DUG Rock User Manual

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Introduction

About DUG Rock

DUG Rock is designed to allow petrophysicists to easily interpret lithologies from well logs and generate end member trends for reservoir and non-reservoir lithologies. End-member lithological trends have applications in forward modelling and interpretation of seismic inversion products.

DUG Rock functions and features

Lithology and Fluid Picking

- DUG Rock allows you to pick lithologies based on information from the well log curves.
- Picks are populated into DUG Rock's crossplot charts and summarized into a spreadsheet-like table for easy referencing of any specific pick.
- The quality of log data for a pick can be identified, allowing inclusion or exclusion at a later time.

Highlight Picks

- Too many picks from different well logs may cause confusion when viewing crossplot charts. The Highlight Picks function allows you to select a pick from any crossplot chart and it will automatically highlight its position on the well log curves as well as on the Data Summary Panel for easy reference.

Customization of Well Log Tracks

- DUG Rock allows you to display fully customizable well log tracks that are individually set to view different curves in a standard form. This aids in lithology and fluid identification.
- DUG Rock allows you to manipulate well log tracks and well log curve display settings based on different criteria.

Crossplotting and Automatic Lithology Trend Formation

- The four main crossplot charts show the picks (visually coded to show well and lithology), and the trends calculated from the pick values.
- Lithology trends and standard deviation are calculated automatically when five or more picks are made. The dashed lines are drawn at plus and minus two standard deviations from the mean. DUG Rock also provides live update crossplotting and trend calculation as picks are interpreted.
- DUG Rock is built with a composite function so you can create composite trends by combining one or more lithologies. In addition, you may import trends for reference and comparative displays or export trends for input into DUG Distill.
- DUG Rock provides interactive changing of crossplot and trend display. The pick and trend colours, appearance, and crossplot scales are customizable to your preferences.
- Synchronized navigation between logs, crossplots, and tabulated pick data for any number of wells.

Gassmann Substitution

- Gassmann substitution adjusts the pick elastic properties to account for in-situ fluid, to correct back to a specified reference fluid (usually brine).
- Velocity and density of the reference fluid are customizable.

Image Capturing Capability

- DUG Rock allows you to choose a standard size for images, particularly crossplots and well log curves, for presentation and reporting purposes.
- Images can be saved as PNG or JPG file format.

Session Saving

- DUG Rock saves all data and display settings for future interpretation sessions.

How to Use this Manual

This manual is a comprehensive user guide for the latest version of DUG Rock.

DUG Rock manual structure

This manual consists of 3 main parts:

1. **Setup and Requirements** — This section serves as an introduction to DUG Rock. It includes a brief description of the features that this software has to offer, details on system and data requirements, and how to download and install DUG Rock.
    - *Introduction*
    - *Installation and Requirements*

2. **User Interface and Settings** — In this section, we introduce you to the basic user interface, the menu options, and various views that are available to display and configure your data.
    - *User Interface*
    - *Menus and Settings*

3. **Tutorial Workflow** — This section is a step-by-step guide of the common workflow to produce and generate interpretation results in DUG Rock.
    - *Tutorial Overview*
    - *Load Input Files*
    - *Picking*
    - *Crossplot*
    - *Trending*
    - *Save Session*.

Installation and Requirements

Prerequisites

Well Log Curves

DUG Rock requires the following well log curves to provide a complete set of trends:

Mandatory well log curves:

- Depth – Measured Depth
- Compressional Sonic — e.g. DT, DTCO, DT4P
- Shear Sonic — e.g. DTS, DTTS, DTSM
- Density — e.g. RHO, RHOB, ZDEN.

Kelly Bushing and Water Depth are required to correct the MD (Measured Depth) to BML (Below Mud Level).

Optional well log curves (recommended but not essential)

- True Vertical Depth (TVD) — To output trends relative to true vertical depth in deviated wells
- Gamma Ray — For log navigation, lithology interpretation (e.g. GR, GMR, SGR)

If a complete set of well log data is available, DUG Rock will automatically display the following well log curves in the Track Interpretation window:

- Caliper
- Spontaneous Potential
- Resistivity
- Neutron Porosity
- Photoelectric Effect.

The following well log curves can be used in reservoir trending if desired:

- Interpreted Porosity
- Interpreted Matrix Density.

Data Input File

DUG Rock requires well log data in Log ASCII Standard [LAS] Version 2.0 format. Other formats (LIS, DLIS, etc.) are not supported by DUG Rock and must be converted to LAS before they can be used by DUG Rock.

Sample data including wells, picks and trends, can be downloaded from our website.

Data Output Files

DUG Rock produces two output files:

- Session files with the extension *.*rock*.
- Trend files with the extension *.*trend*; these are used by DUG Distill, or by DUG Rock as reference trends.

System Requirements

DUG Rock is compatible with modern Windows, Mac OS X, and Linux operating systems.

The recommended system requirements for DUG Rock to achieve its optimal functionality are:

- 2 GB RAM
- 32-bit dual core 2GHz processor
- Windows (XP, Vista, or Windows 7); Mac OS X 10.5+; or modern Linux.

Software Installation

When you purchase DUG Rock, we will send you an email with the download link, username and password, and instructions to set it up.

Note: It is also important to keep the software up to date. You can download all software updates from our website.

Installation steps

Windows (msi), Mac OS X (dmg), and Linux (rpm) packages are standard installer packages for those platforms. You can usually install these packages simply by double-clicking on them.

If you downloaded the ZIP file for Linux, you can unpack it into any directory, and run the “rock” script inside.

Support

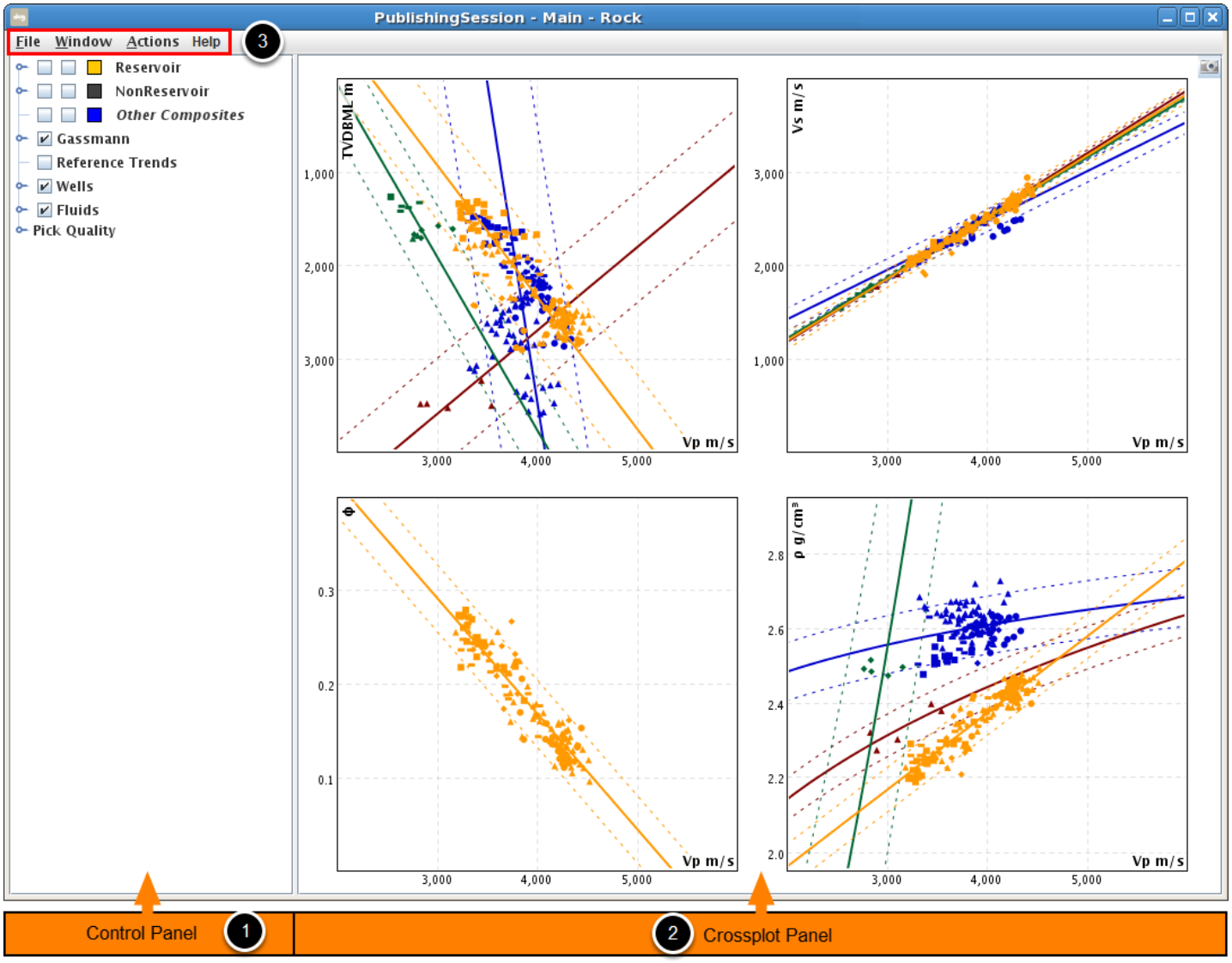
If you have questions or issues with the software, please contact support@dugeo.com.

Please include a description of the issue, along with any output that the program displayed on the console.

User Interface

Screen Display

DUG Rock provides an intuitive user interface to help you learn its features and functions. See below for the screen layout and references to DUG Rock view panels and tabs.



For more information on the user interface, see:

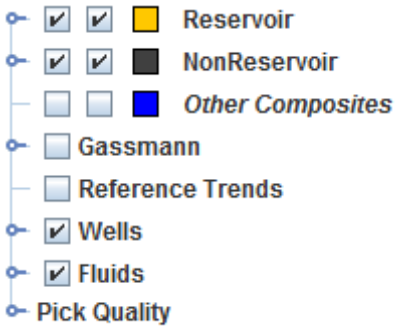
1. *Control Panel*
2. *Crossplot Panel*
3. *Menus and Settings*.

Using the Control Panel

The Control Panel is designed in tree structure for easy reference. Basic information such as lithologies, wells and pick quality can be easily traceable in the Control Panel.

The tree structure of the Control Panel also includes check boxes to easily display/hide information in the crossplots (see *How to Display/Hide Information in the Crossplots*).

Control Panel structure



The Control Panel tree consists of:

- **Reservoir/Non-Reservoir Lithologies** — See *Creating New Lithology* and *Editing a Lithology* to create and edit a lithology from the Control Panel.
- **Other Composites** — See *Composite Lithologies* to compare and combine groups of lithologies into composites to form a single trend.
- **Gassmann** — See *Gassmann Substitution* to learn how it works and how to apply it in DUG Rock.
- **Reference Trends** — See *Reference Trends* to import and remove reference lithology trends from other projects for comparison.
- **Wells** — See *Load Input Files* chapter to learn how to load and configure wells from the Control Panel.
- **Fluids** — See *Creating a New Fluid* and *Editing a Fluid* to create and edit a fluid from the Control Panel.
- **Pick Quality** — See *Pick Quality* to include/exclude picks assigned to the quality in the crossplot charts from the Control Panel.

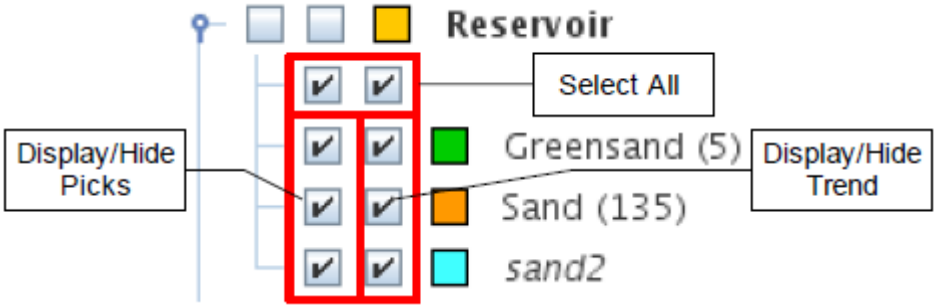
How to Display/Hide Information in Crossplots

Displaying/hiding information in crossplots is made simple with the Control Panel's tree structure. This function is applicable to the following elements:

- **Reservoir** – Display/Hide Picks and(or) Trends
- **NonReservoir** – Display/Hide Picks and(or) Trends
- **Wells** – Display/Hide picks from the well
- **Fluids** – Display/Hide different fluids in crossplots
- **Pick Quality** – Display/Hide different pick quality in crossplots.

After customizing what is displayed or hidden in the crossplot charts, you may want to *Customize, Capture & Save Crossplot Charts for Presentation & Reporting*.

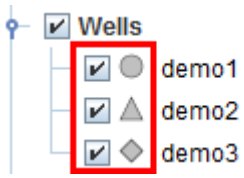
Reservoir/Non-reservoir picks and trends



Picks and trends can be hidden or displayed by selecting/deselecting their check boxes in the Control Panel.

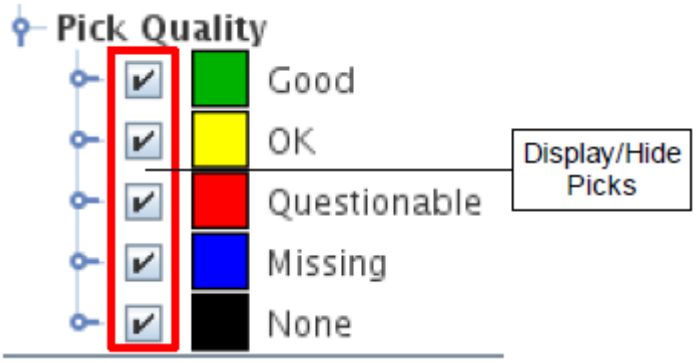
1. In the Control Panel, expand a Reservoir or Non-Reservoir tree to view the list of lithologies.
2. By default, all the non-reservoir lithologies are selected. Click the first row of check boxes to hide/show all **Picks** or **Trends**, or click on individual check boxes to hide/show the selected picks or trends. The first column of check boxes is for picks, while the second column is for trends. Crossplot charts only display porous (reservoir) lithology picks and trends. The rest are hidden.
3. The colour of the lithologies can also be changed by clicking on the colour box beside the check boxes, and selecting from the colour palette.

Well picks



1. In the **Wells** tree, all the wells are selected by default. If you wish to view picks for only one well, clear the other wells' check boxes. In effect, crossplot charts display only picks and trends for that one well. **Note:** When you turn off or clear a particular well check box, the picks and trends of that well will not be calculated and displayed in the crossplot charts.
2. The shape of each well's icon can also be changed by clicking the icon beside the check box and selecting the desired shape.

Fluids and Pick Quality



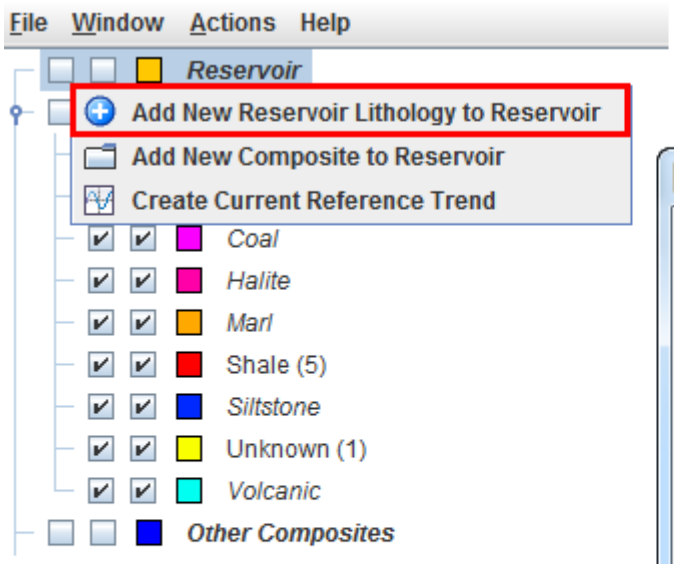
Apply the same steps in **Fluids** and **Qualities** trees.

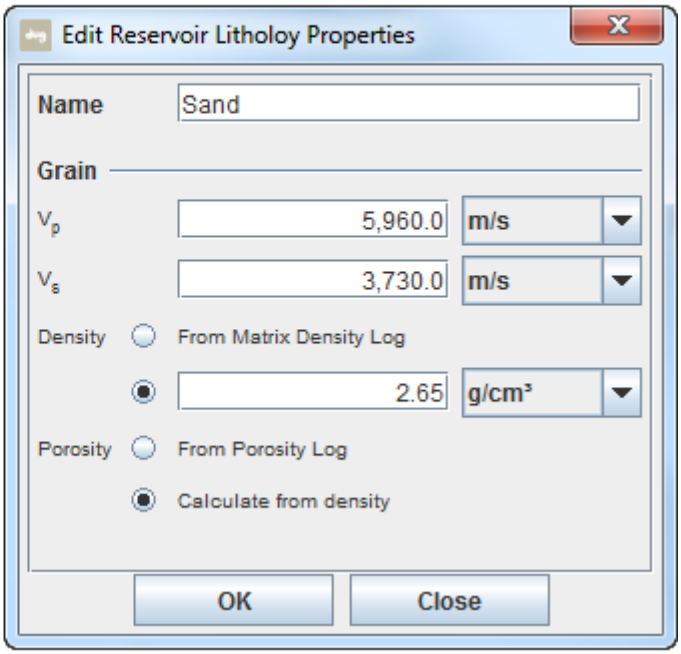
Whenever a check box is cleared, all picks and trends that are relevant to the fluid or quality category will be hidden from the crossplot charts (see *Pick Quality*).

Creating New Lithology

If the lithology is not available in the **Lithology** drop down list, you may need to create a new lithology from the Control Panel.

Create new lithology

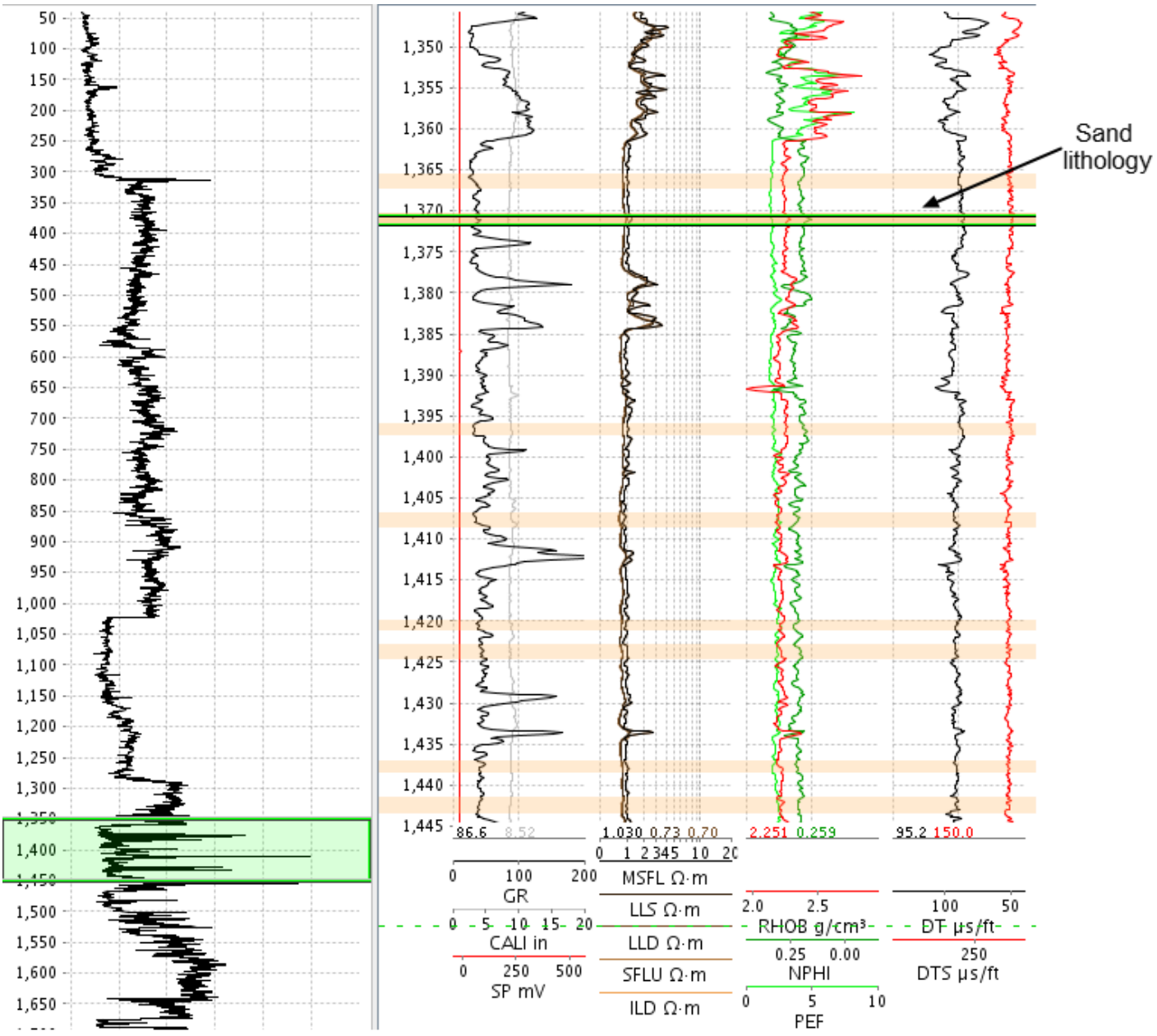




1. To add a new lithology, right click on **Reservoir** or **NonReservoir** in the Control Panel and select **Add New Lithology**.
2. Let's assume that you wish to create a sand reservoir lithology. Enter *Sand* as the lithology name at the **Name** text box. The **Grain** section allows you to input grain properties. Enter the **Vp**, **Vs** and **Density** values.

   (The VP, VS and Density values for sand (quartz) are 5960 m/s, 3730 m/s and 2.65 g/cm^3 respectively). Click **OK** to end the creation.
3. Then, perform picking in the Wireline Log Traces Panel.

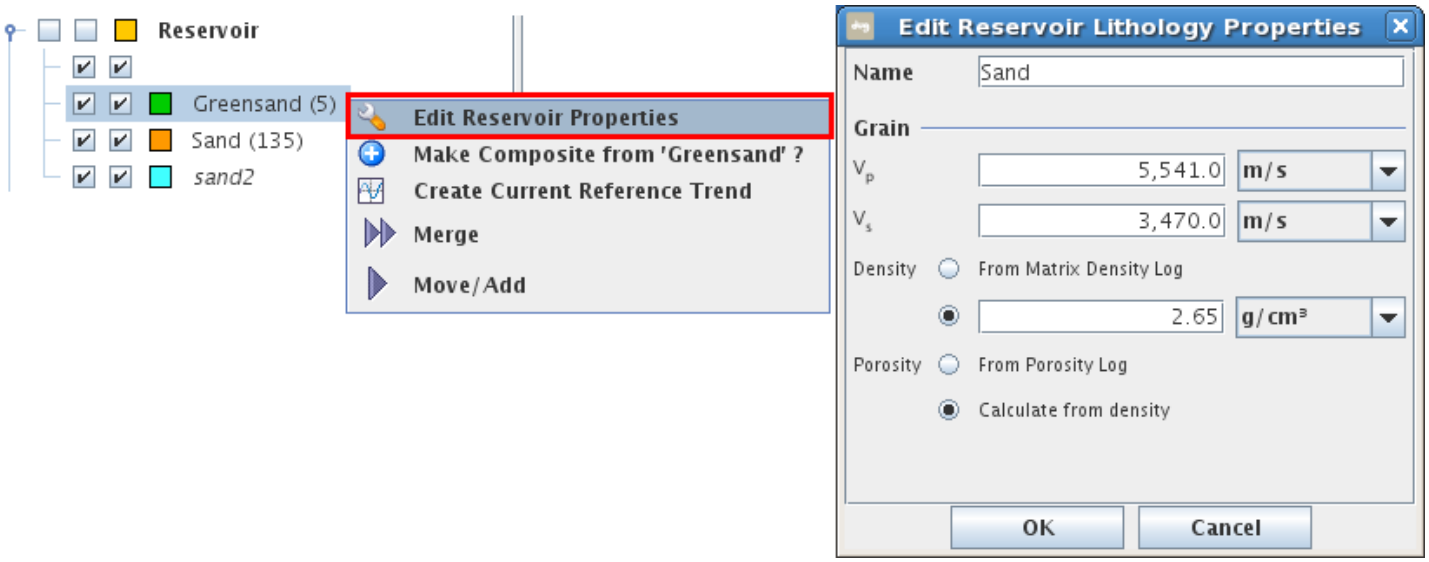
Note: You may perform more than one pick for the same lithology at different depths.



Sand picking

Editing a Lithology

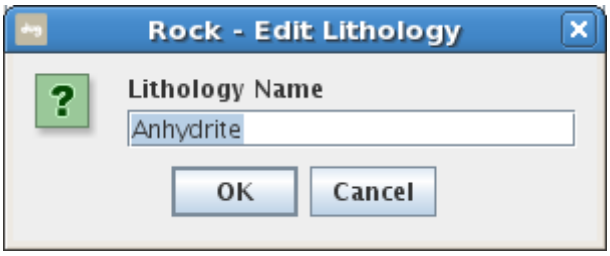
Reservoir



For reservoirs,

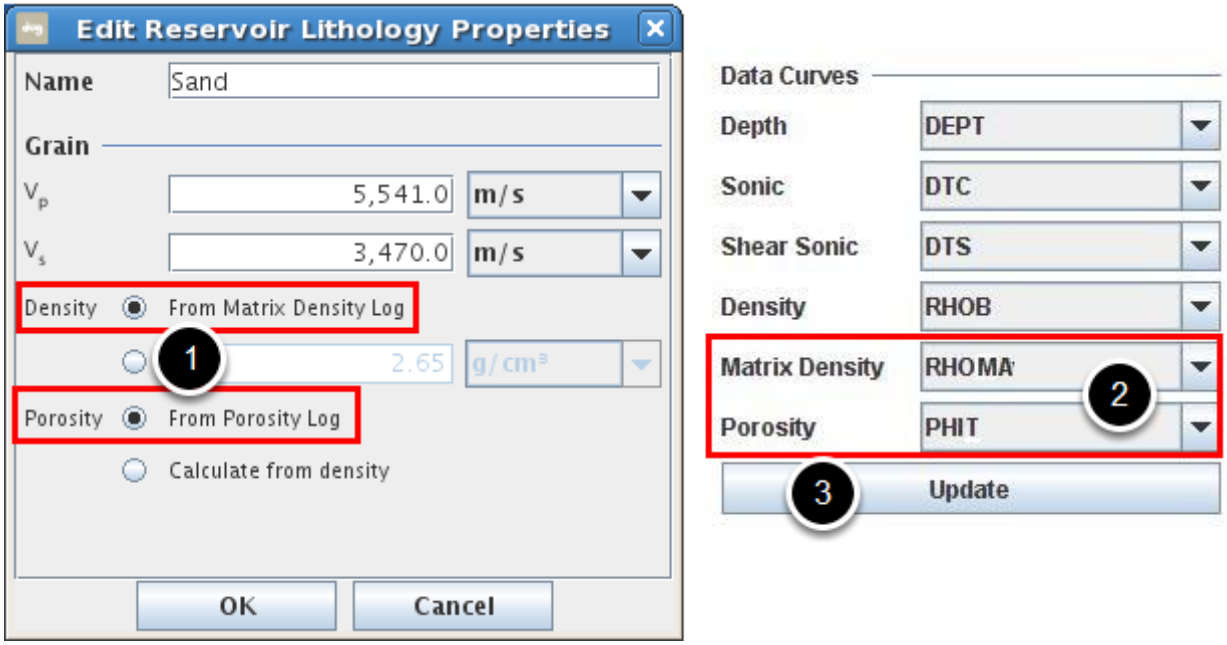
1. Expand the Reservoir tree structure to reveal individual reservoirs in the Control Panel.
2. Right-click the reservoir that requires editing and select **Edit Reservoir Properties**. The Edit Reservoir Lithology Properties dialog box appears.
3. From the dialog box, edit the name of the reservoir, the Vp, Vs, density and porosity of the reservoir.
4. Click **OK** to update the reservoir.

Non-Reservoir



For Non-Reservoir, only the lithology name is allowed for editing.

Compute porosity



You may select a matrix density curve and/or a porosity curve as inputs to compute the porosity which will display in the Data Summary Panel. This function provides flexibility for you to choose the matrix density and porosity values based on your need, to use for Gassmann substitution.

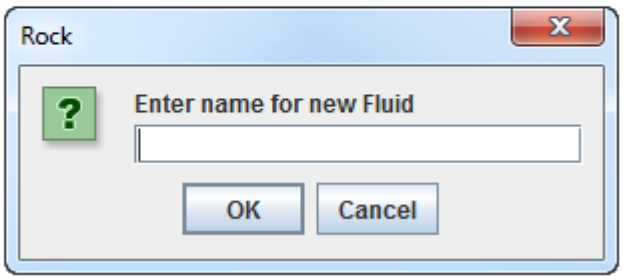
Matrix Density can be inputted as a **RHOMA** data curve whereas **Porosity** can be inputted as a **PHIT** data curve.

To use the Matrix Density and Porosity:

1. Select **From Matrix Density Log** and/or **Porosity from Log**, the **Density** text box under the Grain Properties becomes unavailable. Then, click **OK**.
2. Select a well and right-click to Configure Well. In **Data Curves** section, do one or both of the following:
    - Select **RHOMA** for Matrix Density
    - Select **PHIT** for Porosity.

3. Click **Update** to compute the porosity and it will reflect in the *Pick Summary Table* and Crossplot Charts.

Creating a New Fluid



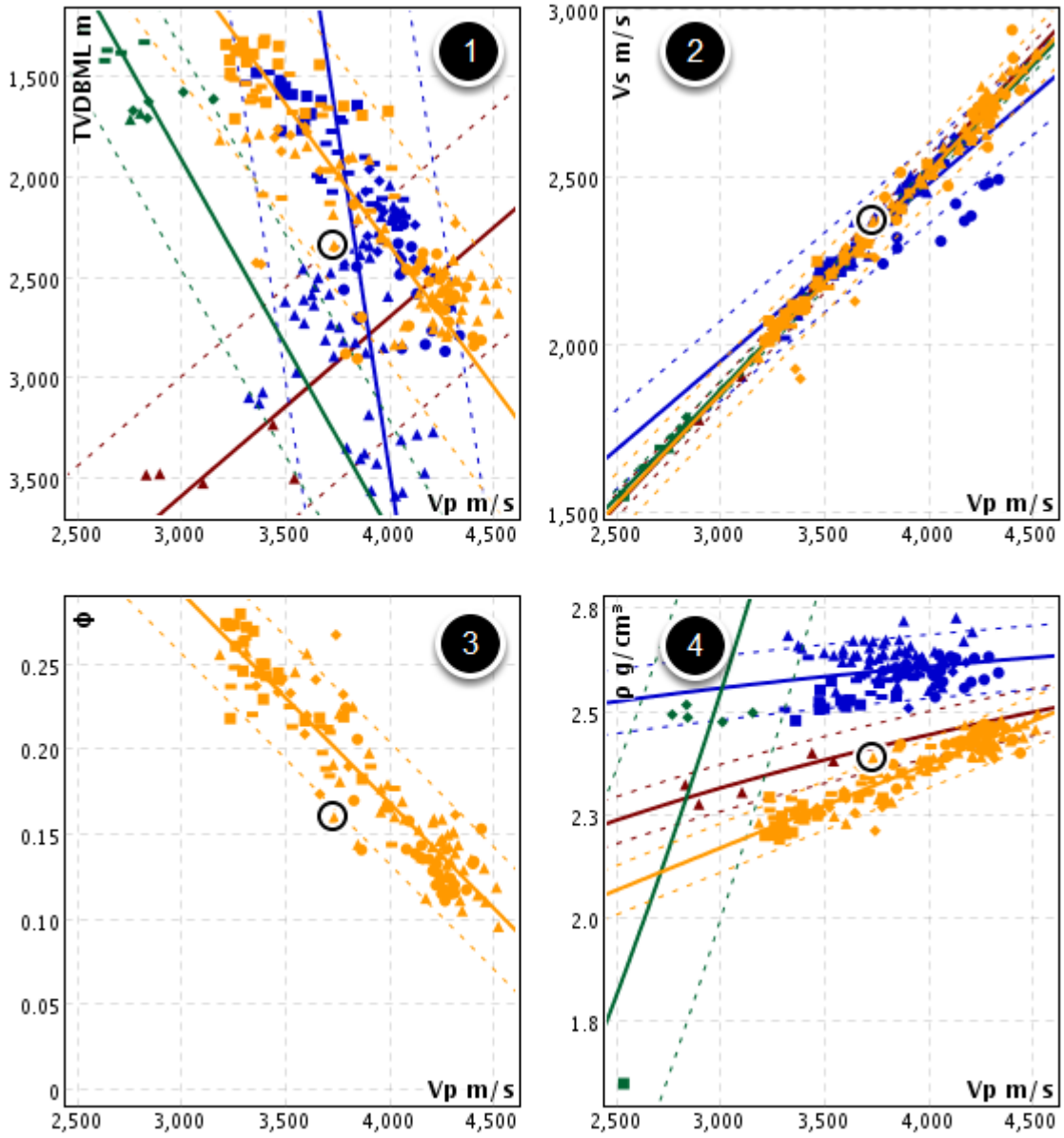
1. Expand the Fluids tree structure to reveal individual fluids in Control Panel.
2. Right-click Fluids and select **Add New Fluid**. The **Create New Fluid** dialog box appears.
3. Enter name for new fluid and click **OK**.

Editing a Fluid

1. Expand the Fluids tree structure to reveal individual fluids in Control Panel.
2. Right-click the specific fluid that requires editing, and select **Edit Fluid Properties**. The **Edit Fluid** dialog box appears.
3. Edit the name of the fluid and click **OK**.

Crossplot Panel

All lithology pickings in the wireline log traces will be displayed in chart form in the Crossplot Panel.



Pickings are displayed in crossplot charts.

There are four predetermined crossplot charts:

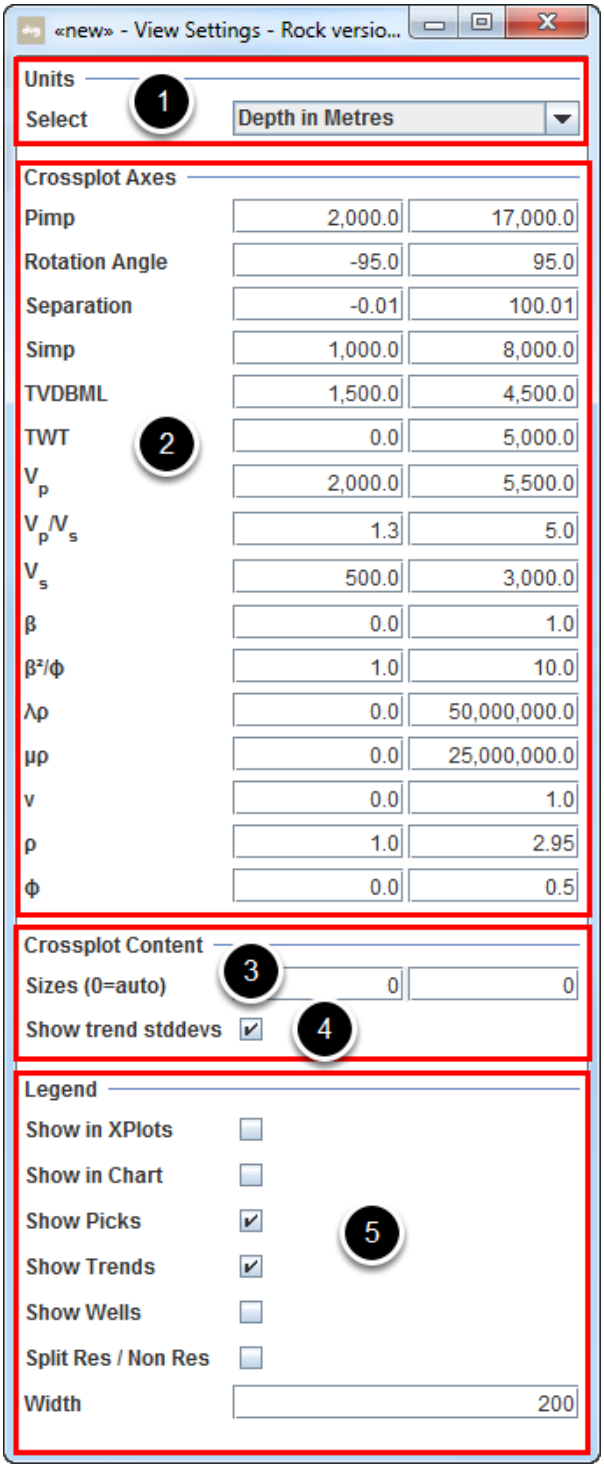
1. True Vertical Depth Below Mud Line (TVDBML) versus Compressional Velocity (VP)
2. Shear Velocity (VS) versus Compressional Velocity (VP)
3. Porosity versus Compressional Velocity (VP)

4. Density versus Compressional Velocity (VP).

Trends are calculated based on the lithology pickings and eventually will form the trends in the crossplot charts.

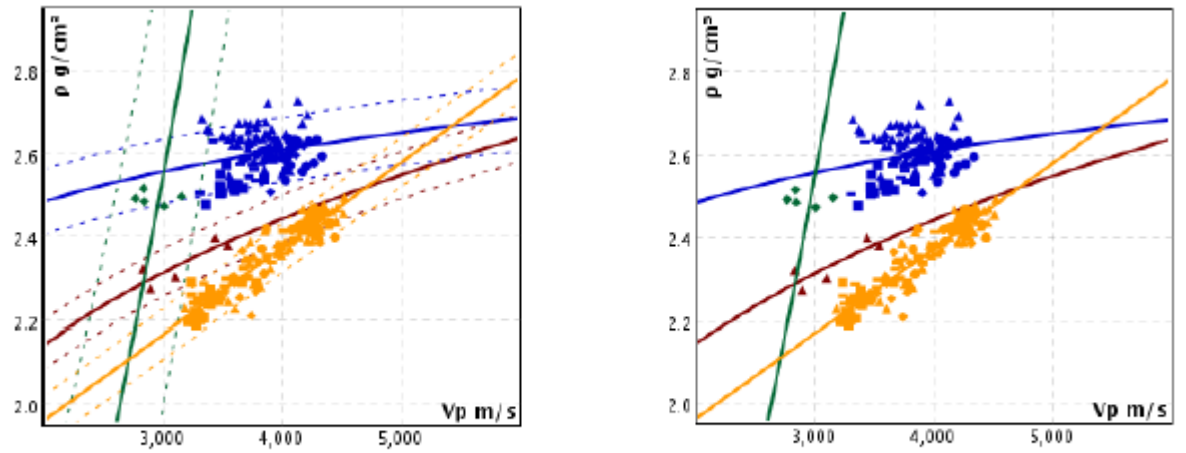
View Settings

View Settings window allows the personalisation of the crossplot panel.



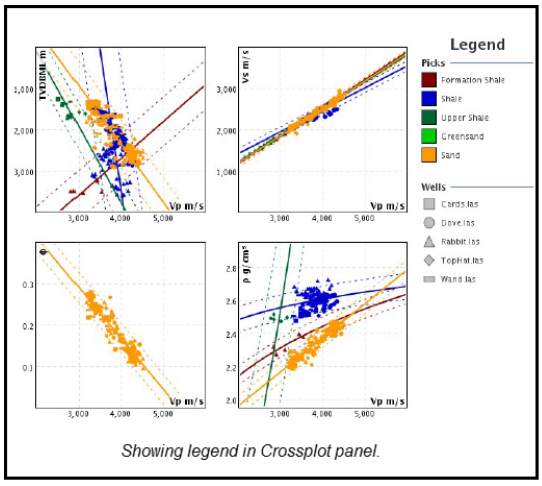
1. At **Units**, select if the preference unit of depth is in metres or feet.

2. In the **Crossplot Axes** section, adjust the axes size, minimum and maximum, for any crossplot chart.
3. At **Crossplot Content Sizes**, adjust the minimum and maximum values to change the size of the crossplots, which can be used to get fixed-size image for report.

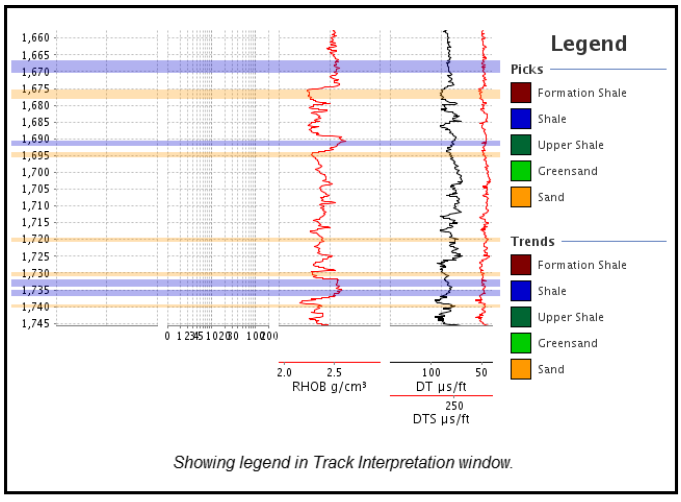


Switching between showing/hiding standard deviations (dotted lines) in the crossplot.

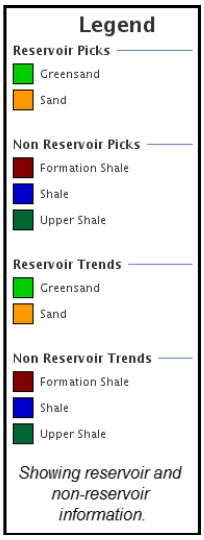
4. Show/Hide trend standard deviations in crossplots.



Showing legend in Crossplot panel.



Showing legend in Track Interpretation window.



Showing reservoir and non-reservoir information.

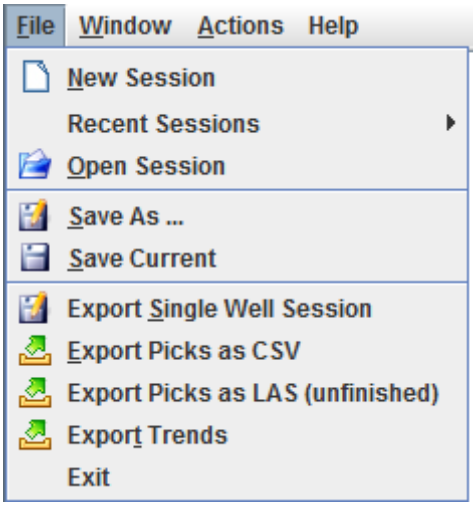
5. Show/Hide Legend for easy reference.
    - **Show in XPlots** — Legend appears in crossplot panel.
    - **Show in Chart** — Legend appears in Track Interpretation window.
    - **Show Picks** — Legend contains Picks information.
    - **Show Trends** — Legend contains Trends information.
    - **Show Wells** — Legend contains Well information.
    - **Split Res / Non Res** — Legend is split to reservoir and non-reservoir.
    - **Width** — Adjust the width size of legend.

Menus and Settings

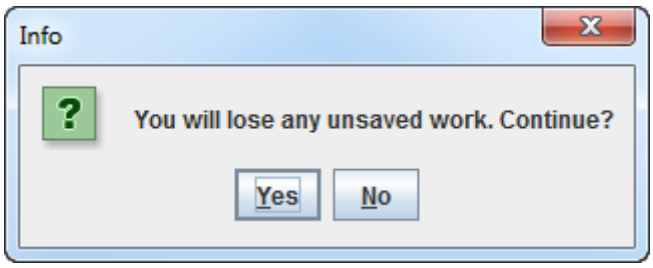
File Menu

There are nine (9) options available in the **File** menu:

- New Session
- Recent Sessions
- Open Session
- Save As
- Save Current
- Export Single Well Session
- Export Picks
- Export Trends
- Exit.



New Session



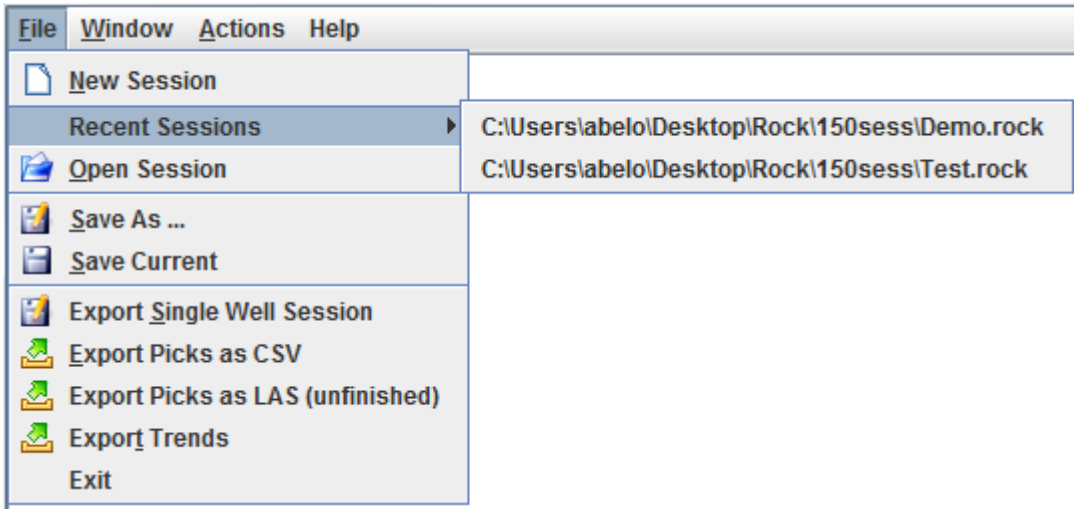
A session is a collection of a series of processes that are stored during a saving action. This provides a convenient way for you to store and retrieve the data in the application.

New Session serves as a quick removal of the existing session and load new session or wells into DUG Rock.

1. In the **File** menu, click **New Session**.
2. An **Info** dialog box appears for confirmation to continue **New Session** process.

Note: Make sure you have saved the current session, if valuable, before selecting **Yes**. Rock closes the current session once you confirm the process.

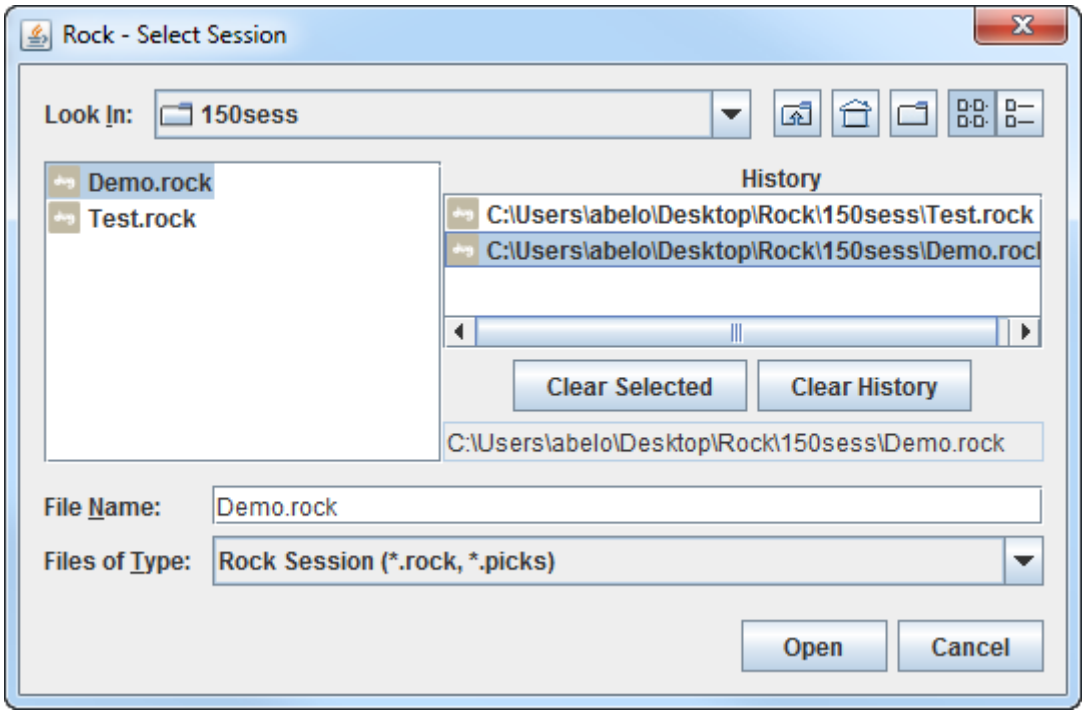
Recent Sessions



Recent Sessions option allows you to instantly trace recently opened sessions for quick loading.

1. In the **File** menu, navigate to **Recent Sessions**, which will display a list of recently-used sessions.
2. Select a session from the list to load.

Open Session

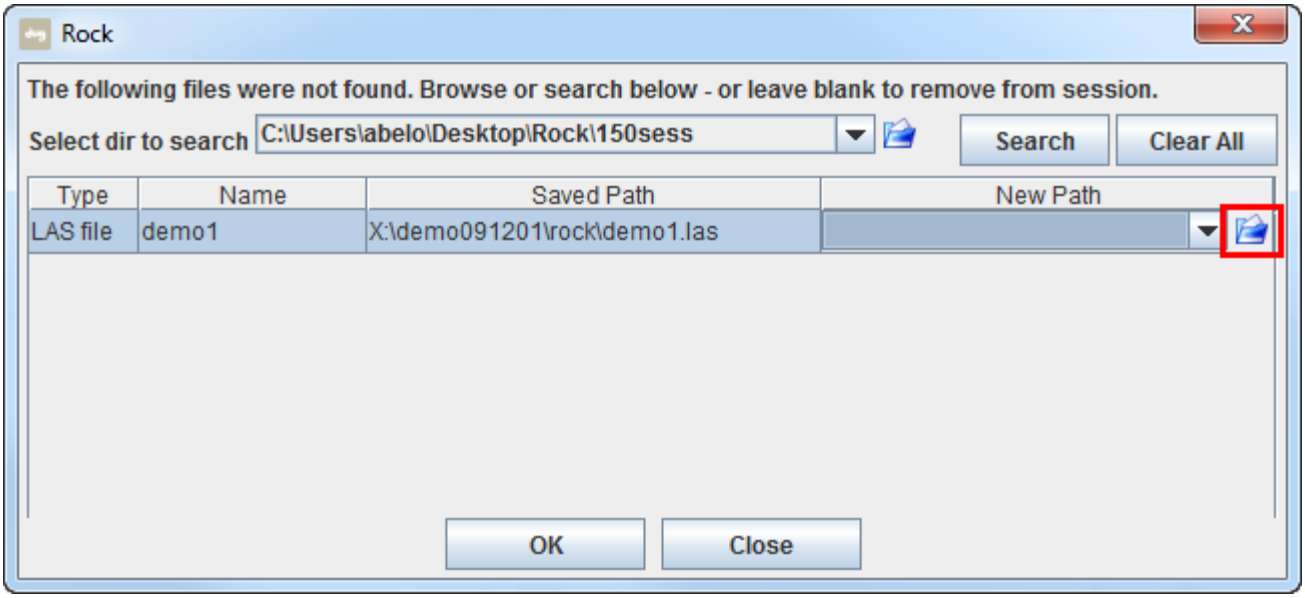


Open Session allows you to retrieve the previous saved session for editing or reference. DUG Rock can store picking and lithology information in session files with the file extension **.picks*.

1. In the **File** menu, click **Open Session**. The **Open Session** dialog box appears.
2. Click the **Look In** drop down list. Select the session file (**.picks* file) that you wish to open. Ensure that the **Files of Type** is **Rock Session (*.rock, *.picks)**.
   You may clear the history by selecting the listed *.picks file in the **History** column and do one of the following:
   - Click **Clear Selected** to clear the selected file, or
   - Click **Clear History** to clear all the listed files.

3. Click **Open** to open the session.

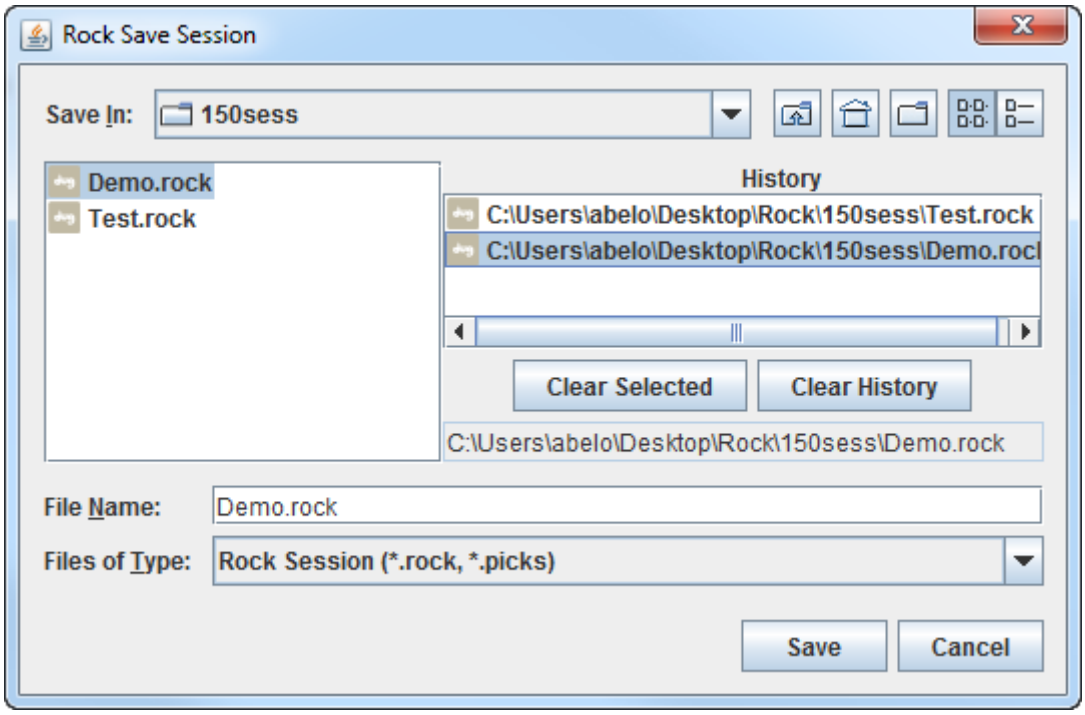
Locate Missing File(s)



If the well log files (*.*las*) are moved, renamed or altered, DUG Rock will not be able to automatically locate them. In such cases, DUG Rock will prompt the user to manually locate the missing files.

1. Click the **Select File** button to locate the missing file.
2. If the file has been moved, navigate to the new location, click on the file and click **Open**. The new location of the file will appear in the **New Path** column.
3. Click **OK** to confirm and display the session.

Save As



DUG Rock stores picking and lithology information in session files with the **.rock* file extension by default.

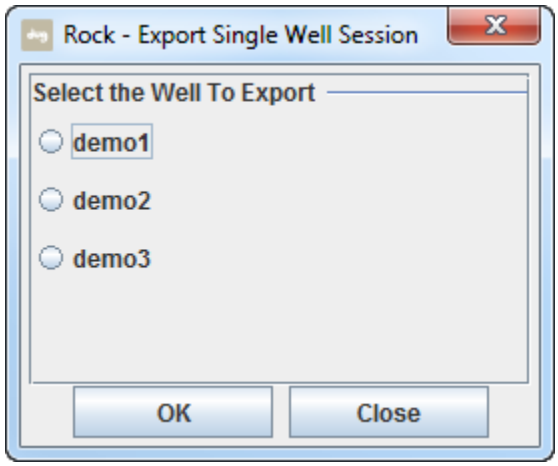
1. In the **File** menu, click **Save As**. The **Rock Save Session** dialog box appears.
2. Click the **Save In** drop down list. Select the folder that you wish to save your session file in. Enter a file name in the **File Name** text box (**.rock* is recommended).
   The **History** column on the right will list all the saved historical session files. You may clear the history by selecting the file in the **History** column and do one of the following:
   - Click **Clear Selected** to clear the selected file, or
   - Click **Clear History** to clear all the listed files.
3. Click **Save** to save the session in **.rock* or **.picks* format.

Note: Well logs are saved separately in **.las* files, and referenced by the session files when a session is opened. Hence, files referenced during a DUG Rock session must be saved correctly. If the session file is to be archived or transferred to another system, ensure that the associated well log files are saved as well.

Save Current

Save Current is a fast way for saving a currently open session.

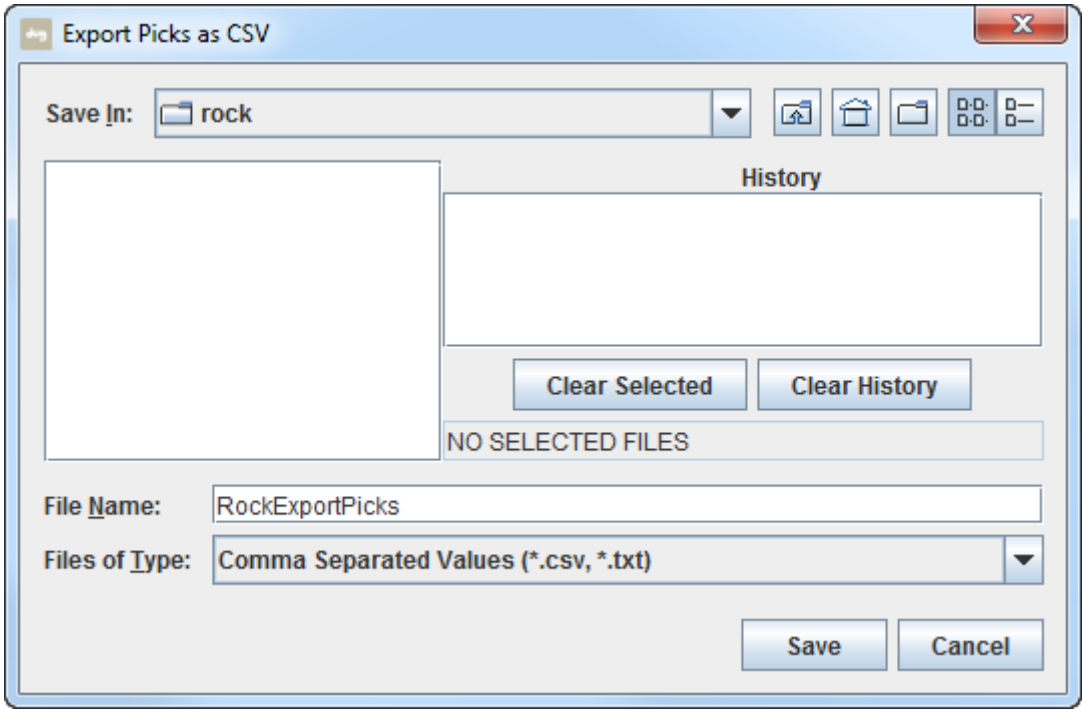
Export Single Well Session



Export Single Well Session option allows you to save a single well out into a new session.

1. In the **File** menu, click **Export Single Well Session**. The **Rock – Export Single Well Session** dialog box appears.
2. Select the well to export and click **OK** and save the well session.

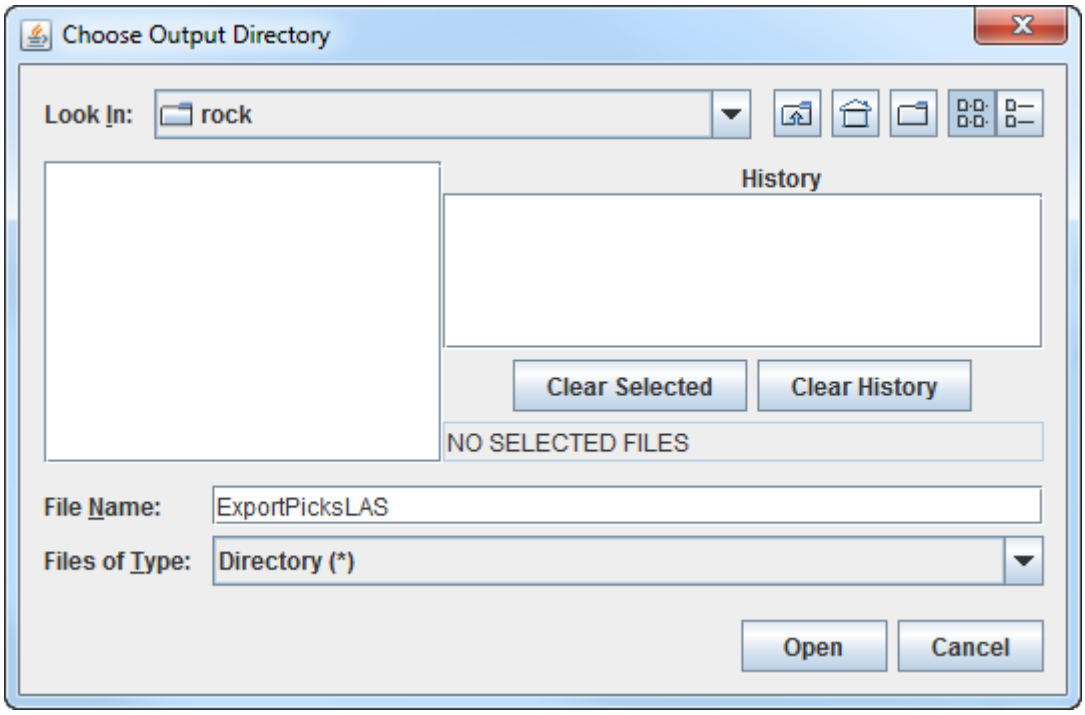
Export Picks



Picks and lithologies can be exported to a text format, which can then be used in most spreadsheet programs or other software if required.

1. In the **File** menu, click **Export Picks as CSV**. The **Export Picks** dialog box appears.
2. Click the **Save In** drop down list. Select the folder that you wish to export to. Enter a file name in the **File Name** text box.
   The history column on the right will list all the historical files. You may clear the history by selecting the listed export picks file(s) in the history column and do one of the following:
   - Click **Clear Selected** to clear the selected file, or
   - Click **Clear History** to clear all the listed files.

3. Click **Save** to export picks to a text file.

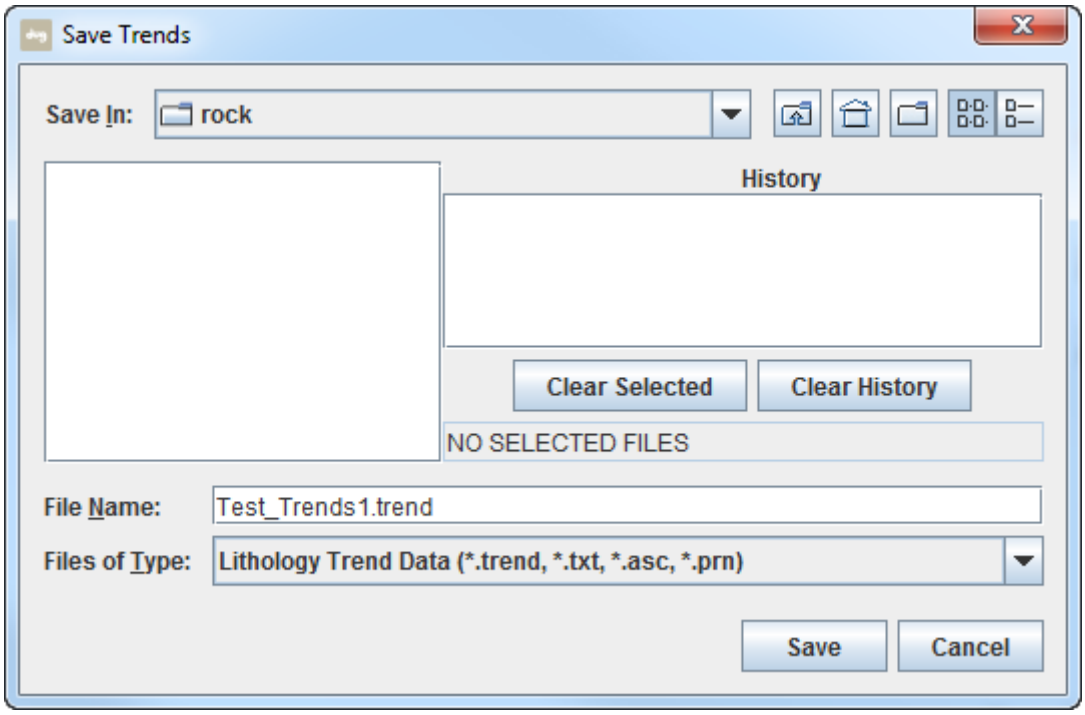


Picks and lithologies can also be exported to *.*las* format.

1. In the **File** menu, click **Export Picks as LAS**. The **Choose Output Directory** dialog box appears.
2. Click the **Look In** drop down list. Select a location to save the directory. Enter a directory name in the **File Name** text box.
   The history column on the right will list all the historical files. You may clear the history by selecting the listed export picks file(s) in the history column and do one of the following:
   - Click **Clear Selected** to clear the selected file, or
   - Click **Clear History** to clear all the listed files.

3. Click **Open** to export picks to LAS file.

Export Trends

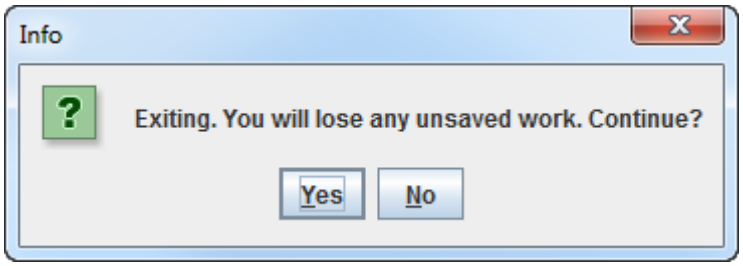


All the derived trends from the different lithologies produced by DUG Rock can be saved into **.trend* file format, which can then be used as an input file in other applications (eg, DUG Distill) for further litho-fluid analysis and interpretation. It can also be used for trends comparison and for future reference in other projects.

1. In the **File** menu, click **Export Trends**. The **Save Trends** dialog box appears.
2. Click the **Save In** drop down list to identify the folder that you wish to save in.
   The history column on the right will list all the historical files. You may clear the history by selecting the listed session file(s) in the history column and do one of the following:
   - Click **Clear Selected** to clear the selected file, or
   - Click **Clear History** to clear all the listed files.
3. Enter a name in the **File Name** text box with the extension **.trend*.
4. Click **Save**.

See *Appendix* for the **.trend* file format sample.

Exit



The **Exit** option in the **File** menu allows you to quit from DUG Rock. DUG Rock system interface will close when you select this option.

1. In the **File** menu, click **Exit DUG Rock.** An Info warning appears for confirmation to quit DUG Rock.
2. Click **Yes**.

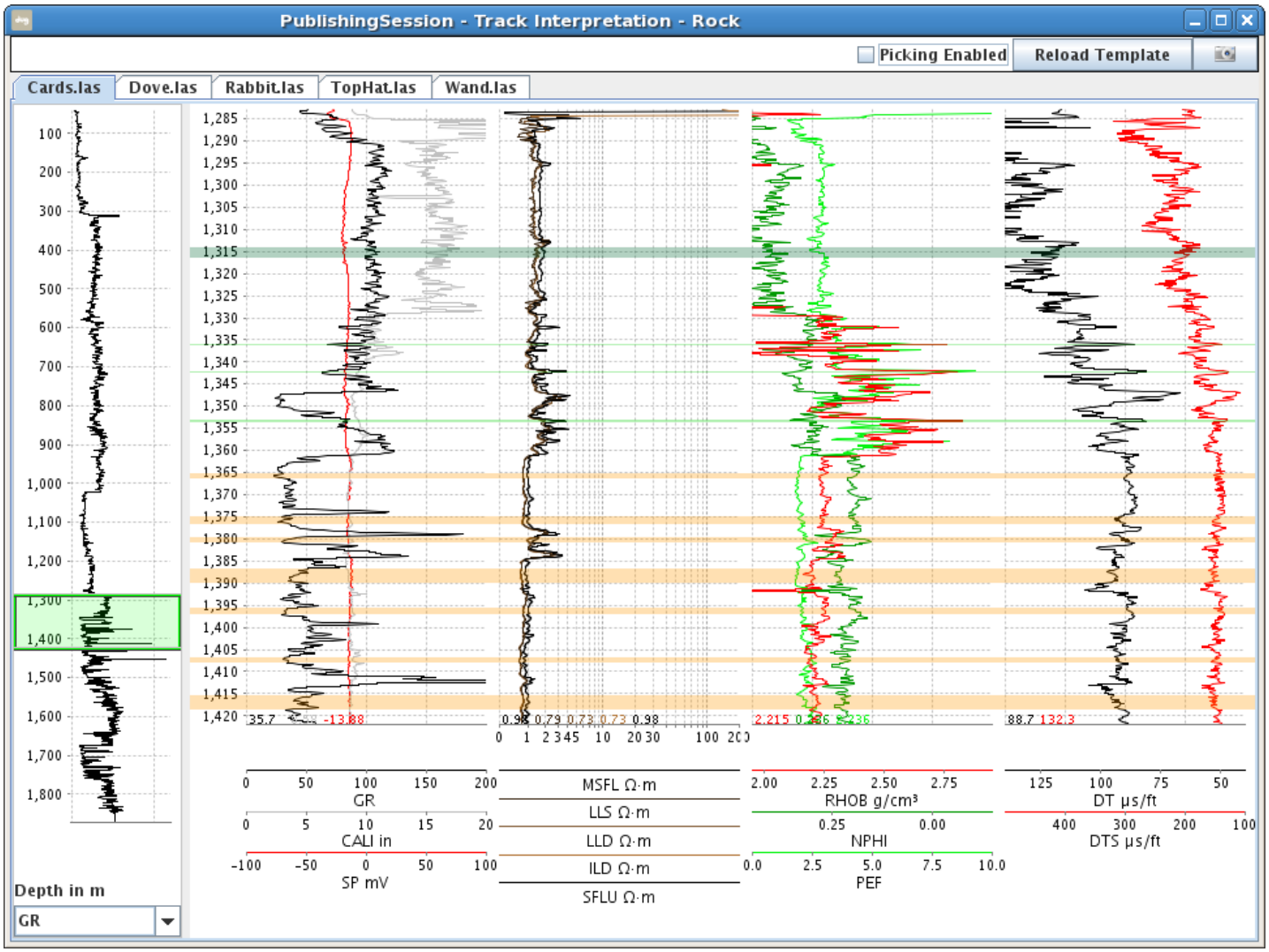
Note: Make sure the session and wells are saved prior to exiting or you will lose all your work.

Window Menu

There are seven options available in the **Window** menu:

- Track Interpretation
- Pick Summary Table
- Pick Info
- Trends Summary Table
- Additional Crossplots
- View Settings
- Biot QC Trends View.

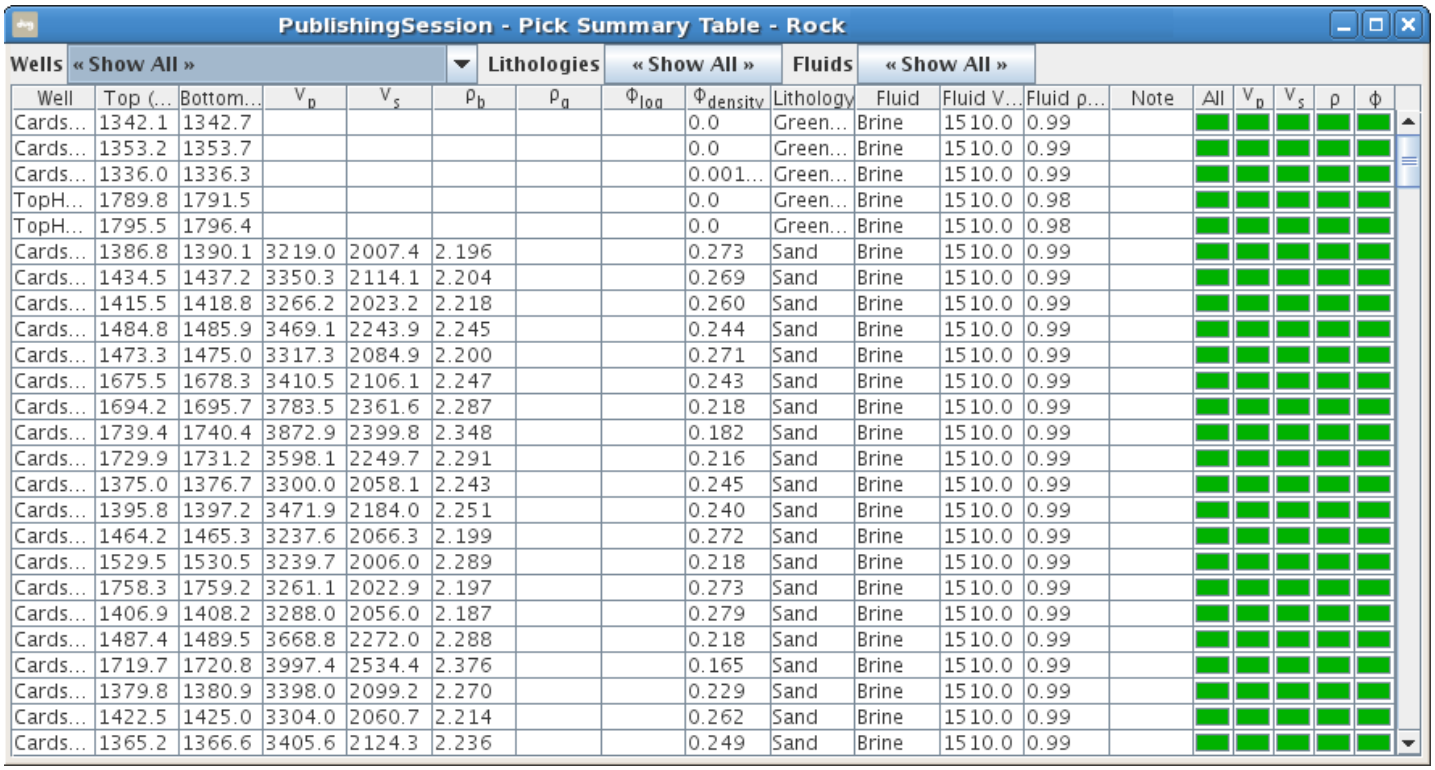
Track Interpretation



Track Interpretation opens the Navigation Panel and Wireline Log Traces Panel mostly for lithology picking purposes.

For more information, see *Track Interpretation*.

Pick Summary Table

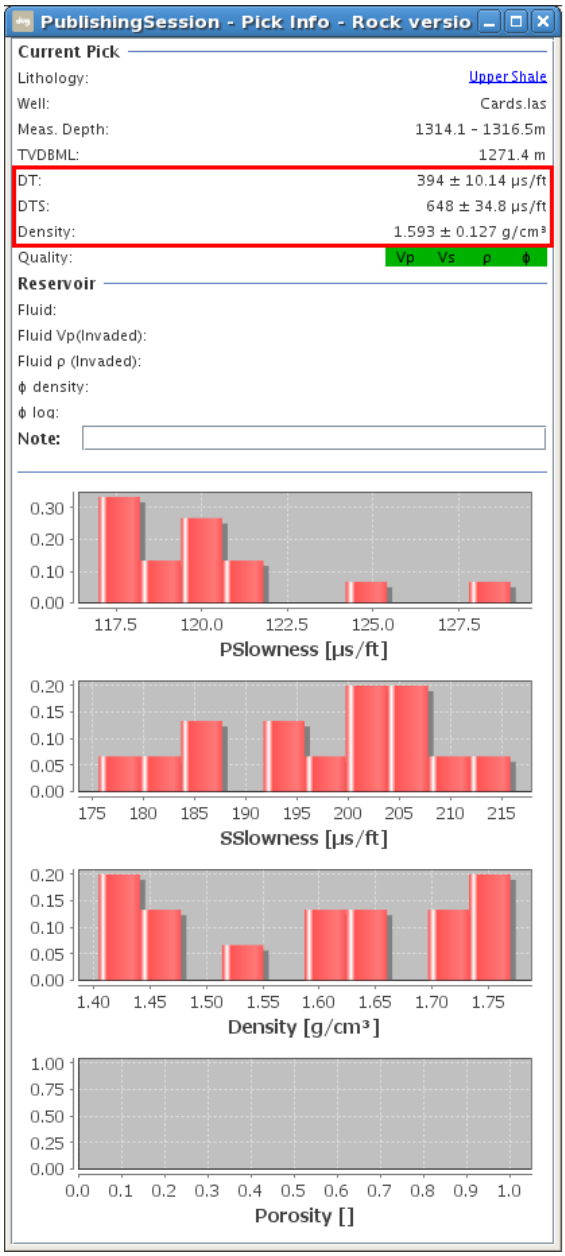


Well	Top (...	Bottom...	V_p	V_s	ρ_b	ρ_a	Φ_{log}	$\Phi_{density}$	Lithology	Fluid	Fluid V...	Fluid ρ...	Note	All	V_p	V_s	ρ	ϕ
Cards...	1342.1	1342.7						0.0	Green...	Brine	1510.0	0.99						
Cards...	1353.2	1353.7						0.0	Green...	Brine	1510.0	0.99						
Cards...	1336.0	1336.3						0.001...	Green...	Brine	1510.0	0.99						
TopH...	1789.8	1791.5						0.0	Green...	Brine	1510.0	0.98						
TopH...	1795.5	1796.4						0.0	Green...	Brine	1510.0	0.98						
Cards...	1386.8	1390.1	3219.0	2007.4	2.196			0.273	Sand	Brine	1510.0	0.99						
Cards...	1434.5	1437.2	3350.3	2114.1	2.204			0.269	Sand	Brine	1510.0	0.99						
Cards...	1415.5	1418.8	3266.2	2023.2	2.218			0.260	Sand	Brine	1510.0	0.99						
Cards...	1484.8	1485.9	3469.1	2243.9	2.245			0.244	Sand	Brine	1510.0	0.99						
Cards...	1473.3	1475.0	3317.3	2084.9	2.200			0.271	Sand	Brine	1510.0	0.99						
Cards...	1675.5	1678.3	3410.5	2106.1	2.247			0.243	Sand	Brine	1510.0	0.99						
Cards...	1694.2	1695.7	3783.5	2361.6	2.287			0.218	Sand	Brine	1510.0	0.99						
Cards...	1739.4	1740.4	3872.9	2399.8	2.348			0.182	Sand	Brine	1510.0	0.99						
Cards...	1729.9	1731.2	3598.1	2249.7	2.291			0.216	Sand	Brine	1510.0	0.99						
Cards...	1375.0	1376.7	3300.0	2058.1	2.243			0.245	Sand	Brine	1510.0	0.99						
Cards...	1395.8	1397.2	3471.9	2184.0	2.251			0.240	Sand	Brine	1510.0	0.99						
Cards...	1464.2	1465.3	3237.6	2066.3	2.199			0.272	Sand	Brine	1510.0	0.99						
Cards...	1529.5	1530.5	3239.7	2006.0	2.289			0.218	Sand	Brine	1510.0	0.99						
Cards...	1758.3	1759.2	3261.1	2022.9	2.197			0.273	Sand	Brine	1510.0	0.99						
Cards...	1406.9	1408.2	3288.0	2056.0	2.187			0.279	Sand	Brine	1510.0	0.99						
Cards...	1487.4	1489.5	3668.8	2272.0	2.288			0.218	Sand	Brine	1510.0	0.99						
Cards...	1719.7	1720.8	3997.4	2534.4	2.376			0.165	Sand	Brine	1510.0	0.99						
Cards...	1379.8	1380.9	3398.0	2099.2	2.270			0.229	Sand	Brine	1510.0	0.99						
Cards...	1422.5	1425.0	3304.0	2060.7	2.214			0.262	Sand	Brine	1510.0	0.99						
Cards...	1365.2	1366.6	3405.6	2124.3	2.236			0.249	Sand	Brine	1510.0	0.99						

This table displays information about the lithology pickings done in Track Interpretation, such as density, fluid Vp, type of lithology and more.

See *Pick Summary Table*.

Pick Info



Mean

The statistics assume a normal distribution (bell shaped curve)

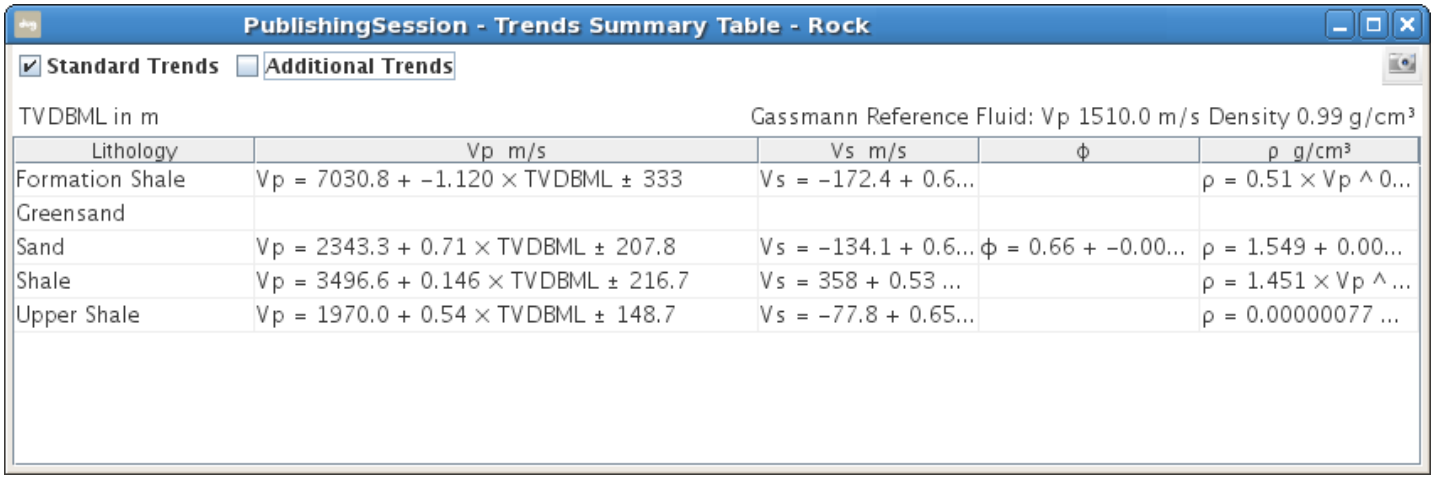
The **Pick Info** window provides detailed information of the highlighted pick in the Wireline Log Traces Panel. This section also displays Histograms for quality control of the end member picking.

There are four histograms available, which are P-slowness, S-slowness, Density and Porosity. These histograms provide a visual representation of the distribution of the elastic properties over the blocked interval, which allows you to determine if any anomalous data is being included in the upscaling of the interval.

A good end member pick will display a normal distribution in a bell shaped curve on the histogram. Normal distribution means the distribution is concentrated in the centre and decreases on either side. The data in a normal distribution has less of a tendency to include unusually extreme values in the evaluation.

Note: A pick must be selected in order to view pick info.

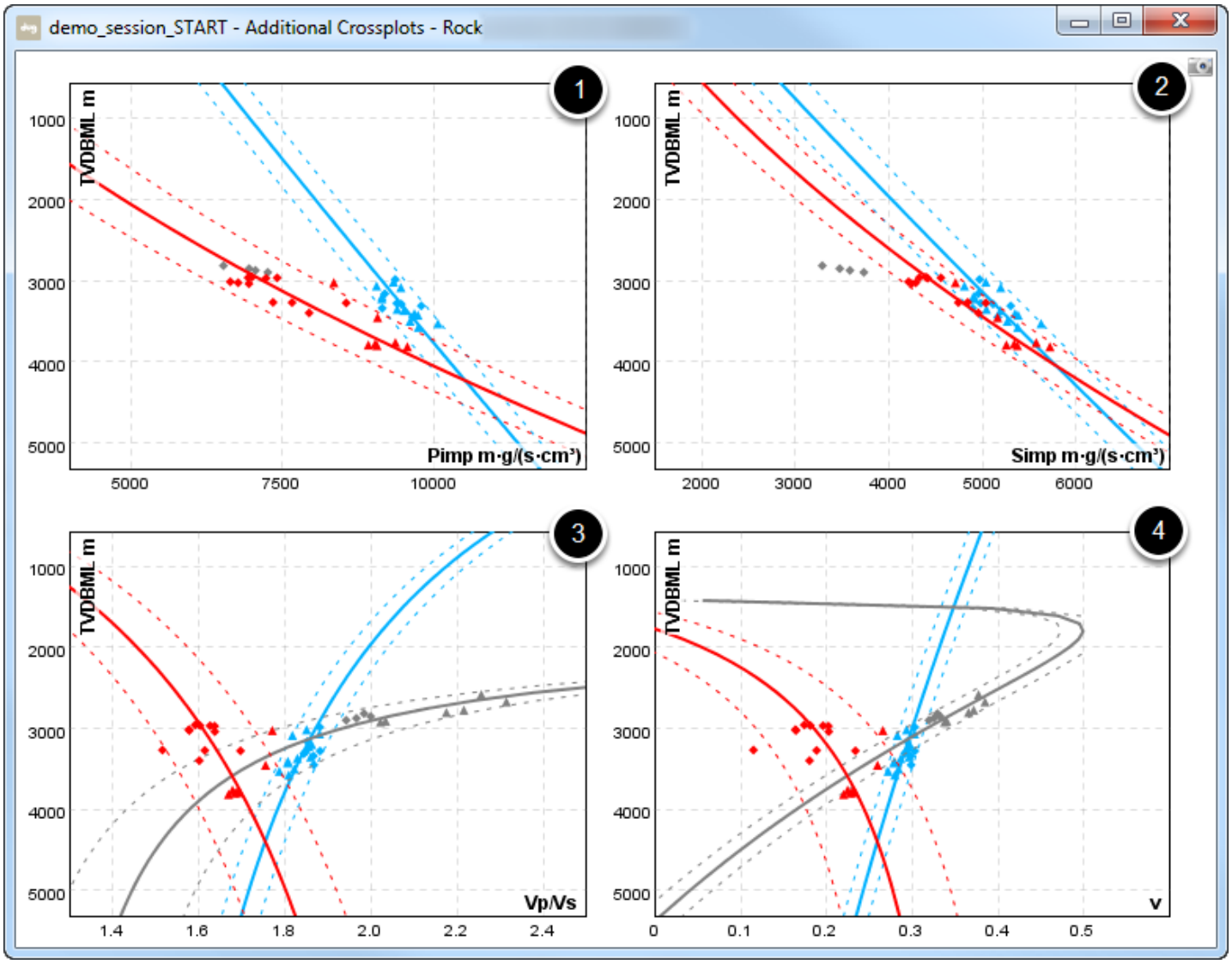
Trends Summary Table



Trends Summary Table provides the formulas behind creating trends in DUG Rock. This table shows only the formulas for **Standard Trends** by default. Select **Additional Trends** to display more formulas for creating additional trends in DUG Rock.

- Standard Trends include Vp, Vs, density and porosity.
- Advanced Trends include all the standard trends plus **Pimp**, **Simp**, **Vp/Vs** and **v**.

Additional Crossplots



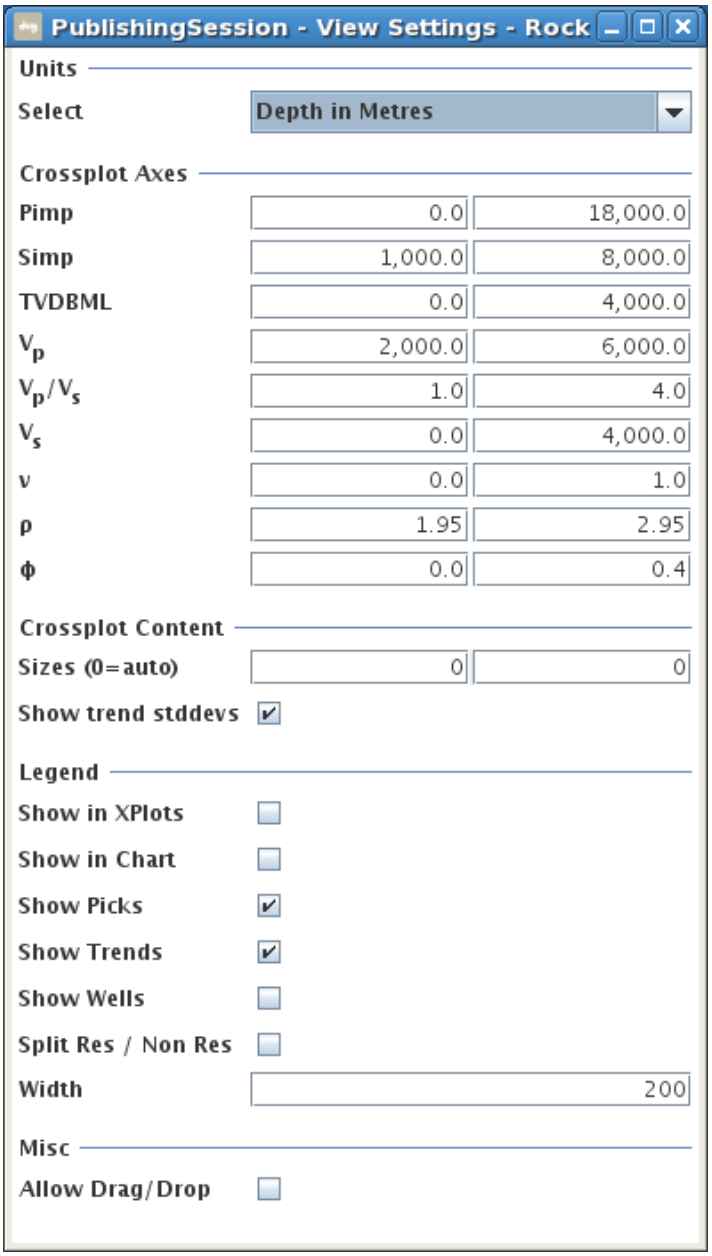
DUG Rock calculates trends for additional elastic properties from the four main trends and presents them in the **Additional Crossplots** view.

Unlike the four primary plots, the four additional crossplots display trends in relation to burial depth (depth below mudline).

1. P-Impedance vs. Depth
2. S-Impedance vs. Depth
3. Vp / Vs vs. Depth
4. Poisson's Ratio vs. Depth

These plots provide an intuitive comparison of lithology behavior with depth.

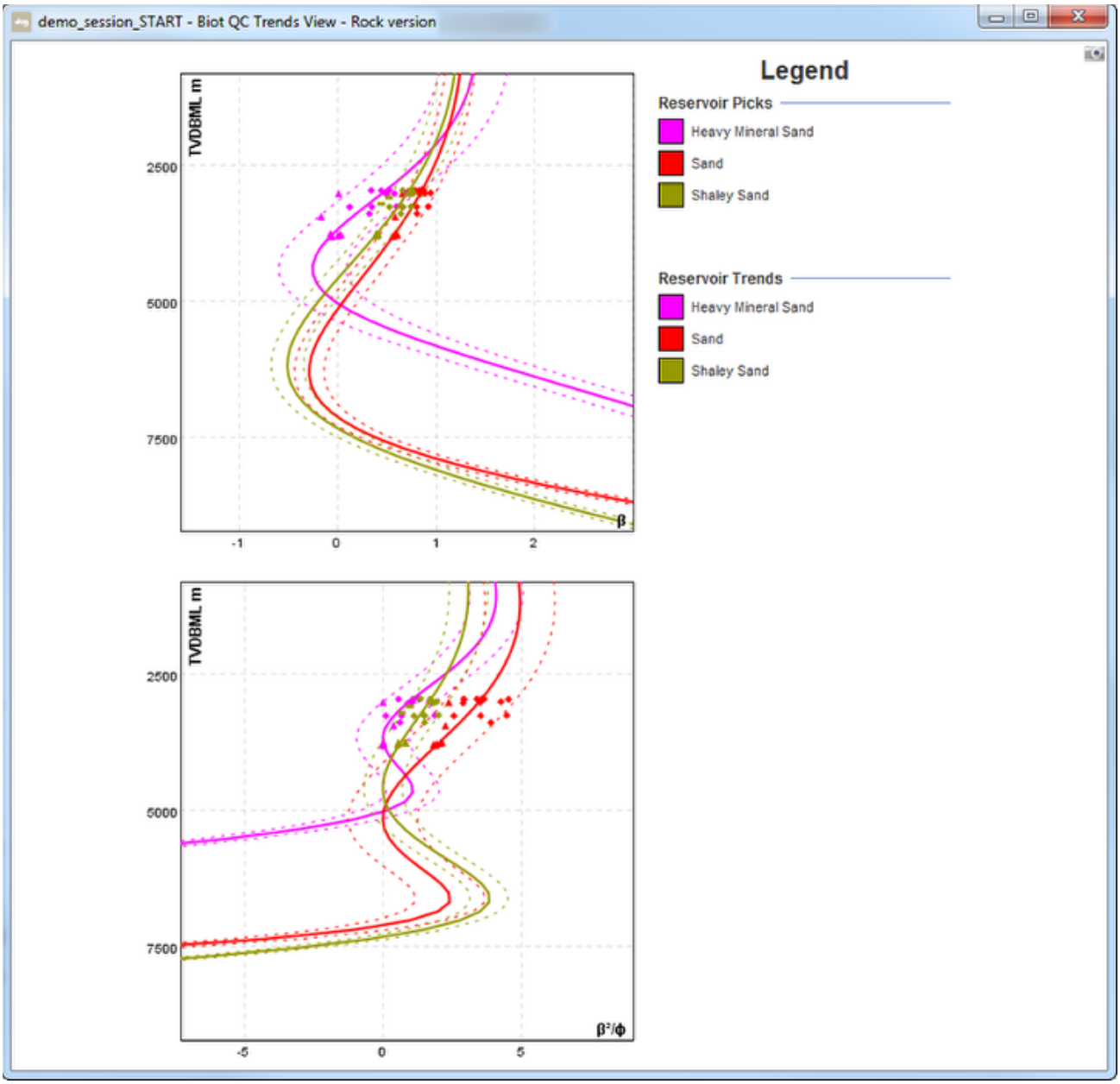
View Settings



View Settings allows you to configure how the crossplot panel looks. Here, you can select the Units for the data being displayed, the min-max of each crossplot axes and size of the plot (0 will be autofit), and whether to show or hide legends.

For more information, see *View Settings*.

Biot QC Trends View



The physical properties implied by extrapolated trends may become unrealistic, resulting in non-physical lithologies.

Use this chart to evaluate the Biot coefficient for the depth range of interest. The Biot coefficient is determined for each pick, and a trend is calculated for each set of picks. Trend lines are drawn for any "leaf" reservoir trends (not composites).

Picks with a Biot coefficient greater than 1.0 are invalid / non-physical.

The Biot Coefficient

Pore fluid pressures will reduce the effective stress supported by the rock mineral frame. The most common form for the effective stress law is:

$$\sigma_e = \sigma_a - nP_p$$

where

- σ_e is the effective stress
- σ_a is the applied stress on the rock surface
- P_p is the pore pressure.

The effective stress coefficient '*n*' is also called Biot's poroelastic term, or the Biot Coefficient. The Biot Coefficient is calculated as:

$$n = 1 - K_d/K_o$$

where

- K_d is the dry rock bulk modulus
- K_o the mineral bulk modulus.

Because the rock modulus is usually much lower than the mineral modulus, *n* is often close to unity.

The valid physical range for the Biot Coefficient is from (total porosity) to 1.

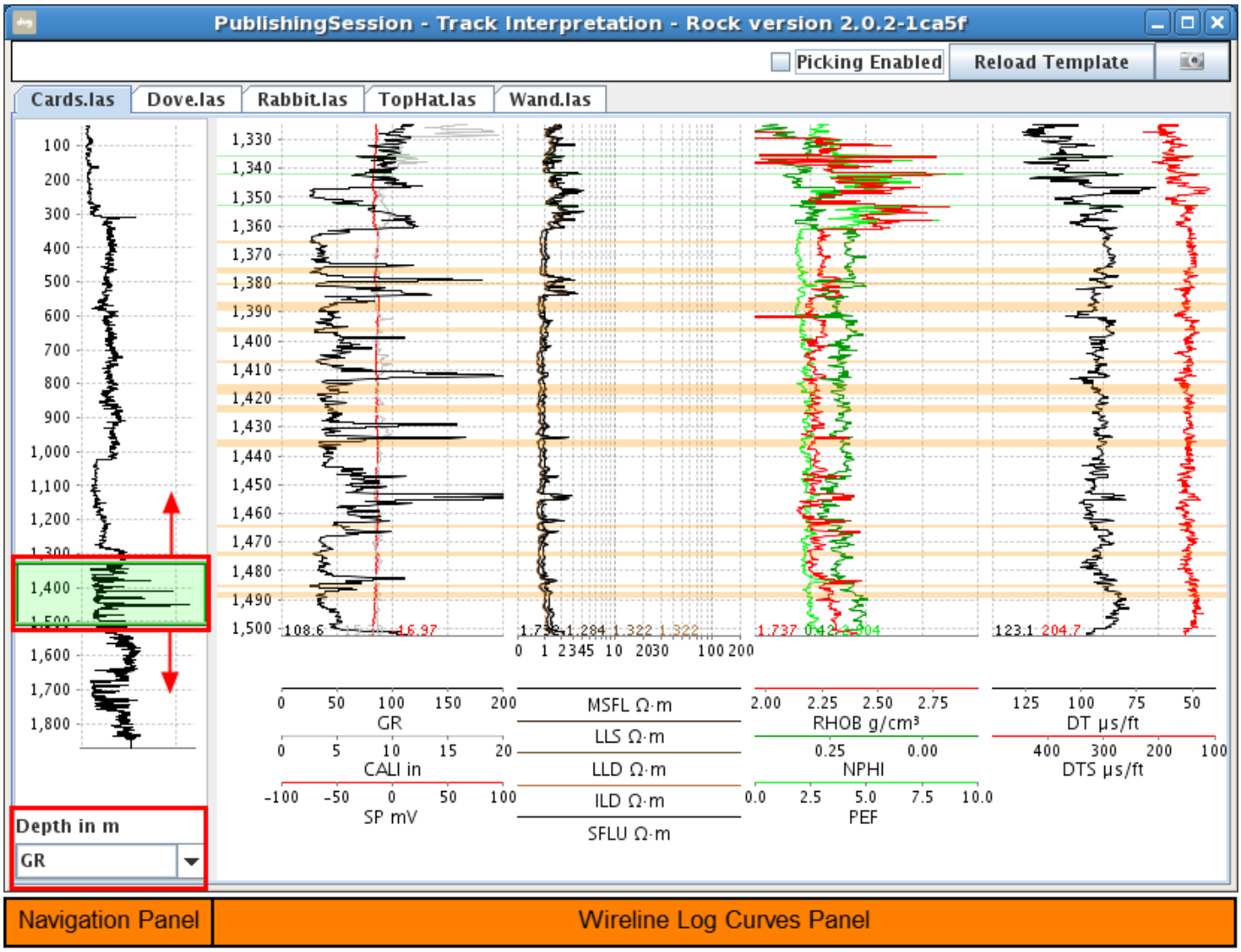
- Values below Phi-T violate the Voigt bound.
- Values above 1 are not physically valid.

Track Interpretation

There are two sections available in the Track Interpretation window:

- **Navigation Panel** allows you to zoom in the Wireline Log Traces Panel or to select a particular mnemonic to display for quick reference.
- **Wireline Log Traces Panel** allows you to perform lithology picking in the well.

For more information on analysing each track, see *Method of Analysis*.



Navigation Panel

Gamma Ray (**GR**) curve is the default mnemonic in the Navigation Panel. You may select a different curve (other mnemonic) from the drop down list to display a clearer view of that mnemonic associated with the Wireline Log Curves.

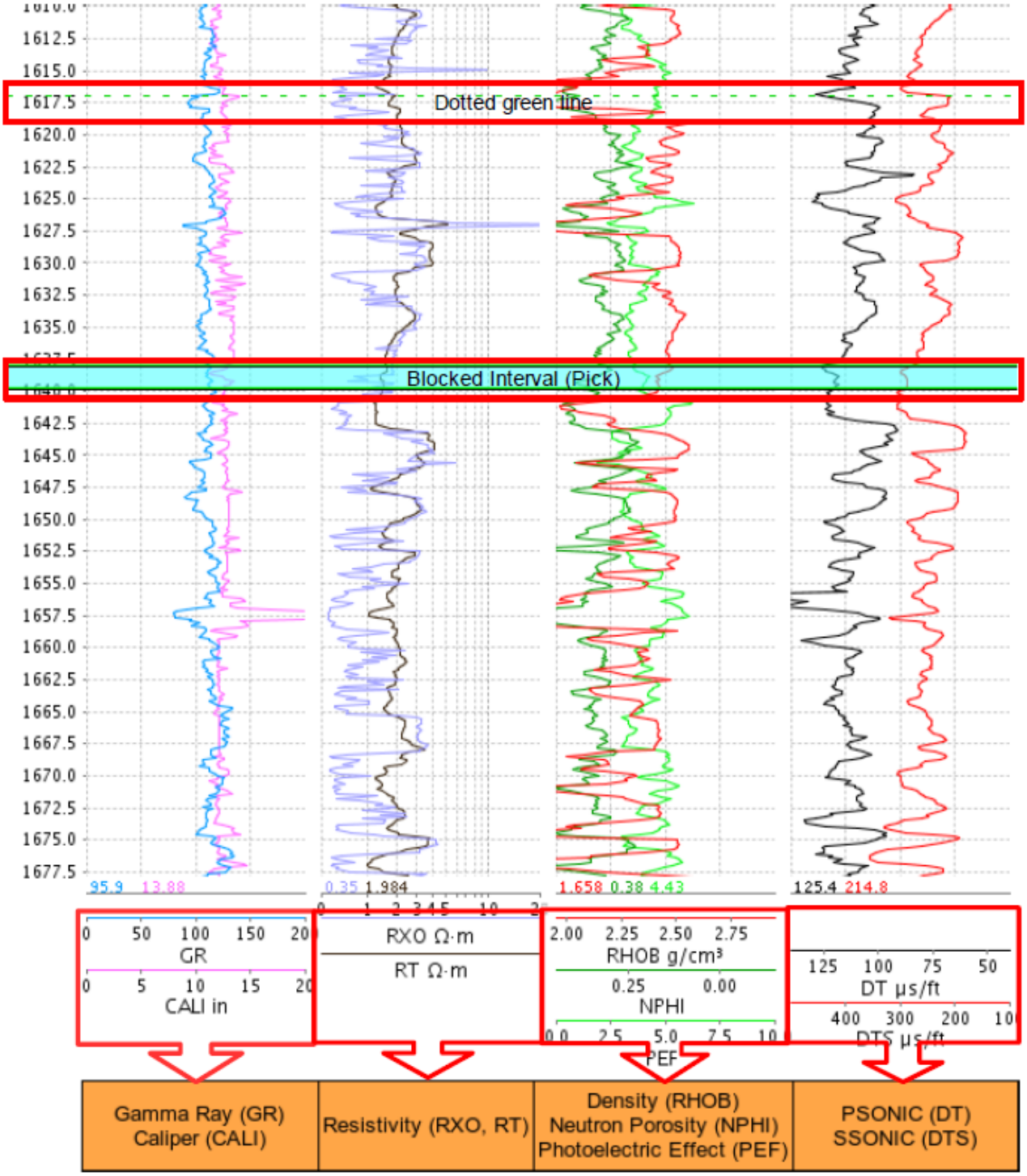
1. For a closer view of the curve in the Wireline Log Traces Panel, shrink the region box in green by adjusting the top and bottom edges.
2. Click and drag the region box up and down to get to the preferred depth of the curve view.
3. If you wish to select a different curve, refer to the drop down list for the preferred curve view. By default, the Gamma Ray (GR) curve is displayed.

Wireline Log Traces Panel

Track 1	Track 2	Track 3	Track 4
Gamma Ray (GR) Caliper (CALI) Spontaneous Potential (SP)	Resistivity (ohm-m)	Density Neutron Porosity Photoelectric Effect	Sonic

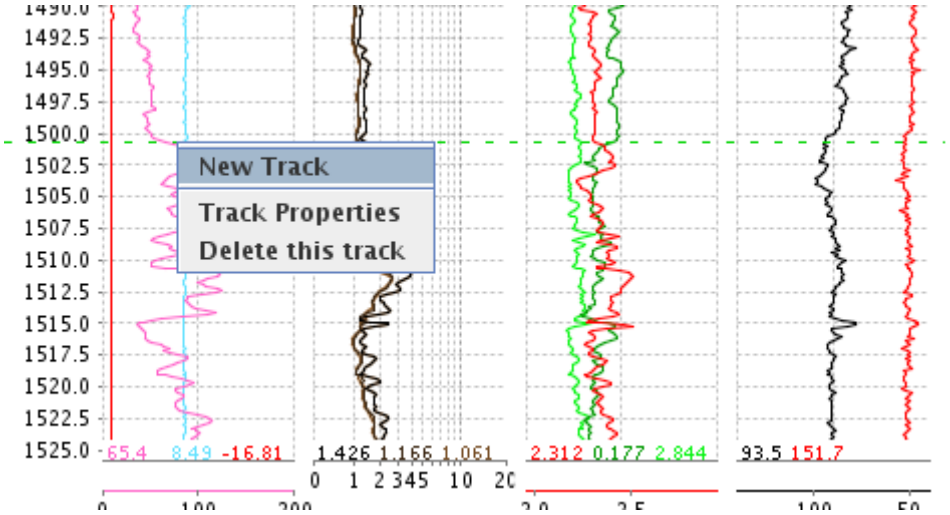
Wireline Log Traces Panel allows you to perform end members picks for reservoir and non-reservoir lithologies. The lithology picks will be calculated and form trends.

1. Generally, four tracks are available in the Wireline Log Traces Panel. It provides visualization of the well log data. See table above: each track has its dedicated mnemonic class(es) that is predetermined by the system.



2. Log curve values are reported below each track for the current cursor position.

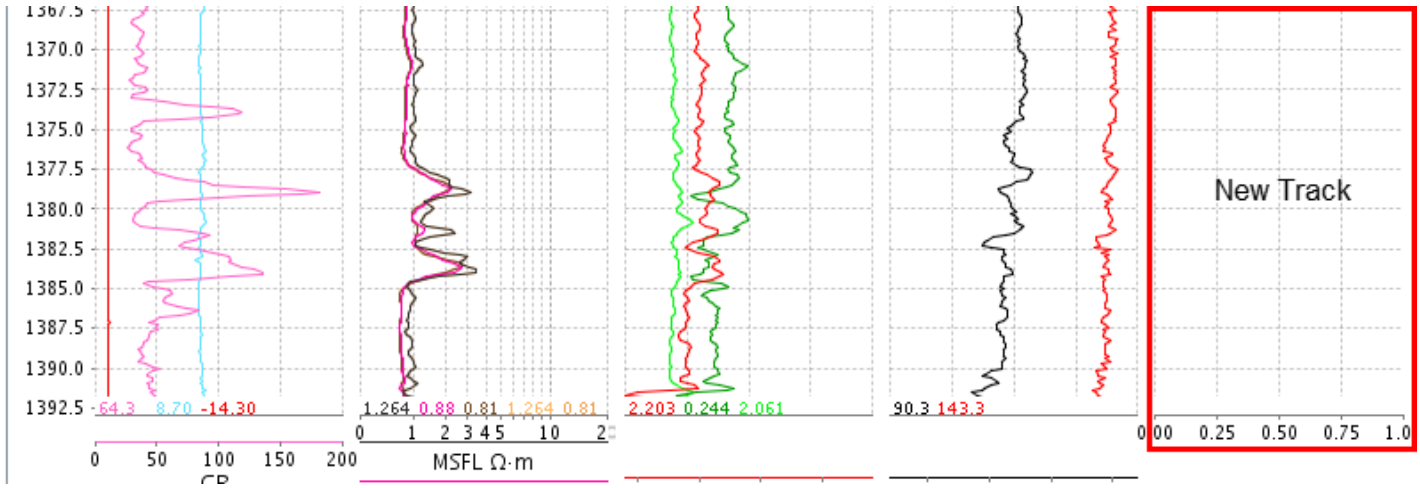
Wireline Log Traces Settings



Options are available for you to customize the wireline log curves to make each of the track more presentable and informative.

To call out the options, you may right click on any region of each track. The wireline log curve options list appears. You can control and change the setting for that particular track. Options available are New Track, Track Properties and Delete Track.

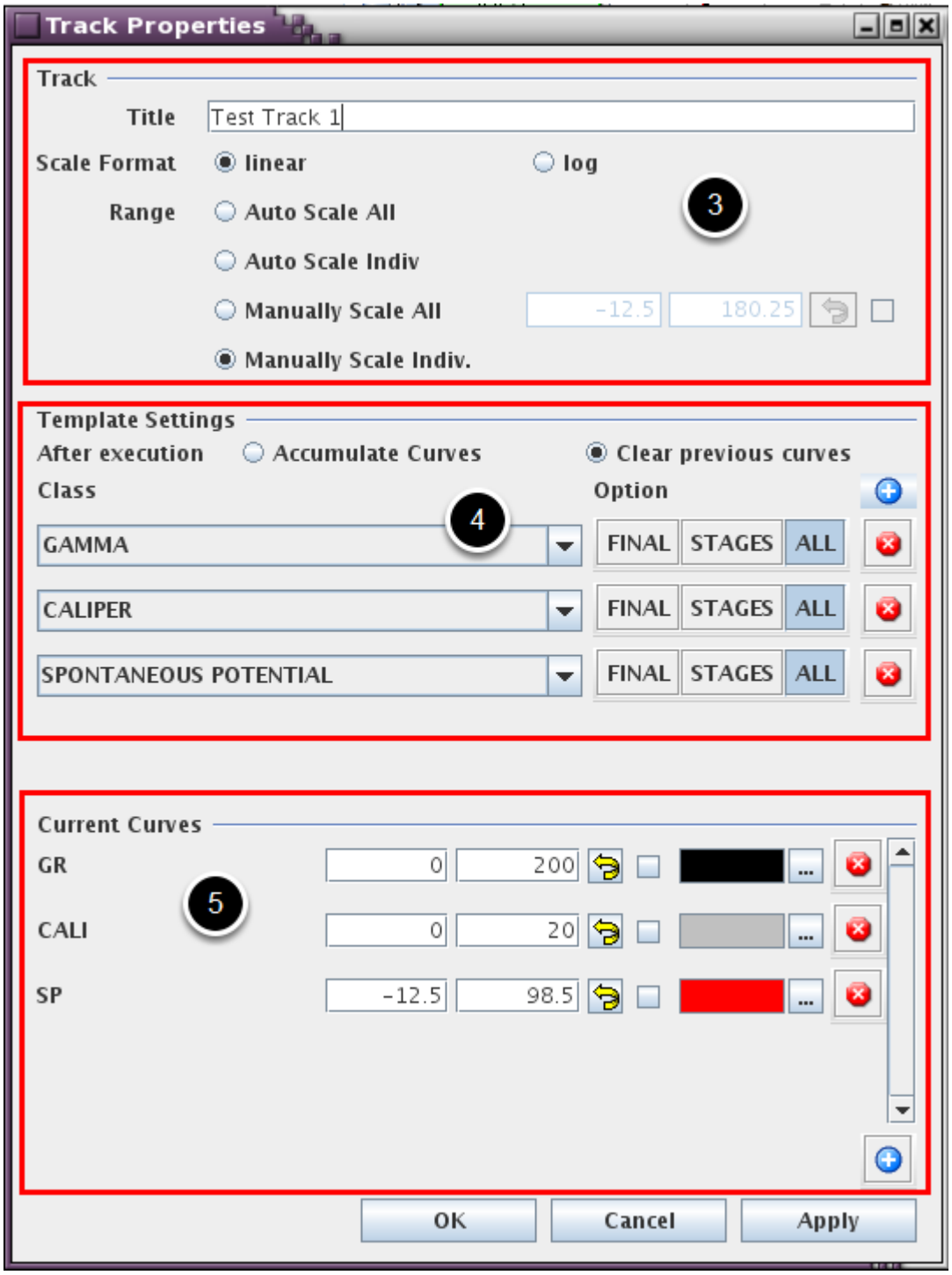
New Track



To add a new track in the Wireline Log Traces Panel:

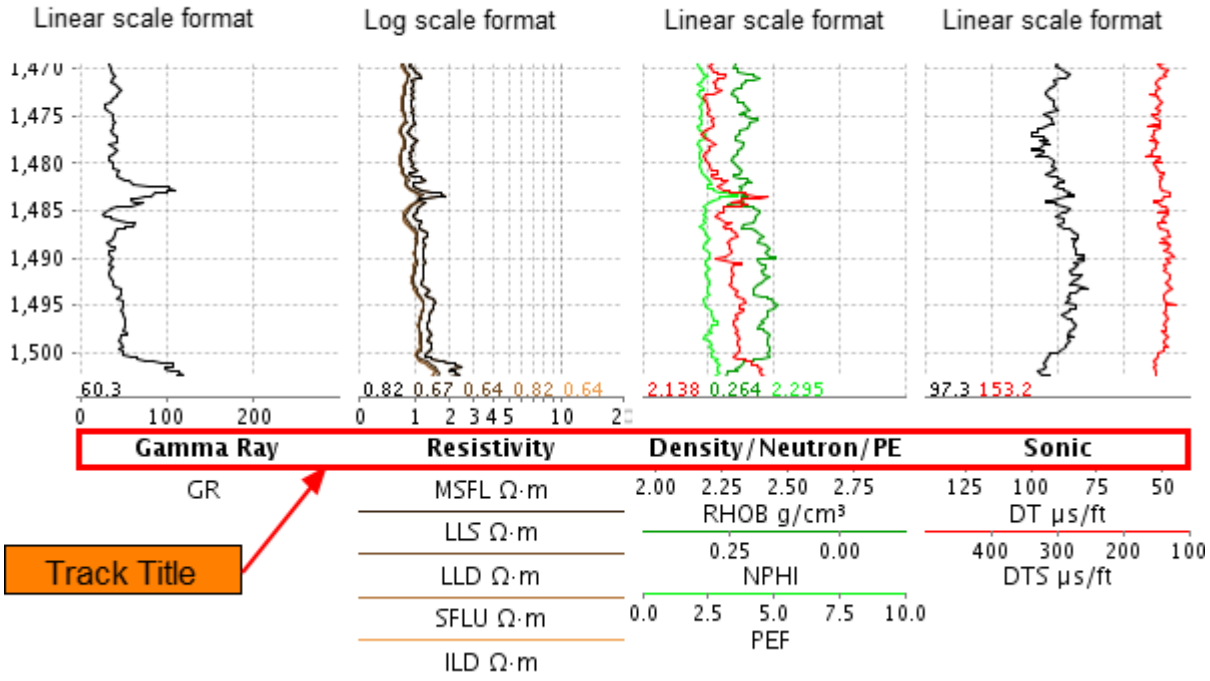
- Right-click on the track and select **New Track**. An additional track is added on the right.
- Right-click and select **Track Properties** to configure and display curve in new track.

Track Properties

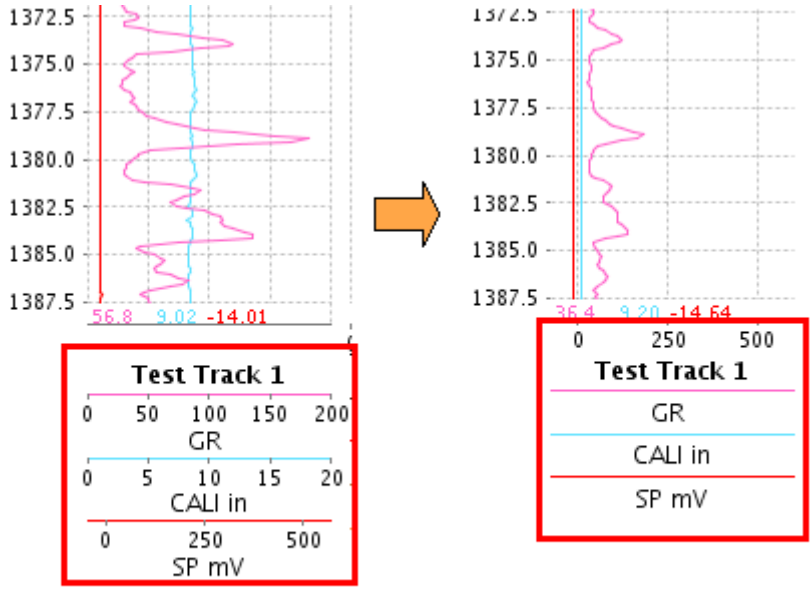


To customize the wireline log curves (track) settings:

1. Right-click on the track and select **Track Properties** to customize the track settings.
2. The **Track Properties** dialog box appears. This dialog box has three sections: **Track**, **Template Settings** and **Current Curves**.



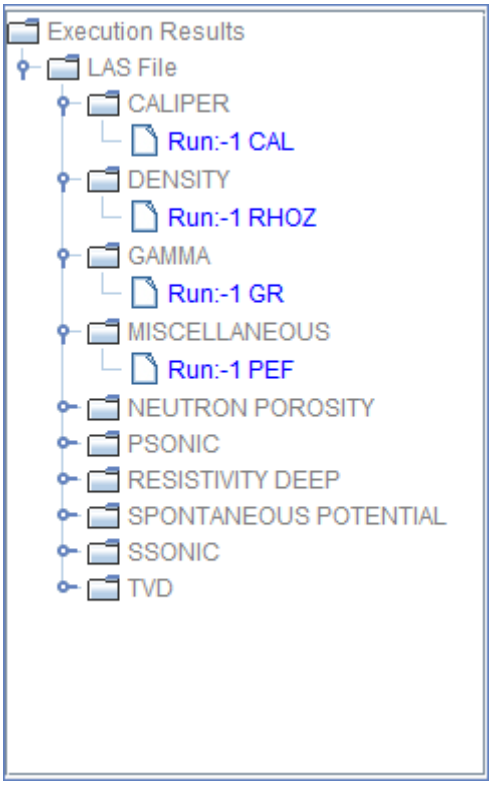
3. **Track Section —** This section allows you to alter the track title, scale format and the range of the selected track.
    - To change the track Title, enter a name in the **Title** text box and click **Apply**. The name displays underneath the selected track in the Wireline Log Traces Panel.
    - For resistivity data, the **Scale Format** is defaulted to log. Others are defaulted to linear. You can change the scale format to be either **linear** or **log** (logarithmic), if necessary. Click **Apply** to change the scale format.
    - To change the track **Range**, select from the list the track scale range that is appropriate. Click **Apply** to confirm. The selected track scale is standardized across all the curves in the selected track.
    - For **Manually Scale All** option, enter minimum and maximum scale values into the numeric boxes. If you wish to reset the values to its original values, click the Reset icon. Select the check box to flip the grid's scale.



Auto-scale is applied to all the curves in the track

4. **Template Settings Section —** The Template Settings section displays the dedicated mnemonic class for each track. This section offers you the flexibility to set the mnemonic class(es) for each track in the Wireline Log Traces Panel and to set the plotting in crossplot charts. You may add or remove the class display in the selected track.
    - To add a **Class**, click the Add icon. A blank drop down list appears. Click the drop down list to select a class in which you wish to display the curve in the track and click **Apply** to confirm.
    - To delete a **Class**, click the Remove icon next to the class that you want to remove in the **Template Settings** section and click **Apply** to confirm.
      You have to save the session whenever you add or delete a class as the change of the Template Settings will only take effect when you re-open the saved session.
    - To change the **Option**, there are three options available:
        1. **ALL** - selected by default, as this results in plotting all traces (picks) in that class.
        2. **FINAL** - only the last trace (pick) of that class will be plotted in crossplot charts.
        3. **STAGES** - pick a number and that number trace (pick) of that class will be plotted in crossplot charts.
           Click **Apply** to confirm.

5. **Current Curves Section —** This section displays all the curves in the selected track. You may add or remove other curve(s) in the selected track.
    - To add a curve, click the Add icon in **Current Curves** section. The **Execution Results** list appears. Double click to select the curve that you want to display together with the current curve in the selected track. The selected curve is added in the **Current Curves** section. Click **Apply** to confirm.



- To delete a curve, click the Remove icon next to the curve that you want to remove. Click **Apply** to confirm.
- To change the colour of the curve, click the **Colour** button to select the colour from the list. Alternatively, you may click **...** to select more colours from the colour palette. Click **Apply** to confirm the colour.

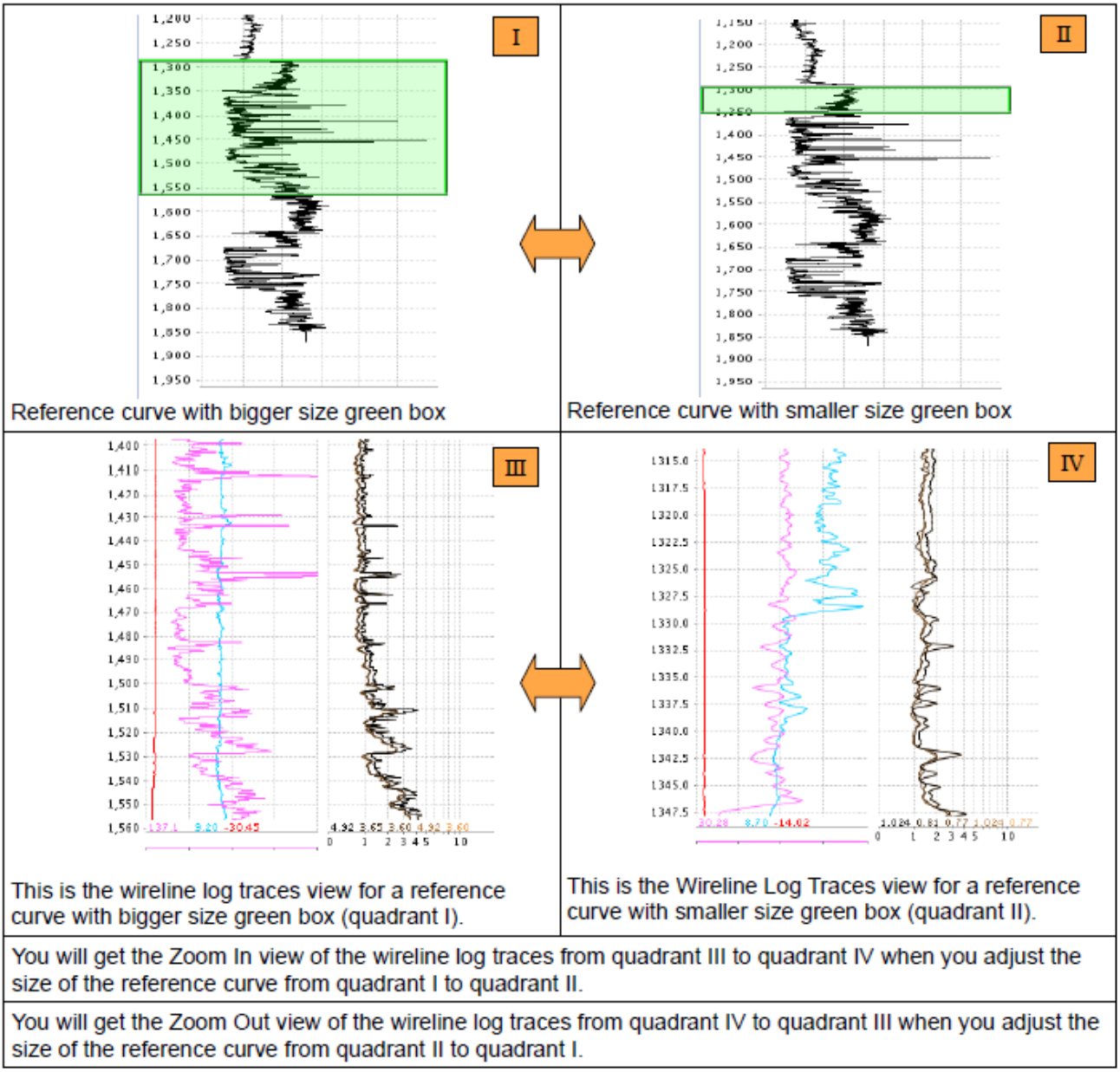
Delete track

To delete the wireline log traces (track):

1. Right-click on any region of the track that you wish to delete.
2. Select **Delete this track** option to delete the track.

Note: You can only delete one track a time.

Zooming in and out from the Navigation Panel



Reference curve with bigger size green box

Reference curve with smaller size green box

This is the wireline log traces view for a reference curve with bigger size green box (quadrant I).

This is the Wireline Log Traces view for a reference curve with smaller size green box (quadrant II).

You will get the Zoom In view of the wireline log traces from quadrant III to quadrant IV when you adjust the size of the reference curve from quadrant I to quadrant II.

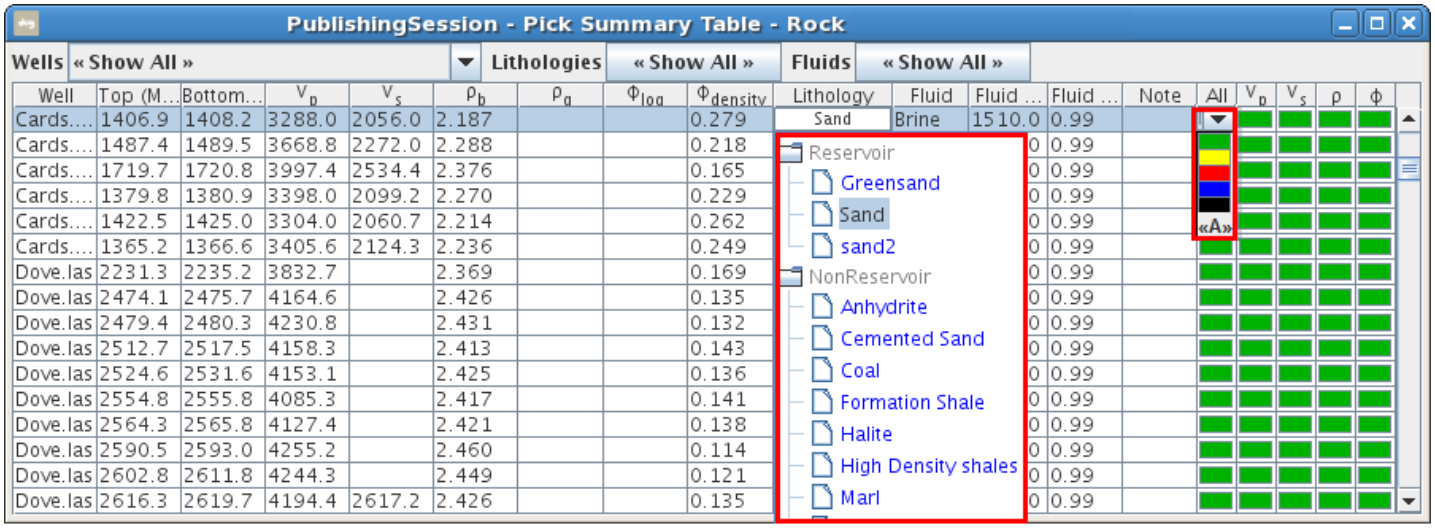
You will get the Zoom Out view of the wireline log traces from quadrant IV to quadrant III when you adjust the size of the reference curve from quadrant II to quadrant I.

Wireline Log Traces Panel can be zoomed through reference curve in the Navigation Panel. To zoom, do one of the following:

- **Zoom In Wireline Log Traces** — Point to the bottom or upper edge of the reference curve green box. Pull the bottom and/or upper edge to adjust to a smaller green box.
- **Zoom Out Wireline Log Traces** — Point to the bottom or upper edge of the reference curve green box. Pull the bottom and/or upper edge to adjust to a bigger green box.

Pick Summary Table

When picks are performed in the wireline log traces, the picks data will be tabulated in the Pick Summary Table. You are allowed to change the lithology, fluid and qualities of the picks in the Pick Summary Table. Other values tabulated are fixed and cannot be changed in the Pick Summary Table.



Changing the lithology and quality from its drop down list.

To change the lithology, fluid and quality types in the Pick Summary Table:

1. Ensure the **Picking Enabled** function is activated in the **Track Interpretation** window.
2. Click the selected **Lithology**, **Fluid** or **Qualities**. A drop down list appears.
3. Select the option from the **Lithology**, **Fluid** or **Qualities** drop down list.

Quality options

Quality options allow you to decide on the level of confidence you have in the elastic properties across a blocked interval. The **Quality** option is defaulted to **Good** which is in green. The selected **Quality** option for the pick will automatically be displayed with the assigned colour in the crossplot. You can choose to display/ hide picks for a particular quality from the Control Panel (see *How to Display/Hide Information in Crossplots*).

To change the **Quality** option:

1. Click the **Quality** drop down list to select the quality option e.g. **None**, **Missing**, **Questionable**, **OK**, **Good** for the Compressional Velocity (Vp) , Shear Velocity (Vs), density (ρ) and porosity (φ). Select **<<A>>** in the quality option for missing porosity. The quality option is only applicable after picking.
2. There is a specific colour assigned to each **Quality** option. The colour assigned cannot be altered. See below for a list of assigned colours and symbol to the corresponding **Quality** option. This is displayed in the Picking section:
    - **None** – Black

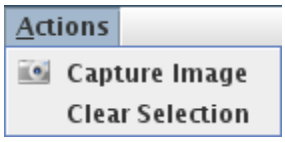
- **Missing** – Blue
- **Questionable** – Red
- **OK** – Yellow
- **Good** – Green.

For more information, see also *Pick Quality*.

Actions Menu

There are two options available in the **Actions** menu:

- Capture Image
- Clear Selection.



Capture Image

Capture Image option allows you to capture the images in a standard and presentable format for reporting. You can produce a better quality report by using this option to capture standard images. You can save the image in either PNG or JPG format. It is recommended that the image be saved in PNG format to take advantage of higher resolution image and smaller file size.

1. Click the **Capture Image** icon.
2. Hover the mouse over an area of the display that you wish to capture. The currently selected area will be shadowed. To increase the selection to include surrounding panels, press the space bar or PageUp. When satisfied with the selected area, left click or press Enter to capture the image.
3. The **Save Image to File** dialog box appears.
4. If you wish to cancel the saving process, press Esc or Cancel the Save dialog box.

For more information on capturing images, see *Customize, Capture & Save Crossplot Charts for Presentation & Reporting*.

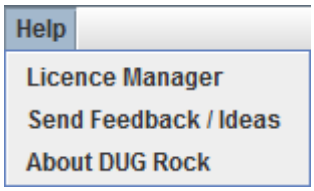
Clear Selection

The Clear Selection option unselects the current pick.

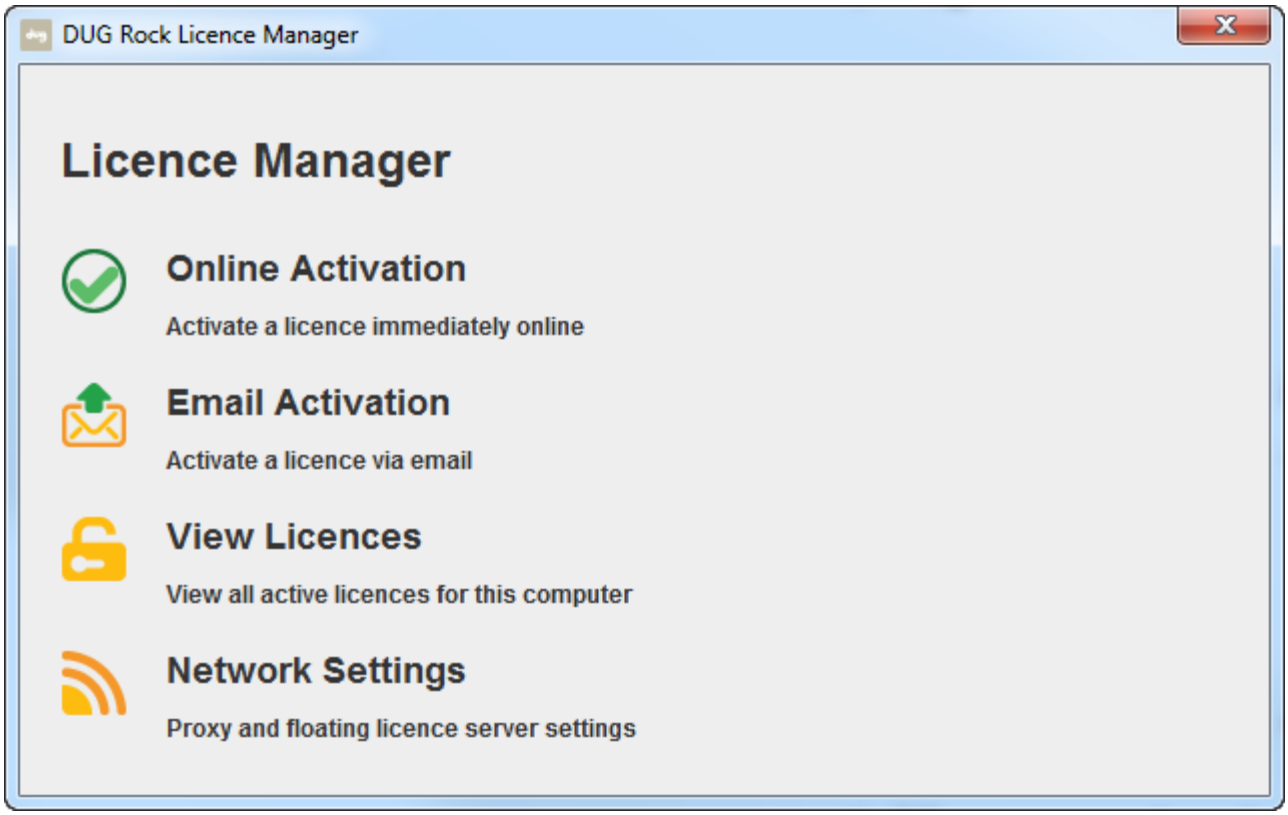
Help Menu

There are three options available in the Help menu:

- Licence Manager
- Send Feedback/Ideas
- About DUG Rock.



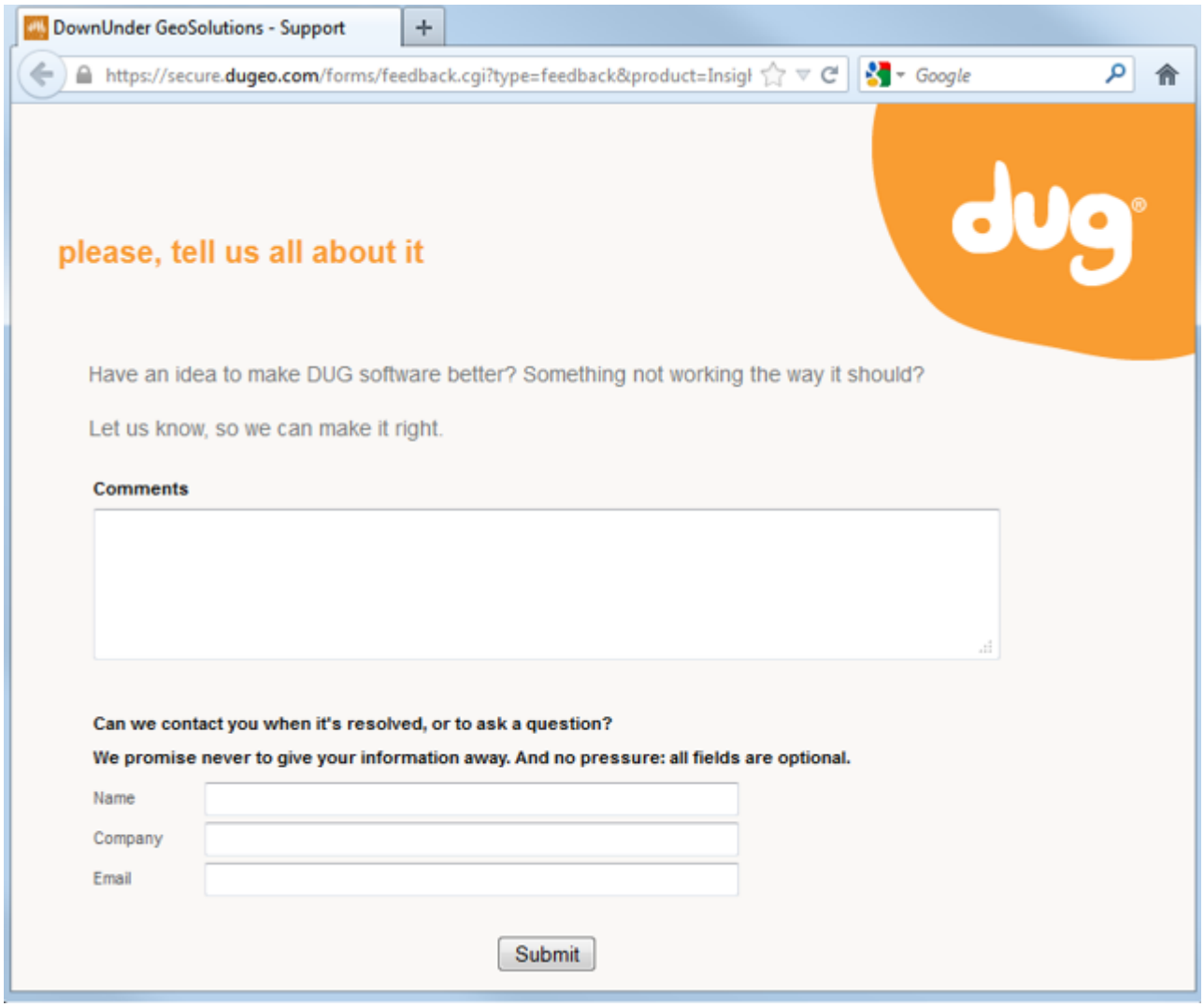
Licence Manager



The Licence Manager can be used to activate your licence, view your active licences and configure your network settings.

Refer to the *Licensing* chapter in the Insight manual for more information.

Send Feedback/Ideas



If you have any ideas or feedback you would like us to know about, send them to us to help us improve DUG Rock.

About DUG Rock

This will display the software version number, copyright information and Insight's website address.

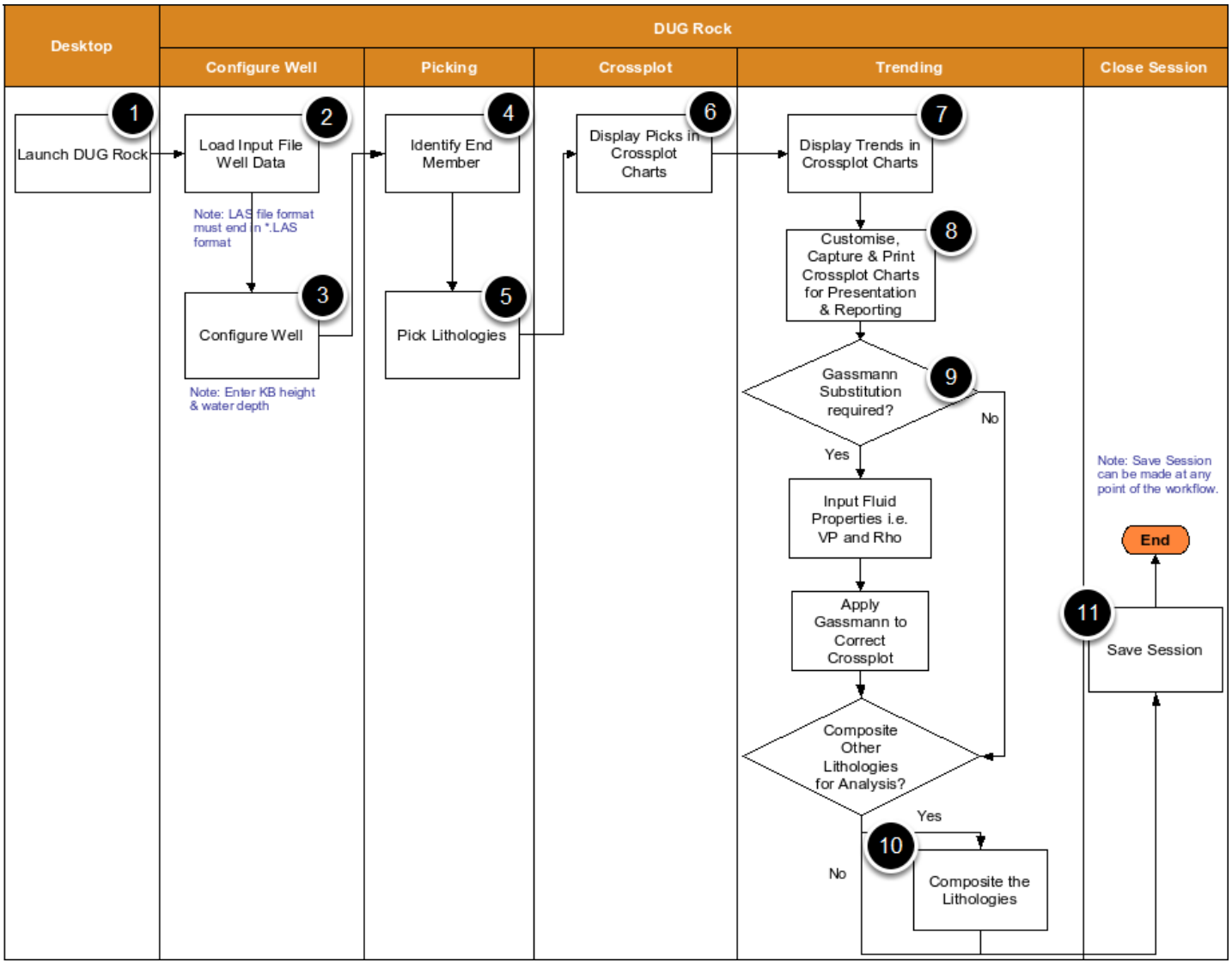
To make sure you have the most recent version, compare the version number with the version on our website.

Tutorial Overview

Workflow

The workflow diagram below depicts the common processes to be carried out step-by-step to produce and generate interpretation results in DUG Rock. The subsequent sections will describe the steps for identifying and interpreting the rock physics trends for probability prediction of lithologies and fluids.

Note: Sample data including wells, picks and trends, can be downloaded from our website.



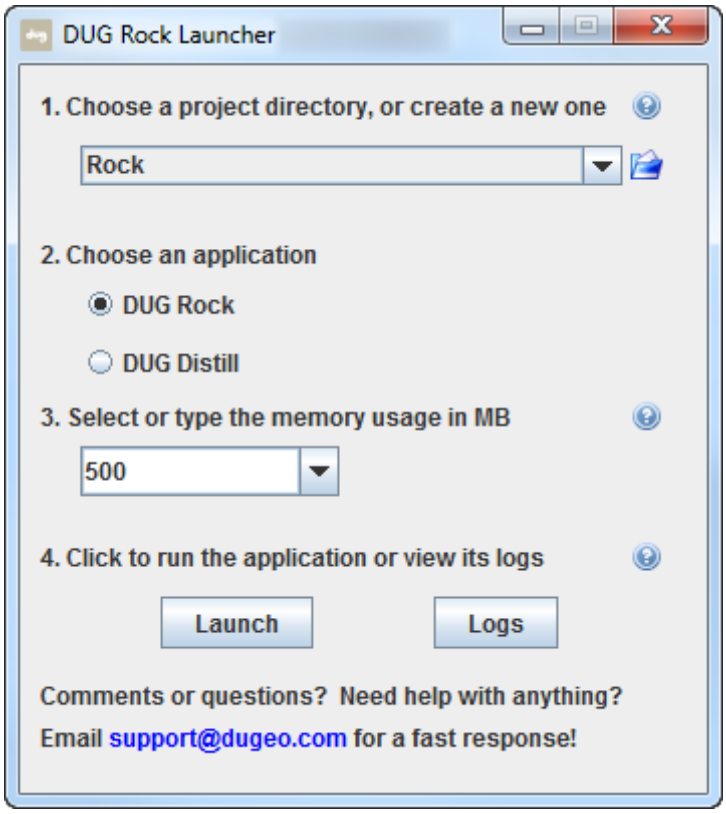
Click on the links below to jump to that particular section:

1. *Launch DUG Rock*
2. *Load Well Data*
3. *Configure Well*

4. *Identify End Member*
5. *Pick Lithologies*
6. *Display Picks in Crossplot Charts*
7. *Display Trends in Crossplot Charts*
8. *Customise, Capture and Print Crossplot Charts for Presentation and Reporting*
9. *Gassman Substitution*
10. *Composite Lithologies*
11. *Save Session*.

Launching DUG Rock

How to Launch DUG Rock for Windows



1. Double click the DUG Rock icon in the Desktop or Start Menu to launch DUG Rock. The DUG Rock Launcher will appear.
2. Click on the Folder icon to select a project or create a new project.
3. Select the **DUG Rock** application.
4. Type or choose the maximum amount of memory that this application is allowed to use. By default, 500 Mb is selected and is generally enough.
   Note: If you have a large number of wells or other data, you may see a message telling you that you need to increase this number. However, avoid choosing an amount that is too large for your computer. Running out of physical memory will make all applications run extremely slow. Please check with your IT department if you are unsure.
5. Click **Launch**.

How to Launch DUG Rock for Mac OS X

DUG Rock can be installed anywhere on your system. Most people choose to drag it to the **Applications** folder.

Double click the **DUG Rock** icon in the Applications folder or your alternate installation location. The DUG Rock Launcher will appear. Follow the steps above to launch DUG Rock.

How to Launch DUG Rock for Linux

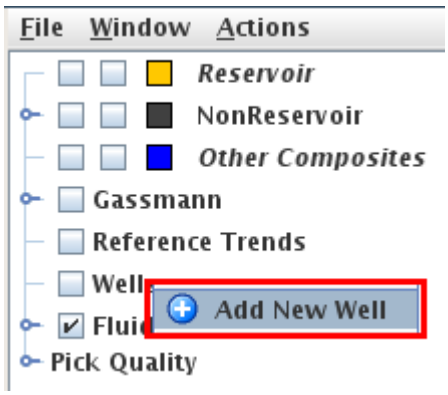
1. Open the **Main Menu** on your task bar
2. Open the **Office** or **Graphics** sub-menu
3. Click **DUG Rock.** The DUG Rock Launcher will appear. Follow the steps above to launch DUG Rock.

Load Input Files

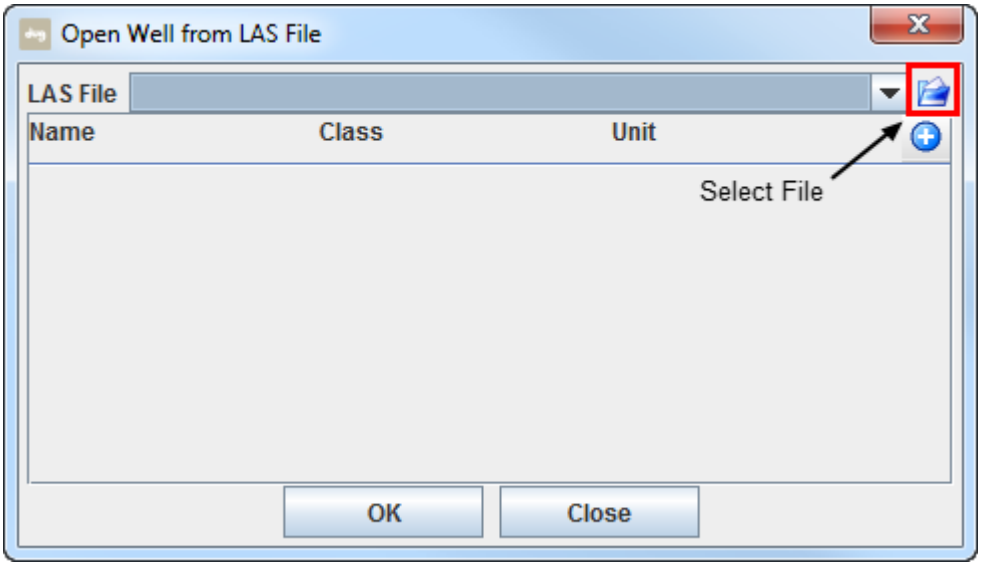
Load Well (LAS) Files

The first step when using DUG Rock is usually to introduce well data from LAS files. For deviated wells, you should have a True Vertical Depth (TVD) curve in your LAS file before loading.

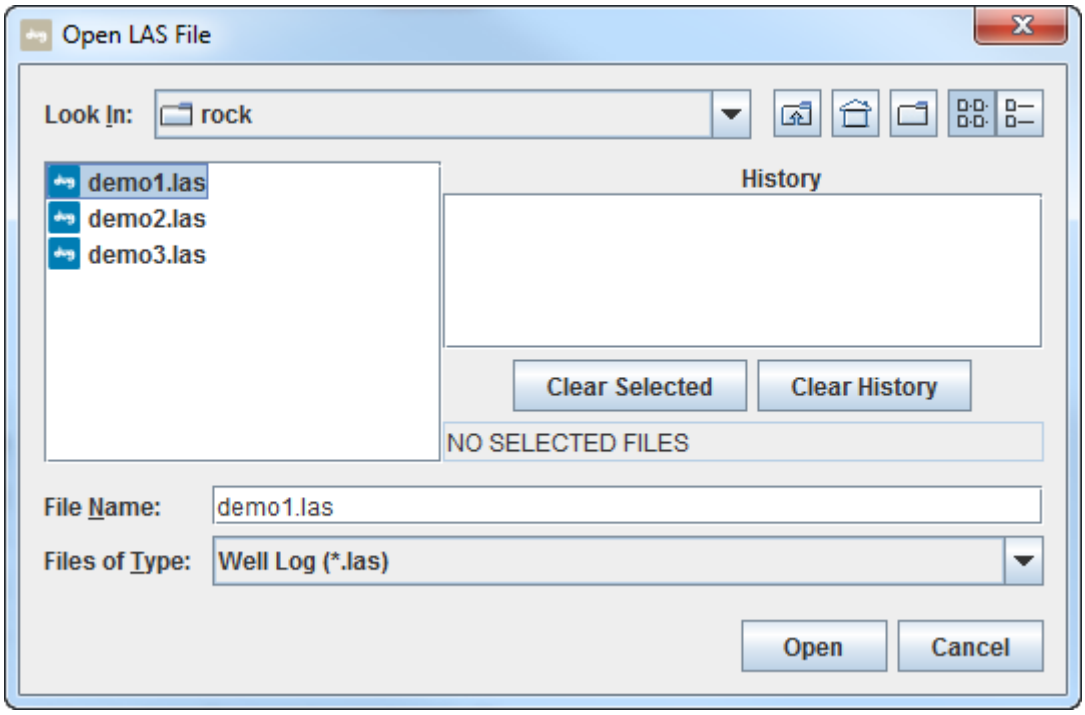
How to Load the Input File(s)



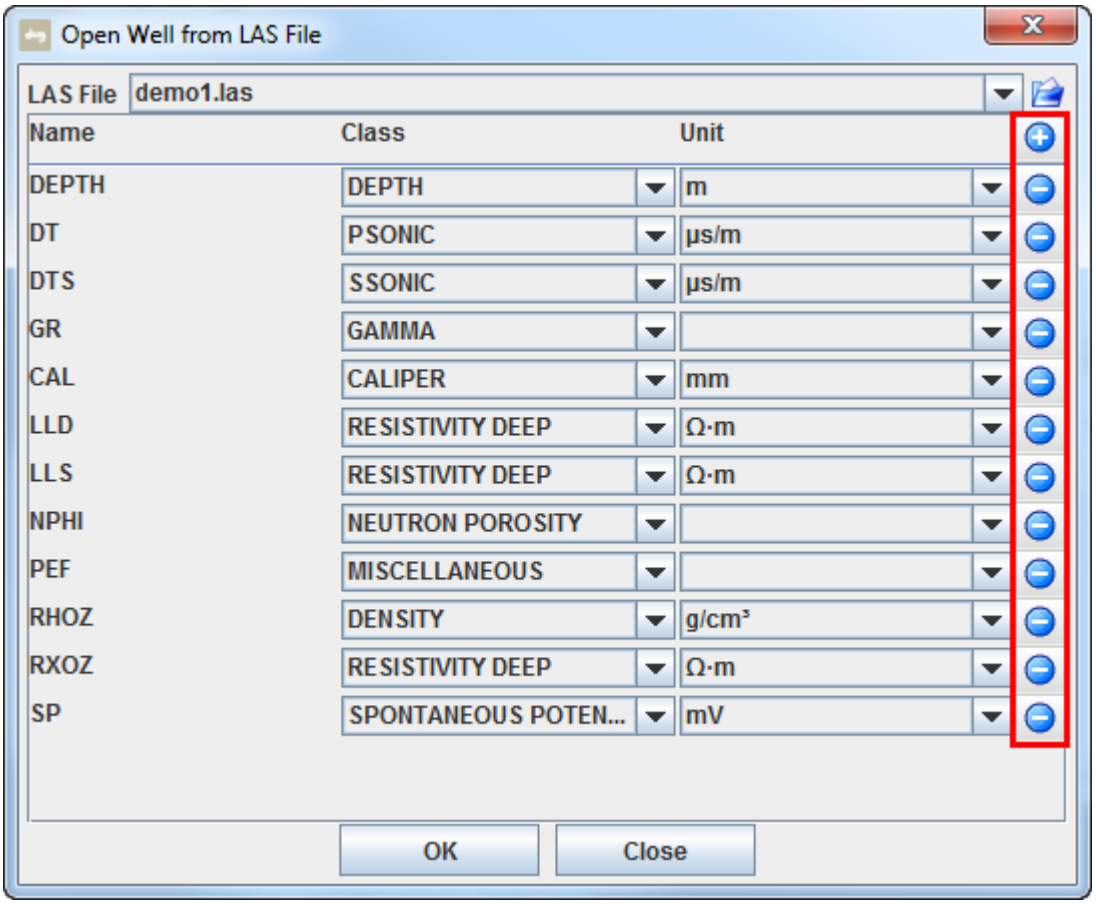
1. From the Control Panel, right-click **Wells** to select **Add New Well**. The **Open Well from LAS File** dialog box appears.



2. Click the **Select File** folder icon. The **Open LAS File** dialog box appears.

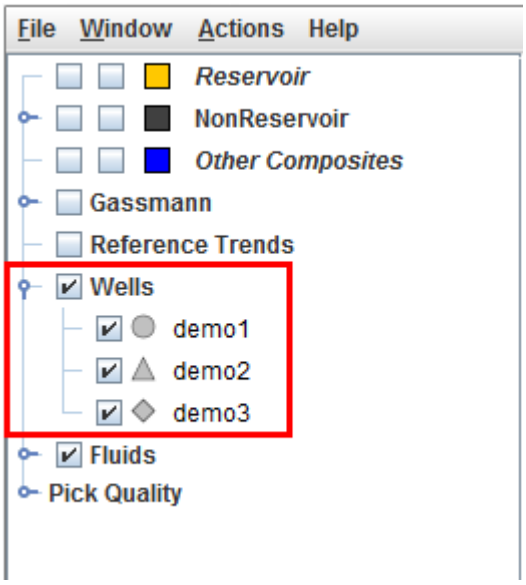


3. From the dialog box, locate the well log file with a file extension **.las*. Click the **.las* file and then click **Open**. The dialog box closes to make way for the **Open Well from LAS File** dialog box. All the well curves in the LAS file will be displayed.



4. To add or remove a well curve, click on the **Add Row** or **Remove Row** buttons respectively.
5. Verify the **Units** and **Class** column to ensure the designated class matches the curve data.
6. Click **OK** to open the LAS file.

Note: When there are two different depth curves available in the LAS file, you must assign the Class **Depth** to the appropriate **MD** Curve. Then assign **Miscellaneous** to other depth curves as you cannot have more than one class of depth.



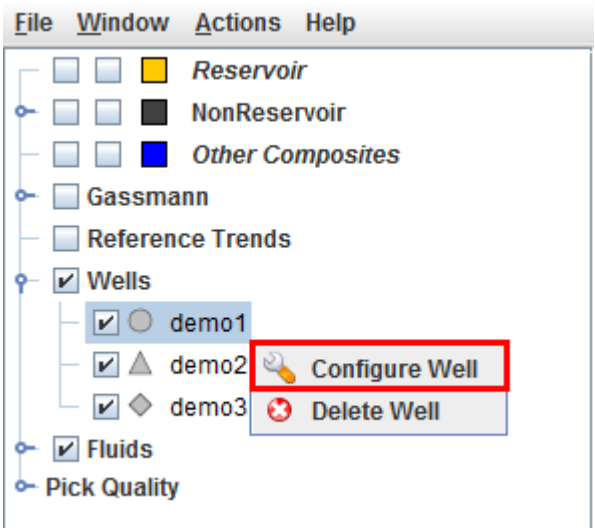
7. To see the list of wells that have been loaded, expand the **Wells** tree in the Control Panel.
8. Repeat the steps above to open multiple LAS files. All the selected well log files are displayed as shown in the image.

Configure Well

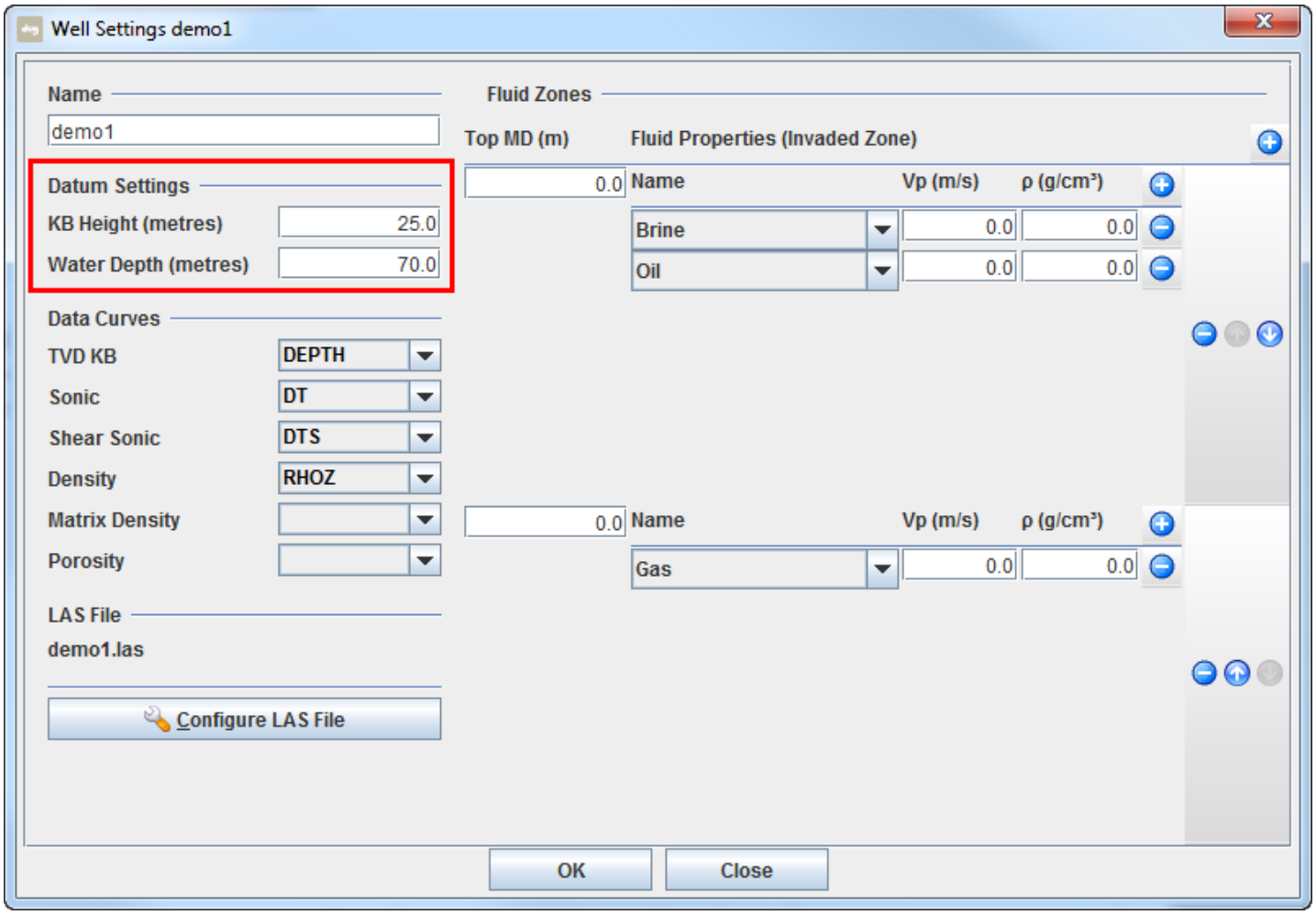
Three well log files are opened from the previous *Load Well (LAS) Files* section.

The next step is to configure the wells. It is good practice to first configure the well in DUG Rock after loading the well log data.

Well settings



1. Right click on any one of the well log file in the Control Panel and select **Configure Well**.
2. The **Well Settings** window will appear.



3. At **Datum Settings**, specify the Kelly Bushing Height (**KB Height**) and **Water Depth**. For example, 25.0m for KB Height and 70.0m for Water Depth.
   All lithology trends are plotted below mud line (BML), therefore, both the KB Height and Water Depth are required to correct the MD (measured depth) to BML.

Note: If your TVD curve is TVDSS, you will need to input your KB depth as 0.0. If your TVD curve is TVDKB, then you will need to input the correct KB (or equivalent) depth.

4. In **Data Curves**, DUG Rock will auto-populate the curves according to your selection. The **Configure LAS File** allows the reselection of curve class and units.
   All the mnemonics that are specified in the LAS files are automatically listed within the Data Curves section. You are allowed to change the mnemonic of the specific Class in the Data Curves section to suit your analysis requirement.

Picking

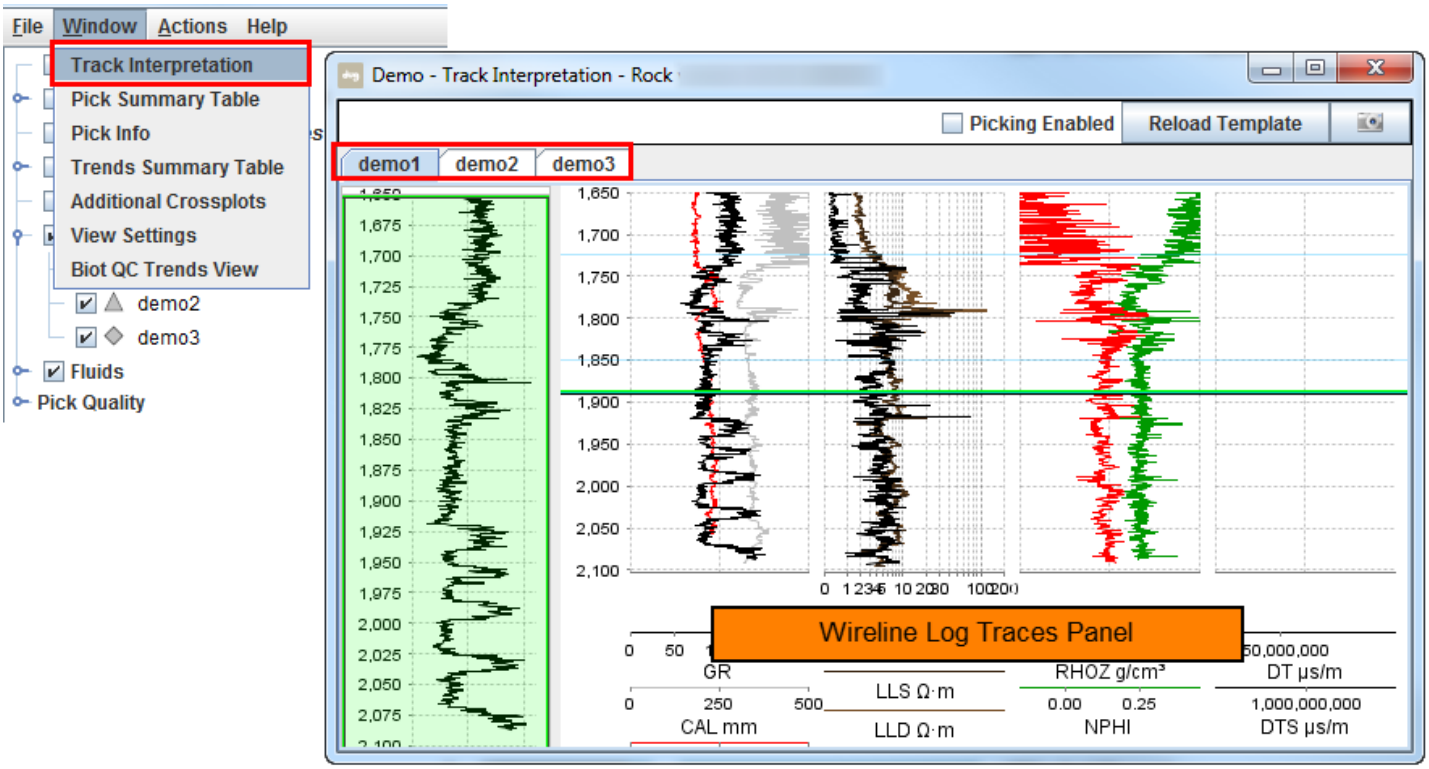
Identify End Member

After the wells configuration, you can move on to the picking process. However, before the lithology picking process is performed, you must determine the rock formation in a different depth from an external source (for example, the drilling report). After that, identify and pick the end members for reservoir and non-reservoir lithologies in the Wireline Log Traces Panel.

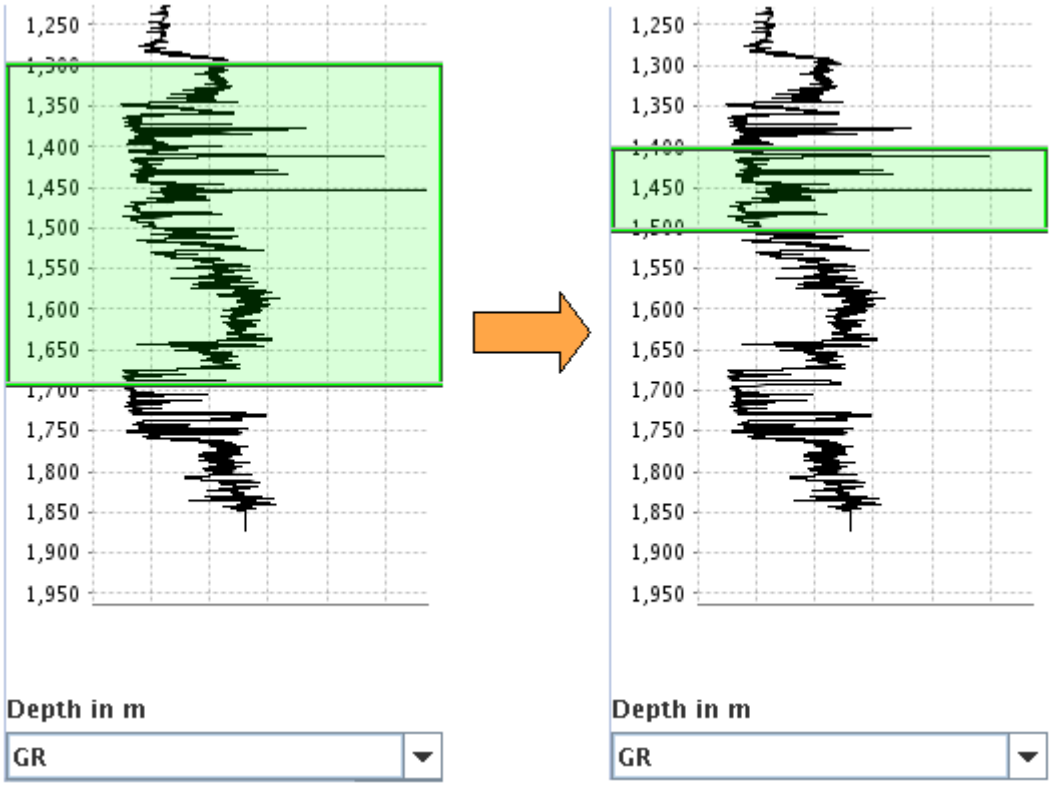
An end member is the cleanest example of lithology (typically sand and shales) which is identified in the lithological analysis. Ideally, an end member clean sand should have 100% quartz based on mineralogy. Practically, however, this is not the case and a particular end member lithology will represent the 'cleanest' picks of that lithology where log data is deemed reliable. This means that within a given end member there will be a degree of mineralogical variability, which could include variations in clay, cement and matrix minerals. Interpreting 'clean' picks involves consideration of all relevant logs (including gamma ray, resistivity, neutron, density, sonic and other relevant logs). Often a simple gamma ray cut-off is insufficient.

Let's assume that the petrophysical analysis is carried out and an end member is identified between 1,450 metres and 1,460 metres. Before the picking process is performed, you have to adjust the reference curve to a size of approximately 100m in depth to facilitate the picking process in the Wireline Log Traces Panel.

How to Identify End Member in Wireline Log Traces

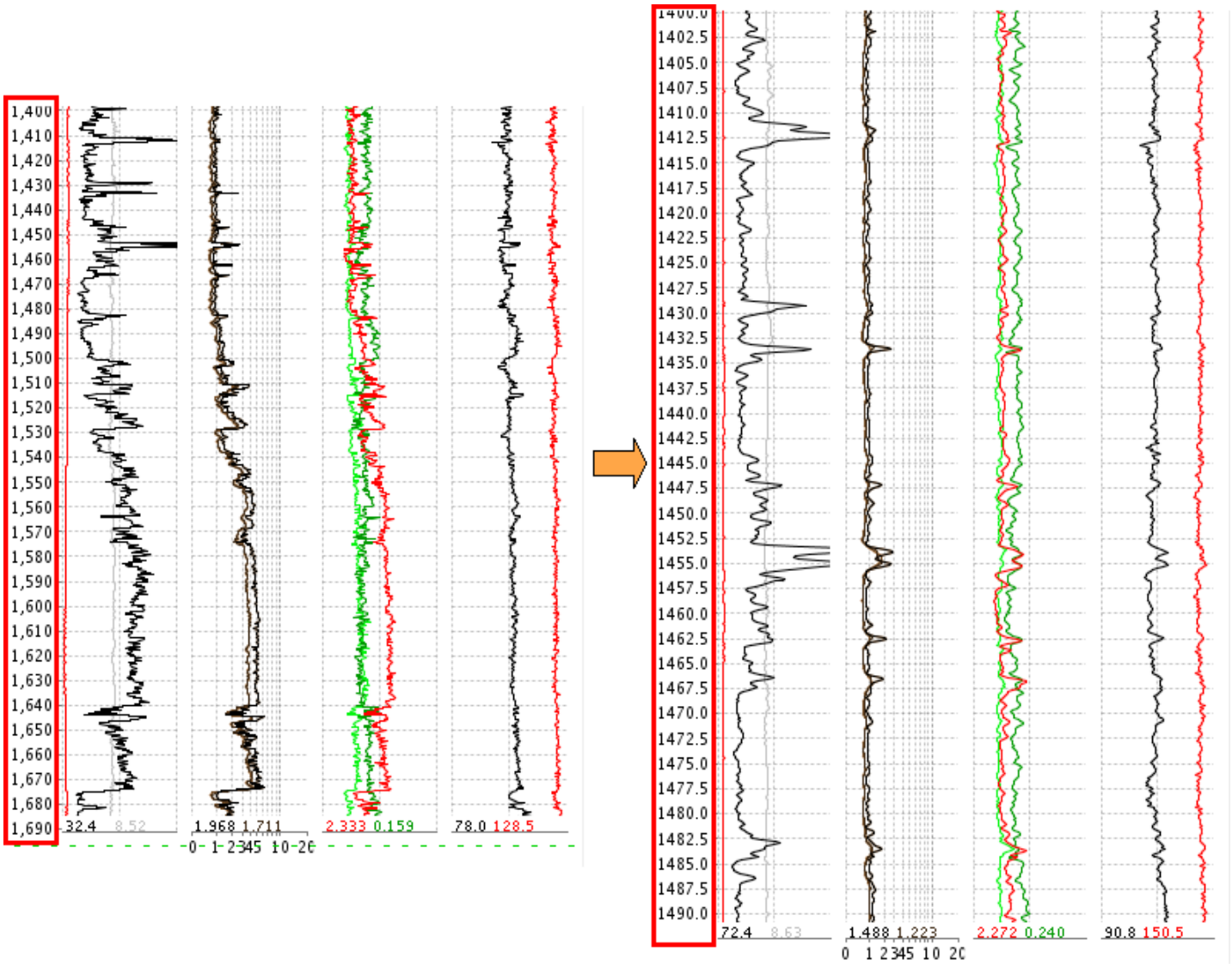


1. From the Control Panel, open the **Window** menu.
2. Select **Track Interpretation**. The Track Interpretation window will be displayed (see *Track Interpretation*).
3. Click on the well tabs to view and configure the wireline log traces.



Shrink the green box by dragging the top and/or bottom edges to a size of approximate 100m in depth.

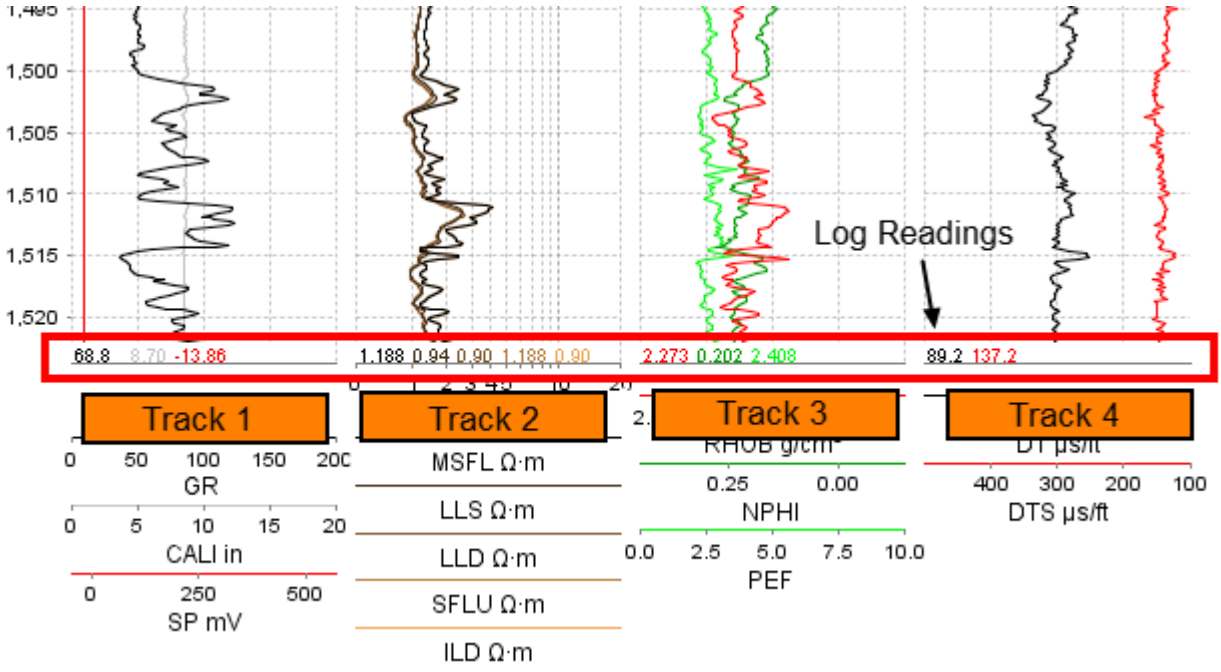
Refer to the **Wireline Log Traces Panel** to see the wireline log curves being zoomed in to a more readable data form.



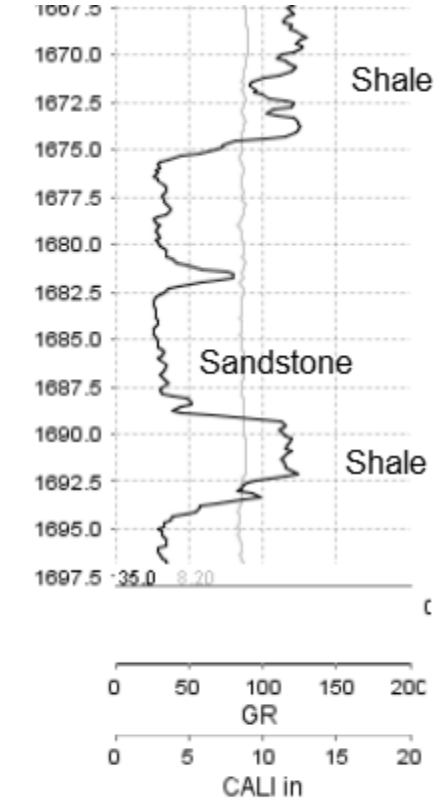
Displaying the zoom-in effect on wireline log traces after adjusting the reference curve.

Method of Analysis

There are four tracks in the Wireline Log Traces Panel. By default, all tracks are displayed in linear scale format except for the resistivity track which is displayed in logarithmic scale format. However, you may adjust the tracks and the scale format from the track settings based on your preference at a later time (see *Track Properties*).

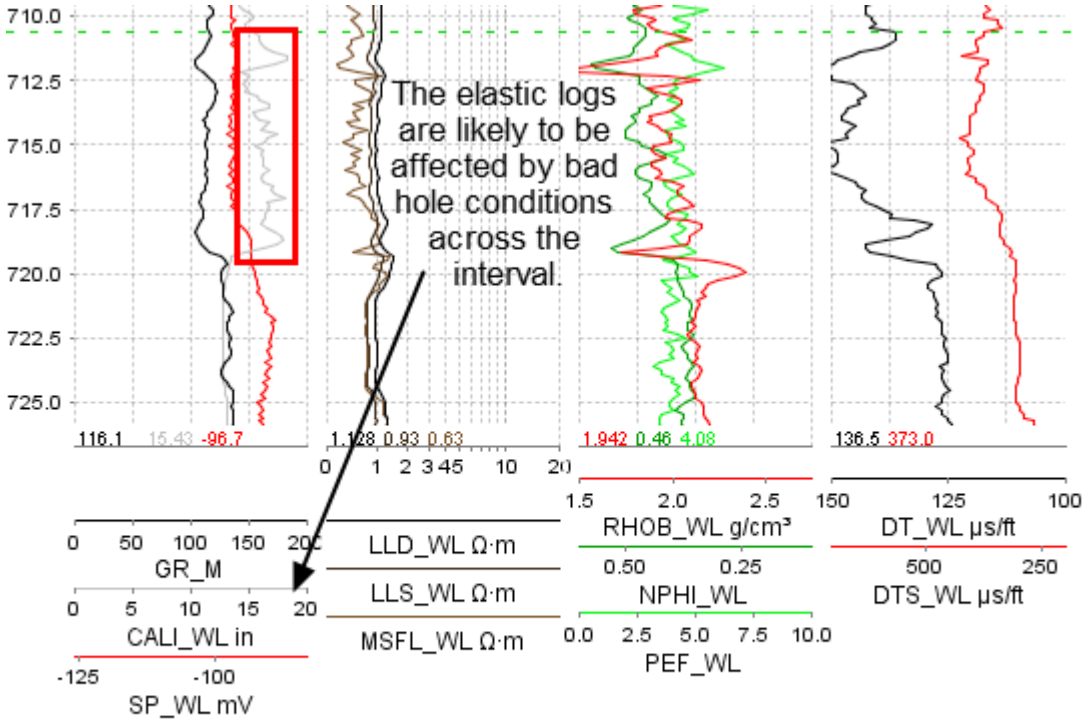


Track 1



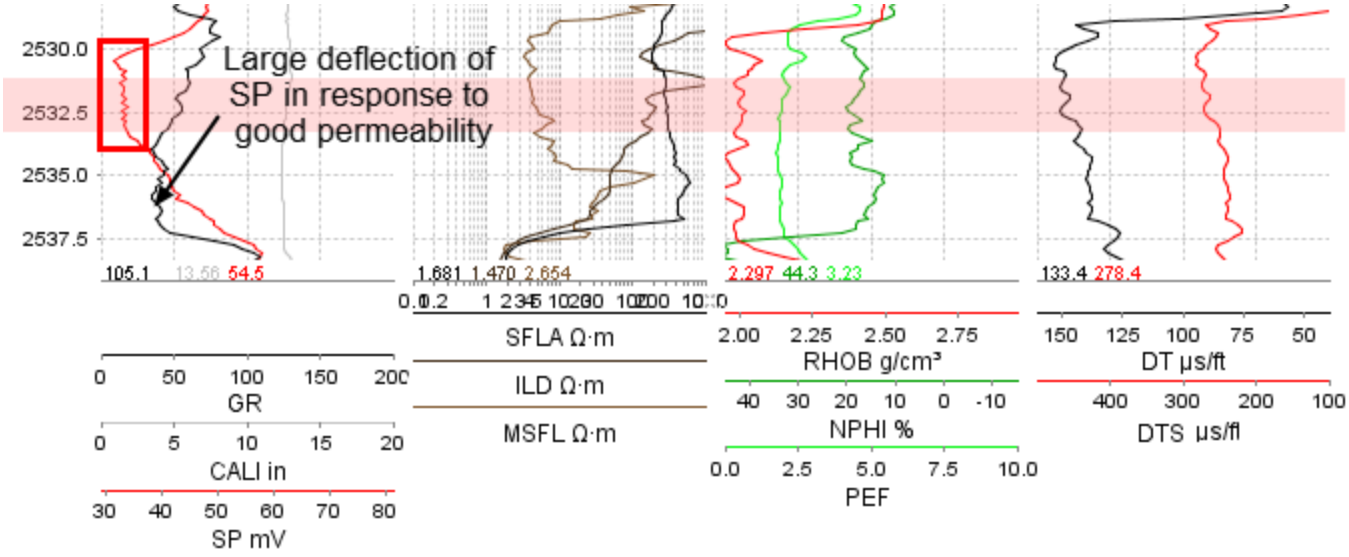
Using the Gamma Ray log response to identify shale and sandstone.

Gamma Ray log is shown in the first track in the Wireline Line Log Traces Panel by default. Typically the log is plotted on a scale from 0 to 200 with the units of API, but it is adjustable. Gamma Ray measures the natural radioactivity and can be used to determine what types of rocks are present in the well. The gamma radiation level shows increasing radiation to the right and decreasing radiation to the left. The characteristic of gamma ray is associated with three components, namely potassium, uranium and thorium. For example, shale contains more radioactive elements which emit more gamma rays. This is because radioactive potassium is a common component in clay content and tends to absorb uranium and thorium, therefore its curve will tend to shift to the right, whereas sandstone, which emits few gamma rays, will tend to shift to the left. However, sandstone can also contain radioactive minerals such as potassium feldspar, clay filling or rock fragments that cause it to have higher than usual gamma readings.



Identifying areas of bad hole using Caliper log.

Caliper log is one of the mnemonic classes shown in the first track, if selected. Caliper log is used to measure borehole diameter and is normally used for quality control, to supplement other logs during the picking process. Bad or poor hole areas can usually be determined if the caliper log has a high deflection.

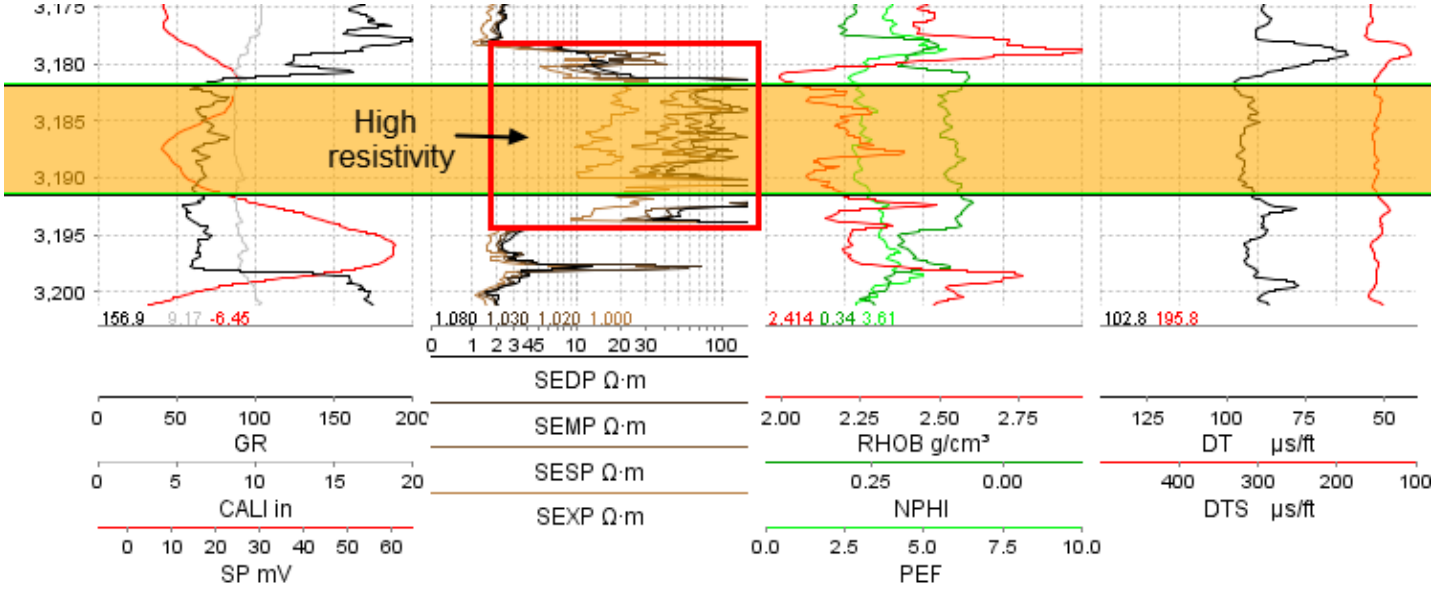


Identifying porous sandstones with high permeability.

Spontaneous Potential (SP) log is shown in the first track, if selected. SP is measured in millivolts (mV). The SP log measures the electrical potential generated between the borehole fluid and the surrounding reservoir rock and fluids. This can be used to identify permeable beds and determine the salinity of the formation water

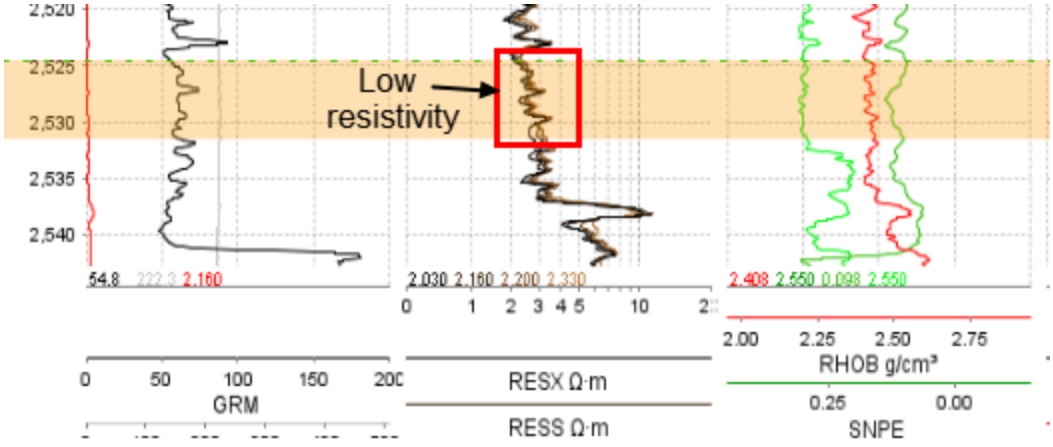
relative to that of drilling mud. For example, porous sandstone with high permeability will show large potential deflection, relative to the impermeable shale, and the SP will remain unaffected in an impermeable situation. The magnitude and the direction of the SP deflection will be very much dependent on the drilling mud used (e.g. fresh water base mud or salt water base mud). If the drilling mud is more saline than the formation water (Rmf > Rw), the SP will show a deflection to the right which is considered to be a positive deflection.

Track 2



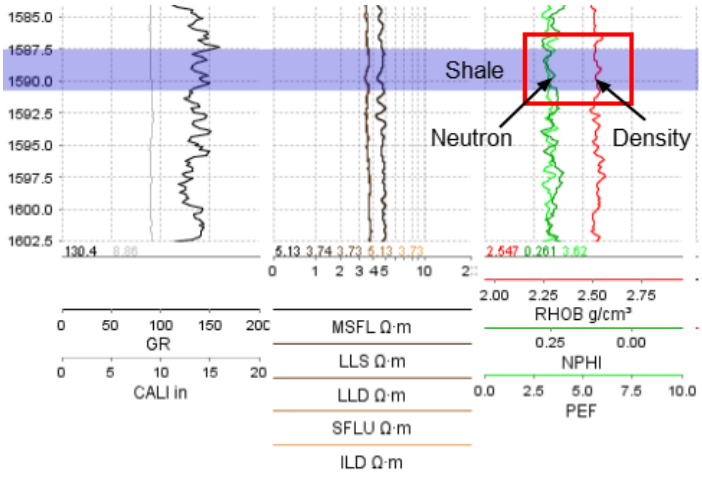
High resistivity with large negative neutron/density crossover indicates the presence of hydrocarbon.

Resistivity logs are shown by default in the second track and are scaled in units of ohm-meters. This log is presented on a logarithmic scale form. Resistivity logs measure the electrical properties of rock and fluid. When a formation contains hydrocarbon, its resistivity will be high and will show a deflection to the right, whereas when the formation is porous and contains brine water, its resistivity will be low and will show a deflection to the left. See image below of brine sand with low resistivity.

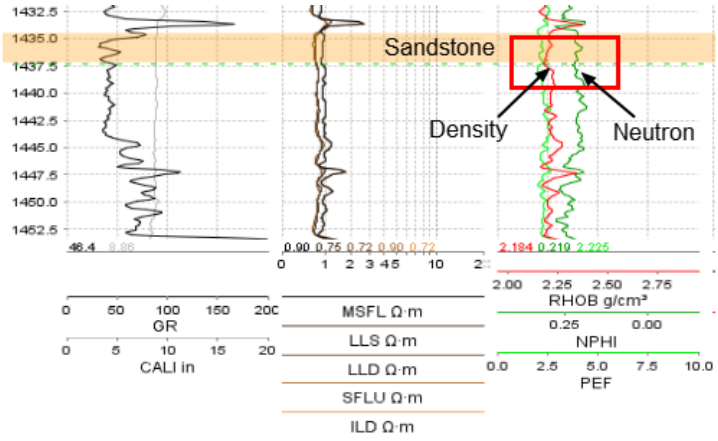


Brine sand with low resistivity

Track 3

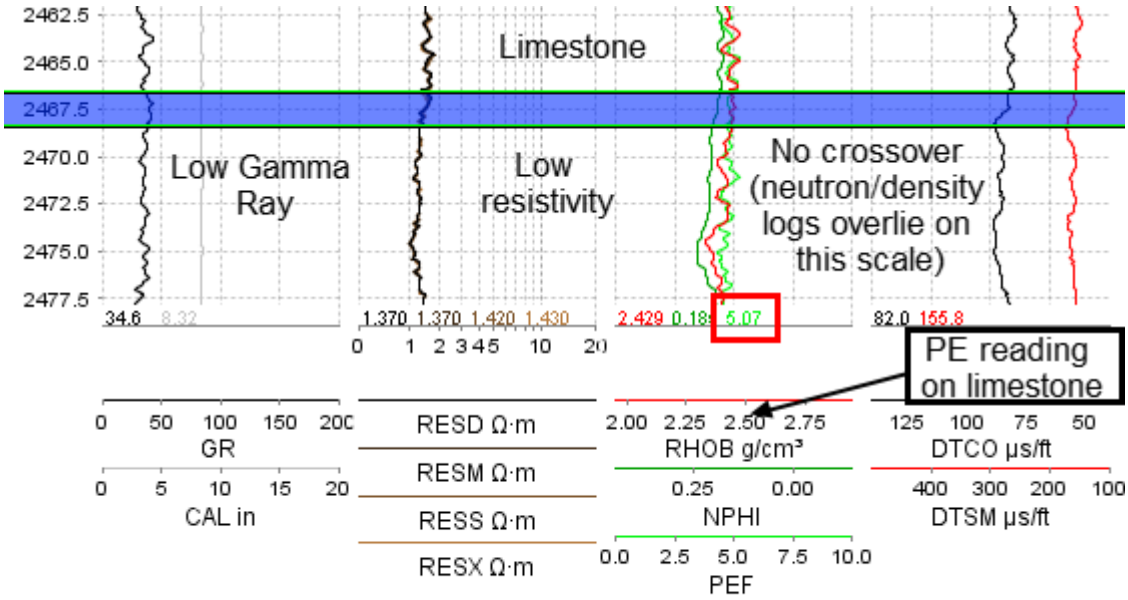


(a) Displaying the positive separation on neutron/density crossover.



(b) Displaying the negative separation on neutron/density crossover.

Density, **Neutron** and **Photoelectric** logs are displayed in the third track in the Wireline Log Traces Panel. The crossover of the neutron/density logs can distinguish the reservoir or non-reservoir lithologies. For example, shale will indicate a positive separation on neutron/density crossover (i.e. density log plots to the right of the neutron log), whereas sandstone will indicate a clean negative separation on neutron/density crossover.

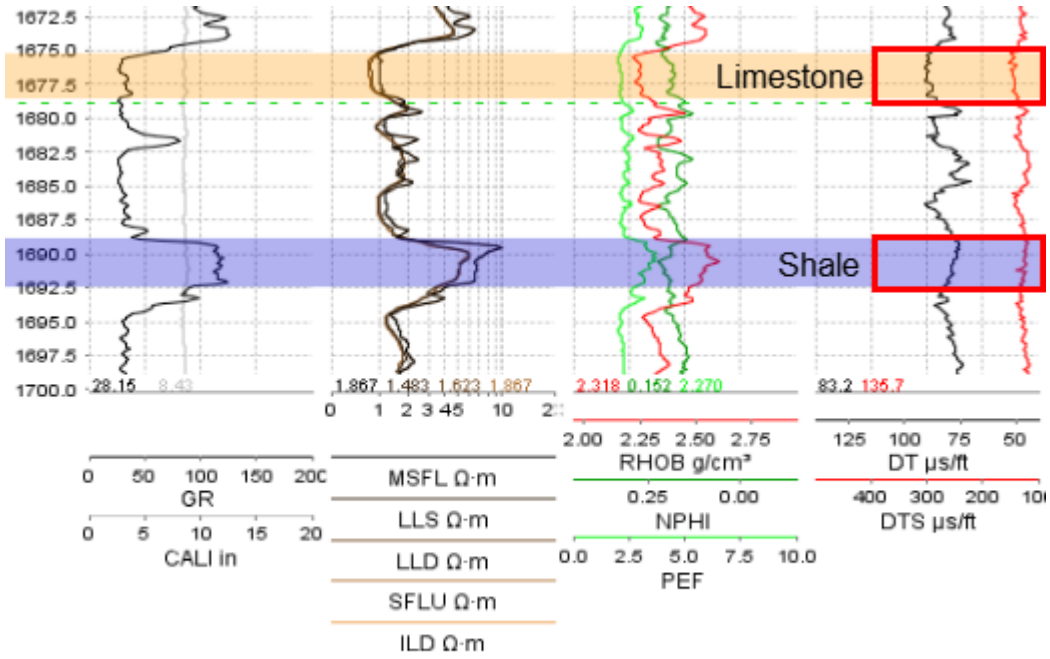


Displaying the Photoelectric log response on limestone.

The inclusion of the photoelectric (PE) log can provide an additional validation to the lithology interpretation. For example, limestone will show no crossover on the neutron/density logs (i.e. neutron and density logs overlie) due to its high matrix density. With the simultaneous consideration of photoelectric log, limestone can

be easily recognized when the PE value shows about 5 barn/electron. See *Common Logging Tool Response* for better interpretation.

Track 4



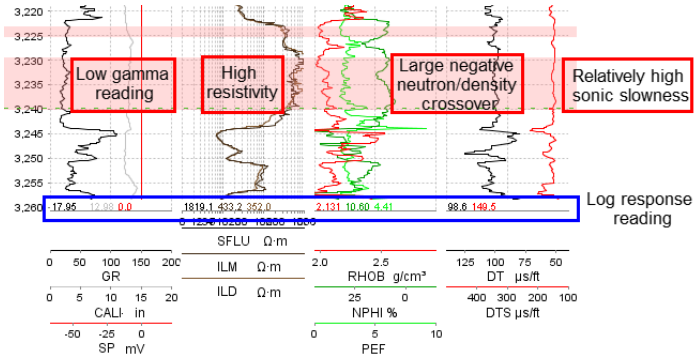
Sandstone has higher sonic slowness response compared with Shale.

Sonic logs are shown in the fourth track by default to determine the porosity by measuring how fast sound waves travel through rocks. Sound waves travel faster in rocks with low fluid content than those rocks with higher fluid contents.

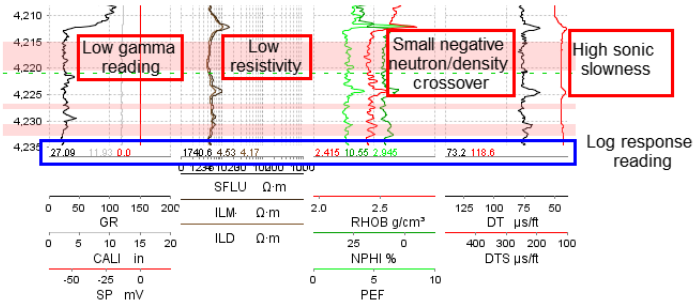
End Member Interpretation

The availability of the relevant logs is essential for end member interpretation in DUG Rock. You may not be able to get a good interpretation without involving relevant logs such as gamma ray, resistivity, density, neutron, sonic logs and so forth. Therefore, the simultaneous consideration of the relevant logs is important to get an accurate interpretation for end member picking.

Note: The coloured blocks in the examples below are the end members picking. Different types of end member are assigned to different colours. The picking process will be further explained in *Picking Lithologies*.

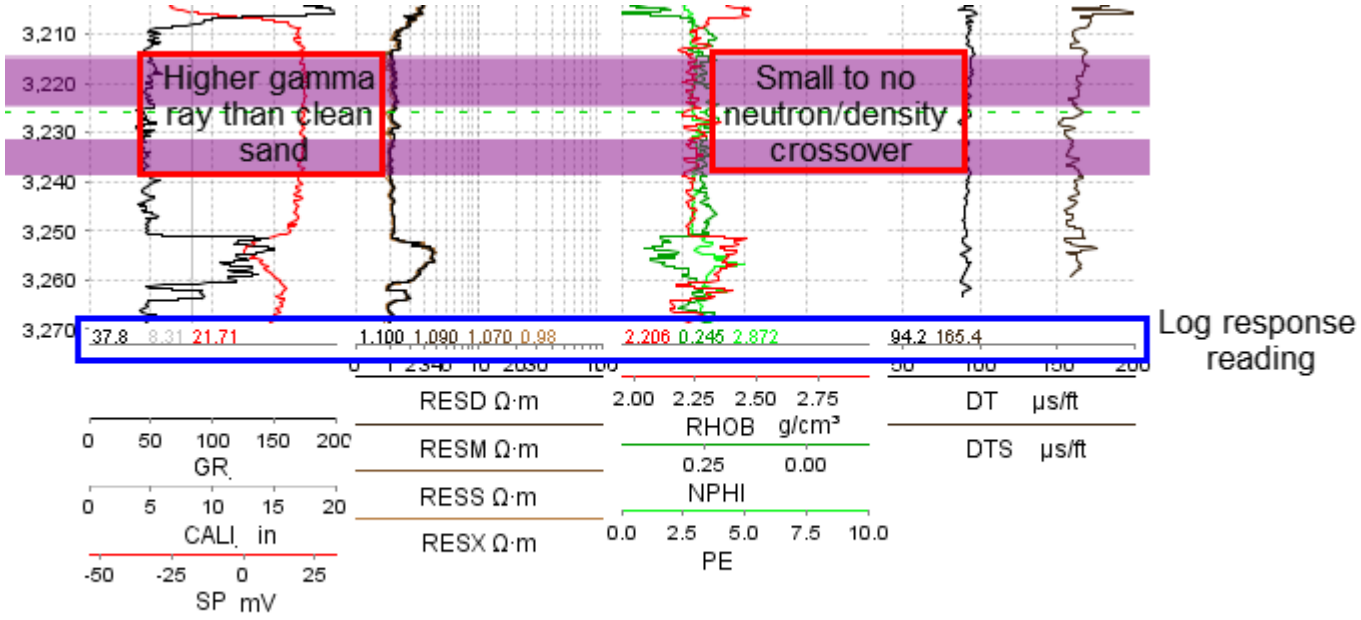


(a) Example well illustrating the end member of picks. The pink intervals represent gas sand.



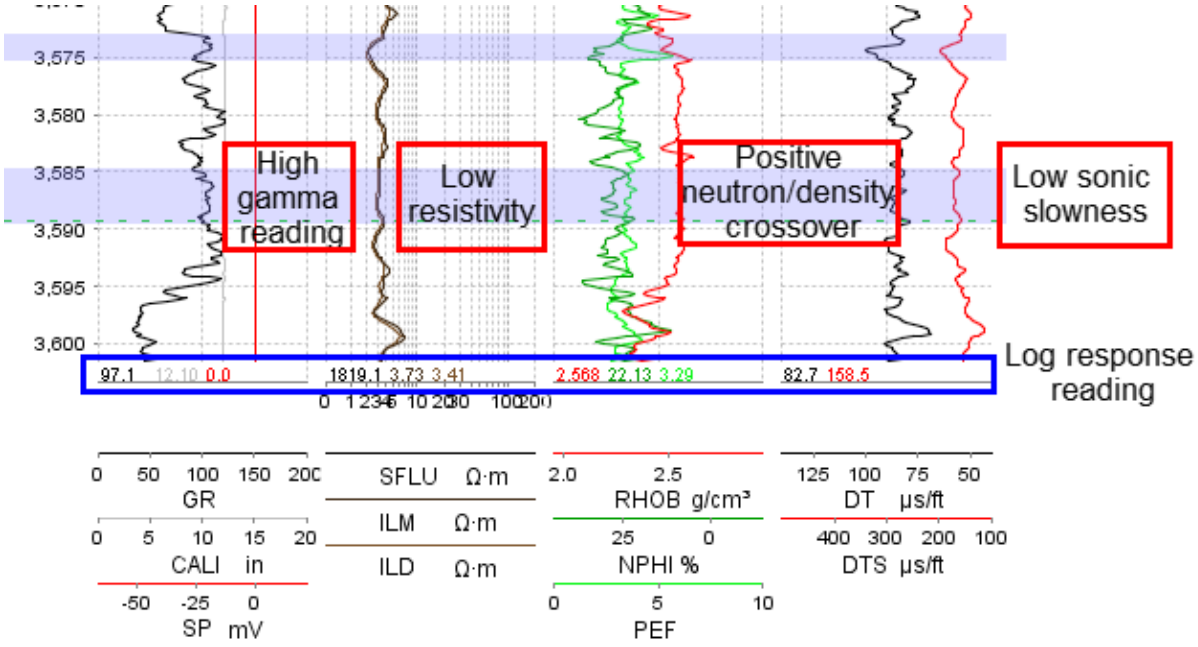
(b) Displaying end member of brine sand picking.

Refer to Figure (a) at depth interval of 3230m to 3240m and Figure (b) at depth interval of 4210m to 4220m. Both intervals have low gamma readings, which are 17.95 and 27.09 API respectively. These low gamma readings indicate the presence of sandstone at these depth intervals. Resistivity readings are influenced by variations in fluid content. Notice that in Figure (a), the resistivity logs show a very high resistivity and large negative neutron/density crossover which contrasts with Figure (b). When there is high resistivity and large negative neutron/density crossover, this generally indicates the presence of hydrocarbon.



(c) Displaying end member of shaley sand picking.

In comparison with sandstones, shaley sandstones have higher radioactivity because they contain a significant quantity of clay. Thus, they have a higher gamma reading than clean sandstone but a lower gamma reading than shale at 37.8 API. Another characteristic for shaley sand is that it has a small to negligible neutron/density crossover.



(d) Displaying an end member of shale picking.

By contrast, there is a sharp increase in gamma readings for shale, which in this case is 97.1 API. This is because shale contains more radioactive elements. Therefore, its gamma reading is higher than sandstone. The overlay of the neutron and density logs reflects their varying responses to the composition of the sandstone and shale. The distinctions between shale and sandstone are that shale has high gamma ray

readings and positive neutron/density crossover, whereas sandstone has lower gamma ray reading and negative neutron/density crossover.

Common Logging Tool Response

See the table below for the common logging tool responses for various lithology types to allow you to identify and pick the end member effectively and efficiently. The logging tool response varies according to the mineral content.

Types	Mineral	Common Logging Tool Response Readings					
		Gamma Ray (API)	Resistivity (Ohm-m)	NPHI (%)	Density (RHOB) (g/cm^3)	PE (B/E)	Sonic (DT) (us/ft)
Common Lithologies	Limestones	18 - 100	$80 – 6 \times 10^3$	0 - 30	2.2 – 2.70	5.09	47.6 - 53
	Sandstones	18 - 160	Up to 1000	0 - 40	1.9 - 2.65	1.81	53 - 100
	Shales	24 - 1000	0.5 - 1000	25 - 75	1.8 – 2.75	3.36	60 - 170
Silicates	Quartz		$10^4 – 10^{12}$	-2	2.64	1.8	56.0
Carbonates	Calcite		$10^3 – 10^{12}$	0	2.71	5.1	49.0
	Dolomite		$1 – 7 \times 10^3$	0 - 30	2.85	3.1	44.0
	Siderite		$10^4 – 1000$	12	3.89	15.0	47.0
Clay	Chlorite	180 - 250		52	2.76	6.3	
	Kaolinite	80 - 130		37	2.41	1.8	
	Illite	250 - 300		30	2.52	3.5	
Micas	Biotite	~275	$10^{14} – 10^{15}$	21	~2.99	6.3	50.8
	Glauconite			38	2.86	4.8	
	Muscovite	~270	$10^{11} – 10^{12}$	20	2.82	2.4	49.0
Feldspars	Microcline	~220		-3	2.53	2.9	
	Orthoclase	~220		-3	2.52	2.9	69.0
Coals	Anthracite		$10^{-3} – 5$	38	1.47	0.16	~105
	Bituminous		$10 – 10^6$	60	1.24	0.17	~120
	Lignite		4×10^3	52	1.19	0.20	~160
Sulfides	Pyrite		$10^{-1} – 10^{-4}$	-3	4.99	17.0	39.2
Evaporates	Halite		$<10^4 – 10^{14}$	-3	2.04	4.7	67.0
	Anhydrite		$10^4 – 10^{10}$	-2	2.98	5.1	50.0
	Gypsum		1000	60	2.35	4.0	52.5
	Sylvite	500+	$10^{14} – 10^{15}$	-3	1.86	8.5	
	Polyhalite	~200		25	2.79	4.3	
Fluids/ Gas	Water		infinity	100	1.0 – 1.05		189
	Oil		$10^9 – 10^{16}$	60	0.7 – 0.9		215
	Gas		infinity	50	0.15 – 0.4		

Well Log Characteristics

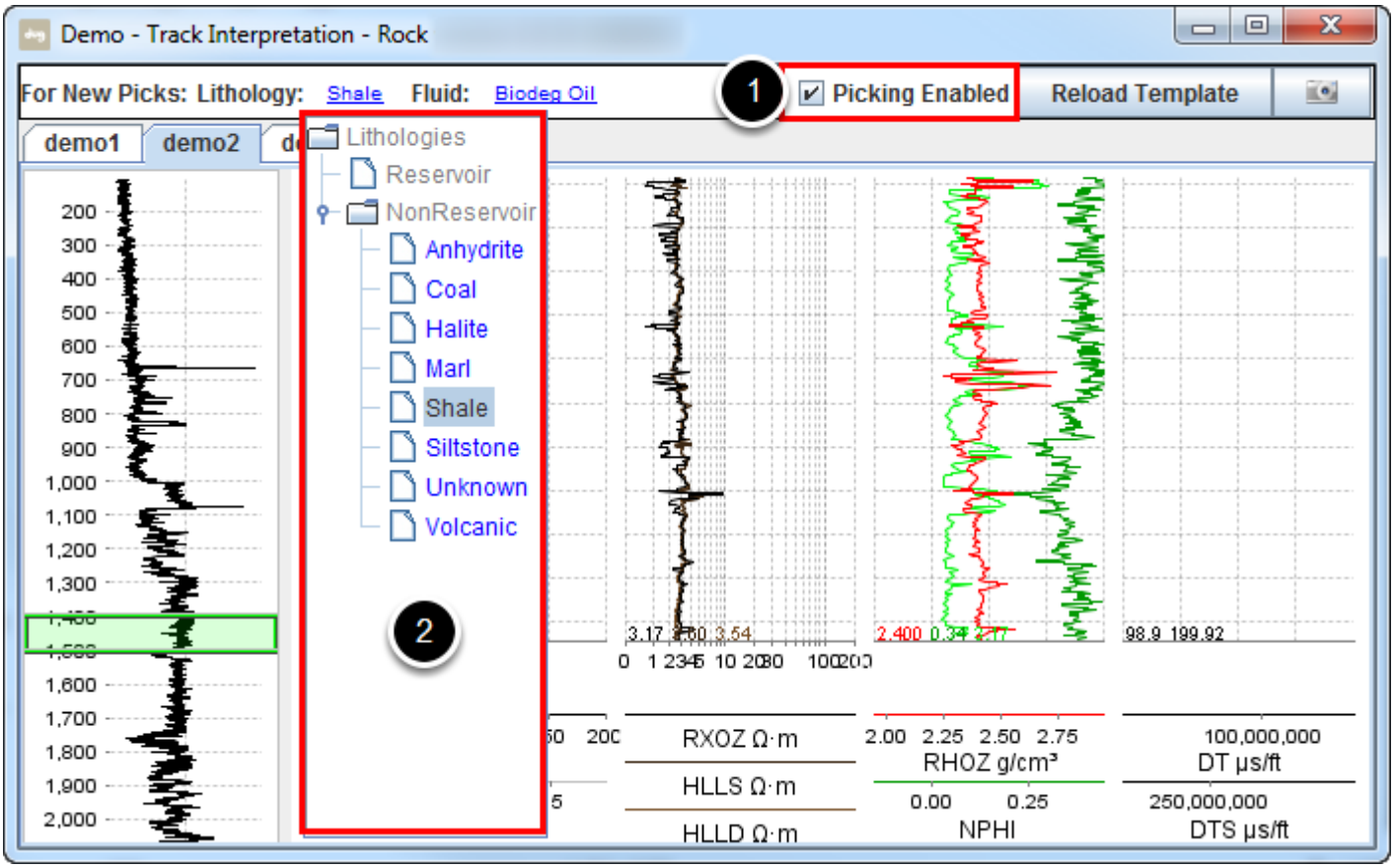
Below are examples of the well log characteristics for reference.

Lithology	Characteristics
Limestone	• Very low gamma ray • High resistivity • Low sonic slowness
Sandstone • classic quartz rich sand	• Low gamma ray • Clean neutron/density crossover • Generally good porosity/permeability in the cleanest sands • High sonic slowness
Shaley sand • sandstone with significant quantity of clay	• Higher gamma ray than clean sand, but lower than shale • Small to no crossover on neutron/density log. • Higher density than sand
Green sand	• Higher gamma ray than sand • Higher density than sand
Cemented sand • poor porosity and permeability	• Same gamma ray as sand • Higher resistivity than sand • Very high density with comparison to sand • Low sonic slowness
Hot sand • sandstone with high content of radioactive minerals (i.e glauconite, potassium)	• Higher gamma ray than classic sandstone • Clean and negative neutron/density crossplot
Shale	• High gamma ray • Large positive separation on the neutron/density log • High density • Low sonic slowness
Silty shale • tends to occur as a gradation from shale to sandstone • harder than the normal shales	• High gamma ray • High density
Pyritic shale	• High gamma ray • High density • Low sonic slowness
Organic shale • tends to be interbedded and gradational with the 'normal' shale trend	• Very high gamma ray • Positive separation on the neutron/density crossover • Very low density
Radiolarite • contains abundant *radiolaria*	• Medium gamma ray • Slightly lower density than shale
Siltstone	• Slightly higher gamma ray than clean sand, but lower than shale • Slightly lower density than sand • Very little to no neutron/density crossover
Carbonate • tends to be massive and is	• Very low gamma ray compared to clean sand • Very small or no crossover on the neutron/density log
present in the shallow portion of the wells	• High density
Marl • tends to be massive and are present in the shallow portion of the wells	• Higher gamma ray than carbonate • Small positive crossover on neutron/density log • Lower density than carbonate
Coal	• Low gamma ray • High resistivity • Very low density

Picking Lithologies

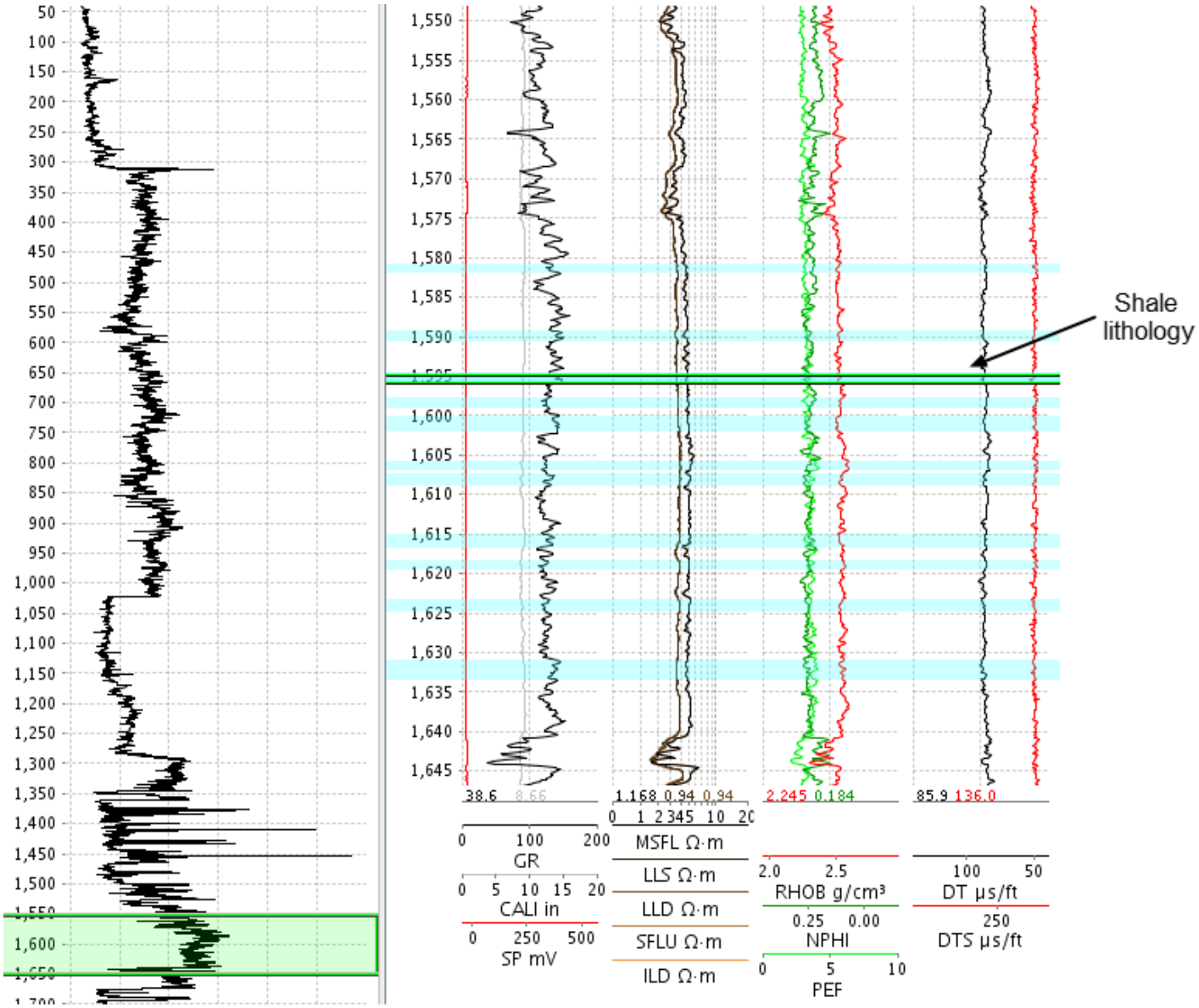
Once you have identified the end members for the reservoir or non-reservoir lithologies, you can perform the 'picking' process in the Wireline Log Traces Panel. The selected 'clean' interval (end member) will be blocked, upscaled and the relevant properties (both mean and uncertainty) over this interval will be recorded.

How to Pick Lithologies



1. Click the **Picking Enabled** check box.
2. Select a lithology from the **Lithology** drop down list for picking.
   If the lithology is not available, you can *Create a New Lithology*.
3. Then, perform picking in the Wireline Log Traces Panel.

Note: You may perform more than one pick for the same lithology at different depths.

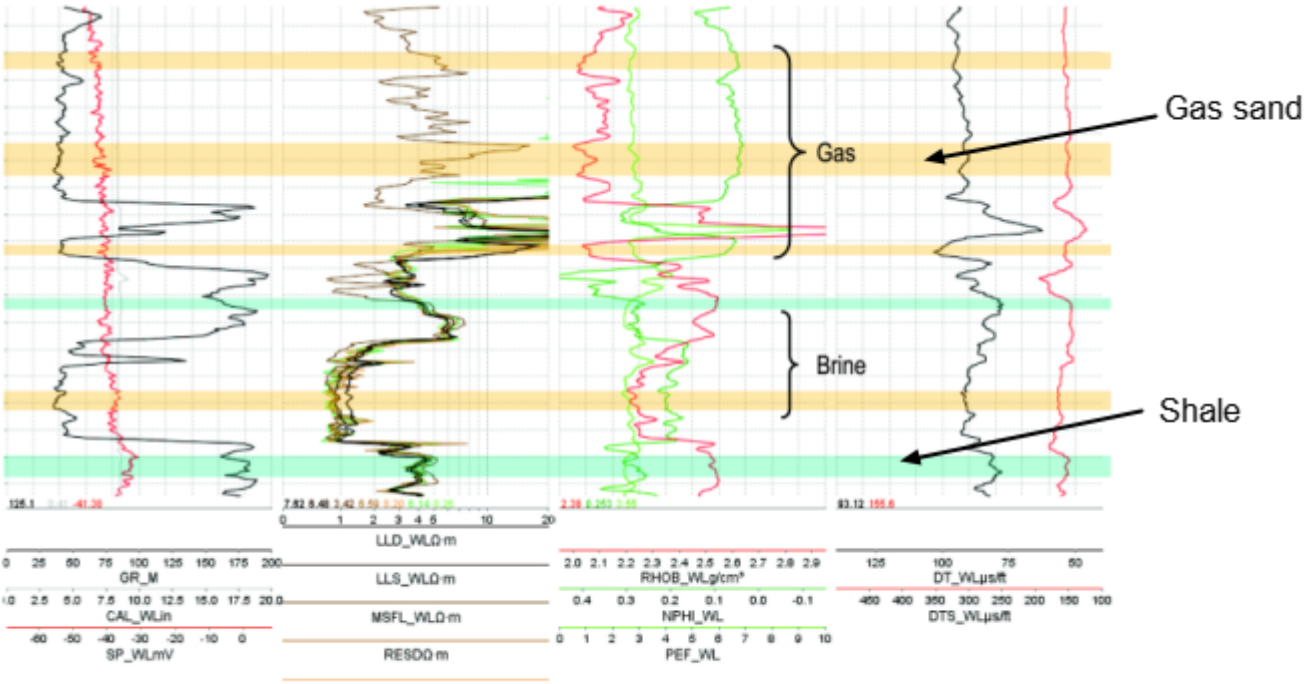


Shale picking

4. Repeat the above steps to perform other lithology pickings.
5. Once picking for all identified lithologies in the well curves has been completed, clear the **Picking Enabled** check box to end the picking.
6. Click on another well tab and repeat the above steps to pick relevant lithologies.

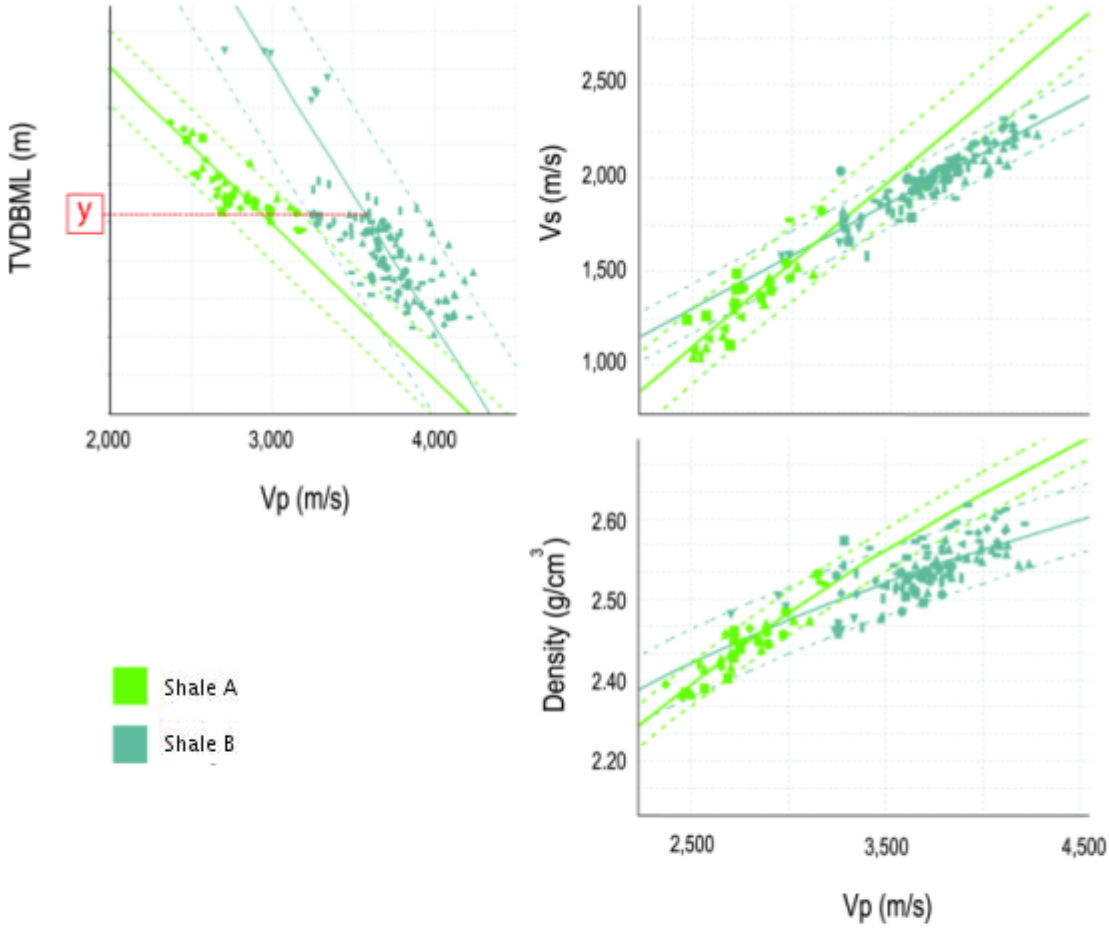
Note: Refer to *Editing a Lithology* to edit and delete a lithology.

Example



Example well illustrating the end member picks. Straw coloured picks represent sands whereas aqua represents shale.

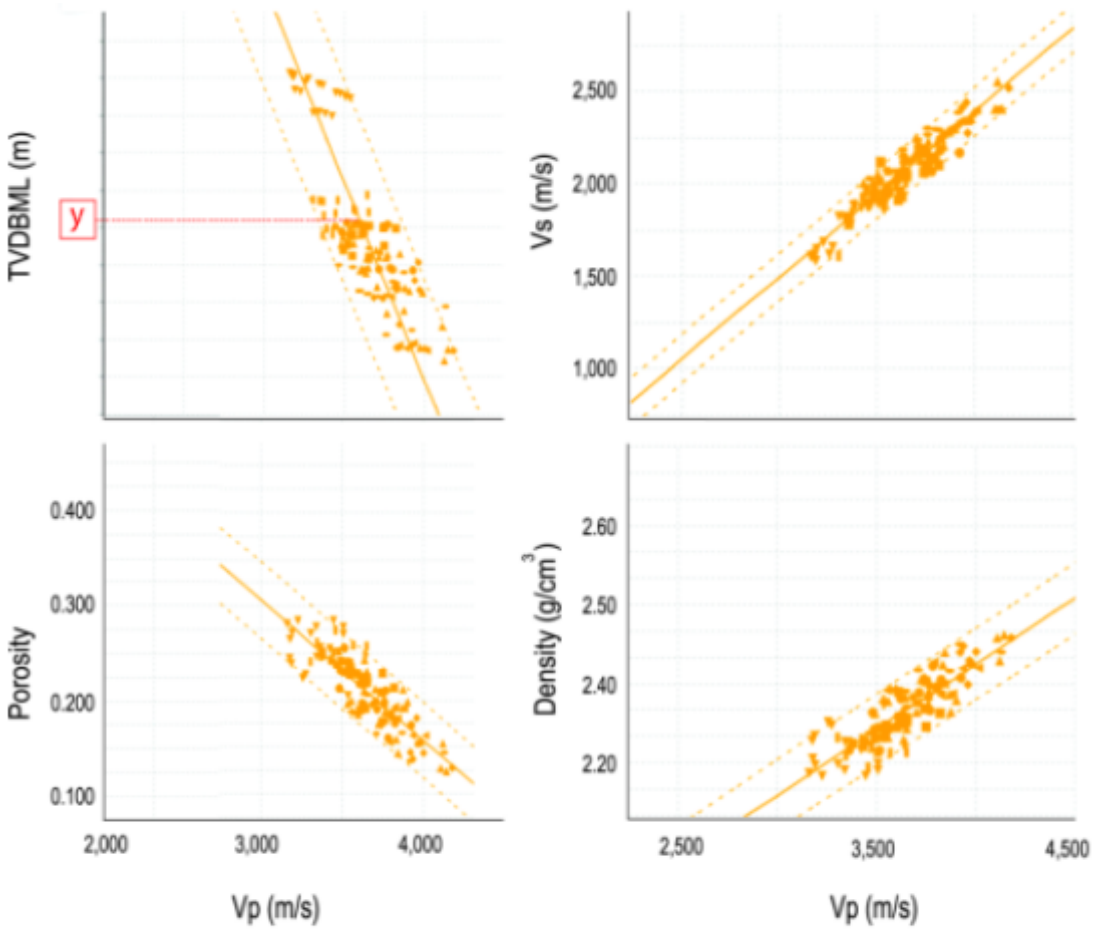
This image shows an example of the end member interpretation. The straw coloured picks are the end member sands and the blue picks are the end member shales. Before being used, each pick is upscaled and averaged to become one point on the crossplots.



Illustrates two shales trends. Each picked interval from the end member interpretation is upscaled and then plotted as a single point on the crossplot charts. Y indicates the pivot point above which shales are softer than sands and below which shales are harder than sands.

Depth dependent end member elastic (lithology and fluid) property trends, based on available log data, are derived along with their uncertainties. The solid fitted line is the mean trend, while the dotted lines on either side capture two standard deviations of scatter.

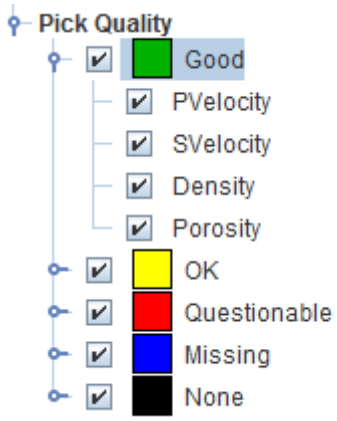
The trends crossover at about a depth labeled Y metres. That means above Y metres the shale is softer than the sand. Below Y metres, the shale is harder than the sand.



Illustrates sand trends. Each point represents an interpreted, upscaled end member interval.

Pick Quality

The Pick Quality tree allows you to include and exclude the picks assigned to the quality from the trend calculations.



There are four parameters that can be assigned to quality:

- Compressional Velocity (Vp)
- Shear Velocity (Vs)
- Density (ρ)
- Porosity (φ).

For various reasons, one or more of the picks may not be behaving in a normal manner or in good quality. Therefore, the use of various quality types can help you to distinguish poor picks from others. Turning off one or more poor quality types of the picks will result in removing the poor quality picks in the crossplot charts, and those poor quality picks will be excluded from the trends calculation. This will allow you to produce better and more reliable trends.

The qualities can be categorized into five categories. You may select any based on your need:

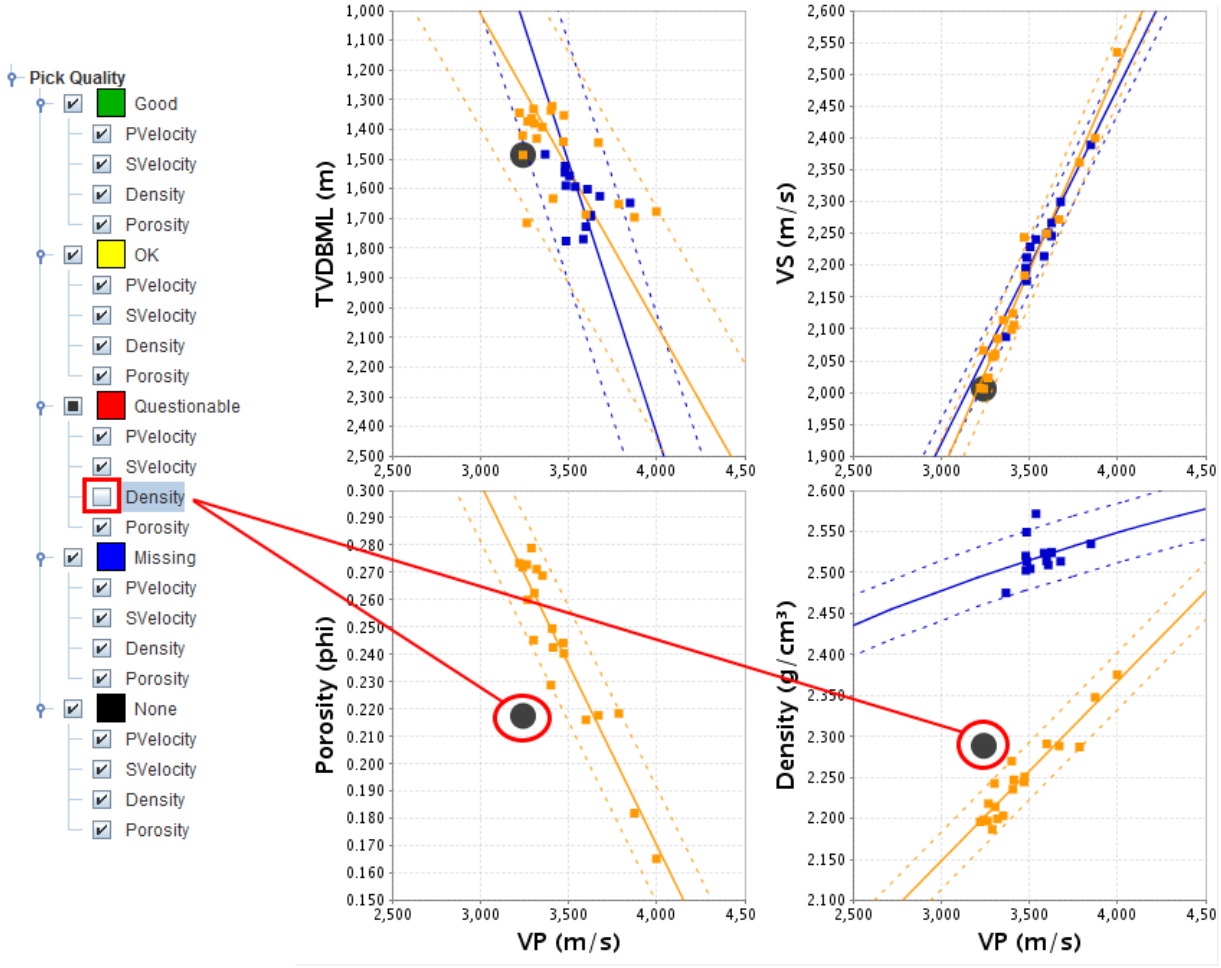
- None
- Missing
- Questionable
- Okay
- Good

There are several ways to determine the quality types:

- Bad hole or large hole size (Caliper is a useful tool to determine the bad hole)
- One of the logging tools may not be functioning correctly
- Suspicious lithology – for example, different mineralogy.

You may see a better effect after removing those picks.

To include or exclude the picks assigned to that quality from the trend calculation, select or deselect the check boxes.



Assuming that the highlighted pick is a questionable pick, after turning off the quality type, the pick associated with density in the crossplot charts disappears.

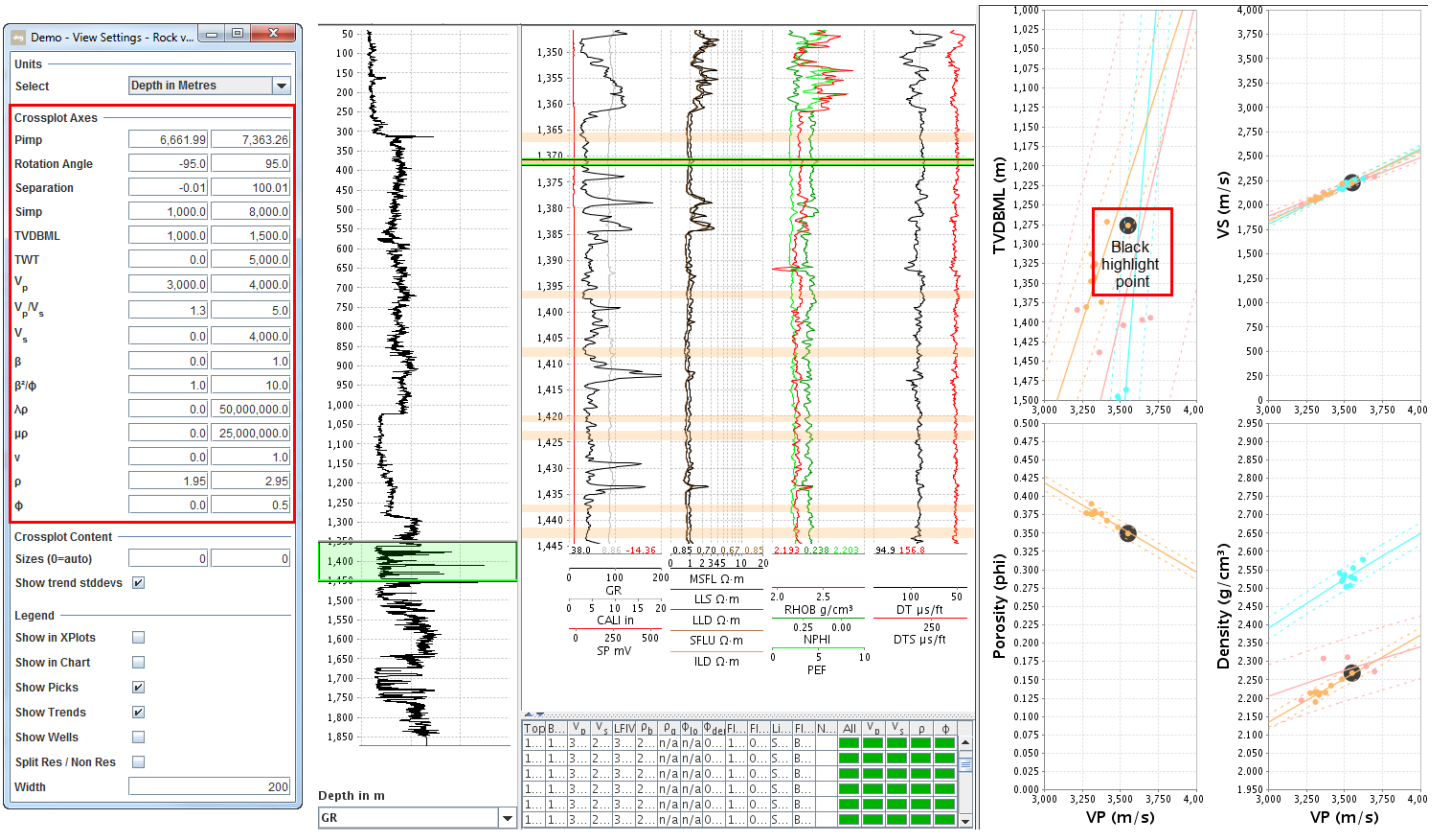
Crossplot

Display Picks in Crossplot Charts

As you perform picking in the Wireline Log Traces Panel, the pick is simultaneously highlighted in a black highlight point and displayed automatically in the crossplot charts.

You may adjust the axis limits of the crossplot charts from the *View Settings* as described below.

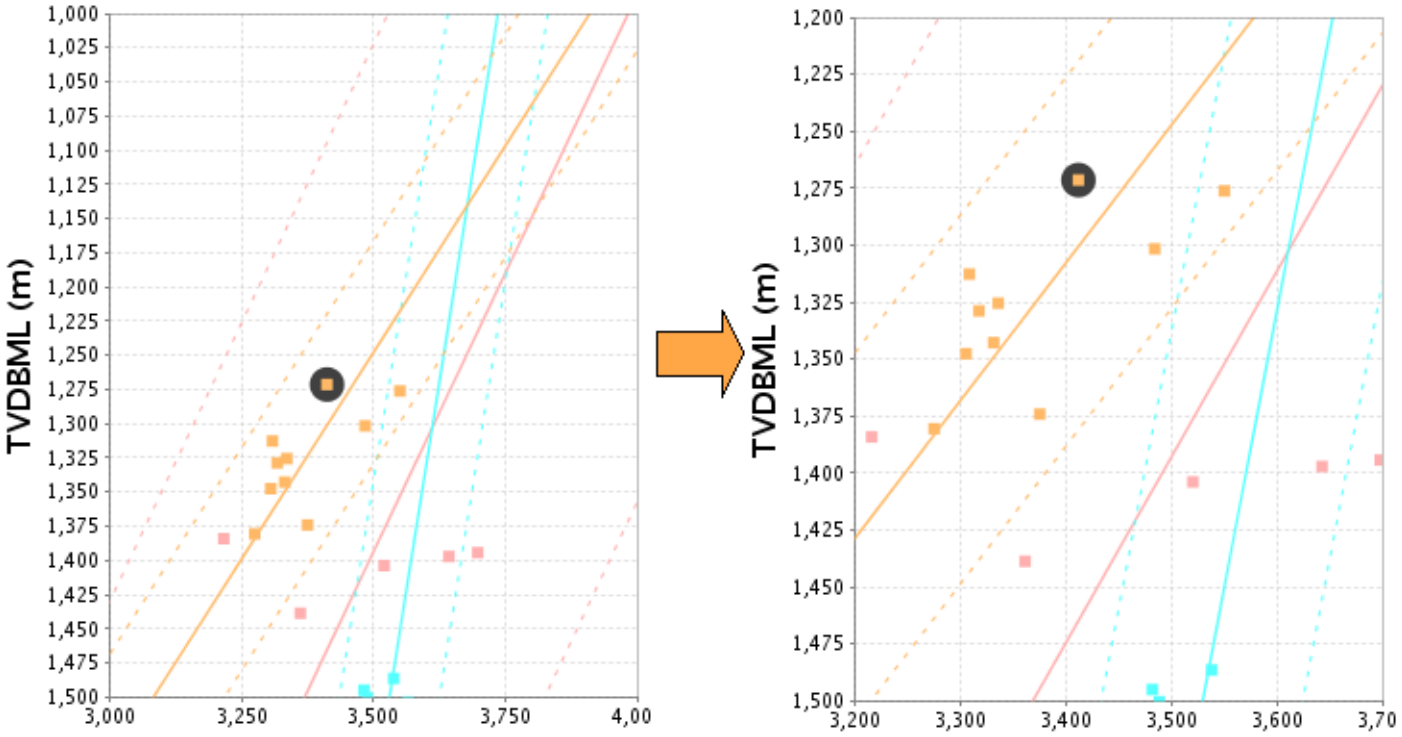
How to Adjust Axis Limits on Crossplot Charts



Black highlight point displays when picking is performed

DUG Rock automatically links the pick in the Crossplot Panel to the associated well and to where the pick is located in Wireline Log Traces Panel. More information on the pick can be gained by viewing the *Pick Summary Table*. For a more visible and less cluttered view on the picks in Crossplot Panel, you may adjust the crossplot charts' axes.

1. From the Control Panel, open the **Window** menu and select *View Settings*.
2. In the **Crossplot Axes** section, enter the minimum and maximum values in the text boxes for the appropriate axis. The changes will be applied on-the-fly.



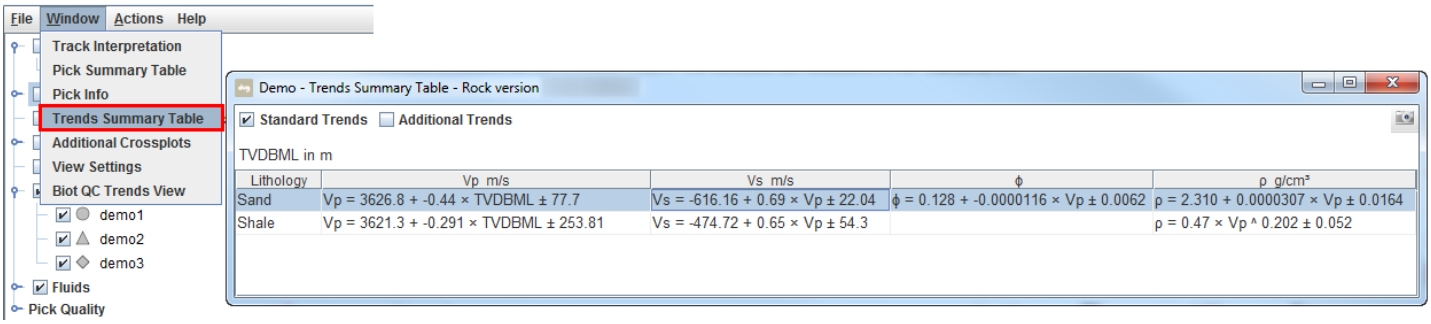
Zoom-in effect after adjusting axis limits.

Trending

Introduction to Trends

DUG Rock calculates trends from lithology picks using linear regression. A lithology requires five or more picks to calculate the trend and standard deviation. The trend formulas are displayed in the Trends Summary Table.

Trends Summary Table



1. From the Control Panel, open the **Window** menu.
2. Select **Trends Summary Table**.
3. In the table, select to only display **Standard Trends** or to include **Additional Trends**.
    - Standard Trends include Vp, Vs, density and porosity.
    - Advanced Trends include all the standard trends plus **Pimp**, **Simp**, **Vp/Vs** and **v**.

4. The formulas will be displayed accordingly in the table.

Display Trends in Crossplot Charts and Save Trends

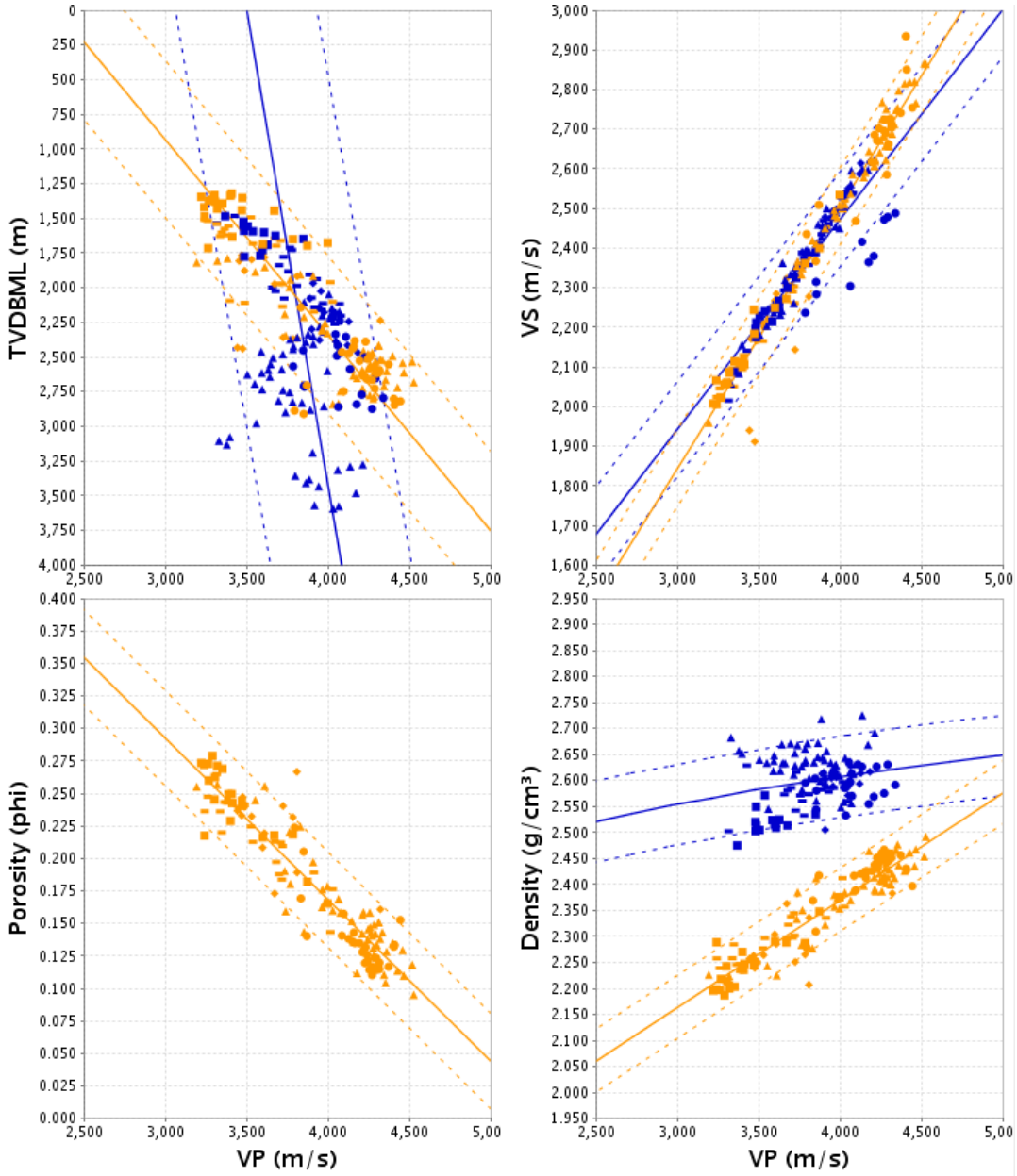
Four primary trends are calculated for *reservoir* lithologies: TVDBML vs Vp, Vs vs Vp, Porosity vs Vp and Density vs Vp.

Three trends are calculated for *non-reservoir* lithologies (the porosity trend is excluded).

Trends can be exported and used as input in other applications (see *Export Trends*), for example:

- DUG Distill — Stochastic modelling and simulation
- DUG Insight — Model building.

Crossplot charts



The trends are formed by regression analysis.

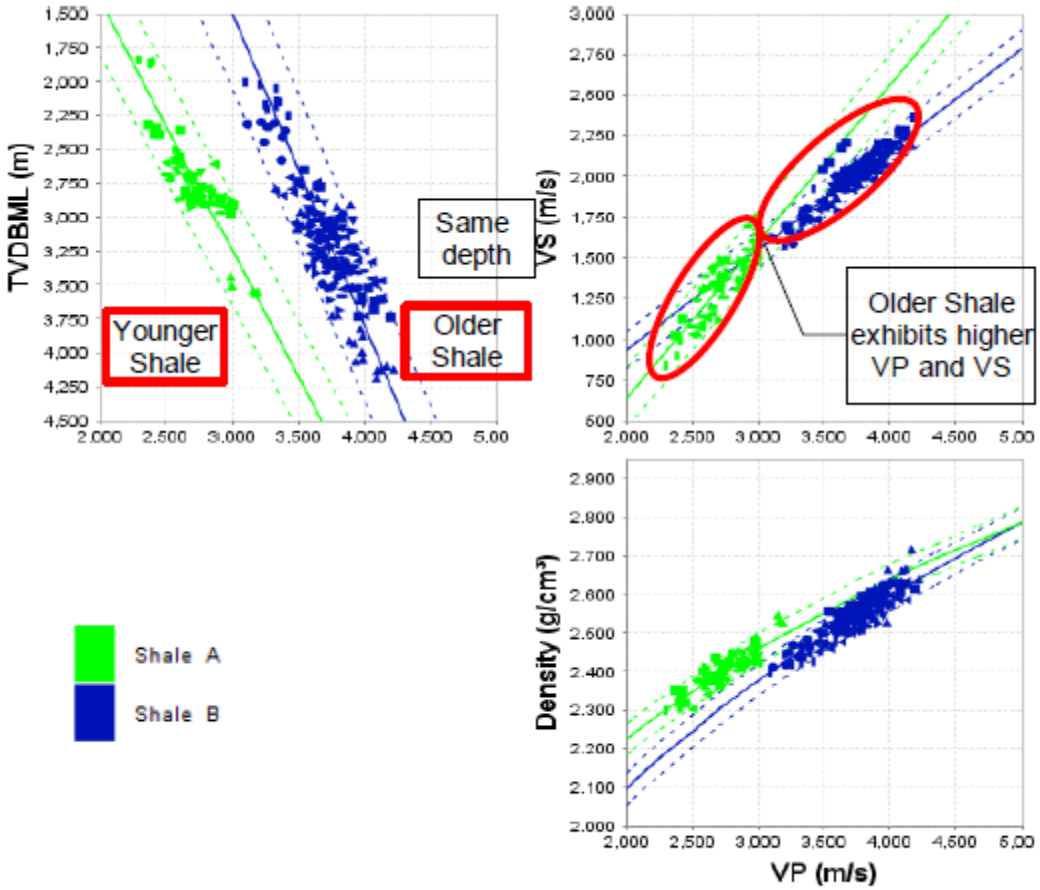
To view the formulas used to form these trends, open the **Trends Summary Table** (see *Trends Summary Table*).

Crossplots and Trends Interpretation

There are several factors that influence lithologies and their trends:

Compaction / Stratigraphic

As the depth of burial increases, compaction of the sediments generally occurs. The depth of burial of a sediment increases with time and as the weight of the overlying sediments increases, the lower layer must support the weight of the upper layer. This causes some of the liquid to be expelled and porosity will decrease with depth. Consequently, both sonic velocity and density of a sedimentary rock generally increases with depth. Therefore, in this case, a younger shale in the upper layer tends to have a lower bulk density and velocity (both compressional and shear velocity), whereas an older shale, that is buried to a deeper level, tends to have higher bulk density and velocity.



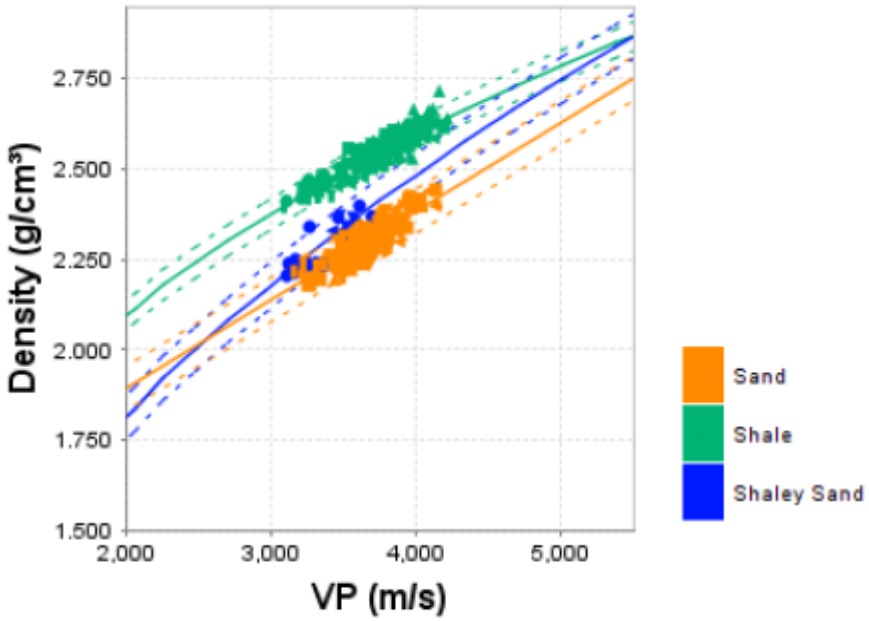
Displaying the upper layer shale and the lower layer shale.

Over time, sedimentation differs due to changes in the environment of deposition, resulting in variations in sedimentary layers. This image illustrates the comparison between Shale A and Shale B. Shale A is younger than Shale B as it tends to have lower compressional velocity at the same depth in the TVDBML versus VP crossplot. These two shales have different geological settings and depositional environments, which results in Shale A having a lower velocity than Shale B at any given depth.

In DUG Rock, the reservoir lithology trends are formed based on a linear regression where its compressional velocity varies linearly with density. In contrast, non-reservoir lithology trends are formed based on a non-linear Density versus Vp (Compressional Velocity) equation:

$$Density = a \times Vp^{b}$$

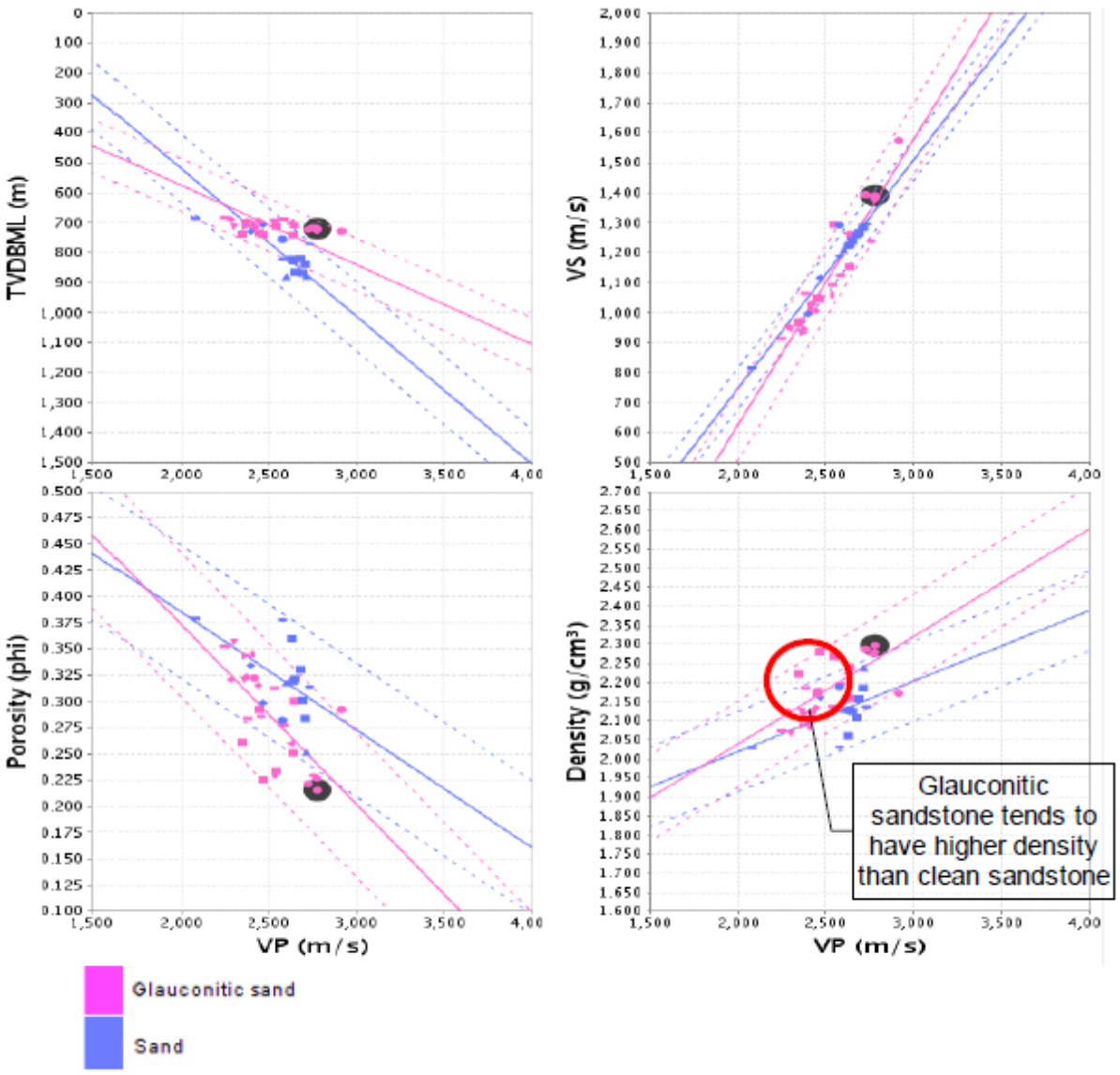
where a and b are constant, and Vp is compressional velocity.



Displaying density relative to VP comparison among shale, shaley sand and sand.

This image illustrates the comparison of density relative to VP among shale, sand and shaley sand. Notice that shale plots are at a higher density position, relative to Vp, than sand and shaley sand. This is because in nature, shale tends to consist of minerals with a higher matrix density than quartz (the main constituent of shaley sand and sand). This results in a higher density for shale compared to shaley sand and sand.

Environment / Mineralogy

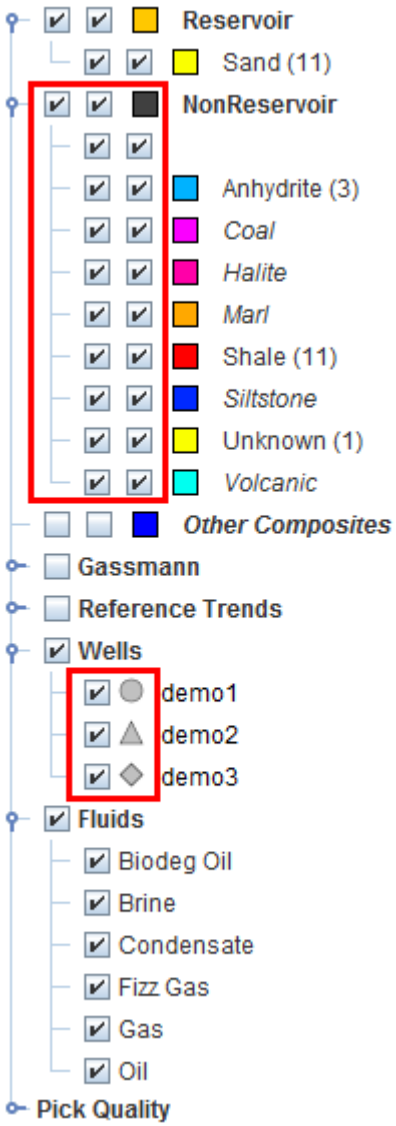


The environment of the deposition may affect the mineralogy of the various lithologies. For example, glauconitic sandstone. Glauconitic sandstone is an authigenic sandstone which forms on the continental shelf during a marine transgression, where sedimentation occurs at a slow accumulation rate. Glauconite contains iron, which results in a higher density than a clean quartz-rich sandstone. Therefore, it plots at higher density relative to velocity on the crossplot charts.

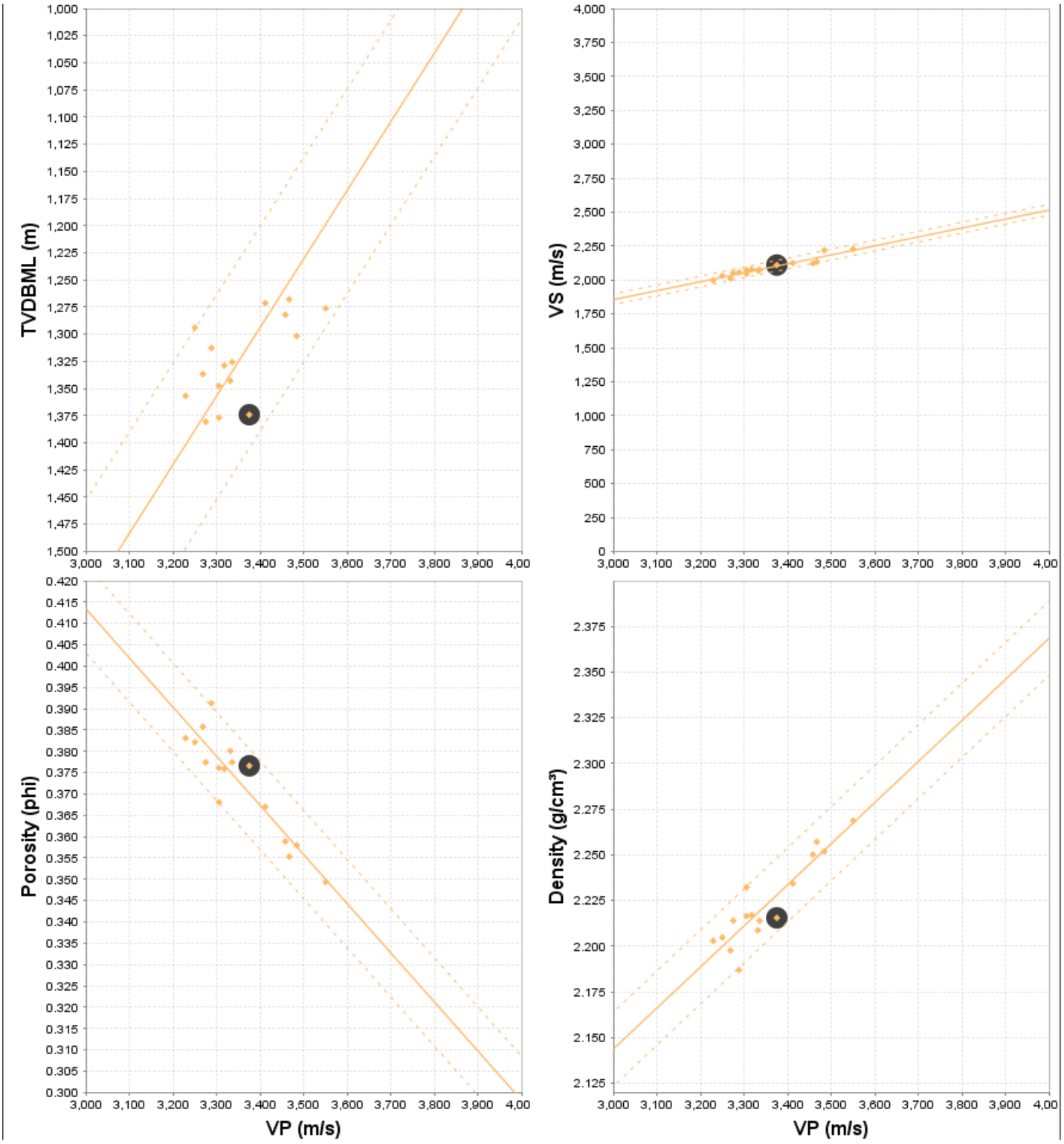
Customize, Capture & Save Crossplot Charts for Presentation & Reporting

There may be times when certain information from the crossplot charts is required for presentation and reporting. In this instance, you may need to customize picks and trends, capture and save the crossplot chart(s).

Customize Picks and Trends View in Crossplot Chart



Picks and trends displayed in the Crossplot Panel can be filtered by adjusting the settings in the Control Panel (see *How to Display/Hide Information in Crossplots*).

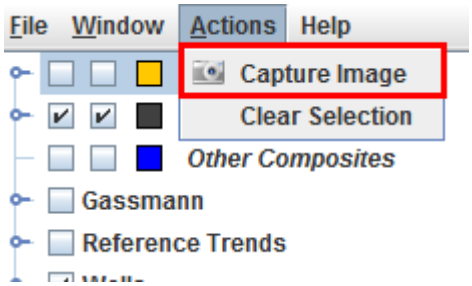


Displaying reservoir lithology.

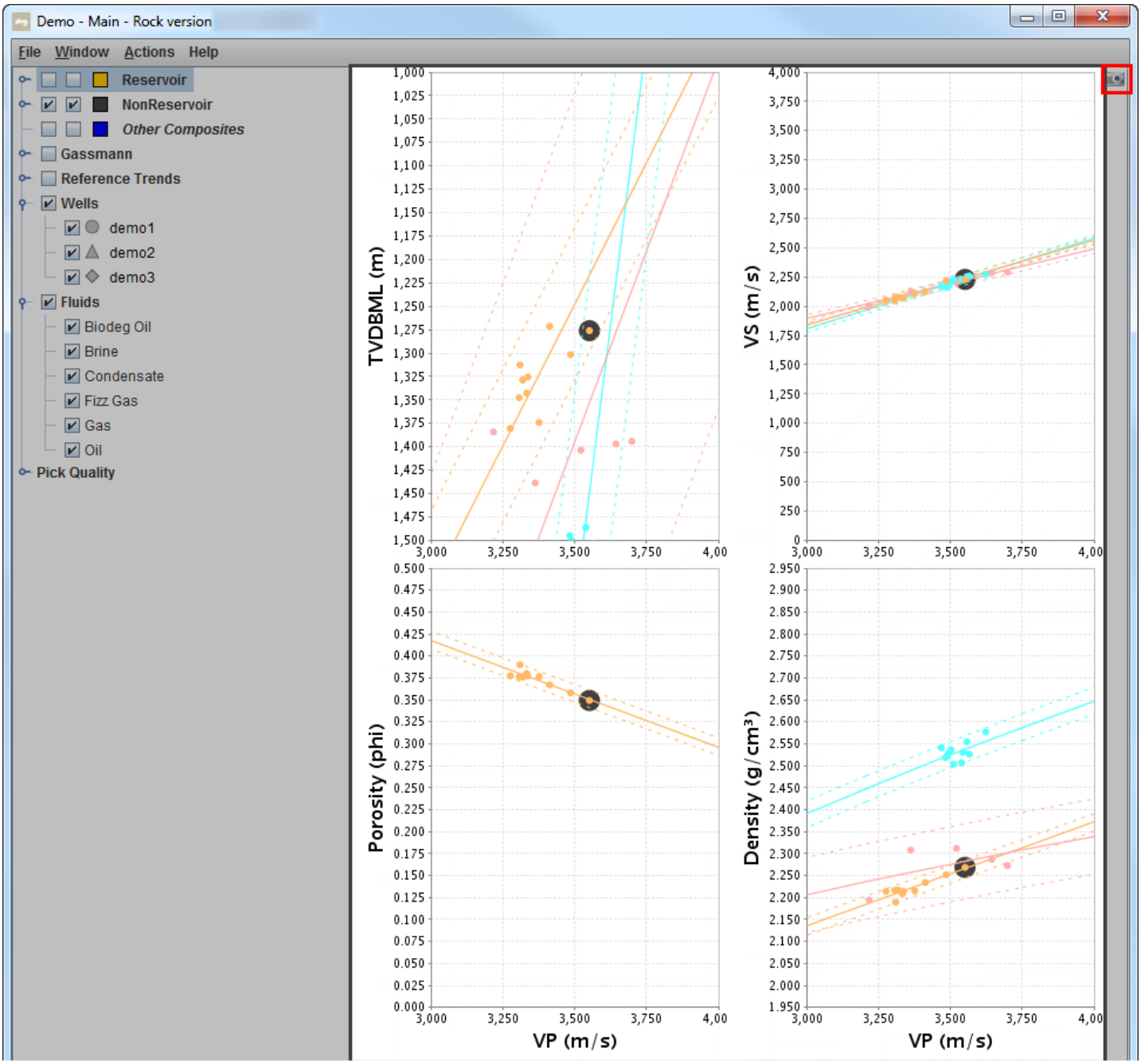
Presentation / Reporting

You may use the **Capture Image** function to capture the Crossplot Charts, save the image into *.*png* and then insert the captured image into your report or presentation slides. This allows you to capture a consistently standard size of image for presentations and reporting.

Capture Image



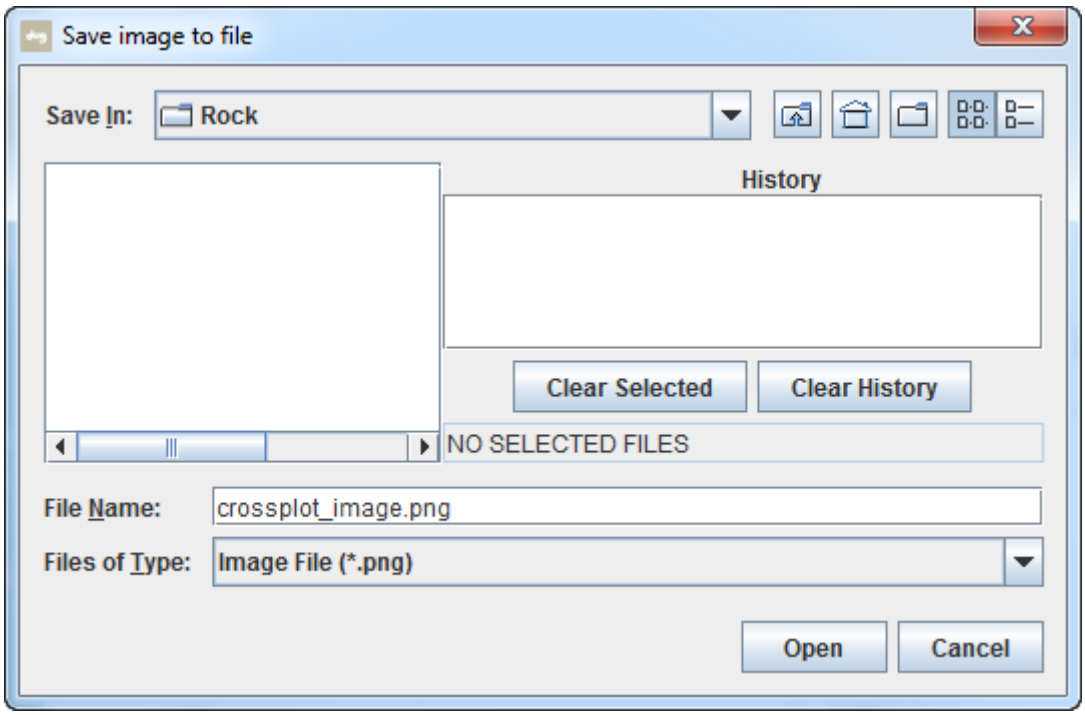
1. In the **Actions** menu, click **Capture Image**. Alternatively, click on the camera icon at the top right of the crossplot panel.
2. Point to any crossplot chart. Right click, press space or press Page Up to highlight all four crossplot charts.



Capturing all the highlighted crossplot charts.

3. Then left click or press Enter, the **Save image to file** dialog box appears.

Save Crossplot Chart



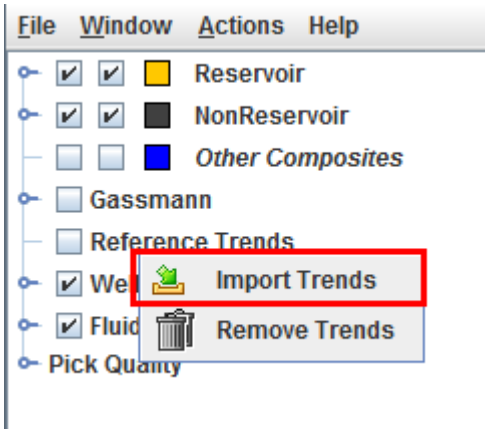
4. Enter a name in the **File Name** text box. For example, *crossplot_image.png*. Select a location from the **Save In** drop down list to save your image. For example, *Rock_demo* folder.
5. Click **Save** to store the image.

Reference Trends

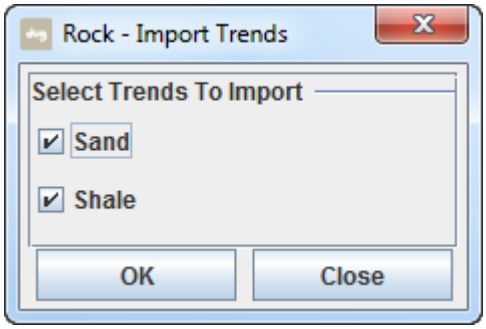
Reference Trends allows you to add reference lithologies for trends comparison. You may add reference lithologies trends from other projects to the current project for comparison of the compaction factor, environment factor, and the elastic properties of the same lithology formation.

For example, assume we have Composite Late Cretaceous shale trend for project A and another Composite Late Cretaceous shale trend for project B (which has been done). We can then import Composite Late Cretaceous shale trend from project B into project A, and compare the result. If the trends comparison turns out to be the same, we can conclude that they are deposited in the same compaction factor, environment, and have the same elastic properties.

Import Trends

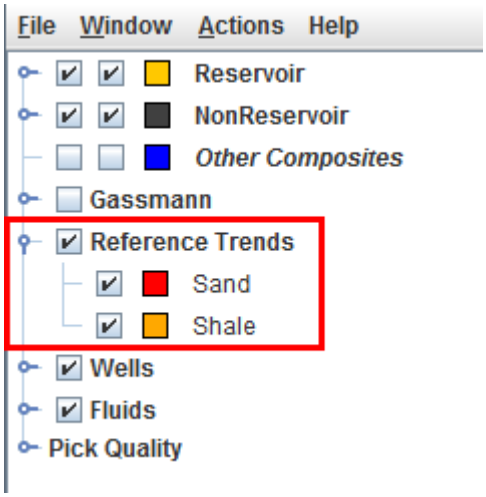


1. Right click on **Reference Trends** and select **Import Trends**. The Import Trends window will be displayed.
2. In the Import Trends window, select the trend file (**.trend, *.txt, *.asc, *.prn*) and click **Open**.

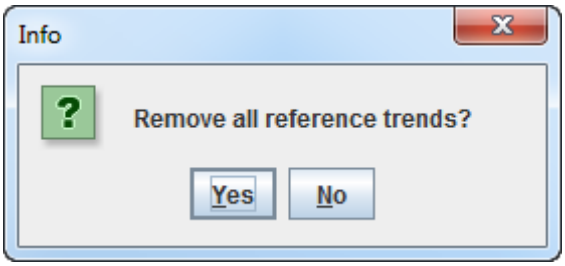


3. Select which trends in the trend file you wish to import.
4. Click **OK**.

The trends will be displayed in the Control Panel under Reference Trends. To display it on the crossplots, select their check boxes.



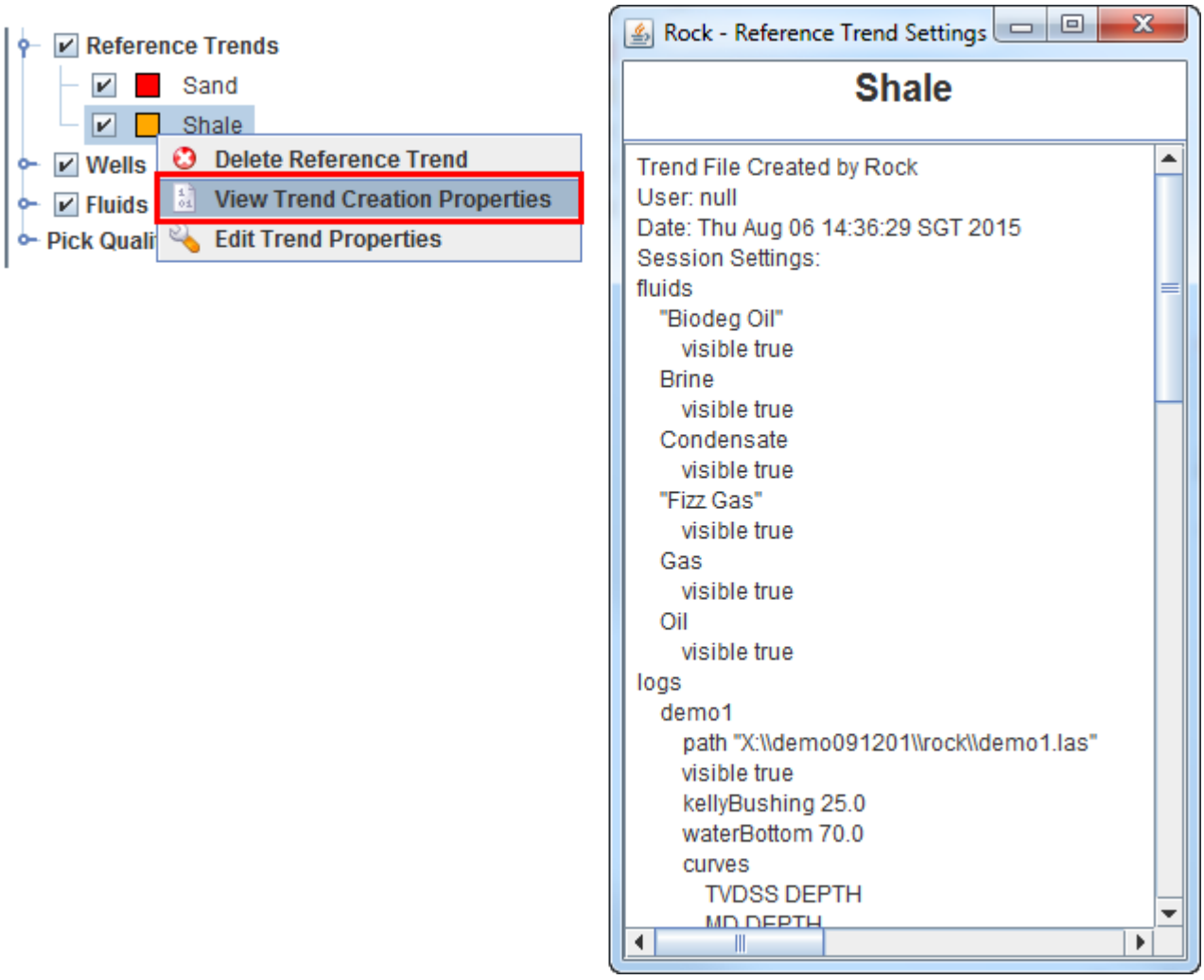
Remove Trends



To remove all reference trends, right click on **Reference Trends** in the Control Panel and select **Remove Trends**.

To remove individual reference trends, right click on the individual trends and select Delete Reference Trend.

Trend Creation Properties



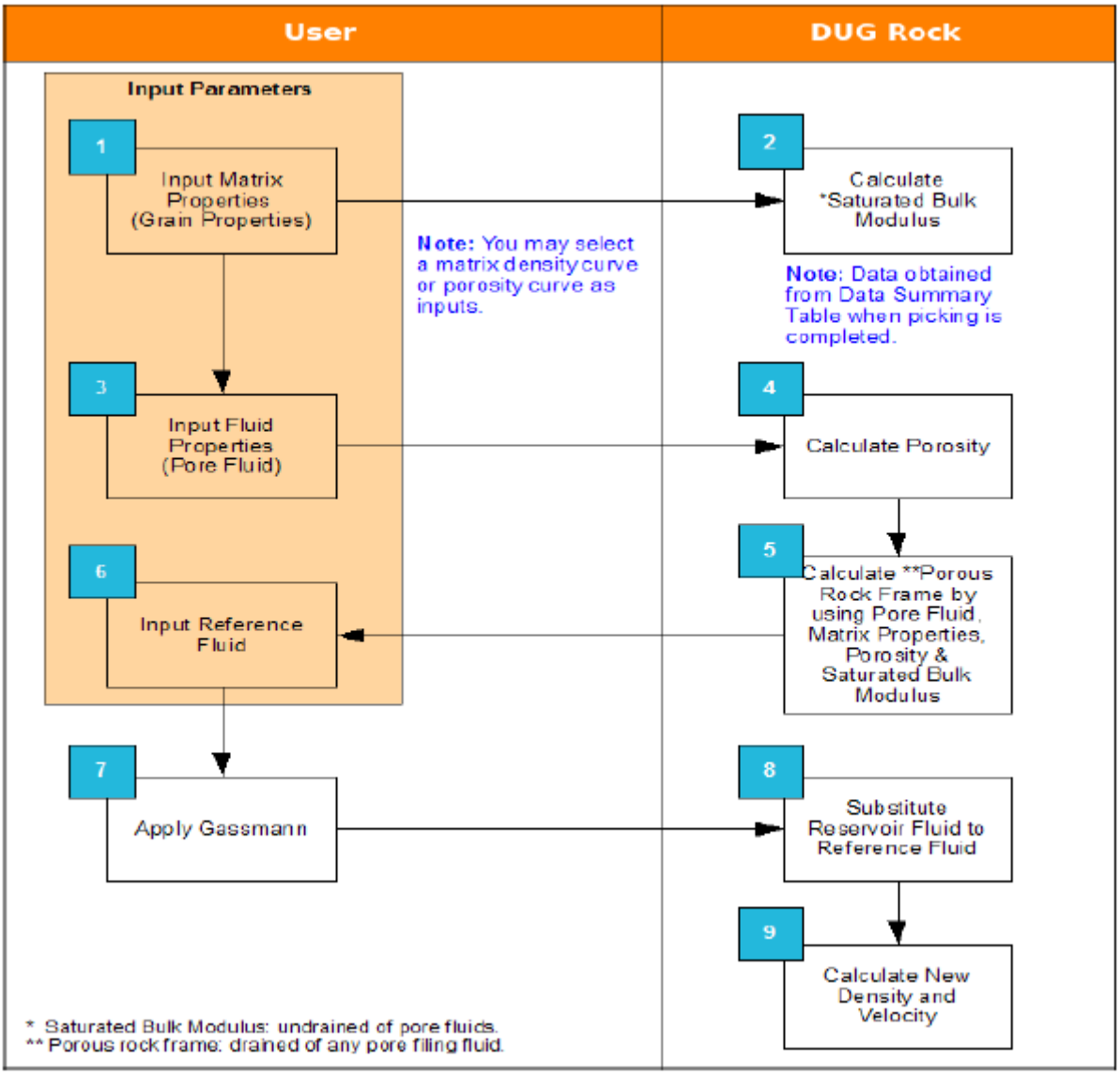
To view information of the trend, right click the trend and select **View Trend Creation Properties**.

Gassmann Substitution

The main reason for carrying out Gassmann substitution is to obtain the depth-dependent elastic rock property trends that illustrate how rocks behave elastically with depth. Gassmann substitution removes the inherent scatter in rock properties caused by the variation in fluid properties, by correcting the logs back to a known reference fluid (e.g. brine). The application of Gassmann substitution helps in obtaining the variation in elastic rock properties with depth, without the added variability due to changes in fluid type. This correction is important in rock physics analysis and can be used to provide the interpreter with a tool for modelling and quantifying various fluid scenarios with depth.

Theoretically, Gassmann substitution is used to calculate the rock properties at simulated in-situ reservoir conditions. Gassmann fluid substitution involves the transformation of bulk modulus from one fluid type to another, which means it models the changes from the original fluid (usually involves gas, water or oil) to a reference fluid (usually an average brine) by removing the original fluid prior to modelling a reference fluid. Replacement of gas or oil by the denser brine increases the bulk density of the formation and sonic velocity. Therefore, after the application of Gassmann substitution, the density and velocity of the reservoir increases.

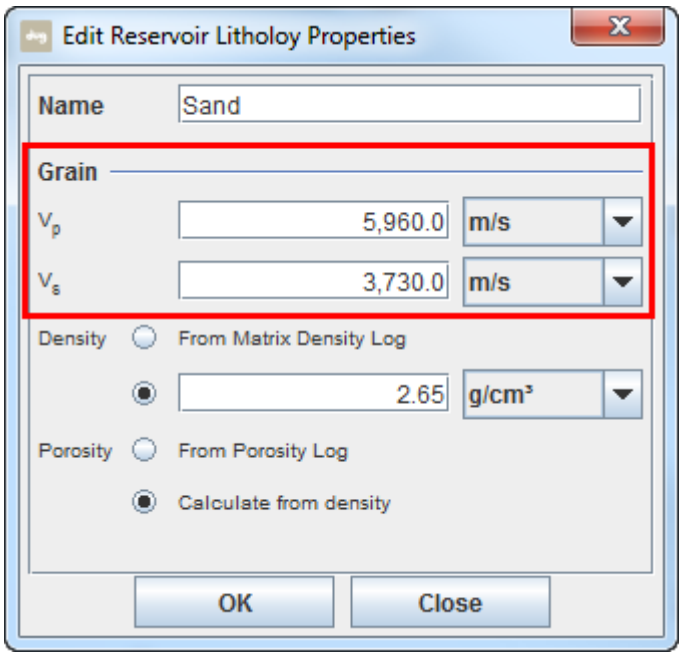
How Gassmann Substitution works in DUG Rock



Before you begin Gassmann substitution in DUG Rock, you must determine the following four components from the analysis of wireline log data:

1. Matrix Properties (Grain Properties)
2. Fluid Properties (Fluid VP and Rho)
3. Porosity
4. Reference Fluid (VP and Rho).

Matrix Properties (Grain Properties)

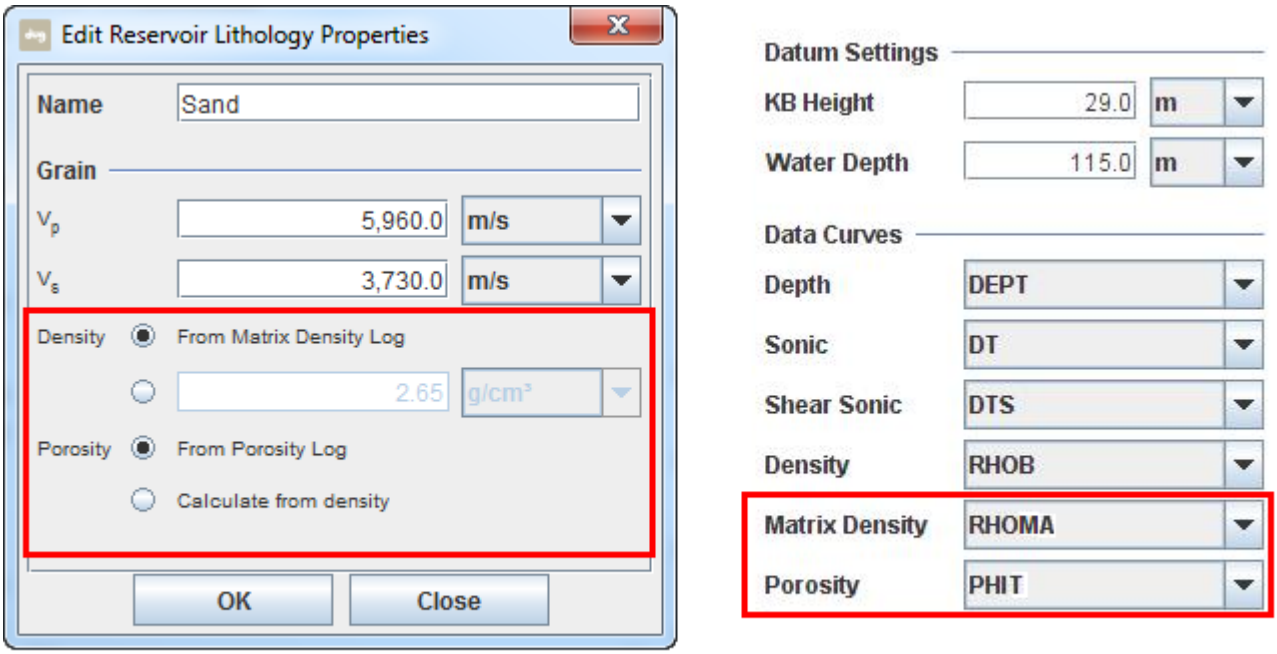


Prior to applying Gassmann substitution, information on the matrix properties (grain properties) must be available. Ensure the grain properties (VP, VS and density) of the reservoir are entered correctly. Refer to the table below for common minerals matrix properties.

Grain Properties	VP	VS	Density
Quartz	5,960	3,730	2.65
Limestone	6,835	3,711	2.71
Dolomite	7,458	4,557	2.85

Common matrix properties.

In addition, you can select the **From Matrix Density Log** (e.g. RHOMA) and/or **From Porosity Log** (e.g. PHIT) as inputs to compute porosity, if they are available. Data (Vp, Vs and ρ_b) will be obtained from the *Pick Summary Table* to calculate the Saturated Bulk Modulus which eventually will be used to compute Gassmann substitution. After verifying the matrix properties values, proceed to enter fluid properties.



Using other data curve sources to compute porosity.

Fluid Properties

Next, you need to know the bulk modulus and density of the pore filling fluids (fluid properties). The fluids properties can be obtained and calculated using formation pressure, temperature, salinity and the fluid properties equation, for example, *Batzle and Wang (1992)*. See table below for common fluid properties.

Fluid Properties	Fluid VP (Velocity Range)	Fluid Rho (Density Range g/cc)
100% of Oil	900 – 1,350	0.5 – 1.0
100% of Gas	450 – 800	0.1 – 0.2
100% of Brine	1,450 – 1,600	0.9 – 1.2

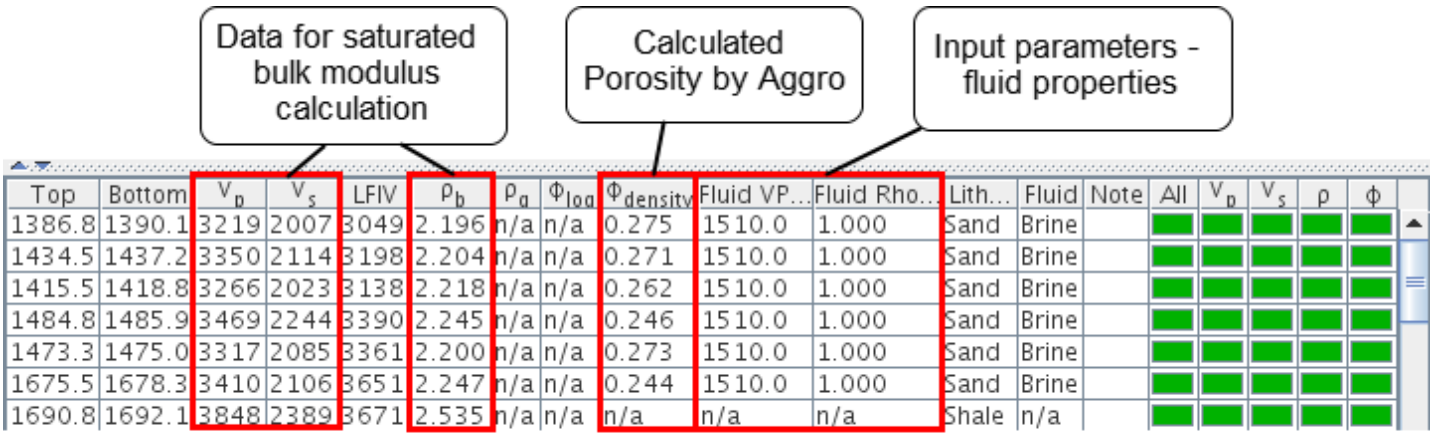
Common fluid properties.

Porosity

After the matrix properties and fluid properties have been determined and entered into the Lithology Grain section and *Pick Summary Table* respectively, DUG Rock will then automatically calculate the porosity of the rock and derive the bulk modulus of the porous rock frame from the *Pick Summary Table*. Next, calculate the reference fluid.

Reference Fluid

The reference fluid can be identified through the porosity, the matrix properties and the fluid properties of the reservoir. You may enter the reference fluid, usually calculated from average brine properties of the area of study. Then, apply Gassmann to substitute the reservoir fluid to the reference fluid.



Top	Bottom	V_p	V_s	LFIV	ρ_b	ρ_a	Φ_{log}	$\Phi_{density}$	Fluid VP...	Fluid Rho...	Lith...	Fluid	Note	All	V_p	V_s	ρ	ϕ
1386.8	1390.1	3219	2007	3049	2.196	n/a	n/a	0.275	1510.0	1.000	Sand	Brine						
1434.5	1437.2	3350	2114	3198	2.204	n/a	n/a	0.271	1510.0	1.000	Sand	Brine						
1415.5	1418.8	3266	2023	3138	2.218	n/a	n/a	0.262	1510.0	1.000	Sand	Brine						
1484.8	1485.9	3469	2244	3390	2.245	n/a	n/a	0.246	1510.0	1.000	Sand	Brine						
1473.3	1475.0	3317	2085	3361	2.200	n/a	n/a	0.273	1510.0	1.000	Sand	Brine						
1675.5	1678.3	3410	2106	3651	2.247	n/a	n/a	0.244	1510.0	1.000	Sand	Brine						
1690.8	1692.1	3848	2389	3671	2.535	n/a	n/a	n/a	n/a	n/a	Shale	n/a						

Pick Summary Table

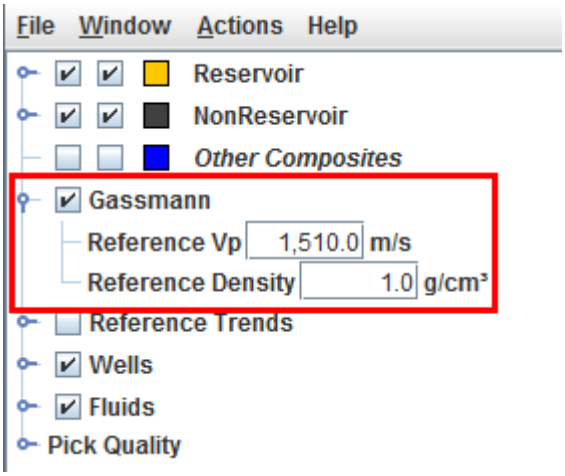
As a result of Gassmann substitution, new density and velocity values of the reservoir will be derived and the reservoir property trends will be corrected based on the reference fluid filling the pore spaces.

Gassmann Substitution – Input Fluid Properties

When there is hydrocarbon identified during the picking stage, Gassmann substitution proves to be a crucial step to provide a trend that is independent of fluid type. Gassmann substitution cancels out hydrocarbon or gas effect on well logs by correcting the log values back to a reference fluid (usually an average brine). Velocity and density of the reference fluid is input in the Gassmann substitution section and generally is an average of the brine properties of the area of study.

The default reference fluid VP is 1,635.25m/s and Rho 1.0g/cm^3. Normally, these values are replaced with the average fluid VP and Rho of brine sand based on the information that is displayed in the *Pick Summary Table*.

How to Set VP and Rho Values for Gassmann Substitution



1. In the Control Panel, expand the Gassmann tree.
2. Manually calculate the Fluid VP and Rho average values obtained from the *Pick Summary Table*.
3. Enter the average value of the VP and Rho in the **VP** and **Rho** text box at the **Gassmann Substitution** tree.

Top	Bottom	V_p	V_s	LFIV	ρ_b	ρ_a	Φ_{log}	$\Phi_{density}$	Fluid VP...	Fluid...	Litho...	Fluid	Note	All	V_p	V_s	ρ	ϕ
1434.5	1437.2	3350	2114	3198	2.204	n/a	n/a	0.271	1510.0	1.000	Sand	Brine						
1415.5	1418.8	3266	2023	3138	2.218	n/a	n/a	0.262	1510.0	1.000	Sand	Brine						
1484.8	1485.9	3469	2244	3390	2.245	n/a	n/a	0.246	1510.0	1.000	Sand	Brine						
1473.3	1475.0	3317	2085	3361	2.200	n/a	n/a	0.273	1510.0	1.000	Sand	Brine						
1675.5	1678.3	3410	2106	3651	2.247	n/a	n/a	0.244	1510.0	1.000	Sand	Brine						
1694.2	1695.7	3784	2362	3675	2.287	n/a	n/a	0.220	1510.0	1.000	Sand	Brine						
1690.8	1692.1	3848	2389	3671	2.535	n/a	n/a	n/a	n/a	n/a	Shale	n/a						
1732.0	1734.1	3625	2267	3702	2.525	n/a	n/a	n/a	n/a	n/a	Shale	n/a						
1666.8	1670.4	3676	2300	3643	2.514	n/a	n/a	n/a	n/a	n/a	Shale	n/a						

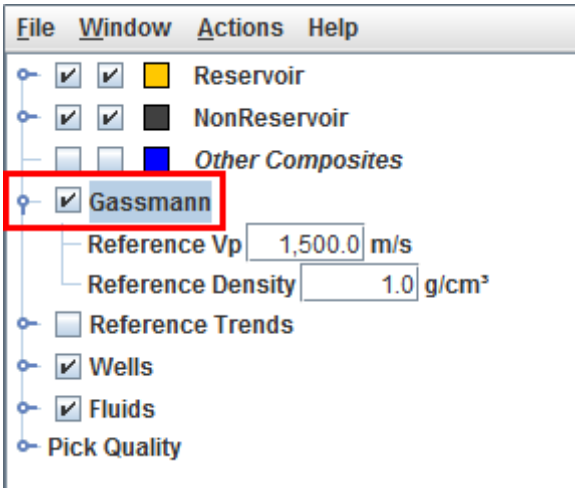
Calculation of the fluid properties is done externally and then input manually into the Pick Summary Table.

Gassmann Substitution – Apply Gassmann to Correct Crossplot

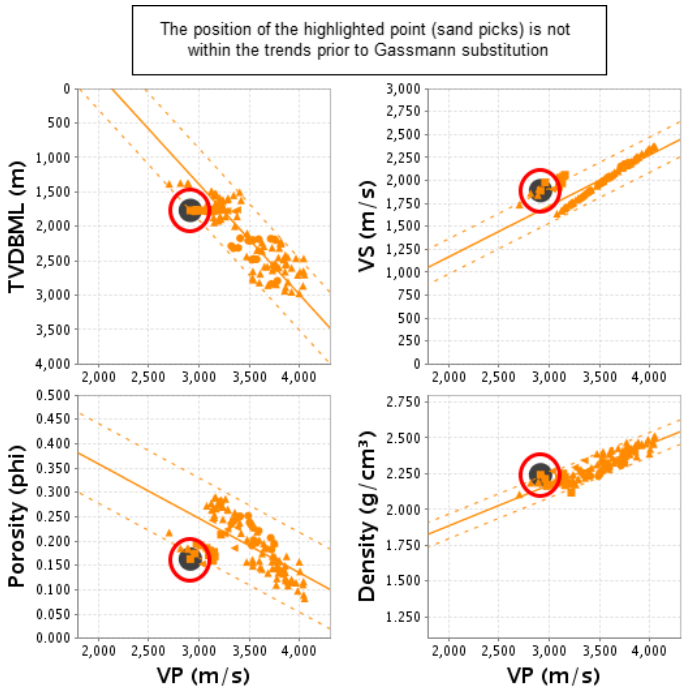
After setting the VP and Rho values for the reference fluid, you may apply the Gassman substitution to create new velocity and density parameters for the reservoir lithologies. DUG Rock Gassmann substitution's logic is based on Gassmann's Theory.

Gassmann substitution carried out on sandstones generally tightens up the rock property trends, removing scatter as a result of variations in fluid properties. This can also provide confidence in the calculated fluid properties.

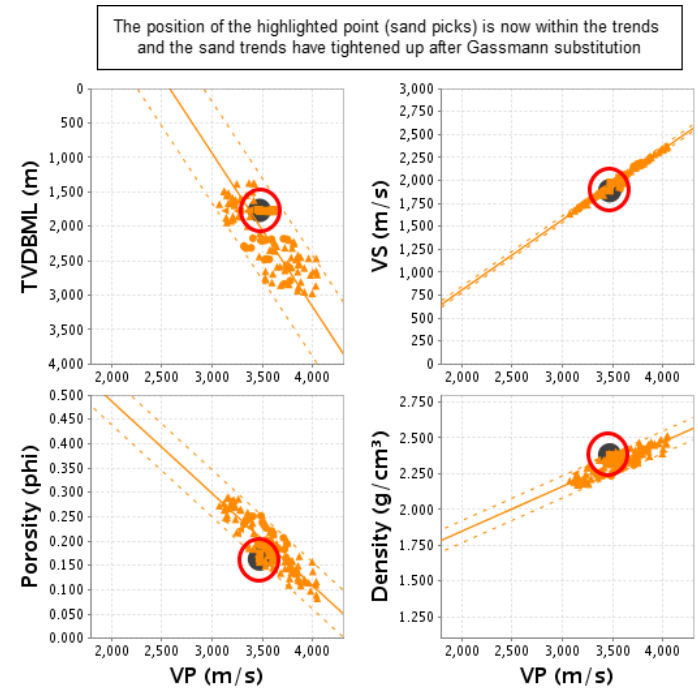
How to Apply Gassmann Substitution



1. In the Control Panel, select the Gassmann check box to apply Gassmann Substitution.
2. See before and after Gassmann Substitution effect in the image below.



Before Gassmann substitution

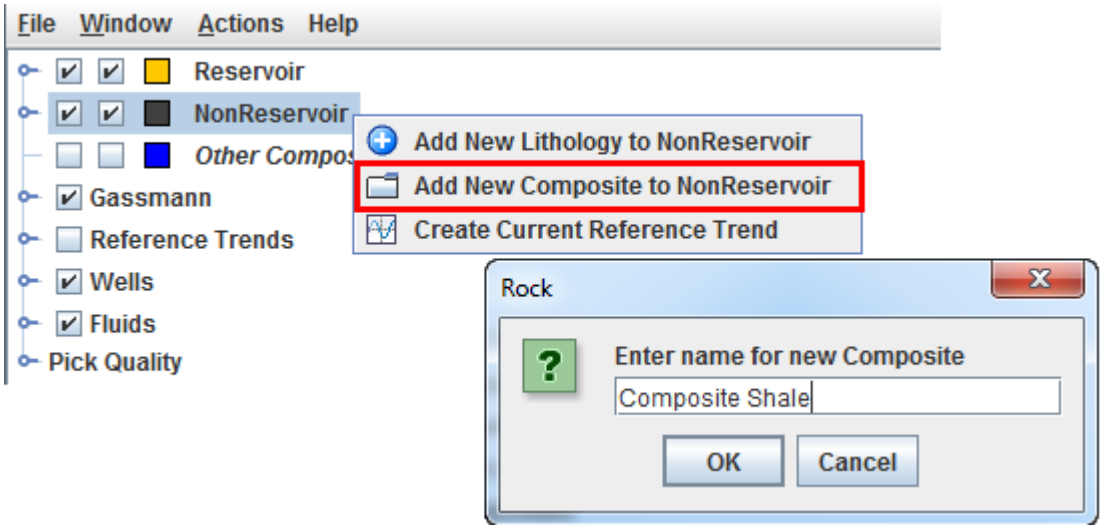


After Gassmann substitution

Composite Lithologies

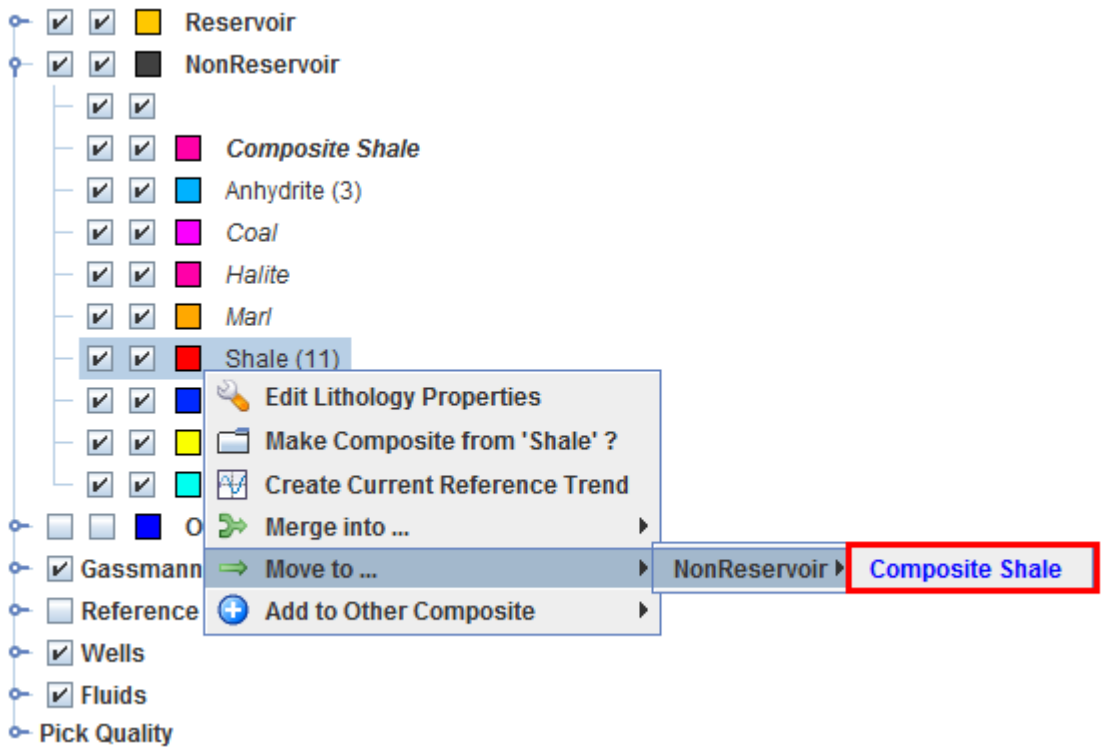
There may be a need to compare or combine groups of lithologies. If lithologies behave elastically in a similar way with depth, then it may be necessary to generate a trend of combined lithologies. DUG Rock provides a composite function that is capable of combining several lithologies to form a single trend.

How to Create Composite Lithologies

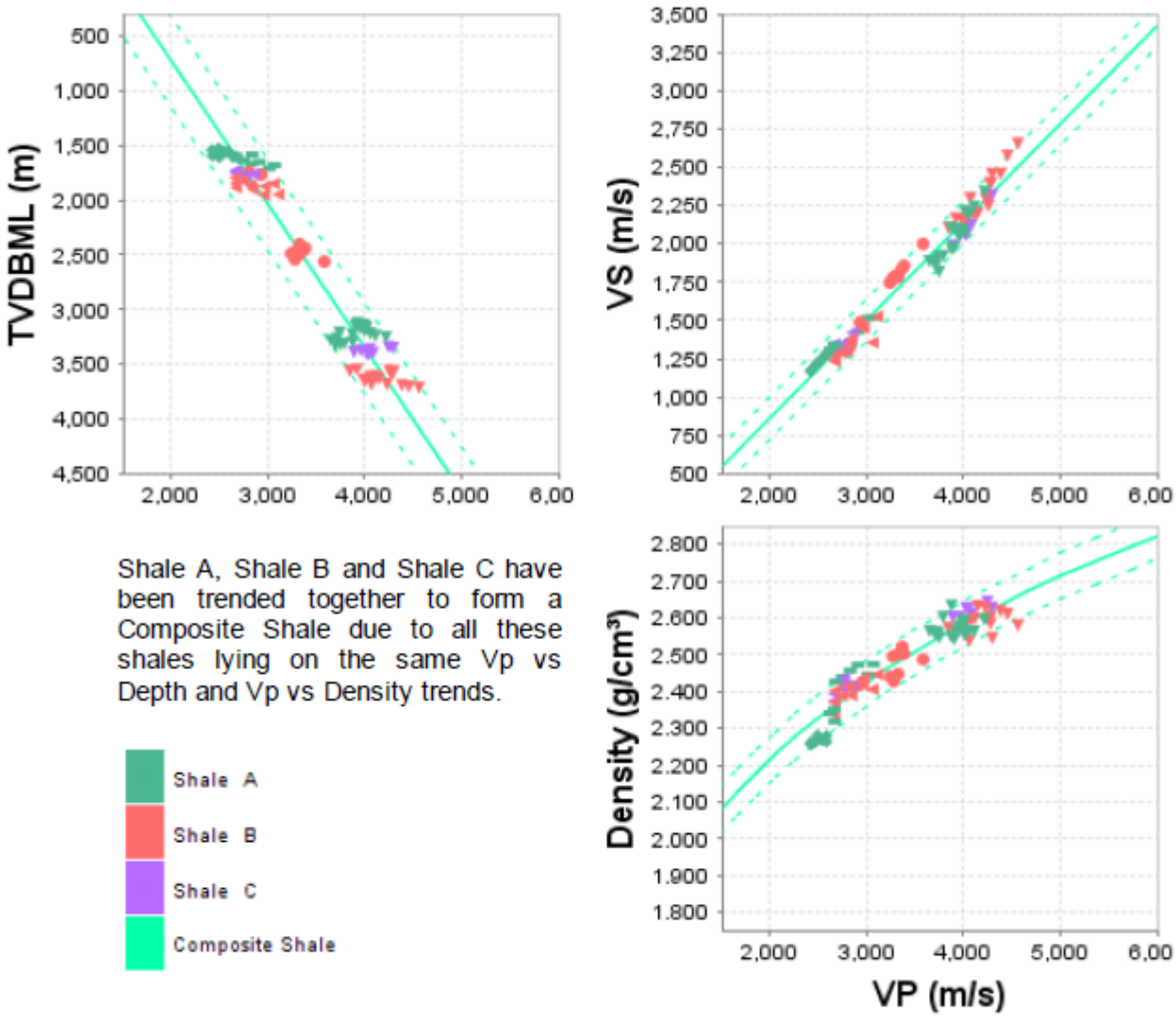


You can create a reservoir or non-reservoir composite from the Control Panel.

1. Simply right click on Reservoir or NonReservoir, and select **Add New Composite**.
   For other composites that do not fall into either category, you can create them in ***Other Composites***.
2. Enter a name for the new composite lithology for easy reference and click OK. Let's assume that you want to composite non-reservoir lithologies: enter a new composite name, for example, *Composite Shale*.



3. To add lithologies to the composite, right click on any other lithology and select **Move to**. Choose the composite that you have just created.
   Alternatively, you can also click and drag lithologies into a composite.
4. You can also add new lithologies to the composite. Right click on the composite and select **Add New Lithology to Composite**.

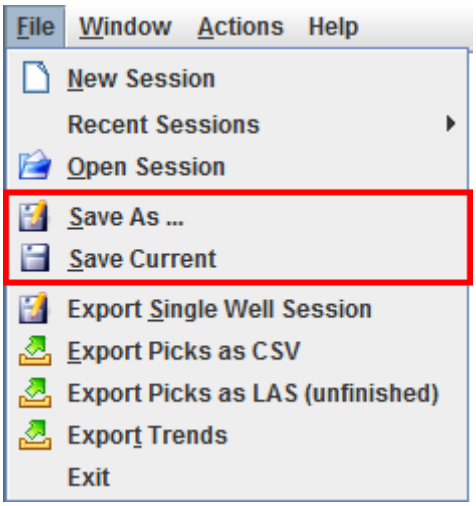


Displaying non-reservoir composite lithology (Composite Shale).

Save Session

How to Save a Session

This is a crucial step. The Save Session function allows you to store all the activities performed in DUG Rock at any time. All the hard work of identifying end members and customizing picks and trends can be saved. Before saving the session, it is good practice to first organize the location of the wells data files (*.*las* files) into one folder. The session that is saved should be placed into the same folder to facilitate future reference. Once the session is saved, any moved or redirected wells data files cannot be located by DUG Rock and the files will have to be located manually.



1. In the **File** menu, click **Save As**. The **Save Session** dialog box appears.
   If you have previously saved the session, click **Save Current**.
2. Select a location for the session to save in. Enter a name in the **File Name** text box.
3. You must ensure your session is saved in the same folder as your *.*las* files. To verify that your session is saved in the same folder as your *.las files, click the **Files of Type** drop down list and select **All Files**. DUG Rock will look for the *.las files in the same folder where you saved the session.
4. Click **Save** to store the session in the folder.

Appendix

Sample File Formats

Sample *.las File Format

File Edit View Bookmarks Tools Settings Help

```
~Version Information
VERS            .               2.0                         : CWLS Log Ascii Standard - Version 2.0
WRAP            .               NO                          : One line per depth step
~Well Information Block
#MNEM           .UNIT           DATA                        : INFORMATION
#-------------- .----------     ---------------             : -------------------------
STRT            .m              39.9288                     : START DEPTH
STOP            .m              1871.9292                   : STOP DEPTH
STEP            .m              0.1524                      : STEP DEPTH
NULL            .               -999.25                     : NULL DATA VALUE
WELL            .               Card                        : WELL
~Parameter Information Block
#MNEM           .UNIT           DATA                        : INFORMATION
#-------------- .----------     ---------------             : -------------------------
~Curve Information Block
#MNEM           .UNIT                                       : CURVE  DESCRIPTION
#-------------- .----------                                 : -----  ------------------
DEPT            .m                                          : 0      Depth
CALI            .in                                         : 1.....
RHOB            .g/cm³                                      : 2.....
DRHO            .g/cm³                                      : 3.....
GR              .                                           : 4.....
NPHI            .                                           : 5.....
PEF             .                                           : 6.....
DT              .µs/ft                                      : 7.....
MSFL            .Ω·m                                        : 8.....
LLS             .Ω·m                                        : 9.....
LLD             .Ω·m                                        : 10....
SFLU            .Ω·m                                        : 11....
ILD             .Ω·m                                        : 12....
SP              .mV                                         : 13....
DTS             .µs/ft                                      : 14      FILL
~A      DEPT         CALI        RHOB        DRHO          GR         NPHI          PEF          DT         MSFL         LLS         LLD         SFLU         ILD          SP         DTS
   39.928800  -999.250000 -999.250000 -999.250000 -999.250000 -999.250000 -999.250000 -999.250000 -999.250000 -999.250000 -999.250000 -999.250000 -999.250000 -999.250000  88.490922
   40.081200  -999.250000 -999.250000 -999.250000   11.546900 -999.250000 -999.250000   57.750000 -999.250000 -999.250000 -999.250000 2000.000000 2000.000000  435.000000  88.490922
   40.233600  -999.250000 -999.250000 -999.250000   12.289100 -999.250000 -999.250000   57.750000 -999.250000 -999.250000 -999.250000 2000.000000 2000.000000  435.000000  89.951138
   40.386000  -999.250000 -999.250000 -999.250000   12.328100 -999.250000 -999.250000   57.750000 -999.250000 -999.250000 -999.250000 2000.000000 2000.000000  435.000000  93.632332
   40.538400  -999.250000 -999.250000 -999.250000   11.007800 -999.250000 -999.250000   57.750000 -999.250000 -999.250000 -999.250000 2000.000000 2000.000000  435.000000  91.374240
   40.690800  -999.250000 -999.250000 -999.250000    9.960900 -999.250000 -999.250000   57.750000 -999.250000 -999.250000 -999.250000 2000.000000 2000.000000  435.000000  92.170761
   40.843200  -999.250000 -999.250000 -999.250000    9.914100 -999.250000 -999.250000   57.750000 -999.250000 -999.250000 -999.250000 2000.000000 2000.000000  435.000000  93.040342
   40.995600  -999.250000 -999.250000 -999.250000    9.210900 -999.250000 -999.250000   57.750000 -999.250000 -999.250000 -999.250000 2000.000000 2000.000000  435.000000  92.752172
   41.148000  -999.250000 -999.250000 -999.250000    8.875000 -999.250000 -999.250000   57.750000 -999.250000 -999.250000 -999.250000 2000.000000 2000.000000  435.000000  92.464001
   41.300400  -999.250000 -999.250000 -999.250000    9.914100 -999.250000 -999.250000   57.750000 -999.250000 -999.250000 -999.250000 2000.000000 2000.000000  435.000000  92.175831
   41.452800  -999.250000 -999.250000 -999.250000    9.562500 -999.250000 -999.250000   57.750000 -999.250000 -999.250000 -999.250000 2000.000000 2000.000000  435.000000  85.656953
   41.605200  -999.250000 -999.250000 -999.250000    9.187500 -999.250000 -999.250000   57.750000 -999.250000 -999.250000 -999.250000 2000.000000 2000.000000  435.000000  87.922058
   41.757600  -999.250000 -999.250000 -999.250000    9.156200 -999.250000 -999.250000   57.750000 -999.250000 -999.250000 -999.250000 2000.000000 2000.000000  435.000000  90.187163
   41.910000  -999.250000 -999.250000 -999.250000   11.523400 -999.250000 -999.250000   57.750000 -999.250000 -999.250000 -999.250000 2000.000000 2000.000000  435.000000  90.964368
```

Sample *.trend File Format

File Edit View Search Tools Documents Help

New Open Save Print... Undo Redo Cut Copy Paste Find Replace

TrendSample.trend

```
# Gassmann Reference Fluid
reference.type                                fluid
reference.vp                                 1510.0
reference.vp.error                                0
reference.rho                                  0.99
reference.rho.error                               0


## Lithology: Sand
Sand.type                          reservoir
Sand.vp.A                         2036.1782
Sand.vp.B                            0.9515
Sand.vp.C                            0.0000
Sand.vp.error                         192.9090
Sand.vs.A                            -96.152592
Sand.vs.B                             0.651594
Sand.vs.error                        16.170911
Sand.rho.A                            1.500581
Sand.rho.B                            0.000217
Sand.rho.error                        0.018981
Sand.phi.A                            0.692421
Sand.phi.B                           -0.000131
Sand.phi.error                        0.011434
Sand.grain.vp                      5960.000000
Sand.grain.vs                      3730.000000
Sand.grain.rho                        2.650000

## Lithology: Shale
Shale.type                       nonreservoir
Shale.vp.A                          2670.5547
Shale.vp.B                             0.5479
Shale.vp.C                             0.0000
Shale.vp.error                       109.2668
Shale.vs.A                           249.095508
Shale.vs.B                             0.556413
Shale.vs.error                        19.941171
Shale.rho.A                            1.143943
Shale.rho.B                            0.096569
Shale.rho.error                        0.018204
```

Ln 63, Col 45 INS

Acknowledgments

This product includes 3rd-party software, including:

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