

# Relinquishment Report PL 724

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# 1 LICENCE HISTORY

## 1.1 Licence Owners

The PL 724 was awarded in APA 2013 with a 40% equity to Aker BP ASA as operator and a 30% equity to MOL Norge AS and DEA Norge AS, respectively. In APA2014, the PL 724 B was awarded for the extension application to secure the entire extent of the main prospect. The licence group and ownership is the same today as at the time of award.

## 1.2 Award and Work Programme

The licence area covers part of the block 2/2, 2/5 and 2/8 as seen in **Fig. 1.1**

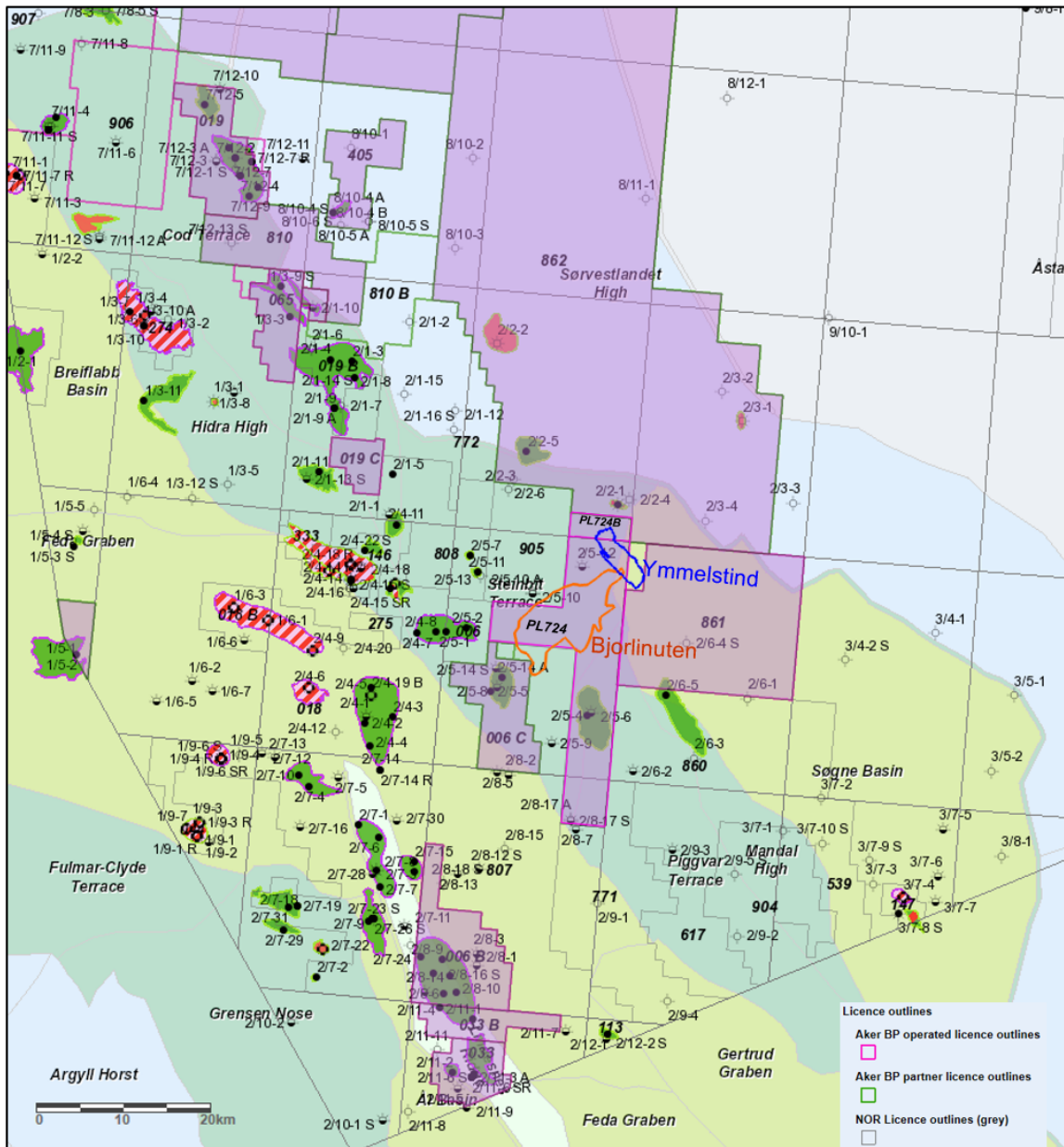


Fig. 1.1 PL724 and PL724B licence area with outline of prospect Ymmelstind and Bjorlinuten

The licence was awarded with an initial period with a firm work commitment to reprocess 3D seismic data and conduct geological & geophysical studies leading to a drill-or-drop decision after two years. The work programme for the licence is the same as when awarded, except the commitment to reprocess 3D seismic data has been changed to acquisition of specified 597 km<sup>2</sup> of the PGS survey MC3D-CGRN13.

### **1.3 Identified Prospectivity**

During the licence period, 16 EC/MC meetings were held by the operator to share and discuss prospectivity evaluations with the licence partners. Two prospects have been identified. The main prospect, Ymmelstind, is of Late Jurassic age. A secondary prospect, Bjorlinuten, is of Palaeocene age. The identified prospects in the licence have reservoir presence and seal effectiveness as shared risks. These two critical risk factors are common themes throughout the greater Mandal High area.

Insufficient resource potential of the main prospect Ymmelstind, makes it marginal economic to make a drill decision. Therefore, a decision was taken to drop PL 724 and PL724 B licence.

# 2 DATABASE

## 2.1 Seismic Database

The seismic database for the licence at time of application consisted of the PGS Megamerge, ST99M1, PON12M01, MC3D-CGR2010, DNO0601 and SH9302 3D seismic surveys along with a number of regional 2D lines.

Subsequent to the award of PL724, the partnership has agreed to purchase 587 km<sup>2</sup> of 3D seismic data MC3DCGRN13 acquired by PGS in 2013. This dataset has been used for licence detailed prospectivity evaluation and inversion study. Seismic data sets used in this licence are shown in Fig. 2.1

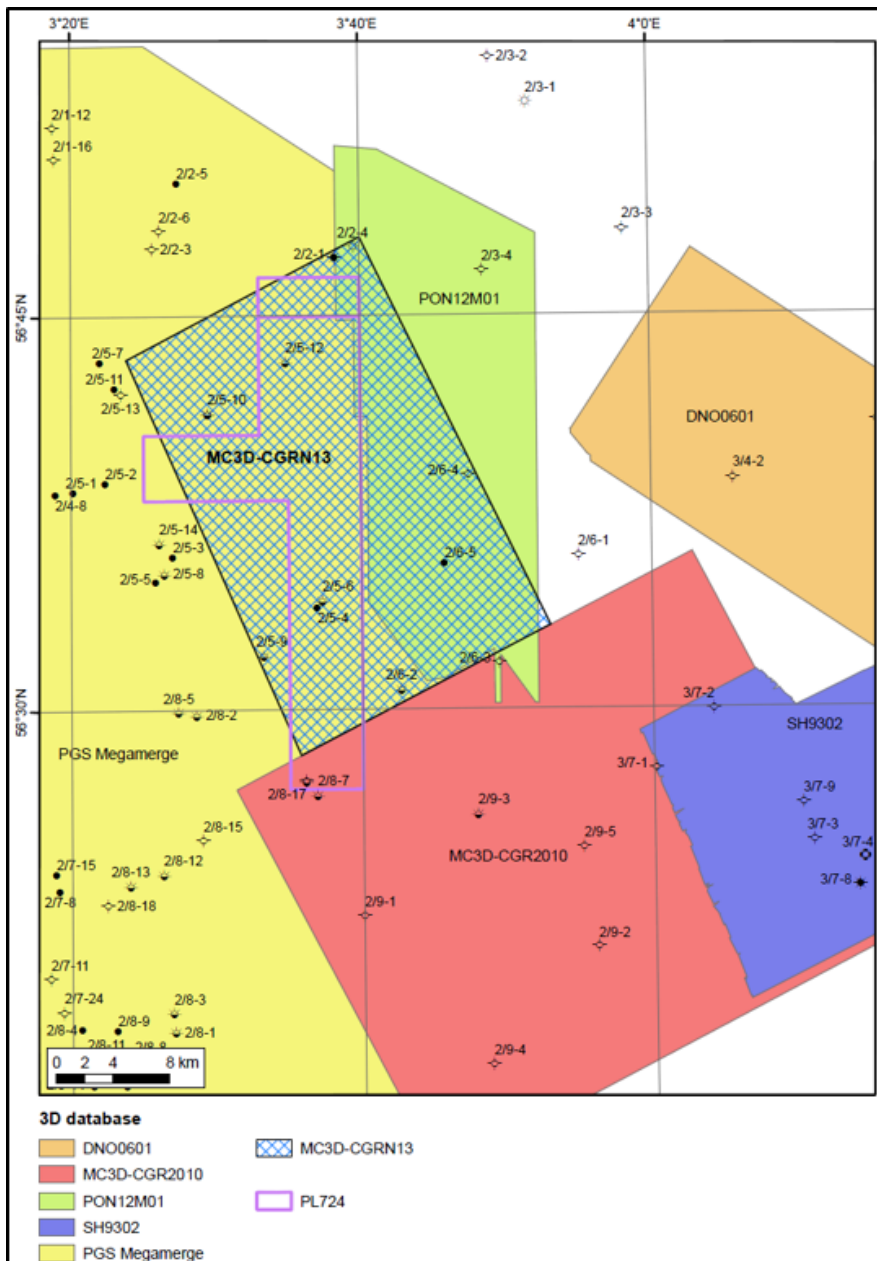


Fig. 2.1 Seismic database

## 2.2 Well Data

The key exploration wells directly included in geological and geophysical studies are listed in Table 2.1 along with other wells, of which several are implemented. The well database consists of all available data, i.e. HQLD, HQPD, deviation surveys, mud logs, velocity and check-shot data, core analysis, raw and interpreted bio-stratigraphic data, core photos, analysis and descriptions, source/maturation measurements and fluid sample analyses.

Table 2.1 Well database

Well	Status	Year P&A	TD (MD) (m)	TD stratigraphy (age)
2/1-12	dry	1999	3550	Middle Jurassic
2/2-1	oil/gas	1982	4003	Late Permian
2/2-3	dry	1983	4100	Triassic
2/2-4	gas	1988	4020	Triassic
2/2-5	oil	1992	4082	Late Jurassic
2/2-6	dry	2010	4105	Late Jurassic
2/3-1	gas	1969	2934	Late Permian
2/3-3	dry	1971	2973	Late Permian
2/3-4	dry	1984	3386	Late Permian
2/4-17	gas/condensate	1992	5258	Early Permian
2/4-21	gas/condensate	2012	5575	Late Jurassic
2/5-1	oil	1970	3972	Late Jurassic
2/5-4	oil	1972	3490	Late Cretaceous
2/5-6	oil/gas shows	1978	4132	Triassic
2/5-7	oil	1984	4531	Triassic
2/5-9	oil shows	1992	5460	Late Jurassic
2/5-10	oil shows	1993	4701	Triassic
2/5-10A	oil shows	1993	4715	Triassic
2/5-12	oil shows	2002	4153	Late Jurassic
2/5-13	dry	2009	4675	Triassic
2/5-14S	shows	2009	3845	Late Cretaceous
2/6-1	dry	1969	3336	Late Permian
2/6-2	oil shows	1980	4760	Late Permian
2/6-3	dry	1983	4060	Basement
2/6-4S	dry	1990	3617	Late Permian
2/6-5	oil	1997	3260	Basement
2/8-2	oil shows	1970	3246	Early Cretaceous
2/8-5	oil shows	1974	3304	Early Cretaceous
2/8-7	oil shows	1975	2868	Late Permian
2/8-12S	oil/gas shows	1989	5300	Triassic
2/8-14	oil shows	1991	4392	Late Jurassic
2/8-17A	dry	1998	2853	Late Permian
2/8-17S	oil shows	1998	2641	Late Cretaceous
2/9-2	dry	1979	4367	Early Permian
2/9-3	oil shows	1989	4859	Early Permian
2/9-4	dry	2010	5500	Early Permian
3/4-1	dry	1994	3107	Late Permian
3/7-1	dry	1973	1973	Basement
3/7-2	dry	1981	4330	Early Permian
3/7-3	dry	1981	3540	Late Permian
3/7-4	gas/condensate	1990	3723	Late Permian
3/7-5	oil shows	1992	3666	Late Permian
3/7-6	oil shows	1996	4120	M. Jurassic
3/7-7	oil shows	2010	3930	Late Jurassic

## 2.3 Special Studies

A number of geological and geophysical studies have been performed:

- In order to improve the data quality in the Jurassic interval, a re-processing pilot study was performed by PSSGeo. In addition to this study, PGS was performed a re-processing project to optimize data quality with removal of seabed multiples.
- In-house AkerBP rock physics, AVO and inversion study to derisk reservoir
- Internal petroleum system modelling studies to increase understating of migration and key uncertainties
- AkerBP internal sedimentological review of the Upper Jurassic stratigraphy and facies on and around licence area
- Borehole Image (BHI) study was performed by Badley Ashton on selected wells led to a better understanding of depositional and structural setting
- A surface geochemistry study (ORG and MicroPro) that analysed geochemical and micro bacterial signature

Surface geochemistry study was conducted in 2017 as a potential method to reduce prospect risk. For Ymmelstind Prospect the chemical signatures are interpreted as inconclusive and the findings unable to influence the prospect risk analysis.

### 3 Review of geological framework

Petroleum system modelling was carried out as part of a regional study to characterise Upper Jurassic source rock facies and understand migration.

Results indicate Ymmelstind fetch area sufficient to fill small 4-way closures with minimum source thickness of 100m and Upper Jurassic (tight) stratigraphic traps in source rock consistently received oil charge throughout area. Migration pathways into the Ymmelstind Prospect are limited by faulting Fig. 3.1 and trapping against fault is necessary for large HC column heights. This study also pointed out lower expulsion efficiency of source with HI < 350 mg/g and recent entry into oil-window with short residence time.

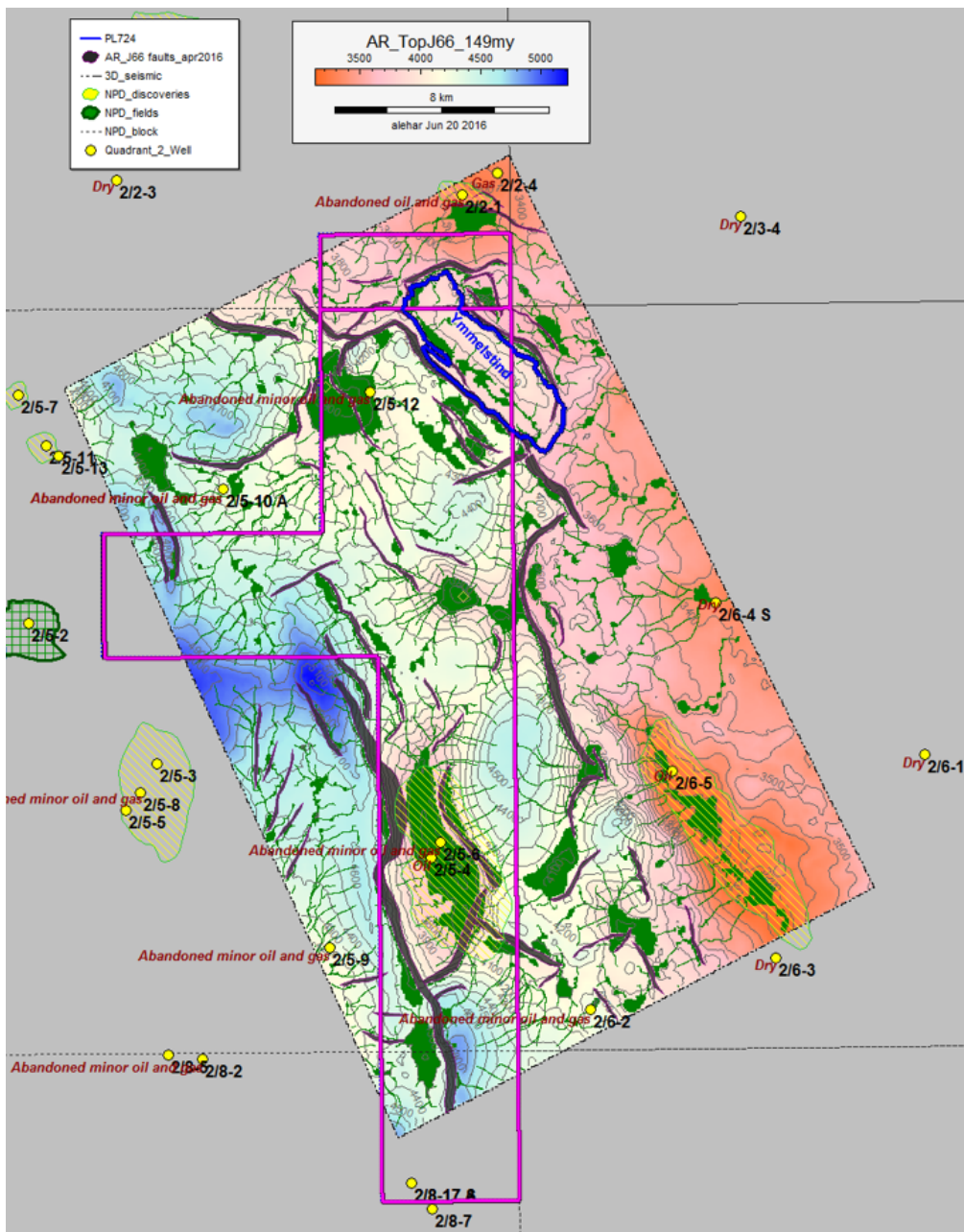


Fig. 3.1 Map illustrating hydrocarbon expulsion from Upper Jurassic source rock Model Thermal gradient 35°C/km, source rock thickness 100 m

# 4 PROSPECTIVITY

At the time of application for the PL 724 acreage, multiple opportunities were identified by the partnership within the Upper Jurassic play. After integrating results of several studies and reinterpretation of the new 3D seismic data, one key prospect known as Ymmelstind and a secondary prospect Bjorlinuten, remain as opportunities within PL 724 licence area.

## 4.1 Ymmelstind

The primary prospect, the Ymmelstind Prospect (Fig. 4.1), is of Volgian or Tithonian age, and located in a syn-sedimentary wedge near the intersection of the Steinbit Terrace, Sørvestlandet High and the Søgne Basin. The proposed reservoir is predominantly composed of gravity flow sediments. Erosion of the Upper Jurassic shallow marine sands deposited along the Coffee Soil Fault Complex is the main source for the reservoir sandstone in the wedge. Hydrocarbons are inferred to have migrated locally into the prospect from the Kimmeridgian and Volgian hot shale.

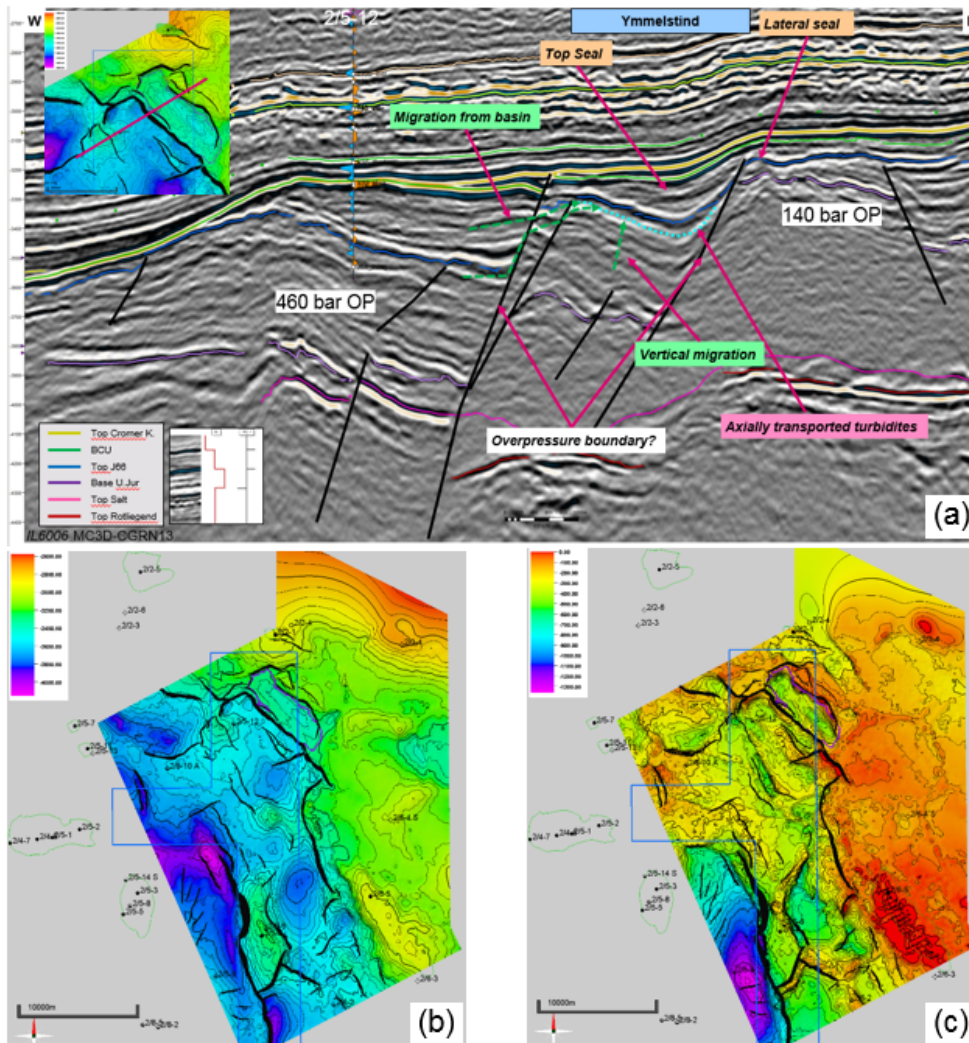


Fig. 4.1 Ymmelstind Prospect (a) Seismic line west to east showing Ymmelstind petroleum system (b) Top Reservoir J66 TWT structural map, C.I 50ms (c) Top J66 - Base Jurassic TWT thickness, C.I 50ms

**Reservoir:** Geophysical analyses shows clear indication of sand on inversion data throughout the Ymmelstind Prospect. Crossplot data shows AI VpVs values to be similar to sands in well 2/2-5. Geological model and analogue suggest that deposited sand prone turbidites are likely to have been deposited axially in structurally controlled depo-centers. Well 2/2-5 penetrated turbiditic sands of similar age and same burial depth as in Ymmelstind. The reservoir quality in 2/2-5 is excellent with porosities up to 25% and permeabilities up to 1 Darcy.

The main reservoir risk is sand presence. Sub-optimal seismic data quality containing multiples within the reservoir zone, specifies risk of reservoir continuity.

**Trap and seal:** Stratigraphic trap in a down thrown rotated fault block with thick Upper Jurassic syn-rift package. Thickness evaluations shows a clear thickening of the sequence from the platform into the Ymmelstind fault block, and dependent on assumptions; sand is confidently mapped within a package on the fault block. Farsund Formation shale form the top and base seal for the Ymmelstind Prospect.

Pressure data from the area suggest isolated pressure cells. The overpressure in the Ymmelstind area is estimated to be in the range of 144-340 bar. Lack of oil in Gyda sands in wells 2/2-1 and 2/2-4 (valid structural closure with seal, along Ymmelstind spill path) indicates a possible pressure boundary between Ymmelstind and the platform area (Fig. 4.1 ). Main risk relates to the juxtaposition of possible Basal and Bryne sands in the footwall. Within the data limits, thief sands presence cannot be excluded.

**Source:** Extensive geochemistry work has been done on a large, regional scale, and proves the presence of a good Upper Jurassic source rock in both Mandal (thin), Farsund and Haugesund formations. The total source thickness exceeds 300m in nearby wells. Ymmelstind fetch area (the fault block) is sufficient to charge around  $9.5 \times 10^6 \text{ Sm}^3$ oe, enough to fill Min and Mean cases. Upper Jurassic stratigraphic traps within source rocks consistently received charge throughout the area, given sand presence. If vertical migration fails, migration from the west is uncertain due to low connectivity to the basin and the western boundary fault potentially seals off Ymmelstind from source. Expulsion efficiency of the Mandal Formation is a risk (Ziegs et al., 2017).

The probability of discovery is estimated to 17% shown in summary Table 4.1 and the base case hydrocarbon recoverable reserves are estimated at  $7.6 \times 10^6 \text{ Sm}^3$  total resources. The main risks associated with the Ymmelstind Prospect are trap (sealing) and the secondary risk is the presence of the reservoir.

Table 4.1 Risk summary Ymmelstind

Descriptions		Risk
Reservoir	PR(presence)	0.6
	PR(quality)	0.9
Trap & Seal	PT(geometry)	1.0
	PS(seal)	0,4
Source	PS(presence)	1.0
	PS(migration & timing)	0.8
<b>COS</b>		<b>0.17</b>

### 4.1.1 Technical Evaluation

An economic evaluation was carried out for the Ymmelstind Prospect. Ymmelstind is economic @ truncated Pmean  $\sim 8.4 \times 10^6$  Sm<sup>3</sup> with an internal rate of return (IRR%) of 20% (65 USD/bbl. scenario).

The prospect provides a positive risked value at the commercial chance of success: ECOS 13%. At the time, AkerBP would have liked to see a lower risk and a more robust risked value to make the opportunity commercially attractive.

Ymmelstind Prospect in PL 724 is located approximately 50 km northeast of the Valhall Field (a potential host) and 35 km northeast of the Ekofisk Field. Average water depth in the Ymmelstind area is 60 m. Based on nearby infrastructure and Pmean resource estimate, a subsea tie-back is assumed as the most likely development solution. A subsea tie-back to Valhall is used as base case, due to uncertainties regarding the modification scope and cost on the Ekofisk Field.

## 4.2 Bjorlinuten

The Bjorlinuten Prospect is defined by distinct soft seismic reflector above top chalk (hard). The prospect is interpreted in the overlying stratigraphic hard event which gives a channel/fan-like pattern (Fig. 4.2) and shows the soft event in between where the interval is thickening. The soft event correlates to sand in wells to the southeast. In nearby well 2/5-14S on SE Tor the unit ties to a thin Borr sand (with oil shows), but here there is only one single reflector at about top chalk. The Borr sand is not present in wells updip of the Bjorlinuten Prospect.

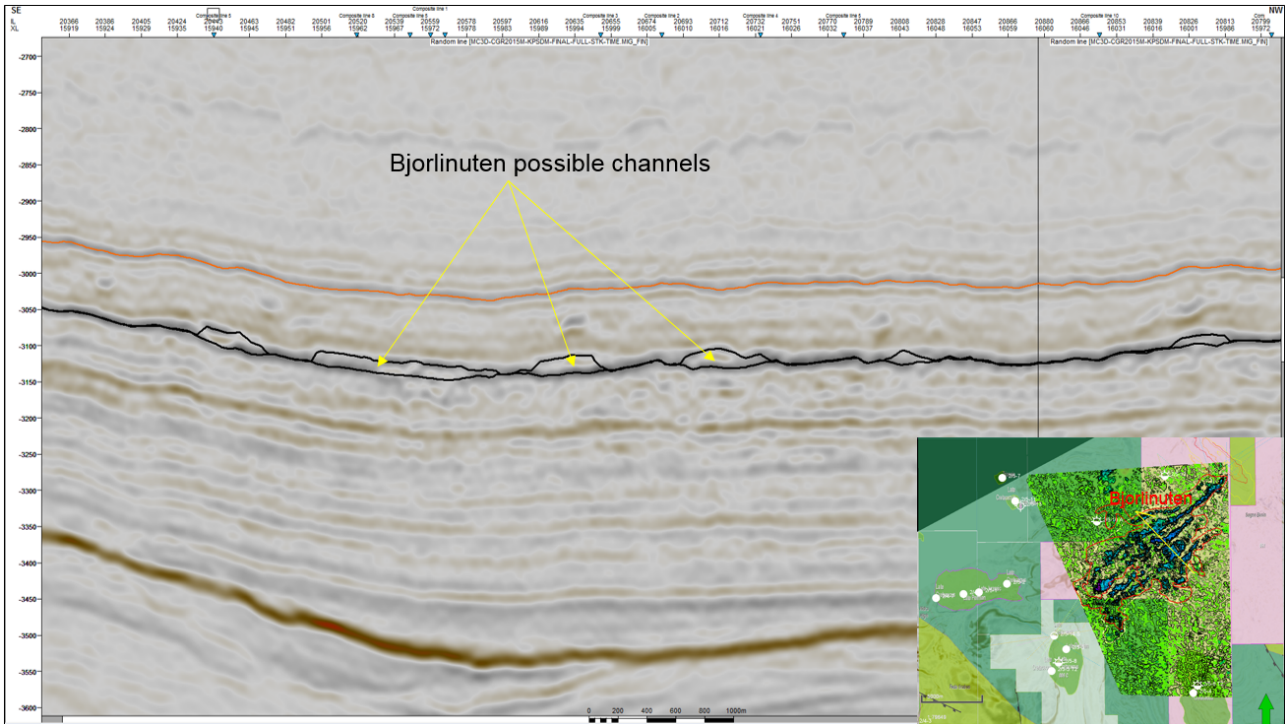


Fig. 4.2 Bjorlinuten Prospect Seismic line SE-NW shows possible channels

Volume estimates are based upon parameters from nearby wells/prospects in Paleocene, and gross rock volume based on mapped top/bottom of reservoir interval. This isopach is varied to capture uncertainty in reservoir/sand thickness. The mean recoverable volume is currently estimated to be  $7.0 \times 10^6 \text{ Sm}^3 \text{ oe}$ .

Main risk is seal. The challenge is in all dimensions, top seal risk related to presence of Heimdal sands in nearby wells and the lateral seal towards entry point of reservoir. The Base seal depends on chalk with questionable sealing capacity probably eroded by slumping.

Migration of hydrocarbons is also a risk, although located above a prolific source kitchen, the prospect may be in a migration pathway shadow. Migration routes are not well understood in the area.

### 4.3 Leads

A number of leads have been evaluated during the licence period, see Fig. 4.3 . A short description of the leads are given below.

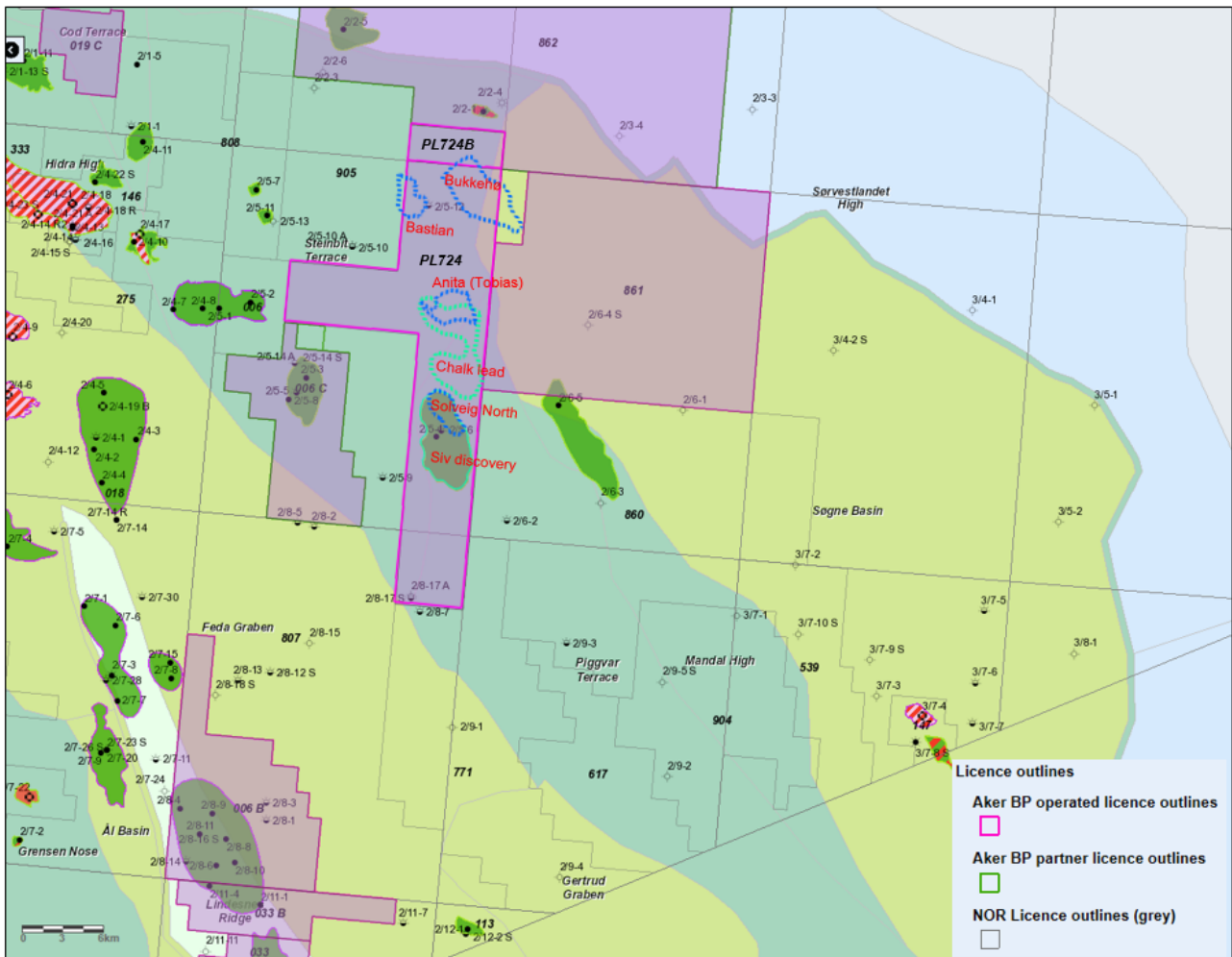


Fig. 4.3 Area of the PL724 and PL724B licence with outline of leads

**Bukkeho Lead :** The lead is located in the northeastern corner of the licence area, in the same fault block as the Ymmelstind Prospect. The proposed reservoir is a combination of fluvial sandstones in the Bryne Formation and the transgressive basal Upper Jurassic sandstone. There are significant uncertainties in definition of the fault bounded trap, distribution of the proposed reservoir sands and migration of hydrocarbons into the trap.

**Bastian Lead :** Trap definition is a complex structural closure and it is likely that the structure is heavily segmented. Bastian seems to be favorably located for reservoir (Bryne/Ula Fm.), on a sand fairway. Definition is still uncertain on deeper levels and it is hard to predict reservoir levels. Limited volume potential.

**Anita (Tobias) Lead :** It is defined by a salt induced structural 3-way closure at the Bryne/Ula levels showing complex deformation from salt movement with low internal consistency of reflectors. The closure is relatively small and preservation of the Upper-Middle Jurassic reservoir is uncertain.

**Solveig North Lead :** Small structural closure on Bryne/Ula level and main risk is migration.

*Chalk Lead* : Chalk level structural closure and the main uncertainty tight reservoir.

## 4.4 Discoveries

### Siv Discovery

The discovery well, 2/5-4, was drilled by Amoco in 1972. Hydrocarbon shows were encountered in the upper part of Ekofisk Formation and in the upper part of Tor Formation. Shows were also reported in slices cut from Ekofisk and Tor formations with a Schlumberger core slicer after the well was drilled to TD. DSTs were run in the Ekofisk and Tor formations.

DST 1 tested the interval 3137 - 3170 in the top of the Tor Formation and flowed initially 556 Sm<sup>3</sup> oil, 30500 Sm<sup>3</sup> gas and 484 Sm<sup>3</sup> water, declining to 396 Sm<sup>3</sup> oil, 20900 Sm<sup>3</sup> gas, and 363 Sm<sup>3</sup> water /day through a 32/64" choke. Evaluation of wireline logs and cores concludes with a low porosity, with low hydrocarbon saturation in the matrix. Oil shows are mainly confined to fractures. Challenges with production from this type of reservoir includes rapid decline in formation pressure, low oil rates and capacity to handle large amounts of produced water.

DST 2 in the Ekofisk Formation proved a tight formation with no flow to surface. There is no resource potential in the Ekofisk Formation in the Siv structure based on interpretation of the available data.

It is not possible to see any commercial value of the hydrocarbon accumulation in the chalk reservoirs with the present technology.

## 5 CONCLUSION

Geological studies carried out to put the licence area into regional geologic context as part of the work programme has improved the understanding of PL 724. Detailed seismic interpretation, geophysical evaluation and petroleum system modelling study have highlighted the significant challenges to de-risk the seal of the main Ymmelstind Prospect on the licence. Reservoir has also been identified as a risk.

Technical and economical evaluation of the licence has illustrated that the identified prospectivity in PL 724 does not meet current (07.02.2018) commercial viability criterion and an unanimous decision to drop the licence was taken by the partnership in 2017.

## 6 REFERENCES

Ziegs, V., Horsfield, B., Skeie, J.E. and Rinna, J. (2017) Petroleum retention in the Mandal Formation, Central Graben, Norway. *Marine and Petroleum Geology* 83, 195-214.