

PL 998

Relinquishment Report



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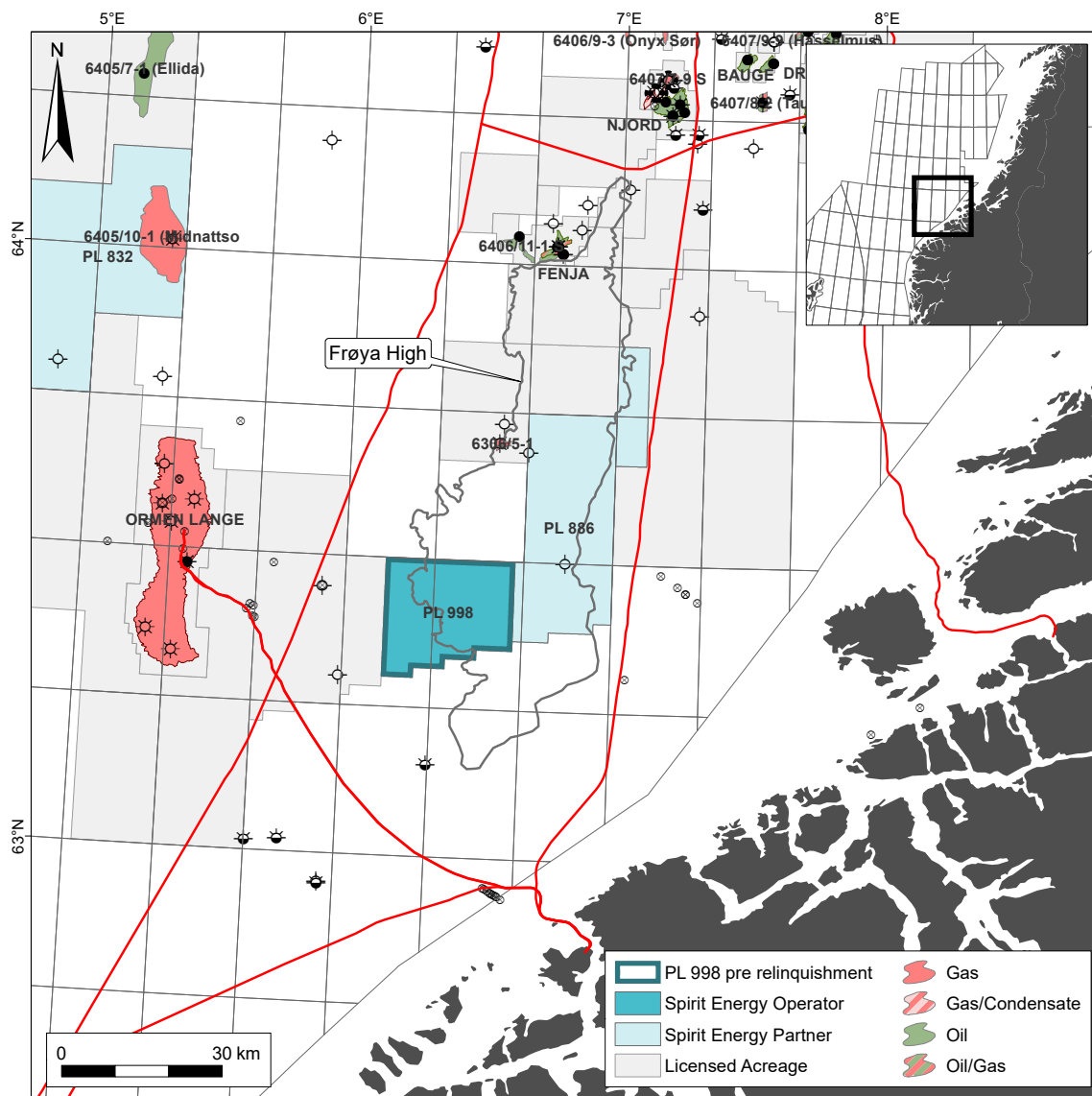
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1 KEY LICENSE HISTORY

Summary

PL 998 is located in blocks 6306/7 and 8 on the south-western flank of the Frøya High (Fig. 1.1). The license was awarded to Spirit Energy (40%) as operator in February 2019, following the award of the APA 2018 application. The partners are Lundin Energy Norway (30%), Petrolia Noco (20%) and Neptune Energy Norge (10%). Acquisition or reprocessing of 3D seismic constituted the main part of the work programme prior to Drill or Drop. The 3D seismic survey SEN1101LNR17, reprocessed in PL 886 was acquired by the PL 998 license partners and this fulfills the work programme. The main prospect in the license is the Mist Central structure, defined as a fractured basement prospect. The Mist Central Prospect was called the Aegir South Prospect in the APA 2018 application, and the Mist North Lead was formerly known as the Agir North Lead. The partnership decided to change the name as the name Aegir is already in use on the Ægir Ridge.



PL998-RelinqReport-Location
16.12.2020

Fig. 1.1 PL 998 Location map. Black outline represents the outline of the Frøya High at Base Cretaceous level. Red lines represent pipeline infrastructure.

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Overview of Meetings

All meetings held in the license are summarised in Table 1.1. Presentation material and minutes from MC and EC meetings can be found on L2S.

Table 1.1 Meetings held in PL 998.

Meetings in PL 998	
2019	
ECMC meeting #1	21.05.2019
MC meeting #2	14.11.2019
2020	
EC work meeting	25.06.2020
EC work meeting	03.11.2020
MC meeting #3	24.11.2020

Work Programme

The work programme involved the acquisition of new 3D seismic data or reprocessing of existing 3D seismic covering the license area. This was met by the acquisition of the SEN1101LNR17, the product of a 2017-2018 reprocessing of the SEN1101 survey. This was undertaken by Lundin on behalf of the PL 886 license partnership and purchased by the PL 998 license partnership. A number of G&G studies were undertaken up until the autumn of 2020. Seismic interpretation and the studies formed the basis for the prospectivity evaluation of several play opportunities within the license area. The main prospect is a basement structure called Mist, which is split into Mist Central and Mist North. Mist Central is the main prospect, however, following the evaluation, it has a limited volume range and significant risks associated with the top seal. The Mist North Lead is difficult to map and also shares the same risks as the Mist Central Prospect. Based on this, the partnership is in agreement to relinquish PL 998 in its entirety prior to the Drill or Drop decision on the 1st of March 2021.

Relinquishment

The partnership unanimously decided to relinquish PL 998 in December 2020.

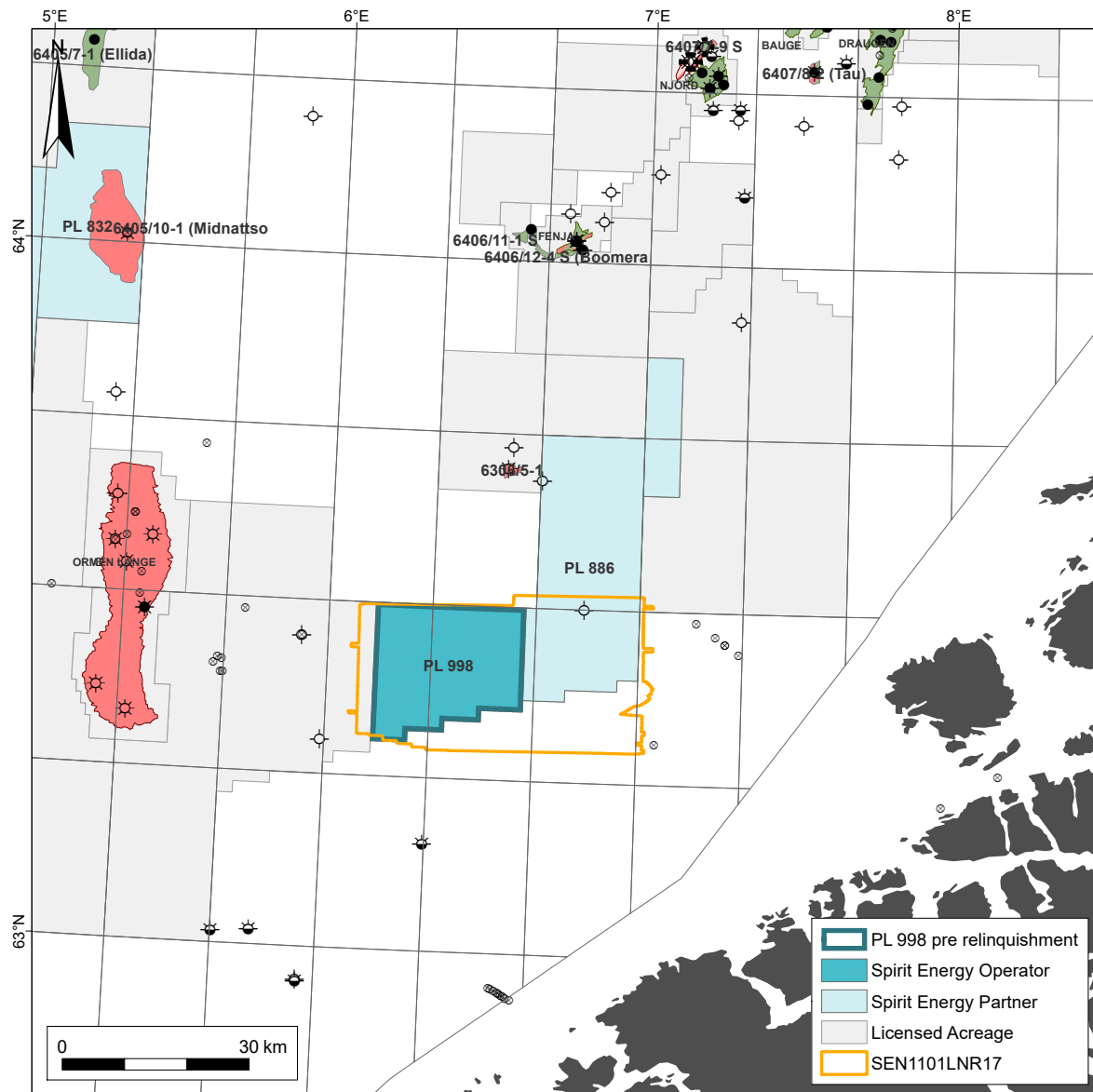
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2 DATABASE

Seismic Database

The primary seismic dataset used in the interpretation of the PL 998 license area was the SEN1101LNR17 KPSDM dataset. The data quality in the overburden is very good to excellent, however, due to lack of sonic well log data in nearby wells from the basement section, the velocity model below the top basement is relatively unconstrained. The lack of continuous reflectors makes it challenging to optimise the gather stacks for optimal imaging within the basement.

The SEN1101LNR17 survey is available in Diskos and the outline of the survey is shown in Fig. 2.1. All public 2D and 3D seismic data relevant to seismic interpretation and mapping of the license area were included in the common license seismic database.



PL998-RelinqReport-Database
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Fig. 2.1 3D license database.

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Well Database

All public wells on the Frøya High and immediate surrounding areas were included in the common database. No special reports are included.

Studies

The following studies are included in the common license database:

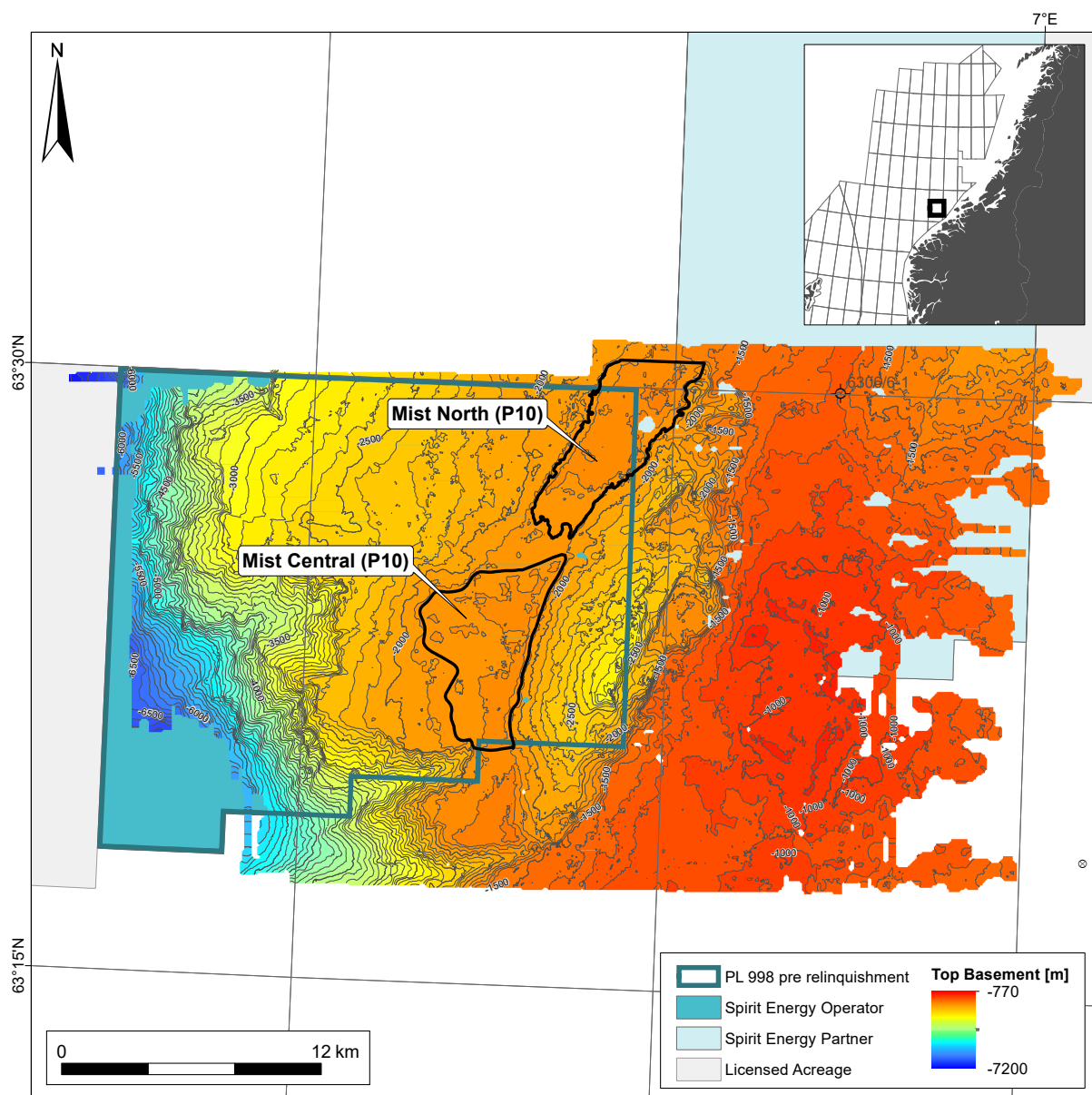
1. **COOP3 (Crustal Onshore-Offshore Project 3)** – An onshore-offshore basement research project was undertaken by NGU in the period 2015-2019. COOP3 was aiming at interpreting crustal structures and temperatures in the study area from high-quality potential field and heat flow data. Basement characteristics such as lithology, deep weathering, heat production and age dating were important constraints in the modelling. The Project was based on existing and new geophysical and geological data including well logs and petrophysical data. The CAS-15 aero-magnetic survey was fundamental input to a PL 998 gravimetric and magnetic study which complemented the seismic interpretation.
2. **Geochemical analysis of well 6306/10-1 (Skalmen) (2019)** – Study conducted by APT on behalf of PL 749. The project involved geochemical analyses of a number of samples from the 6306/10-1 well which found oil shows in the Paleocene Egga Mbr, the Melke Fm and the Garn Fm as well as weathered and fresh granitic gneissic basement. The objective was to understand the quality of the shows, source rock(s) and biodegradation. The study included age-related biomarker analysis. This study was traded with the PL 998 partnership.
3. **Regional geochemistry and basin modelling study (2016)** - Report in powerpoint presentation format from the regional geochemistry and basin modelling study conducted by IGI in 2016, on behalf of PL 749. Basin modelling includes thermal 1D and 3D modelling results and migration modelling results. The input data (seismic interpretation and geochemical database) is not part of the common database. This study was traded with the PL 998 partnership.

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3 REVIEW OF GEOLOGICAL FRAMEWORK

Geological setting

PL 998 covers the south-western part of the Frøya High and Mist Central, the main prospect, is sitting on a subtle narrow north-south oriented ridge flanking the Mandel Basin (informal name) to the east (Fig. 3.1). The Frøya High is an underexplored area, during maturation of different possible geological models a number of studies have been undertaken to fully understand and integrate the data available. Some of these studies have been conducted by PL 749 and traded by the PL 998 partnership (2 Database), whereas the studies in the following section have been conducted by PL 998 during the license period.



PL998-RelinqReport-TopReservoir
17.12.2020

Fig. 3.1 Top Basement map. Top Basement depth map. Contour interval is 100m. Mist Central is the main prospect along the subtle Mist Ridge as defined at Top Basement level. North along the ridge is a basement lead called Mist North.

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Geological studies

A number of geological studies have been undertaken during the license period to evaluate the potential plays on the Frøya High with the overall objectives to 1) understand regional geological evaluation and 2) to reduce prospect risks and uncertainties. A brief summary of each study is provided below.

In addition, four G&G studies were undertaken by PL 998:

1. **Geochemical re-analysis of basement samples in well 6306/10-1 (Skalmen) (2020)** - Study conducted by APT on behalf of PL 998. Basement samples were washed and hand-picked to remove caved material from the Jurassic, which contain organic matter causing contamination of the geochemical signals in the original analysis (2 Database).
2. **Gravimetric and magnetic modelling of two 2D-sections across the southern Frøya High (2020)** - Study conducted by Getech Ltd (UK), on behalf of PL 998. The aim of this study was to investigate if gravimetric and magnetic data could aid in determining if the basement was purely of crystalline origin or if there was the possibility that old (Paleozoic) basin remnants could be present below what is interpreted as "top basement" on seismic.
3. **"Seep to Source" study (2020)** - Study conducted by NGU on behalf of PL 998. The purpose of this study was to investigate, by use of 1) multi beam acquisition, gas seepage into the water column in the PL 998 area and 2) sampling by use of ROV and geochemical analysis of gas seeps to determine the origin of the gas, i.e. thermogenic vs biogenic.
4. **Rock Physics/AVO summary** - The SEN1101LNR17 seismic data was post-stack conditioned to remove noise and a seismic to well tie was performed using well 6306/6-1. A Coloured Inversion operator was designed for this well and convolved with the full stack seismic to provide a Coloured Inversion volume with the primary objective of mapping the areal extent of the Jurassic Rogn Fm sands found in the well. In addition, the SEN1101LNR17 angle stacks were spectrally matched prior to the creation of an AVO Class volume. This enabled the identification and isolation of AVO Class 2, 2P, 3 and 4 anomalies, mainly utilised for prospect identification in the Tertiary section. High definition spectral decomposition and RGB blending were also used to help identify prospectivity. Among the identified potential prospectivity were channels and injectites. However, a combined analysis of the Coloured Inversion and the AVO Class volume showed that none of these features were anomalous from the AVO background trend nor clearly hydrocarbon filled.

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4 PROSPECT UPDATE

At the time of relinquishment, Mist Central has been evaluated as the main prospect, with Mist North as a follow-up lead. Leads at other stratigraphic levels identified at the time of the APA 2018 application have been dropped, following negative conclusions based on the license G&G evaluation.

The Mist Central basement prospect is located on a long, narrow ridge just west of the informally named Mandel Basin (Fig. 3.1). Three local dip-closures are mapped along the ridge, Mist South just outside of PL 998 (not evaluated), Mist Central (main prospect) and Mist North (lead). All potentially prospective levels have been mapped on the newly reprocessed 3D broadband data SEN1101LNR17. The seismic imaging quality down to top basement is very good to excellent, apart from areas where local sills, dykes and volcanoes are present in the overburden and cause local disturbances in the seismic imaging. Seismic imaging within basement itself is difficult, as few coherent reflectors exist. It is interpreted that the main events represent local reflections of fault planes/shear zones and local dykes/sills within the basement itself.

The Mist Central prospect is a low relief structure in the central parts of the Mist Ridge. It has a small four-way dip closure in the crestal area and a larger trap depends on fault seal along large scale east-west oriented shear zones in the south and north (Fig. 4.1). The main risks of the Mist Central Prospect are top seal and presence of effective reservoir (fracture corridors), as well as migration into the structure. Top seal by Upper Jurassic and Lower Cretaceous shales are required (Fig. 4.2). The nearest well 6306/6-1 encountered 90 m of high porosity sandstones in the Upper Jurassic and it cannot be ruled out that these sands are present across the Mist Central Prospect. The Lower Cretaceous is shale dominated in the 6306/6-1 well, however, it is anticipated that shoreface sandstones might be present in proximity to paleo-highs and it is believed that the Mist Central Prospect is situated close to a paleo-island along the fault scarp as a result of footwall uplift. For the trap to hold a deeper hydrocarbon column than the dip closure, fault seal is required along east-west trending shear zones believed to be present along the southern and northern boundaries of the trap. Side seal is also required towards the Mandel Basin in the east. The sedimentary rocks there are of unknown age, but currently interpreted to be of Triassic age, which is a period of substantial continental sandstone deposits. The chance of geological success (COSg) is 6%, mainly reflecting the risk on top seal in the dip closure. A break-down of the individual risk elements is found in Table 4.1.

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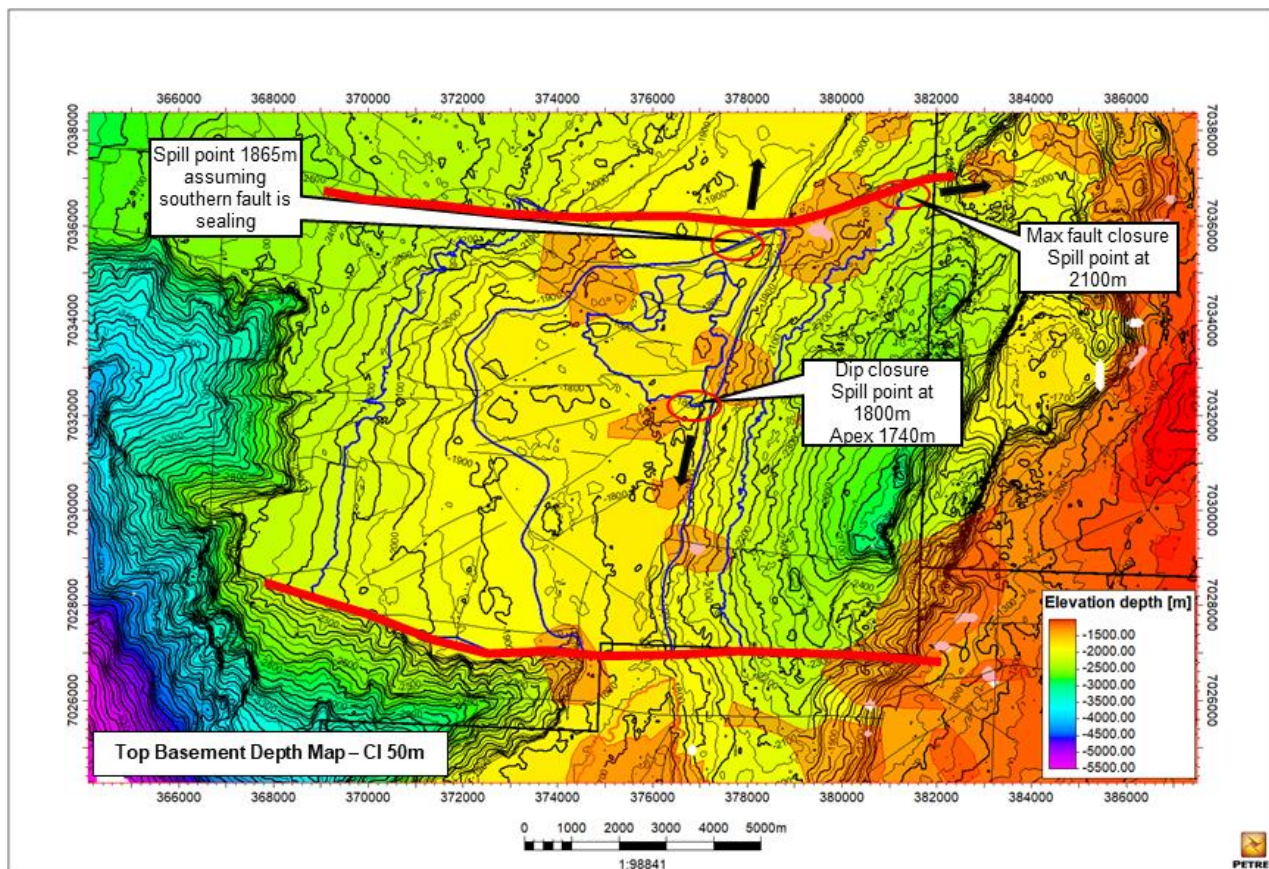


Fig. 4.1 Mist Central trap configuration Top basement depth map showing the Mist Central trap configuration. The crest of the prospect is at 1740 m and displays a dip closure down to 1800 m. Beyond this, an E-W striking shear zone in the south, is required to seal to trap a hydrocarbon column down to 1865 m. To retain an even longer hydrocarbon column, a sealing shear zone to the north is also required. The outline of each scenario is shown on the map as blue outlines. The orange shapes show the location of sills and volcanoes in the overburden. Black lines represent smaller scale faults within the basement.

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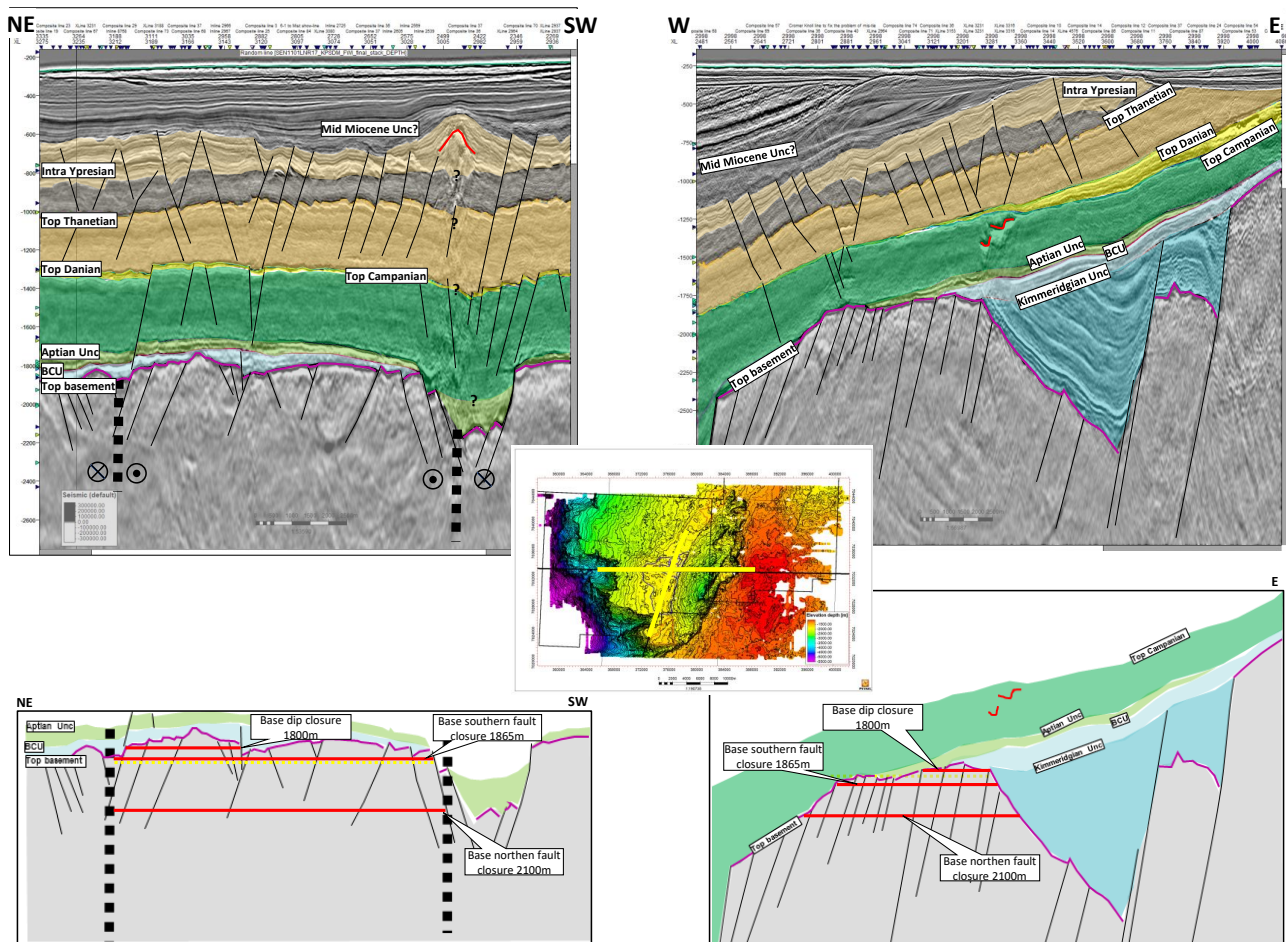


Fig. 4.2 Cross sections through Mist Central The top figures are coloured on the seismic. The lower cross sections are more schematic and show the hydrocarbon filling scenarios.

Mist Central is located adjacent to a large working petroleum system that has charged the Ormen Lange Field (gas), as well as the Midnattsol (gas) and Ellida (oil) discoveries to the west and the Skalmen structure (6306/10-1) to the south-east. There are several potential source rocks that may have charged the Mist Ridge, the most important being Cretaceous in age. Geochemical analysis of nearby well 6306/10-1 concludes that Cretaceous sourced hydrocarbons have migrated into fractured basement. However, the hydrocarbon phase remains uncertain.

Mist Central is expected to be hydrostatically pressured and there is little evidence to support breach of the trap due to Late Paleocene/Early Eocene volcanic activity or late tilting of the Frøya High in response to deglaciation.

The recoverable resource range (oil case) is 1.54 (P90) – 9.41 (P50) – 109.8 (P10) mmboe. This reflects a large GRV range in fractured basement, including wide porosity (1 - 2 -14% of GRV) and recovery factor ranges (5 - 15 -50%). Only an oil case has been evaluated volumetrically, however, uncertainty relating to hydrocarbon phase remains high in this underexplored area (Table 4.1).

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Table 4.1 Mist Central volumetrics (oil case). *The volumetrics have been run using Geox.*

Table 4: Discovery and Prospect data (Enclose map)									
Block	6306/8	Prospect name	Mist Central	Discovery/Prospect/Lead	Prospect	Prospect ID (or New)	NPD will insert value	NPD approved (Y/N)	
Play name	NPD will insert value	New Play (Y/N)	Yes	Outside play (Y/N)	Yes				
Oil, Gas or O&G case:	Oil	Reported by company	Spirit Energy Norway	Reference document				Assessment year	2020
This is case no.:	1 of 1	Structural element	Freya High	Type of trap	Fault Closure	Water depth [m MSL] (>0)	250	Seismic database (2D/3D)	3D
Resources IN PLACE and RECOVERABLE Volumes, this case									
Main phase				Associated phase					
Low (P90)				Low (P90)					
Oil place resources	Oil [10 ⁹ Sm ³] (>0.00)	1.37	Base, Mode	Base, Mean	High (P10)	Low (P90)	Base, Mode	Base, Mean	High (P10)
	Gas [10 ⁹ Sm ³] (>0.00)			39.80	87.10	0.12	0.17	3.58	7.79
Recoverable resources	Oil [10 ⁹ Sm ³] (>0.00)	0.22		7.66	15.80	0.02	0.12	0.72	1.46
	Gas [10 ⁹ Sm ³] (>0.00)								
Reservoir Chrono (from)	Ordovician(?)	Reservoir litho (from)	Granitic basement	Source Rock, chrono primary	Alb-Aptian	Source Rock, litho primary	Lange Fm	Seal, Chrono	Upper Jurassic
Reservoir Chrono (to)		Reservoir litho (to)		Source Rock, chrono secondary	Kimmeridgian	Source Rock, litho secondary	Spekk Fm	Seal, Litho	Rogn Fm
Probability [fraction]									
Total (oil + gas + oil & gas case) (0.00-1.00)	0.06	Oil case (0.00-1.00)	0.06	Gas case (0.00-1.00)		Oil & Gas case (0.00-1.00)			
Reservoir (P1) (0.00-1.00)	0.60	Trap (P2) (0.00-1.00)	0.20	Charge (P3) (0.00-1.00)	0.60	Retention (P4) (0.00-1.00)	0.80		
Parameters:									
Low (P90)				High (P10)					
Base				Comments					
Depth to top of prospect [m MSL] (> 0)			1740	The probability of Mist Central is based on the P90 volumes, i.e. the dip closure. The risk increases significantly when fault seal is included. This is reflected in the volume distribution by using weighted HC contact distributions. Therefore, the Mist Central prospect volumetrics has been run as a complex trap, using weighted distribution for HC contact to reflect a dip closure at the crest and a fault bound trap as the trap is filled beyond the dip closure. A weighting of 0.5 has been used for HC contacts down to the dip closure spill and 0.35 used for the southern fault seal down to its local spill at 1865m. 0.15 weighting on HC contact has been used to reflect the chance of having both faults acting as seal beyond 1865m down to structural spill at 2100m.					
Area of closure [km ²] (> 0.0)			3.8						
Reservoir thickness [m] (> 0)			1000						
HC column in prospect [m] (> 0)			43						
Gross rock vol. [10 ⁹ m ³] (> 0.000)			66						
Net / Gross [fraction] (0.00-1.00)			1.00						
Porosity [fraction] (0.00-1.00)			0.01						
Permeability [mD] (> 0.0)									
Water Saturation [fraction] (0.00-1.00)			0.80						
Bq [Rm3/Sm3] (< 1.0000)									
LiBo [Sm3/Rm3] (< 1.00)			0.7140	0.8000					
GOR, free gas [Sm ³ /Sm ³] (> 0)				0.9090					
GOR, oil [Sm ³ /Sm ³] (> 0)			60	80					
Recov. factor, oil main phase [fraction] (0.00-1.00)			0.05	0.15					
Recov. factor, gas ass. phase [fraction] (0.00-1.00)			0.05	0.15					
Recov. factor, gas main phase [fraction] (0.00-1.00)									
Recov. factor, liquid ass. phase [fraction] (0.00-1.00)									
For NPD use:									
Temperature, top res [°C] (>0)	60	Innrap, av geolog-init:		NPD will insert value	Registrert - init:		NPD will insert value	Kart oppdater	NPD will insert value
Pressure, top res [bar] (>0)	174	Dato:		NPD will insert value	Registrert Dato:		NPD will insert value	Kart dato	NPD will insert value
Cut off criteria for N/G calculation	1.	2.	3.					Kart nr	NPD will insert value

There are few wells that have penetrated and tested fractured basement on the NCS and none are in production to date. Due to this, the Operator has worked extensively with worldwide analogues both offshore and onshore, other industries (e.g. tunnelling, nuclear- and geothermal energy) and research institutions to better understand the reservoir properties of fractured basement rocks. Spirit Energy is also partner in the Greater Warwick area on the Rona Ridge, West of Shetland, UK, and have based several of the volumetric input parameters on well data from this area. The input parameters used in the volumetric calculations can be found in Table 4.1.

There are no leads defined in the license at the time of relinquishment. The Upper Jurassic leads that were defined at the time of the APA application along the eastern margin of the Mandel Basin as well as just west of the Mist Ridge were investigated using coloured inversion, calibrated to well 6306/6-1. No evidence of pinch-outs required for these stratigraphic leads were identified either from spectral decomposition, eXchroma or coloured inversion techniques and the prospectivity is hence downgraded. Seismic interpretation, RGB blending and amplitude investigations in the Cretaceous and Tertiary sections did not reveal any potential onlap traps along the flanks nor any stratigraphic traps within the license area (3 Review of Geological Framework).

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5 TECHNICAL EVALUATIONS

There is currently no infrastructure with processing capability in the vicinity of PL 998, the nearest being the Njord Field approximately 80 km to the north. As such, a tie-back solution is not feasible until processing facilities closer to PL 998 have been developed. Based on technical evaluations, the minimum economic field size for a stand-alone development in the Frøya High area is at least 100 mmboe. The volume range of the Mist Central Prospect is below 100 mmboe (except the P10 case which is 110 mmboe) and due to this it was decided not to undertake a full technical and economic evaluation for this prospect.

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6 CONCLUSIONS

The prospectivity within the PL 998 license has been thoroughly evaluated. The conclusion is that the Mist Central Prospect is a high risk prospect (COSg = 6%) with a volume range not commercially viable (1.5-110 mmboe) and an additional uncertainty regarding hydrocarbon phase. The main risk is the top seal, however, a complex trap fault seal risk is also introduced outside the crestal dip closure. The leads identified in the APA 2018 application have all been evaluated and deemed non-prospective, apart from the Mist North Lead at basement level. This, however, would be dependent on a successful well in Mist Central to be further matured.

The partnership has unanimously decided to relinquish PL 998 in its entirety.