Quantitative Geomodelling with Qualitative Inputs: Optimizing a Waterflood and Reversing Production Decline

Close, D.I.* and Slikas, M.
Apache Canada Ltd., Calgary, AB, Canada

Summary

This case study, focused on a Cretaceous aged Mannville Group pool under water flood, illustrates the benefits of utlizing a quantitative and deterministic geomodelling workflow for reservoir characterization. Geophyiscal, geological and petrophysical data are integrated into a deterministic static model for simulation. The results of the simulation, in conjunction with pressure transient analysis in a specific well and material balance calculations, have been used to alter the water injection. The altered water injection has halted the production decline and lead to improved recovery with no capital spending.

Introduction

Despite being on water support for approximately 10 years, reservoir pressure in the pool has continued to decline and development activity has been stymied by a lack of understanding of reservoir connectivity and continuity. Regulatory permission to increase the voidage replacement ratio from 1 to 2 was obtained, however, increased injection volumes did not arrest the decreasing reservoir pressure. The reservoir characterization and simulation study presented herein was initiated to improve understanding of the reservoir and to provide recommendations regarding flood optimization and infill drilling.

Detailed petrophysical analyses were completed on all wells within the field with sufficient log data. The processed log data were then used to create a relatively simple facies log comprising sand, shaley-sand and shale; where only the latter is considered non-reservoir. 3D seismic reflection data were reprocessed, including 5D interpolation and pre-stack time migration, to prepare the data optimally for AVO inversion. Collation of all available production and pressure data completed the data preparation for the reservoir characterization study.

Geological Modelling with Geophysical Inputs and Calibration by Simulation

Geophysical and geological interpretations were initially undertaken independently from reservoir engineering studies that proceeded simultaneously. The static model constructed from the available geological, geophysical and petrophysical data was then utilized to successfully history match the observed production and pressure data. A number of iterations were required, although only relatively small changes to the static model were required.

To help constrain static model properties amplitude variance with offset (AVO) inversion was tested.

However, AVO inversion results are enigmatic, primarily due to amplitude anomalies associated with overlying coal intervals. In spite of the limits of the attempts at quantitiative interpretation of the seismic data, the full stack amplitude data and attributes thereof are invaluable for identifying reservoir boundaries that have not previously been interpreted. A stratigraphic boundary inferred from seismic data interpretation to the south of the best producing interval cannot be inferred from log data alone.

AVO inversion was tested extensively, as a means to provide improved reservoir delineation and also to quantitatively assess the effect on wavelet extraction and inversion of the 5D interpolation of the reflection data prior to pre-stack time migration (PSTM). Although the continuity of reflection events with gathers is improved (Figure 1) and there is a commensurate effect on the extracted wavelets (Figure 2) the inversion results at a blind QC were not substantially improved in the interpolated data inversion. Despite efforts to optimize the inversion results, quantitative and reliable estimates of Vp:Vs and density could not be obtained. Although AVO inversion does not provide uplift in this study area, wedge modelling suggests that reflection amplitude is indicative of reservoir thickness (Figure 3).

Reservoir facies based on seismic amplitude data can be broadly reconciled with log based facies. Although there is, in general, good correlation between seismic predicted reservoir and log measured reservoir intervals, there remains substantial amounts of detailed editing that must be completed manually to construct a complete geological or facies model (Figure 4). Although manual construction of geological models within Petrel (or equivalent geomodelling software) is relatively time-consuming and subjective, it remains necessary that knowledge regarding the geology of a field or reservoir is captured in such a model; by using purely stochastic techniques and log data it is inevitable that the knowledge and experience of geological staff is sometimes not captured. This is a critical point to understand in all geomodelling studies.

To assist in confirming the facies model based on geological and geophysical data, dynamic modelling was completed. The results of the simulation emphatically confirm the primary conclusion of the geological modelling; that is that the injection into the well to the south of the reservoir is wasted effort as the well is not connected to the reservoir. These results concur with previously completed material balance calculations and pressure transient analysis. As a result of this study, injection has ceased at this location and the injection volume re-allocated to more appropriate injectors; which increases the field EUR by approximately 2 MMBOE with no capital expenditure.

Conclusions

The integration of geophysical data in the geomodelling workflow can provide quantitative uplift, even where only qualitative reservoir properties can be predicted. To facilitate this it is necessary to proceed to simulation and achieve a successful history match of production and pressure data, as this provides an independent calibration of the geological model. In this case study we have illustrated a successful example of this workflow where actionable recommendations were made and production decline arrested as a result.

Acknowledgements

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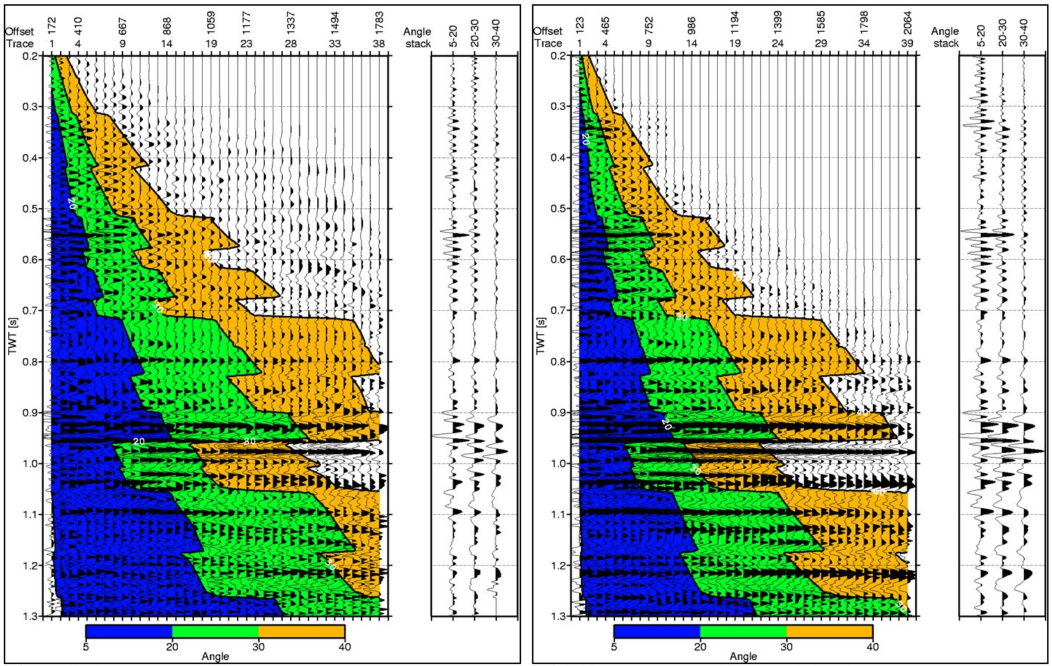
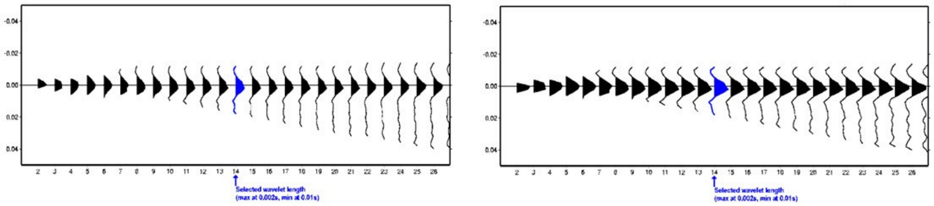


a) PSTM

b) 5D Interpolation + PSTM

Figure 1: Comparison of a single gather after migration with and without 5D interpolation. Colours on the gathers illustrate angle range and condensed panels to the right of the gathers show the stacked trace for each angle range.



a) PSTM

b) 5D Interpolation + PSTM

Figure 2: Wavelets extracted at a well location from different near (5-20 degree) angle stacks.

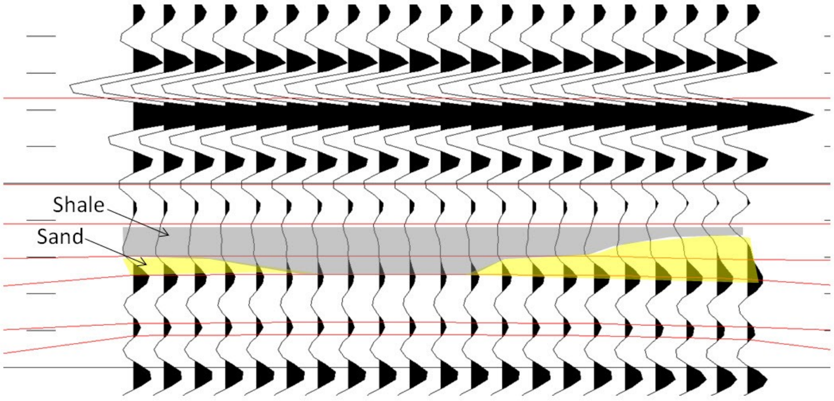


Figure 3: Wedge modelling indicates that as the thickness of reservoir sand increases through the zone of interest the corresponding peak in the full-stack seismic reflection data increases in amplitude.

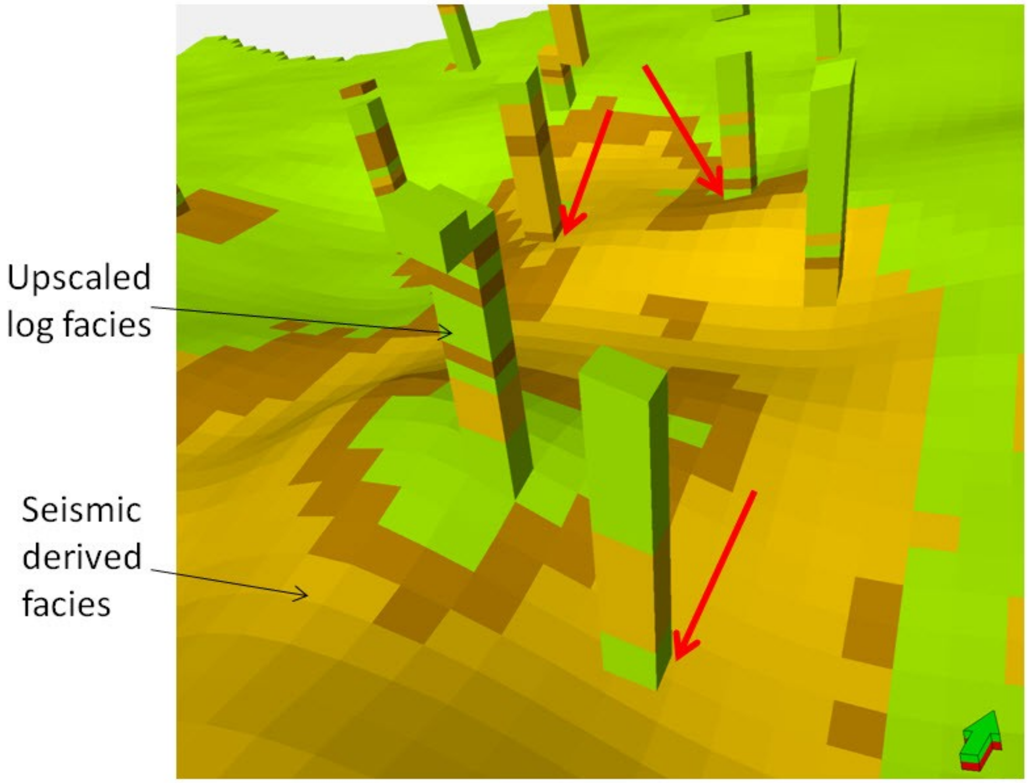


Figure 4: Upscaled log facies and facies defined by seismic amplitude data sampled into the model, where a mis-tie occurs between the facies (as highlighted by the red arrows) the seismic facies are adjusted to match the log based facies.