Status report at PL655 license expiry

Introduction

PL655 is located on the northern Nordland Ridge in the Norwegian Sea. Seismic reprocessing, geological and geophysical studies have been performed in order to decrease uncertainty and risk in the mapped prospectivity. The main hydrocarbon potentials are within the Hanse Prospect. Additional prospectivity is represented by the down faulted block, the Gamma prospect. The prospect assessment showed high risk and low volume opportunities within PL655. This caused drop decision in PL655 in October 2016.

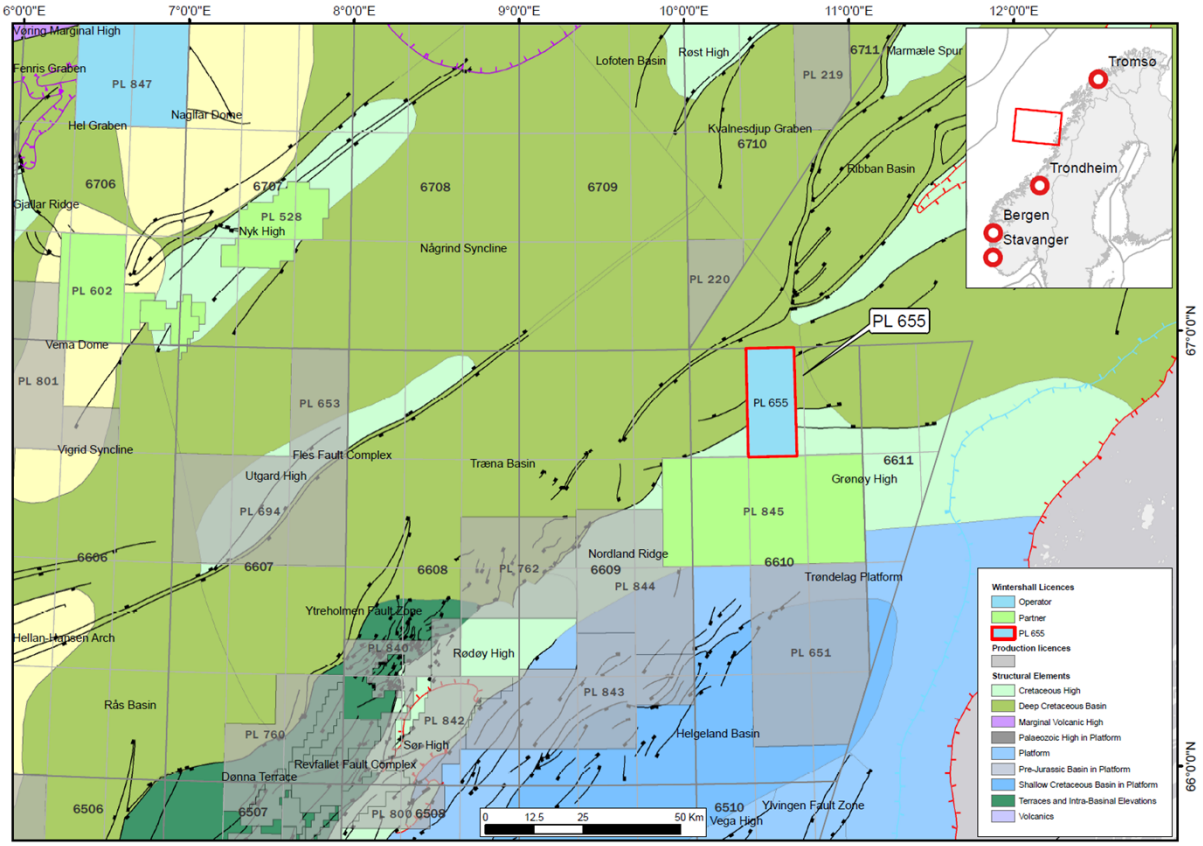

Figure 1: Location of PL655 at northern Nordland Ridge, Grønøy High, Norwegian Sea. (Factmap, npd.no).

1. Key license history

The PL655 license was awarded 03.02.2012 from the APA2011. The license group consist of Wintershall Norge AS, Lotos Exploration and Production Norge AS, Centrica Resources (Norge) AS and VNG Norge AS. The license is located within block 6610/2, totaling 346.127 km^2.

Table 1: PL655 License participants and ownership

Company name	License interest (%)
Wintershall Norge AS (Operator)	30%
Lotos Exploration and Production Norge AS	30%
Cetrnica Resources (Norge) AS	20%
VNG Norge AS	20%

The initial work progr

am was seismic reprocessing, geological and geophysical studies, focusing on the exploration potential of the Middle and Lower Jurassic sequences at Nordland Ridge.

Initial key dates in PL655:

- 3rd February 2014: Drill-or-Drop decision
- 3rd February 2019: End of initial period

The preexisting ST9404(NPDID: 3686) and ST9604(NPDID: 3786) 3D seismic datasets poorly imaged the prospective parts in the license acreage. The license therefore agreed reprocessing of the 3D datasets to ensure better structural definition of the prospects. A total of 1040 km^2 of 3D seismic WIN12002WIM13 completed in 2014.

A pre-stack depth migration (PSDM) test was run on the dataset. The 3D PSDM swath (WIN15M02 – 200 km^2). Due to time required for PSDM processing of for the full seismic dataset (713 km^2) an 18 month extension of the Drill-or-Drop decision and the initial period was applied for. The latter was granted by the Ministry of Petroleum and Energy.

Updated key dates in PL655:

- 3rd August 2015: Drill-or-Drop decision
- 3rd August 2020: End of initial period

Broadband processing technique was also applied to the PL655 seismic dataset. A new 14-month extension of the Drill-or-Drop decision and the initial period was applied for. The latter was granted by the Ministry of Petroleum and Energy. The final broadband PSDM seismic dataset WIM16M01 was ready June 2016.

New updated key dates in PL655:

- 3rd October 2016: Drill-or-Drop decision
- 3rd October 2021: End of initial period

Yearly ECMC meetings as well as several work meetings have been arranged to ensure good collaboration and communication within the license group. Meeting category and dates are listed in Table 2. In addition, informal meetings has occurred during e.g seismic processing follow up.

Table 2: Listing of meetings held within PL655.

	Combined ECMC meeting	EC Workmeeting
Dates	08.05.2012	28.06.2013
	27.11.2012	09.03.2015
	30.10.2013	15.04.2015
	31.10.2014	11.03.2016
	15.09.2015	31.05.2016

Limited volume potential and high risk within the prospects were evident with the results from updated seismic interpretation and special studies. As a result, the PL655 choose to relinquish the license having completed the work program.

2. Database

2.1. Seismic data:

The northern Nordland Ridge area already contained 3D seismic datasets of different age and origin. The partnership initiated a merge and reprocessing of existing 3D seismic datasets the first licensing year in line with the work program of the license. Parts of the seismic cubes, ST9404 and ST9604 were used as input and pre-stack merge to create the WIN12002WIM13. This was the preferred option in the partnership. This first reprocessing project resulted in a poor dataset, contaminated with residuals.

The second attempt of reprocessing included new de-multiple techniques, broadband processing and pre-stack depth migration. Improved seismic could potentially reveal possible fluid contacts within the prospects. A clear uplift in the signal:noise ratio and more continuous reflectors helped on the seismic image even though a limited origin. The uplift in the broadband processing has been severe, but in hindsight, short cable length gave limiting depth and angles to perform AVO studies at the deepest possible target, the Gamma Prospect.

Table 3: Overview over PL655 seismic data. All reprocessed 3D seismic datasets had the ST9404 and ST9604 as basis data.

Description	License proprietary 3D seismic datasets
First processing	WIN12002WIM13
Test swath PSDM processing	WIN15M02
Final Broadband PSDM processing	WIM16M01

Mapping was conducted using the new seismic dataset together with other relinquished 2D and 3D seismic datasets. Relevant maps were generated and used in evaluation of the PL655 license.

2.2. Well data:

All relevant well information from the PL655 common well database was also integrated into the overall evaluation of the prospectivity. The nearby 6610/2-1S controls the input parameters in the volume calculation because of its vicinity to the Hanse Prospect. The wells have been used for petrography studies as well as full petrophysical CPI evaluation. The released nearby wells utilized are presented in Table 4.

Table 4: Common well database and corresponding NPDID.

Well Name	NPDID
6609/5-1	445
6609/6-1	5626
6610/2-1S	2874
6610/3-1R	2193
6610/7-2	26
6710/10-1	7091

2.4. Special studies:

In addition to the seismic mapping numerous geological and geophysical studies has been performed for the PL655 license. This includes:

- AVO forward modelling
- AVO interpretation
- Petroleum Basin Modelling
- Full petrophysical re-evaluation of the nearby wells
- Fault seal modelling

The license group also had access to the studies:

- The Nordland Stratigraphic Database (Ichron 2010)
- Nordland Fluid Inclusion Study (FIT)

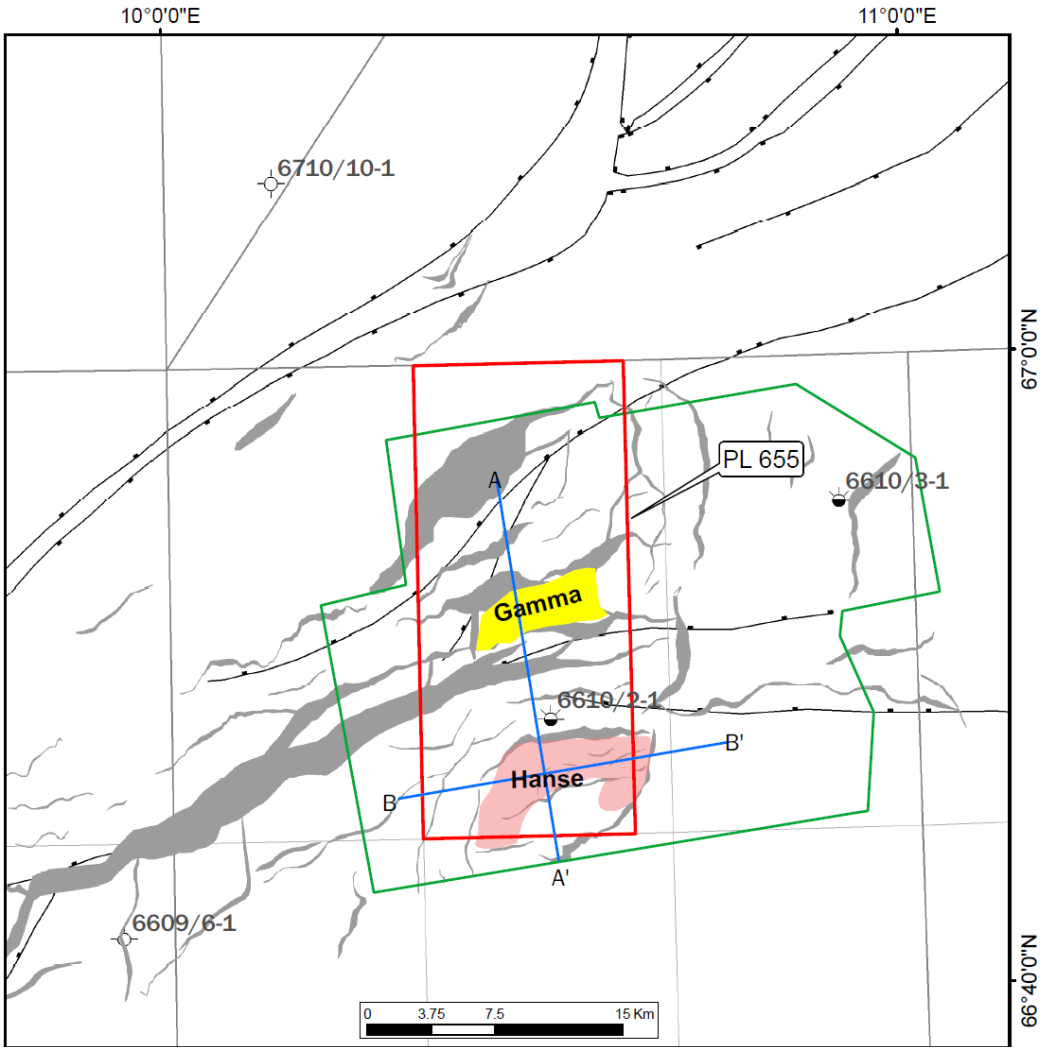

Figure 2: The outline of the initial Hanse and Gamma prospects together with main fault element and four nearby well penetrations. The nearby well 6610/2-1S has been key in the assessment of the prospectivity. The outline of the final seismic dataset, WIN16M01, in green shown in this map. PL655 license outlined in red. Seismic sections shown in Figure 3 and Figure 5 are indicated.

3. Review of geological and geological studies

PL655 is located on Nordland Ridge. The Nordland Ridge is transected by deep faults separating three highs, regarded as sub elements of the ridge. PL655 is part of Grønøy High. The structuring of Nordland ridge started in Late Carboniferous- Early Permian time. The continued fault activity in trough Triassic culminated in an increase in faulting in Middle Jurassic-Early Cretaceous. The Early Cretaceous uplift and erosion of the ridge have caused upper Cretaceous deposits to overlie truncated Lower to Middle Jurassic strata at Grønøy High. Some inversion took place in Early Tertiary which can be seen along Nordland ridge. (Blystad et al, 1995).

The rifting in late Triassic to middle Jurassic is key for the deposition of reservoir in Hanse and Gamma prospects. Åre and Tilje formations developed well in this area from Rhaetian to Pliensbachian. These sands proven in nearby wells 6610/7-1, 6610/2-1s and 6610/3-1R. Porosities and permeability's are excellent in well 6610/2-1s, in the range of 15 - 30% and 100's - 1000's mD.

The northern Nordland Ridge area got all the petroleum system elements like reservoirs, source rocks, seal and trap. The drilled wildcats prove charge, abundant oil shows are reported from most of the offset wells.

Seismic mapping revealed the Hanse Prospect, which was seen as the main prospect of PL655 license. There was initially uncertainty around the seal on top of Nordland Ridge because Late Cretaceous Lysing Formation sandstones are lying directly upon the Jurassic Tilje Formation sandstones in 6610/2-1S well.

A Petroleum Basin modelling was performed using Åre Fm and Spekk Formation source rocks. Åre Formation source rock was modelled to give the most contribution to Hanse Prospect. The Basin modelling and the reported shows in the nearby wells are positive news for the charge and migration elements of Hanse and Gamma prospects.

The structural interpretation and Fault seal study indicates a leaking fault at top Åre Formation level at the Hanse Prospect. Initially the main volume contribution was believed to come from the Åre Formation reservoir since the Tilje Formation reservoir has suffered from more erosion. The location of the fault was near the crest of Åre Formation reservoir. The modelled lack of fault seal was regarded as a high side seal risk for Hanse Prospect at Åre Formation level. This limited the volume potential for Åre Formation in the Hanse Prospect.

The enhanced seismic quality allowed interpretation of the top Lysing Formation, which is sandy in 6610/2-1S. The Top Lysing Formation marker was interpreted over western parts of the Hanse Prospect before it pinches out. Lysing Formation is likely to be sandy as in the nearby well. This was regarded as a very high risk. The interpretation of the Lysing Formation sandstone is suggesting that we have to use a water up to situation to the Top Lysing Formation in 6610/2-1S well. This suggest that the Lysing Formation sandstone in 6610/2-1S well is in communication with the interpreted marker above the Hanse Prospect. The result is limiting the volume potential of the Hanse prospect, which initially was the main prospect of the license.

Initially the perception of a Hanse Prospect was a large untested fault block within the Nordland Ridge. Studies performed during the license timeline has revealed very high risk at top seal and side seal and less potential volumes.

4. Prospect update report

4.1. Gamma Prospect

In PL655 the prospect group identified several prospects. The main prospects that could develop the area was the Hanse and Gamma prospects. Hanse Prospect was seen as the main prospect.

Initial prospectivity also included leads on Upper Cretaceous age. Lysing, Nise and Springar Formation sandstones, Paleocene age Tang Formation sandstone and Eocene age Tare Formation sandstones. For the Paleocene and Eocene sandstones, no four-way dip closures are identified. Stratigraphic traps can be present. The Upper Cretaceous leads were three way closures against fault, but size of these closures are limited. These leads have been worked through the initial period. Studies like petroleum basin modelling and AVO forward modelling targeting these strata have been performed, but the overall outcome has been negative for the leads.

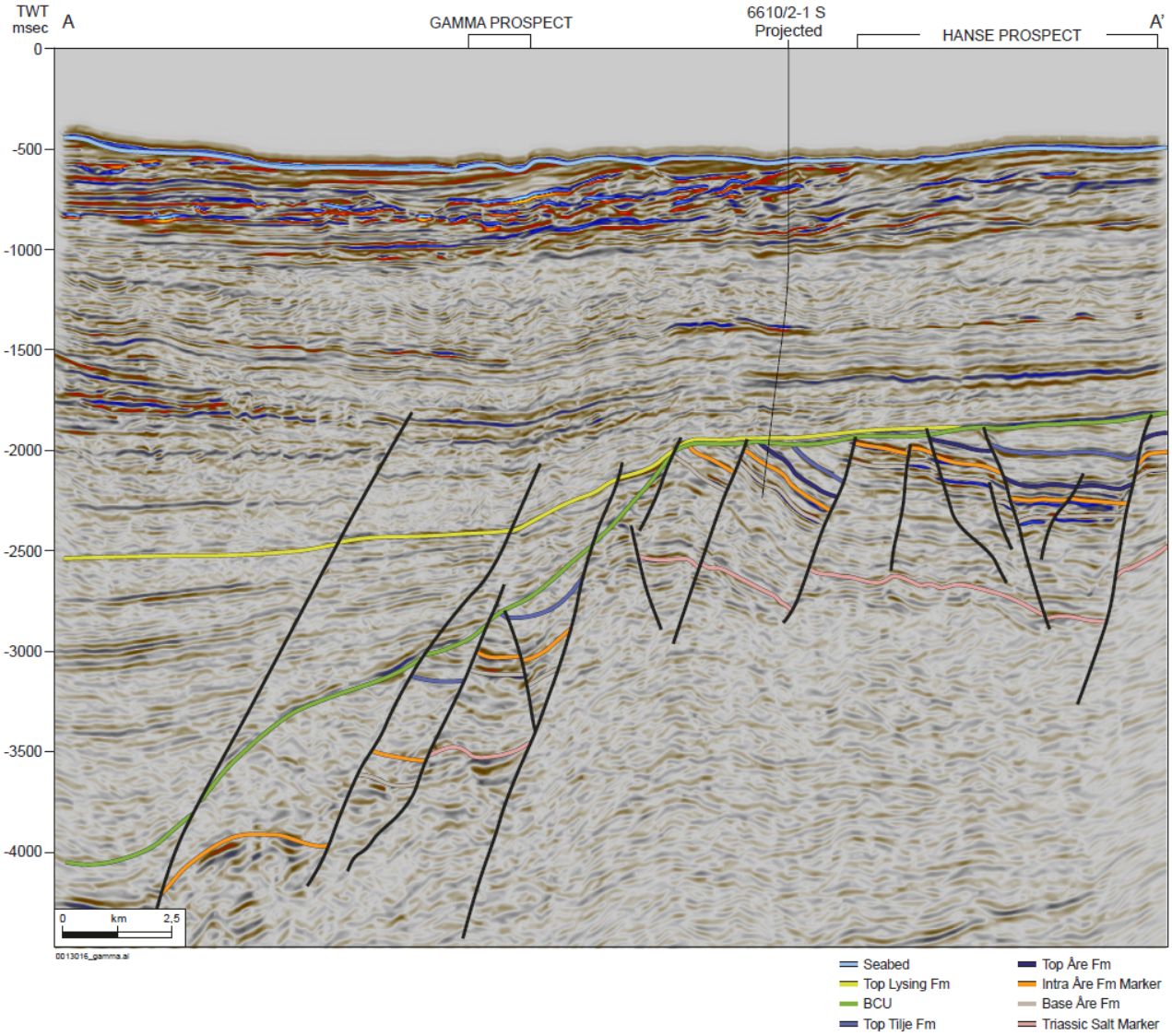

Figure 3: Seismic section across Gamma Prospect. The prospect is a down faulted block at Nordland Ridge. The top seal is interpreted to be Lange Fm. WIN160M01 3D seismic survey with interpreted surfaces. Blue is an increase in acoustic impedance. Location of this seismic section is shown in Figure 2.

The improved seismic image allowed a better structural image of the Gamma prospect allowing a fault seal study. The study resulted in negative news for the sealing capabilities of the prospect boundary faults. The improved 3D seismic image decreased the size of the fault block. The strata is highly dipping. Lack of the Upper Jurassic Spekk Formation indicated less top seal potential.

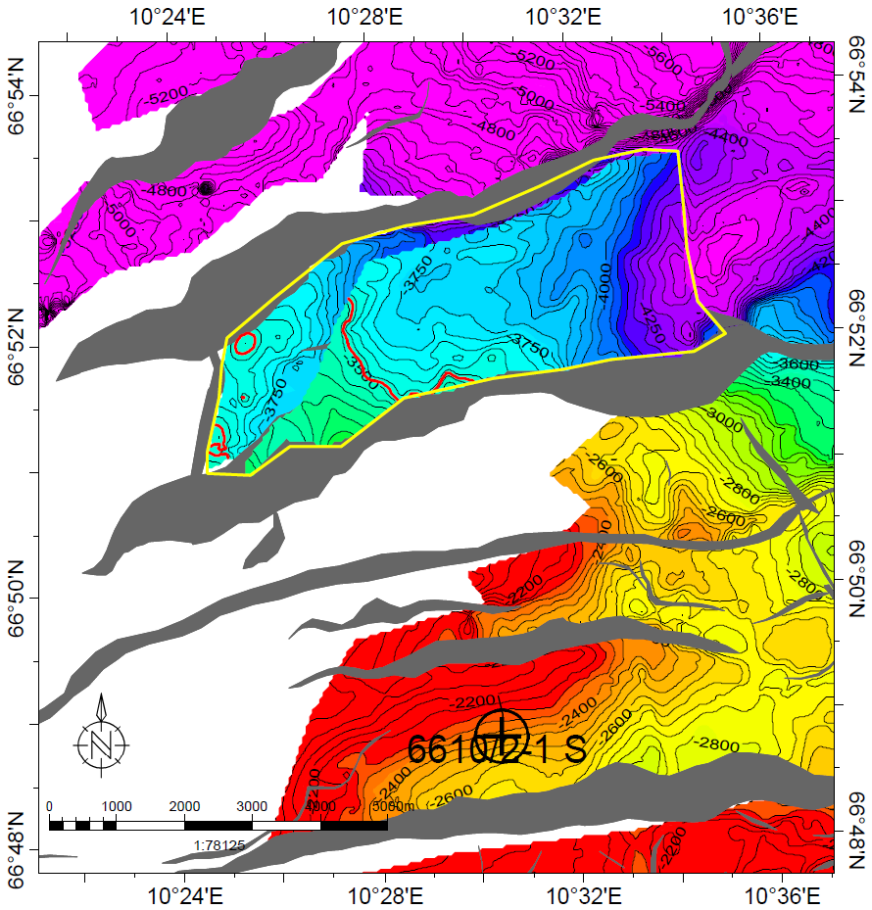

Figure 4: Top Åre Formation depth map with an overlay of Tilje Formation in Gamma Prospect(Yellow outline). Both Åre and Tilje Formations are eroded in the west. The remaining petroleum potential outlined in red, (P50 contact). Most of the volumes are situated in the Tilje Formation. The remaining volume potential is presented in ***Table 6*** *.*

The Volume calculation was challenging in Gamma Prospect fault block. The uncertainty in the seismic mapping gives a higher spread in the volume distribution, resulting in a-normal column heights. What seems to be exaggerated hydrocarbon columns gives to small volume compared to the minimum economical field size. Figure 4 show volume contribution from both Åre and Tilje Formation in Gamma Prospect. The calculated volumes are presented in Table 6.

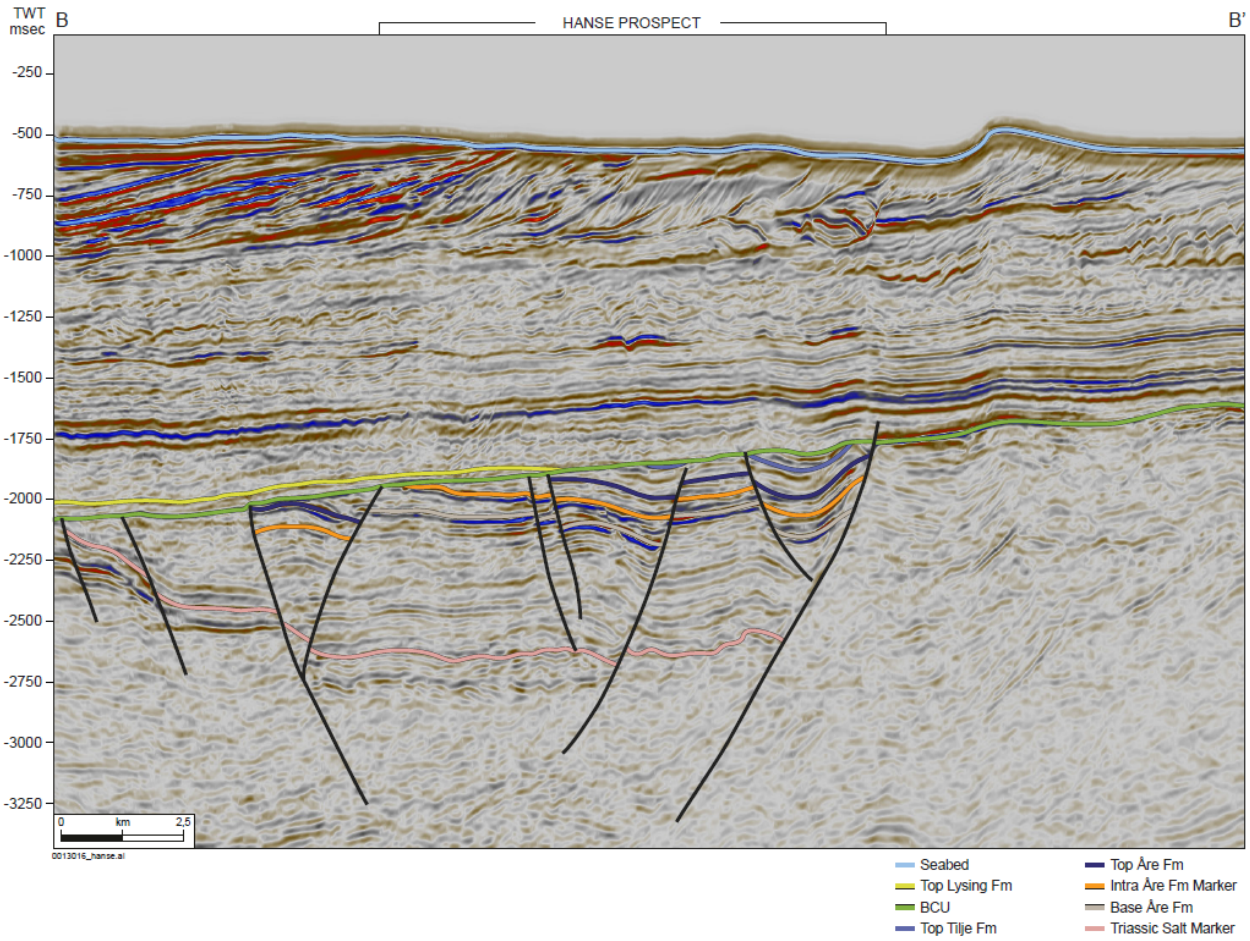

Figure 5: Seismic section across Hanse Prospect. The prospect is part of a not eroded remnant within Nordland Ridge, surrounded by older stratigraphy. Two reservoirs are present in Hanse Prospect, Tilje Formation and Åre Formation. The western prospect boundary fault is modelled to be leaking offset to this location. WIN160M01 3D seismic survey with interpreted surfaces. Blue is an increase in acoustic impedance. Location of this seismic section is shown in Figure 2.

4.2. Hanse Prospect

The Hanse Prospect, regarded as main prospect of the license have two major risks elements. Side seal of northwestern fault and top seal. Interpretation of Lysing Formation across the western part of Hanse prospect and lack of DHI do not allow large column heights to be used in volume calculations. The Operator have limited the HC column to the Lysing Fm penetration in 6610/2-1S. The calculated volumes are situated in the Tilje Formation, there is no volume contribution from Åre Formation reservoir. The calculated volumes are presented in Table 5.

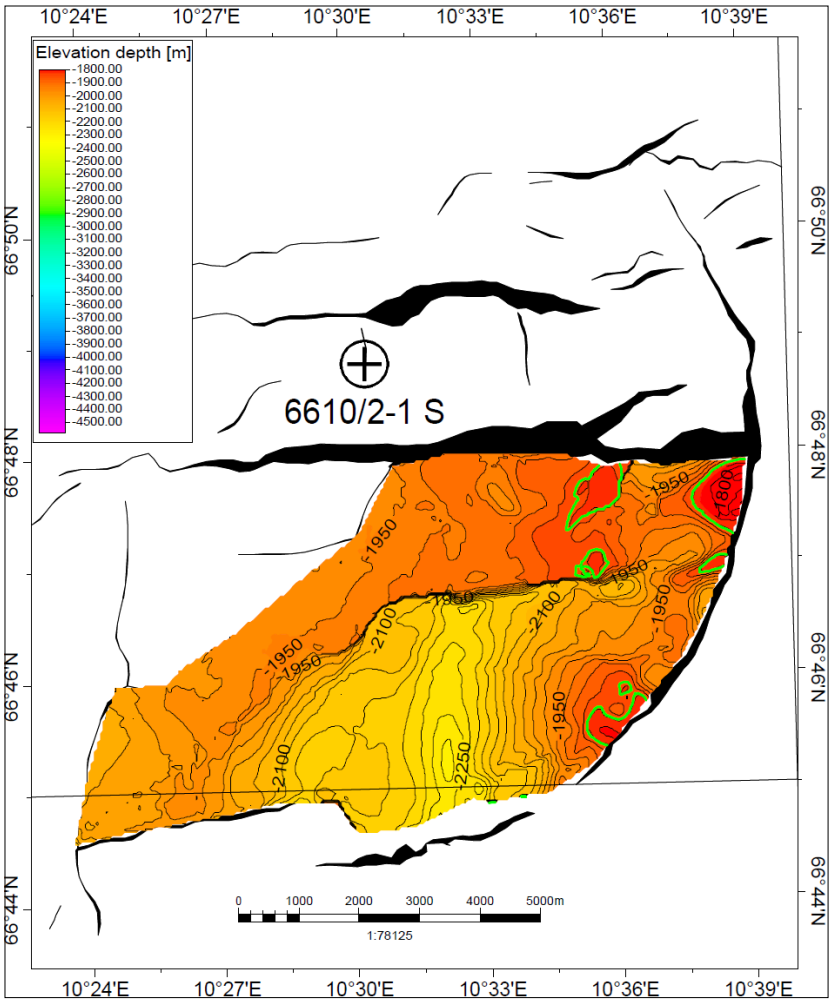

Figure 6: Combined Top Tilje Formation and BCU map over Hanse Prospect. The Tilje Formation is eroded in the northwest. The remaining volume potential is outlined in green (P50 contact – 1836,8m). The remaining volumes is presented in ***Table 5****.*

4.3. Volumes and risk

The Hanse prospect risk assessment concluded with a geological chance of success at 8,9%. The Hanse Prospect volumes are listed in Table 5.

Table 5: Hanse Prospect Volumes

	MSV	P90	P50	P10
Oil 1e6 Rec STB	15.33	0.85	7.56	40.11
Total Rec 1e6 STB OE	16.06	0.90	7.90	41.87

The Gamma Prospect was regarded as the second possibility in the license. The Prospect is poorly defined in seismic. The uncertainty in imaging gives it more spread in the volume distribution.

The geological chance of success is 14 %. The Gamma prospect volumes are listed in Table 6.

Table 6: Gamma Prospect Volumes

	MSV	P90	P50	P10
Oil 1e6 Rec STB	36.91	0.05	9.76	102.41
Total Rec 1e6 STB OE	36.7	0.05	10.21	107.8

5. Conclusions

The remaining potential within the Hanse Prospect is within the Tilje Formation. Bright amplitudes recognized at Top Tilje Formation level is present in seismic data. The amplitudes are interpreted to be presence of hydrocarbons and represent remaining volume potential. However, the potential volumes does not make it above the minimum economical field size needed for this area (mean 15,3 10^6 STB Oil).

The volume potential in Gamma Prospect is larger than Hanse Prospect, but risk is higher.

On this basis, the license group agreed that the prospects within the license sorted in the high risk - low volumes category. All partners accepted to drop the license unanimously, October 2016.

6. References

- Blystad et al, 1995; NPD Bulletin nr.8, Structural elements of the Norwegian continental shelf. Part II: The Norwegian Sea Region.
- www.npd.no, Factmap