Relinquishment Report PL 583

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1 Key license history

The production License 583 was awarded to Spring Energy Norway AS (30%, operator), Svenska Petroleum Exploration AS (25%), Bayerngas Norge AS (25%) and Lundin Norway AS (20%) after the APA 2010. The license became effective the 4th of February 2011.
Spring Energy AS was later purchased by Tullow Oil in 2013. Svenska Petroluem Exploration AS was purchased by DetNorske in 2015. Bayerngas Norge AS and Lundin Norway AS dropped the license in 2015, when the remaining partners took over the license shares. The final license configuration was Tullow Oil Norge AS 55% and DetNorske 45%. Fig. 1.1 shows the license area including mapped prospects and leads.

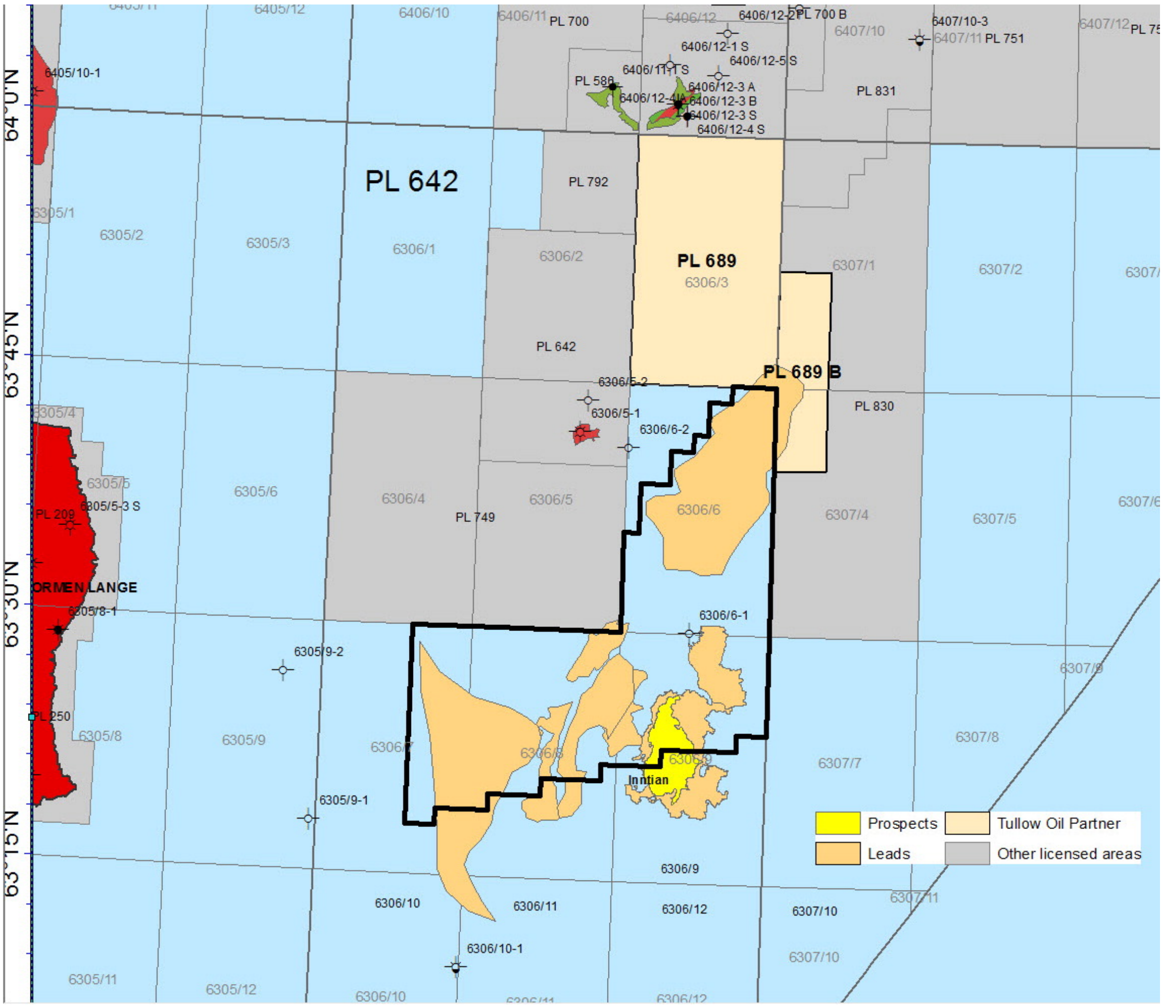


Fig. 1.1 Area of the PL583 license.

In order to try to improve the seismic data quality the license was granted extensions of the license period three times. One additional year in both 2013 and in 2015, and three extra months in 2016.

The work commitment of the license was to acquire a new 3D, and to reprocess vintage 2D lines. The work commitment has been fulfilled.

A unanimous decision to relinquish the licence was taken by the PL583 Management Committee in May 2016.

2 Database

Seismic database

The work commitment for PL583 was to acquire 2D and 3D seismic data. The license group decided to acquire a new 3D data set, and to reprocess a selection of vintage 2D seismic lines. The new 3D seismic data is named SEN1101 (Fig. 2.1). In 2014, a site survey was acquired (TUN14301), this dataset is included in the common license database. The seismic 2D lines which are a part of the common license database, are listed and shown in Fig. 2.1.

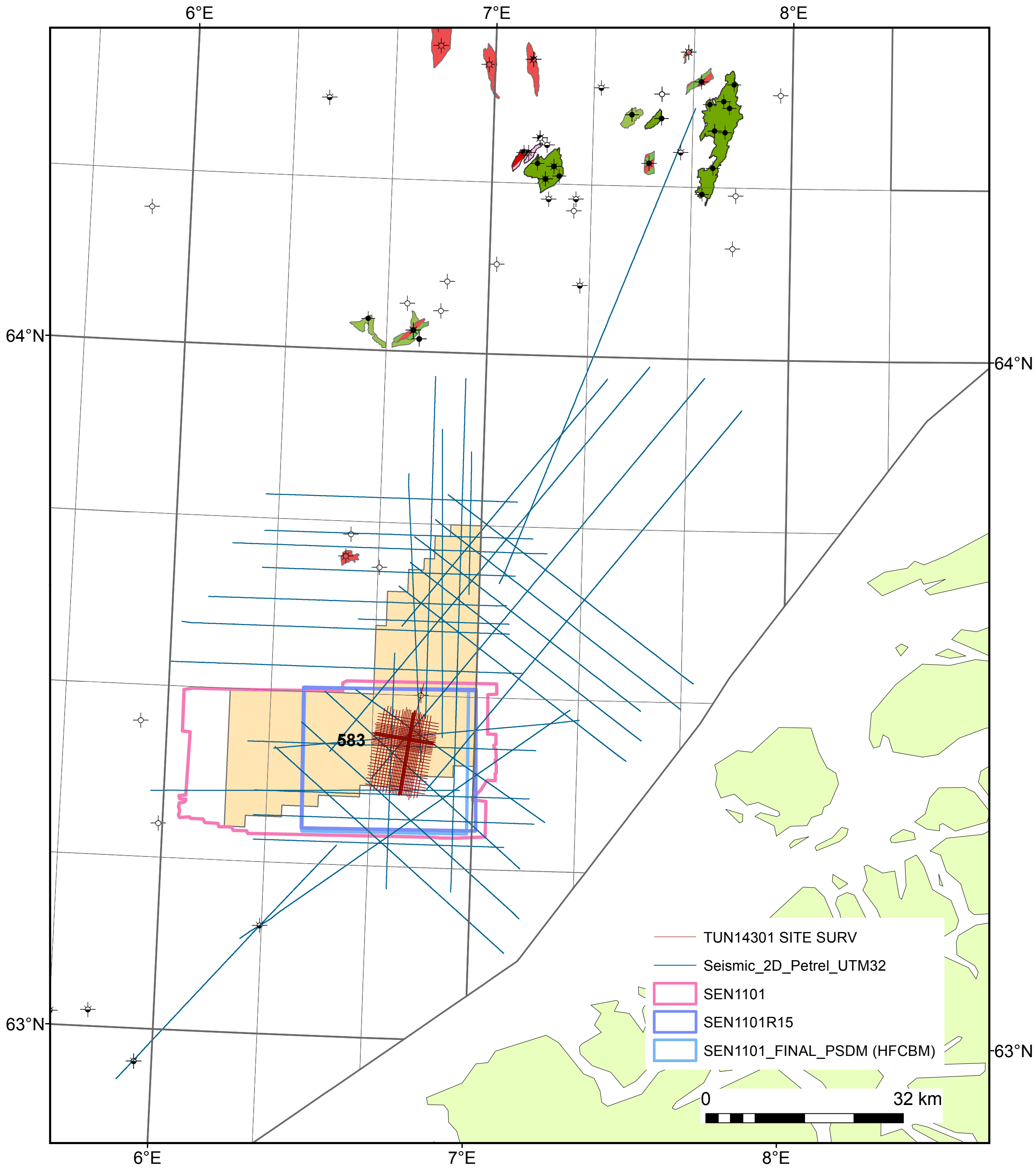


Fig. 2.1 PL583 geophysical database. *Also shown are the 2D seismic reprocessed by the PL583 license.*

The SEN1101, together with both the reprocessed vintage 2D lines, and the site survey, has formed the base for all technical work, in addition, multiple geophysical data products has been utilized, i.e. angle stacks, simultaneous elastic inversion and rock physics litho-cubes.

Fig. 2.1 shows the 2D seismic data acquired and reprocessed by the license.

At an early stage all the refraction data were collected. This added more information on the velocities in the basement, but also showed limited resolution.

The SEN1101 3D cube was reprocessed by SIP in 2015. The main goal was to improve the velocity field in order to try to enhance the imaging of the pre Cretaceous layers.

QEYE undertook an inversion of the SEN1101 PSDM data. Unfortunately, no firm conclusions on either hydrocarbon phase, nor reservoir quality could be established.

Well database

The well database was selected to include key wells within vicinity of the licensed area, in order to make a robust structural framework. It was also decided to include IKU shallow stratigraphic wells along the Møre margin, since these also contain important information regarding expected reservoir parameters and facies.

The following wells constituted the PL583 common well database: 6306/6-1, 6306/6-2, 6306/5-1, 6305/9-1, 6306/10-1, 6305/8-1, 6406/11-1S, 6307/7-U-2, 6307/7-U-3, 6407/9-1, 6406/12-1S, 6406/12-2, 6407/10-1, 2 & 3 (Fig. 2.2).

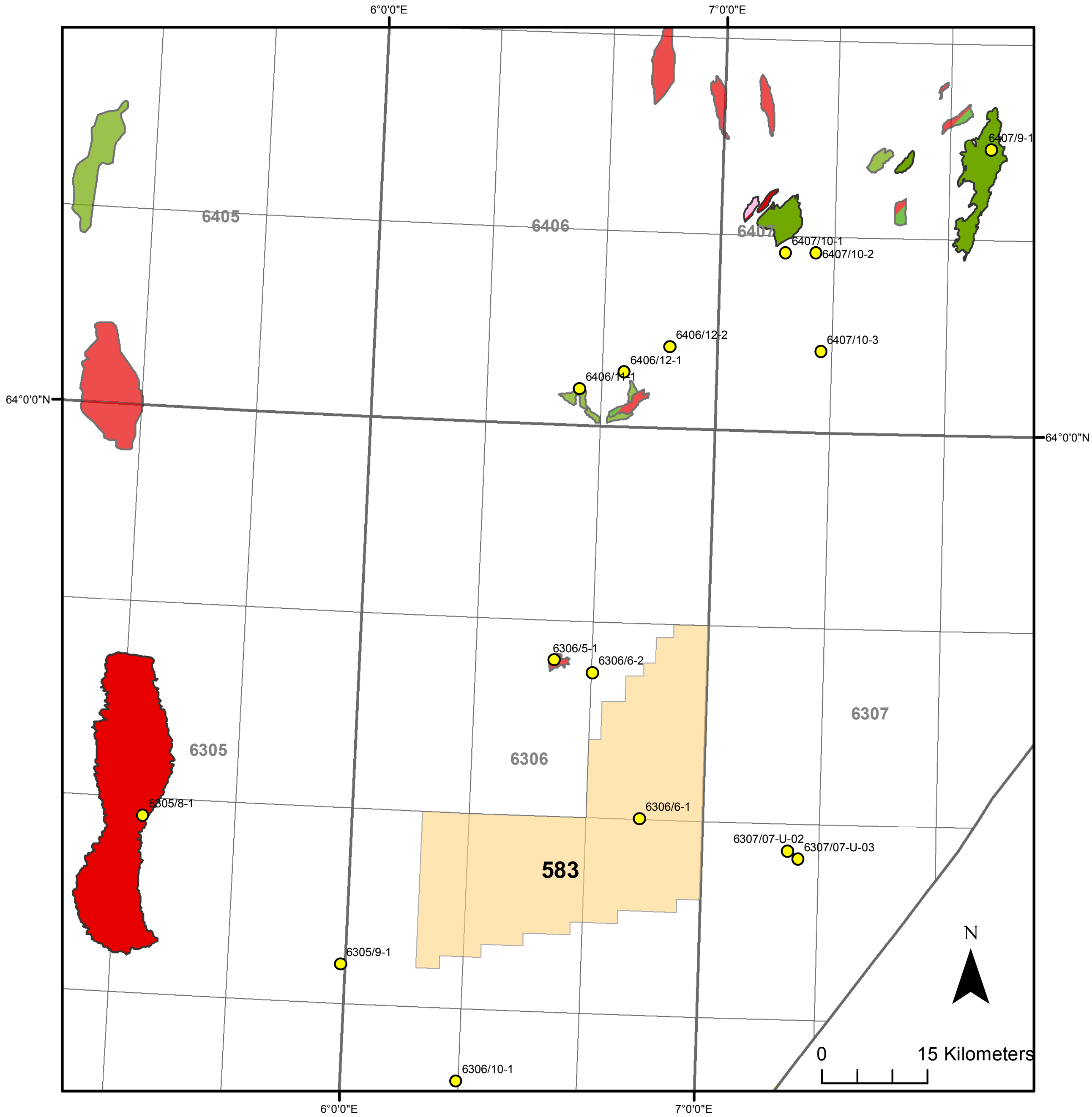


Fig. 2.2 PL583 well database. *The well database for PL583 were selected based upon relevance for the main plays (see Table 4.1).*

3 Review of geological framework

The Frøya High is a N-S oriented basement high, about 120 km long and 30-40 km wide. The Frøya High is a part of the Trøndelag Platform. The High is delimited towards the west by the Klakk Fault Complex from the Møre Basin. Towards the north the Vingleia Fault Zone delimits the Frøya High from the Halten Terrace, and the eastern margin is defined by the fault zone separating it from the Froan Basin.

The Late Jurassic rifting phase, had significant effect on structuring of the PL583 area, i.e. deep erosion of structural highs and rotated fault blocks. The Upper Jurassic Viking Group consists of the Melke, Spekk and Rogn Fms. The Melke and Spekk Fms were deposited in marine shelf conditions with limited coarse clastics from elevated provenance areas. The Rogn Fm is deposited in structurally elevated areas in a nearshore environment adjacent to local provenance areas. The rifting phase lasted into Early Cretaceous whereby the Møre and Vøring basins subsided rapidly. Renewed rifting was initiated during Late Cretaceous/Early Tertiary times as the initial stage of sea-floor spreading occurred. The whole of the Haltenbank area developed subsequently into a passive, subsiding continental margin controlled by sediment loading and lithospheric cooling and contraction Fig. 3.1.

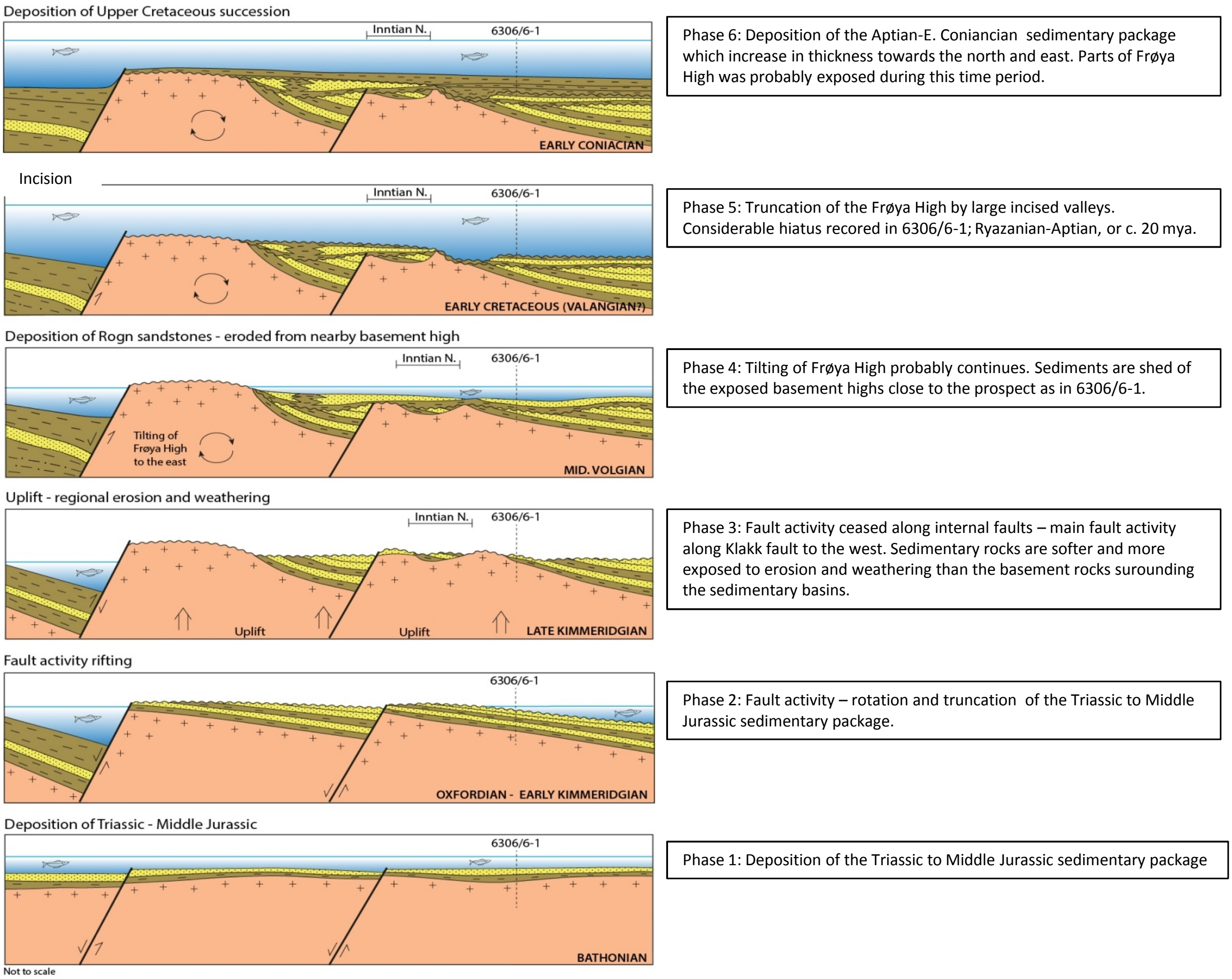


Fig. 3.1 Geological development of the Frøya High. *Cartoon diagram highlights the most important phases in the Upper Jurassic play model on the Frøya High.*

The sandstones cored in well 6306/6-1 are likely to be representative of the main reservoir facies for the main prospect with PL583; the Inntian prospect. The core in well 6306/6-1, taken towards the top of the Upper Jurassic unit, consists of fine to coarse grained sediments with up to 30% porosity and 200 mD permeability. Locally there are cemented horizons, reflecting limited clastic input. The Upper Jurassic facies distribution highly controlled by local tectonics. The resulting lateral facies distribution is expected to change drastically and so are the vertical facies stacking patterns. Based on detailed well and seismic studies a detailed map of Rogn Fm sand distribution map was made for the PL583 area (Fig. 3.2).

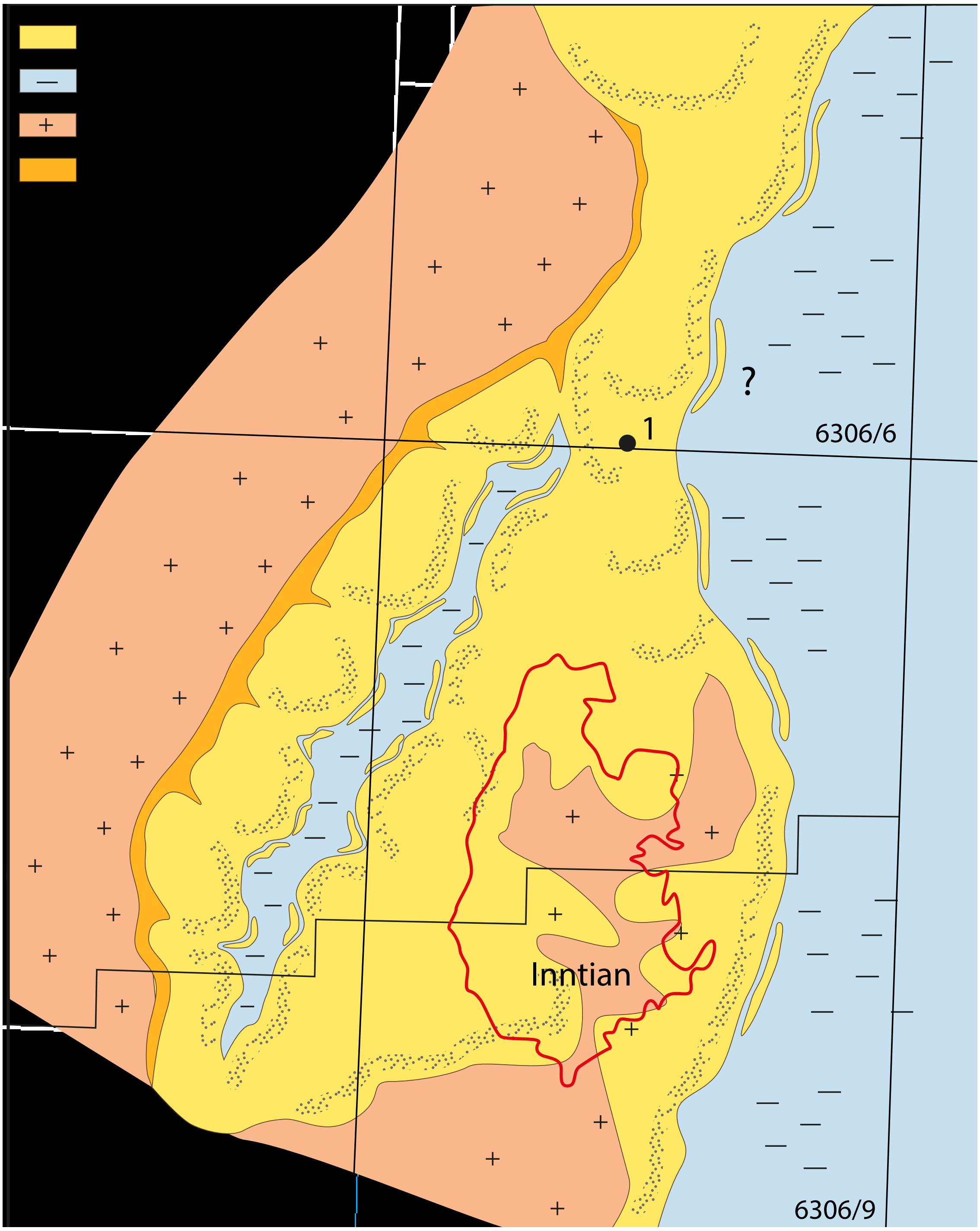


Fig. 3.2 Distribution of the Rogn Fm sandstone in the PL583 area. *Map has been based on BCU-Basement isopach, depositional patterns from Geoterric Frequencey blending and well 6306/6-1.*

A large 4-way closure at top basement level, just below the Inntian prospect, has been mapped. Consequently, a lot of effort has been undertaken in order to unravel reservoir properties within the basement (Fig. 3.3).

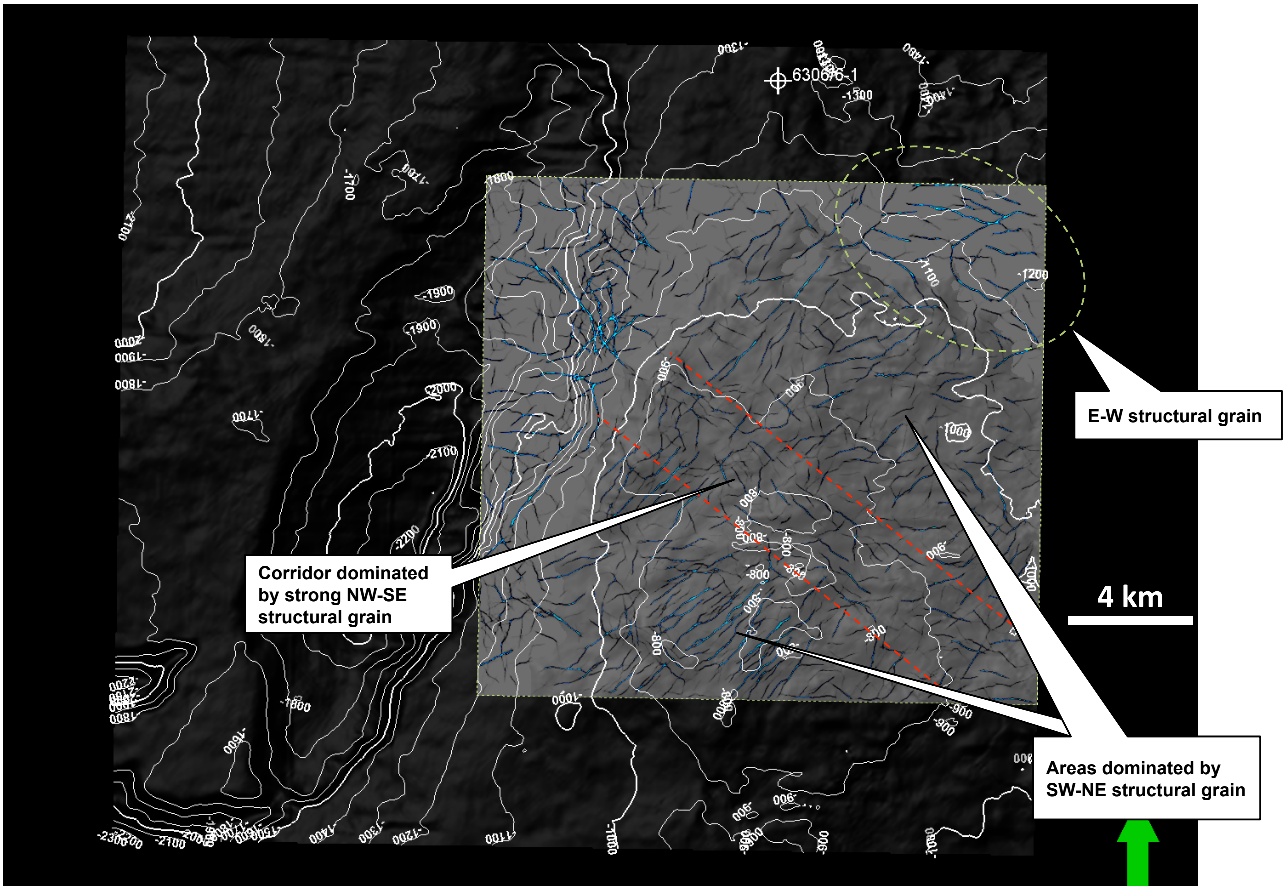


Fig. 3.3 Faults and fractures in the basement. *From the basement study in the PL 583 the license. Shows top basement (transparent) and time slice from ant track cube (z= -1068 ms TWT).*

Given the relative shallow depth to basement (>1000m), a risk for biodegradation of any reservoired is likely.

A number of geological and geophysical studies have been performed:

- Volcanic Basin Petroleum Research (VBPR) mapping of sill and intrusions
- Earlier sampled seabed intrusions were re-analysed with respect to age and composition
- PL583 cruise that sampled several identified locations, both gas chimneys and mud volcanoes
- Descriptions of the basement rocks in the area, together with new descriptions of already sampled basement rocks in the exploration wells in the area
- In-house Tullow rock physics and AVO screenings
- Tullow internal sedimentological review of the Upper Jurassic stratigraphy and facies on and around the Frøya High
- Tullow internal petroleum system modelling studies to increase understating of migration and sensitivities of biodegradation

4 Prospect update

The PL583 license contain one main prospect (Inntian prospect) and several leads.

Inntian Prospect

Inntian is interpreted as a 4 way dip closure trap at Base Cretaceous level. The closure is present in both time and depth domain, and has been mapped in all of the seismic volumes acquired across the structure. The main reservoir is Upper Jurassic Rogn Fm, proved in the nearest well (6306/6-1), and in several other wells on the Frøya High. A depth structure map of the Inntian prospect is shown in Fig. 4.1.

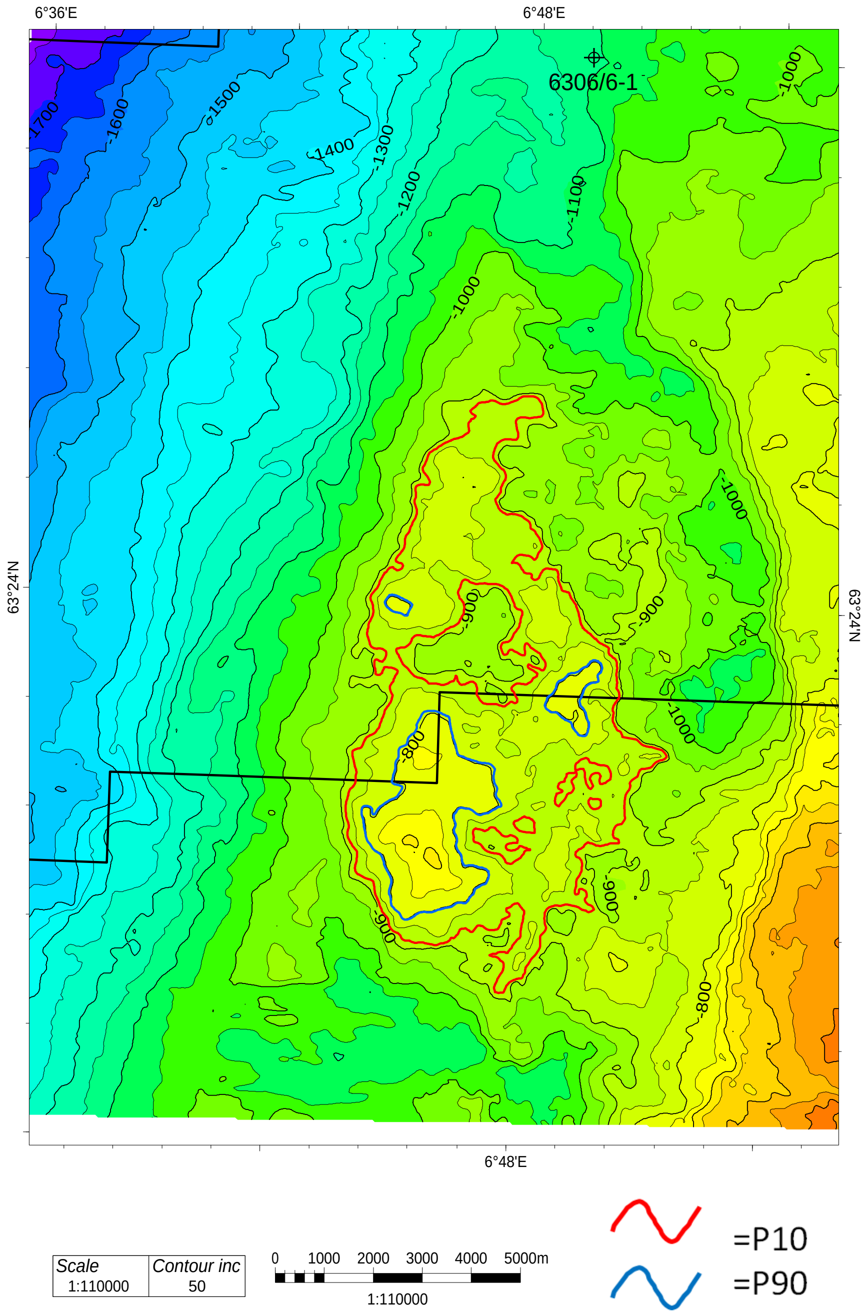


Fig. 4.1 BCU depth map, highlighting the P90 and P10 Inntian prosepct outlines

Top and base of the Rogn Fm inside the isopach between BCU and Top Basement is very hard to interpret with confidence within the closure area. The seismic sections in Fig. 4.2 and in Fig. 4.3 illustrates this. The partly poor seismic imaging is probably due to the rather heterogeneous nature of the reservoir, with rapid facies variations both laterally and vertically as discussed in 3 Review of geological framework. Another challenge regarding the seismic imaging of this region, are the numerous volcanic sill and dykes, see Fig. 4.3.

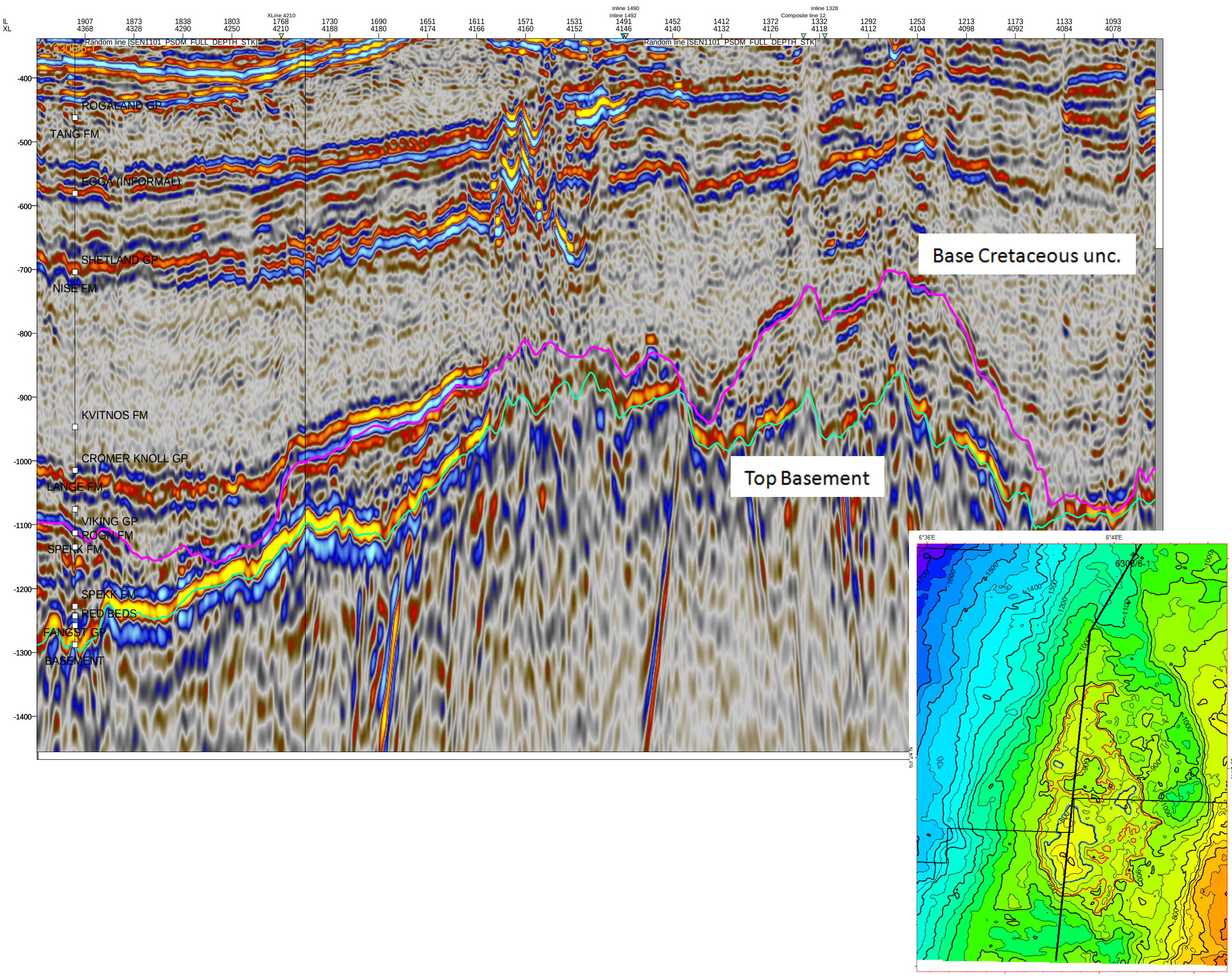


Fig. 4.2 North-South Seismic section through the Inntian prospect. *Seismic line is in depth (m). North is left and south is right on the seismic section.*

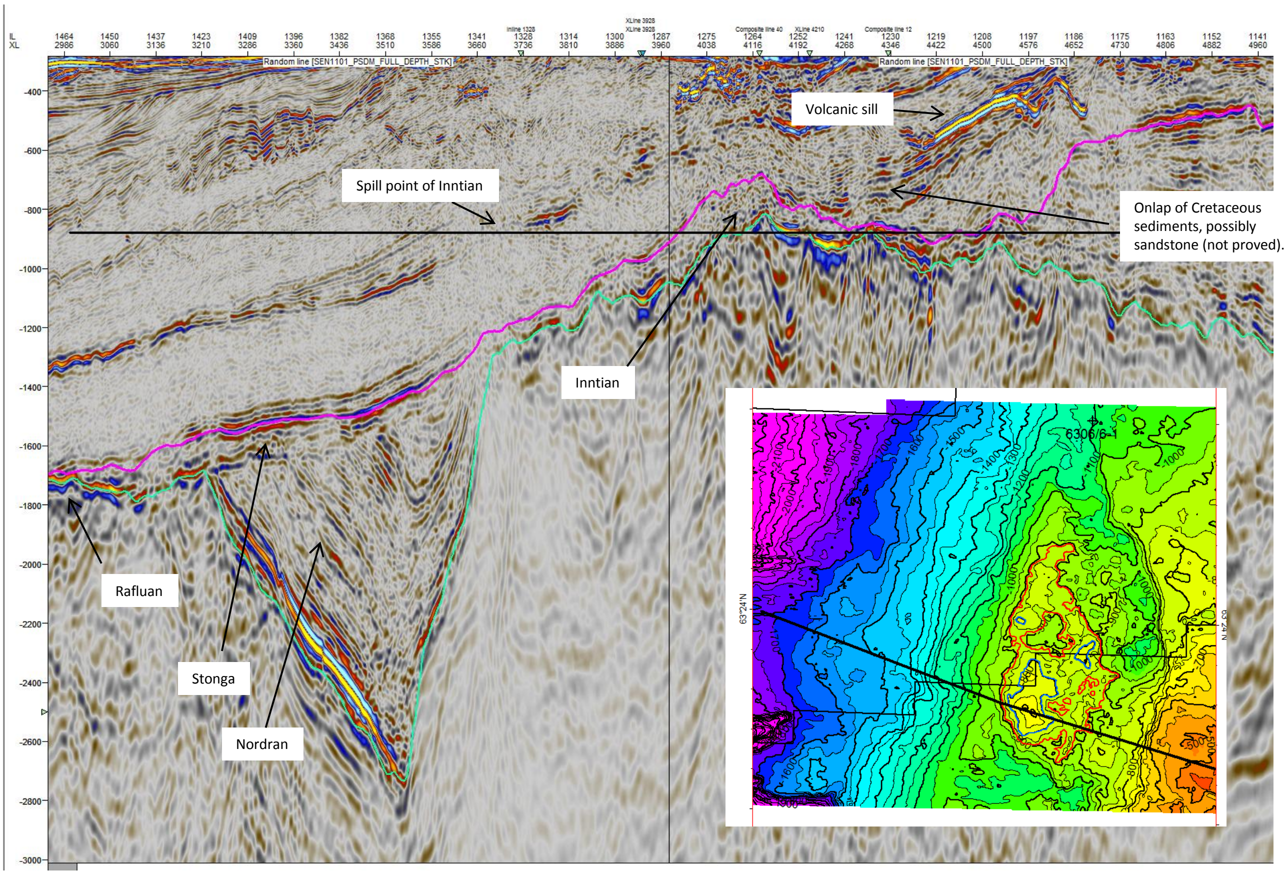


Fig. 4.3 West - East random line through the Inntian prospect. *West is to left in the figure, East to the right.*

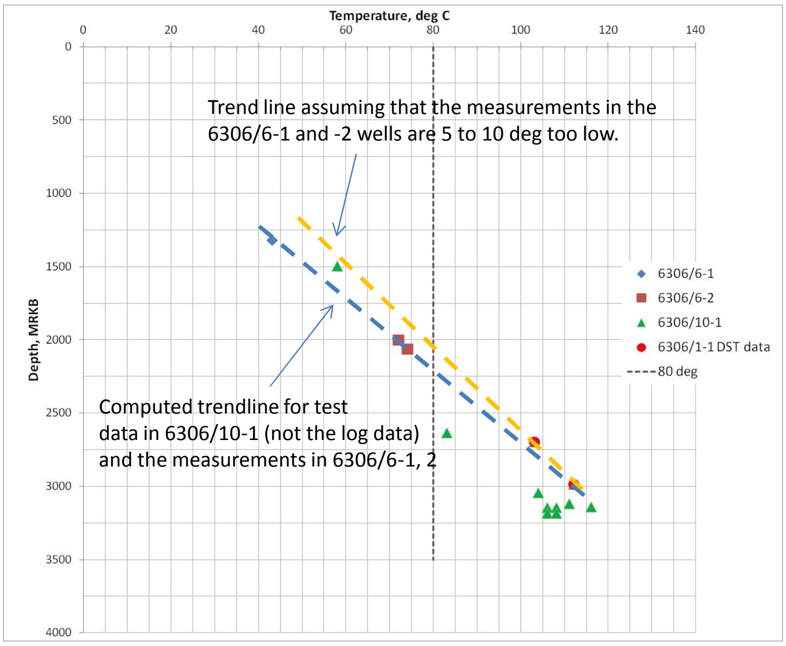
In the volumetric calculations, the calculated reservoir parameters of the Upper Jurassic reservoir in the 6306/6-1 well, has been used to guide the reservoir parameters for Inntian prospect. Within the Inntian closure, there is a possibility that some of the sediments above the Top Basement may be older than Upper Jurassic, but a firm seismic tie to prove this has not been possible to establish.

Inntian Risk Evaluation & discussion

Due to the limited burial depth (apex top reservoir 680m, the main risk is considered to be biodegradation. Most likely the reservoir has never been buried deep enough to have pasteurized the formation water in the reservoir (i.e. above 80 °C). Hence, the oil may be severely degraded. Fig. 4.4 shows temperature data from wells in the area. An uplift estimate of 1000m and maximum burial of 2100 m for the Rogn FM,is estimated from velocity data in the 6306/6-. The present day regional geothermal gradient is estimated to be ~40 °C/km. Assuming the same amount of uplift for the Inntian prospect, and present day geothermal gradient, the Inntian prospect would need another 400-500 meters burial to reach a paleo-temperature of 80 °C.

The Inntian structure is located 30 to 35 km from any proven mature source rocks. Despite this fact, there is a continuous good focus in the migration pathway towards the structure, both from the North and from the West. However, the long lateral migration distance, increases the chance of the hydrocarbons to fail to reach and fill the structure.

Data from 6306/6-1,2 and 6306/10-1 gives 80 deg at ~2000 - 2250 m depth (incl. water).



Max depth Rogn in 6306/6-1 well: 2100m burial depth.

Present depth Rogn @ apex: 690 m burial depth

These estimates gives total burial of Inntian of 1600 – 1700m.

Draugen Field is 1620m today, has been 200 m deeper.
The Draugen oil is slightly biodegraded, but is a 42 API high quality oil.

Fig. 4.4 Estimated regional temperature gradient from wells in the PL583 area.. *A 80 oC is marked on figure, which is assumed to be the maximum temperature that biodegradable bacterias can survive (Wilhelms et al., 2001). Figure clearly shows that maximum burial depths need to be 2000 m or more to reach 80 oC.*

As illustrated in Fig. 4.3 a possible onlap of sandy Cretaceous sediments has been identified close to the apex of the Inntian structure. The general appearance of these sediments makes it tempting to invoke sandstones inside this package, but this is not proved in the nearest wells. When looking at the site survey (TUN14003), it seems that the Inntian structure is draped by a continuous layer of lower Cretaceous sediments. This layer may prevent any thief sands to erode into the Inntian reservoir and destroy trap integrity. Still, the observation adds an uncertainty on the seal potential for the Inntian prospect.

The chance presence of reservoir is expected to be high on the Inntian prospect. The nearest well ~7 km north (6306/6-1), does contain 72 m net sand with a mean porosity of 20%. However, as discussed in 3 Review of geological framework, the reservoir properties can change significantly over short lateral distances. Current understanding of the Rogn Fm system indicate a high chance of Rogn sand within the Inntian prospect outline (Fig. 3.2), however the quality and thickness of the Rogn Fm at the Inntian location, is uncertain. Furthermore, in-house AVO modelling shows that, if a high quality hydrocarbon filled reservoir with non biodegraded oil excist at Inntian it should yield an AVO anomaly. Inntian is not associated with an AVO anomaly.

The final risk risk and volumes for all the prospects and leads in this license is summarized in Table 4.1.

Remaining Prospectivity

A number of leads have been evaluated during the license period, see Fig. 4.5 and Table 4.1. A short description of the leads are given below, based on their stratigraphic level.

Table 4.1 Risk and volumes for the Inntian prospect and leads evaluated in PL583

Prospect/Lead /Discovery	RC	Reservoir interval	HC type	In License	Prob. of Disc.	Unrisked Resources (P Mean)		Top Res Depth	WD
				%	%	10^6 Sm^3 OE	MMBOE	m	m
Inntian (P)	8	Rogn	Oil	32	16	25.9	163	680	240
Flesa (L)	9	Basement (?)	Oil	52	11	8,4	53	780	240
Nordran		Middle Jurassic Fangst Gp (?)	Oil	86	<10	19		1500	
Svartran		Middle Jurassic Fangst Gp (?)	Oil	100	<10			900	
Stonga		Upper Jurassic Rogn	Oil	100	<10	5,6		1250	
Rafluan		Basement	Oil	100	<10	3		1810	
Bleika		Paleocene Egga	Oil	73	<10	n.a.	n.a.	1500	
Svingla		Upper Jurassic Rogn	Oil		<10				

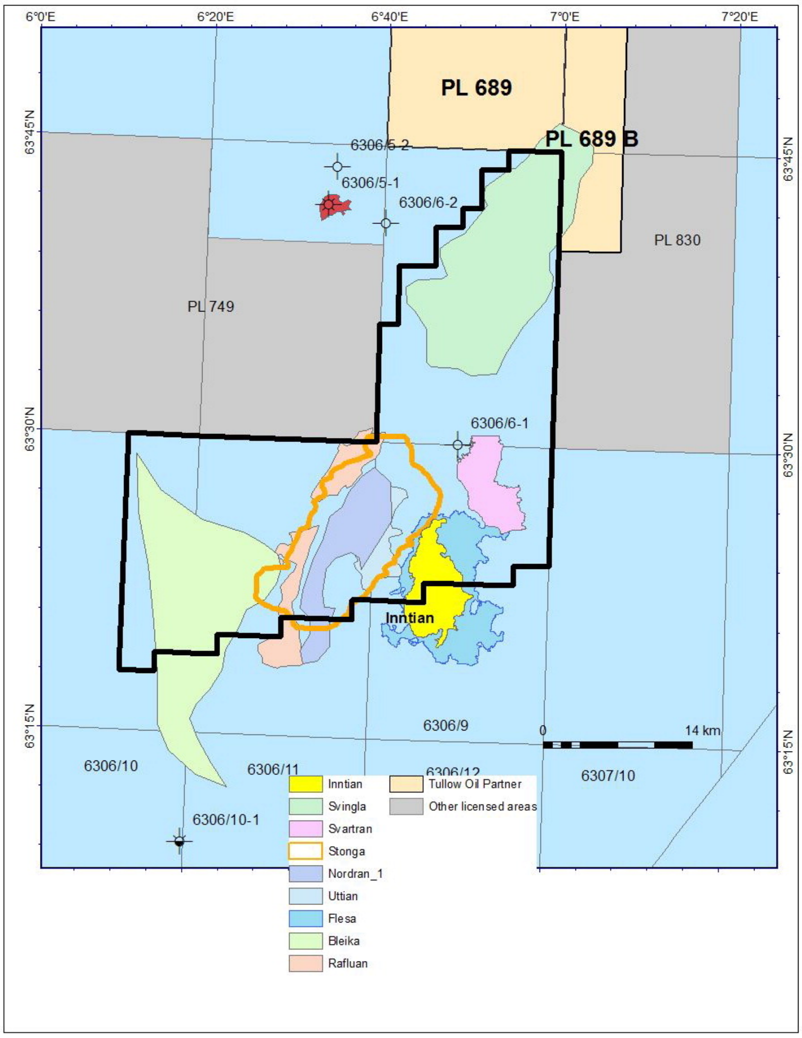


Fig. 4.5 All the leads that have been identified and evaluated in the PL 583 license.. *See Table 4.1 for volumes and risk.*

Basement

Two leads has been identified in the basement: the Flesa and the Rafluan leads. The Flesa lead sits directly below the Upper Jurassic Inntian prospect, and is, like the Inntian prospect, a 4 way dip closure. The Rafluan is also a 4 way dip closure, but much smaller than the Flesa lead. The reservoir quality of the basement is regarded as the main uncertainty in both of these two leads.

Mid Jurassic

Svartran lead is a combination trap, with fault dependency towards west and stratigraphic pinch out towards the south. Stratigraphy is unknown, but Triassic or Jurassic sediments is very likely. The Svartran lead is in a migration shadow for the generating basin towards the west and north. Down flank towards the south the trap is outside the coverage of the 3D cube, and difficult to delimit.

Nordran is located in the rotated half graben just West of the Inntian prospect. Any filling of this lead is dependant upon downwards migration into the graben from the kitchen to the west. The top seal consist of the Upper Jurassic Stonga prospect, and is expected to be rather sandy.

Upper Jurassic

In the APA 2010 application the Upper Jurassic Svingla lead had a significant volume potential. The Svingla lead is not covered with 3D, but the license reprocessed a number of 2D lines that covers this lead. The new mapping did not prove any sealing of the Svingla towards the south and east.

The Upper Jurassic Stonga lead is located just above the Nordran lead. As a play, the Stonga is in a very similar position to the Inntian prospect, but is fully dependant upon updip sealing towards the east. If no sealing is present here, the Stonga lead is in direct communication with the Inntian prospect. On some lines one can argue that the Rogn Fm is very thin/absent, but as a whole, the lateral seal risk is regarded very high.

The Uttian lead was defined from AVO screening as a quite clear AVO class three along the BCU. The AVO anomaly is however interpreted to originate mainly from stratigraphic thinning and tuning effects.

Cenozoic

The only Cenozoic lead identified is the Bleika lead. Bleika is a stratigraphic pinch out trap in the western part of the area. The Paleocene Egga Mbr sandstone is the reservoir unit. Egga sandstone is proved in the 6306/6-1 well, and also in the two other wells in the 6306/9 block. The 3D data do not give good evidence that the Egga sandstone disappears completely from west towards east. Hence, the lateral sealing potential is a high risk. Also, if hydrocarbon filled Egga sandstone is present (same pay as in the Ormen Lange Field) a clear brightening in the seismic data at this level should be present, this is not observed on present 3D data set across the Bleika lead.

5 Technical evaluations

The development solution for Inntian will be a stand-alone FPSO as there is no processing infrastructure in reasonable tie-back distance from the prospect. About 32% of the prospect is within the PL 583 license whereas the remaining is in non licenced area. The evaluation assumes development of the entire Inntian prospect.

Gas export will be either to Polarled or Åsgard Transportation System. Both pipelines are relatively close to Inntian.

Inntian is assumed to require 15 horizontal producers and 9 vertical injectors. The design capacity of the FPSO is set to 55 kbpd of oil. Total cost is estimated to:

Exploration and appraisal: 900 MNOK
Pre FID cost: 850 MNOK
Development cost 23 400 MNOK
Wells (15 P+ 9 WI) 6 000 MNOK
Subsea and flowlines 7 200 MNOK
FPSO: 7 200 MNOK
Gas export pipeline: 600 MNOK
Owners cost: 2 400 MNOK

The resulting economic performance is shown in Fig. 5.1

		50 USD/bbl	70 USD/bbl
IRR	%	7.6%	13.0%
NPV10	MNOK	-960	1232
EMV	MNOK	-182	154
MEFS	mmboe	193	134
Break even oil price	USD/bbl	58	58

Fig. 5.1 >Inntian economic performance

The conclusion is that the geological risk is viewed to be too high to justify an exploration well in particular since geophysical evaluations strongly suggest that presence of oil in combination with good reservoir properties is unlikely. Furthermore, a development limited to cover the license area will require an oil price in the range of 80-90 USD/bbl. The risk is therefore much higher than the upside.

6 Conclusions

The estimated in-place volumes of oil in the Inntian prospect within PL583 have through the license work program been reduced. The main reason for this is a smaller closure compared to the APA 2010 volumes. The final risk factor of 16% is the same as it was in the APA 2010 application.

The evaluated resources are above the commercial threshold, also when only the volumes within the license border is considered, but the upside is of limited value. Particularly when combined with the risk level. The license reached a unanimous conclusion to relinquish the license and not drill an exploration well.

Biodegradation and lateral seal is considered as the main risk factors. In the final evaluation, it was particulary the lateral seal that added to the total risk picture, an element not considered that important in earlier evaluations.