PL541 RELINQUISHMENT REPORT

Repsol Exploration Norge AS

19 May 2015

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PL541 Relinquishment report

[redacted]

1. Key licence history

The PL541 licence was awarded on the 19th of February 2010 from the APA2009 round. The application was submitted by an AMI consisting of Edison International, Repsol Exploration Norge and Skagen44. It covered the blocks 3/6, 3/9 and 4/4, all within the northern part of the Siri Fairway. The area included the dry well 3/6-1. Just south of the area, across the border to Denmark, is situated the Siri oil field, producing from several Paleocene/Eocene discoveries in the Siri Fairway. The application comprised 4 play types with 9 prospects and 1 lead. The awarded area covered just block 4/4 with 7 of the prospects. The major one was Brattholmen (Paleocene) with approximately 90% of the total estimated unrisked oil. The others were 2 in Oligocene Vade Fm (gas), 2 in Paleocene Lista Fm (oil) and 2 in Triassic Skagerrak Fm (gas).

Licensee	Interest at award	Interest at relinquishment
Edison Norge AS	35%	25% (10% to Explora Petroleum 20/12-13)
Repsol Exploration Norge AS	50%	35% (15% to Explora Petroleum 31/12-13)
Skagen44 AS	15%	7.5% (7.5% to Concedo 31/7-13)
Concedo ASA	-	7.5%
Explora Petroleum AS	-	25%

Table 1.1: Licencees and interests in PL541.

Operator has been Repsol Exploration Norge. The license has had several work and EC meetings. MC meetings have been held 12/3-10, 7/11-10, 18/11-11, 28/11-12, 22/11-13, 18/11-14, and 17/2-15.

Upon the award, the initial period was valid until the 19th of February 2016. A 1 year extension of all deadlines from Decision to continue (BoV) was approved by the MPE on 26th November 2013. The new Initial period was set to 19th February 2017.

Work programme task	Due date	Result
Re-process 3D seismic	19th February 2012	Fulfilled
Decision to drill an exploration well	19th February 2012	Drill
Decision to continue (BoV)	19th February 2015	Not continue
Decision to submit a PDO	19th February 2017	-

Table 1.2: Work programme for PL541.

A unanimous decision to drill an exploration well was made 18th November 2011.
The well 4/4-1 was drilled in September-October 2013. No hydrocarbons were encountered.

A unanimous decision to not continue the license was made 17th February 2015. The well 4/4-1 had shown that the major prospect in the license was dry and that it would have been smaller than prognosed. In addition, further geological studies showed that migration into other areas of the license was unlikely.

2. Database

2.1 Seismic Database

- **ST9602**: 3D seismic, public, field data purchased from WesternGeco and multi-client re-processed in 2010 and named **SIRINOR.**
- **MC3D-Q4**: 3D seismic, public.
- **NODAB-97**: 3D seismic, purchased from GEUS.
- **G9603**: 3D seismic, purchased from WesternGeco, merge of Siriwest3D and SH9204.

2.2 Well database

- Public Norwegian wells: 3/4-1, 3/5-1, 3/5-2, 3/6-1, 3/7-2, 3/7-4, 3/7-5, 11/10-1.
- Danish wells purchased from GEUS: Nini-2, Nolde-1, Sandra-1, Siri-1, Siri-2, Siri-3, Siri-3A, Siri-4, Sissel-1, Sofie-1.
- Danish wells traded with DONG: Sara-1, Sara-1A.
- Drilled well by PL541: 4/4-1.

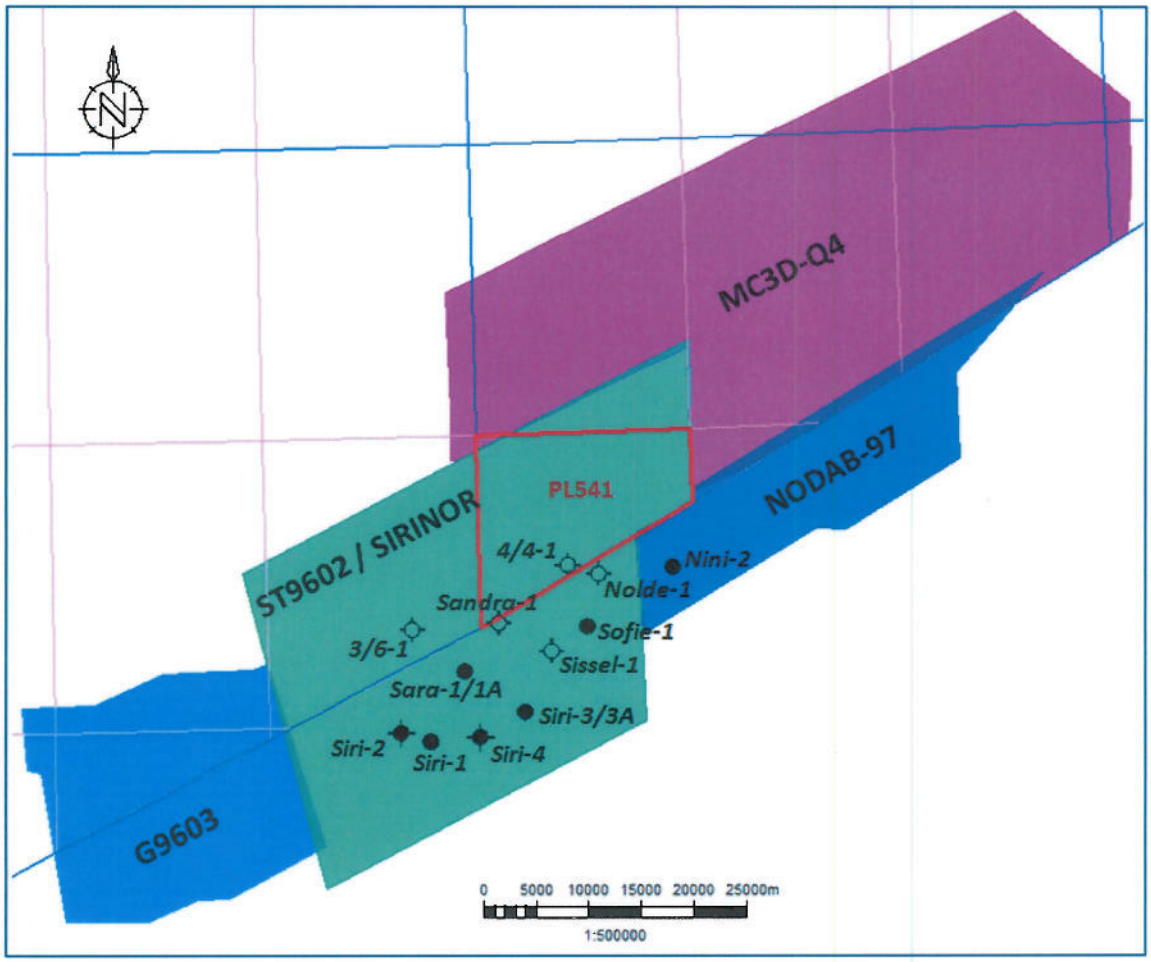

Figure 2.1: PL541 seismic database and key wells from the well database.

3. Review of geological framework

PL541 is situated in the Danish-Norwegian basin, adjacent to the Danish territory, Figure 3.1. The Paleocene/Eocene Siri fairway crosses the southern part of the license from NE to SW. Also the large Paleozoic Krabbe fault zone crosses the license in W, from N to S. The Permian salt has been mobilized considerably, with a major impact on the Triassic formations. The salt has also had an impact on the sedimentation and tilting of the Tertiary layers. In PL541 there are two major salt domes, and one of them is forming the trap of the Paleocene Brattholmen prospect, Figure 3.2. The prospect is a 3-way dip closure against a fault to the East, with a stratigraphic component due to the pinching out of the turbiditic sands towards the fault.

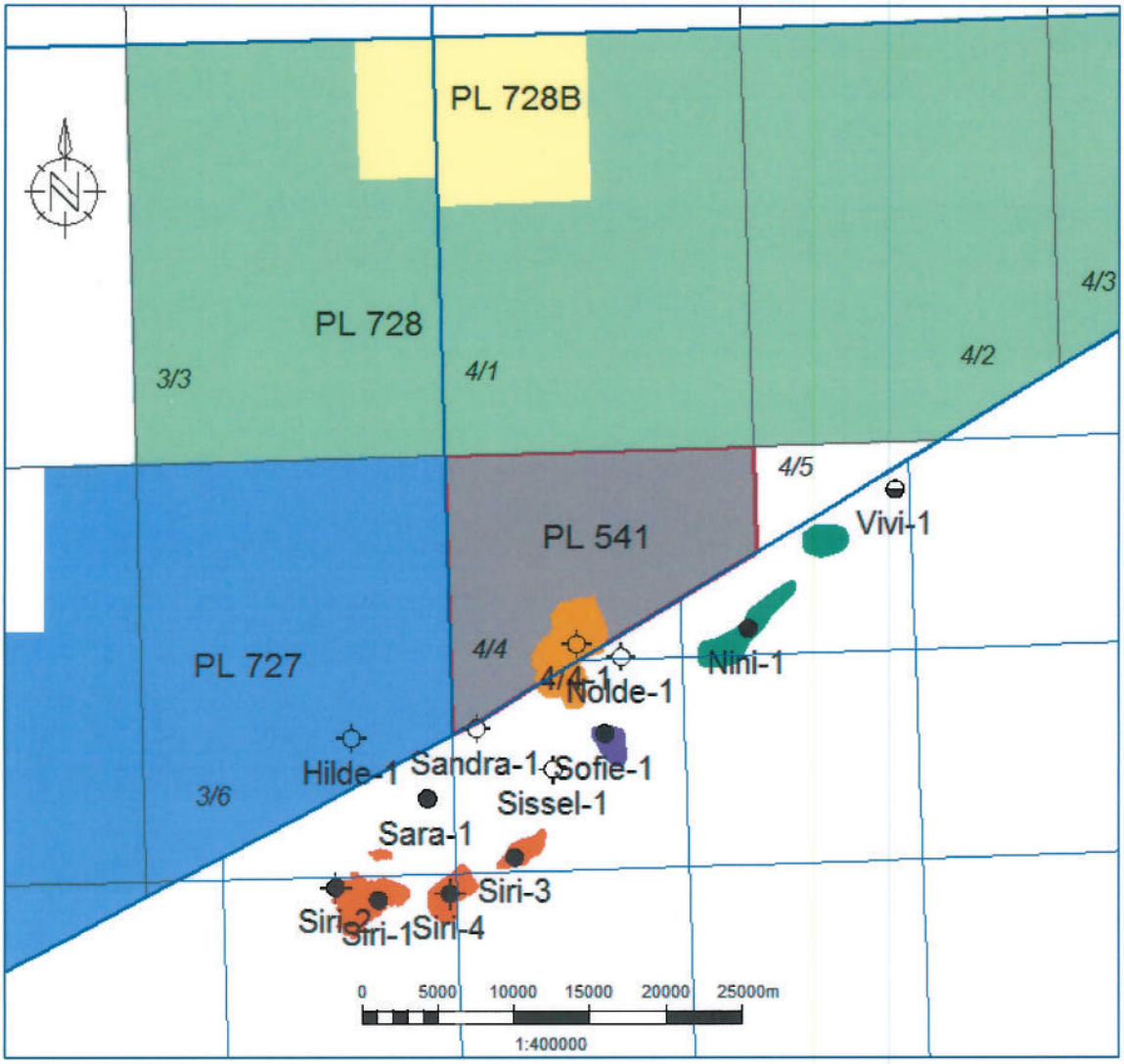

Figure 3.1: PL541 with the Brattholmen prospect and neighbouring wells and licenses.

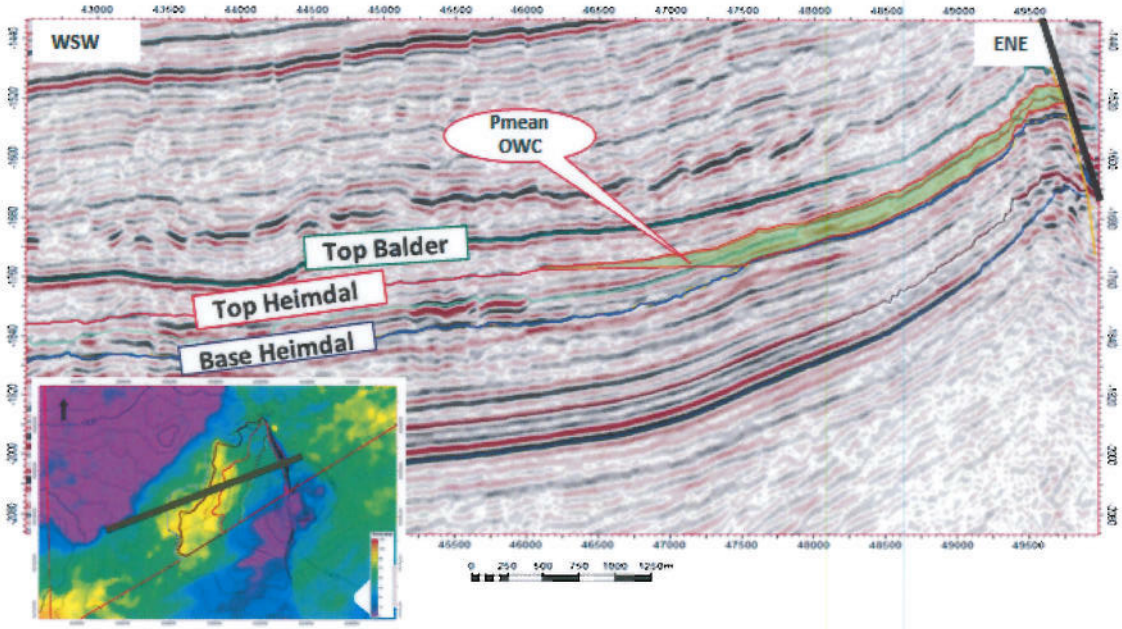

Figure 3.2: Pre-drill Brattholmen prospect in the Lista Fm and with base case OWC level.

The ST9602 was the only 3D seismic covering the license. The original field tapes were used as input to a completely new re-processing. The work was done by WesternGeco, as a multi-client job with the neighbouring PL540. Focus was to improve the data primarily at the Paleocene-Chalk level. New velocity picking was done, taking anisotropy into account. The re-processing also included pre-stack time migration (Kirchhoff with anisotropy) and several new processes for removing noise and multiples. The gathers were also prepared for a planned pre-stack inversion. The final version was ready for interpretation in late December 2010. The re-processing had improved the data much with respect to noise, multiples and reflector continuity, Figure 3.3. This improved the resolution at target level, and very much in the shallow part.

To enhance the frequency content, a smaller part of the 3D seismic around the Brattholmen prospect was re-processed a second time. The job was done by Geokinetics in 2011, using their SBLA process. The enhancement was mainly used to interpret the base of the reservoir. However, after 4/4-1 was drilled, a comparison with the synthetic seismic at the well shows that the reliability of the additional information from the enhanced data is very variable.

The seismic interpretation focussed on the Siri fairway comprising the Paleocene Brattholmen prospect. Ties were obtained from the key wells. The Top Balder, Top Sele and Top Chalk were interpreted with good confidence regionally. Top Upper Lista (with Heimdal sand), Top Lower Lista (with Ty sands) and Top Våle were interpreted with lower confidence. Especially Top Upper Lista had a large degree of uncertainty since the well ties varied from peak, trough to zero crossing. In addition, these horizons were not continuous from the nearby well-ties.
To aid the interpretation several seismic attributes were also used, like max amplitude, semblance and instantaneous phase. Spectral decomposition was also made, but with inconclusive results. Finally, several horizons above and below the Rogaland Gp were regionally interpreted for input to other studies: basin modelling, geological re-construction, depth conversion, and geomechanics for the drilling of 4/4-1.

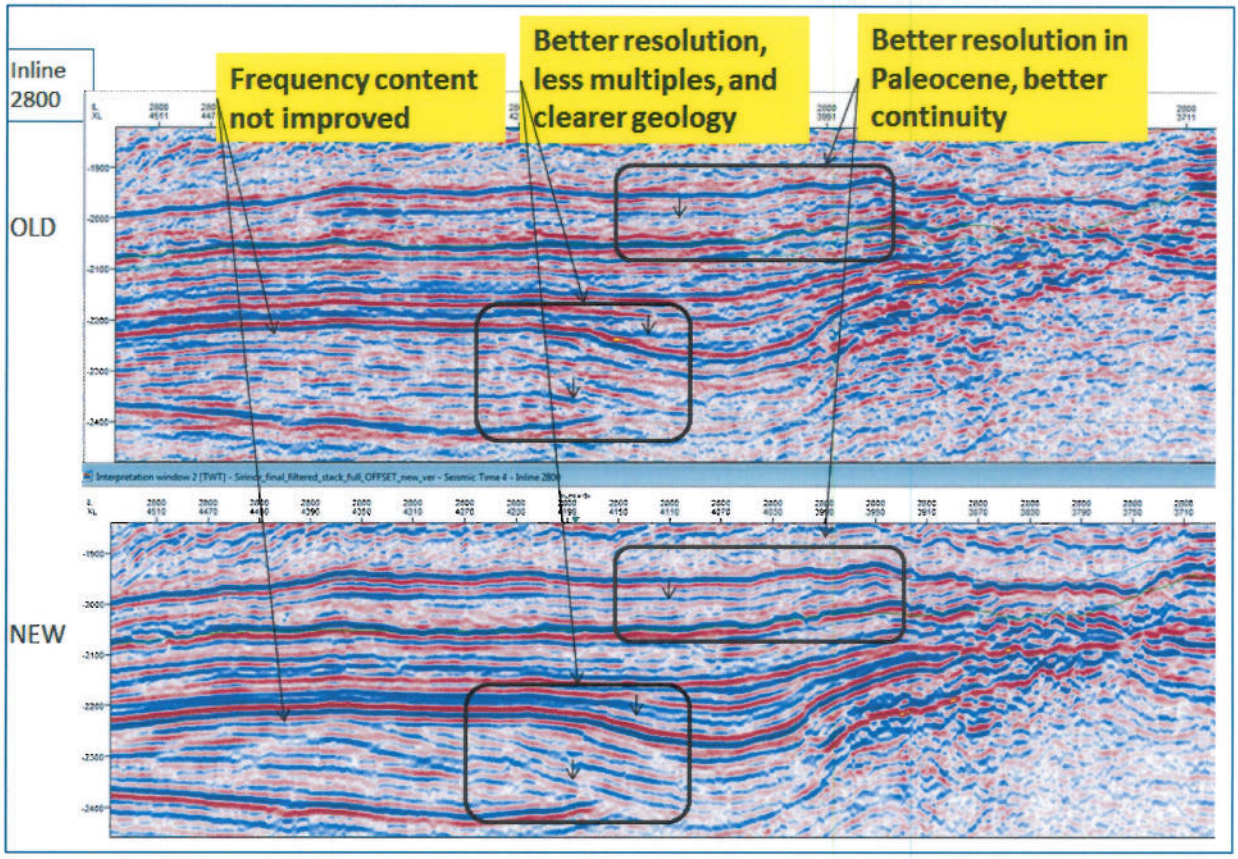

Figure 3.3: Re-processing results at target level and deeper.

An AVO inversion was done by Schlumberger as a multi-client job for PL540 and PL541. The result was ready in early 2011. It was a two-step process: gather amplitudes first inverted to obtain geophysical parameters, which in turn were inverted for the reservoir parameters total porosity, shale volume and water saturation. Unfortunately, the process was not able to utilize the wells nearest to PL541, so the results were much less reliable away from the Siri-field area were most of the wells could be applied. The indications of differential compaction seen in the seismic in PL541 had poor correlation with the shale/sand ratio from the inversion. The water saturation was the most uncertain parameter and it showed poor results in the area of PL541 (and PL540). However, this parameter was very dependent on the influence of the Nolde well which had unreliable acoustic logs. The main use of the inversion was therefore to let the acoustic impedance be a guide in the interpretation of the horizons due to the increased resolution offered. After the 4/4-1 well was drilled, it was confirmed that the inversion had poor match for porosity and shale content at the well.

Core descriptions were studied to classify the facies of the Paleocene sands in Sandra-1 and Siri-1. Together with interpretations of the seismic and the seismic attributes, this was used to create a sedimentological model describing the deposition of the turbidite flows in the Siri canyon. The model was made in 2011 and further updated in 2013, and helped de-risking the Brattholmen prospect. The facies distribution had an impact on the estimation of the reservoir volumes and on where to position the exploration well. A field trip was made in 2011 to the Tabernas Basin in southern Spain for studying the similar types of facies associated with turbidites.

The migration into the Siri fairway is proven by the many Danish discoveries. The source rocks are the Upper Jurassic Mandal and Farsund Fms in the Tail End Graben. Migration is assumed to have gone up through the Coffee Soil Fault and then north-east wards in the Paleocene sands. A Multi 1D Basin modelling was done in 2011, and showed that additional hydrocarbons also could have been expelled from the same source rocks in the Søgne Basin. However, the internal migration pathway within the Paleocene sands is complicated to map, and the pressure measured in several wells indicates lack of present day communication among several of them.

A fault seal analysis was made in 2011 of the large fault bounding the Brattholmen prospect to the East. The study showed that the fault has a high sealing potential for the Paleocene sands.

A 1D CSEM feasibility study was done by EMGS in 2010. For reservoir thickness and resistivity from nearby wells, the modelled EM anomaly was moderate and could be hard to separate from the background resistivity. No further 3D CSEM study or acquisition was therefore made.

A shallow coring was made to investigate the rigidity of the seabed before finalizing the position of the jack-up rig for 4/4-1. One of the cores was afterwards analysed by Gore and Associates in 2013. The results showed presence of thermogenic hydrocarbon compound signature. However, the results had a high degree of uncertainty since the core had not been ideally stored before the analysis was made.

4. Prospect Update

The objective of the well 4/4-1 was to evaluate, in terms of fluid and reservoir, the Paleocene Heimdal sandstone Mbr of the Lista Fm. The expected recoverable mean resources were estimated to 98.9 mmboe, with a geological probability of success of 17.2%. Main risks were migration, lateral seal and to some extent reservoir quality. TD was to be in the Tor Fm in order to check for possible hydrocarbon presence in the Ekofisk Fm. Minor shows had been seen in the nearby Nolde-1 well. However this was not considered to be a secondary prospect as the top of the Ekofisk Fm was prognosed to be significantly deeper in 4/4-1 than in Nolde-1.

The well 4/4-1 was spudded 13th September 2013 with the JU rig Maersk Giant. TD was reached 3rd October 2013. The well found the expected reservoir in the Lista Fm below unexpected Hermod sandstone Mbr in the Sele Fm. No hydrocarbons or shows were discovered in any formations. Pre-drill reservoir prognosis had a NTG of 55% and porosity of 29.5%. The observed net sands sums up to 20.75m, giving a NTG of 38%. Porosity is interpreted to be 29.4%. The petrographic study indicates very good to excellent reservoir quality.

The top of the reservoir sand proved to be the Hermod Mbr instead of the Heimdal Mbr, which in turn was encountered 32m deeper, Figure 4.1. The lower part of the pre-drill prospect proved to be the Våle Fm consisting mostly of marl, with 2.6m sand at the base, which reduced the reservoir thickness with 27%.

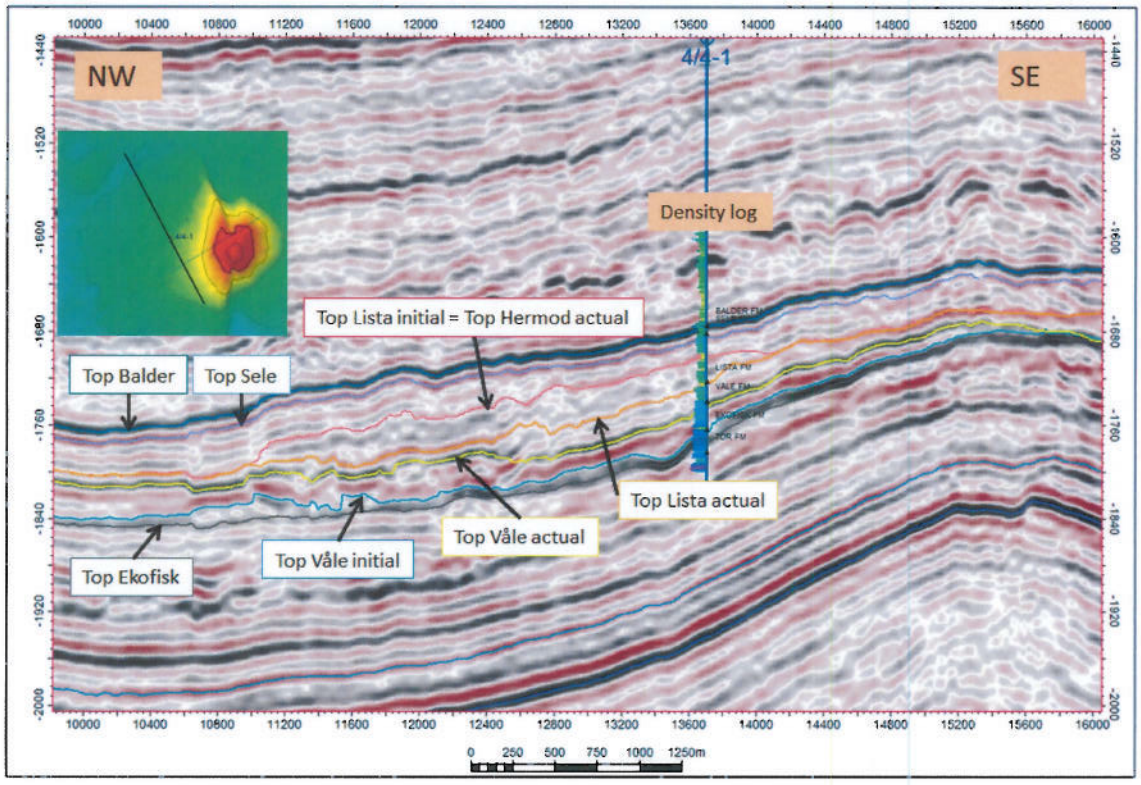

Figure 4.1: Pre- and post-drill interpretations of horizons at 4/4-1, X-line2625.

A zero-offset and offset VSP was also acquired. The VSP seismic showed hardly better resolution of the Rogaland Gp than the re-processed 3D surface seismic. Modelling showed that at least 60Hz seismic would have been necessary to confidently interpret the top and base of the Hermod Mbr and to resolve the thinner Heimdal Mbr sand.

Pressure measurements in 4/4-1 indicated that the sand encountered in Sele Fm, Lista Fm and Våle Fm all were in communication. The pressure was well above the hydrostatic, indicating that the large fault bounding Brattholmen to the East was not leaking. In addition, the pressure gradient was similar to the one measured in the water zone of Sara-1/1A, which had oil in the Heimdal Mbr sand. The Sara discovery is a very subtle 4-way closure, which probably is filled to spill.

A 3D geological reconstruction was undertaken in 2014 to better understand why the hydrocarbons in the Sara-closure had not spilled up to 4/4-1. The study showed that the Sara-closure once has been approximately 12 times larger than today, and that the spilling has happened in the Pleistocene, mostly caused by post-glacial uplift. The hydrocarbons have probably re-migrated eastwards and perhaps filled the Frigg Mbr sands in the Horda Fm at the Danish Sofie-wells. However, the Sofie-discovery is quite small, so any exceeding hydrocarbons from the Sara-discovery are likely to have continued further into Danish territory. The Sissel-1 well in-between was dry and has a distinctly higher pressure, indicating no communication with Sara-1/1A or Sofie-1.

The 3D geological reconstruction also indicated no re-migration in the Paleocene sand from the Danish Nini-discoveries to PL541 in N/NW. A pronounced SW-NE elongated low has probably acted as a barrier between the license and these traps ever since the migration into the Siri-fairway started in the Miocene.

The other prospects from the application, see Figure 4.2, have only been studied to a lesser extent. Each of them is small and would only have become interesting as future tie-ins to a Brattholmen field. A re-interpretation verified approximately the sizes of the closures of the two Northern Paleocene prospects Lyngholmen and Larsholmen. However, the geological re-construction showed that the charging of these traps has an even higher risk than initially. The two Oligocene gas prospects, Risholmen and Grasholmen were not tested by 4/4-1, but the seismic data clearly indicate presence of gas. For Risholmen new volumes were estimated to be more than twice the gas volumes in the application. The two Triassic prospects Kobbholmen and Bukkholmen still have very high risks, especially due to the lack of proven mature source rock in the area. See Table 4.1 for volumes of the remaining prospects.

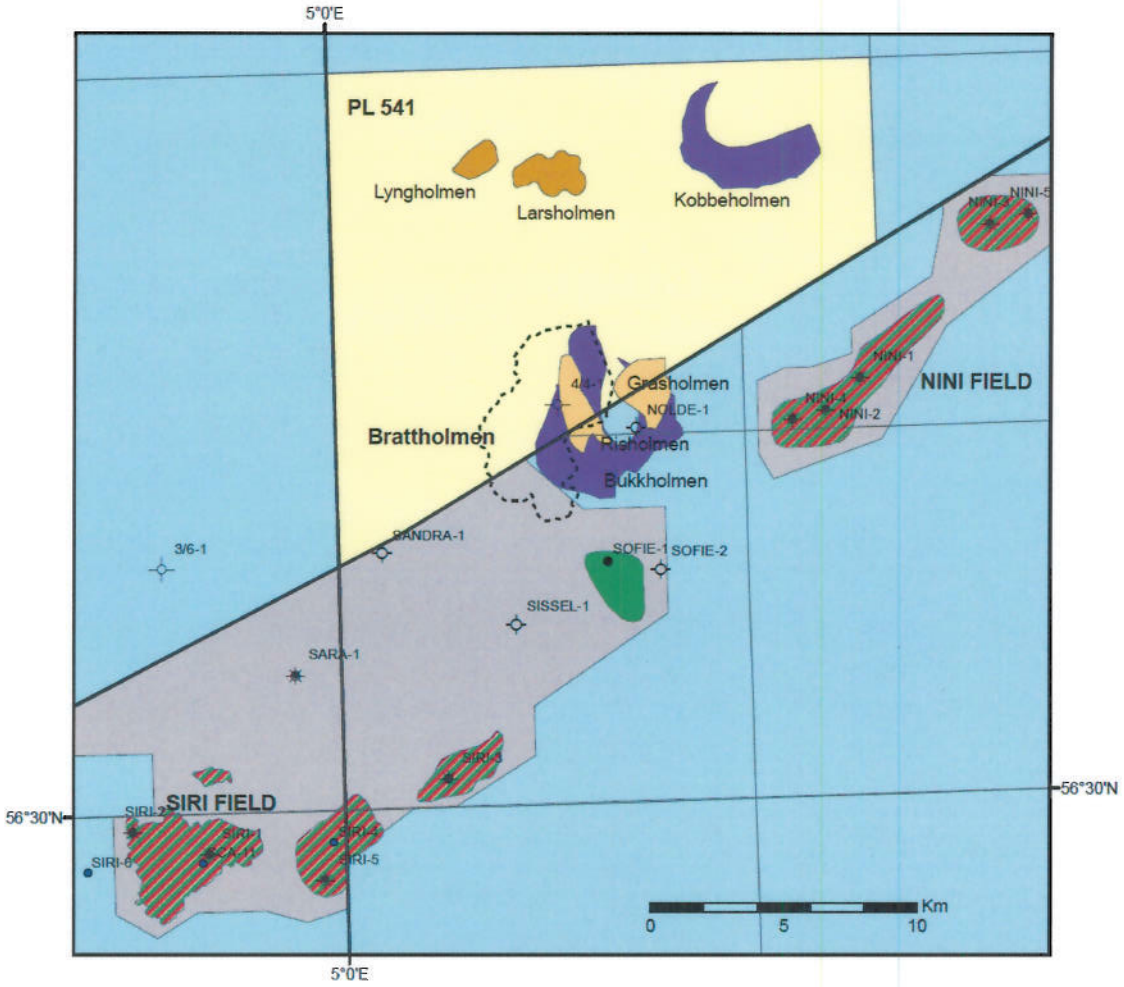

Figure 4.2: Remaining prospectivity in PL541.

Prospect	Estimated volumes $10x^6$ scm o.e.	Main phase and estimate background
Grasholmen (Vade Fm)	0.21	Gas, estimate from application, inside PL541
Risholmen (Vade Fm)	1.97	Gas, updated estimate, inside PL541
Larsholmen (Lista Fm)	1.18	Oil, estimate from application
Lyngholmen (Lista Fm)	0.51	Oil, estimate from application
Bukkholmen (Skagerrak Fm)	5.41	Gas, estimate from application, inside PL541
Kobbholmen (Skagerrak Fm)	2.59	Gas, estimate from application

Table 4.1: Volumes of remaining prospectivity in PL541, main + associated phase.

No new interesting prospects were identified from the various studies done of the Paleocene formations in PL541.

5. Technical evaluations

All the remaining untested prospects from the application have small volumes and do not qualify for a stand-alone development. A development of these would have relied on a field development of a successful Brattholmen. A development of Brattholmen assumed a stand-alone jacket for production. The oil was planned to be exported by offshore loading and a temporary storage in an FSU. Any gas was planned to be exported via a pipe-line to the Danish Harald field which is connected to Nybro in Denmark.

6. Conclusions

The work programme for PL541 has been fulfilled with relevant G&G studies. The conclusions of these led to a drilling decision to test the Brattholmen prospect. Well 4/4-1 was drilled in 2013 and proved turbiditic sands of Paleocene and Eocene ages, but dry. The migration, which had the highest risk, is regarded as the main reason for the failure. Additional studies showed that no re-migration from the Danish discoveries is likely to have continued into PL541. The risks of the remaining prospectivity in the license are regarded to be similar or higher than before the G&G studies were performed. In addition, the potential volumes are very small and do not qualify for a stand-alone development. Based on these findings, the partners in PL541 made a negative BoV decision, so the licence expired on February 19th 2015.