Lundin
Norway

PL 952 Relinquishment Report

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1 Summary and Conclusion

The PL 952 licence is located close to the Nucula discoveries with a proven hydrocarbon system and play in Realgrunnen SGp and Snadd Fm. The main prospect in the early phase of the license was the Marmelen wedge and the secondary prospect was the Kolje Lobe. The Marmelen wedge was a structural three-way closure, charged by fill spill from Nucula. The secondary prospect, the Kolje Lobe, is probably eroded Realgrunnen/Snadd sandstones from the Finnmark Platform, re-deposited down-dip from the Troms Finnmark Fault Complex. The prospect is a Kolje Fm play proven by the Ensis well 7125/4-3, the well is located on the northern edge of the Kolje Lobe. During the license period the Realgrunnen lead was matured to the Dobbeltdekker prospect. The prospect is located on a fault-block down-flank the Nucula discovery. The Dobbeltdekker prospect consists of two prospect levels in the Snadd Fm; one of early Norian? - latest Carnian and one of late Carnian ages.

The main risk of the Marmelen prospect was the sealing capacity of the trap. The MC3D-MFZ02 3D survey was reprocessed and the seismic imaging was improved. Following the evaluation of the reprocessed 3D survey an internal inversion study and an external fault seal study (Badley, 2019) were carried out. The inversion study resulted in an oil bearing response at the Kobbe Fm reservoir level. In contradiction, the fault seal study identifies leakage from the Marmelen three-way structural trap through relay ramps at all reservoir levels, subsequently the prospect was downgraded and is considered of no further interest for the licence.

The Kolje lobe prospect is evaluated as a thin reservoir, and a FIT study conclude that the reservoir most likely contains a hydrocarbon gas phase (FIT, 2019). The reservoir has a low net pay and shallow gas is considered non-commercial.

The Dobbeltdekker prospect consists of channel systems and the main risk is stratigraphic trap and up-flanks leakage into the PL 393. The upper prospect is a crossing channel system with a positive hydrocarbon response based on the inversion study and 2D seismic modelling. However, the prospect is considered high risk due to the stratigraphic trap and probable presence of sub-seismic thief sands that may create leakage into the PL 393. The lower prospect consists of one large channel and the main risk is the stratigraphic trap. The channel shows no amplitude conformance with structure, and the inversion study indicates a brine bearing sand response. Multiple smaller channels can be observed up dip and the trap is considered very high risk.

The evaluation of PL 952 resulted in a prospect portfolio consisting of the Kolje Lobe and the Dobbeltdekker prospects. The decision to relinquish the license was made by the partnership on the 6th of February 2020. Approval of the relinquishment was received by the MPE 25th of March 2020 which lapsed with effect from the 2nd of March 2020.

2 Introduction

PL 952 comprises 665 km² of blocks 7124/5, 7124/6, 7124/8, 7124/9, 7125/4, 7125/5, 7125/6 and 7125/7 on the southern margin of the Måsøy Fault Complex (Fig. 2.1). The license is bordered in the south by the Finnmark Platform, about 40 km of the Norwegian coastline, 105 km south west of the Snøhvit field and 80 km west of the Goliat field.

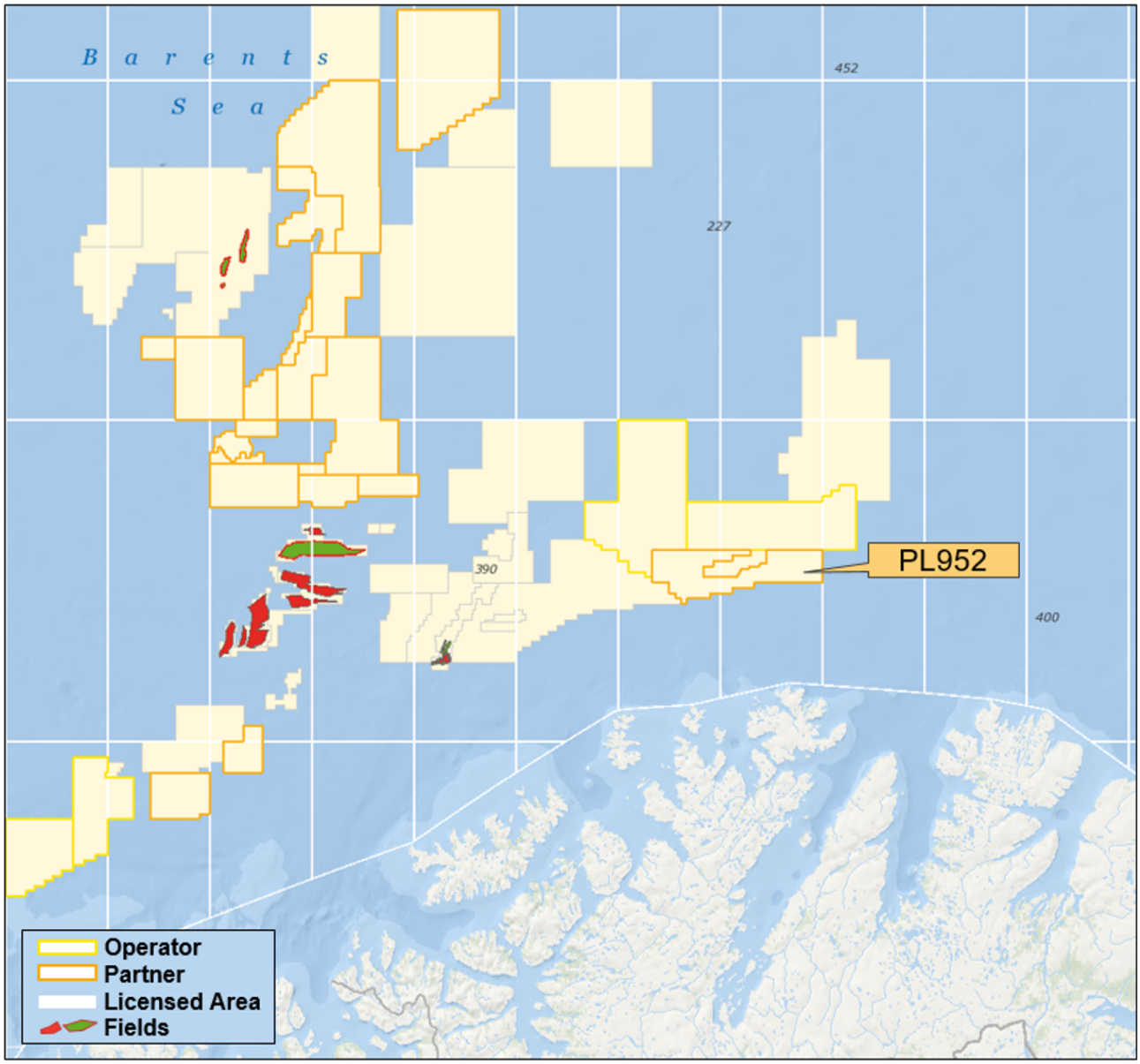

Fig. 2.1 PL 952 *located in the southwestern Barents Sea*

The APA 2017 evaluation (APA Marmelen, 2017) generated two prospects, one discovery, and numerous leads, several of which are untested plays with interesting upside potential (Fig. 2.2). This, and the proximity to the Nucula discovery, made the licence area very interesting both with respect to the chance of finding hydrocarbons and the possibility to tie in new discoveries to a potential future joint development in the Nucula area.

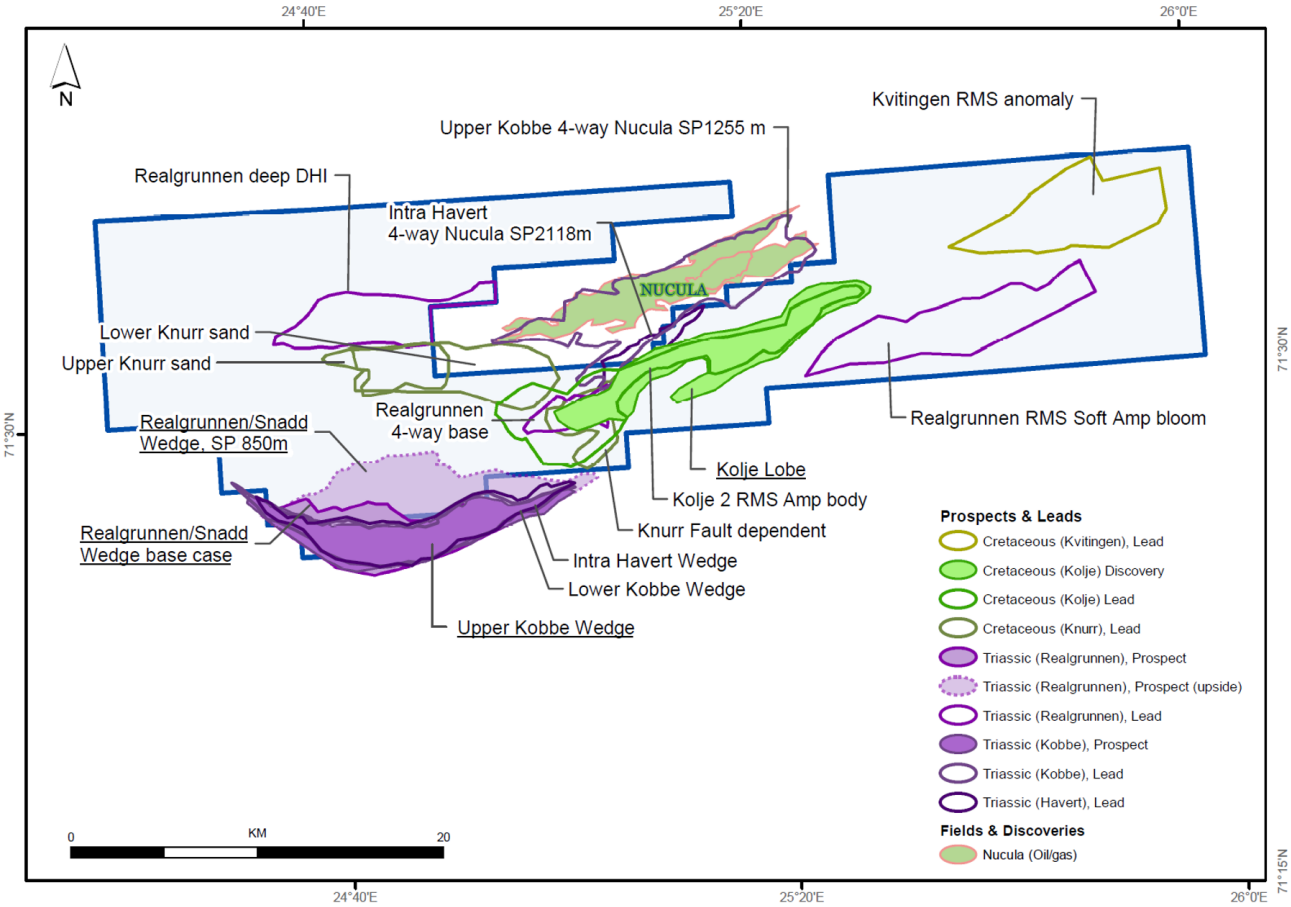

Fig. 2.2 Prospectivity portfolio at APA 2017

The main prospects in the application were the multi target Marmelen wedge with reservoirs in Snadd, Kobbe, and Havert fms. In order to de-risk the prospect the MC3D-MFZ02 3D survey was reprocessed, a fault seal study, an AVO analysis and an inversion study was carried out.

3 License award

PL 952 was awarded as an APA 2017 license on 2nd of March 2018, with a seven year initial license period to Lundin Norway AS (60% and operator) and Suncor Energy Norge AS (40%). As of 7th of June 2018 Lundin reduced equity from 60% to 50% in PL 952 and Edison Norway acquired equity of 10% in the license. The license group had a deadline for decision to drill or drop (DoD) the license 2nd of March 2020, and the decision to drop the license was made 6th of February 2020.

4 Completed work program and special studies

The work program was to reprocess 3D-seismic (Fig. 4.1), conduct seabed and fault seal studies. In addition, multiple special studies both internally and externally have been done in order to de-risk the prospects. The license had a core work shop and a field excursion to Portugal to study analog fluviodeltaic systems.

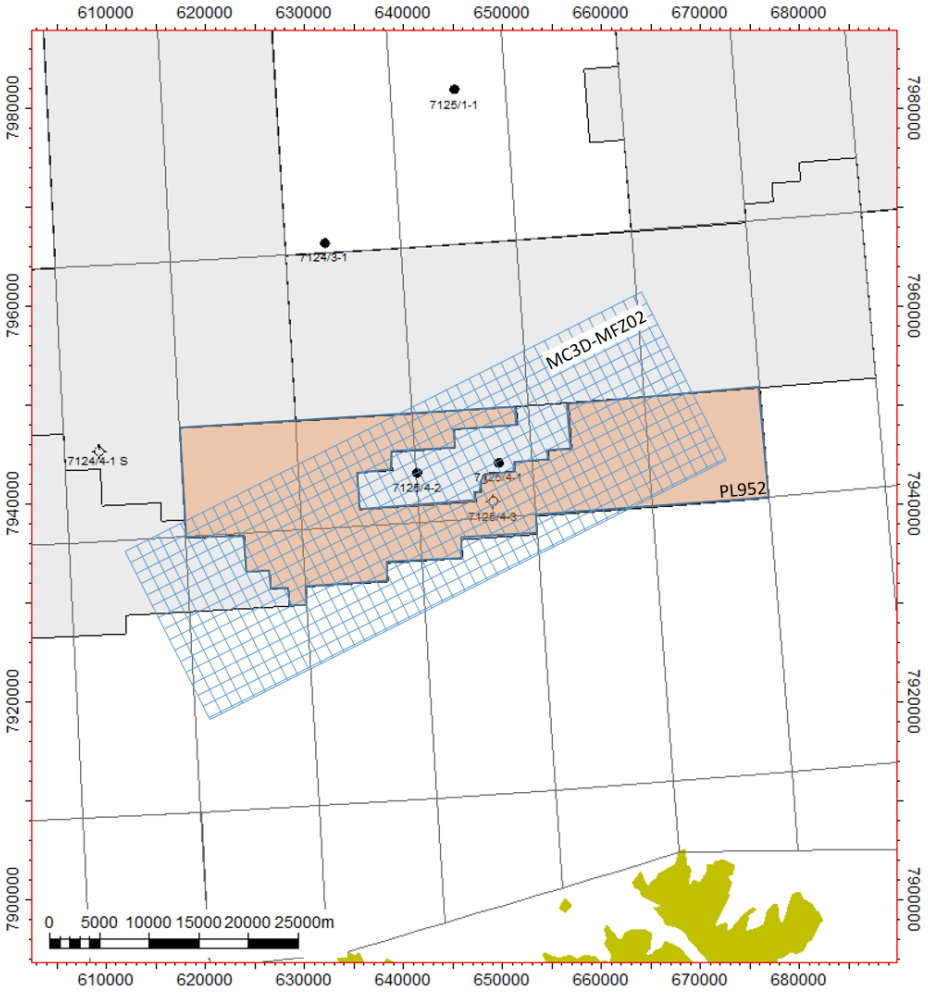

Fig. 4.1 The location of the MC3D-MFZ02 3D seismic survey *and the PL 952 license area.*

The following de-risking activities have been performed:

- **Reprocessing MC3D-MFZ02**:
  The reprocessing was carried out by *WesternGeco* and resulted in the seismic cube *MFZ02LNR18*. *The* seismic imaging and resolution of stratigraphy and faults was improved.

- **Structural study** (Badley, 2019):
  An overview of the Marmelen prospect, faults- and surface interpretation on the improved seismic volume *MFZ02LNR18* were given as input to the structural study. Additional input was a psedo-well with a constructed Vshale log, based on key well 7125/4-1, but adjusted to fit the predicted lithology in the Marmelen prospect.

  Result

Several relay ramps were identified connecting Marmelen hangingwall and footwall reservoirs. The fault seal study proved relay ramps at all reservoir levels located in the apex of the Marmelen closures (Badly, 2019). The licence concluded that there is no working trap in the Marmelen prospect.

- **FRM and AVO**:
  Fluid replacement modelling (FRM) of the most relevant wells (7125/4-1, 7125/4-2 and 7125/4-3) have been performed to understand the prestack seismic response in the virgin case (i.e. the fluid types that the wells found) and substituting to brine, oil and gas.

  Amplitude versus offset (AVO) studies have been done to understand the lithology and fluid responses on several stratigraphic levels: Kolje (for the Kolje Lobe prospect), Realgrunnen, Snadd and Kobbe (for the Marmelen and Dobbeltdekker prospects). These studies have been used directly in the prospect evaluation both for the volume calculations and the risking. For the Kolje Lobe prospect AVO was also used to estimate net pay directly from the seismic which again was used for the volume calculations.

- **Seismic inversion**:
  A large seismic inversion study was performed by Lundin on all stratigraphic levels with the aim to predict lithology and fluid with probabilities. The quality of the seismic data was a limiting factor for the deepest reservoirs and also partly in the Marmelen prospect to the southeast. A probability cube was created, showing the probability of brine, gas and oil saturation for the main reservoirs in the Marmelen and the Dobbeltdekker prospects. The probability cube shows potential for oil saturation in the Kobbe Fm in the Marmelen prospect and in the upper (Norian? - latest Carnian) Dobbeltdekker prospect.

- **Biostratigraphic study**:
  The stratigraphic development in the main reservoirs was revised for the Marmelen prospect, the Realgrunnen SGr. Palynological slides from the Nucula wells were borrowed from NPD and near base Hekkingen to intra Snadd was re-analysed in house.
  -7125/4-1 : 28 samples (868 – 1042 m)
  -7125/4-2 : 7 samples (926 – 1062 m)

  Result
  The implications of the biostratigraphic studyare that we still have Realgrunnen (base Fruholmen Fm) present in 7125/4-2, 7125/4-1 and in the Marmelen Wedge area.

- **Core workshop and analogue field excursion**:

  Core Workshop
  The partnership and Skolithos team reviewed core sedimentology and ichnology from a number of offset wells. Relevant cores from the Realgrunnen SGp, Snadd Fm, Kobbe Fm & Havert Fm was chosen. A broad selection was picked to demonstrate variation in facies from the following wells: 7122/6-1, 7122/6-2, 7123/4-1 S & 7123/4-1 A (Tornerose); 7122/7-1, 7122/7-3, 7122/7-4 S, 7122/7-5 & 7122/7-6 (Goliat); 7124/3-1 (Bamse); 7125/1-1 (Binne); 7125/4-1 (Nucula) and 7226/11-1 (Norsel).

  Field trip
  The partnership had a 5 day field trip to Portugal to visit the coastal exposures of the Jurassic, Cretaceous and Miocene. Realgrunnen analogues were studied on the field trip organised by the company *Skolithos*.

- **Seabed study**:
  Seabed mapping and drop core sampling were performed in 2018. Observations and interpretations on 3D seismic was done in shallow sections in order to map out possible shallow gas. The PL 952 seabed data acquisition is part of long term Lundin involvement on license and R&D cruises over a long period (2008-2019).

  The scope of the seabed study was to detect for water column gas flares. Mapping of bathymetry and identification of seafloor features and their relation to the subsurface. Detect the presence of carbonates, bacterial mats or other anomalies related to fluid leakage on the seafloor. Sampling of sediments associated with fluid leakage.

  Results:
  The cruise experienced a lot of bad weather reducing the intended scope of work. No surveying using HUGIN were carried out due to bad weather. 3 gravity core samples were collected from three large depressions coinciding with fault boundaries from the study area (gravity core locations are shown in red in Fig. 4.2). The seismic data from the study area shows that the depressions are located above the main fault. The fault appears to have caused the depression

  Multibeam and Backscatter data were acquired over parts of PL 952 acreage (multibeam- and backscatter survey shown in Fig. 4.2). The multibeam data indicates water depths from 278 to 324 m. The new high resolution multibeam bathymetry shows no pockmarks, and indicate no recent gas escape. No active gas flares have been identified on multibeam.

  Possible carbonate mounds observed on multibeam may indicate previous gas escape activity (locations of possible carbonate mounds are shown in blue in Fig. 4.2). No indications of gas leakage along main boundary fault to the Finnmark Platform has been detected. Possible shallow gas in Quaternary sand has been identifies (with location shown in Fig. 4.2).

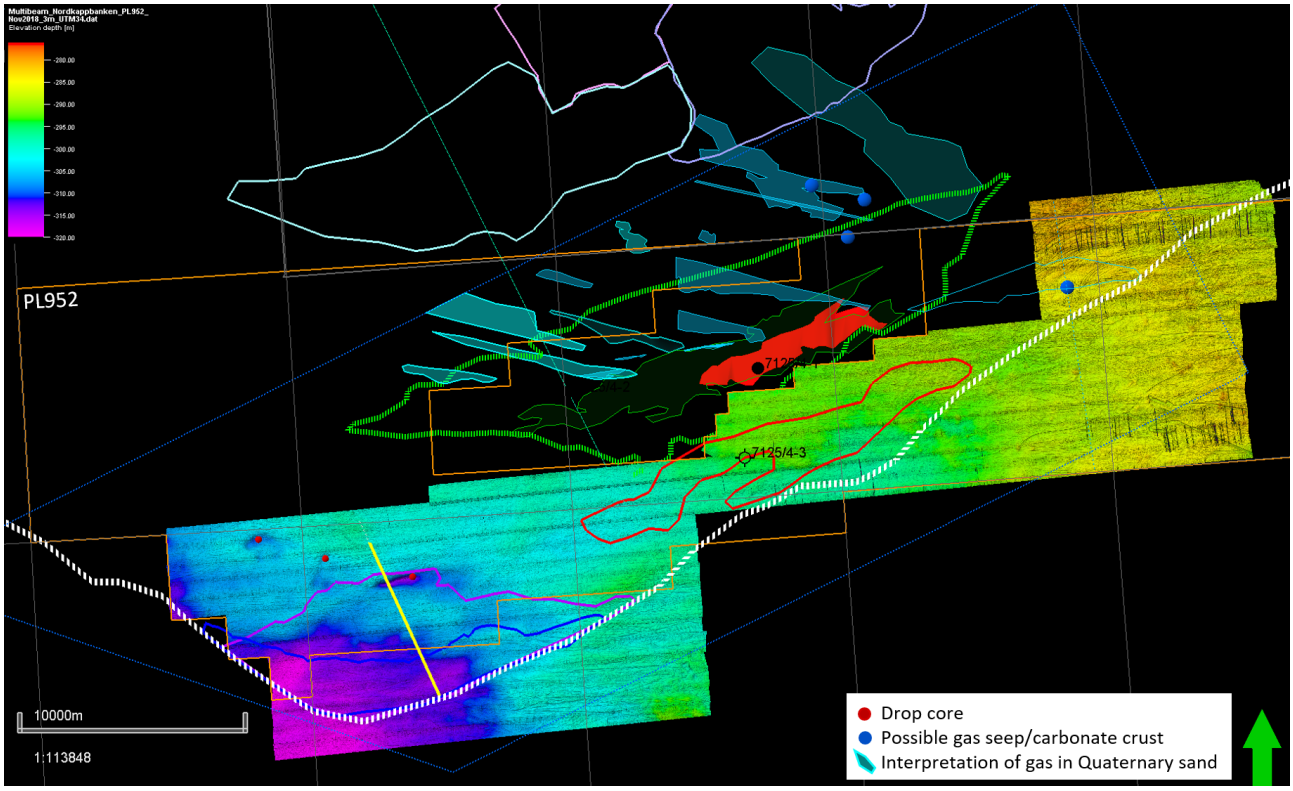

Fig. 4.2 Seabed study. *Showing the multibeam data in PL952, the location of gravity core (red), location of observation of probable carbonate crust and the location of interpretad gas in Quaternary sand.*

- **SATLOG and FIT**:

  SATLOG fluid type indicators show oil prone fluids in Nucula 1 (7125/4-1), and Nucula 2 (7125/4-2) proven oil & gas filled reservoirs, while the same indicators flag gas in Kolje sands in Ensis (7125/4-3). The Kolje fluid, however, shows signs of elevated gravity which may support wet gas or even light oil interpretation (most optimistic case). FIS anomalies not present, no cemented HC inclusions, could indicate late migration after cementation (FIT, 2019).

5 Prospectivity evaluation

A summary of pre award licence identified prospectivity is shown in Fig. 2.2.

Marmelen Wedge

The Marmelen Wedge was the main prospect when the PL 952 was applied for (APA, 2017). The prospect had two prospect levels, Realgrunnen/Snadd- and Kobbe Fms, and two underlying leads in lower Kobbe- and intra Havert Fms. The Marmelen wedge is a hangingwall 3-way anticlinal trap located south west in the PL 952. The main risk factors of Marmelen prospect was the trap and sufficient oil charge.

The improved MFZ02LNR18 was used as input in the in house inversion study that indicated oil in the Kobbe Fm. However, the fault seal study revealed several relay ramps associated with the prospect trap. The main leakage points are located in the apex of the prospect area. Fig. 5.1 shows a map of intra Kobbe Fm with four relay ramps (also illustrated in Fig. 5.2 and Fig. 5.3). The prospect was downgraded and considered of no further interest for the licence based on the fault seal study.

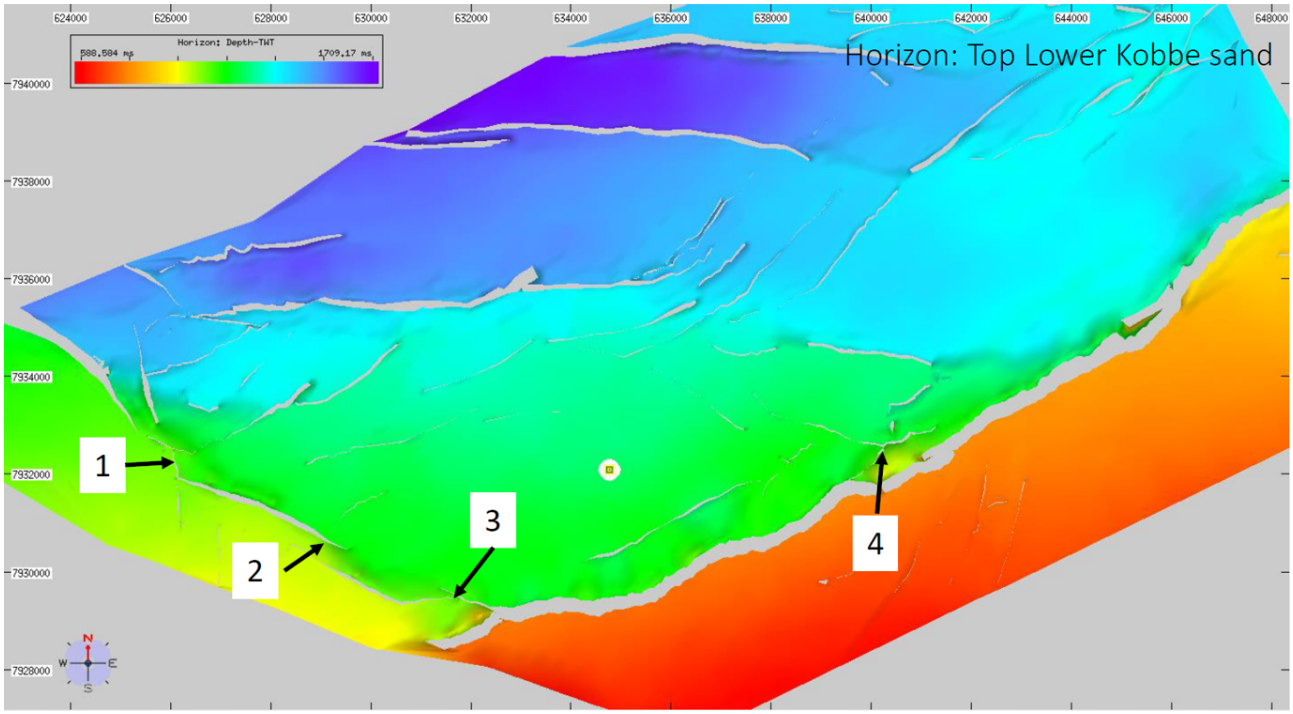

Fig. 5.1 Fault seal study by Badley 2019 *proving multiple relay ramps from the Marmelen wedge and updip to the Finnmark Platform. The areas (1) and (4) do not post a large risk to the viability of the prospect. However, the main leakage points of the prospect are area (2) and (3) create a leakage pathway from the apex of the prospect and updip to the Finnmark Platform.*

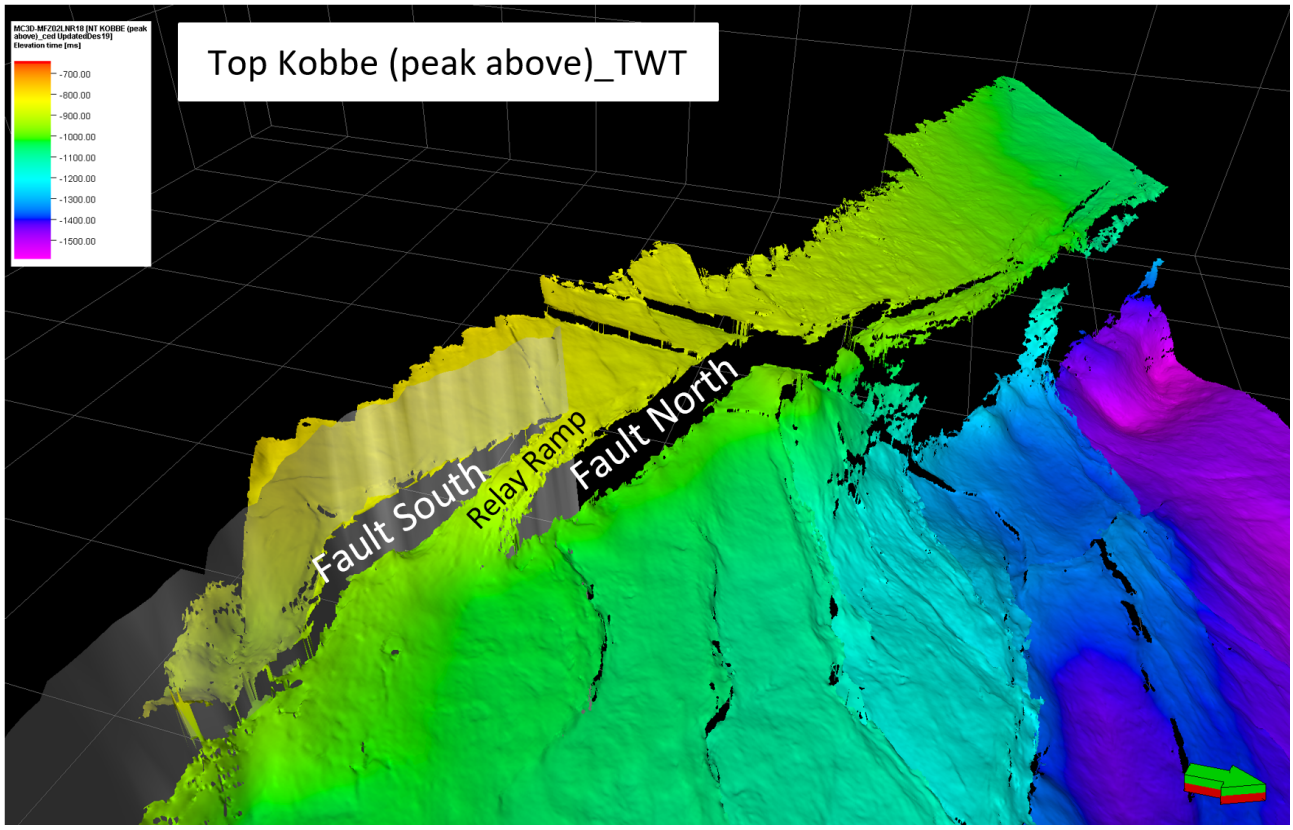

Fig. 5.2 Marmelen Top Kobbe 3D view. *Relay ramp (2), identified in the Badley study, is located in the apex of Kobbe Marmelen prospect and is considered a leakage point.*

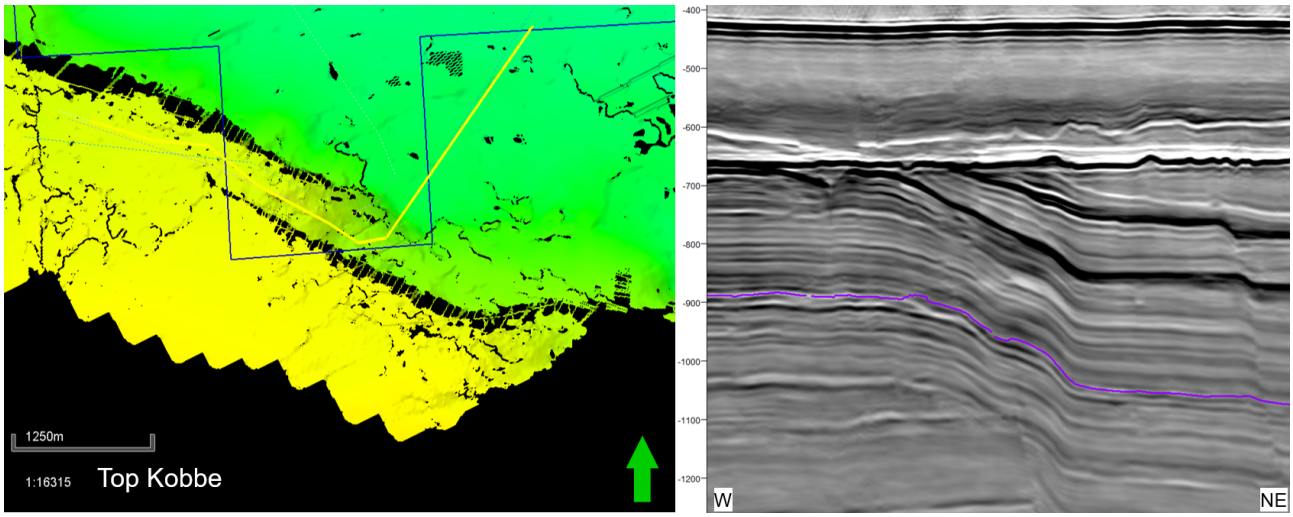

Fig. 5.3 Top Kobbe surface and a seismic profile *illustrate the relay ramp (2) identicied in the Badley fault seal study. The relatively wide ramp is shown on the left side by the Top Kobbe interpretation. The seismic profile with top Kobbe horizon shows the unbreached seismic reflectors at multiple levels.*

Dobbeltdekker

The Dobbeltdekker consists of two Snadd Fm channel prospect levels; one of early Norian? - latest Carnian and one of late Carnian ages (Fig. 5.4). The main risk for both prospects are the high risk stratigraphic traps. The prospects are located on a NW-SE fault segments, down flanks of the Nucula discovery in PL 393. Both prospects are dependent on internally sealing shales to avoid spill into the neighbouring license PL 393.

The upper prospect level has a positive hydrocarbon saturation response both from the inversion study (Fig. 5.5 left side) and from 2D modelling. However, amplitude maps show medium to poor amplitude conformance with structure (Fig. 5.6) and it is considered a high risk of sub-seismic sands that could leak.

The late Carnian prospect has a negative hydrocarbon saturation response from the inversion study (Fig. 5.5 right side). The prospect shows poor/no amplitude conformance with structure and the amplitudes are related to lithology (Fig. 5.7). East of the prospect outline smaller channels are observed going into the prospect and up-flank the fault complex, the trap is considered very high risk. The calculated recoverable volumes for the two levels of the Dobbeltdekker prospect are listed in Table 6.1.

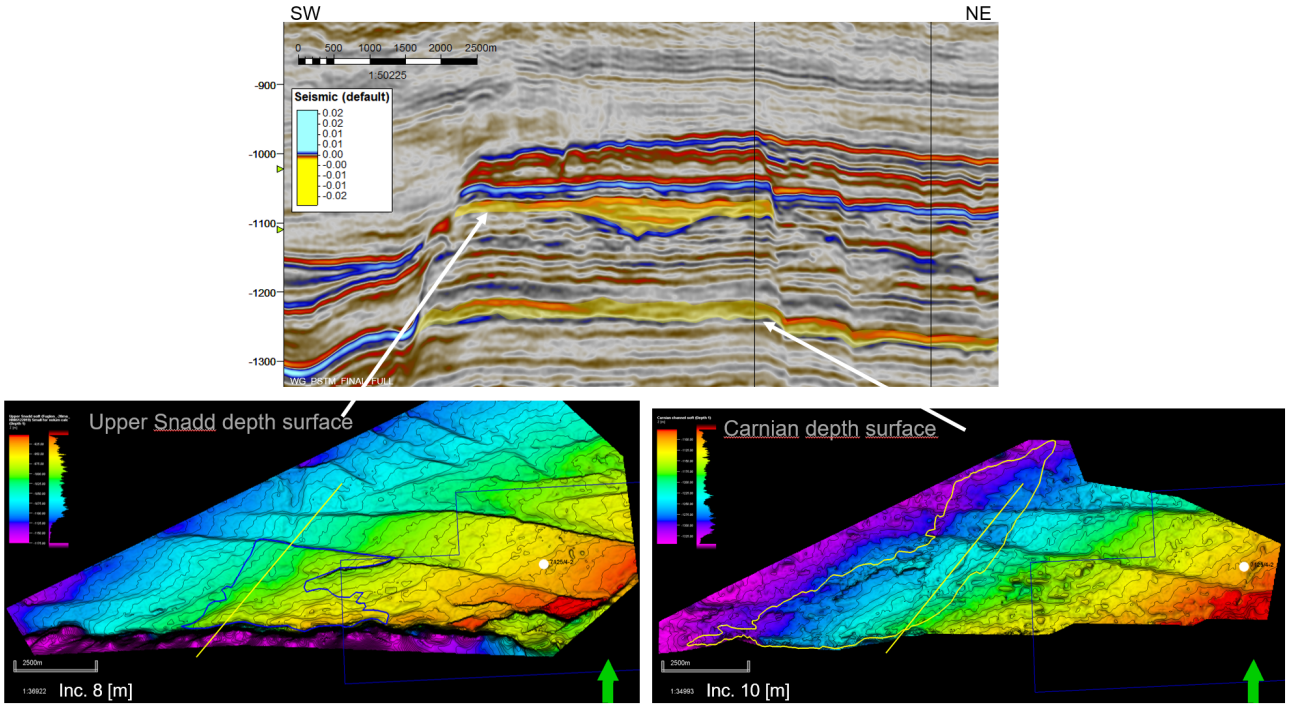

Fig. 5.4 Dobbeltdekker prospect *A seismic section showing sand infill of the two Snadd Fm prospect levels, one of early Norian? - latest Carnian age (upper level) and one of late Carnian age (lower level). Lower left is a depth map of the early Norian? - latest Carnian prospect level, lower right is a depth map of the late Carnian prospect level.*

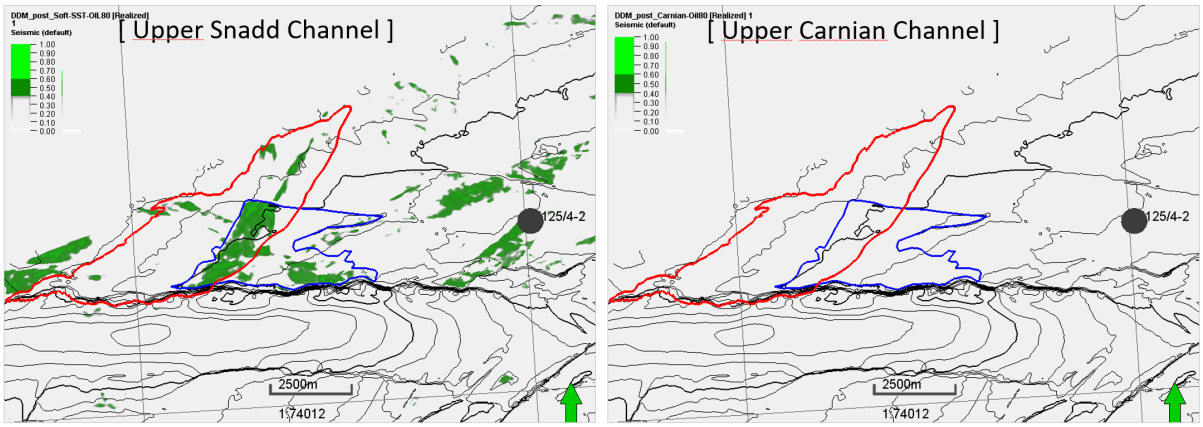

Fig. 5.5 Inversion study, possibility for oil in Snadd Fm sandstone. *The Early Norian? - latest Carnian Channel sandstones (left side) indicate a oil response in the inversion study. The late Carnian Channel sanstones (right side) does not show a oil (or gas) respons from the inversion study.*

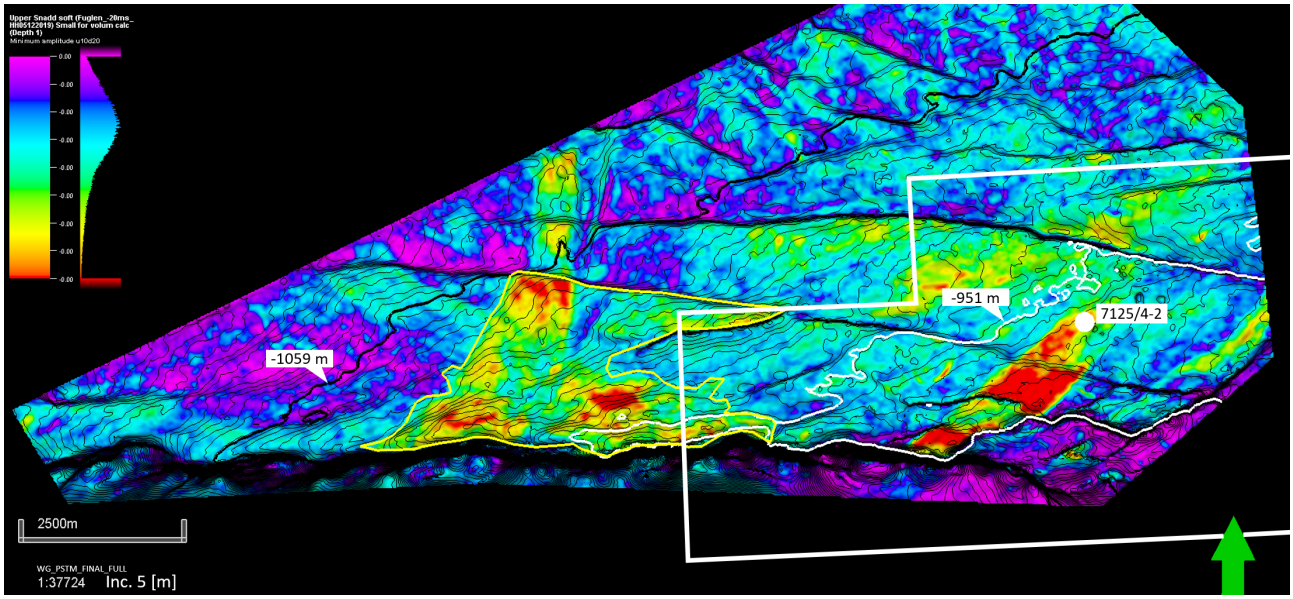

Fig. 5.6 Upper Snadd minimum amplitude map. *The early Norian? - latest Carnian prospect outline is shown in yellow. The prospect has en apex at -959 m and a possible HC contact down to -1059 m (shown by the black contour line). The white contour line shows a possible OWC from Nucula-2 well (7125/4-2) at -951 m*

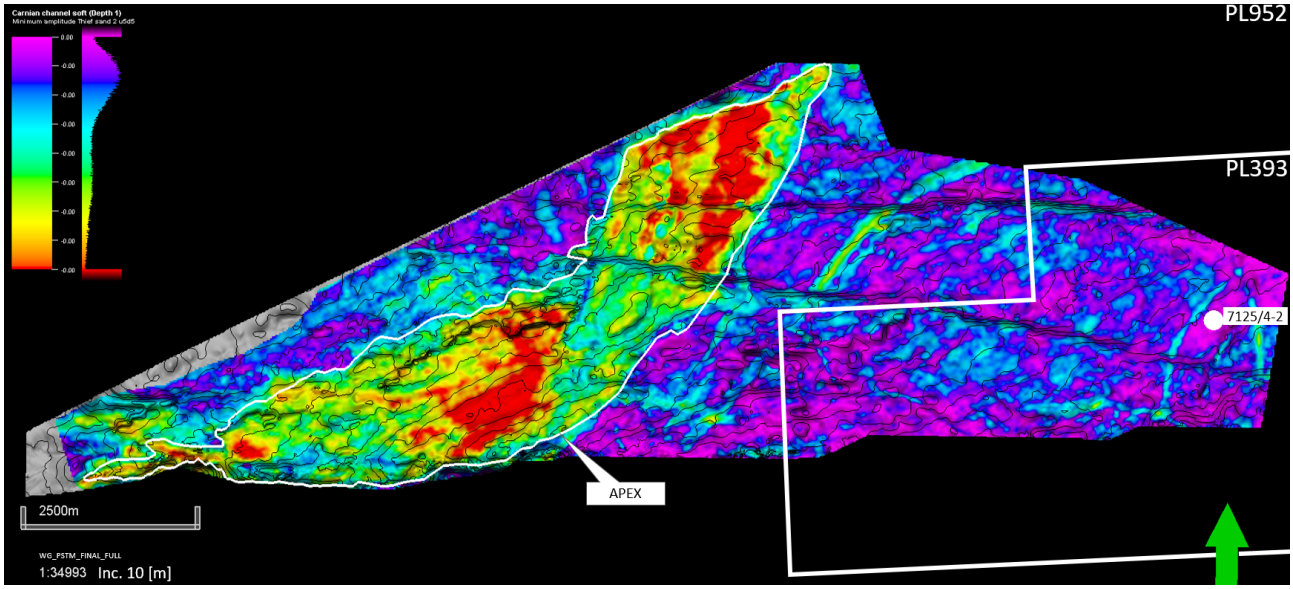

Fig. 5.7 Late Carnian minimum amplitude map *The Dobbeltdekker late Carnian prospect is shown by the white outline. Apex of the prospect is at 1200 m depth. There is poor amplitude conformence with structure and the amplitudes are belived to be a respons of lithological differences and not HC. Smaller channels can be observed in the east of the prospect and upflanks.*

Kolje Lobe

The Kolje Lobe prospect is defined as a lobe or a wedge limited to the southeast by the Troms Finnmark Fault Complex. The prospect commonly consists of one single seismic event at top Kolje Fm stratigraphical level. The seismic event is limited by the Troms Finnmark Fault Complex to the southeast and gets gradually weaker and disappears towards the Nucula structural high to the northwest. The seismic event also disappears towards the northeast and the southwest.

The Ensis well (7125/4-3) drilled through the lobe and encountered 4.4 m net sand with high resistivity (Fig. 5.8). Probably due to limited data acquisition in this shallow section of the well, it

was not reported by the operator. Further analysis of the well reveals that the sandy intervals in the upper part of the Kolje Fm most likely are saturated with a wet gas (FIT, 2019). No fluid contact was found in Kolje sands in the well and a gas-down-to situation is assumed.

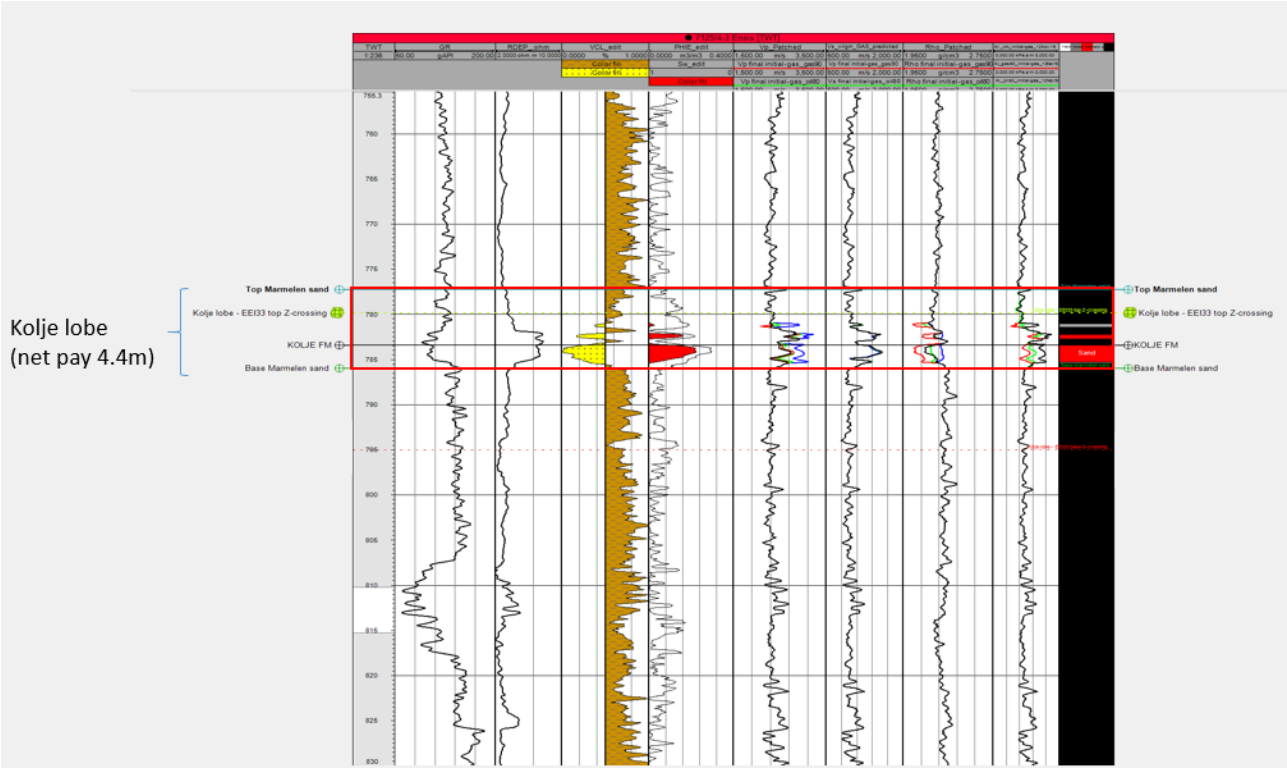

Fig. 5.8 The Ensis (7125/4-3) well logs *The well penetrated the Kolje Lobe prospect. It encountered hydrocarbons (most likely wet gas) in a 4.4 m thick Kolje Fm sand but this was not reported by the operator.*

The base of the lowest sand is at 680 m MSL in the Ensis well. Fluid substitution and seismic modelling of the well indicates that a gas should give a strong seismic amplitude response compared to both an oil and brine filled sand. The amplitudes of the seismic reflector defining the Kolje Lobe is strong in the central parts of the prospect (Fig. 5.9 b), but no clear seismic amplitude conformance with depth which could indicate a fluid contact deeper than 680 m MSL (highlighted in white in Fig. 5.9 a and b).

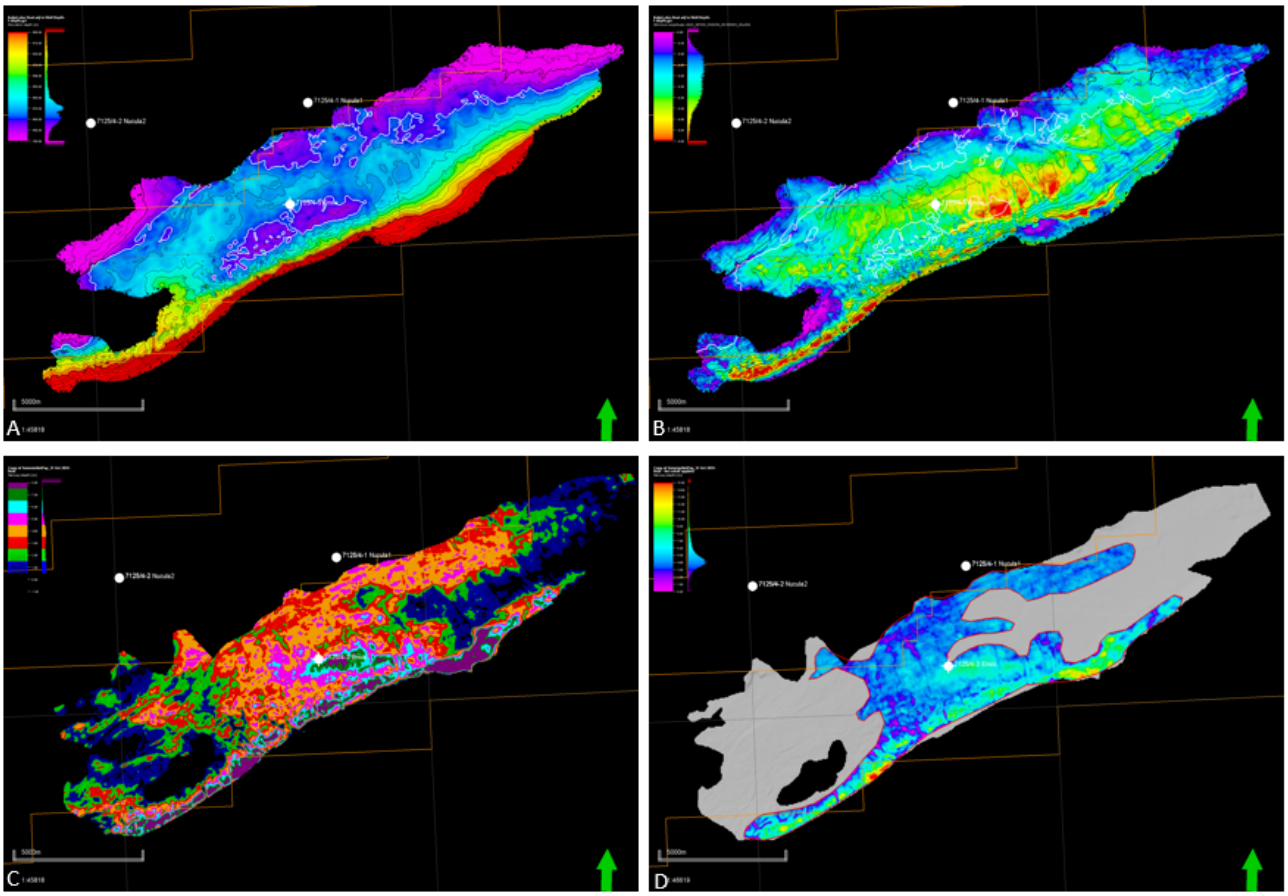

Fig. 5.9 Maps of the Kolje Lobe prospect *a) Structural depth map of the Kolje Lobe b) Minimum amplitude map (40 ms window), does not show amplitude conformance with structure. c) Net pay estimated from seismic data and calibrated to the Ensis well. d) Net pay map with thicknesses over 4m.*

The sands found in the upper part of the Kolje Fm in the Ensis well are probably derived from the Finnmark Platform from assumed reworked sandy Realgrunnen SGp and Snadd Fm. Seismic inversion indicates high probability for thin sands within the Kolje Lobe prospect as shown by the Ensis well. Seismic amplitude variation seen along the top Kolje reflector is probably to a high degree caused by seismic tuning and net pay has been estimated directly from the seismic following a method described by Connolly (2007). Fig. 5.9 c shows net pay estimated from seismic data and calibrated to the Ensis well. In Fig. 5.9 d only net pay thicknesses over 4 m are shown. The net pay estimations with a 4 m cut-off are used directly for the volume calculations of the Kolje Lobe prospect. The recoverable calculated volumes for the Kolje Lobe prospect are shown in Table 6.1.

The Ensis well most likely found wet gas in the Kolje sands, with volumes that are found to be non-commercial.

6 Remaining prospectivity evaluation

Fig. 6.1 illustrates the remaining prospectivity in Pl 952, and volumes are listed in Table 6.1

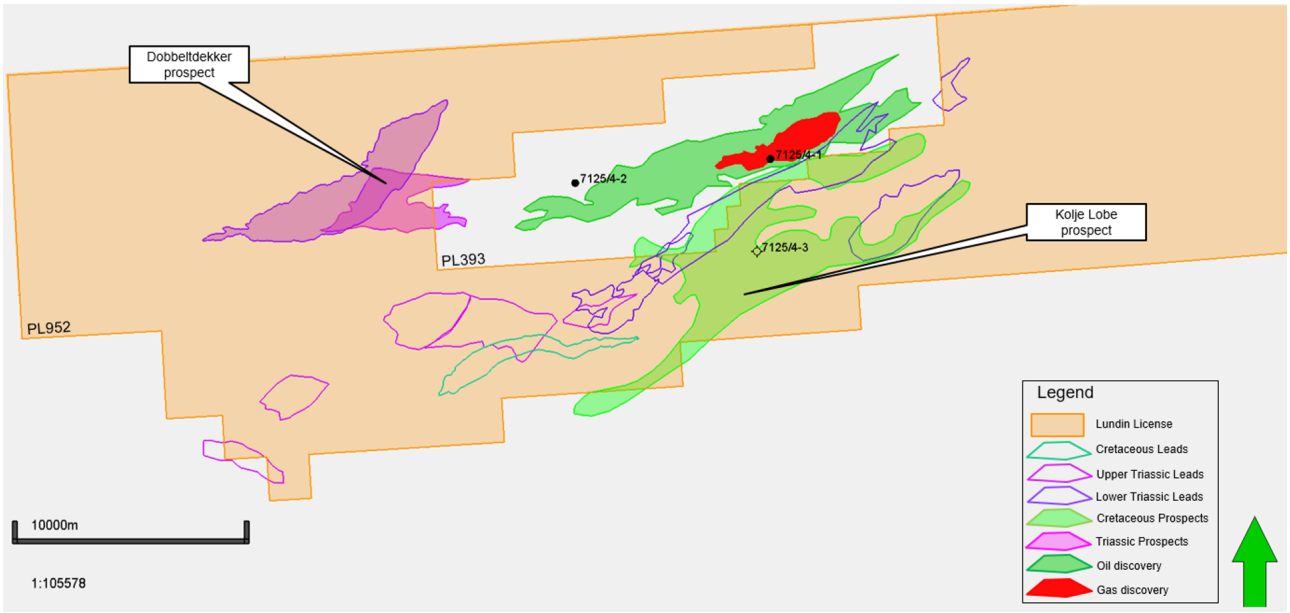

Fig. 6.1 Remaining prospectivity *The remaining prospectivity in PL 952, with the multi level prospect Dobbeltdekker, the Kolje Lobe prospect and multiple leads.*

The evaluation of the reprocessed 3D seismic data together with geological and geophysical studies such as: PSA, inversion study and structural fault seal analysis have resulted in a remaining prospectivity portfolio of the Dobbeltdekker prospect, the Kolje Lobe prospect and multiple leads. The remaining prospectivity have marginal economical volumes and the prospectivity is associated with high risk. The decision to relinquish the license has been made by the partnership.

Table 6.1 Calculated volumes of the remaining prospectivity *The calculated recoverable volumes for the Dobbeltdekker prospects and the Kolje Lobe with P90, P50 and P10, for oil and gas case. The Dobbeltdekker is only calculated for the oil case with a 10% gas cap, and the Kolje lobe is only calculated for a gas case. The probability for discovery is not calculated for Kolje Lobe because it is considered a discovery.*

PL952	P/L	Case: Oil/Gas/ Oil&Gas	Unrisked recoverable resorces						Probability discovery	Reservoir	
			Oil			Gas				Stratigraphy/Chrono	Depth (mMSL)
			P90	P50	P10	P90	P50	P10			
Dobbeltdekker Upper Snadd	P	Oil	6.3	17.1	38	-	-	-	0.10	Upper Snadd Fm (Triassic)	959
Dobbeltdekker Carnian	P	Oil	9.4	20.2	38.9	-	-	-	0.06	Intra Snadd (Triassic)	1200
Kolje Lobe	P	Gas	-	-	-	0.4	1.4	2.7	-	Kolje (Cretaceous)	570

7 References

Badleys, Fault Seal Analysis of Marmelen Prospect, PL952 Lundin, October 2019

Connolly, P. A simple, robust algorithm for seismic net pay estimation. The Leading Edge, October 2007

FIT, A Stratigraphic Reconstruction of Bulk Volatile Chemistry from Fluid Inclusions in: 7125/4-3, Multiclient Barents Sea, May 2019

Lundin Norway in cooperation with Edison Norway, APA 2017 Application for Marmelen Prospect Blocks 7124/5, 7124/6, 7124/8, 7124/9, 7125/4, 7125/5, 7125/6 and 7125/7, September 2017