

PL677

# Relinquishment Report

Hyrokkin



Partner:

 MOLGROUP NORGE

# Relinquishment Report PL677

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# 1 Introduction

## 1.1 License Owners

Aker BP ASA 90 % (Operator)

MOL Norge AS 10 %

## 1.2 Award and Work Program

The production license 677 was awarded in the APA2012 on the 08.02.2013 with a drill decision within two (2) years and an initial period of seven (7) years.

The initial partners in the license were Det norske oljeselskap ASA (60 % and Op) and Fortis Petroleum Norway AS (40 %). In 2014 Itacha Petroleum Norge AS acquired a 10% share from Fortis, in 2015 Itacha became part of MOL Norge AS, in 2016 Det norske changed name to Aker BP ASA, and in 2018 Aker BP acquired Fortis' 30 % share in the license.

License work obligations for PL677:

- 1) Reprocess 3D seismic
- 2) Drill or drop decision within 2 years

The work obligations has been fulfilled.

## 1.3 Identified Prospectivity

PL677 is located west of the Heimdal Terrace and east of the Shetland Platform, at the north-eastern margin of Volve Sub-basin in the southern part of the Viking Graben, see location in Fig. 1.1. The license is near the Norway/UK border, and cover parts of 25/1 & 4, south of the Frigg Field, west of the Vilje Field and north of the Alvheim Field.

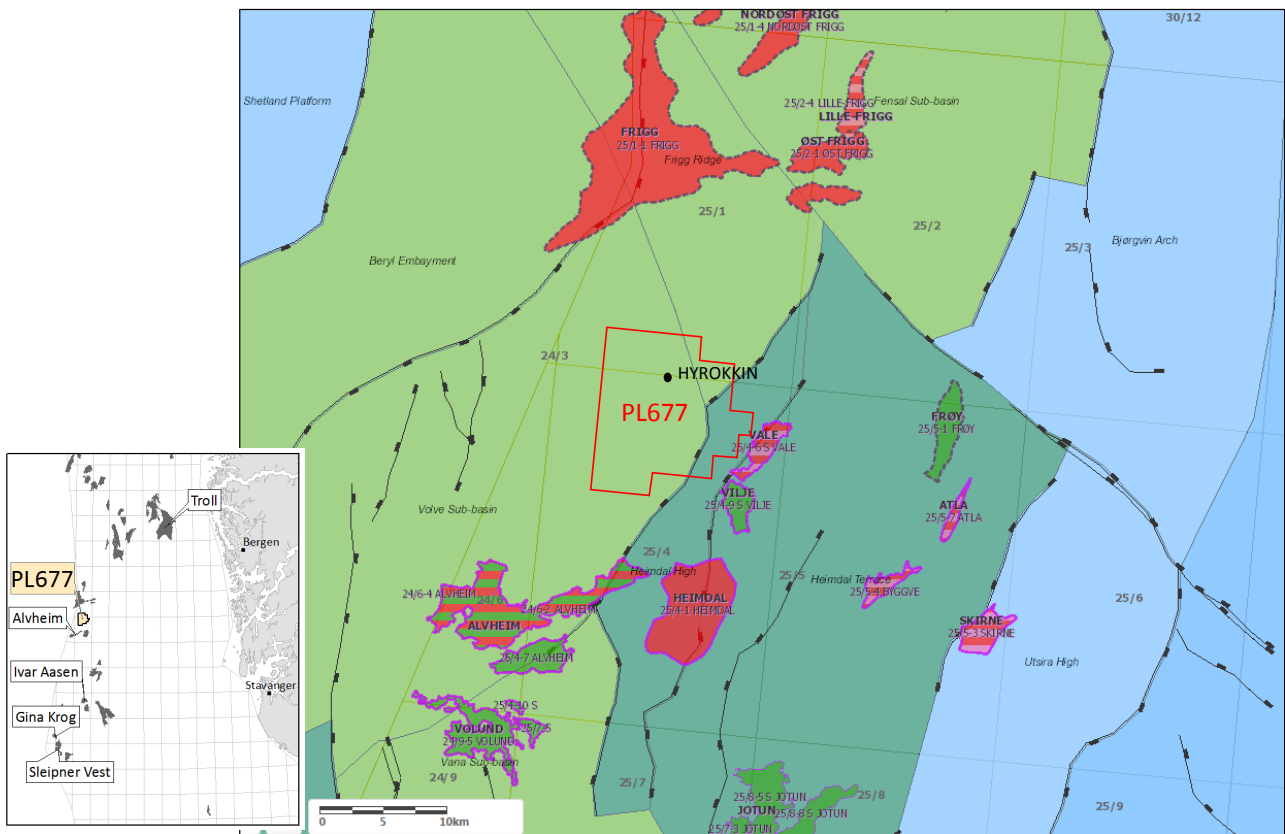


Fig. 1.1 Structural map with PL677 and Hyrokkin location. *PL677 is shown in red*

Several Paleocene prospects were/are identified in the license: Hyrokkin Main and East, Helblinde and Surt. A map with an overview of the prospects is shown in Fig. 1.2, and a simplified stratigraphy figure of the main prospect, Hyrokkin, is shown in Fig. 1.3.



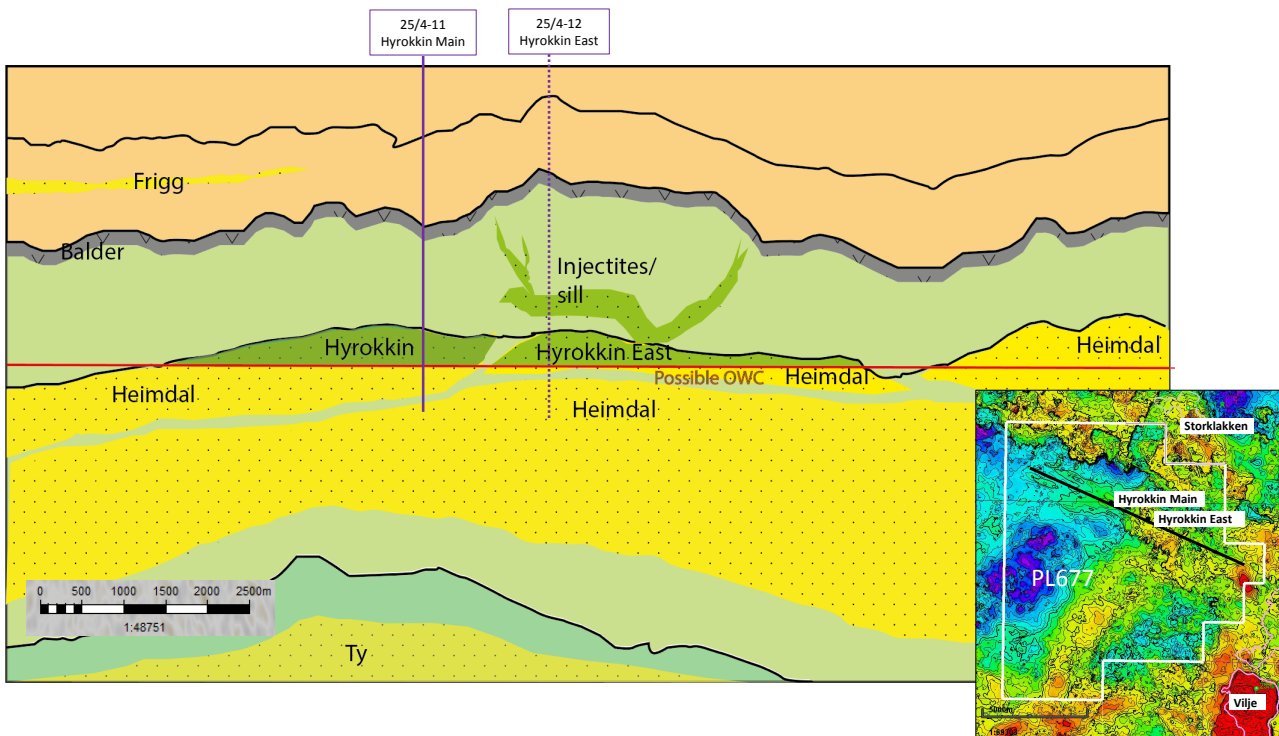


Fig. 1.3 Simplified stratigraphy of the Hyrokkin Prospect. A geosection to the left, with the position of the planned wells 25/4-11 and 25/4-12. 25/4-12 has not been drilled since -11 was dry. An index map is placed to the right.

The main prospect identified within PL677 acreage was Hyrokkin. Hyrokkin was tested with well 25/4-11 in August 2017, and was targeting Paleocene Heimdal sandstone. The Hyrokkin Main Prospect consists of the npc-1 play with deep marine sandstones of the Heimdal Formation. The Paleocene deep-marine sandstone play is very well established in this area, and the play is proven in the area through several discoveries and producing fields (Alvheim, Vilje). The Hyrokkin Main Prospect, was a combined structural/stratigraphic trap in the Heimdal Formation. The main part of the prospect is associated with an amplitude versus offset (AVO) anomaly, which correlates well with existing discoveries in the area and thus probably indicated the presence of hydrocarbons. The hydrocarbons are sourced from the underlying Upper Jurassic, Draupne and Heather formations. If discovery in Hyrokkin Main, the plan was to drill Hyrokkin East with the same target and reservoir unit as Hyrokkin Main, Paleocene Heimdal sandstones. In addition, Hyrokkin East has an upper sand, interpreted as a sill/injectite above the Heimdal fan.

Fig. 1.3 and Fig. 1.4 show the target- and spud locations for both Hyrokkin Main and Hyrokkin East. Hyrokkin Main is identified with an amplitude anomaly, comparable with the amplitude anomaly at the Vilje Field, see Fig. 1.5 . The DHI's are represented by high negative anomalies on the surface attribute (Far, 25-35 degrees). Vilje is an oil discovery in Heimdal Formation, same reservoir as found in Hyrokkin. The amplitude anomaly is seen at Heimdal reservoir level in the seismic cross- and inline in Fig. 1.6.

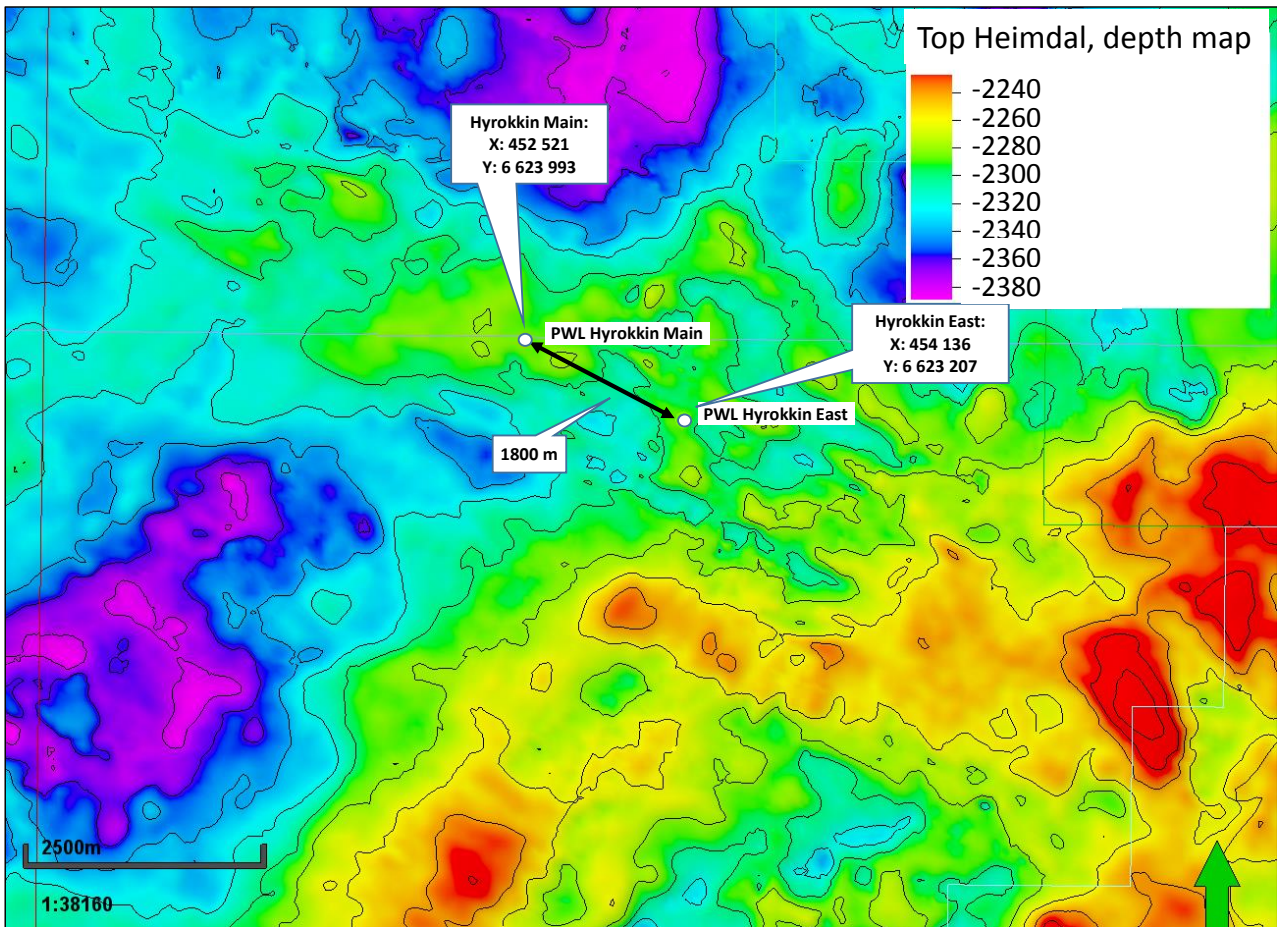


Fig. 1.4 Top Heimdal depth map. C.i. 20 m. *Main target to the west, and optional target to east if discovery in main.*

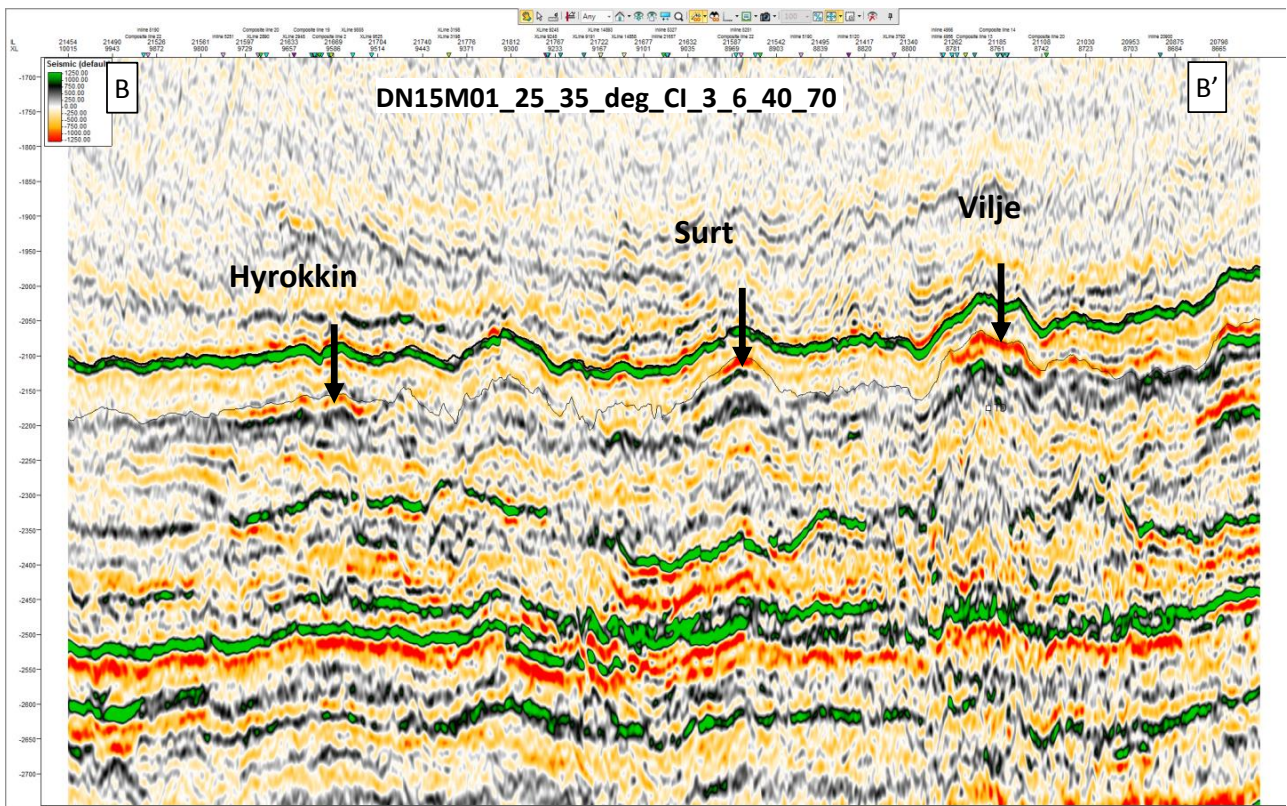
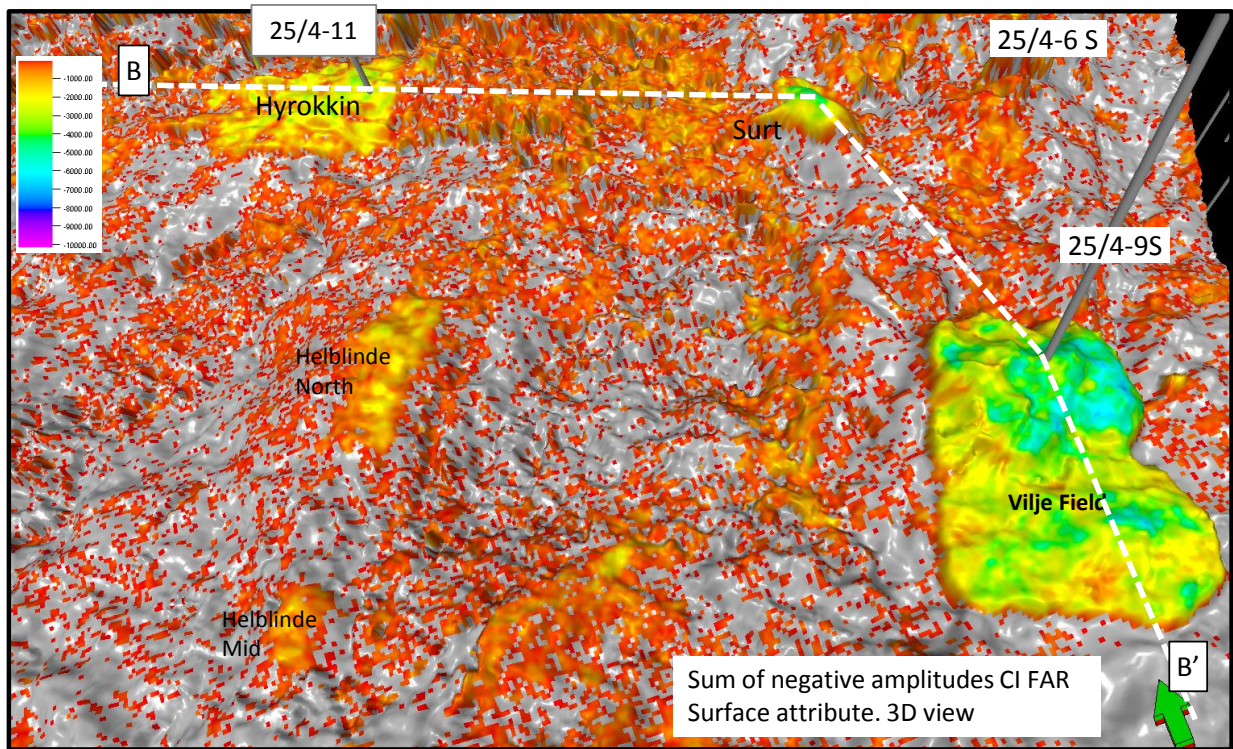


Fig. 1.5 Upper map: 3D map showing amplitudes at Hyrokkin Main, Surt and Vilje. Lower figure: seismic section, indicated with white line on the upper map. *Comparable amplitudes at 25-35 deg*

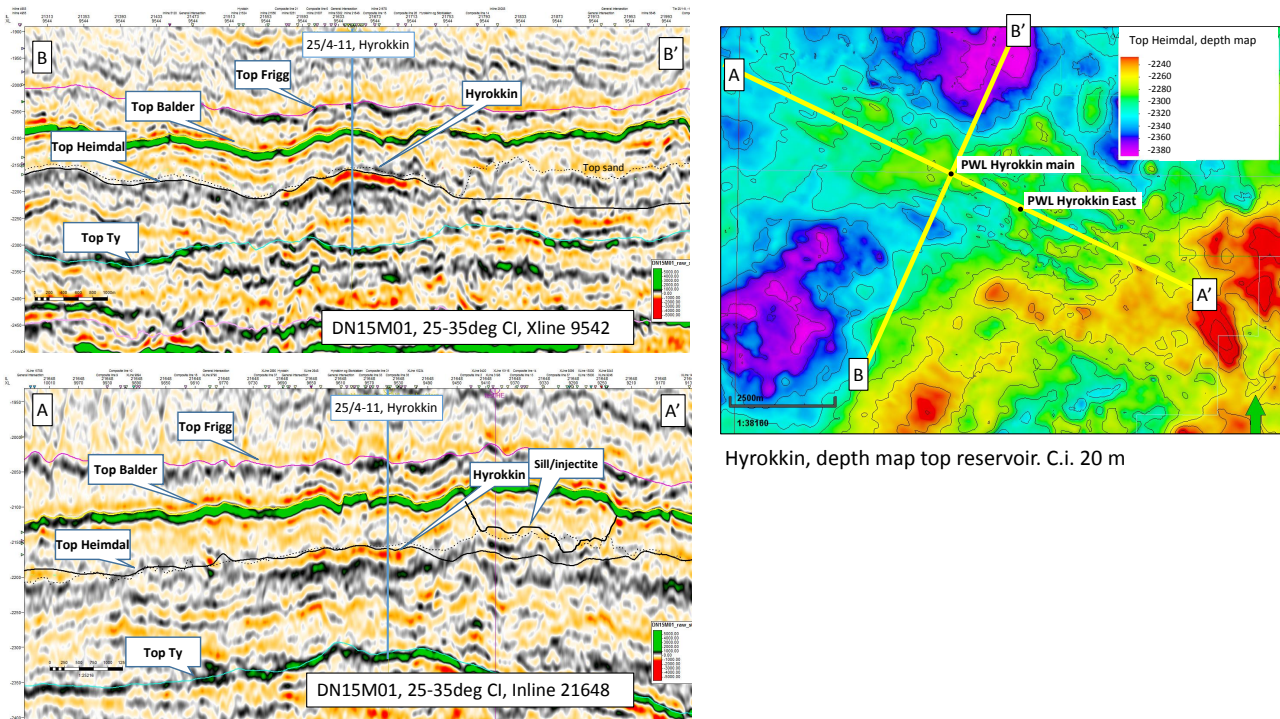


Fig. 1.6 Inline and crossline through Hyrokkin Main. *Hyrokkin Main* shows high negative anomalies on far offset, 25-35 deg. *Hyrokkin East* is also seen to the east on the A-A' seismic inline, but different from Main, *Hyrokkin East* brights only on ultrafar (35-50 deg) as described in Chapter 1.3.

The deep-water fan deposits of the Heimdal Formation in the Greater Alvheim- Heimdal area are sand-rich with excellent reservoir properties. Amalgamation of individual channel lobes has resulted in sheet-like and relatively uniform sandstone bodies covering large areas. These are characterized with high net/gross ratios typically 80-90%, porosity in the mid to high twenties, and permeability up to several Darcies. The main part of the Hyrokkin Prospect is located at the depositional axis of such a channel lobe complex (Upper Lobe), but it is in a more distal facies than Alvheim. The excellent reservoir parameters observed in surrounding discoveries were considered to be representative for the Hyrokkin reservoir, but it could be thinner and the N/G could be lower since it is in a more distal facies.

The result from the Hyrokkin well, 25/4-11, showed an excellent reservoir which was water-wet. Average porosity in the Heimdal Formation is 30 %, but the best porosities are about 36 % at the uppermost Heimdal sand. Net/Gross in Heimdal: 0.78, and SWT =1. A CPI is shown in Fig. 1.7.

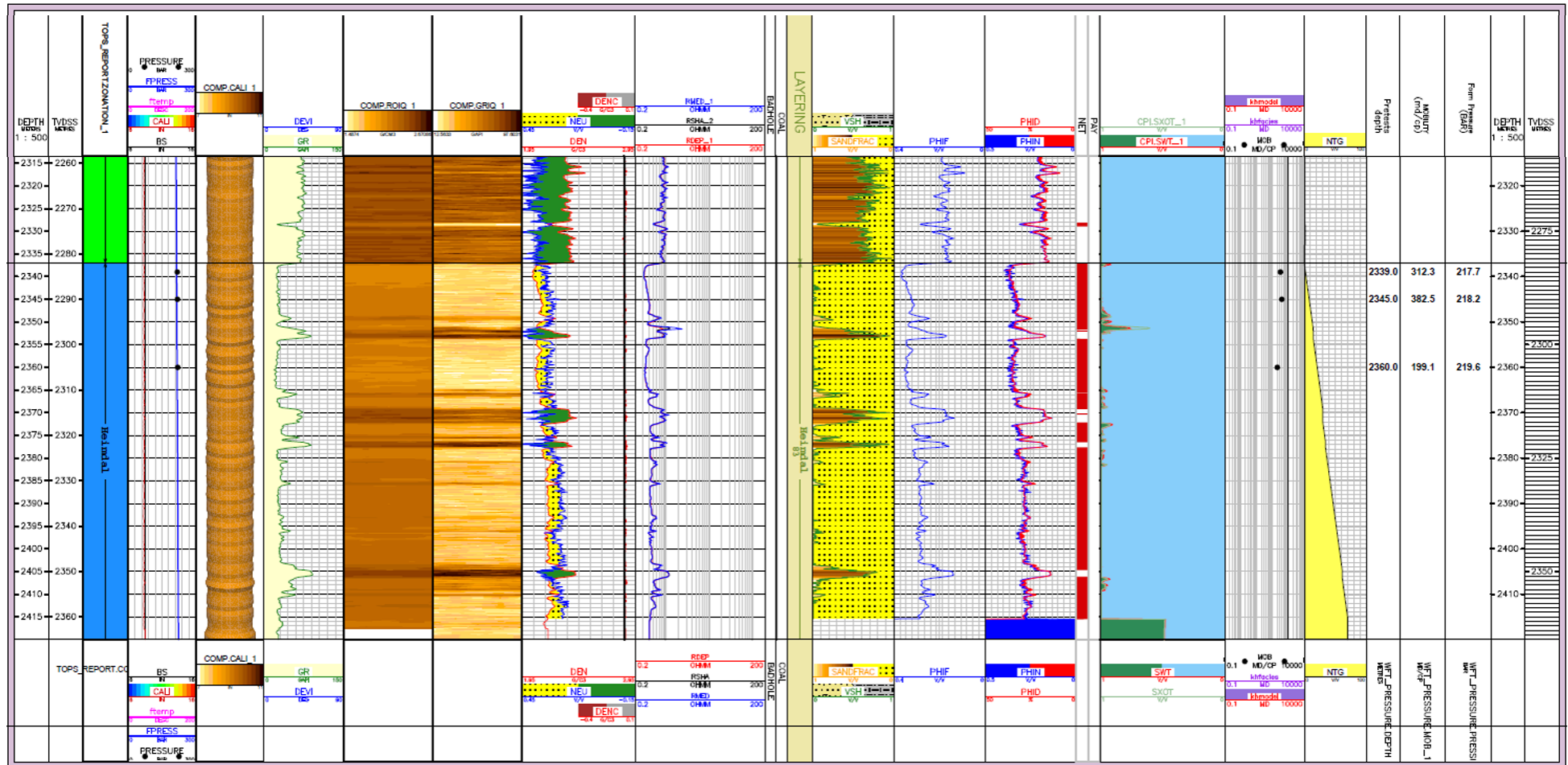


Fig. 1.7 CPI, 25/4-11, Hyrokkin

## 2 Database

### 2.1 Seismic Database

The Hyrokkin prospect was interpreted on the 3D survey DN15M01, which covers all prospects and whole of the PL 677 area. The seismic database agreed in the license is seen in Fig. 2.1. Key wells used for e.g. interpretation, well ties and volume calculations are marked with red circles in the map.

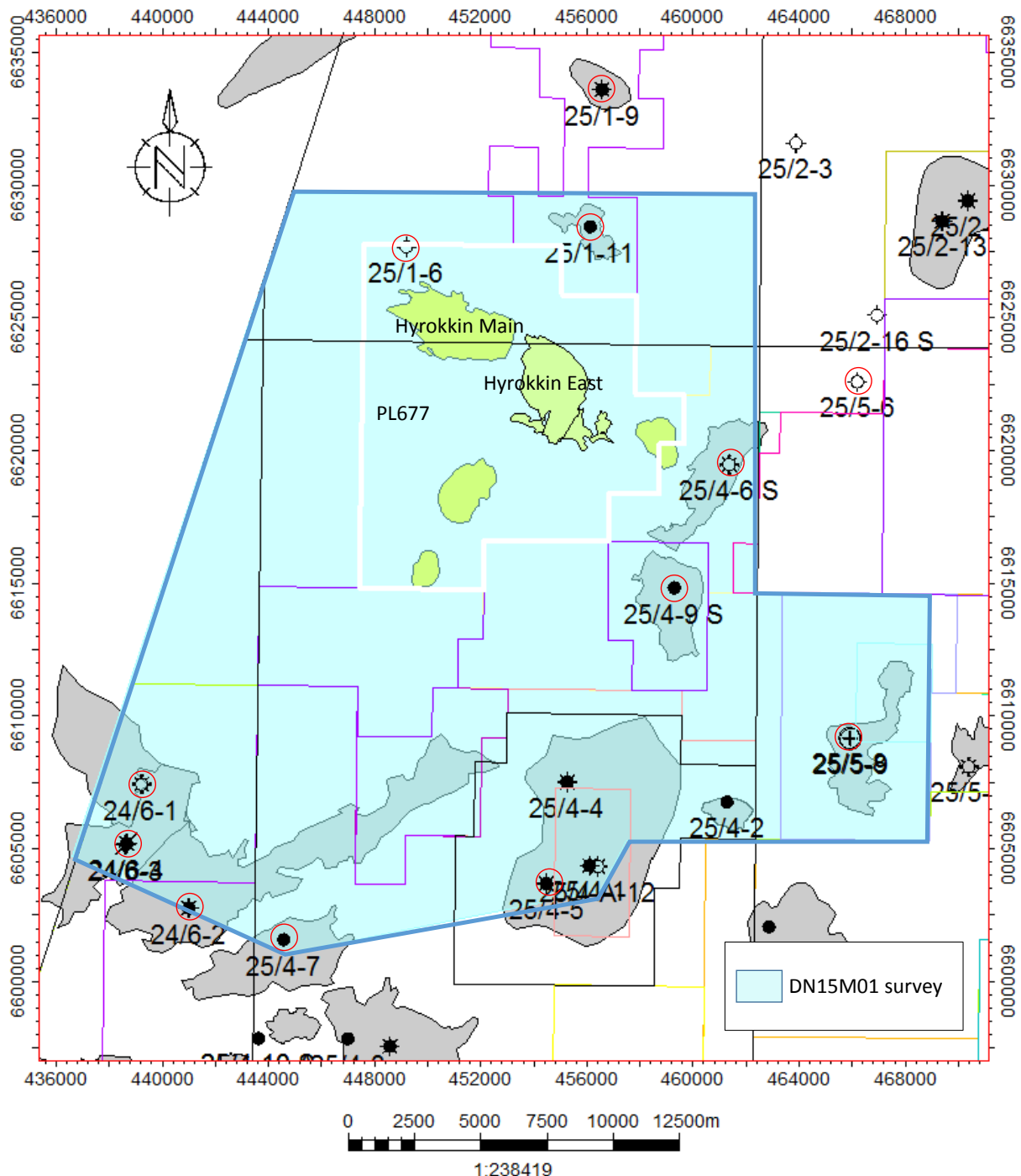


Fig. 2.1 Seismic database

## 2.1.1 Seismic reprocessing

3D seismic reprocessing was done as described in 1.2 Award and Work Program. This was fulfilled by the reprocessed survey DN15M01, which is a part of the Greater Alvheim Area work carried out by Det norske (now AkerBP).

The Greater Alvheim reprocessing includes MC3D-NVG (NVG09/NVG10/NVG11), MC3D-SVG11, MC3D-BYL2013, MV3D-Q16203 and NH9603. DN15M01 is reprocessed using a state of the art PSDM processing flow including Complete Wavefield Imaging (CWI) comprising of Full Waveform Inversion (FWI) with Separated Wavefield Imaging (SWIM) for quality control, TTI Velocity Model Building with dual azimuth model building over the NH9603 area and Final TTI Q-Kirchhoff Migration. This was done to increase the seismic resolution and improve the disturbed imaging beneath the shallow channels in the area. The seismic database is listed in Table 2.1.

Table 2.1 Seismic database

3D Seismic survey	Survey Type	Year	Offset data	Comment
DN15M01	PSDM reprocessed 3D	2015	Yes	Detnor reprocessing including MC3DNVG09/10/11, MC3DSVG11, MC3D-BYL2013, MV3DQ16203 and NH9603

## 2.2 Well Data

A list of well data/reference wells is presented below in Table 2.2 , and a map showing the location of the reference wells is presented in Fig. 2.2.

Table 2.2 Hyrokkin reference wells

Wells	Operator	Year	Water depth (m)	TD Formation	TD depth (mMD)
25/1-6	Elf	1978	105	Jorsalfare	2895
25/1-11R	Det norske	2010	107	Heimdal Fm	2338
25/1-11A	Det norske	2010	107	Heimdal Fm	2410
25/4-6S	Elf	1991	114	Statfjord Gp	4170
25/4-9S	Norsk Hydro	2003	120	Heimdal Fm	2377
25/4-4	Elf	1975	116	Våle Fm	2681
25/4-5	Elf	1980	121	Smith Bank Fm	4355
25/4-7	Marathon	2003	119	Heimdal Fm	2286
24/6-2	Norsk Hydro	1998	124	Heimdal Fm	2722
24/6-4	Marathon	2003	119	Heimdal Fm	2325
24/6-1	Total	1985	122	Statfjord Gp	4937



structures and injectites. Spectral decomposition is a frequency transform of a relatively short time window to capture details from a certain stratigraphic interval. By decomposing the signal into discrete frequency bands, some details not distinguished in a full bandwidth signal will become visible. In the case of a discrete layer in a background model, low frequencies will tune at thicker intervals than high frequencies. By exploiting RGB colour blending techniques, the discrete frequency components can be blended to illustrate thickness changes, highlighting depositional features and exploring for anomalies related to hydrocarbons. If a fluid contact is present, this will also impose a tuning response towards a dipping reservoir. Results from these studies are integrated with the prospect evaluation for better evaluation.

## **OGS**

OpenGeoSolution based in Calgary, Canada carried out a spectral inversion and curvature analysis study on the whole DN15M01 dataset. Spectral inversion maximises the detection and resolution of layering that can be characterised using the bandwidth of available signal. This is done by uncoupling the source wavelet shape from the interference profile within the bandwidth of usable signal. Traditional techniques link resolution and detection to the source wavelet shape in context of a single layer embedded in a quiet background. Spectral inversion on the other hand, relates resolution and detection to the available signal bandwidth, signal-to-noise ratio, the complexity of the local layering architecture, and the complexity of impedance contrasts within the local distribution of layering.

# 3 Remaining Prospectivity

## 3.1 Hyrokkin East

One of the remaining prospects, Hyrokkin East, is strongly affected by the result of Hyrokkin Main. Hyrokkin East has the same target and reservoir unit as Hyrokkin Main; Paleocene Heimdal sandstones, but in addition also an upper sand: interpreted as a sill/injectite above the Heimdal fan. Since the Heimdal reservoir in Hyrokkin Main was waterfilled, it is hard to believe that the same unit in Hyrokkin East is oil filled. Hyrokkin East has not as convincing attribute anomalies as the Main segment either. The model is that a thin, sandy sill/injectite, overlies the Heimdal reservoir. The observations are high negative anomalies on ultrafar (35-50 degrees), this could be explained by a thin oil filled sand, but also merely lithology/good quality sand. This sill/injectite remains untested in Hyrokkin East. Fig. 3.1 shows an inline with ultrafar brightening, an amplitude map on the Heimdal fan and the top reservoir of the upper sand: sill-injectite. The amplitude anomaly is also seen at Heimdal reservoir level and in the sill/injectite above in the seismic cross-and inline in Fig. 3.2.

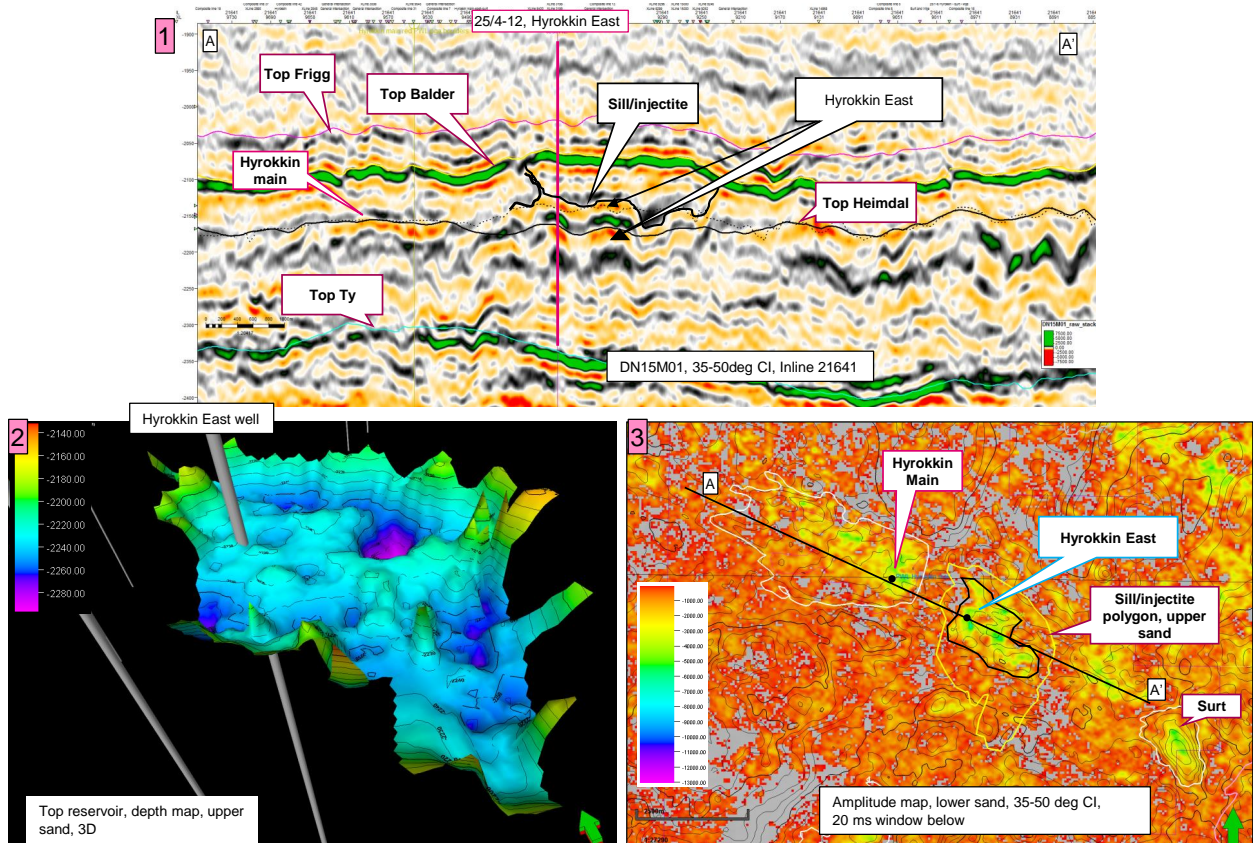


Fig. 3.1 Hyrokkin East. Figure no 1 shows inline 21641 (A-A') with ultrafar brightening (35-50 deg) both on the upper sand/sill-injectite and the lower sand/Heimdal fan. Figure 2 shows the top reservoir of the upper sand in 3D. Figure 3 shows an amplitude map on the lower sand/Heimdal fan.

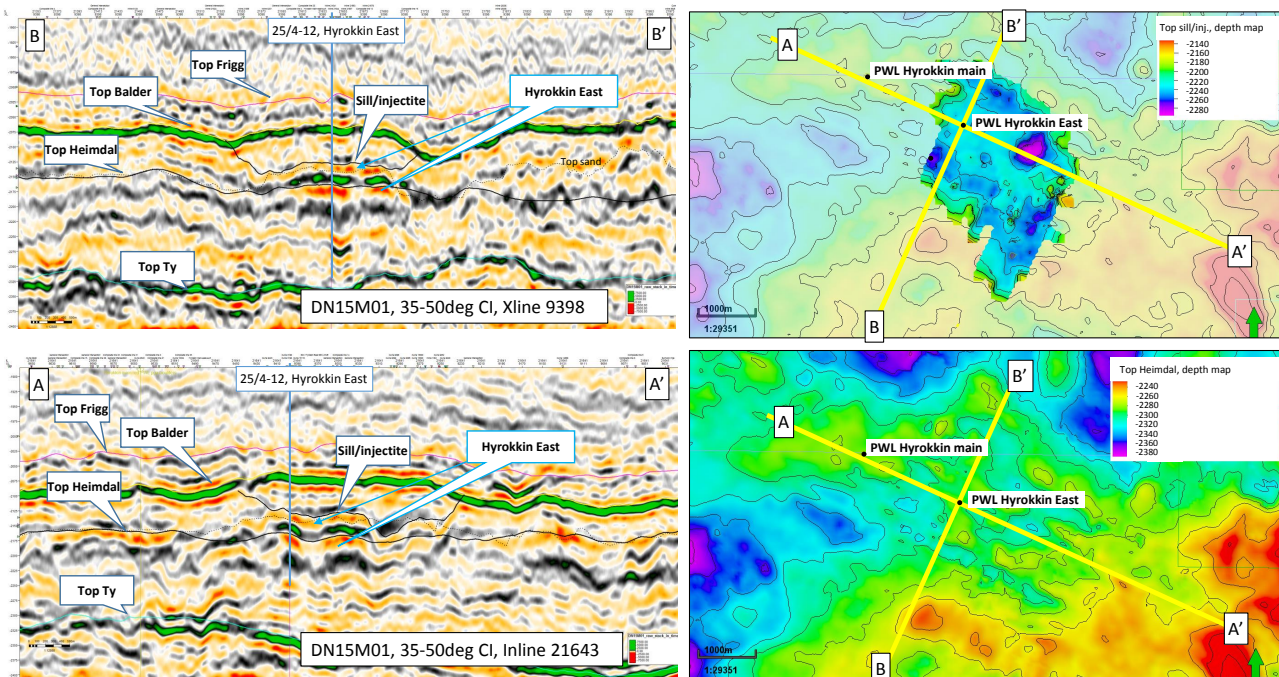


Fig. 3.2 Inline and crossline through Hyrokkin East. Uppermost map to the right: Top upper sand/sill-injectite. Top Heimdal map below in 70 % transparency. Lowermost map to the right: Top Heimdal. Both: depth maps, c.i. 20 m

The Hyrokkin East Prospect is an injectite-sill complex of sands below the top Balder. Top Balder has a clear 4-way closure above the prospect, and a jack-up effect is seen. The sill/injectites seems to be in communication with the underlying Heimdal sand. The main risk on Hyrokkin East is the seal. These sill/injectites are seen below the Balder reflector, but some injectites reaching the sandy Frigg Formation, cannot be excluded. Experience from other injectite discoveries in the area, e.g. the Volund Field, is that the injection process has enhanced the reservoir properties. The injected sandstones at the Volund Field commonly have an average porosity of 34 %, while the in situ Hermod sandstones tend to be 27-28 %. This experience makes us believe that the upper sand in Hyrokkin East will have even better reservoir properties than the in-situ Heimdal sand. A simplified stratigraphy of the Hyrokkin Prospects is shown in Fig. 1.3. The Draupne and Heather source rocks have expelled significant volumes of both oil and gas as proven by the many discoveries in the area, then presence and maturation of source should work in the area. Vertical migration into the Paleocene section occurs either along faults or induced by hydraulic fracturing of the Upper Jurassic and Cretaceous cap rocks. Since Hyrokkin Main was water filled it is a risk that Hyrokkin East is in a migration shade.

### 3.2 Surt & Helblinde

Two other Heimdal prospects, Surt and Helblinde, also remains in the license, these are less affected by the result of the Hyrokkin well than Hyrokkin East, but the volumes are small.

#### Surt

The Surt prospect is a small 4-way closure with a contour consistent amplitude anomaly, located on the border of PL677 and PL036, with about 2/3 of the volumes in PL677, it is located about 4 km north of Vilje Field. Top reservoir depth map is shown in Fig. 3.3 with a indicated seismic line shown in Fig. 3.4. The prospect is associated with an amplitude versus offset (AVO) anomaly, which correlates well with existing discoveries in the area and thus probably indicate the presence

of hydrocarbons. The Surt Prospect is an analogue to the nearby Vilje Field. A seismic line correlating the amplitude at Surt with the Vilje discovery is seen in Fig. 3.4 , and an amplitude map showing the comparison of AVO at Surt and Vilje is shown in Fig. 3.5.

The Surt Prospect reservoir consists of deep-marine sandstones of the Paleocene Heimdal Formation. The sandstones are deposited as channel/lobe complexes sourced from the East Shetland Platform with excellent reservoir characteristics. Surt Prospect has the same seismic characters as the Vilje Field and reservoir parameters are believed to be similar. The Surt Prospect consist of a 4-way closure with corresponding Class III AVO anomaly (increasingly negative amplitude with offset). The overlaying Lista shales forms the seal. Underlying thick sequence of Draupne Formation shale is the source for hydrocarbons. Migration is believed to be vertical along Cretaceous basin margin faults penetrating Jurassic carrier beds. With the proximity and similar seismic characters to the Vilje Field, the Surt Prospect is expected to be oil filled, but small volumes. The area of the Surt Prospect is calculated to be 1,5 km<sup>2</sup>.

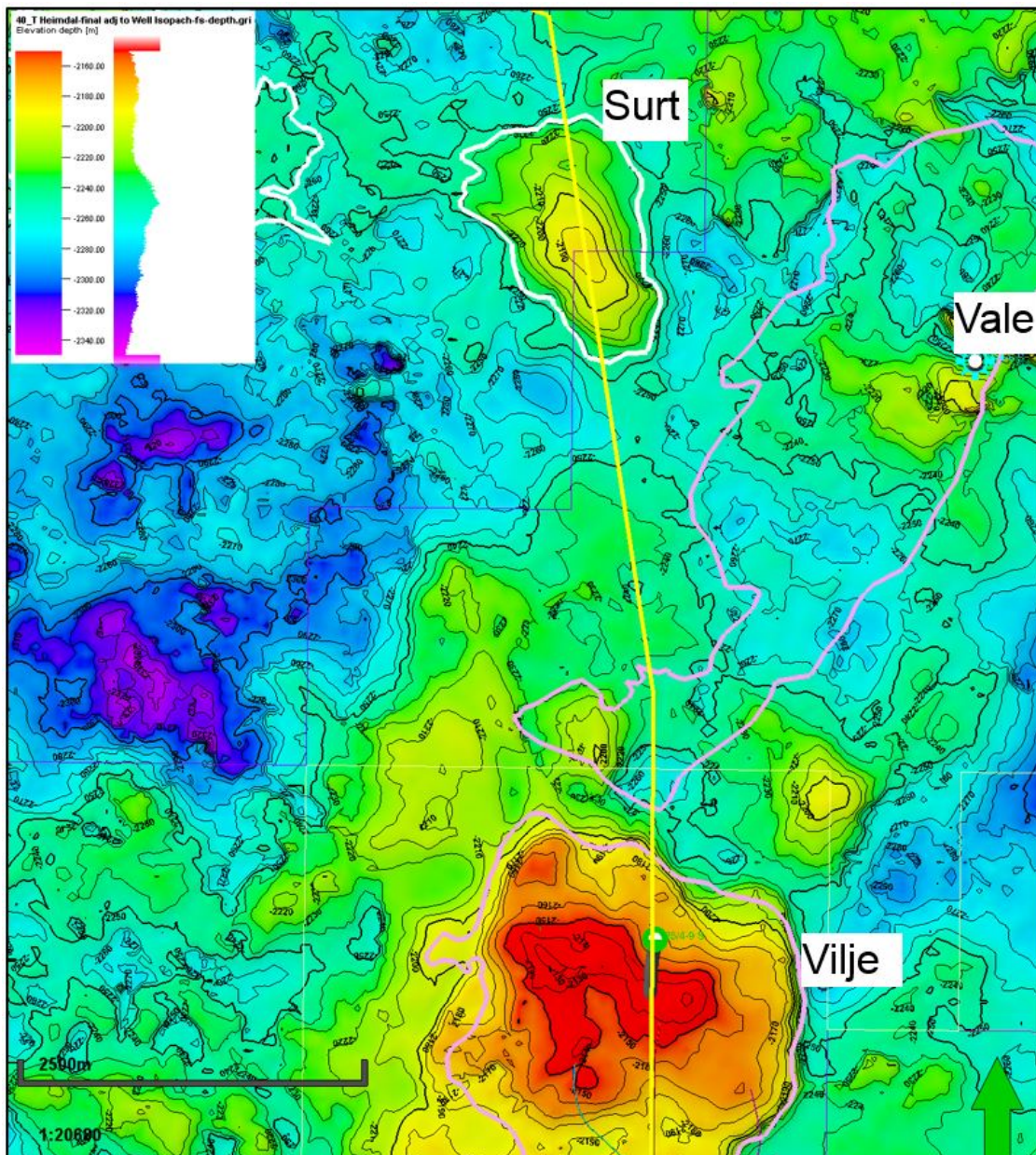


Fig. 3.3 Surt Prospect. Top Heimdal depth map with Surt, Vilje and Vale.

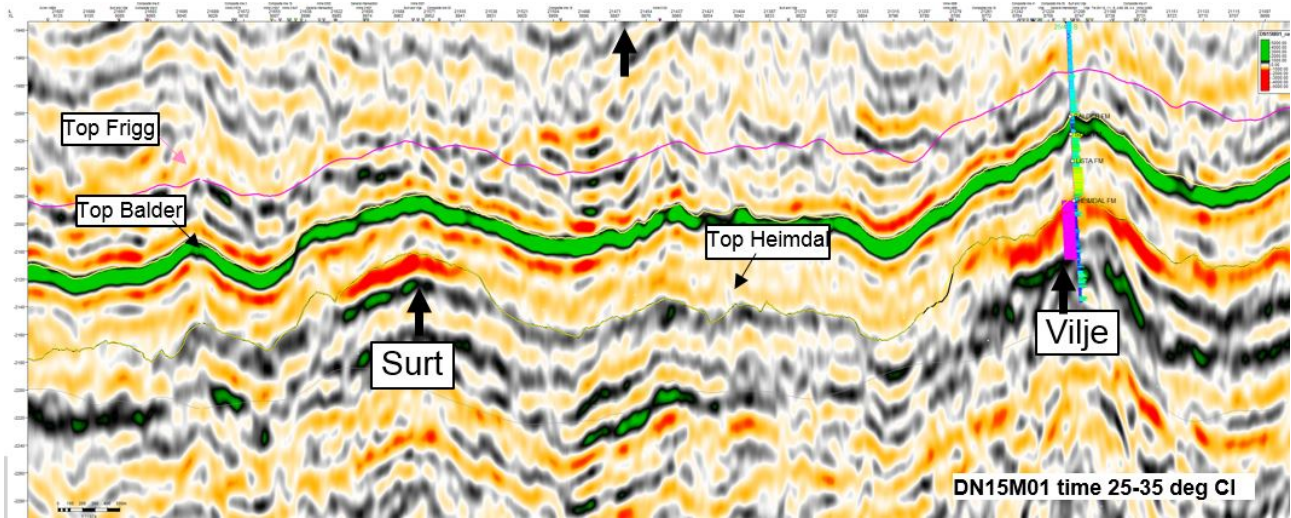


Fig. 3.4 Seismic composite line from Surt prospect to Vilje discovery Location of the seismic line is shown in yellow at Fig 3.3.

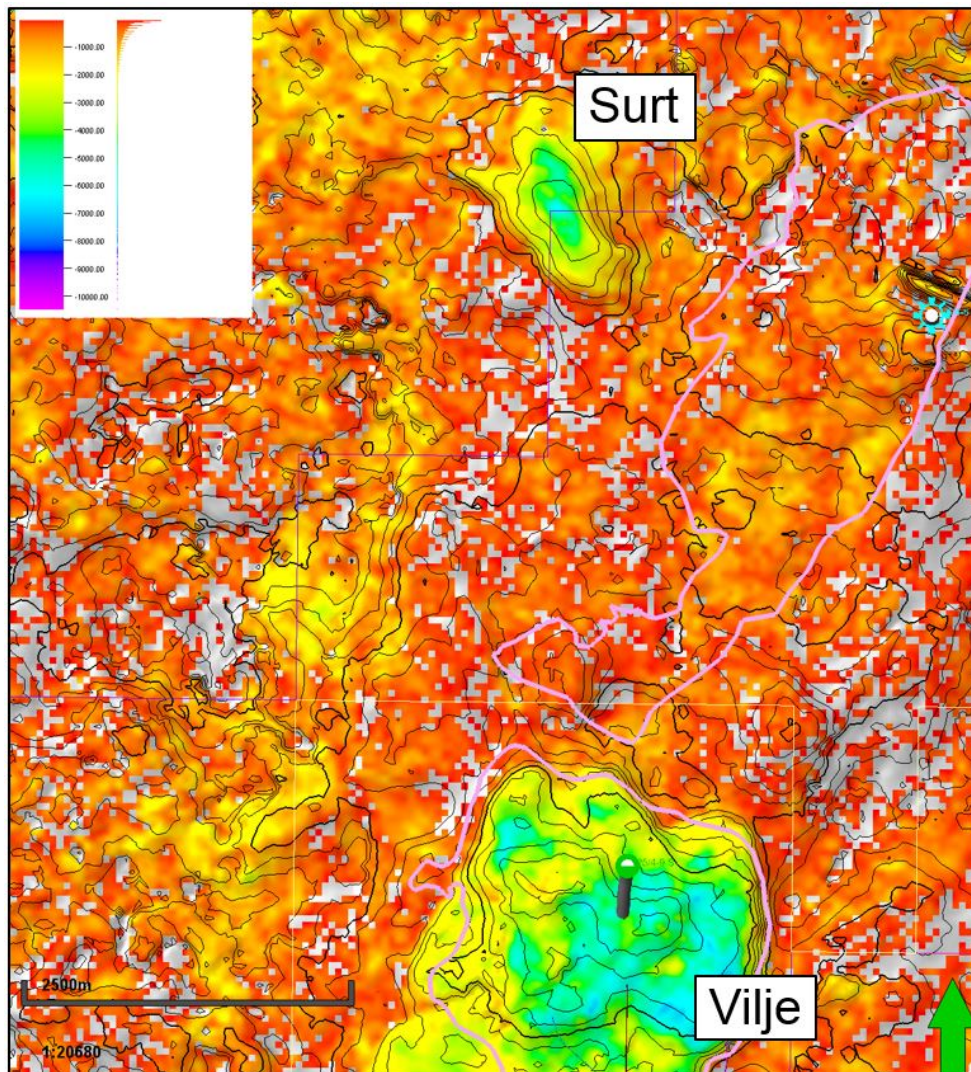


Fig. 3.5 Amplitude map, Surt and Vilje. Sum of negative Amplitudes map (+5/-15 window) on Top Heimdal 25-35 deg.

## Helblinde

Helblinde North is a small 4-way closure on Top Heimdal, similar to Surt, Helblinde Mid is an even smaller 4-way closure. Same as Surt the Helblinde Prospect is a 4-way closure corresponding to a Class III AVO anomaly, and the overlaying Lista shales forms the seal. Reservoir is also expected to be the same, deep-marine sandstones of the Paleocene Heimdal Formation with excellent reservoir properties. Top reservoir depth map and amplitude map is shown in Fig. 3.6, and a composite line showing the amplitude versus offset anomaly is shown in Fig. 3.7, the seismic line location is shown in yellow in Fig. 3.6. Same as Surt, the Helblinde Prospect is expected to be oil filled, but with small volumes. Helblinde North is calculated to be 2,9 km<sup>2</sup> and Helblinde Mid 0.8 km<sup>2</sup>.

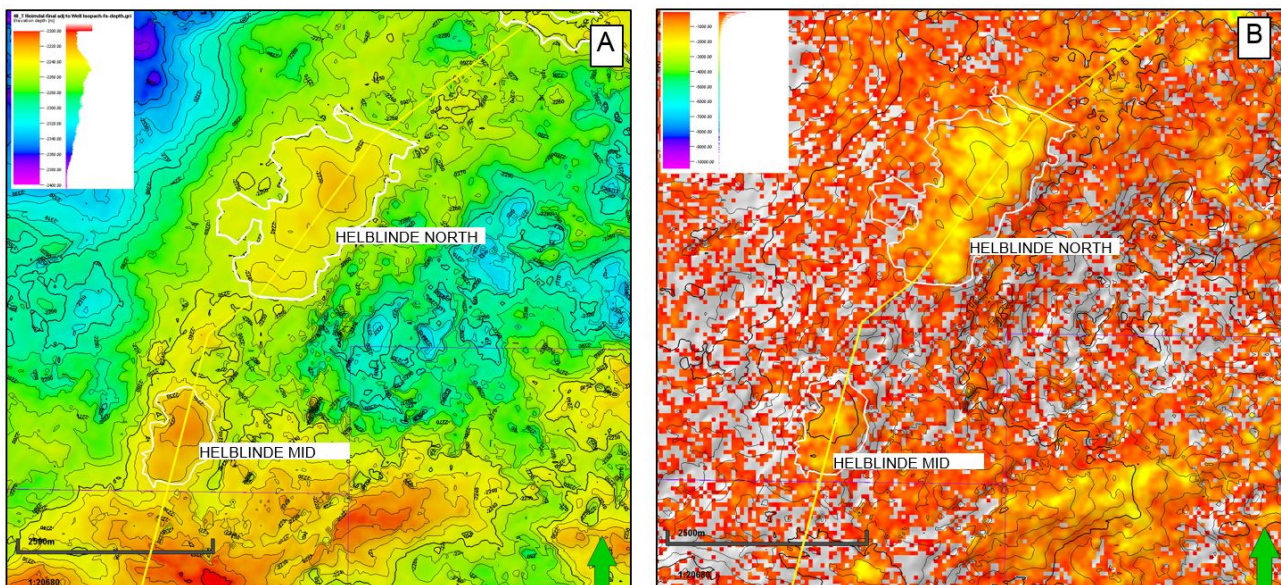
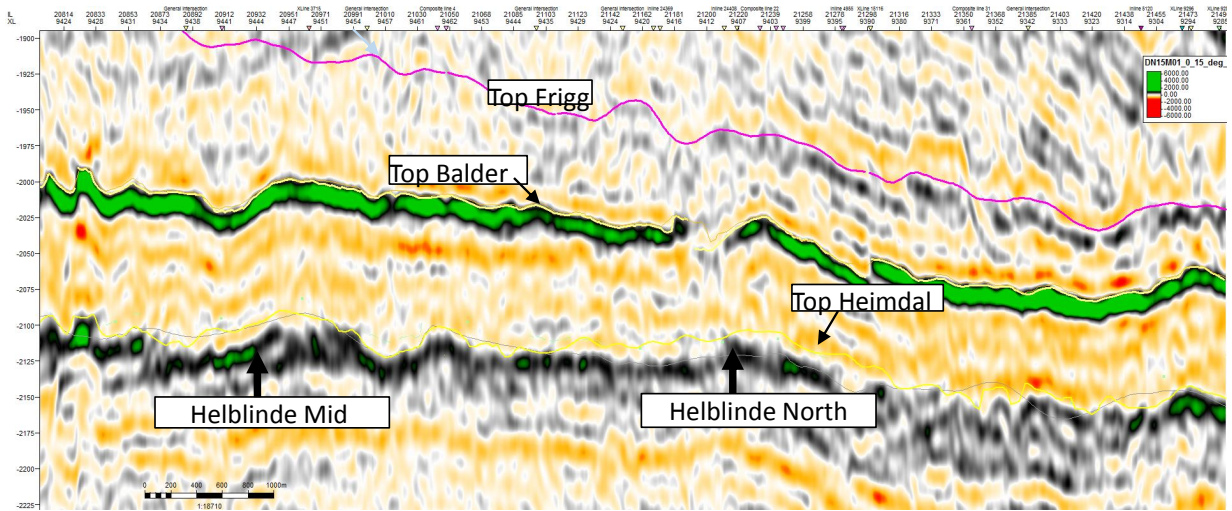
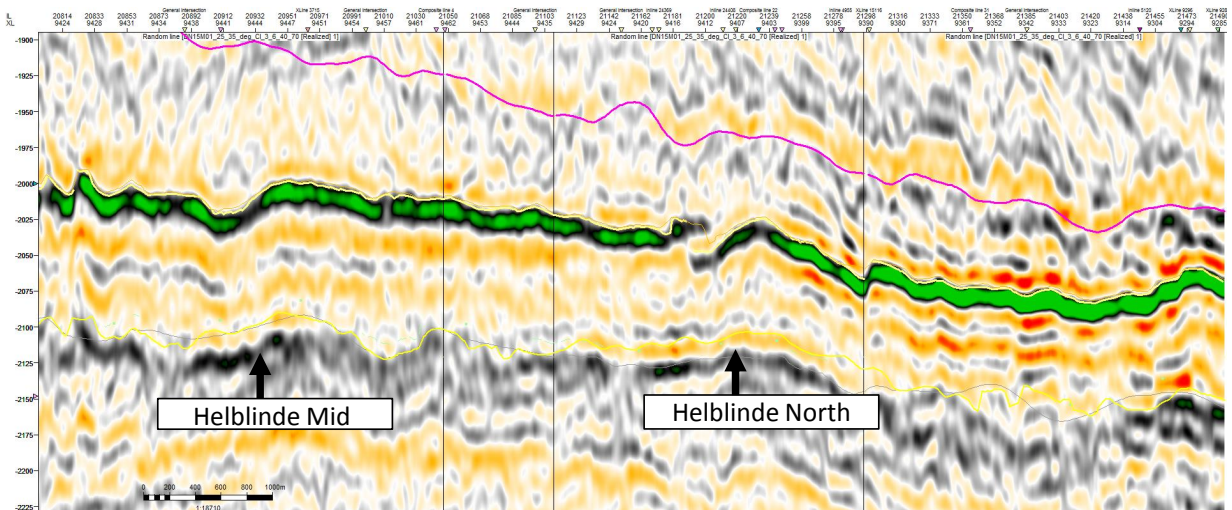


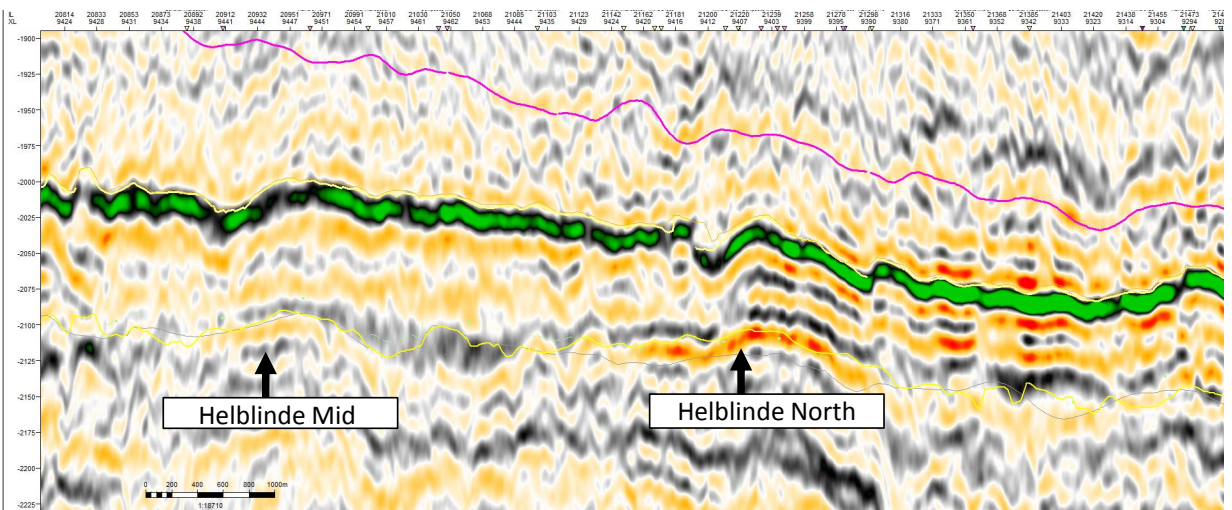
Fig. 3.6 Top reservoir depth map and amplitude map, Helblinde. A: reservoir depth map with Helblinde North and Mid in white. Interpreted on DN15M01. B: Sum of negative Amplitudes map (+5/-15 window) on Top Heimdal 25-35 deg.



DN15M01 time 0-15 deg CI



DN15M01 time 25-35 deg CI



DN15M01 time 35-50 deg CI

Fig. 3.7 Composite line through Helblinde. A composite line with time 0-15 deg CI, 25-35 deg CI and 35-50 deg CI, showing AVO at Helblinde.

## 4 Conclusion

The PL677 has 3 remaining prospects, Hyrokkin East, Surt and Helblinde. One of the remaining prospects, Hyrokkin East, is strongly affected by the result of Hyrokkin Main. Since the Heimdal reservoir in Hyrokkin Main was waterfilled, it is hard to believe that the same unit in Hyrokkin East is oil filled. The remaining sill/injectites above top Heimdal in Hyrokkin East, as described in 3.1 Hyrokkin East, has not convincing attribute anomalies. Surt and Helblinde is 4-way closures with far offset brightening. The anomalies shows good correlation with Vilje field. The brightening is believed to be due to hydrocarbon filled good quality sands. However, these volumes are below minimum economical field size and it is not interesting to make a positive drill decision. The volumes and risks are shown in the table below, see Table 4.1.

Table 4.1 Remaining prospects with volumes

PL677					Gross recoverable reserves/Total resources		
PROSPECTS	RESERVOIR LEVEL	HC	RF (%)	POS (%)	Low (MMBOE)	Base (MMBOE)	High (MMBOE)
Hyrokkin East	Heimdal/ Paleocene	Oil	40	24	17	23	28
Helblinde	Heimdal/ Paleocene	Oil	40	57	5	8	11
Surt	Heimdal/ Paleocene	Oil	40	63	5	7.6	10.6

## 5 References

**Partyka et al. (1999):** Interpretational applications of spectral decomposition in reservoir characterization, *The Leading Edge*, Vol.18, 353- 360.



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