Enhanced regional imaging of Late Jurassic depositional systems across the Northern Viking Graben, Norwegian North Sea

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Summary

In this paper, we present the importance of a regional dataset, acquired and processed with the latest seismic imaging technologies to better understand the depositional environments of one of the main hydrocarbon plays in the Northern North Sea – the Upper Jurassic sandstones. Here we use frequency decomposition colour blending (RGB) to identify depositional pathways of Late Jurassic sands, where they can be seen to feed in from the east extending across to the west through deep water canyon systems, largely controlled by fault systems.

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Introduction

The northern North Sea is an area with very active in oil and gas exploration resulting in several commercial discoveries made over recent years. The Late Jurassic sands are one of the major reservoir plays in the Northern Viking Graben, in particular on the Horda Platform. These deep-water sands are deposited on fault terraces and are largely controlled by regional faulting (Fraser et al, 2003). In recent years, the Late Jurassic Intra-Heather Formation sands (Sognefjord, Fensfjord Formation and equivalents) have been re-explored over the Horda Platform, the Uer and Lomre Terraces and in the Måløy Slope. Wells targeting these sands have resulted in new discoveries such as Swisher and Blasto.

Submarine canyons are an important pathway for the transfer of these sands in deep water environments (Tillmans et al, 2020). Active rifting during the Permo-Triassic and then later in the Jurassic, has resulted in a series of regional fault terraces thought to be a major influence on canyon pathways and hydrocarbon reservoir sand deposition. The structural framework of the terraces evolves from distributed faulting in the early syn-rift phases to localized faulting on fewer large-scale normal faults in the later syn-rift phases (Tillmans et al, 2020).

Enhanced imaging of these sub-marine canyon systems has been achieved in recently processed dual azimuth (DAZ) seismic data, a combination of legacy north-south acquired data and new east-west 3D acquisition enabling deep illumination of prospective Upper Jurassic play targets. The data allows the interpreter to map out these canyon system pathways with more confidence and they can be nicely highlighted by seismic attribute mapping over the Horda Platform using frequency colour blending. In this paper we attempt to demonstrate the importance of how new regional seismic data and seismic attribute mapping are integral to understanding Late Jurassic reservoir distribution in a mature hydrocarbon basin.

Attribute mapping to identify sand bodies

Seismic attributes, which are measurable properties of seismic data, such as amplitude, dip, phase, frequency, and polarity, aid interpretation in identifying geological features, relationships, and patterns which may not necessarily be clearly understood on full stack data (Roden et al, 2015)

This study uses a regional 3D DAZ seismic volume, CGG’s NVG dataset, and a number of wells in the area north of Troll and west of Fram, to present the subtle details found within the seismic data at reservoir level through attribute analysis. Prior to performing attribute analysis on the data, such as spectral decomposition and red, green, and blue (RGB) colour blending, the Upper Jurassic reservoir sands were determined from log data through previously drilled wells. Data such as gamma ray (GR) logs help identify certain depositional intervals depicting cleaner sands from interbedded sands and resistivity logs show differentiation between hydrocarbon and non-hydrocarbon bearing intervals. Some characteristics of depositional sand pathways are clearly identified from full stack DAZ seismic imaging as shown in Figure 1, where the section shows a canyon system in the Upper Jurassic stratigraphy. The magenta interpretation indicates the canyon base, and we can clearly see canyon fill deposits with thinning of the fill over a minor canyon interfluve.

Frequency decomposition has become a vital part of the analysis of stratigraphic formations within 3D seismic data (McArdle et al, 2015). An RGB colour blending model is an effective way of displaying the responses between different frequency bands. In an effort to improve the interpretation of seismic attributes, interpreters tend to co-blend up to three attributes together to better visualize features of interest (Roden et al, 2015). The combination of these frequencies can reveal great details within the colour blends and highlight subtle features of sub-seismic resolution (McArdle et al, 2012).

Here we use frequency decomposition colour blending (RGB) to identify depositional pathways of Late Jurassic sands, where they can be seen to feed in from the east extending across to the west through deep water canyon systems, largely controlled by fault systems.

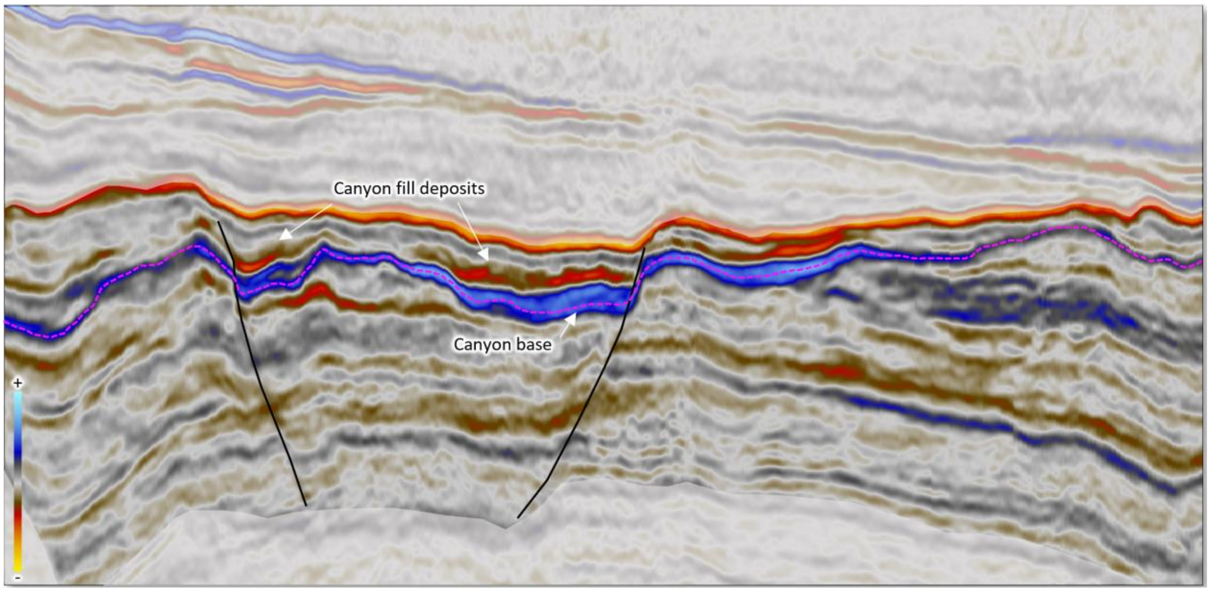

Figure 1 *A full stack DAZ seismic section through an Upper Jurassic canyon system. The magenta interpretation highlights the undulating topography of the canyon base with clear sediment fill in the lows*

Depositional sand systems

In order to select the most dominant frequencies, the seismic was analyzed by using an amplitude spectrum, which was extracted from the data. This allows accurate identification of frequency ranges at the Upper Jurassic target interval. A frequency decomposition RGB blend was created on a horizon stack window ranging from the Base Cretaceous Unconformity (BCU) down to the top of the Brent Group and was determined using the following colour channels: red - 20Hz, green - 30Hz and blue - 40Hz.
An advantage to using a regional seismic dataset can be seen by the colour blending results in Figure 2, which shows a single horizon stack taken within the Upper Jurassic section over an area of >500km^2. Here an attempt can be made to try to better understand depositional sedimentary architectures and local interactions of emerging faults with potential turbidite lobes or channels seen in the area. We can attempt to interpret the Upper Jurassic deep water sediment routing systems across the closely spaced down-stepping fault terraces highlighted by the arrows and shown in white, respectively. This is also indicated by the downdip transport shown by the incision of subtle channels fanning out into lobe complexes (pink stapled lines). Bright amplitude anomalies in the hanging wall of the basin-bounding north-south fault in the east are identified as feeding canyons. When using these selected RGB frequencies we observe how sand has been distributed into smaller basins. The sinuosity of these bright amplitudes is shown to be largely controlled by topography and influenced by fault geometries.

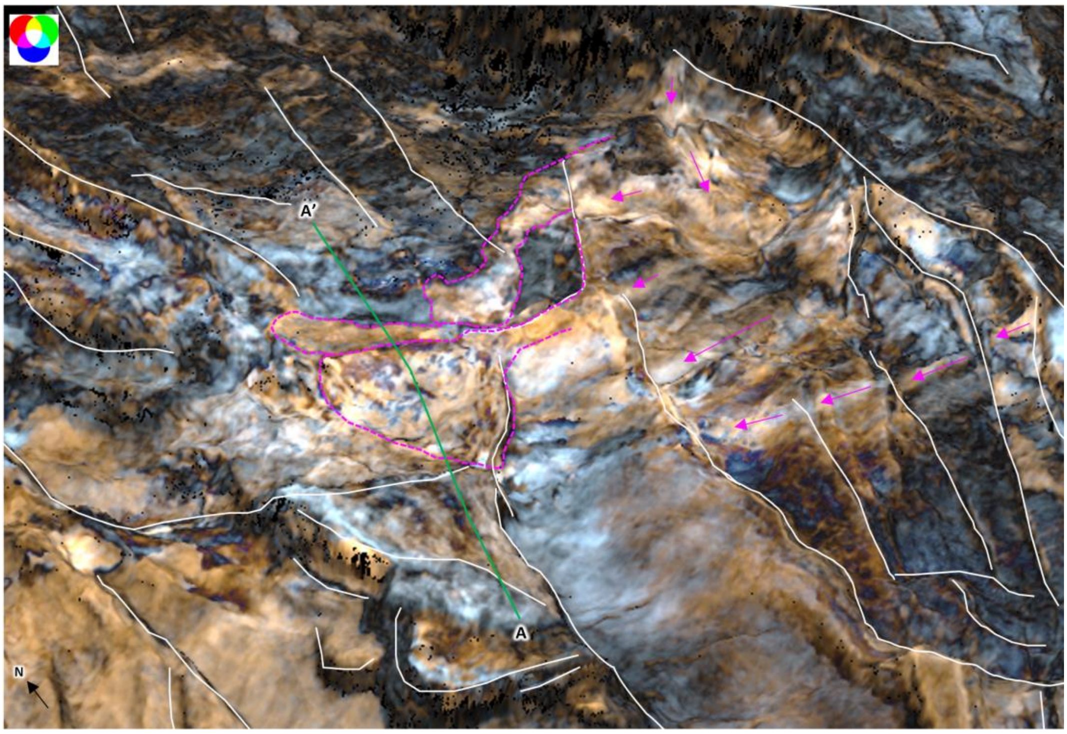

Figure 2 *Frequency decomposition RGB-blend of an Upper Jurassic maximum flooding surface (MSF) horizon stack, red colour channel is 20 Hz, green colour channel is 30 Hz, blue colour channel is 40 Hz. NE trending fault systems are show in white, submarine lobe systems shown in stapled pink line and sediment routing systems shown by the pink arrows. Line A-A' in green shows the location of the arbitrary line in Figure 3*

The results from the frequency decomposition highlight the intricacies of Upper Jurassic sand distribution. We see several depositional lobes at the base of the system fed along canyon systems from the east. Down-slope from the lobes, we can identify an intra-basinal high (Figure 3). In DAZ seismic sections across this high and the sub-marine lobe units we see condensed stratigraphy where sand facies tend to pinch or become faulted out as we down-step to the southwest. The interpretation of the horizon stack (stapled yellow) clearly shows the base of the sub-marine fan fill down flank from the intra-basin high bounding fault. In this interval, we can observe multiple thin stacked sand sequences interbedded with mudstones of the Draupne and Heather formations. We also see an up-dip pinch out of this lobe sequence as we extend northeast and out of the identified lobe complex.

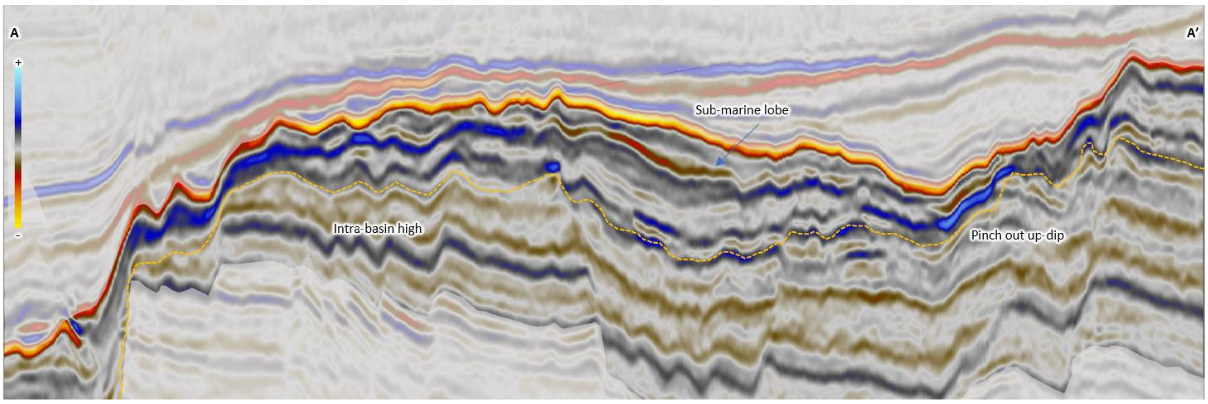

Figure 3 *Line A-A' location is shown in Figure 2. The line transects an intra basin high in the SW and continues across submarine lobe units and then up dip across a local fault. The yellow stapled interpretation is indicating the depth of the MFS horizon stack shown in Figure 2.*

Conclusion

In this paper, we present the importance of a regional dataset, acquired and processed with the latest seismic imaging technologies to better understand the depositional environments of one of the main hydrocarbon plays in the Northern North Sea – the Upper Jurassic sandstones. Using attribute analysis, we can identify different areas of the Upper Jurassic depositional systems from canyons to basin lobes, supported by seismic sections. As we are able to image a near full depositional system of one of many maximum flooding surfaces in the NVG area, it shows the great need for interpretation on large regional datasets to support near-field exploration to identify remaining hydrocarbon potential in the region.

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