# PL 508 S

# Relinquishment report

## Stavanger, November 2011

**Nexen Exploration Norge AS**

# *1. Key License History*

This report summarizes the technical evaluation completed on Norwegian offshore licenses PL508 S awarded to *Nexen Norge AS* (Operator-*40%), Wintershall Norge AS (30%) and Aker Exploration Norge AS (later Det norske oljeselskap ASA 30%).* The PL508 S license was awarded to the partnership on January 23rd, 2009, applicable to all levels below the Top Cretaceous Unfonormity. The license (773,487 km²) is located within the blocks 29/3, 29/6, 30/1, and 30/4 in the North Viking Graben (Figure 1).

The license was held on a drill/drop basis 3 year evaluation period, expiring on January 23rd, 2012. The initial work obligations within 3 years from award were to a) acquire 3D seismic data over the license area, b) conduct relevant geological studies, and c) conclude the drill or drop decision. A new 834 $km^2$ 3D survey (NX0803) was acquired from August through September 2008. Subsequently two additional 3D surveys NX0901 (1204 km2) and NX0902 (184 km2) were acquired in June-July 2009 (see Figure 1 for outlines). These three data sets were merged in 2010 into one seismic survey (NX10M02) which was the primary seismic dataset that was used to evaluate the hydrocarbon potential on the license block. One comprehensive geological study was completed during the evaluation period which addressed the reservoir quality assessment of deep Jurassic reservoirs (Mortimer *et al*, 2010).

The partnership met on a regular basis to discuss the technical and business aspects of the license blocks. A summary of these meetings and workshops that were held are listed in Table 1.

**Table** 1**. Partnership meeting summary**

| Number | Date | Meeting Type | General Meeting Summary |
|---|---|---|---|
| 1 | 13/3/2009 | MC/EC | Integration of PL462 S and PL508 S work program |
| 2 | 4/12/2009 | MC/EC | Status G&G, budgets and work program |
| 3 | 16/12/2010 | MC/EC | Prospect key risks, Drill Recommendation, License Budgets |
| 4 | 27/9/2011 | MC/EC | Drop Recommendation, License Budgets |

Interpretation of the 3D seismic cube NX10M02, resulted in several Mid-Jurassic prospects, where Orkla, downfaulted from Valemon, turned out to be the largest. However, severe risk on containment, reservoir compartmentalization and reservoir quality caused the partnership to agree upon relinquishment.

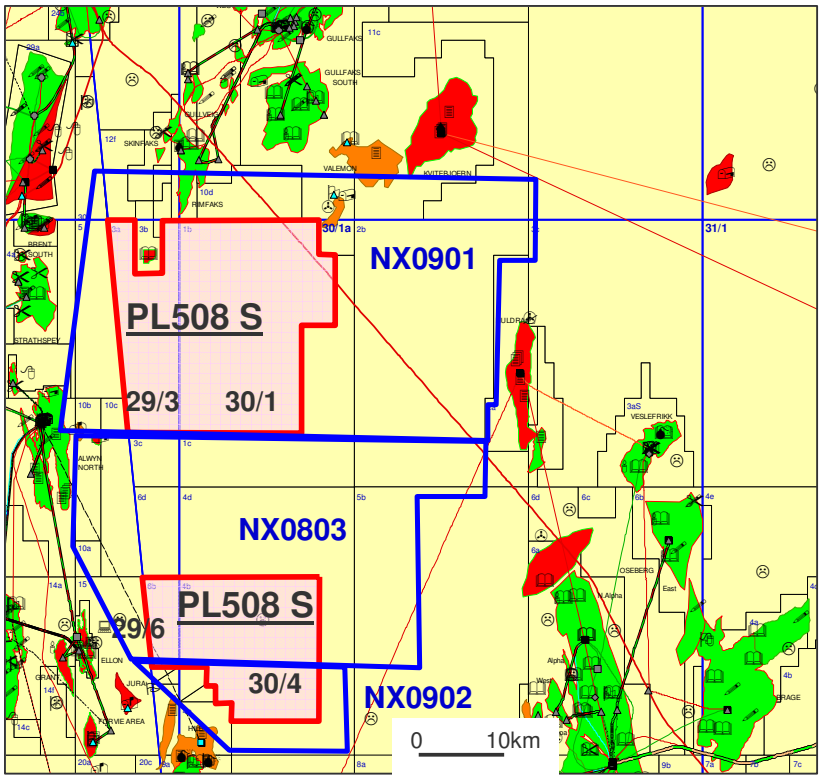


**Figure 1 PL508 S area basemap (red) including block lines, discoveries, pipelines (red) and seismic coverage (blue).**

# 2. Database

## 2.1. Seismic Acquisition and Processing

The primary geophysical control used in the license was the proprietary 3D survey NX10M02. The survey covers 2210 km² and the water depths range from 120 to 160 m. The primary target zone was the Middle Jurassic Brent Group section located near 4 seconds. The survey was acquired by the Geco Triton vessel between August and September 2008 and by CGG's Geo Challenger during June-July 2009, subsequently processed by WesternGeco in Stavanger and Geotrace in Woking UK (Hamilton, 2010).

## 2.2. Seismic Interpretation

Detailed seismic interpretation was tied to seven key wells, 29/3-1, 29/6-1, 30/4-1, 30/4-2, 34/10-23, 34/10-42 S and UK 3/10b-1 (Figure 2). The following seven stratigraphic horizons were interpreted in time from Triassic to present day over the combined block areas (

Table **2**).

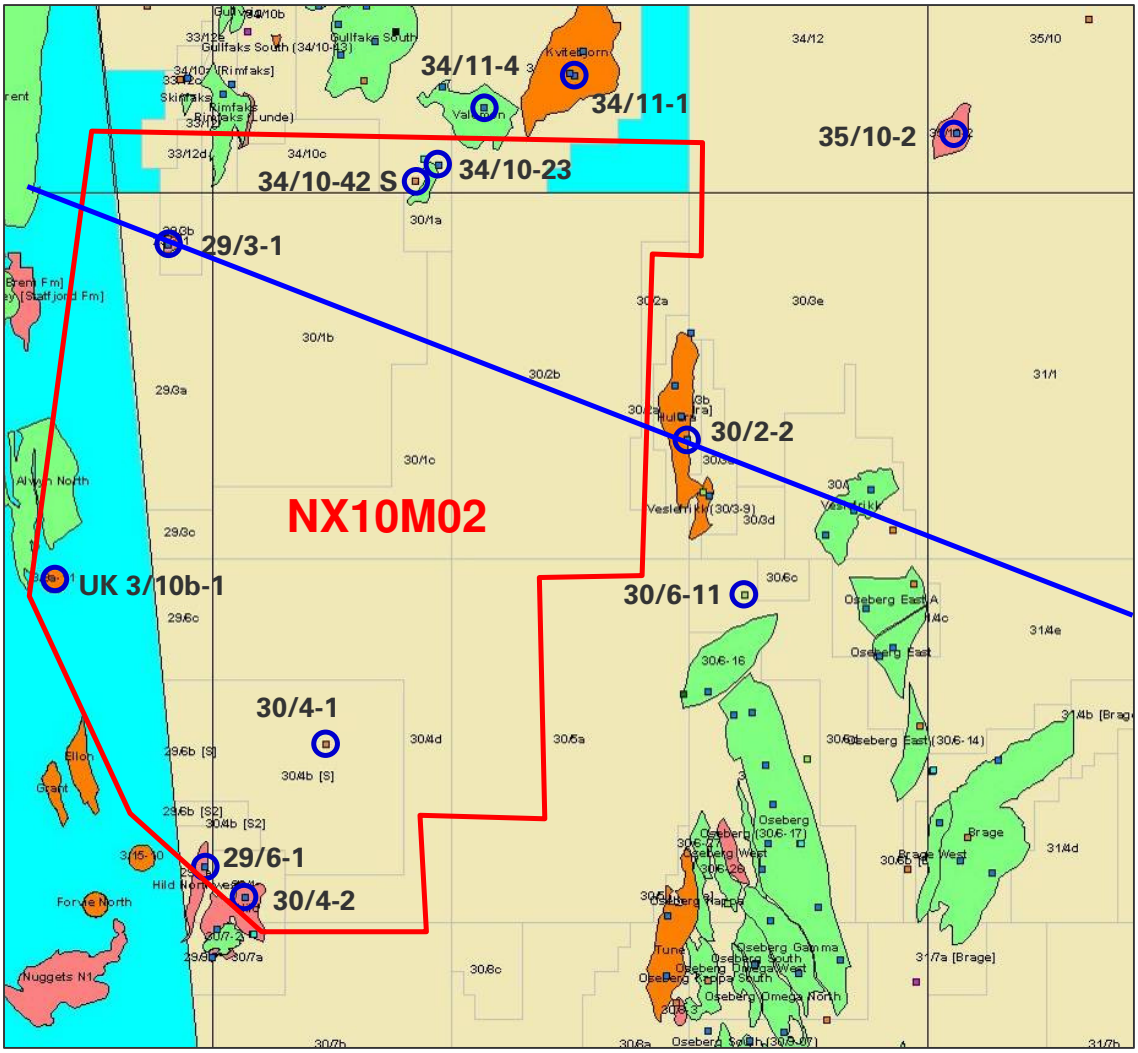


**Figure 2 Seismic survey NX10M02 and well data base used in the evaluation of PL 462 S. The blue line is the transverse shown in Figure 3.**

## Table 2. Interpreted Horizon picks over PL508 S

| Horizon Pick | Group | Age |
|---|---|---|
| Seabed | Nordland | Recent |
| Jorsalfare Fm | Shetland | Maastrichtian |
| Rødby Fm. | Cromer Knoll | Albian |
| Base Cretaceous / Draupne Fm. | Viking | Volgian |
| Heather Fm. | Viking | Oxfordian |
| Top Reservoir | Brent | Bajocian |
| Cook Fm. | Dunlin | Pliensbachian |

# 3. Review of Geological Framework

## 3.1. Structural Setting

The PL508 S license is situated in the Rungne sub-basin of the North Viking Graben. The sub-basin is limited to the west by major N-S trending fault complexes marking the boundary between the North Viking Graben to the East and the East Shetland Basin to the west. The northern part of the license is characterized by the intra-basinal Jurassic high Tjalve Terrace where the Kvitebjørn, Valemon and Valemon S (34/10-23) fields are located. The Jurassic fault pattern in the graben is mostly N-S trending with a NE splay from the Hild field (30/4-2). Between the Tjalve Terrace and the Huldra platform there are also some strike-slip movement which offsets the Rungne sub-basin with the Magne sub-basin. This combination of lateral and extensional tectonics creates a complex fault pattern at the Tjalve terrace with at least 3 different fault directions that increases the risk of reservoir compartmentalization. The main faults are associated with sub-seismic faults which may act as barrier for fluid flow and may result in anomalous gas/water contacts as observed at Valemon wells 34/10-23 and 34/10-42S.

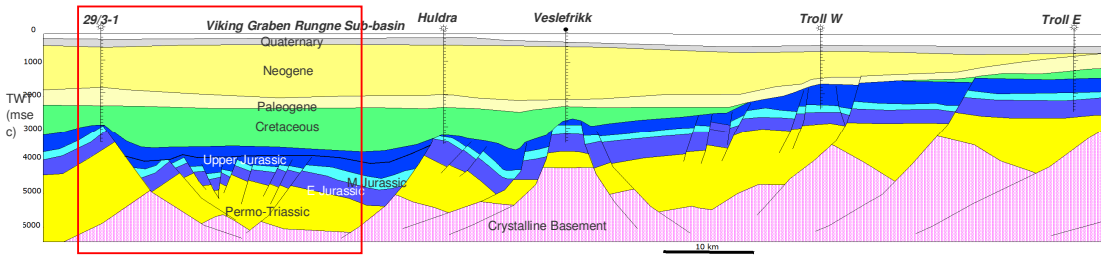


**Figure 3 Geological cross section over the license (red box) from 29/3-1 to the Troll field. Location of the traverse is given in Figure 2.**

The main prospectivity in the license is within the rifted Jurassic fault blocks, either rotated within the basin or detached from the terraces (Figure 4). The crest for the Brent reservoir ranges from 4250 – 4600 m SS, with the shallowest compartment being the primary Orkla prospect.

## 3.2. Reservoir

An external reservoir study was commissioned to look at the reservoir quality in deep reservoirs (>4000m) in wells adjacent to the PL508 S license blocks (Mortimer *et al*, 2010). Five main Triassic through Jurassic age stratigraphic units (Lunde Fm, Statfjord Fm, Dunlin Gp, Brent Gp, and Viking Gp.) were studied in detail from 11 cored wells (approximately 750m of core). For each of the stratigraphic units, an analysis and integration of a) stratigraphy and sedimentology, b) petrography and diagenesis, and c) reservoir quality trends and prediction were completed.

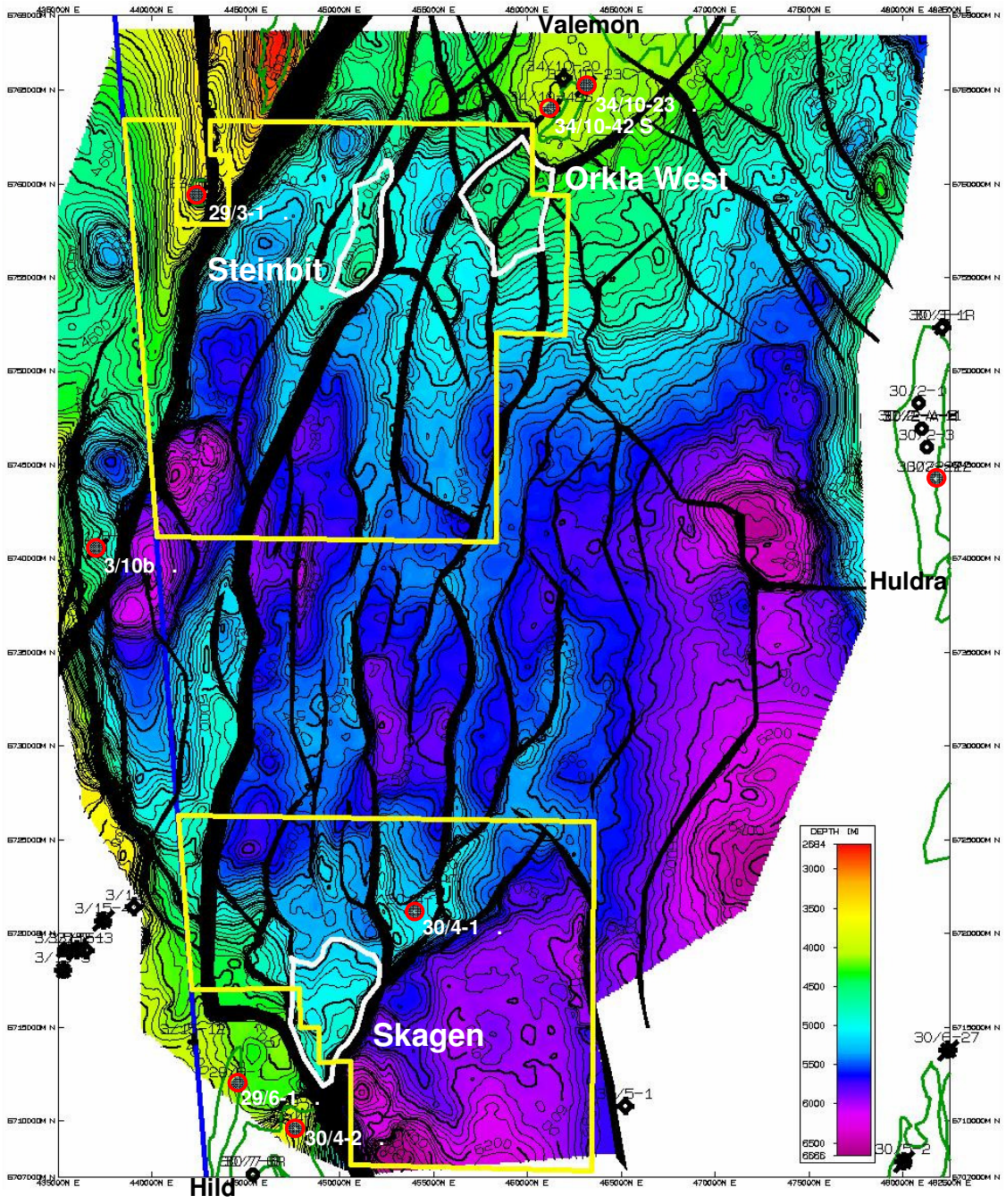


**Figure 4 Top Brent Group depth map of the Rugne sub-basin in the Viking Graben. Some of the main prospects and leads are shown. The yellow line denotes the PL508 S license boundary.**

The primary reservoir interval in the PL508 S area is the Middle Jurassic Brent Group. These units were deposited during a northward progradation and subsequent retreat of a major wave dominated delta during Aalenian to Bajocian time. A variety of facies types were observed including higher energy fluvial and tidal channels, shoreface and tidal bar deposits to lower energy lagoonal, lacustrine and tidal flats. Secondary reservoir targets were also possible in the Dunlin Units 3 and 4 (Cook equivalent) and Statfjord Formation. Within the license block area,

very little reservoir potential was found to be present in the Lunde Formation, and lower part of the Dunlin Formation. There is also little potential in the Upper Jurassic Heather and Draupne Formations. None of the adjacent wells have pay sand in these units and there are no indications on the seismic data that there are any sands present.

Detailed petrographic work, including XRD, SEM, cathodoluminescence, and fluid inclusion analysis was performed to assess the depositional and diagenetic history of the area. Based on this work, the composition of the Brent Group sediments is generally classified as a quartz arenite to sublithic arenite. Primary depositional reservoir quality is strongly facies dependent. As one might expect, the higher energy facies are coarser grained, have better sorting, and have increases in porosity and permeability. The lower energy facies are finer grained, poorly sorted and have an increase in ductile grains. The overall reservoir quality has been subsequently strongly influenced by secondary processes. Authigenic cements and clays were observed including quartz overgrowths, carbonates, illite, kaolinite, and grain coating chlorite. In the case of chlorites, there is a significant positive impact for porosity preservation at depth as chlorites inhibit quartz overgrowth cementation for the Dunlin Group sands.

Since all prospects are deep and in high temperature environment they have undergone diagenesis and compaction which reduce the ability for fluid flow. Figure 5 shows core measurements of porosity and permeability as a function of depth and facies. The Mid Jurassic prospects in PL 508 S range from 4250-5500 mSS in depth. The lack of regional core data at this depth made it somewhat uncertain how the trends are at greater depths.

# *4. Prospect Update*

## *4.1. Orkla West*

The Orkla Prospect is the shallowest prospect that was evaluated. The primary target is interpreted to be the Middle Jurassic Brent Group deltaic deposits. Orkla is comprised of several fault blocks, where the two western ones are within PL508 S and included in the volumetrics. The crest of each individual Brent reservoir is ranging from 4250 – 4600 mSS (Figure 6). Predicted temperatures and pressures are in the HPHT category with 150°C (300°F) and 810 bar (11750 psi).

**Source and Migration (P3)**: Mature organic rich shales of the Draupne and Heather Formations are present in a large fetch area to the south of the Orkla prospect. Current temperature and structure estimates suggest the primary Draupne source rock is currently within the gas window. Present day migration into Brent reservoir carrier beds would be achieved via downdip source-reservoir fault juxtaposition. New seismic data show reduced risk on charge since the faults blocks are more or less open to the kitchen area and Brent Group acts as carrier bed, and the major fault trends are N-S.

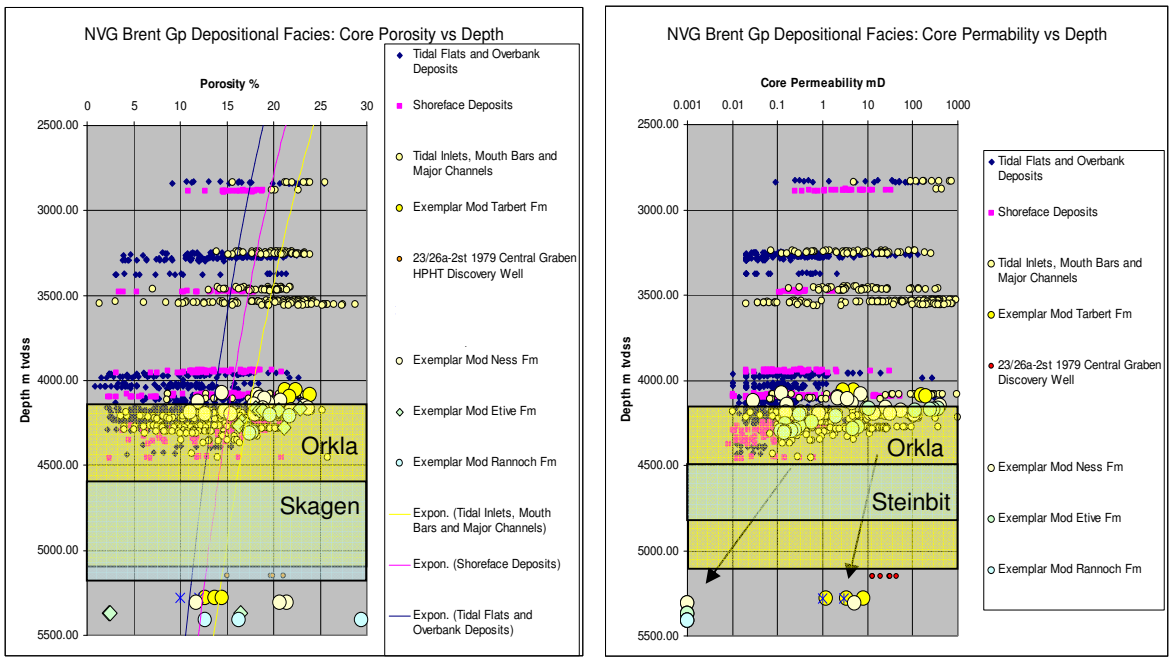


**Figure 5 Core measurements of porosity and permeability and Exemplar modeling as a function of depth and facies. Conclusion is that even if some facies preserve porosity at depths >4300 m, the permeability is too low to give commercial flow rates.**

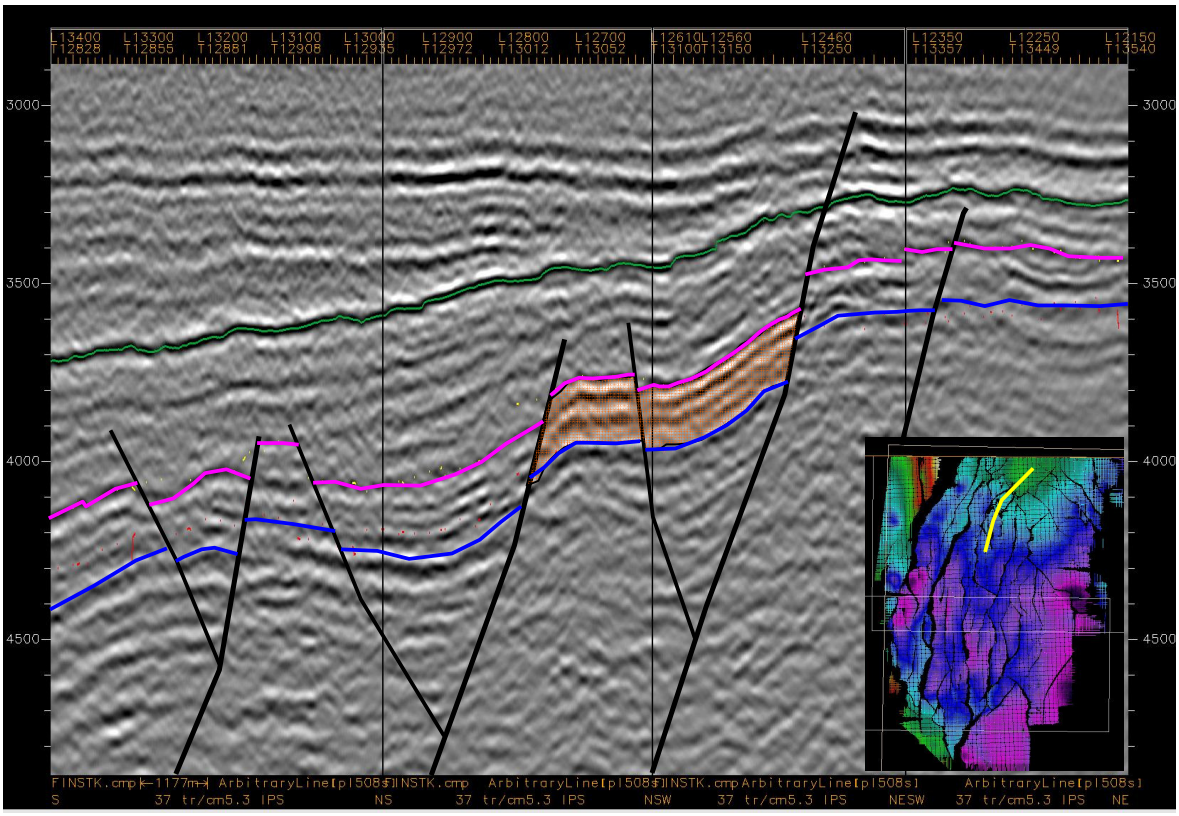


**Figure 6 Seismic section along the Orkla prospect (yellow line in the inserted map). Orkla is a Mid-Jurassic block detached from the Tjalve Terrace shown as shaded area on the figure.**

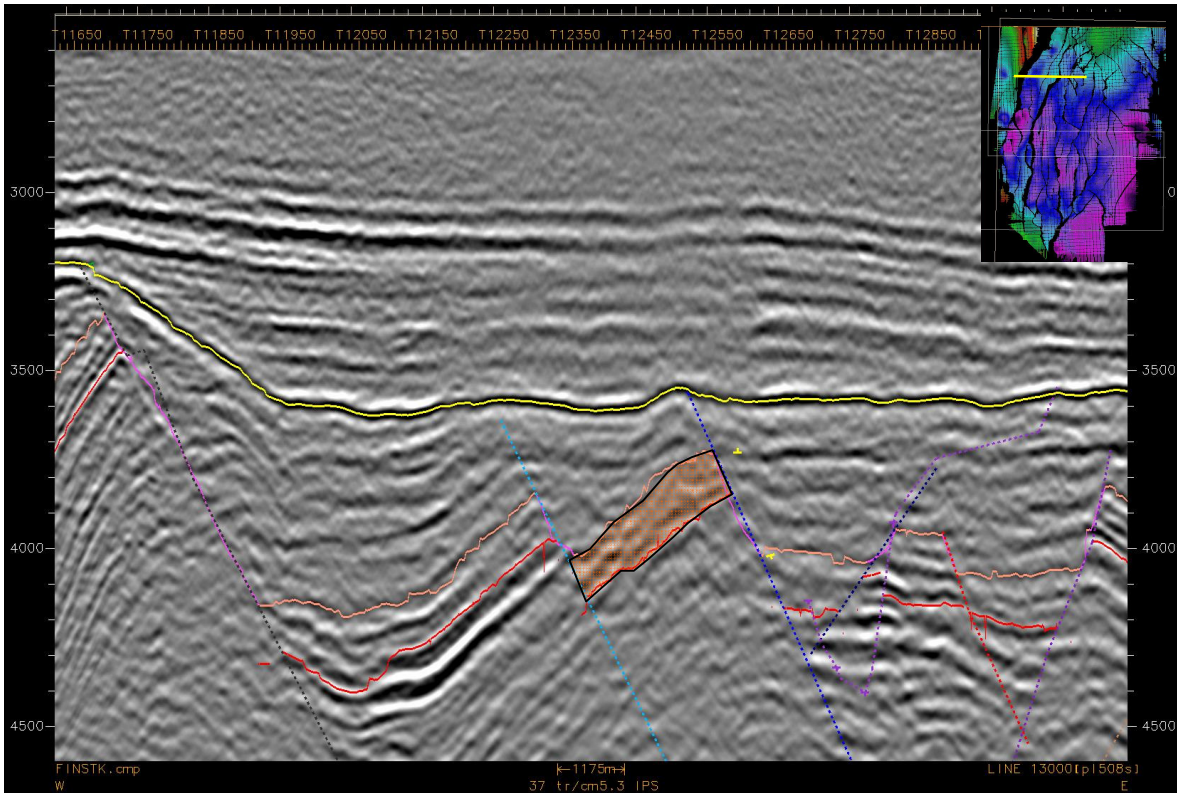


**Figure 7 Crossline 13470 with Steinbit prospect highlighted.**

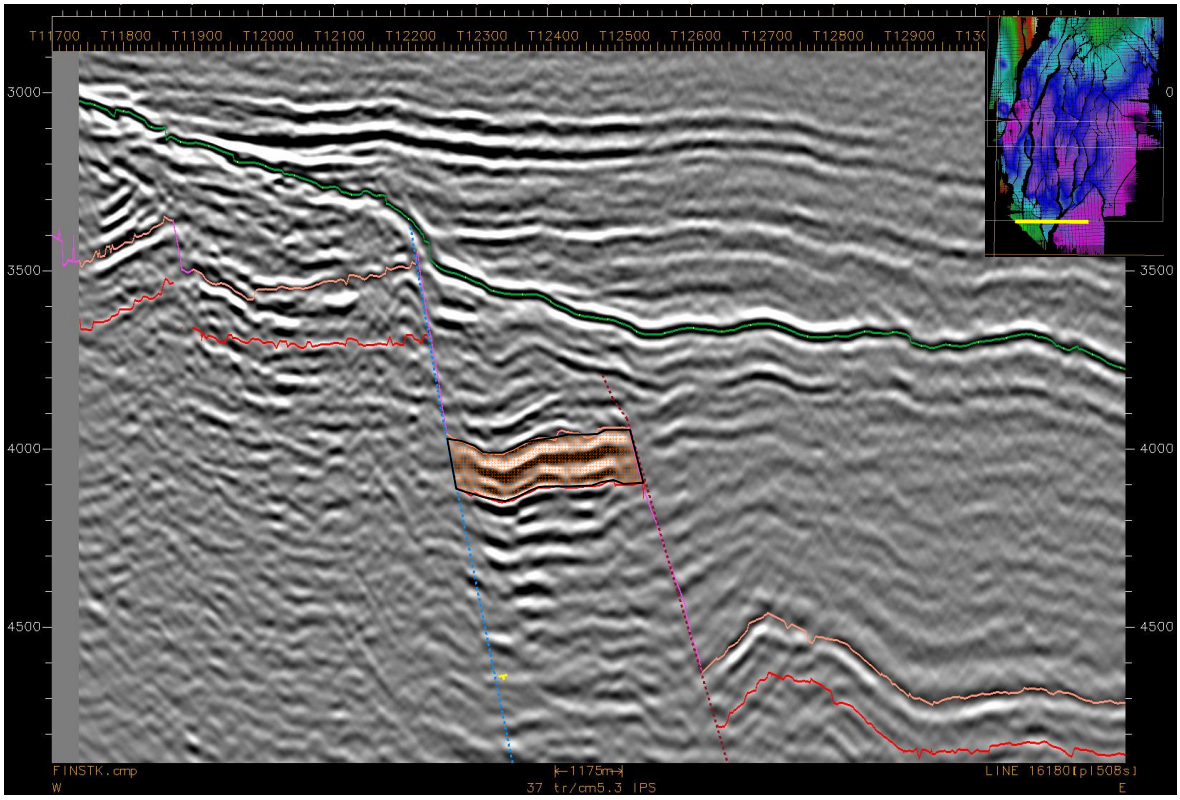


**Figure 8 Inline 12540 with the Skagen prospect highlighted.**

**Retention and Seal (P4):** The Orkla prospect is defined by a downfaulted 3-way dip closure. Since the vertical throw of the major updip fault is at most 200 m, there will be Brent-to-Brent juxtaposition along the entire fault, also within the critical triple-junctions. Even the presence of strike-slip movements the fault seal capacity is assumed to be the main risk element, together with reservoir deliverability. Top seal failure is assumed to be of low risk since there are thick sequences of Heather shale overlaying the prospect.

The overall technical risk factor is Pg ~0.25. The recoverrable reserves are estimated to be 0,9 – 4,3 – 13,1 GSm3 for the low, base and high estimates, respectively.

### *4.2. Steinbit:*

There are several rotated Jurassic fault blocks in the Rungne basin (Figure 4). The largest inside PL508 S is the Steinbit prospect which is in the Northern segment of the License (Figure 7). The depth to the crest is 4500 m, which means the reservoir is deeper than Orkla The prospect is a high side fault closure which spills to the north. The risk on rentention is low since there is no sand-sand juxtaposition or reactivated faults associated with the prospect. However, since the prospect is located deeper than the assumed cut-off of flowing reservoir in the basin there is a considerable risk on effective reservoir. The recoverable gas resources are 0,1 – 1,5 – 9,0 GSm3 for the low, base and high estimates, respectively. The overall risk is Pg ~0,23. The limited size and high risk on reservoir quality make it challenging to mature this lead into a drillable prospect.

### *4.3. Skagen:*

Skagen is the largest prospect in the southern segment of PL508 S (Figure 8). It is a well defined trap forming a downflank fault block detached from the Hild platform. The fault throw is ~300 m at the crestal point (4550 m TVDSS) and will, unlike Orkla, offset the entire Brent unit. Similar to Steinbit, Skagen has lower risk on retention but higher risk on effective reservoir. The estimated recoverable gas resources are 0,6 – 4,1 – 14,7 GSMm3 for the low, base and high estimates, respectively. The overall risk is Pg ~0,23.

## *5. Conclusions*

The technical evaluation indicates that there is a significant risk that the Brent reservoir will not flow at commercial rates. This is due to reduced permeability resulting from the potential for secondary diagenesis at the anticipated reservoir depth in PL508 S. Even in cases where secondary porosity has evolved, the permeability increase is insufficient to significantly improve the production rates. The Orkla prospect is further complicated by complex faulting in which trap and retention risk would require each compartment to be appraised separately. None of these

compartments alone is large enough to prove up enough volumes for commercialization. Other prospects in the license are also likely to be more compartmentalized than mapped.

None of the adjacent wells show any indication of Upper Jurassic or Cretaceous sands, and there is no seismic indication of prospectivity at these levels within the license. The partnership has therefore agreed to relinquish the license due to lack of drillable prospects.

**References**

Hamilton, J., 2010: Processing of 3D Seismic Data NX10M02, PL462S & PL508S in Norwegian Blocks 29/3, 209/6, 30/1, 30/2 & 30/4. Geotrace Project No. c2279. July 2010.

Mortimer, E.G., Lucas, P.M., Rich, B., 2010: Reservoir Quality Assessment for Deep Jurassic Reservoirs Around Licence Areas PL462S, PL508S and PL465, and NOCS Blocks 29/3, 30/1, 34/10 and 35/10, Fugro Robertson Limited Report 9772: May 2010.

Table 3: Prospect data Orkla West

| Block | Prospect name | Discovery/Prosp/Lead | Prosp ID (or New!) | NPD approved? |
|---|---|---|---|---|
| 30/1, 2 | Orkla West | Prospect | *NPD will insert data* | *NPD will insert data* |

| Play (name /new) | Structural element | Company/ reported by / Ref. doc. | Year |
|---|---|---|---|
| *NPD will insert data* | Rungne Sub-basin | Nexen/PL508S Relinquishment | 2011 |

| Oil/Gas case | **Resources IN PLACE** | | | | | |
|---|---|---|---|---|---|---|
| Gas | Main phase | | | Ass. phase | | |
| | Low | Base | High | Low | Base | High |
| Oil 106 Sm3 | | | | 0,4 | 2,6 | 9,0 |
| Gas 109 Sm3 | 1,3 | 6,6 | 22,5 | | | |
| | **Resources RECOVERABLE** | | | | | |
| | Main phase | | | Ass. phase | | |
| | Low | Base | High | Low | Base | High |
| Oil $10_6$ $Sm_3$ | | | | 0,2 | 1,1 | 3,6 |
| Gas $10_9$ $Sm_3$ | 0,3 | 4,3 | 13,1 | | | |
| | Which fractiles are used as: | | Low: | P90 | High: | P10 |

| **Type of trap** | **Water depth** (m) | **Reservoir Chrono** (from - to) | **Reservoir Litho** (from - to) |
|---|---|---|---|
| 3-way close | 135 | Bath-Bajocian | Brent Group |
| | **Source Rock, Litho** | **Seal, Chrono** | **Seal, Litho** |
| Kimm-Oxf | Heather - Draupne Fm | Oxfordian | Heather Fm |

| Seismic database (2D/3D): | 3D - NX10M02 |
|---|---|

| **Probability of discovery:** | | | | |
|---|---|---|---|---|
| Technical (oil+gas case) | 0,25 | | Prob for oil/gas case | |
| Probability (fraction): | Reservoir (P1) | Trap (P2) | Charge (P3) | Retention (P4) |
| | 0,7 | 0,8 | 0,9 | 0,5 |
| **Parameters:** | Low | Base | High | Comments |
| Depth to top of prospect (m) | 4250 | 4350 | 4450 | |
| Area of closure ($km_2$) | 2,4 | 9,5 | 21,3 | |
| Reservoir thickness (m) | 160 | 200 | 240 | |
| HC column in prospect (m) | 100 | 230 | 400 | |
| Gross rock vol. ($10_9$ $m_3$) | 0,23 | 1,07 | 3,29 | |
| Net / Gross (fraction) | 0,13 | 0,29 | 0,45 | |
| Porosity (fraction) | 0,11 | 0,17 | 0,22 | |
| Water Saturation (fraction) | 0,5 | 0,4 | 0,3 | |
| Bg. (<1) | 0,0026 | 0,0034 | 0,0041 | |
| Bo. (>1) | | | | |
| GOR, free gas ($Sm_3$ /$Sm_3$ ) | | | | |
| GOR, oil ($Sm_3$ /$Sm_3$ ) | | | | |
| Recovery factor, main phase | 0,47 | 0.65 | 0,72 | |
| Recovery factor, ass. phase | 0,3 | 0,4 | 0,5 | |
| Temperature, top res (deg C): | 150 | Pressure, top res (bar) : | 810 | |

Table 4: Prospect data Steinbit East

| Block | Prospect name | Discovery/Prosp/Lead | Prosp ID (or New!) | NPD approved? |
|---|---|---|---|---|
| 30/1 | Steinbit East | Prospect | *NPD will insert data* | *NPD will insert data* |

| Play (name /new) | Structural element | Company/ reported by / Ref. doc. | Year |
|---|---|---|---|
| *NPD will insert data* | Rungne Sub-basin | Nexen/PL508S Relinquishment | 2011 |

| Oil/Gas case | **Resources IN PLACE** | | | | | |
|---|---|---|---|---|---|---|
| Gas | Main phase | | | Ass. phase | | |
| | Low | Base | High | Low | Base | High |
| Oil 106 Sm3 | | | | 0,05 | 0,9 | 6,2 |
| Gas 109 Sm3 | 0,2 | 2,3 | 15,4 | | | |
| | **Resources RECOVERABLE** | | | | | |
| | Main phase | | | Ass. phase | | |
| | Low | Base | High | Low | Base | High |
| Oil $10^6$ $Sm^3$ | | | | 0,02 | 0,4 | 2,5 |
| Gas $10^9$ $Sm^3$ | 0,1 | 1,5 | 9,0 | | | |
| | Which fractiles are used as: | | Low: | P90 | High: | P10 |

| **Type of trap** | **Water depth** (m) | **Reservoir Chrono** (from - to) | **Reservoir Litho** (from - to) |
|---|---|---|---|
| 3-way close | 135 | Bath-Bajocian | Brent Group |
| **Source Rock, Chrono** | **Source Rock, Litho** | **Seal, Chrono** | **Seal, Litho** |
| Kimm-Oxf | Heather - Draupne Fm | Oxfordian | Heather Fm |

| Seismic database (2D/3D): | 3D - NX10M02 |
|---|---|

| **Probability of discovery:** | | | | |
|---|---|---|---|---|
| Technical (oil+gas case) | 0,23 | | Prob for oil/gas case | |
| Probability (fraction): | Reservoir (P1) | Trap (P2) | Charge (P3) | Retention (P4) |
| | 0,4 | 0,9 | 0,9 | 0,7 |

| **Parameters:** | Low | Base | High | Comments |
|---|---|---|---|---|
| Depth to top of prospect (m) | 4400 | 4500 | 4600 | |
| Area of closure ($km^2$) | 0,7 | 5,2 | 22,0 | |
| Reservoir thickness (m) | 160 | 200 | 240 | |
| HC column in prospect (m) | 100 | 230 | 400 | |
| Gross rock vol. ($10^9$ $m^3$) | 0,03 | 0,37 | 2,26 | |
| Net / Gross (fraction) | 0,13 | 0,29 | 0,45 | |
| Porosity (fraction) | 0,11 | 0,17 | 0,22 | |
| Water Saturation (fraction) | 0,5 | 0,4 | 0,3 | |
| Bg. (<1) | 0,0026 | 0,0034 | 0,0041 | |
| Bo. (>1) | | | | |
| GOR, free gas ($Sm^3$ /$Sm^3$ ) | | | | |
| GOR, oil ($Sm^3$ /$Sm^3$ ) | | | | |
| Recovery factor, main phase | 0,47 | 0,65 | 0,72 | |
| Recovery factor, ass. phase | 0,3 | 0,4 | 0,5 | |
| Temperature, top res (deg C): | 150 | Pressure, top res (bar) : | 810 | |

Table 5: Prospect data Skagen

| Block | Prospect name | Discovery/Prosp/Lead | Prosp ID (or New!) | NPD approved? |
|---|---|---|---|---|
| 30/4 | Skagen | Prospect | *NPD will insert data* | *NPD will insert data* |

| Play (name /new) | Structural element | Company/ reported by / Ref. doc. | Year |
|---|---|---|---|
| *NPD will insert data* | Rungne Sub-basin | Nexen/PL508S Relinquishment | 2011 |

| Oil/Gas case | **Resources IN PLACE** | | | | | |
|---|---|---|---|---|---|---|
| Gas | Main phase | | | Ass. phase | | |
| | Low | Base | High | Low | Base | High |
| Oil 106 Sm3 | | | | 0,3 | 2,5 | 10,1 |
| Gas 109 Sm3 | 0,9 | 6,3 | 25,2 | | | |
| | **Resources RECOVERABLE** | | | | | |
| | Main phase | | | Ass. phase | | |
| | Low | Base | High | Low | Base | High |
| Oil $10^6$ $Sm^3$ | | | | 0,1 | 1,0 | 4,0 |
| Gas $10^9$ $Sm^3$ | 0,6 | 4,1 | 14,7 | | | |
| | Which fractiles are used as: | | Low: | P90 | High: | P10 |

| **Type of trap** | **Water depth** (m) | **Reservoir Chrono** (from - to) | **Reservoir Litho** (from - to) |
|---|---|---|---|
| 3-way close | 135 | Bath-Bajocian | Brent Group |
| **Source Rock, Chrono** | **Source Rock, Litho** | **Seal, Chrono** | **Seal, Litho** |
| Kimm-Oxf | Heather - Draupne Fm | Oxfordian | Heather Fm |

| Seismic database (2D/3D): | 3D - NX10M02 |
|---|---|

| **Probability of discovery:** | | | | |
|---|---|---|---|---|
| Technical (oil+gas case) | 0,23 | | Prob for oil/gas case | |
| Probability (fraction): | Reservoir (P1) | Trap (P2) | Charge (P3) | Retention (P4) |
| | 0,4 | 0,9 | 0,9 | 0,7 |

| **Parameters:** | Low | Base | High | Comments |
|---|---|---|---|---|
| Depth to top of prospect (m) | 4450 | 4550 | 4650 | |
| Area of closure ($km^2$) | 1,7 | 11,1 | 22,8 | |
| Reservoir thickness (m) | 160 | 200 | 240 | |
| HC column in prospect (m) | 100 | 230 | 400 | |
| Gross rock vol. ($10^9$ $m^3$) | 0,15 | 1,01 | 3,69 | |
| Net / Gross (fraction) | 0,13 | 0,29 | 0,45 | |
| Porosity (fraction) | 0,11 | 0,17 | 0,22 | |
| Water Saturation (fraction) | 0,5 | 0,4 | 0,3 | |
| Bg. (<1) | 0,0026 | 0,0034 | 0,0041 | |
| Bo. (>1) | | | | |
| GOR, free gas ($Sm^3$ /$Sm^3$ ) | | | | |
| GOR, oil ($Sm^3$ /$Sm^3$ ) | | | | |
| Recovery factor, main phase | 0,47 | 0,65 | 0,72 | |
| Recovery factor, ass. phase | 0,3 | 0,4 | 0,5 | |
| Temperature, top res (deg C): | 150 | Pressure, top res (bar) : | 810 | |