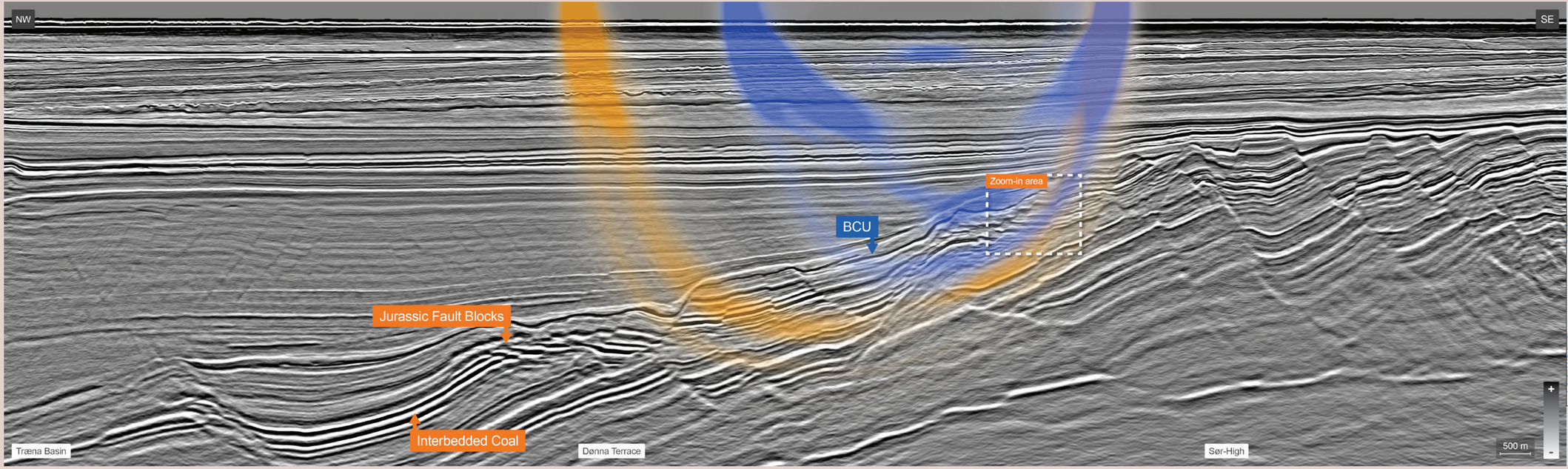
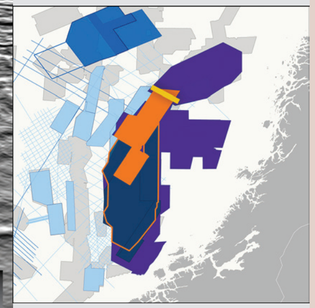
New GeoStreamer X multi-azimuth seismic dataset in the Norwegian Sea unlocks new prospectivity

GeoStreamer X combines multi-sensor towed streamer broadband seismic fidelity and wide-tow source efficiency, with multiazimuth illumination. Earlier this year, PGS added a new GeoStreamer X dataset to its already extensive Norwegian Sea data library. Through a continuous data rejuvenation strategy, utilizing acquisition innovations, imaging advancements and collaboration with industry operators in the area, significant improvement in terms of resolution and signal-to-noise ratio were achieved compared to legacy datasets. The pre-stack image quality is essential for the evaluation and derisking of prospects, and augments interest in the Cretaceous section. We reveal new prospectivity and exploration potential in undrilled structures demonstrating that the Norwegian Sea is still attractive for petroleum exploration.



This 2022 GeoStreamer X multiazimuth full-stack section from the Norwegian Sea includes the Sør High, Dønna Terrace, Ytreholmen Fault Zone and crosses the Urd and Verdande areas. The section represents the dominant Lower Cretaceous (Lysing and Lange Formations) and Jurassic (Fangst and Båt Groups) plays. The difference of the depth of penetration of refracted energy for 7 km and 10 km cable lengths is shown here using FWI refraction sensitivity kernels and illustrates the uplift achieved through the utilization of long streamer-tails. Images from the marked zoom-in area appear in Figure 2.



The GeoStreamer X 2022 survey is shown in orange, highlighting the location of the line displayed. The survey area for the GeoStreamer X 2023 survey and the 2024 programs is also outlined in orange.

CONTENT MARKETING

GeoStreamer X innovative acquisition design and advanced processing

Key to enhanced subsurface imaging

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THE NORWEGIAN SEA is renowned for its high-quality hydrocarbon reservoirs situated within complex geological settings. Tilted fault blocks, formed during Late Jurassic rifting, host prolific pre-rift petroleum plays, characterized by high-quality Jurassic sandstone reservoirs located in structural traps. Recent advances in seismic processing deliver improved data quality and have redirected attention toward marine post-rift deep-water clastic systems and stratigraphic traps within the Cretaceous section. Looking ahead, the drilling will continue to focus on more complex accumulations for both exploration opportunities and potential field development extensions. A critical factor in evaluating these opportunities lies in high-resolution, AVO-friendly seismic data that provides comprehensive subsurface illumination beyond what single azimuth data can offer.

GEOSTREAMER X: FROM ACQUISITION INNOVATIONS TO SUPERIOR IMAGE

The 2022 GeoStreamer X acquisition program covers an area of approximately 6,777 km². The acquisition program was designed with an azimuth orientation perpendicular to the existing GeoStreamer datasets acquired between 2011 and 2016. Through a combination of reprocessing existing data and employing state-of-the-art depth imaging techniques, a large scale and uniform multi-azimuth dataset was created for the region.

The innovative GeoStreamer 2022 acquisition configuration employs a wide-tow triple source setup, allowing dense crossline sampling. The source array separation was 250 m between the outer arrays, and the data was recorded using 14 streamers spaced at 75 m intervals (12×7 km and 2×10 km long). The 2 long streamers, referred to as streamer-tails, were extended to achieve longer offsets, which provide greater depths during FWI-based velocity model building. The difference of the depth of penetration between the 7 and 10 km streamers is shown using FWI sensitivity kernels on the foldout line and illustrates the uplift from 10 km-long streamer-tails.

Additionally, the cables are towed as close as possible to the source arrays, allowing near offset reduction to 65 m. These near traces help to improve the de-multiple flow and led to an improved and detailed image in the very shallow overburden. The significantly enhanced near-offset distribution provides further comprehensive azimuthal coverage and together with the already existing GeoStreamer azimuth allows the utilization of all traces together in a regularization scheme.

IMPROVED SUBSURFACE RISK AND UNCERTAINTY ASSESSMENT

Rigorous control over the Amplitude vs Offset (AVO) behaviour throughout the entire processing sequence has yielded a dataset well-suited for exploration, near-field exploration, infrastructure-led exploration (ILX), and appraisal activities. The final dataset's quality has been quantitatively assessed by well to seismic ties across 43 wells in both the Cretaceous and Jurassic intervals. The cross-correlation coefficients, averaging over 0.7 on the multi-azimuth full stack, underscore a significant improvement in signal-to-noise ratio when compared with single azimuth legacy data. This uplift is particularly evident in low-reflectivity Cretaceous sections, as illustrated in the well-to-seismic tie panel for the 6406/3-9 well shown in Figure 1.

Improved GeoStreamer X multiazimuth illumination leads to significant enhancement in structural and stratigraphic imaging in both the Jurassic and Cretaceous sections. Fault plane imaging depends on illumination direction and in some cases, minor fault features that are not visible on the single azimuth data become apparent. The estimation of fault offset magnitudes can also depend on the illumination angle – one zoom-in example from the foldout line (marked with a rectangle) is presented here in Figure 2. Analysis of this new perspective can lead to better structural fidelity and structure uncertainty understanding, and consequently to improved appraisal of e.g. trap geometry, block compartmentalization, and fault property estimation.

The new data represents a significant advancement to unlock the full Cretaceous potential. It allows interpreters to investigate subtle structural features that constrain and compartmentalize prospects. The true value of this lies in enhanced trap geometry analysis and reservoir characterization, which accurately captures prospect segmentation and internal reservoir continuity.

GEOSTREAMER X HELPS UNLOCK REMAINING PROSPECTIVITY

To further assess the remaining prospectivity within the area, the dataset was inverted in a pre-stack simultane-

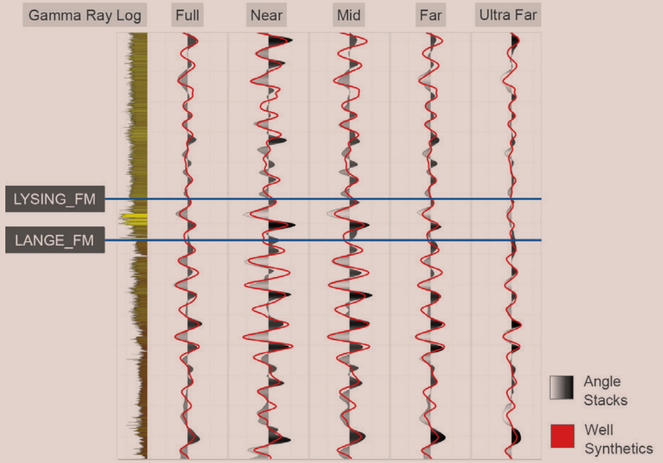

Figure 1: Representative well-to-seismic tie (well 6406/3-9; oil discoveries within Lysing Fm. and Lange Fm.) within the Cretaceous, in the low reflectivity section. Consistent Amplitude-vs-offset (AVO) behavior through the partial stacks indicates high potential for successful seismic reservoir characterization.

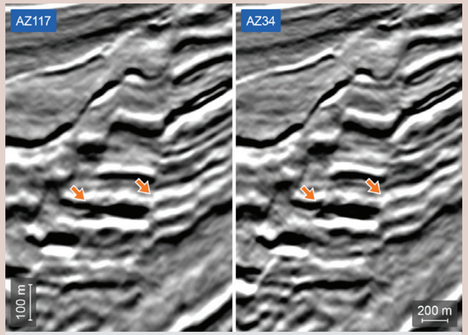

Figure 2: A comparison of Middle Jurassic depth sections of new azimuth (Azimuth 34; left) and reprocessed legacy (azimuth 117; right) downdip of the Svale field (area marked on foldout line) illustrates the dependency of structural imaging on illumination direction. While reflector termination against faults is improved, fault plane positioning and inferred fault zone width diverge. Interpretation of individual fault blocks would result in variable fault offset estimations between the two azimuths. Also, internal faulting of fault blocks and reflectivity within the blocks can show significant variations.

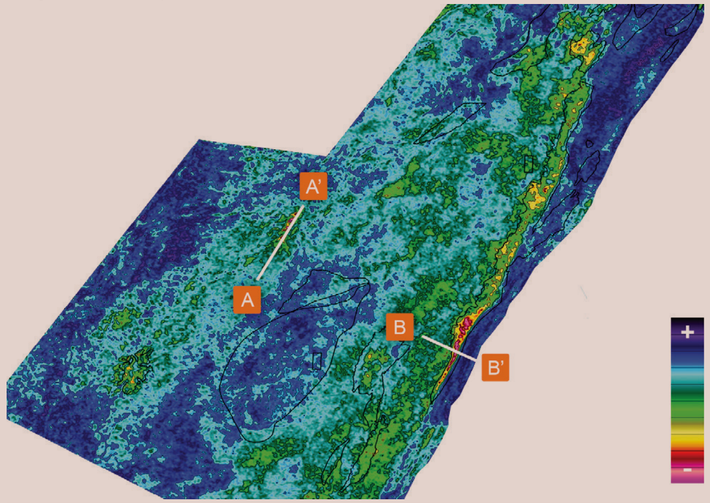

Figure 3: A map of inverted Vp/Vs ratio distribution within Lysing Fm, underlying existing fields and discoveries of Ærfugl, Ærfugl Nord, Marulk or Nidhogg, with the location of seismic lines through Ærfugl field (B - B') as well as the undrilled prospect (A – A') shown in Figure 4. Outlines of existing fields added for easier orientation.

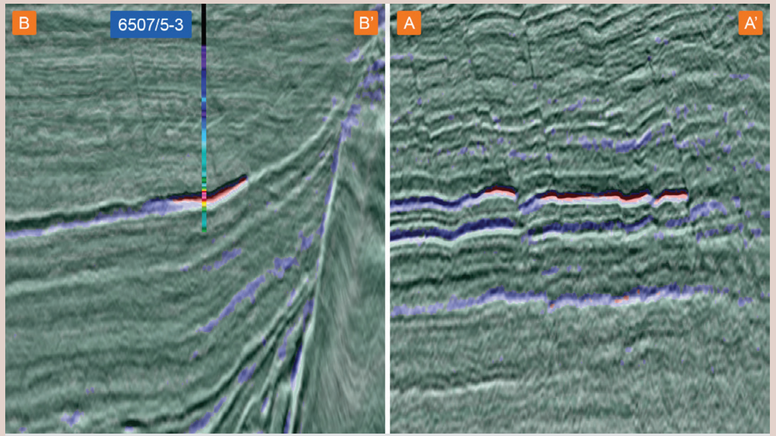

Figure 4: Example of stochastic litho-fluid classification of inversion results; Lysing Fm. known accumulation - Ærfugl line through discovery well 6507/5-3 (line B – B' shown in Figure 4); Vp/Vs log upscaled to seismic resolution displayed on the well track) and undrilled prospect (line A – A' shown in Figure 4); red – gas bearing sand, blue – water bearing sand, green – claystones.

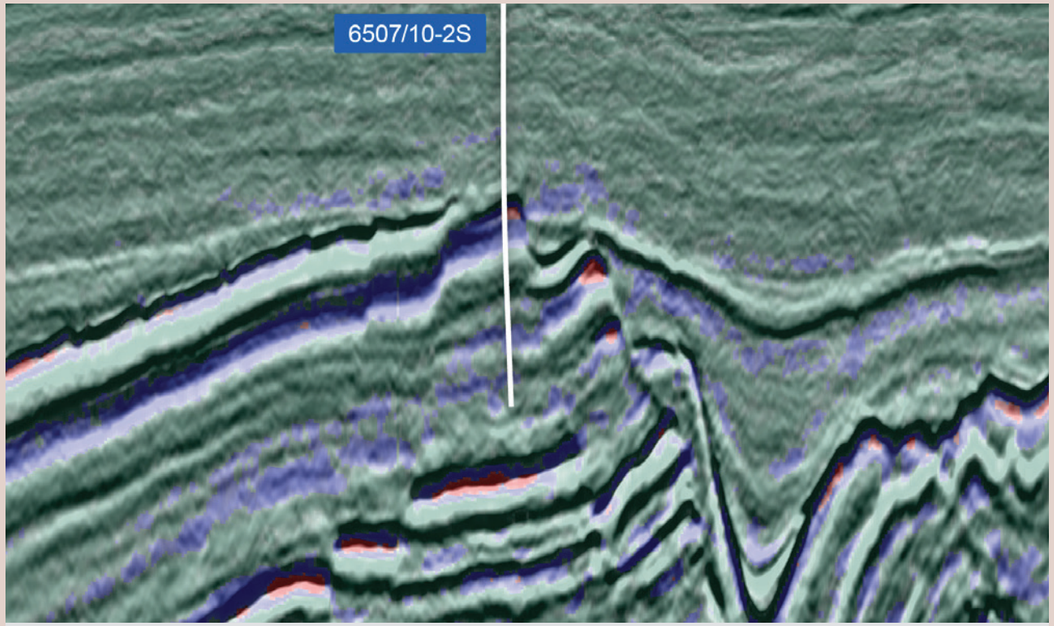

Figure 5: Line through Novus discovery well (6507/10-2S) litho-fluid classification result, highlighting the possibility of additional resources on a down-thrown fault block. Red – gas bearing sand, blue – water bearing sand, green – claystones.

ous inversion scheme to P-Impedance and Vp/Vs. Furthermore, by leveraging PGS' comprehensive petrophysics and rock physics rockAVO library, stochastic depth dependent rock physics modeling of Cretaceous and Jurassic intervals was conducted. The inversion results were subsequently classified using a Bayesian scheme in terms of the most likely lithology-fluid class.

The facies classification process integrates both seismic and well information, yielding a probabilistic description of the subsurface. These results correlate well with known accumulations, the Ærfugl litho-fluid classification line through discovery well 6507/5-3 is presented on Figures 3 and 4 (left), together with the identified prospect Figure 4 (right) - and provides further reassurance regarding hydrocarbon fill as a cause of the prospects anomalous seismic amplitude and AVO response.

In the Jurassic, there is potential for added reserves in existing developments and discoveries. Figure 5 shows Well 6507/10-2S (Novus discovery well) drilled by Faroe Petroleum Norge in 2014 about 13 km south of the Heidrun platform encountered oil and gas (24,5 m column total) in a reservoir with better-than-expected quality. After resources evaluation, the discovery was deemed non-commercial – despite easy tieback to Heidrun facilities.

After our analysis of the inversion results and litho-fluid classification, we reveal the possibility of added resources in a down-thrown fault block. The litho-fluid classification in the existing discovery agrees very well with hydrocarbon column height encountered in the well. If confirmed, a similar 50 m hydrocarbon column in the downthrown block within the Middle Jurassic Garn Fm. reservoir would affect subsurface volume estimation and the economics which could in turn result in development plans being brought forward. A similar but small anomaly in an underlying section suggests the presence of additional reserves at deeper stratigraphic levels.

GEOSTREAMER X SOLVES EXPLORATION CHALLENGES

Through a small number of example extractions, we have demonstrated how an innovative acquisition set-up with wide-towed sources and a state-of-the-art depth imaging workflow, result in a high quality, multiazimuth broadband seismic dataset that has the potential to help overcome the main exploration challenges in the Norwegian Sea. Adding a second perspective/illumination direction allows for the assessment of the uncertainty in fine structural details and delivers a significantly improved understanding and characterization of shallow to deep reservoirs. Leads and opportunities suitable for near-field exploration have been mapped using an integrated quantitative interpretation workflow. There are many more to be unraveled!

SUBSURFACE STORAGE

"But is the secrecy around pressures something that we just have to accept in the same way as there is competition between oil companies chasing for oil or gas? I am not convinced of that yet."

Henk Kombrink – GEO EXPRO