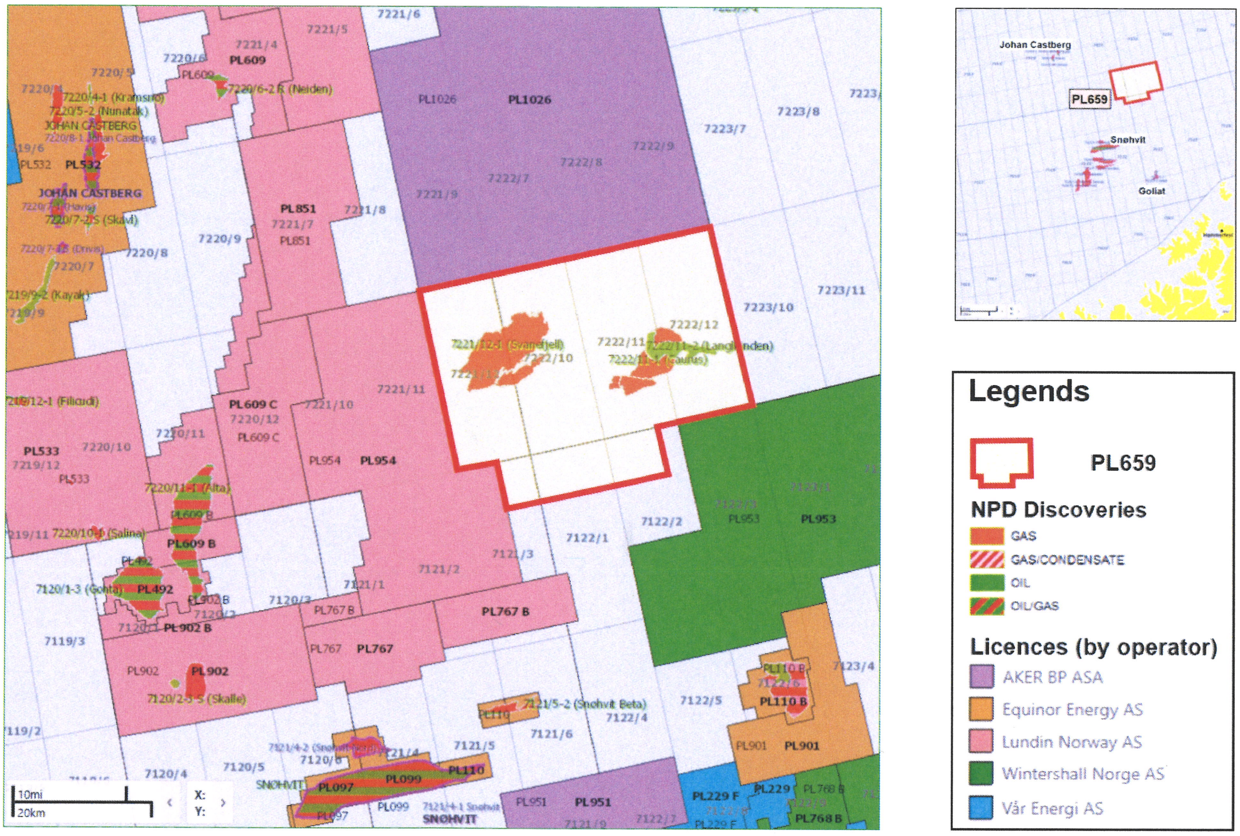
AkerBP

petoro

Lundin
Norway

PL659
Relinquishment Report



Approvals according to Aker BP D&W Document Approval Matrix					
		Role	**Name**	**Signature**	**Date**
C	Coordinate	Licence Geologist	[redacted]		
V	Verify	QA, Strategy & Portfolio			
A	Approve	Exploration Manager Barents Sea			

C	**Coordinate** - Accountable for getting the work done and self-verification. May be delegated or performed by a team
V	**Verify** - Verifying the quality of the work done, and signs off on the document
A	**Approve** - Approve the work done, and passing of the gates

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Relinquishment Report PL659

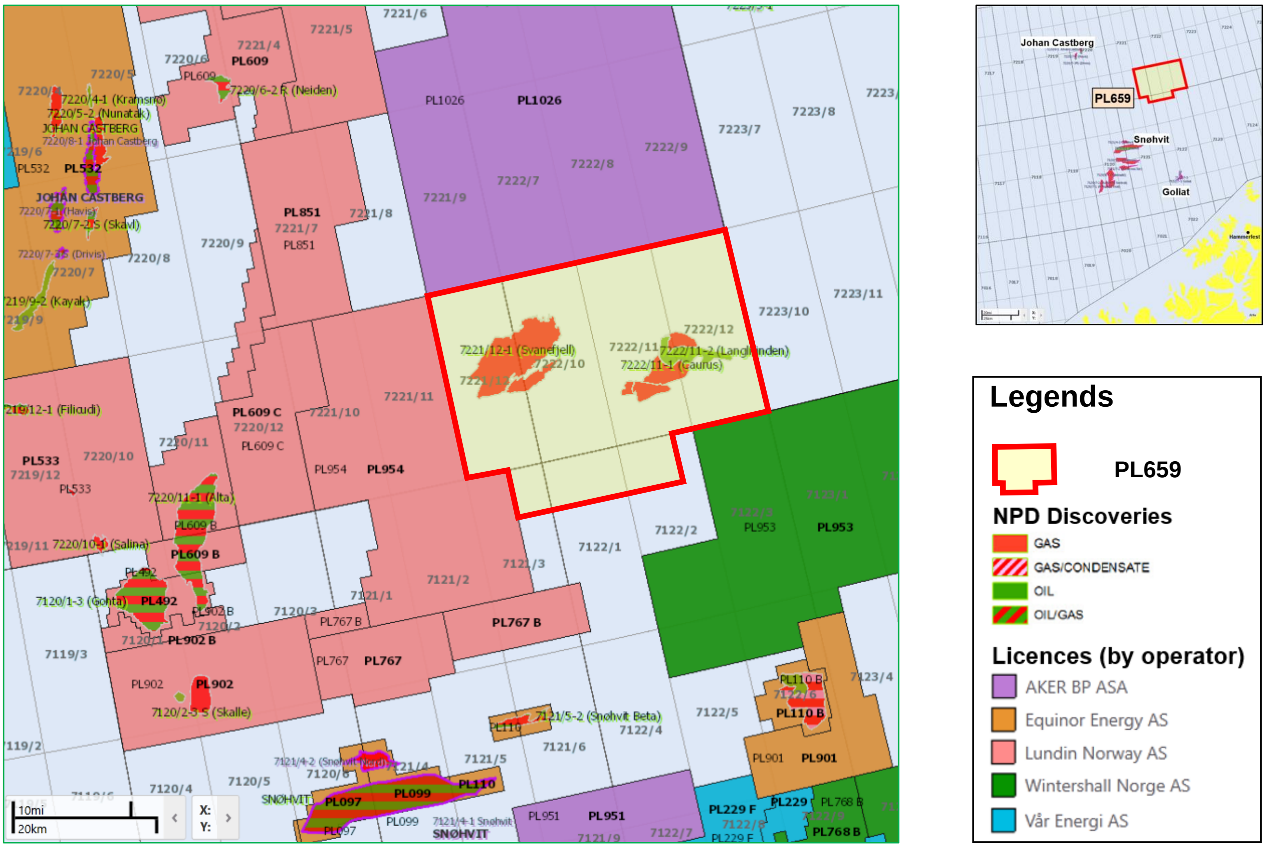

Fig. 1 PL659

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1 Introduction

The purpose of this report is to sum up the PL659 (Fig. 1.1) licence history and G&G work performed by the licence group, in addition to present an overview of acquired data and studies and their results. A review of remaining prospectivity within the licence area is also given.

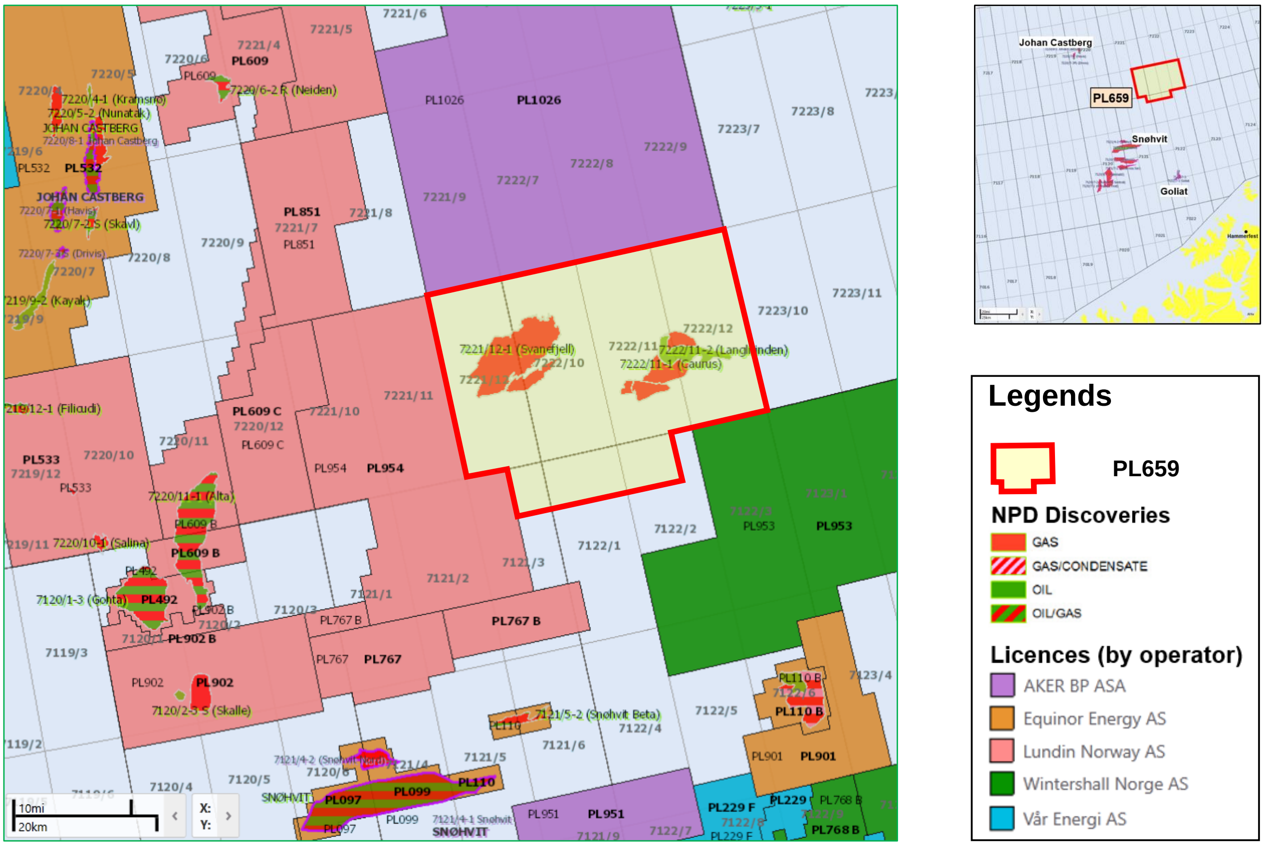

Fig. 1.1 PL659 location map.

1.1 Licence History and Owners

Licence history

Following encouraging production test results from the gas discovery well 7225/3-1 on the Norvarg Dome in 2011, Det norske believed that the Caurus Discovery could have a substantial commercial upside potential. The Middle Triassic Kobbe Formation was classified as attractive after the promising DST of the Kobbe Formation reservoir in the Norvarg well (7225/3-1), and blocks surrounding the Caurus well (7222/11-1) was applied for and awarded to Det Norske as part of the APA2011 round. The hydrocarbon potential within the blocks applied for is summarised in Fig. 1.2 as a gas discovery in the Snadd Formation (Late Carnian) and a small gas/oil discovery in the Kobbe Formation, a prospect within a mega-closure in the Kobbe Formation (Anisian) and five leads in the Snadd, Kobbe, Klappmyss and Havert formations, respectively.

Prior to the test of the Norvarg well a *kh of 15 mDm* was interpreted from the KTIM-log (Schlumberger CMR-tool), while the actual DST showed a kh of 50 mDm, thus 3-4 times higher productivity than prognosed. Based on these results a similar approach was used for the Caurus well (7222/11-1T2) and here the estimated kh was as high as 147 mDm. It was therefore assumed that the reservoir quality seen in well 7222/11-1 T2 could be even better than in the corresponding formation in the Norvarg Well 7225/3-1 and that a DST in the Caurus well will flow better than the Norvarg well.

The Langlitinden well (7222/11-2) was spudded 14 January 2014 and drilled to a total depth of 2918mMD with TD in the Klappmyss Formation, classified as a technical oil discovery, but with no commercial hydrocarbon volumes. The Lower-Middle Triassic play *is considered adequately tested and invalidated* by the Caurus (7222/11-1) and Langlitinden (7222/11-2) wells and therefore considered as *non-economical due to very poor reservoir quality*. After the Langlitinden well and interpretation of new acquired 3D seismic in 2014-2015, the exploration focus changed from the *Kobbe Formation* to the *Snadd Formation*.

A huge 4-way dip closure associated with an amplitude brightening conform with the closure, stratigraphically located at the Top Snadd Formation level in blocks 7222/10 and 7222/9, had been mapped on 2D seismic data and presented as a lead (lead E (Svanefjell) Fig. 1.2) in the APA2011 application. These amplitudes, observed on 2D seismic, was thought to be associated with *thin gasfilled sands* as seen in Well 7222/11-1. If so, the volume potential is very small due to the shallow burial depth of the lead (<700mMSL) and the poor reservoir potential.

Following the 2014 acquisition and 2015 processing of the EastLoppaRidge 3D survey the former Upper Triassic Snadd Formation lead was upgraded to a prospect.

In order to de-risk and mature the Top Snadd lead to a drillable prospect the license partners applied for an extension of the initial license period. The first extension application was sent to the authorities on the 05.01.2016 and granted on the 05.04.2016 with new Bok deadline set to the 03.02.2018. The second application for extension was sent to the authorities on the 09.01.2017 and granted on the 24.4.2017 with new Bok deadline set to the 03.02.2019.

A decision to drill the now called Svanefjell prospect was taken in Q3 2016. The well was spudded 4 May 2018 and drilled as a vertical well down to TD at 724 mRKB in the uppermost Snadd Formation. It was permanently plugged and abandoned 27 May 2018 and classified as a technical gas discovery (15m gross pay and 9m net pay) with no commercial HC volumes. However, a residual oil column of ~14m is clearly evident on cores and logs.

After the Svanefjell well, technical and economic evaluations of the remaining prospectivity indicated a low volume potential and marginal to non-economical volumes remaining within the acreage. The license group therefore agreed to relinquish the license.

The main activities and committee meetings in PL659 are summarized in Table 1.1 .

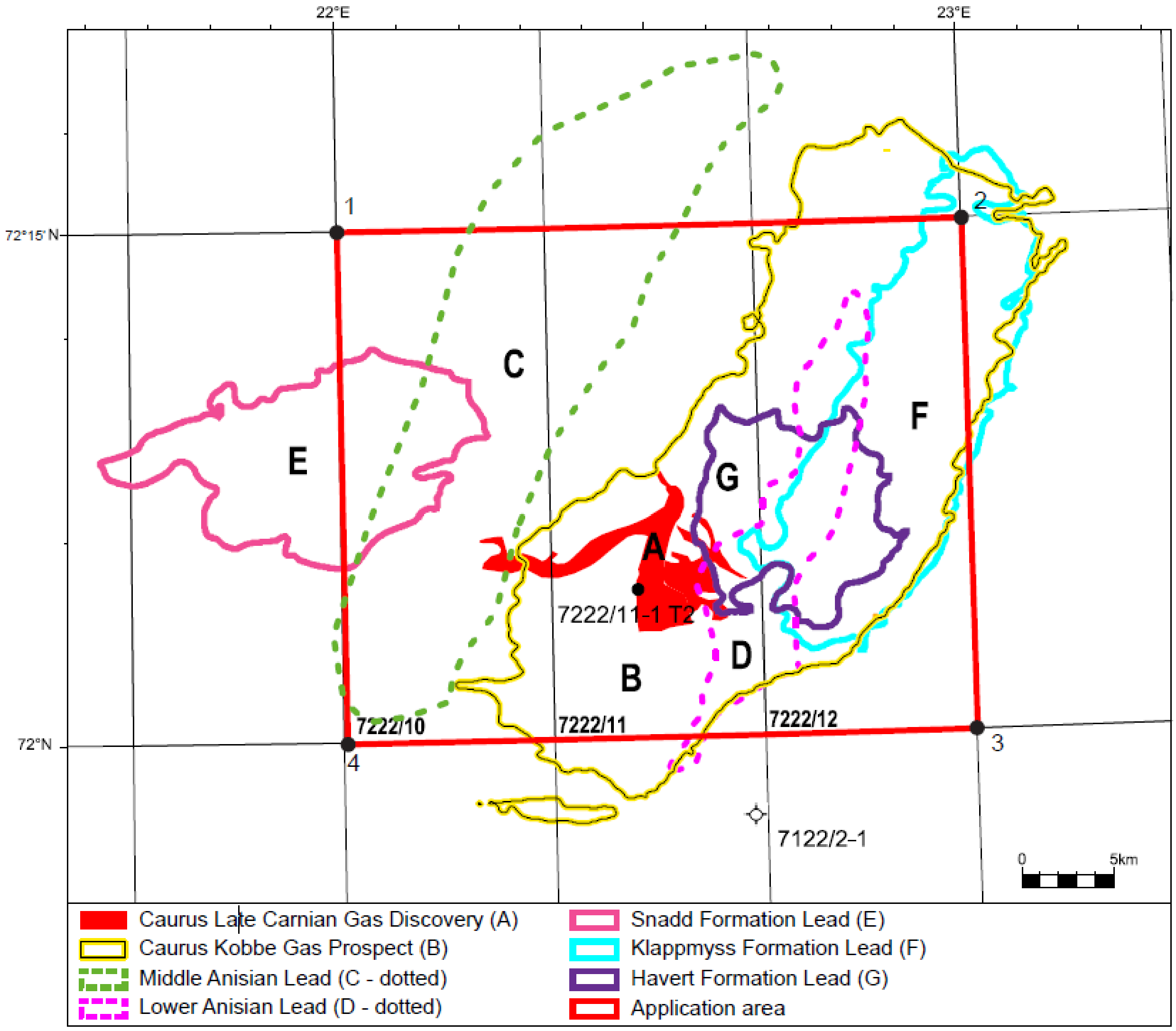

Fig. 1.2 APA 2011 Det norske Discoveries, prospects and leads. *Solid outlines refer to structural spill. Dotted lines refer to stratigraphic trap concepts.*
Annotation refers to A) Caurus Late Carnian Gas Discovery, B) Caurus Kobbe Gas Prospect, C) Middle Anisian Lead, D) Lower Anisian Lead, E) Snadd Formation Lead, F) Klappmyss Formation Lead, and G) Havert Formation Lead.

Table 1.1 MCEC activities in the license *Summary of activities in the license from it was awarded to relinquishment*

Date	Activity	Description
2012		
03.02.2012	License award	from the APA 2011 licensing round
16.02.2012	MCEC meeting #1	Formal and administrative issues, prospect inventory, common database etc. Spring and Lundin presented their view on the prospectivity in the license.
19.06.2012	EC meeting	G&G status presented
30.09.2012	new seismic data	PSDM SG9803 Finalized, did not show anything new with respect to the reprocessed PSTM SG9803STR09
06.12.2012	MCEC meeting	A proposal for Langlitinden well location was presented and Spring presented the result of the P-Cable acquisition in the area. Det norske presented geophysical work ; AVO and inversion study.
	decision	**Decision to drill an exploration well on the Langlitinden prospect in January 2014**
2013		
16.01.2013	EC Work meeting	Det norske presented their view of the Caurus depositional environment. Lundin presented their view on the Matrosen prospect
04.04.2013	EC Work meeting	Det norske presented status on the well planning & Lundin and Det Norske presented their view of the prospectivity of the Snadd Fm.
06.06.2013	EC Work meeting	well planning status & data acquisition was presented for 7222/11-2 Langlitinden exploration well
19.09.2013	EC meeting	Status on Langlitinden well planning
31.10.2013	MCEC meeting	Status on Langlitinden well planning
19.11.2013	EC meeting	Langlitinden, DWOP (Drilling well on paper)
2014		
18.02.2014	EC work meeting	Langlitinden well, criteria for doing a DST, discussion
01.04.2014	EC meeting	well operations and cost summary. Well results, remaining prospectivity and seismic acquisition tender presented.
22.10.2014	EC core viewing	core viewing Langlitinden
27.11.2014	MCEC meeting	Preliminary geochemistry results and volume estimate of the Langlitinden discovery. Status on the seismic data that was acquired in the western part of the license, WG14001, during the summer.
2015		
17.04.2015	EC workmeeting	Geochemistry on Langlitinden
16.06.2015	EC meeting	Review of seismic proessing, Exploration status, G&G work, Volume estimate Svanefjell prospect.
24.11.2015	MCEC meeting	Shallow reservoir drilling study, Svanefjell volume update, proposal to apply for License extension
2016		
15.01.2016	Application for extension	Granted 05.04.2016
27.04.2016	EC meeting	shallow reservoir study, Geophysical evaluation, sedimentological evaluation, EM inversion result, volume and risk
09.06.2016	MC work meeting	Langlitinden audit
22.06.2016	MCEC meeting	Review of volume and risk, technical economical review, Det norske propose to take a drill decision in 2017. Point resources presented work done on understanding the base reflection in the Svanefjell prospect
Q3	decision	**Decision do drill an exploration well on the Svanefjell prospect in Mai 2017**
13.12.2016	MCEC meeting	License status, well location and planning status, 2017 work program and budget
2017		
09.01.2017	Application for extension	Granted 24.04.2017
17.03.2017	EC Work meeting	AkerBP presented 2 alternative well locations, then Lundin presented their proposal for the Svanefjell well loaction
23.11.2017	MCEC Meeting	AkerBP presented the Svanefjell site survey evaluation, depth prognosis, preliminary data acquisition program & well design.
11.12.2017	EC Meeting	concept phase HAZID meeting, Svanefjell well
2018		
22.01.2018	EC Review	Location specific Emergency Prepardness Analysis with regards to the Svanefjell wildcat well
15.02.2018	EC work meeting	AkerBP presented the drilling program & location for a potential appraisal location in case of success in the Svanefjell wildcat well
25.06.2018	EC core viewing	Svanefjell core viewing in Stavanger
26.09.2018	EC work meeting	well operation and cost summary, data acquisition summary, well results, remaining prospectivity
05.12.2018	MCEC Meeting	remaining prospectivity, license recommandation, work program and budget
2019		
14.01.2019	decision	**Decision to relinguish the license**

Stakeholders

The original stakeholders in PL659 consisted of:

- Det Norske (30% and operator)

- Petoro (30%)

- Lundin (20%)

- Spring (10%)

- Rocksource (10%)

As of 13.02.2013 Spring Energy changed their name to Tullow Oil Norway while Rocksource changed their company name to Pure E&P Norway on the 02.07.2015 and further to Point Resources on the 19.05.2016.

On the 31.03.2014 Det Norske transferred a 10% share to Atlantic Petroleum Norge, which later changed the company name to M West Energy (20.01.2017).

In June 2016, Det norske oljeselskap ASA agreed with BP p.l.c. to merge with BP Norge AS and as of 30.09.2016, the company changed its name to Aker BP ASA. Later that year (09.12.2016), Tullow Oil Norge transferred their 15% share to Aker BP, followed by M West Energy transferring their 10% share to Point resources on the 27.01.2017. A few days later (31.01.2017), Point Resources transferred their 15% share to Aker BP, finally concluding the transfer of ownership in PL659. The stakeholders in PL659 at the time of relinquishment:

- AkerBP ASA 50.0% (operator)

- Petoro AS 30.0%

- Lundin Norway AS 20.0%.

1.2 Award and Work Program

Award

The PL659 acreage was awarded to Det Norske on the 3 February 2012 as part of the APA2011 awards.

Work obligations

The work obligations included one firm exploration well, minimum 100m into the Klappmyss Formation, and to acquire minimum 350km^2 3D seismic data to cover the western part of the licence, all within 4 years from the award. The license commitment were fulfilled by drilling the Langlitinden well (7222/11-2) in 2014 and by the acquisition of the East Loppa Ridge 3D survey in 2014. Processing of the EastLoppaRidge-survey was completed by Schlumberger Geosolutions in 2015.

1.3 Identified Prospectivity

Langlitinden prospect

The main target for well 7222/11-2 was the Langlitinden prospect, defined as a channel feature located in the Triassic Kobbe Formation (Fig. 1.3a & b). Secondary targets were fluvial channels belonging to the Snadd Formation, defined by amplitude anomalies (Fig. 1.3c).

The well proved movable oil within the Langlitinden channel in the Kobbe Formation, whereas all secondary targets in the Snadd Formation were proved water bearing. No pressure gradients or hydrocarbon contacts were established, and reservoir was found tight and non producible. Mean recoverable volumes in the Langlitinden after drilling were estimated to be 1.8 MSm3, with a mean recovery factor of 30%. Inplace volumes are calculated to be 6.1 MSm3 of oil.

7222/11-2 was permanently plugged and abandoned 27 February 2014, classified as a technical discovery with no commercial hydrocarbon volumes.

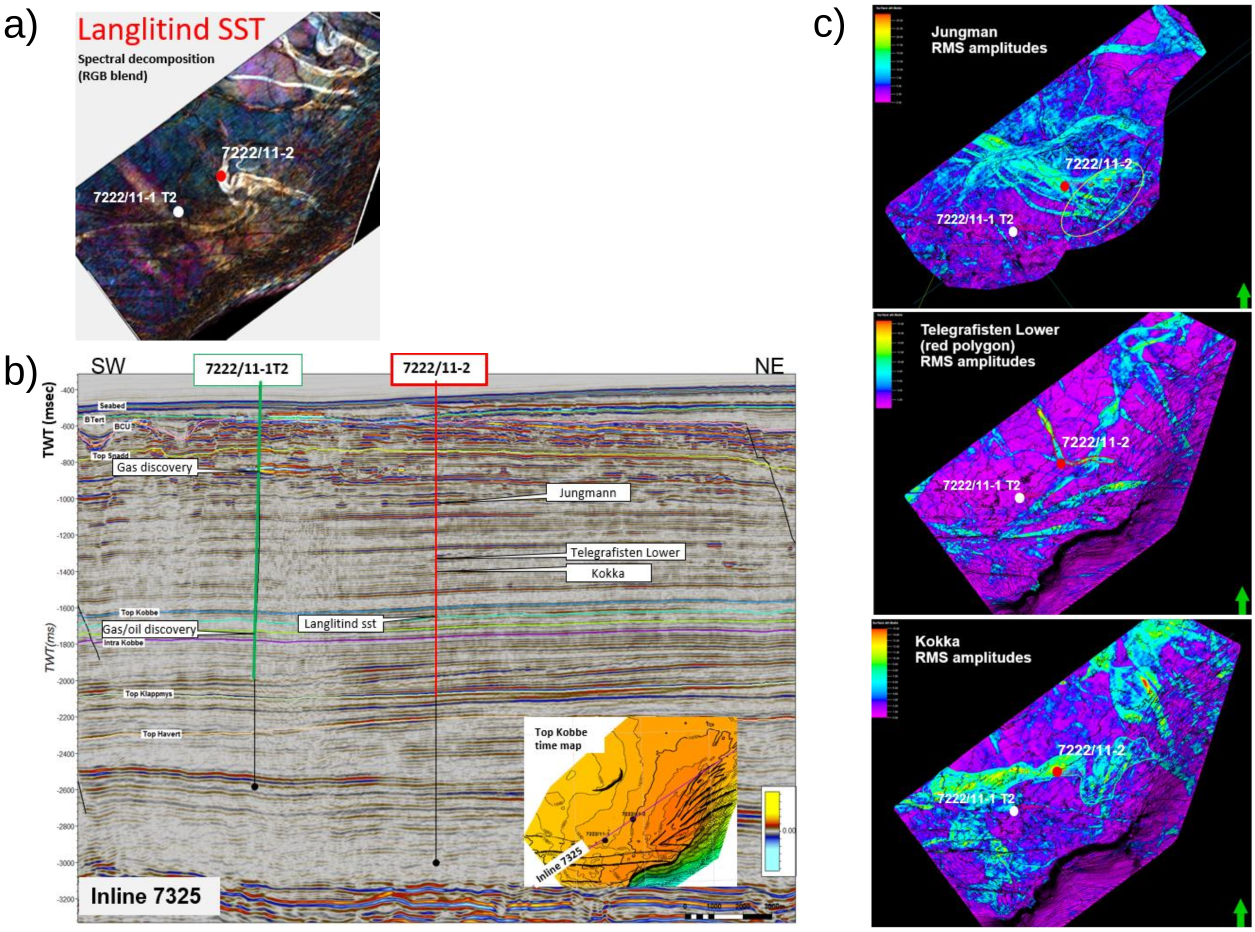

Fig. 1.3 Langlitinden prospect

1) Target the main channel sst in the Kobbe Fm and prove reservoir properties.

2) Evaluate three separate leads in the Snadd Fm.

Svanefjell prospect

The Svanefjell well (7221/12-1) was spudded 4 May 2018 and drilled as a vertical well down to TD at 724 mRKB in the uppermost Snadd Formation (Fig. 1.4). The primary objectives of the well was to prove presence of moveable hydrocarbons (HC) and to evaluate the reservoir potential of the Svanefjell Prospect. The prospect, stratigraphically belonging to the Upper Triassic Snadd Formation, was defined within a 4-way fault dependent closure with the possibility of HC-filling below structural spill (stratigraphic component). The well encountered a total gas column of 15 m in the Snadd Formation of which 9 m was in sandstones with moderate to good reservoir quality (Fig. 1.5). However, a residual oil column of ~14m is clearly evident on cores and logs (Fig. 1.6).

7221/12-1 was permanently plugged and abandoned 27 May 2018 and classified as a technical gas discovery with no commercial HC volumes.

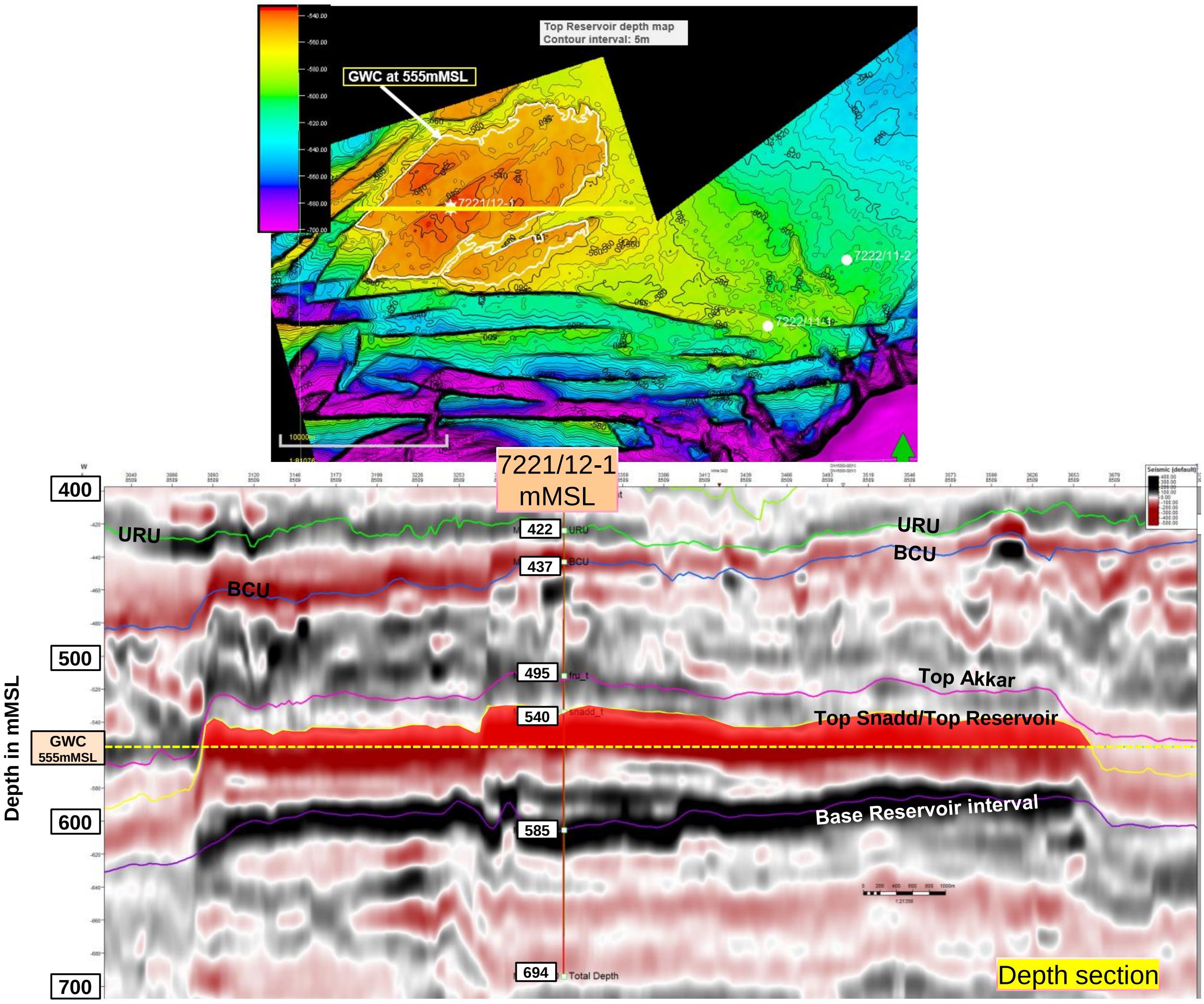

Fig. 1.4 Geoseismic depth section through the 7221/12-1 well.
Top reservoir at well location: 540mMSL.
GWC (yellow dotted line): 555mMSL.
Present Spill (in the north): 565mMSL
Black peak (base reservoir) represents palaeo-OWC at 585mMSL (i.e., palaeo-spill point).

CPI

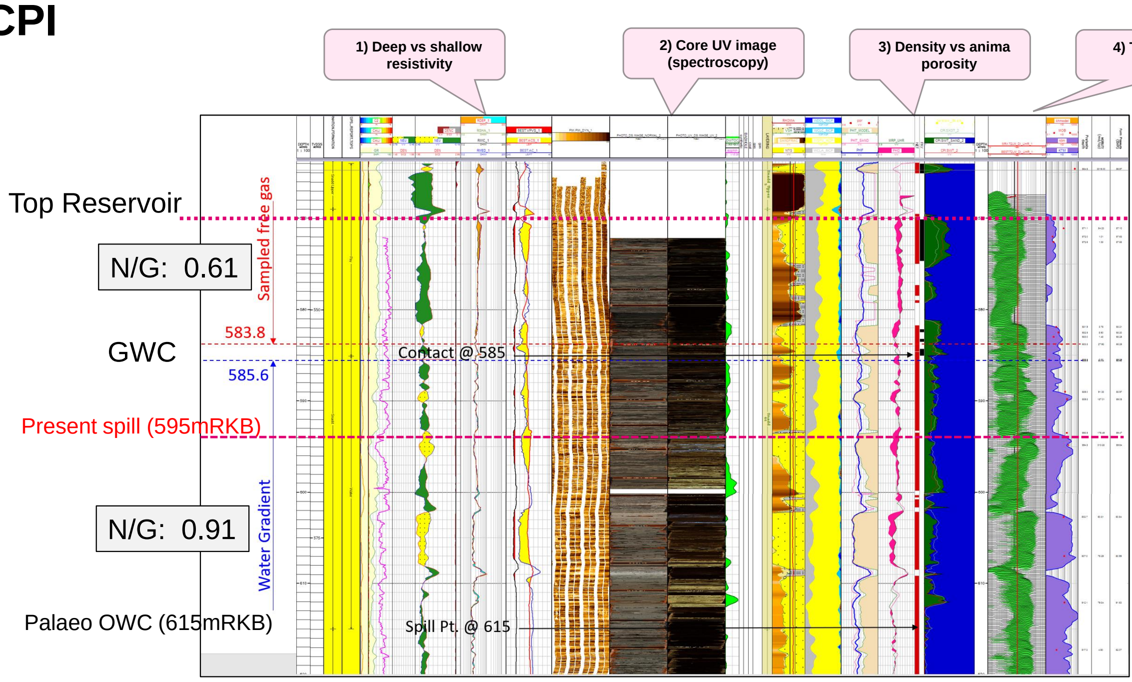

Fig. 1.5 Svanefjell well: CPI

1) Prove of moveable HC (orange),

2) Prove of residual oil:

Residual Oil under UV (UV-yellow stain in core).

3) Prove of trapped gas:

- Gas trapped in small pores (anima porosity) effecting the sonic.

4) T2 distribution track:

- Left: immoveable HC

- Right: moveable HC

Core summary

- Best sand in lower part (fine to very fine)
  - Core 1: 27m (574-601mRKB)
  - Core 2: 25m (601-626mRKB)
- More argillaceous in upper part.
- Good shows down to palaeo-spill at 585mMSL/615mRKB
- Gas zone:
  - Direct fluorescence
  - No odor
  - No stain
- Residual oil zone:
  - Oil stain (Weak to good)
  - Dir. Fluorescence
  - Weak to fair odor

**Core photo:
584mMSL / 614mRKB**

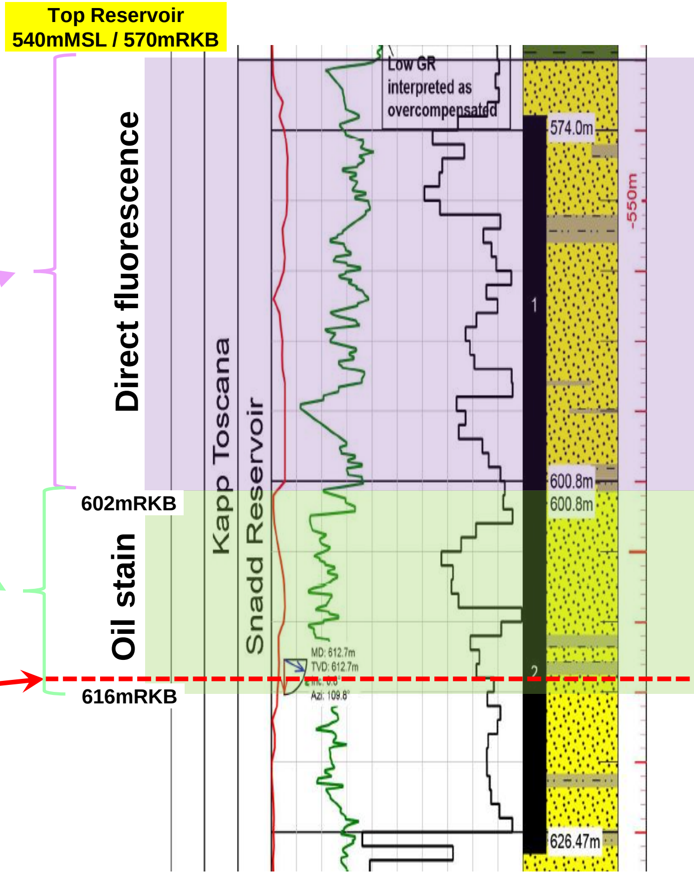

Fig. 1.6 Core summary

2 Database

2.1 Seismic Database

The seismic database utilized in the prospect evaluation are listed in Table 2.1 and shown for 3D and 2D seismic separately in Fig. 2.1 & Fig. 2.2, respectively.

Table 2.1 3D and 2D seismic database

Name	type	year of acquisition	reprocessed	Marked available	NPDID
WG14001 / Eastlopparidge	3D	2014	-	yes	8017
SG9803STR09	3D	1998	2009/2010	yes	3940
Merge_Eastlopparidge_SG9803STR09	3D	1998 & 2014	inhouse merge	no	8017 & 3940
NBR08	2D	2008		yes	4573
NBR09	2D	2009		-	Could not find on NPD factpages
NBR10	2D	2010		yes	7219
NBR11	2D	2011		yes	7408
DN1301 (Langlitinden)	2D site survey	2013		no	7778
DN16303 (Svanefjell)	2D site survey	2016		no	8381
ABP17306 (Svanefjell stratigraphic)	2D site survey	2017		no	8484

Fig. 2.1

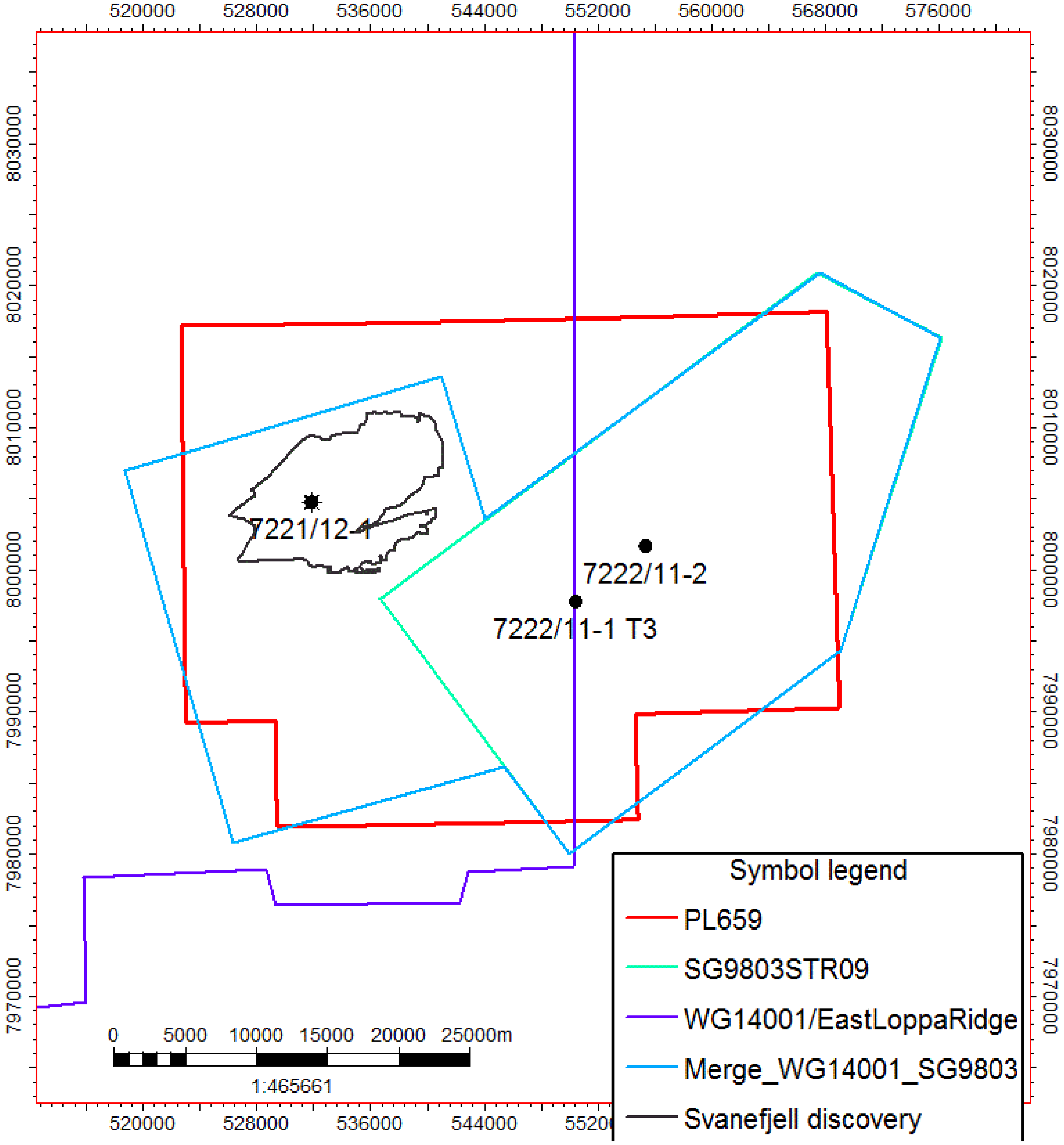

Fig. 2.1 3D seismic database

Fig. 2.2

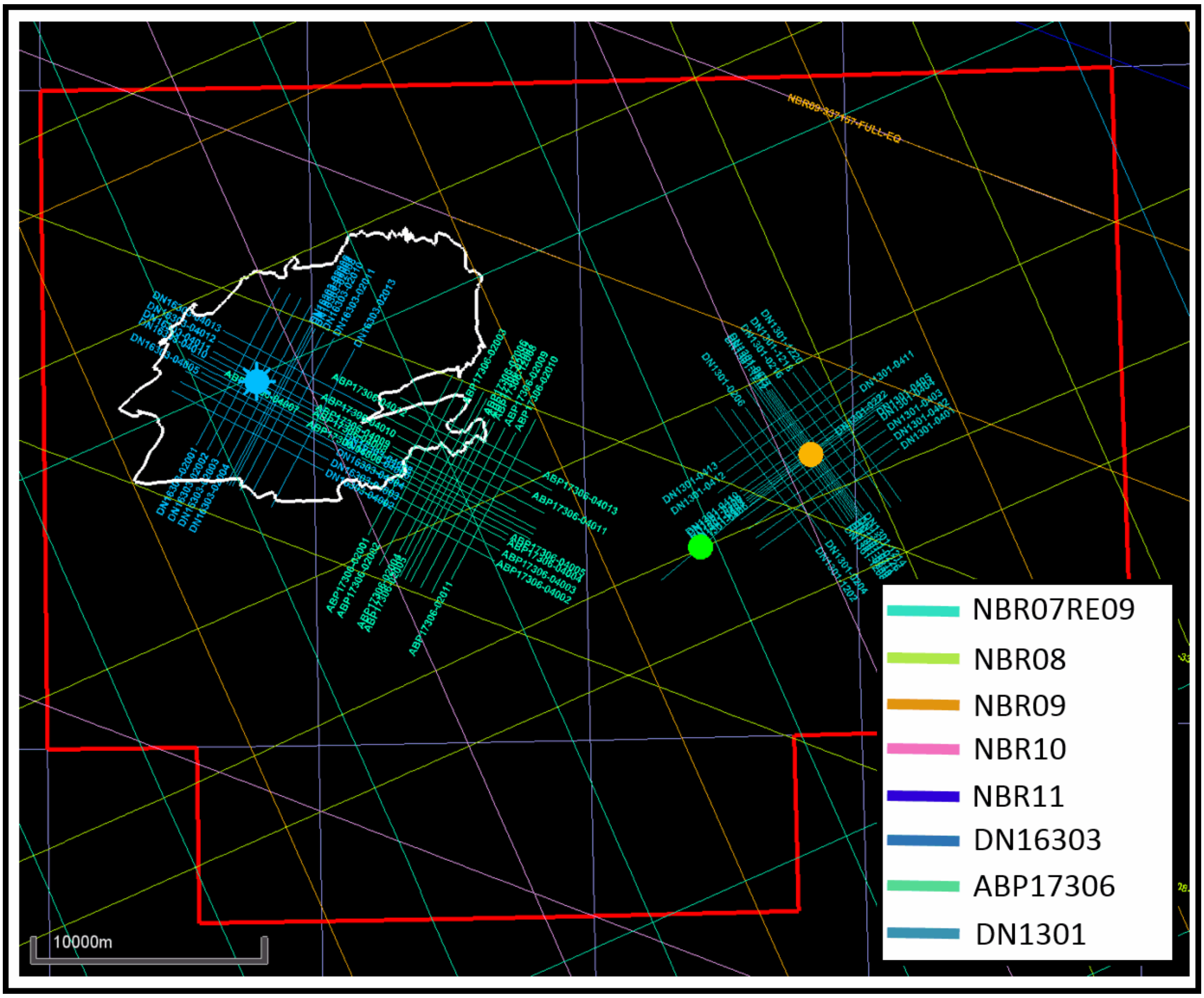

Fig. 2.2 2D Seismic data

The SG9803STR09 was acquired for Saga Petroleum by Schlumberger in 1998 and reprocessed by Geotrace in 2009-2010.

The WG14001/EastLoppaRidge is an isometrix broadband survey acquired by Western Geo in 2014 and processed by Schlumberger Geosolutions in 2015.

Two site surveys was acquired with regards to the Svanefjell prospect, the DN16303 acquired in 2016 over the main wildcat well location and the ABP17306 acquired in 2017 which covers the Svanefjell stratigraphic location in case of a HC fill below structural spill scenario in the Svanefjell main. The DN16303 Svanefjell prospect site survey are of excellent quality and has been important to evaluate shallow geohazards and distinguish the different events, both pre- and post-well. A time shift of -5 milliseconds was applied to the DN16303 site survey to match with the EastLoppaMerge 3D and to the regional NBR 2D seismic lines.

All seismic data used in the evaluation is of zero phase normal polarity; an increase in acoustic impedance is a peak and coloured blue/black and a decrease in acoustic impedance is a trough and coloured red/yellow.

2.1.1 Survey merge and Elastic Impedance Inversion

The Svanefjell prospect is located in the WG14001/EastLoppaRidge seismic dataset. Due to the shallow depth of the prospect in combination with seismic source-to-first-receiver distance in the acquisition geometry, the prospect is only covered by angle of incidence data from 26 degrees.

The EastLoppaRidge seismic dataset was without any well control until the 7221/12-1 well was drilled, however partially overlapping the SG9803STR09 seismic dataset with well control from Caurus and Langlitinden wells (Fig. 2.1). Both the lack of well control and data coverage of incidence angles below 26 degrees pose a significant limitation on the range of seismic Quantitative Interpretation methodology (QI) applicable for seismic reservoir prospect characterization of the Svanefjell prospect. In addition, these seismic datasets are of very different character and age (2.1 Seismic Database).

In this study we therefore device a rigorous post stack survey calibration workflow as illustrated by Fig. 2.3 to account for any differences between the surveys with the objective to run convolutional model based seismic inversion on a merged dataset of these two.

It is clear from Fig. 2.4 that the survey calibration has a significant positive impact on the comparability between the amplitudes for EastLoppaRidge and SG9803STR09 and that the survey calibration was necessary to undertake in order to obtain comparable amplitudes. Still, the limitations of data coverage persists, such that an Elastic Impedance (EI) Inversion followed by a Bayesian classification was the only robust option with regards to QI seismic amplitude studies for seismic reservoir characterization that could be performed on these data.

With the low amounts, low frequency and consistent cross survey residuals from the inversion seen in Fig. 2.5 in addition to the correct classification of Gas sand contained within the outlined Caurus channel at the Caurus well location and the probability of oil sand is seen in the Caurus channel where the well penetrated an residual oil below the GWC Fig. 2.6 , we demonstrate that the applied survey calibration was sufficient for using quantitative amplitude methods such as EI inversion and Bayesian classification. In more detail, the inversion QC with the extracted wavelet from the Caurus well used in the inversion and the Low Frequency Model are shown inFig. 2.7 . A cross plot of actual EI from the Svanefjell discovery vs pre-well predicted EI from the seismic inversion in and around the prospect interval is available in Fig. 2.8 that show a good coincidence with the 1-to-1 line where the data if perfect would fall. This show the excellent quality of the pre-well EI inversion.

Fig. 2.3 Survey calibration and merge workflow
A schematic illustration of the workflow used in survey calibration and merge.

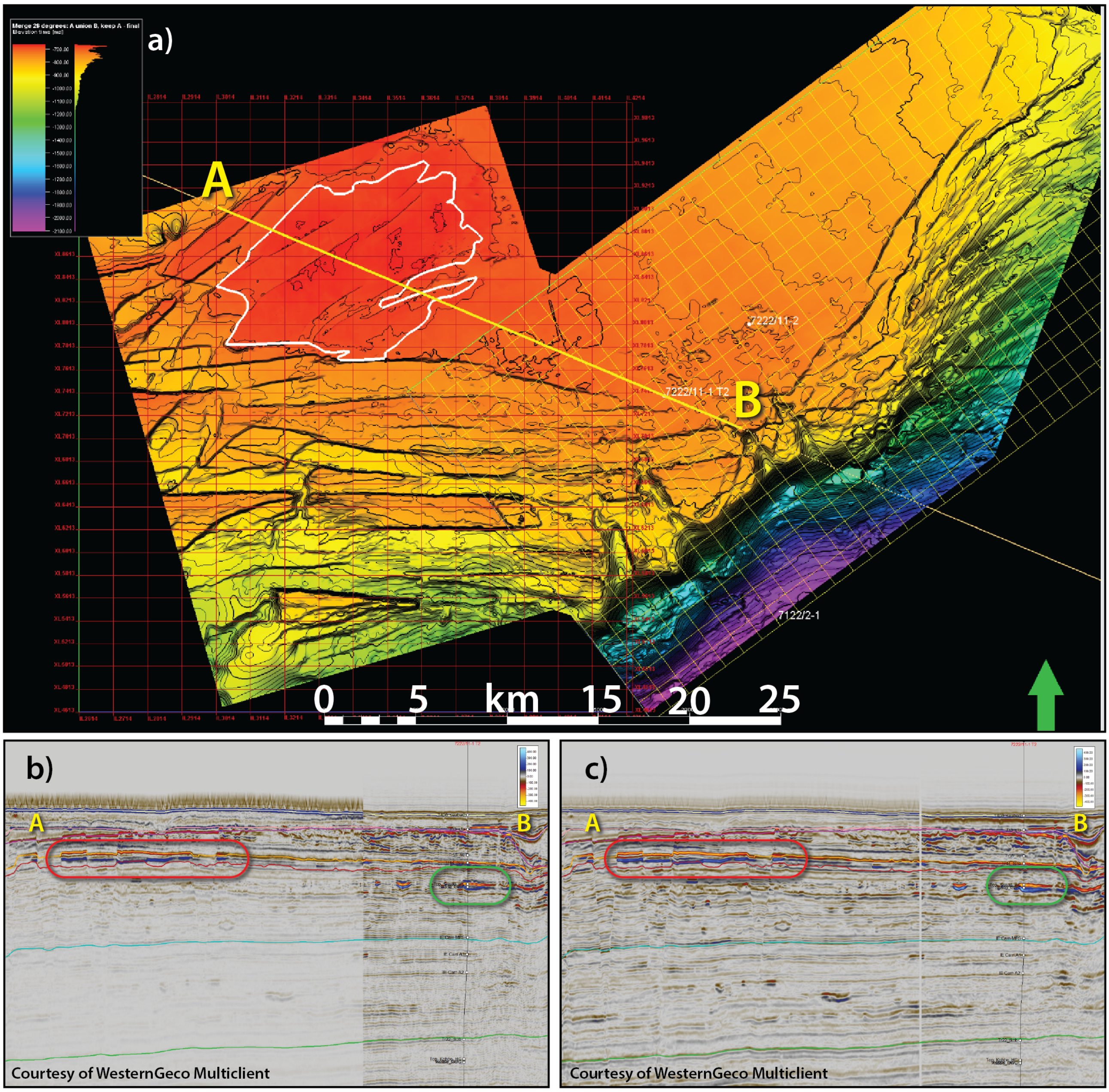

Fig. 2.4 Comparison of seismic data on random line through the well location before and after survey calibration.

a) a time map of the top reservoir for the Svanefjell prospect highlighted with the white polygon and the position of the used random line. b-c) Seismic before and after survey calibration along the shown random line and well position. the prospect is highlighted in red and the Caurus discovery in green.

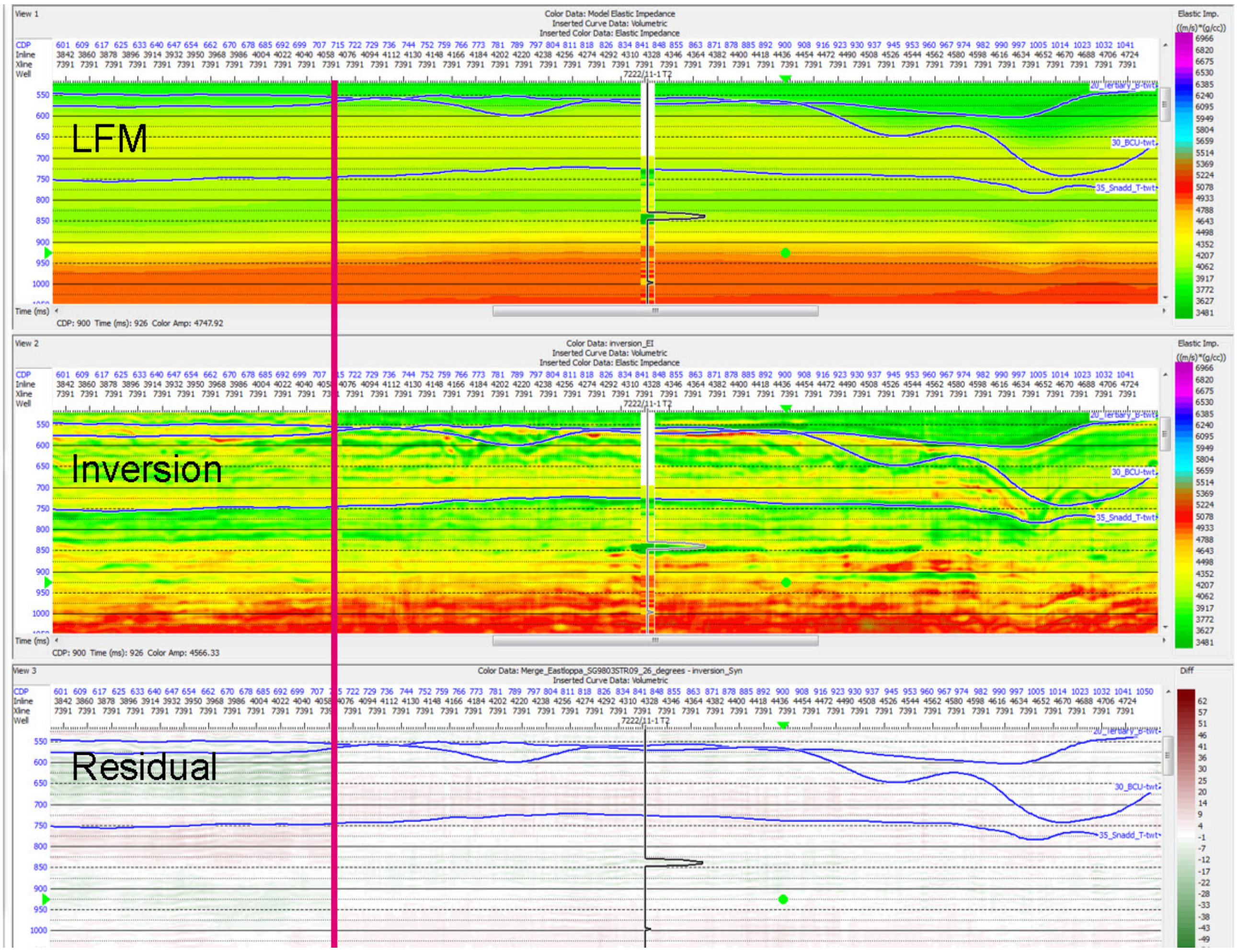

Fig. 2.5 EI seismic inversion.

Elastic impedance inversion trough the Caurus well true EI log overlayed in colors and pay flag plotted as curve. Upper) the low frequency model for inversion. Middle) the inverted Elastic Impedance is in very good coinsidence with the true Elastic Impedance well log and a good indication that the inversion predicts accurate values of EI. Lower) Residual from inversion. The residuals are small, very low frequent and consistent across surveys. This is a good indication that the objectives with survey matching was reached.

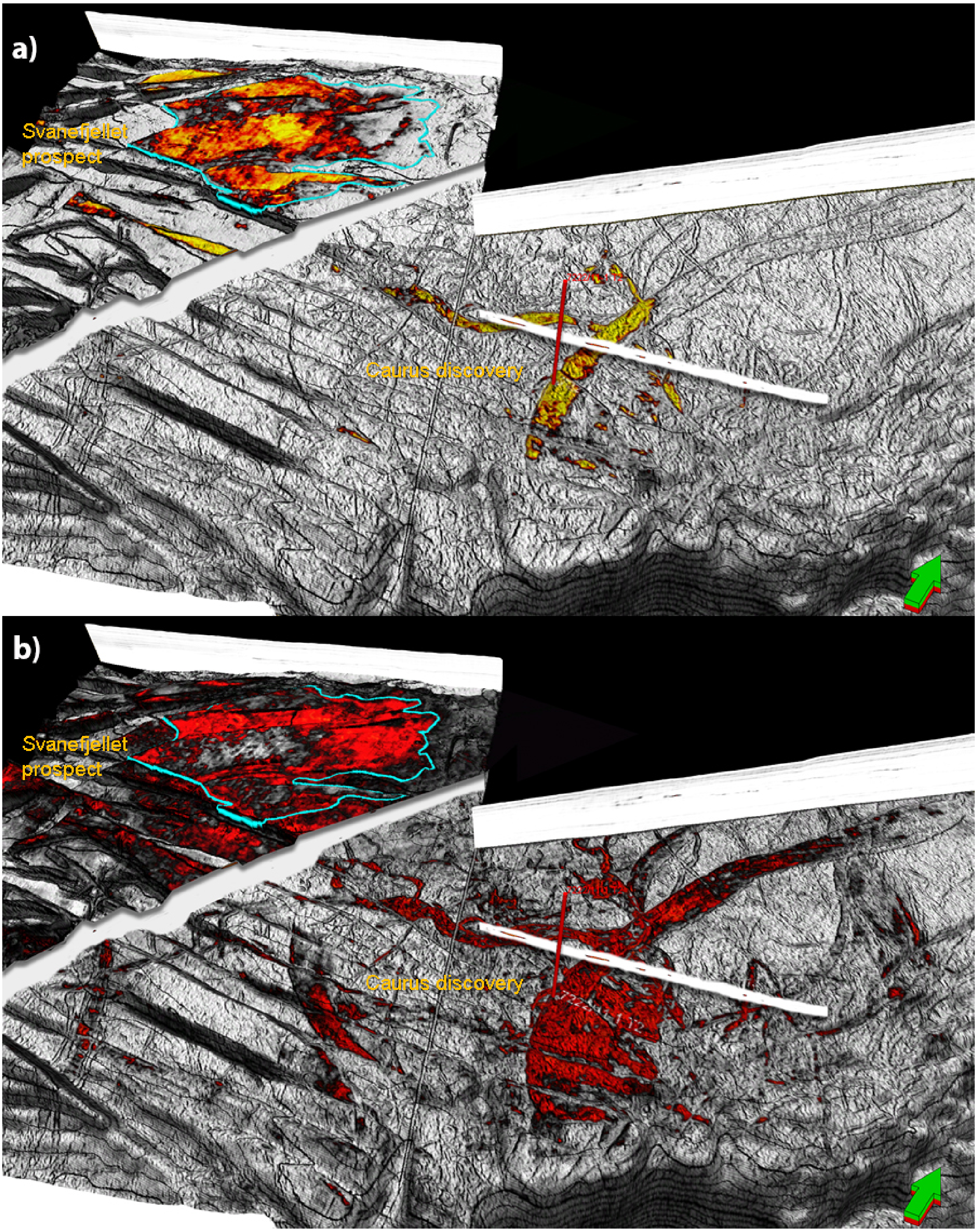

Fig. 2.6 Probabilities from Bayesian Classification of Elastic Impedance Inversion.
Probabilities for a) Gas sand and b) Oil sand at the Caurus gas discovery and at the Svanefjell prospect. Observe the clear definition of Gas sand at the Caurus gas Discovery, clearly contained within the overlayed edge attribute outlining the Caurus sand channel. The oil sand probability is evident on the Svanefjell prospect and the Caurus channel, even though the Caurus well only proved residual oil below the GWC.

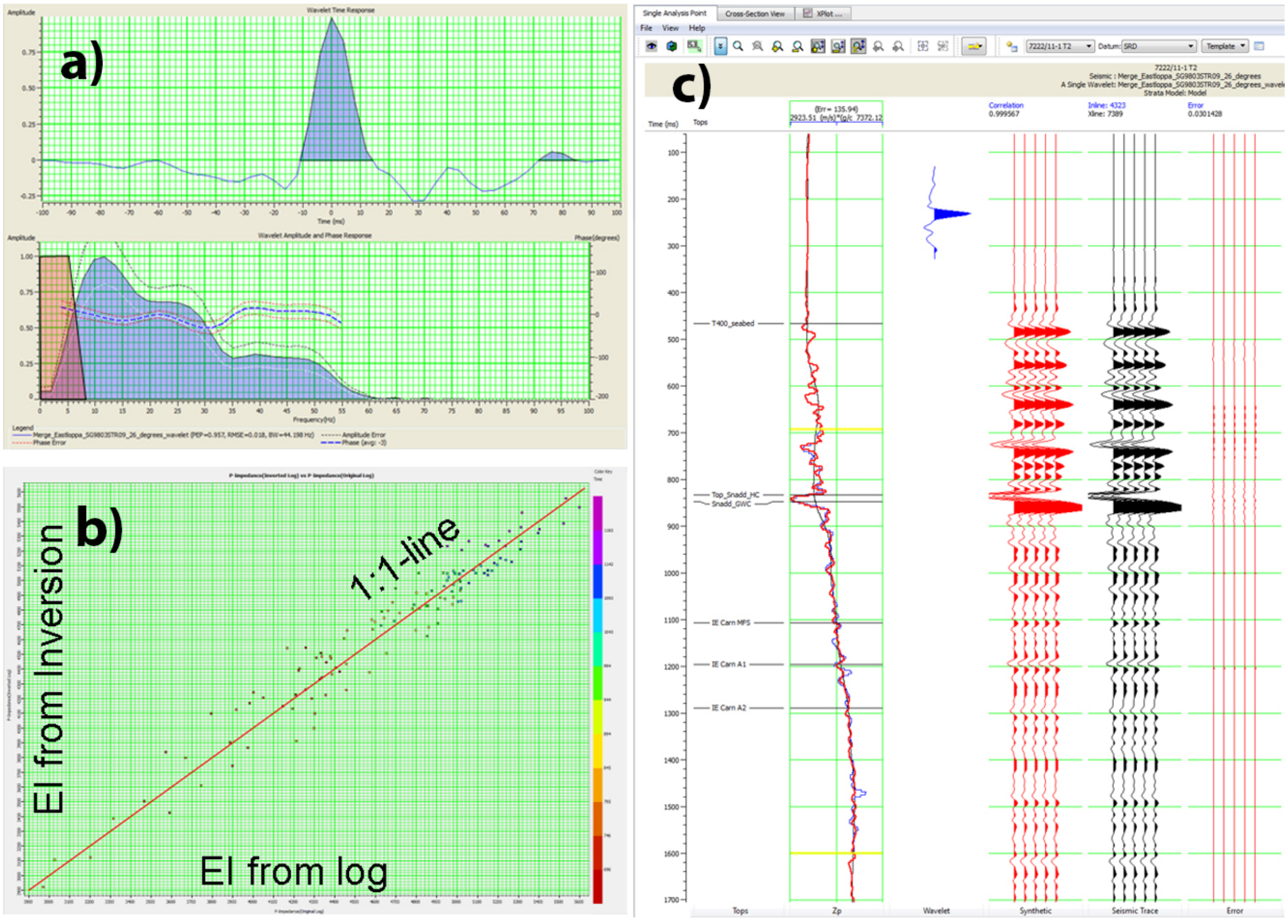

Fig. 2.7 Detailed Inversion QC.
a) in blue the wavelet extracted from the Caurus well and used in the inversion, upper) time plot, lower) frequency and phase plot. The wavelet is close to zero phase and broad in frequency. The frequency content of the Low Frequency Model is indicated in red in the frequency plot with high cut frequencies 5-8 Hz. b) is a cross plot of true EI from well data on the horizontal axis and EI from inversion on the vertical axis. There is a good coincidence between true and inverted values, hence a good quality of the inversion at the well location. c) is the well track QC of the inversion, with track 1 showing the low frequency model in black curve, true EI from well data in blue curve and the inverted EI in red curve. Track 2 is the synthetic inversion from inversion and track 3 is the real seismic from well location. Track 4 is showing in red the residual, difference between synthetic and real seismic from track 2 and 3. The inversion is in good coincidence with both seismic and well data, hence a good quality seismic inversion.

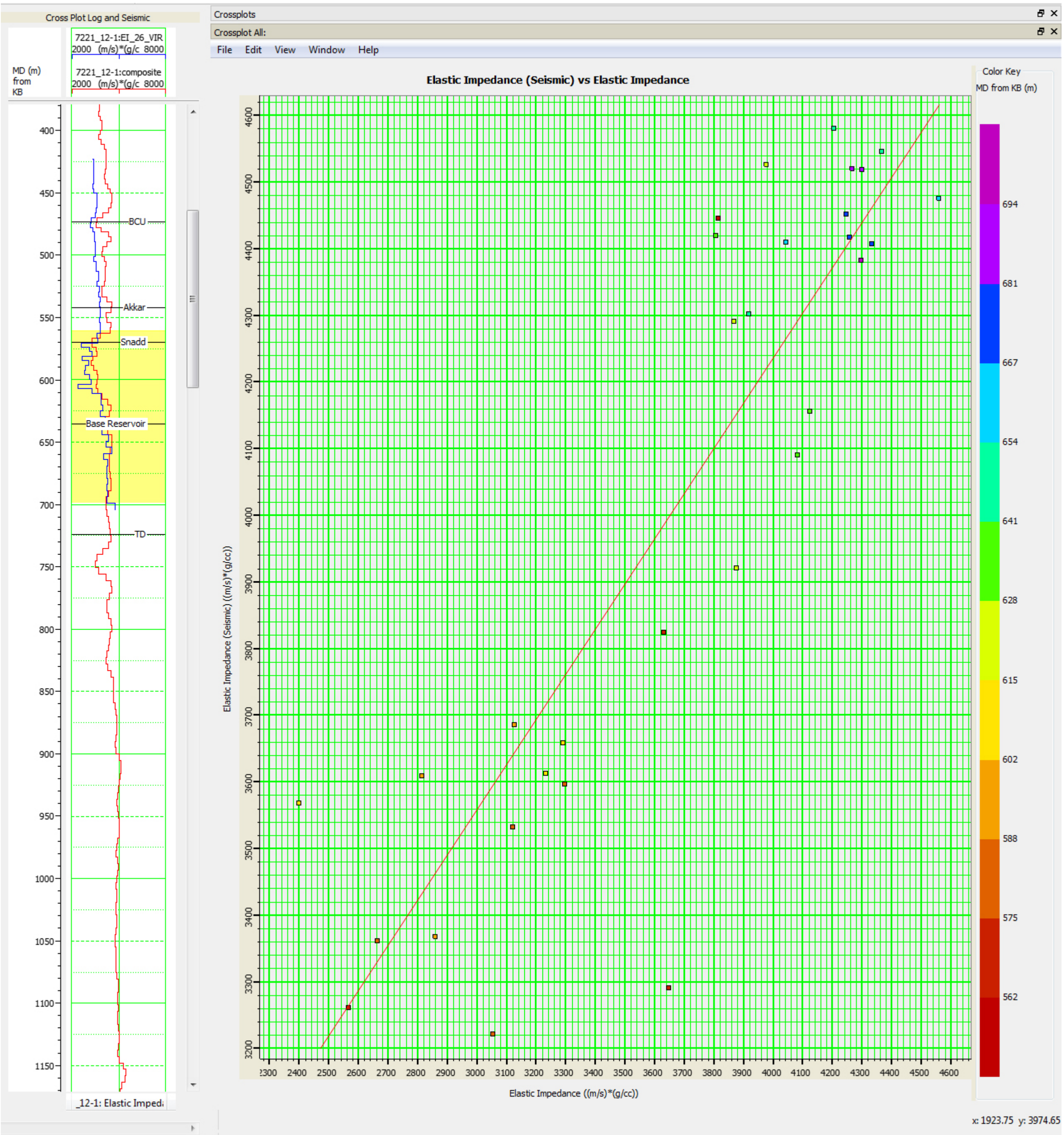

Fig. 2.8 Post-well EI inversion QC of pre-well EI estimates.
Cross plot of the pre-well predicted EI from inversion against the post-well true measurement from well data show an excellent quality of the pre-well inversion. A 1-to-1 line is drawn in red where the perfect data would plot.

2.2 Well Data

The well database utilized in the license work are listed in Table 2.2 and shown in Fig. 2.9.

Table 2.2 Key wells

Well	Name	Year	Water depth	TD (age)	TD (MD, m RKB)	NPDID
7221/12-1	**Svanefjell**	**2018**	**345**	**Late Triassic**	**724**	**8441**
7222/11-1	**Caurus**	**2008**	**356**	**Middle Triassic, Kobbe Fm.**	**2658**	**5916**
7222/11-2	**Langlitinden**	**2014**	**338**	**Early Triassic, Klappmyss Fm.**	**2918**	**7317**
7225/3-1	**Norvarg**	**2013**	**377**	**Permian, Isbjørn Fm.**	**4150**	**6587**
7120/1-1		1985	342	Late Permian, Ørret Fm.	2569	484
7120/2-1		1985	387	INDETERMINATE	3502	473
7121/1-1		1985	396	Late Triassic, Snadd Fm.	916	521
7122/2-1		1992	363	Middle Jurassic, Srø Fm.	2120	2018
7122/6-1	Tornerose	1987	401	Middle Triassic, Snadd Fm.	2707	1140
7122/6-2	Tornerose	2006	408	Middle Triassic, Kobbe Fm.	3070	5327
7123/4-1S	Tornerose	2008	413	Middle Triassic, Snadd Fm.	2920	5786
7123/4-1A	Tornerose	2008	413	Late Triassic, Snadd Fm.	2855	5808
7124/3-1	Bamse	1987	273	Late Carboniferous, Ørn Fm.	4730	1066
7125/1-1	Binne	1988	252.2	Middle Triassic, Kobbe Fm.	2200	1350
7125/4-1	Nucula	2007	293	Early Trassic, Klappmyss Fm.	1615	5450
7125/4-2	Nucula	2008	294	Early Triassic, Klappmyss Fm.	1750	5944
7220/6-1		2005	368	Pre-Devonian, Basement	1540	5039
7222/6-1S	Obesum	2008	364	Early Triassic, Havert Fm.	2895	5755
7223/5-1		2009	340	Early Triassic	2549	5960
7224/6-1	Arenaria	2008	266	Middle Triassic	2338	5835
7224/7-1		1988	269	Early Triassic	3067	1245
7226/2-1	Ververis	2008	347	Early Triassic	2992	5807
7226/11-1		1988	237.5	Pre-Devonian	5200	1177

Fig. 2.9

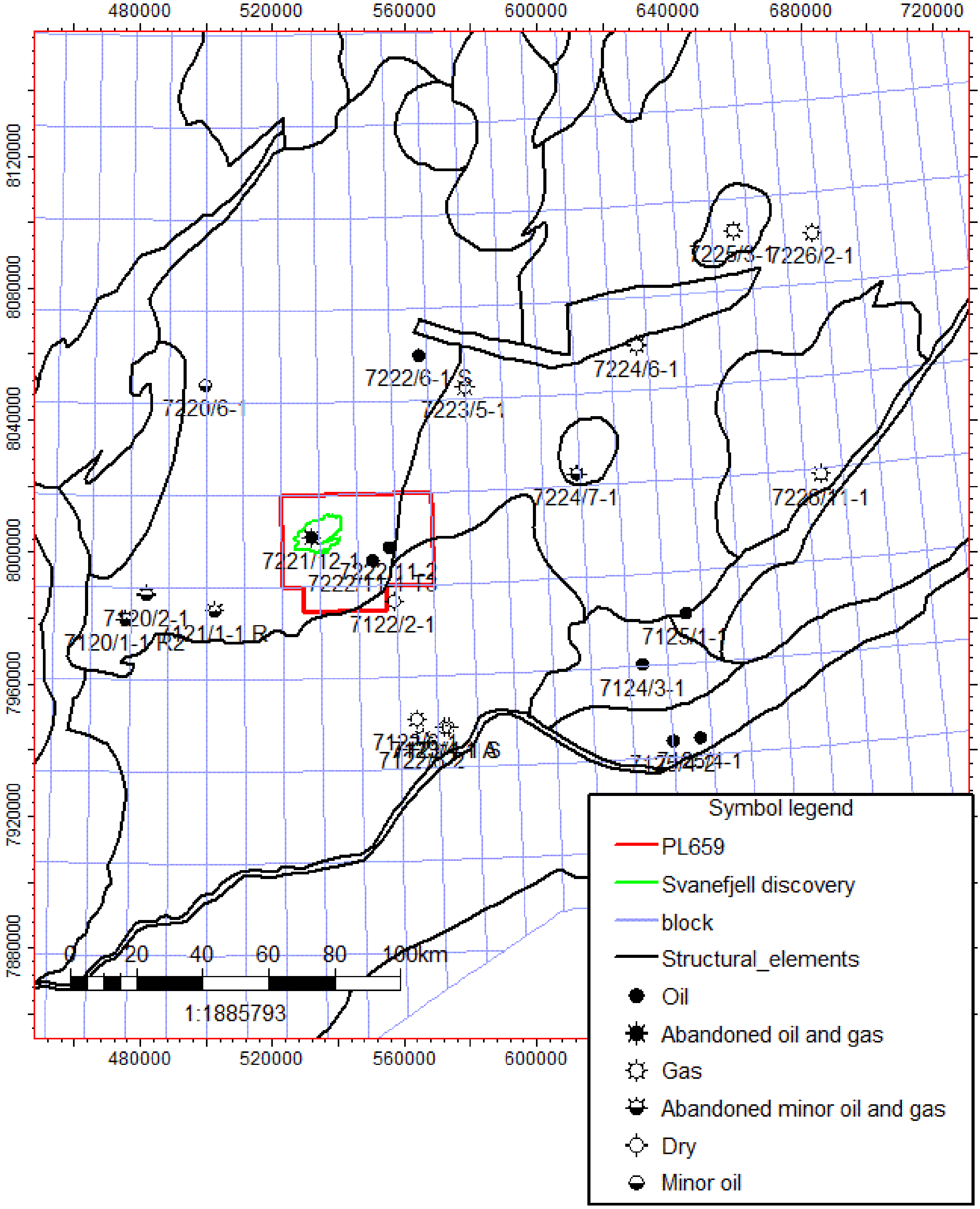

Fig. 2.9 well database

2.3 Special Studies

Bayesian Classification of EI inversion

On the basis of a good EI inversion an extension to Bayesian Classification was developed and applied to this dataset, producing probabilities for Lithology and Fluid Classes given the EI seismic data and an EI based Bayesian Classification scheme trained on fluid substituted well data. As shown by the Fluid Replacement Modelled Elastic logs in Fig. 2.10 , the sands in Snadd in the Caurus discovery expel a high degree of fluid sensitivity.

An Elastic Impedance transform to EI(26) was applied to the brine, oil and gas substituted logs and cross plotted as shown in Fig. 2.11 . From Fig. 2.11 where the data is coloured by VSH one can observe the degree of non-uniqueness the interaction between fluid saturation and cleanness of sand provides. This makes unique discrimination between sand quality and saturation infeasible. A threshold method was therefore applied to the Lithology and Fluid Classification based on volumetric logs, defining sands as clean sands with VSH < 0.2, as 0.2 is observed to be the approximate point where gas sands starts to significantly increase its elastic impedance as a function of VSH. Saturation of different hydrocarbon phases was also kept constant in the classification to 80% and brine to 100% as given from the Fluid Replacement study. This forms the basis of the Bayesian Classification scheme into Lithology and Fluid Classes (LFC) of Shale, Brine sand, Oil sand and Gas sand as demonstrated by Fig. 2.12 . A constant prior probability was assigned to the sand LFCs with equip-probabilities of 10% and the remaining 70% was assigned to the Shale class. A parsimonious undefined class was also defined to pick up data points that was outlying the span of the Bayesian Classification Scheme to indicate potential problem areas and mismatches between the inversion and the classification scheme, however no points in the zone of interest was classified in this undefined class indicating a good coincidence between inversion and classification scheme. From the classification scheme some degrees of non-uniqueness and effects of overlap with adjacent classes can be observed, and is indicating that i.e. Oil sand will have higher degrees of non-uniqueness and lower prediction strength than i. e. Gas sand due to overlap in Oil sand properties with neighbouring LFCs (Fig. 2.12). From Fig. 2.12 it can also be observed that, due to the low prior probability for Brine sand vs the higher prior probability for shale, it will not be possible to distinguish Brine sand from shale.

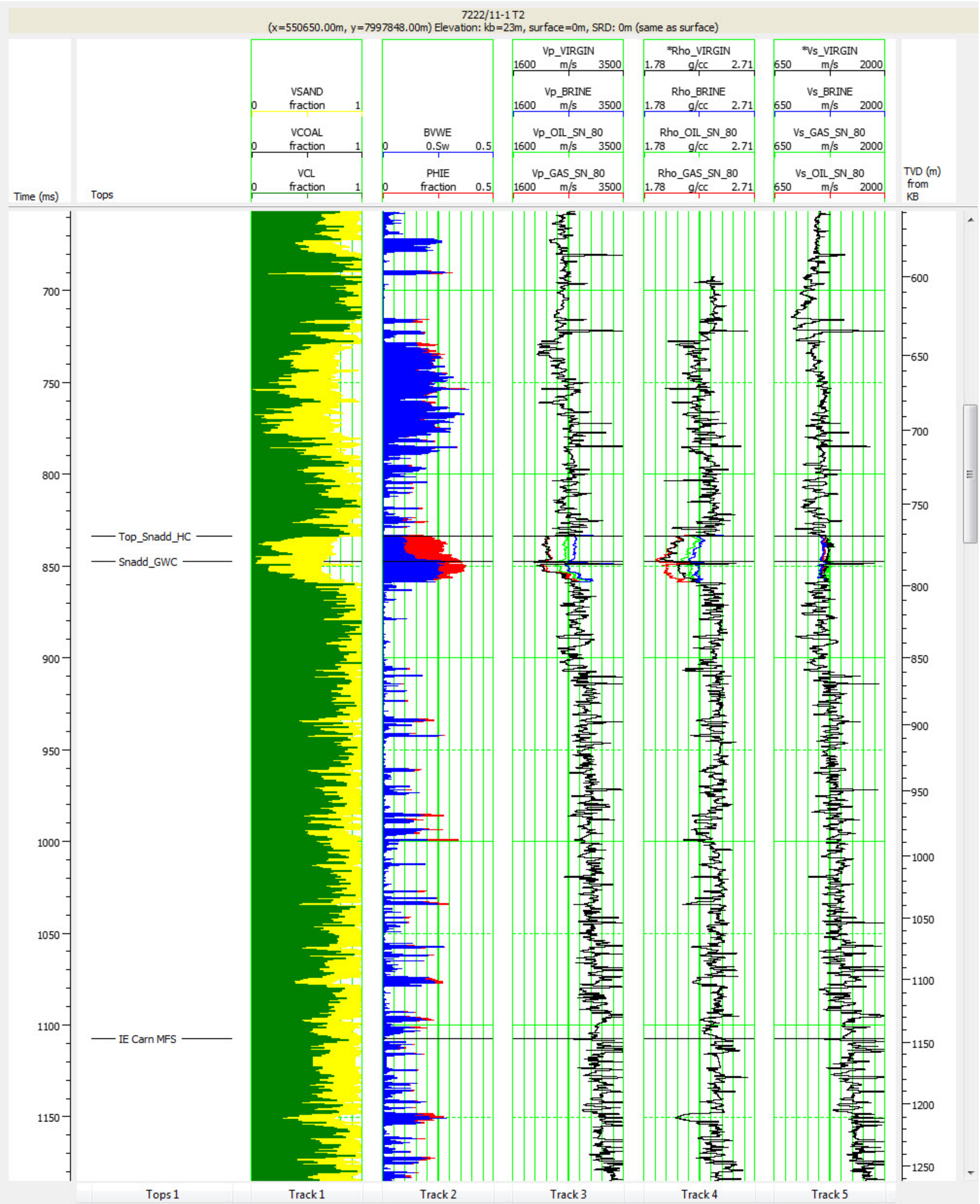

Fig. 2.10 Elastic properties of Caurus channel.

A well data display showing track 1) the CPI volumetrics logs, track 2) porosity and water saturation, tracks 3-5) and elastic virgin and fluid substituted logs for Vp, Density and Vs respectively. In black the Virgin logs, in blue the water case, in green the oil case, and red the gas case. These sands expel a high degree of fluid sensitivity.

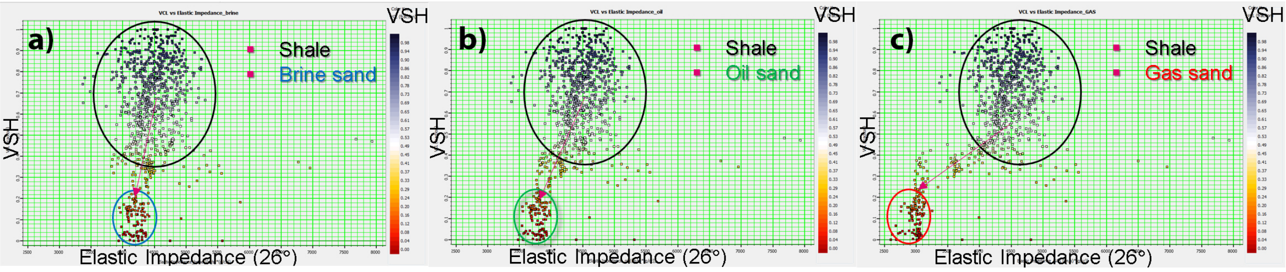

Fig. 2.11 Cross plot of Elastic Impedances from Caurus Well.

All shale are the same in the plots and all data are color coded by volume of shale. a) brine sand properties from brine substituted logs show a significant overlap with the shale properties. b) as brine is substituted with oil the effect makes oil sand more distinguishable from shale. Mind the none uniqueness provided by variation in VSH potentially making shaly oil sands indistinguishable from shale as indicated by the red arrow. c) substituting from brine to gas makes a distinct drop in clean sands. However, as indicated by the red arrow, there are significant overlap to oil sands and even shale for shaly sand. This makes unique discrimination of sand quality and fluid saturation unfeasible.

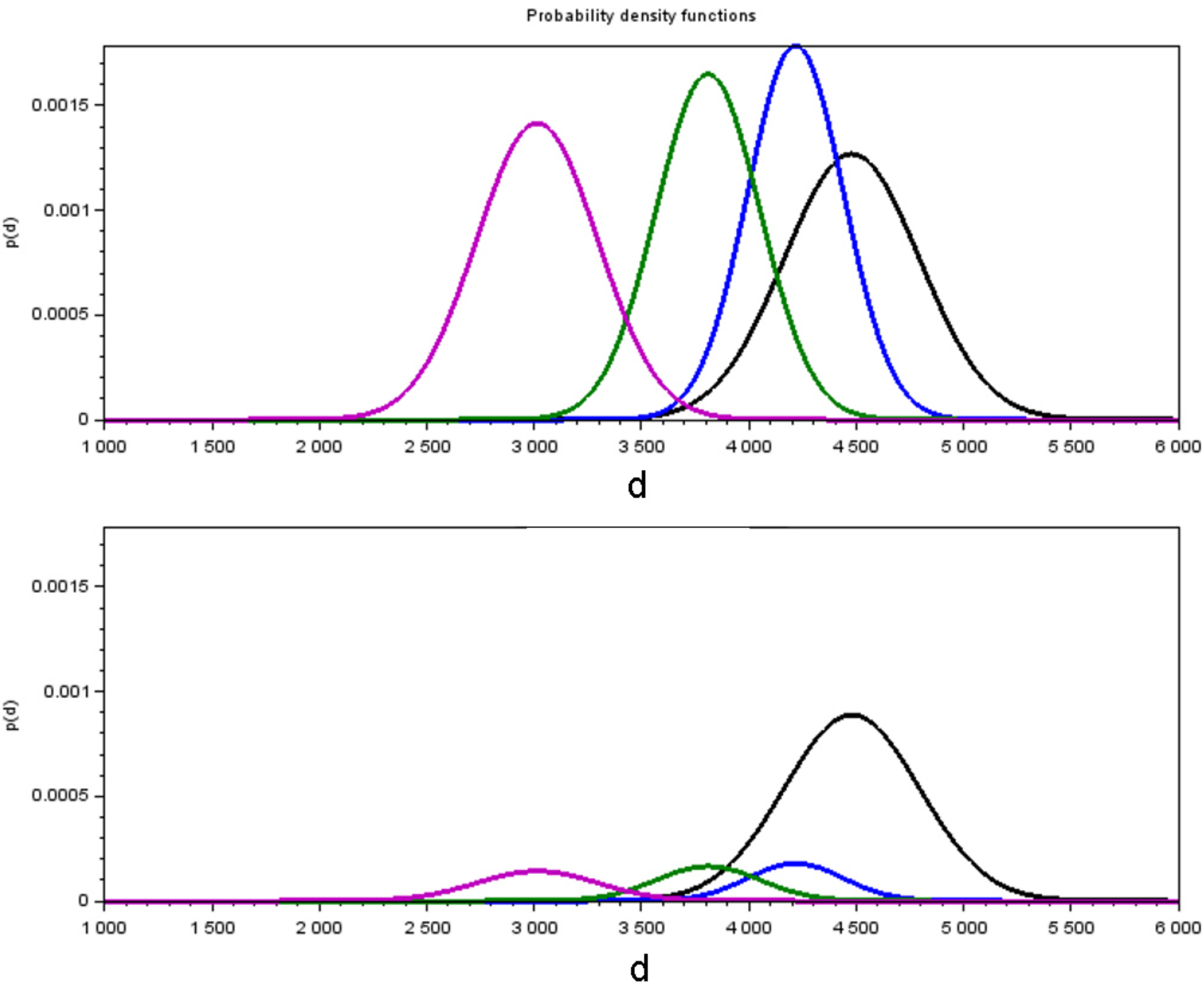

Fig. 2.12 Lithology and Fluid Classes Probability Density Functions.

Upper) The Probability Density Function for different Lithology and Fluid Classes as a function of Elastic Impedance. Magenta is for Gas sand, green for Oil sand, blue for Brine sand, and black for shale. Lower) The effect of the Bayesian Prior, where sand facies are given a equi-probability of 10% whereas the shale facies are given a probability of the remaining 70 %.

Fig. 2.6 forms the basis of the understanding from QI seismic reservoir characterization, where the Bayesian classification based on the Caurus well data has been applied to the EI(26) inversion. The results from the seismic QI study are coinciding with the well observations in the well with sands only inside channels, and a structurally conform gas sand above an Oil sand. Interestingly the oil leg probability shut-off is not so conform with structure and perhaps an indication of the immobility or residual saturation of the oil in the Caurus discovery. Similarly, for the Svanefjell prospect we see a high probability for Gas sand at the top of the structure with a conform shut-off of Gas sand probabilities with structure. This is attributed to either depth conversion or lateral variations in the sand quality from clean to shaly. The Oil sand probability is high under the Gas sand and is semi-conform with structure for Svanefjell, same as for Caurus. The probability for Oil Sand is slightly higher on Svanefjell than for Caurus, but variation in saturation cannot be uniquely distinguished from variation in sand quality and porosity given only one angle of data observation. One clear indication of this non-uniqueness was the higher probability gas channel that cross through the higher probability oil sand, interpreted as a very clean high porous oil sand with lower EI than encompassed by the Bayesian Classification scheme trained on the basis of only one well. These uncertainties was accounted for in the prospect risking and well results confirmed the results being within this span.

AVO modelling

AVO modelling was done on the Caurus well as part of the Svanefjell pre-drill prospect evaluation and of the Svanefjell well after drilling. The AVO modelling confirms with the pre-well expectation of changes in AVO responses and AVO classes as a function of fluid saturation from AVO well modelling of the Caurus well as shown in Fig. 2.14 . All hydrocarbon cases and the virgin case from both wells are class 3 AVO responses and observed on EI(26) as a low EI response as a function of hydrocarbon saturation. Gas has softer far data amplitude and lower EI than oil. The Fluid Replacement Modelled elastic properties of the Caurus well show a consistent change as a function of fluid replacement indicating a good fluid sensitive reservoir Fig. 2.10 and similar responses are seen for the Svanefjell well in Fig. 2.13. Both Svanefjell and Caurus discoveries have fluid sensitive reservoir sands. The results from AVO well modelling are shown in Fig. 2.14 and the AVO well modelling of the Caurus discovery well and the Svanefjell discovery reflect these bespoke observations of elastic properties on a seismic scale. Reasons for small differences between the Svanefjell virgin log where the gas mobile zone and non-mobile potential 3 phase saturation zone and the EI seismic observation can potentially be caused by a variety of effects i. e. in frequency content and fluid mobility as a function of relative differences in sampling frequencies from log to seismic, lateral changes away from the well only visible in seismic data and the higher porosity, cleaner sands in this thinner interval. If the inversion was perfectly matching the EI log in the Svanefjell well also the lower non-mobile zone would map as a gas sand. Overall its a satisfying fit between prediction and results, given low frequency model well extrapolation, seismic quality, bandwidth and coverage. The variations and deviations are well within prediction span and uncertainty.

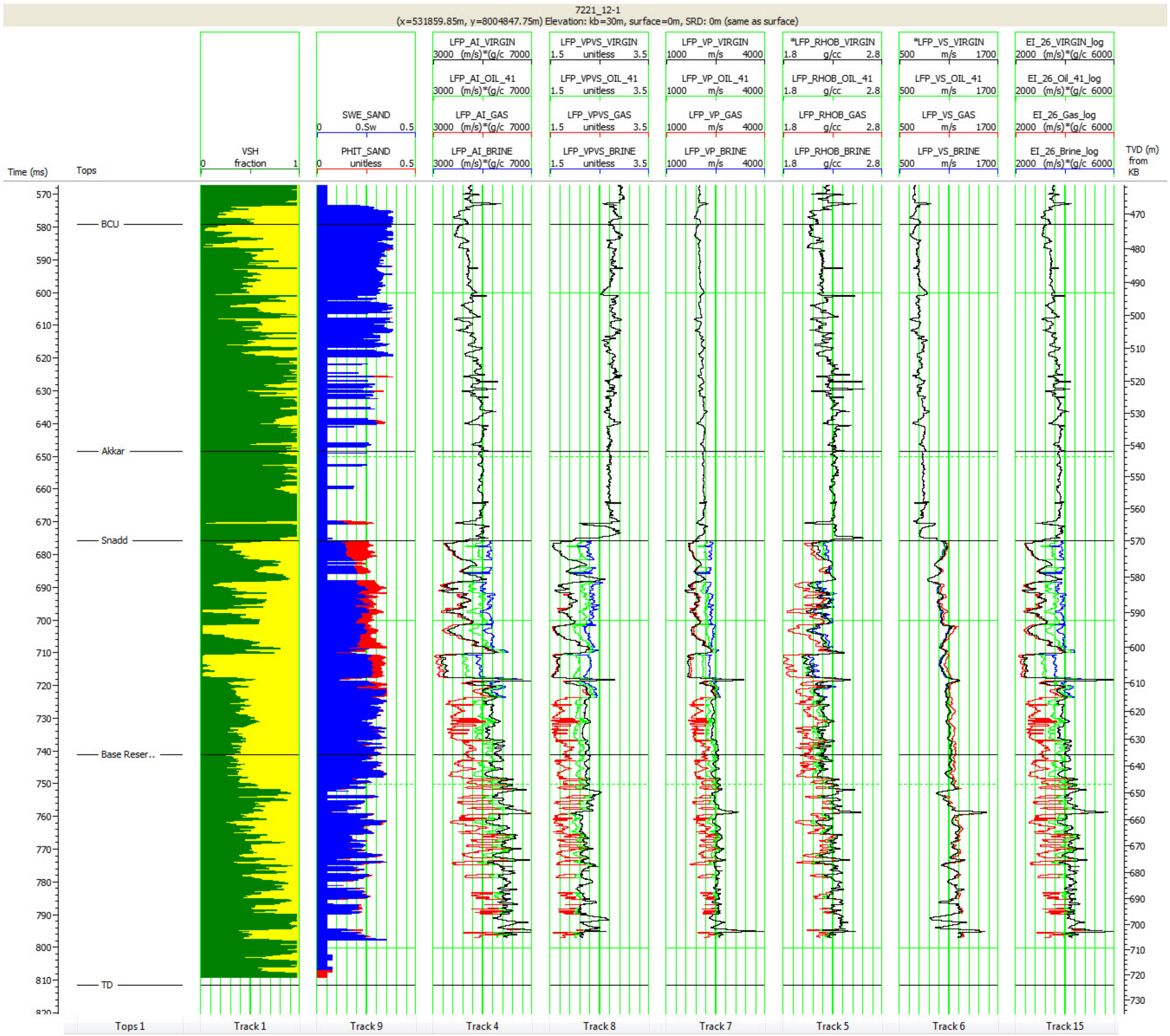

Fig. 2.13 Elastic properties of the Svanefjell discovery.

A well data display showing track 1) the CPI volumetrics log, track 2) the porosity and water saturation, track 3-8) Fluid Replacement modeled elastic properties respectively Acoustic impedance, Vp/Vs-ratio, Vp, density, Vs and EI(26) with virgin case in black, Brine case in Blue, Oil case in green and Gas case in red. The Fluid Replacement modeling indicate a reservoir rock with a high degree of fluid sensitivity.

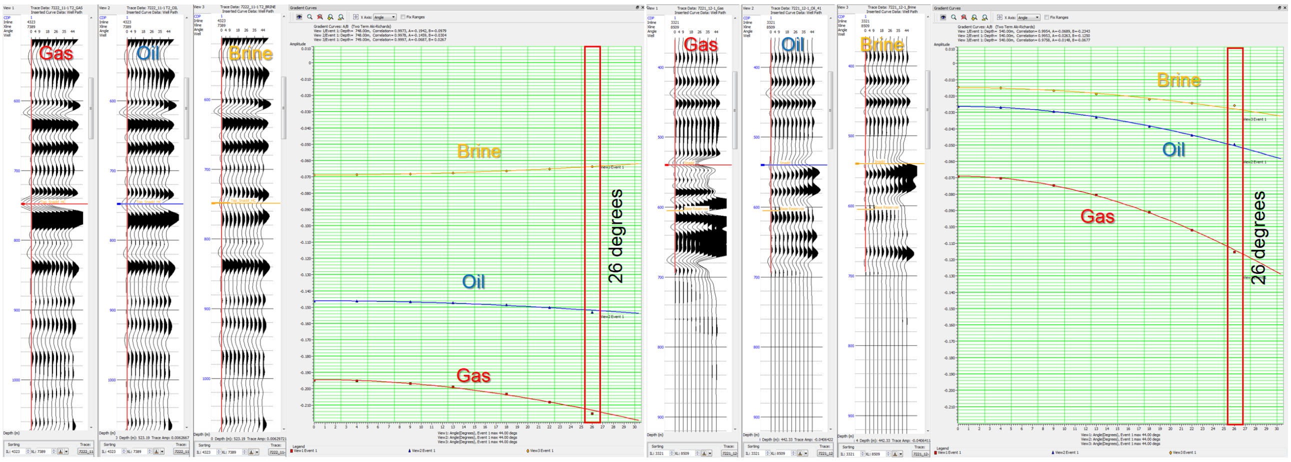

Fig. 2.14 Seismic AVO well modeling of Fluid Replacement Modeled well logs.
Left) the Carus discovery well modeling, and right) the Svanefjell discovery well modeling of Brine, Oil and Gas cases respectively in orange, blue and red curves. A red square is placed over the 26 degree incidence angle.

Geomorphology

A thorough investigation of the geomorphological expressions both through amplitude driven features expressed in the spectral decomposition attributes and features expressed in edge attributes. Three selected frequency bands were RGB colour blended and three selected edge attributes were CMY colour blended as shown in Fig. 2.15. It can be seen that not all features with an amplitude expression were expressed by the edge attributes, i.e. the inferred contact, and opposite not all geomorphological features with an edge expressions were expressed by the amplitude attributes, i.e. dim channels. Therefore, we combined these two blends using a bump mapping technique that allow us to further blend and co-visualise all these attributes in one map as displayed in Fig. 2.15 right. It is clear that the combined picture of all six attributes is much richer in information. The colours from the spectral decomposition were also preserved.

As distinctly illustrated in Fig. 2.15 we expected the prospect to have a complex channelized geology, possibly stacked and crossing sandier channels ranging from straight to meandering with point bars. We also expected an upper more continuous sheet like sand at top reservoir. These expectations were confirmed in the well.

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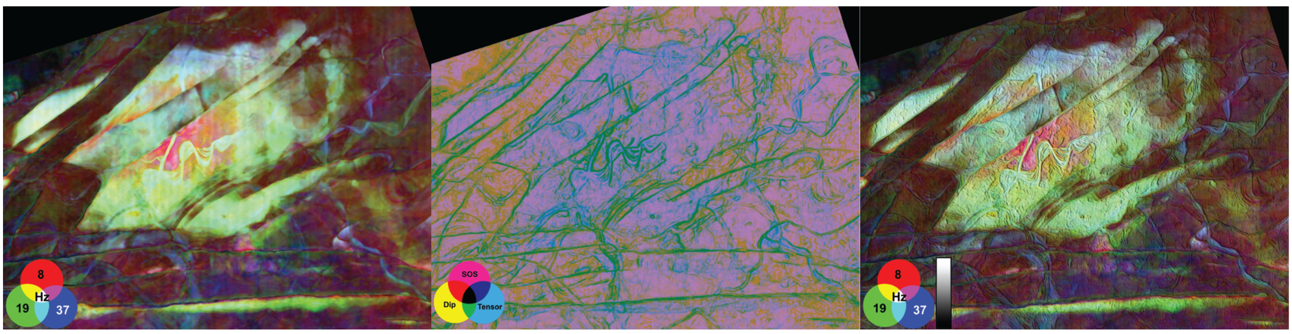


Fig. 2.15 Geomorphological expressions.
Left) the Spectral decomposition frequency blend, center) the edge detection attributes blend, right) the bump map blending of the Spectral decomposition in colors and edge detection attributes as relief. Its clear that the bump mapping technique provide more information in the same image.

3 Remaining Prospectivity

A total of four technical discoveries have been done within the PL659 acreage (Fig. 3.1).

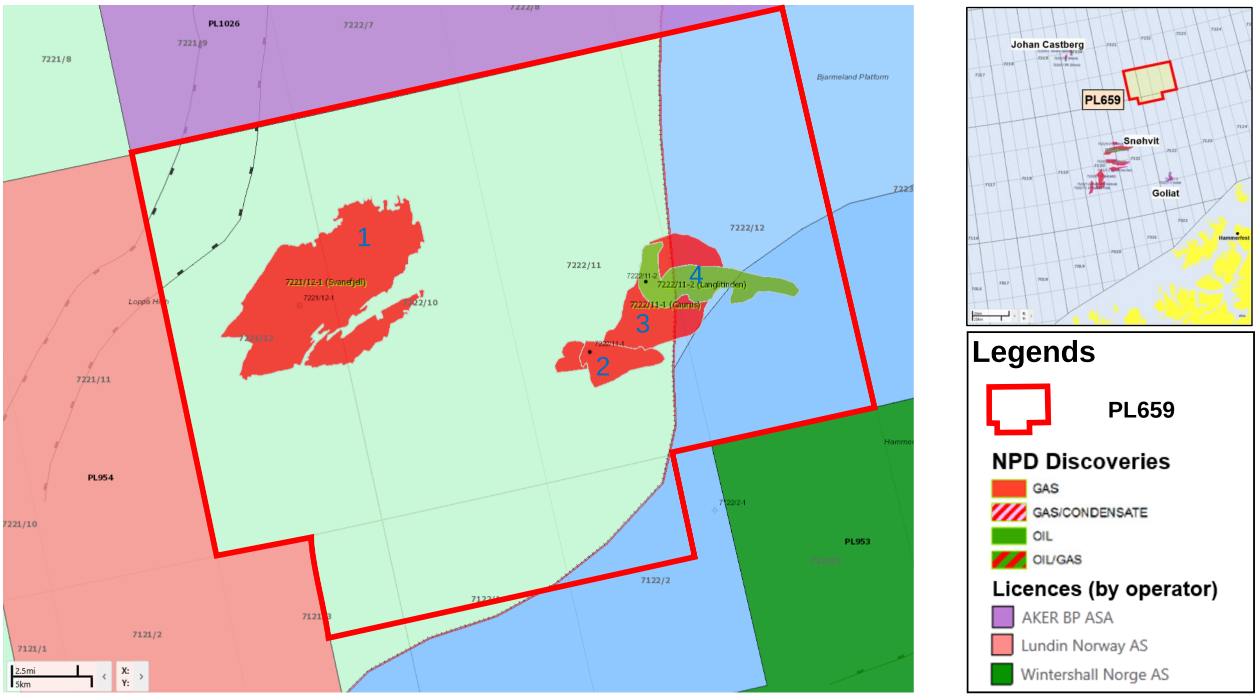


Fig. 3.1 Four technical discoveries within PL659: *1) Svanefjell discovery (Snadd Fm), 2) Caurus discovery (Snadd Fm), 3) Caurus discovery (Kobbe Fm) and 4) Langlitinden discovery (Kobbe Fm).*

The Langlitinden prospect (Fig. 3.2, polygon B) including the E-lead (later named the Svanefjell prospect) have been drilled and tested (1.3 Identified Prospectivity). In addition, all leads (Fig. 3.2, C, D, F and G) belonging to the Lower-Middle Triassic plays are *considered adequately tested and invalidated by the Caurus (7222/11-1) and Langlitinden (7222/11-2) wells* (1.3 Identified Prospectivity).

The remaining prospectivity is presented below in Fig. 3.3, consisting of an untested, early Carnian age channel complex situated within a 4-way fault dependent closure, and three middle Carnian leads. The details are presented below.

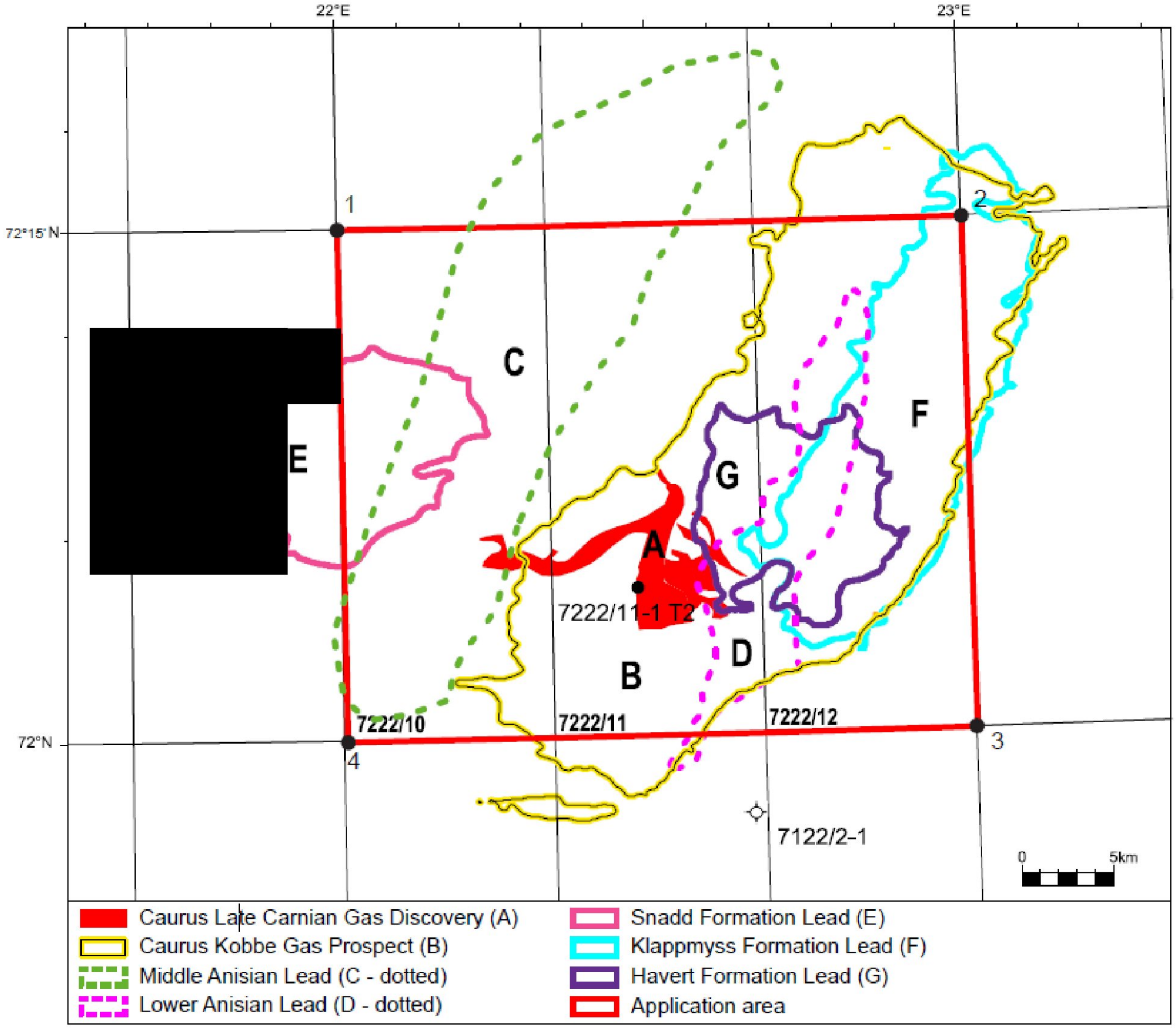


Fig. 3.2 APA 2011 Det norske Discoveries, prospects and leads. *Solid outlines refer to structural spill. Dotted lines refer to stratigraphic trap concepts.*
Annotation refers to A) Caurus Late Carnian Gas Discovery, B) Caurus Kobbe Gas Prospect, C) Middle Anisian Lead, D) Lower Anisian Lead, E) Snadd Formation Lead, F) Klappmyss Formation Lead, and G) Havert Formation Lead.

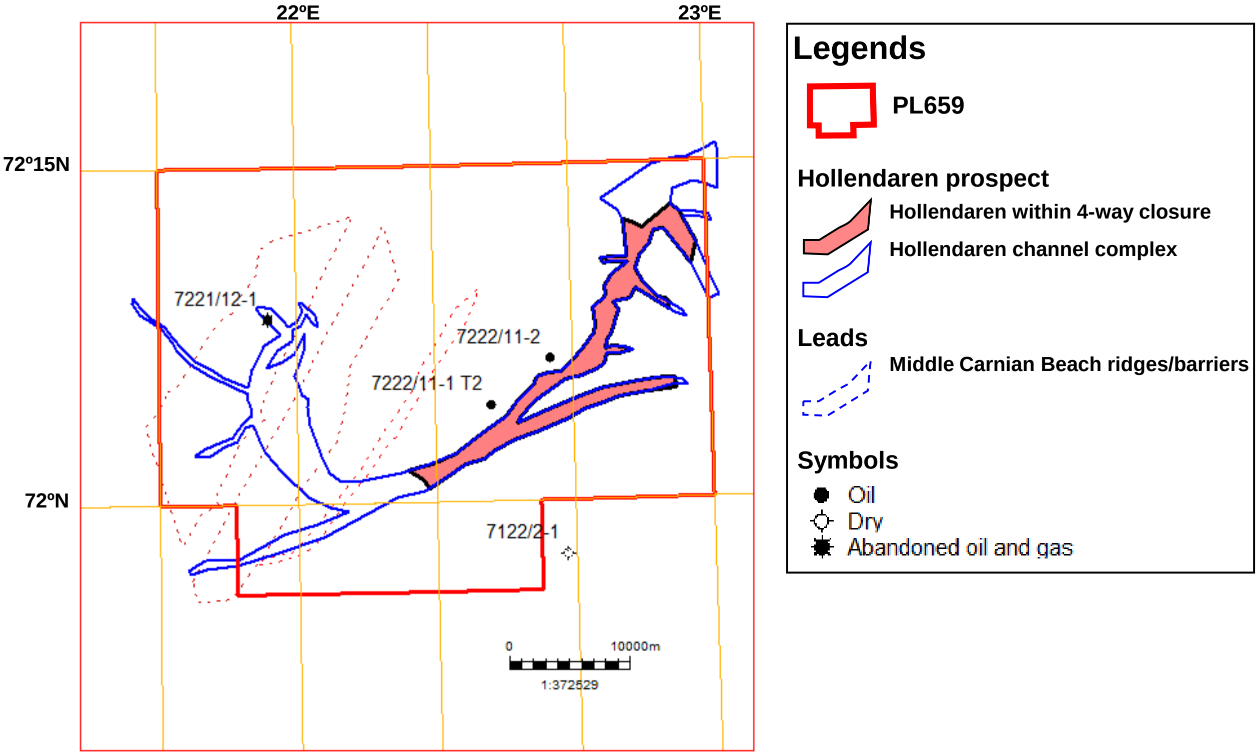


Fig. 3.3 Remaining prospectivity. *One untested prospect and three leads.*

3.1 Hollendaren

The Hollendaren Prospect was identified by Lundin (Telegrafisten Upper) and further refined by AkerBP (Fig. 3.4). The prospect is a combined stratigraphic and structural closure with intra Snadd Formation fluvial sandstone reservoir, sealed by intra Snadd marine shales and charged by the Steinkobbe source rock (ref. Caurus, Langlitinden and Svanefjell discoveries).

Within the structural closure the Hollendaren Prospect proves an areally extent of 73km^2 with apex at 1300mMSL and structural spill at 1440mMSL. The gross rock volume (GRV) is only extracted from the channel facies (i.e., 73km^2). The main risk is thought to be *fault integrity* as vertical migration is evident and proved by several shallow hydrocarbon accumulations.

However, the Hollendaren Prospect is considered commercially unattractive based on the volume and risk estimates.

- **Recoverable oil** (P90 - Mean - P10): **11 -73 - 163 mmbbl**
- **Technical COS:** **18%**.

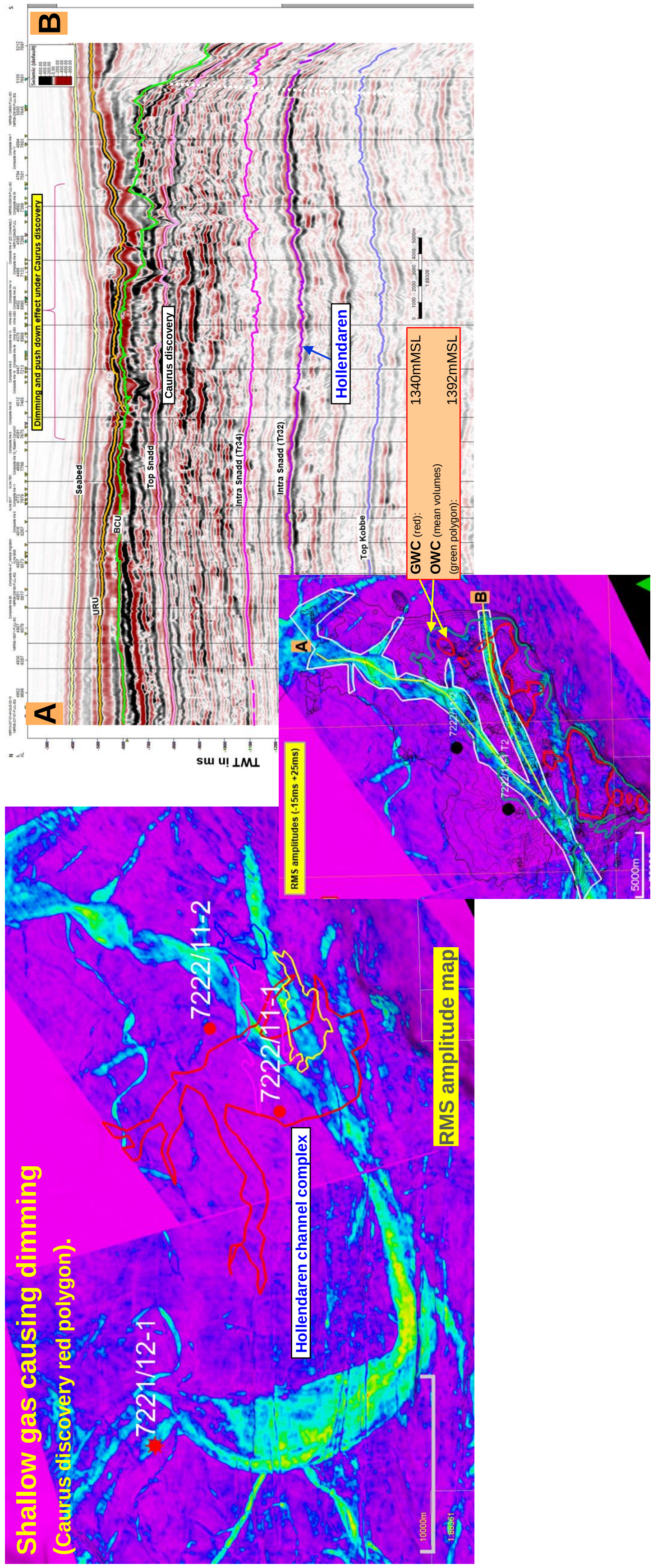


Fig. 3.4 Shallow gas and dimming *Hollendaren Prospect*

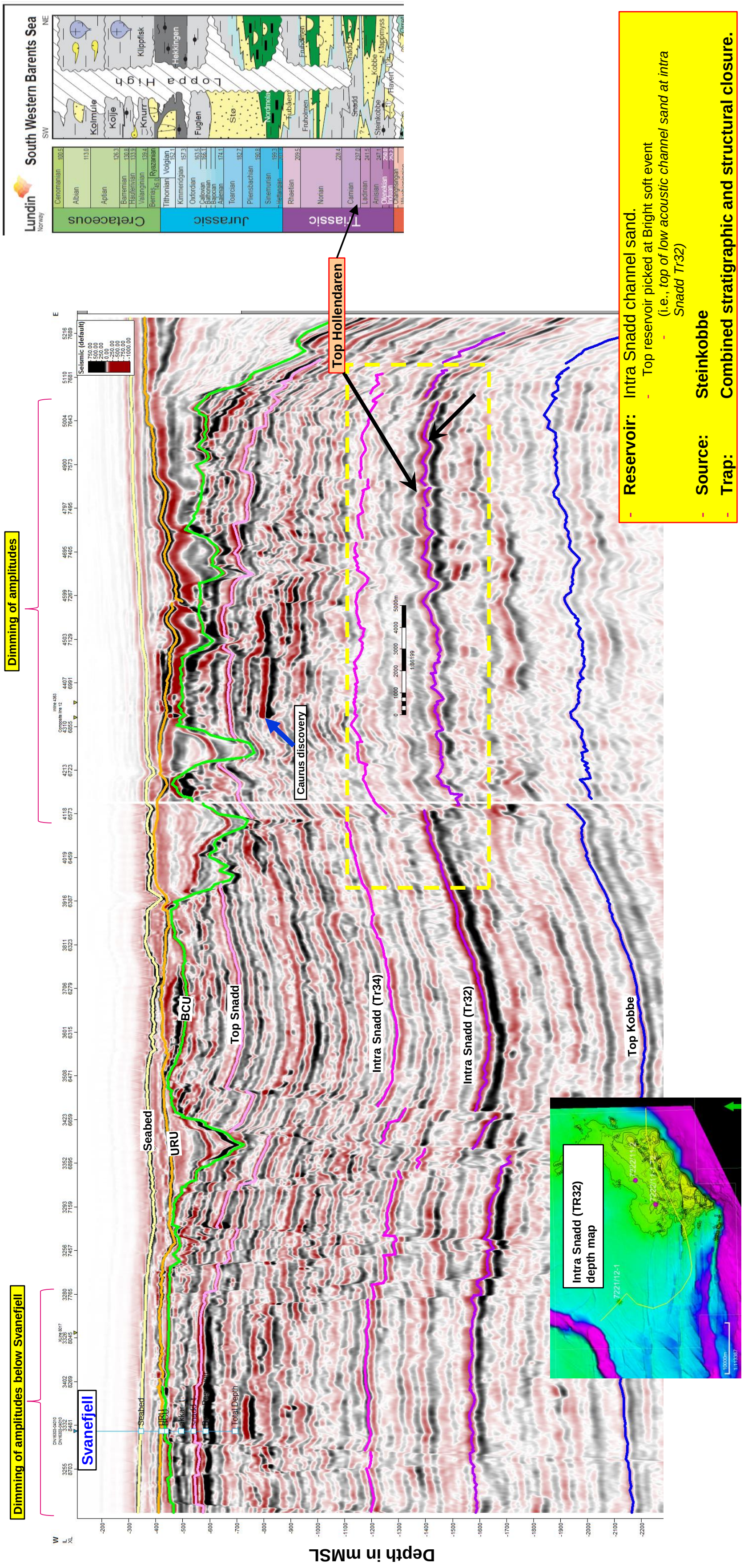


Fig. 3.5 Hollendaren Prospect (1) *Seismic profile from Svanefjell to the Caurus channel area.*

Hollendaren Prospect

Main risks and uncertainties:

- ***Fault seal:*** 0.4
  - Vertical migration is proven and observable on seismic data.
  - Faults cutting the stratigraphy all the way to URU is a challenge.
  - Probably the main risk factor controlling potential accumulations (trap integrity).
- ***Migration and timing:*** 0.7 (to low)
  - Oil/residual oil has been proven at stratigraphic levels both below (Kobbe) and shallower (Caurus/Svanefjell) than the Hollendaren prospect. There is a high chance that the prospect has been charged or has worked as "hotel".
- **Reservoir:**
  - **Intra Snadd channel sand:** 0.72 (presence & quality)
    - The channel complex is easily defined on 3D seismic data (presence: 0.9)
    - The quality and lateral changes are more uncertain (0.8)

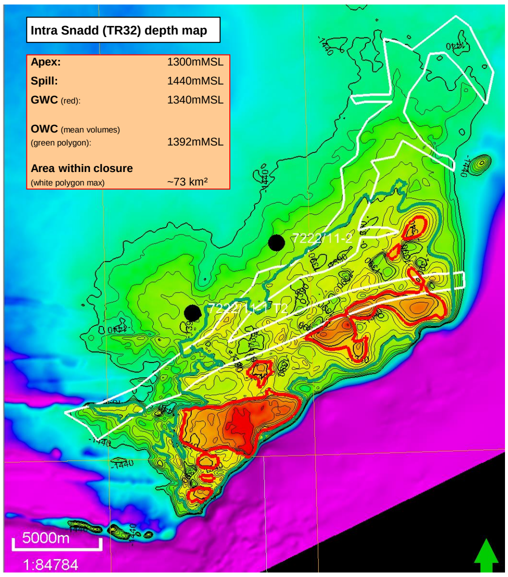
GeoX Risk Parameters:	
Reservoir Presence	0.9
Reservoir Quality	0.8
Seal Presence	0.4
Trap Geometry	1
Source Presence	1
Migration & Timing	0.7
P(disc)	0.2
Marginal Play probability	0.9
COS	0.18

Volume estimates (oil):
P90 / Mean / P10: **36 – 243 – 541** mmboe (inplace)
P90 / Mean / P10: **11 – 73 – 163** mmboe (recov)

Structural dip (undulating surface): ~2-9°

Case	P(case)
Success discovery	18.1%
Above screening threshold	
Oil only	4.5%
Gas only	9.1%
Oil and gas	4.6%
Oil	9.1%
Gas	13.7%

P(oil): 9%
P(gas):14%



Volume estimates:
- GRV within channel polygon (white) and down to structural spill (1440m).

Fig. 3.6 Hollendaren prospect (2) *Volume and risk evaluation.*

3.2 Leads

Several potential stratigraphic pinch-out traps are seen within the PL659 acreage which includes shallow marine to coastal deposits such as barrier islands and beach ridges (Fig. 3.7) and fluvial channels (Fig. 3.8). The main challenge in the are for both these type of deposits seem to be the lack of a viable trapping mechanism.

The Caurus well (7222/11-1) tested an isolated barrier which was water wet but proved good reservoir properties. A potential pinch-out trap are probable in a NW-SE direction but not in an NE-SW direction (parallel with the palaeo-coast) as the barriers and beach ridges continue towards the north and out out the licence. In addition, the RMS amplitude maps reveals no amplitude conformance with structure and are strongest down dip (i.e., in the south with spill towards the north), hence, the amplitude changes seems to be related to lithology change, not presence of hydrocarbons.

The fluvial channels (Fig. 3.8) seem to be interconnected and have probably acted as "hotels" and carriers for migrating hydrocarbons. The gas accumulation in the Caurus Channel seems to be trapped in a combined stratigraphic and structural closure, showing the importance of the structural component.

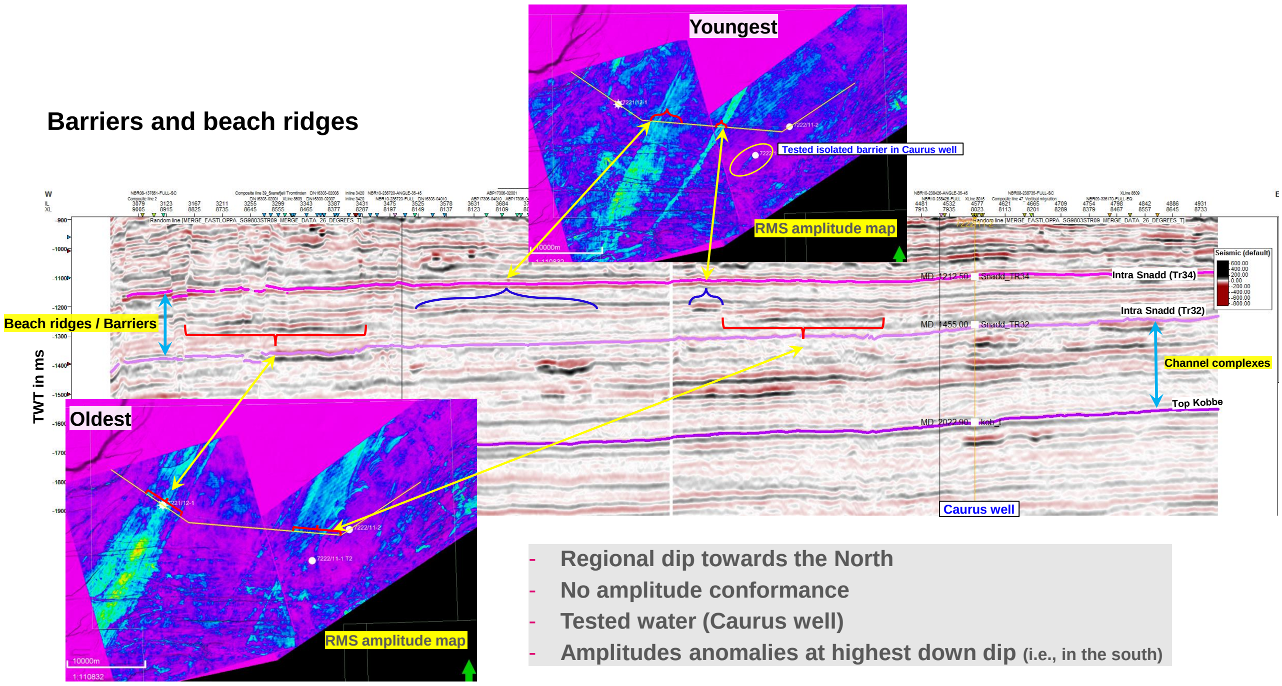


Fig. 3.7 Barriers and beach ridges

Channel connectivity

- Channels interconnected
- Amplitude anomalies due to lithology
- Channels have probably acted as carrier beds

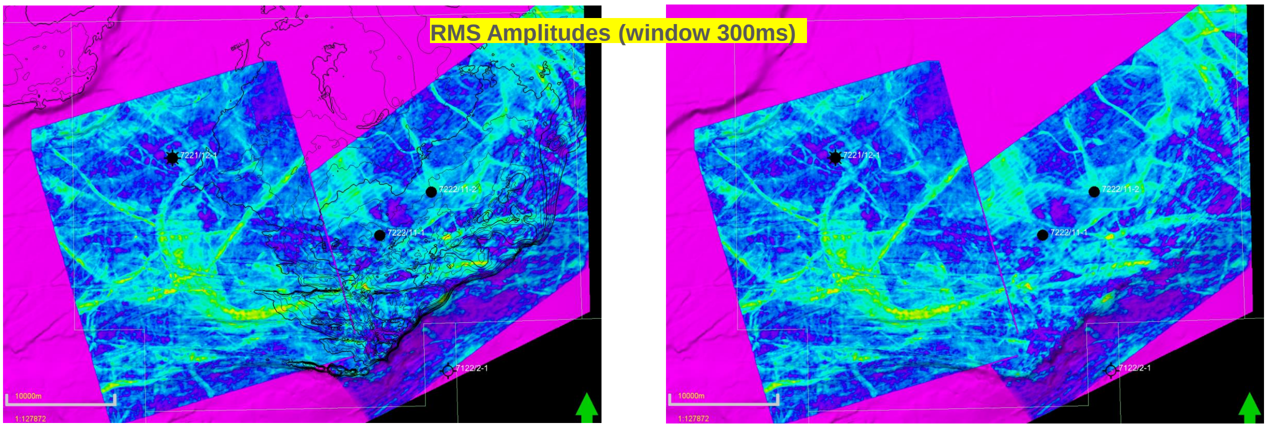


Fig. 3.8 Channel connectivity

4 Technical Evaluation

The licence acreage consist of four technical discoveries (ref Fig. 3.1), where one oil discovery and one gas discovery are within the Kobbe Formation and two gas discoveries are within the Snadd Formation. Volume estimates for the Kobbe oil/gas discovery done by Statoil (now Equinor) in 2008 are very small and not presented below.

Kobbe Fm:

- **Inplace:** (P90/Mean/P10) **24-33-45 mmboe**
- **Recoverable** (P90/mean/P10): **7-10-13 mmboe**

In the pre well technical and economic evaluation, a base case (246 mmboe) is presented that includes additional upside volumes from the Snøtinden prospect (Fig. 4.1). The economy is marginal and the Langlitinden oil discovery is negative as a standalone according to this analysis. Given the fact that the proven recoverable volumes in the Langlitinden well is only ***10 mmboe*** with additional low reservoir quality (i.e., low permeability), a development of the Langlitinden oil discovery is not likely.

[redacted]

Fig. 4.1 Tech Ec Langlitinden. *Recoverable oil volumes to small to be commercial.*

Snadd Fm:

Caurus channel:

- **Inplace:** (P90/Mean/P10) **5.6-6.8-8.0 GSm3**
- **Recoverable** (P90/mean/P10): **2.9-3.5-4.2 GSm3**

Svanefjell:

- **Inplace:** (P90/Mean/P10) **3.1-3.5-4.0 GSm3**
- **Recoverable** (P90/mean/P10): **1.5-1.8-2.1 GSm3**

Recoverable **gas** volumes in Snadd are to small to be commercial.

5 Conclusion

The licence acreage has proven an effective hydrocarbon system that includes three technical discoveries. However, several challenges do exist that highly affect the prospectivity within the licence area.

Kobbe play:

- Despite two oil discoveries the play is considered *as non-economical* due to the low quality and limited lateral distribution of sandstone reservoir.

Snadd play:

- All in all, there are few to non viable traps (both structural & stratigraphic) within the Snadd Formation.
- Main risk based on well results are seal/trap failure and preservation of oil in trap during uplift and gas expanison.

Challenges:

- Low relief acreage, *hence vulnerable for tectonic tilting*.
- Potential reservoirs are interconnected (laterally & vertically)
- Regional dip is North-South (*i.e., spill towards the North*).
- Prove of vertical leakage along fault planes (*tectonic breaching of the top seal*).

Realgrunnen play:

- The prospectivity is sparse with some potential remaining in structural highs or "Mesas" between the canyons.
- The resource potential is however very limited.
- *The play is therefore considered as non-economical*.

Due to these facts, the partnership decided to relinquish PL659.

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