INTEGRATED RESERVOIR CHARACTERISATION OF A PERMIAN ROTLIEGEND PROSPECT

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Summary

This study aimed to provide greater insight into the question of whether a near-field Paleozoic interval could retain sufficient reservoir quality to be attractive for future exploration. To meet this challenge, an integrated multidisciplinary approach was adopted that brought together detailed geological analysis with seismic inversion. Both of which were complimented by synchronized concurrent seismic reprocessing. The project workflow began with a stratigraphic review before investigating the detailed sedimentology and diagenesis for reservoir characterisation, with the latter incorporating burial history modelling to constrain the role of compaction. The results of seismic attribute analysis and seismic inversion performed during data reprocessing were then integrated with the geological story to generate a truly holistic reservoir quality evaluation.

Integrated Reservoir Characterisation of a Permian Rotliegend Prospect

Introduction

This study aimed to provide greater insight into the question of whether a near-field Paleozoic interval could retain sufficient reservoir quality to be attractive for future exploration. To meet this challenge, an integrated multidisciplinary approach was adopted that brought together detailed geological analysis with seismic inversion, both of which were complemented by synchronized concurrent seismic reprocessing.

The study area contains historical exploration wells with hydrocarbon shows as well as nearby producing fields. However, at the level of the Permian, significant uncertainty still exists over whether the Permian Rotliegend equivalent has retained enough porosity and permeability to host a viable conventional prospect.

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Study Dataset

The study utilised a 3D seismic data volume and five wells, which all have well TDs within the Permian except for one well, which has a TD age range of Late Carboniferous to Early Permian. Existing data in the form of conventional core analysis, high-resolution core photography, wireline logs, and various historical well reports were combined with new analyses, including chemostratigraphy, petrophysics, facies analysis, QEMSCAN® analysis, SEM and XRD. This was further integrated with seismic-derived data including well synthetics and inverted elastic attributes. A phased approach was taken, with a stratigraphic review and facies analysis undertaken in phase 1, reservoir characterisation in phase 2 and basin and diagenetic modelling in phase 3. Results from the concurrent 3D seismic re-processing were shared and integrated throughout.

Early Phase Stratigraphic Review

A stratigraphic review of historical reports and data was undertaken at the beginning of the project. This led to greater well top confidence and a consistent stratigraphic framework that tied well with the 3D seismic volume. The new chronostratigraphic and lithostratigraphic framework was delivered during the early evolution phases of the reprocessing project, resulting in both projects using a consistent set of stratigraphic tops. This also led to further constraint of the velocity model, which had important implications for seismic imaging and later inversion work. The review also significantly impacted the regional understanding of the younger Jurassic section by assigning previously undefined sections of the most proximal control well to the Jurassic, which highlighted the possibility of more areally extensive Jurassic sandbodies that could be targets for exploration. (Figure 1).

Integrated Spatially Constrained Depositional Model

Digital core description was undertaken on 3 key wells in the study area (Figure 1). Example core photograph images can be found in Figure 2. The core analysis indicated two dominant depositional environments: aeolian and fluvial/alluvial. Combining geological information from the 3D seismic volume with chemostratigraphic results, mineralogy and electrofacies, a coeval aeolian and fluvial/alluvial depositional model was proposed for the study area (Figure 2).

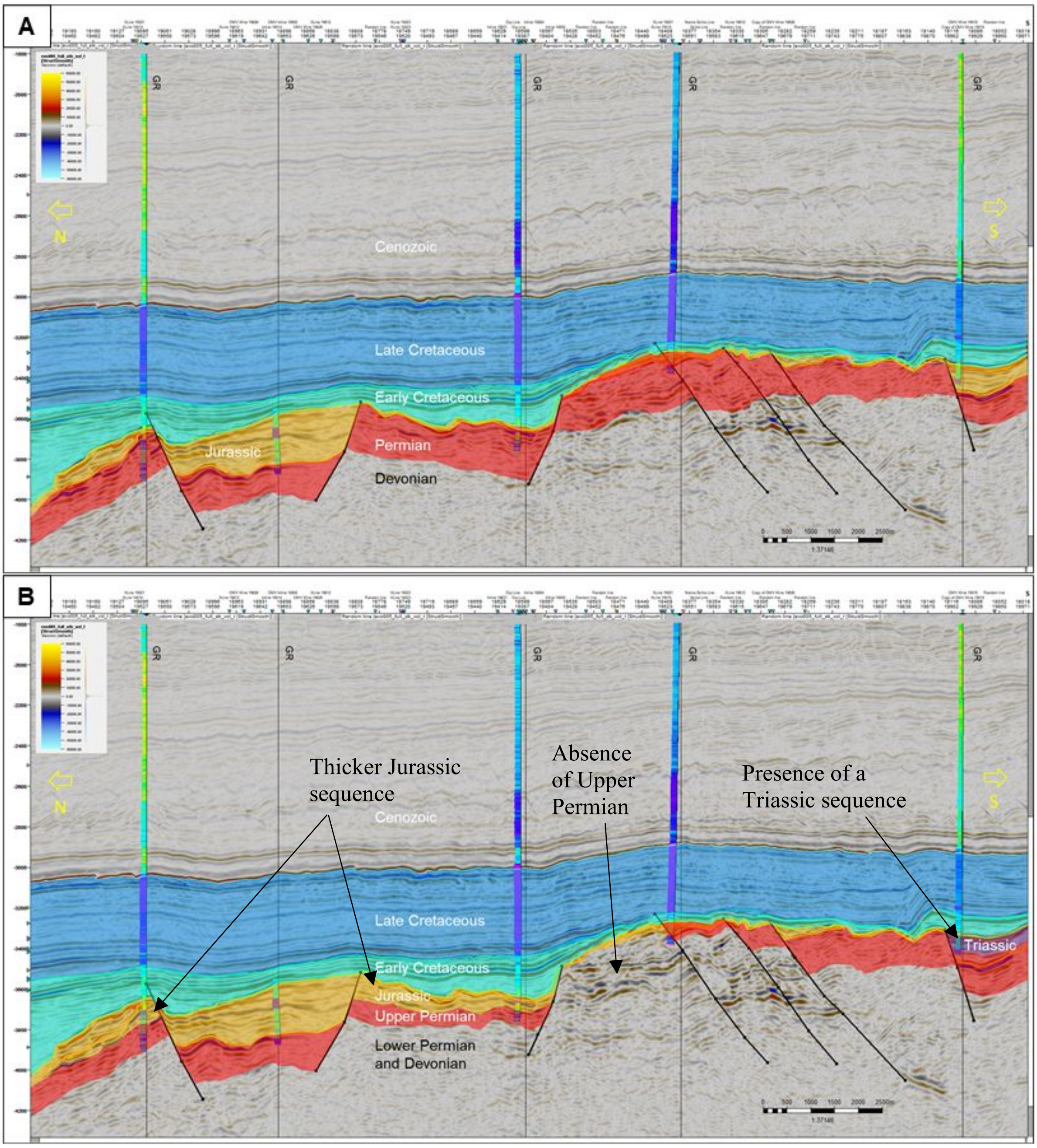

***Figure 1 A)** Example 3D seismic line through the study wells displaying the change in regional stratigraphic understanding before the early phase stratigraphic review and **B)** the new understanding after the stratigraphic review.*

Integrated Reservoir Quality Controls and Diagenetic History

Coding the CCA data with facies and depositional textures highlighted weak primary controls and the importance of secondary controls on reservoir quality. The integration of the above analysis demonstrated that the aeolian and fluvial/alluvial environments had unique effects on the secondary controls and overall diagenetic histories (Figure 3).

For example, the aeolian environment demonstrated widespread grain coating clays, which suppressed later overgrowths, that were not seen in the fluvial/alluvial environment. Also, an early phase gypsum/anhydrite cement, which occluded primary intergranular porosity, was not seen in the fluvial/alluvial environment (Figure 3). Kaolinite in-filling primary intergranular pores was dominantly found within the fluvial/alluvial environment but was seldom recognised within the aeolian environment

(Figure 3). Overall, compaction was the most dominant post-depositional control on reservoir quality. This was modelled, in combination with 1D burial histories, using Trinity software, to provide a more robust porosity prediction, and recognise areas that had enhanced porosity within the study area (Figure 4D).

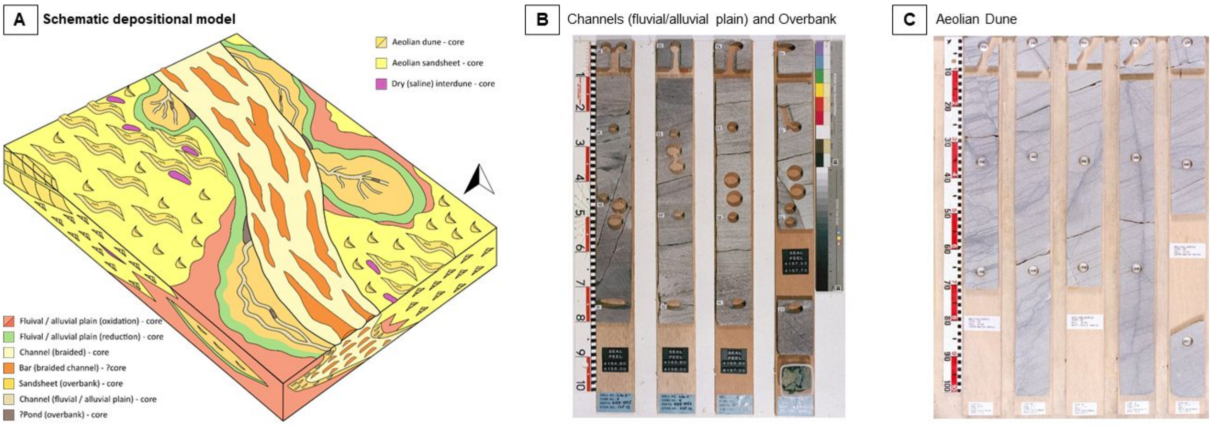

Figure 2 A) *Schematic depositional model of the Rotliegend in the study area.* ***B, C)*** *Example white light core photographs of the different depositional environments encountered within three cored wells.*

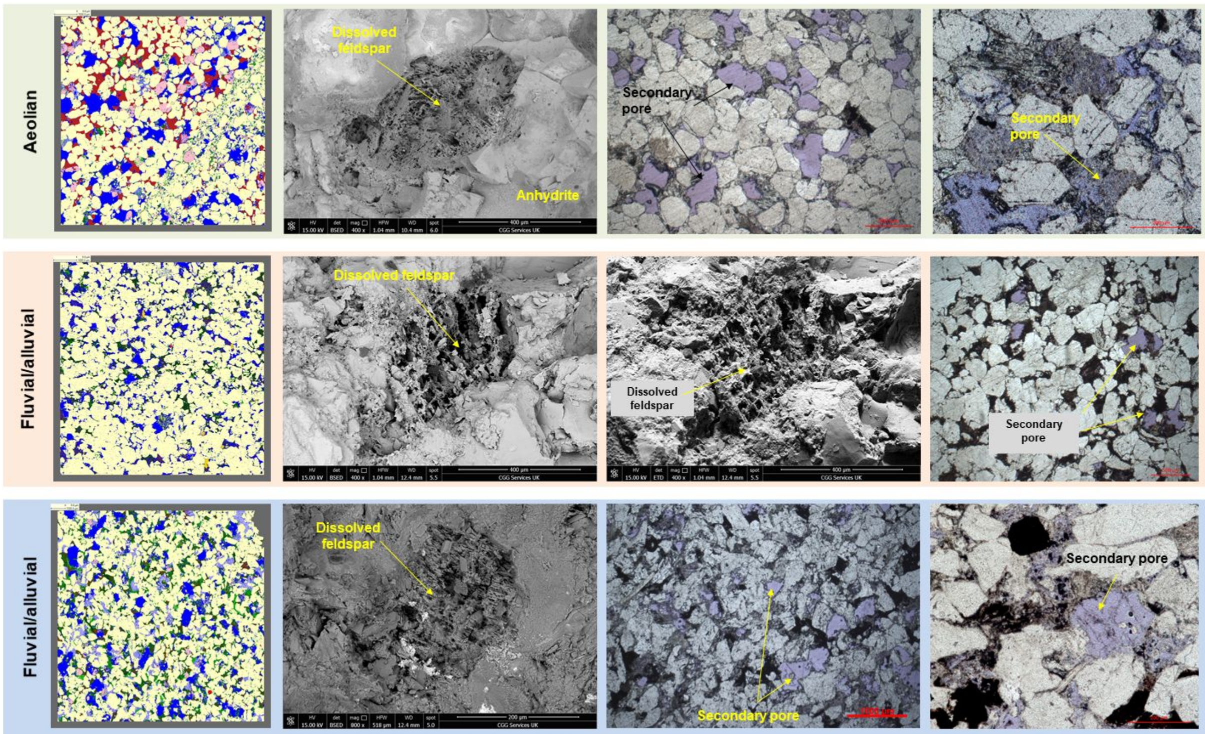

Figure 3 *QEMSCAN ®, SEM and thin section images demonstrate that all depositional environments show secondary porosity enhancement. Note the presence of anhydrite (red colour, upper left QEMSCAN image) within the aeolian environment, which is absent in the fluvial/alluvial environments.*

Integrated Reservoir Quality Prediction

The application of a basin modelling approach allowed for a porosity prediction based upon modelling the effects of compaction and quartz cementation. The results of the pseudo-3D modelling compared well with that from the seismic inversion derived porosity, with both displaying similar mapped porosity ranges (Figure 4: D-E). The diagenetic observations from petrography were factored into the pseudo-3D modelling to enhance the prediction of porosity ranges for the respective depositional environments.

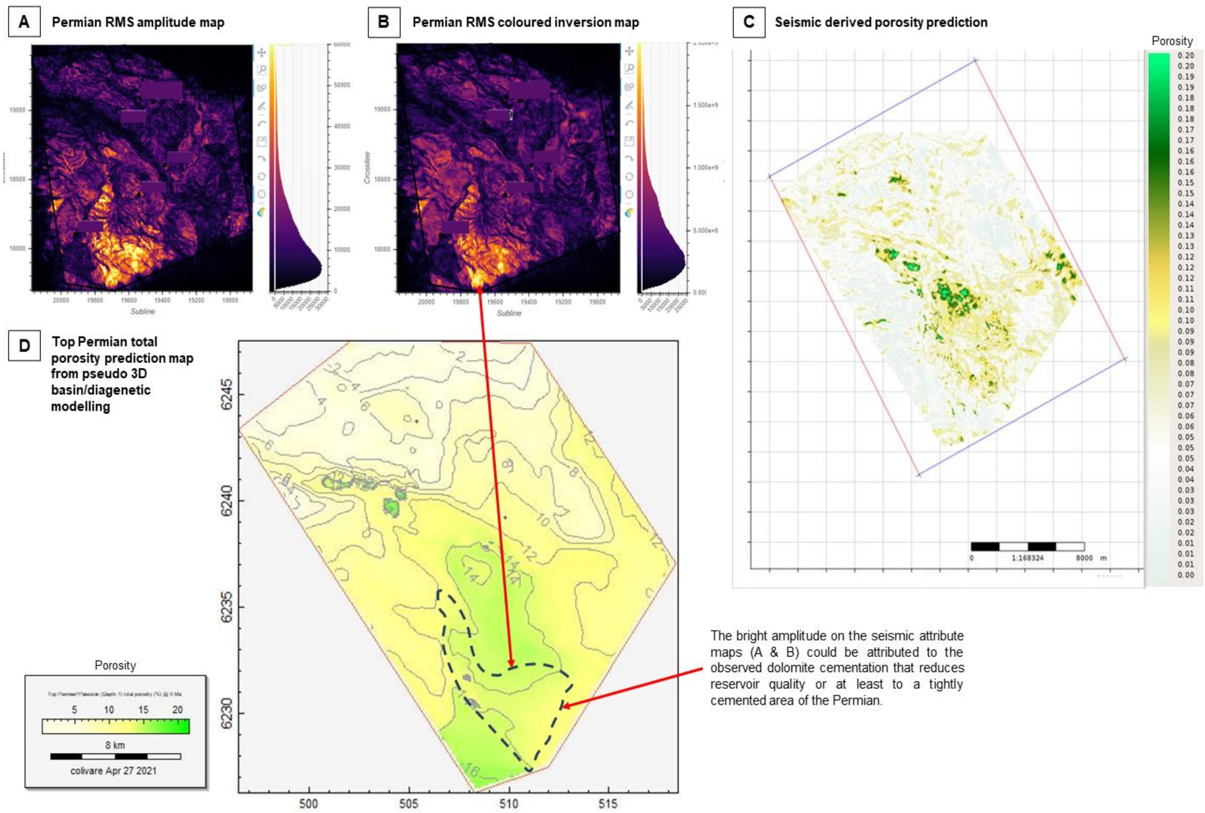

Figure 4 A) *RMS amplitude map of the Rotliegend, displaying an amplitude anomaly towards the south.* ***B)*** *RMS coloured inversion map displaying the same anomaly towards the south.* ***C)*** *Porosity prediction based on a linear regression between acoustic impedance and porosity at the well and applied to the 3D acoustic impedance volume.* ***D)*** *Pseudo-3D modelled total porosity map for top of the Permian.*

Conclusions

The results of the analyses described here have highlighted areas between the existing well control points with predicted higher porosities. These areas can be tied back to a complex diagenetic history affecting the original fluvial/alluvial and aeolian depositional facies. Furthermore, this geologically driven result is confirmed by seismic inversion.

This study emphasises the importance of a re-assessment of historical data by combining new and innovative solutions and integrating both geology and geophysics. This was shown in this study to produce greater subsurface insight and further demonstrates how mature basins continue to host deeper intervals with future reservoir potential.

Acknowledgments

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