Detailed Mapping of Sand Injectites Integrating Seismic Attributes and Machine Learning in the Norwegian North Sea

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Abstract

Recent exploration activities within Paleocene and Eocene remobilized sands have proven the injectite play in the Northern Viking Graben, previously actively explored in the Southern Viking Graben area. Wells targeting these sands have led to discoveries such as Kveikje (2022) and Heisenberg (2023) in the near-field exploration of greater Fram area. In recent months two new injectite prospects have been announced in the study area as potentially hydrocarbon bearing with a high chance of success, according to the operator. This is a result of advancements in seismic imaging technology to significantly improve data quality and give a better understanding of the complex geometries of sand intrusives. Using seismic data, we can identify large-scale sand injectites or sandstone intrusions as discordant amplitude anomalies, where these injectites formed due to post- depositional remobilization and injection of the source sands into their sealing mudstone-dominated sequence.

High-resolution dual azimuth seismic data integrated with well data have been used in this study to investigate the occurrence of injectites with a particular focus on the Paleogene interval. This study proposes a robust methodology for the detailed mapping of sand injectites by leveraging seismic attributes and integrating machine learning (ML) techniques, such as ML faults and ML injectites. Firstly, we utilized RGB frequency blending results from spectral decomposition analysis to map possible depositional pathways of the parent sands. Then after analysing the responses from the seismic attributes, we identified the distribution of sand injectites within different stratigraphic intervals.

Using identifyed injectites we employ ML algorithms to train predictive models. We extracted the fluid and lithology information from the seismic data. Angle stacks are converted to intercept and gradient volumes and a coloured inversion is applied to produce the acoustic and gradient impedance (AI and GI respectively). A projection to the chi angle is executed by using AI and GI as inputs, which allows us to highlight the lithology and fluid information. For this project, a rotation of $\chi = 45°$ is used for lithology, and $\chi = 20°$is used for fluid. Using a specialised flow, we extract the injectite information from the lithology and fluid volumes to form an initial injectite mask and trained ML model against the angle stacks. Once complete, the inferred result over the full study area is assessed by geologist. Over the course of the training iterations, the ML was upgraded from a 2D to a 3D training and inference, improving the continuity and reliability of the final injectite mask. As a result, multiple injectites were created as geo-bodies. This allowed for a better understanding of the lateral distribution and complex geometries of the injectites.

By analyzing the responses from the seismic attributes at the location of the initial discoveries, we successfully identified other areas exhibiting similar characteristics, indicating the potential presence of prospective sand injectites. These intrusions propagate into low permeable, polygonally faulted mudstones which create a suitable seal. Finally, the identification of injectite geo-bodies from the ML predictions, provide further insights into these subsurface reservoirs. A better understanding of this mechanism enables more efficient exploration and exploitation of hydrocarbon resources.