Combining Seismic Imaging with Geologic Process-Guided Modelling to Improve Channel Reservoir Characterization

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Summary

This presentation describes a project that first used advanced seismic imaging to identify a channel system and delineate its features and facies — not only reflecting surfaces but also intervals. Mathematically derived seismic attributes made full use of the frequency content in high-resolution seismic data. Geobodies were extracted and handed off to a modelling technology guided by geologic processes instead of purely stochastic sampling methods. This enabled us to identify elements accurately and precisely at a sub-seismic scale, including undetected potential barriers to fluid flow.

Introduction

Accurate identification and portrayal of a channel system is rarely easy. Exploiting it is even harder. The depositional processes and crosscutting relationships do not leave behind simple linear features with well-defined boundaries. Conventional examination of poststack seismic reflections leaves much to be desired. Is it a channel-levee system or an accretionary channel-infill architecture? Are there impermeable shale-drape and mud-plug boundaries separating permeable sands? The answers to such questions have a profound impact not only on drilling success rates, but also on fluid flow and hence exploitation, especially in tertiary production.

When it comes to reservoir modelling, conventional stochastic modelling misses many details, especially with respect to compartmentalization within a complex reservoir. Such compartmentalization often results in the loss of ability to recover large amounts of hydrocarbons.

Using traditional poststack seismic, we noticed indications of potential channels within the shallow section of a 3-D seismic volume shot over a deeper Jurassic reservoir in the North Sea. To describe the geologic framework, we first mapped stratigraphic sequence boundaries immediately above and below the channels. These boundaries were used to create a framework for geologic scenario models.

The interpreted system was then mapped with the aid of seismic attributes. Every year, more attributes become available to make the most use of the information in seismic signals. Seismic facies classifications based on the attributes enabled us to detect geobodies, which we then used to guide the distribution of lithologies in a geomodel.

Our modelling technique provided a step change over purely stochastic modelling by basing the distribution of clastic lithologies on geologic processes. Stochastic (geostatistical) modelling methods, in contrast, do not provide the same level of detail for stratigraphic layering and facies relationships. We placed lithofacies and sedimentary structures within the reservoir model using rules based on depositional processes observed in laboratory and outcrop studies. This allowed us to create digital representations of the distribution of rock bodies within the reservoir, ending up with a finely layered model that mimicked the distribution you would see in outcrop and core.

The final goal was achieved. We were able to identify flow barriers, at a sub-seismic scale, associated with changes in mud content, boundary layer shales at the base of a main fluvial channel, and abandoned channel fill. By populating geologic process-guided facies models with porosity and permeability characteristics, we were able to create geomodels that described the distribution of these properties at a scale appropriate for reservoir simulation.

Method

(a) Seismic Interpretation and Attribute Analysis

We used a variety of waveform picking parameters, including a correlation window, search windows and a quality factor, to interpret the upper and lower sequence boundaries.

To establish the channel boundaries, we calculated several semblance sub-volumes to determine the parameters that would best image the area of interest. Based on the sub-volume results, we then ran the semblance attribute over the entire seismic volume.

To establish the channel geomorphology and composition, we used spectral decomposition, sweetness, and relative acoustic impedance. We used these to differentiate the channel content from the surrounding host.

We applied several seismic facies classifications to the attribute volumes to identify different channel facies and to detect the geobodies based on these facies.

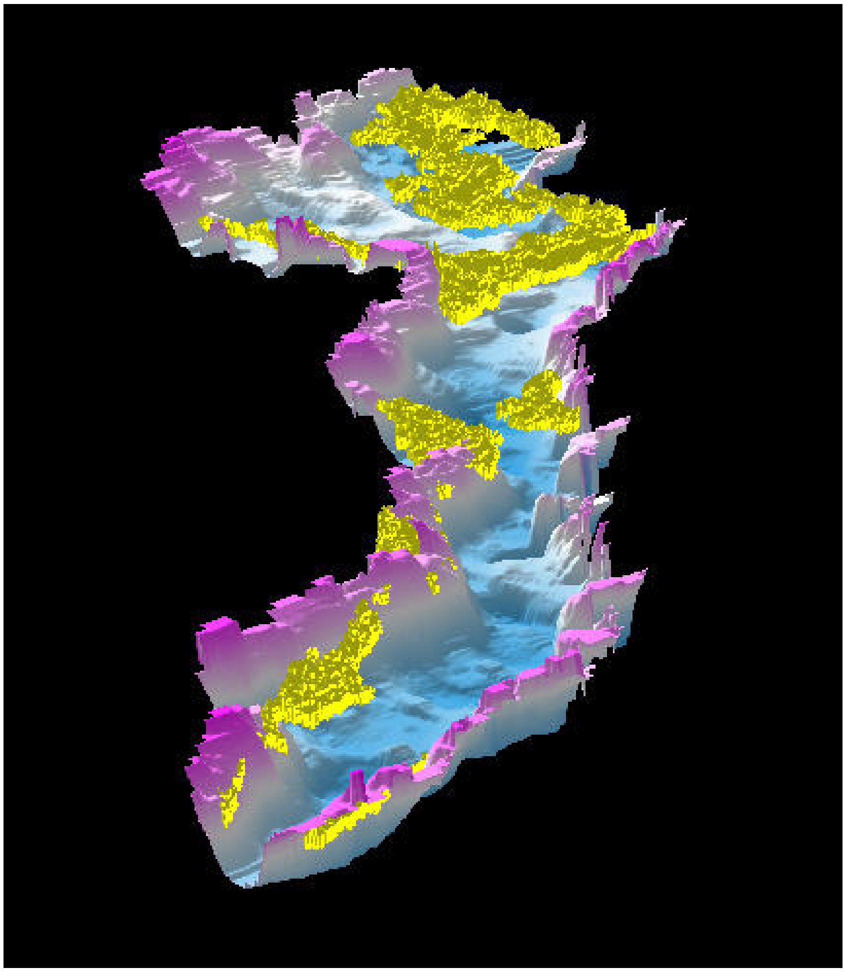

Figure 1: Reservoir sand geobodies.(yellow) extracted from seismically defined channel

(b) Process Guided Modelling

The geomodeller reviewed the results of seismic imaging with the geophysicist. We developed two geologic scenarios to explain the morphology displayed within the seismic volume. One scenario was based on a confined accretionary channel, and the other a channel-levee architecture. We decided to model both to see what impact differing views on architecture might have on reservoir distribution. The workflow consisted of four steps. First, a common framework grid was established using the top and base of the parasequence mapped by our geophysicist. Next, the channels were mapped deterministically using digitized channel centerlines, and measured width and thickness as input. Third, geologic process-guided modelling templates were assigned to each scenario along with porosity and permeability values for each lithofacies. Finally, geometry and lithofacies distribution grids were developed, along with property grids including porosity, permeability and net-to-gross.

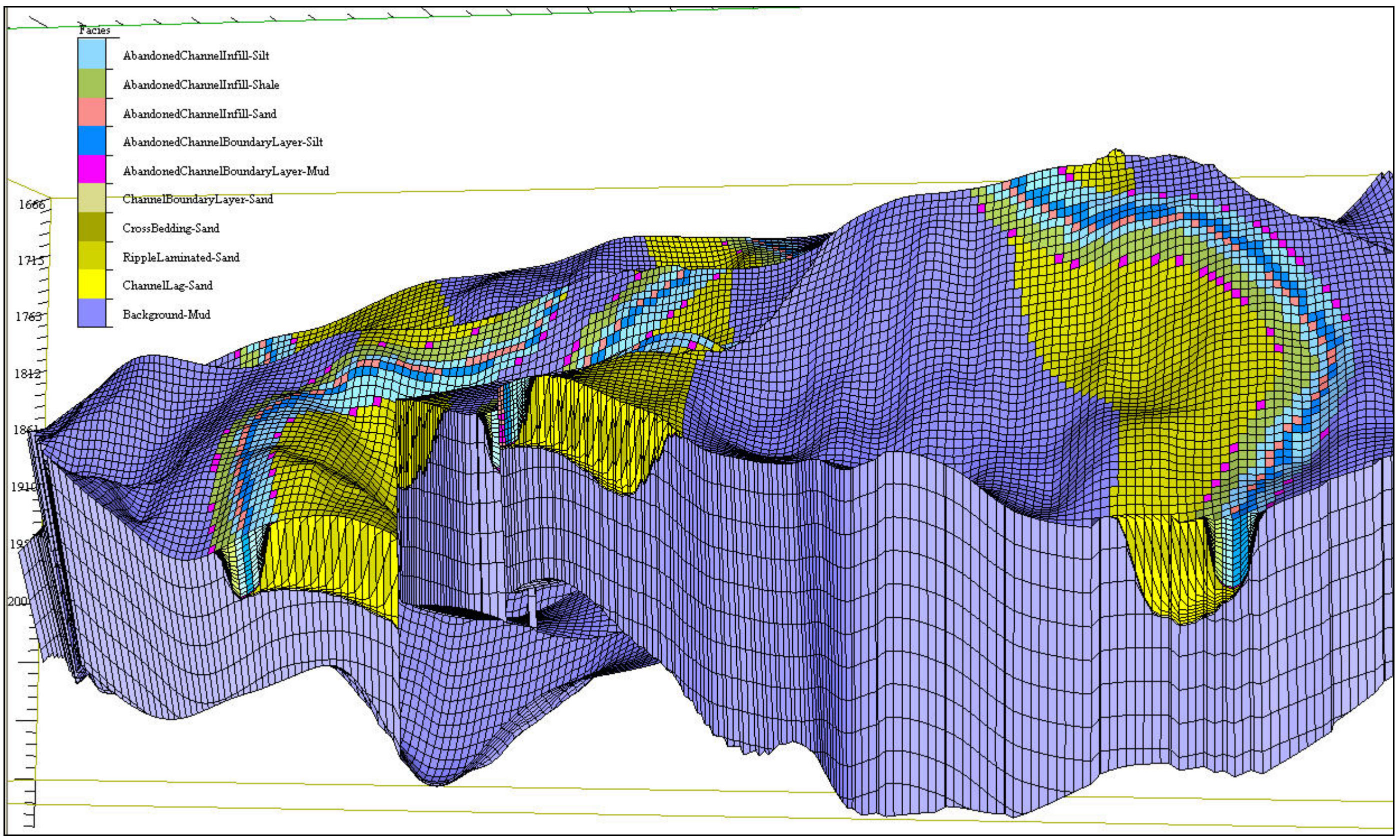

Figure 2: Accretionary channel infill model: stratigraphic layering and facies distribution

Conclusions

By combining seismic imaging techniques with process-guided facies modelling, we were able to create channel reservoir models that were clearly more realistic than those which could have been developed using a purely stochastic modelling approach.

Acknowledgements

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