Velocity Modeling with Complex Tectonics; Example from the San Joaquin Forearc Basin, California*

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Abstract

Lateral velocity variations across steep thrust faults or steeply dipping beds are difficult to incorporate in velocity models where structure is usually controlled by unfaulted, single-z grids. The west side of the San Joaquin basin is a tectonically complex environment with steep dips, unconformities, variable fault geometries, complex basement lithologies, and outcrops to the west. All of these contribute to a complex structural model that is important to capture in velocity modeling to allow for the most accurate depth conversion. In the past, geologic models had to be manually manipulated to account for discrete fault blocks. This process is time-consuming and difficult to update as interpretations change. Here we show how we are able to build a dynamic framework and resulting velocity model that accounts for fault offset, unconformities, and geologic history.

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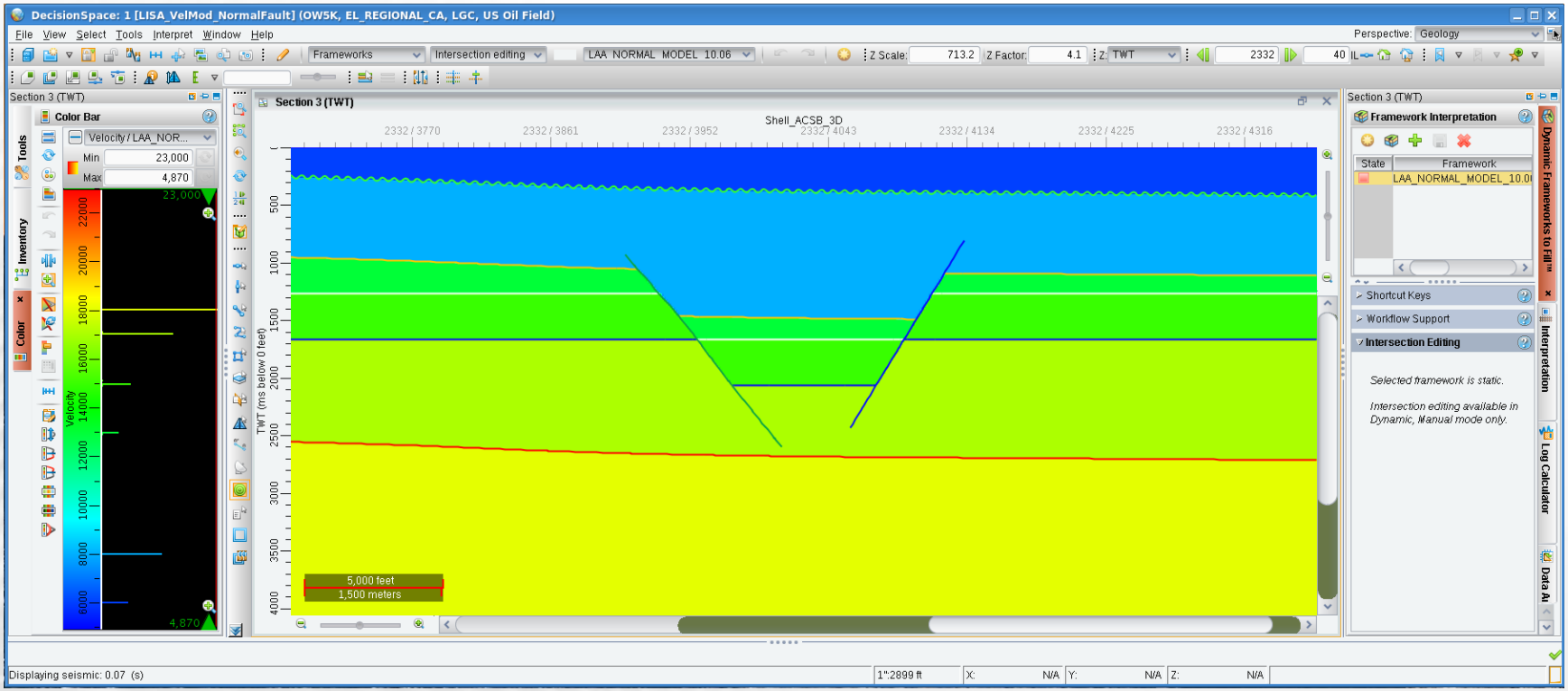
Introduction

- Geophysicist build velocity models
- With limited well data, horizons are useful for controlling the structure of the velocity model
- In complex structural settings, horizons are typically offset by faults, sometimes with offsets significant enough to affect the velocity model
- In normal fault regimes, current software can often handle offset horizons
- In reverse fault regimes, incorporating reverse fault offset is time consuming and often neglected.

Outline

- Evolution of 3D modeling with faults
  - Normal faulting
- Workflows for multiple z's
- Evolution of the Framework
  - Multiple inputs
- Framework as input to velocity model
  - Maintains offset, i.e. does not require a gridded surface
- Velocity Model
  - Honors conformance relationships, offsets
  - Formation control

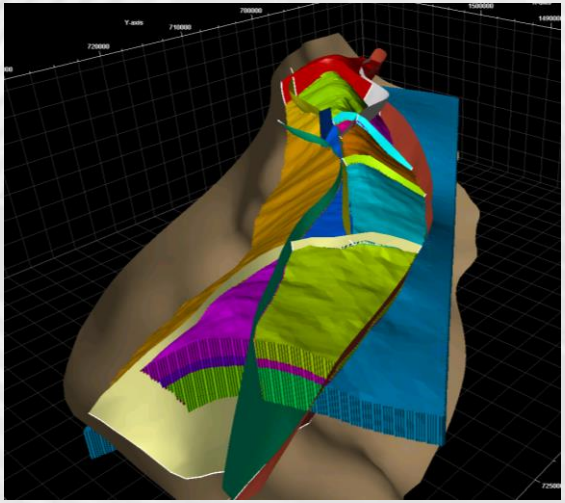
Velocity models in normal fault regimes



Normal fault offset does not require multi-z values so gridding algorithms can handle this

Most software cannot handle reverse fault structural modeling for application to velocity modeling

Some software can build multi-z structural models but they cannot be used in velocity modeling

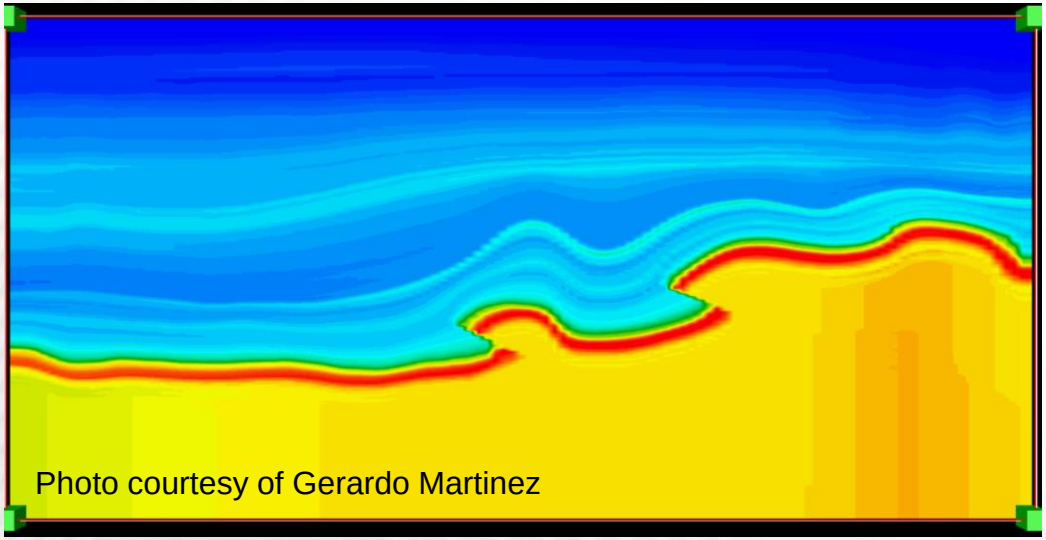


Workarounds have been developed for this but are static and time-consuming.

Typical Workflow

- MIMIC within Landmark's Depth Team module can be used to model complex geologic relationships, but models are time consuming and static.
- Interpret separated blocks, focusing on the foot wall or the hanging wall,
- Convert grids and smooth
  - For every fault affecting a horizon we have two new horizons, the upper and lower blocks in our model, and the velocity functions will be truncated against each block to create isolated blocks for each surface

Static velocity solution - MIMIC



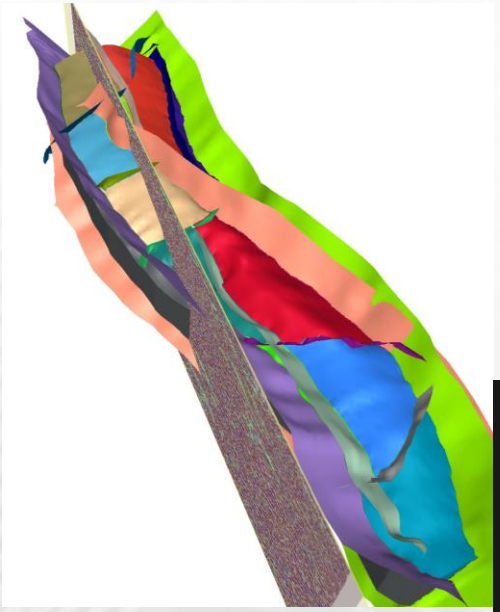
Now, make one change to the original interpretation and start over!

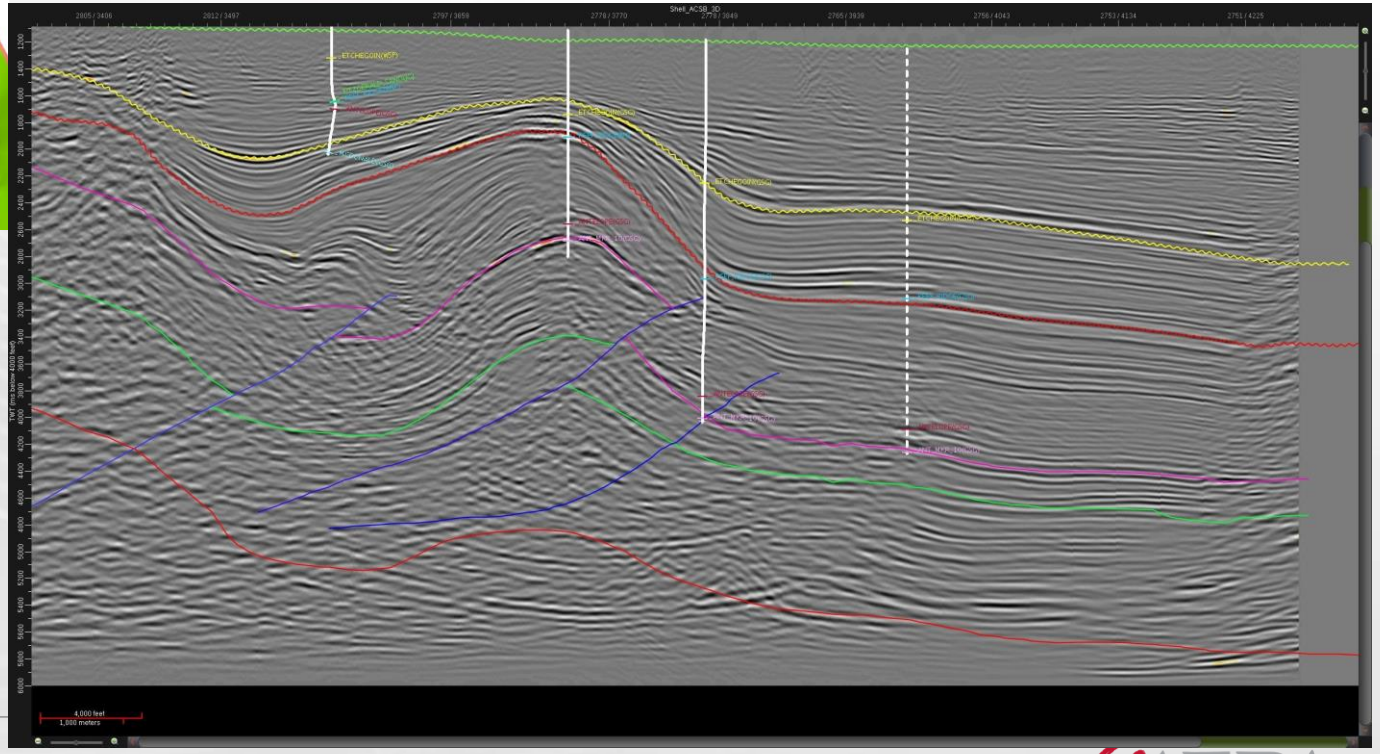
Gridded (non-faulted) solutions may be adequate but what if you are interested in a sub-thrust area?

Objective

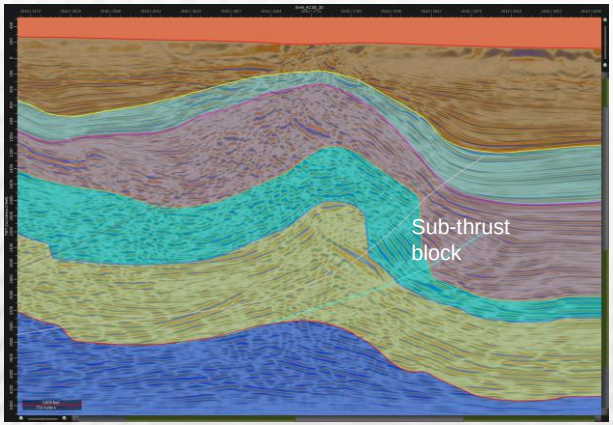
- To find a simpler method of incorporating multi-z structural models into a velocity modeling workflow.
  - Workflow must be dynamic!

Structural Modeling





Reverse faults can produce subthrust HC plays. Offset juxtaposition can be effective fault traps



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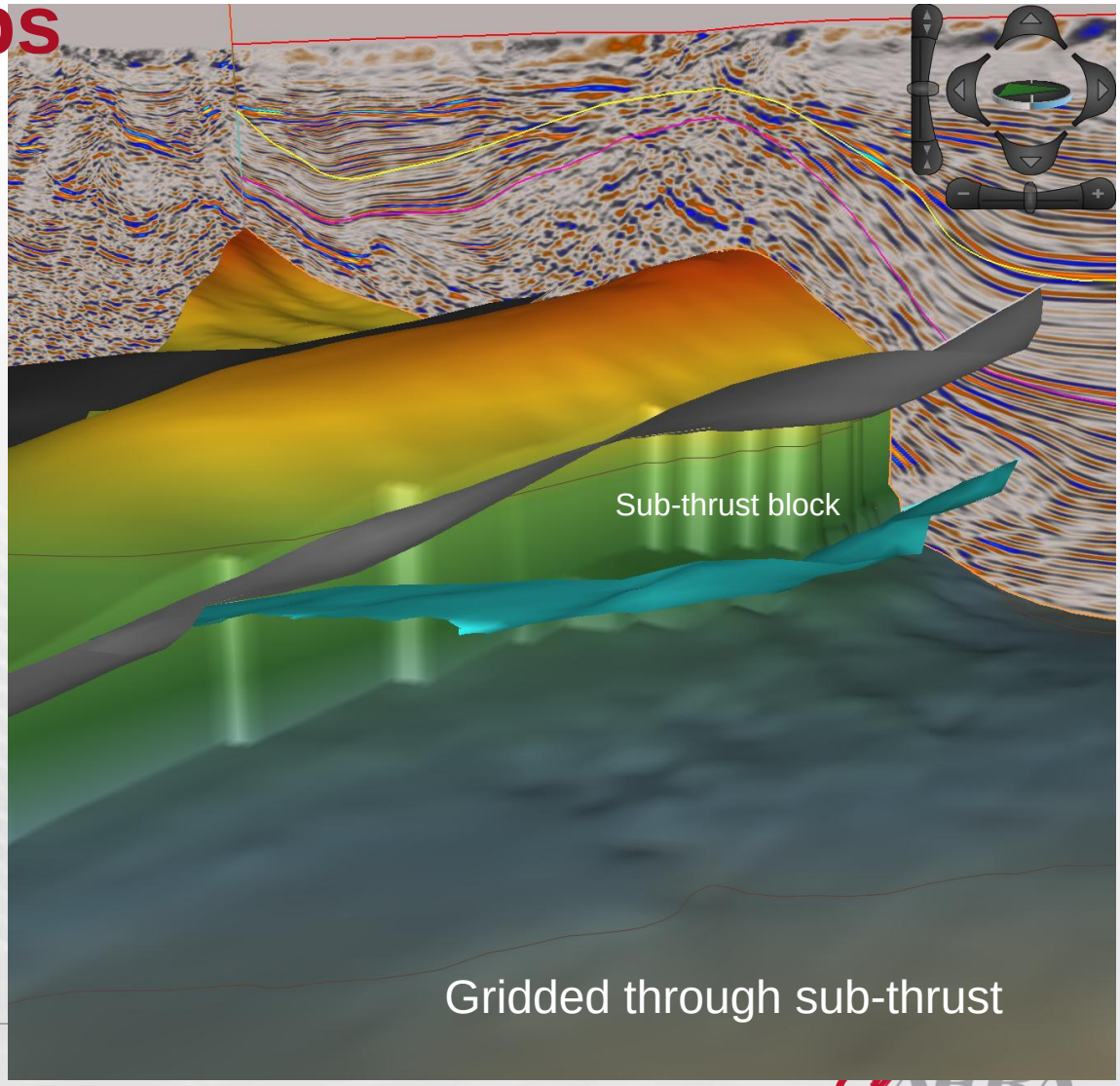
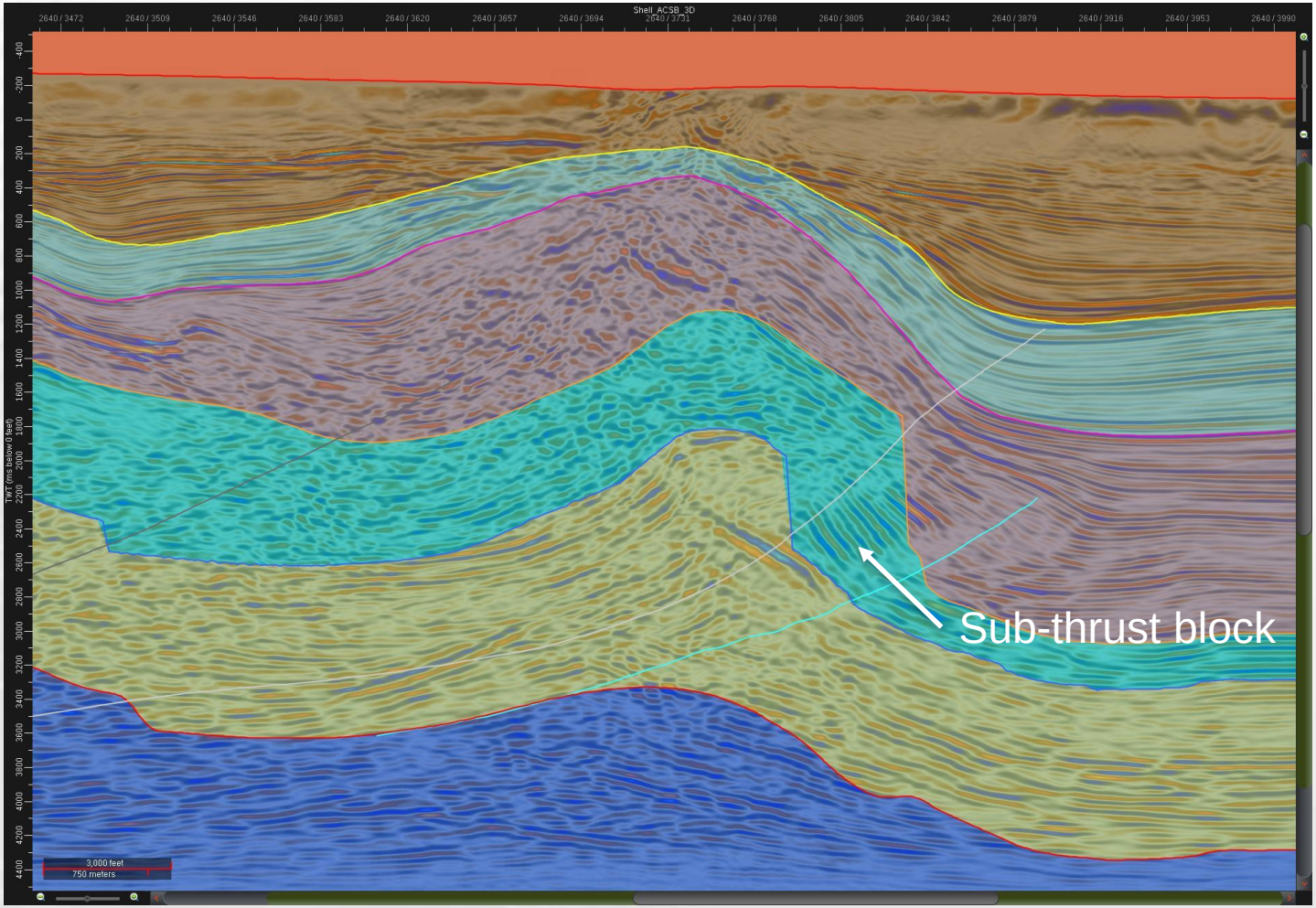


No reverse faulting (i.e. gridded surfaces)



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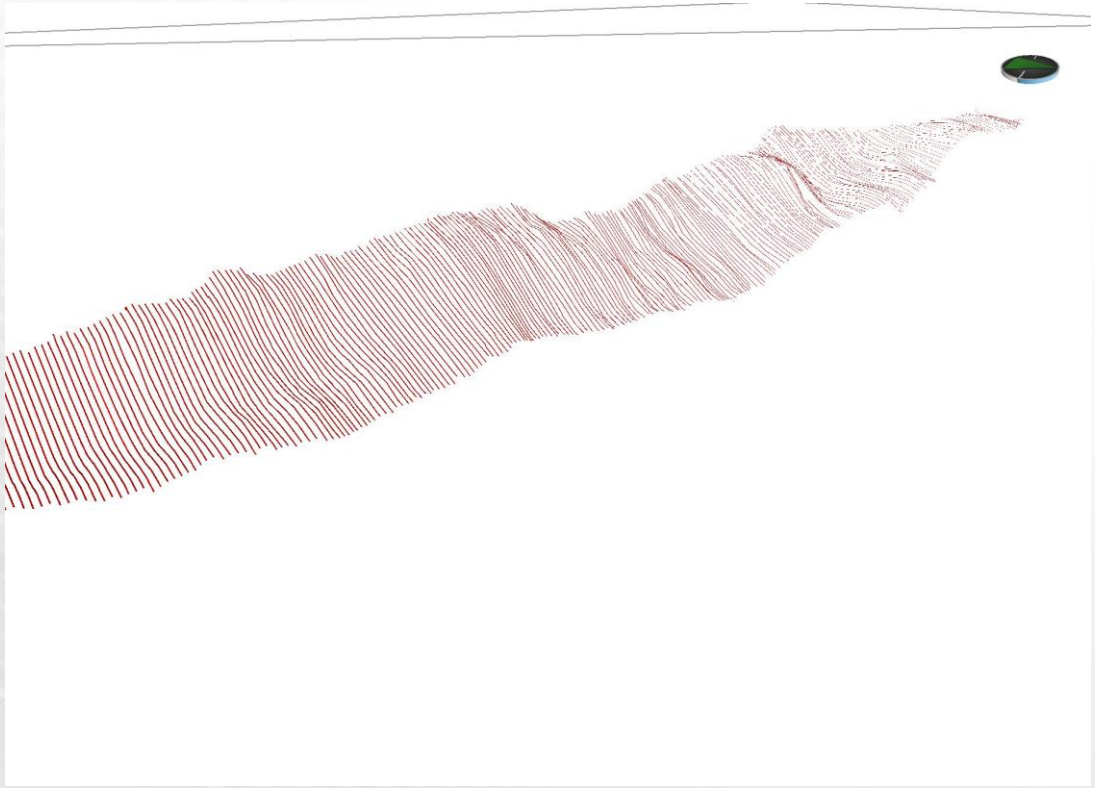
Horizons interpreted as fault blocks



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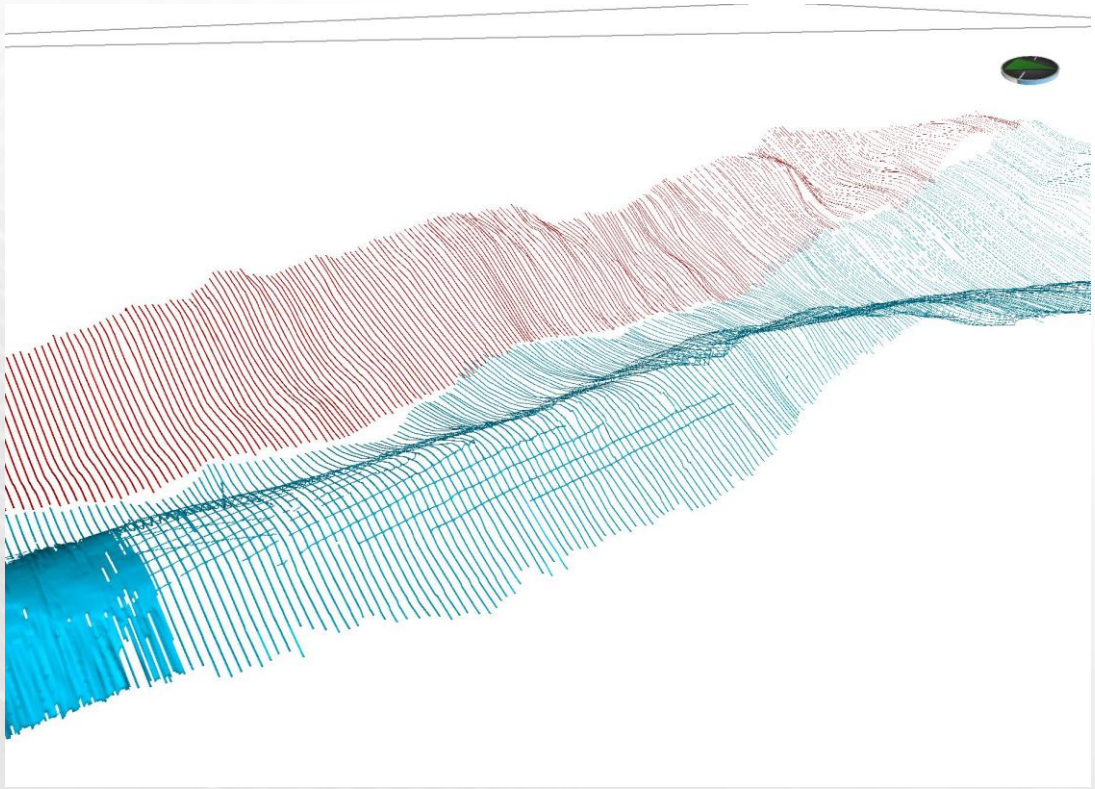

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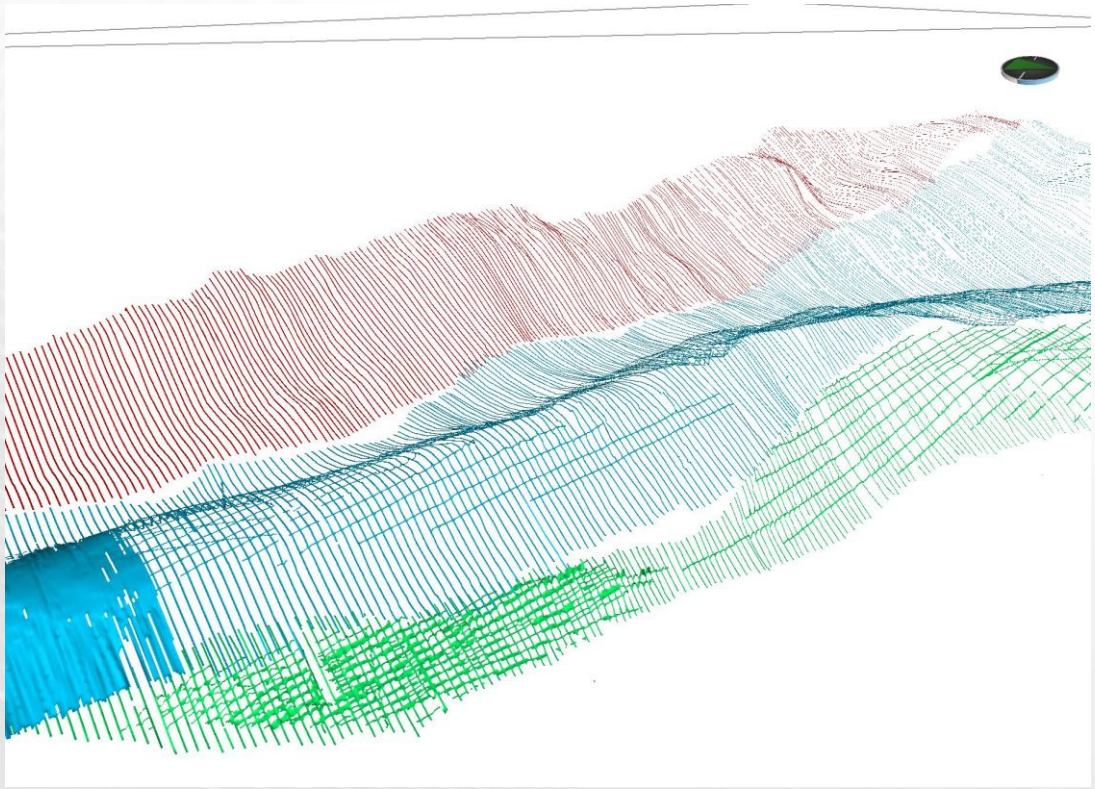
Horizons interpreted as fault blocks



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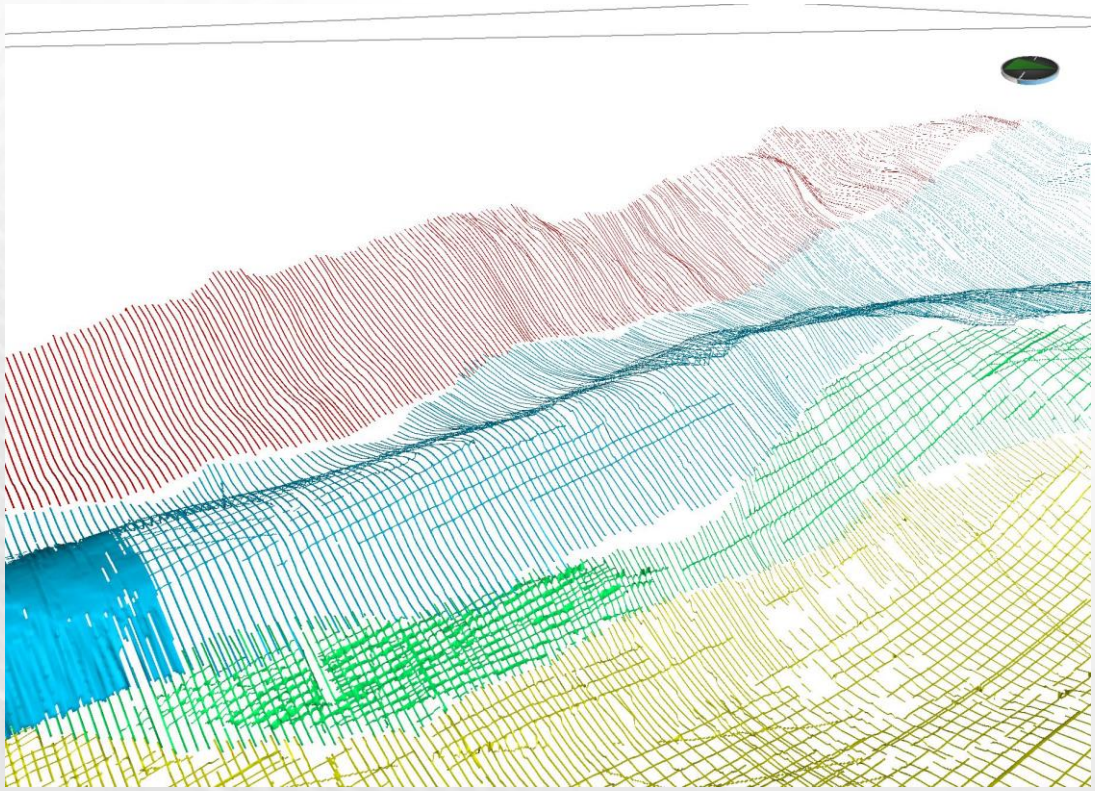
Horizons interpreted as fault blocks



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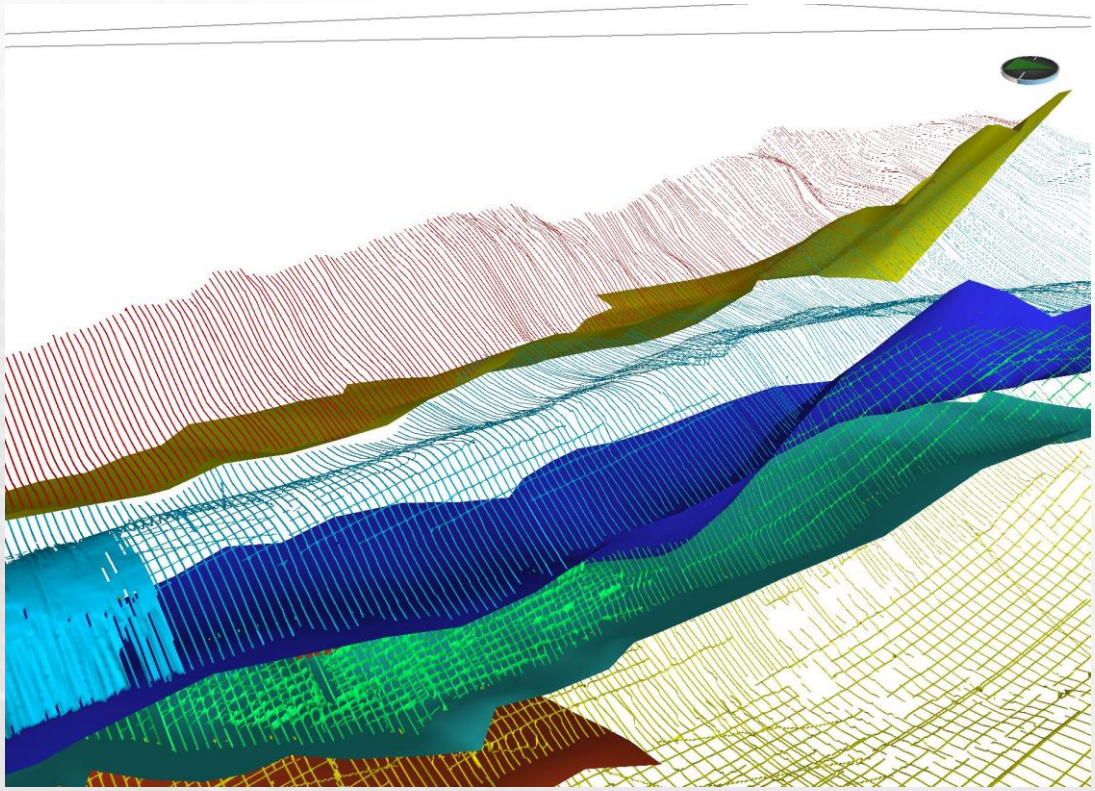
Fault interpretation



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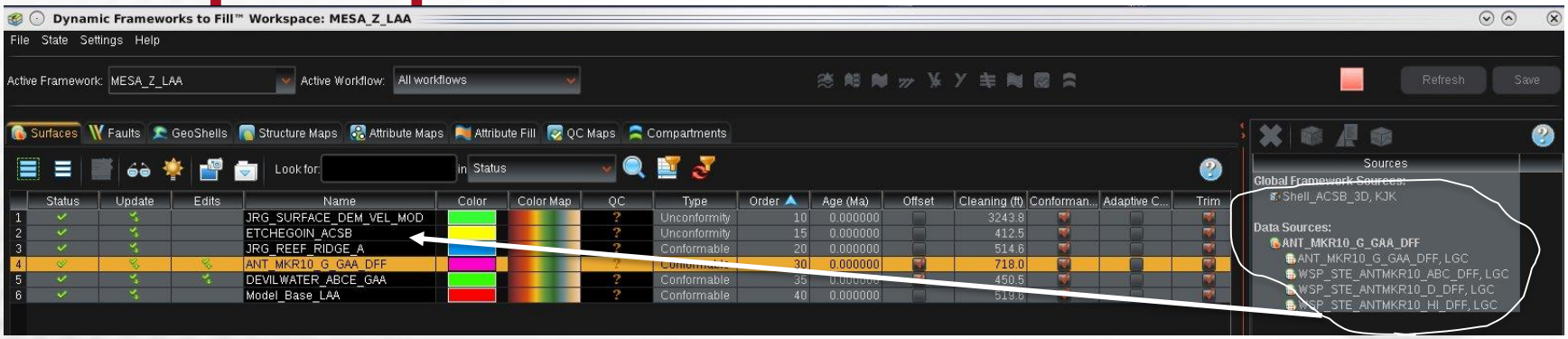
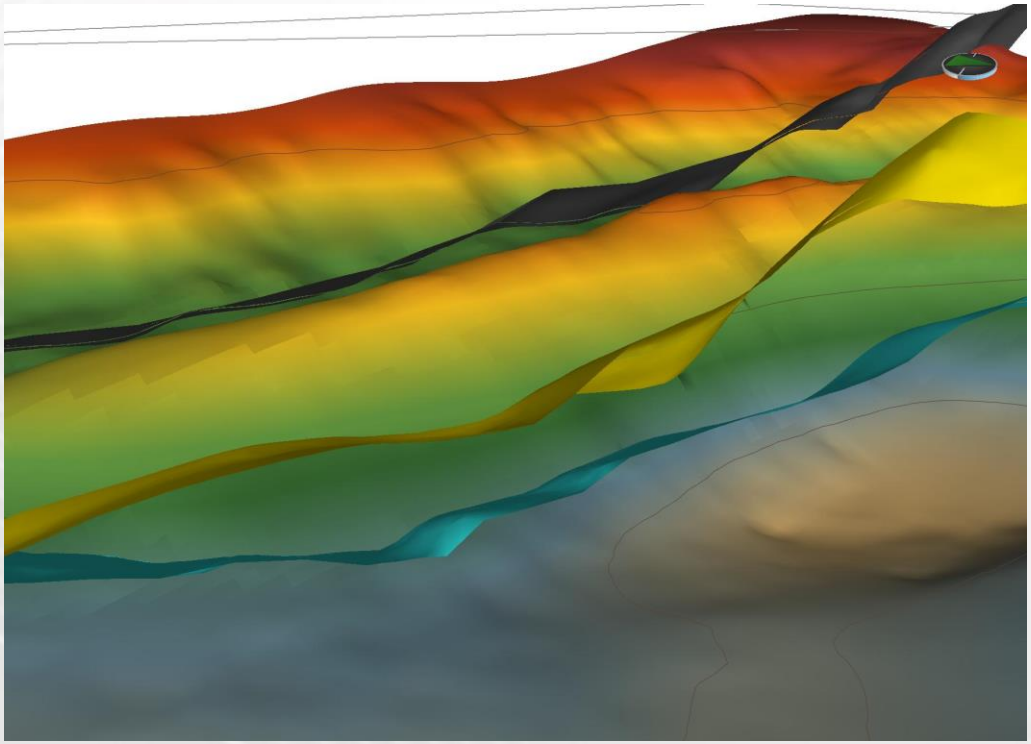
DecisionSpace® Framework uses multiple inputs



Each piece of the interpretation is used for the same surface.
This maintains the connection between stratigraphic layers (important for geocellular modeling, volumetrics, etc)
Petrel can do this as well, but because of the model complexity and the volume-based modeling algorithm, every iteration of the model is extremely time consuming (~10-20 minutes to update for simple models).
DSG frameworks update in seconds.

Final Framework Surface



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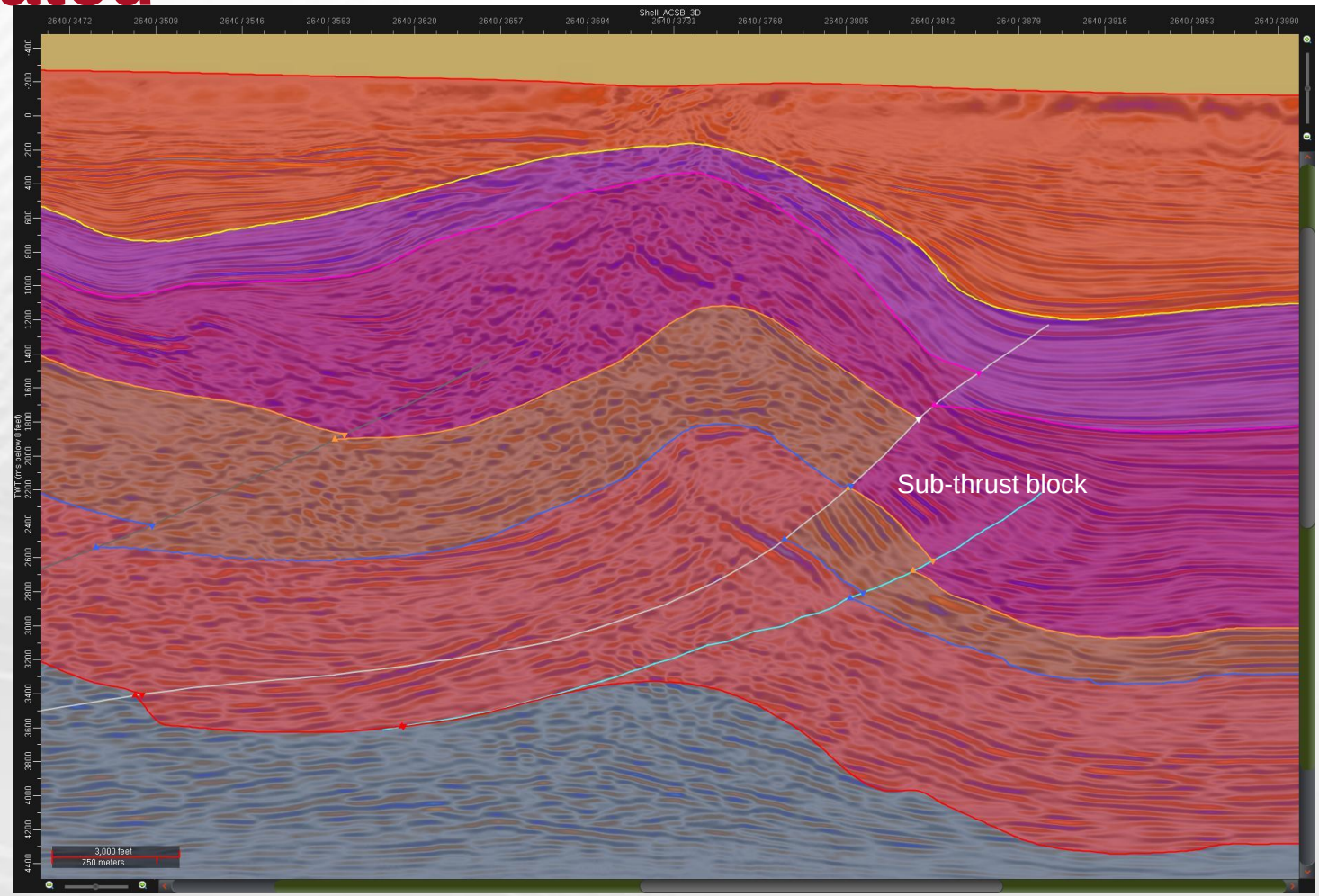
Stratigraphic layers are offset and still related



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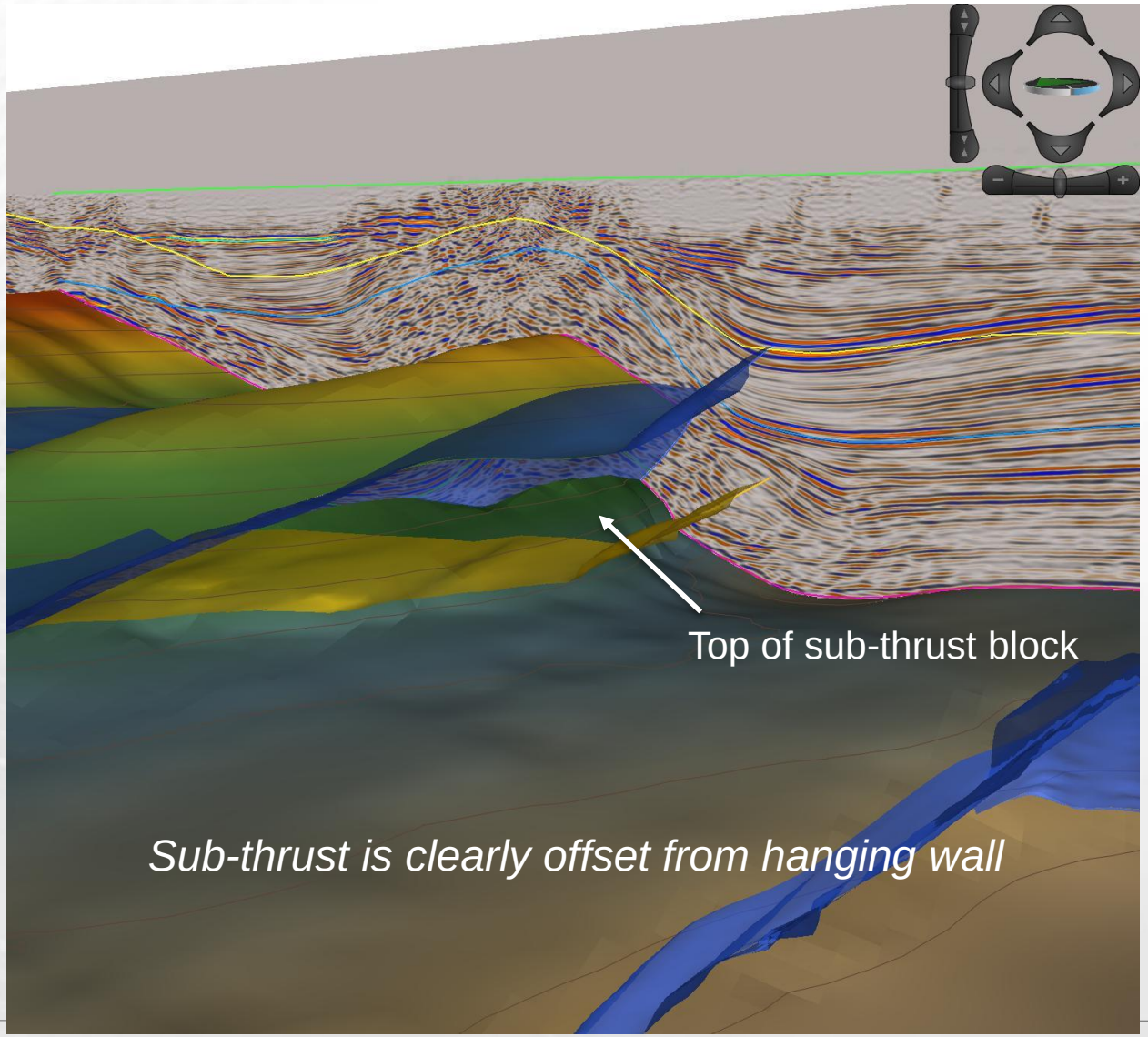
Faulted surface with offset maintained



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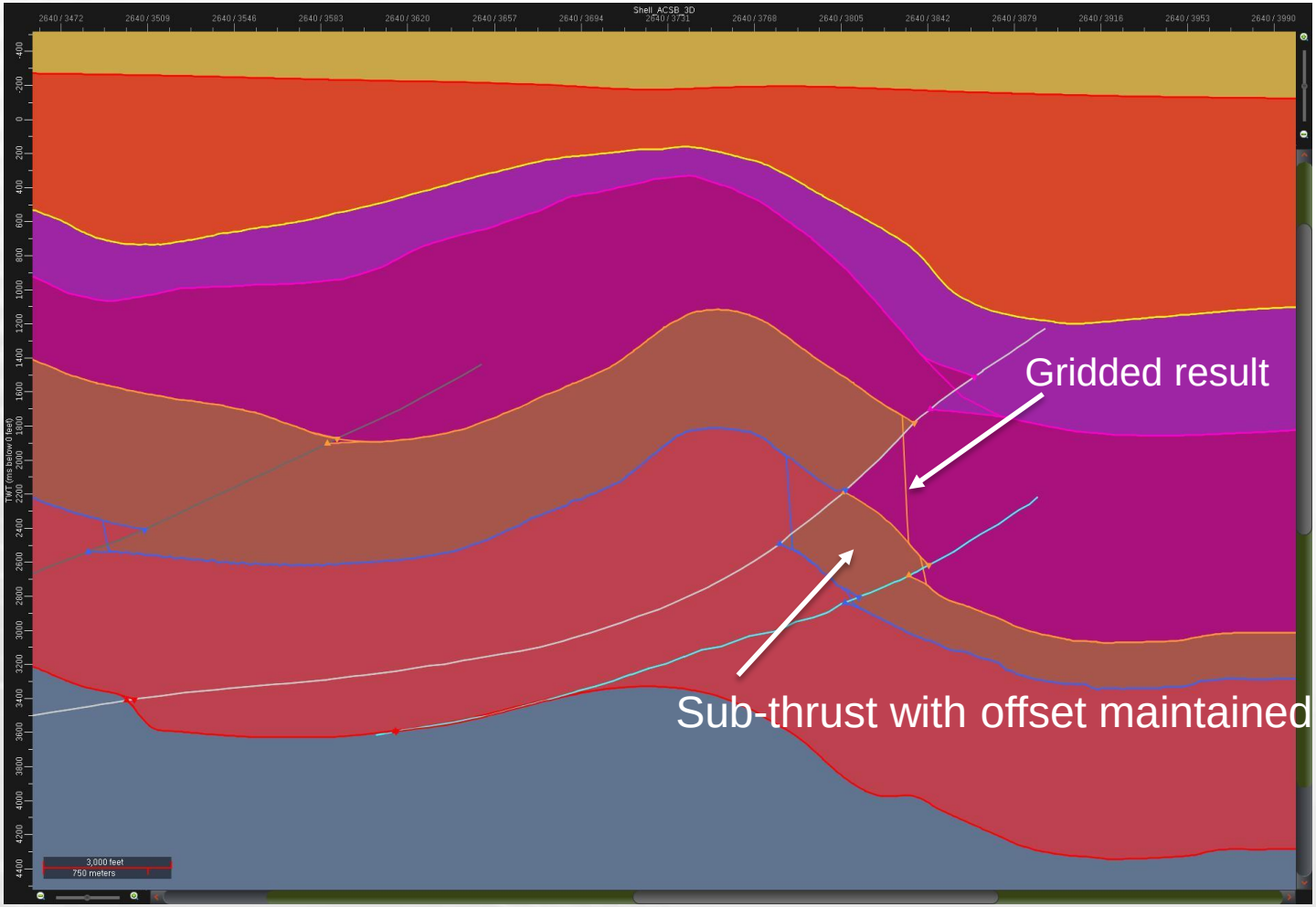
Gridded surfaces can misrepresent the lead location and size



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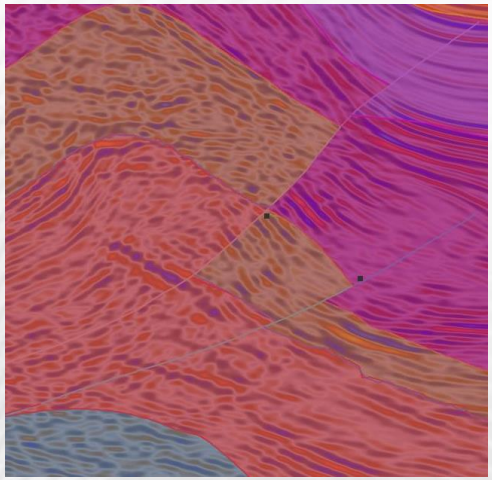
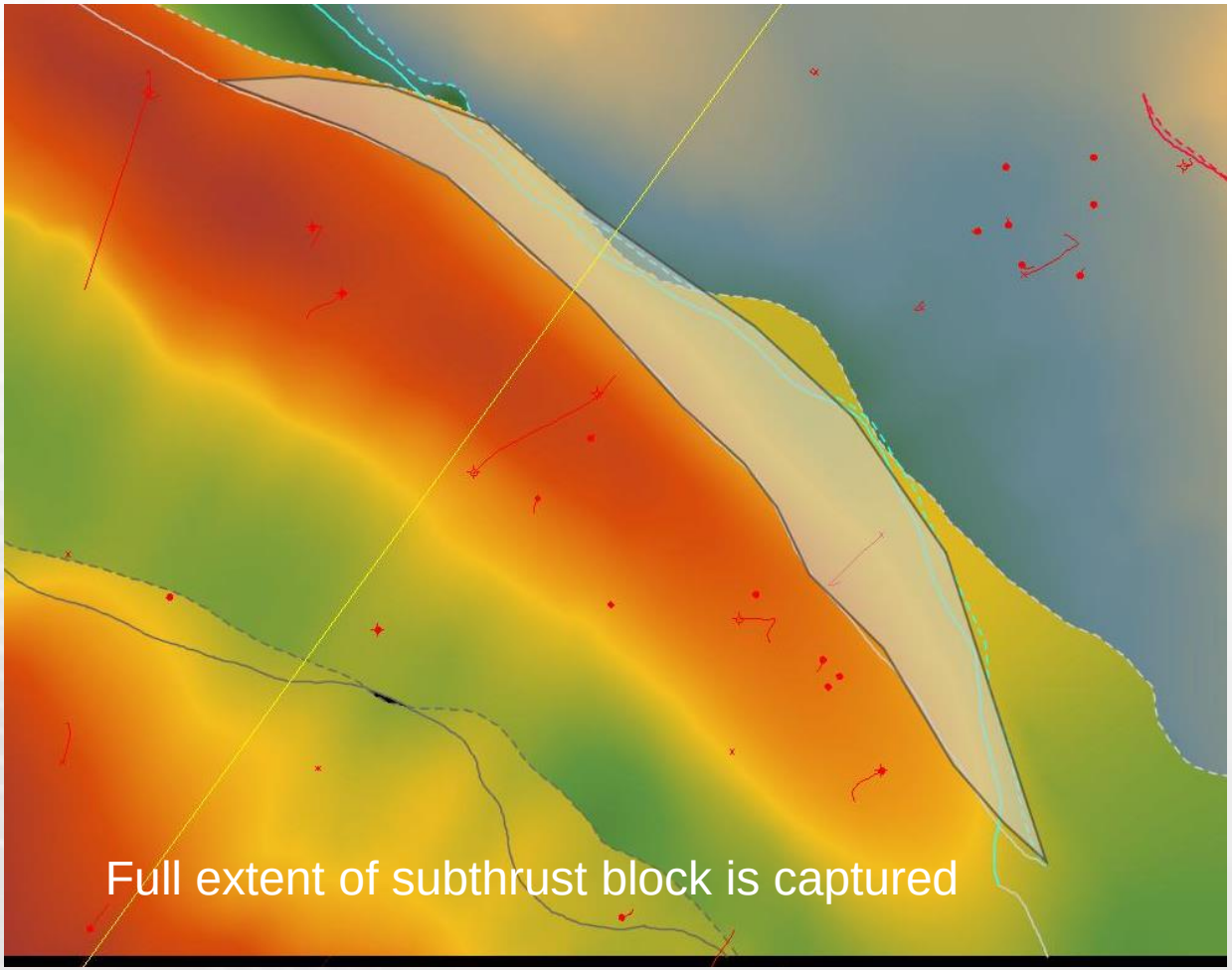
Faulted model captures full sub-thrust

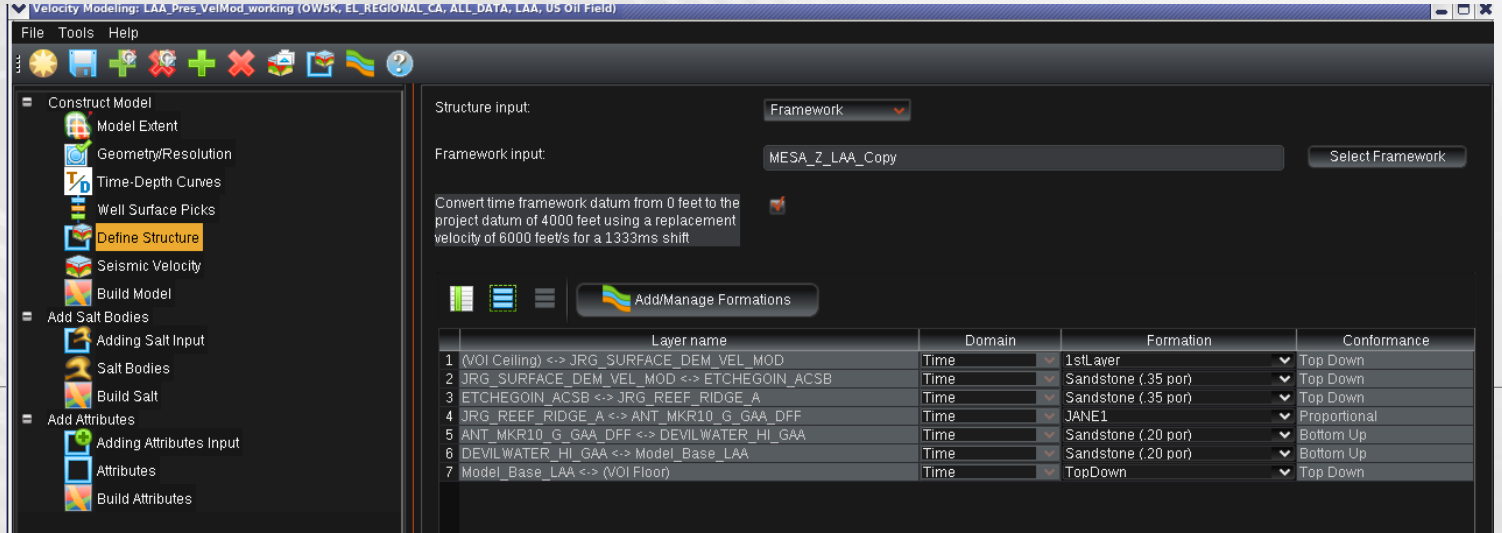


Usually, the interpreter has to choose to interpret the footwall or hanging wall, depending on the goal. But for velocity modeling, this becomes tricky

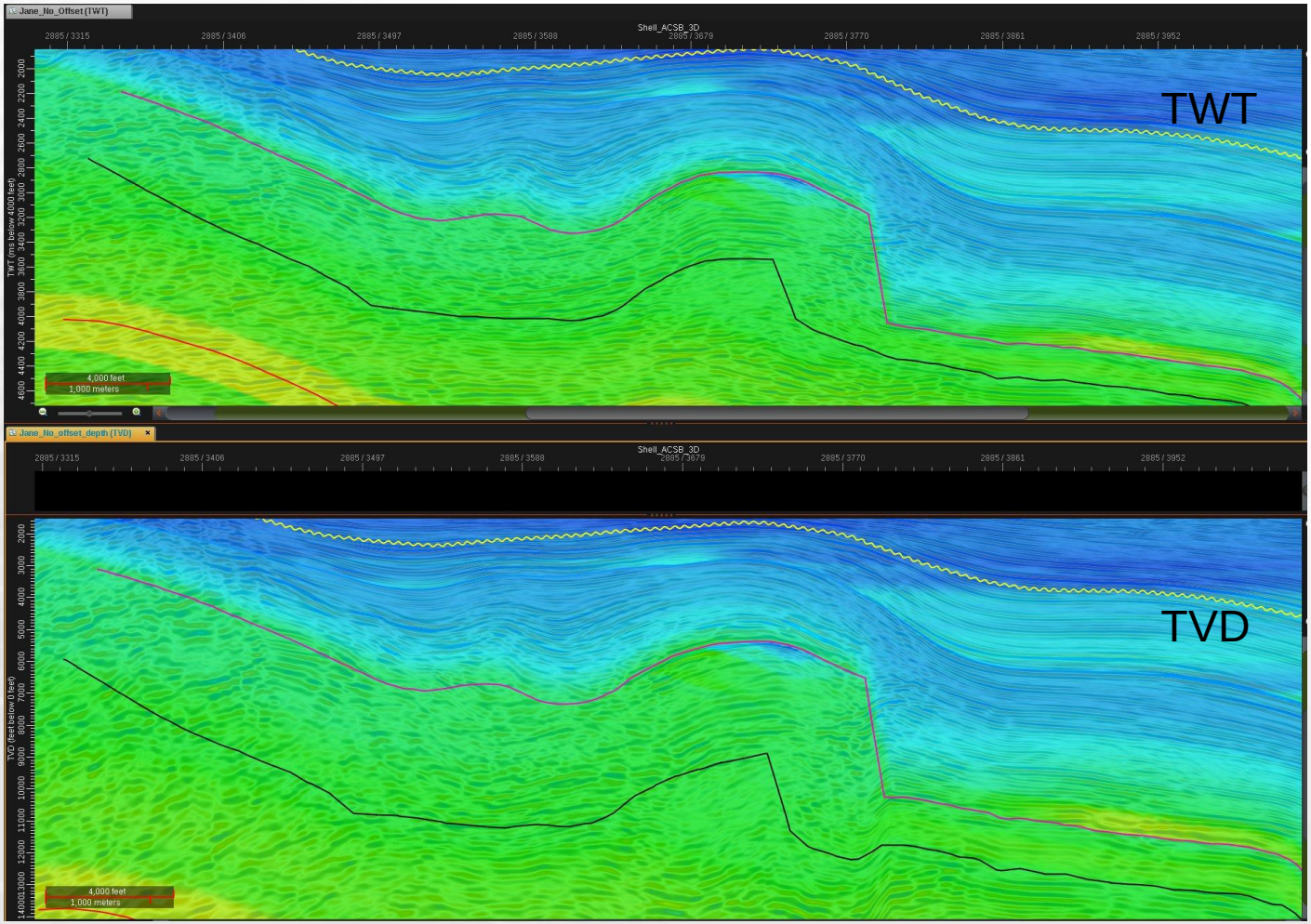


Velocity modeling with reverse faults

- Typically, at this point, no matter how beautiful the structural model is, the velocity model step will require output from the structural model as gridded, continuous surfaces
- DecisionSpace® Geoscience Velocity Modeling module can use the Framework (the dynamic solution) as input to the velocity model



Velocity Model - Unfaulted horizons



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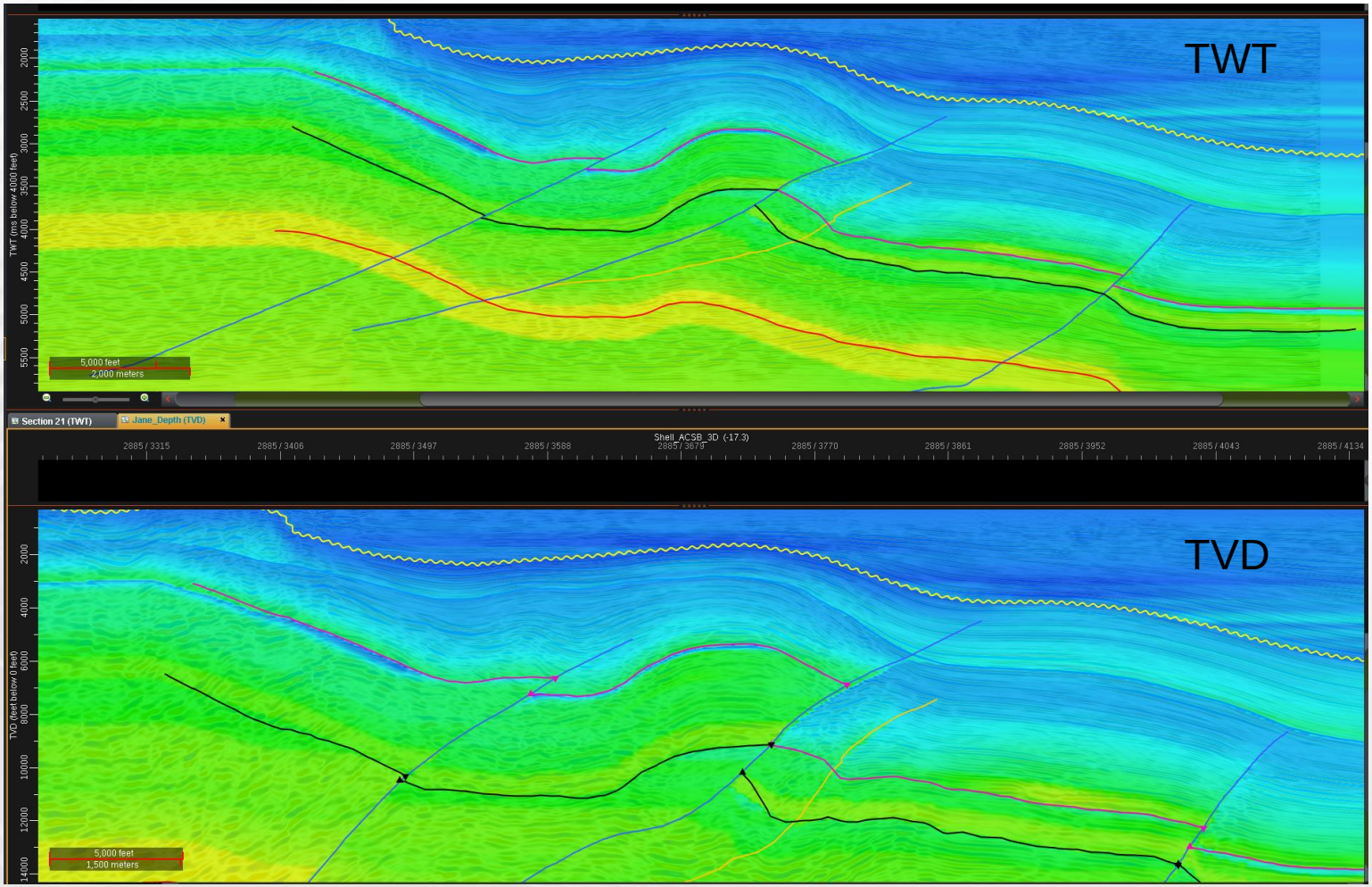
Velocity model - Reverse faulted horizons



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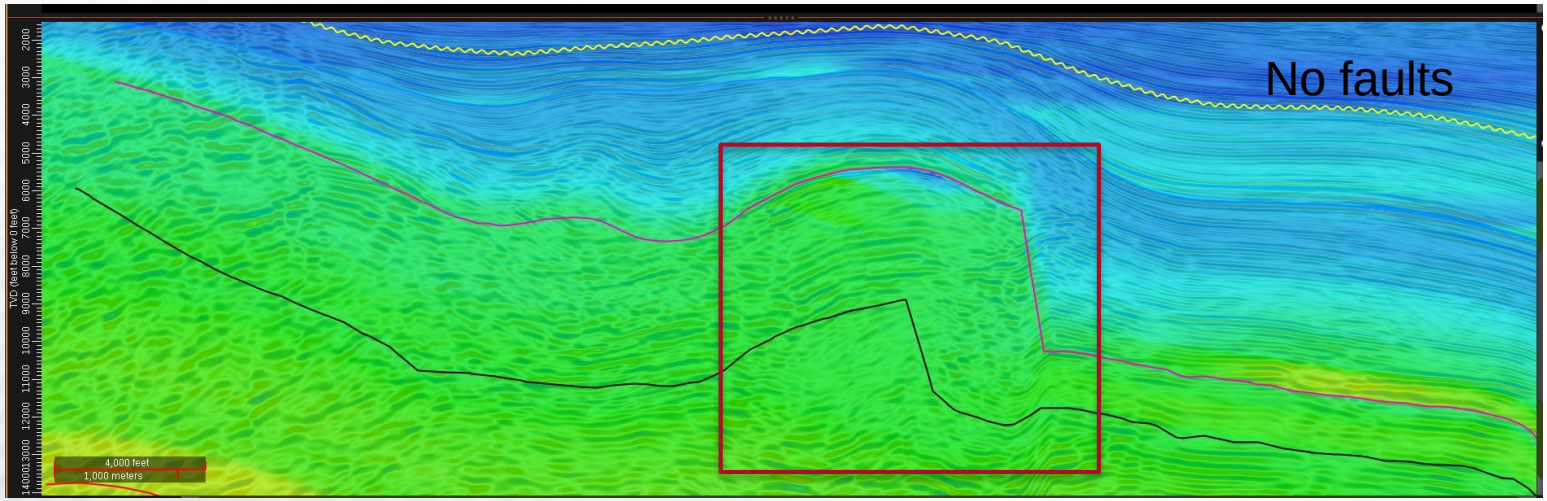
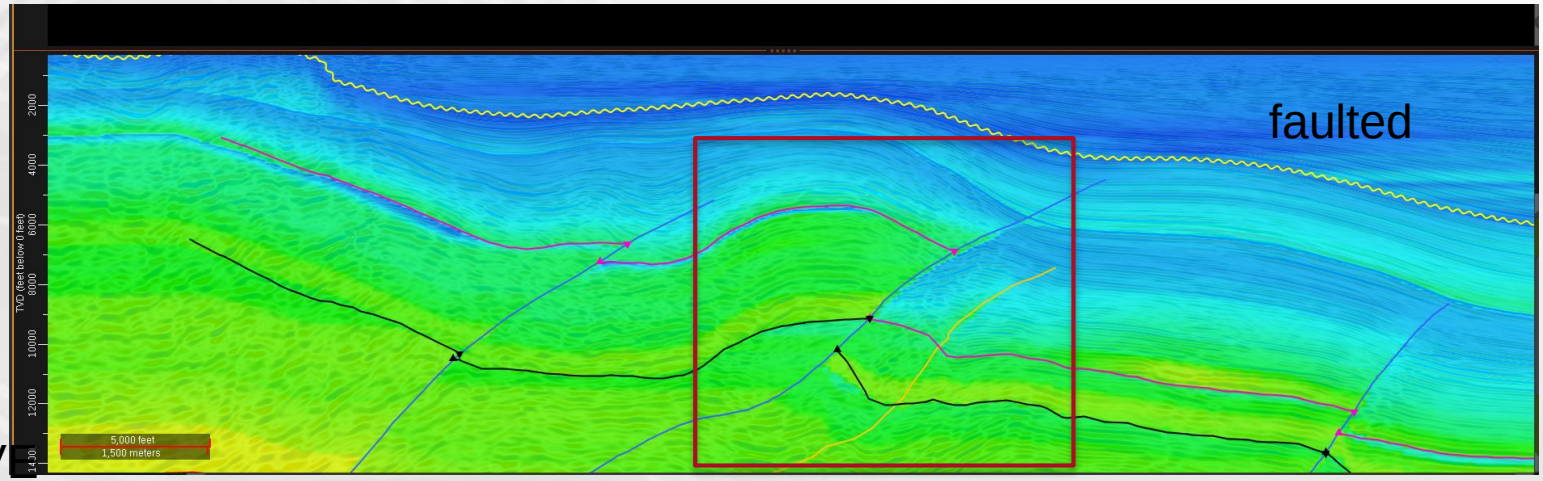
Model comparison in subthrust - TVD





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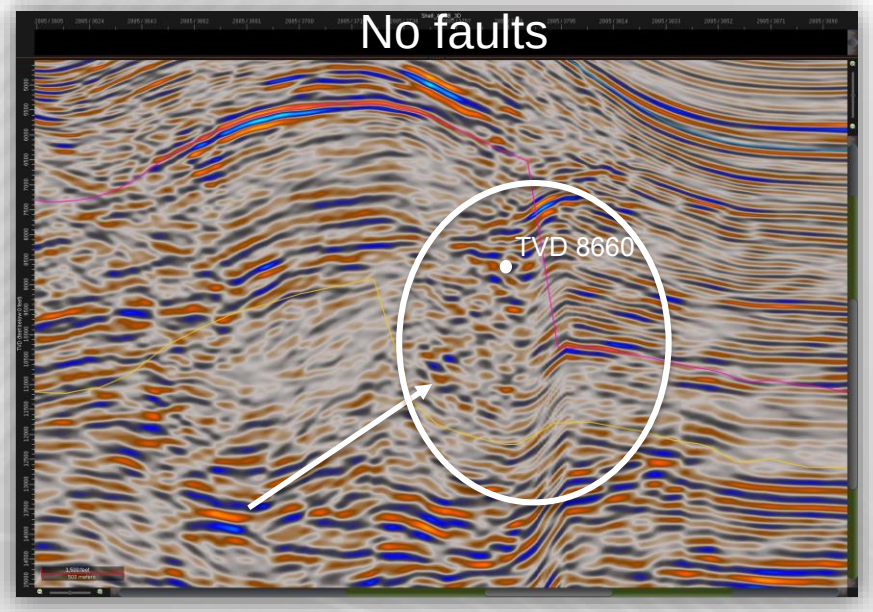
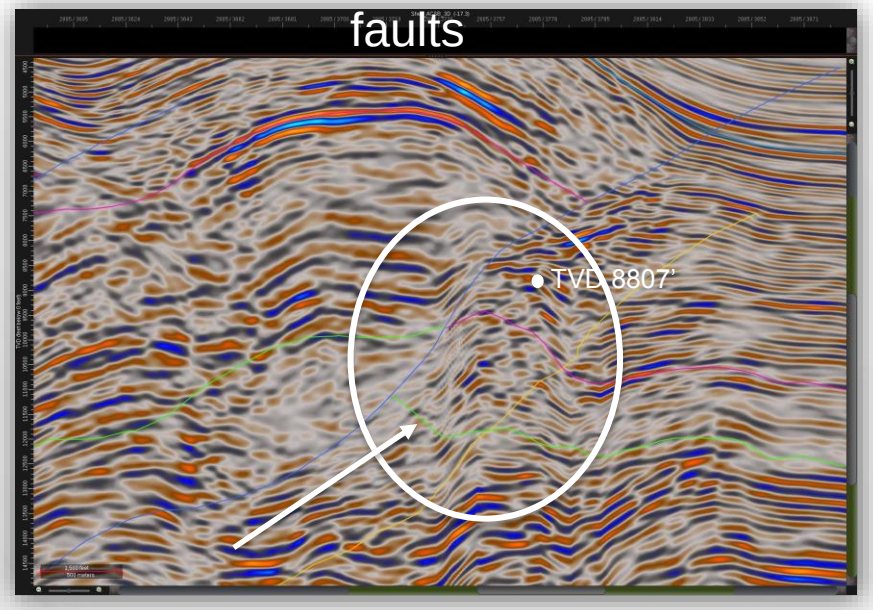
Imaging in subthrust very different – though both not ideal





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Sub-thrust seismic geometry changes significantly between the two models.

Depths are hundreds of feet different and dips change as much as 90°.

Though neither model can change the poor imaging in the subthrust.

Conclusions

- Normal fault structural regimes are easily accommodated in velocity models due to single-z values
- Reverse fault structural models are time-consuming, static, and difficult to incorporate in velocity models
- DecisionSpace® Geoscience uses Dynamic Frameworks to fill to incorporate complex multi-z interpretations in a dynamic and easily modified environment AND these models can be incorporated into a velocity model

Conclusions, continued

- Although other products may for multiple inputs into their structural modeling, reverse faulted models cannot usually be incorporated into a velocity model for depth conversion
- We are getting closer to a robust structural modeling technique for more reasonable depth conversion in areas of compressional deformation.
- As we get closer to a good solution, it is important for geophysical interpretations to take advantage of these techniques to build more robust velocity models.

Questions?

- Thank you for the Pacific Section and Rocky Mountain Section AAPG
- Thank you to Aera Energy LLC for supporting this presentation and conference.