Greater Johan Castberg area, Barents Sea: Outstanding near-offset coverage and long-offset FWI

High-quality seismic data is a key requirement for successful field development and exploration. To help with this process, CGG, together with TGS, recently acquired a multi-client TopSeis™ 3D seismic survey in the Johan Castberg area of the Barents Sea. The survey, known as "Greater Castberg" (blue polygon in figure 4), was acquired and imaged using the latest advances from CGG's proprietary TopSeis solution. An innovative, highly efficient acquisition spread was deployed, enabling the 5168 km² survey to be acquired in only 90 days during the autumn of 2019.

The latest TopSeis advances include a wide distribution of five sources over the spread together with one source in front of the spread (see figures 2 and 6). This delivers a very dense crossline sampling and an approximately 12 times higher trace density than would be possible with conventional solutions. Maximum offsets of up to 8.2 km from the front source provide long-offset data for advanced data-driven velocity model building.

An early fast-track dataset shows outstanding imaging of the Greater Castberg area's highly diverse and complex geology. An advanced fast-track volume will be ready for licensing in May and the final dataset will be available in Q1 2021.

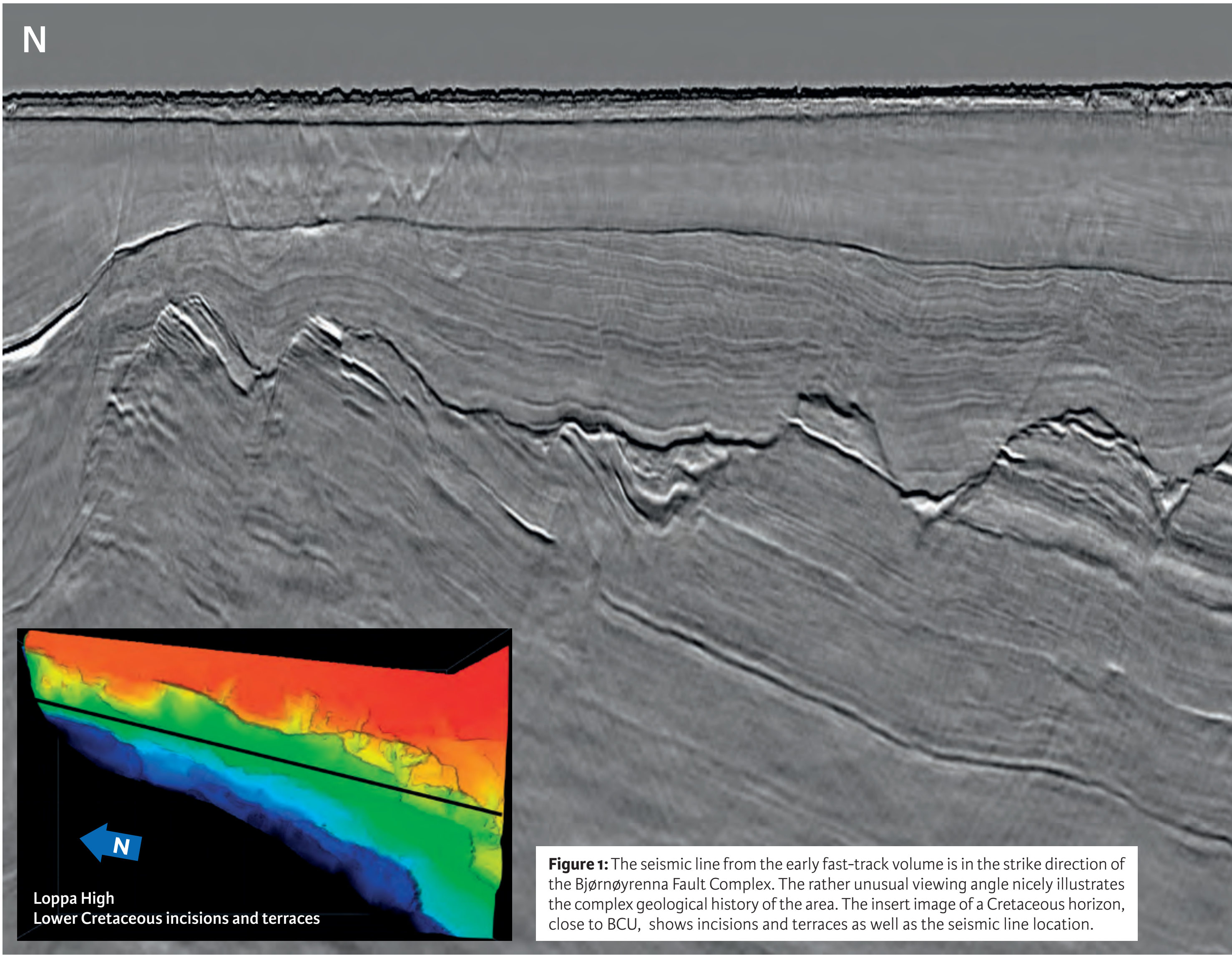


Figure 1: The seismic line from the early fast-track volume is in the strike direction of the Bjørnøyrenna Fault Complex. The rather unusual viewing angle nicely illustrates the complex geological history of the area. The insert image of a Cretaceous horizon, close to BCU, shows incisions and terraces as well as the seismic line location.

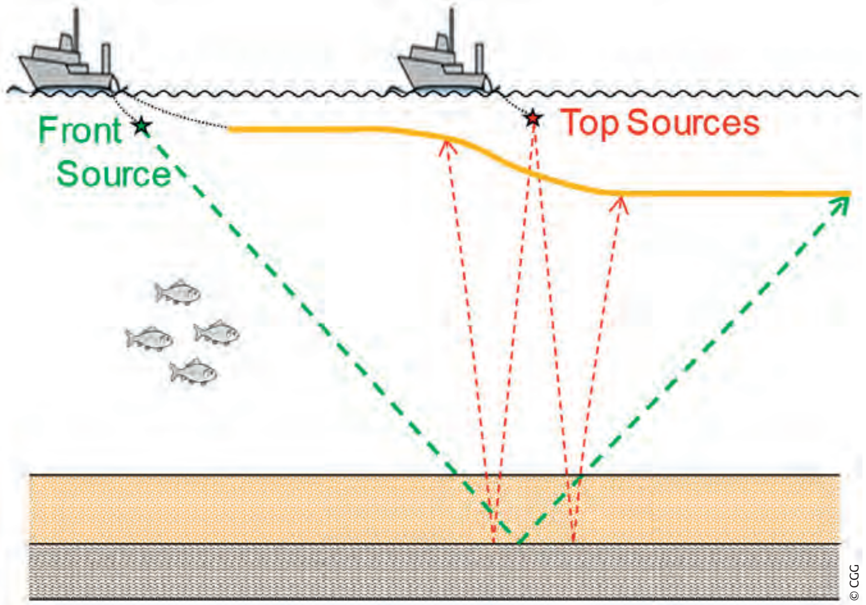


Figure 2: The latest TopSeis advances include a wide distribution of five sources over the spread together with one source in front of the spread.

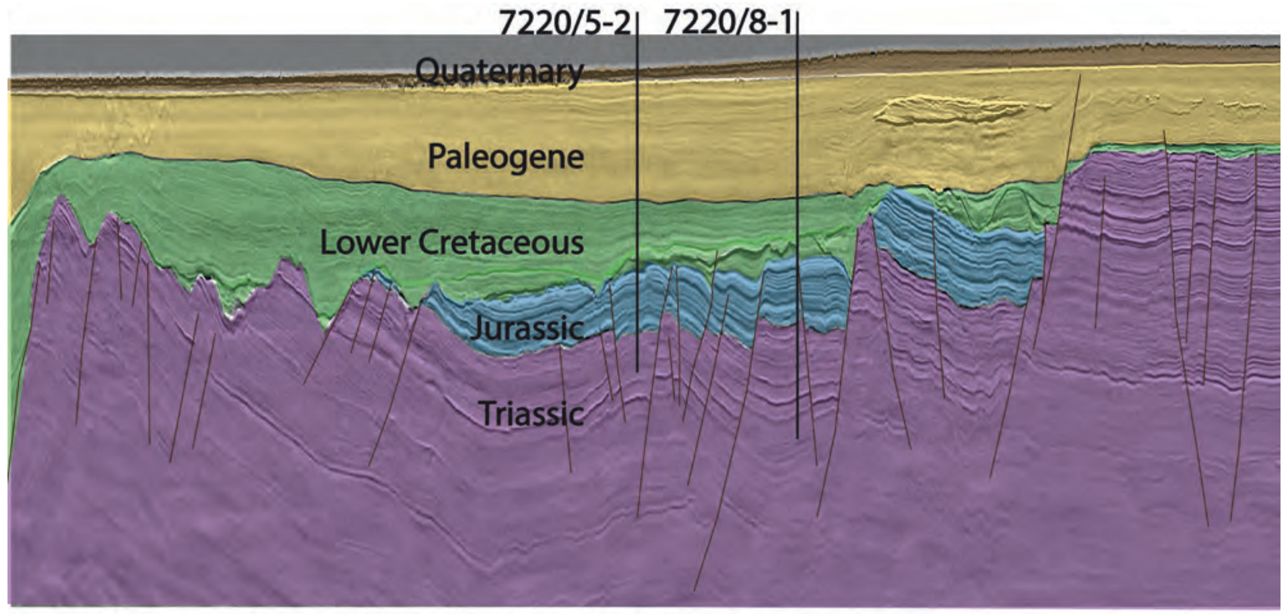


Figure 3: The same seismic line as below with interpretation included.
Detailed stratigraphy, faults and large-scale incised valleys from the Early- to Mid-Cretaceous erosion can be mapped.

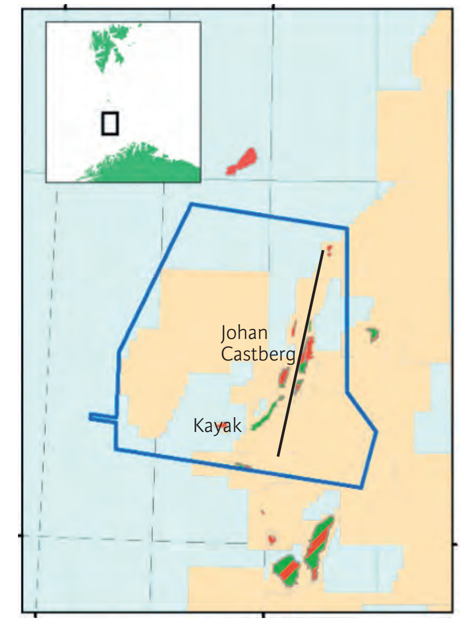
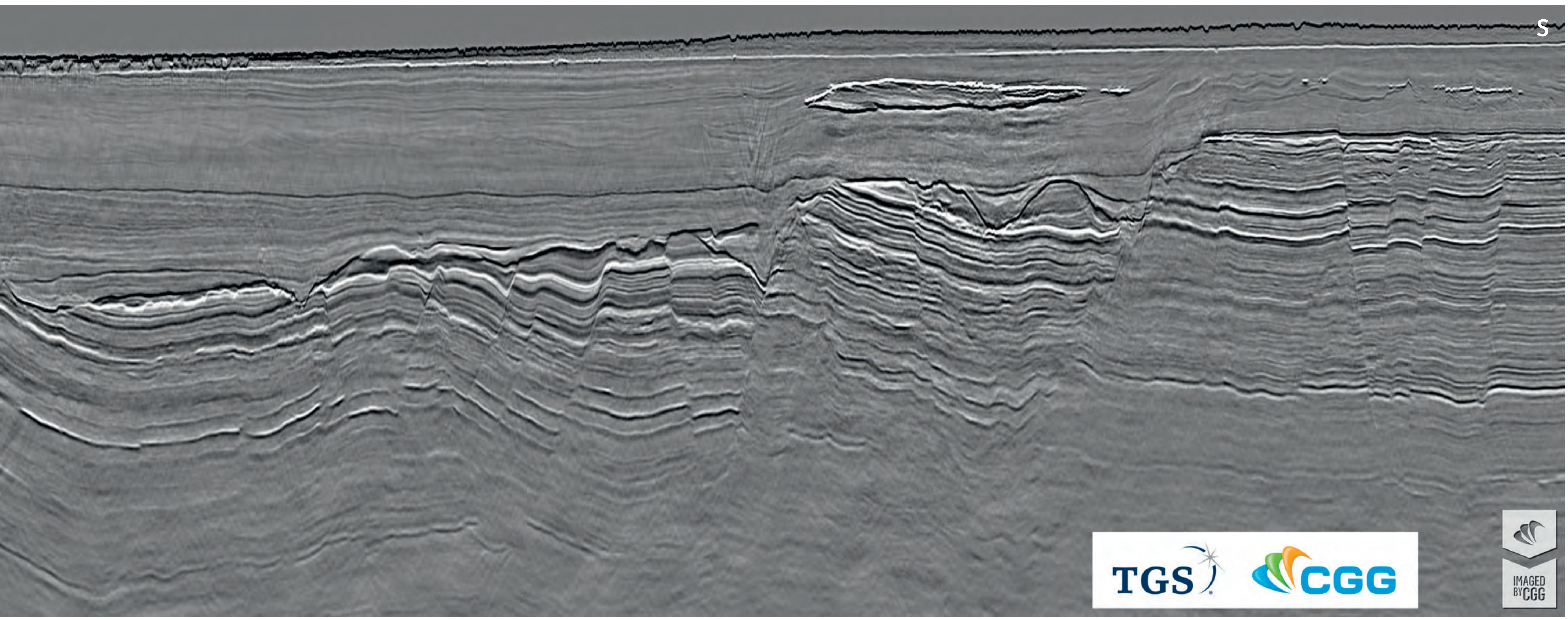


Figure 4: Blue polygon showing location of the Greater Castberg survey. Black line indicates seismic section below.



High-resolution source-over-the-spread imaging with long-offset FWI

The Greater Castberg area offers a number of exploration models in both proven and unproven plays. High-quality seismic data is key to better imaging.

Text: VETLE VINJE, IDAR KJØRLAUG, GUSTAV AA. ERSDAL, MARIT STOKKE BAUCK, ANNA RUMYANTSEVA and SILJE ROGNE, CGG

With the Johan Castberg development project progressing towards production starting in 2022, this first infrastructure will open up this part of the Barents Sea for further exploration activity.

Greater Castberg seismic challenges

Well-known imaging challenges faced in the Barents Sea are the region's hard and rugose seafloor and shallow reservoirs. Shallow gas and gas hydrate anomalies also pose severe challenges to imaging the strata below. The rugose seabed is caused by numerous iceberg scouring marks, as clearly shown on the auto-tracked seabed horizon in **figure 5**.

TopSeis solution for high-resolution images

To overcome the challenges of imaging the shallow Barents Sea reservoirs, CGG and Lundin Norway developed an innovative source-over-spread acquisition and imaging solution, known as TopSeis™ (Vinje et.al. 2017, Dhelie et.al. 2018).

The original TopSeis solution involved a pure streamer vessel and a pure source vessel. Positioning the source vessel at the center of the deep-towed spread with sources wide apart delivers a split-spread seismic dataset rich in near-offset traces. These near-offset traces are recorded in the deep, quiet part of the cable, far from the noisy front part of the cable and the swell noise from the water surface. The first full-scale source-over-spread acquisition conducted in 2017, combined with an advanced imaging sequence, provided an excellent uplift in the resolution of the seismic image and better bandwidth than the vintage data.

Increased industry interest in this new technology led CGG to start working with TGS in 2018 to design a new acquisition campaign that would improve images and AVO over the Greater Castberg area.

Sources in front and increased efficiency

A shortcoming of the original TopSeis design was the limited maximum offsets, caused by source placement in the center of the spread. This was solved by also equipping the streamer vessel with seismic sources. The deployment of a large front source generated the extra far-offset data necessary to accurately model-build through FWI, while the smaller distributed source-over-the-spread secured the near-offset and high-trace-density benefits for a high-resolution image.

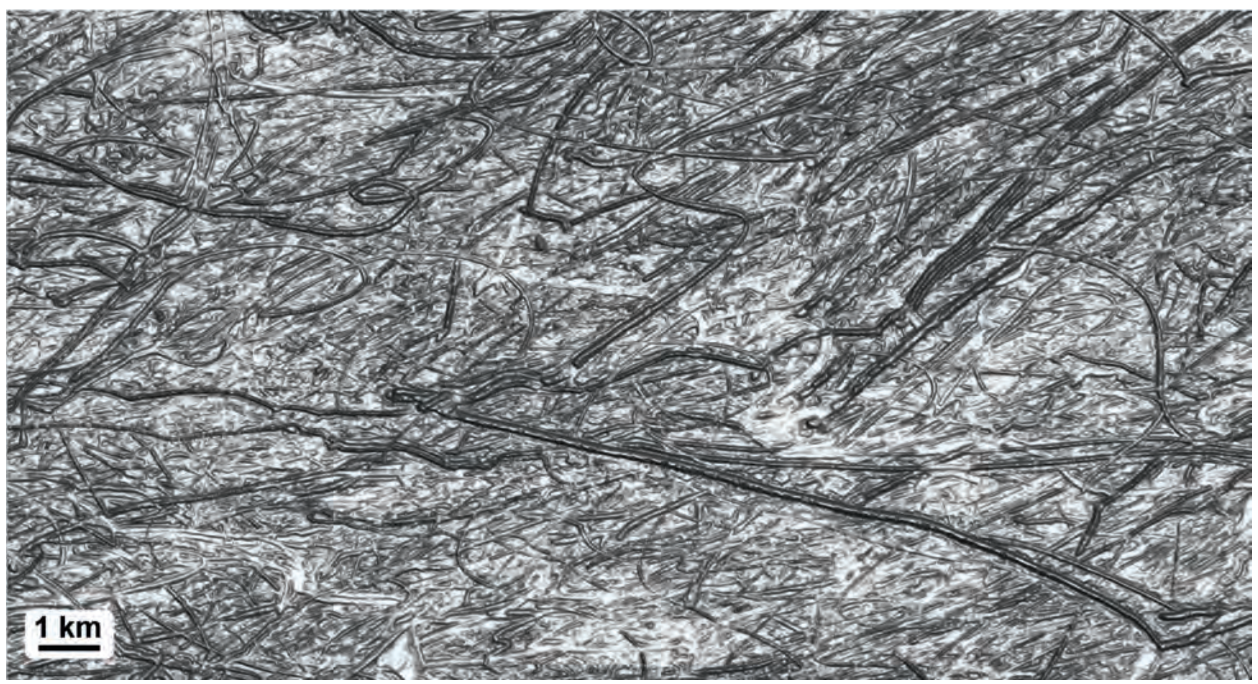


Figure 5: Interpretation of the seabed from the **Greater Castberg 2019 TopSeis** early fast-track volume gives an impressive image of the details of iceberg scouring marks.

For the 2017 survey, a sail line spacing of 300 m was selected, due to the limited source separation (133 m) achievable at the time. Although this provided good near-offset coverage and a high trace density, it was not very efficient. Additional field tests in the summer of 2018 demonstrated that it was possible to increase wide-source tow separation to a new safe limit of 300 m, thus increasing the sail line spacing to 500 m. To maintain the trace density, the number of sources was increased from three to five.

After a year of extensive testing and development (Camerer et.al. 2018, Vinje & Elboth 2019), the acquisition geometry shown in **figure 6** was deployed for the Greater Castberg 2019 TopSeis survey.

Complex geology revealed

The Greater Castberg survey covers an area with a complex structural evolution.

Some of the key structural elements are the deep Bjørnøya Basin in the west, the Bjørnøyrenna Fault Complex, Polheim Subplatform and the Loppa High in the east.

The foldout section along strike in the Bjørnøyrenna Fault Complex clearly shows two stages of post-Caledonian extension: The Middle Jurassic-Early Cretaceous rift system and the Late Cretaceous-Paleogene rifting. Both are associated with uplift of the Loppa High. The dataset clearly reveals the paleo Loppa High as an elevated tectonic element in the Paleozoic to Triassic, with erosion and incision into basement (**Figure 7**).

The shallow marine inner-shelf-to-fluvial sediments of the Triassic to Middle Jurassic Realgrunnen Subgroup were deposited in the western Barents Sea. Near-shore channels and sand bars can potentially be identified in the relatively continuous and homogenous packages seen in the seismic data (**Figures 1** and **8**).

In Johan Castberg, hydrocarbons are present in the Early and Middle Jurassic Nordmela and Stø formations of the Realgrunnen Subgroup, as shown by the double flat spot seen within the Skrugard discovery (**Figure 8**). The oil and gas is thought to be primarily sourced from the Upper Jurassic Hekkingen Formation. The discoveries also indicate complex fill histories, which include a paleo oil charge, Tertiary uplift (> 2 km), dismigration, in-reservoir biodegradation, and late-stage refill with gas (Z. Matapour and references therein).

In the Bjørnøyrenna Fault Complex, wedge-shaped sedimentary units are seen in the Middle to Late Jurassic and Early Cretaceous section. Uplift and erosion of basin margins with subsidence along the major boundary faults during the Early Cretaceous led to the deposition of gravity flows into the basin. This resulted in incised valleys forming during several Early Cretaceous erosional events, as seen in the insert figure on **figure 1.**

Figure 9 shows a seismic profile through the Kayak discovery (**figure 4**). Several pulses of sediment input are gradually filling up the fault terraces and occasionally spilling over into the deeper basin. Kayak well 7219/9-2 confirmed hydrocarbons in the late Cretaceous sands.

The Greater Castberg seismic dataset covers a number of viable play types, such as:

- Fractured and weathered basement, with potentially minor sand-filled half grabens (**figure 7**)

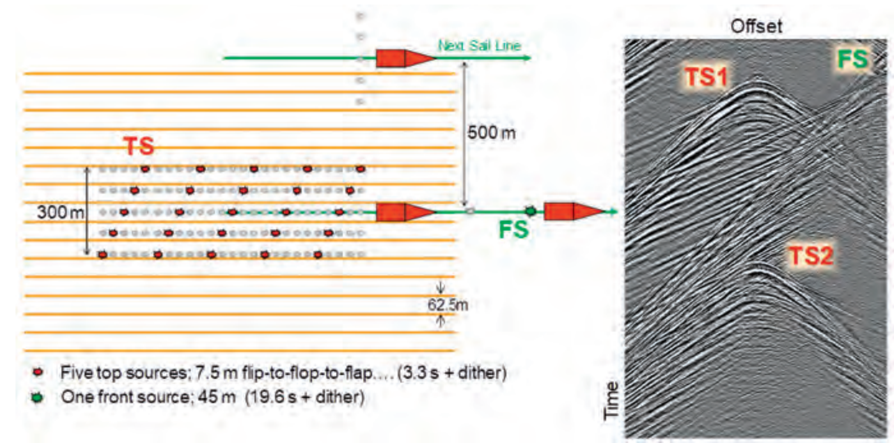


Figure 6: Greater Castberg 2019 TopSeis survey configuration and an example of blended seismic data. Five sources, with a 300 m separation, a wide tow of 16 cables and a sail line separation of 500 m. This design is even more time-effective than standard conventional marine surveys in the Barents Sea. This solution provides 6.25 x 6.25 m bin size, a trace density about 12 times higher than conventional solutions and maximum offsets from the front source of up to approximately 8.2 k.

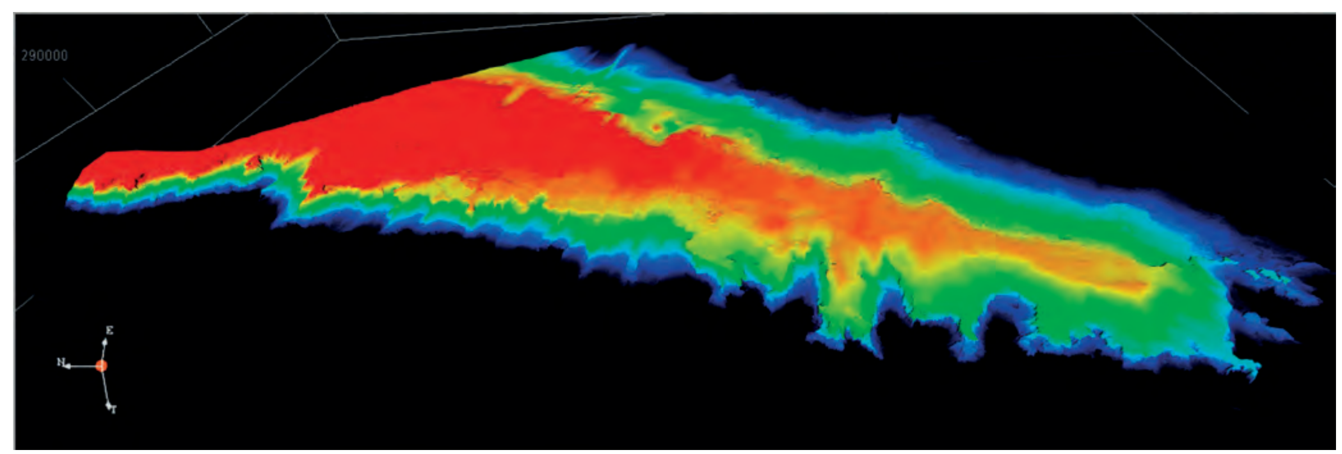


Figure 7: Interpretation of top Basement horizon from the early fast-track volume. Incisions and structure within the Basement over the paleo Loppa High can be seen.

- Paleozoic carbonates as found within the Alta-Gotha discoveries
- Rotated fault blocks with Realgrunnen sand reservoirs and primarily Upper Jurassic Hekkingen Formation charge (**Figure 8**)
- Early Cretaceous syn-rift sediments as seen in the Kayak discovery (**Figure 9**)
- Early Cretaceous stratigraphic traps in low-stand submarine fan deposits
- Cretaceous Kveite Formation - Paleocene Torsk Formation shallow-marine-to-offshore sands as seen in the Pingvin discovery.

The right technology in the right place at the right time

The Greater Castberg 2019 TopSeis survey demonstrated that high-resolution seismic data can be acquired efficiently with a high trace density of near offsets while maintaining far-offsets required for accurate data-driven model building. CGG's pioneering processing and imaging technologies leverage these unique datasets to deliver high-quality imaging, that enables detailed and regional-scale interpretation and mapping of important geologic features for play and prospect definition in an area of the Barents Sea where a number of play models are proven and production infrastructure will soon be in place.

References are found in our website-version: expronews.com/

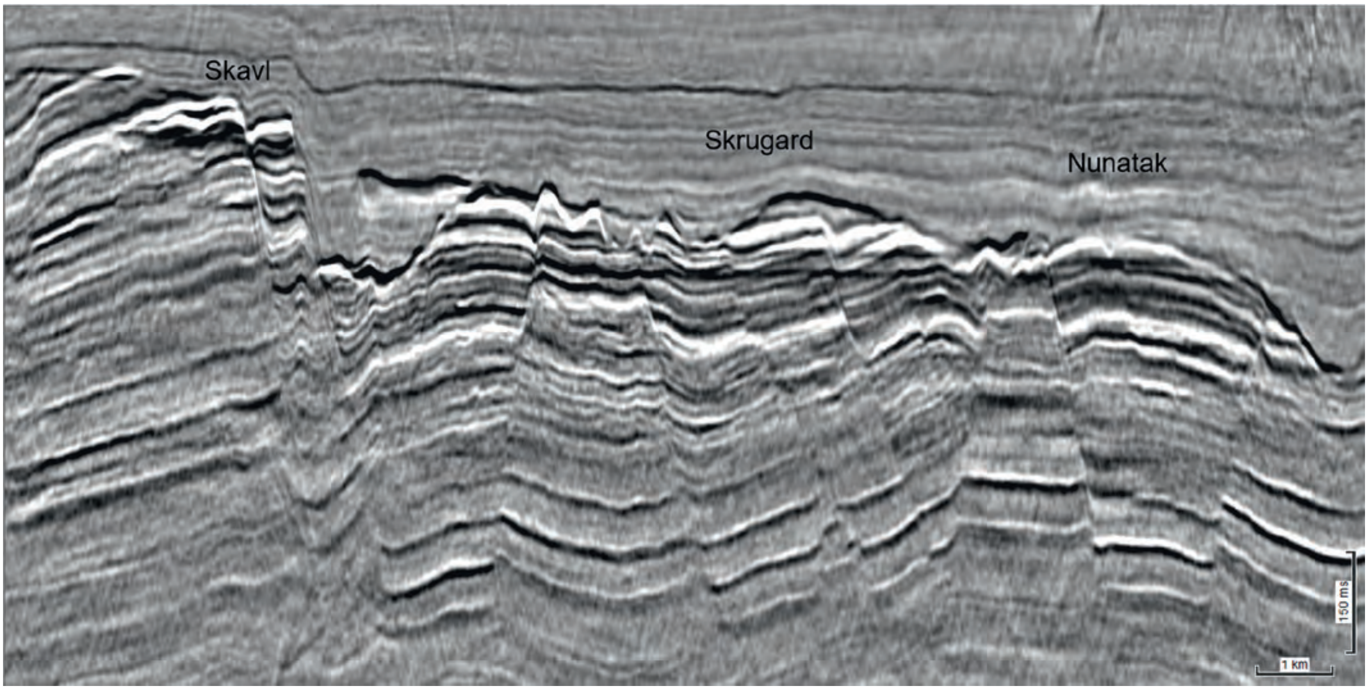


Figure 8: Seismic image from Greater Castberg early fast-track data crossing three discoveries. The Skrugard discovery from 2011 is now together with the later Havis and Drivis discoveries known as the Johan Castberg field. According to NPD, production from Skavl (oil/gas) is likely, but production from Nunatak (gas) is unlikely.

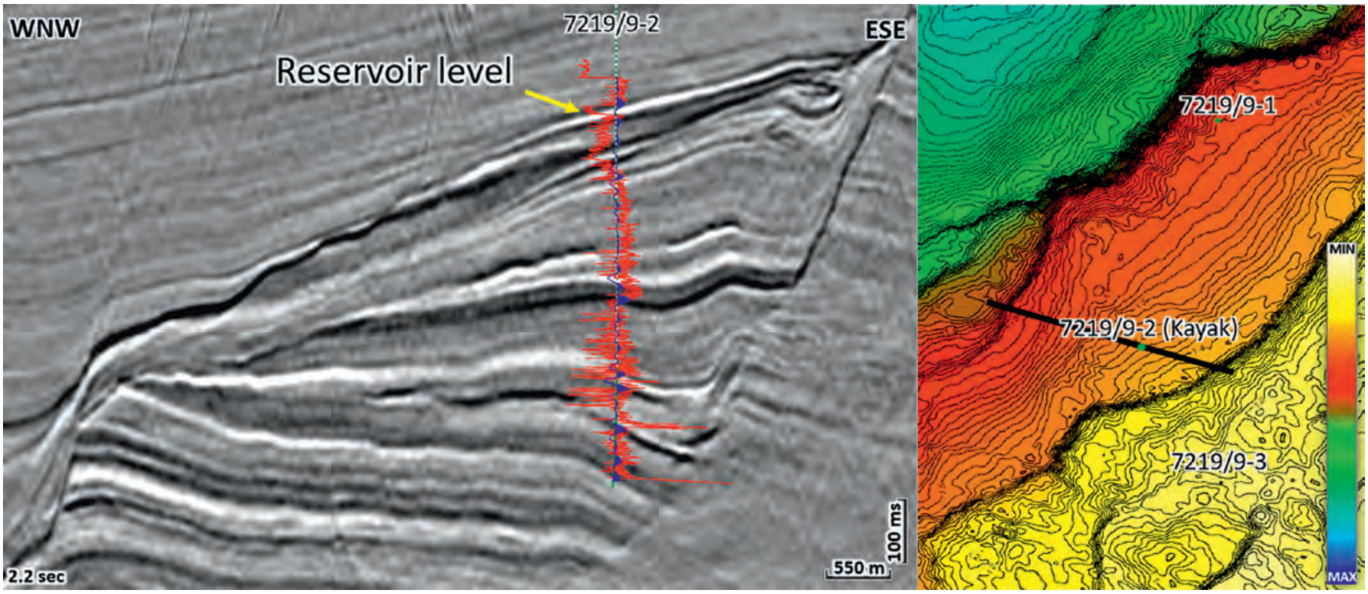


Figure 9: Kayak well 7219/9-2 with gamma log and synthetic trace. Several lobes of sand are visible as the prominent white events which tie to the low gamma ray values on the well log.