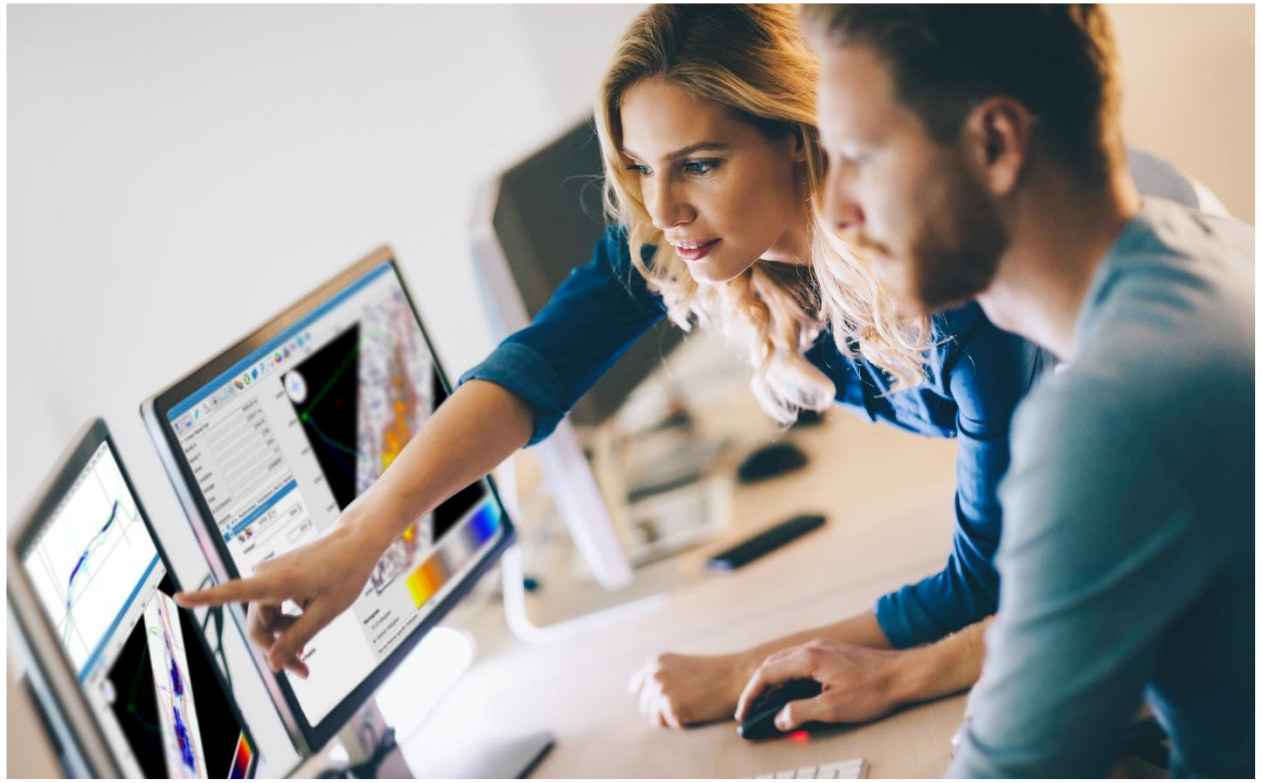
The GATHERing Knowledge Exchange

Accelerating insights from 4D seismic data

with new multidimensional data structures



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Scenario modelling exercises

18 October 2023

SHARP REFLECTIONS
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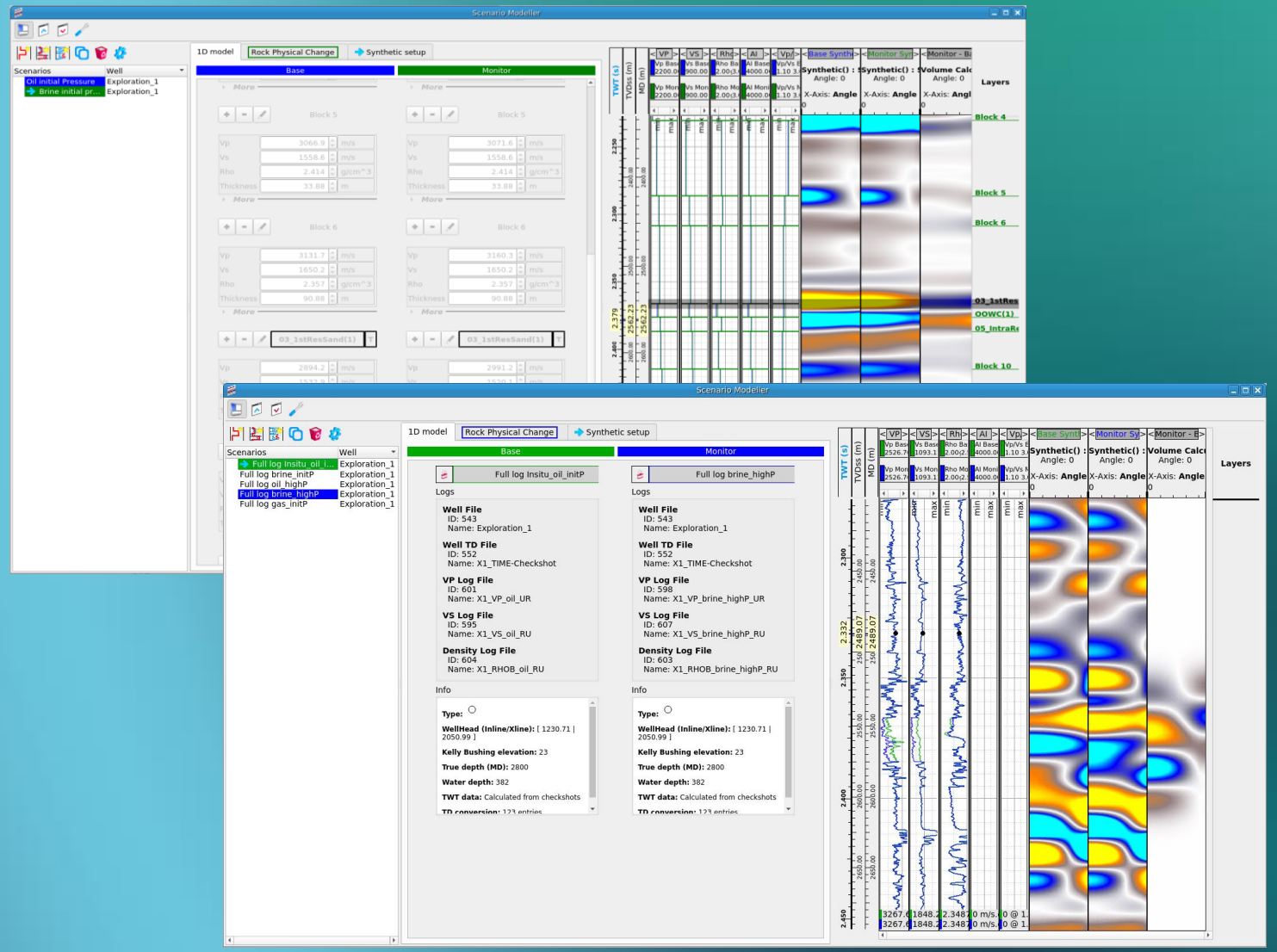
Scenario modeler introduction



The new scenario modelling tool was designed to allow the rapid creation of seismic synthetics. This can be used for several workflows such as modelling production scenarios, comparing wavelets Three methods for creation of scenarios are supported:

- Simple user defined layered models
- Blocky log based models
- Full well log based synthetics

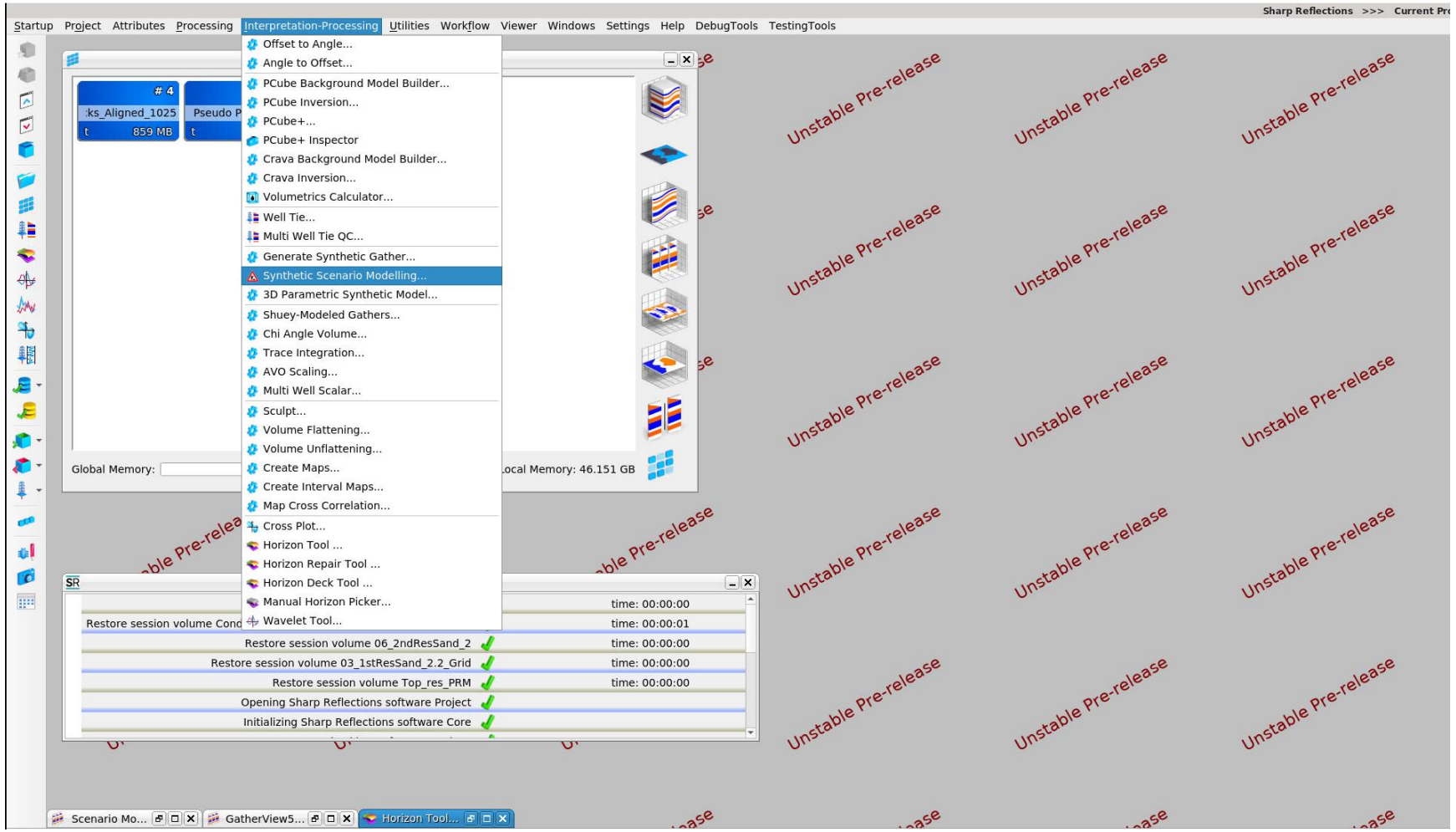
SHARP REFLECTIONS

Scenario modelling

This tutorial uses the project **4D_Tutorial_Leiden**

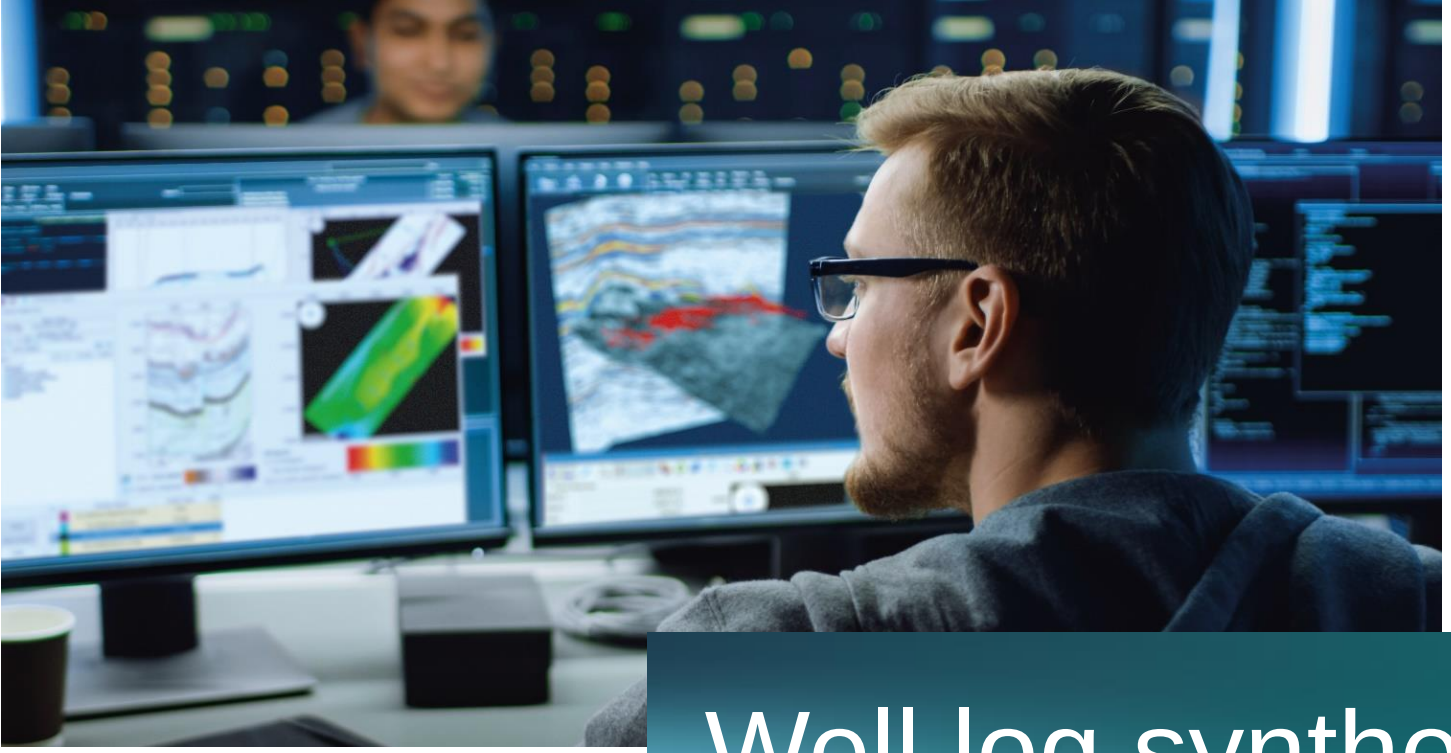
- Using log sets to create and compare well log synthetics
- Comparing production scenarios using blocky models
- Making Rock Physics changes to blocks
- Creating Blocky models

Scenario modeler



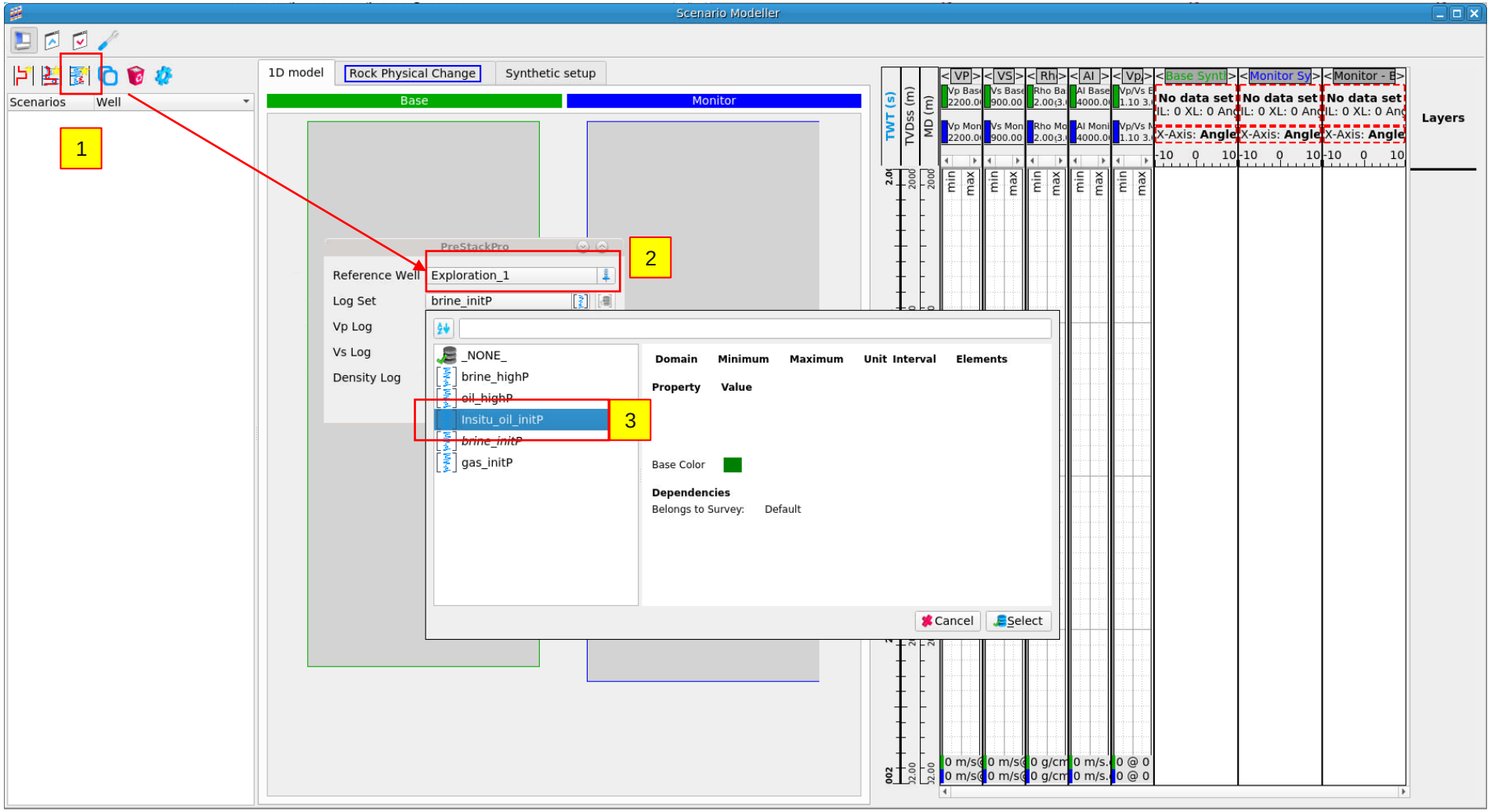
This tutorial uses the **4D_Tutorial_Leiden** project. This can be opened from Project -> Open Project and then browsing to the project folder and double clicking the config_PreStackPro.xml

This exercise predominantly uses the new scenario modelling tool which is found under Interpretation-Processing -> Synthetic Scenario Modelling



Well log synthetics

Well log synthetics – in situ Oil

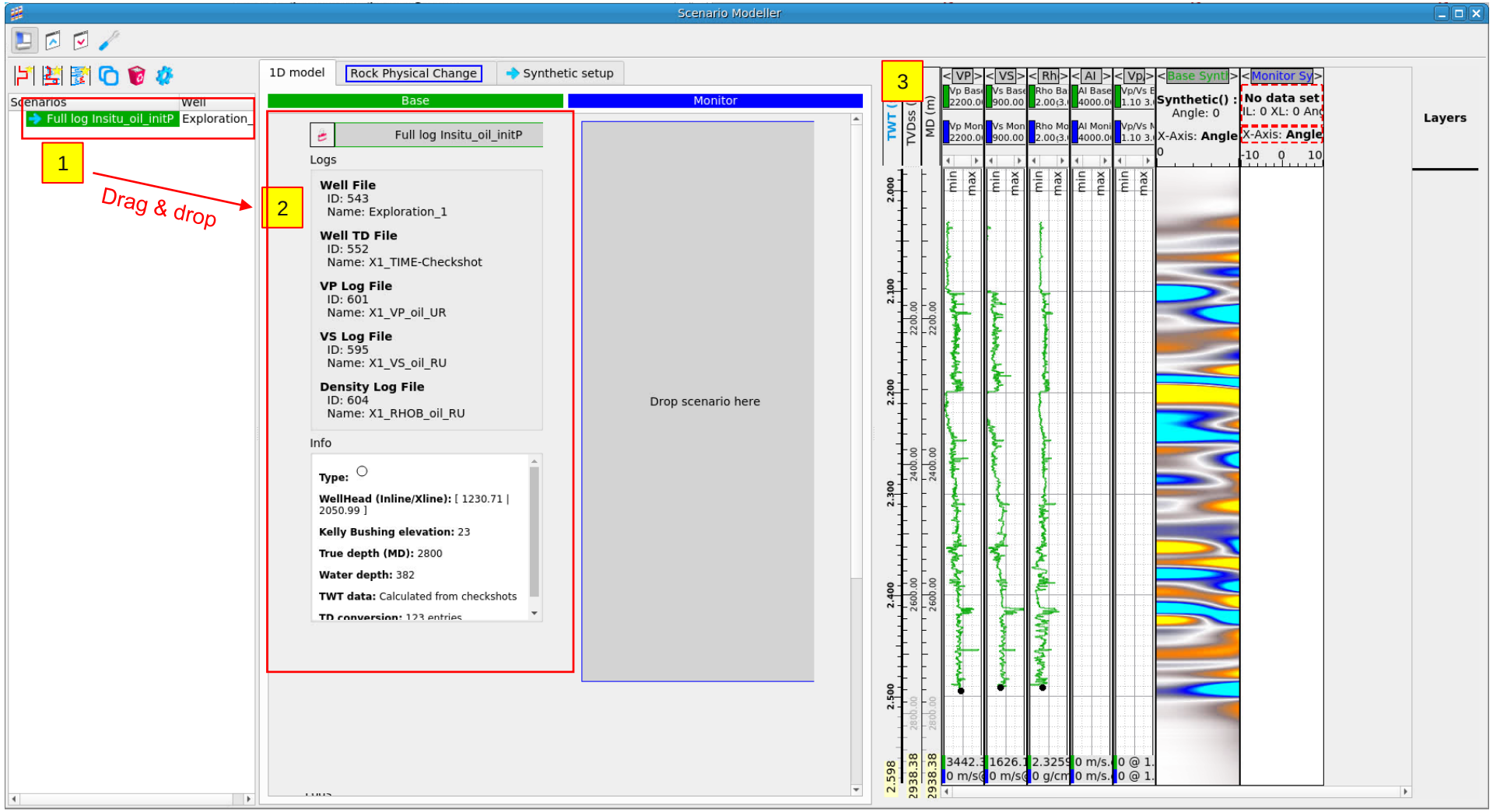


With the **4D_Tutorial_Leiden** project open

We are going to create a full well log synthetic for the in situ oil filled case at the exploration well

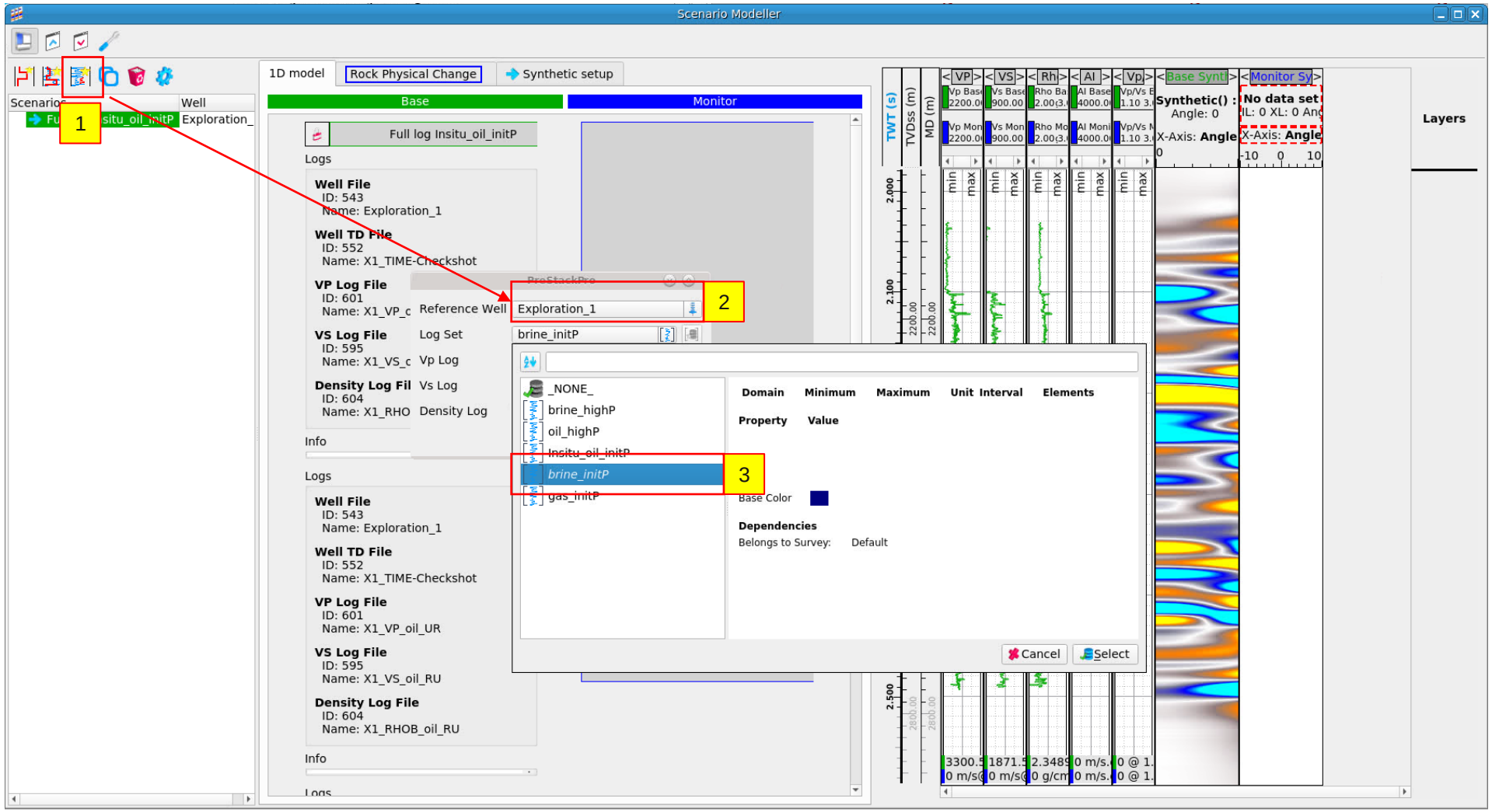
1. Open Synthetic Scenario Modelling from Interpretation-Processing
2. Click the well synthetic icon 
3. Select the Exploration_1 well
4. Select the Insitue_Oil_initP logset

Well log synthetics – in situ Oil



1. You should now have a first scenario which has inherited the logset name
2. Drag and drop this into the base panel
3. The logs and synthetic should display in the tracks to the right

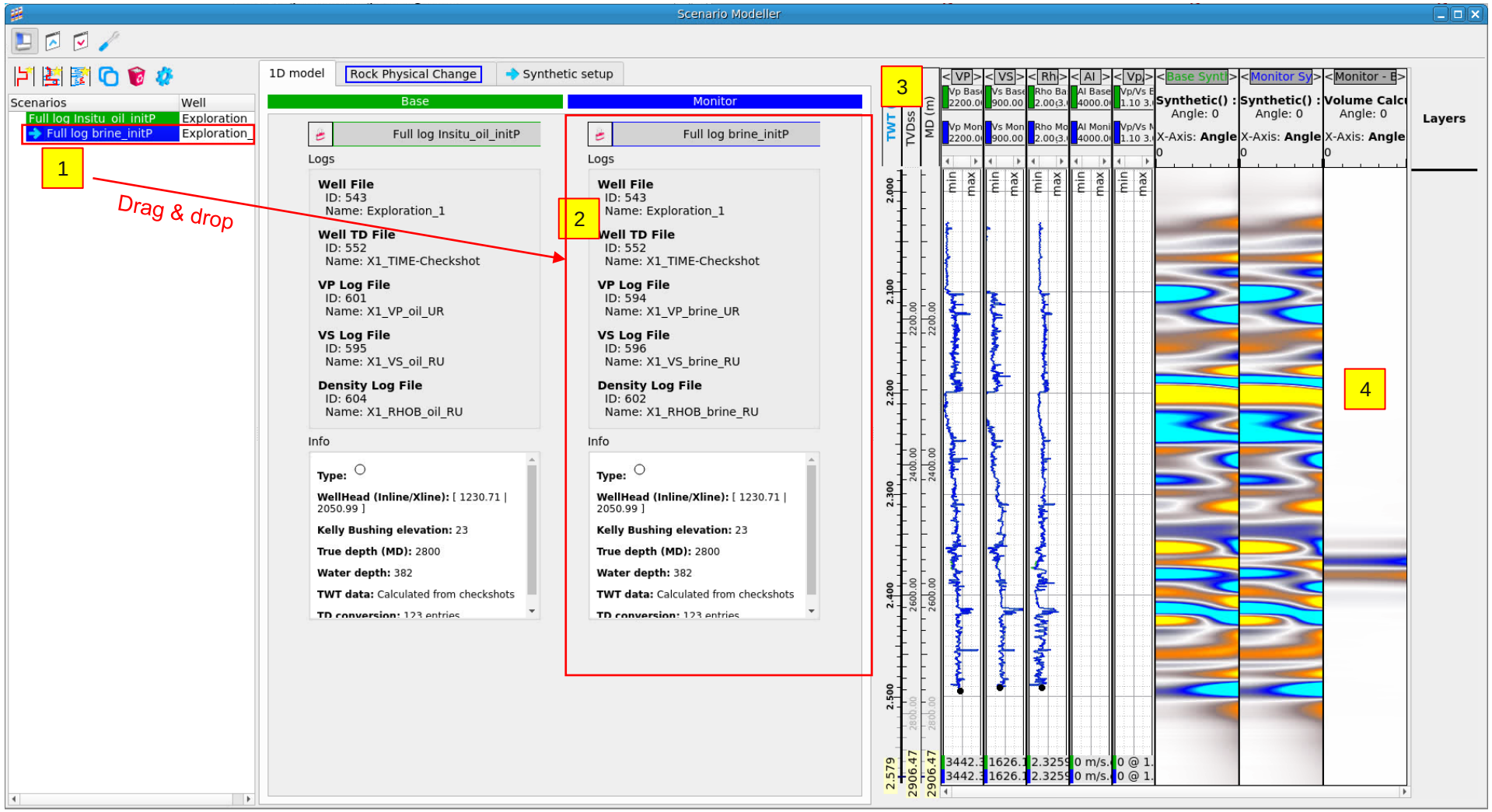
Well log synthetics – Brine sub log set



We are now going to repeat the steps to create a second scenario using the brine fill log set at the exploration well

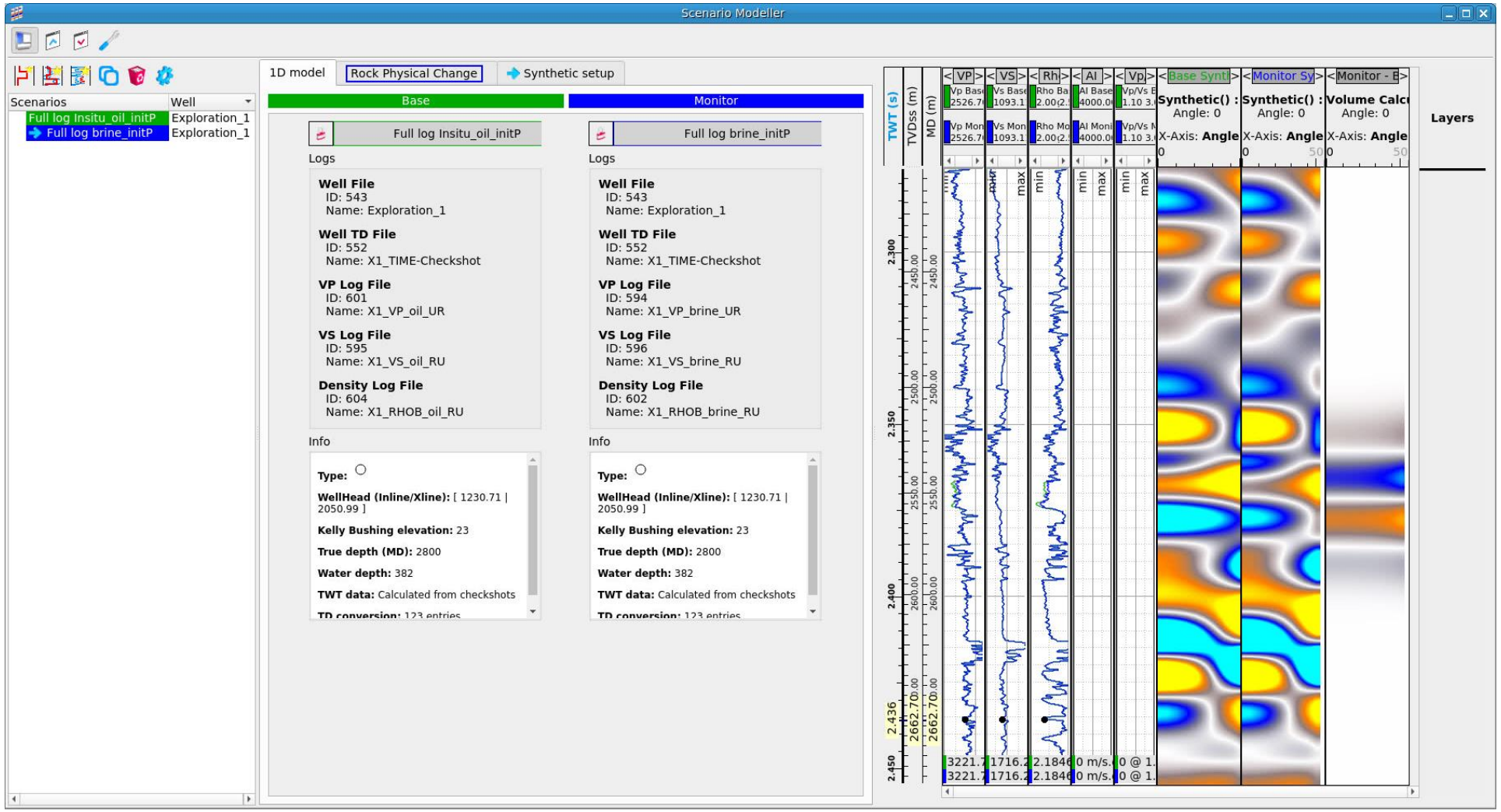
1. Click the well synthetic icon
2. Select the Exploratio_1 well
3. Select the brine_initP logset

Well log synthetics – Brine sub log set



1. You should now have a second scenario for a brine filled reservoir
2. Drag and drop this into the monitor panel
3. The logs and synthetic should display in the tracks to the right
4. As you now have base and monitor you should get a difference track displayed as well

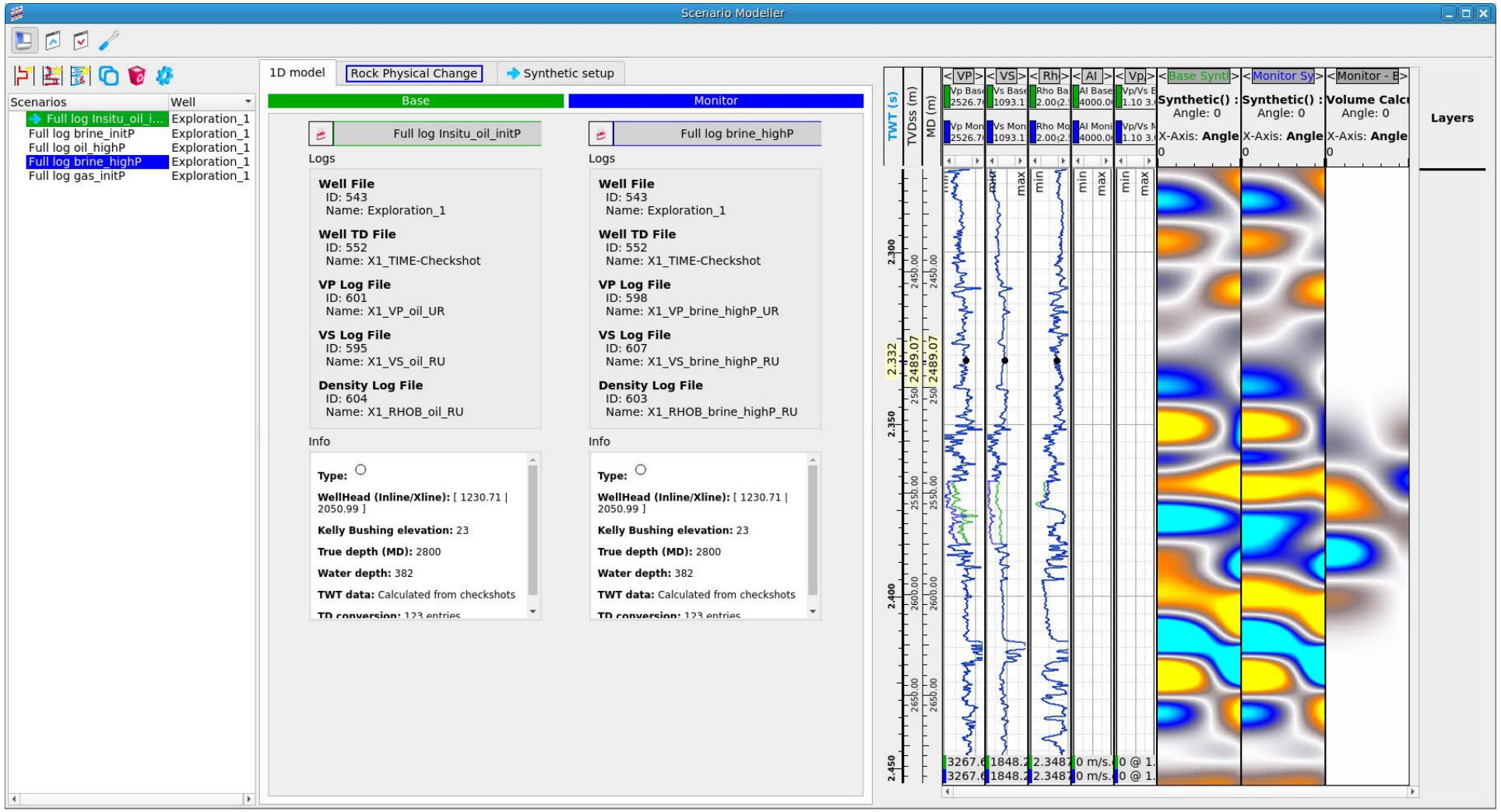
Time-lapse differences



1. Zoom in on the region of the time shifts by hovering over the track scale and scrolling on the mouse
2. You may also have to zoom the horizontal scale on the log track to see where they differ in Vp and Rho

Note how the change from oil to brine in the upper reservoir layer cause a hardening response

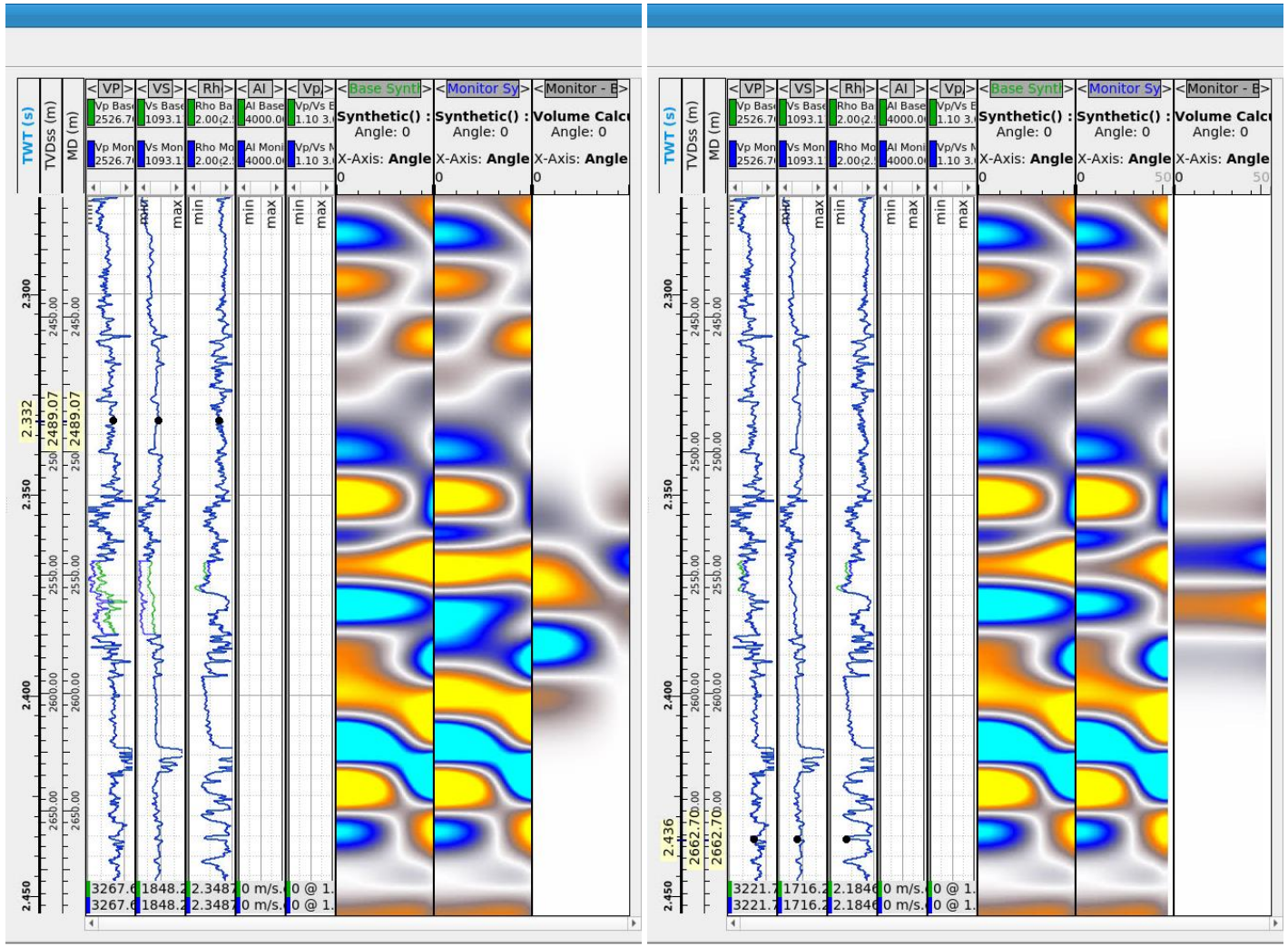
Other full well synthetics – Optional extension



There are another 3 log-sets in the project that represent the case of the upper reservoir with increased pressure, filled with both oil and brine as well as a gas filled case.

If you want, you can repeat the steps above to create scenarios for all the log sets. Alternatively, you can load the session “Full logs all logsets”

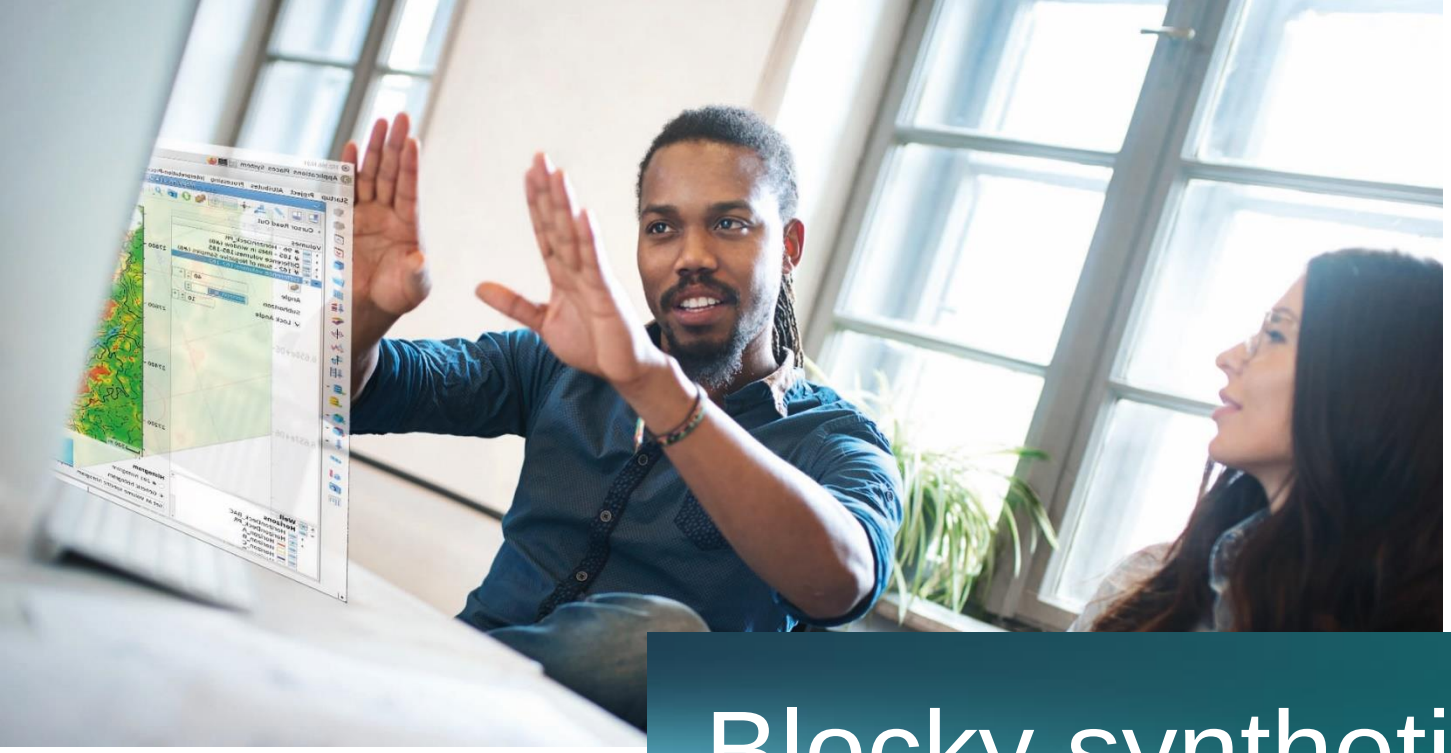
Other full well synthetics – Optional extension



Now you have 5 scenarios try comparing how the time lapse signal changes for the different production scenarios. Here are a few suggestion:

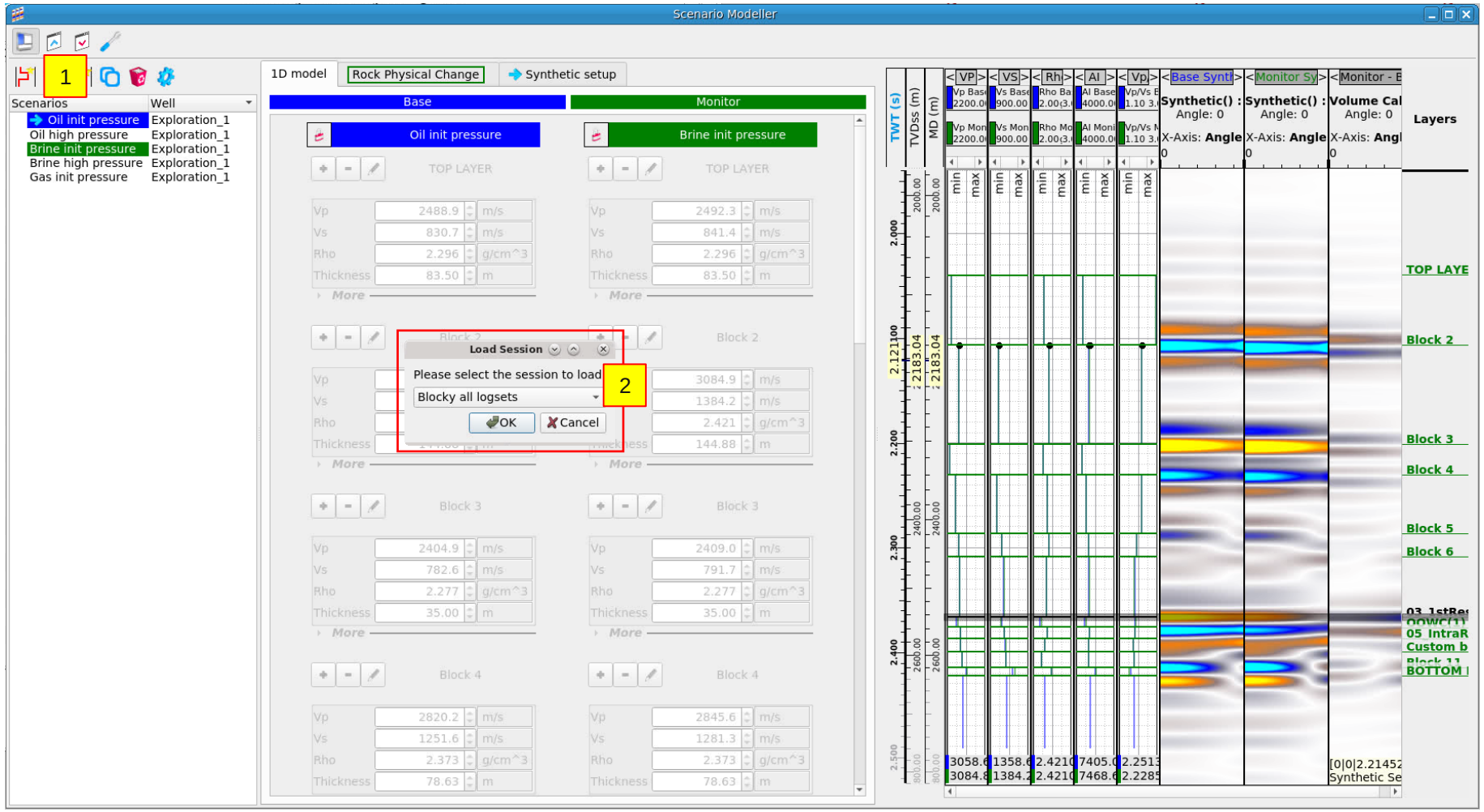
Base		Monitor
Oil initial Pres	→	Oil high Pres
Oil initial Pres	→	Brine high Pres
Oil initial Pres	→	Brine initial Pres
Oil initial Pres	→	Gas initial Pres

Note you can set a scenario as base or monitor by dragging and dropping or right clicking on it in the tree and using the set as bas/monitor option



Blocky synthetic scenarios

Equivalent Blocky models

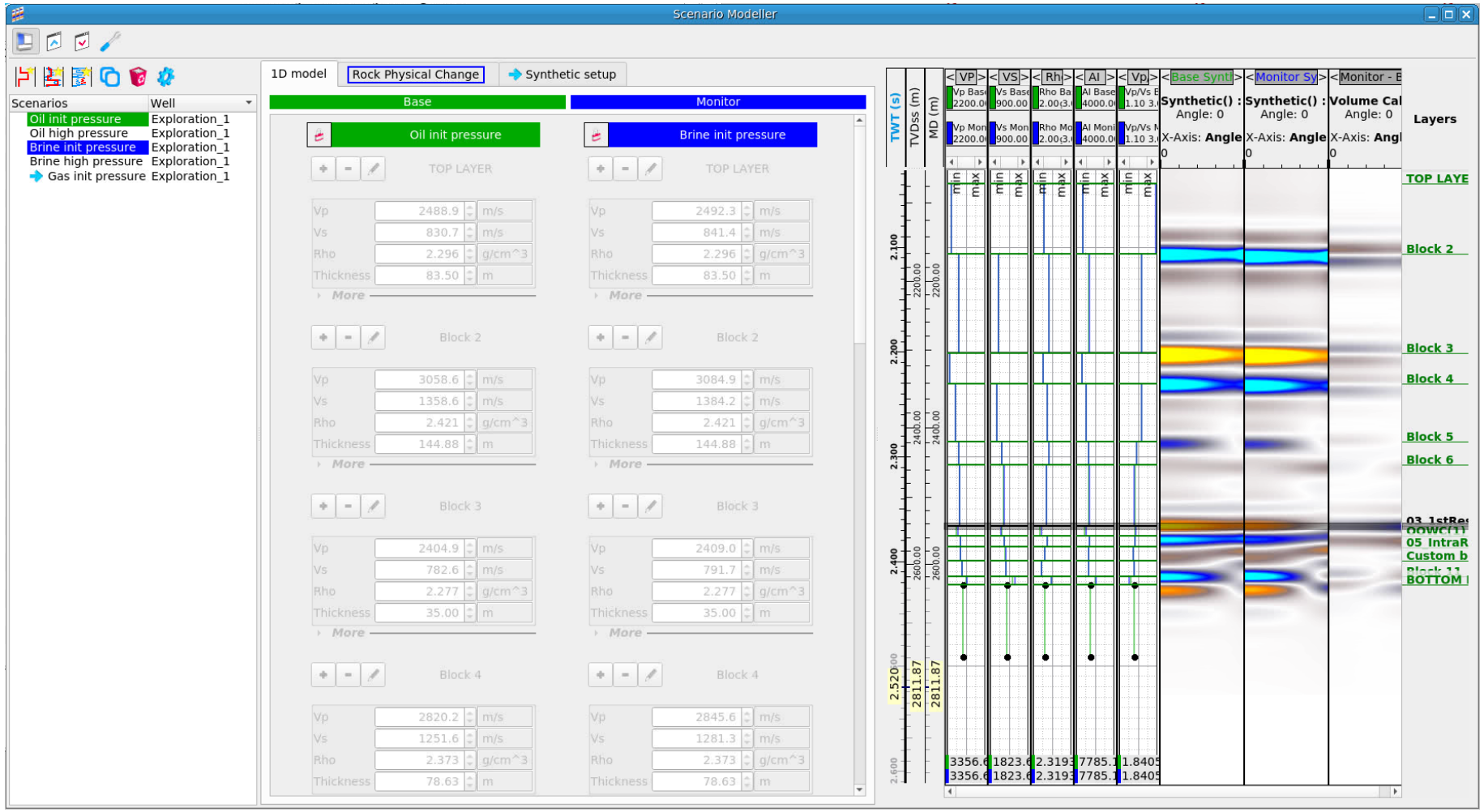


Now open another scenario modeler window

1. Load session
2. Select the session “Blocky all logsets”

This session has pre-made blocky equivalents for the full well log synthetic you created in your previous session

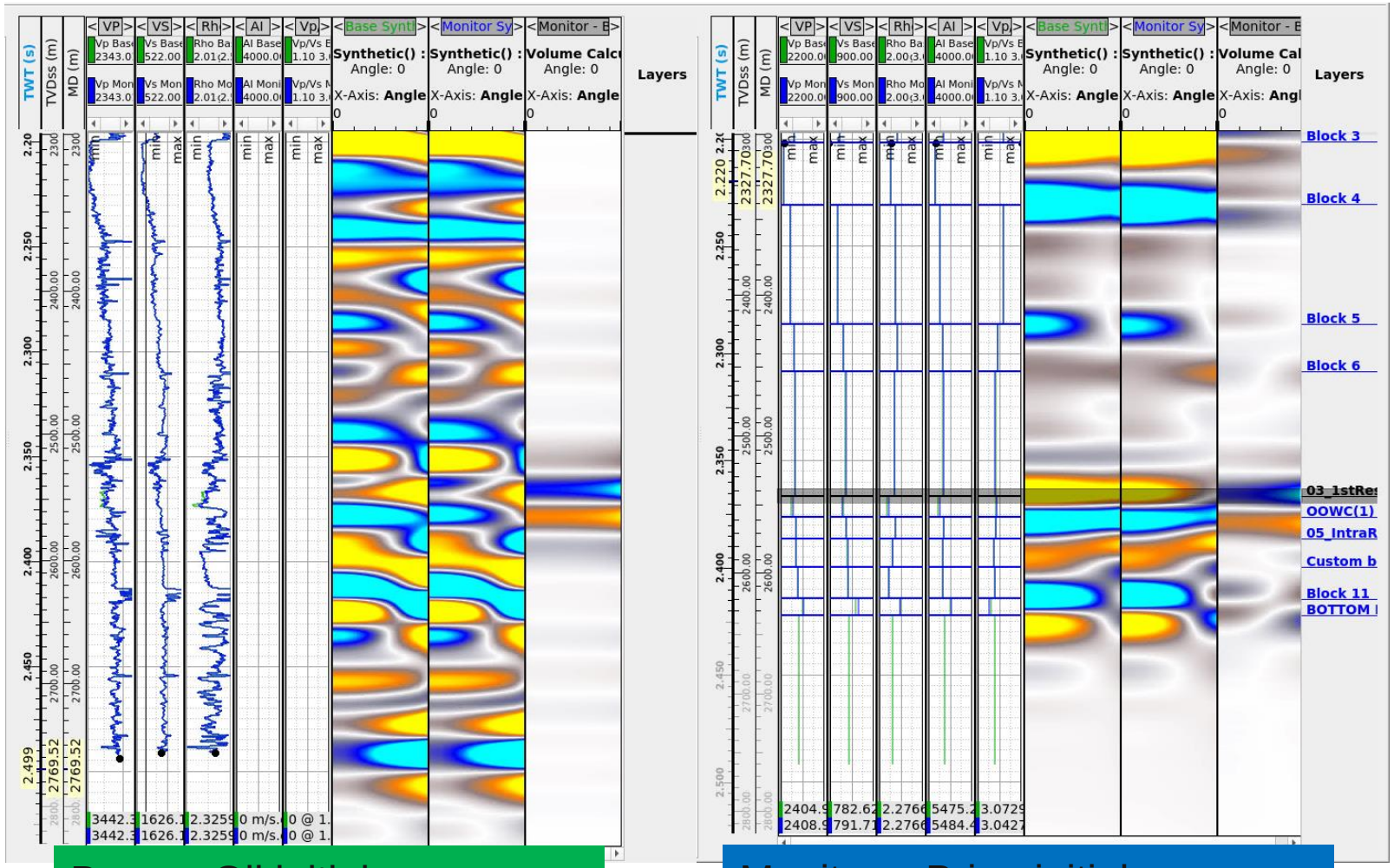
Equivalent Blocky models



1. Drag the Oil initial pressure scenario int the base panel
2. Drag the Brine initial pressure scenario into the monitor panel

Compare the synthetics from for the full log scenarios you makes with the equivalent blocky scenarios.
Also compare the 4D differences.

Comparing Blocky and full log synthetics



Base = Oil initial pressure

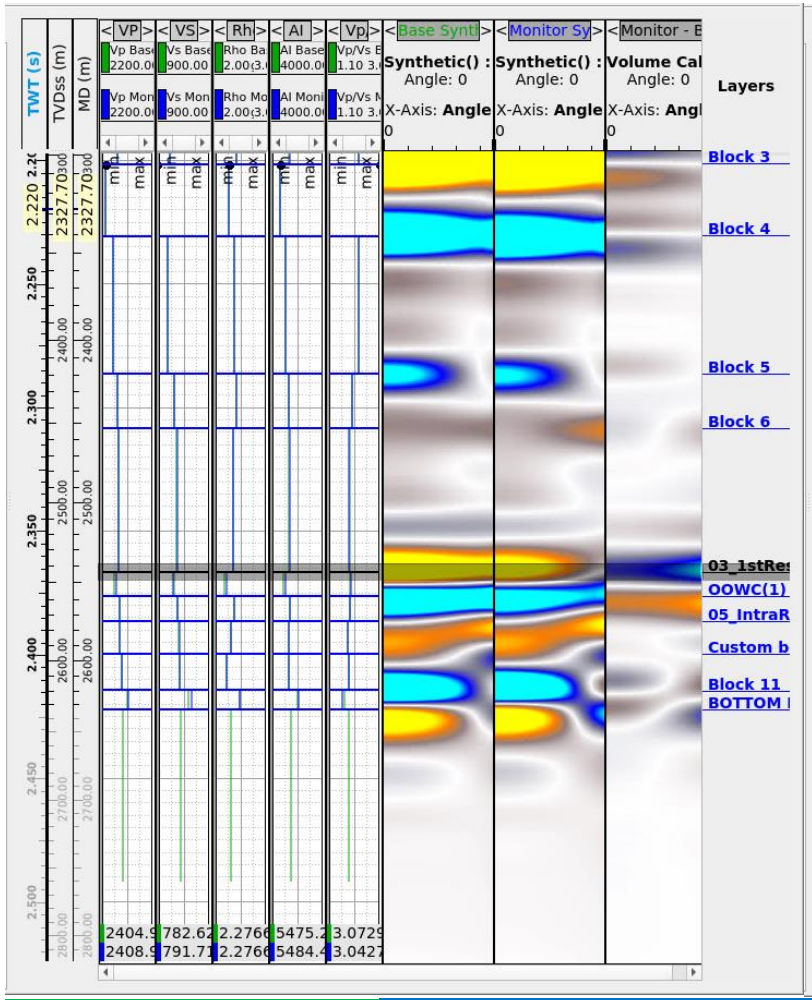
Monitor = Brine initial pressure

Here we can see that both the blocky and full resolution logs are giving very similar 4D differences

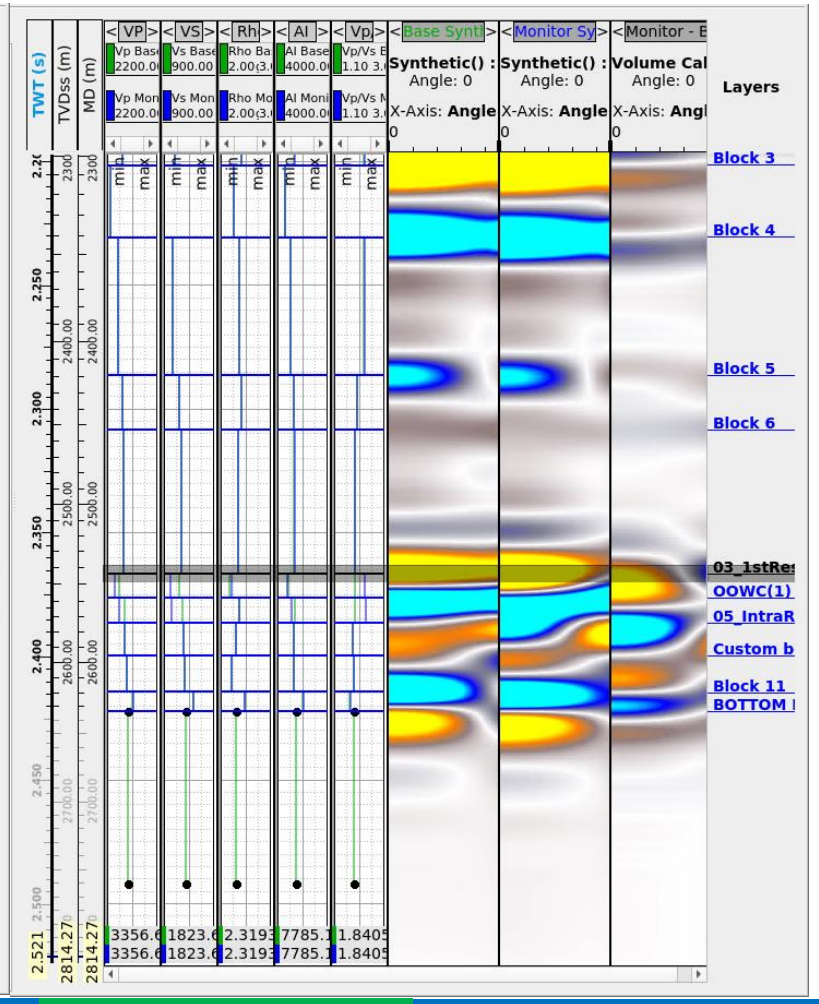
This is a nice result as it show that we can successfully predict the 4D differences between production scenarios with relatively simple blocky models

Note: to get the two viewers on identical color scales you may have to capture the histogram from one to the other. This is accessed by right clicking one of the seismic track titles and then right clicking the color bar

Comparing Blocky production scenarios



Base = Oil initial pressure | Monitor = Brine initial pressure



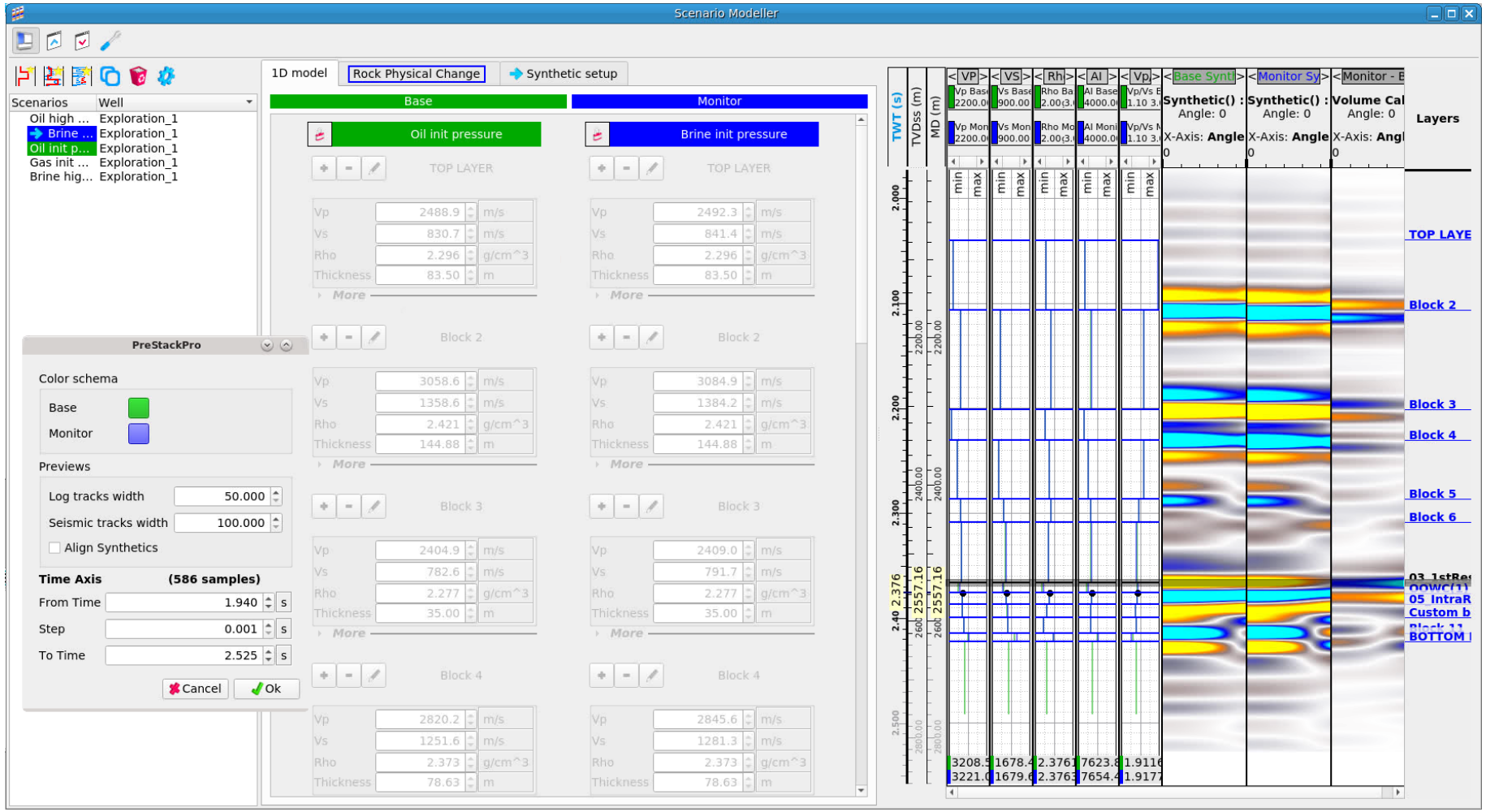
Base = Oil initial pressure | Monitor = Brine high pressure

Using our blocky models Try comparing the timelapse response for some different pairs of scenarios such as the pair show to the right of this slide, where we simulate oil being replaced by brine with a pressure increase.
Here are some suggestions:

Base		Monitor
Oil initial Pres	→	Oil high Pres
Oil initial Pres	→	Brine high Pres
Oil initial Pres	→	Brine initial Pres
Oil initial Pres	→	Gas initial Pres

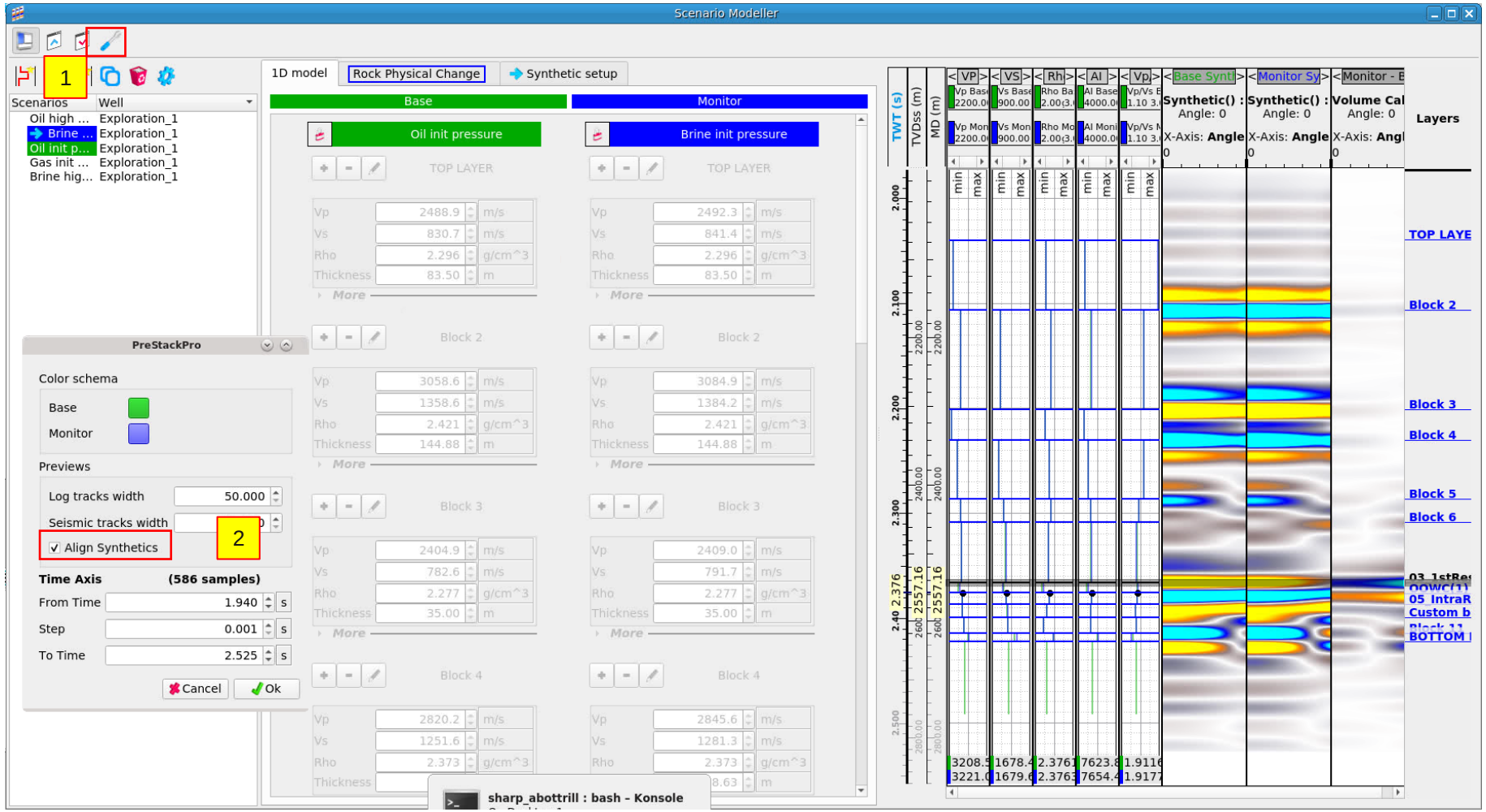
Do you think the changes in amplitude would allow us to differentiate between the different production scenarios? What attributes might be useful to help us?

Aligned Blocky synthetics – Hot off the press



The other interesting thing to note is that if we zoom out to the whole model, we see small amplitude changes above and below the reservoir. This is due to the blocky models having their own Time-Depth relationship with a tie point (black bar). Therefore, here we are seeing the effects of a velocity change in the reservoir generating timeshifts in the synthetics between the 2 scenarios.

Aligned Blocky synthetics – Hot off the press



If you would prefer to see the model comparison without timeshifts:

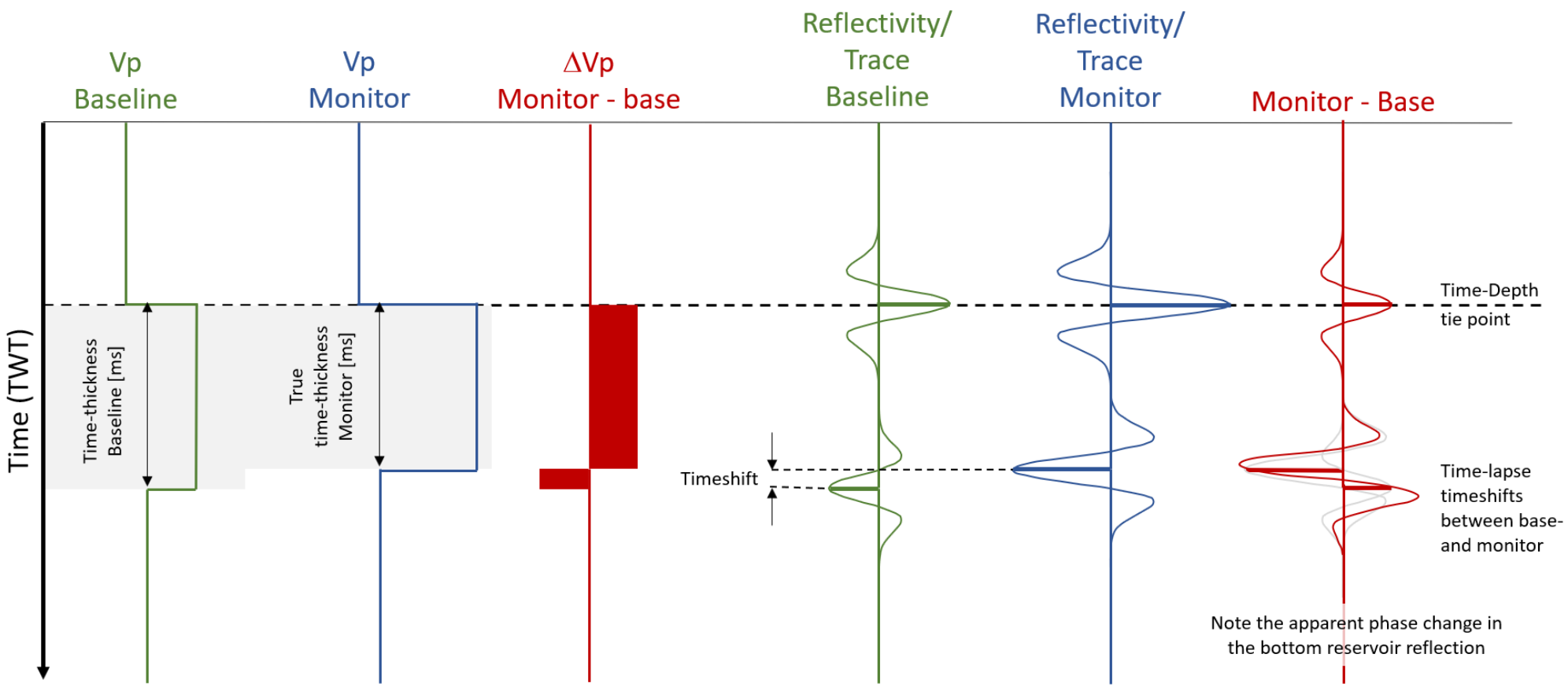
1. Click on the spanner icon to open the settings dialog
2. Tick on the Align synthetics option

What this does is calculating both synthetics using the time depth relationship from the base. This is useful as allows you to directly compare the amplitude changes without the complication of timeshifts.

Theory – Synthetics with time shifts

Vertical axis TWT: **TD curve from Vp for each scenario**

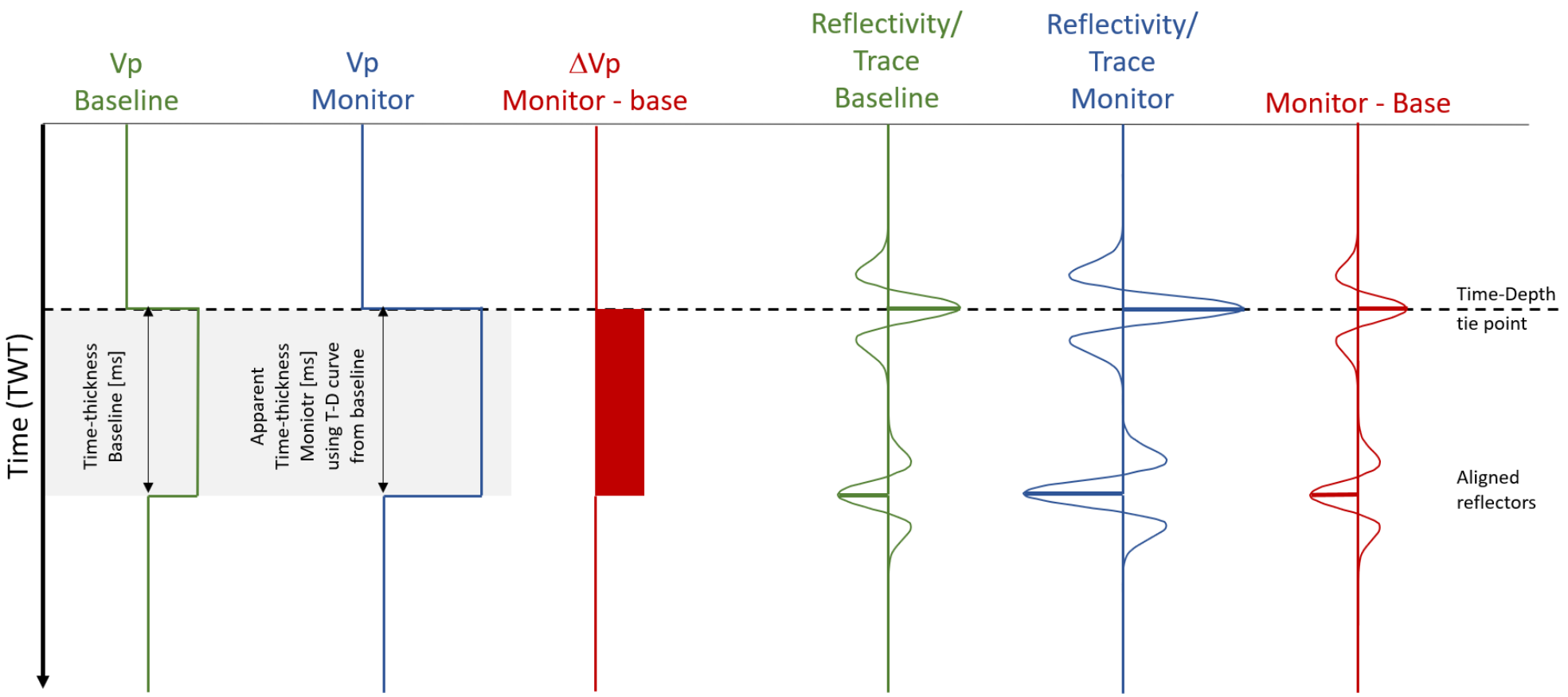
→ Synthetics with timeshifts, showing "true" time-lapse signal, but spurious amplitude changes



Using the velocity model for each scenario to convert from depth→time (v=s/t; therefore t=s/v; or summation of interval traveltimes from interval thickness and velocity), each scenario has a unique time-depth relationship. Therefore reservoir layers (or more generally any layer) with a Vp change in the monitor survey changes their time-thickness with respect to the baseline (reference) scenario. As can be seen in the sketch above , this causes misalignment of base- and monitor surveys, aka time-lapse timeshifts

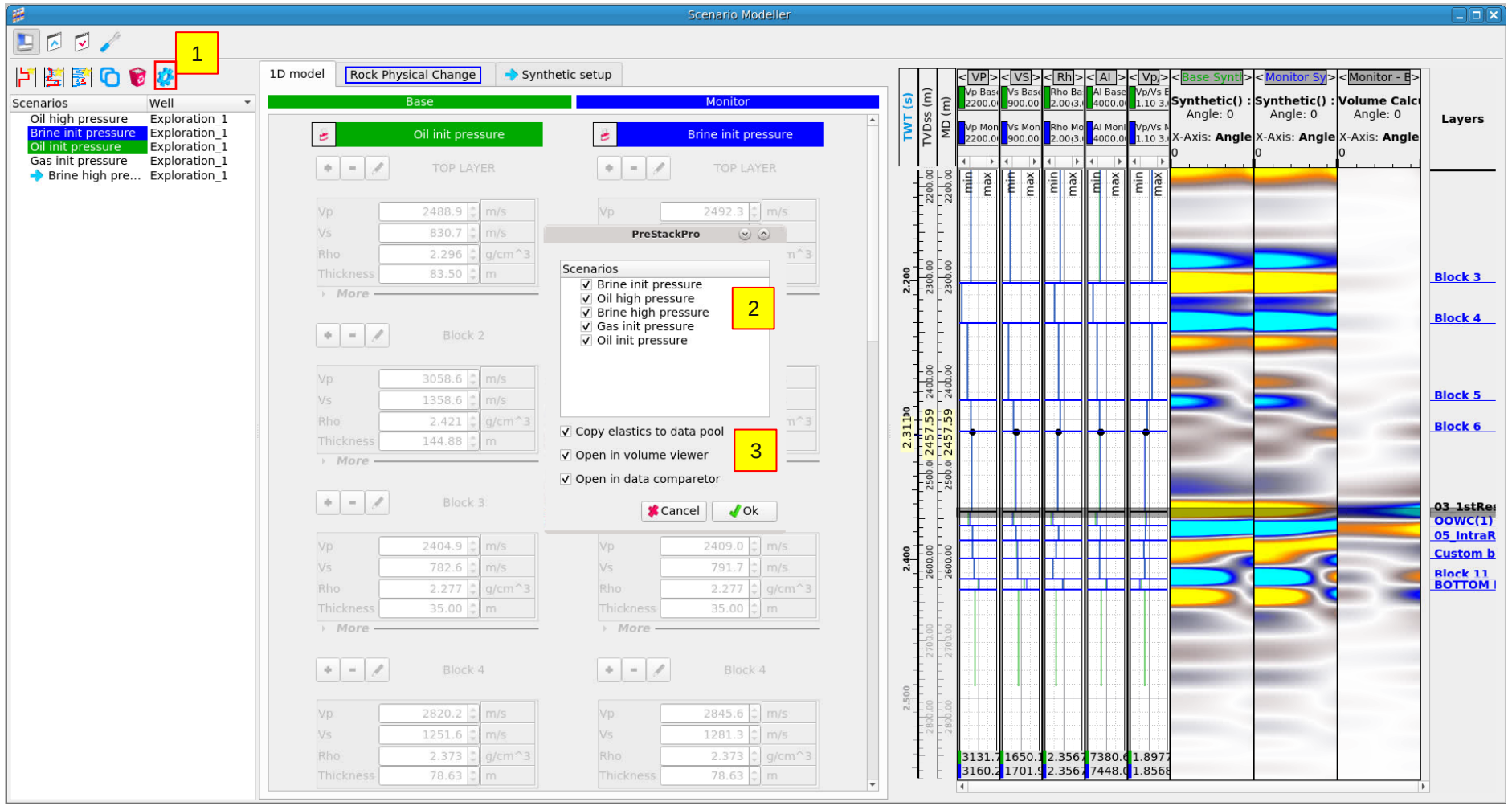
Theory – Synthetics without time shifts

Vertical axis time: **TD curve common for each scenario** (e.g., from baseline or well)
→ Synthetics without timeshifts, showing "true" amplitude changes



Synthetic seismic is calculated using a convolutional model, with the elastic property model in two-way time.
We need a time-depth relationship to convert the elastic model from depth to time. Using the time-depth relationship from the baseline for depth→time conversion for all surveys, the time-thickness of the reservoir layers stays constant for all scenarios (despite the velocity change in the reservoir layer)

Copy scenarios to the data pool



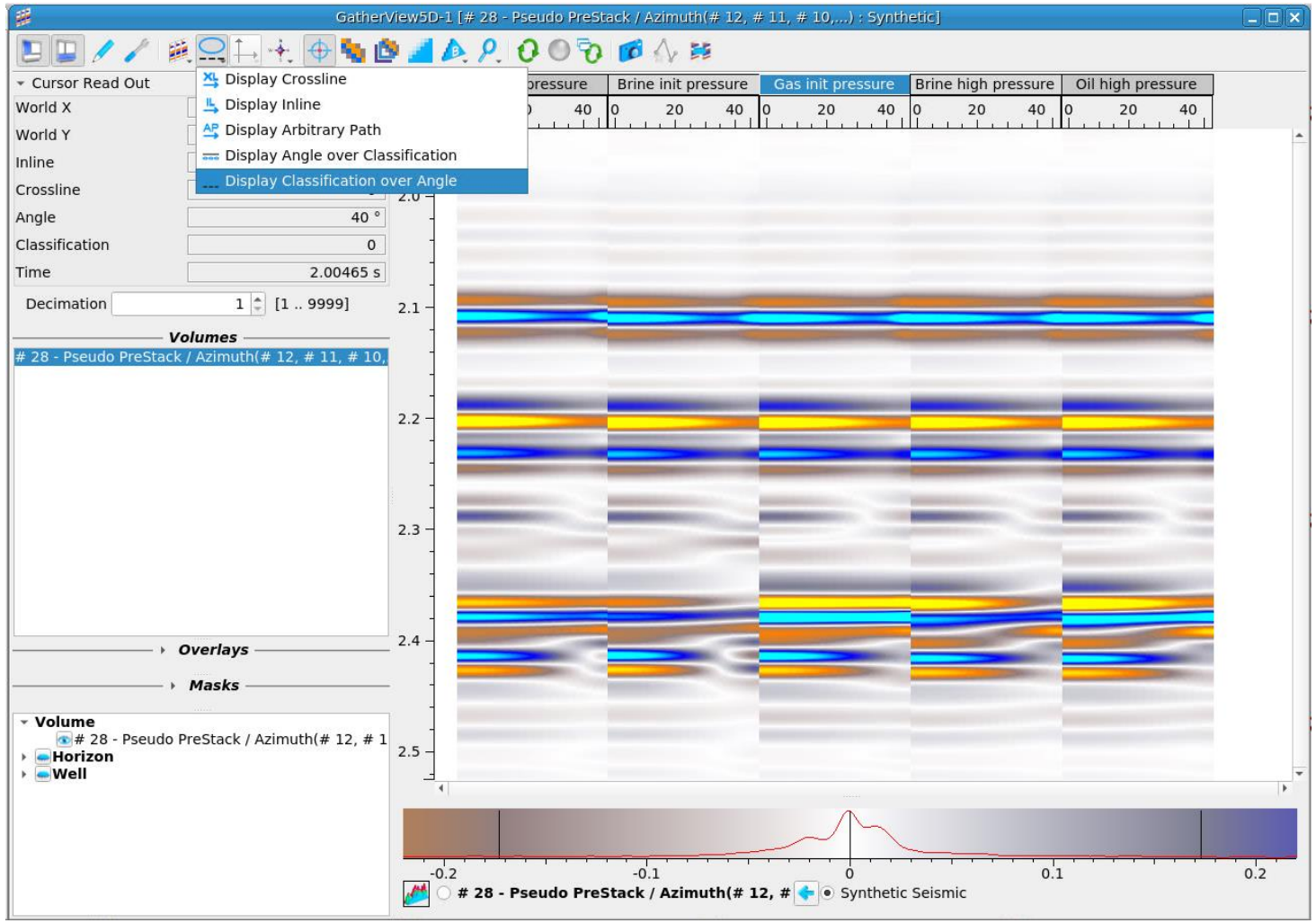
Let's now export our blocky scenarios to the data pool for analysis in other tools

1. Use the gear icon to open the copy to data dialog.
2. Select all the scenarios you want to export
3. You can also check the copy elastics option as well as open in Volume and data comparator options

This will create a volume with the scenarios along the second gather (Vintage) axis

Note you can only copy scenarios with the same gather geometry to a single object

Viewing the synthetic output in other viewers

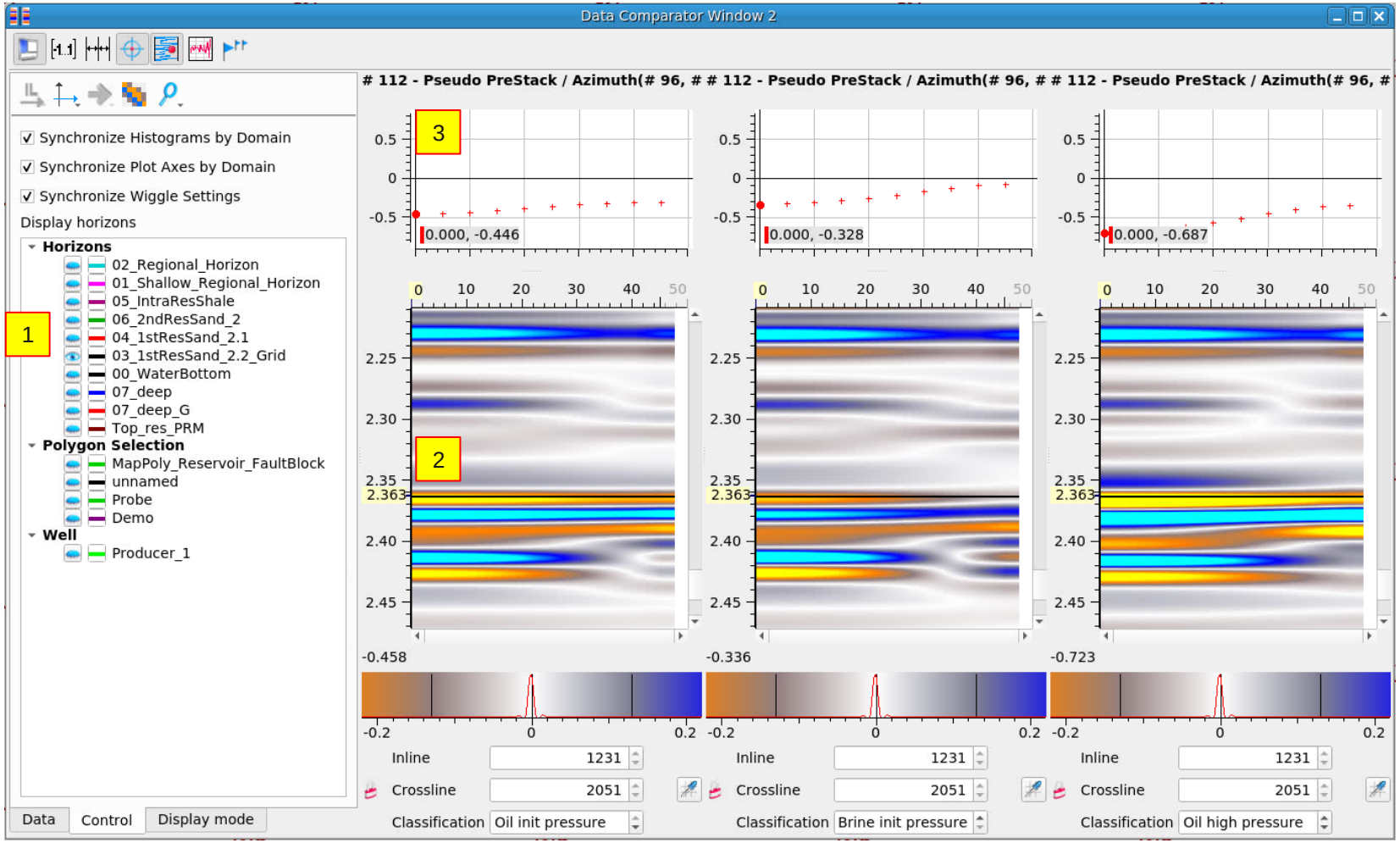


In the gather viewer that opened you can view all your scenario synthetic side by side.

Try also turning on some of the horizons to help you visualize where you would expect changes in the synthetic

To get the view of all scenarios side by side you need to select the “Display classification over Angle” option. If the viewer is launched from the tool it should already be in that view model.

Viewing the synthetic output in other viewers



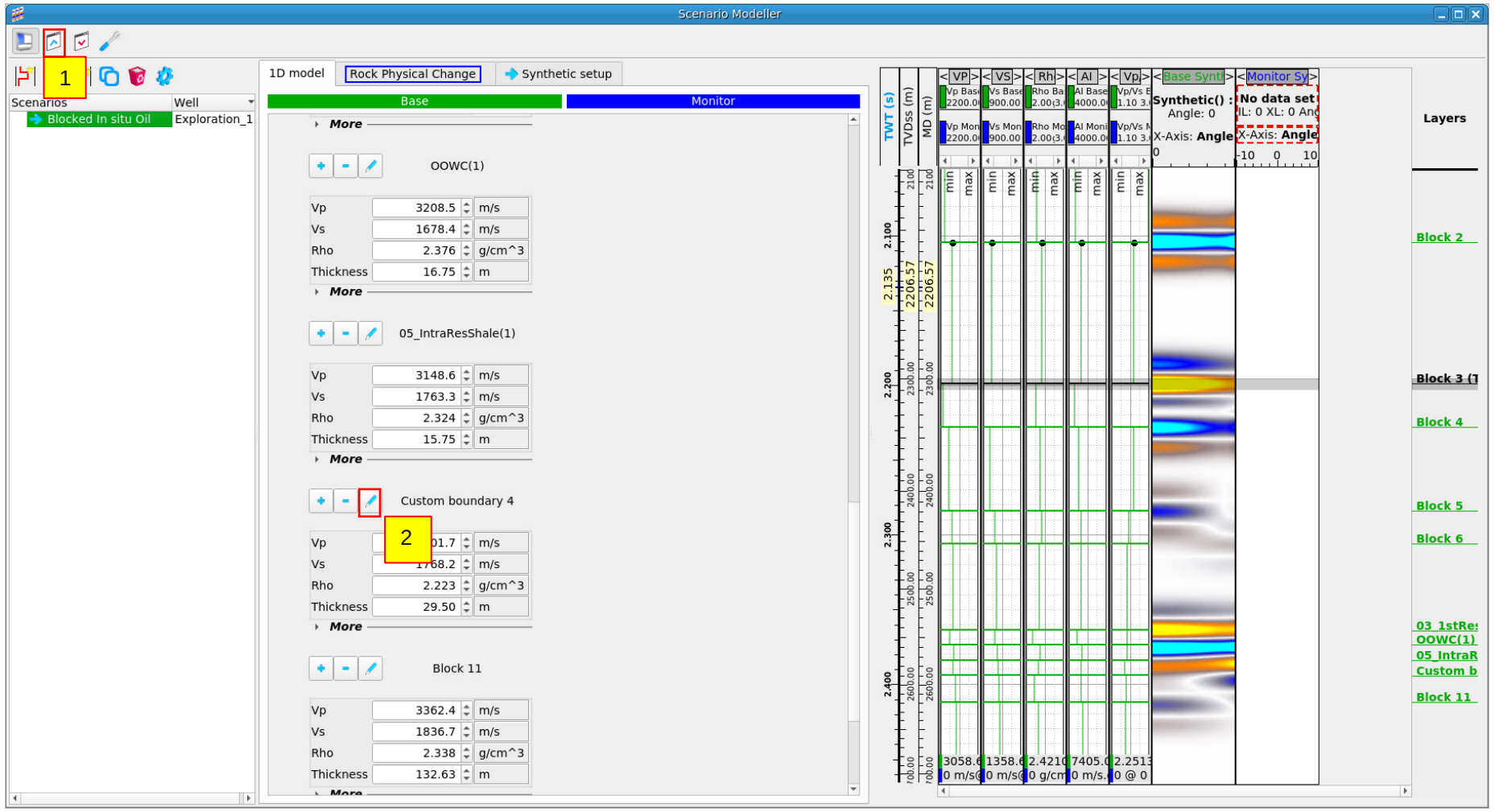
1. In the Data Comparator turn on the 03_1stResSand_2.2_Grid horizon to help you visualize where you would expect changes the synthetic seismic at top reservoir to be
2. Pin the crosshair by right clicking in one of the panels at this horizon.
3. Compare the AVO responses for different scenarios

Do you think there is enough of a difference in AVO response at top reservoir to separate them in intercept gradient space?

Rock Physics modifications

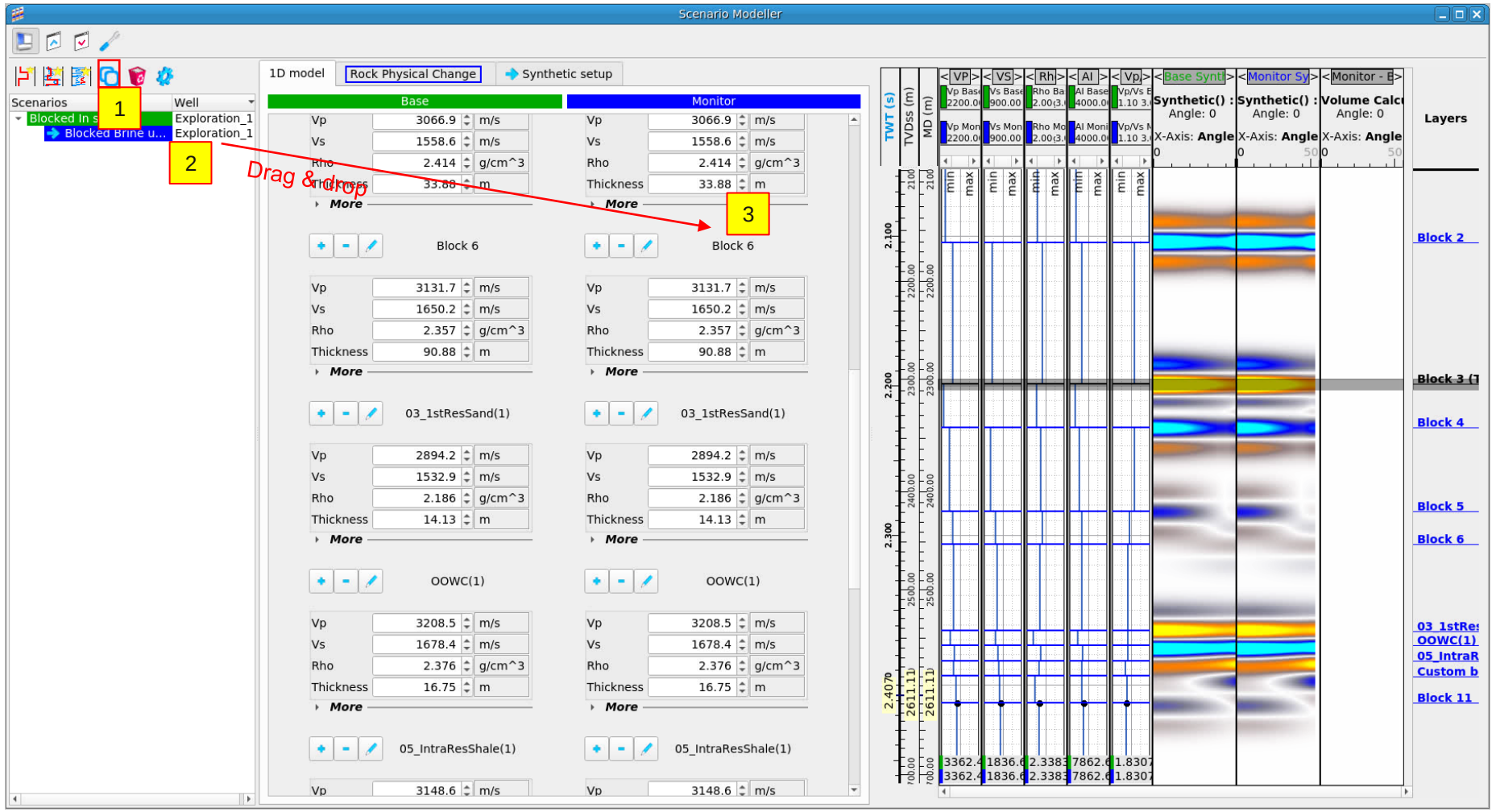
Additional exercise if time allows

Working with blocked scenarios



1. Reopen a new scenario modelling window and load the session “Blocky Oil inSitu”
2. We can rename some of the blocks to make their names more meaningful, using the pencil icon. For example, Block 3 can become the BCU and our custom boundary can be lower reservoir. To do this you might have to unlock the scenario using the padlock at the top of the scenario by its name

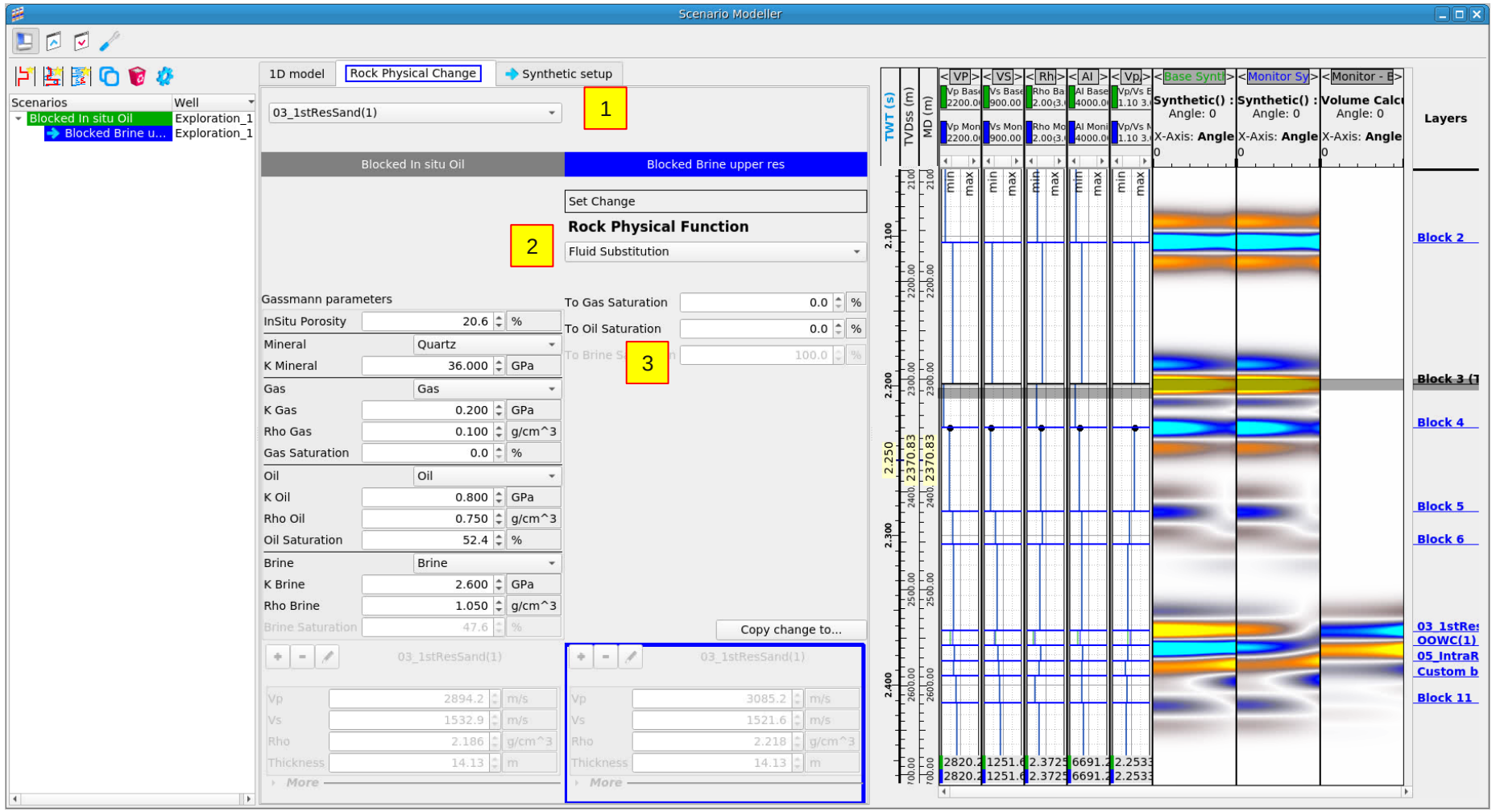
Working with blocked scenarios



1. Copy this base scenario using the copy icon
2. Rename this copy to Brine upper res by right clicking on it
3. Then drag and drop the copy into the monitor pane

Note here you could freehand change the elastic properties of any of the blocks and observer the effect. However for a more meaningful change we can set up a Rock Physics model that applies to a block

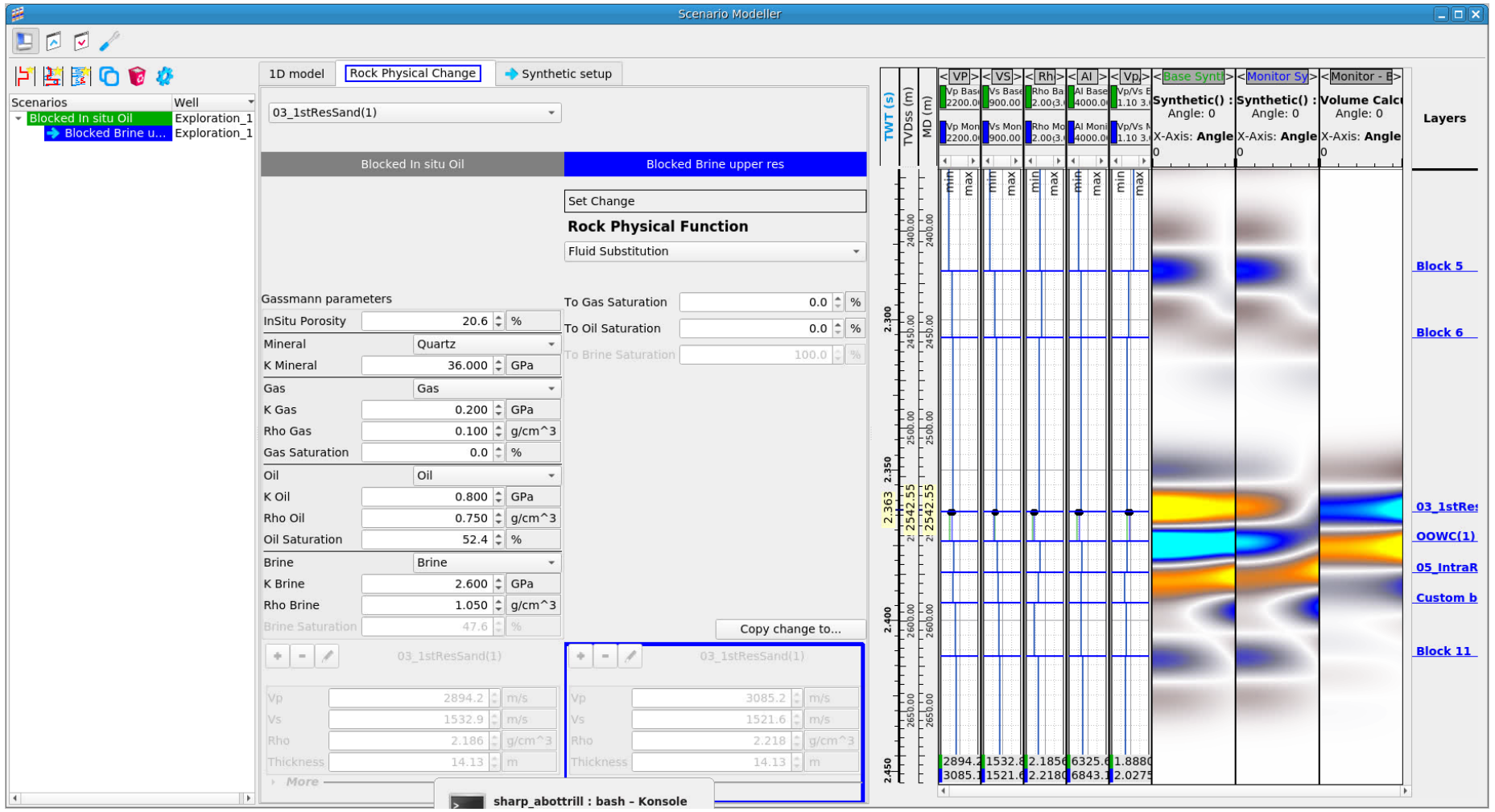
Rock Physics change – fluid substitution



1. From the Rock Physical change tab first select the layer 03_1stResSand
2. Then select fluid substitution as the Rock Physics function
3. Finally set the Monitor Gas and Oil Saturations to zero (100% Brine), to simulate a total water sweep.

At the bottom of the window greyed out you can see what the Rock Physics function has done to the elastic properties

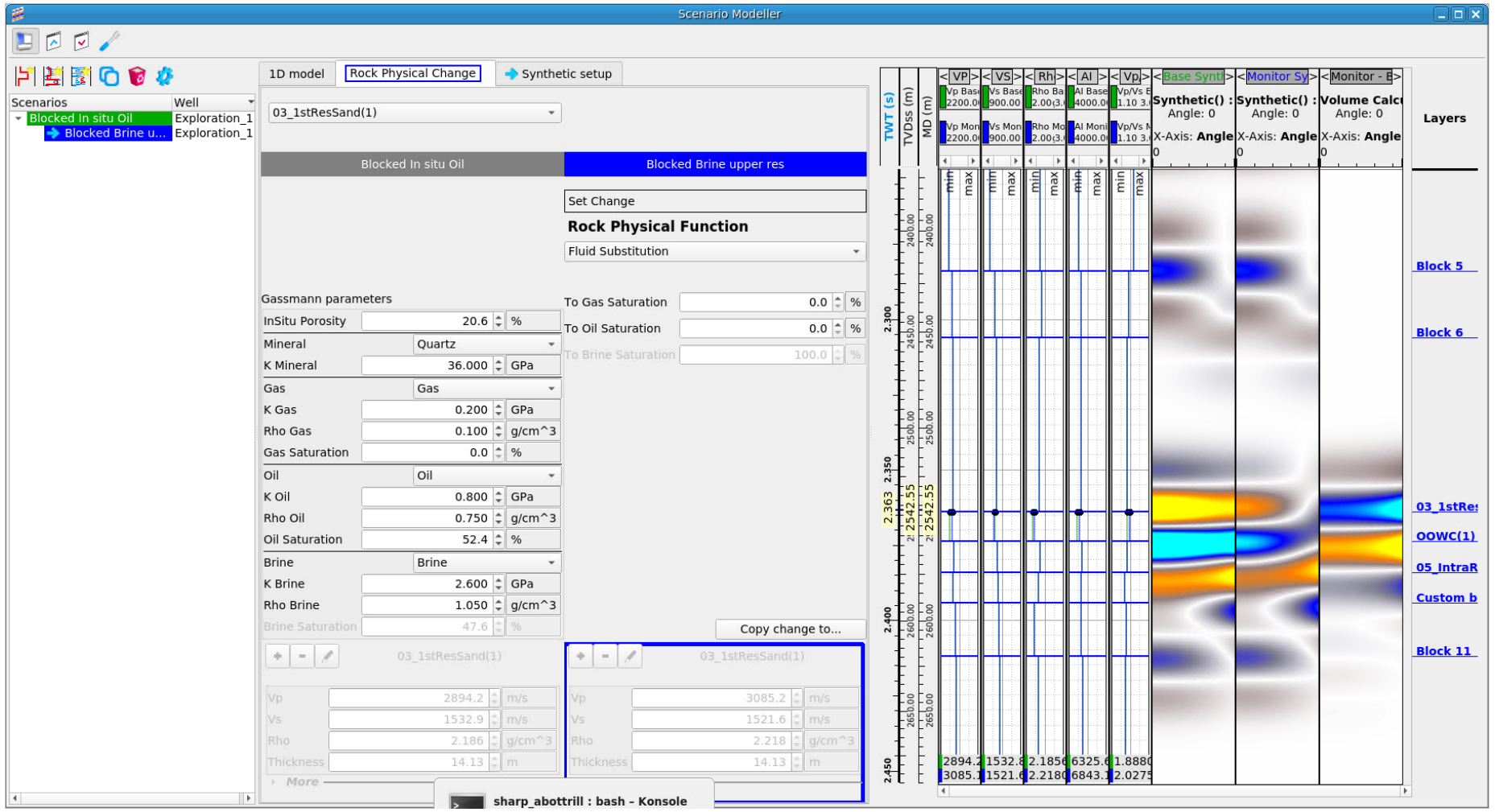
Rock Physics change – fluid substitution



If we zoom in on the upper reservoir it is interesting to note that we get a very similar pattern of time lapse differences as we did for the full well synthetic

However, it is worth observing that there are now small amplitude changes below the reservoir. This is because unlike for full well synthetics these blocky models write their own time depth relationship, as discussed previously

Rock Physics change – Try out some others



Now make additional copies of the base scenario and try to simulate a few different scenarios

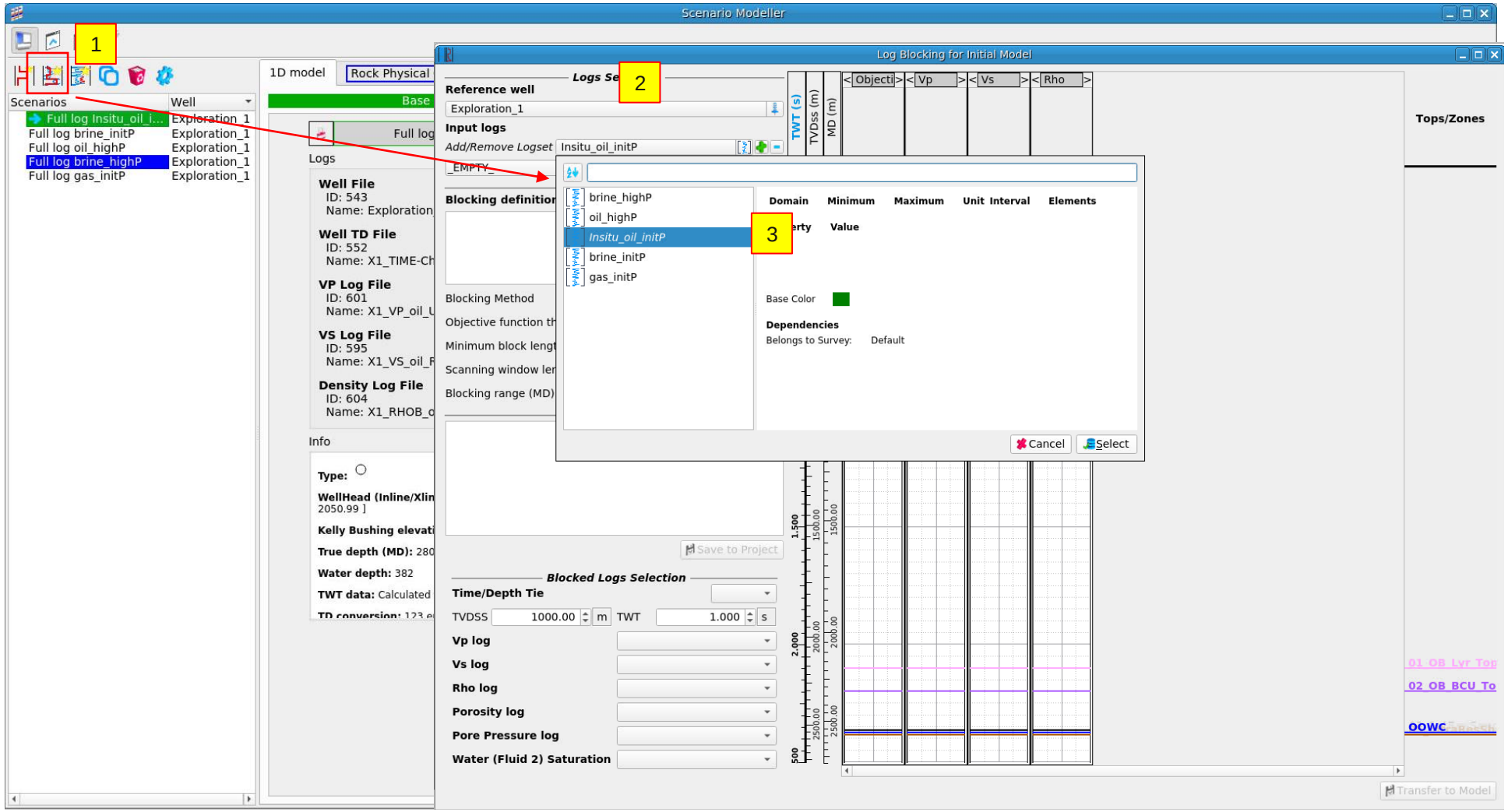
Here are some suggestions

- High pressure Oil in upper res
- High pressure water sweep
- High pressure water in the lower reservoir
- Moving OWC

Creating Blocky scenarios

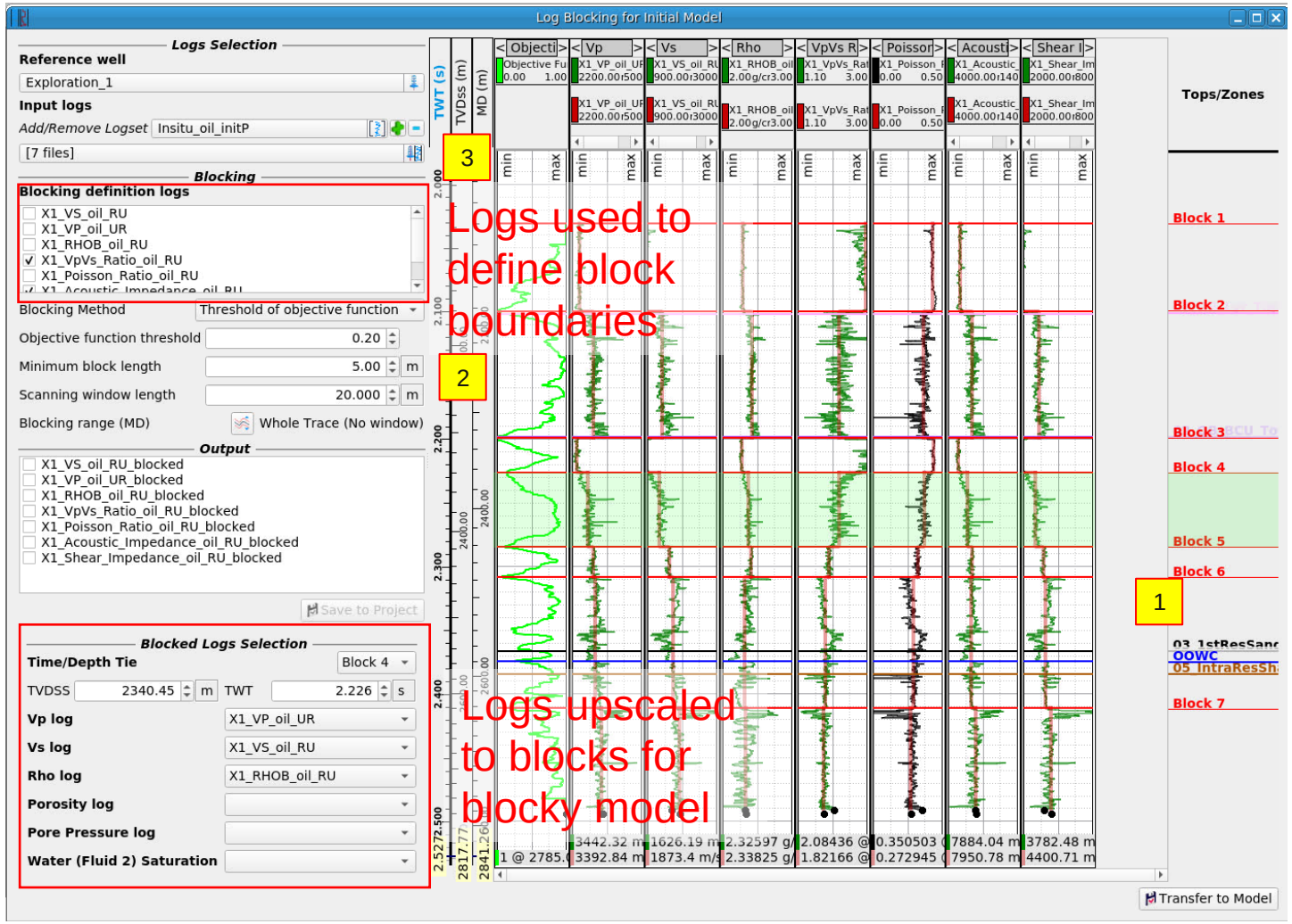
Additional exercise if time allows

Creating an initial blocky scenario



1. Click the log blocking icon 
2. Check that the Exploration_1 well is selected
3. Select the in situ oil log set and click the plus button to add it

Creating an initial blocky scenario

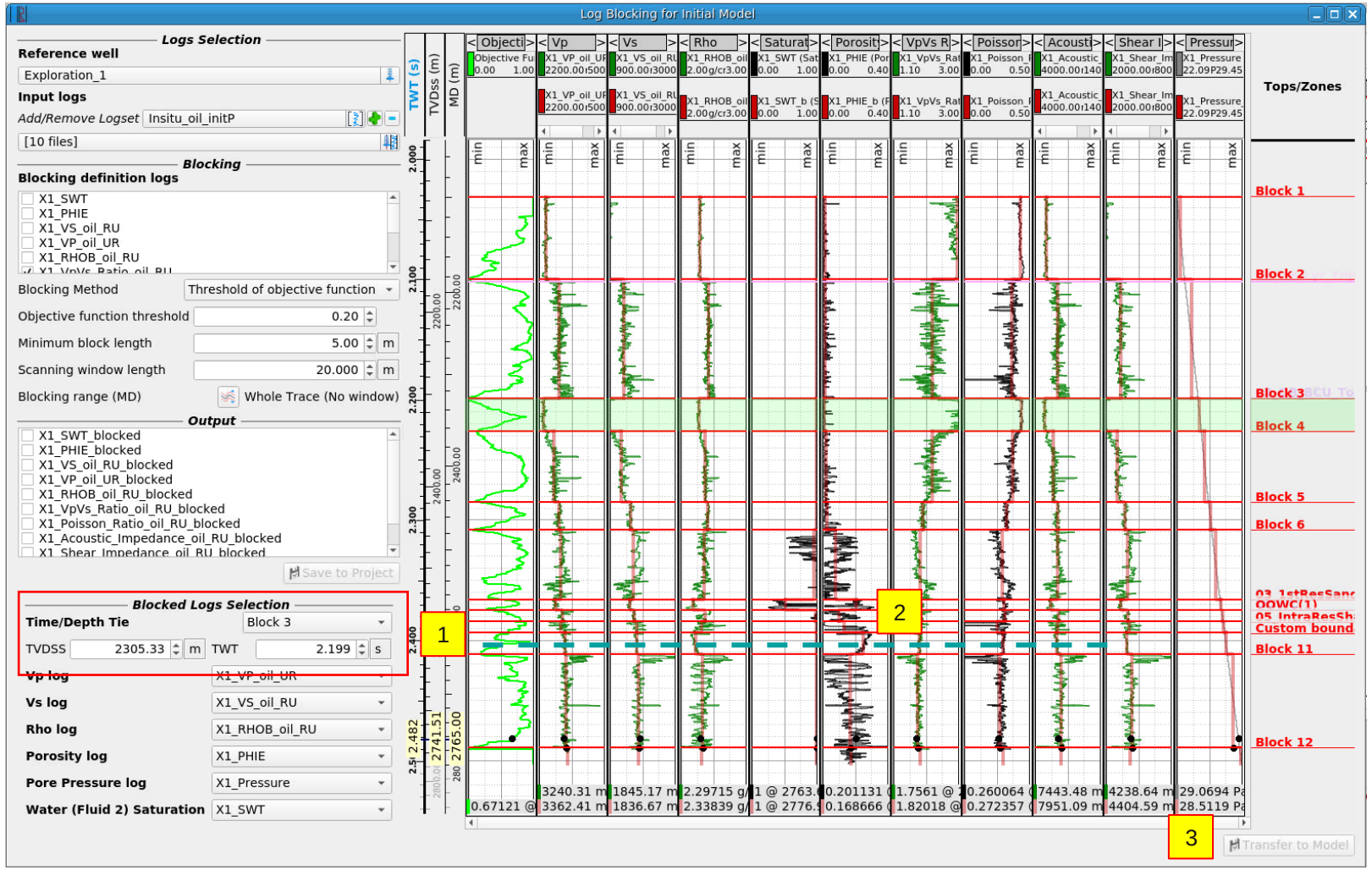


By default, if a log set is added to the blocking tool the AI and Vp/Vs ratio are used for defining block boundaries

The default values do quite a good job here for the overburden but the top reservoir and fluid contacts aren't well picked up

1. Add the 3 tops 03_1stResSand, OWC and 05_IntraResShale as block tops by right clicking on their name and selecting add as boundary at
2. Try changing the objective function threshold and see what this does to the number of blocks?
3. It would also be useful to add a porosity, Water saturation and pore pressure

Creating an initial blocky scenario



1. We can also add a manually placed boundary that represents the base of the inter reservoir shale. This is done by holding Ctrl and clicking in the log tracks. It might be useful to look at both the porosity density and water saturation tracks to place this correctly
2. Finally, we are going to set the tie point to Block 3 which will hopefully corresponds with the top of the BCU
3. We are then going to transfer this back to the Scenario modeler

Try a few different versions and see which you prefer

The GATHERing Knowledge Exchange

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