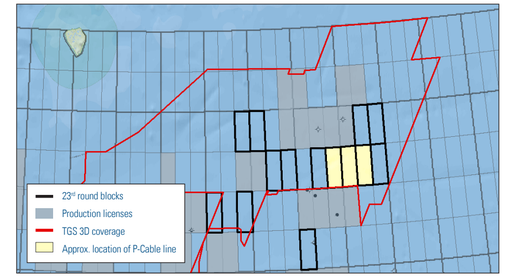
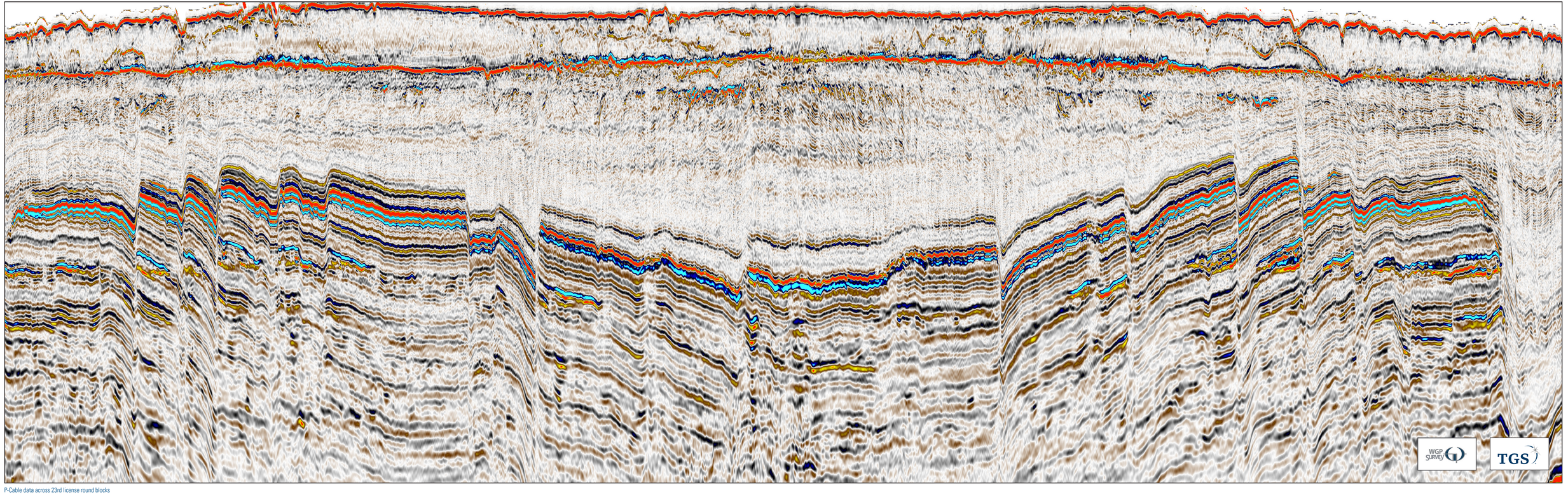
Hoop Basin

Drilling success and playground for new exploration methods





P-Cable data across 23rd license round blocks

Hoop Basin

The Hoop Fault Complex area of the Barents Sea has seen great exploration success lately. The area offers a condensed Paleozoic and Mesozoic succession with multiple-interval exploration targets in well-defined structural traps. In particular, the Jurassic succession in shallow fault blocks has been successful, with several light oil discoveries in good reservoirs. The Hoop Fault Complex is now one of the core areas for the Norwegian 23rd licensing round.

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The Hoop Fault Complex has been a focus area for several exploration companies since 2009 and the first 3D seismic data set was acquired by TGS. Five exploration wells have been drilled, resulting in two light oil discoveries in good Jurassic reservoir rocks. The relatively shallow exploration targets make the area suitable for other geophysical methods than "normal" 2D and 3D seismic data. The industry demands higher resolution data. The large Hoop Fault Complex data set has been reprocessed using broadband processing techniques and P-Cable 2D and 3D seismic is being acquired to satisfy industry demand. The ongoing seafloor sampling might reveal information about the presence and phase of hydrocarbons in the structures, and Controlled Source Electro-Magnetic (CSEM) data has been proven as a useful tool in the area.

While all these methods are valuable on their own, the integration of several data sets will be essential for hydrocarbon exploration in the Hoop Fault Complex area.

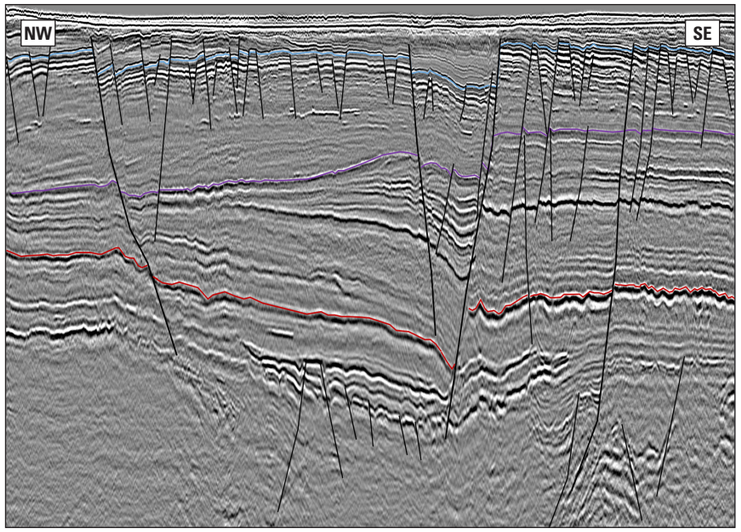

Fig. 1 - Interpreted seismic line across the Hoop Graben. Horizons: Blue = Top Jurassic, Purple = Mid Triassic, Red = Top Permian.

STRUCTURAL GEOLOGY OF THE HOOP FAULT COMPLEX AREA

The Hoop Fault Complex has experienced several episodes of faulting. Deep in the section faults are cutting Carboniferous and possibly older strata. The Triassic, Jurassic and Cretaceous successions are offset by a younger series of faults trending north-northeast south-southwest. These faults and successions make up the characteristic Hoop Graben, which can be seen in Figure 1. Overprinting these episodes of faulting, the Upper Triassic to the onset of the Cretaceous section has also been affected by a late east-west trending system of faults. These faults are important for the definition of fault-bounded structural closures in the Jurassic section, which have been targeted in the successful Wisting Central and Hanssen wells. The different structural styles seen in the Hoop Fault Complex can have large implications for the migration and re-migration of hydrocarbons into the shallow structures.

POTENTIAL RESERVOIR ROCKS

Post-Eocene erosion has removed a lot of Cretaceous and possibly younger strata from the Hoop Fault Complex area. This has implications for hydrocarbon exploration. The erosion of the upper part of the section has made older strata more easily accessible for explorationists.

In certain areas near the Hoop Fault Complex, the Permian and possibly the Carboniferous section are shallow enough to be considered exploration targets. Carbonate buildups are possible targets in this section. Carbonate rocks that have experienced subaerial exposure might have developed good secondary porosity. With Lundin's exploration success on the Gohta prospect further south in the Barents Sea in mind, this is also something that should be explored.

The most prominent sedimentary features in the Hoop Fault Complex area are the deltaic deposits of the Triassic. These can be seen as large-scale northwest prograding clinoform packages. The clinoforms packages thin towards the north-west, and the most westerly position of paleo-coastline appear to be in the Hoop Fault Complex area for the Klappmyss, Kobbe and Snadd formations. Statoil's Atlantis, which tested the Triassic section in a large closure adjacent to the Hoop Graben, was not successful. While the main target was the Middle Triassic Kobbe formation, the well result was a small gas discovery in thin Upper Triassic sands. An excellent quality oil-prone marine source rock of the Middle Triassic, the Steinkobbe Member of the Kobbe Formation, has been confirmed by Sintef IKU's shallow stratigraphic boreholes near the Svalis dome. Large deltaic channel systems of the Upper Triassic Snadd Formation can be seen as bright amplitude anomalies on seismic data. More exploration effort and the use of higher resolution data is needed to thoroughly explore the Triassic section in this area.

So far the Jurassic succession has been the most successful in terms of hydrocarbon exploration in the Hoop Fault Complex area. The Upper Jurassic Hekkingen Formation source rock is believed to be mature along the flanks of the basins adjacent to the Hoop Fault Complex. Excellent reservoirs have been confirmed, and oil has been proven in two recent wells. The Wisting Central and Hanssen wells proved oil in Jurassic fault blocks approximately 500 to 800 meters below the seabed. Both discoveries were supported by bright amplitude anomalies, flat spots and distinct anomalies on CSEM data. Another recent well, Apollo, targeted a Jurassic fault block, but there were no flat spots or positive CSEM anomalies. The well was dry. The recently completed Mercury well tested Jurassic reservoirs in a CSEM supported fault block closure, but only a small gas discovery was made. Many structures supported by flat spots, amplitude and CSEM anomalies can be found in the 23rd licensing round blocks and elsewhere in the Hoop Fault Complex area.

In the Hoop Graben and the Fingerdjupet sub-basin further west, varying thicknesses of the Lower Cretaceous succession have been preserved. The Cretaceous section can be seen as large clinoforms resulting from south-southeast coastal progradation events. Erosion products from footwall uplift along major faults can be deposited in the basin as good reservoir rocks.

HOOP AND GEOPHYSICAL METHODS

The large interest from the industry and recent exploration success has made the Hoop Fault Complex area an area for acquisition of many kinds of geophysical data. TGS acquired the first multi-client 3D seismic data set in 2009, covering most of the Hoop Graben. More 3D data has been acquired year by year, and now the TGS multi-client 3D coverage is over 20,000 km² and spans from the Stappen High in the west to past the Hoop Graben in the east. The shallow discoveries and similar leads in the Jurassic section calls for a better resolution in the seismic data, and by using the TGS Clari-FiTM processing technique, the 3D data has been de-ghosted and the frequency range of the upper part of the seismic section has nearly been doubled.

TGS is currently acquiring P-Cable 2D and 3D data in collaboration with WGP-Survey. Acquired using 16 streamers with 12.5 m (!) streamer separation, the data is extremely high resolution. The P-Cable data sets have frequencies up to 250Hz, and provide an excellent image of the reservoirs, fluid contacts and migration paths for the Jurassic section.

There are many examples showing that CSEM is a valuable geophysical method in the Hoop Fault Complex area. Both the Wisting Central and

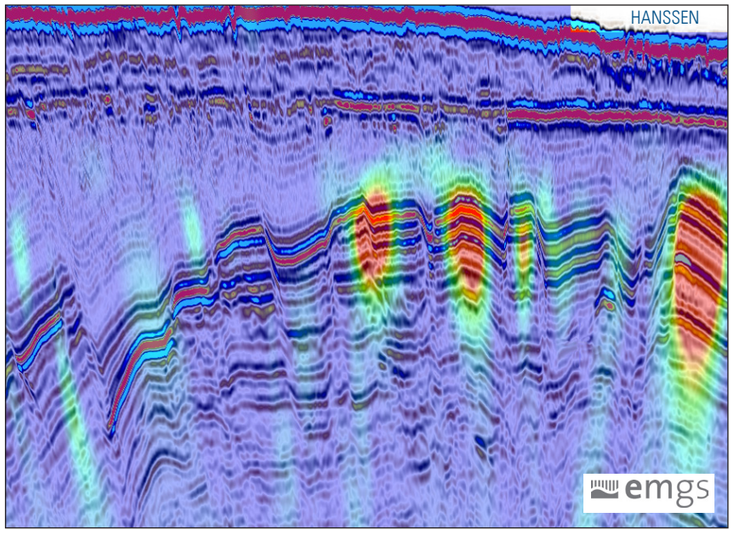

Fig. 2 - Co-display of seismic and CSEM data. The Hanssen oil discovery can be seen on the right. CSEM data courtesy of EMGS.

Hanssen discoveries were supported by positive CSEM anomalies, as was the small gas discovery in the Mercury prospect. The dry Apollo well was not supported by CSEM. TGS and EMGS have jointly acquired CSEM data in the area. While all CSEM anomalies are not equally easy to understand, many structures with anomalies similar to Wisting Central and Hanssen can be applied in the 23rd licensing round.

TGS and VBPR are currently conducting seafloor sampling in the Hoop area. The aim of the survey is to characterize the fluid phase (oil vs. gas) of potentially charged structures. The recovered samples will follow a comprehensive analytical program, including standard seep studies (APT), amplified geochemical imaging (AGI) micro-biological investigations (MicroPro) and biostratigraphy (APT). The results can provide a new insight into the subsurface geology and petroleum systems of the area. The sampling locations are picked based on the re-processed Hoop Fault Complex 3D dataset as well as P-Cable data.

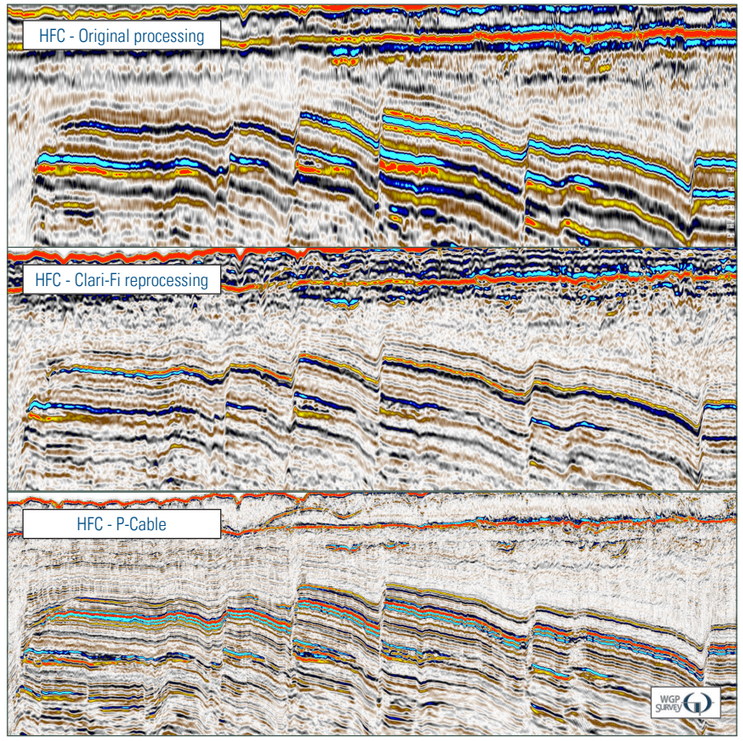

Fig. 3 - Comparison between different Hoop datasets – conventional processing, Clari-Fi 2ms Hi-Res reprocessing and P-Cable data

INTEGRATION OF DATA SETS

Integration of different geophysical and geological data sets are essential for efficient exploration in the Hoop area. It is a complex area and one data set alone will not provide all the answers. TGS offers a turn-key suite of products for exploration in this highly prospective area, from micro- to macro-scale. Long offset 2D and the 20,000 km² of broadband processed 3D enables TGS' clients to understand the regional geology, map all structural closures, and examine sediments ranging in age from Carboniferous or older to Quaternary. It will also give the opportunity to perform AVO studies on the many leads and prospects. The shallow Jurassic leads can be examined in the greatest detail using P-Cable 2D and 3D data, and CSEM will help understand the presence and saturation of hydrocarbons in the structures. Further de-risking of prospects can be done by examining the results from the seafloor sampling. The sampling transects are placed over many of the most relevant structures in the 23rd licensing round blocks and can give important information on fluid phase in charged structures.

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