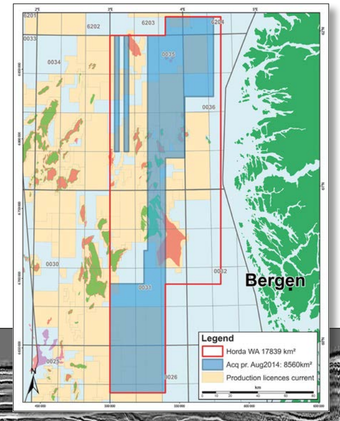
Horda Platform: Exploring the Cretaceous

Hydrocarbon exploration in the northern North Sea has been primarily within pre- and syn-rift Jurassic sandstones. This is with the exception of chalk reservoirs in the Ekofisk field and Palaeogene sand reservoirs of the Frigg field. Now, with ignited interest in the Horda Platform, and particularly after the discovery of the Grosbeak and Skarfjell oilfields, attention has been directed towards the hydrocarbon potential within post-rift Cretaceous sands. The prospectivity of the Cretaceous sands was demonstrated more than three decades ago with the Agat discoveries.

This annotated seismic line has been taken from CGG's new Horda multi-client survey; it is orientated south to north-east. The seismic section cuts through the Troll, Grosbeak, Skarfjell, Gjøa and Agat fields. A clear gas-water contact can be seen in the Troll field from the fast-track seismic section. The combination of BroadSeis™ and BroadSource™ help image shallow stratigraphy as well as deeper Jurassic reservoirs.

Map showing the location of the new CGG multi-client survey. The annotated seismic line runs from south to north-east across the area.



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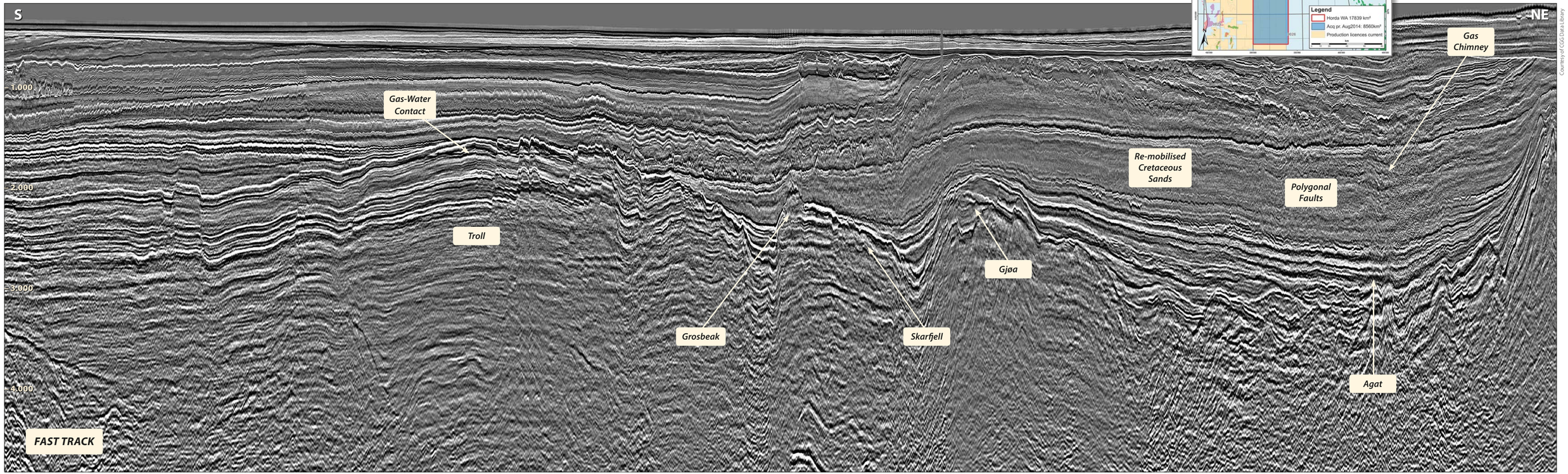

Courtesy of CGG Data Library

Cretaceous Reservoirs in the Northern North Sea

Recent discoveries and development of hydrocarbon fields on the Horda Platform have led to considerable interest in the northern North Sea.

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Exploration activity in the late '70s and '80s led to the discovery of giant fields such as Troll, Oseberg, Gullfaks, Snorre and Statfjord and showed that large accumulations of oil and gas can be found in the northern North Sea. The recent discovery of the Johan Sverdrup and Edvard Grieg fields further south suggests that hidden gems can still be found within this part of the North Sea. The southern and eastern parts of the Horda Platform are currently still fairly undeveloped. With new play models being recognised in the North Sea, several companies have shown a renewed interest within the area. The complexity in migration of petroleum systems and late westward tilting of the entire region suggest the possibility of re-migration of hydrocarbons and new trapping potential. CGG's high-quality broadband data provides new insight into the imaging and mapping of such features, which conventional data does not allow.

New 3D Survey

CGG recently acquired a new 3D multi-client broadband seismic survey on the eastern rim of the northern Viking Graben, offshore Norway. The Horda survey will reach in excess of 18,000 km^2 by the end of 2015, with 8,650 km^2 acquired in 2014. It extends from the Horda Platform in the south-east to the Sogn Graben in the north and covers the entirety of quadrant 35 and large parts of quadrants 31, 32 and 36. The survey was acquired with the use of CGG's broadband technologies, BroadSeis and BroadSource, with the main objective being to provide a large and uniform dataset with increased seismic resolution. With usable frequencies ranging from 2.5 to 200 Hz, this allows for enhanced imaging from the shallow section to deeper areas of interest. CGG's six-octave BroadSeis technology combined with long offsets and a dense streamer configuration helps provide a platform for further activity in the region from exploration to production.

Horda Platform

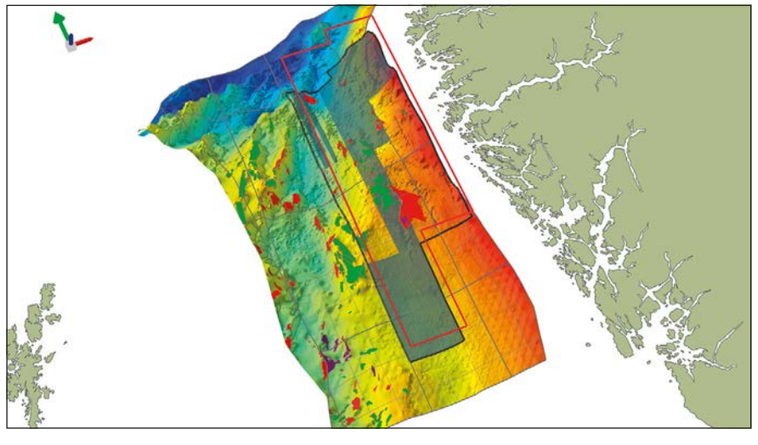
The present structural shape of the North Sea has been influenced by three main tectonic events: Permo-Triassic rifting, Late Jurassic-Early Cretaceous rifting and Late Cretaceous rifting. This was subsequently followed by a drift phase and Eocene seafloor spreading.

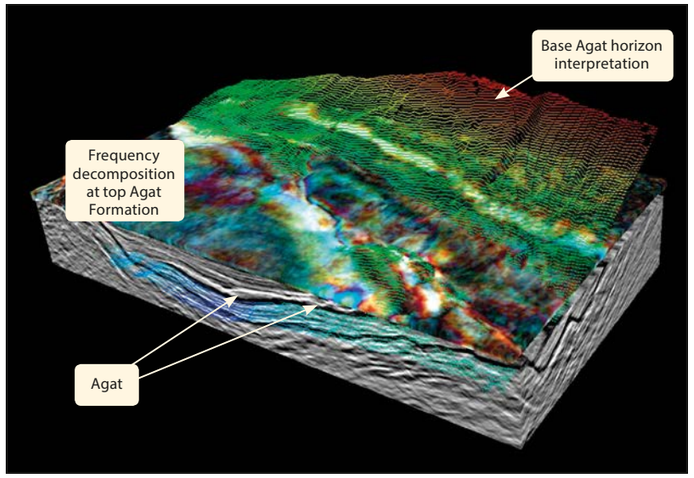
Prior to the Late Jurassic, deposition had been dominated by fluvial to near-shore marine environments. Following the Late Jurassic-Early Cretaceous rift episode, deepwater sedimentation prevailed due to alterations of bathymetry in the North Sea. Lower Cretaceous sediments infill half grabens in the region as a result of this rift phase. The Horda Platform is a prominent structural high, located to the east of the deeply faulted Viking Graben in the northern North Sea. The Horda Platform post-dates the Triassic rift period as sediment deposition of this age can be seen to infill half grabens at depth. Jurassic sediments are found to be sub-horizontal in large parts of the Horda Platform, allowing for a clear contrast from dipping lower Triassic strata.

Petroleum Systems

The prolific Middle to Late Jurassic Heather and Draupne formations make up the primary source rocks for oil and gas in the North Viking Graben. The shales are the lateral equivalent of the Kimmeridge Formation in the southern Norwegian and UK parts of the North Sea. The source rocks were deposited in a restricted marine environment and are known to be interbedded with localised sandstones throughout the sequence. In the central part of the North Viking Graben, both formations are extremely thick and of good quality for generating both oil and gas at different depths. Petroleum generated in the Graben migrated both westwards towards the Tampen spur area and eastwards towards the Horda Platform.

CGG's Horda survey seen outlined in red with the grey polygon illustrating data already acquired. Oil and gas fields are overlain on a regional interpretation of the Base Cretaceous Unconformity.





Colour blend 3D visualisation highlighting the Agat sands with horizon interpretation.

The main reservoirs in the province are pre- and syn-rift sandstones of the Middle and Late Jurassic; these consist of the Brent and Viking groups. The Brent Group is up to 250m thick in the area and was deposited as a major deltaic clastic wedge, which prograded northwards to finally become swamped by the southerly marine transgression. The Upper Jurassic reservoirs, like those found within the Troll field, have a depositional environment of open marine in the west to shoreface and restricted marginal marine in the east. Secondary reservoirs can be located within Triassic, Lower Jurassic, Cretaceous, Paleocene and Lower Eocene intervals. Fluvial and marginal marine sandstones make up the Triassic reservoirs found in the Snorre and Visund fields. Lower Jurassic sandstones consist of the Statfjord Formation, found deposited in alluvial to marginal marine environments, and the Cook Formation, which is comprised of marine sandstones, siltstones and shales.

Imaging of Cretaceous Sands

Deposition of Cretaceous reservoirs in the North Sea is strongly influenced by the basin topography created by Jurassic rifting. The availability of new broadband data allows for a more accurate approach to mapping out petroleum systems and understanding new play models. Potential reservoir sandstones within the Cretaceous can be much easier to identify and the risk of mapping isolated sand bodies is reduced. Since the discovery of the Agat gas field, more attention has been given to both Lower and Upper Cretaceous sandstone plays. The Agat field is made up of two complex small discoveries in stratigraphically trapped sub-marine sandstone lobes of the Cromer Knoll Group, but the extent of the sandstones have been difficult to map on conventional seismic.

The Lower Cretaceous Agat Formation sands can be observed predominantly in the northern area of the Horda survey, infilling faulted basement highs. The top of the formation displays high amplitudes, and sand distribution can be seen quite prominently on the seismic.

Well 35/9-3 encountered hydrocarbons in the Cretaceous sequence within the Agat and Kyrre formations. The well results indicated over 1,000m of Kyrre Formation interbedded sands and shales. The sand section has been interpreted as sub-marine channel fills and fans. The seismic figure shows the high amplitude and the isolated nature of these sandstones found at the base of the Kyrre sequence. With the increasing low and high frequencies achieved with BroadSeis and BroadSource, better differentiation can be made with facies and stratigraphy. Stratigraphic pinch-outs of sand bodies can be clearly seen within the thick polygonal faulted shale section. The BroadSeis data helps identify features such as clastic intrusions typically characterised by winged edges and a strong amplitude response.

Being able to better image and identify potential reservoir sandstones within the Cretaceous section allows for a better understanding of newer plays in the northern North Sea. CGG's BroadSeis data with BroadSource is the ideal tool to determine if these sand bodies are of commercial interest, and, with the support of a number of oil companies, the survey area is now being extended to the west, to provide a dataset of over 35,000 km^2 of full-bandwidth data. These datasets are being processed with reservoir characterisation in mind, including the integration of well and gravity data, as well as extensive QC using AVO tools, to deliver a dataset that is reservoir-ready and will require only minimal pre-conditioning before use in elastic inversion. ■

Seismic line taken from the Horda survey focusing on the Cretaceous section. The line clearly shows high-amplitude sands within the Kyrre and Agat formations.