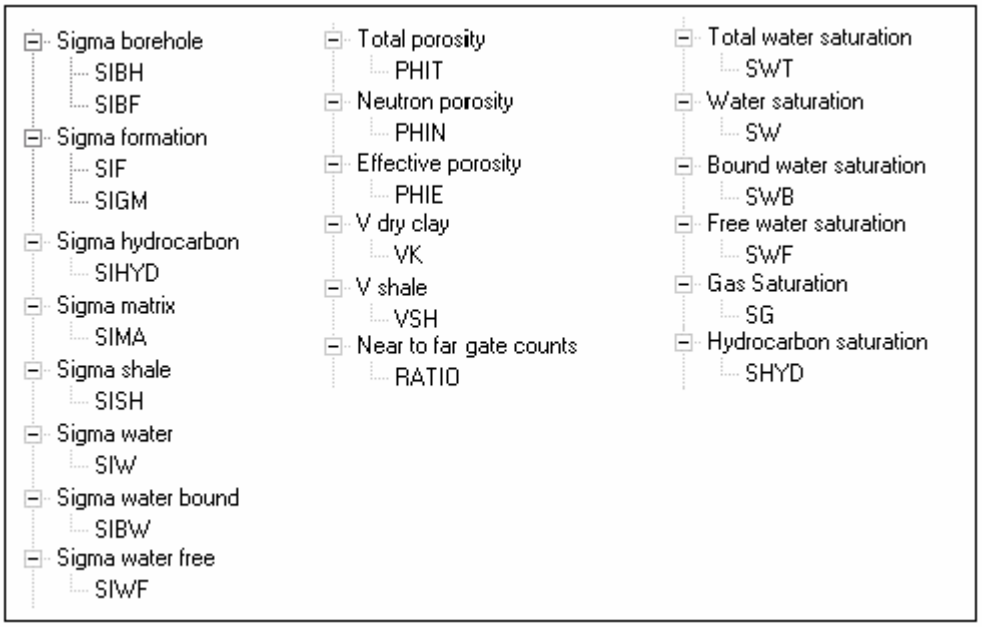
D10 • Pulsed Neutron Logging

D10.1 • PNL data types

The table below summarizes the new data types, as well as the default mnemonics that have been added specifically for the PNL. Data are loaded as usual, either with the Load option of the Survey panel, or the Load Well Data option of the Document panel.

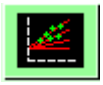


D10.2 • PNL control panel

Accessed in the control panel by with 



Info/New, create a PNL interpretation or to view/edit the interpretation Settings.



View edit the cross plots for each defined PNL zone. Cross plots can be used to determine/calibrate the relevant Σ values. Cross plot values can then be used to modify the corresponding logs.



Generates the calculated formation water saturation.



Used to load/select additional Sw curves to create a Time lapse presentation.

D10.3 • Elements of a PNL interpretation

A typical PNL interpretation, as shown in the data browser, will contain some of the following elements (the example below results from a Shaly, single water interpretation. A PNL interpretation seeks its input locally only. To add channels inside an interpretation, one can use the options in the Infos/New dialog, or drag and drop channels using the data browser.

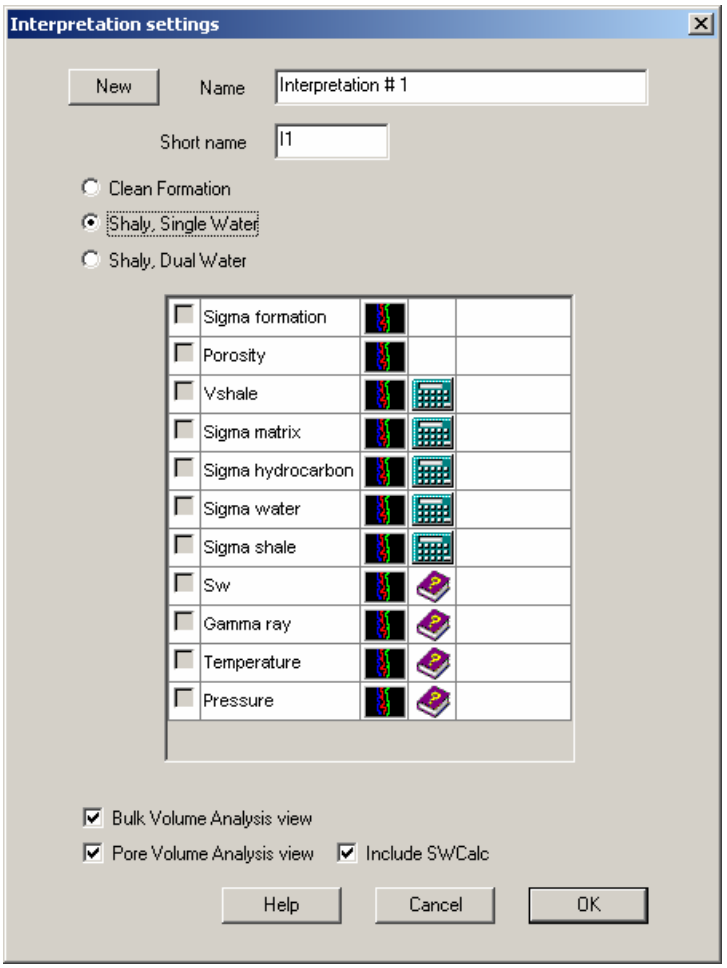
Interpretation # 1		
Input PNL zones (PNL zones)	⊟	Crossplot zones for determination of Σma, Σhyd, Σw, Σbw and Σfw as appropriate to the Single or Dual water model
Effective porosity (PHIE)	⊟	Input effective porosity.
Sigma formation (SIGM) Sigma hydrocarbon((SIHYD) Sigma matrix (SIMA) Sigma shale (SISH) Sigma water (SIW)	⊟	Input interpretation Σ's.
Sw (SW)	⊟	Original water saturation from an open hole log
Vsh, Vshale (VSH)	⊟	Shale volume calculated from a GR log or originating from a previous hope hole log
Output Sw, calculated (SWCalc)	⊟	Calculated current water saturation
Time Lapse Sw Sw, calculated	⊟	Time lapse with saturations sequentially from oldest to most recent.

D10.4 • Interpretation Settings dialog

Clicking on the 

button will invoke the interpretation settings dialog.

The user interpretation can define a Name and Short Name for the current active interpretation.



Three different models are available:

Clean formation
No shale.

Shaly, single water
The global model does not take into account the difference between bound and free water.

Shaly, dual water
The global model assumes that the water in the clean rock may or may not have the same salinity as the water bound to the clay particles in the shale.

If a neutron porosity has been defined (mnemo PHIN), then a box appears in the PNL Interpretation Settings dialog and allows the user to enter a value for 'ϕNsh' used to correct the neutron porosity for shale.



Based on the selected model the grid will indicate the list of required channels to perform the interpretation.

The user can specify if an automatic bulk volume and pore volume analysis user view is made (BVA and PVA, only for time lapse). The user can also specify if the calculated saturation is put automatically in the time-lapse survey and appears automatically in the pore volume analysis user view. These options are detailed later in the software reference.



D10.5 • Interpretation Input Channels

Defining the input channels



Equivalent to the Define option used in PL interpretation Infos/New dialog. This option invokes the lateral average dialog where the user defines which of the loaded up/down passes should be averaged, or copied. This is used mainly to define channels such as sigma formation Σf, porosity ϕ, gamma ray GR, water saturation Sw, temperature or pressure.



The compute option can be used to initialize a channel if it has not been loaded or when this is the user's choice. The channels are initialized using correlation or user input. When the compute option is disabled, the user can click on it to call a message of what should be done to enable the button.

The following channels can be defined with the compute option:

Vsh : Shale volume
Σma : Σ matrix
Σsh : Σ shale
Σh : Σ hydrocarbons
Σw : Σ water
Σwf : Σ free water
Σwb : Σ bound water
Swb : bound water saturation

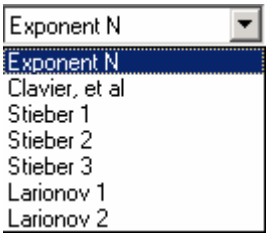
Checkbox At the beginning of each line, a checkbox indicates whether there exists a channel of the considered type within the interpretation.
Mnemonic The last cell on each line gives the mnemonic of the current channel.

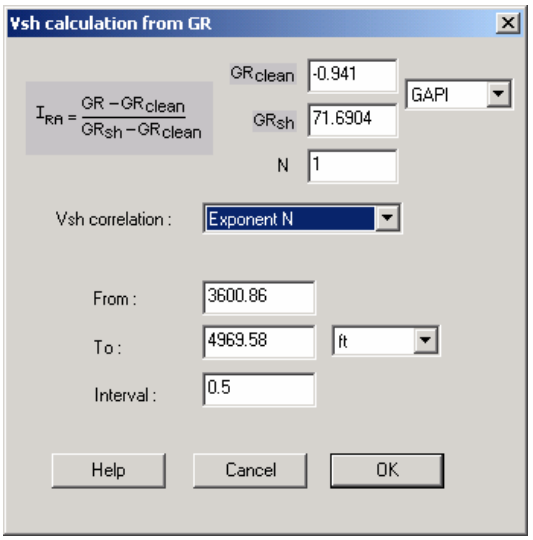


For optional channels, gives a brief explanation of what the channel may be used for.

Vsh (shale volume)

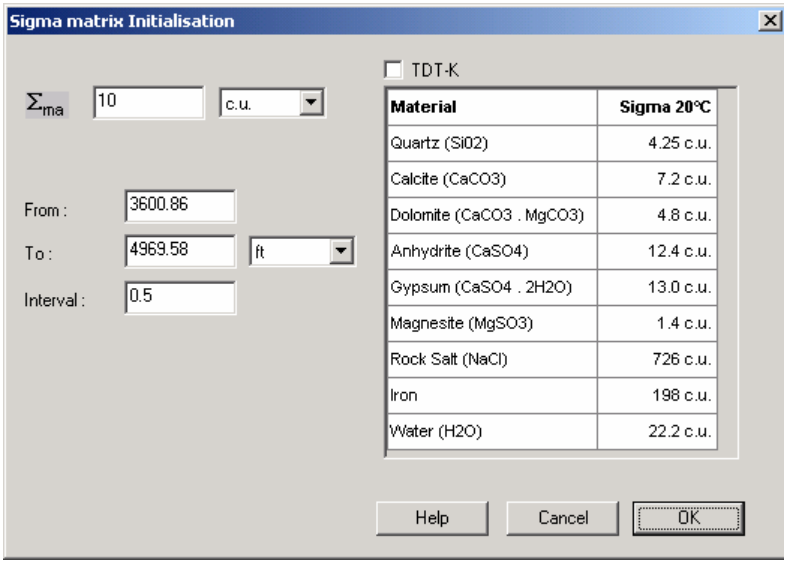
This value can be loaded from a file or computed using the gamma ray log. A gamma ray clean and shale value is entered as a radioactive indicator. The default values are respectively the GRmin and the GRmax read from the GR input channel. The radioactive index I_{RA} is calculated and the selected correlation is applied for the computation of Vsh. A detailed explanation of the available correlations is described in the technical reference, section E07.

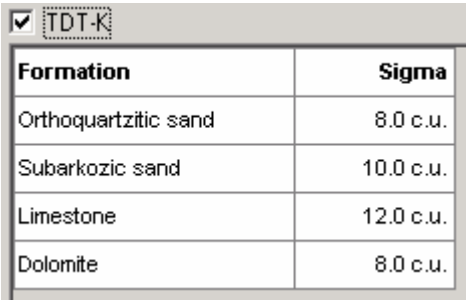




Sma (S matrix)

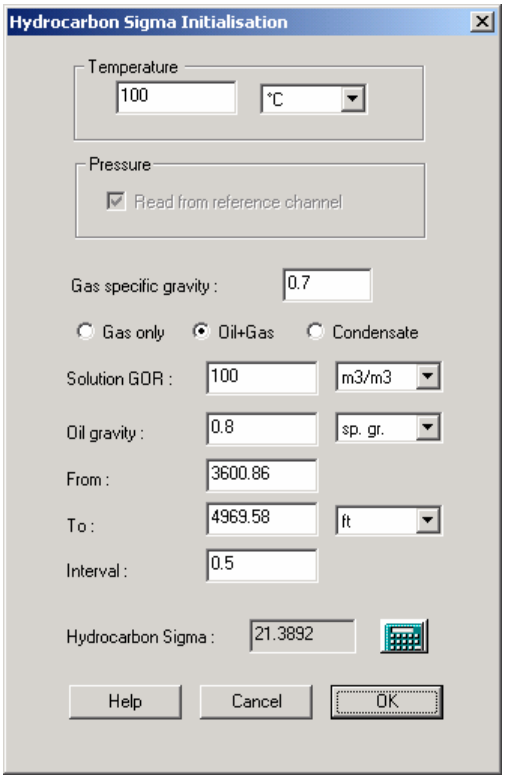
User defined Σma. The dialog contains a table with indications of the value with respect to the lithology and content of the formation. No processing is done in this dialog, but the user can switch between the default TDT-D and TDT-K indicator tables.





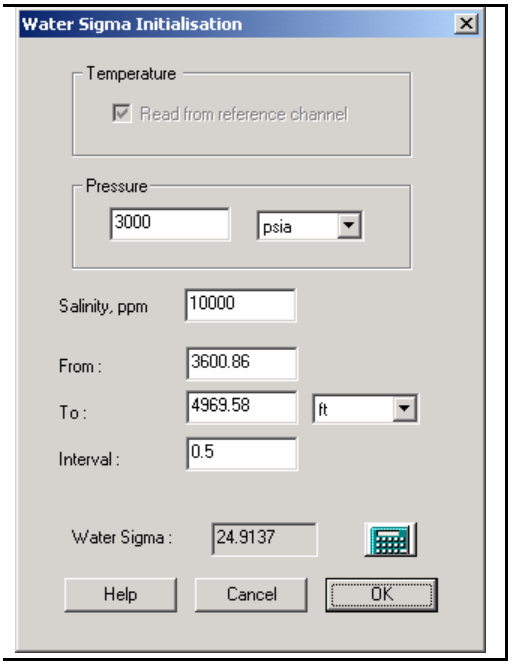
Σh (Σ hydrocarbons)

Σ hydrocarbon is determined using the original correlations developed by Clavier et al.
The correlation requires a temperature and a pressure; if a pressure and a temperature channel have been loaded as inputs, Emeraude will use those to calculate Σh. Otherwise the user can enter fixed values.



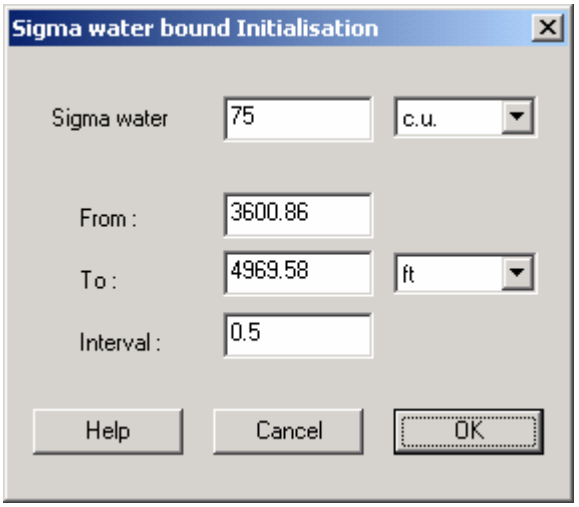
Σw (Σ water) / Σwf (Σ free water)

Σwf (or Σwf) is determined using the original correlation developed by Clavier et al.
The correlation requires a temperature and a pressure; if a pressure and a temperature channel have been loaded as inputs, Emeraude will use those to calculate Σwf. Otherwise the user can enter fix values.



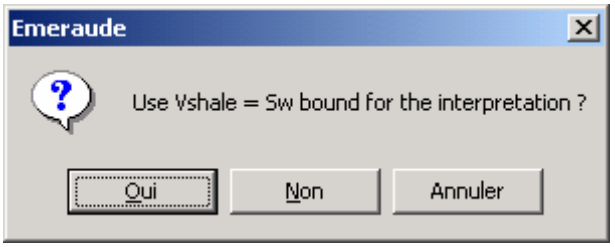
Swb (Σ bound water)

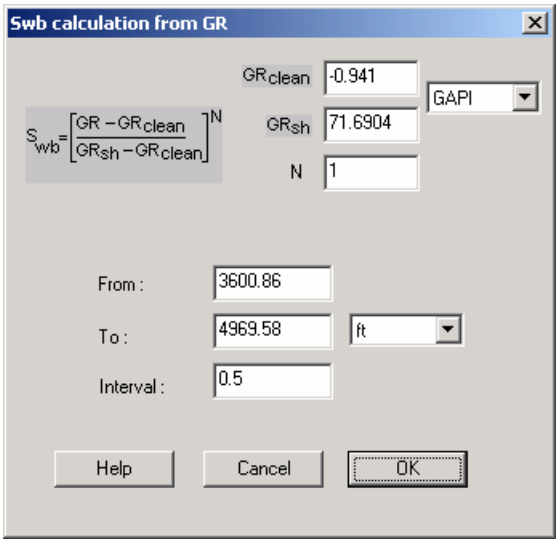
Σ bound water is a user input, and is best determined using the cross plot analysis available in Emeraude.



Swb (bound water saturation)

The bound water saturation can be set equal to Vshale.

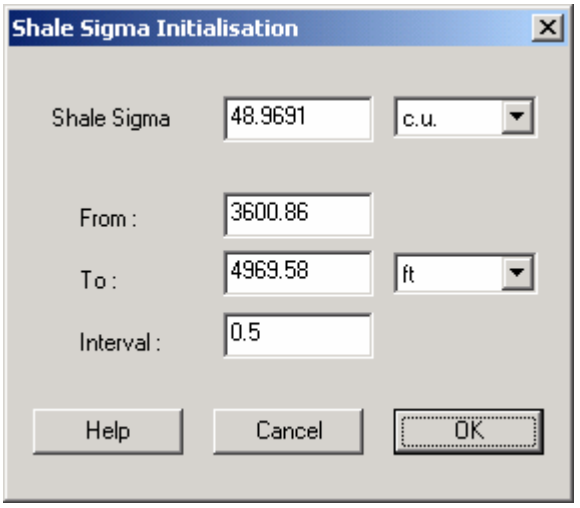




If Emeraude should calculate this value, it is necessary to have defined a gamma ray log in the interpretation. A gamma ray clean and shale value is entered. The default values are respectively the GRmin and the GRmax read from the GR input channel. The exponent N is the Curve Convexity Factor, which is larger than 1 and acts as a smoothing factor (same as the Vshale calculation from GR dialog).

Σsh (Σ shale)

This value is used in the shaly single water model. The value is initialized with the maximum value of the loaded Σf. The user can change this value through the Shale Sigma Initialization dialog.



For the remaining parameters, only the define option via the lateral average is available. These parameters are not compulsory for the computation of the water saturation but are required for some options within the cross plot dialog:

Pressure PNL and Temperature PNL

A pressure and temperature channel can be used to calculate Σw and Σh via the compute option.

Gamma Ray PNL

The gamma ray channel is a shale indicator and is used to calculate Vsh (shale volume) and Swb (bound water saturation).

Sw PNL

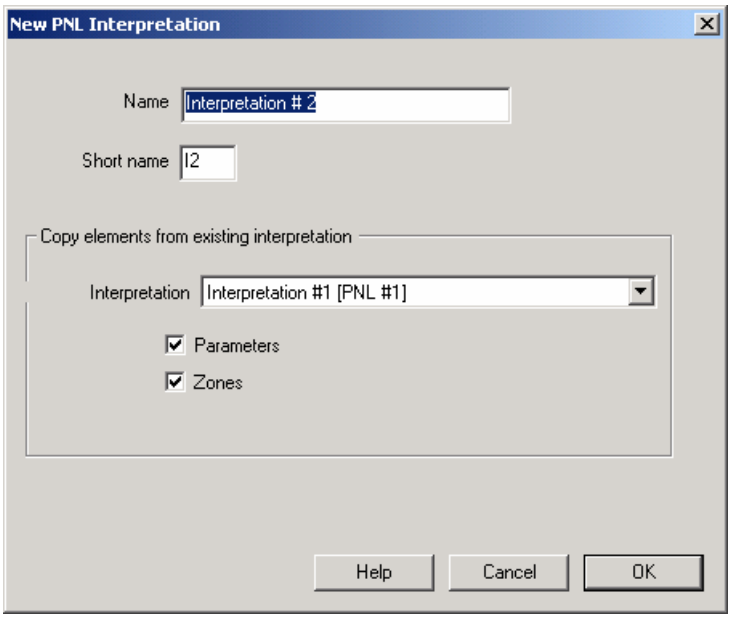
The derived open hole water saturation (or older Pnl interpretation computed water saturation) is used to calculate Σ_{eq} and ϕ_{eq} used in the corresponding cross plot in oder to estimate Σw and Σma.

D10.6 • New Interpretation

The 

button load the New PNL Interpretation dialog. Name and Short Name of the new interpretation can be entered.

Elements can be copied from an existing interpretation, such as Parameters and Zones.



D10.7 • Cross plot zones

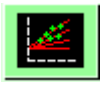
Zone creation

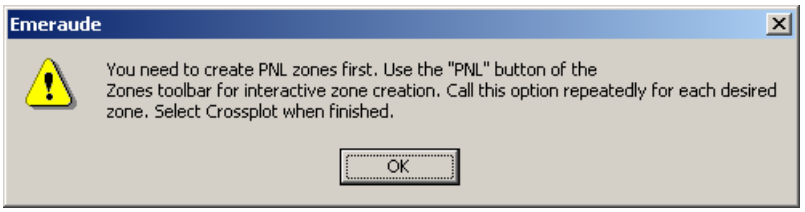
The Zones icon 

from the Zone tool bar is used to interactively define the zones used in the cross plots. The interactive definition process is the same as for other zones, and the PNL zones are shown blue markers in the Z plot.

Zone can be edited manually when using the 

icon: a tabbed dialog is displayed with one particular zone type in each page

When calling the Crossplot option 
with no zone defined, the user is being asked to create a PNL zone.



Edit

If one double-clicks on a zone in the Z plot, opens a spreadsheet with the limits of the zones of this type. Existing values can be modified. It is possible to add and delete calibration zones inside the grid.

Adjust

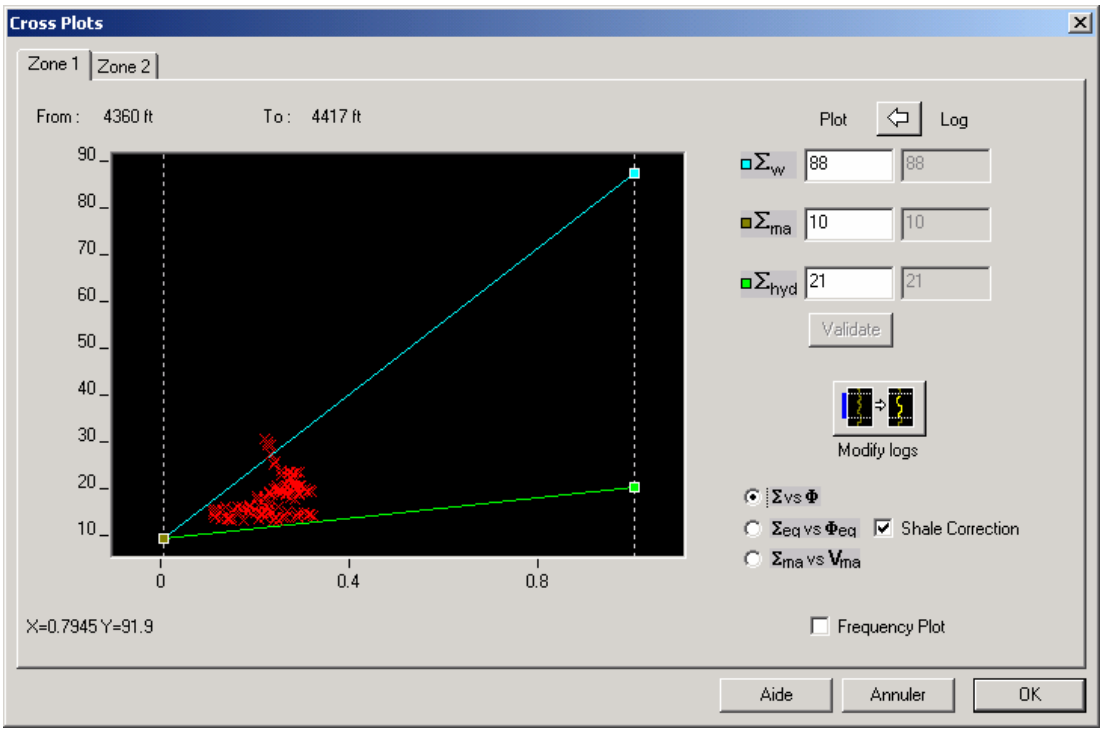
Click once on the graphic representation of the zone in the Z plot, the zone is shaded and two white handles are opened at the top and bottom. Click and drag these handles to adjust the limits of the zone.

Delete

After selecting a zone by clicking on it in the Z plot, press the Del key.

D10.8 • Cross plot

For each defined zone a cross plot is created.
For unclean formations only (single water, shaly) the user has the option to correct the data Σ and ϕ for shale correction by checking the checkbox Shale correction. This option needs a Vshale channel to be input into the interpretation.



The available crossplots depends on the model chosen in the Intepretation settings dialog:

Clean formation

$\Sigma - \phi$	The last two crossplots require a water saturation channel to be input into the interpretation; this water saturation is usually derived from the original open log or from an older PNL interpretation.
Σ_{eq} - ϕ_{eq}	
Σ_{ma} - V_{ma}	

Single water, shaly

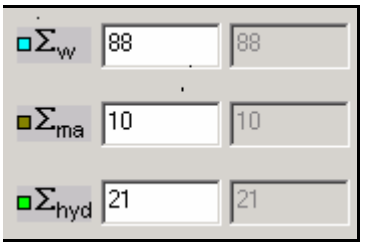
$\Sigma-\phi$
Σ_{eq} - ϕ_{eq}
Σ_{ma} - V_{ma}

The last two crossplots require a water saturation channel to be input into the interpretation; this water saturation is usually derived from the original open log or from an older PNL interpretation.

Dual water, shaly

Σ_{wa} - S_{wb} This crossplot requires a water saturation channel to be input into the interpretation; this water saturation is usually derived from the original open log or from an older PNL interpretation.

At the top right of the cross plot dialog are displayed the plot and the log values.



Dragging a line

Clicking the left mouse button inside the cross plot the user can drag a line and reposition it. Moving the mouse up and down changes the line intercepts only, moving the mouse left and right changes the slope of the line.
When dragging the line the Σ values are updated in the plot column.

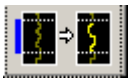
User input

Values can be typed in the plot column and validated by clicking the button Validate
Not that the log values are still the original values, the user can reinitialize with the log values by using the ⇦ button.

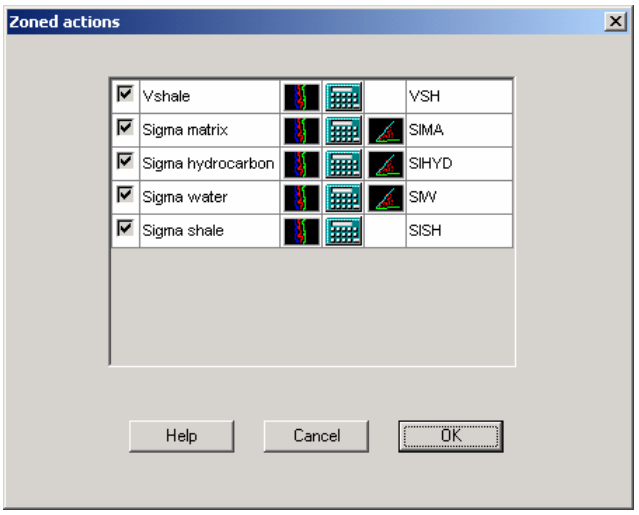
Frequency plot

The user may choose to see the frequency plot by checking the check box. This option is used in the Σ_{ma} - V_{ma} cross plot; it shows the total number of plotted points for each value of Σma. The plot should show a funneling of points with increasing Σma, pointing to a reliable value of Σma.

When the crossplots are used to determined satisfactory local values, it is then necessary to modify the logs accordingly. This is done with the Modify logs option.

Modify logs 

The option in this dialog is used to define whole or part of a missing channel and redefine whole or part of an existing channel:



 Using lateral average of some curve located in the passes.

 Using the compute option.

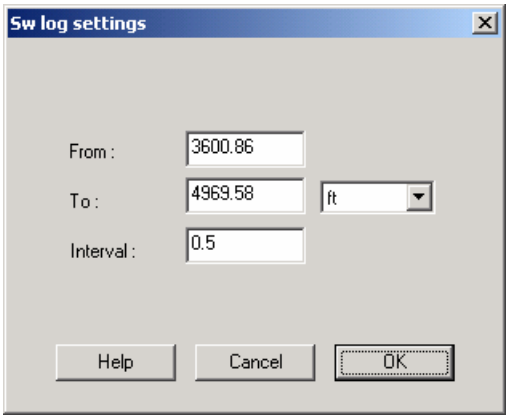
Those two options are described in the above Interpretation settings section.

 Using the cross plot value to update the logs. A dialog will pop up showing the depth range over which the considered log channel will be modified. The default depth range is the range of the current cross plot zones. The range may have to be modified if the change applies to the whole log interval. Log range and Zone range are shortcuts to set/reset the range of the modification.

D10.9 • Calculate water saturation, Sw

Clicking on the 

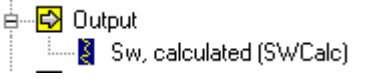
brings a dialog box where the user can chose the depth range over which the water saturation will be calculated.



The default range is the Σ log total data range. The range can be changed by the user to include the whole or part of the log range.

This option is offered when all the required inputs are defined. A calculated water saturation curve is produced with the mnemonic SWCalc.

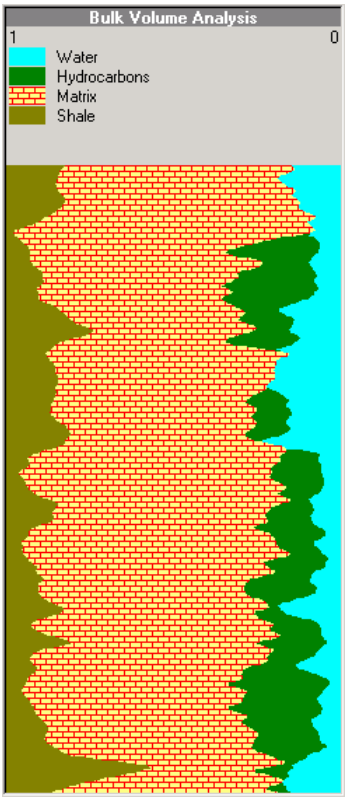
Under the data browser, this curve can be found under the “Output” interpretation sub-level.



Bulk volume analysis view

Assuming that you do not uncheck this option in the Infos/New dialog, Emeraude builds the view automatically:

The view has an inverted scale [1 – 0], and displays the channels: PHIE, 1 – Vsh, BW where BW is calculated from SWCalc.



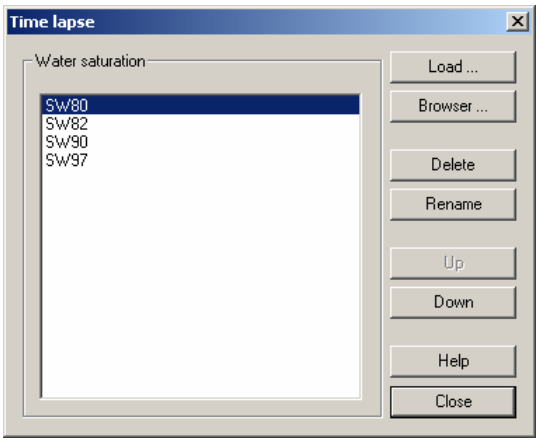
With a Dual Water model the Shale volume is split into clay and bound water.

The Bulk Volume Analysis view is an interpretation view which presence/absence can be controlled by the checkbox of the Interpretation Infos/New dialog.

Aspects, scales, areas can be edited using the corresponding options of the log popup menu accessed with a right click on the plot.

D10.10 • Time lapse

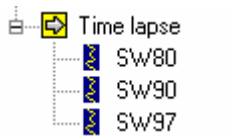
The Time lapse button is used to select all Water Saturation curves to be used to produce a Time Lapse plot of Pore Volume Analysis. Water saturations can be loaded directly, or copied from another location inside the Browser.



The order, and name of the curves can be redefined.

The Calculated Sw may be used automatically, in which case it is assumed to be the most recent curve. You can also disable this option in Infos/new, add the calculated Sw manually, and assign it another position in the sequence using the Up/Down options.

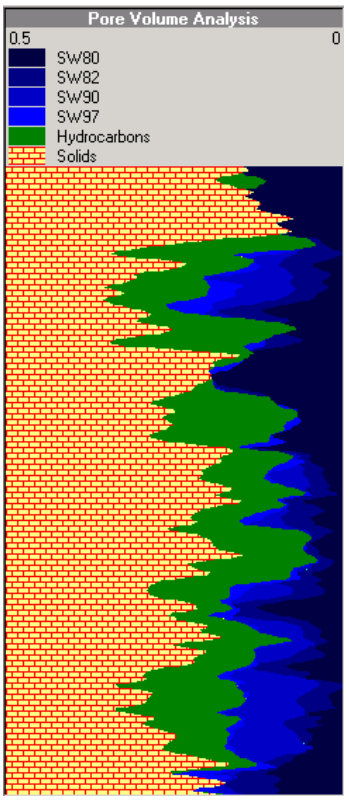
In the data browser, all curves appear under a “Time lapse” Interpretation sub-level. They can be renamed directly in the data browser (like a Data Store channel).



With the “Pore volume analysis view” option of the Infos/New dialog checked, Emeraude will calculate automatically the bulk volume of water for each water saturation selected for time lapse. The Effective porosity is that of the interpretation input. The view shows the evolution and display successive bulk volumes of water that have replaced the bulk volume of hydrocarbons.

Pore Volume Analysis view

The view has an inverted scale [0.5 – 0], and displays the channels: Bwi's, PHIE.

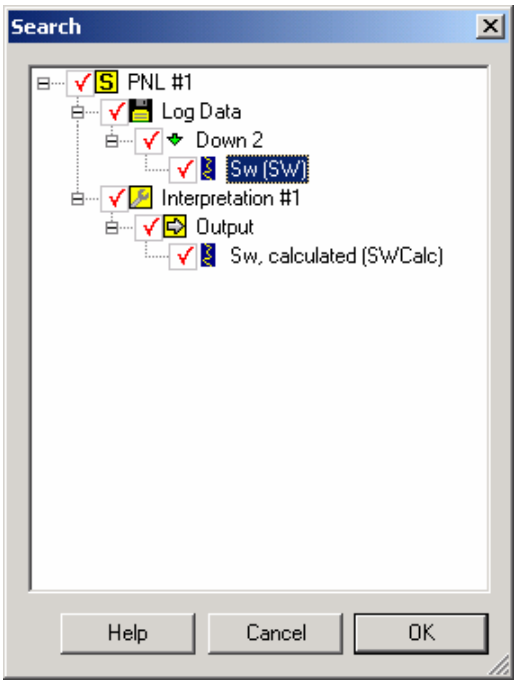


The Pore Volume Analysis view is an interpretation view which presence/absence can be controlled by the checkbox of the Interpretation Infos/New dialog.

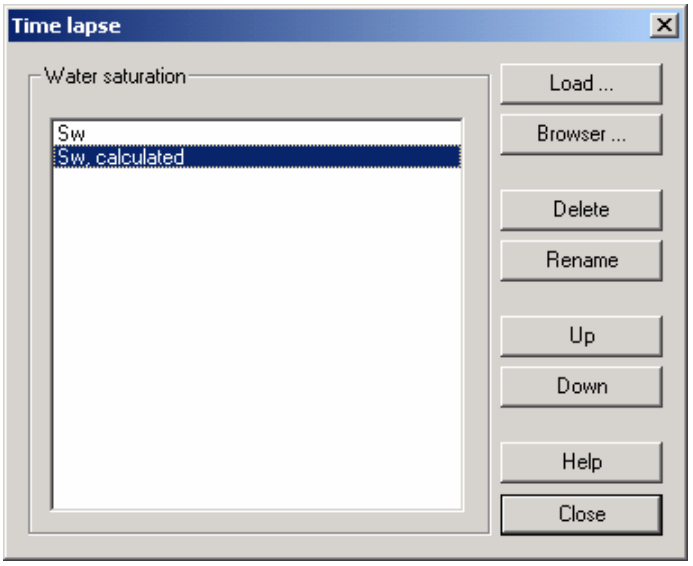
Aspects, scales, areas can be edited using the corresponding options of the log popup menu accessed with a right click on the plot.

The calculated Sw is placed in the PVA view automatically if the option 'Include SWCalc' has been selected by the user in the 'Info/New' dialog.

If the option 'Include SWCalc' has not been previously selected, it can still be dropped under the Time lapse node in the browser or included through the time lapse dialog. The Browser ... button accesses a 'selective' data browser showing only the relevant (already loaded or calculated) Sw curves that can be chosen for inclusion in the time lapse interpretation. The channels are selected by checking the relevant curves with a red check mark . The load button calls the normal load dialog for loading other Sw curves to the time-lapse analysis.



The included curves will be under the time-lapse node in the browser and should be loaded in such a manner that the oldest saturation is loaded first and other saturations should be loaded chronologically.

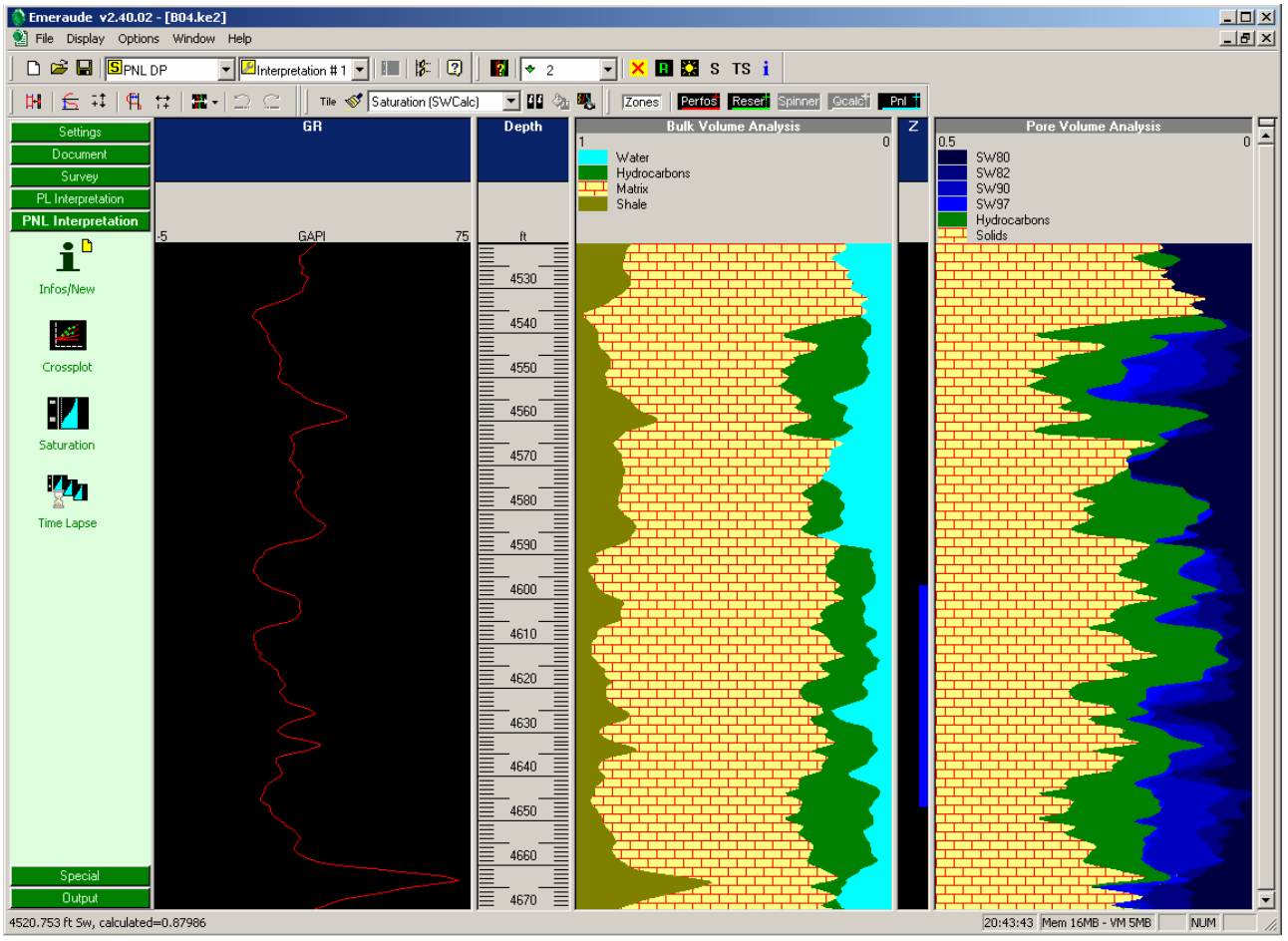


Failure to do this would result in an incorrect shading sequence for the time-lapse presentation, yielding an incorrect visual representation of the replacement of hydrocarbons by water. However, if the order is not correct, the user has the option to re-order the sequence correctly using the 'Up' and 'Down' buttons in the 'Time lapse' dialog.

The water saturation channels can be renamed via the 

button.

.



The curves are shaded in shades of blue (the lighter blue the most recent saturation curve). This shading can be changed from the popup menu, Fill area, or clicking the button  and then clicking in the appropriate track.

