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Quantifying Structural Uncertainty in 3D Seismic Interpretation to Optimize Gross Rock Volume (GRV) - A Case Study in a Clastic Oil and Gas Field, Onshore India

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Abstract

The structural interpretation of 3D seismic data often comes with an uncertainty in regard to the correct placement of faults and surfaces, due to their vertical resolution and signal quality. There is a danger that the Gross Rock Volume (GRV) might therefore lead to unrealistic reserves estimation that affect future field development plans. To account for optimum GRV,therefore the quantification of structural uncertainty is vital.

In this study and through the introduction of a new model-driven interpretation workflow, an attempt has been made during seismic interpretation to define vertical and lateral uncertainties for every pick of horizons and faults based on seismic signal quality and the geological concepts of the field. As a result, a standard deviation map for each horizon has been produced along with base horizons and faults that will define the variation of horizons between the wells.

Similarly, based on the geological knowledge of the reservoir and seismic signal quality, various fault parameters, such as lateral position, dip, strike and throw, have been changed in a defined range to run multiple realizations based on geosciences input and not only stochastic. These multiple realizations, along with fluid contact and calibration at well locations, need to be run to estimate P10, P50 and P90 of GRV values. The optimum value thus obtained will be used for further field development planning.

Introduction

The current pilot study was conducted in a clastic reservoir located in the onshore Cambay basin on the western margin of India in Gujarat state. The main objective of the study was to estimate the vertical and lateral extent of the main reservoir and quantify the Gross Rock Volume (GRV) uncertainty. Since the seismic data quality is fair and to avoid velocity model uncertainties, the structural interpretation has been carried out in the time domain.

Workflow – Model-Driven Interpretation

The conventional workflow for quantifying uncertainty in the reservoir model consists of building a reference model as well as a full-field structural model through subsurface data (e.g. seismic) integration, followed by creating a 3D Grid on which multiple subsurface realizations can be carried out to capture uncertainty. This will provide probabilistic volume ranges from which P10, P50, P90 volumes can be estimated.

With this conventional approach, uncertainty is quantified using a simple scalar option where the surface points (high, base and low) are either positioned up or down. Additionally, faults are kept constant in all realizations and the constant uncertainty ranges have a corresponding impact on the standard deviation maps.

The main limitation to this approach, however, is that there is no clearly defined approach for setting the uncertainty parameters in the structural model – parameters that might vary from interpreter to interpreter both in terms of the horizon (stratigraphic) and fault configurations (location and displacement).

The advanced workflow introduced in this case study is based on Emerson's Roxar RMS 2013 reservoir modeling software and addresses this limitation.Roxar RMS 2013 comes with model-driven interpretation capabilities that enable users not only to create the geological model while conducting seismic interpretation, but also capture uncertainty during the interpretation process (Garrett, et al., 2013).
The workflow has a number of stages – seismic interpretation, structural uncertainty modeling, 3D Gridding, and Volumetric (GRV) calculation.

In the new workflow 'uncertainty envelopes' represent uncertainties that change size based on the interpreter's estimate of uncertainties on each interpreted location (Figure 1). The uncertainty envelopes used during the interpretation are used to quantify uncertainty during structural uncertainty modeling.

In fault uncertainty modeling, the new workflow defines the movement of fault parameters within the fault volume envelope. In the case of horizon uncertainty modeling, the vertical uncertainty within the envelope defines the shift in horizon surfaces up or down. As compared to conventional workflows, where uncertainty can only be moved vertically by the constant factor, in the new workflow for each point uncertainty is guided by the data(Garrett, et al., 2013). This provides the users with additional confidence in their GRV calculations.

Following the model-driven interpretation process, standard deviation maps are extracted that are used to capture the uncertainty during the building of a structural model and are then taken through the remaining elements of the workflow (creating a 3D grid) to create multiple realizations.

Whereas the conventional workflow approach comes with constraints, in the new workflow uncertainty is guided by the data. This ability to provide users with unique tools for quantifying geologic risk early in the interpretation process leads to better decision-making and improved investment returns.

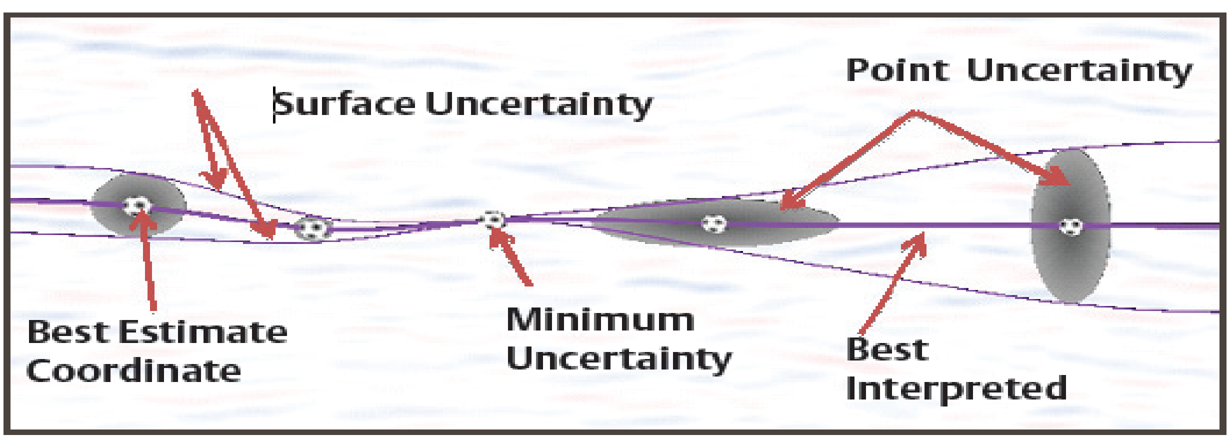

Figure 1: Showing the uncertainty ellipses used during horizon and fault marking. Here the height of the ellipse represents the vertical uncertainty and the width of the ellipse represents the lateral uncertainty.

Capturing Uncertainty In The Onshore Reservoir, Cambay Basin

In the target Indian reservoir, interpreters have used the above mentioned model-driven interpretation tool within Roxar RMS 2013 to define lateral and vertical uncertainty at every pick during the seismic interpretation workflow in the time domain (Figure 2). This approach enables users to define uncertainties related to horizons and faults at all stages of the workflow - from seismic interpretation through to structural modeling.

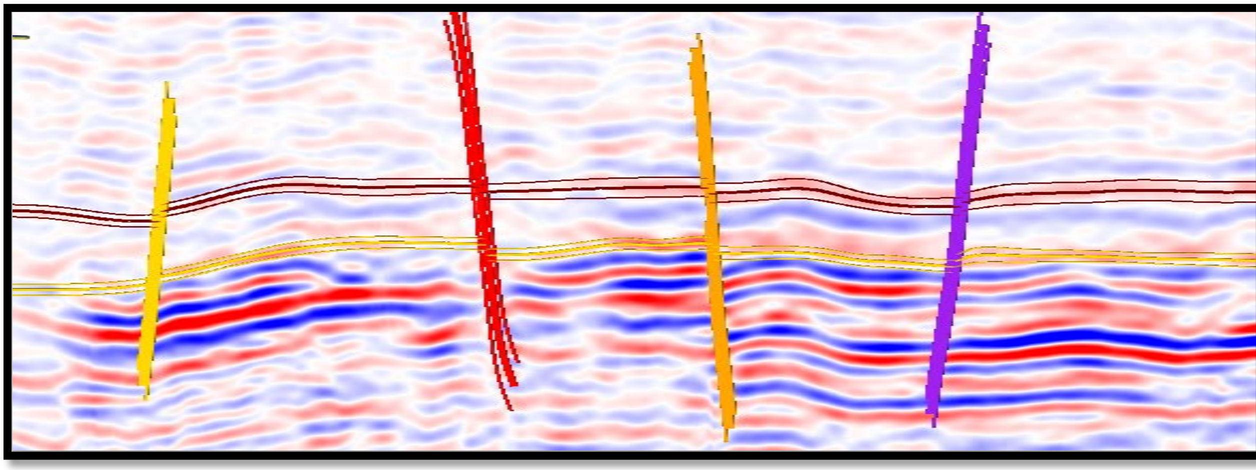

Figure 2: Real data in time from the field. As part of the advanced workflow, the interpreter created an uncertainty range in all the faults and horizons.

Figure 3 for example, illustrates the control points that were used for the two surfaces – the upper surface control points, the lower surface control points, and the base case surfaces with the fault network. In all these illustrations, each point represents a best estimate coordinate with different uncertainty ranges then applied for each point.

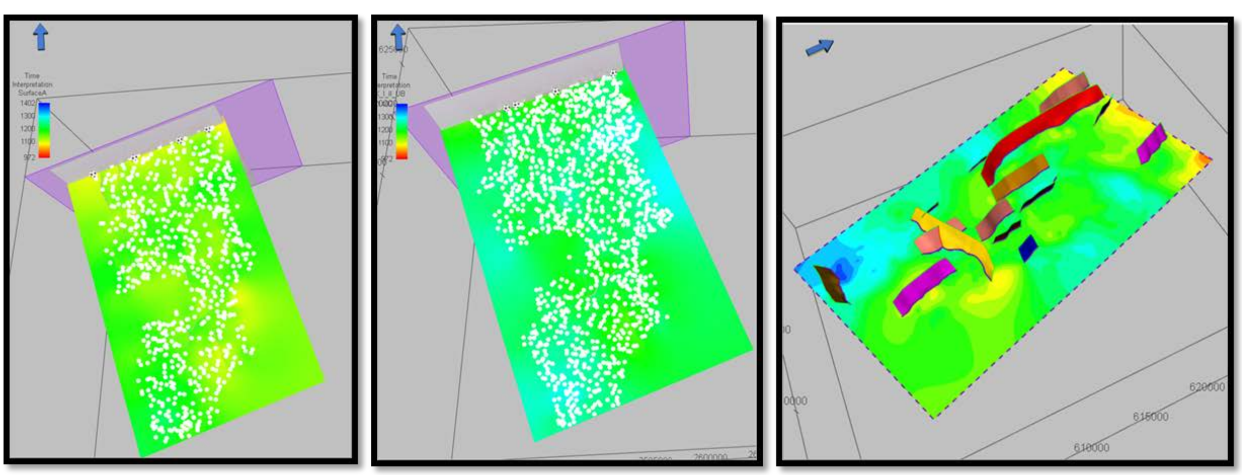

Figure 3: The Control Points Used for the Two Surfaces.

Figure 4illustrates the fault uncertainty envelopes. The uncertainty along the faults can be provided during interpretation for each point or can be kept constant and defined manually on both the hanging wall and the footwall side during the structural modeling workflow.

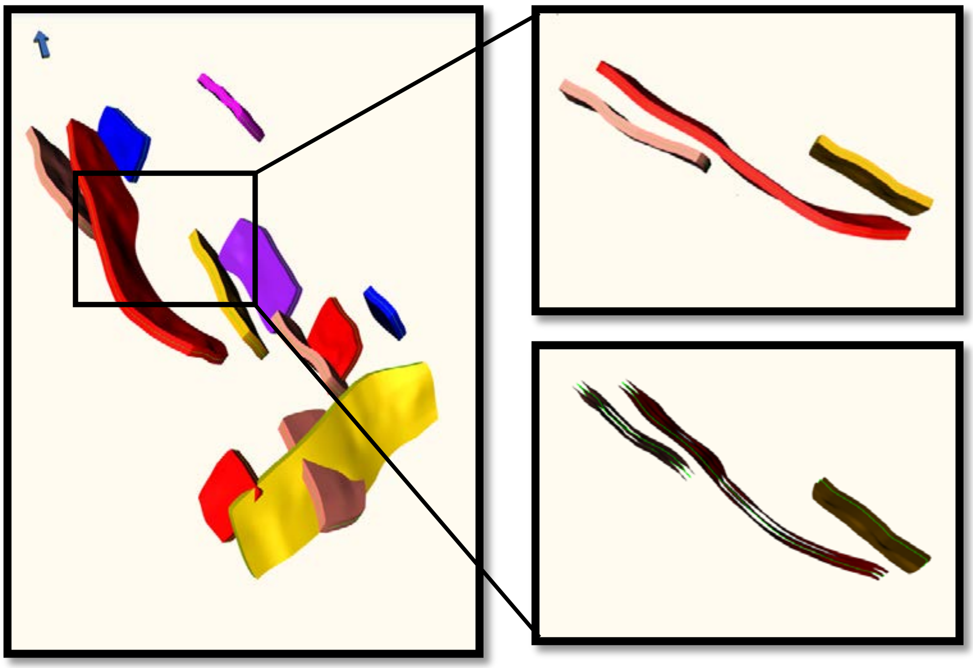

Figure 4: Fault Uncertainty Envelopes.

The Standard Deviation Maps and Multiple Realizations

Uncertainty is represented by an ellipsoid “envelope” associated with each point measurement. The ellipsoid has two parameters, lateral and vertical uncertainty. RMS computes three surfaces based on the interpretation and its uncertainty. First, a best estimate surface is computed. This surface satisfies geologic constraints and the best estimate coordinate. Next, an upper and lower bound are computed (surface uncertainty envelope) based on surfaces that satisfy the upper and lower bounds of uncertainty in the vertical direction (time or depth) of the best estimate coordinate.

Standard deviation maps were derived from the uncertainty envelopes, which were marked while performing the seismic interpretation to capture the uncertainty at every point. As an illustration a standard deviation map displayed in the Figure-5.

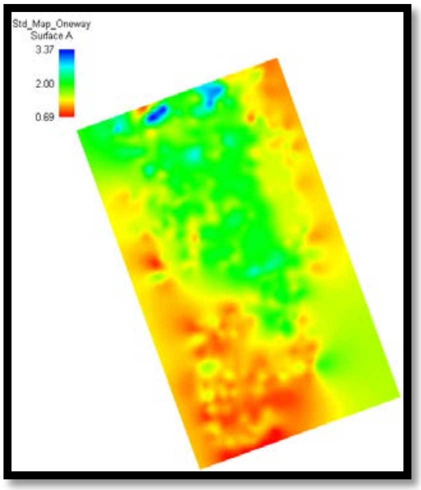

Figure 5: Standard Deviation Map.

Results –Multiple models and Gross Rock Volume

To run the multiple realizations, an uncertainty workflow (figure 7) has been set up which integrates the uncertainty captured while performing the seismic uncertainty.

The standard deviation has also been used to generate multiple structural models using multiple realizations. Figure 6 shows the faults displacement and horizons variations in three different realizations.

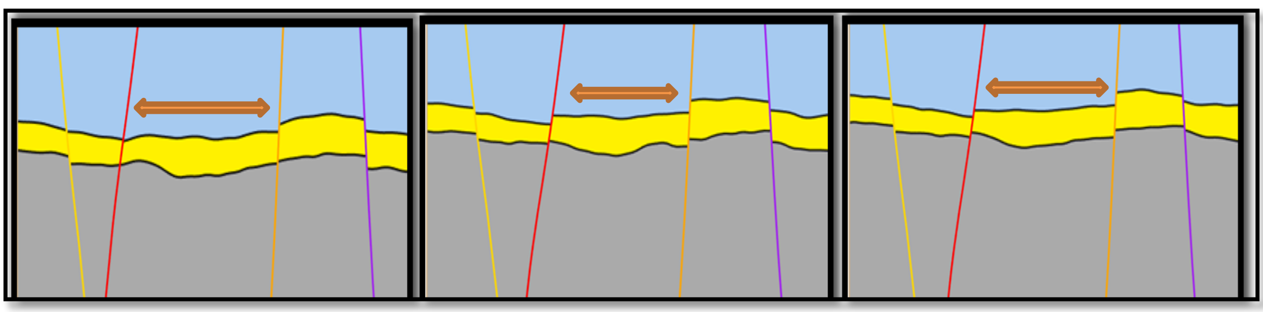

Figure 6: Fault Displacement in Three Different Realizations.

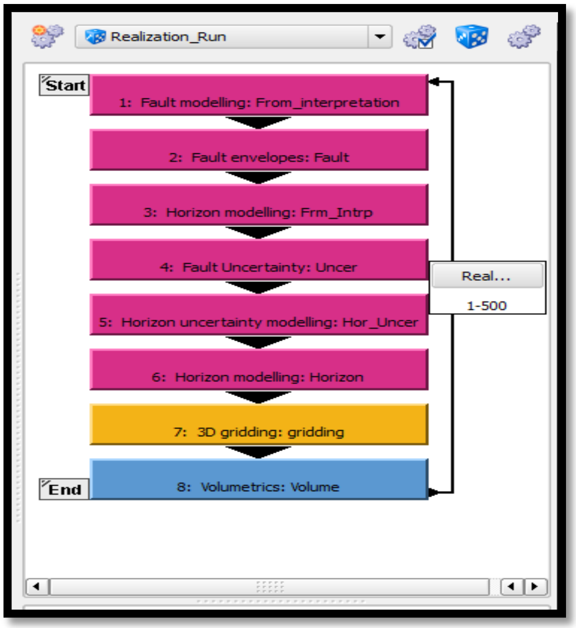

Figure 7: Uncertainty Workflow

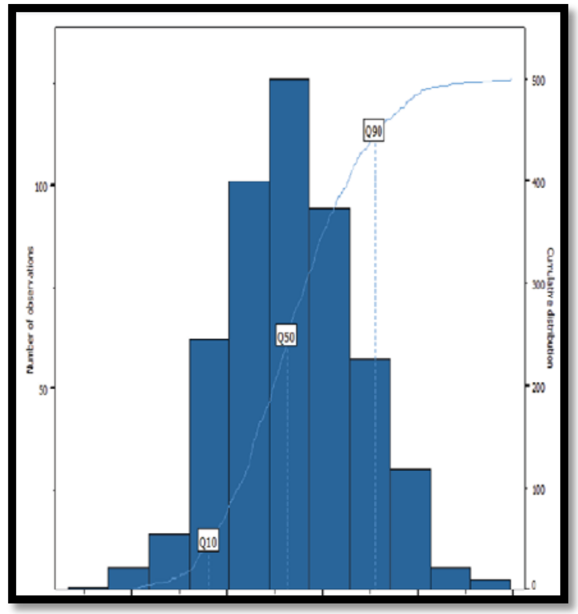

Figure 8: GRV Uncertainty Results

Around 500 realizations have been generated to capture the entire extent of GRV uncertainty for the main reservoir interval and the results have been captured in Figure 8.The final results show that the change in GRV based on P10, P50 and P90 values ranges to ~2%, implying that the structural uncertainty for the reservoir is considerable and the structural interpretation from the given seismic data can be taken ahead for further field development studies.

Conclusions

This case study outlined in this paper illustrates the benefits of GRV uncertainty quantification through the new model-driven interpretation workflow within Roxar RMS 2013.

As opposed to conventional workflows where uncertainty is quantified using a simple scalar option, faults are kept constant in all realizations, and the standard deviation maps are affected by constant uncertainty ranges, the new workflow allows uncertainty to be guided by the quality of the seismic data. Fault positions are changed for each realization and the standard deviation maps reflect the confidence level in seismic data quality. In summary, interpreters are given the flexibility to follow the data and honor the geology. The results achieved in the above study, though confined in the time domain, undoubtedly demonstrate certain benefits for the users that include:

1. Greater confidence in seismic data;
2. A better understanding of the structural uncertainty of the field at an early stage of the field's life;
3. Valuable inputs for further field development studies; and
4. Multiple structural models around defined uncertainty ranges based on seismic data quality and the reservoir's geologies.

Furthermore, a quick evaluation of the data through model-driven interpretation at the beginning of the field's lifecycle leads to better decision making for future investments as wells as improved field screening. GRV is controlled by the field's structure and is one of the main controlling factors of In-place hydrocarbon volumes (Hosani, et al., 2014). Therefore a reasonable quantification of the field reserves at this stage reduces the overall risk.

GRV uncertainty is often the most significant uncertainty, especially in the early phases of field appraisal and development with the correct handling of structure and contacts often the key to realistic uncertainty assessment(Hosani, et al., 2014). This paper has demonstrated how realistic GRV uncertainty is being achieved with benefits for all.

Acknowledgement

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