



5. 5 Layer Modeling

5.5.1 Basic

5.5.1.1 Layer Description

5.5.1.2 Synthetic- and Property-Log Generation

5.5.1.3 Cross-Plots



5.5 Layer Modeling

Pseudo-wells are stratigraphic columns with attached well logs, but without geographical location. Any pseudo-well can be seen as a possible realization of a newly drilled well in the area. The pseudo-wells generation is achieved following a model that has to be defined. To achieve *Layer Modeling*, preliminary an extended well data analysis has to be carried out. The stratigraphy must be defined and then the well logs behavior have to be known in order to be used in the modeling. During the modeling process, the stratigraphy description is fixed and cannot be edited.

The Layer Modeling is accessible from the *Analysis* menu but also from the *Manage Stratigraphy* window.

Analysis Processing Scene View Utilities

Attributes ...

Volume Builder ...

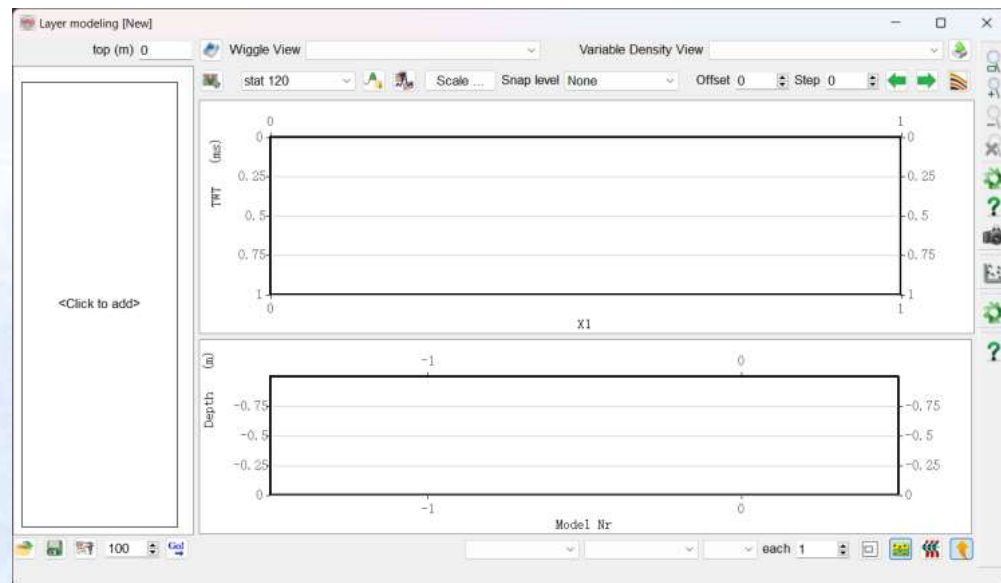
Cross-plot Data

Wells

Layer Modeling

Mistie Analysis

Basic ...

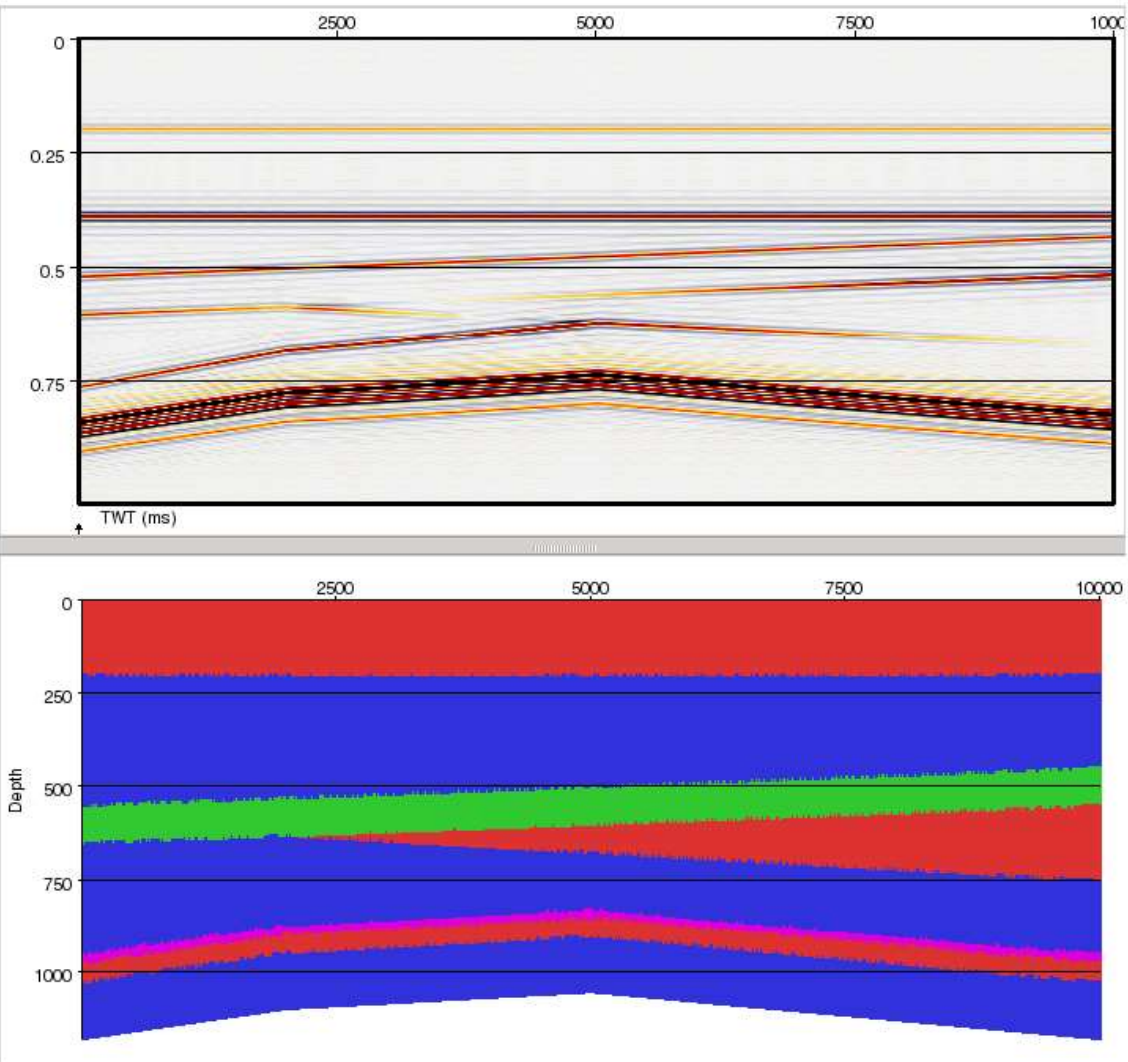




Basic modeling can be achieved in OpendTect. More advanced modeling are available in SynthRock plugin.

The Layer modeling workflow is divided into three main steps:

1. Model definition: using the stratigraphy description, properties are assigned to the different lithologies within each units. These properties are fixed or can vary. The model definition is used to generate the pseudo-wells.
2. Synthetic and Log generation: the pseudo-wells are generated and their associated properties can be displayed. With a wavelet extracted from the real seismic, zero-offset synthetics are generated. Using a ray tracer synthetics can be computed for different offsets and restricted angle stacks can be created. Thus their behavior with varying offset can be analyzed.
3. Pseudo-well data analysis: the properties from modeled logs and synthetic seismic can be compared and analyzed layer by layer, lithology by lithology.



Example of a basic block model



5.5.1 Basic

Each layer in the stratigraphy column is characterized by different rock properties. The model, based on the stratigraphy, is assigning properties to each lithology, layer by layer. The model is built using a blocky approach. The different properties are selected within a list. Their value can either be constant or vary within a given range.

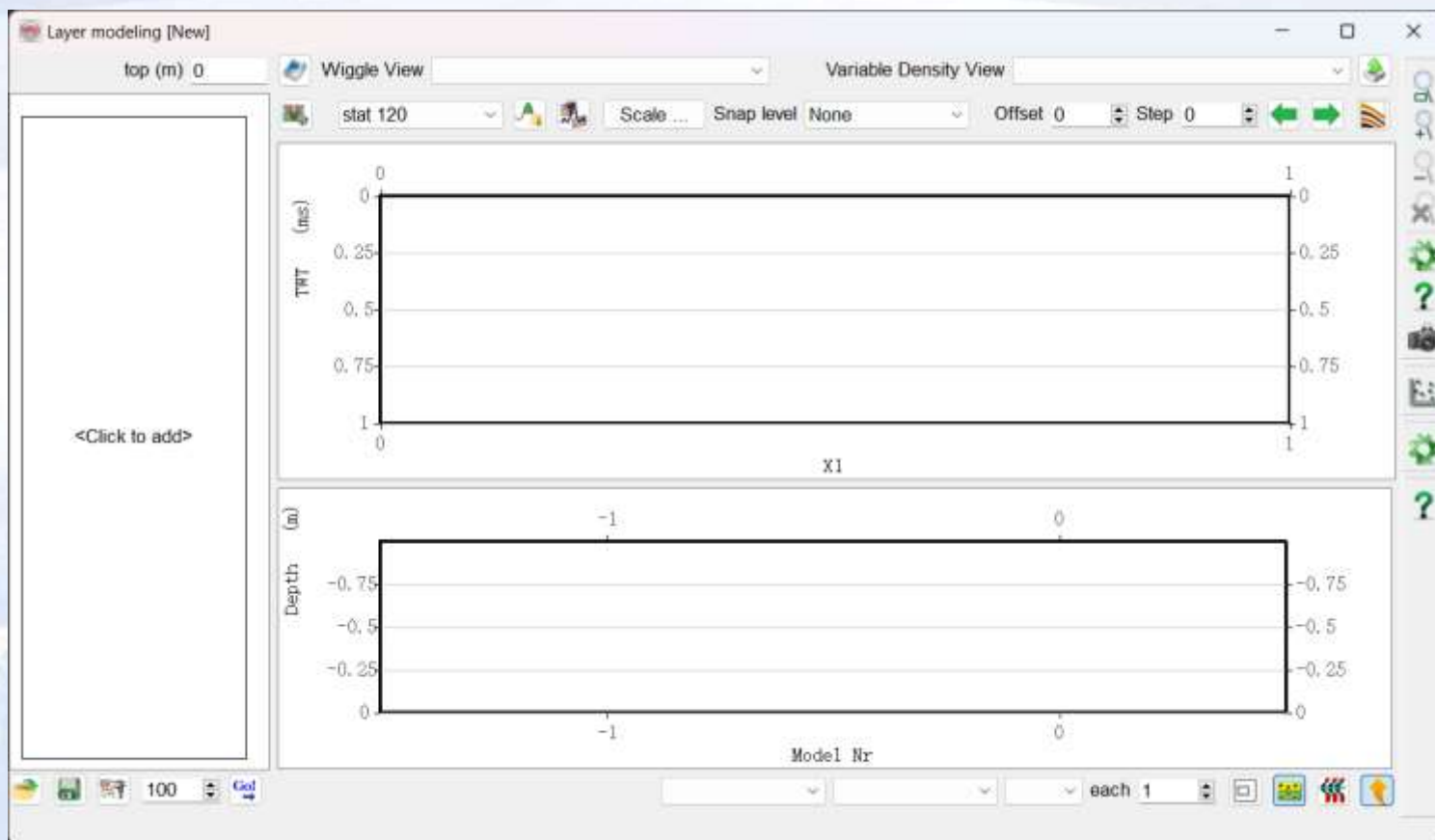
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5.5.1.1 Layer Description


First of all, the Layer Succession has to be defined and will be used to create the pseudo-wells.

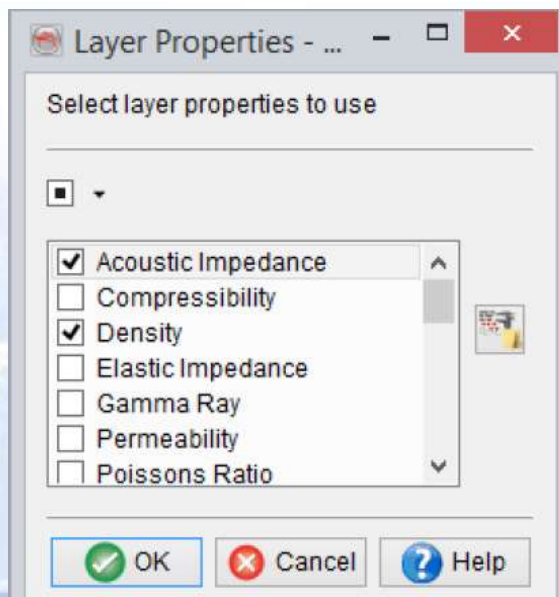





Layer Modeling Window (in red : Layer Description elements)

To start defining layers properties, the user has to click on "click to add" on the left rectangle. Once one layer has been defined, click on Ok and the layer appears in the left rectangle. To add a layer, click-right on the rectangle and select "Add above/-below": you can then define a new layer. "Edit Layer" is also accessible from this right-click menu. The description can be saved in clicking on the  icon and later be accessed in clicking on the  icon.

1. First of all the properties to be defined for the modeling have to be selected within a list. The properties in the list have been defined in the Layer properties Manager which is accessible from the  icon and can be edited.



The selection can always be edited in clicking on the  icon . To be able to generate synthetics, Density and Pwave velocity are selected by default. For the moment, it is not possible to combine properties together. So for example to get the Acoustic Impedance, you have to model the Acoustic Impedance log.

2. The Layers have been defined in the Stratigraphy Manager. To each lithology of each layer are assigned properties and if within the survey this property is expected to remain constant or to vary within a given range. The thickness of each layer can also stay constant or be varied. The variation is linear.



The thickness is a default property. When defining a thickness range, the starting thickness can be set to a negative value: it will appear as a truncation in the pseudo-wells.

The fluid content can also be specified. It had to be specified previously in the Content manager.

When clicking on OK, the Layer Description will appear on the left rectangle. To edit the properties of one or more layer, just click on it.



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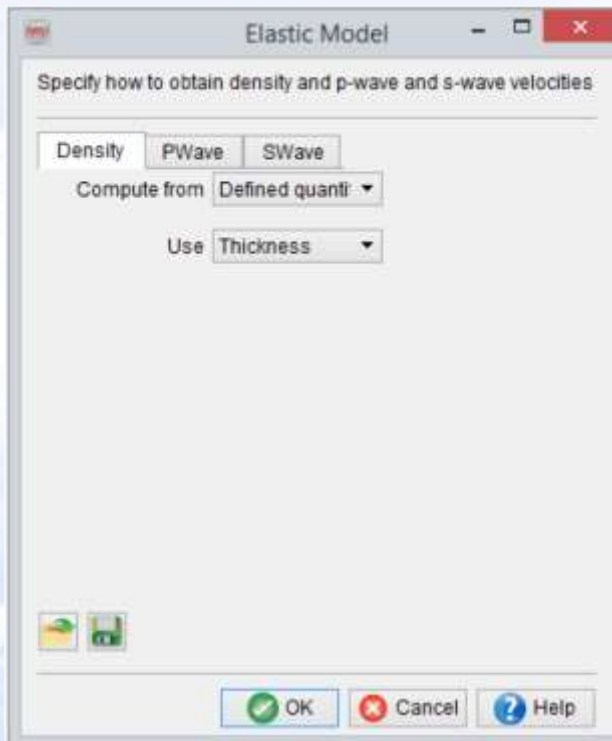
ells are generated when clicking on Go, in the lower left side of the
umber of pseudo-wells to be generated is user-defined.

[illegible]



5.5.1.2.1 Synthetic Layer Properties

The synthetic seismic generation requires different quantities : Density, P wave velocity and S wave velocity. These quantities can be specified in clicking on the icon  : they can be computed using formulas and the appropriate modeled quantities. If the quantity has been modeled, it can be used as Defined quantity .



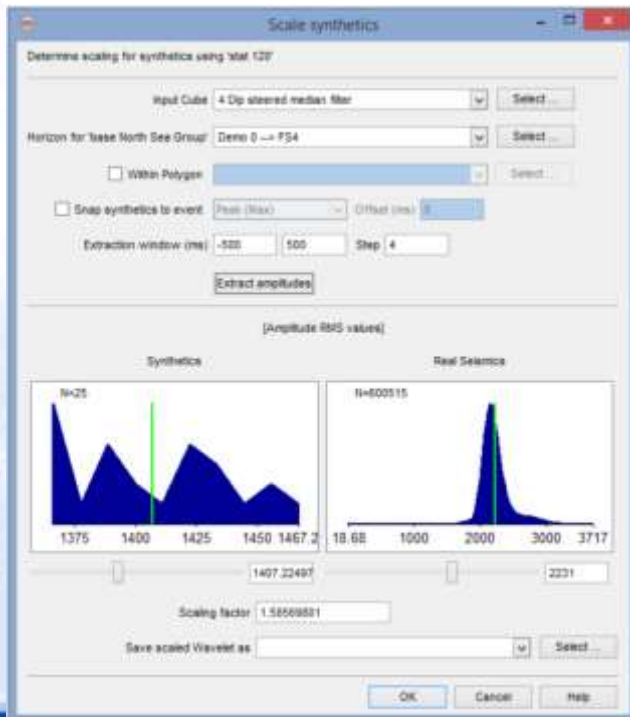
Possibilities to compute the layer properties



5.5.1.2.2 Wavelet

The wavelet can be selected from the one already available in the project and listed or a new one can be created in the Wavelet manager accessible from the icon 📁.

Some workflows need to have the synthetic with the same amplitude that the real seismic. The purpose to the scaler is to scale the wavelet by comparison between the synthetic seismic computed at a given horizon and the real seismic extracted in a defined time window regarding this same horizon. To do so click on *Scale*.






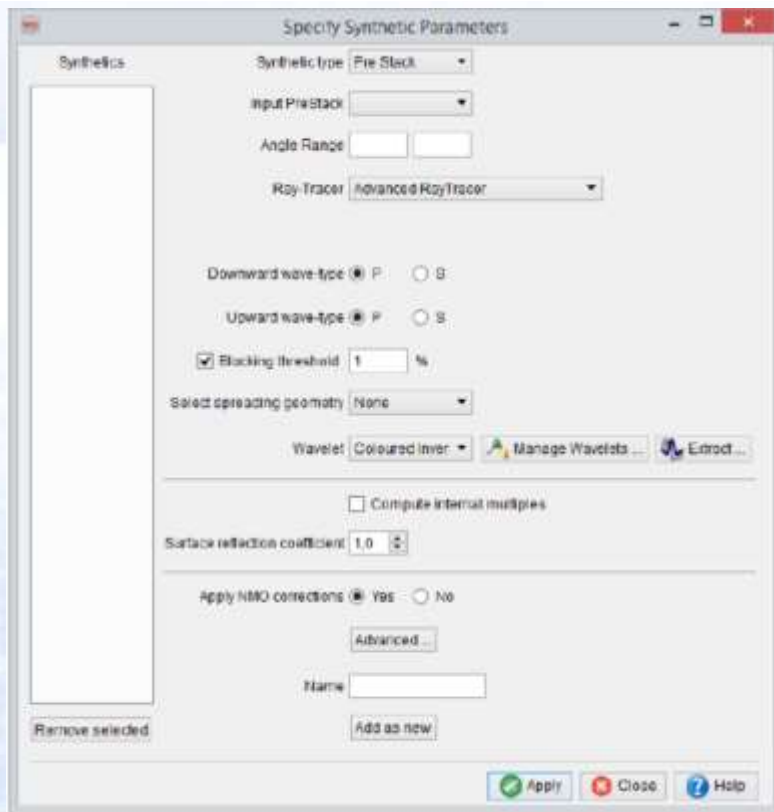
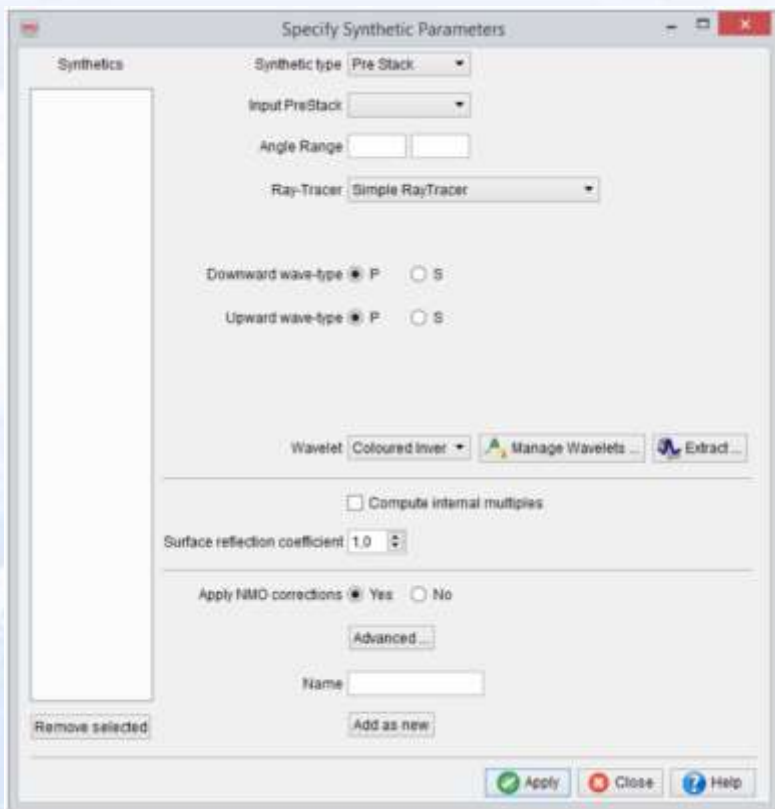
First of all you need to select your reference seismic as *Input Cube*, then the reference horizon for the extraction of the real seismic data. The reference for the extraction in the synthetics is the reference stratigraphic level selected in the main window. The extraction must be done at a level interpreted in the pseudo-wells and in the real seismic. It is possible to restrict the extraction to an area defined by a polygon. Also the reference level in the pseudo-wells does not necessary correspond to a specific event in all the wells, on the contrary horizons are most often interpreted following a same event. Thus it is possible to snap the synthetics to a specific event. Finally the extraction window around this reference level has to be specified. It will depends on the thickness of the interval of interest of your data. Once all these parameters have been given, you can *extract values*.

The histograms for the synthetics and the the real seismic are displayed side by side to be easily compared. A same point is identified in the two cases and the difference between the two amplitude values is used to determine the *scaling factor*. The scaled wavelet can then be saved and used afterwards.



5.5.1.2.3 Ray Tracing

The ray tracer, available via the  icon, allows the creation of synthetics for different offsets and to perform different angle stacks. The source/receiver depths have to be provided. The offset range has also to be specified. The arrival times are calculated by ray-tracing through a horizontally layered isotropic earth model.







Ray Tracing parameters in the simple and advanced mode

In the advanced mode, the surface coefficient can also be defined if known as well as the spreading geometry.

When pressing Go , the synthetics for different offsets are computed. The view is set to be *Free view* by default, you are then able to display a single offset or a limited offset stack in ticking the *Stack* option.

When one offset is displayed, it is possible to make the offset vary from a given *Step* using the arrows .


From the icon , it is possible to display the gathers for the different models.


For further information, please refer to Appendix E - Synthetic Data Generation

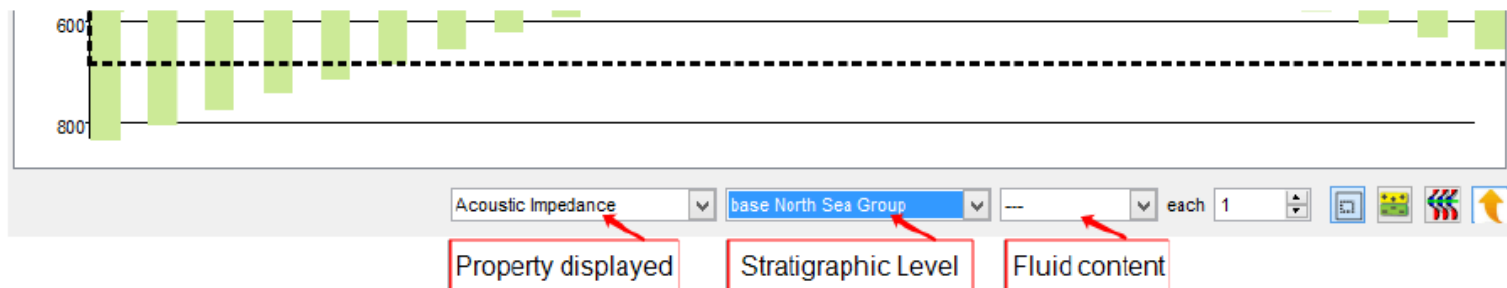


5.5.1.2.4 Display

There are several display options within the Layer Modelling feature:

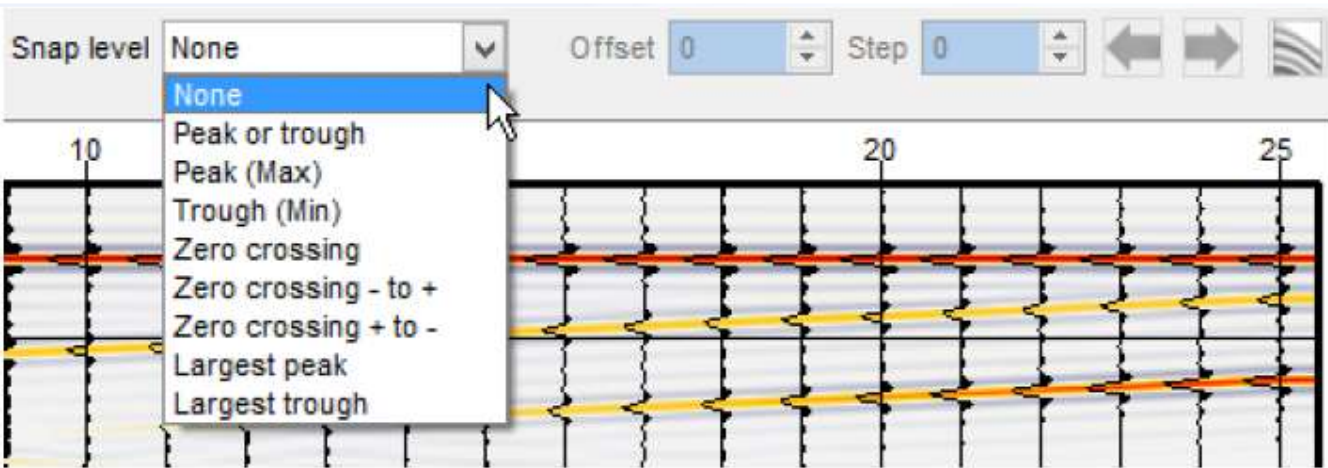
By default the property logs are displayed regarding the block. When toggled on the  icon, the representation is one color per lithology. The property displayed is selected in the selection menu in the lower part of the window.

When the  icon is on, if the user zoom on the synthetics, it will not affect the property logs view. The icon is on by default.






The stratigraphic level is a marker. The marker position has been modeled and so its position within the pseudo-well can be displayed. In the real wells, markers come from the log data and geological information. It does not necessarily correspond to a given seismic event. On the synthetic from the pseudo wells, it is possible to snap a selected marker to a seismic event (point, trough, zero-crossing...). This has to be done carefully as some information can be lost: there may be lateral variations of the rock properties that may impact on the phase of the seismic.





Synthetics display parameters are accessible when clicking on 

Specify Display Properties

Title

Wiggle Variable Area Variable Density Annotation



Use clipping Symmetrical ▾



Percentage clip


Specify mid value ☐ Yes ☒ No

Display blocky (no interpolation) ☐ Yes ☒ No

Overlap ratio

☐ Negative fill  ☒ Positive fill 

☒ Draw Wiggles  ☐ Ref line 

 Apply

☐ Save as Default

Specify Display Properties

Title


Wiggle Variable Area Variable Density Annotation


Use clipping Symmetrical ▾

Percentage clip

Specify mid value ☐ Yes ☒ No

Display blocky (no interpolation) ☐ Yes ☒ No

Color Table  Chimney ▾

 Apply

☐ Save as Default



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Specify Display Properties

Title

Annotation color Black

Axis 'Trace number'

Show ☒ Annotation ☒ Grid lines

Axis 'TWT (s)' ☒ Annotation ☒ Grid lines

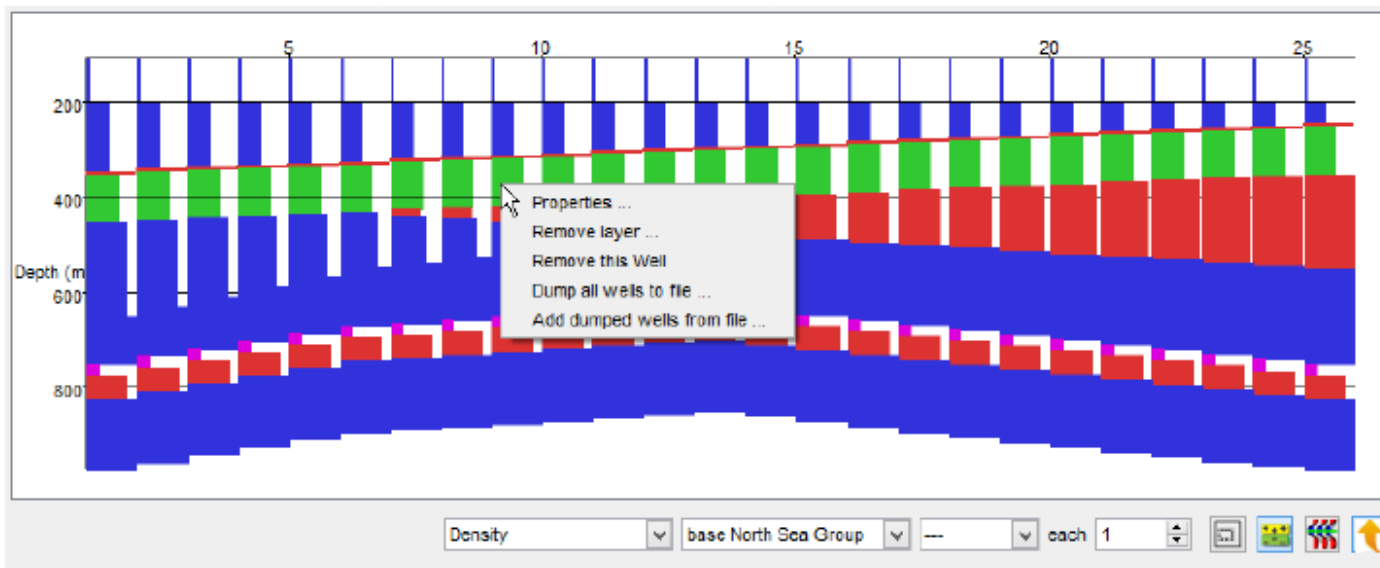
The "Wiggle Variable area" section concerns the display of the synthetic log itself.
The "Variable density" section concerns the background, i.e the interpolation between the synthetic traces.

☐ Save as Default



5.5.1.2.5 Layer Properties

Once the simulation has been run, the pseudo wells will have been generated and these well properties are then displayed in the lower section. The synthetics are also generated and display in the upper half of the window. When clicking on a given pseudo-well, a line appears to show the selected pseudo-well and right-clicking on a particular layer of this selected pseudo-well gives a menu to various options.





For this selected pseudo-well, the *Properties...* option gives access to the characteristics of this specific layer in term of thickness and modeled properties. In the layer-based modeling (basic or stochastic), these values can be manually modified. The fluid content can also be edited. Changes are saved when clicking *Ok* and the display is automatically updated.

Layer properties

Layer: 'Cretaceous.Rijnland.Vleiland.shale'

Lithology: shale

Top depth (m): 443.75

Thickness: 83.33333568 m (Meter)

Density: 2441.66674805 kg/m3 (Kg/m3)

Pwave velocity: 3000 m/s (Meter/second)

Acoustic Impedance: 7937500 m/s x kg/m3 (Meter/se)

Content: -

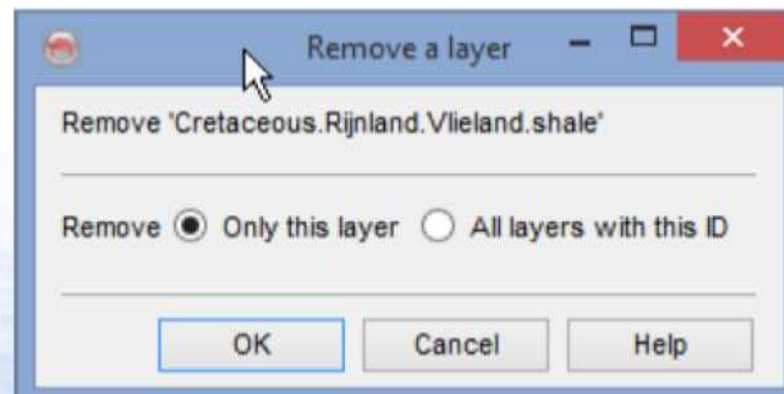
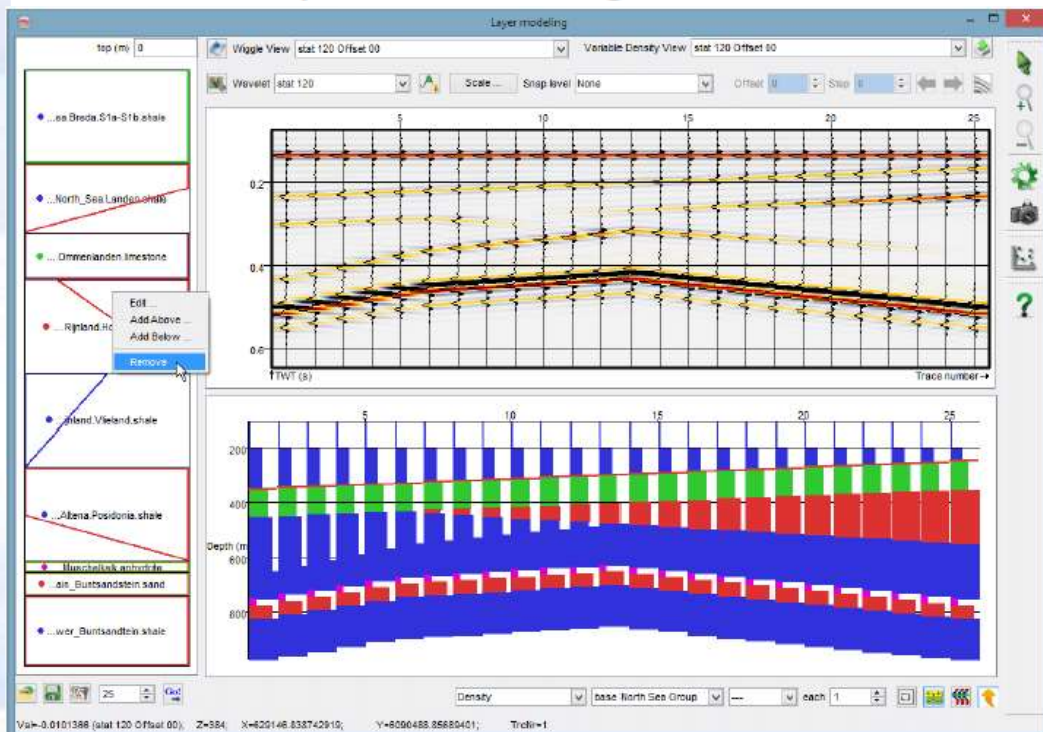
OK Cancel Help

In the SynthRock plugin, in the Profile mode, a similar window is available on right-clicking on any trace on the lower rectangle where a selected property is displayed for the different pseudo-wells. In selecting *Inspect values*, the window opens. In this case it is an informative window: the different property values can not be changed. The fluid content however can be edited. The lithology in this case is unknown as it is based solely on well log(s).



5.5.1.2.6 Remove Layer


The existing layers of a model can be removed at any time, by right clicking on the left hand side pane, containing the simulation information.

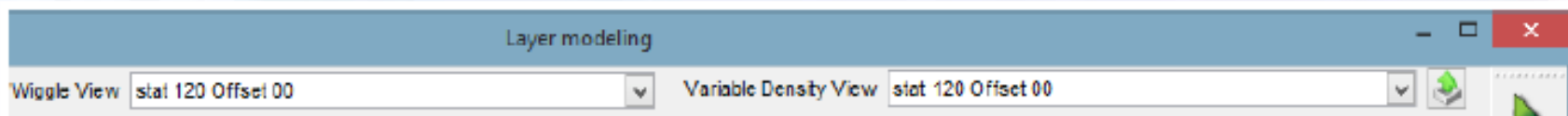


Thereafter, the regeneration of the pseudo-wells can be done by clicking on .

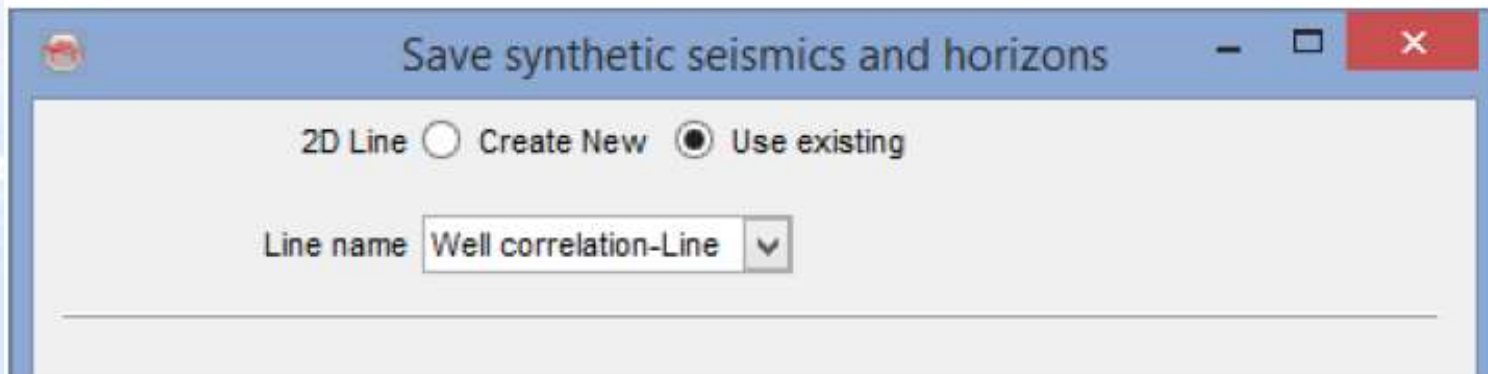


5.5.1.2.7 Export Synthetic Datasets

The synthetic seismic data (both poststack and prestack), the layer property synthetics in Time (e.g. AI, Density etc.) and the stratigraphic levels/markers, from all modeling modules (i.e. Basic, Profile and Stochastic) can be exported along 2D lines. The stratigraphic levels/markers in the modeled pseudo-wells are essentially exported as 2D horizons. This is achieved by clicking on the  icon at the top right of the modeling window (see below).



Export of the synthetics can be done onto an already existing 2D line or a new line created on the fly.





Selecting an existing 2D line

If the 2D line is created on the fly, the *Geometry for line* has to be defined as well. It can be done by defining a straight line between two X-Y coordinate pairs.

Save synthetic seismics and horizons

2D Line ☒ Create New ☐ Use existing

New Line Name

Geometry for line

Coordinates: from

to

Creating a straight 2D line between two X-Y coordinate pairs

The 2D line can also be created, on the fly, along an existing polygon.

Save synthetic seismics and horizons

2D Line ☒ Create New ☐ Use existing

New Line Name

Geometry for line

Polygon



Creating a 2D line along a polygon

Finally, the 2D line can also be created along an existing random line.

Save synthetic seismics and horizons

2D Line ☒ Create New ☐ Use existing

New Line Name

Geometry for line

RandomLine Geometry

Creating a 2D line along a random line

Now, a selection on poststack data, 2D horizons and prestack data can be made for exporting along the 2D line.

☒ Post-stack line data

☒ 2D horizons

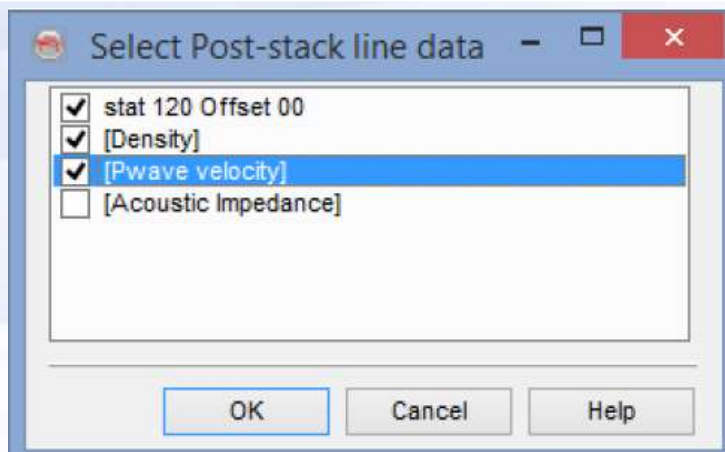
☒ Prestack data

Output object names will be generated.
You can specify an optional prefix and postfix for each:

Prefix Postfix

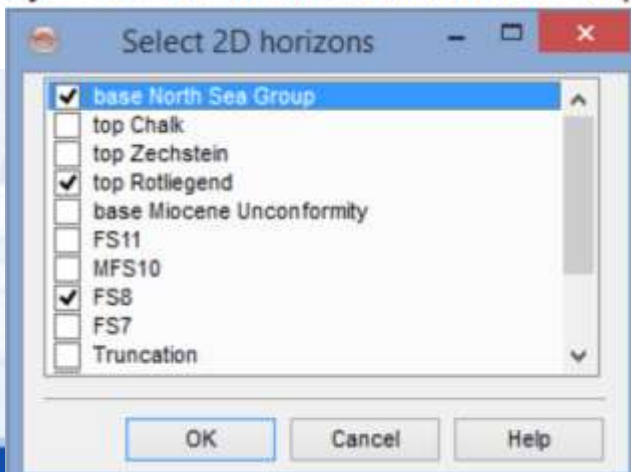


For poststack data, user can select synthetic seismic and various layer property synthetics (e.g. Acoustic Impedance, Density etc.).



Poststack data selection for export

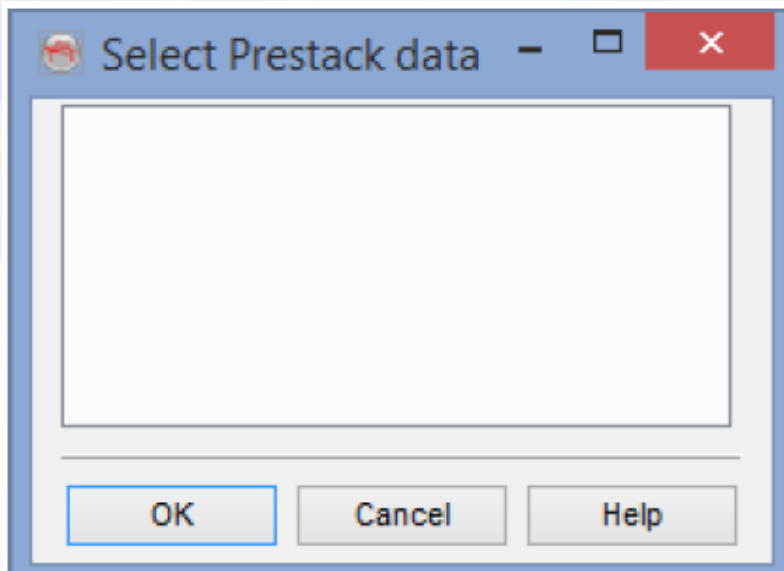
Similarly for 2D horizons, various levels present in the pseudo-wells can be selected.





2D horizon data selection for export

and finally (if any) prestack data can be selected.




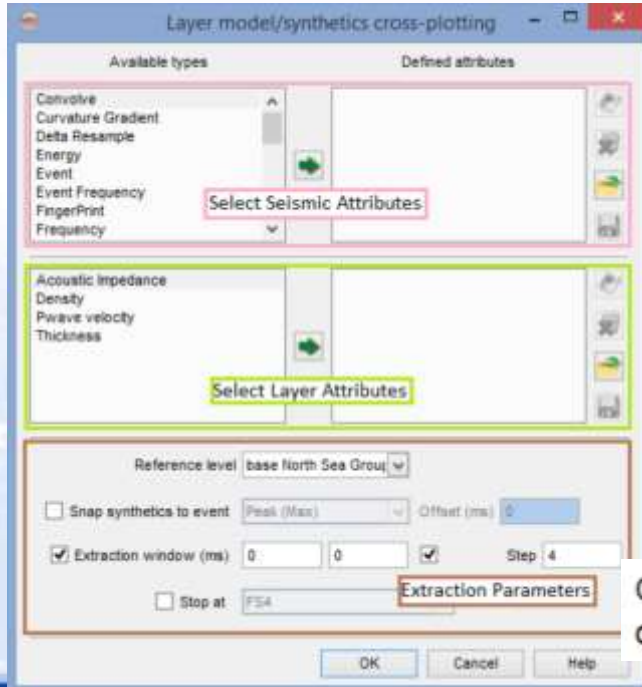
Prestack data selection for export

Optionally, a prefix and/or postfix can be specified for various data items. Pressing *Ok* will export the selected data items along the 2D line.



5.5.1.3 Cross-Plots

The cross-plot tool in the Basic layer modeling can be started from the icon . It allows to analyze seismic and layer attributes from the modeled data. On the main window, the user select the attributes to be extracted and the extraction parameters. The extraction window is related to a reference level. Its length is user-defined. The appropriate extraction window size has to be defined regarding the interval of interest. The user has to provide a step that corresponds to the sample rate within the extraction window.

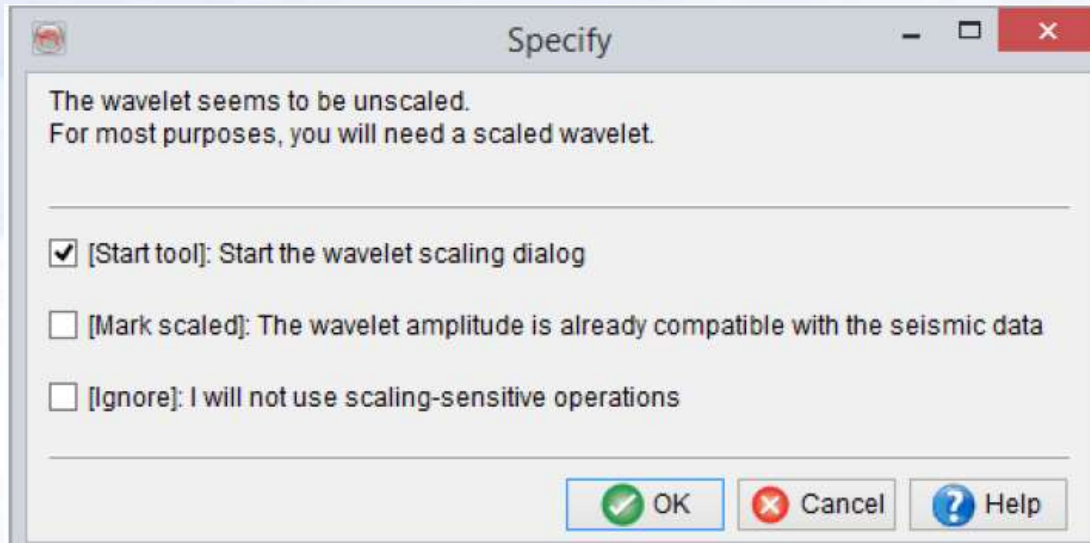


Once the attributes and the extraction parameters defined, the crossplot window opens and is similar to the one available for the classic seismic/well analysis.



5.5.1.3.1 Wavelet Scaling

If the wavelet has not been scaled to the real seismic, a pop up window will first appear prior to access to the attribute selection window.



The user has 3 choices :

- [Start tool] to start the Scale wavelet window
- [Mark scaled] if the wavelet is considered as scaled or does not need to be scaled
- [Ignore] if the attributes that are going to be extracted will not need a scaled wavelet

Once the wavelet is scaled or marked as scaled, it will be remembered and the window will not appear again.



5.5.1.3.2 Seismic Attributes

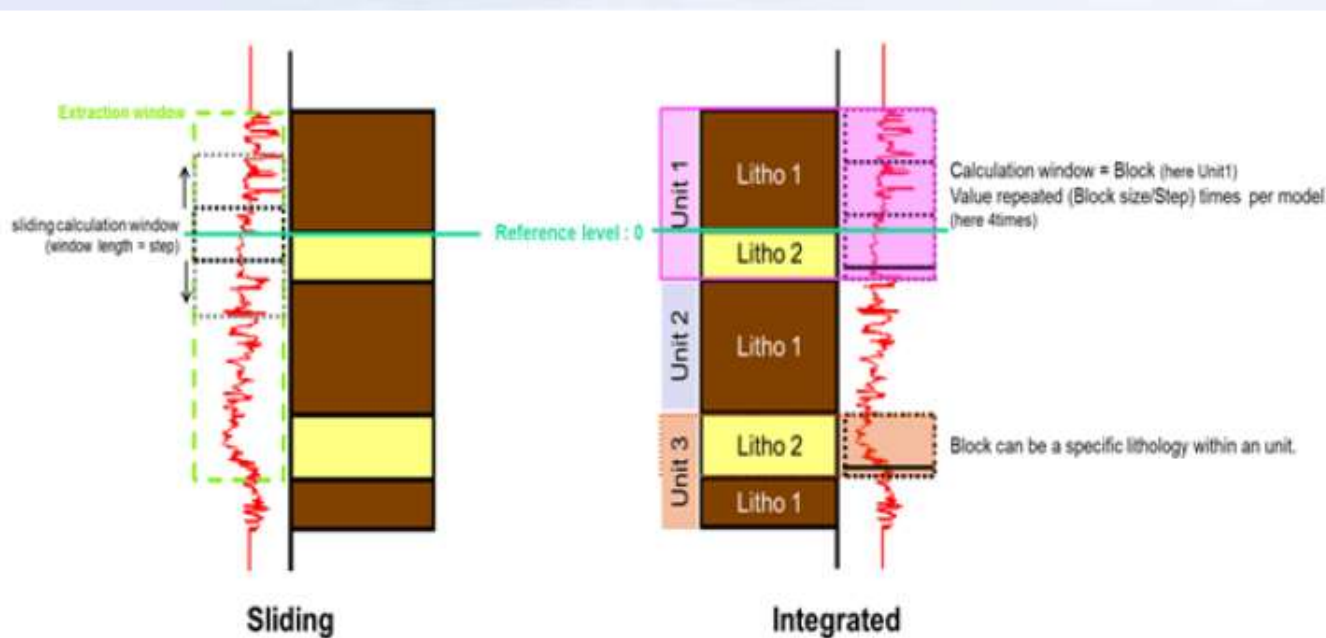
The seismic attribute selection/definition is comparable to the main attribute window: the same attributes are available. An attribute can be selected in the list of *Available* types and add to the *Defined attributes* using the ➡ button. The parameters of the attribute have to be specified. Synthetic seismic generated from the models can be used as input data. All the listed attributes are not necessary using synthetic seismic.

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5.5.1.3.3 Layer Attributes

For each modeled property, data can be extracted either along the log using a defined extraction window or by layers:





Sliding: the property value is extracted within the extraction window where a calculation window slides along the well. The size of the calculation window is defined by the step provided by the user on the first crossplot window. The output is the nearest sample, the average, the median, the RMS or the most frequent. At the end the attribute has $[number\ of\ pseudo-wells * round\ up\ (Extraction\ window\ size / Step)]$ samples.

Integrated: Different lithologies have different properties. In the Layer Description, the behavior of each lithology has been defined for the modeling. The modeled properties can then be extracted and easily compared with the crossplot tool. Each modeled property can be extracted at the different level of the framework, for one or more lithology of one or more layer. One value corresponds to one model. The output will be the average, the median, the standard deviation, the minimum or the maximum of the extracted data for each model. The number of sample depends on the step and the thickness of the extraction block. The thickness of the block may vary from one pseudo-well to another depending on the model definition. Thus the number of sample can vary from one pseudo-well to another. For one attribute, the number of sample is equal to the sum of the round up $(Extraction\ block\ thickness / Step)$ of each pseudo-well.



Add attribute

Define parameters for Acoustic Impedance attribute

Type ☐ Sliding ☒ Integrated

Contributing units

- ☐ **
 - ☐ Quaternary
 - ☐ Pleistocene
 - ☐ Tertiary
 - ☐ Upper_North_Sea
 - ☐ Middle_North_Sea
 - ☐ Lower_North_Sea
 - ☐ Chalk
 - ☐ Cretaceous
 - ☐ Chalk
 - ☐ Rijnland
 - ☐ Scruff

- ☐ sand
- ☐ shale
- ☐ limestone
- ☐ dolomite
- ☒ halite
- ☐ anhydrite

Statistics on results

Transform values

Name

OK Cancel Help

In both case, it is possible to transform the attribute value in applying the function power, log or exponential. The attribute is extracted on each pseudo-well.