Geological – Seismic Work Flows and the Construction of Integrated Maps

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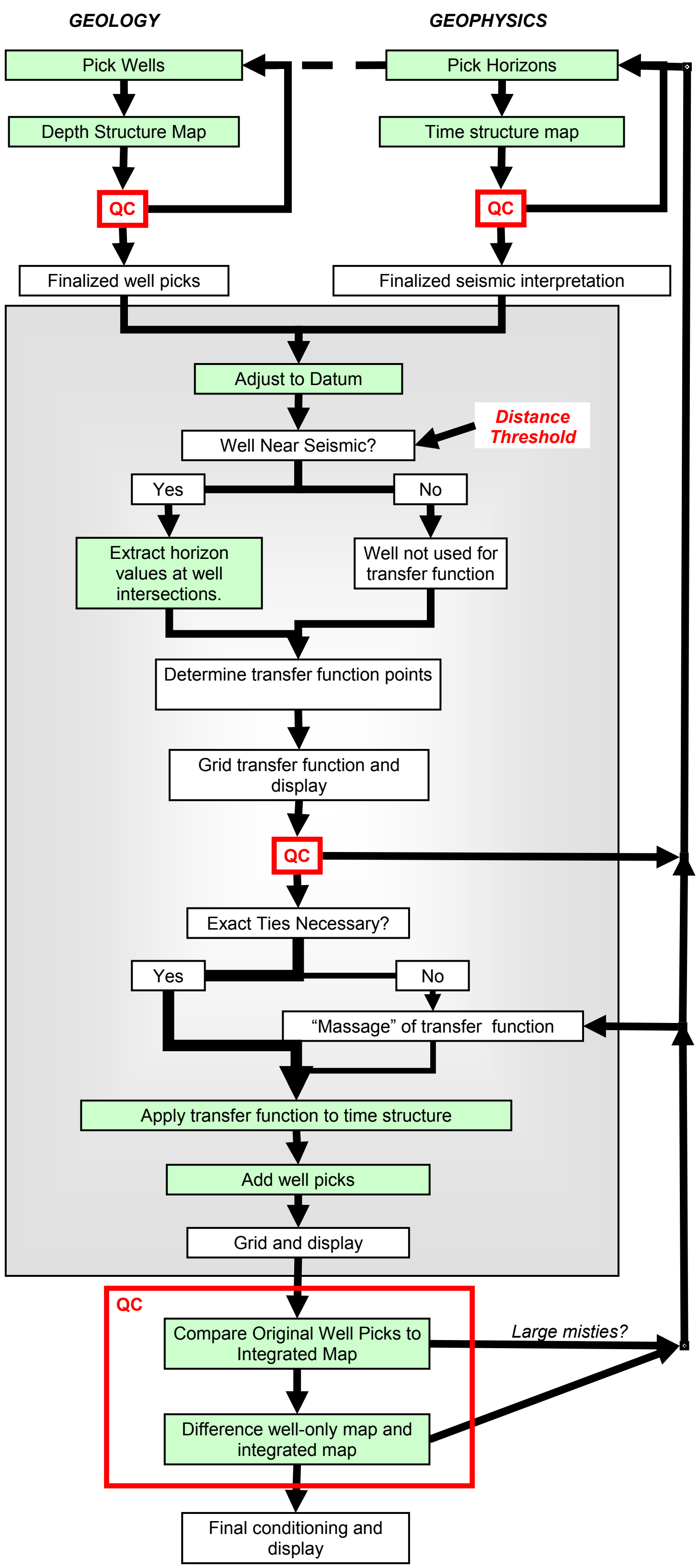
Introduction

Geologists and geophysicists working together in the E&P business have been actively working at integrating their complimentary interpretations for over 50 years. Modern G&G software toolkits enable better attempts at this in 2007 versus previously. However, in the authors' opinion, many existing methods tend to focus on software brand-centric work flows rather than on problem-centric and geoscientist-centric work flows. This study explores a work flow designed to demonstrate a geological / seismic data integration methodology which is map-focused and generic in nature.

The creation of integrated maps requires disciplined, systematic but flexible techniques for combining two domains: seismic time interpretations and geological well-based depth interpretations. Geological maps based on well picks only tend to be both sparsely-populated and locally-accurate, often emphasizing what has been drilled rather than highlighting undrilled trends and features. Seismic maps tend to have a higher spatial resolution (due to data distribution) and show both drilled and undrilled features (some of potential future interest), but are often uncalibrated in depth. The best possible maps are integrated well and seismic maps in depth which show the potential of undrilled features/ anomalies properly tied to, and in the context of, what has already been drilled. Practice has shown that these are difficult to create easily and in a timely fashion. Our experience is that the best quality products require multiple iterations.

An intelligent work flow is required to optimize the well-seismic integration process and produce high quality maps and the most useful results. The work flow must be efficient, understandable, and repeatable. The objective of this study was to develop a work flow that fits these characteristics and can be readily applied to exploration / exploitation projects in Western Canada.

A case example from an Eastern Alberta Lower Cretaceous play is used to demonstrate the work flow and its value. The study area contains a mix of muliple vintage seismic (2D and 3D) plus well data. Integrated mapping using the work flow produces maps which show potential targets not highlighted by either well mapping or seismic mapping alone.


GEOLOGY
GEOPHYSICS
Pick Wells
Pick Horizons
Depth Structure Map
Time structure map
QC
QC
Finalized well picks
Finalized seismic interpretation
Adjust to Datum
Well Near Seismic?
Distance Threshold
Yes
No
Extract horizon values at well intersections.
Well not used for transfer function
Determine transfer function points
Grid transfer function and display
QC
Exact Ties Necessary?
Yes
No
"Massage" of transfer function
Apply transfer function to time structure
Add well picks
Grid and display
QC
Compare Original Well Picks to Integrated Map
Large misties?
Difference well-only map and integrated map
Final conditioning and display

Methodology

The integration process is a map-focused, iterative, QC-enabled work flow. It is designed to use the best available data and interpretation from both the geology and geophysics side, and to enhance integration between results from the two disciplines.

A map-focused approach is important as it is during the mapping phase of any E&P project that information from the well and seismic domains are combined. The map-focus also pushes the process towards a final exploration/ exploitation goal more quickly and intuitively.

The work flow is software independent; it can be applied and adjusted to interact with current software toolkits the geologist and/or geophysicist are using.

Interactive QC steps are integral to the process, and are both map-based (using difference maps, bubble maps, and mistie maps) and statistics-based (using cross-plotting, trending, and outlier identification).

Iteration is explicit in the workflow. At all reasonable checkpoints, data can be corrected and interpretations can be updated. Multiple feedback loops exist to minimize the amount of re-work required after QC.

Key to the process is the development of a transfer function based on intersection of the well data with available seismic data. The transfer function is used to convert a seismic-only time-structure map to a depth map.

The final output of the work flow is an integrated map that both ties the well data and preserves the higher spatial resolution derived from seismic data.

Case Study

An Eastern Alberta Lower Cretaceous play is used as a case study. It is in a region with combined stratigraphic-structural plays and multiple reservoir targets for both oil and gas. Many of the targets are below direct seismic resolution, but indirect seismic methods can be used. The focus of the study included multiple horizons.

The focus area-of-interest is 57 km^2, and includes 171 wells. There are 16 2D seismic lines of 8 vintages, and one 3D survey covering portions of the area.

To reduce the effects of shallow velocity anomalies isochrons and isopachs from the 2WS surface are used rather than direct seismic structure mapping.

A final well structure map of the top Mannville was produced by the project geologist using all the available well data. As is normal, several iterations and QC steps were run through before the geologist was satisfied with his map.

A final time structure map of the top Mannville was produced by the geophysicist. The process involved interpreting all the available seismic data, performing a mistie analysis and correction, and correcting for end of line effects via several iterations and QC steps.

Of the 171 wells, 35 lie within a distance threshold of 50 m of the available seismic data, and 32 of those have log data to the top Mannville. These wells were used to produce synthetic seismograms and do a detailed analysis of the formation-top to seismic event correlation. This correlated well-seismic data was used to create a transfer function to transform the top Mannville-2WS isocrhon from seismic data to an isopach. Several iterations of this step were performed, with QC maps and statistics of the transfer function created to identify / correct/ eliminate any outlier or poorly correlated data. Note that in this case, because an isopach and isochron of exactly the same interval were correlated, the transfer function is equated to interval velocity.

When the transfer function was mapped, it showed a pronounced trend along an east-west direction, suggesting that there is a thickening trend of the isopach not easily detectable by seismic mapping alone.

Once the transfer function was generated, it was used to transform the seismic 2WS – top Mannville isochron to an isopach. This "seismic isopach" was then combined with the available well isopach data and re-mapped. Again, several iterations were done to produce the best results. The isopach was then added to a well structure map of the 2WS surface to produce the final integrated top Mannville map. Opportunity identification then took place.

The difference between the final integrated map and the final well structure map is used to highlight anomalies that are undetectable using well data alone.

The Following Figures will be Discussed as Part of the Presentation at the Convention

a data distribution map

a final well structure map based on well tops only

a final seismic time-structure map based on seismic data only

a map of the transfer function used, including a cross-plot of the transfer function values showing outliers and clustering

a map of the final integrated top Mannville surface

a difference plot showing the change from the non-integrated maps to the integrated maps

a bubble plot showing the well-seismic misties before and after integration