A Method for Assembling and Maintaining a Large Geologically Complex Geocelluar Model: Example from Elk Hills Field, California*

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Abstract

Fields with many thousands of wells, active drilling programs, and complex geologic frameworks are inherently difficult to model in a geocellular framework due to conflicting or changing interpretations, variable data quality, time constraints, and restrictions imposed by the corner point grid. Common solutions are simplification and non-reproducible editing of the underlying data and interpretation. In the Eastern Shallow Oil Zone, Elk Hills field, California we built and maintain a large, relatively uncompromised geocellular model for use by the reservoir management team for simulation studies, reservoir surveillance, and development planning using a methodology that incorporated changing interpretations and data while simultaneously progressing with model construction. The underlying interpretation consists of approximately 165,000 stratigraphic picks and 3,200 fault cuts in 3,500 wells over an area of 20,000 acres. Thirty-six reservoir units, 41 non-reservoir units, and 52 normal faults are characterized in the model volume of interest. Erosional unconformities and stratigraphic pinch outs exist in a majority of what are thin-bedded reservoir units. We developed a set of workflows and multi-user tools to (1) remove spatially redundant data; (2) identify interpretation errors based on stratigraphic position; (3) modify interpretation to be compatible with modeling software; (4) record and communicate interpretations to be modified and excluded until changes are complete; (5) document and implement changes to underlying data. An audit trail for each issue and solution is maintained and so that it can be repeated automatically each time the geologic model is updated. The result is a large geocellular model that is easily updated, reproducible, and well documented.

A method for assembling and maintaining a large geologically complex geocellular model: example from Elk Hills field, California

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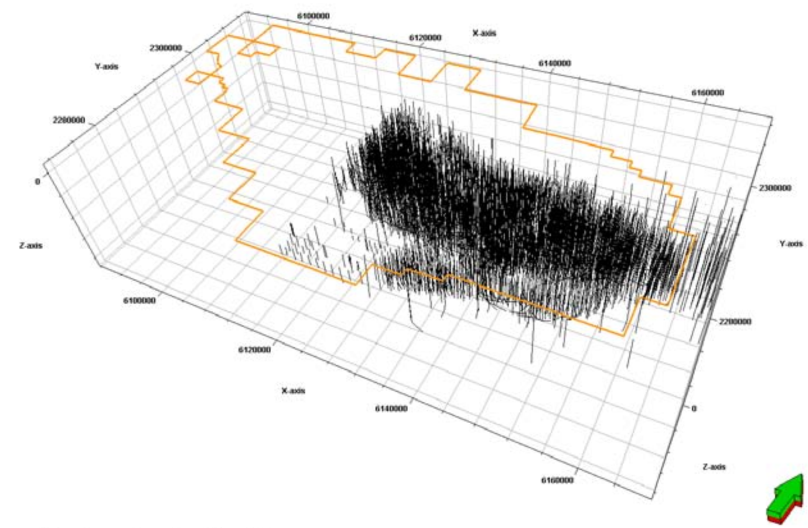
Eastern Shallow Oil Zone (ESOZ) Geocellular Modeling Project

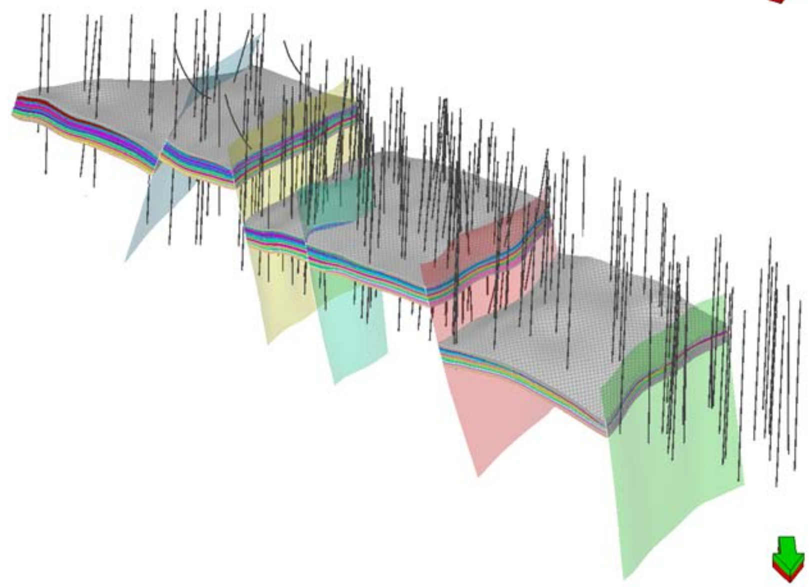
Requirements

- Dynamic interaction between several interpreters and model framework construction/maintenance
  - Interpretation is being fine tuned in conjunction with and in response to the model framework
  - Tight timeline
- Data audit trail
  - What data are not being used and why
  - Edits must be reproducible
- Create a process to “feed and care” for the model
  - Maintain the project with current data and interpretations
  - Periodically update the structural and stratigraphic framework
  - Make updates to the property models as necessary



Challenges

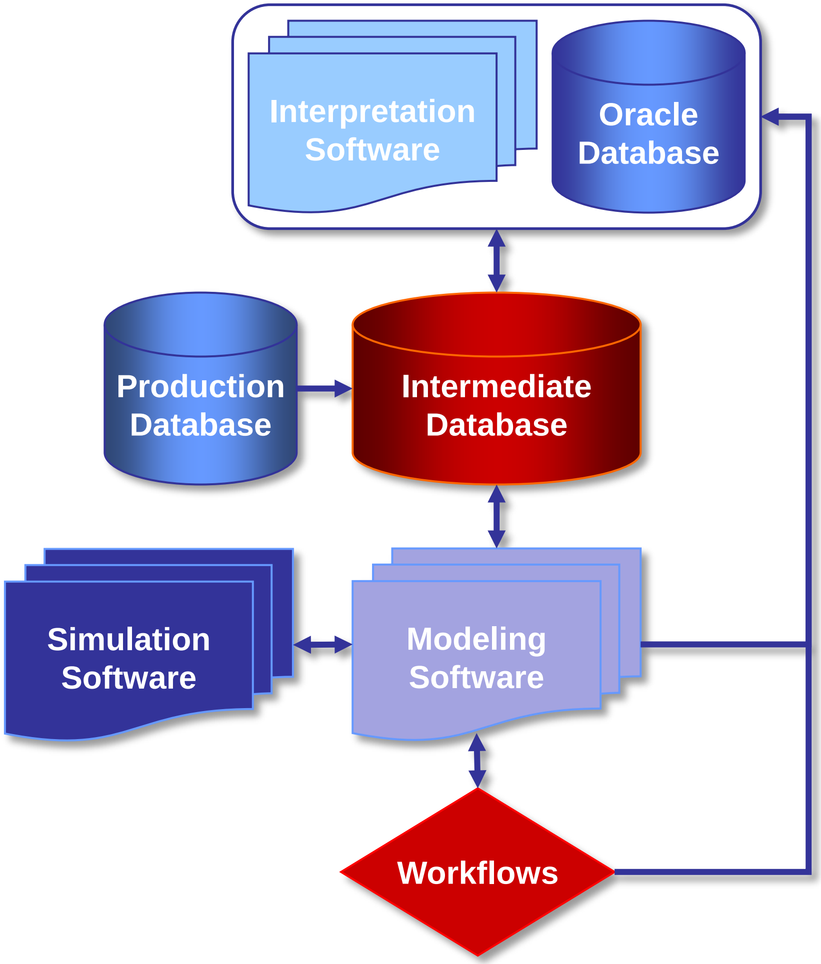
- Detailed interpretation
  - ~165,000 surface picks that define 36 reservoir and 41 non-reservoir units
  - ~3,200 fault cuts that define 52 normal faults
- Thin beds with pinch outs and erosional unconformities
- Large and Dynamic Database
  - ~3500 wells
  - New wells are added frequently
  - Several vintages of data (1930’s to the present)
  - Maturing interpretation
- Modeling software and hardware limitations



Modeling Tools and Workflows

In order to meet the requirements and address the challenges we developed a set of tools and workflows

- Intermediate database
  - Remove spatially redundant data
  - Identify and remove interpretation errors associated with stratigraphic position
  - Remove “stacked” picks
  - Modify interpretation
  - Document and remove problem data and interpretation data and prevent them from being reintroduced until they are resolved
- Modeling software workflows
  - Interpretation points to augment the well and fault data in from the wells
  - Fault resolution
  - Export model grids back to the interpretation software package to close the loop



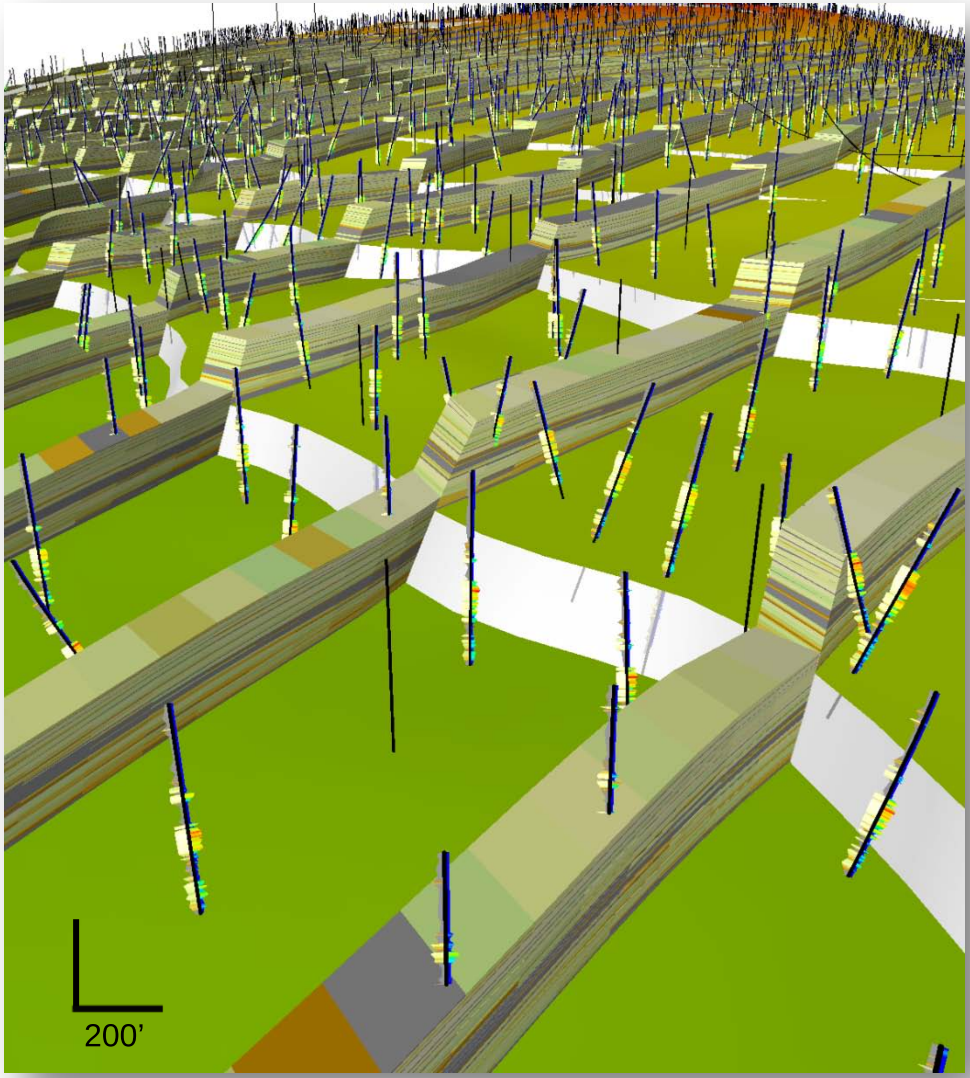
Geocellular Model Summary

How is the model currently being used?

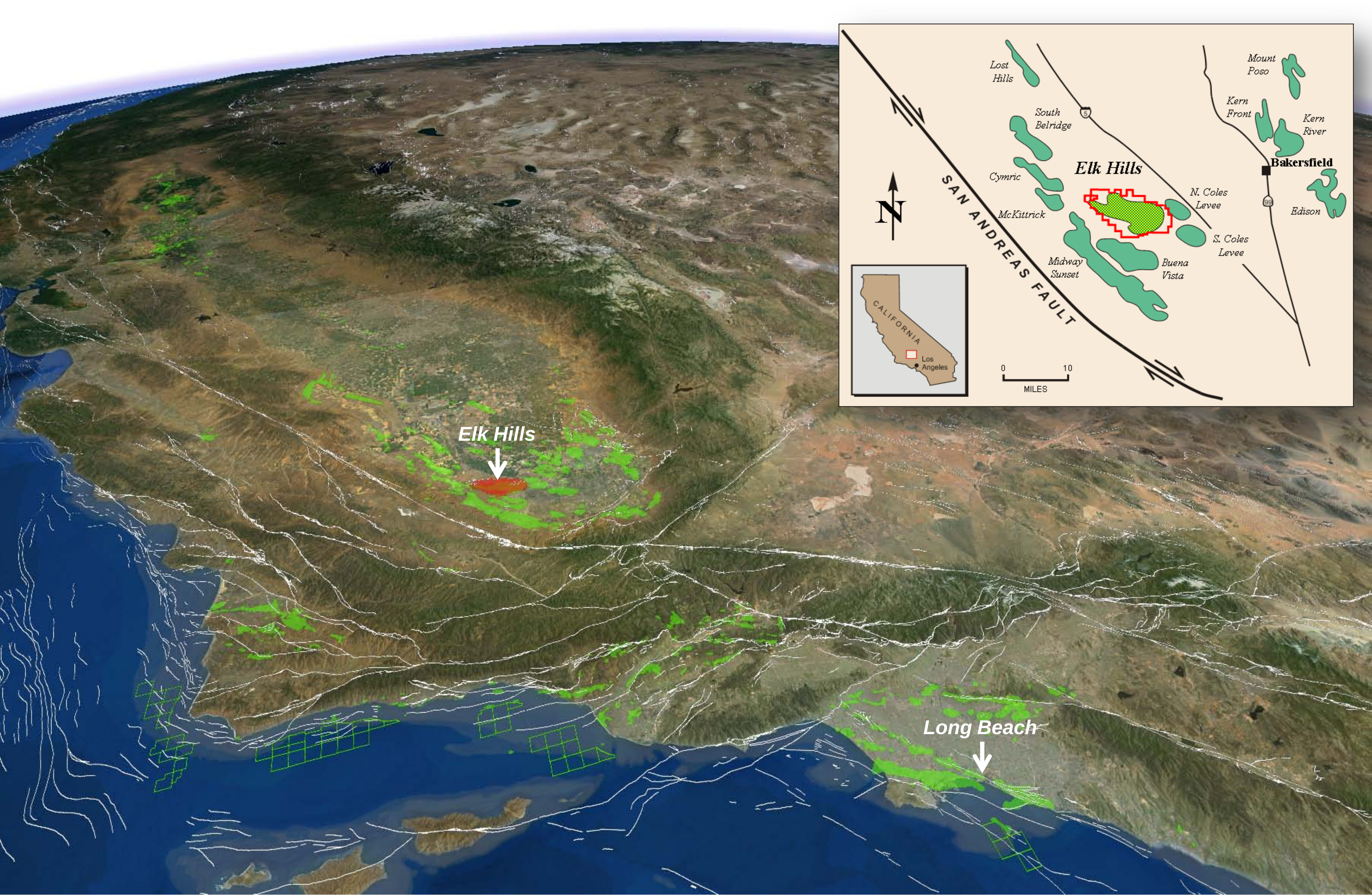
- Full field simulation studies
- IOR and EOR simulation studies
- On-demand static models for simulation
- Reservoir surveillance
- Well planning

Geocellular Model Size and Dimensions

- 70,883,982 = All Cells
  - All Cells (nI x nJ x nK) = 309 x 346 x 663
  - Cell dimensions are 125’ x 125’ x 2’
- 1,913,929 = Active Cells
  - Not all reservoirs are present or charged in all parts of the field
  - The low number of active cells is achieved by filtering out:
  - Cells with zero thickness
  - 0 net-to-gross



Elk Hills Location ~110 Miles North of Long Beach



ESOZ Geologic Overview and Background Information

Structure

- East nose of a plunging anticline
- Extensional faults strike NE-SW

Stratigraphy

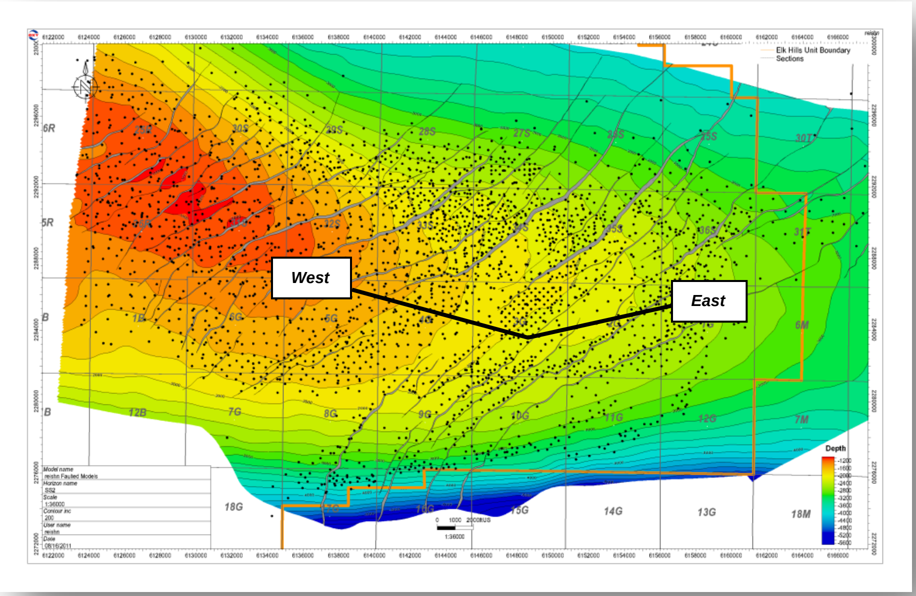
- Pliocene age unconsolidated shallow marine clastics
- 6 major units
- 36 minor reservoir and 41 non-reservoir units

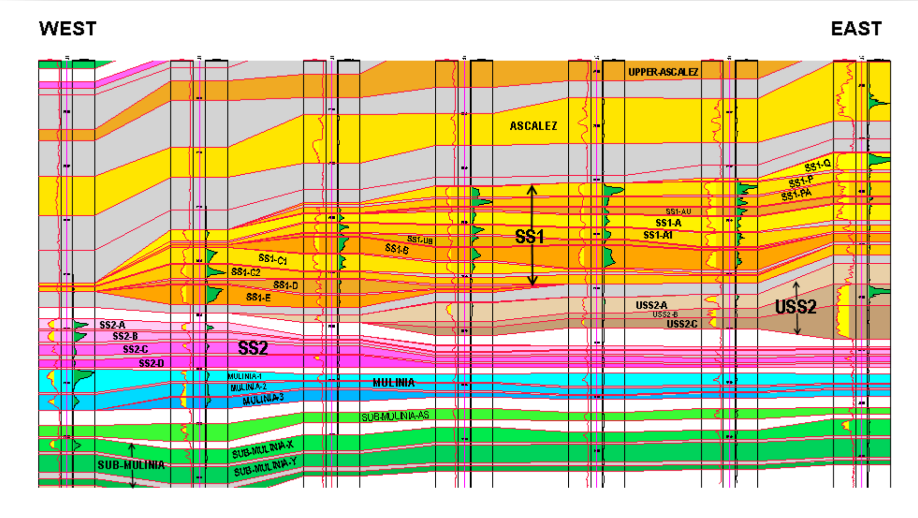
Reservoir

– Area	19,960 acres
– Depth	2,500 to 3,900 ft. TVD
– Gross interval	~500 to 700 ft.
– Net sand	10 to 100 ft.
– Porosity	28 to 34%
– Permeability	50 to 5,000 md
– Oil gravity	15 to 30 degree API
– Original pressure	~1,500 psia
– Current pressure	30 to 1,200 psia

History

- On production since the year 1919
- Operated by the United States government as a national petroleum reserve until 1998
- Purchased by Occidental Petroleum Corporation (Oxy) in 1998
- Oxy is the current operator





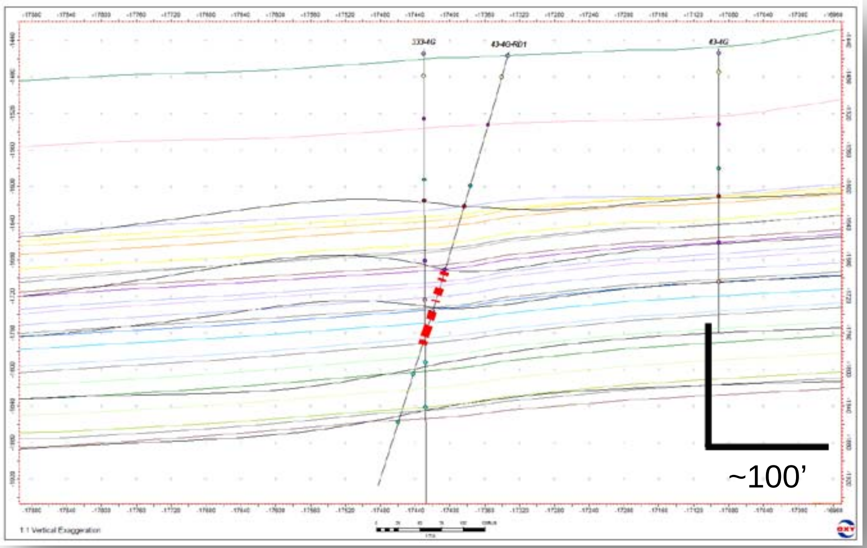
The Intermediate Database – Spatially Redundant Data

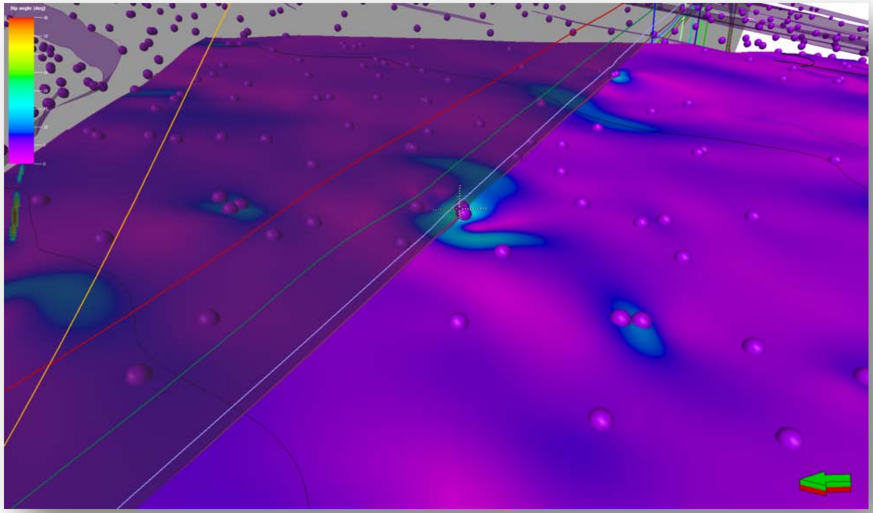
Pass through wells, re-drills, and sidetracks present problems associated with poor or non-existent deviation surveys

- Wells that occupy the same or adjacent grid cell will cause artificial dip changes that cause thin bedded zones to be locally pinched out or expanded

The solutions the problem are to either remove the data or move the well

- Removing the data is preferable particularly if the information associated with it is redundant to the adjacent well(s)





The Intermediate Database – Modeling Software Compatibility

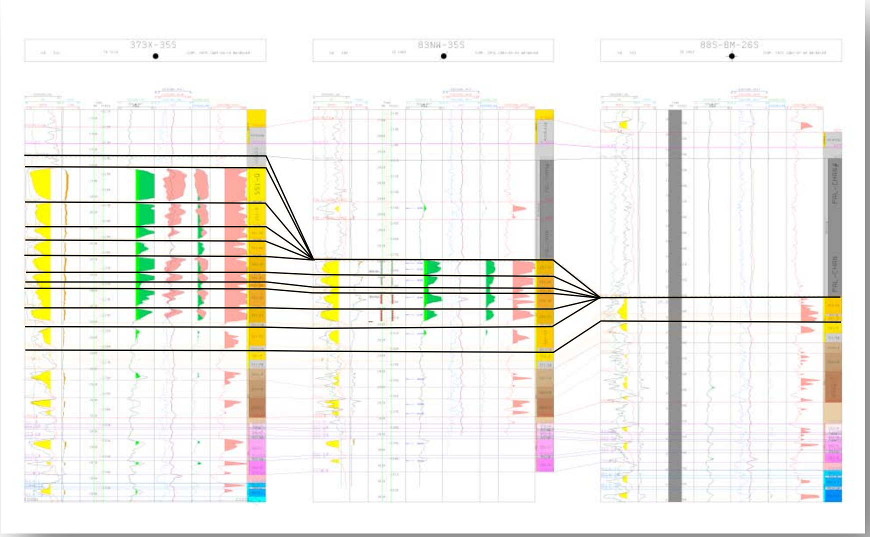
The ESOZ interpretation data set uses “stacked picks” to define the pinch out lines in the interpretation software

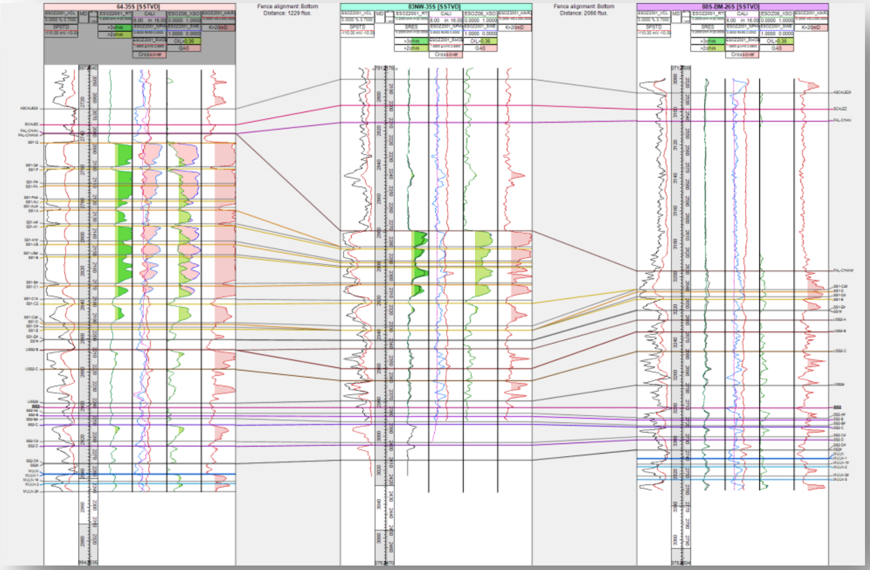
- “Stacked picks” are picks set to the same measured depth in a well in order to define a pinch out with 0 thickness
- This interpretation methodology is not compatible with modeling software in use

Using a stratigraphic column, all but the lowest pick in the column are removed when stacked at the same measured depth

- This does not require any change to the methodology used in the interpretation software
- The “stacked picks” are removed before they are imported into the modeling software

Other interpretation changes included name substitution and depth changes to picks to remove stacking



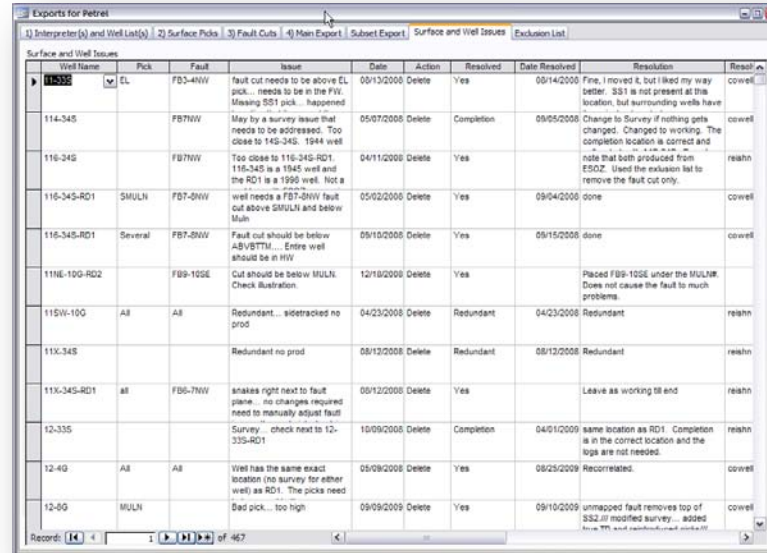


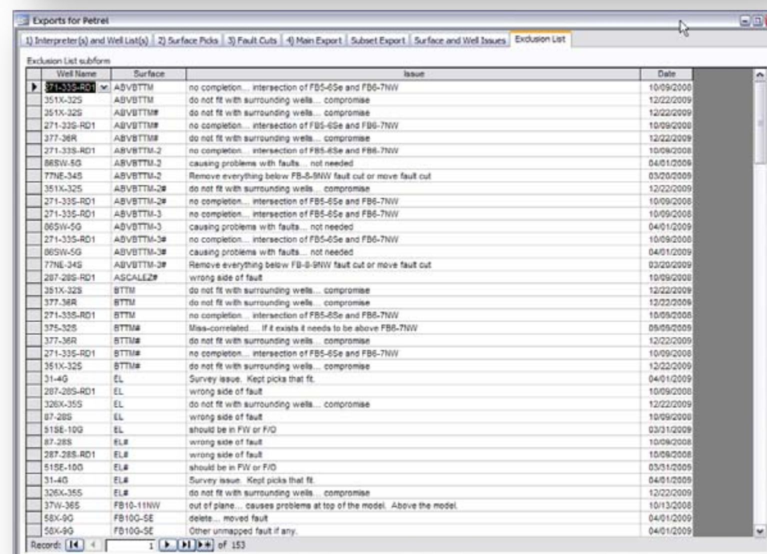
The Intermediate Database – Dynamic Documentation

For problems that were not systematic we created a document to record well/interpretation issues and remove the associated data until it was resolved

- Allowed us to identify localized interpretation issues to be fixed
- Is a way for us to record issues that cannot be fixed
- We used this document to record and implement changes to well position described earlier

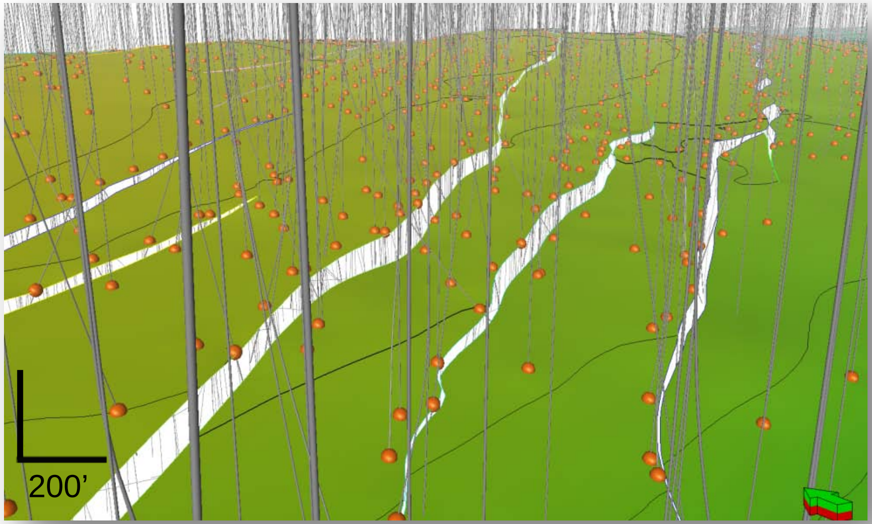
Model updates that involved data updates would occur several times a day or week as needed

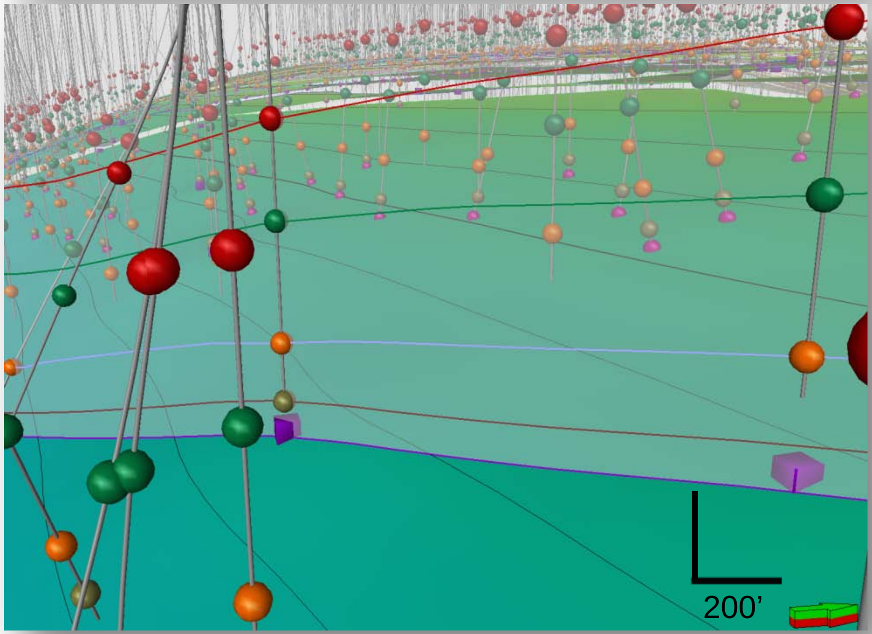




Modeling Software Workflows – Interpretation Points

- The ESOZ reservoir is highly sampled with respect to well penetrations however it is not systematic
  - In many areas the hanging wall block adjacent to a fault is more highly sampled than the footwall block
  - Wells with incomplete penetrations result in inconsistent thinning or thickening despite a conformable relationship between the surfaces
- The solution to both problems is to introduce and auxiliary point set to control the offset along the faults and thickness below incomplete penetrations





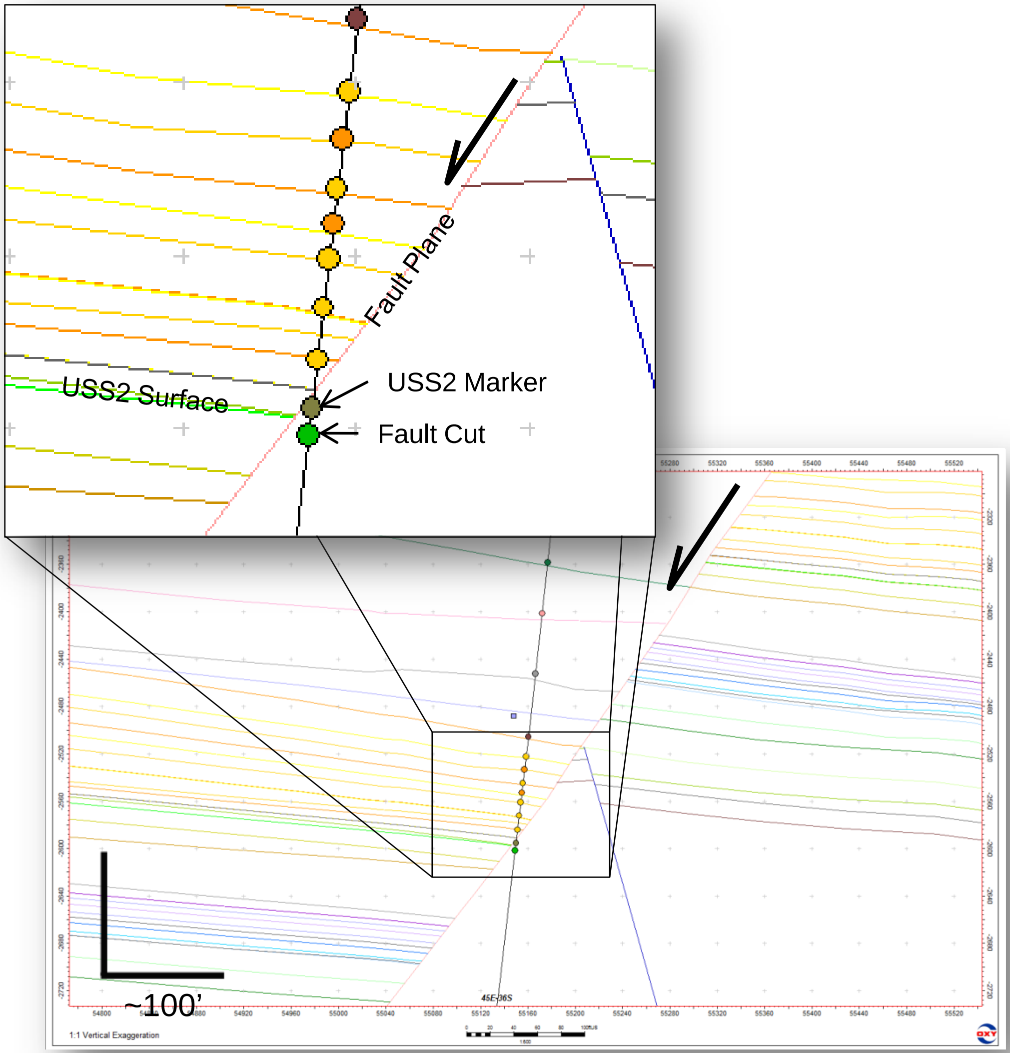
Modeling Software Workflows – Fault Resolution Issues

The corner point gridding scheme limits the resolution of the final fault planes in the model

- Reducing the resolution can result in horizon picks ending up in the wrong fault block
- This is a serious problem that can make the geocellular model unusable

The solution to this limitation is to identify and remove horizon picks that end up in the wrong fault block

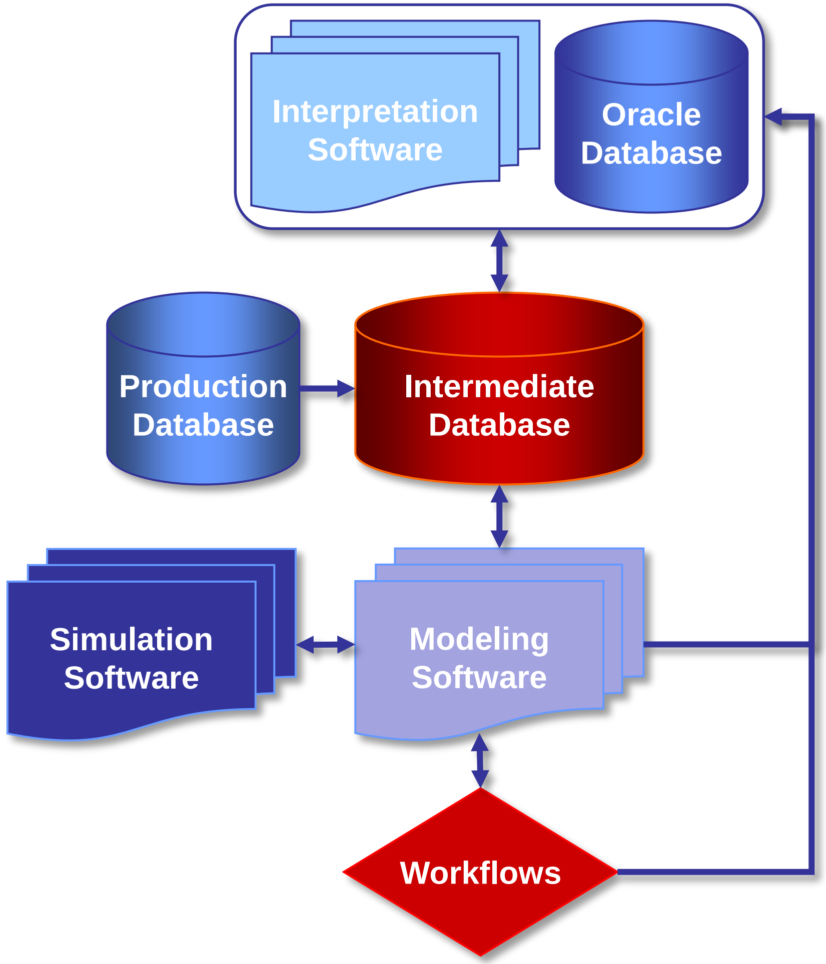
- Several workflows internal to the modeling software package are used
- This is accomplished by comparing the position of a pick relative to the full resolution fault plane and the final geocellular model resolution fault plane
- Picks that change fault blocks are flagged to be ignored by the modeling process
- The portion of the well that changed fault blocks is also flagged so the relative miss-positioned log data can ignored for the property modeling processes



Modeling Software Workflows – Export Model the Framework

Closing the loop

- With each model update the framework is exported from the modeling software in a format compatible with the software tools used by the team of geologists and engineers
- The geocellular model framework can then be examined to ensure that it is consistent with the underlying interpretation and field behavior



Conclusion

- There are no perfect vendor solutions for dealing with large complex data sets
  - Their work process assumptions are built into the software and can be at odds with your reality
- Creating specific tools and workflows are sometimes necessary to deal with problems specific to your field
- In the case of the ESOZ we have created a geocellular model that is continually updated as necessary and builds on previous work
- The changes that have been made to the data and interpretation are well documented and transparent.