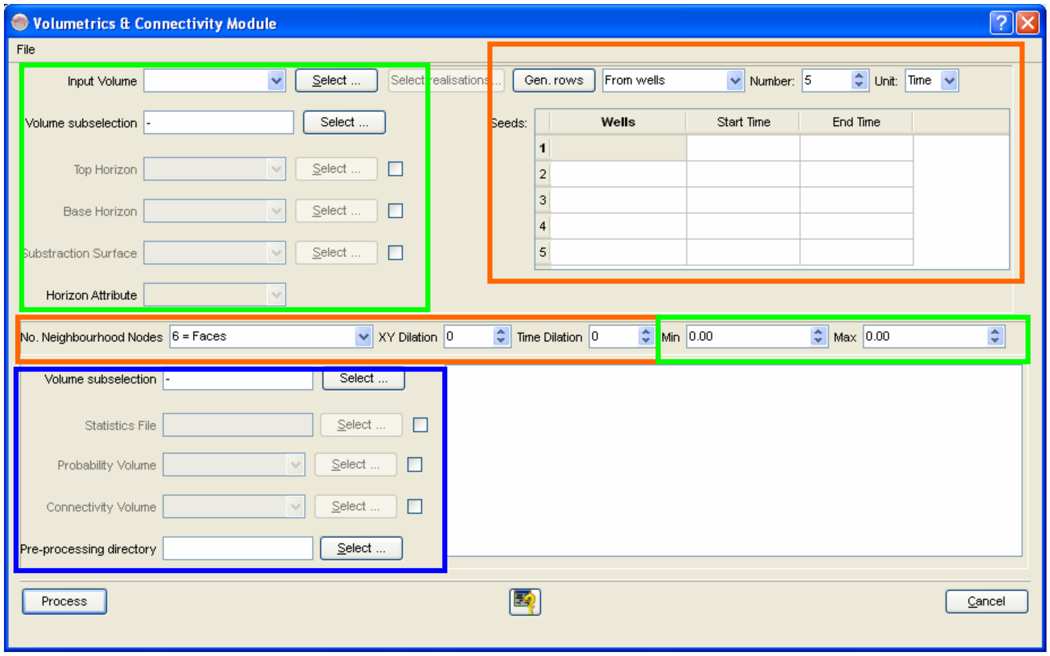


The following dialog appears before up-dating the database.



To know when a step needs to be re-run have a look at the display below where the various steps are colour coded (**pre-processing**, **processing**, **database saving**).

For example changing the seeds or the connectivity cut-offs has no effect on the **pre-processing** therefore, the user can answer yes to the second question.



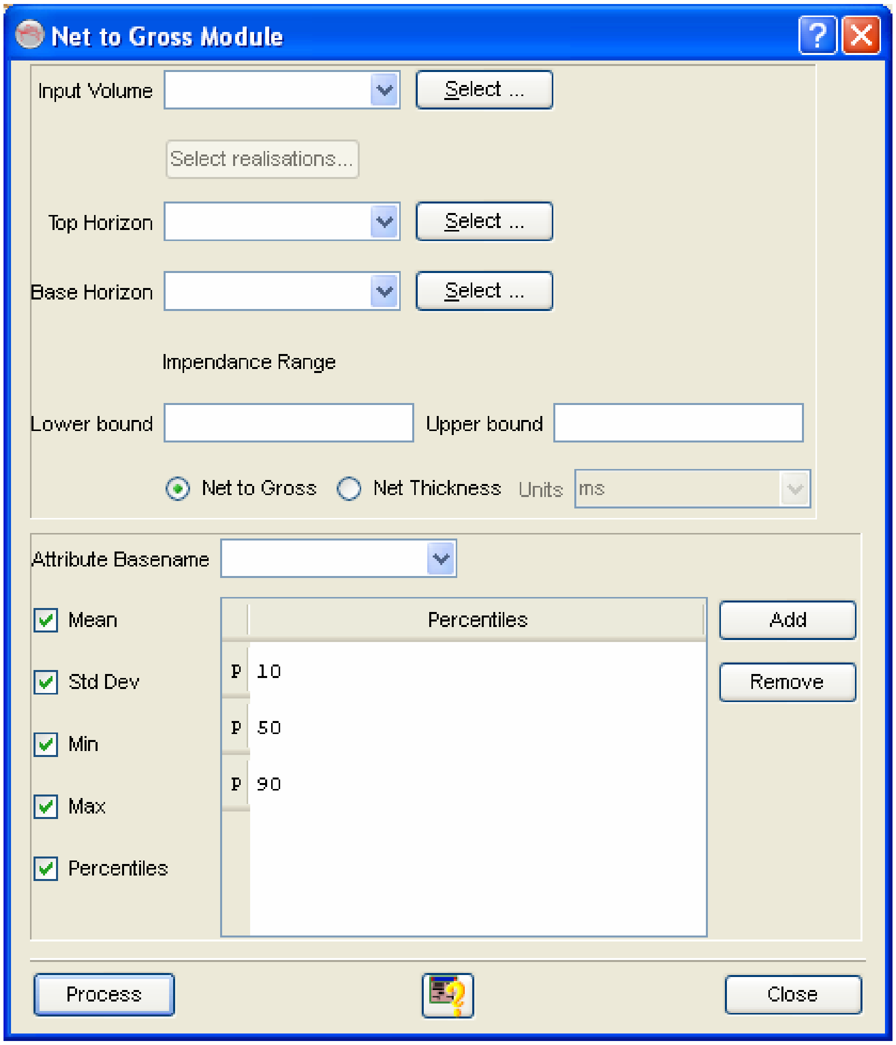
8. Net to Gross Module

The Net to Gross module is designed to compute Net to Gross or Thickness maps between 2 horizons from a seismic volume. The first step is to calculate at each seismic trace position and for each realisation the Net to Gross ratio (NtG) which is the ratio of the number of seismic samples matching a given impedance criteria within two horizons by the total number of seismic samples between these horizons. This impedance range is chosen to represent some reservoir or petrophysical criteria. The outputs are attribute maps attached to the top horizon and can be any of mean, standard deviation, min, max, percentile either as Net to Gross or Net Thickness. They are computed at each trace position using the set of realisations selected. The final property value can be Net to Gross ratio or Net Thickness (in ms or sec) where ***Net Thickness*** = ***Net to Gross*** * ***Gross Thickness*** and the Gross Thickness is the Thickness (in ms or sec) between the 2 horizons.

Net to Gross can be run on a single seismic volume such as the output from a deterministic inversion or it can be run on a multiple realisation set, processing results for each realisation and then allowing computation of Net to Gross or Net Thickness maps..

The Earthworks' Net to Gross module is available as follows:

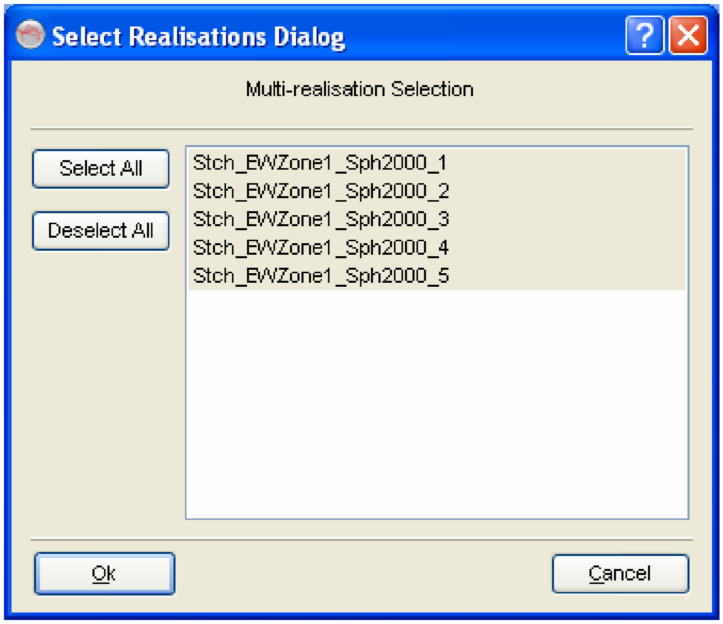
- **Click `Utilities`**
- **Click `MPSI Utilities`**
- **Select `Net to Gross…`**



This module works using pre-saved cubes that have either been saved to disc using the OpendTect processing engine or imported as seismic volumes.

The Input Volume may be a multi-realisations set but can also be a single-attribute data volume such as the output from a deterministic inversion, in which case only the mean is output (as all other outputs are identical to the mean)

If the Input Volume is a multi-realisation set the following window appears where the user is required to select the realisations for processing.



The computation is done between 2 picks horizons. The output could Net to Gross ratio (NtG) or Net Thickness (Net) in ms or sec. Outputs can be any of:

- Min: Min NtG or Net value at each in-line, cross-line position for all realisations
- Max: Max NtG or Net value at each in-line, cross-line position for all realisations
- Mean: Mean NtG or Net value at each in-line, cross-line position for all realisations
- Std Dev: Standard Deviation NtG or Net value at each in-line, cross-line position for all realisations
- Px%: Any number of user defined NtG or Net Percentile (P10, P50, …, P90). Px% values are computed using the Excel method where P0%=Maximum Net to Gross, P100%= Minimum Net to Gross and intermediate Px% values are based on a 1/ (N-1) increment where N is the total number of samples. As standard in our industry P10 >= P50 >= … >= P90. Values are computed scanning all realisations at each in-line and cross-line position. Default values of 10, 50, 90 can be overwritten by editing the ewparameters.xml file located in the arkcls\ew\app\mpsi directory of the installation area.

8.1 Main parameter options

The selections that the user must make and options available are described below.

Selection	Meaning	Effects
Input Volume	The set of stochastic	▪ Needs to be a saved cube in the OpendTect's database.

	impedance realisations to be processed	▪ Can be a multi-realisation or a single attribute data
Top Horizon	Top horizon that will act as an upper boundary. Output Attribute Maps will be assigned to this horizon	
Base Horizon	Base horizon that will act as a lower boundary	
Lower Bond	The minimum cut-off in the same amplitude units as the input volume. Will retain every sample greater or equal to this value	
Upper Bond	The maximum cut-off in the same amplitude units as the input volume. Will retain every sample less or equal to this value	
Attribute Basename	An user defined string that prefixes any selected outputs (e.g. if set to NtG, outputs will be named NtG_min, NtG_max… depending on the user defined outputs choices)	
Net to Gross & Net Thickness	Determine whereas to output Net to Gross or Net Thickness maps. If Net Thickness is ticked then the output unit (ms or sec) can be selected	
Mean	Tick to output NtG or Net arithmetic average map	
Std Dev	Tick to output NtG or Net standard deviation map	
Min	Tick to output NtG or Net minimum map	
Max	Tick to output NtG or Net maximum map	
Percentiles	Tick to output NtG or Net percentiles maps	
Percentiles List	User can edit, add or remove any percentile probability. Default values of 10, 50, 90 can be overwritten by editing the ewparameters.xml file located in the arkcls\ew\app\mpsi directory of the installation area. Px% values are computed using the Excel method where P0%=Maximum Net to Gross, P100%= Minimum Net to Gross and intermediate Px% values are based on a 1/ (N-1) increment where N is the total number of samples. As standard in our industry P10 >= P50 >= … >= P90	

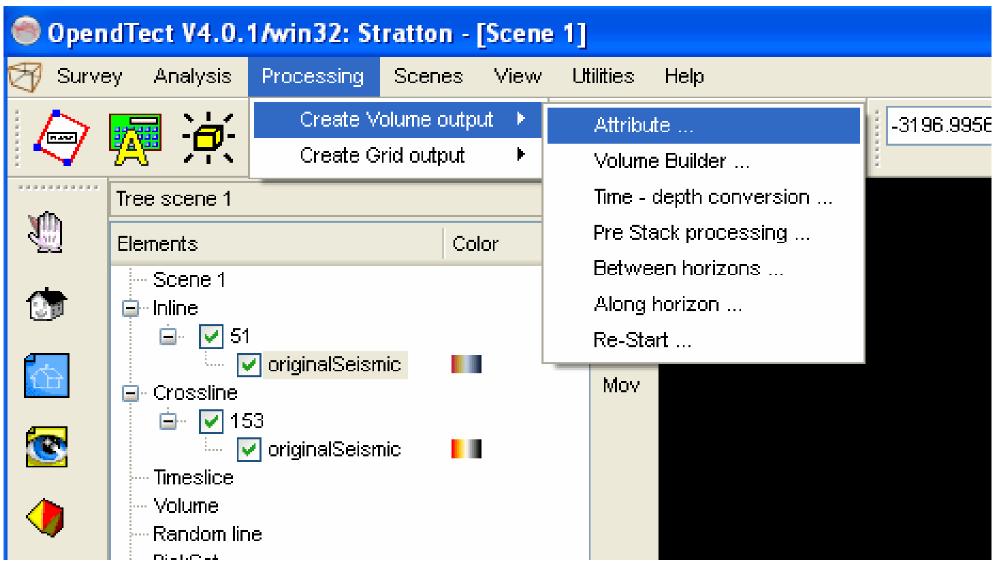
Outputs maps are stored as Surface data attached to the top horizon in OpendTect. In order to know how to visualise them, refer to section *4.6 Horizon* of OpendTect main documentation. They can be exported to plain ASCII file as described in the section *5.4.2. Export Horizon* of OpendTect main documentation. Section 1*0.8 of MPSI Worked Example* shows how to visualise the output maps in OpendTect.

9. BATCH PROCESSING UTILITIES

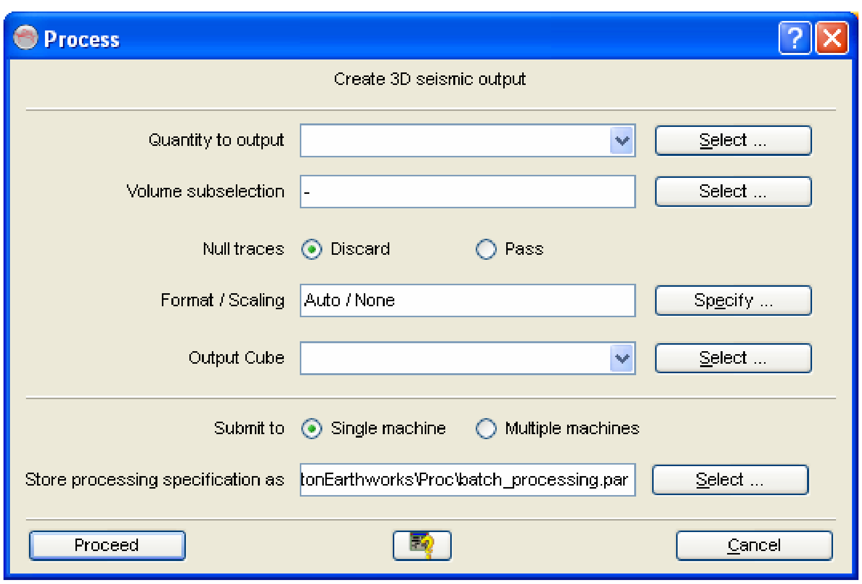
OpendTect batch jobs for 3D volumes can be processed on *single* machines or on *multiple* machines. See the OpendTect documentation for a detailed description of the batch process.

In general, to create a stored (permanent disk location) version of any of the attributes, the user will open the following menu:

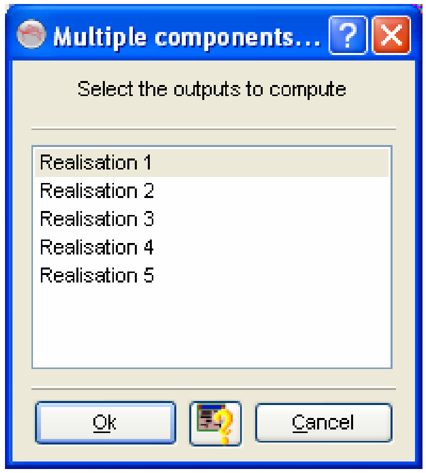
- **Click `Processing`**
- **Select `Create Volume output`**
- **Select `Attribute`…**



This will open the following dialog where the user can specify the attribute to output, any subset of the volume to be processed and specify the name of the output cube.

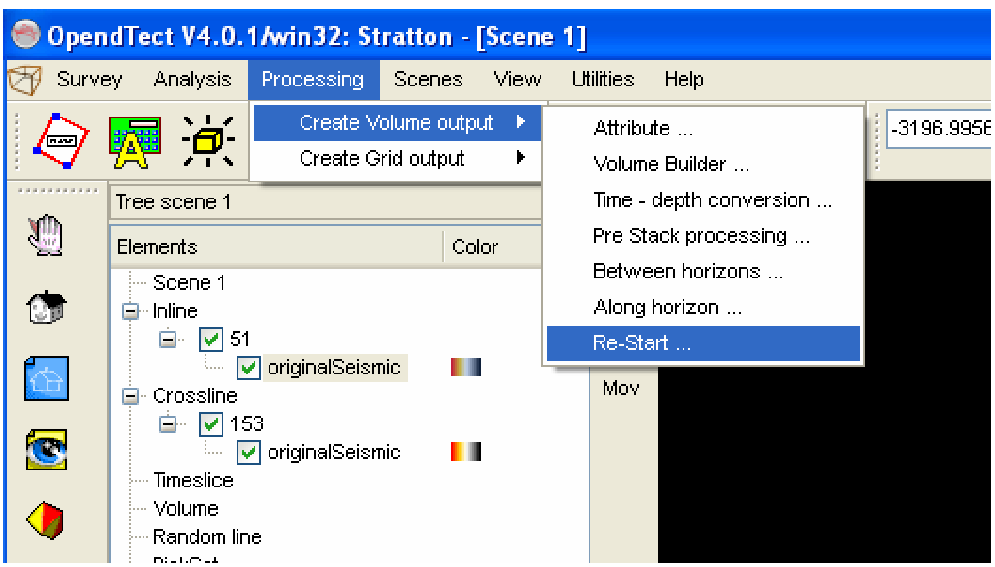


If this attribute is a stochastic attribute (or any multiple-component attribute) the following panel appears where it is possible to select the realisation to output.

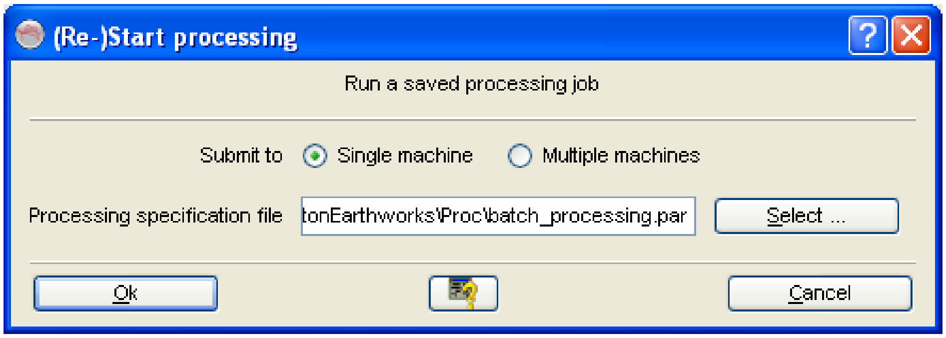


Any pre-saved parameter file can be re-run from:

- **Click `Processing`**
- **Select `Create Volume output`**
- **Select `Re-start`**



These actions reveal the following window



Specify the name of the parameter file saved, select whether to run on single or multiple machines and press Ok to commence batch processing.

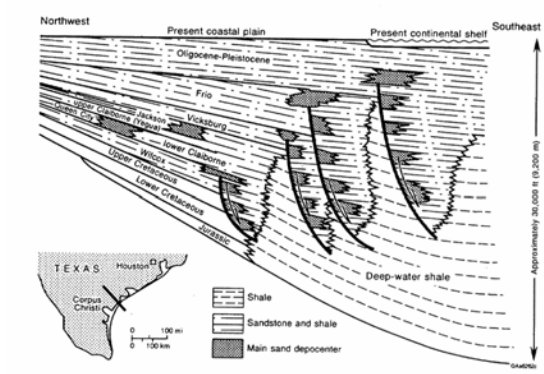
10. WORKED EXAMPLE

The aim of this section is to guide the user though a typical workflow and demonstrate the impact on the results of some of the main options available to the user. To expedite the workflow for advanced users or for those unable to follow the workflow in one continuous phase the worked example has been saved in sessions which relate to each of the sections below. At the end of each section the session is saved and the user entering the workflow should refer to the end of the previous section for the name of the session to restore, by:

- **Select `Survey` from pull-down menu**
- **Select `Session`**
- **Select `Restore`**
- **Choose <Session name to restore>**

10.1 Example dataset: Stratton Field

The dataset used here is the Stratton Field 3D seismic and well log data package prepared by the Bureau of Economic Geology, Austin, Texas, USA. Stratton Field is an on-shore gas field producing from the Oligocene Frio Formation in the NW Gulf Coast Basin, Gulf of Mexico. The Frio formation is a sediment supply dominated depositional sequence characterized by rapid deposition and high subsidence rates and forms of the major progradational off-lapping stratigraphic units in the basin.



The top of the middle Frio formation is about 1200 ms, corresponding to a sub-sea elevation of around -4,500 ft. There is little faulting in this interval and the formations relatively undeformed and flat lying. Reservoir facies of the middle Frio are interpreted as multiple amalgamated fluvial channel-fill and splay sandstones. The composite channel fill deposits range from 10 to 30 ft thickness and show either an upward fining or a blocky log profile. The composite channel deposits can be up to 2,500 ft in width. Splay deposits show typical thicknesses of 5 to 20 ft and are proximal to the channel systems. Porosities in these fluvial reservoirs range from 15 – 25 % with air permeabilities of less than 1 to greater than 4,000 milliDarcies.

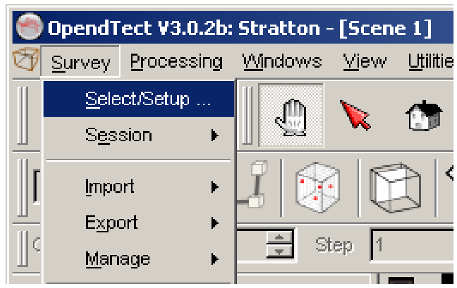
There are a total of 21 wells in the field. Wells 01, 02, 03, 04, 05, 06 and 21 have limited log suites and in particular do not have acoustic impedance data available. Well 16 is only logged over a deeper section and does not have any data over the modelled interval. We will use in this example wells 08, 10, 11, 12, 14, 15, 17, 18, 19 and 20, a total of ten wells.

Two seismic horizons have been picked from coloured impedance data and used to provide the structural framework. These are a middle Frio pick (MFrio) and a pick which corresponds to the top of the Upper C38 formation.

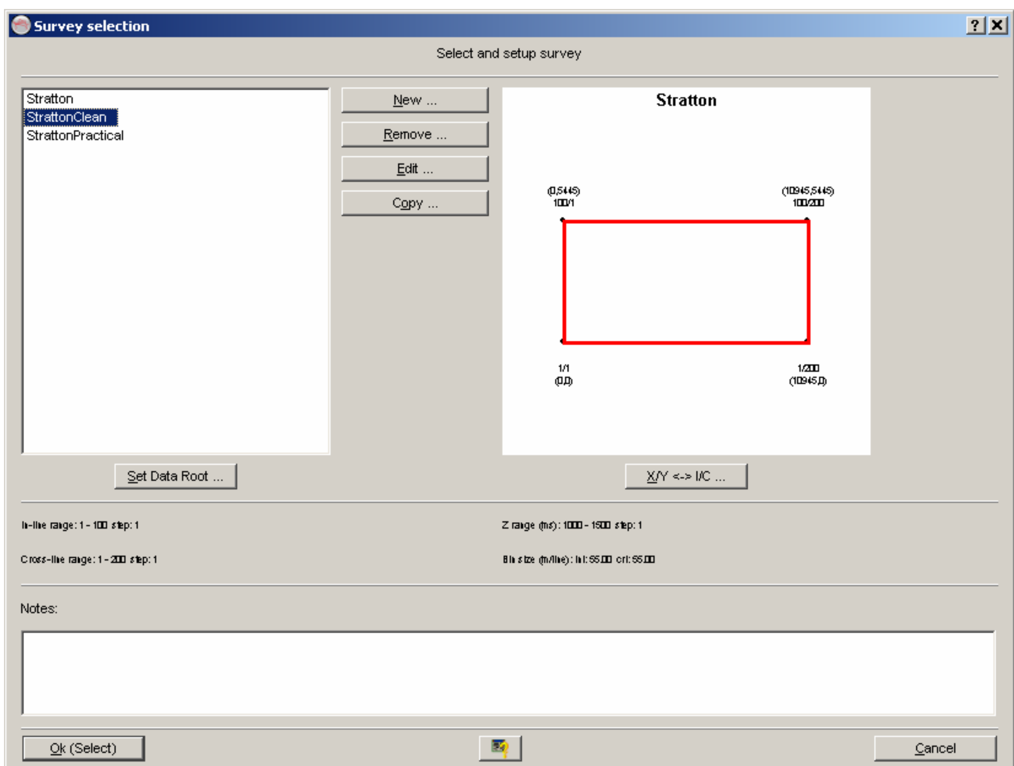
10.2 Stratton Field setup

Once OpendTect has been started the Stratton survey must be setup. This can be done using the following:

- ➢ **Survey**
- ➢ **Select / Setup …**



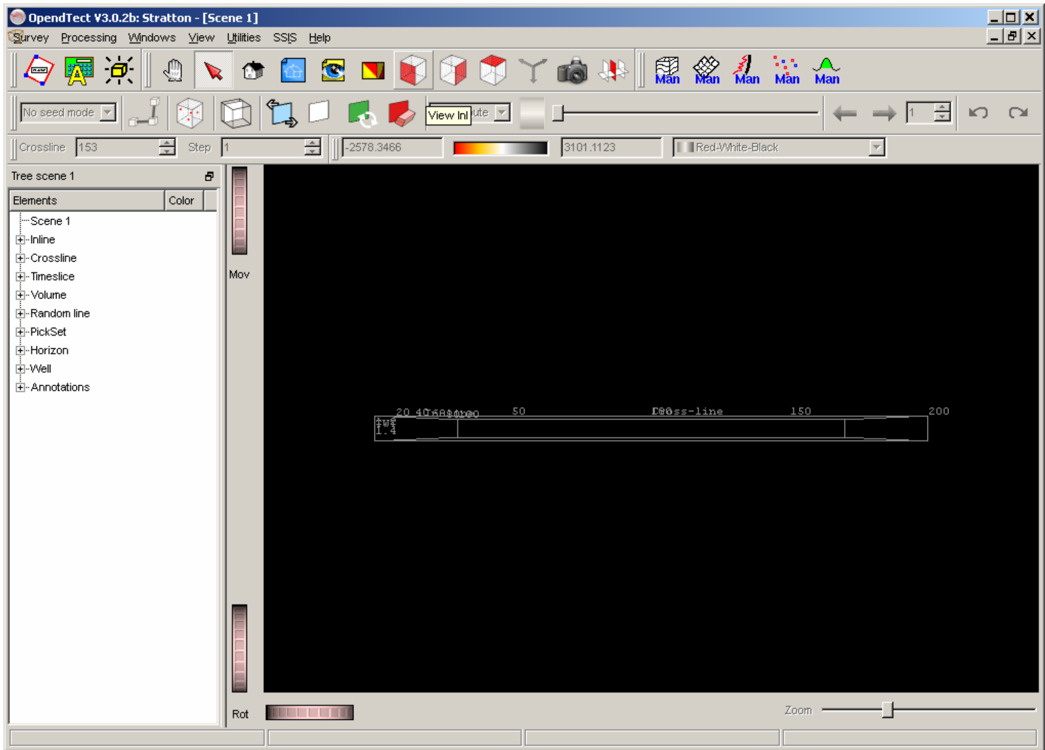
The following screen will be made available for the user to choose the survey to setup.



A 'clean' version of the dataset has already been created and this can be setup using the following actions

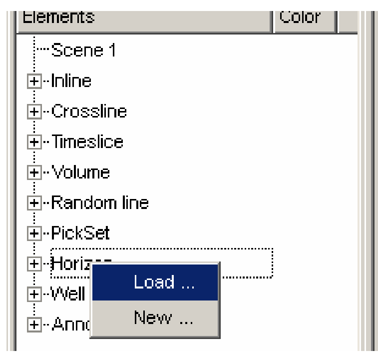
- ➢ **Select `StrattonClean`**
- ➢ **Click Ok**

The above sequence of actions will reveal a screen in OpendTect that looks like the image below

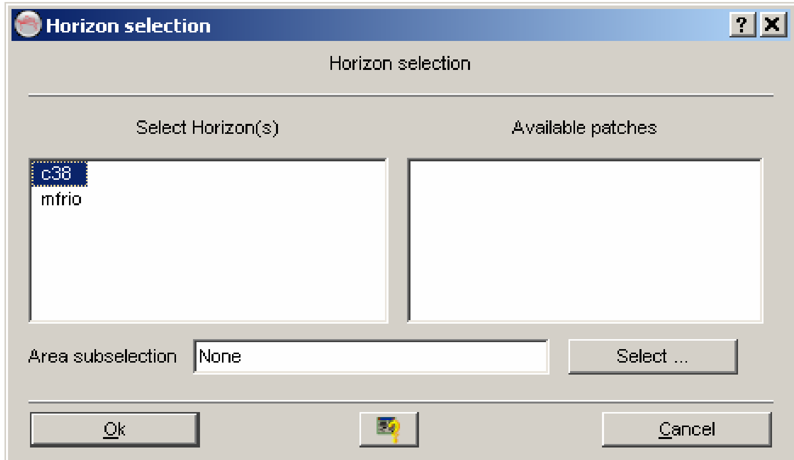


The next stage is to load in the seismic horizons that create the structural framework

- **Right-click Horizon**
- **Select Load …**

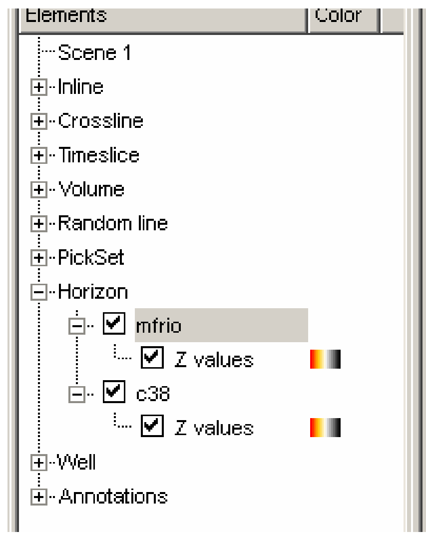


The following window will appear



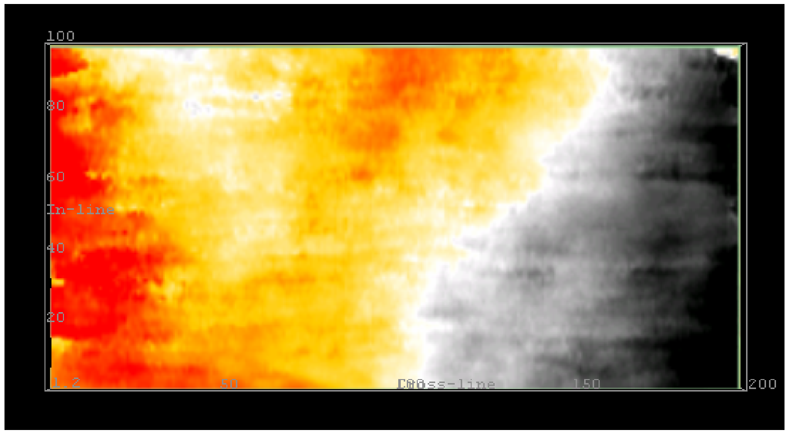
The user should select the upper MFrio and C38 horizons and then select Ok

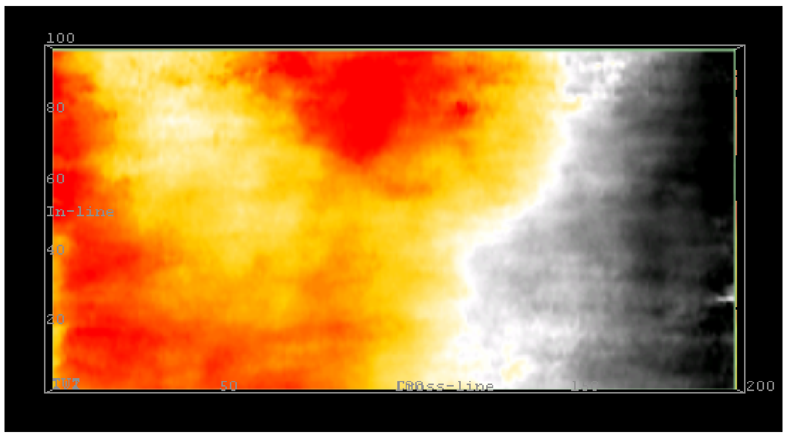
- **Select <Horizon>**
- **Click Ok**



OpendTect will display the horizon labels and place ticks in the boxes to show that they are displayed (see right).

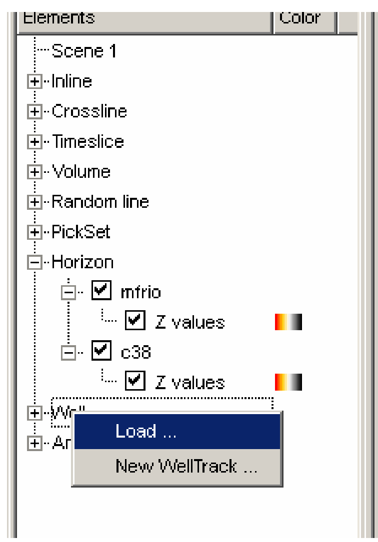
A plan view can be used to display the horizons. The icon  in the toolbar along the top of the main window can be used. Both horizons will not be visible at once but removing the tick of the MFrio horizon will show that of the C38 horizon. Both horizons are shown in plan view below





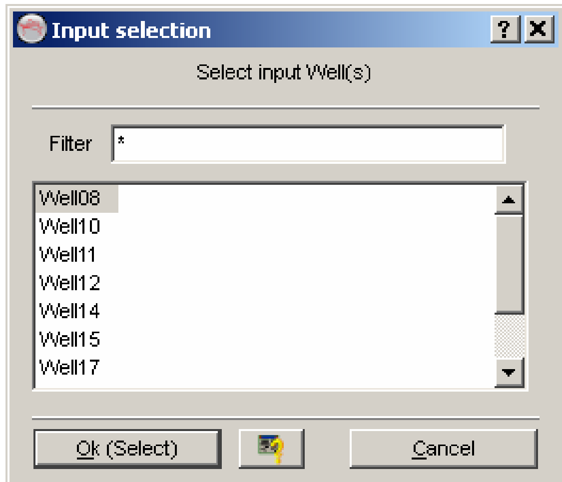
The next stage is to load the wells. This is done in a similar way to that of the horizons:

- **Right-click Well**
- **Select Load …**

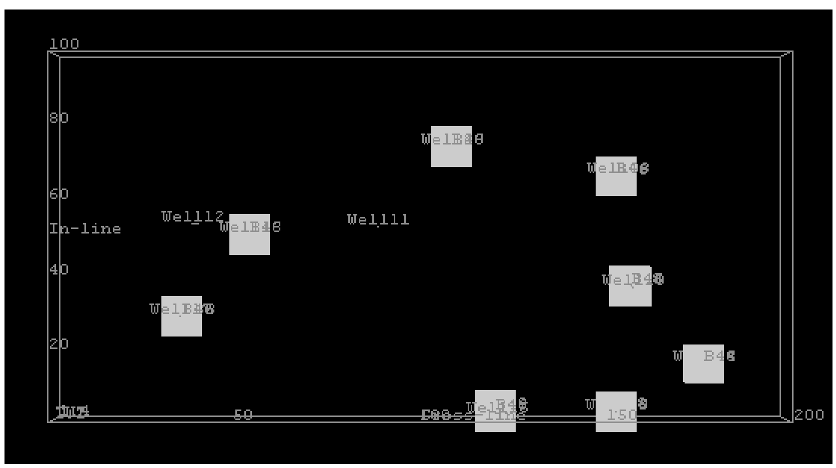


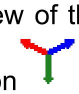
The following window will be revealed and the user can select individual wells or highlight all wells and to select all.

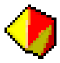
- **Click well(s)**
- **Hold <Ctrl> for more than one well**
- **Hold <Ctrl + Shift> for range of wells**
- **Click Ok**



The locations of the wells appear on the plan view and if the horizons are switched off (as described above) the plan view will be the same as below

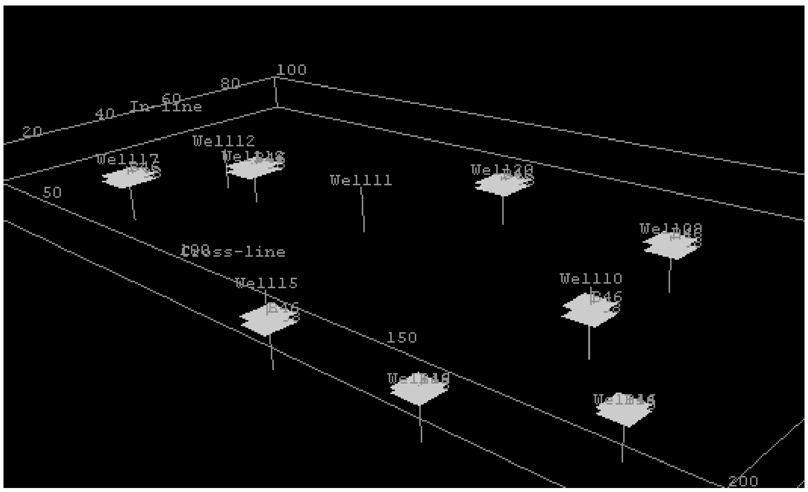


If the user switches from interact mode  to view mode  using the icons in the toolbar running along the top of the window, the mouse icon changes and the user can by clicking and holding the left mouse button rotate the view of the volume. To assist with the orientation of the rotation, axis can be turned on . Furthermore, the view may be switched between orthographic and perspective views of the volume

. The mouse wheel may be used to zoom in and out of the view. If the user follows the next set of actions

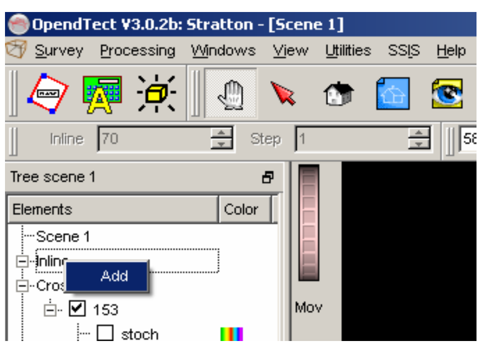
- **Click view mode**
- **Click rotation axis on**
- **Click perspective view on**
- **Click and hold left mouse button and rotate view**
- **Use mouse wheel to zoom in**

The view of the volume will look something similar to:



The original seismic data will be visualized before it is used to construct a 3D model. It is displayed by constructing an inline (at 51) and a crossline (at 153):

- **Right-click Inline**

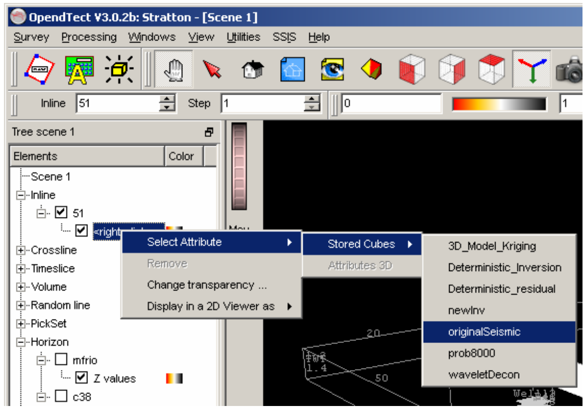


The white section along the length of the volume will appear at line 51.

The seismic volume may be added (for line 51) by

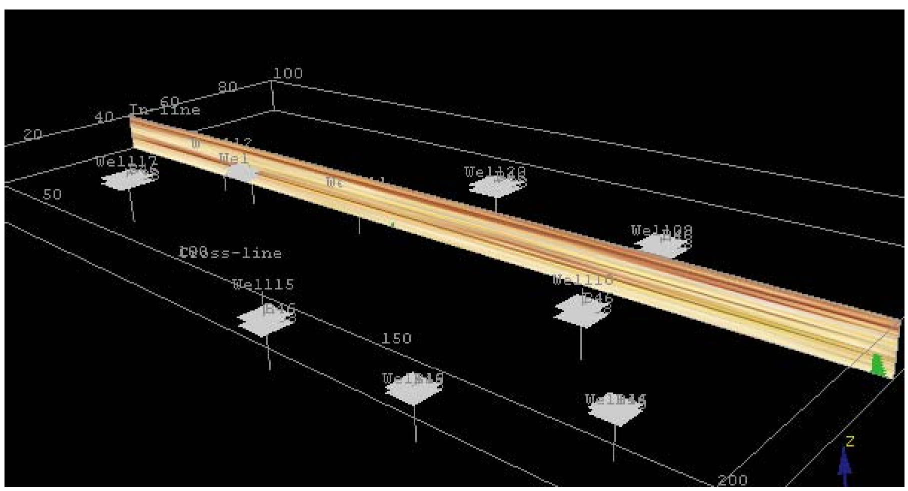
- **Right-click Inline**

- **Select `attribute`**
- **Select `Stored Cubes`**
- **Select `originalSeismic`**



The location of the inline and crossline may be modified near the top of the window.

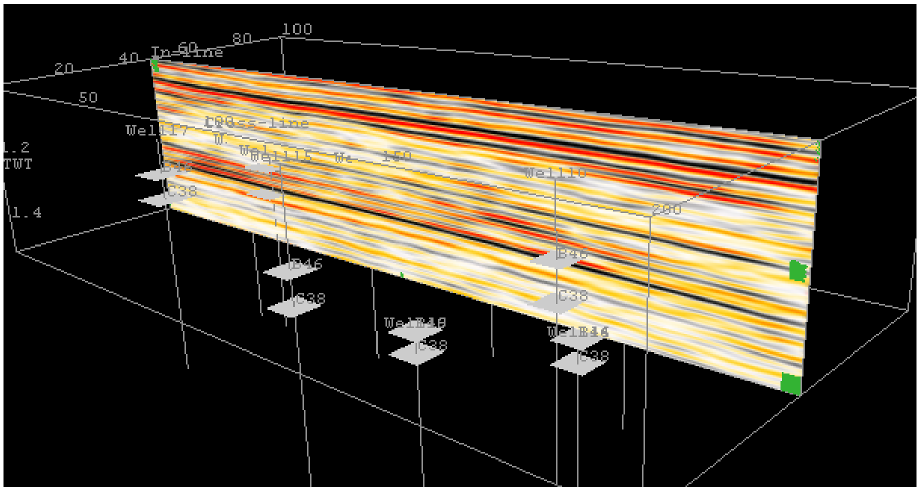
The view that will be evident after following the above actions should be similar to:



We need to change the scaling in the z-dimension to exaggerate the distance to be able to visualize more clearly the pattern. This can be performed by

- **Select `View` from pull-down menu**
- **Select `Z-scale`**
- **Enter a value of 10**

If the user clicks the view all icon  the view is reset to show all of the available volume. The view of the inline section should look something like the image below

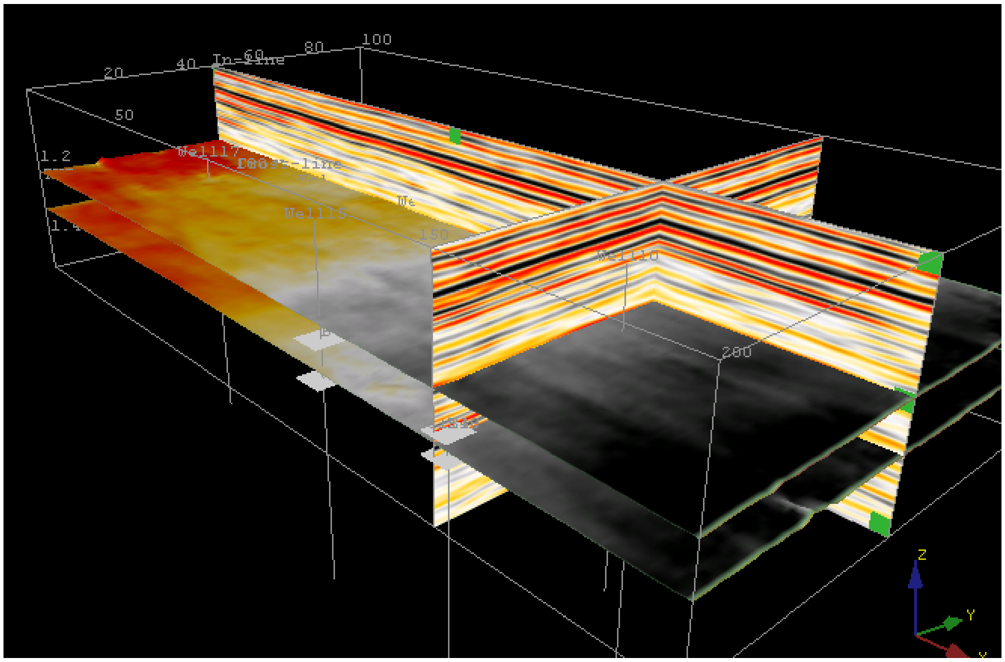


The colours used in the display are available for selection in the top right part of the OpendTect window. It is also possible to display the colour bar in the 3D view by pressing the display colour bar button 

A cross-line may be added following a similar procedure to that of the inline:

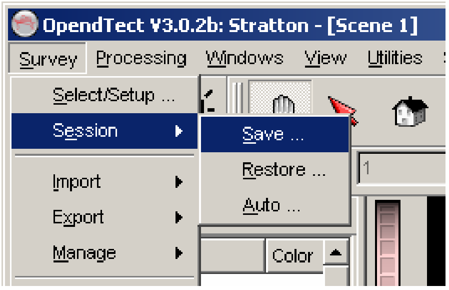
- **Right-click `Crossline`**
- **Select `attribute`**
- **Select `Stored Cubes`**
- **Select `originalSeismic`**
- **Enter a Crossline location of 153**

If we switch on the horizons the view that the user will now see includes horizons, wells and the seismic information for inline 51 and crossline 153 and it should look similar to the image below

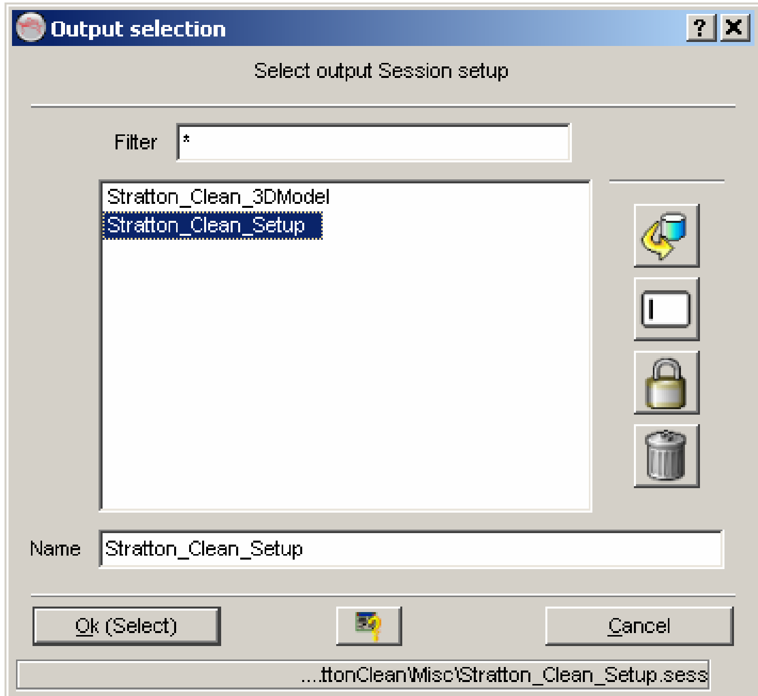


At this stage we should save our progress using the actions below and this will enable the user to return to this stage without having to repeat the setup

- **Select `Survey` from pull-down menu**
- **Select `Session`**
- **Select `Save`**
- **E.g., Stratton_Clean_Setup**

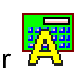


The following window will appear for the user to enter the location to save the session. The icons on the right of the window are used to navigate to other locations on the disk.

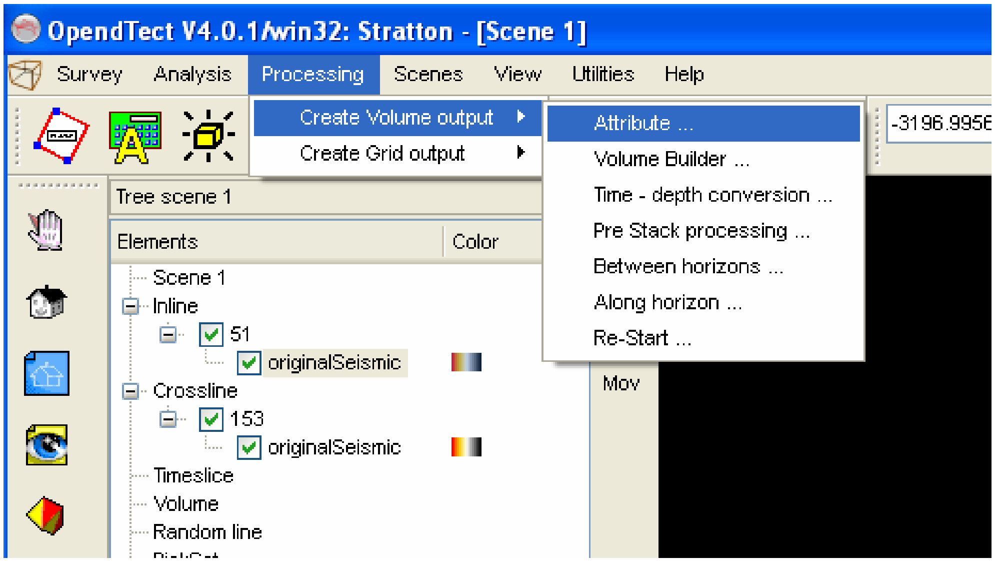


10.3 EW3DModel attribute

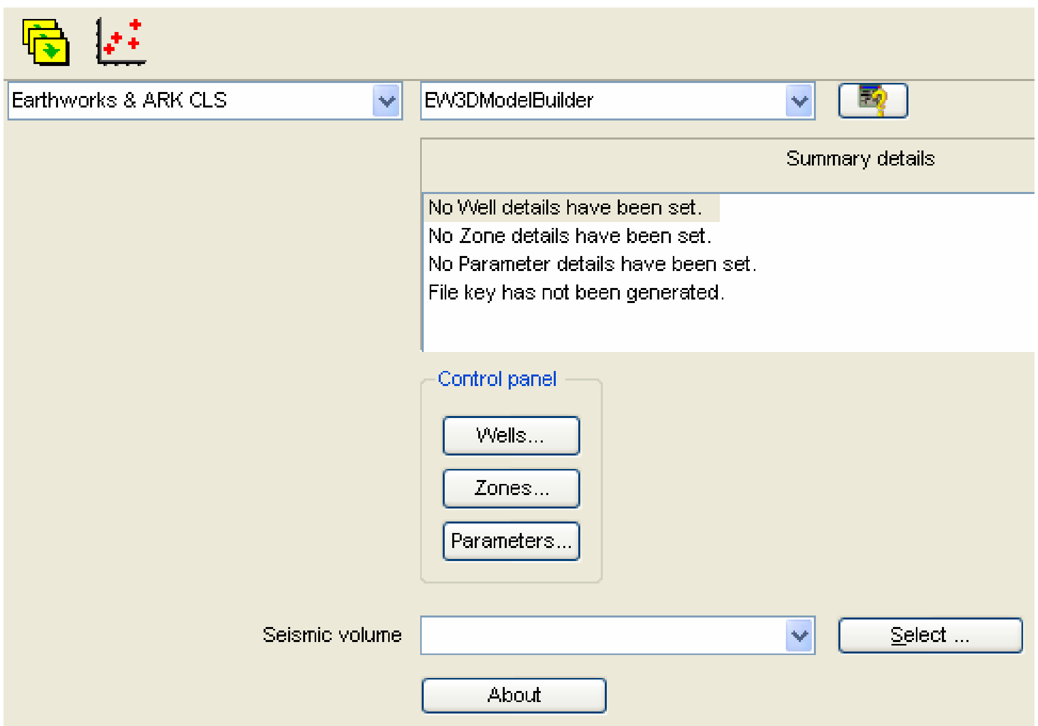
We will build a model from the Stratton Field dataset that has three layers defined by the model top, the seismic horizons MFrio and C38 and the model base. Some 3D representations will be demonstrated. Though mainly 2D planes, in either the horizontal or vertical orientation, will be used to compare the differences between the main options.

The user should proceed to `attribute Analysis` using either  or

- **Click `Analysis`**
- **Select `Create Volume output`**
- **Select `Attribute`** …



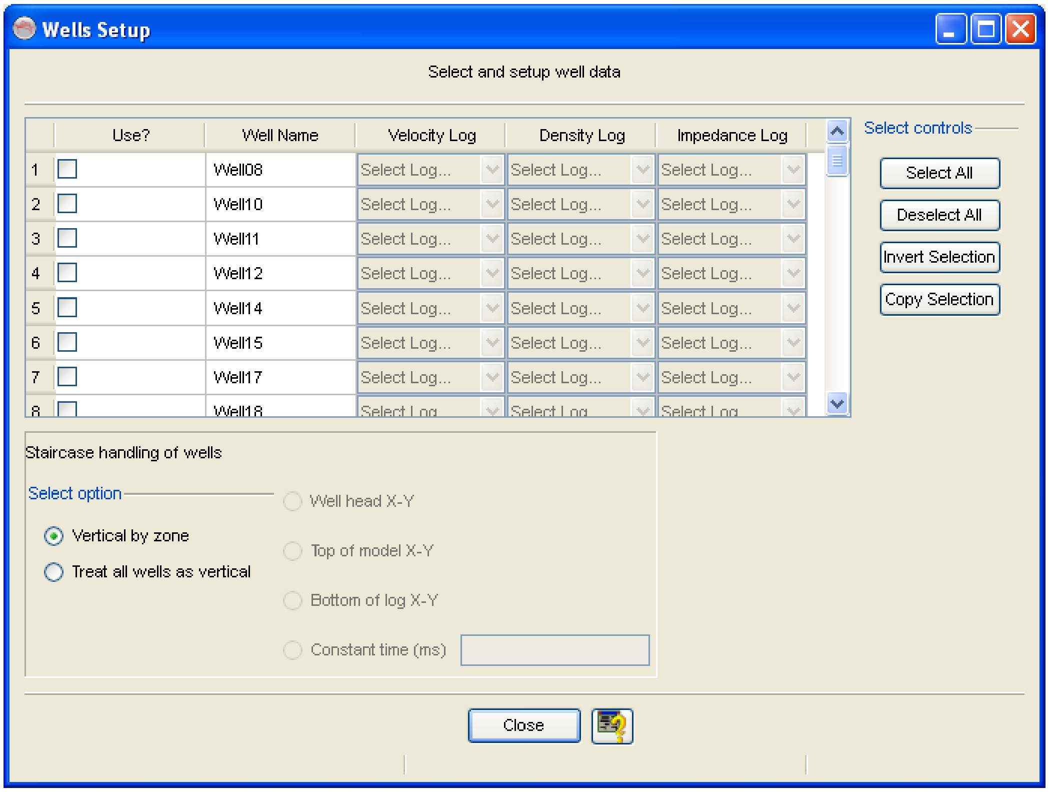
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EW3DModelBuilder`**



In the summary details there are no well, zone or parameter details set. These must be set first using the Earthwork (EW) Control Panel below the summary details:

- **EW Control Panel**
- **Click `Wells`**
- **Select `Vertical By Zone`**

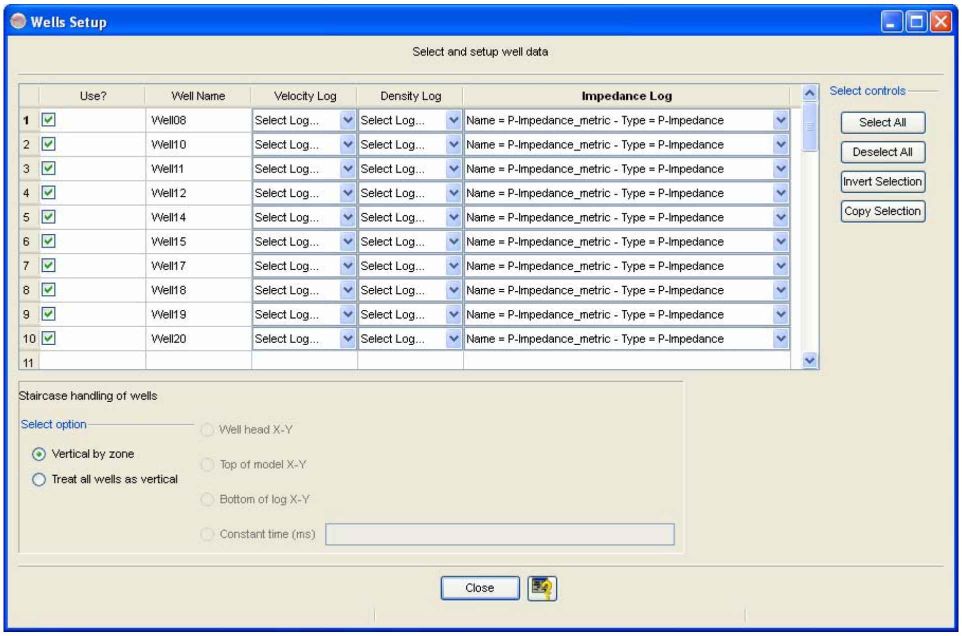
The following screen will reveal the wells that the software has found within your current survey environment set-up and the opportunity to select which of those available wells to use and the type of data to use



We will use all available wells and impedance log data and initially we will treat the wells as vertical by zone:

- **Click `Select All`**
- **Select `Name = P-Impedance`**
- **Resize the column to see the entire log name**
- **Highlight current cell**
- **Press `Copy Selection`**
- **Click `Close`**

In this case the window in OpendTect will look the image below

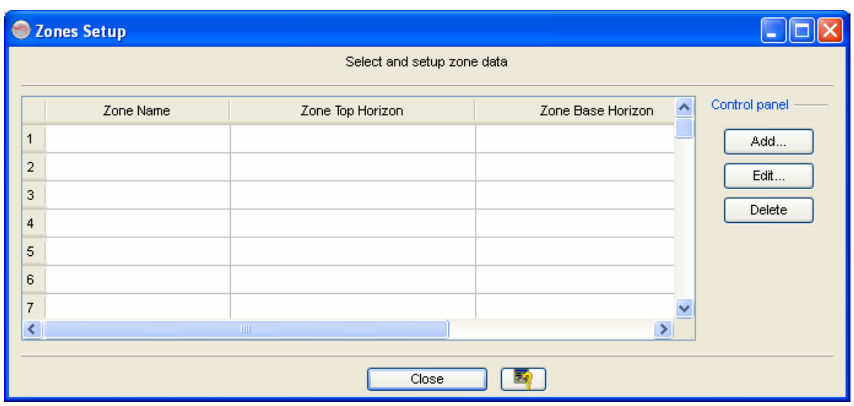


On returning to the Attribute set window the user can see that the summary details have changed and that the number of wells in the selection is now 10.

Next we need to select the zones from the EW Control Panel

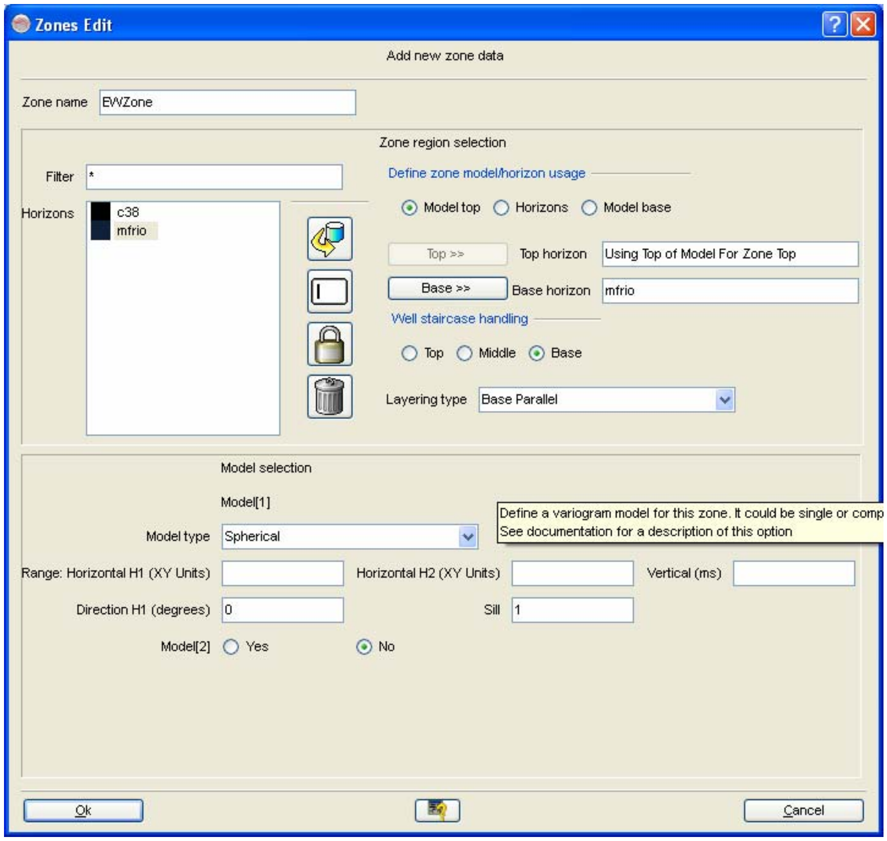
- **EW Control Panel**
- **Click `Zones`**

The window will appear as that below and requires the addition of zones



In this case the user must add a zone and the following window will appear

- **Click `Add`** ...

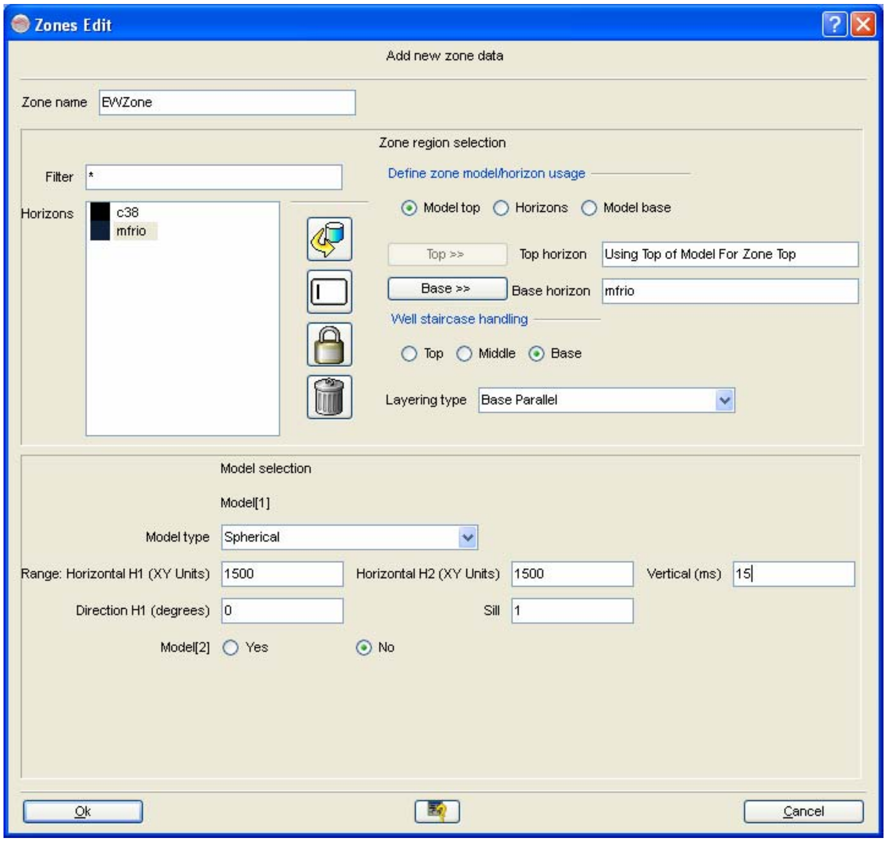


The user is now required to enter information about the zone model and horizon usage, the well staircase handling and the layering type as described in detail in previous sections of this manual

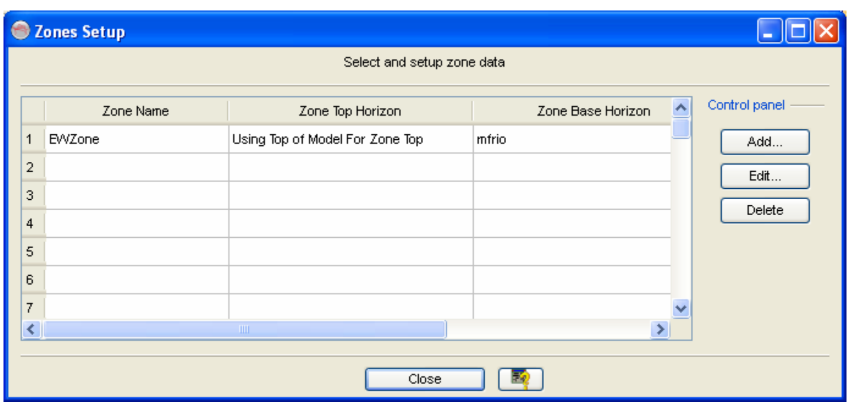
- **Note that this is the top zone called EWZone**
- **Note that the Top Horizon is `Using Top of Model for Zone Top`**
- **Select `MFrio` horizon**
- **Click `Base` >> to enter MFrio**
- **Check `Base` under Well Staircase Handling**
- **Select `Base Parallel` for Layering Type**

The next stage is model selection which involves choosing the model type and entering the parameters for the spatial correlation to be used in the 3D model. The window below displays all of the options that the user should have entered

- **Model Type pull down menu and select `Spherical`**
- **Enter a Vertical Range (ms) of 15**
- **Enter a Horizontal Range H1 (XY Units) of 1500**
- **Enter a Horizontal Range H2 (XY Units) of 1500**
- **Direction H1 (degrees) of 0**
- **Enter a Sill of 1**
- **Enter Model(2) No**
- **Click Ok**



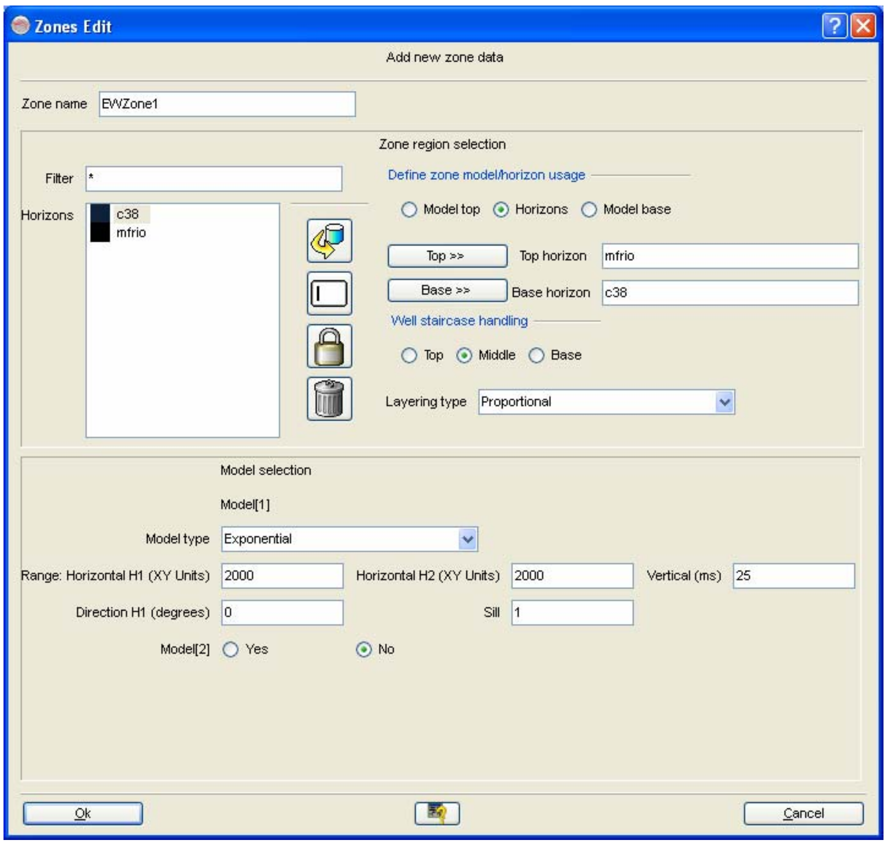
Upon return to the zone data window a description of the first zone will be visible and will appear as the image below



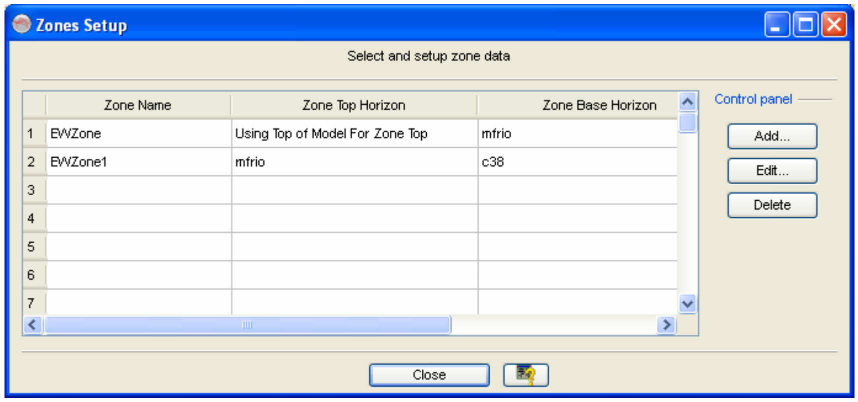
The user needs to add the next zone and so the procedure describe above is repeated and the software automatically increments the zone number and uses the previous zone base (MFrio) as the top of the next zone. It also assumes that the next zone is the model base. The screen with all the correct settings for this zone is shown below

- **Click `Add`**
- **Check `Horizons`**
- **Select `C38` horizon**

- **Click `Base` >> to enter C38**
- **Check `Middle` under Well Staircase Handling**
- **Select `Proportional` for Layering Type**
- **Model Type pull down menu and select `Exponential`**
- **Enter a Vertical Range (ms) of 25**
- **Enter a Horizontal Range H1 (XY Units) of 2000**
- **Enter a Horizontal Range H2 (XY Units) of 2000**
- **Direction H1 (degrees) of 0**
- **Enter a Sill of 1**
- **Enter Model(2) No**
- **Click Ok**

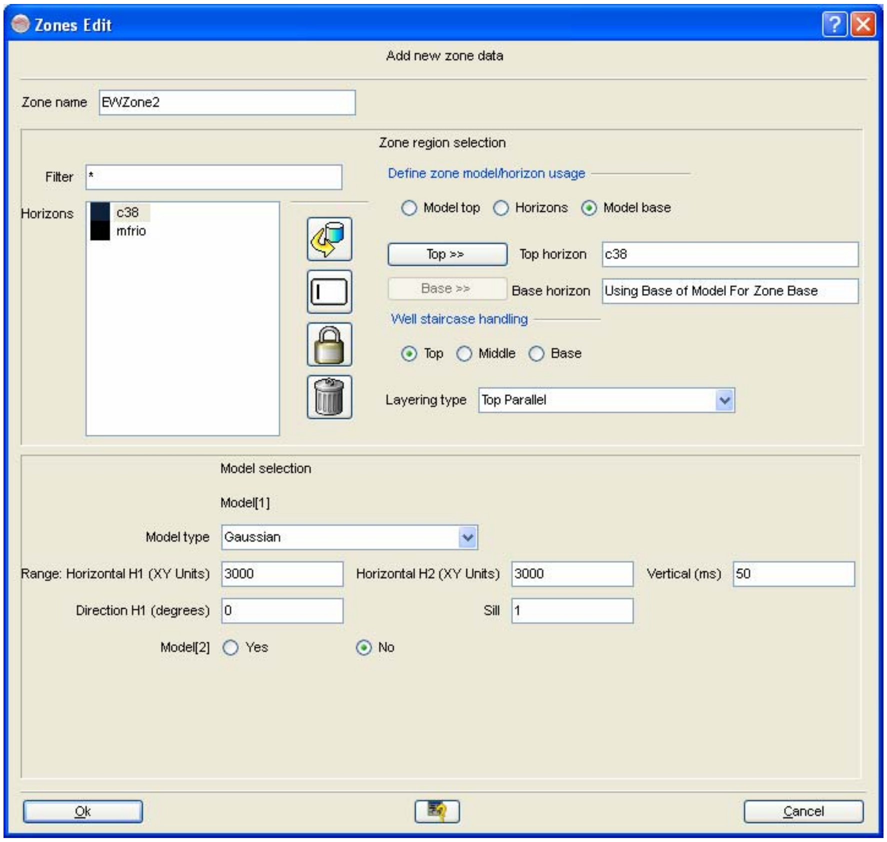


After returning to the Zones Setup table the display is now:

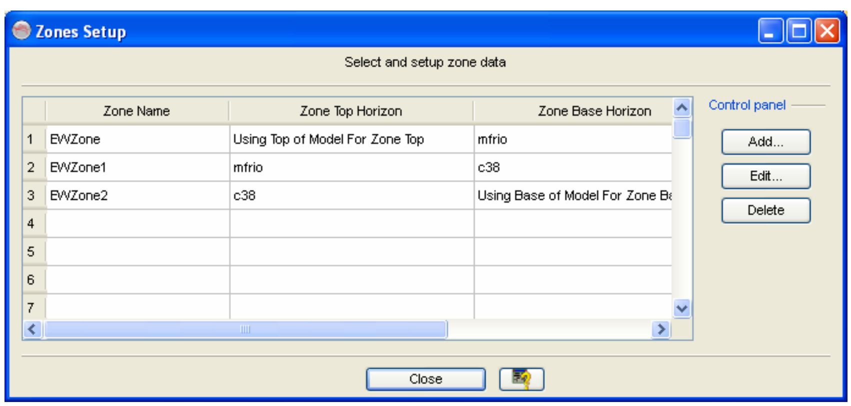


The user needs to add the final zone in this example and the procedure describe above is repeated. The software automatically increments the zone number and uses the previous zone base (C38) as the top of the next zone. It also assumes that the next zone is the model base. The screen with all the correct settings for this zone is shown below

- **Click `Add`**
- **Check `Model Base`**
- **Note that the Base Horizon is `Using Base of Model for Zone Base`**
- **Check `Top` under Well Staircase Handling**
- **Select `Top Parallel` for Layering Type**
- **Model Type pull down menu and select `Gaussian`**
- **Enter a Vertical Range (ms) of 50**
- **Enter a Horizontal Range H1 (XY Units) of 3000**
- **Enter a Horizontal Range H2 (XY Units) of 3000**
- **Direction H1 (degrees) of 0**
- **Enter a Sill of 1**
- **Enter Model(2) No**
- **Click Ok**



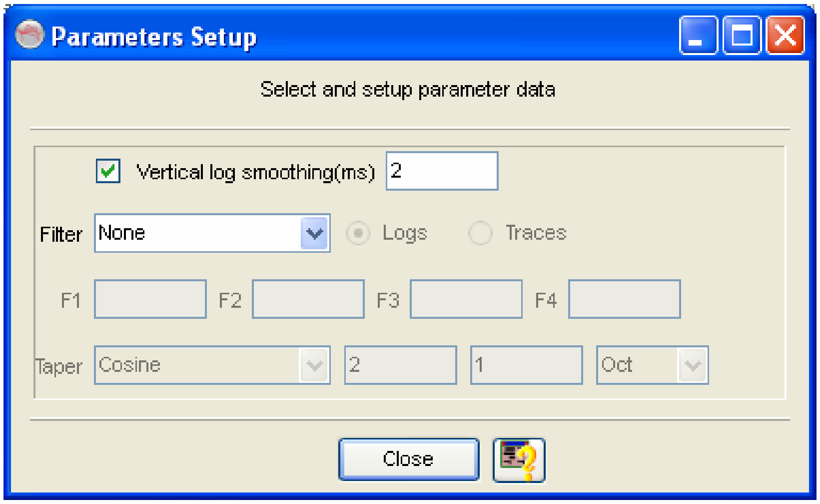
Upon return to the zone data window a description of the first zone will be visible and will appear as the image below



On return to the Attribute set window the user can see that the summary details have changed and that the number of zones in the selection is now 3.

The parameters must be set by clicking the button in the EW Control Panel and choosing a smoothing factor

- **Click `Parameters`** ...
- **Click Vertical log smoothing**
- **Enter a value of 2**
- **Click Ok**

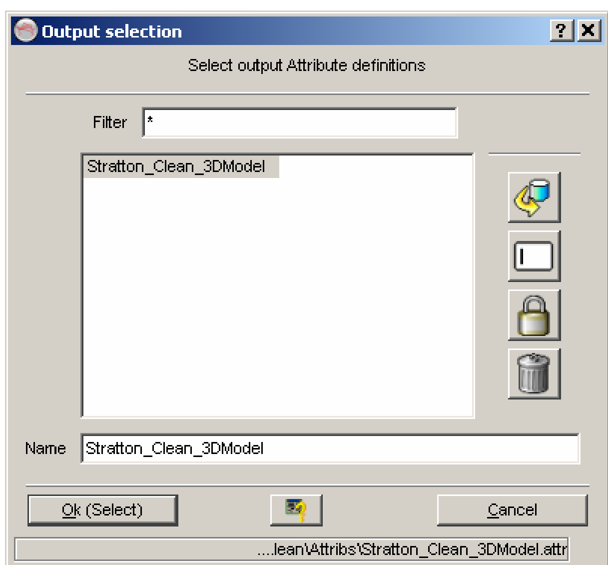


On return to the Attribute set window the user can see that the summary details have changed again and that the parameters have been set.

Next we need to select the seismic volume used in the model and then enter an attribute name and (after a short delay) add it to the list of attributes

- **Click Select …**
- **Select OriginalSeismic**
- **Enter a <new attribute name> e.g., 3DModel**
- **Click `Add as new`**
- **Click Ok**

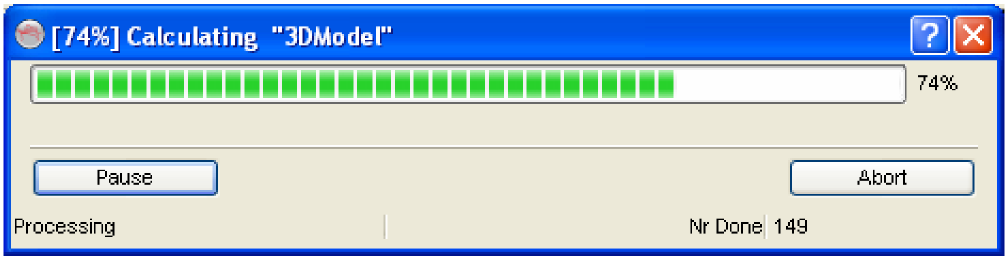
At this stage the user can dismiss the window and the attribute will be saved. Since this is the first attribute to be created the user will be prompted for a new name (e.g. 3DModel).



The model can then be added as inline and cross-line sections by:

- **Right-clicking inline 51**
- **Add attribute**
- **Right click and Select Attribute**
- **Select Attributes 3D**
- **Select the attribute previously 'added as new'** `3DModel`

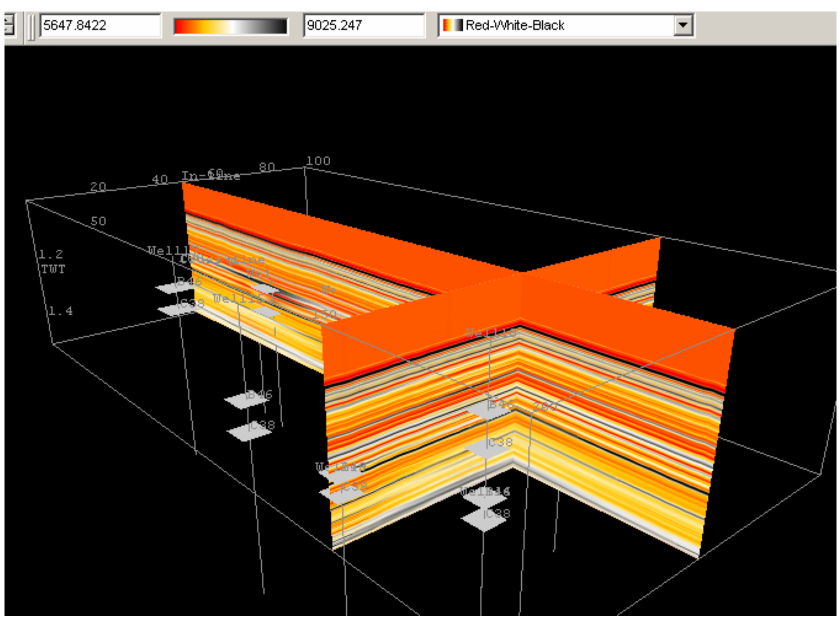
The following process bar will appear, shortly followed by the new attribute.



The same procedure should be performed for the cross-line

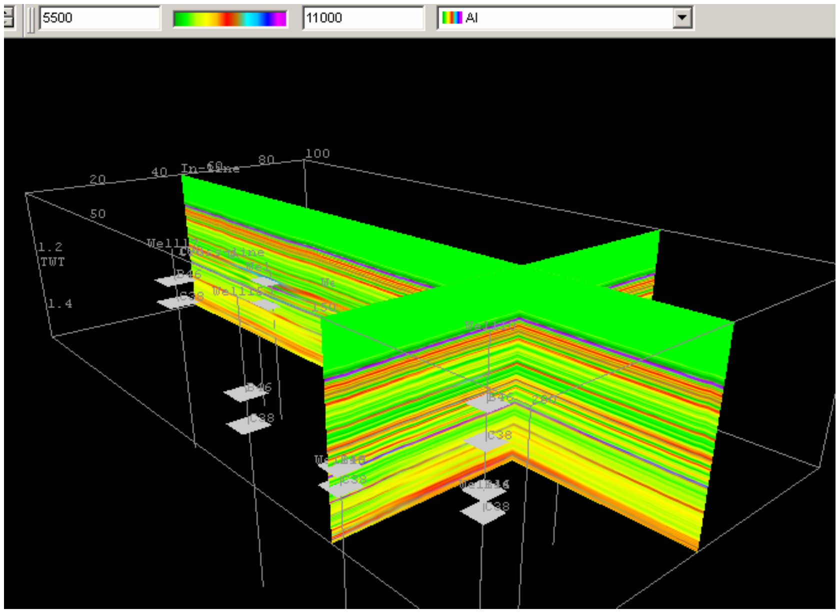
- **Right-clicking Crossline 153**
- **Add attribute**
- **Right click and Select Attribute**
- **Select Attributes 3D**
- **Select the attribute previously 'added as new'** `3DModel`

To improve the view of the 3DModel we should remove the horizons. In this case the view in OpendTect should look similar to the image below



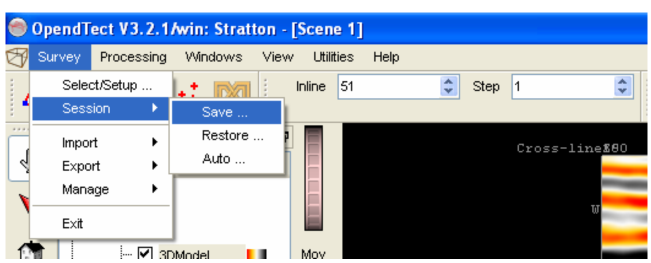
Note the difference in minimum and maximum values for the colour units which can be confirmed by clicking on the text of the new attribute. The colour scheme can be changed and the same minimum and maximum values should be chosen

- **Click Inline 51 3DModel**
- **Select AI colour scheme**
- **Enter minimum value of 5500**
- **Enter maximum value of 11000**
- **Click Inline 51 3DModel**
- **Select AI colour scheme**
- **Enter minimum value of 5500**
- **Enter maximum value of 11000**

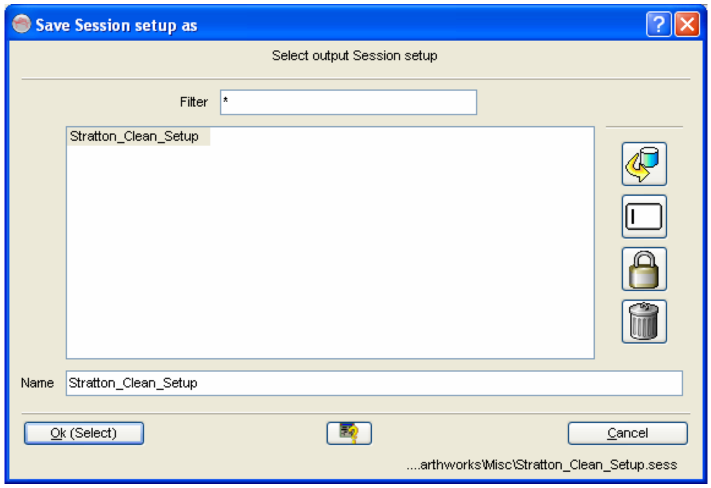


At this stage we should save our progress using the actions below and this will enable the user to return to this stage without having to repeat the setup

- **Select `Survey` from pull-down menu**
- **Select `Session`**
- **Select `Save`**
- **E.g., Stratton_Clean_3DModel**



The following window will appear for the user to enter the location to save the session. The icons on the right of the window are used to navigate to other locations on the disk.



10.4 EW2DErrorGrid

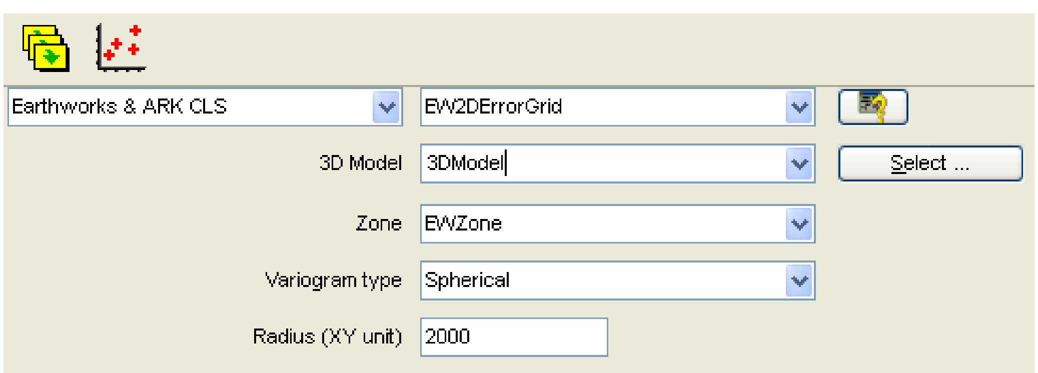
The next stage is to build an error grid which requires variogram models and the influence radius (range). The error grid requires the previously constructed 3DModel and is produced by:

- **Click `Analysis`**
- **Select `Attributes`…**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `2DErrorgrid`**
- **Select `3DModel`**
- **Select the top zone `EWZone`**
- **Select variogram function type `Spherical`**
- **Enter radius of influence around wells `2000`**

Finally ensure that the settings are saved as a new attribute

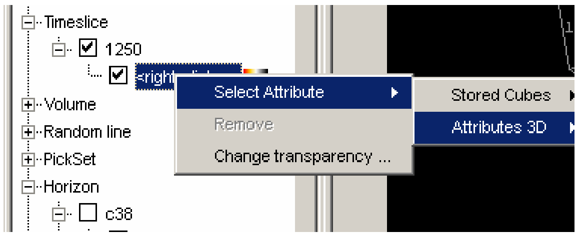
- **Enter a <new attribute name> e.g., 2DError_EWZone**
- **Click `Add as new`**
- **Click Ok**

The attribute set for the 2DError grid should look similar to the screenshot below



The 2DErrorgrid is displayed below by creating a new attribute as before but this time in a timeslice. It is important to note that the 2D error grid will be the same for all timeslices.

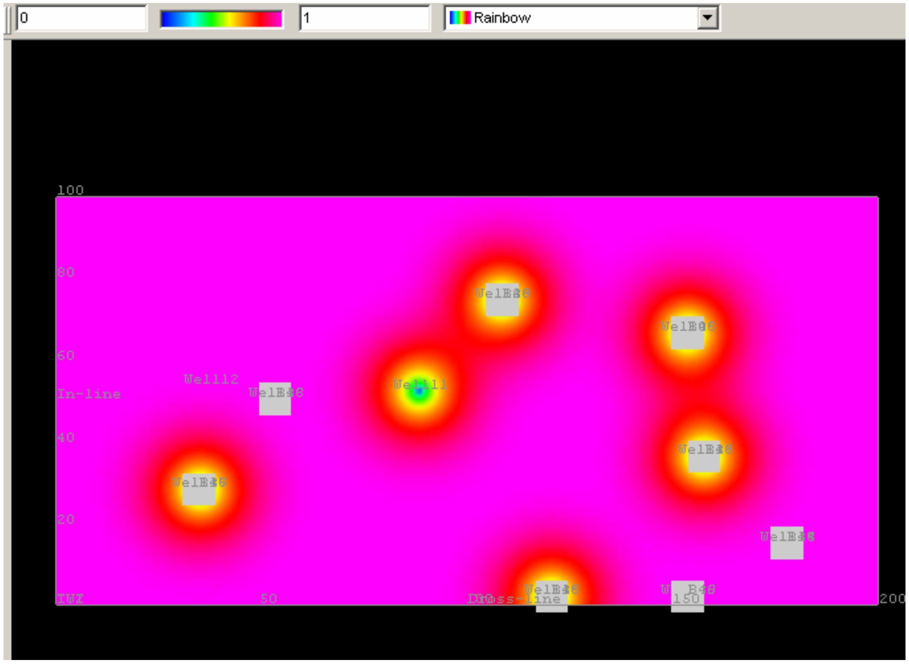
- **Right-click `Timeslice`**
- **Select `Add`**
- **Right-click `Timeslice`**
- **Select `attribute`**
- **Select `Attributes 3D`**
- **Select 2DError_EWZone**



The error grid is displayed at timeslice 1250. To view the location of the wells and improve the visualization of the error grid we can switch off the inline and crossline 3DModel, use a timeslice with a larger value and use a plane view combined with a perspective view

- **Remove tick from Inline 51**
- **Remove tick from Crossline 153**
- **Change Timeslice to 1400**
- **Click icon to view inline followed by icon to view plan**
- **Change colour scheme to `Rainbow`**
- **Range of values from `0 to 1`**

The view will look like the following image.



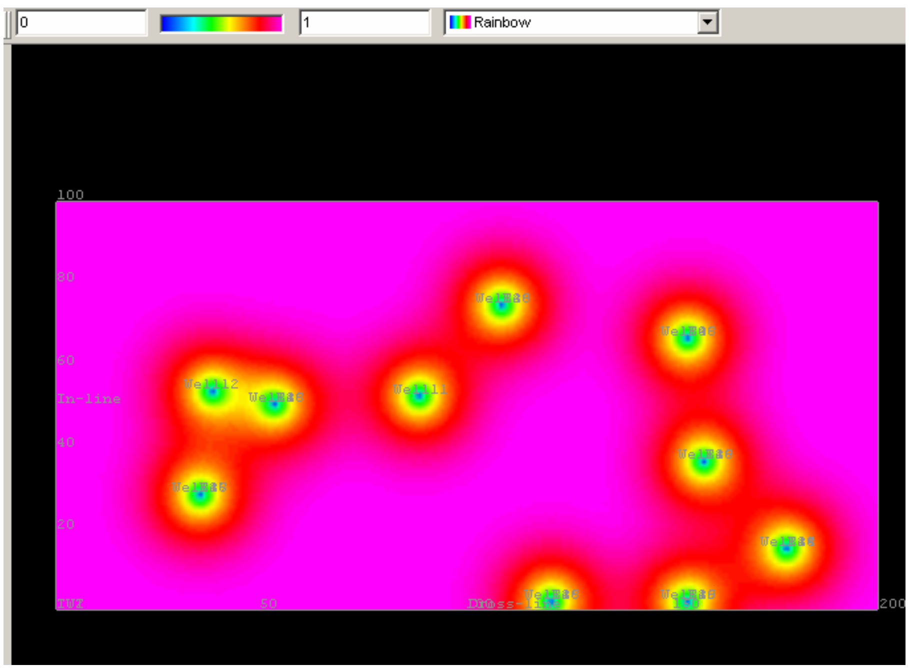
The well tops can be removed from each well to produce the view below:

- **Right-click <well number>**
- **Select `Show`**
- **Remove tick from `Markers`**

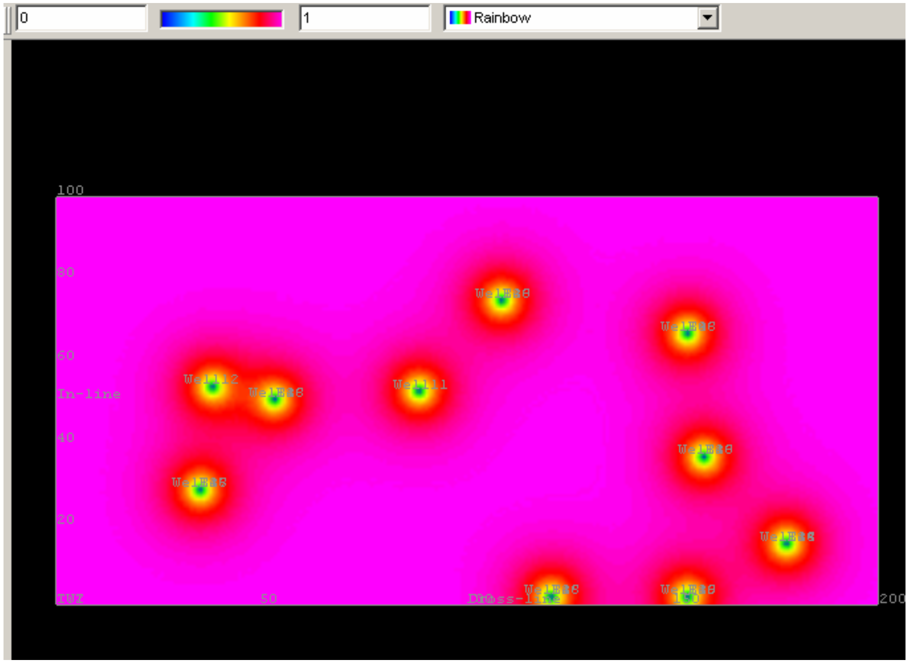
NB. Some wells do not have markers and so these cannot be removed.

There are four wells that do not have a radius of influence (bullseye). This is because we chose the top zone (EWZone) to form the errorgrid. If we repeat the above procedure but for the middle zone the view will look like the image below

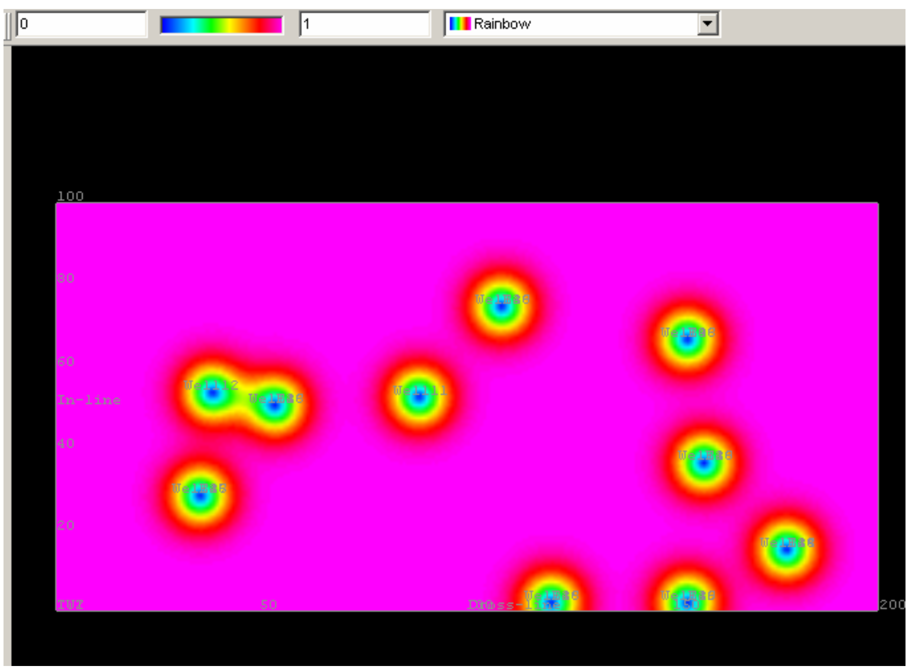
- Click `Analysis`
- Select `Attributes…`
- Change `All` to `Earthworks & ARK CLS`
- Select `2DErrorgrid`
- Select `3DModel`
- Select the top zone `EWZone1`
- Select variogram function type `Spherical`
- Enter radius of influence around wells `2000`
- Enter a <new attribute name> e.g., 2DError_EWZone1
- Click `Add as new`
- Click Ok
- Right-click Timeslice 1400
- Select `attribute`
- Select `Attributes 3D`
- Select `2DError_EWZone1`
- Change colour scheme to `Rainbow`
- Range of values from `0 to 1`



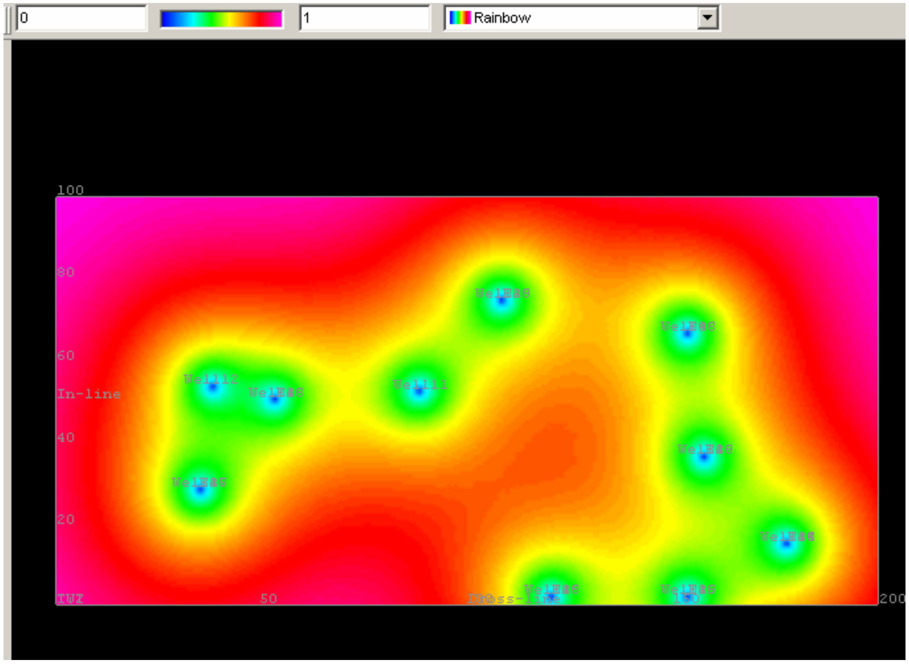
To demonstrate the influence of the model type we can repeat the above procedure but changing only the model from Spherical to **Exponential** and the view will look like the image below.



To demonstrate the influence of the final model type we can repeat the above procedure but changing only the model from Exponential to **Gaussian** and the view will look like the image below.

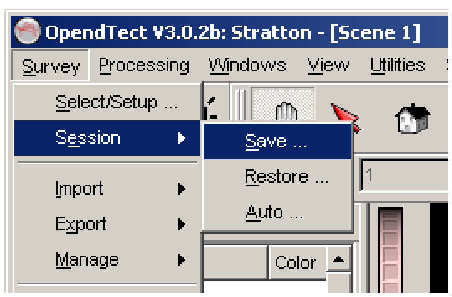


To illustrate the impact of the well radius of influence on the 2D Error grid the **Spherical** model is used with a much longer range (5000 X-Y units) and displayed using the same colour range

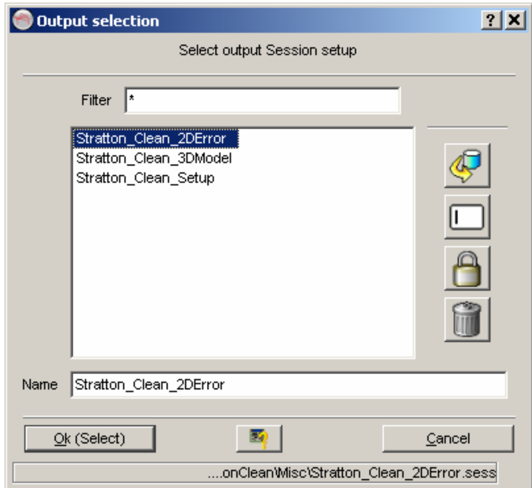


At this stage we should save our progress using the actions below and this will enable the user to return to this stage without having to repeat the setup

- **Select `Survey` from pull-down menu**
- **Select `Session`**
- **Select `Save`**
- **E.g., Stratton_Clean_2DError**



The following window will appear for the user to enter the location to save the session. The icons on the right of the window are used to navigate to other locations on the disk.

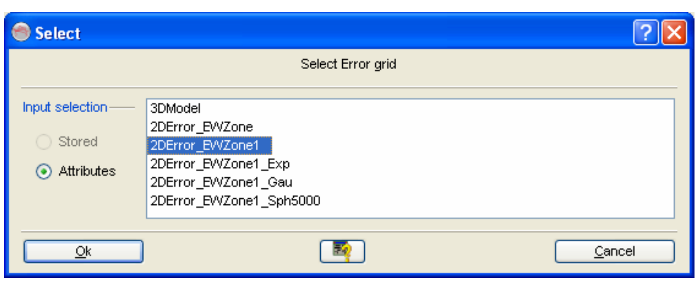


10.5 Deterministic Inversion

The next stage is to build a deterministic inversion. This requires a 2D error grid which requires variogram models and the influence radius (range). The error grid requires the previously constructed 3DModel, as previously described.

The deterministic inversion requires

- **Click `Analysis`**
- **Select `Attributes…`**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EWDeterministicInversion`**
- **Select the 3D model to use**
- **Select the 2D error grid `2DError_EWZone1`**



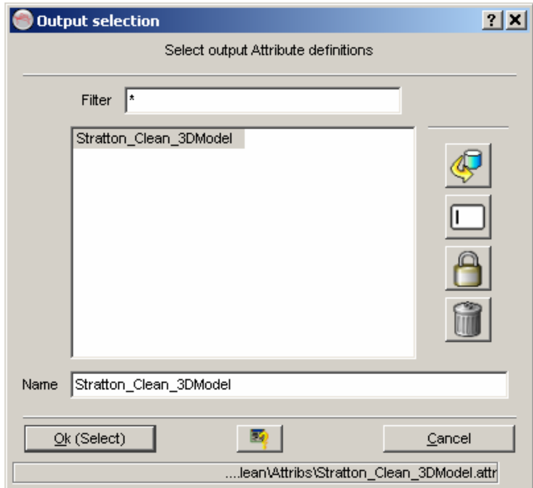
- **Select the (stored) seismic volume `OriginalSeismic`**
- **Select a wavelet `wave0v1_1ms.asc`**
- **Select Wavelet Polarity - `Normal`**
- **Sample Trace at – `Well Only`**
- **Wavelet Scalar - `Compute`**
- **Apply Ln error correction - `Yes`**
- **Enter a maximum constraint (at well) `0.9`**
- **Enter a minimum constraint (far from well) `0.1`**
- **Accept the block size `2`**

The attributes for the deterministic inversion are displayed in the image below. Ensure that these settings are saved as a new attribute

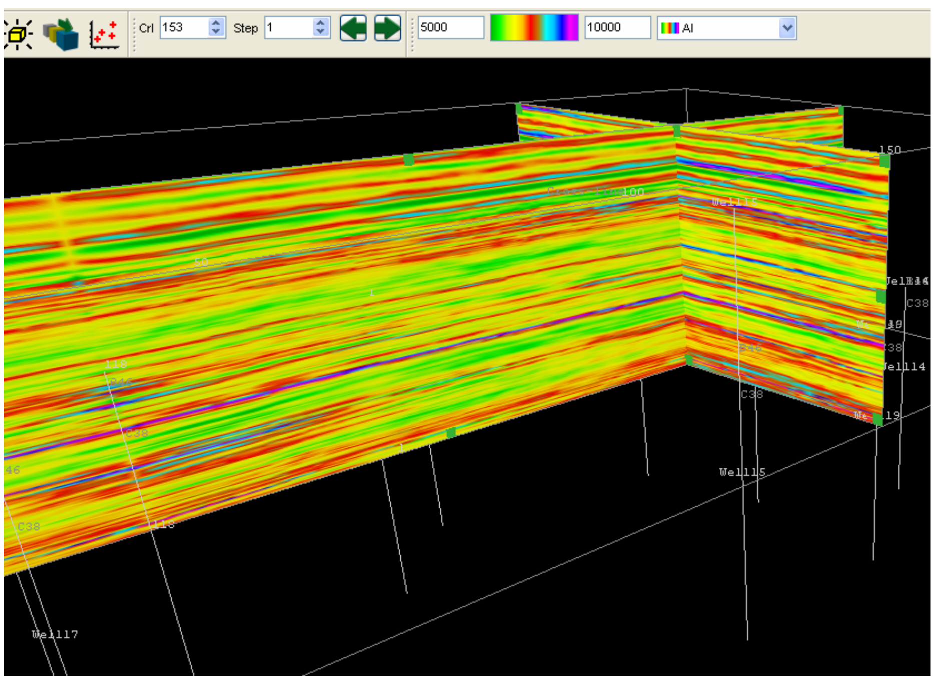
- **Enter a <new attribute name> e.g., Det_EWZone1_Sph2000**
- **Click `Add as new`**
- **Click Ok**

At this stage the user can dismiss the window and the attribute will be saved. Since this is the first attribute to be created the user will be prompted for a name where the attribute can be saved.

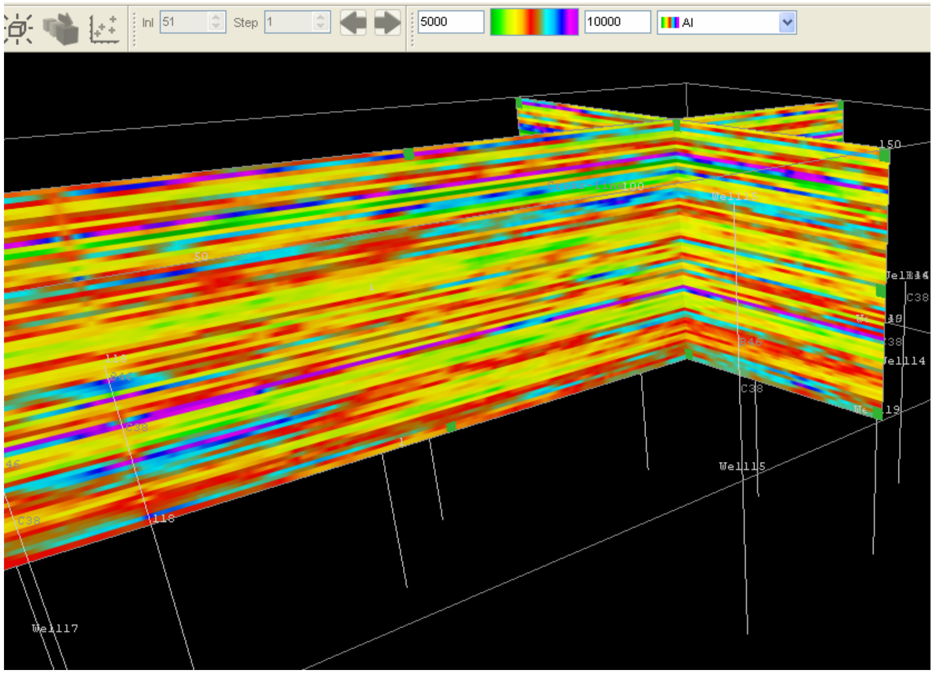
We will use the existing attribute file (Stratton_Clean_3DModel).



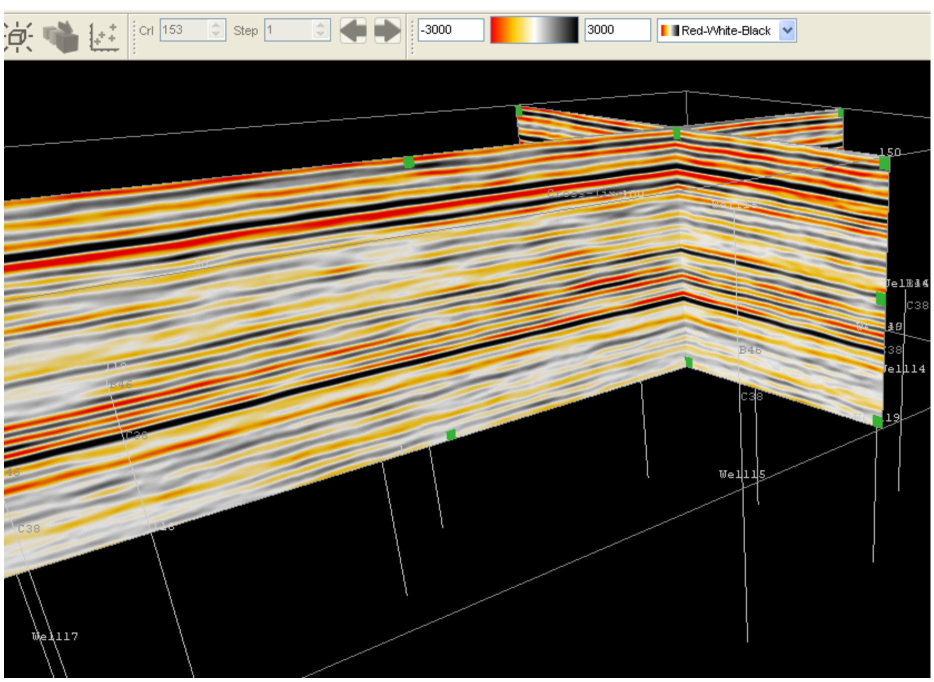
The deterministic inversion results may be calculated for the inline (51) and crossline (153) and displayed using the AI colour scheme (between 5500 and 10000) as performed in the previous sections. In this case the view will look like the image below

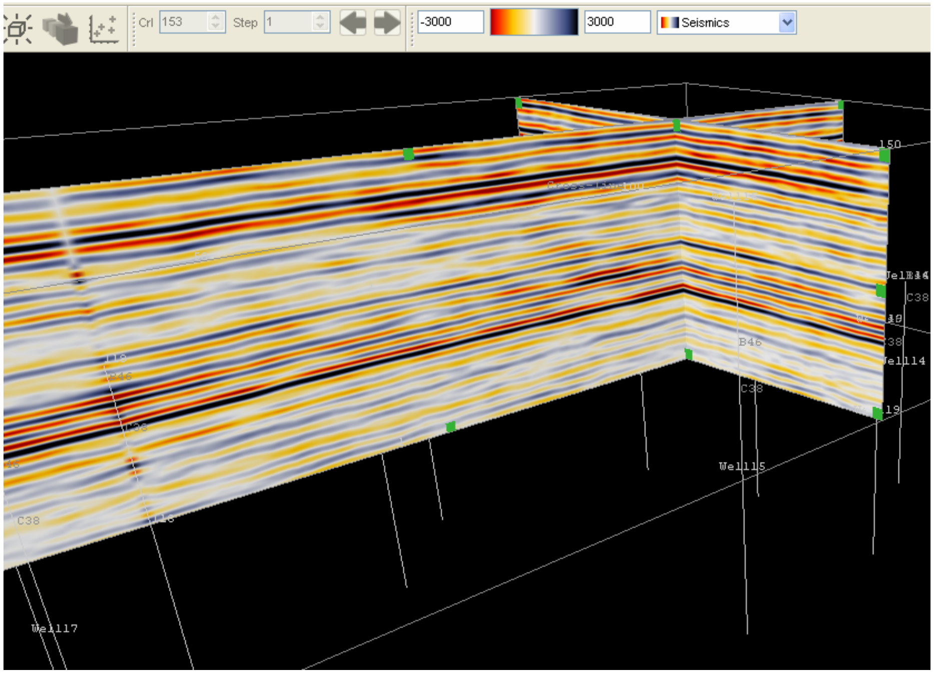


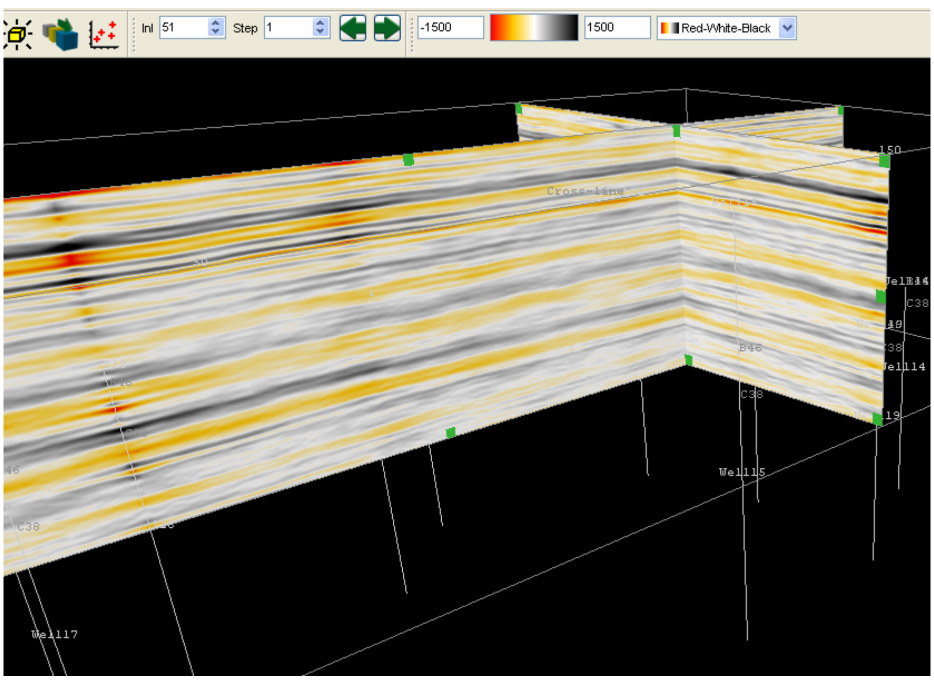
The effect of changing the block size from 2 samples to 7 samples is readily apparent in the next screenshot where all the other attribute parameters remain the same. Ensure that the colour range values are the same as in previous displays.



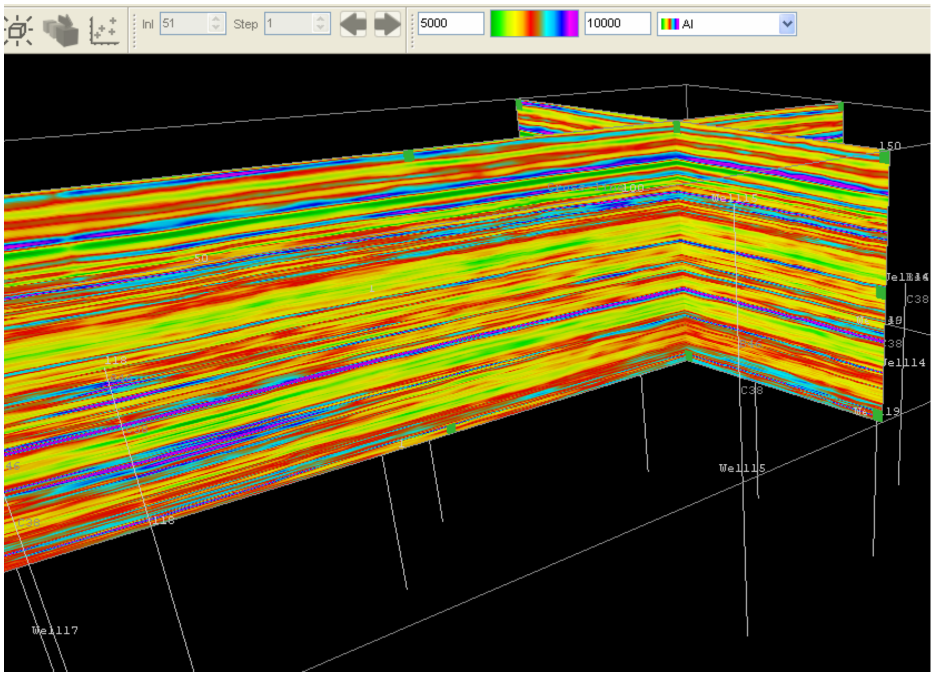
The original seismic, synthetic trace computation and residuals are displayed in the next screenshots where all the other attribute parameters remain the same. Change the colour bar to be the seismic one (Red-White-Black) and the range values to be --3000, +3000, and display the original seismic and the synthetic seismic to compare, the difference between the 2 is the residual displayed in the 3rd picture having set the colour bar to half of the initial amplitudes -1500 and +1500.

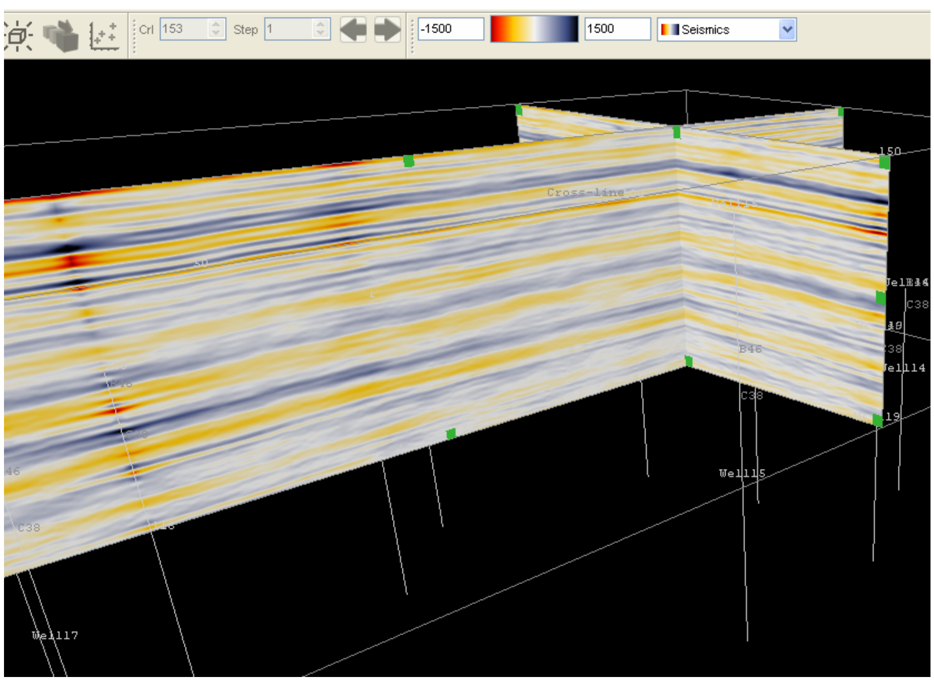






MPSI default scalars (displayed in the console window) give a good starting point but the user always needs to QC the results at the target well location. In our case we might find that we would like to scale a bit more to match the seismic amplitudes and have less model contribution (continuous cylinder at the well position). It can be done by changing respectively the wavelet scalar and the well max and min constraint. The following screenshots show the effect in the inverted impedance and residuals of setting the wavelet scalar to 3200 and the min and max constraint to 0.1 and 0.5.

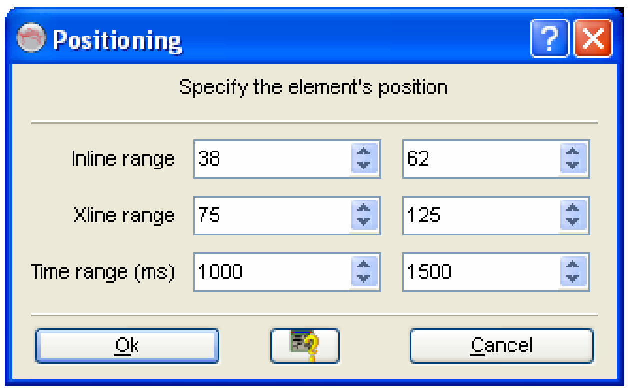

Inl
51
Step
1
5000
10000
AI
Well117
Well15


Crl
153
Step
1
-1500
1500
Seismics
Cross-line
Well117
Well15

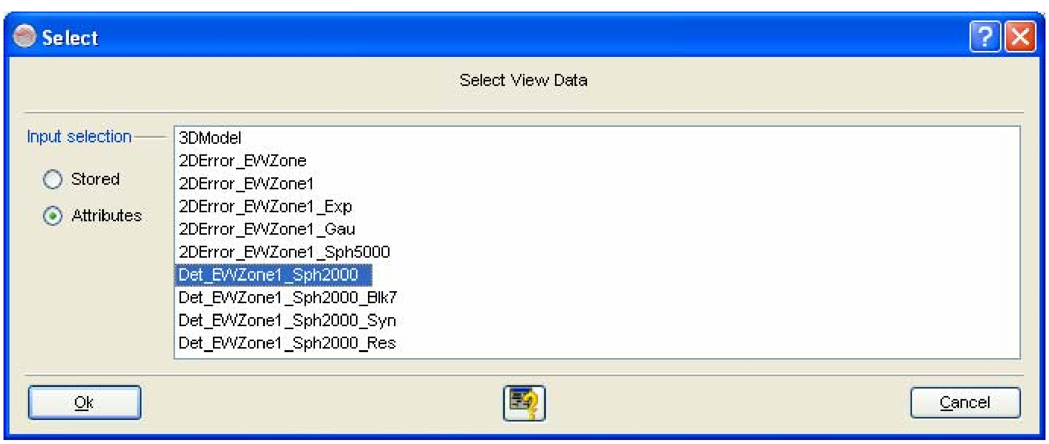
Wavelet scalar, and Well min and max constraints are important parameters and need to be fully tested by the user at the well location before moving forward. Wavelet scalar test are generally performed by setting min and max constraints to 0.1. Default LN normal correction has generally a small contribution, but it is advised to QC by turning the scalar on and off. The user can increase or decrease the influence of this parameter by overriding the default setting.

We will also produce the results for a volume

- **Right-click volume**
- **Select Add**
- **Right-click** `volume`
- **Select** `Position`
- **Enter Time range min** `1000`
- **Enter Time range max** `1500`

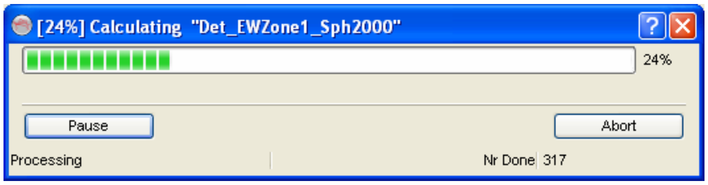


The response will be a window which requests the user to enter the attribute to be created in the volume. We will select the Deterministic Inversion results we created previously.



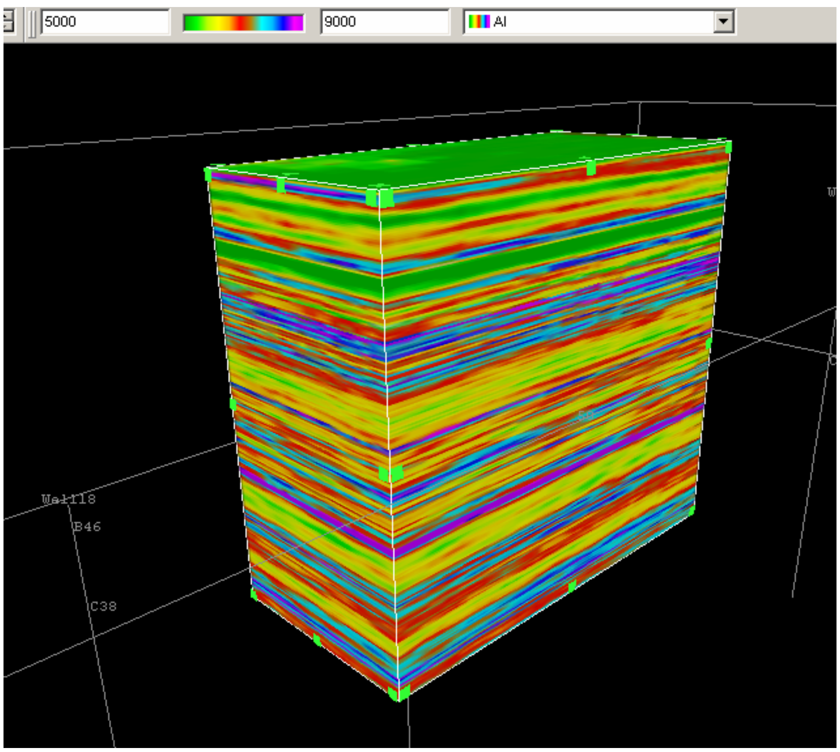
- **Select** `Det_EWZone1_Sph2000`.
- **Click Ok**

The following progress bar will appear before the volume will be displayed on the screen.



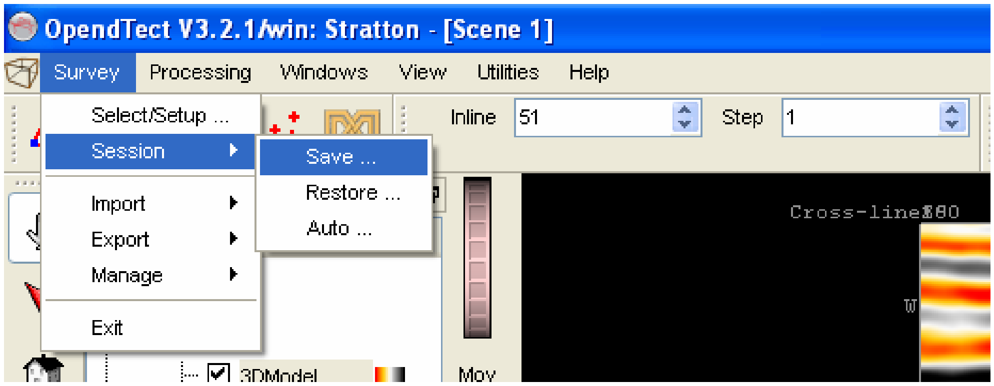
- **Under Volume tick `Volren`**
- **Rotate and zoom the image**
- **Select the AI colour scheme**
- **Select the value range between 5000 and 9000**

The display will look similar to the image below.



At this stage we should save our progress using the actions below and this will enable the user to return to this stage without having to repeat the setup

- **Select `Survey` from pull-down menu**
- **Select `Session`**
- **Select `Save`**
- **E.g., Stratton_Clean_Deterministic**



10.6 Stochastic Inversion.

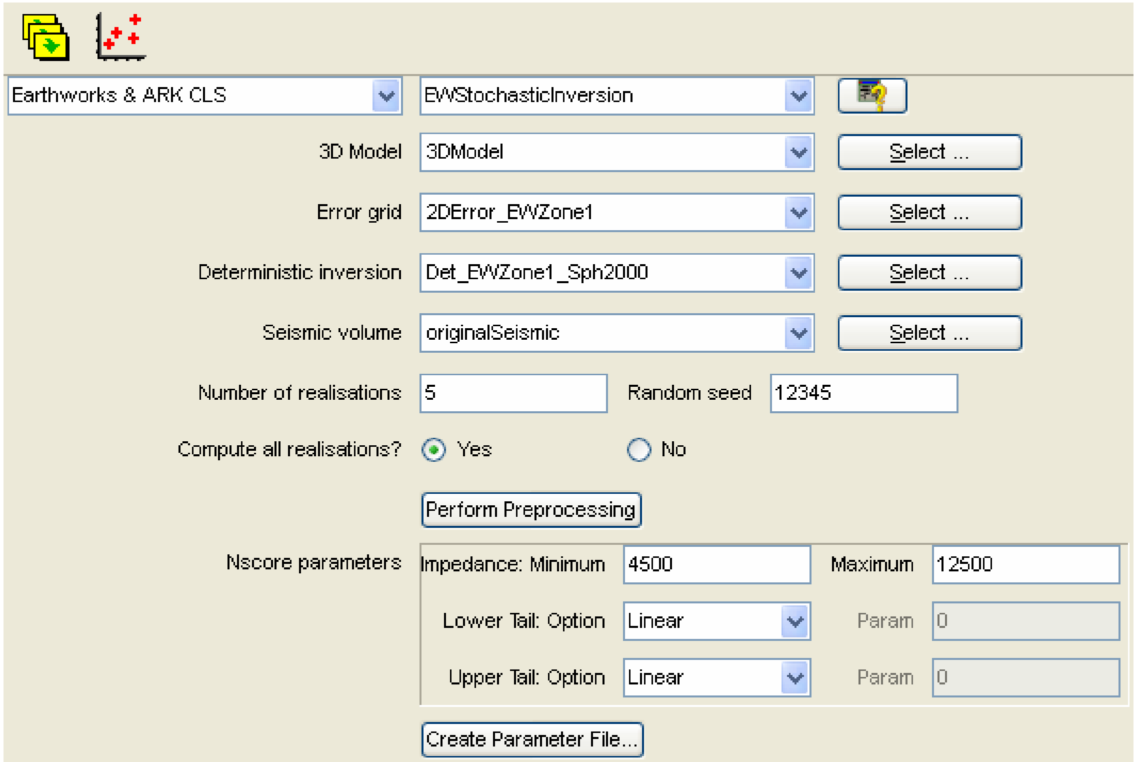
The final stage is to build a stochastic inversion. Amongst other things, it requires a 3D Model, a 2D error grid, and a deterministic inversion:

- **Click `Analysis`**
- **Select `Attributes…`**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EWStochasticInversion`**
- **Select the 3D model to use `3DModel`**
- **Select the 2D error grid `2DError_EWZone1`**
- **Select the Deterministic Inversion `Det_EWZone1_Sph2000`**
- **Select the (stored) seismic volume `OriginalSeismic`**
- **Number of realisations `5`**
- **Enter a random seed value `12345`**
- **Compute all realisations `Yes`**
- **Click `Perform pre-processing`**

The pre-processing takes a few minutes. After that, enter the normal score transform parameters. Normal score transform parameters should be determined after inspecting a histogram of the data. It is recommended to set the minimum and maximum impedance points to be close to or slightly larger than the range of the data.

- **Enter minimum Impedance value `4500`**
- **Enter maximum Impedance value `12500`**
- **Accept lower tail option `Linear`**
- **Accept upper tail option `Linear`**

The display and the entered attributes should look like the image below



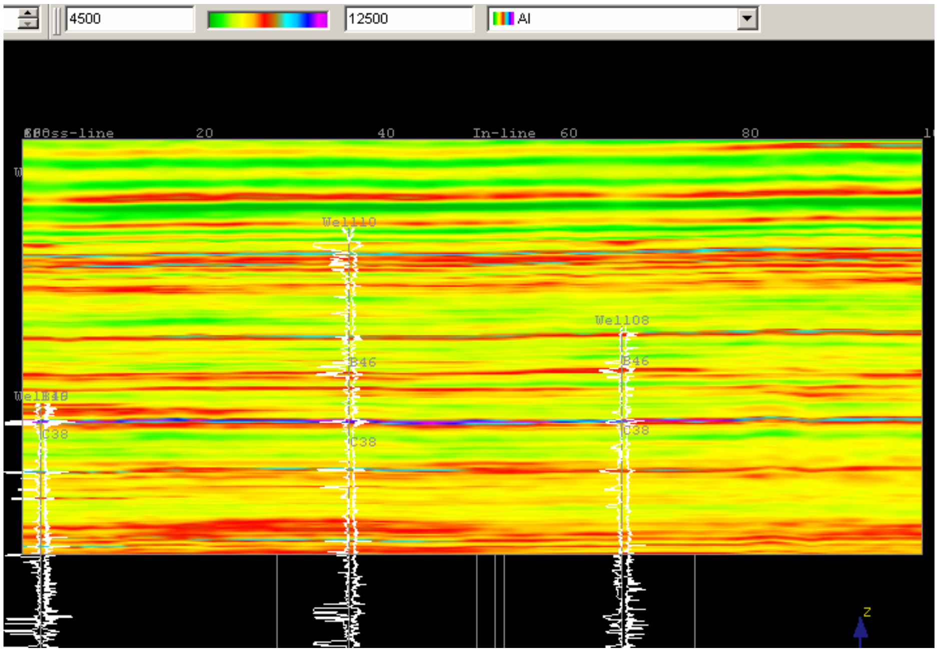
Ensure that these settings are saved as a new attribute

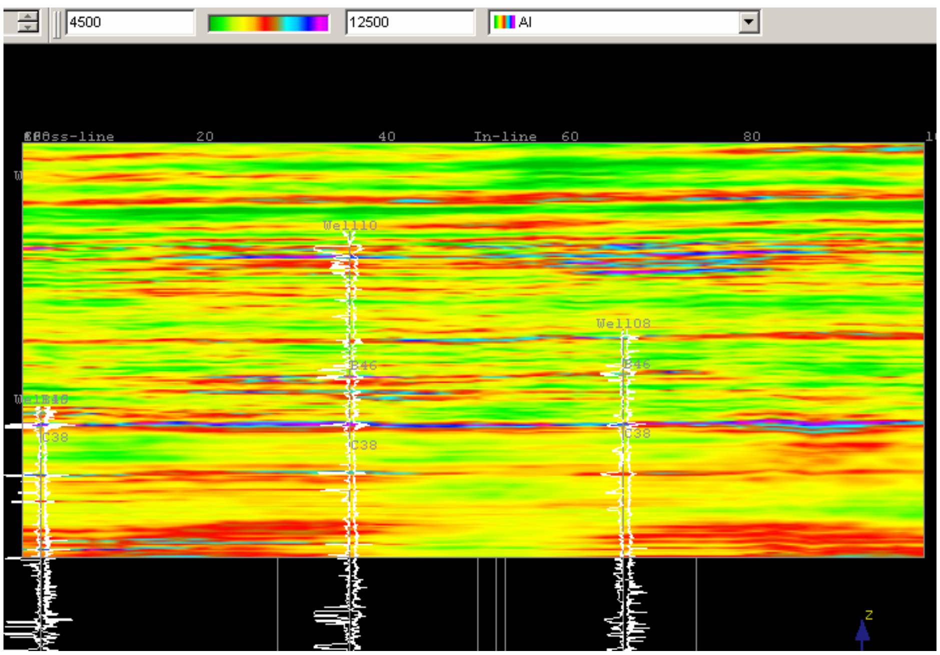
- **Enter a <new attribute name> e.g., Stch_EWZone1_Sph2000**
- **Click `Add as new`**
- **Click Ok**

The results of the deterministic inversion are presented first below using crossline 153 for comparison with the stochastic inversion results second for the same crossline. Note that the colour scheme has been set to AI the values are displayed in the same range (4500 to 12500) and the crossline is viewed with wells 08, 10 and 19 in the foreground. Other wells have been turned off to so that only the three wells closest to the crossline are visible. The projection is orthographic.

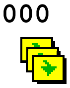
Logs for wells 08, 10 and 19 have been added to judge the performance of the inversions.

- **Right-click well 08**
- **Select Properties**
- **Select Left Log**
- **Select VClay**
- **Select data range 1 to 0**
- **Un-tick log filled**
- **Log screen width 10**
- **Select Right Log**
- **Select P-Impedance**
- **Un-tick log filled**
- **Log screen width 10**
- **Apply to all wells**



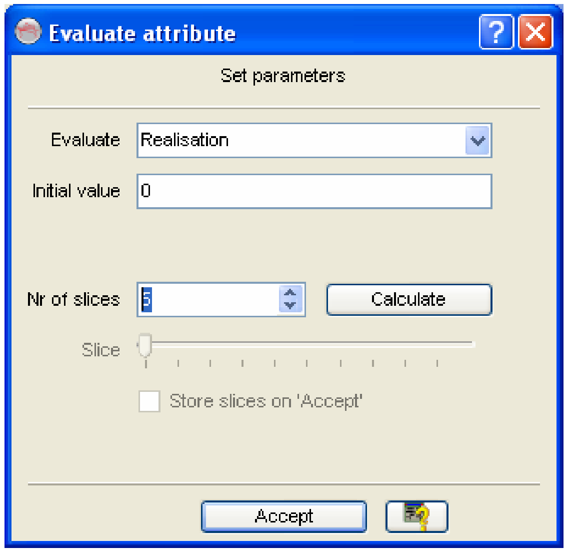


The results of the stochastic inversion appear to have higher frequencies compared to the deterministic inversion, because now we have added the additional uncertainty element to create a realisation. The other four realisations that were created can be viewed by:

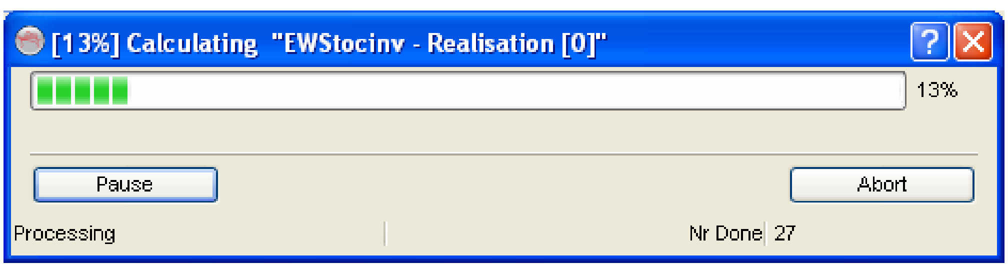
- **Click `Analysis`**
- **Select `Attributes…`**
- **Select `Stch_EWZone1_Sph2000`**
- **Click the evaluate button** 

The following window will appear. It requires the number of realisations to evaluate. The first realisation is 0. Set the number of slices to 5 as shown below

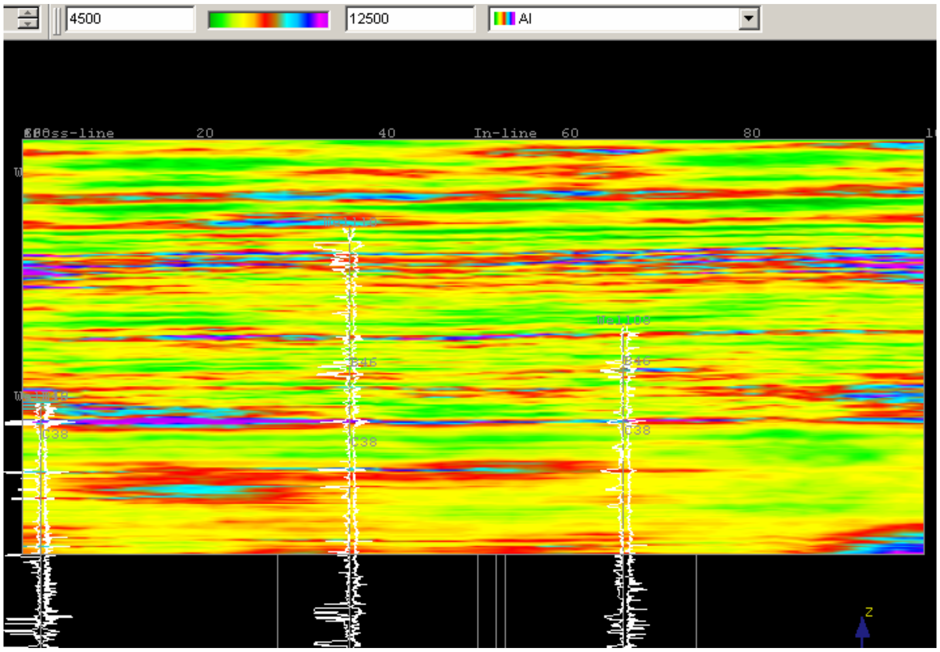
- **Click the calculate button**

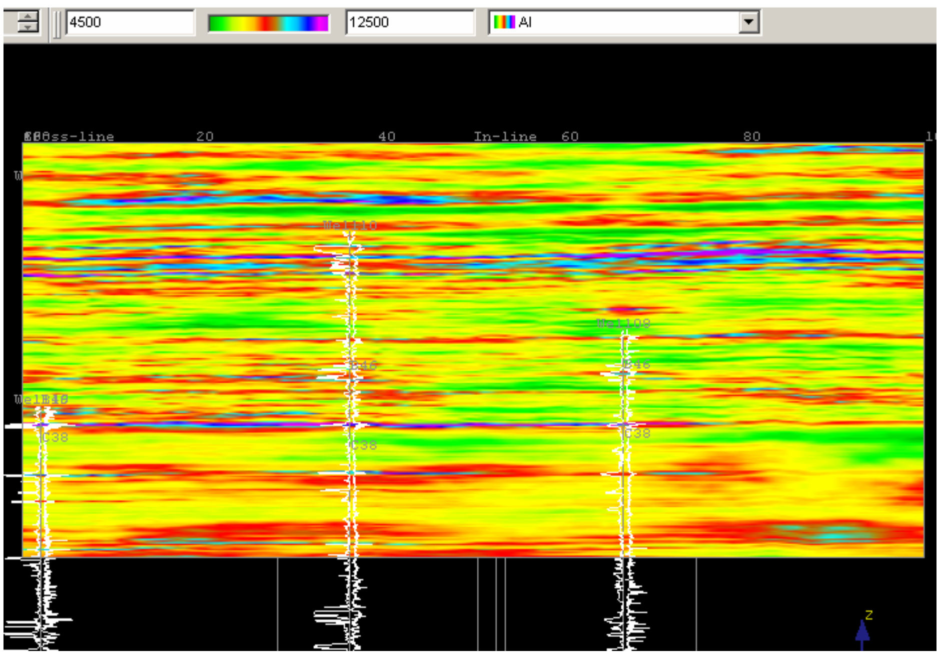


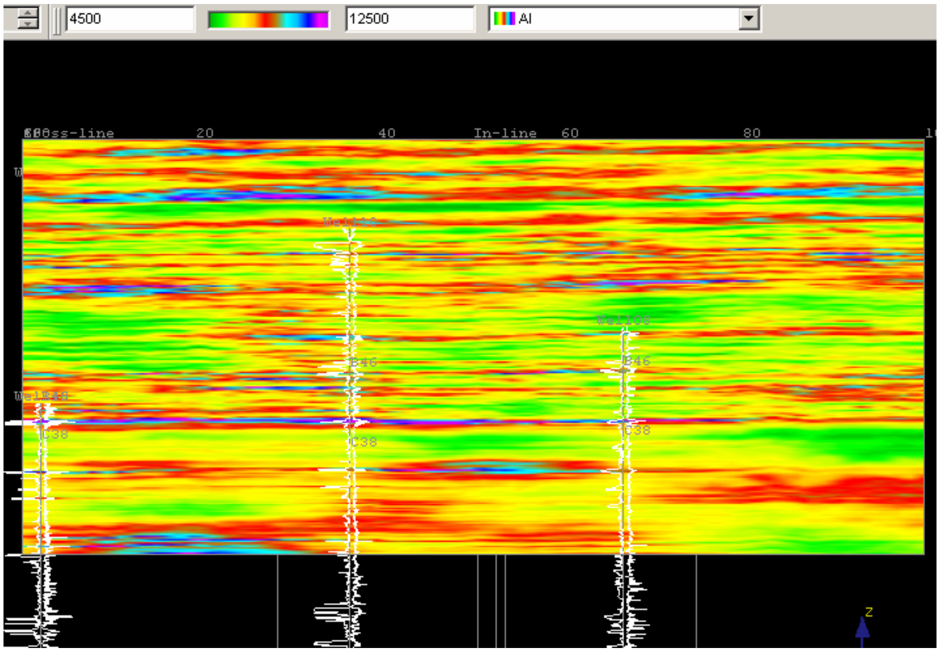
The realisations will be calculated for each realisation and the progress bar below will be visible.

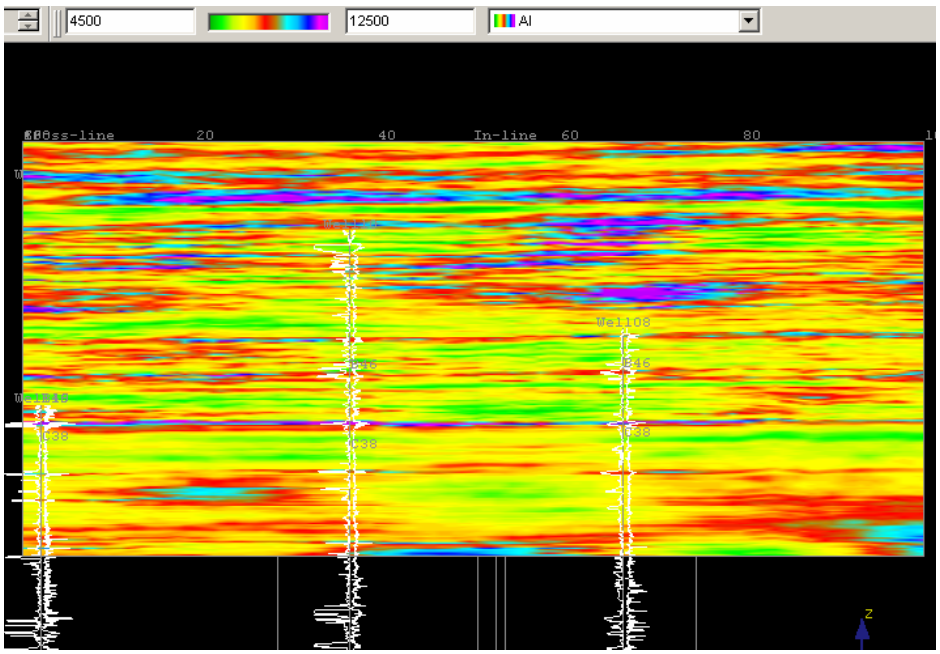


When the progress bar reaches 100% the evaluate window may be used to visualise the realisation by moving the slider along. To make the realisations comparable remember to change the colour scheme to AI and to enter the values from 4500 to 12500. In this case the four remaining realisations will appear as the images below:


4500
12500
AI
In-line
20
40
60
80

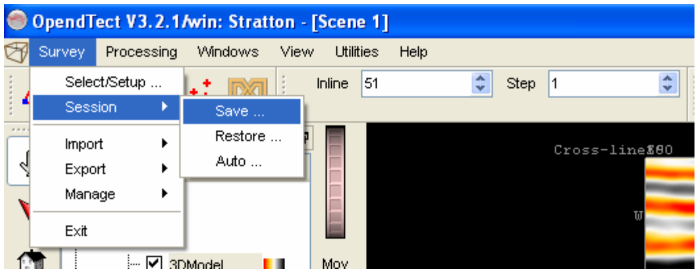

4500
12500
AI
In-line
20
40
60
80





At this stage we should save our progress using the actions below and this will enable the user to return to this stage without having to repeat the setup

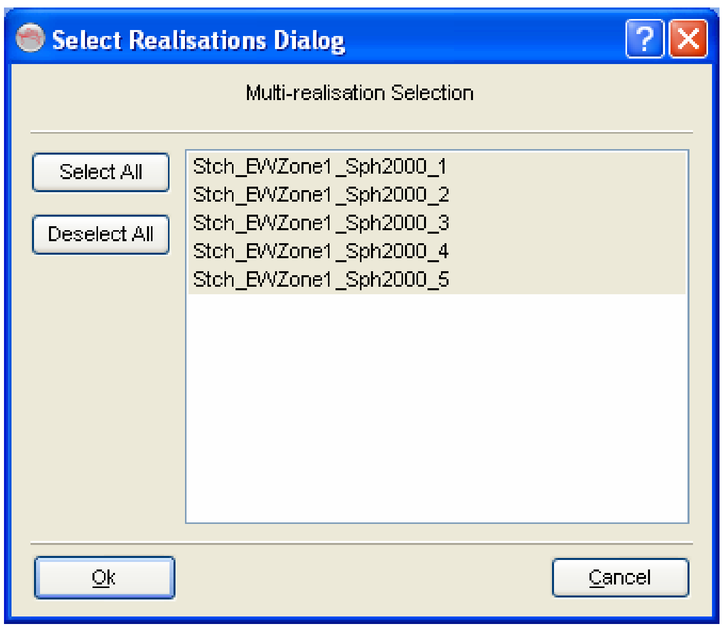
- **Select `Survey` from pull-down menu**
- **Select `Session`**
- **Select `Save`**
- **E.g., Stratton_Clean_Stochastic**



10.6.1 Mean and standard deviation cubes

The stochastic inversion procedure produced 5 realisations which can be summarized using the mean

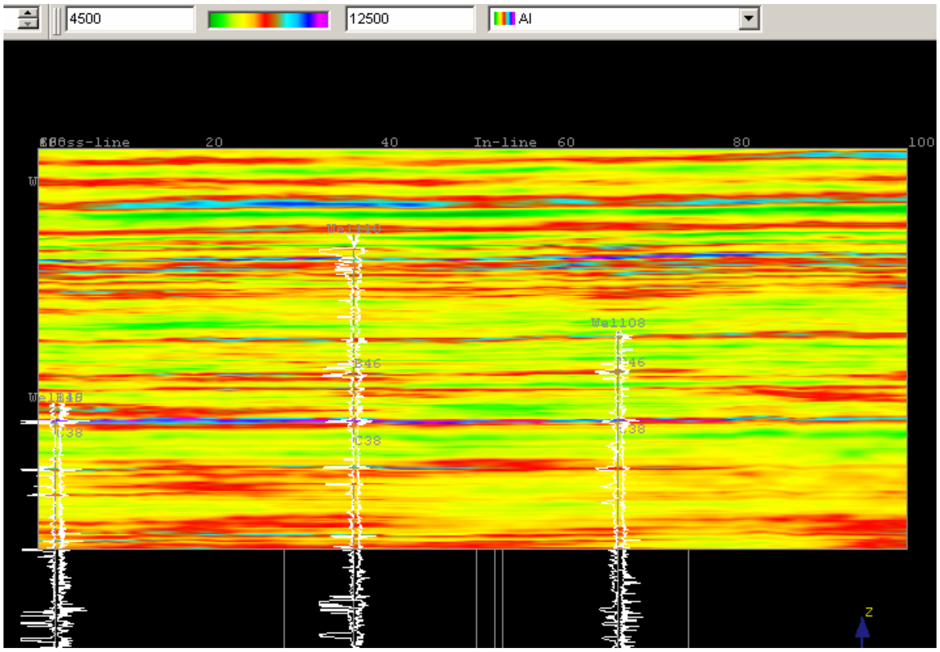
- **Click `Analysis`**
- **Select `Attributes…`**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EWUtilities`**
- **Select `Mean Cube`**
- **Select the multi-realisation data to use `Stch_EWZone1_Sph2000`**
- **Select all of the realisations**



Finally, ensure that the settings are saved as a new attribute

- **Enter a <new attribute name> e.g., `Mean_EWZone1_Sph2000`**
- **Click `Add as new`**
- **Click Ok**

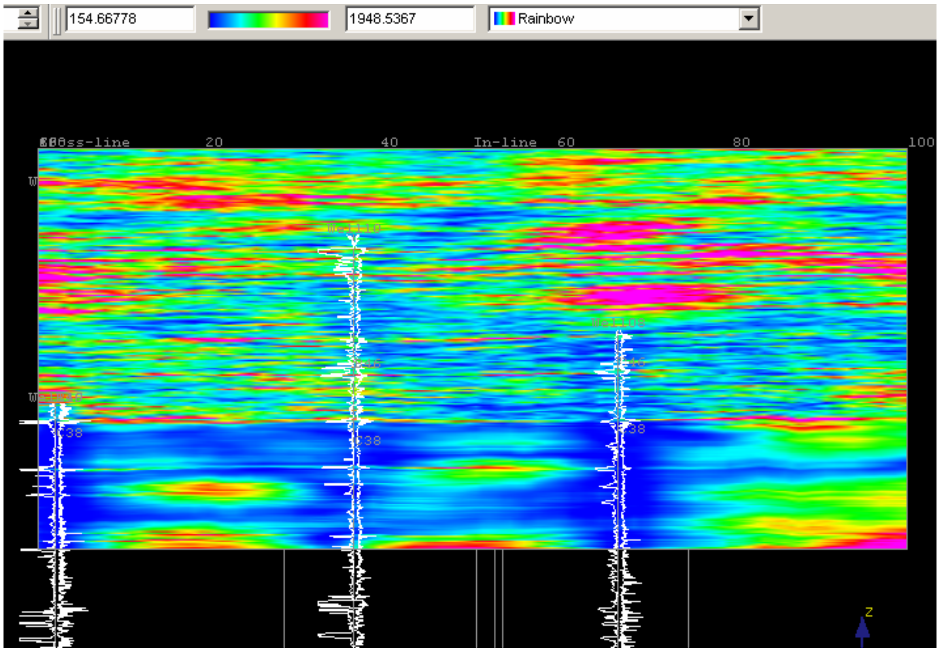
Display the results of the mean stochastic inversions using crossline 153 as before for comparison with the deterministic and stochastic inversion realisations. Ensure that the colour scheme has been set to AI and the values are displayed in the same range (4500 to 12500) and the crossline is viewed with wells 08, 10 and 19 in the foreground. Other wells have been turned off to so that only the three wells closest to the crossline are visible. The projection is orthographic.



As expected, the average of the realisations is much less erratic than the realisations displayed previously and it looks very similar to that of the deterministic inversion. This finding emphasizes the need to consider the variability in the cube realisations using the standard deviation.

- **Click `Analysis`**
- **Select `Attributes…`**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EWUtilities`**
- **Select `Std Cube`**
- **Select the multi-realisation data to use `Stch_EWZone1_Sph2000`**
- **Select all of the realisations**
- **Enter a <new attribute name> e.g., `Std_EWZone1_Sph2000`**
- **Click `Add as new`**
- **Click Ok**

Display the results of the standard deviations of the stochastic inversions across crossline 153 as before for comparison with the deterministic and stochastic inversion realisations. The colour scheme is set to rainbow and the crossline is viewed with wells 08, 10 and 19 in the foreground. Other wells have been turned off so that only the three wells closest to the crossline are visible. The projection is orthographic.

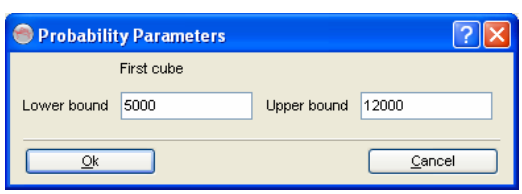


The standard deviation crossline shows that there is much greater variability in the stochastic simulations near the top of the model where there is relatively little well constraint on the model.

10.6.2 Probability cube

Using the 5 available realisations the probability of occurrence may be calculated for the range of impedance values (e.g., 5000 to 12000)

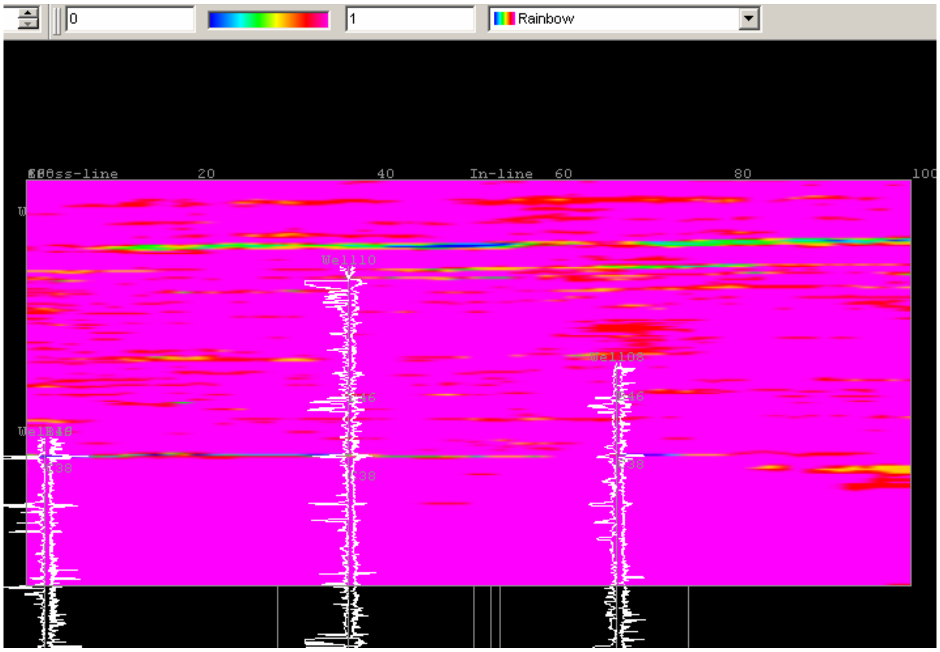
- **Click `Analysis`**
- **Select `Attributes`…**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EWUtilities`**
- **Select `Probability`**
- **Select the multi-realisation data to use `Stch_EWZone1_Sph2000`**
- **Select all of the realisations**
- **Click `Parameters`…**
- **Enter the lower and upper impedance (5000 and 12000)**



Finally, ensure that the settings are saved as a new attribute

- **Enter a <new attribute name> e.g., `ProbCube_EWZone1_Sph2000`**
- **Click `Add as new`**
- **Click Ok**

The probability of locations within the cube having values of acoustic impedance between 5000 and 12000 are displayed below. Note that the colour scheme has been set to Rainbow and the values are set between 0 and 1.



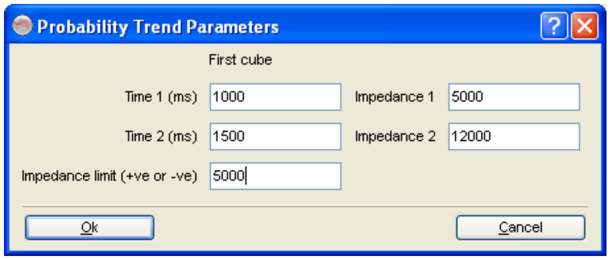
Evidently, the majority of values fall between the range of impedance values with the exception of small bands. The majority of these bands occur in the upper portion of the section and in particular above the wells.

A more realistic example for this data set would be to set the probability to be within 8150-50000 (m/s*g/cc), 8150 being the cut-off between shale and sand and 50000 representing a very high value (beyond the range of this data set impedance maximum value)

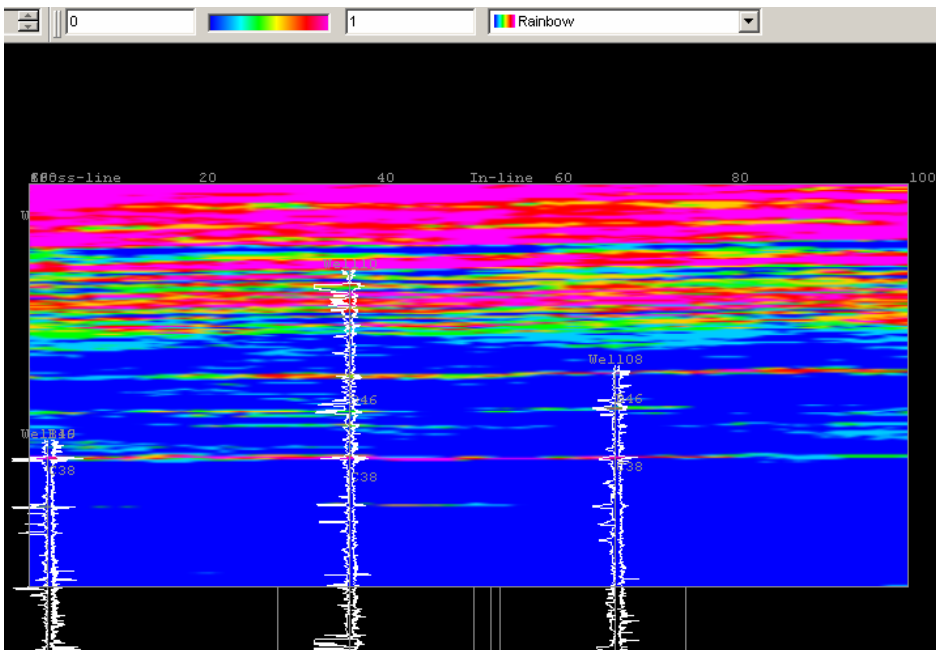
10.6.3 Probability cube trend

Using the 5 available realisations the probability of occurrence may be calculated in combination with a trend

- **Click `Analysis`**
- **Select `Attributes`…**
- **Change `All` to `Earthworks & ARK CLS`**
- **Select `EWUtilities`**
- **Select `Probability Trend`**
- **Select the multi-realisation data to use `Stch_EWZone1_Sph2000`**
- **Select all of the realisations**
- **Click `Parameters`…**
- **Enter the lower and upper impedance (5000 and 12000)**
- **Enter the lower and upper times for the trend (1000 and 1500 ms)**
- **Enter the impedance limit (5000)**

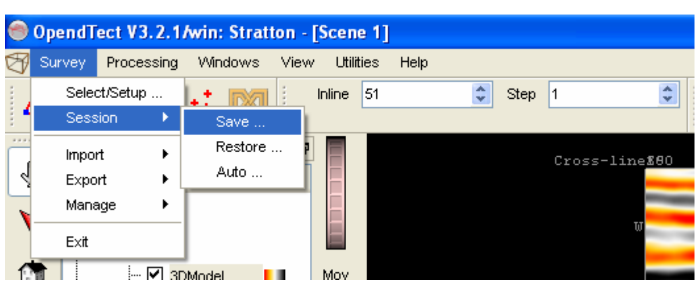


- **Enter a <new attribute name> e.g., `ProbTrend_EWZone1_Sph2000`**
- **Click `Add as new`**
- **Click Ok**



At this stage we should save our progress using the actions below and this will enable the user to return to this stage without having to repeat the setup

- **Select `Survey` from pull-down menu**
- **Select `Session`**
- **Select `Save`**
- **<Stratton_Clean_Stochastic_Utils>**



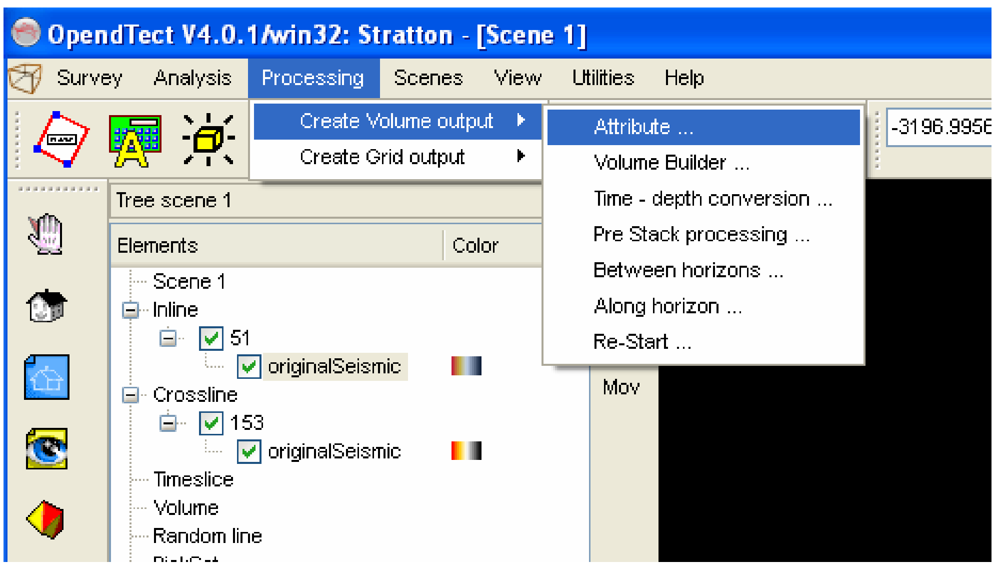
10.7 Connectivity and Volumetrics Module.

From the 5 realisations already processed we can run the connectivity and volumetric module.

10.7.1 Data preparation

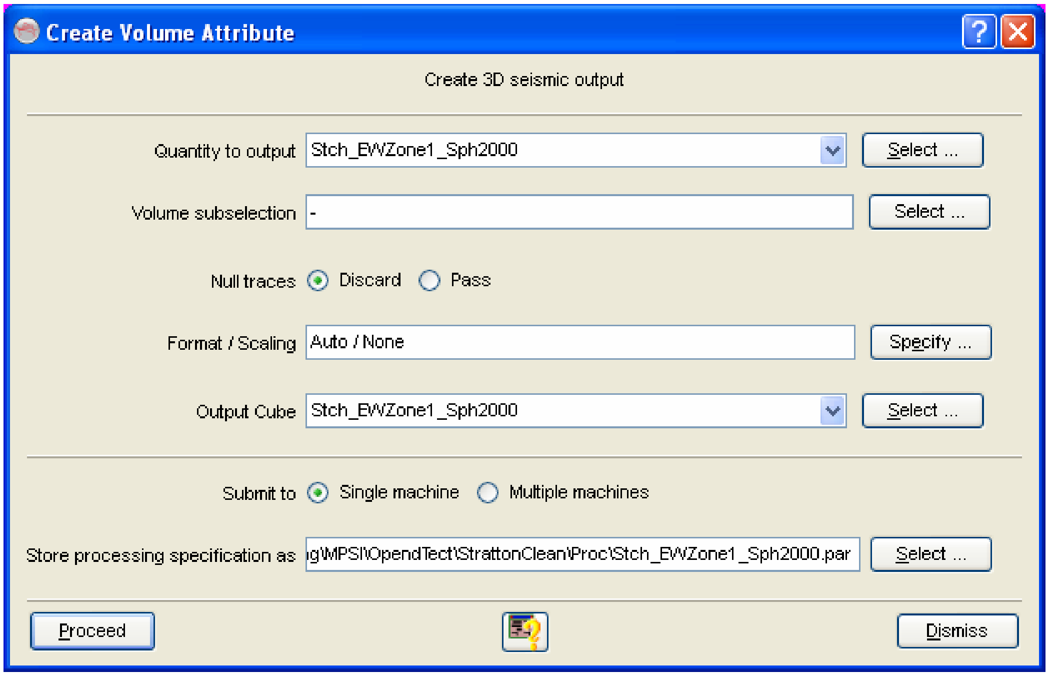
The first step is to generate and save the stochastic inversion realisations in the database.

- **Click `Processing`**
- **Select `Create Volume output`**
- **Select `Attribute`…**



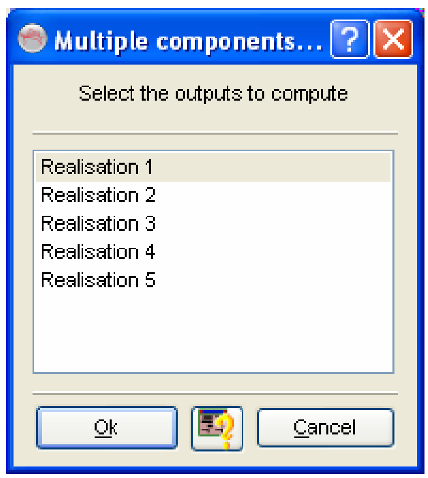
This will open the following dialog where the user can specify the attribute to output, any subset of the volume to be processed and specify the name of the output cube.

- **Select `Stch_EWZone1_Sph2000`**



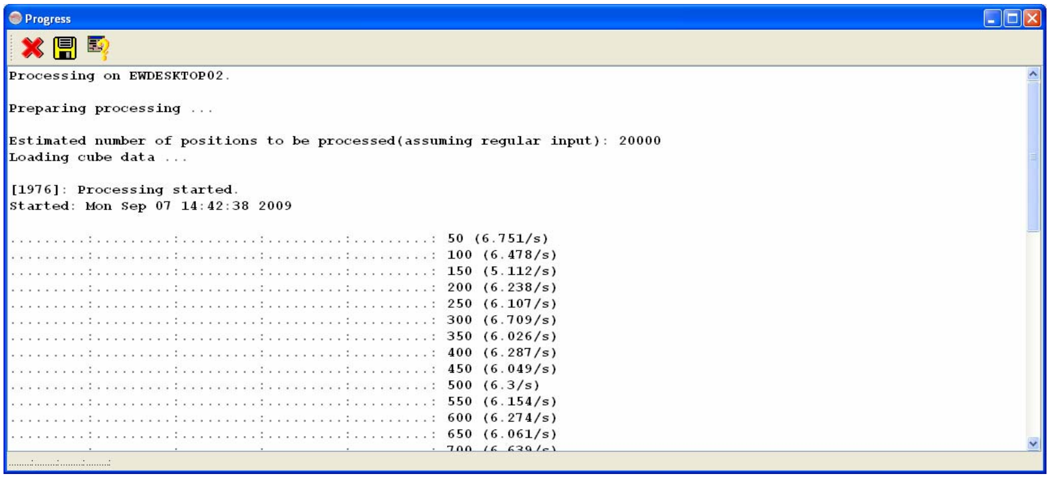
➢ **Press `Process`**

The following panel appears where it is possible to select the realisations to output.



➢ **Select all realisations**
➢ **Press `Ok`**

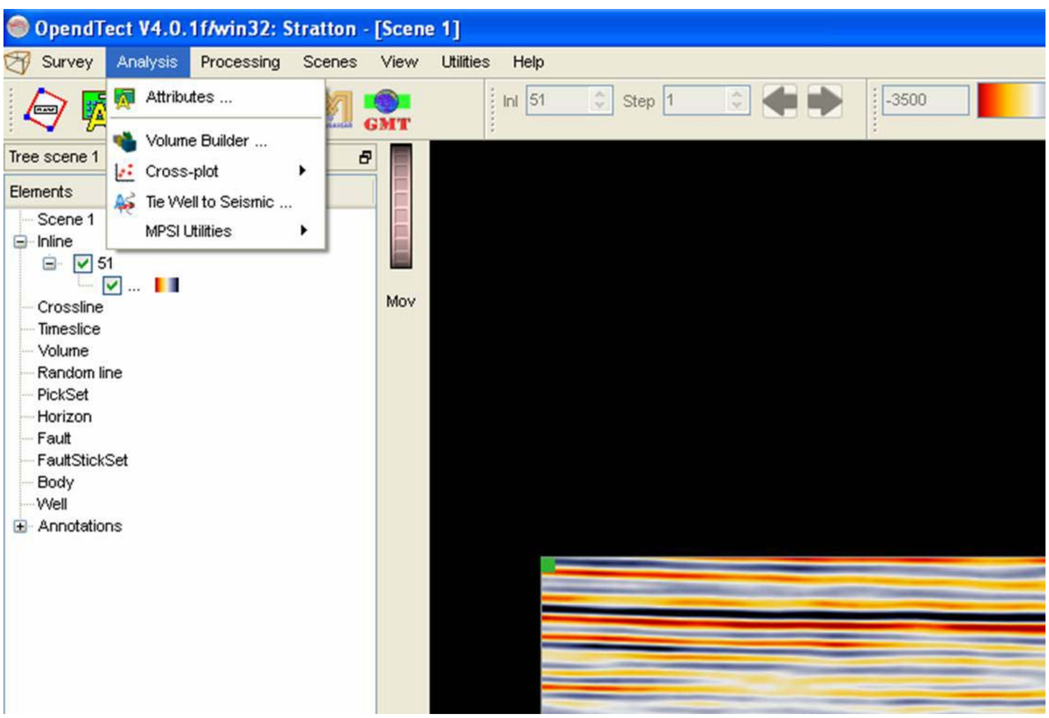
This process will compute the stochastic inversion realisations for 20000 traces and save them in database. According to the computer processor, RAM and IO access speed this can take several minutes to an hour. Leave this job running in the background. The processing window will report the progress.



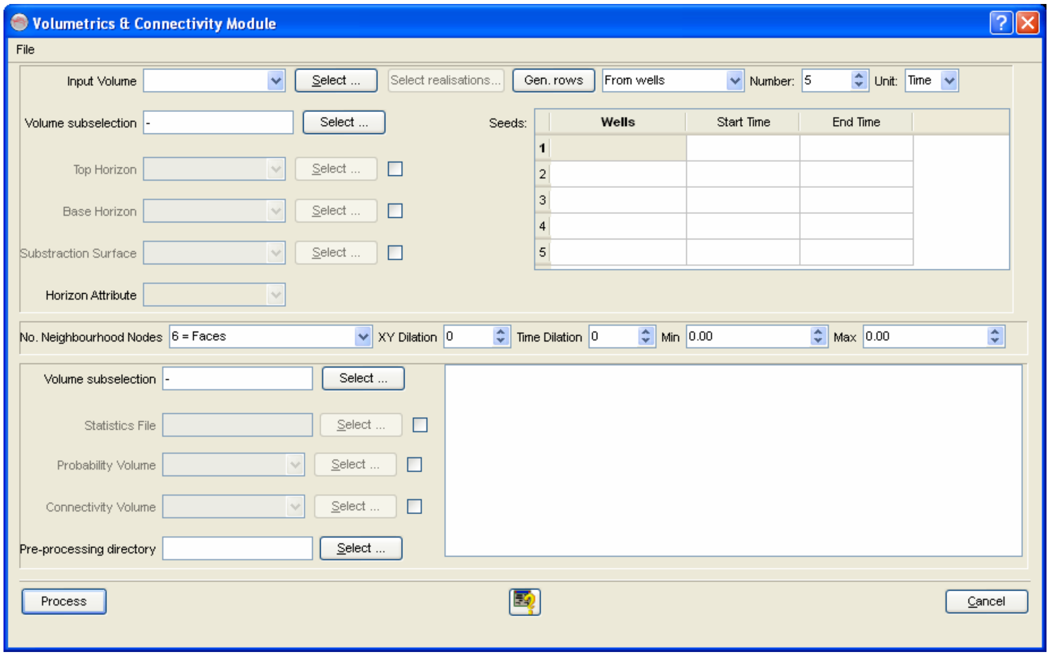
10.7.2 Connectivity computation

The second step is to create a directory in which to save the connectivity pre-processing files. For example <OD survey>\ StrattonClean\Volumetrics\Stch_EWZone1_Sph2000

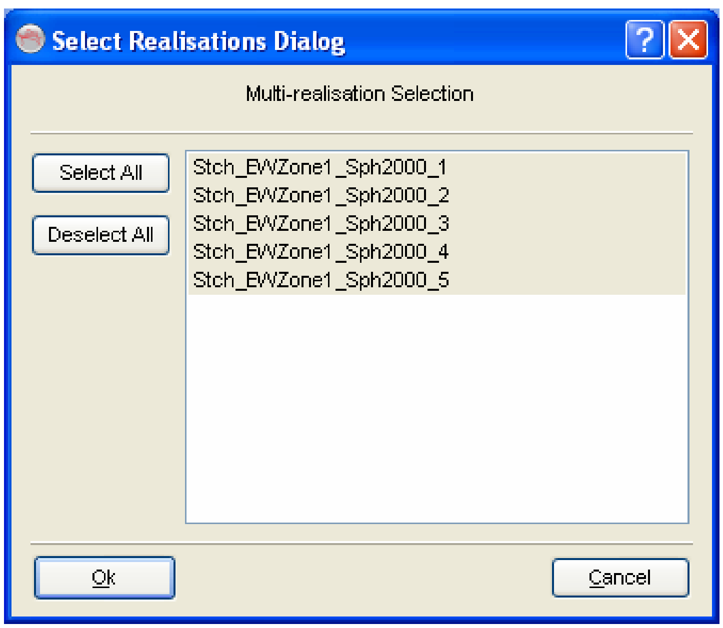
The next step is to enter the connectivity settings.



- **Click Analysis**
- **Click MPSI Utilities**
- **Select Volumetrics…**



➤ **Select as `Input Volume` the recently created `Stch_EWZone1_Sph2000`**



➤ **Select `All` realisations**
➤ **Press `Ok`**

Now we will enter the seeds to compute the sand connectivity between well08 and well10 within the 1300-1350ms time gate. To do that:

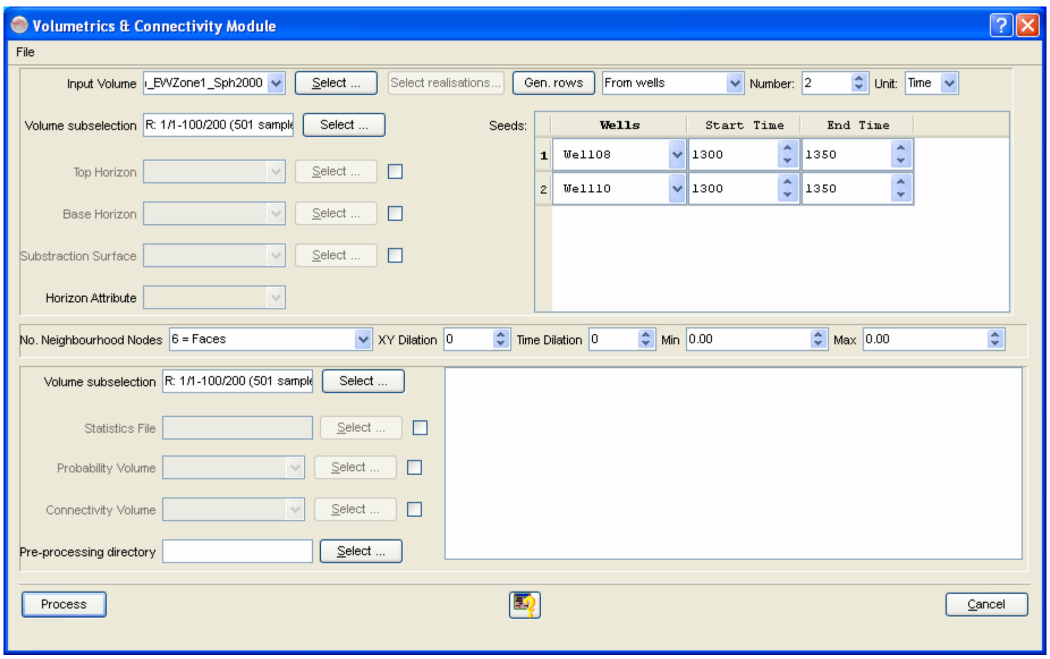
➤ **Set `Number` to be equal to 2**

- **Select `From Well`**
- **Press `Gen. Row`**

Then in the seed tables:

- **Select `Well08` for the first row and first column**
- **Set `Start Time` to be 1300**
- **Set `End Time` to be 1350**
- **Select `Well10` for the second row and first column**
- **Set `Start Time` to be 1300**
- **Set `End Time` to be 1350**

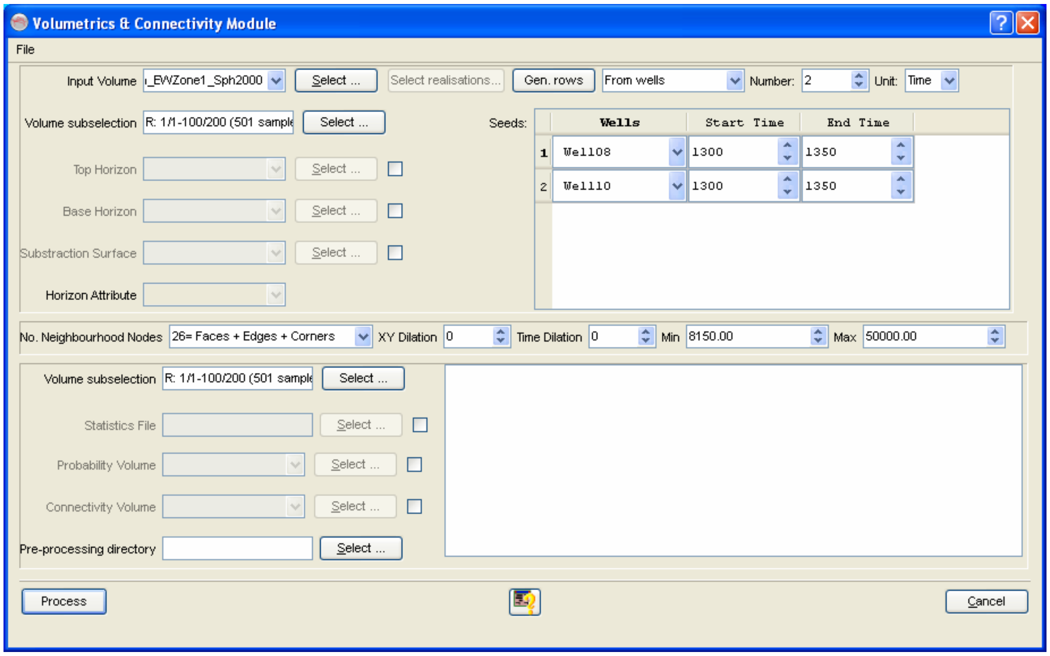
At this stage the settings should look like the ones below:



Now we will define the search pattern, applying a connectivity cut-off of 8150 (m/s*g/cc) corresponding to the sand cut-off in this dataset.

- **Set `No. Neighbourhood Nodes` to 26**
- **Leave `XY Dilation` to 0**
- **Leave `Time Dilation` to 0**
- **Set `Min` to 8150**
- **Set `Max` to 50000**

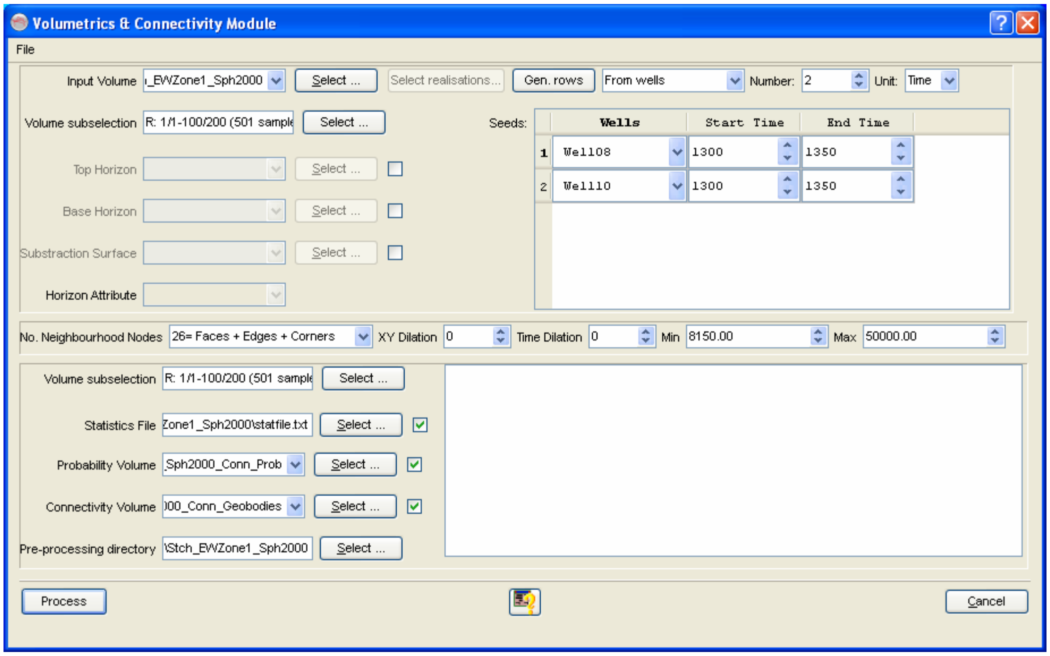
The settings should look like those below:



Now we will define the output field.

- **Set `Pre-processing directory` or working the directory to the one defined earlier. For example <OD survey>\ StrattonClean\Volumetrics\Stch_EWZone1_Sph2000**
- **Set the `Statistic File` to be within this directory and called it statfile.txt**
- **Select a `Probability Volume` and set the name to be Stch_EWZone1_Sph2000_Conn_Prob**
- **Select a `Connectivity Volume` and set the name to be Stch_EWZone1_Sph2000_Conn_Geobodies**

The settings should look like the ones below:



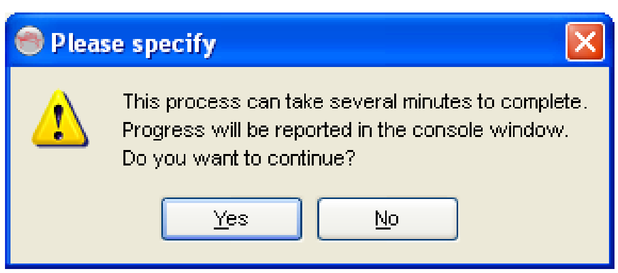
At this point the settings can be saved to a file for later usage.

- **Select File**
- **Select Save**
- **Select the current working directory**
- **Call the file setting.xml**

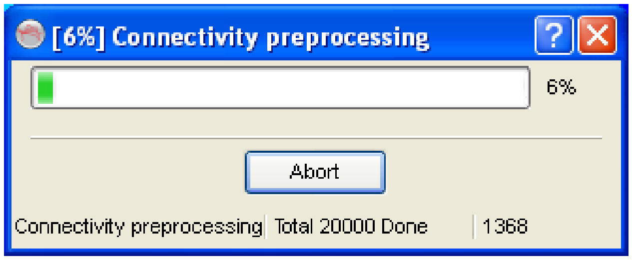
We can now run the connectivity.

- **Press Process**

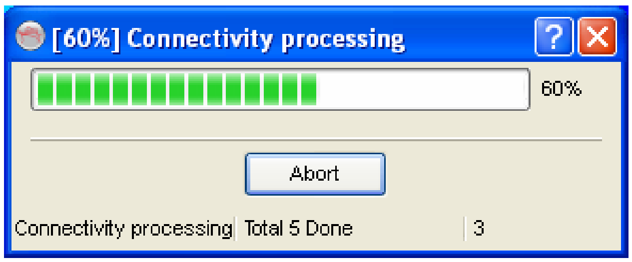
Enter `Yes` to any subsequent questions.



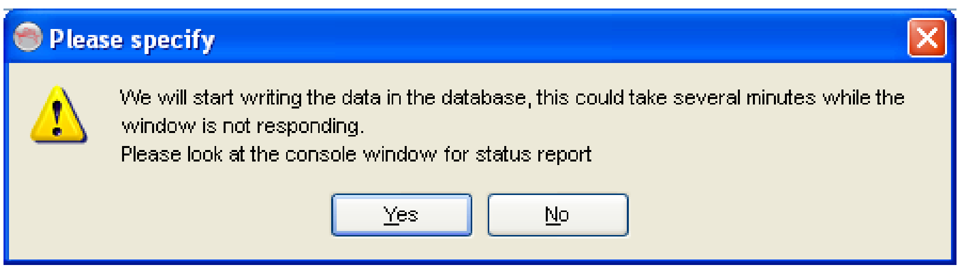
If the pre-processing is re-run the following progress bar should appear.



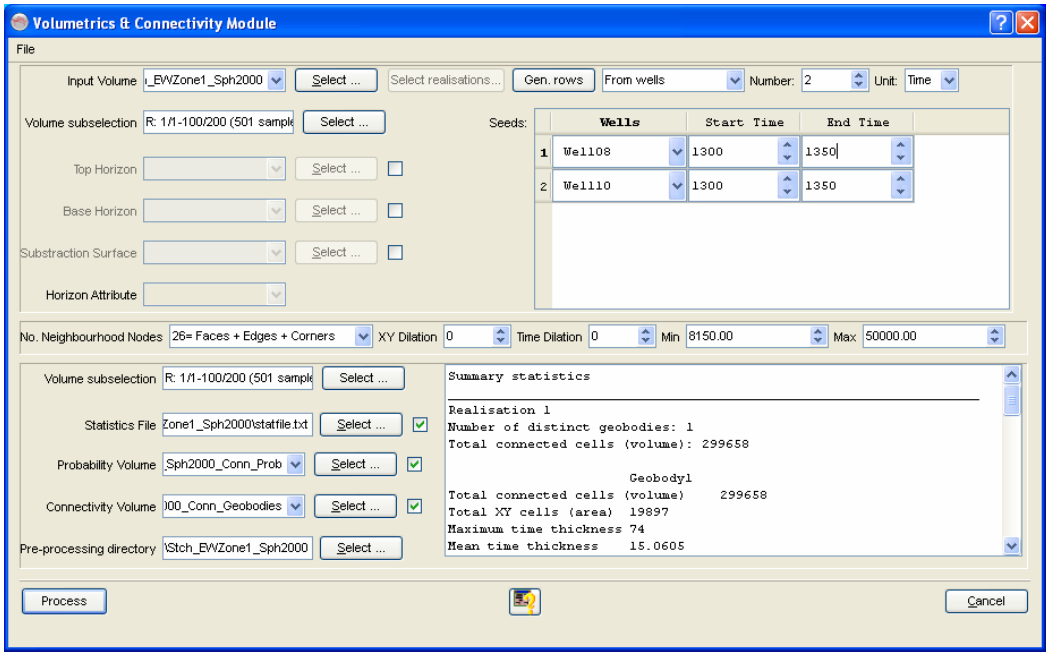
This can take several minutes to complete. When done the connectivity computation is launched. This takes no more than few minutes.



The next step is to write the data in the database. Answer Yes to the following question. It can take several minutes to complete.



At the end of the run summary statistics are displayed in the text field on the bottom right hand side of the panel.

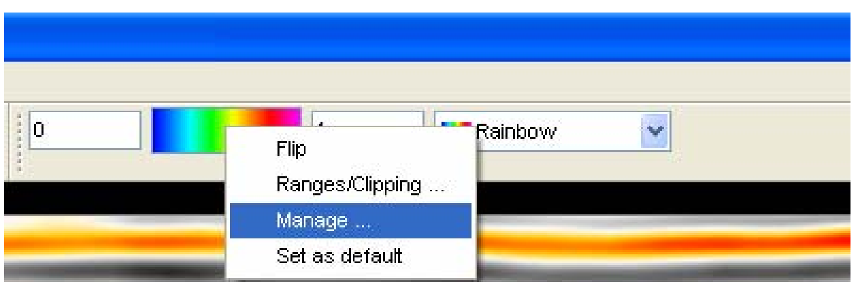


It is now possible to change the seeds without having to re-run the pre-processing. Adding more seeds, changing their location, dilation and number of Neighbourhood nodes can all be changed without re-running the pre-processing. So re-running a new connectivity using the same input cubes and volume and the same impedance cut-offs should run significantly faster. The output results could be saved in different output files for different runs.

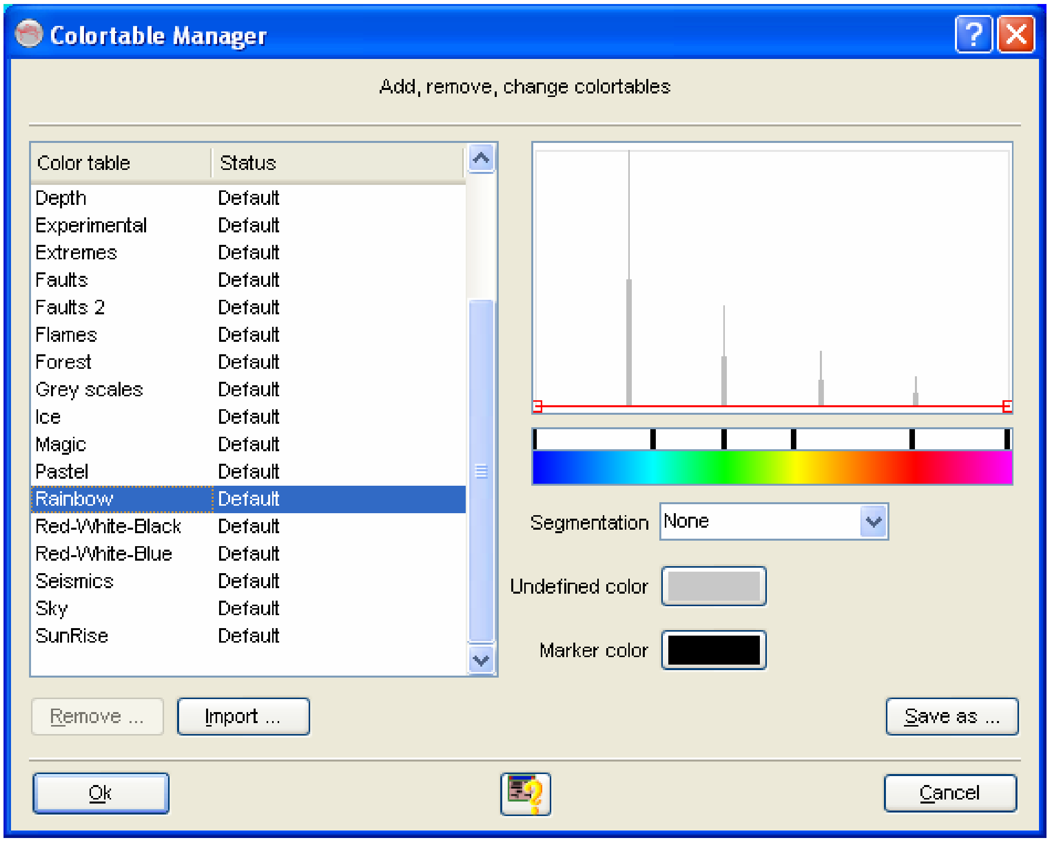
10.7.3 Data visualisation

To visualise the geobodies it is useful to create our own colour bar.

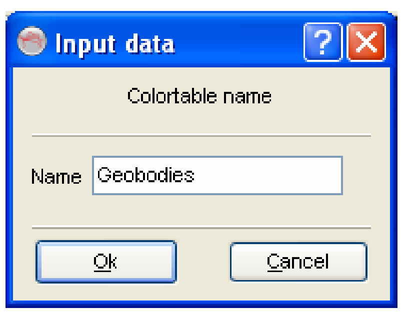
- **Select the Rainbow colour bar**
- **Select `Manage`...**



The Colour table manager appears.



- **Select Rainbow colour bar**
- **Press `Save as`…**

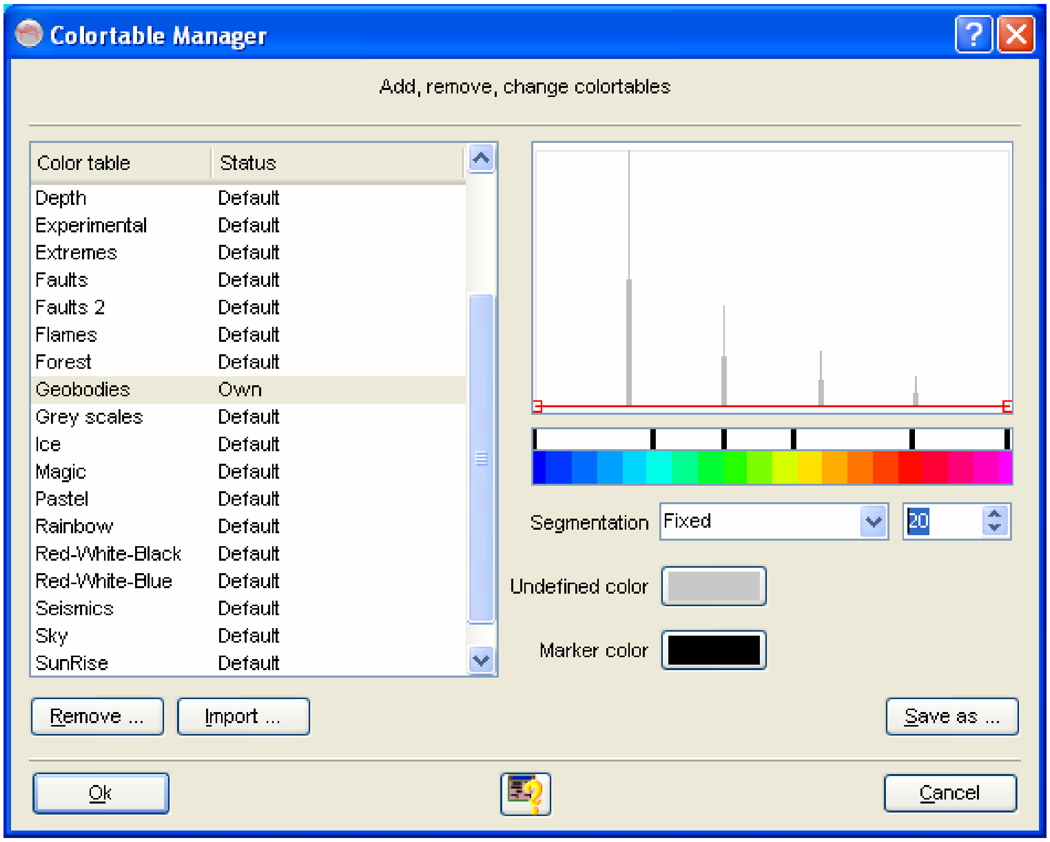


- **Enter Geobodies**
- **Press `Ok`…**

We should now have a new

- **Select the Geobodies Colour table in the list on the left hand side**
- **Set the `Segmentation` to `Fixed`**
- **Set the `Segmentation` to 20**

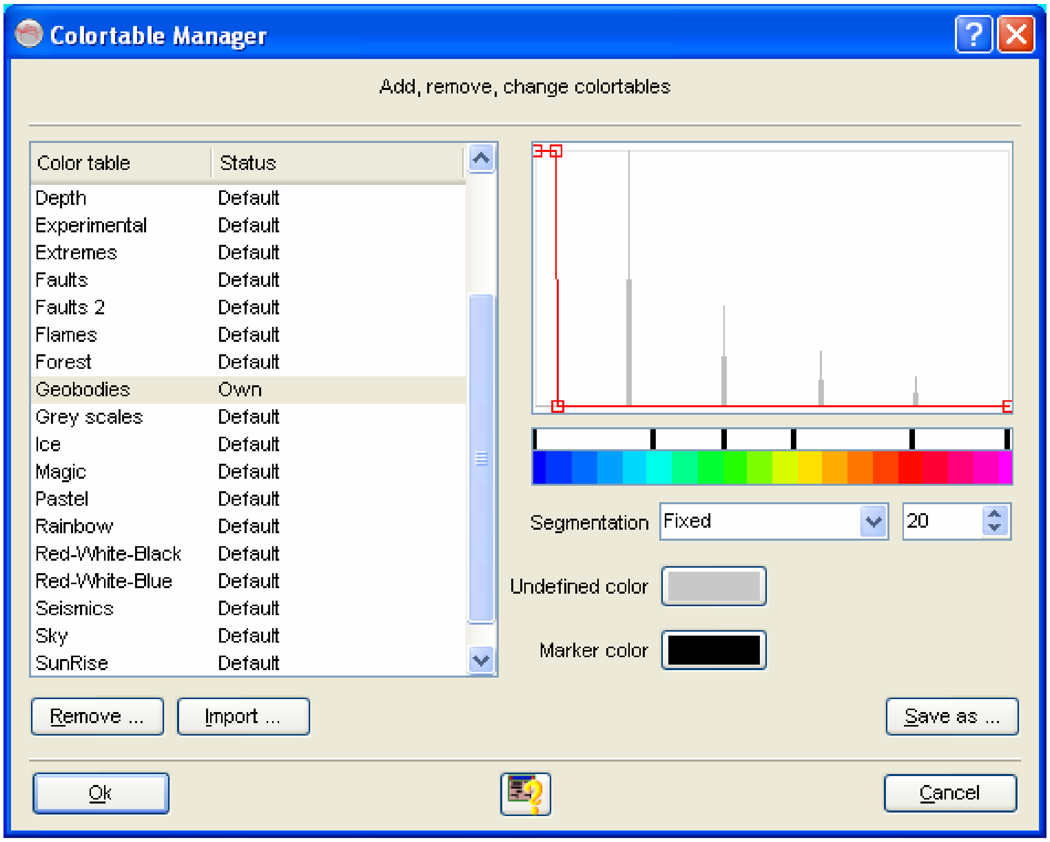
We should now have the following entries:



A geobody cube is composed of integers, with each geobody identified by an integer greater than 0 and the background matrix being 0. To visualise them we need to set the background matrix transparent. Basically the transparency is the red line on the right hand side display; the `x-axis` is the colour bar value and the `y-axis` the transparency values from 0 to 1. Manually editing the transparency is a bit of an art:

- **Double click the red line to obtain a new point (marked by red squares)**
- **Double click a second time to create a new point a new point (we shall now have 4 points)**
- **Drag the two first point up to a transparency of 1, and aligned them at the first segment boundaries**
- **Drag the 3rd point down to a transparency of 0, at the same position as the second point (i.e. at the boundary between the first and second segment)**

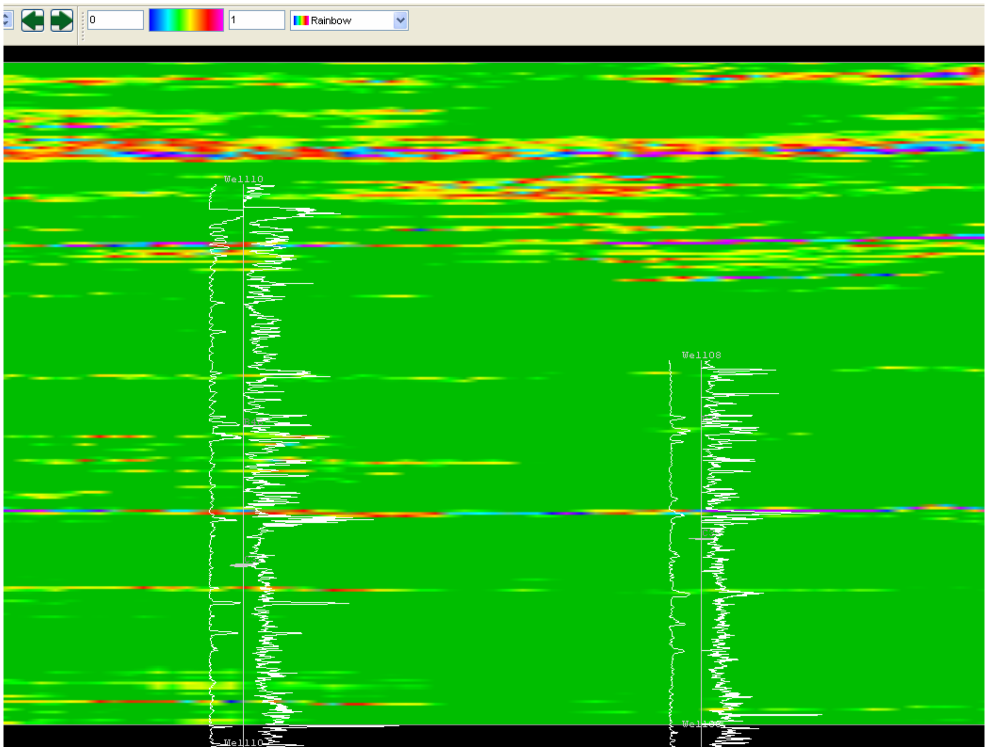
The final display should look like the one below:



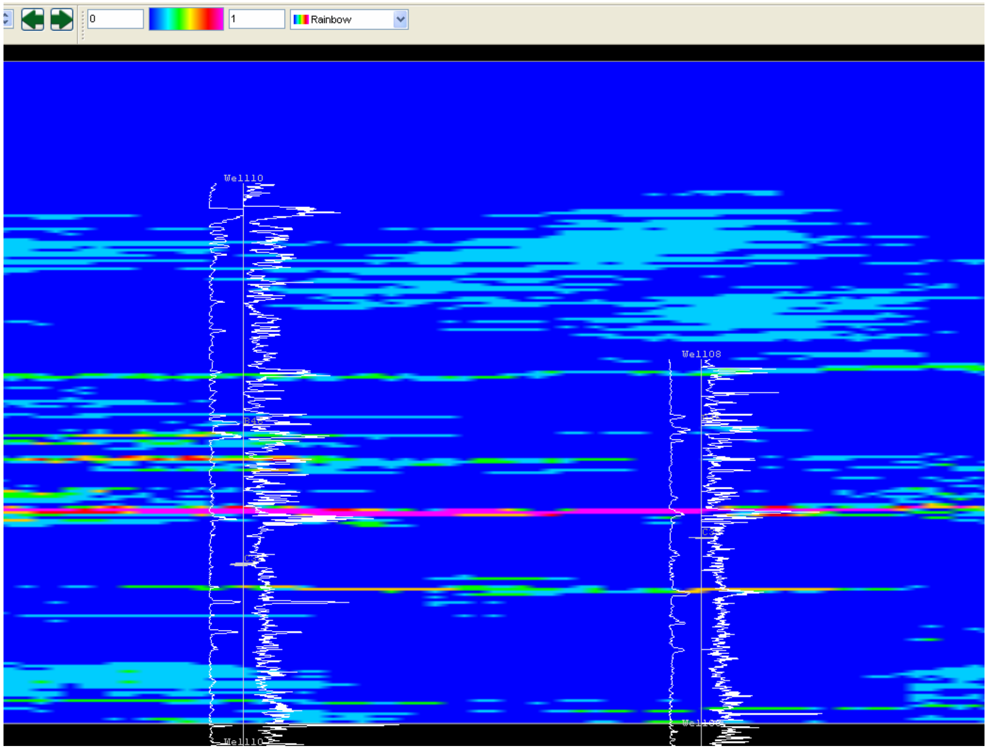
- **Press `Ok`**

Connectivity displayed will be carried on crossline 153. Set the display as mentioned in the previous settings or restore the previous session (`Stratton_Clean_Stochastic_Utils`).

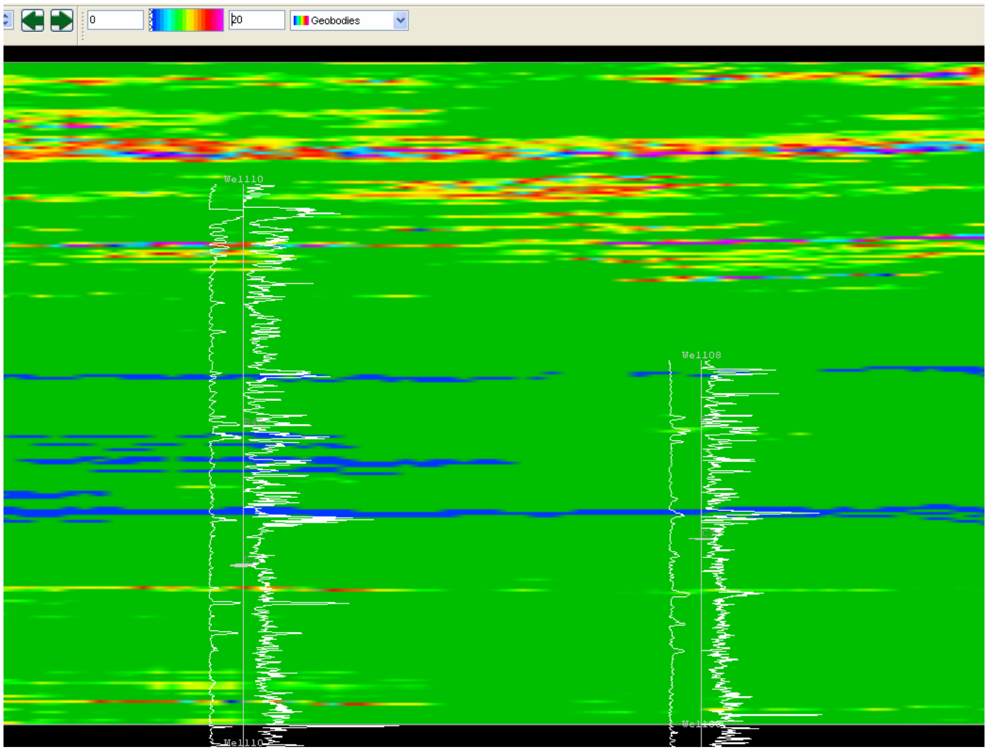
- **Right-clicking cross-line 153**
- **Add attribute**
- **Right click and `Select Attribute`**
- **Right click `Stored Cubes`**
- **Select Stch_EWZone1_Sph2000**
- **Select the first realisation**
- **Set the colour bar to AI**
- **Set the range to be 8150-12500**



- Right-clicking cross-line 153
- Add attribute
- Right click and `Select Attribute`
- Right click `Stored Cubes`
- Select Stch_EWZone1_Sph2000_Conn_Prob
- Select the first realisation
- Set the colour bar to Rainbow
- Set the range to be 0-1

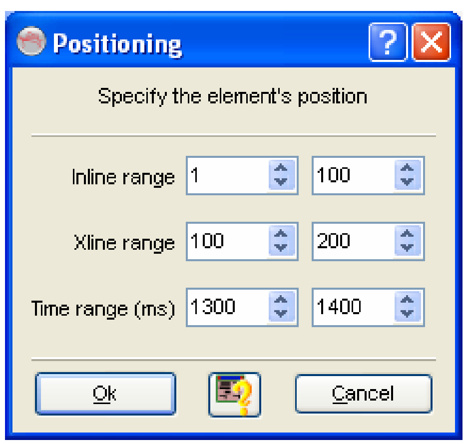


- Right-clicking cross-line 153
- Add attribute
- Right click and `Select Attribute`
- Right click `Stored Cubes`
- Select Stch_EWZone1_Sph2000_Conn_Geobodies
- Select the first realisation
- Set the colour bar to Geobodies
- Set the range to be 0-19
- Unclick Stch_EWZone1_Sph2000_Conn_Prob



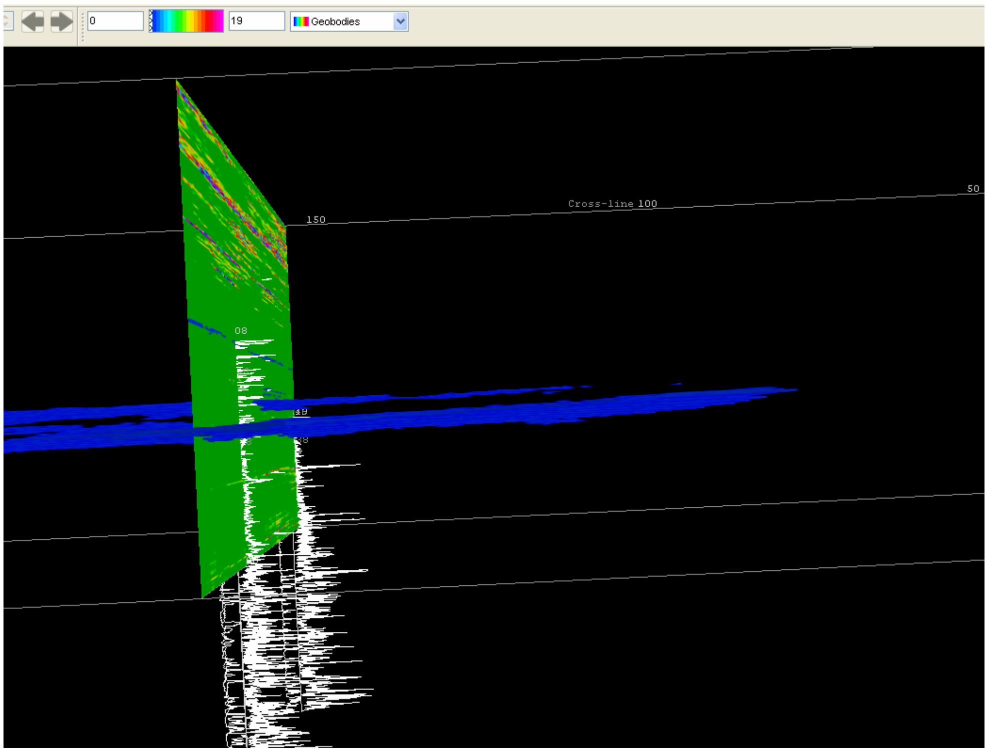
Geobodies are better displayed on a volume.

- **Right-clicking `Volume`**
- **`Add`**
- **Right click and `Position`**
- **Enter the following settings**



- **Right click and `Select Attribute`**
- **Right click `Stored Cubes`**
- **Select Stch_EWZone1_Sph2000_Conn_Geobodies**
- **Select the first realisation**
- **Set the colour bar to Geobodies**
- **Set the range to be 0-19**
- **Unclick `Inline`, `Crossline`, `Time`**

- **Tick `Volren`**
- **Switch to Perspective camera**
- **Zone and rotate the view to check the geobodies**



The same analysis can be carried for the 4 remaining realisations.

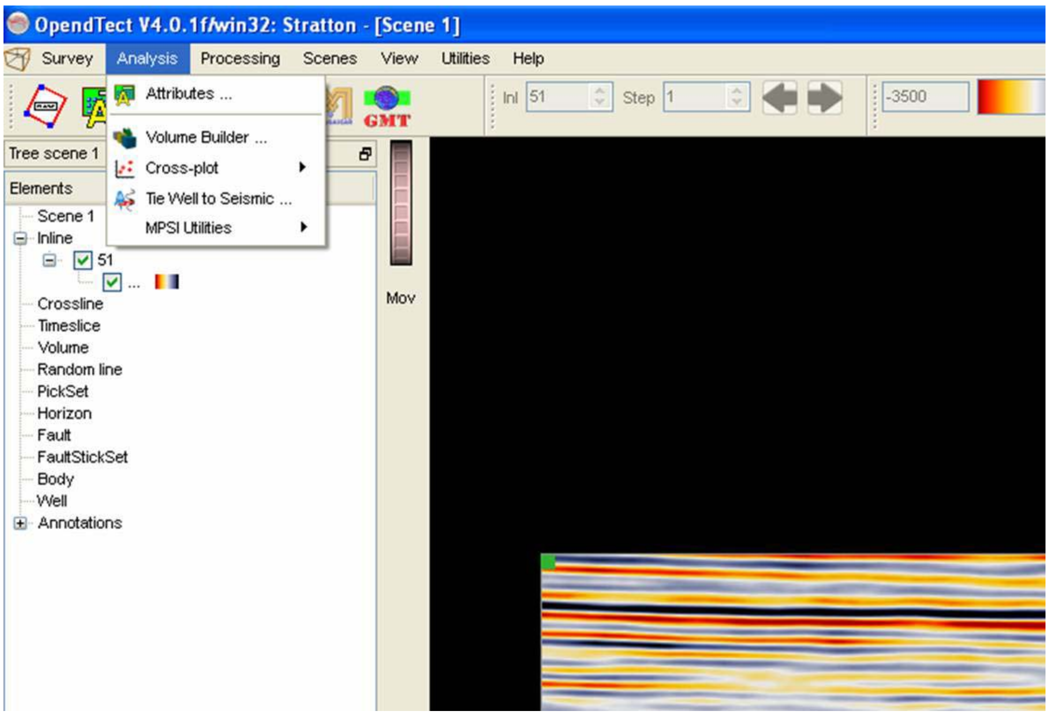
- **Select `Survey` from pull-down menu**
- **Select `Session`**
- **Select `Save`**
- **<Stratton_Clean_Stochastic_Conn>**

10.8 Net to Gross Module.

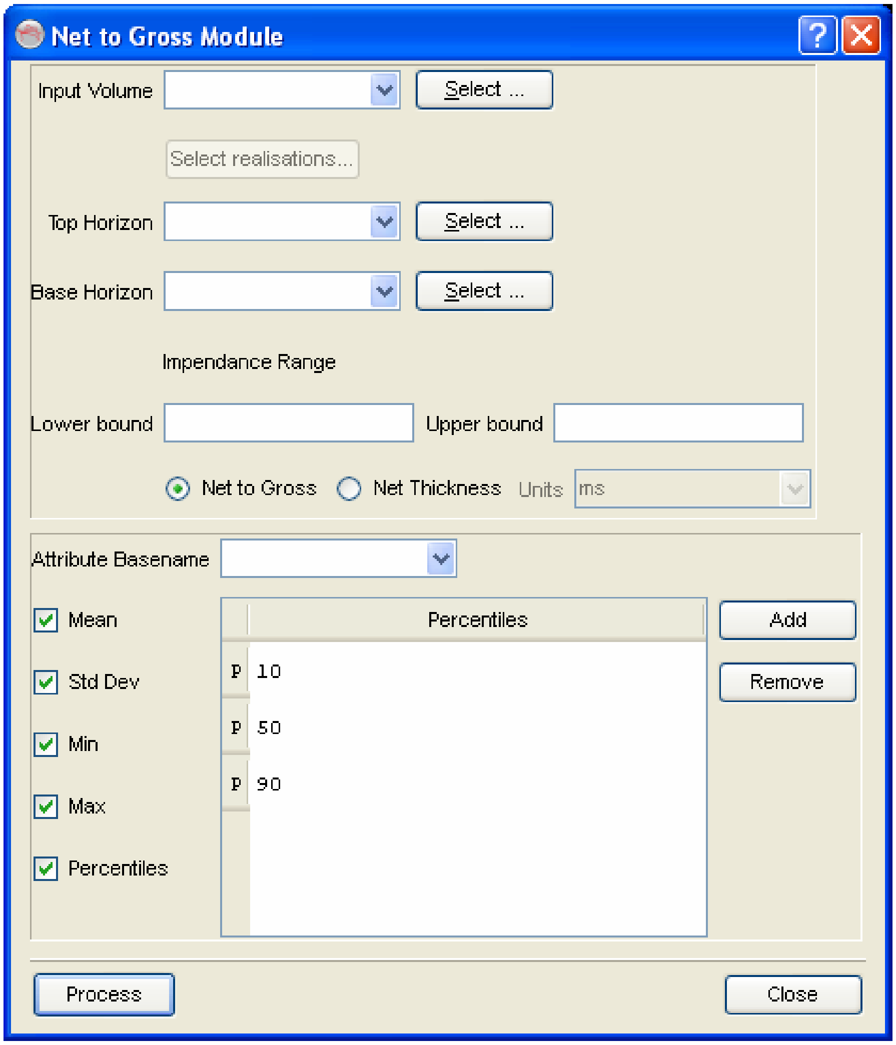
From the 5 realisations already processed we can run the Net to Gross module.

10.8.2 Net to Gross computation

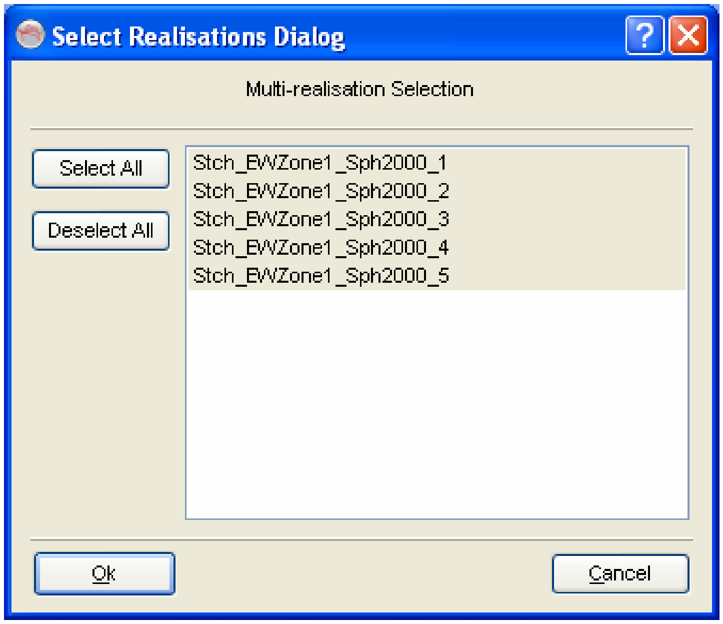
Open the Net to Gross Dialog.



- **Click** `Analysis`
- **Click** `MPSI Utilities`
- `Select Net To Gross…`



- **Select as `Input Volume` the recently created `Stch_EWZone1_Sph2000`**



- **Select All realisations**
- **Press Ok**

- **Select Mfrio as Top Horizon**
- **Select C38 as Base Horizon**

Set an impedance cut-off of 8150 (m/s*g/cc) corresponding to the sand cut-off in this dataset.

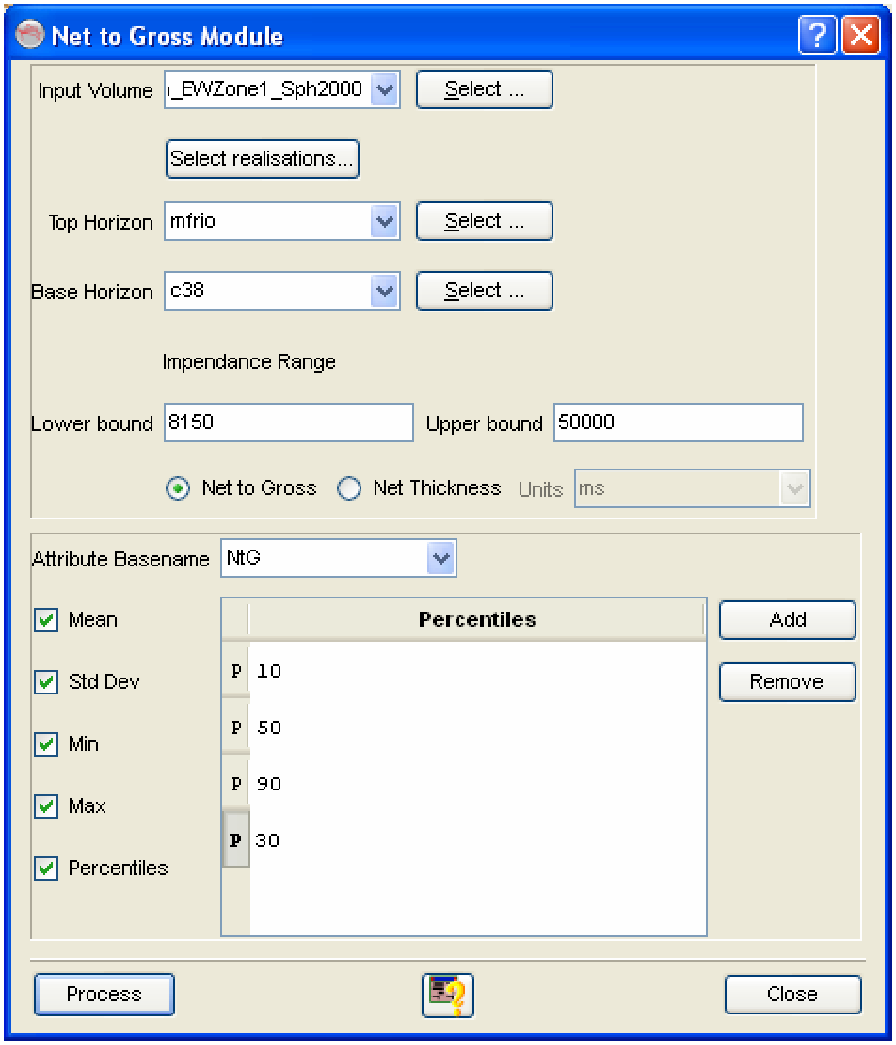
- **Set Lower bound to 8150**
- **Set Upper bound to 50000**

We want to output Net to Gross maps.

- **Click Net to Gross**
- **Set Attribute Basename to NtG**

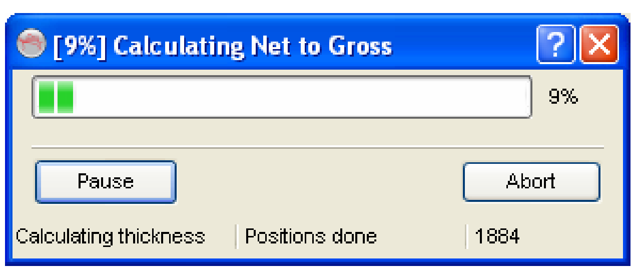
We then need to select our outputs. Keep the default setting but add in the Percentile table a 30% percentile. Note that percentile values can be edited by right clicking the text.

The settings should look like these below:



We can now run the computation.

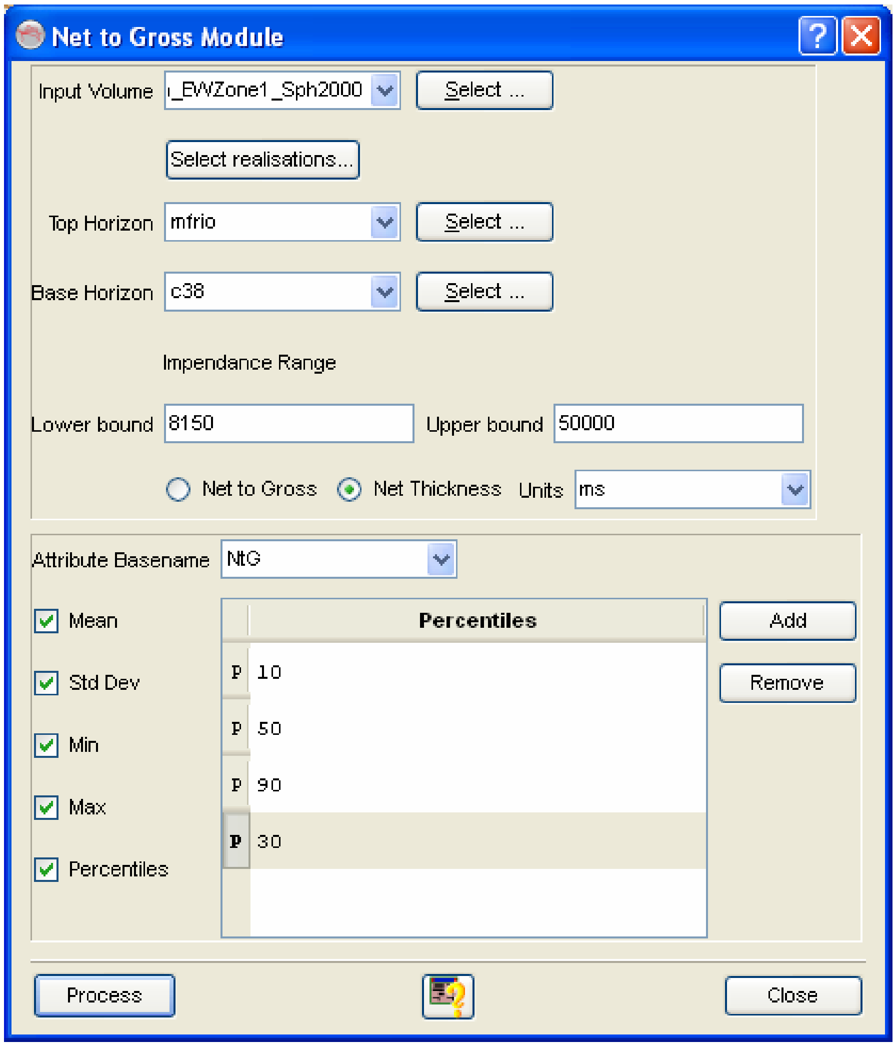
➢ **Press Process**



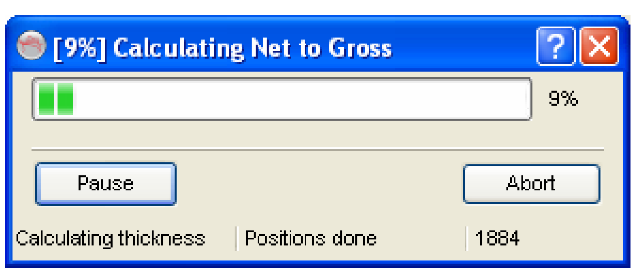
This only takes few seconds to complete.

Without closing the window we can now change the output to Net Thickness

- **Click `Net Thickness`**
- **Set `Attribute Basename` to Net**
- **Set the `Units` in ms**



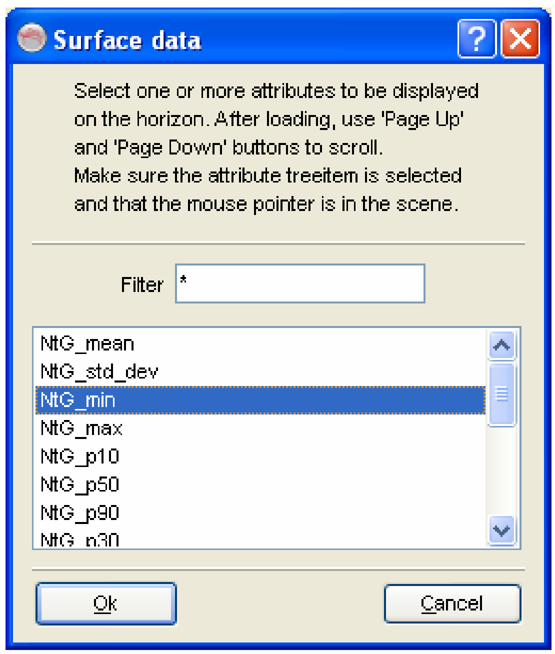
- **Press Process**



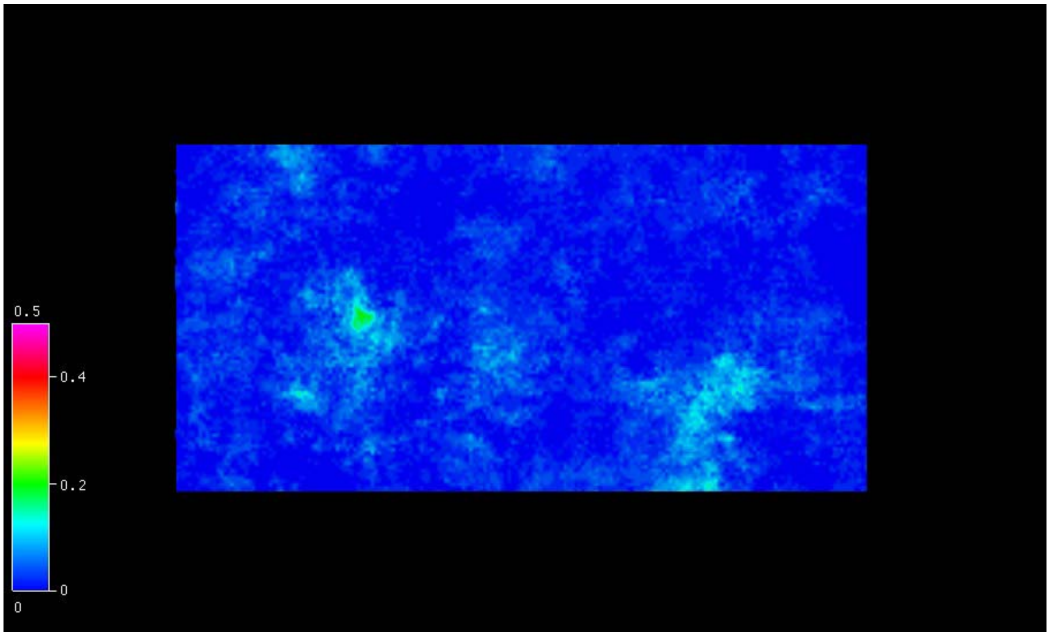
We can now visualise the results.

10.8.2 Data Visualisation

- **Click icon to view inline followed by icon to view plan**
- **Right click horizon MFrio**
- **Add attribute**
- **Right click and `Select Attribute`**
- **Right click `Surface Data`**

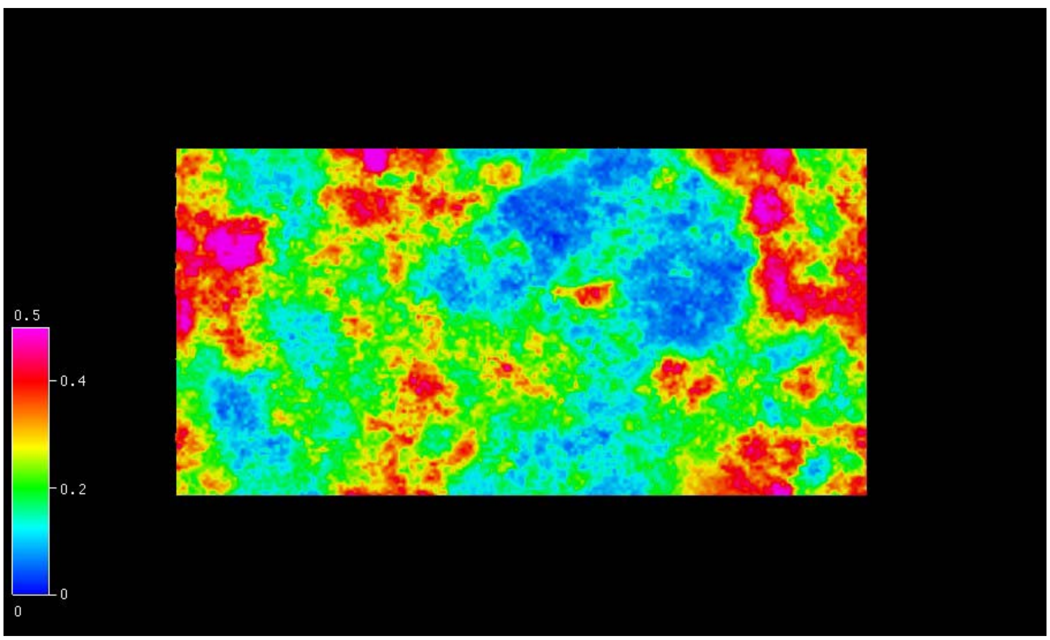


- **Select NtG_min**
- **Set the colour bar to Rainbow**
- **Set the range to be 0-0.5**

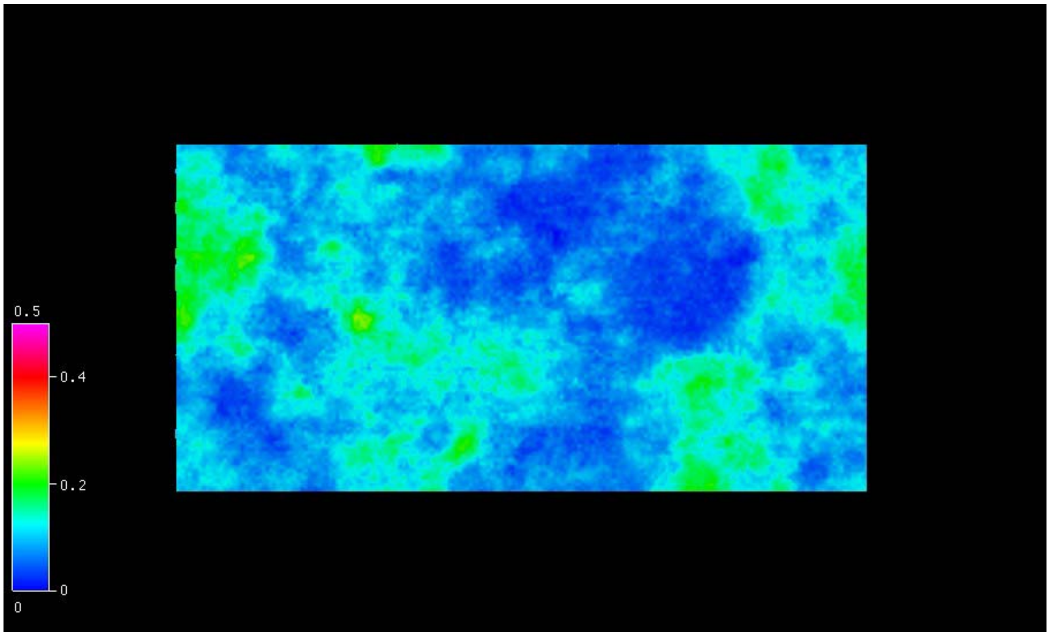


NtG Min

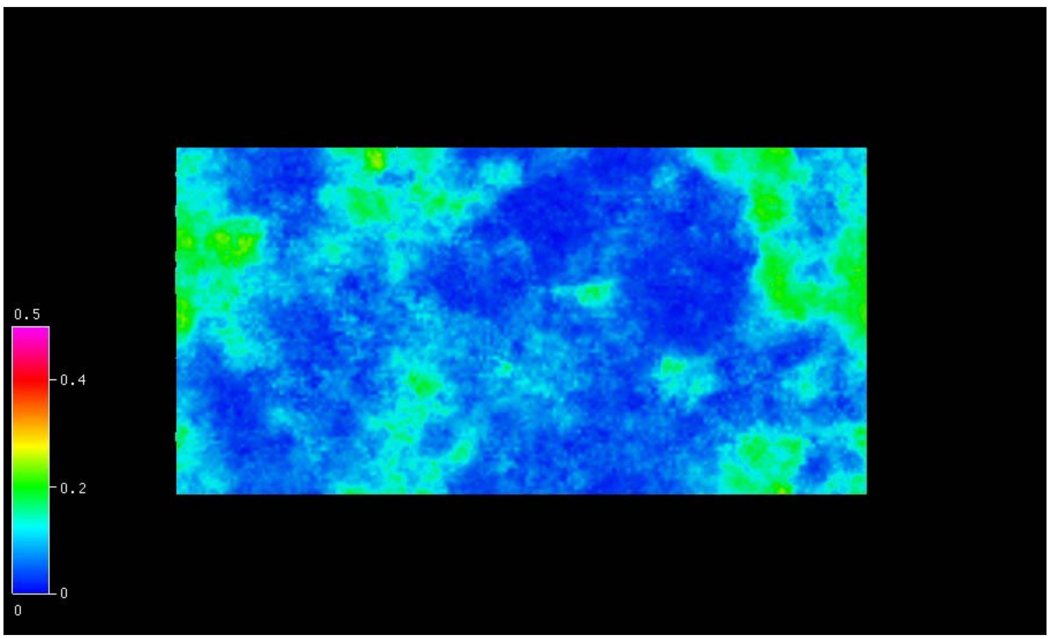
We can display the other NtG maps in the same way.



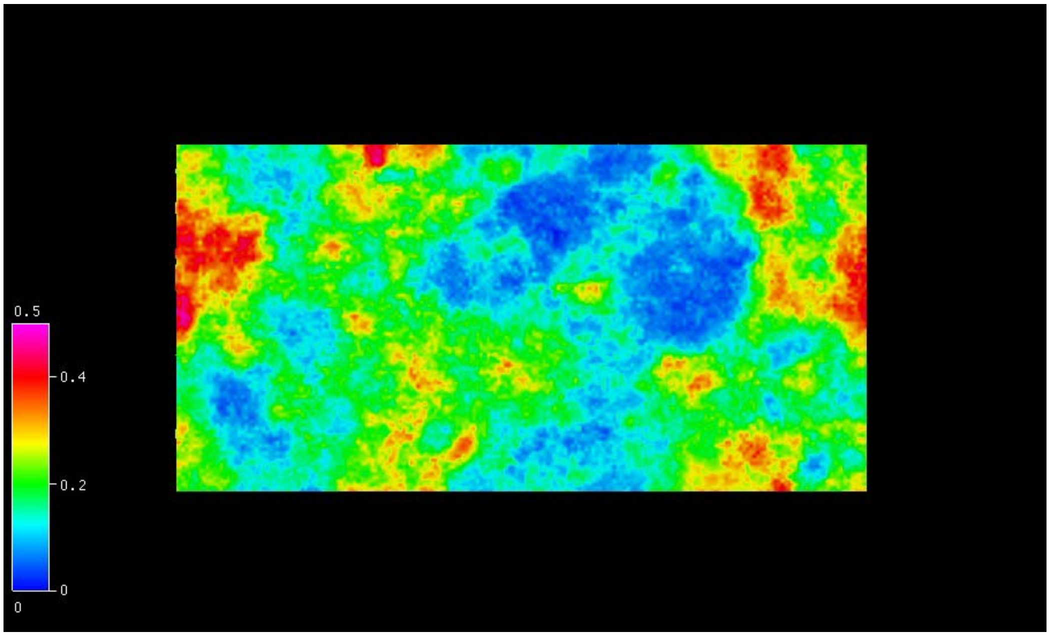
NtG Max



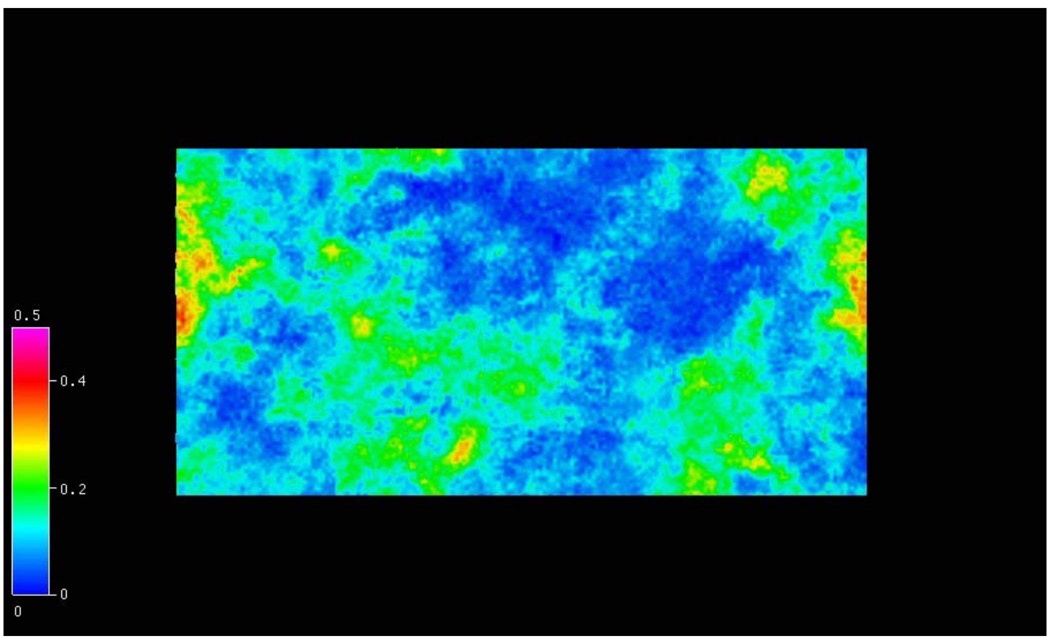
NtG Mean



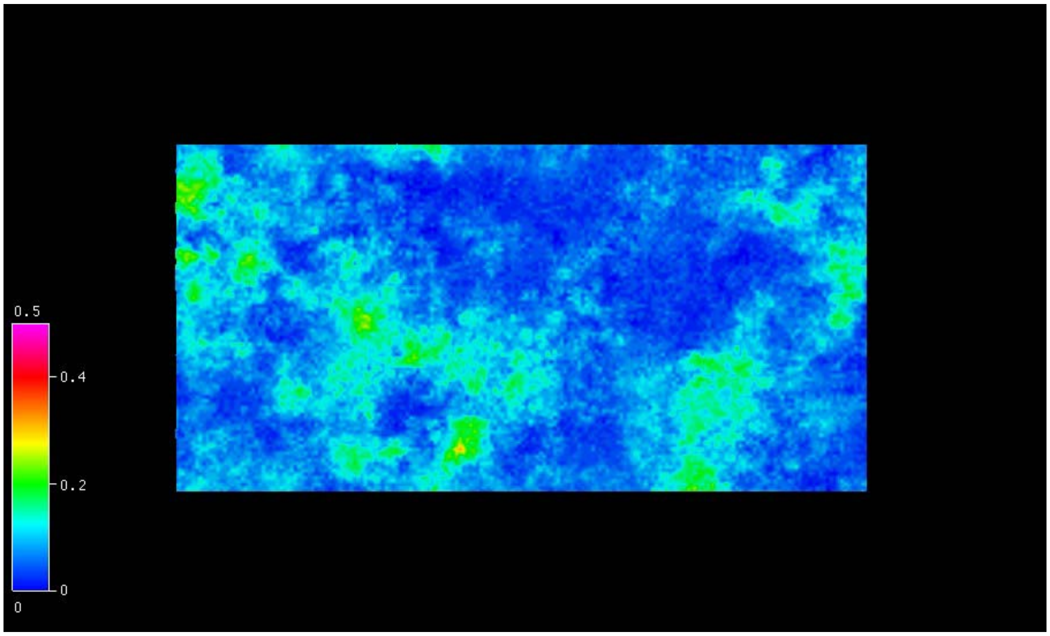
NtG Standard Deviation



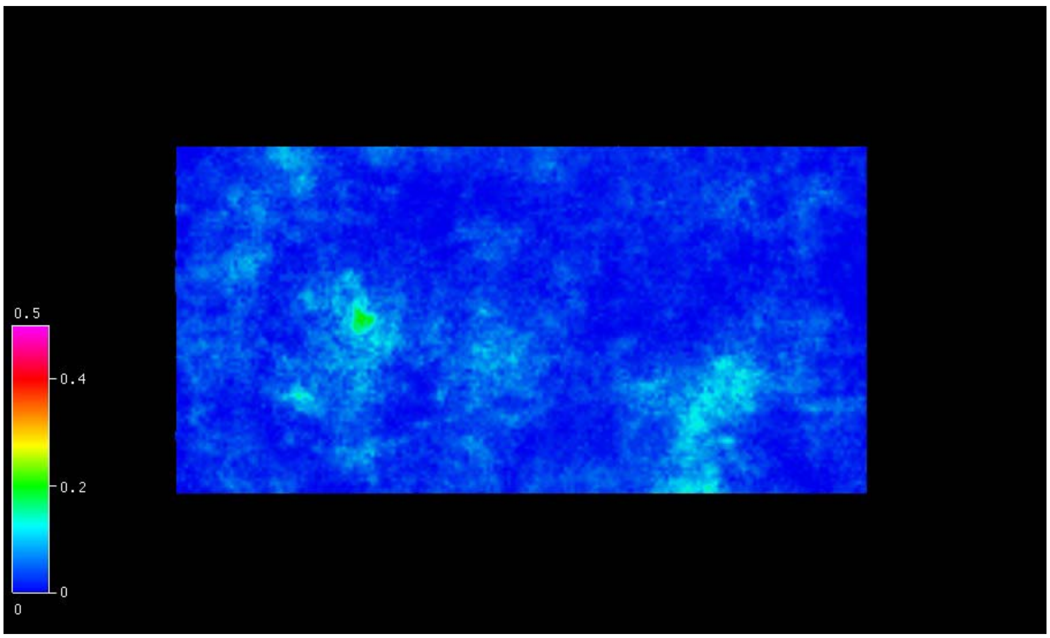
NtG P10



NtG P30

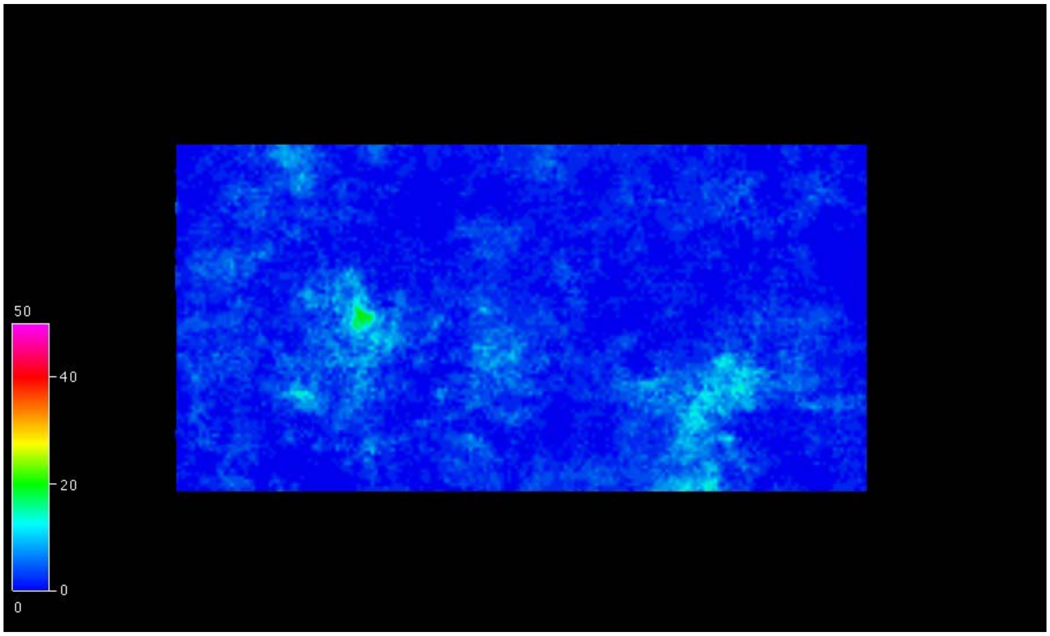


NtG P50

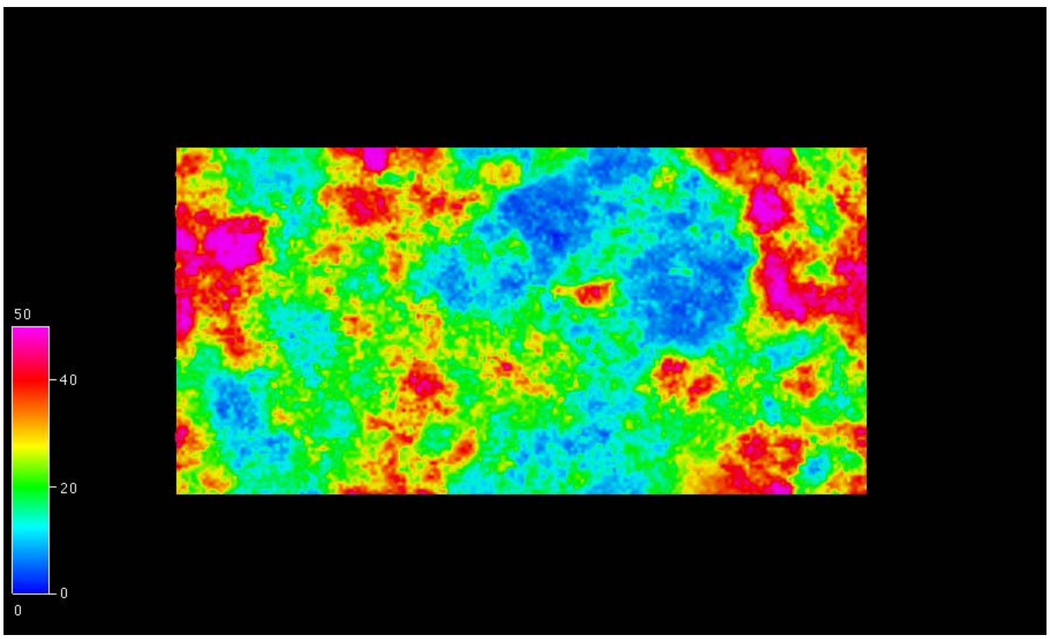


NtG P90

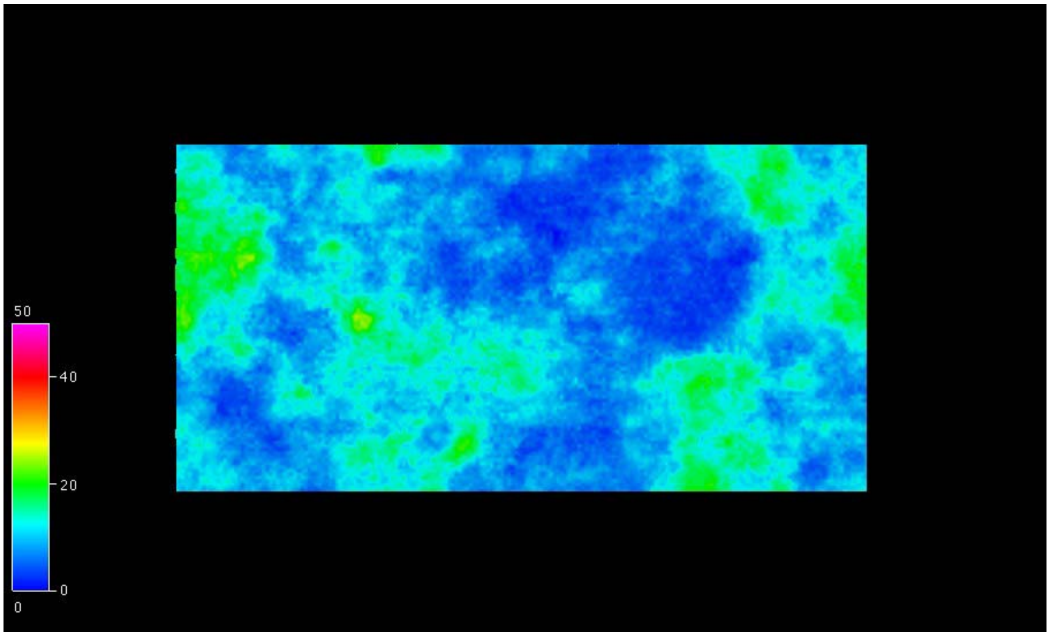
The same exercise can be done for Net Thickness setting the colour range between 0-50



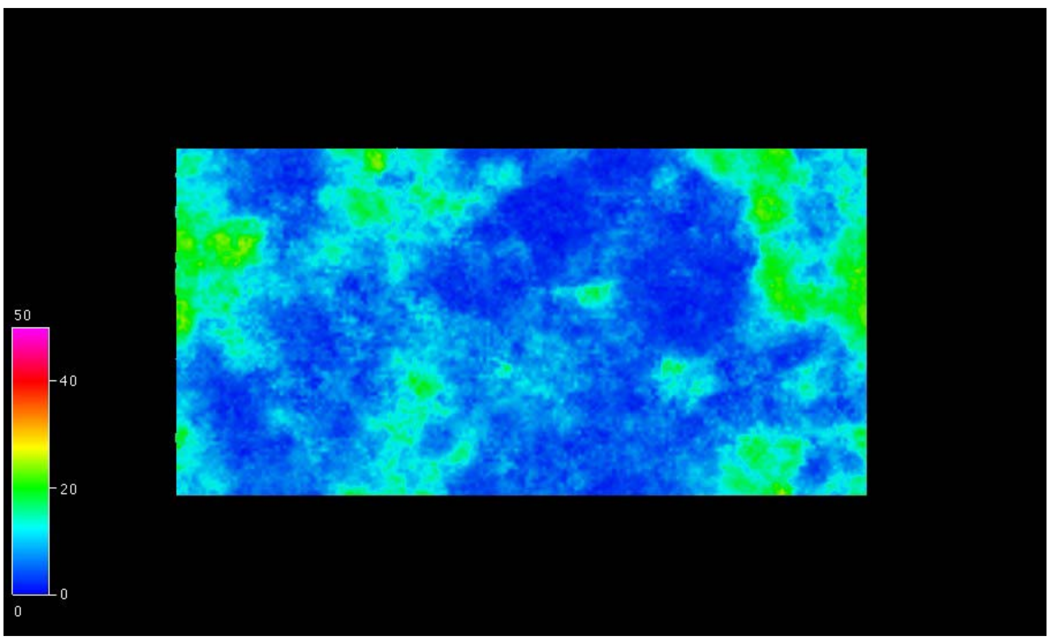
Net Min in ms



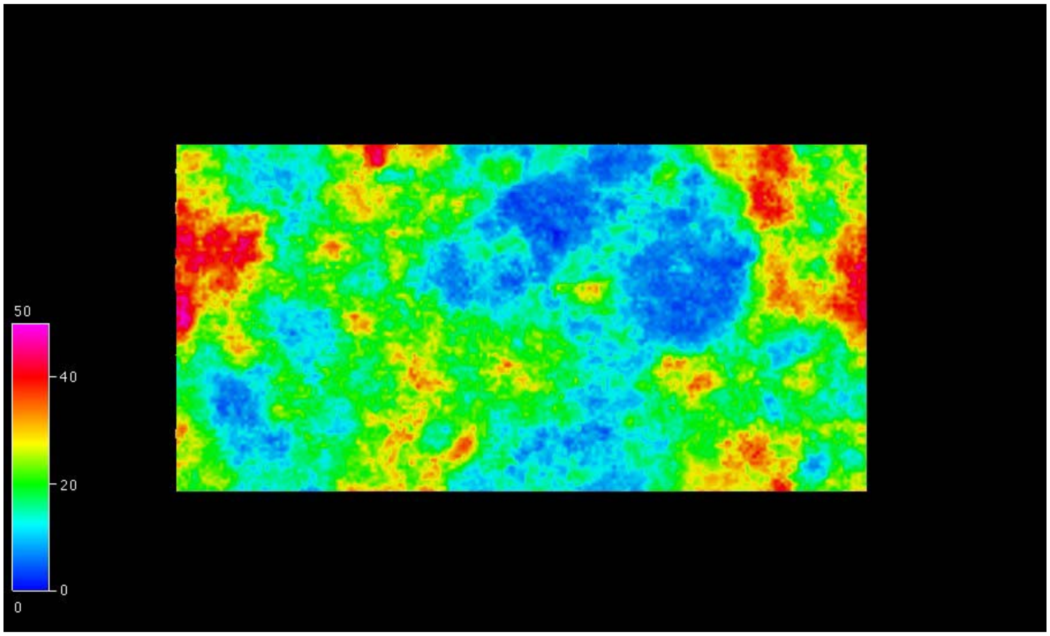
Net Max in ms



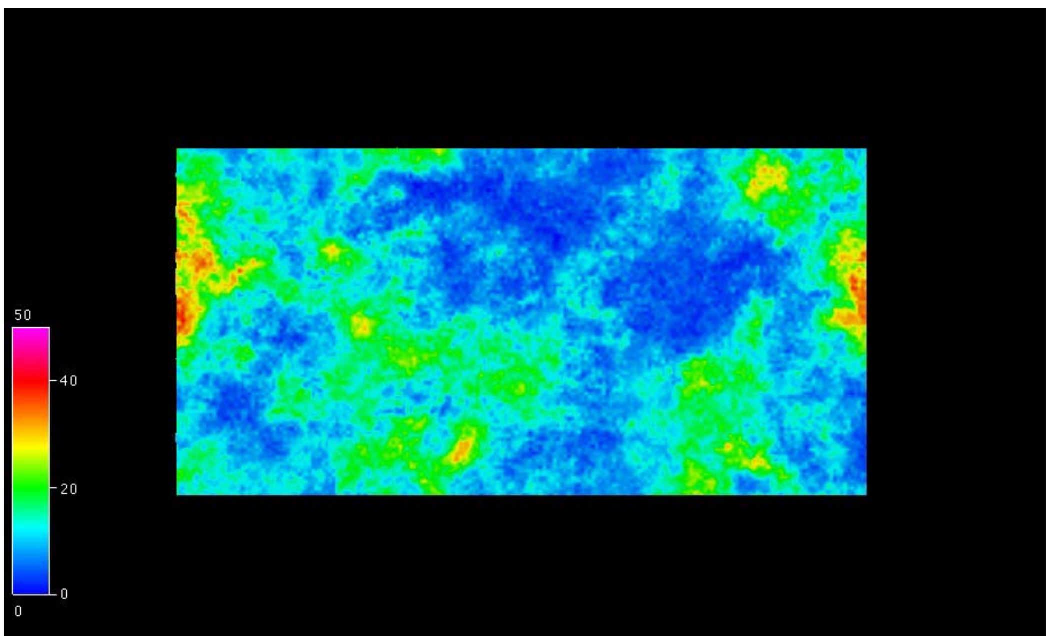
Net Mean in ms



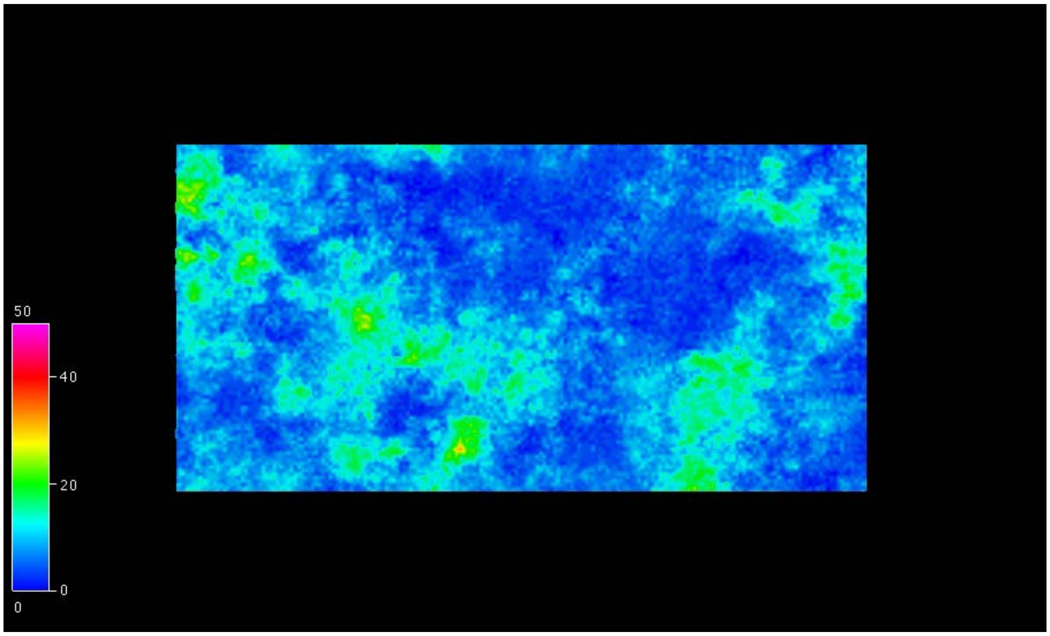
Net Standard Deviation in ms



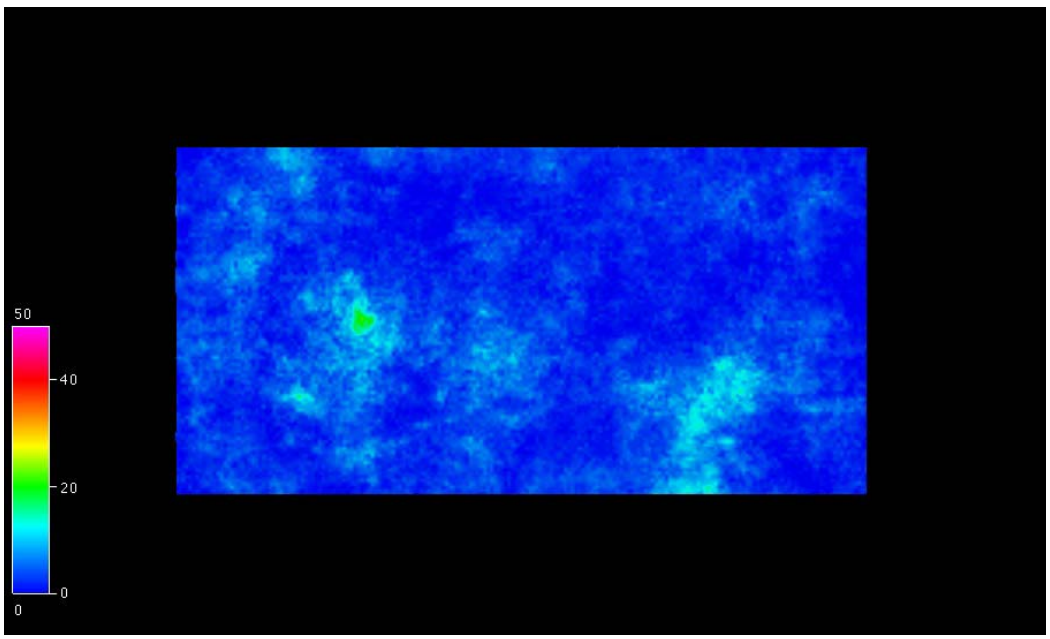
Net P10 in ms



Net P30 in ms



Net P50 in ms



Net P90 in ms