The GATHERing Knowledge Exchange

Accelerating insights from 4D seismic data

with new multidimensional data structures

Jorg Herwanger, Andy Bottrill, Cerys Biancardi

Crossplot Exercises

20 October 2023

SHARP REFLECTIONS
DISCOVER MORE

Crossplot Tutorial

This tutorial cover some of the new functionality in the Crossplot tool:

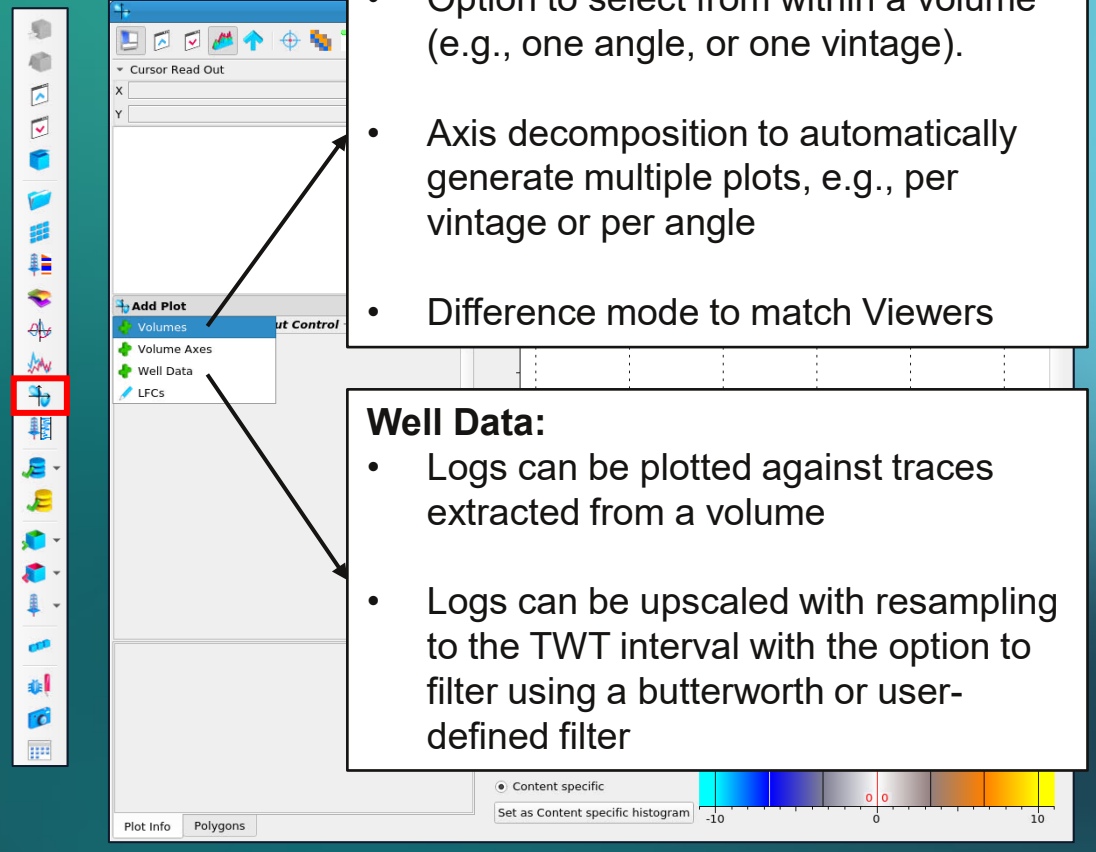
- Making a multiple vintage plot, with point-clouds auto generated for each vintage
- Generating a difference plot showing a point-cloud for every incremental difference between vintages
- Restricting plots to a Map Polygon and interactively control the plots by moving the polygon
- Using the crossplot to make a mask volume to visualise areas-of-interest on a Stack Viewer and then the 3DViewer

Introduction: what's new in the Crossplot

In this release there are three key improvements:

1. Sub-selection from a volume and automatic decomposition of multi-axis volume plots
2. Rock physics overlays to help QC elastic properties
3. The option to plot volume versus well log, which includes improved upscaling of logs

This tutorial contains exercises for 1 and 2.



Volume vs volume:

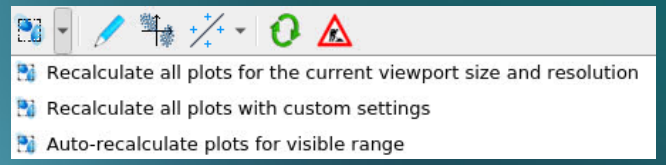
- Option to select from within a volume (e.g., one angle, or one vintage).
- Axis decomposition to automatically generate multiple plots, e.g., per vintage or per angle
- Difference mode to match Viewers

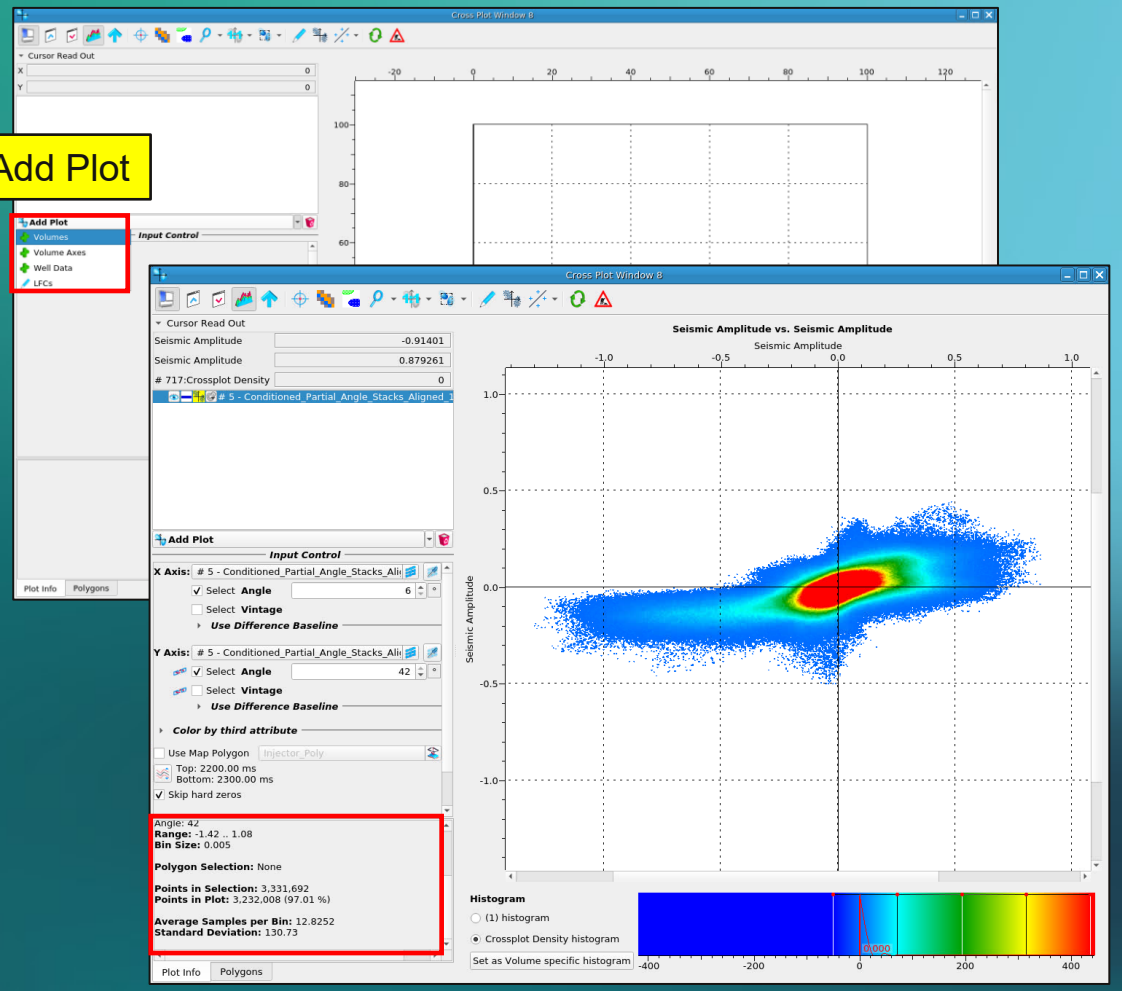
Well Data:

- Logs can be plotted against traces extracted from a volume
- Logs can be upscaled with resampling to the TWT interval with the option to filter using a butterworth or user-defined filter

Introduction: general crossplot controls

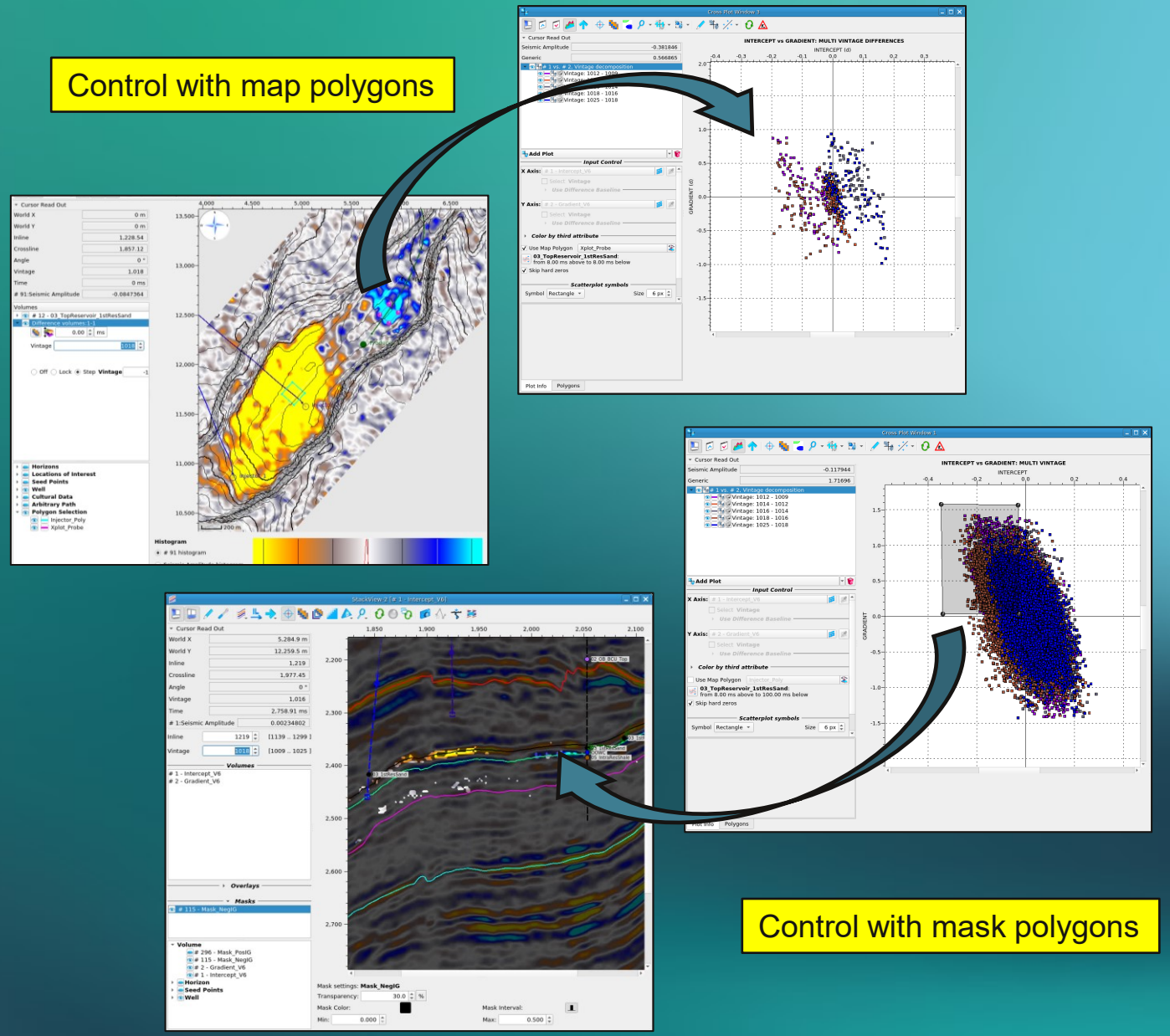
- Plots are created by clicking the **Add Plot** button and selecting the type of plot from the list
- The crossplot window can be reduced in size by dragging the edges of the window
- Plots can be zoomed using the mouse, or by right-clicking on an axis and typing in a range
- Plots can be scatter plots OR density plots. Toggle between these options using the icon next to the plot name: 
- If there are too many points to display as a scatter plot, this icon will be yellow 
- Details of the plot are listed in the bottom-panel. It will show the bin details and number of points in the plot. If this is not what you expected/require go to the binning icon and recalculate or choose custom settings





Crossplot Part 1

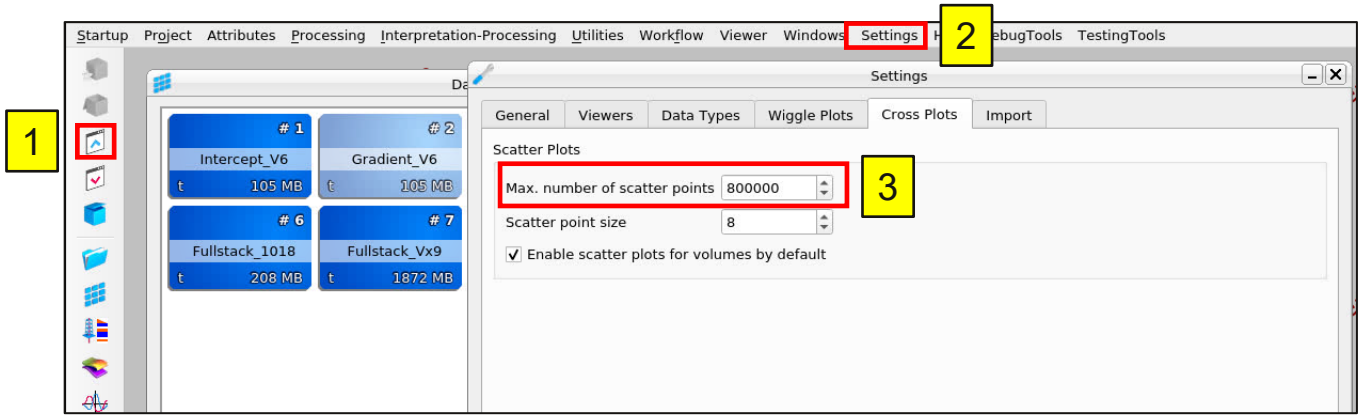
- In this section we will be investigating how Intercept and Gradient vary across the reservoir.
- We will use map polygons to control the points in a crossplot
- We will end with using a mask polygon to link a zone of interest in the plot back to a Stack Viewer

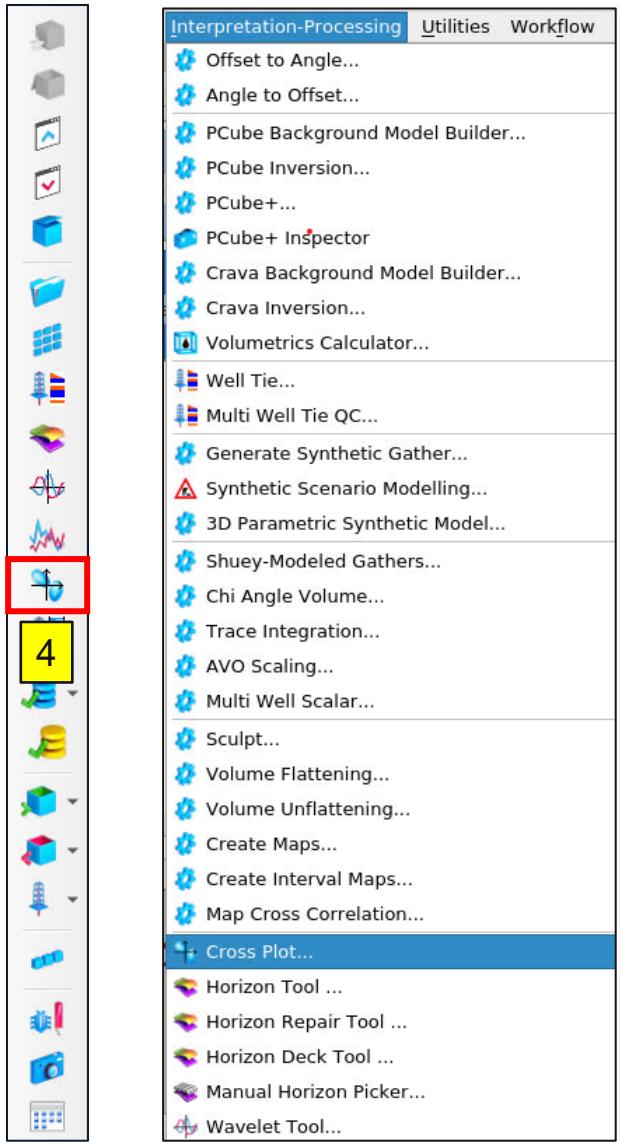


Crossplot part 1: Start up

This tutorial uses the project **4D_Tutorial_Leiden**

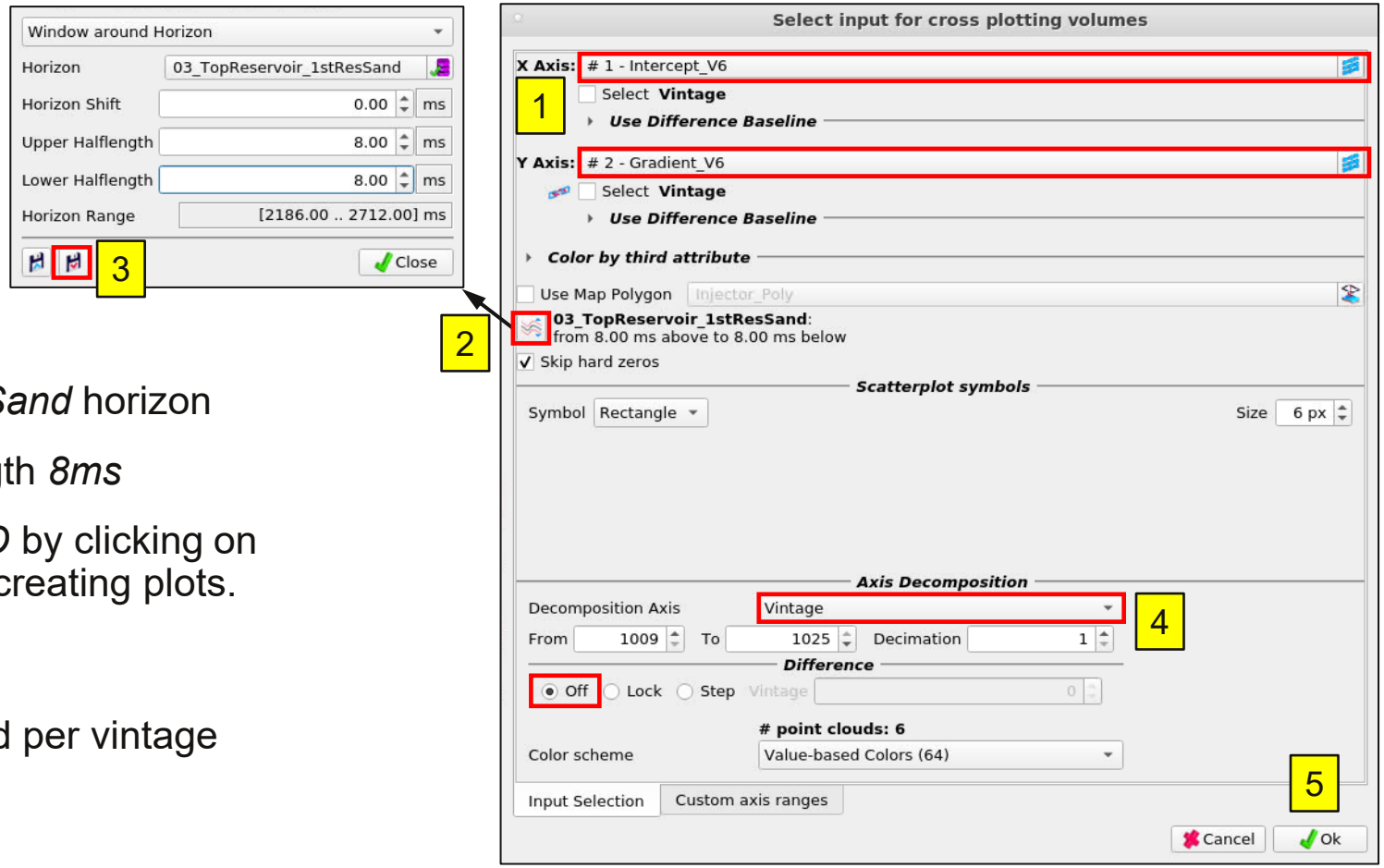
1. Load the session: **START_CROSSPLOT_TUTORIAL**
2. Go to Settings > Settings > Cross Plots
3. Increase the **Max. number of scatter points to 800,000**
4. Open a **Crossplot** by either clicking on the icon in the left-hand toolbar, or via the main menu Interpretation – Processing





Crossplot: Setup an Intercept vs Gradient plot

1. Click on **Add Plot** then **+ Volumes**
2. Select the volumes to plot:
   - X axis: *Intercept-V6 volume*
   - Y axis: *Gradient-V6 volume*
3. Click on the window icon
   - Select the *03_TopReservoir_1stResSand* horizon
   - Upper halflength *8ms*, Lower halflength *8ms*
   - Save the window range as *INT-GRAD* by clicking on the red save icon. This saves time recreating plots.
4. Select Axis Decomposition:
   - Select **Vintage** to create a point cloud per vintage
   - Leave the difference mode off
5. Press OK



Crossplot info: Volume vs volume options

Axis Controls are flexible and offer a variety of ways of plotting volume data:

- Select from within a volume, e.g., one vintage out of many
- Select a difference, e.g., far – near, or vintage 1012 – 1009 for one or both axes

There are some limitations:

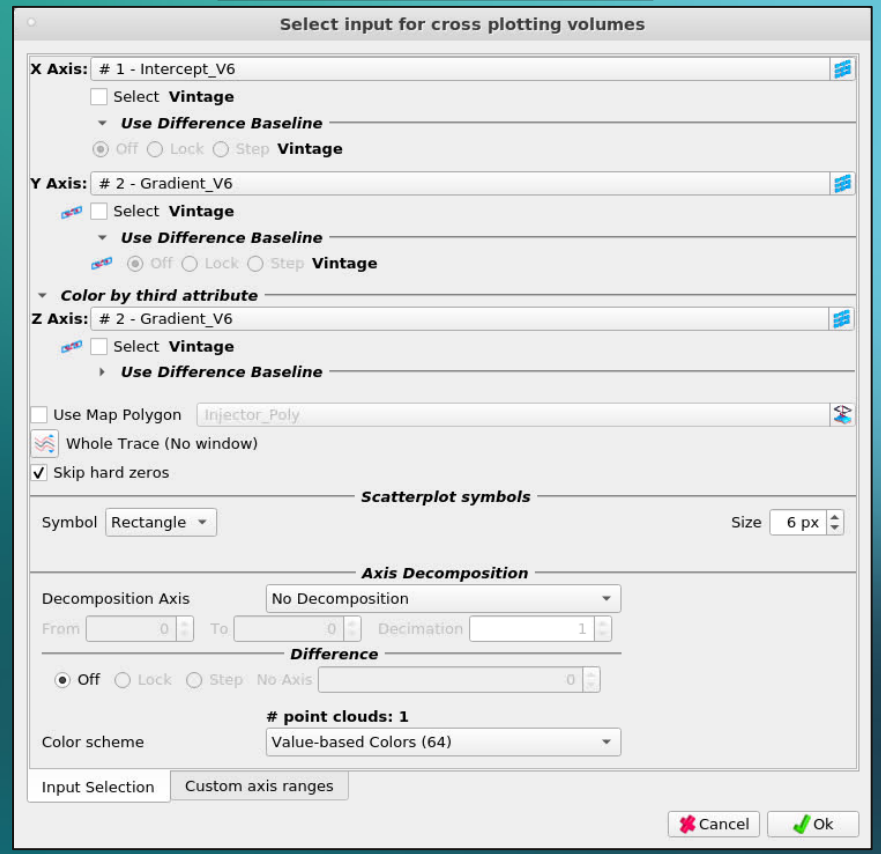
- X and Y must be the same time or depth domain
- X and Y must have the same *number* of vintages/angles/azimuths.

Plots can be coloured by a 3rd attribute

A time (or depth) window and/or a restriction to a map polygon can be set in this startup window OR later in the Cross Plot itself.

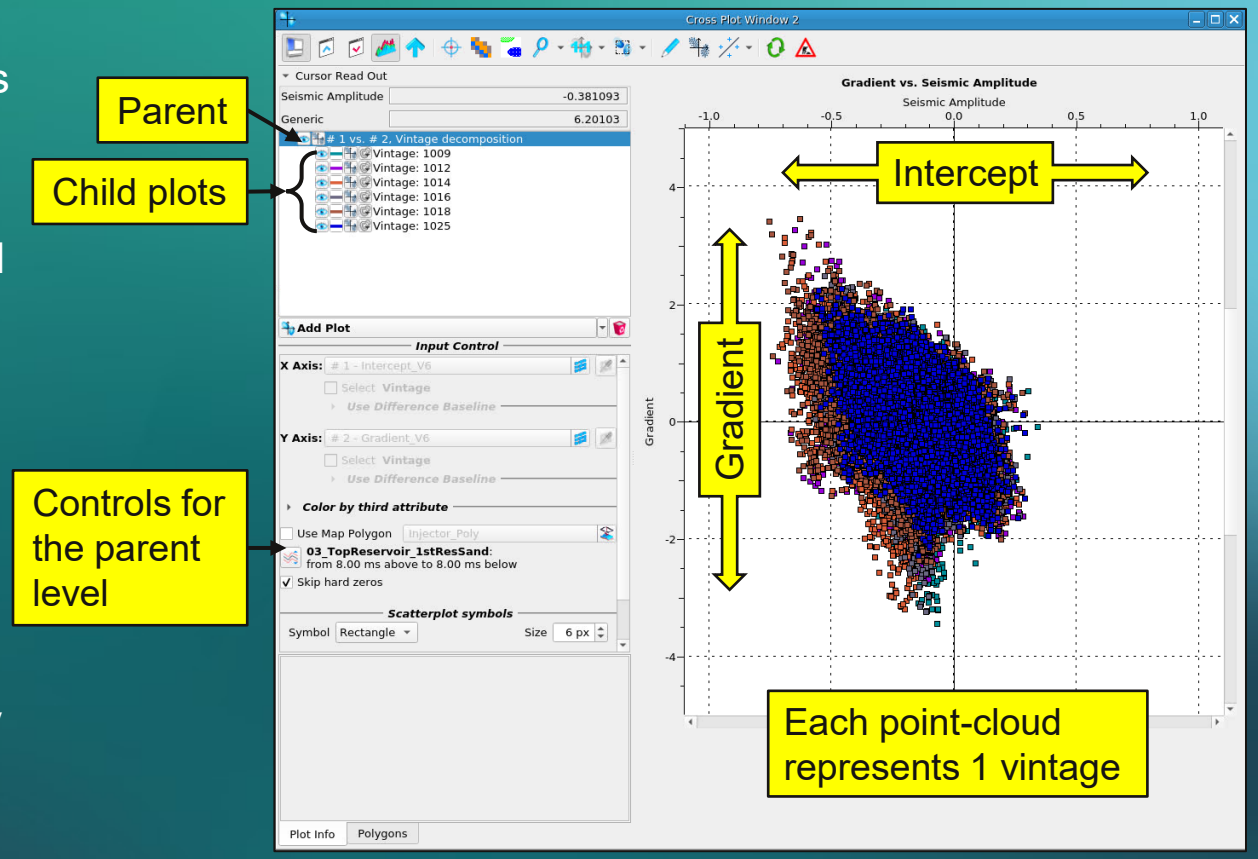
Multiple plots can be autogenerated using the **Axis Decomposition** Mode, for example, a multi-vintage volume can be decomposed so each vintage has its own point-cloud.

Input window for a **volume vs volume** plot



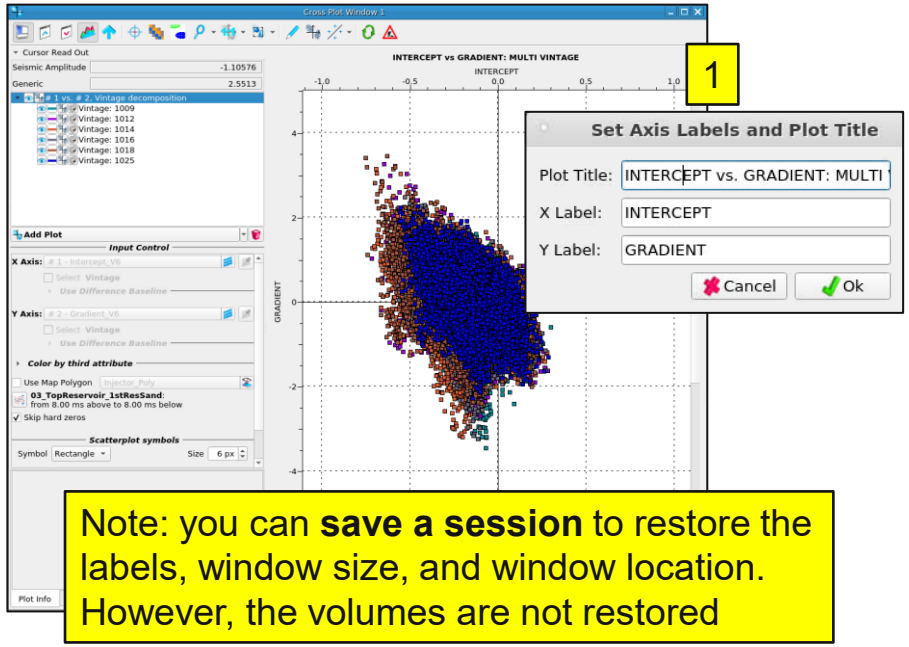
Crossplot info: Decomposed plots

- The decomposed plot will be populated with the 6 vintages plotted as individual “children” point-clouds with one parent
- The **parent level** controls the display for all the “child” plots. Changes to any of these will update all the child point-clouds:
  - Window (around a horizon in this case)
  - Map Polygon (restricts to within a map polygon)
  - Symbol type and size
- The colour of individual child point-clouds can be changed, by clicking on the colour icon.
- The colour scheme for all child plots by changed by right-clicking on the parent and selecting a colour-scale from the list



Crossplot

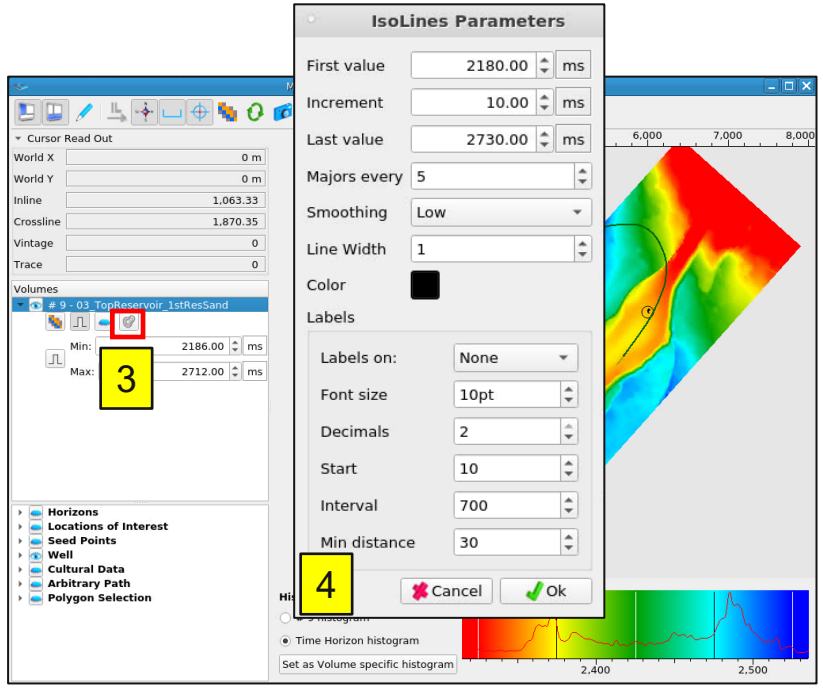
1. Double click on the title and change both the **title** and the X and Y **axes labels**. This can also be done by clicking on the pen icon 
2. Resize the window so you can view the Crossplot and Map Viewer at the same time



Note: you can **save a session** to restore the labels, window size, and window location. However, the volumes are not restored

3. In the Map Viewer *03_TopReservoir_1stResSand* is displayed. Click on the isoline (contours) icon

4. Add contours to the horizon displayed: make the increment 10 with no labels

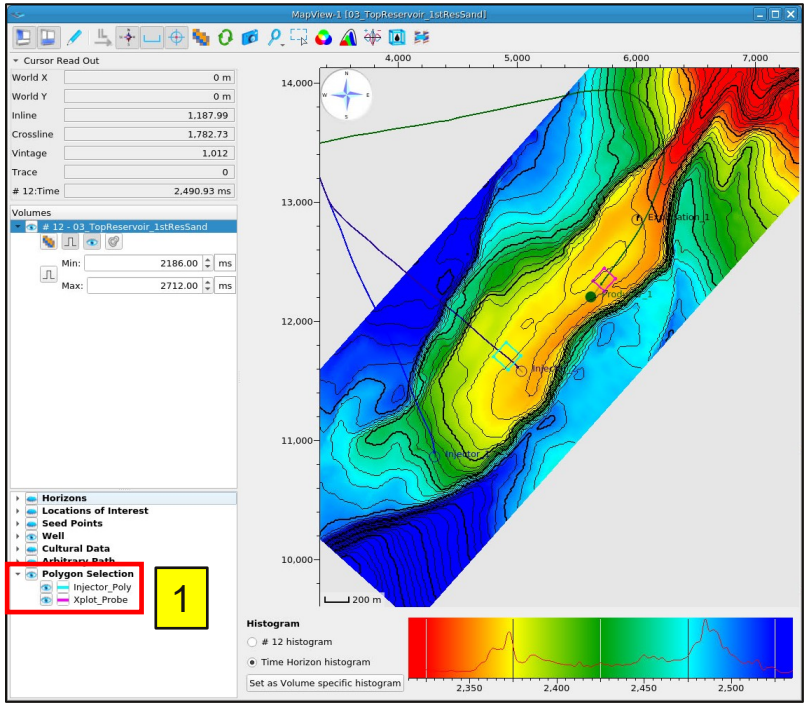


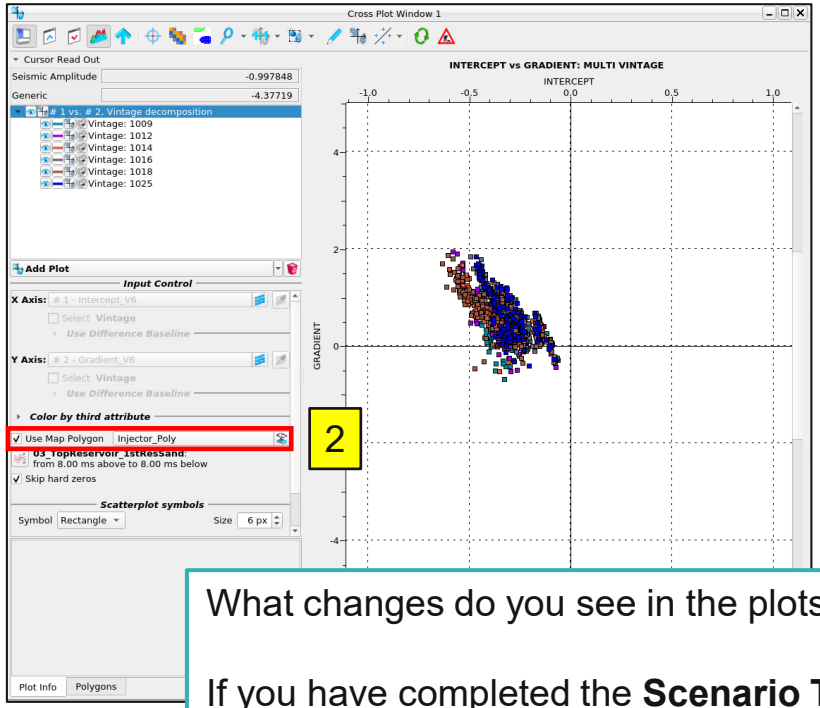
Crossplot: Using map polygons

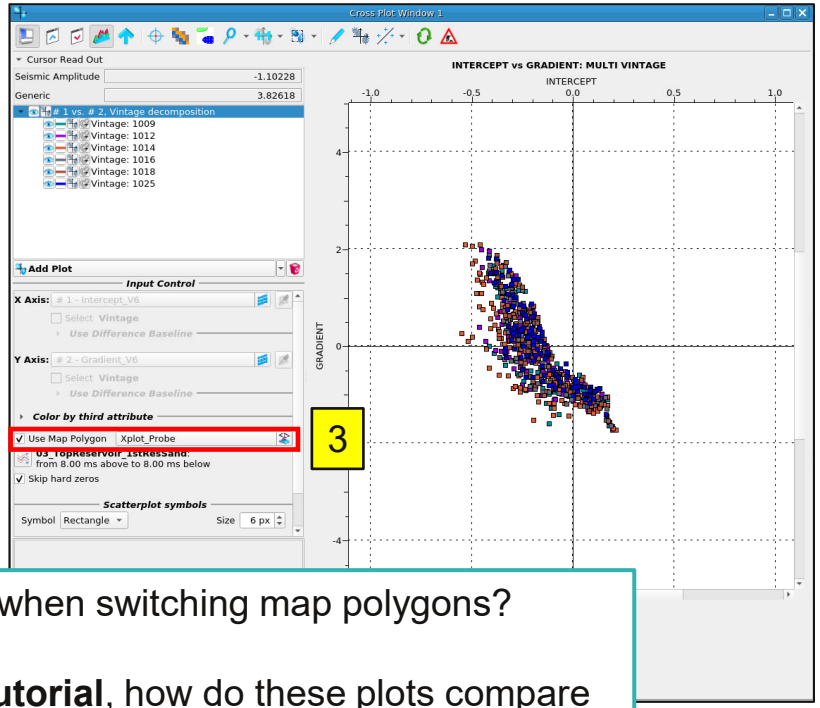
1. Map Viewer: toggle on both polygons: *Injector_Poly* and *Xplot_Probe*

2. Crossplot: Toggle on “Use Map Polygon” and select ***Injector_Poly***

3. Crossplot: Switch the map polygon to ***Xplot_Probe***







What changes do you see in the plots when switching map polygons?

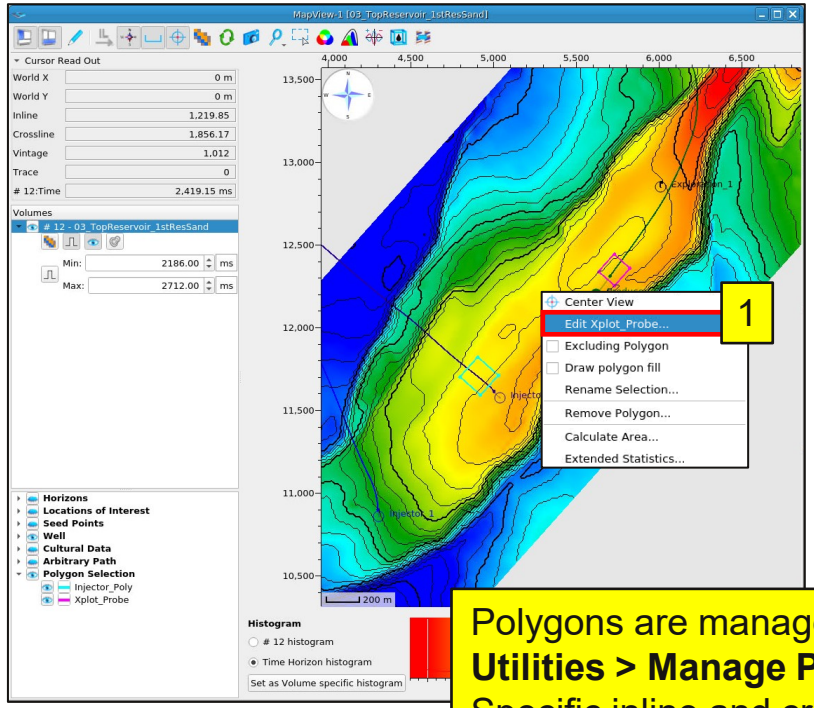
If you have completed the **Scenario Tutorial**, how do these plots compare to the models?

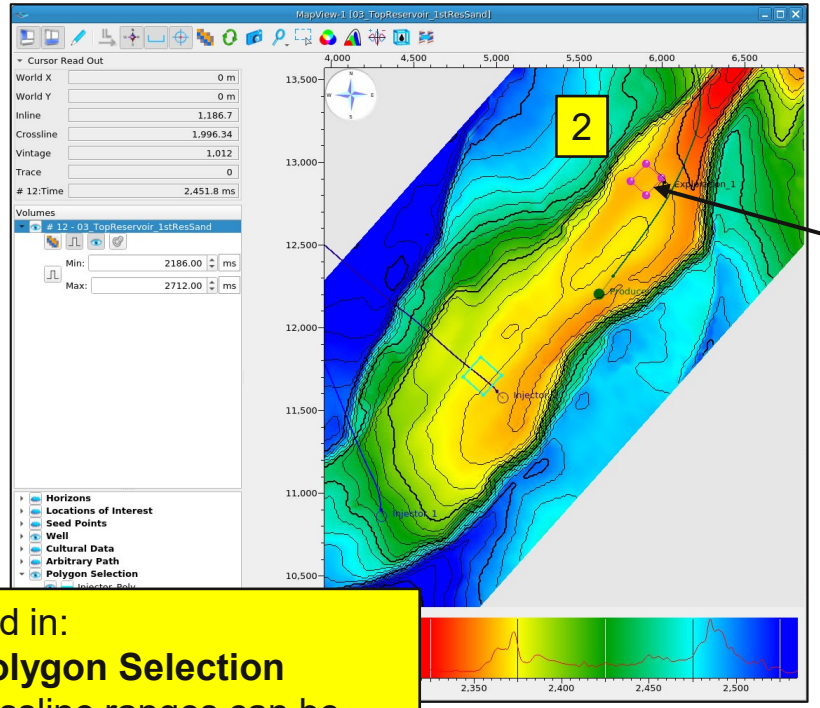
Crossplot: Dynamic map polygons

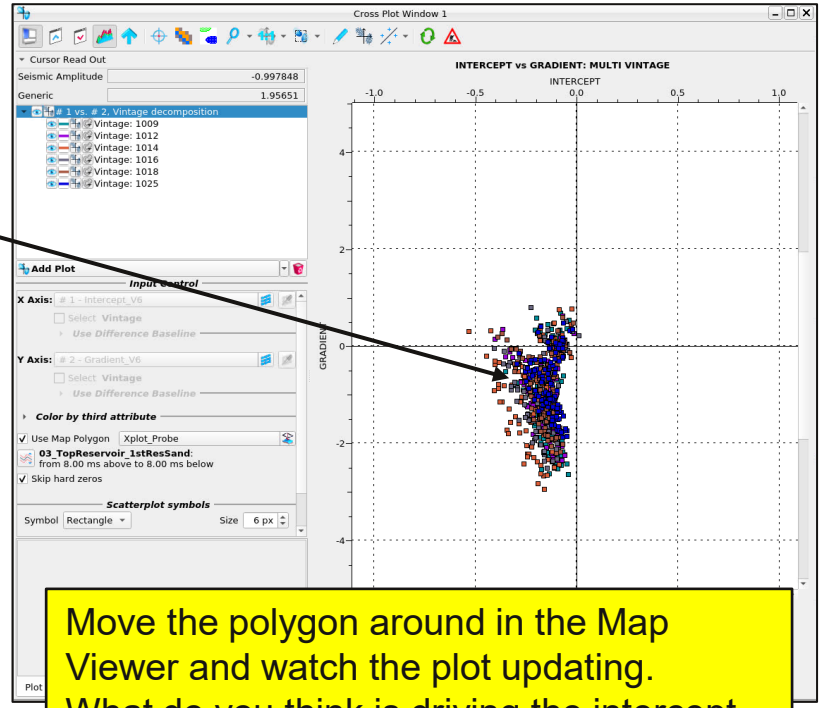
1. Map Viewer: right-click on the *Xplot_Probe* polygon > select **Edit Xplot_Probe…**

2. Map Viewer: Move the polygon by placing cursor in the centre of it and panning it across the horizon.

3. Crossplot: The points in the plot will automatically update, as the polygon is moved around the Map Viewer







Polygons are managed in:
Utilities > Manage Polygon Selection
Specific inline and crossline ranges can be typed for a polygon, and can be non-editable

Move the polygon around in the Map Viewer and watch the plot updating.
What do you think is driving the intercept and gradient changes?

Crossplot info: Difference Modes

The multi-vintage intercept & gradient volumes comprise 6 vintages: 1009, 1012, 1014, 1016, 1018, 1025

The 3 difference modes are common to all viewers:

Off Each vintage has its own point-cloud, no differences are calculated

Lock Differences are calculated with a locked reference, in this example: vintage 1009. Each point-cloud is the difference between a monitor vintage and reference vintage 1009

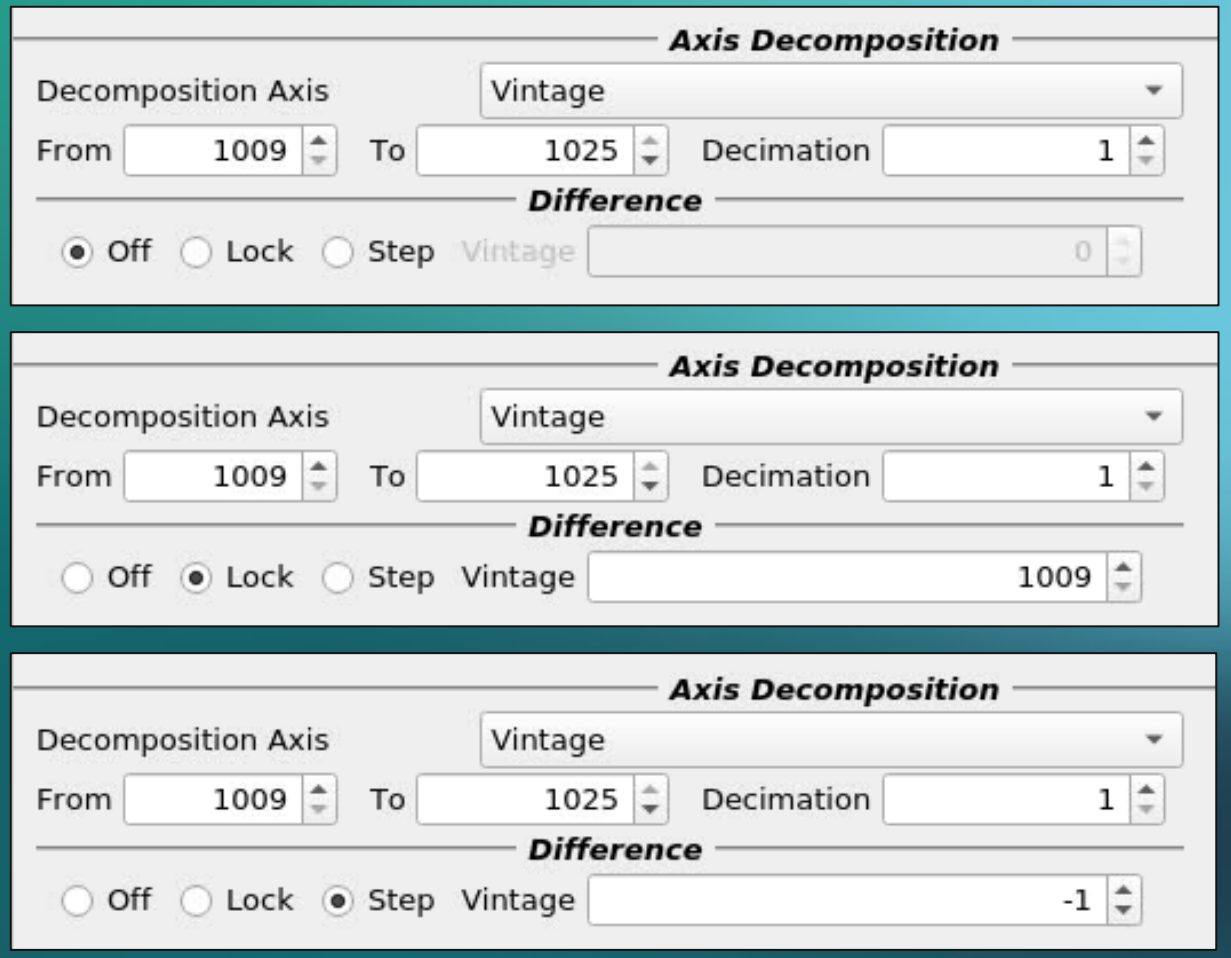
Step Differences are calculated incrementally. The default is -1. Examples of steps:

Step of -1 = 1012 – 1009, 1014 – 1012, etc.

Step of - 2 = 1014 – 1009, 1016 – 1012. etc.

Step of +1 = 1009 - 1012, 1012 – 1014. etc.

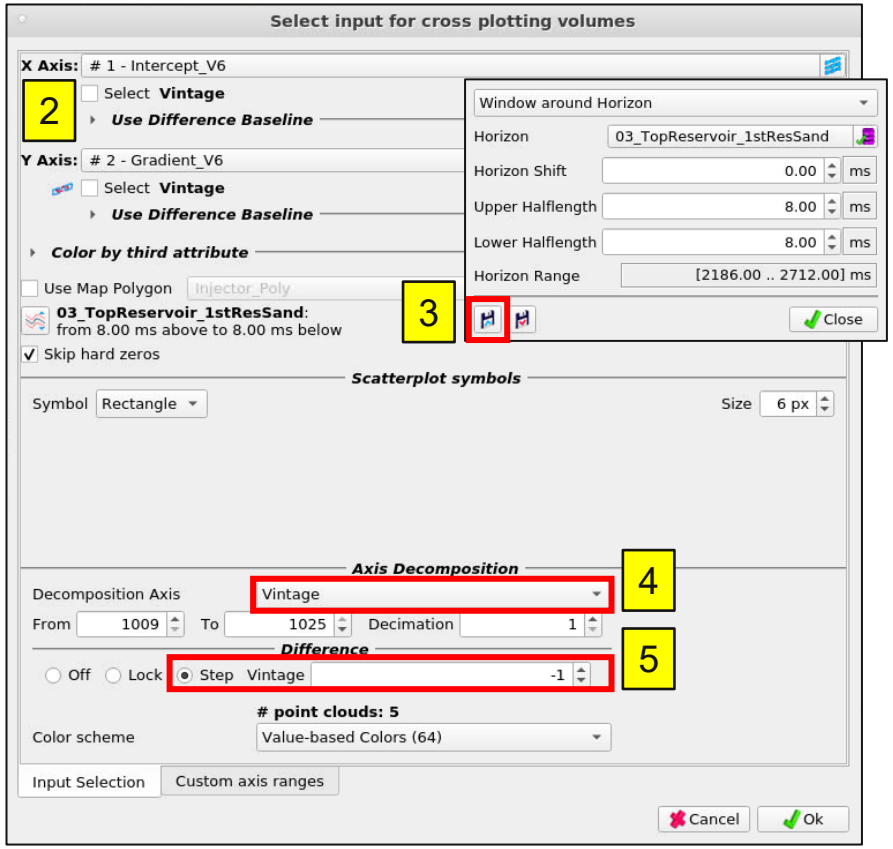
Step of +2 = 1009 - 1014, 1012 – 1016. etc.



Crossplot: plotting using differences

1. Open a **2nd CrossPlot window** 
2. Select *Intercept_V6* and *Gradient_V6*
3. Click on the Edit Window Parameters, use the **load icon** to restore your saved window parameters (*INT-GRAD)*
4. Use Axis Decomposition: Vintage
5. For the Difference mode toggle **Step** and **-1**

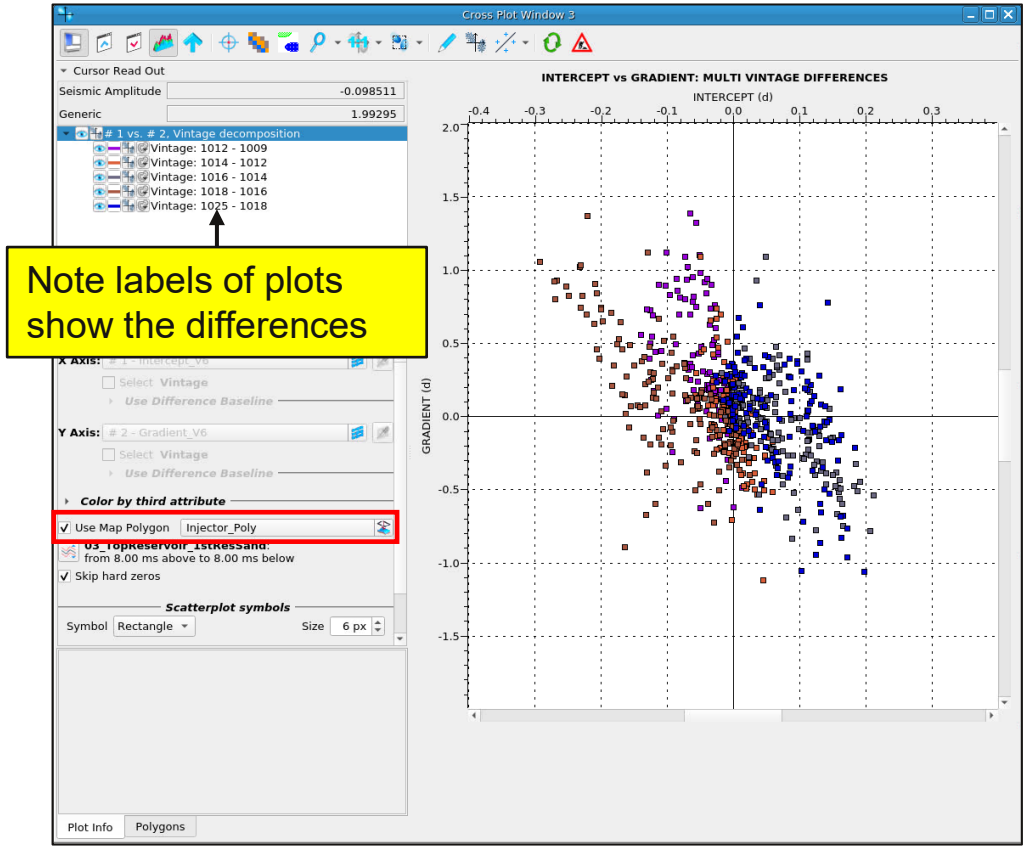
This will make a plot in which each point-cloud is the intercept and gradient difference between vintages



Crossplot: plotting using differences

Note the names of the vintage “child” plots automatically contain the vintage differences, e.g., 1012 – 1009

1. Toggle on **Use Map Polygon**
2. Switch the polygon to *XPLOT_PROBE_POLY* and move the polygon around the Map Viewer
3. Compare the two crossplots
4. Move the *XPLOT_PROBE_POLY* polygon in the Map Viewer. **It will update both crossplots**

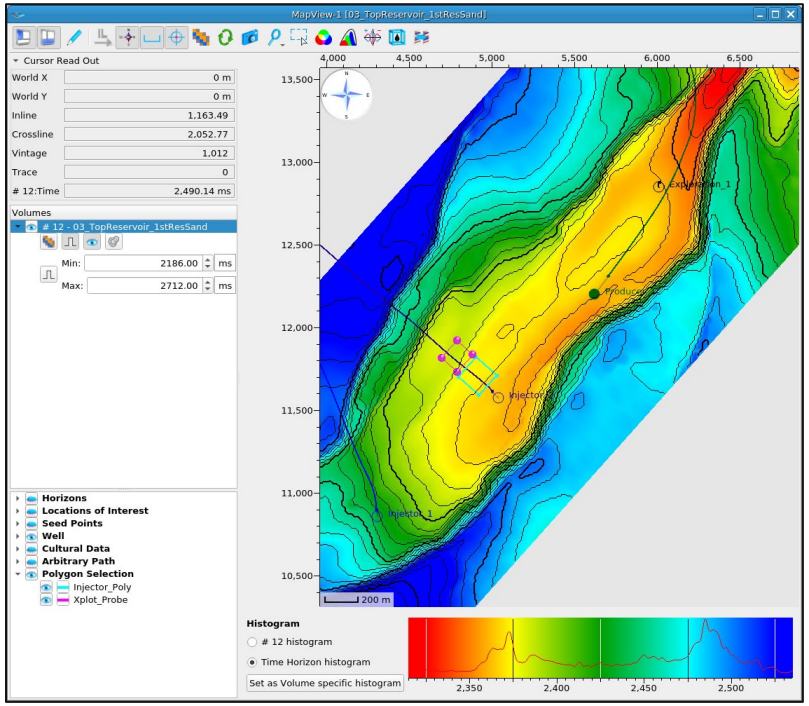


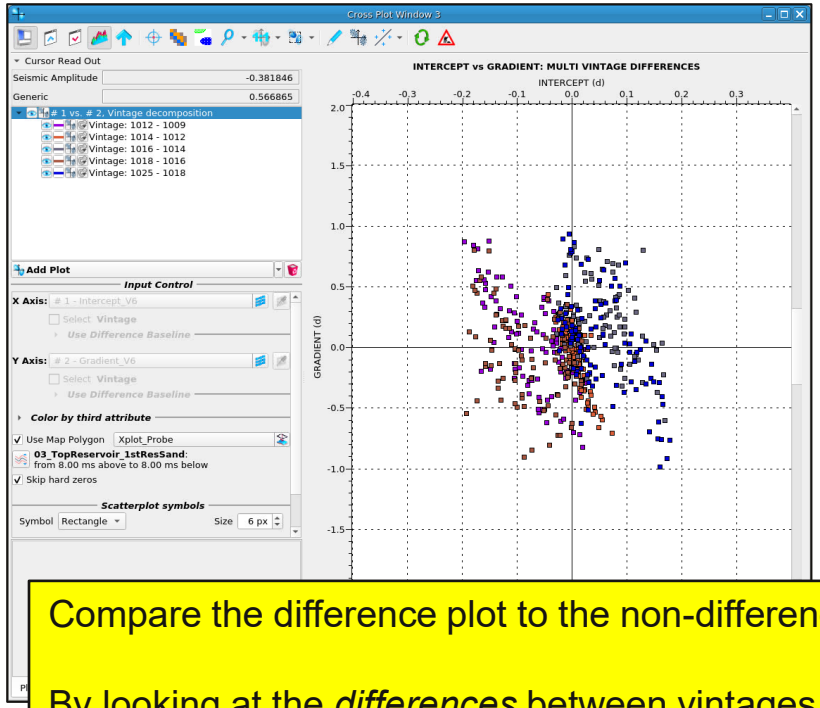
Crossplot: Difference mode

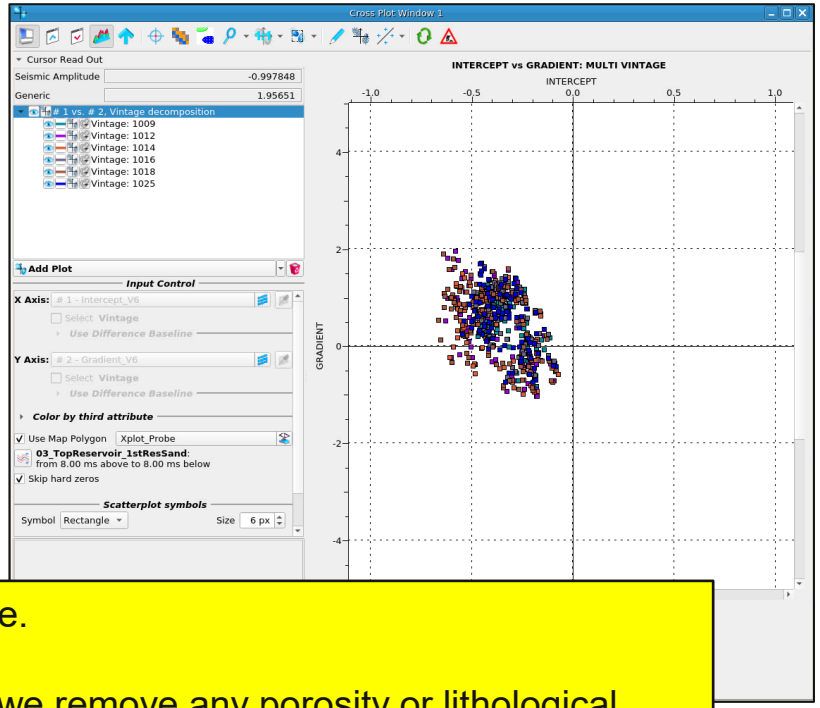
Map Viewer: when you move the map polygon, **both** crossplots will update

Intercept & Gradient Step Differences
Point cloud is the difference between vintages

Intercept & Gradient
Point-cloud is each vintage







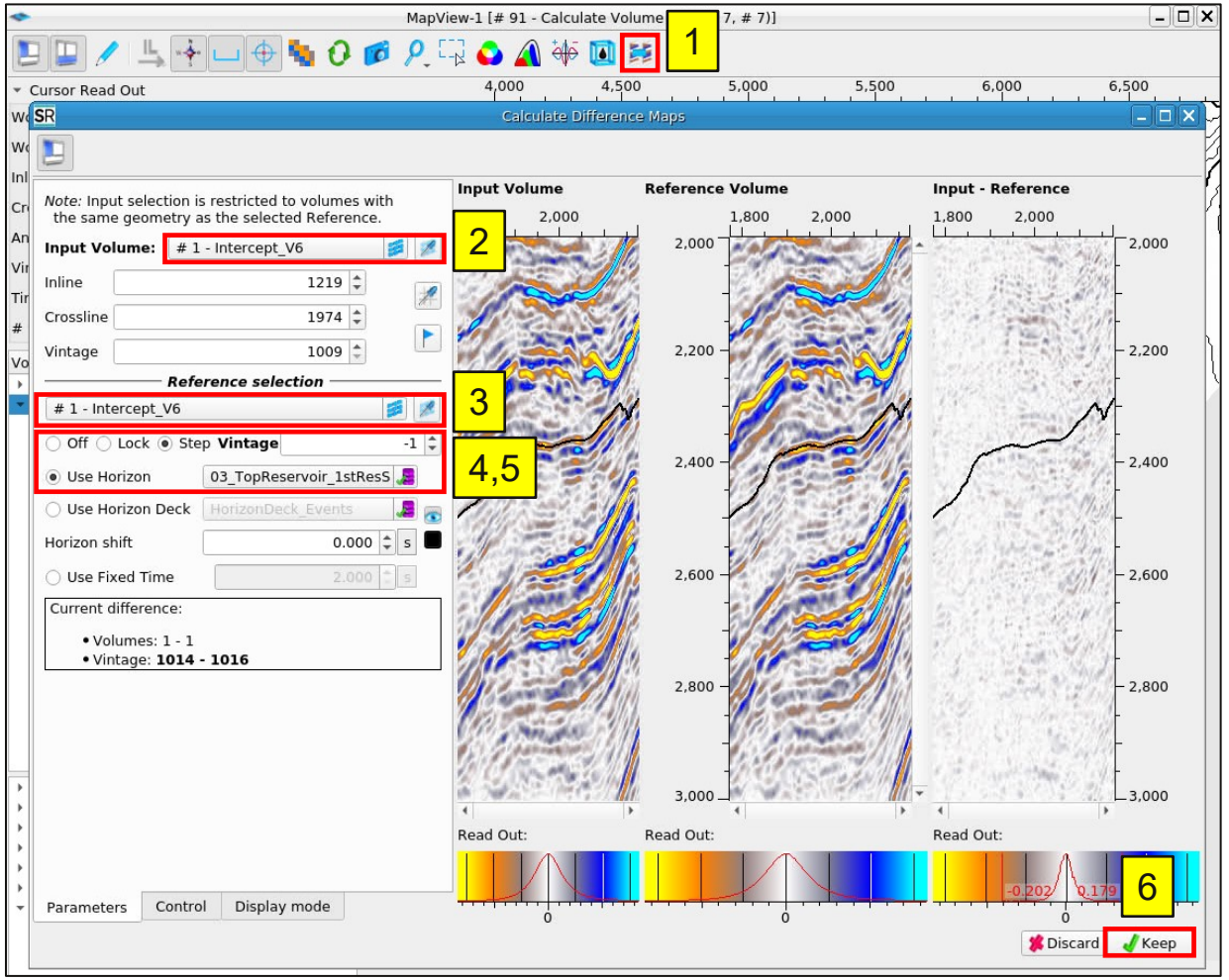
Compare the difference plot to the non-difference.

By looking at the *differences* between vintages, we remove any porosity or lithological variation in the reservoir from the plot. Theoretically, only properties that change between vintages are fluids & pressures.

Crossplot and attribute maps

Now we are going to investigate the amplitude variation in an attribute map using the crossplotter:

1. In the Map Viewer: click the difference icon 
2. Input volume: *Intercept_V6*
3. Reference volume: *Intercept_V6*
4. **Vintage Step -1** This will display incremental differences between vintages
5. Use horizon: *03_TopReservoir_1stResSand* to extract the intercept on the horizon
6. Click **Keep**



Map Viewer: differences between vintages

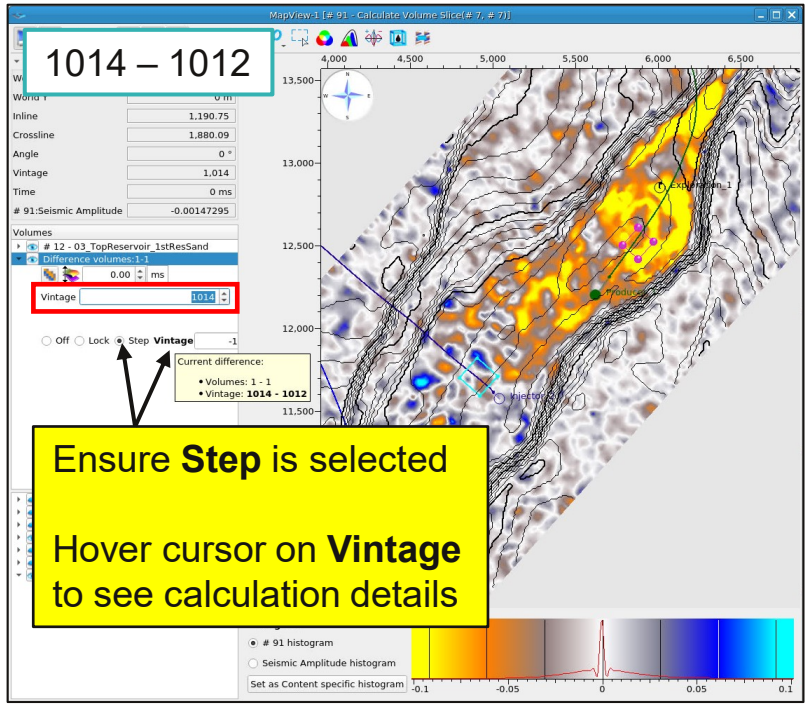
The map shows the intercept amplitude differences between each vintage

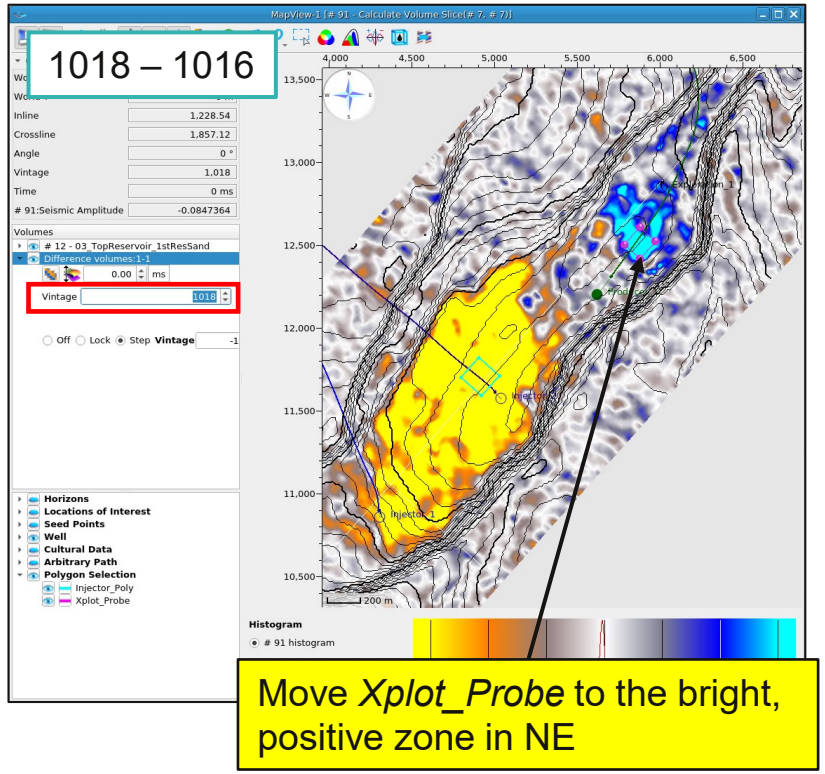
1. **Scroll the Vintages** and view the amplitude changes
2. Select vintage ***1018***
3. Move the *Xplot_Probe* to the high positive difference near the Producer well

What do the amplitude variations mean?

Let's focus on the differences between 1018 and 1016

Map Viewer: Step -1 difference mode gives incremental, amplitude differences between vintages on the Top Reservoir horizon.

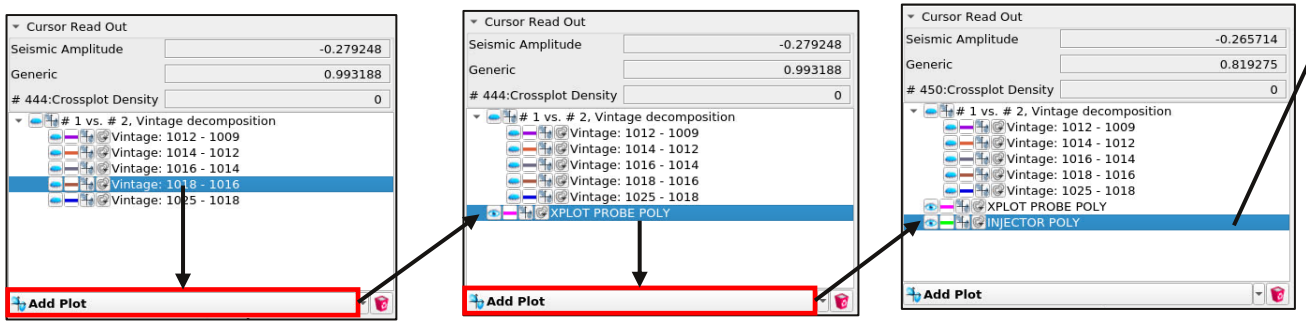


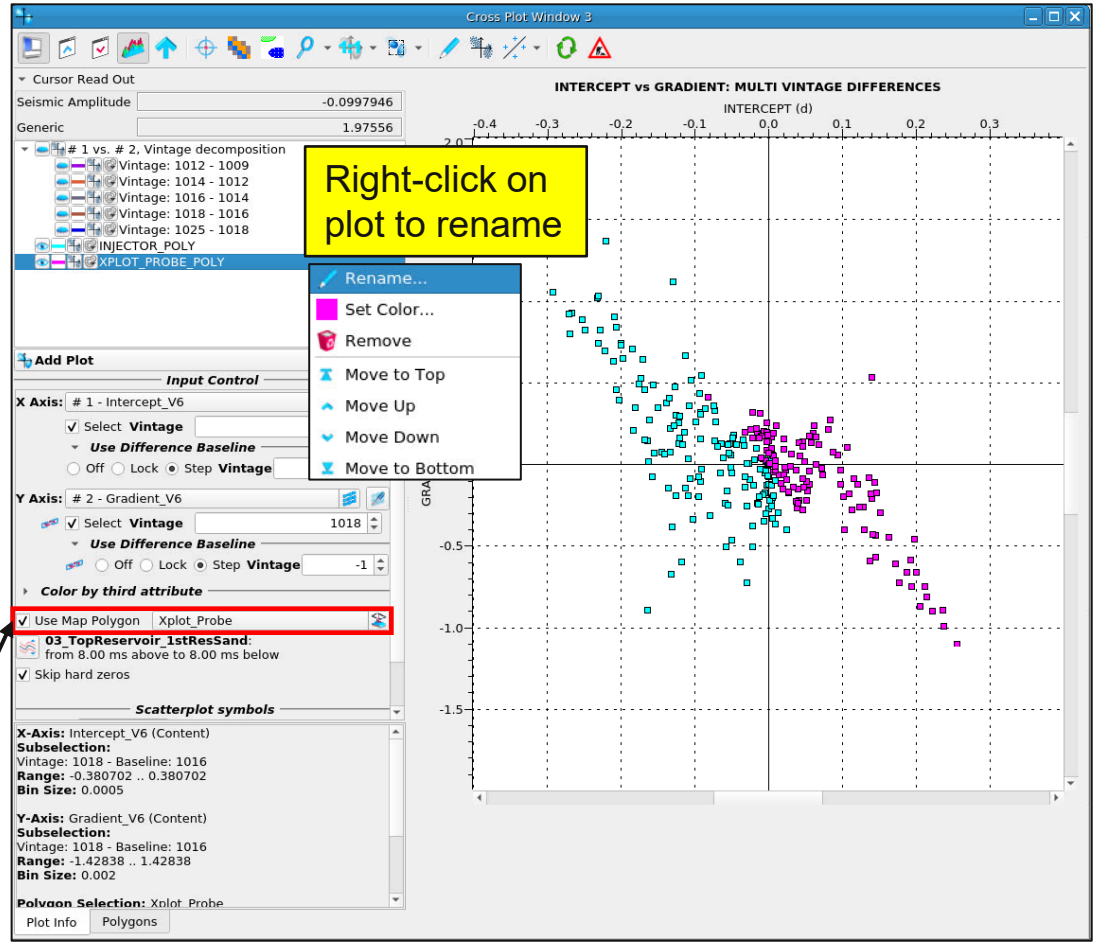


Crossplot: comparing child differences

Whichever plot is selected (blue) will be copied when clicking Add Plot.

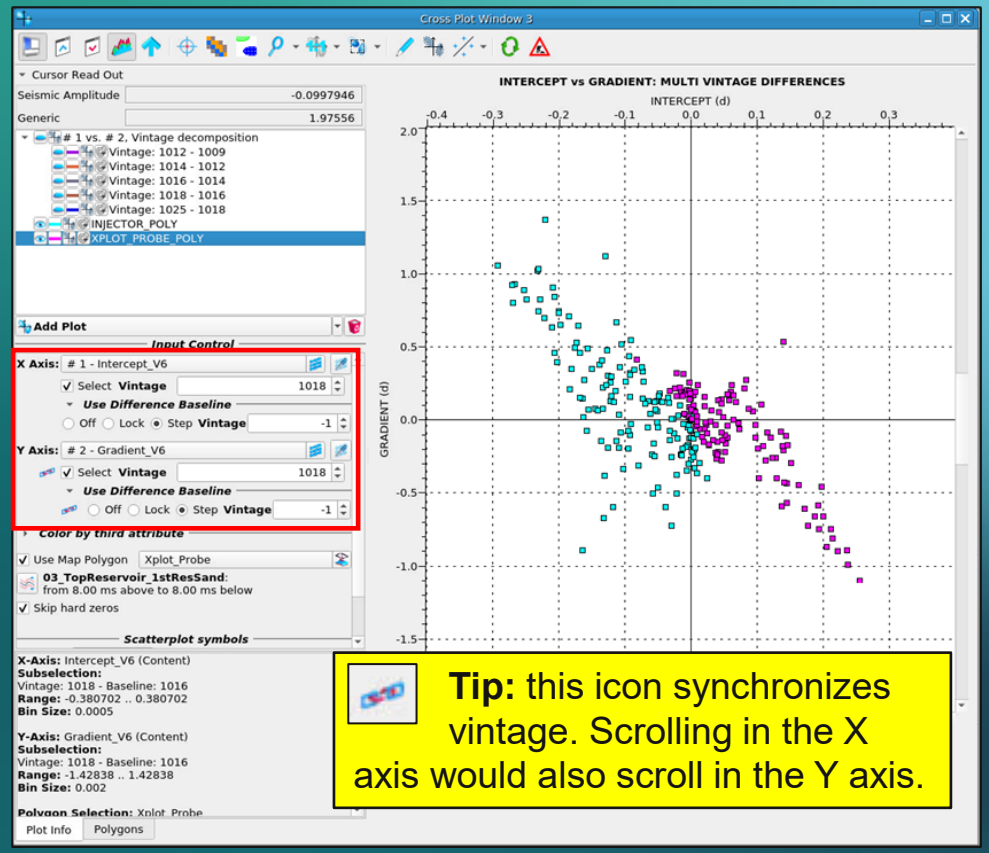
1. In the **difference** plot: toggle **off** the parent using the eye
2. Select the **1018 – 1016** child (it turns blue)
3. Click **Add Plot**: a plot of just 1018 – 1016 is made
4. Check the map polygon is set to *Xplot_Probe.* Right-click on the new plot and rename it to XPLOT PROBE POLY.
5. With the new plot selected (blue) click **Add Plot**
6. For this 3rd plot, change the map polygon to *Injector_Poly*, and rename it to INJECTOR POLY





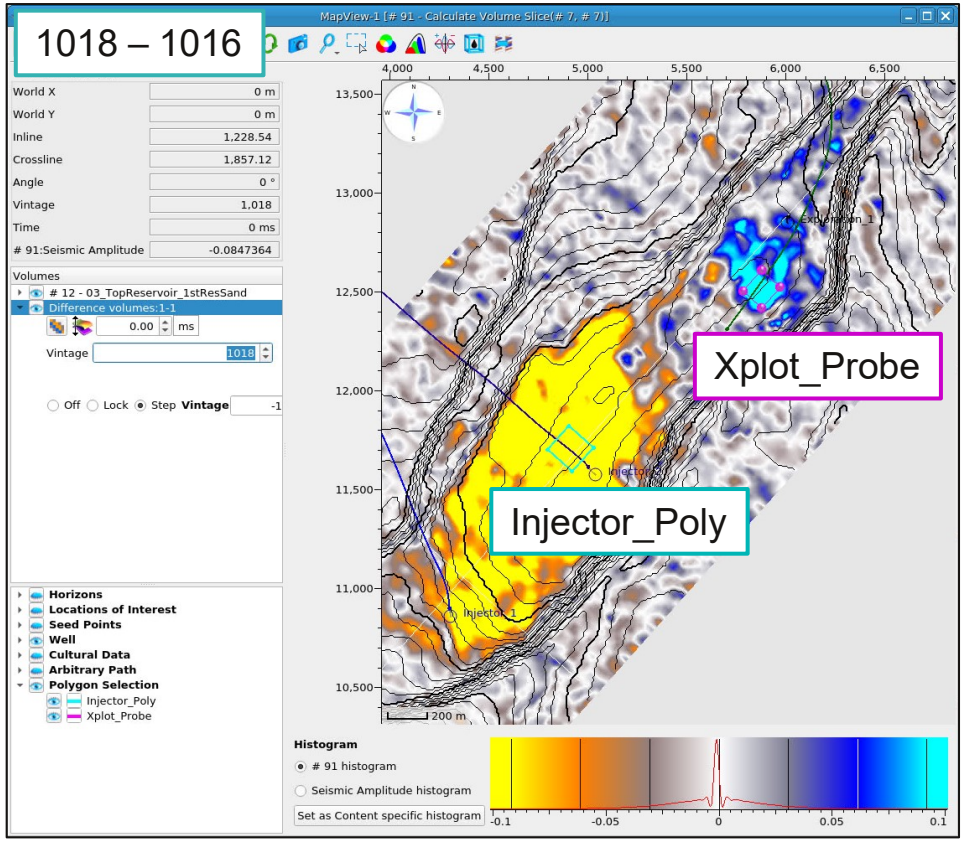
Crossplot info: no decomposition

- By copying one child plot, we make a single non-decomposed plot.
- Note: These plots can also be generated by not selecting axis decomposition when creating a new plot.
- For a non-decomposed plot, **the vintage and difference controls are active.** The user has complete control over the vintage and/or difference plotted on each axis
- The X and Y axis can be controlled independently to each other with a difference on one axis and no difference on the other

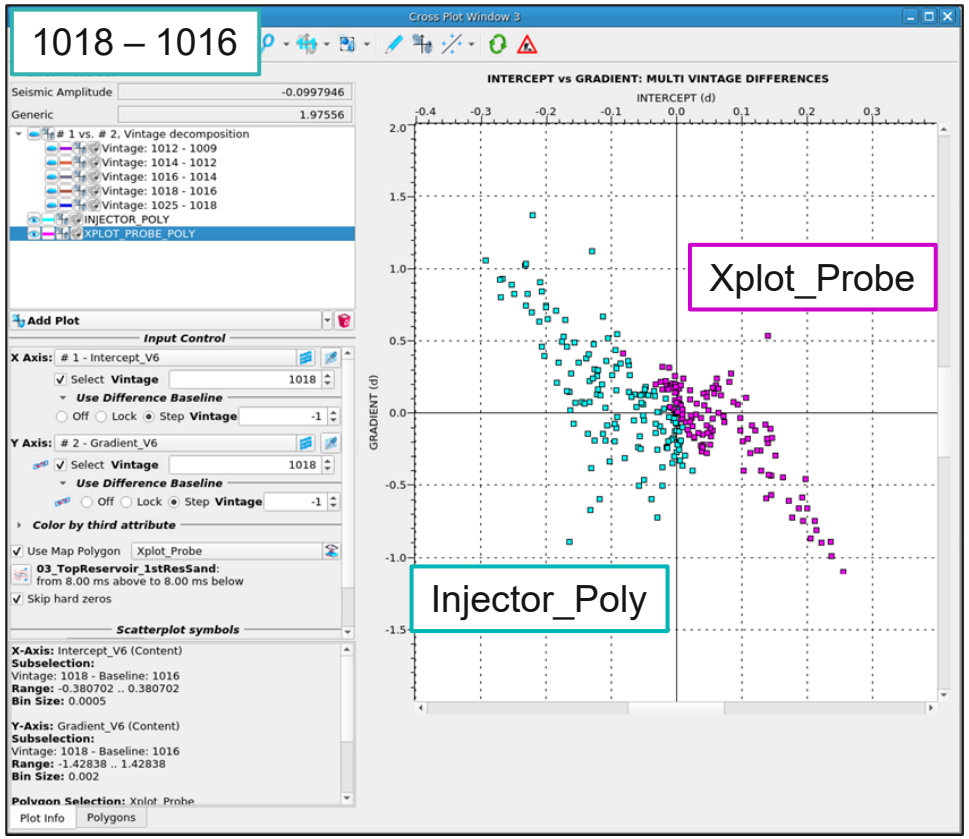


Crossplot: comparing vintage differences

Map Viewer: decreases in Intercept are yellow, increases are blue, with polygons located in each zone.



Crossplot: the same polygons in the Intercept / Gradient difference plot add context to the amplitude map



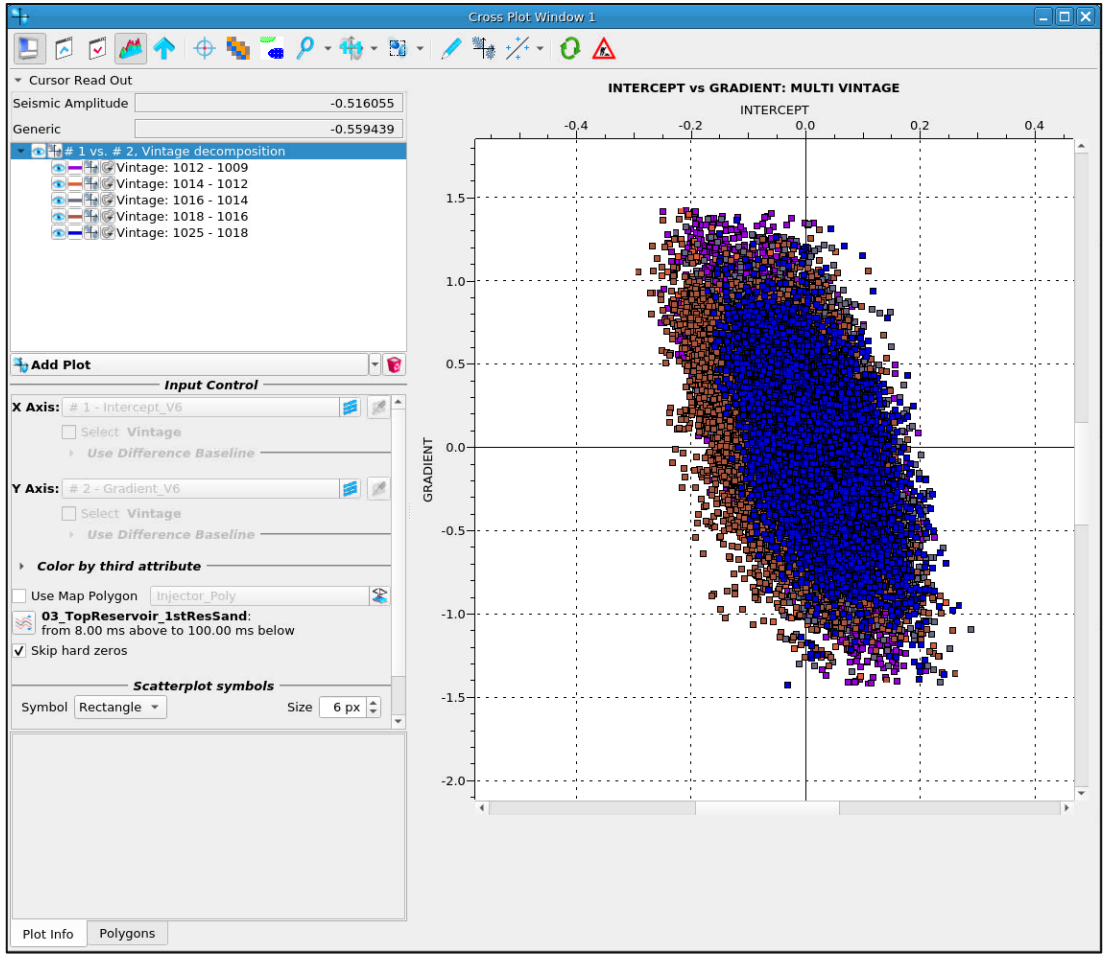
Crossplot info: mask volumes

- So far in this tutorial we have crossplotted intercept & gradient and investigated the plot by using map polygons controlled via the Map Viewer.
- Now we will close the loop by using mask polygons in the crossplotter to find points of interest back in the input volumes.
- We do this via a **mask volume**, that is generated using a **mask-polygon.**
- Mask volumes are binary;
  - points within the mask-polygon are given a value of 1
  - points outside the mask-polygon are given a value of 0
- Mask volumes can be viewed in any viewer and can be saved to the project.

Crossplot: mask polygons

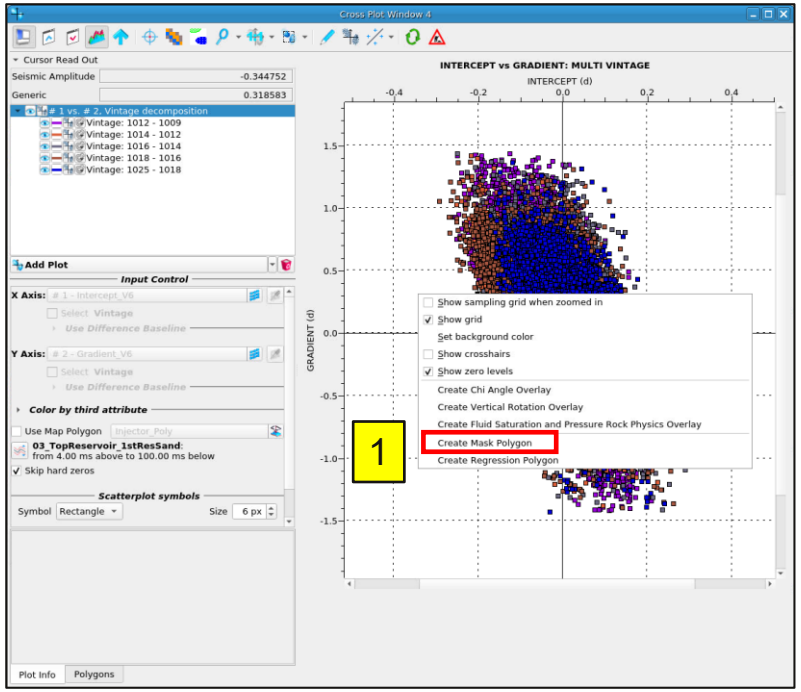
In this exercise we will practise making a decomposed crossplot and then create a mask volume:

1. **Close all previous plot windows**
2. Open a **new crossplot window**
3. **Add Plot** then **+ Volumes**
4. Choose the same Intercept and Gradient input volumes
5. Do **not** limit to a map polygon.
6. Set the time window using the horizon: *03_TopReservoir_1stResSand* and a window of **8ms** above to **100ms below.**
7. Set the **axis decomposition** to vintage difference of **step -1**

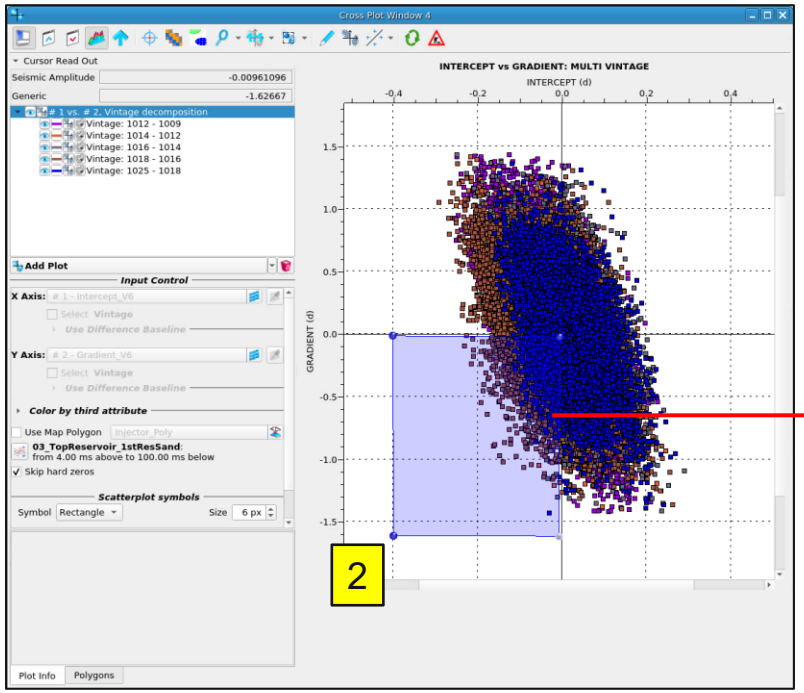


Crossplot: making a mask polygon

1. Right click in the plot window
 > **Create mask polygon**

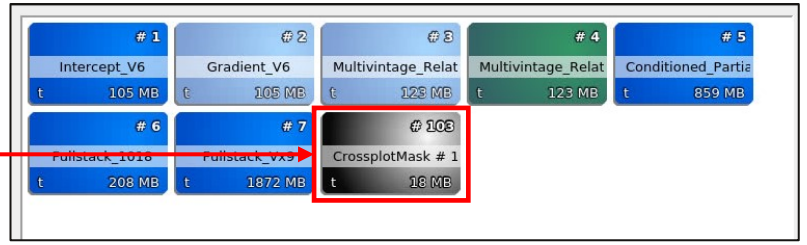


2. Drag the corners of the polygon to make as square the covers a decrease in Intercept and Gradient

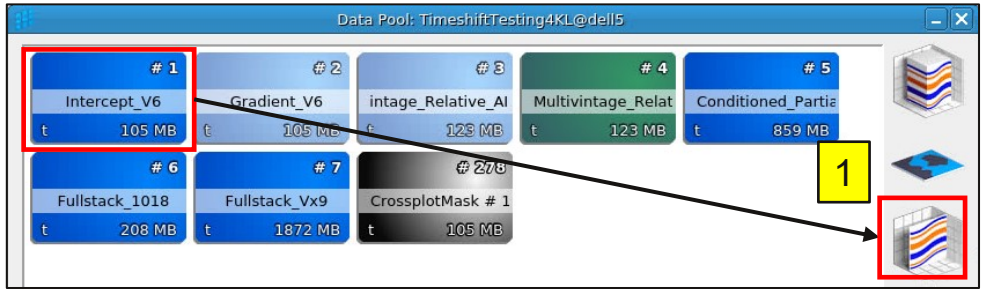


A **Mask Volume** is automatically generated, using the highlighted plot (the decomposed parent in this case).

The mask volume is in the Data Pool and coloured black. This volume will update as the mask polygon is moved/resized.

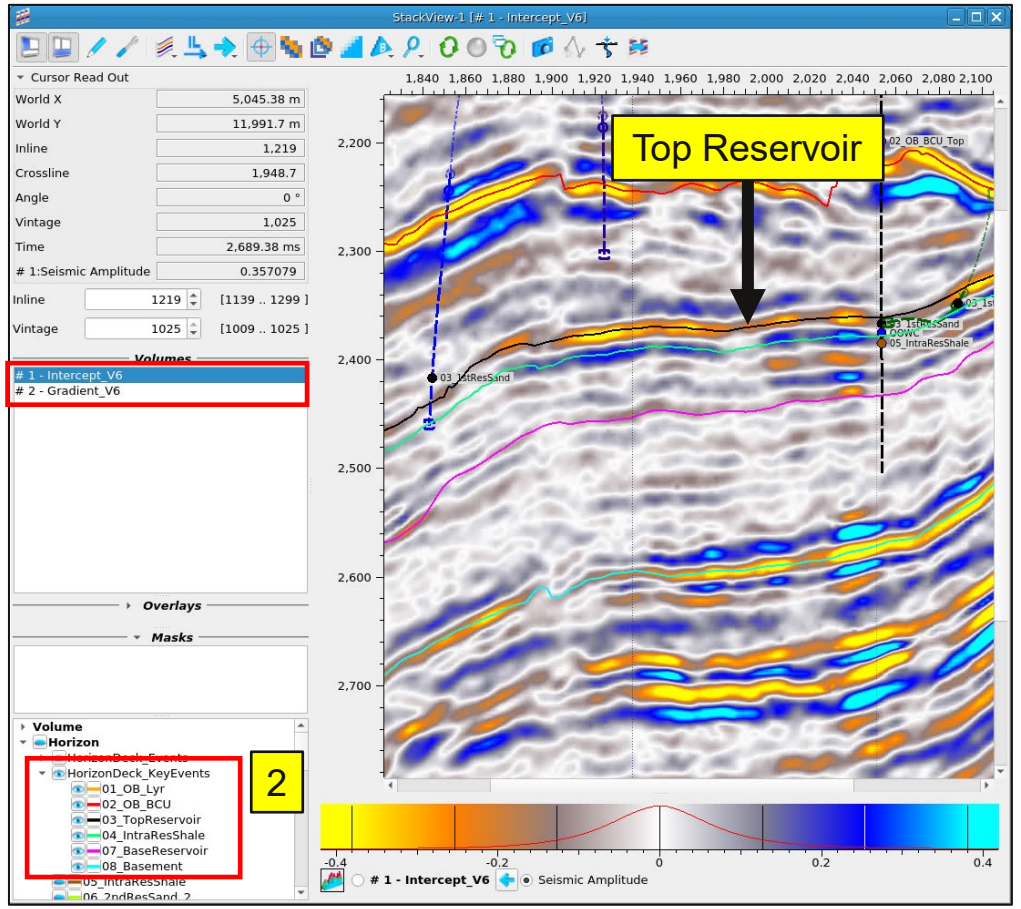


Stack Viewer: visualising the mask volume



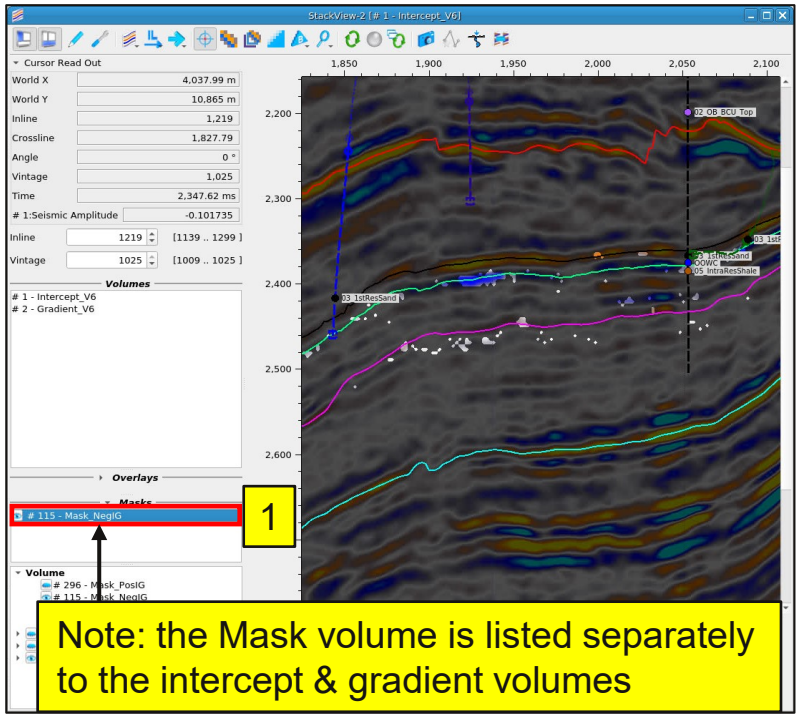
1. Drag and drop the **intercept** volume from the Data Pool into a Stack Viewer
2. Toggle on the horizon deck: ***HorizonDeck_KeyEvents***
3. Toggle on **all wells**
4. Zoom into the reservoir zone (the black horizon is the Top Reservoir)

We will now use this Stack Viewer to display the mask volume

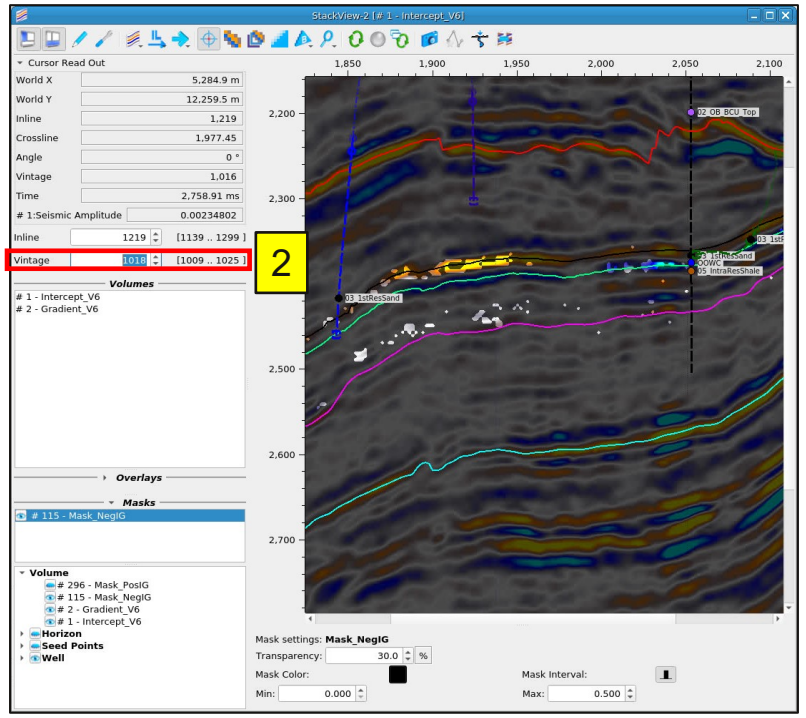


Stack Viewer: visualising a mask polygon

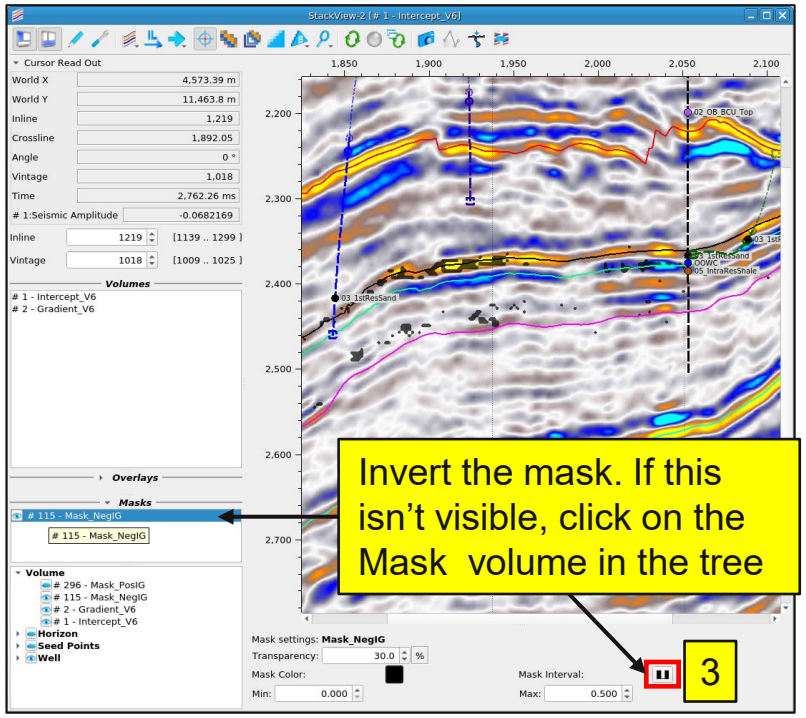
1. Stack Viewer: in the Data Pool drag the mask volume into the Stack Viewer. Most of the Viewer will turn black



2. Scroll the vintages, the Mask volume is vintage aware and will change as you scroll through the vintages in the Stack Viewer

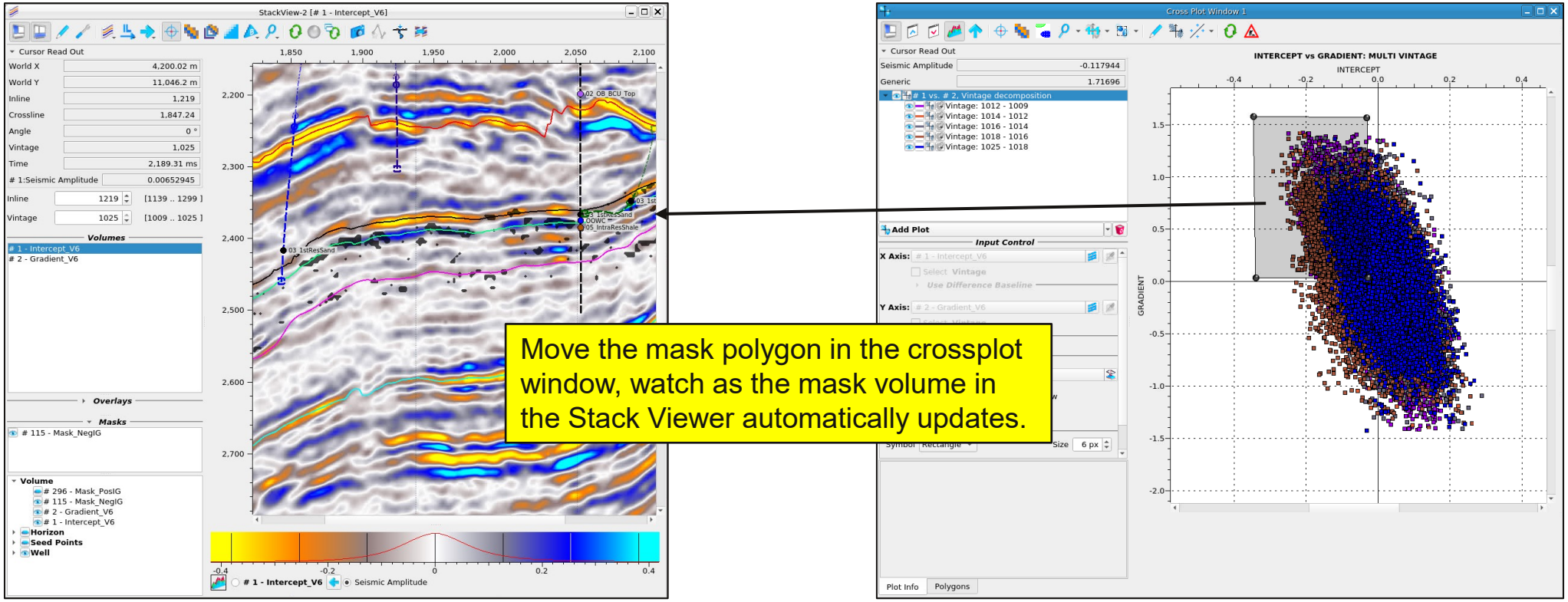


3. The mask display can be **inverted**, showing the mask colour for points inside the polygon. The colour can also be changed.



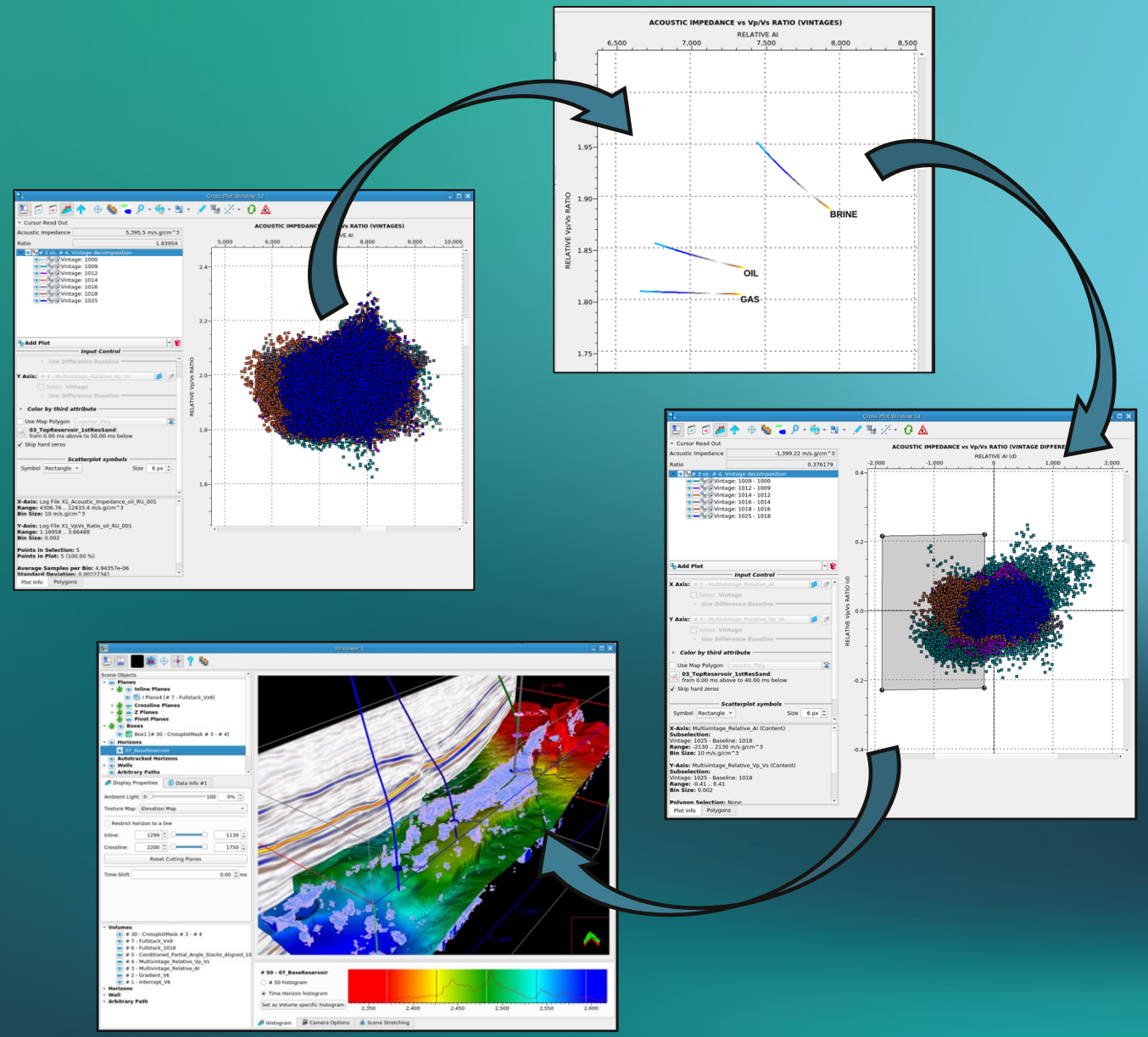
Stack Viewer: visualising a mask polygon

The mask polygon is set to **dynamically update** as default; moving the polygon will update the mask volume. Note, this can be toggled off by right-clicking on the mask polygon. Mask polygons can also be saved to the project and redisplayed on the same plot type



Crossplot Part 2

- In this section we will be investigating elastic inversion volumes in the crossplot
- We will use rock physics overlays to understand the reservoir
- We will generate a mask volume and visualise it in the 3D Viewer

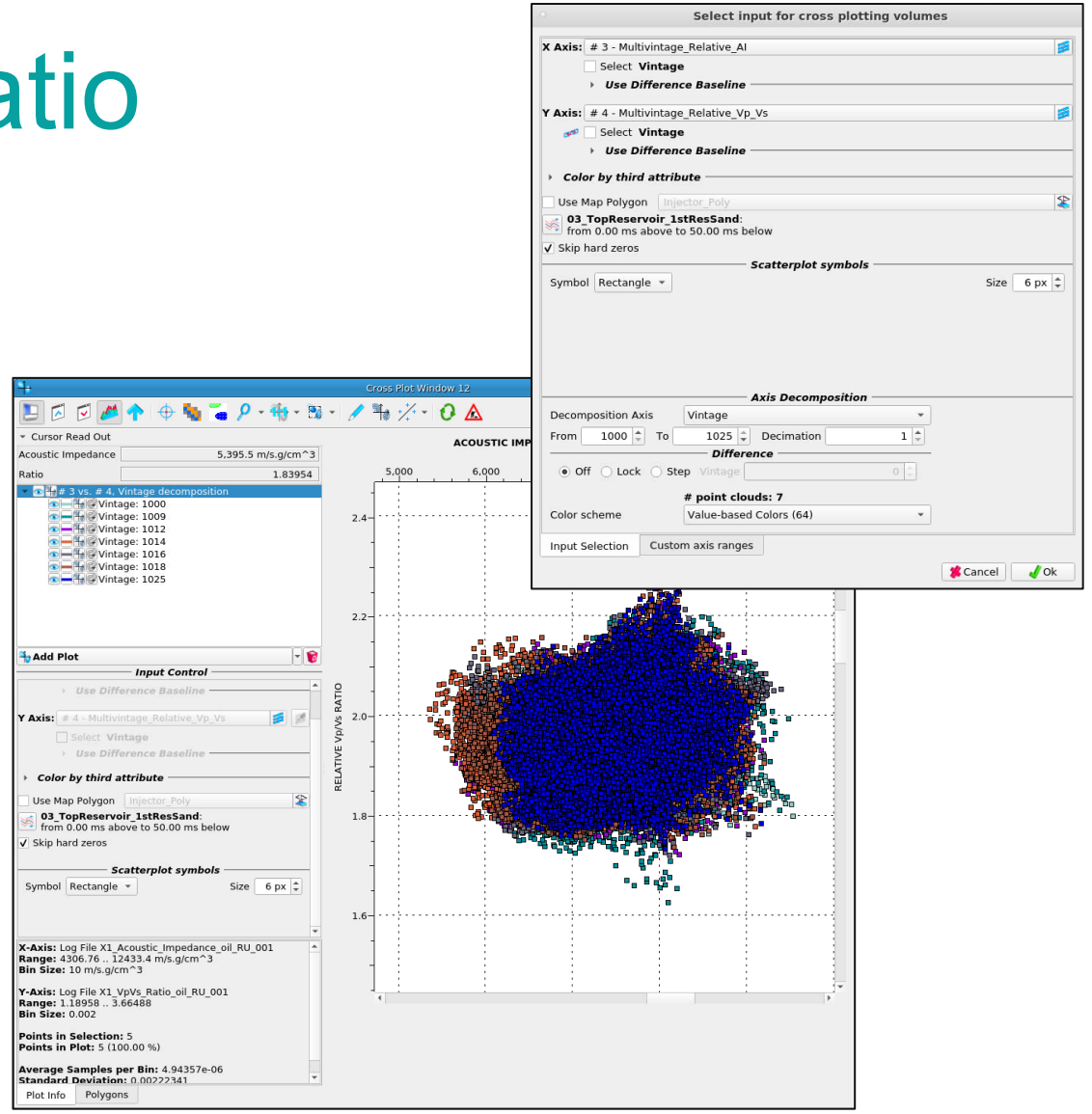


Crossplot: AI vs Vp/Vs ratio

1. Close (or minimize) the previous plots
2. Open a new Crossplot and **Add Plot** then **+ Volumes**
3. X axis select *Multivintage_Relative_AI*
4. Y axis select *Multivintage_Relative_Vp_Vs*
5. Window = load the pre-made window called AI
6. Axis Decomposition: Vintage and difference off

You have made a plot of AI vs Vp/Vs ratio with a point-cloud for each vintage.

How do we calibrate, and understand this plot?



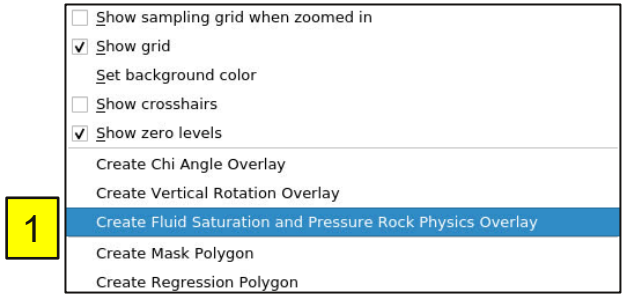
Crossplot: rock physics overlays

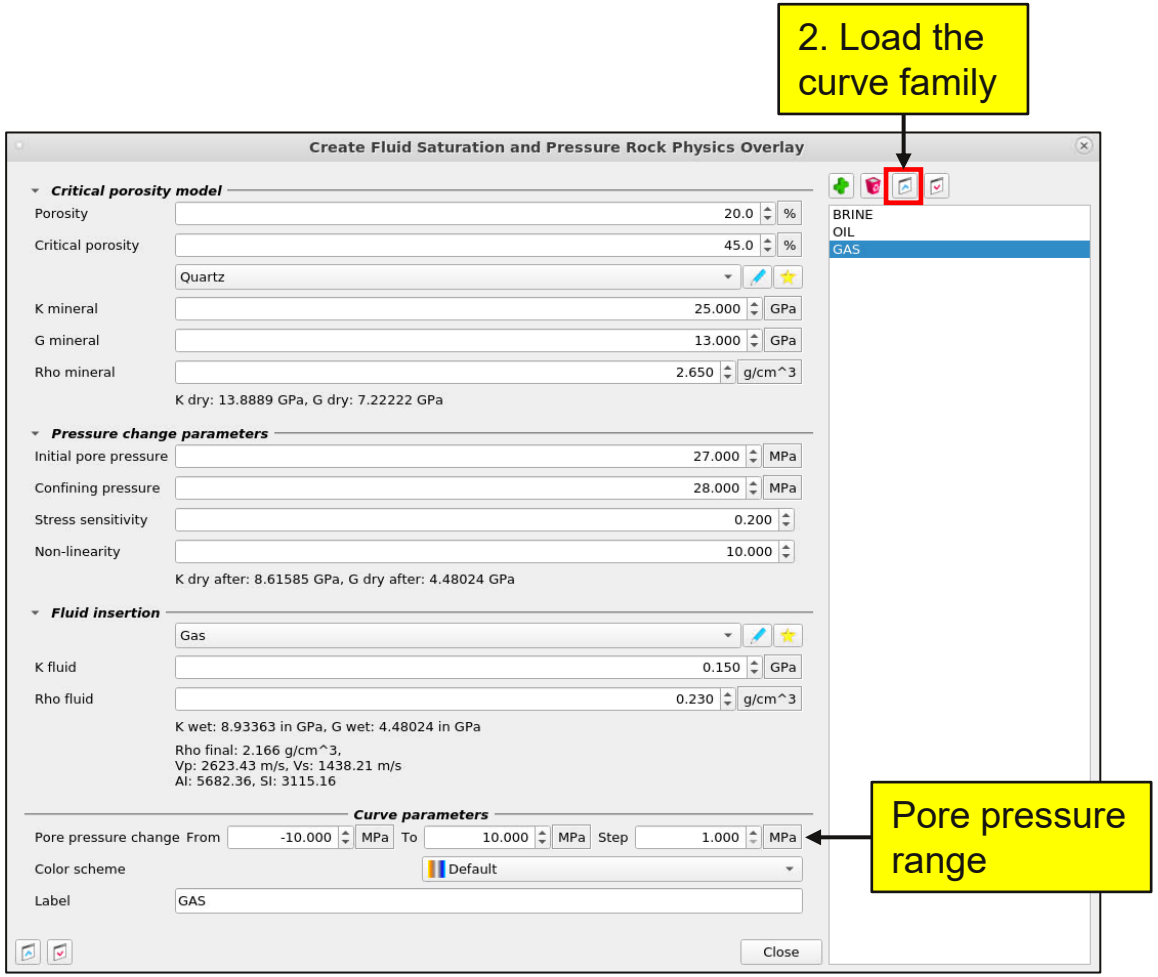
We will add rock physics overlays to calibrate our inversion results.

There are 3 curves for the fluid cases: Brine, Oil, and Gas

Each curve shows the pore pressure variation of +/- 10 MPa

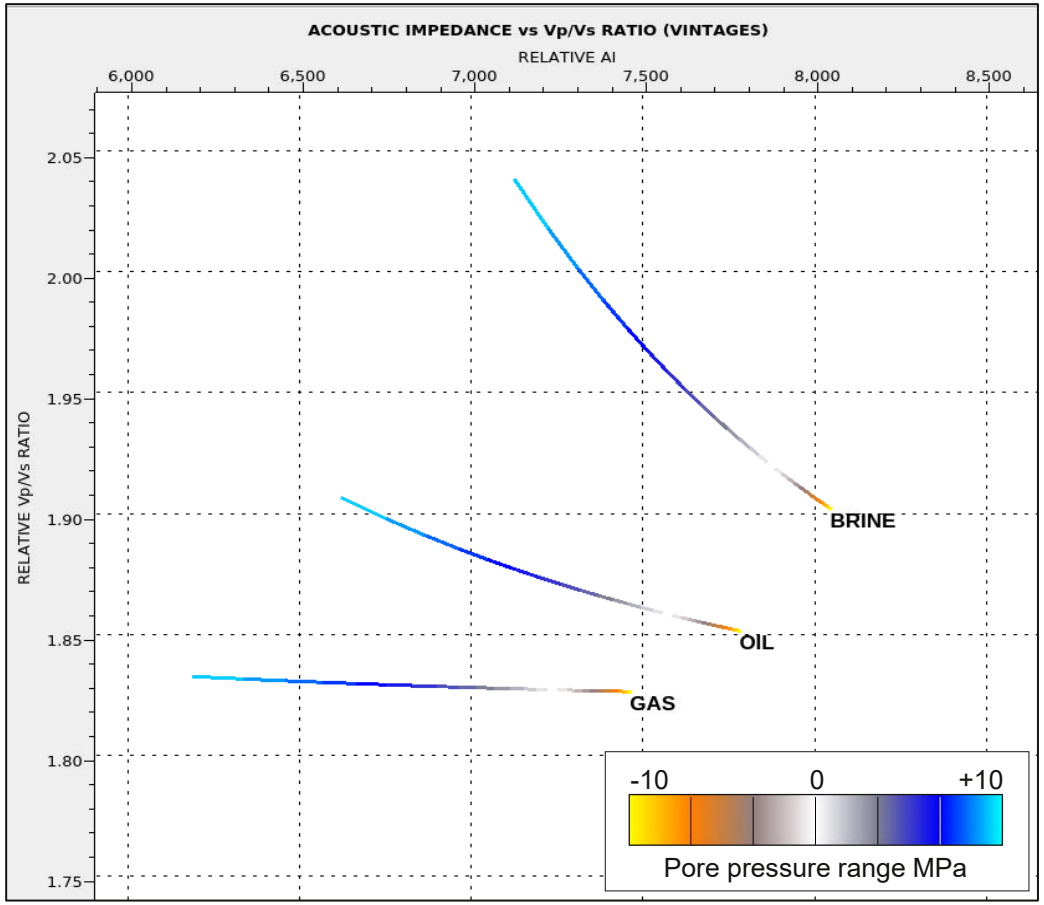
1. In the plot window right-click and select Create Fluid Saturation and Pressure Rock Physics Overlays
2. Load curve family: **Crossplot_Tutorial_Overlays**





Crossplot: overlays

- Change the **porosity** for one of the curves and see how it moves.
- Vary the **fluid properties** and watch the changes to the curves
- How does this compare with the point-clouds?
- Is it possible to distinguish fluid or pressure changes from porosity variation in the reservoir?

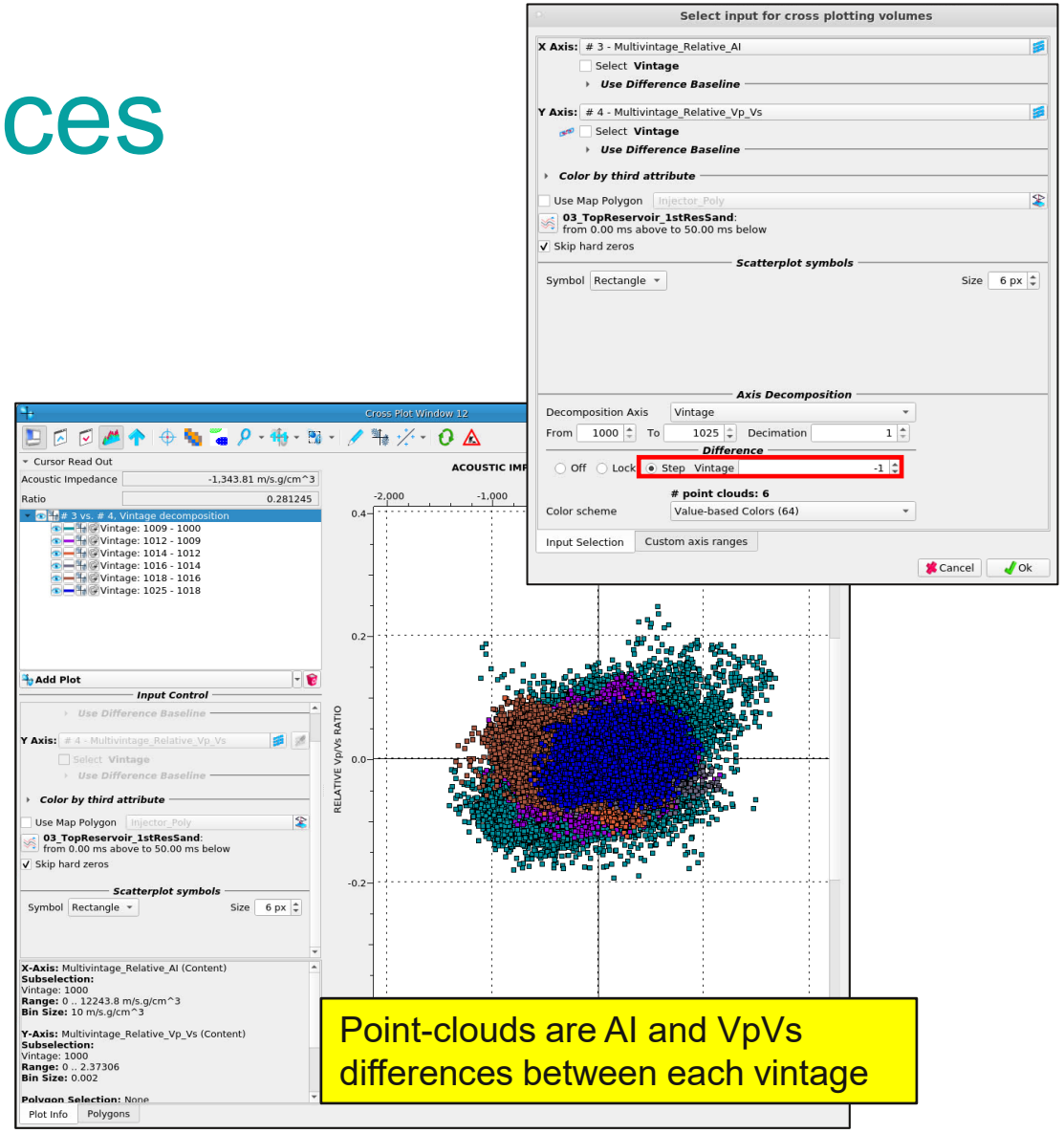


Crossplot: elastic differences

To remove the effect of porosity variation from the crossplot, we will make a difference plot between each vintage.

The only properties that should vary between vintages are fluid and pressure. Porosity does not change between vintages.

1. Open a new crossplot: **Add Plot** then **+ Volumes**
2. X axis select *Multivintage_Relative_AI*
3. Y axis select *Multivintage_Relative_Vp_Vs*
4. Window = load the pre-made window called AI
5. Axis Decomposition: Vintage and **difference step -1**



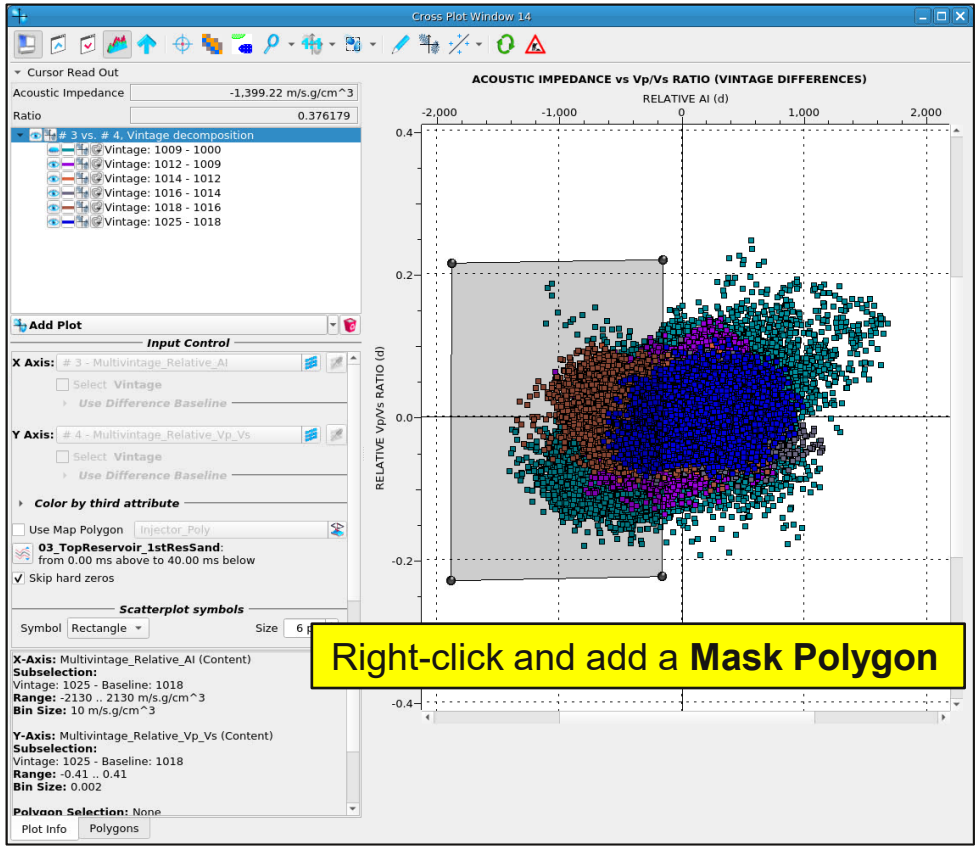
Crossplot: AI vs Vp/Vs mask volume

Now let's visualise the points which have a decrease in acoustic impedance between vintages. As we did with the intercept and gradient plot, we will make a mask volume

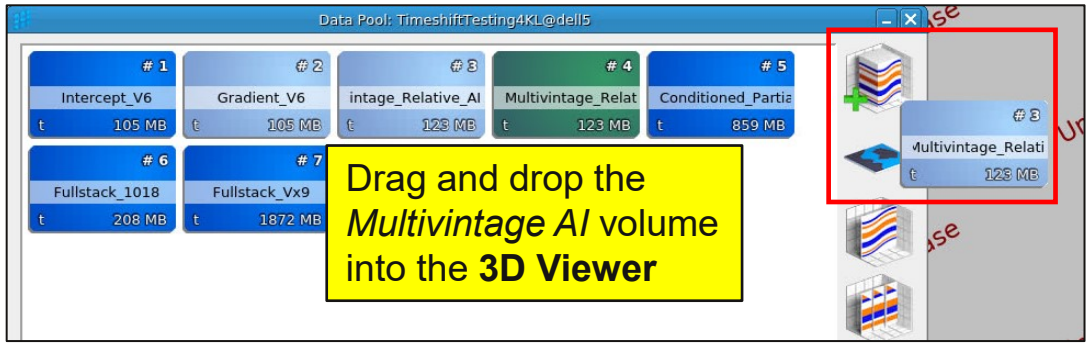
1. Add a mask polygon to the plot
2. Expand it to be a rectangle as shown on the right

This captures all decreases in Acoustic Impedance in the 50ms window below the top reservoir horizon

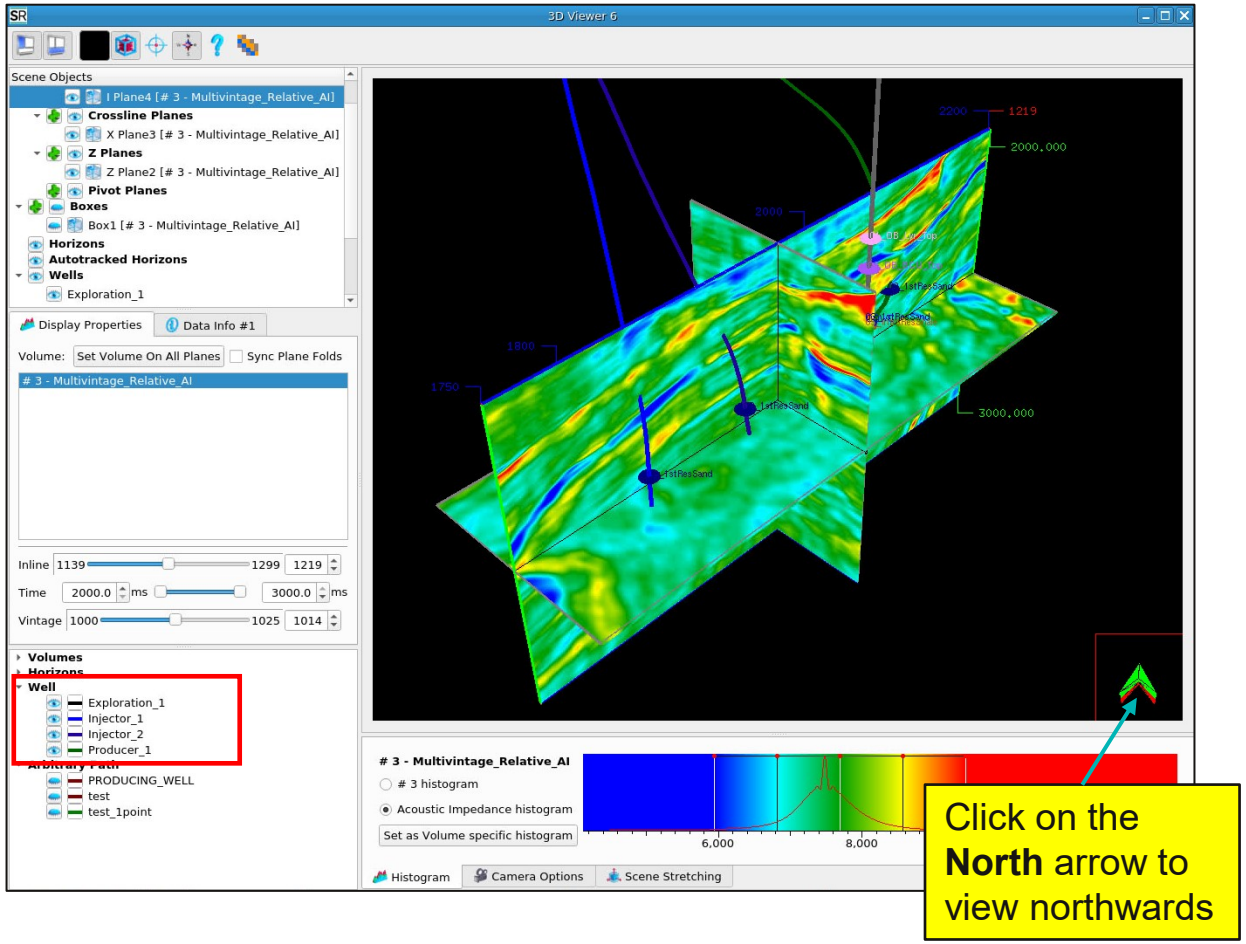
Let's view this mask in the 3D Viewer



3D Viewer: visualising a mask volume

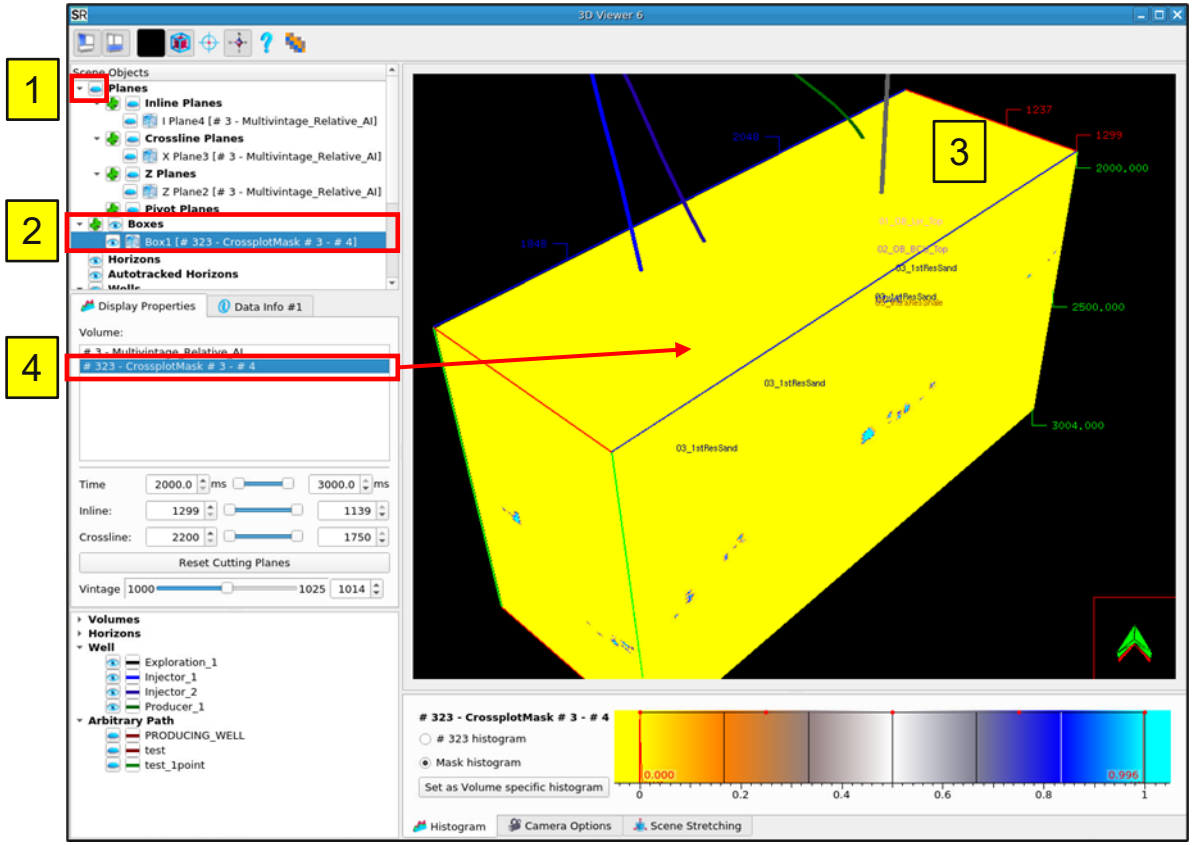


1. Drag and drop the *Multivintage_AI* volume into the **3D Viewer**
2. Drag and drop the **Mask Volume** into the 3D Viewer
3. Toggle on the **wells**
4. **Zoom in** and **click on the North Arrow** to point Northwards.



3D Viewer: visualising a mask volume

1. Click **off** the Planes in the list of Scene Objects
2. Toggle ON the **Box1**
3. Double click on the Box (or select in the Scene Objects list) to make it active
4. Select the **mask volume** in the Display Properties to display in the Box.



3D Viewer: view mask volume as geobodies

1. In the histogram for Box1 right-click and change the colour scale to **Discrete Angles**

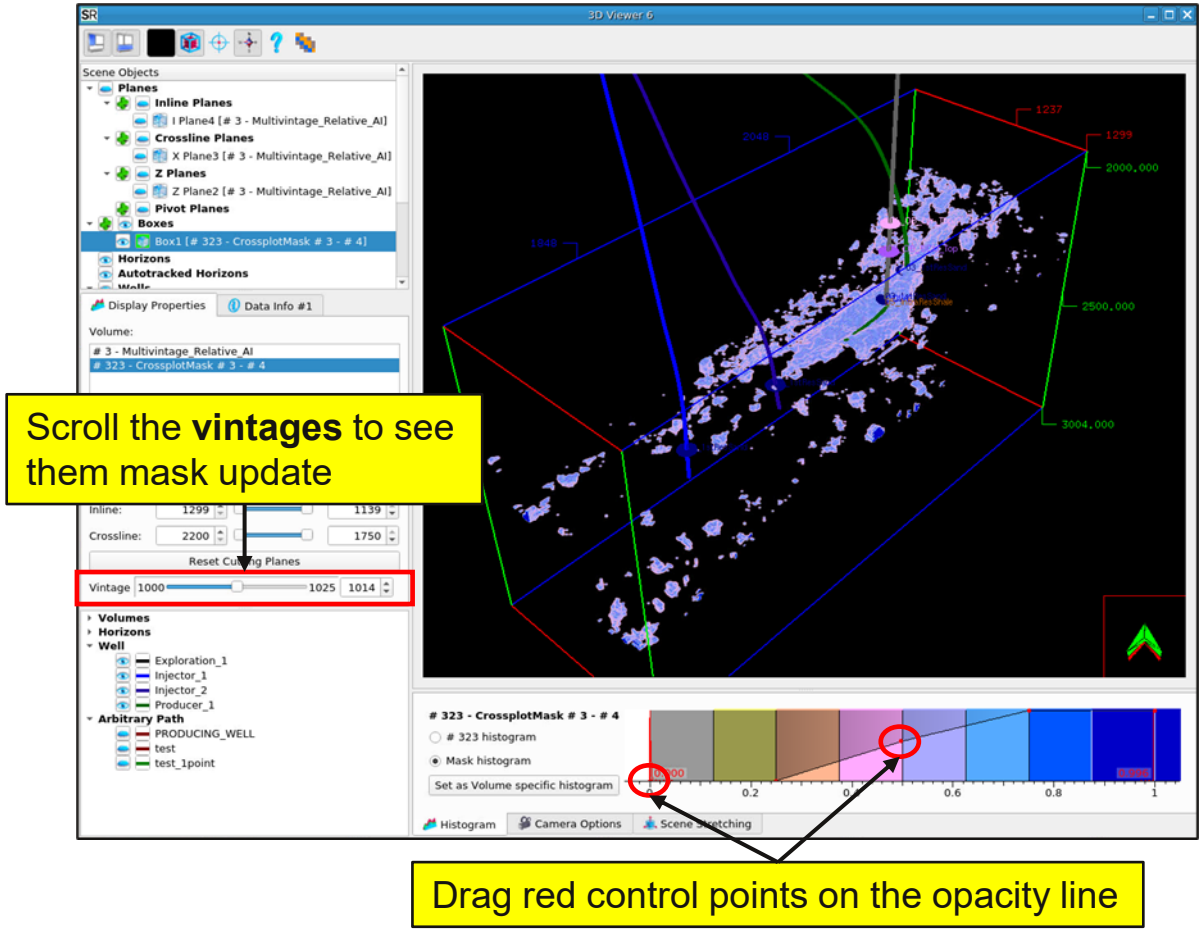
2. Drag the opacity line for the 0 values (white, left side of histogram) down to the bottom. The opacity of Box1 is controlled via this line.

3. Scroll the vintages for the Box1

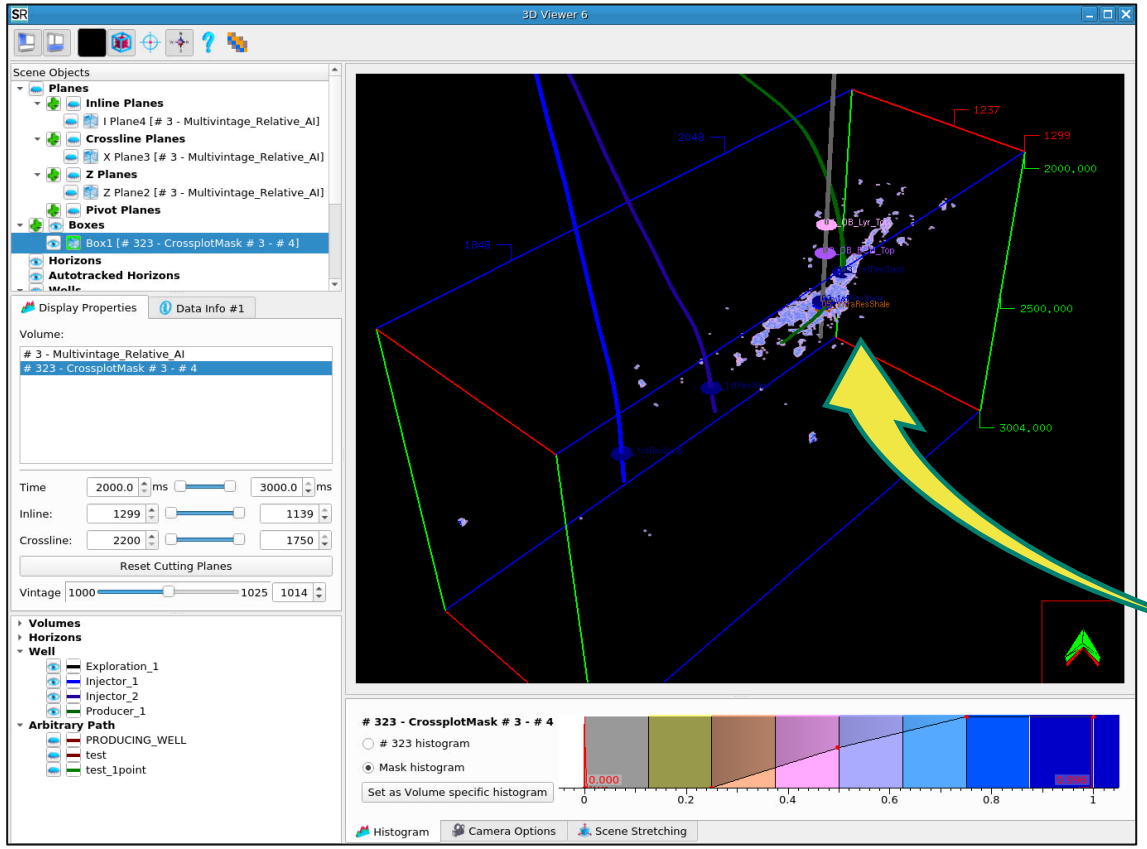
This mask volume is vintage aware and will change as vintage is scrolled.

Are these changes due to fluid movement, or pressure change? Or both?

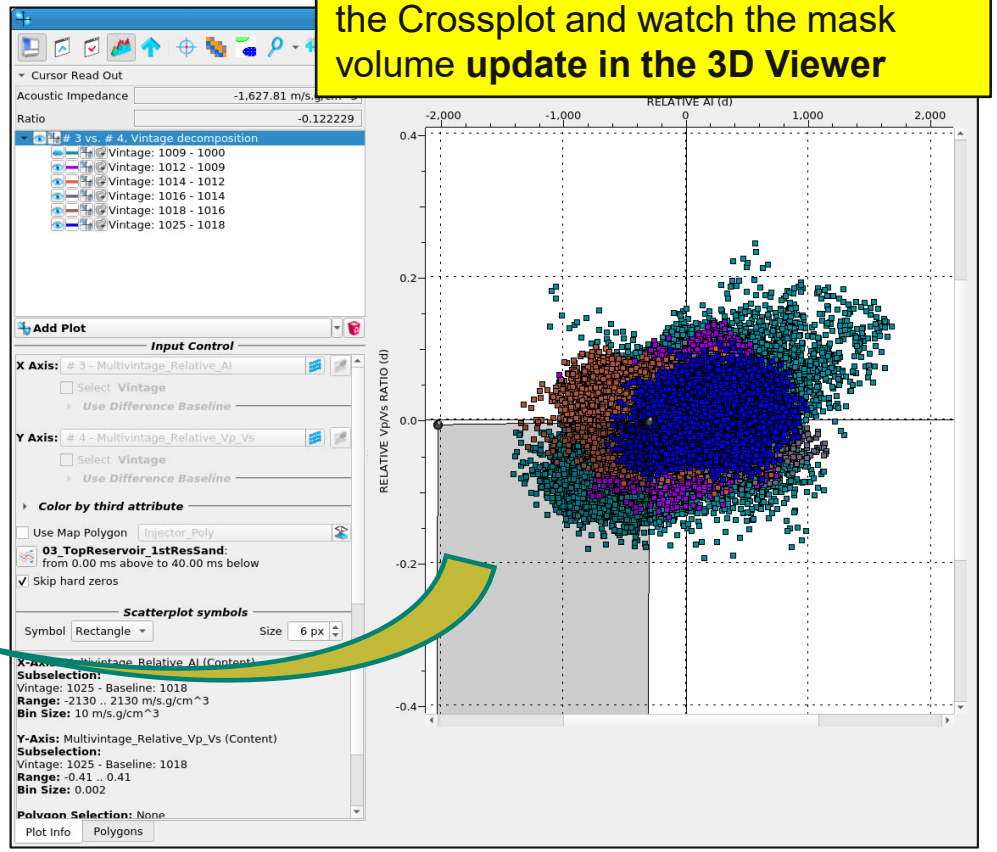
4. Investigate the volume further by moving the mask polygon around in the Crossplot, the 3DViewer will update on-the-fly



Crossplot Visualisation live in 3D

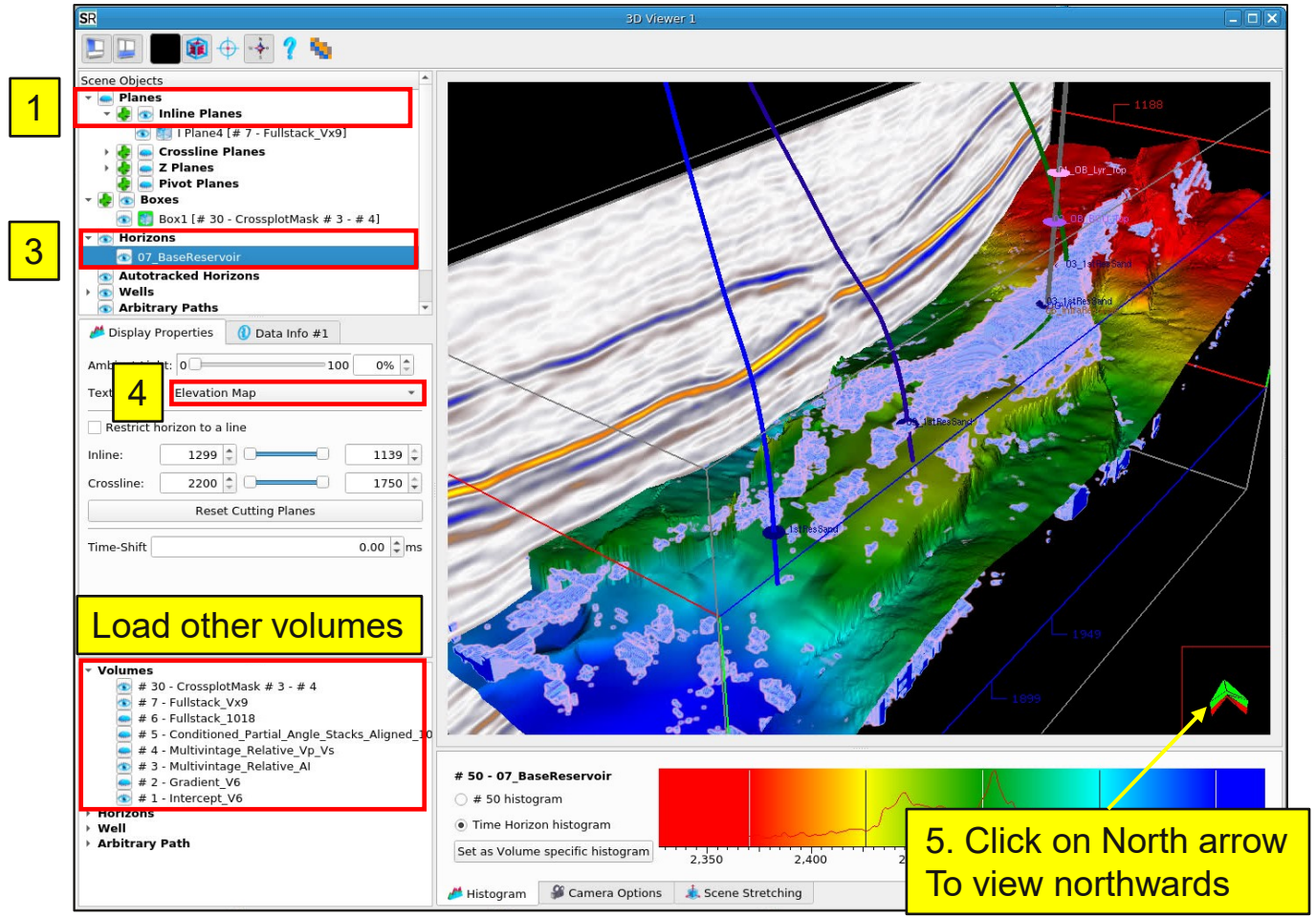


Move the mask polygon around in the Crossplot and watch the mask volume **update in the 3D Viewer**



QC the mask volume

1. Toggle on the Inline plane and view the AI volume to QC the mask bodies, OR toggle on other volumes listed in the data tree
2. Double click on the inline to make it active, hold SHIFT and move the plane around the volume
3. Toggle on the base reservoir horizon: *07_BaseReservoir*
4. Double click on the horizon and in the display properties, select elevation
5. Click on the north arrow to view northwards
6. Use ? help icon for more hotkey options



The GATHERing Knowledge Exchange

SHARP REFLECTIONS