PL895

Relinquishment Report

Bolga

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1 Introduction

1.1 License Owners

Aker BP ASA (60%) - Operator

Equinor Energy AS (40%)

1.2 Award and Work Program

The license was awarded the 10th of February 2017 for an initial period of 7 years following the APA Licensing Round 2016 with a Drill or Drop decision within two years.

License work obligations included the following:

- Acquire 3D seismic
- Perform an EM feasibility study

The initial work obligations have been fulfilled and approved within appointed deadlines. Parts of PGS16005NWS were purchased and fulfill the work obligation of acquiring 3D seismic covering the license. The EM feasibility study is further descibed in 2.3 Special Studies.

1.3 Identified Prospectivity

PL895 is located in the Træna Basin west of the margin of Grønøy High, covering blocks 6609/2, 6609/3, 6609/4, 6609/5, 6609/6 and 6610/1. Closest infrastructure is Norne in south with app. 110km, and Aasta Hansteen in west with app. 120km.

The identified prospectivity is mainly within Cretaceous, but three additional leads are also mapped within the license acreage, in respectively Paleocene, Lysing (Sandvær) and Triassic (Valvær). The two latter leads are leads coming from the APA 2017 and later PL948 where both Aker BP and Equinor have interests.

The main prospect in the license is the Bolga Prospect, and is defined by an amplitude anomaly within the Lange Formation. The trap is a stratigraphic with Lange Formation shales being the top and base seal. In the east the prospect is dependent on detatchment of the reservoir sands and possible juxtaposition of the reservoir towards heterolithic Triassic succession across the main western fault of the Grønøy High.

The prospectivity is summarised in Fig. 1.1.

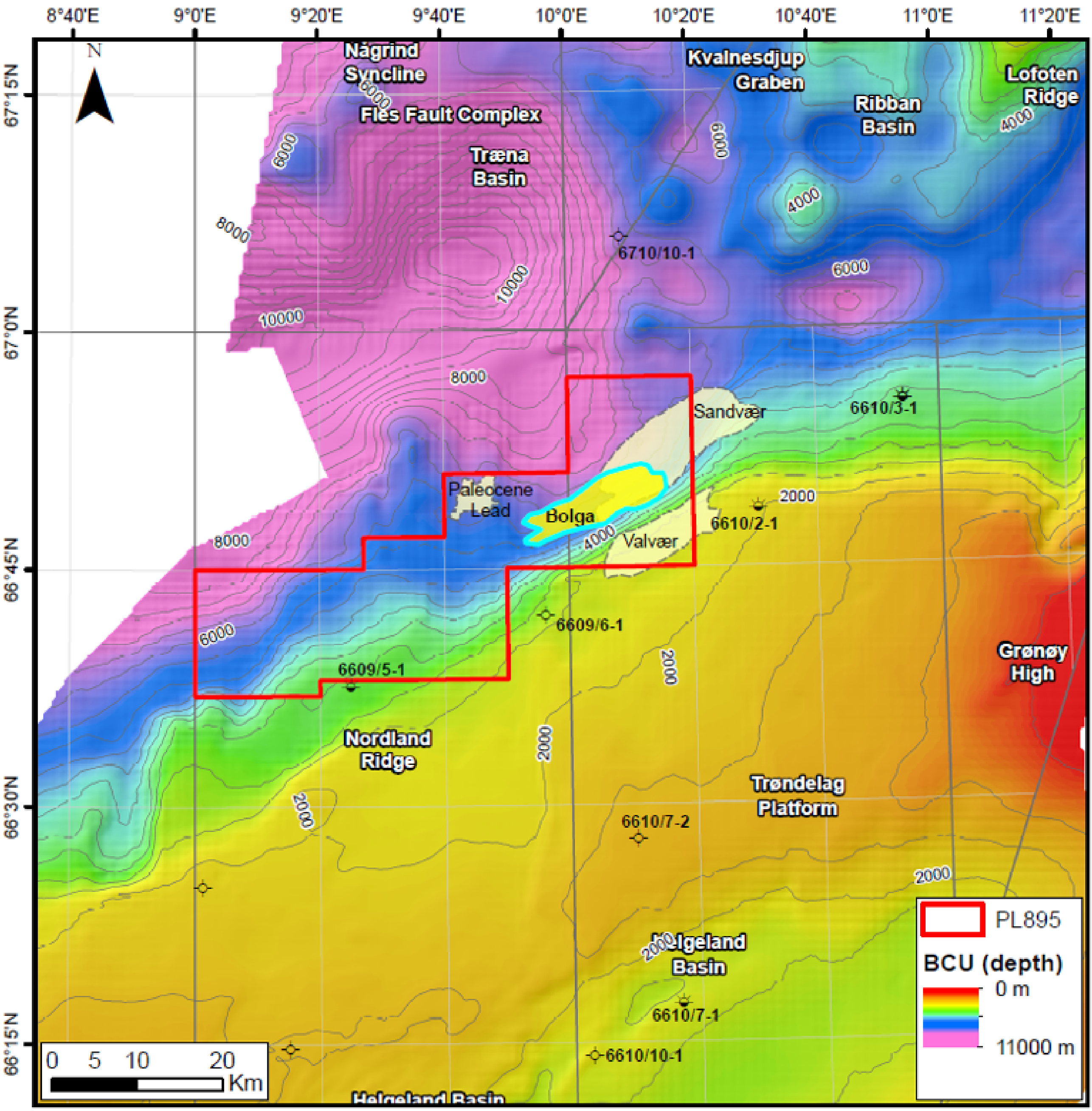

Fig. 1.1 Prospectivity in PL895 *Bolga Prospect is the main prospect evalutated in the license. Sandvær (Lysing), Valvær (Triassic) and Paleocene Lead are leads evaluated.*

2 Database

2.1 Seismic Database

The seismic database is listed in Table 2.1 and Fig. 2.1.

In addition all relevant public data is a part of the database. Especially NOR1001 have been used for the Cretaceous interpretation in addition to the PGS16005, since this seismic volume covers the well 6610/3-1R.

Table 2.1 Seismic database PL895

3D	2D
PGS16005	MNR04RE06-7432
	MNR08-7424B
	CFI_MNR08-7412
	CFI_MNR09-522
	MNR08-532
	MNR08-546
	MNR06-0552
	MNR05-7397

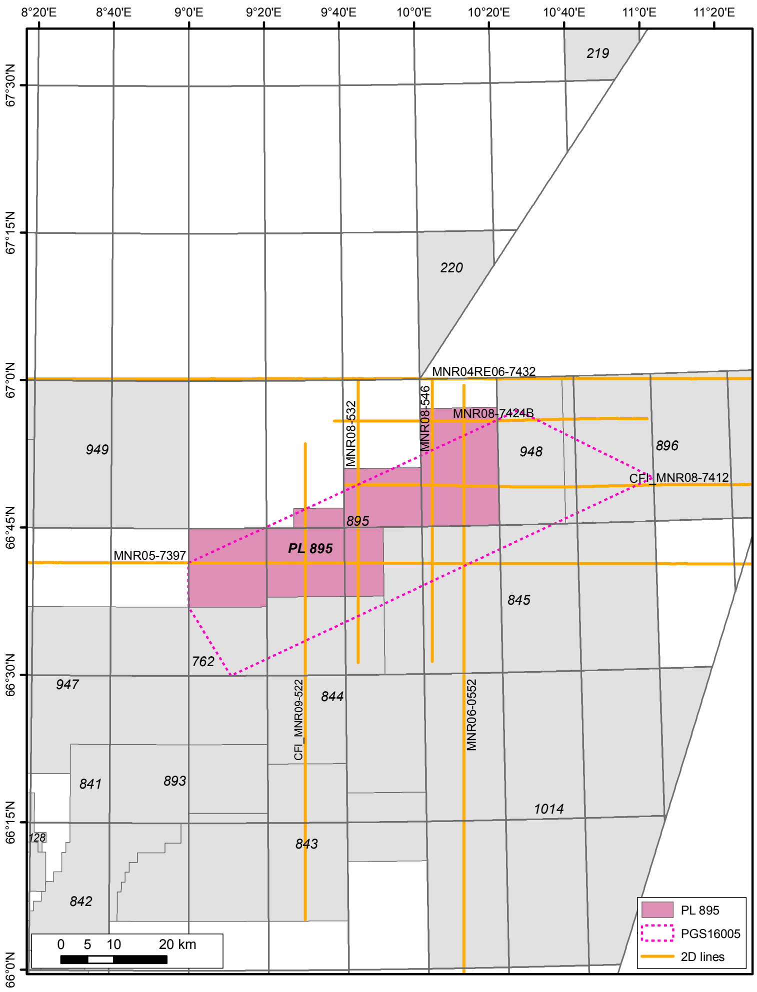

Fig. 2.1 Seismic database PL895 *In addition all relevant public data*

2.2 Well Data

Reference wells used in the technical evaluation of the prospects and leads in PL895 are presented in Table 2.2 and Fig. 2.2.

Table 2.2 Well database PL895

Well	Informal name	Year	Stratigraphy at TD	TD MD(m)	Operator	Status
6507/2-2	Marulk	1992	Åre Fm	3958	Norsk Hydro	Gas
6507/5-2	Skarv	1999	Åre Fm	3897	Amoco	Gas/cond.
6508/1-1A		1999	Melke Fm	2961	Saga Petroleum	Dry
6608/10-12	Skuld	2008	Red beds	3180	StatoilHydro	Oil
6609/5-1		1985	Red beds	3600	Det norske stats oljeselskap	Shows
6609/6-1		2007	Red beds	2710	Norsk Hydro	Dry
6609/7-1		1983	Basement	1969	Philips Petroleum	Dry
6609/10-1		1983	Red beds	2167	Saga Petroleum	Dry
6610/2-1S		1996	Red beds	2673	Den norske stats oljeselskap	Shows
6610/3-1 R		1993	Red beds	4200	Den norske stats oljeselskap	Shows
6710/10-1		2000	Springar Fm	2267	Den norske stats oljeselskap	Gas

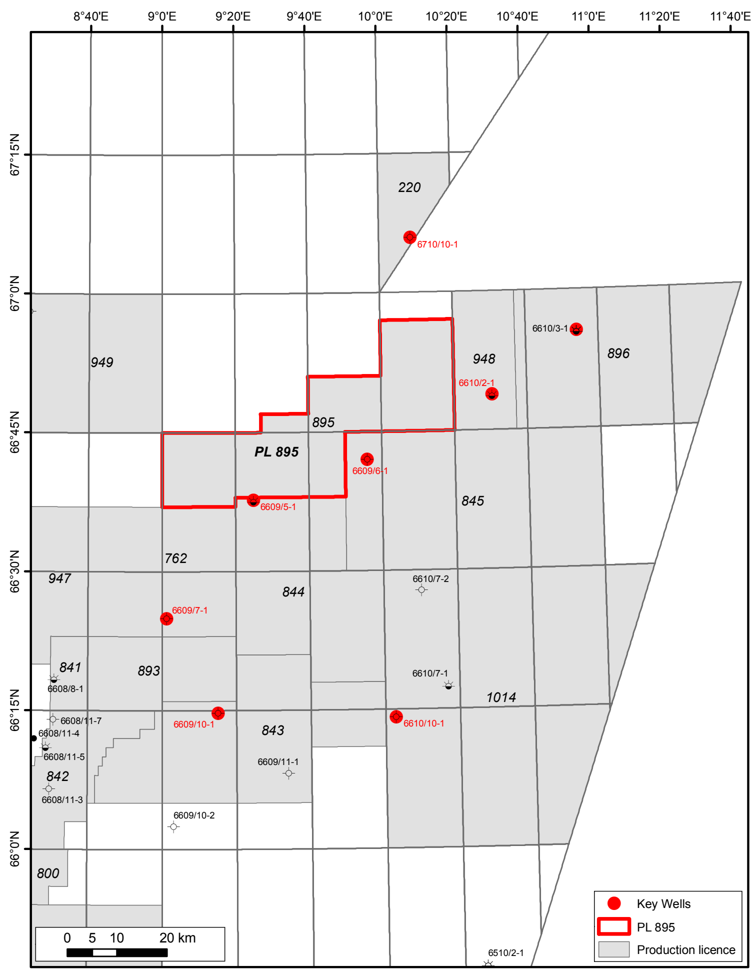

Fig. 2.2 Reference wells for PL895

2.3 Special Studies

Seismic conditioning and analysis

Extensive geophysical work has been carried out on both the PGS16005 and NOR1001 surveys. This includes denoising, spectral balancing and variable time adjustment of every angle stack to optimize for further AVO work. EEI cubes (Intercept vs Gradient rotations) resulting in lithology and fluid cubes are also produced.

EM feasibility study

A 2D EM feasibility is performed for the Bolga prospect. The large target depth and relative complicated structural setting is challenging for an EM survey. The synthetic EM line crosses the Bolga Prospect from SE to NW. The background resistivity values are based on 2D inversion of EM data acquired in PL 559, the GRAP survey by EMGS. Background resistivity based on EM data is often a better resistivity estimate compared to well data since well log data in most cases only measures horizontal resistivity. Fig. 2.3 shows the horizontal and vertical resistivity of the synthetic model. The thick high resistive layer is included to account for sills. The resistivity in the expected reservoir is varied to determine the minimum transverse resistance which can be detected by an EM survey. Fig. 2.4 shows the inversion result for the 50 Ωm case. The frequencies used are 0.1, 0.1 0.4 and 1.0 Hz. The result is very patchy, however, an increase in resistivity following the reservoir is seen. For resistivity less than 50 Ωm this anomaly disappears. 50 Ωm in a 60m interval correspond to 3000 Ωm^2 transverse resistance as a lower detection limit. Since the NTG of the reservoir is probably much less than unity the resistivity in the hydrocarbon filled net reservoir sands need to be higher than the 50 Ωm to give the same transverse resistance. Based on the high transverse resistance necessary to detect the reservoir it is not recommended to use EM for prospect derisking.

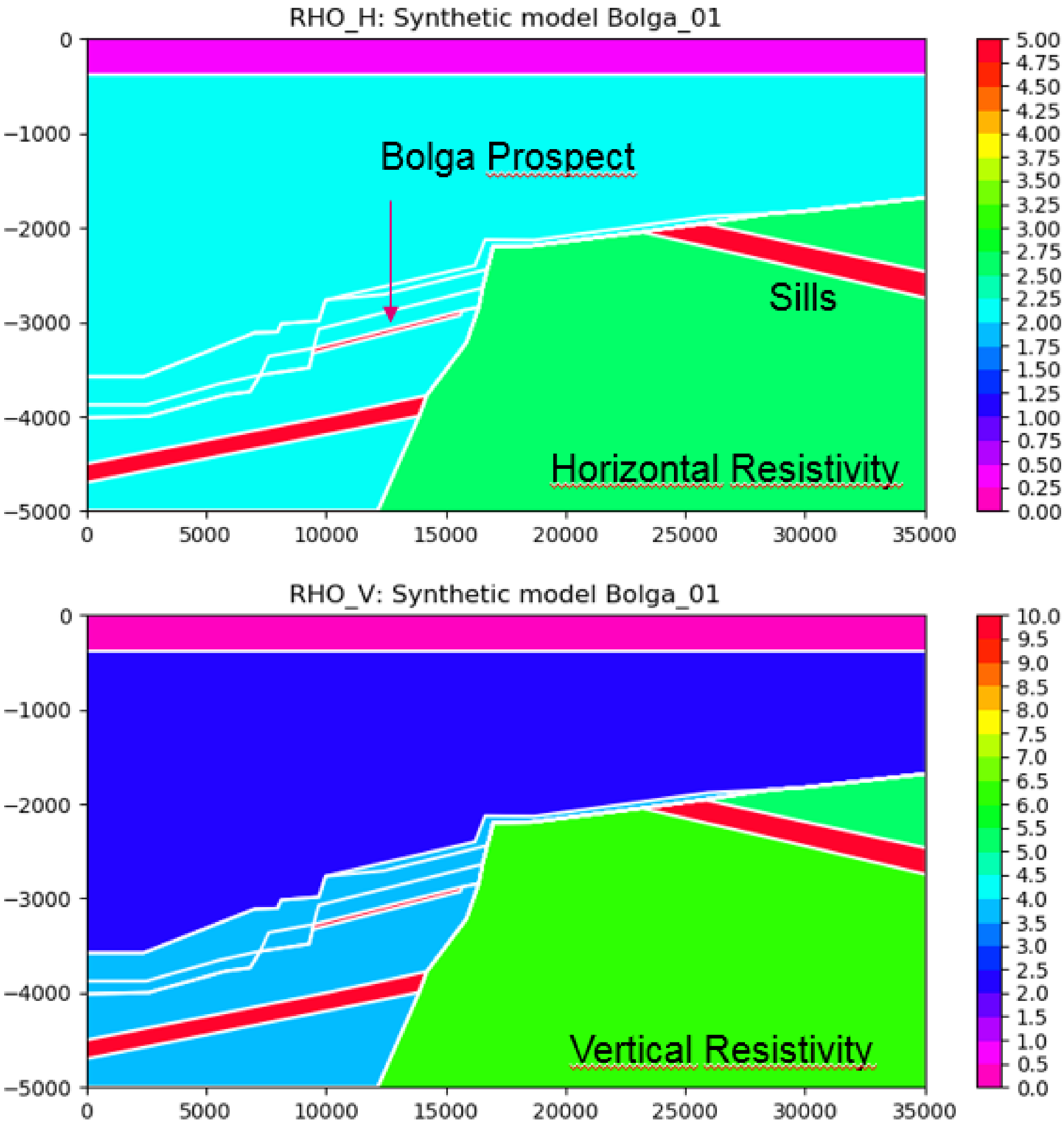

Fig. 2.3 Synthetic resistivity model *The upper panel shows the horizontal resistivity and the lower panel the vertical resistivity. The reservoir thickness is 60 m.*

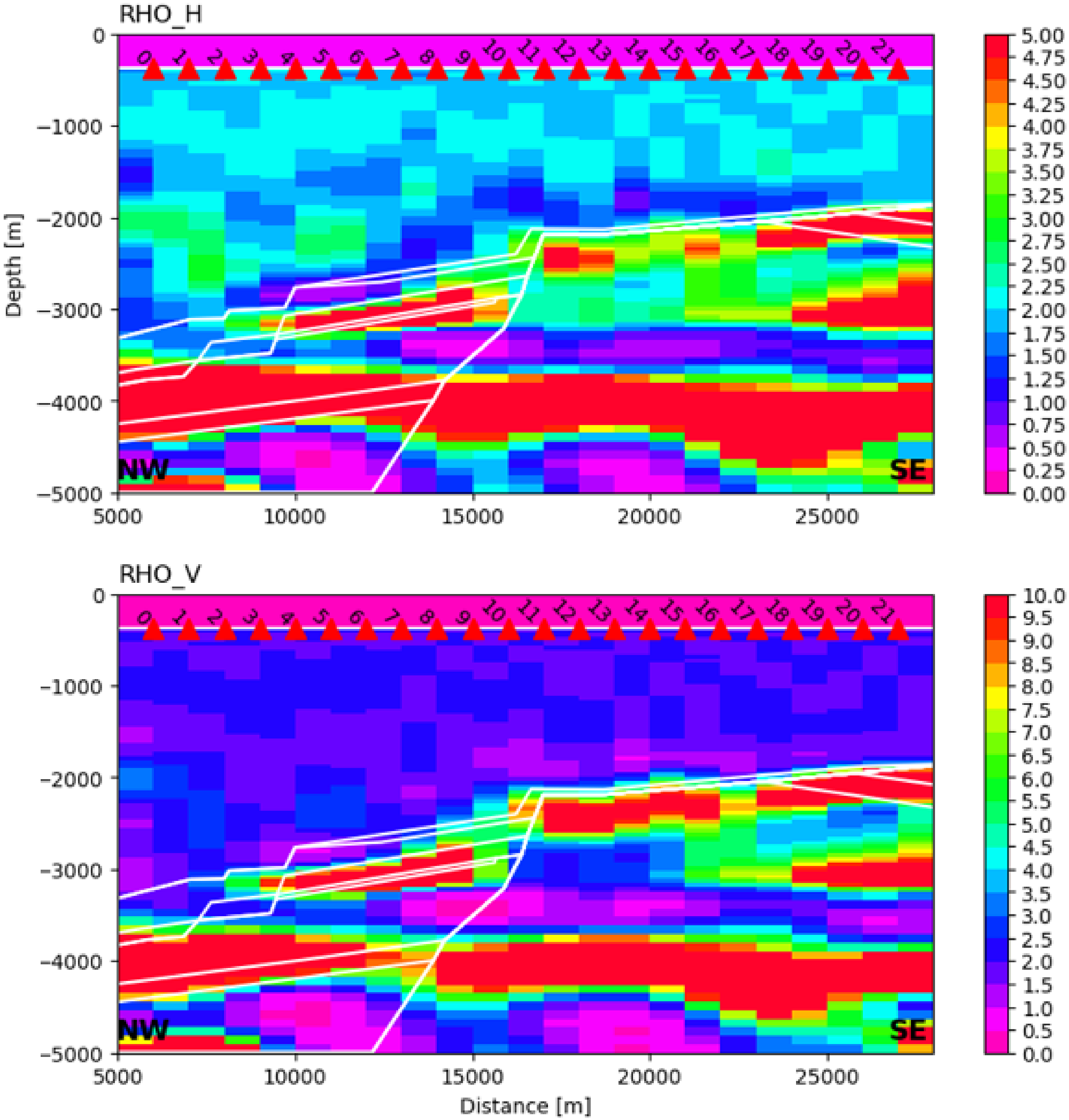

Fig. 2.4 Inversion result *The upper panel shows the horizontal resistivity and the lower panel the vertical resistivity. Random noise is added to the synthetic data.*

Spectral decomposition

Spectral attribute analysis through spectral decomposition (Partyka et al. 1999) on PGS16005 has been performed at several stratigraphic levels within the Lange Formation. The spectral decomposition was carried out in order to understand reservoir distribution, in particular to enhance the imaging of depositional patterns.

Spectral decomposition is a frequency transform of a relatively short time window to capture details from a certain stratigraphic interval. By decomposing the signal into discrete frequency bands, some details not distinguished in a full bandwidth signal will become visible.

No depositional patterns were observed from the result of the spectral decomposition analysis of the Lange Formation interval.

Geophysical modelling

Forward modelling and half-space modelling have been performed on the well 6610/3-1 R for the Lange, Lysing and Kvitnos Formation sands.

The forward modelling of the Upper Lange sands gives a peak dimming with angle. The half-space modelling of a clean Upper Lange sand gives a peak dimming in brine case and through brighting with angle in for both oil and gas case.

Since the Lange Formation sands are proven to be heterolithic sands with variable quality, different NTG and porosities have been taken into account when further modelling resulting in following:

A soft response brighting with angle can be observed for both a gas filled poor quality sand and a water-wet good quality sand (Fig. 2.5).

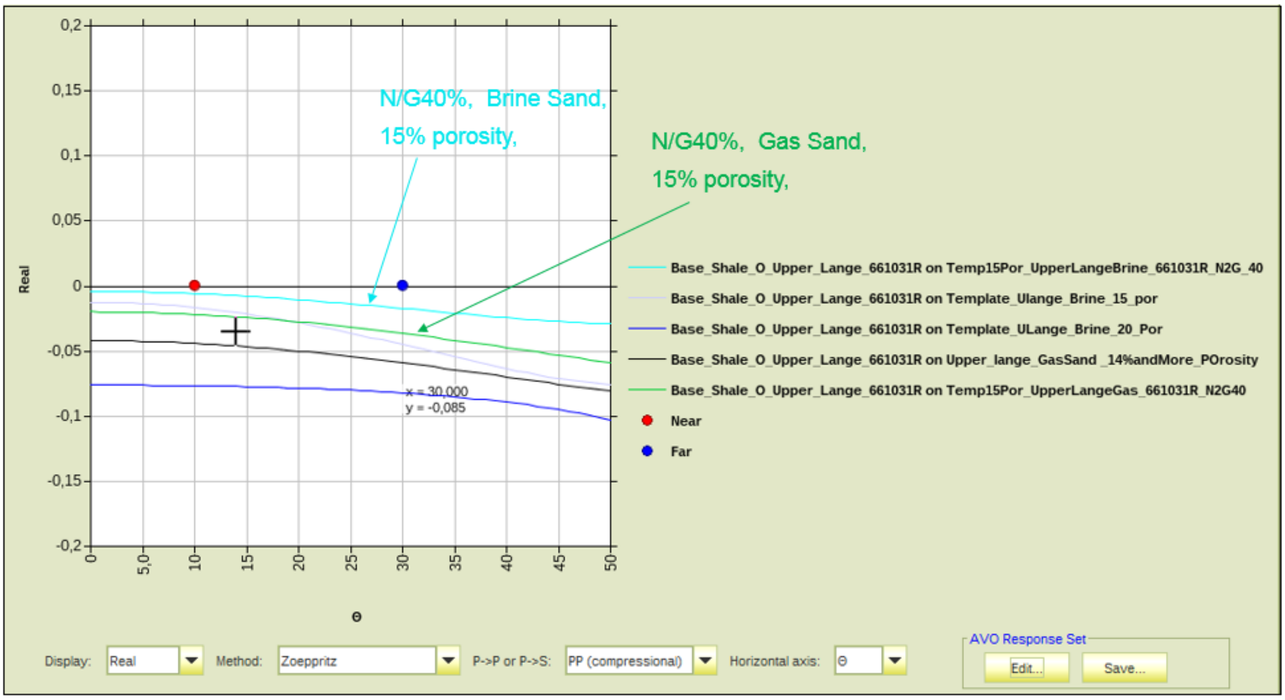

Fig. 2.5 Half-space modelling of 6610/3-1 R

3 Remaining Prospectivity

3.1 Bolga Prospect

The main prospect in the license is the Bolga Prospect, and is defined by an amplitude anomaly within the Lange Formation. The trap is a stratigraphic with Lange Formation shales being the top and base seal. In the east the prospect is dependent on detatchment of the reservoir sands and possible juxtaposition of the reservoir towards heterolithic Triassic succession across the main western fault of the Grønøy High (Fig. 3.1).

The Lange sands within the Bolga Prospect is interpreted to be density flows depositing within the major rift basin Træna Basin after the late Jurassic - Early Cretaceous rift period. The Træna Basin is interpreted to be a major depocenter throughout Cretaceous, with successions exceeding 15-17km. The sands deposited within this basin can be interpreted to have different source areas. The mainland Norway is the main topography subject to erosion, but also local highs as Nordland Ridge are also exposed and eroding into the Triassic successions.

6610/3-1 R well located northeast of the License proved two sandy sequences within the Lange Formation, and the uppermost heterolithic sequence is interpreted to be time equivalent to the reservoir in the Bolga Prospect (Fig. 3.2). Nevertheless, the sands are interpreted to be two local sands, potentially deposited from the Nordland Ridge/Grønøy High. The reservoir quality of the uppermost Cenomanian-Turonian sand in the 6610/3-1 R well is poor, giving 11% in porosity and 0.33 in NTG from the uppermost 60 meters of the heterolithic sands (Fig. 3.4).

The Spekk Formation is deeply buried in the Træna Basin, and most hydrocarbons sourced from Spekk as a potential source rock are expelled before the prospect is in place. Hence, Spekk is ruled out as a source rock after basin modelling of the area. The Bolga Prospect is believed to be sourced from Cretaceous shales, from a Blodøks equivalent (as in the North Sea), but is difficult to interpret and model. However, this source rock is proven in Aasta Hansteen in west and in the Elida/Midnattsol discoveries in the southern part of the Norwegian Sea.

Sills from the volcanic activity in the Palecoene/Eocene period can be interpreted throughout the area, and a major sill complex is interpreted below the Bolga Prospect leading to and up the western bounding fault of Grønøy High (high reflective reflectors in Fig. 3.1). This form an additional risk to the trap of the Bolga Prospect. Only a minor amount of hydrocarbons are expelled since Eocene times.

Amplitude anomaly

The Bolga Prospect is defined as a soft amplitude anomaly, brighting with offset data (Fig. 3.3). After geophysical modelling (forward modelling and half-space modelling) of the 6610/2-1 R well, the soft amplitudes in the Bolga Prospect are believed to represent two possibilities:

- Gas filled poor quality sands
- Water wet good quality sands

Corresponding amplitude response is observed in the 6610/3-1 R well, but the well is classified as dry (scattered shows observed throughout the well).

The amplitudes within the prospect are neither depth consistent, and it is therefore a significant risk that the observed anomalies mainly relates to lithology and not presence of hydrocarbons.

Main risks: Trap and source & migration.

Volumes

A gas case is calculated for the Bolga Prospect.

The GRV is calculated using the area vs depth method of the top reservoir surface and using a constant thickness of the reservoir (63m from the Upper Lange Fm in well 6610/3-1R).

Petrophysical parameters as input to the volume calculation is summarised in Table 3.1. Well 6610/3-1 R is used as minimum case based on geophysical modelling on the well.

Table 3.1 Petrophysical parameters and recovery factors

Parameter	Min	Mode	Max
N/G	0.33	0.4	0.5
Porosity	0.11	0.15	0.18
Gas saturation	0.1693	0.1776	0.1855
Recovery factor Non assoc. Gas	0.45	0.55	0.65
Recovery factor Condensate	0.35	0.45	0.55

Table 3.2 Bolga Prospect: Risk and total recoverable volumes

Prospect	Bolga Prospect		
Reservoir	0.81		
Trap	0.24		
Charge	0.42		
Retention	1		
COS	0.082		
	P90	Mean	P10
Total Rec. volumes (MM Sm3): Spread in HC column (200-300-500m)	1.64	2.9	4.5
Total Rec. volumes (MM Sm3): Filled to spill*	5.86	7.93	10.2

* Filled to spill results in a HC column of 780m, hence an additional case with spread in HC column is calculated in.

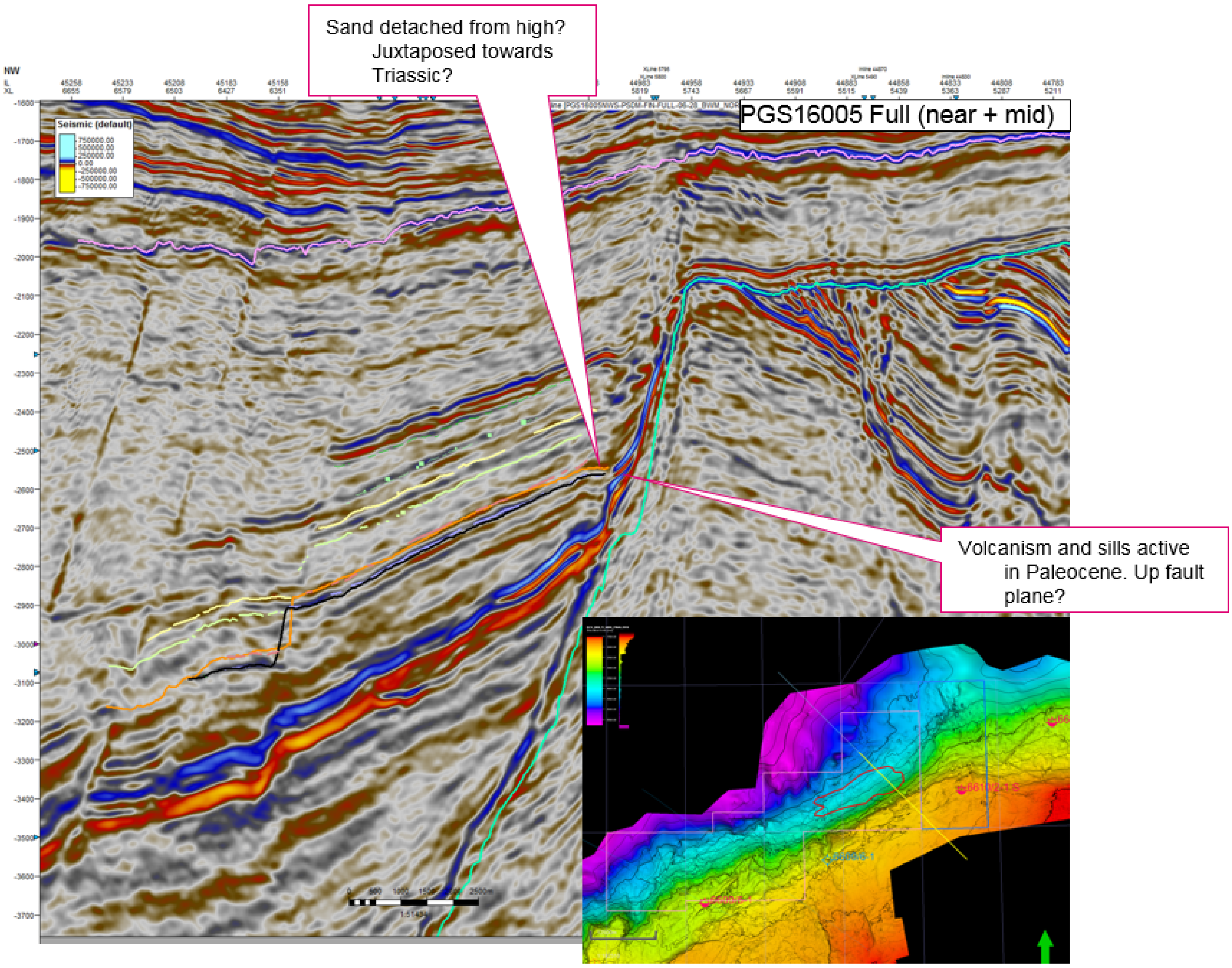

Fig. 3.1 Upper Lange Fm Bolga Prospect target *Illustrating the trap risks; sills below the prospect and leaking up along the main fault, the risk of reservoir sands not being detatched from the High and potential juxtaposition towards Triassic on the Nordland Rdige/Grønøy High.*

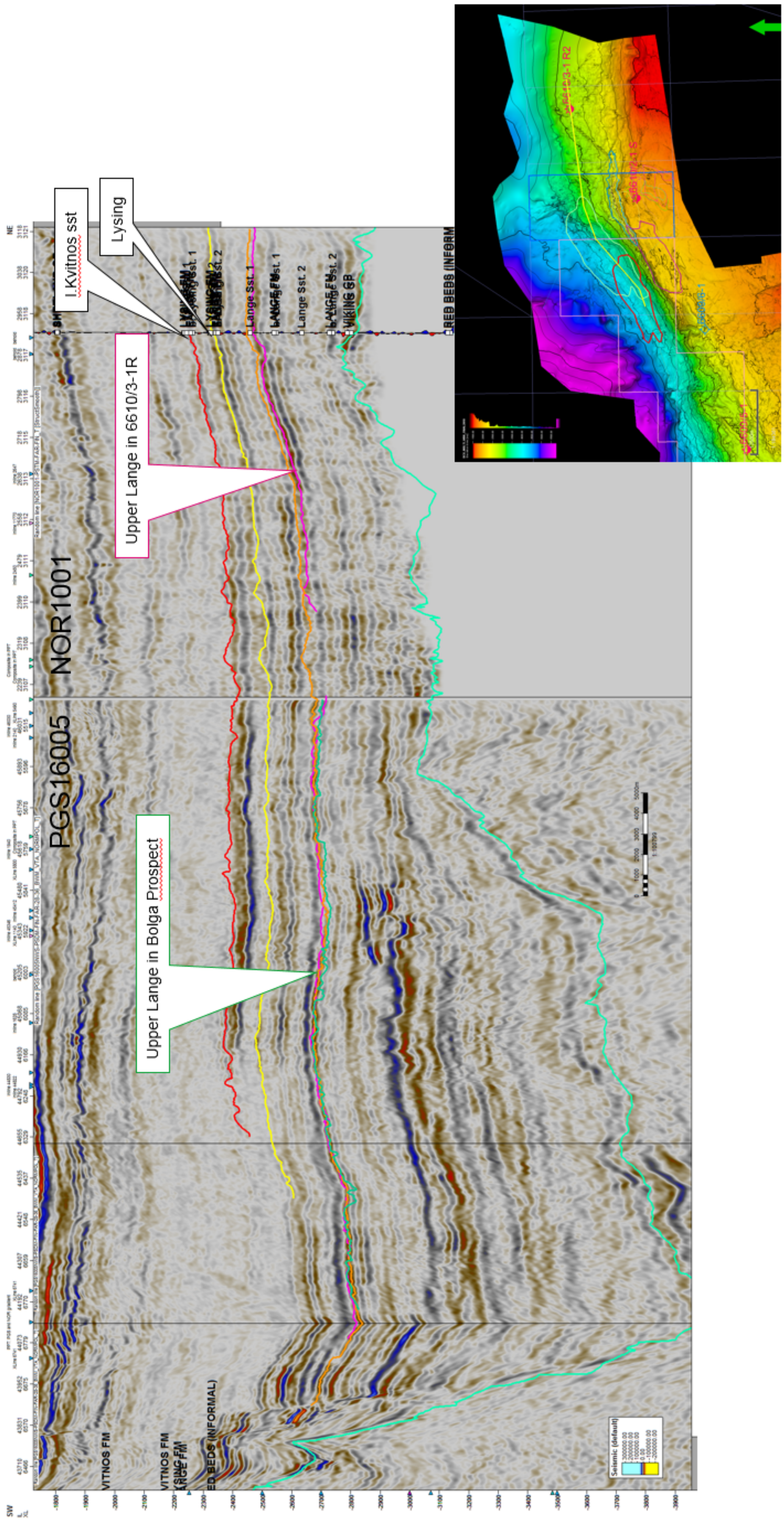

Fig. 3.2 Cretaceous interpretation *From 6610/3-1R in NE to the Bolga Prospect in SW*

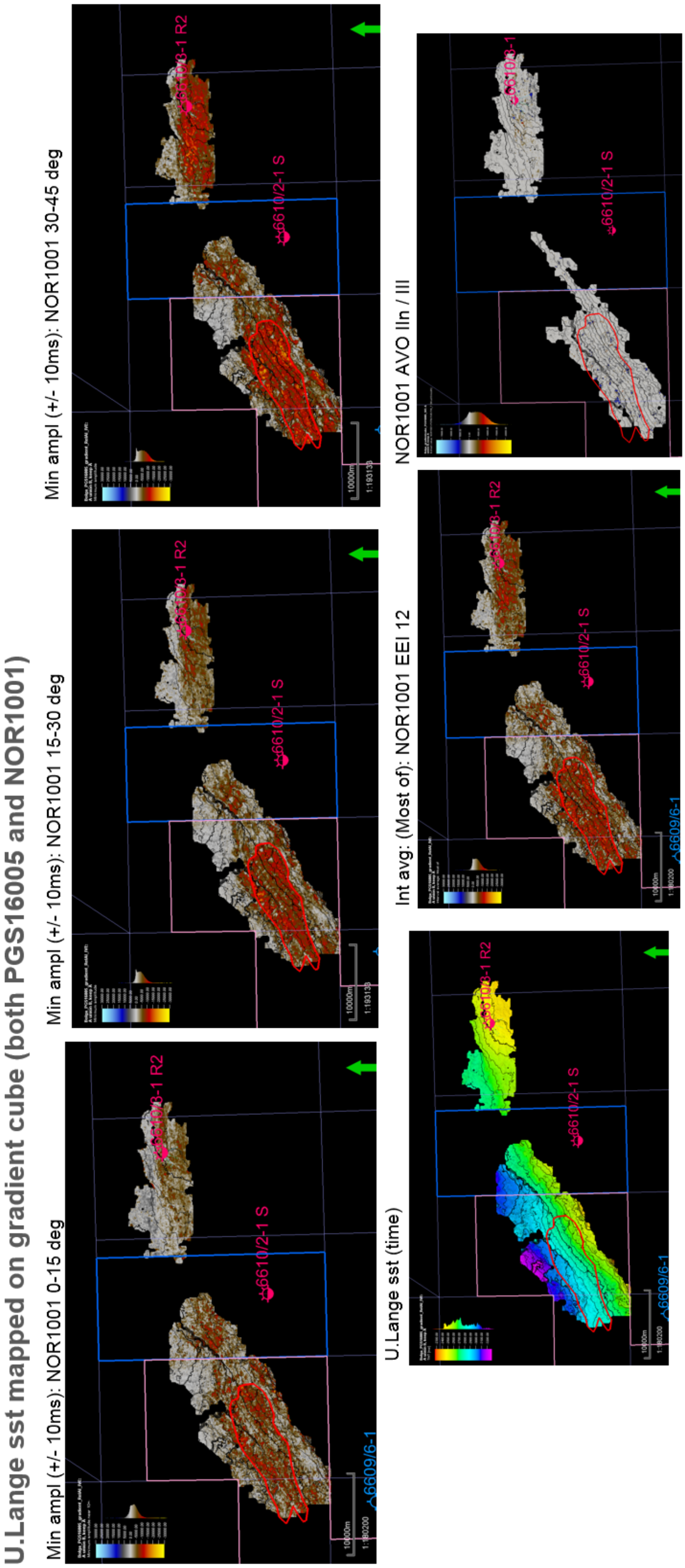

Fig. 3.3 Bolga Prospect maps *Time map, minimum amplitude attribute maps on angle stacks, EEI fluid cube and AVO cube.*

- Kvitnos sst:
  - Gross: 37.5m
  - NTG: 0.19 (net 7.1m)
  - Por: 10% (PHI_T_model)
- Lysing sst:
  - Gross: 40m
  - NTG: 0.49 (net 19.7m)
  - Por: 10.2% (PHI_T_model)
- U.Lange sst case 1:
  - Gross: 63m
  - NTG: 0.33 (20.4m)
  - Por: 0.11 (PHI_T_model)
  - The best sand stringers around ~15% porosity

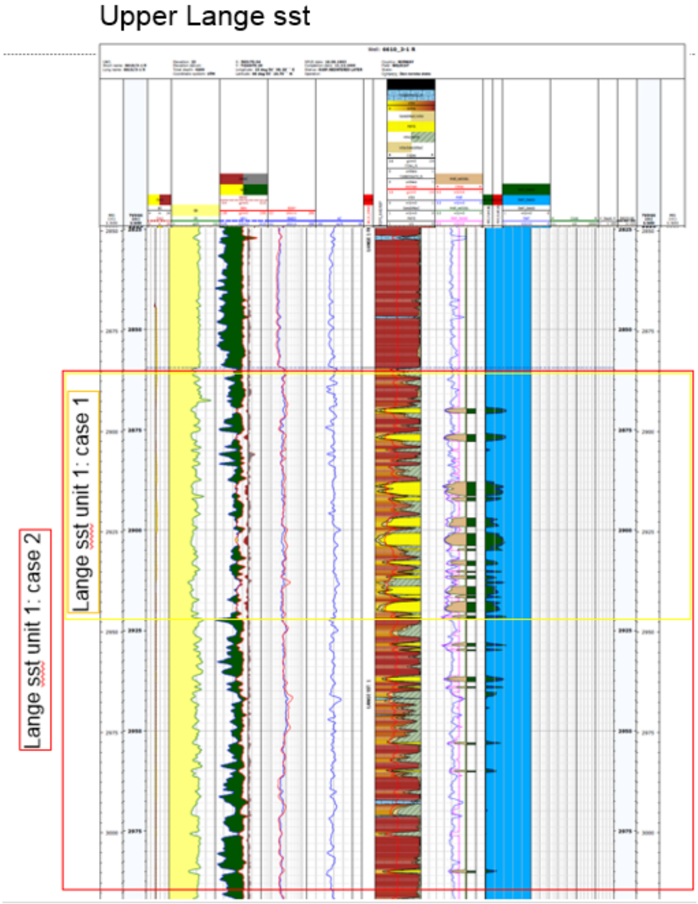

Fig. 3.4 CPI for Cretaceous targets *Kvitnos, Lysing and upper Lange Fm levels.*

3.2 Lysing Sandvær Lead

A Lysing Lead (Sandvær) is defined partly within the License. The remaining part of the prospect extends into the PL948 in east.

The lead is defined on an amplitude anomaly, soft response brighting with offset, and is dependent of a stratigraphically trap (Fig. 3.5). A similar response is drilled by the well 6610/3-1 R proving Lysing sands around the western margin of Nordland Ridge/Grønøy High, the reservoir quality is summarised in Fig. 3.4. The well was dry, and the amplitude anomaly is believed to be a lithology effect rather than fluid indicator.

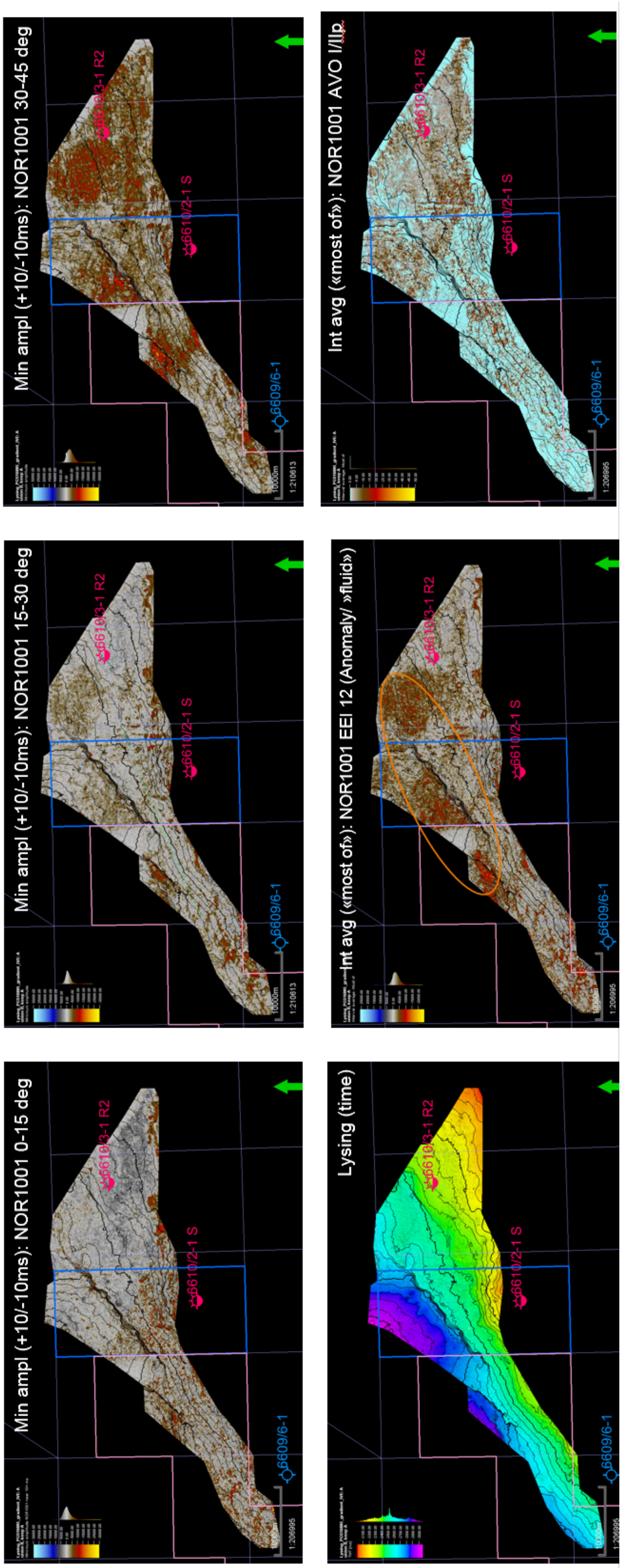

Fig. 3.5 Lysing maps *Time map, minimum amplitude attribute maps on angle stacks, EEI fluid cube and AVO cube*

3.3 Paleocene Lead

A Lead within the Paleocene is defined within the Tang Formation within the block 6609/3 of the license. This is a structural closure on the top Tang Formation level, and the area of the closure is approximately 17.7 km2 (Fig. 3.6). The well 6610/3-1R drilled a thick succession (165m) within the Tang Fm with excellent quality.

No depth consistent amplitudes is observed on this closure (Fig. 3.6).

A series of small closures on Tare Formation stratigraphical level are also interpreted (Fig. 3.7). The closures are located above the western bounding fault of the Nordland Ridge/Grønøy High, and seem to be linked to the volcanic activity in the Paleocene/Eocene. Neither of the nearby wells have proven the Tare Formation to be sandy in the area.

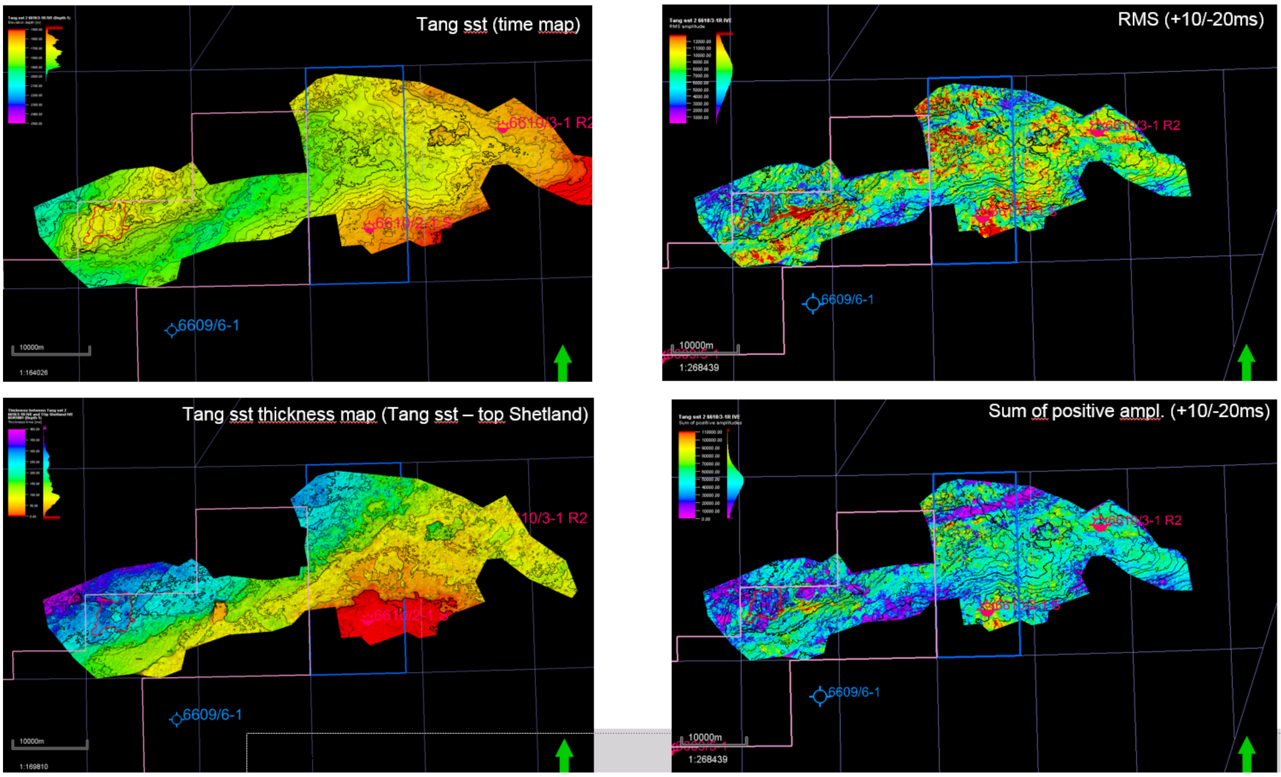

Fig. 3.6 Time map, thickness map and ampltiude maps of the Tang Fm

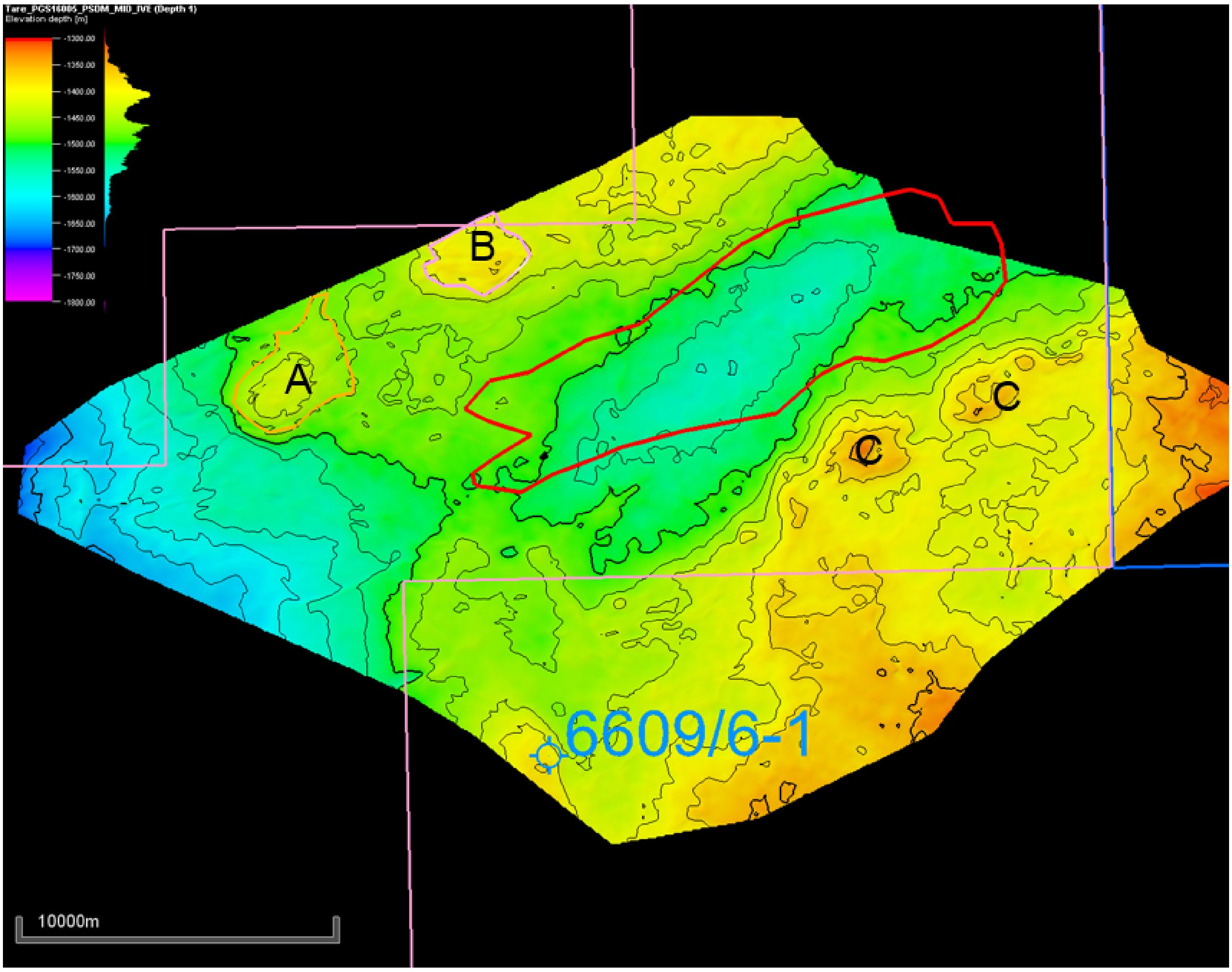

Fig. 3.7 Closures on the Tare Formation time map *A (8.6km2) and B (5km2) structural closures, C structural closures linked to volcanic activity. Only minor sand stringers are observed in nearby wells in Tare Fm.*

3.4 Triassic Valvær Lead

A Triassic Lead Valvær is defined partly within the License. The remaining part of the prospect extends into the PL948 in east.

The lead is defined as a sub-salt lead, and the top reservoir is interpreted on the lowermost salt layers in the Triassic. The crest of the structure is eroded, and Cretaceous sands are onlapping the high (present in 6610/2-1S), leaving high risk on the trap (Fig. 3.8, Fig. 3.9).

The reservoir quality in the sub-salt succession is uncertain as most sand in the Triassic succession are proven to be above the salt layers in the youngest Triassic. But continental deposits and fluvial systems are rapidly changing laterally, and challenging to predict on seismic since it is often a matter of seismic resolution. The well 6610/7-2 south of the license area is the closest well drilling through the salt, and proved a mud-prone sub-salt succession.

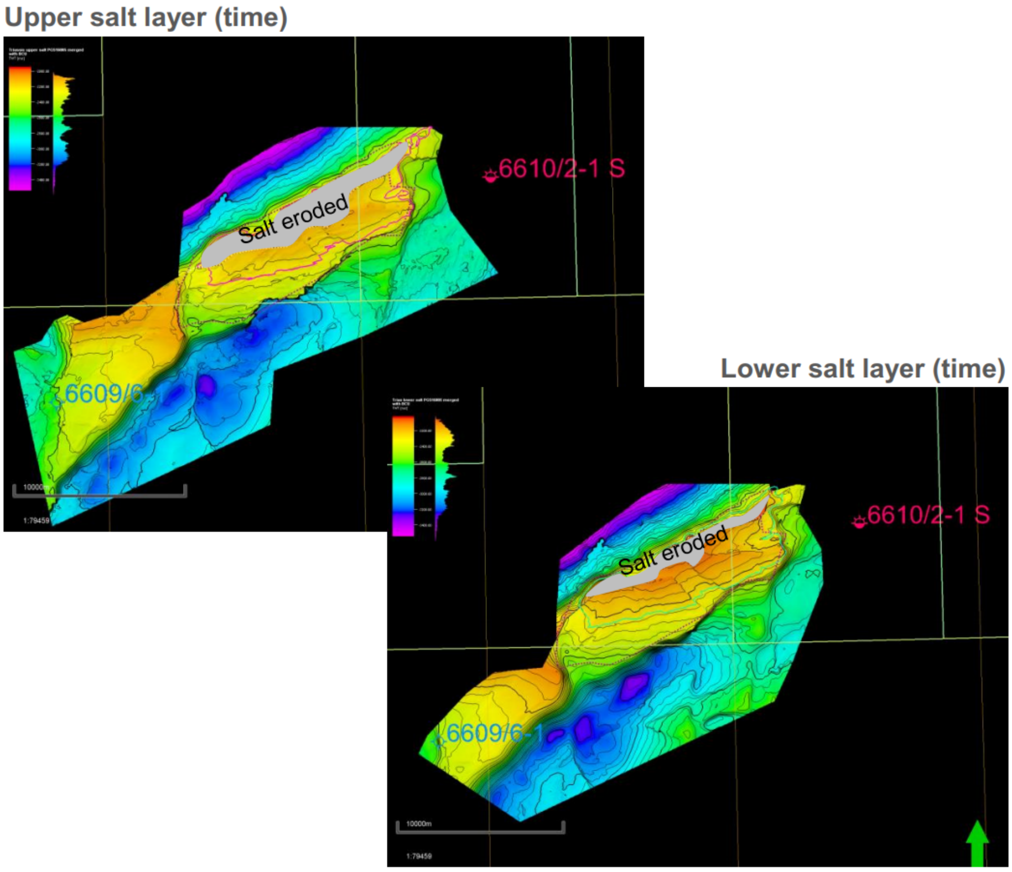

Fig. 3.8 Triassic Lead time maps *The map is merged with the BCU interpretation over the eroded crest and in the basin the the NW*

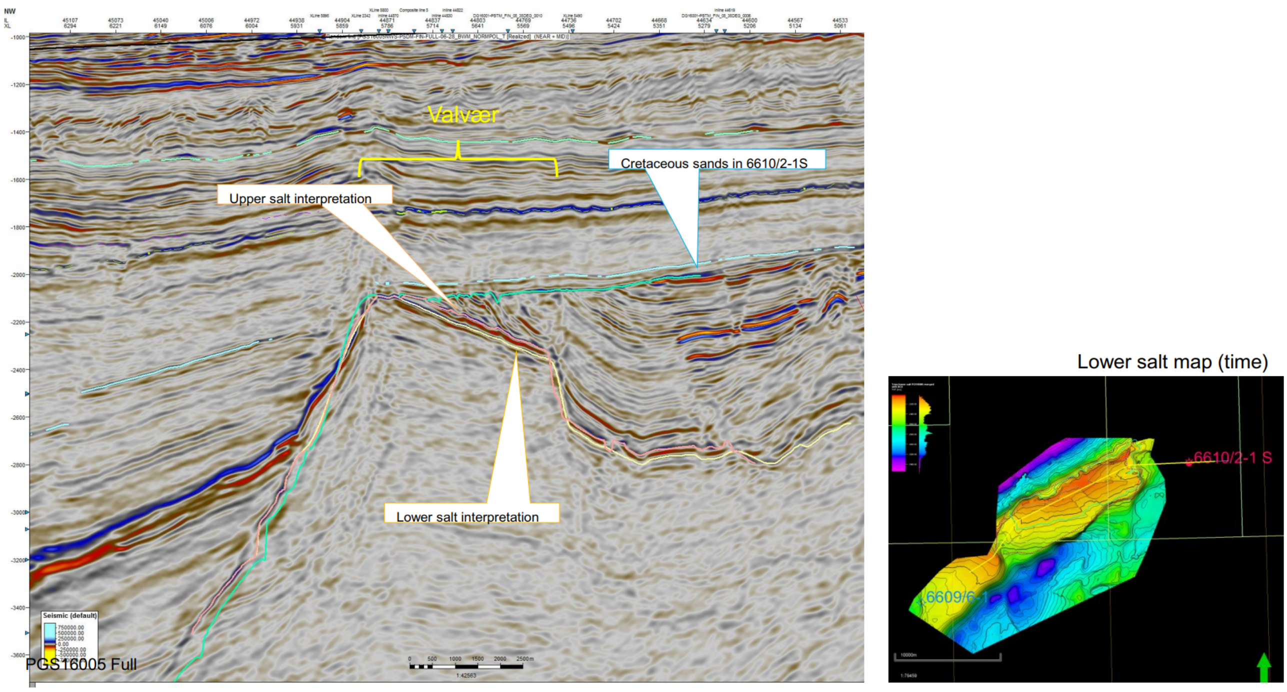

Fig. 3.9 Triassic Lead dip line

4 Conclusion

One prospect is defined in the PL895, the Bolga Prospect. The prospect is identified as an amplitude anomaly, but with no depth consistency. The amplitudes are believed to represent lithology.

Main risks are trap and source & migration, and the volume potential has decreased significantly with interpretation on 3D seismic (PGS16005).

The three mapped leads in Triassic, Lysing and Paleocene all have significant risk on reservoir, trap and charge.

5 References

Partyka et al. (1999): Interpretational applications of spectral decomposition in reservoir characterization, The Leading Edge, Vol.18, 353- 360.

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