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Mysterious Palaeozoic Carbonates In Nordland Ridge-Application Of Multi-Disciplinary Approach To Subsurface Data

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Summary

The carbonate package of Upper Permian (Zechstein) age in Mid-Norway is underexplored. Sedimentological analysis of the four wells that penetrated this interval confirm the model of platformal carbonates located on depositional highs and more restricted carbonates deposited within the basins. Only one intriguing well situated on the Nordland ridge exhibits +250 m of heavily dolomitised carbonates carrying no clues about depositional settings. The original depositional character of these unusual foliated dolomites is a mystery and their coarse nature along with other evidence is indicative of fault-related hydrothermal activity. In order to gain insight into the internal heterogeneity and architecture of the Upper Permian carbonates, advanced sedimentological and geophysical technologies deemed necessary. The geological information extracted from the outcome of these technologies in particular analysis on IsoMetrix high resolution 3D seismic is far more diagnostic than conventional reflection seismic data interpretation. An Upper Permian carbonate play may be matured further only by utilizing these advanced technologies.

In the Norwegian Sea (Mid Norway), four exploration wells distant from each other are the only data sources providing hard evidence for the Palaeozoic carbonates. Rock samples (cores and/or cuttings) were analysed to understand their depositional settings, diagenesis, reservoir quality and HC distribution/timing; in order to evaluate the full potential of a prospect in the Nordland Ridge area. The interval of interest is the carbonate package of Upper Permian (Zechstein) age. During this period, Mid Norway was located in a "transitional" area between cold-water carbonates of the Barents Sea to the north, and arid, hot environments of the Zechstein Basin to the south. Outcrops of these carbonates (Karstryggen and Wegener Halvø Formations) in East Greenland demonstrate the development of ooid shoals and bryozoan reefs in shallow-water, platformal settings on structural highs. Potential development of similar carbonate reservoirs is the motivation for targeting Palaeozoic carbonates in the Nordland Ridge area. The four exploration wells from Mid Norway confirm the model of platformal carbonates located on depositional highs (i.e. Nordland Ridge and eastern parts of the Norwegian Sea) and more restricted carbonates deposited within the basins. The depositional facies have a control on reservoir quality with shallow-shoal bioclastic dolomites demonstrating moderate reservoir quality, but slope and tidal flat settings having limited reservoir development. However, one intriguing well, situated near a fault on the Nordland Basin, exhibits >250m of carbonates which are entirely dolomitised and preserve no depositional clues what-so-ever. The dolomites are unusual in that they are foliated, and their coarse nature along with other evidence is indicative of fault-related hydrothermal activity. Their original depositional character, however, remains a mystery.

Interrogation of high quality, IsoMetrix 3D seismic data indicates that efforts to significantly improve seismic imaging of Palaeozoic carbonates is critical to advancement in the area of reservoir characterization.

Stratal geometries and internal architecture within Palaeozoic successions have been diagenetically destroyed, partly due to strong hydrothermal events: hypogenic Karstification, intense fracturing, brecciation and dissolution, and recrystallization. The resultant heterogeneity has a major effect on the geophysical response. Primary seismic reflection events do not necessarily respond to the internal variability of rock properties and cannot detect the heterogeneous nature of the depositional unit. The application of multiple geophysical techniques, integrated with scanning electron microscope, quantitative rock property measurements, provided new insight to the internal heterogeneity of the Palaeozoic carbonates in the study area on the Nordland Ridge.

Seismic reservoir characterization and simultaneous elastic inversion provided rock property volumes including: density, porosity, P and S impedance, Vp/Vs etc. 3D visualization technology highlighted the lateral variation of these physical properties. In order to maximise the information available for the 3D seismic interpretation, STFT (Short Term Fourier Transform) spectral decomposition was performed to produce discrete frequency components. These components were generated to enhance the geologic features of interest and reduce seismic redundancy. In addition, several seismic attributes were generated using all angle stacks. The components of the generated multi-dimensional dataset contain geologically meaningful patterns or clusters, noise and redundant data. Using a linear transformation procedure namely: principal component analysis, the large

dataset is represented in a new vectorial space with a smaller dimension. The components with most contribution to geological patterns were selected. This procedure segregated the noise and redundant data into separate components. Classification of seismic data using these principal components created a 3D multi-attribute, seismic facies classification volume.

The Three-term Aki-Richards equation to 55^{O} was used to generate AVO attribute volumes from the pre-stack data. The two attribute volumes created were SPRC(scaled poissons ratio change($\alpha A + \beta B$)) and AVO product (A*B). Once the AVO attributes were generated, the aerial extent of the anomalies were mapped and AVO gradient analysis was conducted for each anomaly on the pre-stack gathers. The distribution of these anomalies is very complex, but indicates some correlation with the heterogeneous patterns detected by previous geophysical analysis.

The geological information extracted from inverted rock property volumes, principal component analysis and AVO is far more diagnostic than the seismic reflection data. Conventional reflection seismic data interpretation and traditional simple geological models cannot predict the influence of localized hydrothermal activity and hypogenic karstification on reservoir quality.

The new insight into the internal heterogeneity and architecture of the Palaeozoic carbonates is essential for further de-risking of the prospects in the Nordland Ridge area. A Paleozoic carbonate play may be matured further only by utilizing high quality seismic data and advanced geophysical technologies.