DATA DRIVEN RESERVOIR PROPERTIES ESTIMATION USING MAZ TOWED MULTISENSOR STREAMER SEISMIC: A NORWEGIAN CASE STUDY

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Summary

This paper will focus on a data driven approach for reservoir properties estimation of a recently acquired and processed multi-azimuth multisensor survey in the prolific South Viking Graben, Norway.
The implemented technologies and methodologies will be performed without the need of building a low frequency model necessary to achieve absolute reservoir properties and applied on the under-explored Vana sub-basin in the Upper Jurassic interval. This case study will highlight that a combination of an innovative acquisition, quantitative interpretation, and seismic morphology interpretation delivered enhanced imaging and understanding of the Jurassic interval.

Data Driven Reservoir Properties Estimation Using MAZ Towed Multisensor Streamer Seismic: A Norwegian Case Study

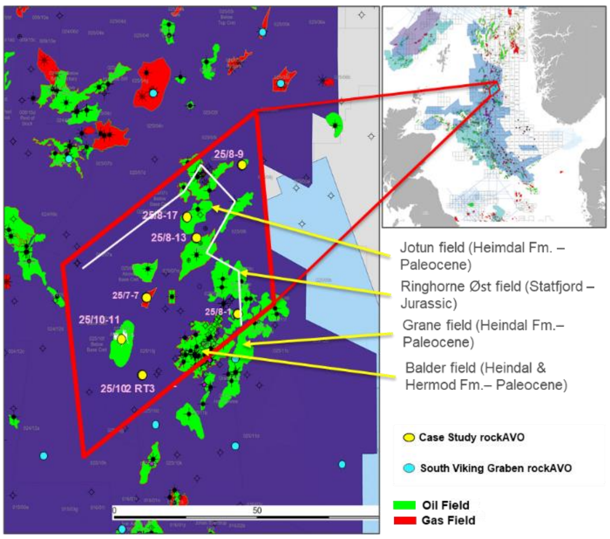
Introduction

The Viking Graben in the North Sea has delivered a significant number of successes across multiple plays ranging from the shallow Tertiary to the deep Permian and is still an area of intense exploration, near-field exploration and field development. However, accurate imaging, identifying, mapping and evaluating each target with seismic technology has required a step change in the robustness with the objective to estimate and predict elastic and reservoir properties more accurately and reliably. Additionally, for an explorer or operator, these techniques should be cost efficient. To address these challenges, various seismic acquisition techniques have been deployed recently in this mature region, for example Dunlop et al. (2020) reported Ocean Bottom Node (OBN) surveys acquired over two seasons and a multi-azimuth (MAZ) towed streamer configuration acquisition presented by Widmaier et al. (2020).
In the present paper, we are aiming to build on the previous case study with a similar MAZ dataset further south (Reiser et al., 2021), but going a step by estimating reservoir properties, such as volume of shale (Vsh) and porosity. This will be driven using only the seismic data information, i.e. removing the need of building a low frequency model necessary to achieve absolute reservoir properties.

We will first describe the overall dataset used for this case study, show the main workflow implemented and report observations, and draw conclusions and suggest a way forward.

Area of Interest (AOI) and database

The area of interest (AOI) is located in the South Viking Graben (Figure 1) on the Norwegian side over the Utsira High and the adjacent Vana basin.



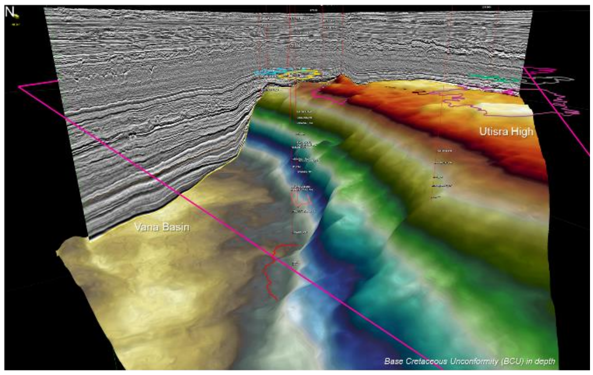


Figure 1. Left: Location of the 2020 multi-azimuth survey (red polygon) and its surrounding multi-client surveys in the UK-Norway North Sea. The study area represents approximately 1170 km^2. This figure shows the various fields present and the wells (yellow dots) used for the interactive rock physics modelling analysis. Right: 3D visualization of a MAZ full stack seismic random line (white line on the basemap) crossing some of the fields/discoveries and the Base Cretaceous Unconformity (BCU, in depth). The vertical red lines represent the interactive rock physics modelling wells used for the project.

The main fields over the AOI (Figure 1) are: the Balder field discovered in 1967 producing from the Heimdal and Hermod Formations (Paleocene age) as well as some injected sands, the Ringhorne field part of the Balder complex produces from the Hugin (late Jurassic), Ty (early Paleocene) and Hermod Formation (Late Paleocene), the Grane field on the eastern part of the survey produces from the Heimdal Formation (Paleocene) with very good reservoir quality, and the Jotun field, further north in the survey was producing (currently shut down) from the Heimdal Formation. Few discoveries have been made in the deeper Vana basin part of the survey: the 25/10-11 well drilled in 2011 targeting the early Jurassic interval encountered some minor oil and gas in this interval, the Busta prospect (25/7-7) and 25/7-2 drilled by ConocoPhillips targeting the Jurassic Intra-Draupne formation encountered some gas condensate and light oil. Overall, the Vana sub-basin is under-explored and will be the main focus of this case study.

The MAZ survey has the same configuration as the 2019 survey (O'Dowd et al., 2020) with minor differences: two new deep-tow azimuths of 12 streamers by 6 km by 93.75 m, including two 10 km long streamers for an improved Full Waveform Inversion (FWI), and a wide-towed triple source with 250 m separation between outer source arrays for more reliable near offsets coverage in the 50-125m range. The streamer spread has been towed with a nominal tow depth of 25m and between 28-30 m depth for the long tails, respectively, in order to provide an improved signal to noise ratio along with enhanced low frequency recordings. This seismic acquisition has the benefits of providing richer azimuth/offset information and illumination at all depths. The additional acquisition azimuths (two in the 174^0 and 234^0 direction) are complementary to the completely reprocessed 2011 narrow-azimuth multi-client broadband data (114^0), creating a homogenous multi-azimuth dataset.

In terms of the processing and imaging sequence, a state-of-the-art pre-processing sequence from raw field data to demultiple ensured a seamless merge of all the azimuths into a single 5D dataset prior to Kirchhoff Pre-Stack Depth Migration (KPSDM). The Titled Transverse Isotropy (TTI) velocity model was obtained through a comprehensive Velocity Model Building (VMB) flow where Full Waveform Inversion (FWI) using refractions and reflections in a MAZ setting was key in resolving both shallow and deep velocity anomalies such as shallow channels, high velocity injectites and chalk / basement layers.

Figure 2 illustrates the uplift obtained from high-grading existing data (legacy 2011 or azimuth 1140) with complementary new acquisition and more advanced imaging workflows. The improvements are observed from shallow to deep, in higher contrast, continuity, and resolution of reflectors, and as well as clear improvements in the interpretability, definition of the faults and structural elements.

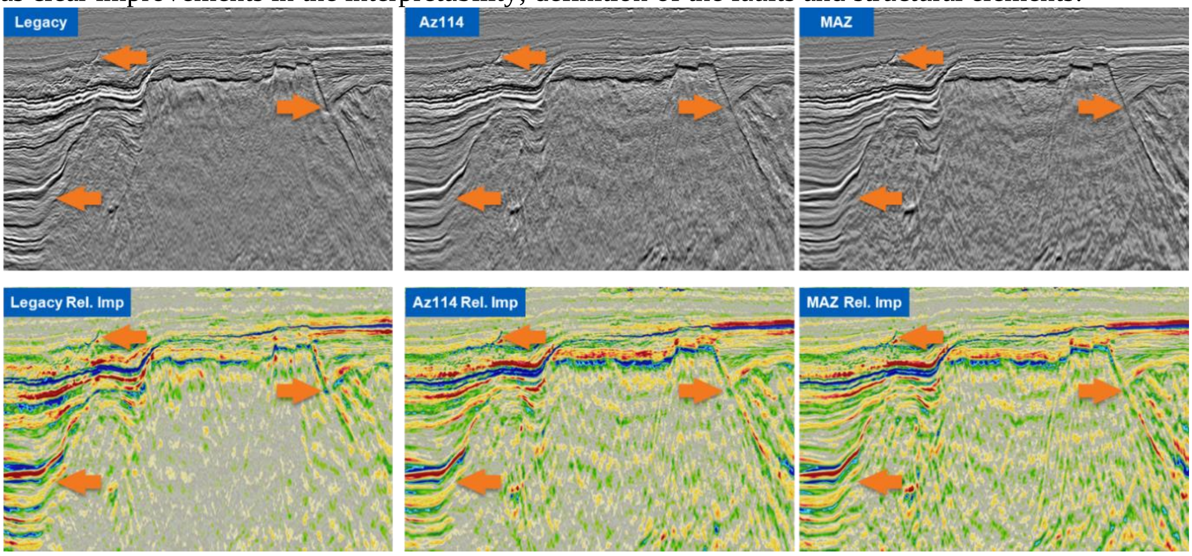


Figure 2. *Top row represents the full stack amplitude seismic with the legacy (left), the azimuth 114 (middle panel) and the MAZ (right) data. The bottom row represents the results of the relative acoustic impedance (no low frequency model) of the three different input seismic. A series of image/inversion improvements can be seen comparing legacy to reprocessed narrow azimuth 114 to the multi-azimuth dataset. Enhancement can be observed from the shallowest part of the section to the deepest part with clearer faults definition in the Utsira High (right) and towards the Vana basin (left), with better delineation of the deepest and shallowest events.*

Over this area, one of the challenges in the AOI is the presence of an over-pressure zone in the Jurassic interval in the Vana sub-basin causing a drop in the velocity (Figure 3) to around 2.6-2.7 km/s at around 4.4km depth. Well, 25/7-02 recorded some abnormal pore pressure in the Jurassic section. No wells in the deeper part of the basin have been drilled nor "sampled" this over-pressured zone for the elastic attribute calibration.

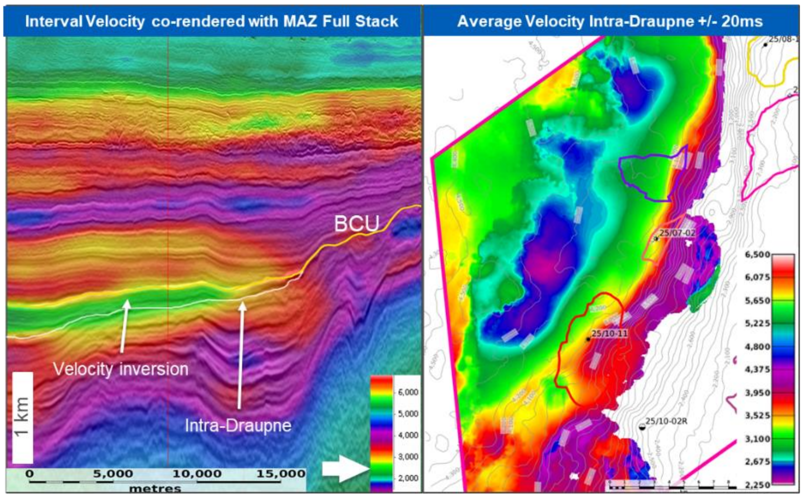


Figure 3. *Velocity section co-rendered with the MAZ full stack seismic and map display of the average velocity around a Jurassic Intra-Draupne formation horizon. A distinct velocity inversion can be seen on the in the central part of the Vana basin.*

Data driven quantitative interpretation workflow and results

Based on the above observations, and with the objective to extract reservoir properties such as volume of sand and porosity, instead of estimating absolute elastic attributes, it was decided to use only the seismic amplitudes. The properties will thus not have any direct input from the seismic velocity, usually used for the low frequency model building. The over-pressured area and associated very low seismic velocity would have biased significantly the estimation of reservoir properties (Figure 4).

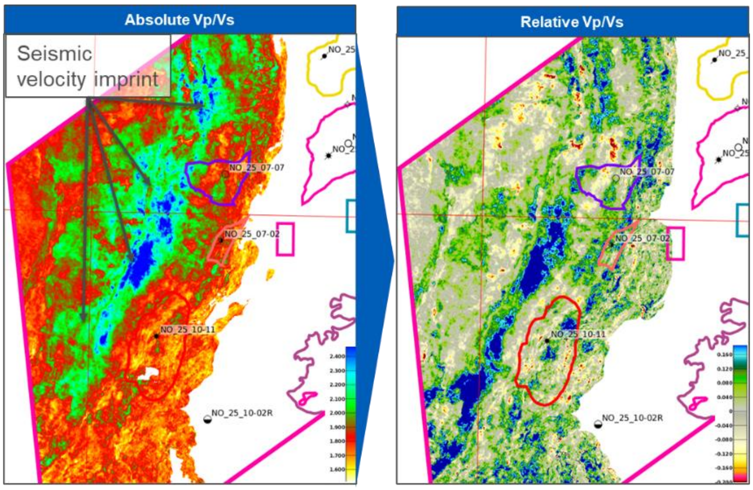


Figure 4. *Seismic velocity imprint on the absolute Vp/Vs extraction can be clearly observed (left) at the Upper Jurassic level (around the intra-Draupne interval) as opposed to the seismically derived relative Vp/Vs (right).*

Subsequently, a multi-attribute rotation scheme has been the implemented to derive the reservoir properties. The multi-attribute rotation scheme (M.A.R.S.) is a methodology that uses a numerical solution to estimate a transform to predict petrophysical properties from elastic attributes (Alvarez et al., 2015). This is achieved by estimating a new attribute in the direction of maximum change of a target property in an n-dimensional Euclidean space defined by a number of elastic attributes, and subsequent scaling of this attribute to the target unit properties. The first step is to compute the transform from well-log-derived elastic attributes to the reservoir properties, which is subsequently applied to seismically derived elastic attributes. Such transforms were used to estimate reservoir properties, porosity and volume of shale (Figure 5) based on the derived elastic properties (relative acoustic impedance and Vp/Vs).

It is possible to map and detect untested porous sands located in the Vana basin based on the above attribute (Figure 5). These sand geobodies could correspond to ponded sands associated with deep-water mass deposit transport (MDT) systems (e.g. Cardona et al., 2020) which accumulated in a distal position (suggesting good grain sorting) roughly parallel to the Utsira high slope. These bodies represent reasonable sized porous sand accumulations that may be attractive exploration targets.

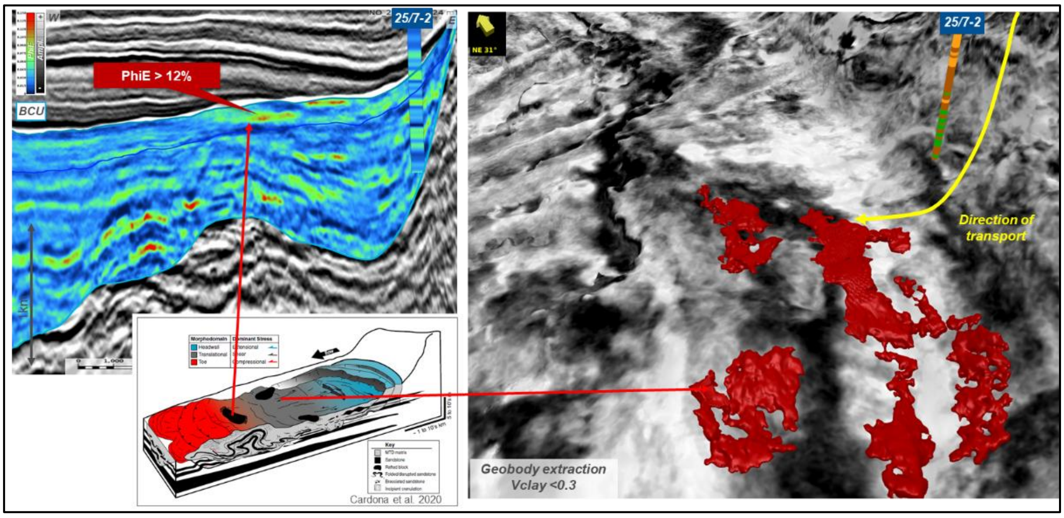


Figure 5. *Porosity estimation (left) using the transform based on data driven elastic attributes. Well 25/7-2 is a blind well and its porosity log is represented with the same color scheme as the seismic attributes. Right: Combination of volume of shale and porosity allow the mapping of the most porous sandstone in the Intra-Draupne interval.*

Conclusions

This paper has demonstrated that new opportunities can be found for near-field exploration in a mature basin such as the Norwegian south Viking Graben. A combination of an innovative acquisition, an entirely seismic driven reservoir properties estimation, and seismic morphology interpretation delivered enhanced imaging and understanding of the Jurassic interval.

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References

Alvarez, P., F. Bolivar, M. Di Luca, and T. Salinas, 2015, Multi-attribute rotation scheme: A tool for reservoir property prediction from seismic inversion attributes: Interpretation, 3, SAE9–SAE18, http://dx.doi.org/10.1190/INT-2015-0029.1.

Cardona, S., Wood, L.J., Dugan, B., Jobe, Z., Strachan L., [2020] Characterization of the Rapanui mass-transport deposit and the basal shear zone: Mount Messenger Formation, Taranaki Basin, New Zealand. Sedimentology (2020) doi: 10.1111/sed.12697

Dunlop, R., Brown, N., Taylor, B., Neill, E., [2020] Step Change in Efficiency and Economies of Scale in OBN Seismic, Conference Proceedings, Second EAGE Marine Acquisition Workshop, Aug 2020, Volume 2020, p.1 – 5. https://doi.org/10.3997/2214-4609.202034025

O'Dowd D., Widmaier M., Roalkvam C., Ciotoli M., Limonta L., [2020] Redefining High Resolution Multi-Azimuth Towed Streamer Acquisition on the Norwegian Continental Shelf, Conference Proceedings, EAGE 2020 Annual Conference & Exhibition Online, Dec 2020, Volume 2020, p.1 - 5 https://doi.org/10.3997/2214-4609.202011886

Reiser C., Bird T., [2021] Multi-Azimuth Quantitative Interpretation: A Case Study from the South Viking Graben, Norway. Conference Proceedings, 82nd EAGE Annual Conference & Exhibition, Oct 2021, Volume 2021, p.1 – 5, https://doi.org/10.3997/2214-4609.202112898

Widmaier, M., O'Dowd, D., Roalkvam, C., Ciotali, M. and Limonta, L. [2020] Addressing imaging challenges in the Viking Graben with multi-azimuth acquisition, longer offsets, and wide-tow sources. 90th SEG Annual International Meeting, Expanded Abstracts, 21-25.